LEVEL F

Piston Engine Fundamentals

TC010-05-01S

Mazda Motor Corporation
Technical Service Training

Masters

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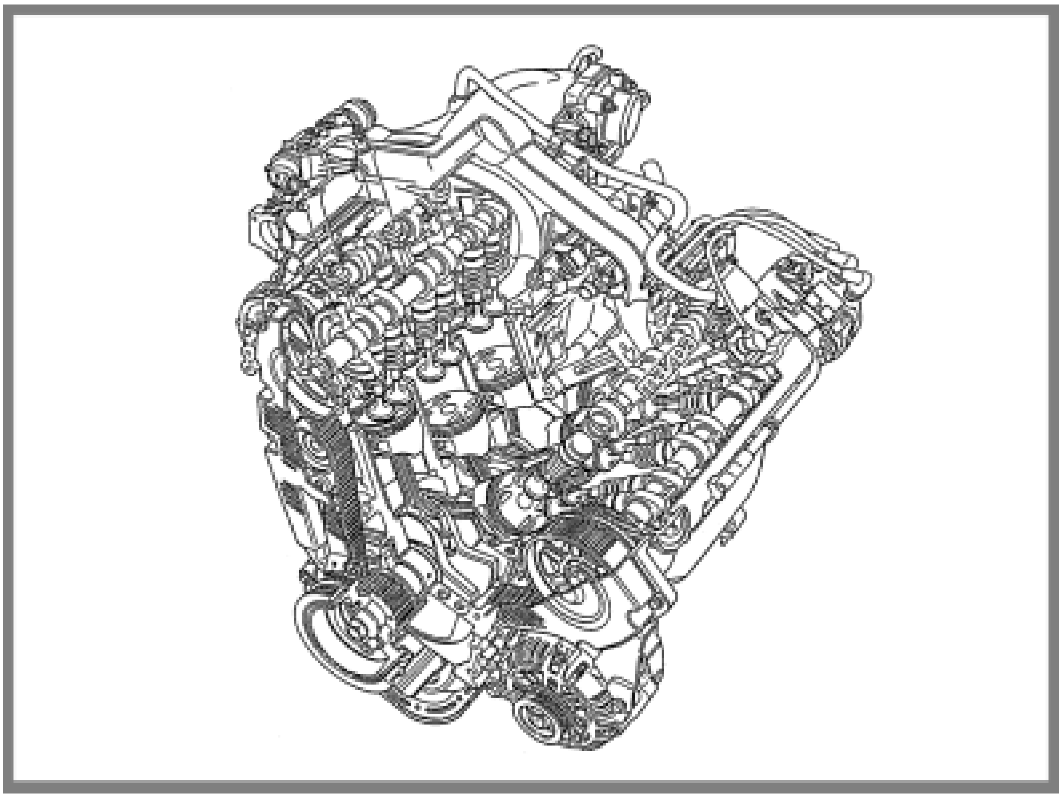
1 – INTRODUCTION



COURSE OVERVIEW

Welcome to the Mazda self-study guide *Piston Engine Fundamentals.* Before you begin, please read the following information.

Audience and Purpose

This guide is designed for entry-level automotive technicians. It introduces the basic principles of engine operation, as well as descriptions of major engine components.

The guide assumes that you have little or no knowledge about engine operation. The information covered in this guide is required for Mazda's Engine Course.

1 – INTRODUCTION

Course Content and Objectives

In addition to this Introduction (Section 1), this guide includes five major sections and a glossary. The objectives for each section follow.

2 – Basic Engine Operation

- Describe how engines generate and control power.
- Describe the four-stroke cycle.
- Define engine design characteristics, such as bore, stroke, and displacement.

3 – Short Block

- Identify the major parts of the short block.

4 – Valve Train

- Identify the major parts of the valve train.

5 – Lubrication System

- Identify the major parts of the lubrication system and describe how they lubricate engine parts.

6 – Cooling System

- Identify the major parts of the cooling system and describe how they control engine temperature.

7 – Glossary

- Define terms used throughout this guide.

HOW TO USE THIS GUIDE

To get the most benefit from this guide, complete the sections in order, from 1 through 6. Allow enough time to complete each section, and don't try to complete the whole book in one sitting. **You will retain more of what you learn if you split up the reading and review exercises over several days.**

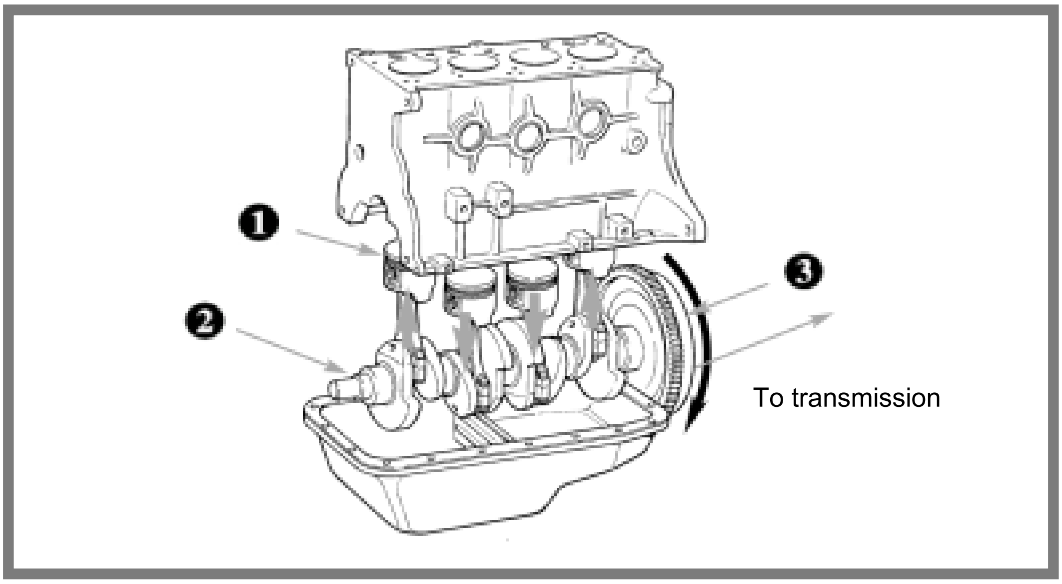
Section Objectives

Each section begins with a list of learning objectives. These objectives tell you exactly what you will learn in the section. Read these objectives before you begin a section. When you have completed the section, go back and review the objectives to make sure you have learned the material.

Text and Illustrations

Each section includes text and illustrations that explain important concepts and terms. Read the text carefully and study the illustrations. You may also want to take notes as you go along.

Each illustration includes numbered "callouts" that identify engine parts or processes described in the text. The numbered items beside the illustration identify the parts that are called out, as shown in the following example from Section 2.



1. **Piston**
2. **Crankshaft**
3. **Flywheel**

Review Exercises

This guide includes nine sets of Review Exercises, which appear at various points throughout the guide. These exercises are designed to check your understanding of the material. Make sure you answer the questions in each Review Exercise. Then check your answers with the answer key.

If you're not sure about one or more of your answers, go back and read the material again. Make sure you understand the previous material before you move on to new material.

2 – BASIC OPERATION

In a car or truck, the engine provides rotating power to drive the wheels. This power is transferred to the wheels through the transmission and driving axle. The source of this rotating power is the energy released when fuel burns in the engine's cylinders.

This section provides an overview of how the engine converts energy from burning fuel into power that drives the vehicle's wheels.

OBJECTIVES

After completing this section, you will be able to describe how:

- The cylinders and pistons convert energy from burning fuel into power.
- The crankshaft converts up-and-down motion into rotational (turning) motion.
- The flywheel stores energy for a smooth transfer of power.
- The four-stroke cycle operates.
- Valves control intake and exhaust in a cylinder.
- Engines are classified by their design characteristics, including:
  - Cylinder configuration
  - Valve train type
  - Bore, stroke, and displacement
  - Compression ratio

HOW POWER IS DEVELOPED

Figure 1 shows how the energy from burning fuel is converted into rotating power. In an engine, a *piston* is closely fitted into a hollow *cylinder*. The cylinder has free space at the top, where a mixture of air and fuel is inserted.

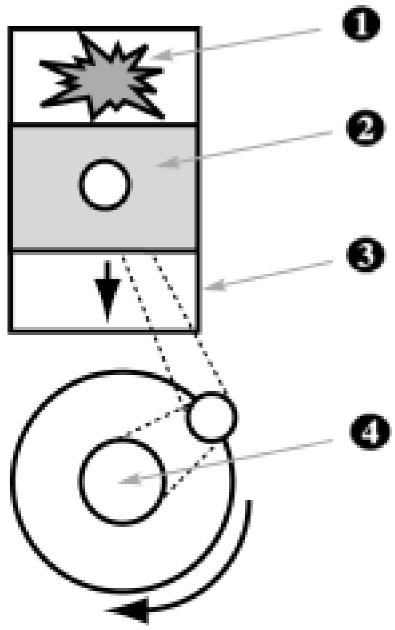


FIGURE 1. Power is developed by burning fuel in a cylinder.

❶ Burning mixture of air and fuel

❷ Piston

❸ Cylinder

❹ Crankshaft

The air-fuel mixture is ignited, and the burning gases from the mixture expand, creating very high pressure. This pressure pushes down on the piston, causing it to move down in the cylinder.

The process shown in Figure 1 is how the engine produces power. Everything else on the engine is designed to control this process, harness the power, and transmit it to the wheels.

Harnessing Power

To harness this power, the up-and-down movement of the piston is changed into a turning (rotary) motion by connecting the piston to a *crankshaft,* as shown in Figure 1.

The engine's cylinders are arranged to fire one after the other. In this way, some pistons are always supplying power to the crankshaft while other pistons are moving up into their cylinders. To keep the crankshaft rotating smoothly, it is connected to a *flywheel,* which is a heavy round plate that turns with the crankshaft. See Figure 2.

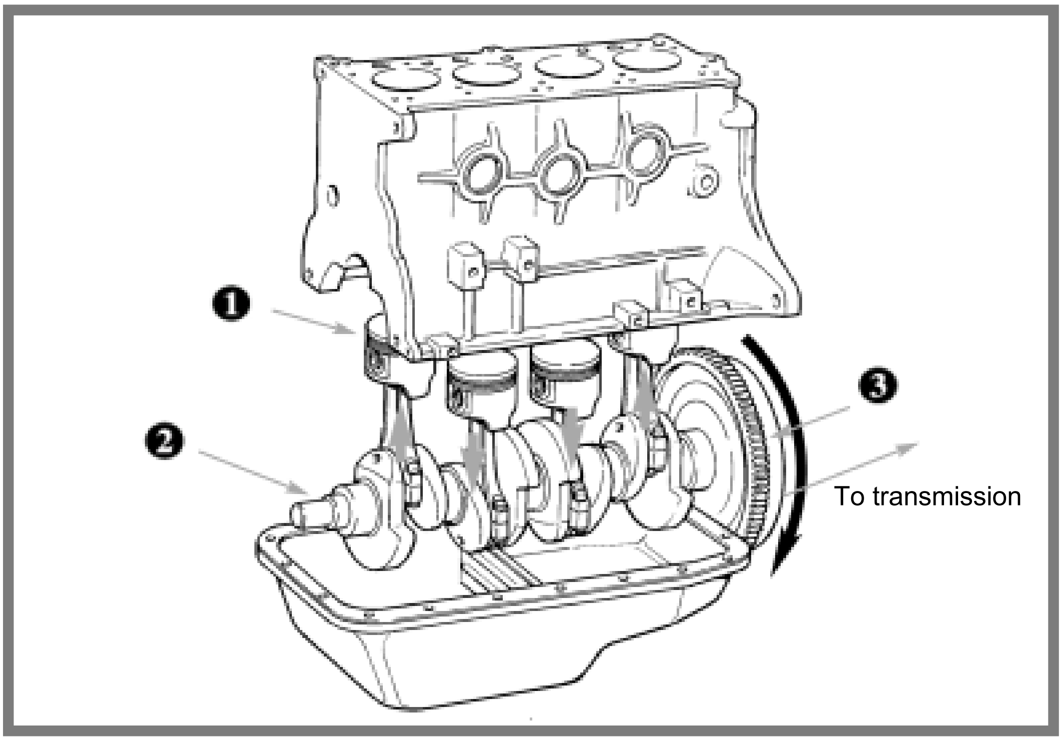


FIGURE 2. The flywheel Keeps the crank- shaft turning smoothly.

❶ Piston

❷ Crankshaft

❸ Flywheel

Because of its weight, the flywheel tends to keep turning smoothly even though power is applied in spurts by the pistons. The end of the crankshaft is also connected to the vehicle's transmission to continue the power flow through the drive train to the wheels.

Controlling Combustion

The process of burning the air-fuel mixture in the cylinder is called *combustion*. The combustion process in an engine requires four steps:

1. Admit the proper mixture of air and fuel into the cylinder.

2. Squeeze (compress) the mixture so it will burn better and deliver more power.

3. Burn the air-fuel mixture.

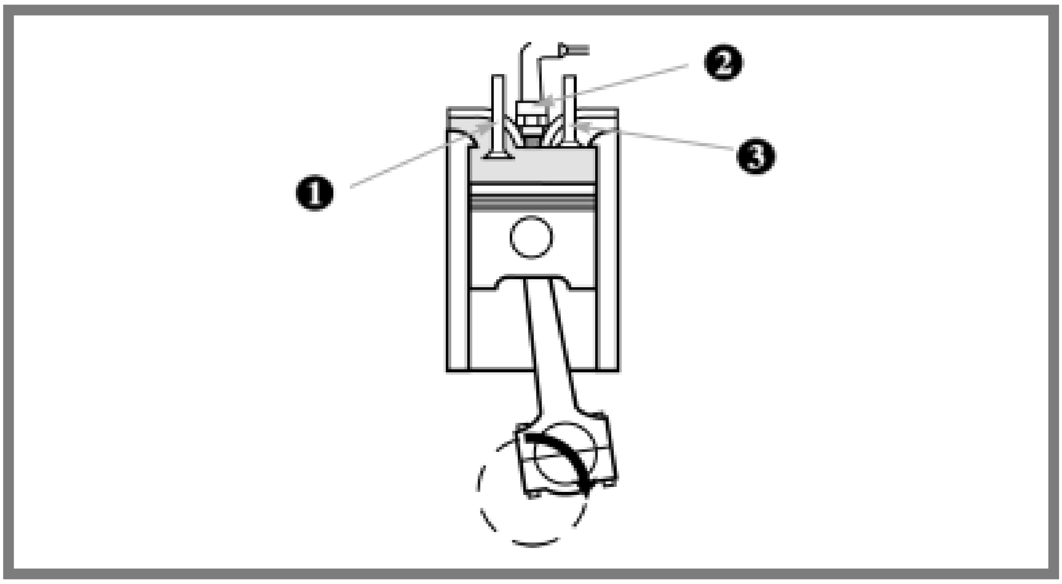
4. Remove the burned gases from the cylinder so intake, compression, and combustion can be repeated.

As Figure 3 shows, each cylinder has several parts that help control the combustion process:

- An *intake valve* lets the air-fuel mixture into the cylinder.
- A *spark plug* ignites the air-fuel mixture.
- An *exhaust valve* lets the burned gases out of the cylinder.

FIGURE 3. Valves and a spark plug help control combustion in the cylinder.

❶ Intake valve
❷ Spark plug
❸ Exhaust valve



THE FOUR-STROKE CYCLE

Most automotive engines use a *four-stroke cycle* to complete the combustion process. A *stroke* is the movement of the piston from its highest point in the cylinder to its lowest point, or from its lowest point to the highest point.

The piston's highest point in the cylinder is called *top dead center,* or *TDC*. The lowest point is called *bottom dead center,* or *BDC*. As Figure 4 shows, a full stroke of the piston takes one half-turn of the crankshaft, or 180 degrees.

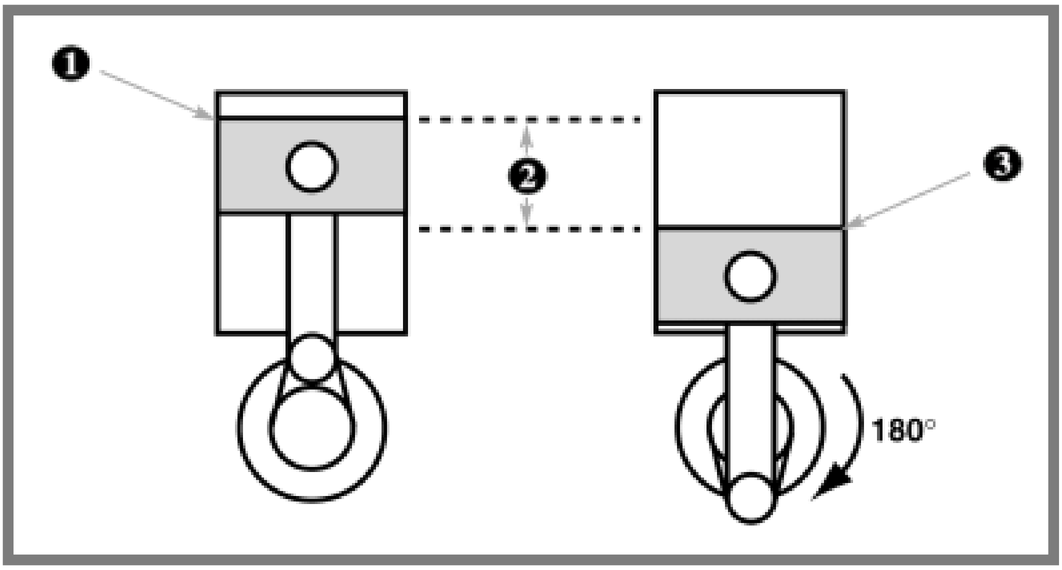


FIGURE 4. A stroke is the distance a piston travels from top dead center to bottom dead center, or from bottom dead center to top dead center.

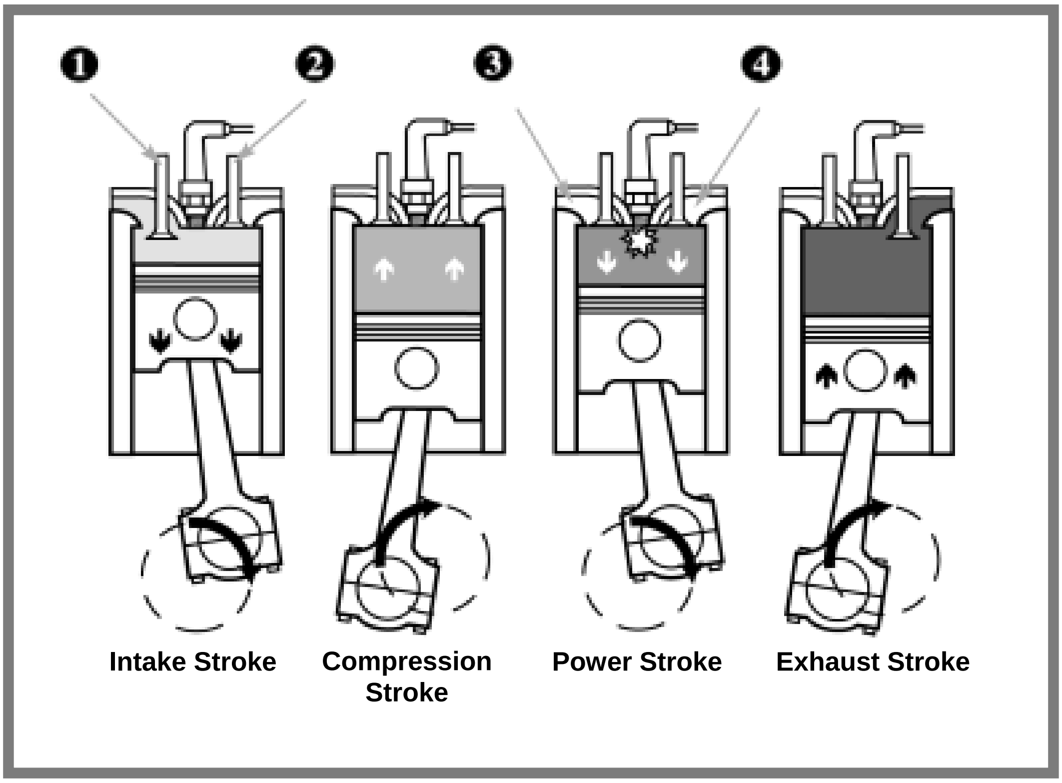
❶ Top dead center (TDC)
❷ One stroke
❸ Bottom dead center (BDC)

The four-stroke cycle requires four up-and-down movements of the piston to complete the cycle. Figure 5 shows the stages of the four-stroke cycle, including the:

1. Intake stroke
2. Compression stroke
3. Power (combustion) stroke
4. Exhaust stroke

FIGURE 5. The four-stroke cycle includes intake, compression, power, and exhaust strokes.

- ❶ **Intake valve**
- ❷ **Exhaust valve**
- ❸ **Intake port**
- ❹ **Exhaust port**



Intake Stroke

The four-stroke cycle begins with the intake stroke. The rotating crankshaft pulls the piston down from TDC. The exhaust valve is closed, and the intake valve is open.

As the piston moves down in the cylinder, it creates a partial vacuum, which draws the air-fuel mixture through the intake valve into the cylinder. The closed exhaust valve prevents the mixture from escaping through the exhaust port.

When the piston is at BDC, the intake stroke is completed. However, the intake valve may be held open slightly longer to let the air-fuel mixture fill the cylinder more completely.

Compression Stroke

As the piston passes BDC and starts up again, the compression stroke begins. The intake valve closes, and the exhaust valve stays closed. With both valves closed, the air-fuel mixture is trapped in the cylinder. As the piston pushes up into the cylinder, it squeezes, or compresses, the air-fuel mixture into a very small volume between the piston and cylinder head.

Compression of the air-fuel mixture is very important for developing power. The greater the compression, the more pressure the mixture will create when it burns. Compression also "pre-heats" the mixture to help it burn better. Because compression is so important, the valves and piston rings must seal the cylinder perfectly, or power will be reduced.

Power Stroke

Just before the piston reaches TDC, a spark from the spark plug ignites the air-fuel mixture, and the power stroke begins. The burning gases expand rapidly, creating very high pressure on top of the piston. Both valves remain tightly closed, so all the force is directed down onto the piston, which is pushed down in the cylinder and turns the crankshaft. The greatest push on the piston occurs in the first half of the power stroke.

By the time the piston approaches BDC, most of the pressure in the cylinder is used up. At this point, the exhaust valve begins to open, relieving any remaining pressure so the piston can move back up into the cylinder during the final stroke.

Exhaust Stroke

During the exhaust stroke, the exhaust valve remains open, and the rotating crankshaft pushes the piston back up the cylinder. The motion of the piston pushes the burned gases out through the exhaust valve.

As the piston passes TDC, the four-stroke cycle begins again with the intake stroke. The exhaust valve stays open momentarily at the beginning of the intake stroke, allowing the momentum of the gases to empty the cylinder completely.

Summary

We have illustrated the four-stroke cycle in only one cylinder. Remember, though, that these four strokes are continuously repeated in all the cylinders.

The four strokes of the cycle — intake, compression, power, and exhaust — require two full rotations of the crankshaft. However, the piston receives direct combustion pressure only during one stroke, or about one quarter of the cycle.

When you realize that no power is being generated during 3/4 of the four-stroke cycle, you can begin to see why the flywheel is so important. The flywheel “stores” the energy that is generated, and uses that stored energy to keep the pistons moving smoothly when they are not receiving combustion pressure.

REVIEW EXERCISE 1

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 15.

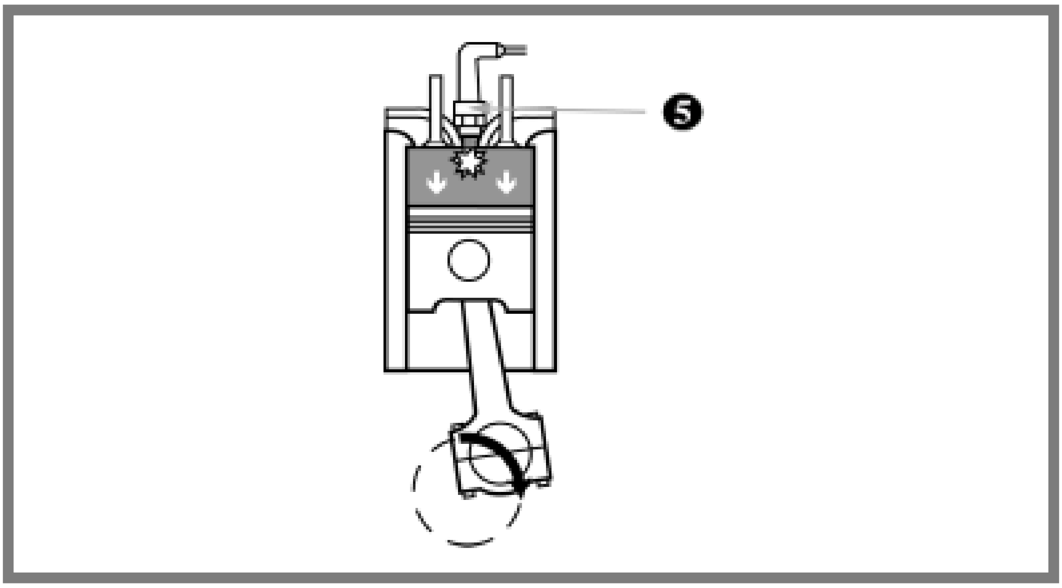
1. In an engine, power is generated when an air-fuel mixture is ignited in the free space at the top of the ____________________.

2. To convert the up-and-down motion of the piston into rotary motion, the piston is attached to a connecting rod, which is connected to the _______________________.

3. The heavy plate connected to the crankshaft that stores the energy generated during combustion is called the _______________________.

2 – BASIC OPERATION

Refer to the illustration below to complete the following two items.



4. This illustration shows the ____________________ stroke of the four-stroke cycle.
5. Item " 5 " in the illustration is the _______________________.

BASIC DESIGN CHARACTERISTICS

There are many variations in basic engine design, and automotive technology has its own vocabulary for describing these designs. Engines are often described by the various arrangements and measurements of their components, including:

- Cylinder configuration
- Valve train type
- Size of the engine's bore, stroke, and displacement
- Compression ratio

Cylinder Configuration

Automotive engines typically have four, six, or eight cylinders, which are arranged either in a line or in a "V" shape. Figure 6 shows the typical arrangement of a
4-cylinder *in-line* engine. As the illustration shows, the cylinders are all in one straight row. Most 4-cylinder engines are built with the cylinders in-line.

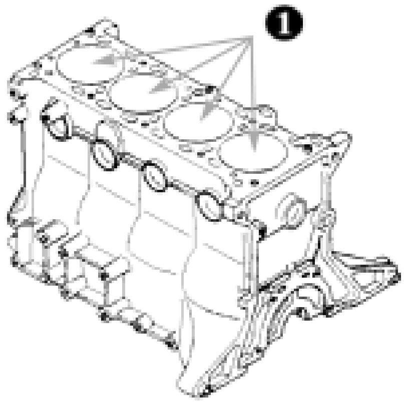


FIGURE 6. A four-cylinder in-line engine has four cylinders arranged in a single row.

1 Cylinders

Figure 7 shows another typical cylinder arrangement, the V-6 engine. The V-6 has two banks of three cylinders arranged in a "V" pattern. Even though the cylinders are in two banks, they are still connected to a common crankshaft.

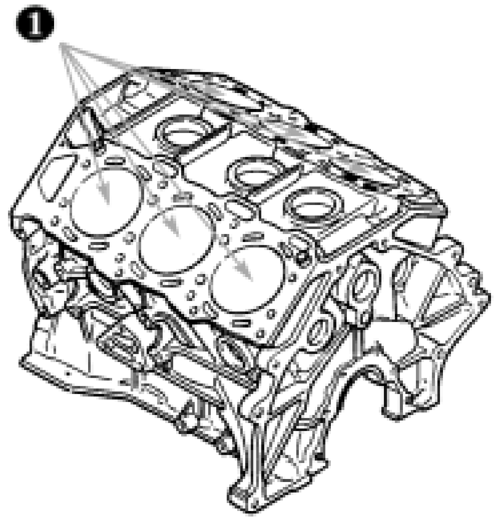


FIGURE 7. A V-6 engine has two banks of three cylinders arranged in a " V" pattern

1 Cylinders

The V-8 engine is a variation of this design. The V-8 includes two banks of four cylinders each, arranged in a "V" pattern.

Valve Train Type

Mazda engines have the valves mounted above the cylinders in the cylinder head. The valves are operated by a *camshaft,* which controls the opening and closing of the valves. An *overhead valve*, or *OHV* design, has the camshaft installed below the valves, in the engine block. If the camshaft is mounted above the cylinders, the design is called *overhead cam,* or *OHC*.

In some engines, a single camshaft is used to operate both the intake and exhaust valves. In many engines, though, a *dual overhead camshaft (DOHC)* design is used. The DOHC design uses one camshaft to operate the intake valves, and the other camshaft to operate the exhaust valves. This arrangement eliminates extra weight, allowing the engine to operate at higher RPMs. Figure 8 shows a DOHC design in a 4-cylinder in-line engine.

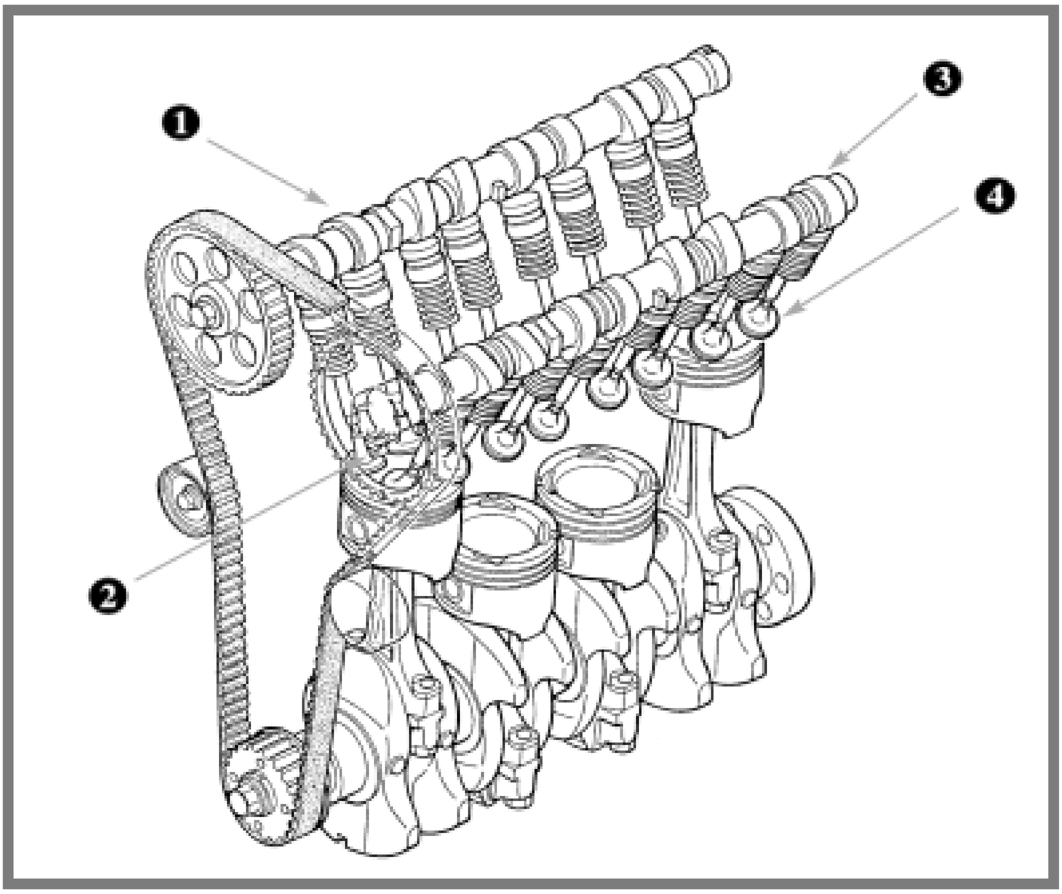


FIGURE 8 The dual overhead camshaft (DOHC) design uses sepa- rate camshafts for the intake and exhaust valves. Two camshafts are used on this 4-cylinder in-line engine

1. **Intake camshaft**
2. **Intake valve**
3. **Exhaust camshaft**
4. **Exhaust valve**

A V-6 or V-8 DOHC engine will have two sets of camshafts, one set for each bank of cylinders. Figure 9 shows the two sets of camshafts on a V-6 engine.

