Phase 2

Trade of Motor Mechanic

Module 3

Unit 1

Engine Components & Operating Principles

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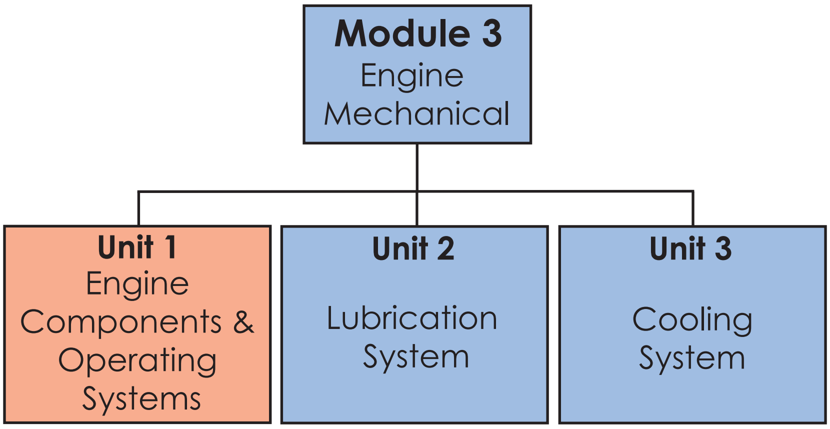
Introduction

Module 3 of this course covers the Engine Mechanical aspect of automotive technology. This is the first unit in module 3 and introduces the fundamental principles associated with the Internal Combustion (petrol) engine.



By the end of this unit you will have dismantled a multi-cylinder engine, identify the components, describe their function, relationship to each other and reassembled them.

An internal combustion engine is any engine that operates by burning its fuel inside the engine.

The four-stroke internal combustion engine is the type most commonly used for automotive purposes today. On the first (downward) stroke of the piston, fuel/air is drawn into the cylinder. The following (upward) stroke compresses the fuel-air mixture, which is then ignited - expanding gases then force the piston downward for the third stroke and the fourth and final (upward) stroke evacuates the used exhaust gasses from the cylinder. Health and safety issues related to this unit will also be covered in this unit.

Unit Objective

By the end of this unit each apprentice will be able to:

- Describe the operation of a 4 stroke cycle, internal combustion (I.C.) spark ignition (S.I.) engine
- Define the quantities, S.I. units and indices of; length, volume, angle, rotational speed, atmospheric air pressure and temperature
- Describe the component arrangement and principle of operation of multi cylinder, 4 stroke S.I. engine
- Define the technical terminology used in I.C. engine construction and operation
- Define the term 'thermal expansion' and describe its effects relative to the principal I.C. engine components
- Dismantle a multi-cylinder engine, identify the principal components, describe their function and method of operation, identify the firing order and reassemble the engine
- State the typical compression ratios of throttle-body, port and direct petrol injection engines
- Calculate the compression ratio of an engine from given values
- Describe the cylinder head, camshaft and valve operating arrangements used in automotive engines
- Distinguish between; tensile, compressive and shear force and identify engine components affected by these forces

1.0 The petrol and diesel 4-Stroke Cycle

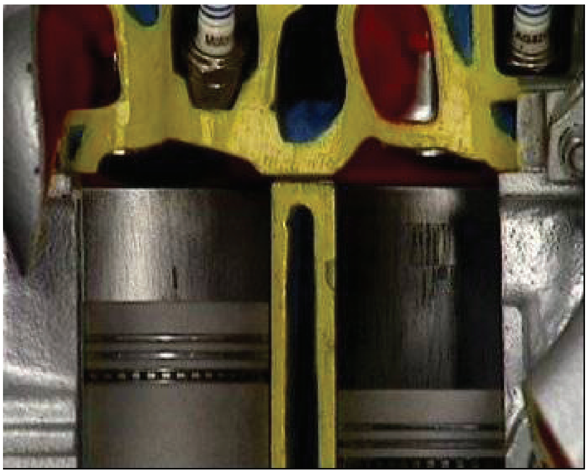
Key Learning Points

- Operation of the reciprocating-piston engine i.e. 4-stroke cycle, hydrocarbon fuel and air (oxygen), combustion process, heat energy conversion to mechanical energy, relationship between volume, pressure and heat of an enclosed gas, conversion of linear motion to rotary motion

1.1 Basic 4-Stroke Principles

In is a cylinder for a 4-stroke Petrol engine the first step is to get the air-fuel mixture into the chamber. Mixture of petrol and air enters through an inlet port that is opened and closed by an inlet valve. This is called Intake. Next is compression. The piston compresses the air-fuel mixture into a smaller volume. A spark across the electrodes of a spark plug ignites it and it burns. This burning is called combustion.

The burning gases expand rapidly (note see gas laws section 1.3) and push the piston down the cylinder (power) until it reaches bottom dead centre. The reciprocating action of the piston turns linear motion into the rotary motion of the crankshaft. The crankshaft forces the piston back up the cylinder, pushing leftover gases out past an exhaust valve (exhaust). And everything is back where it started; ready to repeat the whole process.



The whole process is a cycle. A new mixture enters and is ignited. Combustion occurs; expanding gases drive the piston down and turn the crankshaft which pushes the piston back up the cylinder. How they happen can change but they are always there.

In one 4-stroke cycle, the crankshaft does 2 revolutions. In those 2 revolutions how many strokes does the piston make? It does 4 strokes.

Out of those 4 strokes how many actually produce energy? In one 4-stroke cycle, only 1 stroke out of 4 delivers new energy to turn the crankshaft.

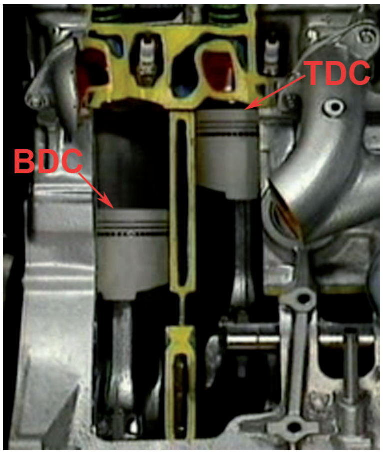
1.2 4-Stroke Engine Cycle

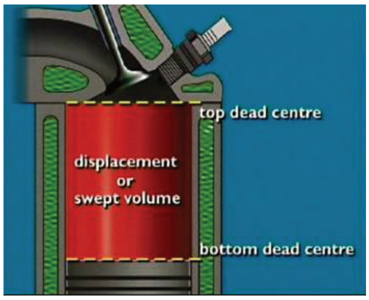
A stroke is the movement of the piston from TDC (top dead centre) to BDC (bottom dead centre), OR BDC to TDC. A 4-stroke engine has the following "strokes", intake, compression, power and exhaust.

A 4-stroke petrol engine uses "internal" combustion, meaning that the heat that causes the air in the cylinder to expand is generated "internally". (A steam engine is actually an "external combustion engine" as its heat source is outside the cylinder!) Those 4 strokes must include *Intake, Compression*, *Ignition* and *Power & Exhaust*.

Intake

The intake stroke starts with the exhaust valve closed the inlet valve opening and the piston at its highest point, top dead centre. It starts





to move down, increasing the volume above the top of the piston. This makes pressure inside the cylinder lower than the pressure outside. This higher outside air pressure forces the air-fuel mixture into the cylinder. The piston reaches bottom dead centre the inlet valve closes and the intake stroke ends.

Compression

Both intake and exhaust valves stay closed as the piston leaves bottom dead centre. The piston moves up, squeezing the air-fuel mixture into a smaller and smaller volume which compresses it. That causes the air/fuel charges temperature to rise and that makes ignition easier and combustion (burning of fuel) more complete.

Ignition

Note: Just before the piston reaches top dead centre the next key event occurs - Ignition.

Power

The air expanding in the cylinder pushes the piston down the cylinder. This is the Power stroke that drives the engine.

Exhaust

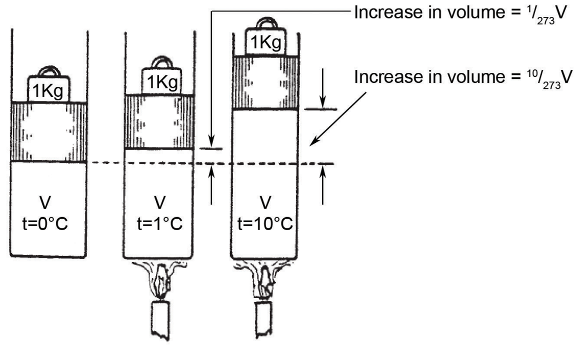
The piston now moves from bottom dead centre to top dead centre. The exhaust valve opens and the piston pushes out the leftover gases.

A complete 4-stroke cycle consists of:

- Intake - takes in air-fuel mixture.
- Compression - squeezes the air-fuel mixture into a smaller and smaller volume.
- Ignition - the mixture under pressure is ignited.
- Power - burning, expanding gases push the piston down creating a power stroke that turns the crankshaft.
- Exhaust - the piston moves upward forcing burned gases from the chamber.

1.3 Charles's and Boyle's Gas Laws

Charles's Law



Charles's Law; Gas expands when heated. If a gas cylinder is heated it will expand just like most other substances. The figure above shows an example of a gas being maintained at a constant pressure by allowing the piston to slide in the cylinder; the pressure of the gas is governed by the 'weight' acting on the piston.

Consider the effect when heat is applied: an increase of temperature will cause the gas to expand and this will be shown by an increase in the volume i.e. the piston moves upwards a small amount. By starting this experiment at 0°C the increase in volume for a 1°C rise in temperature will be 1/273 of the volume that it occupied at 0°C.

This result is generally known as Charles's Law which states that:

The volume of a fixed mass of gas at constant pressure expands by 1/273 of its volume at 0°C per °C rise in temperature.

Charles's Law in symbol form (Assuming the pressure is kept constant.)

$$\frac{\text{Initial Volume}}{\text{Initial Temperature}} = \frac{\text{Final Volume}}{\text{Final Temperature}}$$

$$\frac{V_1}{t_1} = \frac{V_2}{t_2}$$

V_1 = initial volume V_2 = final volume

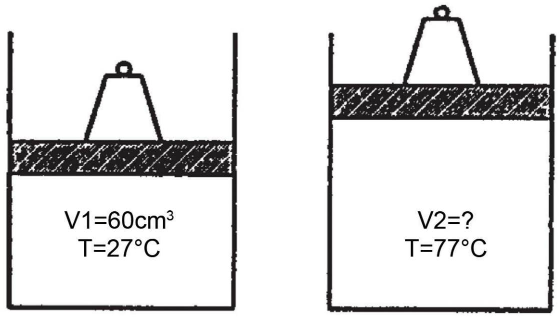
t_1 = initial temperature t_2 = final temperature

The temp scale for t_1 and t_2 must be based on absolute zero. Therefore the Kelvin scale must be used.

Example

Gas in the cylinder shown in the figure below, has a volume of 60 cm_3 at 27°C.

What is the volume of the gas at 77°C?



Let V_2 = final volume (cm^3)

where

V_1 = initial volume = 60

V_2 = final volume =?

t_1 = initial temperature K = 27 + 273

t_2 = final temperature K = 77 + 273

$$\text{Final volume} = \frac{\text{Initial Volume} \times \text{Final Temperature}}{\text{Initial Temperature}}$$

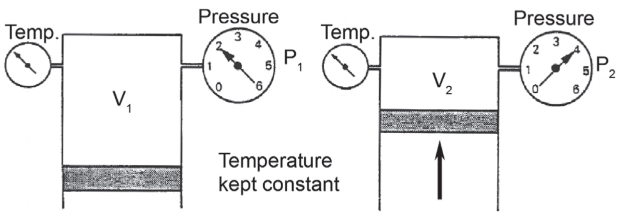
$$V_2 = \frac{V_1 \times t_2}{t_1}$$

$$V_2 = \frac{60 \times 350}{300}$$

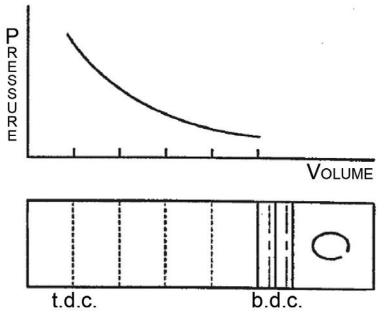
$$V_2 = 70cm^3$$

Boyle's Law

The volume of a fixed mass of gas is inversely proportional to the pressure provided the temperature remains constant.



Assuming the temperature is kept constant the effect of decreasing the volume is to raise the pressure. Compressing the gas into half its original volume doubles the pressure.



The graph shows a decrease in volume causes an increase in pressure.

The pressure/volume relationship is shown above. The pressure of the gas must be expressed as an absolute pressure. Zero on the absolute pressure scale is the point where no pressure exists i.e. a 'perfect' vacuum. Using this scale:

Standard atmosphere pressure = 101.4 kN/m^2 or 760mm of mercury. For practical purposes this can be approximated to:

Atmospheric pressure = 100 kN/m^2 or 100 KPa or 1 Bar

(The Pascal, Pa is the SI unit of pressure: 1 Pa = 1 N/m^2)

Boyle's Law can be expressed as:

$pV = \text{constant or } p_1 V_1 = p_2 V_2$

Where: p_1 and p_2 = initial and final absolute pressures

V_1 and V_2 = initial and final volumes.

During a compression test, this subject shows that a warm engine in good condition should give a minimum compression pressure of about p_1 x compression ratio.

Example

An engine cylinder contains 480 cm^3 of air at an absolute pressure of 1 bar (100 kN/m^2). Assuming the temperature is kept constant what will be the absolute pressure when the volume is reduced to 60cm^3?

$$p_1 \times V_1 = p_2 \times V_2$$

Where: p_1 = initial absolute pressure = 1 bar

p_2 = final absolute pressure =?

V_1 = initial volume = 480 cm^3

V_2 = final volume = 60 cm^3

$$p_2 = p_1 \frac{V_1}{V_2}$$

$$p_2 = \frac{1x480}{60}$$

p_2= 8 bar or 800 kN/m2 or 800 kPa

Since heat is generated by the compression of gas then the increase in pressure caused by this heat will raise the final pressure even higher.

