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Developed by teacher educators and agricultural engineers, this teacher and student reference is for use in a course in small engine operation and maintenance. Content includes: (1) Principles of Good Workmanship, (2) Repairing Starters, (3) Maintaining and Repairing Ignition Systems, (4) Repairing Fuel Systems, (5) Repairing Governors, (6) Repairing Valves, (7) Repairing Cylinders and Piston-and-Rod Assemblies, (8) Repairing Lubricating Mechanisms in 4-Cycle Engines, (9) Repairing Camshaft Assemblies in 4-Cycle Engines, and (10) Repairing Crankshaft Assemblies. Teachers should be graduates in teacher education and students should be of at least high school age with an interest in mechanics and science. Supplementary materials include 328 colored illustrations, an owner's engine information form and a list of references. Volume I of this series containing small engine operation and simple maintenance jobs is available as VT 006 206. (DM)

SMALL ENGINES

CARE - OPERATION - MAINTENANCE & REPAIR

ISSUED BY THE . . .

AMERICAN ASSOCIATION FOR AGRICULTURAL ENGINEERING AND VOCATIONAL AGRICULTURE

an organization of agricultural colleges and divisions of vocational agriculture devoted to the improvement of agriculture through better information and teaching aids.

Prepared by J. Howard Turner, Engineering Editor, and George W. Smith Jr., Art Director and Mrs. Florence Gorham, Illustrator of the American Association for Agricultural Engineering and Vocational Agriculture. Acknowledgement is given to the many individuals, companies and agencies that assisted, page 201.

JUNE 1968

VOLUME II

OF TWO VOLUMES

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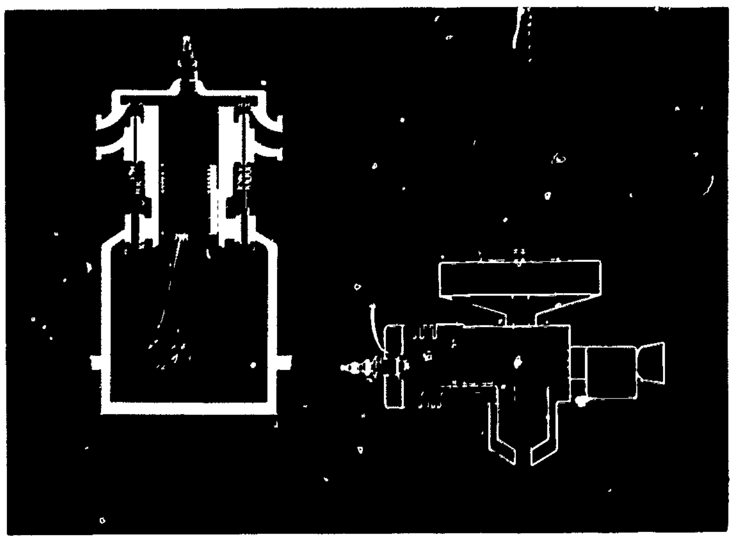

CONTENTS

SMALL ENGINES

CARE - OPERATION - MAINTENANCE & REPAIR

For convenience this book is bound in **two separate volumes.** From **Volume I** you may learn *how to operate and how to do simple maintenance jobs* on your engine.

The information in **Volume II** will help you to expand your knowledge beyond servicing and operating an engine into *major maintenance and repair*. It explains the operating principles of different units such as starters, ignition systems, valves and lubrication systems. It also explains how to tell when such units are not working properly and how to repair them. The principles and procedures are given for each unit in such a sequence that it is not necessary for you to disassemble completely the engine before you start to work on it.

VOLUME II

MAINTENANCE AND REPAIR OF SMALL GASOLINE ENGINES

There is much personal satisfaction in understanding the more detailed operating principles of small engines, in becoming familiar with the common structural parts and their functions, and in knowing how to do the more difficult maintenance and repair jobs. Small engines are similar in principle and in operation to large internal combustion engines. Consequently, you gain a knowledge and an appreciation of how to maintain and repair large engines such as those used in trucks, tractors and automobiles.

You **save both time and money** by doing certain maintenance and repair jobs, or by knowing when they should be done. After you get some experience, you will be able to determine whether or not it is more economical to replace a complete assembly or to purchase parts and repair it. For example, an accessory such as a starter or a carburetor can usually be repaired at a reasonable cost. If you have trouble, however, with such parts as a piston, piston rod or crankshaft, it may be more economical for you to buy a "short block" assembly (Figure 1).

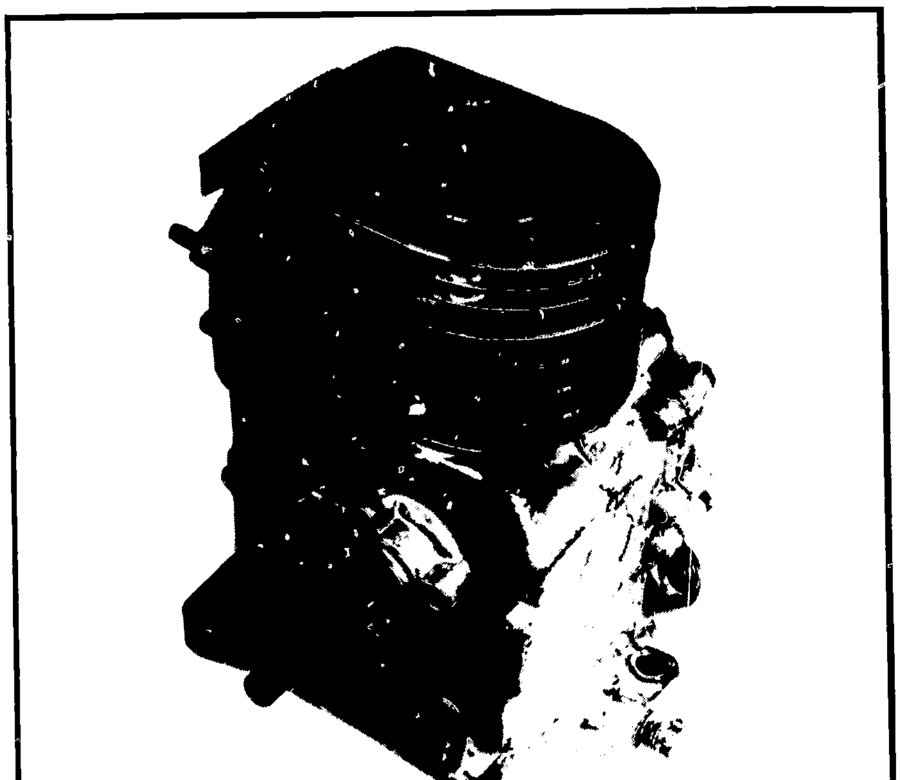

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FIGURE 1. A "short block" assembly which may be purchased as a unit.

A short block assembly is a factory-built cylinder-block assembly which includes the crankcase, piston, piston rings, connecting rod, valves, cylinder and camshaft. It comes ready for you to add the remaining parts, such as the magneto, cylinder head, carburetor and starter. The cost is approximately one half that of a new engine—completely assembled, and it is approximately twice the cost of a new crankshaft.

There are other advantages to maintaining your small engine. You can **make your engine start more easily and run more smoothly, and develop its maximum horsepower.** In addition, there are maintenance jobs which, when done in time, will prevent serious damage to the engine and will make it last much longer.

PRINCIPLES OF GOOD WORKMANSHIP

A systematic approach is best for doing any job, but it is of particular importance when working on engines, A part left out, or incorrectly assembled, may cause more damage than existed originally.

Before working on your engine, **learn as much as you can about it.** Get the operator's manual and service manual if possible. You need these manuals for finding the specifications for your particular engine. Read and follow their instructions. Study the types of accessories on the engine and the functions of the various parts. These are also discussed in this text. In addition, the step-by-step procedures given here are a helpful guide for disassembling, reassembling and making adjustments on all engines. Reasons for doing certain jobs and using certain methods are explained.

Prepare a clean place to work. This helps prevent parts from collecting dirt. If you put dirty parts in the engine, it will not last long because dirt is an abrasive and causes wear.

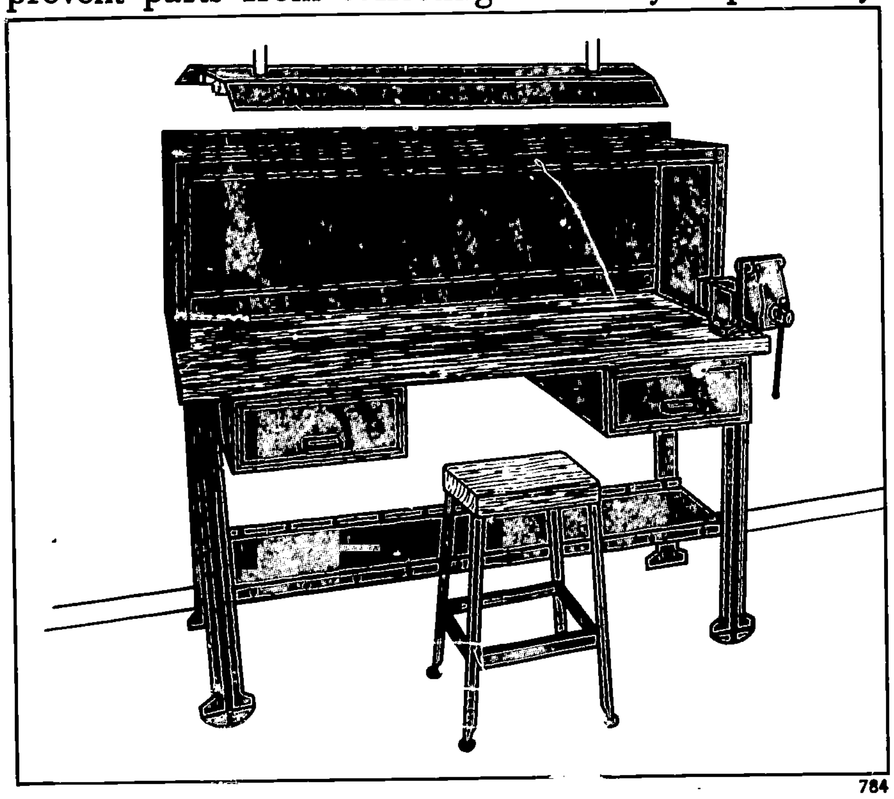

FIGURE 2. Provide a clean, convenient, well-lighted work area.

Use a workbench if possible (Figure 2). It provides a place to lay out parts and tools, and helps keep them clean. Also, working on a workbench is much more comfortable than working on the floor.

Provide plenty of light. Two 150-watt reflector-type bulbs or two 48-inch, 40-watt flourescent tubes mounted 4 feet above the work bench will give enough light spread—without shadows.*

Get an engine stand, if possible (Figure 3). A stand holds the engine securely while you remove most of the parts.

Assemble the proper tools, materials and equipment before starting a job. The basic tools and materials needed for each job are listed in the text. You may need some special tools, however, in addition to this list.

Clean the engine before attempting to repair it. You can remove most of the dirt and grime from an engine before removing many parts. This makes the repair job much cleaner and reduces the possibility of getting harmful dirt particles inside the engine. For procedures, refer to "Cleaning Small Engines," Volume I.

Lay the parts out in order of their disassembly, and let them remain in this order throughout the cleaning and inspection process (Figure 4). This will assure correct reassembly. Another good practice is to **draw a sketch of the assembly be-**

*For a complete discussion on lighting, refer to "Planning the Farm Shop Layout," AAAE & VA, 1965.

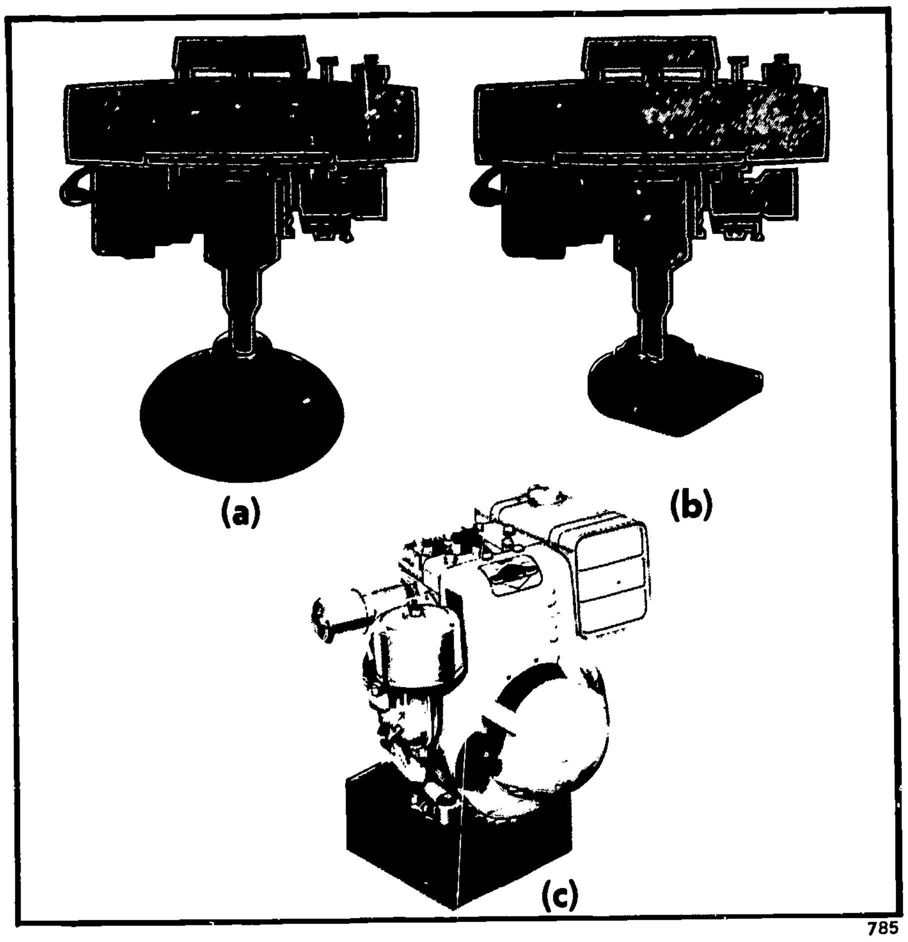

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FIGURE 3. (a and b) Typical commercial engine stands used for holding the engine by the crankshaft while working on it. (c) A stand made from wood.

fore, or while, you take it apart. Then if the parts become mixed, you will have a record of how to put them together again.

Order parts as soon as you are aware of the need for them. When ordering parts for your engine, be sure to give your dealer sufficient information for him to determine the correct parts. Manufacturers of small engines make hundreds of variations in their models according to equipment manufacturer's needs. Therefore it is necessary for the dealer to have the model number and serial number to determine which part fits your engine. A type number is also given on some engines. You will usually find these numbers on the engine nameplate (Figure 5) or stamped on the cooling shroud. If the number is difficult to read, try rubbing it with a piece of chalk. Sometimes this brings out the raised or indented numbers.

If you can, take the old part for comparison when purchasing new parts. If you have access to the part number, give it to the dealer also.

While working on your engine, look for conditions that may cause future trouble. Check unusual wear or damage. You may be able to prevent a future breakdown by making an adjustment or repairing a part before it has failed.

The information presented in this volume is included under the following headings:

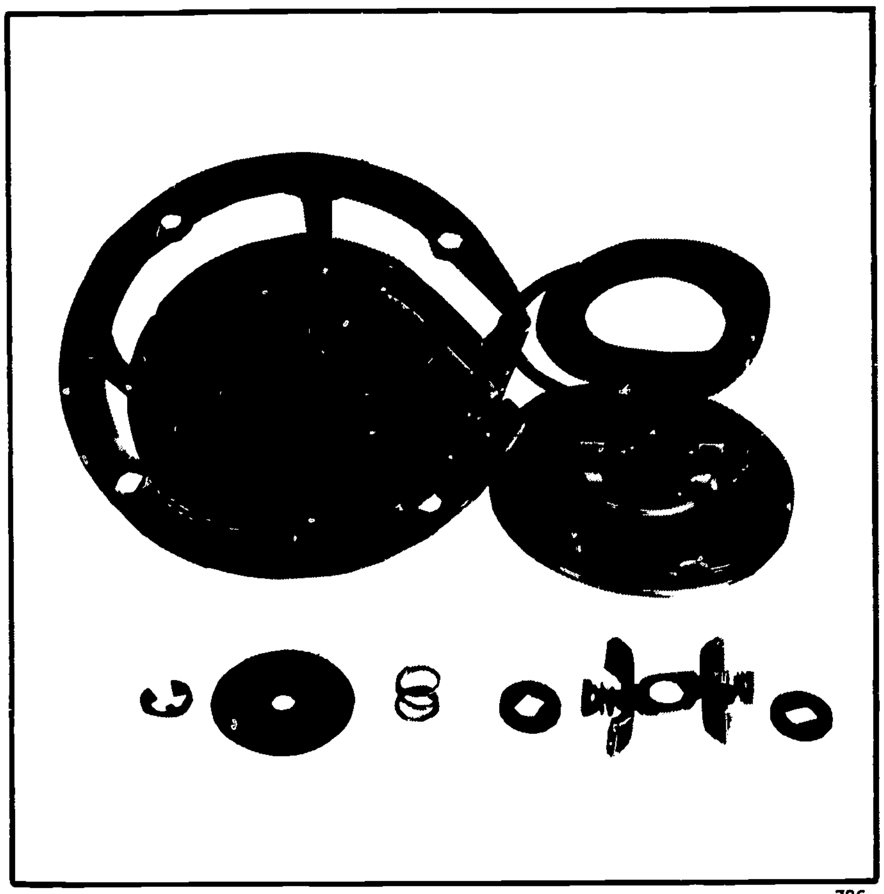

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FIGURE 4. Always lay parts out in order of their disassembly.

I. Repairing starters.
II. Maintaining and repairing ignition systems.
III. Repairing fuel systems.
IV. Repairing governors.
V. Repairing valves.
VI. Repairing cylinders and piston-and-rod assemblies.
VII. Repairing lubricating machanisms in 4-cycle engines.
VIII. Repairing camshaft assemblies in 4-cycle engines.
IX. Repairing crankshaft assemblies.

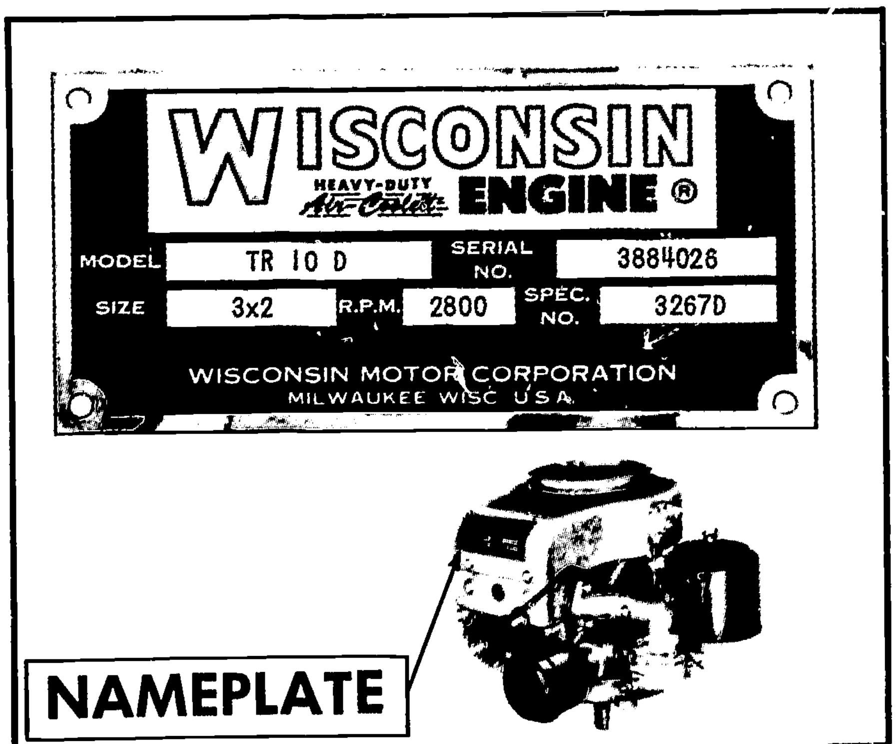

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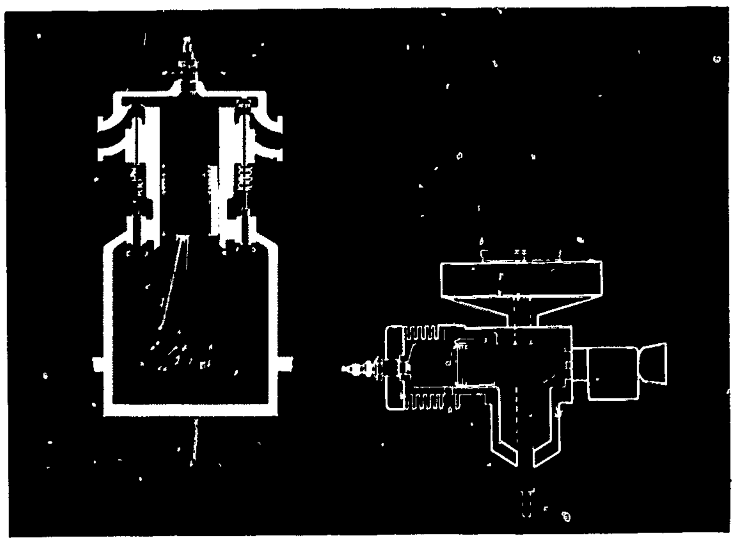
FIGURE 5. The engine nameplate gives information for ordering new parts.