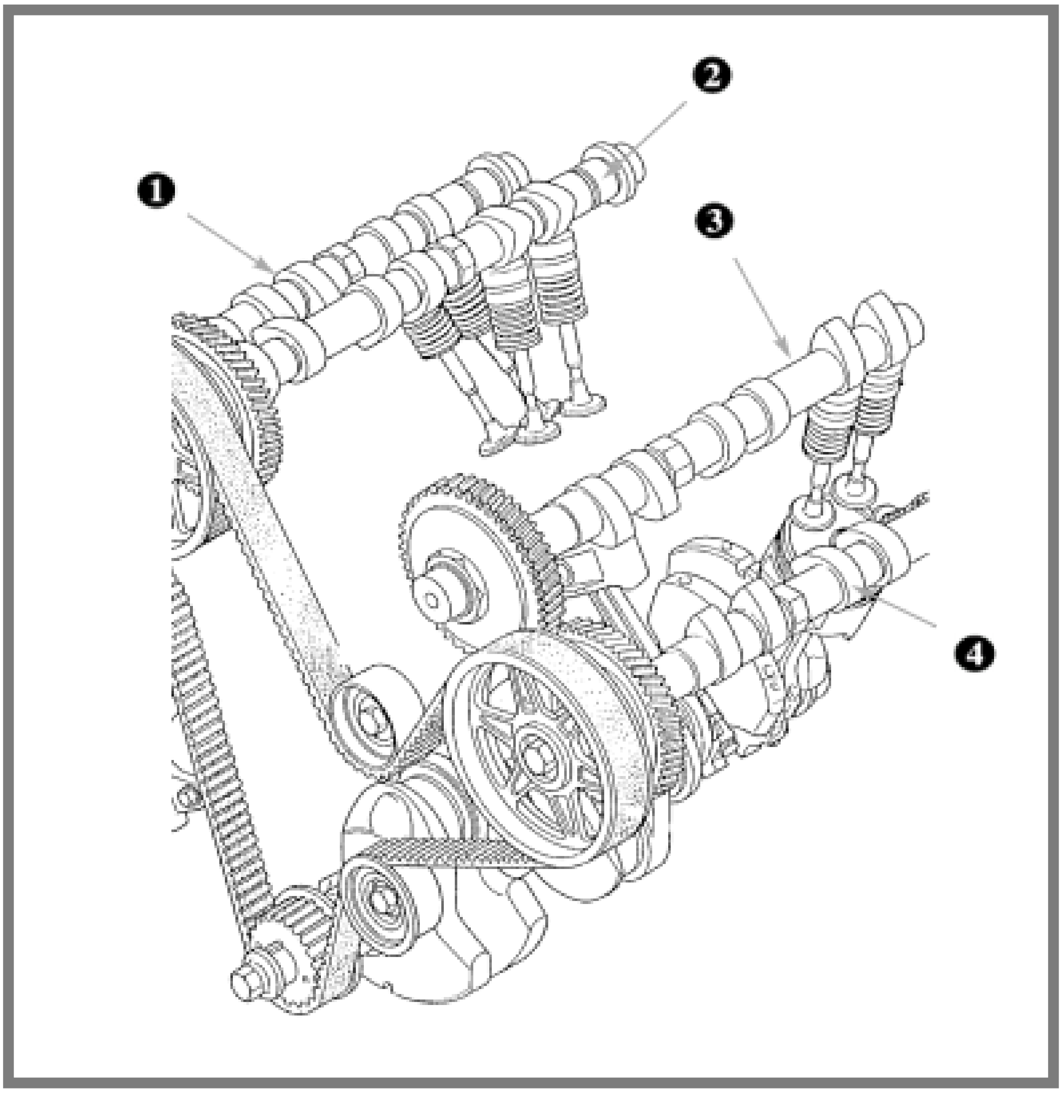


FIGURE 9. A V-6 or V-8 DOHC engine has two sets of camshafts, one for each bank of cylinders. A total of four camshafts are used on this V-6 engine.

1. **Exhaust camshaft, right bank**
2. **Intake camshaft, right bank**
3. **Intake camshaft, left bank**
4. **Exhaust camshaft, left bank**

Bore, Stroke, and Displacement

Bore, stroke, and *displacement* are measurements of the cylinders and pistons in an engine. These three measurements are shown in Figure 10.

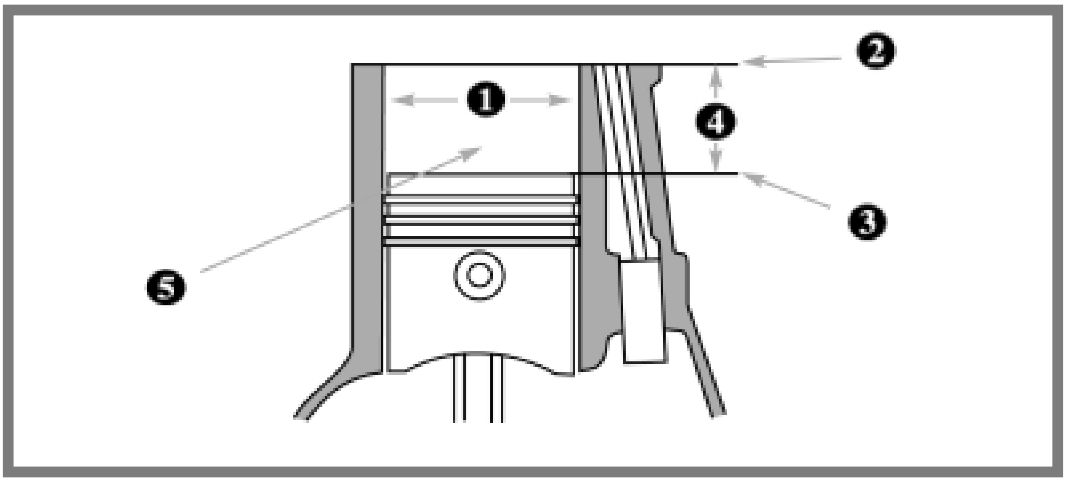


FIGURE 10. Bore and stroke determine the displacement of a cylinder.

1 Bore (mm)
2 TDC
3 BDC
4 Stroke (mm)
5 Displacement (cc or L)

Bore is the diameter of a cylinder, usually expressed in millimeters (mm). *Stroke* is the length of piston travel between TDC and BDC, usually expressed in millimeters.

The *displacement* of a cylinder is the volume of the cylinder between the TDC and BDC positions of the piston. The displacement of an engine is the total displacement of all the cylinders in the engine. Displacement is normally measured in cubic centimeters (cc) or liters (L).

Generally speaking, engine displacement is a rough indicator of power output. For example, a 2000 cc (2.0 L) engine is usually more powerful than a 1500 cc (1.5 L) engine. Displacement can be increased by opening the bore to a larger diameter, or by increasing the length of the stroke.

Compression Ratio

The *compression ratio* measures how much the air-fuel mixture is squeezed during the compression stroke. The compression ratio is the ratio of the cylinder volume at BDC to the volume at TDC. For example, Figure 11 shows a compression ratio of 8 to 1, where the volume at BDC is eight times larger than the volume when the piston is at TDC.

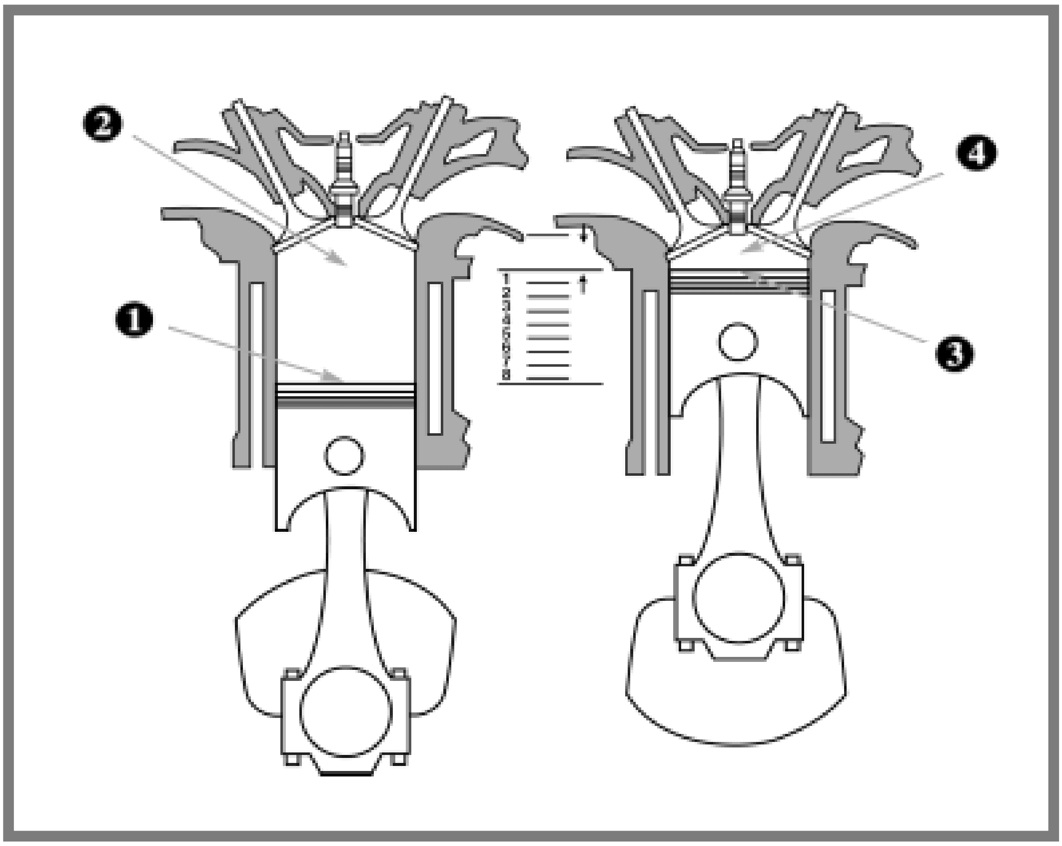


FIGURE 11. The compression ratio compares the cylinder volume at BDC to the volume at TDC.

- ❶ **BDC**
- ❷ **Volume before compression**
- ❸ **TDC**
- ❹ **Volume after compression**

Generally, a higher compression ratio means greater power output. For example, a compression ratio of 8 to 1 will probably produce more power than a ratio of 7 to 1. However, higher compression engines may require premium fuel. Most engines have compression ratios of 9.5 to 1 or less so they can take advantage of regular unleaded fuel.

ENGINE COMPONENTS AND SYSTEMS

In this section, you have learned how the four-stroke cycle produces power in an engine. The rest of this guide covers the following components and systems, which are important to the engine's overall operation:

- **Short block** — A term used in the automotive repair business to describe the cylinder block, crankshaft, bearings, connecting rods, and pistons as a unit.
- **Valve train** — Opens and closes the intake and exhaust valves so that events are properly timed in the four-stroke cycle.
- **Lubrication system** — Lubricates all moving parts to reduce heat and wear.
- **Cooling system** — Maintains ideal operating temperatures in the engine.

Each of these components and systems is described in detail in the following sections of this guide.

REVIEW EXERCISE 2

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 20.

1. A V-6 engine usually has six cylinders arranged in ______________________ banks of _________________________ cylinders each.
2. An engine that uses separate intake and exhaust camshafts mounted above the cylinders is called a _________________________ design.
3. The diameter of a cylinder is called its ___________________________.
4. The ________________________ of an engine measures how much the air-fuel mixture is squeezed before it is ignited.
5. The _______________________ of an engine is the total volume of all the cylinders between the TDC and BDC positions.

3 – SHORT BLOCK

The short block includes the cylinder block, crankshaft, bearings, connecting rods, and pistons. (A partial engine, or long block, is a short block plus cylinder head(s) and cover(s), timing belt and covers, and oil pan.) A low mileage engine with excessive oil consumption or lower end knocking is usually replaced with a short block. This section describes how each part of the short block works.

OBJECTIVES

After completing this section, you will be able to:

- Identify the important parts of the cylinder block and describe their functions.
- Identify the important parts of the crankshaft and describe their functions.
- Describe how main bearings secure and lubricate the crankshaft.
- Describe how the piston is attached to the crankshaft.
- Identify important parts of the piston and describe their functions.
- Describe how pistons are constructed to overcome the problems of heat expansion.
- Identify the piston rings and describe their functions.

3 – SHORT BLOCK

OVERVIEW

The major parts of the short block are shown in Figure 12.

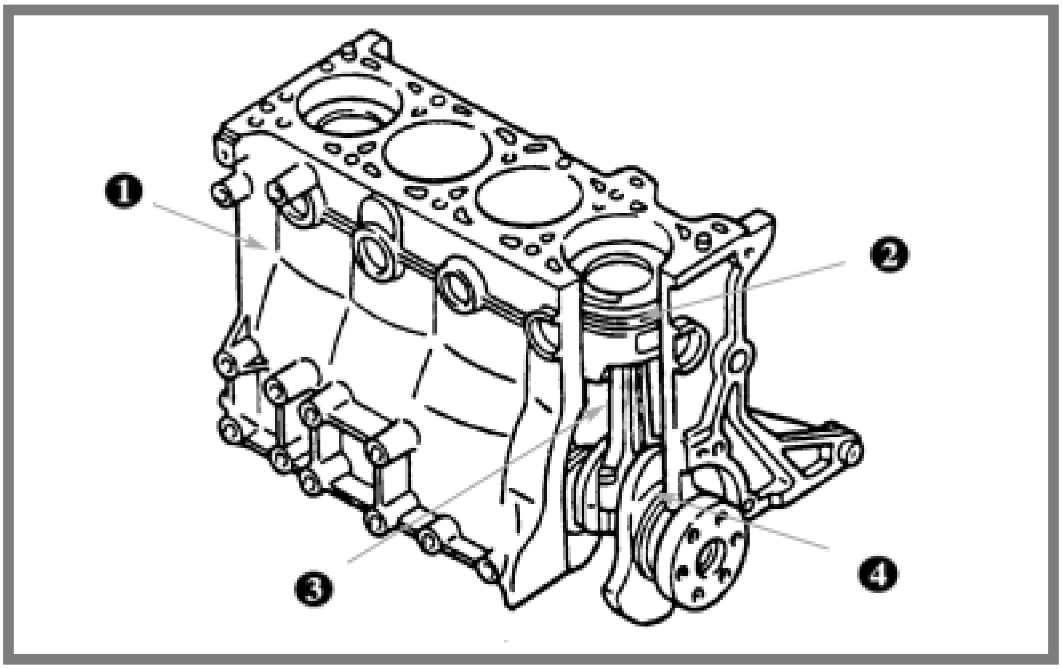


FIGURE 12. A short block is a cylinder block fitted with a complete crank-shaft assembly.

- ❶ **Cylinder block**
- ❷ **Piston**
- ❸ **Connecting rod**
- ❹ **Crankshaft**

The engine's cylinders are bored in the *cylinder block,* which is a large casting made of iron or aluminum. The *combustion chambers* are the spaces where the air-fuel mixture is compressed and burned. Usually, the combustion chambers are formed in the cylinder head, although some engines have chambers in the tops of the pistons.

The pistons are fitted closely inside the cylinders, where they form the "floor" of the combustion chambers. The pistons are linked to the crankshaft by *connecting rods* and *bearings.* The crankshaft is mounted in bearings in the cylinder block.

CYLINDER BLOCK

Figure 13 shows a typical cylinder block for a 4-cylinder in-line engine.

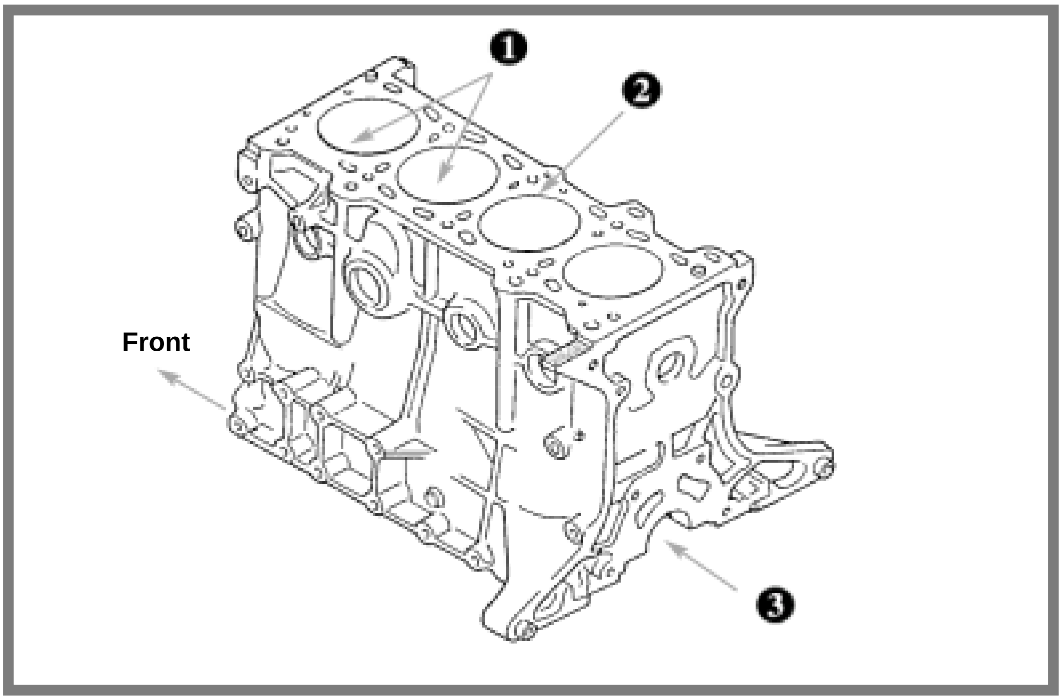


FIGURE 13. The cylinder block is the engine' s main supporting part.

- ❶ **Cylinder bores**
- ❷ **Cylinder head mounting surface**
- ❸ **Crankshaft Opening**

The cylinder block is the main supporting member of the engine. Almost every other engine component is either connected to or supported by the cylinder block. The pistons, connecting rods, and crankshaft work inside the cylinder block.

The cylinder block contains the cylinders, internal passages for coolant and oil, and mounting surfaces for attaching engine accessories, such as the oil filter and water pump. The cylinder head is mounted on top of the cylinder block, and the oil pan is mounted on the bottom.

Construction

Cylinder blocks are usually made of cast iron or aluminum alloy. Cast iron cylinder liners are cast into aluminum alloy blocks. These materials can easily be machined for the cylinder bores and other mating surfaces. Coolant and oil passages are cast into the block when it is manufactured. The block is heavy and rigid, so it can with- stand the vibration and heat stress of engine operation.

The cylinder bores are carefully machined and angled correctly to match the crankshaft. The block material is designed to handle the wear that occurs in the cylinders as the pistons move up and down.

Crankcase

The *crankcase* contains and supports the crankshaft and main bearings. The bottom of the cylinder block forms the upper part of the crankcase. The oil pan attached to the bottom of the cylinder block forms the bottom part of the crankcase.

Crankshaft Main Supports and Bearings

The crankcase includes several support surfaces for the crankshaft. The number of supports varies, depending on the length of the crankshaft. For example, a four-cylinder engine will usually have five of these support surfaces.

The crankshaft mounts on *insert bearings* that are installed on the support surfaces and attached with *bearing caps*. The supports have oil passages that lubricate the crankshaft as it spins against the bearings. These passages align with oil holes in the bearings. The cylinder block also includes a groove for the rear main oil seal, which keeps the oil from leaking out at the rear of the crankshaft and engine.

In automotive technical vocabulary, the term *main* refers to bearings, seals, and other mounting hardware for the crankshaft itself. *Main* distinguishes these mounting parts from other mounting parts that connect to the crankshaft, such as connecting rod bearings.

CRANKSHAFT

The crankshaft is the component that changes the up-and-down motion of the pistons into rotational motion that drives the wheels of the vehicle. The crankshaft attaches to the cylinder block supports with *main bearing caps,* as shown in Figure 14. When the bearing caps are bolted on, they hold the crankshaft in place. When the block is machined, main bearing surfaces are aligned and bored on the crankshaft's center line (line-bored), so bearing caps must never be interchanged.

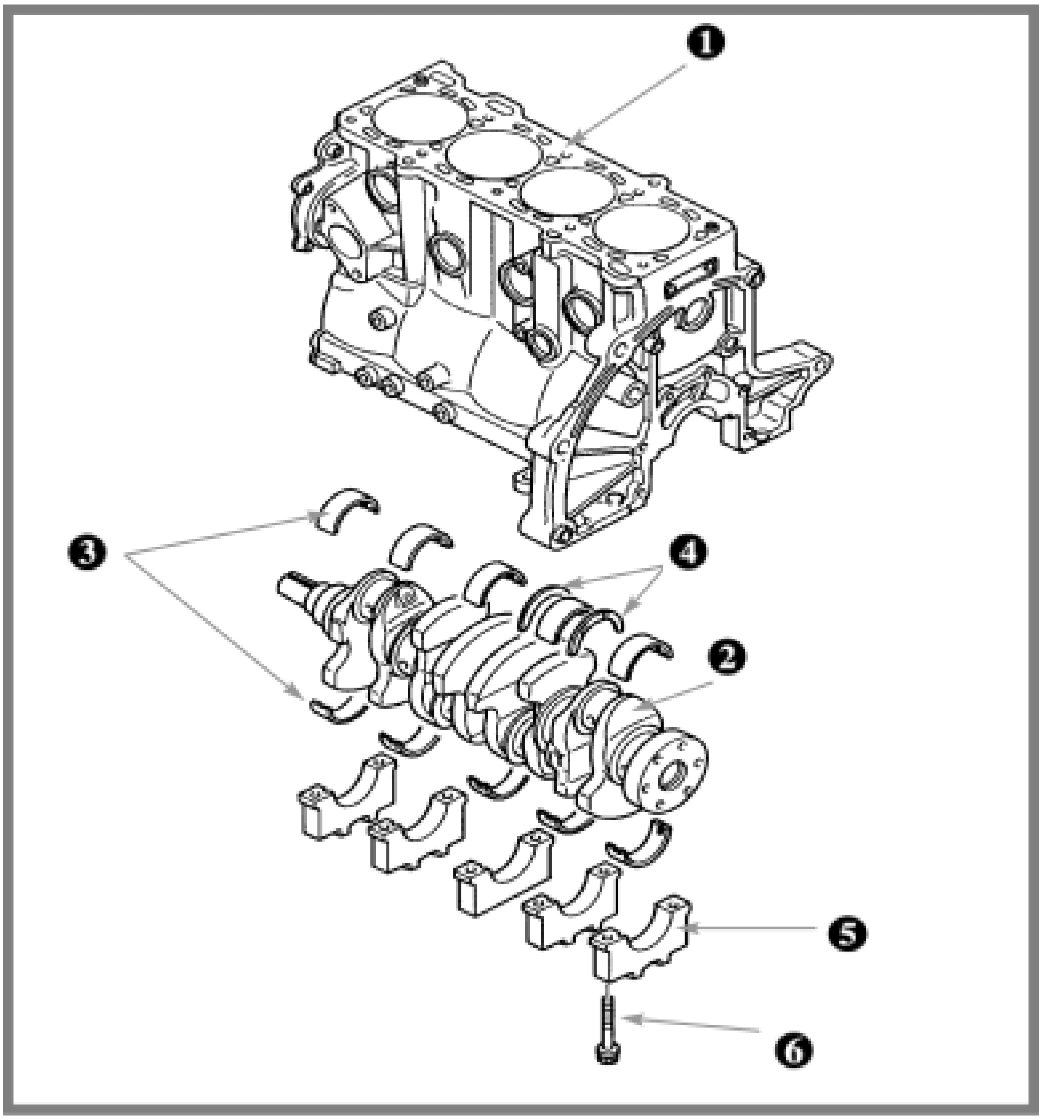


FIGURE 14. Main bearing caps are used to attach the crankshaft to the cylinder block.

- ❶ **Cylinder block**
- ❷ **Crankshaft**
- ❸ **Main bearing**
- ❹ **Thrust bearing**
- ❺ **Main bearing cap**
- ❻ **Main bearing cap mounting bolt**

Features

Figure 15 shows the important features of a crankshaft. The dashed line represents the center of the shaft.

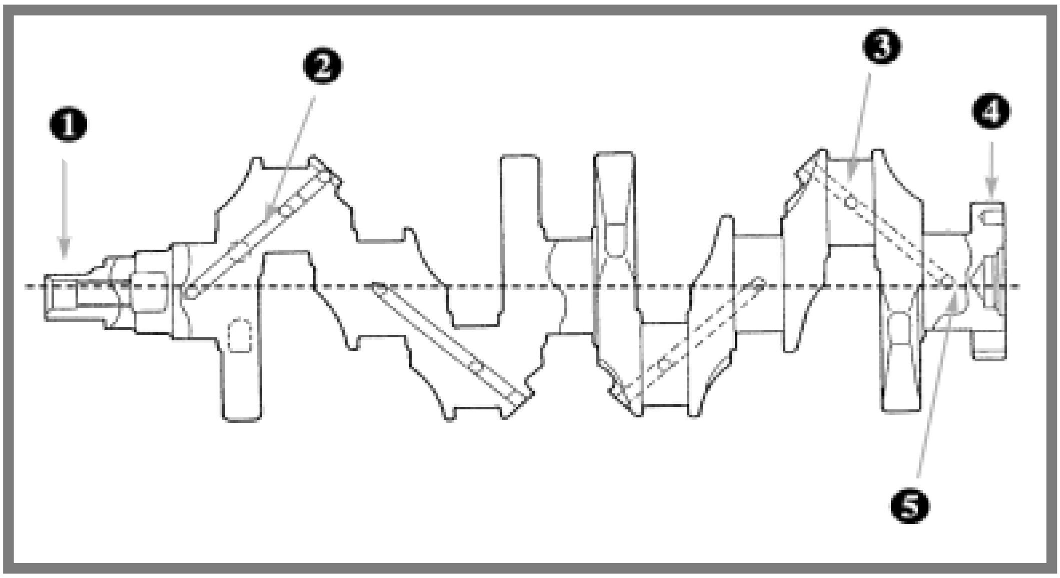


FIGURE 15. Main bearing journals are used to mount the crankshaft. Connecting rod journals connect the pistons to the crankshaft.

- ❶ **Front end**
- ❷ **Oil passage**
- ❸ **Connecting rod journal (crankpin)**
- ❹ **Flywheel end**
- ❺ **Main bearing Journal**

A *journal* is a smooth, round bearing surface. A *main bearing journal* is a surface that mounts on the supports in the crankcase, with an insert bearing between the journal and the support. The main bearing journals actually support the crankshaft in the crankcase. In Figure 15, the main bearing journals are all in a line defined by the center line of the shaft.

The other journals — called *connecting rod journals or crankpins* — are offset from the center line of the crankshaft. These journals are used to attach the connecting rods from the pistons.

The connecting rod journals are positioned on the crankshaft so that the pistons can be at different points in the combustion cycle as the crankshaft turns. This spaces out the power strokes from the cylinders as they fire in turn. The result is a smooth flow of power, rather than a jerky, pulsing motion.

Construction

Because the crankshaft must handle the tremendous forces of the pistons' power strokes, it is usually made of heavy, high-strength cast iron or forged steel for high performance or heavy-duty applications. Some crankshafts have *counter- weights* cast opposite the crankpins, as shown in Figure 16. The counterweights help balance the crankshaft and prevent vibration during high-speed rotation.

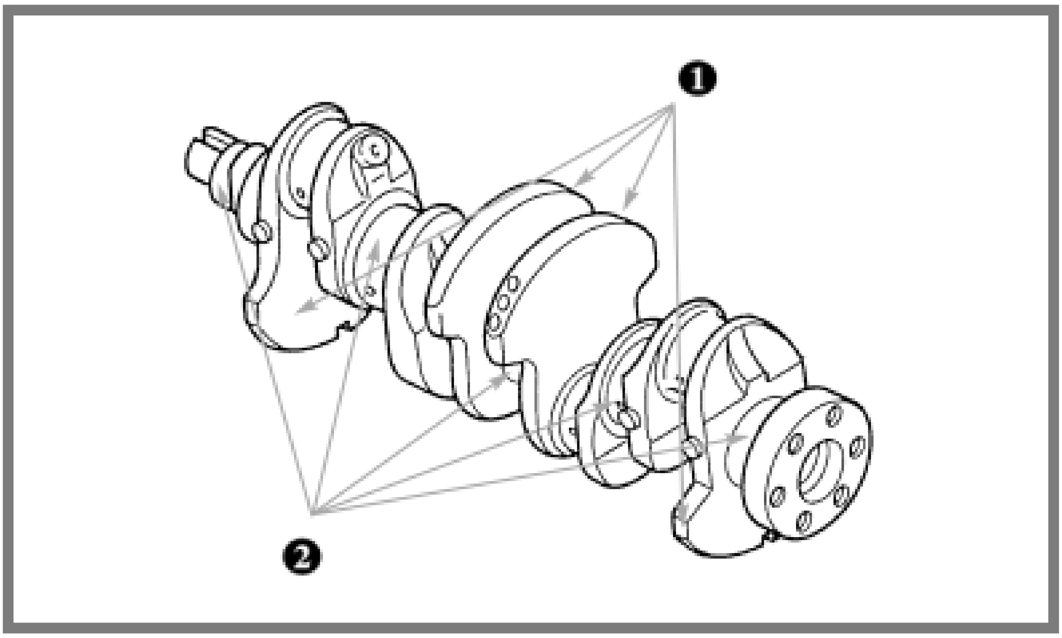


FIGURE 16. Counterweights on the crankshaft improve balance and prevent vibrations.

1 Crankshaft counter-weights

2 Main bearing journals

The main bearing journals on a crankshaft are highly polished and are manufactured to exact roundness so they will rotate properly in the bearing inserts. Oil passages drilled into the main journals receive oil flow from the supports in the cylinder block.

Slanted oil passages are drilled from the main journals to the crankpin journals to lubricate the connecting rod bearings. In addition, one of the main journals — usually in the middle — is machined with a *thrust surface*. This surface rides against a special *thrust bearing* that controls front-to-rear movement of the crankshaft.

Number of Journals

The crankshaft shown in Figure 16 has five main bearing journals and four crankpin journals. This is a common design for a 4-cylinder engine. One piston is connected to each crankpin journal with a connecting rod.

You might expect V-6 and V-8 engines to use longer crankshafts, with more crankpin journals to connect the additional pistons. However, most V-6 and V-8 engines actually have shorter crankshafts because they connect two pistons to each crankpin journal.

For example, a V-6 engine might use a crankshaft with three crankpin journals and four main bearing journals. When the cylinder banks are arranged at 90 degrees from each other, two pistons on the same crankpin journal will always be a half-stroke apart in the cycle.

Vibration Damper

Even though the crankshaft is very strong, it must have a certain amount of “give” that allows it to flex slightly. The downward thrust against the crankpin during the power stroke actually twists the crankpin slightly. This force is immediately relieved, and the crankpin returns to its original shape.

At a normal hot idle, this twisting and untwisting may repeat five times every second. When the vehicle is accelerating under load, the cycle may occur 25 or 30 times per second. The result of this constant twisting and untwisting is *torsional vibration,* or flexing of the crankshaft.

