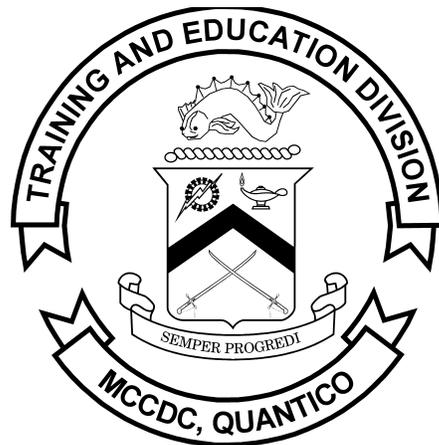


# MARINE CORPS INSTITUTE



## AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

MARINE BARRACKS  
WASHINGTON, D.C.



## UNITED STATES MARINE CORPS

MARINE CORPS INSTITUTE  
912 POOR STREET SE  
WASHINGTON, DC 20391-5680

IN REPLY REFER TO:

35.80a

15 Aug 97

### MCI 35.80a, AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

1. Purpose. MCI course 35.80a, Automotive Engine Maintenance and Repair, has been published to provide instruction on automotive maintenance and repair for all motor transport mechanics as a part of the Marine Corps continuing education program.
2. Scope. MCI 35.80a is designed to provide the skills and knowledge required to repair and maintain the automotive engine. This course also provides diagnostic/troubleshooting techniques and addresses the duties associated with inspecting, testing, and servicing the automotive engine.
3. Applicability. This course is intended for instructional purposes only. It is designed for use by Marines in the ranks of private through sergeant in MOS 3521.
4. Recommendations. Comments and recommendations on the contents of the course are invited and will aid in subsequent course revisions. Please complete the course evaluation questionnaire located at the end of the text and return it to:

Director (CDD-4)  
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Washington Navy Yard  
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Washington, DC 20391-5680

G. White  
Lieutenant Colonel, U.S. Marine Corps  
Deputy Director

# AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

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# Student Information

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<b>Number and Title</b>	MCI 35.80 AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR
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<b>Study Hours</b>	12
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<b>Course Materials</b>	Text
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<b>Review Agency</b>	Motor Transport Company MCSSS, Camp Lejeune, North Carolina 28542
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<b>RRC</b>	4 Reserve Retirement Credits
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<b>ACE</b>	This course is scheduled for review by the American Council on Education during 1997.
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<b>Assistance</b>	For administrative assistance, have your training officer or NCO use the Unit Activity Report (UAR) or MCI Hotline: 1-800-MCI-USMC  For assistance concerning course content matters, call the instructor at DSN 325-7567 or Commercial (202) 685-7567.
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## STUDY GUIDE

Congratulations on your enrollment in a distance training course from the Occupational Specialty Department of the Marine Corps Institute (MCI). Since 1920, the Marine Corps Institute has been helping tens of thousands of hard-charging Marines, like you, improve their technical job performance skills through distance training. By enrolling in this course, you have shown a desire to improve the skills you have and master new skills to enhance your job performance.

The distance training course you have chosen, MCI course 35.80a, Automotive Engine Maintenance and Repair, provides instruction on repairing and maintaining the automotive engine. This course also provides diagnostic/troubleshooting techniques and addresses the duties associated with inspecting, testing, and servicing the automotive engine. This course was developed to increase the basic mechanic's general knowledge of automotive engines. It does not provide information about the engine in a specific vehicle.

Because you have chosen to learn at a distance by enrolling in this MCI course, your professional traits are evident and we know

**YOU ARE PROPERLY MOTIVATED.** You made a positive decision to get training on your own. Self-motivation is perhaps the most important force in learning or achieving anything. Doing whatever is necessary to learn is MOTIVATION. You have it!

**YOU SEEK TO IMPROVE YOURSELF.** You enrolled to improve those skills you already possess and learn new skills. When you improve yourself, you improve the Corps!

**YOU HAVE THE INITIATIVE TO ACT.** By acting on your own, you have shown you are a self-starter, willing to reach out for opportunities to learn and grow.

**YOU ACCEPT CHALLENGES.** You have self-confidence and believe in your ability to acquire knowledge and skills. You have the self-confidence to set goals and the ability to achieve them, enabling you to meet every challenge.

**YOU ARE ABLE TO SET AND ACCOMPLISH PRACTICAL GOALS.** You are willing to commit time, effort, and the resources necessary to set and accomplish your goals. These professional traits will help you successfully complete this distance training course.

## **STUDY GUIDE, continued**

### ***BEGINNING YOUR COURSE***

Before you actually begin this course of study, read the Student Information page. If you find any course materials missing, notify your training officer or training NCO. If you have all the required materials, you are ready to begin.

To begin your course of study, familiarize yourself with the structure of the course text. One way to do this is to read the Table of Contents. Notice the Table of Contents covers specific areas of study and the order in which they are presented. You will find the text divided into several study units and a review lesson. Each study unit is comprised of two or more lessons, lesson exercises, exercise solutions, and references.

### ***LEAFING THROUGH THE TEXT***

Leaf through the text and look at the figures and tables. Read a few lesson exercise items (questions) to get an idea of the type of items in the course. If the course has additional study aids, such as a handbook or a plotting board, familiarize yourself with them.

### ***THE FIRST STUDY UNIT***

Turn to the first page of Study Unit 1. On this page, you will find an introduction to the study unit and generally the first study unit lesson. Study unit lessons contain learning objectives, lesson text, and exercises.

### ***READING THE LEARNING OBJECTIVES***

Learning objectives describe in concise terms what the successful learner, you, will be able to do as a result of mastering the content of the lesson text. Read the objectives for each lesson and then read the lesson text. As you read the lesson text, make notes on the points you feel are important.

### ***COMPLETING THE EXERCISES***

To determine your mastery of the learning objectives and text, complete the exercises developed for you. Exercises may be contained in a lesson, at the end of a lesson, or at the end of a study unit. Without referring to the text, complete the exercise items and then check your responses against those provided.

### ***CONTINUING TO MARCH***

Continue on to the next lesson, repeating the above process until you have completed all lessons in the study unit. Follow the same procedure for each study unit in the course.

## **STUDY GUIDE, continued**

### ***SEEKING ASSISTANCE***

If you have problems with the text or exercise items that you cannot resolve, ask your training officer or training NCO for assistance. If they cannot help you, request assistance from your MCI distance training instructor by completing the Content Assistance Request Form located at the back of the course.

### ***PREPARING FOR THE FINAL EXAM***

To prepare for your final exam, you must review what you learned in the course. The following suggestions will help make the review interesting and challenging.

**CHALLENGE YOURSELF.** Try to recall the entire learning sequence without referring to the text. Can you do it? Now look back at the text to see if you have left anything out. This review should be interesting. Undoubtedly, you'll find you were not able to recall everything. But with a little effort you'll be able to recall a great deal of the information.

**USE UNUSED MINUTES.** Use your spare moments to review. Read your notes or a part of a study unit, rework exercise items, review again; you can do many of these things during the unused minutes of every day.

**APPLY WHAT YOU HAVE LEARNED.** It is always best to use the skill or knowledge you've learned as soon as possible. If it isn't possible to actually use the skill or knowledge, at least try to imagine a situation in which you would apply this learning. For example, make up and solve your own problems. Or, better still, make up and solve problems that use most of the elements of a study unit.

**USE THE "SHAKEDOWN CRUISE" TECHNIQUE.** Ask another Marine to lend a hand by asking you questions about the course. Choose a particular study unit and let your buddy "fire away." This technique can be interesting and challenging for both of you!

**MAKE REVIEWS FUN AND BENEFICIAL.** Reviews are good habits that enhance learning. They don't have to be long and tedious. In fact, some learners find short reviews conducted more often prove more beneficial.

## **STUDY GUIDE, continued**

### ***TACKLING THE FINAL EXAM***

When you have completed your study of the course material and are confident with the results attained on your review lesson(s), take the sealed envelope marked "**FINAL EXAM**" to your unit training NCO or training officer. Your training NCO or officer will administer the final exam and return the exam and answer sheet to MCI for grading. Before taking your final exam, read the directions on the generic DP-37 answer sheet carefully and complete all requested information.

### ***COMPLETING YOUR COURSE***

The sooner you complete your course, the sooner you can better yourself by applying what you've learned! **HOWEVER**--you do have 12 months from the date of enrollment to complete this course. In addition, you may be granted one 6-month extension if approved by your commanding officer. If you need an extension, please complete the Student Request/Inquiry form (MCI-R11) located at the back of the course, and deliver it to your training officer or training NCO.

### ***GRADUATING!***

As a graduate of this distance training course and as a dedicated Marine, your job performance skills will improve, benefiting you, your unit, and the Marine Corps.

***Semper Fi!***

## STUDY UNIT 1

### COMPONENTS OF THE ENGINE

Introduction. Marine Corps units rely heavily upon motor transport to help them accomplish their mission, and the motor transport unit, in turn, stands or falls on the quality of the work performed by the mechanic. Your duty as a mechanic is to maintain vehicles in the best possible operating condition and to restore defective vehicles to a "like new" condition. This calls for an accurate diagnosis of defects and expert workmanship in the repair of those defects.

We will begin by reacquainting ourselves with the engine block, cylinder head, camshaft, pistons, crankshaft, oil pan, valves, timing gears, and the cycle of operation for the four-stroke and two-stroke engines.

#### Lesson 1. ENGINE BLOCK

##### LEARNING OBJECTIVE

Given a description of engine block functions, identify the engine block part described.

The engine block is the main body of the engine; all parts of the engine are either inside the engine block or attached to the outside of it. The engine block is a one-piece casting of iron, but actually it is considered in two parts, the crankcase and the cylinder block.

##### 1101. Crankcase

Look at figure 1-1. To illustrate the two parts of the engine block, an imaginary box has been drawn around the lower portion of the engine block. This lower portion is known as the crankcase.

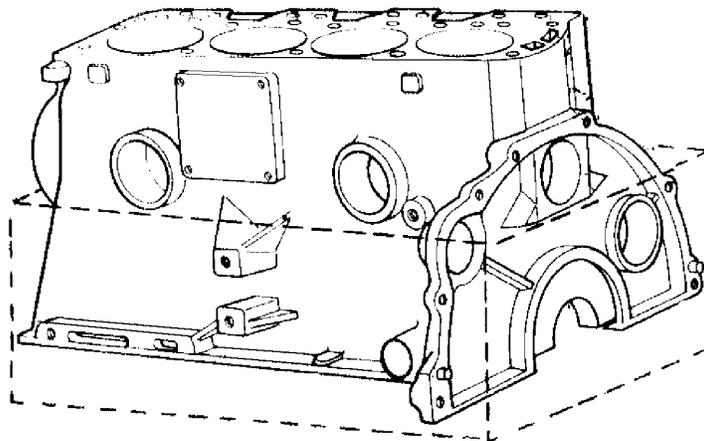


Fig 1-1. Four-cylinder engine block (left rear view).

The crankcase, which supports the crankshaft, is hollow inside with one or more rib-like castings that form the main frame (fig. 1-2). (The crankshaft will be discussed in more detail in Lesson 2 of this study unit.)

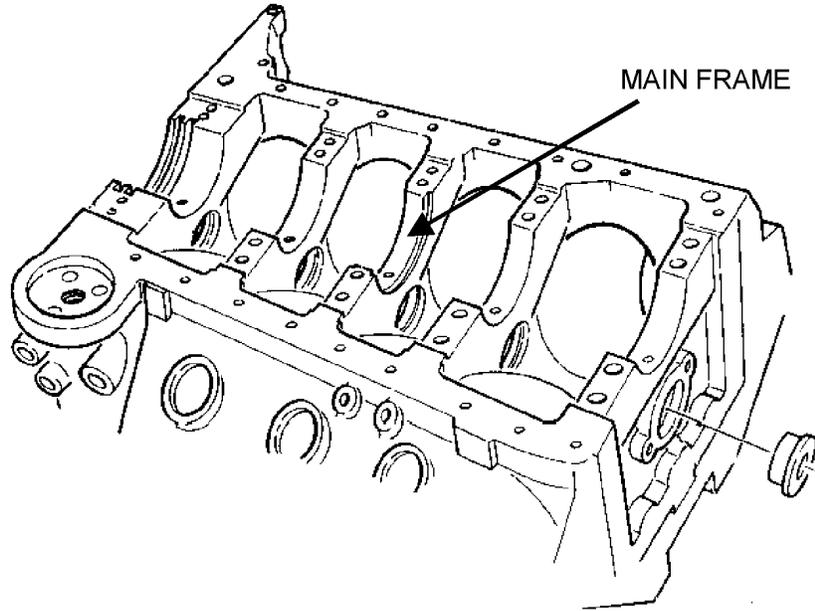


Fig 1-2. Eight-cylinder engine block.

### 1102. Cylinder Block

The upper portion of the engine block is the cylinder block. This portion contains the cylinders, the water passages (commonly known as the "water jacket") (fig. 1-3), and oil passages (fig. 1-4).

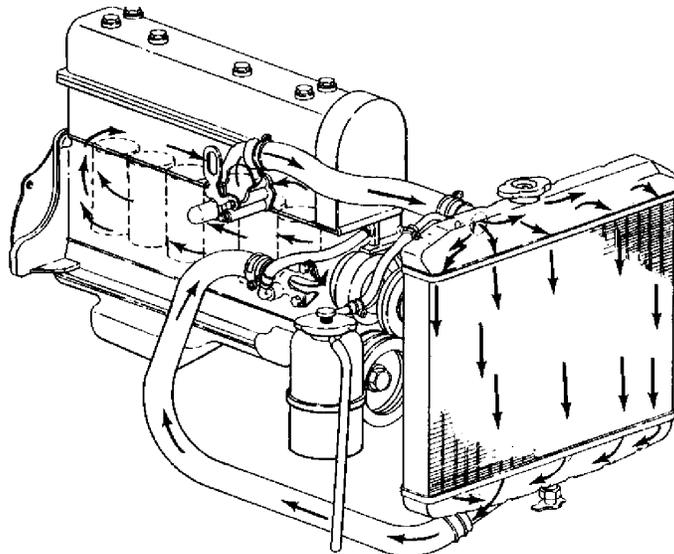


Fig 1-3. Engine block coolant flow.

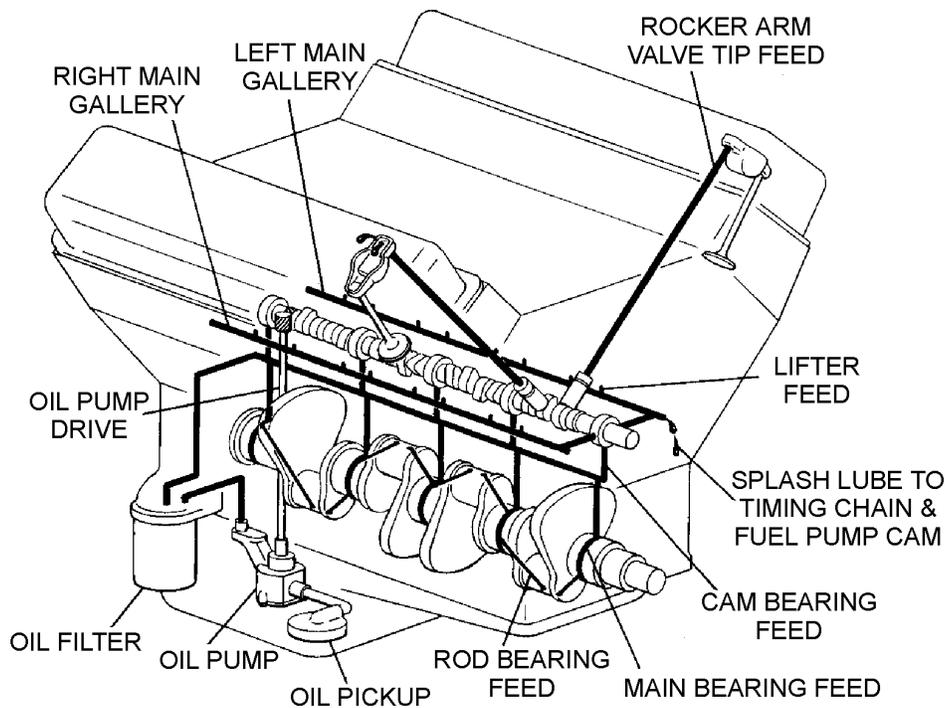


Fig 1-4. Oil passages.

The cylinders are individual housings for the pistons. They are large holes cast into the cylinder block, extending completely through it. The walls of the cylinders are machined smooth to reduce the friction generated by the moving parts inside of them. Some engines have cylinder liners inserted into the cylinder opening.

The water jacket, a large passage cast into the cylinder block, surrounds the cylinders. It contains water or a commercial coolant to maintain a safe temperature while the engine is operating.

Note the oil passages in figure 1-4. The oil passages provide a way to distribute oil under pressure to all moving parts of the engine to reduce wear and to aid the water jacket in cooling the moving parts.

Let's review. What is the main body of the engine? If you said, "engine block," you are correct! What is the lower portion of the engine block called? That's right, the crankcase.

In most cases, the cylinder block contains a camshaft, and, in some cases it contains the valves. (The camshaft and valves will be discussed in detail in Study Unit 2.)

Figure 1-5 shows the top of the cylinder block. In addition to the cylinders, several smaller holes are cut into the surface. Other holes are cut into the water jacket and into the oil passages. The surface of the cylinder block top is machined smooth and must be perfectly flat.

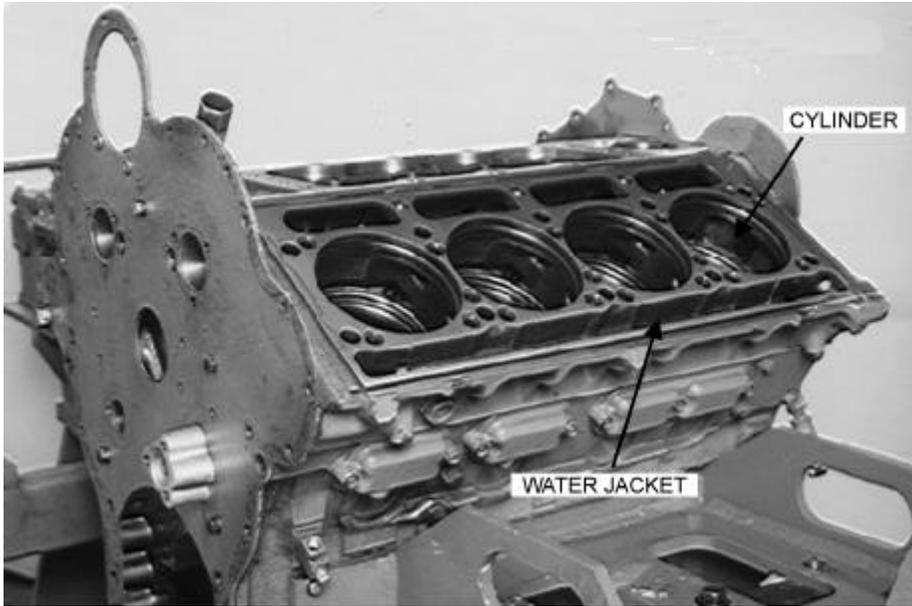


Fig 1-5. Cylinder block (top view of cylinders and water passages).

Lesson 1 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of this lesson.

1. The lower portion of the engine block is known as the \_\_\_\_\_.
  - a. crankcase
  - b. cylinder head
  - c. crankshaft
  - d. cylinder block
  
2. What portion of the engine block contains the cylinders, water and oil passages?
  - a. Cylinder block
  - b. Valve
  - c. Crankshaft
  - d. Cylinder head

Lesson 1 Exercise Solutions

		<u>Reference</u>
1.	a.	1101
2.	a.	1102

Lesson Summary. So far we have discussed the engine block. You know that the engine block is considered in two parts. The lower portion is the crankcase and the upper portion is the cylinder block. We have also discussed the passages cut into the engine block that provide oil circulation for lubrication and water circulation for cooling. Now let's discuss the various components of the engine.

## Lesson 2. ENGINE BLOCK COMPONENTS

### LEARNING OBJECTIVE

Provided descriptions of engine components, functions, or locations, identify the component (or subcomponent) described.

There are many components and subcomponents of the engine block. This lesson will discuss the seven major components and their related parts. These major components are the camshaft pistons, connecting rods, crankshaft, flywheel, vibration damper, and oil pan. Let's begin with the camshaft.

### 1201. The Camshaft

Camshafts are usually made from cast or forged steel. The surfaces of the lobes are hardened for long life. In most cases the camshaft is located in the engine block and is supported, and rotates, in a series of bearings located along its length. Its purpose is to provide for the opening and closing of the engine valves. We will discuss the camshaft in further detail when discussing the valves in Lesson 3.

### 1202. The Pistons

When a flammable gas mixture is ignited and burns, the gases expand producing heat and pressure. If the heat energy has nothing to work on, it will do nothing more than warm an area. The function of the piston is to convert the heat energy into mechanical energy. The piston is a hollow metal tube with the top enclosed. It is on this enclosed top that the heat energy works. The energy produced by the heat drives the piston down inside the cylinder in the same manner that gunpowder would drive a cannonball through the barrel of a cannon when fired. If the energy produced by the burning gases is allowed to pass between the piston and the cylinder walls, it is wasted energy; therefore, you must have a pressure-tight seal between the piston and the cylinder walls. Take a look at the piston in figure 1-6. As you can see, near the top of the piston is a series of lands and grooves.

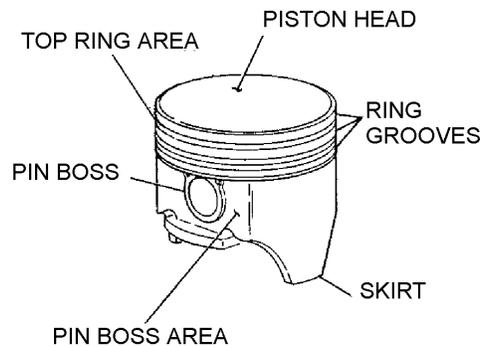


Fig 1-6. The piston.

To obtain a pressure-tight seal, a series of rings is installed into the grooves near the top of the piston. Just below the lands and grooves is a hole that extends through the piston. We will discuss the reason for the piston pin hole in more detail in paragraph 1203. There are two types of rings--compression rings and oil control rings. The top two rings are the compression rings and are responsible for forming the pressure-tight seal.

The piston moving in the cylinder causes friction. Even though the smooth surface of the cylinder walls helps to reduce the friction, the smooth surface is not enough. To further reduce the friction, the cylinder walls must be lubricated with oil but we cannot allow excess oil to remain on the cylinder walls. Oil remaining on the cylinder walls would be burned with the gases when the piston travels down inside the cylinder. Eventually there would be no more oil. To prevent or at least minimize this situation, the bottom ring, the oil control ring (usually a three-piece ring) wipes excess oil from the cylinder wall as the piston travels downward (fig. 1-7).

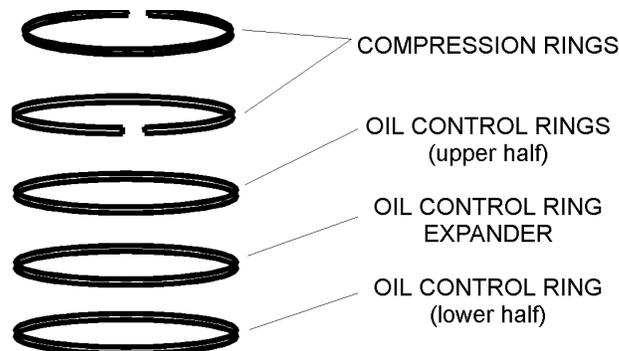


Fig 1-7. Piston rings.

### 1203. Connecting Rod

So far, you have heat energy being converted to mechanical energy by the pistons; but like heat energy, mechanical energy must have something to work on. If not, it is wasted. The piston traveling straight down must cause the wheels of the vehicle to rotate. That is, the up and down motion (reciprocating motion) of the piston must be converted to rotary motion. The crankshaft, which delivers power from the engine, goes around in a rotary motion, but the pistons must be connected to the crankshaft in a way that will allow for this change of motion to occur. A component known as the connecting rod does this.

This is where the hole in the side piston is employed. A snug-fitted pin called the piston pin is manufactured for this hole. The pin attaches the connecting rod to the piston (fig. 1-8). This is done by inserting the pin through the holes in the side of the piston and through the piston pin bushing (a friction-type bearing) located in a hole at the top of the connecting rod. The connecting rod is allowed to swing freely on the piston pin in much the same manner as your hand swings on your wrist. (For this reason, you will often hear the piston pin referred to as the wrist pin.) The bottom of the connecting rod is connected to the crankshaft by a bearing cap.

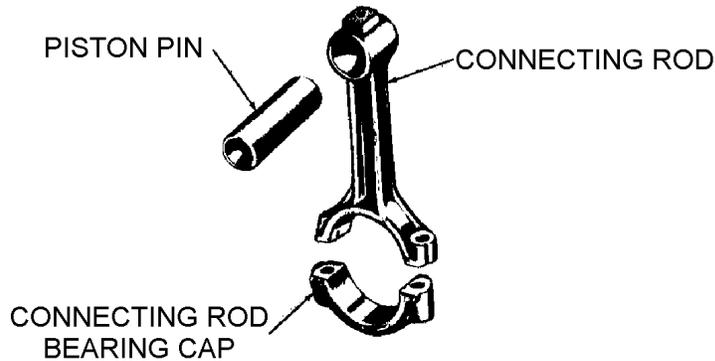


Fig 1-8. Connecting rod and related parts.

OK, so what was "reciprocating motion"? Yes! It's an up and down movement. And what delivers the power from the engine? Very good if you said the crankshaft.

#### 1204. Crankshaft

As stated previously, the crankshaft delivers power from the engine. The function of the crankshaft when aided by the connecting rod is to change the reciprocating motion of the pistons to rotary motion.

The crankshaft extends through the length of the engine and has a series of throws and journals (fig. 1-9). Some of these journals are on the shaft itself, and others are located on the throws. The journals on the centerline of the shaft are main journals; those located on the throws are connecting rod journals. Notice in figure 1-9 that the throws cause the connecting rod journals to be offset from the centerline of the crankshaft.

The main journals connect the crankshaft to the crankcase while still allowing the shaft to rotate. A main bearing cap is bolted over each of the crankshaft's main journals after the crankshaft is positioned in the crankcase.

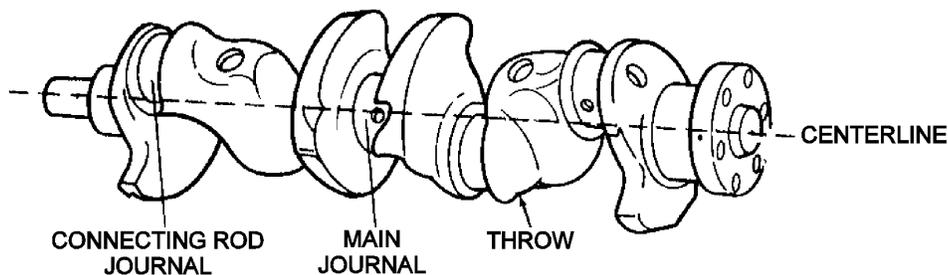


Fig 1-9. Crankshaft construction.

The connecting rod journals provide a place to attach the connecting rod to the crankshaft. After the connecting rod is seated on the crankshaft, a connecting rod bearing cap is bolted over the journal to the connecting rod. Therefore, when the piston is driven down in the cylinder, it drives the connecting rod, which drives the crankshaft throw (or counterweight) causing the crankshaft to rotate (fig. 1-10).

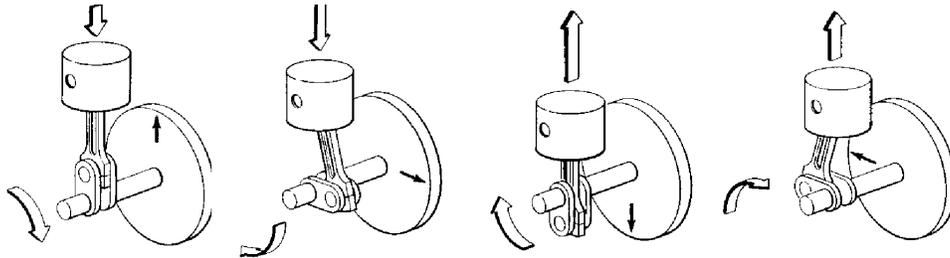


Fig 1-10. The crankshaft changes reciprocating motion to rotary motion.

Have you got all that? Can you remember what the main journals do? That's right. They connect the crankshaft to the crankcase allowing it to rotate. And what offsets the connecting rod journals from the center? You're right if you said the crankshaft throw.

### 1205. Flywheel

In some engines, there is a brief interval when the pistons do not drive the crankshaft. However, with enough momentum, the crankshaft can travel through this brief portion of its rotation. To accomplish this, a large wheel known as the flywheel is bolted to the rear end of the crankshaft.

### 1206. Vibration Damper

Under certain engine speeds and loads, the crankshaft tends to vibrate. To reduce this vibration, a small wheel known as the vibration damper is bolted to the front end of the crankshaft. Vibration dampers often serve as a pulley for the fan, generator, and accessory belts or they may have a pulley attached to accommodate the various belts. Figure 1-11 shows what the components would look like if they were assembled outside the engine block.

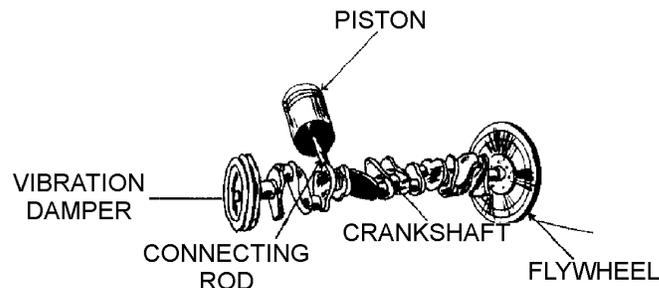


Fig 1-11. Vibration damper location.

With the exception of the flywheel and the vibration damper, all the moving parts discussed up to this point require lubrication (engine oil) stored inside the engine oil pan. So let's discuss the oil pan.

### 1207. Oil Pan

The oil pan is a reservoir for engine oil. It is a large metal pan fitted and bolted to the bottom of the crankcase. It encloses the crankcase and all moving parts (fig. 1-12). Oil is picked up from the oil pan by the oil pump and distributed throughout the engine.

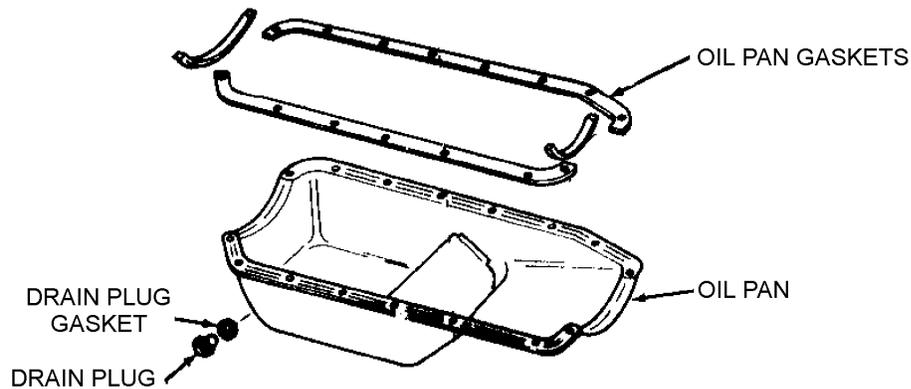


Fig 1-12. Oil pan and related parts.

Lesson 2 Exercise: Complete items 1 through 7 by performing the actions required. Check your responses against those listed at the end of this lesson.

1. What is the function of the piston?  
\_\_\_\_\_
2. Name the two types of piston rings.  
\_\_\_\_\_
3. State the purpose of the connecting rod.  
\_\_\_\_\_
4. The purpose of the crankshaft is to \_\_\_\_\_.
5. The \_\_\_\_\_ is bolted to the rear of the crankshaft and provides the necessary momentum to carry the crankshaft through rotation when not receiving power from the pistons.

6. The \_\_\_\_\_ is bolted to the front of the crankshaft and helps reduce engine vibration.
  7. What is the function of the oil pan?
- 

## Lesson 2 Exercise Solutions

	<u>Reference</u>
1. To convert heat energy into mechanical energy	1202
2. Compression and oil control	1202
3. Connects piston to crankshaft	1203
4. Changes reciprocating motion to rotary motion when aided by the connecting rod	1204
5. Flywheel	1205
6. Vibration damper	1206
7. The oil pan is a reservoir of engine oil. Oil is picked up by the oil pump and distributed throughout the engine.	1207

Lesson Summary. In this lesson you have become familiar with the components of the engine block and their functions. You learned how heat energy is converted to mechanical energy by the piston and how piston reciprocating motion is changed to rotary motion by the connecting rod and crankshaft. The first two lessons were an overview and may have been basically a refresher for you. Next we will break down all the components and discuss them in detail.

---

## Lesson 3. CYLINDER HEAD ASSEMBLY

### LEARNING OBJECTIVE

Given a description of cylinder head components, identify the component described.

The cylinder head assembly is comprised of the cylinder head and the valve mechanism. The valve mechanism is driven by the timing gears. Let's begin by breaking down the components and discussing them in detail.

### **1301. Cylinder Head**

The cylinder head (fig 1-13) is bolted to the machined surface on the top of the cylinder block. Its function is to enclose the top of the cylinders. Both the top of the cylinder block and the bottom of the cylinder head must be machined smooth to allow for an air-tight seal. The cylinder head fits directly over the cylinders and forms the combustion chamber of each cylinder. In these chambers, the engine burns air and fuel to produce mechanical energy.

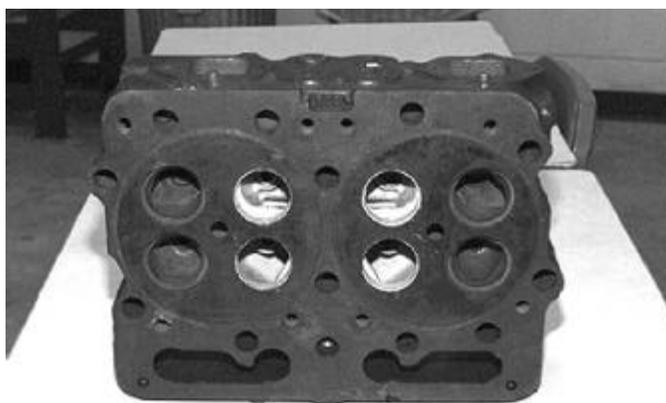


Fig 1-13. Cylinder head assembly.

You can also see that several small holes are cut into the bottom of the cylinder head. When the cylinder head is bolted onto the cylinder block, the holes are aligned which allows oil and water to pass from the cylinder block into the cylinder head. The oil is then circulated back through the block while the water leaves the engine through the large holes on the front of the cylinder head.

Figure 1-14 shows the cylinder head in position to be installed on the cylinder block. A head gasket placed between the cylinder head and cylinder block ensures an airtight seal. Now that you have enclosed the cylinders and formed the combustion chambers, you must have a way to allow the air or air-fuel mixture to enter and exhaust (burned gases) to exit while keeping the combustion chamber closed as the air-fuel mixture burns. All this is done with the intake and exhaust valves.

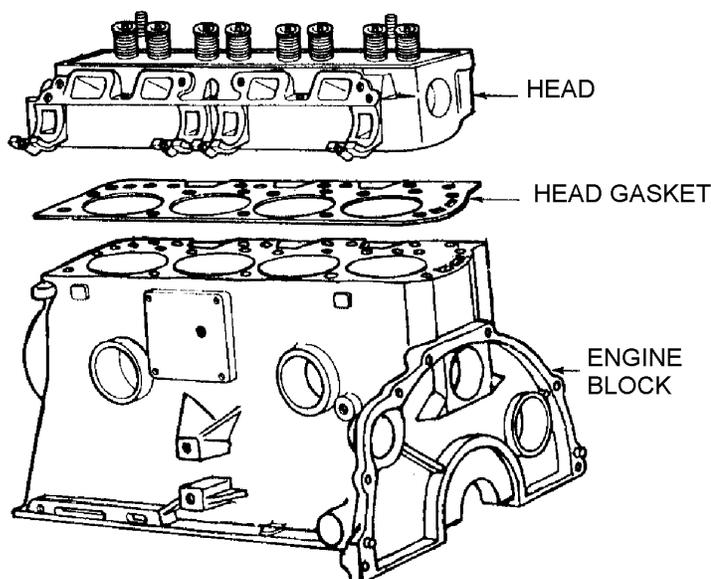


Fig 1-14. Engine block and cylinder head.

## 1302. Valves

To have heat energy, you must burn air and fuel. After you have burned the fuel, you must get rid of the burned gases. Ports are provided in the engine for this purpose. In some engines, valves must open and close these ports at a given time to allow raw fuel to enter and burned gases to leave the combustion chamber. While the fuel is being burned, these valves help to seal the combustion chamber to allow the heat energy to move the piston.

The valve is a long-stemmed metal piece with a circular top known as the valve head. The mechanism required to operate the valve consists of a valve guide, a valve spring, a valve spring retainer, valve spring locks, a camshaft, and timing gears or sprockets and chain. Figure 1-15 illustrates a portion of the valve mechanism.