I. REPAIRING STARTERS

Starters take much punishment. Most operators neglect to maintain their small engines properly. As a result, they are difficult to start. The starter is overworked. For this reason, maintaining and repairing starters are discussed first in this book.

The information on starters applies to **both 4-cycle and 2-cycle engines.**

A good way to keep your starter maintenance at a minimum is to keep your engine in good running condition. This will not prevent, however, all starter troubles. Starters are subject to normal wear and occasional breakdown.

To do a good job when working on starters, you should first have an understanding of the *function of starters* and of the *different types* used on small engines.

FUNCTION OF THE STARTER

The purpose of the starter on an engine is to provide a means for turning the crankshaft until the combustion cycle is started. Once the cycle is started, it continues to repeat itself—the engine runs. The events that take place during each cycle are explained fully under "How Small Gasoline Engines Work," Volume I.

For starting, the crankshaft is *turned fast enough by the starter* for a combustible fuel-air mixture to be drawn into the combustion chamber, compressed and ignited. Once this takes place, the starter is released and the engine runs on its own.

A starter must have:

- A source of power—manual or electric.
- A drive mechansim for engaging the crankshaft during cranking and disengaging the crankshaft after the engine has started.
- A means for transmitting power from the source to the drive mechanism—usually a rope and pulley, V-belt and pulley, a gear drive, or a friction drive.

TYPES OF STARTERS

The starting functions are accomplished by two basic types of starters: **manual** and **electric.**

Most small engines are started by turning the flywheel with a *manual starter* (Figure 6a). *Electric Starters* (Figure 6b), however, are becoming more and more popular—especially on engines of 5 horsepower or more.

There are three common types of **manual starters:**

- Rope-wind (Figure 10).
- Rope-rewind or recoil (Figure 7a).
- Windup, or impulse (Figure 7b).

The **rope-wind starter** is the simplest of starters. It consists of a rope which has a knot on one end and a T-handle secured by another knot on the other end. For starting, the rope is wound around a flange on the flywheel and the engine is turned with a strong, hard tug of the rope.

The **rope-rewind starter** (Figure 7a) operates similarly to the rope-wind starter except it is a

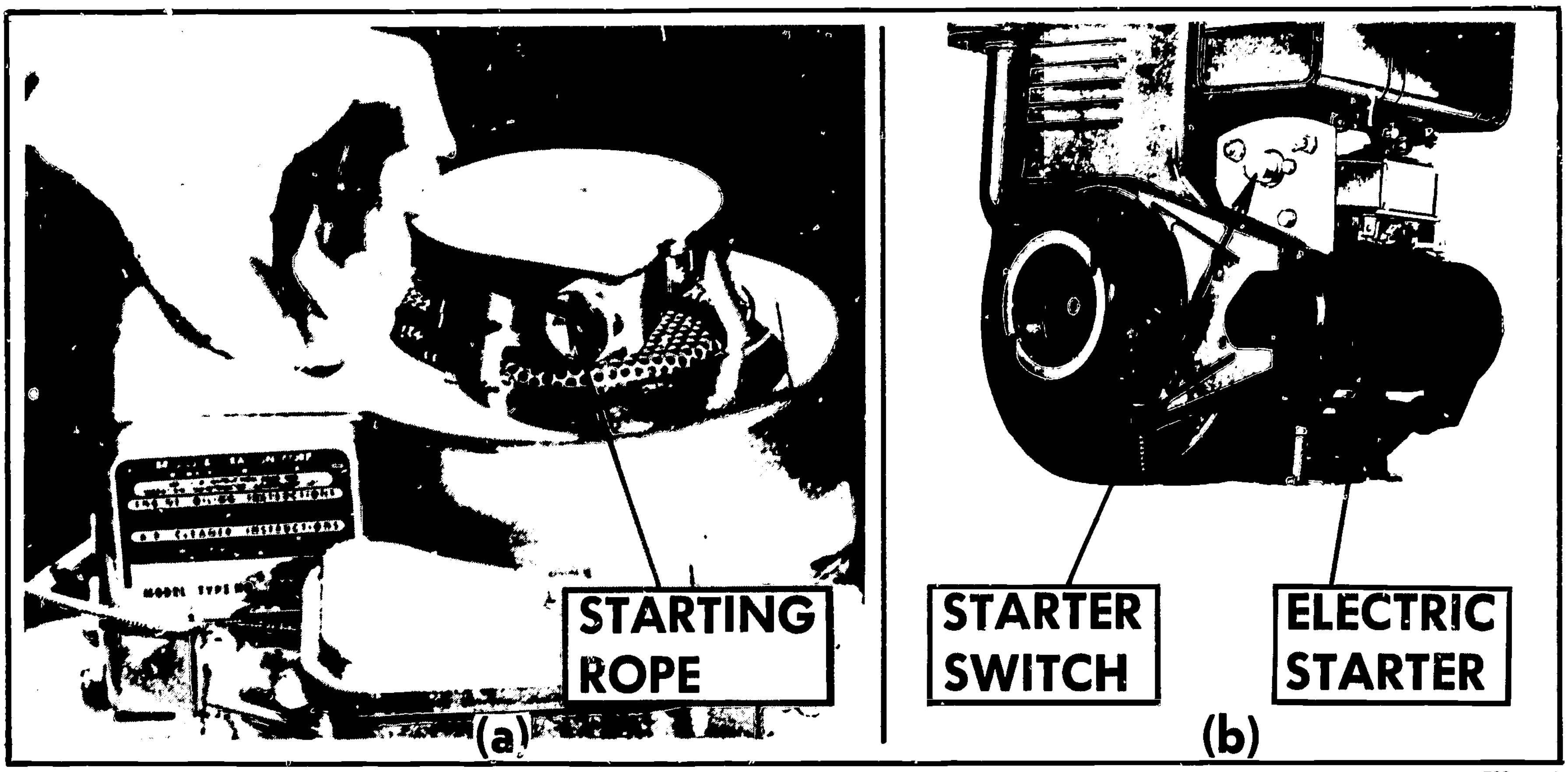


FIGURE 6. (a) One type of manual starter—rope-rewind. (b) An electric starter—combination starter-generator.

little more automatic. After each pull, the rope is automatically rewound by a recoil spring. Since the rope is permanently attached, there is a means of engaging and releasing the starter drive.

The **windup starter** (Figure 7b) has no rope. It is an impulse-type mechanism which consists of a *heavy recoil spring, crank-holding rachet* and a *release mechanism*. When starting the engine, you wind up the spring with the crank; then you release the spring which spins the crankshaft.

The advantage and disadvantages of all three manual-type starters are listed in Table 1, page 10.

The use of **electric starters** is becoming more and more popular on small engines—especially on engines of 5 horsepower and above, such as those used on small tractors. Electric starters practically elimi-

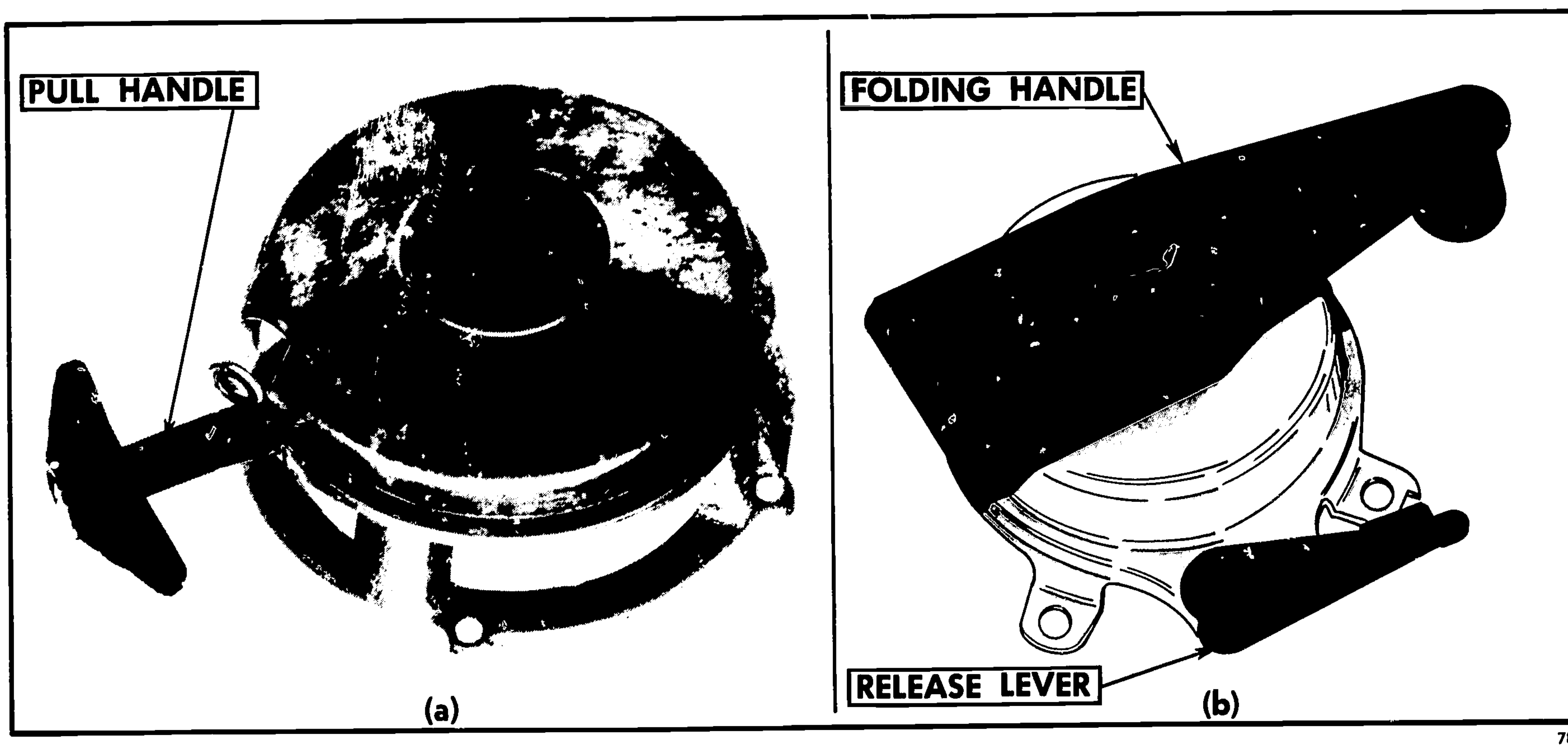


FIGURE 7. (a) A rope-rewind starter. (b) A windup starter.

TABLE I. ADVANTAGES AND DISADVANTAGES OF DIFFERENT TYPES OF MANUAL STARTERS

Type of Manual Starter	Advantages	Disadvantages
Rope-wind	Simple and economical Only maintenance required is to reknot and/or replace rope	Takes time to wind rope and requires, much physical effort to use Loose rope is easy to misplace and/or lose Danger of pulling engine over
Rope-rewind	Rewinds itself; saves time	Requires occasional maintenance Engine cannot be started unless starter is operative
Windup	Requires very little physical effort	Some types are nonreparable Engine cannot be started when starter is out of order

nate manual labor for starting and, when maintained properly, provide a fast and convenient means for starting your small engines. An electric starter will save you much time if you are doing a job that requires frequent stopping and starting such as operating an elevator or a garden tractor (Figure 8).

Some electric starters are designed to operate on alternating current and some on direct current.

Alternating-current starter motors operate on 120-volt current from the home wiring system. An extension cord is used to connect the starter to a convenience outlet (Figure 9a).

Many **direct-current starters** (Figure 9b) are similar to the ones you have on your tractor, truck or automobile. Most electric starters on small engines, however, are designed to start the engine and then to act as a generator when the engine is running. These types of starter-generators are discussed on page 41.

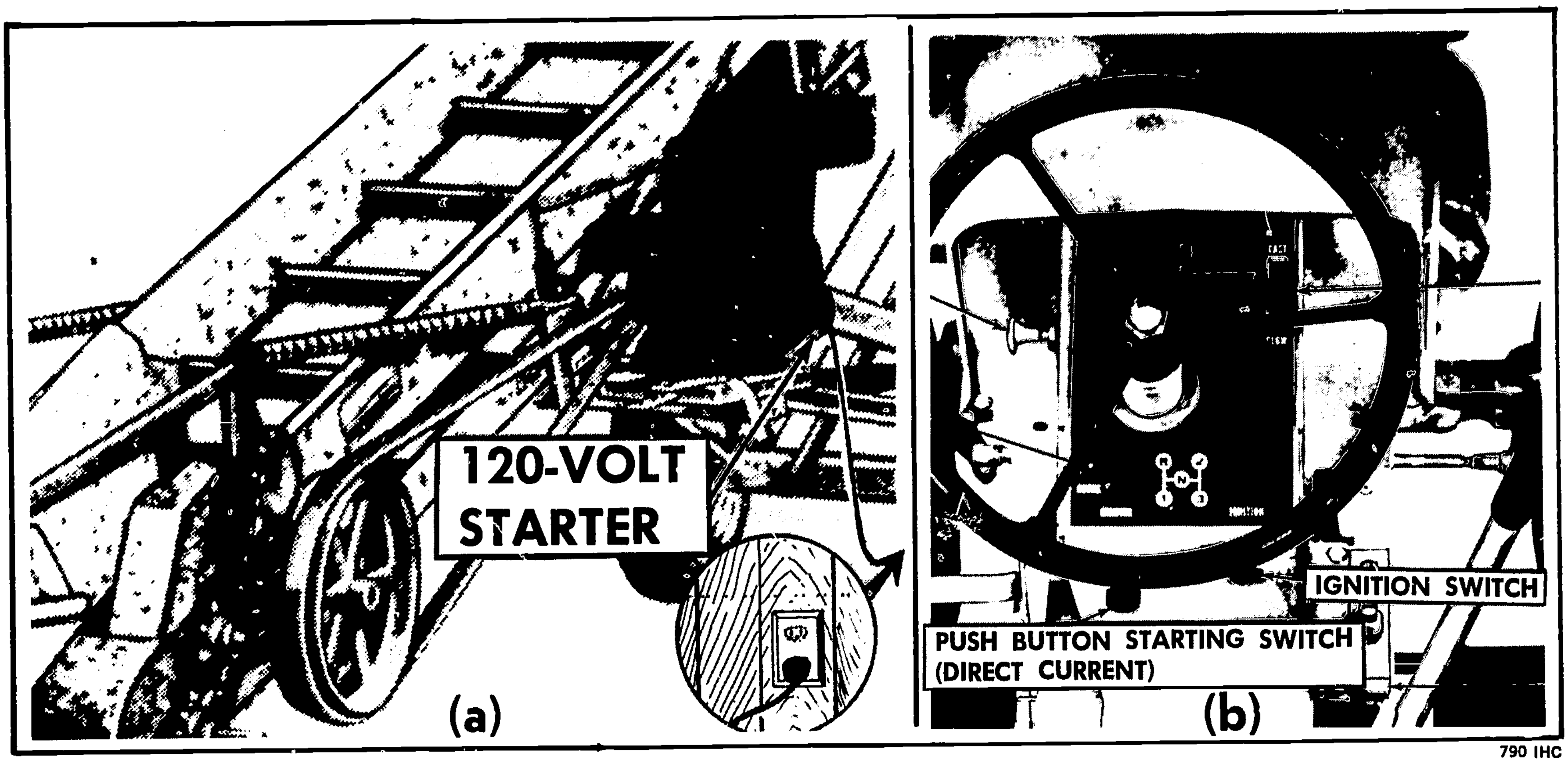


FIGURE 8. Applications of an electric starter. (a) A 120-volt alternating current electric starter on a small engine operating an elevator. (b) A 12-volt battery-operated direct-current starter on a garden tractor.

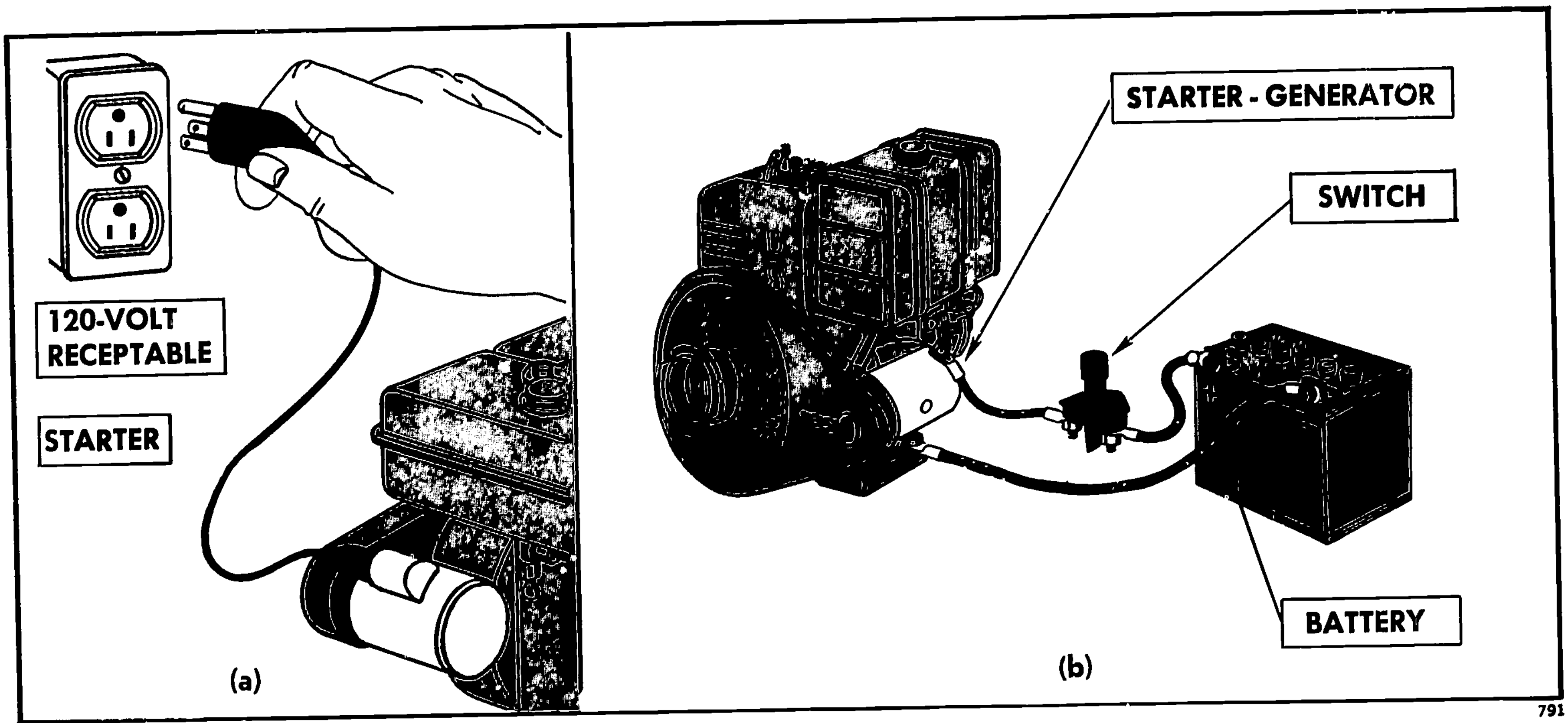


FIGURE 9. Sources of power for electric starters are (a) 120-volt alternating current from the home wiring system, and (b) 6- or 12-volt direct current from a battery-and generator system.

