CHAPTER 7

INTERNAL-COMBUSTION ENGINES

Internal-combustion engines are used extensively in the Navy. They serve as propulsion units in a variety of ships and boats. Internal-combustion engines are also used as prime movers (drive units) for auxiliary machinery. Because they have pistons that employ a back-and-forth motion, gasoline and diesel engines are also classified as reciprocating engines.

This chapter provides you with the general construction features and operating principles of various types of internal-combustion engines. After reading this chapter, you will have a basic understanding of the components that make up an internal-combustion engine and how these components work together to develop power.

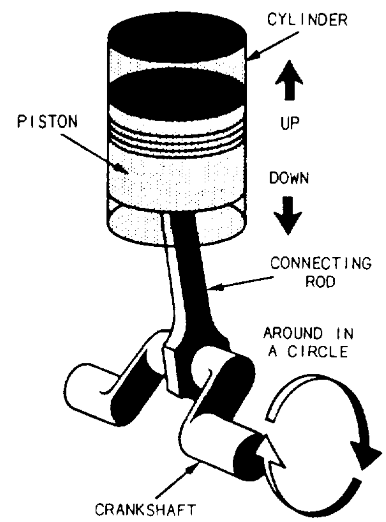


Figure 7-1.—Cylinder, piston, connecting rod, and crankshaft for one cylinder of an engine.

RECIPROCATING ENGINES

The internal-combustion engines (diesel and gasoline) are machines that convert heat energy into mechanical energy. The transformation of heat energy to mechanical energy by the engine is based on a fundamental law of physics. Gas will expand when heat is applied. The law also states that when a gas is compressed, the temperature of the gas will increase. If the gas is confined with no outlet for expansion, the pressure of the gas will be increased when heat is applied. In the internal-combustion engine, the burning of a fuel within a closed cylinder results in an expansion of gases. The pressure created on top of a piston by the expanding gases causes it to move.

The back-and-forth motion of the pistons in an engine is known as reciprocating motion. This reciprocating motion (straight-line motion) must be changed to rotary motion (turning motion) to perform a useful function, such as propelling a boat or ship through the water or driving a generator to provide electricity. A crankshaft and a connecting rod change this reciprocating motion to rotary motion (fig. 7-1).

All internal-combustion engines are basically the same. They all rely on three things—air, fuel, and ignition.

Fuel contains potential energy for operating the engine; air contains the oxygen necessary for combustion; and ignition starts combustion. All are fundamental, and an engine will not operate without all of them. Any discussion of engines must be based on these three factors and the steps and mechanisms involved in delivering them to the combustion chamber at the proper time.

GASOLINE VERSUS DIESEL ENGINES

There are two main differences between gasoline and diesel engines. They are the methods of getting the fuel into the cylinders and of igniting the fuel-air mixtures. In the gasoline engine, the air and gasoline are mixed together outside the combustion chamber. The mixture

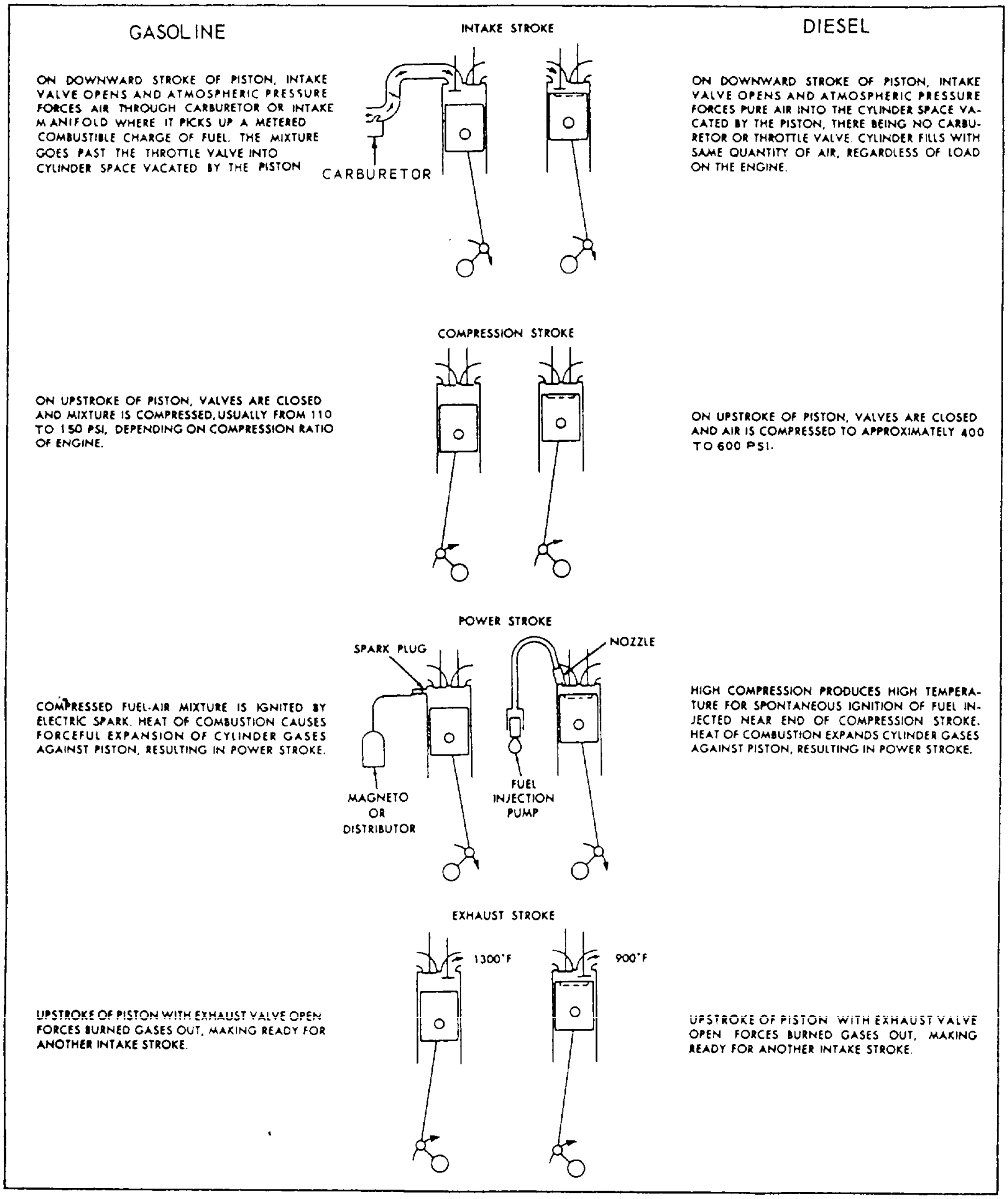


Figure 7-2.—Comparison of events in diesel and gasoline four-cycle engines.

then passes through the intake manifold, where it starts to vaporize. Then the mixture enters the cylinder through the intake valve. Here it is completely vaporized by the heat of compression as the piston moves upward on the compression stroke. When the piston is near the top of its stroke (top dead center or TDC), the mixture is ignited by a spark from the spark plug.

