DOCUMENT RESUME

ED 258 045 CE 041 790

TITLE Automotive Engine Maintenance and Repair.
INSTITUTION Marine Corps Inst., Washington, DC.
REPORT NO MCI-35.8c
PUB DATE 15 Feb 84
NOTE 137p.; For related documents, see CE 041 791-796.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC06 Plus Postage.
DESCRIPTORS Adult Education; *Auto Mechanics; Behavioral Objectives; Continuing Education; Correspondence Study; Course Content; *Engines; Independent Study; Learning Activities; *Mechanics (Process); Military Training; *Motor Vehicles; Programed Instructional Materials; Study Guides

ABSTRACT

This correspondence course, originally developed for the Marine Corps, is designed to provide students with an understanding of automotive engine maintenance and repair. The course contains six study units covering automotive engine maintenance and repair; design classification; engine malfunction, diagnosis, and repair; engine disassembly; engine component repair; and assembling the engine. Each study unit begins with a general objective, which is a statement of what the student should learn from the study unit. The study units are divided into numbered work units, each presenting one or more specific objectives, and illustrated unit texts. At the end of the unit text are study questions with answers. A review lesson completes the course. (KC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED258045

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

- [x] This document has been reproduced as received from the person or organization originating it.
- [ ] Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
ARLINGTON, VA. 22222

35.3
15 Feb 1984

1. PURPOSE

This publication has been prepared by the Marine Corps Institute for use with MCI course 35.8c, Automotive Engine Maintenance and Repair.

2. APPLICABILITY

This manual is for instructional purposes only.

J. M. D. HOLLADAY
Lieutenant Colonel, U.S. Marine Corps
Deputy Director

ERIC

INFORMATION

FOR

MCI STUDENTS

Welcome to the Marine Corps Institute training program. Your interest in self-improvement and increased professional competence is commendable.

Information is provided below to assist you in completing the course. Please read this guidance before proceeding with your studies.

1. MATERIALS

Check your course materials. You should have all the materials listed in the "Course Introduction." In addition you should have an envelope to mail your review lesson back to MCI for grading unless your review lesson answer sheet is of the self-mailing type. If your answer sheet is the pre-printed type, check to see that your name, rank, and social security number are correct. Check closely, your MCI records are kept on a computer and any discrepancy in the above information may cause your subsequent activity to go unrecorded. You may correct the information directly on the answer sheet. If you did not receive all your materials, notify your training NCO. If you are not attached to a Marine Corps unit, request them through the Hotline (autovon 288-4175 or commercial 202-433-4175).

2. LESSON SUBMISSION

The self-graded exercises contained in your course are not to be returned to MCI. Only the completed review lesson answer sheet should be mailed to MCI. The answer sheet is to be completed and mailed only after you have finished all of the study units in the course booklet. The review lesson has been designed to prepare you for the final examination.

It is important that you provide the required information at the bottom of your review lesson answer sheet if it does not have your name and address printed on it. In courses in which the work is submitted on blank paper or printed forms, identify each sheet in the following manner:

DOE, John J. Sgt 332-11-9999
08.4g, Forward Observation
Review Lesson
Military or office address
(RUC number, if available)

Submit your review lesson on the answer sheet and/or forms provided. Complete all blocks and follow the directions on the answer sheet for mailing. Otherwise, your answer sheet may be delayed or lost. If you have to interrupt your studies for any reason and find that you cannot complete your course in one year, you may request a single six month extension by contacting your training NCO, at least one month prior to your course completion deadline date. If you are not attached to a Marine Corps unit you may make this request by letter. Your commanding officer is notified monthly of your status through the monthly Unit Activity Report. In the event of difficulty, contact your training NCO or MCI immediately.

3. MAIL-TIME DELAY

Presented below are the mail-time delays that you may experience between the mailing of your review lesson and its return to you.

	TURNAROUND MAIL TIME	MCI PROCESSING TIME	TOTAL NUMBER DAYS
EAST COAST	16	5	21
WEST COAST	16	5	21
FPO NEW YORK	18	5	23
FPO SAN FRANCISCO	22	5	27

You may also experience a short delay in receiving your final examination due to administrative screening required at MCI.

4. GRADING SYSTEM

LESSONS			EXAMS	
GRADE	PERCENT	MEANING	GRADE	PERCENT
A	94-100	EXCELLENT	A	94-100
B	86-93	ABOVE AVERAGE	B	86-93
C	78-85	AVERAGE	C	78-85
D	70-77	BELOW AVERAGE	D	65-77
NL	BELOW 70	FAILING	F	BELOW 65

You will receive a percentage grade for your review lesson and for the final examination. A review lesson which receives a score below 70 is given a grade of NL (no lesson). It must be resubmitted and PASSED before you will receive an examination. The grade attained on the final exam is your course grade, unless you fail your first exam. Those who fail their first exam will be sent an alternate exam in which the highest grade possible is 65%. Failure of the alternate will result in failure of the course.

5. FINAL EXAMINATION

ACTIVE DUTY PERSONNEL: When you pass your REVIEW LESSON, your examination will be mailed automatically to your commanding officer. The administration of MCI final examinations must be supervised by a commissioned or warrant officer or a staff NCO.

OTHER PERSONNEL: Your examination may be administered and supervised by your supervisor.

6. COMPLETION CERTIFICATE

The completion certificate will be mailed to your commanding officer and your official records will be updated automatically. For non Marines, your completion certificate is mailed to your supervisor.

ERIC

7. RESERVE RETIREMENT CREDITS

Reserve retirement credits are awarded to inactive duty personnel only. Credits awarded for each course are listed in the "Course Introduction." Credits are only awarded upon successful completion of the course. Reserve retirement credits are not awarded for MCI study performed during drill periods if credits are also awarded for drill attendance.

8. DISENROLLMENT

Only your commanding officer can request your disenrollment from an MCI course. However, an automatic disenrollment occurs if the course is not completed (including the final exam) by the time you reach the CCD (course completion deadline) or the ACCD (adjusted course completion deadline) date. This action will adversely affect the unit's completion rate.

9. ASSISTANCE

Consult your training NCO if you have questions concerning course content. Should he/she be unable to assist you, MCI is ready to help you whenever you need it. Please use the Student Course Content Assistance Request Form (ISD-1) attached to the end of your course booklet or call one of the AUTOVON telephone numbers listed below for the appropriate course writer section.

PERSONNEL/ADMINISTRATION	288-3259
COMMUNICATIONS/ELECTRONICS/AVIATION NBC/INTELLIGENCE	288-3604
INFANTRY	288-3611
ENGINEER/MOTOR TRANSPORT	288-2275
SUPPLY/FOOD SERVICES/FISCAL	288-2285
TANKS/ARTILLERY/INFANTRY WEAPONS REPAIR LOGISTICS/EMBARKATION/MAINTENANCE MANAGEMENT/ ASSAULT AMPHIBIAN VEHICLES	288-2290

For administrative problems use the UAR or call the MCI HOTLINE: 288-4175.

For commercial phone lines, use area code 202 and prefix 433 instead of 288.

AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Course Introduction

This manual has been prepared primarily for Marines in OF 35. It covers material basic to understanding automotive engine maintenance and repair. It will increase the students' knowledge about the construction, operation, malfunction diagnosis maintenance, repair, and overhaul of the reciprocating internal-combustion engine.

ADMINISTRATIVE INFORMATION

ORDER OF STUDIES

Study Unit Number	Stuuy Hours	Subject Matter
1	3	Automotive Engine Maintenance and Repair
2	3	Design Classification
3	3	Engine Malfunction, Diagnosis and Repair
4	3	Engine Disassembly
5	3	Engine Component Repair
6	3	Assembling the Engine
	2	REVIEW LESSON
	2	FINAL EXAMINATION
	22	

RESERVE RETIREMENT CREDITS: 7

EXAMINATION: Supervised final examination without textbooks or notes with a time limit of 2 hours.

MATERIALS: MCI 35.8C, Automotive Engine Maintenance and Repair. Review lesson and answer sheet.

RETURN OF MATERIALS: Students who successfully complete this course are permitted to keep the course materials.

Students disenrolled for inactivity or at the request of their commanding officer will return all course materials.

SOURCE MATERIALS

TM9-8000	Principles of Automotive Vehicles, Jan 1965
TM9-2320-211-20	Truck, Chassis, 5-Ton, 6x6, June 1973 w/ch A Jan 1975
TM9-2320-211-35	DS, GS, and Depot Maintenance For Truck, Chassis, 5-Ton, 6x6, September 1964 w/ch 1 June 1965
TM9-2320-218-20	Truck, Utility, 4x4, M151, M151A1, M151A2, Sept 1971 w/ch 3 Oct 1974
TM9-2320-218-34	DS, GS, Maintenance, Truck, Utility, 4x4, 1/4 Ton, Jan 1972 w/ch 2 Oct 1973
TM9-4910-572-14&P	Tester, Cylinder Compression, Sep 1980

TABLE OF CONTENTS

ERIC

HOW TO TAKE THIS COURSE

This course contains six study units. Each study unit begins with a general objective which is a statement of what you should learn from that study unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Read the objective(s) and then the work unit text. At the end of the work unit text are study questions which you should be able to answer without referring to the text of the work unit. After answering the questions, check your answers against the correct ones listed at the end of the study unit. If you miss any of the questions, you should restudy the text of the work unit you understand the the correct response. When you have mastered one study unit, move on to the next. After you have completed all study units, complete the review lesson and take it to your training officer or NCO for mailing to MCI. MCI will mail the final examination to your training officer or NCO when you pass the review lesson.

BEST COPY AVAILABLE

MARINE CORPS INSTITUTE

STUDY GUIDE

Welcome to the Marine Corps Institute correspondence training program. By enrolling in this course, you have shown a desire to improve the skills you need for effective job performance, and MCI has provided materials to help you achieve your goal. Now all you need is to develop your own method for using these materials to best advantage.

The following guidelines present a four-part approach to completing your MCI course successfully:

1. Make a "reconnaissance" of your materials;

2. Plan your study time and choose a good study environment;

3. Study thoroughly and systematically;

4. Prepare for the final exam.

I. MAKE A "RECONNAISSANCE" OF YOUR MATERIALS

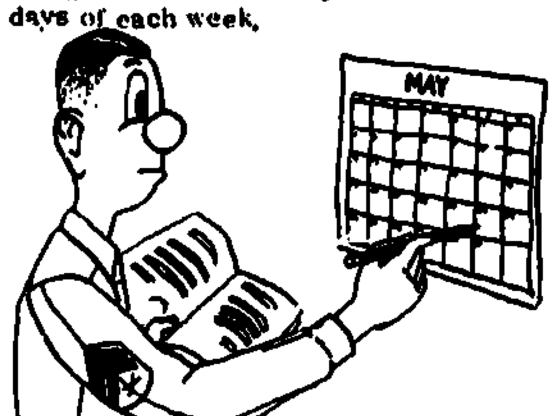
Begin with a look at the course introduction page. Read the COURSE INTRODUCTION to get the "big picture" of the course. Then read the MATERIALS section near the bottom of the page to find out which text(s) and study aids you should have received with the course. If any of the listed materials are missing, see <u>Information for MCI Students</u> to find out how to get them. If you have everything that is listed, you are ready to "reconnoiter" your MCI course.

Read through the table(s) of contents of your text(s). Note the various subjects covered in the course and the order in which they are taught. Leaf through the text(s) and look at the illustrations. Read a few work unit questions to get an idea of the types that are asked. If MCI provides other study aids, such as a slide rule or a plotting board, familiarize yourself with them. Now, get down to specifics!

II. PLAN YOUR STUDY TIME AND CHOOSE A GOOD STUDY ENVIRONMENT

From looking over the course materials, you should have some idea of how much study you will need to complete this course. But "some idea" is not enough. You need to work up a personal study plan; the following steps should give you some help.

(A) Get a calendar and mark those days of the week when you have time free for study. Two study periods per week, each lasting 1 to 3 hours, are suggested for completing the minimum two study units required each month by MCI. Of course, work and other schedules are not the same for everyone. The important thing is that you schedule a regular time for study on the same days of each week.



(B) Read the course introduction page again. The section marked ORDER OF STUDIES tells you the number of study units in the course and the approximate number of study hours you will need to complete each study unit. <u>Plug these study hours into your schedule.</u> For example, if you set aside two 2-hour study periods each week and the ORDER OF STUDIES estimates 2 study hours for your first study unit, you could easily schedule and complete the first study unit in one study period. On your calendar you would mark "Study Unit 1" on the

ERIC

appropriate day. Suppose that the second study unit of your course requires 3 study hours. In that case, you would divide the study unit in half and work on each half during a separate study period. You would mark your calendar accordingly. Indicate on your calendar exactly when you plan to work on each study unit for the entire course. Do not forget to schedule one or two study periods to prepare for the final exam.

Ⓒ Stick to your schedule.

Besides planning your study time, you should also choose a study environment that is right for you. Most people need a quiet place for study, like a library or a reading lounge; other people study better where there is background music; still others prefer to study out-of-doors. You must choose your study environment carefully so that it fits your individual needs.

III. STUDY THOROUGHLY AND SYSTEMATICALLY

Armed with a workable schedule and situated in a good study environment you are now ready to attack your course study unit by study unit. To begin, turn to the first page of study unit 1. On this page you will find the study unit objective, a statement of what you should be able to do after completing the study unit.

DO NOT begin by reading the work unit questions and flipping through the text for answers. If you do so, you will prepare to fail, not pass, the final exam. Instead, proceed as follows:

Ⓐ Read the objective for the first work unit and then read the work unit text carefully. Make notes on the ideas you feel are important.

Ⓑ Without referring to the text, answer the questions at the end of the work unit.

Ⓒ Check your answers against the correct ones listed at the end of the study unit.

Ⓓ If you miss any of the questions, restudy the work unit until you understand the correct response.

Ⓔ Go on to the next work unit and repeat steps Ⓐ through Ⓓ until you have completed all the work units in the study unit.

Follow the same procedure for each study unit of the course. If you have problems with the text or work unit questions that you cannot solve on your own, ask your section OIC or NCOIC for help. If he cannot aid you, request assistance from MCI on the Student Course Content Assistance Request included with this course.

When you have finished all the study units, complete the course review lesson. Try to answer each question without the aid of reference materials. However, if you do not know an answer, look it up. When you have finished the lesson, take it to your training officer or NCO for mailing to MCI. MCI will grade it and send you a feedback sheet listing course references for any questions that you miss.

IV. PREPARE FOR THE FINAL EXAM

How do you prepare for the final exam? Follow these four steps:

Ⓐ Review each study unit objective as a summary of what was taught in the course.

Ⓑ Reread all portions of the text that you found particularly difficult.

Ⓒ Review all the work unit questions, paying special attention to those you missed the first time around.

Ⓓ Study the course review lesson, paying particular attention to the questions you missed.

If you follow these simple steps, you should do well on the final. GOOD LUCK!

STUDY UNIT 1

AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE MAIN COMPONENTS OF THE RECIPROCATING INTERNAL-COMBUSTION ENGINE, HOW THEY ARE CONSTRUCTED, AND HOW THEY OPERATE.

Work Unit 1-1. ENGINE BLOCK

IDENTIFY THE COMPONENT PART THAT CONTAINS THE CRANK CASE AND CYLINDERS.

IDENTIFY THE COMPONENT TO WHICH ALL PARTS ARE EITHER HOUSED OR ATTACHED.

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 merit of the work done by the mechanic. Because of the shortage of good mechanics in the Marine Corps, the chance for advancement in the field is excellent. 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 accurate diagnosing of defects and expert workmanship in the repair of those defects.

To be a good mechanic and advance in rank, there are a few simple guidelines you must follow. First and foremost, you must be competent, but do not rely on your memory for repairing a vehicle. Know your job and use the technical manuals (TM's) published for the vehicle on which you are working. These TM's are available in every maintenance shop in the Marine Corps. You must be efficient; do the job to the best of your ability in the shortest time possible. You must be attentive; devote your undivided attention to your work. If a necessary distraction arises, stop your work until you can once again give it your full attention. You must be orderly; estimate what tools are needed to accomplish the job and lay them out in a convenient area to avoid walking back and forth. While working on a unit which requires disassembly, lay the parts out in the order in which you remove them. Orderliness will not only make reassembly easier, but it will also lessen the chance of losing parts. Keep your area and yourself as clean as possible. Do not allow debris and scattered tools to accumulate in your work area. This makes your area and your person easier to clean at securing time. Be courteous to others and they will be more likely to help you when you need it, and a mechanic frequently needs outside help. You must observe safety procedures. Always be on the lookout for unsafe conditions and avoid horseplay. All the things mentioned here are the things that your supervisor notices and takes into consideration when you are due for promotion.

As a Marine Corps mechanic, most of your work will probably consist of maintenance which involves such things as oil changes, chassis lubrication, inspection of vehicles, 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 while only minor adjustment or repair is required. 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. This procedure saves you, the mechanic, time and can save the Marine Corps thousands of dollars annually. Time and money are saved because you replace or repair the right part the first time. Last, but not least, you will be repairing vehicles. These repairs call for skill in disassembly, replacement, machining, and reassembly of parts.

You will be started on your road to success as a good mechanic by being presented, here, the theory, maintenance, and repair of the reciprocating, internal-combustion engine. If you wish to get the most from this course, it will be to your advantage to acquire an unsalvageable engine, preferably a small military engine such as the one used in a jeep. However, this is not required in order to complete the course successfully. If you are interested in this, you may find your motor transport chief quite helpful in locating an engine if you just ask him. You have some time to obtain the engine as you will not use it until the third study unit.

To properly maintain and repair an engine, you must first know how it is constructed and how it operates.

ERIC

ENGINE BLOCK

The engine block functions as the main body of the engine. It is called the main body because all parts of the engine are either inside of the engine block or attached to the outside of it. The engine block is usually a one piece casting of iron. However, it is going to be discussed in two parts: the crankcase and the cylinder block.

As you can see in figure 1-1, the lower portion of the engine block is the crankcase.

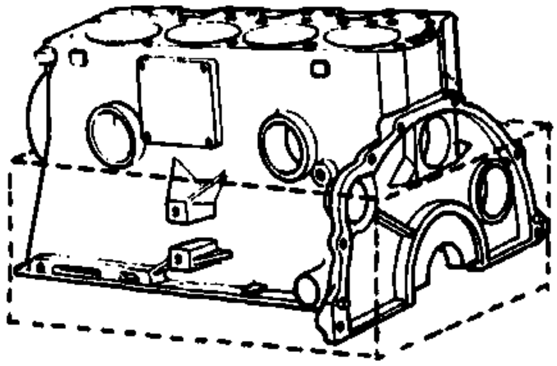


Fig 1-1. Four-cylinder engine block with crankcase enclosed by an imaginary box (left rear view).

The crankcase, which functions as a support for the crankshaft, is hollow inside with one or more rib-like castings which form the main frame (fig 1-2). This is where the crankshaft is supported. The crankshaft will be discussed later.

Fig 1-2. Four-cylinder engine block (bottom view).

14

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

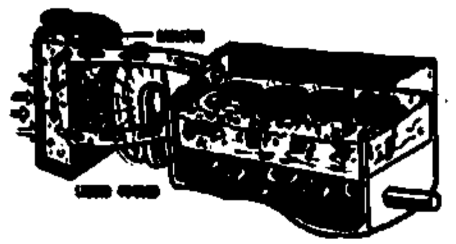


Fig 1-3. Four-cylinder engine block showing water jacket with coolant flow around the cylinders.

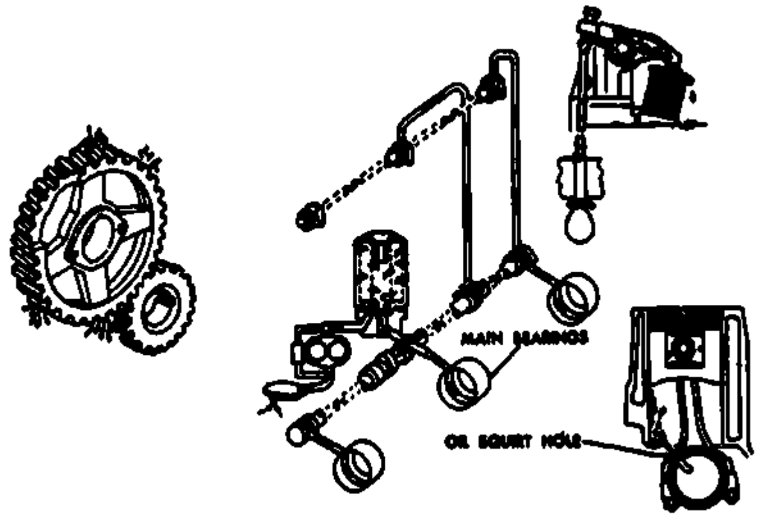


Fig 1-4. Engine lubricating system--oil flow diagram.

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 friction generated by the moving parts inside them.

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.

The oil passages provide a means of distributing oil under pressure to all moving parts of the engine to reduce wear and aid the water jacket in its job of cooling the moving parts.

The cylinder block, in most cases, contains a camshaft, and, in some cases, the valves. These will be discussed later.

Look at the top of the cylinder block in figure 1-5. You will see, in addition to the cylinders, several smaller holes cut into the surface. Some of the others are cut into the water jacket and others are cut into the oil passages. Later, you will learn why this is done. The surface of the cylinder block top is machined smooth and must be perfectly flat. This brings you to the next part that is to be discussed, the cylinder head.

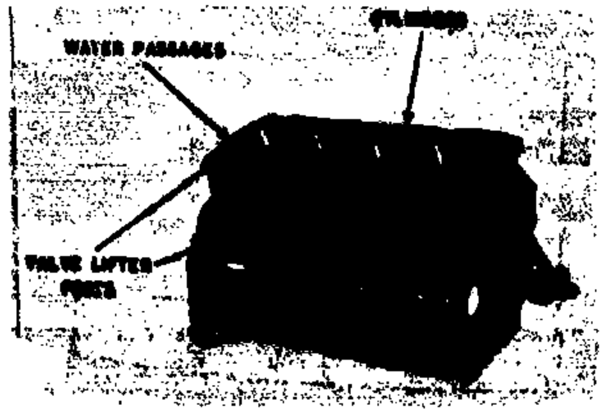


Fig 1-5. View of cylinder block.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What component part contains the crankcase and cylinders?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

2. Identify the component to which all engine parts are either housed in or attached to.

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

Work Unit 1-2. CYLINDER HEAD

IDENTIFY THE COMPONENT THAT ENCLOSES THE TOP OF THE CYLINDERS.

STATE WHERE THE ENGINE COOLANT LEAVES THE ENGINE.

The cylinder head is bolted to the machined surface that was just mentioned. Its function is to enclose the top of the cylinders. If the top of the cylinder block must be smooth and flat, then it is reasonable to assume that the surface of the bottom of the cylinder head, which is bolted to it, must also be machined smooth and perfectly flat. Notice that figure 1-6 shows some cupped out areas in the bottom of the cylinder head. These will fit directly over the cylinders and form combustion chambers. In these chambers, gases are burned to produce energy for the engine.

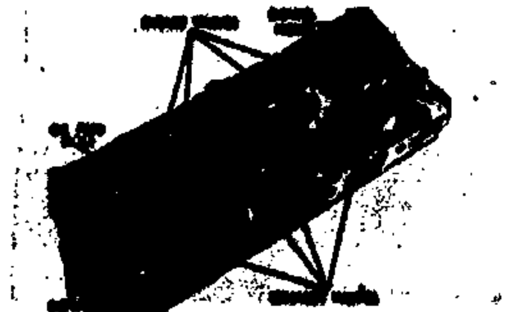


Fig 1-6. Cylinder head assembly.

In addition to the cupped areas, you can see that several small holes are cut into the bottom of the cylinder head. These holes will match the holes in the cylinder block when the head is bolted on so that oil and water may pass from the cylinder block into the cylinder head. From there, the oil is recirculated back through the block, while the water leaves the engine through the large hole on the front of the cylinder head. On most V8 type engines, the coolant leaves through the Thermostat Housing located on the front of the intake manifold. Once water leaves the engine, it is cooled in the radiator and sent back into the cylinder block. It has not been mentioned, but the cylinder head must also have a water jacket and an oil passage to receive the water and oil from the cylinder block. Figure 1-7 shows the cylinder head in position to be installed on the cylinder block. Also, note the head gasket, which must be put between the head and engine block to ensure a good seal between the head and engine block.

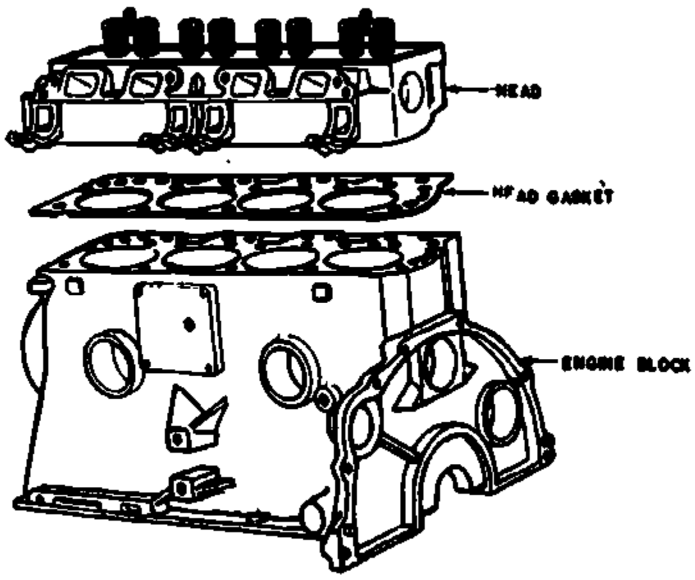


Fig 1-7. Engine block and cylinder head.

Now that you have enclosed the cylinders and formed the combustion chambers where the burned gases produce energy for the engine, you must have something to put this energy to work.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What encloses the top of the cylinders?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

2. Where does the engine coolant leave the engine?

Work Unit 1-3. PISTONS AND RELATED PARTS

STATE THE COMPONENT THAT IS DRIVEN DOWN BY HEAT ENERGY.

NAME THE PART THAT CONTAINS LANDS AND GROOVES FOR RINGS.

The energy produced by the burning gases is heat energy, and, with nothing to work on, heat energy is nothing more than a means of warming an area. The function of the piston is to convert this heat energy into mechanical energy to operate the engine. 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 where it is housed, in the same manner that gunpowder would drive a cannonball through the barrel of a cannon when it is fired. Take a look at this piston in figure 1-8.

Fig 1-8. The piston.

As you can see, near the top of the piston is a series of lands and grooves around the outside of the piston. Just below these lands and grooves is a hole which extends through the piston.

If some of the energy produced by the burning gases is allowed to pass between the piston and the cylinder walls, it becomes wasted energy; therefore, you must have a pressure-tight seal between the piston and the cylinder walls. To get the seal, use the lands and grooves near the top of the piston in the following manner. Install a set of rings in the grooves (fig 1-9). The top two rings, which are called compression rings, form the pressure-tight seal which you need. The piston moving in the cylinder causes friction. Even though the smooth surface of the cylinder walls helps to reduce the friction, it is not enough. To further reduce the friction, the cylinder walls must be lubricated. This presents another problem. When the piston travels down inside the cylinder, oil remaining on the cylinder walls would be burned with the gases and eventually there would be no more oil. This situation is taken care of by the bottom ring, the oil control ring. Its function is to wipe excess oil from the cylinder wall as the piston travels downward. The oil control ring is usually a three-piece ring.

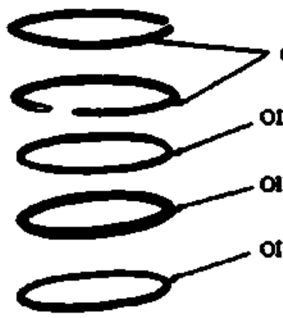


Fig 1-9. Piston rings.

So far you have heat energy being converted to mechanical energy by the piston, but like heat energy, mechanical energy must have something to work on, or it is wasted. The piston traveling straight down must, by some means, cause the wheels of the vehicle to rotate. So the up and down motion, or, more technically, the reciprocating motion, of the piston must be converted to a rotary motion. Now the crankshaft, which delivers power from the engine as you will soon see, turns in a rotary motion. Next the piston must be connected to it in some way to allow this change of motion. Here is where you use the hole in the piston that was mentioned earlier. A snug-fitted pin is manufactured for this hole, which is called the piston pin hole. The pin is used to attach a rod, known as the connecting rod, to the piston (fig 1-10). This is done by inserting the pin through the piston pin hole and a piston pin bushing (a friction type bearing) located in a hole at the top of the connecting rod.

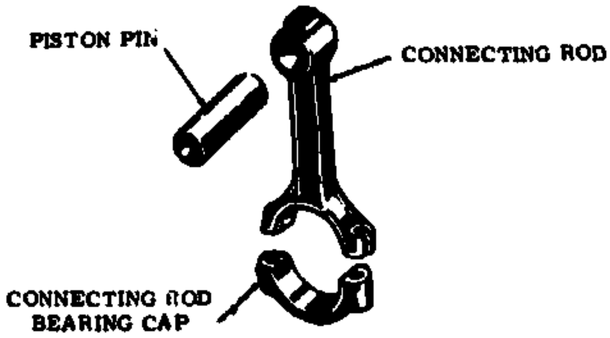


Fig I-10. Connecting rod and related parts.

The connecting rod is allowed to swing freely on the piston pin in much the same manner as your hand swings to and fro 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, the topic of our next discussion.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the component part driven down by heat energy?

____

2. Name the part that contains lands and grooves for rings.

____

Work Unit 1-4. CRANKSHAFT

NAME THE PART THAT DELIVERS POWER FROM THE ENGINE.

STATE WHAT CONTAINS CONNECTING RODS JOURNALS AND MAIN JOURNALS.

As stated previously, the crankshaft delivers power from the engine. The function of the crankshaft is to change the reciprocating motion of the piston to rotary motion.

The crankshaft, which extends through the length of the engine, contains a series of throws and journals (fig I-11). 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. As you have probably noticed in figure I-11, the throws cause the connecting Rod Journals to be offset from the centerline of the crankshaft.

The purpose of the main journals is to allow the crankshaft to be connected to the crankcase and still rotate. A main bearing cap is bolted over each of the crankshaft's main journals, after the crankshaft is positioned in the crankcase.

The purpose of the connecting rod journals is to 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, causing the crankshaft to rotate (fig I-12).