To control torsional vibration, a *vibration damper (*or *harmonic balancer)* is usually mounted on the front end of the crankshaft, often as part of the crankshaft pulley. Figure 17 shows a typical torsional damper.

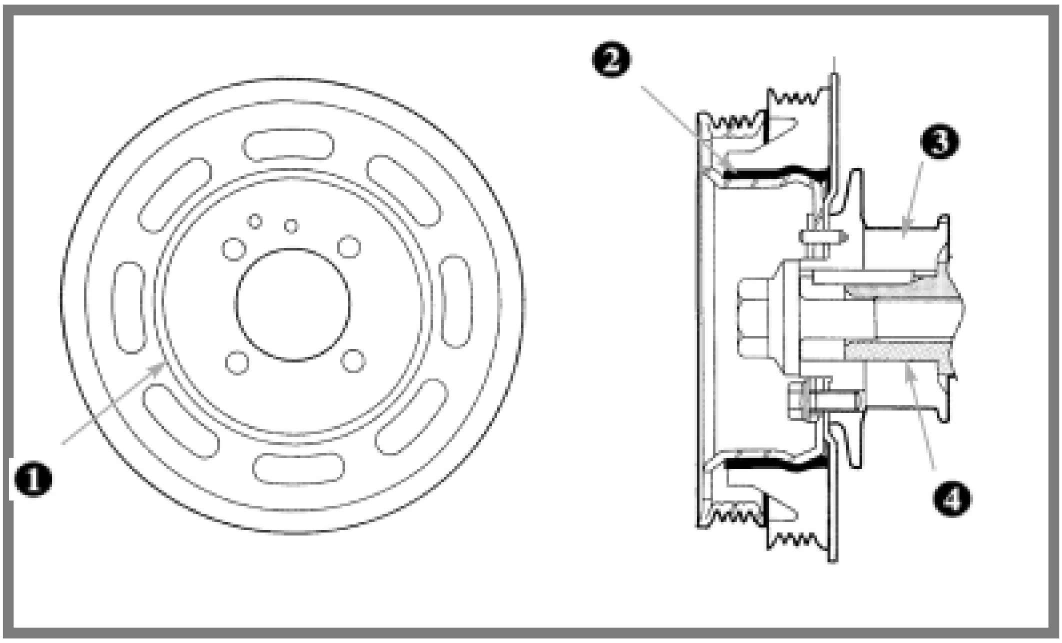


FIGURE 17. The torsional damper controls twisting of the crankshaft.

- ❶ **Torsional damper (crankshaft pulley)**
- ❷ **Rubber**
- ❸ **Timing belt pulley**
- ❹ **Crankshaft**

MAIN BEARINGS

The crankshaft main bearings are split circular sleeves that wrap around the crankshaft main journals. The upper half of the bearing has one or more oil holes to allow lubricant to coat the inside surface of the bearing, as shown in Figure 18. The upper bearing fits into a main support on the bottom of the cylinder block. The lower half of the bearing fits into the bearing cap.

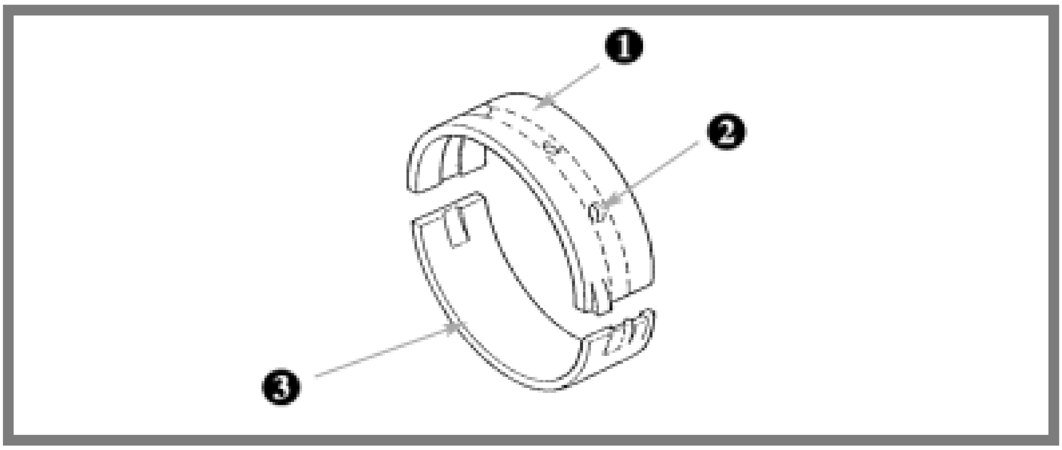


FIGURE 18. Crankshaft main bearings wrap around the main journals.

- ❶ **Upper main bearing**
- ❷ **Oil hole**
- ❸ **Lower main bearing**

The wear surfaces of the bearings are made of softer material than the crankshaft. The softer material reduces friction, and it tends to mold itself around any uneven areas on the main journal. In addition, if wear does occur, it will affect the bearing, which is cheaper to replace than the crankshaft.

Lubrication

In most engines, the upper and lower bearings are not interchangeable because the upper bearings have an oil hole. Pressurized oil is forced through the hole, allowing lubricant to flow around the bearing as the journal turns.

To prevent the bearing from seizing on the crankshaft journal, the inside diameter of the bearing is slightly larger than the journal diameter, usually by a few thousandths of an inch. The gap between the bearing and the journal allows oil to circulate freely between the two surfaces, as shown in Figure 19.

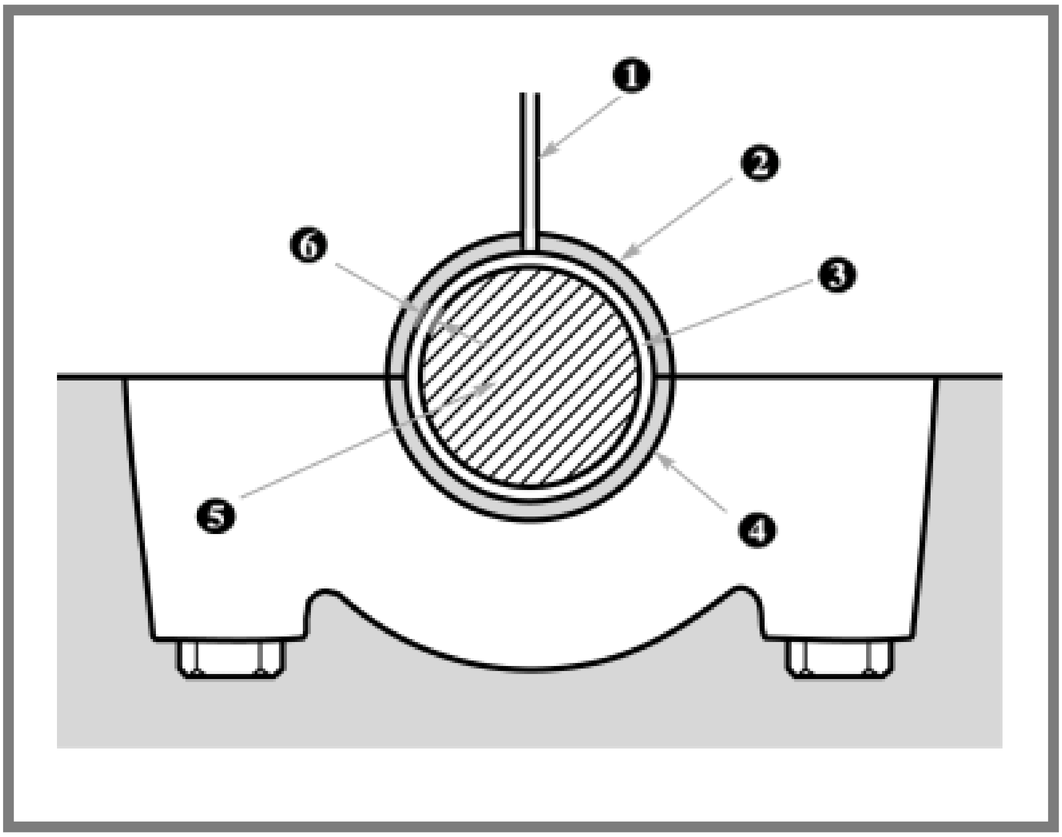


FIGURE 19. Bearing clearance allows oil to circulate between the bearing and journal surfaces.

1. **Oil passage**
2. **Upper main bearing**
3. **Oil film**
4. **Lower main bearing**
5. **Crankshaft main journal**
6. **Bearing clearance**

Clearance

The gap between the bearings and the main journal is called the *bearing clearance*. Clearance is one of the most critical measurements in the engine.

The oil that lubricates the bearings does not actually stay in a continuous film. As the crankshaft turns, the oil works its way to the outer edges of the bearings, where it is thrown off into the crankcase. New oil constantly feeds in through the oil hole to replace the oil thrown off.

The constant flow of oil over the bearings helps cool them and flushes away grit and dirt from the bearing surface. If the clearance is too small, not enough oil will be allowed in to lubricate the bearings. The resulting friction will wear out the bearings quickly. On the other hand, if the clearance is too large, too much oil will flow through the bearings. Oil pressure will drop and the crankshaft journal may start to pound against the bearing rather than spin inside it.

The oil pump in an engine has a limited capacity, and if all the oil is being pumped through a few bearings close to the pump, then other engine parts will be robbed of lubrication. For example, bearings further away from the oil pump will not get an adequate supply of oil, so they will wear out quickly. (The major early symptom for loose or failing bearings is low oil pressure.)

To prevent damage to the bearings — and possibly to the crankshaft — the bearing clearances must be set precisely whenever the bearings or crankshaft are repaired.

Thrust Bearings

In addition to rotating, the crankshaft also tends to move back and forth. This movement is called *end play*. To limit end play, one of the main journals on the crankshaft is machined to accept a *thrust bearing*. This bearing keeps the crank- shaft from moving back and forth. The upper and lower thrust bearings have oil grooves that allow oil to flow around the journal, as shown in Figure 20.

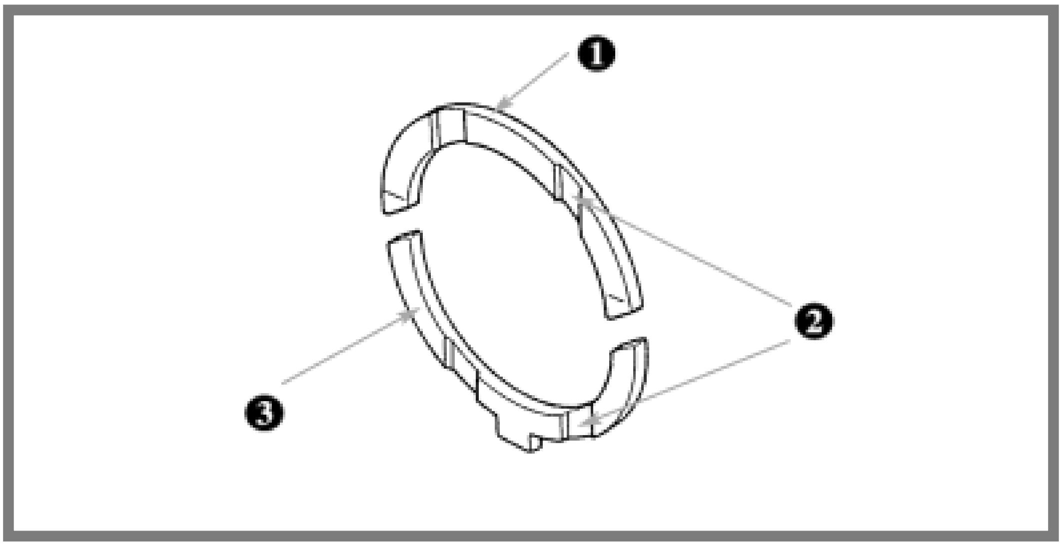


FIGURE 20. The thrust bearing controls the front- to-rear movement of the crankshaft.

- ❶ **Upper thrust bearing**
- ❷ **Oil grooves**
- ❸ **Lower thrust bearing**

REVIEW EXERCISE 3

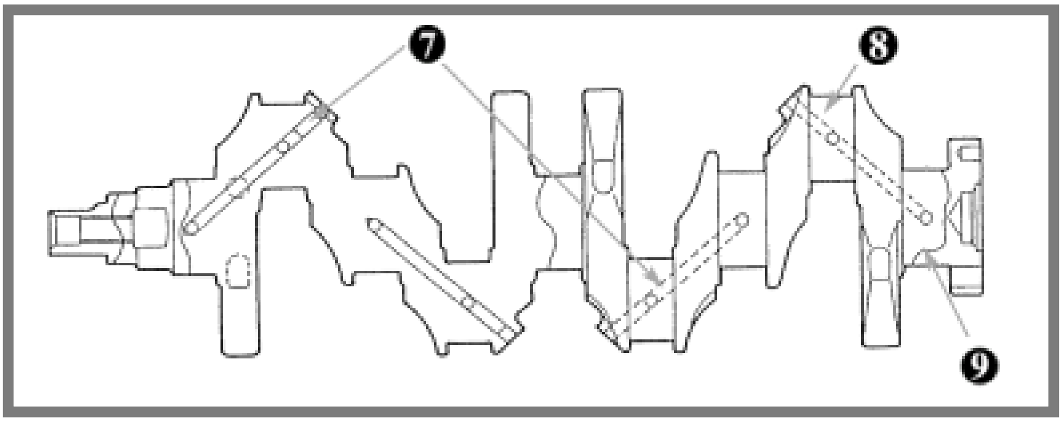
Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 35.

1. The ____________________ is the main supporting member of the engine.
2. The crankshaft is attached to the cylinder block with U-shaped parts called ____________________ .
3. The term *main* refers to parts used to mount the ____________________ .
4. The bearing that controls crankshaft end play is called the ______________________ .

5. The gap between the main bearings and the main journals is called ____________________ .

6. The ____________________ half of the crankshaft main bearing has oil holes and fits into the __________________ .

Match the numbered items on the crankshaft drawing to the definitions below.



7.	_______	A.	main journal
8.	_______	B.	oil passages
9.	_______	C.	crankpin

10. Which of these symptoms would you expect to find in an engine that has worn main bearings? More than one answer may be correct.

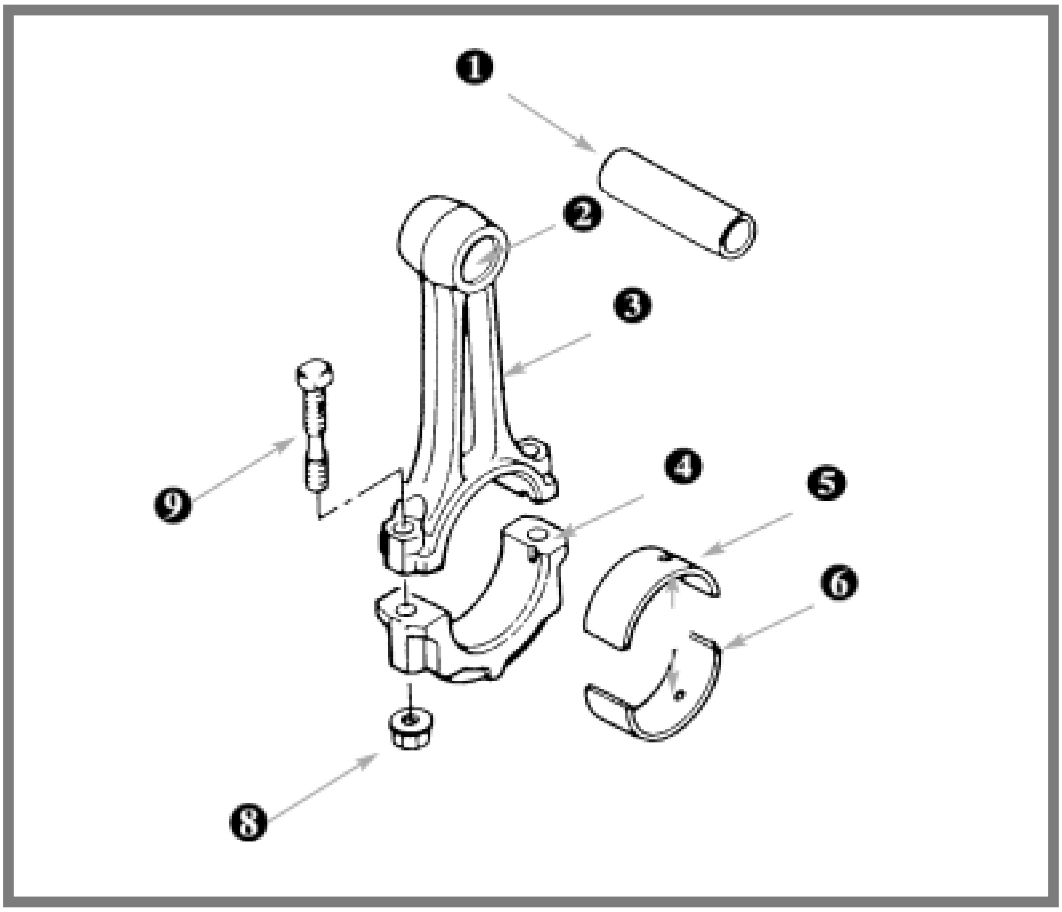
A. low oil pressure
B. leaking gasoline
C. hard starting
D. low rattle noise from engine

CONNECTING RODS

The connecting rod transfers the movement of the piston to the crankpin on the crankshaft. Figure 21 shows the connecting rod and its related parts.

FIGURE 21. The connecting rod is attached to the piston with a piston pin.

1. **Piston pin**
2. **Bushing**
3. **Connecting rod**
4. **Connecting rod bearing cap**
5. **Upper connecting rod bearing**
6. **Lower connecting rod bearing**
7. **Oil holes**
8. **Bearing cap nut**
9. **Bearing cap bolt**



A steel *piston pin* (commonly called the *wrist pin)* connects the piston to the rod. The pin slips through the piston and through the *bushing* (a circular, sleeve-type bearing) in the connecting rod. The pin must be free to turn either in the piston or the connecting rod so the rod can rock back and forth as the crankshaft turns. In some engines, the pin turns freely in both the piston and the connecting rod. Some pins have retainers at both ends to keep the pins from sliding out.

The large end of the connecting rod is connected to the crankshaft with a *connecting rod bearing cap.* This cap is very similar to the main bearing caps, and the clearances are equally important.

Construction

Connecting rods must be very strong and rigid to handle the force of the piston on the power stroke. Connecting rods are usually made of high-strength steel, with an "I" construction for extra rigidity. The rods are kept as light as possible, and weight variation among the rods is carefully controlled so the engine will be balanced.

Like the main bearings, the connecting rod bearing surfaces are line-bored. **They must be reinstalled in the same positions from which they were removed. If they are not, it can cause premature and uneven wear.** Usually, both the rod and cap are stamped to ensure proper reassembly.

Cylinder Wall Lubrication

As shown in Figure 22, an oil jet in the connecting rod lubricates the cylinder walls and cools the piston. The crankshaft oil passages deliver oil to the connecting rod journals. When the bearing holes match up with the oil hole in the connecting rod journal, pressurized oil is squirted through the oil jet.

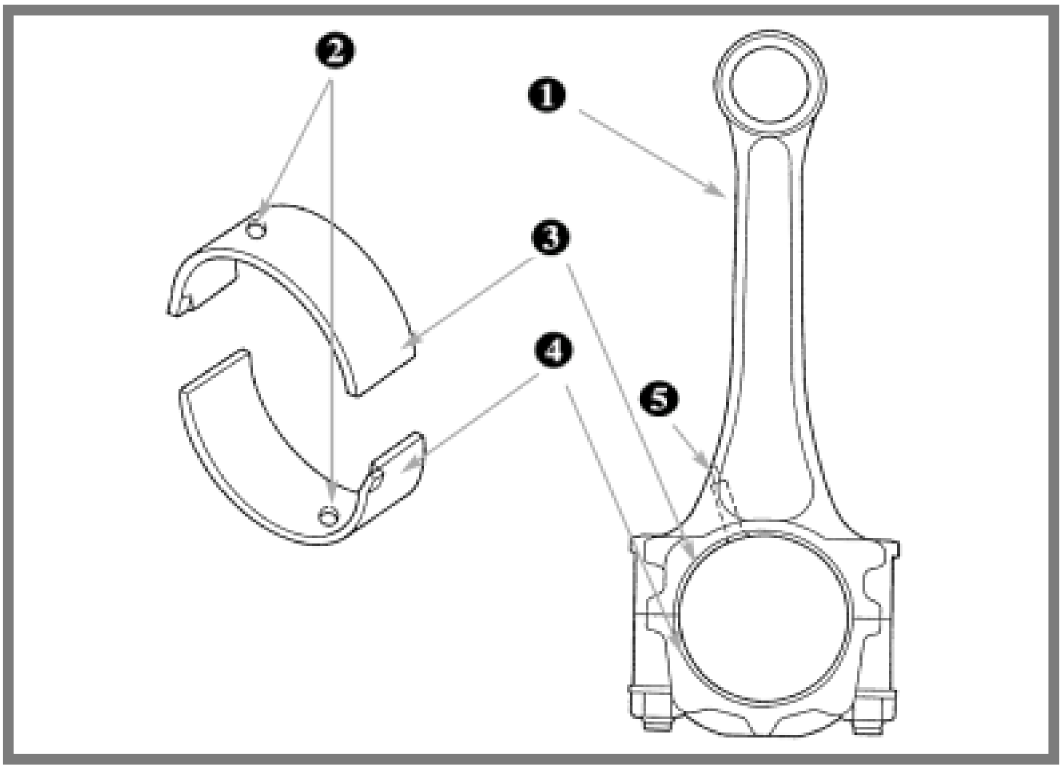


FIGURE 22. The oil jet on the connecting rod squirts oil onto the cylinder wall.

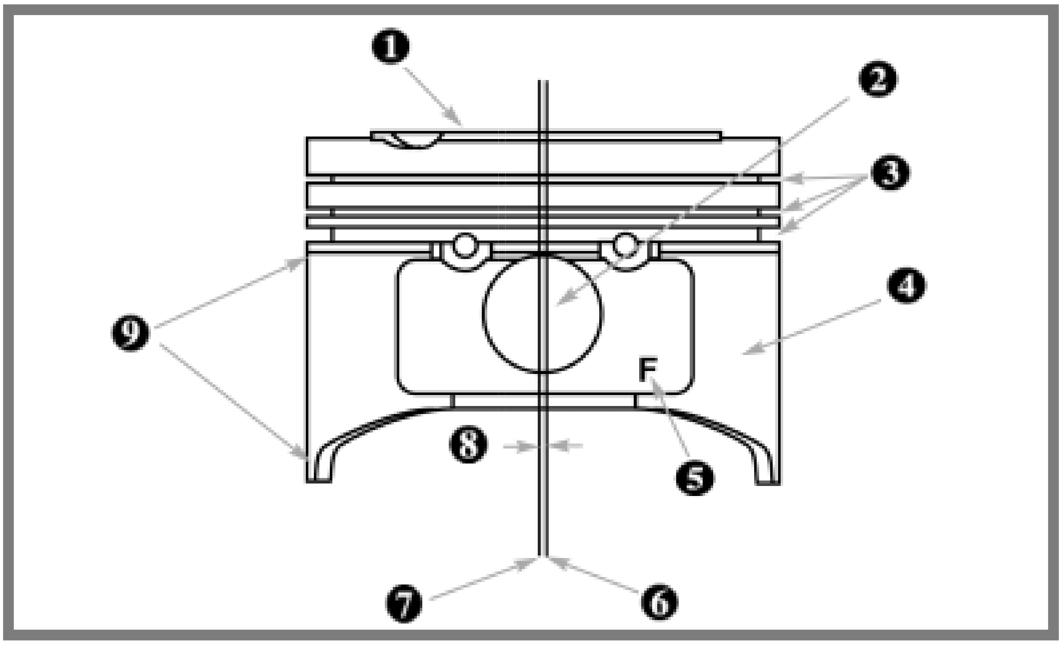
1. **Connecting rod**
2. **Oil holes**
3. **Upper connecting rod bearing**
4. **Lower connecting rod bearing**
5. **Oil jet**

PISTONS

The piston forms the bottom of the combustion chamber in the cylinder. It transfers the power created by the burning air-fuel mixture to the crankshaft. Figure 23 shows a typical piston.

FIGURE 23. The piston forms the bottom of the combustion chamber.

- ❶ **Head**
- ❷ **Piston pin bore**
- ❸ **Piston ring grooves**
- ❹ **Thrust surface**
- ❺ **" Front" mark**
- ❻ **Center of piston**
- ❼ **Center of piston pin bore**
- ❽ **Offset**
- ❾ **Skirt**



The top surface of the piston is called the *head,* or *crown.* The upper part of the piston contains several *grooves* where the piston rings fit. The lower part of the piston, under the rings, is called the *skirt. Thrust surfaces* on the skirt guide the piston in the cylinder bore and prevent the piston from rocking back and forth in the cylinder. Most pistons have a mark on one side that identifies the side of the piston that faces the front of the engine.

The *piston pin bore* is drilled through the piston. The piston pin is inserted through this bore to attach the piston to the connecting rod. In some piston designs, the pin bore is *offset* slightly from the center of the piston. The offset — usually no more than a few thousandths of an inch or 0.5-2 millimeters — helps keep the piston from "slapping" against the cylinder walls during the power stroke.

Construction

Pistons are usually made of aluminum alloys, which are lighter than cast iron or iron-steel alloys. While lighter weight is an advantage, aluminum alloys also tend to expand more with heat. To overcome this problem, some pistons have a steel strut cast into the bottom of the piston head. This strut helps control expansion.

Clearance

Although the piston fits closely in the cylinder bore, it does not seal the combustion chamber. The compression seal is made by the piston rings installed in grooves near the top of the piston. To allow room for the piston rings and lubricating oil, a clearance of a few thousandths of an inch must be maintained between the outside edge of the piston and the cylinder wall.

This clearance lets lubricating oil into the upper part of the cylinder. The clearance also prevents the engine from seizing if one of the pistons expands too much from overheating.

To maintain a consistent clearance from the top to the bottom of the cylinder, the piston usually has a slightly tapered shape, as shown in Figure 24. The top diameter of the piston is slightly smaller than the bottom diameter when the piston is cold. When the engine operates, the top of the piston gets much hotter than the bottom, and the expansion at the top evens up the diameter.

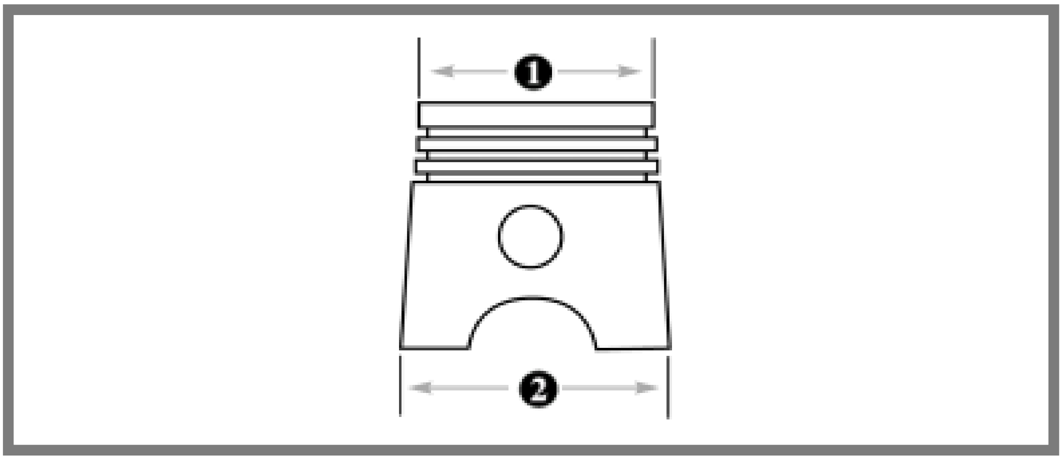


FIGURE 24. The upper part of the piston gets very hot, and its smaller diameter expands to maintain consistent clear-ance from top to bottom.

1 Top diameter (smaller)

2 Bottom Diameter (larger)

Another technique used to make the piston fit better in the cylinder and control heat expansion is called *cam grinding*. Cam-ground pistons are slightly oval shaped, as shown in Figure 25.

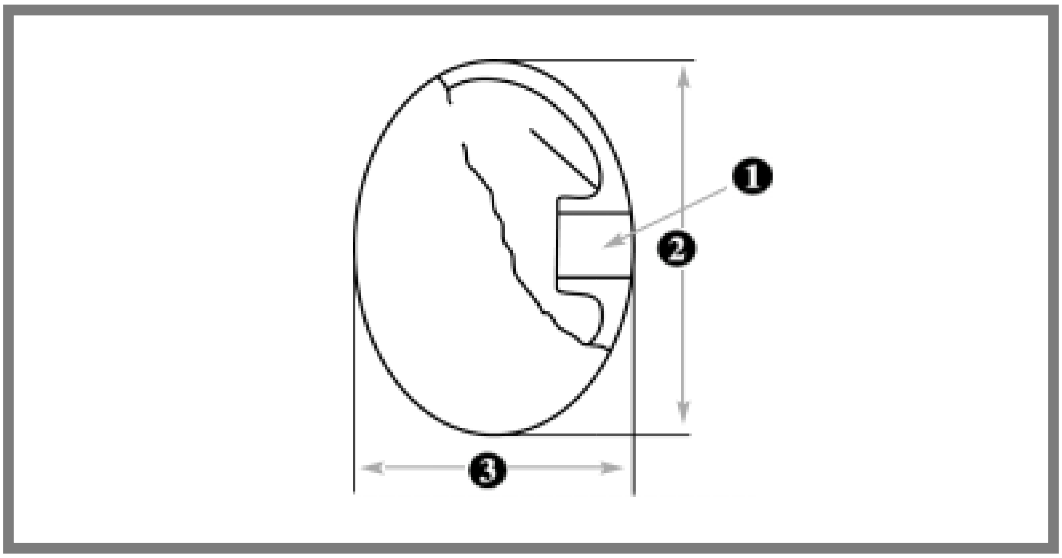


FIGURE 25. The oval shape of a cam-ground piston allows different parts of the piston to expand at different rates. When the piston heats up, it becomes round.

1. **Piston pin bore**
2. **Large diameter.**
3. **Small Diameter**

Surfaces of the piston expand at different rates because they are made of different materials. For example, the area around the piston pin bore is made of denser material to maintain strength. Therefore, this area expands more when it is heated. The oval shape of the piston allows for this expansion. As the piston heats up and expands, its shape becomes a perfect circle.

If the piston clearance becomes too large, the piston can rock in the cylinder, striking the cylinder wall loud enough to be heard. This condition is called *piston slap*. Piston slap usually occurs in older, high mileage engines with worn cylinders.

PISTON RINGS

The piston rings seal the combustion chamber, forming a closed, sealed space where the air-fuel mixture is ignited. In addition to sealing the combustion chamber, the piston rings also:

- Scrape oil from the cylinder walls so it doesn't get into the upper cylinder and burn.

- Carry heat from the piston to the cylinder walls.

Figure 26 shows the rings on a typical piston. The top two rings are called *compression rings*. They are made of cast iron with chrome plating, and come in various shapes. The bottom *oil ring* is made of two separate scuff rings and an expander.

