CHAPTER 6

PRINCIPAL MOVING AND RELATED COMPONENTS

Many of the principal parts that are within the main structure of an engine are moving parts. These moving parts convert the thermal energy released by combustion in the cylinder to mechanical energy, which is then available for useful work at the crankshaft. In this chapter we will discuss the moving and related parts that seal and compress gases in the cylinder and transmit the power developed in the cylinder to the crankshaft. After reading the information in this chapter, you should be able to recognize and describe the basic types, functions, and characteristics of valves, valve actuating mechanisms, piston and rod assemblies, crankshafts, flywheels, and jacking gears.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Explain the purpose of valve-actuating mechanisms.
2. List the principal moving components of a diesel engine.
3. Describe the function of the crankshaft of an engine.
4. List some of the different types of bearings.
5. Explain the purpose of a flywheel.
6. Explain the function of the jacking gear.

VALVE-ACTUATING MECHANISMS

Valve mechanisms may vary considerably in construction and design, even though the function remains the same. The basic types of valve mechanisms are described briefly in Fireman, NAVEDTRA 14104.

Actuating mechanism, as used in this chapter, is that combination of parts that receives power from the drive mechanism and transmits the power to the engine valves. In order for the intake and exhaust valves, fuel injection, and air start to operate, there must be a change in the type of motion. The rotary motion of the camshaft must be changed to a reciprocating motion. The group of parts that, by changing the type of motion, causes the valves of an engine to operate is generally referred to as the valve-actuating mechanism. A valve-actuating mechanism may include the camshaft, cam followers, pushrods, rocker arms, and valve springs. In some engines, the camshaft is so located that pushrods are not needed. In such engines, the cam follower is a part of a rocker arm.

Valves

The intake and exhaust valves used in internal combustion engines are of the poppet type.

Poppet valves have heads with cone-shaped or beveled edges and beveled seats, which give the valves a self-centering action, as shown in Figures 6-1 and 6-2.

Exhaust valves are usually made of silicon chromium steel or steel alloys. Usually, there is a high content of nickel and chromium included in the steel or alloy so that the valves can resist corrosion caused by high-temperature gases. A hard alloy, such as Stellite, is often welded to the seating surface of the valve face and to the tip of the valve stem. The hard alloy increases the wearing qualities of the surfaces, which make contact when the valve closes. Low-alloy steels are generally used for intake valves because these valves are not exposed to the corrosive action of the hot exhaust gases. Consequently, intake valves are capable of longer periods of trouble-free operation.
In some exhaust valves, sodium is used as an agent for cooling the valves. Sodium-filled poppet valves are provided with a chamber that is formed by the hollow stem that extends well up into the valve head. At operating temperatures, the sodium becomes a liquid and splashes up and down inside the hollow valve stem. The sodium is an effective agent that serves to transfer the heat from the hot exhaust valve head through the stem and valve guides and to the engine cooling system. Although sodium-filled exhaust valves are effective, they are not commonly used.

Valve seat inserts (Figure 6-1) are provided in most diesel engine cylinder heads so that valve seat life is extended. Valve seat inserts also have the advantage of being replaceable. Several different types of materials are used in the manufacture of valve seat inserts. Intake valve seats are manufactured from special alloys of cast iron. Exhaust valve seats are made from stellite and hardened chrome vanadium steel. Valve seat inserts are installed with an interference fit.

![Valve operating mechanism diagram](image.png)

**Figure 6-1 — Valve operating mechanism.**

Replaceable valve guides (Figure 6-1) are provided for most diesel engines. Replaceable valve guides are made of a cast iron alloy that has a superior wearability and is more corrosion resistant than the alloy that is used in the cylinder head. Replaceable valve guides not only provide a guide and bearing for each valve stem but also aid in conducting heat from each valve stem to the water jacket that surrounds the guide.

**Valve Springs**

Valve springs are mechanisms that serve to close the valves. Valve springs are made of highly tempered round steel wire that is wound in a spiral coil. Only a small percentage of the spring force is
required to keep the valve tight on the valve seat of the head. The majority of the spring force is used to keep the pushrod (Figure 6-1) or the rocker arm (Figure 6-2) in contact with the cam while the valve is being opened and closed. This force of the valve spring prevents the bouncing or fluttering of the valve that would otherwise occur from the rapid motion of the opening and closing of the valve at high speeds. So the spring can have sufficient force, it is always compressed when it is installed. (It is further compressed, of course, whenever the valve is opened.)

Valve Spring Retainers

Valve springs are mounted between supports. These supports, commonly referred to as spring seats, are located at the ends of the spring. The lower spring seat may be simply a recess in the top of the cylinder head, or a steel washer that rests on top of the cylinder head, and is shaped to fit the bottom coil of the spring. The upper spring seat, called the spring retainer, is a steel washer that is shaped to fit the top of the spring. The upper spring seat is attached to the top of the valve stem by removable fastenings commonly known as valve keepers.

Valve Keepers

A widely used type of valve spring retainer is provided with a conical recess in the upper seat. The valve stem is locked in the recess by means of a conical split collar, called a lock or keeper. This collar fits around the stem and into one or more grooves turned in the valve stems (Figure 6-2).

Valve Rotators

On some engines that are subjected to long periods of idle or light loads, valve rotators may be used to keep the valves from sticking due to distribution of wear on the valve stem and valve guide.
Without rotation, the combustion deposits that form on the valve stem, face, and seat would be cleaned off on one side only. Standard valve spring seats allow rotation but do not assure it. With controlled rotation, carbon deposits are cleaned off all around the valve stem, face, and seat. Valve rotators may be installed below or above the valve spring according to design requirements.

**Camshafts**

A camshaft is a shaft with eccentric projections called cams. The camshaft of an engine is designed to control the operation of the valves and fuel injection pump usually through various intermediate parts. On some engines, a balance shaft is used to counterbalance the rotation of the weighted camshaft and to stabilize the oscillatory impulses developed within the engine. See Figure 6-3 for the location of the balance shaft and weight assemblies.