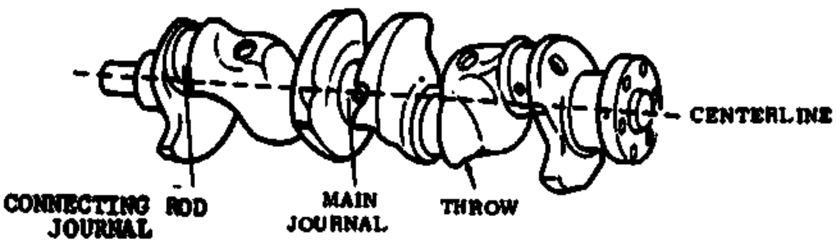


Fig 1-11. Four-cylinder-engine crankshaft.

In some engines there is a short interval when the pistons do not drive the crankshaft. However, if you provide enough momentum, the crankshaft can travel through this short portion of its rotation. To accomplish this, bolt a large wheel, known as the flywheel, to the rear end of the crankshaft. This flywheel is very heavy, and the momentum produced by its turning, enables it to accomplish the function of carrying the crankshaft through rotation when the crankshaft is not receiving power from the piston.

A certain amount of vibration is found in the crankshaft at times, and, to reduce this vibration, a small wheel, called a vibration damper, is bolted to the front end of the crankshaft. This vibration damper often serves as a pulley for the fan, generator, and accessory belts. Figure 1-13 gives you an idea of what the components that have been discussed would look like if they were assembled outside the engine block. With the exception of the flywheel and the vibration damper, all the moving parts discussed up to this point require lubrication. They are lubricated by engine oil stored inside the engine oil pan.

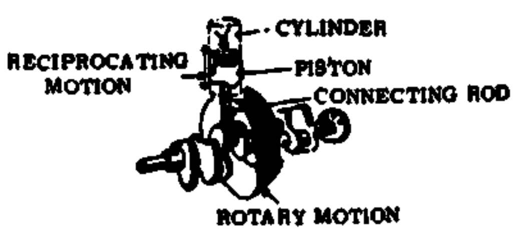


Fig 1-12. The crankshaft changes reciprocating motion to rotary motion.

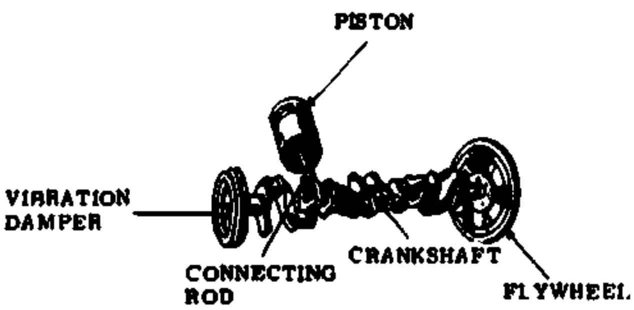


Fig 1-13. Major moving parts of the engine.

OIL PAN

As the name implies, the oil pan is constructed like a large metal pan and is shaped to fit the engine crankcase.

The oil pan, a reservoir for engine oil, is bolted to the bottom of the crankcase, enclosing the crankcase and all moving parts inside it (fig 1-14). Oil is picked up from the oil pan by an oil pump and distributed throughout the engine.

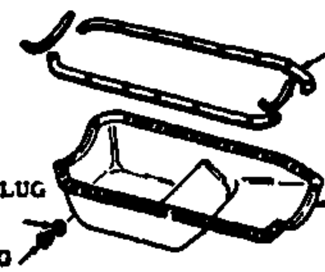


Fig 1-14. Oil pan and related parts.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Power is delivered from the engine by ______________________.

2. What contains connecting rod journals and main journals?

____

Work Unit 1-5. VALVE MECHANISMS

IDENTIFY THE COMPONENT THAT ALLOWS FUEL TO ENTER THE COMBUSTION CHAMBER.

IDENTIFY THE PART THAT HAS A LONG STEM WITH A MUSHROOM TOP.

Remember, earlier when heat energy and mechanical energy were discussed. Well, let's discuss heat energy a little further. To have heat energy, you must burn 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 are required to open and close these ports at a given time to allow raw gases to enter the combustion chamber, and burned gases to leave the chamber. While the fuel is being burned, these valves help to seal the combustion chamber to allow the heat energy to work on the piston. There are several valve arrangements used which will be discussed in work unit 2-2.

The valve is a long-stemmed device with a mushroomed top. It is this top which seals the ports while the gases are being burned. 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 mechanism.

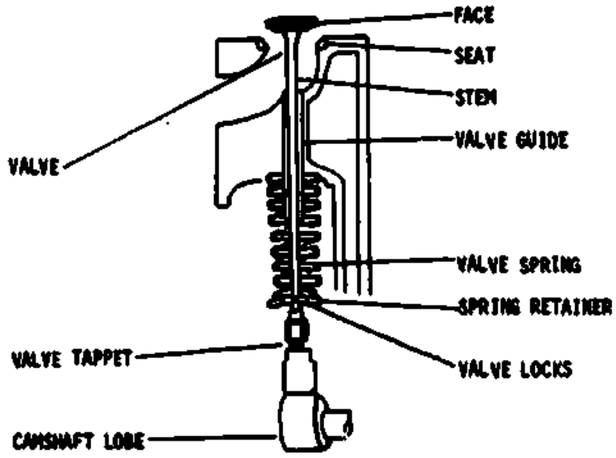


Fig 1-15. Value mechanism, minus the camshaft and timing gears.

On the underside of the valve head (the mushroomed top) is a valve face. This face is machined smooth, and when the valve is in the closed position, it seats firmly on a device pressed into the cylinder block (or the cylinder head, depending upon the valve) around the valve port (where the gases are brought in or let out). This device is called the valve seat, and it is also machined smooth for a pressure-tight fit between the valve face and the valve seat.

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 a valve guide, is pressed into the cylinder block (or again, the cylinder head). The valve stem travels up and down inside the valve guides as it opens and closes.

To close the valve, a valve spring is used. The top of the spring seats against the cylinder block (or cylinder head), and the bottom seats against 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 locks. Therefore, the valve spring is attached to the end of the valve stem and maintains a constant pressure against the valve at one end and the block or the head at the other end. Any time the valve is not forced open by an outside force, the valve spring will keep it closed.

The outside force used to open the valve is the camshaft. This is a long shaft which extends through the length of the cylinder block. It contains a series of egg-shaped lobes known as cam lobes. Figure 1-15 shows one of these lobes in the position required to open the valve. The camshaft, driven by a gear attached to the crankshaft, rotates once for each two revolutions of the crankshaft on a four-stroke cycle engine.

This brings us to the timing gears or sprockets. The timing gears are a set of two gears. One of the gears, the drive gear, is attached to the crankshaft at the front end. The driven gear is attached to the front end of the camshaft (fig 1-16). 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 the combustion chamber or burned gases to leave the combustion chamber.

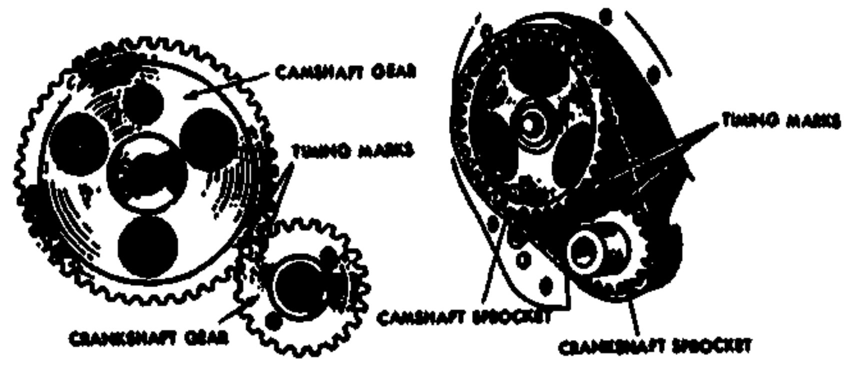


Fig 1-16. Mechanical timing mechanisms.

In some cases, because of the distance between the camshaft and the crankshaft, sprockets and a timing chain are used instead of timing gears (fig 1-16). The only real difference between the sprockets and the gears is that the crankshaft drives the camshaft through the use of a chain instead of direct gear drive.

Now that you have learned the construction of the engine and the function of its major components, let's see what happens when the engine is put into operation.

THE CYCLE OF OPERATION

In order for an engine to operate, certain events must take place. These are intake, compression, power, and exhaust. First, fuel and air must enter the combustion chamber. In the gasoline engine, both fuel and air enter at the same time, while in the diesel engine, air enters the combustion chamber, and the fuel is injected at a given time after the air is compressed. Compression is the next event. Once the air or the fuel/air mixture is in the chamber, it must be compressed so that it will produce a high amount of energy when ignited. Ignition occurs during compression and causes the compressed fuel and air to burn. In the gasoline engine, this is accomplished by an electrical spark. In the diesel engine, it is caused by the heat created when the air is compressed. As soon as the fuel is injected into the chamber, it ignites and begins to burn. The igniting and burning of these gases give us power, which is the next event. Once you have used all the power that the burning gases can deliver, you must get rid of the burned gases. This is the final event and is known as 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 a down-stroke. When it 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 explain these two cycles of operation and how they differ, but first, let's be sure that the strokes are fully understood.

Figure 1-17 illustrates what happens inside the cylinder on both the down-stroke and the up-stroke. 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 the 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.

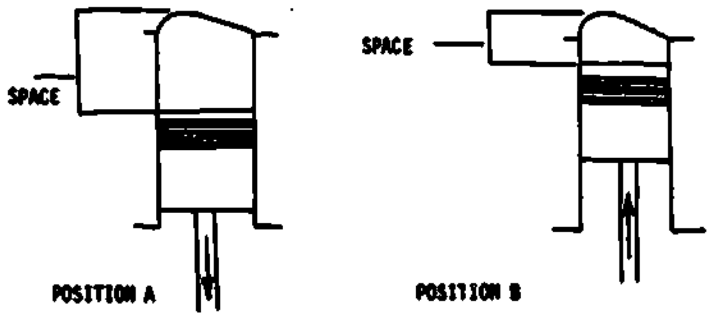


Fig 1-17. The piston strokes.

Now that you understand what takes place during the strokes, let's combine them to operate the engine.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Fuel enters the combustion chamber through which part?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

2. A long stem part with a mushroom top is a(n) ______________________.

   a. engine block
   b. cylinder head
   c. piston
   d. crankshaft
   e. valve

Work Unit 1-6. CYCLE OF OPERATION

IDENTIFY THE CYCLE OF OPERATION FOR A 4-STROKE ENGINE.

IDENTIFY THE EVENT TAKING PLACE WHEN THE PISTON TRAVELS UPWARD INSIDE THE CYLINDER WHILE THE EXHAUST VALVE IS OPEN.

We will begin our discussion of the cycles of operation for the individual engines by discussing the four-stroke engine since it is easier to understand.

Look at what each part does during the cycle of operation. The piston is at top-dead-center (TDC) at the beginning of the intake stroke. The intake valve opens and the piston starts its down-stroke (fig 1-18). This creates a low pressure area inside the cylinder. Atmospheric pressure then forces the fuel-air mixture to enter the cylinder. 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 continue to enter the cylinder for 44° more of crankshaft rotation.

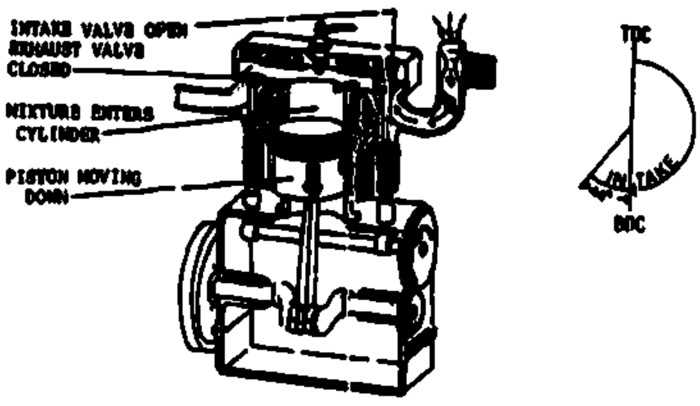


Fig 1-18. Intake stroke.

From the top-dead-center (TDC) position of the piston to the bottom-dead-center (BDC) position of the piston, the crankshaft rotates 180°. By adding the extra 44° after BDC so that the intake valve remains open, you come up with a total of 224° of crankshaft rotation for an intake stroke.

Now 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 fuel-air mixture in the combustion chamber? Refer back to figure 1-17. The space in position "A" has been filled with fuel and air. The mixture cannot escape when the space is decreased in position "B"; therefore, the fuel-air mixture is being compressed. This, then, is the action or operation of the compression stroke. Note in figure 1-19 that the compression begins at 44° after BDC and ends at TDC, hence, it is a relatively short stroke.

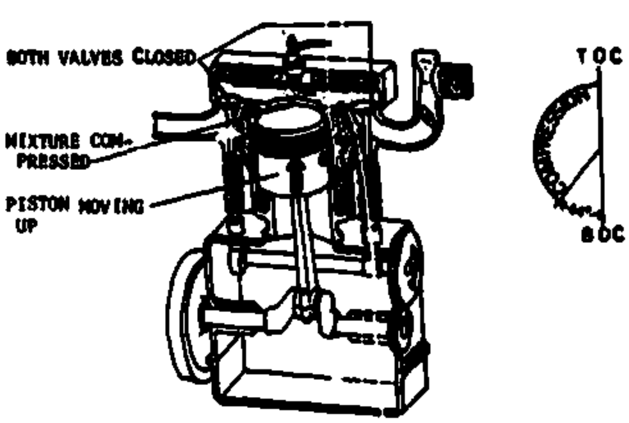


Fig 1-19. Compression stroke.

The crankshaft has now completed one 360° revolution while the piston has completed 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 just after TDC. To illustrate this, look at figure 1-20.

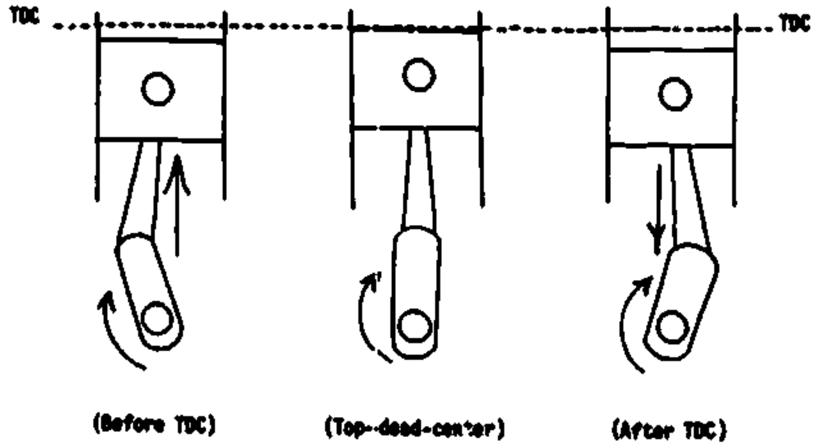


Fig 1-20. End of compression.

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 they drive the piston downward in the cylinder, creating the power stroke. While we are on the subject of burning gases, let's return our attention, for a moment, to figure 1-20. Do you think that igniting the fuel before TDC would tend to drive the piston back down causing the crankshaft to change direction and rotate backward? It definitely may have a tendency to do this if you use the incorrect grade of gasoline, so you must choose fuel to match the design of the engine. Fuels will be discussed later in the course, but for now we will continue with the power stroke.

During the power stroke, the valves remain closed for approximately 132° of the crankshaft rotation. Therefore, the power stroke is also relatively short (fig 1-21). The exhaust valve opens approximately 48° before the BDC. The exhaust stroke begins here even though the piston has not started on its upward travel to drive the burned gases out of the cylinder. Why do you open the exhaust valve so soon? For one reason, the pressure created inside the cylinder by the burning gases is still great enough to start the burned gases on their way out through the exhaust port. Another reason is that you want as much of the hot exhaust gases out of the cylinder as possible when you begin your next cycle of operation with another intake stroke. Therefore, you are allowing 228° of crankshaft rotation to get rid of the exhaust gases. Figure 1-22 illustrates the exhaust stroke.

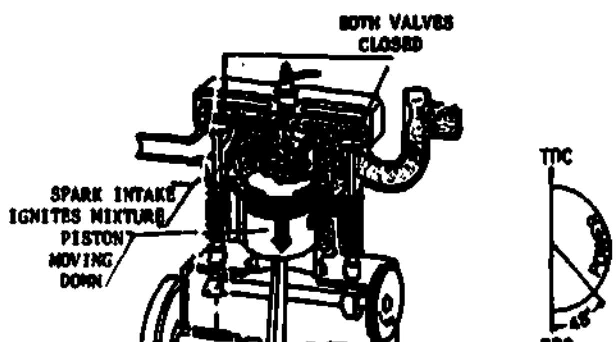
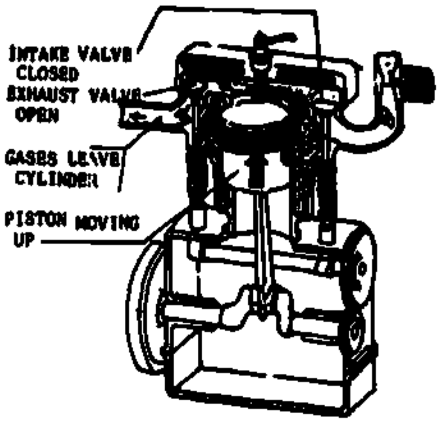


Fig 1-21. Power stroke.



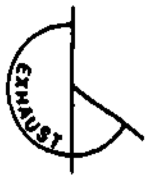


Fig 1-22. Exhaust stroke.

The crankshaft has now completed two revolutions during the cycle of operation and the piston has completed four full strokes. This is always true of a four-stroke engine. However, some four-stroke engines differ from others in another way. Some are called spark-ignition and others are called compression-ignition. Basically, the spark-ignition engine and the compression-ignition engine are the same. The most significant difference is the combustion chambers. The combustion chambers you have seen on the previous pages are all designed for spark-ignition. Also, the principles of operation are for spark-ignition.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the cycle of operation for a 4-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

Work Unit 1-7. TWO-STROKE CYCLE

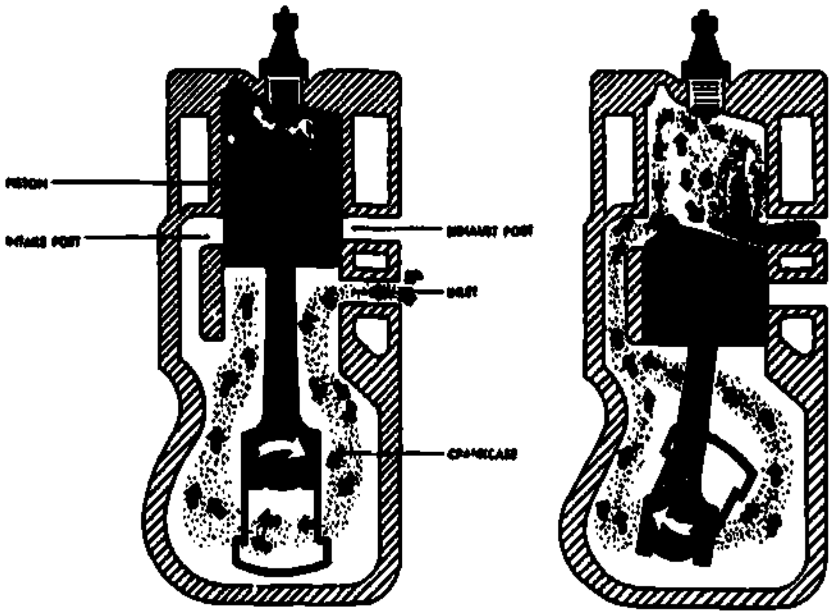
IDENTIFY WHAT TWO EVENTS OCCUR AT THE SAME TIME IN THE TWO-STROKE-CYCLE ENGINE.

IDENTIFY WHAT ENGINE COMPONENT CLOSES THE INTAKE PORT IN THE TWO-STROKE-CYCLE ENGINE.

The two-stroke-cycle engine may be used as either a spark-ignition or compression-ignition engine just as the four-stroke-cycle engine. The basic difference between this engine and the four-stroke-cycle is that 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 1-23 to discover how this is accomplished. During the compression stroke (A), the gases are permitted to flow into the crankcase. The gases which are being compressed at this time ignite, driving the piston down on its power stroke. Near the end of the power stroke, the piston travels by two openings in the cylinder wall (B). One of these is the intake port and the other is the exhaust port. As the piston uncovers these ports, the burned gases are exhausted into the atmosphere. and the raw gases are permitted to leave 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, and the fresh gases inside the cylinder are compressed to begin a new cycle.

ERIC

Therefore, two strokes of the piston or one complete revolution of the crankshaft completes the cycle of operation in the two-stroke engine. Although this is the most common method, there are two-stroke engines which use poppet valves and a super-charger to induct the fuel/air mixture.



(A) (B)

Fig 1-23. Events in a two-stroke-cycle.

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. So rapid, in fact, that it is similar to an explosion.

Note in figure 1-24 that 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, fresh air only 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. Therefore, fuel must be introduced into the cylinder at exactly the proper time. The compression stroke is completed now, and the fuel injector sprays fuel into the combustion chamber. When the fuel is injected, it must first vaporize, 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; therefore, 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 is accompanied by a distinct and audible knock. Increasing the compression ratio in the diesel engine will decrease the ignition lag and thereby decrease the tendency to knock. The pressure of the burning gases drives the piston on through its power stroke just as they do in the spark-ignition engine. The next stroke, of course, is the exhaust stroke, which completes the cycle of operation.

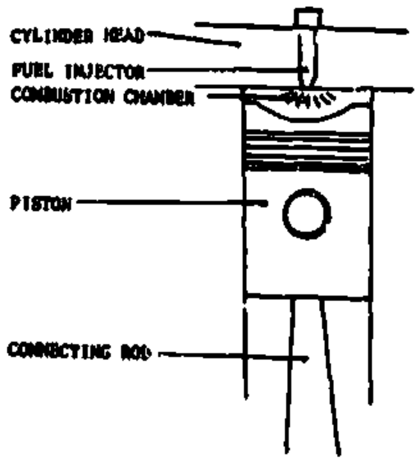


Fig 1-24. Compression ignition.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. 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

2. Which engine component closes the intake port in the two-stroke engine?

   a. Push rod
   b. Piston
   c. Camshaft
   d. Crankshaft

SUMMARY REVIEW

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

Answers to Study Unit #1 Exercises

Work Unit 1-1.

1. a.
2. a.

Work Unit 1-2.

1. b.
2. cylinder head

Work Unit 1-3.

1. Piston
2. Piston

ERIC

Work Unit 1-4.

1. crankshaft
2. crankshaft

Work Unit 1-5.

1. e.
2. e.

Work Unit 1-6.

1. d.
2. b.

Work Unit 1-7.

1. c.
2. b.

ERIC

STUDY UNIT 2

DESIGN CLASSIFICATION

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES YOU WILL IDENTIFY VARIOUS ENGINE DESIGNS AND THE VARIOUS DESIGNS OF COMPONENTS USED IN THE CONSTRUCTION OF ENGINES.

Work Unit 2-1. DESIGN CLASSIFICATION

STATE THE TWO WAYS BY WHICH AN ENGINE BLOCK IS CLASSIFIED.

ENGINE AND ENGINE COMPONENT DESIGN

All engines have the following in common: a requirement for fuel, air, and a method for igniting the fuel/air mixture. The major differences found in engines are their design, which consists of the number of cylinders and their arrangement; the valve arrangement; the method of operation; and the type of fuel and cooling systems. Let's discuss these differences to familiarize you with the equipment you will be working on.

DESIGN CLASSIFICATION

Engines are usually classified according to the number of cylinders they have, the way in which they are arranged in the cylinder block, and the method used to cool the engine. The most common are the in-line, V-type, and the horizontally opposed. These may be water-cooled or air-cooled.

The in-line engine usually has the cylinders cast en bloc in a vertical position directly above the crankshaft (fig 2-1A); however, you may find some with the cylinders cast at a 30° angle to the vertical plane to allow the automobile manufacturer to present a lower silhouette in the car he produces (fig 2-1B). The cylinders are numbered from front to rear and are usually four, six, or eight in number, although some three cylinder in-line engines are used by the Marine Corps.

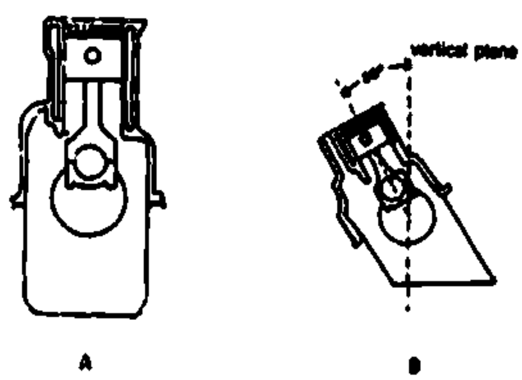


Fig 2-1. Partial cutaway front view of the cast en bloc six-cylinder engines.

The V-type engine is an engine consisting of two or more cylinders, which, when viewed from the front, form the letter "V" (fig 2-2). You may have heard of the "Y" block engine manufactured by one of the major manufacturers. This is merely a V-type engine with a deeper crankcase. In the Y-type engine, half of the cylinders are located on each side at a 45° angle to a vertical plane; therefore, the cylinder banks (each line of cylinders is a bank) are cast at a 90° angle in relation to one another (fig 2-3). Casting a cylinder block in this manner makes the engine shorter than the in-line design. The shorter the engine the more rigid it becomes, thereby reducing engine vibrations.

ERIC

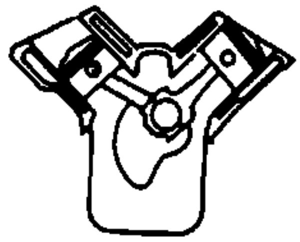


Fig 2-2. Partial cutaway front view of a V-type engine.

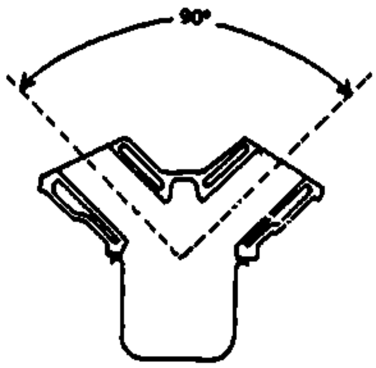


Fig 2-3. The cylinder casting angle of the V-type engine.

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

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

You may have heard an engine referred to as a flat-head six, a flat-head V-8, and over-head-valve six, and overhead-valve V-8, etc. 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 valve arrangement. Let's take a look at the technical terms which refer to valve arrangement.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the two ways by which an engine block is classified

   a. ______________________________

   b. ______________________________

ERIC

Work Unit 2-2. VALVE ARRANGEMENTS

IDENTIFY THE TYPES OF VALVE ARRANGEMENTS USED IN ENGINES.

VALVE ARRANGEMENTS

An engine's valves may be located either in the cylinder head or the cylinder block, or both. If the valves are located in the head, which is the most common arrangement found today, it is known as an I-head engine (fig 2-5). An imaginary line drawn (on the cross-sectional view, fig 2-5) from the center of the valve through the center of the piston, forms an "I" (dotted line in fig 2-5). The valves are positioned upside-down in the cylinder head, directly above the piston. In order for the camshaft to operate the valve, a pushrod and a rocker arm must be incorporated between the tappet and the valve stem.

Fig 2-5. I-head valve arrangement.

The pushrod (fig 2-6) is a long rod which fits onto the top of the valve tappet in the engine block and extends upward through the cylinder head. A shaft, known as the rocker arm shaft is mounted horizontally on the top of the cylinder head along its length. Mounted on the shaft, through bearings, you find a series of rocker arms. One end of the rocker arm rests on the top of the pushrod, and the other end rests on the end of the valve stem. The rocker arm shaft acts as a pivot or fulcrum for the rocker arm as the camshaft lifts the pushrod, which in turn pushes one end of the rocker arm upward. The rocker arm shaft, acting as a pivot, causes the opposite end of the rocker arm to press downward on the valve stem, opening the valve.

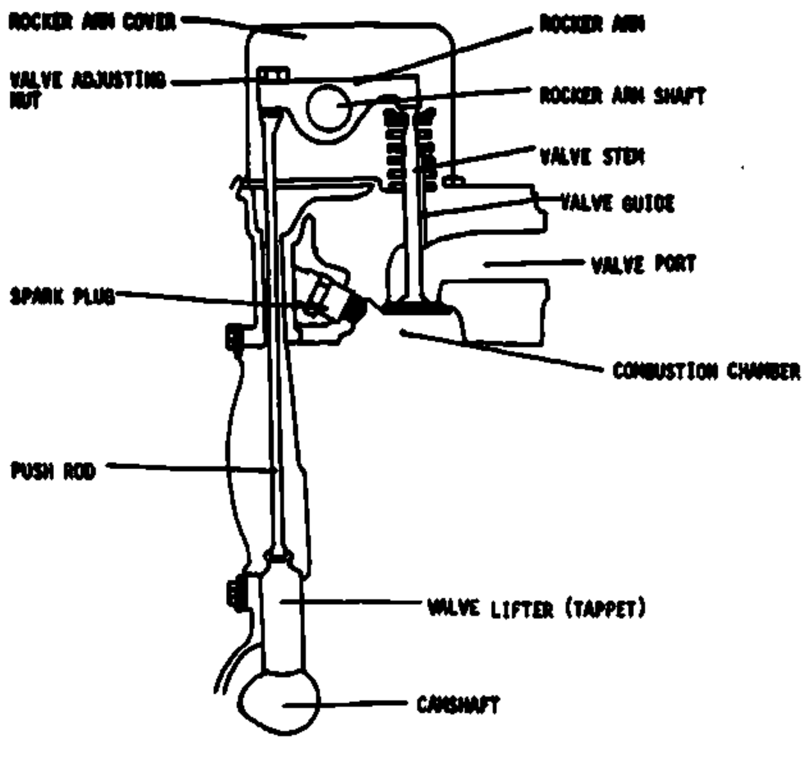


Fig 2-6. The I-head valve train.

The I-head valve arrangement (fig 2-5) is often referred to as overhead valves, probably more often than its technical term.

The flat-head arrangement of valves is technically termed the L-head (fig 2-7). 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. Now, draw another imaginary line down through the center of the piston joining your first line. You will find that you have drawn an inverted "L" (dotted line in fig 2-7).