How starters work and how to maintain and repair them are discussed under the following headings:

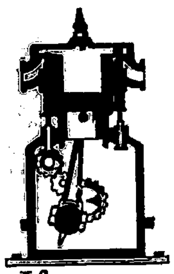
A. Repairing rope-wind starters.

B. Repairing rope-rewind starters.

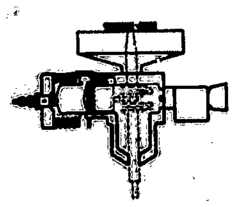
C. Repairing windup starters.

D. Repairing 120-volt alternating-current starters.

E. Repairing direct-current starting and generating systems.



A. REPAIRING ROPE-WIND STARTERS



If your manual starter is the rope-wind type (Figure 6a), you will have little or no maintenance problem except with the rope. The information you need is given under the following headings:

1. Principles of operation.
2. Tools and materials needed.
3. Checking for proper operation.
4. Reknotting or replacing the rope.

PRINCIPLES OF OPERATION

Provisions for turning the crankshaft consist of a rope which is wound onto a pulley. The pulley is attached to the end of the crankshaft or on the flywheel. The rope is long enough for three to five turns on the pulley. This allows the crankshaft to be turned three or four complete revolutions during cranking—which should be sufficient for starting the engine.

One end of the rope is knotted and is engaged in a slot in the pulley flange for cranking. The slot is slanted away from the direction of rotation (Figure 10). When the engine starts, the rope is released.

A T-handle is attached to the opposite end of the rope for pulling by hand.

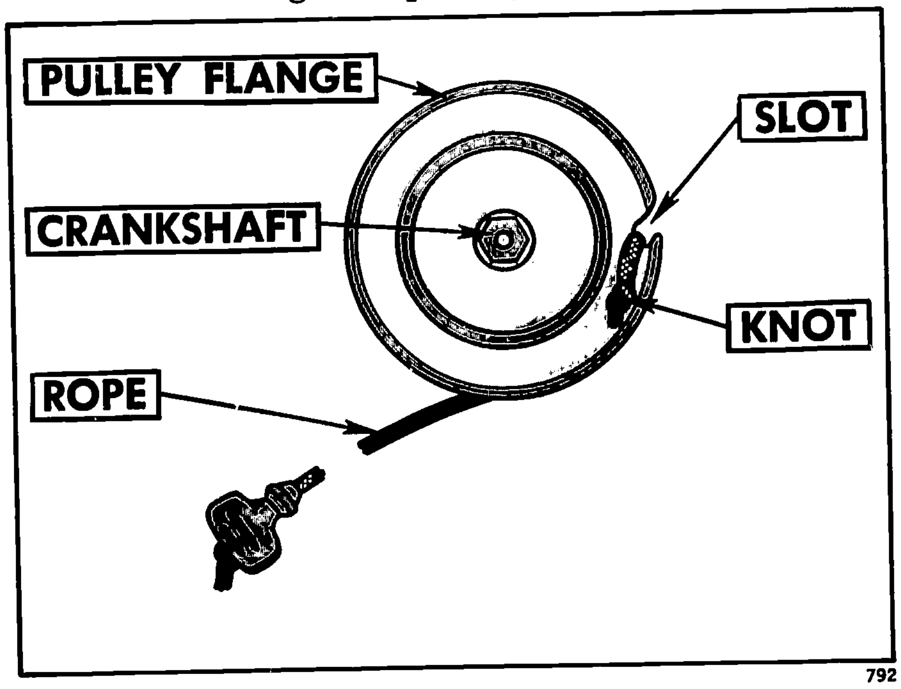


FIGURE 10. Starting rope and pulley. Slanted slot in the pulley flange is for engaging the rope during cranking and for disengaging it after the engine starts.

TOOLS AND MATERIALS NEEDED

1. Pocket knife or diagonal cutting pliers
2. Replacement rope
3. Matches

CHECKING FOR PROPER OPERATION

1. *Disconnect the spark-plug wire to prevent the engine from starting.*

2. *Engage the knot in the slot which is in the pulley flange.*

3. *Wind the rope onto the pulley.*

4. *Pull the rope slowly—turning the crankshaft—until the piston begins compression stroke.*

   You can tell by the increased resistance.

5. *Rewind the rope all the way.*

6. *Brace one hand against the engine to prevent pulling it over, if on light-weight equipment.*

7. *Pull the rope all the way with a sharp, firm pull.*

   The knot should hold firmly until the rope is completely unwound and released from the pulley.

   If for any reason the rope does not release and the engine starts, the rope will rewind on the pulley in the opposite direction. It is important that the rope does not bind.

   If the knot does not hold, remove and replace the knot; or if the rope breaks, replace it. See procedures that follow.

REKNOTTING OR REPLACING THE ROPE

1. *Select the proper size and length of rope.*

   Use a 3/16″ diameter nylon-braided rope. Usually starting ropes are 4 to 5 feet long. The length should be *long enough to wind around the flywheel flange pulley 3 to 5 time, plus about 6 inches for lead between*

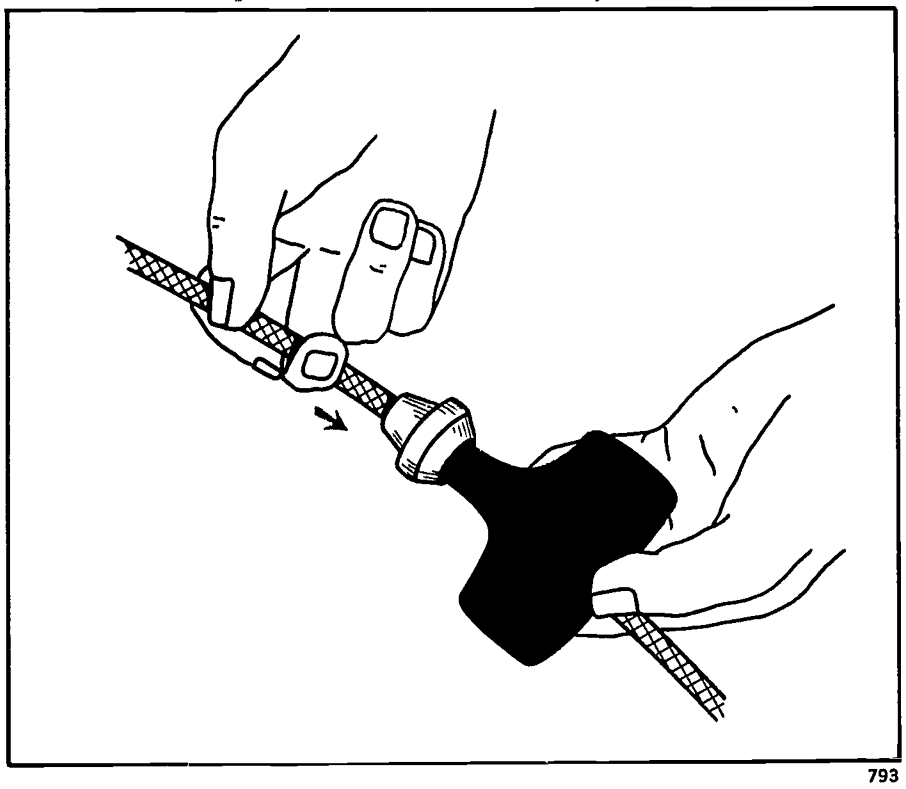


FIGURE 11. Insert the rope into the T-handle before knotting.

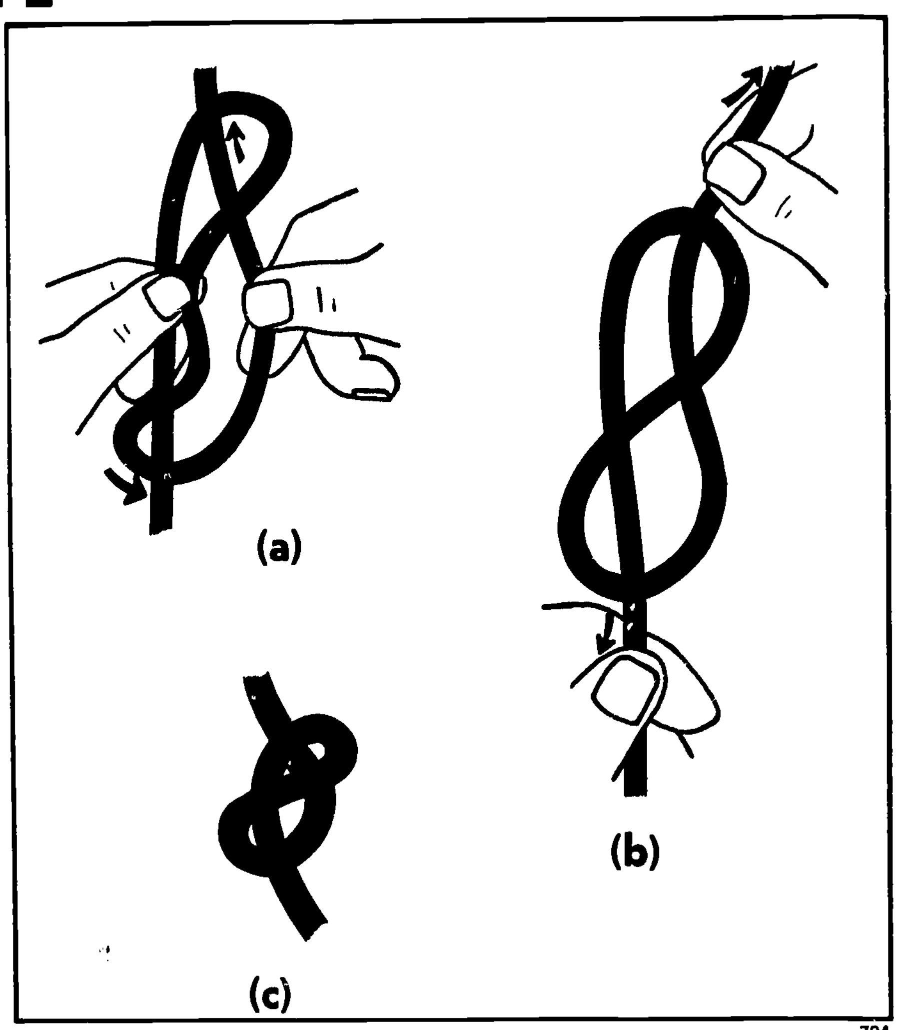


FIGURE 12. Procedures for making a "figure-of-eight" knot. (a) Form loop, wrap loose end around the rope and then feed the loose end through the loop. (b) Tighten knot. (c) Completed knot.

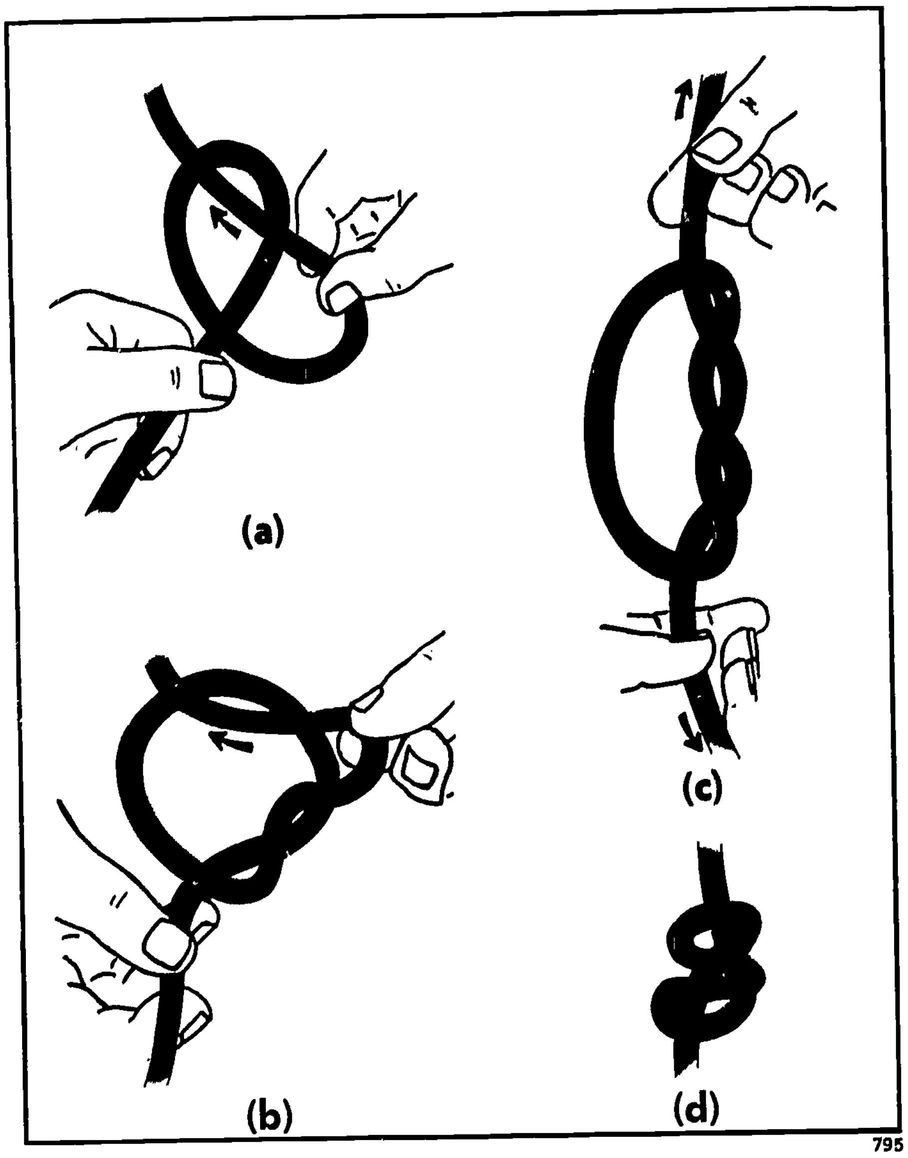


FIGURE 13. Procedures for making a "double-overhand" knot. (a) Feed end through loop. (b) Feed end through a second time. (c) Tighten knot and pull tight. (d) Completed knot.

the pulley and T-handle, and *with an additional 6 inches for knots.*

2. *Seal frayed ends of nylon rope by singeing.*

   Hold a lighted match under the end of the rope until it is fused. This prevents fraying.

   CAUTION! Do not light a match near an open container of gasoline or spilled fuel.

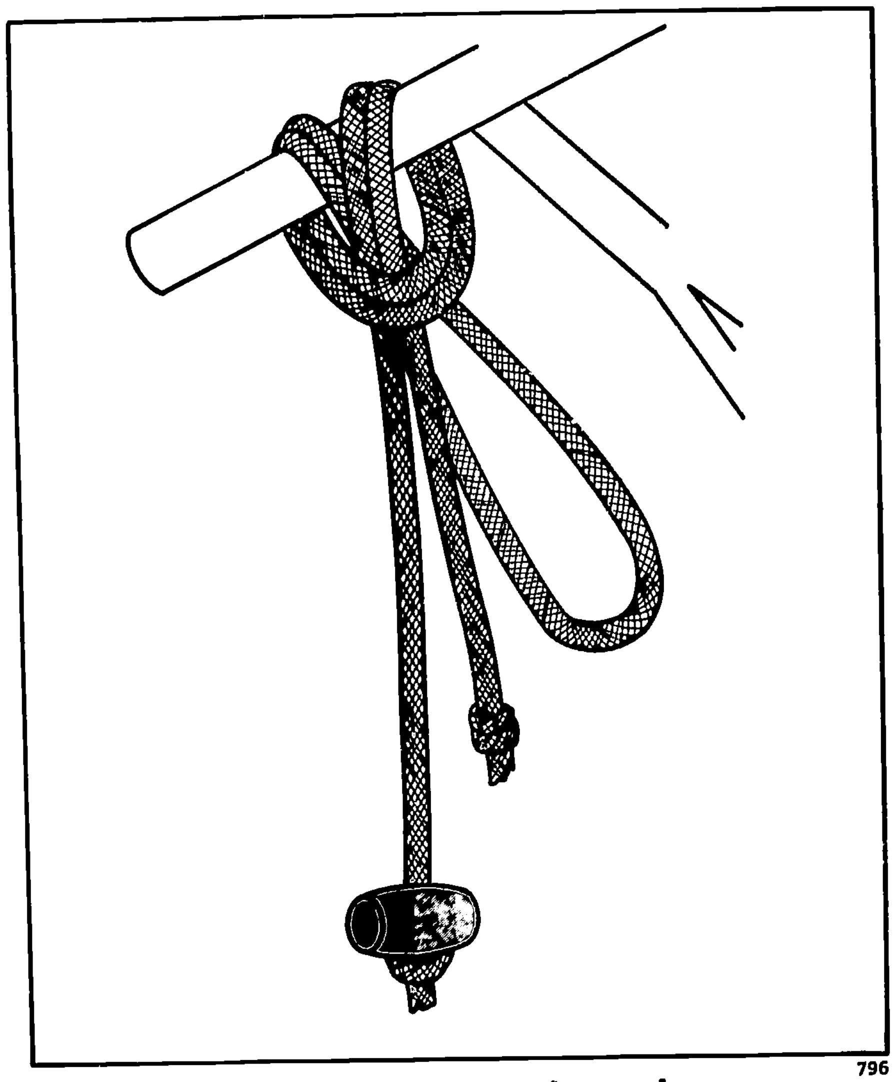


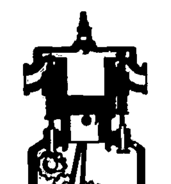
FIGURE 14. A method for stowing the crankrope.

3. *Insert one end of rope into the T-handle (Figure 11).*

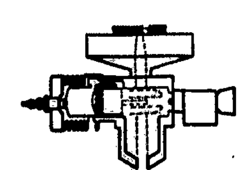
4. *Knot both ends of the rope.*

   Use either a "figure-of-eight" knot (Figure 12), or a "double-overhand" knot (Figure 13).

5. *Stow rope on equipment (Figure 14).* Double rope twice. Make a "girth-hitch" knot and loop it over the handle bar or some safe part of the equipment (Figure 14).



B. REPAIRING ROPE-REWIND STARTERS



Dirt and grease, if allowed to accumulate in the starter, will cause wear and eventual failure. The springs will not flex properly and the parts will wear faster. One good cleaning each season will pay off in longer trouble-free service.

When you are repairing your starter, follow the instructions given by the manufacturer; but if they are not available, the discussions and procedures under the following headings will be helpful:

1. Principles of operation.
2. Tools and materials needed.
3. Checking for proper operation.
4. Replacing the rope.
5. Repairing the drive mechanism.
6. Replacing the recoil spring.

PRINCIPLES OF OPERATION

The rope-rewind starter saves you the trouble of rewinding the rope on the flywheel pulley each time you crank the engine. But you still have to pull the rope. Here is how it works (Figure 15):

When you pull the rope, the **starter pulley** is turned. The **pawls** fly out by centrifugal force and engage the crankshaft adapter so the engine is cranked as the rope is pulled.

At the same time, the **recoil spring** is wound because the inside end of the spring is attached to the pulley and the outside end to the starter housing.

When you release the rope, whether the engine has started or not, the **pulley** is turned in the opposite direction by the tension built up in the recoil spring. The rope is rewound on the pulley.

The **pawls** retract and a small spring holds each of them in the retracted position.

Procedures for repairing the drive mechanism are given under "Repairing the Drive Mechanism," page 20.