The camshaft may be constructed in several ways. It can be forged in one piece (Figure 6-3) in which the cams themselves are integral to the shaft. (This is the most common design in small to medium engines.) A camshaft of a large engine may consist of a shaft with separate forged steel or cast iron cams keyed and shrunk on the. Another construction used on larger engines is a camshaft that is made from sections, which are bolted together. Some engines have two camshafts and others have only one, depending on the design of the engine.

![Figure 6-3 — Cam and balancer shaft assemblies.](image)

To reduce wear and to withstand repeated shock action, camshafts are made of low-carbon alloy steel with the cam and journal surfaces carburized (case-hardened) before the final grinding is done. The cams are arranged on the shaft so that the proper firing order of the cylinders being served can take place. If one cylinder is properly timed, the remaining cylinders are automatically in time. All cylinders will be affected if there is a change in timing. The shape of the cam determines the point of opening and closing; the speed of opening and closing; and the amount of valve lift.

The camshaft in a 4-stroke cycle diesel engine carries the cams for actuating the intake and exhaust valves. In addition, the camshaft may carry cams for fuel injection equipment or air starting valves. In a 2-stroke cycle diesel engine there is no requirement for an intake cam due to the use of intake ports.
The location of the camshaft differs in various engines. The camshaft may be located low (near the crankshaft) and may use long pushrods (Figure 6-1), or the camshaft may be located at the cylinder head level without pushrods (Figure 6-2). Variations of camshaft location are shown in Figure 6-4, View A through C.

**Cam Followers and Lash Adjusters**

In the valve-actuating mechanism, cam followers change the rotary motion of the camshaft to reciprocating motion. This action opens the valves. Cam followers ride the flat of the cam and are raised as the cam rotates by the high side of the cam and lowered by tension from the valve in internal-combustion engines as shown in Figure 6-5.

Hydraulic valve lifters (lash adjusters) are used on some engines to avoid the necessity of a clearance needed in the valve gear to allow for expansion resulting from temperature changes. Hydraulic valve lifters also eliminate the need for manual adjustment to take care of the wear at various points of the valve gear. They may be installed on the rocker arms, valve bridge, or cam follower. Figure 6-6 shows a larger sectional view of the hydraulic lash adjuster shown in Figure 6-7.

Hydraulic lash adjusters may vary in design but generally consist of such basic parts as a cylinder, a piston or plunger, a ball check valve, and a spring. As precision parts, hydraulic valve lifters or adjusters require special care in handling and must be kept exceptionally clean.

**Rocker Arms and Pushrods**

Rocker arms (levers) are part of the valve-actuating mechanism. A rocker arm is designed to pivot on a pivot pin or shaft that is secured to a bracket. The bracket is mounted on the cylinder head. One end of a rocker arm is in contact with the top of the valve stem, and the other end is actuated by the camshaft.
In some installations where the camshaft is located near the cylinder head, the rocker arm may be actuated from the cam by the use of cam followers. Figure 6-7 illustrates a design of this type in which a cylinder head is fitted with three rocker arms or levers. Figure 6-7 is a cutaway view with one rocker arm shown. The two outer arms operate the exhaust valves, and the inner arm operates the fuel injector. Since there are four exhaust valves per cylinder, each exhaust rocker arm must operate a pair of valves through a valve bridge. The valve bridge enables the rocker arm to operate two valves simultaneously. The valve bridge in this engine is made of forged steel and has a hardened ball socket into which the ball end of the rocker arm adjusting screw fits. The valve bridge has two arms, each of which fits over an exhaust valve. The valve bridge spring keeps valve bridge tension off the valve stems until the bridge is actuated by the rocker arm. When the valve end of the rocker arm is forced down by the cam action, the valve bridge moves down, compressing the valve springs and opening the valves. By the time the action of the cam lobe has ceased, the valve springs will have closed the valves. The valve operating mechanism shown in Figure 6-7 is representative of those in which the location of the camshaft eliminates the need for pushrods. (Note that the lobes of the cam come in direct contact with the rocker arm cam rollers.)

Figure 6-7 — A typical valve gear.
In installations where the camshaft is located below the cylinder head, the rocker arms are actuated by pushrods ([Figure 6-8](#)) The lifters (cam followers) have rollers which are forced by the valve springs to follow the profiles of the cams. The pushrods transmit the motion from the roller type of lifter for intake and exhaust valve operation and are activated by their respective intake and exhaust lobes of the camshaft. The intake and exhaust valves in Figure 6-8 are operated by mechanisms similar to those represented in Figure 6-7 with two exceptions. The unit in Figure 6-8 has no design requirement for an injector rocker arm because of the type of fuel system used. Also, the unit in Figure 6-8 is a 4-stroke cycle unit and requires both an intake and exhaust valve rocker arm.

**Figure 6-8 — Valve rocker arm operation.**

**PRINCIPAL MOVING COMPONENTS**

In this chapter, the principal moving component refers to the parts that convert the thermal energy released by combustion in the cylinder to mechanical energy, and then becomes available for useful work. The principal moving parts of an engine consist of the piston and connecting rod assemblies, crankshaft, bearings, and flywheel. Piston and connecting rod assemblies of an engine will include the piston, piston rings, piston pin, and connecting rod. These units and their functions in engine operation are discussed separately in the following sections.
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. Pistons perform a number of functions. A piston, in addition to transmitting the force of combustion to the connecting rod and conducting the heat of combustion to the cylinder wall, may serve as a valve in opening and closing the ports of a 2-stroke cycle engine.

Trunk-Type Pistons

There are two distinct types of pistons: the trunk type and the crosshead type. Variations in the design of trunk-type pistons can be seen in Figures 6-9 and 6-10.