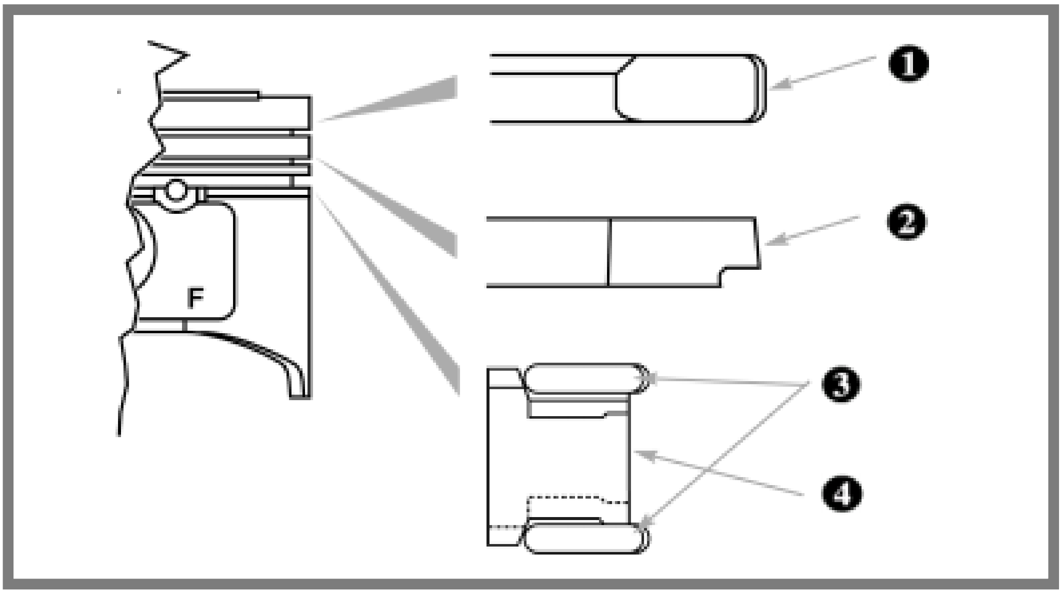


FIGURE 26. A typical piston has two compres- sion rings on top and an oil ring on the bottom.

- **1 Top compression ring**
- **2 Second compression ring**
- **3 Scuff rings on oil ring**
- **4 Expander on oil ring**

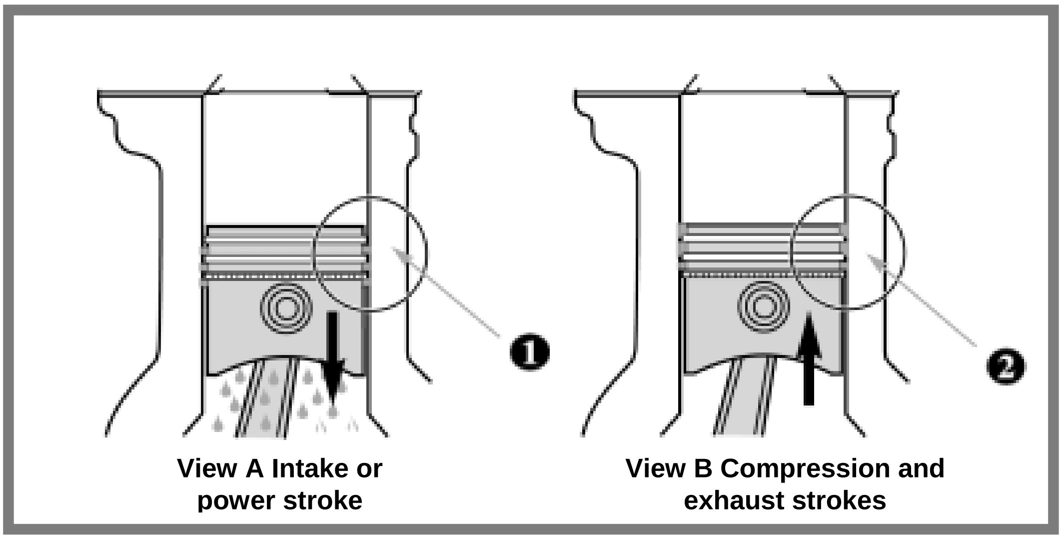
FIGURE 27. Compression rings scrape the cylinder wall and seal the combustion chamber.

❶ **Compression rings scrape cylinder wall**

❷ **Compression rings skim over oil film**

Compression Rings

Compression rings seal, scrape, and cool the cylinder, as shown in Figure 27. Compression rings are designed to twist slightly when they are not under pressure. The top edge of the ring will be twisted away from the cylinder wall, while the bottom edge presses against the wall. So while the piston is moving down during the intake stroke (View A), the lower edge of the compression rings scrape off any oil that was missed by the oil ring.



On the compression and exhaust strokes (View B), the twist lets the compression rings skim over the oil film so the oil is not pushed into the combustion chamber.

During the power stroke (View A), the combustion pressure on the rings forces them to untwist, so both the top and bottom edges of the rings contact the cylinder wall. This creates a tighter seal for the combustion chamber. The untwisted rings also create a path for heat to flow from the piston to the cylinder wall.

Oil Rings

Oil rings help lubricate the cylinder walls and control the flow of oil. Oil is constantly sprayed or splashed onto the walls of the cylinders, where it keeps the metal parts from wearing against each other. Oil also helps cool the cylinder, and it washes carbon and dirt particles from the cylinder walls.

So much oil is on the walls of the cylinders that it won't all fit into the small clearance next to the piston when the compression rings scrape the walls. To provide a place for the extra oil to go, the oil ring is usually *segmented* — made of three pieces — as shown in Figure 28.

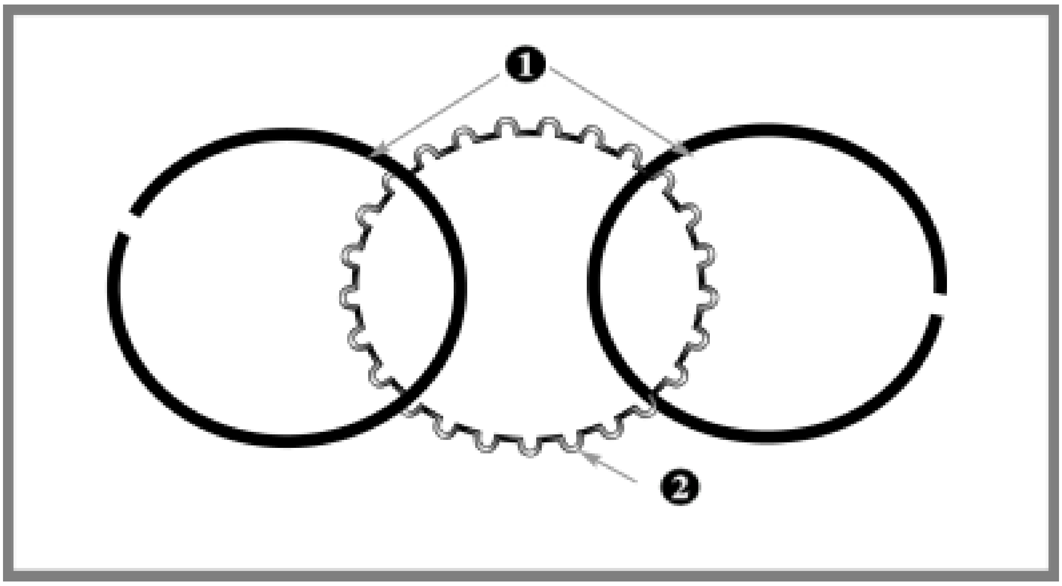


FIGURE 28. Oil rings are usually made of three pieces, or segments.

1 Oil rings
2 Expander ring

As the oil is scraped, it flows behind the expander ring to holes in the ring groove. These holes direct the oil to the open space inside the piston skirt, where it eventually drains back into the crankcase.

The expander ring is a steel ring installed between the two oil rings. These oil rings are made of more flexible material than compression rings. The expander ring holds the oil rings tightly against the cylinder wall, improving their ability to scrape the oil.

REVIEW EXERCISE 4

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 44.

1. The part that attaches the piston to its connecting rod is called the ___________________ .

2. When the pin bore is not drilled directly in the center of the piston, it is called an ___________________ pin bore.

3. Cam-ground pistons have a slightly ___________________ shape.

4. The piston rings that scrape the cylinder walls and seal the combustion chamber are called ___________________ rings.

5. The expander ring is usually part of the ___________________ ring on a piston.

6. Which of these symptoms would you expect to find in an engine that has worn or damaged piston rings? More than one answer may be correct.

   A. excessive oil consumption

   B. blue smoke in exhaust

   C. leaking coolant

   D. high idle

4 – VALVE TRAIN

Engines have passages that let the air-fuel mixture into the cylinders and let exhaust gases out after the mixture has burned. These passages, called *valve ports*, must be sealed very tightly during parts of the four-stroke cycle.
The valves must open and close the ports at precise times.

The engine parts that open and close the valves are called the valve train. This section describes how the valve train operates.

OBJECTIVES

After completing this section, you will be able to:

- Identify the important parts of the cylinder head and gasket and describe their functions.
- Identify important parts of valves and describe how they operate.
- Describe the advantages of multi-valve engines.
- Describe how the valve seals against the valve seat.
- Describe how valve guides hold the valve in the cylinder head.
- Identify important parts of the valve spring and retainer assembly.
- Describe the differences among OHV, SOHC, and DOHC valve trains.
- Identify the four types of Mazda camshaft drives.
- Describe how camshafts are designed.
- Describe the differences between manual valve adjustment and automatic valve adjustment.
- Describe how pushrods and rocker arms transfer motion to the valves.

CYLINDER HEAD

The *cylinder head* bolted on top of the cylinder block, forms the roof of the combustion chamber. The cylinder head:

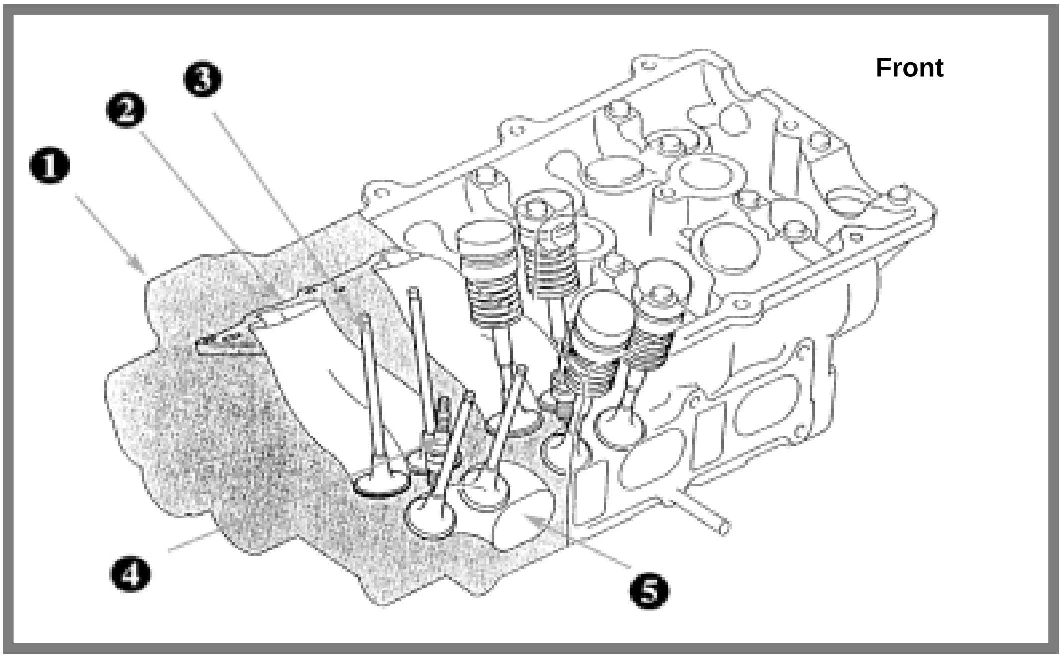
- Seals the tops of the cylinders.
- Holds the spark plugs.
- Provides seats, guides, and ports for the intake and exhaust valves.
- Holds the valve train.
- Provides mountings for the intake and exhaust manifolds.

Construction

Like the cylinder block, the cylinder head is made of cast iron or aluminum alloy. The intake and exhaust manifolds are mounted to the cylinder head, against the valve ports, shown in the side of the head in Figure 29. Most V-6 or V-8 engines have two cylinder heads, one for each bank of cylinders. (This drawing shows the right cylinder head on a typical V-6 engine.) The top part of the cylinder head is manufactured so that the valve rocker arms and/or other parts of the valve train can be mounted on it.

FIGURE 29. The cylinder head contains the valve train components and spark plugs.

❶ Right cylinder head for V-6 engine
❷ Intake port
❸ Valve
❹ Spark plug
❺ Exhaust port



The cylinder head includes spark plug mounting holes, valve ports and seats, and coolant and oil passages.

Sealing

The cylinder head gasket, shown in Figure 30, seals the combustion chambers. The gasket is usually made of steel coated with a softer sealing material.

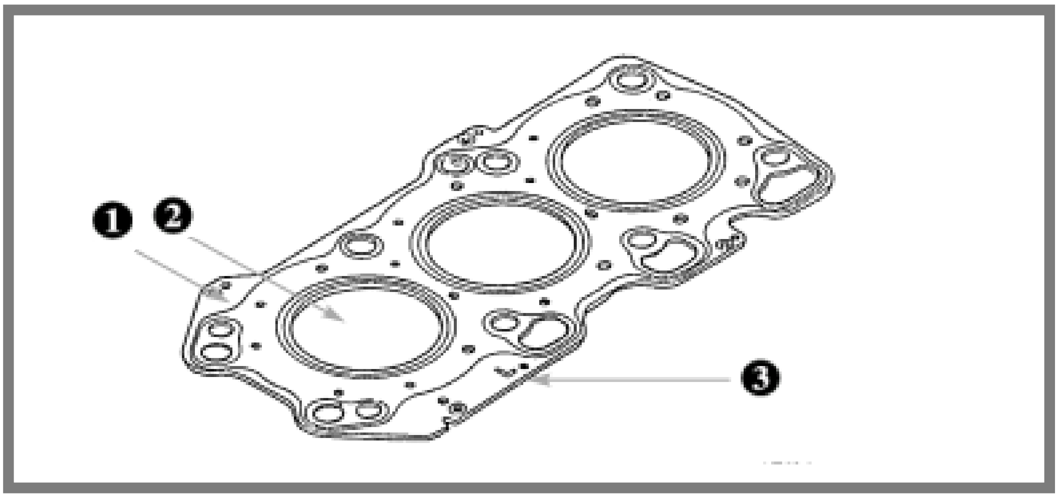


FIGURE 30. The cylinder head gasket seals the combustion chambers and coolant passages.

- ❶ **Left cylinder Head gasket for V-6 engine**
- ❷ **Cylinder opening**
- ❸ **Identifying mark for left cylinder head**

Because this seal is so important to engine operation, the head gasket must be replaced whenever the cylinder head is removed and replaced. **In addition, the sequence and procedure for tightening the cylinder head bolts is critical to good sealing.**

VALVES

As shown in Figure 31, a valve has a round head with a tapered face that seals against a seat in the cylinder head. Because of its stem-and-head construction, the valve is sometimes called a *mushroom* valve.

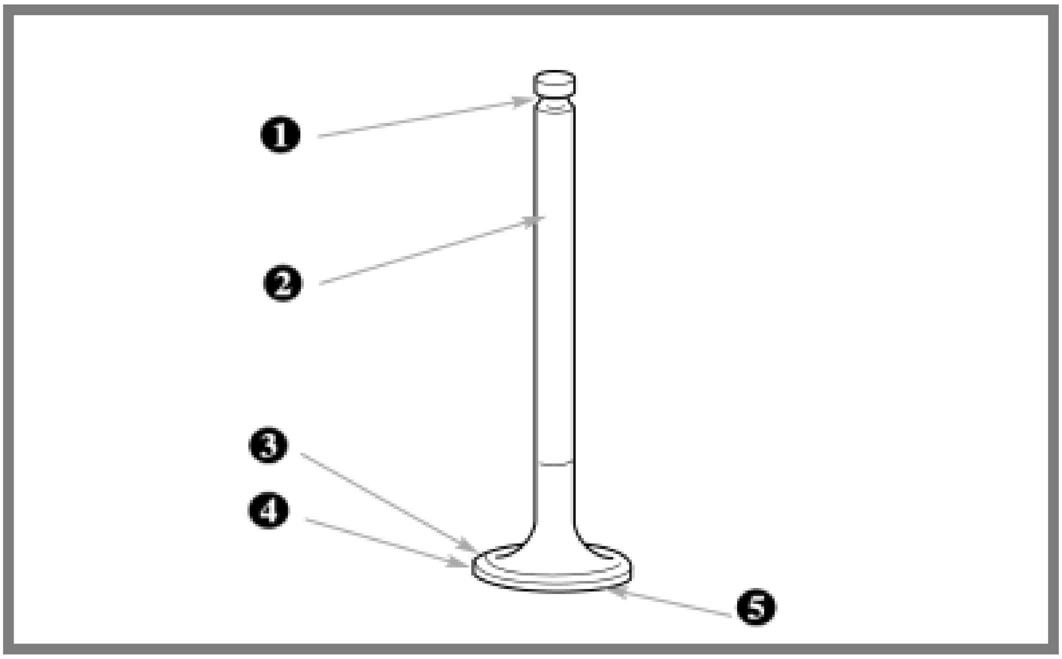


FIGURE 31. Valves seal against a seat in the cylinder head.

1. **Keeper groove**
2. **Stem**
3. **Face**
4. **Margin**
5. **Head**

Components

The *head* of the valve is the larger end that seals the valve port. The surface of the head that seals the port is called the *face,* and it is tapered at an angle. The valve *seat* in the cylinder head is ground to match the angle of the valve face to provide a tight seal.

The *valve margin* is the thickness of the valve head*.* On some valves, the margin can be ground to form a new face finish so the valve can be reused after wearing. The margin also lets the valve transfer some of the heat created in the combustion chamber.

4 – VALVE TRAIN

The valve *stem* is the long, narrow part above the head. The stem has a groove at the end for *keepers.* The *valve spring* pulls the head of the valve up to close the port. The spring is held in place by an upper *spring seat* and the keepers*.* The stem fits inside the *valve guide,* which holds the valve in the cylinder head.

Construction

Valves are made of special high-strength steel that resists heat. Heat resistance is not quite so important to intake valves because they get a cool “bath” every time a fresh air-fuel mixture enters the cylinder. However, exhaust valves receive heat blasts of up to 4000 degrees Fahrenheit every time they open.

As protection from these extreme temperatures, exhaust valves have two ways of transferring the heat from the exhaust gases. First, when the valve is seated, some of the heat is transferred from the valve head to the seat. The seat transfers the heat to the cylinder head, which has coolant passages to control temperature. Second, the valve stem transfers heat to the valve guide, which is located in the cylinder head.

The width of the valve face and margin are critical. The face must be perfectly uniform and wide enough to seal tightly and transfer heat. The margin must be large enough for the valve head to absorb and hold the heat until it can be transferred.

Multi-Valve Design

Mazda engines use three or four valves per cylinder because multiple valves are more precise and efficient. A three-valve design typically uses two valves for intake and one valve for exhaust. A four-valve design uses two valves each for intake and exhaust.

VALVE SEATS

The valve seat is made of very hard metal so it can stand up to constant hammering as the valve opens and closes. When the engine is running at high speed, the valves may open and close up to 25 times per second.

In addition, the intense heat in the combustion chamber and the chemical properties of the exhaust gases can cause corrosion. So the valve seat must also be resistant to heat and corrosion.

If the cylinder head metal meets these requirements, the valve seat may be machined directly into the head. If the cylinder head metal is not strong enough to withstand the hammering, corrosion, and heat, the valve seat may be a hardened steel insert that is pressed into the cylinder head.

The valve seat includes several machined surfaces, as shown in Figure 32. The sealing surface is cut to nearly the same angle as the valve face. To make a tighter seal and prevent build-up of carbon deposits, two other surfaces are machined: a wide-angle upper clearance and a narrow-angle lower clearance.

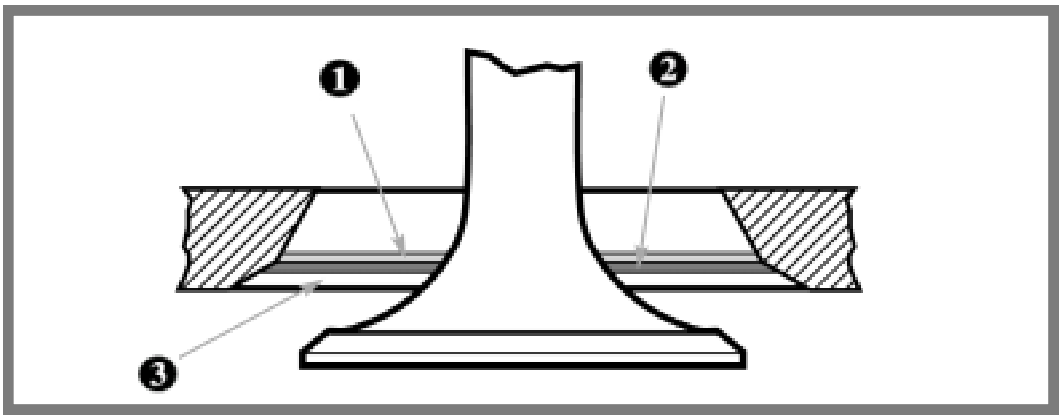


FIGURE 32. Each valve seat has several machined surfaces to make a tight seal.

- ❶ **Upper clearance**
- ❷ **Valve seat**
- ❸ **Lower clearance**

When the upper and lower clearances are correct, and the valve seat has the proper width, the valve face will close tightly against the seat. The machining of these surfaces must be very accurate. If valve seat inserts are used, the surfaces are machined after the insert has been pressed into the valve port. The seat must also be installed properly so that efficient heat transfer can take place.

VALVE GUIDES

Some valve guides are machined directly into the cylinder head casting. Other guides are soft alloy inserts that are pressed into the head, as shown in Figure 33. In some cases, the valve guide is reamed (drilled out) for a close fit to the valve stem after the guide has been installed.

The valve guide fits very closely around the valve stem, with just enough room for lubricant and free movement of the stem. When the guide wears out, it can sometimes be reamed out so that a valve with an oversized stem can be installed. Insert-type guides are replaceable.

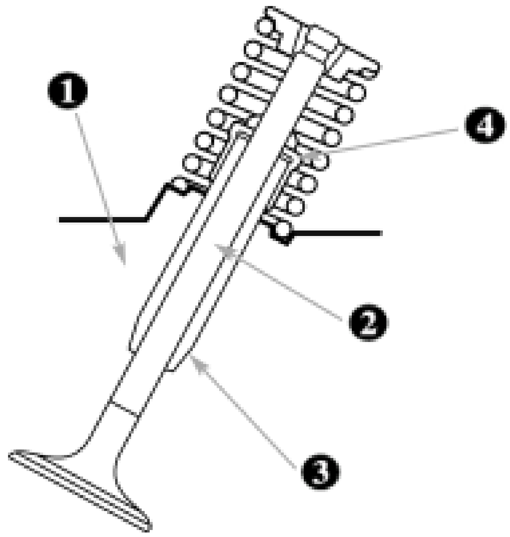


FIGURE 33. Valve guides hold the valve stem so the valve fits squarely on its seat.

- ❶ **Cylinder head**
- ❷ **Valve stem**
- ❸ **Valve guide**
- ❹ **Valve seal**

VALVE SPRINGS

Springs are used to close the valves firmly against their seats. A typical valve spring assembly is shown in Figure 34.

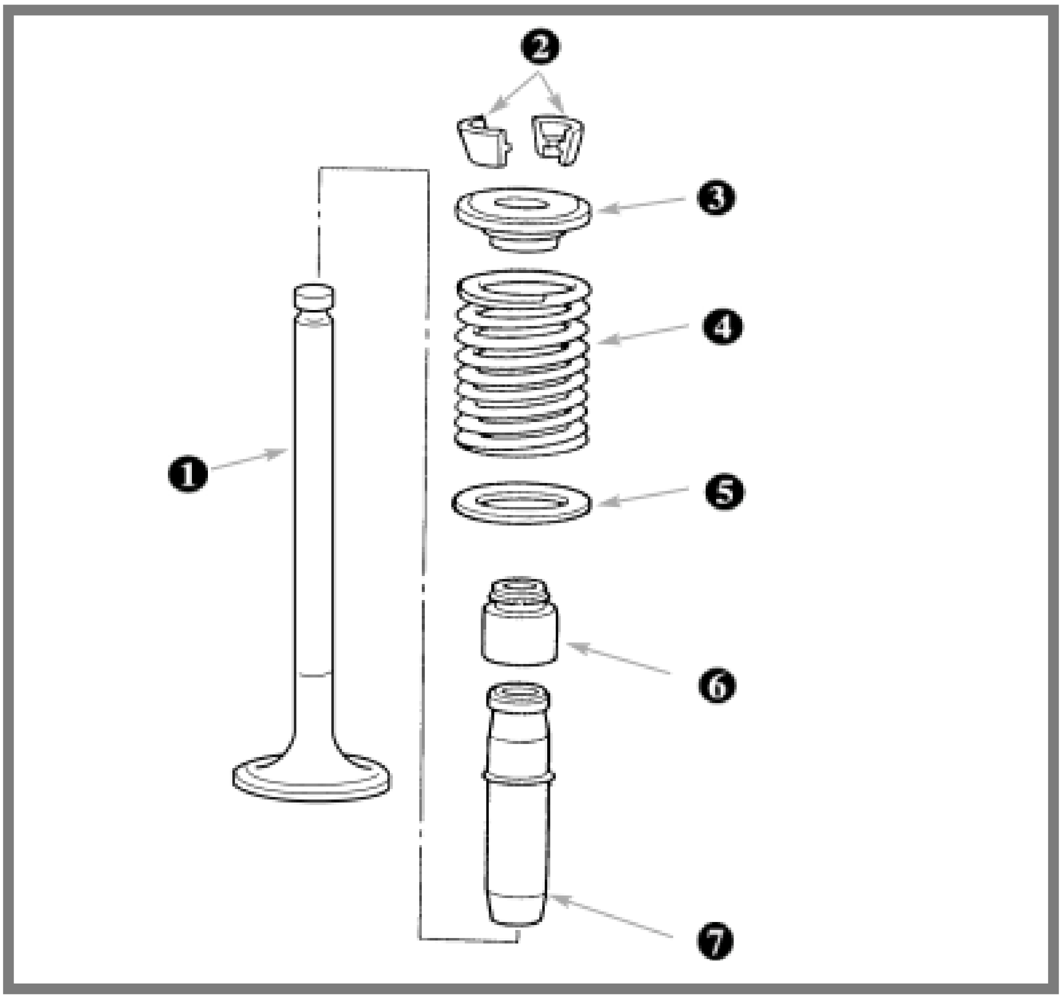


FIGURE 34. Springs are used to close the valves

1. **Valve**
2. **Keepers**
3. **Upper spring seat**
4. **Spring**
5. **Lower spring seat**
6. **Valve seal**
7. **Valve guide**

The valve is installed in the cylinder head, with the spring and upper spring seat over the stem. Then the spring is squeezed, and the keepers are fitted into the groove in the valve stem. The keepers form a collar around the valve stem, and hold the spring in place. On some engines, the keepers allow the exhaust valve to rotate in the valve guide, resulting in equal heat distribution, more even wear, and 'self-cleaning' of the valve-to-seat surface.

Most overhead valves also use an oil seal to prevent oil from being drawn through the valve guide and into the combustion chamber. The seal may be a cup type that fits over the end of the valve guide, or it may be installed directly on the valve stem.

Construction

Valve springs are made of high quality steel to exact specifications for spring force and squareness. The ends are ground flat, and squareness is checked carefully so the spring will not tilt the valve.

Spring Tension

The valve spring requires very high tension to close the valve completely. As the engine speed increases, higher force is needed. If the spring is weak, the valve will tend to *float*, or fail to seat at high speed. This condition causes lost power and burned valves.

On the other hand, the spring tension must be limited because of wear to the cam lobe, lifters, and other valve train parts. Since spring tension can be lost over time, used springs are checked on testers to make sure the tension is correct at the normal working height of the spring.

Working Height

Working height is the length of the installed spring between the retainer and the spring pad on the cylinder head when the valve is fully closed. When valve faces and/or seats are refinished, the working height increases slightly, resulting in less spring tension. To make up for this loss, the technician installs one or two shims under the spring to compress it to the correct height.

OVERHEAD VALVE TRAIN

An overhead valve (OHV) train design means that the valves are mounted in the cylinder head at the top of the combustion chamber. OHV engines have the camshaft installed below the valves, in the cylinder block. Figure 35 shows the major parts of the overhead valve train.

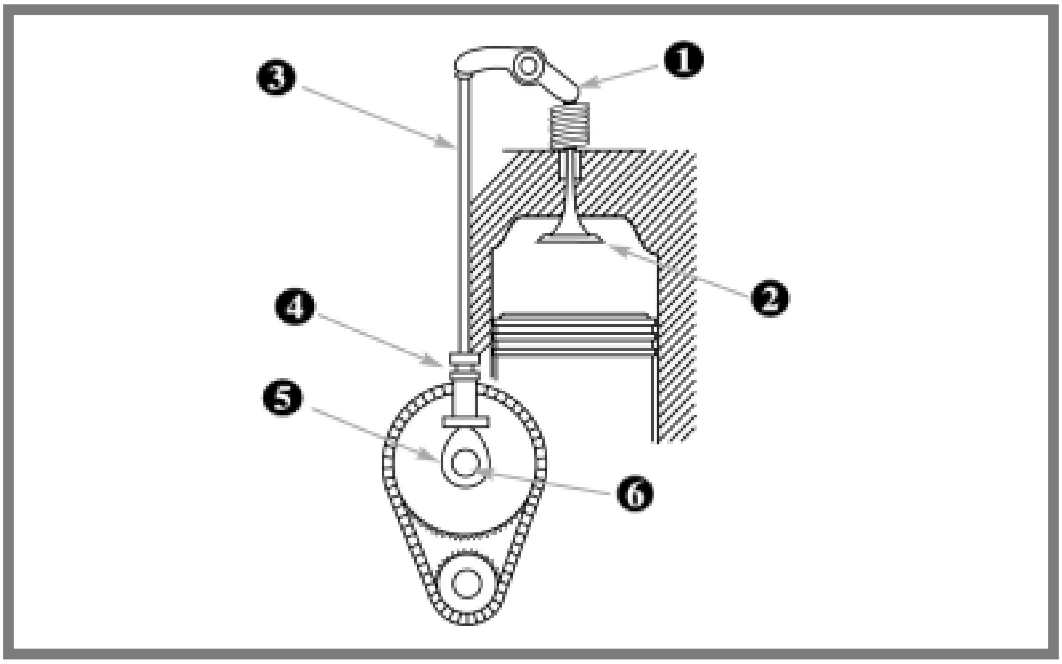


FIGURE 35. In an OHV design, lifters and push rods transfer the action of the camshaft to the rocker arms.

1. **Rocker arm**
2. **Valve**
3. **Pushrod**
4. **Lifter**
5. **Cam**
6. **Camshaft**

As the camshaft turns, the cam lobe moves against the *lifter* (sometimes called a *tappet* or *cam follower*). The lifter pushes up on the pushrod, which contacts the rocker arm. The valve end of the rocker arm pushes down on the valve and opens it. As the cam lobe moves past the lifter, the valve spring pushes against the rocker arm, and the pushrod moves down, allowing the valve to close.

OVERHEAD CAM VALVE TRAIN

The overhead cam (OHC) design provides more direct control over valves than the OHV design. This advantage may explain why overhead cams are the most commonly used design. The overhead cam design includes engines with a single overhead cam (OHC or SOHC), as well as engines with dual overhead cams (DOHC).

Overhead Cam (OHC or SOHC)

In an overhead cam engine, the camshaft is installed in the cylinder head above the valves. The camshaft, shown in Figure 36, is a solid or hollow cast iron shaft with several *cams* on it. Each cam has an off-center bulge on one side called a *cam lobe*. On most Mazda OHC engines, the camshaft runs directly on the cylinder head journal surface without insert bearings.

