DOCUMENT RESUME

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ED 224 894 CE 034 550

TITLE	Automotive Engine Maintenance and Repair, 8-1. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION	Marine Corps, Washington, D.C.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	78
NOTE	139p.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01/PC06 Plus Postage.
DESCRIPTORS	*Auto Mechanics; *Engines; *Equipment Maintenance; Equipment Utilization; *Job Skills; Military Personnel; Military Training; Postsecondary Education; Secondary Education; *Technical Education
IDENTIFIERS	Military Curriculum Project

ABSTRACT

These military-developed curriculum materials consist of six individualized lessons dealing with automotive engine maintenance and repair. Covered in the individual volumes are basic engine construction and operation, engine and engine components design, engine malfunction diagnosis and remedy, engine disassembly, engine repair, and engine repair reassembly. Each lesson contains objectives, text, and review exercises. (MN)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University • 1960 Kenny Road • Columbus, Ohio 43210
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

Agriculture	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Occupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
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1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Table of Contents

Developed by:

United States Marine Corps

Development and Review Dates

Unknown

Occupational Area:

Engine Mechanics

Cost: **Print Pages:**

129

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Text, objectives, exercises

Type of Instruction:

Individualized

Type of Materials:			No. of Pages:	Average Completion Time:
Automotive Engine Maintenance and Repair				
Lesson 1	—	Basic Engine Construction and Operation	15	2 Hours
Lesson 2	—	Engine and Engine Components Design	16	2 Hours
Lesson 3	—	Engine Malfunction Diagnosis and Remedy	12	2 Hours
Lesson 4	—	Engine Disassembly	11	3 Hours
Lesson 5	—	Engine Repair	34	3 Hours
Lesson 6	—	Engine Repair Reassembly	10	3 Hours
Exercises			28	

Supplementary Materials Required:

None

Expires July 1, 1978

Course Description:

This course is designed to provide the student with information about the construction, operation, malfunction diagnosis, maintenance, repair, and overhaul of the internal-combustion, reciprocating engine. It provides the basic theory and would be best used in conjunction with laboratory or on-the-job learning situations.

This course is divided into five lessons with objectives, study assignments and review exercises.

Lesson 1	—	*Basic Engine Construction Operation* describes the main components of the reciprocating, internal-combustion engine, how it is constructed and how it operates.
Lesson 2	—	*Engine and Engine Components Design* identifies the various engine designs, and the various designs of components used in the construction of engines.
Lesson 3	—	*Engine Malfunction Diagnosis and Remedy* covers the procedures for identifying the symptoms of various internal malfunctions of the engine and remedies required to restore the engine to its normal operating condition.
Lesson 4	—	*Engine Disassembly* discusses the procedures used to disassemble a reciprocating internal combustion engine.
Lesson 5	—	*Automotive Engine Maintenance and Repair* covers inspection, testing and basic procedures used in the repair of the engine.
Lesson 6	—	*Engine Repair and Reassembly* describes basic procedures used in the repair of cylinder heads and valve mechanisms, and in the reassembly of an engine after all repairs have been accomplished.

This course is designed for student self-study, but could be most effective in group learning situations. Each lesson contains objectives, text, and review exercises. No answers are available for the review exercises.

UNITED STATES MARINE CORPS
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BOX 1775
WASHINGTON, D.C. 20013

AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Lesson 1

Basic Engine Construction and Operation

STUDY ASSIGNMENT: Information for MCI Students.
Course Introduction.
MCI 35.8, Automotive Engine Maintenance and Repair, chap 1.

LESSON OBJECTIVE: Upon successful completion of this lesson, you will be able to identify the main components of the reciprocating, internal-combustion engine, how they are constructed, and how they operate.

WRITTEN ASSIGNMENT:

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 box.

Value: 1 point each

1. Because all parts of the engine are housed by, or attached to, the engine block, we call it the

   a. crankcase. c. backbone.
   b. cylinder block. d. main body.

2. When the engine block is cast, which item is machined smooth?

   a. Water jacket c. Oil passage
   b. Cylinder d. Crankcase

3. The crankcase serves as a support for the

   a. crankshaft. c. connecting rod.
   b. camshaft. d. cylinder block.

4. The upper portion of the engine block is known as the

   a. cylinder head. c. crankcase.
   b. water jacket. d. cylinder block.

5. Which component encloses the top of the cylinders?

   a. Enclosed end of the piston c. Cylinder block
   b. Crankcase d. Cylinder head

6. Why is the bottom surface of the cylinder head "cupped out" at some points?

   a. To provide oil passages
   b. To provide a passage for the water to leave the engine
   c. To provide combustion chambers
   d. To provide water passages from the engine block

7. Why must the cylinder head have a hole cut into the top?

   a. To provide a means of passing water from the cylinder head
   b. To provide a means of passing water from the cylinder block
   c. To provide a means of passing oil from the block
   d. To provide a means of cooling the oil

8-1

8. The burning gases in the combustion chamber must be converted to mechanical energy by the

a. piston.
b. connecting rod.
c. crankshaft.
d. cylinder head.

9. The grooves near the top of the piston are for the purpose of installing the

a. piston pin.
b. piston in the cylinder.
c. connecting rod.
d. piston rings.

10. The engine component which changes reciprocating motion to rotary motion is the

a. piston.
b. connecting rod.
c. crankshaft.
d. cylinder head.

11. Which item is NOT a part of the crankshaft?

a. Main journal
b. Main frame
c. Crankpin
d. Throw

12. What carries the crankshaft through its rotation when no power is provided by the piston?

a. Throws
b. Flywheel
c. Vibration damper
d. Crankpins

13. What is the purpose of the engine's valves?

a. Change heat energy to mechanical energy
b. Provide a seal for the piston
c. Allow gases to enter and escape
d. Provide a combustion chamber

14. An engine's valve could be described as a long stem with a(an) ____________ top.

a. machined smooth
b. angled
c. mushroomed
d. flat

15. When the valve is closed, the valve face comes into firm contact with the

a. cylinder head.
b. cylinder block.
c. combustion chamber.
d. valve seat.

16. What causes the valve to close?

a. Camshaft
b. Valve spring
c. Valve spring locks
d. Valve spring retainer

17. The camshaft contains a series of ________-shaped cam lobes.

a. triangular
b. egg
c. hexagonal
d. circular

18. For each complete rotation of the crankshaft, the piston makes _____ stroke(s).

a. 1/4
b. 1/2
c. 1
d. 2

19. If timing gears are not installed in a specified position in relation to one another, the valves will

a. open at the wrong time.
b. remain open at all times.
c. remain closed at all times.
d. fail to open and close.

20. When the piston moves down inside the cylinder, space is increased and pressure is

a. decreased. b. increased. c. constant.

21. During the four-stroke-cycle engine operation, the intake event ends when the piston has traveled to which position?

a. 44° after TDC
b. 44° before BDC
c. 44° after BDC
d. 44° before TDC

22. What event is occurring when both valves are closed during engine operation and the piston is traveling down inside the cylinder?

a. Ignition
b. Combustion
c. Compression
d. Power

23. The crankshaft is about to reach the end of its first complete rotation during the cycle of events. What event is about to end?

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

24. Gases are ignited in the diesel engine by heat generated by

a. compression.
b. friction.
c. electrical spark.
d. the fuel.

25. The intake and exhaust ports of the two-stroke-cycle engine are located in the

a. bottom of the cylinder head.
b. top of the cylinder block.
c. piston.
d. cylinder.

26. In the two-stroke-cycle engine, two of the four events occur at the same time. These events are the

a. intake and compression.
b. power and exhaust.
c. intake and exhaust.
d. compression and power.

27. What opens the valve ports of the two-stroke-cycle engine?

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

Total Points: 27

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AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Lesson 2

Engine and Engine Components Design

STUDY ASSIGNMENT: MCI 35.8, Automotive Engine Maintenance and Repair, chap 2.

LESSON OBJECTIVE: Upon successful completion of this lesson, you will be able to identify various engine designs, and the various designs of components used in the construction of engines.

WRITTEN ASSIGNMENT:

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 box.

Value: 1 point each

1. A water-cooled engine is an engine with the cylinders cast as

   a. separate components.
   b. a part of the engine block.
   c. horizontally opposed cylinders only.
   d. finned devices.

2. An in-line engine may be cast with the cylinders in a vertical position or

   a. at a 90° angle to one another.
   b. at a 90° angle to a vertical plane.
   c. at a 45° angle to a vertical plane.
   d. at a 30° angle to a vertical plane.

3. The cylinders of a V-type engine are cast at a ______° angle to a vertical plane.

   a. 30
   b. 45
   c. 60
   d. 90

4. What engine is designed with two banks of cylinders arranged at a 90° angle to a vertical plane?

   a. In-line
   b. V-type
   c. Y-block
   d. Horizontally opposed

5. In addition to being classified according to cylinder arrangement and method of cooling, an engine's classification may also include the

   a. type of cylinders.
   b. valve arrangement.
   c. location of cylinders.
   d. materials used in it.

6. The most common type valve arrangement found in today's engines is the

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

7. The overhead valve mechanism found in the I-head engine has two components located between the tappet and the valve stem. These are the

   a. camshaft and valve spring.
   b. valve spring locks and valve seat.
   c. valve lifter and valve guide.
   d. pushrod and rocker arm.

8. A flat-head arrangement is actually what valve arrangement?

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

9. In the F-head arrangement, the valves are located in

a. the cylinder head.
b. the cylinder block.
c. both the cylinder head and the cylinder block.

10. A cast en bloc engine has the cylinders cast into the block during manufacture. However, some blocks, in order to prolong the life of the engine, use

a. cylinder liners.
b. aluminum pistons.
c. air-cooled cylinders.
d. chrome piston rings.

11. When cylinders become defective, what is a major advantage of the air-cooled engine?

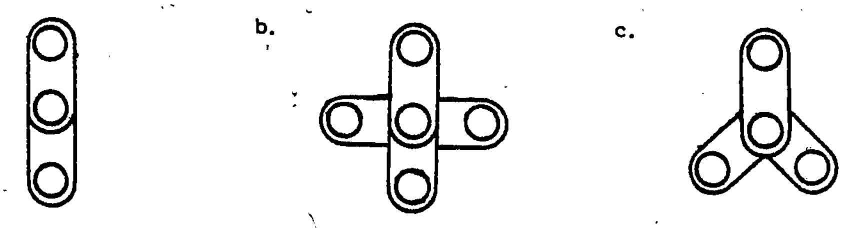
a. The cylinders may be removed
b. Only the defective cylinders need be replaced
c. There is no water jacket to be concerned with
d. The cylinders may be rebored

12. What factors affect the design of a crankshaft for a chosen engine?

a. The firing order of the cylinders
b. The position of the camshaft
c. The cylinder arrangement and number of cylinders
d. The method of cooling the engine

13. By studying these front view sketches of crankpin arrangement, choose the design used in the four-cylinder, in-line engine.

a. b. c.



14. The four-stroke-cycle, four-cylinder engine has a power lapse due to the distance the crankshaft travels between the

a. compression strokes.
b. power strokes.
c. exhaust strokes.
d. intake strokes.

15. Which engine does not eliminate power lapse?

a. In-line three
b. In-line six
c. V-six
d. V-eight

16. A crankshaft containing only three throws is used for how many different cylinder arrangements?

a. One only
b. Two
c. Three
d. Four

17. Some crankshafts used in V-8 engines have throws spaced 180° apart just as the four-cylinder in-line. However, we can differentiate between the two by observing the

a. thickness of the crankshaft.
b. number of main bearing journals.
c. number of crankpins.
d. length of the crankpins.

18. The three-cylinder, in-line engine crankshaft is most similar to the six-cylinder engine with the _____________ cylinder arrangement.

a. in-line
b. slant-six
c. horizontally-opposed

19. The weight of the flywheel to be used with a specific engine depends a lot upon the

a. power lapse.
b. engine weight.
c. engine length.
d. number of cylinders.

20. The flywheel is used primarily to

a. start the engine.
b. reduce engine vibration.
c. balance engine weight.
d. eliminate all vibration in the engine.

21. Crankshaft torsional vibration is reduced by the use of a

a. fan belt pulley.
b. vibration damper.
c. flywheel.
d. series of main bearings.

22. What component decreases the twisting action caused by application of power to the crankshaft?

a. Crankshaft throws
b. Crankpins
c. Vibration damper
d. Flywheel

23. High-compression pistons come extremely close to the top of the combustion chamber on the up-stroke and can be recognized by the space created for the

a. valves.
b. combustion.
c. compression.
d. spark plug.

24. What is the design feature of the piston head used in the compression-ignition engine?

a. The head is flat
b. The head is convex
c. The head is notched
d. The head is concave

25. In most cases the taper of the piston skirt will reduce piston rock. However, in some pistons it is necessary to assist the skirt by

a. adding more piston rings.
b. making the piston longer.
c. offsetting the piston pin.
d. increasing the piston diameter.

26. Which is NOT a basic design of the piston skirt?

a. Split
b. Offset
c. Solid
d. Cutaway

27. Which compression ring design exerts less pounds per square inch of pressure on the cylinder wall?

a. Rectangular
b. Beveled
c. Tapered
d. Grooved outer edge

35.8
lsn 2; p. 3

28. The oil control ring most commonly used in motor vehicles today is the

a. two-piece.
b. three-piece.
c. four-piece.

29. Connecting rod saddles are usually offset to accommodate the piston arrangement in what type of engine?

a. V-type
b. In-line
c. Spark-ignition
d. Compression-ignition

30. The basic difference between the gasoline engine cylinder head and the diesel engine cylinder head is the

a. method of cooling.
b. method of lubrication.
c. rocker arm area.
d. bottom surface.

31. The poppet valve design helps determine the _______ of the valve.

a. size
b. opening
c. temperature range
d. durability

32. In the valve train, we find how many basic designs?

a. Two
b. Three
c. Four
d. Five

17

Total Points: 32

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AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Lesson 3

Engine Malfunction Diagnosis and Remedy

STUDY ASSIGNMENT: MCI 35.8, Automotive Engine Maintenance and Repair, chap 3.

LESSON OBJECTIVE: Upon successful completion of this lesson, you will be able to identify the symptoms of various internal malfunctions of the engine and the remedies required to restore the engine to normal operating condition.

WRITTEN ASSIGNMENT:

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 box.

Value: 1 point each

1. The engine block is sometimes the cause of engine malfunctions because it

   a. is the largest component of the engine.
   b. is relied upon by the functioning components.
   c. cools the engine.
   d. is a major moving part.

2. What is the first visible symptom of scored cylinder walls?

   a. Black soot inside the tailpipe
   b. Loss of power
   c. Loss of compression
   d. A white smoke-like substance from the tailpipe

3. What do we do to determine which cylinder(s) is(are) defective?

   a. Check the spark plug.
   b. Check the tailpipe.
   c. Perform a compression test.
   d. Check the spark in each cylinder.

4. The last two digits of a technical manual number indicate the

   a. revision of the manual.
   b. number of driving and driven wheels.
   c. frequency of scheduled maintenance (in weeks).
   d. echelon for which the manual is intended.

5. If a "dry" compression test reveals low readings, what is the next step to take before rechecking the "low" cylinders?

   a. Warm the engine again.
   b. Check the spark plugs for burnt oil.
   c. Squirt oil into the defective cylinders.
   d. Spin the engine with the starter.

6. If a "wet" compression test reveals a rise in compression, this indicates

a. faulty ring(s).
b. faulty valves.
c. no repair is necessary.
d. leak in engine seals.

7. What is the remedy for scored cylinder walls?

a. Sand the cylinder.
b. Replace the engine block.
c. Install new piston rings.
d. Rebore the cylinders.

8. How may you, as a mechanic, be sure that a water jacket is properly maintained?

a. Check the condition of the coolant.
b. Ask the vehicle operator how often he checks his coolant.
c. Flush each vehicle's cooling system weekly.
d. Inform the vehicle operator he must use chemicals.

9. A vehicle operator complains of an overheating engine. Primarily, what is his problem?

a. A clogged water jacket
b. Coolant is not circulating properly.
c. There is no coolant in the water jacket.
d. The water jacket is leaking.

10. A visual check of the cooling system reveals a low coolant level. After adding water and allowing the engine to run for about 10 to 15 minutes, you then

a. check the coolant level again.
b. check the block for leaks.
c. check the condition of the coolant.
d. consider the condition corrected.

11. External water jacket leaks usually occur in the

a. core plugs.
b. cylinder head.
c. cylinder block.
d. crankcase.

12. If coolant is being lost, and there are no visual leaks, where would you check first for symptoms of an internal leak?

a. Tailpipe
b. Oil
c. Radiator
d. Spark plugs

13. What is the most common cause of an internal engine leak between the oil passage and water jacket?

a. Defective core plugs
b. Cracked block
c. Cracked cylinder head
d. Broken head gasket

14. Which condition is NOT normally a cause of an air-cooled engine overheating?

a. Extremely hot weather
b. Loose shrouds
c. Dirt in the cooling fins
d. A broken fan belt

15. Two adjacent cylinders failing to fire usually indicates

a. two defective cylinders.
b. faulty spark plugs.
c. a "blown" head gasket.
d. water in the cylinders.

16. To remedy the condition of a blown head gasket, the gasket must be replaced only after

a. a good sealer is used.
b. all cylinder head bolts are checked for strength.
c. the cylinder head and block are checked for a flat, smooth surface.
d. obtaining a new cylinder head.

17. A cylinder head may be the source of preignition due to

a. a crack in the head.
b. carbon build-up.
c. water in the cylinder.
d. burning oil.

18. A cracked piston head will result in

a. intake with no compression.
b. compression, but no intake.
c. compression, but no power.
d. no compression and no power.

19. What results of a compression test indicate a need for piston ring replacement?

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

20. If an engine will <u>not</u> start, although the ignition spark and fuel supply are good, what is a possible cause of the malfunction?

a. Worn piston rings
b. Burnt valves
c. Misalined timing gears
d. Worn camshaft bearings

21. What effect will worn camshaft lobes have on the valves?

a. The valves will become burnt.
b. The opening distance will be too great.
c. The opening distance will be too short.
d. They will not close.

22. If valves are adjusted too tightly, what will be the end result?

a. Cracked pistons
b. Worn piston rings
c. Burnt valves
d. A cracked cylinder head

23. If a pushrod becomes bent, what affect will it have on the operation of the valve?

a. The valve opening will increase.
b. The valve opening will decrease.
c. The valve will become burnt.

24. What affect will poor rocker arm lubrication have on the valve train?

a. Frequent need for valve adjustment
b. Late valve opening
c. Weakening of the valve springs
d. Camshaft lobe wear

25. If a compression test indicates an open combustion chamber, what should you do before removing the cylinder head for repairs?

a. Loosen the head bolts and re-test.
b. Run the engine for about 10 minutes and re-test.
c. Change engine oil and re-test.
d. Adjust the valves and re-test.

26. What cools the valves to prevent them from burning?

a. Cylinder head
b. Cylinder block
c. Rocker arm
d. Valve seat

27. What is a major cause of crankshaft failure?

a. Insufficient coolant
b. Improper lubrication
c. Sudden acceleration
d. "Revving" the engine

Total Points: 27

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AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Lesson 4

Engine Disassembly

STUDY ASSIGNMENT: MCI 35.8, Automotive Engine Maintenance and Repair, chap 4.

LESSON OBJECTIVE: Upon successful completion of this lesson, you will be able to identify the basic procedures used in the disassembly of the reciprocating internal combustion engine.

WRITTEN ASSIGNMENT:

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 box.

Value: 1 point each

1. Poor engine repair preparation may result in failure to locate defects and cause

   a. lost parts.
   b. further damage.
   c. broken parts.
   d. cracks in the engine.

2. To prevent foreign matter from entering the engine during engine repair preparation you must

   a. clean the engine with a high pressure hose.
   b. clean the engine with cleaning solvent.
   c. remove ALL accessories.
   d. cover ALL openings.

3. If a high-pressure cleaning unit is not available, the engine may be cleaned with a high pressure water hose and then oil and grease is removed with

   a. a scraper.
   b. a "wipe rag."
   c. cleaning solvent.
   d. gasoline.

4. When the engine is thoroughly cleaned and drained, the next step is to

   a. inspect the outer surface.
   b. remove the cylinder head.
   c. make sure the shop is thoroughly cleaned.
   d. cover all openings into the engine.

5. When do you check most parts to make sure you can use them during the rebuild or repair phase?

   a. During disassembly of the engine
   b. During repair of the engine
   c. During the repair of individual parts
   d. During the reassembly of the engine

6. The cylinder head should be cleaned in an area separated from the engine block so that

   a. you have more working space.
   b. the cylinder head does not become contaminated.
   c. the engine does not become contaminated.
   d. you will not get dirty.

7. The cylinder head will warp easily when removed from the cylinder block. You can prevent this by

a. standing it straight on its end.
b. laying it flat.
c. leaning it against a sturdy object.
d. leaving it on the engine until you work on it.

8. An inspection of the cylinder head gasket will reveal what defect?

a. Defective piston rings
b. Defective valves
c. Leakage
d. Cracked piston head

9. Before removing the rocker arm shaft, what must be accomplished?

a. Remove the cylinder head.
b. Remove the rocker arms.
c. Tighten the valve adjustment.
d. Loosen the valve adjustment.

10. Preliminary inspection of the rocker arm shaft is made by

a. removing rocker arms.
b. measuring the shaft end play.
c. working the rocker arms up and down.
d. checking the valve adjustment.

11. When are the pushrods removed from the engine?

a. After removing the rocker arm cover
b. Before removing the rocker arm shaft
c. Before removing the cylinder head
d. After removing the cylinder head

12. Which test do you perform on the oil pump prior to removing it from the engine?

a. Backlash
b. Runout
c. End play
d. Side play

13. Connecting rod side play is checked between the connecting rod cap and the

a. crankpin.
b. crankshaft throw.
c. piston.
d. piston pin.

14. Why must the ridges in the cylinder be reamed before new piston rings are installed?

a. Because the piston CANNOT be removed
b. New rings will strike the ridge
c. The carbon on the ridge causes preignition
d. The piston cannot travel as high with new rings

15. When should ridges be removed from the cylinder walls?

a. Before installing a new piston or rings
b. Before removing old piston and rings
c. Each time the cylinder head is removed
d. After removing the connecting rod bearing caps

16. What is done to protect cylinder walls during the ridge reaming process?

a. Turn the engine on its side.
b. Turn the engine upside down.
c. Place an oily cloth inside the cylinder.
d. Place a clean cloth inside the cylinder.

17. Why are connecting rod caps and pistons removed one at a time?

a. To keep them in order
b. To prevent loss
c. To prevent damage
d. Because it is easier

18. To ensure proper positioning of connecting rods and caps, what is done to the components?

a. Bolt them together.
b. Mark one with the cylinder number.
c. Mark both on the same side.
d. Lay them in order on the workbench.

19. The piston is removed with a ball peen hammer. How is the hammer used to do this?

a. Tap the connecting rod with the hammer head.
b. Tap the connecting rod with the hammer handle.
c. Push the connecting rod with the hammer head.
d. Push the connecting rod with the hammer handle.

20. When removing the piston, care must be taken to prevent striking the cylinder walls and the

a. crankshaft throw.
b. crankpin.
c. piston rings.
d. piston skirt.

21. If timing gears are not checked before removal, you may have to

a. use them even if they are defective.
b. change them after reinstalling them.
c. check them after you remove them.
d. order them at a later date.

22. The backlash check of the timing gears measures the

a. free play between gear teeth.
b. movement of the gears toward and away from the engine.
c. amount of warpage in the gear.
d. time the valves open and close.

23. To perform the timing gear runout test, the dial indicator plunger is placed on the

a. timing gear retaining bolt.
b. gear tooth.
c. end of the gear.

24. To perform the camshaft end play test, the timing gear must be moved in what manner?

a. Away from the engine
b. One complete rotation
c. Rotated, just touching the teeth of the matching gear

25. The crankshaft gear is removed first because the teeth of the camshaft gear cause it to

a. resist the gear puller.
b. turn with the gear puller.
c. "pop" off the shaft too easily.
d. warp.

26. Why must the crankshaft damper retaining bolt be installed prior to installing the gear puller?

a. To prevent damage to the gear teeth
b. To prevent damage to the shaft threads
c. To prevent damage to the gear puller
d. To prevent warpage of the gear

27. Why is the camshaft gear retaining bolt loosened prior to installing the gear puller?

a. So that the puller will not break free
b. So that the gear will break free
c. To prevent damage to the puller
d. To prevent damage to the threads

28. What type puller is used to remove the clutch pilot bearing?

a. Outside caliper gear puller
b. Bolt on type gear puller
c. Slide hammer type puller
d. Inside caliper gear puller

29. What test is performed on the flywheel prior to removal?

a. Backlash
b. End play
c. Side play
d. Runout

30. What defect do we look for in the flywheel ring gear?

a. Runout
b. Side play
c. Chipped teeth
d. Backlash

31. Crankshaft end play may be measured at the

a. center and flywheel end.
b. center and damper end.
c. flywheel and damper ends.
d. center.

32. If the crankshaft end play is higher than the TM tolerance specifies, you must replace the

a. thrust bearing.
b. rear main bearing.
c. front main bearing.
d. crankshaft.

33. Crankshaft warpage usually occurs during repair when it is

a. laid on a flat surface.
b. stored in a hot room.
c. leaned against an object.
d. stored in a cold room.

