

Basic Engine



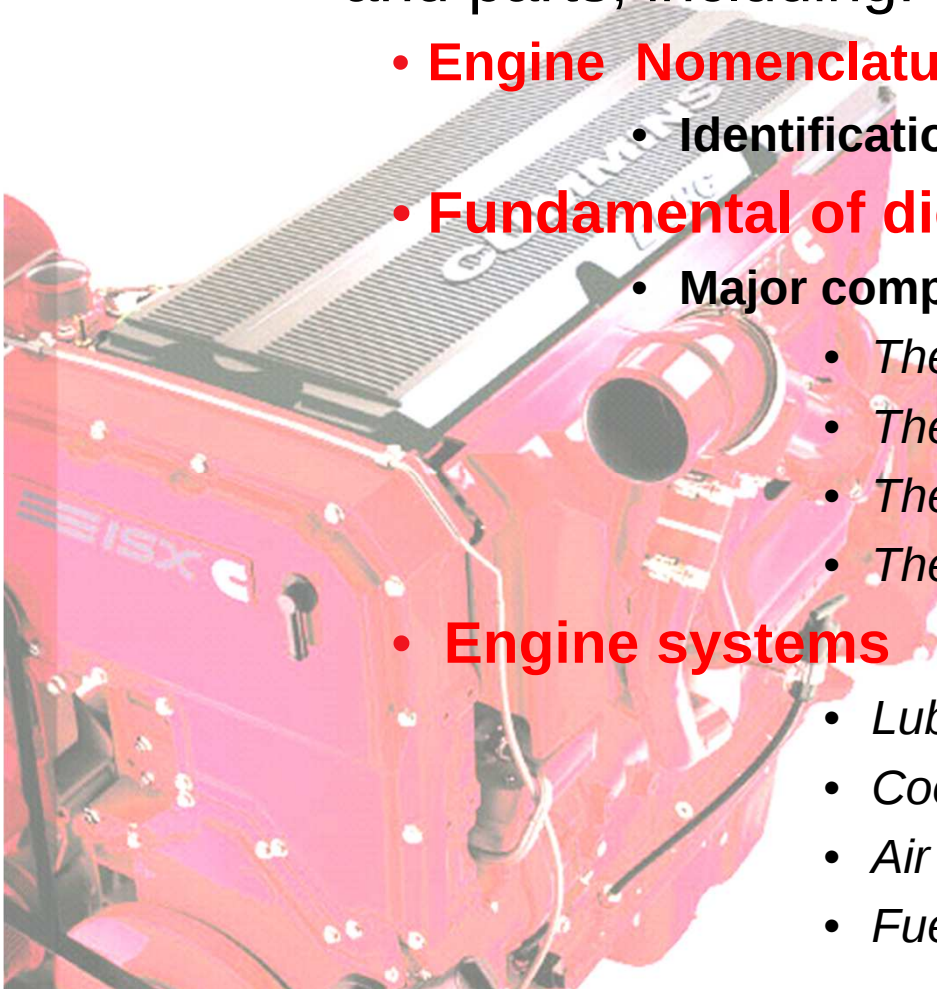
Version 2.0

Learning Objectives



Understand Cummins engine operation and parts, including:

- **Engine Nomenclature**
 - Identification and type
- **Fundamental of diesel engine operation**
 - Major component of diesel engine
 - *The block group*
 - *The head group*
 - *The end and pan group*
 - *The accessories group*
- **Engine systems**
 - *Lubrication*
 - *Cooling*
 - *Air*
 - *Fuel*



CUMMINS PRODUCT LINE



Cummins classifies its engines into three groups according to displacement:



- *Midrange (below 9L)*
- *Heavy Duty (10-15L)*
- *High Horse Power (19L and above)*

Each grouping serves designated markets. however; there tends to be overlap. For example; the majority of engines used in power generation are the High Horsepower group. Some smaller power gen engines fall into the MidRange and Heavy Duty categories as well.



Engine Families

A Series

C8.3/ ISC/ QSC

M11/ ISM/ QSM

ISX/ QSX

QST30

Natural Gas Engines

B Series/ ISB/ QSB

L10/ ISL/ QSL

N Series

K Series/ QSK

QSV

Engine Nomenclature

QS = **Q**uantum **S**ystem. Industrial engine

Operates electrically; “off-highway.”

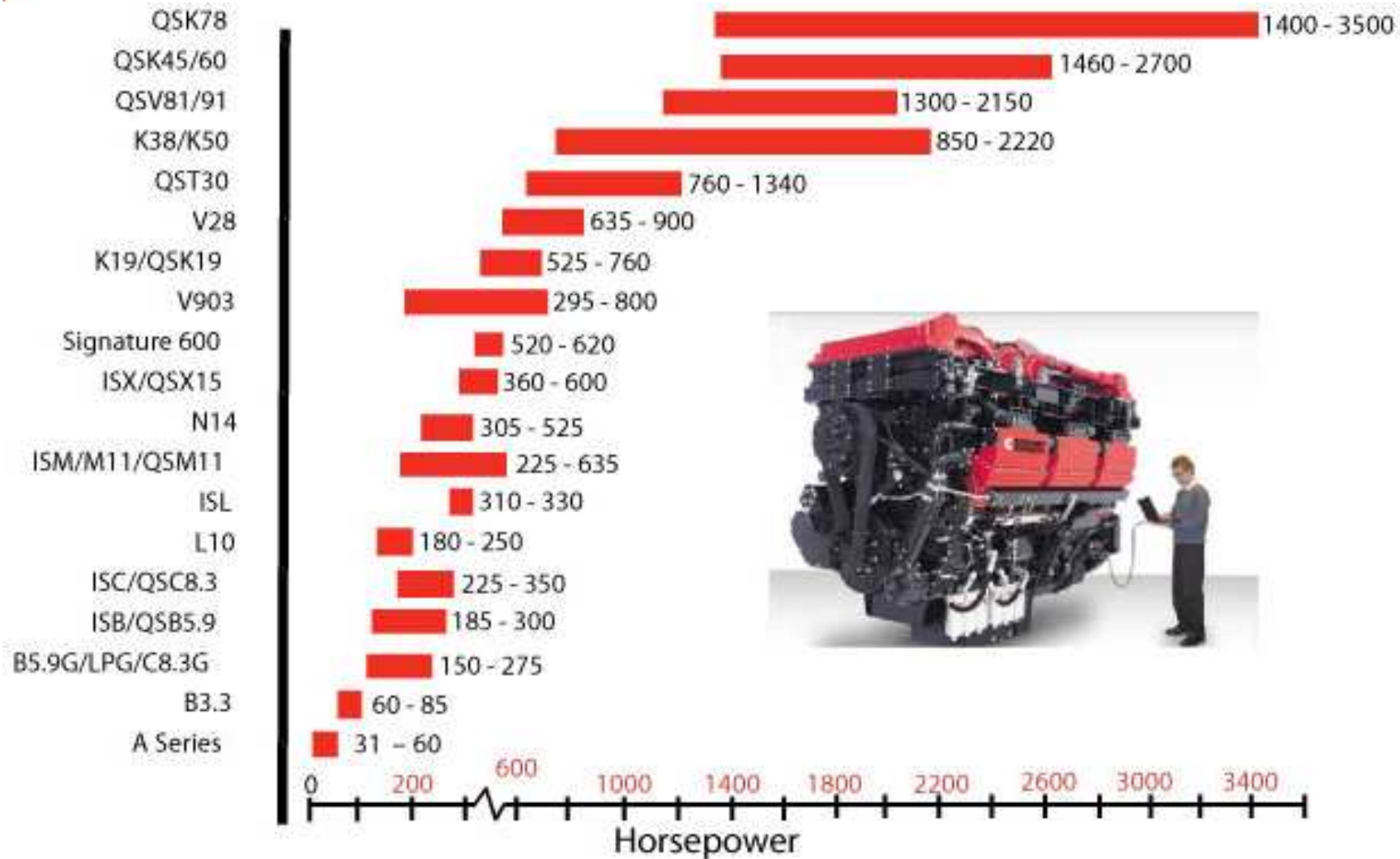
Examples: QSB, QSC, QSL, QSM, QSX, QSK, QSV

IS = **I**nteract **S**ystem. Automotive, operates electrically; “on-highway.”

Example: ISB, ISC, ISL, ISM, ISX



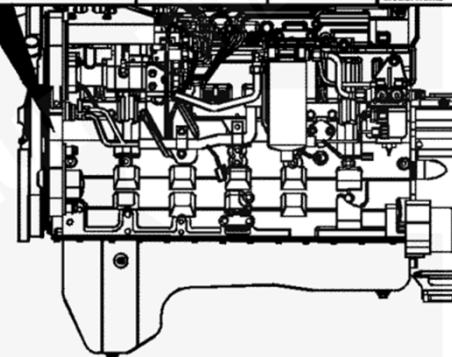
What engines do we sell?



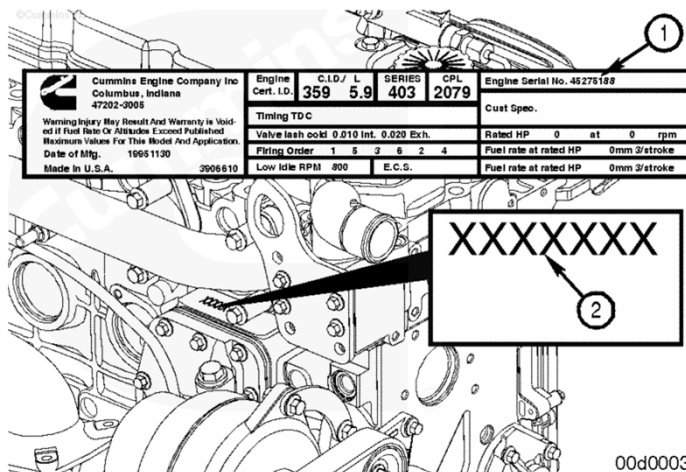


Engine Identification

Cummins Engine Company, Inc. Box 3005 Columbus, Indiana 47202-9005 Warning: Injury May Result And Warranty Is Voided If Fuel Rate Or Altitudes Exceed Published Maximum Values For This Model And Application. Date of Mfg. _____ Made In U.S.A.	Engine Cert. I.D.	C.I.D. / L	SERIES	CPL	Engine Serial No.
	Timing TDC				Injector P/N.
	Valve lash cold int. Exh.				Cust. Spec.
	Firing Order				Rated HP at rpm
	Low Idle RPM				Fuel rate at rated HP mm 3/stroke
	E.C.S.				Model Name

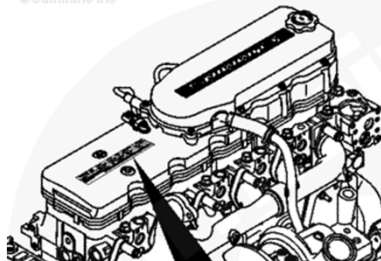


00d00001



00d00032

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MANUFACTURED BY CUMMINS INC. 	Engine No.	Ref. No.	MODEL	Fuel Rate at Adv. HP	CPL		
	Idle Speed (rpm)	Advised HP	at rpm	Family	FEL	EPA	CARB
	Date of Mfg.	Timing - T.D.C. ELECTRONIC	Catalyst No.	E.C.S.			
	Valve lash cold int. Exh.				C.I.D. L. /	E.C.S.	PM
	WARNING: Injury may result and warranty is voided if fuel rate, rpm or altitudes exceed published maximum values for this model and application.						
	IMPORTANT ENGINE INFORMATION: This engine is exempt from the prohibitions of section 267 (a) (1) (2) & (4) of the Clean Air Act as amended. See Exemption Label information for Exemption No. And Effective Date.						

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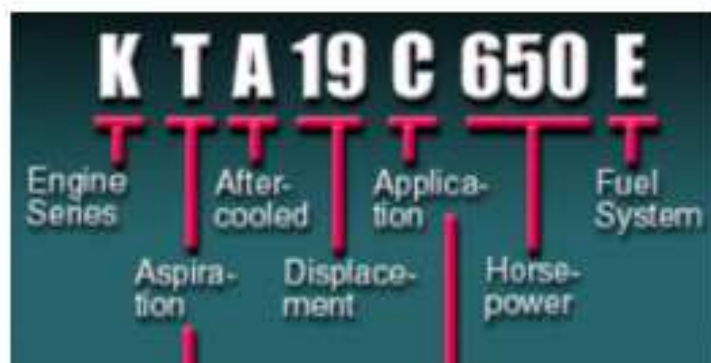


Identify Cummins® nomenclature & data plates location

The Cummins® engine nomenclature provides the data as illustrated in the graphics.

NOTE: The following letters designate some of the different market applications for a Cummins® engine.