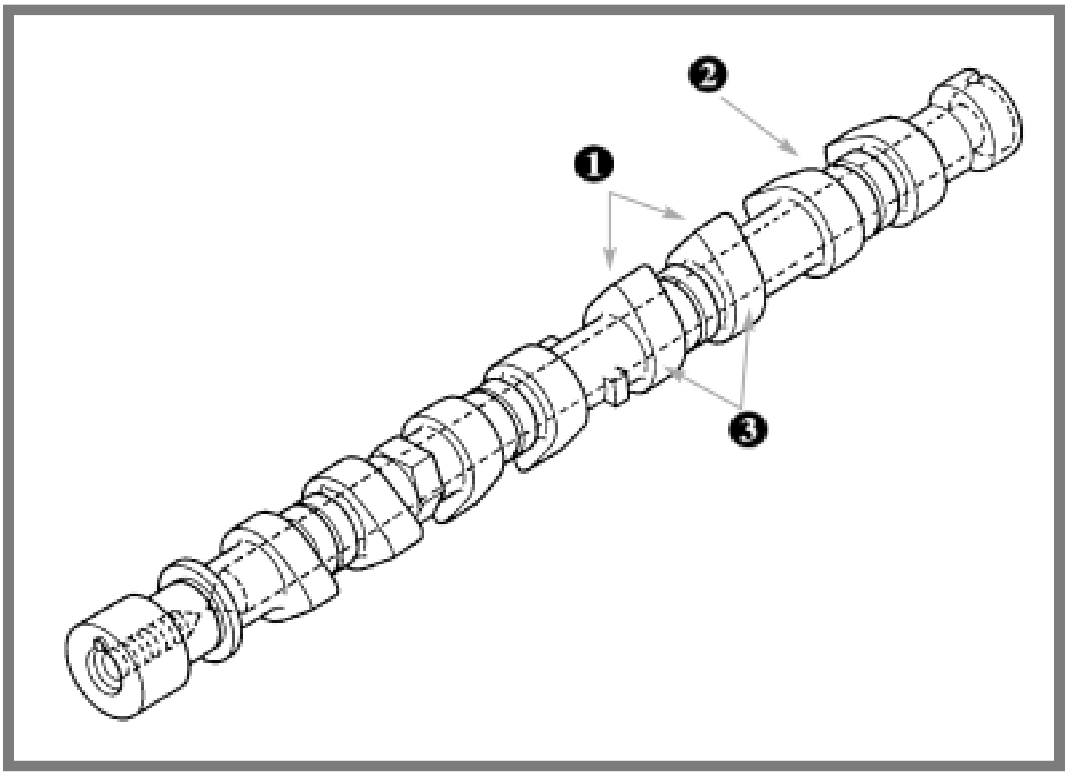


FIGURE 36. The camshaft rides directly on the cylinder head journal surface.

- **1 Cam lobes**
- **2 Camshaft journal**
- **3 Cams**

To make sure that the valves open and close at the right time in the four-stroke cycle, the camshaft is driven by the crankshaft. The camshaft turns at one half the speed of the crankshaft because it takes two revolutions of the crankshaft to complete one cycle. So the camshaft completes a full cycle in one revolution.

As the camshaft turns, a lobe on one of the cams contacts a rocker arm which presses on the valve stem end and opens the valve, as shown in Figure 37. As the lobe turns past the rocker arm, it releases the valve, allowing the spring to close it. The single overhead camshaft includes two or more cam lobes for each cylinder — one lobe for each valve — so that the intake and exhaust valves can open and close at different times.

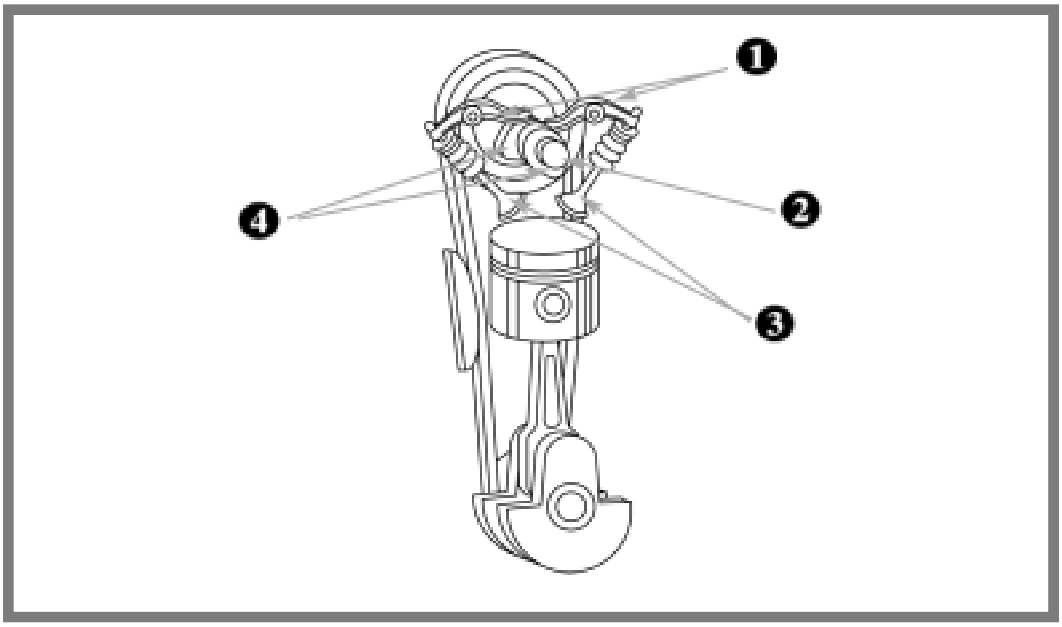


FIGURE 37. As the camshaft turns, the lobe contacts the rocker arms, opening and closing the valves.

1. **Rocker arms**
2. **Camshaft**
3. **Valves**
4. **Cam lobes**

On V-6 and V-8 engines with an SOHC, two separate camshafts are used, one for each bank of cylinders. Even though two camshafts are used, this is still an SOHC design because one camshaft operates all the valves for the cylinder bank.

Dual Overhead Cam (DOHC)

The dual overhead cam (DOHC) design is also very common in light-weight, multi-valve engines that operate at high speeds. Dual camshafts reduce the weight of the valve train parts, which means the engine can generate more power without an increase in displacement and weight.

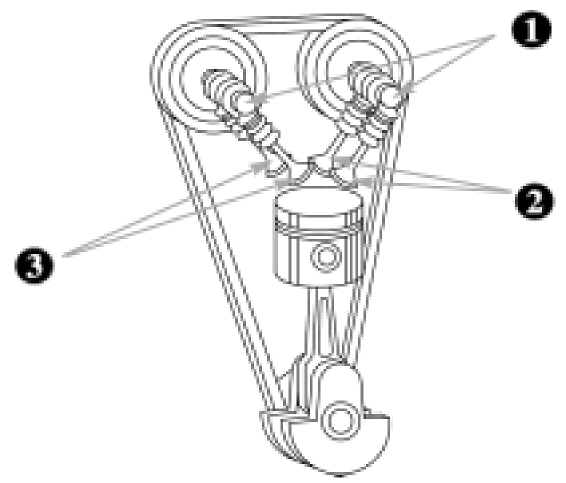


FIGURE 38. Dual camshafts reduce the weight of the valve train and improve intake and exhaust efficiency.

- **1 Camshafts**
- **2 Exhaust valves**
- **3 Intake valves**

V-6 and V-8 engines with dual camshafts actually have four separate camshafts, two for each bank of cylinders.

In addition, the OHC design also allows four valves per cylinder — two intake valves and two exhaust valves, as shown in Figure 38. This arrangement improves the intake and exhaust efficiency of the engine.

CAMSHAFT DRIVES

This section covers four types of camshaft drives:

- OHV Drive
- OHC Drive
- Belt and Chain Drive
- Gear-driven Camshaft with Friction Gear

OHV Drive

In an OHV engine, where the camshaft is mounted below the valves in the block, a crankshaft gear is used to drive a timing chain, which drives the camshaft gear. Figure 39 shows a typical drive for an OHV engine.

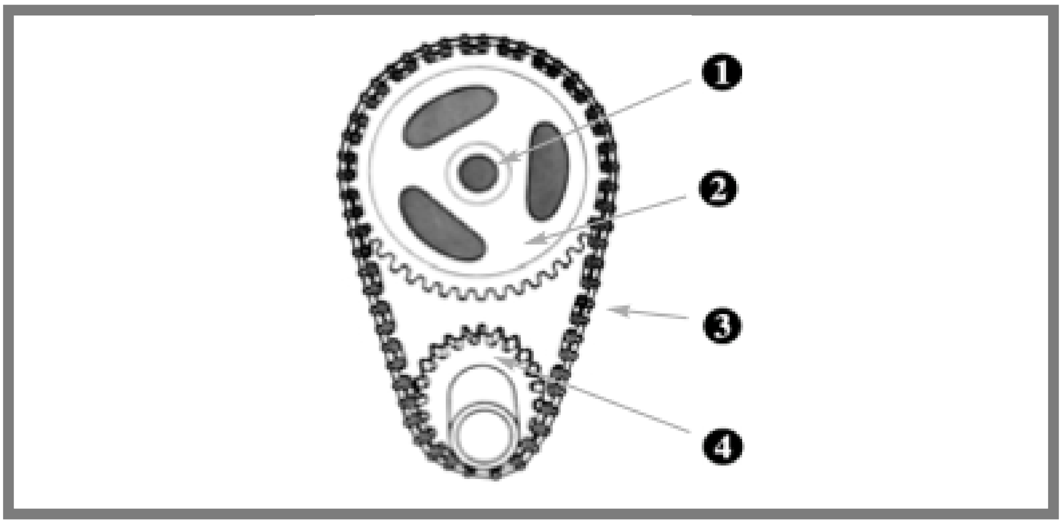


FIGURE 39. OHV drives typically use a timing chain to drive the camshaft.

1. **Camshaft**
2. **Camshaft gear**
3. **Timing chain**
4. **Crankshaft gear**

Chain Adjuster

Timing chain tension changes with engine temperature and wear. A chain adjuster mounted on the cylinder block uses both engine oil pressure and spring tension to automatically maintain timing chain tension.

When the engine is started, oil pressure builds in the adjuster. As shown in Figure 40, oil pressure and spring tension push the chain adjuster sleeve outward if the chain is loose. The ratchet pawl skips to the next tooth, pushing the chain lever against the chain, taking out excess slack. When the engine is stopped, the oil pressure drops, but the ratchet pawl prevents the adjuster sleeve from being pushed back into the chain adjuster.

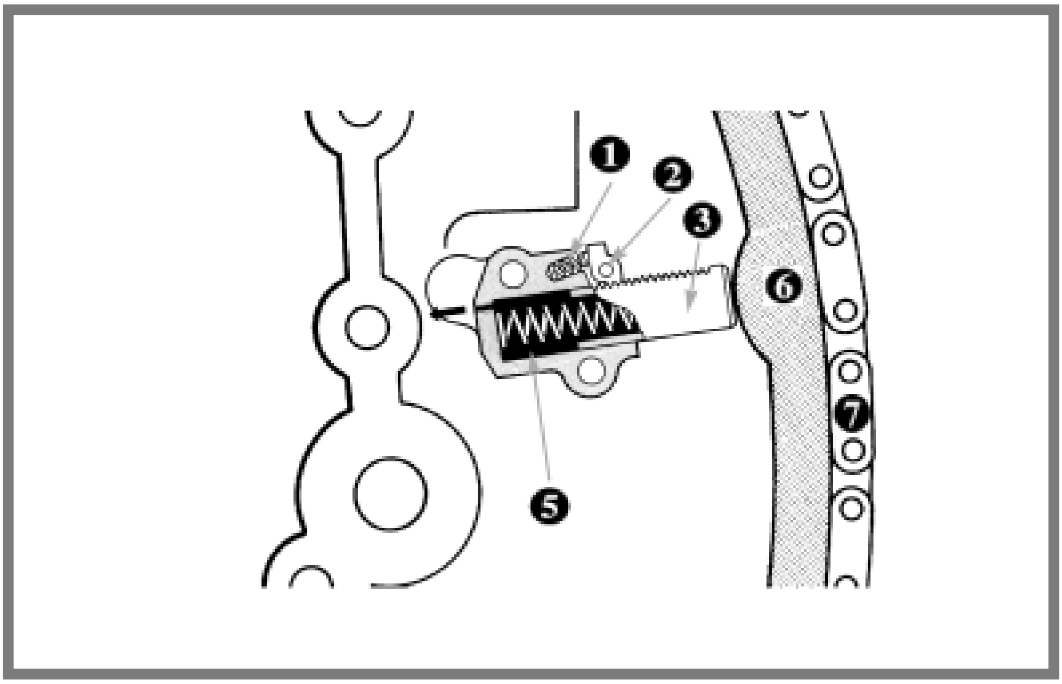


FIGURE 40. The chain adjuster uses oil pressure and spring tension to automatically maintain timing chain tension.

1. **Ratchet spring**
2. **Ratchet pawl**
3. **Chain aduster sleeve**
4. **Drain**
5. **Plunger spring**
6. **Chain lever**
7. **Timing chain**

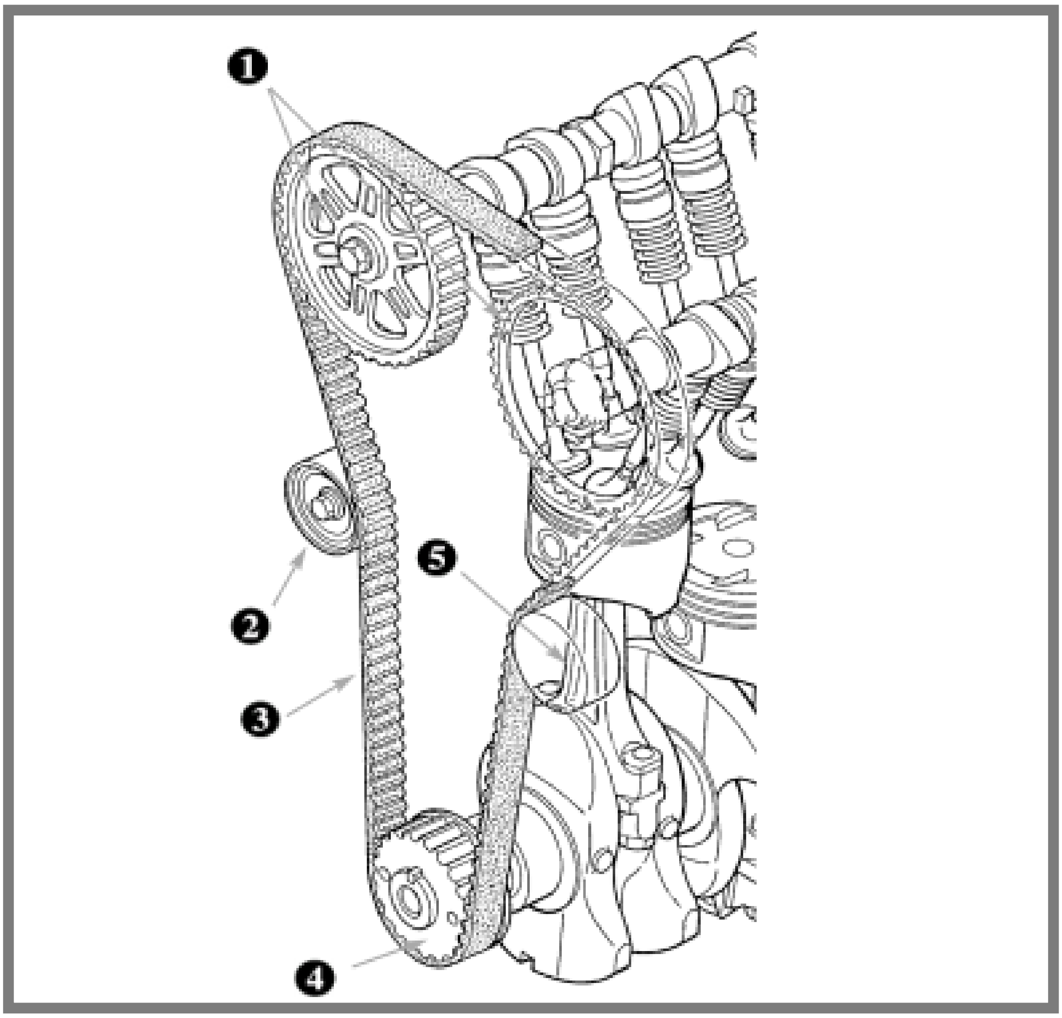
OHC Drive

To drive the camshaft(s), a pulley on the end of the crankshaft drives a timing belt or timing chain that turns the camshaft(s).

Figure 41 shows how this works on an OHC engine (in this case, an engine with dual overhead cams). The timing belt is driven by the crankshaft pulley. The camshaft pulleys connected to this belt then turn each camshaft.

FIGURE 41. A pulley and a belt or chain transfers rotation from the crankshaft to the camshaft.

- ❶ **Camshaft pulleys**
- ❷ **Tensioner pulley**
- ❸ **Timing belt**
- ❹ **Timing belt pulley**
- ❺ **Idler pulley**



As Figure 41 shows, the timing belt pulley has half as many teeth as the camshaft pulleys. This means that the camshafts turn once for every two turns of the crankshaft. OHC drives also include a tensioner pulley and tensioner spring or hydraulic auto tensioner, which maintain timing belt tension and valve timing.

Timing Belt Auto Tensioner

OHC drives use a timing belt auto tensioner, which works similar to the chain adjuster, except that the auto tensioner uses a rod and piston instead of a ratchet. As shown in Figure 42, when the engine is cold, there is little tension on the belt. The auto tensioner rod pushes the tensioner pulley up, taking the slack out of the belt.

When the engine is warm, expansion causes increased belt tension, which pushes the rod into the tensioner.

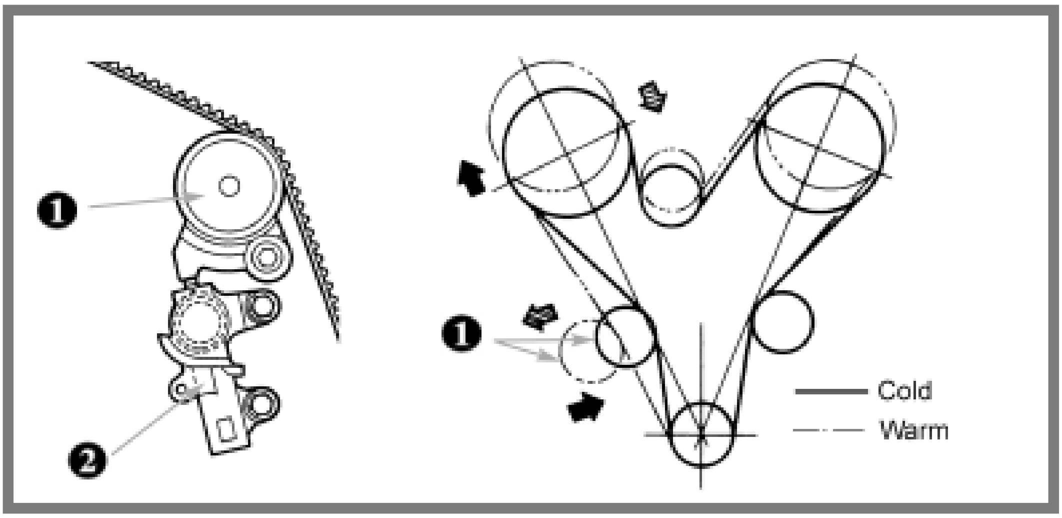


FIGURE 42. The maintenance-free timing belt auto tensioner automatically adjusts the belt tension according to engine temperature.

1. **Tensioner pulley**
2. **Auto tensioner**

Belt and Chain Drive

Another type of DOHC drive is the combination belt and chain drive. In this design, shown in Figure 43, a timing belt drives the intake camshaft, and a timing chain drives the exhaust camshaft. The major advantage of this design is that it allows the valves to be placed at a more vertical angle. This angle produces enhanced combustion efficiency, better fuel economy, and lower emissions.

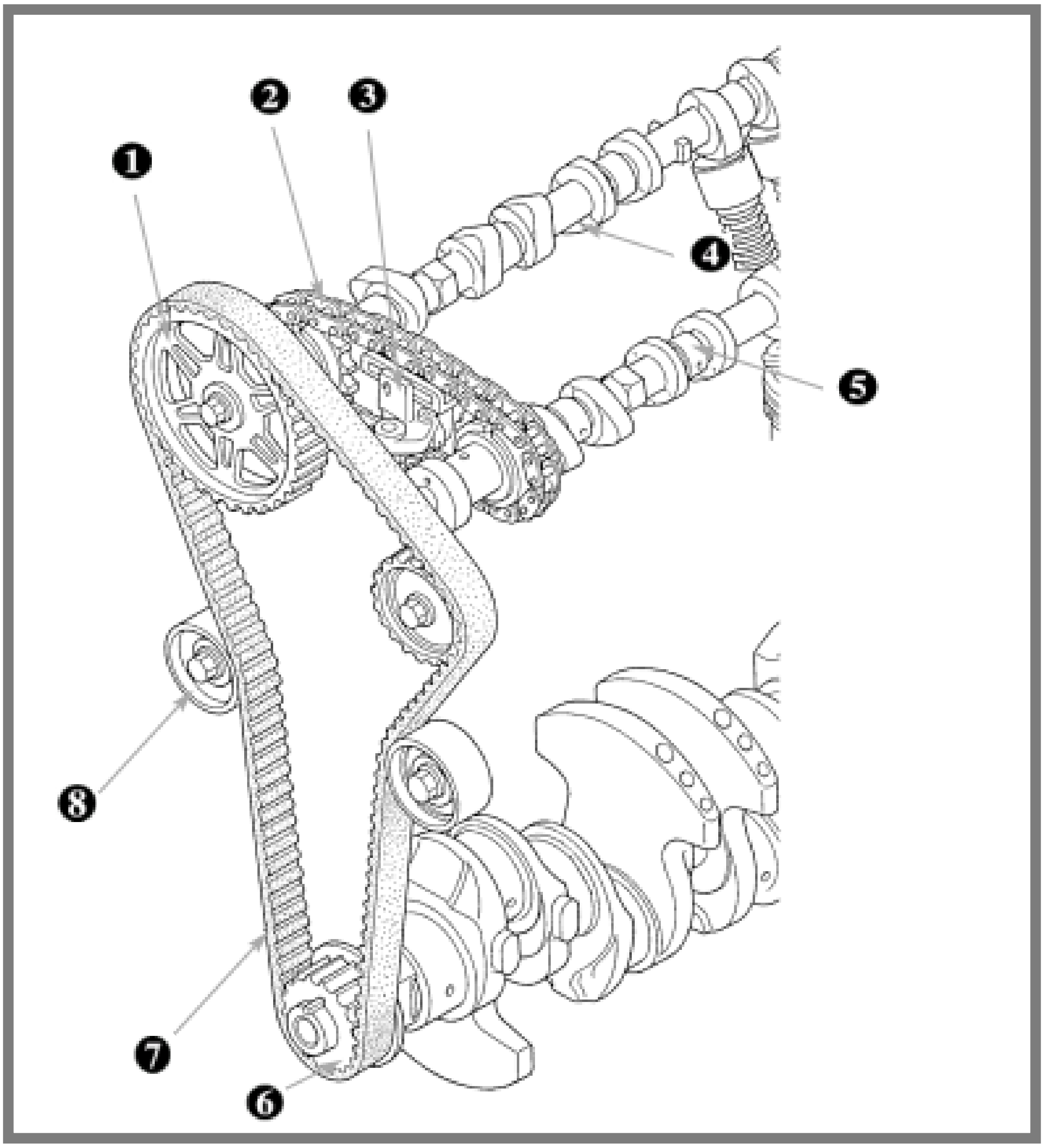


FIGURE 43. The combination DOHC drive uses a timing belt for the intake camshaft and a timing chain for the exhaust camshaft.

1. **Camshaft pulley**
2. **Camshaft chain**
3. **Chain adjuster**
4. **Intake camshaft**
5. **Exhaust camshaft**
6. **Timing belt pulley**
7. **Timing belt**
8. **Tensioner pulley**

Gear-Driven Camshaft with Friction Gear

Mazda also uses another type of cam drive that features a gear-driven camshaft with a friction gear. In this design, shown in Figure 44, the timing belt drives one camshaft on each head. The other camshaft is driven by helical gears. The helical gears turn the driven-side camshaft counter-clockwise. This design creates a more compact valve train, which allows a lower hood line on the vehicle.

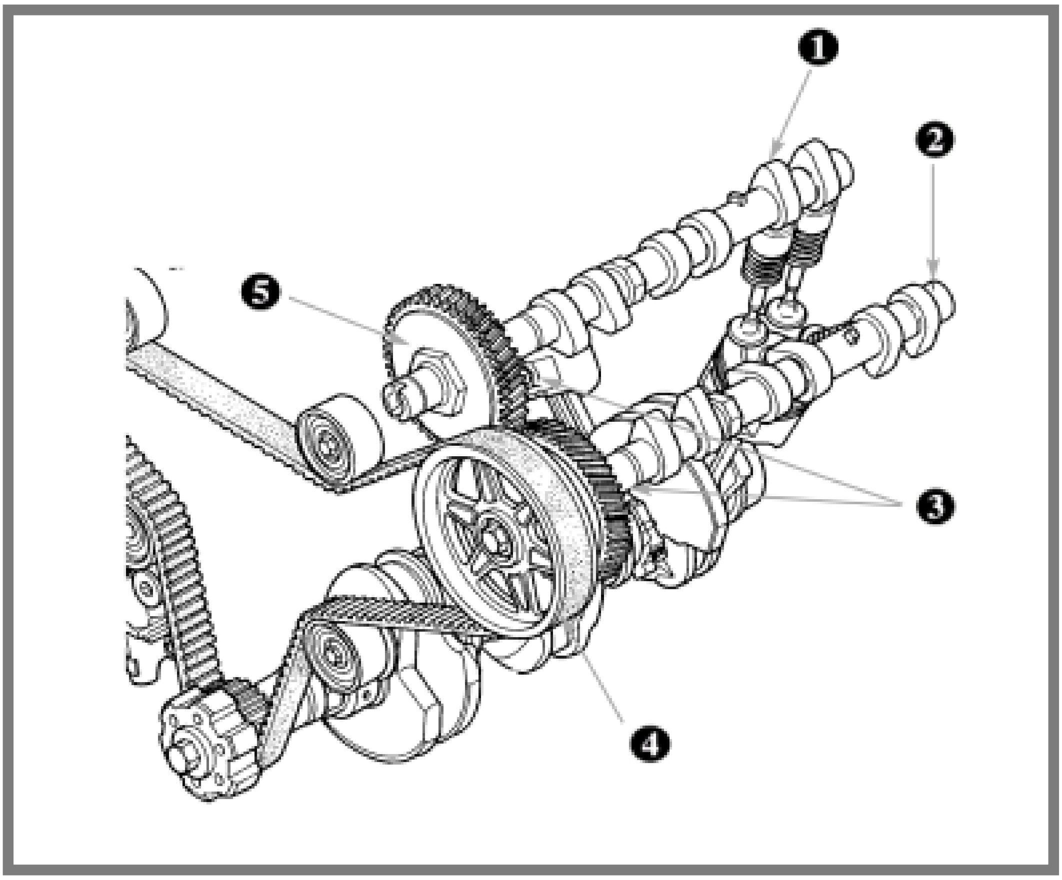


FIGURE 44 The drive camshaft is driven by the timing belt. The driven camshaft is driven by helical and friction gears.

1. **Driven camshaft**
2. **Drive camshaft**
3. **Helical gears**
4. **Timing belt**
5. **Friction gear**

The arrangement of the cam lobes on the two cams causes a clicking noise as the cams turn. To eliminate this noise, the driven gear is equipped with a friction gear.

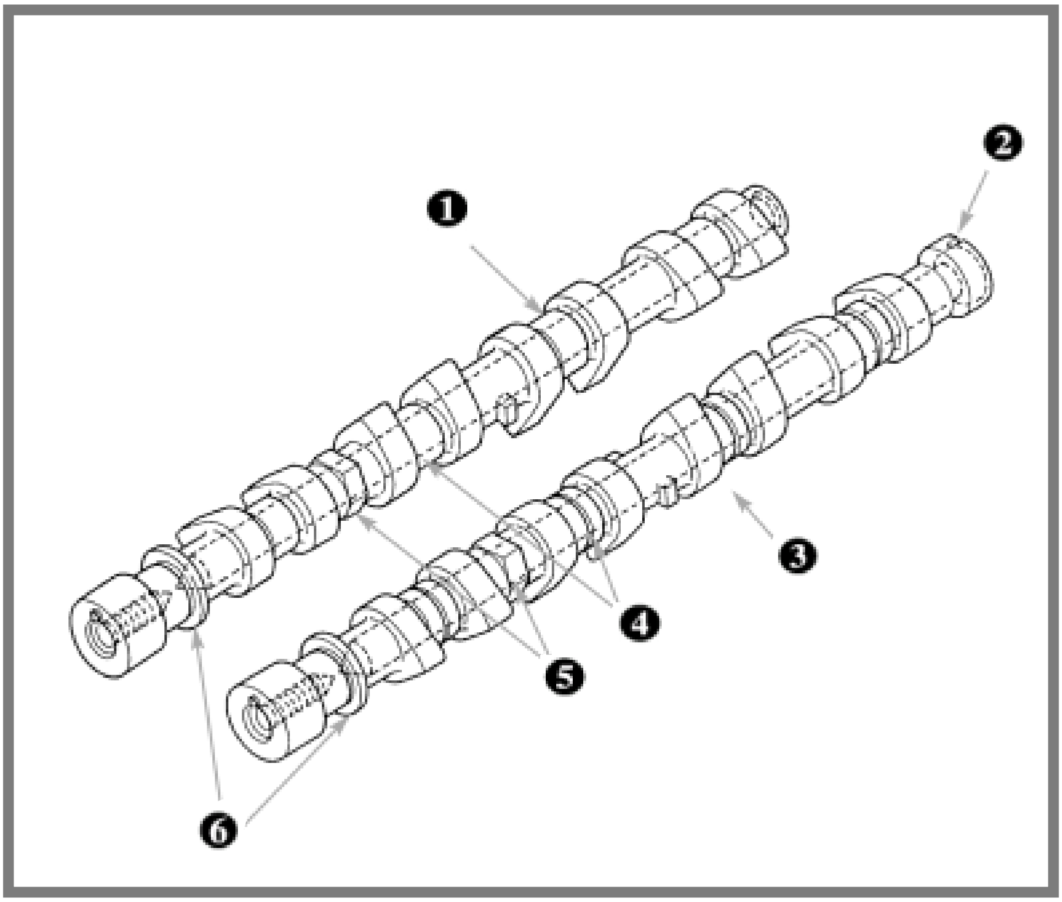
The friction gear has one more tooth than the helical gear. The friction gear causes a slight bind between the drive and the driven cam gears, eliminating any clicking noise resulting from backlash/freeplay between the gears.

CAMSHAFT DESIGN

Figure 45 shows a typical pair of camshafts used in a DOHC engine, with one shaft for the intake side and one for the exhaust side.

FIGURE 45. Camshafts typical- ly have a thrust flange to control front-to-back movement, and a groove to drive the distributor.

- ❶ **Intake camshaft**
- ❷ **Distributor drive groove**
- ❸ **Exhaust camshaft**
- ❹ **Journals**
- ❺ **Cast Hexagons**
- ❻ **Thrust flanges**



Camshafts have thrust flanges either on the front or rear. In the illustration, the flanges are on the front. These flanges match up with thrust surfaces in the cylinder head to control front-to-back movement of the camshaft. These flanges work much like thrust bearings do on the crankshaft. Some camshafts have a separate *thrust plate* that performs the same function as the flange.

Mazda OHC engines do not have insert bearings. Instead, the camshaft rides directly on the polished journal of the head, which serves as the "bearing" surface.

These camshafts also have hexagons cast right into the shafts. The hexagons are used to hold the camshaft and keep it from turning when the camshaft pulley is removed or replaced. The exhaust camshaft includes a groove that drives the *distributor*. The distributor shaft rotates, allowing the distributor to direct electrical current to the spark plugs as they fire in turn.