The diesel engine uses neither spark plugs nor a carburetor. On the intake stroke, only fresh air is drawn into the cylinder through the intake valve and manifold. On the compression stroke, the air is compressed and the temperature in the cylinder rises to a point between 700 °F and 1200 °F. At the proper time, the diesel fuel is injected into the cylinder by a fuel injection system. When the fuel enters the cylinder, it ignites. Figure 7-2 shows the comparison of the four strokes of four-cycle diesel and gasoline engines.

The speed of a diesel or gasoline engine is controlled by the amount of fuel-air mixture that is burned in the cylinders. The primary difference is the method in which the fuel and air enter the combustion chamber. In a diesel engine, the fuel is injected directly into the combustion chamber, where it mixes with air. In a gasoline engine, the fuel and air are mixed in the intake manifold and then drawn into the combustion chamber.

Mechanically, the diesel engine is similar to the gasoline engine. The intake, compression, power, and exhaust strokes occur in the same order. The arrangement of the pistons, connecting rods, crankshaft, and engine valves are also the same.

DEVELOPMENT OF POWER

The power of an internal-combustion engine comes from the burning of a mixture of fuel and air in a small, enclosed space. When this mixture burns, it expands greatly. The push or pressure created is used to move the piston. The piston then rotates the crankshaft. The rotating crankshaft is then used to perform the desired work.

Since the same actions occur in all cylinders of an engine, we will discuss only one cylinder and its related parts. The four major parts consist of a cylinder, piston, crankshaft, and connecting rod (fig. 7-1).

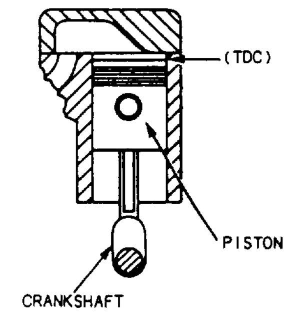
First we must have a cylinder that is closed at one end. The cylinder is stationary within the engine block.

Inside this cylinder is the piston (a movable metal plug) that fits snugly into the cylinder but can still slide up and down easily. Movement of the piston is caused by the burning fuel-air mixture in the cylinder.

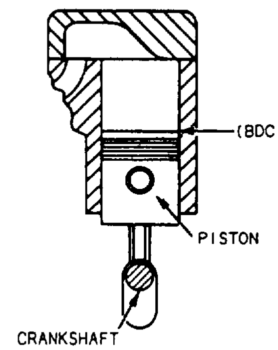
You have already learned that the back-and-forth movement of the piston is called reciprocating motion, which must be changed to rotary motion. This change is accomplished by a throw on the crankshaft and a connecting rod that connects the piston and the crank throw.

The number of piston strokes occurring during any one series of operations (cycles) is limited to either two or four, depending on the design of the engine.

When the piston of the engine slides downward because of the pressure of the expanding gases in the cylinder, the upper end of the connecting rod moves downward with the piston in a straight line. The lower end of the connecting rod moves down and in a circular motion at the same time. This moves the crank throw and, in turn, rotates the shaft. This rotation is the desired result. So remember, the crankshaft and connecting rod combination is a mechanism for the purpose of changing back-and-forth (reciprocating) motion to circular (rotary) motion.



A. PISTON TOP DEAD CENTER (TDC)



B. PISTON BOTTOM DEAD CENTER (BDC)

Figure 7-3.—Piston stroke.

BASIC ENGINE STROKES

Each movement of the piston from top to bottom or from bottom to top is called a stroke. The piston takes two strokes (an upstroke and a downstroke) as the crankshaft makes one complete revolution. When the piston is at the top of a stroke (fig. 7-3, view A), it is said to be at top dead center (TDC). When the piston is at the bottom of a stroke (fig. 7-3, view B), it is said to be at bottom dead center (BDC).

In the basic engine you have studied so far, we have not considered provisions for getting the fuel-air mixture into the cylinder or burned gases out of the cylinder. There are two openings in the enclosed end of a cylinder. One of the openings,