34. When working on an engine which requires the camshaft to be removed before the tappets, damage to the shaft and tappets is prevented by

a. lifting each tappet as necessary while removing the camshaft.
b. turning the engine on its side to allow the tappets to clear the camshaft.
c. turning the engine upside-down.
d. try to remove the tappets first anyway.

35. To remove the camshaft, you remove the thrust plate retaining screws and

a. pull the camshaft forward.
b. pull the camshaft rearward.
c. lift the camshaft carefully out of the block.

Total Points: 35

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AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Lesson 5

Engine Repair

STUDY ASSIGNMENT: MCI 35.8, Automotive Engine Maintenance and Repair, chap 5, para 5-1 through 5-5.

LESSON OBJECTIVE: Upon successful completion of this lesson, you will be able to identify the basic procedures used in the repair of engine components of the reciprocating, internal-combustion engine.

WRITTEN ASSIGNMENT:

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 box.

Value: 1 point each

1. Usability of parts is determined through close inspection and

   a. thorough cleaning.
   b. precision measurement.
   c. length of time already used.
   d. length of time to be used.

2. When cleaning the interior of the engine, emphasis must be placed on clearing the

   a. oil passages.
   b. water passages.
   c. cylinder walls.
   d. crankcase.

3. During inspection of the engine block, you detect nicks, burrs, scores, and cracks in the machined surfaces. What is your next step?

   a. Smooth out the surfaces.
   b. Attempt to seal the cracks.
   c. Discard the block and get a new one.
   d. Seek advice from the machine shop personnel.

4. Dragging a straightedge across the top of the cylinder block is part of the procedure for locating what defect?

   a. Nicks
   b. Burrs
   c. A blown head gasket
   d. A warped cylinder block

5. A cylinder block is submitted to the machine shop for repair only when

   a. cracks are found.
   b. nicks and burrs are found.
   c. the block is warped.
   d. all defects are located.

6. When measuring a cylinder bore to determine the need for repair, what two measurements are taken?

   a. Distortion and out-of-round
   b. Out-of-round and taper
   c. Taper and distortion
   d. Distortion and parallel

7. A distorted cylinder may be repaired by what method?

   a. Honing
   b. Using an oil stone
   c. Reboring
   d. Installing oversized pistons

8. What procedure aids new piston rings in seating?

   a. Reboring
   b. Honing
   c. Using sandpaper on cylinder walls
   d. Using an oil stone on cylinder walls

9. What procedure is used to stop the hone when honing a cylinder?

   a. Switch it off when it is in the bottom of the cylinder and pull it out after stopping.
   b. Switch it off at any point in the cylinder and pull it to the top while it is turning.
   c. Pull it completely out of the cylinder before switching it off.

10. What must be done to the honing stones while honing the cylinder?

    a. Keep the stones wet.
    b. Keep the stones dry.
    c. Keep the stones rotating slowly.
    d. Keep the stones rotating at the highest possible speed.

11. Proper fit of new insert-type liners is accomplished by what method?

    a. Honing
    b. Boring
    c. Shaving
    d. Planing

12. What tool is used in the removal of an insert-type cylinder liner?

    a. Ball peen hammer
    b. Brass drift
    c. Gear puller
    d. Hydraulic ram and remover and replacer kit

13. What must be done to a new cylinder liner after it has been installed?

    a. Apply a light coat of OE 10
    b. Polished with a light sand paper
    c. Tested
    d. Honed

14. The cylinder liner must be pressed into the cylinder until the

    a. micrometer reads zero.
    b. mechanic's scale reads 0.10.
    c. liner flange is seated.
    d. mechanic's square is even.

15. The cylinder bore must be cleaned prior to installing the liner. This is accomplished by

    a. exterior type cleaner.
    b. interior type cleaner.
    c. crocus cloth and dry cleaning solvent.
    d. liner flange type cleaner.

16. Two things NOT used when installing cylinder liners are

    a. the shoe and remover sleeve.
    b. the ram kit and adapters.
    c. crocus cloth, and oil.
    d. OE 10-20 grade oil and proper tools.

17. When the cylinder liner is installed, if it does not fit into position, what action must be taken?

    a. Try a new liner.
    b. Try new sealing rings
    c. Stop and investigate the cause.
    d. Start the entire procedure over.

18. Badly scored valve tappet bores may be repaired by what method?

    a. Honing
    b. Reaming
    c. Using sandpaper
    d. Using crocus cloth

19. Valve tappet clearance is checked with the use of a

a. feeler gage.
b. micrometer.
c. mechanic's scale.
d. dial indicator.

20. Camshaft front and rear bearings are removed from the engine by installing the remover at their respective ends of the engine. The inner bearings may be removed from which end?

a. Front only
b. Rear only
c. Either end

21. Before installing new camshaft bearings, the engine block must be marked to

a. ensure the correct bearing is installed.
b. position the bearing ends properly.
c. ensure the bearing is not installed inverted.
d. ensure the oil passages are alined.

22. What two tools are used to remove core plugs from the engine block?

a. Ball peen hammer and chisel
b. Slide hammer and chisel
c. Ball peen hammer and drill
d. Slide hammer and drill

23. You are installing a new core plug in an engine block. At what point is the plug installed to its proper depth?

a. When the plug seats in the rear, and can be driven no further
b. When the plug is installed evenly, regardless of depth
c. When the installer flange is flush with the block
d. When the outer edge of the plug is flush with the block

24. Damage to the machined surfaces of the crankshaft will result in

a. immediate engine failure.
b. clogged oil passage.
c. rapid bearing wear.
d. loss of oil.

25. Cracks in the crankshaft are signs of

a. poor fit.
b. metal fatigue.
c. poor lubrication.
d. worn bearings.

26. To determine the out-of-round of crankshaft main journals and crankpins, two measurements are taken at what point(s)?

a. The rear of the journal or crankpin
b. The front of the journal or crankpin
c. The center of the journal or crankpin
d. Both ends of the journal or crankpin

27. What instrument is used to measure crankshaft out-of-round?

a. Micrometer
b. Mechanic's scale
c. Dial indicator
d. Square

28. A dial indicator is used to measure crankshaft runout at what point(s) on the crankshaft?

a. All main journals
b. All crankpins
c. The center main journal
d. The center crankpin

29. Crankshaft end play is reduced or eliminated with the use of

a. new center main bearings.
b. new connecting rod bearings.
c. new main thrust bearings.
d. bearing shims.

30. When measuring new bearings for crankshaft end play, what measuring device is used?

a. Dial indicator
b. Feeler gage
c. Micrometer
d. Mechanic's scale

31. What is used to measure the bearing-to-crankshaft fit?

a. Plastigage and feeler gage
b. Feeler gage and dial indicator
c. Dial indicator and micrometer
d. Telescopic gage and plastigage

32. Which condition would not necessarily warrant discarding the flywheel?

a. A chipped ring gear
b. Heat checks
c. Cracks
d. Scoring

33. Prior to placing a piston in a vise for repair, what action must be taken?

a. Remove the connecting rod.
b. Cover the piston rings.
c. Cover the vise jaws.
d. Remove the vise jaw cover.

34. What is the procedure for replacing a flywheel ring gear?

a. Heat the flywheel and new ring gear.
b. Cool the flywheel and new ring gear.
c. Heat the flywheel and cool the new ring gear.
d. Cool the flywheel and heat the new ring gear.

35. In what order are piston rings removed?

a. From the top beginning with the top ring
b. From the top beginning with the bottom ring
c. From the bottom beginning with the top ring
d. From the bottom beginning with the bottom ring

36. The piston pin must be removed in order to accomplish removal of the

a. piston pin retainer.
b. piston rings.
c. connecting rod.
d. piston from the block.

37. What portion of the piston may be cleaned with a wire brush?

a. Head
b. Ring grooves
c. Ring lands
d. Skirt

38. Special tools are designed to clean what portion of the piston?

a. Head
b. Ring grooves
c. Ring lands
d. Skirt

39. Piston fit is checked with the piston in what position?

a. Halfway inside the cylinder
b. Level with the cylinder top
c. Top side up
d. Bottom side up

40. Which tool or combination of tools is used to check piston fit?

a. Dial indicator only
b. Dial indicator and feeler gage
c. Feeler gage and tension scale
d. Feeler gage only

41. The clearance between the piston and the cylinder walls is determined by the

a. thickness of the feeler gage used.
b. size of the tension scale used.
c. tension indicated on the tension scale.
d. thickness of the gage and the pull in pounds.

42. Piston ring end gap and side clearance are checked with a feeler gage. Which is correct for these measurements?

    a. End gap and side clearance are checked with the ring in the cylinder.
    b. End gap and side clearance are checked with the ring installed on the piston.
    c. End gap is checked in the cylinder and side clearance on the piston.
    d. End gap is checked on the piston and side clearance in the cylinder.

43. Piston pin to connecting rod clearance (piston pin fit) is checked with which instruments?

    a. Telescopic gage and feeler gage
    b. Feeler gage and dial indicator
    c. Dial indicator and micrometer
    d. Micrometer and telescopic gage

44. Which tool, or combination of tools is used to remove and install piston pin bushings?

    a. Arbor press
    b. Hammer and chisel
    c. Hammer and drift
    d. Hammer, chisel, and drift

45. To check the out-of-round and taper of a connecting rod bearing, measurements must be taken at each end of the bore. At what points are these measurements taken?

    a. One is taken in-line with the rod and two at 45° angles to the first one.
    b. One is taken at a 90° angle to the rod, and two are taken at 45° angles to the first one.
    c. One is taken in-line with the rod, and one is taken at a 90° angle to the rod.
    d. One is taken at a 45° angle to the rod, and one is taken at a 90° angle to the first.

Total Points: 45

* * *

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AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

Lesson 6

Engine Repair and Reassembly

STUDY ASSIGNMENT: MCI 35.8, Automotive Engine Maintenance and Repair, chap 5, para 5-6 through 5-7, and chap 6.

LESSON OBJECTIVE: Upon successful completion of this lesson, you will be able to identify the basic procedures used in the repair of cylinder heads and valve mechanisms, and in the reassembly of an engine after all repairs have been accomplished.

WRITTEN ASSIGNMENT:

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 box.

Value: 1 point each

1. When removing the valves, which tool is required?

   a. Valve guide reamer
   b. Valve guide remover installer
   c. Valve spring expander
   d. Valve spring compressor

2. The valve spring seat can only be removed after the ______ ______ is(are) removed.

   a. valve guide
   b. stem locks
   c. valve seat
   d. valve springs

3. To check for cylinder head warpage, which gage is used?

   a. Feeler gage
   b. Dial indicator
   c. Plastigage
   d. Micrometer

4. What is the purpose of grinding the cylinder head?

   a. To aid valve seating
   b. To obtain a flat gasket surface
   c. To eliminate burrs
   d. To eliminate the need for a cylinder head gasket

5. What is the purpose of a valve seat runout test?

   a. To ensure that the valve seat is wide enough
   b. To ensure that the valve seat is not too wide
   c. To ensure that the valve seat is round
   d. To ensure that the valve seat is smooth

6. To check valve seat runout, the dial indicator is attached to the

a. cylinder head gasket surface.
b. valve seat.
c. valve guide.
d. spark plug hole.

7. What affect will a valve seat have on the valve if it is not of the proper width?

a. Improper cooling
b. Valve stem warpage
c. Valve stem wear
d. Valve face wear

8. The valve seat may be raised or lowered, as required, by what method?

a. Replacing the valve seat insert
b. Raising or lowering the position of the valve seat insert
c. Grinding the valve seat

9. If a valve seat is warped or damaged beyond repair, what tools are used to remedy the defect?

a. Drill motor and grinding stone
b. Hammer, chisel, and drift
c. Puller and arbor press
d. Puller, hammer, and drift

10. To check valve stem to valve guide clearance, the dial indicator plunger is placed against the valve at what point?

a. Valve head
b. Valve face margin
c. Valve face
d. Valve stem

11. In some cases, a damaged valve guide may be used if an oversized valve can be obtained. What can you do to make the valve guide usable?

a. Hone the bore.
b. Ream the bore.
c. Drill the bore.
d. Sandpaper the bore.

12. In order to remove a valve guide from an L-head engine, what must be done to the guide?

a. Break off the top of the guide.
b. Break off the bottom of the guide.
c. Drill out the guide.
d. Drive it out from the bottom.

13. In order to prevent the valve guide from being driven too deep during installation, what method should be used?

a. Mark the guide at the specified distance from the top.
b. Mark the guide at the specified distance from the bottom.
c. Hold a mechanic's scale alongside the guide while driving it in.
d. Watch the valve seat end of the guide to ensure it is driven flush with the edge of the casting.

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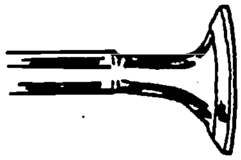
14. The valve illustrated below has what defect?

a. Worn stem
b. Warped stem
c. Cocked stem
d. Burned face



15. If valve face runout exceeds the limits of the manufacturer's specifications, what may be done to correct the defect?

a. Grind the valve seat.
b. Grind the valve face.
c. Grind the valve face margin.
d. Grind the valve stem.

16. In the repair of the valve train, three tests are performed on the valve spring. Which of these tests, when manufacturer's specifications are not met, would NOT require you to discard the valve?

a. Valve spring squareness
b. Valve spring pressure
c. Valve spring installed height

17. To clean the bore of the rocker arm shaft, the ________ must be removed.

a. "O" ring
b. oil tubes
c. springs
d. expansion plug

18. To correct excessive wear of the rocker arm shaft, what action must be taken?

a. Replace the shaft.
b. Grind the shaft.
c. Use oversized rocker arms.
d. Use undersized rocker arms.

19. If wear is not visible on the rocker arm shaft and the rocker arm bore, they must be checked next with what device?

a. Feeler gage
b. Dial indicator
c. Micrometer
d. Mechanic's scale

20. Which pushrod defect cannot be corrected without replacing the component?

a. Nicks
b. Scores
c. Burrs
d. A bent condition

21. If a dial indicator test indicates that a valve tappet has become worn to the extent that it is too small for the tappet bore, what action should you take?

a. Replace the tappet with a new one of the original size.
b. Hone the tappet bore to prevent further wear.
c. Ream the bore and use an oversized tappet.
d. Switch the tappet with one from another bore, as this will compensate for the excessive wear.

22. During the main oil gallery pressure check of the camshaft, air bubbles appearing at the surface of the water indicates a faulty

a. main oil gallery.
b. main bearing surface.
c. oil passage.
d. oil plug.

23. In what position must the camshaft be to perform the cam lobe lift test?

a. In its original position in the engine
b. In an inverted position in the engine
c. Laid on a workbench
d. Standing perpendicular on a workbench

24. Cam lobe lift is measured by placing a dial indicator at the lowest point of the lobe and rotating the camshaft what amount?

a. One-fourth of a turn
b. To the highest point
c. Three-fourths of a turn
d. One complete turn

25. The camshaft is placed in "V" blocks to perform what test?

a. Strength
b. Wear
c. Runout
d. End play

26. A warped camshaft, when reinstalled in an engine, will cause

a. vibration.
b. engine runout.
c. rapid bearing wear.
d. camshaft runout.

27. To determine camshaft bearing running clearance, you must measure the inside diameter of the bearing and the

a. outer diameter of the bearing.
b. outer diameter of the camshaft main bearing journal.
c. inner diameter of the bore of the casting.

28. The crankshaft rear main bearing differs from other main bearings in what respect?

a. It is larger.
b. It is smaller.
c. It has no seal.
d. It has a seal.

29. Before you install the crankshaft main bearing halves in the engine, you must

a. measure them.
b. clean and dry them.
c. clean and lubricate them.
d. torque them.

30. The crankshaft-bearing-half tang must fit into the slots provided or the halves will

a. turn.
b. wear rapidly.
c. not seat.
d. break.

31. When installing bearing caps, what must be done to the bearing cap bolts?

a. They must be thoroughly dried.
b. They must be dipped in cleaning solvent.
c. They must be lubricated with OE 10.
d. They must be lubricated with GAA.

32. How is the center main bearing cap centered?

a. By placing it in position and measuring
b. By prying both sides of the cap against the crankshaft
c. By prying the bearing and crankshaft toward the front of the engine
d. By holding the crankshaft at one end of the engine, while prying the bearing cap into position

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

a. The front
b. The center
c. The rear
d. The first bearing installed

34. After the crankshaft is installed, it must be checked for

a. runout.
b. end play.
c. backlash.
d. running clearance.

35. Which is NOT a necessary check after camshaft installation?

a. End play
b. Backlash
c. Runout
d. Running clearance

36. Which is the correct sequence for tightening flywheel bolts during installation?

a. Clockwise
b. Counterclockwise
c. Every other bolt
d. Across from one another

37. What method is used to install pilot bearings?

a. Arbor press
b. Hammer and drift
c. Slide hammer
d. Gear puller/installer

38. What protects the crankpins during piston installation?

a. The connecting rod cap bolts
b. The connecting rod saddle shoulder
c. A rubber hose installed on the rod cap bolt
d. A rubber hose installed on the rod saddle shoulder

39. When a piston is notched, what does the notch indicate?

a. Front
b. Left side
c. Right side
d. Rear

40. A ring compressor is used during piston installation to ensure that the rings do not

a. slip out of the grooves.
b. bind against the lands.
c. slip out of the cylinder.
d. bind against the top edge of the cylinder.

41. Before tapping or pushing the piston into the cylinder the crankpin should be positioned at what point of its rotation?

a. TDC
b. 90° after TDC
c. BDC
d. 90° before TDC

42. What check should be made after each piston is installed?

a. Connecting rod bearing running clearance
b. Connecting rod end play
c. Connecting rod side play
d. Connecting rod backlash

43. Prior to installing the oil pump, number one piston should be brought to the top of the cylinder, and the timing gear marks alined

a. 180° apart.
b. 90° apart.
c. 45° apart.
d. according to manufacturer's specifications.

44. To install the oil pan, the screws are tightened in what sequence?

a. Front to rear
b. Rear to front
c. Center to ends

45. During valve installation, which of the following items is NOT installed on the valve stem, prior to compressing the valve spring?

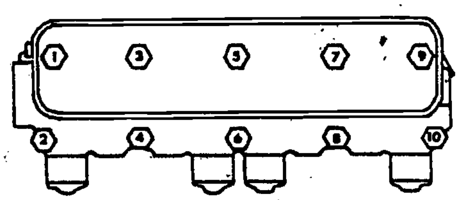
a. Valve stem lock
b. Valve spring sleeve
c. Valve stem seal
d. Valve spring retainer

46. When installing the valves in an L-head engine, what is the first component to be placed in position?

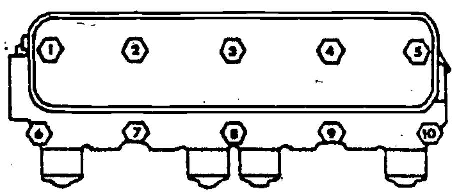
a. Valve
b. Valve spring
c. Valve locks
d. Valve spring retainer

47. Which illustration represents the correct sequence for tightening cylinder head bolts?

a.



b.



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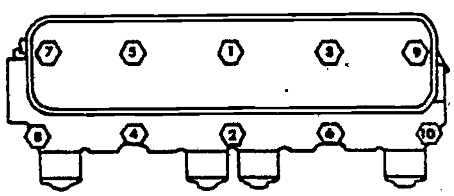

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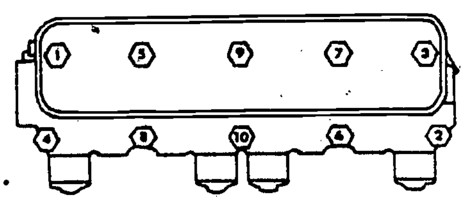

48. Where does the pushrod seat when it is installed in the engine?

a. In the valve tappet bore
b. In the valve tappet recess
c. On the cam lobe
d. On the rocker arm

49. While installing the rocker arm shaft assembly, the rocker arm <u>must</u> seat on both the valve stem and the

a. rocker arm shaft support.
b. rocker arm locating spring.
c. pushrod.
d. tappet.

50. What is the last task to be accomplished in the assembly of the engine?

a. Install the rocker arm shaft.
b. Adjust the valves.
c. Seat the rocker arms.
d. Seat the pushrods.

Total Points: 50

* * *

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AUTOMOTIVE ENGINE MAINTENANCE AND REPAIR

MARINE CORPS INSTITUTE
MARINE BARRACKS
WASHINGTON, D.C.

8-1

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PREFACE

Automotive Engine Maintenance and Repair is designed to help Marines, Private through Sergeant, in MOS 3521, increase their knowledge about the construction, operation, malfunction diagnosis, maintenance, repair, and overhaul of the internal-combustion, reciprocating engine.

SOURCE MATERIALS

TM 9-8000	Principles of Automotive Vehicles, Jan 1956
TM 9-2320-211-20	Truck, Chassis, 5-Ton, 6x6, Jun 1973 w/Ch 1 Jun 1973
TM 9-2320-211-35	DS, GS, and Depot Maintenance For Truck, Chassis, 5-Ton, 6 x 6, Sep 1964 w/Ch 1 Jun 1965
TM 9-2320-213-20	Truck, Platform Utility, 1/2-Ton, 4 x 4, Oct 1965 w/Ch 1 Oct 1965
TM 9-2320-218-20	Truck, Utility, 4 x 4, M151, M151A1, M151A2, Sep 1971 w/Ch 1 Feb 1972
TM 9-2320-218-34	DS and GS Maintenance, Truck, Utility, 4 x 4, 1/4-Ton, Jan 1972 w/Ch 1 Oct 1973
TM 9-2815-213-34	Engine, Diesel, with Accessories, Cummins Model V8-300, Feb 1972
TM 9-2815-214-34	GM Model 3-53 Engine, Diesel, Mar 1970

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Chapter 1

BASIC ENGINE CONSTRUCTION AND OPERATION

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 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.

Let's take a look now at what you will be doing 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 tuneups. 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 and, sometimes the entire vehicle.

We will start you on the road to success as a good mechanic by presenting to you 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 lesson.

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

Section I. ENGINE CONSTRUCTION

1-1. ENGINE BLOCK

The engine block functions as the main body of the engine. We call it 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, we are going to discuss it in two parts; the crankcase and the cylinder block.

First, let's discuss the lower portion of the engine block. This, as you can see in figure 1-1, is the crankcase.

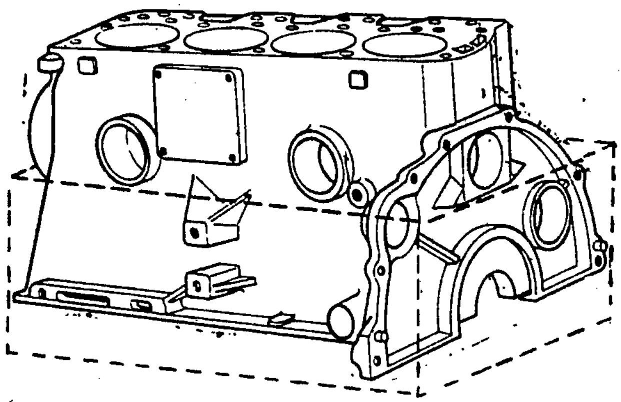

Fig 1-1. Four-cylinder engine block with crankcase enclosed by an imaginary box (left rear view).

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.

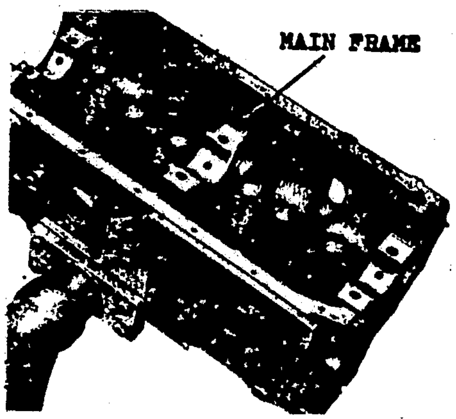

Fig 1-2. Four-cylinder engine block (bottom view).

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

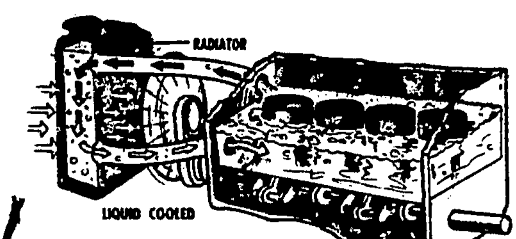

Fig 1-3. Four-cylinder engine block showing water jacket with coolant flow around the cylinders.

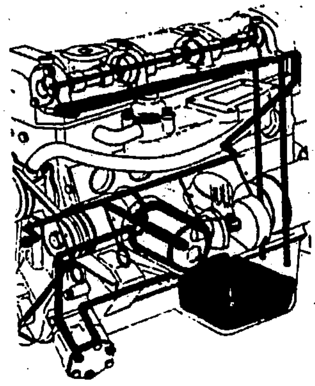

Fig 1-4. Oil passages of a three-cylinder engine.

The cylinders are individual housings for the pistons. They are large holes cut 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 also, in most cases, contains a camshaft, and, in some cases, contains 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. The larger of these are valve ports. Some of the others are cut into the water jacket and others are cut into the oil passages. Later, we will learn why this is done. The surface of the cylinder block top is machined smooth, and must be perfectly flat. This brings us to the next part to be discussed, the cylinder head.

