# DIESEL  ENGINE STUDY COURSE

## Identification of the Diesel Engine Components.

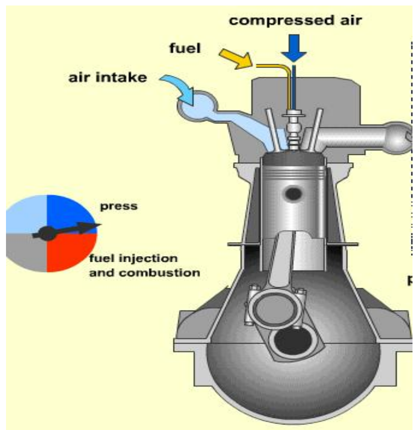
### Introduction.

The diesel engine belongs to the internal combustion reciprocating engine group of which there are two main groups

١. Compression Ignition
٢. Spark Ignition

The diesel fueled engine forms group ١- the compression ignition internal combustion engines.
The spark ignition group includes both  petrol and gas fueled internal combustion engines.

Only the diesel engine will be considered in this course except where comparisons are made between engine types during the study of basic principles at the commencement of the course.




### COMPONENTS OF THE COMPRESSION IGNITION ENGINE

The components of the compression ignition engine are mainly heavier in construction than the spark ignition internal combustion engine. The components need to be made more robust to take the increased stress levels from higher compression ratios and greater torque characteristics of the compression ignition cycle.

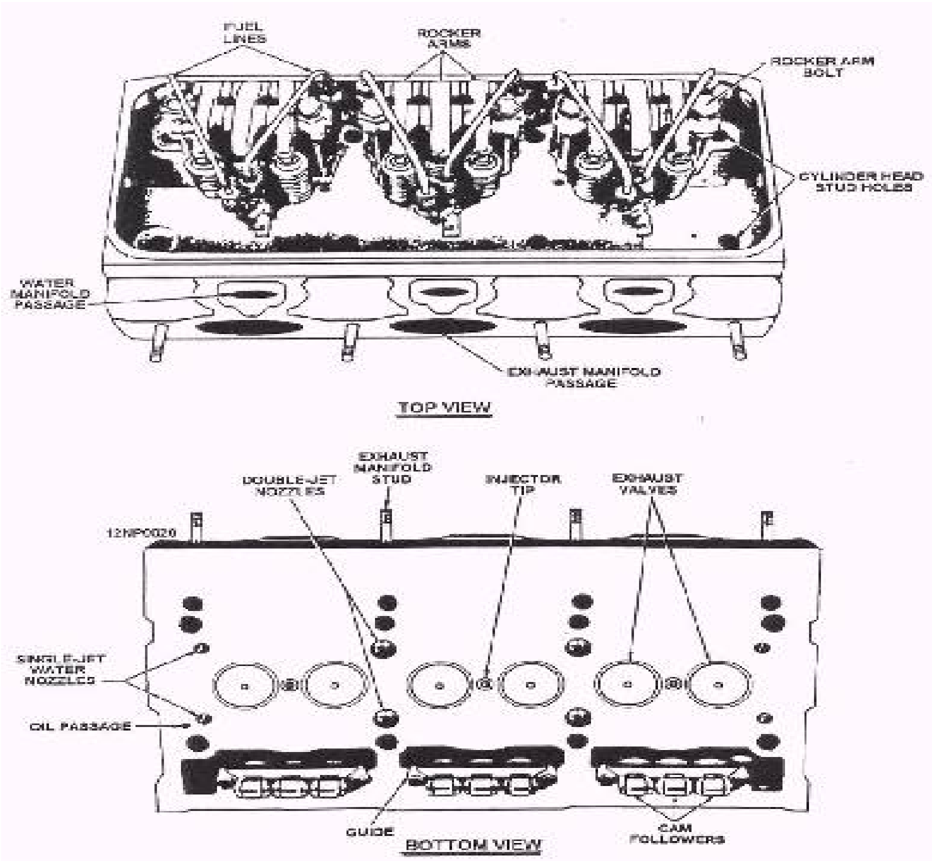
### CYLINDER HEADS

The cylinder head (or cylinder cover) is bolted to the top of the engine block and forms a gas tight seal  over the end of each cylinder. The head may be cast as a separate head to cover each cylinder as is usual with the larger engines or in the case of smaller engines a single casting covering all cylinders. A number of engine parts that are essential to engine operation may be found in or attached to the cylinder head. The cylinder head for a ٤-stroke cycle engine will house intake and exhaust valves, valve guides, and valve seats. The cylinder head will also carry the valve rocker arm assembly, fuel injection valves, heater plugs, the cover for the rocker gear as well as providing for the flow of:- cooling water to essential areas of the head, air supply for combustion and discharged exhaust gases.

The design and material of a cylinder head must be such that it can withstand the rapid changes of temperature and pressure that take place in the combustion space and the mechanical stress that results from the head being bolted securely to the block. Cylinder heads are made of heat-resistant alloy cast iron or aluminum alloy

As an example look at the design of a small Vee type engine
The cylinder head, over each bank of cylinders, is a one-piece casting which can be removed from the engine as an assembly containing such moving parts as the valve rocker arms, exhaust and inlet valves, and fuel injectors.

