Chapter 5

Fundamentals of Engine Construction and Operation

After studying this chapter, you will be able to:
- Describe each stroke of a four-stroke cycle engine.
- Identify and explain the purposes of the major components of the engine compression system.
- Explain the operating principles of liquid cooling systems.
- Identify cooling system parts.
- Explain the engine lubricating system.
- Identify lubrication system parts.
- List common oil classification systems.

Know These Terms

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Radiator fan
Radiator pressure cap
Rocker arms
Serpentine belt
Thermostat
Valve timing
Valve train
Variable valve timing
Vibration damper
Engine problems can have a major effect on vehicle driveability. For example, without good compression or proper valve timing, the engine will not properly operate. This chapter covers the major engine components and reviews engine operation.

Four-Stroke Cycle Engine Operation

One power cycle in an automotive engine is a four-stroke process, which is why these engines are known as four-stroke cycle engines. The piston moves up twice in the cylinder and down twice in the cylinder for each power-producing cycle. This requires two revolutions of the crankshaft. Refer to Figure 5-1 as you read the following paragraphs. Some diesel engines, however, use only two strokes rather than four.

The downward movement of the piston on the intake stroke draws the air-fuel mixture into the cylinder through the intake valve(s). When the piston reaches the bottom of the intake stroke, the intake valves are closed. The piston then moves up in the cylinder, compressing the air-fuel mixture. This is called the compression stroke. When the air-fuel mixture in the cylinder is ignited, the burning fuel and oxygen produce heat. The heat causes the gases in the cylinder to expand, forcing the piston down under pressure. This is called the power stroke.

When the piston reaches the bottom of the power stroke, the exhaust valve is open. The exhaust stroke then begins as the piston moves up the cylinder, pushing the exhaust gases out of the open exhaust valve. One cycle is now complete. The cycle then repeats.

Engine Components

This section describes the major components of the engine compression system. The compression system contains the parts that develop engine compression and allow the heat energy in the burning air-fuel mixture to become mechanical energy.

- Engine block.
- Pistons.
- Rings.
- Connecting rods.
- Crankshaft.
- Cylinder heads.
- Valves and related components.
- Valve train.
- Harmonic balancers.
- Balance shafts.

Although the exact design and number of engine components varies with the type of engine and number of cylinders, the basic components and their functions are the same as described here.

Engine Block

The engine block is the basic support and attaching point for all other engine parts. Engine blocks are made by pouring molten cast iron, steel, or aluminum into molds, Figure 5-2A. After the metal cools, the molding sand is washed out and the block is machined to allow other parts to be installed or attached, Figure 5-2B. The major parts installed in or on the block are the pistons, crankshaft, camshaft, cylinder heads, and manifolds.

Pistons and Rings

Pistons transfer the force of expanding combustion gases to the connecting rods. They are made of aluminum to reduce weight. Most automotive pistons have two compression rings and one oil ring, as shown in Figure 5-3.

Compression rings seal in the pressure created during the compression and power strokes. If this pressure is allowed to leak out, the engine will not start or will have severe power and driveability problems. The compression rings are installed at the top of the piston. A film of oil between the compression ring and cylinder wall seals pressure in the cylinder. This oil film is only about .001" (.0025 mm) thick, but if it is removed, the engine will not develop enough compression to start.

The oil-control ring is installed below the compression rings to prevent excessive oil consumption. During the piston’s intake stroke, vacuum in the cylinder tries to pull oil from the cylinder wall. To reduce oil loss, the oil-control ring scrapes most of the oil from the cylinder wall when the piston is moving down in the cylinder. A small amount of oil passes by the oil-control ring to seal the compression rings against the cylinder wall.

Connecting Rods and Crankshaft

The connecting rods are forged steel rods that connect the piston to the crankshaft. They transfer the force from the piston to the crankshaft. Each connecting rod is connected to a piston by a piston pin. The rod is attached to the crank-
shock by a bearing cap and bearing inserts that surround the crankshaft journal. The piston pin and crankshaft bearings allow the rod to move in relation to both the piston and crankshaft. Refer to Figure 5-4.

The crankshaft converts the straight-line force from the piston and connecting rod into rotary force. It is attached to the engine block by bearing caps and bearings that surround the crankshaft journal. Figure 5-5. This design allows the crankshaft to rotate inside of the bearings with minimal friction. The bearing caps are held to the engine block by two, four, or six bolts torqued to specifications.