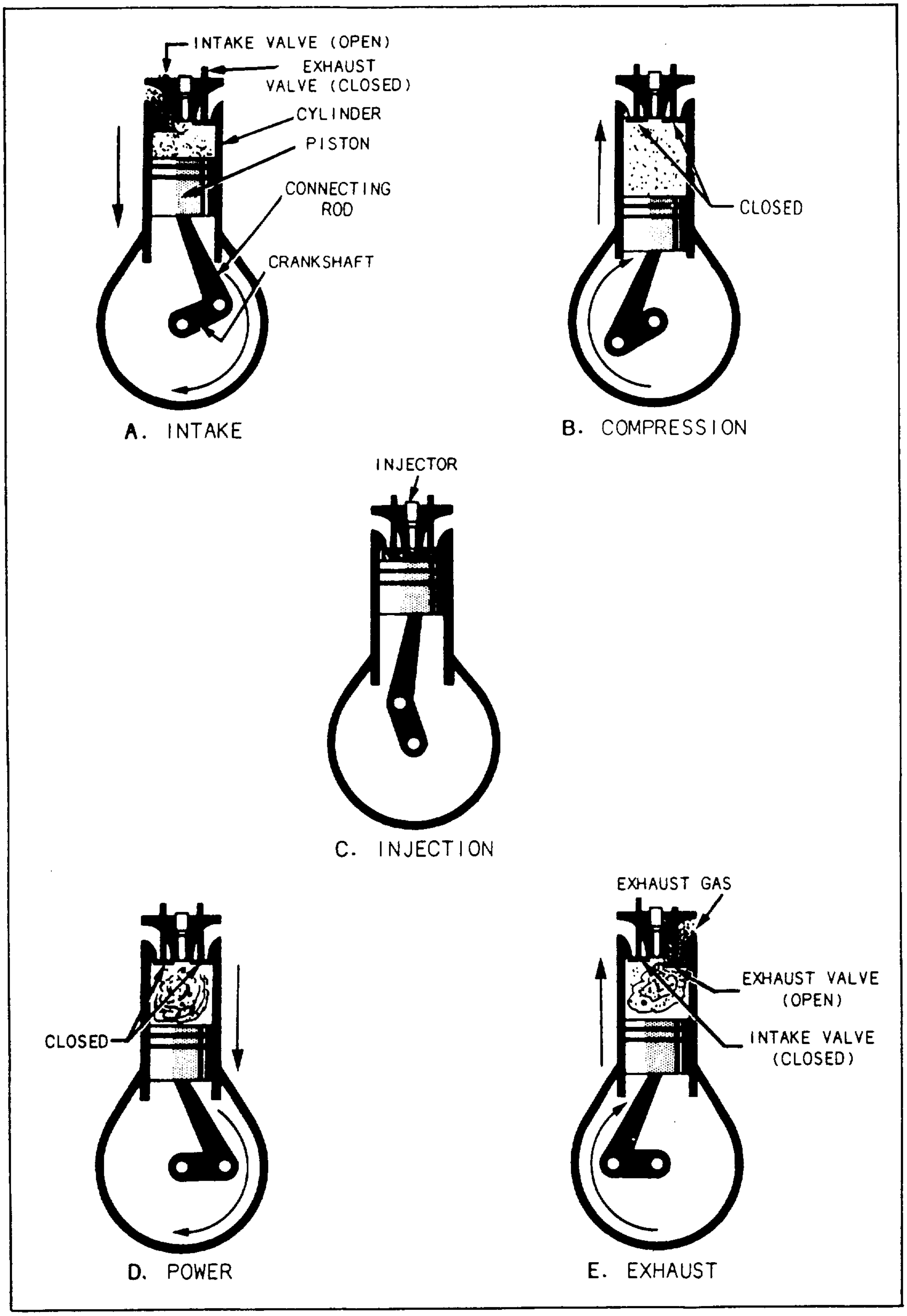


Figure 7-4.—Four-stroke diesel engine.

or ports, permits an intake of air, or an intake of a mixture of fuel and air, into the combustion area of the cylinder (intake valve). The other opening, or port, permits the burned gases to escape from the cylinder (exhaust valve). The two ports have valves in them. These valves close off either one or the other of the ports, or both of them, during various stages of engine operation. The camshaft (a shaft with a number of cam lobes along its length) opens the valves and holds them open for short periods during the piston stroke. The camshaft is driven by the crankshaft through timing gears or by a timing chain. On a four-stroke engine, the camshaft turns at one-half crankshaft speed. This permits each valve to open and close once for every two turns of the crankshaft.

The following sections give a simplified explanation of the action that takes place within the engine cylinder. For the purpose of explanation, we will show the action of a four-stroke diesel engine. This type of engine is referred to as a four-stroke engine because it requires four complete piston strokes to complete one cycle. These strokes are known as the intake stroke, the compression stroke, the power stroke, and the exhaust stroke.

In a four-stroke engine, each piston goes through four strokes, and the crankshaft makes two revolutions to complete one cycle. Each piston delivers power during one stroke in four, or each piston makes one power stroke for each two revolutions of the crankshaft.

We will take one cylinder and trace its operation through the four strokes that make up a cycle (fig. 7-4). The engine parts shown in this figure include a cylinder, a crankshaft, a piston connecting rod, and the intake and exhaust valves. The valve-operating mechanism and the fuel system have been omitted.

During the intake stroke shown in view A, the intake valve is open and the exhaust valve is closed. The piston is moving downward and drawing a charge of air into the cylinder through the intake valve.

When the crankshaft has rotated to the position shown in view B, the piston moves upward to almost the top of the cylinder. Both the intake and exhaust valves are closed during this stroke. The air that entered the cylinder during the intake stroke is compressed into the small space above the piston. This is called the compression stroke.

The high pressure, which results from the compression stroke, raises the temperature of the air far above the ignition point of the fuel. When the piston nears the top of the compression stroke, a charge of fuel is forced into the cylinder through the injector, as shown in view C. The air, which has been heated by compression, ignites the fuel.

NOTE: The injection portion of a cycle is not considered a stroke.

During the power stroke (view D), the intake and exhaust valves are both closed. The increase in temperature resulting from the burning fuel greatly increases the pressure on top of the piston. This increased pressure forces the piston downward and rotates the crankshaft. This is the only stroke in which power is furnished to the crankshaft.

During the exhaust stroke (view E), the exhaust valve is open and the intake valve remains closed. The piston moves upward, forcing the burned gases out of the combustion chamber through the exhaust valve. This stroke, which completes the cycle, is followed immediately by the intake stroke of the next cycle, and the sequence of events continues.

The four-stroke gasoline engine operates on the same mechanical, or operational, cycle as the diesel engine. In the gasoline engine, the fuel and air are mixed in the intake manifold; and the mixture is drawn into the cylinders through the intake valve. The fuel-air mixture is ignited near the top of the compression stroke by an electric spark that passes between the terminals of the spark plug.

Two-stroke diesel engines are widely used by the Navy. Every second stroke of a two-stroke cycle engine is a power stroke. The strokes between are compression strokes. The intake and exhaust functions take place rapidly near the bottom of each power stroke. With this arrangement, there is one power stroke for each