On larger engines with a separate head for each cylinder each head may be removed with its individual valve gear and injectors.




## CYLINDER HEAD STUDS AND GASKETS

A gas tight seal between the cylinder head and the block depends upon both surfaces being level and smooth, good quality gaskets, and the correct tightness (torque settings) of the head studs.

### Studs

Cylinder head studs are manufactured from round rod, generally of alloy steel. Threads are cut on both ends. The threads that screw into the block are generally made with finer threads than those on the nut end. This design allows for a tighter fit in the block, which keeps the stud from loosening when the stud nut is removed.

The successful fitting of the head to the block requires care, attention and adherence to correct procedures. This includes using torque wrenches for exacting the correct stress on each stud and carrying this out in the correct sequence. Assembly procedures will be dealt with in detail in stage ٢ of the course. The correct use of torque wrenches will also be demonstrated.

### Gaskets

Gaskets are used to provide a seal between two surfaces. The type of duty may vary greatly from the somewhat rough surfaces of water pipe flanges to the carefully ground faces of high pressure superheated steam pipes; from the valve cover on a cylinder head to the highly polished surfaces of hydraulic pump components. Each duty requires the correct type and thickness of material so it is important to understand the properties of the various gasket materials and the exact nature of the duty.

The mating surfaces of a cylinder block and head may appear to be quite smooth; however, if these surfaces are highly magnified irregularities can always be seen. Gaskets will compensate for a degree of irregularity but they will not do the impossible. If the surface of the head is rough or worse still distorted then it may be necessary to have the face ground. Fortunately it is more common for the head to be distorted rather than the block. It is easier to grind the head than to remove all the studs to grind the block.

Even though the composition of gasket material varies, they have one common property - compressibility. Materials used in the manufacture of gaskets vary as widely as does gasket design. Gaskets can be made from copper and other relatively soft metals, such as laminated steel sheets, fiber, cork, rubber, and synthetic rubber, and a combination of materials, such as copper and fiber compounds-NOT ASBESTOS.

Combinations of gaskets, seal rings, and grommets or similar devices may be used in head to block assembly to prevent the leakage of oil, water, and combustion gases.

### Vibration Isolators

Vibration isolators are designed to absorb the forces of relatively minor vibrations that are common to operating diesel engines. Such vibrations are referred to as high frequency, low-amplitude vibrations, and they result from an unbalanced condition created by the motion of operating engine parts. Isolators can be equipped with coil springs or flexible pads to absorb the energy of engine vibrations. An isolator reacts in the same manner, whether it is of the spring type or the flexible pad type. Some typical examples are mounting pads for the engine found between the mounting frame of the engine and the main frame. These may be just a simple rubber block with a bolt through the middle or more often and more effective special vibro blocks molded to steel plates on each side and the steel plates are designed to bolt, one to the base and the other to the engine mount. There is no bolting between engine and frame.

Another vibration isolator is the mounting for the radiator to the frame. In this case however the mounts provide a double duty. They also serve to protect the radiator against any distortion from movement of the frame.

### The Sump.

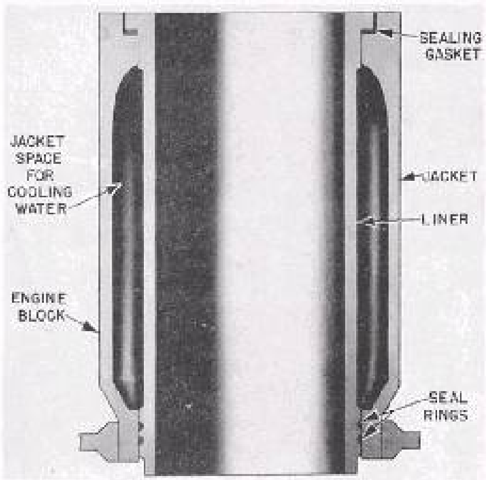
The engine sump is usually manufactured from pressed steel but in some cases they may be cast iron although these are extremely heavy and not seen often these days. The sump is the engine oil reservoir and it may also have a strainer fitted through which the oil must pass before entering the oil pump. The sump will be fitted with an oil drain attachment either for bottom discharge or out through the side for greater accessibility. The fitting of the gaskets between the sump and the block must be done with great care.

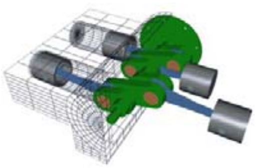
### CYLINDER LINERS

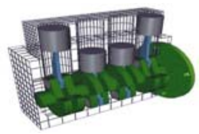
The barrel or bore in which an engine piston moves back and forth may be machined from the cylinder block, or it may be a separate pressed in sleeve or liner. The first type, whilst used in small diesel engines is more common in gasoline engines. It has the disadvantage of not being replaceable. When excessive wear occurs in a block of this type, the cylinder must be rebored or honed. Reconditioning of this type cannot be repeated indefinitely and, in time, the entire block must be replaced. For this reason, most diesel engines are constructed with replaceable cylinder liners.