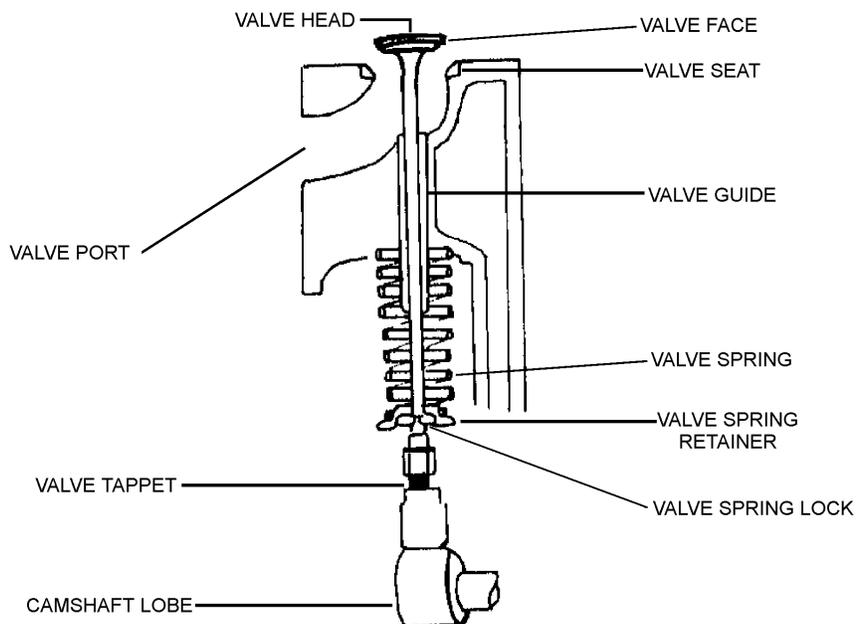


Fig 1-15. Valve mechanism.

On the underside of the valve head is the valve face. This face is machined smooth and when the valve is in the closed position, it seats firmly in the valve seat. The valve seat is a metal ring pressed into the cylinder block (or the cylinder head, depending upon the engine design) around the valve port. The valve face and the valve seat are machined smooth to ensure a pressure-tight fit. It is this portion of the valve mechanism that seals the ports while the fuel is being burned.

The valve must not be allowed to wobble while it is opening and closing or it will not seat properly and pressure will be lost. To prevent the valve from wobbling, a long tube called the valve guide is pressed or cast into the cylinder block and/or cylinder head. The valve stem travels up and down inside the valve guides as the valve opens and closes. A valve spring closes the valve. The spring seats against the cylinder block (or cylinder head) and the valve spring retainer.

The retainer is a washer-like device fitted over the end of the valve stem and held in place by two valve spring locks. Therefore, the valve spring is attached to the end of the valve stem. One end of the spring maintains a constant pressure against the valve stem and the other end maintains pressure against the block (or cylinder head). Any time the valve is not forced open by an outside force, the valve spring will keep it closed.

Now let's check that memory. What ensures an air-tight seal between the cylinder head and cylinder block? If you said machined smooth surfaces and the head gasket, good. You're correct. And what allows fuel to enter and exhaust to exit the combustion chambers? Yes! That's right, the valves.

### 1303. Camshaft

The camshaft provides the outside force to open the valves. It is a long shaft that extends through the length of the cylinder block and it has a series of egg-shaped lobes (cam lobes). Figure 1-15 shows one of these lobes in the position required to open the valve. The camshaft, driven by a gear mechanism attached to both it and the crankshaft, rotates *once* for every *two* revolutions of the crankshaft on a four-stroke cycle engine.

### 1303. Timing Gears

This brings us to the timing gears (or sprockets). The timing gears are a set of two gears (driving and driven). The driving gear is attached to the front end of the crankshaft. The driven gear is attached to the front end of the camshaft. When the gears are installed on the shafts, they must be installed in a certain position in relation to one another, thereby causing each cam lobe to open its valve at precisely the right time to allow fuel to enter or burned gases to leave the combustion chamber. Aligning the timing marks (fig. 1-16) during gear installation accomplishes this.

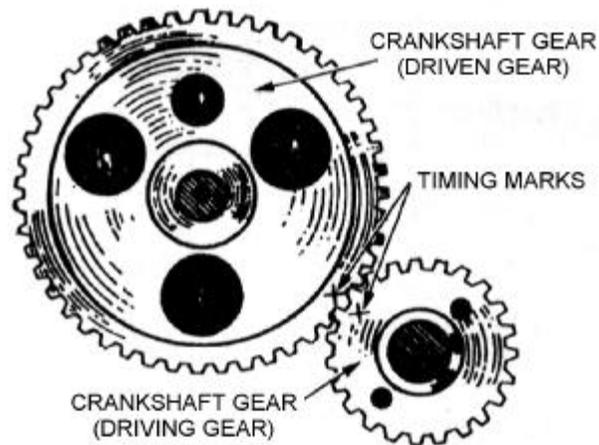


Fig 1-16. Timing gears.

In some cases, because of the distance between the camshaft and the crankshaft, sprockets and a timing chain are used instead of timing gears that mesh directly (fig. 1-17). The only real difference between the sprockets and the gears is that the crankshaft drives the camshaft using a chain instead of a direct gear drive.

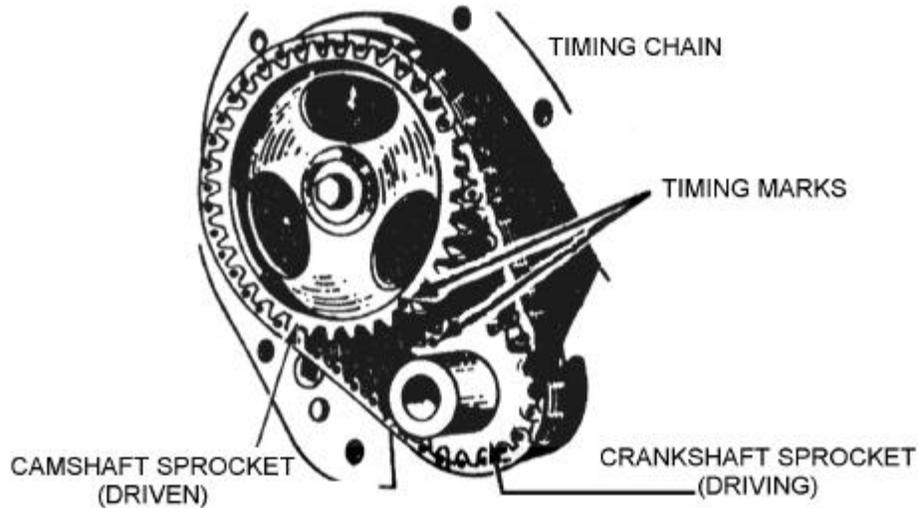


Fig 1-17. Sprocket and timing chain.

Lesson 3 Exercise: Complete items 1 through 3 by performing the action required. Check your responses against those listed at the end of this lesson.

1. What component encloses the top of the cylinders?
  - a. Engine block
  - b. Cylinder head
  - c. Crankshaft
  - d. Valve
  
2. Burnt gases leave the combustion chamber through the \_\_\_\_\_.
  - a. engine block
  - b. intake valved.
  - c. crankshaft
  - d. exhaust valve
  
3. The "driving" timing gear is attached to the \_\_\_\_\_.
  - a. engine block
  - b. cylinder head
  - c. crankshaft
  - d. camshaft

## Lesson 3 Exercise Solutions

1. b.
2. d.
3. c.

### Reference

1301

1302

1303

Lesson Summary. In this lesson you learned that the cylinder head is machined to a perfectly smooth surface that, aided by the head gasket, forms an air-tight seal when bolted to the top of the cylinder block. This is where the combustion chambers are formed. We learned that fuel is allowed into the combustion chambers through the valve openings and that the timing gears are responsible for the opening and closing of the valves. Now that you know the construction of the engine and the function of its major components, let's see what happens when the engine is put into operation.

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## Lesson 4. CYCLE OF OPERATION

### LEARNING OBJECTIVE

Given descriptions of the cycle of operation for 2- and 4-stroke engines, identify the events that occur during engine operation.

Most automotive engines work on the same principle. Whether the cycle of operation is that of a 2- or 4-stroke engine, the same events must occur. In this lesson we will discuss the theory of operation, the 2- and 4-stroke engines, and types of ignition. Let's start by discussing the theory of operation.

### **1401. Theory of Operation**

For an engine to operate, certain events--intake, compression, power, and exhaust--must take place. In the gasoline engine, both fuel and air enter (intake) at the same time and are then compressed (compression). Next, the compressed gases are ignited by an electrical spark. The gases then burn and expand, creating the pressure that drives the piston down (power). Once all the power that the burning gases can deliver has been used, we must get rid of the burned gases. This takes place during the final event known as exhaust.

In the diesel engine, only air enters (intake) the combustion chamber and is compressed (compression) by the upward motion of the piston. The compression of the air causes it to heat up to a very high temperature. Just before top-dead-center (TDC), fuel is injected into the hot compressed air causing the fuel to ignite. The ignited fuel expands, applying pressure to the piston which drives it down (power). As in the gasoline engine, after the burned gases have provided all the power they can, they are expelled (exhaust).

To accomplish these events, the piston must travel up and down inside the cylinder. "Stroke" is the term used for this movement. When the piston travels from its highest point to its lowest point in the cylinder, this is referred to as a down-stroke. When the piston travels from its lowest point to its highest point, this is the up-stroke. For some engines, all the events take place during these two strokes. Others require four strokes to complete the cycle of events. In either case, an engine's cycle of operation must consist of all four events: intake, compression, power, and exhaust. We will cover the two cycles of operation and how they differ, but first, let's be sure you fully understand the strokes.

Figure 1-18 illustrates what happens inside the cylinder on both the down-stroke (position "A") and the up-stroke (position "B"). Notice the large space created between the top of the piston and the top of the combustion chamber. When the stroke occurs, a suction or partial vacuum is created in this space because the pressure in the cylinder drops far below atmospheric pressure. When the piston travels up again, as illustrated in position "B", the pressure in the space rises far above atmospheric pressure.

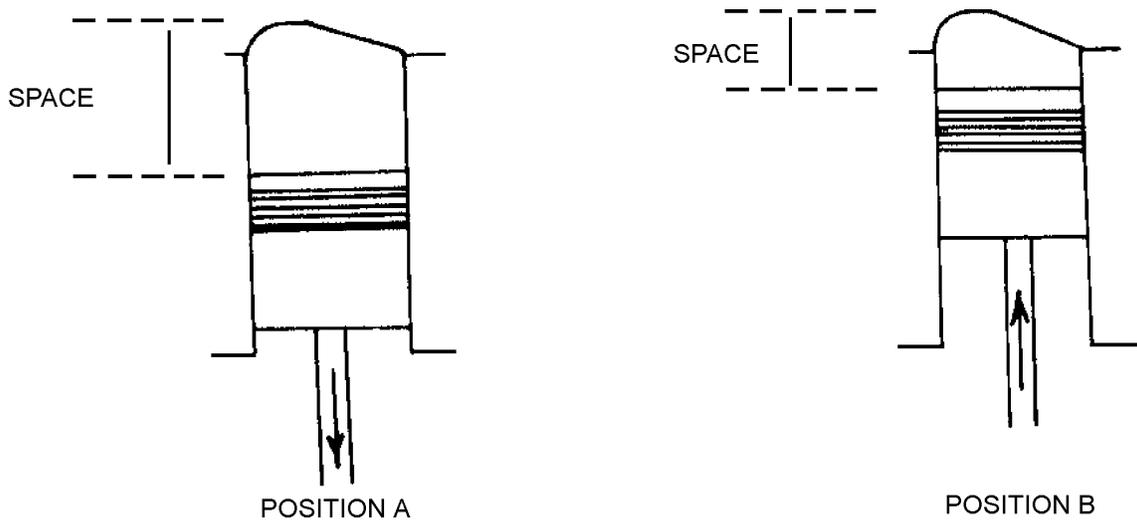


Fig 1-18. The piston strokes.

## 1402. Four-Stroke Cycle Engine

The cycle of operation for the four-stroke engine is easiest to understand because it is less complex. Each part plays a role during the cycle of operation. The piston is at TDC at the beginning of the intake stroke. The intake valve opens and the piston starts its down-stroke (fig. 1-19). This creates a low pressure area inside the cylinder. Atmospheric pressure then forces the fuel-air mixture in to enter the cylinder of the spark-ignition engine. In a compression engine, only air will enter the cylinder at this time. Even after the piston has reached bottom-dead-center (BDC), the cylinder pressure is still lower than atmospheric pressure, so the valve remains open and the gases or air (depending on engine type) continue to enter the cylinder.

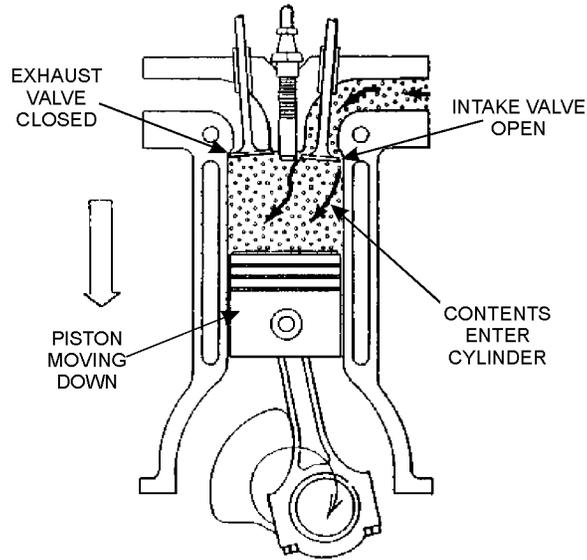


Fig 1-19. Intake stroke.

From the TDC position to the BDC position of the piston, the crankshaft rotates  $180^{\circ}$ . The intake valve closes and the exhaust valve remains closed just as it was during the intake stroke. Both valves are closed, the combustion chamber is sealed and the piston is traveling upward. What is going to happen to all the contents (air-fuel or air depending on engine type) in the combustion chamber? The cylinder contents are being compressed (fig 1-20). This is the action or operation of the compression stroke.

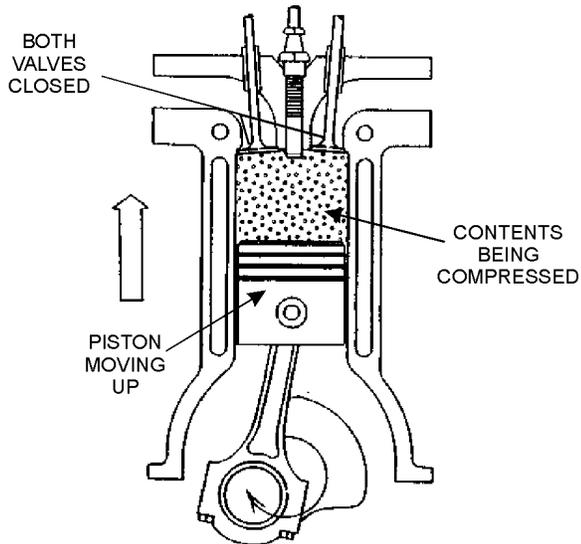


Fig 1-20. Compression stroke.

Let's see if you can answer this without looking back. What is the cycle of operation for a four-stroke engine? Did you say intake, compression, power, and exhaust? If you did, great; you remembered. How many degrees does the crankshaft rotate from TDC to BDC? Right again!  $180^\circ$ . The crankshaft has now completed one  $360^\circ$  revolution while the piston has completed only two strokes of the four-stroke cycle. The piston is at the end of the compression event, which, depending upon the engine design, is just before or after TDC. To illustrate this, look at figure 1-21.

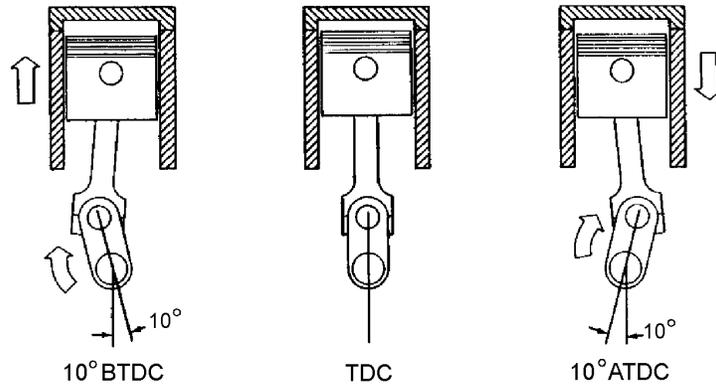


Fig 1-21. End of compression.

At this point, the fuel-air mixture ignites and begins to burn. The burning of these gases causes them to expand with tremendous force and drives the piston downward in the cylinder, creating the power stroke (fig 1-22).

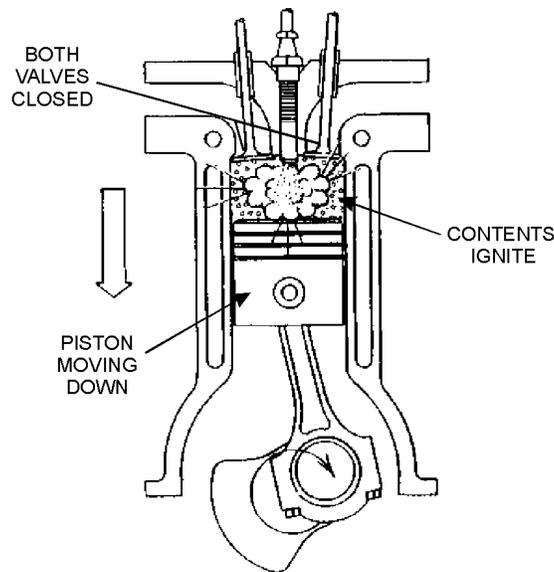


Fig 1-22. Power stroke.

The valves remain closed for most of the power stroke but the exhaust valve opens just before the BDC on this stroke. The exhaust stroke begins here even though the piston has not yet started on its upward travel. Why do the exhaust valves open early? For one reason, the pressure inside the cylinder from the burning gases is still great enough to expel the burned gases out through the exhaust port. Another reason is to get as much of the hot exhaust gases out of the cylinder as soon as possible before the next cycle of operation begins with another intake stroke.

Figure 1-23 illustrates the exhaust stroke. When this stroke is completed, the crankshaft has completed two revolutions during the cycle of operation and the piston has completed four full strokes.

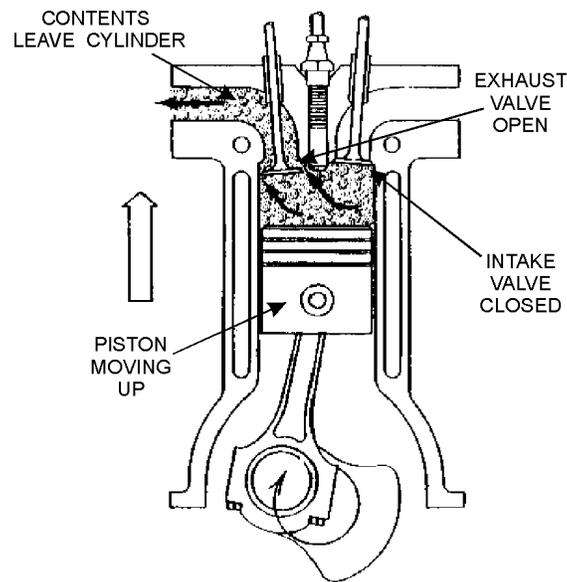


Fig 1-23. Exhaust stroke.

### 1403. Two-Stroke Cycle Engine

The two-stroke cycle and the four-stroke cycle engine may be used as either a spark-ignition or compression-ignition engine. The basic difference between the two-stroke cycle engine and the four-stroke cycle engine is that in the two-stroke engine, all four events (intake, compression, power, and exhaust) must occur within two strokes of the piston instead of within four strokes. This means that every down-stroke is a power stroke and every up-stroke is a compression stroke.

At some time during these two strokes, you must get raw gases into the cylinder and burned gases out of the cylinder. Look at figure 1-24 to discover how this process is accomplished.

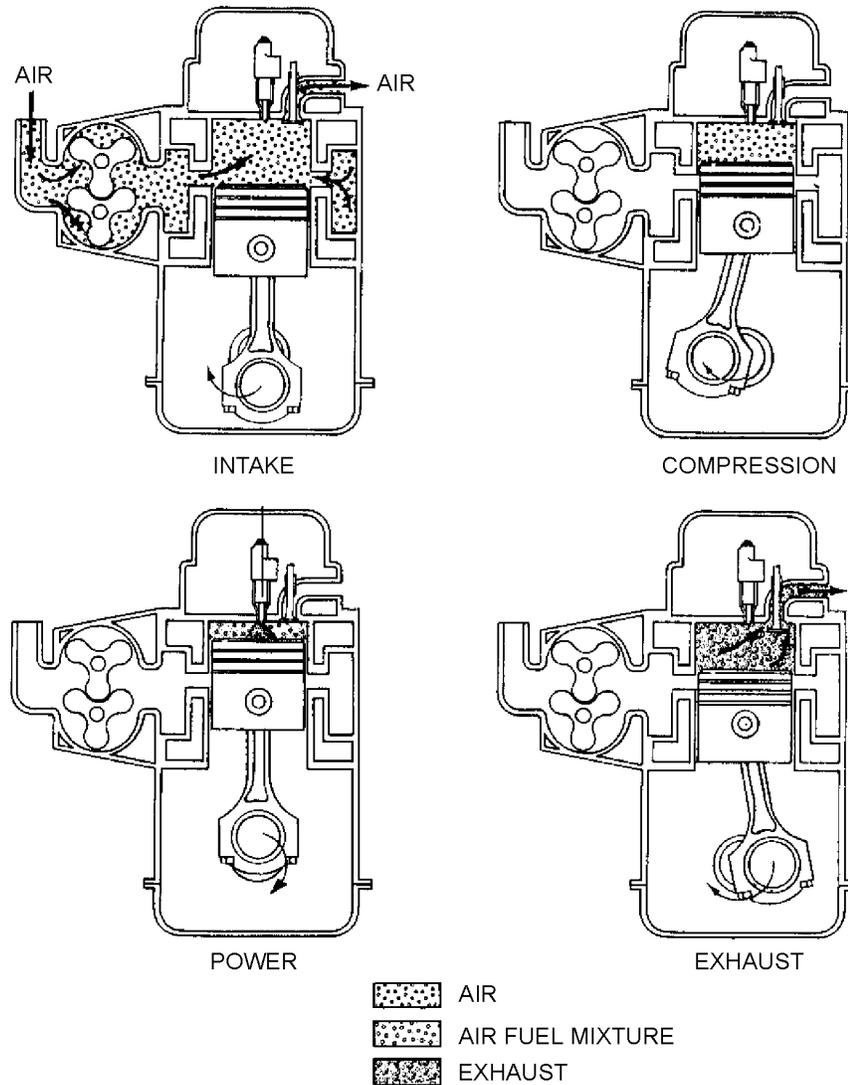


Fig 1-24. Events in a two-stroke cycle.

During the compression stroke, the gases are permitted to flow into the crankcase. The gases, now being compressed, ignite, driving the piston down on its power stroke. Near the end of the power stroke, the piston travels by two openings (the intake and exhaust ports) in the cylinder wall.

As the piston uncovers these ports, the burned gases are exhausted into the atmosphere, and the raw gases are expelled from the crankcase via the cylinder. Therefore, intake and exhaust occur at the same time. The piston now begins to travel upward inside the cylinder, closing both the intake and exhaust ports in the cylinder wall. The fresh gases inside the cylinder are compressed to begin a new cycle. Therefore, two strokes of the piston (or one complete revolution of the crankshaft) completes the cycle of operation in the two-stroke engine.

Can you explain the difference between the four-stroke and two-stroke engine? If you said the four-stroke performs one function per stroke while the two-stroke performs two functions per stroke, you're right.

Now that you know the two- and four-stroke engine cycles of operation, we will discuss the two types of automotive ignitions: the spark-ignition and the compression-ignition. Let's start with the spark-ignition.

#### **1404. Ignition**

The spark-ignition engine has a spark plug installed in each cylinder of the cylinder block and at just the right time, a spark is emitted from the plug. This spark ignites the fuel surrounding it and the remaining fuel burns at a very rapid rate. The rate is so rapid, in fact, that it is similar to an explosion.

The combustion chamber of the compression-ignition engine is NOT located in the cylinder head but in the top of the piston. As the piston travels downward on the intake stroke, only fresh air is taken into the cylinder.

During the compression stroke, this fresh air is compressed into such a small area that it becomes extremely hot due to the high pressure exerted upon it. Fuel must then be introduced into the cylinder at exactly the proper time. Just before the top of the compression stroke, the fuel injector sprays fuel into the combustion chamber. When the fuel is injected, it must first vaporize and then superheat until it finally reaches the spontaneous-ignition lag or ignition delay. At the same time, other portions of the fuel are being injected and are going through the same phases behind the igniting portion. As the flame spreads from the point of ignition, appreciable portions of the charge reach their spontaneous-ignition temperatures at practically the same instant. This rapid burning causes a very rapid increase in pressure, which in some engines is accompanied by a distinct and audible "knock." The pressure of the burning gases drives the piston on through its power stroke and on to the exhaust stroke just like the spark-ignition engine. This completes the cycle of operation.

Note: Increasing the compression ratio in the diesel engine will decrease the ignition lag and thereby decrease the tendency to knock.

Lesson 4 Exercise: Complete items 1 through 4 by performing the action required. Check your responses against those listed at the end of this lesson.

1. What is the sequence of events in the cycle of operation for a four-stroke engine?
  - a. Compression, ignition, power, exhaust
  - b. Ignition, power, exhaust, intake
  - c. Power, exhaust, compression, intake
  - d. Intake, compression, power, exhaust
  
2. What event is taking place when the piston is traveling upward inside the cylinder and the exhaust valve is open?
  - a. Intake
  - b. Exhaust
  - c. Compression
  - d. Power
  
3. What two events occur at the same time in the two-stroke engine?
  - a. Power and intake
  - b. Power and compression
  - c. Intake and exhaust
  - d. Compression and exhaust
  
4. The two most common automotive ignitions are
  - a. spark and ignition
  - b. spark and compression
  - c. ignition and compression
  - d. spark and combustion

Lesson 4 Exercise Solutions

	<u>Reference</u>
1. d.	1402
2. b.	1402
3. c.	1403
4. b.	1404

Lesson Summary. So far we have learned that intake, compression, power and exhaust are the cycle of operation for two- and four-stroke engines. We also discussed two types of ignition, spark-ignition and compression-ignition.

UNIT SUMMARY

In this study unit, you learned the main components of the engine block, how it is constructed, and how the engine operates. In the next study unit, you will study the design and classification of various engines and components used in the construction of engines.

## STUDY UNIT 2

### ENGINE CLASSIFICATION

Introduction. The major similarities among engines are a requirement for fuel and a method for igniting the fuel/air mixture. The major differences among engines are the number and arrangement of the cylinders, the valve arrangement, the method of operation, the type of fuel used, and the cooling system. To properly maintain and repair an engine, you must first know how it is constructed and designed. At the completion of this study unit, you will have a thorough knowledge of the types of engine designs and the components that make up the engine's design.

#### Lesson 1. ENGINE BLOCK

##### LEARNING OBJECTIVE

Given a description of engine block classification, select the type of engine block described.

Engines are classified in three ways--by the arrangement of the cylinders in the engine block, the fuel used (diesel, gasoline, etc.) and by the method used to cool the engine (air or water). The three most common types of engine blocks by cylinder arrangement are the in-line, the "V," and the horizontally opposed.

##### 2101. In-Line Engine Block

The cylinders are positioned vertically, directly above the crankshaft (fig. 2-1A) or with the cylinders cast at a 30° angle to the vertical plane (fig. 2-1B). As you can see, the engine in figure 2-1B presents a much lower silhouette. The cylinders in the in-line engine are numbered from front to rear and there are usually four, six, or eight of them.

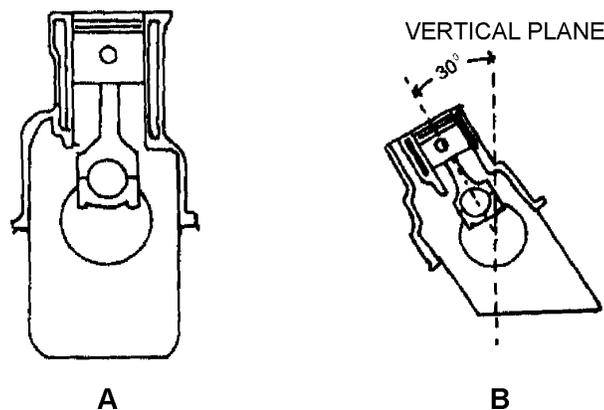


Fig 2-1. Partial cutaway front view of the in-line six-cylinder engine.

## 2102. V-Type Engine Block

The V-type engine consists of two or more cylinders which, when viewed from the front, form the letter "V" (fig. 2-2). The V-type engine block has the cylinders located on each side of the engine at approximately a 45° angle to a vertical plane.

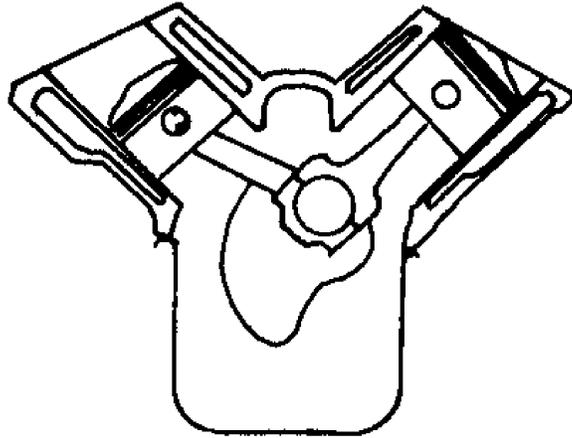


Fig 2-2. Partial cutaway front view of the V-type engine.

The cylinder banks (each line of cylinders) are cast at approximately a 90° angle in relation to one another (fig. 2-3). The casting of the cylinder block in the V-type engine reduces the engine's vibrations because the engine is shorter and more rigid than the in-line engine. Another engine that you may have heard of is the "Y" block. The Y-block is merely a V-type engine with a deeper crankcase.

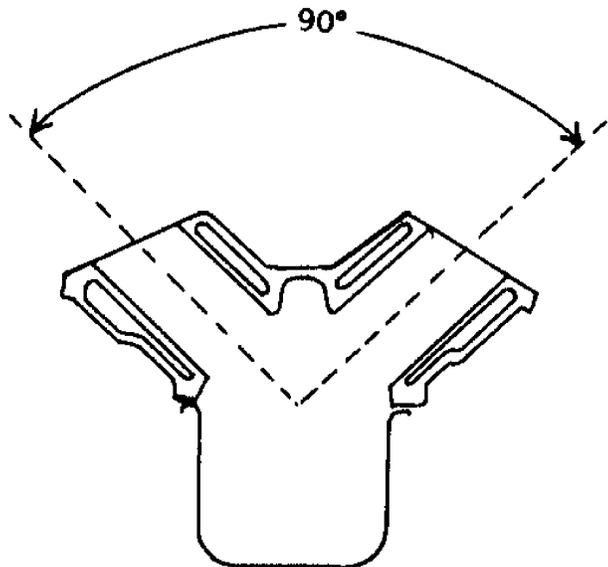


Fig 2-3. The cylinder casting angle of the V-type engine.

### 2103. Horizontally Opposed Engine Block

Horizontally opposed engines consist of two or more cylinders lying on a horizontal plane in two banks with a crankshaft between them (fig 2-4). The cylinders and the crankcase are cast as separate components of the engine and the cylinders may be removed from the crankcase individually.

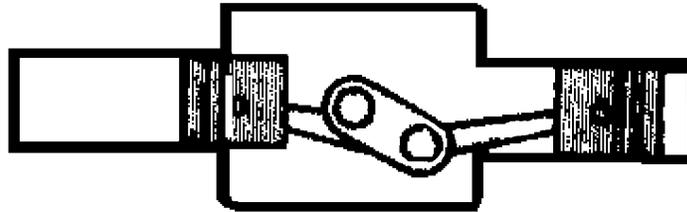


Fig 2-4. Partial cutaway view of the horizontally opposed engine.

OK, let's check your memory. Can you explain the difference between the in-line and the horizontally opposed engine block types? Very good. The in-line engine has the cylinders aligned vertically. The horizontally opposed engine block has cylinders in two banks along a horizontal (rather than vertical) plane with a crankshaft between them.

Now that you are familiar with the first way to classify engine blocks, by cylinder arrangement, let's look at the second way, by cooling systems.

### 2104. Water-Cooled Engines

Water-cooled engines are cooled by the circulation of engine coolant (water and antifreeze) through the engine block. The engine block is cast as one solid piece. In some engines, the cylinders are cut into the cylinder block and are surrounded by the water jacket while others have been designed to use insert-type cylinders (fig 2-5). The engine coolant circulates through the water jacket removing the heat from the cylinder walls. The heated water then moves out to the radiator where it is cooled by fan-assisted air flow. Once cooled, the engine coolant returns to the engine block.

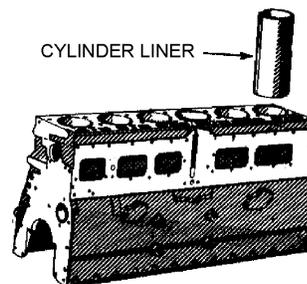


Fig 2-5. Engine with cylinder liners.

Those water-cooled engines designed to use insert-type cylinders will have a longer life span because the cylinder liners are replaceable. There are two types of cylinder liners, wet and dry (fig. 2-6). The dry liner receives full length support from the block while the wet liner receives support only at the top and bottom portions of the liner. Due to the lack of support normally provided by the engine block, the wet liner is much thicker than the dry type.

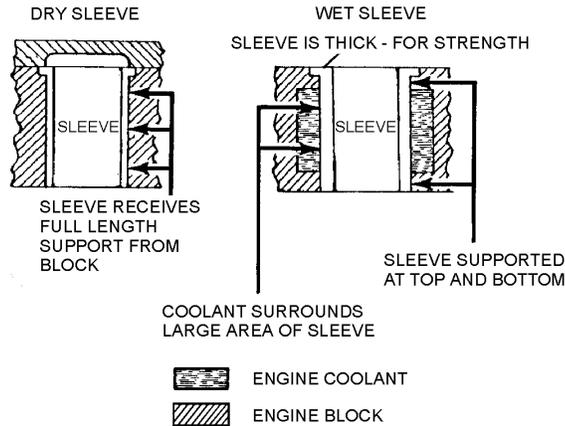


Fig 2-6. Types of cylinder block liners.

### 2105. Air-Cooled Engines

There are various types of air-cooled engines. Some air-cooled engines are similar to water-cooled engines with cylinders in the block. The difference between the two is that the air-cooled engine's cylinder head contains external cooling fins, while other air-cooled engines have no cylinder block, only the crankcase and the cylinders themselves. Each cylinder is cast separately as a cylinder barrel and has cooling fins cast around the outside. The cylinders in this type of engine are replaceable. If one cylinder becomes scored, only the scored cylinder needs to be removed and replaced with a new cylinder. The cylinder head is of the I-head design. The crankcase is cast as a two-piece unit and bolted together (fig. 2-7).

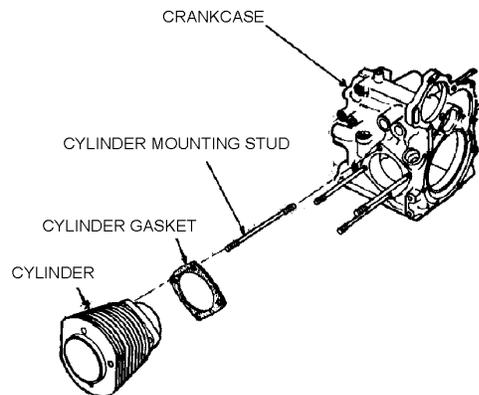


Fig 2-7. Air-cooled engine.

Lesson 1 Exercise: Complete items 1 through 3 and perform the actions required. Check your responses against those listed at the end of this lesson.

1. The \_\_\_\_\_ engine's cylinders are positioned vertically, directly above the crankshaft.
2. The \_\_\_\_\_ engine block has the cylinders located on each side of the engine at approximately a 45° angle to a vertical plane.
3. Which engine block design is case as one solid piece and has cylinders cut into the cylinder block?
  - a. In-line
  - b. V-type
  - c. Horizontally opposed
  - d. Air-cooled
  - e. Water-cooled

#### Lesson 1 Exercise Solutions

	<u>Reference</u>
1. in-line	2101
2. V-type	2102
3. e.	2104

Lesson Summary. In this lesson, you learned that the three most common engine block designs are the in-line, the V-type, and the horizontally opposed. You also now know that the engine block is classified by the cylinder arrangement and by the method with which it is cooled.

Are you ready for more? Let's now discuss the different engine block components, their purpose, and various designs.

## **Lesson 2. ENGINE BLOCK COMPONENTS: PURPOSE AND DESIGN**

### LEARNING OBJECTIVES

1. Given a description of crankshaft design, identify the type of crankshaft described.
2. Identify the two flywheel designs.
3. Select the purpose of the flywheel.
4. Select the reason why most pistons are relieved.
5. Name the two kinds of piston rings.
6. Identify the construction of the connecting rods.
7. Identify the purpose of the connecting rod saddles.

The crankshaft design depends on the number of cylinders the engine has, and, as you already know, how the cylinders are arranged (in-line, V-type, or horizontally opposed).

### **2201. Four-Cylinder Crankshafts**

The crankshaft design determines the firing order of the cylinders by the position of the crankshaft throws and the camshaft.

On the four-cylinder in-line engine crankshaft, the throws are all in the same plane (fig. 2-8). The front and rear throws are  $180^{\circ}$  (on the opposite side of the shaft) from the two center throws. This shaft is used with either three or five main bearing journals, depending on engine block construction. With this crankshaft, power is delivered only to the shaft during  $140^{\circ}$  of each piston's power stroke. Therefore, there is a power lapse of  $40^{\circ}$  between each power stroke of the engine which causes the engine to vibrate. The vibration is partially reduced through the use of a heavy flywheel and a vibration damper, which is discussed in depth in paragraphs 2204 and 2205.