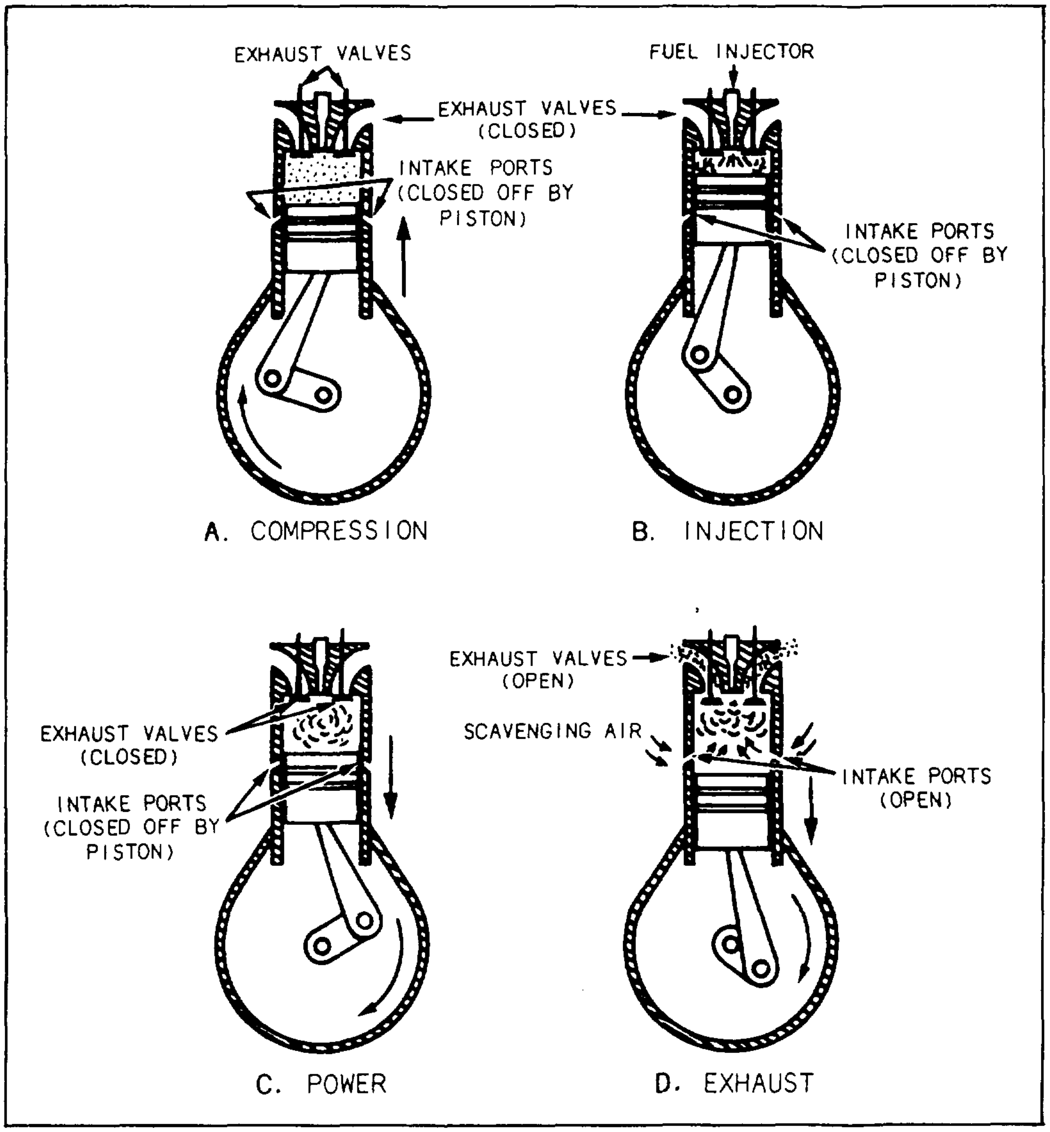


Figure 7-5.—Two-stroke diesel engine.

revolution of the crankshaft, or twice as many as in a four-stroke cycle engine.

NOTE: A two-stroke engine does not have intake valves. It has intake ports (fig. 7-5).

The steps in the operation of a two-stroke diesel engine are shown in figure 7-5. In view A, the piston is moving upward on the compression stroke. The exhaust valve and the intake ports are closed, and the piston is compressing the air trapped in the combustion chamber. At the top of the stroke, with the piston in the position shown in view B, fuel is injected (sprayed) into the cylinder and ignited by the hot compressed air.

In view C, the piston is moving downward on the power stroke: The exhaust valves are still closed; and the increased pressure, resulting from the burning fuel, forces the piston downward and rotates the crankshaft.

As the piston nears the bottom of the power stroke (view D), the exhaust valves open and the piston continues downward to uncover the intake ports. Air is delivered under pressure by a blower for two-stroke diesel engines. In a two-stroke gasoline engine, air comes from the crankcase through the intake ports; and the burned gases are carried out through the exhaust valve. This operation (referred to as scavenging air) takes place almost instantly and corresponds to

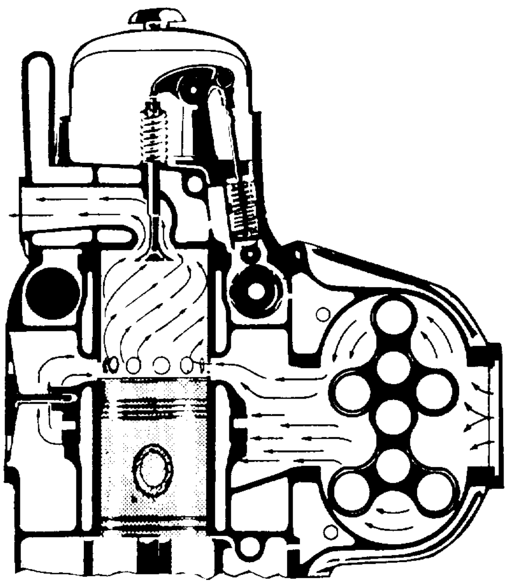


Figure 7-6.—A two-stroke diesel engine cylinder with the piston at the bottom of the power stroke.

the intake and exhaust strokes of the four-stroke cycle.

You might expect a two-stroke engine to develop twice as much power as a four-stroke engine of the same size and to operate at the same speed. However, this is not true. With two-stroke diesel engines, some of the power is used to drive a blower (fig. 7-6) that forces the air charge into the cylinder under pressure. Also, the burned gases are not completely cleared from the cylinder, reducing combustion efficiency. Additionally, because of the much shorter period the intake ports are open (as compared to the period the intake valve in a four-stroke cycle is open), a smaller amount of air is admitted. Therefore, with less air being mixed with the fuel, less power-per-power stroke is produced. Nevertheless, two-stroke diesel engines give excellent service.

VALVE MECHANISM

The valve mechanism of a two-stroke diesel cylinder head is shown in figure 7-7. This cylinder head has two exhaust valves that are opened at the same time by the action of a single cam. They make a tight fit in the exhaust openings (ports) in the cylinder head and are held in the closed position by the compression of the valve springs. The rocker arm and bridge transmit the reciprocating motions of the cam roller to the valves.

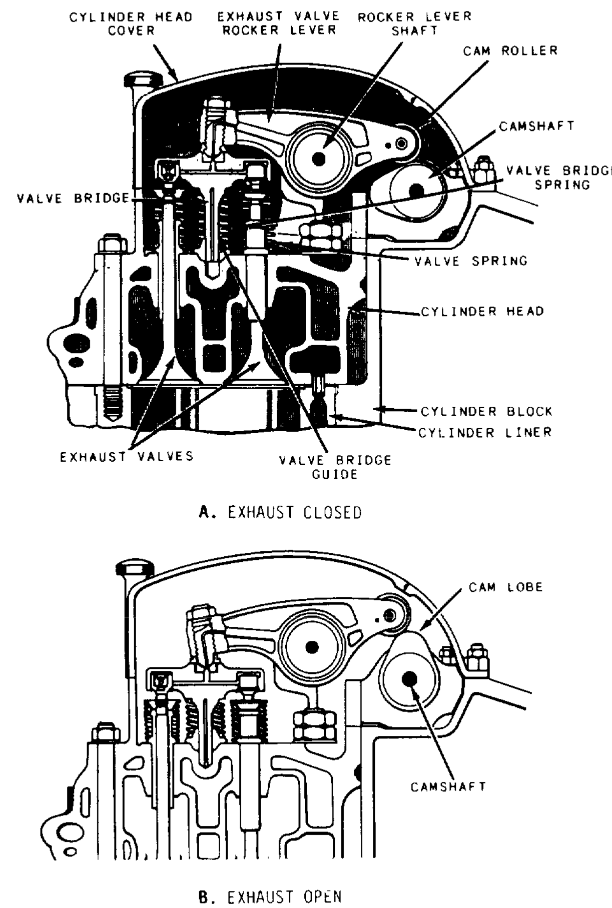


Figure 7-7.—A two-stroke diesel cylinder head, showing the valve-operating mechanism.

In figure 7-7, view A, the cam roller is riding on the base circle of the cam, and the valves are closed. As the camshaft rotates, the cam lobe or nose rides under the roller and raises it to the position shown in view B. When the roller is lifted, the arm rotates around the rocker shaft; and the opposite end of the arm is lowered. This action pushes the bridge and valves down against the pressure of the valve springs and opens the valve passages.