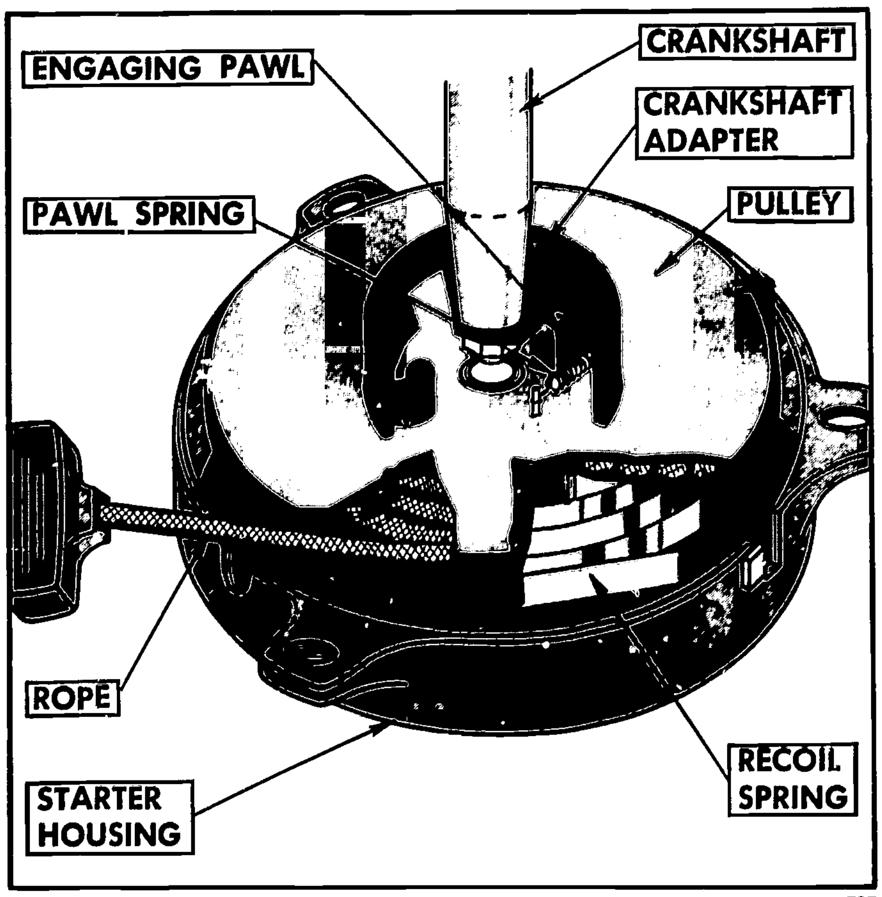


FIGURE 15. Basic parts of a rope-rewind starter are rope, pulley, recoil spring and drive mechanism.

TOOLS AND MATERIALS NEEDED

1. Vise-grip pliers or adjustable end-wrench (depending on your type starter)
2. Wire paper clip
3. Slot-head screwdriver — 8″
4. Nut driver — 7/16″
5. Long-nose pliers — 7″
6. Phillips-head screwdriver — 6″
7. Vise — 4″
8. 8-inch C-clamps (2)
9. 3/4″ x 3″ x 5″ woodstock
10. Small amount of multi-purpose grease
11. Matches
12. Rope
13. Gloves
14. Petroleum solvent (mineral spirits, kerosene, or diesel fuel)

CHECKING FOR PROPER OPERATION

1. *Disconnect the spark-plug wire to prevent the engine from starting.*
2. *Grasp the T-handle with one hand and brace yourself against the engine with the other.*
3. *Pull the rope out slowly (Figure 16).*

   The rope should unwind freely. **Binding** or **hitching** indicates the rope or *recoil spring* is *jammed.*

   If the engine crankshaft does not turn as the rope is pulled out, *the starter drive mechanism* is not engaging. It will need to be repaired or replaced. See procedures under "Repairing the Drive Mechanism," page 20.
4. *Inspect the rope for wear.*

   If the rope breaks, or is worn, replace it. See procedures under "Replacing the Rope," next heading.
5. *Allow rope to rewind.*

   Do not turn T-handle loose and allow it to fly back freely. There is a danger of break-

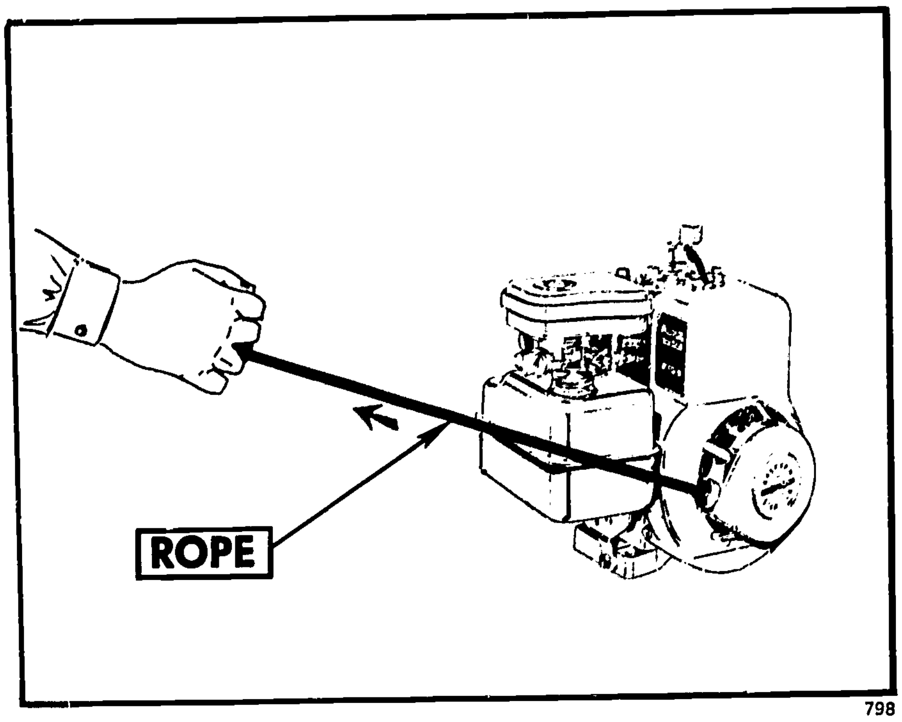


FIGURE 16. Pull the starter rope out slowly for inspection.

ing the recoil spring. This action also causes undue wear on the rope.

If the rope does not rewind, there may be several reasons:

- The rope and/or pulley may be binding.
- The spring may be bent, broken or disengaged.
- There may be insufficient spring tension.
- The starter may be assembled improperly.

Follow procedures under "Replacing the Rope," page 15 and, if necessary, "Replacing the Recoil Spring," page 23.

REPLACING THE ROPE

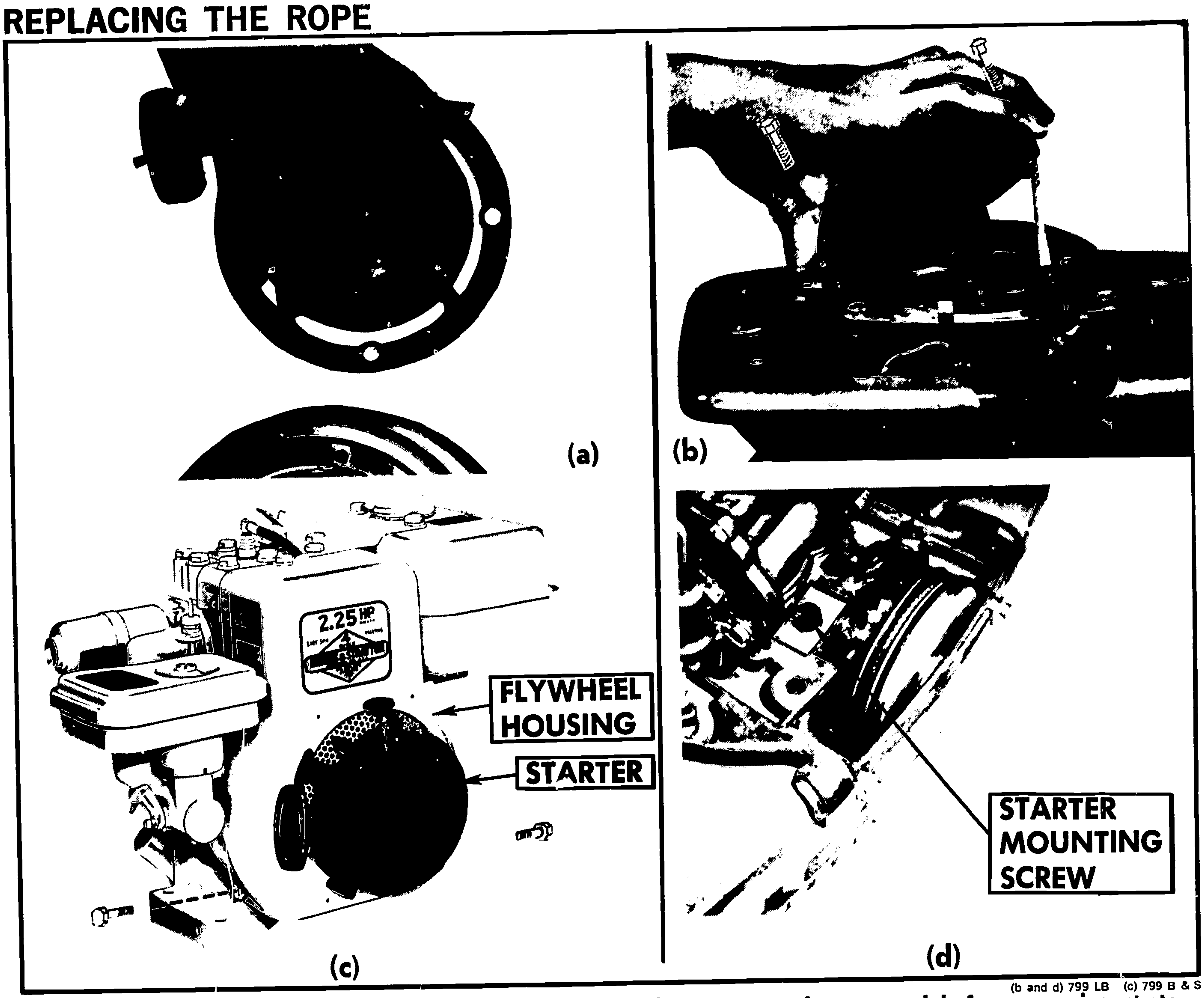


FIGURE 17. Common locations and methods for mounting rewind starters. (a) and (b) Starter surface-mounted and held by cap screws. (c) Starter surface-mounted but as an integral part of the flywheel housing. The flywheel housing must be removed before removing starter. (d) Starter partially enclosed by engine block casting and held by clamp and capscrew.

FIGURE 18. Secure starter housing before attempting to work on the starter. (a) Starter secured in a vise. (b) Starter secured by a C-clamp. (c) Starter and shroud held by a specially cut wooden block, and a vise.

1. *Determine how the starter is mounted.*

   Most starters are attached to the flywheel housing by three or four screws (Figure 17a and b). Some are enclosed in the flywheel housing (Figure 17c). Figure 17c illustrates a type of rewind starter that is secured by a mounting screw and clamp.

2. *Gain access to the starter if necessary.*

   It may be necessary to remove some part of the equipment or a part of the engine cowling.

3. *Remove the starter.*

   The starter is removed as a self-contained unit. The spring will not unwind.

4. *Clamp starter housing in a vise (Figure 18a), or use C-clamps (Figure 18b).*

   Use vise-jaw protectors to prevent damage in the starter housing.

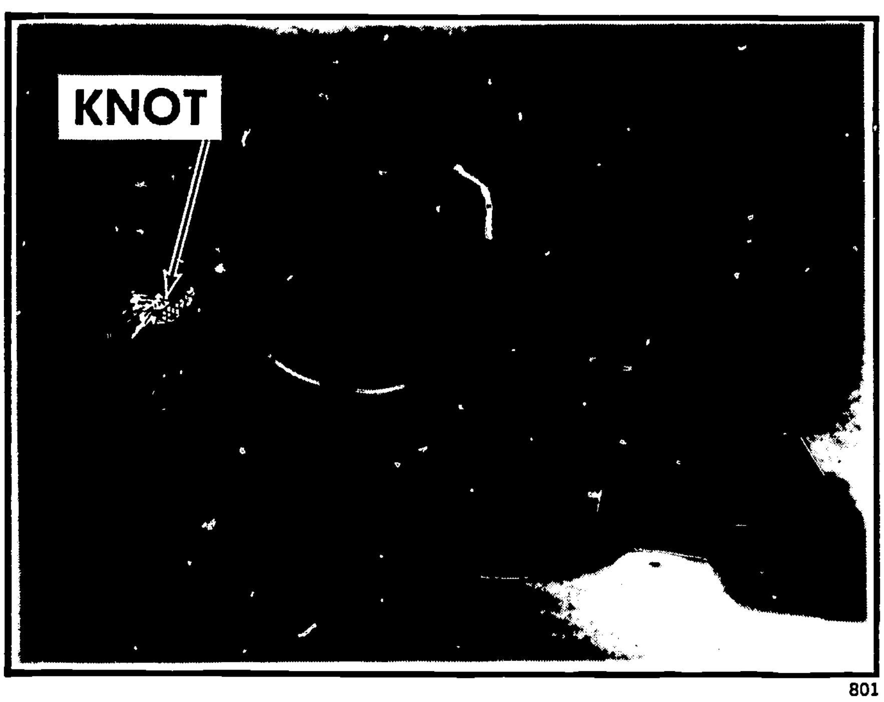


FIGURE 19. A type of starter on which the rope can be replaced without disassembly. Note knot on the outside of the pulley.

5. *Remove and replace the rope.*

   There are two basic methods for replacing the rope on rewind starters. The method you use will depend on the starter design.

   If the knot is visible (Figure 19), you can most likely replace the rope without disassembling the starter. Proceed with steps under "a."

   If the knot is not visible, it will be necessary to disassemble the starter. Proceed with steps under "b."

a. If your starter is designed so you can **replace**

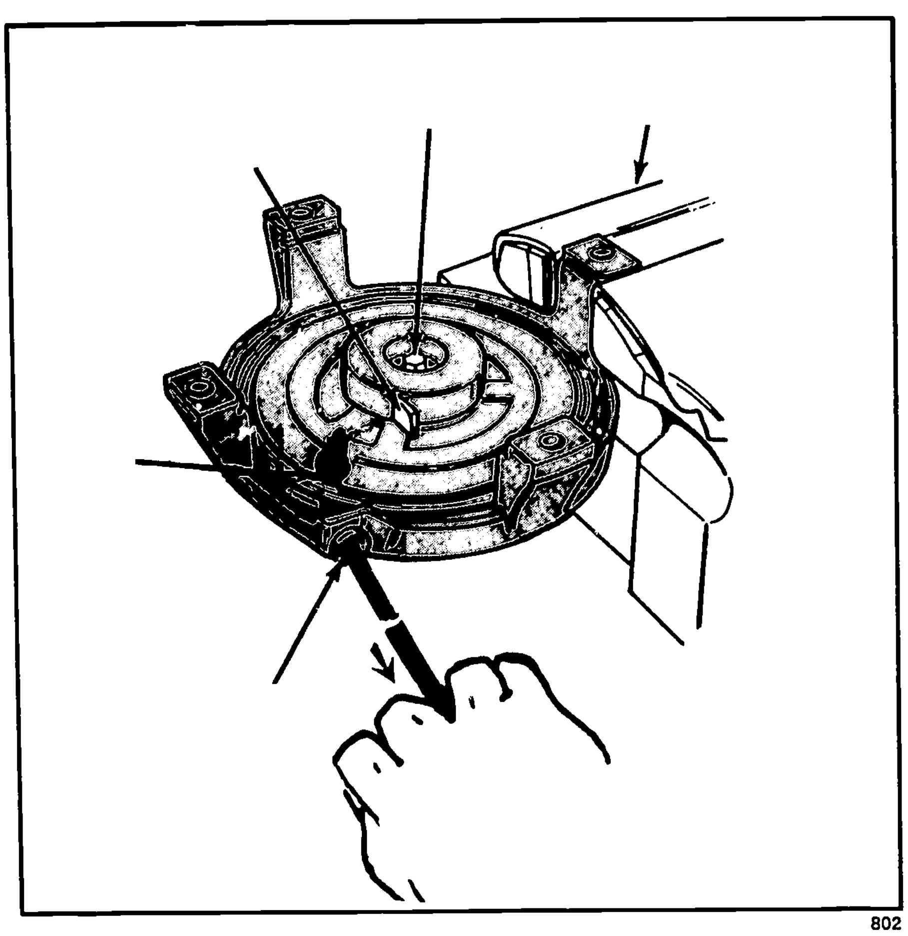
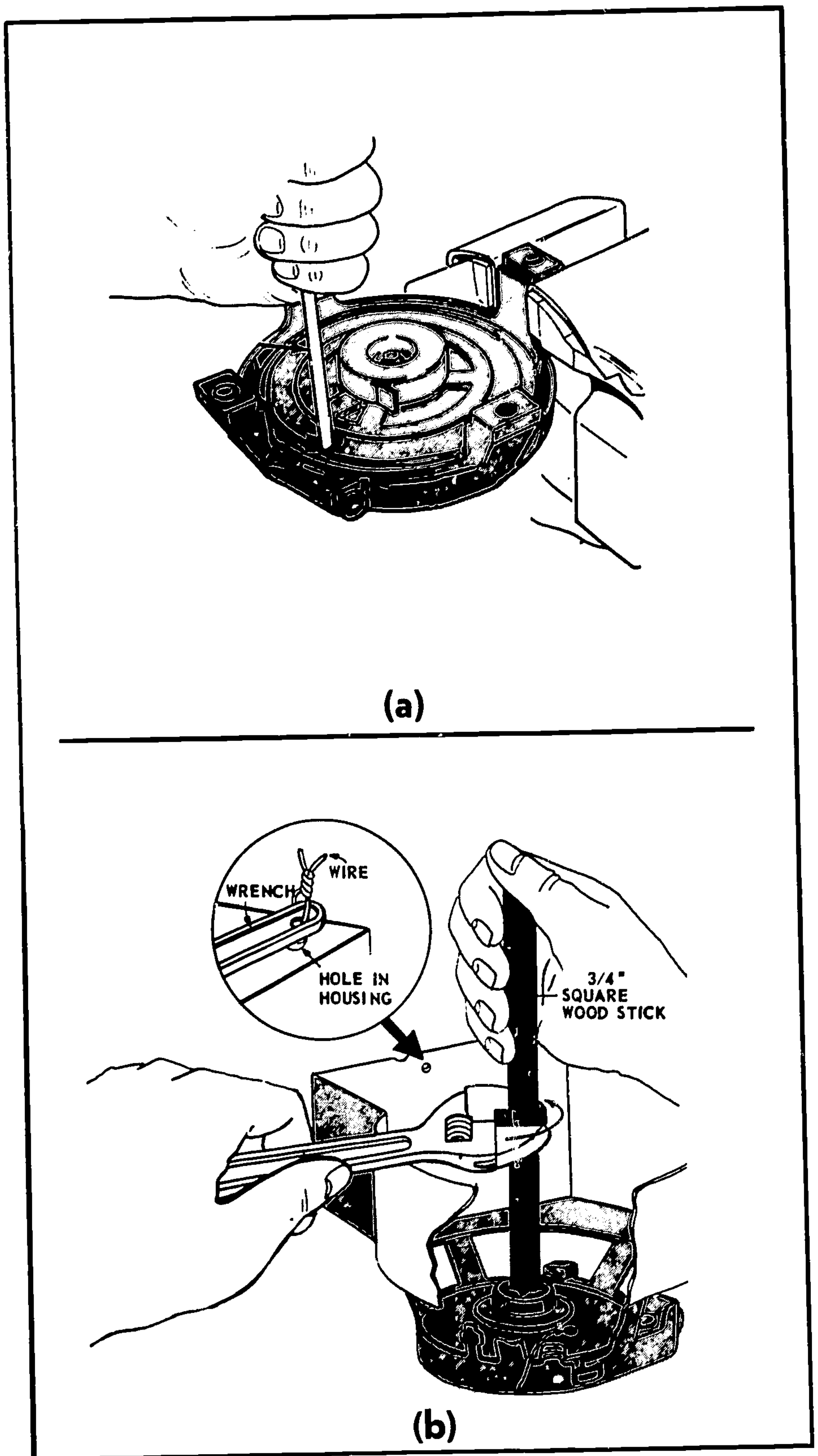


FIGURE 20. The first step in removing the starting rope: Pull the rope all the way out.



(a) 803 TEC (b) 803 B & S

Figure 21. Rewinding the recoil spring. (a) Some starters may be rewound by a screwdriver. (b) Some require special tools.

If the old **rope is broken,** it will be necessary to wind the recoil spring before installing the new rope (Figure 21).

Follow instructions in your service manual if possible. If one is not available, wind the starter spring completely — as far as it will wind — then release one complete turn. This protects the spring from being overwound when the rope is pulled. Otherwise, the spring may break when you operate the starter.