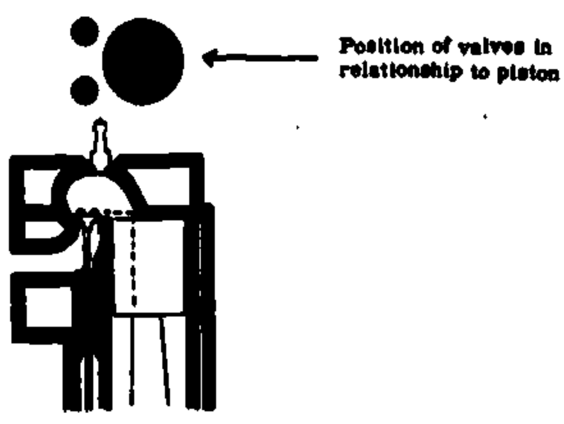


Fig 2-7. The L-head valve arrangement.

In the L-head engine, the valves are located in the cylinder block alongside the cylinder. The mechanism that was discussed in study unit 1 is used in this valve arrangement thus, it would be repetitous to go over it again. If you cannot recall this mechanism, refer back to work unit 1-6 of study unit 1 and refresh your memory.

The valve arrangement that will be discussed is actually a combination of the two previously covered. One valve, usually the intake valve, is located in the cylinder head, and the other (exhaust) in the cylinder block (fig 2-8). Again, draw some 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, this one 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 2-8). 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, F-head.

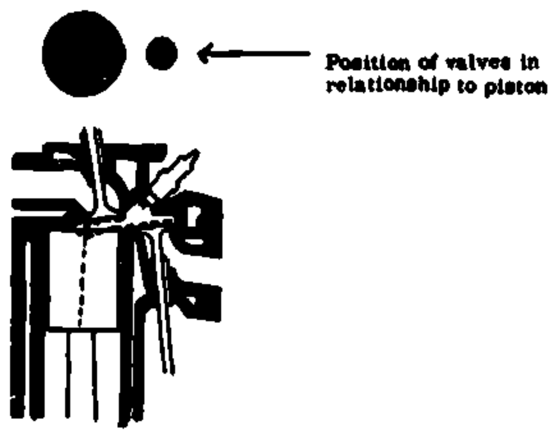


Fig 2-8. F-head valve arrangement.

You should be sufficiently familiar with engine designs now, so let's move along to the designs of the components of the engine.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. What are the types of valve arrangements used in engines?

a. ____________________

b. ____________________

c. ____________________

Work Unit 2-3. ENGINE BLOCKS

WHEN GIVEN AN ASSIGNMENT TO REPAIR A SCORED CYLINDER IN AN AIR COOLED ENGINE, STATE WHAT HAS TO BE DONE

ENGINE BLOCKS

The cylinder arrangements of the engine blocks have already been discussed, but the difference in design between the water-cooled engine and the air-cooled engine has not been mentioned.

The engine block for the water-cooled engine is cast as one solid piece, as the engine studied in the basic engine construction section. In addition to the cylinders being cut into the cylinder block, some engines are designed to use insert-type cylinders known as cylinder liners. Cylinder liners prolong the life span of an engine block because they are replaceable (fig 2-9).

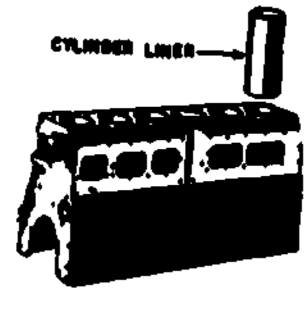


Fig 2-9. Six-cylinder engine with cylinder liners.

The air-cooled engine also utilizes replaceable cylinders. There is no cylinder block on the air-cooled engine, only the crankcase and the cylinders themselves. Each cylinder is cast separately as a cylinder barrel and has cooling fins cast around the outside. If one cylinder becomes scored, only that cylinder needs to be removed and replacod with a new cylinder. Tho crankcase is usually cast as a two-piece unit and bolted together (fig 2-10). The cylinder head is of the I-head design.

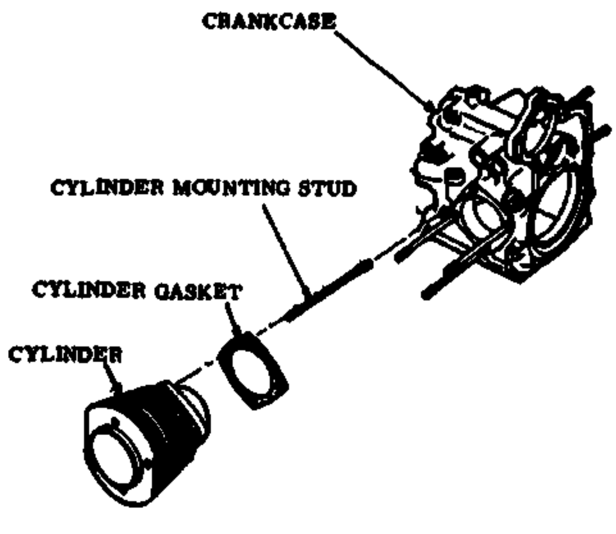


Fig 2-10. Air-cooled engine crankcase and cylinder assembly.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. You have been assigned the task of repairing an air-cooled engine with one scored cylinder. What must you do?

____

Work Unit 2-4. CRANKSHAFTS

STATE THE DIFFERENCE BETWEEN AN IN-LINE FOUR-CYLINDER CRANKSHAFT AND A V-8 ENGINE CRANKSHAFT WHEN BOTH HAVE THE SAME NUMBER OF THROWS.

Crankshaft design depends upon the number of cylinders the engine has and their arrangement: in-line, V-type, or horizontally opposed. The crankshaft design determines the firing order of the cylinders by the position of the crankshaft throws in conjunction with the camshaft.

On the four-cylinder in-line engine crankshaft, the throws are all on the same plane. The front and rear throws are 180° (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 upon engine block construction. With this crankshaft, power is only delivered to the shaft during 140° of each piston's power stroke. Therefore, there is a power lapse of 40° between each power stroke of the engine (fig 2-11). This power lapse causes the engine to vibrate. The vibration is reduced through the use of a heavy flywheel and the vibration damper but is not entirely eliminated.

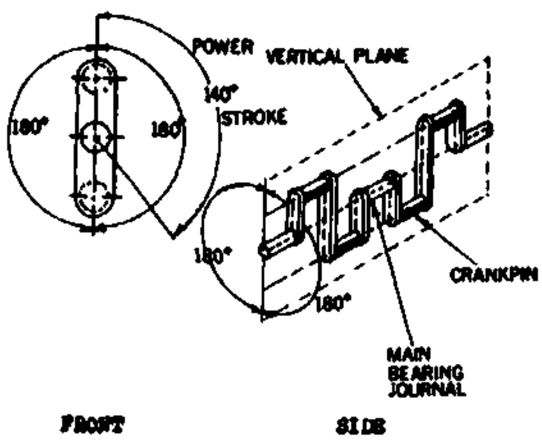


Fig 2-11. Four-cylinder engine crankshaft illustrating amount of rotation during the power stroke and the relationship of the throws.

The power lapse, which was just discussed, is completely eliminated in the in-line, six-cylinder engine due to the arrangement of the throws on its crankshaft. The throws are constructed on three separate planes spaced 120° apart (fig 2-12).

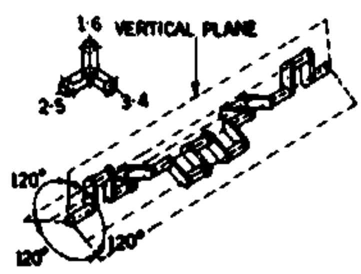


Fig 2-12. Six-cylinder in-line engine crankshaft.

This arrangement of the throws not only eliminates power lapse, but gives the engine power overlap. This condition means simply that each power stroke begins before the previous stroke ends. In the case of the in-line, six-cylinder engine, the power overlap is 20°. In other words, one piston travels through 120° of its power stroke which actually lasts for 140° of crankshaft rotation. At this time, the next piston in the firing order begins its power stroke. Therefore, during the last 20° of the power stroke, two pistons are actually delivering power to the crankshaft. The last 40° of the down-stroke, therefore, is not a power lapse, because the next piston is carrying the crankshaft through this 40°.

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

Another six-cylinder crankshaft is the V-six. Here again, you find the throws arranged 120° apart, but you find only three throws. This is due to the fact that each throw accommodates two pistons. Pistons number 1 and 2 are mounted on the first throw, 3 and 4 on the second (center) throw, and 5 and 6 on the third throw. Due to the V-type design of the engine, you find both power overlap and power lapse. Look at an example of this overlap and lapse. Number one piston begins its power stroke and as the crankshaft reaches 90° of its rotation number six piston, on a separate throw begins its power stroke, so both pistons are delivering power to the crankshaft during 50° of crankshaft rotation. The next piston to deliver power is piston number five. You may recall that number five and number six pistons are the same throw. This means that number six must reach the end of its down stroke before power can be delivered to number five. Therefore, you have 10° of crankshaft rotation with no power being delivered to the crankshaft. This same condition continues with remaining three pistons. The flywheel on this engine may be lighter than that of the four-cylinder in-line due to the decreased power lapse.

If you add one more throw and put each on a separate plane, spacing all the throws 90° apart, you have a crankshaft for a V-type eight-cylinder (fig 2-13). Power overlap in this engine is the same as the V-six, but the additional cylinder eliminates the power lapse. You may find that some V-eight crankshafts have the throws on only two separate planes and look similar to the in-line, four-cylinder crankshaft, but remember that two pistons are mounted on each throw, so the throws have longer crankpins. The crankshaft is supported in the engine block by either three or five main journals, which you will find is true also of the V-six crankshaft.

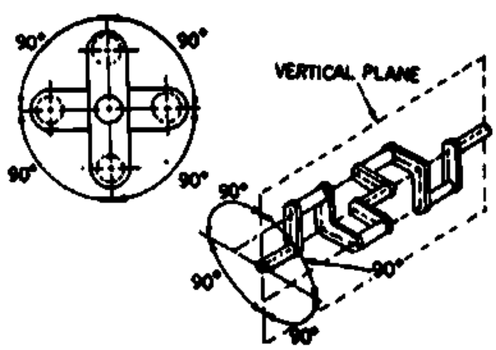


Fig 2-13. V-8 engine crankshaft.

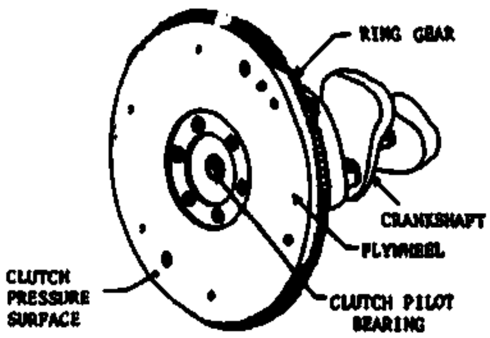
At one time or another, you will come across a three-cylinder, in-line engine's crankshaft. This crankshaft is constructed the same as the six-cylinder in-line with only half as many throws. The power overlap is the same.

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, which are longer to accommodate two connecting rods per crankpin.

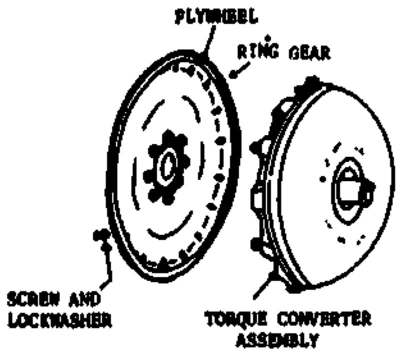
You have found, during this discussion, that the number of throws and their length determine the engine they are designed for. Now that we have discussed crankshafts, power overlap, and power lapse. let's take a look at the flywheel which carries the crankshaft through the periods of power lapse, reduces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

FLYWHEELS

Basically, flywheels are of two designs, one for friction clutch use and another for fluid coupling use (fig 2-14).



Standard transmission (friction clutch) flywheel



Automatic transmission (fluid coupling) flywheel

Fig 2-14. Flywheel designs.

The flywheel, used with the automatic transmission, is 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 itself performs the function of carrying the crankshaft through power lapse.

The flywheel, used with conventional transmissions on the other hand, is constructed of a much heavier metal. The actual weight of the flywheel depends upon the amount of vibration the engine will produce due to differences in power overlap and power lapse.

Most conventional transmission flywheels and automatic transmission flywheels are interchangeable on the same crankshaft so that you have a choice of transmissions, as long as the transmission and flywheel used are designed for that particular engine size and type by the same manufacturer.

Engine vibration is not only produced by differences in power overlap and power lapse, but also by the elasticity of the crankshaft itself. To compensate for this vibration, mount a smaller wheel, known as a vibration damper, on the front end of the crankshaft.

VIBRATION DAMPERS

Vibration dampers are used to damp out crankshaft torsional vibration. This is 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. You need to damp out this twisting action which is the purpose of the damper.

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 2-15. 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. Some small engines which do not produce a lot of power use a solid-design damper.

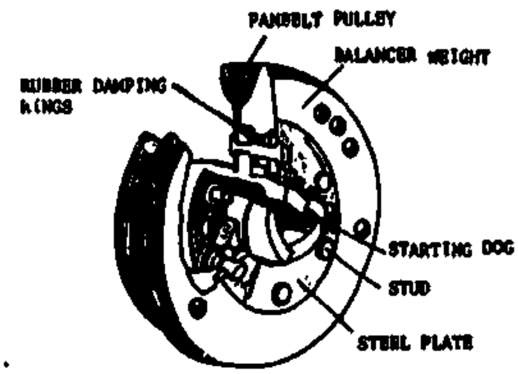


Fig 2-15. A typical vibration damper.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

I. An in-line, four-cylinder engine and a V-8 engine both have the same number of throws on the crankshaft. How are you able to recognize the difference between the two crankshafts?

____

____

Work Unit 2-5. PISTONS

IDENTIFY THE TYPE OF ENGINE THAT PISTONS ARE DESIGNED FOR WHEN THE PISTONS ARE UNUSUAL AND HAVE CONCAVE HEADS.

IDENTIFY THE KINDS OF RINGS USED ON PISTONS.

IDENTIFY THE BASIC CONSTRUCTION OF CONNECTING RODS.

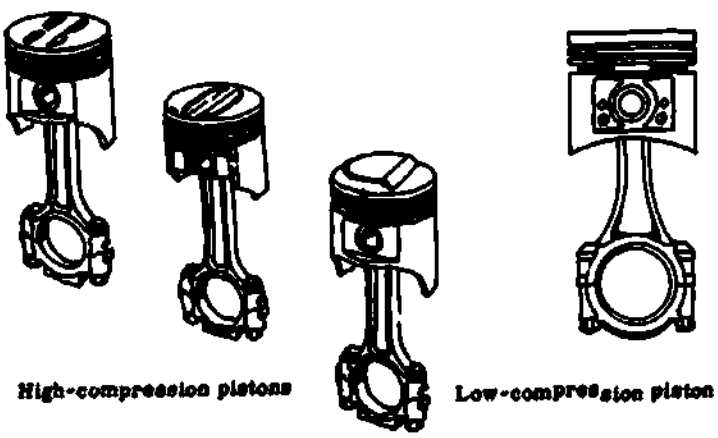


Fig 2-16. Various piston head designs for spark-ignition engines.

The pistons used in diesel (compression-ignition) engines form the combustion chamber because of the cylinder head design; therefore, the pistons will be of a concave-head design. You will find that these pistons too, vary somewhat in their design (fig 2-17).

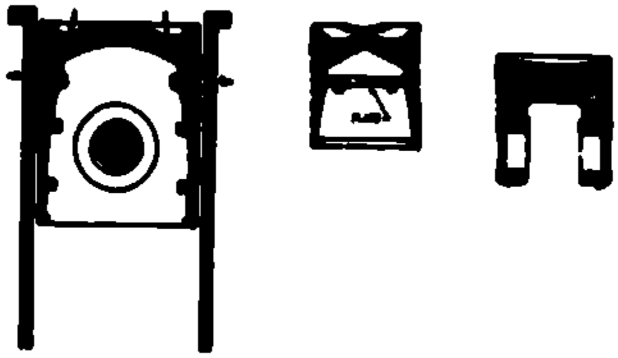


Fig 2-17. Various piston head designs for compression-ignition engines.

Gasoline-engine pistons may have ribs cast on the underside of the piston head for cooling and reinforcement. Some diesel pistons have thicker heads for additional strength and are cooled by an oil jet which shoots oil on the underside of the piston head. Not all diesel pistons are cooled in this manner.

Most pistons, both gasoline and diesel, are relieved (cut flat) around the piston pin hole to allow for expansion and to reduce weight (fig 2-18). Most piston 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 (fig 2-19). 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.

Fig 2-18. Most pistons have reliefs in the skirt surrounding the piston boss.

Fig 2-19. Offset piston pin holes.

The portion of the piston below the piston rings is known as the skirt. You will find a seemingly unending variation in the design of piston skirts (fig 2-10). These designs are desirable to keep the piston as light as possible and to prevent excessive expansion during engine operation. The piston is kept in alinement by the skirt, which is usually cam ground and elliptical in 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.

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

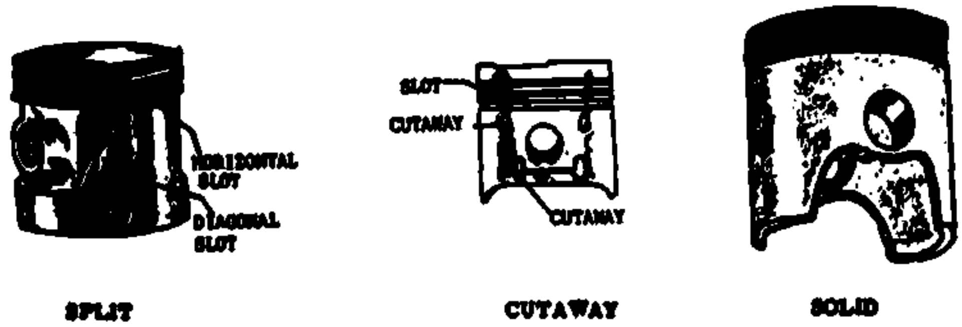


Fig 2-20. The three basic piston skirt designs.

PISTON RINGS

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 (fig 2-21).

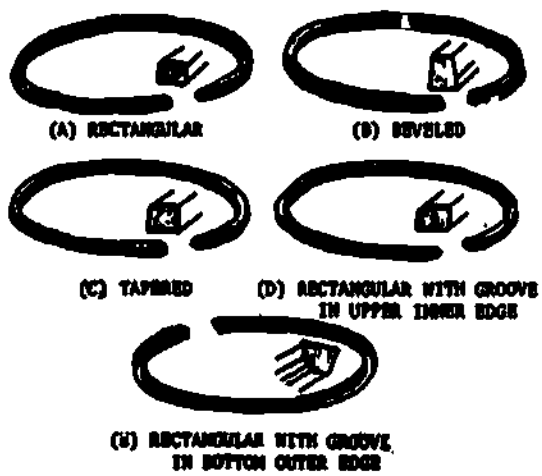


Fig 2-21. Various compression ring designs.

The design of the piston ring depends upon the amount of surface contact desired with the cylinder wall. The most common are the rectangular ring and rectangular with 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.

Other rings are the beveled, the tapered, and the rectangular with a grooved outer edge. All of these give less face contact with the cylinder wall with more pounds per square inch.

Oil control rings may be of a two-, three-, or four-piece construction. The two-piece ring is seldom, if ever, used in modern vehicles, so it will not be discussed in this study unit .

The three-piece oil ring is probably the most common you will find (fig 2-22). It consists of two steel rails, separated by a ventilated steel segment.

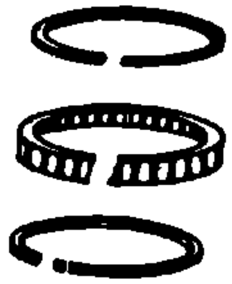


Fig 2-22. Three-piece oil control ring.

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 (fig 2-23).

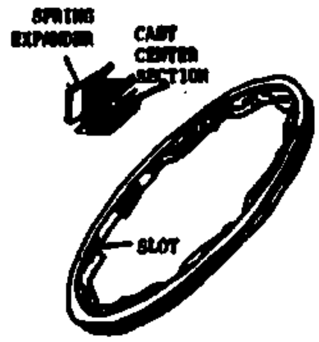


Fig 2-23. Four-piece oil control ring.

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

CONNECTING RODS

Basically, the connecting rods are of an I-beam construction with a piston pin hole at the upper end and a saddle at the lower end with a separate bearing cap which is connected to the connecting rod by two bolts (fig 2-24).

Fig 2-24. 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 2-25). The saddle of some connecting rods may be cut at an angle to facilitate the removal and installation of the piston assembly (fig 2-26). Aside from these two variations, there is little, if any, variation in design.

ERIC
Full Text Provided by ERIC

Fig 2-25. Offset connecting rod saddle used in opposed and V-type engines.

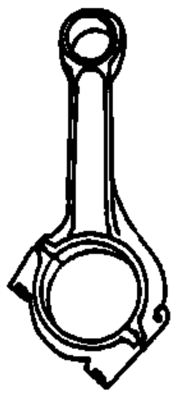


Fig 2-26. Some connecting rod saddles are cut at an angle for easy removal and installation.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. You received pistons that were a little different from the original ones. The piston heads were concaved. What type of engine are these pistons designed for?

   a. The same engine, it is merely a variation in design of the same piston.
   b. They are designed for a similar spark-ignition engine.
   c. They are designed for a similar compression-ignition engine.

2. Why are most pistons relieved (cut flat) around the piston pin hole?

   a. To allow for proper up and down movement
   b. To allow for expansion and to reduce weight
   c. To allow for the piston to remain alined
   d. To stop the piston from slapping the side of the cylinder wall

3. What are the basic parts of a piston?

   a. Piston top, skirts, rings
   b. Piston skirts, rings, grooves
   c. Piston, rings, connecting rods
   d. Compression ring, skirt, oil rings

4. What two kinds of rings are used on pistons?

   a. Expansion rings and slotted rings
   b. Cross rings and oil control rings
   c. Compression rings and groove rings
   d. Compression rings and oil control rings

5. How are connecting rods basically constructed?

a. H-beam
b. I-beam
c. Solid-beam
d. Offset-beam

Work Unit 2-6. CYLINDER HEADS

IDENTIFY THE TYPE OF ENGINE YOU WOULD INSTALL A HEAD ON, IF THE CYLINDER HEAD FITS A FOUR-CYLINDER ENGINE, AND IS PERFECTLY FLAT WITHOUT COMBUSTION CHAMBERS.

CYLINDER HEADS

Cylinder-head design depends upon the valve arrangement of the engine it is used on. Basically, the cylinder head is of two designs, flat-head and valve-in-head. The flat-head is designed for the L-head engine and the valve-in-head is designed for use with the I-head and F-head engines. You are already familiar with these designs to a certain extent if you are familiar with valve arrangement discussed earlier. A major difference in cylinder-head design that has not been discussed is the difference between heads designed for gasoline engines and those designed for diesel engines.

The cylinder heads that were discussed earlier had portions cupped out to form a combustion chamber. These are used for gasoline (spark-ignition) engines.

If you will recall, as stated earlier in this study unit, in the diesel engine the combustion chamber is in the piston. The reason being that the cylinder head for diesel (compression-ignition) engines is perfectly flat on the bottom, except for the exhaust valve ports.

VALVE MECHANISMS

Three of the more common valve designs which are the mushroom, tulip, and semi-tulip valves. With the exception of the top of the valve head (fig 2-27) and 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 in the manufacture, will determine the temperature range of the valve during operation.

As for the valve train, there are two basic designs which have already been discussed, the valve-in-head and the flat-head. There may be very minor differences as to size and pressure determined by the manufacturer's specifications.

Fig 2-27. Three of the more common valve designs.

You should be familiar now with the construction, operation, and design used in the reciprocating internal-combustion engine. The study units to follow will dwell upon the knowledge needed to diagnose problems and the solutions to these problems through engine repair and rebuild.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. You have a cylinder head that fits a four-cylinder engine, but the cylinder head is perfectly flat with no combustion chambers. On which type of engine are you going to install the head?

   a. Three-stroke-cycle spark-ignition
   b. Two-stroke-cycle spark-ignition
   c. Four-stroke-cycle compression-ignition
   d. Three-stroke-cycle compression-ignition

2. What are the three common valve designs?

   a. T-top, mushroom, valve lock
   b. Mushroom, tulip, T-top
   c. Tulip, T-top, valve
   d. Mushroom, tulip, semi-tulip

SUMMARY REVIEW

In this study unit you have learned the various engine designs and various designs of components used in the construction of engines. Next, you will study engine malfunction, diagnosis, and remedy.

Answers to Study Unit #2 Exercises

Work Unit 2-1.

1. a. cylinder arrangement
   b. cooling system

Work Unit 2-2.

1. F-head, I-head, L-head

Work Unit 2-3.

1. Replace only the defective cylinder.

Work Unit 2-4.

1. By the length of the crankpins; V-8 crankshaft has longer crankpins

Work Unit 2-5.

1. c
2. b
3. c
4. d
5. b

Work Unit 2-6.

1. c
2. d

ERIC

STUDY UNIT 3

ENGINE MALFUNCTION, DIAGNOSIS, AND REMEDY

STUDY UNIT OBJECTIVES: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE SYMPTOMS OF VARIOUS INTERNAL MALFUNCTIONS OF THE ENGINE AND THE REMEDIES REQUIRED TO RESTORE THE ENGINE TO THE NORMAL OPERATING CONDITION.

Work Unit 3-1. ENGINE BLOCK

IDENTIFY A CAUSE OF ENGINE COOLANT LOSS.

STATE HOW TO REMEDY A CRACKED CYLINDER BLOCK WITHOUT HAVING TO REPLACE IT.

In order for a mechanic to perform proper and economical maintenance, repair, or rebuild, he must first be capable of detecting and identifying malfunctions and locating their source. This study unit will require you to put the knowledge presented in study units one and two to practical use in determining the results of defective engine components. As you read this study unit, you must constantly keep pictured in your mind the construction and operation of the components being discussed.

ENGINE BLOCK

Although the engine block is not actually a functioning part of the engine, the functioning components rely heavily upon it. Therefore, the block can be the source of some engine malfunctions. For example, take the cylinder walls. The piston rings rely upon 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 your answer covered 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 and be burned there 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.

How do we detect this? 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 cylinder which is defective.

To perform a compression test, you must first know how much compression the engine should produce. Check the technical manual (TM) for second echelon maintenance of your vehicle. This TM will give you the specifications you need. The last two digits of the TM number indicate the echelon of maintenance for which the TM is designed (fig 3-1).

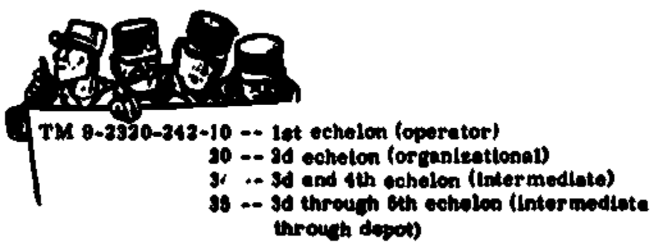


Fig 3-1. The last two digits indicate the echelon for which the technical manual is intended.

Now break out the compression gage kit and check it, making sure that the gage reads zero and that the adapters are clean and free of cracks (fig 3-2). Adapters vary in shape and size to allow the compression gage to be used on various type engines.

Fig 3-2. Check the compression gage kit.

Your next step prior to starting the engine would be to check the vehicle batteries. They must be in good condition and the crankcase oil must be at the full mark on the dipstick (fig 3-3).

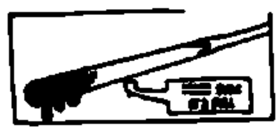


Fig 3-3. Check the oil with the dipstick.

Start the engine and let it warm up to operating temperature. This allows normal expansion of the metals, and will give you a t ue reading when you perform the test. After operating temperature has been reached, turn the ignition switch to the <u>off</u> 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 (fig 3-4).

Fig 3-4. Loosen plugs and clean around them.

Remove 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 would not allow current to flow across the points and a high tension spark would not be produced (fig 3-5).

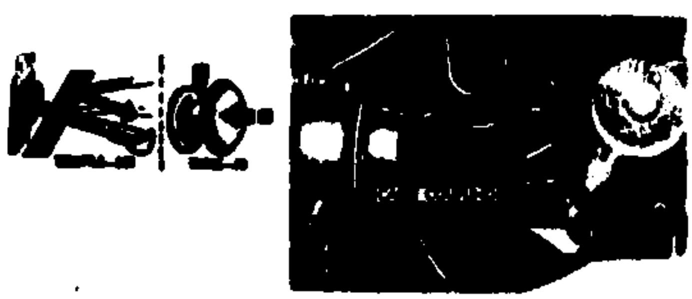


Fig 3-5. Carburetor throat must be open and ignition off.

Now for the test. Choose the proper size adapter for the compression gage. Insert the compression gauge into the spark plug hole of number one cylinder and have a helper crank the engine over about ten times (with ignition off, fig 3-6). During this process, if the operator carefully observes the gauge hand, a sticking valve may easily be detected. The hand progressively rises with each revolation of the starting motor until no further movement of the gauge hand is obtained. The indicated pressure on the gauge represents the maximum compression pressure under prevailing conditions.

Should the gauge hand remain fixed at any one of the "beats" or revolutions of the

ERIC

starting motor and then rise again, the point where it lagged would indicate a valve sticking in the open position. Compression pressures will vary, or be higher in newer engines then older models.

Fig 3-6. Insert compression gage into spark plug hole.

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. This is known as a "dry" compression test. 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. Prior to inserting the gage into the spark plug hole, squirt about four shots of oil from a trigger-type oil can into the hole (fig 3-7) 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 3-7. Preparation for a "wet" test.

This test need be performed only on those cylinders which had low "dry" readings. 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, allowing 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 values or value seats. However, low readings on adjacent cylinders will ordinarily indicate cylinder head gasket leakage between cylinders. If the walls are scored, the defective cylinder must be rebored.

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 clear of rust and corrosion. This is accomplished through a daily check of the coolant and the use of anti-rust chemicals. When chemicals are not available, periodic flushing of the cooling system is necessary. As a mechanic, your responsibilities consist of checking the condition of the coolant when the vehicle is in the shop for maintenance.

A motor vehicle operator approaches you and complains that his engine is overheating. Consider first, is it an air-cooled or water-cooled engine? Let's say it is a water-cooled engine. What cools the 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 3-8). 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?