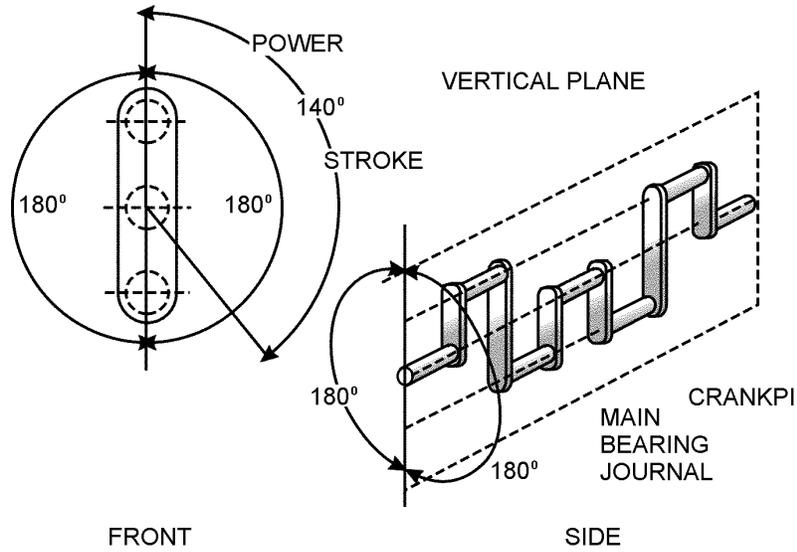


Fig 2-8. Four-cylinder in-line engine crankshaft.

## 2202. Six-Cylinder Crankshafts

The power lapse that we just discussed in the four-cylinder, in-line engine is completely eliminated in the six-cylinder, in-line engine due to the arrangement of the throws on the crankshaft. The throws are constructed on three separate planes spaced  $120^\circ$  apart (fig. 2-9).

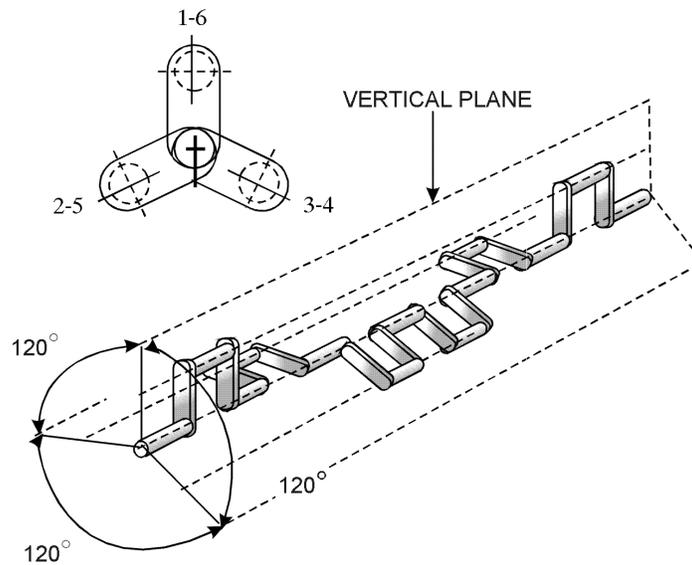


Fig 2-9. Six-cylinder, in-line engine crankshaft.

The  $120^\circ$  arrangement of the throws not only eliminates power lapses, but also gives the engine power overlap. This condition simply means that each power stroke begins before the previous stroke ends. In the case of the six-cylinder, in-line engine, the power overlap is  $20^\circ$ . Though a piston travels through  $120^\circ$  of its power stroke, the power stroke actually lasts for  $140^\circ$  of the crankshaft rotation. In other words, as one piston reaches the  $120^\circ$  of its power stroke, the next piston in the firing order begins its power stroke. This causes two pistons to deliver power to the crankshaft simultaneously during the last  $20^\circ$  of each piston's power stroke.

Therefore, unlike in the last  $40^\circ$  of the power stroke in the four-cylinder, in-line engine, the last  $40^\circ$  of the power stroke in the six-cylinder, in-line engine does not have a power lapse because the next piston is carrying the crankshaft through this  $40^\circ$ .

Additionally, on the six-cylinder, in-line crankshaft, the number one and six throws, the number two and five throws, and the number three and four throws on the same plane. The crankshaft of this engine may be supported by 3, 4, or 7 main journals depending on the manufacturer.

### **2203. V-Type Engine Crankshaft**

Another type of crankshaft is the V-type engine crankshaft. The V-6 engine crankshaft, like the six cylinder, in-line engine crankshaft, has the throws arranged  $120^\circ$  apart. But, the V-type engine crankshaft only has three throws instead of the six. This is due to the fact that each throw accommodates two pistons. Piston number 1 and 2 are mounted on the first throw, pistons 3 and 4 on the second (center) throw, and pistons 5 and 6 on the third throw. This design of the V-type engine gives both power overlap and power lapse.

Let's examine how the overlap and lapse occurs. As the number one piston begins its power stroke and as the crankshaft reaches  $90^\circ$  of its rotation, the number six piston, on a separate throw, begins its power stroke. This causes both pistons to deliver power to the crankshaft during  $50^\circ$  of crankshaft rotation. The next set of pistons to deliver power are pistons that are on the same throw. This means that the number six piston must reach the end of its down stroke before power can be delivered to the number five piston.

Therefore, you have 10° of crankshaft rotation with no power being delivered to the crankshaft. This same condition continues with the remaining three pistons. The flywheel on this engine may be lighter than that of the four-cylinder, in-line engine due to the decreased power lapse. If you added a fourth throw and put each throw on a separate plane and spaced them 90° apart, you would have a crankshaft for a V-8 engine (fig. 2-10). The power overlap in the V-8 engine is the same as the V-6 engine, but the additional cylinders eliminate the power lapse.

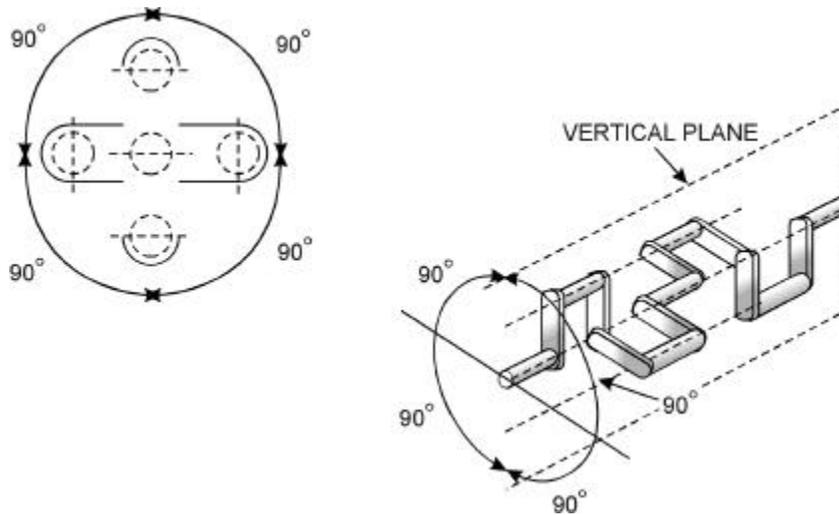


Fig 2-10. V-8 crankshaft.

Someday, you will come across a three-cylinder, in-line engine crankshaft. The three-cylinder, in-line crankshaft is constructed the same way as the six-cylinder, in-line crankshaft with only half as many throws, but with the same power overlap.

Very similar to the three-cylinder, in-line crankshaft is the six-cylinder, horizontally opposed crankshaft. The only difference is the length of the crankpins. They are longer to accommodate two connecting rods per crankpin.

It's almost time to take a break, but first, can you identify the difference between the four-cylinder crankshaft and the V-8 crankshaft? Awesome! You're right again! On the four-cylinder crankshaft, the throws are all on the same plane, whereas on the V-8 crankshaft, the throws are on separate planes.

Also, don't forget that some V-8 engines have throws on only two planes and look very similar to the four-cylinder, in-line crankshaft. The difference is that the two pistons are mounted on each throw and have longer crankpins.

You have found that the number of throws and their length determines the engine that they are designed for. Now that we have discussed crankshafts, power overlap, and power lapse, let's take a look at the flywheel. The flywheel carries the crankshaft through the periods of power lapse, reduces engine vibration, and helps the engine to operate smoothly.

## 2204. Flywheel Designs

The two designs of flywheels are the friction clutch and the fluid coupling (fig. 2-11).

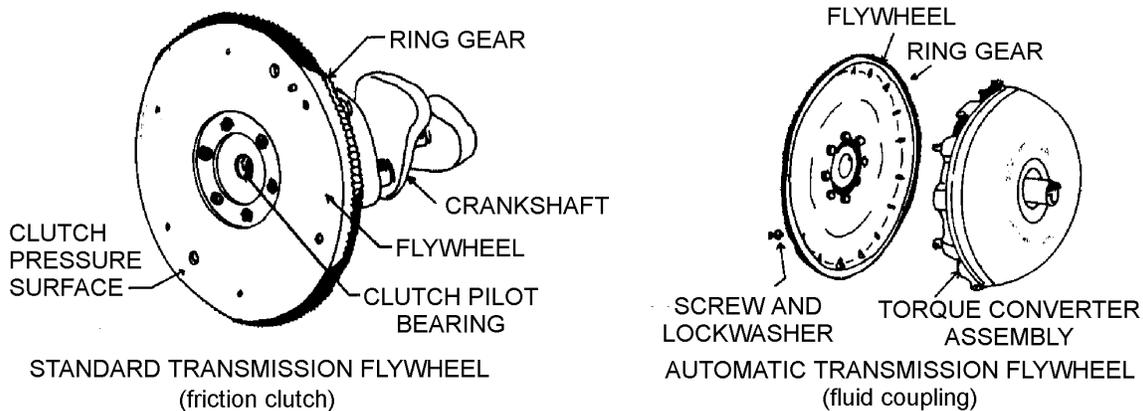


Fig 2-11. Flywheel designs.

The flywheel used with an automatic transmission is made of thin metal containing a ring gear for the starter motor to engage. It is merely a connection between the engine and the fluid coupling of the transmission. The fluid coupling carries the crankshaft through the power lapse. On the other hand, the flywheel used with a standard transmission is constructed of a much heavier metal. The actual weight of the flywheel depends upon the amount of vibration that the engine produces due to the difference in power overlap and power lapse.

Most standard transmission and automatic transmission flywheels are interchangeable on the same crankshaft so that you have a choice of transmissions. But, the transmission and flywheel must be designed by the same manufacturer for that particular engine size and type. Engine vibration is produced not only by the differences in the power overlap and the power lapse, but also by the elasticity of the crankshaft itself. To compensate for the additional vibration, a smaller wheel known as a vibration damper is mounted onto the front of the crankshaft.

## 2205. Vibration Dampers

Vibration dampers are used to dampen out the crankshaft torsional vibration, the twisting action in the crankshaft caused by the sudden application of power. The weight of the flywheel tends to resist the sudden impulse of power applied to the crankshaft. This causes the crankshaft to actually twist. The purpose of the damper is to eliminate this twisting action. Vibration dampers are usually constructed of a small wheel with a larger wheel (balancer weight) mounted around its circumference through a rubber mounting (damping rings).

Refer now to figure 2-12. As the inner wheel is forced to suddenly turn with a jerk, the balancer weight tends to lag behind. The flexible rubber mounting first allows this to happen, until it stretches to its capacity. Then it pulls the balancer weight around with such force that it tends to pass the inner wheel and pull it. This continuous passing and lagging damps out the crankshaft vibration.

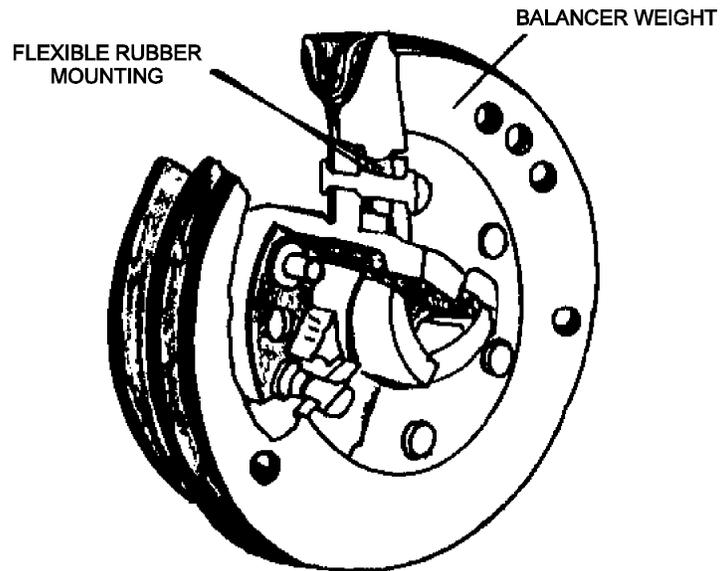


Fig 2-12. A typical vibration damper.

So how's that memory doing? Let's test it, OK? What carries the crankshaft through periods of power lapse? Good! It still works. The flywheel is correct. What is used to "damp out" the torsional vibration caused by the crankshaft? Right again! The vibration damper.

The piston assembly consists of four basic parts: the piston, the rings, the piston pin, and the connecting rod. Let's first discuss the piston.

## 2206. Pistons

Whether it's a diesel or gasoline engine, the basic piston structure remains about the same. Some piston variations may depend on the type of engine being discussed. Figure 2-13 shows a piston cut-away (not all pistons are equipped with reinforcing ribs).

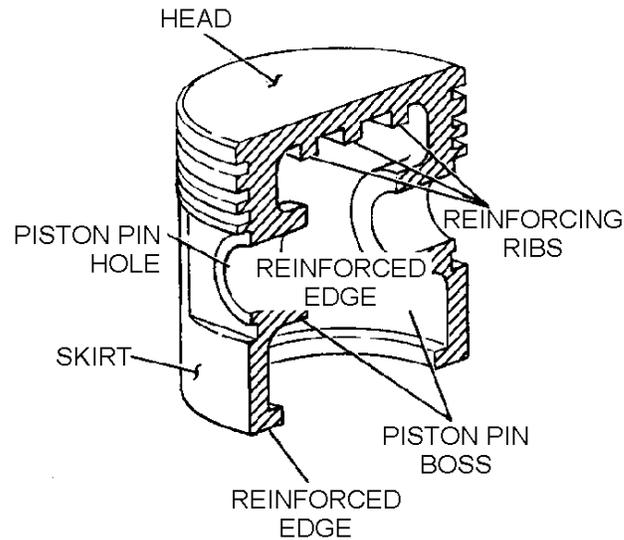


Fig 2-13. Piston structure.

Some pistons used in diesel (compression-ignition) engines form a combustion chamber because of the head design; therefore, the pistons will be of a concave head design. Some diesel pistons are flat and some have thicker heads for additional strength and are cooled by an oil jet that shoots oil on the underside of the piston head. Not all diesel pistons are cooled in this manner. You will find that these pistons vary somewhat in their design.

Gasoline-engine pistons also vary in design. Some are flat on the top and some may have ribs cast on the underside of the piston head for cooling and reinforcement. Some pistons for both the gasoline and the diesel engine are relieved (cut flat) around the piston pin hole to allow for expansion and to reduce weight. Most piston pin bosses (the area immediately surrounding the piston pin hole) are centered; however, some are offset about 1/16 inch to either the compression thrust side or the power thrust side to reduce a condition known as a piston slap (rock) in the cylinders.

This condition is a result of an uneven distribution of pressure on the top of the piston when the gases are ignited. The offset hole tends to hold the piston flat against the cylinder wall under this uneven distribution of pressure.

The portion of the piston below the piston rings is known as the skirt. The piston is kept in alignment by the skirt, which is usually cam ground and elliptical as viewed in the cross-section.

This elliptical shape permits the piston to fit the cylinder, regardless of whether the piston is cold or at working temperature. Its narrowest diameter is at the piston pin bosses, where the metal is thickest. At its widest diameter, the piston skirt, is thinnest. As the piston expands from heat during operation, it becomes round because the expansion is proportional to the thickness of the metal.

You will find a seemingly unending variation in the design of piston skirts (fig. 2-14). These designs are desirable to keep the piston as light as possible and to prevent excessive expansion during engine operation.

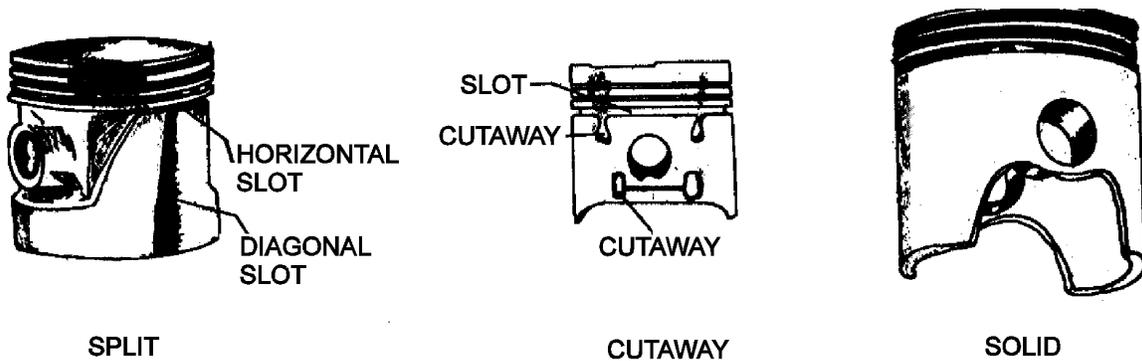


Fig 2-14. The three basic piston skirt designs.

So, have you remembered all that? What type of engine does a concave piston belong to? If you said diesel, you are absolutely right! So, why are most pistons relieved (cut flat) around the piston hole? Right again, to allow for expansion and to reduce weight. And what is the purpose of the piston skirt? Good! It keeps piston alignment.

Piston rings also vary in design, although not as extensively as the pistons. We will now discuss the differences in piston rings.

### 2207. Piston Ring Design

The two types of rings used are compression and oil. Let's discuss the compression rings first. Most compression rings have the same general design. You will find that the primary difference in ring design is on the outer edges of the ring. These design differences are easily distinguished by a cross-sectional view of the ring in figure 2-15.

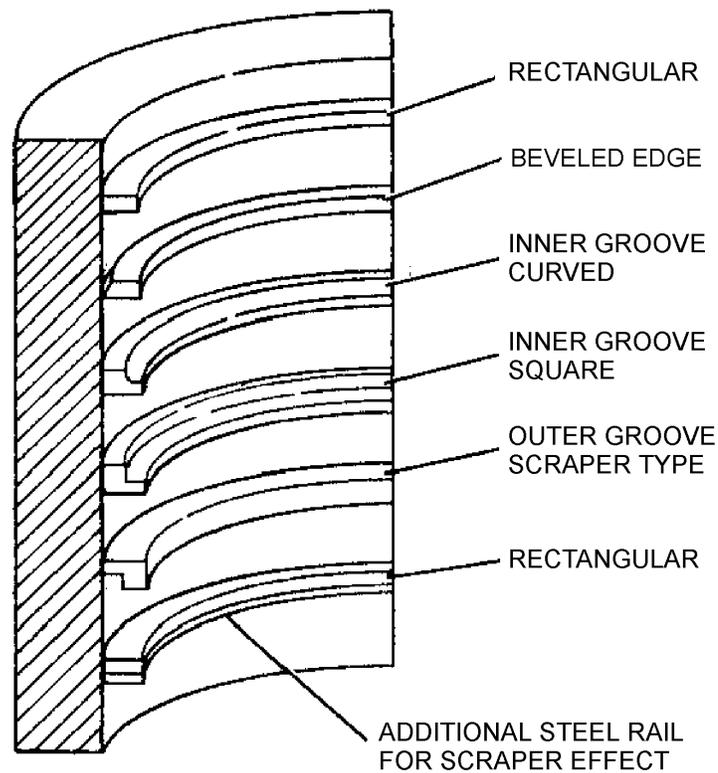


Fig 2-15. Various compression ring designs.

The design of the piston ring depends upon the amount of surface contact desired with the cylinder wall. There are many ring designs--rectangular, beveled edge, rectangular with inner groove curved, rectangular with inner groove square, rectangular outer groove scraper type and rectangular with additional steel rail for scraper effect.

The most common rings used are the rectangular ring and the rectangular with a grooved inner edge. These rings give full face contact with the cylinder wall with less pounds per square inch (psi) exerted. The more pressure exerted by the rings on the cylinder wall, the more drag is created on the engine.

Oil control rings may be of a two-, three-, or four-piece construction. The two-piece ring is rarely used in modern vehicles, so it will not be discussed in this study unit. The three-piece oil ring is probably the most common ring you will find. It consists of two steel rails, separated by a ventilated steel segment. The four-piece oil ring consists of two steel rails separated by a cast-iron center section, which resembles the old cast-iron oil ring mentioned earlier, and a spring steel expander. Figure 2-16 illustrates the various oil control ring designs.

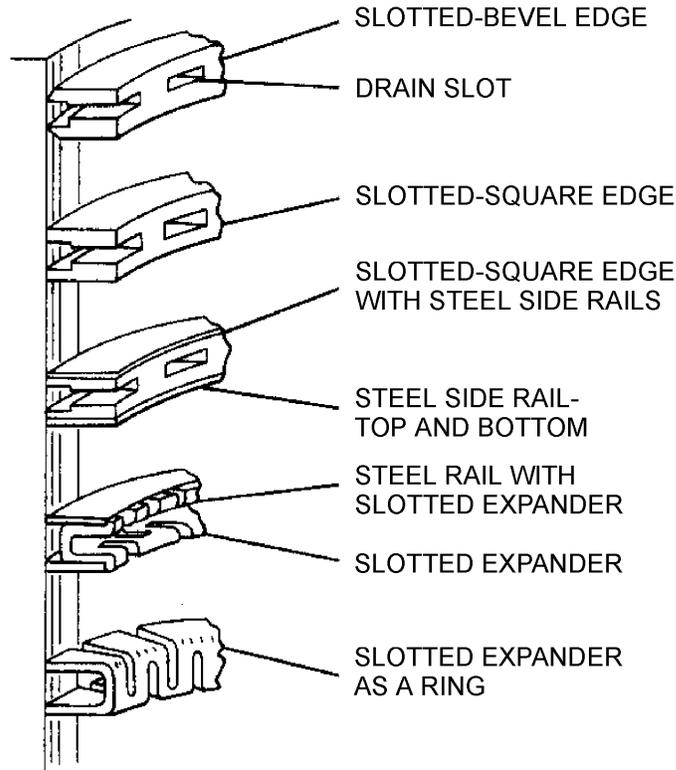


Fig 2-16. Various oil control ring designs.

To complete the discussion of the piston assembly, take a look at the designs of the connecting rods.

## 2208. Connecting Rods

The connecting rods are of an I-beam construction with a piston pin hole at the upper end, a saddle at the lower end, and a separate bearing cap connected to the connecting rod by two bolts or studs and nuts (fig. 2-17).

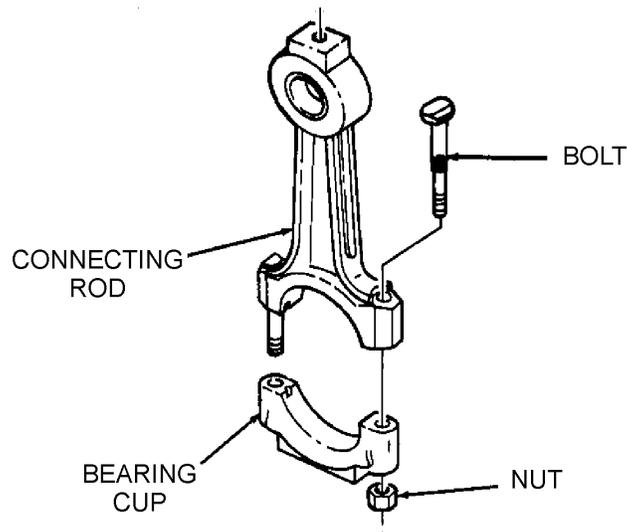


Fig 2-17. Typical connecting rod.

Opposed- and V-type cylinders require a connecting rod with the saddle offset to accommodate the opposing pistons because the cylinders are slightly offset in relation to one another (fig 2-18).

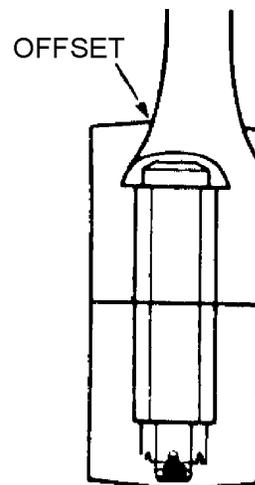


Fig 2-18. Offset connecting rod saddle used in opposed and V-type engines.

The saddle of some connecting rods may be cut at an angle to facilitate the removal and installation of the piston assembly (fig. 2-19). Aside from these two variations, there is little, if any, variation in design.

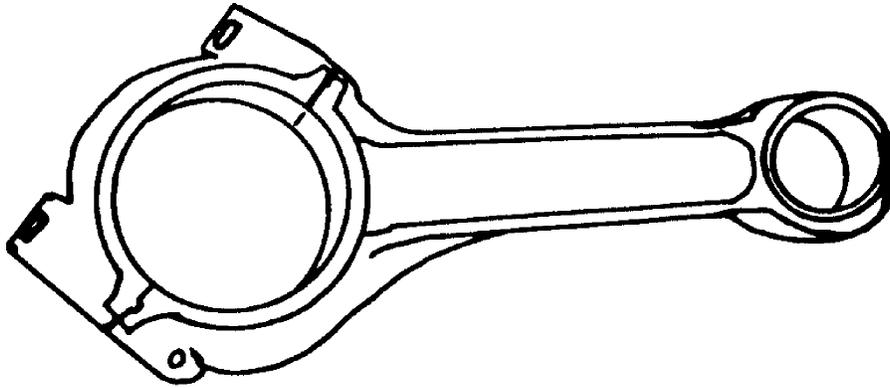


Fig 2-19. Angled connecting rod saddle.

Do you feel like the shop duty expert yet? What have you learned so far? What determines piston ring design? Not bad! The design depends on the amount of surface contact. So what about the connecting rods? Can you remember what a connecting rod consists of? Very Good! I-beam construction, piston hole at the upper end and a saddle at the lower end with a bearing cap connected to the connecting rod by two bolts or studs and nuts.

Lesson 2 Exercise: Complete items 1 through 8 by performing the action required. Check your responses against those listed at the end of this lesson.

1. Which type of crankshaft design has its throws all on the same plane with the front and rear throws  $180^{\circ}$  from the two center throws and power delivered to the shaft only during  $140^{\circ}$  of each piston's power stroke?
  - a. Four-cylinder, in-line engine crankshaft
  - b. Six-cylinder, in-line engine crankshaft
  - c. V-6 engine crankshaft
  - d. V-8 engine crankshaft
  - e. Three-cylinder, in-line engine crankshaft
  
2. Which type of crankshaft design has three throws (two pistons each) spaced  $120^{\circ}$  apart on three separate planes, with both a power lapse and power overlap?
  - a. Four-cylinder, in-line engine crankshaft
  - b. Six-cylinder, in-line engine crankshaft
  - c. V-6 engine crankshaft
  - d. V-8 engine crankshaft
  - e. Three-cylinder, in-line engine crankshaft

3. The purpose of the flywheel is to
  - a. reduce wear and tear on the transmission.
  - b. carry the crankshaft through periods of power lapse.
  - c. allow for proper timing of the engine.
  - d. provide a place to mount the engine to the transmission.
  
4. The two types of flywheel designs are \_\_\_\_\_ and \_\_\_\_\_.
  
5. Most pistons are relieved (cut flat) around the piston pin hole to \_\_\_\_\_
  - a. allow for proper up and down movement.
  - b. allow for expansion and to reduce weight.
  - c. allow for the piston to remain aligned.
  - d. stop the piston from slapping the side of the cylinder wall.
  
6. What two kinds of rings are used on pistons?
 

a. Expansion and slotted	c. Compression and groove
b. Cross and oil control	d. Compression and oil control
  
7. Connecting rods are constructed as
 

a. H-beam.	c. solid-beam.
b. I-beam.	d. offset-beam.
  
8. Why are the saddles of some connecting rods cut at an angle?  
\_\_\_\_\_

## Lesson 2 Exercise Solutions

	<u>Reference</u>
1. a.	2201
2. b.	2202
3. b.	2203
4. friction clutch and fluid coupling	2204
5. b.	2206
6. d.	2207
7. b.	2208
8. To facilitate removal and installation of the piston	2208

Lesson Summary. In this lesson, you not only learned about crankshaft and piston variations, but also that the flywheel is responsible for carrying the crankshaft through power lapses and that the vibration damper helps reduce engine vibration. Let's continue now by discussing the cylinder head and related components.

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### **Lesson 3. CYLINDER HEAD COMPONENTS: PURPOSE AND DESIGN**

#### LEARNING OBJECTIVES

1. Given a description of cylinder head design, identify the type of engine described.
2. Given a description of valve design, identify the type of valve described.
3. Identify the valve arrangement of the I-head, L-head, and F-head engines.

#### **2301. Cylinder Head Design**

Cylinder-head design depends on the valve arrangement of the engine it is used on. The cylinder head is of two designs, flat-head and valve-in-head. The flat-head is designed for use with the L-head engine and the valve-in-head is designed for use with the I-head and F-head engines. Remember, some diesel engines have the combustion chamber located in the top of the piston.

You may have heard of an engine referred to as a flat-head six, a flat-head V-8, an over-head-valve six, or an over-head-valve V-8. These are common terms referring to the valve arrangement and the cylinder block. Therefore, you might say that engines are not only classified by cylinder arrangement and numbers, but also by valve arrangement. Let's take a look at the technical terms which refer to valves and valve arrangements.

#### **2302. Valves**

Three of the more common valve designs are the mushroom, the tulip and the semi-tulip (fig. 2-20). With the exception of the top of the valve head and the valve-lock grooves, all poppet valves have basically the same design, though sizes will vary. The design of the top of the valve, in conjunction with materials used by the manufacturer, will determine the temperature range of the valve during operation.

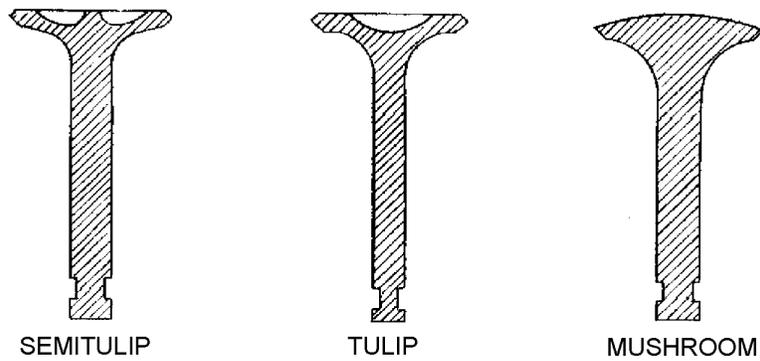


Fig 2-20. Three of the more common valve designs.

### 2303. I-head, L-head, and F-head Valve Arrangements

An engine's valves may be located either in the cylinder head, the cylinder block, or both. If the valves are located in the head, which is the most common arrangement found today, the engine is known as an I-head engine. The valves are positioned upside-down and directly above the piston in the cylinder head. On the cross-sectional view, an imaginary line has been drawn (fig. 2-21).

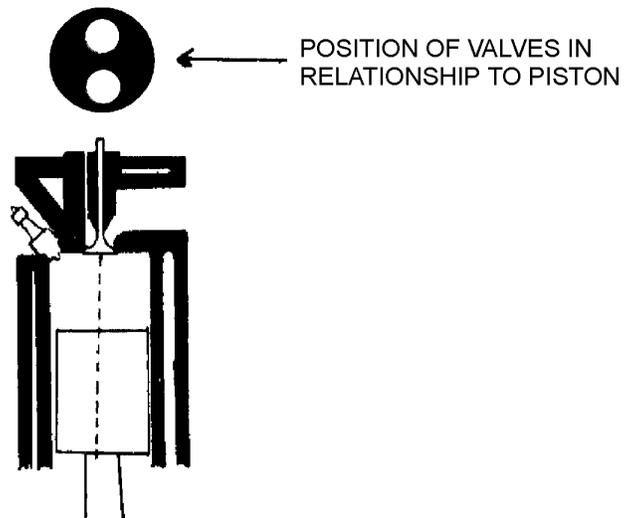


Fig 2-21. I-head valve arrangement.

For the camshaft to operate the valve, a pushrod and a rocker arm must be incorporated between the valve lifter (tappet) and the valve stem (fig. 2-22). The I-head valve arrangement is often referred to as overhead valves, probably more often than its technical term.

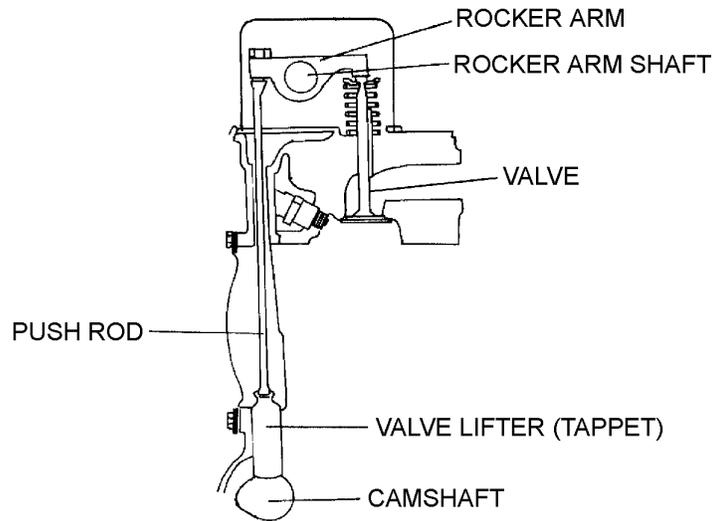


Fig 2-22. The I-head valve train.

The flat-head arrangement of the valves is technically termed as the L-head. In the L-head engine, the valves are located in the cylinder block alongside the cylinder. Draw an imaginary line across the valve head of the cross-section of this engine and continue the line over to the center of the piston head. You should be able to see an inverted "L" (dotted line in fig. 2-23).

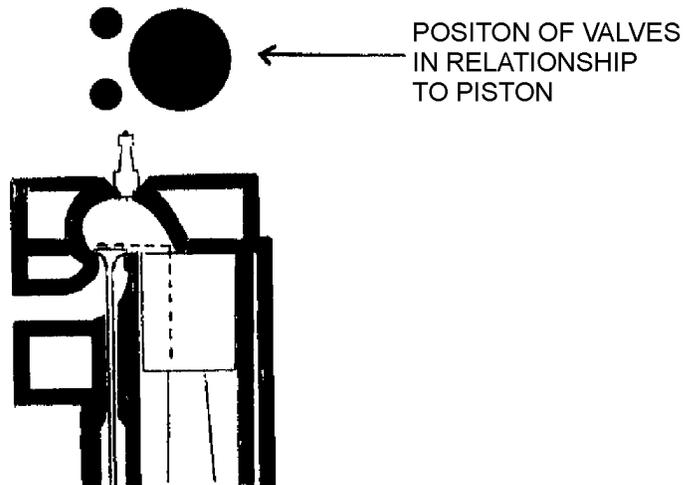


Fig 2-23. The L-head valve arrangement.

The F-head arrangement is sometimes termed valve-in-head/valve-in-block. However, you will almost always hear it referred to by its more technical name, the F-head. This valve arrangement is actually a combination of the two we just covered. One valve, usually the intake valve, is located in the cylinder head and the exhaust valve is in the cylinder block.

Again, draw imaginary lines to help you remember the valve arrangement. Draw an imaginary line across the exhaust valve and continue it across to the center of the piston head. Now, draw another line across the intake valve head. Continue this line until it is the same length as the first. Now draw another line down the center of the piston, joining the ends of both the previous lines. You should find that you have drawn a distorted "F" (dotted line in fig. 2-24).

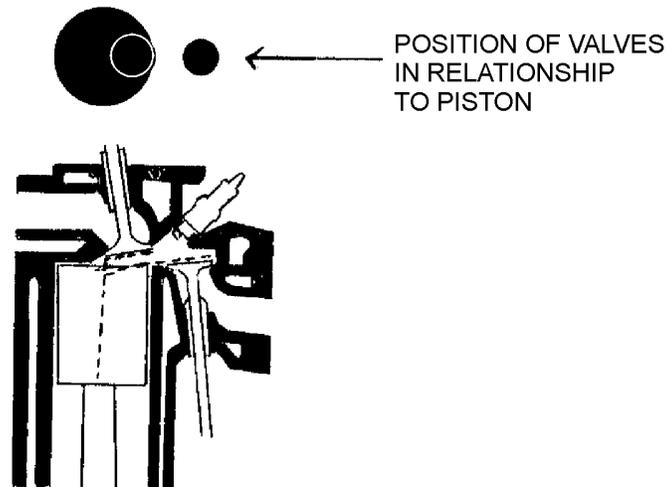


Fig 2-24. F-head valve arrangement.

Lesson 3 Exercise: Complete items 1 through 3 by performing the action required. Check your responses against those listed at the end of this lesson.

1. The valve-in-head cylinder design is designed for use with which type(s) of engine?
 

a. F-head	c. I-head and F-head
b. L-head	d. I head and L-head
  
2. The engine with the intake valve located in the cylinder head and the exhaust valve located in the cylinder block is the \_\_\_\_\_ engine arrangement.
 

a. I-head	c. L-head
b. F-head	d. V-head

3. What are the three common valve designs?
  - a. T-top, mushroom, and valve lock
  - b. Mushroom, tulip, and T-top
  - c. Tulip, mushroom, and valve
  - d. Mushroom, tulip, and semi-tulip
  
4. Valves are located in the \_\_\_\_\_ and/or the \_\_\_\_\_.
  - a. cylinder head; cylinder block
  - b. cylinder block; crankcase
  - c. cylinder walls; crankcase
  - d. crankcase; cylinder head
  
5. The valve arrangements used most are the \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
 

a. I-head, T-head and L-head	c. L-head, F-head and Y-head
b. I-head, L-head and F-head	d. M-head, F-head and L-head

### Lesson 3 Exercise Solutions

		<u>Reference</u>
1.	c..	2301
2.	b.	2303
3.	d.	2302
4.	a.	2303
5.	b.	2303

Lesson Summary. In Lesson 3, you learned that the cylinder head design depends upon the engine's valve arrangement. The cylinder head consists of two basic designs--the flat-head and the valve-in-head. The combustion chambers on a gasoline (spark-ignition) engine are located in the head and the combustion chambers on the diesel engine are located in the pistons. Finally, you learned the three most common valves (mushroom, tulip and semi-tulip) and the three types of valve arrangements (I-head, L-head and F-head).