The crown, or head, of a piston acts as the moving surface that changes the volume of the content of the cylinder (compression), removes gases from the cylinder (exhaust), and transmits the energy of combustion (power). Generally, the crown end of a piston is slightly smaller in diameter than the skirt end. The resulting slight taper allows for
expansion of the metal at the combustion end. Even though slight, the taper is sufficient so that at
normal operating temperatures, the diameter of the piston is the same throughout.

Manufacturers have produced a variety of crown designs—truncated, cone, recessed, dome or
convex, concave or cup, and flat. Piston crowns of concave design are common in marine engines
used by the Navy; however, other types may be encountered. An advantage of the concave shape is
that it assists in creating air turbulence, which mixes the fuel with air during the last part of
compression in diesel engines.

Some concave types of pistons have recesses in the crown to allow room for the parts that protrude
into the combustion space. Examples of such parts are the exhaust and intake valves, the air starting
valve, and the injection nozzle. In some 2-stroke cycle engines, piston crowns are shaped with
irregular surfaces which deflect and direct the flow of gases.

The skirt of a trunk-type piston receives the side thrust created by the movement of the crank and
connecting rod. In turn, the piston transmits the thrust to the cylinder wall. In addition to receiving
thrust, the skirt aids in keeping the piston in proper alignment within the cylinder. Some pistons are
plated with a protective coating of tin which permits close fitting, reduces scuffings, and prolongs
piston life. Still other pistons may be given a phosphate treatment to aid skirt lubrication. This process
etches the surface and provides a nonmetallic, oil-absorbent, antifriction coating that promotes rapid
break-in and reduces subsequent wear.

Most trunk-type pistons are of one-piece construction. Some trunk pistons are made of two parts and
two metals; the trunk or skirt is made of cast iron or an aluminum alloy, and the crown or head is
made of steel. In some pistons of this type of construction, the crown is fitted to the trunk with a
ground joint, while in others the parts are welded together. Without grooves and lands, the piston
rings cannot be properly spaced or held in position. The number of grooves and lands on a piston will
vary considerably, depending on such factors as the size and the type of the piston, See Figures 6-9
and 6-10.

Some pistons have oil drains (small holes) in the bottom of some of the grooves (Figure 6-9); some
pistons have oil drains in the skirt of the piston or in the land. These holes serve as oil returns,
permitting lubricating oil from the cylinder wall to pass through the piston into the crankcase.

Generally, the bosses (hubs) of a piston are heavily reinforced openings in the piston skirt, (Figure 6-
10). Some bosses are a part of an insert which is secured to the inside of the piston. The principal
function of the bosses is to serve as mounting places for the bushings or bearings which support the
piston pin. The bosses provide a means of attaching the connecting rod to the piston. Generally, the
diameter of the piston at the bosses is slightly less than the diameter of the rest of the piston. This
difference serves to compensate for the expansion of the extra metal in the bosses.

Because of the intense heat generated in the combustion chamber, adequate cooling must be
provided. The heat transmitted through the rings (approximately 30 percent of the heat absorbed by
the piston) to the cylinder wall is not sufficient in many engines to keep the unit cooled within
operating limits. Most pistons have fins or ribs and struts as internal parts (Figure 6-9). The additional
surfaces of these parts help to dissipate heat; much of the heat is carried away by oil which may be
pump-forced, sprayed, splashed, or thrown by centrifugal force onto the underside of the piston
assembly. A different approach to cooling the piston head is with the use of drilled passages from the
connecting rod through the piston pin to the piston bosses. Drilled passages in the piston direct the oil
to cavities in the piston crown. Oil discharged from these cavities is controlled so a sizeable amount is
retained at all times to cool the crown by “cocktail shaker” action as the piston moves up and down in
the cylinder. A cutaway view of this type of design is shown in Figure 6-17. Oil is the principal means
of cooling for most piston assemblies. Intake air is also used in the cooling of hot engine parts. In
order to exhaust or scavenge a cylinder of burned gases and cool the engine parts, the intake and
exhaust valves or ports are so timed that both are open for a short time at the end of the exhaust
stroke. This action allows the intake air to enter the cylinder, clean out the hot gases, and, at the same time, cool the parts.

Crosshead Pistons

A type of crosshead piston is currently being used in some engines (Figure 6-11). The crosshead piston is a two-piece unit with a crown that can withstand the high heat and pressure of a turbocharged engine and a skirt specifically designed to absorb side thrust.

The crown and skirt are held together by the piston pin. The downward load on the crown pushes directly on the pin through a large slipper bearing (bushing). The separate skirt has less thermal distortion than the crown piece and is free of downward thrust loads. It specifically guides the piston in the cylinder, takes up side thrust, and carries the oil scraper rings. The crown carries the compression rings. Since the crown is separate, it takes only a slight amount of side thrust and is not forced to slide sideways under the compression rings when they are pressed hard against the bottoms of their grooves by combustion gas pressure. Lubricating oil is fed upward by pressure to cool the piston pins and piston crown.

Piston Rings

Piston rings are particularly vital to engine operation in that they must effectively 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. In Figures 6-9, 6-10, and 6-12 the compression rings are located toward the crown or combustion end of the piston. The ring closest to the crown is sometimes referred to as the firing ring. Two different examples of piston ring location are shown in Figures 6-10 and 6-12. In Figure 6-10, both compression and oil rings are located toward the crown above the pin bosses. In Figure 6-12, the compression rings are located above the bosses and the oil rings are located below the bosses.

The terms above and below adequately identify ring location when the crown of the piston is at the top, as it is in the in-line and V-type engines. These terms may lead to confusion, however, when reference is made to ring location on the upper pistons of opposed-piston engines. Piston ring location can be more accurately identified by reference to the crown or combustion end and to the skirt or crankshaft end of the piston. There are many variations in the design of compression and oil rings. Some common variations are illustrated in Figure 6-13, frames 1-5.
Figure 6-12 — Typical piston, piston rings, pin, and relative location of parts.