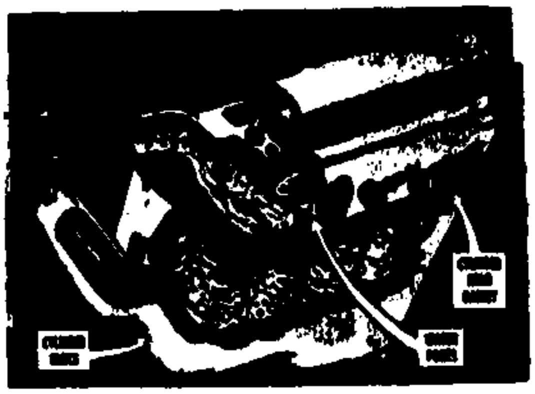


Fig 3-8. Engine water jacket.

If you decided that the water jackets are dry or clogged, you are right. The first check should be to see if the water level in the radiator is visible. If it is, the water jackets must be clogged, and the entire cooling system must be flushed. If it is not visible, fill the radiator. Allow the engine to run for 10 to 15 minutes so that pressure will build up inside the water jacket. Now check the outside of the engine for leaks. Leaks will usually occur in the core plugs (fig 3-9) which cannot be repaired but must be replaced. If there are no visible leaks, the engine must have an internal leak. The walls of the jacket could be cracked into the cylinder wall. What do you think would happen in this case? If there is a crack between the cylinder and the water jacket, what happens during the compression and power strokes? Have you ever blown through a straw into a glass of water? Remove the radiator cap and take a look inside with the engine running. If you see bubbles, what could be causing them (fig 3-10)?

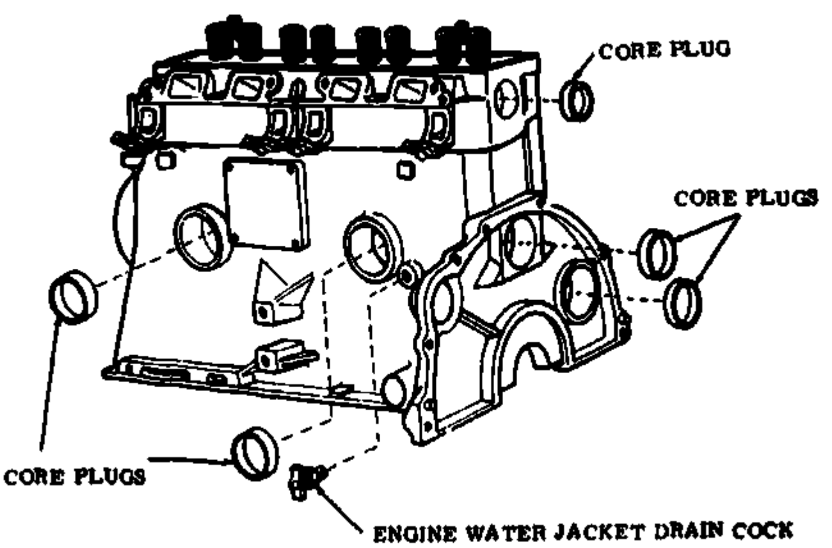


Fig 3-9. Possible areas of coolant leakage.

50

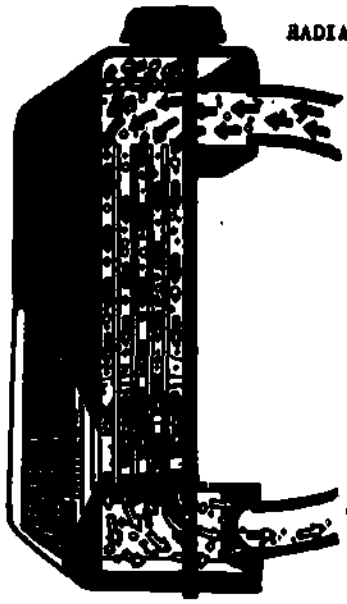


Fig 3-10. Cutaway view of radiator showing bubbling in the top as opposed to the normal swirling coolant.

The answer is simply the pressure of the compression and power strokes is leaking into the water jacket. Of course, during the intake stroke, the water is being drawn into the cylinder (fig 3-11).

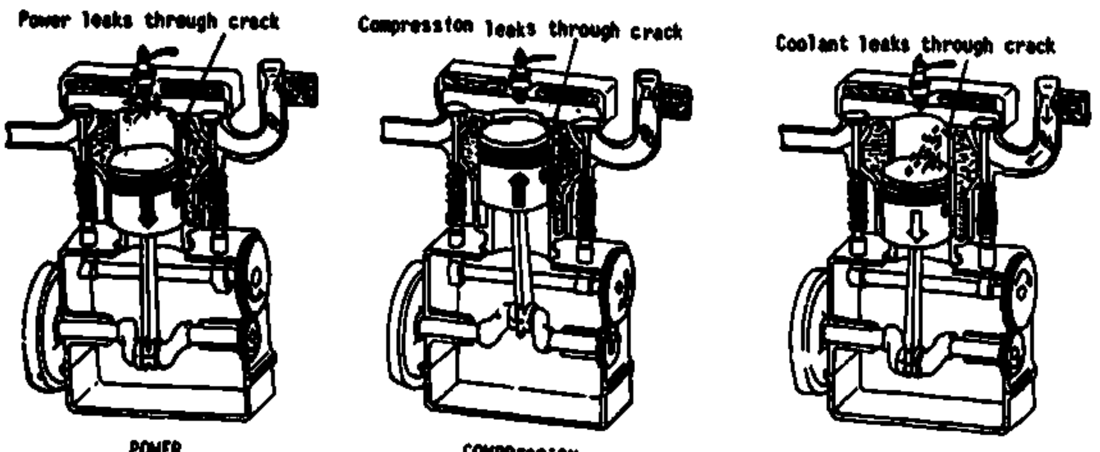


Fig 3-11. Cracked water jacket.

Let's confirm the defect now. Is steam being emitted from the tailpipe? Steam looks like burning oil, but it disappears soon after it leaves the tailpipe (fig 3-12), while oil will linger. 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 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 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 be ground if necessary.

Fig 3-12. Steam dissipates rapidly.

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 capable of passing beween the fins to carry the heat away from the engine (fig 3-13). This problem is usually remedied by cleaning the fins with a high-pressure air gun.

Fig 3-13. 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. It may cool the engine near the fan, but the remaining portion of the engine would 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 as a hotspot in the combustion chamber will cause the fuel to ignite prematurely, affecting the performance of the engine.

Oil is also a major factor in the cooling of an air-cooled engine. An oil cooler is provided, which is very similar to a miniature radiator. This cooler 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.

Defective oil passages are usually the result of contaminated oil. Here again, a little preventive maintenance solves the problem before it begins. Prescribed periodic oil and oil filter changes will prevent this condition. The condition of clogged oil passages may be detected by an indication of abnormally high or low oil pressure readings 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 3-14). If the return passages are clogged, oil will be found "standing" in the top of the cylinder head where the rocker arms are located. To remedy this situation, you may remove the rocker arm shaft and 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 accomplished and as frequently as possible until the oil additives have ample time to clean the system.

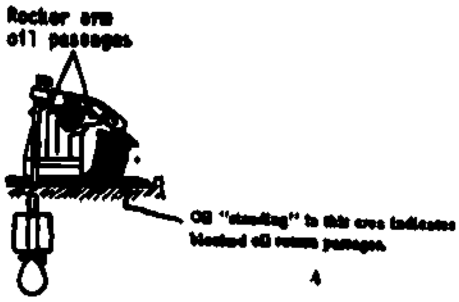


Fig 3-14. The rocker arm lubrication method.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. A vehicle operator complains of an excessive loss of engine coolant. You cannot find any external leaks, but upon further inspection, you find coolant in the crankcase oil. What is the most likely cause of this condition?

   a. A leak between the water jacket and the water pump
   b. A leak between the water pump and the water jacket
   c. A leak between the water jacket and the crankcase
   d. A leak between the radiator hoses and cylinder block

2. A cracked cylinder block may have to be replaced, but in some cases the defect may be remedied by

   ____

3. Defective or clogged oil passages are usually the result of what?

   a. Contaminated antifreeze
   b. Contaminated gasoline
   c. Contaminated oil
   d. Contaminated air filter

Work Unit 3-2. CYLINDER HEAD

IDENTIFY WHAT MUST BE DONE, IF A CYLINDER HEAD BECOMES WARPED, AND IS NO LONGER SMOOTH.

The same problems, diagnoses, and remedies apply to the cylinder head as apply to the engine block with some additions. For instance, 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. This is usually indicated by two adjacent (side-by-side) cylinders failing to deliver power (misfiring). When this condition exists, 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 3-15). A compression test would indicate little or no compression in either of these two cylinders. To remedy this problem, the head and block must be checked for a perfectly flat condition and machined flat (commonly termed, "grinding the head or block").

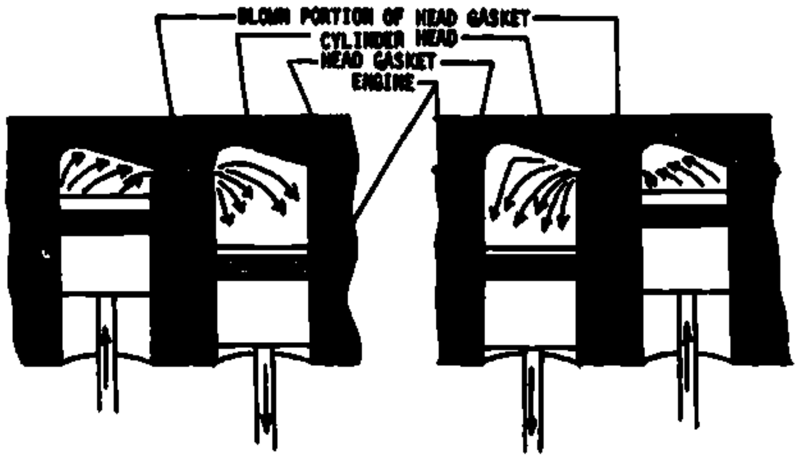


Fig 3-15. Flow of air due to blown cylinder head gasket.

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

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

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 could misfire
   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.

Work Unit 3-3. PISTON ASSEMBLY

IDENTIFY READINGS THAT YOU WILL GET ON THE COMPRESSION GAGE FROM DEFECTIVE RINGS.

IDENTIFY HOW TO REMEDY THE CONDITION OF AN ENGINE WITH WORN PISTON RINGS.

The piston assembly is a common cause of engine malfunction. 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 it 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, and, therefore, compression and power cannot take place. Another factor which 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 which may be produced by a cracked piston. Before pulling the cylinder head off to verify a misfire which we suspect is a cracked piston, let's test the cylinder in case the malfunction is caused by another source. What tests are we going to perform on the cylinder?

First, perform a complete "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 any others which may be found defective during the "dry" test. If a piston is cracked, the "dry" test and the "wet" test should produce the 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 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," a blue smoke should be emitted from the tailpipe. This smoke will resemble the steam emitted due to a crack between the water jacket and the cylinder, but will not dissipate as fast. 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.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. If piston rings are worn excessively, burnt oil will be emitted from the tailpipe. However, you must 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. Low "dry" test and noticeably higher "wet" test
   b. Low "dry" test and low "wet" test
   c. High "dry" test and low "wet" test
   d. High "dry" test and noticeably higher "wet" test

2. You have an engine with worn piston rings. This condition may be remedied by

   a. honing the cylinder wall.
   b. reboring the cylinder.
   c. replacing the piston rings.
   d. replacing the piston.

Work Unit 3-4. VALVE MECHANISMS

IDENTIFY THE RESULTS OF TIMING GEAR OR TIMING CHAIN AND SPROCKET MALFUNCTION.

STATE THE REPAIR NEEDED WHEN AN ENGINE WITH TOO TIGHT VALVES NEEDS MORE THAN A VALVE ADJUSTMENT.

STATE WHAT DEVICE IS 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 the valve. Now let's think about some of the malfunctions which can occur in this mechanism. Let's begin with the timing gears since they are the source of movement within the mechanism.

Recall the function of the timing gears or timing chain and sprockets. If they are installed with one tooth out of alinement, the engine will hardly operate. If they are installed with two or more teeth out of alinement, it is very likely that the engine will not operate at all. 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 number one spark plug wire in the distributor, remove the distributor cap, and turn the crankshaft until the rotor button is in position to ignite that spark plug (fig 3-16). Number one spark plug should be firing somewhere near this point. You can't see the spark, but by observing the timing marks located on the crankshaft damper, you know that they should be near alinement 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 this malfunction as?

ERIC

Fig 3-16. Tactical vehicle distributor.

If the camshaft is driven by gears a gear-tooth has most probably been chipped off the gear. If it is driven by 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 would throw the valve timing off. The mechanical timing mechanism (timing gears or sprockets and chain) must be repaired by replacing those components which are defective.

The camshaft will seldom, if ever, be the source of malfunction. However, there have been cases of camshaft lobes wearing to the extent that they would drastically affect the performance of an engine. This was due to lack of lubrication between the camshaft lobes and the valve tappets, in which case the tappets experience excessive wear also.

Can you determine the result of this condition in valve operation?

The camshaft lobes open the valves to allow the fuel-air mixture to enter and the burned gases to leave the combustion chamber. Therefore, if the lobes and the tappets are worn, the valve opening is affected in the distance the valve opens as well as the amount of time it remains open (fig 3-17). This cuts the amount of fuel-air mixture which is allowed into the engine.

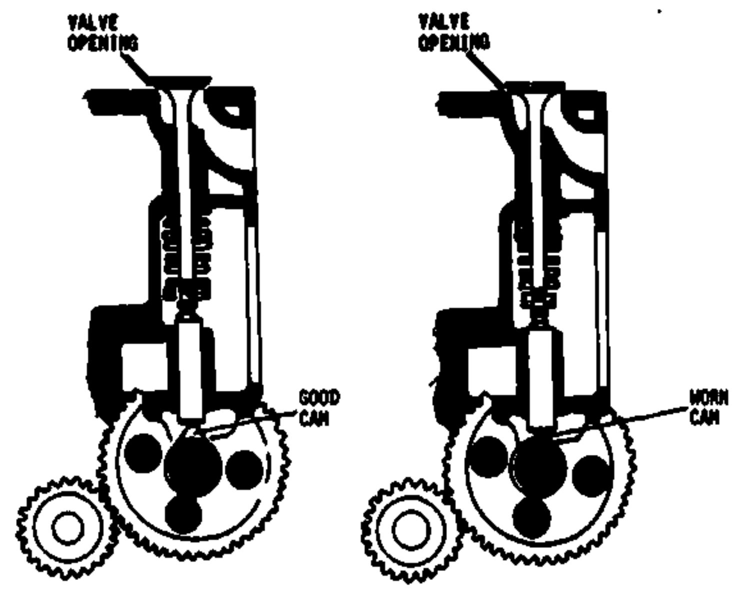


Fig 3-17. Comparison of the opening of the valve with a good cam lobe and a worn cam lobe.

With less fuel-air mixture, naturally, the engine suffers a loss in performance. This situation may be remedied in its early stages by valve adjustment. A good sign to watch for is the engine requiring frequent valve adjustments or, in the case of engines with non-adjustable hydraulic valves, check the bottom of the tappets for wear when they are removed. The only remedy for this condition in the latter stages is replacement of the camshaft and tappets. In the early stages, valve tappet wear is easily detected through the sound the tappets make. It is similar to the noise of a pencil point tapping on a desk.

A valve which remains open for a longer period than necessary is just as bad as one which opens too late and closes too soon. This will cause the valve to become burnt. What component in the valve mechanism would be at fault if the valves were remaining open for a prolonged period of time?

Prolonged valve opening may result from two conditions, weak valve springs and valves adjusted too tightly. A weak valve spring will not close the valve as rapidly as it should, and if the valves are adjusted too tightly, the camshaft lobe will open them sooner than desired and allow them to be closed later. Compression can only be created in the combustion chamber while the valves are closed. Therefore, if the valve remains open during the compression stroke, compression will drop in direct proportion to the amount of time the valve remains open.

From this point on, we will discuss the valve-in-head valve train design since it covers the components of the valve-in-block valve train as well. If the valve guide becomes rough or burred, the valve stem tends to hang (stick) inside it. This will hold the valve open too long, and put added pressure on the pushrod. If this pressure becomes great enough, it will cause the pushrod to bend. What do you think the symptom would be if this condition occurred?

When a pushrod becomes bent, its length would be shortened. This would produce the same effect as worn tappets or camshaft lobes. Therefore, the first symptom would be the sound emitted from the valve train, which is 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 eventually it would bend again. A bent pushrod must be replaced with a new part. What must be done prior to replacing a bent pushrod? You must eliminate the source of the problem. Therefore, you must repair or replace the valve guide before installing the new pushrod.

Worn rocker arms and rocker arm shaft are a cause of valves opening too late and closing too soon. The symptom again is the sound similar to the tapping pencil. The cause of this problem is poor or no lubrication. The pivot (fig 3-18) of the rocker arm and rocker arm shaft will become worn. This condition may be verified by removing the rocker arm cover and observing the rocker arms while the engine is operating. If lubrication is sufficient, oil will squirt from the rocker arms as they rock back and forth. 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.

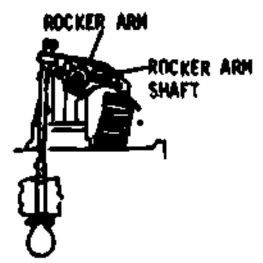


Fig 3-18. The pivot point for the rocker arm, the rocker arm shaft.

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 cracked piston head, a valve adjusted too tightly, etc.). We don't think that it is a cracked piston because no sound is present to indicate this. You will probably have to remove the cylinder head, but first, adjust the valves to ensure that they are not too tight. Now, after performing another "wet" test on the cylinder, the result is the same. You are encountering the most common cause of an open cylinder, a burnt valve. When a valve becomes burnt, it means that the face of the valve has lost its machined smooth finish due to partial melting of the metal caused by extreme heat within the valve. When this happens, the valve must be ground. The valve face is cooled by the valve seat when the valve is closed. The valve seat, of course, is cooled by the water jacket. Can you determine why this condition would occur?

In order to cool sufficiently, a valve must remain seated for a certain period of time to give the seat ample time to transfer the heat from the valve to the coolant within the water jacket. If the valve is adjusted too tightly, this 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 3-19). Therefore, you have an open combustion chamber even when the valves are closed.

Fig 3-19. The effect of scorching and melting.

To ensure proper cooling of the valves, they must be adjusted by inserting a feeler gage between the rocker arm and the valve stem, then turn the adjusting nut until a slight drag is felt (fig 3-20). The TM for the specific engine will state the procedures to be followed as well as the clearance required.

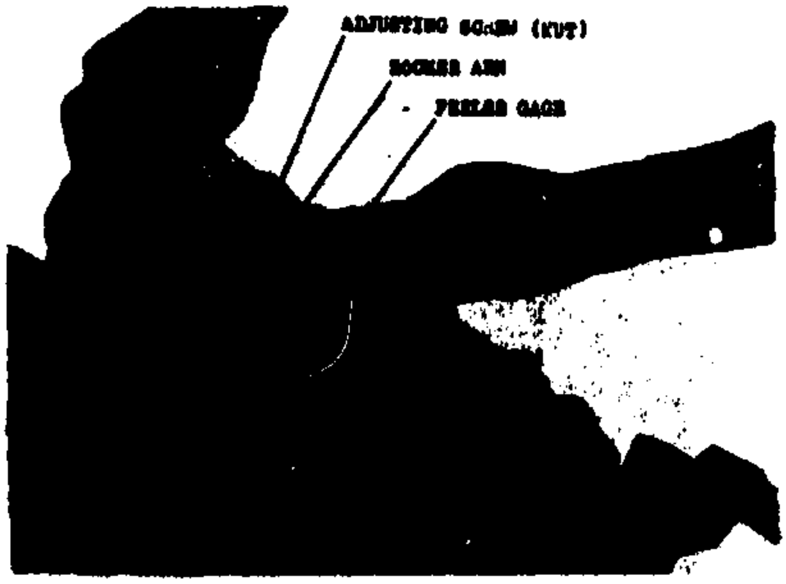


Fig 3-20. Adjusting valves on an I-head engine.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. You have an engine which 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 number one piston is at TDC compression. What is the most probable cause for this condition?

   a. Defective points
   b. Defective camshaft
   c. Defective valve springs
   d. Defective timing

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

   ____

3. What device is used for valve adjustments?

   ____

Work Unit 3-5. CRANKSHAFT

IDENTIFY THE MAJOR CAUSE OF CRANKSHAFT FAILURE.

IDENTIFY THE REMEDY USED TO CORRECT A KNOCK CREATED BY THE CRANKSHAFT BEARINGS.

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 one portion of the shaft "seizing" during operation. This condition is due to poor lubrication. There is no method of repair for a broken crankshaft; therefore, it must be replaced.

Improper lubrication is the major cause of crankshaft failure. Both the main journals and the crankpins rotate inside friction-type bearings. Without lubrication, these bearings would last only a few seconds. With improper lubrication, such as heavily diluted oil, improper viscosity, or insufficient quantity of oil, the bearings will break down far earlier during the life of an engine than they should. When the bearings break down, an excessive amount of free play exists between the bearing and the crankshaft. This can be detected through a "knocking" sound inside the oil pan.

ERIC

If detected early enough, this condition may be remedied by merely replacing the bearings. If not, the crankshaft must be "turned" (ground to eliminate blemishes), and the bearings replaced with a different size bearing.

In some cases, the bearing will seize the crankshaft and result in a broken (thrown) connecting rod or a broken crankshaft as mentioned earlier.

We have discussed how to detect, recognize, and locate engine malfunction. We have briefly covered some of the remedies for these malfunctions. Now, let's disassemble an engine and prepare it for whatever repairs are necessary.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

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. What is the remedy which usually corrects a knock created by the crankshaft bearings?

   a. Replace the camshaft.
   b. Replace the rod bearings.
   c. Replace the crankshaft bearings.
   d. Replace the push rod bearings.

SUMMARY REVIEW

You have now learned to identify 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.

Answers to Study Unit #3 Exercises

Work Unit 3-1.

1. c.
2. sealing the cylinder block
3. c.

Work Unit 3-2.

1. c.
2. d.

Work Unit 3-3.

1. a.
2. c.

Work Unit 3-4.

1. d.
2. Reface or replace the valves
3. Feeler gage

Work Unit 3-5.

1. b.
2. c.

5J

STUDY UNIT 4

ENGINE DISASSEMBLY

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE PROCEDURES USED IN THE DISASSEMBLY OF THE RECIPROCATING INTERNAL COMBUSTION ENGINE.

Work Unit 4-1. ENGINE REPAIR PREPARATION

IDENTIFY THE FIVE PROCEDURES TO BE FOLLOWED IN PREPARING AN ENGINE FOR REPAIR OR REBUILD.

Many engines have been repaired or rebuilt and returned to operation, but a short time later they are found back in the maintenance facility. Probably the greatest cause of this is improper disassembly. Most mechanics who experience this situation concentrate all their efforts on repair of the components known to be defective, and careful reassembly. They fail to see the importance of proper disassembly. As you can see, we are devoting an entire study unit to the disassembly phase. You will soon realize that this is just as important as repair and reassembly.

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 cause further damage.

With the engine removed from the vehicle, you can begin your preparation. Imagine yourself as a surgeon and the engine as your patient. If foreign matter enters your patient's body, infection will result, and your operation is a failure. Let's make sure that ALL openings into the engine are well covered (fig 4-1).

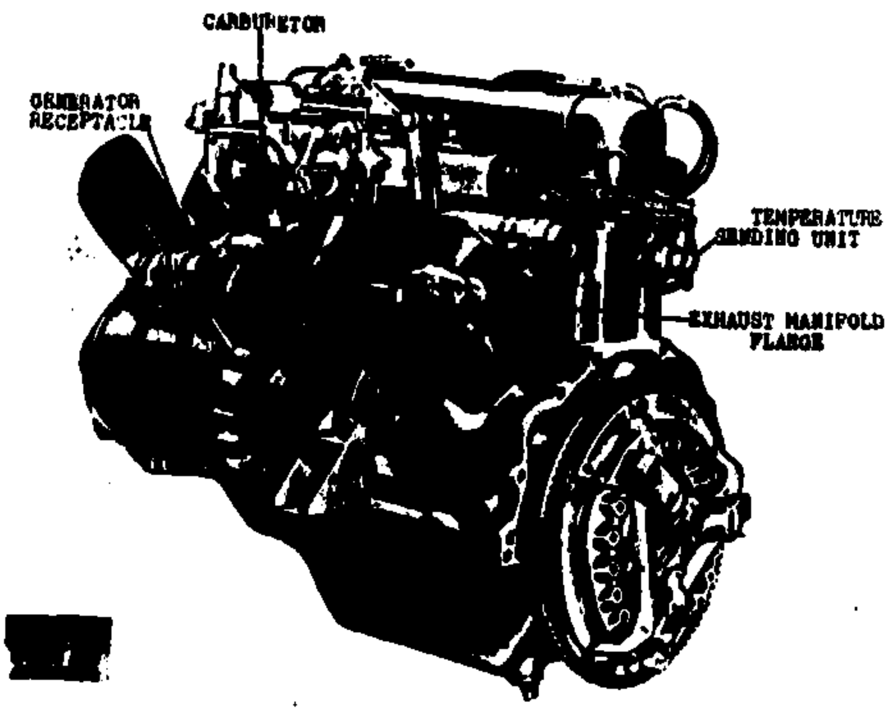


Fig 4-1. Engine preparation.

Now that all openings are covered, you must clean the engine thoroughly to prevent foreign matter from entering the engine during disassembly. This could cause damage to the internal parts later. First, let's 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 which may be on the engine. Using two separate containers, 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.

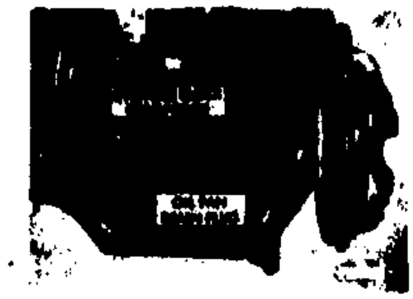


Fig 4-2. Drain the engine.

With the engine thoroughly cleaned and drained, make 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 your 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 (fig 4-3).

<u>Note:</u> The removal and installation of the intake and exhaust manifolds will be covered in another course. It is essential, however, that these components be inspected and properly alined for the engine to operate correctly.

Fig 4-3. Cylinder block installation on repair stand--left side.

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.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. The cause of repaired/rebuilt engines being returned to maintenance too soon after repair is ______________________.

   a. improper disassembly
   b. defective components
   c. proper disassembly

2. Which is NOT included in the engine repair preparation?

   a. Cover all openings
   b. Clean engine with gasoline
   c. Check parts as they are removed
   d. Inspect the outer surface

Work Unit 4-2. CYLINDER HEAD REMOVAL

IDENTIFY THE PROCEDURAL DIFFERENCE INVOLVED IN REMOVING THE CYLINDER HEAD FROM AN L-HEAD ENGINE AND FROM AN I-HEAD OR F-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. Therefore, 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. Simply 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 and cause unnecessary repairs in most cases. 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 your cylinder head and cylinder block gasket-surface inspection in that particular area later.

Removing an I-head or F-head engine's cylinder head will require a little more effort. First, remove the rocker arm cover and discard the gasket and the retainer seals (fig 4-4).

Fig 4-4. Remove the rocker arm cover.

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. 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 4-5). If the pressure is not relieved, damage to the rocker arm shaft could result when it is being removed.

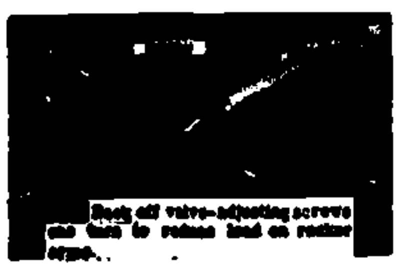


Fig 4-5. Relieving rocker arm pressure.

When the pressure is relieved, remove the rocker arm attaching bolts and nuts (fig 4-6) and lift the rocker arm shaft from the engine. If the engine does not have a rocker arm shaft, simply remove the rocker arms.

Fig 4-6. Removing the rocker arm shaft.

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. Remember, you should inspect the cylinder head assembly later.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. The valve push rods are removed as one step in the removal of which component of the I-head engine?

   a. Cylinder head
   b. Piston
   c. Crankshaft
   d. Sleeves

Work Unit 4-3. OIL PUMP REMOVAL

IDENTIFY THE TEST MADE PRIOR TO REMOVING THE OIL PUMP ASSEMBLY.

NAME THE INSTRUMENT THAT MEASURES BACKLASH.

Turn the engine upside down now, and remove the oil pan so that you can work inside the crankcase. Discard all gaskets and neoprene seals.

Remove the oil pump, the pick-up tube, and the oil strainer as a complete assembly. But first, make sure those oil pump drive gears are in good condition. 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.

Backlash is measured with a dial indicator. This instrument is attached to or placed upon the engine block and the levers adjust until the tip of the plunger may be placed against one tooth of the driven gear. Now, the instrument is again adjusted 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 it back until it contacts the next tooth and stops. The distance the dial reads from one tooth to the next is the backlash (fig 4-7). Record the backlash and check it against tolerances listed in the TM for your vehicle. If the backlash is not within tolerances, make a note of this so you will not forget to remedy it.

Fig 4-7. Measuring oil pump gear backlash.

Now, remove the oil pump and the pick-up tube and strainer screen assembly (fig 4-8). Discard the gasket.

Fig 4-8. Oil pump and pick-up tube and screen assembly.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Prior to removing the oil pump assembly, what test is made?

   a. Oil pump bypass
   b. Oil pump flow
   c. Oil pump gear backlash
   d. Oil pump vacuum

2. The instrument that measures backlash is ______________________________.

Work Unit 4-4. PISTON REMOVAL

STATE HOW THE CONNECTING ROD SIDE PLAY IS MEASURED.

DESCRIBE THE PRECAUTION TAKEN TO PROTECT CYLINDER WALLS AND PISTONS DURING THE RIDGE REAMING PROCEDURE.

IDENTIFY HOW THE PISTON IS REMOVED, AFTER REMOVING THE CONNECTING ROD BEARING CAPS.

There is quite a bit of work to be done before you can actually remove the 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 cap and its crankshaft throw (fig 4-9). Try several leaves of the gage, if necessary, until one is inserted which has a slight drag. Record the number stamped on that leaf. After all connecting rods have been checked, open your TM to the proper specifications and list the rods which are not within the specified tolerance.

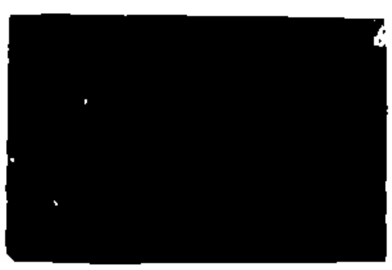


Fig 4-9. Measuring connecting rod side play.