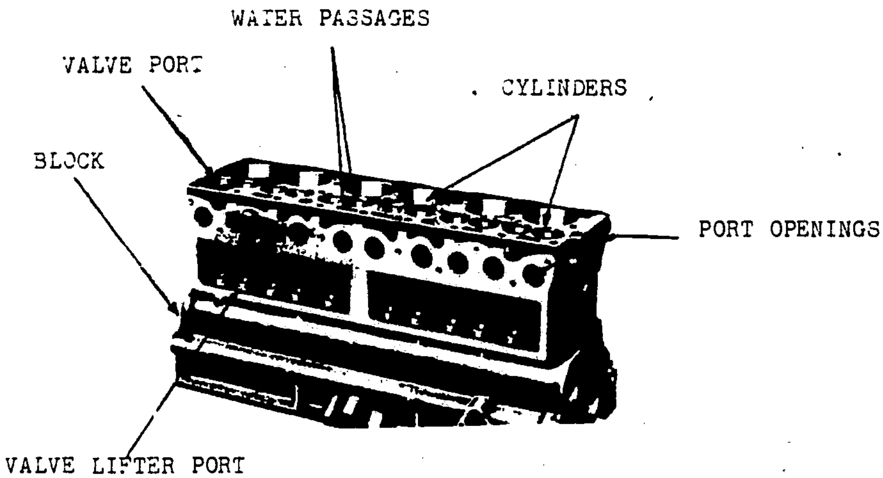

Fig 1-5. Six-cylinder engine block (right rear view).

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1-2. CYLINDER HEAD

The cylinder head is bolted to the machined surface we 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.

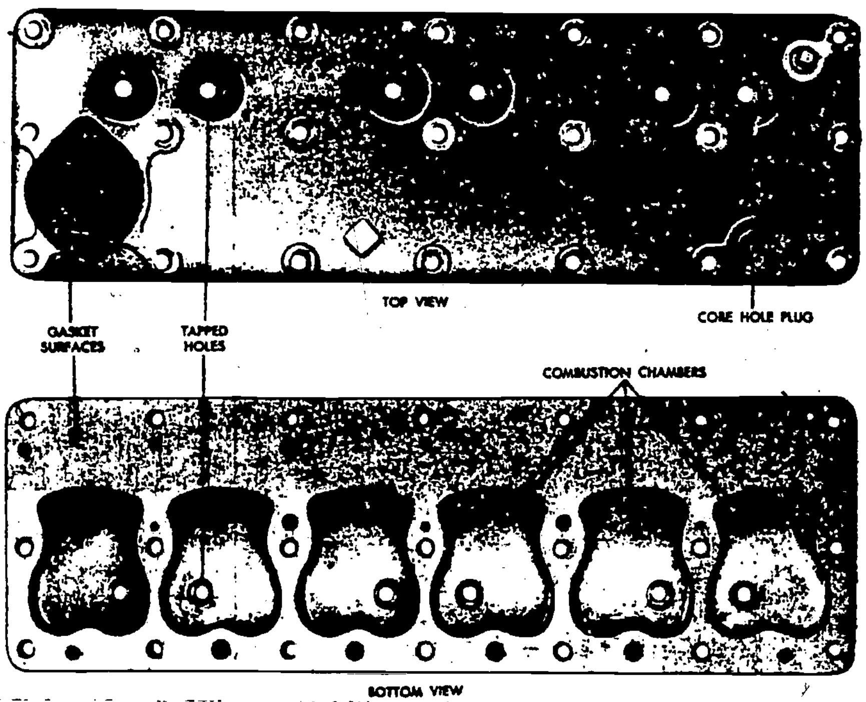

Fig 1-6. Cylinder head of a six-cylinder engine (valves housed in engine block).

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 which you see in the top of the cylinder head. 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.

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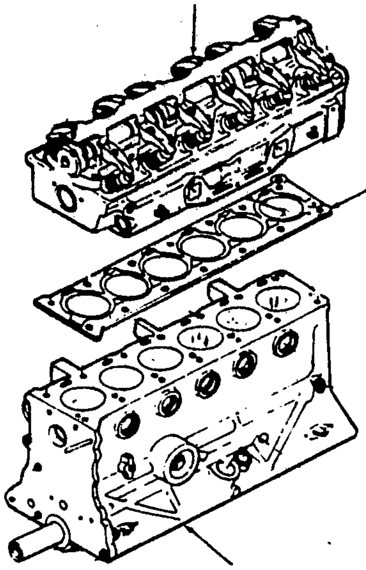

Fig 1-7. Six-cylinder engine block and cylinder head (valves housed in head).

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

1-3. PISTON AND RELATED PARTS

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. We want to convert this heat energy into mechanical energy to operate the engine. This is the function of the piston. 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. Let's take a look at this piston we are talking about in figure 1-8.

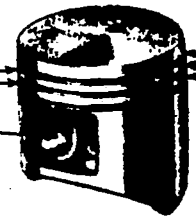

Fig 1-8. The piston.

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 we allow some of the energy produced by the burning gases to pass between the piston and the cylinder walls, it becomes wasted energy; therefore, we must have a pressure-tight seal between the piston and the cylinder walls. To get the seal, we make use of the lands and grooves near the top of the piston in the following manner. We 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 we 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, if the oil remained on the cylinder walls, it 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.

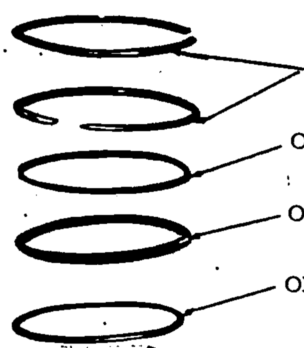

Fig 1-9. Piston rings.

So far we 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 we 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 we use the hole in the piston that was mentioned earlier. A snug-fitted pin is manufactured for this hole, which we will call 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.

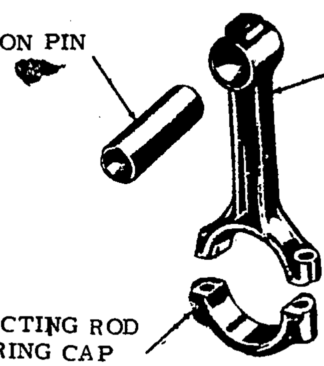

Fig 1-10. Connecting rod and related parts.

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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.

1-4. CRANKSHAFT

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 1-11). Some of these journals are on the shaft inself, and others are located on the throws. The journals on the centerline of the shaft are main journals; those located on the throws are crankpins. As you have probably noticed in figure 1-11, the throws cause the crankpins 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 main journals after the crankshaft is positioned in the crankcase.

The purpose of the crankpins 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 crankpin 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 1-12).

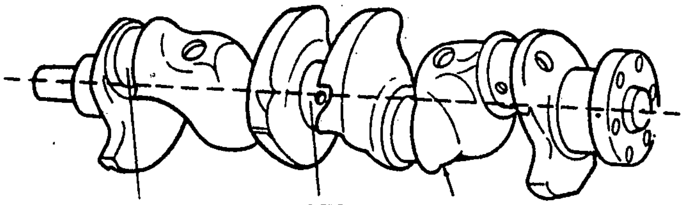

Fig 1-11. Four-cylinder-engine crankshaft.

In some engines there is a short interval when the pistons do not drive the crankshaft. However, if we provide enough momentum, the crankshaft can travel through this short portion of its rotation. To accomplish this, we 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 us an idea of what the components we have 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 to this point require lubrication. They are lubricated by engine oil stored inside the engine oil pan.

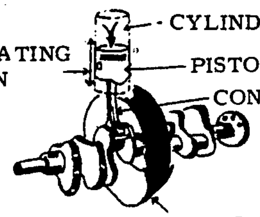

Fig 1-12. The crankshaft changes reciprocating motion to rotary motion.

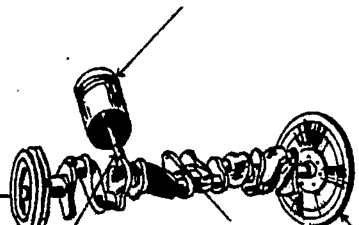

Fig 1-13. Major moving parts of the engine.

1-5. 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.

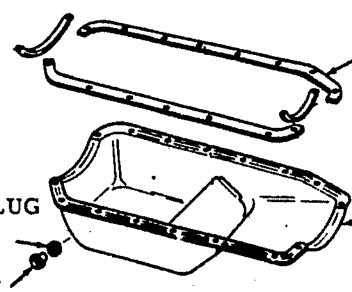

Fig 1-14. Oil pan and related parts.

1-6. VALVE MECHANISMS

Remember earlier we were discussing heat energy and mechanical energy? Well, let's discuss heat energy a little further. To have heat energy, we must burn fuel. After we have burned that fuel we 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 paragraph 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.

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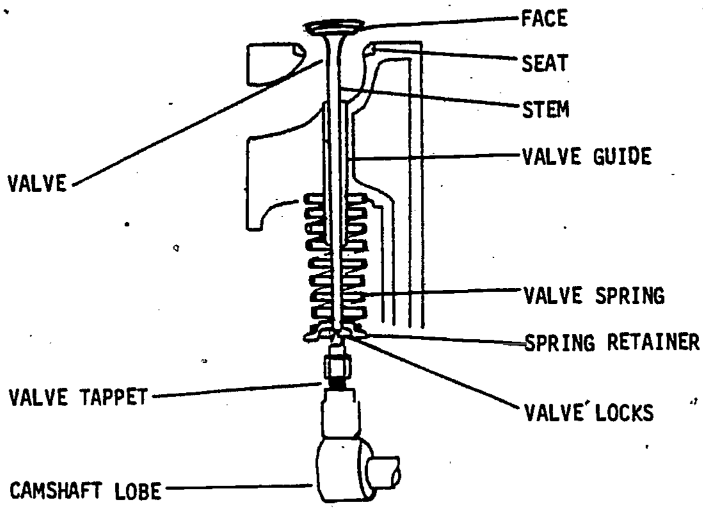

Fig 1-15. Valve mechanism, minus the camshaft and timing gears.

On the underside of the valve head (the mushroomed top) is a valve face. The 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 guide 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.

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 near 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.

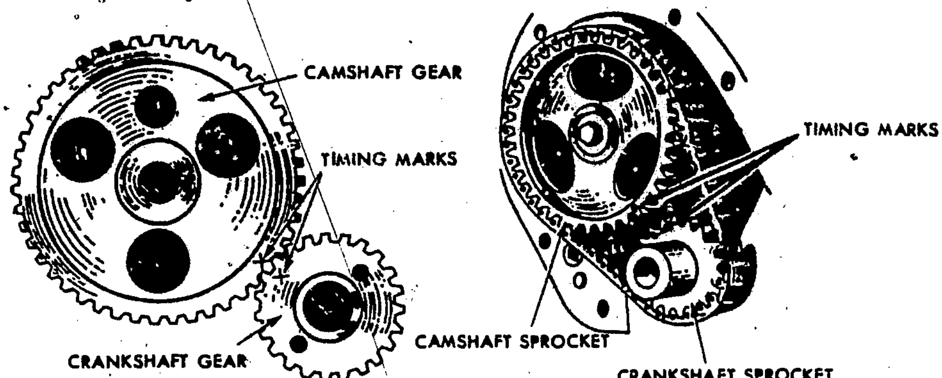

Fig 1-16. Mechanical timing mechanisms.

In some cases, due to 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, the crankshaft drives the camshaft through the use of a chain instead of direct gear drive.

Now that we 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.

Section II. ENGINE OPERATION

1-7. 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 we have used all the power that the burning gases can deliver, we 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. Each time the crankshaft makes a complete revolution, the piston accomplishes two strokes. 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.

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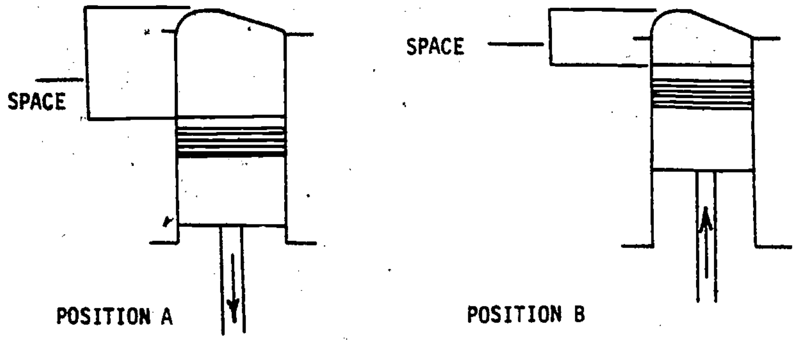


Fig 1-17. The piston strokes.

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

1-8. THE FOUR-STROKE CYCLE

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

Let's 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.

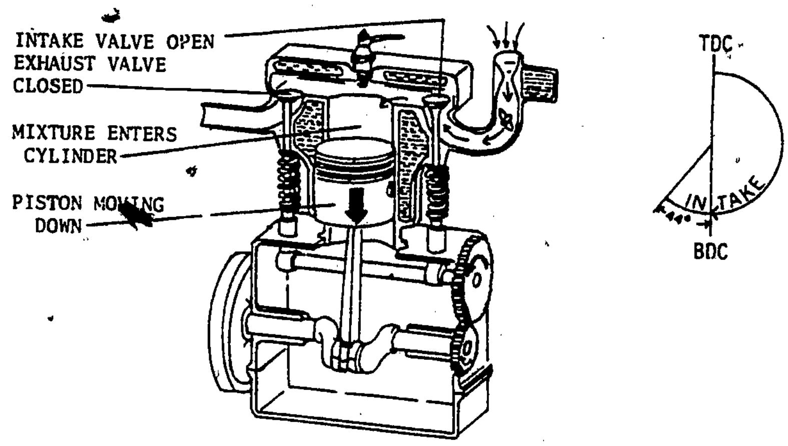


Fig 1-18. Intake stroke.

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 that the intake valve remains open, we 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.

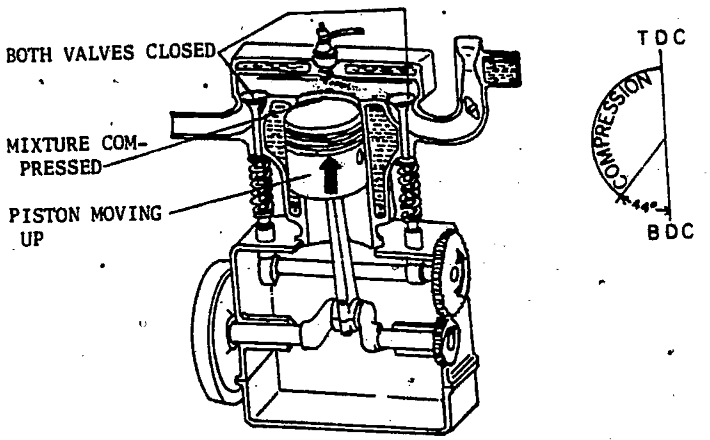


Fig 1-19. Compression stroke.

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, let's look at figure 1-20.

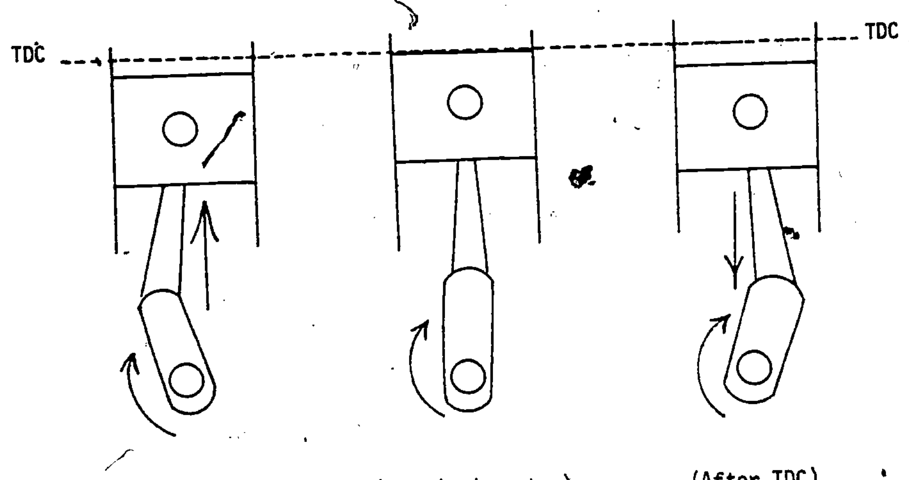


Fig 1-20. End of compression.

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 the 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 [illegible] rotate backward? It definitely may have a tendency to do this if we use the incorrect grade of gasoline, so we must choose our fuel to match the design of the engine. We will discuss fuels later in the course, but now to 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 we 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 we want as much of the hot exhaust gases out of the cylinder as possible when we begin our next cycle of operation with another intake stroke. Therefore, we are allowing 228° of crankshaft rotation to get rid of the exhaust gases. Figure 1-22 illustrates the exhaust stroke.

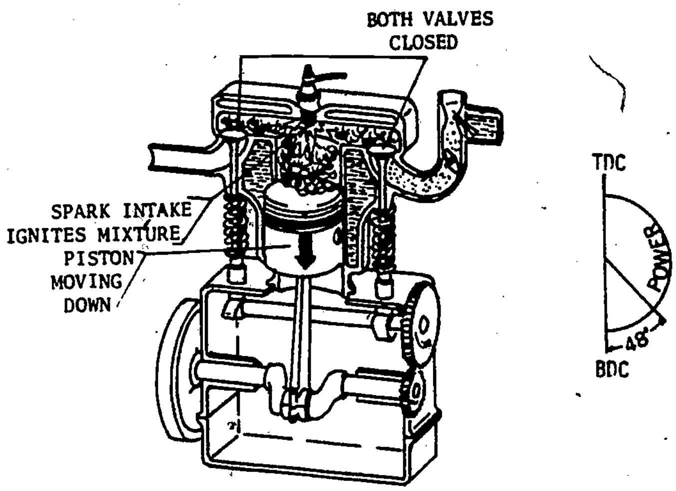


Fig 1-21. Power stroke.

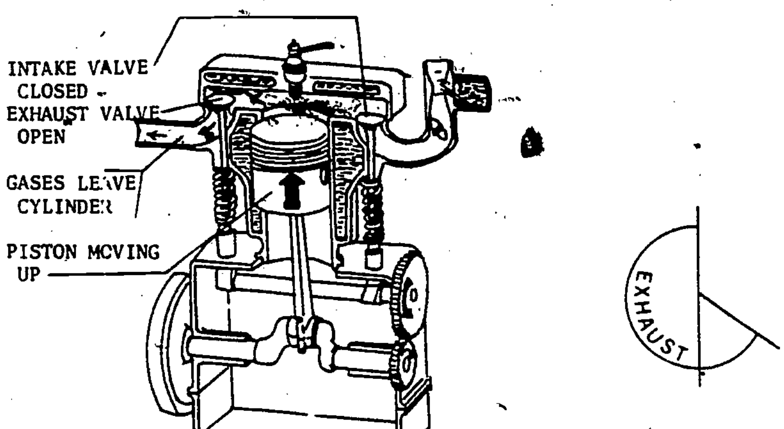


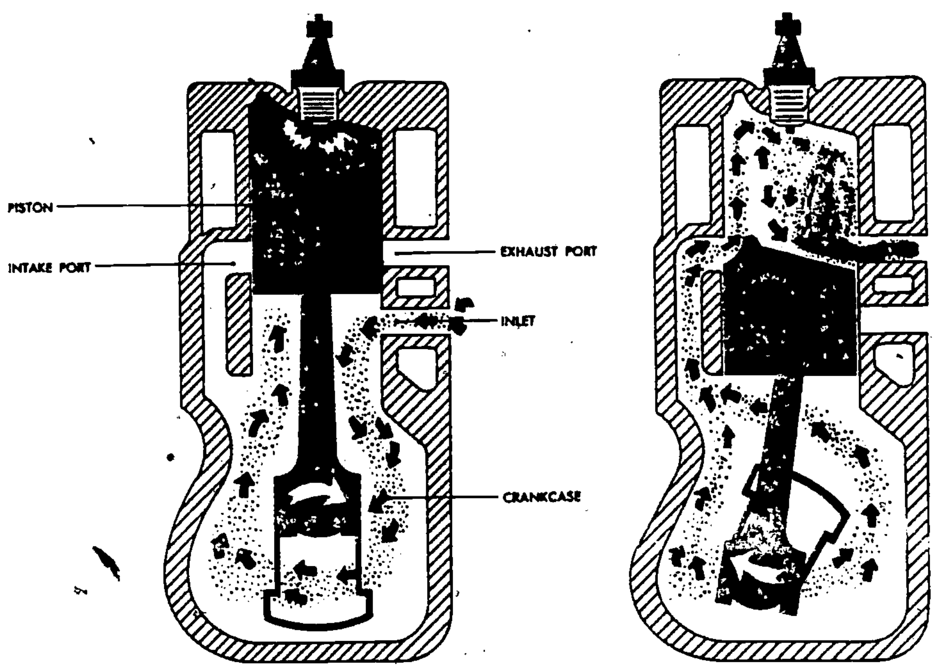
Fig 1-22. Exhaust stroke.

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-cycle engine.

Some four-stroke-cycle engines differ from others however, 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 being the combustion chambers (see para 1-10). 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.

1-9. TWO-STROKE-CYCLE

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 we must get raw gases into the cylinder and burned gases out of the cylinder. Let's turn our attention to figure 1-23 and 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. Therefore, two strokes of the piston or one complete revolution of the crankshaft completes the cycle of operation in the two-stroke-cycle engine. Although this is the most common method, there are two-stroke-cycle 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.

1-10. 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. So hot in fact, that the presence of fuel in the cylinder at this time would cause burning. 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. Immediately upon contact with the hot air, the fuel begins to burn, and 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.

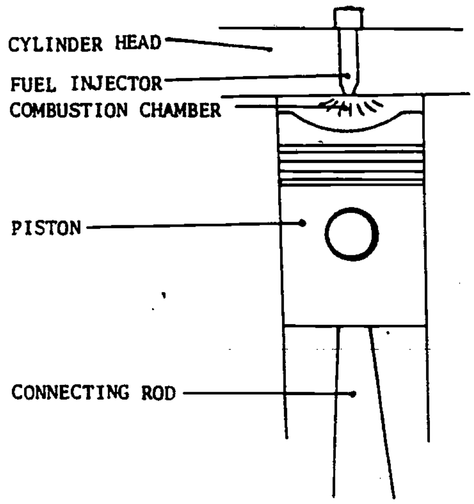


Fig 1-24. Compression ignition.

Chapter 2

ENGINE AND ENGINE COMPONENTS 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; their method of operation; and the type of fuels and cooling systems. Let's discuss these differences to familiarize you with the equipment you will be working on.

Section I. ENGINE DESIGN

2-1. 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, the V-type, and the horizontally opposed. These may be water-cooled or air-cooled. Water-cooled engines have the cylinders cast into the block (cast en bloc).

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.

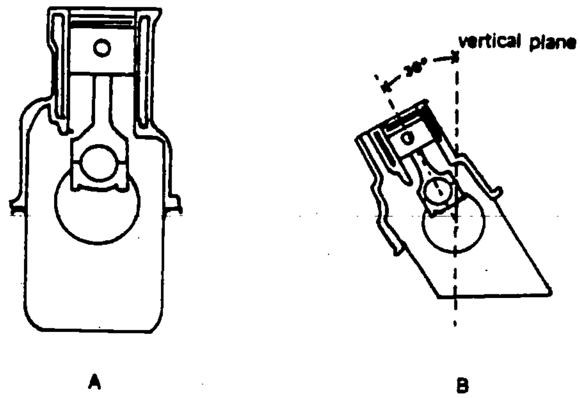


Fig 2-1. Partial cutaway front view of the cast en bloc six-cylinder engines.

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 V-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 vibration.

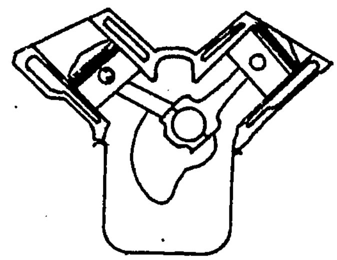


Fig 2-2. Partial cutaway front view of a V-type engine.

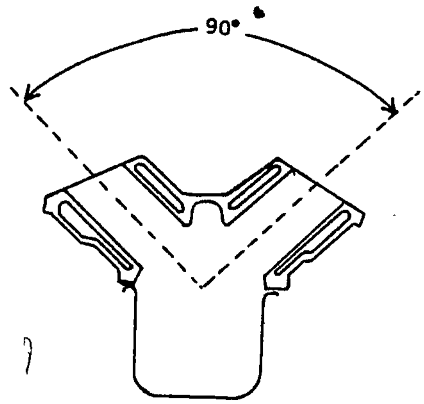


Fig 2-3. The cylinder casting angle of the V-type engine.

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.

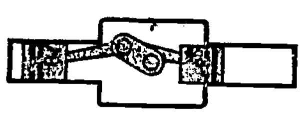


Fig 2-4. Partial cutaway view of an horizontally opposed engine.

You may have heard an engine referred to as a flat-head six, a flat-head V-8, an overhead-valve six, and overhead-valve V-8, etc. These are common terms referring to the valve arrangement and the cylinder block. Therefore, we 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.

2-2. 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.