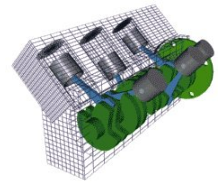
The material of a liner must withstand the extreme heat and pressure developed within the combustion space at the top of the cylinder and, at the same time, must permit the piston and its sealing rings to move with a minimum of friction. Close-grained cast iron is the material most commonly used for liner construction. (Steel, however, is sometimes used.) Some liners are plated on the wearing surface with porous chromium, because chromium has greater wear-resistant qualities than other materials. Also the pores in the plating tend to hold the lubricating oil and aid in maintaining the lubrication oil film that is necessary for reduction of friction and wear.

Cylinder liners may be divided into two general classifications or types—dry or wet. The dry liner does not come in contact with the engine coolant. Instead, it fits closely against the wall of the cooling jacket in the cylinder block. With the wet liner, the coolant comes in direct contact with the liner. Wet liners have a cooling water space between the engine block and liner.







### Dry Liners

Dry liners have relatively thin walls compared with wet liners. Heat from the thin liner wall is transferred to the block and then dissipated into the cooling water jacket

### Wet Liners

In wet liners the cooling water is in direct contact with the liner. Seals are fitted at both ends of the liner to prevent the leakage of coolant into the oil pan, or from around the liner lip. Generally, the seal at the combustion end of a liner consists of either a gasket under the liner flange or a machined fit. Rubber or neoprene rings generally form the seal at the bottom or crankshaft end of the liner. Liners of this type are constructed to permit lengthwise expansion and contraction. The walls of a wet liner must be strong enough to withstand the full working pressure of the combustion gases.

## PRINCIPAL MOVING PARTS

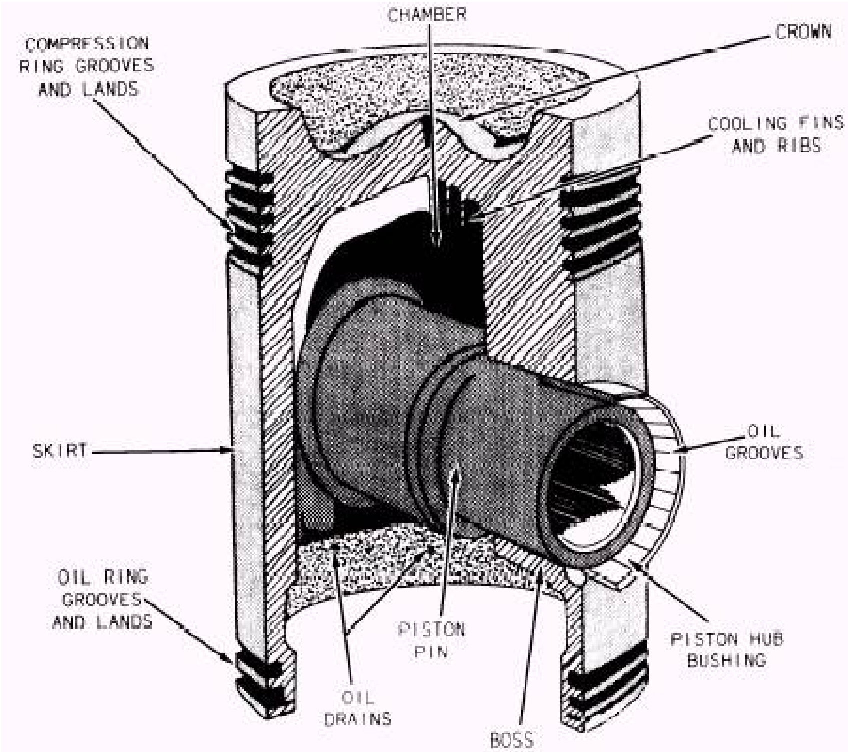
Many of the principal parts that are within the main structure of an engine are moving parts. These moving parts convert the thermal energy of fuel combustion to mechanical energy into the reciprocating motion of the pistons and connecting rods. The force is then converted to rotary motion by the crankshaft and used to provide the service required. At this stage we will restrict the discussion to those moving components up to and including the crankshaft. Other parts that serve to develop and transmit power, such as timing gears and gear trains will be discussed later in the course. At the conclusion of this section, you should be able to recognize and describe the basic types, functions, and characteristics of valves, valve-actuating mechanisms, piston and rod assemblies, crankshafts and flywheels.

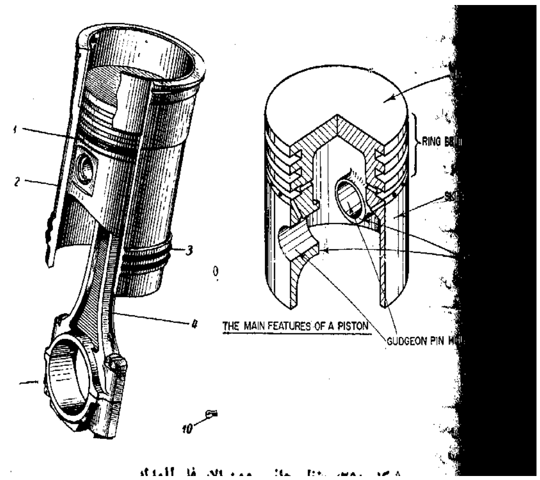
### PISTONS

As one of the major moving parts in the power-transmitting assembly, the piston must be so designed that it can withstand the extreme heat and pressure of combustion. Pistons must also be light enough to keep inertial loads on related parts to a minimum. The piston aids in sealing the cylinder to prevent the escape of combustion gases. It also transmits some of the heat through the piston rings to the cylinder wall.