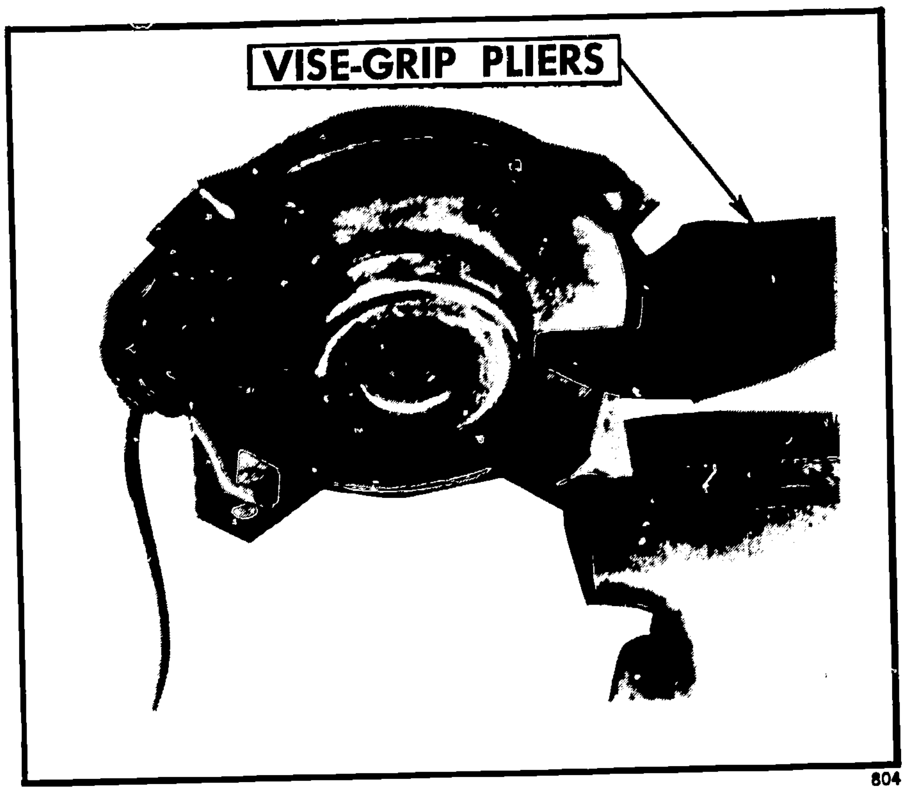


FIGURE 22. Use of vise-grip pliers to hold pulley.

the starter rope without disassembling the starter, proceed as follows:

(1) *Pull the rope all the way out (Figure 20) if not broken.*

(2) *Clamp the pulley with vise-grip pliers (Figure 22) or a C-clamp, or tie the wrench handle (Figure 21b, inset).* This keeps the spring from unwinding and holds the pulley in position for installing the rope.

(3) *Cut the knot and slide the rope out (Figure 23).*

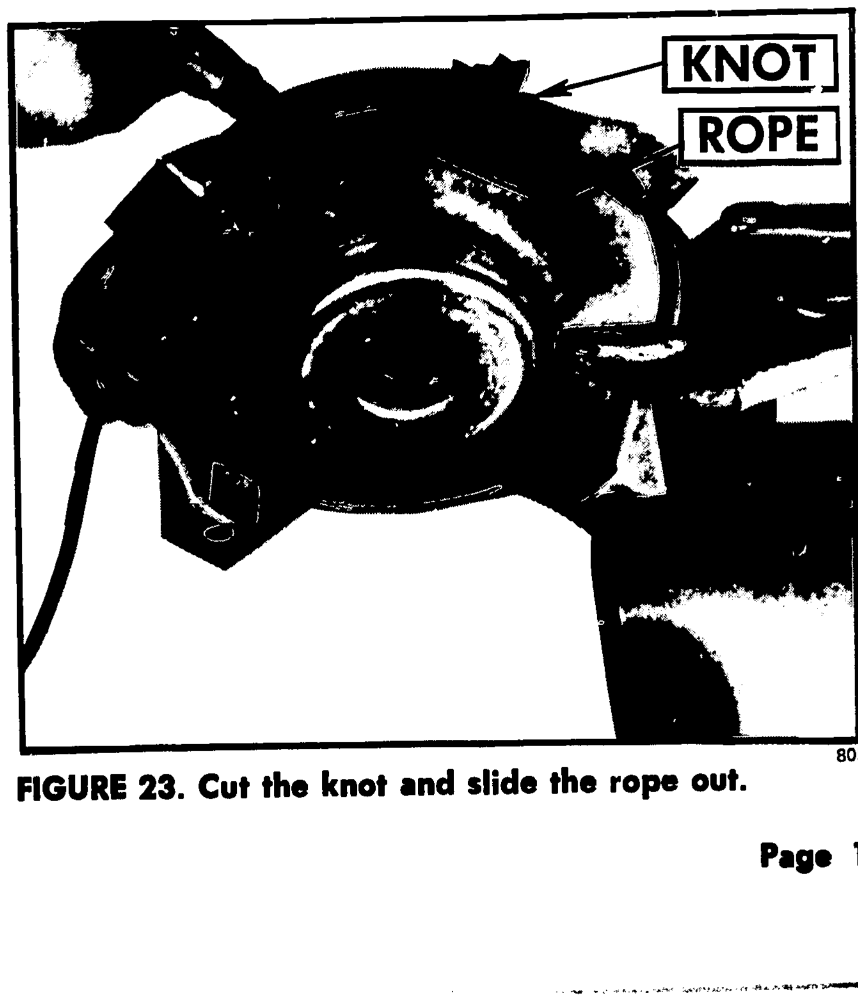


FIGURE 23. Cut the knot and slide the rope out.

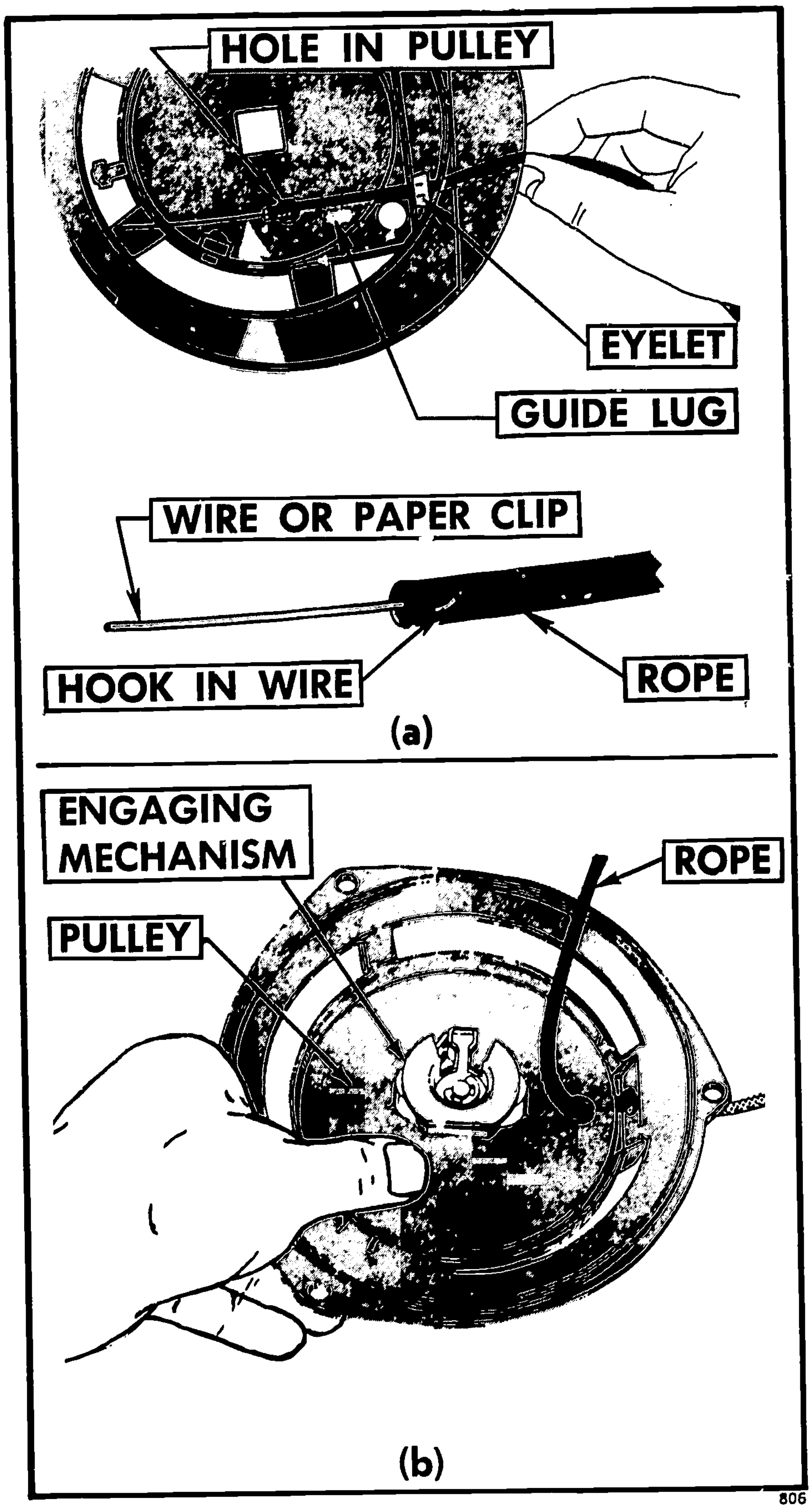


FIGURE 24. Threading the rope. (a) A wire or paper clip makes a convenient guide for threading the rope. (b) Sometimes no guide is needed if the holes are aligned.

(4) *Select new rope.*

Rope should be the same length and diameter as that which was used originally. Rope lengths for this type of starter vary from 3 to 4 feet. If you do not know which length is correct, start with at least 5 feet and adjust the length as directed in steps 10 and 11.

Their diameters vary from 1/8″ to 3/8″. The most common diameter rope used is 5/32″. The rope should fill the pulley groove without binding.

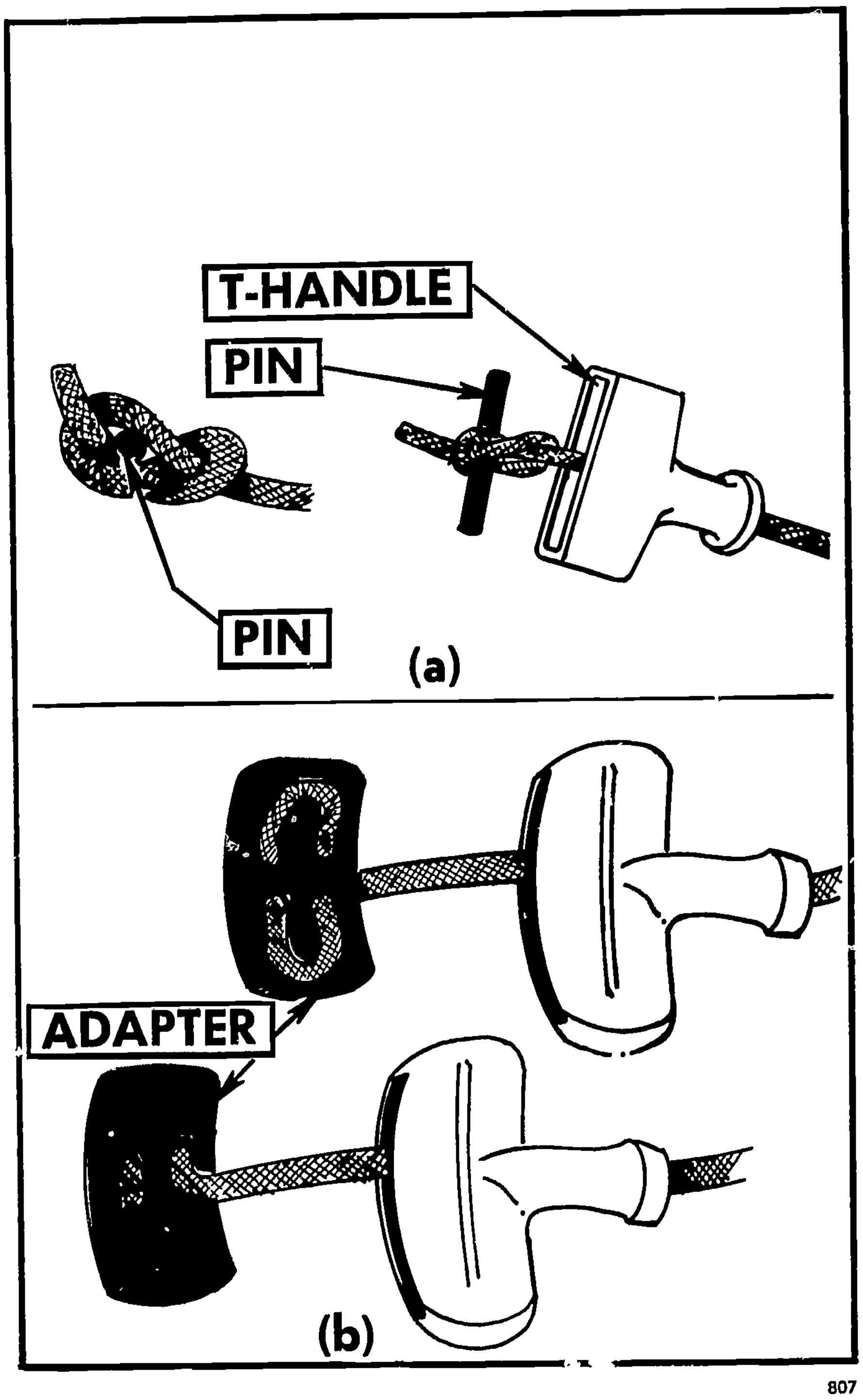


FIGURE 25. Methods for securing the starter rope T-handle. (a) A knot and pin. (b) A special insert adapter. Rope threads into insert and is held by clamping action.

(5) *Singe the end of nylon rope with a match flame.*

This prevents fraying.

(6) *Thread rope through housing eye and through pulley eye (Figure 24).*

It is helpful to use a paper clip or a small piece of wire, hooked into the end of the rope to thread the rope through the eye (Figure 24a).

(7) *Tie knot in rope and pull knot against hole in pulley.*

(8) *Allow rope to rewind on pulley until pulley groove is full.*

(9) *Attach T-handle (Figure 25).*

Pull out (unwind) enough rope to attach T-handle.

b. If your starter is designed so that it is necessary to **disassemble it before replacing the rope,** proceed as follows:

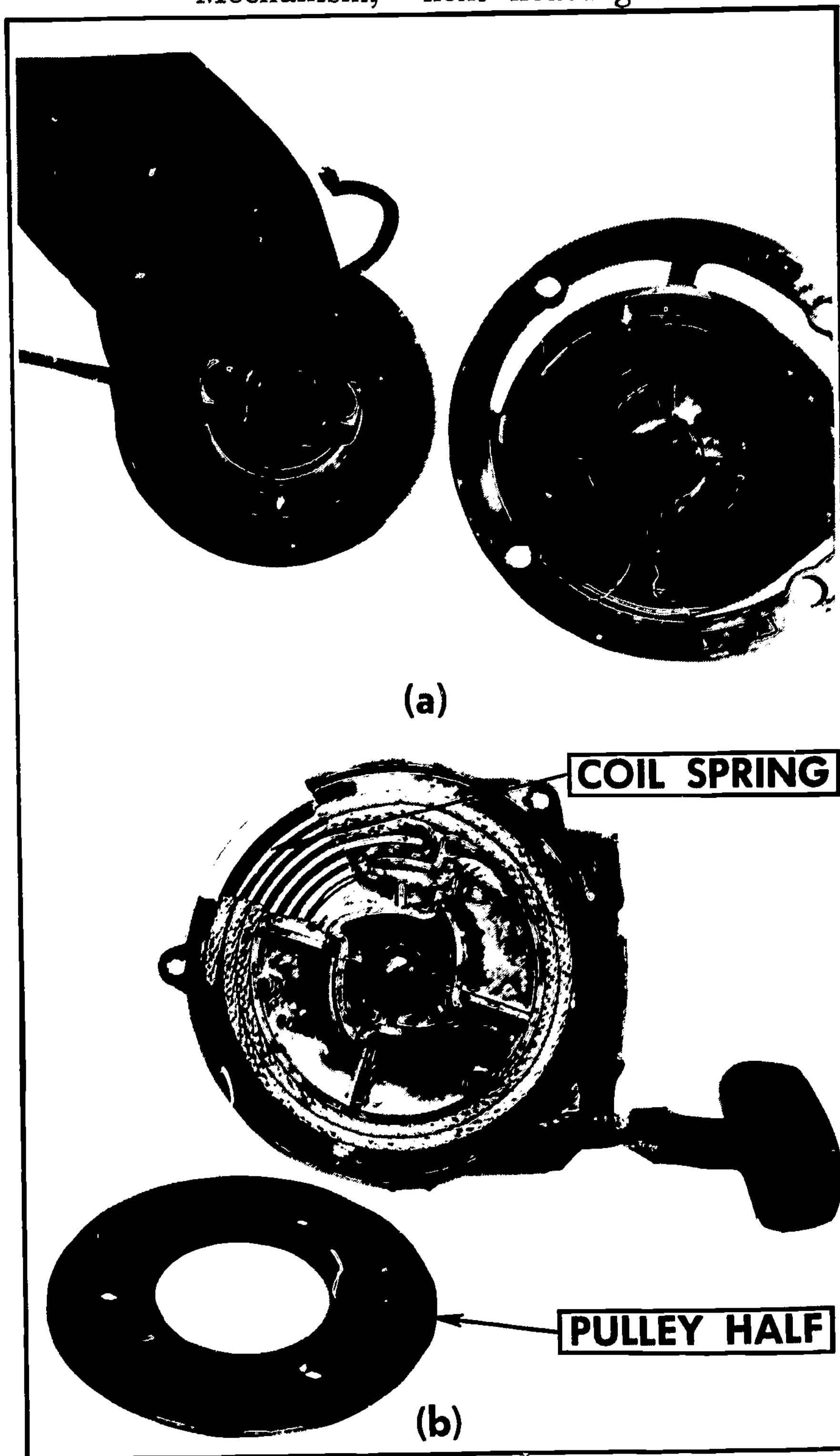
(1) *Disconnect the rope from the T-handle end (Figure 25) and allow the spring to unwind slowly.*

This action removes the tension on the spring.

Hold the pulley with a gloved hand, or cloth, to prevent injury.

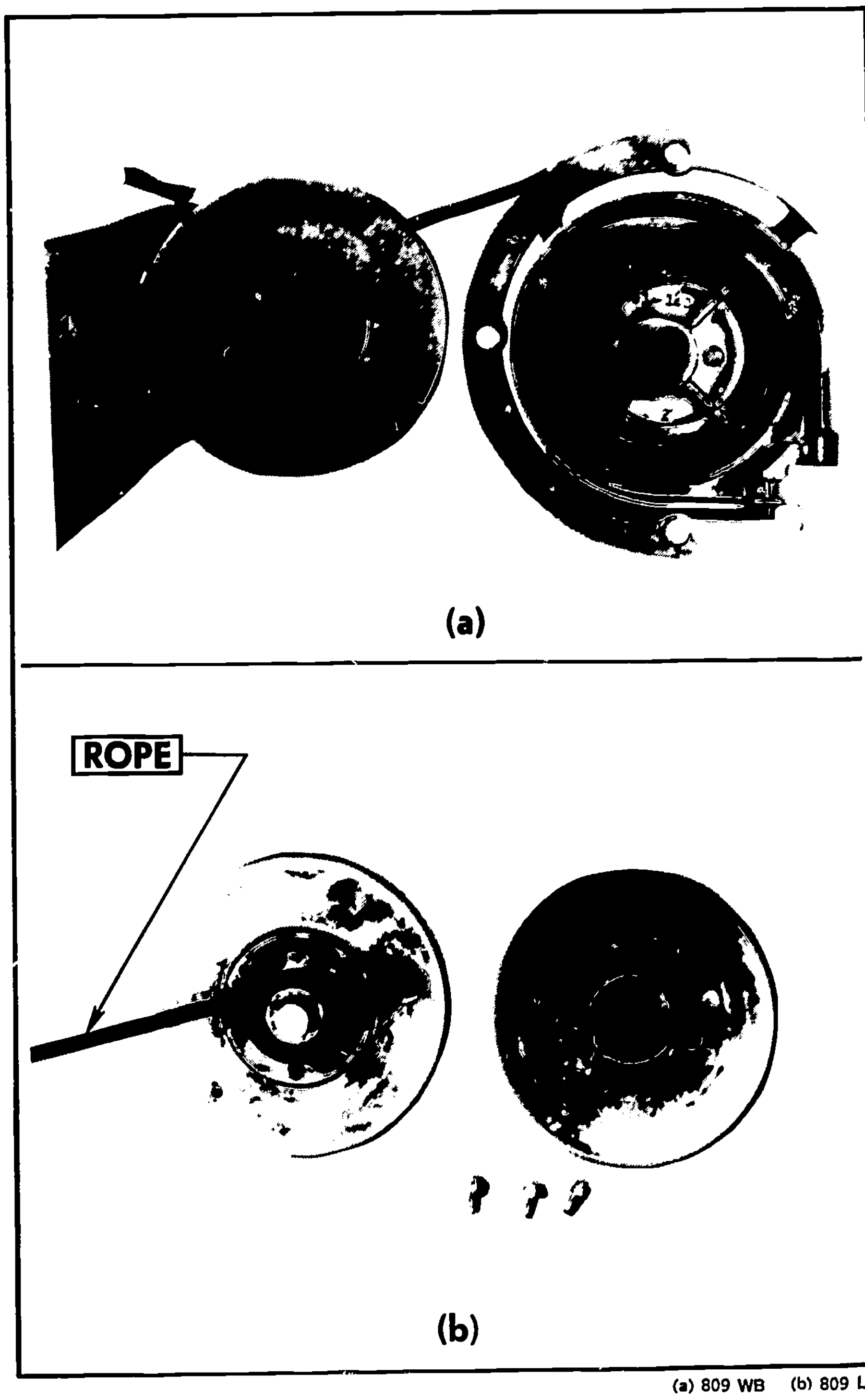
(2) *Remove the starter drive from pulley assembly.*

For procedures see "Repairing the Drive Mechanism," next heading.