On some types of engines, the camshaft is located near the crankshaft. In these designs, the action of the cam roller is transmitted to the rocker arm by a pushrod.

The camshaft must be timed with the crankshaft so that the lobes will open the valves in each cylinder at the correct instant in the operating cycle. In the two-stroke engine, the camshaft rotates at the same speed as the crankshaft.

The four-stroke engine has an intake valve and an exhaust valve in every cylinder. Each valve is

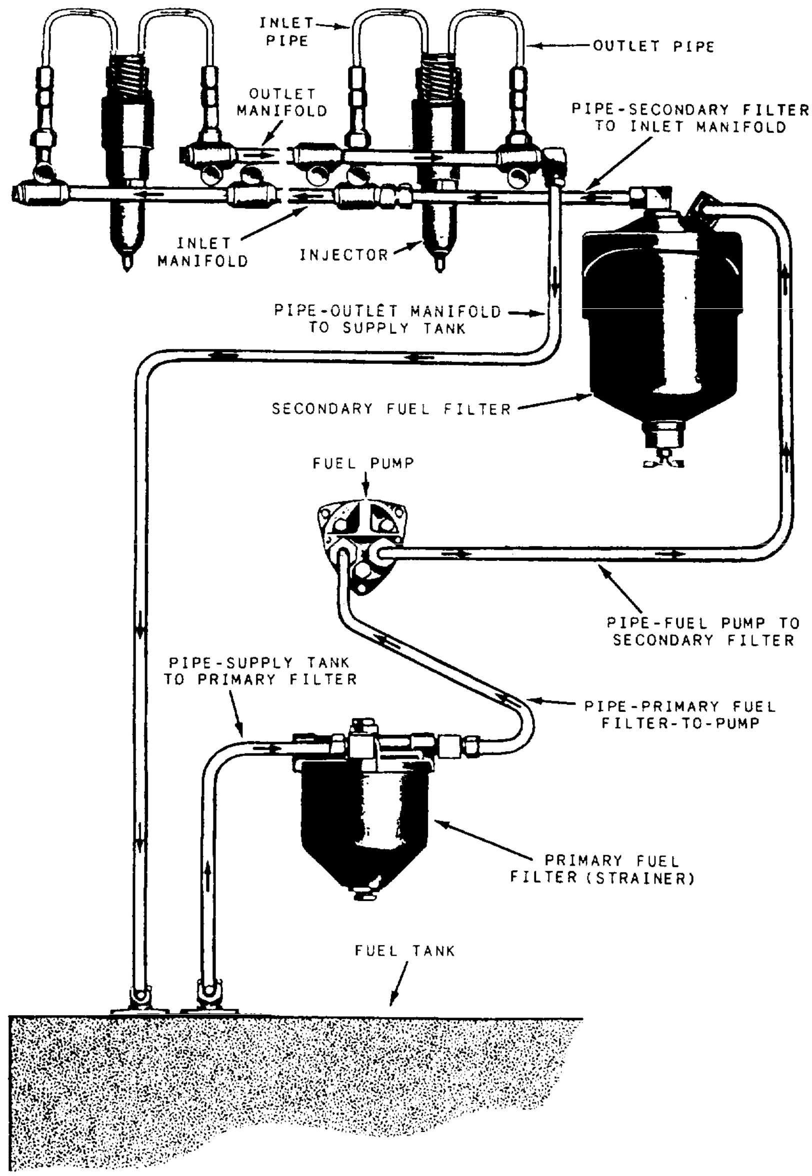


Figure 7-8.—The fuel supply system of a typical diesel engine.

operated by a separate cam. The intake valve is held open during the intake stroke, and the exhaust valve is opened during the exhaust stroke. Since two revolutions of the crankshaft are necessary to complete a cycle, the camshaft of these engines turns only half as fast as the crankshaft.

COMPRESSION IGNITION SYSTEM

In the four-stroke cycle engine, air enters the cylinders through intake valves. As each piston moves downward on the intake stroke, the volume in the combustion chamber increases and the pressure decreases. The normal atmospheric pressure then forces the air into the cylinder through the intake valve.

Since the two-stroke cycle engine does not go through an intake stroke, a means must be provided to force air into the cylinders. The air enters through intake ports (uncovered when the piston approaches the bottom of the power stroke). (See fig. 7-5.) Since the exhaust valves are open when the intake ports are being uncovered, the incoming air forces the burned gases out through the exhaust valves and fills the cylinder with a supply of fresh air.

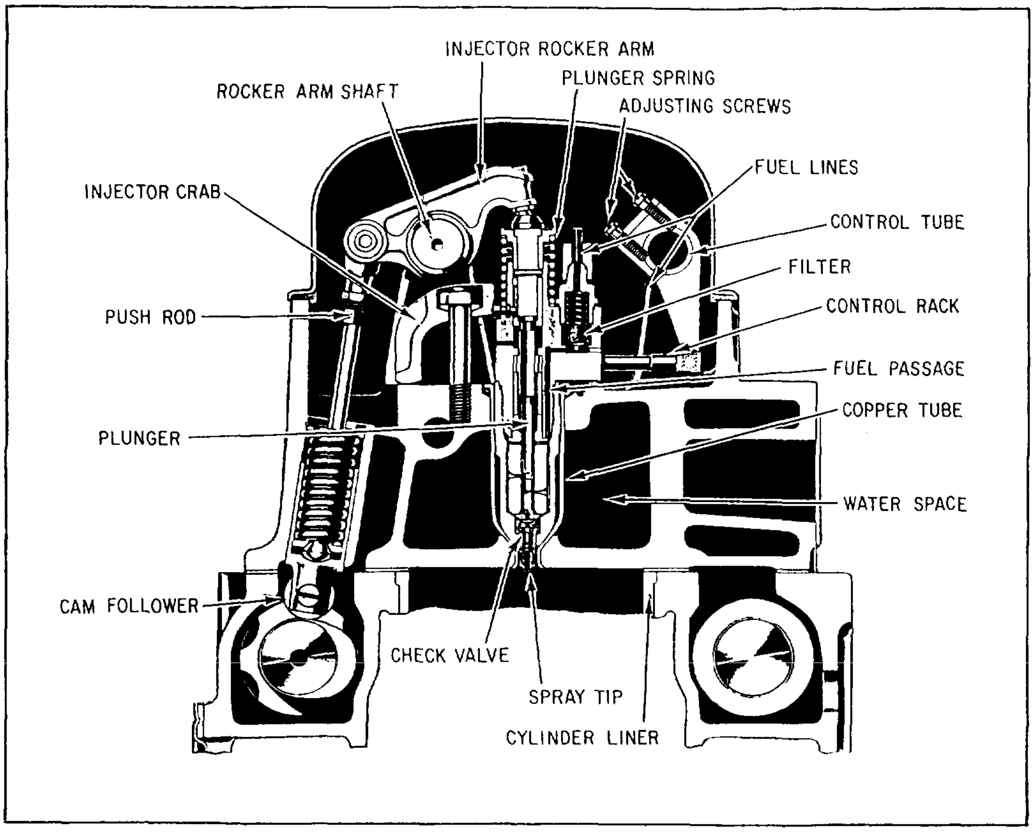


Figure 7-9.—Mounting of the unit injector in the cylinder head.