Cylinder Heads

The cylinder head contains the combustion chamber for each cylinder and forms the top of the cylinder. Cylinder heads contain the intake and exhaust valves and, in some cases, the camshaft and lifters. They also contain oil galleries, coolant passages, and openings to allow the flow of intake and exhaust gases. Cylinder heads are made from either cast iron or aluminum. A sheet metal, cast aluminum, or plastic valve cover is installed over the upper valve train components. Figure 5-6 shows a typical cylinder head.

Coolant passages between the cylinder heads and engine block must be sealed to prevent coolant leakage. Also, the pressure of expanding combustion gases must be contained within the cylinder. Head gaskets are used between the head and engine block for these purposes. They are thin and made from steel, copper, and fiber. The cylinder head and head gasket are secured to the block with head bolts. These must be torqued to specifications. A few engines have studs and nuts, rather than head bolts.

Valves and Related Components

One or more intake valves are used to control the flow of the air into each cylinder. One or more exhaust valves are used to control the flow of exhaust gases out of each cylinder. Valves also seal the cylinder during the compression and power strokes. They are occasionally called mushroom valves due to their resemblance to a mushroom. Intake and exhaust valves are identical in shape, but intake valves are usually larger. Opening and closing of the valves are controlled by the valve train.

The valve spring holds the valve against its seat, keeping it closed. Valve springs are always slightly compressed when installed. This ensures that the valve closes tightly. The spring is held to the valve by valve spring retainers. The retainers are a cap which covers the spring. A locking device, usually called a split keeper, locks the cap to the valve stem. A valve and spring assembly is shown in Figure 5-7. The assembly is held together by the pressure of valve spring acting against the cylinder head.

The valve stem slides up and down in a valve guide. The guide may be integral to the cylinder head or a removable insert. It keeps the valve steady and provides a smooth surface on which the stem can slide. The oil seal at the top of each valve stem prevents engine oil from entering the combustion chamber. Without a seal, oil would be pulled from the cylinder head, between the valve stem and guide, and into the combustion chamber. The valve seal may be an umbrella type or an O-ring installed between the valve stem and valve retainer.

When the valve is in contact with its seat, heat is transferred from the valve to the cylinder head. This transfer is most critical for exhaust valves, since they absorb more heat of combustion. If the heat is not transferred to the head, the valve may melt. Some valves are filled with metallic sodium to further aid in heat transfer. The intake valves are cooled by the incoming air and are not as prone to damage.

The valve-to-seat contact is controlled by the valve clearance. Valve clearance is the amount of looseness in the valve train between the camshaft and valve stem. Valve clearance can sometimes be adjusted. Valve clearance has more effect on valve life than on engine performance.

Valve Train

The valve train is the group of components that control the opening and closing of the valves. Valve train operation is similar in both overhead camshaft and cam-in-block engines. The engine crankshaft turns camshaft via a chain, belt, or gear set. The camshaft controls the distance the valves open and the duration of time over which they are open. There is one camshaft lobe for each valve.
Valve response with less play and friction between the components. Overhead camshafts are either belt or chain driven. Overhead camshaft engine. They use the same principle as the hydraulic lifter, but are installed on the rocker arm or on the opposite side of the valve stem. Overhead cam-in-block engines. However, some overhead cam-shaft engines also have chain camshaft drives. Note the timing marks on both the camshaft and crankshaft timing gears.

Hydraulic lifters use the engine oil pressure to automatically eliminate play from the valve train. Hydraulic lifters are used on almost all cam-in-block engines. (Ford)

Valve Timing

The valves must open and close in proper relation to the movement of the piston or the engine will not run. This relationship is called valve timing, not to be confused with ignition timing. Valve timing is determined by the relative positions of the crankshaft and camshaft. The intake valve must also open wide enough and long enough to allow the air-fuel mixture to get into the cylinder. The exhaust valve must do the same to allow the exhaust gases to get out of the cylinder.

Lift is how wide the valve opens. Duration is the amount of time that the valve stays open. Overlap is the amount of time that both intake and exhaust valves are open. Lift and duration are determined by the shape of the camshaft lobes. Valve timing, lift, and duration have a big effect on engine drivability.