(a) 808 WB (b) 808 LB

FIGURE 26. Gaining access to the rope. (a) A 1-piece pulley removed. (b) A 2-piece pulley with one half removed.



(a) 809 WB (b) 809 LB

FIGURE 27. Installing the rope. (a) Threading the rope through the 1-piece pulley hub. (b) Anchoring the rope between pulley halves of the 2-piece type.

IMPORTANT! Always make a mental note of how an assembly is put together before taking it apart. Clean, inspect and lay the parts out in the order that they must go together for reassembly. If necessary, draw a sketch. Then you should have no difficulty reassembling them.

(3) *Clean and inspect the starter drive mechanisms for damage and wear.*

(4) *Remove or disassemble the pulley (Figure 26).*

There are two types of pulleys: (1) one-piece type (Figure 26a), and (2) two-piece type (Figure 26b).

If your starter has the **one-piece type pulley,** remove it to gain access to the pulley and leave the spring in the housing (Figure 26a).

If your starter has the **two-piece type pulley,** remove only one side of the pulley. The spring will remain intact under the other half of the pulley (Figure 26b).

(5) *Remove the rope.*

Cut knot from rope, or detach it from rope holder.

(6) *Select rope as described in step (4) under "a," preceding.*

(7) *Singe ends of rope to prevent fraying.*

(8) *Install new rope (Figure 27).*

There are various means for anchoring the rope to the pulley.

Examine the pulley to determine which method to use.

(9) *Wind rope on pulley, thread outer end through eyelet of the starter housing, and attach T-handle.*

6. *Reassemble and/or replace pulley.*

Connect spring to pulley if it was disconnected. Most service manuals illustrate the proper sequence for assembling starters and other mechanisms.

Apply light coat of graphite lubricant on the metal rubbing parts.

Do not lubricate nylon bearings or gears. Dirt sticks to the grease and causes wear.

7. *Install the drive mechanism.*

Refer to "Repairing the Drive Mechanism," under the next heading.

8. *Rewind recoil spring and secure it with vice-grip pliers or a C-clamp.*

For rewinding recoil spring, see "Replacing the Recoil Spring," page 23.

9. *Check starter for proper operation before installing the starter on the engine.*

Pull the rope out. It should pull easily with no binding.

Observe the drive mechanism. The mechanism that engages the flywheel cap should extend.

Allow the rope to retract. It should rewind all the way. The engaging mechanism should retract.

10. *Reinstall starter on engine.*

Be sure to align the drive mechanism with the crankshaft. Some are equipped with an alignment rod on the mechanism which is inserted into a hole in the center of the crankshaft, or in the keyway. If the starter drive is not properly aligned, it will not engage and disengage satisfactorily; neither will it last long.

11. *Recheck starter for proper operation.*

REPAIRING THE DRIVE MECHANISM

There are many different types of rope-rewind starter drives, but the basic principle of operation is the same for each. If you understand how they work, you will have no trouble repairing them.

All of them are some form of a ratchet drive. When the starter is operated, the ratchet engages a flywheel adapter which is attached to the crankshaft. When the engine starts and when the starter is not being operated, the ratchet disengages from the flywheel adapter.

The main difference in the drives is in the engaging mechanisms. Four types and how they work are described as follows:

Centrifugal pawls (Figure 28) — When

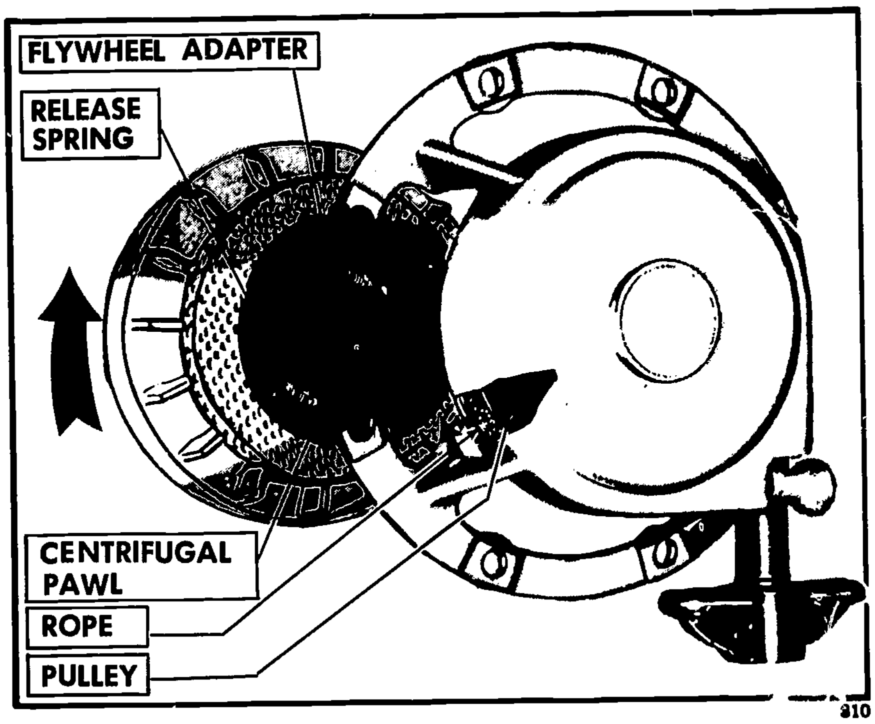


FIGURE 28. Centrifugal-pawl starter drive principle.

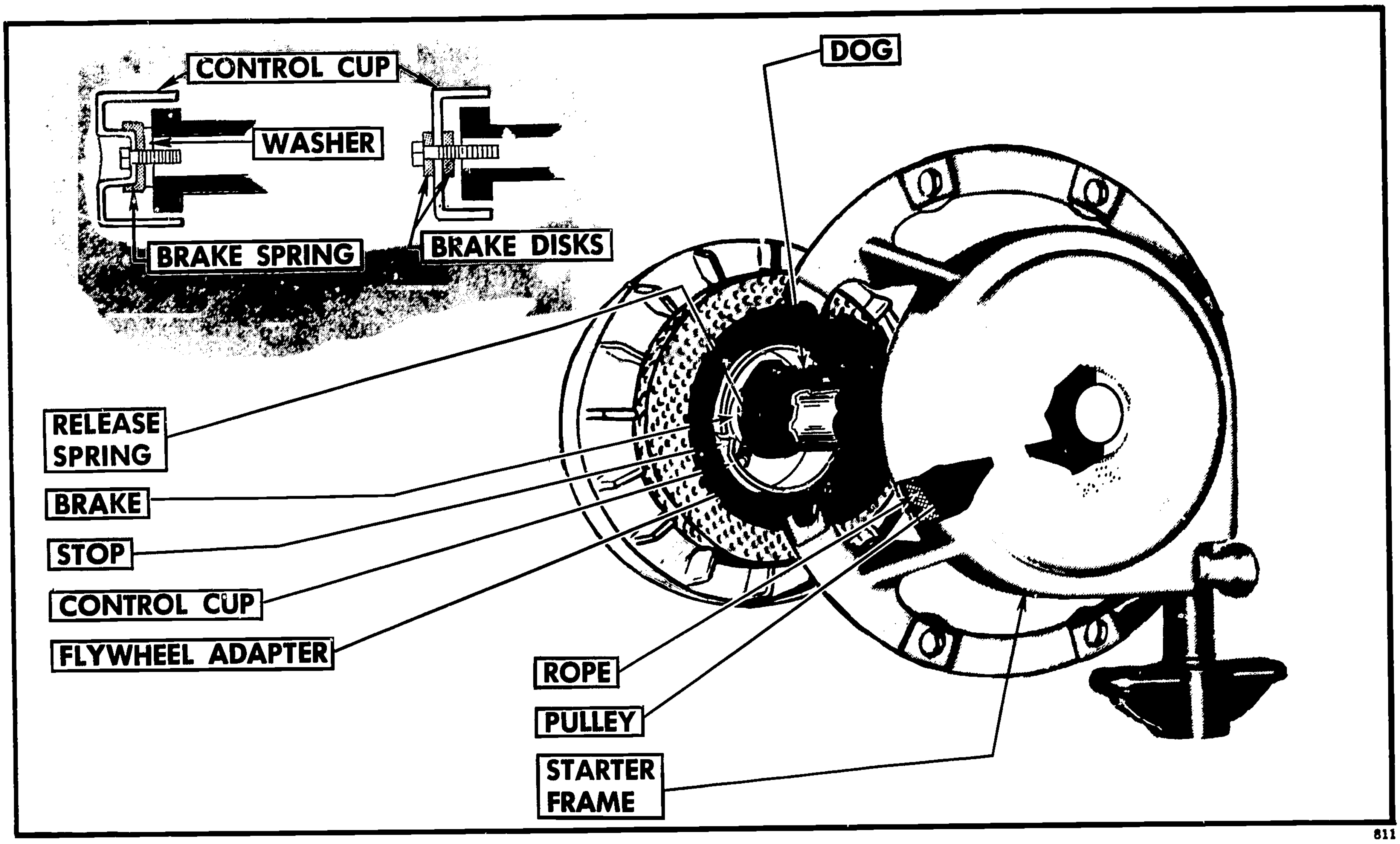


FIGURE 29. Cam-operated dog drive.

the starter is operated (rope is pulled), the pawls move out as a result of centrifugal force and engage the corrugated surface of the flywheel adapter, which is attached to the flywheel and the crankshaft. The crankshaft turns.

When the engine starts and the starter is released, the pawls are retracted by the release springs.

- **Cam-operated dog(s) (Figure 29)** —

When the starter is operated the brake holds the control cup still until the dog is forced through the slot in the control cup far enough to engage the flywheel adapter.

The brake is attached to the starter frame at one end, and the brake shoe exerts pressure on the control cup. The friction is provided by brake disks or a spring clamp (Figure 29).

The flywheel adapter is connected to the crankshaft; so the crankshaft turns.

When the starter is released (rope is allowed to recoil) and the engine starts, the brake holds the control cup until the dog is retracted by the release spring. The stop prevents the dog from retracting all the way into the cup. If this should happen, it would not be aligned at the slot for the next operation. This type of starter drive may have one or more dogs.

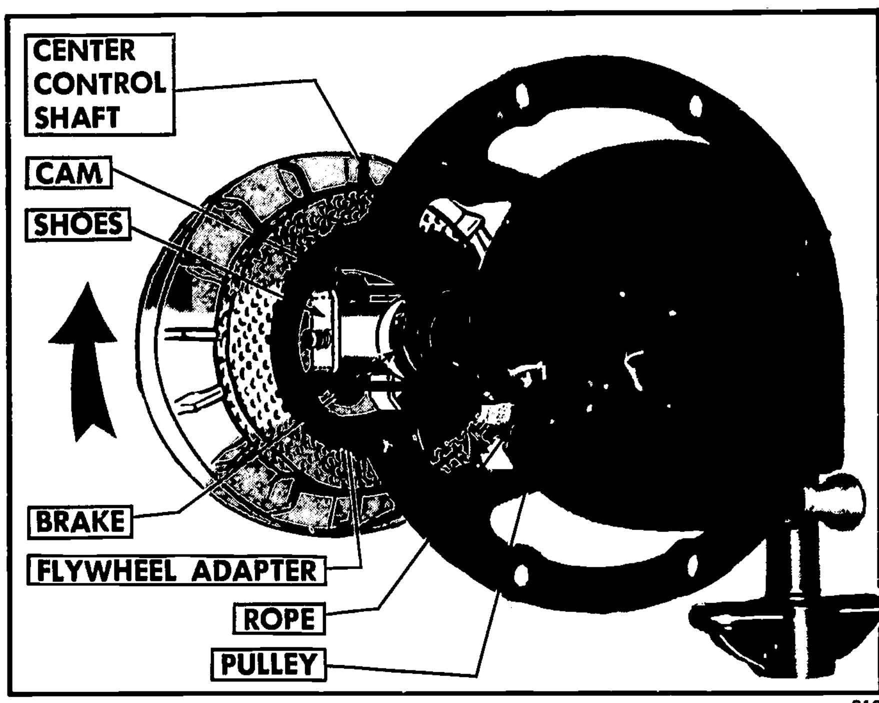


FIGURE 30. Cam-operated-shoe starter drive principle.

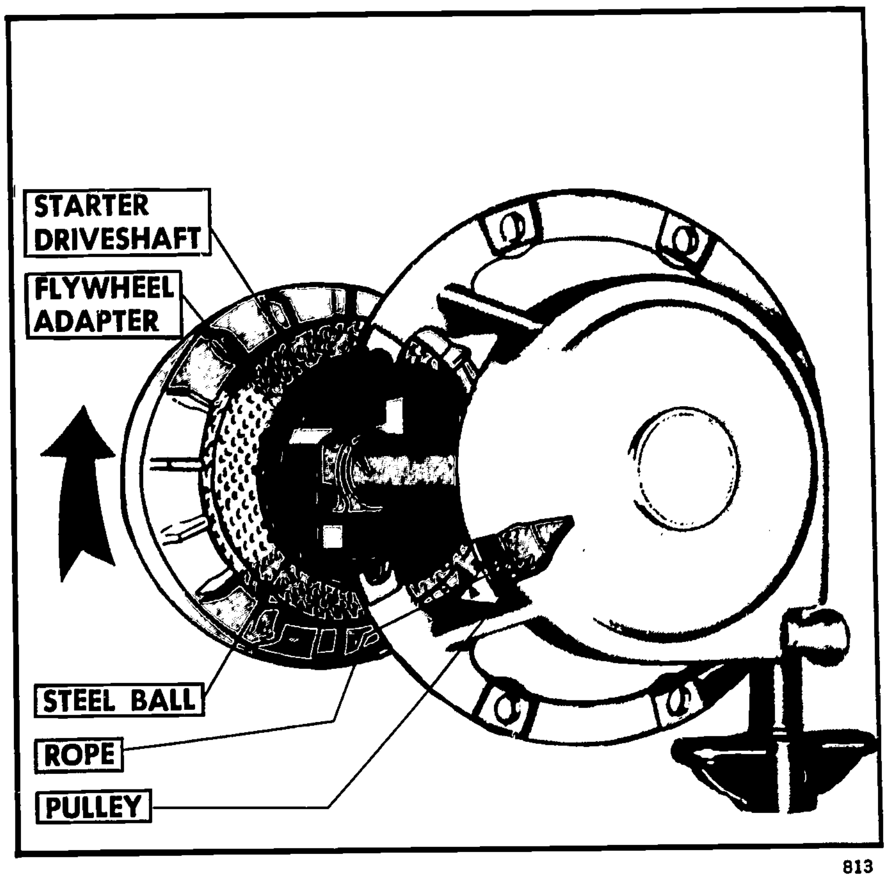


FIGURE 31. Wedging-steel-ball starter drive principle.

Cam-operated shoes (Figure 30)—When the starter is operated, the brake holds the spring-loaded cross member until the shoes are forced out against the flywheel cup by the cams. The crankshaft turns.

When the starter is released and the engine starts, the brake holds the spring-loaded cross member until the shoes are retracted. Springs on the ends of the cross member help to center it and to retract the shoes.

Wedging steel balls (Figure 31) — When the starter is operated, a steel ball is wedged between the cam on the starter driveshaft and the cam on the flywheel adapter. The crankshaft turns.

When the engine starts, the starter is released because the flywheel adapter runs at crankshaft speed. There is no longer any wedging action to hold the steel ball(s). They are forced into the recesses in the flywheel adapter by centrifugal force. They remain in this position as long as the engine is running.

Proceed as follows:

1. *Remove the starter and anchor it in a vise.* Follow steps 1 through 4, under "Replacing the Rope," page 15.
2. *Check the drive mechanism for proper operation.*

   Pull the rope and observe the action of the engaging mechanism. See that it extends when the rope is pulled and retracts when the rope is released.
3. *Remove the drive mechanism (Figure 32).*
4. *Disassemble the drive mechanism.*

   If you wish to identify the different parts, check your service manual or parts catalog. Most starters can be reversed for different directions of engine rotation. The engaging mechanisms for certain of these drives can

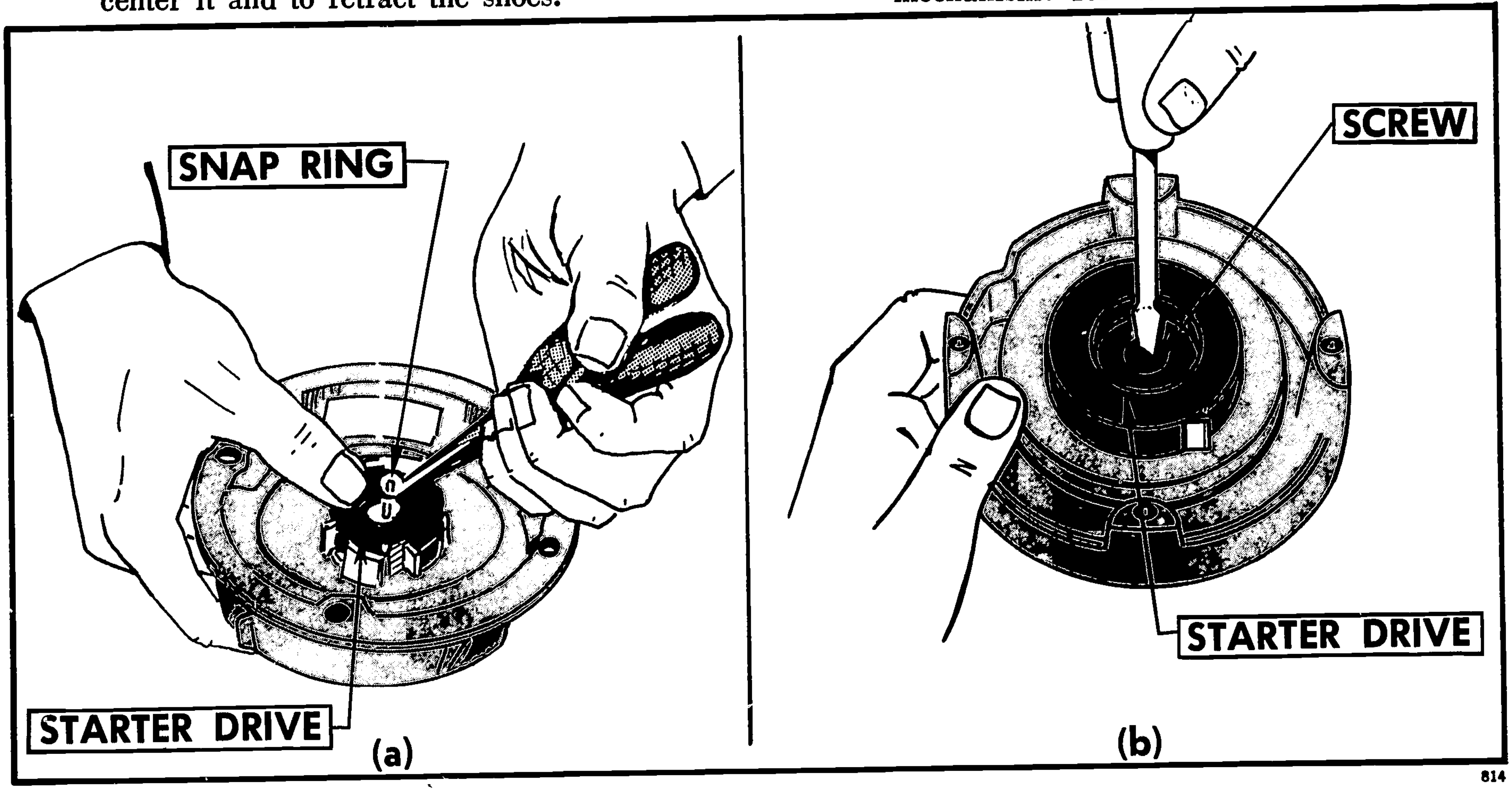


FIGURE 32. Removing the drive mechanism. (a) Some drives are held by a snap ring. (b) Some are held by a screw.

be easily reversed if not laid out in proper order during disassembly. If assembled in reverse, the engine-engaging mechanism will not engage the flywheel adapter when you pull the rope.