Auxiliary Drives

Some camshafts also have extra lobes, gears, or grooves that drive the fuel pump or oil pump.

Lubrication

Oil passages in the cylinder head distribute oil through holes in the bearing surface to lubricate the journals. The cam lobes are lubricated by oil dripping back into the oil pan or by tubes delivering oil directly to the cams.

Camshaft Measurements

Critical measurements include:

- Clearance between the camshaft journals and bearing surface
- Journal roundness
- Camshaft end play

If any of these measurements are outside factory specifications, the engine may run poorly.

4 – VALVE TRAIN

REVIEW EXERCISE 5

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 66.

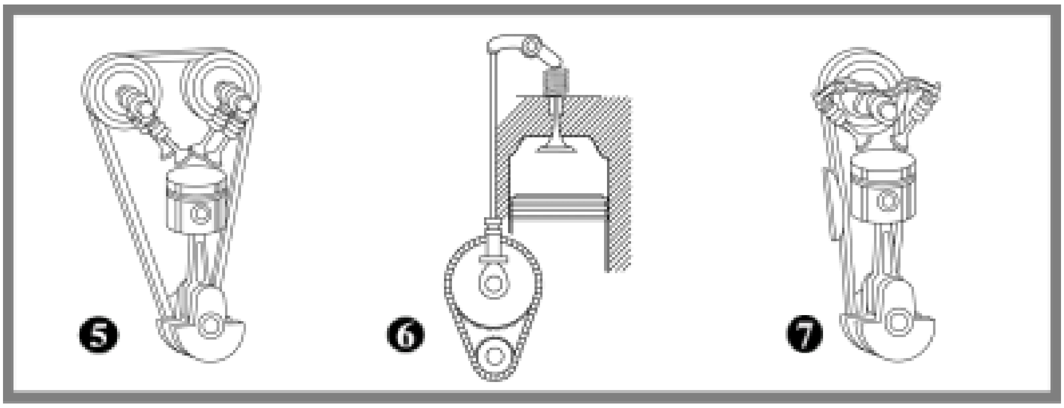
1. The surface of the valve head that contacts the valve seat is called the ____________________.

2. The _____________ holds the valve stem so the valve fits squarely on its seat.

3. Exhaust valves are more likely to be damaged by _______________ than intake valves.

4. The length of an installed valve spring between the retainer and the spring pad is called the __________________ .

Match the numbered illustrations to the valve train descriptions below.



5. _______ A. Overhead valve train (OHV)

6. _______ B. Single overhead camshaft (SOHC)

7. _______ C. Dual overhead camshafts (DOHC)

8. In an indirect camshaft drive, the camshaft pulley is driven by a _______________ or _______________ connected to a pulley on the crankshaft.

9. Which of these symptoms would you expect to see in an engine that has worn valves? More than one answer may be correct.

   A. low oil pressure

   B. poor engine performance

   C. overheating

   D. rough idle

VALVE ADJUSTMENT

When a valve closes, there must be a small amount of clearance between the end of the valve stem and the rocker arm. This clearance is called by various names such as *valve lash, tappet clearance,* or *valve clearance.*

Engines that have solid lifters require periodic valve adjustments to make sure the clearance is correct. The proper valve clearance eliminates noise and excess friction.

In some engines, the clearance is adjusted by using *shims,* which are small metal disks that come in various thicknesses. Figure 46 shows a tappet and adjustment shim. By changing the thickness of the shim, the technician adjusts the valve clearance.

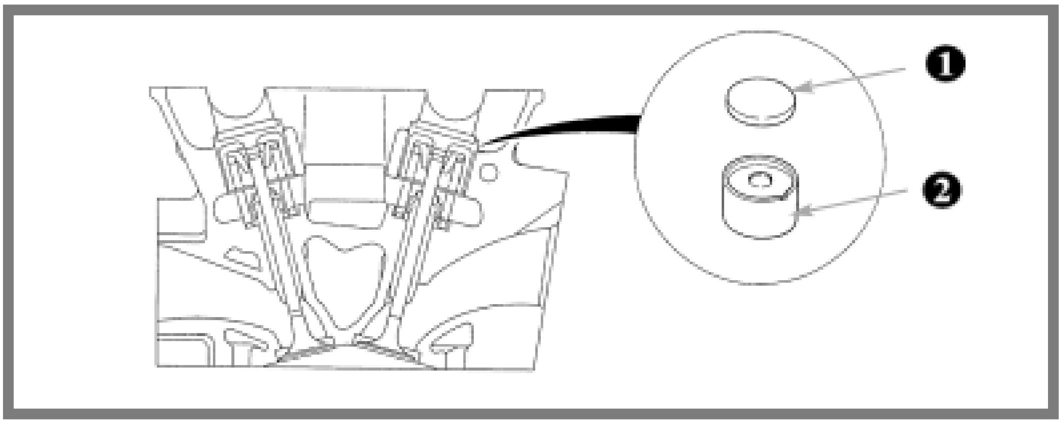


FIGURE 46. In some engines, a shim is used to adjust the valve clearance.

1 Adjustment shim
2 Tappet

Valve Clearance

The purpose of valve clearance is to make sure that the valve can close tightly against its seat during compression and combustion. With no clearance, the valve can be held slightly off its seat, causing compression pressure to leak past the valve. When the valve remains partially open, the valve head does not transfer heat to the seat, and combustion gases will gradually burn the valve away.

On the other hand, if there is too much clearance, the valve train parts can hammer against each other, causing a ticking noise often called *ticking* valves.

HYDRAULIC LASH ADJUSTERS (HLA)

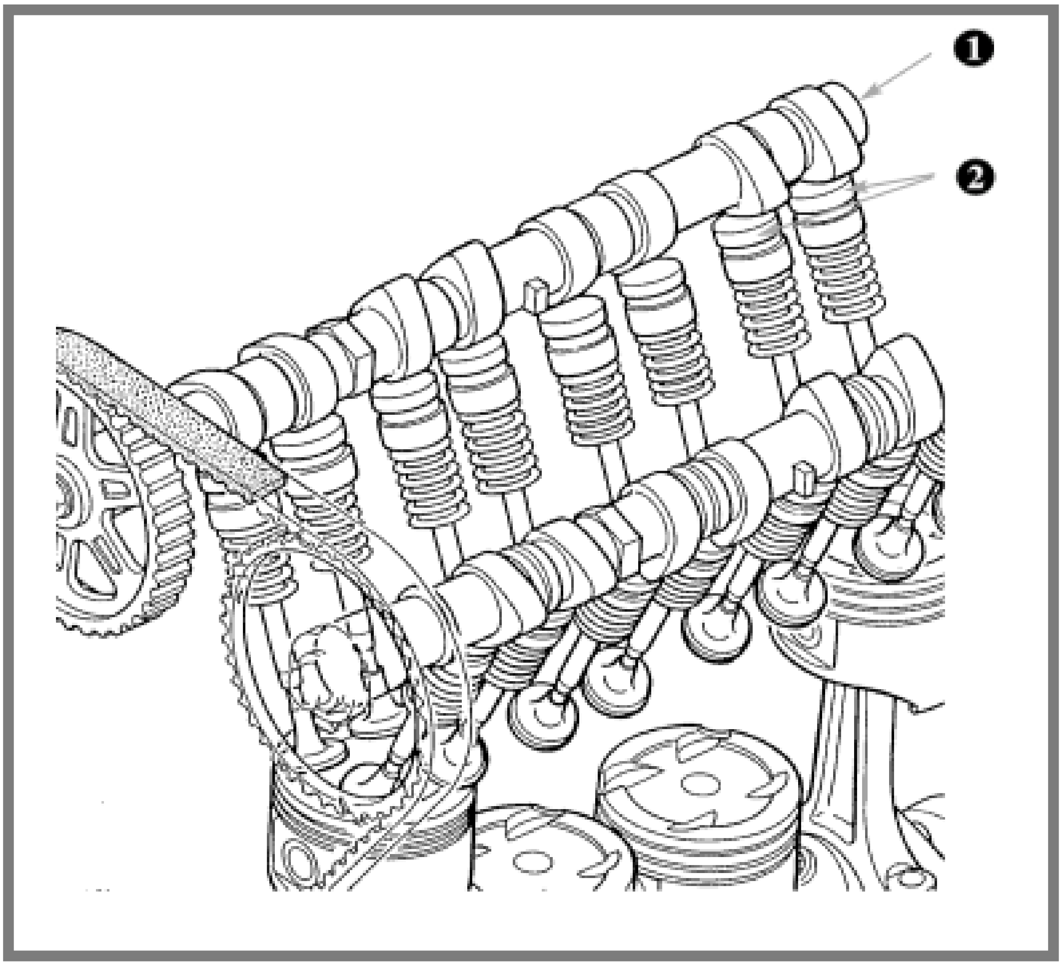
On other engines, the valve clearance is adjusted automatically by *hydraulic lash adjusters (HLAs)*. HLAs eliminate the need for manual valve adjustments.

Description and Operation

The HLA is mounted above the valve stem. A bucket-type HLA is positioned between the top of the valve stem and the camshaft, as shown in Figure 47. In this design, the camshaft directly contacts the top of the HLA. In some engines, a rocker arm-mounted HLA fits between the valve stem and the rocker arm. (Rocker arm-mounted HLAs are described on page 68.)

FIGURE 47. Hydraulic lash adjusters automatically adjust valve clearance.

- ❶ **Camshaft**
- ❷ **Bucket-type hydraulic lash adjusters (HLAs)**



Bucket-Type HLA

The bucket-type HLA, shown in Figure 48, has a bucket body that contains two oil chambers. Movement of oil between these two chambers is controlled by a check ball and spring.

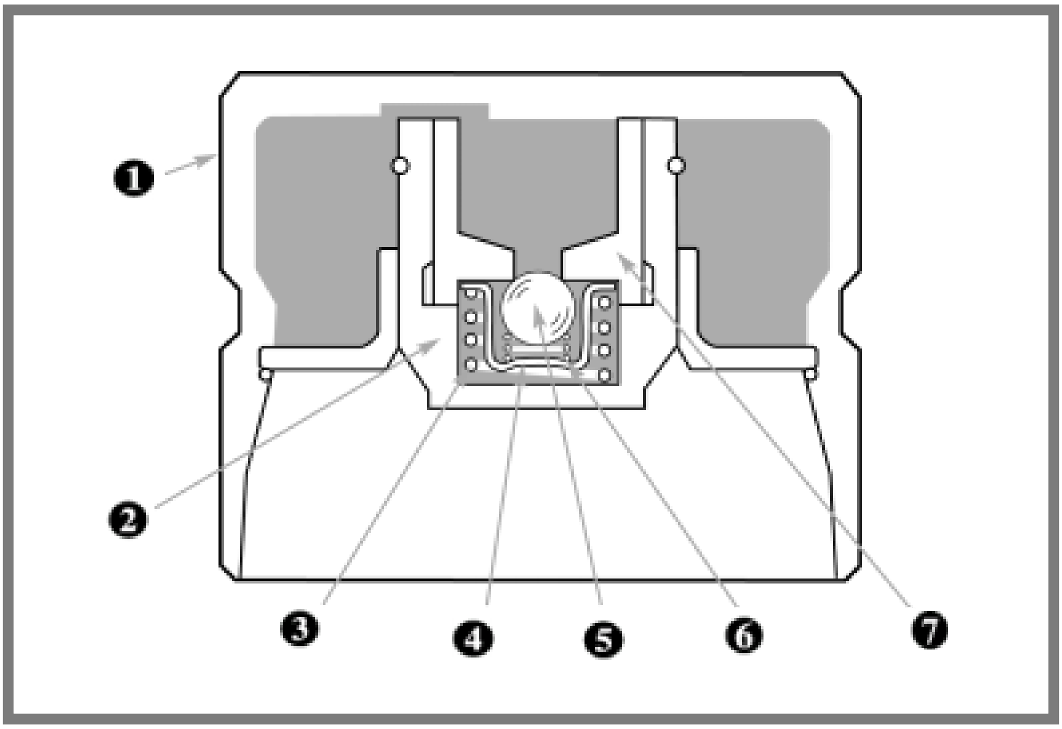


FIGURE 48. A bucket-type HLA has two oil chambers, a check ball, and a plunger.

1. **Bucket body**
2. **Body**
3. **Plunger spring**
4. **Check ball cage**
5. **Check ball**
6. **Check ball spring**
7. **Plunger**

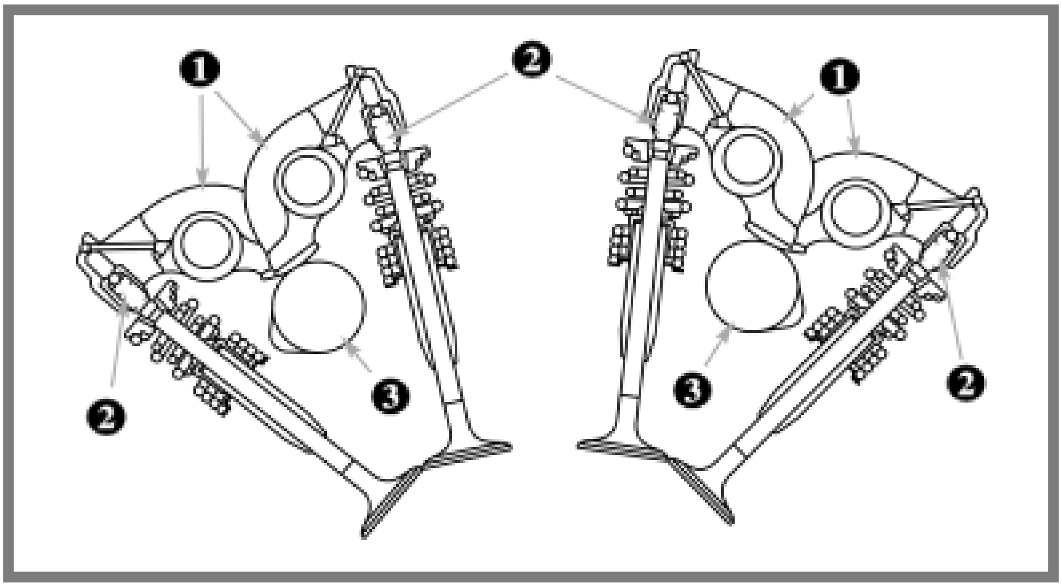
As the oil moves from one chamber to the other, a spring-controlled plunger moves up and down, and contacts the top of the valve stem.

Rocker Arm-Mounted HLA

Rocker arm-mounted HLAs operate much like bucket-type HLAs, except that the top of the HLA contacts the rocker arm, rather than the camshaft. Figure 49 shows how rocker arm-mounted HLAs are positioned in a DOHC engine.

FIGURE 49. Rocker arm-mounted HLAs are positioned between the valve stem and the rocker arm.

- ❶ **Rocker arms**
- ❷ **HLAs**
- ❸ **Camshafts**



An HLA mounted on a rocker arm does not have a bucket body, but the check ball, plunger, and body work the same way to maintain a valve clearance of 0.

Regular Oil Changes

Because the plunger and body of the HLA fit so closely together, regular oil changes according to the maintenance schedule are very important. Even small particles of dirt can clog an HLA, resulting in a ticking noise. Regular oil changes help prevent HLA noise.

PUSHRODS (OHV)

In an OHV engine, pushrods transfer the lifting motion from the camshaft and lifters to the valves. Pushrods are made of stiff steel tubing, with cups or balls on the ends to mate with the lifters and rocker arms.

The pushrods flex slightly in normal operation, and this flexing is taken into account when the cam lift is designed. On some engines, pushrods come in varying lengths to provide an initial clearance adjustment with hydraulic lifters.

ROCKER ARMS

The rocker arm reverses the direction of lift from the pushrod or camshaft to the valve. Mazda engines use shaft-pivoted rocker arms, as shown in Figure 50. The rocker arm is made of aluminum, and a pivot is drilled out so the rocker arm can run on a hollow rocker arm shaft.

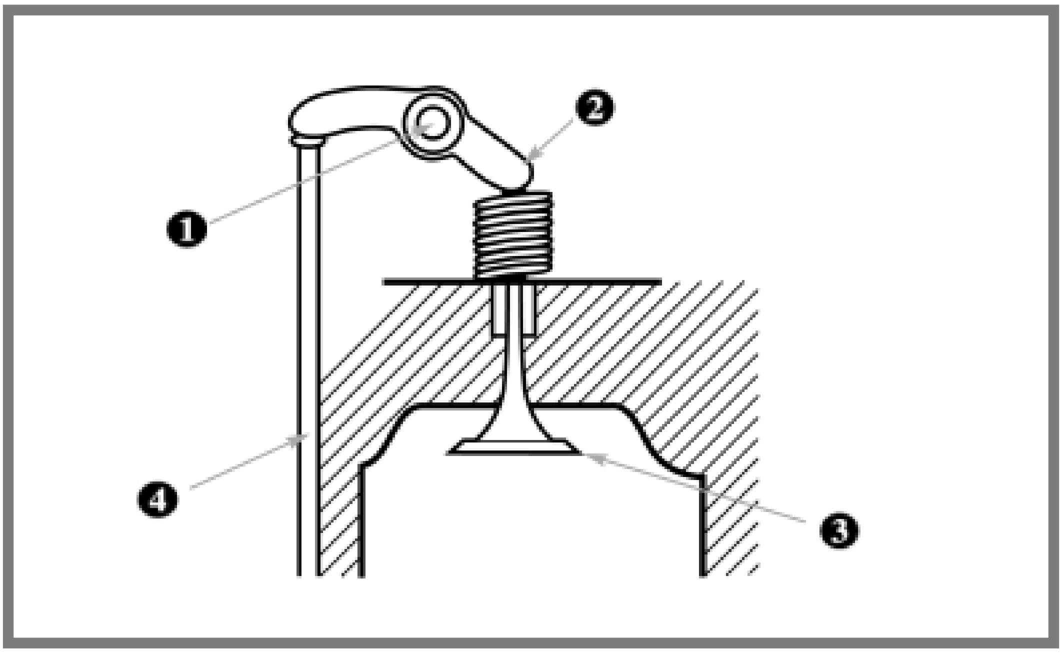


FIGURE 50. Rocker arms are fitted to shafts.

1. **Rocker arm shaft**
2. **Shaft-pivoted rocker arm**
3. **Valve**
4. **Pushrod**

4 – VALVE TRAIN

REVIEW EXERCISE 6

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 73.

1. The space between the end of the valve stem and the rocker arm is called ________________________________.

2. A(n) __________________ uses oil pressure and a plunger to eliminate the need for manual valve adjustments.

3. In an OHV engine, the ______________________ transfers the lifting motion from the camshaft and lifters to the valves.

4. A ___________________________ changes the direction of pushrod or camshaft motion.

5. A ticking noise from the top of the engine at one half crankshaft speed may be caused by:

   A. excessive valve clearance
   B. worn cylinders
   C. a clogged HLA
   D. carbon build-up

5 – LUBRICATION SYSTEM

The lubrication system provides a steady supply of pressurized oil to the moving parts of the engine. Lubrication reduces friction and keeps parts from wearing against each other. Oil also helps cool, clean, and reduce noise by constantly recirculating the engine oil through an external filter. This section describes how the lubrication system works.

OBJECTIVES

After completing this section, you will be able to:

- Identify important parts of the lubrication system and describe how they operate.
- Describe how oil flows through the lubrication system.
- Describe the differences between rotor-type and gear-type oil pumps.
- Describe how the oil filter traps dirt and debris in the oil.
- Describe the materials used in oil seals and gaskets.

SYSTEM COMPONENTS

Some important parts of the lubrication system are shown in Figure 51. These parts are described in the following paragraphs.

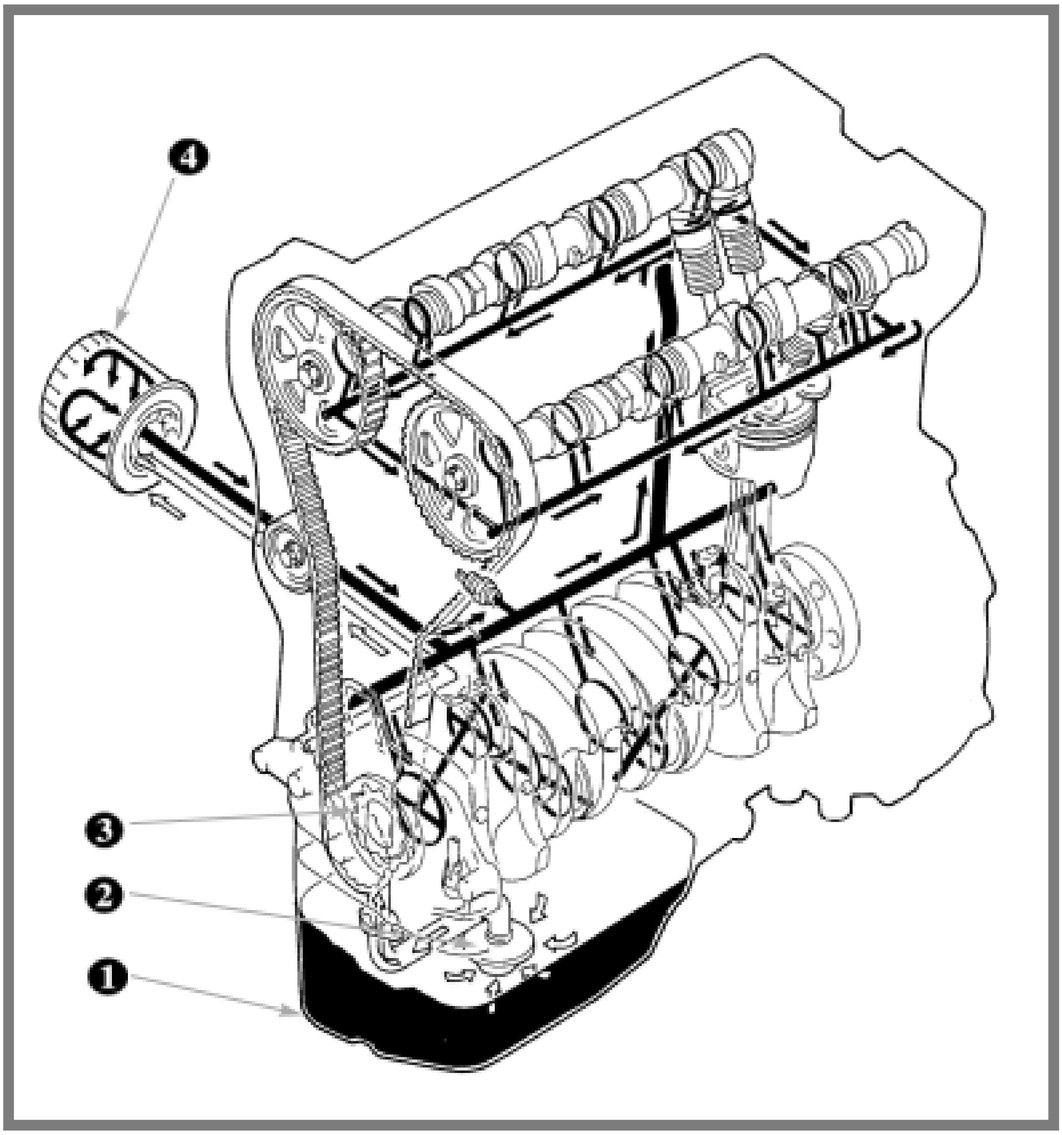


FIGURE 51. The lubrication system provides a steady supply of pressurized oil to moving engine parts.

- ❶ **Oil pan**
- ❷ **Oil strainer**
- ❸ **Oil pump**
- ❹ **Oil filter**

Oil Pan

Bolted onto the engine under the crankcase, the oil pan is a holding area — also called a *reservoir* or *sump* — for the engine oil. The oil pan transfers heat from the oil to the outside air, and it allows dirt picked up in the engine to settle out at the bottom. Many oil pans include a baffle to prevent oil from sloshing.

Oil Strainer (Pick-Up)

The *oil strainer* or pick-up, is located in the bottom of the oil pan, where it is completely covered by the engine oil. The oil pump draws oil through the strainer. The oil strainer has a filter screen to keep large pieces of dirt and debris out of the circulating oil.

Oil Pump

The oil pump provides the “push” that circulates the pressurized oil throughout the engine.

Oil Filter

The oil filter traps smaller particles of metal, dirt, and debris carried by the oil so they don’t recirculate through the engine. The filter keeps the oil clean to reduce engine wear.

There are several other important parts of the lubrication system not shown in Figure 51. These are described below.

Oil Seals

At various points in the engine, seals and gaskets are installed to prevent oil from leaking out of the engine or into places in the engine where oil should not be present.

Dipstick

The engine oil dipstick is used to measure the level of oil in the oil pan. One end of the dipstick dips into the top of the oil reservoir, and the other end has a handle so it can be pulled out easily. The end that dips into the oil pan has a gauge on it that show whether oil should be added to the engine.

It's important to keep the oil level above the "ADD OIL" line at all times. The crankcase should never be overfilled or allowed to drop too low. Too much oil may permit the crankshaft to contact the oil and churn it until it turns to foam. The oil pump can't pump foam, and foam will not lubricate. Low oil levels can result in excessively high oil temperatures, which may lead to bearing failure. An oil level that is too high or too low can also increase oil consumption.

Consult the Workshop Manual or Owner's Manual for the correct oil capacity and recommended oil.

Oil Pressure Indicator

The instrument panel usually has some type of oil pressure indicator that warns the driver when the lubrication system cannot maintain the oil pressure needed by the engine. This indicator may be a gauge or a warning light.

HOW OIL CIRCULATES

Figure 52 shows how oil circulates through the lubrication system. The numbers in this figure match the numbered steps in the description that follows.

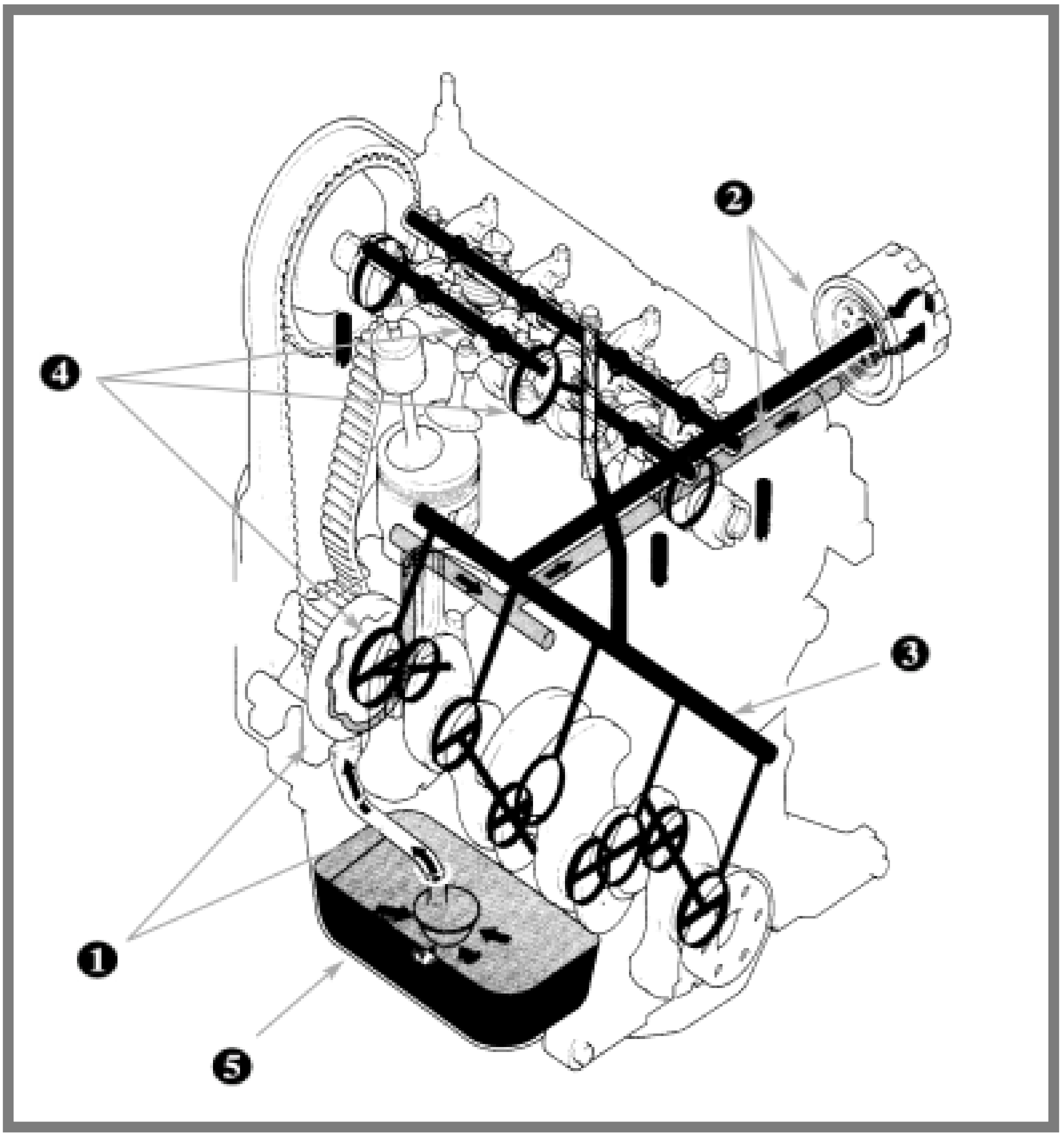


FIGURE 52. Oil circulates from the bottom of the oil pan up through the oil filter, into the cylinder block and cylinder head, through the crankcase, and back down into the oil pan.

1. The oil in the oil pan is drawn up through the oil strainer by the oil pump. The strainer filters out large particles.

2. Oil flows through the oil filter, which cleans the oil of smaller particles of dirt and debris.

3. From the oil filter, the oil flows into the main oil passage — or *gallery* — in the cylinder block.

4. From the main gallery, oil flows through smaller passages to the camshaft, pistons, crankshaft, and other moving parts. Oil holes and jets direct the flow of oil to critical parts, such as the bearings and pistons.

5. As the oil lubricates the surfaces of moving parts, it is constantly pushed off by new oil, which cools the parts. The oil drips from the lubricated surfaces back into the oil pan. In the oil pan, the oil cools before being drawn back through the oil strainer to repeat the cycle.

PRESSURE LUBRICATION

Full pressure is used to pump oil through the main oil gallery, which is a hollow passage cast into the cylinder block. Oil from the main gallery lubricates the crankshaft main bearings, connecting rod bearings, camshaft, and hydraulic lash adjusters (if equipped).

In other parts of the engine, the volume is reduced as oil flows through smaller passages. The reduced volume ensures that the main bearings get enough oil and that excess oil is not introduced into the combustion chambers. The parts that are lubricated by reduced oil pressure include pushrod ends (in OHV engines) and rocker arms.

OIL PUMPS

The oil pump pulls oil from the oil pan and pressurizes it so it will flow through the lubrication system. The oil pump is usually mounted on the cylinder block or the front engine cover. Most oil pumps are driven by the camshaft or crankshaft, using a gear and chain.

Engine oil pumps are classified as *positive displacement pumps*. This means that all oil entering the pump also comes out. Oil is not allowed to circulate inside the pump.

Pressure Relief Valve

Oil pumps include a pressure relief valve, which limits the oil pressure that the pump can develop. The faster an oil pump is driven, the more oil it pumps. So the capacity of the pump will always be more than the engine needs.

If all the oil from the pump were forced into the oil passages, the oil would quickly heat up and break down. To limit the oil pressure, the pressure relief valve opens at a preset pressure and sends some of the oil from the pump's outlet back into the inlet. In some engines, the oil from the pressure relief valve is diverted back into the oil pan.

Excessive oil pressure damages seals and gaskets, causing oil leaks. Two main types of oil pumps are typically used: rotor-type pumps and gear-type pumps.