For example,



*For **aspiration**, T=turbocharged, TA=turbocharged & aftercooled

***Displacement** is listed in liters.

***Application:** A=agricultural
L=locomotive

C=construction
M=marine

F=fire pump
R=rail car

G=generator
P=industrial power unit



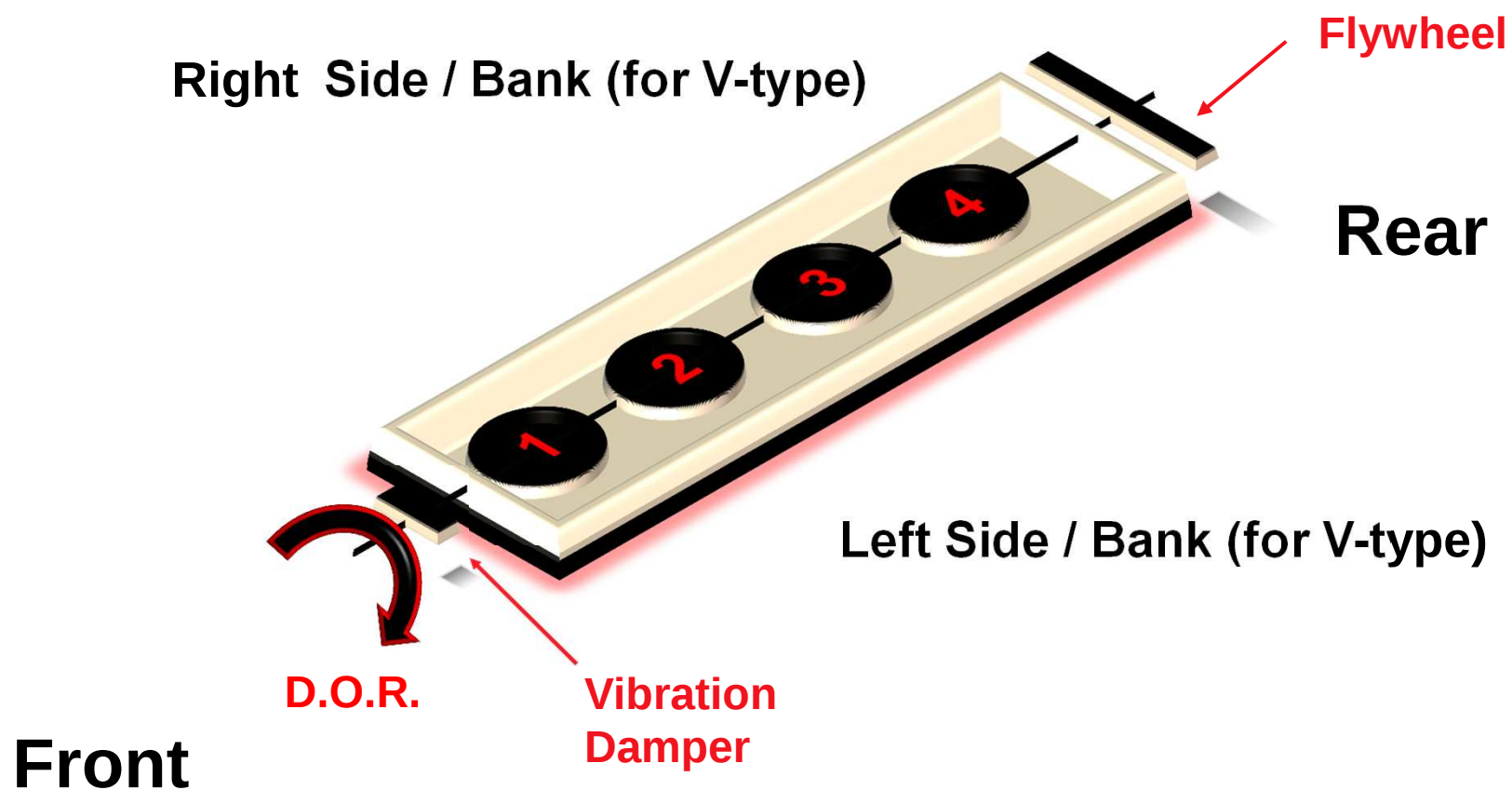
Cummins Applications in Thailand Example:





Engine Identification

(view from TOP side of Engine)





What is an Engine ?

A mechanism for converting **HEAT ENERGY** (e.g.. fuel) into useful **MECHANICAL WORK**.

What are the Elements for Combustion ?

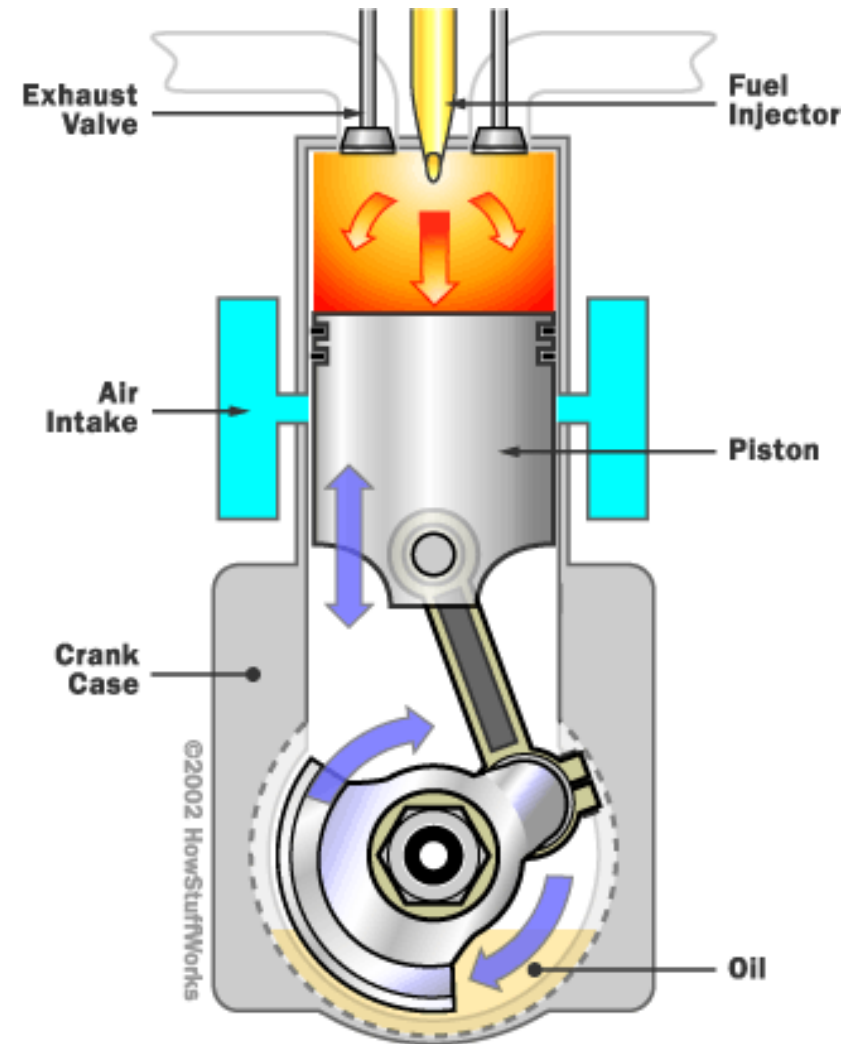
IN PROPER RATIO →	ELEMENTS + STROKES = COMBUSTION		
	AIR	INTAKE	HEAT
	FUEL	COMBUSTION	WORK
	HEAT	POWER	
		EXHAUST	

Engine Introduction

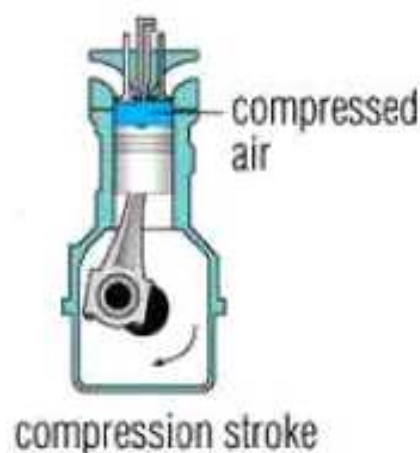
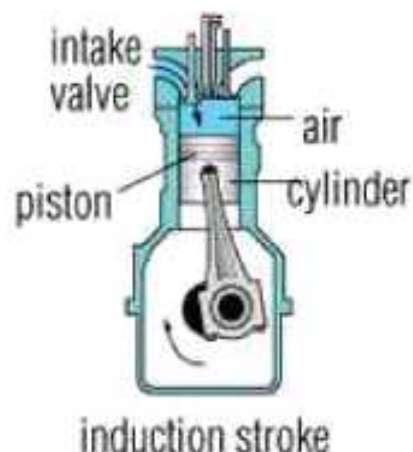


The Two-Stroke Diesel Cycle

1. When the piston is at the top of its travel, the cylinder contains a charge of highly compressed air. Diesel fuel is sprayed into the cylinder by the injector and immediately ignites because of the heat and pressure inside the cylinder.
2. The pressure created by the combustion of the fuel drives the piston downward. This is the **power (expansion) stroke**.
3. As the piston nears the bottom of its stroke, all of the exhaust valves open. Exhaust gases rush out of the cylinder, relieving the pressure.
4. As the piston bottoms out, it uncovers the air intake ports. Pressurized air fills the cylinder, forcing out the remainder of the exhaust gases.
5. The exhaust valves close and the piston starts traveling upward, re-covering the intake ports and compressing the fresh charge of air. This is the **compression stroke**.
6. As the piston nears the top of the cylinder, the cycle repeats.

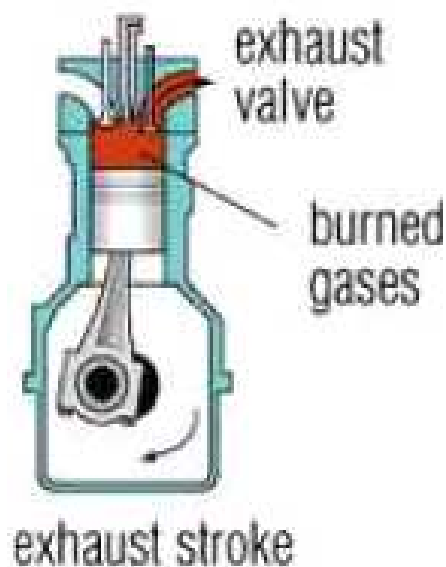
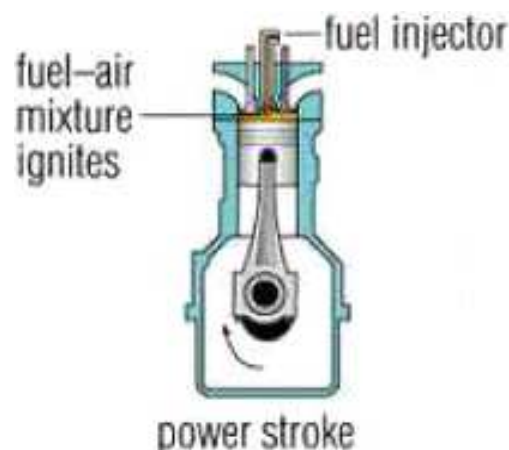


The Four- Stroke Engine Cycle



1. The **induction (intake) stroke** begins as the piston is at the top of the cylinder, and the intake valve begins to open. As the piston moves downward, air is drawn into the cylinder through the intake valve. The piston reaches the bottom of its stroke, and as the crankshaft continues to turn, the piston begins moving
2. The upward movement of the piston closes the valves, compressing the air in the cylinder. Pressure increases and the temperature rises to about 1650°F, far above the temperature needed to ignite diesel fuel. This is the **compression stroke**.