Example

A compression test is conducted on an engine having a compression ration of 9.2: 1

Estimate the compression pressure.

Estimated initial pressure = 1 bar.

Excluding effect of 'compression heat' during the test.

Estimated compression pressure = 1 x 9.2 = 9.2 bar

Or 920 kN/m^2 or 920 kPa.

Previous examples show that in most applications of gas laws there is alteration to the pressure volume and temperature of the gas. These situations can be met by combining the two gas laws to give:

$$\frac{p_1 V_1}{t_1} = \frac{p_2 V_2}{t_2}$$

Example

Under normal operating conditions the compression stroke of a C.I. engine causes air in a cylinder of volume 1200 cm^3. During this stroke the pressure increases from 100 kPa (1 bar) to 4000 kPa (40 bar). If the initial temperature is 87°C what is the final temperature?

$$\frac{p_1 V_1}{t_1} = \frac{p_2 V_2}{t_2}$$

$$p_1 V_1 t_2 = p_2 V_2 t_1$$

$$t_2 = \frac{p_2 V_2 t_1}{p_1 V_1}$$

Where:

p_1 = pressure = 1 bar

p_2 = pressure = 40 bar

V_1 = volume = 1200 cm^3

V_2 = volume = 75 cm^3

t_1 = temperature = 87 + 273 = 360 K

Substituting the values gives:

$$t_2 = \frac{40 \times 75 \times 360}{1 \times 1200} = \frac{4 \times 75 \times 36}{12_{\to 3}} = \frac{75 \times 36_{\to 12}}{3_{\to 1}} = 75 \times 12 = 900K$$

900K = 900 – 273 – 627°C

This example shows that if fuel oil having a self ignition temperature of about 400°C is injected into this heated air then combustion of fuel will occur.

2.0 SI Units and Measurements

Key Learning Points

- Definition, quantities, S.I. units and indices of; length, volume, angle, mass, rotational speed, force, atmospheric air pressure, torque, temperature

2.1 SI Units of Measurement

The international system of units consists of a set of units together with a set of prefixes. The units of SI can be divided into two subsets. There are the seven base units. Each of these base units is dimensionally independent. From these seven base units several other units are derived. In addition to the SI units there are also a set of non-SI units accepted for use with SI.

A prefix may be added to units to produce a multiple of the original unit. All multiples are integer powers of ten. For example, kilo- denotes a multiple of a thousand and milli denotes a multiple of a thousandth hence there are one thousand millimetres to the meter and one thousand meters to the kilometre. The prefixes are never combined: a millionth of a kilogram is a milligram not a micro kilogram.

SI Units

Length	metre (m)
Mass	kilogramme (kg)
Volume	cubic metre (m^3)
Torque	Newton metre (Nm)
Force	neuton (N)
Temperature	Kelvin (K)
Rotational speed	revolutions per minute (RPM)
Angle	Degrees (example 90°)
Atmospheric air pressure	Pascal (Pa)

Prefixes are used in front of the basic unit to avoid writing in full a number which consists of many digits; e.g. it is easier to write 52 km than 52 000 m. These prefixes are shown in Table 1.

Prefix	*Symbol*	*Standard Value*	*Value (written in full)*
kilo	k	10^3	1000
deca	da	10^1	10
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001

Table 1. Prefixes for SI units

The number that indicates the power to which 10 is raised is called an 'index' (plural, indices).

3.0 Multi Cylinder Operation and Component Arrangement

Key Learning Points

Multi cylinder engine block configuration; inline, 'V' and horizontally opposed, firing orders - stroke chart design, basic valve timing

3.1 Engine Configurations

The way engine cylinders are arranged is called the engine configuration. Tilting an engine reduces its height. This can reduce the height of the bonnet as well.

As the number of cylinders increases the length of the block and the crankshaft can become a problem. One way to avoid this is with a V configuration. This design makes the engine block and the crankshaft shorter and more rigid.

Horizontally-opposed/boxer engines have 2 banks of cylinders 180 degrees apart on opposite sides of the crankshaft. A useful design when little vertical space is available. It is shorter than a comparable in-line engine but wider than a V-type.

3.2 Multi-Cylinder Engines

The power developed by an engine can be increased by:

1. Enlarging the cylinder or
2. Increasing the number of cylinders.

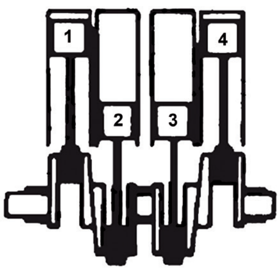
A single large cylinder would seem the most popular choice since there are fewer parts to manufacture and maintain but the disadvantages far outweighs the advantages. A large single cylinder engine needs a heavy flywheel to carry the piston over its idle strokes and to smooth out the torque fluctuations. Due to the fact that there is only one power stroke per two revolutions of the crankshaft the piston and con-rod would also be heavier which means the engine speed would be limited and acceleration slow. As a result the power output-weight ratio would be low.

A multi-cylinder engine of the same cubic capacity and weight would have more power strokes per revolution. Lighter pistons, con-rods and flywheel which means that the torque would be smoother, better balance engine, higher engine speed and more power output.

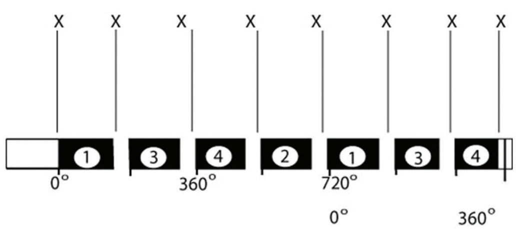
Car engines are usually four cylinder four stroke engines arranged inline. Other variations are the opposed arrangement (Volkswagen) and the vee arrangement.

Four-Cylinder In-Line Arrangement

Inline Engine: The cylinders are arranged in a line a flat four throw crankshaft. Five main bearings are normally employed to give maximum support.



Equal firing angles of 180°



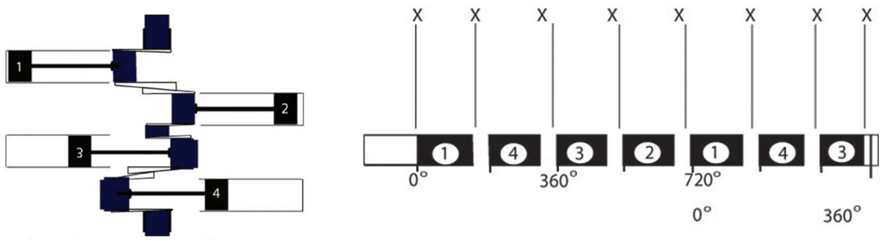
Four Cylinder in-line arrangement

Pistons 1 and 4 will be at the top together while pistons 2 and 3 will be at the bottom. The pair will move up and down together but each will be on a different stroke. For example if No. 1 is going down on its induction stroke No. 4 will be going down on its power stroke similarly 2 and 3. In this arrangement the firing interval is 180° of crankshaft rotation.

Four-Cylinder Horizontally-Opposed/Boxer Arrangement

Horizontally-opposed/boxer arrangement (Volkswagen): The air-cooled Volkswagen uses this arrangement for their engine. The cylinders are arranged horizontally in pairs on each side of a flat four crankshaft, the engine being air cooled a lot of space is needed between the cylinders for the cooling fins and an inline engine would be too long. Engine balance is superior to the inline arrangement.

Equal firing angles of 180°



Four-cylinder Horizontally-opposed/boxer arrangement

3.3 Firing Order

The *firing order* is the sequence of sparking of the spark plugs in a reciprocating engine or the sequence of fuel injection in each cylinder in a Diesel engine. Choosing an appropriate firing order is critical to minimizing vibration and achieving smooth running, for long engine fatigue life and user comfort.

In a straight engine the spark plugs (and cylinders) are numbered, starting with number 1, from the front of the engine to the rear. In most cars the front of the engine also points to the front of the car, but some manufacturers in some models place the engine 'backwards', with number 1 towards the firewall.

Examples of firing orders

Number of cylinders	*Firing order*	*Example*
3	1-2-3	Daihatsu charade (03-)
4	1-3-4-2	Toyota Yaris 1lt (99-06)
5	1-2-4-5-3	Volvo C70 (97-98) 2.5
6	1-5-3-6-2-4	Bmw Z4 (E85) 3.0

3.4 Power Chart 4-cylinder Engine

Degrees of Crankshaft Rotation

	180°	360°	540°	720°
Cylinder 1.	P	E	I	C
Cylinder 2.	E	I	C	P
Cylinder 3.	C	P	E	I
Cylinder 4.	I	C	P	E

I–Intake *C-Compression* *P-Power* *E-Exhaust*

Firing Order 1342

Single cylinder Power Stroke Every

$$\frac{720}{1} = 720°$$

Twin cylinder (Side by Side)

$$\frac{720}{2} = 360°$$

3 cylinder Inline

$$\frac{720}{3} = 240°$$

4 cylinder inline

$$\frac{720}{4} = 180°$$

3.5 Understanding Power and Torque

When a piston is forced down the cylinder during the power stroke it applies the force to the connecting rod. The connecting rod then causes the crankshaft to turn. The force that makes the crankshaft turn is called torque. The metric unit for the measurement of torque is Newton meters.

If we assume that a shaft has a lever attached perpendicular to its axis and that lever is 1 meter long. If a force of 100 Newton were applied to the end of the lever, the torque applied to the shaft is 100 Newton per meter or 100 Newton meters.

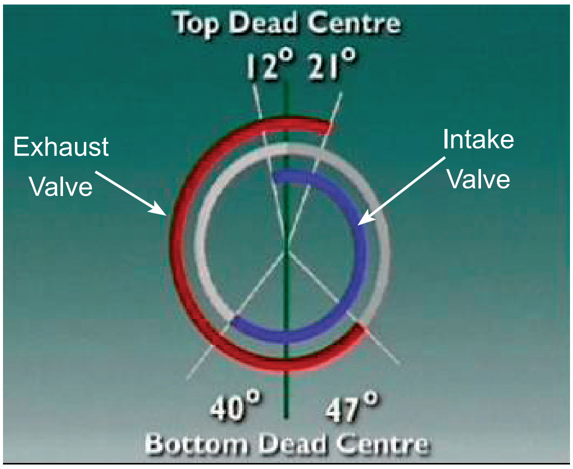
Power is a term used to describe how much work is done in a period of time. An engine produces *power* by applying *torque* to a *rotating* shaft. So the measurement of engine power is calculated from the amount of torque applied to the crankshaft and the speed at which it is turning. When expressing engine power it is necessary to express not only the power value but to include the engine speed at which it occurs.

The metric measurement of power is the watt.

The watt is the metric system measurement of power, however engine power is expressed in kilowatts as the watt has such a small value. A kilowatt is equivalent to 1000 Newton per meter per second.

3.6 Valve-Timing Diagram

The intake valve usually opens earlier than top dead centre (shown in blue) and stays open a little past bottom dead centre. The exhaust valve opens a little before bottom dead centre (shown in red) and stays open a little past top dead centre.



When the valves actually open and close, it can be measured by angles. To make these angles easier to read we use a spiral instead of a circle.

This intake valve opens 12° before the piston reaches top dead centre. And it closes 40° after bottom dead centre. The exhaust valve opens 47° before bottom dead centre - and stays open - until 21° past top dead centre. This gives exhaust gases more time to leave.

By the time the piston is at 47° before bottom dead centre on the power stroke, combustion pressures have dropped considerably and little power is lost by letting the exhaust gases have more time to exit.

When an intake valve opens before top dead centre and the exhaust valve opens before bottom dead centre it is called lead. When an intake valve closes after bottom dead centre and the exhaust valve closes after top dead centre it is called lag.

On the exhaust stroke the intake and exhaust valve are open at the same time for a few degrees around top dead centre. This is called valve overlap. On this engine it is 33°. Different engines use different timings.

Manufacturer specifications contain the exact information.

4.0 Technical Terminology

Key Learning Points

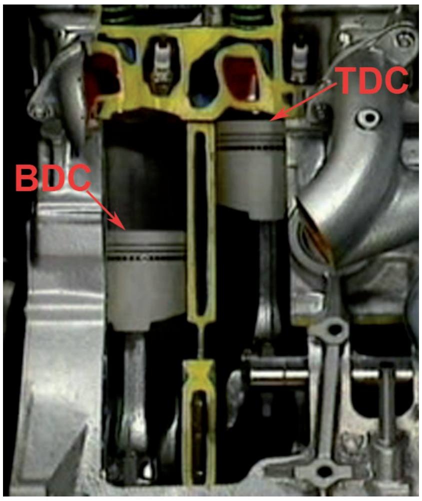
- Terminology used e.g.; stroke, TDC, BDC, OHC, DOHC.

4.1 Terminology

A stroke is the movement of the piston from *TDC* (top dead centre) to *BDC* (bottom dead centre), or *BDC* to *TDC*.

TDC	Top dead centre
BDC	Bottom dead centre
OHC	Overhead camshaft
DOHC	Double overhead camshaft

Top dead centre (*TDC*), is the position of a piston in which it is furthest from the crankshaft. The position closest to the crankshaft is known as *bottom dead centre* (*BDC*).



Overhead camshaft (OHC) valvetrain configurations place the camshaft within the cylinder head above the combustion chambers and drive the valves or lifters

Double overhead cam (also called DOHC, dual overhead cam, or twin cam) valve train layout has two camshafts being located within the cylinder head.

Additional information is available from the automotive technical manuals.