### UNIT SUMMARY

In this study unit, you have learned the various engine and component designs used in the construction of engines. Knowing this information will help you diagnose and repair when called upon to do so; and in the next study unit you will learn just that.

## STUDY UNIT 3

### ENGINE MALFUNCTION, TROUBLESHOOTING, AND REMEDY

Introduction. As a Marine Corps mechanic, most of your work will probably consist of maintenance that involves such things as oil changes, chassis lubrication, inspections and tune-ups. If performed properly, maintenance can save you a lot of heavy repair work. It helps you to spot troubles at an early stage when only a minor adjustment or repair is required. This procedure saves you time and the Marine Corps thousands of dollars annually. Time and money are saved because you replace or repair the right part the first time. This study unit will provide you the knowledge needed in identifying malfunctions and their causes and applying the appropriate remedy.

#### Lesson 1. ENGINE BLOCK

1. Given specific engine block malfunctions, identify the cause of the malfunction.
2. Given a variety of engine malfunctions, identify the remedy for each malfunction.

Probably the most important thing for a mechanic to know is how to diagnose troubles in a motor vehicle. This diagnosis consists merely of performing checks and tests in a logical, systematic sequence. Let's begin discussing one of the most probable causes for engine malfunctions--the cylinders.

#### 3101. Cylinder Malfunctions

Although the cylinder block is not actually a functioning part of the engine, the functioning components rely on it heavily. Therefore, the block can be the source of some engine malfunctions. For example, take the cylinder walls. The piston rings rely on the smooth surface to enable them to move up and down with the piston and yet maintain a pressure-tight seal. If this pressure-tight seal is lost, there will be a loss of compression and power. There will also be a loss of engine lubricating oil.

If a cylinder wall becomes scored (deeply scratched), what would be a good indication of this condition? If you said excessive consumption of oil through burning, you are off to a good start. Scores in the cylinder wall allow oil to bypass the rings and enter the combustion chamber where it is burned with the fuel-air mixture. This will eventually cause the cylinder to misfire. There will be evidence of misfiring due to loss of compression during the compression stroke and pressure during the power stroke. However, in the early stages this will only show up on test equipment during engine analysis.

### 3102. Cylinder Troubleshooting and Remedies

If you suspect oil burning, take a look at the inside of the tailpipe. It will be covered with a coating of black soot. To further confirm your suspicions, have the motor vehicle operator "rev" or "gun" the engine. A light blue smoke will come from the tailpipe. Once your suspicions are confirmed, you must be certain the oil burning is not caused by some other defect. Perform a compression test on the engine. This will also help you to locate the defective cylinder.

Now, break out the compression gage kit and check the parts of the kit, making sure the gage reads zero and the adapters are clean and free of cracks. Adapters vary in shape and size to allow the compression gage to be used on various type engines.

Your next step before starting the engine is to check the vehicle batteries. They must be in good condition and the crankcase oil must be at the full mark on the dipstick.

Start the engine and let it warm up to operating temperature. This allows normal expansion of the metals and will give you a true reading when you perform the test. After operating temperature has been reached, turn the ignition switch to the off position.

Loosen all the spark plugs a turn or two, and, with a low pressure air hose, blow all dirt and other foreign matter from around the spark plugs.

Remove all the spark plugs and clean any grease or oil from the spark plug hole with a clean rag. Now open the throttle and choke to set the throttle plate and choke in the wide open position. Switch the ignition off or remove the primary wire (cable coupling) from the distributor. This will prevent current from flowing across the points and a high tension spark will not be produced.

You will perform a "dry" compression test first. Choose the proper size adapter of the compression gage. Insert the compression gage into the spark plug hole of the number one cylinder (fig 3-1) and have a helper crank the engine over about ten times. During this process, if the operator carefully observes the gage hand, a sticking valve may easily be detected. The hand progressively rises with each revolution of the starting motor until no further movement of the gage hand is obtained.



Fig 3-1. Inserting compression gage into spark plug hole.

The indicated pressure on the gage represents the maximum compression pressure under prevailing conditions. Should the gage hand remain fixed at any one of the "beats" or revolutions of the starting motor and then rise again, the point where it lagged would indicate a valve sticking in the open position. Compression pressures will vary and will be higher in newer engines compared to older ones.

Write down the amount of pressure indicated by the gage. Repeat this procedure on each cylinder, counting the number of turns on each cylinder, until all cylinder compression readings have been recorded. If the readings do not vary in pressure more than 10 pounds per square inch (psi), your oil consumption is probably due to other causes. If the variation is more than 10 psi, a "wet" compression test should be performed. This test is performed in the same manner as the "dry" test except for one step. Before inserting the gage into the spark plug hole, squirt about four shots of oil from a trigger-type oil can into the hole (fig 3-2) and have the operator spin the engine with the starter switch. Now you are ready to insert the gage and proceed as if you were taking a "dry" test.



Fig 3-2. Preparation for a "wet" test.

Perform the test on only those cylinders that had a low "dry" reading. The results of the test may show a rise in pressure or the readings may remain the same. If a rise in pressure is shown, there is a possibility of scored walls that allow pressure to bypass the piston. The cylinder head must be removed to make a visual inspection of the cylinders. If the pressure remains the same in the "wet" test as it was with the "dry" test, the source of the problem is defective valves or valve seats. However, low readings on adjacent cylinders usually indicate cylinder head gasket leakage between cylinders. If the walls are scored, the defective cylinder must be rebored.

Let's stop for a second and see what you've learned so far. What would cause a loss of compression in a cylinder? Good! A scored or deeply scratched cylinder wall. How would you remedy this problem? Right again. You would rebore the defective cylinder.

### 3103. Water Jacket Malfunctions

Water jackets, when properly maintained, will seldom be a source of malfunctions. Proper maintenance of the water jacket consists merely of keeping it filled and free of rust and corrosion. This is accomplished through a daily check of the coolant and the use of antirust chemicals. When chemicals are not available, periodic flushing of the cooling system is necessary.

When a motor vehicle operator approaches you and complains that his engine is overheating, consider first whether it is an air-cooled or water-cooled engine. Let's say it is a water-cooled engine. You know that water or a commercial coolant is used in the system and it circulates through the engine block and cylinder head surrounding the cylinders and combustion chamber (fig 3-3). A quick visual inspection will eliminate the fan, fan belt, and water pump. Apparently then, if the engine is "running hot," this coolant is not circulating. There are two very good reasons for coolant not circulating. What do you think the reasons would be?

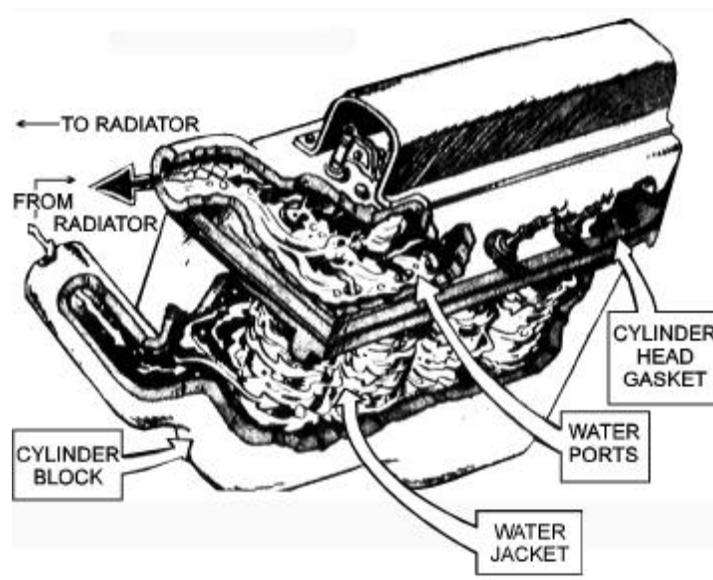


Fig 3-3. Engine water jacket.

### 3104. Water Jacket Troubleshooting and Remedies

If you decided that the thermostat is faulty or the water jackets are dry or clogged, you are right. First, start the engine and fill the radiator. Watch through the radiator opening to see if the water is circulating. If it isn't, you should troubleshoot the thermostat first. Do this by simply removing the thermostat and checking the radiator again for circulation. If you still don't have circulation, the water jackets must be clogged and the entire cooling system must be flushed.

Allow the engine to run for 10 to 15 minutes so that pressure will build up inside the water jackets. Now check the outside of the engine for leaks.

Note: Leaks will usually occur in the core plugs (fig 3-4). They cannot be repaired but must be replaced. If there are no visible leaks, the engine must have an internal leak.

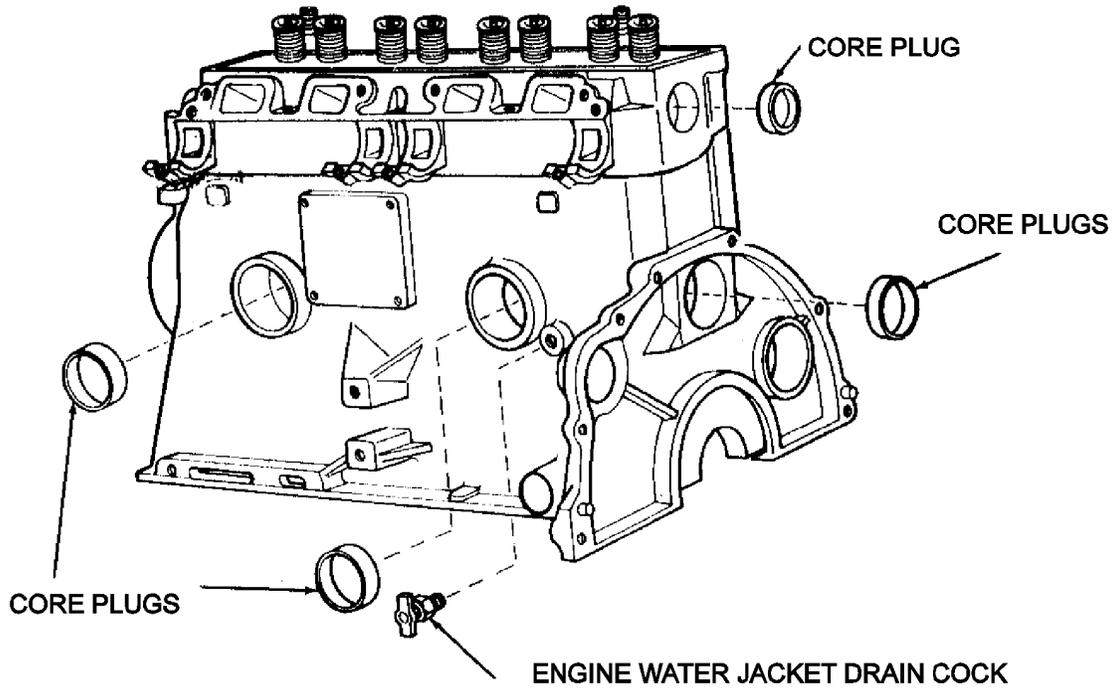


Fig 3-4. Possible areas of coolant leakage.

The walls of the jacket could be cracked into the cylinder wall. The way to check for a cracked water jacket is to remove the radiator cap with the engine running and look inside (fig 3-5).

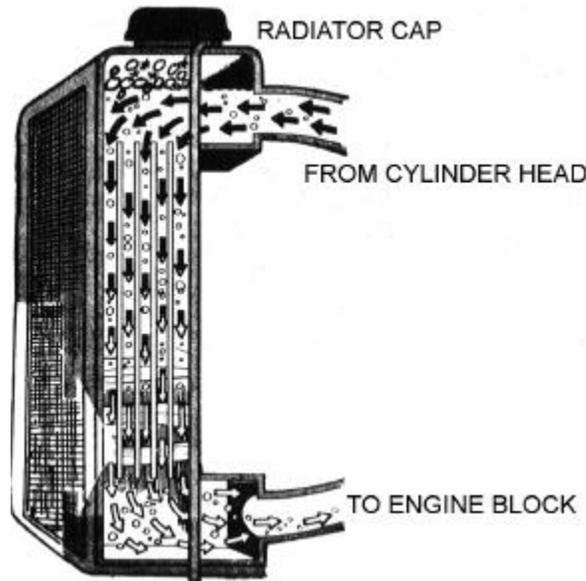


Fig 3-5. Cutaway of radiator showing bubbling as opposed to normal swirling of coolant.

If bubbles are present, they are most likely due to a blown head gasket but in some cases may be caused by pressure escaping through a crack in the cylinder wall and into the water jacket. This is the path of least resistance during the compression and power strokes. Of course, during the intake stroke, the water will be drawn into the cylinder (fig 3-6).

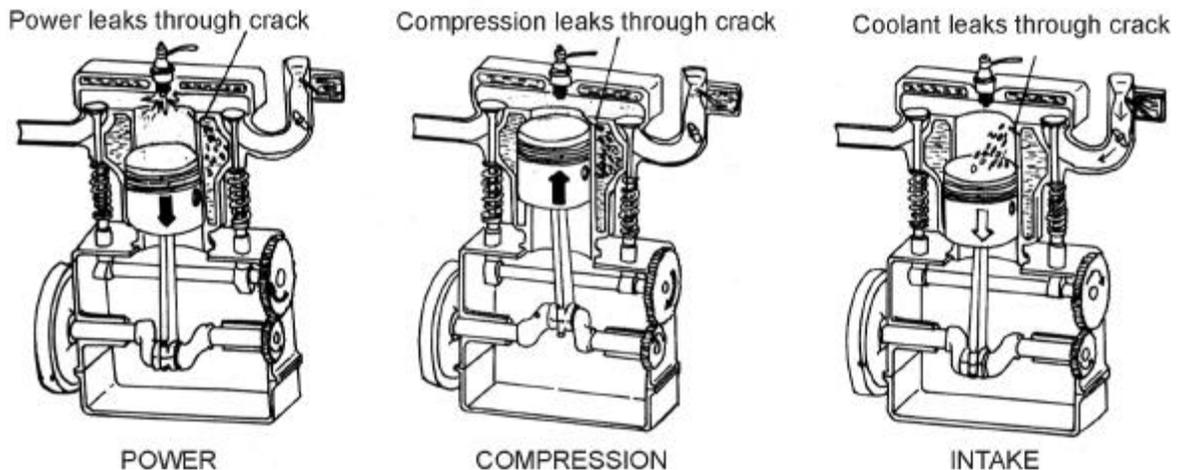


Fig 3-6. Cracked water jacket.

Let's confirm the defect now. Is steam being emitted from the tailpipe? Steam may look like burning oil, but it disappears soon after it leaves the tailpipe while smoke from burning oil lingers. What if you are losing coolant internally and there are no bubbles and no steam? Take another look at the water in the radiator while the engine is not operating. Perhaps you can detect an oily film on the water. It could be that the water from the water jacket is leaking into the oil passages, or that oil is leaking into the jacket. Pull the "dipstick" out of the engine and examine the oil on the end of it. If it appears milky or foamy, you can assume that a leak exists between the water jacket and oil passages.

In rare cases, this may be the result of a cracked engine block, but it is usually due to a broken head gasket. In the cases of this type of crack, the block can probably be sealed. If it is the head gasket, both the cylinder head and the block must be checked for a smooth, flat surface and then ground (machined smooth) if necessary.

What would cause bubbles to be in the radiator? If you said water jacket crack in the cylinder wall, you are absolutely right. What would be another way of confirming this? Very good! With the engine running, check the tailpipe to see if steam is being emitted. A cracked cylinder block may have to be replaced, but in some cases the defect may be remedied. How? You're good! By sealing the cylinder block.

### 3105. Air Cooling System Malfunctions

If an overheating problem exists in an air-cooled engine, and the fan and belt are serviceable, the cooling fins may have a build-up of dirt or other foreign matter between them. Air must be able to pass between the fins to carry the heat away from the engine (fig 3-7).

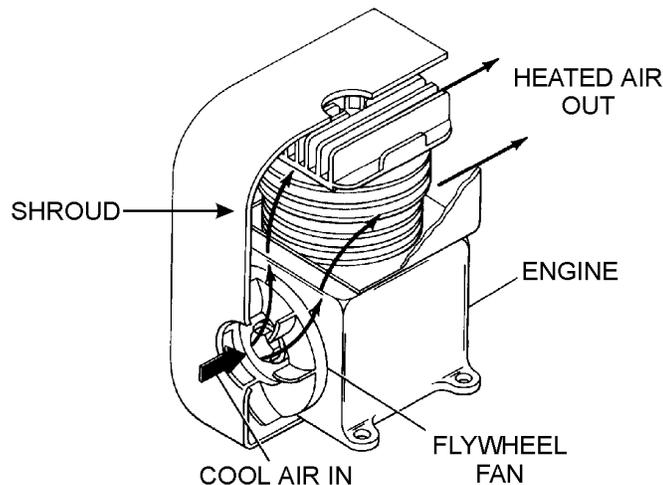


Fig 3-7. Cooling fins.

A shroud (a contoured sheet of metal which channels air flow) usually covers the entire engine, or at least the larger portion of it. This shroud directs the flow of air around the engine and through the cooling fins.

Naturally, if the shroud is loose, it will not hold enough air inside to properly cool the engine. The part of the engine near the fan may be cool, but the remaining portion of the engine will likely overheat.

Each fin cools a particular portion of the engine, and, if the fins become chipped, that portion of the engine will form a "hotspot." This is extremely critical in the cylinder head since a hotspot in the combustion chamber will cause the fuel to ignite prematurely, affecting engine performance. Oil is also a major factor in the cooling of an air-cooled engine. An oil cooler, which is very similar to a miniature radiator, is provided. Here again, a little preventive maintenance solves problems before they begin. Prescribed periodic oil and oil filter changes will prevent oil from clogging and reducing oil circulation. Poor oil circulation will cause the engine to overheat by not lubricating high friction surfaces properly.

The condition of clogged oil passages may be detected by an abnormally high or low pressure reading on the instrument panel's oil pressure gage and verified by removing the rocker arm cover. Either some or all of the rocker arms may not be receiving oil if the pressurized passages are clogged (fig 3-8). If the return passages are clogged, oil will be found "standing" on the top of the cylinder head where the rocker arms are located. To remedy this situation, you may have to remove the rocker arm shaft, soak it in a strong parts cleaner, and clear all oil passages with a soft wire. The oil should be changed immediately after this is done and as frequently as possible until the oil additives have had ample time to clean the system.

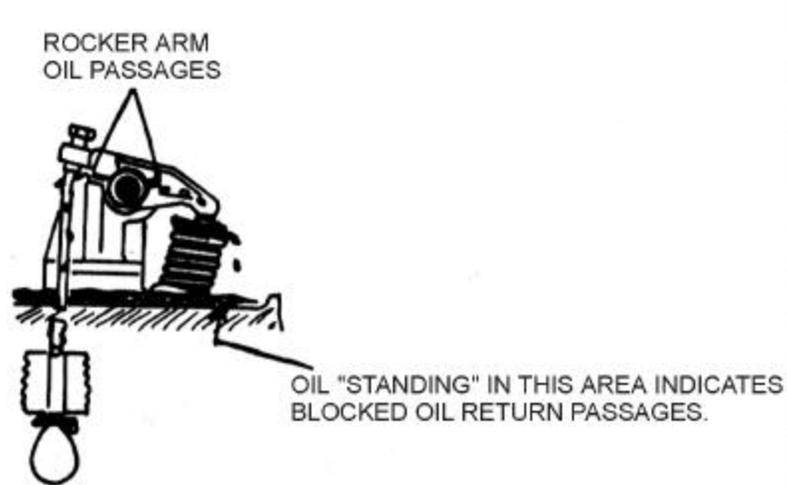


Fig 3-8. Evidence of clogged oil return passages.

### 3106. Air Cooling System Troubleshooting and Remedies

Conduct a visual inspection of the cooling fins for dirt and/or damage. Dirt clogging the fins is usually remedied by cleaning the fins with a high-pressure air gun. Inspect the shroud to ensure it is firmly in place.

Check the oil cooler. It must be cleaned periodically with an air gun, or the engine will overheat. The oil passages must be kept extremely clean. This is accomplished by timely oil changes and oil filter changes.

What would cause a "hotspot" to form in a certain area of the engine? Great! A chipped or broken cooling fin is correct. What causes clogged oil passages? That's correct, dirty oil.

Lesson 1 Exercise: Complete items 1 through 7 by performing the actions required. Check your responses against those listed at the end of this lesson.

1. Which of the following would cause loss of compression in a cylinder?
  - a. Scored cylinder wall
  - b. Defective coil wire
  - c. Defective sparkplugs
  - d. Warped flywheel
  
2. The malfunction that most closely matches the symptoms of excessive loss of engine coolant, bubbling radiator, and steam emitting from the tailpipe is a leak between the water
  - a. jacket and the water pump.
  - b. jacket and head gasket.
  - c. jacket and the crankcase.
  - d. pump and the water jacket.
  
3. A cracked cylinder block may have to be replaced, but in some cases the defect may be remedied by
  - a. dipping the cylinder block.
  - b. sealing the cylinder block.
  - c. welding the cylinder head.
  - d. flushing the cylinder block.
  
4. To determine that oil burning is caused by a cylinder malfunction and not something else, you would \_\_\_\_\_ .
  
5. What are two possible causes for liquid coolant not circulating?  
\_\_\_\_\_  
\_\_\_\_\_
  
6. If an overheating problem exists in an air-cooled engine and you've determined that the fan and belt are serviceable, what is the likely cause?  
\_\_\_\_\_
  
7. One way to eliminate most oil cooler malfunctions is by \_\_\_\_\_  
\_\_\_\_\_

## Lesson 1 Exercise Solutions

	<u>Reference</u>
1. a.	3101
2. b.	3104
3. b.	3104
4. Perform a compression test on the engine	3102
5. Faulty thermostat; dry or clogged water jackets.	3104
6. Cooling fins are broken or clogged with dirt	3105
7. timely oil and oil filter changes	3106

Lesson Summary. In Lesson 1 you learned common engine block malfunctions which included scored cylinders and cracked water jackets. You also learned the correct procedures in troubleshooting and the remedies for each malfunction.

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## Lesson 2. CYLINDER HEAD

### LEARNING OBJECTIVE

Identify the appropriate action to troubleshoot cylinder head malfunctions.

The same problems, diagnoses, and remedies that applied to the engine block also apply to the cylinder head. Some additional ones apply to the cylinder head as well.

### **3201. Cylinder Head Malfunctions**

A cracked cylinder head will produce the same results as a cracked engine block, and the same holds true for clogged oil passages in the cylinder head. A common problem in cylinder heads is a "blown" head gasket (fig. 3-9). This is usually indicated by two adjacent (side-by-side) cylinders failing to deliver power (misfiring).

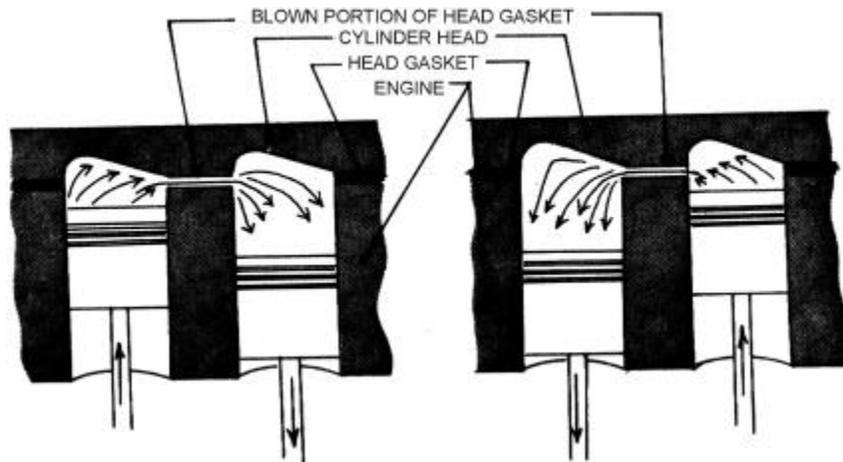


Fig 3-9. Flow of air due to blown cylinder head gasket.

Carbon build-up is another problem encountered with heads. The carbon tends to hold heat which ignites the fuel prematurely. When preignition is experienced in the engine and it cannot be remedied through the electrical system, the head is usually at fault.

### 3202. Cylinder Head Troubleshooting and Remedies

If the two adjacent cylinders are misfiring, perform a compression test to verify the problem before removing the cylinder head (it could be faulty ignition). When a head gasket "blows," the break is usually between two adjacent cylinders, and air, instead of being compressed, simply moves back and forth between the cylinders (fig 3-9). A compression test would indicate little or no compression in either of these two cylinders. To remedy this problem, the head gasket must be replaced. The cylinder head and block must be checked to ensure the surface has not warped. A perfectly flat surface is required to ensure an air-tight seal. If an uneven surface is detected on either the cylinder head or the cylinder block, it must be machined flat (commonly termed shaving or grinding the head or block).

If preignition exists, and after troubleshooting the electrical system, it is determined that the cylinder head is the cause, remedy the malfunction by removing the head and cleaning out all carbon deposits.

Lesson 2 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of the lesson.

1. If the bottom of a cylinder head is not perfectly smooth, a "blown" head gasket is likely to result. What is a symptom of this malfunction?
  - a. Black smoke from the exhaust
  - b. The engine will not turn
  - c. Two adjacent cylinders fail to deliver power
  - d. Blue smoke from the exhaust

2. If a cylinder head becomes warped, it is no longer perfectly smooth and must be
  - a. bolted extra tightly on the cylinder block.
  - b. installed with a good sealer on the head gasket.
  - c. rebored in all cases.
  - d. machined to a flat, smoothed surface before installation.

Lesson 2 Exercise Solutions

		<u>Reference</u>
1.	c.	3201
2.	d.	3202

Lesson Summary. You learned in Lesson 2 that the most common cylinder problem is a "blown" head gasket. To remedy a defective head gasket, you must first ensure the cylinder head and cylinder block surfaces are perfectly flat and smooth. Once that is accomplished, you replace the head gasket.

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**Lesson 3. PISTON ASSEMBLY**

LEARNING OBJECTIVE

Given specific instances of piston assembly malfunctions, identify the appropriate troubleshooting action.

**3301. Piston Malfunctions**

The piston assembly is a common cause of engine malfunctions. Let's start with the defect that could be most injurious to the engine due to broken fragments, a cracked piston head. If the piston head has a hole or crack in it, how would that affect the intake, compression, and power strokes?

If you knew that a cracked piston would allow pressure to pass through it, you are on the right track. When a piston is cracked or has a hole in it, a partial vacuum cannot be created on the intake stroke; therefore, compression and power cannot take place.

Another factor that will help you with your diagnosis is the sound usually produced by a cracked piston head. Remove a spark plug from an engine and let it run for a moment or two. The "clacking" sound produced by the missing spark plug is very similar to the sound that may be produced by a cracked piston.

Before pulling the cylinder head off to verify a misfire you suspect is a cracked piston, test the cylinder in case the malfunction is caused by another source. What tests are you going to perform on the cylinder?

### 3302. Piston Troubleshooting and Remedies

Complete a "dry" compression test to ensure that this is the only defective cylinder. To make repairs on one cylinder and reassemble the engine only to find that other cylinders are defective due to worn rings is a waste of effort and money. Upon completion of the "dry" test, a "wet" test must be performed on the known defective cylinder and on any others that are found defective during the "dry" test. If a piston is cracked, the "dry" test and the "wet" test should produce the about same readings. If the "wet" test reading rises above that of the "dry" test and you do not suspect a scored cylinder wall, what might be a cause of the rise in pressure?

By injecting oil into the cylinder for the "wet" test, you have improved the seal between the piston rings and the cylinder walls. Therefore, if the readings noted on the "wet" test are substantially higher than those of the "dry" test, you may safely assume that the piston rings are worn and must be replaced. In some instances, however, the crack in the piston head may be so slight that the oil will form a temporary seal. If the piston rings are worn to the extent that the engine is losing compression, a coating of black soot from burned oil should be apparent on the inner wall of the tailpipe. Additionally, when the engine is "revved" or "gunned," blue smoke should emit from the tailpipe. This smoke will not dissipate as fast as steam does. When the spark plugs are removed, they will also be coated with black soot on the electrode end (firing end). The only remedy for worn rings is to replace them.

Lesson 3 Exercise: Complete items 1 through 3 by performing the action required. Check your responses against those listed at the end of the lesson.

1. The engine you are working on has a loss of power, and you can here a "clacking" noise coming from one of the cylinders. You do a compression test. The "wet" and "dry" reading are the same. What is the most likely diagnosis?
  - a. Worn piston rings
  - b. Worn piston pin
  - c. Cracked piston
  - d. Worn connecting rod
  
2. If piston rings are worn excessively, burnt oil (blue smoke) will emit from the tailpipe. You must, however, perform a compression test to verify that the condition is not caused by another source. What readings will you get on the compression gage from defective rings?
  - a. "Wet" test reading is higher than the "dry" test reading.
  - b. "Dry" test reading is higher than the "wet" test reading.
  - c. "Dry" test reading and the "wet" test readings are the same.
  - d. "Wet" test reading is lower than the "dry" test reading.

3. You have an engine with worn piston rings. This condition is remedied by
  - a. honing the cylinder wall.
  - b. reboring the cylinder.
  - c. replacing the piston rings.
  - d. replacing the piston.

### Lesson 3 Exercise Solutions

	<u>Reference</u>
1. c.	3302
2. a.	3302
3. c.	3302

Lesson Summary. In this lesson you have learned that the piston assembly is a common cause of engine malfunction. You also learned how to pinpoint the defect by performing both a "wet" and "dry" compression test. Lesson 4 addresses the major cause of crankshaft failure and its remedy.

## Lesson 4. CRANKSHAFT

### LEARNING OBJECTIVES

1. Identify the major cause of crankshaft failure.
2. Identify the troubleshooting action to take for specific crankshaft malfunctions.

### **3401. Common Crankshaft Malfunctions**

Another common source of malfunction within the engine is the crankshaft and its related parts. On rare occasions, the crankshaft will actually break into two pieces. This is usually due to metal fatigue, but it may also be the result of poor lubrication that has caused a portion of the shaft to "seize" during operation.

### **3402. Crankshaft Troubleshooting and Remedies**

As mentioned before, improper lubrication is the major cause of crankshaft failure. Both the main journals and the crankpins rotate inside friction-type bearings. Without proper lubrication, the crankshaft bearings would last only a few seconds. Improper lubrication can occur with oils that are heavily diluted, contaminated, or of improper viscosity. An insufficient quantity of oil will also cause the bearings to break down long before they should.

The result of bearing breakdown is an excessive amount of free play between the bearing and the crankshaft. This can be detected by a "knocking" sound inside the oil pan. If detected early enough, the condition may be remedied merely by replacing the bearings.

If not, the crankshaft must be "turned" (ground to eliminate blemishes), and the bearings replaced with a standard undersize bearing. In some cases, the bearing will seize the crankshaft and cause a connecting rod and/or the crankshaft itself to break. There is no method of repair for a broken connecting rod or crankshaft; they must be replaced along with other damaged parts.

Lesson 4 Exercise: Complete items 1 through 3 by performing the action required. Check your responses against those listed at the end of the lesson.

1. What is the major cause of crankshaft failure?
  - a. Improper end play
  - b. Improper lubrication
  - c. Excessive low speed operation
  - d. Bent push rods
  
2. The result of bearing breakdown is an excessive amount of free play between the bearing and the crankshaft. This can be detected by a \_\_\_\_\_ sound inside the oil pan.
  - a. ringing
  - b. knocking
  - c. scraping
  - d. rubbing
  
3. What remedy would you use to correct a knock created by the crankshaft bearings?
  - a. Replace the camshaft
  - b. Replace the rocker arm bearings
  - c. Replace the crankshaft bearings
  - d. Replace the push rod bearings

#### Lesson 4 Exercise Solutions

	<u>Reference</u>
1. b.	3401
2. b.	3402
3. c.	3402

Lesson Summary. You now know that the crankshaft needs lubrication to function properly and that early detection of crankshaft bearing breakdown can be accomplished by listening to the engine for knocking sounds from inside the oil pan. Early detection of this problem allows for the replacement of the bearings rather than the entire crankshaft. In Lesson 5 you'll learn the causes and remedies for valve mechanism malfunctions.

## **Lesson 5. VALVE MECHANISMS**

### LEARNING OBJECTIVES

1. Identify the remedy for each instance of valve mechanism malfunction.
2. Identify the device used for valve adjustment.

As you know from the previous unit, the valve mechanism consists of timing gears, a camshaft, valve tappets, valve springs, and valves. Now let's think about some of the malfunctions that can occur in this mechanism. Let's begin with the timing gears since they are the source of movement within the mechanism.

### **3501. Timing Gear Malfunctions**

Assume that a vehicle has just been towed into your shop because it will not start although yesterday it was operating fine. You have checked the ignition and all spark plugs are firing well. You have checked the fuel system and everything is fine there. Next, you check the TM for location of the number one spark plug wire in the distributor. You then remove the distributor cap and turn the crankshaft until the rotor button is in position to ignite that spark plug.

The number one spark plug should be firing somewhat near this point. You can't see the spark, but by observing the timing marks located on the crankshaft damper, you know that the marks should be near alignment with the timing mark pointer on the engine block. They are not. Keeping in mind that this engine was running perfectly yesterday, what would you diagnose the cause of this malfunction to be?

The function of the timing gears or timing chain and sprockets is to open and close the valves. If they are installed with one tooth out of alignment, the engine will hardly operate. If they are installed with two or more teeth out of alignment, it is very likely that the engine will not operate at all.

If the camshaft is driven by gears, a gear tooth has probably been chipped off the gear. If it is driven by a chain and sprockets, the chain may have become worn so badly that it jumped a tooth or two on the crankshaft sprocket or camshaft sprocket. Either of these occurrences will throw the valve timing off.

### **3502. Timing Gear Mechanism Troubleshooting and Remedies**

The mechanical timing mechanism (timing gears or sprockets and chain) must be repaired by replacing the defective components. The camshaft will seldom malfunction. However, camshaft defects can drastically affect the performance of an engine. A lack of lubrication between the camshaft lobes and the valve tappets will cause excessive wear.

The camshaft lobes open the valves to allow the fuel-air mixture to enter and the burned gases to leave the combustion chamber. If the camshaft lobes and the valve tappets are worn, the valve's precise opening distance and the amount of time it remains open are affected. This reduces the amount of fuel-air mixture allowed into the engine, and with less fuel-air mixture, the engine naturally suffers a loss in performance (fig 3-10).

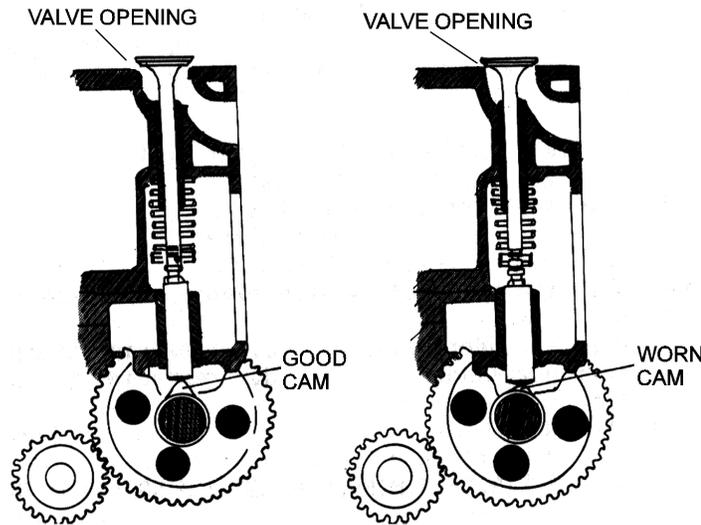


Fig 3-10. Comparison of valve openings with good vs worn cam lobes.

In the early stages, valve tappet wear is easily detected by the sound the tappets make. It is similar to the noise of a pencil point tapping on a desk. If detected early enough, the situation can be remedied by adjusting the valves. For engines with nonadjustable hydraulic valves, check the bottom of the tappets for wear when they are removed. The only remedy for this condition is replacement of the camshaft or tappets.

### 3503. Valve Malfunction

One of the most common malfunctions involving the valve is a "burned" valve. This is caused when the valve remains open too long. When a valve becomes burned, it means that the face of the valve has lost its machined smooth finish. This is due to partial melting of the metal which is caused in turn by extreme heat the valve has experienced.

To cool sufficiently, valves must remain seated long enough to give the seat ample time to transfer the heat from the valve to the coolant within the water jacket. The valve face is cooled by the valve seat when the valve is closed and the valve seat, of course, is cooled by the water jacket. If the valve is adjusted too tightly, this closure period becomes shortened. As a result, the valve will become overheated and the face will scorch and melt to the extent that it will not form a pressure-tight seal (fig 3-11).



Fig 3-11. Example of valve wear.

Prolonged valve opening may result from weak valve springs. A weak valve spring will not close the valve as rapidly as it should. Weak valve springs can not be repaired; they must be replaced.

#### **3504. Valve Troubleshooting and Remedies**

Let's return to the compression test for a moment. If a "dry" test and a "wet" test result in the same low reading, this indicates an "open" combustion chamber (a blown head gasket, a cracked piston head, a valve adjusted too tightly, etc.). A visual inspection would eliminate the head gasket and you can eliminate a cracked piston if there is no sound to indicate it. You will probably have to remove the cylinder head, but first, let's adjust the valves to ensure that they are not too tight. Adjust the valves by inserting a feeler gage between the rocker arm and the valve stem and turning the adjusting nut until a slight drag is felt (fig 3-12).



Fig 3-12. Adjusting valves.

What is a slight drag? To get a feel for it, find a sheet of notebook paper. While holding one side of the paper stationary, use your thumb and forefinger to grasp the other side. Without allowing the paper to move, apply pressure between the thumb and forefinger and try to pull the paper. By releasing a slight amount of pressure and allowing the paper to slide between your thumb and forefinger, you will get an idea of how a slight drag feels. The TM for the specific engine will state the procedures to be followed for adjusting the valves as well as the clearance required.