A. Diagonally Cut Compression Ring
B. Lap-Joint Compression Ring
C. Oil Ring
D. Slotted Oil Ring
E. Three Piece Oil Ring

Figure 6-13 — Types of piston rings.
**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 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. One 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: (1) distribute enough oil to the cylinder wall to prevent metal-to-metal contact, and (2) 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. Some types of oil rings are shown in Figure 6-13, frames 3, 4, and 5.

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. For example, a General Motors 6-71 piston has two sets of oil control rings placed on the skirt below the piston pin. Both sets are identical; each consisting of three pieces (two rings and an expander) (Figure 6-12). The ring illustrated in Figure 6-13, frame 5, is also a three-piece oil ring. In rings of this type, the two “scrapping” pieces have very narrow faces bearing on the cylinder wall, which permit the ring assembly to conform rapidly to the shape of the
since the ring tension is concentrated on a small area, the rings will cut through the oil film easily and remove the excess oil. The bevel on the upper edge of each ring face causes the ring to ride over the oil film as the piston moves toward top dead center (TDC), but as the piston moves downward for intake and power, the sharp, hook-like lower edge of each ring scrapes or wipes the oil from the cylinder wall.

Another example of differences in terminology and location is found in the Fairbanks-Morse (FM) 38D8 1/8. A piston in this type of engine has three oil rings all located on the skirt end. The two nearest the crankshaft end of the piston are called oil drain rings, while the ring nearest the pin bosses is referred to as the scraper. The drain rings are slotted to permit oil to pass through the ring and to continue on through the holes drilled in the ring grooves. Figure 6-13, frame 4 shows one type of slotted oil ring. Additional information concerning pistons and piston rings can be found in Naval Ships' Technical Manual, Chapter 233.

### Piston Pins and Piston Bearings

In trunk-type piston assemblies, the only connection between the piston and the connecting rod is the pin (sometimes referred to as the wrist 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 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 in a single-acting engine equipped with trunk-type pistons (Figure 6-14, frames 1 and 2).

Side thrust is exerted at all points during a stroke of a trunk-type piston, except at 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. In Figure 6-14, frame 1, gas pressure is forcing the piston downward (power). Since the crankshaft is rotating clockwise, 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.

In Figure 6-14, frame 2, the piston is being pushed upward (compression) by the crankshaft and connecting rod. This 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 Pins

Pins are usually hollow and made of alloy steel, machined, hardened, and precision-ground to fit the bearings. Their construction provides maximum strength with minimum weight. Some pins are chromium-plated to increase the wearing qualities. The pins are lubricated by splash from the crankcase, by oil forced through drilled passages in the connecting rods, or by the use of piston oil spray nozzles.

Piston pins must be secured in position so they do not protrude beyond the surface of the piston or have excessive end-to-end motion. Otherwise, the pin will tend to damage the cylinder wall. Piston pins may be secured in the connecting rod assembly in one of three ways: (1) rigidly fastened into the piston bosses, (2) clamped to the end of the rod, or (3) free to rotate in both piston and rod. When piston pins are secured by these methods, the pins are identified as (1) stationary (fixed), (2) semi-floating, and (3) full floating, respectively.

Stationary

The stationary pin is secured to the piston at the bosses, and the connecting rod oscillates on the pin. Since all movement is by the connecting rod, uneven wear may occur on the contacting surfaces in this type of installation. For this reason, use of this type of pin is not typical in Navy diesel engines.

Semifloating

Semifloating pins are secured in the middle to the connecting rod (*Figure 6-15*). The ends of the pin are free to move in the piston pin bearings in the bosses.

Full-Floating

Full-Floating pins are not secured to either the piston or the connecting rod. Pins of this type may be held in place by caps, plugs, and snap rings, or spring clips which are fitted in the bosses (*Figure 6-12*). The securing devices for a full-floating pin permit the pin to rotate in both the rod and piston pin bosses. Of the three types of piston pins, the full-floating piston pin is the most common.

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 (Figure 6-16). Some sleeve bushings have a press fit, while others are “cold shrunk” into the bosses.

Bearings of the sleeve bushing type for both the bosses and the connecting rod are shown in Figure 6-16.

**NOTE**
The bosses are a part of an insert.

![Piston and connecting rod (Fairbanks-Morse).](image)

**Figure 6-16 — Piston and connecting rod (Fairbanks-Morse).**

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 semifloating pins (Figure 6-15) 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 case-hardened steel sleeve, and the bushing has a shrink fit in the rod bore. In other bushings, the bushing fit is such that a gradual rotation (creep) takes place in the eye of the connecting rod.

In another variation of the sleeve-type bushing, a cast bronze lining is pressed into a steel bushing in the connecting rod.

**Connecting Rods**

The connecting rod is the connecting link between the piston and the crankshaft. It is one of the most highly stressed parts of an engine in that the connecting rod transmits the forces of combustion to the crankshaft.

In general, the type of connecting rod used in an engine depends on the cylinder arrangement and the type of engine. Several types of connecting rods have been designed. Only two, however—the conventional rod and the fork and blade rod—are those likely to be found in marine engines used by the Navy and are the ones discussed here.
Conventional Rods

The conventional rod, illustrated in Figure 6-16, is typical of those used in many in-line and V-type engines. When used in V-type engines, two rods are mounted on a single crankpin. The two cylinders served are offset so that the rods can be operated side by side.

Rods are generally made of drop-forged, heat-treated carbon steel (alloy steel forging). Most rods have an I- or H-shaped cross section which provides maximum strength with minimum weight. The bore (hub, eye) at the piston end of the rod is generally forged as an integral part of the rod, (Figure 6-16). The use of semifloating piston pins eliminates the need for the bore (Figures 6-11 and 6-15). The bore at the crankshaft end is formed by two parts; one an integral part of the rod and the other a removable cap (Figure 6-16). Rods are generally drilled or bored to provide an oil passage from the crankshaft to the piston end of the rod.