Pistons have been constructed of a variety of metals—cast iron, nickel-coated cast iron, steel alloy, and aluminum alloy. Pistons of cast iron and aluminum are most commonly used at the present time. Cast iron gives longer service with little wear; it can be fitted to closer clearances, because it expands less with high temperatures, and it distorts less than aluminum. Lighter weight and higher conductivity are the principal advantages of aluminum pistons.

Cast iron is generally associated with the pistons of slow-speed engines, but it is also used for the



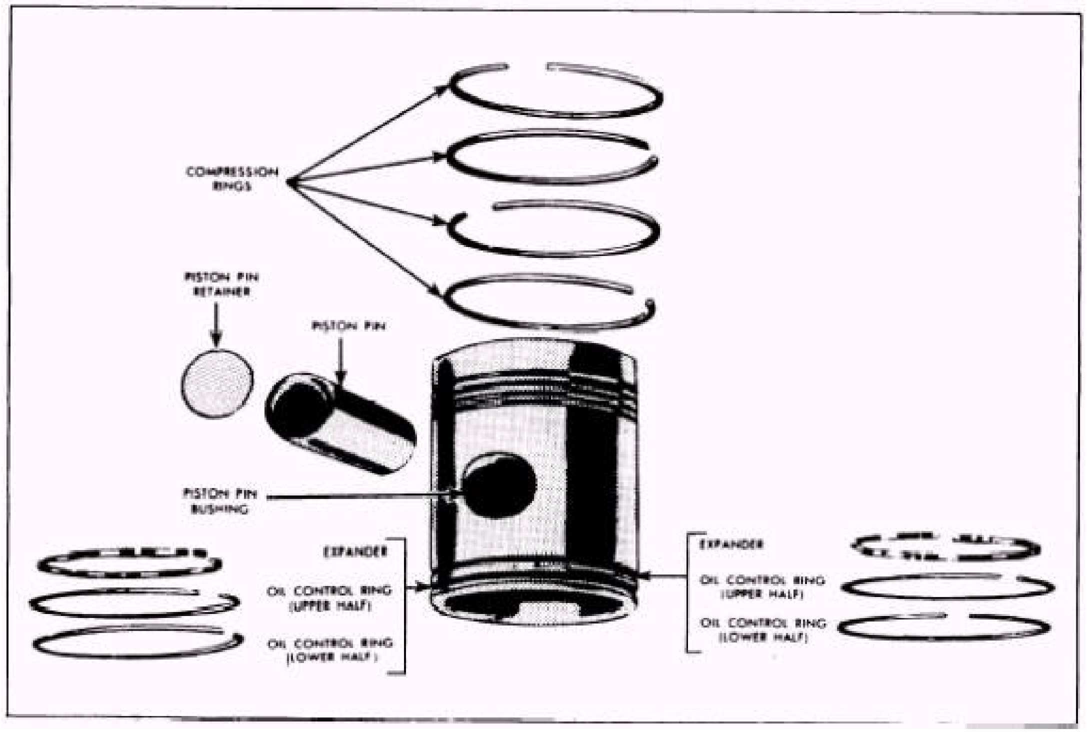




pistons of some high-speed engines. In these pistons, the piston walls are of very thin construction, requiring additional cooling.

## PISTON RINGS

Piston rings perform three functions: seal the cylinder, distribute and control lubricating oil on the cylinder wall, and transfer heat from the piston to the cylinder wall. All rings on a piston perform the latter function, but two general types of rings—compression and oil—are required to perform the first two functions.

The number of rings and their location will also vary considerably with the type and size of the piston.




**Compression Rings**

The principal function of compression rings is to seal the cylinder and combustion space so that the gases within the space cannot escape until they have performed their function. Some oil is carried with the compression rings as they travel up and down the cylinder for lubrication. Most compression rings are made of gray cast iron. Some types of compression rings, however, have special facings, such as bronze (inserted in a slot cut in the circumference of the ring) or a specially treated surface. Rings with the bronze inserts are sometimes called GOLD SEAL rings, while those with special facings are referred to as BIMETAL rings. The bimetal ring is composed of two layers of metal bonded together, the inner layer being steel and the outer layer being cast iron.

Compression rings come with a variety of cross sections; however, the rectangular cross section is the most common. Since piston rings contribute as much as any other one thing toward maintaining pressure in a cylinder, they must possess sufficient elasticity to press uniformly against the cylinder walls. The diameter of the ring, before installation, is slightly larger than the cylinder bore. Because of the joint, the ring can be compressed to enter the cylinder. The tension that is created when the ring is compressed and placed in a cylinder causes the ring to expand and produce a pressure against the cylinder wall.