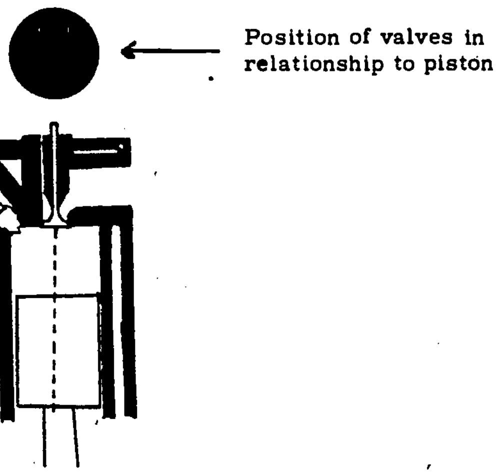


Fig 2-5. I-head valve arrangement.

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, we 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.

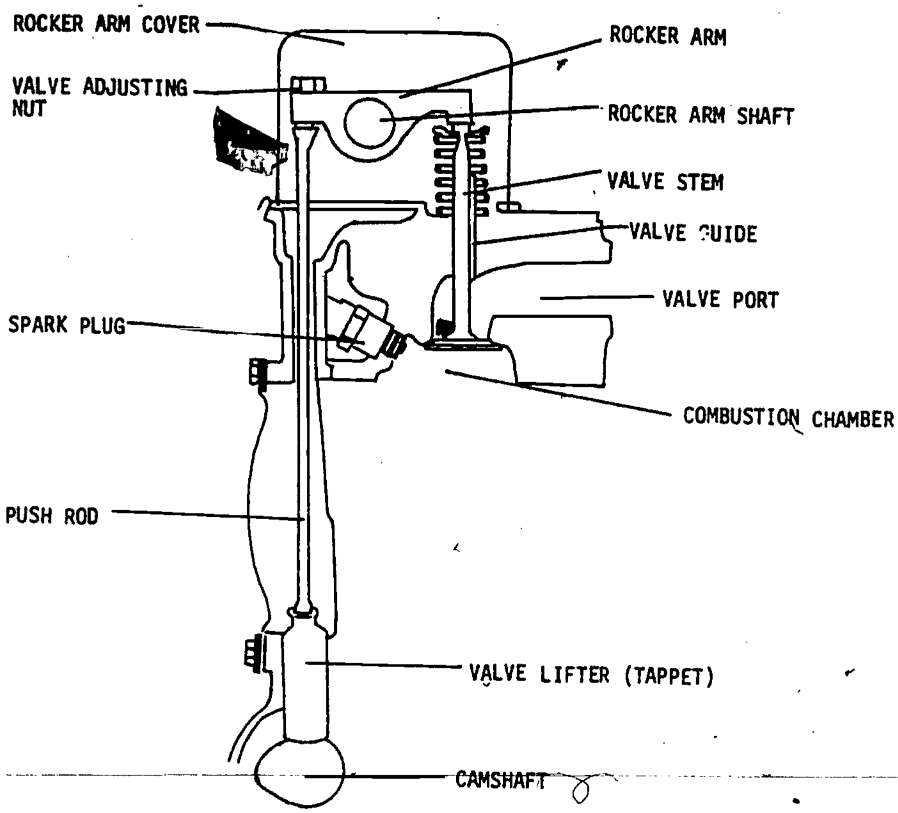


Fig 2-6. The I-head valve train.

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).

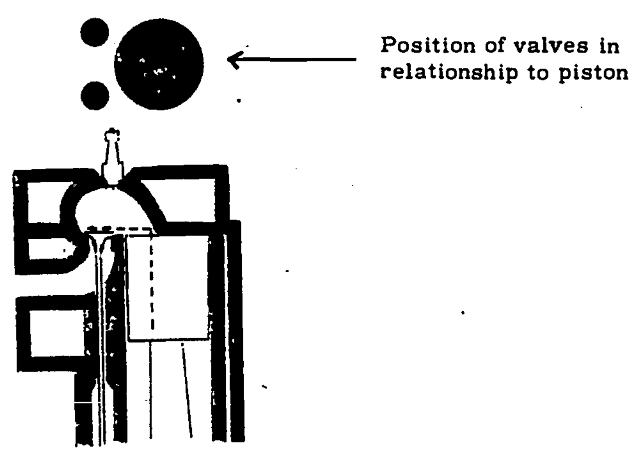


Fig 2-7. The L-head valve arrangement.

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

The final valve arrangement we will discuss 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, let's 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 through 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.

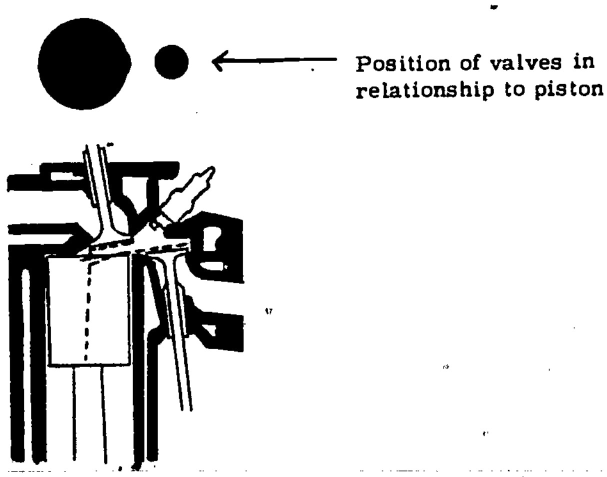


Fig 2-8. F-head valve arrangement.

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

Section II. ENGINE COMPONENTS DESIGN

2-3. ENGINE BLOCKS

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

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, however, some engines are designed to use insert-type cylinders known as cylinder liners. Cylinder liners prolong the life of an engine block because they are replaceable (fig 2-9).

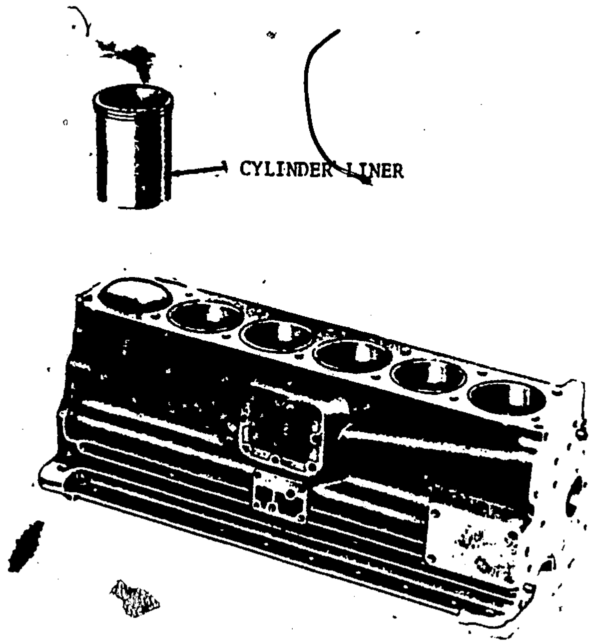


Fig 2-9. Six-cylinder engine with cylinder liners.

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 defective, only that cylinder need be removed and replaced with a new cylinder. The crankcase is usually cast as a two-piece unit and bolted together (fig 2-10). The cylinder head is of the I-head design.

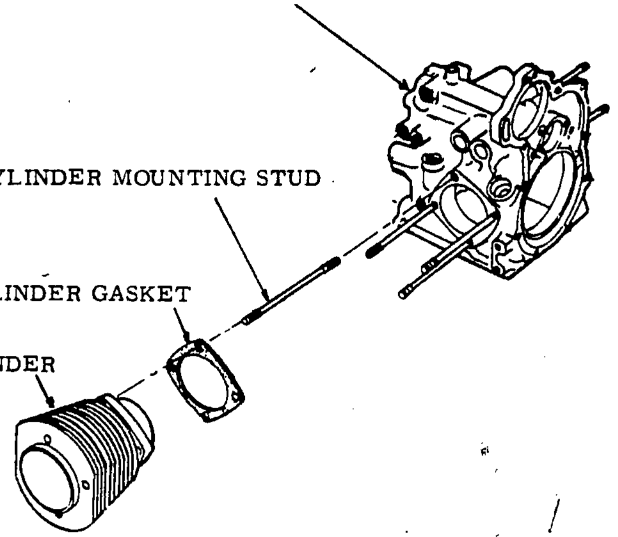


Fig 2-10. Air-cooled engine crankcase and cylinder assembly.

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2-4. CRANKSHAFTS

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 the engine block construction. The longer the block, the more throws are needed. 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.

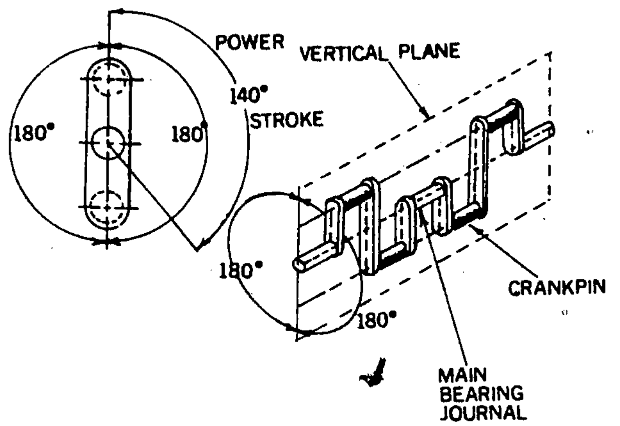

Fig 2-11. Four-cylinder engine crankshaft illustrating amount of rotation during the power stroke and the relationship of the throws.

The power lapse, which we have 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).

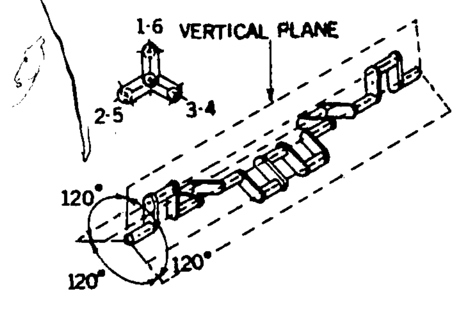

Fig 2-12. Six-cylinder in-line engine crankshaft.

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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, we 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, we find the throws arranged 120° apart, but we find only three throws. Other engines which use three throws are the horizontally opposed six and the 3-cylinder in-line. 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, we find both power overlap and power lapse. Let's 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 on 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, we have 10° of crankshaft rotation with no power being delivered to the crankshaft. This same condition continues with the remaining three pistons. The flywheel on this engine may be lighter than that of the four-cylinder in-line due to the decreased power lapse.

If we add one more throw and put each throw on a separate plane, spacing all the throws 90° apart, we have the 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. We 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 we find is true also of the V-six crankshaft.

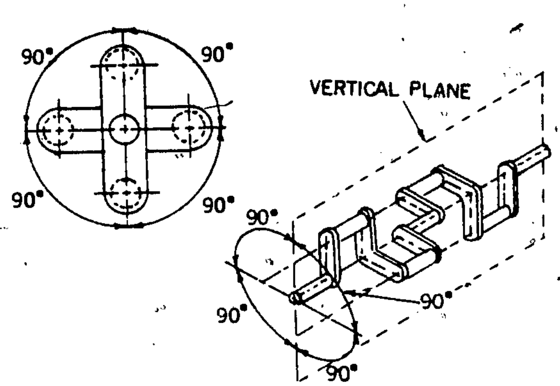


Fig 2-13. V-8 engine crankshaft.

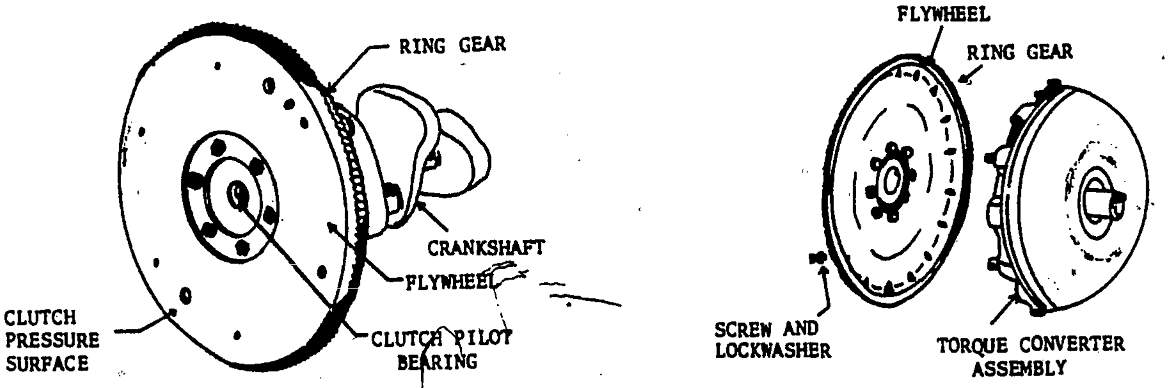
At one time or another, you will come across a three-cylinder, in-line engine's crankshaft. This crankshaft is constructed the same as the six-cylinder in-line with only half as many throws. The power overlap is the same. These crankshafts are used in diesel engines.

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.

We have found, during this discussion, that the number of throws and their length determines 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 periods of power lapse, reduces vibration, and helps the engine to operate smoothly.

2-5. 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, so 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, we mount a smaller wheel, known as a vibration damper, on the front end of the crankshaft.

2-6. VIBRATION DAMPERS

Vibration dampers are used to damp out crankshaft torsional vibration. This is a 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. We need to damp out this twisting action. This 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.

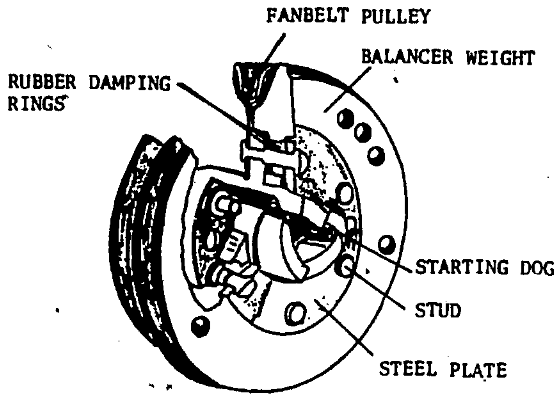


Fig 2-15. A typical vibration damper.

2-7. PISTONS

Basically, pistons are designed with the top (head) flat, raised, or concave with variations of these basic designs.

Let's look at the flat-head piston first. This design is used in gasoline engines. Low-compression gasoline engines usually stay with the basic design, but in high-compression engines in which the TDC position is extremely close to the top of the combustion chamber, the piston heads are notched, cut out, or raised on one side to allow maximum compression with room for the valves to open (fig 2-16).

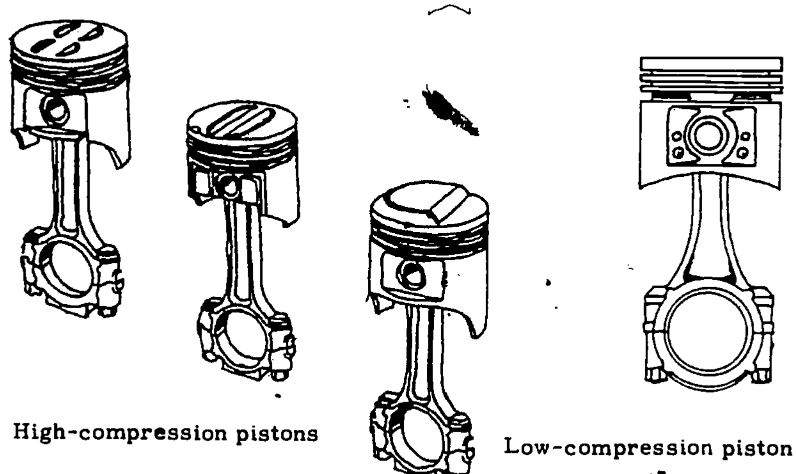


Fig 2-16. Various piston head designs for spark-ignition engines.

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).

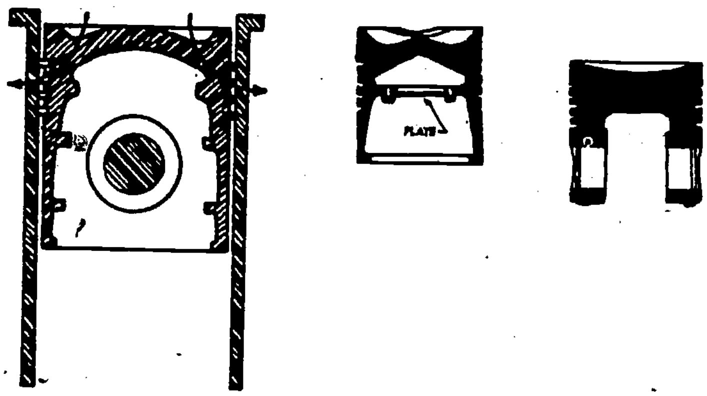


Fig 2-17. Various piston head designs for compression-ignition engines.

Gasoline-engine pistons may have ribs cast on the underside of the piston head for cooling and reinforcement. 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.

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 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.

PISTON BOSS RELIEF

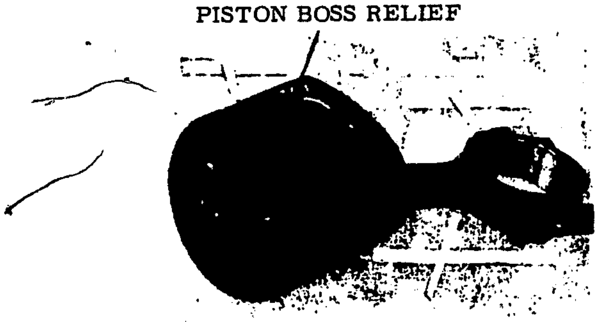
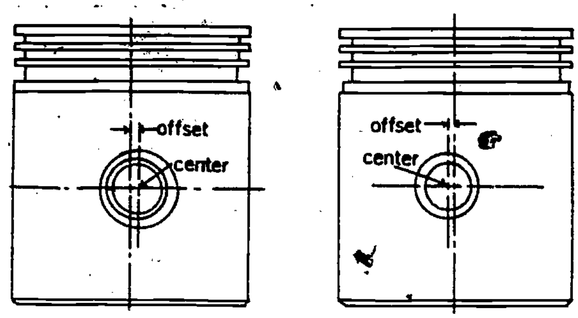


Fig 2-18. Most pistons have reliefs in the skirt surrounding the piston boss.



COMPRESSION SIDE THRUST SIDE

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 2-20). 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 differences in piston rings.

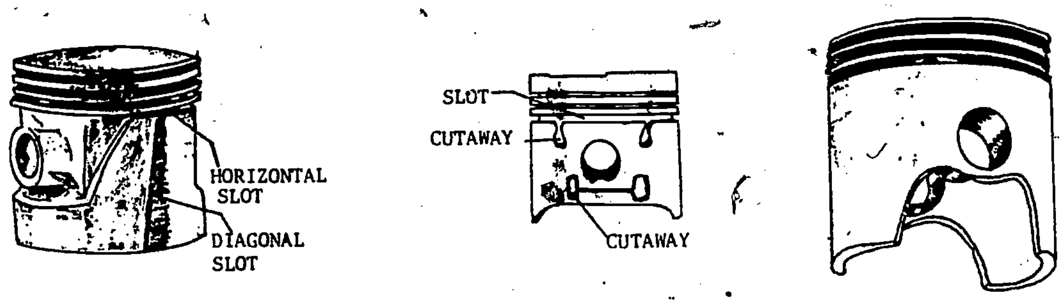


Fig 2-20. The three basic piston skirt designs.

2-8. PISTON RINGS

Most compression rings have the same general design. You will find that the primary differences in ring design are on the outer edges of the ring. These design differences are easily distinguished by a cross-sectional view of the ring (fig 2-21).

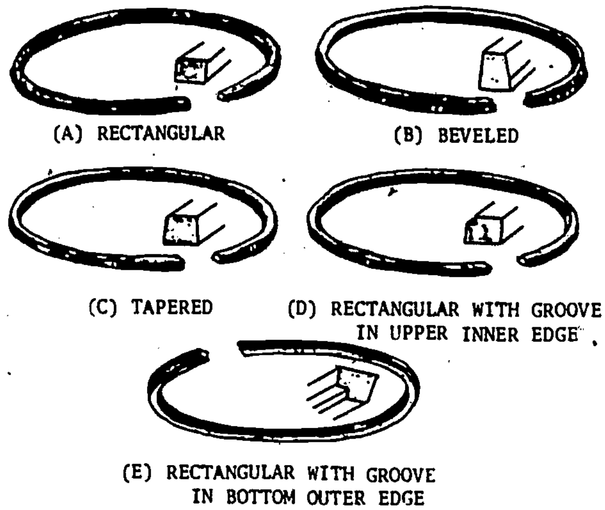


Fig 2-21. Various compression ring designs.

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 fullface 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 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 motor vehicles, so we will not discuss it in this chapter.

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.

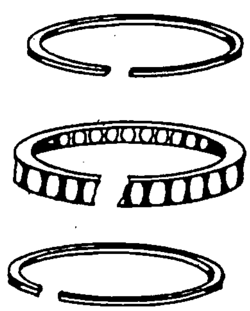


Fig 2-22. Three-piece oil control ring.

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).

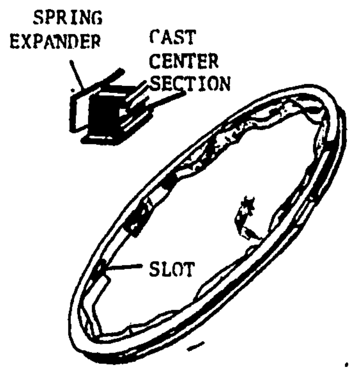


Fig 2-23. Four-piece oil control ring.

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

2-9. CONNECTING RODS

Basically, the connecting rod is 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).

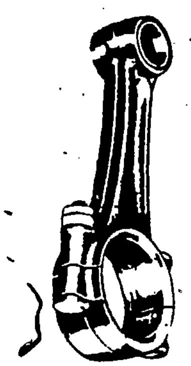


Fig 2-24. Typical connecting rod.

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.

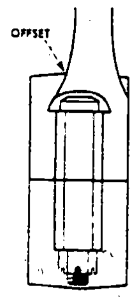


Fig 2-25. Offset connecting rod saddle used in opposed- and V-type engines.

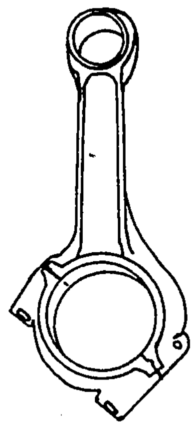


Fig 2-26. Some connecting rod saddles are cut at an angle for ease of removal and installation.

2-10. 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 arrangements discussed earlier. A major difference in cylinder-head design which has not been discussed is the difference between heads designed for gasoline engines and those designed for diesel engines.

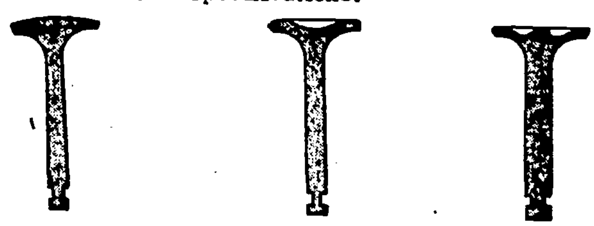
The cylinder heads we discussed earlier had portions cupped out to form a combustion chamber. These are used for gasoline (spark-ignition) engines.

If you will recall, we also stated earlier in this chapter that 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.

2-11. VALVE MECHANISMS

We will discuss 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, through 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 we have already 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.



MUSHROOM TULIP SEMI-TULIP

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 lessons to follow will dwell upon the knowledge needed to diagnose problems and the solutions to these problems through engine repair and rebuild.

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Chapter 3

ENGINE MALFUNCTION, DIAGNOSIS, AND REMEDY

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 chapter will require you to put the knowledge presented in lessons one and two to practical use in determining the results of defective engine components. As you read this chapter, you must constantly keep pictured in your mind the construction and operation of the components being discussed.

3-1. 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 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).

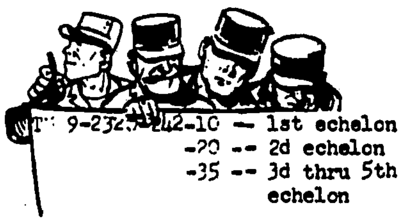

Fig 3-1. The last two digits indicate the echelon for which the technical manual is intended.

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.

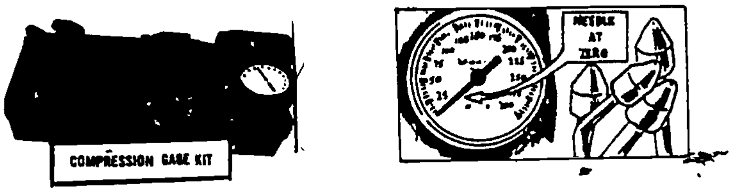

Fig 3-2. Check the compression gage kit.

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).

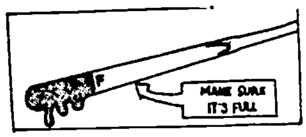

Fig 3-3. Check the oil with the dipstick.

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

Loosen all the spark plugs a turn or two, and with a low pressure air hose, blow all dirt and other foreign matter from around the spark plugs (fig 3-4). Remove the spark plugs and

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

clean any grease or oil from the spark plug hole with a clean rag. Now open the throttle and choke, and 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).