The Four- Stroke Engine Cycle

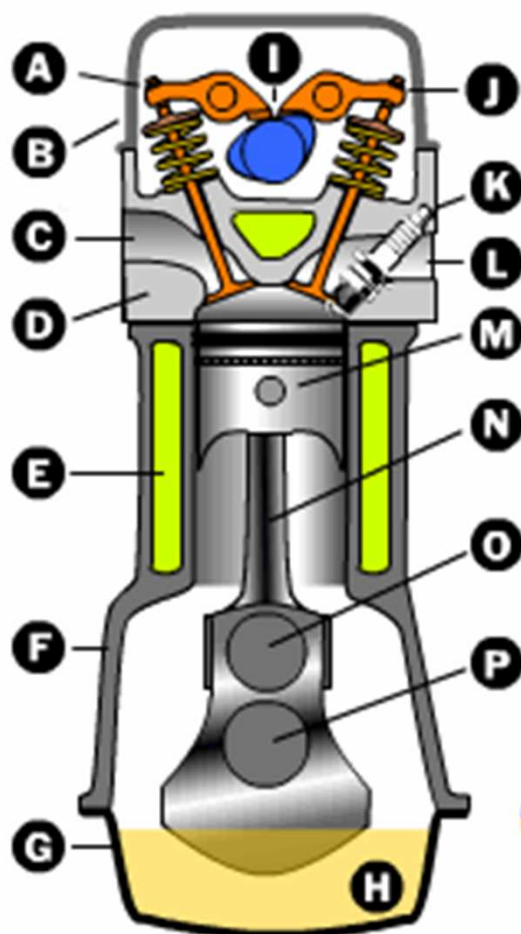


3. As the piston nears the top of the cylinder, fuel is injected into the hot, pressurized air. The high temperature and pressure cause the fuel to suddenly ignite in a combustion reaction with the air. The rapid release of energy due to combustion causes a further increase in the pressure in the cylinder, forcing the piston down. This is the **power (expansion) stroke.**

4. As the piston nears the bottom of its stroke, the exhaust valve begins to open. The four-cycle stroke is completed as the piston again moves upward, this time with the exhaust valve open, forcing the combustion products (burned gases) out of the cylinder. This is the **exhaust stroke.** As the piston nears the top of the cylinder at the end of the exhaust stroke, the exhaust valve closes, the intake valve opens, and the air intake stroke begins again.



The Four- Stroke Engine Cycle

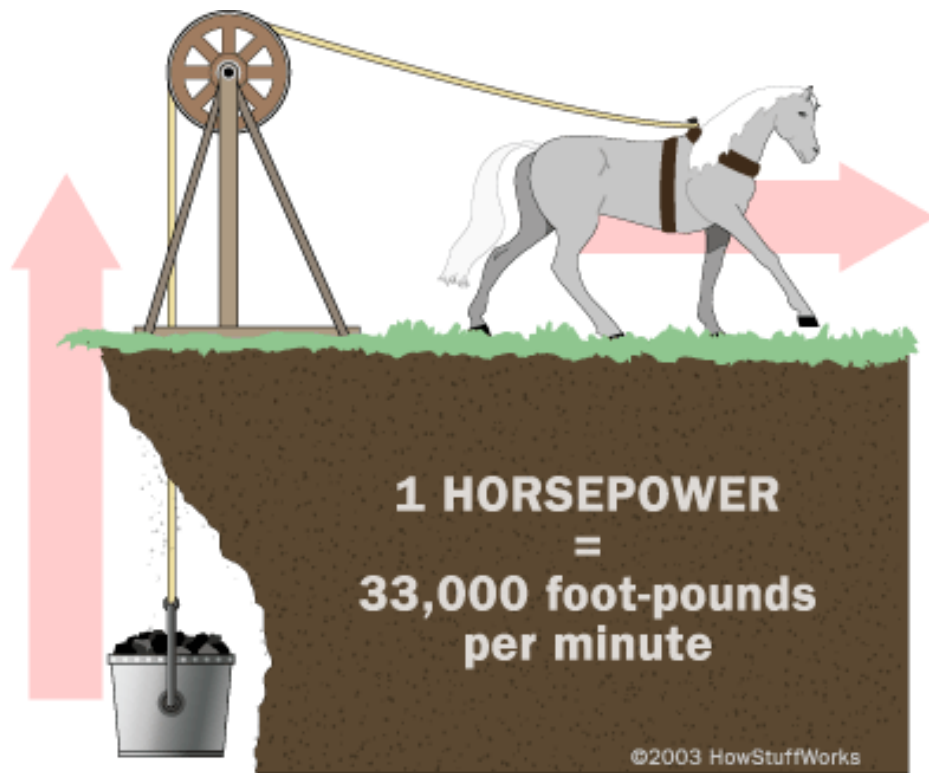


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- | | |
|--|---|
| A Intake Valve, Rocker Arm & Spring | I Camshaft |
| B Valve Cover | J Exhaust Valve, Rocker Arm & Spring |
| C Intake port | K Spark Plug |
| D Head | L Exhaust Port |
| E Coolant | M Piston |
| F Engine Block | N Connecting Rod |
| G Oil Pan | O Rod Bearing |
| H Oil Sump | P Crankshaft |

- 1** INTAKE
- 2** COMPRESSION
- 3** COMBUSTION
- 4** EXHAUST
- Spark**
- Top Dead Center**

Engine Introduction



Horsepower

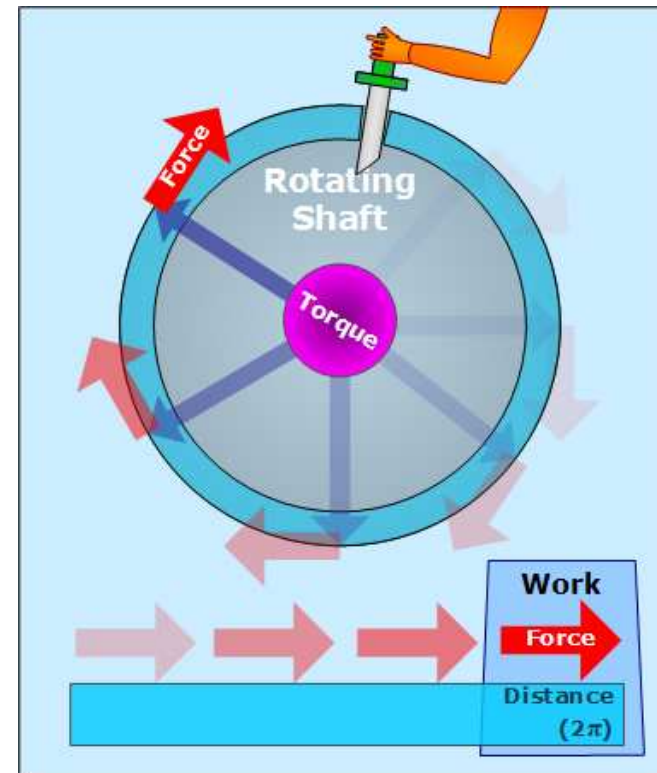
- A unit of measure of engine performance.

Engine Introduction



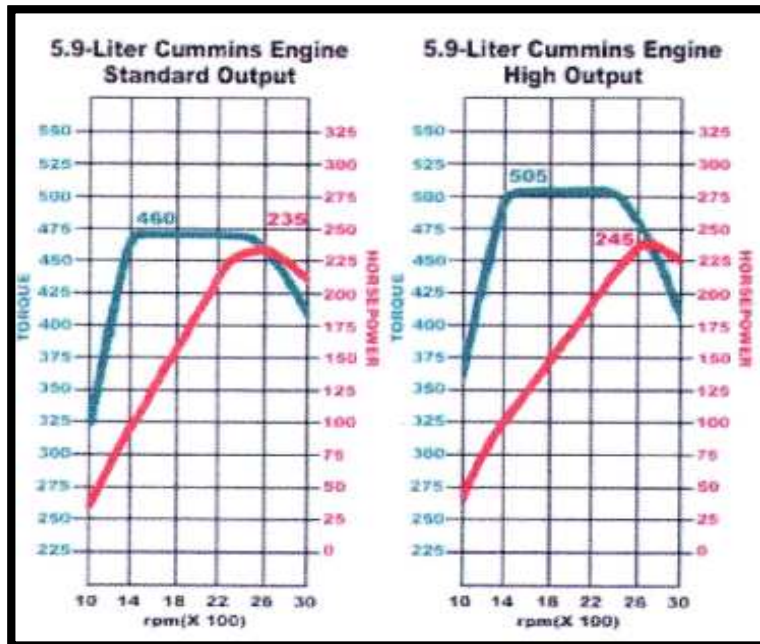
Torque

- A measure of the force of rotation of a driven shaft.



$$\text{Torque} = \text{force} \times \text{distance}$$

Engine Introduction



$$\frac{(\text{TORQUE} \times \text{ENGINE SPEED})}{5,252} = \text{HORSEPOWER}$$

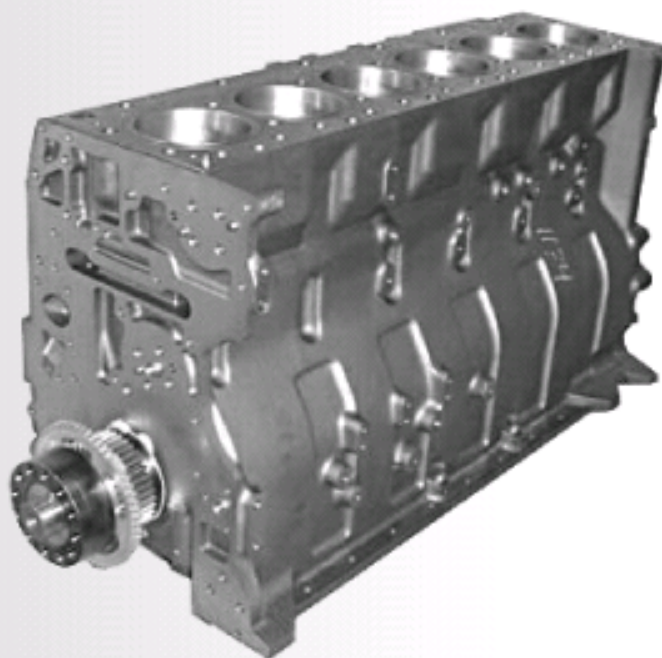
Major component of diesel engine

- The block group
- The head group
- The end and pan group
- The accessories group



The Block Group

Cylinder Block and Cylinders



Structural foundation of the engine.

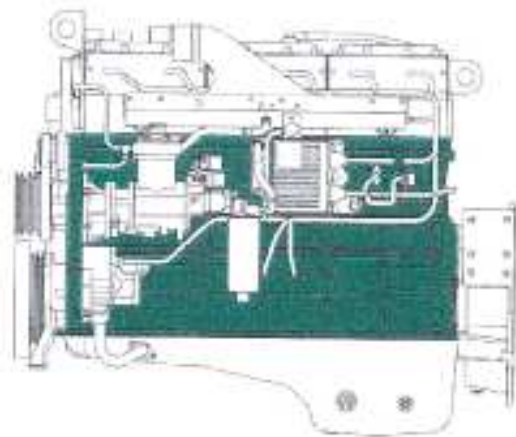
The cylinder block consists of 2 basic sections:

The cylinder and the crankcase.

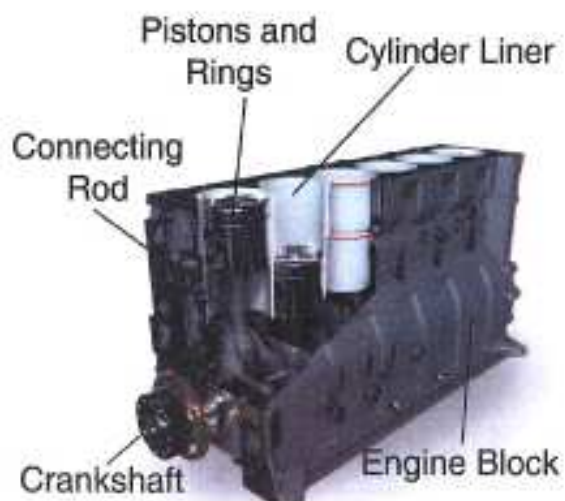
- The **cylinder section** contains cylinder bores, top deck, lower deck and an outer wall.
- The **crankcase section** contains skirts which enclose the crankcase. The bottom edge of skirts provide pan rails which connect the oil pan to the engine.



The Block Group



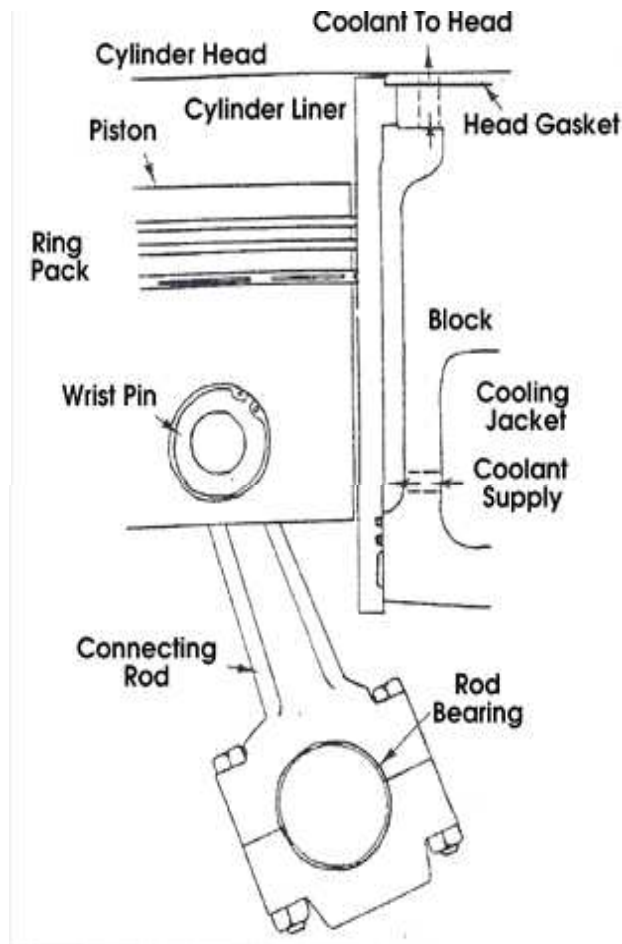
Components in the Block Group



The **cylinder** is a round, straight-sided cavity in the engine block in which the piston ride.