The pressure exerted by rings closest to the combustion space is increased by the action of the confined gases during compression and combustion. The gases enter behind the top ring, through the clearance between the ring and groove, and force the ring out against the cylinder and down against the bottom of the groove. The gas pressure on the second ring and each successive compression ring is progressively lessened since the gas that reaches these rings is limited to that passing through the gap of each preceding ring.

When a piston assembly is disassembled, you can look at the compression rings and tell whether they have been functioning properly. If a ring has been working properly, the face (surface bearing against the cylinder wall) and the bottom of the ring will be bright and shiny because of contact with the cylinder wall and the groove. The top and back (inside surface) of the ring will be black, since they are exposed to the hot combustion gases. Black areas on sealing surfaces indicate that hot gases have been escaping.

Under normal operating conditions, with engine parts functioning properly, there will be very little leakage of gas because of the excellent sealing of the piston rings. The oil that prevents metal-to-metal contact between the rings and cylinder wall also helps, to a degree, in making the seal. When a proper seal is established, the only point at which gas can leak is through the piston ring gap. The gap of a piston ring is so small, compared to the total circumference of the ring, that the amount of leakage is negligible when rings are functioning properly.

### Oil Rings

Although oil rings come in a large variety of designs, they must all do two things: (١) distribute enough oil to the cylinder wall to prevent metal-to- metal contact, and (٢) control the amount of oil distributed.

Without an adequate oil film between the rings and the cylinder, undue friction occurs, resulting in excessive wear of the rings and the cylinder wall. On the other hand, too much oil is as undesirable as not enough oil. If too much oil is distributed by the rings the oil may reach the combustion space and burn, wasting oil and causing smoky exhaust and excessive carbon deposits in the cylinder. Such carbon deposits may cause the rings to stick in their grooves. Sticking rings lead to a poor gas seal. Thus, oil rings provide an important function in proper control and distribution of the lubricating oil. Different manufacturers use a variety of terms in their technical manuals to identify the oil rings of an engine—such terms as oil control, oil scraper, oil wiper, oil cutter, oil drain, and oil regulating. Regardless of the identifying terms used, all such rings are used to limit the oil film on the cylinder walls and to provide adequate lubrication to the compression rings.

Most oil control rings use some type of expander to force them against the cylinder wall. This aids in wiping the excess oil from the cylinder wall.

## PISTON PINS AND PISTON BEARINGS

In trunk-type piston assemblies, the only connection between the piston and the connecting rod is the pin (usually referred to as the **gudgeon** pin) and its bearings. These parts must be of especially strong construction because the power developed in the cylinder is transmitted from the piston through the pin to the connecting rod. The pin is the pivot point where the straight-line, or reciprocating, motion of the piston changes to the reciprocating and rotating motion of the connecting rod. Thus, the gudgeon pin is subjected to two principal forces—the forces created by combustion and the side thrust created by the change in direction of motion. Before discussing the pin further, let us consider the side thrust which occurs. Side thrust is exerted at all points during a stroke of a piston, except at top dead center (TDC) and bottom dead center (BDC). The side thrust is absorbed by the cylinder wall. Thrust occurs first on one side of the cylinder and then on the other, depending on the position of the piston and the connecting rod and the direction of rotation of the crankshaft. Since the crankshaft is rotating clock-wise, the force of combustion and the resistance of the driven parts tend to push the piston to the left. The resulting side thrust is exerted on the cylinder wall. If the crankshaft were rotating counterclockwise, the situation would be reversed.

When the piston is being pushed upward (compression) by the crankshaft and connecting rod it causes the side thrust to be exerted on the opposite side of the cylinder. Thus, the side thrust alternates from side to side as the piston moves up and down. Side thrust in an engine cylinder makes proper lubrication and correct clearance essential. Without an oil film between the piston and the cylinder wall, metal-to-metal contact occurs and results in excessive wear. If the clearance between the piston and cylinder wall is excessive, a pounding noise, called PISTON SLAP, will occur as the thrust alternates from side to side.

### Types of Piston Pin Bearings

The bearings used in connection with most piston pins are of the sleeve bearing or bushing type. These bearings may be further identified according to location—the piston boss piston pin bearings and the connecting rod piston bearings.

The bearings or bushings are made of bronze or similar material. Since the bushing material is a relatively hard-bearing metal, surface-hardened piston pins are required. The bore of the bushing is accurately ground in line for the close fit of the piston pin. Most bushings have a number of small grooves cut in their bore for lubrication purposes  Some sleeve bushings have a press fit, while others are "cold shrunk" into the bosses.
If the piston pin is secured in the bosses of the piston (stationary) or if it floats (full-floating) in both the connecting rod and piston, the piston end of the rod must be fitted with a sleeve bushing. Pistons fitted with semi-floating pins require no bearing at the rod end.