On the compression stroke, the exhaust valves are closed, the intake ports are covered, and the air is trapped in the cylinder. The rising piston compresses the air and raises its temperature. By the time the piston reaches the top of the stroke, the volume of the combustion chamber has been greatly reduced. The relation between the volume of the cylinder with the piston at the bottom of its stroke and the cylinder volume with the piston at the top of its stroke is called the COMPRESSION RATIO.

As the compression ratio is increased, the temperature of the air in the cylinder increases. Current gasoline engines operate at compression ratios between 6:1 and 11:1, but compression ratios of diesel engines range between 12:1 and 19:1. Remember, that on the compression stroke of a diesel engine the air is compressed to a range of 400 to 600 psi, which results in a temperature ranging from 700°F to 1200°F. However, when the fuel is injected into the cylinder and begins to burn, the pressure may increase to more than 1500 psi and the temperature may rise as high as 1800°F.

You can find more detailed information on compression ignition systems in *Engineman 3*, NAVEDTRA 10539.

FUEL SYSTEM

The fuel system of a diesel engine draws fuel from the service tank and injects it into the engine cylinders. Figure 7-8 shows the units found in a typical unit-injector fuel system. The fuel pump draws the fuel from the tank through a primary strainer and delivers it under low pressure to the injector by way of the secondary filter. The injector is operated by a rocker arm. It meters, pressurizes, and atomizes the fuel as it is injected into the combustion chamber. The outlet line carries the excess fuel from the injector back to the fuel tank. In some units, a transfer pump is installed between the tank and the strainer. In other units, the injection pump and injection nozzles are separate units instead of a combined unit, as shown in figure 7-9.

A diesel engine will not operate efficiently unless clean fuel is delivered to the injector or injection nozzles. As the fuel is pumped into the fuel service tanks, it is purified. From the service tank the fuel is filtered before reaching the injection system, where the larger particles of the solids suspended in the fuel are trapped in the strainer. The filter separates the fine particles of foreign matter that pass through the strainer. Most strainers have a drain plug for removing the water, sludge, and other foreign matter. The strainers should be drained once each day.

There are many methods of fuel injection and just as many types of injection pumps and nozzles. The unit injector, shown in figure 7-9, consists basically of a small cylinder and a plunger and extends through the cylinder head to the combustion chamber. A cam, located on the camshaft adjacent to the cam that operates the exhaust valves, acts through a rocker arm and depresses the plunger at the correct instant in the operating cycle.

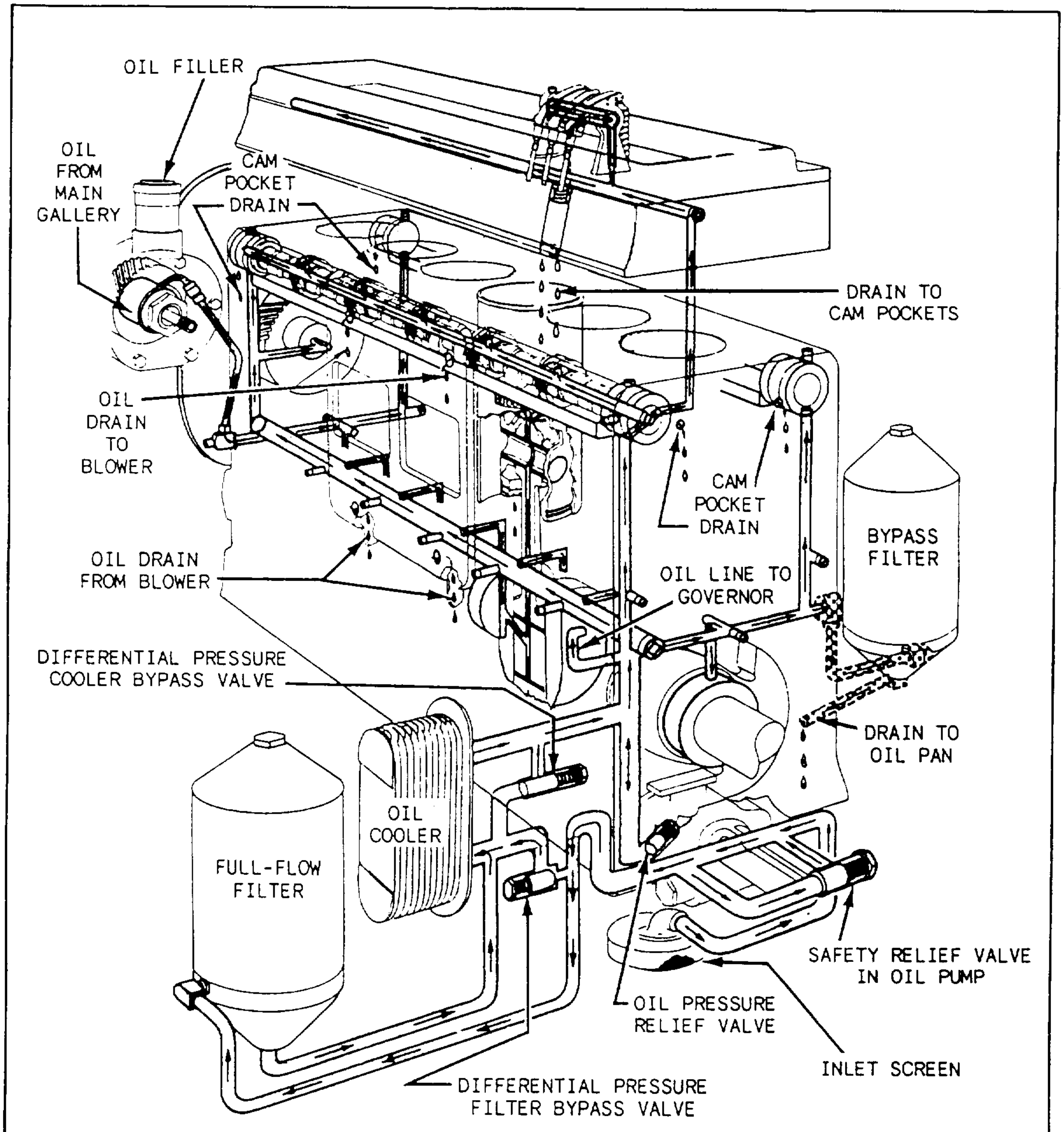


Figure 7-10.—Typical lubication system.