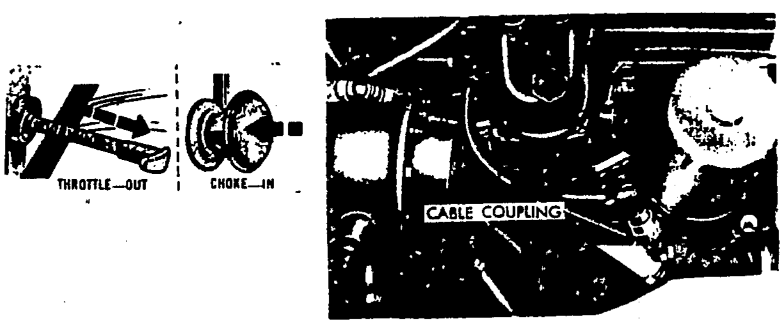

Fig 3-5. Carburetor throat must be open and ignition off.

Now for the test. Choose the proper size adapter for the compression gage. Insert the compression gage 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). Write down the amount of pressure indicated by the gage. Repeat this procedure on each cylinder until all cylinder compression

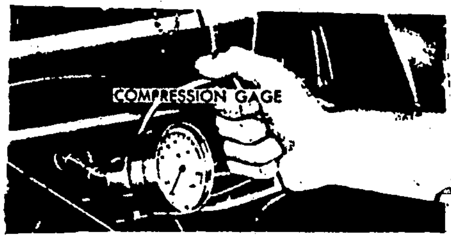

Fig 3-6. Insert compression gage into spark plug hole.

readings have been read and 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"

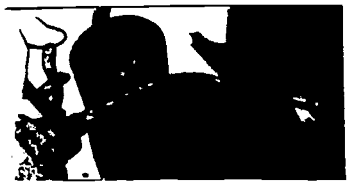

Fig 3-7. Preparation for a "wet" test.

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 not the cylinder walls. If the walls are scored however, 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 think the reasons would be?

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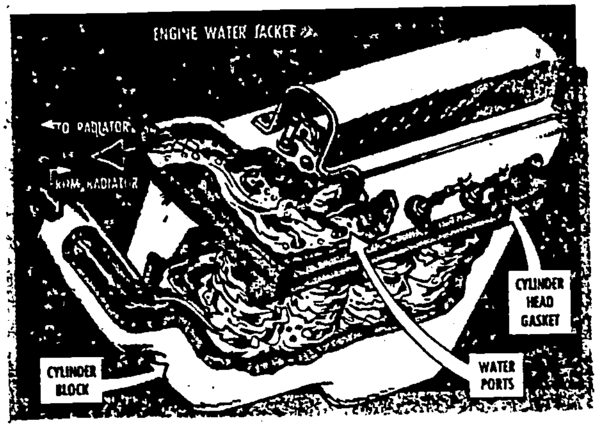

Fig 3-8. Engine water jacket.

If you chose 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

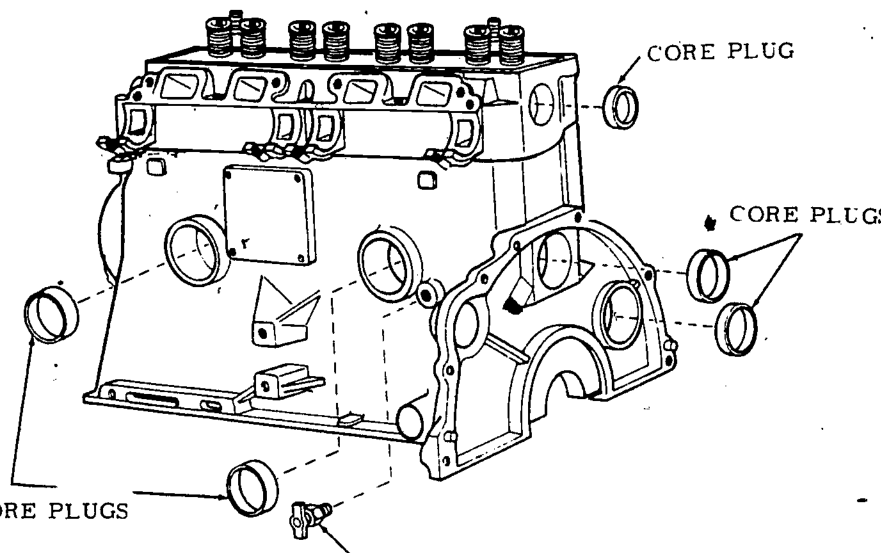

Fig 3-9. Possible areas of coolant leakage.

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 that (fig 3-10)?

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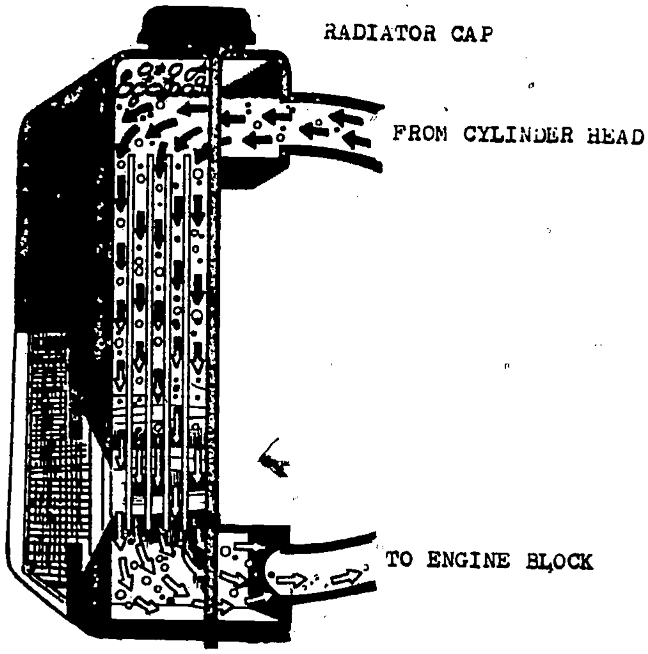

Fig 3-10. Cutaway view of radiator showing bubbling in the top as opposed to the normal swirling coolant.

The answer is simply that 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).

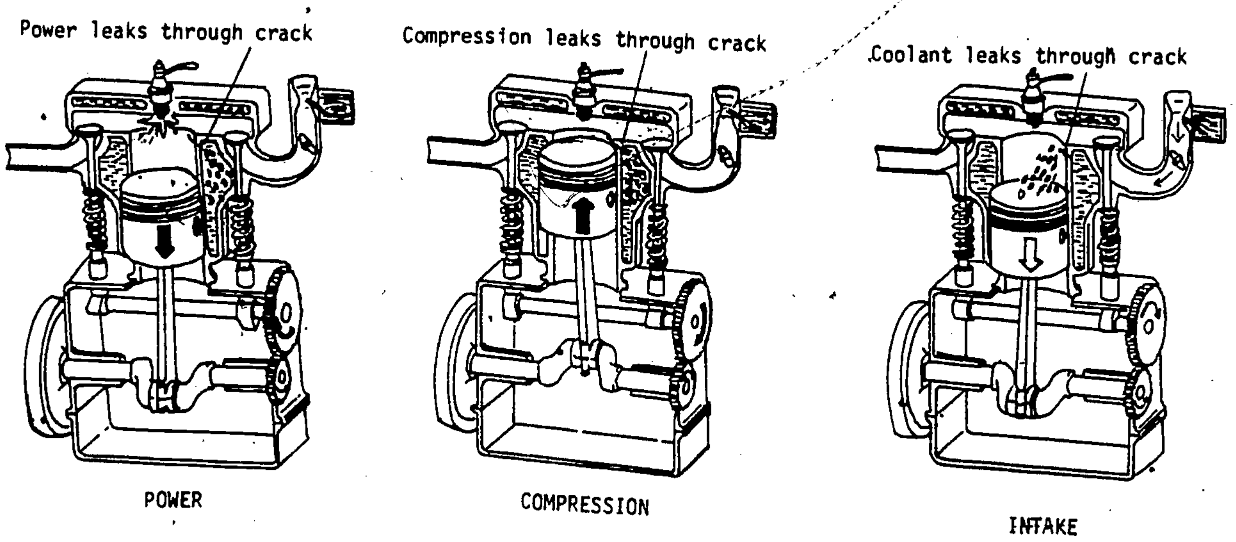

Fig 3-11. Cracked water jacket.

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

Fig 3-12. Steam dissipates rapidly.

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, and that the oil from the oil passages is leaking into the water 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 the 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.

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 between 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.

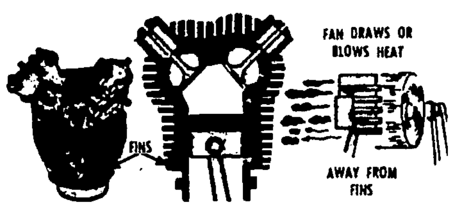

Fig 3-13. Cooling fins.

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 is the solution to 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.

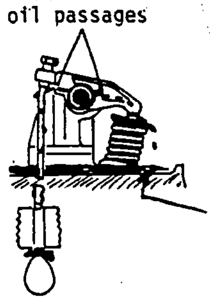

Fig 3-14. The rocker arm lubrication method.

Another non-moving component which is a source of engine malfunctions is the cylinder head.

3-2. CYLINDER HEAD

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 those 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").

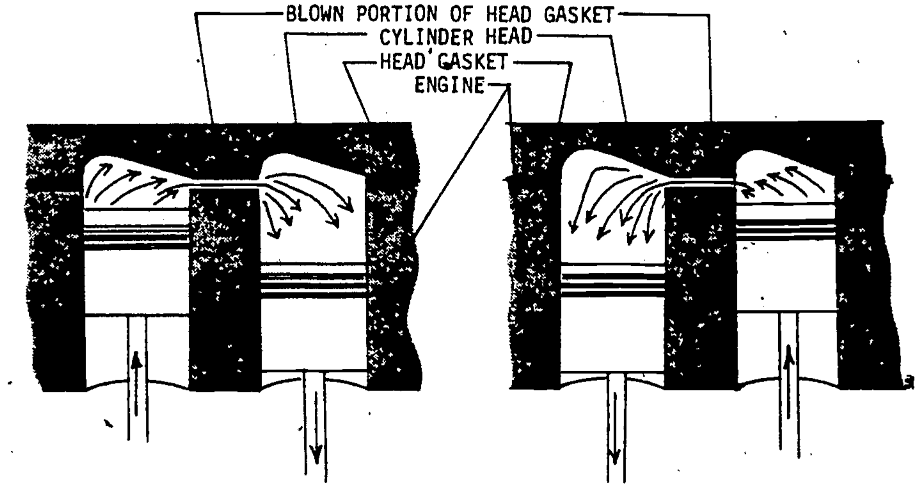

Fig 3-15. Flow of air due to blown cylinder head gasket.

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 off all carbon deposits. The carbon tends to hold heat, which ignites the fuel prematurely.

Now that we have discussed the engine block and the cylinder head, let's move on to the major parts and their malfunctions.

3-3. PISTON ASSEMBLY

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.

The more moving components a mechanism has, the more chance there is of defects. A typical example of this is the valve mechanism.

3-4. VALVE MECHANISMS

As you know from the previous lesson, 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. We will 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 one tooth out of alinement, the engine will hardly operate. If they are installed two or more teeth out of alinement, it is very likely that the engine will not operate at all. Let's 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 the 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?

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 a 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.

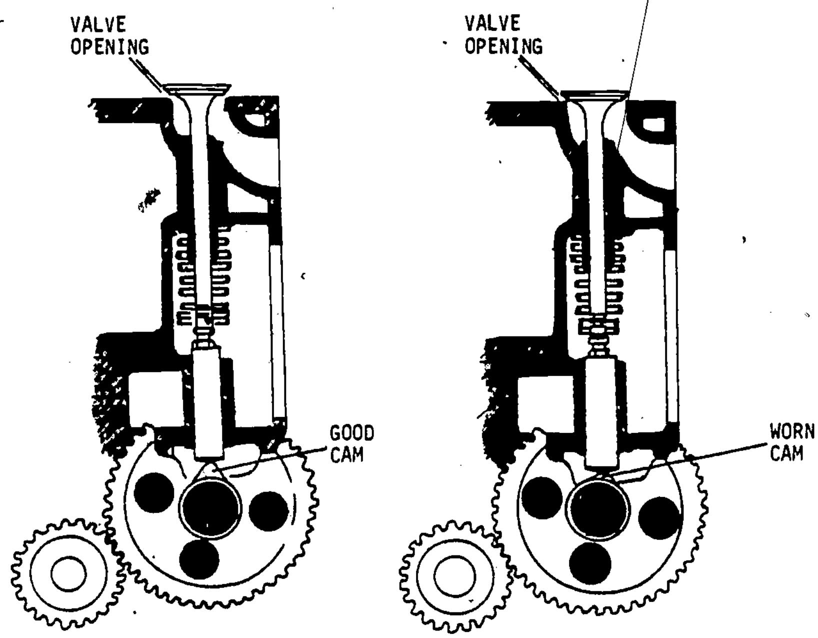

Fig 3-17. Comparison of the opening of the valve with a good cam lobe and a worn cam lobe.

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. As you know, the pushrod is a long thin rod. 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, as well as putting 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?

If the 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 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. It will do no good however, to replace these components unless you clear the oil passages leading to them.

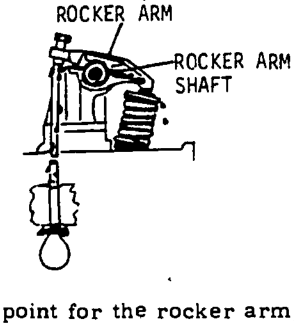

Fig 3-18. The pivot point for the rocker arm, the rocker arm shaft.

Let's return to the compression test for a moment. If a "dry" test and a "wet" test result in the same 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. There are usually two reasons for a valve becoming burnt. Can you determine why this condition would occur?

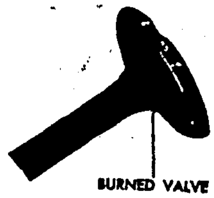

Fig 3-19. The affect of scorching and melting.

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, we have an open combustion chamber even when the valves are closed.

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 turning 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.

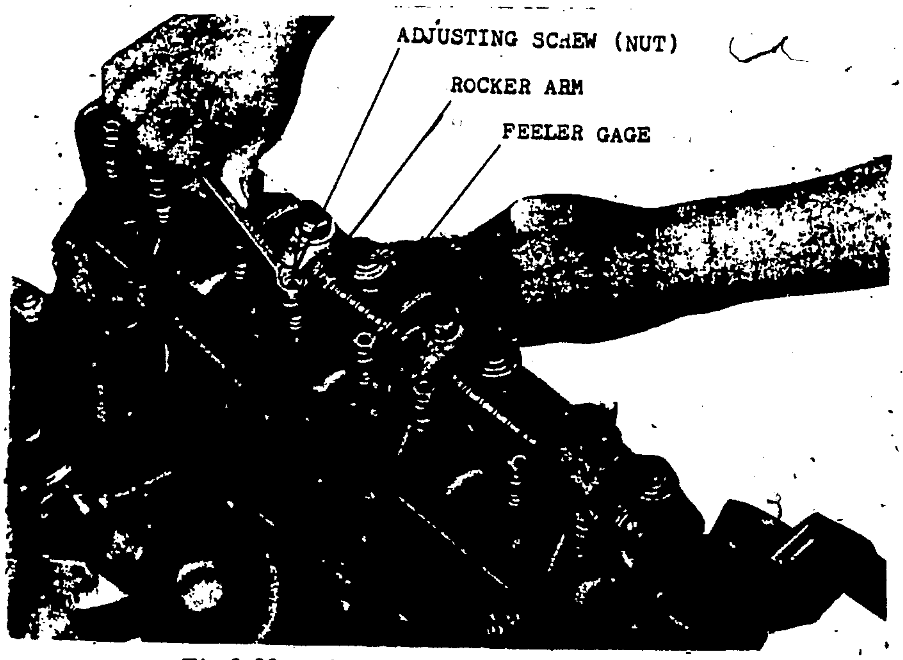

Fig 3-20. Adjusting valves on an I-head engine.

3-5. CRANKSHAFT

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 matter of 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. 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 malfunctions. 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.

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Chapter 4

ENGINE DISASSEMBLY

4-1. INTRODUCTION

Many engines have been repaired or rebuilt and returned to operation, but a short time later we find them 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 chapter to the disassembly phase. You will soon realize this is just as important as repair and reassembly.

4-2. ENGINE REPAIR PREPARATION

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, we begin our preparation. Imagine yourself a surgeon, and the engine 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).

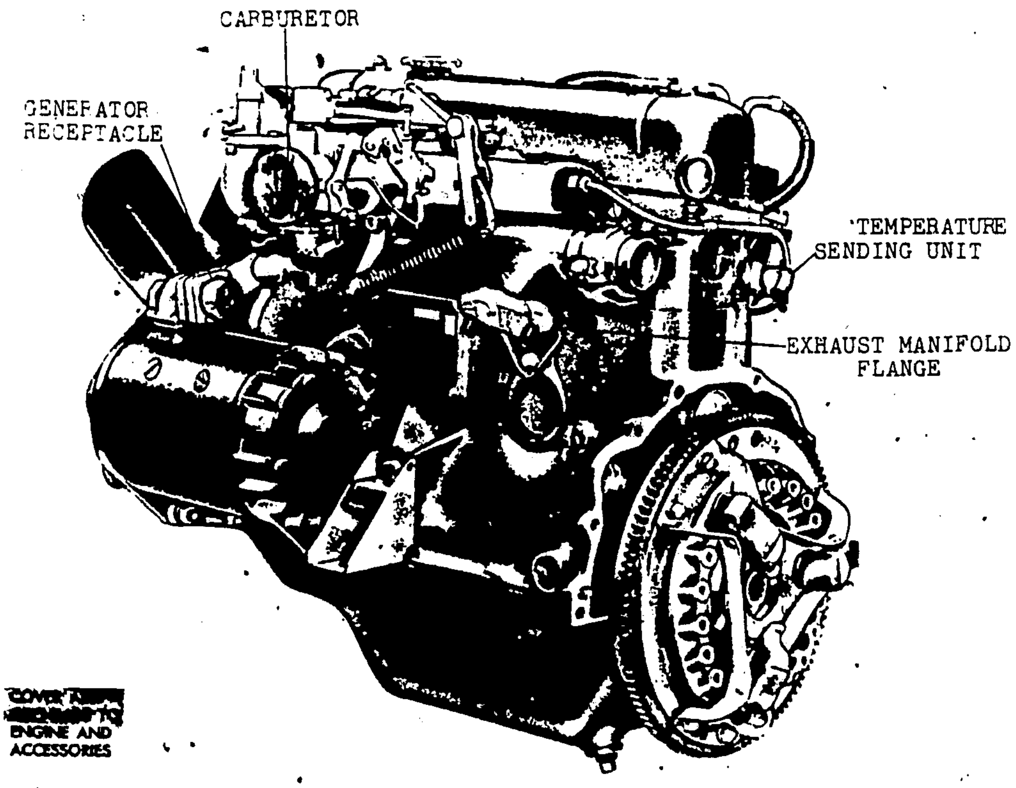

Fig 4-1. Engine preparation.

Now that all the 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.

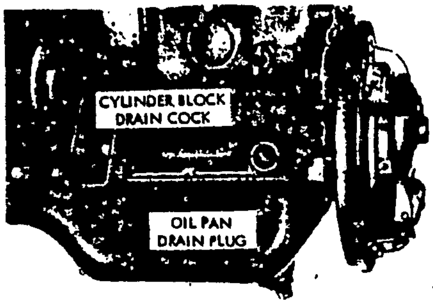

Fig 4-2. Drain the engine.

With the engine thoroughly cleaned and drained, let's 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 our engine block is damaged beyond repair.

At this point, we are ready to disassemble the engine. Let's mount the engine on the repair stand and begin the actual disassembly (fig 4-3).

Note: 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.

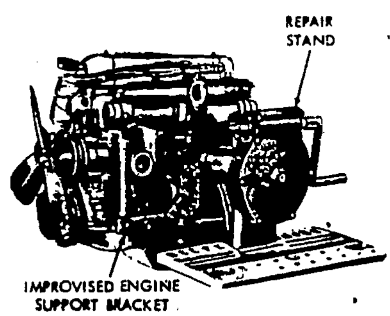

Fig 4-3. Engine mounted on repair stand.

As you disassemble the engine, check each part to make sure it can be used in the repair of the engine. If we wait until reassembly, it will cause extra work and unnecessary time.

4-3. CYLINDER HEAD REMOVAL

We 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.

Removal of the cylinder head from an L-head engine is very simple. Simply remove the cylinder head bolts from the head, lift it 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.

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

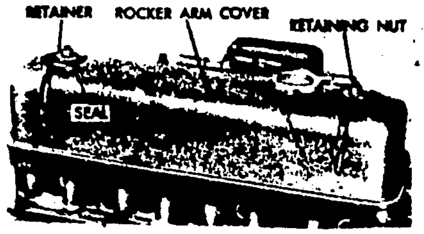

Fig 4-4. Remove the rocker arm cover.

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.

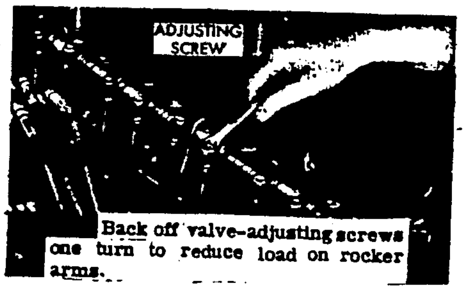

Fig 4-5. Relieving rocker arm pressure.

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 has no rocker arm shaft, simply remove the rocker arms.

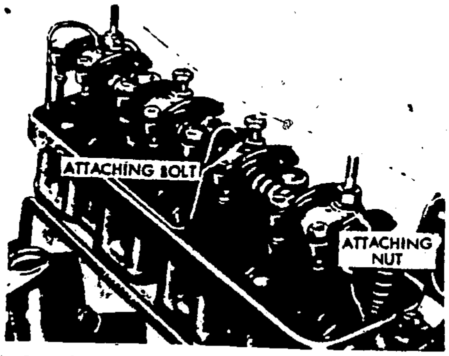

Fig 4-6. Removing the rocker arm shaft.

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, we will inspect the cylinder head assembly later.

4-4. OIL PUMP REMOVAL

Let's turn the engine upside down now, and remove the oil pan so that we may work inside the crankcase. Discard all gaskets and neoprene seals.

We will remove the oil pump, the pick-up tube, and the oil strainer as a complete assembly. But first, let's 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 we 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 adjusted 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 the tolerances listed in the TM for your vehicle. If the backlash is not within tolerances, make a note of this so you do not forget to remedy it.

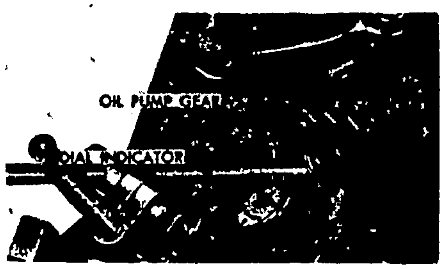

Fig 4-7. Measuring oil pump gear backlash.

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

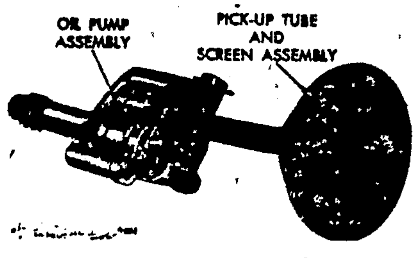

Fig 4-8. Oil pump and pick-up tube and screen assembly.

4-5. PISTON REMOVAL

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.

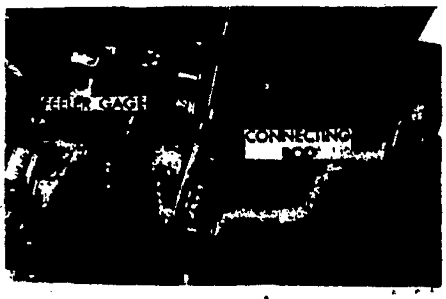

Fig 4-9. Measuring connecting rod side play.

Let's 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).

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.

Now, you may remove the piston assembly by placing the handle end of your ball peen hammer against the end of the connecting rod, and carefully pushing the piston out through the top of the cylinder (fig 4-12). Make sure that the connecting rod DOES NOT strike the crankpin or the cylinder wall. Even the slightest scratch will cause you extra work to remove. Repeat this procedure on each piston until they are all removed.

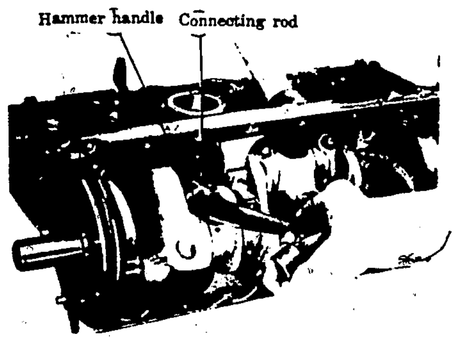

Fig 4-12. Removing the piston assembly.

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 portion with a center punch numbering them as you numbered the rods.

4-6. TIMING GEAR REMOVAL.

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 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.

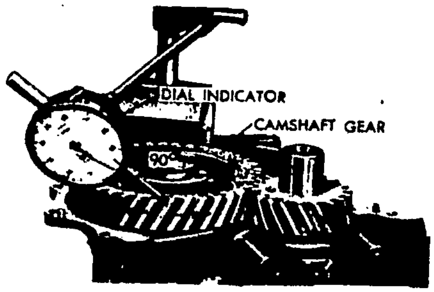

Fig 4-13. Checking timing gear backlash.

The next check will be performed to find out if the gear is warped. There is little or no chance of the crankshaft gear warping 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.