Multiple cylinders are arranged side by side in the engine block and lined with a hard metal. They are housed in the outer wall of the cylinder block between the top deck and the lower deck. In heavy-duty machined and pressed into the block

The Block Group



Cylinder Liner

Holds the cylinder inside the cylinder block.

A cylinder liner is typically cast from gray iron, and can be either wet or dry.

❖ The majority are **wet liners**, which have grooves on the outside surface to provide a coolant seal. They have better cooling and a more even temperature distribution.

❖ **Dry liners** press against the metal surface of the cylinder block itself, and do not come in contact with coolant.





The Block Group

Piston

Lubricated sliding shaft that fits tightly inside the opening of a cylinder



The piston changes the volume enclosed by the cylinder, exerts a force on a fluid inside the cylinder and covers and uncovers ports.

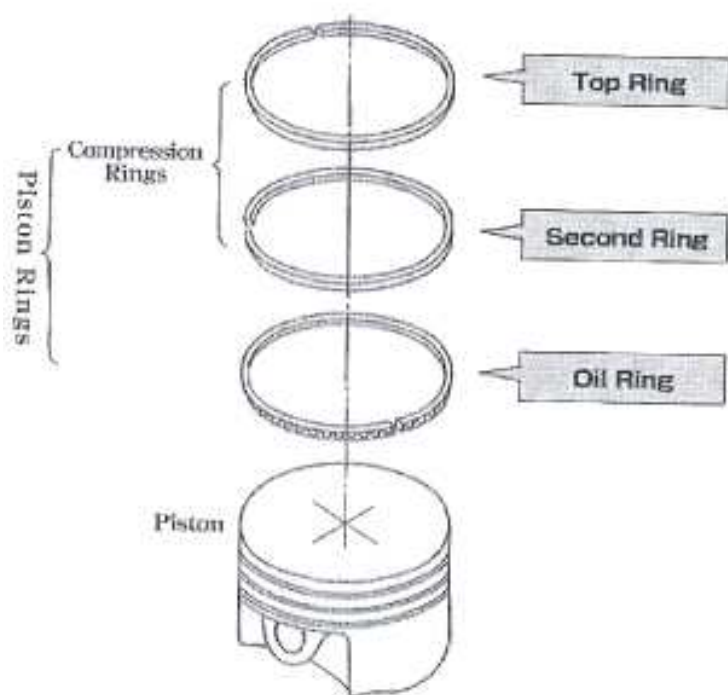
It is manufactured mostly from aluminum, but sometimes iron or steel, and is mounted to the connecting rod with **a wrist pin.**

The Block Group

Piston Rings

Provide a combustion chamber seal and adequate lubrication as the piston moves up and down in the cylinder.

The piston rings, made of steel, are located in grooves in the piston. In most engines the rings include two **compression rings** and one **oil control ring**.





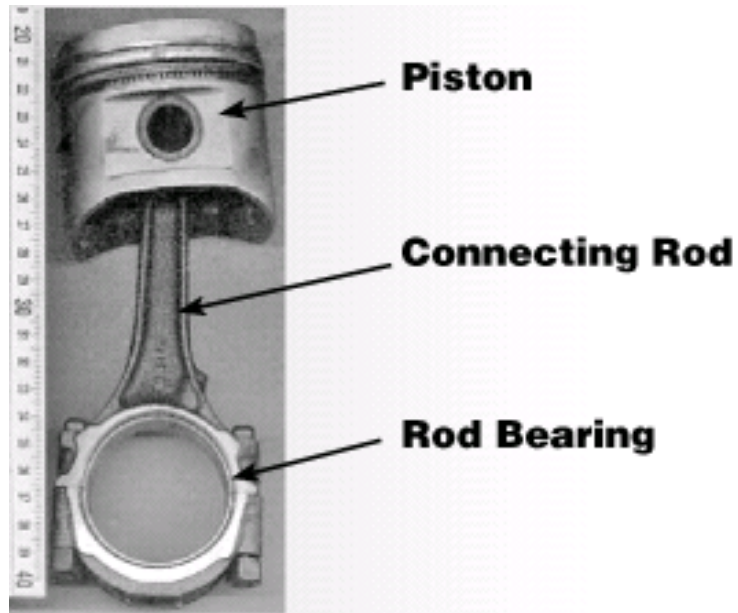
The Block Group



Connecting Rod

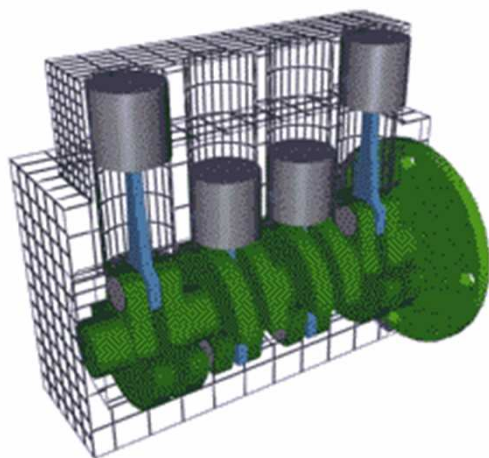
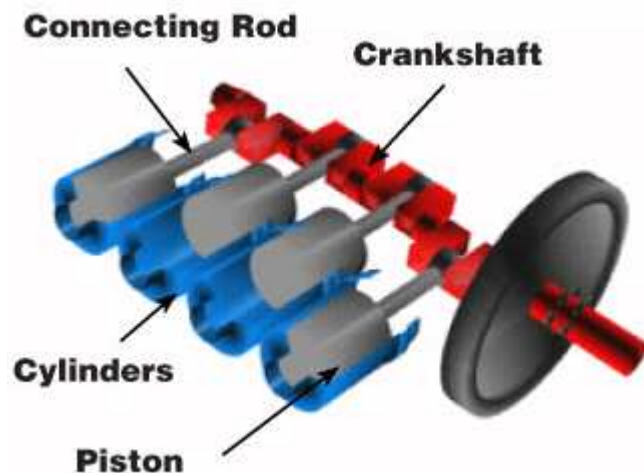
Links the piston to the crankshaft. As the crankshaft turns, the offset of the connecting rod journal relative to the axis of the crankshaft causes the piston to move up and down in the cylinder

The Block Group



The connecting rod consists of a small end through which the piston pin is mounted, and a big end which is split and bolted around the rod journal bearing of the crankshaft. The design goal of the connecting rod may be simply stated as to provide maximum rigidity with minimum weight. Weight must be minimal as the connecting rod is a significant source of inertia force.

The Block Group



Crankshaft

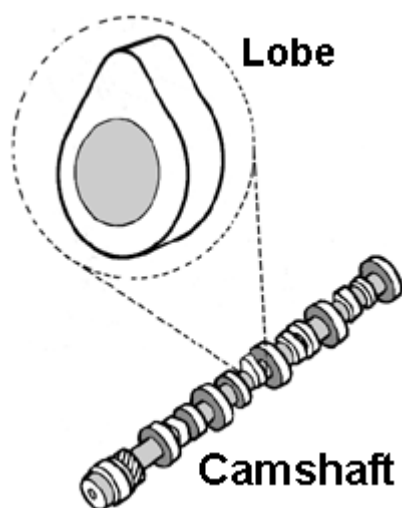
Translates reciprocating linear piston motion into rotation.

The crankshaft is usually made from steel and is responsible for moving the piston up and down inside the cylinder via the connecting rod. It spins in main bearing mounted in the block within the **crankcase**.

The Block Group

Camshaft

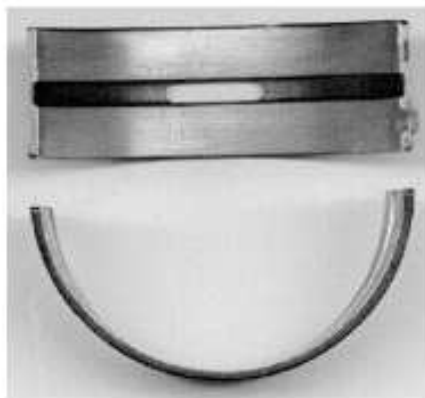
Translates circular movement to reciprocating movement which is used to operate intake and exhaust valves.



Camshaft

Cam Lobe

The Block Group



Bearings and Bushings

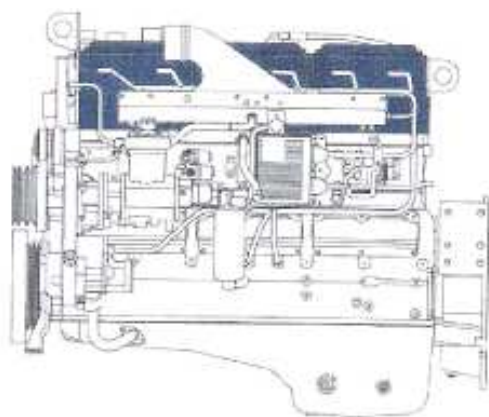
Permit constrained relative motion between two mechanical parts.



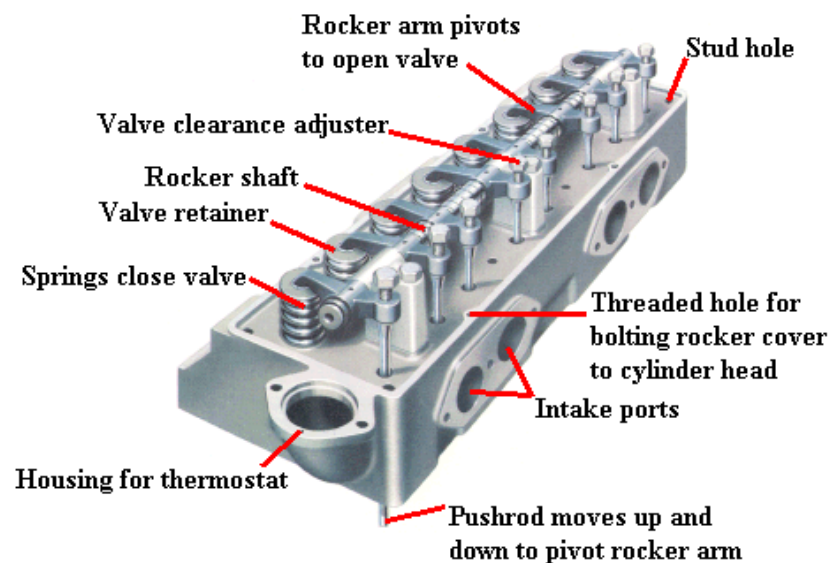
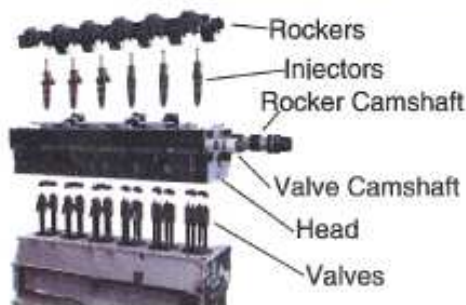
The Head Group

Cylinder head

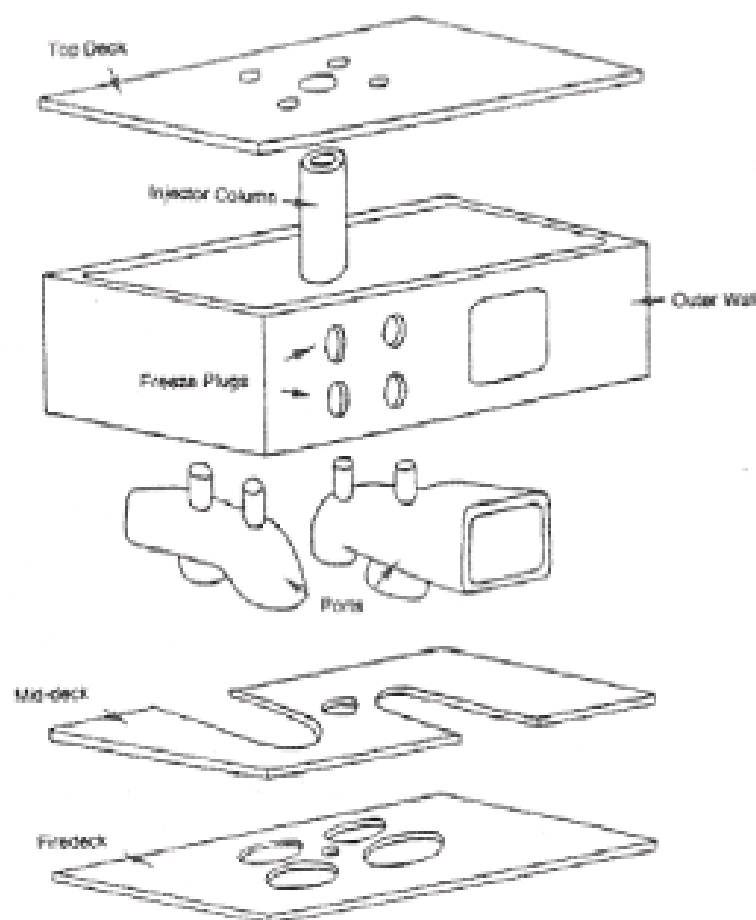
Seals the tops of the cylinders, closing off the combustion chambers.