The crankshaft always turns two complete revolutions for every one revolution of the camshaft. This is because any cylinder in a four-stroke cycle engine, whether gasoline or diesel, requires two complete revolutions of the crankshaft to complete all four cycles. However, each valve in the engine opens only once during all four strokes. To accomplish this, the driving gear on the crankshaft always has half the number of teeth as the driven gear on the camshaft.

Push Rods and Rocker Arms

Push rods are used only on cam-in-block engines. They transmit the lifter motion to the rocker arm. Many push rods are hollow. Oil from the lifter flows through them to lubricate the rest of the valve train. Rocker arms are pivoting levers that convert the upward movement of the push rod or lifter into downward movement of the valve.

Variable Valve Timing Devices

In the past, the valve timing set by the relationship between the valves and pistons, one of three types of camshaft drive mechanisms is used. In all cases, the gear or sprocket on the crankshaft has exactly half the number of teeth on the camshaft gear or sprocket. This causes the camshaft to turn at exactly half of the crankshaft speed.

A few vehicles use a gear drive, Figure 5-11. This type of drive has two meshing gears. The crankshaft gear rotates to drive the camshaft gear.

The majority of overhead valve, cam-in-block engines use a chain drive, Figure 5-12. The camshaft gear drives the crankshaft gear.

A few overhead camshaft engines use a chain drive. However, most overhead camshaft engines use a belt drive, Figure 5-13. In this design, the belt is driven by a crankshaft sprocket. The belt then drives the camshaft sprocket. On these designs, the belt often drives the water pump and oil pump. Some overhead camshaft engines use a system that is a combination of chain and belt drives.

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Variable Valve Timing Devices

In the past, the valve timing set by the relationship of the drive and driven sprockets or gears could not be changed once the engine was assembled. An increasing
number of engines have some form of variable valve timing. **Variable valve timing** allows the timing of the valve opening and closing to be varied based on driving conditions. Two general types of variable valve timing are used on engines:

- **Camshaft timing adjustment.** These adjusters are mounted on the end of the camshaft where it is fastened to the driven sprocket or gear.
- **Camshaft lift and duration adjustment.** These adjusters are mounted at the camshaft lobes and rocker arms.

The vehicle computer operates the adjusters based on sensor inputs. The types of variable valve timing devices are discussed in more detail in Chapter 10.

**Vibration Damper**

When the engine cylinders fire, force is transmitted to the crankshaft. When it receives this force, part of the crankshaft tends to rotate before the rest of the crankshaft. This causes a twisting of the crankshaft. When the force is removed, the partially twisted shaft unwinds. This unwinding action, although minute, causes what is known as torsional vibration. To stop the vibration, a **vibration damper**, sometimes called a harmonic balance, is attached to the front of the crankshaft. It consists of two heavy rings connected by rubber plugs, spring-loaded friction discs, or a combination of the two.

When a cylinder fires and the crankshaft speeds up, the outer ring of the damper has a tendency not to rotate. As a result, the rubber connecting the two rings of the damper flexes. As the crankshaft tries to unwind after the cylinder has fired, the outer ring of the damper again tends not to rotate in the opposite direction and the rubber flexes. The unwinding force of the crankshaft is cancelled out by the damper. On some newer engines, the crankshaft pulley is an integral part of the damper.

The engine flywheel also absorbs vibration. The flywheel used with manual transmissions is heavy and absorbs vibration. Automatic transmission flywheels are lightweight steel stampings. The torque converter absorbs most of the vibration.

**Balance Shafts**

In some engines, one or more **balance shafts** are added to counterbalance vertical and torsional vibrations. A balance shaft has offset weights that rotate in the opposite direction of the crankshaft. These shafts are either turned by the camshaft through direct gearing or by the crankshaft through a belt or chain. Balance shafts help to provide a smoother idle and less vibration from the engine.

**Engine-Related Systems That Can Affect Driveability**

The following sections cover systems related to the engine that can affect driveability. These systems are all part of the overall basic engine and affect engine operation if they are not properly operating.

**Cooling System**

The **cooling system** is a set of components that remove unwanted engine heat and regulate engine temperature. A cooling system is needed because not all of the heat of combustion creates pressure to move the pistons. The excess heat must be removed to prevent engine damage. Even a slightly overheating engine experiences excess wear due to the tighter-than-normal clearances between moving parts. An excessively hot engine tends to ping, diesel, or be hard to start. It may also be hot enough to melt the exhaust valves. This is usually called valve burning.