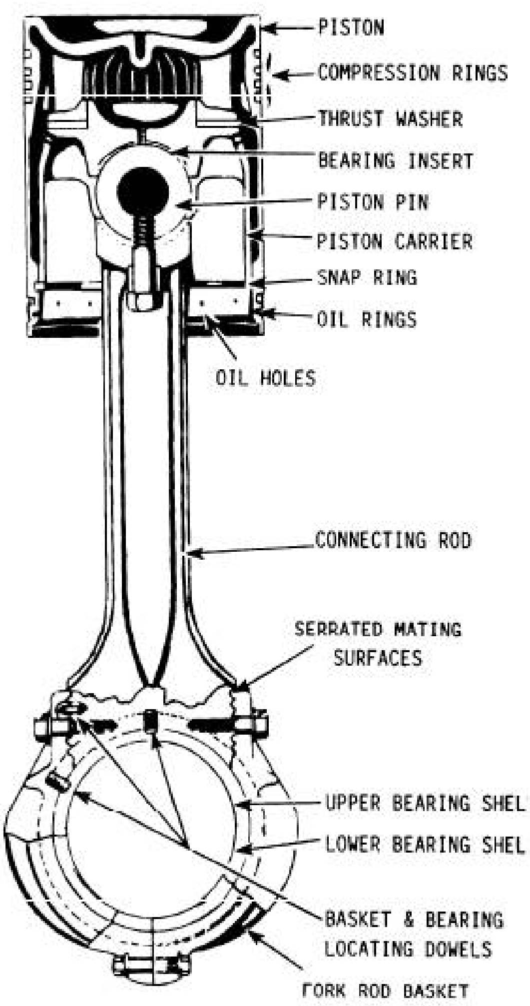
Sleeve bushings used in the piston end of connecting rods are similar in design to those used in piston bosses. Generally, bronze makes up the bearing surface. Some bearing surfaces are backed with a casehardened steel sleeve, and the bushing has a shrink fit in the rod bore. In another variation of the sleeve-type bushing, a cast bronze lining is pressed into a steel bushing in the connecting rod.

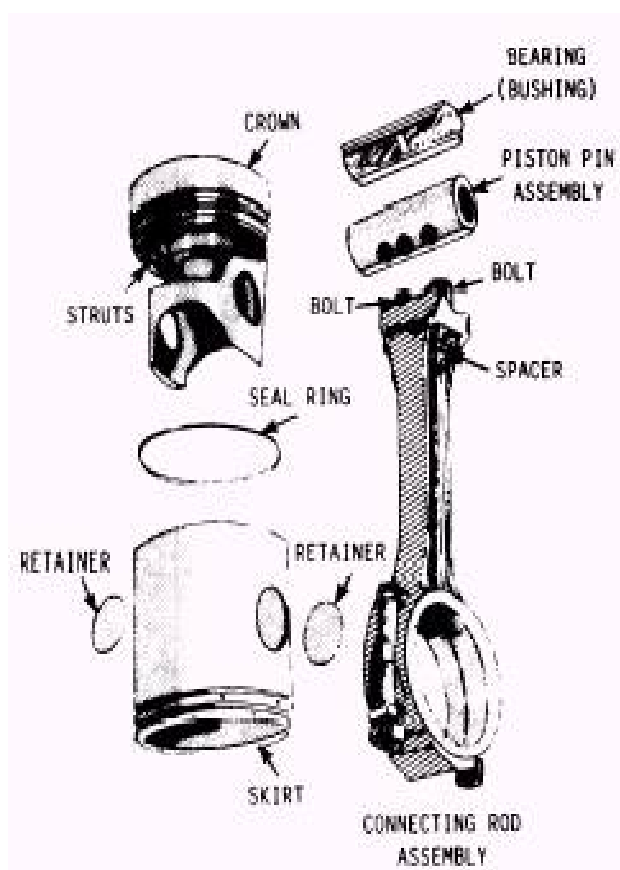
## CONNECTING RODS (conrods)

The connecting rod is the connecting link between the piston and the crankshaft. It is a highly stressed part of an engine as it must transfer the forces of combustion from the piston to the crankshaft. In addition to this conrods may perform another duty by conveying lubricating oil through an internally drilled oil way to lubricate the gudgeon pin and in some cases to cool the piston.

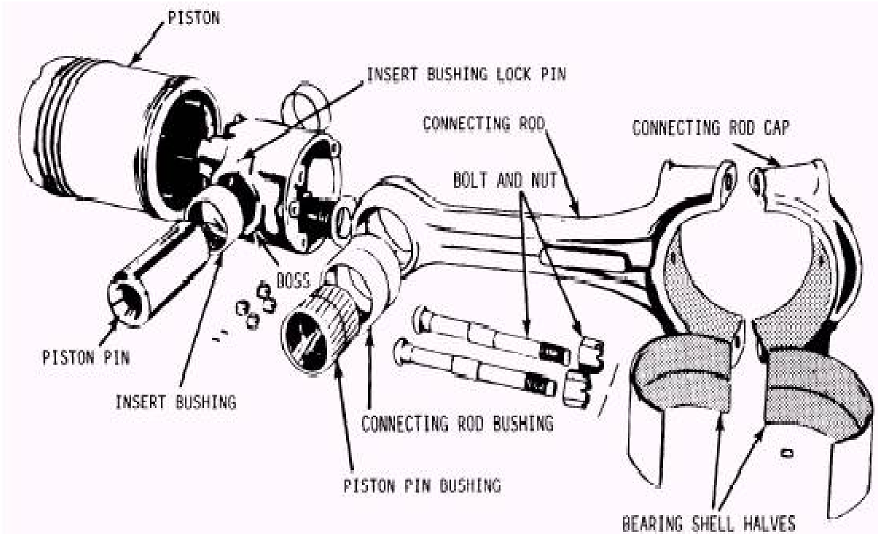
The end of the conrod that is connected to the crankshaft is called *the bottom end* and houses the bearing in which the crankshaft bottom end journal turns.