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 wear 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 4-10).

OLD RING MATCHES RIDGE   NEW RING STRIKES RIDGE

Fig 4-10. Results of installing new piston rings with ridges at the top of the cylinder.

The ridges at the top of the cylinders must be removed prior to installing new piston rings and now is the best time to accomplish 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 4-11) 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 which 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 4-11. Removing ridges from the cylinder.

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. This makes it easier to remove the bolts from the connecting rod bearing cap. 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 them both with a number stamp or center punch ON THE SAME SIDE, numbering them in their proper sequence in the engine. This is done so that when the pistons are reinstalled, they will be in the same cylinder and in the same position. At this time using a hammer handle, push on the end of the connecting rod forcing the piston up and out the top of the cylinder.

Fig 4-12. Removing the piston assembly.

If the ridges are not removed at this time, extra force will be required, and chances are 99 out of 100 that the hammer will slip, causing 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 the piston first. If the piston heads are not marked, then you would proceed as follows. As each piston is removed, mark the forward piston with a center punch numbering them as you numbered the rods.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. How do you measure connecting rod side play?

___

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

___

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

   a. driving the piston down past the crankshaft.
   b. striking the connecting rod with a hammer, driving the piston out through the top.
   c. pushing down on the piston with a breaker handle.
   d. pushing on the end of the connecting rod with a hammer handle forcing the piston up.

Work Unit 4-5. TIMING GEAR REMOVAL

STATE WHERE THE DIAL INDICATOR PLUNGER IS PLACED WHEN CHECKING THE TIMING GEAR BACKLASH.

STATE WHY CAM SHAFT END PLAY IS CHECKED.

STATE WHY THE TIMING GEAR RUNOUT TEST IS PERFORMED.

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 at this time, you cannot check them until they are reinstalled during reassembly, and this means extra work, because you may have to change them after reinstallation.

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 4-13). The instrument is placed upon the cylinder block or, depending upon the manufacturer's design, attached to the cylinder block. Adjust the linkage between the dial and the portion on 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.

ERIC

Fig 4-13. Checking timing gear backlash.

The next check will be performed to find out if the gear is warped. There is little or no chance of the crankshaft gear warpage due to its small size. Therefore, leave the base of the dial indicator in its present position, and check only the camshaft gear. This check is called the timing gear runout test. Simply adjust the dial indicator linkage so that the plunger rests on the end of the gear with the dial indicating zero (fig 4-14). Turn the camshaft gear one complete rotation and record the highest reading observed on the dial indicator.

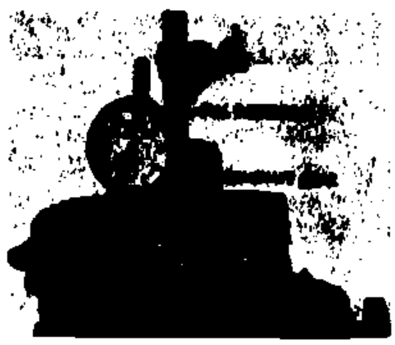


Fig 4-14. Checking timing gear runout.

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 only be made 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 reading of the dial indicator (fig 4-15).

With all the checks accomplished, check your readings against the specifications in the TM for your vehicle. If the gear backlash or runout is beyond tolerance, the gears may be discarded. If the camshaft end play is excessive, this means you will have to replace the camshaft thrust bearing before reinstalling the camshaft.

Fig 4-15. Measuring camshaft end play.

ERIC

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 prior to installing the gear puller (fig 4-16). If the gear puller is installed without the retainer bolt, thread damage will result. When the gear puller is installed as shown in figure 4-16, you simply turn the center bolt of the puller clockwise, while holding the gears to prevent them from turning. The TM for this vehicle will instruct you as to the best method of holding the gears.

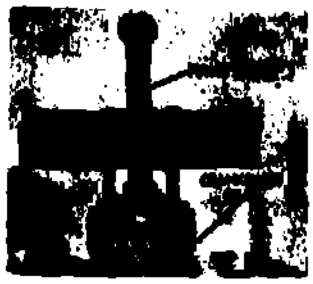


Fig 4-16. Removing the crankshaft gear.

Removal of the camshaft gear is accomplished with the same tool (fig 4-17). The retaining bolt, being still attached, is loosened a few turns prior to installing the puller. Install the puller basically the same as 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.

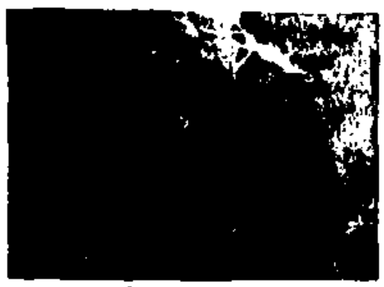


Fig 4-17. Removing the camshaft gear.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. To check timing gear backlash, the dial indicator is placed on the engine block and the plunger is placed on the

2. Why is camshaft end play is checked?

3. Why is a timing gear runout test performed?

Work Unit 4-6. CRANKSHAFT REMOVAL

IDENTIFY HOW FLYWHEEL RUNOUT IS MEASURED.

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, and the block provides a rigid base. The puller (fig 4-18) is inserted into the hole located in the center of the pilot bearing and spread to form a firm fit inside the bearing (fig 4-19) 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.

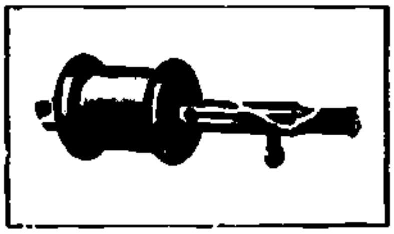


Fig 4-18. Clutch pilot bearing puller.

Fig 4-19. Removing the clutch pilot bearing.

Before removing the flywheel, perform a runout test just as you did for the camshaft timing gear. A warped flywheel will cause the clutch to engage unevenly and the clutch pedal will "bounce." Figure 4-20 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 unless facilities are available to grind it.

Fig 4-20. Measuring flywheel runout.

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, check the crankshaft end play. This may be done by placing the dial indicator at either end of the engine block. Use the end which is most convenient (fig 4-21). Place the dial indicator on the engine block and set the plunger as indicated in figure 4-21 with the dial set at zero.

A. Flywheel end. B. Damper end.

Fig 4-21. Checking crankshaft end play.

With the dial set at 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 higher than the TM allows, the crankshaft thrust bearing will have to be replaced during the repair phase.

All the necessary checks have been made, and 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.

First, loosen ALL bearing cap retaining bolts and leave them in place. Next remove each main bearing cap and identify it by marking the number of the bearing on the same side of ALL bearing caps and bearings. This is to 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.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. 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. The direction of the dial indicator
   b. Counterclockwise, then clockwise
   c. Clockwise, then counterclockwise
   d. One complete rotation

Work Unit 4-7. CAMSHAFT REMOVAL

STATE HOW DAMAGE MAY OCCUR TO THE CAMSHAFT AND TAPPETS DURING CAMSHAFT REMOVAL.

The final components to be removed from the engine block are the camshaft and valve tappets. In some cases, the valve tappets may be removed first, and in other cases, the camshaft must be removed first. This depends upon the design of the tappets. Try to lift the tappets out of their holes with your fingers. DO NOT use force. If they cannot be removed, 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 (fig 4-22) and pulling the camshaft forward carefully out of the engine block (fig 4-23).

70

Fig 4-22. Camshaft thrust plate.

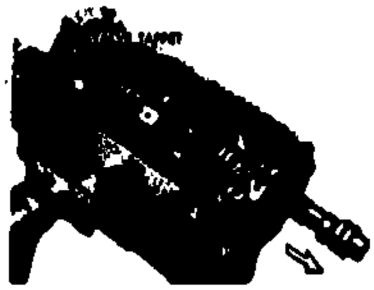


Fig 4-23. Removing the camshaft.

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. 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.

With the camshaft and tappets removed, you are now ready to begin restoring the engine to a like-new condition.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

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

SUMMARY REVIEW

You have learned the procedures used in the disassembly of the reciprocating internal combustion engine.

Answers to Study Unit #4 Exercises

Work Unit 4-1.

1. a.
2. b.

Work Unit 4-2.

1. a.

Work Unit 4-3.

1. c.
2. Dial indicator

Work Unit 4-4.

1. By placing a feeler (thickness) gage between the connecting rod and the crankcase.
2. The engine is turned on its side.
3. c.

Work Unit 4-5.

1. timing gear tooth
2. to determine if a new camshaft thrust bearing is needed
3. to determine the amount of warpage in the timing gear

ERIC

Work Unit 4-6.

1. d.

Work Unit 4-7.

1. If the tappets are allowed to rest on the camshaft lobes

ERIC

STUDY UNIT 5

ENGINE COMPONENT REPAIR

STUDY UNIT OBJECTIVES: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE BASIC PROCEDURES USED IN THE REPAIR OF RECIPROCATING, INTERNAL-COMBUSTION ENGINE COMPONENTS.

Section I. ENGINE BLOCK REPAIR

Work Unit 5-1. ENGINE BLOCK

IDENTIFY WHAT MUST BE ACCOMPLISHED TO ENSURE A THOROUGH ENGINE BLOCK INSPECTION.

IDENTIFY WHAT WILL BE REVEALED WHEN CHECKING THE CYLINDER HEAD GASKET SURFACE OF THE BLOCK WITH A STRAIGHT EDGE AND FEELER GAGE.

IDENTIFY THE DEVICE USED TO CHECK CYLINDER BORE OUT-OF-ROUND.

IDENTIFY THE PROCEDURE TO BE FOLLOWED WHEN CHECKING A CYLINDER BORE DURING ENGINE BLOCK REPAIR.

IDENTIFY WHAT REMOVES THE MIRROR-SMOOTH FINISH ON CYLINDER WALLS.

IDENTIFY HOW A SLIGHTLY SCORED CYLINDER WALL CAN BE REPAIRED.

IDENTIFY WHAT ACTION YOU WOULD TAKE IF SEVERELY SCORED CYLINDER WALLS ARE FOUND.

Up to this point you have inspected and measured several parts to determine the need for replacement. But, take a look at the amount of parts you have laid out (fig 5-1).

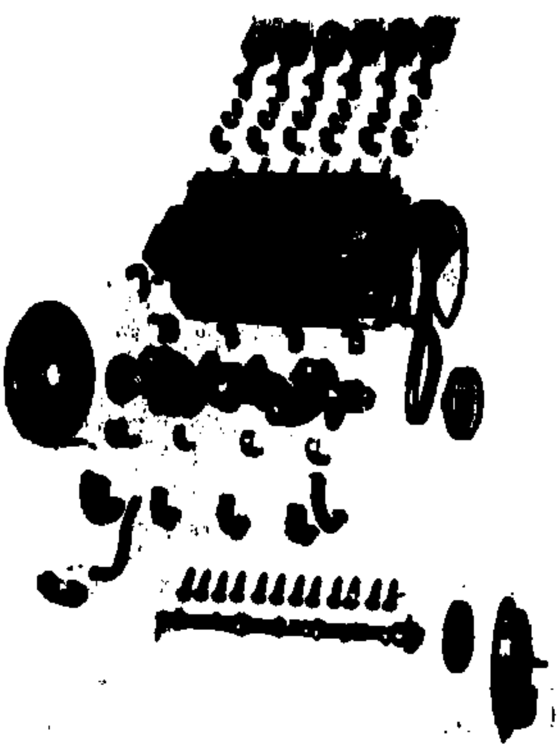


Fig 5-I. Typical parts of a dismantled engine (cylinder head not included).

Look at figure 5-1. By this time, you should be able to name each part with the exception of one, the front oil seal plate. Can you do this? If not, it would be advisable to learn them now. Do not use this text. It would be better to use your available TMs, especially the parts manuals. These are the manuals from which you must order replacements for your defective parts.

Do you know your parts now? If so, let's continue.

Each of the parts found in figure 5-1 must be checked to determine whether it is usable. Again, this is accomplished by close inspection and precision measurements.

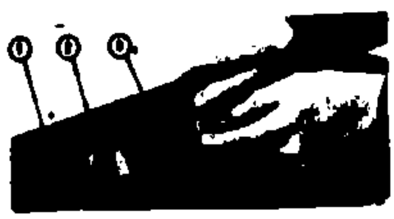
In most cases, the parts may be installed as they are repaired. But, since you are primarily concerned at present with repair, reassembly will be covered in the next study unit. Begin your repair with the engine block.

Before going into the repair of 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 a 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.

The block must also be checked for warpage. If the block is warped, it may result in 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. You just might find that the block you are working on cannot be ground under any circumstances.



1. Cylinder block. 2. Straight edge. 3. Feeler.

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 defects. There may be more work for them, and they might as well accomplish it all at the time you submit the block for repair. When all defects are located, send the block to the machine shop if necessary and accomplish your repair upon its return.

Next, check the cylinders for distortion, more commonly called "out-of-round," and cylinder taper. This is done by taking measurements in each cylinder at the points indicated in figure 5-3. 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 without removing the gage (fig 5-4). Record the reading at the top of measuring point A (fig 5-3) and move the gage to the bottom of the cylinder and record the reading there. Repeat this procedure at point B (fig 5-3). Now, 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.

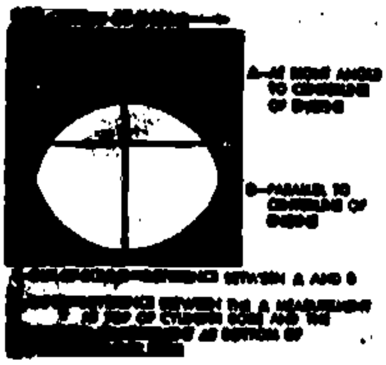


Fig 5-3. Measurement points for cylinder out-of-round and taper.

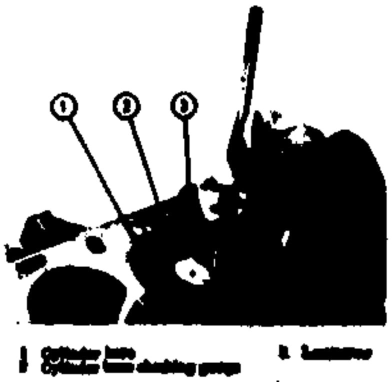


Fig 5-4. Checking cylinder out-of-round and taper.

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

If scores or rough areas are present in the cylinder walls, they might possibly be remedied with a cylinder hone. You must hone the cylinder walls anyway to remove the mirror smooth finish. This is done to 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 5-5). A heavy-duty electric drill motor is then attached to the hone, a small amount of engine oil applied to the honing stones, and the drill put into operation. During the honing process, move the hone up and down inside the cylinder. When you feel that you have eliminated any scores or 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.

<u>Caution</u>: 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.

Fig 5-5. Honing the cylinder.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Engine block inspection must be thorough. This 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 thoroughly 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?

   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 be following?

   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. In order to remove the mirror-smooth 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 it with the use of a

   a. lapping machine.
   b. fine sandpaper.
   c. honing tool.
   d. coarse sandpaper.

7. You have just inspected the cylinders of an engine which you are repairing and found 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.

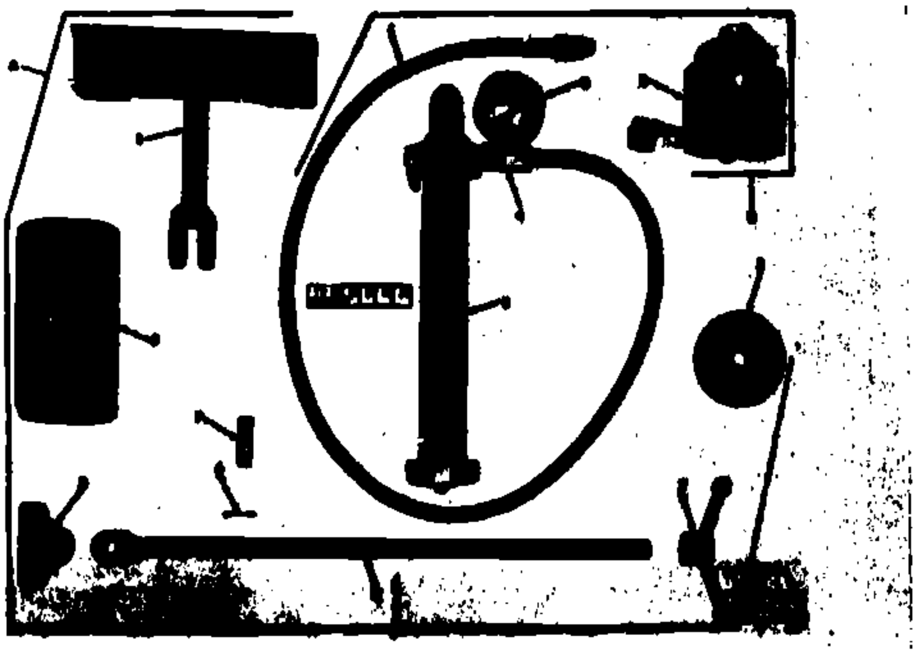
Work Unit 5-2. CYLINDER LINERS

STATE HOW A CYLINDER LINER MUST BE POSITIONED OVER THE CYLINDER BORE DURING INSTALLATION.

STATE WHY WHEN REPLACING A CYLINDER LINER YOU WOULD STOP PUMPING WHEN THE NEEDLE MOVES INTO THE DANGER ZONE (RED AREA).

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 which do not meet requirements specified in repair and rebuild standards. Use the hydraulic ram kit and the cylinder liner remover and replacer kit (fig 5-6).



A - Cylinder liner remover and replacer kit
1. Cylinder liner replacer support assembly
2. Cylinder liner replacer plate
3. Cylinder liner remover and replacer handle
4. Cylinder liner remover and replacer rod
5. Cylinder liner remover shoe
6. Cotter pin, 1/8 x 1-1/2
7. 3/4 x 2-39/64 clevis pin
8. Cylinder liner remover sleeve

B - Hydraulic ram kit
1. Hose assembly
2. Hydraulic ram
3. Pressure gage
4. Hose and gage adapter
5. Hydraulic Pump assembly

Fig 5-6. Hydraulic ram kit and cylinder liner remover and replacer kit.

To remove the defective liner (fig 5-7) (numbers in parentheses refer to fig 5-7), use the procedure outlined below. Assemble the remover and replacer rod (1) and remover shoe (14) and secure the clevis pin (15) and cotter pin (8). Insert the rod up through the cylinder liner, from the bottom of the crankcase, until the shoe seats in the bottom of the liner. With an assistant holding the rod and shoe in position, position the remover sleeve (5) over the liner to be removed.

Install the remover and replacer plate (4) on the sleeve with the larger diameter away from the sleeve.

Position the hyraulic ram (3) and remover and replacer handle (2) on the rod. Tighten the handle clockwise until shoe, sleeve, plate, and ram are properly seated.

Remove the protective caps from the hydraulic ram inlet. Install the hose and gage adapter (10) in the hydraulic pump assembly (11) and connect the hose assembly to the ram inlet.

Note: The pistons in the hydraulic ram have a two-inch maximum travel; therefore, it will be necessary to remove the liner in two-inch increments.

Place the hydraulic pump release lever in the proper position for pumping (lever to left). Actuate the pump arm with slow, even pressure. When the sleeve has been moved approximately two inches, turn the hydraulic pump release lever to the release position (lever to right). This will allow the ram piston to drop into position for another two-inch lift. Turn the handle (2) down against hydraulic ram, reposition the release lever, and repeat the pumping operation until the liner can be removed from the cylinder.

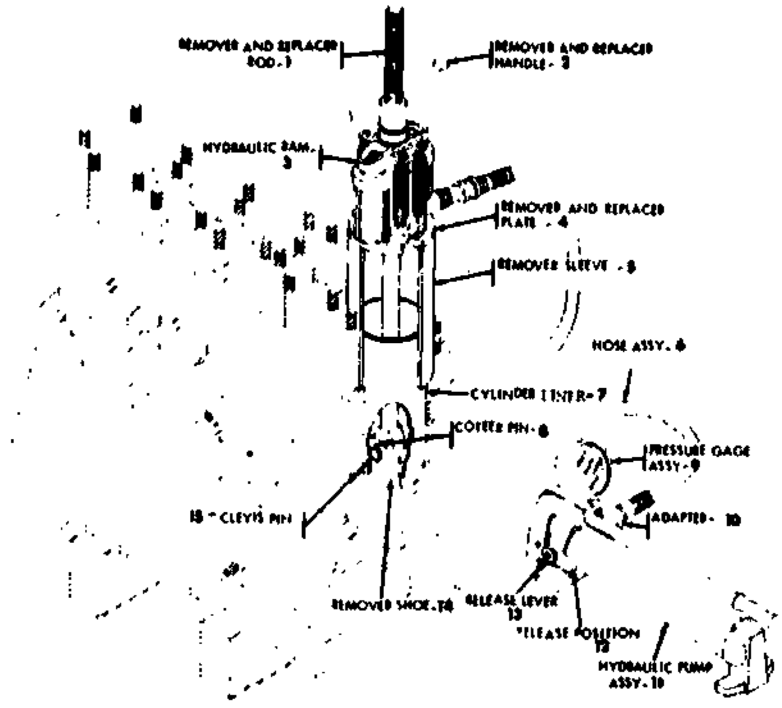


Fig 5-7. Cylinder liner remover and replacer kit showing position of shoe against liner during liner removal (section view).

Remove the hydraulic ram kit, remover and replacer kit, and liner.

Clean the cylinder bore with crocus cloth dipped in drycleaning solvent. Clean the bore thoroughly and wash with drycleaning solvent.

Before installing the new liner, place the oil pan gasket surface of the crankcase on suitable blocks. Position the replacer support assembly (16, fig 5-8) under the cylinder bore requiring a new cylinder liner (fig 5-8).

Remove the cotter pin (8), the clevis pin (15), and the remover shoe (14), shown in figure 5-7, from the remover and replacer rod (1).

Note: The shoe and the remover sleeve (14) and (5) are not shown in figure 5-8. They are not required when installing new cylinder liners.

Insert the rod down through the cylinder bore and engage the rod eye with the clevis of the support assembly. Install the clevis pin through the support clevis and the rod eye. Secure the clevis pin with the cotter pin.

Position the new cylinder liner over the cylinder bore with the flange end up. Place the remover and replacer plate (4, fig 5-8) over the liner with the small diameter of the plate seated in the liner.

Position the hydraulic ram (3, fig 5-8) and remover and replacer handle (2, fig 5-8) on the rod.

Tighten the handle until the ram plate is properly seated. The cylinder liner must be properly alined with the cylinder bore before attempting to press it in.

Note: Nominal fit of cylinder liner in bore is 0.002- to 0.003-inch interference (tight) fit.

Connect hose assembly (6, fig 5-8) to hydraulic ram inlet.

Note: Remember that the pistons in the hydraulic ram have a two-inch maximum travel. It will be necessary for you to install the liner in two-inch increments.

Place the hydraulic pump release in the proper position (to left) for pumping. Actuate the pump arm with slow, even strokes. When the sleeve has been pressed in the bore approximately two inches, turn the hydraulic pump release lever to release position (to right). This will allow the ram piston to drop into position for another two-inch press.

<u>Caution</u>: The pressure gage attached to the pump indicates pressure exerted for cylinder liner installation. If indicator needle moves into "danger zone" (red area), stop pumping action immediately and investigate the cause. If cylinder liner cannot be installed without the indicator needle entering the danger zone, remove the liner as directed in figure 5-7. Repeat the installation procedure using a different liner.

Turn the handle down against the hydraulic ram, reposition the release lever on the the pump, and repeat the pumping operation. You would continue this procedure until the liner flange is properly seated in the cylinder.

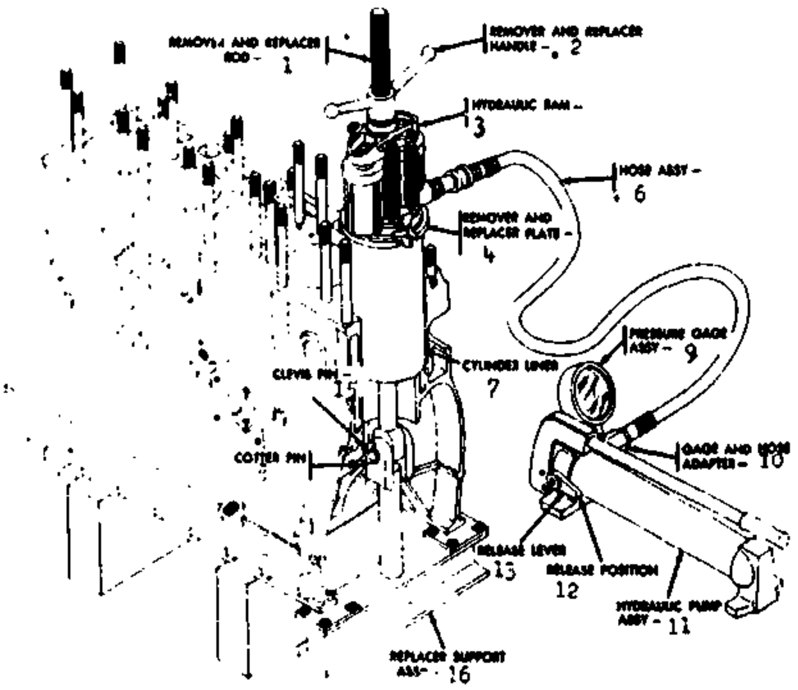


Fig 5-8. Cylinder sleeve remover and replacer kit and ram kit showing proper method of cylinder liner installation.

Fig 5-8. Cylinder sleeve remover and replacer kit and ram kit showing proper method of cylinder liner installation.

Remove hydraulic ram kit and remover and replacer kit.

The new cylinder liners must be honed for proper fit of new piston rings. To do this, refer to the TM that pertains to the engine you are working on.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. When a cylinder liner is installed, it must be positioned in what manner over the cylinder bore?

___

2. While replacing a cylinder liner, the indicator needle moves into the "danger zone" (red area). You would stop pumping and do what?

___

Work Unit 5-3. VALVE TAPPET BORES

STATE HOW WORN OR DAMAGED TAPPET BORES ARE REPAIRED.

STATE WITH WHAT TEST INSTRUMENT VALVE TAPPET BORES ARE MEASURED.

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 this fails, you must ream the bores and replace valve tappets with new, oversized tappets. The bores may be reamed with a reamer as illustrated in figure 5-9. Whether or not the bore is burred or scored, it must be checked for proper valve tappet fit. This applies to new tappets as well as the old tappets. The bores may be checked for proper tappet fit by attaching a dial indicator to the engine block and seating the plunger against the side of the tappet after inserting it into the bore. With the thumb and forefinger, move the tappet toward the dial and away from it, observing the distance indicated on the dial face (fig 5-10). Check your results against the tolerances listed in the TM. If the tappet appears too small, order oversized tappets. Check the new tappets for proper fit using the same method discussed for the old tappets.

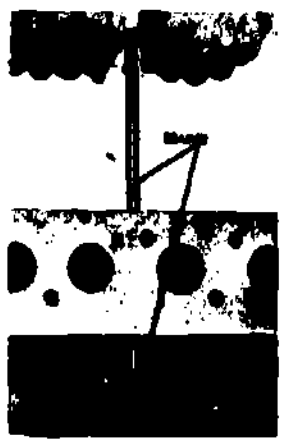


Fig 5-9. Reaming valve tappet bore.

Fig 5-10. Checking valve tappet clearance.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Valve tappet bores are measured for tappet fit with a

   a. spring tension gage.
   b. mechanics scale.
   c. dial indicator.
   d. feeler gage.

2. If nicks and scores appear in the tappet bores, they can usually be eliminated with crocus cloth. However, some damaged or worn bores must be repaired by

____

Work Unit 5-4. CAMSHAFT BORES

STATE HOW CAMSHAFT BORES ARE CHECKED.

DETERMINE HOW YOU WOULD REMOVE CAMSHAFT BEARINGS.

STATE HOW YOU WOULD CHECK CAMSHAFT BEARINGS FOR PROPER INSTALLATION.

Now, check the camshaft bearing bores. 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 5-11 illustrates the type puller used to remove the old bearings and replace the new bearings.

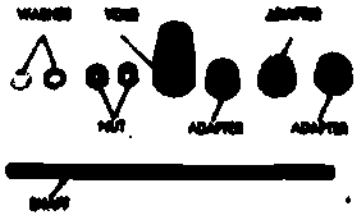


Fig 5-11. Camshaft bearing remover/installer.

The front and rear bearings are removed from the front and rear respectively, while other bearings may be removed from either end, depending upon the length of the engine.

To remove the rear camshaft bearing, first remove the camshaft bearing plug by knocking it out from within the engine with a wooden dowel or suitable metal bar (fig 5-12).

Fig 5-12. Camshaft rear bearing plug.

With the rear bearing plug removed (fig 5-13), you may now install the camshaft bearing remover/replacer by selecting the adapter appropriate to the bearing diameter, inserting the short threaded end of the remover/replacer shaft through the bearing bore, and attaching the adapter and yoke to the shaft as indicated in figure 5-14. Then, with an appropriate size wrench, turn the yoke nut clockwise while holding the shaft with a pin punch or other suitable tool (fig 5-14).

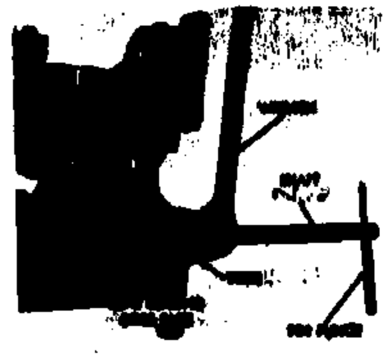


Fig 5-13. Rear bearing bore recess (bearing plug removed).

Fig 5-14. Removing the rear camshaft bearing.

The inner camshaft bearings and the front camshaft bearings are removed in the same manner. As stated before, the end from which you remove them depends upon the length of the engine (it is usually best to remove them from the closest end). Figure 5-15 will give you an idea of how the inner bearings are removed.

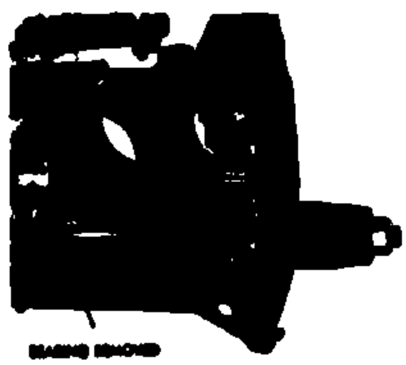


Fig 5-15. Removing inner camshaft bearings.

Having removed the bearings, you will notice holes drilled at certain points. The bearing bores have holes which match the holes in the bearings. These are oil holes, and it is very important that these holes be matched perfectly when installing the new bearings. The life of the bearings depends upon it.