5. *Clean and inspect parts.*

   Look for worn or damaged parts, and bent or broken springs.

   Replace with new ones.

6. *Reassemble drive.*

   Be sure to install the starter spring and drive mechanisms properly for the direction of rotation of your engine. Most starter drives can be reversed to accommodate different directions of engine rotation. If you get the engaging mechanism in backwards, it will not work. Remember that the starter dog, shoe or pawl must point toward the direction of rotation. This is in order for it to engage the flywheel adapter while the starter is being operated.

   The friction shoes, such as the ones shown in Figure 30, must have the sharp edges toward the direction of rotation.

7. *Lubricate the drive lightly with graphite or multi-purpose grease—do not pack.*

   Do not put grease on the wedging steel balls as shown in Figure 31. Grease and dirt will cause them to stick. They may not engage the flywheel adapter. If they do, they may not release properly.

8. *Reassemble the starter drive.*

9. *Check for proper operation before installing the starter.*

10. *Install the starter.*

11. *Check for proper operation on the engine.*

REPLACING THE RECOIL SPRING

Two types of recoil springs are used in rewind starters: (1) a removable type, and (2) a packaged type.

One **removable type** of spring is designed to be unwound and stretched out in order to supply increased tension. You can recognize these by the end of the spring being accessible from the outside of the starter housing (Figure 33).

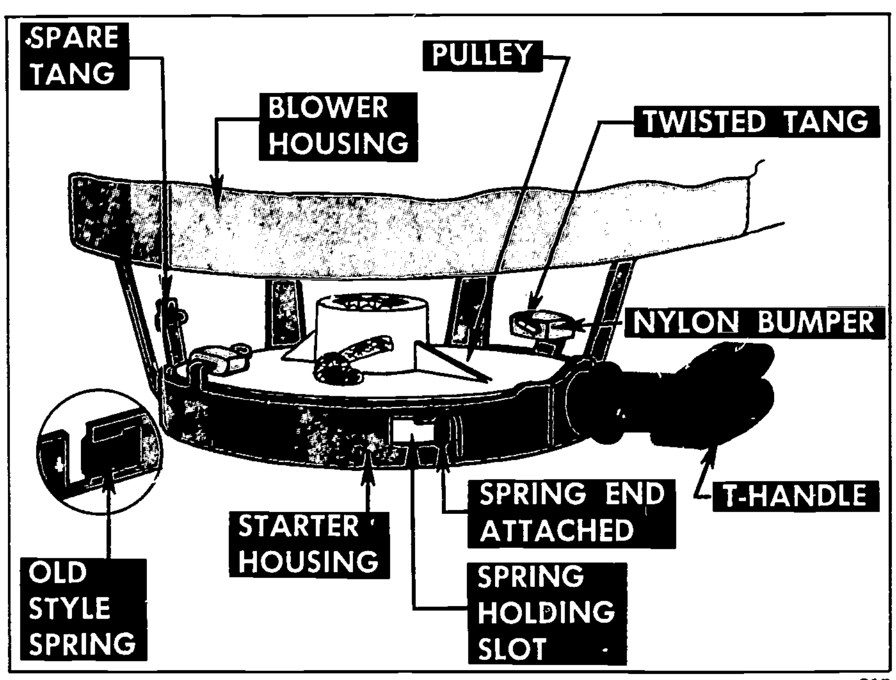


FIGURE 33. The removable type of recoil spring is visible on the outside of the starter housing (inverted view).

A **second removable type** spring is somewhat stiffer and comes precoiled, but not completely ready for installation. It must be compressed (partially wound) before installing in the starter housing. It is **not accessible from the outside of the starter housing.**

The **packaged type** spring is a stronger spring than the two previously described. It comes precoiled and compressed inside a retainer housing. Replacement springs for this type of starter comes precoiled. Some are incased in a permanent type retainer. Others are incased in a temporary retainer which is discarded upon installing the new spring. In either type starter, if the recoiled spring is damaged, broken or disconnected, it will be necessary to disassemble the starter to repair it.

a. If your starter recoil spring is the **removable type (accessible from the outside of the starter housing)**, proceed as follows:

   1. *Remove and secure the starter.*

      Follow steps 1 through 4 under "Replacing the Rope," page 15.

   2. *Release the spring tension.*

      Disconnect the rope from the pulley end if it is accessible (Figure 33). If it is not, disconnect it from the T-handle and allow the spring to unwind slowly. This is

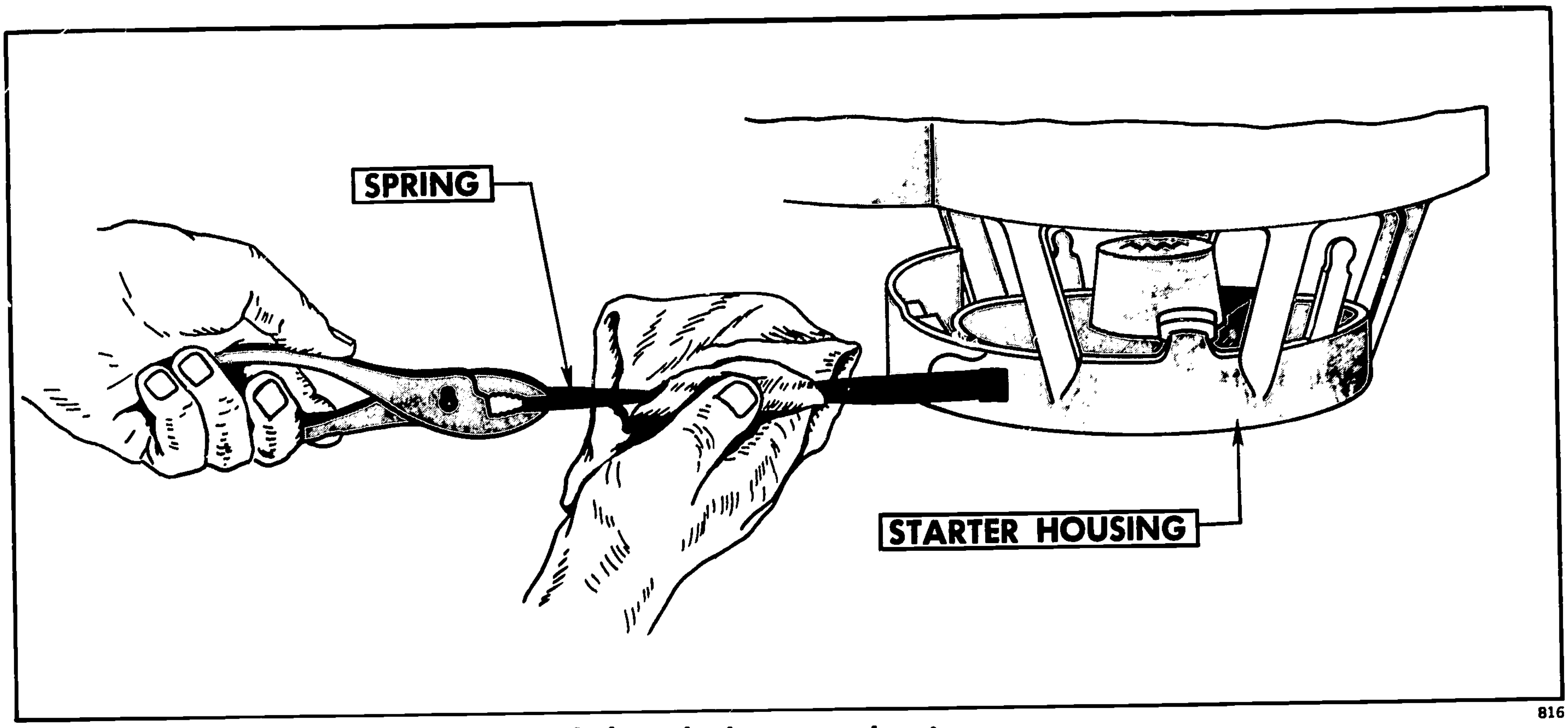


FIGURE 34. The recoil spring is unwound through the starter housing.

done by holding the pulley with gloved hands or with a cloth to protect your hands.

3. *Pull spring out as far as possible (Figure 34).*

   Grasp the end of the exposed spring with pliers, unhook it from the housing, and pull it out by hand. This unwinds the spring.

4. *Remove the pulley.*

   If the pulley is **held in place as the one in Figure 33,** raise one tang with a screwdriver and lift the pulley out.

   If the pulley is **held in place by the starter-drive mechanism,** remove it before attempting to remove the pulley.

5. *Disconnect the recoil spring from the pulley (Figure 35).*

   If the hook is broken, form a new hook with a grinder. Grind a notch on each side of the end of the spring.

6. *Straighten spring (36).*

   If you are going to use the old spring, clean and straighten it.

   Hold the spring coil in your left hand. With a cloth (or gloves) in your right hand grasp the spring between the thumb and fingers with the thumb on the outside curve of the spring. Pull the spring through, straightening it against your

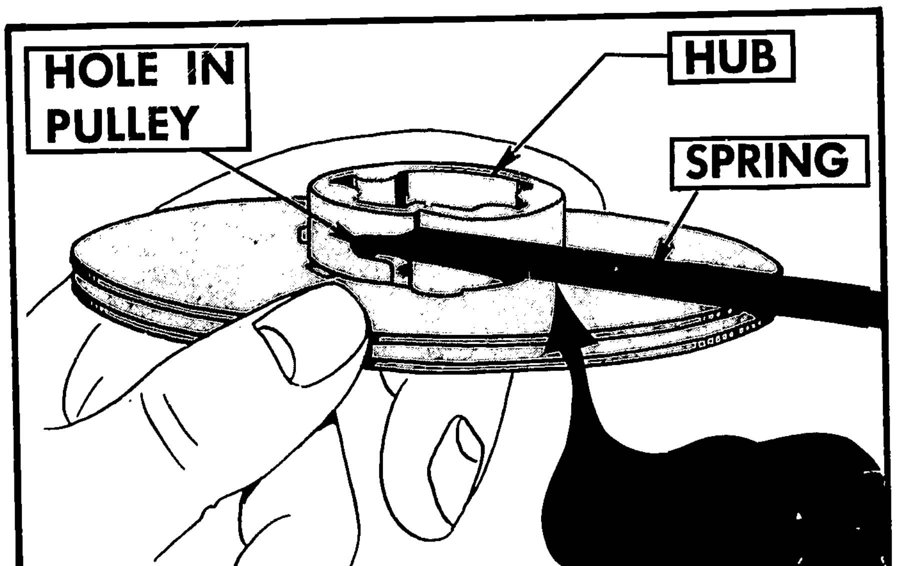


FIGURE 35. Unhook recoil spring from the pulley.

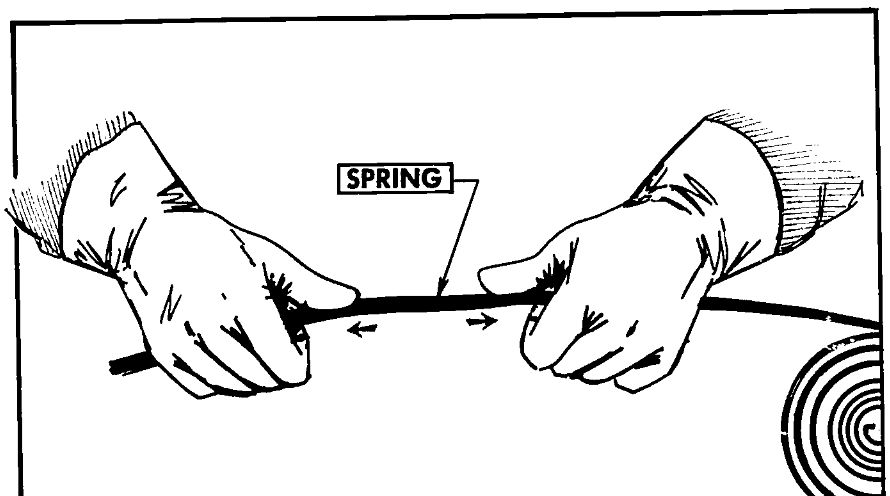


FIGURE 36. Straightening the recoil spring to provide more tension.

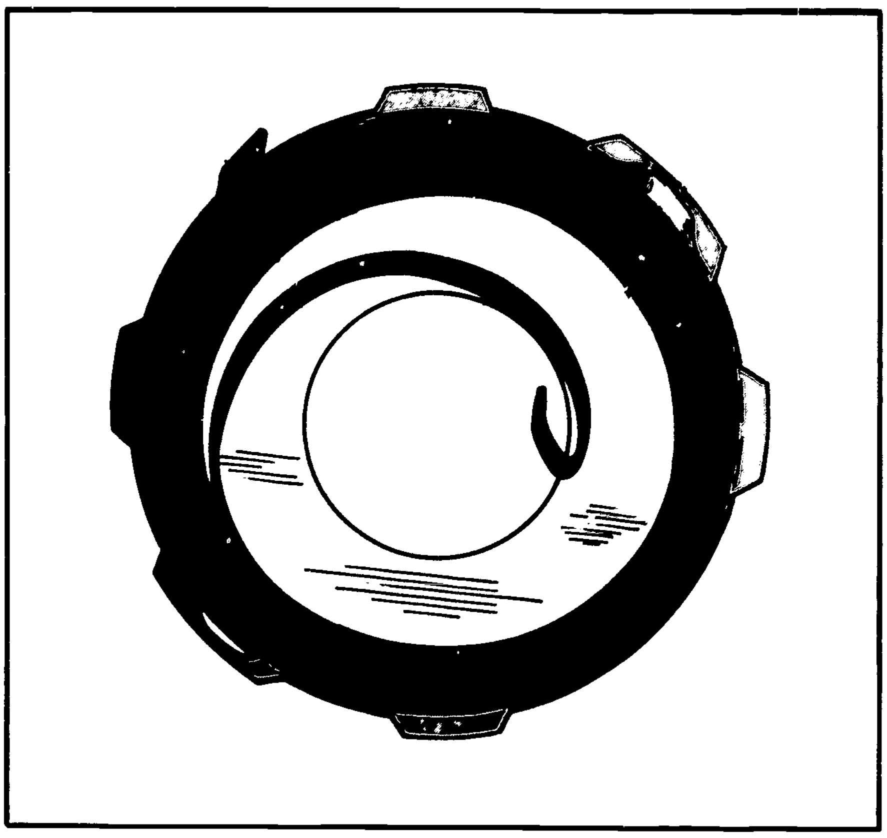


FIGURE 37. Most packaged springs are enclosed in a retainer housing.

thumb as you pull. This will strengthen the spring tension when it is recoiled.

7. *Clean and inspect other parts of the starter.*
8. *Attach new spring to the pulley (Figure 35).*

   Remember that you are tightening the spring as you crank the engine. Install it so that this will take place.
9. *Install pulley.*
10. *Wind the recoil spring (Figure 21).*

    A general rule is to wind the spring until it is tight; then back off one turn to prevent the spring from breaking when you operate the starter. Refer to step 5, under "Replacing the Rope," page 15, for additional information.

    Anchor the outer end of the spring during the rewinding process.
11. *Attach rope to pulley.*

    If rope is to be replaced, refer to "Replacing the Rope," page 15.
12. *Release pulley slowly.*

    Hold with a gloved hand or cloth to prevent injury.
13. *Check starter for operation.*
14. *Install starter on the engine.*
15. *Recheck starter for operation on the engine.*

c. If your starter recoil spring is of the **packaged type (Figure 37)**, proceed as follows:

1. *Follow steps 1 through 5 under "b" under the heading "Replacing the Rope," page 15.*
2. *Remove recoil spring (Figure 38).*

   Some springs are *packaged in a housing* (spring retainer) and should not be removed from the retainer housing. They are easy to replace (Figure 37).

   Other springs come in a *temporary retainer* for easy installation of the new spring, and the retainer is discarded.

   If the spring is *designed for removal* from the housing (pre-coiled removable type), be careful when removing it. When the tension is released, it will spring partially open.
3. *Clean and inspect all parts of the starter.*
4. *Lubricate the new spring and starter sparingly.*

   Use graphite or multi-purpose grease sparingly as recommended by your manufacturer. Do not lubricate nylon bearings or nylon gears. The lubricant is not needed and grease will pick up dirt.
5. *Install new spring.*

   If the spring is in a **permanent retainer,**

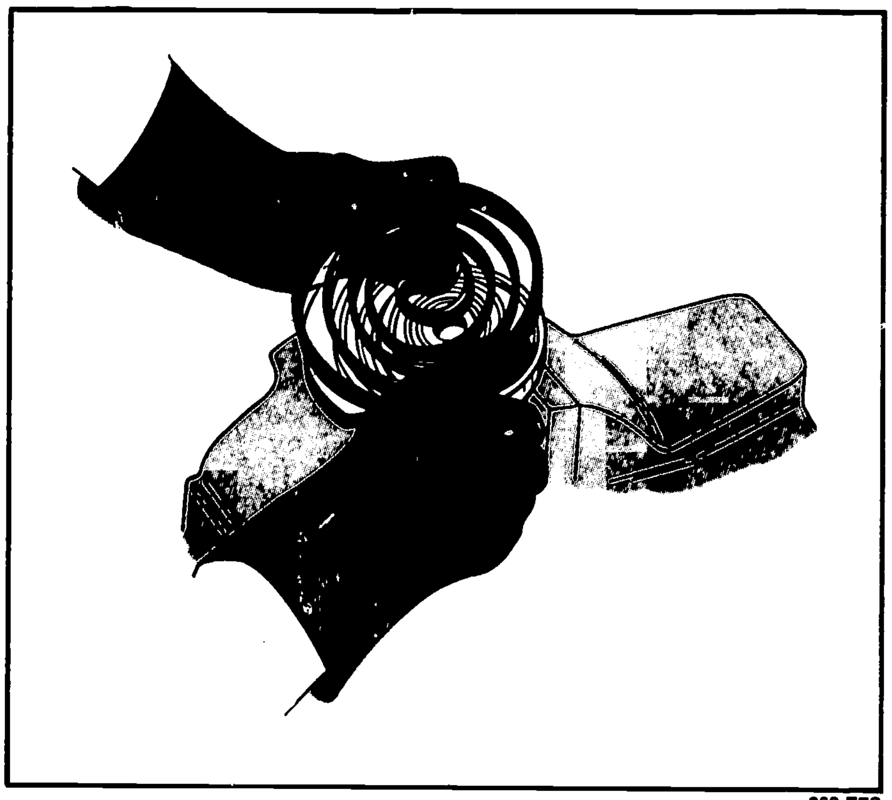


FIGURE 38. Some recoil springs are partially coiled but not packaged.

install retainer and spring (Figure 37).

If the spring is in a **temporary retainer,** press it into the housing and discard the retainer.

If it is necessary to **recoil the spring before installing it,** be sure to wear gloves to protect your hands (Figure 38).