Some of the engine heat is removed by the exhaust gases and some radiates out of the engine block and heads. The rest of the heat must be removed by the cooling system. The amount of heat removed must be controlled so that the engine does not run cooler than its normal operating temperature. An engine that runs too cold wastes fuel, drives poorly, pollutes the air, and quickly wears out.

All cooling systems remove excess heat from the engine and transfer it to the surrounding air. The two main kinds of cooling systems are liquid cooling and direct air cooling. In liquid cooling, the heat is absorbed by a liquid, which then transfers it to the air. In direct air cooling, the heat is directly transferred to the air.

**Liquid Cooling**

All cars and light trucks manufactured today have a liquid cooling system. The engine block and cylinder head has many internal passages through which coolant circulates. The coolant is moved through the cooling system by a pump. As the coolant circulates through the passages, it picks up heat from the surrounding metal. The coolant then flows from the engine into the radiator. As the coolant travels through the radiator, heat is transferred from the coolant to the air passing through the radiator. A fan draws air through the radiator at low speeds. At higher speeds, the movement of the vehicle forces air through the radiator. The cooled liquid then returns to the engine to pick up more heat. Figure 5-14 shows a typical cooling system.

**Engine Coolant.** The **engine coolant** is the medium of heat transfer. It must be able to absorb and release heat without damaging any cooling system parts. Engine coolant...
is a mixture of antifreeze and water. There are many types of antifreeze. Some contain ethylene glycol or propylene glycol. Also included are corrosion inhibitors to reduce rust and corrosion of the engine block and radiator. Small amounts of water-soluble oils are added to lubricate seals and moving parts. Antifreeze solutions use organic acid technology (OAT) to lengthen the life of the coolant.

Pure ethylene glycol freezes at about 9°F (-13°C) and water freezes at 32°F (0°C). When ethylene glycol and water are mixed, however, the freezing point of the mixture is lower than either liquid alone. A 50:50 mixture of ethylene glycol and water freezes at about –35°F (-37°C). A mixture of 2/1 ethylene glycol and 1/1 water freezes at about –67°F (-55°C). A 50:50 mixture of propylene glycol and water freezes at about –26°F (-32°C). Most engine manufacturers recommend a 50:50 mix of either ethylene glycol or propylene glycol antifreeze and water.

A mixture of antifreeze and water has a higher boiling point than plain water. A 50:50 mixture boils at about 222°F (106°C). This gives added boil-over protection for summer driving. Up to a 70:30 mixture of antifreeze and water is sometimes used in severe climates and operating conditions.

Antifreeze is colored with dyes. Color does not determine whether a particular antifreeze is suitable for a particular engine. Consult the service information for a vehicle to determine which antifreeze to use.

Warning: Most antifreeze is poisonous to humans and animals. Ingesting a very small amount of antifreeze can lead to kidney failure and death.

Coolant Pump. The coolant pump, or water pump, consists of a cast iron or aluminum housing containing an impeller. The impeller is constructed with blades, Figure 5-15. As the impeller rotates, coolant is thrown to the outside of the impeller. This type of pump is known as a centrifugal pump. It is capable of circulating several hundred gallons of coolant per hour at about 1 psi or 2 psi.

The pump intake is connected by a flexible hose to the lower radiator hose connection. Figure 5-15. The coolant pump uses an impeller to move the coolant through the engine. Coolant pumps are either belt- or gear-driven.

Radiator. The radiator is a heat exchanger consisting of tubes and fins. As the coolant flows through the tubes, heat is transferred to the fins. The fins then transfer the heat to the air passing through the radiator. In most vehicles, the radiator is capable of removing more heat than the engine can produce. Actual radiator efficiency depends on the flow rate of the coolant and the outside air temperature.

Most radiators are cross-flow radiators. In this design, coolant flows from one side of the radiator to the other. Tanks on the left and right sides of the radiator direct coolant into the radiator tubes or to an outlet that leads back to the engine.

Radiators used on cars with automatic transmissions/transaxles have a heat exchanger mounted in the radiator to cool the transmission fluid. Hydraulic pressure in the transmission/transaxle forces the fluid through the heat exchanger. The fluid, which is at a higher temperature than the coolant, gives up heat to the engine coolant. The transmission cooler is always mounted in the radiator tank that feeds coolant back into the engine.