With a piece of chalk or other suitable marking material, mark the location of the oil holes in the engine block illustrated in figure 5-16.

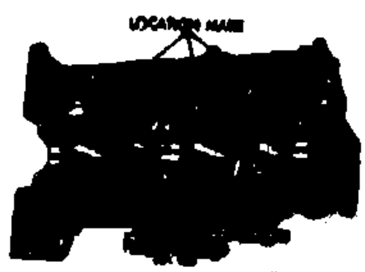


Fig 5-16. Marking location of oil holes in camshaft bearing bores.

Now, install the new bearings. Begin with the last bearing removed by placing it on an adapter of the remover/replacer which is larger in diameter than the bearing (fig 5-17).

Fig 5-17. Camshaft bearing installed on remover/replacer adapter.

Now, place the bearing and adapter against the bore in which it is to be installed. Insert the shaft (with yoke attached) 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 (fig 5-18).

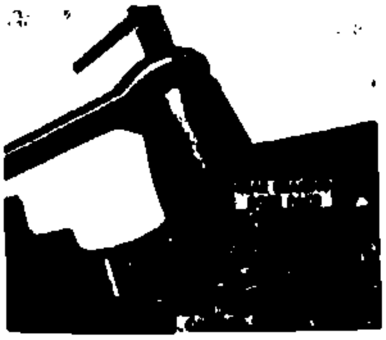


Fig 5-18. Installing camshaft bearings.

Once installed, inspect the bearing oil holes to ensure that they are alined with the oil holes of the bearing bore (fig 5-19). If not, they must be removed and reinstalled correctly.

Fig 5-19. Ensure oil holes are alined.

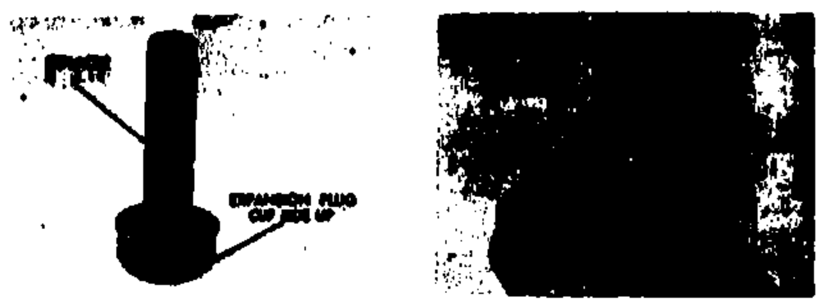
With the installation of the last camshaft bearing, you are ready to take the final step in the repair of the engine block--replacement of the expansion (core) plugs. Defective expansion plugs cannot be detected until they actually begin to leak. Therefore, it is advisable to replace all expansion plugs during the rebuilding of an engine.

The soundest method of removing the old plugs is to drill a 1/2-inch hole in the center of the plug and remove it with a slide-hammer type puller as illustrated in figure 5-20. You might have noticed that this is the same puller used to remove the clutch pilot bearing from the rear of the crankshaft.

Fig 5-20. Removing expansion plugs.

When you have removed the expansion plugs, the new plugs are easily replaced with the expansion plug replacer, illustrated in figure 5-21A. Simply place the expansion plug on the end of the replacer and, placing it against the expansion plug recess (fig 5-21B), 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.



A B

Fig 5-21. Replacing expansion plugs.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Camshaft bores must be checked before the camshaft is installed. How are the bores checked?

____

2. Camshaft bearings are removed by using a

______________________________.

3. After you have installed new camshaft bearings, make sure that they are installed correctly by checking the

______________________________.

Section II. ENGINE BLOCK PARTS

Work Unit 5-5. CRANKSHAFT

DETERMINE THE ACTION TO BE TAKEN WHEN A CRANKSHAFT IS FOUND TO HAVE BAD CRACKS.

STATE THE NECESSARY PROCEDURE TO FOLLOW WHEN INSTALLING MAIN BEARING CAPS.

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 failuro 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 are vital to the life of the bearings. One clogged passage can make you do extensive repairs shortly after the rebuild is completed. In the Marine Corps, this costs the taxpayer, but in a civilian shop, the money comes out of the mechanic's pocket. 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 use of an oil stone. If grooves or deep nicks appear on finished surfaces, the crankshaft must be ground in 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 which 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 on each of the journals or crankpins (fig 5-22). These measurements are made with an outside micrometer by adjusting the micrometer until it may be passed across the journal with a very slight drag.

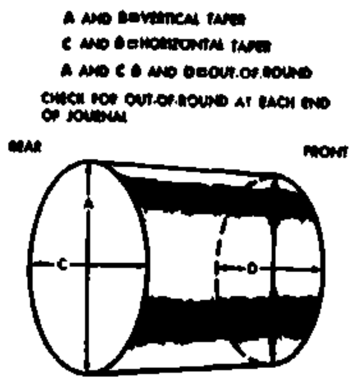


Fig 5-22. Crankshaft journal and crankpin measuring points and formula for amount of out-of-round.

This is illustrated in figure 5-23. 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.

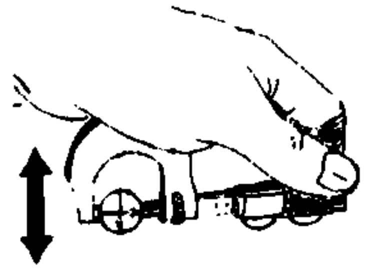


Fig 5-23. Measuring crankshaft main journals and crankpins for out-of-round with a micrometer.

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 a good basic knowledge which 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 discarded. Before having the crankshaft ground, make sure the shaft is worth grinding. What if it is not alined? A warped crankshaft is of no value to you in the rebuild or repair of an engine. With the use of a pair of "V" blocks (which may be fabricated locally) and a dial indicator gage, you can determine the runout of the crankshaft by placing the gage point on the crankshaft journal and rotating the crank (fig 5-24).

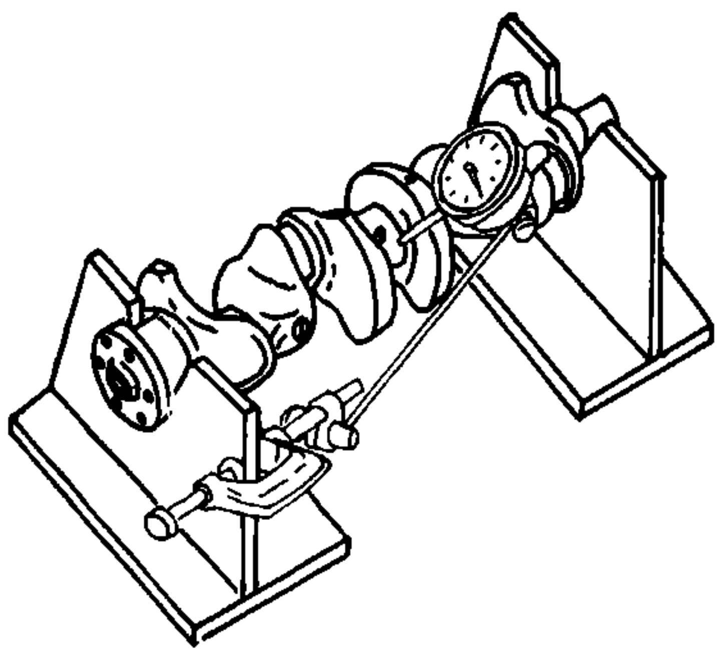


Fig 5-24. Measuring crankshaft runout (warpage).

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 must be replaced as well as excessively worn bearings. 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, which have flanged ends (fig 5-25). The bearing (A) should be placed in its position in the engine block or bearing cap, and the space between the flange and the block or cap measured with a feeler gage (B).

Fig 5-25. Checking main thrust bearing for end play.

If the fit is good at these points, remove the bearing halves and place them in the appropriate journals of the crankshaft. Now, with a feeler gage, measure the end play between the bearing block. This measurement, of course, is taken on the outside of the flanges. Both of these measurements should be checked in the TM.

After making these tests, 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 5-26.

Fig 5-26. 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 two other points 45° from the original measurement. These measuring points are illustrated in figure 5-27.

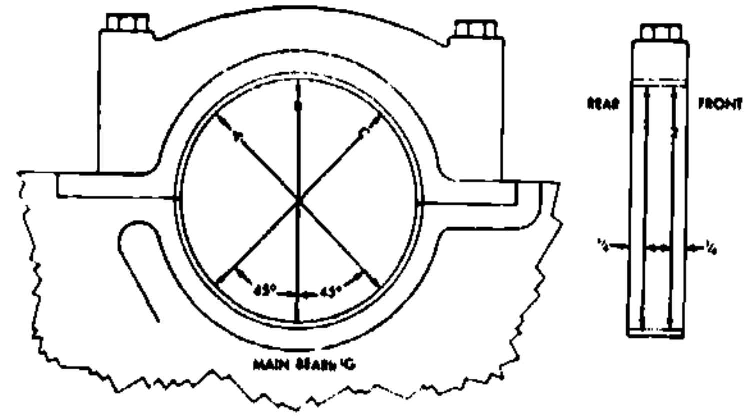


Fig 5-27. Points of measurement for crankshaft main bearings.

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, check them against the crankshaft journal measurements. The difference found between these measurements is the running clearance of the main bearings, which must be checked against the tolerances listed in the TM to determine whether the bearings are suitable for use.

Note: In order 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 which 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 which is used to take the measurements as well as to protect the material.

To use this method, the engine is turned bottom side up and the crankshaft is placed in its proper position in the main bearing frame with the upper crankshaft bearing halves installed. Then a small strip of the plastigage is placed along the length of the journal. The lower crankshaft main bearing half is placed inside the main bearing cap and the cap is installed and tightened to its specified torque. After this is accomplished, the bearing cap is removed and the flattened strip of plastigage is measured with the paper used to package it (fig 5-28).

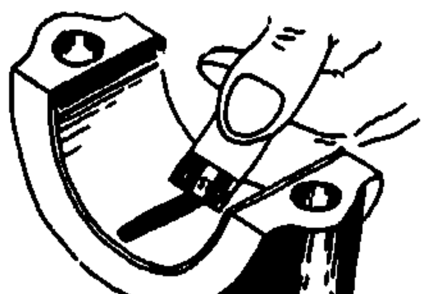


Fig 5-28. Measuring crankshaft bearing running clearance (using plastigage).

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 prior to obtaining the plastigage to ensure that you are using the proper gage.

Note: When using plastigage, contact areas must be clean and dry, the crankshaft must not be rotated, and all caps must be installed and tight.

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 (fig 5-29).

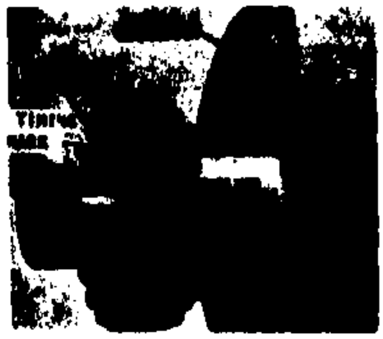


Fig 5-29. A properly installed crankshaft timing gear.

EXERCISE: Answer the following questions and 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. When installing main bearing caps, what procedure should you follow?

____

Work Unit 5-6. FLYWHEEL

DETERMINE THE ACTION TAKEN TO INSTALL A NEW FLYWHEEL RING GEAR.

With all repairs completed on the crankshaft, the next component that you have to be concerned with is the flywheel. Inspect it 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° Fahrenheit. After it has reached this temperature, install it on the flywheel and allow it to cool.

ERIC

In some cases, the clutch pilot bearing is installed in a bore located in the flywheel and, in other cases, it is 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 alined. In the case of a bronze bushing-type bearing, you should always install a new one. In the case of ball or r 'ler 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.

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 which was discussed earlier in the course, with the rubber mounting between the wheel and outer ring (weight), inspect the rubber for deterioration. This can cause damage.

If any defects are apparent in the vibration damper, discard it and obtain a new one.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. You have removed a flywheel ring gear. What action is taken to install a new gear?

____

Work Unit 5-7. PISTON ASSEMBLY

NAME THE DEVICE USED TO CHECK PISTON FIT.

DETERMINE WHICH COMPONENTS MUST ALWAYS BE REPLACED WHEN REPAIRING PISTONS.

STATE THE DEVICE USED TO CHECK PISTON RING END GAP.

STATE THE DEVICE USED TO CHECK PISTON RING SIDE CLEARANCE.

STATE THE DEVICE USED TO CHECK PISTON PIN FIT.

STATE THE DEVICE USED TO CHECK CONNECTING ROD BEARING BORE.

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 upon it, and of course the friction caused by this. Keeping this in mind, let's begin the repair of the piston assembly.

To repair the piston, it must first be disassembled. Cover your vise jaws with a soft material. 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 in them. With the piston secured in the vise (see figs 5-30 and 5-31), remove the rings, beginning with the top ring and working down to the bottom. Ring expander tools are provided for this to prevent damage to the piston by scratching and burring. Figure 5-30 shows tools commonly used in the removal and installation of piston rings. Figures 5-30 and 5-31 illustrate the use of these tools.

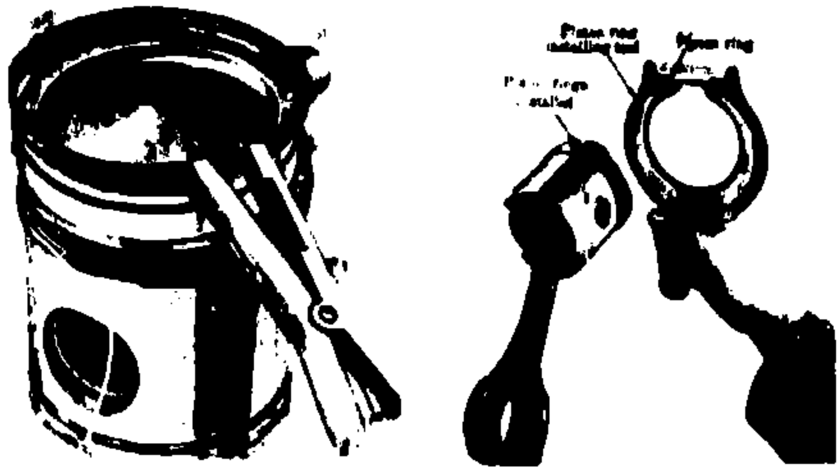


Fig 5-30. Common ring expander tools used to remove and install piston rings.

You might also notice that the illustrations in figure 5-30 and 5-31 picture three types of pistons: diesel, gasoline, and multi-fuel, respectively. Either of these tools may be used on any piston. Basically, piston rings are the same.

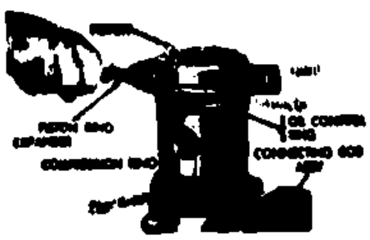


Fig 5-31. Removing and installing piston rings.

After all the rings have been removed, the oil control ring expander must also be removed (fig 5-32). 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.

Fig 5-32. Removing the oil control ring expander.

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. The pin will not come out until the piston pin retainer (fig 5-33) is removed. This may be done with a suitable pair of pliers. After the retainers have been removed, the piston pin may be removed by either pressing it out with your thumb or driving it out with a brass drift if necessary. Again, exercise extreme caution to prevent damage. Remove the connecting rod. Now, place the piston pin back inside the piston pin hole of the piston in the same end of the hole from which it was removed. Lay the separated piston and connecting rod and repeat the same procedure with the remaining pistons.

Fig 5-33. Remove the piston pin retainer.

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 wire brush to remove the carbon deposits on the <u>head</u> of the piston ONLY (fig 5-34).

Fig 5-34. Cleaning the pistons.

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 5-35 illustrates the use of a piston ring groove cleaner. The tool is held in its track in two places by the guide and t' blade cuts the carbon away as it is rotated around the piston.

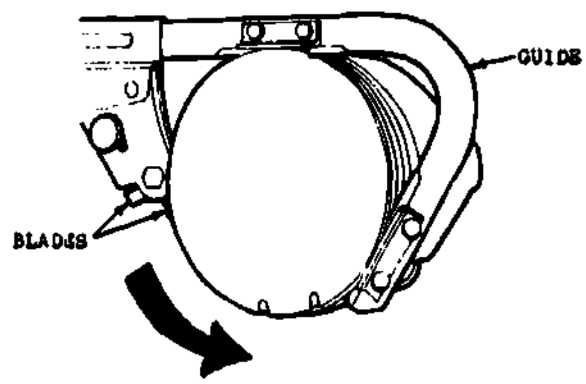


Fig 5-35. Cleaning piston ring grooves.

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. Figure 5-36 gives a good example of pistons which are and are not reusable. Note that these pistons have ring grooves at the bottom as well as the top. The pistons are designed for a diesel (compression-ignition) engine. Pistons which are cracked must be discarded.

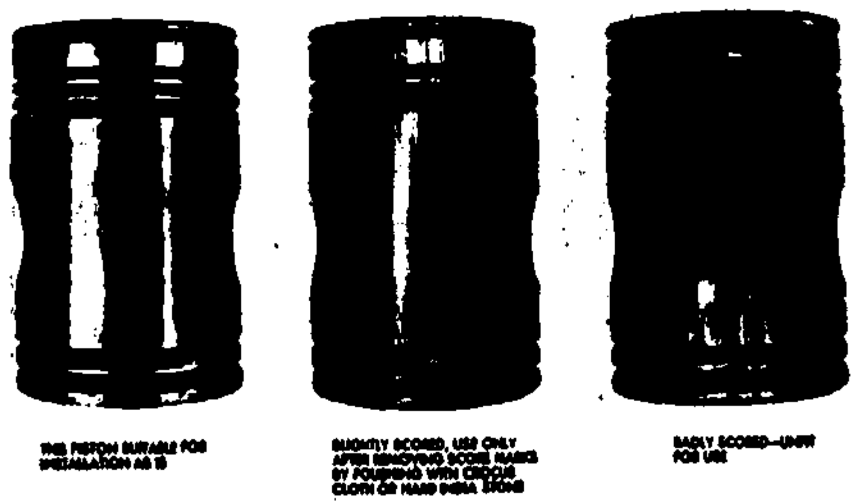


Fig 5-36. Comparison of serviceable and unserviceable pistons.

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. Now, turn to the piston repair section of your TM to determine the width and thickness of the feeler gage to be used for this measurement. It usually requires a feeler gage leaf about 1/2 inches wide and from .0015- to .0045- inch thick. Attach this gage to a tension scale. The gage must be longer than the piston. Position it in the cylinder along the cylinder wall so that it extends deeper into the cylinder than the piston will at its TDC position. Place the piston in an upside-down position inside the cylinder bore slightly below the top edge of the cylinder (exact distance, if required, will be listed in the TM). Figure 5-37 illustrates the piston and gage properly prepared for the measurement of the piston fit.

Note: The piston pin hole should be parallel to the crankshaft just as if you were installing the piston for operation.

Fig 5-37. Checking piston fit and center.

93

Holding the piston in place, pull the feeler gage out, keeping it straight as illustrated in figure 5-37. Make a note of the pull required to remove the gage by reading the scale. Both the scale reading and the thickness of the feeler gage determine the clearance between the piston and the cylinder walls. The chart pictured in figure 5-38 is a handy tool to help determine the clearance. To use it, find the diagonal line which represents the thickness of the gage you are using, follow the line to a point horizontal with the amount of pull required to remove the feeler gage from the cylinder, and read down to the lower set of numbers. The lower set of numbers indicates the clearance. For example, assume that you are using a .004 inch feeler gage and you must exert 5 pounds pull to remove the gage from the cylinder. Locate the .004 gage line, follow it down to the 5 pound line, and follow the vertical line to the bottom. As you can see, the vertical line is halfway between the .003 and the .004 (clearance in inches) lines. This indicates that the piston fit clearance is .0035 inches. Now, try one yourself. Without looking at the answer at the bottom of the page, figure out the clearance using a .002 inch feeler gage which requires an 8-pound pull to be removed. When you have your answer, look at the correct answer at the bottom of this page. If your answer is incorrect, chances are you need to study decimals to refresh your memory. If the diagonal line does not cross at an intersection of a vertical and horizontal line, you must use your judgment. An example of this would be the use of an .003-inch gage at 7-pounds pull. A close judgment here would be .0019-inch clearance. This is arrived at by dividing each section between vertical lines into five equal parts.

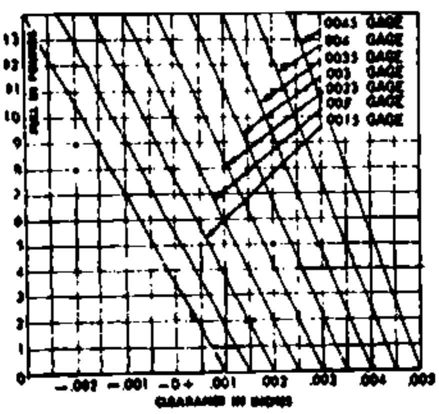


Fig 5-38. Piston clearance chart.

If you find that the piston does not fit properly, then you must obtain the proper size piston. If no standard or oversize piston is available which will fit, then the block must be rebored to an adequate size or be discarded. The fit tolerances are located in the TM under piston repair standards.

With the piston properly fitted, you must now select the proper piston rings. New rings must be used. These rings must not only fit the piston, but the cylinder well. 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 5-39).

Answer: .0005 inch

Fig 5-39. Checking piston ring end 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 inte[illegible] and check the clearance with a feeler gage. This is known as piston ring side clearance [illegible] 5-40). Now, match your findings with the manufacturer's specifications.

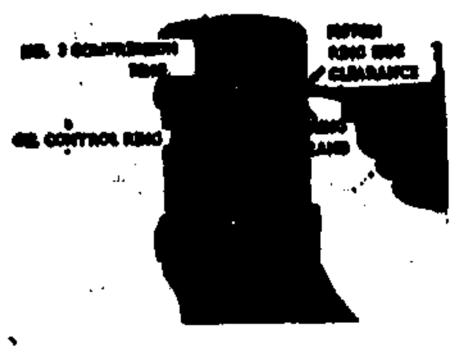


Fig 5-40. Checking piston ring side clearance.

Note: The oil ring is installed prior to the compression rings. The oil control ring is installed by hand and the ring expander tool is used to install compression rings. Figures 5-31 and 5-32 illustrate the removal and installation.

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) and the outer diameter of the piston pin (fig 5-41).

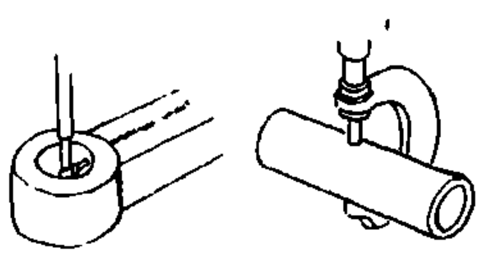


Fig 5-41. Measuring piston pin clearance with telescopic gage and micrometer.

If the piston pin bushing is worn excessively, it must be removed and a new one installed. This should be done with an arbor press. Figure 5-42 illustrates the use of the press to install the new bushing. Removal is similar to installation.

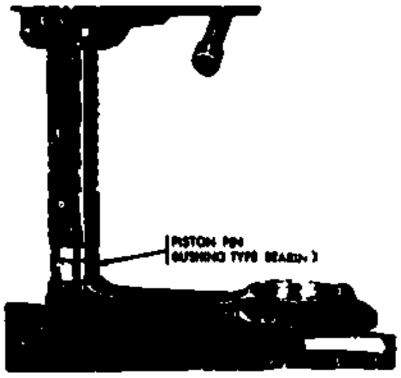


Fig 5-42. Installing piston pin bushings.

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.

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 (fig 5-43).

Fig 5-43. Measuring connecting rod 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° 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° 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.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What device is used to check piston fit?

____

2. Which components must always be replaced with new components when repairing pistons?

____

3. What device is used to check piston ring end gap?

____

4. What device is used to check piston ring side clearance?

____

5. What device is used to check piston pin fit?

____

6. What device is used to check connecting rod bearing bore?

____

Section III. CYLINDER HEAD REPAIR

Work Unit 5-8. CYLINDER HEAD INSPECTION

STATE THE FIRST STEP USED IN THE REMOVAL OF A VALVE SPRING.

DETERMINE WHAT YOU ARE CHECKING FOR WHEN YOU USE A STRAIGHT EDGE AND FEELER GAGE ON A CYLINDER HEAD.

STATE THE PROCESS USED WHEN A WARPED CYLINDER HEAD IS REPAIRED BY A MACHINE SHOP.

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 into the repair of the cylinder head. If you happen to be working on a cylinder head from an L-head engine, you will not have to be concerned with disassembly. However, as a mechanic, you will be required to repair I-head and F-head engines as well as L-head engines. Therefore, this knowledge is essential to your job.

Begin disassembly by removing the valves. With a valve spring compressing tool (fig 5-44), compress the valve spring and remove the valve stem locks. The spring is compressed by

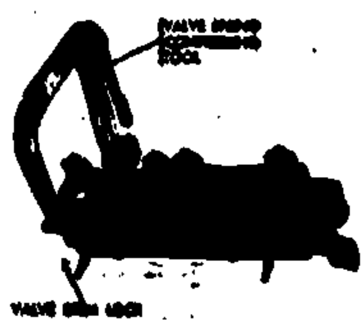


Fig 5-44. Removing the valves.

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 be removed from the bottom side of the cylinder head by hand also (fig 5-45).

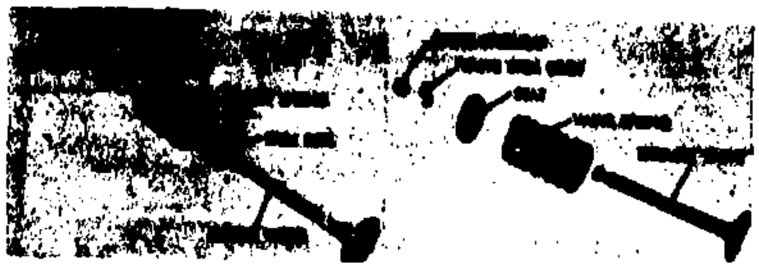


Fig 5-45. Intake and exhaust valves and their related parts.

Next, check the rocker arm retaining studs for thread damage and cracks. If they are damaged, they may be removed by threading two nuts on the stud, tightening them against one another, and removing the stud by placing a wrench on the lower nut and turning it in a counterclockwise direction.

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 (fig 5-46).

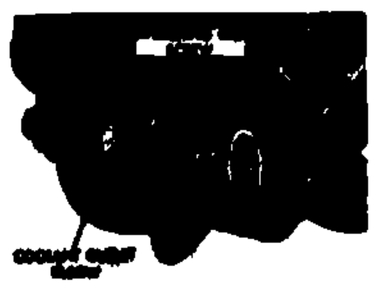


Fig 5-46. Coolant outlet connection (thermostat housing).

Remove the thermostat from its recess in the cylinder head and drop it into boiling water to check its operation. The thermostat should open.

Check the heater outlet plug to ensure that it is not leaking. Leakage is usually indicated by rust forming around the plug. If leakage is apparent, remove the plug and check the threads. Remove the expansion plugs and replace them as you did in the engine block. Figure 5-47 illustrates the heater plug and the expansion plug.

Fig 5-47. Typical heater outlet and expansion plugs.

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 5-48 is a good illustration of how and where these checks should be made. The cylinder head picture is taken from a three-cylinder diesel engine equipped with four valves per cylinder. The lines drawn across the surface indicate the positions in which the straightedge should be placed for checking.

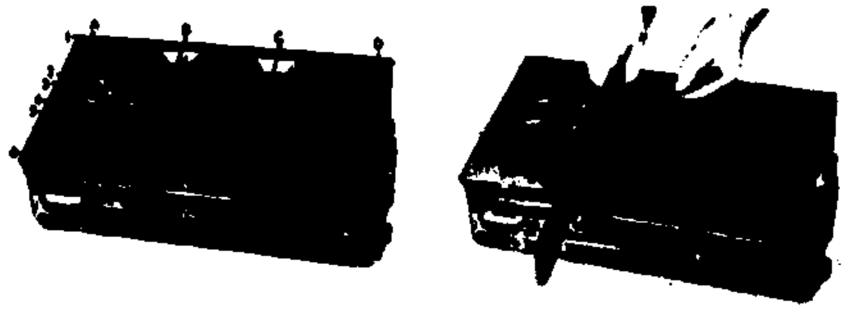


Fig 5-48. Checking cylinder head flatness.

If you were working on a cylinder head from an L-head engine, this is the only check you would be required to make. 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.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

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. When a warped cylinder head is repaired by the machine shop, which process is used?

   ____

Work Unit 5-9. VALVE GRINDING PROCEDURES

STATE WHAT YOU MUST CHECK FOR TO ENSURE THAT THE VALVE SEATS ARE SMOOTH AND ROUND.

STATE WHAT DEVICE IS USED TO CHECK FOR VALVE SEAT RUNOUT.

STATE WHAT DEGREE STONE YOU WOULD USE TO REMOVE MORE STOCK FROM THE TOP OF THE SEAT, IF YOU USED A 45° STONE TO REFACE THE VALVE SEAT.

STATE THE CORRECT PROCEDURE FOR REPLACING VALVE SEAT INSERTS.

STATE BY WHAT METHOD A BURRED VALVE GUIDE IS REPAIRED.

STATE WHAT MUST BE CONSIDERED WHEN INSTALLING A NEW VALVE GUIDE.

Assuming that you are working on an I-head or F-head engine, your next step would be to perform a valve seat runout check. If you were working on an L-head engine, the valve seat runout check must also be accomplished, but this would be done on the engine block. This check ensures that the seat is perfectly round. A dial indicator type gage known as a runout gage may be used for this check. 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 5-49). 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 5-49. Checking valve seat runout.

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. Figure 5-50 illustrates a typical valve seat, showing the width area. The measurements DO NOT apply to all valve seats. Check your TM. If the valve seat is not of proper width, the seat must be ground (refaced). The valve seat pictured in figure 5-50 might require three grinding stones: 60°, 45°, and 30°. The 45° stone is used to reface the seat, and the 60° and 30° stones are used to raise or lower the seat and change the seat width. Figure 5-51 illustrates the use of grinding stones.

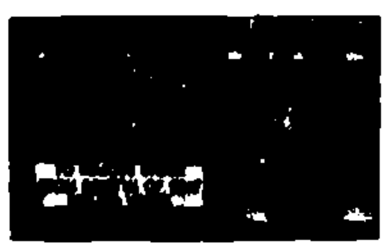


Fig 5-50. Valve seat measuring points.