When the injector plunger is depressed, a fine spray of fuel is discharged into the cylinder through small holes in the nozzle. The smooth operation of the engine depends, to a large extent, on the accuracy with which the plungers inject the same amount of fuel into every cylinder.

The amount of fuel injected into the cylinders on each stroke is controlled by rotating the plungers of a unit injector. The throttle, which regulates the speed of the engine, is connected to the injectors through a suitable linkage. A change in the throttle setting rotates the plungers and varies the amount of fuel injected into the cylinders on each stroke.

LUBRICATION SYSTEM

The lubrication system of an internal-combustion engine is very important. If the lubricating system should fail, not only will the engine stop, but many of the parts are likely to be damaged beyond repair. Therefore, when lubrication failure occurs, the engine can seldom be run again without a major overhaul.

The lubricating system delivers oil to the moving parts of the engine to reduce friction and to assist in keeping the parts cool. Most diesel and gasoline engines are equipped with a pressure lubricating system that delivers the oil under pressure to the bearings and bushings and also lubricates the gears and cylinder walls. The oil usually reaches the bearings through passages drilled in the framework of the engine. The lubricating system of a typical diesel engine is shown in figure 7-10.

All of the engine parts are lubricated with oil delivered by a gear-type oil pump. This pump takes suction through a screen from an oil pan or sump. From the pump, the oil is forced through the oil filter and the oil cooler into the main oil gallery. The oil is fed from the main gallery, through individual passages, to the main crankshaft bearings and one end of the hollow camshaft. All the other moving parts and bearings are lubricated by oil drawn from these two sources. The cylinder walls and the teeth of many of the gears are lubricated by oil spray thrown off by the rotating crankshaft. After the oil has served its purpose, it drains back to the sump to be used again.

The oil pressure in the line leading from the pump to the engine is indicated on a pressure gauge. A temperature gauge in the return line provides an indirect method for indicating variations in the temperature of the engine parts. Any abnormal drop in pressure or rise in temperature should be investigated at once. It is advisable to secure (shut down) the engine until the trouble has been located and corrected.

Constant oil pressure, throughout a wide range of engine speeds, is maintained by the oil pressure relief valve that allows the excess oil to flow back into the sump. All of the oil from the pump passes through the filter unless the oil is cold and heavy or if the filter (or oil cooler) is clogged. In such cases, the bypass valve (filter bypass valve or cooler bypass valve) is forced open; and the oil flows directly to the engine. Part of the oil fed to the engine is returned through the bypass filter, which removes flakes of metal, carbon particles, and other impurities.

COOLING SYSTEM

Marine engines are equipped with a water-cooling system to carry away the excess heat produced in the engine cylinders. Fresh water (coolant) is circulated through passages in the cylinder walls and in the cylinder head, where it becomes hot from absorbing engine heat. The hot coolant then passes through a heat exchanger, where it gives up its heat to a cooling medium, becomes cool, and returns to the engine to remove more heat. The cooling medium may be either air or seawater.

A heat exchanger using air as the cooling medium works like an automobile radiator. A heat exchanger using seawater as the cooling medium may be mounted either on the engine or on the ship's hull. Engine-mounted heat exchangers require seawater to be pumped to and from them; whereas, hull-mounted heat exchangers (keel coolers) are in constant contact with seawater and require the fresh water (coolant) to be pumped through the cooler.

STARTING SYSTEMS

There are three types of starting systems used in internal-combustion engines—electric, hydraulic, and compressed air.

As a Fireman, you will probably have more contact with the electric starting system than you will with the other two types. Lifeboats aboard ships use an electric starter to start the engine.

Electric starting systems use direct current because electrical energy in this form can be stored in batteries and drawn upon when needed. The battery's electrical energy can be restored by

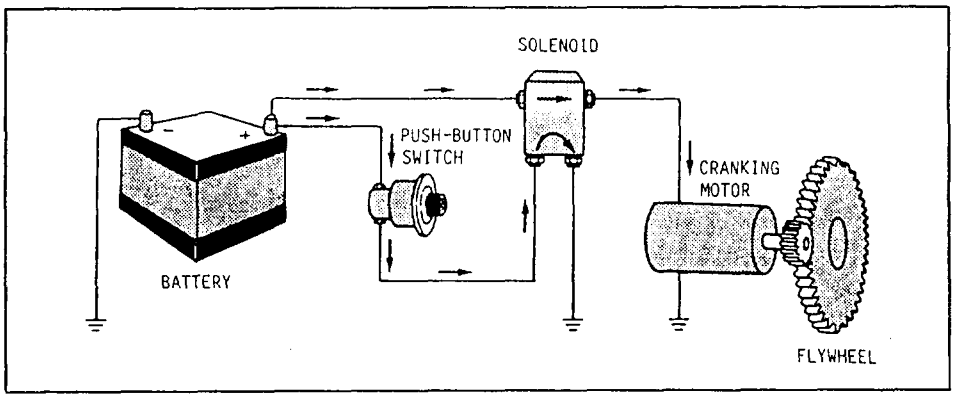


Figure 7-11.—Electric starting system.

charging the battery with an engine-driven generator.

The main components of the electric starting system, as shown in figure 7-11, are the battery, cranking motor, and associated control and protective devices.

Electric Starting Systems

The starting motor for diesel and gasoline engines operates on the same principle as a direct current electric motor. The motor is designed to carry extremely heavy loads but, because it draws a high current (300 to 665 amperes), it tends to overheat quickly. To avoid overheating, NEVER allow the motor to run more than the specified amount of time, usually 30 seconds at a time. Then allow it to cool for 2 or 3 minutes before using it again.

To start a diesel engine, you must turn it over rapidly to obtain sufficient heat to ignite the fuel. The starting motor is located near the flywheel, and the drive gear on the starter is arranged so that it can mesh with the teeth on the flywheel when the starting switch is closed. The drive mechanism must function to (1) transmit the turning power to the engine when the starting motor runs, (2) disconnect the starting motor from the engine immediately after the engine has started, and (3) provide a gear reduction ratio between the starting motor and the engine.

The drive mechanism must disengage the pinion from the flywheel immediately after the engine starts. After the engine starts, its speed may increase rapidly to approximately 1,500 rpm. If the drive pinion remained meshed with the flywheel and also locked with the shaft of the starting motor at a normal engine speed (1,500 rpm), the shaft would be spun at a rapid rate (22,500 to 30,000 rpm). At such speeds, the starting motor would be badly damaged.

Hydraulic Starting Systems

There are several types of hydraulic starting systems in use. In most installations, the system consists of a hydraulic starting motor, a piston-type accumulator, a manually operated hydraulic pump, an engine-driven hydraulic pump, and a reservoir for the hydraulic fluid.

Hydraulic pressure is provided in the accumulator by the manually operated hand pump or from the engine-driven pump when the engine is operating.