Radiator Fan. The radiator fan draws extra air through the radiator to aid in heat transfer at low speeds. Most fans are electric. See Figure 5-17. The fan is controlled by either thermostatic switches installed in a passage of the cooling system or through the engine control computer. The fan remains off until the coolant temperature reaches a certain point. The fan will continue to run after the engine temperature is shut off until the coolant temperature falls to a certain point. In addition, the fan is turned on any time the air conditioner compressor is operating, no matter what the coolant temperature.

Some longitudinal engines have belt-driven fans. These fans are usually installed on the end of the coolant pump shaft so that the same pulley drives the pump and the fan. Many belt-driven fans have a fluid clutch installed between the drive pulley and fan assembly, Figure 5-18.

The fluid clutch allows the fan to freewheel at highway speed. This reduces the load on the engine.

Warning: Most antifreeze is poisonous to humans and animals. Ingesting a very small amount of antifreeze can lead to kidney failure and death.
The cooling system is pressurized to raise the boiling point of the coolant. The boiling point of any liquid goes up as the pressure is increased. For every 1 psi (6.9 kPa) increase in pressure, the boiling coolant point increases by 3°F (1.7°C). Therefore, a 15 psi (105 kPa) pressure cap will raise the boiling point of the coolant by 45°F (25°C).

Coolant-Recovery System. The coolant-recovery system is designed to keep the cooling system as full as possible at all times. The system consists of a tank connected by a hose to the radiator overflow neck, as shown in Figure 5-20. The plastic tank is called the recovery tank. Coolant that is pushed out of the radiator as the engine heats up enters the recovery tank. When the cooling system loses heat, a lower pressure is created in the radiator. The difference between this pressure and atmospheric pressure draws coolant from the recovery tank into the radiator.

Warning: Some coolant-recovery systems are pressurized. The cap on the recovery tank is a pressure cap like the one found on the radiator. Never open a pressurized recovery tank if the cooling system is under pressure.

Thermostat. The thermostat helps the engine to quickly warm up by keeping coolant from circulating through the radiator when the engine is cold. The thermostat is located at the engine outlet groove neck. This is where coolant leaves the engine on its way to the radiator.

The thermostat consists of a heat-sensitive material, such as wax, sealed in a chamber with a piston at one end. The piston is attached to a valve that opens or closes the thermostat to control coolant flow, Figure 5-21.

When the coolant is cold, the wax is contracted and holds the piston in the closed position. As the coolant warms up and circulates under the thermostat, the wax expands and pushes on the piston. This cracks the valve open and allows coolant to begin circulating through the radiator. As the coolant continues to warm up, the valve continues to open until the wide-open temperature is reached. The thermostat has no effect on engine temperature once the coolant temperature is at or above the thermostat's wide-open temperature.

Most engines use a thermostat with a wide-open temperature of between 190–195°F (87.8–90.6°C). In very cold weather, the thermostat may not fully open. Especially when the vehicle is only operated for a short period of time, the coolant may never reach the wide-open temperature.

Hoses and Tubing. The radiator is fixed to the chassis and stationary. However, the engine moves on its mounts as torque increases and decreases. Therefore, the radiator is usually connected to the engine by flexible hoses. These hoses are made of rubber or neoprene molded around a fiber mesh. Clamps are used to secure the hoses to the radiator and engine.

Some engines have a bypass hose that allows the coolant to circulate inside the engine until the thermostat opens. On other engines, the bypass is built into the engine to prevent coolant flow. The bypass system prevents damage to rapidly heating parts, such as exhaust valves or cylinder walls, by allowing coolant to circulate past the parts before the thermostat opens.

Some cooling systems have fixed metal tubing to route coolant along straight runs. The tubing is either directly connected to components or connected via a flexible hose. Many cooling systems have fixed metal tubing to route coolant along straight runs. The tubing is either directly connected to components or connected via a flexible hose. This tubing is made of soft steel or aluminum.

Many cooling systems also have one or more small bleeder valves. If a portion of the cooling system is higher than the radiator fill cap, the system will have at least one bleeder valve. Bleeder valves are used to remove air from the cooling system during service. Pockets of air in the cooling system can block coolant flow, resulting in hot spots or engine overheating.

Engine Belt. An engine belt drives the coolant pump and other engine accessories. The belt is called a serpentine belt because it winds around several pulleys, Figure 5-22. It is driven by a pulley on the front of the crankshaft. The belt must be in good condition and properly adjusted. Most engines have an automatic tensioner to keep the serpentine belt properly adjusted.