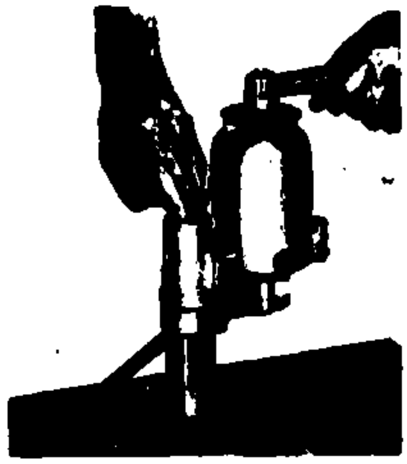


Fig 5-51. Grinding valve seats.

As you can see, the stone is attached to an electric drill motor. Care must be exercised to prevent the grinding of too much metal from the surface of the seat.

In some cases, the valve seat may be damaged by heat until it is warped or charred beyond repair standards. In this case, the damaged seat must be replaced. Valve seats are usually of the insert type. The valve seat is removed with special tools designed for that purpose. A typical tool is illustrated figure 5-52. The installation of valve seats is done with an arbor press as illustrated in figure 5-53. Extreme caution must be taken to prevent damage to the valve seat insert during installations.

Fig 5-52. Removing valve seat inserts.

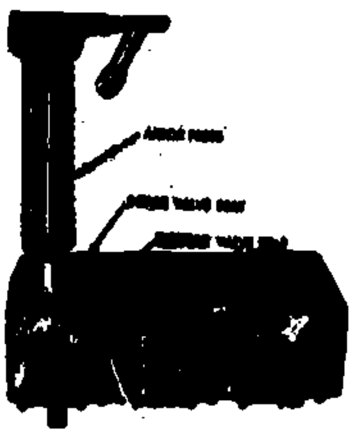


Fig 5-53. Installing valve seat inserts.

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. Attach a dial indicator to the cylinder head or engine block as the case may require. Insert the valve stem into the valve guide to a point just above the cylinder head gasket surface and place the dial indicator plunger against the valve face margin. With the valve held away from the indicator and against the valve guide, set the dial indicator to read zero.

Fig 5-54. Measuring valve stem to valve guide clearance.

Now, push the valve toward the dial indicator and observe the reading indicated on the dial (fig 5-54). Check this against the tolerance listed in the TM. 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 valve is to be replaced, an oversized valve stem may be necessary. In this case, and in the event the guide is damaged, the valve guide will require reaming. A valve guide reamer is designed for this purpose. Figure 5-55 is an example of a valve guide reamer prepared for use. As you can see, it is turned by hand. The use of a drill motor might result in damage to the guide.

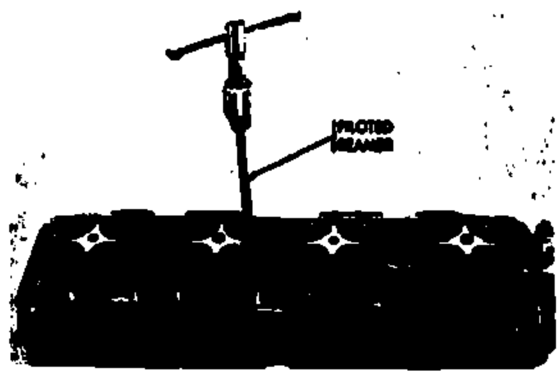


Fig 5-55. Reaming valve guides for oversized valves stems.

If a visual inspection reveals that the valve guide is damaged beyond repair by nicks, burrs, or excessive wear in the bore, 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. If the engine is of the L-head type, the bottom of the guide has to be broken off in order to drive it completely out. This is accomplished by placing a drift against the side of the valve guide and striking the drift with a ball peen hammer. When installing valve guides, they must be stopped at a point predetermined by the manufacturer. This point is specified in the TM for the engine which you are repairing. Figures 5-56 and 5-57 show a typical valve guide installation and one manufacturer's point.

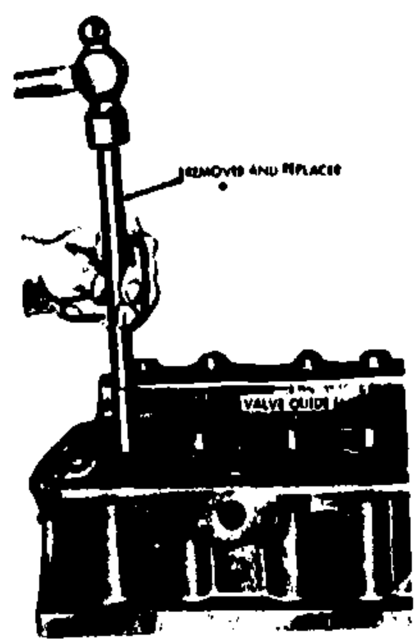


Fig 5-56. Installing valve guides.

The guide depth (fig 5-57) must be accurate; therefore, a mark should be made on the valve guide at the specified distance from the top of the guide. This will prevent driving it too far into the cylinder head or cylinder block.

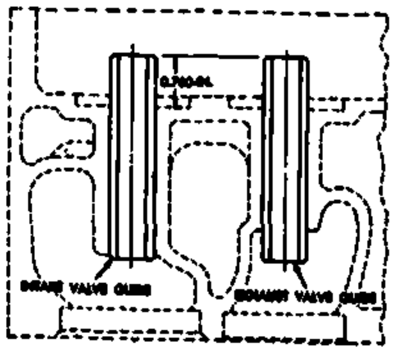


Fig 5-57. Valve guide stopping point for a specific vehicle.

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.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What must you check for to ensure that the valve seats are smooth all around the seat?

____

2. The device used to check for valve seat runout is ____________________

3. If a 45° stone wheel was used to reface the valve seat, but you wanted to remove more stock from the top of the seat, you would use a

   a. 20° stone wheel.
   b. 40° stone wheel.
   c. 60° stone wheel.
   d. 80° stone wheel.

4. What is the correct procedure for replacing valve seat inserts?

____

____

5. A burred valve guide may be repaired by what method?

____

6. If a valve guide must be replaced, the defective guide is driven out and a new one driven in. What must be considered when installing the new guide?

____

ERIC

Work Unit 5-10. VALVE MECHANISM

STATE WHAT DEVICE IS USED TO CHECK VALVE SPRING PRESSURE.

STATE WHICH DEVICE IS USED TO CHECK FOR VALVE STEM TO VALVE GUIDE CLEARANCE.

STATE WHICH VALVE SPRING TEST MUST BE CORRECTED BY REPLACING THE VALVE AND/OR THE VALVE SEAT.

STATE THE CORRECT PROCEDURE FOR CHECKING VALVE TAPPETS.

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, and stem warpage, wear, and cocked condition (fig 5-58).

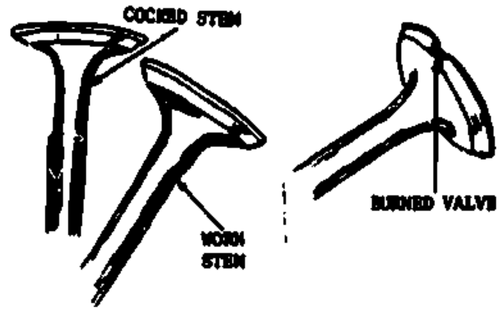


Fig 5-58. Defective valves.

When you have determined that the valve is serviceable, or 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, the valve is placed in the valve face runout gage and rotated (fig 5-59). Check the maximum reading obtained against the tolerance in the TM. If the runout exceeds specifications, the face must be ground. After grinding, the valve must be lapped to the seat.

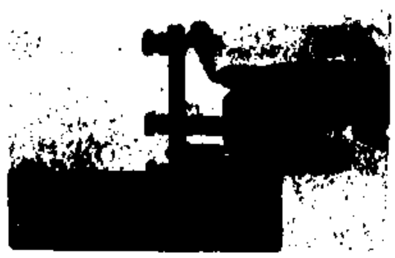


Fig 5-59. Checking valve face runout.

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 gage similar to the gage pictured in figure 5-60. If the valve spring has become weak, discard it and obtain a new one. Check the TM for the proper valve spring pressure. The spring is compressed to a height specified by the manufacturer in the TM for the engine being repaired.

Fig 5-60. Checking valve spring pressure.

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 5-61). Valve springs are not repairable; therefore, just as the case with the weak spring, the spring must be discarded.

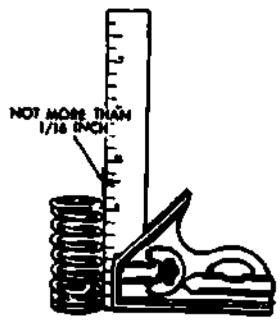


Fig 5-61. Checking valve spring squareness.

Now, you are ready to install the valves in the cylinder head or 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. This is done by placing a mechanic's scale alongside the valve spring (fig 5-62). 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 5-62. Checking valve spring installed height.

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

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, which do not incorporate the use of 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 (fig 5-63), which consists of a hollow shaft with a series of rocker arms, shaft supports, and springs.

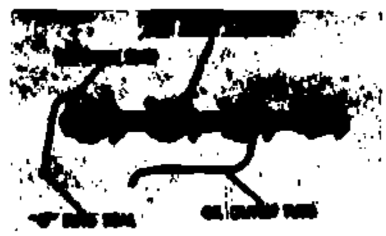


Fig 5-63. Rocker arm shaft assembly.

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. Now, with the appropriate wrench, remove the oil inlet and outlet tubes to ensure that they are clear and free of obstructions. Check the adjusting screws in the rocker arms for damage or excessive wear. Remove the screws ONLY if they need to be replaced.

If the rocker arm shaft appears to be clogged, preventing the flow of oil to the rocker arms, remove the expansion plugs (fig 5-64) and clean the bore thoroughly.

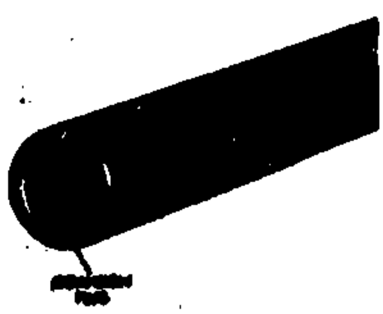


Fig 5-64. Rocker arm shaft expansion plug.

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, prior to 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 micrometers. If you will recall, the use of these measuring instruments is illustrated in figure 5-41. Check your measurements against the maximum wear limits in the TM.

Now, check the locating springs to 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. However, you must be sure that the tappet fits the tappet bore of the engine block also. This may be accomplished with a dial indicator which is placed against the side of the tappet, and the tappet moved back and forth (fig 5-65). If wear is excessive, an oversized tappet should be obtained and the valve tappet bore reamed for proper fit. Although the engine illustrated is a L-head, other engines are checked in the same manner. With the repair of the valve tappet and bore, we have completed the repair of the valve train. The next and final component of the valve mechanism is the camshaft.

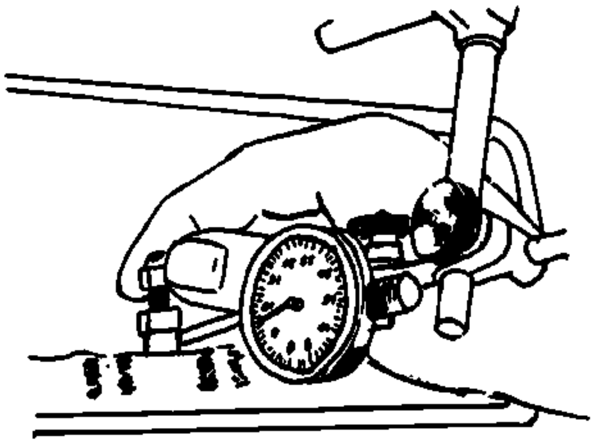


Fig 5-65. Measuring valve tappet fit (L-head engine).

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What device is used to check valve spring pressure?

____

2. What device is used to check for valve stem to valve guide clearance?

____

3. 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?

____

4. The correct procedure for checking valve tappets is to position the tappet in the bore and

____.

Work Unit 5-11. CAMSHAFT

STATE WHAT DEVICE IS USED TO CHECK CAMSHAFT LOBE LIFT.

Clean the camshaft in cleaning solvent and blow all oil passages clear with a high-pressure airhose. 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 pressure capacity of the camshaft main oil galleries (M151 only). Obtain a rubber hose with the same inner diameter as the main bearing surface's outer diameter. Place a section of the hose over each of the main bearing surfaces, clamp them tight with a hose clamp, and fit an air-hose adapter to the end of the shaft (fig 5-66).

Fig 6-66. Preparing camshaft for main oil gallery pressure check.

Immerse the rear end of the camshaft in water and apply 60 psi air pressure to the air hose adapter. If bubbles appear in the water, check the oil plug and replace it if necessary.

If the oil gallery checks out OK, move on and check the cam lobe lift. Place the camshaft back in its location in the engine block and attach a dial indicator as illustrated in figure 5-67.

Fig 5-67. Measuring cam lobe lift.

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.

Recalling the runout test of the crankshaft, remember that you placed the crankshaft in a set of V-blocks (fig 5-24). The camshaft is checked in the same manner by placing the dial indicator plunger on the center camshaft main bearing journal. This test is to ensure that the camshaft is in proper alinement to minimize bearing wear. The TM lists the allowable limits of runout. Defective camshafts must be replaced.

Another check which must be made prior to 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 (fig 5-68). Aline the hole of the bearing with the mark and draw the bearing into position.

Fig 5-68. Installing camshaft bearings.

After installing the bearings, measure the inner diameter of the camshaft bearings with a telescopic gage (fig 5-69). This illustration deals with the overhead camshaft engine, in which you find the camshaft located in the cylinder head. However, the bore check is made in the same manner regardless of the type engine.

Fig 5-69. Checking camshaft bore inner diameter (overhead cam engine).

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. Figure 5-41 will refresh your memory.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. What device is used to check camshaft lobe lift?

Answers to Study Unit #5 Exercises

Work Unit 5-1.

1. d
2. c
3. a
4. d
5. b
6. c
7. d

Work Unit 5-2.

1. With the flange end up
2. Investigate the cause

ERIC

Work Unit 5-3.

1. c
2. reaming

Work Unit 5-4.

1. By measuring the inner diameter of the bore with the bearing installed
2. camshaft bearing remover/installer
3. hole alinement

Work Unit 5-5.

1. Discard the crankshaft as it cannot be repaired when cracks occur.
2. a set of "V" blocks
3. Measure the running clearance of each bearing.

Work Unit 5-6.

1. Heat the ring gear and cool the flywheel.

Work Unit 5-7.

1. Feeler gage
2. Piston rings
3. Feeler gage
4. Feeler gage
5. Micrometer
6. Micrometer

Work Unit 5-8.

1. compress the valve spring
2. warpage
3. grinding

Work Unit 5-9.

1. Runout/out-of-round
2. dial indicator
3. 60° stone wheel
4. Remove the defective seat with a puller and press the new seat into position with an arbor press.
5. By reaming the valve guide and installing oversize valves
6. The guide depth

Work Unit 5-10.

1. micrometer
2. Dial indicator
3. valve spring installed height
4. check the side clearance with a tension scale

Work Unit 5-11.

1. Dial indicator

STUDY UNIT 6

ASSEMBLING THE ENGINE

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE BASIC PROCEDURE USED IN THE REASSEMBLY OF AN ENGINE AFTER ALL REPAIRS HAVE BEEN ACCOMPLISHED.

Work Unit 6-1. PREASSEMBLY

STATE WHAT MUST BE DONE PRIOR TO THE INSTALLATION OF ALL BEARINGS, SHAFTS AND CONTACT SURFACES.

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.

To ensure proper lubrication of moving parts, all bearings, shafts, and contact surfaces must be lubricated prior to installation. For this purpose, 10 weight engine oil (OE 10) should be used.

Never use old gaskets and seals. This is a source of leakage which 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.

With the above facts firmly in mind, you are ready to assemble the engine which you have taken so much care to repair properly.

To prevent confusion, we are going to use illustrations of one engine only in this study unit. Basically, all engines are assembled in the same manner. Therefore, this study unit will provide a basic knowledge and your TM will provide you with details of the particular engine which you will be rebuilding or repairing.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. What must be done prior to the installation of all bearings, shafts and contact surfaces?

Work Unit 6-2. CRANKSHAFT INSTALLATION

STATE WHEN THE CRANKSHAFT REAR MAIN BEARING SEAL IS TRIMMED.

STATE WHICH BEARING IS TIGHTENED TO MANUFACTURER'S SPECIFICATIONS FIRST, WHEN INSTALLING THE CRANKSHAFT.

The crankshaft is the first component that must be installed if the engine is to be reassembled in a logical order. This may vary depending on the type of engine you are rebuilding. Prior to actually placing the crankshaft in the engine, 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. The excess portion (ends) of the seals should not be trimmed at this time. In the case of the engine illustrated here, there is an encased rear main oil seal and two side seals on the bearing cap. Figure 6-1 shows the side seals installed.

ERIC

Fig 6-1. Rear main bearing side seals.

There are various types of seals (felt packing, neoprene, encased, etc.). Figure 6-2 and 6-3 show the encased rear main oil seal and the special tool used to install it.

Fig 6-2. Crankshaft rear main bearing seal.

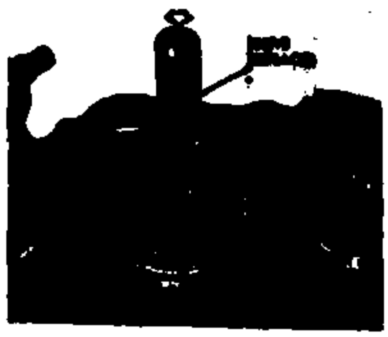


Fig 6-3. Driving the crankshaft rear main bearing seal into the engine block.

Installing the seal is a simple procedure, but care must be exercised to ensure that the seal is driven into the block evenly, or damage may result. This is accomplished after the crankshaft has been installed in the engine.

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 6-4). Make sure the bearing halves are thoroughly cleaned and, as mentioned previously, all friction

Fig 6-4. Installing main bearing halves.

surfaces coated with OE 10. 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 the bearing turns, this will cause almost immediate damage.

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 prior to installing the crankshaft in the block.

To hold the crankshaft in place, you must install the bearing caps. First, install the front main bearing cap. Place the front main bearing in its position and apply a light coat of automotive grease (GAA) to the threads of the bearing cap bolts. You might as well apply GAA to all bearing cap bolts at this time to save effort later. Tighten the bearing cap with the bolts until the cap fits snugly. Now, repeat this procedure with the rear main bearing cap. When the rear bearing fits snugly, you have caused the rear main seal to seat and you will find that there is an excess of material in the seal. Some seals may be trimmed with the crankshaft installed (fig 6-5), while on other engines, you may be required to remove the cap after seating the seal in order to trim excess material.

Fig 6-5. Trimming excess material from the crankshaft rear main oil seal.

Now place the rear main bearing cap back into position if it was necessary to remove it, and tighten it to a snug fit. The next bearing cap to be installed is the center main.

Place the center main bearing cap into position and center it. This can be done by holding the crankshaft at one end of the engine, while prying the bearing cap into position (fig 6-6). When the cap is centered, tighten the bolts to torque specifications found in the TM. The center main bearing is always tightened first. Remember, when tightening components

Fig 6-6. Centering the center main bearing cap.

to torque specifications, do NOT apply full torque immediately. A good example is the center bearing. Tighten one side five or ten pound-foot, 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. This job is accomplished with a torque wrench as illustrated in figure 6-7.

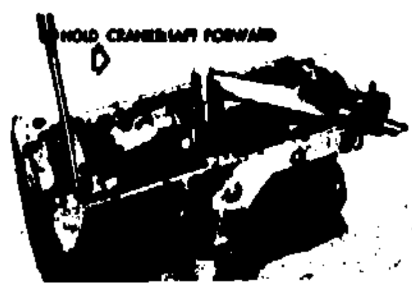


Fig 6-7. Tightening bearing caps to torque specifications.

If the engine is equipped with more than three main bearings, work out from the center. For example, if the engine has five main bearings, tighten the bearings on either side of the center bearing and then tighten the front and rear main bearings.

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

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. When is the crankshaft rear main bearing seal trimmed?

____

2. When installing the crankshaft, which bearing is tightened to manufacturer's specifications first?

____

Work Unit 6-3. CAMSHAFT INSTALLATION

STATE WHAT YOU MUST DO FIRST TO PROPERLY ALINE THE TIMING GEARS.

STATE FROM WHICH DIRECTION THE CAMSHAFT IS INSTALLED INTO THE ENGINE BLOCK.

If the valve tappets are of the mushroomed bottom type, install them first by placing them into the valve tappet bores with the engine inverted (bottom side up) as illustrated in figure 6-8. If they are not of this type, you must install the camshaft first, then insert the tappets into their bores. Make sure that the tappets are installed in their original bores and that new tappets are installed in their fitted 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 OE 10 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 6-9), and number one piston is at TDC. Install the thrust plate bolts.

Before the installation of the camshaft is completed, perform the same checks that you performed prior to the removal of the shaft. Do you remember what those checks were? The checks which must be performed on the camshaft are the end play, backlash, and timing gear runout. If you are not familiar with the procedure for performing these tests, refer back to study unit 4, Engine Disassembly to refresh your memory at this time. With the completion of these tests, the camshaft timing gear retaining bolt may be tightened, and the camshaft installed.

ERIC

Fig 6-8. Installing mushroomed-type valve tappets.

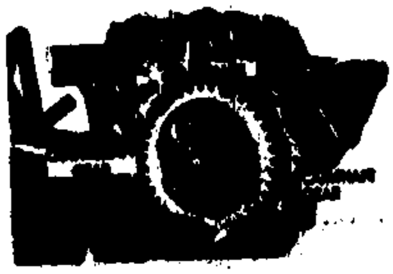


Fig 6-9. Positioning timing marks on the camshaft and crankshaft.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What must you do first to properly aline 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 camshaft is installed by placing it in the engine block from what direction?

Work Unit 6-4. FLYWHEEL INSTALLATION

GIVEN ILLUSTRATIONS DEPICTING SEQUENCES FOR TIGHTENING FLYWHEEL RETAINING BOLTS, DETERMINE WHICH SEQUENCE IS CORRECT.

The installation of the flywheel is relatively simple. Position the flywheel on the rear of the crankshaft and install the flywheel retaining bolts. Tighten the bolts to manufacturer's torque specifications, in sequence, across from each other as illustrated in figure 6-10.

Fig 6-10. Tightening sequence for flywheel retaining bolts.

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.

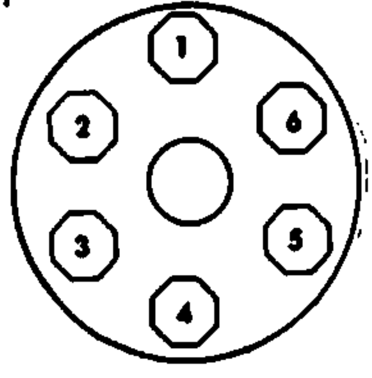
PILOT BEARING INSTALLATIONS

A pilot bearing may be of two types: ball bearing or bushing. Some bearings are installed in the end of the crankshaft, while others are installed in the center of the flywheel. When installing these bearings, it makes no difference which type you are installing; they are both 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 <u>must</u> be driven in evenly. Prior to installation, the bore in which the bearing fits should be coated with a light film of automotive grease (GAA).

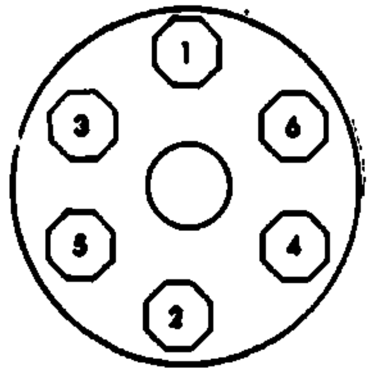
EXERCISE: Answer the following question and check your responses against the one listed at the end of this study unit.

1. Which of the sequences illustrated is correct for tightening flywheel retaining bolts?

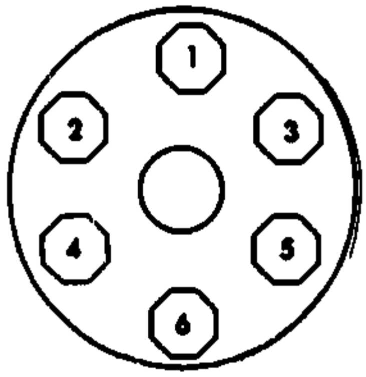
a.



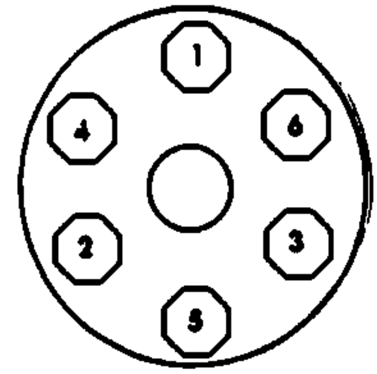
c.



b.



d.



Work Unit 6-5. PISTON INSTALLATION

IDENTIFY WHICH PROCEDURE IS FOLLOWED TO PREVENT DAMAGE TO THE CRANKPIN DURING PISTON INSTALLATION.

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 prior to installation, and installing a rubber hose on the bolts (fig 6-11).

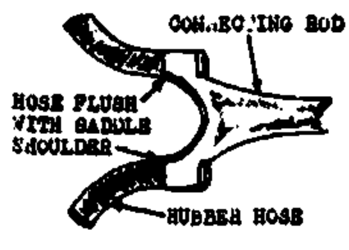


Fig 6-11. Rubber hose installed on connecting rods to protect crankpin.

The rubber hose may be a vacuum hose or any small hose which 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 (fig 6-11). To further prevent damage, check the connecting rod saddle to ensure that the shoulders are in perfect alinement with the crankpin.

Most pistons are notched or marked in some manner to indicate the front of the piston. Make sure that the notch or mark is positioned toward the front of the engine (fig 6-12).

Fig 6-12. Installing piston in engine.

The tool illustrated in figure 6-12 is installed on the piston prior to positioning it for installation. This is a ring compressor which compresses the rings around the piston so that they do not bind against the top edge of the cylinder.

When all of the above procedures have been accomplished, the piston is pushed or tapped gently into the cylinder until the connecting rod saddle seats on the crankpin. To accomplish this, the crankshaft should be rotated until the crankpin of the cylinder in which you are installing the piston is at BDC.

As each piston is installed in the cylinder, the connecting rod cap should be installed prior to moving to the next piston. The connecting rod side play is also checked and matched at this time with the specifications listed in the TM (fig 6-13).

Fig 6-13. 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 you did with the main bearings. Coat them with OE-10 as you do all friction surfaces. When this procedure is finished with each piston, install the oil pump.

EXERCISE: Answer the following question and check your response against the one listed at the end of this study unit.

1. To prevent damage to the crankpin during piston installation, what procedure should be followed?

   a. Pound with the handle of your hammer.
   b. Use your hands ONLY.
   c. Cover the bearing cap bolts with a small piece of rubber hose.
   d. Turn the crankpin 160°.

Work Unit 6-6. OIL PUMP AND OIL PAN INSTALLATION

IDENTIFY WHAT MUST BE DONE TO THE ENGINE PRIOR TO INSTALLING AN OIL PUMP.

IDENTIFY WHAT SEQUENCE YOU ARE GOING TO USE TO TIGHTEN THE OIL PAN SCREWS.

OIL PUMP INSTALLATION

Although oil pump installation is not covered in this course, the oil pump is checked and repaired as necessary during engine rebuild. The oil pump will be covered in detail in a subsequent course which deals with the lubrication system.

After the oil pump has been checked, repaired, and reassembled, lubricate the entire pump with OE-10. Now, during the installation of the oil pump, keep in mind that the oil pump usually drives the distributor and must be installed in the correct position. If it is not installed properly, the spark plugs may not fire at the proper time and the engine will not operate.

Before installation is made, the number one piston must be at TDC, and the timing marks of the crankshaft and camshaft timing gears alined according to manufacturer's specifications. Once this is accomplished, check your TM and install the oil pump according to instructions therein.

<u>Note</u>: The oil pick-up tube and screen are installed on the oil pump prior to installing the pump.

OIL PAN INSTALLATION

You are now ready to install the oil pan. If cork gaskets are to be used, they must be soaked in water prior to installation in order to ensure a proper fit. 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 of the pan. This will cause the gaskets to seat properly and eliminate chances for oil leakage. Return now to the top of the engine and install the valves.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Prior to installing an oil pump, what must be done to the engine?

   a. Move the number two piston to BDC and aline the timing marks.
   b. Move number one piston to TDC and aline the timing marks.
   c. The engine must be filled with oil.
   d. The engine must be placed on "V" blocks.

2. You are installing the oil pan on an engine. You have installed screws and are about to tighten them to manufacturer's specifications. What sequence are you going to use?

   a. Begin with the rear screws and alternate sides, working toward the front of the engine.
   b. Begin with the front screws and alternate sides, working toward the rear of the engine.
   c. Begin with the center screws and alternate sides, working toward either end of the engine.
   d. Tighten all the screws on one side of the engine, then tighten all the screws on the other side.

Work Unit 6-7. VALVE AND CYLINDER HEAD INSTALLATION

IDENTIFY THE CORRECT TIGHTENING SEQUENCE FOR CYLINDER HEAD BOLTS.

WHEN INSTALLING PUSHRODS, STATE WHERE THE BOTTOM OF THE PUSHROD MUST BE PLACED TO PREVENT ITS DAMAGE.

IDENTIFY THE CORRECT PROCEDURE FOR INSTALLING THE ROCKER ARM SHAFT.

WHILE ASSEMBLING AN ENGINE, NAME THE TYPE OF ADJUSTMENT THAT OCCURS WHEN YOU ADJUST THE VALVES BY MOVING EACH PISTON TO TDC, CAUSING BOTH INTAKE AND EXHAUST VALVES TO CLOSE.

VALVE INSTALLATION

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.

Now we will discuss the method of installing valves in both the head and the block, beginning with valves in the head.

Be certain that you install each valve in its original location. 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 valve is an intake valve, place the valve stem seal over the valve stem from the top of the head.

The valve spring and valve spring retainer are placed over the valve stem and the valve spring is compressed with the same tool used to compress the valve spring for valve removal (fig 6-14).

Fig 6-14. Compressing the valve spring.

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 prior to the locks. If a valve stem cap is to be used, it will be 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 two typical 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.

Before getting into the installation of the cylinder head, take a look at the installation of valves when they are to be installed in the cylinder block. The first component to be installed is the valve spring. The spring is placed in position against its upper seat and the valve spring retainer is placed beneath it. The valve spring compressing tool is placed beneath the retainer. The spring is then compressed and the valve stem is dropped into its position (fig 6-15).