The bore of the crankshaft end of a conventional rod is fitted with a precision bearing of the shell type, (Figure 6-16). In design and materials, rod bearings are similar to the main journal bearings, which are discussed in connection with crankshafts later in this chapter. Connecting rod bearings of most engines are pressure-lubricated by oil from adjacent main bearings, through drilled passages. The oil is evenly distributed over the bearing surfaces by oil grooves in the shells. Bearing shells have drilled holes which line up with an oil groove in the rod bearing seat. Oil from this groove is forced to the piston pin through the drilled passage in the rod. Figure 6-17 illustrates a drilled type of connecting rod, which in this example is used in conjunction with a "cocktail shaker" type of piston.

Fork and Blade (Plain) Connecting Rods

While two conventional rods are used to serve two cylinders in some V-type engines, a single assembly consisting of two rods is used in other engines of this type. As the name implies, one rod is fork-shaped at the crankshaft end to receive the blade rod. In general, fork and blade rods are similar to conventional rods in material and construction. However, design at the crankpin end (Figure 6-18) obviously differs from that of the conventional rods.
The bearings of fork and blade rods are similar to those already discussed, except that the upper shell must have a bearing surface on the outer surface to accommodate the blade rod.

**Connecting Rod Bolts**

Connecting rod bolts are the securing link between the piston assembly and the crankshaft. The rod bolts, because of the need for great strength, are generally made of heat-treated alloy steel. Fine threads with close pitch are used to give maximum strength and to permit secure tighten.

The majority of rod bolts used are machined to provide high fatigue resistance by having a large portion of the body of the bolt turned to a diameter of less than the root diameter of the thread. Thus, all the body, except the ends and the center portion (which acts as a dowel), is machined to the smaller diameter. Refer to the bolts in *Figure 6-16*. As an additional precaution in some connecting rods, the mating surfaces between the foot of the rod and the connecting rod cap are serrated to help the bolts resist side forces (*Figures 6-15 and 6-17*).

**CRANKSHAFT**

As one of the largest moving parts in an engine, the crankshaft changes the movement of the piston and the connecting rod into the rotating motion that is needed to drive such items as reduction gears, propeller shafts, generators, and 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 nitride (heat-treated) to increase the strength of the shafts and to minimize wear. While crankshafts of a few larger engines are of the built-up type (forged in separate sections and flanged together), the crankshafts of most modern engines are of one-piece construction (*Figure 6-19*).

![Crankshaft Diagram](image)

*Figure 6-19 — One-piece crankshaft.*

**Crankshaft Terminology**

The parts of a crankshaft may be identified by various words. However, the terms in *Figure 6-19* are the ones that are most commonly used in the Naval Sea Systems Command (NAVSEA) technical manuals for the engines used by the Navy.
The main journals serve as the points of support and as the center of rotation for the shaft. As bearing surfaces, the main journals and the connecting rod journals of crankshafts are surface-hardened so that a longer wearing, more durable bearing metal can be used without causing excessive wear of the shaft.

As illustrated in Figure 6-19, crankshafts have a main journal at each end of the shaft with an intermediate main journal between the cranks. Each crank (throw) of a shaft consists of three parts—two webs and a pin—as shown in Figure 6-19. Crank webs are sometimes called cheeks or arms. The cranks, or throws, provide points of attachment for the connecting rods, which are offset from the main journals.

In many crankshafts, especially in large engines, the connecting rod journals and main journals are of hollow construction. Hollow construction not only reduces weight considerably but also increases torque capability of the crankshaft and provides a passage for the flow of lubricating oil (Figure 6-20).

The forces that turn the crankshaft of a diesel engine are produced and transmitted to the crankshaft in a pulsating manner. These pulsations 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. Several types of torsional dampers are currently in use.

On some crankshafts, part of the web of the crankshaft extends beyond the main journal to form or support counterweights. These counterweights may be integral parts of the web (Figure 6-19) or may be separate units attached to the web by studs and nuts, or setscrews (Figure 6-21).
Counterweights balance the off-center weight of the individual crank throws and thereby compensate for centrifugal force generated by each rotating crank throw. If such vibrations are not controlled, the shaft would become damaged. Excessive vibration may lead to complete failure of the engine. Counterweights use inertia to reduce the pulsating effect of power impulses in the same manner as the flywheel. Flywheels are described later in this chapter.

Crankshafts and Lubrication

Whether a crankshaft is of solid construction (Figure 6-19) or of hollow construction (Figure 6-20), the main journals, the connecting rod journals, and the webs of most shafts have drilled passages for lubricating oil. Two other variations in the interior arrangement of oil passages in crankshafts are shown in Figure-22, frames 1 and 2. A study of these two oil passage arrangements will give you an idea of the part the crankshaft plays in engine lubrication. In the system illustrated in Figure 6-22, frame 1, each oil passage is drilled through from a main bearing journal to a connecting rod journal. The oil passages are in pairs that crisscross each other in such a way that the two oil holes for each journal are on opposite sides of the journal. These holes are in axial alignment with the oil grooves of the bearing shells when the shells are in place. Since the oil groove in a bearing goes at least halfway around the bearing, a part of the groove will always be aligned with at least one of the holes.

In the oil passage arrangement shown in Figure 6-22, frame 2, (the shaft is shown in Figure 6-19), the passage is drilled straight through the diameter of each main and connecting rod journal. A single diagonal passage is drilled from the outside of a crankshaft web to the center of the next main journal. The diagonal passage connects the oil passages in the two adjoining connecting rod journals and main journals. The outer end of the diagonal passage is plugged. Lubricating oil under pressure enters the main bearing and is forced through the diagonal passage to lubricate the connecting rod bearing. From there it flows through the drilled connecting rod to lubricate the piston pin and cool the piston.