Now, perform another "wet" test on the cylinder. If the result is the same, you are encountering the most common cause of an open cylinder, a burned valve. To correct this, the valve must be ground back to its original machined finished or replaced.

OK, let's see what you've learned so far. What component in the valve mechanism would be at fault if the valves were remaining open for a prolonged period of time? Very Good! The valve springs. And how can we solve this problem? That's correct! Valve springs can not be repaired; they must be replaced.

### **3505. Valve Guide/Pushrod Malfunctions**

From this point on, we will discuss the valve-in-head valve train design since it includes the components of the valve-in-block valve train as well. If the valve guide becomes rough or burred, the valve stem will tend to hang (stick) inside it. This will hold the valve open longer than it should and put added pressure on the pushrod. If the pressure becomes great enough, it will cause the pushrod to bend. Now, what do you think the symptoms of a bent pushrod are? Good. When a pushrod bends, its length is shortened; this would produce the same effect as worn tappets or camshaft lobes.

### **3506. Valve Guide/Pushrod Troubleshooting and Remedies**

The first symptom of a bent pushrod would be a sound from the valve train similar to the tapping of a pencil. A bent pushrod cannot be straightened perfectly, and even if it could, it would be weakened to the point that it would bend again eventually so a bent pushrod must be replaced with a new part. What must be done prior to replacing a bent pushrod? That's right, you must eliminate the source of the problem. Therefore, you must repair or replace the valve guide before installing the new pushrod.

### **3507. Rocker Arm Malfunctions**

Rocker arms and the rocker arm shaft become worn and defective when they do not receive the proper amount of lubrication. The cause of poor lubrication is usually a clogged oil passage located in the cylinder head. Defective rocker arms or rocker arm shafts cause the valves to open too late and close too soon.

### 3508. Rocker Arm Troubleshooting and Remedies

The symptom again is the sound similar to the tapping pencil. The pivot (fig 3-13) of the rocker arm and rocker arm shaft become worn. This condition may be verified by removing the rocker arm cover and observing the rocker arms while the engine is operating. If no oil is present, the rocker arms and the rocker arm shaft must be replaced. However, it will do no good to replace these components unless you clear the oil passages leading to them.

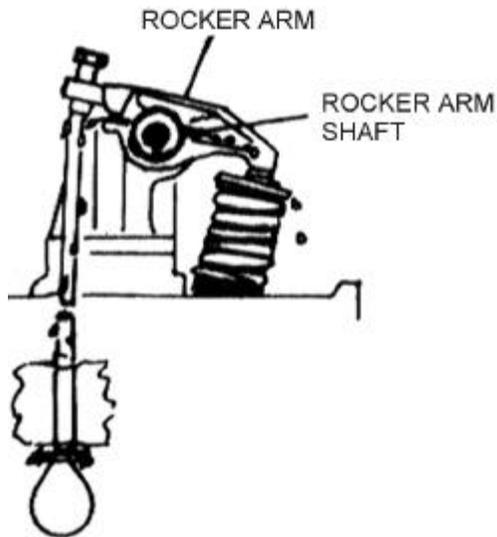


Fig 3-13. The pivot point for the rocker arm, the rocker arm shaft.

Lesson 5 Exercise: Complete items 1 through 6 by performing the action required. Check your responses against those listed at the end of the lesson.

1. You have an engine that will not start no matter what you try. Yet, one hour ago, the engine was running fine. The fuel and ignition systems are performing well except the rotor button in the distributor is halfway between two spark plug wires when the number one piston is at TDC compression. What is the most probable cause for this condition?

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2. What might be done to repair an engine that has been running for a prolonged period with valves adjusted too tightly and a valve adjustment will not improve its performance?

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3. What device is used for valve adjustments?  
\_\_\_\_\_
4. Faulty \_\_\_\_\_ would most likely be the cause of the valves remaining open for a prolonged period of time.
5. Valves are adjusted by inserting a feeler gage between the \_\_\_\_\_ and the \_\_\_\_\_.
6. Rocker arms and the rocker arm shaft become worn and defective when they do not receive the proper \_\_\_\_\_.

### Lesson 5 Exercise Solutions

	<u>Reference</u>
1. Defective timing	3501
2. Reface or replace the valves	3502
3. Feeler gage	3504
4. valve springs	3503
5. rocker arm, valve stem.	3504
6. amount of lubrication	3507

Lesson Summary. Lesson 5 taught you how to recognize engine malfunctions and the troubleshooting procedures of the valve mechanism which includes the timing gears, valves, valve guides, pushrods, and rocker arms.

### UNIT SUMMARY

You have now learned to diagnose the various symptoms of the internal malfunctions of an engine. You have also learned the remedies required to restore an engine to normal operating condition after malfunctions have been identified. Now, let's disassemble an engine and prepare it for whatever repairs are necessary.

## STUDY UNIT 4

### ENGINE DISASSEMBLY

Introduction: The disassembly of the engine is as important, if not more so, than the assembly. Many engines have been repaired or rebuilt and returned to operation, but a short time later, are back in the maintenance facility. The greatest cause of this is improper disassembly. Most mechanics concentrate all their efforts on repair of the components known to be defective, but if they also carefully inspect each and every part during engine disassembly, they can replace a defective component at that time, instead of waiting until reassembly to find and replace the component.

Proper disassembly requires complete organization. Components that are paired, such as valves and tappets, develop wear patterns inherent to each other and must remain paired. This is also true for pistons and connecting rods, tappets and camshaft lobes, bearings and journals, and pistons and their original cylinder, just to name a few. As the engine is disassembled, the parts removed need to be laid out in the order they were removed. This prevents replacing pistons in the wrong cylinder, tappets in the wrong bore, bearings on the wrong journal, etc.

As you can see, an entire study unit is devoted to the disassembly phase. You will soon realize that proper disassembly is just as important as repair or reassembly.

#### Lesson 1. REMOVING THE CYLINDER HEAD

##### LEARNING OBJECTIVES

1. List the four procedures in preparing an engine for disassembly.
2. Identify the differences in removing the cylinder heads from the L-head engine and the I-head or F-head engine.
3. Identify the disassembly procedure for the rocker arm.

The first engine component removed is the cylinder head assembly, but before any disassembly is started, you must prepare the engine. A good repair or rebuild job begins with engine preparation. Without good preparation, you may not only fail to locate unknown defects, but you may also cause further damage.

#### **4101. Engine Preparation**

With the engine removed from the vehicle, you can begin your preparation. The first procedure is to cover all openings of the engine with clean, lint free rags. Look at figure 4-1. Note the arrows indicating typical openings to be covered. Now imagine yourself as a surgeon and the engine as your patient. If foreign matter enters your patient's body, infection may result, and your operation could be a failure.



Fig 4-1. Engine preparation.

#### **4102. Engine Cleaning**

Now that all openings are covered, the second procedure is to clean the engine thoroughly to prevent foreign matter from entering the engine and causing internal damage during disassembly. First, take a high-pressure cleaning unit and steam clean the entire outer surface of the engine. If a cleaning unit is not available, use a high-pressure water hose to remove the dirt and loose matter. Next, with cleaning solvent and a stiff brush, remove any grease or oil that may be on the engine. The third procedure is to drain the engine. Using two separate containers, one for oil and the other for the coolant, remove the oil pan drain plug and open the cylinder block drain cock and drain the engine completely (fig 4-2). While the engine is draining, you might use this time to make sure that your working area is thoroughly clean to prevent any chance of getting the internal parts of the engine contaminated with dirt.



Fig 4-2. Drain the engine.

With the engine thoroughly cleaned and drained, the fourth procedure is to conduct a good visual inspection of its outer surfaces for cracks and broken parts as you begin removing the accessories. If these conditions exist, you must get a decision from a machinist on the feasibility of repairing the defects. New or rebuilt parts are of no value if the engine block is damaged beyond repair.

At this point, you are ready to disassemble the engine. Mount the engine on the repair stand and begin the actual disassembly. Remember to lay the parts out in an orderly manner as you disassemble the engine. Doing so will make assembly easier.

Note: The removal and installation of the intake and exhaust manifolds are not covered in this course. It is essential, however, that these components be inspected and properly aligned for the engine to operate correctly.

As you disassemble the engine, check each part to make sure it can be used in the repair of the engine. If you wait until reassembly, it will cause extra work and unnecessary time if you have to remove a part you earlier assumed was good without checking. The three most common cylinder head engine types will be taught. Let's begin with the L-head engine.

#### **4103. L-head Engine**

You have already inspected the outer surfaces of the cylinder head along with the rest of the engine. The internal portion of the head must be cleaned before it can be inspected. When you remove the cylinder head, lay it aside and inspect it later in a separate area. To clean it now would result in carbon deposits flying through the air, possibly contaminating the rest of the engine.

The removal of the cylinder head from an L-head engine is very simple. Remove the cylinder head bolts from the head, lift the cylinder head from the engine, and lay it flat on a flat surface. To stand it on end or lean it against another object would result in the head warping which in many cases could require repairs that would not have been necessary. At this time, also remove the cylinder head gasket, inspect it for signs of leakage, and discard it. Any signs of leakage should be recorded so that you may concentrate on the cause during your cylinder head and cylinder block gasket surface inspection.

#### **4104. I- or F-head Engine**

Removing an I- or F-head engine's cylinder head requires a little more effort. First, remove the rocker arm cover and discard the gasket and retaining seals. At this time, check the retainer seal surface of the cover for dents. Check for any other dents. Some mechanics have a tendency to over-torque the retaining nuts and bolts; this bends the retainer seal surface of the cover. If a dent exists, you may straighten it at this time or record the defect so that it is not forgotten.

With the cover removed, back off (loosen) the valve adjustment at least one complete turn to relieve the pressure on the rocker arms (fig 4-3). If the pressure is not relieved, damage to the rocker arm shaft could result when it is being removed.



Fig 4-3. Relieving rocker arm pressure.

When the pressure is relieved, remove the rocker arm attaching bolts and nuts and lift the rocker arm shaft from the engine. If the engine does not have a rocker arm shaft, simply remove the rocker arm.

Once the shaft is removed, you might make a preliminary inspection by removing a couple of rocker arms and checking their pivot points on the shaft. If you find grooves worn into the shaft, discard both the shaft and the rocker arms, retaining all other parts.

To prevent damage to the pushrods when the cylinder head is removed, take them out of their holes (before removing the cylinder head) and lay them in order on your workbench or in the area you are storing the parts you have removed. You might as well take this opportunity to ensure that all the pushrods are perfectly straight. A bent rod will continue to bend when reinstalled in the engine. Discard any bent rods and make a note of the holes from which they were removed. Now, loosen the cylinder head bolts, lift the head from the engine, and lay it on a flat surface.

Lesson 1 Exercise: Complete items 1 through 3 by performing the action required. Check your responses against those listed at the end of the lesson.

1. List the four procedures in preparing the engine for disassembly.

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2. Which of the following head removal procedures best describes the difference between the L-head and the I- and F-head?
  - a. L-head - remove cylinder head bolts, lift off head; I-and F-head - remove cover, loosen valve adjustment, remove rocker arm, remove pushrods, remove cylinder head bolts, and lift off head.
  - b. L-head - loosen valve adjustment, remove pushrods, remove cylinder head bolts, lift off head; I-and F-head - remove rocker arm cover, remove cylinder head bolts, lift off head.
  - c. L-head - remove rocker arm, loosen valves, remove head; I-and F-head - remove cylinder head bolts, remove pushrods, and remove cylinder head.
3. The valve adjustment nuts must be loosened to relieve pressure on the
  - a. rocker arms.
  - b. crankshaft.
  - c. pistons.
  - d. flywheel.

Lesson 1 Exercise Solutions

	<u>Reference</u>
1. Cover all openings Clean the engine Drain the engine Inspect the outer surfaces	4101/4102
2. a.	4103/4104
3. a.	4104

Lesson Summary. Lesson 1 taught you that proper disassembly is just as important as the repair and reassembly phases. You also learned the procedural differences when removing cylinder heads from the L-, I-, and F-head engines. Now that you've removed the cylinder head, let's remove the other engine components.

## Lesson 2. REMOVING THE OIL PUMP ASSEMBLY

### LEARNING OBJECTIVE

Identify the correct procedure for removing the oil pump assembly.

#### 4201. Oil Pump Removal Preparation

In vehicles such as the LVS, the oil pump is located inside the oil pan. For this reason it has what is known as an **internal** oil pump. To remove the oil pump, turn the engine upside down and remove the oil pan. Discard all gaskets and neoprene seals. Before removing the oil pump, make sure those oil pump drive gears are in good condition by performing a gear backlash test. It would just be extra work to remove the oil pump now, repair the engine, and reinstall the pump if the gears are worn excessively. Free play (backlash) between the gear teeth would grow larger and larger, and you would have to replace the oil pump in the near future. Remember, the engine is to be repaired to a like-new condition.

Oil pump gear backlash is measured with a dial indicator. This instrument is attached to or placed on the engine block and the levers adjusted so that the tip of the plunger can be placed against one tooth of the driven gear. Now adjust the instrument until the dial reads zero.

After the instrument is set up in this manner, turn the driven gear against the plunger tip until it is stopped by the driving gear. Then, turn the driven gear back until it contacts the next tooth and stops. The distance the dial reads, from one tooth to the next, is the backlash (fig 4-4). Record the backlash and check it against tolerances listed in the TM for your vehicle. If the backlash is not within the tolerances, make a note of this so you will not forget to remedy it later.

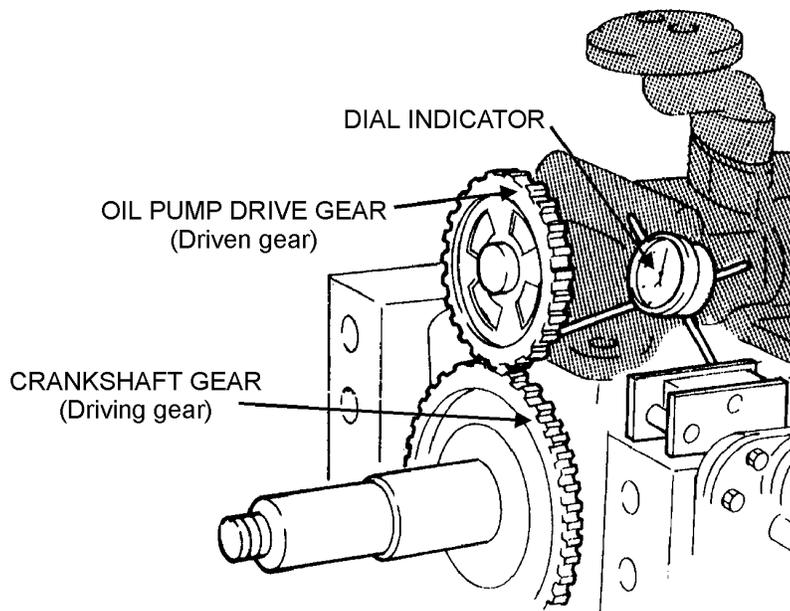


Fig 4-4. Oil pump backlash test.

## 4202. Oil Pump Removal Procedures

With the backlash checks complete, the oil pump is now ready to be removed. With the engine inverted on an engine stand, unbolt and remove the oil pump, the oil pickup tubes, and the oil pickup screens as one complete assembly. Discard the gasket. You can now work inside the crankcase.

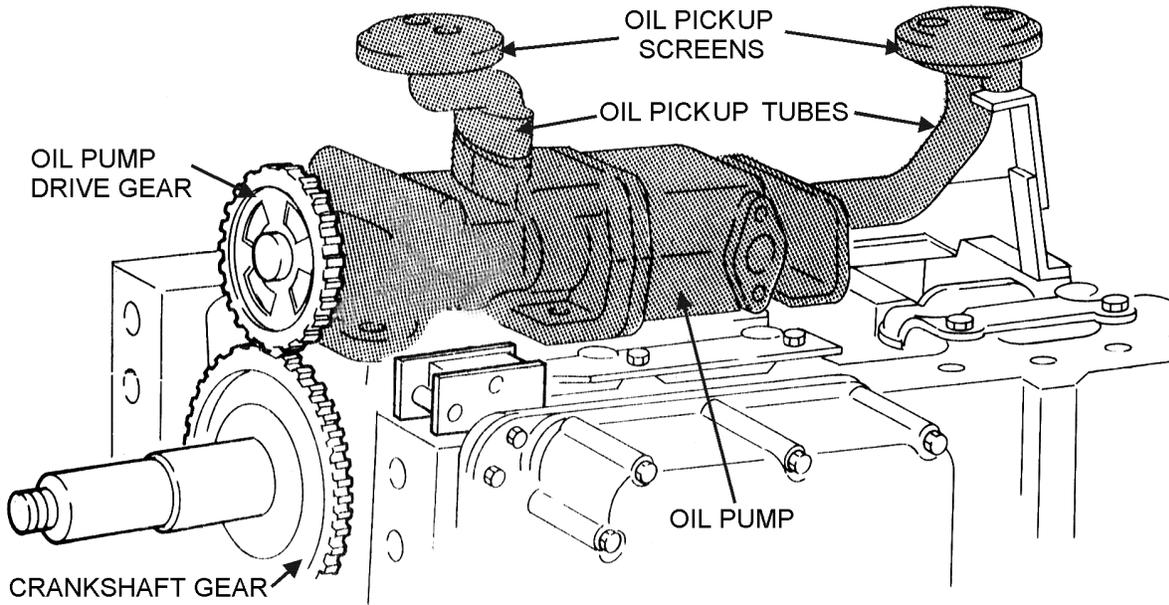


Fig 4-5. Internal dual gear oil pump (LVS).

Lesson 2 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of the lesson.

1. Before removing the oil pump, what test should you make?
  - a. Oil pump bypass
  - b. Oil pump flow
  - c. Oil pump gear backlash
  - d. Oil pump vacuum.
2. How is the oil pump removed?

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### Lesson 2 Exercise Solutions

	<u>Reference</u>
1. c.	4201
2. Unbolt and remove as one complete assembly	4202

Lesson Summary. Lesson 2 detailed the importance of oil pump removal. It also explained how to check the oil pump gears for backlash. Let's continue the engine disassembly by removing the piston assembly.

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### **Lesson 3. REMOVING THE PISTON ASSEMBLY**

#### LEARNING OBJECTIVE

Identify the correct procedure for removing the piston assembly.

#### **4301. Piston Removal Preparation**

There is quite a bit of work to be done before you can actually remove a piston assembly. The first thing to do is check the connecting rod side play. This is done by inserting a feeler (thickness) gage between each connecting rod bearing cap and its crankshaft throw (fig 4-6). Try several leaves of the gage, if necessary, until you find one that can be inserted with a slight drag. Record the number stamped on that leaf. After all connecting rods have been checked, find the side play specifications in your TM and list the rods that are not within the specified tolerance.

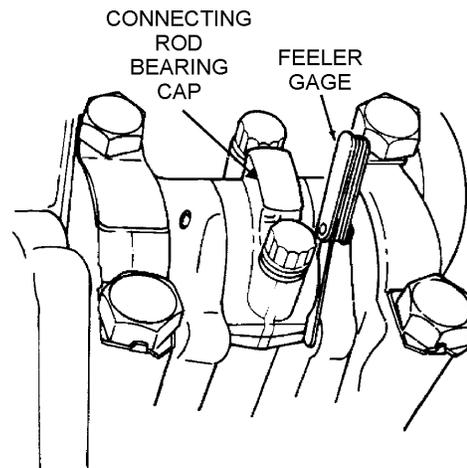


Fig 4-6. Measuring connecting rod side play.

#### **4302. Cylinder Ridges**

Turn the engine upright again and take a look at the cylinders. Around the very top you can see or feel a ridge. This ridge is produced by carbon deposits and ring wear because the rings do not travel this high. The rings of the piston cause wear on the cylinder as they travel up and down. The top edge of the rings also wears to a curved shape. The ridge at the top of the cylinder will match the shape of the top edge of the ring. When new rings are installed, they have no wear and will strike the ridge, causing ring and, possibly, cylinder wall and piston damage (fig 4-7).



Fig 4-7. Result of installing new piston rings with ridges at the top of the cylinder.

### 4303. Cylinder Ridge Removal

The ridges at the top of the cylinders must be removed before installing new piston rings and now is the best time to do this. By removing the ridges at this time, you eliminate the chance of damage to the piston when it is removed.

You will use a tool known as a ridge reamer (fig 4-8) to remove the ridges. Turn the crankshaft until the piston of the cylinder about to be reamed is at BDC. Now, get a clean cloth and place it inside the cylinder to catch **ALL** metal filings that might fall into the cylinder. If they are not caught, these filings can cause cylinder wall scoring. While reaming, be very careful **NOT** to cut into the ring travel area of the cylinder. This will not only damage the cylinder wall but the piston as well. Before turning the crankshaft to bring the next piston to BDC, **BE SURE that ALL metal filings are removed and discarded.**



Fig 4-8. Ridge reaming tool.

#### 4304. Piston Removal Procedures

When all cylinders have been reamed, you are ready to remove the piston assemblies. Again, turn the engine upside down. The connecting rod caps and pistons must be removed one at a time to prevent damage to the engine. Turn the crankshaft until the piston to be removed is at BDC. Remove the two cap nuts and lift the cap from the crankpin. Check the cap and the rod to make sure they are marked. If they are not marked, mark the caps and rods with a number stamp or center punch. If a center punch is used, place the number of dots that coincides with the cylinder number. For example, the cap and rod for the #3 cylinder would have three dots. Place all markings **ON THE SAME SIDE**, numbering them in cylinder number sequence starting with the forward cylinder. This is done so that when the pistons are reinstalled, they will be in the same cylinder and in the same position. Using a hammer handle, push on the end of the connecting rod, forcing the piston up and out the top of the cylinder (fig. 4-9).

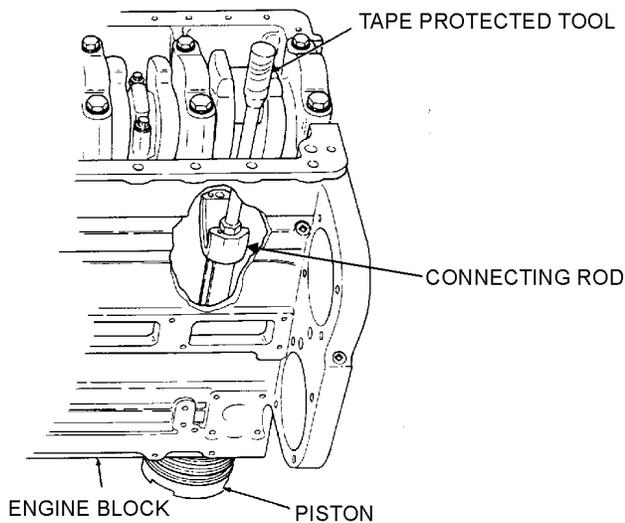


Fig 4-9. Removing the piston assembly.

**Caution:** If the ridges are not removed at this time, extra force will be required. Chances are 99 out of 100 that the hammer will slip and cause the connecting rod to strike the crankpin or cylinder wall.

**Note:** Most pistons are marked at the factory with a notch or arrow, so check each piston first. If the pistons are not marked, as each piston is removed, mark the forward piston with a center punch, numbering them as you numbered the rods.

Lesson 3 Exercise: Complete items 1 through 4 by performing the action required. Check your responses against those listed at the end of the lesson.

1. How do you measure connecting rod side play?

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2. Why must cylinder ridges be removed before installing new piston rings?

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3. What precaution is taken to protect cylinder walls and pistons during the ridge reaming procedure?

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4. After removing the connecting rod bearing caps, the piston is removed by

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#### Lesson 3 Exercise Solutions

	<u>Reference</u>
1. Place the feeler gage between the connecting rod cap and the crankshaft throw.	4301
2. Because the ridges match the shape of the old piston ring, a new piston ring will strike the ridge and cause damage.	4302
3. A clean cloth is placed inside the cylinder .	4303
4. Pushing on the end of the connecting rod with a hammer handle forcing the piston up.	4304

Lesson Summary. In this lesson you learned how to remove the pistons, check the cylinders for ridges, and remove the ridges from the cylinder. Remember to remove the ridges before you remove the piston. Let's now turn our attention to the timing gears.

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#### **Lesson 4. REMOVING THE TIMING GEAR ASSEMBLY**

##### LEARNING OBJECTIVE

Identify the correct procedure for removing the timing gear assembly.

#### 4401. Timing Gear Removal Preparation

To remove the timing gears, you must first remove the crankshaft damper and pulley, the timing gear cover, and the crankshaft oil slinger. After these items are removed, make sure that the timing gears are in good condition. If you do not check them now, you cannot check them until they are reinstalled during reassembly, and this may mean extra work if you have to change them after reinstallation.

#### 4402. Timing Gear Tests

The first check to make is for free play (backlash) between the gears. If the backlash is excessive, the valves will open and close later than they should. For this check, use a dial indicator (fig 4-10). The instrument is placed on the cylinder block or, depending on the manufacturer's design, attached to the cylinder block so that the dial plunger rests on the face of one gear tooth of the camshaft gear. When making this adjustment, be sure that the teeth of the two gears are in firm contact and that the dial reads zero. Now, turn the camshaft gear just enough to cause it to touch the next tooth on the crankshaft gear. Record the reading on the dial indicator and make the next check.

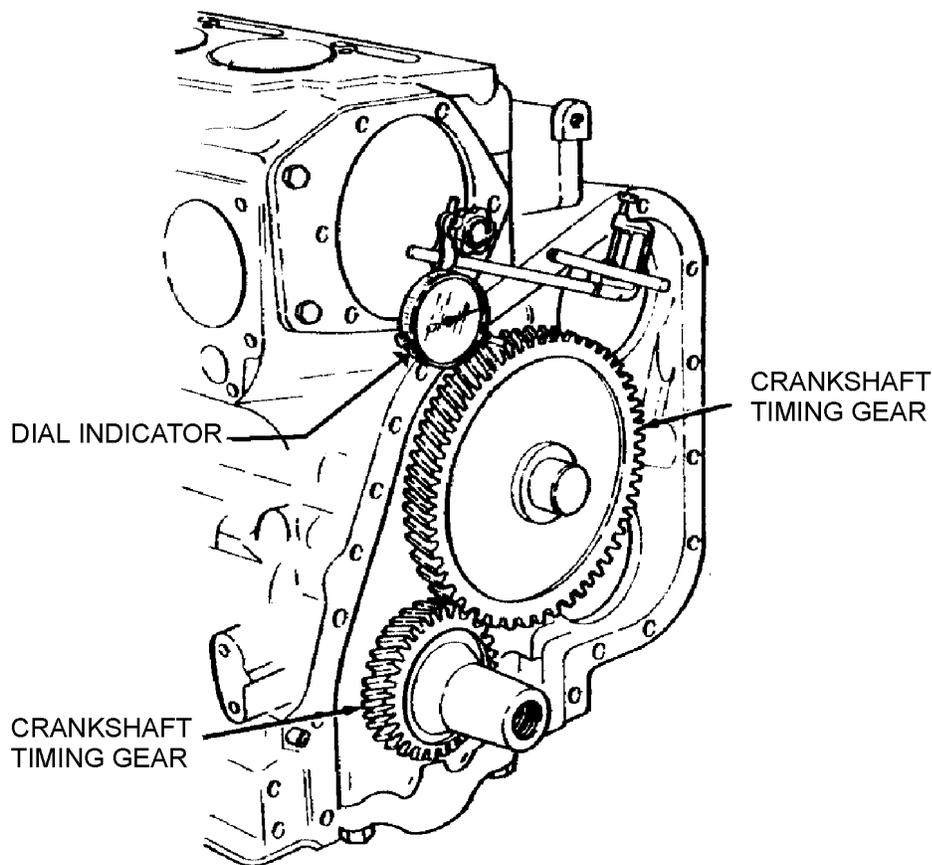


Fig 4-10. Checking timing gear backlash.

Before removing the timing gears, make one more check, the camshaft end play. This will determine if it will be necessary to replace the camshaft thrust bearing. Although this check has no direct connection with the condition of the timing gears, it can be made only with the camshaft gear installed.

With the dial indicator base in the same position, place the plunger on the end of the camshaft gear retainer bolt. Now, place the end of the pry bar between the gear and the engine block and gently pry the gear away from the engine. Record the dial indicator reading. With all the checks done, check your readings against the specifications in the TM for your vehicle. If the gear backlash or runout is beyond tolerance, the gears must be discarded. If the camshaft end play is excessive, this means you will have to replace the camshaft thrust bearing before reinstalling the camshaft.

### **4403. Timing Gear Removal**

Now, you can remove the timing gears. The crankshaft gear is removed first to prevent damage to the camshaft gear. If you remove the camshaft gear first, you will be turning the gear puller in a clockwise direction while the camshaft gear is attempting to rotate in a counterclockwise direction due to the design of the gear teeth. This causes added resistance to the puller.

Install the crankshaft damper retaining bolt before installing the gear puller. If the gear puller is installed without the retainer bolt, thread damage will result. After the gear puller is installed, simply turn the center bolt of the puller clockwise while holding the gears to prevent them from turning. The TM for the vehicle will instruct you as to the best method for holding the gears.

Removal of the camshaft gear is accomplished with the same tool. The retaining bolt, while still attached, is loosened a few turns before installing the puller. Install the puller basically the same way you did for crankshaft removal. Turn the puller clockwise, allowing the gear to break free of the camshaft. The puller then may be removed, the retainer bolt removed, and the gear lifted from the camshaft.

Lesson 4 Exercise: Complete items 1 through 3 by performing the action required. Check your responses against those listed at the end of the lesson.

1. To check timing gear backlash, the dial indicator is placed on the cylinder block and the plunger is placed on the \_\_\_\_\_ .
2. Why is camshaft end play checked?  
\_\_\_\_\_
3. When removing the timing gears, why is the crankshaft gear removed first?  
\_\_\_\_\_

## Lesson 4 Exercise Solutions

	<u>Reference</u>
1. Timing gear tooth	4402
2. To determine if a new thrust bearing is needed	4402
3. To prevent damaging the camshaft	4403

Lesson Summary. Lesson 4 taught you how to prepare the timing gear for removal, how to remove it, and how to perform the various tests that are required before reassembly. You are now ready to remove the crankshaft.

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## Lesson 5. REMOVING THE CRANKSHAFT ASSEMBLY

### LEARNING OBJECTIVE

Identify the correct procedure for removing the crankshaft assembly.

#### **4501. Pilot Bearing Removal**

Before removing the crankshaft from the engine, remove the clutch pilot bearing and the flywheel from the crankshaft. The pilot bearing is removed at this time because it has to be removed with a slide hammer puller (fig 4-11), and the block provides a rigid base.

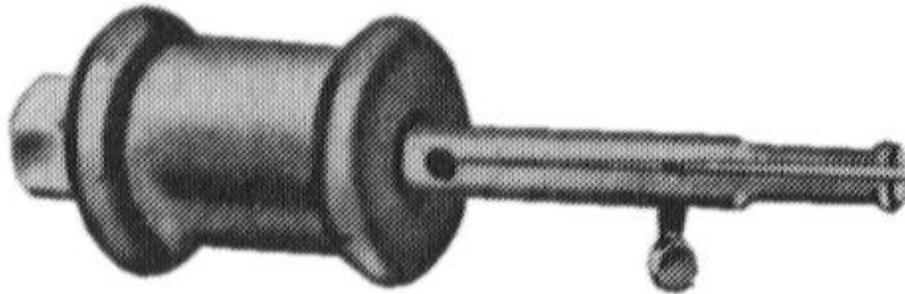


Fig 4-11. Clutch pilot bearing puller.

The puller is inserted into the hole located in the center of the pilot bearing and spread to form a firm fit inside the bearing (fig 4-12) using the thumbscrew. When a firm fit is obtained, slide the slide hammer to the rear with force until the bearing is forced completely out of the crankshaft.



Fig 4-12. Removing the clutch pilot bearing.

#### 4502. Flywheel Test

On vehicles equipped with a standard transmission, perform a runout test before removing the flywheel. A warped flywheel will cause the clutch to engage unevenly and the clutch pedal will "bounce." Figure 4-13 illustrates the use of a dial indicator with a "C" clamp. Again, the dial is set at zero and the flywheel is turned one complete rotation. Note that the plunger is placed near the friction surface edge. Record the highest reading. If the runout is excessive according to the TM, the flywheel must be replaced, or if facilities are available, you may grind it.

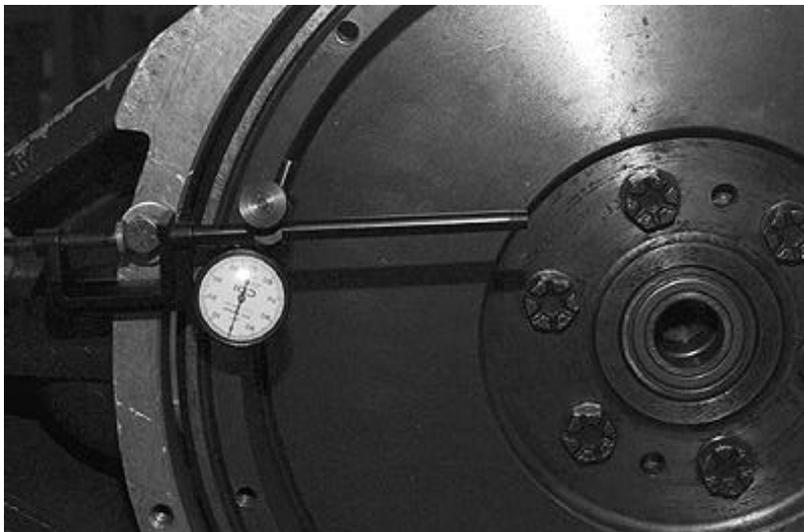


Figure 4-13. Measuring flywheel runout.

### 4503. Flywheel Removal

Now, remove the flywheel. Remove the bolts or nuts from the area around the center of the flywheel and carefully lift the flywheel from the crankshaft. Be careful so that you DO NOT drop the flywheel. This may cause damage to the ring gear. When the flywheel is removed, check the ring gear for chipped or missing teeth. If these conditions exist, the ring gear must be replaced, either by installing a new ring gear on the flywheel or by replacing the entire flywheel.

With the flywheel removed, perform the crankshaft end play test.

### 4504. Crankshaft End Play

The crankshaft end play test is done by placing the dial indicator at either end of the engine block. Use the end which is most convenient. Attach the dial indicator on the engine block and place the dial indicator plunger on the crankshaft as in figure 4-14.

Reset the dial indicator to zero. Pry the crankshaft in the direction of the dial indicator by placing a pry bar between the crankshaft journal and a main bearing cap. Record the reading. If the reading is greater than the TM allows, the crankshaft thrust bearing will have to be replaced during the repair phase. Now that all necessary checks have been made, you are ready to remove the crankshaft. During removal, remember there are many bearings and bearing surfaces. Extreme care must be exercised so that you DO NOT "nick" or scratch any bearing surfaces or drop any of these components.

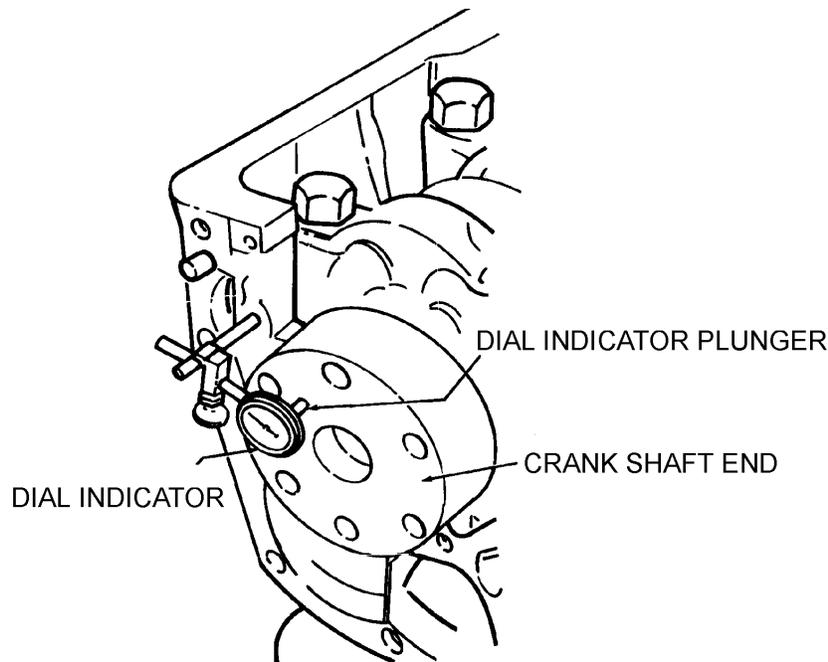


Fig 4-14. Checking crankshaft end play.

## 4505. Removing the Crankshaft

First, loosen ALL bearing cap retaining bolts and leave them in place. Next remove each main bearing cap and identify it by marking its bearing number on the side. Be sure to mark the same side of ALL bearing caps and bearings. This will help ensure that the bearings are reinstalled in their proper place and position when the engine is reassembled. Place the bearing caps in order on the workbench with the bearing and bolts installed. Lift the crankshaft out of the crankcase very carefully and stand it on end, or hang it in a rack.

Caution: If you lean the crankshaft against another object in an upright position, **IT WILL WARP.**

Lesson 5 Exercise: Complete items 1 through 4 by performing the action required. Check your responses against those listed at the end of the lesson.

1. What special tool is used to remove the pilot bearing?  
\_\_\_\_\_
2. To measure flywheel runout, the dial indicator plunger is placed on the face of the flywheel, and the flywheel is moved in what manner?
  - a. In the direction of the dial indicator
  - b. Counterclockwise, then clockwise
  - c. Clockwise, then counterclockwise
  - d. One complete rotation
3. After the flywheel has been removed, inspect the \_\_\_\_\_ for chipped or missing teeth.
4. To measure crankshaft end play, pry the crankshaft
  - a. away from the dial indicator.
  - b. toward the dial indicator.
  - c. to the left.
  - d. to the front.