In general, the type of connecting rod used in an engine depends on the cylinder arrangement and the type of engine. Connecting rods come in a variety of profiles but we shall only study the rods



and bearings found in our engines.




## CRANKSHAFT

The crankshaft changes the movement of the piston and the connecting rod into the rotary motion required to drive such items as reduction gears, propeller shafts, generators, or pumps.

As the name implies, the crankshaft consists of a series of cranks (throws) formed as offsets in a shaft. The crankshaft is subjected to all the forces developed in an engine. Because of this, the shaft must be of especially strong construction. It is usually machined from forged alloy or high-carbon steel. The shafts of some engines are made of cast-iron alloy. Forged crankshafts are nitrided (heat-treated) to increase the strength of the shafts and to minimize wear.

The crankshafts found in our engines are all drop forged from one solid block usually referred to as one piece construction

### Crankshaft Terminology

Some parts of a crankshaft may be called different names however to save any confusion we will use the following terms as our standard reference for the main parts.

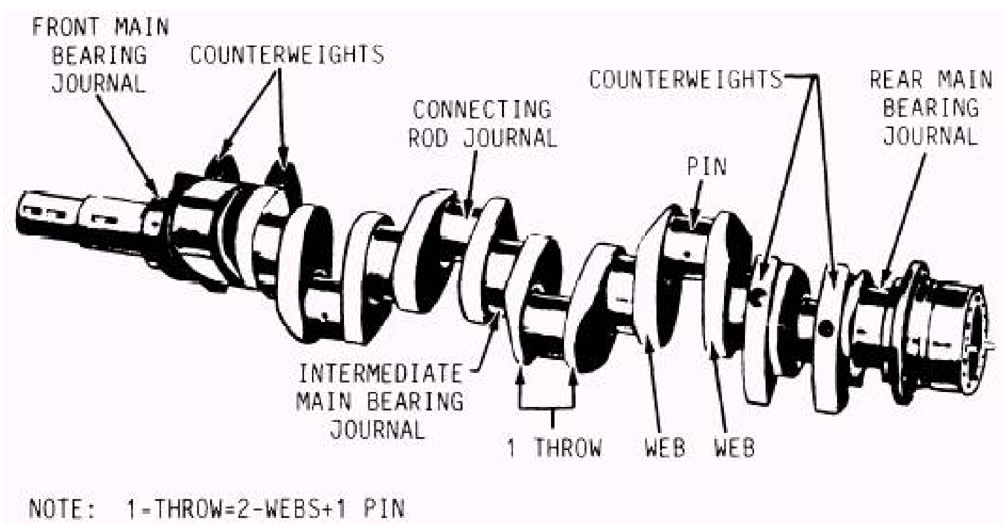
The **Main Bearings** support the crankshaft. They are located in the main bearing housings that are machined into the main engine block. The section of the shaft that turns in the main bearing is called the crankshaft **main bearing journal**. The section of the crankshaft which turns inside the connecting rod bottom end bearing is known as the **bottom end journal**. The main journals and the bottom end journals are surface-hardened and ground so that a longer wearing, more durable bearing metal can be used in the main and bottom end bearings without causing excessive wear of the shaft.

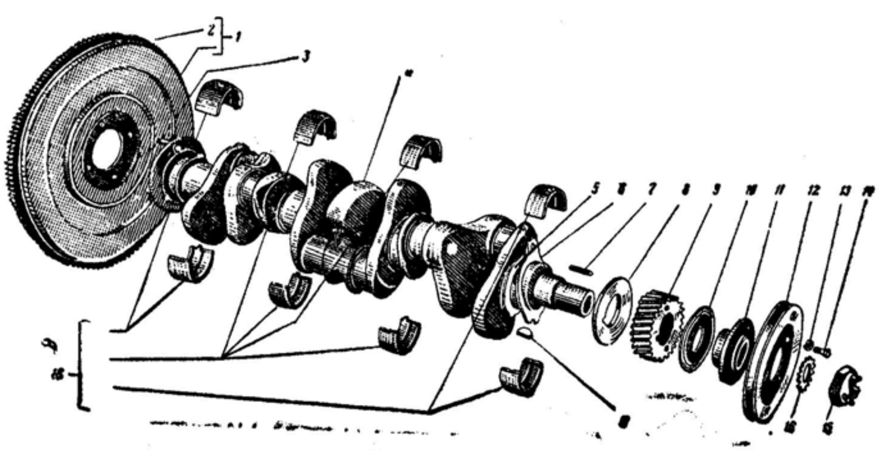
Crankshafts have a main bearing journal at each end of the shaft with an intermediate main journal between the **cranks**. Each crank of a shaft consists of three parts, two **webs** and a **pin**, (**journal**) The journal, provides the surface on which the connecting rod bottom end bearing turns.