Components in the Head Group



The Head Group

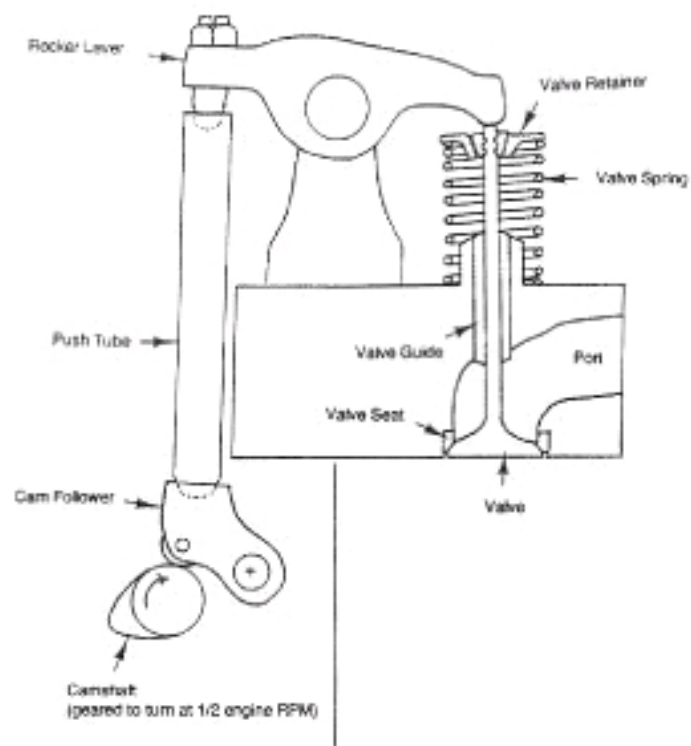


The cylinder head consists of three flat, parallel plates(or decks). The bottom deck, called the **firedeck**, sits on the top of the block, sealing the combustion chamber. The **middle deck** sits somewhere between the firedeck and the **top deck**, and is sliced to accommodate the ports. The top deck forms the upper surface of the head and serves as the mounting surface for the valve train and fuel injectors. The three decks are encased in a side wall running around the perimeter of the head.

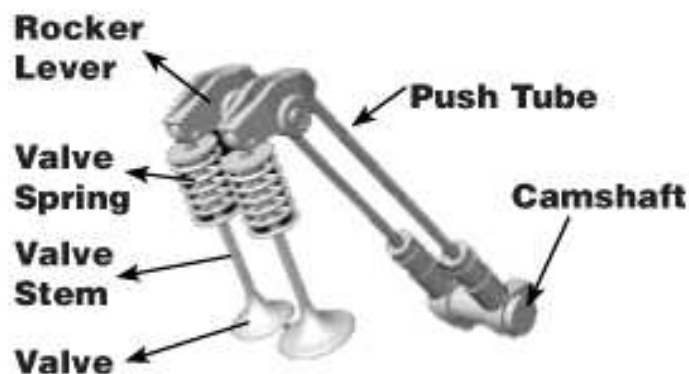
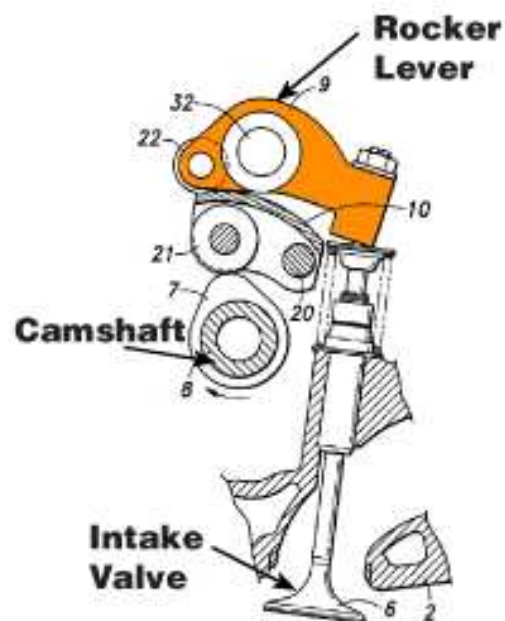
The Head Group

Valves, Valve Guides and Valve Seats

Valves open and close the intake and exhaust ports in the cylinder head.



The Head Group



Rocker Lever

Translates motion from the cam lobe to the intake valve to open the valve.

One end of the rocker lever is raised and lowered by the rotating lobes of the camshaft (via the tappet and push tube), while the other end acts on the valve stem. When the cam lobes raises the outside of the lever, the inside presses down on the valve stem, opening the valve. When the outside of the lever is lowered by the camshaft, the inside rises, allowing the valve spring to close.



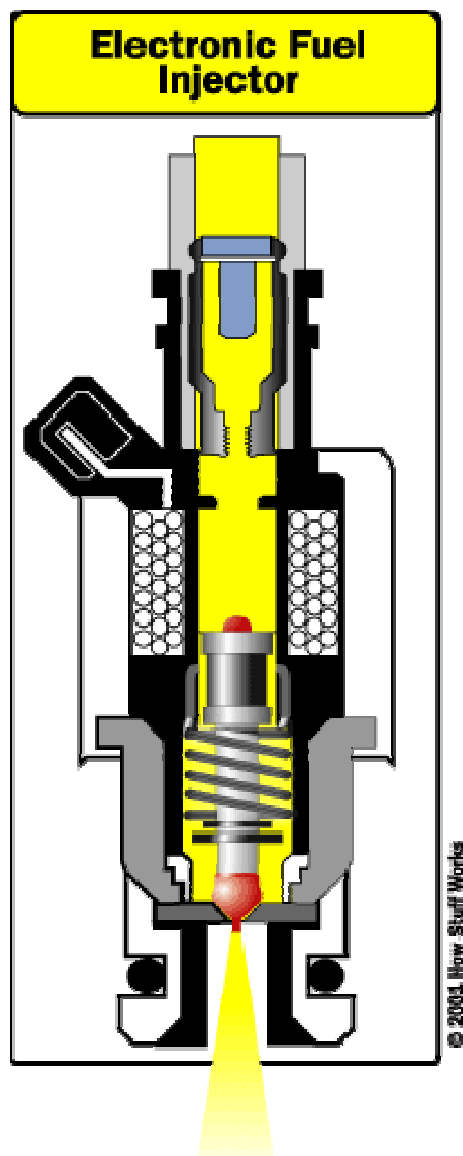
The Head Group



Fuel Injector

Pump-like device that converts the pressure energy of a motive fluid (diesel fuel) to velocity energy.

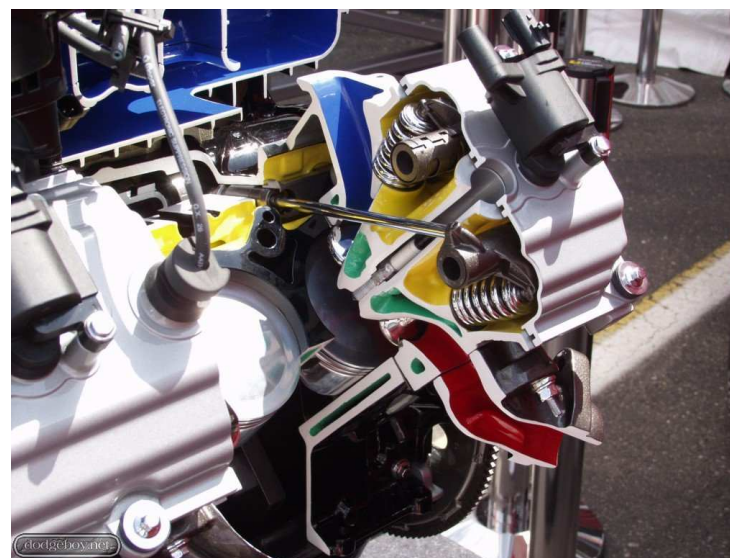
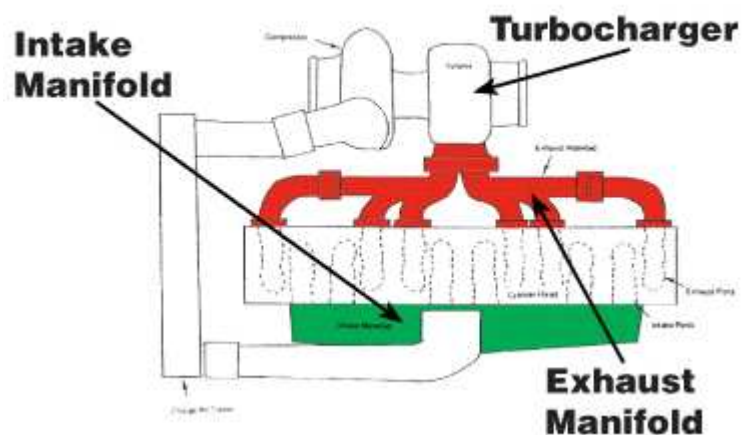
The Head Group



Near the end of the compression stroke, diesel fuel is introduced into the combustion chamber through an injector. The fuel ignites from contact with the air that, due to compression, has been heated to an excessively high temperature.

When the injector is energized an electromagnet moves a plunger that opens the valve, allowing the pressurized fuel to squirt out through a tiny nozzle. The nozzle is designed to atomize the fuel to make a fine mist so it burns easily.

The Head Group



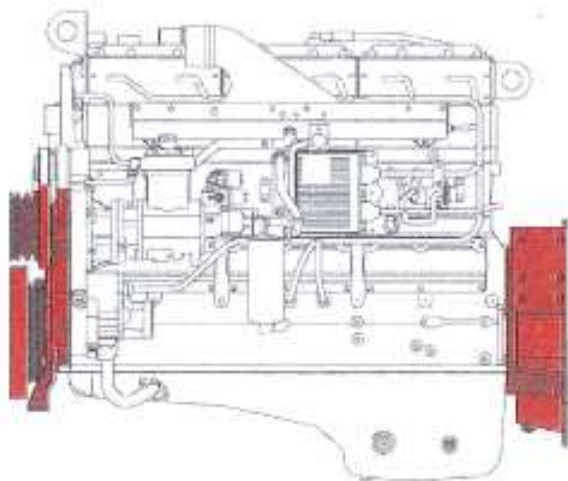
Intake Manifold

Supplies air/fuel mixture to the cylinders.

Exhaust Manifold

Collects the exhaust gases from multiple cylinders into one pipe.

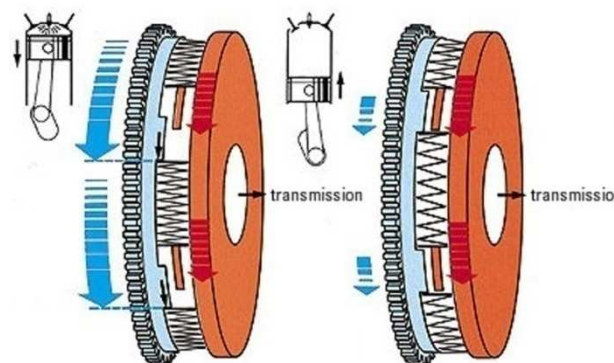
The End and The Pan Group



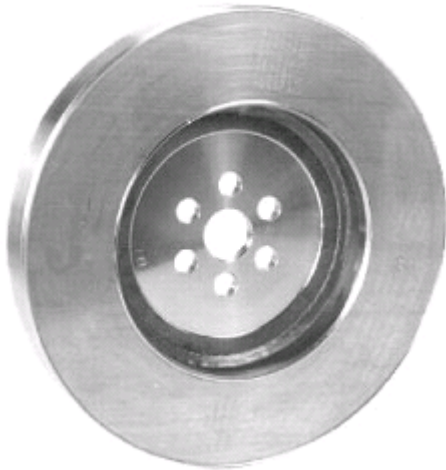
Flywheel

Reduces variation in engine speed. The flywheel is housed in the **bell housing**, which is bolted to the engine block. The housing also contains the torque convertor or clutch of the transmission, and serves as a structural member in mating the engine to the transmission (or other driven device).