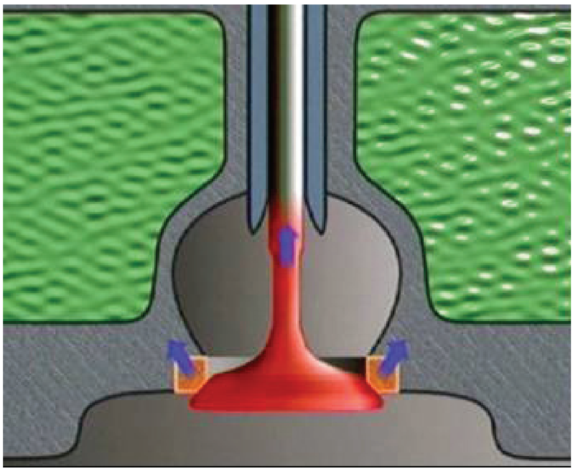
5.0 Thermal Expansion' and its Effects

Key Learning Points

- Thermal expansion and contraction; linear, superficial and volumetric, piston/ring gap/clearance/s

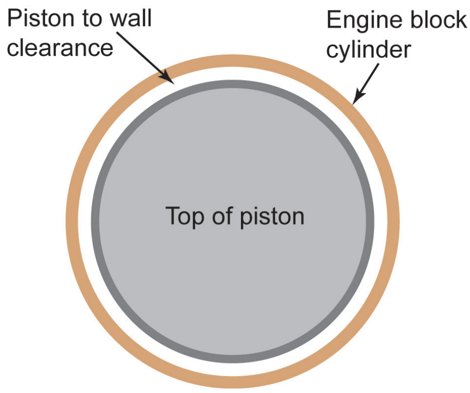
5.1 Thermal Expansion

Thermal expansion refers to the way some materials expand when they're heated. The same amount of heating can produce different amounts of expansion in different substances. Therefore it is important that when an engine is designed allowance must be made for thermal expansion and contraction.



Components that are subject to heating have to allow for this expansion in their design. An engine exhaust system is subjected to very hot exhaust gases so its components expand and contract as they heat and cool. Mountings in the system are designed to allow this to happen.

Material expansion due to the heat occurs in many areas of an internal combustion engine. One measurement that is critical is the piston-to-wall clearance. This is the difference between the diameter of the piston and the diameter of the cylinder wall.



Materials will expand when heated and contract when cooled down. For example if an engine block is cast iron and a piston is aluminium the piston and cylinder will expand differently. If the block and piston are made of the same material the piston-to-wall clearance will expand at the same rate and the clearances will be different.

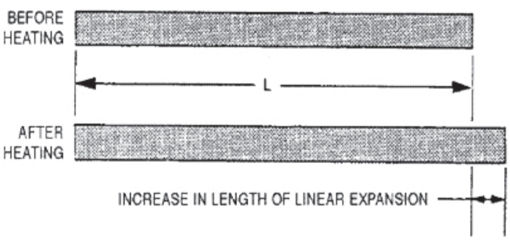
Another example of linear expansion can be found in piston-ring end gap. This is the space between the ends of a piston ring when installed in the cylinder. The ring undergoes linear expansion as the engine heats up which causes the end gap to get smaller (the ring tries to grow together as it gets hot). If there is not enough end gap when the engine is put together the ends of the ring may butt together when the engine gets hot and this could seriously damage the engine.

5.2 Thermal Expansion Calculation

Expansion of Solids

Heating a solid causes it to expand in all directions but one of the most important considerations is its increase in length, or linear expansion.

Linear expansi



Simple Experiment to Show Linear Expansion

Equipment

- Vessel to boil water (thermostat tester).
- Exhaust or inlet valve.
- Electronic Vernier calipers or some accurate measuring device.
- One thermometer.

Thermostat tester with valve immersed in water:

Results

Original length of valve	=	110.9
Final length of valve	=	111.02
Valve extension	=	0.12
Original temperature of water	=	11°C
Final temperature of water	=	100°C
Change in temperature	=	89°C

Co-efficient of Linear Expansion =

$$\frac{\textit{Valve extension}}{\textit{Original length} \times \textit{change in temperature}}$$

$$= \frac{0.12}{110.9mm \times 89°C}$$

$$= \frac{0.12}{9670.1}$$

Co-efficient of Linear Expansion = 0.0000121

6.0 Principal Components and Function of the Engine

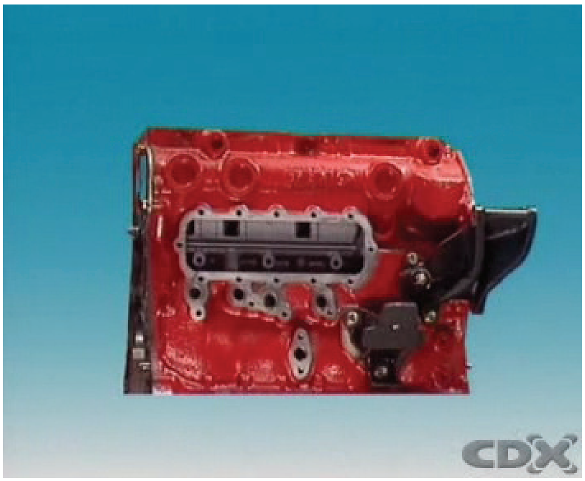
Key Learning Points

- Engine dismantled, basic examination for serviceability, e.g. pistons, timing belts/chains etc. and reassembled using manufacturer's recommended torque tightening procedures

6.1 Cylinder Block

The cylinder block is the largest part of the engine. Its upper section carries the cylinders and pistons. Normally the lower section forms the crankcase and supports the crankshaft. It can be cast in one piece from grey iron. Or it can be alloyed with other metals like nickel or chromium.

All cylinder blocks are made with ribs webs and fillets to provide rigidity but also keep weight to a minimum.



Cylinder Block

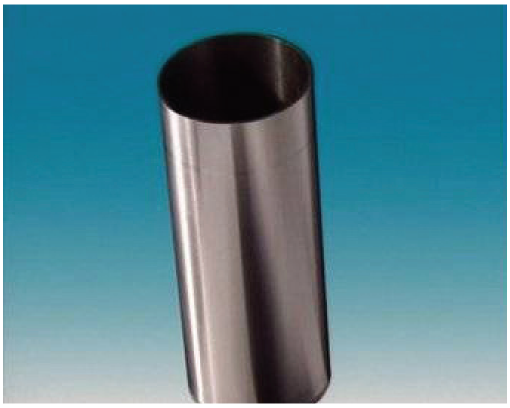
6.2 Cylinder Block Construction

As more manufacturers try to make vehicles lighter and more fuel efficient more and more engine blocks are being cast from aluminium.

A block made of aluminium alloy is lighter than if it were made of cast iron. So if two engines are generating the same power the alloy version would have a better weight-to-power ratio than the cast iron version.

6.3 Cylinder Sleeves

Cylinder sleeves are used in engine blocks to provide a hard-wearing material for pistons and piston rings. The block can be made of one kind of iron that's light and easy to cast while the sleeve uses another kind that is better able to stand up to wear and tear.



There are three main types of sleeves – dry, flanged dry and wet.

The dry sleeve can be cast in or pressed into a new block or used to recondition badly-worn or damaged cylinders that can't easily be re-bored. It's a pressed fit in its bore in the cylinder blocks. Its wall is about 2mm thick. Its outer surface is in contact with the block for its full length. Its top finishes flush with the top of the block and can hardly be seen. Once in place dry sleeves become a permanent part of the cylinder block.

A flanged dry sleeve is like a normal dry sleeve but a flange at the top fits into a recess in the surface of the engine block. It's not a tight fit and it can be replaced if it's worn.

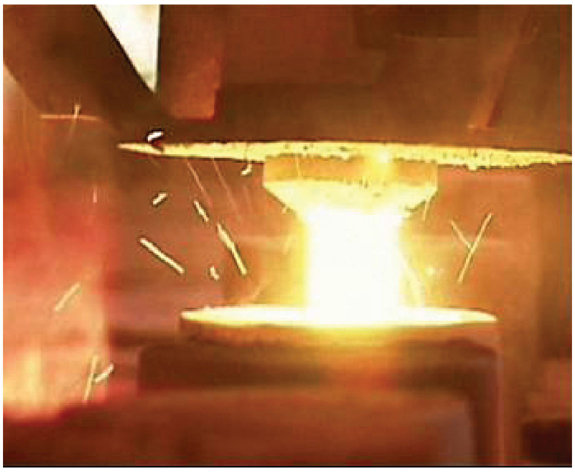
With a wet sleeve the outer surface is part of the water-jacket around the cylinder. It's called wet because it has coolant against its outer surface. This helps speed up heat transfer between the sleeve and coolant. The sleeve is sealed at the top to prevent coolant leaks. This stops coolant entering the combustion chamber and the bottom of the crankcase. A flange at the top of the sleeve fits into a recess in the block. The lower end has 1 or 2 neoprene sealing rings.

The walls on wet sleeves are thicker than on dry sleeves. They don't have the same support from the block as dry sleeves so they depend on their wall thickness to stop distortion.

In diesel engines vibration caused by combustion can cause cavitation. This damage appears similar to corrosion and it can eventually destroy the cylinder.

6.4 Grey Iron

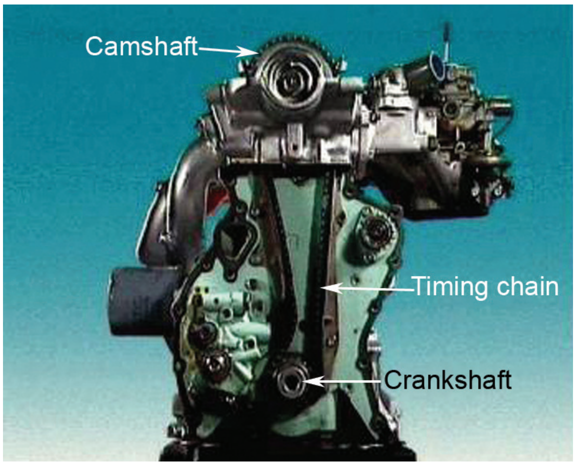
Grey iron is a form of cast iron. There are many different kinds of cast iron depending on the particular materials they contain.



Grey iron is a cast iron that contains carbon in the form of graphite plus silicon, manganese and phosphorus. The fractured surface of a cast iron with graphite appears grey hence the name. It is brittle and cannot absorb shocks. It resists heat and corrosion it can be cast into many different shapes including engine blocks.

6.5 Timing Belts & Chains

Timing belts and chains are used on overhead camshaft engines because the camshaft is further from the crankshaft.



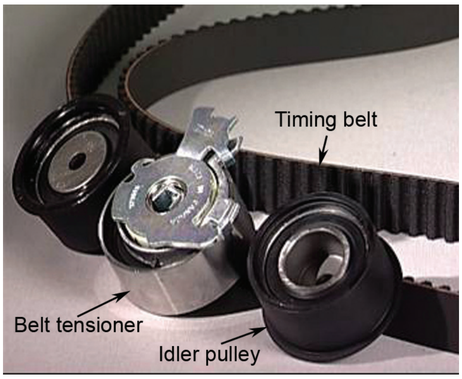
This is a typical chain drive system. It uses a hydraulic tensioner which is fed by oil under pressure from the lubrication system. The chain also uses guides to reduce noise and vibration.

The toothed timing belt is made of fibreglass or wire- reinforced synthetic rubber. Its teeth match those on the crankshaft and camshaft pulleys.

Timing belts are quieter than chains but usually require regular manual tensioning. They also have a shorter life than chains. If a belt breaks it can cause a lot of damage on some engines.

6.6 Timing belts & Tensioners

The toothed or synchronous timing belt is used for driving camshafts, balance shafts, water pumps and diesel injection pumps.



It has an inner woven core made from fibreglass, Kevlar, or steel braid, coated with synthetic rubber or neoprene. The teeth which may be square or curved are moulded to close tolerances to match the drive teeth on the crankshaft and timing gears. A moulded plastic cover protects the belt from oil or water contamination.

Timing belts have a high working efficiency due to the low friction properties of their construction. This means they require no lubrication and are silent in operation.

Although it stretches little in use the tension of the timing belt is important. This is normally set with an adjustable idler pulley that applies tension via a spring. This pulley is fixed to the engine by a fastener. Adjustment is performed manually after the timing belt is installed.

Timing belts should be checked and replaced according to manufactures specifications.

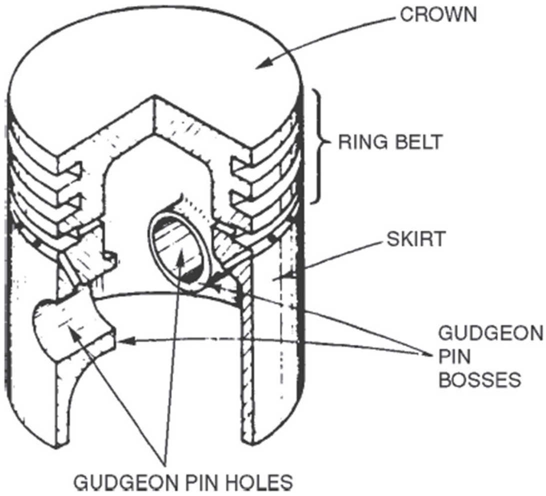
6.7 Pistons

The piston with its connecting rod and bearing transfers the force of the combustion and expansion of the power stroke to the crankshaft.

The piston itself, its rings and the piston or gudgeon pin are together called the piston assembly.

The shape of the piston crown depends on the shape of its combustion chamber and its compression ratio. In diesel engines the combustion chamber may be formed totally or in part in the piston crown depending on the method of injection so they use pistons with different shapes.

The piston crown may be flat, concave, dome, or recessed. The piston must stand up to great heat and pressure. It also must change direction from about 10 times a second to up to hundreds of times a second. To allow for this many pistons are machined into a slightly oval shape. This is called cam grinding. Then as the piston heats up and expands it becomes round.



Other methods to control expansion include steel struts or ribs, expansion slots in the skirt, or slots called heat dams that restrict movement of the heat.

6.8 Piston Rings

Piston rings keep a tight seal within the cylinder to stop the heat and pressure in there from escaping. They also stop oil passing up into the combustion chamber. New rings and cylinders have minor irregularities and when these wear off the rings will make a better fit.

To help this along the rings can be given a porous coating. It's softer and wears more quickly than the ring material which is usually cast iron. To prevent wear the face of the piston ring can be coated with a harder material like chromium that operates well against cast iron without scuffing. They are split so they can be fitted into grooves in the piston and to expand against the cylinder walls. When they're removed their diameter's larger than the piston's. So when they're installed they're compressed and the gap is almost closed. Tension in the rings keeps them against the walls.