### Lesson 5 Exercise Solutions

	<u>Reference</u>
1. slide hammer	4501
2. d.	4502
3. ring gear	4503
4. b.	4504

Lesson Summary. Lesson 5 discussed the crankshaft removal which includes the removal of the pilot bearing, clutch (if so equipped), and flywheel. Testing the flywheel for warp and the crankshaft for excessive end play were also discussed. The final components to be removed from the engine block are the camshaft and valve tappets.

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## **Lesson 6. REMOVING THE CAMSHAFT ASSEMBLY**

### LEARNING OBJECTIVE

Identify the correct procedure to remove the camshaft assembly.

#### **4601. Valve Tappet Removal**

In some cases, the valve tappets may be removed first, and in other cases, the camshaft must be removed first. This depends on the design of the tappets. Try to lift the tappets out of their holes with your fingers. **DO NOT** use force. Once removed, lay the tappets on your workbench in the same order in which they are to be installed in the cylinder block. Make sure they are reinstalled in that same order during reassembly.

#### **4602. Camshaft Removal**

If the engine you are working on contains valve tappets that require the camshaft to be removed first, turn the engine upside down so that the tappets fall away from the camshaft. Attempting to remove the camshaft with the tappets resting on it will result in damage to both the camshaft and the tappets. You may remove the camshaft by removing the thrust plate retaining cap screws and pulling camshaft forward carefully out of the engine block (fig 4-15).

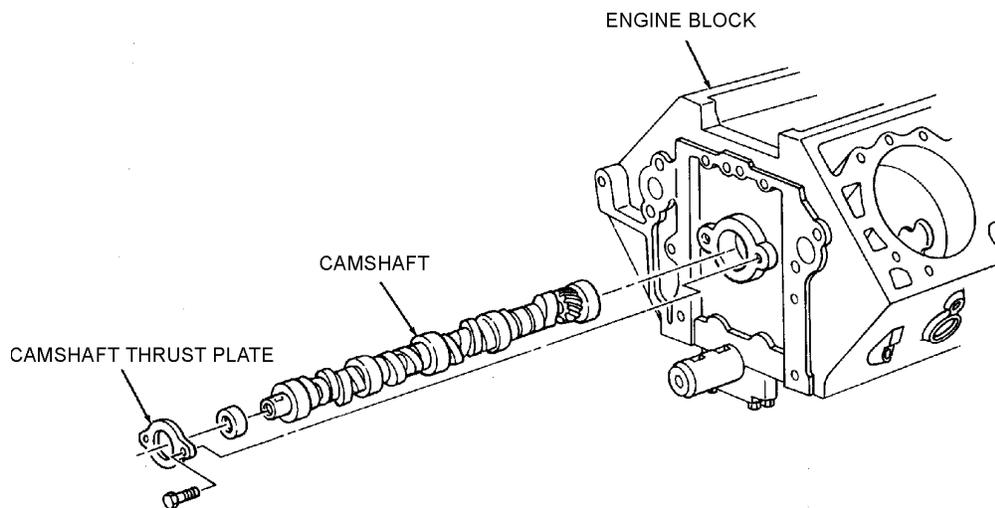


Fig 4-15. Removing the camshaft.

If you were unable to remove the tappets before removing the camshaft, they may be removed at this time from the bottom of the cylinder block. With the camshaft and tappets removed, you are now ready to begin restoring the engine to a like-new condition.

Lesson 6 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of the lesson.

1. What important procedure must be followed when reinstalling used valve tappets?

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2. When removing the camshaft, damage may occur to both the camshaft and tappets if what condition occurs?

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#### Lesson 6 Exercise Solutions

	<u>Reference</u>
1. Reinstall the valve tappets in the same order removed	4601
2. If the tappets are left to rest on the camshaft	4602

Lesson Summary. Lesson 6 taught the removal of the camshaft and valve tappets. Remember to keep the valve tappets in the order they were removed and replace them in the same order.

#### UNIT SUMMARY

The disassembly of the engine and its components was covered in this study unit. If you had difficulty with this study unit for any reason, it would be advisable for you to go back over it again. Remember, proper disassembly is the first step in rebuilding a dependable engine. This includes testing components such as the oil pump and timing gears for backlash, the crankshaft for end play, and the connecting rods for side play just before their removal. With that said, let's move to Study Unit 5 and begin troubleshooting and repairing the engine.

## STUDY UNIT 5

### ENGINE REPAIR

Introduction. During the engine disassembly phase, you performed preliminary inspections and tests on some of the engine components. Now comes the challenge. You will begin the actual repair, which includes more in-depth inspecting and testing of the engine block and its components. Study Unit 5 consists of lessons concerning the inspection and repair of the engine. Remember, Marines are counting on you to return this engine to them in like-new condition. With that in mind, let's repair the engine!

#### Lesson 1. ENGINE BLOCK

##### LEARNING OBJECTIVES

1. Identify the action to take in specific instances of engine block (cylinder, valve, and camshaft) repair.
2. Identify the tool or instrument used in measuring cylinder bore, valve tappet bore, and camshaft bearing installation.
3. Identify the procedure performed when inspecting various parts of the engine block.

By this time you should be able to identify each component of the engine block. You should also feel confident with the troubleshooting procedures and ready to move forward to the actual inspection and repair of the engine.

#### 5101. Engine Block Inspection and Repair

Figure 5-1 illustrates typical parts of a disassembled engine. Each part must be inspected.



Fig 5-1. Disassembled engine

In most cases, the parts may be installed as they are repaired. But, since you are primarily concerned at the present with repair, reassembly will be covered in the next study unit. Begin your repair with the engine block.

Before repairing the engine block, there is a little more cleaning to be done. You cleaned the external portion of the block during the engine repair preparation phase; now the inside must be cleaned. Only after this is done can a thorough inspection be made. With a high-pressure steam-cleaning unit or cleaning solvent, clean all water and oil passages and the cylinder walls. If the oil passages are not clear when you reassemble the engine, all the efforts to rebuild or repair the engine will be wasted because you are likely to experience lubrication failure. Now, examine the block thoroughly for cracks. When a crack is present, it is usually indicated by a thin line of rust. These cracks may be found any place on or inside the block. They are most easily detected in machined surfaces such as the gasket surfaces and the cylinder walls.

After this has been done, or even while it is being done, check all machined gasket surfaces for nicks, burrs, and scores. Any burrs and scores may be smoothed out with an oil stone, but if the block is cracked, seek the advice of the machine shop personnel. They may be able to seal it; however, if they cannot make the repairs, the block must be replaced.

### **5102. Cylinder Block Inspection and Repair**

The cylinder block must also be checked for warpage. If it is warped, the cause may be a leaking or "blown" cylinder head gasket. Lay a straight edge across the top of the cylinder block where the cylinder head gasket is placed. Now, drag the straight edge along the surface of the cylinder block and look for "daylight" between the straight edge and the cylinder block. In those places where you detect a gap between the straight edge and the block, check the clearance with a feeler gage by inserting the leaves of the gage between the straight edge and the block (fig 5-2). Record all your readings and check your results against the tolerances listed in the TM. If the cylinder head gasket surface is found to be warped, the machine shop personnel will have to grind it flat if tolerances permit. **CHECK THE TM FIRST!** You just might find that the block you are working on cannot be ground under any circumstances.



Fig 5-2. Checking cylinder block warpage.

If the block must be ground, make a note of this. DO NOT submit the work to the machine shop until you have found all the defects. There may be more work for machine shop personnel and they might as well complete it all at the time you submit the block for repair. After all defects are located, send the block to the machine shop if necessary and accomplish your repair upon its return.

### 5103. Cylinder Inspection and Repair

Next, check the cylinders (or cylinder liners) for distortion (more commonly called "out-of-round") and cylinder taper. This is done by taking measurements in each cylinder. These measurements are made with a cylinder bore checking gage, which is a dial indicator. The gage may be moved from the top to the bottom of the cylinder, allowing you to measure the taper at each measuring point (usually two measurements at the top and two at the bottom, but check specific TM for engine measuring points) without removing the gage (fig 5-3).

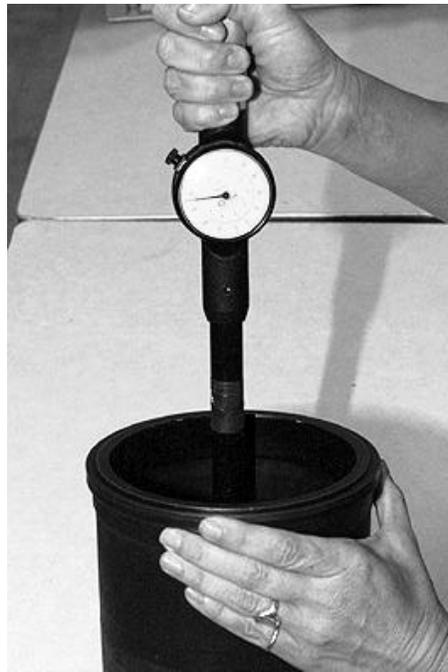


Fig 5-3. Checking cylinder out-of-round and taper.

Record the reading at each measuring point. Determine the amount of out-of-round by subtracting the smaller of the two top measurements from the larger. To determine the amount of cylinder taper, subtract the top readings from the bottom readings. Check your TM specifications to determine whether the taper and out-of-round are within reusable limits.

Assume for the moment that the cylinders are not reusable in their present condition. In this case, you must rebores the cylinders and replace the present pistons with oversized pistons. The machine shop personnel will rebores the cylinders for you. If reboring is not required it will be your job to prepare the cylinders for reassembly. This procedure is known as honing.

You must hone the cylinder walls to remove the mirror smooth finish. This will also remove minor scores and rough areas and aid the new piston rings in seating when they are installed. The hone is placed inside the cylinder and adjusted to a snug fit (fig 5-4). Attach a heavy-duty electric drill motor to the hone and apply a small amount of engine oil to the honing stones. Begin drilling, moving the hone up and down inside the cylinder.



Fig 5-4. Honing the cylinder.

**Caution:** During the honing process, the honing stones **MUST BE KEPT WET**; so, continue to squirt oil on the honing stones to prevent them from becoming dry.

When you feel that you have eliminated the scores and rough spots, switch the drill off and remove it. Now, wipe the cylinder walls dry and inspect them to ensure that all defects are removed. If defects remain in the cylinder, and it appears that a considerable amount of honing will be necessary to remove them, consult the machine shop personnel. It may be necessary to rebore the cylinder.

#### **5104. Cylinder Liner Replacement**

If the engine you are working on is equipped with insert-type cylinders (mentioned earlier in the course), the inserts may be replaced rather than bored. If you find that you must replace a cylinder insert (liner), the piston must be replaced also. The piston and liner are issued as a matched set.

Replace cylinder liners that do not meet requirements specified in repair and rebuild standards. Use the cylinder liner remover and replacer (fig 5-5)

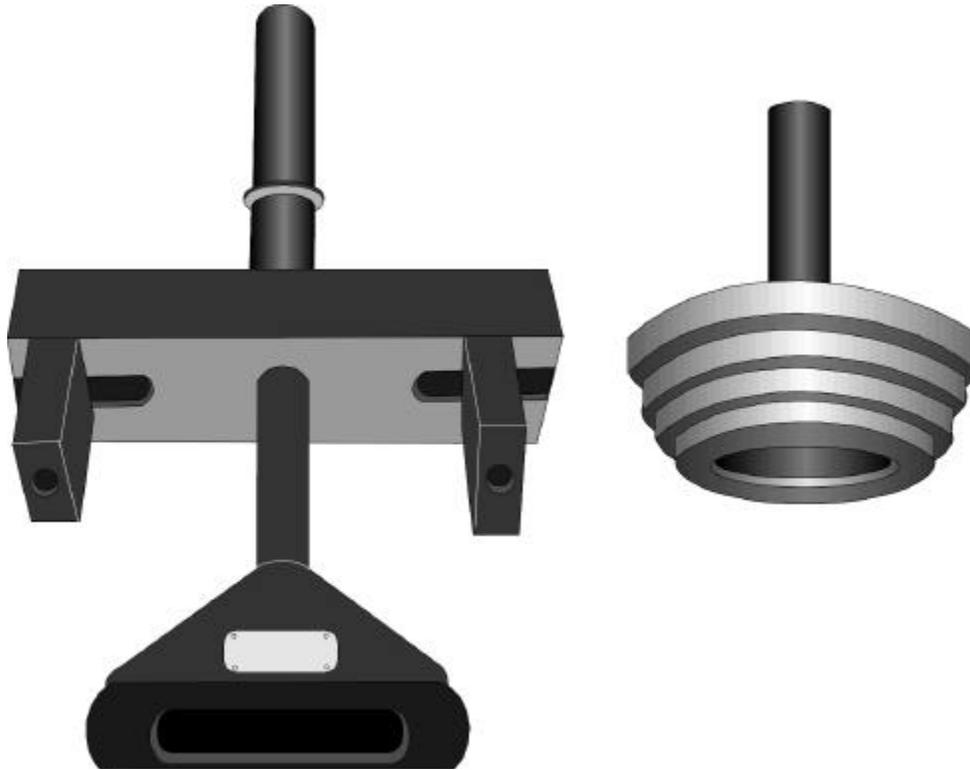


Fig 5-5. Cylinder liner remover and replacer tools.

When a cylinder liner is installed, it must be positioned over the cylinder bore with the flange end up. Let's continue now with the valve tappet bore.

### **5105. Valve Tappet Bore Inspection and Repair**

Now that you have checked and repaired the cylinder bores, proceed with the valve tappet bores if the engine you are working on requires it. The tappet bores are checked visually. Check the bore walls for scoring and burring first. If scores or burrs exist, they must be removed. If the defects are not too deep, you may remove them with crocus cloth. However, if the defects can't be removed with crocus cloth, you must replace the cylinder head or the engine block depending on tappet location.

### **5106. Camshaft Bores Inspection and Repair**

Now, check the camshaft bearings. Inspect the bearing surfaces first to determine whether new camshaft bearings are needed. If the bearings show signs of scoring, pitting, or excessive wear, they must be replaced so that the valves will open and close properly for maximum engine performance.

Figure 5-6 illustrates the camshaft bearing remover/installer used to remove and replace the old bearings.

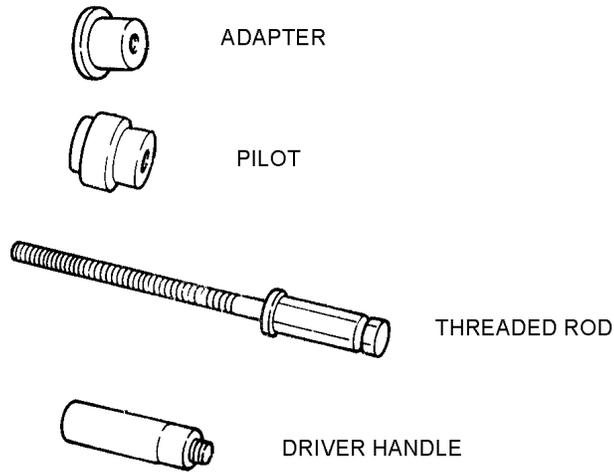


Fig 5-6. Camshaft bearing remover/installer.

Remove the camshaft bearings: The front and rear (outer) bearings are removed from the front and rear respectively using the driver handle and appropriate adapter. First remove the camshaft bearing plug by knocking it out from within the engine with a wooden dowel or suitable metal bar. With the rear bearing plug removed, you may now install the adapter appropriate to the bearing diameter and the driver handle (fig 5-7). Remove the bearing by driving it through the bearing bore.

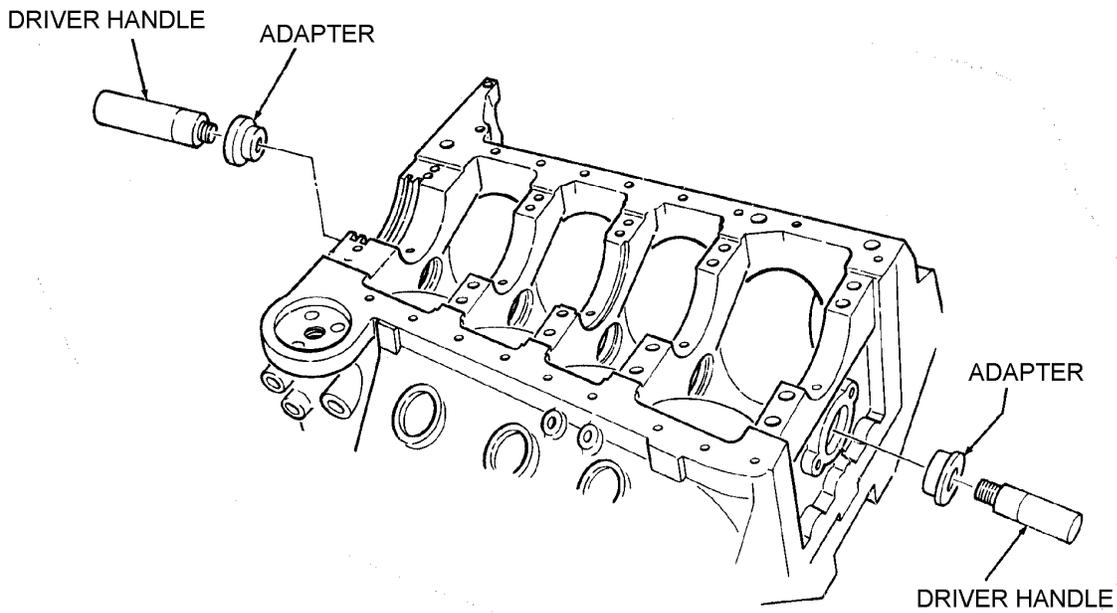


Fig 5-7. Removing outer camshaft bearings.

Remove the inner camshaft bearings by placing the pilot in the outer bearing bore and running the threaded rod through the pilot through the inner bearing. Attach the appropriate adapter to the threaded rod and draw the inner bearing out of its bore by turning the threaded rod. As stated before, the end from which you remove them depends on the length of the engine (it is usually best to remove them from the closest end). Figure 5-8 will give you a better idea of how the inner bearings are removed.

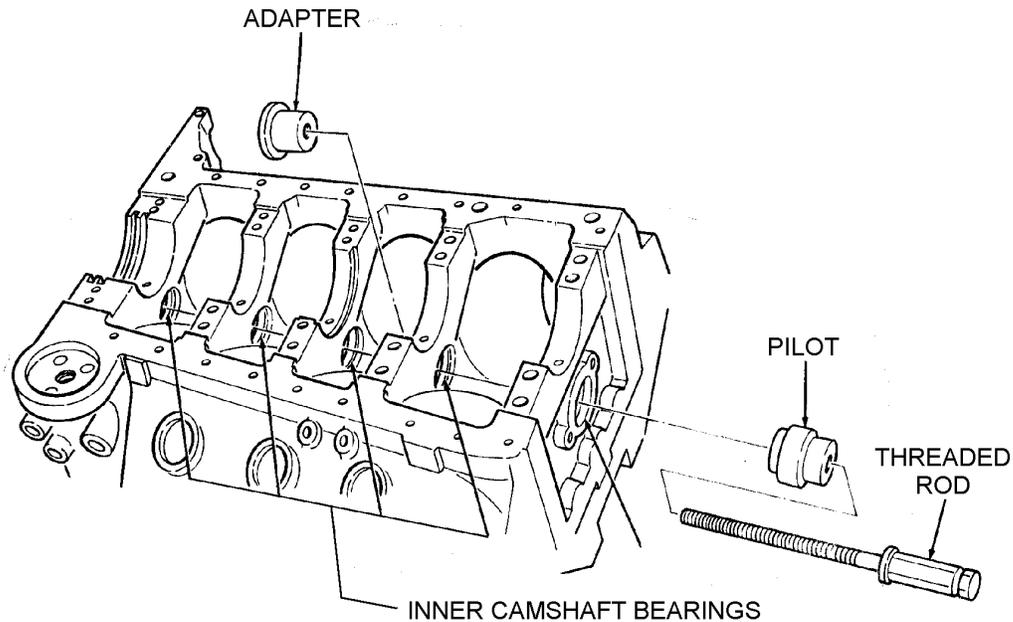


Fig 5-8. Removing the inner camshaft bearings.

With a piece of chalk or other suitable marking material, mark the location of the oil holes in the engine block.

Install the new camshaft bearings: Install the new bearings beginning with the last bearing removed. Place it on an adapter of the remover/replacer which is larger in diameter than the bearing.

Now, place the bearing and adapter against the bore in which it is to be installed. Insert the shaft through the adapter, install the adapter nut, and with the appropriate wrench, draw the bearing into the bore until the adapter flange is flush with the bearing bore.

Once installed, measure inner bore diameter and inspect the bearing oil holes to ensure that they are aligned with the oil holes of the bearing bore. If not, they must be removed and reinstalled correctly.

Remove the expansion plugs: With the installation of the last camshaft bearing, you are ready to take the final step in the repair of the engine block--replacement of the expansion (core) plugs.

Defective expansion plugs cannot be detected until they actually begin to leak. Therefore, it is advisable to replace all expansion plugs during the rebuilding of an engine.

A sound method of removing a plug is to drill a 1/2-inch hole in the center of the plug and remove it with a slidehammer type puller (fig 5-9). You might have noticed that this is the same puller used to remove the clutch pilot bearing from the rear of the crankshaft.

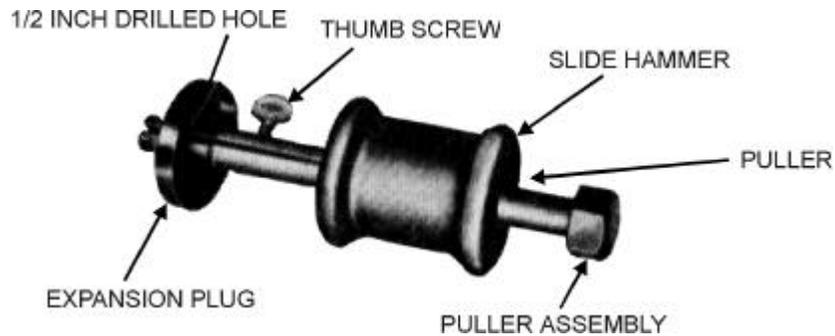


Fig 5-9. Removing expansion plugs.

Install the expansion plugs: After you have removed the expansion plugs, the new plugs are easily replaced with the expansion plug replacer, illustrated in figure 5-10A. Simply place the expansion plug on the end of the replacer and, placing it against the expansion plug recess (fig 5-10B), strike the end of the replacer gently until it seats evenly in the recess. Once it has seated, continue striking it until the flange of the replacer is flush with the engine block. With the installation of the last expansion plug, you are ready to set the engine block aside and begin work on the crankshaft.

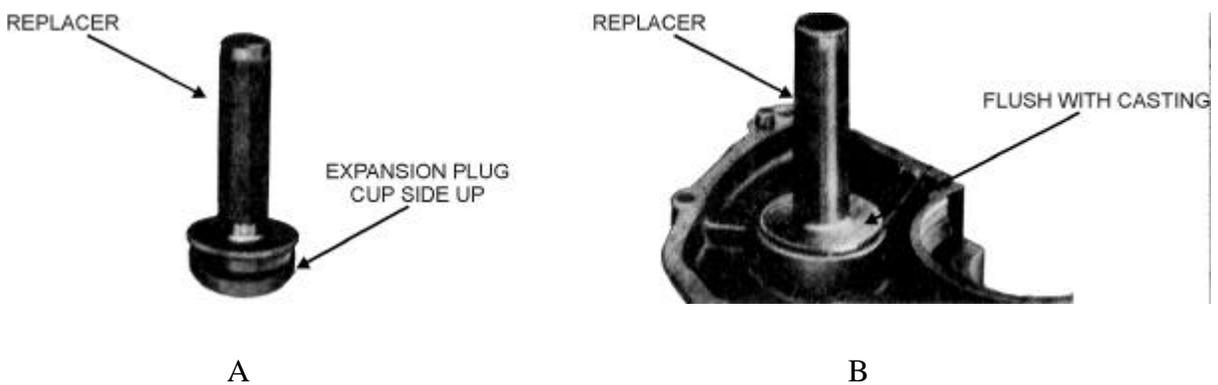


Fig 5-10. Replacing expansion plugs.

Lesson 1 Exercise: Complete items 1 through 10 by performing the actions required. Check your responses against those listed at the end of this lesson.

1. A thorough engine block inspection can only be accomplished after
  - a. the block has been reassembled.
  - b. the block has been cleaned externally.
  - c. all repairs have been made.
  - d. the block has been cleaned internally and externally.
  
2. Checking the cylinder head gasket surface of the block using a straight edge and feeler (thickness) gage will reveal any
  - a. cracks.
  - b. scores.
  - c. warpage.
  - d. nicks.
  
3. Cylinder bore out-of-round is checked by what instrument?
  - a. Dial indicator
  - b. Feeler gage
  - c. Micrometer
  - d. Tension gage
  
4. You are checking a cylinder bore during engine block repair. Which of the following procedures should you follow?
  - a. Take one measurement at the top and one at the bottom to determine out-of-round.
  - b. Take two measurements at the top, at right angles, to determine end out.
  - c. Take two measurements at the top and one at the bottom to determine degree of piston skirt wear.
  - d. Take two measurements at the top and two at the bottom to determine out-of-round and taper.
  
5. To remove the mirror-smooth glaze finish of the cylinder walls during engine repair, the cylinder must always be
  - a. lapped.
  - b. honed.
  - c. scraped.
  - d. replaced.
  
6. Severely scored cylinder walls and distorted cylinders may be rebored by machine shop personnel. However, if the cylinder is only lightly scored, the mechanic may repair the cylinder with a
  - a. lapping machine.
  - b. fine sandpaper.
  - c. honing tool.
  - d. coarse sandpaper.

7. You have just inspected the cylinders of an engine you are repairing and find that some have been badly scored. What action do you take to correct these defects?
  - a. Discard the engine block
  - b. Ream the cylinders
  - c. Hone the block at the piston skirts
  - d. Have the machine shop rebore the cylinder
  
8. What must be done after the camshaft bearings are installed?
 

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9. Camshaft bearings are removed by using a
 

---
  
10. After installing new camshaft bearings, ensure the bearing oil holes are
 

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#### Lesson 1 Exercise Solutions

	<u>Reference</u>
1. d.	5101
2. c.	5102
3. a.	5103
4. d.	5103
5. b.	5103
6. c.	5103
7. d.	5103
8. With bearing installed, measure inner bore diameter.	5106
9. camshaft bearing installer/remover	5106
10. aligned with oil holes of the bearing bore	5106

Lesson Summary. Lesson 1 explains the importance of engine block inspection. You learned how to check the engine cylinder block for warp and the cylinder walls for damage. You also learned the procedures for repairing or replacing damaged areas of the engine block. Now you are ready to learn the details of inspecting and repairing engine block components.

## **Lesson 2. ENGINE BLOCK COMPONENTS**

### LEARNING OBJECTIVES

1. Identify the procedure to repair the crankshaft.
2. Select the appropriate measurement procedure to use when inspecting the crankshaft.
3. Identify the procedure to repair the flywheel.
4. Identify, from a list, the tools used for checking specific engine block components.
5. Identify the procedure to repair the piston assembly.

Each engine block component requires thorough cleaning and examination. One clogged passage can make you do extensive repairs shortly after the rebuild is completed. In the Marine Corps, this is at the expense of the taxpayer, but in a civilian shop, the money comes out of the mechanic's pocket.

### **5201. Crankshaft**

The crankshaft must be handled with extreme care to avoid fracturing or otherwise damaging the finished surfaces. Damage to these surfaces will cause rapid wear of bearings and seals, resulting in engine failure soon after the rebuild is accomplished.

Your first step is to clean the crankshaft. The crankshaft may be cleaned with cleaning solvent or a strong parts cleaner if the solvent cannot do a thorough job. After the initial cleaning, use an air hose to blow out the small passages in the shaft. These are oil passages and they are vital to the life of the bearings. Once the crankshaft has been thoroughly cleaned, inside and outside, inspect it visually for cracks, burrs, and grooves. Cracks, if present (and sometimes they are hard to find) are a sign of metal fatigue; therefore, the crankshaft should be discarded and a new one obtained. If you locate burrs on the finished surfaces, you can usually eliminate them with the oil stone. If grooves or deep nicks appear on finished surfaces, the crankshaft must be ground on a lathe to a smaller size if possible.

Consult the machine shop personnel concerning the grinding of the crankshaft. If they cannot do the job, discard the crankshaft and obtain a new one through the supply system.

Assuming that you have inspected the crankshaft and found no major defects that could not be remedied with the oil stone, take some measurements to make sure that the crankshaft main journals and the crankpins are not out-of-round. An out-of-round journal or crankpin is just as bad as a burr, nick, or groove.

Each journal and crankpin must be measured across its diameter in two places at 90° angles to each other. Make these measurements with an outside micrometer by adjusting the micrometer until it may be passed across the journal with a very slight drag. This is illustrated in figure 5-11. The size of the circle is not necessarily the size of the journal or crankpin. The arrow to the right indicates the directions in which the micrometer is moved.

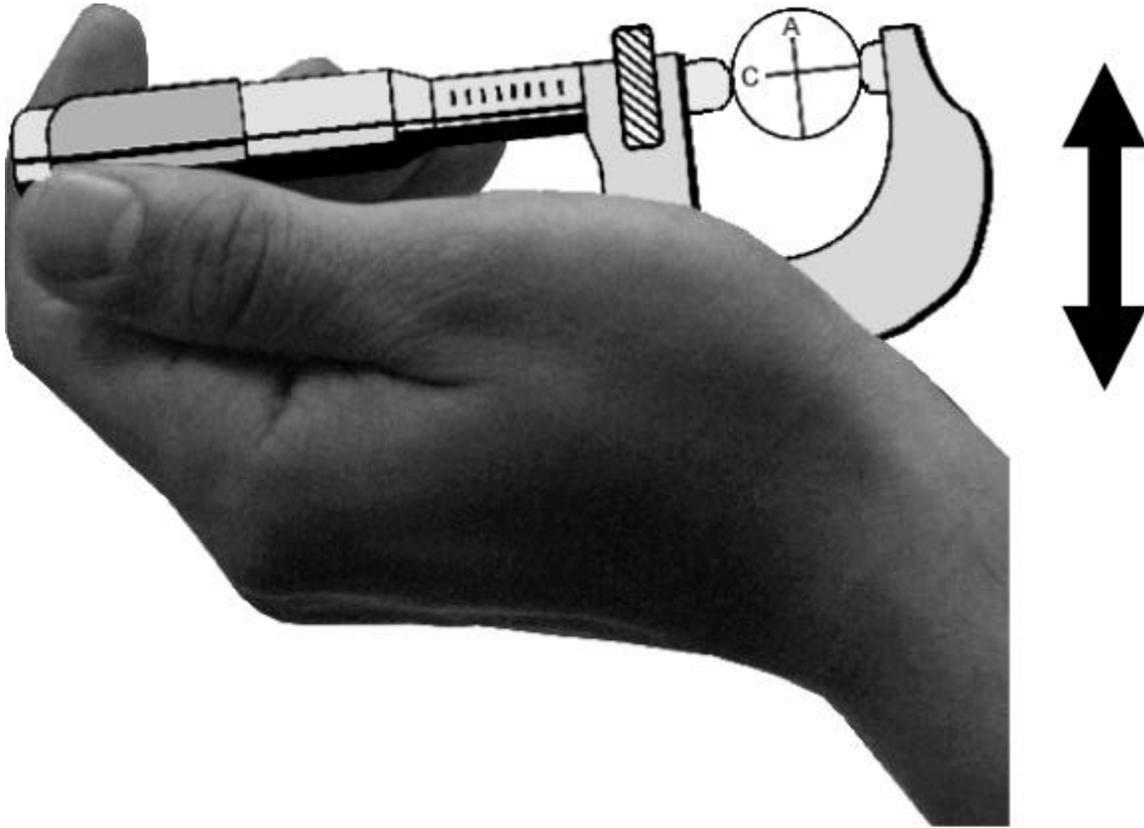


Fig 5-11. Measuring crankshaft main journals and crankpins for out-of-round with a micrometer.

Before attempting to use the micrometer, be thoroughly familiar with its care and use. TM 9-243, *Use and Care of Handtools and Measuring Tools*, provides good basic information that will enable you to properly use this measuring tool.

If the main journals and crankpins are found to be out-of-round, they must be ground or the shaft should be discarded. Before having the crankshaft ground, make sure the shaft is worth grinding. What if it is not aligned?

A warped crankshaft is of no value to you in the rebuild or repair of an engine. With a pair of "V" blocks that may be fabricated locally and a dial indicator gage, you can determine the runout (warpage) of the crankshaft by placing the gage point on the crankshaft journal and rotating the crank (fig 5-12).

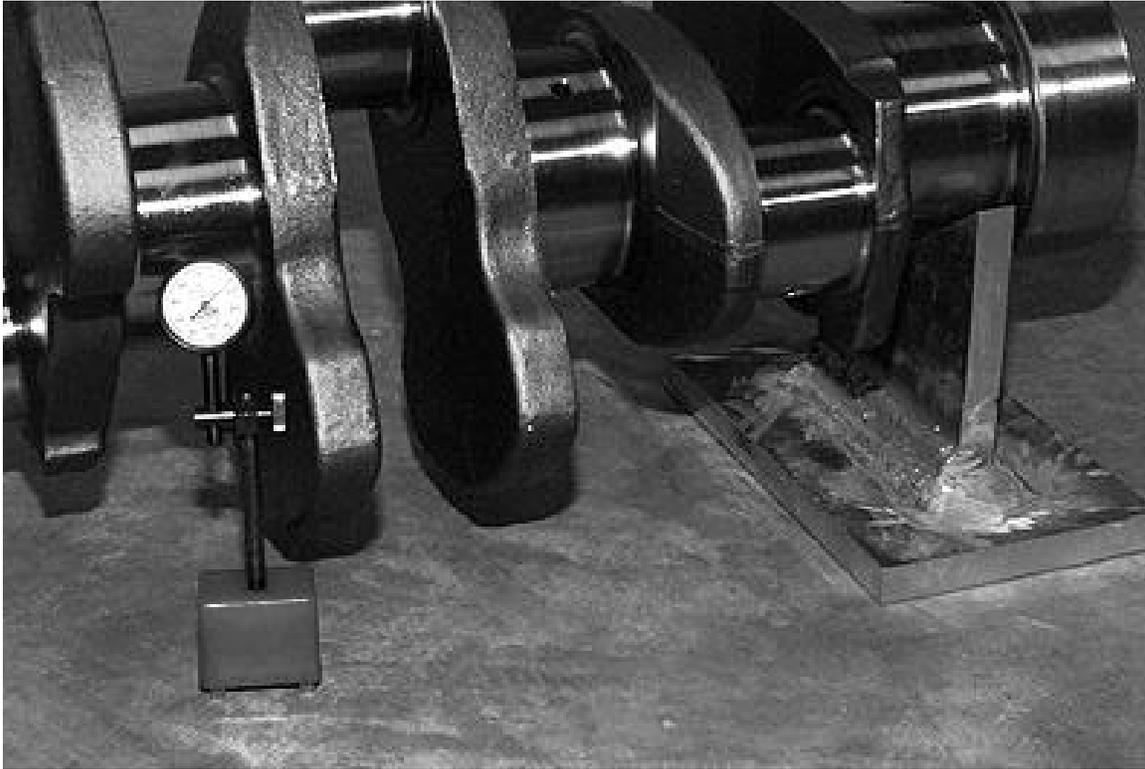


Fig 5-12. Measuring crankshaft runout (warping).

If the crankshaft is found to be warped, replace it with a new shaft. If there is no warpage, check the woodruff key slot at the end of the crankshaft. Sometimes this slot will become enlarged. Make sure the woodruff key fits snugly into the slot; and while you are checking the key fit, check the key itself for burrs and nicks. Most of these may be eliminated with an oil stone. Just be careful that you do not decrease the size of the key when eliminating these defects.

Now, let's clean the main bearings thoroughly and inspect each bearing half. Scored or chipped bearings as well as excessively worn bearings must be replaced. At this point, you may begin to eliminate crankshaft end play if it was found to be excessive during disassembly. This is done by replacing the main thrust bearings.

You must determine whether or not the bearing halves fit the crankshaft properly. This may be accomplished by two different methods. First, let's study the telescopic gage method. The use of these measuring devices requires skill and knowledge of their functions and must be learned from an experienced mechanic if an accurate reading is to result. Basically, the measurements are taken at six points in each crankshaft bore with the telescopic gage shown in figure 5-13.



Fig 5-13. Measuring the crankshaft bore with a telescopic gage.

Measure each bore near both ends to determine the taper of the bore. Each end is measured across the bore at a right angle to the split of the bearing halves, then at two other points  $45^{\circ}$  from the original measurement. These measuring points are illustrated in figure 5-14.

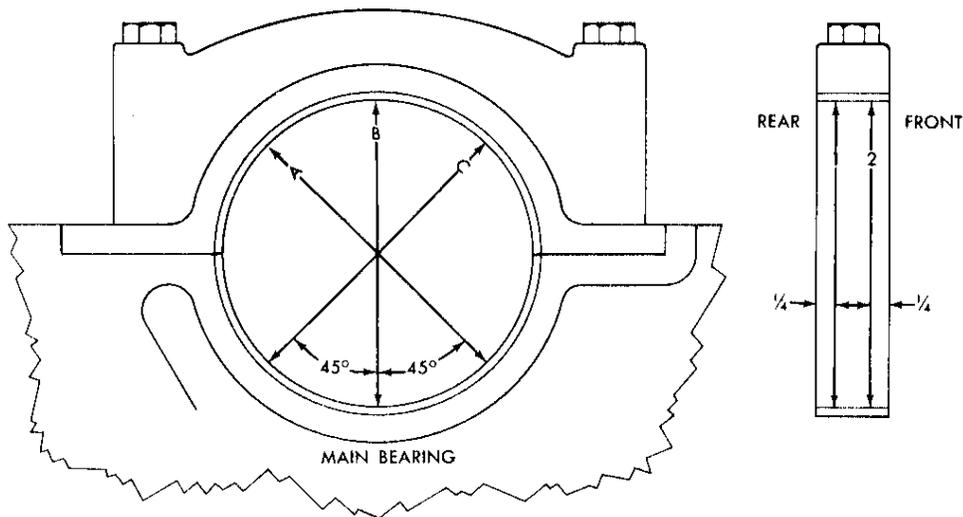


Fig 5-14. Points of measurement for crankshaft main bearings.