Rotor-Type Pump (Trochoid)

A *rotor-type,* or *trochoid*, pump uses two rotors, one turning inside the other, to pressurize the oil. The two rotors turn at slightly different speeds. The rotors have smooth, rounded lobes. These types of rotors are called trochoid gears. Figure 53 shows a typical rotor-type oil pump.

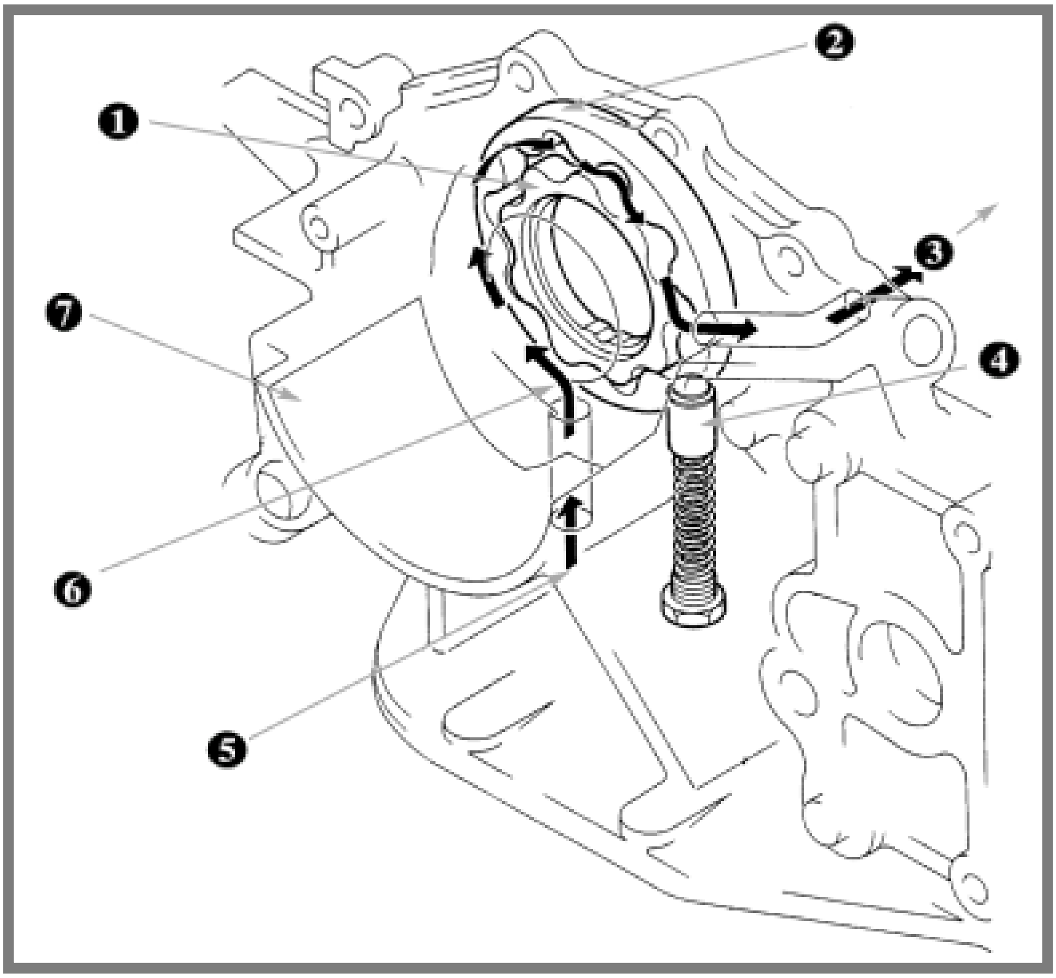


FIGURE 53. A rotor-type, or trochoid, oil pump uses rotors with rounded lobes to push oil through the pump.

- ❶ **Inner rotor**
- ❷ **Outer rotor**
- ❸ **Outlet port**
- ❹ **Pressure relief valve**
- ❺ **Inlet port**
- ❻ **Engine oil**
- ❼ **Pump body**

In this design, the inner rotor is driven by the crankshaft. The inner rotor turns the outer rotor. As the two rotors turn, pumping cavities are formed between the lobes on the two rotors. Oil is drawn into these cavities at the inlet port of the pump. The pumping cavities become smaller and larger as the lobes on the two rotors mesh. This squeezing action pushes the oil through the pump to the outlet port.

The simple design of the rotor-type pump makes it very reliable. In addition, rotor-type pumps can withstand high-speed operation, and they produce a smooth flow of oil, rather than a pulsing action.

The rotor-type pump used on Mazda engines has a small hole at the outlet side to allow air to escape. If there is no oil in the pump because the vehicle has not been driven for a long time, the air hole vents the air quickly when the engine is started. This allows oil to flow almost immediately to critical engine parts.

Gear Pump

In a *gear-type* oil pump, two gears are used to push the oil through the pump. Figure 54 shows how a typical gear-type pump operates.

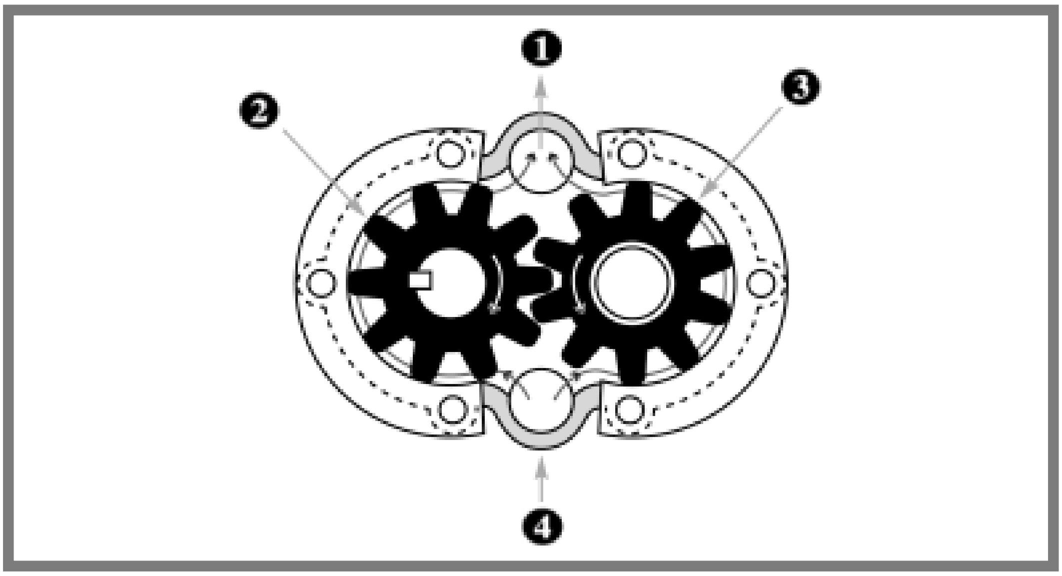


FIGURE 54. A gear-type oil pump uses a drive gear and a driven gear turning in opposite directions.

- **❶ Outlet port**
- **❷ Drive gear**
- **❸ Driven gear**
- **❹ Inlet port**

The drive gear is driven by the camshaft or crankshaft. As the drive gear turns, it meshes with the driven gear, which turns in the opposite direction. As the gears turn within the pump body, they create a *vacuum* — an area that has no gas or fluid in it — at the inlet port. Oil is drawn into this vacuum. The oil moves between the gears and the pump body to the outlet port.

OIL FILTER

The engine oil filter traps very small particles that may get through the oil strainer. Mazda oil filters are the *full-flow* type. This means that all the oil pumped by the oil pump passes through the oil filter. The filter contains a paper *element* that screens out particles in the oil.

A typical oil filter is shown in Figure 55. Oil flows from the oil pump and enters the oil filter through several holes. The oil first flows around the outer part of the filter element. Then it passes through the filter material into the center of the element. Finally, the oil flows out to the main gallery through a tube in the center of the filter.

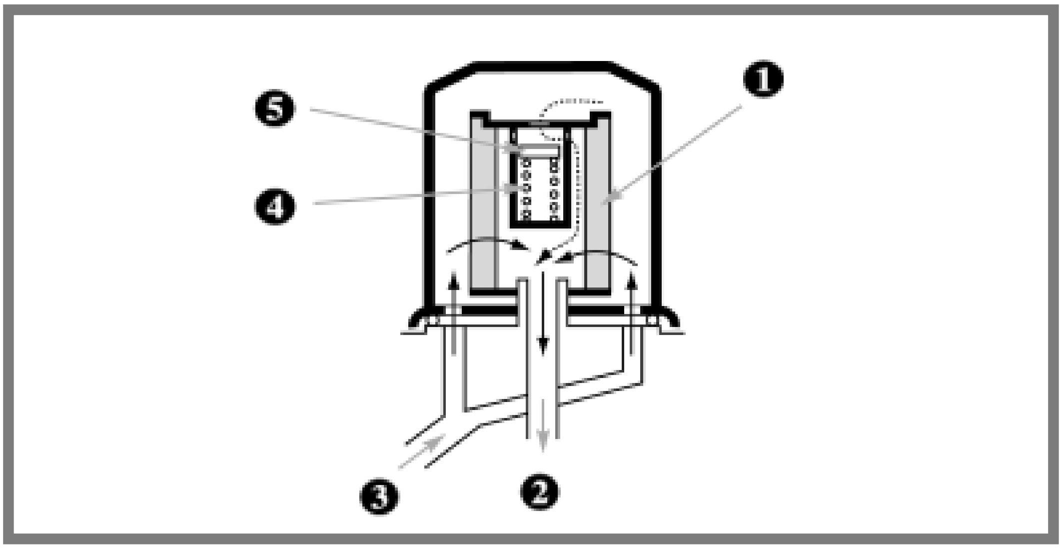


FIGURE 55. The paper element in the oil filter traps particles and dirt in the oil.

- ❶ **Paper element**
- ❷ **Flow to main gallery**
- ❸ **Flow from oil pump**
- ❹ **Spring**
- ❺ **Bypass valve**

The filter screws onto the main oil gallery tube. A seal prevents oil from leaking at the connection between the filter and the cylinder block.

Bypass Valve

As the element in the oil filter becomes dirty, the oil pump must work harder to push oil through the filter. If the filter becomes fully clogged, the engine could be starved of oil, and important parts such as the crankshaft bearings could be damaged.

To prevent this type of damage, the filter also includes a spring-loaded bypass valve. This valve “senses” the back-pressure from the filter as it becomes clogged. When the back-pressure becomes great enough to overcome the spring on the bypass valve, the valve opens, allowing some of the oil to bypass the filter and go directly to the oil gallery tube.

Anti-Drainback Diaphragm

Mazda oil filters also contain an *anti-drainback diaphragm*, which keeps oil in the filter when the engine is shut off. The diaphragm covers all the filter inlet holes when the oil pump stops. When the engine is shut off, the pressure of the oil in the filter forces the diaphragm down on the holes, sealing oil in the filter.

When the engine starts again, oil flows immediately from the filter. In this way, critical engine parts receive lubrication right away. As the pressure from the oil pump grows, the diaphragm is pushed away from the holes, allowing normal oil flow to begin again.

SEALING MATERIALS

At various locations in the engine, seals and gaskets keep the oil from leaking. The most common material used for sealing the lubrication system is synthetic rubber. In critical areas, it may be bonded to metal or fiber. Natural rubber is never used because engine oil will break it down.

When seals or gaskets are replaced, the surfaces must be cleaned completely before the new seal or gasket is installed. In addition, the bolts that secure the seal must be tightened to the correct tightness, or *torque*, in the proper order.

When a properly installed seal or gasket begins to leak, the cause is usually excessive internal pressure, worn bearings, a bent shaft, or a rough sealing surface.

REVIEW EXERCISE 7

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 85.

1. The component in the bottom of the oil pan that filters out large particles is called the ______________________.

2. The largest oil passage in the cylinder block is called the __________________________.

3. As oil is pushed off lubricated surfaces by new oil, it collects at the bottom of the engine in the ______________________ .

4. An oil pump that uses two rotors, one turning inside the other, is called a _____________________ -type pump.

5. The ________________________ contains a bypass valve and an anti-drainback diaphragm.

6. Which of these symptoms would you expect in an engine that has a damaged oil pump? More than one answer may be correct.

   A. high idle

   B. noisy engine

   C. dirty oil filter

   D. low oil pressure

6 – COOLING SYSTEM

Most engines are cooled by a steady flow of liquid coolant through the cylinder block and heads. The cooling system is one of the automobile's most important systems. It removes excess heat produced during combustion and keeps the engine operating at its most efficient temperature. If the cooling system fails, the engine can overheat and seize. An operating temperature that is too cool results in poor gas mileage and incomplete combustion. The hot coolant is also used to operate the heater for the passenger compartment. This section describes how the cooling system works.

OBJECTIVES

After completing this section, you will be able to:

- Identify important parts of the cooling system and describe how they work.
- Identify the important parts of a water pump and describe how they operate.
- Describe the differences between downflow and crossflow radiators.
- Describe how the radiator reservoir works.
- Identify the important parts of the pressure cap and describe how they work.
- Describe how the thermostat works.
- Describe the differences between mechanical and electric fan drives.
- Describe how a viscous drive clutch works.

COMPONENTS

The cooling system maintains an efficient operating temperature. About one third of the heat created by combustion is removed by the cooling system. Important parts of the cooling system are shown in Figure 56. These parts are described in the following paragraphs.

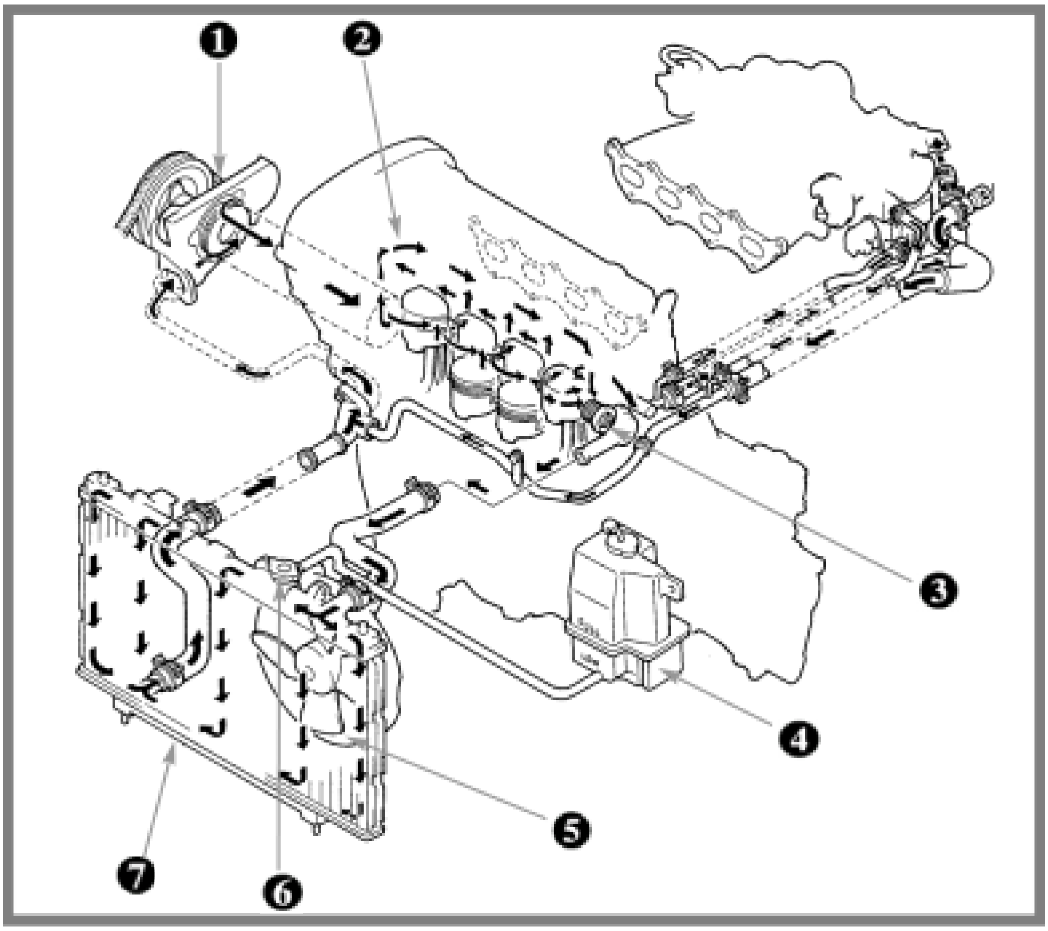
Coolant

In early engines, water alone was used as coolant. Today, most engines use an ethylene-glycol-based coolant mixed with water that lowers the freezing point of water, raises the boiling point of water, adds water pump lubrication, and prevents engine corrosion.

Because coolant is toxic, never dump it down a drain.

FIGURE 56. The cooling system circulates coolant throughout the engine.

- ❶ **Water pump**
- ❷ **Coolant passages**
- ❸ **Thermostat**
- ❹ **Radiator reservoir**
- ❺ **Fan**
- ❻ **Pressure cap**
- ❼ **Radiator**



Water Pump

The water pump circulates coolant throughout the cooling system.

Coolant Passages

Coolant passages are cast into the cylinder block and cylinder head. These passages carry coolant around the cylinders and combustion chambers. The coolant picks up heat and carries it away from these parts.

Thermostat
The thermostat regulates engine temperature by controlling the flow of coolant until a certain preset temperature is met. This helps the engine warm up quickly and maintain a more even temperature.

Radiator Reservoir

As coolant becomes hot, it expands. The coolant recovery system stores the excess coolant released from the radiator. When the engine cools, the coolant in the reservoir is drawn back into the cooling system. This keeps the cooling system constantly full, increasing cooling system efficiency.

Fan

The radiator fan pulls cool outside air over the radiator surface to pick up heat from the coolant for faster heat transfer, especially during idling. Models equipped with air conditioning usually have an additional fan for increased cooling.

Pressure Cap

The pressure cap maintains pressure in the system which raises the boiling temperature of the coolant, preventing the coolant from evaporating or boiling off. This cap also allows excess pressure to escape from the system.

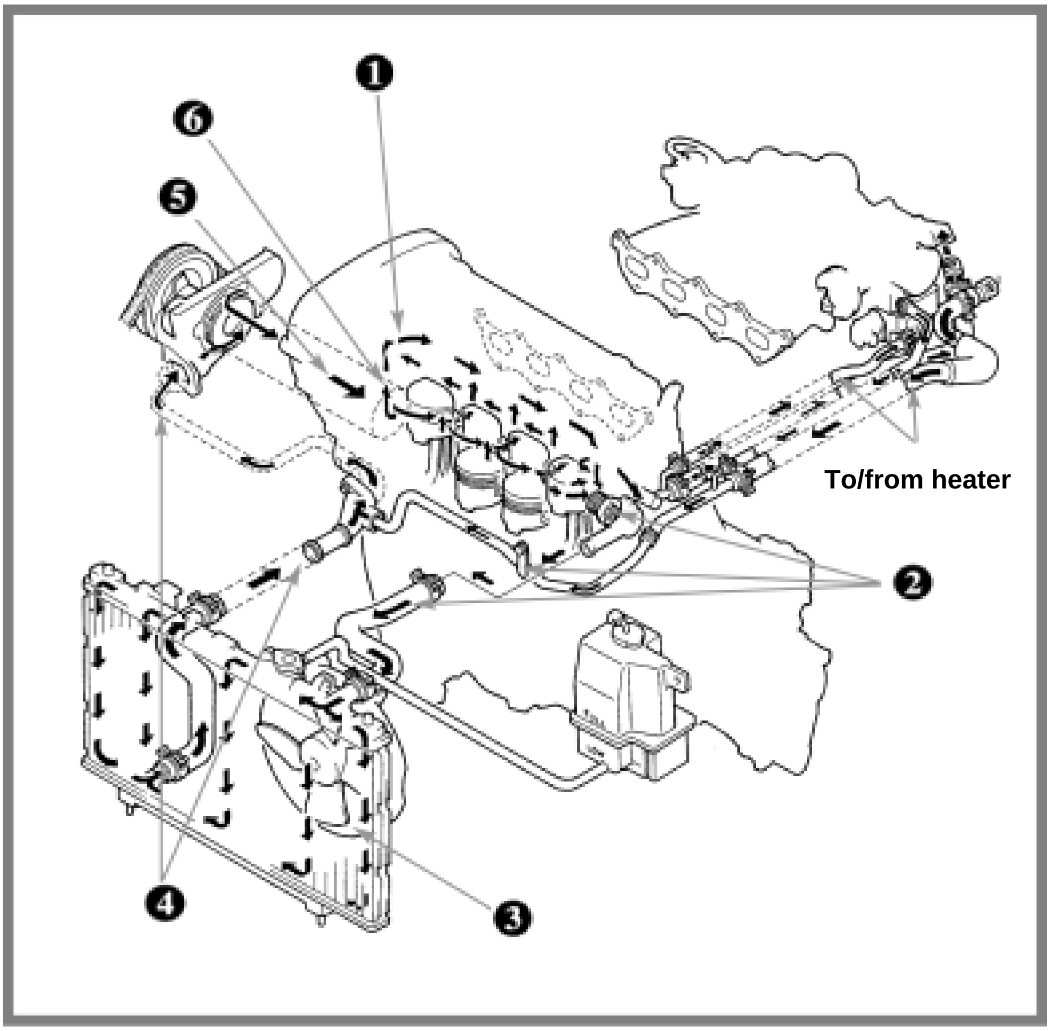
Radiator

The radiator transfers heat from the coolant to the outside air. The radiator core contains tubes and fins. Coolant flows through the tubes, and the fins increase the radiator’s surface area exposed to the air. This allows the air to carry away more heat, reducing the coolant temperature.

HOW COOLANT CIRCULATES

Figure 57 shows how coolant circulates through the cooling system. The numbers in this figure match the numbered steps in the description that follows.

FIGURE 57. Coolant flows from the cylinder head passage through the radiator and water pump to the cylinder block.



1. When a cold engine is started, the water pump only circulates coolant through the cylinder head and engine block coolant passages, quickly raising the engine temperature.

2. When enough heat is created to open the thermostat, the water pump circulates coolant throughout the engine and into the radiator.

3. The hot coolant flows from the upper tank of the radiator, to the lower radiator tank. Cool air passing over the radiator fins removes heat from the coolant.

4. From the lower tank, coolant flows through the lower radiator hose to the water pump inlet.

5. The water pump circulates the coolant through the pump outlet into the cylinder block coolant passage.

6. Coolant flows from the cylinder block passage into the cylinder head coolant passage to complete the circuit.

As Figure 57 also shows, some of the coolant may be diverted to the heating system, which heats the passenger compartment of the vehicle.

WATER PUMPS

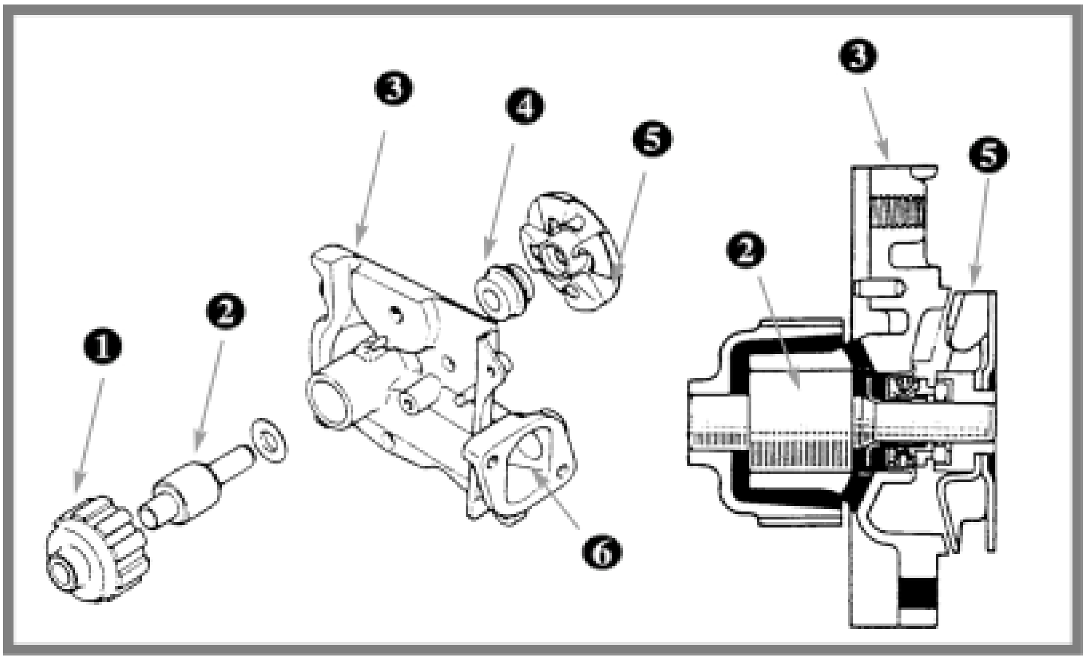
Most water pumps are impeller or *non-positive displacement* pumps. This means that all the water that enters the pump does not necessarily have to come out of the pump. This design is different from the oil pump (a positive displacement type), in which all the oil that enters the pump is pumped out.

Impeller-Type Pump

Water pumps are usually designed as simple *impeller*-type pumps. Figure 58 shows the parts of a typical impeller-type water pump.

FIGURE 58.
Water pumps are simple impeller-type pumps.

1. Pump pulley
2. Shaft and bearing assembly
3. Pump body
4. Water seal
5. Impeller
6. Pump inlet



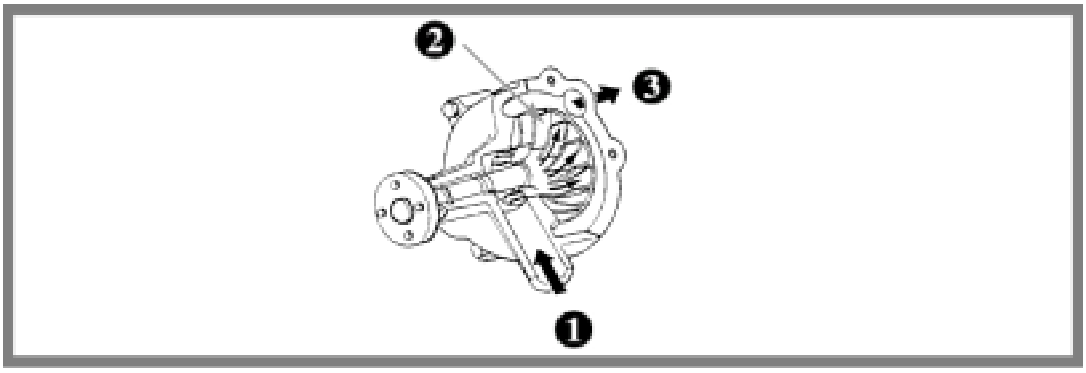
The water pump has a pump *body,* which holds the *impeller* (also called a vane or rotor). The impeller turns on a shaft that is connected to a pulley driven by the crankshaft. The impeller shaft is supported by a bearing. A *water seal* keeps coolant from leaking out of the pump. A worn bearing or impeller shaft causes the seal to leak.

Centrifugal Operation

The impeller-type pump operates on centrifugal action, which is the tendency of a rotating weight to be pushed outward. Coolant flows through the pump inlet and enters the center of the impeller, as shown in Figure 59. As the impeller rotates, it “slings” the coolant to the outside edges of the impeller. The coolant is trapped by the pump body and forced into the pump outlet.

FIGURE 59.
Centrifugal force pushes coolant from the center of the impeller to the outside edges of the impeller.

1. Pump inlet
2. Impeller
3. Pump outlet



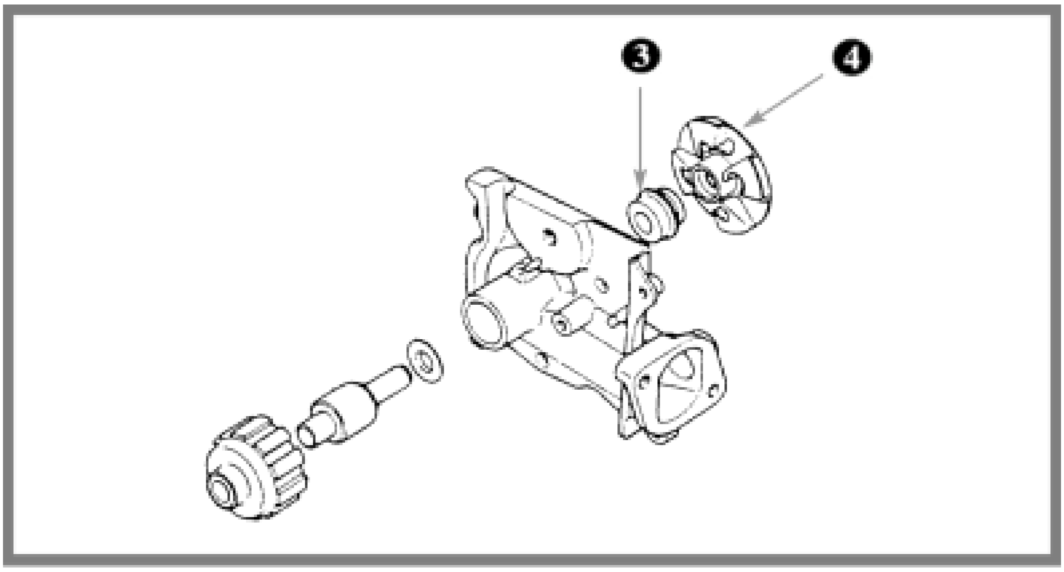
REVIEW EXERCISE 8

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 91.

1. Coolant lowers the freezing point of water and ______________________ the boiling point.

2. The _____________________ helps the engine warm up by restricting coolant flow until a certain temperature is reached.

Use the water pump illustration below to complete the following two items.



3. Item ❸ in this illustration is the _______________________.

4. Item ❹ in this illustration is the _______________________.

5. Which of these symptoms would you expect to find in an engine that has a failing water pump? More than one answer may be correct.

   A. overheating

   B. noisy tappets

   C. hard starting

   D. gasoline fumes

RADIATORS

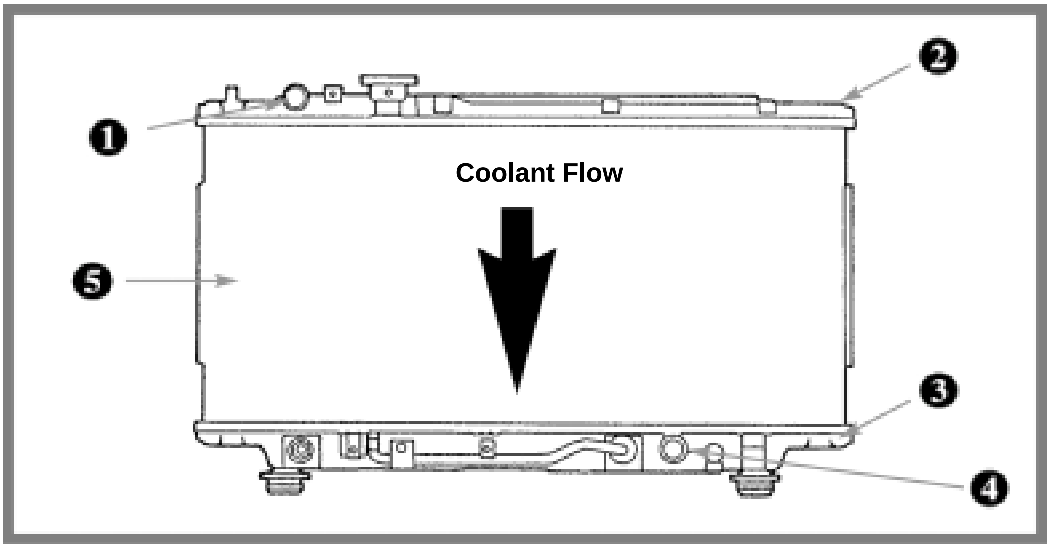
Mazda uses both downflow and crossflow radiators.