In engines that use crankshaft oil passage arrangements the connecting rods are drilled to carry the lubricating oil to the piston pins and piston. Not all engines have drilled connecting rods. In some V-type engines, drilled passages supply oil to the main and connecting rod bearings, but oil for the lubrication and cooling of the piston assembly may be supplied by centrifugal force or by separate supply lines.
Crankshaft Throw Arrangements

The smooth operation of an engine and its steady production of power depend, to a great extent, on the arrangement of the cranks on the shaft and on the firing order of the cylinders. For uniform rotation of the crankshaft in most multi-cylinder engines, the power impulses must be equally spaced with respect to the angle of crankshaft rotation. Whenever possible, they must also be placed so that successive explosions do not occur in adjacent cylinders.

Crankshafts may be classified according to the number of throws. The 6-throw shaft illustrated in Figure 6-19 is for a 6-cylinder, in-line, and 2-stroke cycle engine. Shafts of similar design can be used in V-type engines.

The number of cranks and their arrangement on the shaft depend on a number of factors, such as the arrangement of the cylinders (in-line or V-type), the number of cylinders, and the operating cycle of the engine. How these factors influence throw arrangement and firing order can be seen in a comparison of Figure 6-23, Examples a through e. The arrangement of throws with respect to one another and with respect to the circumference of the main journals is generally expressed in degrees. In an in-line engine, the number of degrees between throws indicates the number of degrees the crankshaft must rotate to bring the pistons to TDC in firing order. This is not true in engines where each throw serves more than one cylinder. Figure 6-23 lists the examples of throws with respect to cylinder arrangement, the number of cylinders served by each throw, and the firing order of the cylinders. (The sketches are not drawn to scale and do not indicate relative size, but are for illustrative purposes only.)

In studying the examples in Figure 6-23, remember that the crankshaft must make only one revolution (360°) in a 2-stroke cycle; whereas two revolutions are required in a 4-stroke cycle. Note the throw arrangement in Example a of a 4-stroke cycle engine. Since the 4-cylinder engine in Example a operates on the 4-stroke cycle, throws 1, 3, 4, and 2 (see firing order), must be 180° apart in order for the firing to be spaced evenly in 720° of crankshaft rotation. Note too, that in all the other examples, the throws are equally spaced, regardless of cylinder arrangement, cycle of operation, or number of cylinders.

In Examples b and c, the shaft design and the number of degrees between throws are the same. Yet the shaft in Example c fires twice as many cylinders. This is possible because one throw, through a fork and blade rod, serves two cylinders which are positioned in 60° banks. Thus, even though both engines operate on the 4-stroke cycle, the 12-cylinder engine requires only 60° shaft rotation between power impulses. There are six throws shown in Examples b and d, yet they are 120° apart in one and 60° apart in the other. Why? The cylinder arrangement, the total number of cylinders, and the number of cylinders served by each throw are the same. In Examples b and d, the operating cycle is the controlling factor in throw arrangement. In Examples d and e, other variations in shaft throw arrangement and firing order are shown. Note that the differences are governed to a great extent by the cylinder arrangement, the number of cylinders served by the shaft and by each throw, and the operating cycle of the engine.
<table>
<thead>
<tr>
<th>EXAMPLE</th>
<th>NUMBER CYLINDERS</th>
<th>CYLINDER ARRANGEMENT</th>
<th>CYCLE</th>
<th>NO CYL SERVED BY EACH THROW</th>
<th>THROW ARRANGEMENT (SIDE VIEW)</th>
<th>THROW ARRANGEMENT (END VIEW)</th>
<th>FIRING ORDER</th>
<th>NO DEGREES BETWEEN THROWS (SEE SKETCHES)</th>
<th>NO DEGREES SHAFT ROTATION BETWEEN FIRINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>4</td>
<td>IN-LINE</td>
<td>4 - Stroke</td>
<td>1</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td>1-3-4-2</td>
<td>4 THROWS 180° APART</td>
<td>180</td>
</tr>
<tr>
<td>(b)</td>
<td>6</td>
<td>IN-LINE</td>
<td>4 - Stroke</td>
<td>1</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td>1-5-3-6-2</td>
<td>6 THROWS 120° APART</td>
<td>120</td>
</tr>
<tr>
<td>(c)</td>
<td>12</td>
<td>V</td>
<td>4 - Stroke</td>
<td>2</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td>1-2-3-4-5-6</td>
<td>6 THROWS 120° APART</td>
<td>60</td>
</tr>
<tr>
<td>(d)</td>
<td>6</td>
<td>IN-LINE</td>
<td>2 - Stroke</td>
<td>1</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td>1-5-3-6-2-4</td>
<td>6 THROWS 60° APART</td>
<td>60</td>
</tr>
<tr>
<td>(e)</td>
<td>12</td>
<td>V</td>
<td>2 - Stroke</td>
<td>2</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td>1-2-3-4-5-6</td>
<td>6 THROWS 60° APART</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 6-23 — Example of crankshaft arrangement.
BearingS

The bearings of an engine make up an important group of parts. Bearings serve to support rotating shafts and other moving parts and to transmit loads from one part of the engine to another. Engine bearings consist of two basic types: antifriction bearings and friction bearings. Both types are used in Navy diesel engines.

Antifriction Bearings

Antifriction bearings can be grouped into six general classifications: ball bearings, cylindrical roller bearings, and needle bearings, tapered roller bearings, self-aligning roller bearings, and thrust bearings. The use of antifriction bearings is mostly limited to the exterior areas of an engine. They are used in cooling pumps, fuel-injection pumps, governors, starters, flywheel pilot bearings, turbochargers, and blowers.

All antifriction bearings employ a rolling element (rollers, balls, or needles) between the inner and outer rings (races). Either the inner ring or the outer ring will remain stationary. See Figure 6-24 for cutaway views of two types of antifriction bearings. 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. The material used for ball bearings is usually heat-treated chromium-alloy steel.