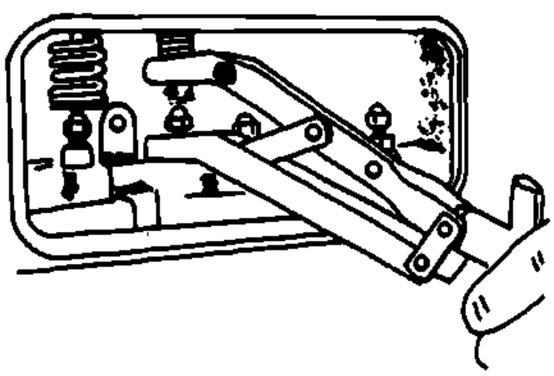


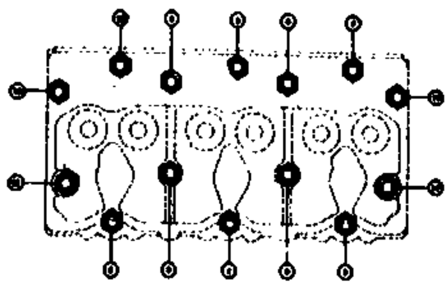
Fig 6-15. Compressing valve spring of valve-in-block engine.

After dropping the valve into position, insert the valve stem locks, and release the spring. You will find that a coat of GAA applied to the valve stem locks will serve to hold them in place while the spring compressor is being released. This is also true of the valve-in-head design.

CYLINDER HEAD 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 that one first. Inspect your new 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 alinement of the holes in the block with the holes in the gasket. If the holes are not alined, 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. To tighten the cylinder head bolts, a torque wrench must be used. Check the TM for the proper torque specifications and tighten the cylinder head bolts to approximately 75% of the specified torque, beginning with the center bolt or bolts and working toward the ends. Repeat this procedure, adding 5 to 10 pounds each time, until all bolts are tightened to the manufacturer's specifications. Figure 6-16 gives examples of cylinder heads having two and three rows of head bolts. Note the tightening sequence for both.



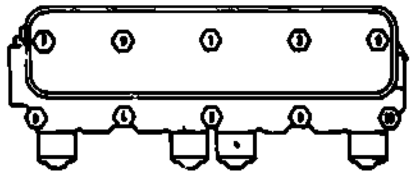


Fig 6-16. Typical tightening sequence for cylinder heads.

The installation of the cylinder head on the I-head and F-head engines is the same as 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 top of the valve tappet or the engine will not operate and the pushrod will be damaged (fig 6-17).

Fig 6-17. Installing pushrods.

The next step is to assemble and install the rocker arm shaft. Each component is reassembled in its original position (fig 6-18). After reassembly, the rocker arm shaft assembly is placed on the cylinder head so that the studs pass through the retaining bracket (rocker arm shaft support). The nuts are then tightened on the studs 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 6-18. Rocker arm shaft assembled.

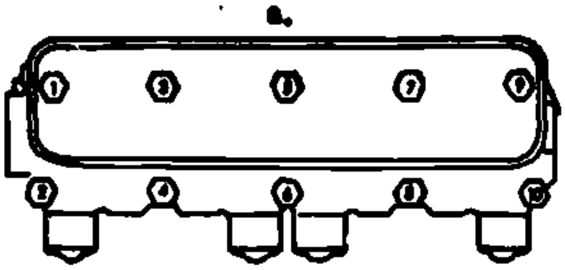
After the rocker arm shaft is installed, the valves must be adjusted to the manufacturer's specifications as discussed earlier in the course. This is normally accomplished with the engine operating at normal operating temperature, however, you can make a cold adjustment initially without the engine operating. 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 accomplished, 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.

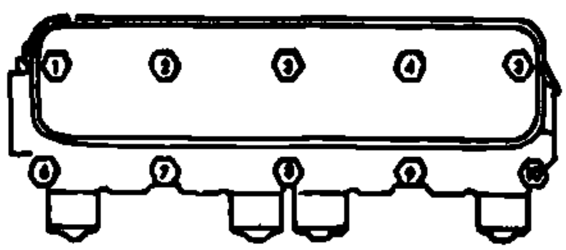
EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. From the following illustrations, identify the correct tightening sequence for cylinder head bolts.

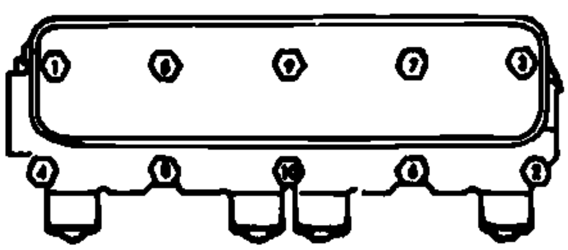
a.



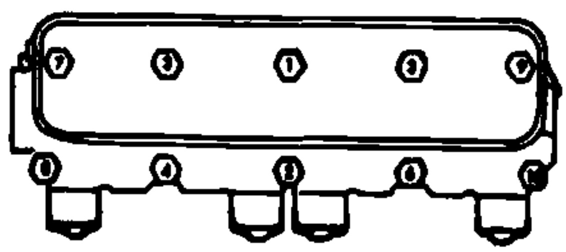
c.



b.



d.



2. When installing pushrods, they will be damaged unless the bottom of the pushrod is what?

   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. While assembling the engine, you adjust the valves by moving each piston to TDC, causing both intake and exhaust valves to close. This is known as a adjustment.

Summary Review

You have now learned the basic procedure used in the reassembly of an engine after all repairs have been accomplished.

Answers to Study Unit #6 Exercises

Work Unit 6-1.

1. They must be lubricated.

Work Unit 6-2.

1. After installing the rear main bearing cap
2. The center

Work Unit 6-3.

1. You must turn the crankshaft until the number one piston is at TDC and the timing gear mark is in the specified position.
2. From the front direction

Work Unit 6-4.

1. c.

Work Unit 6-5.

1. c.

Work Unit 6-6.

1. b.
2. c.

Work Unit 6-7.

1. d.
2. b.
3. c.
4. cold

ERIC

AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Review Lesson

Instructions: This review lesson is designed to aid you in preparing for your final examination. You should try to complete this lesson without the aid of reference materials, but if you do not know an answer, look it up and remember what it is. The enclosed answer sheet must be filled out according to the instructions on its reverse side and mailed to MCI using the envelope provided. The questions you miss will be listed with references on a feedback sheet (MCI-R69) which will be mailed to your commanding officer with your final examination. You should study the reference material for the questions you missed before taking the final examination.

A. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

1. What component part contains the crankcase and cylinders?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

2. All engine parts are housed by or attached to the

   a. engine block.
   b. cylinder head.
   c. piston.
   d. crankshaft.
   e. valve.

3. What encloses the top of the cylinders?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

4. Water leaves the engine from the

   a. engine block.
   b. cylinder head.
   c. piston.
   d. crankshaft.
   e. valve.

5. What component is driven down by heat energy?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

6. What contains lands and grooves for rings?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

7. What component part delivers power from the engine?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

8. What component part contains crankpins and main journals?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

9. Which component has a long stem with a mushroom top?

   a. Engine block
   b. Cylinder head
   c. Piston
   d. Crankshaft
   e. Valve

10. Fuel enters the combustion chamber through the

   a. engine block.
   b. cylinder head.
   c. piston.
   d. crankshaft.
   e. valve.

11. Intake, compression, power and exhaust, are the cycles of operation for which type of engine?

   a. 2-cycle
   b. 2-cylinder
   c. 2-stroke
   d. 4-stroke

12. What action takes place when the piston is traveling upward and the exhaust valve is open?

   a. Intake
   b. Exhaust
   c. Compression
   d. Power

13. Which two events takes place 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

14. In the two-stroke engine, which component closes the intake port?

   a. Pushrod
   b. Piston
   c. Camshaft
   d. Crankshaft

15. Three arrangements of cylinders in automotive engine blocks are in line, opposed and

   a. V-type.
   b. F-type.
   c. L-type.
   d. T-type

124

16. Engine classification is made by the following methods of cooling:

   a. Oil or water.
   b. Liquid or hydraulic
   c. Liquid or air.
   d. Air or fan.

17. What three types of valve arrangements are currently used in automotive engines?

   a. Flat head, A-head, D-head
   b. H-head, Flat head, Z-head, Overhead
   c. F-head, I head, L-head
   d. A-head, Z-head, Overhead

18. How do you repair a scored cylinder in an air cooled engine?

   a. Completely rebore the engine.
   b. Replace only the defective cylinder.
   c. Rebore all cylinders and replace all pistons.
   d. Replace only the cylinder head.

19. How do you recognize a V-8 crankshaft as opposed to an in-line four cylinder crankshaft?

   a. The throws are shorter.
   b. The throws are longer.
   c. The throws are spaced 120° apart.
   d. The throws are spaced 130° apart.

20. Your current engine pistons are a little different from the originals and the heads are concave. These pistons are designed for what type of engine?

   a. The same engine
   b. They are designed for a similar spark-ignition engine.
   c. They are designed for similar compression ignition engine.
   d. They are not designed for any engine.

21. On what type of engine would a perfectly flat cylinder head without a combustion chamber be installed?

   a. Three-stroke spark-ignition
   b. Two-stroke spark-ignition
   c. Four-stroke compression ignition
   d. Four-stroke spark-ignition

22. A vehicle operator complains of excessive loss of engine coolant. You find no external leaks, however, you do find coolant in the engine oil. What is the most likely cause of this?

   a. A leak between the water jacket and water pump
   b. A leak between the water pump and fan
   c. A leak between the water jacket and the crankcase
   d. A leak between the radiator hose and cylinder block

23. How would a cracked cylinder block be repaired without replacing the block?

   a. By replacing the head gasket
   b. By replacing the cylinder head
   c. By sealing the head gasket
   d. By sealing the cylinder block

24. What condition indicates a "blown" head gasket?

   a. Black smoke from the exhaust
   b. The engine will not turn
   c. Two adjacent cylinders misfiring
   d. Blue smoke from exhaust

25. How is a warped cylinder head repaired?

a. By bolting it extra tightly on the cylinder block
b. By installing it with a good sealer on the head gasket
c. Reboring it in all cases
d. Machining it to a flat smooth surface before installation

26. What readings will a compression gage indicate if you vehicle has defective piston rings?

a. Low "dry" test and high "wet" test
b. Low "dry" test and low "wet" test
c. High "dry" test and low "wet" test
d. High "dry test and high "wet" test

27. What is the remedy for worn piston rings?

a. Honing the cylinder walls
b. Reboring the cylinder
c. Replacing the piston rings
d. Replacing the piston

28. What causes engine starting failure when the rotor buttom in the distributor is halfway between two spark plug terminals with number one piston at TDC compression?

a. Defective points
b. Defective camshaft
c. Defective valve springs
d. Defective timing

29. What corrective action is required for a long running engine with too tightly adjusted valves?

a. Replace the valves.
b. Replace the valve springs.
c. Ream the valve guides.
d. Replace the valve tappets.

30. The device used to check valve adjustment is called a(n)

a. micrometer.
b. feeler gage .
c. dial indicator.
d. valve spring tester .

31. What could cause crankshaft failure?

a. Improper end-play
b. Improper lubrication
c. Excessive low-speed operation
d. Bent pushrods

32. What is the corrective action for worn crankshaft bearings that cause knocking?

a. Replace the camshaft
b. Replace the rod bearings
c. Replace the crankshaft bearings
d. Replace the pushrod bearings

33. What is the authorized cleaning solution used in engine repair preparation?

a. None is required
b. Authorized drycleaning solution
c. Gasoline
d. Authorized oil solution

34. Why are the pushrods removed before the cylinder head is removed?

a. To prevent damage to the cylinder head
b. To prevent damage to the cylinder blocks
c. To prevent damage to the pushrods
d. To prevent damage to the pistons

35. What is the required test prior to removing the oil pump assembly?

a. Oil pump bypass
b. Oil pump flow
c. Oil pump gear backlash
d. Oil pump vacuum

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

a. Piston head and cylinder walls are coated with oil
b. Engine is turned upside down
c. Clean rags are placed in cylinders to catch metal shavings
d. Engine is turned on its side

37. How is the piston removed after removing the connecting rod bearing caps?

a. By driving the piston down past the crankshaft
b. By striking the connecting rod with a hammer driving the piston out through the top
c. By pushing down on the piston with a breaker handle
d. By pushing on the end of the connecting rod with a hammer handle forcing the piston up

38. The connecting rod side play is measured by placing a feeler gage between the connecting rod and the

a. piston.
b. connecting ring.
c. piston pin.
d. crankshaft.

39. Check the crankshaft end-play to determine if it needs a

a. crankshaft lobe.
b. crankshaft sprocket.
c. crankshaft thrust bearing.
d. crankshaft timing gear chain.

40. To check timing gear backlash, the dial indicator is placed on the engine block and the plunger is placed on the

a. timing gear tooth.
b. camshaft tooth.
c. crankshaft end.
d. camshaft end.

41. 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

42. When removing the camshaft, damage may occur to both the camshaft and tappets if the tappets are

a. pulled away from the camshaft lobes.
b. allowed to rest on the camshaft lobes.
c. removed first.
d. not removed in sequence.

43. When checking a cylinder bore, what procedure should be followed?

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.

44. Thorough inspection of an engine block is 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 throughly cleaned internally and externally.

45. What is the action required to correct serious defects in engine cylinders?

a. Discard the engine blocks.
b. Ream the cylinders.
c. Hone the block and piston skirts.
d. Have the machine shop rebore the cylinders.

46. What action is required to remove a mirror smooth finish on cylinder walls?

a. Lapping
b. Honing
c. Scraping
d. Replacing

47. How are slightly scored cylinder walls repaired?

a. By a lapping machine
b. By using fine sandpaper
c. With a honing tool
d. By using coarse sandpaper

48. What are you looking for when inspecting a cylinder head with a straigt edge and feeler gage?

a. Warpage
b. Cracks
c. Burrs
d. Nicks

49. When replacing a cylinder liner, if the indicator on the hydraulic ram needle moves into the "danger zone" (Red Area), you would stop pumping and

a. investigate the cause.
b. move the sleeve up and down inside the bore .
c. measure the diameter of the sleeve.
d. measure the inner diameter of the bore.

50. How is a cylinder liner positioned during replacement?

a. With the flange up
b. With the tapered end up
c. With either end up
d. With the flange end down

51. How is a valve-tappet-fit measured?

a. By a spring tension gage
b. By a mechanic's scale
c. By a dial indicator
d. By a feeler gage

52. How are damaged or worn valve-tappet bores repaired?

a. By reaming them
b. By replacing them
c. By installing a new insert
d. By replacing the block

53. How are camshaft bores checked?

a. By checking the bearing surfaces with a spring tension gage
b. By measuring the inner diameter of the bore with the beaming installed
c. By checking the bearing surfaces of the camshaft with a torque device
d. By replacing the camshaft

54. What tool is used to remove camshaft bearings?

a. A ball peen hammer and punch
b. A ball peen hammer and chisel
c. A camshaft bearing remover/installer
d. A type "B" puller

55. How are camshaft bearings checked for proper installation?

a. By the bearing ends
b. By hole alinement
c. By bearing edges
d. By hearing length

56. What is the remedial action for any nicks, burrs, and cracks found on the crankshaft journals?

a. Use a crocus cloth on the nicks and burrs and seal existing cracks.
b. Have machine shop personnel grind the crankshaft to possibly eliminate cracks.
c. Discard the crankshaft because cracks cannot be repaired.
d. Have the crankshaft retempered as cracks indicate metal fatigue.

57. In what device is the crankshaft placed to perform a runout test with a dial indicator?

a. A vise
b. A test vat
c. A set of "V" blocks
d. A set of 2 x 4 blocks

58. What is the required action when installing main bearing caps?

a. Aline the crankshaft after each bearing is installed.
b. Measure the running clearance of each bearing.
c. Switch the caps to different bearings.
d. Center the main bearing.

59. How do you install a new flywheel ring gear?

a. Place the flywheel on two wooden blocks.
b. Replace it with a brass drift and a heavy ball peen hammer.
c. Heat the ring gear and cool the flywheel.
d. Heat the flywheel and heat the ring gear.

60. When repairing pistons, which components are replaced?

a. Piston rings
b. Piston pins
c. Connecting rods
d. Connecting rod caps

61. If you check a cylinder head gasket surface with a straight edge and feeler gage you are looking for

a. cracks.
b. scores.
c. warpage.
d. nicks.

62. The process used to repair a warped cylinder head is

a. smoothing with a field stone.
b. use of sandpaper
c. use of a drill and grinding stone .
d. machining (milling) to a smooth finish .

63. What is the first step in valve spring removal?

a. Remove the valve locks.
b. Compress the valve spring.
c. Remove the valve spring sleeves.
d. Remove the valve spring spacers.

64. What device is used to check for valve seat runout?

a. Dial indicator
b. Micrometer
c. Feeler gage
d. Valve spring tester

65. How is a burred valve guide repaired?

a. By spinning the valve stem inside the guide
b. By grinding the valve guide and installing oversize valve guides
c. By reaming the valve guide and installing oversize valves
d. By using an oversized valve seat

66. What is the required action when installing a valve guide?

a. Check the guide pressure
b. Check the outer edge
c. Check the installed width
d. Check the guide depth

67. What device is used to check valve spring pressure?

a. Feeler gage
b. Micrometer
c. Valve spring tester
d. Dial indicator

68. What device is used to check valve guide clearance?

a. Dial indicator
b. Feeler gage
c. Micrometer
d. Valve spring tester

69. Which valve spring test is corrected by replacing the valve and/or the valve seat?

a. Valve spring pressure
b. Valve spring roundness
c. Valve spring installation height
d. Valve spring spinning test

70. What is the correct procedure for checking valve tappets in the bore?

a. Check the freedom of up-and-down movement by feel.
b. Check the side clearance with a tension scale.
c. Check the up-and-down movement with a meter.
d. Check the side play with a dial indicator.

71. What device is used to check camshaft lobe lift?

a. Feeler gage
b. Dial indicator
c. Micrometer
d. Valve spring tester

72. What is the correct procedure for replacing valve seat inserts?

a. Remove the defective seat with a hammer and chisel, then tap new seat into position gently with a hammer and drift.
b. Remove the defective seat with a puller and hammer the new seat into position.
c. Remove the defective seat with a puller and press the new seat into position with an arbor press.
d. Remove the defective seat with a hammer and chisel.

73. What is used to remove more stock from the top of the valve seat when a 45° stone wheel has been used to reface the valve seat?

a. 20° stone wheel
b. 40° stone wheel
c. 60° stone wheel
d. 80° stone wheel

74. What is the required check to ensure smooth valve seats?

a. Runout/out-of-round
b. Backlash
c. Backplay
d. Endplay

75. During engine reassembly, what must be done to all bearing, shafts and contact surfaces prior to installation?

a. Rebuild them.
b. Wash them in water.
c. Lubricate them.
d. Heat them to room temperature.

76. During crankshaft installation, when is the center main bearing tightened?

a. First
b. Third
c. Last
d. Second

77. When is the crankshaft rear main bearing seal trimmed?

a. Prior to installing the pump
b. After installing the bearing on the crankshaft
c. After placing the oil pump into the engine
d. After installing the rear main bearing cap

78. What is the first step in properly alining the timing gears?

a. Install both the crankshaft gear and the main gear.
b. Turn the crankshaft 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 is in the specified position.
d. Turn the camshaft until the timing gear mark is at BDC.

79. A timing gear runout test is performed to determine the

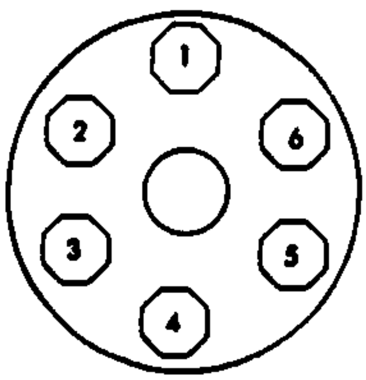
a. distance between the two gears.
b. distence the gear moves on the pulley.
c. amount of warpage in the timing gear.
d. amount of minutes in the timing gear.

80. Where in the engine block is the camshaft installed?

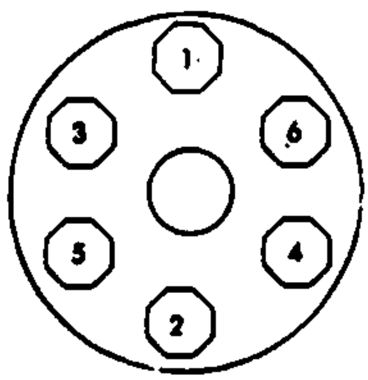
a. Front of the block
b. Top of the block
c. Bottom of the block
d. Side of the block

81. Using the following figures, identify the correct tightening sequence for flywheel retaining bolts.

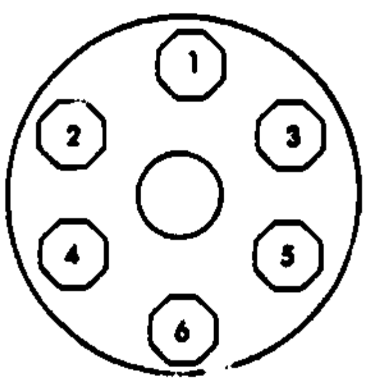
a.



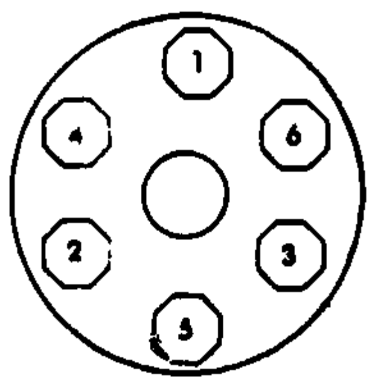
c.



b.



d.



82. What required action will prevent damage to the crankpin during piston installation?

a. Use the handle of your hammer to pry up
b. Use the handle of your hammer to pound with
c. Cover the bearing cap bolts with a small piece of rubber hose
d. Turn the crank pin 160°

ERIC

83. What must be done to the engine prior to installing an oil pump?

   a. Move the number two piston to BDC and aline the timing marks.
   b. Move number one piston to TDC and aline the timing marks
   c. Fill the engine with oil.
   d. Place the engine on "V" blocks.

84. What sequence is used to tighten bolts on an engine oil pan to manufacturer's specifications?

   a. Begin with rear bolts and alternate to the front.
   b. Begin with front bolts and alternate to the rear.
   c. Begin with the center bolts and alternate to the sides, working toward either end of the engine.
   d. Tighten all the screws on one side of the engine, then tighten all the screws on the other side.

85. When assembling the engine, the first valve adjustment made is called a

   a. hot.
   b. cold.
   c. simple.
   d. secondary .

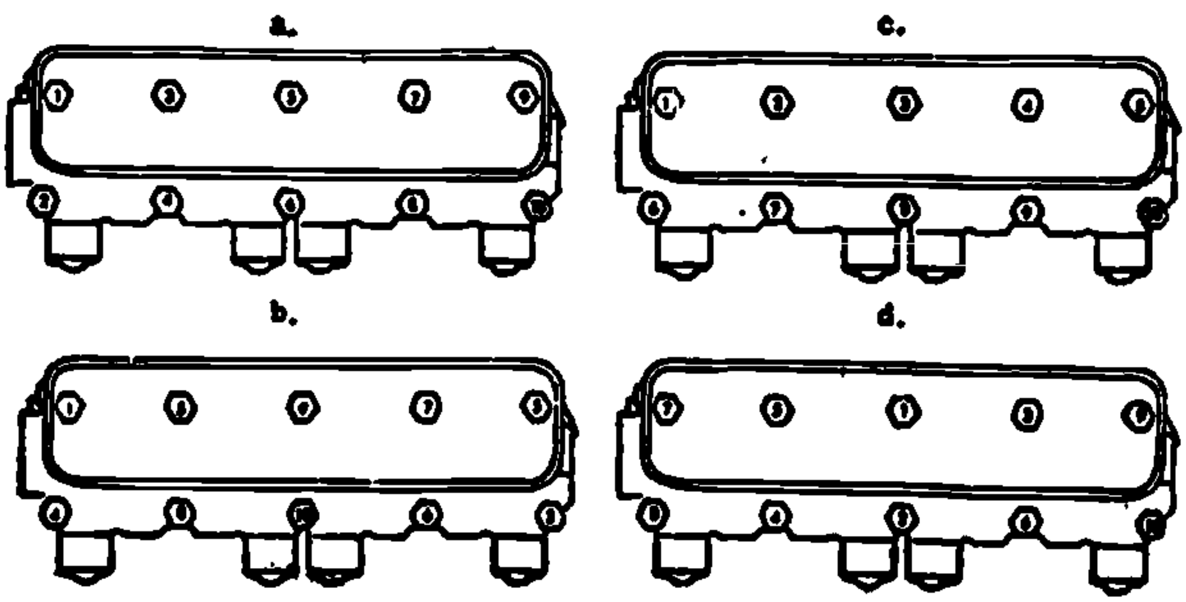
86. The correct procedure for installing the rocker arm shaft is to

   a. install the shaft on 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 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.

87. To prevent damage during pushrod installation, the bottom of the pushrod should be

   a. clean and dry.
   b. seated in the tappet.
   c. polished.
   d. oiled.

88. From the following figures, identify the correct tightening sequence for cylinder head bolts.



ERIC

B. Column 1 (items 89-95) lists tests or checks for automotive maintenance and repair. Column 2 (a. through e.) lists the devices/method used to perform the various tests or checks. Match each test or check in column 1, with the appropriate method or device in Column 2. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

Column 1 Test or check	Column 2 Method/device
89. Piston fit	a. Dial indicator
90. Piston pin fit	b. Feeler gage and tension scale
91. Connecting rod bearing bore	c. Valve spring tester
92. Piston ring side clearance	d. Feeler gage
93. Camshaft lobe lift	e. Micrometer
94. Piston ring end gap	
95. Cylinder bor out-of-round	

Total Points : 95

* * *

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-421-325:346

ERIC

BEST COPY AVAILABLE

T&E-1

STUDENT COURSE CONTENT ASSISTANCE REQUEST

DATE: ____________

COURSE NUMBER ____________ COURSE TITLE ____________

NAME ____________ RANK ____________ MOS ____________

SOCIAL SECURITY NUMBER ____________

COMPLETE MILITARY ADDRESS: ____________

1. Use this form for any questions you may have about this course. Write out your question and refer to the study unit, work unit, or study question which you are having problems with. Complete the self-addressed block on the reverse side. 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.

MY QUESTION IS: ____________ OUR ANSWER IS: ____________

DATA REQUIRED BY THE PRIVACY ACT OF 1974
(5 U.S.C. 522A)

1. AUTHORITY: Title 5, USC, Sec. 301. Use of your Social Security Number is authorized by Executive Order 9397 of 22 Nov 43.

2. PRINCIPAL PURPOSE(S): The Student Course Content Assistance Request is used to transmit information concerning student participation in MCI courses.

3. ROUTINE USE(S): This information is used by MCI personnel to research student inquiries. In some cases information contained therein is used to update correspondence courses and individual student records maintained by the Marine Corps Insitute.

4. MANDATORY OR VOLUNTARY DISCLOSURE AND EFFECT ON INDIVIDUAL NOT PROVIDING INFORMATION: Disclosure is voluntary. Failure to provide information may result in the provision of incomplete service to your inquiry. Failure to provide your Social Security Number will delay the processing of your assistance request.

INSTRUCTIONS TO STUDENT

1. **Fold so that MCI address is outside**
2. **Insert course number in square marked "Course Number" below**
3. **Seal with scotch tape or one staple**
4. **Mail to MCI**

DEPARTMENT OF THE NAVY

MARINE CORPS INSTITUTE
MARINE BARRACKS
P.O. BOX 1775
ARLINGTON, VIRGINIA 22222

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD 317

U.S. MAIL

COURSE NUMBER

THE DIRECTOR
MARINE CORPS INSTITUTE
BOX 1775
ARLINGTON, VIRGINIA 22222

ATTN: MOSTD

Use this space for additional comments.

ERIC

COURSE IMPROVEMENT SURVEY

The Marine Corps Institute would appreciate your help in improving the course you have just completed. If you would take a few minutes to complete the following survey, we would have valuable information to help us improve this course. Your answers will be kept confidential and will in no way affect your grade.

Course Number ☐ Rank ________ MOS ________

Name (Optional) ____________________

Military Address (Optional) ____________________

1. Did you find inaccurate or outdated information in this course? ☐ Yes ☐ No

   List the areas you found inaccurate or out of date. Give page or paragraph if possible.

   ____

2. How long did it take you to finish the course?

   ☐ 1-5 hours ☐ 11-15 hours ☐ More than 20 hours
   ☐ 6-10 hours ☐ 16-20 hours

3. Were the procedures taught in this course understandable and useful? ☐ Yes ☐ No

   If "No," how could they be improved? ____________________

4. How much of the material taught in this course can you apply to your job?

   ☐ Almost all ☐ Very little ☐ None
   ☐ More than half ☐ Less than half

5. Did you have trouble reading or understanding the material in this course? ☐ Yes ☐ No

   If "Yes,", explain ____________________

6. Were the illustrations in this course helpful? ☐ Yes ☐ No

   If "No," how could they be improved? ____________________

7. Put an "X" in a box on the scale below to show how well you feel the lessons and the course materials prepared you for the final examination. (On this scale "10" indicates that the material prepared you very well, a "5" indicates adequate preparation, and a "1" indicates very poor preparation.)

   Very Poor — Adequate — Very Well

1	2	3	4	5	6	7	8	9	10

8. If you asked MCI for help, were the answers to your questions helpful?

   ☐ Yes ☐ No ☐ No questions sent to MCI

9. Please list below any suggestions you may have to improve this course. Try to be specific; give page or paragraph numbers. (You may also use the space on the back or attach additional sheets.)

BEST COPY AVAILABLE

DEPARTMENT OF THE NAVY

MARINE CORPS INSTITUTE
MARINE BARRACKS
P.O. BOX 1775
ARLINGTON, VIRGINIA 22222

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD 317

NAME	RANK	SSN
MILITARY ADDRESS		

DEPARTMENT OF THE NAVY

MARINE CORPS INSTITUTE
MARINE BARRACKS
P.O. BOX 1775
ARLINGTON, VIRGINIA 22222

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD 317

THE DIRECTOR
MARINE CORPS INSTITUTE
BOX 1775
ARLINGTON, VIRGINIA 22222

ATTN: MOSTD

DETACH BEFORE MAILING