Components in the Ends Group



The End and The Pan Group



Vibration Damper

Absorbs the firing pulses of the crankshaft to avoid transferring them to the geartrain.

The End and The Pan Group



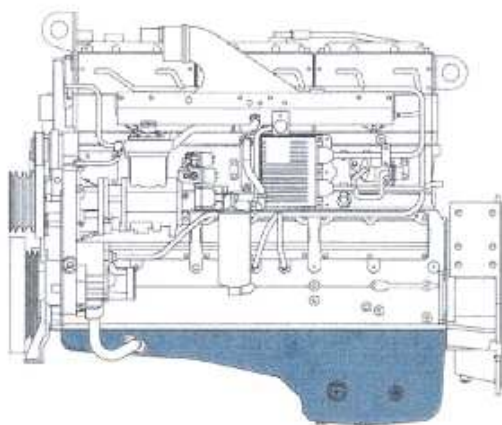
Gasket

Provides a seal between parts.

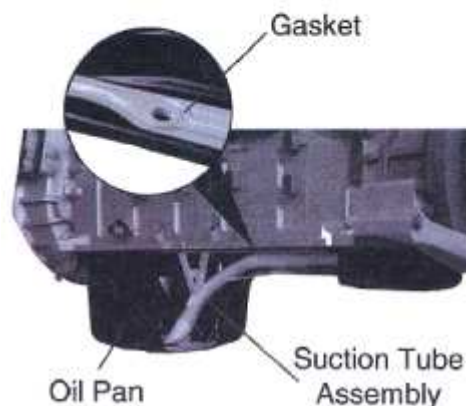
A gasket is a seal that fills the space between two mechanical objects in order to prevent leakage between the two objects while under compression. It must also have the capability to maintain that seal for a prolonged period, to provide resistance to the medium being sealed, and to withstand the temperature and pressure of the application.



The End and The Pan Group



Components in the Pan Group



Oil Pan

Lower section of crankcase used as lubricating oil reservoir.

Oil is drawn from the oil pan by the suction tube assembly, then circulates throughout the engine. Once the oil has cooled and lubricated all metal-contacting surfaces, it gravity-flows back into the oil pan.



Major component of diesel engine



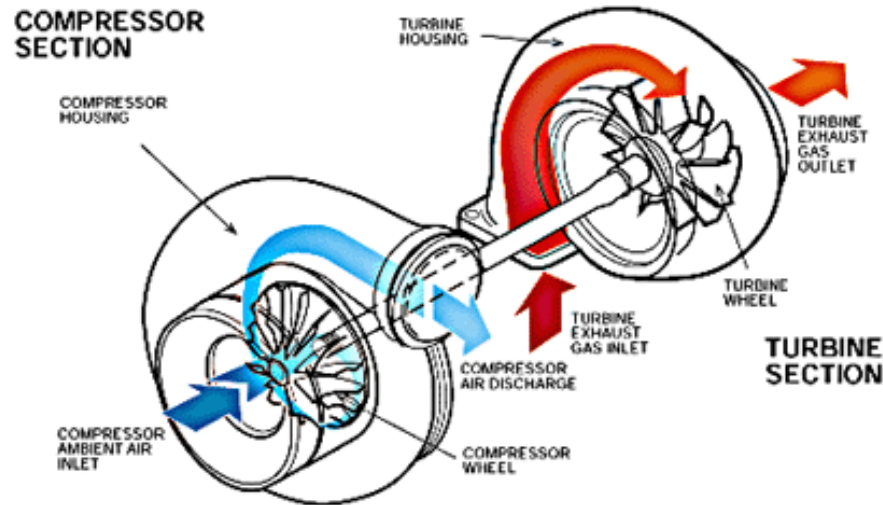
The Accessories Group



Components in the accessories group include:

- Turbocharger
- Water Pump
- Fan Hub
- Air Compressor
- Oil Pump
- Fuel Pump
- Gear Train

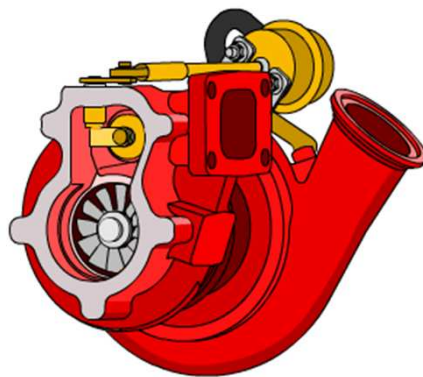
The Accessories Group



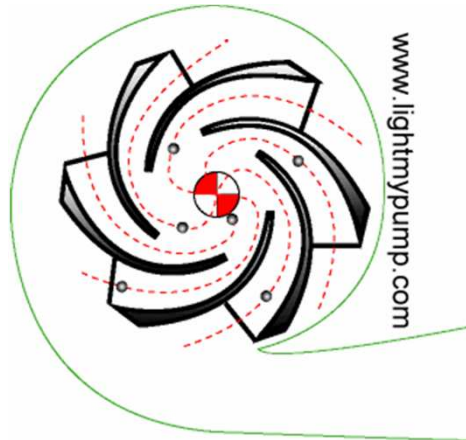
Turbocharger

Uses exhaust energy to compress the incoming air prior to introduce it to the cylinder.

A turbocharger compresses the air flowing into the engine, allowing more air into the cylinder. More air allows for the addition of more fuel, increasing power from each explosion in each cylinder.



The Accessories Group



Water Pump

Circulates engine coolant through the cooling system.

Coolant is supplied to the engine through the **lower hose** and the water pump. The water pump is engine-driven and moves the coolant to a high-pressure **water header** typically running the length of the engine.



Engine Fix UK



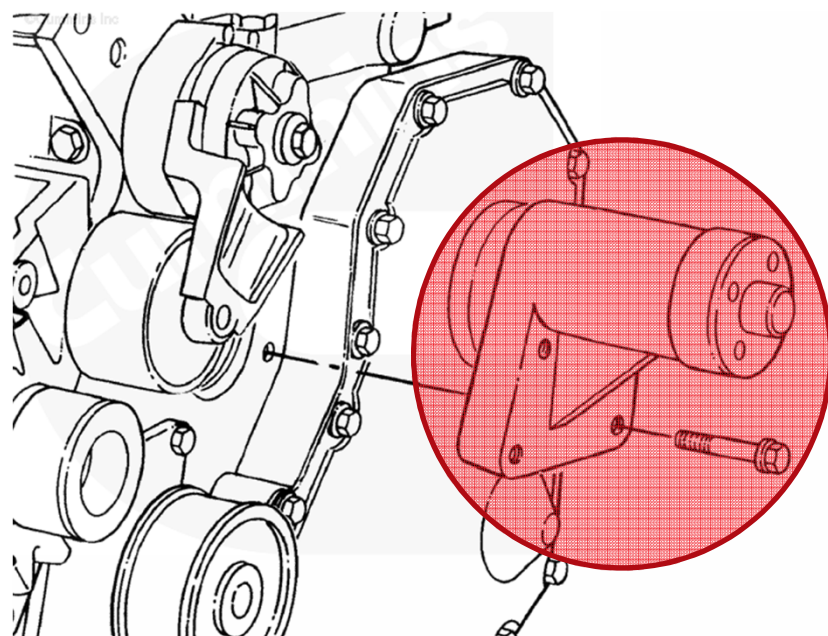


The Accessories Group

Fan Hub

Mounts the fan to the front of the engine.

The fan controls cooling system temperature as it senses when the cooling system needs to be activated. The fan is controlled by the fan clutch, which powers it on and off (according to what other systems are functioning and producing heat) and prevents the engine from overheating.



fa900mc



The Accessories Group

Air Compressor

Compresses air, which activates breaks.

Diesel engine brakes are activated by air (as opposed to being hydraulically actuated), and therefore need air pressure to function. The air compressor is engine driven, and a required level of air pressure must be achieved to allow proper functioning.





The Accessories Group



Oil Pump

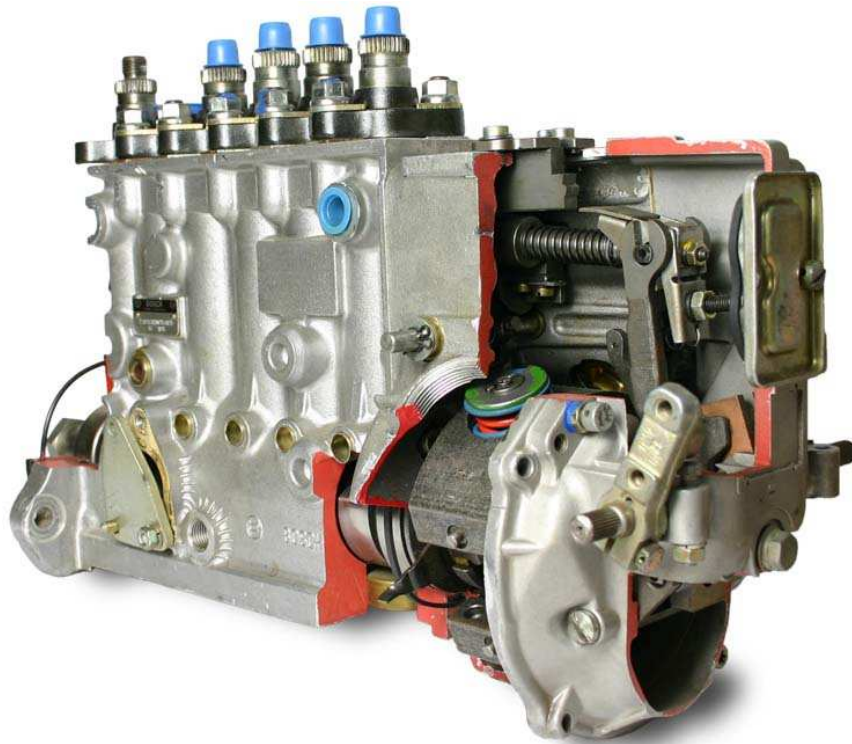
Part of the lubrication system; transports oil to various moving parts inside the engine.

The oil pump draws the oil out of the engine's oil pan through a wire mesh strainer and pumps the oil through an oil filter before it circulates throughout the engine to all metal-contacting surfaces.





The Accessories Group



Fuel Pump

Regulates engine speed by injecting a specific amount of fuel at a specific time.

The fuel pump controls how much fuel is pumped; if less fuel is pumped into the cylinders, this reduces engine speed. If more fuel is pumped this increases the speed of the engine.



The Accessories Group

Gear Train



A system of gears arranged to transfer rotational torque from one part of a mechanical system to another.

The gear train drives various engine support systems which are not powered by any other source. These systems can include lubrication and fuel systems, air and freon compressors, cooling and power steering pumps.