Excessive tightness in the belt places a heavy load on the bearings in the coolant pump and possibly the crankshaft bearings. This will cause premature wear. Looseness in the belt permits slippage. This can reduce the speed of the coolant pump, alternator, and belt-driven fan. As a result, the engine may overheat or the battery may become discharged. An excessively loose belt will have a tendency to whip or flap, which can cut hoses or cause intermittent loading of the bearings in the coolant pump.

Direct Air Cooling

Direct air cooling is a method of directly transferring engine heat to the surrounding air. It uses a fan to force air around the cylinders and cylinder heads, which are the hottest parts of the engine. The fan is driven by the crankshaft via a belt. The cylinders and heads of an air cooled engine are made with fins to present a larger heat transfer surface. The engine is surrounded by a sheet metal shroud to direct more air over the hottest engine parts. Air-cooled engines are no longer used on cars and light trucks.
Lubrication is the most obvious job of engine oil. Oil reduces friction by forming a layer between moving parts. All engine parts, no matter how finely machined, have microscopic high spots. As one part moves across another, these spots will contact each other. As a result, the parts begin to wear and overheat from friction. The oil separates the moving parts, preventing the high spots from touching. The oil acts like a set of microscopic ball bearings, allowing the parts to slide against each other. Friction is greatly reduced.

Sealing is another task of engine oil. A thin film of oil between the piston rings and cylinder wall seals in pressure. If this oil is not present, pressure leakage (loss of compression) will prevent the engine from running.

Cleaning is also an important job of engine oil. Engines constantly collect impurities. Unburned gasoline, carbon from the combustion process, and water vapor get into the crankcase. These impurities can form sludge and varnish deposits in an engine. The deposits can cause the engine to overheat, burn oil, and prematurely wear out. Engine oil contains detergents that prevent formation of sludge by picking up impurities and holding them in suspension. When the oil circulates through the oil filter, the impurities are trapped.

The American Petroleum Institute (API) classifies oil according to various factors that affect oil’s ability to prevent friction and deposits in an engine. The API service classification is printed on the oil container, Figure 5-24. The API service classification is SM for most gasoline engines and CH4 for most diesel engines. Oils with other classifications are only for use in older engines. However, older engines can use engine oil with the newest classification.

In addition to the API grades, the International Lubricants Standardization and Approval Committee (ILSAC), made up of American and Japanese vehicle manufacturers, classifies oils according to manufacturer test criteria. Classifications are called GF for gasoline fueled. At the present time, GF-4 is the latest standard.

Oil Pan

Oil that drips or is squirted out of any part of the lubrication system eventually drains into the oil pan. The oil pan is a reservoir for engine oil and helps the oil to lose the heat that it picked up in the engine. The air passing underneath the vehicle removes this heat from the oil pan.

Intake and exhaust valves are located in the cylinder head above the piston. These moving parts, as well as connecting rod journals and rod bearings, engine oil provides shock absorption. The oil cushions the shock when the rod changes direction at high speeds. This extends bearing life and prevents engine knocking. Other moving parts, such as the piston skirts and cam lobes, are also cushioned by oil.

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Figure 5-24. A—Oil containers carry an American Petroleum Institute (API) marking indicating the oil viscosity and classification. B—Oil temperature range chart.

Oil Pick-Up Screen

The oil pick-up screen prevents any large particles, such as dirt, sand, or metal shavings, from being circulated in the lubrication system. The oil screen is installed on the intake side of the oil pump. Figure 5-26. It is always located at the lowest point in the oil pan. In this way, the screen is always covered by oil. This keeps the oil pump from drawing in air if the oil level drops because of oil consumption or sloshing during turns or hard braking.

Since it traps only large particles, the oil screen usually does not become plugged until the engine reaches very high mileage. Most oil screens cannot be removed and cleaned unless the oil pan is removed.
Oil Pump

The engine oil pump develops oil pressure and flow to circulate oil throughout the lubrication system. Usually, it is driven by a gear on the camshaft or crankshaft. Most gear-driven oil pumps are mounted near the bottom of the engine and connect to the camshaft drive gear through a shaft. Some oil pumps are installed in the engine front cover and are directly driven by the engine crankshaft. The oil pump speed varies with engine speed, since the pump is driven by the engine.