Note that the illustration indicates that the end measurements are taken 1/4-inch in from each end. This is an approximate figure. Check your TM for specific distance.

After EACH use of the telescopic gage, such as measuring point "B," a micrometer must be used to measure the telescopic gage length since it has no measurements on it. When all measurements have been taken, subtract the corresponding crankshaft journal measurements.

The difference found between these measurements is the running clearance of the main bearings, which must be compared with the specifications listed in the TM to determine whether the bearings are suitable for use.

Note: To obtain accurate measurements, the bearing caps must be torqued to the specified torque listed in the TM.

Another method of determining running clearance is the plastigage method. Plastigage is a commercial name that has been accepted as a common term in the automotive field. It is a small string of plastic material packaged in a strip of paper. The paper is used to take the measurements as well as to protect the material. When using plastigage, the contact areas must be clean and dry, the crankshaft must not be rotated, and all caps must be installed and tight.

Turn the engine upside down. Place the crankshaft in its proper position in the main bearing frame with the upper crankshaft bearing halves installed. Then, place a small strip of the plastigage along the length of the journal. Place the lower crankshaft main bearing half inside the main bearing cap. Install the main bearing cap and tighten it to specified torque. After you have done this, remove the bearing cap and measure the flattened strip against the paper gage provided in the package (fig 5-15).

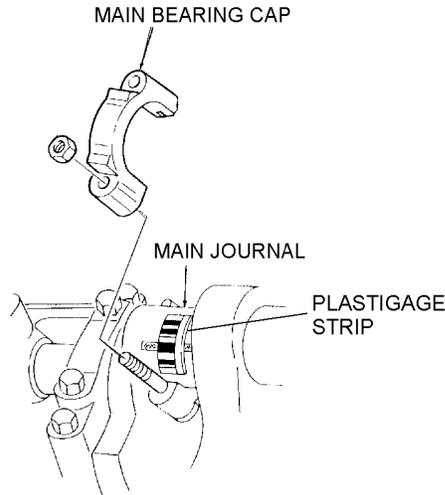


Fig 5-15. Measuring crankshaft bearing running clearance using plastigage.

Plastigage may be obtained in three ranges. The color of the plastic string indicates the range as follows: Green is for bearings requiring 0.001 to 0.003 inches, red is for bearings requiring 0.002 to 0.006 inches, and blue is for bearings requiring 0.004 to 0.009 inches running clearance. Check your TM specifications before obtaining the plastigage to ensure that you are using the correct type.

Now, install the crankshaft timing gear and you are ready to proceed to the next component. Drive the woodruff key into the woodruff key slot and slide the gear onto the shaft with the timing mark visible from the front of the shaft.

Let's see what you've learned so far. What precision tool is used to measure a crankshaft for out-of round? If you said a micrometer you are absolutely right. And what precision tool is used to check the crankshaft for warpage? That's right, a dial indicator.

With all repairs completed on the crankshaft, the next component that you have to be concerned with is the flywheel.

### **5202. Flywheel**

Inspect the flywheel thoroughly for scoring, cracks, and heat checks (discoloration due to extreme heat). If any of these defects appear, replace it with a new one.

Now, inspect the flywheel ring gear for worn, chipped, or cracked teeth. In most cases, this will be cause for discarding the flywheel. However, in some cases you might be required to replace only the ring gear. If you must replace the ring gear, cut the defective gear off with a chisel and cool the flywheel to the lowest temperature possible within your means (this may be room temperature or lower). The new ring gear must be heated to approximately 600<sup>o</sup> Fahrenheit. Cooling the flywheel and heating the ring gear aides in the shaping and bonding of the two pieces.

In some cases, the clutch pilot bearing is installed in a bore located in the flywheel and, in other cases, it is installed in a bore located in the rear end of the crankshaft. In either case, force the pilot bearing into its bore and make sure it is snug and properly aligned. In the case of a bronze bushing-type bearing, you should always install a new one. In the case of ball or roller type bearings, make sure the bearing is operating smoothly.

If the above defects are not corrected, poor clutch engagement results as well as the destruction of the clutch components in many cases.

### **5203. Vibration Damper**

Now, inspect the vibration damper for chips and cracks. Chips will result in vibration due to an unbalanced condition and cracks will result in the eventual destruction of the damper and possible damage to other components. If the damper is the type discussed earlier in the course, with the rubber mounting between the wheel and outer ring (weight), inspect the rubber for deterioration. The deteriorated condition can cause damage. If any defects are apparent in the vibration damper, discard it and obtain a new one.

## 5204. Piston Assembly

Although the piston assembly performs a relatively simple function, the specifications are quite critical due to the speed that the piston travels, the pressure exerted on it, and of course the resulting friction. Keeping this in mind, let's begin the repair of the piston assembly.

To repair the piston, it must first be disassembled. To prevent damaging the piston's surface, cover the vise jaws with a soft material (figure 5-16). Soft tin or aluminum covers should be available in every shop. If not, you may fabricate a pair. With the jaws of the vise covered, secure the connecting rod of the piston assembly in them (fig 5-16). With the piston secured in the vise, remove the rings the shortest distance off the piston to prevent damaging the piston surface. Ring expander tools provided for this purpose will prevent scratching and burring the piston. Figure 5-17 shows tools commonly used in the removal and installation of piston rings. Any of these tools may be used on any type of piston.



Fig 5-16. Secure piston in vise.

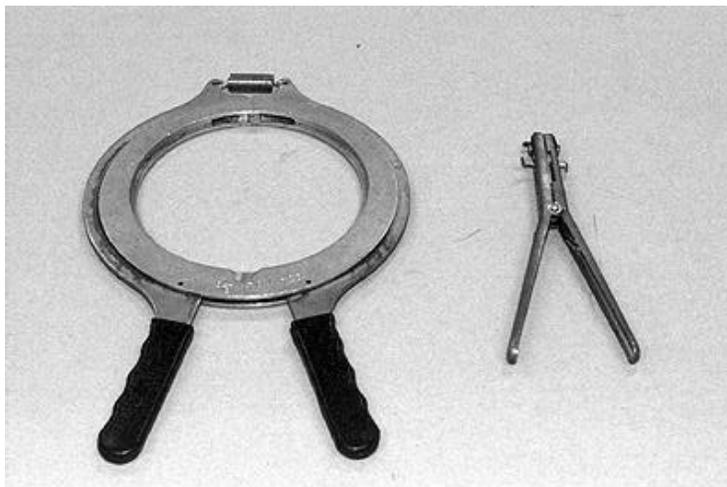


Fig 5-17. Common ring expander tools used to remove and install piston rings.

After all the rings have been removed, the oil control ring expander must also be removed. In most cases, the oil ring, as well as the expander, must be removed by hand. Extreme caution must be exercised to prevent scratching the piston during this procedure.

To prepare for the next disassembly step, mark the piston and its connecting rod to ensure that the same rod and piston are kept as a set. The piston pin must also be included in the marking. Piston pins are NOT interchangeable. Interchanging piston pins usually results in a piston pin knock (loose pins). You are now ready to remove the piston pin, separating the piston from the connecting rod. Some pistons may require heating and having the pin pressed out while others may have piston pin retainers. Consult the appropriate TM for the proper piston pin removal procedure. Again, exercise extreme caution to prevent damage.

Remove the connecting rod. Mark the connecting rod and piston pin to ensure their return to the original piston. Lay the separated piston and connecting rod on a clean surface and repeat the same procedure with the remaining pistons.

Once the pistons are disassembled, clean and inspect them. The best method of cleaning them is by dunking them in cleaning solvent and using a brush to remove the carbon deposits on the head of the piston ONLY. The ring grooves must be cleaned also. Special tools are designed for this purpose, but if none are available, an old ring may be used provided the edges are not sharp enough to scratch or burr the piston. Figure 5-18 illustrates the use of a piston ring groove cleaner. The tool is held in its track in two places by the guide, and the blade cuts the carbon away as it is rotated around the piston.

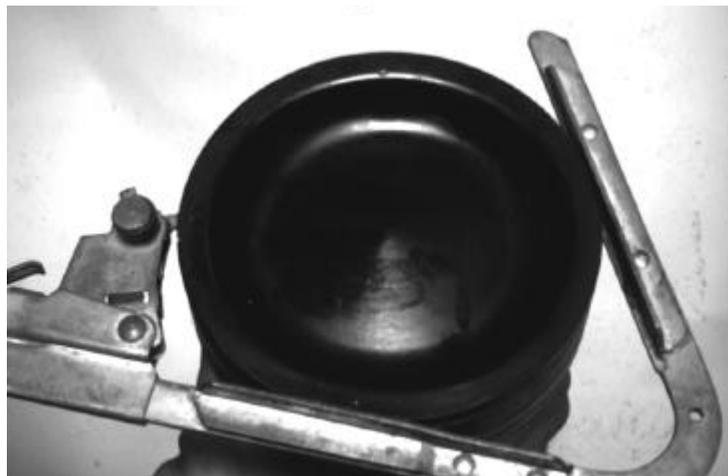


Fig 5-18. Cleaning piston ring grooves.

After cleaning the grooves, blow the piston clean with a compressed air hose, making sure all holes are completely clear. When this is accomplished, inspect the piston thoroughly for scoring, burrs, and cracks. Light scores and burrs may be eliminated with crocus cloth, after which the piston is again serviceable. However, if all scores and burrs cannot be eliminated, discard the piston and use a new one. Cracked pistons must be discarded.

Before continuing let's review what you've learned. How would you repair a lightly scored piston? Crocus cloth is correct. And what must you do if the crocus cloth is unable to remove the scores? That right, you must replace the piston.

After repairing or replacing defective pistons, you must be certain that they are going to fit properly into the cylinders. The next step is to check this piston fit. Both the piston and the block must be at room temperature to make this measurement, and the piston and cylinder walls must be clean and dry. With the piston properly fitted, you must now select the proper piston rings. New rings must be used. These rings must fit both the piston and the cylinder. First determine whether they fit the cylinder. Select a compression ring from each set and place it inside the cylinder. This may be done by pushing the ring down into the cylinder with the head of the piston. With a feeler gage, determine the gap between the ends of the rings (fig 5-19).

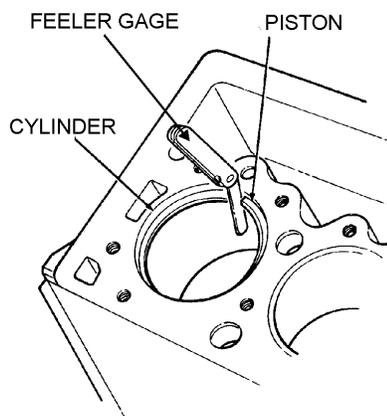


Fig 5-19. Measuring piston ring gap

If the ring fits the cylinder bore properly, see if it also fits the piston properly. You know that it will fit around the piston, but will it be loose in the groove? To determine this fit, insert the ring in the groove for which it is intended and check the clearance with a feeler gage. This is known as piston ring side clearance (fig 5-20). Now, match your findings with the manufacturer's specifications.

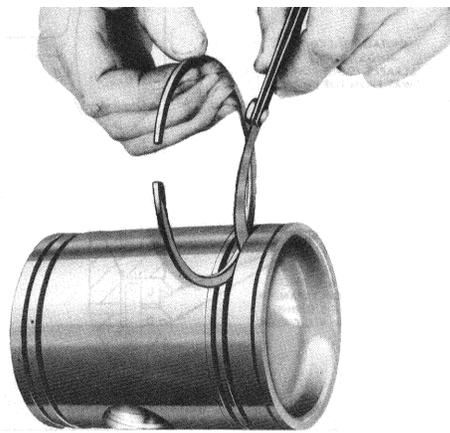


Fig 5-20. Measuring piston ring side clearance.

With all the pistons repaired, let's begin work on the connecting rods. Clean the connecting rod in cleaning solvent; probe the oil passage and squirt holes with soft wire; and, blow loose foreign matter out with an air hose. Clean the rod bearings also.

You must make a thorough inspection of the connecting rod and bearings. Begin with the connecting rod bearing cap and saddle. Check for scuffing, pitting, and burring. Slight imperfections may be removed with crocus cloth or a fine stone. If they cannot be removed, the rod and cap must be replaced. Check the condition of the connecting rod bearing and the piston pin bearing. If excessive wear or pitting is evident, discard these bearings.

If the piston pin bearing appears serviceable, check the piston pin fit. This may be done by measuring the inner diameter of the piston pin bushing (bearing) with a T-gage (fig 5-21) and the outer diameter of the piston pin with a micrometer. (fig 5-22).

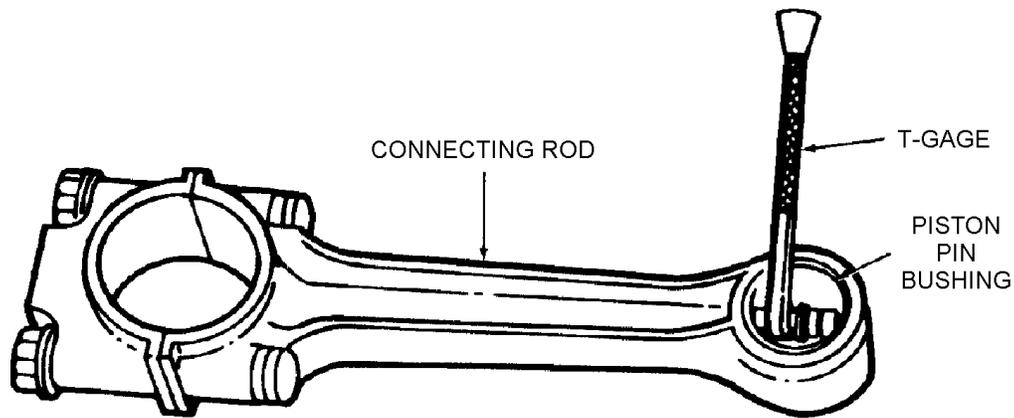


Fig 5-21. Measuring piston pin bushing (bearing) with telescopic gage.

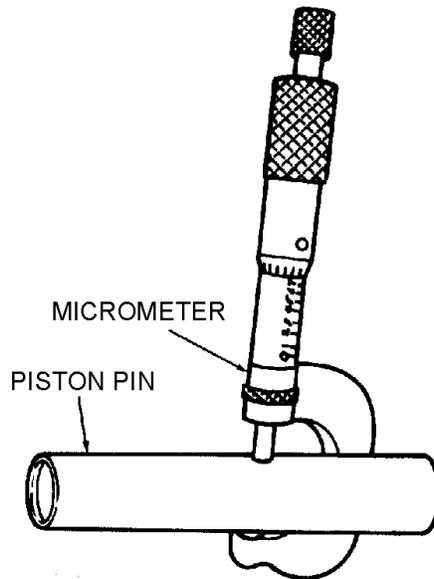


Fig 5-22. Measuring outer diameter of the piston pin with a micrometer.

If the piston pin bushing is worn excessively, it must be removed and a new one installed. This should be done with an press. Figure 5-23 illustrates the use of the press to install the new bushing. Removal is similar to installation. Installing a new bushing does not necessarily mean that it will fit the piston pin. Again check the inner diameter of the piston pin bushing and match it against the outer diameter of the piston pin.



Fig 5-23. Installing piston pin bushings.

With the piston pin bushing checked, and replaced if necessary, place the connecting rod bearing halves in the connecting rod saddle and cap and bolt the two together. Now check out-of-round and taper of the connecting rod bearing. To determine this, measurements are taken in two places at each of the connecting rod bearing bore, just as you did with the crankshaft main bearing bores.

On each end of the bore, take a measurement with a telescopic gage and micrometer in direct line with the connecting rod and another at a  $90^{\circ}$  angle to the connecting rod. The difference between these measurements gives you the out-of-round.

Perform the same procedure at the opposite end of the bore. To find the taper, figure the difference between the two in-line measurements and the difference between the two  $90^{\circ}$  measurements.

Now check the largest out-of-round figure and the largest taper figure against the tolerances listed in the TM. If the bearing is not reusable, install new bearings and repeat the procedure. This will complete the repair of the piston assembly, and we can move on to the repair of the cylinder head. Connecting rod bearing running clearance is checked by the same method as the main bearing, using micrometers.

Lesson 2 Exercise: Complete items 1 through 11 by performing the action required. Check your responses against those listed at the end of this study unit.

1. A crankshaft is inspected and found to have bad cracks in the journals. What action should be taken?  
\_\_\_\_\_
2. A warped crankshaft cannot be used in an engine. To ensure that the crankshaft is not warped, perform a runout test with a dial indicator by placing the crankshaft in \_\_\_\_\_.
3. You have removed a flywheel ring gear. What actions do you take to install a new gear?  
\_\_\_\_\_
4. Which components must always be replaced with new components when repairing pistons?  
\_\_\_\_\_

Matching: For items 5 through 11, match the required action in column 1 to the precision tools in column 2. Answers in column 2 may be used more than once.

Column 1	Column 2
<u>Required Action</u>	<u>Precision Tool</u>
___ 5. Check piston ring end gap	a. Feeler gage
___ 6. Check piston ring side clearance	b. Telescopic gage
___ 7. Measure crankpins for out-of round	c. Micrometer
___ 8. Check piston pin fit	d. Dial indicator gage
___ 9. Check piston in cylinder fit	e. Feeler gage with tension gage
___ 10. Determine crankshaft runout (warpage)	
___ 11. Measure crankshaft bore	

Lesson 2 Solutions:

	<u>Reference</u>
1. Discard the crankshaft; cracks can not be repaired.	5201
2. a set of "V" blocks	5201
3. Heat the ring gear and cool the flywheel	5202
4. Piston rings	5204
5. a.	5204
6. a.	5204
7. c.	5201
8. c.	5204
9. e.	5204
10. d.	5201
11. b.	5201

Lesson Summary. This lesson has taught you how to inspect and repair the crankshaft, flywheel, vibration damper, and the piston assembly. Let's now discuss the cylinder head.

-----

### **Lesson 3. CYLINDER HEAD**

#### LEARNING OBJECTIVES

1. Identify the correct procedure to repair specific parts of the cylinder head.
2. Identify the device to be used to repair specific parts of the cylinder head.
3. Identify the specification checks performed on the cylinder head for the L-head, F-head, and I-head engines.
4. Identify the procedure for installing valves.

The cylinder head from an L-head engine dose not require major disassembly. Therefore the disassembly portion of this study unit refers mostly to the I-head and F-head engines. The cylinder head is cleaned and inspected just as the engine block was; therefore, it is unnecessary to go into a detailed description. Let's get right to inspection and the repair of the cylinder head.

#### **5301. Cylinder Head Inspection and Repair**

Begin disassembly by removing the valves. With a valve spring compressing tool compress the valve spring and remove the valve stem locks. There are various types of valve spring compressors. The one described is one of the more common.

The spring is compressed by placing the solid end of the compressing tool on the valve head and the split end of the spring retainer, then compress it with the lever located on the tool.

Once this is accomplished, you can easily remove the valve stem locks with your fingers. Cup your hand over the end of the spring now and release the lever. The valve spring and its related parts are then removed by hand. The valve may also be removed from the bottom side of the cylinder head by hand.

Keeping each valve and its related components together, lay them out on a clean surface and carefully inspect each piece for damage (fig 5-24).

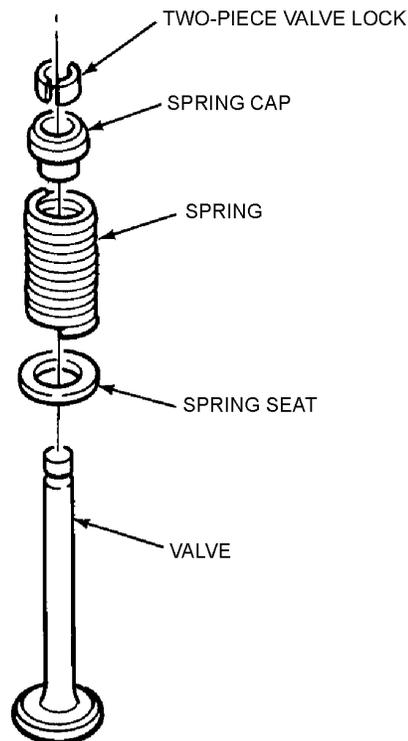


Fig 5-24. Valves and related parts.

Now, remove the coolant outlet connection and check the thermostat operation. To remove the outlet connection, simply remove the cap screws retaining it and lift it from the head.

Remove the thermostat and drop it into boiling water to check its operation. The thermostat should open.

Remove the expansion plugs and replace them as you did in the engine block.

Check the head for nicks, burrs, and cracks. Smooth any nicks and burrs with oil stone. A cracked head may be sealed in some cases. The cylinder head is now ready for specification checks.

The flatness check is performed to ensure that the head is not warped. This check is made in the same manner as the cylinder head gasket surface of the cylinder block. A straight edge and a feeler gage are used to determine the amount of warpage. Figure 5-25 is a good illustration of how to perform the checks.

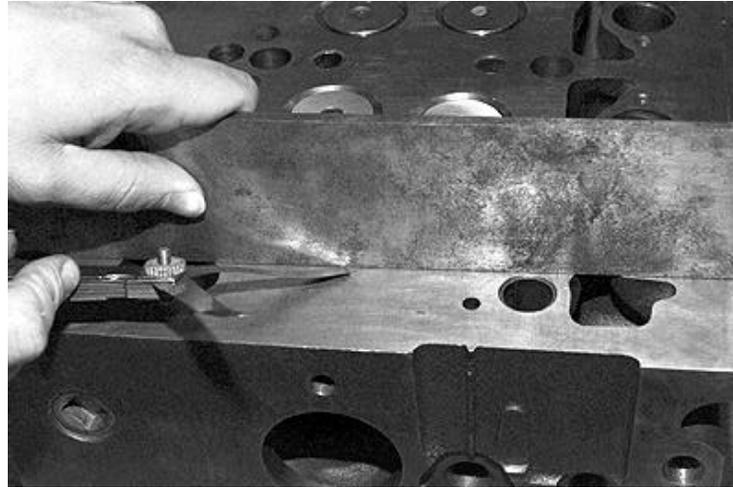


Fig 5-25. Checking cylinder head flatness.

Figure 5-26 shows where these checks should be made. The lines drawn across the surface indicate the positions in which the straight edge should be placed for checking. If you were working on a cylinder head from an L-head engine, this is the only check you would be required to make.

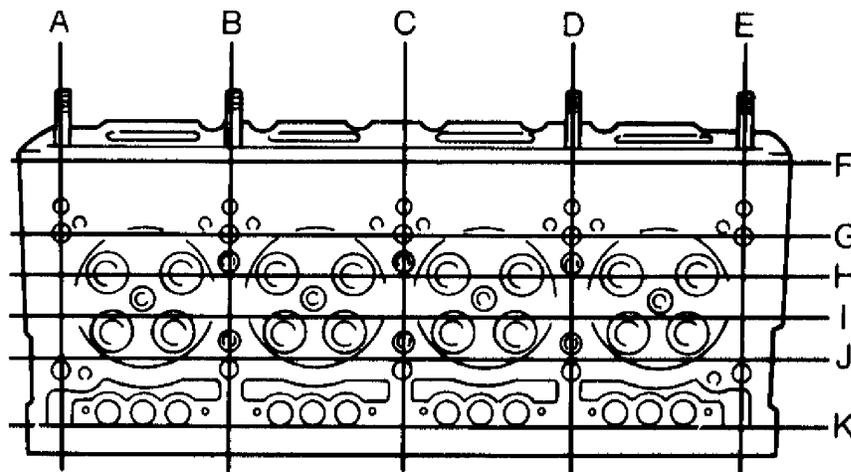


Fig 5-26. Positions for checking cylinder head for flatness.

If the results of the check reveal that the cylinder head warpage exceeds the tolerances listed in the TM, you must have the head ground to obtain a new, flat surface. In some cases, the head may have already been ground as far as allowed and in other cases, heads are manufactured in such a design that they cannot be ground at all. In these cases, discard the cylinder head and obtain a new one through the supply system.

### 5302. Valve Seat Inspection and Repair

Your first step would be a visual inspection. It is important that the valve seat be of the proper width to ensure an air-tight seal and proper valve cooling. Although the entire surface of the valve seat is machined smooth, only a small portion of that surface is actually contacted by the valve when it is closed.

If the head is equipped with cast in seats, improper fit or damaged seats would need to be ground (refaced). Grinding requires the use of a electric drill motor (fig 5-27) and grinding stones of various degrees of angle. Consult the appropriate TM for the proper angle.



Fig 5-27. Grinding valve seats.

Care must be exercised to prevent the grinding of too much metal from the surface of the seat. Check contact surfaces between the valve and valve seat by applying a light coat of Prussian blue dye to the valve face. Lower the valve stem into the valve guide and let the valve drop against the valve seat. Apply pressure valve head until valve face makes good contact with valve seat, **BUT DO NOT ROTATE**. Push up on valve stem until valve face is about one inch above valve seat. Drop valve back into valve seat and reapply pressure to valve head. Repeat this procedure several times to get a good imprint in the Prussian blue dye. Being careful not to smear the dye, remove valve. The imprint in Prussian blue dye should have an even seat mark all the way around the center of the valve face.

If the head you are working on has replaceable seats (valve seat inserts), badly damaged seats must be replaced. Remove and replace valve seat inserts as illustrated in figure 5-28A and B.

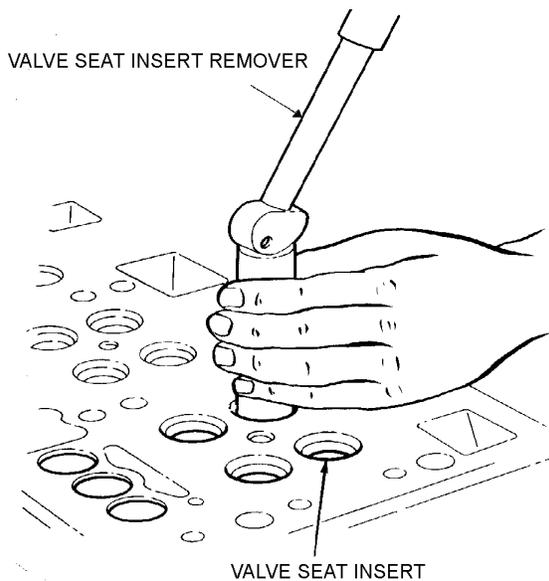


Fig 5-28A. Removal of valve seat inserts.

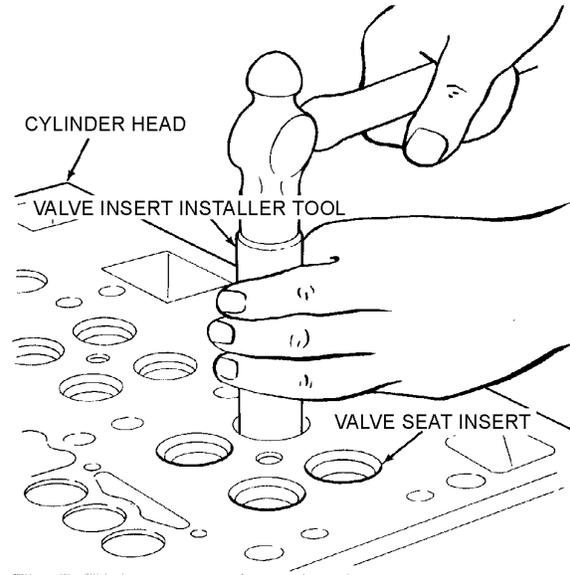


Fig 5-28B. Replacement of valve set inserts.

After valve seats have been replaced, perform a runout check. The valve seat runout check ensures that the seat is perfectly round. This is accomplished by the use of a dial indicator type gage known as a runout gage. The gage manufacturer provides instructions for its use, but basically, you insert the base of the gage into the valve guide, adjust the measuring device to seat on the contact surface of the valve seat, and run the measuring device around the valve seat (fig 5-29). The maximum reading reached on the dial indicator tells what the runout is. The runout is then checked against the tolerance listed in the TM.

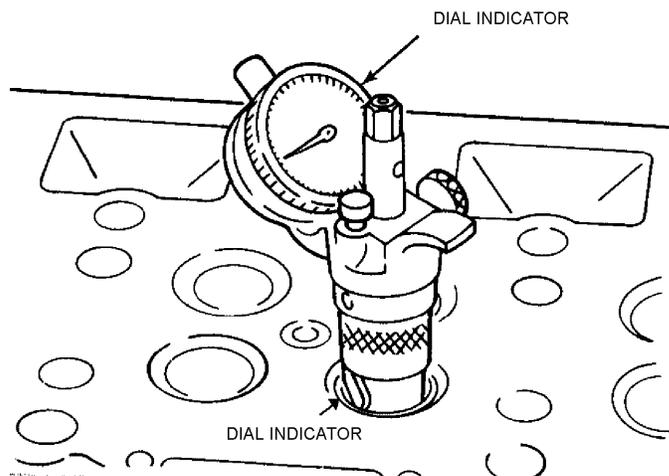


Fig 5-29. Checking valve seat runout.

### 5303. Valve Guide Inspection and Repair

Although you may have repaired or replaced the valve seats, the valves will not seat properly unless the valve stem clearance is correct. Check the valve stem clearance now to help ensure proper valve seating. Measure the inside diameter of the valve guide with a telescopic gage and the outside diameter of the valve stem with a micrometer. To obtain valve-to-guide clearance, subtract valve stem diameter from valve guide diameter. Check appropriate TM for proper specifications.

If the reading you have obtained is greater than the tolerance, either the valve or the valve guide must be replaced. Check the condition of both and determine which needs replacement. In some cases, both may have to be replaced. If the cylinder does not have replaceable guides, ream the guide and use an oversized valve.

If the engine is equipped with replaceable valve guides and a visual inspection reveals that the valve guide is damaged beyond repair, it must be replaced. To replace the valve guide, the old guide must be driven out of the cylinder head or cylinder block and a new one driven in. This is accomplished by placing the valve guide remover inside the valve guide and drive the guide out through the cylinder head with a ballpeen hammer.

When installing valve guides, use the appropriate valve guide installer tool and press (fig 5-30). Position valve guide squarely on guide bore and gently press guide into bore. The installer will position guide to the correct depth.

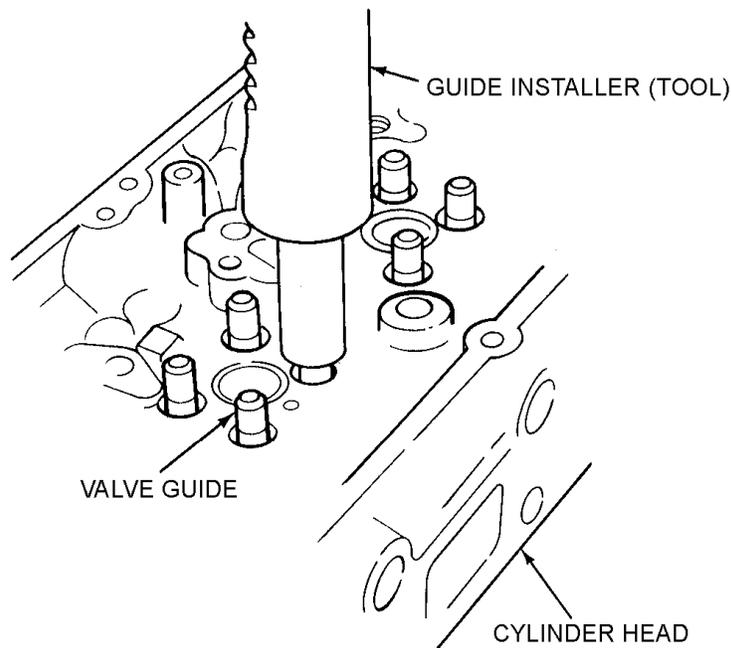


Fig 5-30. Installing valve guides.

This should complete the repairs of the cylinder head, or in the case of the L-head engine, the cylinder block. The final component to be repaired is the valve mechanism.

Lesson 3 Exercise: Complete items 1 through 6 by performing the action required. Check your responses against those listed at the end of this lesson.

1. The first step in the removal of the valve spring is to  
\_\_\_\_\_.
2. You are inspecting a cylinder head to determine if it is reusable. First you inspect the head visually, then, with a straight edge and feeler gage, you check it for  
\_\_\_\_\_.
3. What is used to check valve face to valve seat contact?  
\_\_\_\_\_.
4. The device used to check for valve seat runout is \_\_\_\_\_.
5. What is the correct procedure for replacing valve seat inserts?  
\_\_\_\_\_  
\_\_\_\_\_.
6. A nonreplaceable burred valve guide may be repaired by what method?  
\_\_\_\_\_.

Lesson 3 Solutions:

	<u>Reference</u>
1. Compress the valve spring	5301
2. warpage	5301
3. Prussian blue dye	5302
4. dial indicator type runout gage	5302
5. Remove the defective seats with a puller Install the new seats into position with appropriate tool	5302
6. Reaming	5303

Lesson Summary. This lesson focused on repairing the cylinder head and related parts. You've learned the importance of a thorough inspection, to include precision measurements. Let's now move on to the final portion of engine repair, the valve mechanism.

## **Lesson 4. VALVE MECHANISM**

### LEARNING OBJECTIVES

1. Identify the tool used to measure or check specific parts of the valve mechanism.
2. Identify the valve spring test that cannot be corrected by replacing the valve spring.
3. Identify the reason for the camshaft runout test.

The valve mechanism consists of many associated components. The valves, valve springs, rocker arms, and camshaft just to name a few. It is important to conduct a thorough inspection of each component. The failure of just one valve spring can have an impact on the engine's performance.

### **5401. Valve Inspection and Repair**

Begin the repair of the valve mechanism by repairing the valves. Clean the valves thoroughly with a wire brush or buffing wheel to remove all carbon and varnish. When this is done, inspect the valves for pitting, burnt surfaces, scoring, stem warpage, wear, and cocked condition.

When you have determined that the valve is serviceable or have replaced it with a new one, check the valve face runout. This is necessary to determine whether the valve will form a pressure- and vacuum-tight seal with the valve seat. To perform this check, use the Prussian blue dye as explained in paragraph 5303.

### **5402. Valve Spring Inspection and Repair**

To ensure that the valve seats properly, forming a pressure and vacuum tight seal, you must not only have a lapped fit between the valve and seat, but a valve spring of the proper pressure and squareness. To measure the pressure, use a spring tester as pictured in figure 5-31.



Fig 5-31. Checking valve spring pressure.

If the valve spring is at the specified height, check the spring strength on a pressure gage and compare it with manufacture's requirements in TM. If the valve spring has become weak, discard it and obtain a new one.

To determine valve spring squareness, simply place a square alongside the valve spring in the vertical position and measure the point of greatest distance between the two (fig 5-49). Valve springs are not repairable; therefore, just as the case with the weak spring, the spring must be replaced.

Now, you are ready to install the valves in the cylinder head or in the cylinder block, as the case may be. Insert the valve stem into the valve guide from the combustion chamber side of the head and place the valve spring over the end of the valve stem. Now place the valve spring retainer on the valve spring and attach the valve spring compressor in the same position as when you were removing the valves. Compress the valve spring and insert the valve stem locks. Release the valve spring compressor and the valve is installed.

With the valve installed, there is still one check which must be made, the "installed height" of the valve spring (fig 5-32). This is done by placing a machinist's square alongside the valve spring. Check your measurement against the tolerance listed in the TM. If the installed height does not meet specifications, either the valve or the valve seat insert must be replaced.

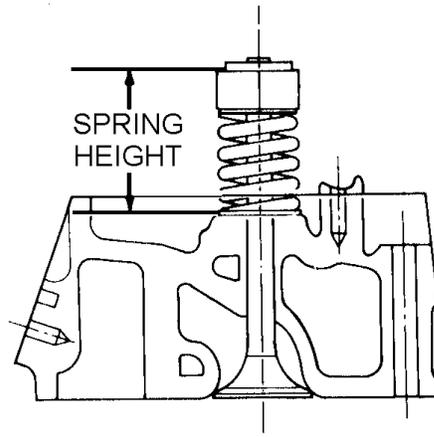


Fig 5-32. Checking valve spring installed height.

Note: If you are repairing an L-head engine, the procedure is the same as outlined on previous page except you will be working with the engine block instead of the cylinder head.

### 5403. Valve Train Inspection and Repair

Unlike the L-head engine, the I-head and F-head engines are equipped with rocker arms which directly activate the valves. Of course, the F-head engine also has valves in the block as well as the head. The in-block valves are not activated by rocker arms.

If rocker arms are used, there are a number of components required to operate them. These components make up the "valve train" and each must be inspected and repaired as necessary. Let's begin with the rocker arm shaft assembly, which consists of a hollow shaft with a series of rocker arms, shaft supports, and springs.

To inspect and repair the rocker arm shaft, first disassemble it. Mark the rocker arms to identify their position on the shaft. They should not be interchanged. Now, remove the cotter pin or other retaining device from each end of the shaft and remove the rocker arms, rocker arm supports, and springs simultaneously. Check the adjusting screws in the rocker arms for damage or excessive wear. Remove the screws **ONLY** if they need to be replaced.

If you will recall from earlier discussion, wear between the rocker arm and the rocker arm shaft will make it necessary to adjust the valves more often than normal. Therefore, before reassembling the shaft, check for this wear. If you can see wear on the shaft or in the bore of the rocker arm, then you know the defective part must be replaced. If not, measure the outer diameter of the shaft and the inner diameter of the rocker arm bore. These measurements are taken with T-gage (telescopic) and micrometer. Check your measurements against the maximum wear limits in the TM.

If equipped with locating springs, ensure that none are broken and make sure that the ends of the oil tubes are not split. If everything is in good shape, reassemble the rocker arm shaft and move on down the valve to the valve train to the pushrods.

Check the ends of the pushrods for nicks, scores, burrs, and apparent excessive wear by cleaning them thoroughly and giving them a good visual inspection. Check them for a bent condition also. In some cases, nicks, scores, and burrs can be corrected with an oil stone. A bent pushrod must be replaced.