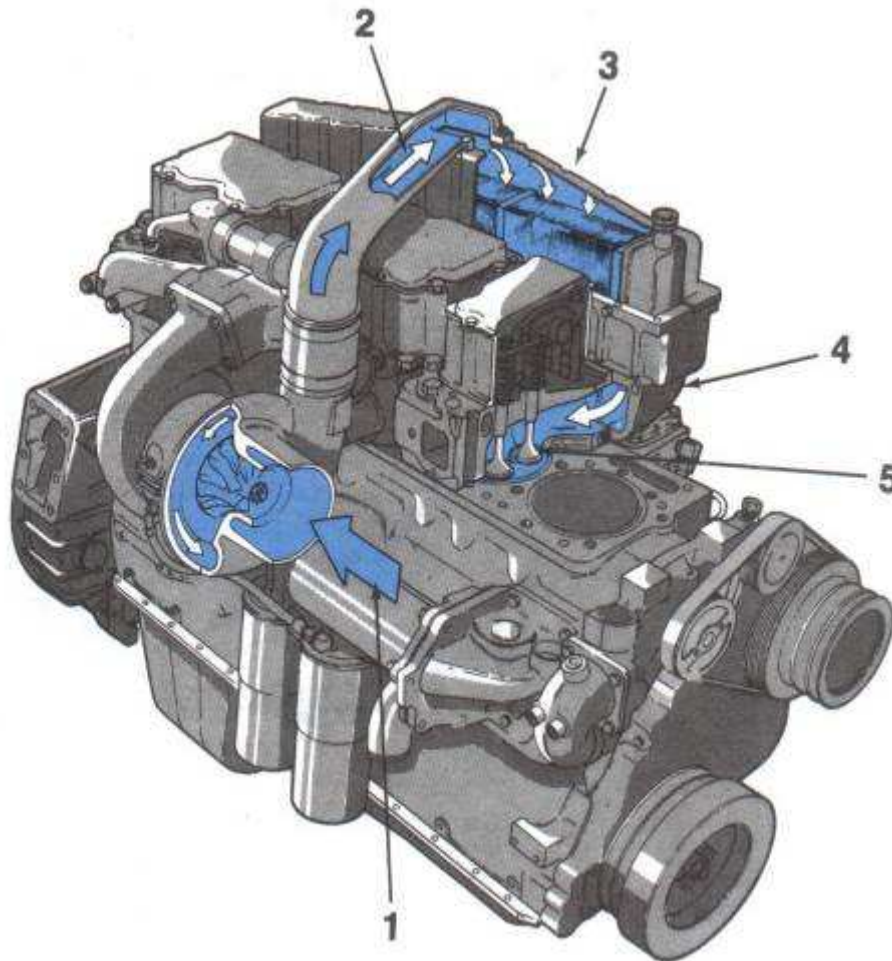


Engine systems

Basic Flow Systems required to maintain the engine operational are:-

- ❖ Air
- ❖ Fuel
- ❖ Lubrication
- ❖ Cooling

Air System



1. Intake Air Inlet to Turbocharger
2. Air Crossover
3. Aftercooler
4. Intake Manifold
5. Intake Valve Ports

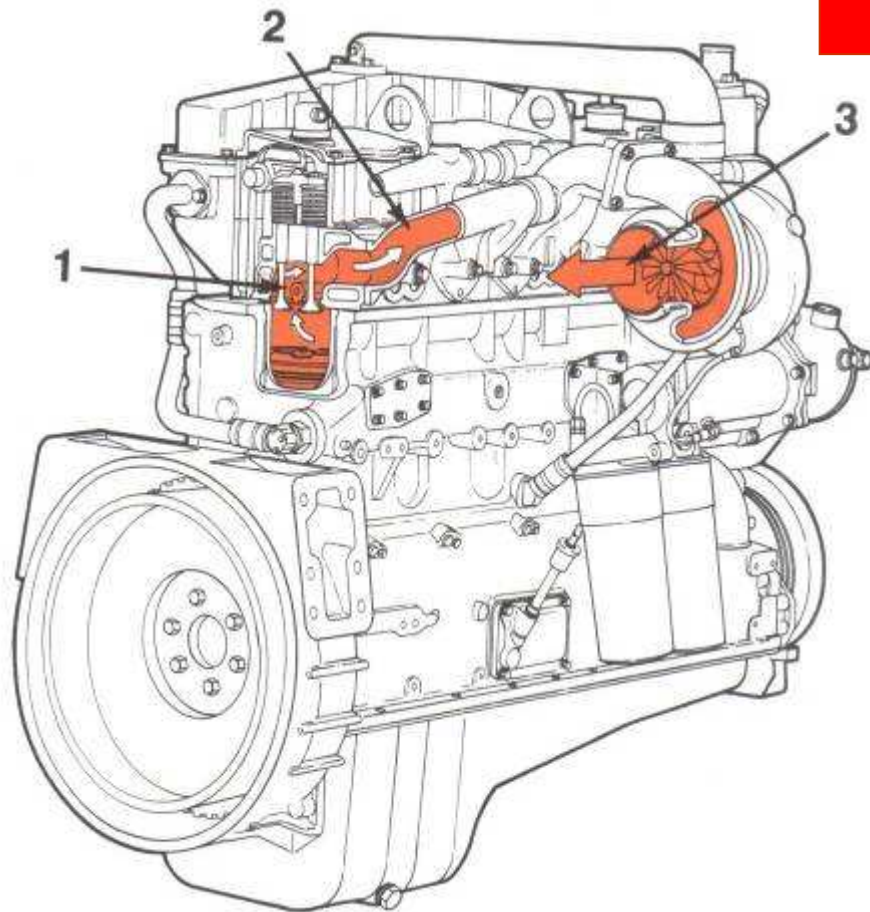
Uses exhaust gas energy to compress the incoming air prior to introducing it into the cylinder.

AIR SYSTEM (INTAKE)

Air System



AIR SYSTEM (EXHAUST)



- 1. Exhaust Valve Ports
- 2. Exhaust Manifold
- 3. Turbo Exhaust Outlet

Air System



KEY POINTS

Air Filtration

- sufficient capacity required to provide full protection (depends on Light, Medium or Heavy Dust environment)

Inlet/Exhaust Restriction

- must be within limits when operating at rated load. (air requirements listed in Engine Data Sheet)

Inlet Location

- have to avoid the ingestion of rain, exhaust gases & hot air (special consideration required for high ambient temp.)

Clamping and Plumbing

- loose clamps or other components will operate and cause no apparent damage for long time! (check for rust, dirt and rubbing brackets/cables)

Exhaust Location

- located to minimize noise and contamination of air (with regards to all codes, standards and regulations)

Air System



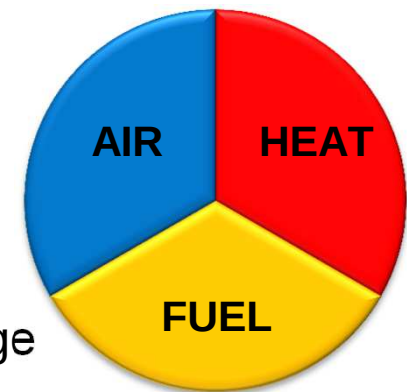
FUNCTION : To provide the engine with an adequate supply of clean, dry and moderate temperature air for combustion

It does this by :-

Air Flow - must be sufficient with proper ventilation
(consume about 71 L/min of free air per HP output)

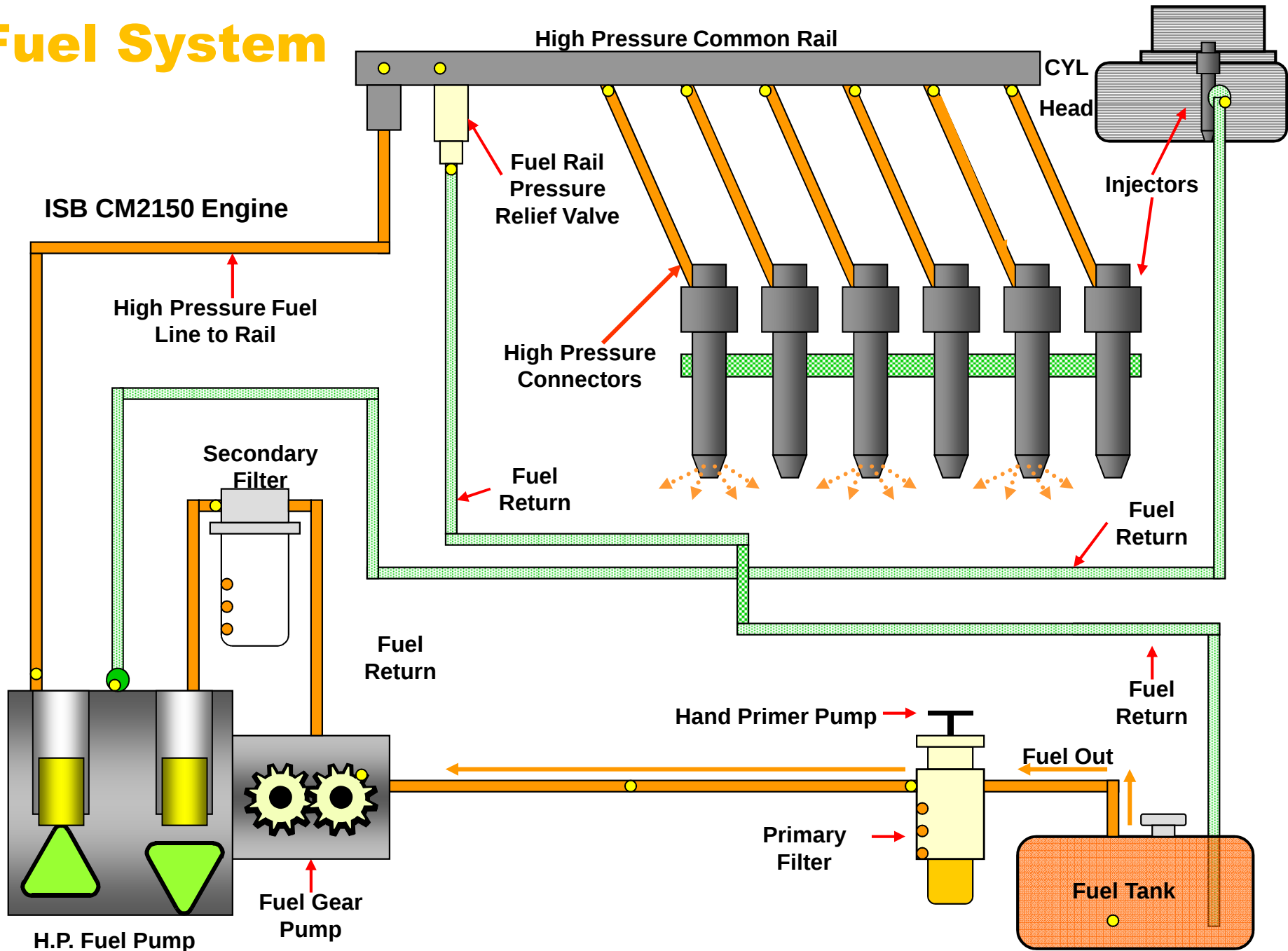
Air Cleaner - require efficiency of 99.7% throughout its flow range
(efficiency based on the SAE J726 test code)

Air Temperature - moderate air temp. for adequate oxygen for combustion
(Nat. Asp. engines in temperate climates rarely $> 24^{\circ}\text{C}$
but Turbocharged engines may exceed 160°C)



A well-designed air system is a vital part of every successful engine installation. The reward of a good air system design is enhanced durability and reliability of the engine, thus the equipment..

Fuel System



Fuel System



KEY POINTS

Fuel Specifications

- poor quality fuel can affect engine life (check for Cetane #40, Sulphur (1.0% Max.) & Water)

Fuel Filter

- check daily for water & drain as needed. Change as required.(high filter restriction causes low power output without smoke)

Fuel Tank & Plumbing

- subjected to regulation on design, size & location

Inspect / Clean

- from fuel tank, supply & return line, pump & injectors (need to service/calibrate at recommended intervals)

Fuel Temperature

- high temp. may lead to power loss & governor instability (fuel system component wear due to lower lubricity)

Fuel Consumption

- depends on rating, load factor, duty cycle, etc...

Fuel System



FUNCTION : To keep the engine in proper operation, the fuel must be of correct quality, quantity, timing and condition for combustion

It does this by :-

Fuel Quality - recommended Grade No.2 (as per ASTM D975) & Cetane 40

Fuel Quantity - dependent on metering time by fuel pump or injector

Injection Timing - accurate setting required on fuel pump or engine

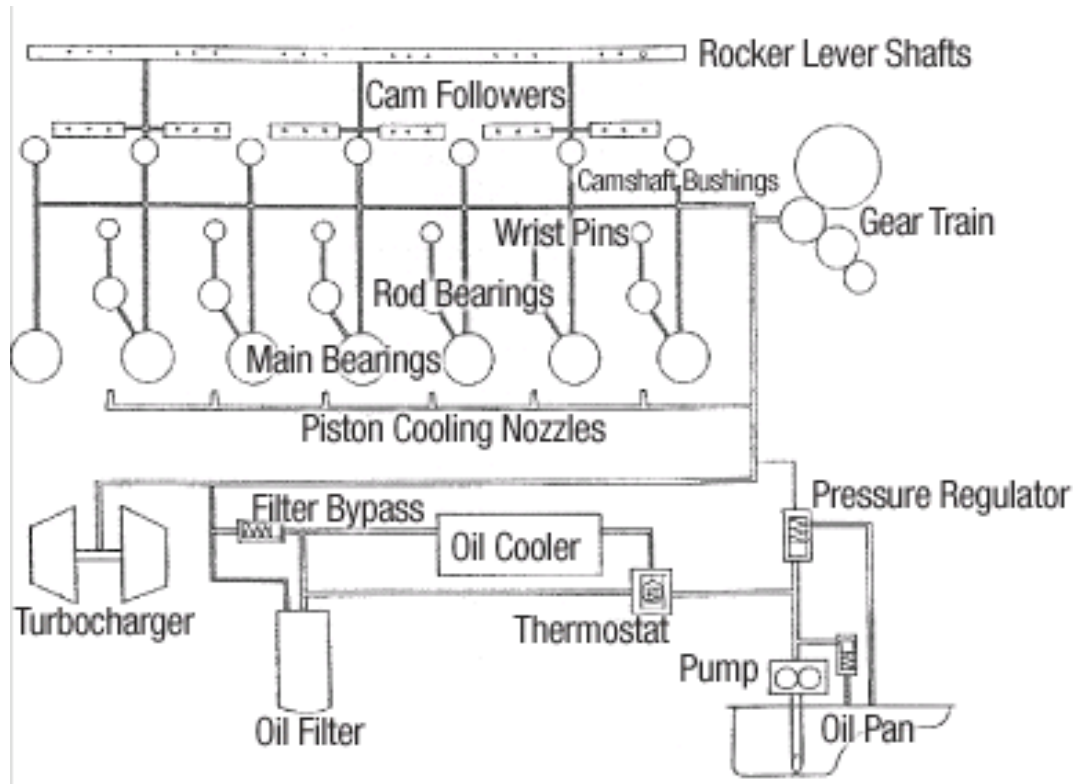
Condition - dependant on size and number of cup/nozzle spray holes

Governor - control the engine speed range from low idle to rated/high idle.