Engine oil pumps are always constant-displacement types. A constant-displacement pump delivers the same amount of oil with each revolution. The faster the pump revolves, the more oil it delivers. Figure 5-27 illustrates the external-gear and rotor designs of oil pump. The external-gear design is most common; however, more and more engines are equipped with rotor pumps.

When the pump gears rotate, the gear teeth unmesh in the inlet area. This creates a low-pressure area that draws oil from the oil pan or oil tank. The oil is carried around the housing in the spaces between the gears and housing. When the gear teeth mesh at the outlet, a high-pressure area is created. The oil is squeezed out of the discharge port. The process is then repeated.

Pressure Regulator

The oil pump has enough capacity to deliver sufficient oil pressure and flow at idle speeds. At higher engine speeds, the pump will produce too much oil pressure and flow. This may rupture seals or filter elements, affect hydraulic lifter operation, or cause oil burning.

Oil pump output is controlled by a pressure regulator. The pressure regulator consists of a valve that is held closed by a spring. Oil pressure from the pump pushes against the valve on the opposite side from the spring. When the oil pressure reaches a certain point, the spring is compressed and the valve opens. This dumps excess oil into the sump, which is at a lower (near atmospheric) pressure. As a result, the oil pressure is regulated. Engine oil pressure is usually regulated to about 35–45 psi (240–310 kPa). Minimum pressure at idle should be 15–20 psi (105–140 kPa).

Oil Filter

The oil filter removes small particles and contaminants from the engine oil. It consists of a stamped metal housing containing, typically, a pleated paper filter element. Other types of elements may be used. The filter is always installed on the outlet side of the oil pump. Oil under pressure flows into the filter, through the filter element, and out of the filter.

The oil filter contains an internal bypass. This allows oil to flow past the filter if the element becomes clogged. However, the oil is not filtered when this happens. Some oil filters have an anti-drainback valve. This valve closes to keep oil from draining out of the filter when the engine is not operated for long periods.

The oil filter is replaced during an oil change as part of normal engine maintenance. A typical oil filter, such as the one shown in Figure 5-29, can be removed from the engine by unscrewing it from the mounting pad. In some engine designs, the oil filter is mounted on the firewall or elsewhere in the engine compartment. Some oil filters are installed in the oil pan or an engine-mounted canister and do not have housings.

Oil Galleries

Oil galleries are internal engine passages that carry the oil. They are cast or drilled into the engine block and heads. Galleries extend from the pump and filter to the crankshaft and camshaft bearings, valve filters, and rocker arm shafts. Galleries are drilled in the crankshaft to allow oil to reach the connecting rod bearings. Removable plugs are located at the rear of some engine blocks to allow the galleries to be cleaned during an overhaul.

Summary

The four-stroke cycle operates through two revolutions of the crankshaft. The intake stroke draws air and fuel into the cylinder. The compression stroke compresses the air-fuel mixture. When the mixture ignites, it pushes the piston down for the power stroke. On the exhaust stroke, the upward movement of the piston pushes the exhaust gases out of the cylinder. The cycle then repeats.

The major components of a reciprocating-piston engine are the engine block, pistons and rings, connecting rods, crankshaft, cylinder head(s), valves, and valve train. The valves are driven by the crankshaft through a set of gears, a gear and chain arrangement, or sprockets and a drive belt. On some engines, valve operation is controlled by a mechanism operated by a computer.

The cooling system removes unwanted engine heat and regulates engine temperature. Cars and light trucks have a liquid cooling system. Coolant is pumped through engine passages by a belt-driven pump. A radiator removes heat from the coolant. Engine coolant is a mixture of anti-freeze and water. Antifreeze may be ethylene glycol or propylene glycol.

Poor lubrication can eventually result in drivability symptoms. The lubrication system circulates engine oil to internal engine parts. Oil galleries are internal passages that carry the oil throughout the engine. The oil pump is driven by a gear on the camshaft or by the engine timing belt. A pressure regulator controls oil pump output. The engine oil provides lubrication, reduces friction, helps with cooling, seals, provides shock absorption between parts, and cleans parts. It is formulated to prevent sludge formation.