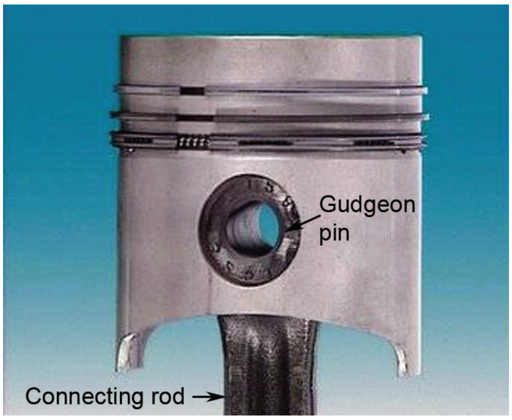
There are 2 main types of piston rings - compression rings and oil rings.

Compression rings must seal against compression loss during the compression stroke or the air-fuel mixture won't be fully compressed. They must also seal properly during the power stroke or combustion gases are forced past the piston into the crankcase. This is called blowby.

Oil-control rings prevent excessive oil working up into the combustion chambers. It can be a one-piece ring that depends on its own tension to hold it against the cylinder walls. Slots in the ring and holes in the piston behind the ring let oil return to the sump.

6.9 Connecting Rod

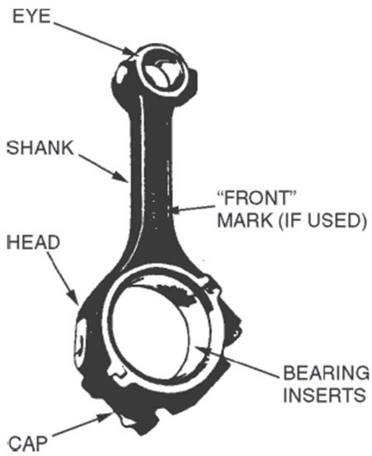
The connecting rod connects the piston to the crankshaft. It is fastened to the piston at its little end by a piston pin also known as a gudgeon pin.



In some engines the pin is a press fit in the small end of the connecting rod. In others it is clamped to the connecting rod with a clamping bolt.

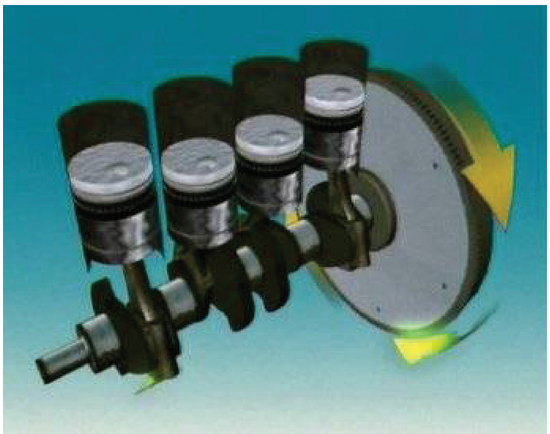
Another method lets the pin float in both the piston and connecting rod and it is held with circlips. There is a bearing in the small end of the connecting rod.

The big end of the connecting rod has a detachable cap and carries 2 halves of the big end bearing. The big end is attached to the crankshaft at the crankpin journal. Connecting rods must be very strong, rigid and as light as possible. They are subject to stretching, compressing and bending, so they are highly stressed.



They are cast or forged to form an "H" near the small end and an I near the big end. This shape provides greater strength to resist the stresses than a solid rod of the same mass. To maintain engine balance all the connecting rods in an engine are a matched set.

6.10 Crankshaft



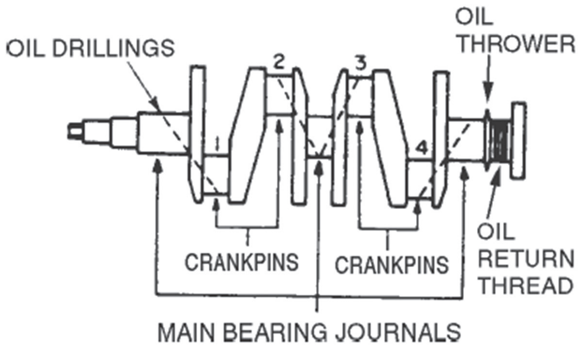
The crankshaft is attached to the connecting rod in offset areas called throws - where the downward power pulses change into rotating motion.

Crankshafts must be strong enough to do this without bending or twisting. They are a one piece casting, or forging, of heat-treated alloy steel of great mechanical strength. Counterweights are formed to balance the throws and also the big end of the connecting rod.

Fine balancing is done by drilling out or adding small weights. The crankshaft rotates in the engine on journals which run in bearings called the main bearings.

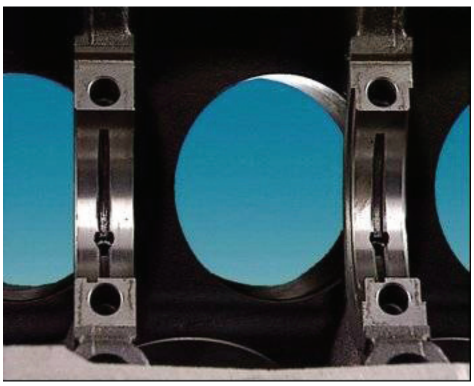
The rear of the crankshaft is drilled and tapped for flywheel attachment. Near the front of the crankshaft a timing gear or sprocket is attached to drive the camshafts.

Many in-line and V engines have a harmonic balancer attached to the crankshaft. The harmonic balancer is more correctly called the crankshaft torsional vibration damper. It prevents crankshaft vibration. In most cases the harmonic balancer incorporates the drive pulley.



6.11 Engine bearings

No engine can run without bearings. Bearings are used in engines to support and protect rotating parts and allow them to turn freely. The connecting rod must be able to spin freely on the crankshaft. The crankshaft must be able to spin freely in the engine block.



Connecting rod bearings and the crankshaft main bearings are called split-sleeve types which means they are in two halves called inserts, slippers or shells.

These precision-inserts have a steel back with a very thin layer of bearing material bonded to it. The bearing material is an alloy that can include metals such as tin, lead, aluminium and copper. Bearings designed for light duty may be made of white metal. It's an alloy of tin and lead, with small amounts of copper and antimony.

Bearings need a difficult mix of properties. They must be hard enough to resist wear but soft enough not to damage the shaft. The soft bearing surface also allows any hard abrasive particles to become embedded in the surface. They can become so deeply embedded; they are prevented from touching the rotating shaft by the film of oil.

In a main bearing the upper half of the bearing fits into a machined section of a crankcase web. The lower half is carried in the bearing cap which bolts onto the crankcase web. One main bearing has thrust faces which accept the end movement of the crankshaft. These can be in the form of flanges that are part of the bearing. Alternatively a separate thrust washer can be fitted into a machined recess in each side of the bearing cap. Sometimes a mating recess for each side is machined into the cylinder block and mating halves fitted to both.

In a connecting rod bearing (big end) its upper half is carried in the big end of the connecting rod. The lower half is in the connecting rod cap.

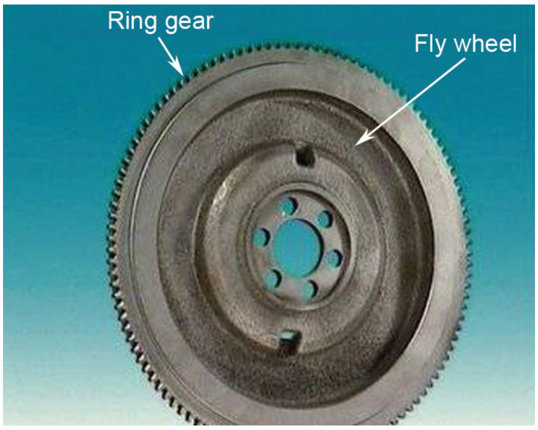
Under normal running conditions, spinning shafts ride on a microscopic wedge of oil. Oil flows through a long gallery in the cylinder block. Each main bearing has its own oil supply passageway from this gallery. Passageways (galleries) drilled in the crankshaft carry oil from the main bearing journals to con rod journals.

Oil flow maintains the oil wedge between the shaft and bearing and carries away particles that could cause wear. Engine manufacturers specify the clearance required between the bearing material and the crankshaft. This clearance gives the best combination of oil pressure and flow.

As clearance increases with wear, oil flow increases, causing oil pressure to drop. Then the shaft may rub against the bearing surface and wear even faster.

6.12 Flywheel

A flywheel is a large rotating mass mounted on the rear of the crankshaft.

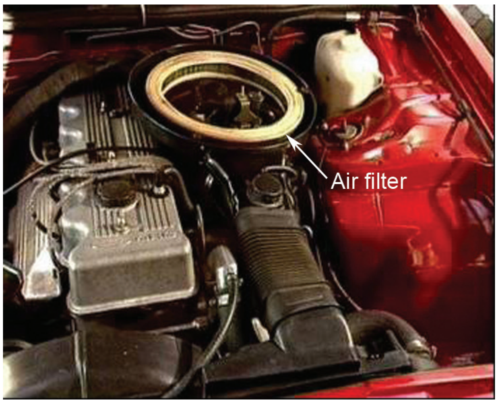


On a car with manual transmission the flywheel is very heavy and its momentum helps smooth out engine operation.

The flywheel links the crankshaft to the transmission through the clutch. The flywheel has a machined rear surface. It is the clutch's main driving member. Holes are drilled and tapped into the flywheel for attaching the clutch pressure plate.

On a car with automatic transmission the flywheel is usually called a drive or flex- plate. The drive plate is lighter than a conventional flywheel because of the weight provided by the torque converter. The outer edge of the flywheel or drive plate has a gear called a ring gear. The electric starter pinion engages on this gear to rotate the engine for starting.

6.13 Air Cleaners



An air cleaner filters air that passes through it to stop harmful particles reaching the engine.

The air cleaner on a carburetted engine can be on top of the carburettor or beside the engine connected to the carburettor by a hose or duct. Position is usually decided by how much space there is or bonnet profile.

On some electronically fuel injected engines the air cleaner is on top of the throttle body similar to a carburettor. Other air cleaners are connected by ducts.

Diesel engines often have more than one air cleaner. This may be due to their severe working conditions. They're usually mounted away from the engine to obtain cleaner cooler air. A lot of air passes through the intake system into the engine. In a petrol engine it's about 15 times the amount of fuel by weight. By volume that's 10,000 times more air than fuel.

The air-fuel mixture enters the engine so the air needs to be clean. Any abrasives that enter the engine can cause wear and damage. It also has a silencing effect muffling noise produced by the air entering the engine. It can act as a flame trap. So if a petrol engine backfires the air cleaner can contain the flame within the intake manifold or carburettor.

6.14 EFI Air Cleaners

An air cleaner on a multi-point electronic fuel injected engine usually has a different shape from that on a carburetted engine but it serves the same purpose.

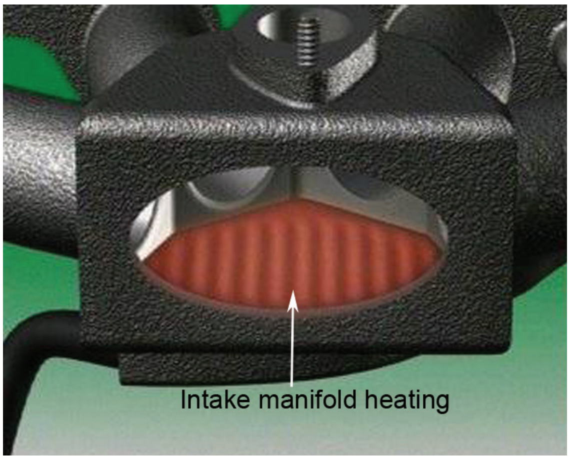
In many vehicles the air cleaner is mounted where it can get cool, clean air. This air is then carried to the throttle body by a long flexible duct.

Inside the air cleaner a filter element of pleated paper filters the air and reduces noise.

Some electronically fuel-injected systems have an airflow sensor after the air cleaner element. It accurately measures all air entering the engine and adjusts the air-fuel mixture accordingly. So it's essential there are no air leaks or it will upset this mixture.

6.15 Intake Manifolds

The intake manifold is usually a metal part with several tubular branches though it can also be made of a special plastic.



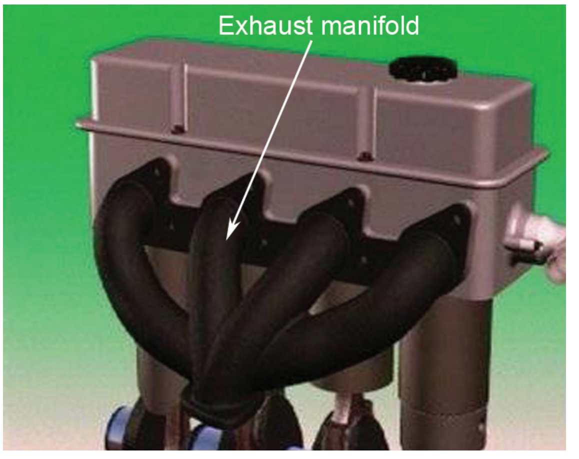
In carburetted engines the intake manifold carries the air-fuel mixture into the engine.

The cross-sectional area of each tube needs to be kept small to maintain the high air speeds that improve vaporization.

At the same time it cannot be too small since that restricts the airflow to the engine at higher speeds.

Electronic fuel injected engines with throttle body injection also have intake manifolds that carry air-fuel mixture.

6.16 Exhaust Systems



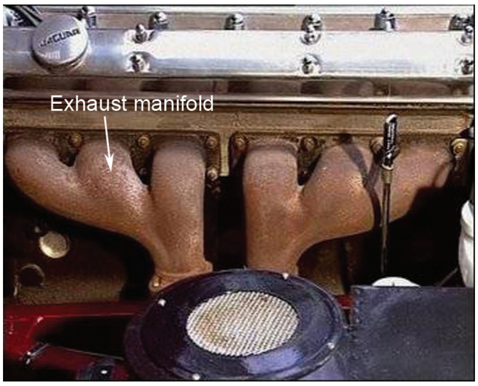
During engine operation, each time the exhaust valve opens, pulses of hot exhaust gases are forced into the exhaust manifold. These hot rapidly expanding gases produce a lot of noise, some of it at very high frequency.

The exhaust system does several jobs. It has to reduce the noise of the exhausting gases to acceptable levels.

It has to discharge the gases safely far enough away to prevent them re-entering the vehicle.