When the starting lever is operated, the control valve allows hydraulic oil (under pressure of nitrogen gas) from the accumulator to pass through the hydraulic starting motor, thereby cranking the engine. When the starting lever is released, spring action disengages the starting pinion and closes the control valve. This stops the flow of hydraulic oil from the accumulator. The starter is protected from the high speeds of the engine by the action of an overrunning clutch.

The hydraulic starting system is used on some smaller diesel engines. This system can be applied to most engines now in service without modification.

Air Starting Systems

Starting air comes directly from the ship's medium-pressure (MP) or high-pressure (HP) air service line or from the starting air flasks which are included in some systems for the purpose of storing starting air. From either source, the air, on its way to the starting air system, must bypass through a pressure-reducing valve, which reduces the higher pressure to the operating pressure required to start a particular engine.

A relief valve is installed in the line between the reducing valve and the starting system. The relief valve is normally set to open at 12 percent above the required starting air pressure. If the air pressure leaving the reducing valve is too high, the relief valve will protect the system by releasing air in excess of a preset value and permit air only at safe pressure to reach the starting system of the engine.

START AIR MOTOR SYSTEM.— Some engines, usually gas turbine types, are designed to crank over by starting motors that use compressed air. Air-starting motors are usually driven by air pressures varying from 90 to 200 psi.

COMPRESSED AIR ADMISSION SYSTEM.— Most large diesel engines are started when compressed air is admitted directly into the engine cylinders. Compressed air at approximately 200 to 300 psi is directed into the cylinders to force the piston down and thereby, turn the crankshaft of the engine. This air admission process continues until the pistons are able to build up sufficient heat from compression to cause combustion to start the engine.

GASOLINE ENGINES

The main parts of the gasoline engine are quite similar to those of the diesel engine. The two engines differ principally in that the gasoline engine has a carburetor and an electrical ignition system.

The induction system of a gasoline engine draws gasoline from the fuel tank and air from the atmosphere, mixes them, and delivers the mixture to the cylinders. The induction system consists of the fuel tank, the fuel pump, the carburetor, and the necessary fuel lines and air passages. Flexible tubing carries the fuel from the tank to the carburetor, while the intake manifold carries the fuel-air mixture from there to the individual cylinders. The fuel-air mixture is ignited by an electric spark.

The carburetor is a device used to send a fine spray of fuel into a moving stream of air as it moves to the intake valves of the cylinders. The spray is swept along, vaporized, and mixed with the moving air. The carburetor is designed to maintain the same mixture ratio over a wide range of engine speeds. The mixture ratio is the number of pounds of air mixed with each pound of gasoline vapor. A rich mixture is one in which the percentage of gasoline vapor is high, while a lean mixture contains a low percentage of gasoline vapor.

The electrical ignition system is designed to deliver a spark in the combustion chamber of each cylinder at a specific point in that cylinder's cycle of operation. A typical ignition system includes a storage battery, an ignition coil, breaker points, a condenser, a distributor, a spark plug in each cylinder, a switch, and the necessary wiring.

There are two distinct circuits in the ignition system—the primary and the secondary. The primary circuit carries a low-voltage current. The secondary circuit is high voltage. The battery, the ignition switch, the ignition coil, and the breaker points are connected in the primary circuit. The secondary circuit, also connected to the ignition coil, includes the distributor and the spark plugs.

The storage battery is usually 6, 12, or 24 volts. One terminal is grounded to the engine frame, while the other is connected to the ignition system.

The ignition coil, in many respects, is similar to an electromagnet. It consists of an iron core surrounded by primary and secondary coils. The primary coil is made up of a few turns of heavy wire, while the secondary coil has a great many turns of fine wire. In both coils, the wire is insulated and the coils are entirely separate from each other.

The breaker points form a mechanical switch connected to the primary circuit. They are opened by a cam that is timed to break the circuit at the exact instant that each cylinder is due to fire. A condenser is connected across the breaker points to prevent arcing and to provide a better high-voltage spark.

The distributor, connected to the secondary or high-voltage circuit, serves as a selector switch that channels electric current to the individual cylinders. Although the breaker points are connected in the primary circuit, they are often located in the distributor case. The same drive shaft operates both the breaker points and the distributor.

The spark plugs, which extend into the combustion chambers of the cylinders, are connected by heavily insulated wires to the distributor. A spark plug consists essentially of a metal shell that screws into the spark plug hole in the cylinder, a center electrode embedded in porcelain, and a side electrode connected to the shell. The side electrode is adjusted so that there is a small space (gap) between it and the center electrode. This gap varies depending on the engine. When the plug fires, an electric spark jumps across the gap between the electrodes.

When the engine is running, the electric current in the primary circuit flows from the battery through the switch, the primary winding in the ignition coil, the breaker points, and then back to the battery. The high voltage is produced in the secondary winding in the ignition coil, then flows through the distributor to the individual spark plugs and back to the ignition coil through the engine frame. It is interesting to note that the high voltage that jumps the gap in the spark plugs does not come from the battery but is produced in the ignition coil.

The ignition coil and the condenser are the only parts of the ignition system that require an explanation. The soft iron core and the primary windings function as an electromagnet. The current flowing through the primary windings magnetizes the core. The same core and the secondary windings function as a transformer. Variations in the primary current change the magnetism of the core, which in turn produces high voltage in the secondary windings.

With the engine running and the breaker points closed, low-voltage current flows through the primary circuit. When the breaker points open, this current is interrupted and produces high voltage in the secondary circuit. The electricity, which would otherwise arc across the breaker points as they are separating, now flows into the condenser.

The principal purpose of the condenser is to protect the breaker points from being burned. The condenser also aids in obtaining a hotter spark.

The contact-point ignition system is an older type. The electronic ignition system is of the newer type. The basic difference between the contact-point and the electronic ignition systems is in the primary circuit. The primary circuit in the contact-point system is opened and closed by contact points. In the electronic system, the primary circuit is opened and closed by the electronic control unit.

The secondary circuits are practically the same for the two systems. The difference is that the distributor, ignition coil, and wiring are altered to handle the higher voltage that the electronic ignition system produces.

One advantage of this higher voltage of approximately 47,000 volts is that spark plugs with wider gaps can be used. This results in a longer spark, which can ignite leaner fuel-air mixtures. As a result, engines can run on leaner mixtures for better fuel economy and lower emissions.

Another difference is that some electronic ignition systems have no mechanical advance mechanisms—centrifugal or vacuum. Instead, the spark timing is adjusted electronically.

The starting system of the gasoline engine is basically the same as that of the diesel engine. The generator keeps the battery charged and provides the current to operate the lights and other electrical equipment. The starter motor draws current from the battery and rotates the flywheel and crankshaft for starting.

SUMMARY

This chapter was designed to give you a brief understanding of diesel and gasoline internal-combustion engines. You will find these engines on all ships in the Navy. It will be of great value to you to learn more about them by reading the referenced material given throughout this chapter.