Review Questions—Chapter 5

1. Name the four strokes in a four-stroke cycle engine.
2. List the major parts installed on or in the engine block.
3. The _____ transfer the force of the expanding combustion gases to the connecting rods.
4. A _____ is a belt between the compression rings and cylinder wall seals pressure in the cylinder.
   (A) carbon
   (B) oil
   (C) unburned fuel
   (D) None of the above.
5. The _____ converts the straight-line motion of the piston into rotary motion.
   (A) piston
   (B) crankshaft
   (C) flywheel
   (D) connecting rod
6. What holds intake and exhaust valves closed?
   (A) The camshaft.
   (B) Compression pressure.
   (C) Valve spring pressure.
   (D) Expanding combustion gases.
7. The camshaft turns at ____ the speed of the crankshaft.
   (A) about half
   (B) exactly half
   (C) about twice
   (D) exactly twice

8. ____ and ____ are the two general types of variable valve timing.

9. List two devices used to reduce engine vibration.

10. Cars and light trucks manufactured today are ____ cooled.
    (A) air
    (B) liquid
    (C) oil
    (D) thermostatically

11. The purpose of antifreeze is to:
    (A) reduce rust and corrosion in the engine and radiator.
    (B) lower the freezing point of the engine coolant.
    (C) increase the boiling point of the engine coolant.
    (D) All of the above.

12. By pressurizing the cooling system, the boiling point of the engine coolant is ____

13. Engine oil is used to ____ various parts of the engine.
    (A) cool
    (B) lubricate
    (C) cushion
    (D) All of the above.

14. Engines are usually lubricated by:
    (A) pressurized oil.
    (B) splashed oil.
    (C) a combination of pressurized/splashed oil.
    (D) None of the above.

15. Engine oil pressure is controlled by a pressure regulator, typically in the range of:
    (A) 5–15 psi (35–105 kPa)
    (B) 15–20 psi (105–140 kPa)
    (C) 20–35 psi (140–240 kPa)
    (D) 35–45 psi (240–310 kPa)

ASE Certification-Type Questions

1. Technician A says that an engine must have sufficient compression before it will start and run. Technician B says that compression is developed on the power stroke of a four-cycle engine. Who is correct?
   (A) A only.
   (B) B only.
   (C) Both A & B.
   (D) Neither A nor B.

2. All of the following statements about oil control rings are true, except:
   (A) oil control rings are installed below the compression rings.
   (B) there should be no oil at the compression rings.
   (C) oil control rings scrape oil from the cylinder walls when the piston is moving down.
   (D) defective oil control rings will cause high oil consumption

3. Technician A says that the intake valves are cooled by incoming air. Technician B says that the intake valve must be in contact with its seat long enough to transfer heat to the cylinder head. Who is correct?
   (A) A only.
   (B) B only.
   (C) Both A & B.
   (D) Neither A nor B.

4. Cylinder heads contain all of the following, except:
   (A) intake valves.
   (B) exhaust valves.
   (C) EGR valves.
   (D) camshafts.

5. The valve train is the group of components that opens the ____.
   (A) intake valves
   (B) exhaust valves
   (C) EGR valve
   (D) Both A & B.

6. A hydraulic lash adjuster, similar in operation to a hydraulic lifter, maintains the proper valve clearance on ____ engines.
   (A) cam-in-block
   (B) roller-lifter
   (C) overhead cam
   (D) All of the above.

7. Technician A says that overhead camshafts are usually driven by a belt. Technician B says that in cam-in-block, overhead valve engines, the camshaft is usually directly driven by two meshing gears. Who is correct?
   (A) A only.
   (B) B only.
   (C) Both A & B.
   (D) Neither A nor B.

8. Most vehicle manufacturers recommend a ____ mix of water and antifreeze.
   (A) 10:90
   (B) 50:50
   (C) 30:70
   (D) 80:20

9. Oil screens on the inlet to the oil pump are to remove:
   (A) large particles of dirt or metal.
   (B) small particles of dirt or metal.
   (C) chemical contaminants.
   (D) particles the oil filter does not catch.

10. Technician A says that engine oil pumps are constant-displacement pumps. Technician B says that the engine oil pan serves as the reservoir for engine oil. Who is correct?
    (A) A only.
    (B) B only.
    (C) Both A & B.
    (D) Neither A nor B.
Electricity is used throughout the vehicle. Some vehicles use electricity to assist the gasoline or diesel engine in moving the vehicle. In other vehicles, such as this car from Smart, only electricity propels the vehicle. (Daimler)