Some of these gases are highly poisonous. In an enclosed space, carbon monoxide can cause death in minutes. It is odourless and colourless, which makes it difficult to detect and removing it is especially important. In modern vehicles, it also keeps harmful emissions to a minimum.

6.17 Exhaust Manifold



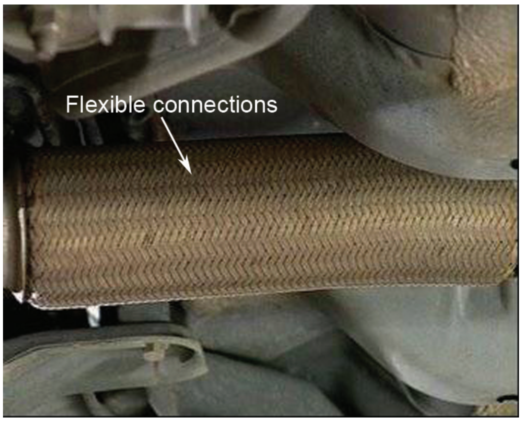
The exhaust manifold is bolted to the cylinder head or onto the exhaust ports. On passenger vehicles the exhaust manifold is usually made of cast iron. Sometimes there is a separate passage for each exhaust port.

The length of the passages in the exhaust manifold should be designed so that pulses of exhaust gases from one cylinder assist the flow of gases from another. It has large tubular sections to improve gas flow and no sharp bends to slow the gases down.

As well the exhaust manifold must be shaped to allow for the location of the engine and the bodywork of the vehicle. Some vehicles use heat shields to protect nearby components and the passenger compartment from the heat radiated from the exhaust components.

6.18 Flexible Connections

There is a flexible connection between an engine pipe and an intermediate pipe. It is used close to the engine.

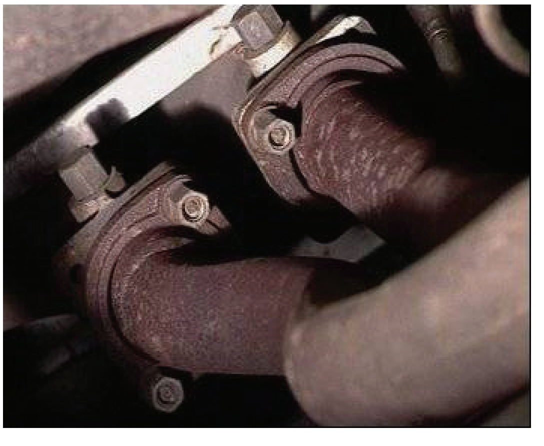


Its main functions are to allow engine movement and reduce vibration without passing it along the exhaust - especially in front wheel drive vehicles. It also helps with the alignment of the pipes.

6.19 Exhaust Pipe

The engine pipe is attached to the outlet of the exhaust manifold. It can be designed to branch in various ways.

The system needs flexible mountings to allow for engine movement and prevent noise and vibration being transmitted into the vehicle body.



On some front-wheel drive systems the exhaust system is designed to be strong enough to form part of the engine mounting system. Rubber mountings are popular because of rubber's natural dampening effect. They also allow for thermal expansion during use.

6.20 Silencer Box

The silencer box is located in the exhaust system between the exhaust manifold and the exhaust outlet.

It is usually made of sheet steel coated with aluminium to reduce corrosion. Some are made of stainless steel.

A silencer box contains perforated pipes, baffles and resonance chambers. Many also contain sound-absorbing material such as fibreglass or wire wool.

Some silencer boxes combine baffles and pipes to change the flow of gases without restricting them. Gases enter through the inlet and must reverse their direction of flow before they exit through the outlet. This is called a reverse-flow silencer box. Some silencer boxes use double outer-skins to minimize heat and noise transmission.

Some exhaust systems use a resonator as well as a silencer box. It looks like a silencer box but it usually has a straight-through design and it contains sound absorbing material. It's designed to remove types of sound that silencer boxes can't remove.

7.0 Compression Ratios

Key Learning Points

- Compression ratios of the throttle-body, port and direct injection petrol engines

7.1 Specific Compression Ratio

Because of the varying compression ratios from different manufacturers for the throttle-body, port and direct injection petrol engines, it is impossible to specify a compression ratio. Therefore, please refer to Automotive Technical Manuals.

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

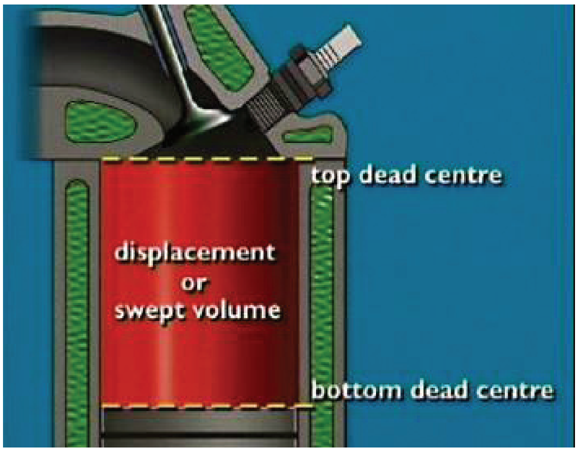
8.0 Calculating the Compression Ratio

Key Learning Points

- Calculation of compression ratios, use of correct formula

8.1 Compression Ratio

An engine's compression ratio can be a guide to the power it can generate.



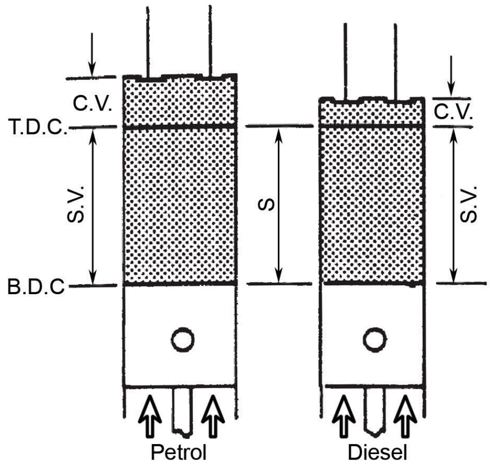
It's not always obvious whether one engine is bigger than another. The size of the engine block can be misleading. Two blocks can be the same size but one has cylinders bored out to larger volumes.

The standard measure of size is called displacement. Displacement is the volume a piston displaces in the cylinder as it moves from its lowest point, or bottom dead centre, to its highest point, top dead centre. This is also called swept volume. Notice that displacement does NOT include the volume above top dead centre.

Engine size is then the sum of the displacements of all of the cylinders of the engine. It is called total engine displacement. For this engine it is 2 litres or approximately 120 cubic inches.

8.2 Compression Ratio Calculation

The compression ratio shows how far the air taken in during the intake stroke is compressed in the cylinder during the compression stroke. In other words, it is the ratio of the cylinder and combustion chamber volume with the piston at BDC to the combustion chamber volume with the piston at TDC. This value is calculated as follows:



$$Compression\ Ration = \frac{Total\ Volume}{Clearance\ Volume}$$

$$Compression\ Ration = \frac{Swept\ Volume + Clearance\ Volume}{Clearance\ Volume}$$

Example

$$Compression\ Ration = \frac{SV + CV}{CV} = \frac{315cc + 32cc}{32cc} = 10.8$$

Compression Ration = 10.8 : 1

9.0 Cylinder Head, Camshaft and Valve Operating Arrangements

Key Learning Points

- Cylinder head; casting materials, combustion chamber design/shape e.g. wedge, hemispherical etc., basic camshaft(s) construction/ design/drive arrangements
- Camshaft removal - refitting to manufacturers recommended procedures, danger of camshaft breakage due to incorrect removal/fitting procedures, valve timing set correctly

9.1 Cylinder Heads

The cylinder head bolts onto the top of the cylinder block where it forms the top of the combustion chamber.

In-line engines of light vehicles have just one cylinder head for all the cylinders. Larger in-line engines can have 2 or more heads.

Just as with engine blocks cylinder heads can be made of cast iron or aluminium alloy.

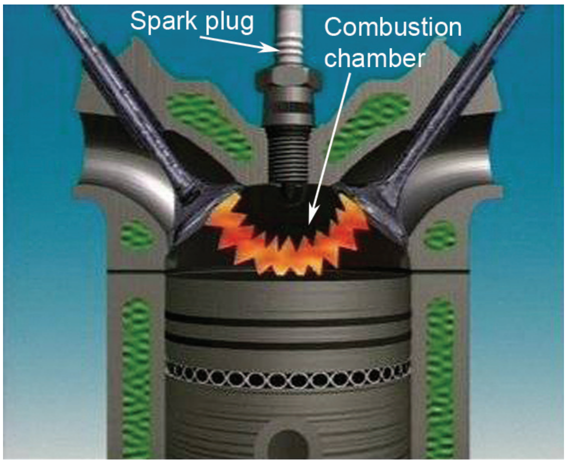
9.2 Cylinder Head Design

Cylinder heads are designed to help improve the swirl or turbulence of the air-fuel mixture and prevent fuel droplets settling on the surfaces of the combustion chamber or cylinder walls.

When air-fuel mixture is compressed between the piston and the flat part of the cylinder head it produces what's called "squish". That means squeezing of the gases to increase their velocity and turbulence.

In petrol engines the three most popular combustion chamber designs are called *hemispherical pent roof, bath-tub and wedge.*

A *hemispherical or pent-roof combustion chamber* has the intake valve on one side of the chamber and the exhaust valve on the other. This provides cross flow. Air-fuel mixture enters on one side and exhaust gases exit on the other. Positioning the valves in this way leaves room for relatively large valves and ports and that helps the engine breathe. Breathing refers to the engine taking in the air or air-fuel mixture. Fuel starts to burn at the plug then burning travels outward in all directions. This is called flame propagation or spread. With the plug in the middle of the hemisphere the flame front has less distance to travel than in some other designs which gives rapid and effective combustion. This design is common in a lot of passenger vehicles.

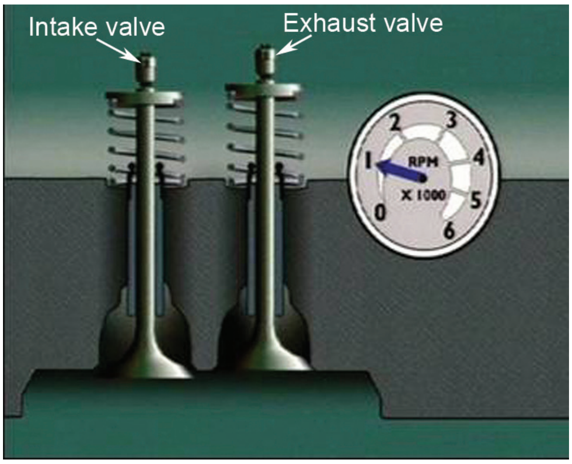


The *bath-tub combustion chamber* is oval-shaped like an inverted bathtub. Valves are mounted vertically and side by side making them simple to operate. The plug is to one side and that creates a short flame path. It all helps increase turbulence.

The *wedge-shaped combustion chamber* tapers away from the plug which is at the thick end of the wedge. The valves are in line and inclined from the vertical. This design usually has a smaller surface area than the others with less area where fuel droplets can condense. Less fuel is left unburned after combustion which reduces hydrocarbon exhaust emissions. And since the flame is directed toward the small end of the wedge, damage caused by detonation is reduced.

9.3 Intake and Exhaust Passages

The size of passages in the head can affect engine output. Smaller intake and exhaust passages and ports allow more torque at low engine speeds. This is because smaller passages improve mixing of air and fuel at low speeds which causes more efficient combustion.



At high speeds however these smaller passages restrict airflow. To reduce the effect of this, this engine has two inlet valves. One opens at low speed and the other operates at higher engine speeds. Larger passages produce greater power at high engine speeds.

When all intake and exhaust ports are on one side, it is called a counter-flow head. They can be cast separately or siamesed.

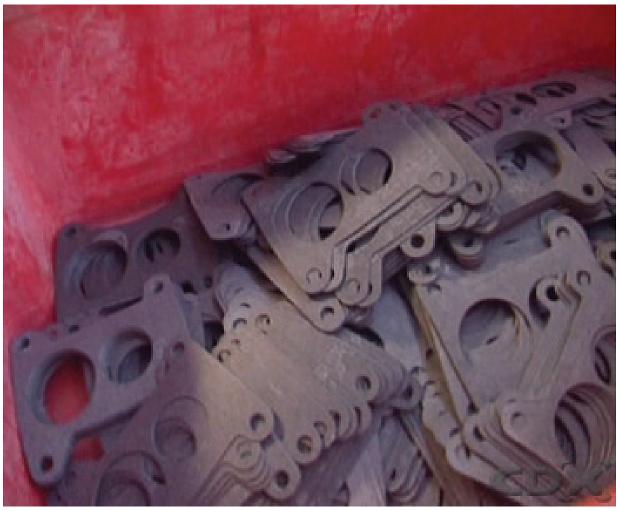
When all of the intake ports are on one side and exhaust ports are on the other, it is called a cross-flow head. This allows for straighter passageways and higher efficiency.

9.4 Gaskets and Oil Seals

Gaskets form a seal by being compressed between stationary parts where liquid or gas could pass. Most gaskets are made to be used only once. They can be made of soft materials such as cork, rubber, paper, heat resistant materials or graphite; or they can also be made of soft alloys and metals such as brass, copper, aluminium or soft steel sheet metal. Such materials may be used individually or in some cases as blends to produce the required functional material.

Some of these modern special materials that are now used for the side layers of head gaskets are designed to withstand temperatures up to 1150 degrees Celsius.

Some joints between surfaces on modern engines are being sealed with special sealants which eliminate the use of gaskets in some applications. Pure rubber or conventional cork-rubber is unable to deal with the stresses and pressures in modern engines.



Gaskets around a rotating part would quickly wear out and leak. To seal these parts oil seals are needed. The most widely used is the lip type dynamic oil seal. It has a shaped dynamic rubber lip that's held in contact with the shaft to be sealed by a circular coil spring called a garter spring.