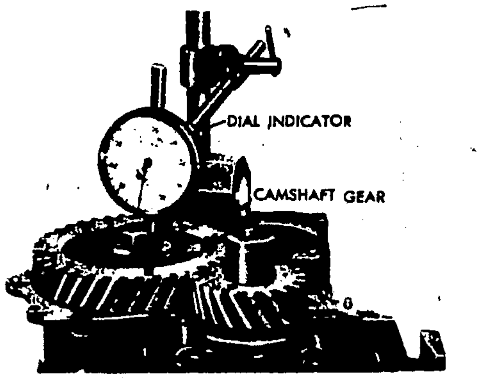

Fig 4-14. Checking timing gear runout.

Before removing the timing gears, let's 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 your 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.

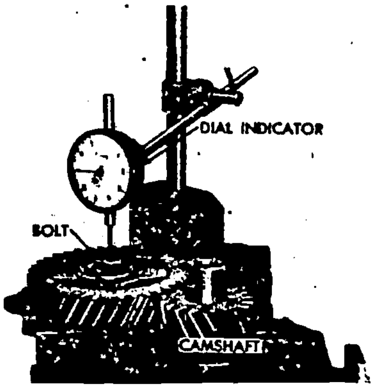

Fig 4-15. Measuring camshaft end play.

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 counter-clockwise 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 clock-wise, 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.

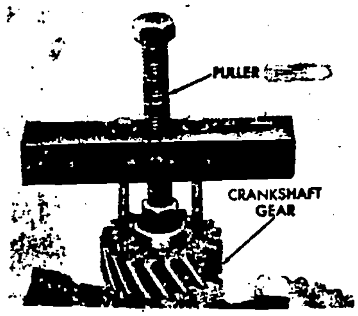

Fig 4-16. Removing the crankshaft gear.

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.

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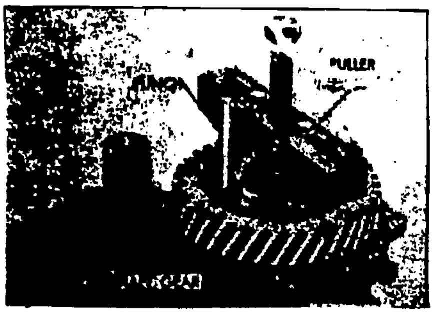


Fig 4-17. Removing the camshaft gear.

4-7. CRANKSHAFT REMOVAL

Before removing the crankshaft from the engine, remove the clutch pilot bearing and the flywheel from the crankshaft.

The pilot bearing is removed at this time because it has to be removed with a slide hammer puller, 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.

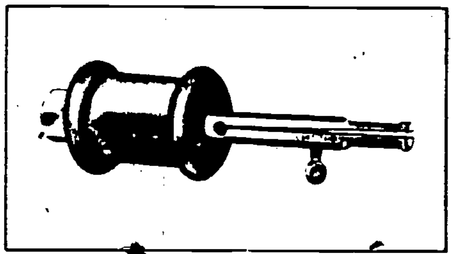


Fig 4-18. Clutch pilot bearing puller.

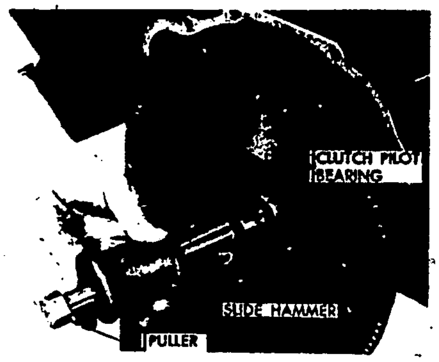


Fig 4-19. Removing the clutch pilot bearing.

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.

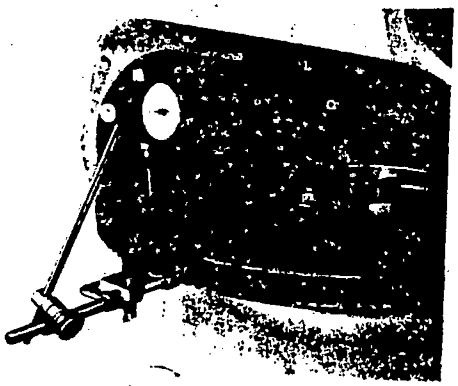
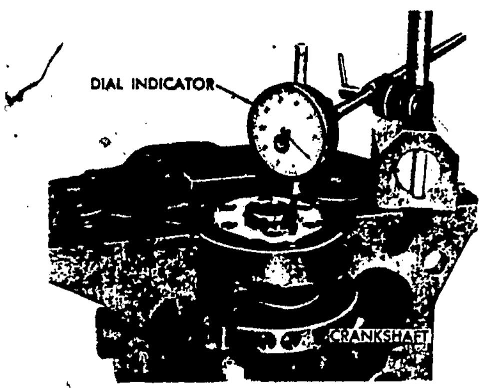


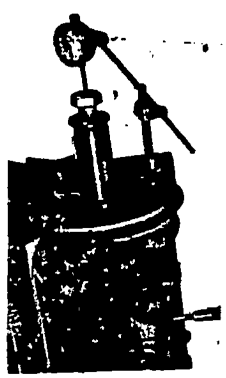
Fig 4-20. Measuring flywheel runout.

Now, let's 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 lay it on a flat surface. If you lean the crankshaft against another object in an upright position, IT WILL WARP.

4-8. 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).

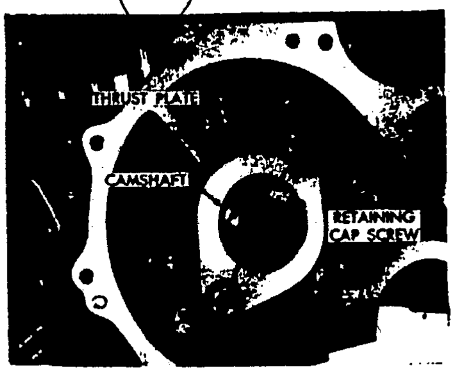


Fig 4-22. Camshaft thrust plate.

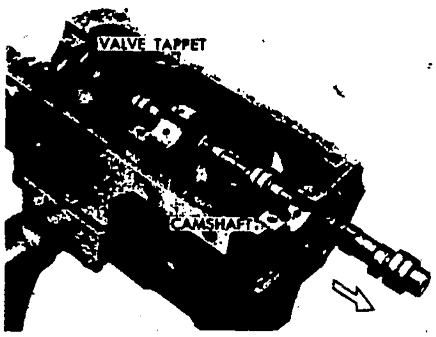


Fig 4-23. Removing the camshaft.

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.

Chapter 5

ENGINE REPAIR

Up to this point we 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).

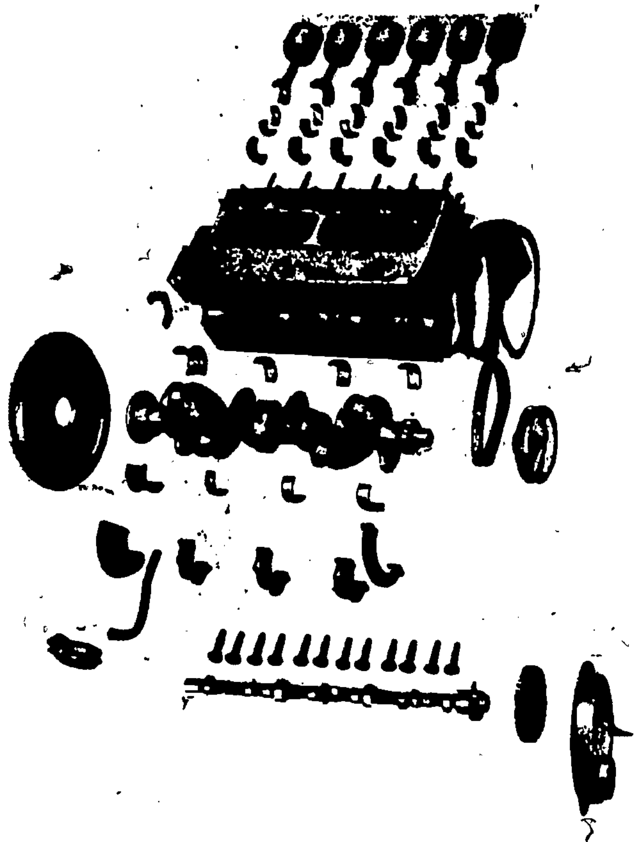


Fig 5-1. Typical parts of a dismantled engine (cylinder head not included).

Looking 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 is better to use your available TM's, 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 we are primarily concerned at present with repair, reassembly will be covered in the next chapter. Let's begin our repair with the engine block.

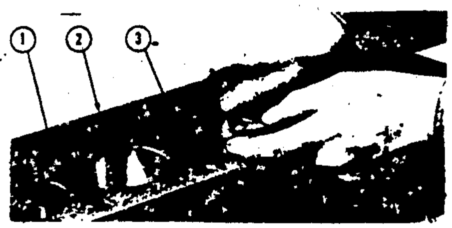
5-1. ENGINE BLOCK

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 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 straightedge across the top of the cylinder block where the cylinder head gasket is placed. Now, drag the straightedge along the surface of the cylinder block and look for "daylight" between the straightedge and the cylinder block. In those places where you detect a gap between the straightedge and the block, check the clearance with a feeler gage by inserting the leaves of the gage between the straightedge 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. Straightedge. 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.

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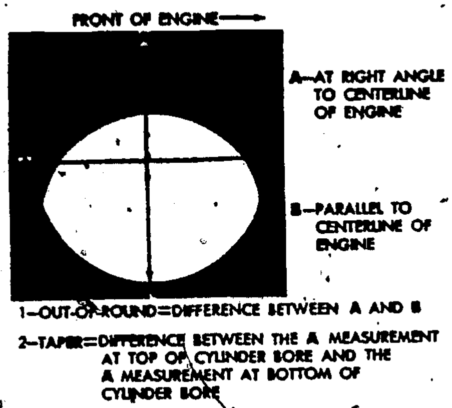


Fig 5-3. Measuring points for cylinder out-of-round and taper.

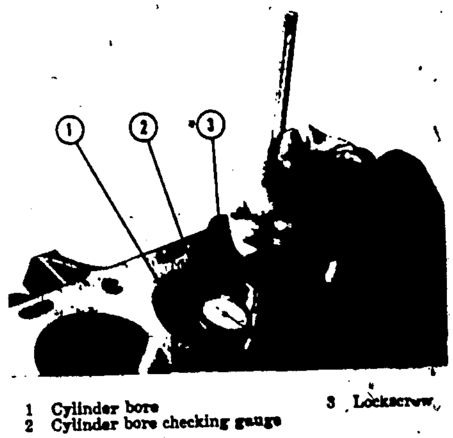


Fig 5-4. Checking cylinder out-of-round and taper.

Let's 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 move it upward inside the cylinder as it slows to a stop. Loosen the adjustment of the hone 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. A word of caution here. 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.

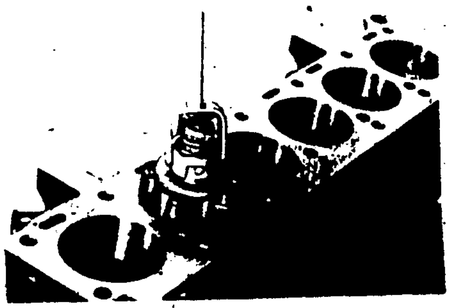
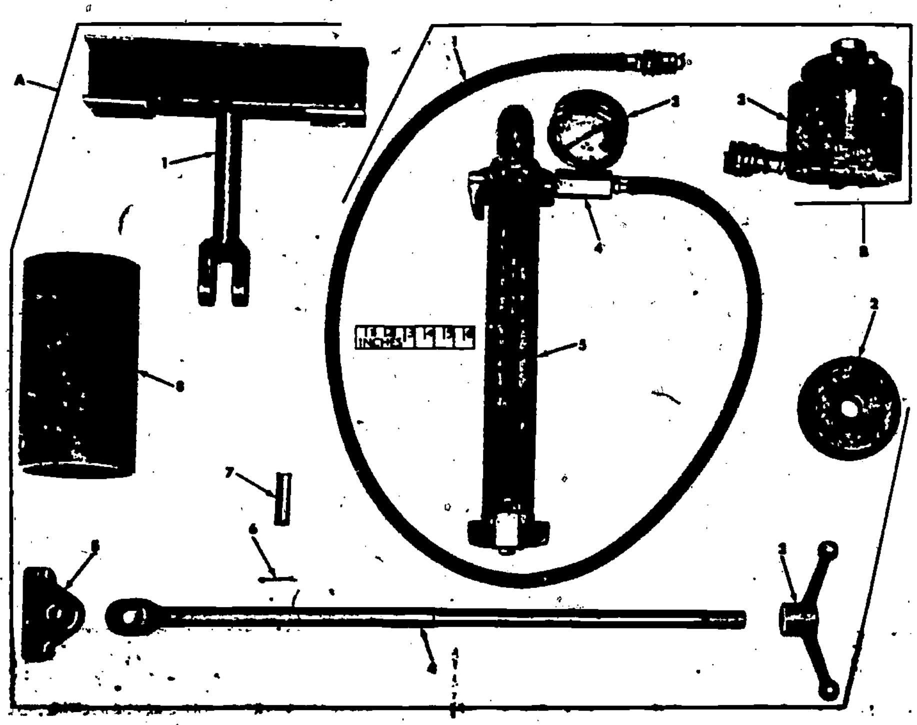


Fig 5-5. Honing the cylinder.

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 parens 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 sleeve.

Position the hydraulic 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 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.

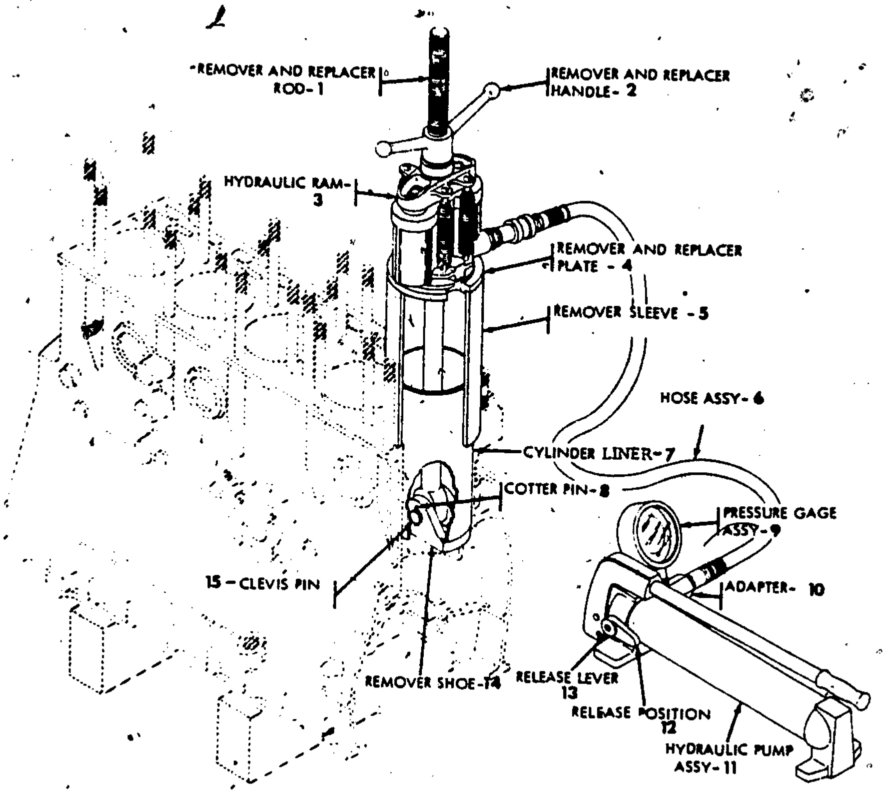


Fig 5-7. Cylinder liner remover and replacer kit showing position of shoe against liner during liner removal (sectional view).

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 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 into 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.

Caution: 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 pump, and repeat the pumping operation. You would continue this procedure until the liner flange is properly seated in the cylinder.

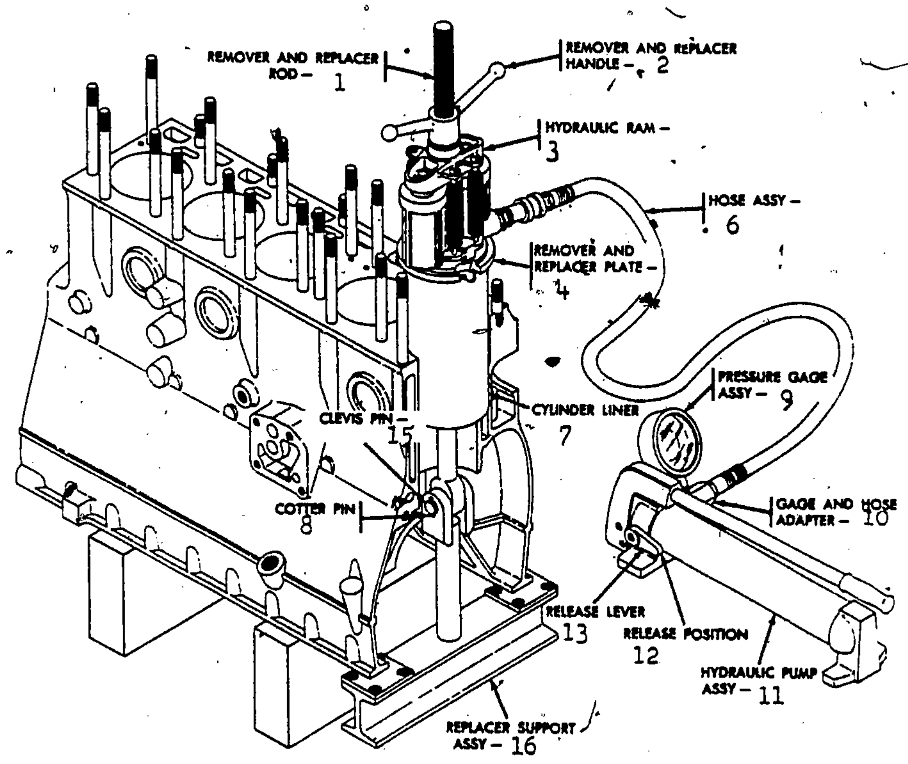


Fig 5-8. Cylinder sleeve remover and replacer kit and ram kit showing proper method of cylinder liner installation.

Remove hydraulic ram kit and remover and replacer kit.

The new cylinder liners must be honed. To do this, refer to the TM that pertains to the engine you are working on.

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 then 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

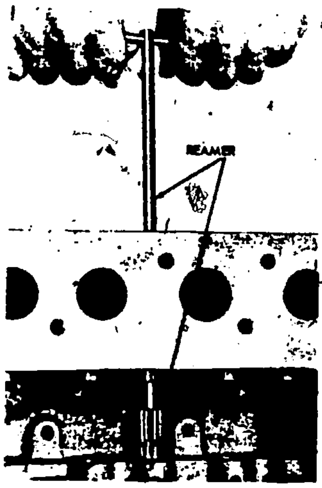


Fig 5-9. Reaming valve tappet bore.

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 old tappets.

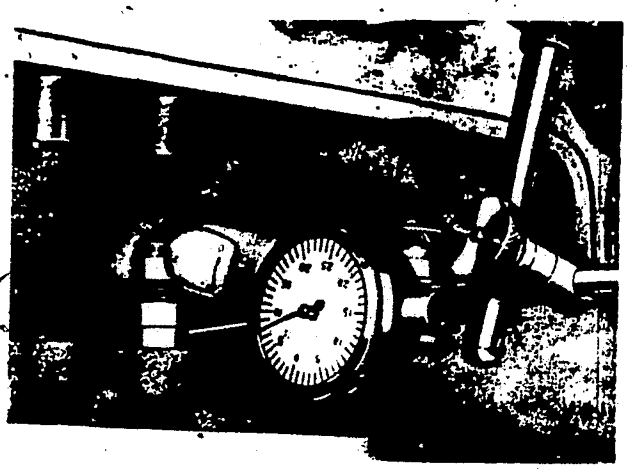


Fig 5-10. Checking valve tappet clearance.

Next, 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.

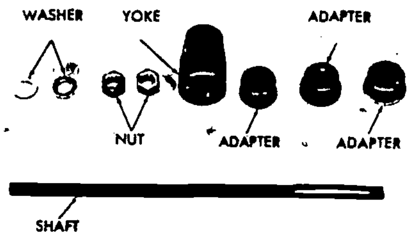


Fig 5-11. Camshaft bearing remover/installer.

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).

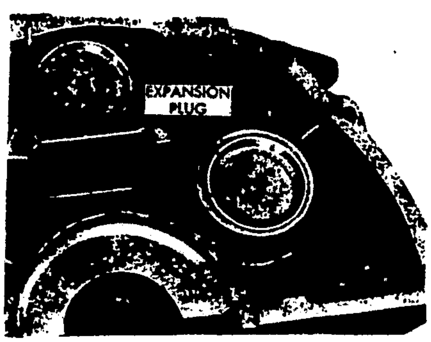


Fig 5-12. Camshaft rear bearing plug.

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).

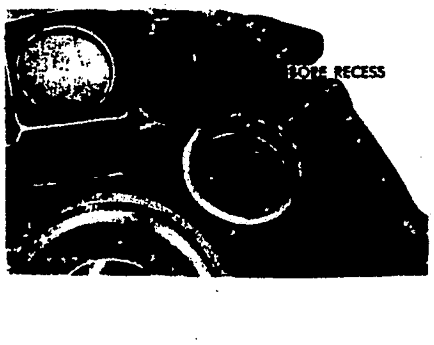


Fig 5-13. Rear bearing bore recess (bearing plug removed).

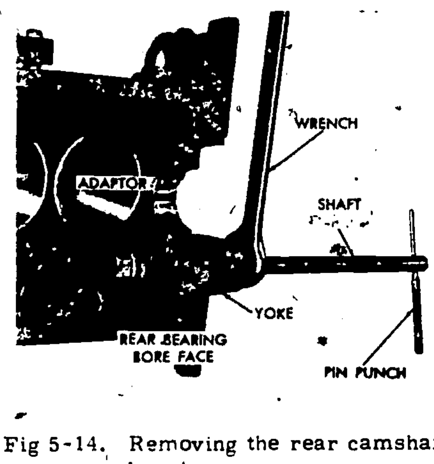


Fig 5-14. Removing the rear camshaft bearing.

The inner camshaft bearings and the front camshaft bearing are removed in the same manner. As stated before, the end from which we 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.

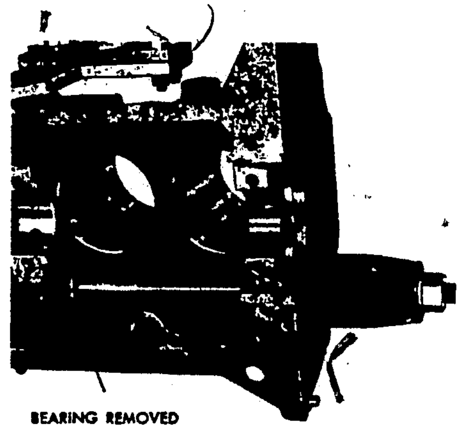


Fig 5-15. Removing inner camshaft bearings.

The bearings having been removed, 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.

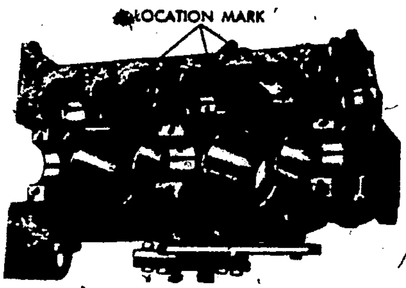


Fig 5-16. Marking location of oil holes in camshaft bearing bores.

Now, let's 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).

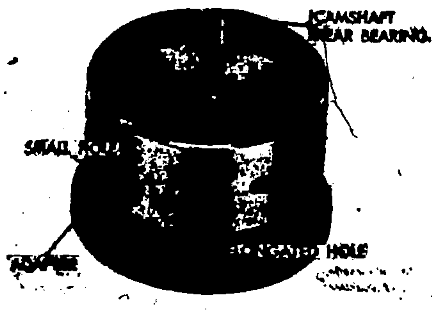


Fig 5-17. Camshaft bearing installed on remover/replacer adapter.

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).

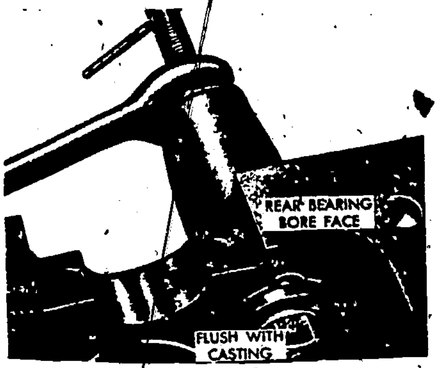


Fig 5-18. Installing camshaft bearings.

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.

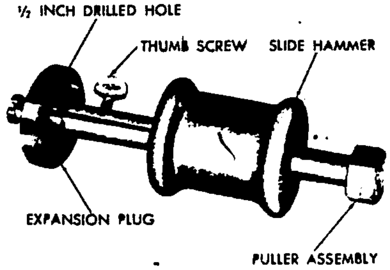


Fig 5-20. Removing expansion plugs.

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, we are ready to set the engine block aside and begin work on the crankshaft.