As an Engineman, 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, and the required lubricant.
Friction Bearings

In diesel engines, friction bearings serve to support the crankshaft, connecting rod, camshaft, and gear train. In some engine applications, friction bearings also support the rocker arm shaft as well as various pumps.

A type of friction bearing that is representative of most of the bearings used in Navy diesel engines is the precision bearing. Precision-type bearings that act as supports for the crankshaft are referred to as main journal bearings. In our discussion of friction bearings, we will use the main journal bearing as a representative sample.

Main journal bearings are of the sliding contact, or plain, type consisting of two halves, Figure 6-25. The location of main engine bearings in one type of block is shown in Figure 6-26. The main journal bearings of most marine engines used by the Navy are of aluminum, aluminum alloy, or trimetal construction. In the trimetal type of construction, the bearing has a steel back bonded with a layer of bronze to which is bonded a layer of bearing material. The bearing material is either lead-based babbitt or tin-based babbitt. Regardless of the construction materials, the function and performance of main journal bearings are basically the same, with the exception of bearings, which are constructed not only to support the crankshaft but also to hold the crankshaft in position axially. This is done by flanges, which are part of the bearings, as shown in Figure 6-26. Such flanges are on both halves of a bearing.

These types of bearings are called thrust bearings. Some engines use separate flat thrust washers on each side of one main bearing to control the crankshaft thrust (back and forth movement).

Main bearings and their housing and caps are precision machined with a tolerance sufficiently close that, when properly installed, the bearings
are in alignment with the journals and fit with a predetermined clearance. The clearance provides space for the thin film of lubricating oil which is forced, under pressure, between the journals and the bearing surfaces. Under normal operating conditions, the film of oil surrounds the journals at all engine load pressures. Lubricating oil enters the bearing shells from the engine lubricating system through oil grooves in the bearing shells, *Figures 6-25 and 6-26*. These inlets and grooves are located in the low-pressure area of the bearing.

Main bearings are subjected to a fluctuating load, as are the connecting rod bearings and the piston pin bearings. However, the manner in which main journal bearings are loaded depends on the type of engine in which they are used.

In a 2-stroke cycle engine, a load is always placed on the lower half of the main bearings and the upper half of the piston pin bearings. In the connecting rod, the load is placed upon the upper half of the connecting rod bearings at the crankshaft end of the rod. This is true because the forces of combustion are greater than the inertial forces created by the moving parts.

In a 4-stroke cycle engine, the load is applied first on one bearing shell and then on the other. The reversal of pressure is the result of the large forces of inertia imposed during the intake and exhaust strokes. In other words, inertia tends to lift the crankshaft in its bearings during the intake stroke and exhaust stroke. Additional information on bearings can be found in Naval Ships’ Technical Manual, Chapter 244.

**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 installation of 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 (1) keeps variations in speed within desired limits at all loads; (2) limits the increase or decrease in speed during sudden changes of load; (3) aids in forcing the piston through the compression event when an engine is running at low or idling speed; and (4) 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.

In some engines, a flywheel is the point of attachment for items such as a starting ring gear or a turning ring gear, *Figure 6-27*. 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.

**JACKING GEARS**

Diesel drive installations are equipped with a means of jacking, or barring, over. A great majority of diesel engines are jacked over by hand. One method of rotating the engine is with the use of a turning
bar. In this installation, holes are provided around the circumference of the rim for insertion of the turning bar so that the crankshaft can be manually rotated, Figure 6-27. This is a very simple but effective means that allows for the precise positioning of the crankshaft when required for timing.

Still another method of rotating the crankshaft is the engine barring device consists of a pinion and a hex head drive shaft. The drive shaft is mounted in a housing containing an eccentric sleeve arrangement for engaging the pinion with the ring gear on the flywheel. The only maintenance required for the jacking gear is periodic inspection for wear and minor lubrication of the moving parts of the pinion assembly.

The diesel engine lube oil system shall be primed before starting and before the engine is turned over (by hand or by a motor-driven jacking gear) prior to starting. Priming of the engine should continue only until a slight pressure is registered on the engine lube oil pressure gauge or until oil is observed at each main bearing. Continue priming until a slight pressure is registered on the engine lube oil pressure gauge or until oil flow is observed at each site flow indicator. Before starting the engine after a prolonged shutdown, inspect the air receiver and blower discharge passages and remove any accumulation of lube oil. When an engine room is secured and the ship is being towed, or is being propelled by units other than its main engines, the bearings of the shafts and machinery that are turned by propeller drag shall be adequately lubricated. If adequate lubrication is unavailable, the jacking gear shall be engaged and locked. Even with the jacking gear engaged and the brake set, oil shall be supplied to the bearings underway, if practical; to provide additional safety in case the jacking gear brakes should start to slip.

The barring device can also be operated by an air (motor) wrench placed over the hex head of the drive shaft. Main drive engines, as well as some auxiliaries, are usually equipped with safety devices that prevent the engine from starting while the jacking gear is engaged. The type of safety devices will depend on the type of starting system used.

**SUMMARY**

The valve-actuating mechanisms are those parts that transform the rotary motion of a drive mechanism into reciprocating motion. Reciprocating motion is used for the operation of engine cylinder valves. The camshaft is the principal part of a valve-actuating mechanism. Rotary motion of the cams on the camshaft is changed to reciprocating motion, and power is transmitted to the various cylinder valves (intake, exhaust, fuel injection, and air start) by means of rocker arm or tapped assemblies. These assemblies make contact with the cams by the use of cam followers.

The process of transmitting the power developed in an engine to useful energy involves the motion of many parts. The major parts are the piston, connecting rods, and crankshaft; however, many related parts must be considered in the process of changing reciprocating motion to rotary motion. For example, a piston, which may be of the trunk type or the crosshead type, receives the force of combustion and transmits it to the crankshaft through a connecting rod.
To accomplish their functions, pistons are fitted with piston rings, such as compression and oil control rings. Piston rings function to maintain a gastight seal between the piston and cylinder wall, to assist in cooling the piston, and to control cylinder wall lubrication.