One important duty that most crankshafts do is to provide a means of lubricating the bottom ends, the gudgeon pins and also provide cooling oil to the underside of the pistons. This is done by drilling a hole from the main bearing journal up through the web coming out at the center point of the bottom end journal. From here the oil can lubricate the bottom end bearing. By a hole drilled up the center of the conrod to the top end oil can reach both the gudgeon pin and the underside of the piston.

The forces that turn the crankshaft of a diesel engine are produced and transmitted to the crankshaft in a pulsating manner. These pulsa-tions create torsional vibrations, which are capable of severely damaging an engine if they are not reduced, or dampened, by opposing forces. Many engines require an extra dampening effect to ensure satisfactory operation. It is provided by a torsional vibration damper mounted on the free end of the crankshaft. There are several types of torsional dampers in use.

On some crankshafts, part of the web of the crankshaft extends beyond the main journal to form or support counterweights. These counter-weights may be integral parts of the web or on larger engines they can be separate units attached to the web by studs and nuts, or cap bolts. Counterweights balance the off center weight of the individual crank throws and thereby compensate for centrifugal force generated by each rotating crank throw. Without such balance, the crank action will create severe vibrations, particularly at the higher speeds. If such vibrations are not controlled, the shaft would eventually break through metal fatigue. Excessive vibration could well bring about the complete failure of the engine. Counterweights use inertia to reduce the effects of power impulses in the same manner as the flywheel. Flywheels are described later in this lesson.



شكل (٣٢) اقسام المحور القلاب

## BEARINGS

Bearings serve to support rotating shafts and other moving parts and to transmit loads from one part of the engine to another

## ANTI-FRICTION BEARINGS

Anti-friction bearings can be grouped into six general classifications: ball bearings, cylindrical roller bearings, needle bearings, tapered roller bearings, self-aligning roller bearings, and thrust bearings. The use of anti-friction bearings is mostly limited to the exterior areas of an engine. You will find them in use in cooling pumps, fuel-injection pumps, governors, starters, flywheel pilot bearings, turbochargers, and blowers.

All anti-friction bearings employ a rolling element (rollers, balls, or needles) between the inner and outer cases. Either the inner case or the outer case will remain stationary. Because of the small contact area between the rolling elements and the inner and outer rings and the necessity for the bearing to withstand the high compression stress, the material used for the construction of roller bearings is usually carbonized steel alloy and that used for ball bearings is usually heat-treated chromium-alloy steel.

As an engine man, you will come into contact with various items of equipment that may require bearing replacement. Bearings that are similar in appearance may not be suitable as replacement bearings. Ball and roller bearings are identified by a numerical code, which indicates the bore in millimeters or sixteenths of an inch. The internal fit, or tolerance and any special characteristics are also coded by number. Letter codes indicate the type of bearing, the outside diameter (OD), the width of the cage, the seal or shield, the modification.

## FLYWHEELS

The speed of rotation of the crankshaft increases each time the shaft receives a power impulse from one of the pistons. The speed then gradually decreases until another power impulse is received. If permitted to continue unchecked, these fluctuations in speed (their number depending upon the number of cylinders firing on one crankshaft revolution) would result in an undesirable situation with respect to the driven mechanism as well as to the engine. Therefore, some means must be provided so that shaft rotation can be stabilized. In most engines, this is accomplished by mounting a flywheel on the crankshaft. In other engines, the motion of such engine parts as the connecting rod journals, webs and lower ends of the connecting rods, and such driven units as the clutch and generator serves the purpose. The need for a flywheel decreases as the number of cylinders firing in one revolution of the crankshaft and the mass of moving parts attached to the crankshaft increase.

A flywheel stores up energy during the power event and releases it during the remaining events of the operating cycle. In other words, when the speed of the shaft tends to increase, the flywheel absorbs energy. When the speed tends to decrease, the flywheel gives up energy to the shaft in an effort to keep shaft rotation uniform. In doing this, a flywheel (١) keeps variations in speed within desired limits at all loads; (٢) limits the increase or decrease in speed during sudden changes of load; (٣) aids in forcing the piston through the compression event when an engine is running at low or idling speed; and (٤) provides leverage or mechanical advantage for a starting motor.

Flywheels are generally made of cast iron, cast steel, or rolled steel. Strength of the material from which the flywheel is made is of prime importance because of the stresses created in the metal of the flywheel when the engine is operating at maximum designed speed.

A flywheel is the point of attachment for items such as a starting ring gear or a turning ring gear. The rim of a flywheel may be marked in degrees. With a stationary pointer attached to the engine, the degree markings can be used for a determination of the position of the crankshaft when the engine is being timed.

## GEARS

### Idler Gears

. An idler gear is placed between two other gears to transfer motion from one gear to the other without changing their direction. By varying the number of teeth on the drive gear to the number on the driven gear a variation in speed can be effected. For example the crank shaft may turn at ١٥٠٠ Revs per minute (RPM) but on a four cycle engine the cam shaft must turn at half that speed i.e. ٧٥٠ RPM. The number of teeth on the crankshaft will be half the number on the camshaft. This is really a very simple example of a reduction gear system. A more complex system would be the common gearbox on a car. It just uses a combination of gear *ratios* in order to maintain engine speed as the load increases or decreases.