Lack of maintenance on the Fuel System will result in difficult starting, low power output, unstable operating speed, smoke, etc..

Over-fuelled (resulting in over-load/speed) operation is not warrantable.

Lubricating System



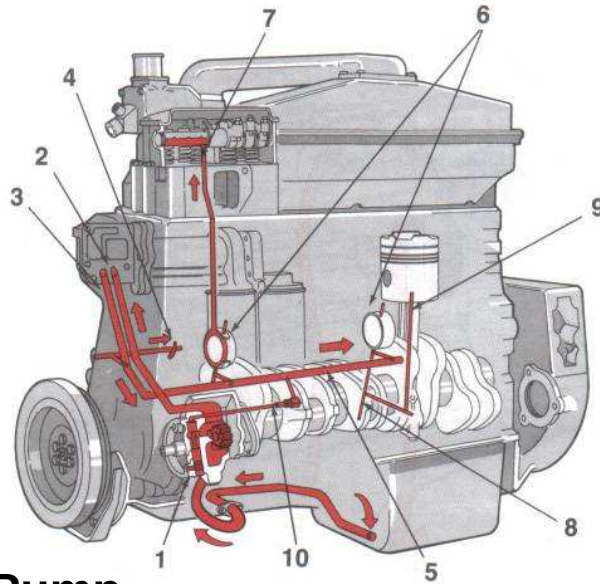
Lubricates bearing surface and cools bearings by absorbing friction-generated heat.



Lubricating System

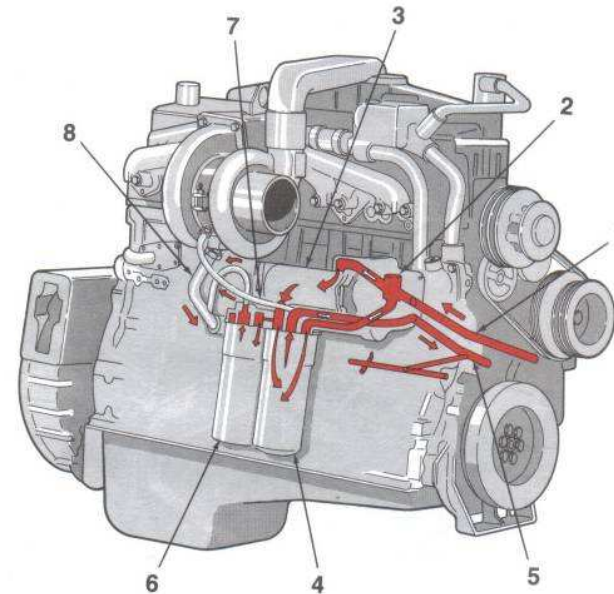


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1. Oil Pump
2. To Oil Cooler
3. From Oil Cooler
4. Piston Cooling Nozzle
5. Main Oil Rifle
6. Cam Bushings
7. To Overhead
8. Main Bearing
9. Con-Rod Drilling
10. Rifle Pressure Signal Line

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1. From Oil Pump
2. Oil Cooler Bypass Valve
3. Oil Cooler
4. Full Flow Oil Filter
5. To Main Oil Rifle
6. Bypass Oil Filter
7. Turbocharger Supply
8. Turbocharger Drain

Lubricating System



KEY POINTS

- Oil Quality** - all oil is **not** created equally
- Oil Specifications** - **15W40**; CE or C/CD or CD/SF or better
- Oil Change Interval** - is in direct proportion to **Life to Rebuild**
- Oil Filters** - must be **filled** during oil change to prevent bearing damage
- Oil Handling** - Tank, Hoses, Nozzles are to kept **CLEAN**
- Oil Consumption** - is usually a good yardstick of engine useful **life**
- Fast or Cold Start** - the delay of oil flow to the main bearings and high bearing loads can cause permanent bearing damage.



Lubricating System



FUNCTIONS of Lubricating Oil :-

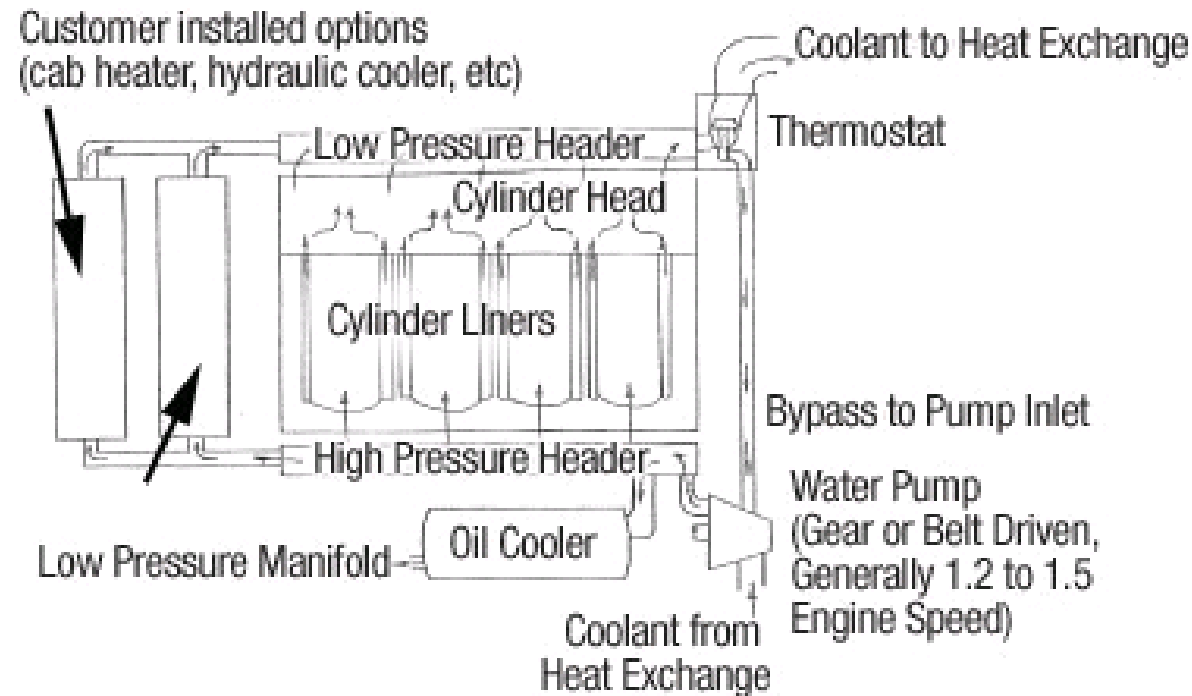
- Lubrication** - by providing a film between moving parts to reduce wear and friction.
- Cooling** - by serving as a heat transfer media to carry heat away from critical areas (temp. controlled by oil cooler)
- Sealing** - by filling in the uneven surfaces in the cylinder wall, valve stems and turbocharger oil seals
- Cleaning** - by holding contaminants in suspension to prevent a build up of deposits on the engine surfaces

In addition, it must also provide :

- Dampening & Cushioning of components**
- Protection from oxidation and corrosion**
- Hydraulic action for components**

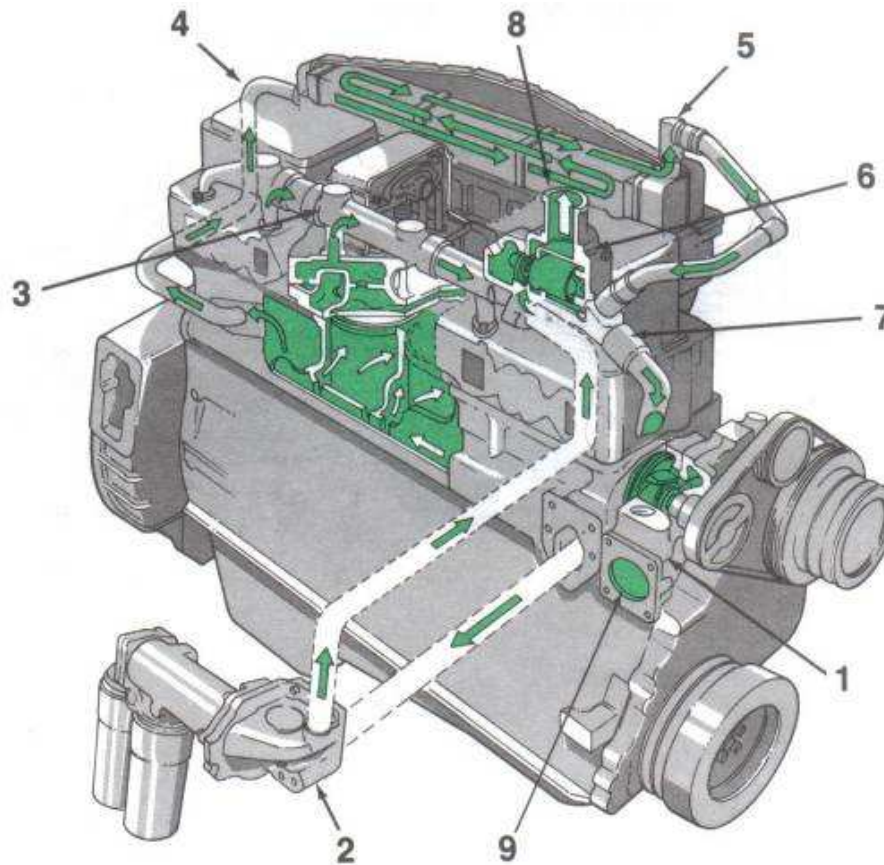
Engine Lube Oil must be changed when it can no longer perform its functions. Oil does not wear out, but it becomes contaminated to the point that it can no longer satisfactorily protect the engine. Contamination of the oil is a normal result of engine operation.

Cooling System



**Uses a liquid coolant to transfer waste heat out of
The block and the internals of the engine.**

Cooling System



1. Water Pump
2. Oil Cooler
3. Water Manifold
4. Aftercooler Inlet
5. Aftercooler Outlet
6. Thermostat
7. Bypass
8. To Radiator
9. Water Pump Inlet

Cooling System



FUNCTION : To keep the engine temperatures within acceptable limits
(same function for all internal combustion engines)

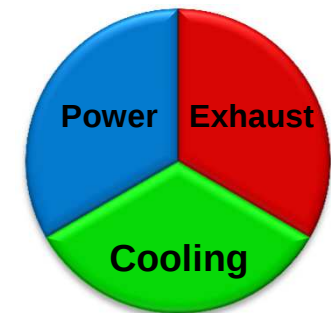
It does this by :-

Absorption - absorbing heat from the engine components

Circulation - circulate the coolant in the engine

Dissipation - dissipate the heat through a heat exchanger (e.g. Radiator)

Control - control coolant temperature by the thermostat



The cooling system has a critical task to perform. If cooling is reduced or interrupted even for an instant, it can result in serious damage to the engine.

Cooling System



KEY POINTS

Coolant

- tap water has always been the basis for cooling liquid
(cheap and available but contains variety of minerals/chemicals)

Chemical Balance

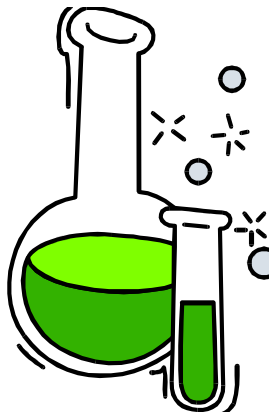
- check and add coolant additive as recommended
(protect against Corrosion and Scale Formation)

Cooling System Pressure

- slight leaks can allow pressure drop to zero
(allows pump cavitation, lowers boiling temperature of coolant, etc...)

Air Flow Through Radiator

- can be reduced by debris, fan slippage and recirculation between the fan and shroud.





Conclusion

Having a basic understanding of Cummins diesel engines and how they operate is important not only to engineers, but to all employees and distributors of Cummins products.

By breaking down the engine into different engine groups and systems it is easier to understand how each individual component contributes to unleashing the Power of Cummins. Not only in our engines, but our employees and distributors.