Trunk-type pistons are fastened to the connecting rods by pins which may be stationary, semifloating, or full-floating. Side thrust created by combustion and the motion of the moving parts is received by the cylinder wall through a trunk-type piston. The crosshead assembly absorbs the side thrust in engines fitted with the crosshead-type piston.

The crankshaft, the largest of the moving parts of an engine, receives the power impulses from all cylinders of the engine, transforms the motion of the pistons and connecting rods into rotary motion, and transmits the resulting torque to the flywheel or driven unit.

Other important parts which must be considered in connection with moving parts of an engine are bearings. Bearings may be of the antifriction type or friction type. Both types can be found on diesel installations. Antifriction bearings are commonly used in the engine accessories while friction bearings are commonly used within the internal structure of the engine.

As in the case of the principal stationary parts of the engine, you should be thoroughly familiar with all of the major moving and actuating components of an engine. You should know the functions and operating principles of these parts and how these parts are related to the stationary parts. You should be able to associate each component, as discussed separately, with other related components of the engine and how each part or assembly is related to the cycle of engine operation. If you are uncertain concerning any of these areas, go back and review this information before proceeding to the next chapter.
End of Chapter 6
Principal Moving and Related Components

Review Questions
6-1. What type of intake and exhaust valves are used on internal-combustion engines?
   A. Gas-operated check
   B. Spring-activated
   C. Cone shaped seat
   D. Poppet

6-2. In a 2-stroke cycle diesel engine, the camshaft does NOT carry a cam for actuating what component?
   A. Exhaust valves
   B. Intake valves
   C. Unit injectors
   D. Air start valves

6-3. What is the usual metallurgical makeup of valve bridge and serves to extend the life of valve seats?
   A. Forged steel
   B. Ground tempered steel
   C. Annealed high-carbon steel
   D. Chrome-plated alloy steel

6-4. Why is the crown of a piston smaller than a skirt?
   A. It has more rings on it
   B. It runs hotter
   C. It absorbs no side thrust
   D. It gets worn down faster

6-5. How are the pistons held in place on an engine?
   A. Crowns
   B. Bosses
   C. Lands and grooves
   D. Skirts

6-6. What is the maximum amount of combustion heat absorbed by the piston that is removed through the rings to the cylinder wall?
   A. Approximately 20%
   B. Approximately 30%
   C. Approximately 40%
   D. Approximately 50%
6-7. What are some of the ways that heat is transferred through the cylinder walls to cool a piston?

A. Intake air and lubricating oil
B. Intake air and exhaust
C. Piston speed and crankcase air
D. Lubricating oil and cooling fins

6-8. Which of the following characteristics does NOT apply to compression rings?

A. They commonly have a rectangular cross-section
B. Their diameter is slightly larger than the cylinder bores
C. Combustion gases act only on the combustion areas
D. They transfer heat to cylinder wall

6-9. How would you classify the shape of crankshaft?

A. Several flanges forged together
B. Several throws in a row formed as offsets
C. A shaft with a crank at the end
D. A series of bearing and weights

6-10. What is the function of the drilled passages in the crankshaft?

A. To relieve excess oil pressure at the connecting rods
B. To carry oil to the connecting rods
C. To carry lubricating oil to the piston pin and the piston
D. To lighten the crankshaft by the amount that offsets the weights of any counterweights used

6-11. Where does the oil travel after passing the crankshaft?

A. Through the main journal and the connecting rod journal
B. Through the connecting rod bearing and the piston pin
C. Through the connecting rod bearing and the connecting rod
D. Through the connecting rod and the piston crown

6-12. What is the purpose for main journals on a crankshaft?

A. Used to ensure balance of rotation
B. Used as the attach point for the connecting rod
C. Used as the point of support and the center of rotation of the shaft
D. Used as the attachment for the flywheel

6-13. In addition to reducing the weight considerably, why is a crankshaft hollow in construction?

A. Provide passage for lubricating oil
B. Ensure timing of the engine
C. To balance the crankshaft
D. To offset the weight of the flywheel
6-14. What components do NOT use antifriction bearing?

A. Starters  
B. Camshafts  
C. Governors  
D. Blowers

6-15. What do the letter codes identify on the ball/roller bearing?

A. Outside diameter  
B. Weight of the bearing  
C. Material of the bearing  
D. The depth of the bore

6-16. What type of bearing serves to hold the crankshaft in position axially?

A. Main  
B. Thrust  
C. Roller  
D. Ball

6-17. What type of bearing is a precision bearing?

A. Fixed  
B. Floating  
C. Non-friction  
D. Friction

6-18. What event during the combustion cycle does the flywheel store energy?

A. Intake  
B. Compression  
C. Power  
D. Exhaust

6-19. What accessories are usually attached to an engine’s flywheel?

A. Lubricating oil pump  
B. Governor  
C. Water pump  
D. Turning ring gear

6-20. When the engine’s speed decreases, the flywheel gives up energy to the crankshaft for uniform rotation, the flywheel will?

A. Keeps variation in speed within desired limits at all loads  
B. Keeps variation in speed within desired limits different loads  
C. Increases in speed during sudden change of load  
D. Decreases in speed during sudden change of load
6-21. What measures are in place to ensure the engine doesn’t start while the jacking gear is engaged?

A. “DO NOT START” sign attached to gear  
B. Area roped off  
C. Engine safety devices  
D. Engine can operate while engaged

6-22. What is the jacking gear used for on diesel engines?

A. To start the engine  
B. To reverse the engine  
C. Inspection of the crankshaft  
D. To position the crankshaft for timing

6-23. What situation should the engine’s jacking gear be engaged and locked?

A. When adequate lubricating oil is unavailable  
B. During trend analysis  
C. During maintenance  
D. During full power run
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