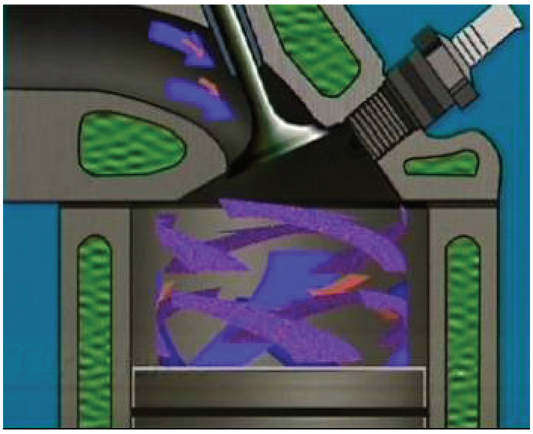
A similar sealing principle is used to seal the valve stem to prevent oil entering the engine combustion chamber. Rotating or sliding shafts can also be sealed by using "O" rings but generally they are not as durable in most applications as the lip-type seal. As a general rule oil seals must be replaced when a component is overhauled.

9.5 Head Gaskets

Head gaskets seal and contain the pressures of combustion within the engine between the cylinder head and the block. Some high temperature head gaskets are designed to conduct heat laterally to transfer heat from the engine to the coolant faster. They are normally constructed with a steel core. Special facing materials are added to both sides of the gasket core to provide a comprehensive seal under varying torque conditions.

9.6 Turbulence

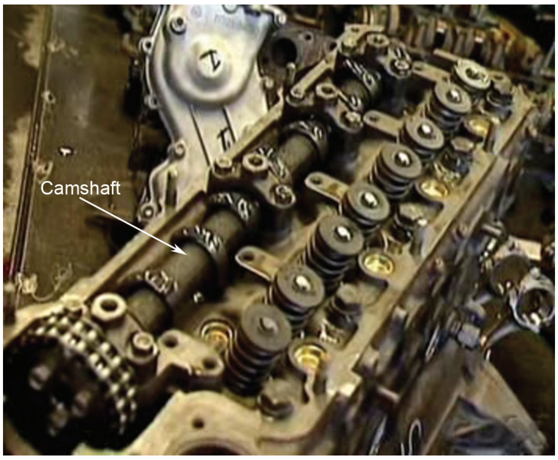
Turbulence refers to the swirling motion of a liquid or a gas.



It helps to maximise the mixing of air and fuel which helps make sure the combustion process occurs efficiently. Without turbulence the air-fuel mixture can form local areas of high pressure and temperature that can cause detonation during combustion. A high level of turbulence can prevent this.

9.7 Overhead Camshaft

In modern engines the pushrod system is being replaced by the simpler overhead camshaft arrangement.

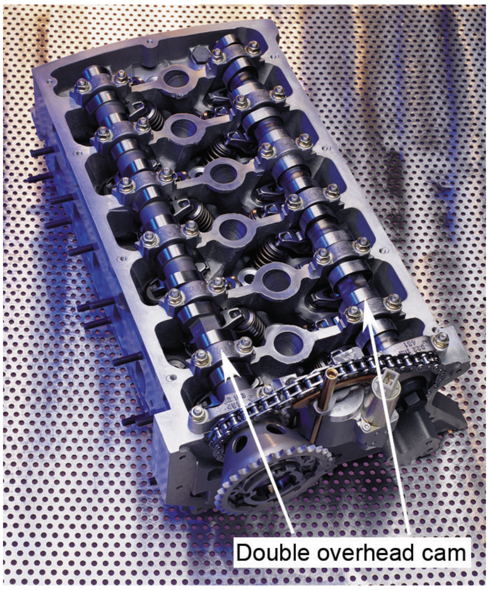


Single overhead cam

The overhead camshaft is located in the cylinder head. There can be 1 or 2 camshafts.

Single overhead camshafts can use rocker arms. The cam can lift one end of the rocker arm or it can press down on the rocker arm.

On double overhead camshaft systems the most common arrangement is to use a bucket tappet or lifter. It operates in a guide that protects the valve against side thrusts which it would receive if the cam operated directly against the valve.



The adjustment of valve clearance is usually done by changing accurately machined spacers. Spacers are available in a range of thicknesses and they're exchanged to obtain the correct clearance. Some overhead cam engines use a hydraulic lash adjuster to reduce lash in the valve train. They have zero clearance at the valve stem so there's no need for tappet adjustment.

9.8 Cam Lobes

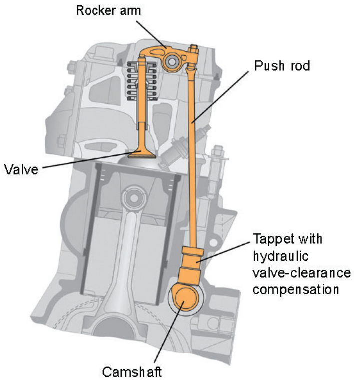
The cam lobe performs 3 jobs. It opens a valve at the proper time and gives it proper lift. It lets it stay open for a sufficient time. Then it lets it close at the proper time. Accurate valve timing is crucial.

Valve timing can vary from engine to engine as set out in manufacturers' specifications in the valve timing diagram.

9.9 Valve Trains

The valve train includes all of the components that are driven from the camshaft to the top of the valves. There are different types of valve trains depending on how many camshafts there are and where they are located.

In an overhead valve or pushrod system the valves are in the cylinder head but when the camshaft is in the block near the crankshaft a valve lifter or tappet rides on the cam. As the cam lobe reaches the lifter, it rises, transfers the motion to the pushrod. This then moves a rocker which in turn pushes the valve open.

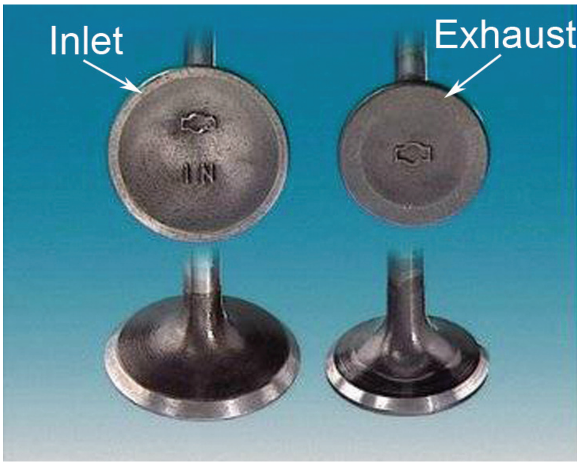


The gap between the valve tip and the valve train is called valve clearance or valve lash. This must be maintained when the cam is not applying pressure to open the valve. It can be adjusted on some engines with a screw and locknut built into the rocker arm. These adjustments are needed regularly.

Many engines now use hydraulic valve lifters. Their purpose is to make the engine quieter and eliminate the need for valve clearance adjustment. When the engine is operating, oil under pressure from the engine's lubrication system is supplied to the lifter.

9.10 Valves

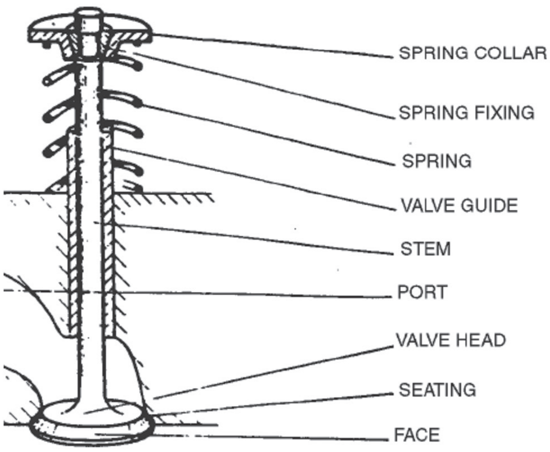
Petrol engines must control the flow of combustible mixture they take in and when it goes in.



Diesel engines are different. Their power and speeds are controlled by the amount of fuel injected so it isn't necessary to control airflow into the intake manifold.

Almost all 4-stroke petrol and diesel engines use valves which are located in the cylinder head.

Valves experience enormous stress even in normal conditions. In a 4-cylinder car driven at around 90 kph each valve opens and closes about 30 times a second. Exhaust valves withstand huge temperatures and they can become red-hot.



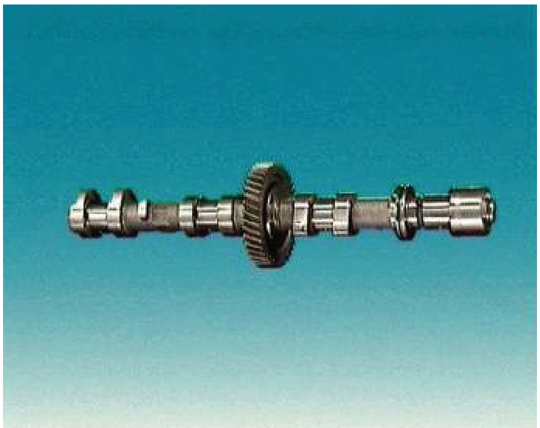
A valve must not soften at high temperatures. It needs good hot strength to stand up to being forced against the seat and to prevent tensile failure in the stem. It needs good fatigue properties to overcome cracking.

Inlet valves are made of steels mixed with chromium or silicon to make them more resistant to corrosion and manganese and nickel to improve their strength. Exhaust valves are made of nickel-based alloys. Some high performance applications use especially hard-wearing titanium alloys.

9.11 Camshafts & Drives

The position of the camshaft depends on the design of the engine. It can be in the engine block close to the crankshaft - this is called a pushrod or overhead valve system. Or there can be one or two camshafts mounted in the cylinder head.

The camshaft is made of hardened iron alloy or steel some is made from chilled cast iron and it can be cast or machined. The cam lobes are ground to the proper shape and position in relation to one another.

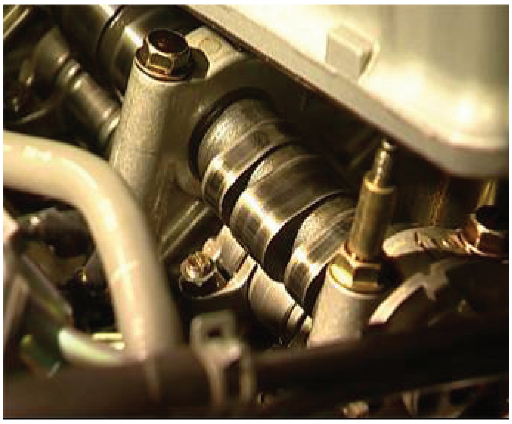


When removing and refitting the camshaft always refer to manufactures recommendations as there is a danger of camshaft breakage due to incorrect removal/fitting procedures.

The camshaft has a cam for each valve. In some cases there is an additional cam known as an eccentric to operate the fuel pump. A gear on the camshaft drives the ignition distributor and often an oil pump.

9.12 Variable Valve Timing

Engines with fixed valve timing can only operate most efficiently at one specific speed. Engines that can vary valve timing and/or valve lift can operate efficiently at a wider range of speeds and deliver better performance at high speeds with a flatter torque curve.



There are two types of variable valve timing or VVT – cam phasing and cam changing.

Cam phasing VVT varies valve timing by shifting the phase angle of the camshaft. At high engine speeds the inlet camshaft phasing can be rotated in advance to enable earlier intake therefore increasing the amount of valve overlap. This is controlled by the engine management system and actuated by hydraulic valve gears.

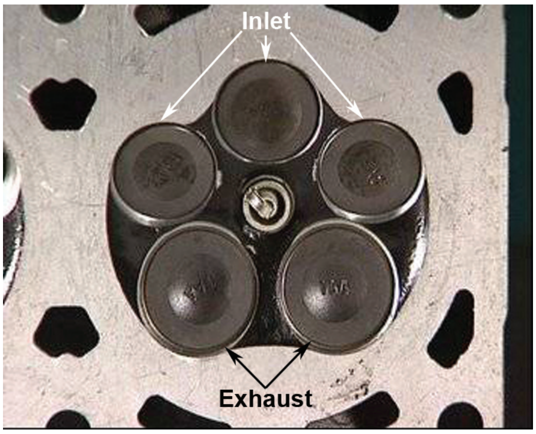
Cam changing VVT uses different cam profiles to lift the valves depending on engine load and speed. One common system uses two rocker arms for normal operation on its two intake valves with a third higher profile and rocker arm between the other two arms. At engine speeds above 5000 to 6000 rpm the engine ECU activates an oil pressure controlled pin that locks the three rocker arms together. The centre rocker arm follows a larger and more aggressive profile transferring its movement to the intake valves which now open further and for longer.

When engine speeds fall below the threshold speed oil pressure is removed from the pin and a spring deactivates the pin. The rocker arms are no longer locked together and the valves are controlled by the less aggressive outer lobes.

Cam changing VVT can also be used in a similar way to deactivate a second intake valve at low engine speeds increasing the velocity and swirl of the air/fuel mixture as it enters the combustion chamber.

9.13 Intake Valves

Intake valves pass only air or air-fuel mixture so they run at much lower temperatures than exhaust valves.



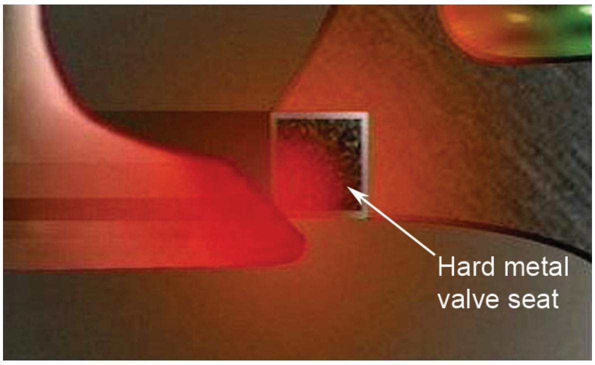
They are usually larger than exhaust valves because the pressure forcing the charge into the cylinder is much lower than the pressure forcing the exhaust gases out of the cylinder. Exhaust gases under pressure need much less space.

Different engines use different valve combinations.

Having more than one inlet valve provides better breathing. An additional inlet valve allows larger inlet passages and a freer flow into the cylinder so the engine receives a better charge.

Similarly, two exhaust valves mean the cylinder can be designed with larger exhaust ports, which provides a freer flow of exhaust gases out of the cylinder.