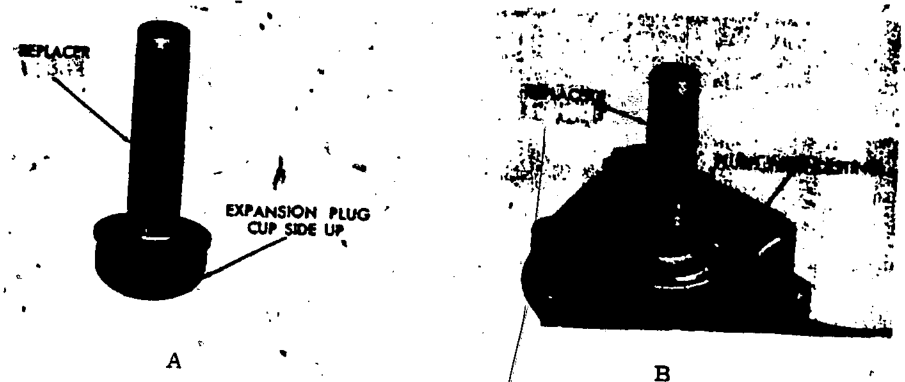


Fig 5-21. Replacing expansion plugs.

5-2. CRANKSHAFT

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

Your first step is to clean the crankshaft. The crankshaft may be cleaned with cleaning solvent or a strong parts cleaner if the solvent cannot do a thorough job. After the initial cleaning, use an air hose to blow out the small passages in the shaft. These are oil passages and are vital to the life of the bearings. One clogged passage can cause you to have to make 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 end of the journal or crankpin (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.

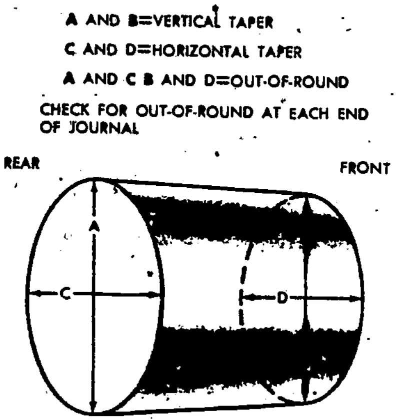


Fig 5-22. Crankshaft journal and crankpin measuring points and formula for amount of out-of-round.

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.

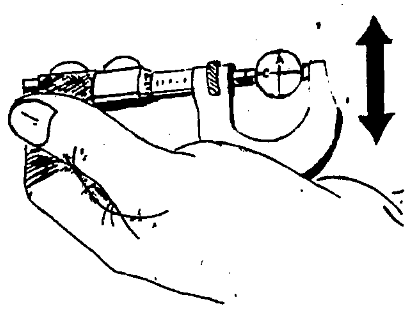


Fig 5-23. Measuring crankshaft main journals and crankpins for out-of-round with a micrometer.

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 however, 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 (fig 5-24).

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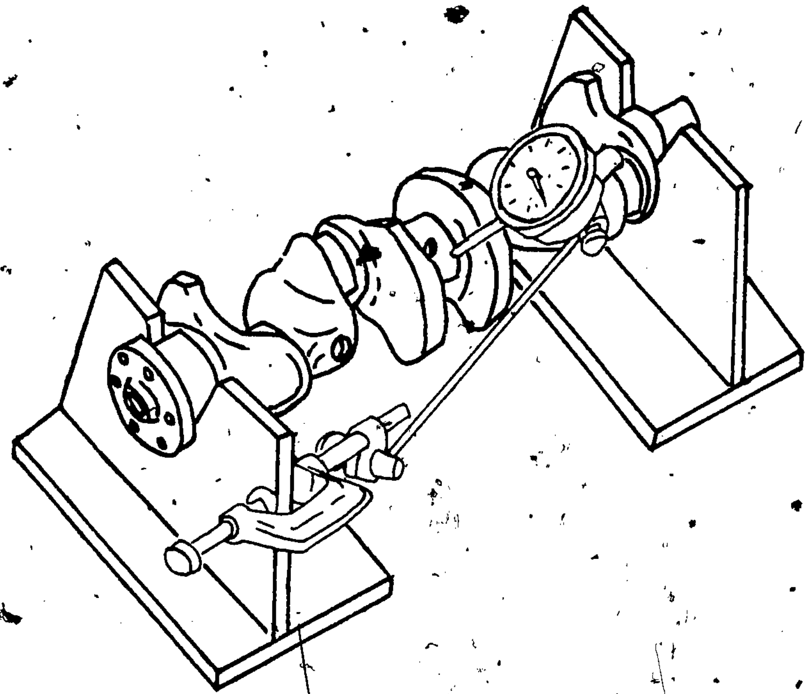

Fig 5-24. Measuring crankshaft runout (warpage).

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 halves and the main journal throws in the same manner as you did between the bearing and the 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, however, 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.

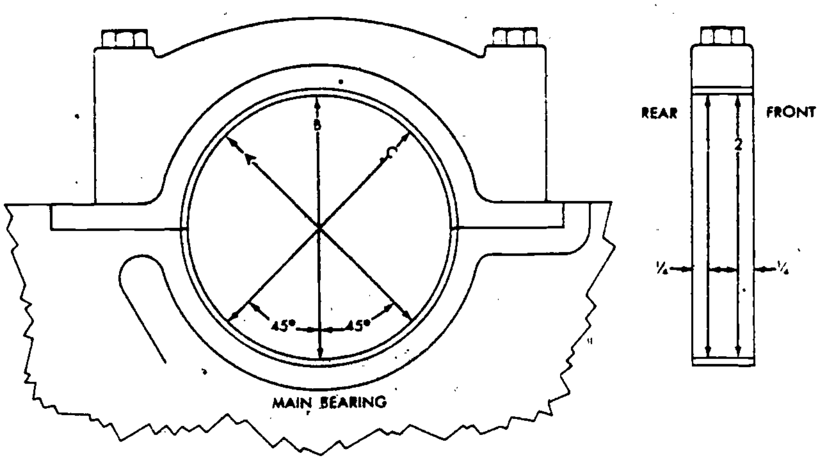

Fig 5-27. Points of measurement for crankshaft main bearings.

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).

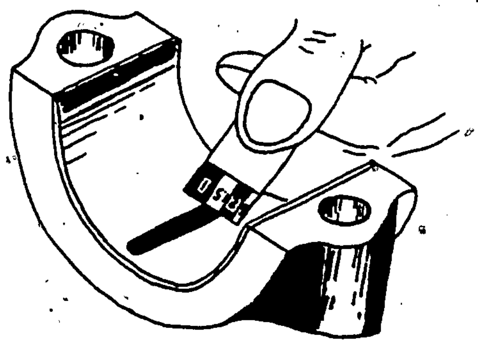

Fig 5-28. Measuring crankshaft bearing running clearance (using plastigage).

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 we 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).

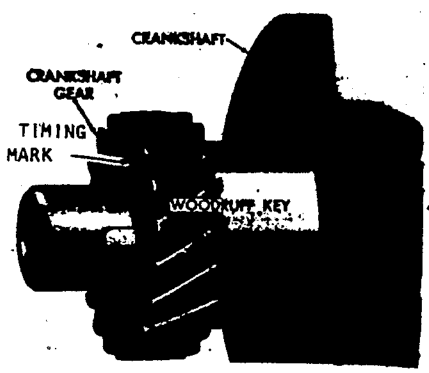

Fig 5-29. A properly installed crankshaft timing gear.

5-3. FLYWHEEL

With all repairs completed on the crankshaft, the next component 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.

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 roller type bearings, make sure the bearing is operating smoothly.

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

5-4. 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 we discussed earlier in the text, 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.

5-5. PISTON ASSEMBLY

Although the piston assembly performs a relatively simple function, the specifications are quite critical due to the speed of the piston travel, 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.

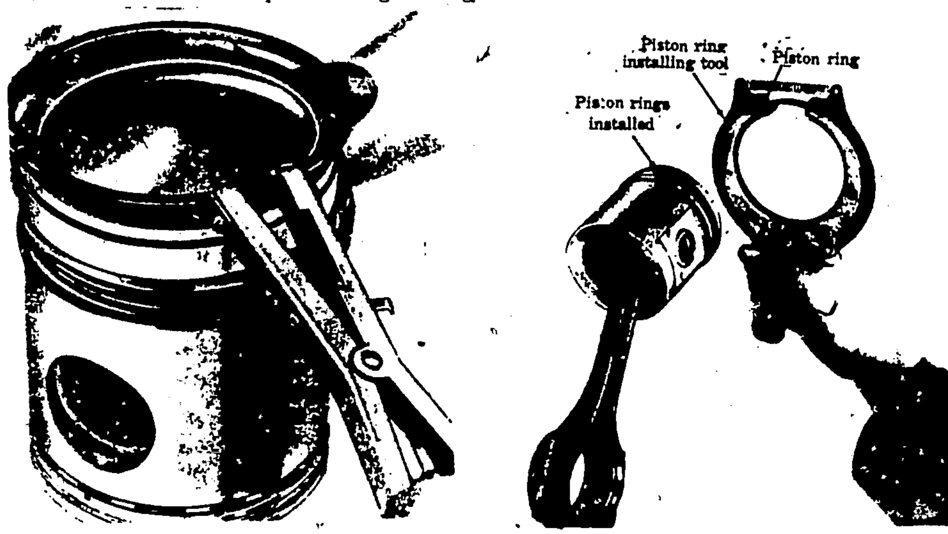

Fig 5-30. Common ring expander tools used to remove and install piston rings.

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.

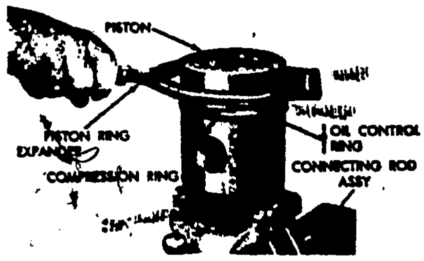

Fig 5-31. Removing and installing piston rings.

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.

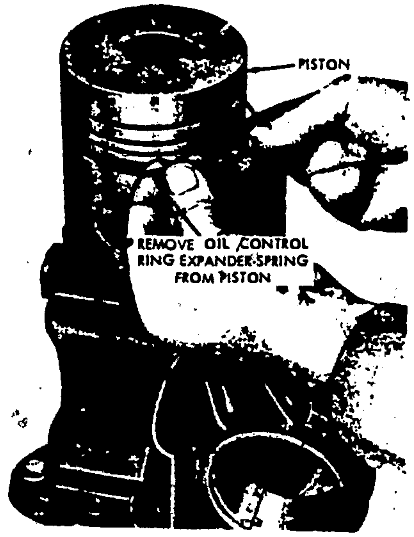

Fig 5-32. Removing the oil control ring expander.

To prepare for the next disassembly step, mark the piston and its connecting rod to ensure 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, however, 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 down and repeat the same procedure with the remaining pistons.

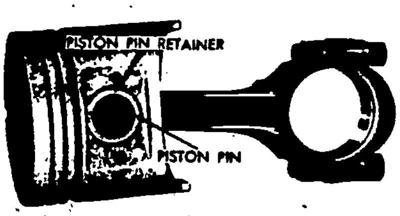

Fig 5-33. Remove the piston pin retainer.

Once the pistons are disassembled, clean and inspect them. The best method of cleaning them is dunking them in cleaning solvent and using a wire brush to remove the carbon deposits on the head of the piston ONLY (fig 5-34).

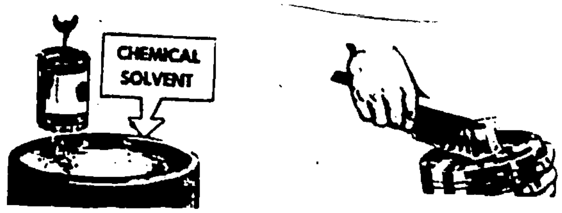

Fig 5-34. Cleaning the pistons.

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 the blade cuts the carbon away as it is rotated around the piston.

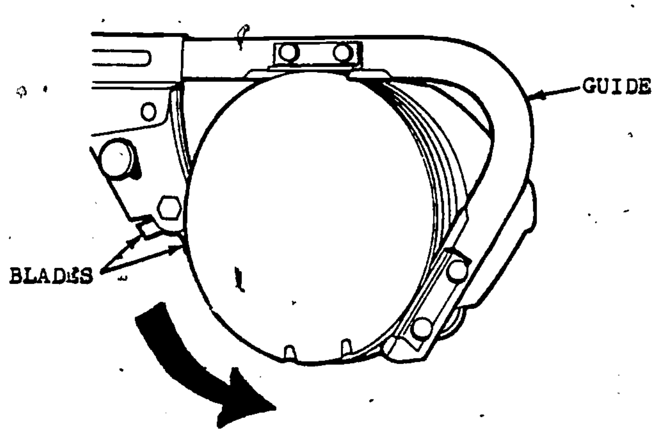

Fig 5-35. Cleaning piston ring grooves.

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.

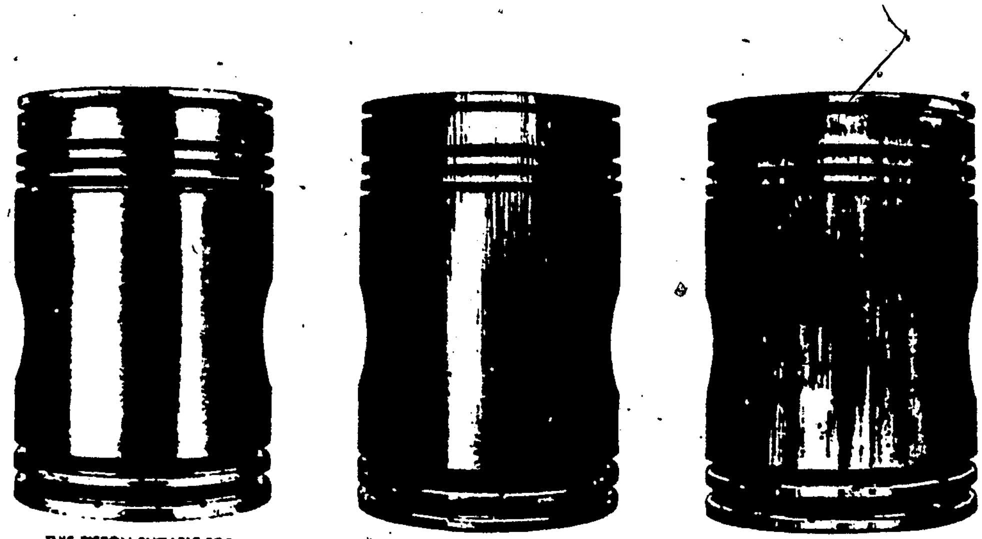

Fig 5-36. Comparison of serviceable and unserviceable pistons.

After repairing or replacing defective pistons, you must be certain 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 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.

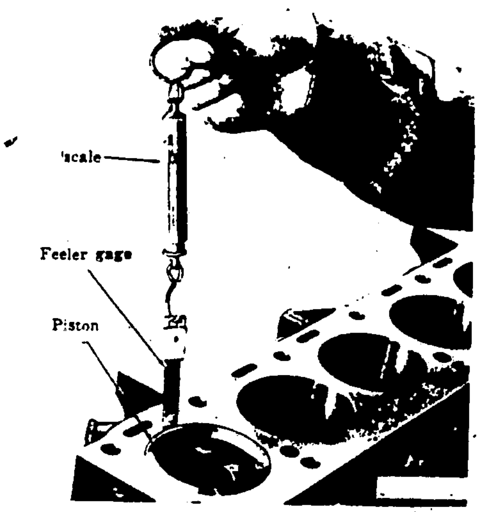

Fig 5-37. Checking piston fit and center.

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 tells the clearance. For example, assume that you are using a .004 inch feeler gage and you

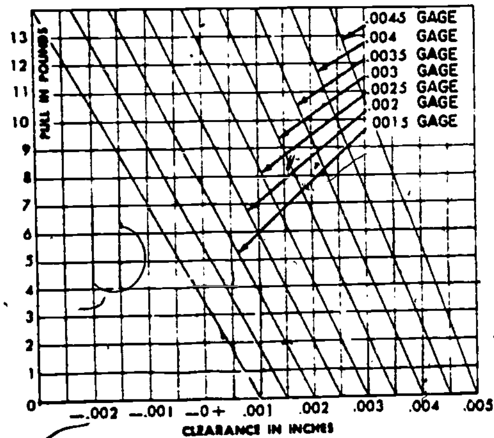

Fig 5-38. Piston clearance chart.

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 a little 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.

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 as well. Let's first determine whether they fit the cylinder. Select a compression ring from each set and place it inside the cylinder in which it is to be used. Make sure that the ring is level with the top edge of 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

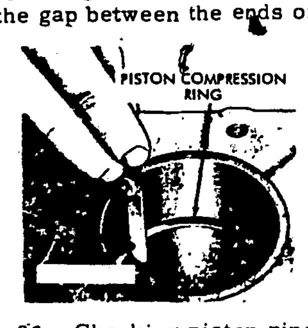

Fig 5-39. Checking piston ring end gap.

If the ring fits the cylinder bore properly, see if it also fits the piston properly. We know that it will fit around the piston, but will it be loose in the groove? To determine this fit, insert the ring in the groove for which it is intended and check the clearance with a feeler gage. This is known as piston ring side clearance (fig 5-40). Now, match your findings with the manufacturer's specifications.

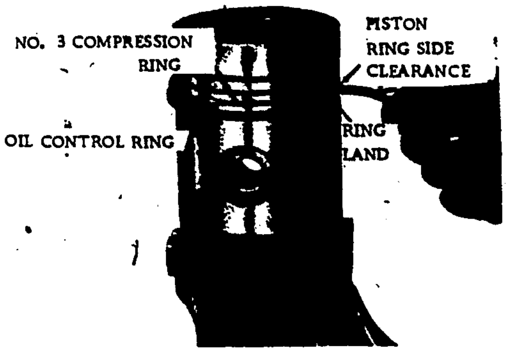

Fig 5-40. Checking piston ring side clearance.

Note: The oil control 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 these 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).

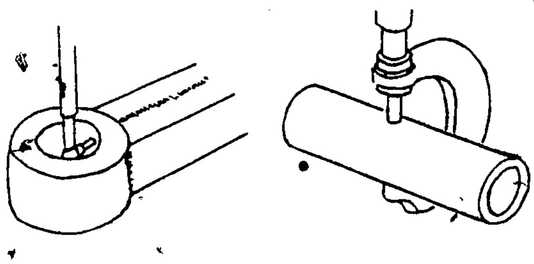

Fig 5-41. Measuring piston pin clearance with telescopic gage and micrometer.

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.

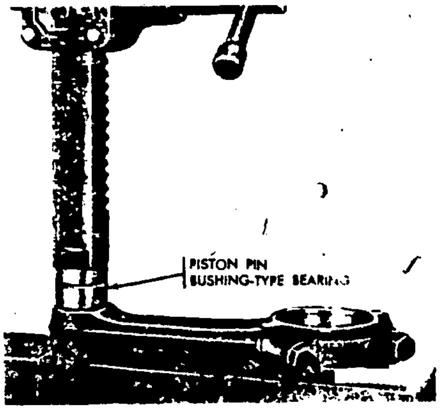

Fig-5-42. Installing piston pin bushings.

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 end of the connecting rod bearing bore, just as we did with the crankshaft main bearing bores (fig 5-43).

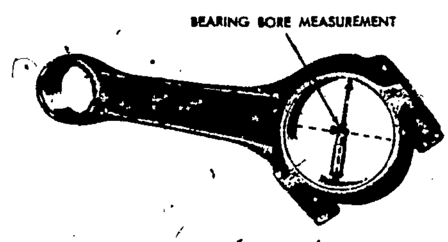

Fig 5-43. Measuring connecting rod bearing bores.

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 us 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.

5-6. CYLINDER HEAD

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

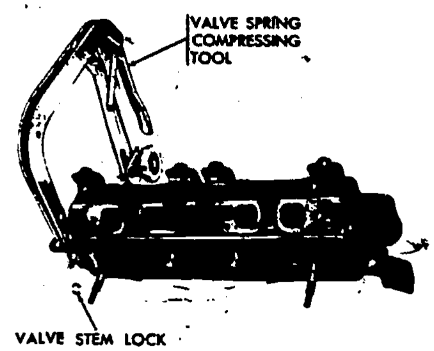

Fig 5-44. Removing the valves.

placing the solid end of the compressing tool on the valve head and the split end on the spring retainer, then compressing it with the lever located on the tool. Once this is accomplished, you may 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).

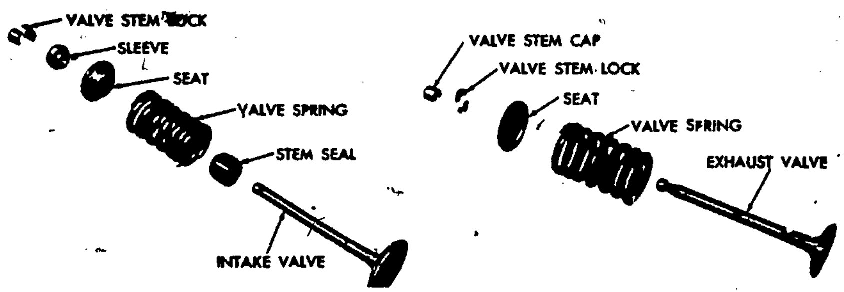

Fig 5-45. Intake and exhaust valves and their related parts.

Check the rocker arm retaining studs next 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 in a counter-clockwise direction.

Next, 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).

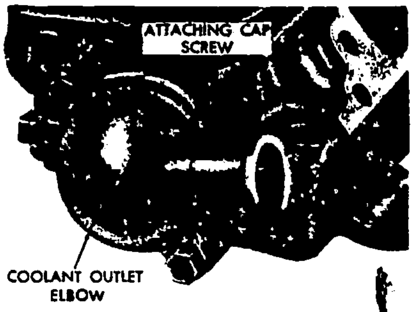

Fig 5-46. Coolant outlet connection (thermostat housing).

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.

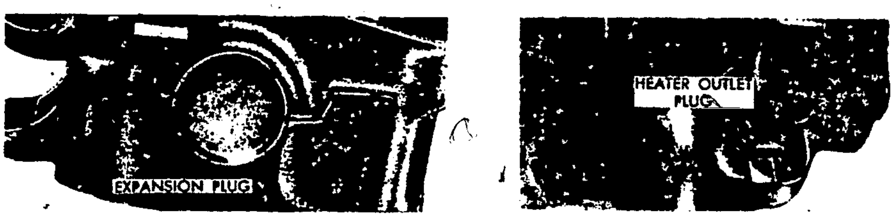

Fig 5-47. Typical heater outlet and expansion plugs.

Check the head for nicks, burrs, and cracks. Smooth nicks and burrs with an oil stone. A cracked head may be sealed in some cases. The cylinder head is now ready for specification checks. We will begin with the flatness check 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 straightedge 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 pictured 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.

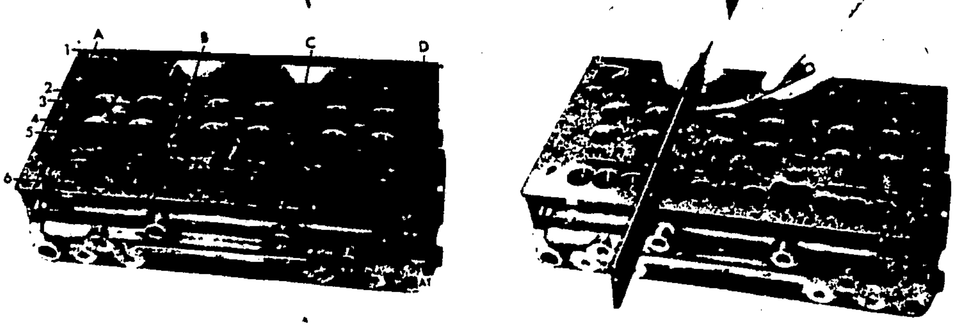

Fig 5-48. Checking cylinder head flatness.

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 revealed 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 some 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.

Assuming that we are working on an I-head or F-head engine, our next step will be a valve seat runout check. If we 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.

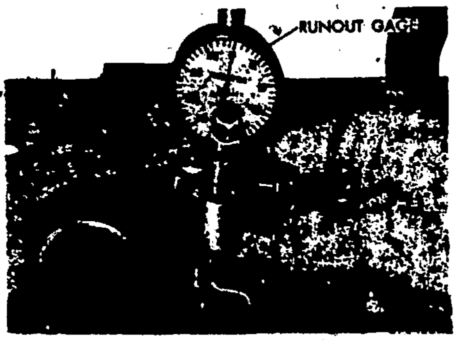

Fig 5-49. Checking valve seat runout.

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 used to reface the seat, and the 60° and 30° stones to raise or lower the seat and change the seat width. Figure 5-51 illustrates the use of grinding stones.

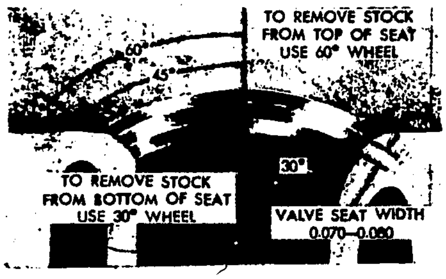

Fig 5-50. Valve seat measuring points.