Downflow-Type

Figure 60 shows a typical downflow-type radiator. As its name suggests, the downflow radiator has an upper and lower tank. Tubes connect the tanks. Coolant flows down from the upper tank through the core and into the lower tank. Cooling takes place as the liquid passes through the radiator core. If the vehicle has an automatic transmission, the radiator may have a separate cooler at the bottom for the automatic transmission fluid.

FIGURE 60. A downflow-type radiator has an upper and lower tank.

- ❶ **Coolant inlet**
- ❷ **Upper tank**
- ❸ **Lower tank**
- ❹ **Coolant outlet**
- ❺ **Core**



Crossflow-Type

The crossflow-type radiator is also commonly used. In this design (shown in Figure 61), the tanks are on the side of the core, so the coolant flows through tubes from one side to the other.

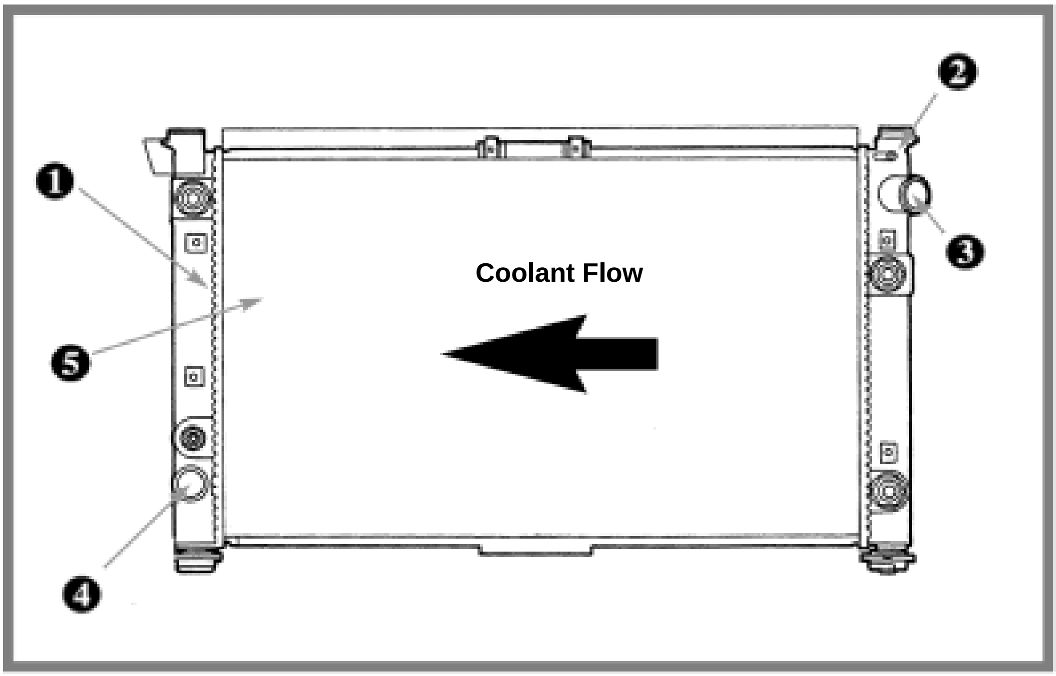


FIGURE 61. A crossflow-type radiator has side tanks.

1. Right tank
2. Left tank
3. Coolant inlet
4. Coolant outlet
5. Core

Radiator Reservoir

Coolant level is checked and coolant is added at the radiator reservoir. A hose connects the reservoir to the radiator filler neck, as shown in Figure 62. As engine temperature rises, the expanding coolant flows from the radiator into the reservoir. When the engine is stopped, the coolant temperature drops and contracts. A partial vacuum develops in the cooling system, drawing coolant from the reservoir backinto the cooling system.

As shown in Figure 62, the reservoir has an *overflow tube* that allows coolant to escape if the cooling system is overfilled or when the engine overheats.

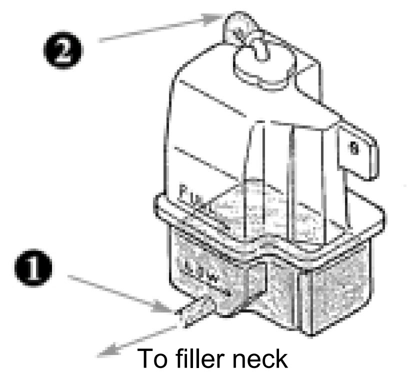


FIGURE 62. As the coolant expands, the excess coolant flows into the reservoir. As it contracts, it is drawn back into the radiator.

- ❶ **Radiator reservoir hose**
- ❷ **Overflow tube**

PRESSURE CAP

The pressure cap on the radiator maintains pressure in the cooling system. The boiling point of a liquid rises with the amount of pressure it is under. For example, water at sea level boils at about 212 degrees Fahrenheit. Water in a typical pressurized cooling system boils at more than 250 degrees Fahrenheit. So pressurizing the cooling system effectively raises the operating temperature of the engine.

Figure 63 shows a typical radiator pressure cap, which fits on the filler neck on the radiator. The cap includes a pressure valve (or *blow-off* valve) and a vacuum valve. Both are spring-loaded to remain closed when the system is within operating ranges.

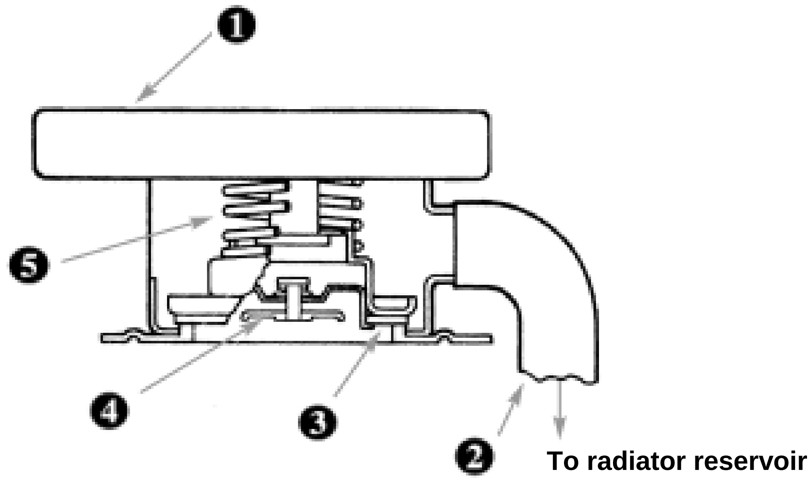


FIGURE 63. The pressure cap raises the operat- ing temperature of the engine.

- **1 Pressure cap**
- **2 Radiator reservoir hose**
- **3 Pressure valve**
- **4 Vacuum valve**
- **5 Filler neck**

If the pressure in the cooling system exceeds the specified limit, the pressure valve opens to avoid bursting the radiator or hoses. Steam and coolant can then escape through the reservoir hose (attached to the filler neck) into the radiator reservoir.

When the engine is shut off, steam in the system condenses back into liquid, creating a vacuum in the system. In this case, the vacuum valve on the pressure cap opens, allowing coolant from the reservoir back into the radiator through the radiator reservoir hose. Without a vacuum valve, the radiator tanks and hoses could collapse.

The pressure cap protects the cooling system from springing leaks due to excess pressure or vacuum. For the cap to work correctly, the entire cooling system must be air-tight.

Testers are used to check the cooling system for proper sealing. The tester is attached to the radiator filler neck and pumped up to see if the system will maintain pressure. The cap is also tested separately.

Removing the radiator cap while the engine is running, or when the engine and radiator are hot is dangerous. Coolant and steam may escape and cause serious injury. Turn off the engine and wait until it is cool before removing the cap. Even then, be very careful.

THERMOSTAT

The thermostat restricts the flow of coolant through the system until the engine reaches its operating temperature. This helps the engine warm up quickly, which improves fuel economy and emissions. A quick warm-up also keeps combustion chamber gases from blowing by the pistons and entering the crankcase, contaminating the oil.

The thermostat contains a heat-sensitive wax pellet, as shown in Figure 64. When the engine is cold, the wax remains solid, and the spring holds the valve closed.

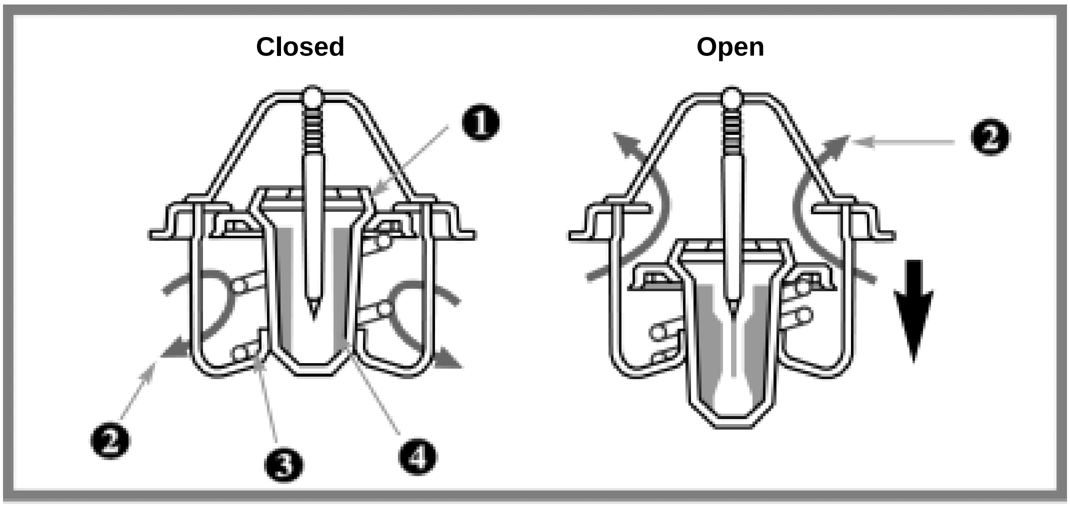
FIGURE 64. A wax pellet expands and contracts to open and close the thermostat valve.

❶ Valve

❷ Coolant flow

❸ Spring

❹ Wax



When the coolant heats up, the wax turns to liquid and expands. The expansion pushes the body of the valve down, which opens the flow of coolant to the radiator.

To provide an outlet for air in the cooling system, many thermostats include a *jiggle pin*, either in the thermostat itself or in the thermostat housing. Figure 65 shows how a jiggle pin works.

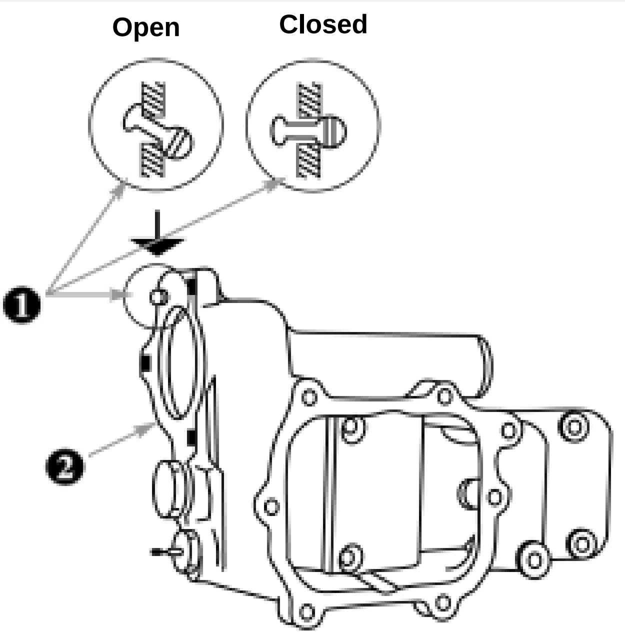


FIGURE 65. The jiggle pin opens when air is in the cooling system.

1 Jiggle pin

2 Thermostat housing

When there is air in the cooling system, the weighted end of the jiggle pin drops down, allowing the air to escape. When the engine is operating, pressure from the water pump pushes the jiggle pin against its seat. The closed jiggle pin prevents coolant from flowing to the radiator until the thermostat opens.

FAN DRIVES

The cooling system fan draws air through the radiator core to cool the engine coolant. Most fans have four or more blades to increase their cooling capacity. A fan *shroud* may surround the fan to concentrate the flow of air.

On some engines, an electric motor drives the fan. In this design, a *thermoswitch* (engine coolant temperature sensor) monitors the coolant temperature. When the coolant reaches a preset temperature, the thermoswitch activates an electrical *relay*, which turns on the fan motor. When the coolant temperature drops, the thermoswitch turns off the fan motor.

On other engines, the coolant fan is driven by a pulley and belt. This design is called a *mechanical drive*.

Viscous Drive Clutch

Most mechanical drive fans use a clutch drive, which allows the fan to turn at lower speeds when the temperature is lower. If the fan were constantly turned at the speed of the engine, the fan would become very noisy at high speeds, and it would sap engine power.

One of the most common types of fan clutches is the viscous type. A viscous drive is a fluid coupling. *Viscous* refers to the *viscosity,* or thickness, of the fluid — usually a silicon oil — that is used to control the clutch. A typical viscous drive clutch is shown in Figure 66.

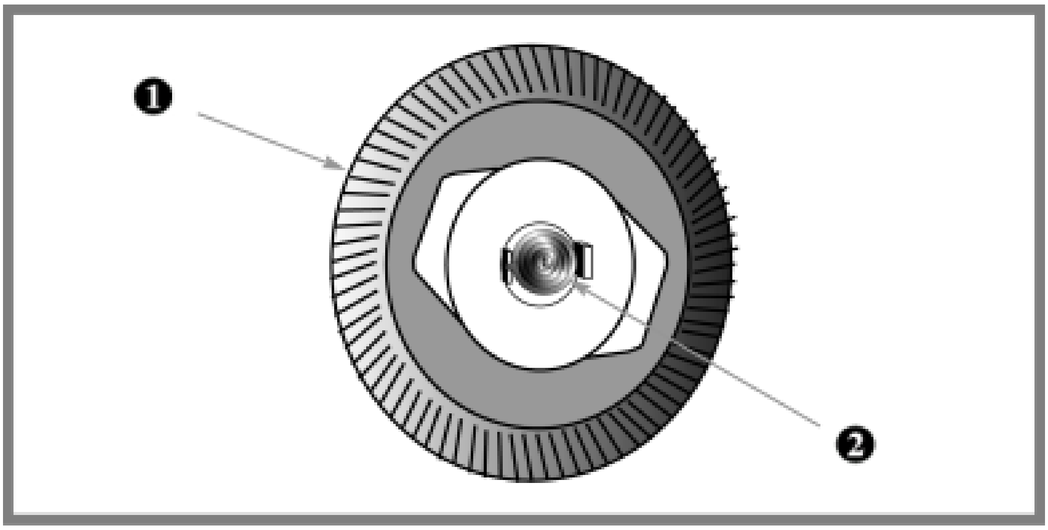


FIGURE 66. A viscous drive fan clutch conserves engine power by match- ing fan speed to air temperature.

1 Clutch plate

2 Bi-metal thermostat

The amount of coupling is controlled by a *bi-metal* thermostat, which is a spring made of two types of metal. The spring expands at higher temperatures and contracts at lower temperatures. The thermostat is connected to a valve that controls the amount of fluid available to couple the clutch.

The thermostat responds to the temperature of the air passing through the radiator. If the air temperature is cold, the flow of fluid in the clutch is restricted. Little or no coupling occurs, and the fan turns very slowly or not at all. At higher temperatures, the fluid operating on the clutch increases, causing a tighter coupling and faster fan speed.

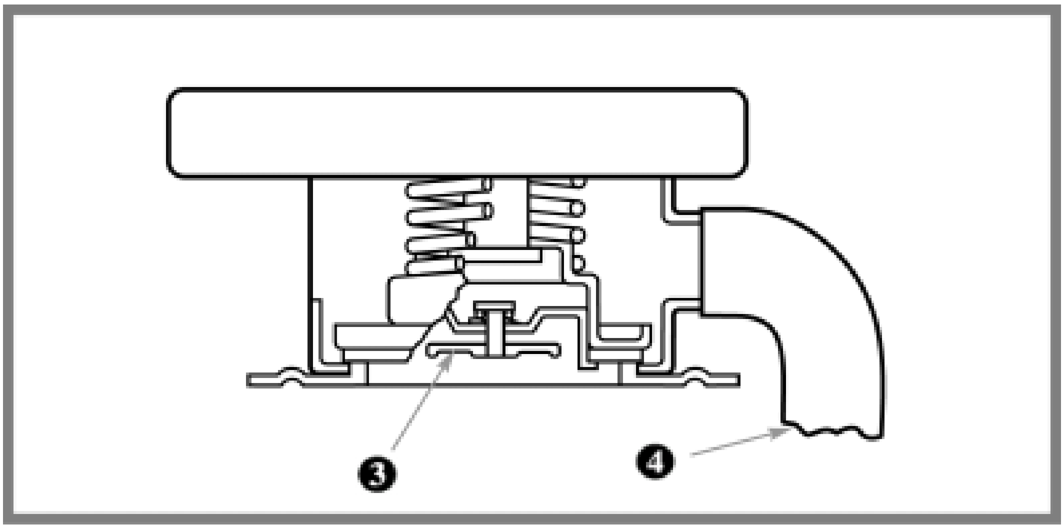
REVIEW EXERCISE 9

Fill in the words that correctly complete these sentences. Check your answers with the answer key on page 98.

1. A radiator that has side tanks, rather than top and bottom tanks, is called a ______________________ radiator.

2. A coolant fan that is driven by the engine is called a ______________________ drive.

Use the pressure cap illustration below to complete the following two items.



3. Item ❸ in this illustration is the ______________________.

4. Item ❹ in this illustration is the ______________________.

5. Which of these symptoms would you expect to find in an engine that has a faulty thermostat? More than one answer may be correct.

   A. leaking oil

   B. fan not rotating

   C. overheating

   D. noisy engine

anti-drainback diaphragm — an oil filter component that keeps oil in the filter when the engine is shut off.

BDC — See *bottom dead center*.

bearing cap — a U-shaped component used to attach the crankshaft, connecting rod, or camshaft to its support surface.

bearing clearance — the gap between a main bearing and a main journal.

belt and chain drive — a camshaft drive in which a timing belt drives the intake camshaft, and a timing chain drives the exhaust camshaft.

blow-off valve — See *pressure valve*.

bore —the diameter of a cylinder, usually expressed in millimeters (mm).

bottom dead center — the position of a piston at its lowest point in the cylinder; abbreviated as *BDC*.

bushing — a circular, sleeve-type bearing.

bypass valve — an oil filter component that "senses" back-pressure from a clogged filter and allows some oil to bypass the filter.

cam follower — See *lifter*.

cam lobe — an off-center bulge on a camshaft that pushes against a lifter or rocker arm to control the opening and closing of a valve.

cam-ground piston — a piston that is slightly oval shaped to allow for heat expansion.

camshaft — a solid or hollow cast iron shaft with offset lobes, or cams, that control the opening and closing of the valves.

camshaft flange — a raised surface on the camshaft that matches a thrust surface in the cylinder head to control front-to-back movement of the camshaft.

combustion — the process of controlled burning of an air-fuel mixture in the cylinders.

combustion chambers — the spaces in the cylinder head where the air-fuel mixture is compressed and burned.

compression ratio — the ratio of the cylinder volume at bottom dead center to the volume at top dead center.

compression rings — the top two rings mounted on the piston that seal, scrape, and cool the cylinder.

compression stroke — the part of the four-stroke cycle in which the upward stroke of the piston compresses the air-fuel mixture into a very small volume at the top of the cylinder.

connecting rod — attaches a piston to the crankshaft; the connecting rod transfers the movement of the piston to the connecting rod journal on the crankshaft.

connecting rod bearing — a split circular sleeve that wraps around a connecting rod journal on the crankshaft.

connecting rod journal — a smooth round surface, offset from the center line of the crankshaft, that is used to attach the connecting rods from the pistons; also called a c*rankpin*.

coolant passage — a passage cast into the cylinder block or cylinder head to carry coolant around the cylinders.

7 – GLOSSARY

cooling system — the engine components that circulate coolant to maintain proper operating temperatures in and around the cylinders.

counterweight — a weight cast into the crankshaft opposite a connecting rod journal; counterweights help balance the crankshaft and prevent vibration during high-speed rotation.

crankcase — the chamber at the bottom of the cylinder block where the crankshaft turns.

crankpin — See *connecting rod journal*.

crankshaft — the shaft that changes the up-and-down motion of the pistons into rotational motion.

crossflow-type radiator — a radiator with side tanks that allow coolant to flow through the core from side to side.

cylinder — See *cylinder bore*.

cylinder block — the main supporting member of the engine that contains the cylinders, pistons, connecting rods, and crankshaft.

cylinder bore — a machined space in the cylinder block where the pistons are housed.

cylinder head — a structural member of the engine that is bolted to the top of the cylinder block; the cylinder head seals the tops of the cylinders, and contains the valve train components and spark plugs.

cylinder head gasket — seals the connection between the cylinder block and cylinder head; the gasket is usually made of steel coated with a softer material.

dipstick — a fluid level gauge used to measure the level of engine oil in the oil pan.

displacement —the volume of a cylinder between the top dead center and bottom dead center positions of the piston; the displacement of an engine is the total displacement of all the cylinders in the engine, usually expressed in cubic centimeters (cc) or liters (L).

distributor — directs electrical current to the spark plugs as they fire in turn.

distributor groove — a groove on the exhaust camshaft that drives the distributor.

DOHC — See *dual overhead cam*.

downflow-type radiator — a radiator with upper and lower tanks that allow coolant to flow through the core from top to bottom.

dual overhead cam — an engine design in which the valves and two camshafts are mounted above the cylinders; one camshaft operates the intake valves and the other operates the exhaust valves; abbreviated as *DOHC*.

electric fan drive — a radiator fan drive that uses an electric motor to operate the fan only when a thermoswitch senses that the coolant has reached a preset temperature.

end play — movement of the crankshaft or camshaft from front to rear.

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exhaust stroke — the part of the four-stroke cycle in which the piston moves up into the cylinder, pushing burned gases out through the exhaust valve.

exhaust valve — lets burned gases out of the cylinder.

face — See *valve face*.

fan — pulls cool outside air over the radiator surface to pick up heat from the coolant.

filter element — the paper material in an oil filter that screens out dirt and debris.

flex-blade fan — a radiator fan that flattens out as its speed increases.

float — See *valve "float."*

flywheel — a heavy, round metal plate attached to the crankshaft; the flywheel keeps the crankshaft turning smoothly.

four-stroke cycle — in most piston engines, the set of piston movements that produce power through combustion; includes the intake, compression, power, and exhaust strokes.

full-flow oil filter — an oil filter that filters all the oil pumped by the oil pump.

gear-driven camshaft with friction gear — a camshaft drive in which a timing belt drives one camshaft on each head; the other camshaft on each head is driven by helical gears and a friction gear.

gear-type pump — a pump that uses two gears, turning in opposite directions, to pressurize liquid.

harmonic balancer — See vibration damper.

head — See *cylinder head, piston head,* or *valve head*.

head gasket — See *cylinder head gasket*.

hydraulic lash adjuster — a component mounted above the valve that uses hydraulic pressure to automatically adjust the valve clearance to 0; abbreviated as *HLA*.

impeller-type pump — a pump that uses a vane or rotor and centrifugal action to pressurize liquid; most water pumps are impeller-type pumps.

in-line — an engine design with the cylinders arranged in a single row.

insert bearings — smooth surfaces fitted into the support surfaces on the bottom of the cylinder block; the crankshaft main journals are supported by insert bearings.

intake stroke — the part of the four-stroke cycle where the piston moves down in the cylinder, creating a partial vacuum that sucks the air-fuel mixture through the intake valve into the cylinder.

intake valve — lets the air-fuel mixture into the cylinder.

jiggle pin — a thermostat component that allows air in the cooling system to escape.

journal — a smooth round surface on a shaft that allows the shaft to turn freely.

keeper — small, semi-circular metal parts that fit in a groove at the end of the valve stem to hold the valve spring in place.

lash — See *valve clearance*.

lifter — the component in an overhead valve engine that transfers the rotary motion of the camshaft into the up-and-down motion of the pushrod.

long block — See *partial engine*.

lubrication system — the engine components that distribute oil to moving parts to reduce heat and wear.

main bearing — a split circular sleeve that wraps around a crankshaft main journal; the upper bearing fits into a main support on the bottom of the cylinder block; the lower bearing fits into a bearing cap.

main bearing journal — a smooth round surface on the crankshaft that supports the crankshaft in the crankcase and allows it to turn freely.

main gallery — the largest oil passage in the cylinder block.

margin — the extra material on a valve head behind the valve face that can be ground to form a new face finish so the valve can be reused after wearing.

mechanical fan drive — a radiator fan drive that uses a pulley and belt to drive the fan.

mushroom valve — See *valve*.

non-positive displacement pump — a pump that does not have to pump out all the liquid that enters it; most water pumps are non-positive displacement types.

offset piston — a piston with the piston pin bore drilled slightly away from the center of the piston; offset pistons reduce piston slap.

OHC — See *overhead cam*.

OHV — See *overhead valve*.

oil filter — traps small particles of metal, dirt, and debris carried by the oil so they don't recirculate through the engine.

oil pan — a pan bolted to the engine under the crankcase that serves as a holding area for engine oil.

oil pick-up — See *strainer*.

oil pressure indicator — a gauge or warning light on the instrument panel that shows when the lubrication system cannot supply all the oil needed by the engine.

oil pump — provides the "push" to circulate pressurized oil throughout the engine.

oil ring — three pieces, or segments, mounted below the compression rings on the piston that scrape oil from the cylinder wall and direct it into the open space inside the piston skirt; the oil ring typically includes two scraper rings and an expander ring.

oil seals — installed at various points in the engine to prevent oil from leaking out of the engine or into places where oil should not be present.

overflow tube — a cooling system component that allows coolant to escape if the cooling system is overfilled or if the engine is overheating.

overhead cam — an engine design with the camshaft and the valves mounted above the cylinders; the camshaft directly operates the valves; abbreviated as *OHC*.

overhead valve — an engine design with the valves mounted above the cylinders; the camshaft, located in the engine block, operates each valve through a pushrod and rocker arm; abbreviated as *OHV*.

partial engine — a short block plus cylinder head(s) and cover(s), timing belt and covers, and oil pan.

piston "slap" — the sound made by a piston as it hits the cylinder wall during the power stroke.

piston — forms the bottom of the combustion chamber and receives the energy created by combustion; pistons move up and down in the cylinders.

piston head — the top surface of a piston.

piston pin — a steel pin (also called a wrist pin) that attaches the piston to the connecting rod.

piston pin bore — a cylindrical hole drilled through the piston; the piston pin is inserted through the piston pin bore.

piston rings — rings mounted on the piston to seal the combustion chamber, scrape oil from the cylinder walls, and carry heat from the piston to the cylinder walls.

positive displacement pump — a pump that pumps out all the liquid that enters it; liquid is not allowed to circulate inside a positive displacement pump; most oil pumps are positive displacement types.

power stroke — the part of the four-stroke cycle where a spark from the spark plug ignites the air-fuel mixture, creating very high pressure on top of the piston, which is pushed down in the cylinder and turns the crankshaft.

pressure cap — screws onto the radiator filler neck and maintains pressure in the cooling system to raise the boiling temperature of the coolant.

pressure relief valve — an oil pump component that allows oil to be diverted from the pump when maximum oil pressure has been reached.

pressure valve — a spring-loaded valve in the radiator pressure cap that allows steam and coolant to escape to the radiator reservoir when high pressure builds in the cooling system.

pushrod — a component in an overhead valve engine that transfers motion from the lifter to the rocker arm, which opens and closes the valve.

radiator — the part of the cooling system that dissipates the heat the coolant has absorbed from the engine.

radiator reservoir — holds coolant that flows from the radiator when the engine is very hot; when the engine cools, the coolant in the reservoir is drawn back into the cooling system.

retainer — See *valve retainer*.

rocker arm — a valve train component that pushes down on the valve spring, allowing the valve to open; the rocker arm is moved by a pushrod or camshaft.

rocker arm shaft — a hollow shaft used to mount shaft-pivoted rocker arms.

rotor-type pump — a pump that uses two rotors, one turning inside the other, to pressurize liquid; most oil pumps are rotor-type pumps, also called *trochoid pumps*.

seat — See *valve seat*.

short block — describes the cylinder block, crankshaft, bearings, connecting rods, and pistons as a unit.

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skirt — the lower part of the piston, from below the piston rings to the bottom of the piston.

spark plug — produces a spark to ignite the air-fuel mixture in the cylinder.

spring seat — washer-like parts that hold the valve spring in place.

strainer — a component in the oil pan that draws oil from the pan for circulation throughout the engine; screens out large pieces of debris in the oil.

stroke — the length of piston travel between top dead center and bottom dead center, usually expressed in millimeters.

tappet — See *lifter*.

tappet clearance — See *valve clearance*.

TDC — See *top dead center*.

tensioner pulley — a pulley that maintains timing belt tension and prevents the timing belt from slipping.

thermostat — restricts the flow of coolant until the engine reaches its operating temperature.

thermoswitch — an electrical component that senses the coolant temperature and activates an electric motor for the radiator fan.

thrust bearing — a special bearing that matches up with a thrust surface on the crankshaft to control front-to-rear movement of the crankshaft.

ticking — See *valve "ticking."*

timing belt — a belt connecting the crankshaft pulley to the camshaft pulley(s) used to drive the camshaft(s).

timing chain — a chain connecting the crankshaft gear to the camshaft gear used to drive the camshaft.

top dead center — the position of a piston at its highest point in the cylinder; abbreviated as *TDC*.

torque — turning or twisting effort.

torsional vibration — the constant twisting and untwisting of the crankshaft caused by the downward thrust of the pistons.

trochoid pump — See rotor-type pump.

V-6 — an engine design in which the cylinders are grouped into two banks of three cylinders each, arranged in a "V" pattern.

V-8 — an engine design in which the cylinders are grouped into two banks of four cylinders each, arranged in a "V" pattern.

vacuum valve — a spring-loaded valve in the radiator pressure cap that allows coolant to return to the radiator when the engine cools.

valve "float" — the failure of a valve to seat at high speed, usually caused by a weak valve spring.

valve "ticking" — a noise created when the valve train parts hammer against each other, usually because the valve clearance is too large; an HLA noise caused by dirt or air trapped in the HLA.

valve — seals against a seat in the cylinder head and opens and closes at precise intervals to allow the air-fuel mixture into the cylinder or exhaust gases out of the cylinder.

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valve adjustment — the process of setting the valve clearance to proper specifications; valves can be manually or hydraulically adjusted.

valve clearance — the small gap between the end of the valve stem and the rocker arm; also called *lash*.

valve face — the tapered surface of the valve head that seals against the valve seat in the cylinder head.

valve guide — a hollow insert or passage in the cylinder head that holds the valve stem.

valve head — the larger end of the valve that seals the valve port.

valve lash — See *valve clearance*.

valve port — a passage controlled by a valve that lets the air-fuel mixture into the cylinders through the intake port; lets exhaust gases out through the exhaust port after the mixture has burned.

valve seal — seals the valve stem in the valve guide, preventing oil from entering the combustion chamber.

valve seat — the surface on the cylinder head where the valve head closes to seal the valve port.

valve spring — holds the valve closed when the cam lobe is not pressing it open.

valve stem — the long, narrow part of the valve above the valve head.

valve train — the engine components that open and close the intake and exhaust valves so that the four-stroke cycle is timed properly.

vibration damper — controls torsional vibration of the crankshaft; mounted on the front end of the crankshaft, often as part of the pulley; also called a *torsional damper* or *harmonic balancer*.

viscous drive clutch — a type of radiator fan clutch controlled by a thermostat and fluid coupling; a viscous drive clutch allows the fan to turn slow at low temperatures and fast at high temperatures.

water pump — provides the “push” to circulate coolant throughout the cooling system.

working height — the length of an installed valve spring between the retainer and the spring pad on the cylinder head when the valve is fully closed.

wrist pin — See *piston pin*.

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