9.14 Valve Seats



A poppet or mushroom valve has 2 main parts a stem and a head. It fits into a port in the head. Its face makes a gas-tight seal against the seat.

During operation the head near the face of the valve (through conduction) transfers heat to the seat. Some is conducted up into the valve stem. The stem transfers heat on to the guide so the stem is the valve's coolest part.

The valve seat and guide are also cooled by coolant in passages around the valve ports.

When a valve does not seat properly there's a smaller area where heat transfer can occur. That means the face will overheat. Local hot spots can reach such extreme temperatures that the edge of the valve can actually burn. The width of the valve seat is important. A narrow seat is desirable because a thin circular contact with the valve face forms an efficient seal.

But a wider seat is better for transferring heat from the valve to the cylinder head. A common compromise is for the inlet valve to have a narrower seat than the exhaust valve.

9.15 Valve Seats in Cylinder Heads

In some cast-iron cylinder heads the seats are cut directly into the edge of the valve port. These valve seat areas are machined from the metal of the cylinder head. In some engines the valve seat area is hardened during manufacture.

In others hard metal valve seat inserts are pressed into the machined holes. Valve seat inserts are metal rings that match the shape of the valve. They are usually made of an iron alloy. They are used in aluminium cylinder heads to provide a sealing surface for seating the valve.

The faces of the valve are ground at an angle of 45 degrees or 30 degrees. Some engines use 30 degrees or 45 degrees face angles for inlet valves and 45 degrees for exhaust valves.

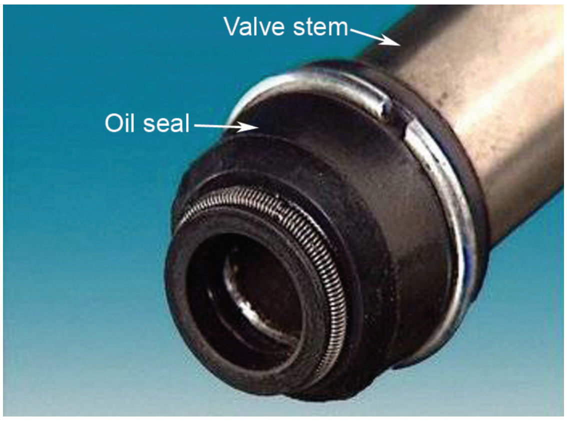
9.16 Valve Rotation

As the valve opens and closes it has a natural tendency to rotate very gradually so that it keeps seating in a new place. This produces a slight wiping action which helps keep the face and seat free of carbon. It also helps prevent sticking in the valve guide and distributes heat around the valve seat.

Many heads use replaceable valve guides that are a form of metal bush pressed into holes in the cylinder head. Other cylinder heads have guides cast as part of the cylinder head then bored to the size of the valve stem during manufacture.

9.17 Valve Stem Oil Seals

Oil seals are fitted to the valve stems or the guides on both intake and exhaust valves. They prevent too much oil passing down into the combustion chamber.



The coil spring on the outside holds the sealing edge against the valve stem. The angle at the top of the seal forms a small reservoir of oil to lubricate the stem and guide. Umbrella seals shed the oil and keep it away from the end of the valve guide. Worn seals or guides or too much valve-guide clearance will let oil pass the intake valve.

The inlet valve is more likely to pass oil through its guide than the exhaust valve. This is because of the low pressure in the inlet port that draws in the oil.

Valves are normally held on their seats by 1 or 2 coil springs that are compressed between the cylinder head and a retainer on the valve stem.

The spring retainer is held on the end of the valve stem by conical shaped collets. Collets are also known as cotters, keepers or keys. The springs usually have their coils closer at the bottom than the top. This makes different parts of the spring vibrate at different frequencies and prevents wasteful valve spring vibration. They can also be made of wire with an especially shaped strong section that limits valve bounce.

10.0 Tensile, Compressive and Shear Force Identification

Key Learning Points

- Stress; examples of engine components that involve, tensile, compressive or shear stress

10.1 Tensile, Compressive and Shear Force

Nature of Stress

Direction of the loading indicates the type of stress. The main type of stresses are:

- Tensile
- Compressive
- Shear

Basically three different types of stresses can be identified. These are related to the nature of the deforming force applied on the body. That is whether they are tensile compressive or shearing.

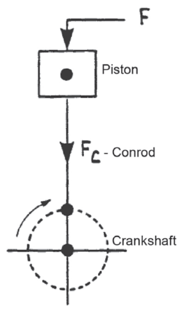
Compressive Force

Compression force is defined as the pressure felt by an underlying object. This is a force that is exerted upon an object from the outside Example: Piston acting on the conrod while on the compressive stroke.

Compressive Force

Maximum force on pistons at T.D.C. of power stroke (F)

F_C = compressive force in Conrod.



This compressive force (F_C) at this point has a tendency to compress or shorten the Conrod.

Note: $F_C = F$

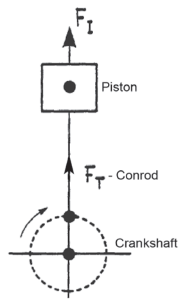
Tensile Force

Tensile force is the force which is transmitted through a string, rope, or wire when it is pulled tight by forces acting from each end. The tensional force is directed along the wire and pulls equally on both ends of the wire. An example within the engine would be the connecting rod when the piston is pulled down the cylinder during intake.

Tensile Force

Piston at T.D.C. end of exhaust stroke.

Upward inertia force (F_I) produce a tensile force on Conrod (F_T).

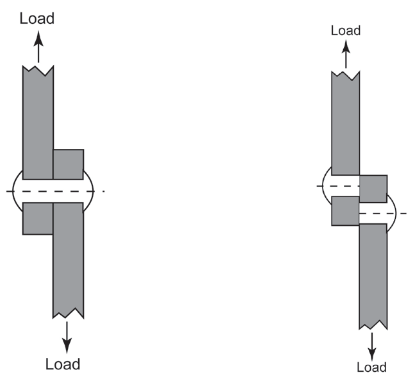


Tensile force on rod at this point has a tendency to stretch the Conrod.

Note: $F_I = F_T$

Shear Force

The picture below shows a rivet joining two pieces of metal together. The forces acting on the two pieces of metal are trying to pull them apart. Because the loads are not exactly in line thy are said to be off-set and the load on the rivet is called a shearing load. That is the rivet is said to be in shear. If the rivet material does not have sufficient shear strength to resist the loads, the rivet will break and the loads will move apart as shown. The same effect can be caused by loads pushing on the ends of the pieces of metal joined by the rivet. An example with the engine would be crankshaft sprocket being rotated by the timing belt. The force exerted of the sprocket would be shear force.



Self Assessment

Q1: Inlet and exhaust valves are generally located in the: (Tick ONE box only)

- ❑ 1. Inlet and exhaust manifolds
- ❑ 2. Cylinder head
- ❑ 3. Cylinder block
- ❑ 4. Crankcase

Q2: Which component acts as a reservoir of oil for the engine? (Tick ONE box only)

- ❑ 1. The rocker cover
- ❑ 2. The sump or oil pan
- ❑ 3. The crankcase
- ❑ 4. The cylinder block

Q3: What is the purpose of the shroud on some diesel inlet valves? (Tick one box only)

- ❑ 1. To promote turbulence in a petrol engine
- ❑ 2. To promote turbulence in a diesel engine intake system
- ❑ 3. To promote turbulence in a two stroke engine
- ❑ 4. To promote turbulence in a diesel engine exhaust system

Q4 What advantages do alloy heads have over cast iron ones? (Tick one box only)

- ❑ 1. They do not warp as easily but are able to dissipate heat more easily
- ❑ 2. They are heavier but able to dissipate heat more easily
- ❑ 3. They are lighter and able to dissipate heat more easily
- ❑ 4. They are lighter but are not able to dissipate heat easily

Q5: During cranking the starter motor pinion gear meshes with the: (Tick one box only)

- ❑ 1. Cluster gear
- ❑ 2. Ring gear
- ❑ 3. Idler gear
- ❑ 4. Timing gear

Q6: Horizontally-opposed engines have: (Tick one box only)

❑ 1. 1 crankshaft and 2 banks of cylinders
❑ 2. 1 crankshaft and 1 bank of cylinders
❑ 3. 2 crankshafts and 2 pistons per cylinder
❑ 4. 2 crankshafts and 2 banks of cylinders

Q7: The intake manifold on a conventional petrol engine carries: (Tick one box only)

❑ 1. Air and fuel
❑ 2. Fuel only
❑ 3. Air only
❑ 4. Fuel and water

Q8: What assists in controlling lateral movement of the crankshaft? (Tick one box only)

❑ 1. Main bearing shells
❑ 2. Big end bearings
❑ 3. Crankshaft lateral bearings
❑ 4. Crankshaft thrust bearings

Q9: The injectors in multi-point fuel injection usually spray fuel directly into the: (Tick one box only)

❑ 1. Air cleaner
❑ 2. Intake port
❑ 3. Throttle body
❑ 4. Engine cylinder

Q10: Dry cylinder sleeves are used in some engines because they: (Tick one box only)

❑ 1. Allow cam-ground pistons to be fitted
❑ 2. Reduce the effects of expansion
❑ 3. Improve heat transfer
❑ 4. Can be made of harder material

Q11: Cylinder blocks are usually made of either iron or: (Tick one box only)

❑ 1. Steel
❑ 2. Copper
❑ 3. Aluminium
❑ 4. Titanium

Q12: What is the main benefit claimed for a wet sleeve? (Tick one box only)

- ❑ 1. Heat is transferred directly to the coolant
- ❑ 2. It is easier to re-bore than a cast sleeve
- ❑ 3. The wet sleeve doesn't corrode as quickly
- ❑ 4. The cooling water cannot enter the sump

Q13: What is the main design feature of the hemispherical combustion chamber? (Tick one box only)

- ❑ 1. Only pushrods and rockers can be used
- ❑ 2. Only overhead camshafts can be used
- ❑ 3. Valves are inclined at about 90º to each other
- ❑ 4. The valves are side by side and in line

Q14: The main reason for fitting a gasket between two surfaces is to: (Tick one box only)

- ❑ 1. Form a seal between two mating parts
- ❑ 2. Provide for large misalignment of parts
- ❑ 3. Allow rapid heat transfer
- ❑ 4. Prevent distortion of mating surfaces

Q15: The exhaust valve seat is made wider than the inlet valve seat because: (Tick one box only)

- ❑ 1. The seat pressure is higher
- ❑ 2. The exhaust valve seat is subject to higher temperatures in operation
- ❑ 3. The intake valve is cooled by incoming mixture
- ❑ 4. A wider seat allows the use of high-lift cams

Q16: Oil is more likely to pass down the inlet valve stem than the exhaust because: (Tick one box only)

- ❑ 1. The inlet valve runs cooler
- ❑ 2. The inlet valve has more stem clearance
- ❑ 3. The inlet valve is exposed to fuel
- ❑ 4. Of low pressure created in the inlet ports

Q17: Holes may be drilled in the crankshaft between the main bearing journals and the crankpins to: (Tick one box only)

- ❑ 1. Eliminate stress
- ❑ 2. Assist crankshaft cooling
- ❑ 3. Reduce torsional vibration
- ❑ 4. Carry oil to the big end bearings

Q18: How is the soft bearing surface of engine slipper or shell bearings protected from damage by the hardened crankshaft? (Tick one box only)

- ❑ 1. The crankshaft runs on a thin wedge of oil
- ❑ 2. The bearing work-hardens
- ❑ 3. Anti-wear additives protect the bearings
- ❑ 4. Small particles prevent metal to metal contact

Q19 The camshaft of an overhead valve train is driven by: (Tick one box only)

- ❑ 1. Timing sprocket
- ❑ 2. Timing gear
- ❑ 3. Timing chain or belt
- ❑ 4. Timing idler belt or sprocket

Q20: Injectors for diesel engines spray fuel into the: (Tick one box only)

- ❑ 1. Intake manifold
- ❑ 2. Combustion chamber
- ❑ 3. Air cleaner
- ❑ 4. Exhaust manifold

Q21: The component that operates between the valve and the camshaft in an overhead cam engine is the: (Tick one box only)

- ❑ 1. Pushrod
- ❑ 2. Rocker arm
- ❑ 3. Valve spring retainer
- ❑ 4. Valve rotator

Q22: Internal Electrolysis and/or corrosion damage of the engine cylinder block and engine cylinder head can be prevented by the use of: (Tick ONE box only)

- ❑ 1. Pure de-mineralized water in the cooling system
- ❑ 2. A chemical based coolant in the cooling system
- ❑ 3. A sealed radiator system
- ❑ 4. A copper cored radiator

Q23 Automotive engines rely on a high or low co-efficient of friction for effective performance? (Tick ONE box only)

- ❑ 1. High
- ❑ 2. Low

Q24: Which is the most common oil filtering system employed on automotive vehicles? (Tick ONE box only)

- ❑ 1. Full flow
- ❑ 2. By-pass
- ❑ 3. Half-pass
- ❑ 4. Treble-pass

Q25: Technician A says that the camshaft turns at half the speed of the crankshaft. Technician B says that the camshaft turns at the same speed of the crankshaft. Who is correct? (Tick ONE box only)

- ❑ 1. Technician A
- ❑ 2. Technician B
- ❑ 3. Both Technician A and Technician B
- ❑ 4. Neither Technician A nor Technician B

Q26: The primary function for the engine water pump is to: (Tick ONE box only)

- ❑ 1. Circulate the coolant through the engine
- ❑ 2. Pressurize the cooling system
- ❑ 3. Circulate the coolant when the thermostat is closed
- ❑ 4. Pump the heated coolant into the heater core

Q27: To return the inlet and exhaust valves to their seats after opening by the cam, most four stroke engines use: (Tick ONE box only)

- ❑ 1. Pressure differential
- ❑ 2. Gravity
- ❑ 3. Springs
- ❑ 4. Mechanical levers

Q28: In a four-stroke engine, which stroke occurs immediately before the power stroke? (Tick ONE box only)

- ❑ 1. Combustion
- ❑ 2. Exhaust
- ❑ 3. Intake
- ❑ 4. Compression

Q29: The terms 'bottom dead centre' and 'top dead centre' refer to the position of the: (Tick ONE box only)

- ❑ 1. Connecting rods
- ❑ 2. Crankshaft
- ❑ 3. Camshaft
- ❑ 4. Pistons

Q30: The purpose of the crankshaft is to: (Tick ONE box only)

- ❑ 1. Convert reciprocating motion into rotary motion
- ❑ 2. Join the connecting rods to the pistons
- ❑ 3. Allow continuous movement of the pistons
- ❑ 4. Hold the connecting rods together

Q31: The component that joins the piston to the crankshaft is the: (Tick ONE box only)

- ❑ 1. Connecting rod bearing
- ❑ 2. Connecting rod
- ❑ 3. Gudgeon pin
- ❑ 4. Main bearing

Suggested Exercises

- Use an electronic data facility to procure manufacturer's appropriate data for use with practical exercises
- Dismantle an engine to industry recommended procedures
- Identify its components; mark/identify parts, as recommended, for correct assembly
- Identify cams, firing orders, strokes, valve operating mechanisms etc. and reassemble the engine
- Given swept volume and clearance volume values, calculate compression ratios

Training Resources

- Technical information in book/electronic form on the Internal Combustion engine principle/cycle of operation (4 stroke), multi-cylinder unit design and principles of assembly techniques
- Bench unit engines, secure on suitable support stands
- Related tools e.g. torque spanners, ring squeezers etc.
- Practical training demo units/components

Task Sheets

Testing Cylinder Compression

Preparation and Safety

Objective

Safely perform a cylinder compression test.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Before performing a compression test, disable the ignition system to prevent electrical shock.
- Be aware of moving drive belts and accessories when the engine is being cranked.
- If you have a helper cranking the engine make sure they only crank it when you tell them to.
- Make sure the compression tester will safely handle the compression of the engine you are testing. Diesel (CI) engines operate at much higher compression pressures than petrol (SI) engines.

- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- Be sure to follow the vehicle and equipment manufacturer's compression testing procedure.
- Select the proper adapter for the engine you are testing. Make sure it matches the 'reach' of the spark plugs.
- When refitting the spark plugs to aluminium heads, use anti-seize compound on the spark plug threads.
- Reinstall the spark plugs by hand to prevent cross threading. Make sure the spark plugs thread into the hole, 5 complete threads (once they 'start') before using a ratchet, or tension wrench to tighten them.
- Always torque the spark plugs to the manufacturer's specifications.
- Re-enable the ignition system and start the vehicle to verify proper engine operation.

Step-by-step Instruction

1. *Prepare the vehicle*: Locate the specified testing procedure for the vehicle you are working on and check the engine is at normal operating temperature. Locate the spark plugs & remove the high-tension leads. Make sure you can identify the correct leads for each cylinder. Remove each spark plug and place them on a bench in the correct order.
2. *Perform a 'dry' test*: Attach the compression tester to the first cylinder and have an assistant crank the engine at full throttle. Note your findings. Repeat this test for each cylinder in turn.
3. *Perform a 'wet' test*: Insert a small amount of engine oil into the first cylinder and re-attach the compression tester. Have an assistant crank the engine again and note your findings. Remove the compression tester from the first cylinder and cover the cylinder opening with a rag to catch any residual lubricant from the cylinder already tested. Repeat this test for each cylinder in turn. Take your findings to your instructor.

4. *Inspect the spark plugs*: Inspect the spark plugs and using an appropriate reference chart; note any problems with each plug.

5. *Reassemble the engine*: Reassemble the engine with either new or cleaned spark plugs. Refit the high-tension leads in the correct order.

6. *Start the engine*: Start the engine to make sure the leads has been refitted in the correct firing order and that the engine runs correctly.

Checking Idle Speed

Preparation and Safety

Objective

Check and compare engine idle speed with the manufacturer's specifications.

Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

If you are not certain what are appropriate or required, ask your instructor.

Safety Check

- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always make sure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- Checking the idle speed can only be done with a tachometer, which measures the engine revolutions per minute (rpm). Most modern vehicles are fitted with a built-in dashboard tachometer, but if the vehicle you are working on does not have this feature, use a separate inductive type tachometer that attaches to the engine. The manufacturers of these tools provide specific instructions on how to do this. You will need to adjust this external tachometer for your particular engine cylinder configuration and type of ignition system. This will give you an accurate measurement of the number of engine revolutions per minute.
- "Kicking" the throttle once the engine has warmed up will help allow the engine to settle into its normal idle condition. Note the reading again. "Kicking" gives you an accurate reading of the normal idle speed. In some systems, the automatic choke system does not cut out until the throttle has been depressed. Also, "kicking" the throttle and letting the engine settle again will confirm that the vehicle does not have a sticky throttle cable that may give you a false idle reading.

Step-by-step Instruction

1. *Start the engine and note idle speed*: Switch on the ignition and start the engine from cold. Without revving the engine, note the rpm reading from the tachometer once it has stabilized and is running smoothly.

2. *Rev the engine briefly and note speed again*: Allow the engine to warm up to its normal operating temperature and note the idle speed again. Kick the throttle briefly to rev the engine and let it settle back to idle speed and note any change in the tachometer reading.

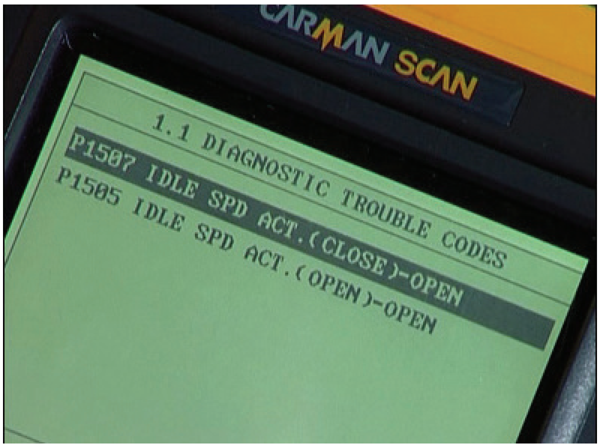
3. *Compare readings with specifications*: Compare your idle speed readings with the specifications in the vehicle workshop manual. If your readings are outside the acceptable range, this could indicate a problem in the air or fuel system and should be reported to your instructor.

Obtaining & Interpreting Scan Tool Data

Preparation and Safety

Objective

Retrieve, record and clear stored OBD I & II diagnostic trouble codes using a scan tool.



Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

If you are not certain what are appropriate or required, ask your instructor.

Safety Check

- If the vehicle is to be run inside the workshop use exhaust extraction hoses.
- Output solenoids can be energized from the scan tool, activating components without warning. It is imperative that the operator should follow the service manual procedures.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- Make sure that you follow service manual procedures for the vehicle you are working on.
- The standard procedure for retrieving codes for an OBD I vehicle, is to access the codes, write them down, clear the codes, start the vehicle and recheck for any codes that reset.
- The standard procedure for diagnosing an OBD II vehicle is different as it requires that the codes should NOT be cleared until the vehicle is repaired. Clearing the codes also clears all of the freeze frame data in the system that is useful for the diagnosis process.
- It may take several 'trips' for the code to reset, so with OBDII you must complete the diagnosis process first before clearing the codes.
- Always check for any applicable service bulletins when diagnosing computer related problems, as they can provide valuable information about new faults that emerge on vehicles as their operational characteristics change as the vehicles get older.

Step-by-step Instruction

1. *Connect the scan tool*: Locate the scan tool access point and connect the scan tool using the appropriate connector for the vehicle. Turn on the vehicle ignition. Turn on the scan tool. Run the scan tool diagnostic program and navigate through each of the different systems in turn to access the diagnostic trouble codes from the vehicles electronic control module. Note your findings for each vehicle system.
2. *Check your findings*: Look up what each code means and present the information to your instructor. Any fault indicated by the

diagnostic trouble codes will need to be corrected before you clear the codes.

3. *Clear fault codes*: To clear the fault codes from the vehicle; select the delete codes option on the scan tool. Check that the codes have cleared and turn off the vehicle ignition.

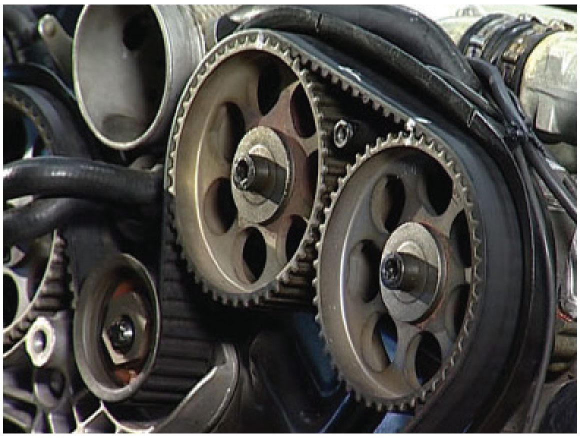
4. *Recheck for fault codes*: Turn on the vehicle ignition. Run the scan tool diagnostic program and navigate through each system again to check the codes do not reactivate. If the fault codes reactivate, take your findings to your instructor. Turn off the vehicle ignition. Turn off the scan tool and disconnect from the access point.

Removing & Replacing a Cam Belt

Preparation and Safety

Objective

Safely remove and replace a cam belt.



Personal Safety

Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

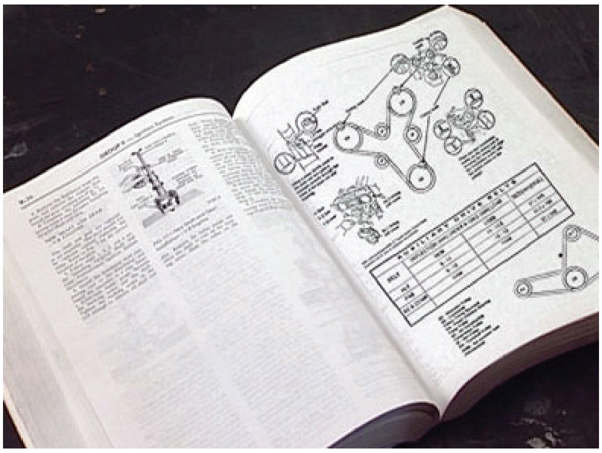
- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Never perform any service tasks on the engine while it is running.
- When turning the engine by hand, make sure your hands and fingers do not get caught between the timing belt and pulley.
- In order to access the timing cover and belt, it may be necessary to remove the power steering pump and/or the air conditioning compressor. Always refer to the manufacturer's manual for the correct removal and refitting procedure.
- Always wear protective clothing and the appropriate safety equipment.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

- Cam belts are primarily used on overhead camshaft engines.
- Some manufacturers have single overhead cam (OHC) double Overhead Cam (DOHC) and overhead valve (OHV) versions of the same engine. If this is the case a cam belt (although of different length) will be used on all versions of the engine.
- The number of pulleys driven by the cam belt will differ from manufacturer to manufacturer. A simple OHC fitment will have three pulleys: Crankshaft, camshaft and tensioner. Whereas a complex DOHC "v" engine fitment will have 8 pulleys: One crankshaft, four camshafts and three idler pulleys.



- Use the manufacturers recommended cleaning instructions. Some camshaft and crankshaft pulley damper units are dissolved by solvents.

- Always follow manufacturer's recommendations regarding cam belt change intervals and replacement procedures.
- Cam belts should be kept in their packaging until required. They should be stored in an environment that has minimal humidity, consistent temperatures and is free from dust and oil contamination.
- Do not bend, twist or crimp a cam belt, as the damage will result in premature failure.
- Before fitting a new cam belt, make sure the drive pulleys are clean and free from damage and wear.
- Make sure that idler and tension pulleys turn freely and are correctly aligned.
- If a cam belt is to be reused make sure it is refitted so it turns in the same direction as before.
- Some cam belts have directional arrows and aligning marks on their outer surface to assist with fitment and engine timing.
- After fitting a new cam belt the tension pulley or adjuster should be near its minimum adjustment. If it is not, check for correct fitment.
- Always double check the various timing marks on the timing gears and timing belt for correct positioning before turning the engine over.
- Always turn the engine in its normal direction of rotation. Turning the engine in reverse may cause the spring-loaded tensioner to slacken and cause the belt to jump teeth on its pulleys.
- If an engine is undergoing repairs that require the cam belt to be removed and the belt is within 10,000 km of the manufacturer's replacement interval, the belt should be changed.
- Always refit the cam belt cover once the replacement is complete otherwise the service life of the belt will be severely reduced.

Step-by-step Instruction

1. *Disconnect the battery*: Locate the battery and its negative terminal. Loosen the terminal clamp and remove the terminal from the battery post. Store the terminal so it cannot come in contact with the battery post.
2. *Remove drive belts and cover*: Remove any drive belts located at the front of the engine to gain full access to the timing belt cover.
   - Turn the engine by hand to top dead centre for number 1 cylinder firing.
   - Loosen and remove the front pulley attached to the crankshaft.
   - Loosen the fasteners that locate the timing belt cover and remove it.
3. *Remove the timing belt*: Loosen the belt tensioner and pry it away from the belt and re-tighten the fastener to prevent it from springing back and placing tension on the belt. Remove the timing belt.
4. *Fit timing belt*: Place the belt over the pulleys and position it correctly. Make sure that the crankshaft is still at top dead centre and the camshaft aligning marks are correctly aligned. Manufacturer's service manuals normally have a diagram to follow.
5. *Adjust tensioner*: Slowly loosen the fastener that secures the belt tensioner and allow it to slide gently back against the cam belt. Turn the engine by hand in the direction of normal rotation for at least two complete turns to allow the tensioner to find its correct tension. Lightly tighten the fastener so it cannot move.
6. *Check the timing marks*: Reposition the engine at top dead centre for number one cylinder firing and check that the location of all the timing marks are still in accordance with the manufacturers directions. Now tighten the tensioner-securing fastener to the recommended torque.
7. *Refit timing cover*: Replace the timing cover and refit any fasteners. Refit the front pulley and tension to the correct torque and replace any ancillary drive belts to drive ancillary equipment in accordance with vehicle specifications.
8. *Start engine*: Start the engine and check for correct operation.

Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- http://www.cdxglobal.com/
- http://auto.howstuffworks.com/
- http://www.autoshop101.com/
- http://www.cdxetextbook.com/
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.

Notes

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