Valve tappets cannot be repaired. Therefore, if the tappet is damaged or excessively worn, it must be replaced. Damage can be checked by visual inspection as can excessive wear on the bottom of the tappet.

#### **5404. Camshaft Inspection and Repair**

Clean the camshaft in cleaning solvent and blow all oil passages clear with air pressure hose. Check the machined surfaces of the camshaft for nicks, scoring, burrs, and excessive wear. Eliminate all defects possible with crocus cloth or a smooth stone. If you cannot eliminate defects, the camshaft must be replaced.

Next check the cam lobe lift. Place the camshaft in a set of "V" blocks and attach a dial indicator. Turn the camshaft until the dial indicator plunger rests on the lowest part of the lobe. Now, set the dial indicator at zero and turn the camshaft until the plunger rests on the highest point of the lift. Compare your reading to the specifications in the TM. If the lobe lift on all lobes does not meet specifications, replace the camshaft with a new one.

The camshaft is checked for runout by placing the dial indicator plunger on the center camshaft main bearing journal. This test is to ensure that the camshaft is in proper alignment to minimize bearing wear. The TM lists the allowable limits of runout. Defective camshafts must be replaced.

Another check which must be made before installing the camshaft is the camshaft bearing running clearance. The inner diameter of the bearing bore is measured with the bearing installed. The procedure is the same as was used to remove the bearings. **MAKE SURE THE OIL PASSAGE HOLE POSITION IS MARKED.** Align the hole of the bearing with the mark and draw the bearing into position. After installing the bearings, measure the inner diameter of the camshaft bearings with a T-gage and micrometer.

Now, measure the outer diameter of the camshaft main bearing journals on the camshaft. If they are within acceptable limits according to your TM, you are ready to reassemble the engine. Remember that the running clearance (the difference between the bore measurements and the journal measurement) must be within manufacturer's allowable limits. The outer diameter of the journals is measured with a micrometer as were the piston pin, crankshaft journals, etc.

Lesson 4 Exercise: Complete items 1 through 7 by performing the action required. Check your responses against those listed at the end of this lesson.

Matching: For items 1 through 5, match the required action in column 1 to the precision tool in column 2.

<u>Column 1</u> <u>Action</u>	<u>Column 2</u> <u>Tool</u>
___ 1. Check valve spring squareness	a. Dial indicator gage
___ 2. Measure spring installed height	b. Machinist's rule
___ 3. Measure cam lobe lift	c. Micrometer
___ 4. Measure inner diameter of the camshaft bearings	d. Measuring square
___ 5. Measure outer diameter of the camshaft main bearing journals.	e. Feeler gage with tension gage
___ 6. If not within manufacturer's specifications, which valve spring test cannot be corrected by replacing the valve spring, but must be corrected by replacing the valve and/or the valve seat?	f. Telescopic gage

7. What is the reason for the camshaft runout test?
- 

#### Lesson 4 Solutions

	<u>Reference</u>
1. d.	5402
2. b.	5402
3. a.	5404
4. f.	5404
5. c.	5404
6. The installed spring height test.	5402
7. To ensure camshaft alignment and minimize bearing wear	5404

Lesson Summary. In this lesson, you learned how to inspect and repair the valves, valve springs, the valve train, and the camshaft.

#### UNIT SUMMARY

In this study unit you learned what is repairable and what must be replaced. You learned the intricate process of measuring components to ensure they meet manufacturer's specifications. Don't rely on memory when it comes to specifications; remember to use the technical manual!

You've cleared the last hurdle and are headed for the finish line, engine assembly.

## STUDY UNIT 6

### ENGINE ASSEMBLY

Introduction. After all machining procedures on the cylinder block have been performed correctly, the engine is ready for reassembly. Let's not forget that while assembling the engine, specifications are still just as important as they were during the repair of the individual components. Remember also that dirt is harmful to the engine. Even the slightest particle is abrasive and can shorten the life of the engine by many miles or hours of operation. With the above facts firmly in mind, you are ready to assemble the engine with which you have taken so much care to repair properly.

#### Lesson 1. CRANKSHAFT INSTALLATION

##### LEARNING OBJECTIVE

Identify the procedures to install the crankshaft.

The crankshaft is the first component installed, but before reassembling the engine, you must perform certain preassembly procedures.

##### **6101. Preassembly**

To ensure proper lubrication of moving parts, all bearings, shafts, and contact surfaces must be lubricated before installation and engine oil should be used for this.

Never reuse old gaskets and seals. Once a seal has been removed, it is damaged and damaged seals can be a source of leakage that results in premature wear and damage to moving parts.

During assembly of the engine, almost every nut and bolt to be tightened has a specific torque. These torque specifications are listed in the TM and must be strictly adhered to. Over-tightened bolts and nuts will result in excess stress on the metal, and under-tightened nuts and bolts will result in oil or vacuum and pressure leaks.

Basically, all engines are assembled in the same manner. This study unit provides a basic knowledge of assembly, and your TM will provide you with details of the particular engine you will be rebuilding or repairing.

## 6102. Installing the Crankshaft

The crankshaft is the first component that must be installed if the engine is to be assembled in a logical order. This may vary depending on the type of engine you are rebuilding. Before actually placing the crankshaft in the engine, position the engine block with the crankshaft side up. Install the rear main bearing seals (the rear main bearing is the only main bearing with seals). These seals are installed in grooves provided to the rear of the point from which the rear main journal of the crankshaft rests in the engine and on the groove provided in the rear main bearing cap. There are various types of seals (felt packing, neoprene, encased, etc.). Figure 6-1 and 6-2 show two common types of rear seals.



Fig 6-1. Encased seal



Fig 6-2. Two-piece seal

The encased seal is installed after the crankshaft has been installed in the engine. Care must be exercised to ensure that the seal is driven into the block evenly, or damage may result.

To install the crankshaft, first install the upper halves of the crankshaft's main bearings in the engine block, and the lower halves in the main bearing caps (fig 6-3). Make sure the bearing halves are thoroughly cleaned and, as mentioned previously, all friction surfaces coated with engine oil.

The bearing tangs must fit into the slots in the cap and block evenly, or they will be flattened. The tang is provided to prevent the bearing from turning with the crankshaft. If a bearing turns, it will cause almost immediate damage.

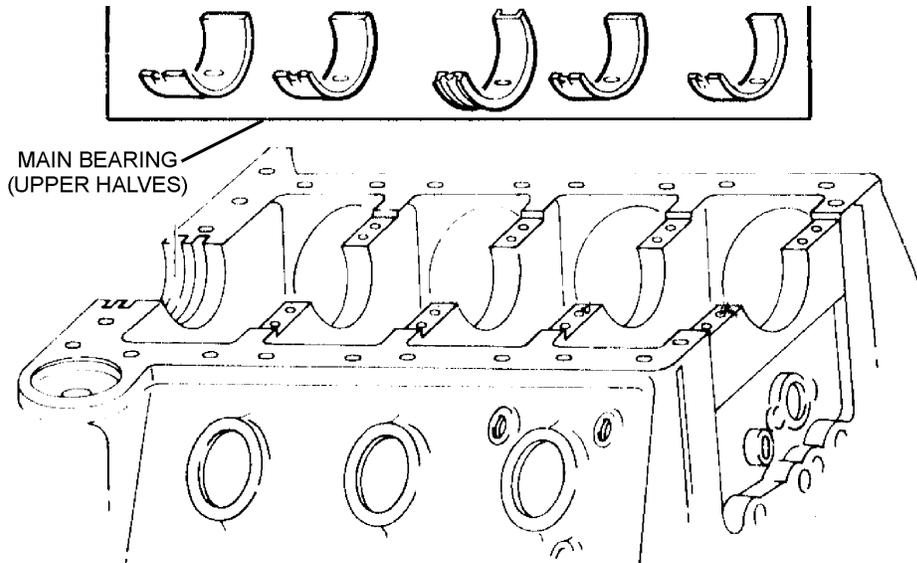


Fig 6-3. Installing main bearing halves.

With all bearings in place, lower the crankshaft into the block carefully so that no parts are damaged. Though not always necessary, it is usually best to install the woodruff key and crankshaft timing gear before installing the crankshaft in the block.

To hold the crankshaft in place, you must install all the bearing caps. First, install the front main bearing cap. Place the front main bearing in its position. Some manufacturers recommend lubricating the threads of the bearing cap bolts before installation and torquing.

Tighten the bearing cap bolts until the caps fit snugly. Once this has been done, center the crankshaft thrust bearings and tighten them according to manufacturer's recommendations.

Consult the specific TM for the engine in question. Remember, when tightening components to torque specifications, do NOT apply full torque immediately.

With a torque wrench, tighten one side to five or ten pound-feet, then tighten the other side equally. Switch back to the first bolt and repeat the procedure until both bolts are tightened to manufacturer's specifications.

When the bearings are installed, the crankshaft must be checked for end play just as you did before removing the crankshaft during disassembly. With this done and with problems corrected by installing another crankshaft thrust bearing if necessary, the crankshaft installation is now completed and you can install the camshaft and tappets.

Lesson 1 Exercise: Complete items 1 through 4 by performing the actions required. Check your responses with those provided at the end of the lesson.

1. Before crankshaft installation, all bearings, shafts and contact surfaces must be  
\_\_\_\_\_.
2. Old gaskets and seals are not reused in engine repair. Why not?  
\_\_\_\_\_.
3. When installing the crankshaft, tighten bearings to specifications in accordance with  
\_\_\_\_\_.
4. To install the crankshaft, first
  - a. install the upper halves of the main bearings in the engine block
  - b. install the lower halves of the main bearing in the engine block
  - c. tighten the bearing cap bolts until the caps fit snugly
  - d. center the crankshaft thrust bearings and tighten them

#### Lesson 1 Exercise Solutions

	<u>Reference</u>
1. Lubricated with engine oil	6101
2. Old gaskets are damaged and can be a source of leakage	6101
3. the specific TM	6102
4. a.	6102

Lesson Summary. In this lesson you learned the preassembly procedures and the importance of lubricating before installation. You also learned how to install the crankshaft and associated bearings and seals. Let's continue the engine's assembly with the installation of the camshaft.

## Lesson 2. CAMSHAFT INSTALLATION

### LEARNING OBJECTIVES

1. Identify the checks that must be performed on the camshaft.
2. Identify the appropriate assembly procedure for installing the camshaft.

### **6201. Installing the Valve Tappets, Camshaft and the Camshaft Timing Gear**

Install the camshaft first, then insert the tappets into their bores. If you reuse the valve tappets, make sure that they are reinstalled in their original bores.

Install the woodruff key and camshaft timing gear on the camshaft and insert the camshaft into its position from the front of the engine. Be careful to ensure that all machined surfaces have been coated with engine oil and that they are not damaged during installation.

When meshing the crankshaft and camshaft timing gears, make sure that the timing marks are positioned according to the manufacturer's specifications in the TM (fig 6-4), and number one position is at TDC. Install the thrust plate bolts.

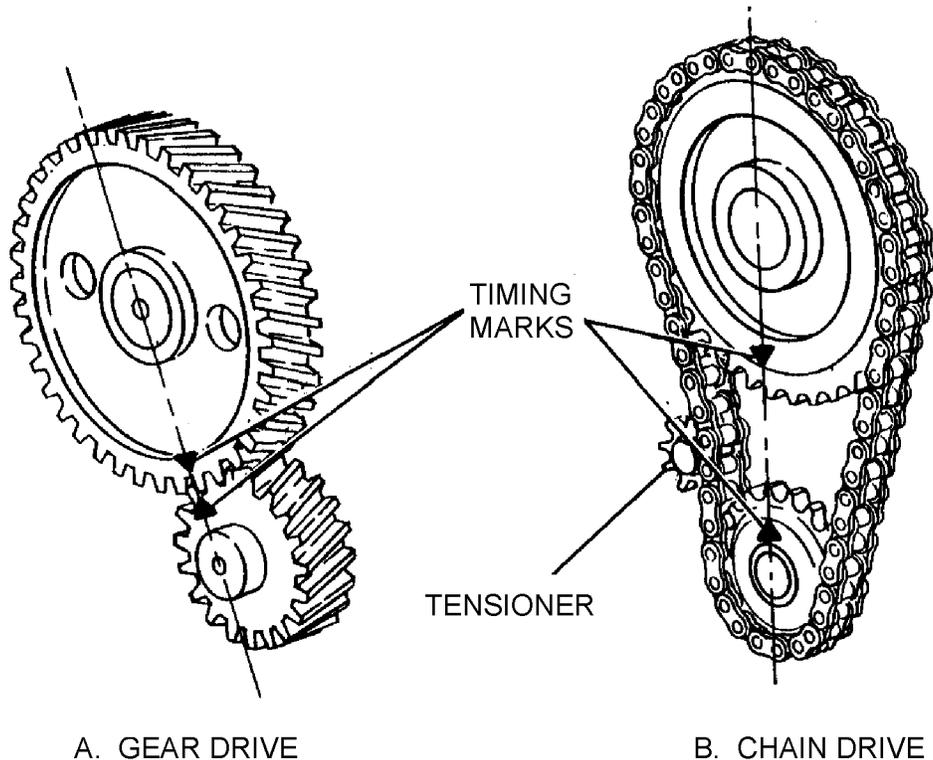


Fig 6-4. Positioning timing marks on the camshaft and crankshaft

## 6202. Timing Gear Tests

With the timing gears in place but before completing the installation of the camshaft, perform the same checks that you performed before you removed the shaft. Do you remember what those checks were?

The two checks that must be performed on the camshaft are backlash (the measurement of the amount of freeplay between the gear teeth, and camshaft end play which determines if the thrust bearing has excessive free play. If you are not familiar with the procedure for performing these tests, refer to Study Unit 4, Engine Disassembly, Timing Gear Tests to refresh your memory.

Lesson 2 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of this lesson.

1. What must you do first to properly align the timing gears?
  - a. Install both the crankshaft gear and the main gear.
  - b. Turn the camshaft until both valves in number one cylinder are open.
  - c. Turn the crankshaft until the number one piston is at TDC and the timing gear mark in the specified position.
  - d. Turn the camshaft until the timing gear mark is at BDC.
  
2. The two timing gear checks that must be performed after reinstalling the timing gears are \_\_\_\_\_ and \_\_\_\_\_ .

### Lesson 2 Exercise Solutions

	<u>Reference</u>
1. c.	6201
2. Backlash and camshaft end play	6202

Lesson Summary. Lesson 2 explained the procedure for installing the valve tappets and camshaft. You also learned that you must perform tests after installing the timing gears. In the next lesson, you'll learn about installing the flywheel and the pilot bearings.

### Lesson 3. FLYWHEEL AND PILOT BEARING INSTALLATION

#### LEARNING OBJECTIVES

1. Identify the test performed on the flywheel.
2. Identify the assembly procedure for installing the two types of pilot bearings.

#### **6301. Flywheel Installation**

The installation of the flywheel is relatively simple. Position the flywheel on the rear of the crankshaft and install the flywheel retaining bolts. Keep in mind that not all flywheels are the same. Tighten the bolts to manufacturer's torque specifications, in sequence, and according to the appropriate technical manual (TM).

When the flywheel retaining bolts have been tightened, you must perform a flywheel runout test to ensure that the flywheel is not warped. If the flywheel is warped, what effect will this have on clutch operation? If you cannot answer this question, refer back to Study Unit 4 to refresh your memory.

#### **6302. Pilot Bearing Installation**

A pilot bearing is one of two types: a ball bearing or a bushing. Some bearings are installed in the end of the crankshaft, while others are installed in the center of the flywheel. Both types are installed by simply driving them into their respective position with a bearing installer or a soft metal drift, such as a brass drift. However, they must be driven in evenly. Before installation, the bore in which the bearing fits should be coated with a light film of grease.

Lesson 3 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of this lesson.

1. What test is performed on the flywheel after installation?

\_\_\_\_\_

2. Name the two types of pilot bearings.

a. \_\_\_\_\_

b. \_\_\_\_\_

## Lesson 3 Exercise Solutions

1. Runout test
2. ball bearing and bushing

### Reference

6301  
6302

Lesson Summary. In this lesson you learned proper sequence for tightening the flywheel bolts during installation. You also know that the two different types of pilot bearings are ball and bushing. In the next lesson, you'll learn about piston installation.

---

## Lesson 4. PISTON INSTALLATION

### LEARNING OBJECTIVES

1. Identify the procedure to prevent damage to the crankpin during piston installation.
2. Identify the tool used to compress the rings on a piston before piston installation.

### **6401. Piston Preparation**

You can now begin installing the pistons. The piston is installed from the top of the cylinder, which can present a problem. If, while installing the piston, the shoulders of the connecting rod saddle strike the crankpin of the crankshaft, nicks, scratches, and burrs may result. This may be prevented by installing the connecting rod bearing cap bolts in the connecting rod before installation, and installing a rubber hose on the bolts (fig 6-5).

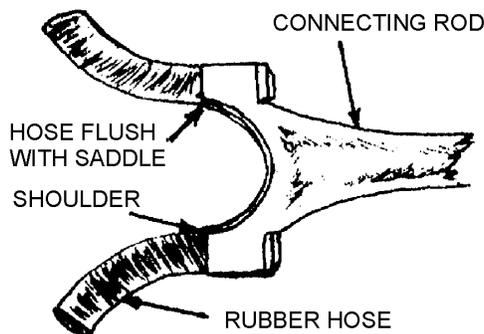


Fig 6-5. Rubber hose installed on connecting rods to protect crankpin.

The rubber hose may be a vacuum hose or any small hose that will fit snugly over the bearing cap bolts. The hose should be thick enough so that the outer edge of the hose is flush with the inner shoulders of the connecting rod saddle. To further prevent damage, check the connecting rod saddle to ensure that the shoulders are in perfect alignment with the crankpin. Most pistons are notched or marked in some manner to indicate the front of the piston. Make sure that the mark is positioned toward the front of the engine.

## 6402. Piston Installation

The tool illustrated in figure 6-6 is a ring compressor. It is installed on the piston before installation. The ring compressor compresses the rings around the piston so that they do not bind against the top edge of the cylinder.

After the ring compressor is installed on the piston, position the piston on top of the cylinder opening. Push or tap the piston gently into the cylinder until the connecting rod saddle seats on the crankpin (fig 6-6). To do this, rotate the crankshaft until the crankpin of the cylinder in which you are installing the piston is at BDC (bottom dead center).

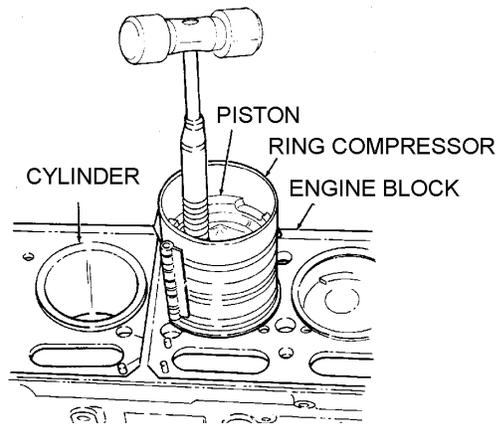


Fig 6-6. Installing piston in engine.

As you install each piston in the cylinder, install the connecting rod cap and tighten it snugly to prevent the bearing from turning before you move on to the next piston. Check the connecting rod side play (fig 6-7) and compare it with the specifications listed in the TM.

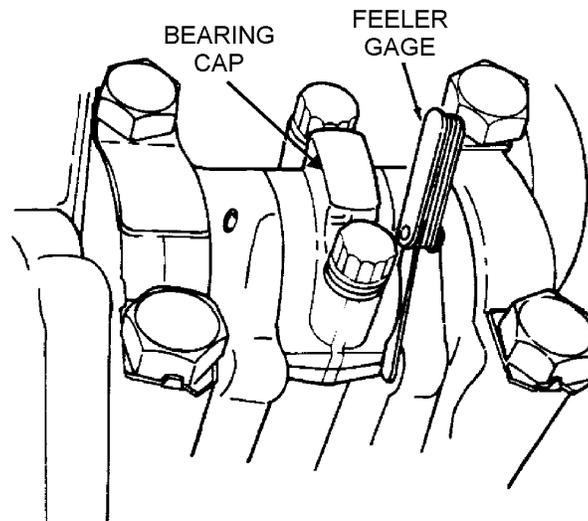


Fig 6-7. Checking connecting rod side play.

Don't forget to tighten the connecting rod cap nuts to the manufacturer's specifications and check the bearing clearance--just as you did with the main bearings. Coat them with engine oil as you do all friction surfaces. When this procedure is finished with each piston, install the oil pump.

Lesson 4 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of this lesson.

1. What procedure is used to prevent damage to the crankpins during piston installation?
  - a. Pound with the handle of your hammer
  - b. Use only your hands
  - c. Cover the bearing cap bolts with a small piece of rubber hose
  - d. Turn the crankpin 160°
  
2. The tool used to compress the rings on a piston before installation is the
  - a. dial indicator.
  - b. feeler gauge.
  - c. ring compressor.
  - d. rubber hose.

#### Lesson 4 Exercise Solutions

	<u>Reference</u>
1. c.	6401
2. c.	6402

Lesson Summary. Lesson 4 explained the procedures for piston installation. It may have been helpful to you to learn some "tricks of the trade" for preventing damage to the crankpin. So far you have learned to install the crankshaft, camshaft, bearings and seals, flywheel, pilot bearing, and the piston assemblies. Let's now finish up the bottom of the engine with the installation of the oil pump and oil pan.

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### **Lesson 5. OIL PUMP AND OIL PAN INSTALLATION**

#### LEARNING OBJECTIVES

1. Identify how the engine is prepared before the installation of an oil pump.
2. Identify the oil pan bolt tightening sequence.

### 6501. Oil Pump Installation

After you have checked the oil pump, prime the pump with the appropriate engine oil by pouring engine oil into the oil pump inlet until the oil flows from the outlet valve. Once you have primed the oil pump, install it according to the appropriate TM.

### 6502. Oil Pan Installation

You are now ready to install the oil pan. Place all gaskets on the oil pan in their proper position and use sewing thread or a fine string to hold the gasket in position if necessary. This is done by tying the string through several screw holes of the oil pan and oil pan gaskets. On most late model engines, this is not usually necessary. Place the oil pan carefully in position so as not to disturb the position of the gaskets and thread the center screw on each side of the oil pan into the block. This will hold the pan in position while you insert the remaining screws.

After you have inserted all of the screws, begin tightening them, using the manufacturer's specifications for proper torque. The first two screws inserted should be the first screws tightened, and you should then work from the center, toward each end, alternating from side to side, and front to rear of the pan. This will cause the gaskets to seat properly and eliminate chances for oil leakage. Rotate the engine back to its upright position.

Lesson 5 Exercise: Complete items 1 and 2 by performing the action required. Check your responses against those listed at the end of this lesson.

1. Before installing an oil pump, what must you do?
  - a. Move the number two piston to BDC and align the timing marks.
  - b. Fill the oil pump with oil (prime the pump).
  - c. Fill the engine with oil.
  - d. Place the engine on "V" blocks.
  
2. You are installing the oil pan on an engine. What bolt tightening sequence are you going to use?
  - a. Begin with the rear screws and alternate sides, working toward the front
  - b. Begin with the front screws and alternate sides, working toward the rear
  - c. Begin with the center screws working toward each end of the engine, and alternate from side to side and front to rear.
  - d. Tighten all the screws on one side of the engine; then tighten all the screws on the other side.

### Lesson 5 Exercise Solutions

	<u>Reference</u>
1. b.	6501
2. c.	6502

Lesson Summary. In Lesson 5 you learned that the oil pump must be primed and installed according to the specifications listed in the appropriate TM. You also learned that to prevent oil pan leaks, you must tighten the bolts in the proper sequence. You are now ready to install the valves and cylinder head.

---

## **Lesson 6. VALVE AND CYLINDER HEAD INSTALLATION**

### LEARNING OBJECTIVES

1. Identify the correct procedure for installing each of the following components: the valves, pushrods, rocker arm shaft, and cylinder head.
2. Identify the correct tightening sequence for cylinder head bolts.

You already know that valves are located in the cylinder block of the L-head engine, in the cylinder head of the I-head engine, and in both the block and the head of the F-head engine.

### **6601. Valve Installation**

From constant use, valves shape themselves to the valve seat. When reusing old valves, be certain that you install each valve in its original location to ensure proper seating. This holds true for all valves, whether you are installing them in the head or in the block. Insert the valve stem first into the valve guide from the bottom of the head. If the valves are equipped with seals, place the valve spring and valve spring retainer over the valve stem and compress the valve spring into place with the valve spring compressing tool.

After compressing the valve spring, insert the valve stem locks. However, in some cases you may find that a sleeve is used. This is placed on the valve stem before the locks. If a valve stem cap is used, it is placed over the end of the valve stem after the locks are in place and the valve spring released. Figure 6-14 is an example of valves and their associated components. You might note that the valve stem locks are sometimes referred to as keys. When all valves are installed in the cylinder head, the head is ready to be installed on the cylinder block.

### **6602. Cylinder Head and Pushrod Installation**

Now you are ready to install the cylinder head. Since the L-head engine is the simplest of heads to install, let's discuss it first. Inspect your cylinder head gasket. In many cases, you will find one side marked "TOP." Be sure to place the gasket on the cylinder block so that the word "TOP" may be seen. In cases where the gasket is not marked, inspect the alignment of the holes in the block with the holes in the gasket. If the holes are not aligned, you have the gasket inverted, or bottom side up.

Now, place the cylinder head in position over the gasket and insert the cylinder head bolts. Screw the bolts into the cylinder block until they are snug against the cylinder head. You must use a torque wrench to tighten the cylinder head bolts.

Check the TM for the proper torque specifications and sequence. Figure 6-8 gives examples of cylinder heads having two and three rows of head bolts. Note the tightening sequence for both.

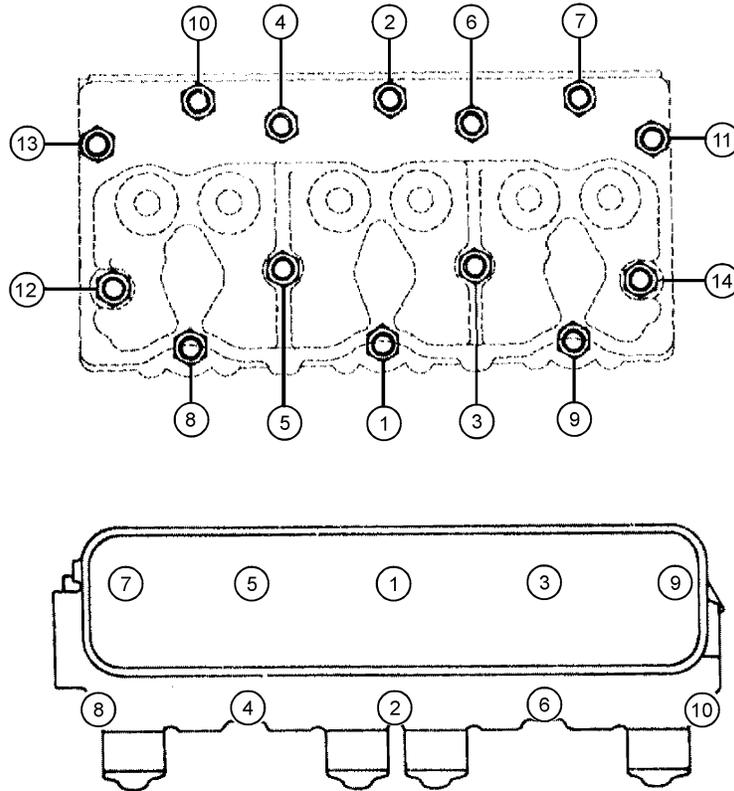


Fig 6-8. Typical tightening sequence for cylinder heads.

The installation of the cylinder head on the I-head and F-head engines is the same as that for the L-head up to this point. However, before head installation is considered complete on these two engines, the rocker arms and pushrods must also be installed.

The pushrods are inserted through holes provided in the cylinder head. The bottom end of the pushrod must seat in the recess located in the tip of the valve tappet or the engine will not operate and the pushrod will be damaged.

### 6603. Rocker Arm Installation

The next step is to assemble and install the rocker arm shaft as shown in figure 6-9 on the next page. Each component is reassembled in its original position. After reassembly, the rocker arm shaft assembly is placed on the cylinder head then tightened to the manufacturer's specifications located in the TM.

Note: Care must be exercised to ensure that each rocker arm seats on both the valve stem and the pushrod.

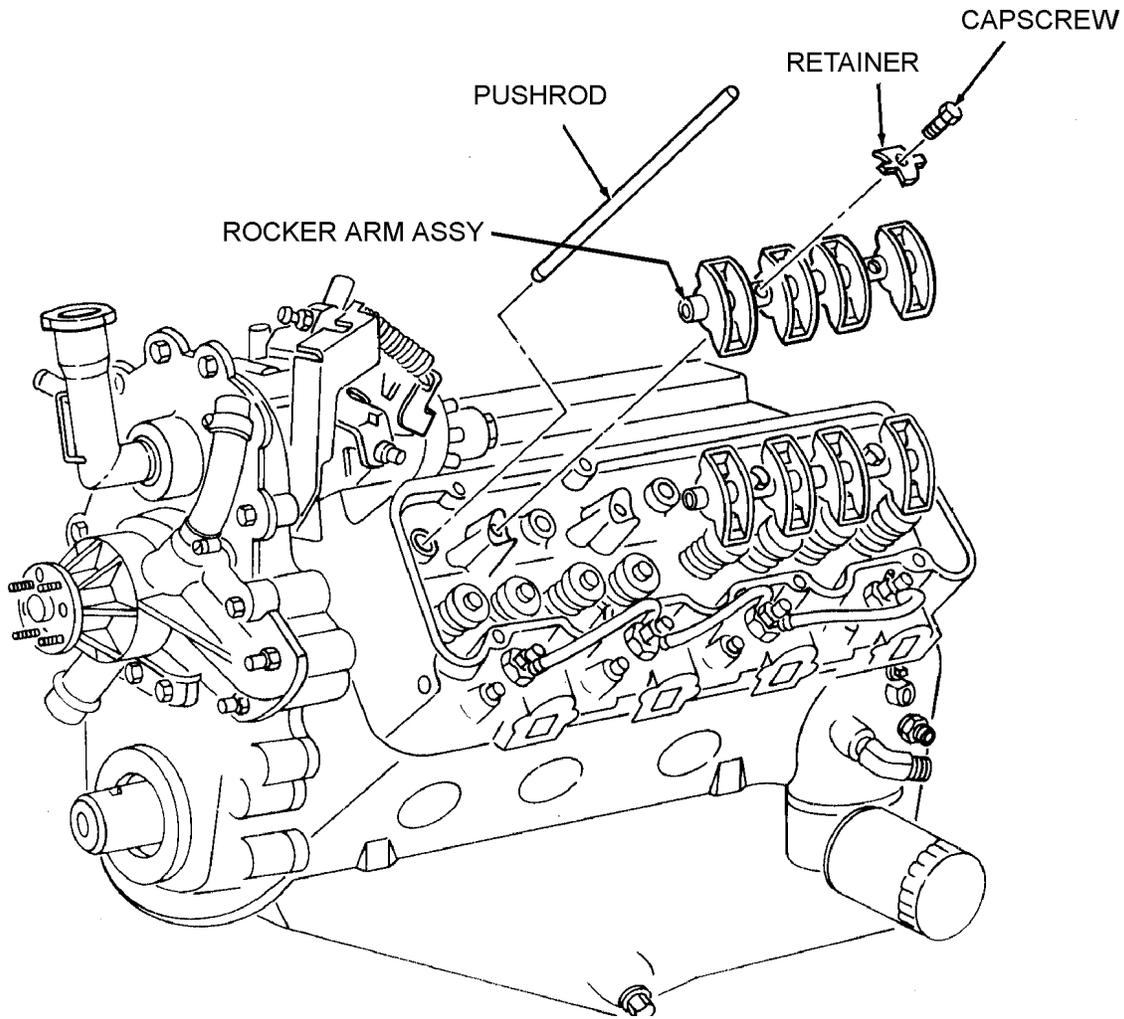


Fig 6-9. Rocker arm shaft assembled.

After the rocker arm shaft is installed, the valves must be adjusted to the manufacturer's specifications as discussed earlier in the course. This is normally done with the engine at normal operating temperature; however, you can make a cold adjustment initially without the engine operating. This will make the hot adjustment easier and quicker. The last items to be installed should be the side pan and/or the rocker arm cover.

With this done, you have completed the rebuild of the engine and it is ready to be installed in the vehicle for a run-in test after all accessories have been installed. Accessories will be discussed in subsequent courses.

Lesson 6 Exercise: Complete items 1 and 4 by performing the action required. Check your responses against those listed at the end of this lesson.

1. When installing the valves, what is the proper procedure?
  - a. Insert the valve spring into the valve guide.
  - b. Insert the valve stem first into the valve guide.
  - c. Place the seal on the valve guide.
  - d. Place the valve spring and valve retainer over the valve guide.
  
2. Pushrods, when being installed, can become damaged unless the bottoms of the pushrods are
  - a. clean and dry.
  - b. seated in the tappet.
  - c. polished.
  - d. oiled.
  
3. Which is the correct procedure for installing the rocker arm shaft?
  - a. Install the shaft on the supports, assemble the components to the shaft, and adjust the rocker arms.
  - b. Adjust the rocker arms, assemble the components to the shaft, and install the shaft on the shaft supports.
  - c. Assemble the components to the shaft, install the shaft on the shaft supports, and adjust the rocker arms.
  - d. Install the shaft on the supports, adjust the rocker arms, and assemble the components to the shaft.
  
4. From the following illustrations, identify the correct tightening sequence for cylinder head bolts.
  - a. 

①	②	③	④
⑥	⑦	⑧	⑨
  - b. 

①	③	⑤	⑦
②	④	⑥	⑧
  - c. 

⑦	⑤	⑩	③	②
⑧	⑥	⑨	④	①
  - d. 

⑦	⑤	①	③	⑨
⑧	④	②	⑥	⑩

## Lesson Exercise Solutions

### Reference

1.	b.	6601
2.	b.	6602
3.	c.	6603
4.	d.	6602

Lesson Summary. In Lesson 6 you learned how to install the cylinder heads and related parts. This completes Study Unit 6. Congratulations! You have reassembled an engine that you've repaired.

### UNIT SUMMARY

You have now learned the basic procedure used in the reassembly of an engine after all repairs have been done. Although you have learned the basic procedure, never perform this procedure from memory. Your TMs and repair manuals are there for a purpose and should be consulted on any and all procedures. You now have the technical knowledge of the technology and you're ready to try out your skills.

## **BIBLIOGRAPHY**

### **SOURCE MATERIALS**

TM 9-243, Use and Care of Handtools and Measuring Tools

TM 9-2320-272-34-1, Direct and General Support Maintenance, 5 Ton, 6 X 6, M939 and M939A1

TM 9-2320-297-34, Direct and General Support Maintenance, 22<sup>1</sup>/<sub>2</sub> Ton, 8 X 8, LVS

TM 9-8000 Principles of Automotive Vehicles

**MARINE CORPS INSTITUTE  
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MCI 35.80a Automotive Engine Maintenance and Repair**

Use this form for questions you have about this course. Write out your question(s) and refer to the study unit, lesson exercise item, or the review lesson exam item you are having a problem with. Before mailing, fold the form and staple it so that MCI's address is showing. Additional sheets may be attached to this side of the form. Your question(s) will be answered promptly by the Distance Training Instructor responsible for this course.

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**MCI 35.80a Automotive Engine Maintenance and Repair**

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This questionnaire is extremely important to the Marine Corps Institute. The course you have just completed has undergone extensive development and revision. As an integral part of the continued success of this course, **YOUR HELP IS NEEDED**. By completing this questionnaire, your responses may result in a need to review the course.

Please take five minutes to complete the questionnaire and return it to MCI in the self-addressed envelope provided with your course materials. Additional comment sheets may be attached to this questionnaire. If you want to be contacted by the course instructor, please provide your name, rank, and phone number. Regardless of whether you want to be contacted or not, please enter your primary military occupational specialty (MOS).

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Telephone Number (Optional)		
DSN	Commercial (Area Code)	

Information About the COURSE:

1. How long did it take you to complete this course including the review lesson examination?  
\_\_\_ Less than three hours                      If more than fifteen hours  
\_\_\_ Three to six hours                            enter number of hours  
\_\_\_ Seven to ten hours                           here: \_\_\_\_\_  
\_\_\_ Eleven to fourteen hours
  
2. Were the learning objectives stated at the beginning of each lesson clear?  
(Circle your response)  
  
a. Yes                      b. No

If you circled "NO" please list below the study unit and lesson number for those unclear objectives.

**MARINE CORPS INSTITUTE  
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Information About the COURSE (continued):

3. Did the figures, that is illustrations, photographs, tables, charts, etc., clearly support the information/text within the lesson? (Circle your response)
- a. Yes      b. No

If you circled "NO" please list the figure or table number(s) below.

\_\_\_\_\_

4. Did the exercise at the end of a lesson or study unit test your skills and knowledge gained by studying the lesson? (Circle your response)
- a. Yes      b. No

If "NO" please list the exercise question/item number, the lesson number, and the study unit number below. (Attach additional sheet, if necessary)

Question Number	Lesson Number	Study Unit Number
_____	_____	_____

5. When you read the lesson the first time, did it make sense to you? (Circle your response)
- a. Yes      b. No

If "NO" please list the lesson number and/or paragraph number below.

\_\_\_\_\_

6. Would you recommend that a revision be made to any portion of this course? (Circle your response)
- a. Yes      b. No

If "YES", is your recommendation based on (check all that apply):

___ Outdated procedures or process.	Enter Study Unit Nos. ___
___ Outdated equipment or material.	Enter Study Unit Nos. ___
___ Information not accurate.	Enter Study Unit Nos. ___
___ Other (Please describe)	

7. Comments: Please attach separate sheet.

# MARINE CORPS INSTITUTE--STUDENT REQUEST/INQUIRY-MCI - R-11 (3/96)

MCI 35.80a

Automotive Engine Maintenance and Repair

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