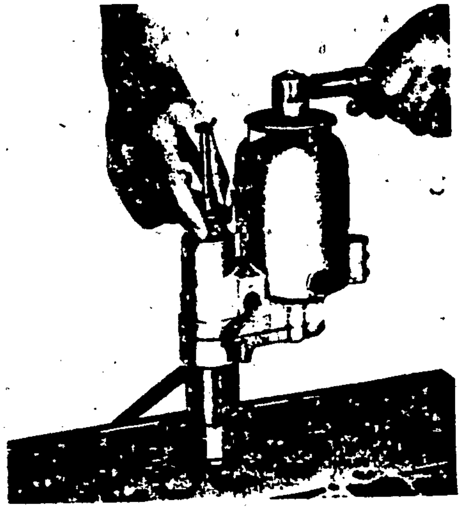

Fig 5-51. Grinding valve seats.

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 found in 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 installation.

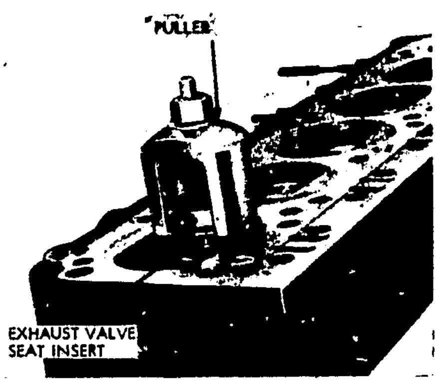

Fig 5-52. Removing valve seat inserts.

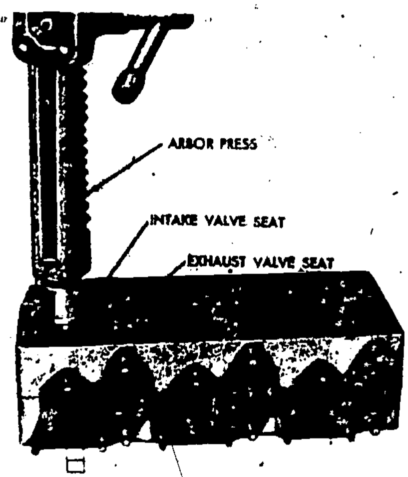

Fig 5-53. Installing valve seat inserts.

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.

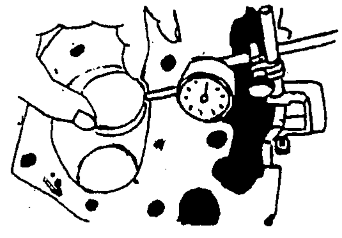

Fig 5-54. Measuring valve stem to valve guide clearance.

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.

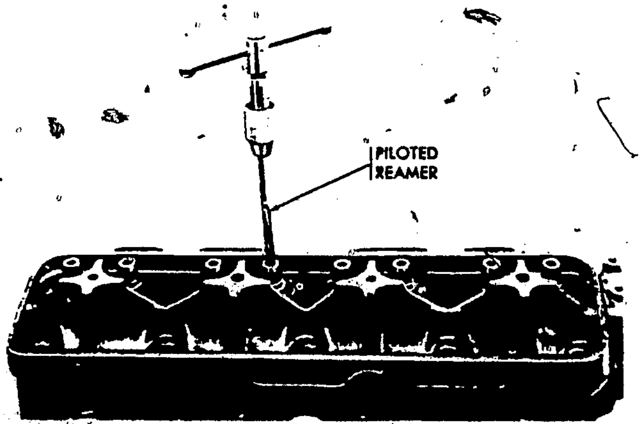

Fig 5-55. Reaming valve guides for oversized valves stems.

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 stopping point.

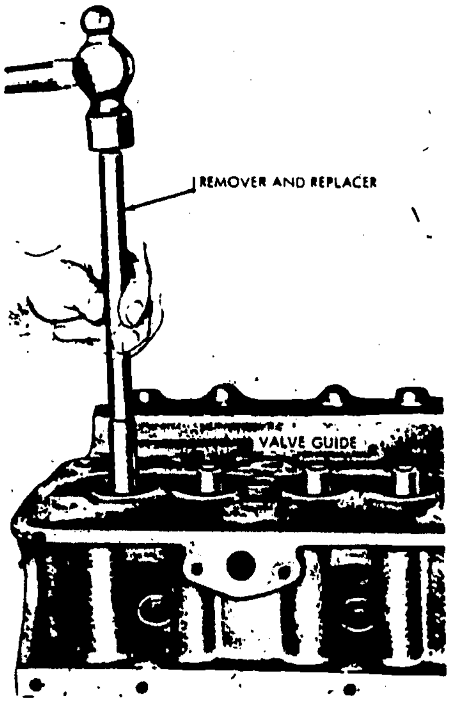

Fig 5-56. Installing valve guides.

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.

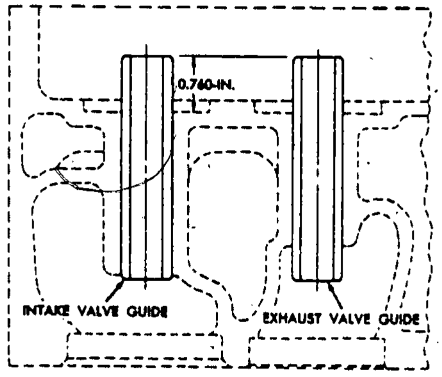

Fig 5-57. Valve guide stopping point for a specific vehicle.

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.

5-7. VALVE MECHANISM

Let's 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. This done, inspect the valves for pitting, burnt surfaces, scoring, and stem warpage, wear, and cocked condition (fig 5-58).

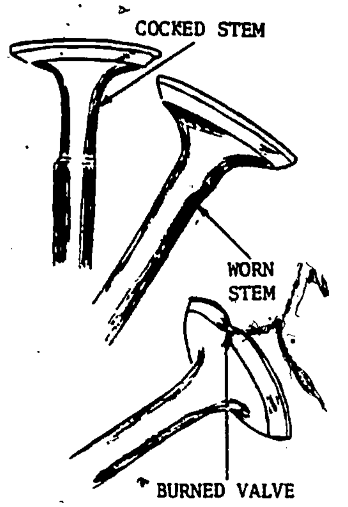

Fig 5-58. Defective valves.

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. This is a job for the machine shop.

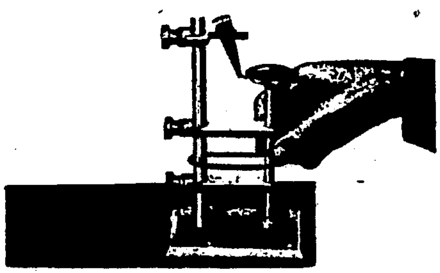

Fig 5-59. Checking valve face runout.

To ensure that the valve seats properly, forming a pressure- and vacuum-tight seal, you must not only have a good 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.

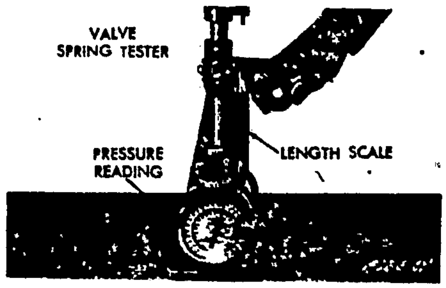

Fig 5-60. Checking valve spring pressure.

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.

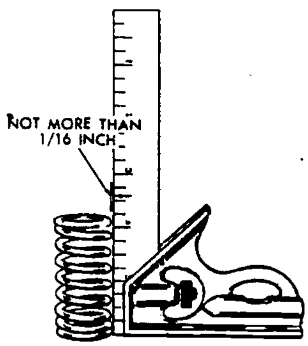

Fig 5-61. Checking valve spring squareness.

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.

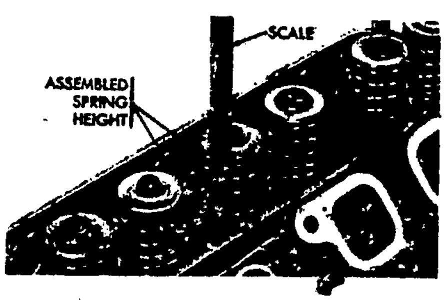

Fig 5-62. Checking valve spring installed height.

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.

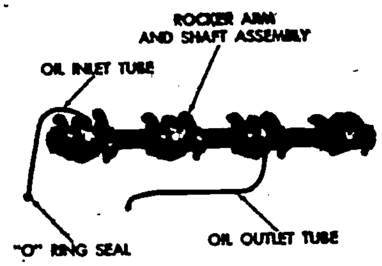

Fig 5-63. Rocker arm shaft assembly.

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 and 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.

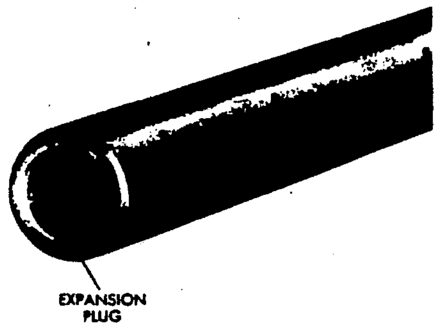

Fig 5-64. Rocker arm shaft expansion plug.

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 we will move on down 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 an 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.

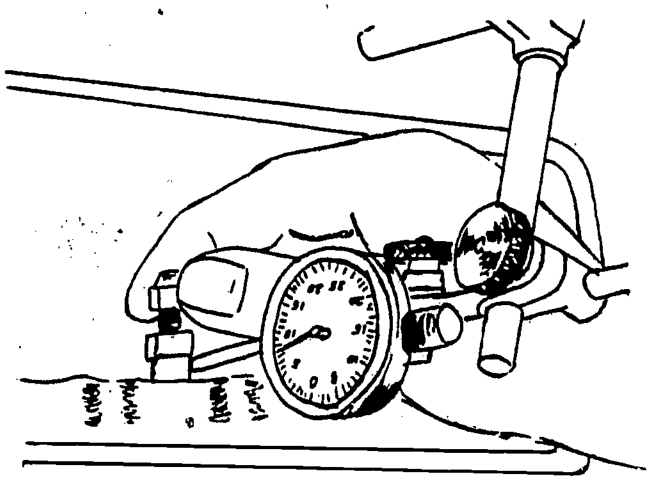

Fig 5-65. Measuring valve tappet fit (L-head engine).

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).

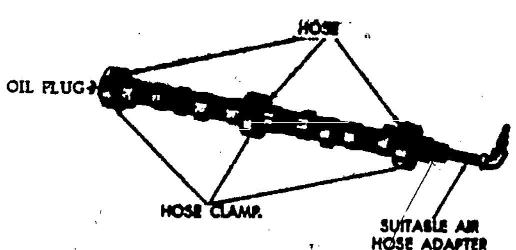

Fig 5-66. Preparing camshaft for main oil gallery pressure check.

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 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.

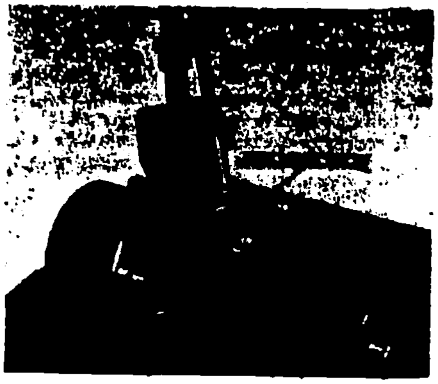

Fig 5-67. Measuring cam lobe lift.

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.

Recall now, 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 we 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.

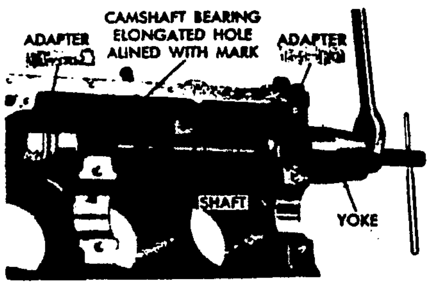

Fig 5-68. Installing camshaft bearings.

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.

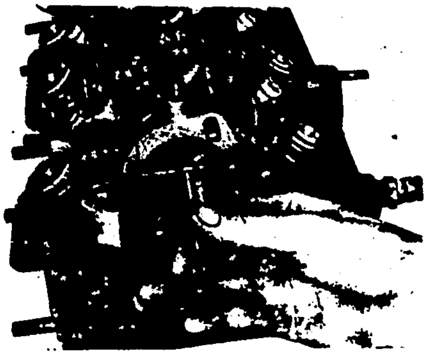

Fig 5-69. Checking camshaft bore inner diameter (overhead cam engine).

Now, measure the outer diameter of the camshaft main bearing journals on the camshaft and 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 measurement 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.

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Chapter 6

ASSEMBLING THE ENGINE

6-1. INTRODUCTION

Let's not forget, while assembling the engine, that 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, water, 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 chapter. Basically, all engines are assembled in the same manner. Therefore, this chapter will provide a basic knowledge and your TM will provide you with details of the particular engine which you will be rebuilding or repairing.

6-2. CRANKSHAFT INSTALLATION

The crankshaft is the first component to 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, you will 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 that 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, there is an encased rear main oil seal and two side seals on the bearing cap. Figure 6-1 shows the side seals installed.

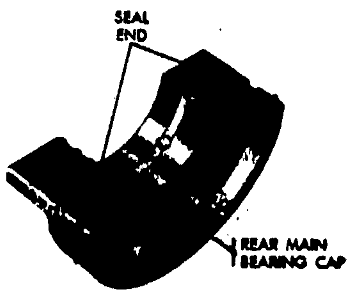

Fig 6-1. Rear main bearing side seals.

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.

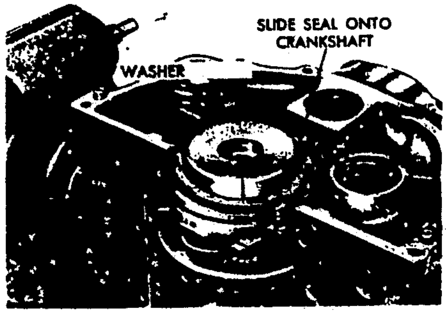

Fig 6-2. Crankshaft rear main bearing seal.

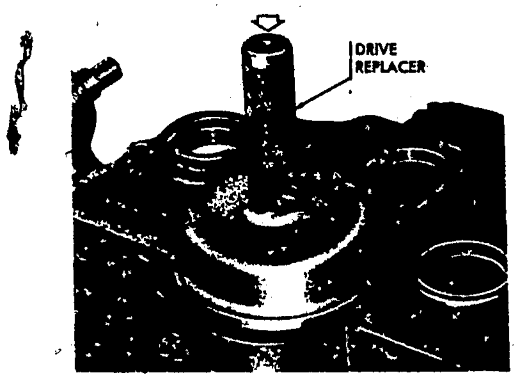

Fig 6-3. Driving the crankshaft rear main bearing seal into the engine block.

The procedure is simple, 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 main bearings in the engine block, and the lower halves in the main bearing caps (fig 6-4). Make sure the

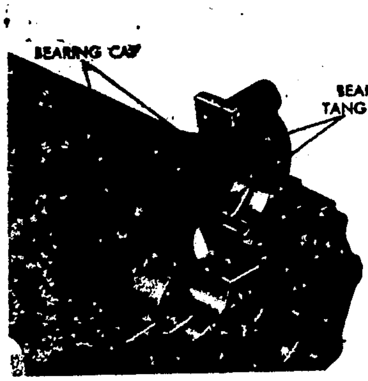

Fig 6-4. Installing main bearing halves.

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bearing halves are thoroughly cleaned and, as mentioned previously about all friction 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 ONLY snug. Now, repeat this procedure with the rear main bearing cap. With the rear bearing being snug, 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.

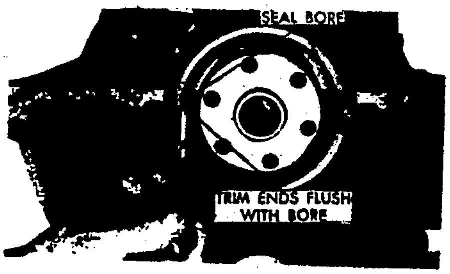

Fig 6-5. Trimming excess material from the crankshaft rear main oil seal.

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 may 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

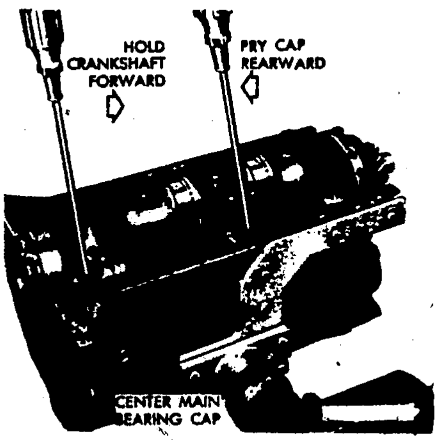

Fig 6-6. Centering the center main bearing cap.

center main bearing is always tightened first. Remember, when tightening components to torque specifications, do not apply full torque immediately. A good example is the center bearing. Tighten one side five or ten lb-ft, 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.

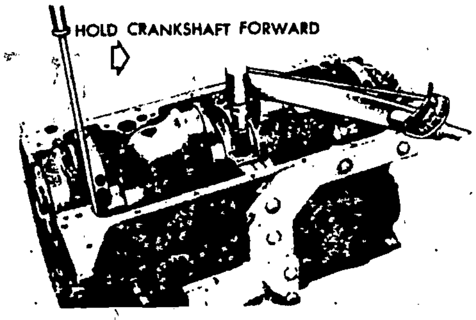

Fig 6-7. Tightening bearing caps to torque specifications.

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 completed and you can install the camshaft and tappets.

6-3. CAMSHAFT INSTALLATION

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.

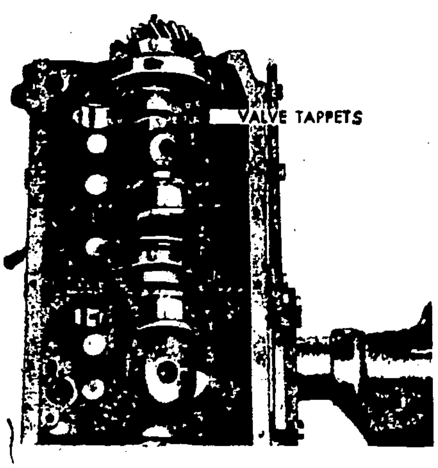

Fig 6-8. Installing mushroomed-type valve tappets.

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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 position is at TDC. Install the thrust plate bolts.

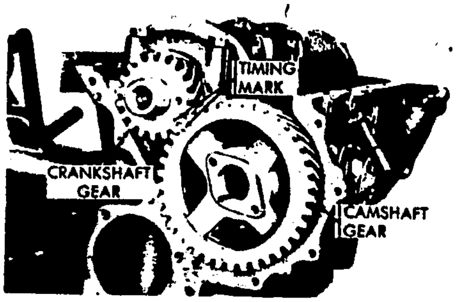


Fig 6-9. Positioning timing marks on the camshaft and crankshaft.

Before installation of the camshaft is completed, perform the same checks that you performed prior to 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 chapter 4, Engine Disassembly and refresh your memory at this time. With the completion of these tests, the camshaft timing gear retaining bolt may be tightened, and the camshaft is installed.

6-4. FLYWHEEL INSTALLATION

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

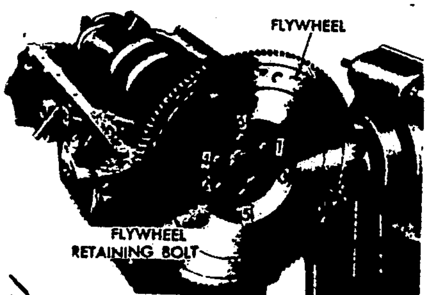


Fig 6-10. Tightening sequence for flywheel retaining bolts.

When the flywheel retaining bolts have been tightened, you must perform a flywheel runout test to ensure 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 chapter 4 and refresh your memory.

6-5. PILOT BEARING INSTALLATION

The 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 must 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).

6-6. PISTON INSTALLATION

You can now begin installing the pistons. The piston is installed from the top of the cylinder, which could 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).

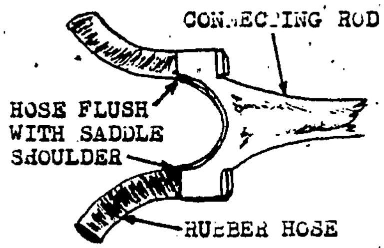


Fig 6-11. Rubber hose installed on connecting rod to protect crankpin.

The rubber hose may be vacuum hose or any small hose which will fit snugly over the bearing cap bolts. The hose should be thick enough however, 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).

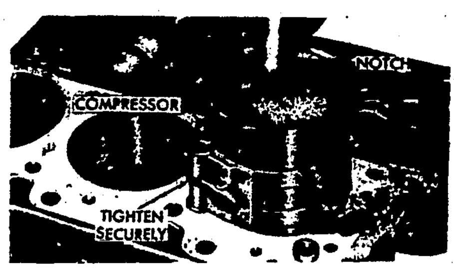


Fig 6-12. Installing piston in engine.

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 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 TDC.

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 with the specifications listed in the TM at this time (fig 6-13).

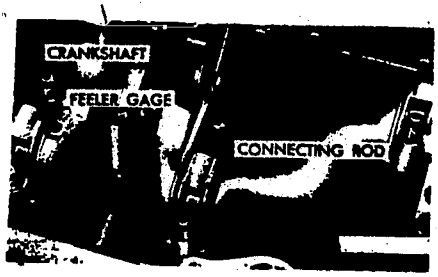


Fig 6-13. Checking connecting rod side play.

Don't forget to tighten the connecting rod cap nuts to manufacturer's specifications and check bearing clearance, just as we 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.

6-7. OIL PUMP INSTALLATION

Although 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 installed improperly, 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.

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

6-8. OIL PAN INSTALLATION

We 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.

6-9. VALVE INSTALLATION

We 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. 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. The valve is inserted, stem first, into the valve guide from the bottom of the head. If the valve is an intake valve, the valve stem seal is then placed 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).

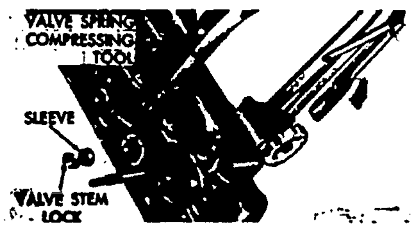


Fig 6-14. Compressing the valve spring.

After compressing the valve spring, we insert the valve stem locks. In some cases however, 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 5-44 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, let's 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 compressing tool is placed beneath it. The spring is then compressed and the valve stem is dropped into its position (fig 6-15).

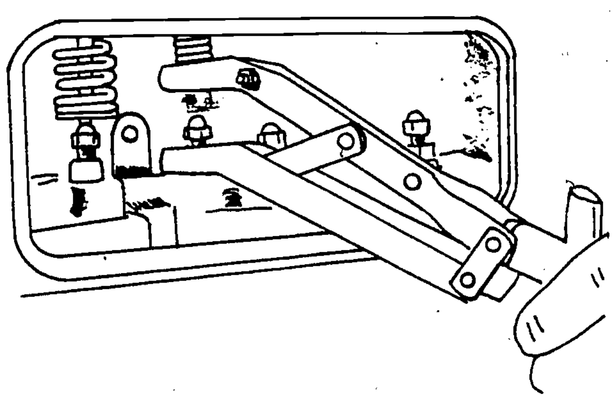


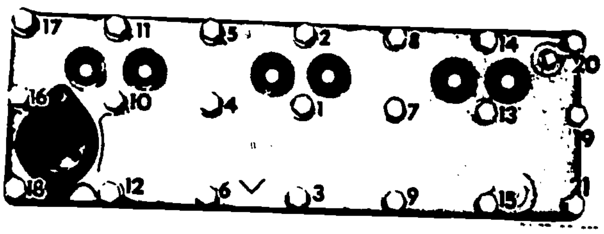
Fig 6-15. Compressing valve spring of valve-in-block engine.

After dropping the valve into position, place the valve spring retainer over the end of the valve stem, 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.

6-10. CYLINDER HEAD INSTALLATION

Now, we 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.



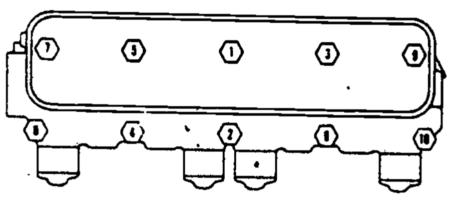


Fig 6-16. Typical tightening sequence for cylinder heads.

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).

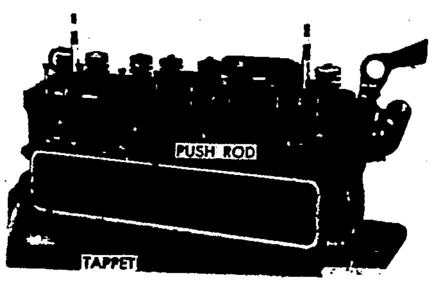


Fig 6-17. Installing pushrods.

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The next step is to assemble and install the rocker arm shaft. Each component is reassembled in its original position (figure 6-18). After assembly, 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.

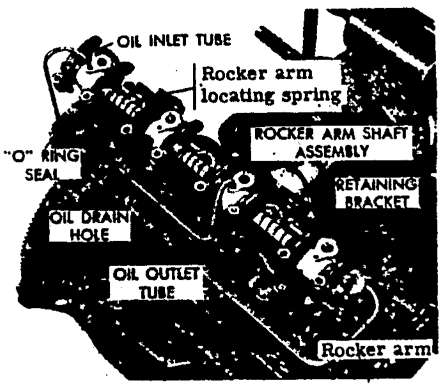

Fig 6-18. Rocker arm shaft assembled.

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 might 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.

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