Be sure to install the spring properly for the direction of your engine rotation. Wind it so it will tighten when wound in the direction of the engine rotation.

6. *Install pulley and rope if needed.*

   See "Replacing the Rope," page 15.

7. *Rewind spring (Figures 21a and 39).*

   If rope is replaced before assembling the pulley, the spring is wound by wrapping the rope around the pulley and pulling it (Figure 39). Repeat this procedure until the spring is wound tightly. Then release one turn and attach the T-handle.

8. *Secure the starter drive assembly.*

   Tighten nuts or screws.

9. *Check starter for proper operation.*

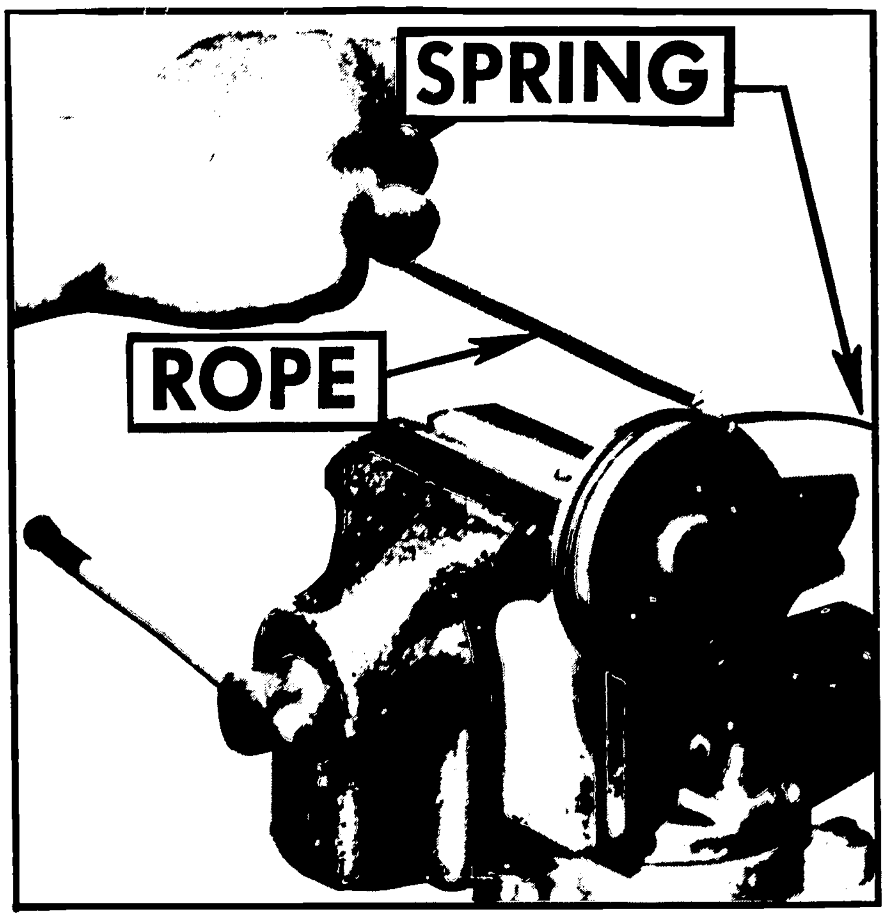
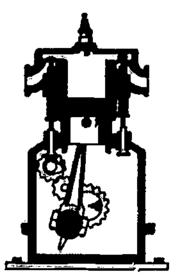


Figure 39. One method for rewinding a packaged-type spring.

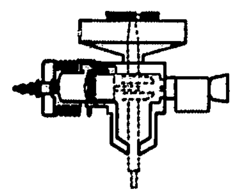
10. *Install starter on engine.*

    Align drive properly.

11. *Recheck starter operation on the engine.*



C. REPAIRING WINDUP STARTERS



Windup starters are designed to reduce the amount of manual effort in starting your small engine. All you have to do is wind up a heavy recoil spring with a hand crank. When the spring is released, it turns the crankshaft for starting the engine.

Procedures for maintaining windup starters are discussed under the following headings:

1. Principles of operation.
2. Tools and materials needed.
3. Checking for proper operation.
4. Repairing the windup starter.

PRINCIPLES OF OPERATION

The principal parts of a simplified windup starter are shown in Figure 40. Although the parts of your starter may be different from those shown, they serve the same purposes.

The principal parts and their functions are as follows:

- A **crank handle** for winding the recoil spring — usually the handle folds for compactness.
- A **recoil spring,** which furnishes power for starting the engine.
- A **ratchet** (gear and spring) for holding the outside end of the recoil spring — it holds the crank handle in any position and thus prevents the handle from rebounding when it is released. It also provides for winding the spring with any length stroke.
- A **control mechanism** which holds the in-

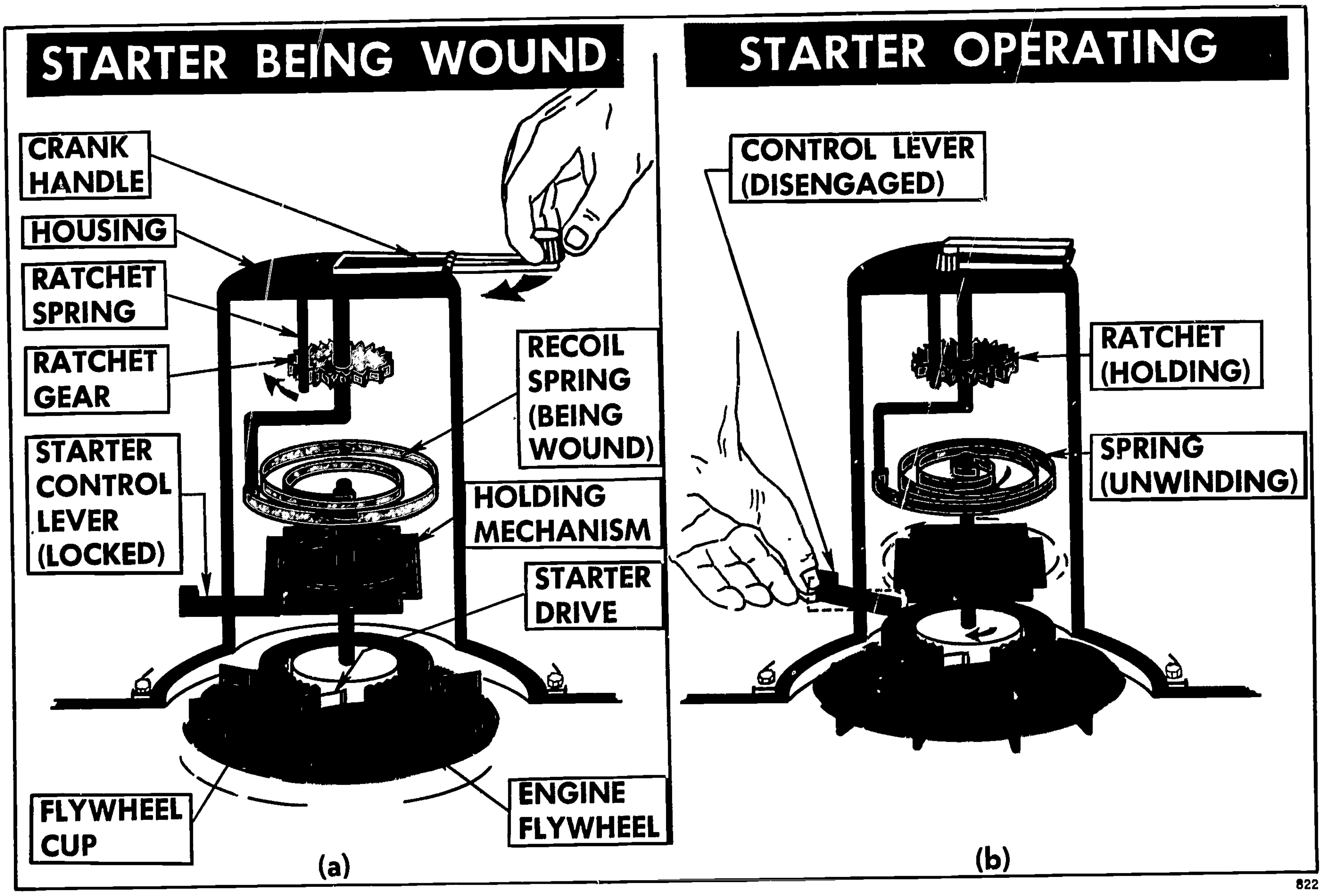


FIGURE 40. How a windup starter works. (a) The main spring is wound by a hand crank. As the recoil spring is wound, the starter drive is kept from turning by the starter-control lever. When the cranking action is completed, the recoil spring is held in position by the ratchet spring on the ratchet gear. (b) When the spring is wound and the starter control lever is disengaged, the spring unwinds and spins the starter-drive mechanism which in turn spins the flywheel.

side end of the spring and which also serves as a trip release for activating the starter.

- A **starter-drive** mechanism which transfers the rotary motion of the unwinding spring to the flywheel and crankshaft for starting.

Starter drives, on windup starters, are similar to those on rope-rewind starters except they are stronger. See Figures 28 and 29.

Some windup starters have provisions for winding the spring directly (Figure 40), while others are equipped with reduction gears (Figure 41). The purpose of the reduction gears is to make it easier to wind the recoil spring. This arrangement, however, requires more turns of the handle to wind the spring. For example, if the drive gear is one fourth the diameter of the driven gear it will require only one fourth the effort to turn the handle; but you will have to make four times as many turns to wind the spring as you would for a direct drive starter.

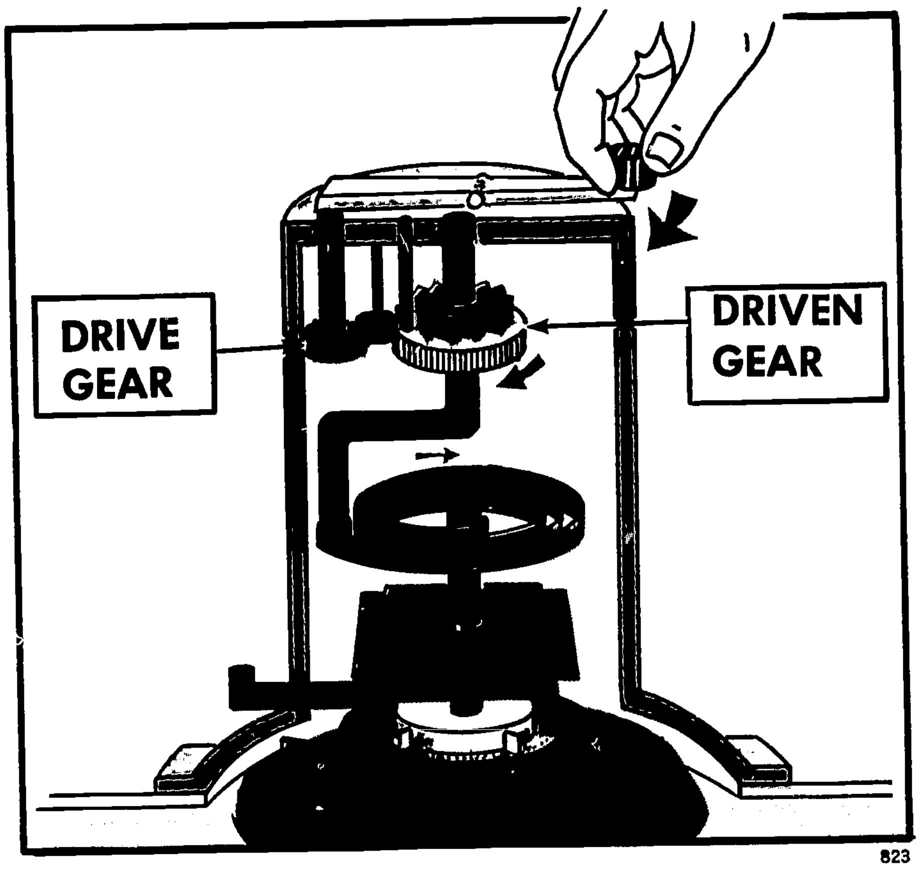


FIGURE 41. A reduction-gear windup starter.

TOOLS AND MATERIALS NEEDED

1. Vise—4″ jaws
2. 8-inch C-clamp (2)
3. Slot-head screwdriver—8″
4. Open-end wrenches—7/16″, 1/2″ and 9/16″
5. Needles-nose pliers—7″
6. Combination pliers—7″
7. Multi-purpose grease

CHECKING FOR PROPER OPERATION

1. *Lock the starter spring with the control lever (Figure 42a).*

   Some are locked automatically as the handle is raised.
2. *Remove any load from the engine.*
3. *Unfold the handle if it is of the folding type (Figure 42b).*
4. *Wind the spring (Figure 42c).*

   Most starters are wound in a clockwise direction.

   If the **spring does not wind,** it is probably broken.
5. *Fold the handle before starting.*
6. *Move release lever to starting position (Figure 42d).*

   A lever is the usual means of starting cranking action. It releases the holding mechanism in the center of the spring assembly. The engine should spin three or four revolutions.

   Some starters are actuated (set in motion) by folding the handle and pressing it down. If the starter **spins but does not crank the engine,** the drive mechanism is not engaging. Refer to "Repairing the Drive Mechanism," page 20.

   If the starter **engages the flywheel cup but does not crank the engine fast enough for starting,** the spring may be weak. Before replacing the spring, however, check the flywheel for freedom of rotation. See step 2.

   If there is **a slight hesitation on the part of the starter**—it starts to turn slowly and then spins the engine—it is because the starter is engaged at the time the piston is coming up on compression stroke. This is normal because of the high turning resistance of the engine during the compression stroke.

   If your engine **does not start after two or three tries** with the windup starter, check your starting procedures. Refer to "Starting the Engine," Volume I.

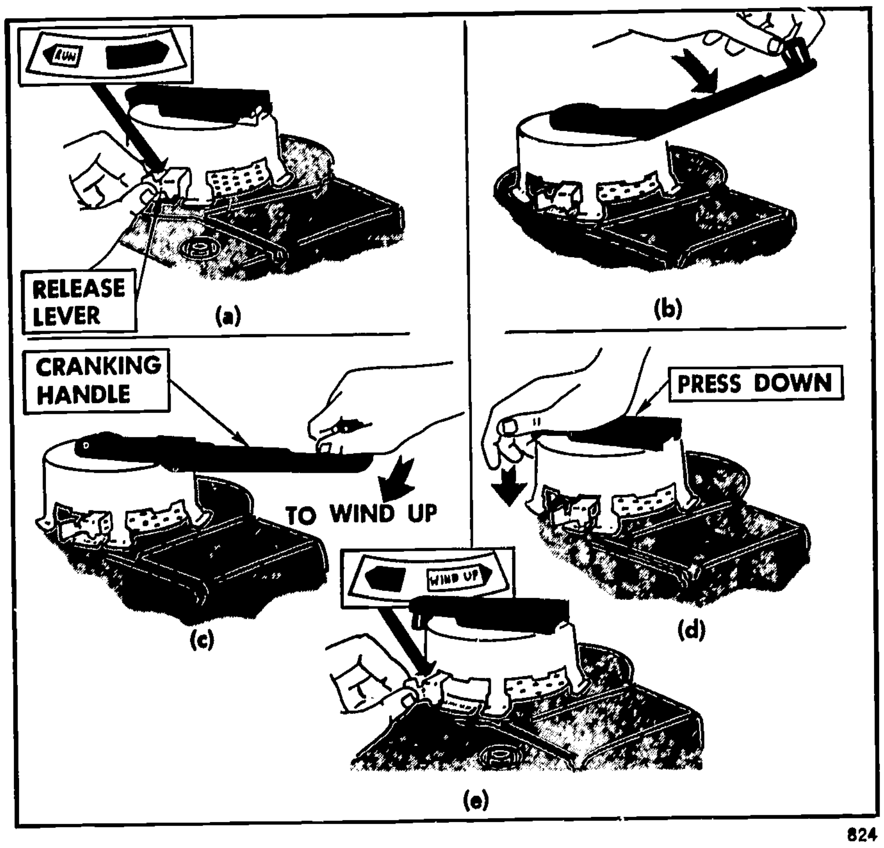


FIGURE 42. Steps in operating a windup starter. (a) Lock the spring by moving the control lever to "wind up." (b) Open the crank handle. (c) Wind the recoil spring. (d) Fold handle. (e) Move control lever to "run" to start the engine.

REPAIRING THE WINDUP STARTER

1. *Release the starter control (Figure 42d and e).*

   This relieves the tension on the spring.

   CAUTION! Never attempt to work on a windup starter without first deactivating (unwinding) the spring.
2. *Remove the starter assembly from the engine (Figure 43).*
3. *Disassemble the starter (Figure 44).*

   Some windup starters are disassembled from the drive end and others are disassembled from the handle end. If the handle is riveted or welded onto the shaft, you should remove the drive mechanism first. The drive mechanism and retainer screw are similar to those on rope-rewind starters — only heavier.

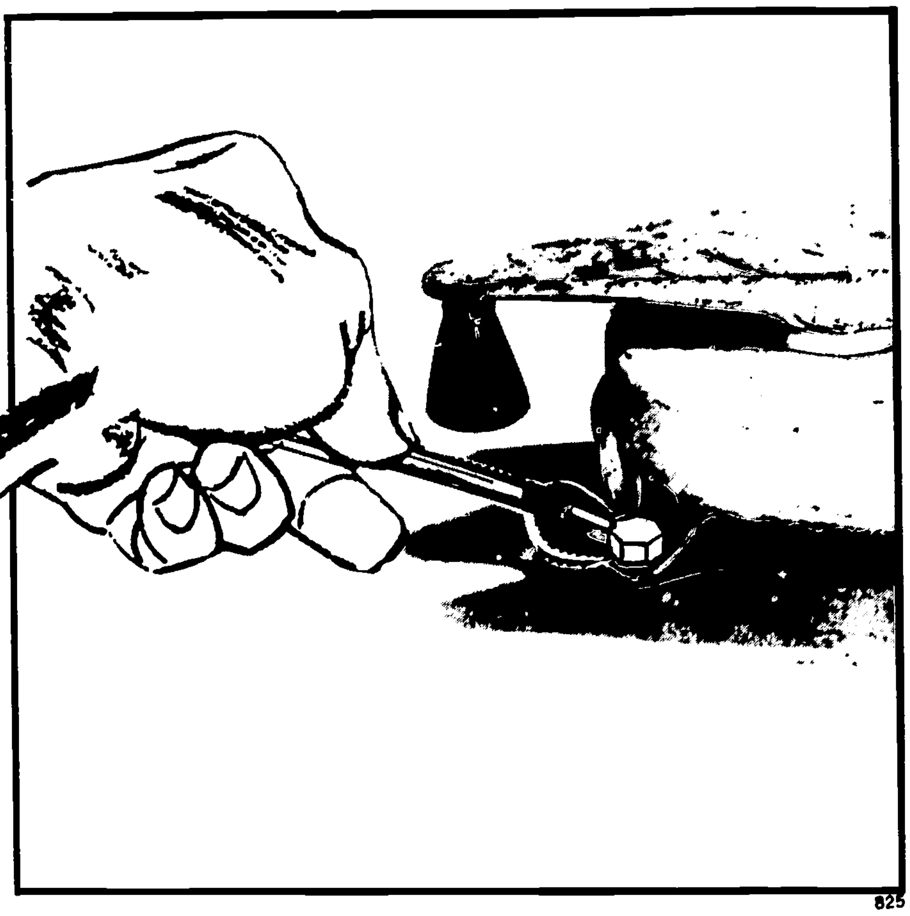


FIGURE 43. Removing the windup-starter assembly from the engine.

4. *Remove the drive assembly if necessary.*

   Refer to "Repairing the Drive Mechanism," page 20.

5. *Remove the main spring assembly (Figure 45).*

   Do not remove the spring from its retainer unless you have specific instructions from your manufacturer to do so.

   CAUTION! Very few main springs are intended to be removed from the retainer. If you are not certain yours is to be removed, do not do it. They are very strong and most of them will straighten out instantly (Figure 46).

   Included in this assembly will be a ratchet of some kind, perhaps a drive gear and washer. Watch for small springs and spacers. Clean, inspect and lay out the parts. Check the condition of the spring. Is it worn, bent or cracked?

6. *Clean and inspect the housing.*

   Look for breaks, cracks, worn gear teeth and a worn ratchet; also, for broken springs and worn bearing surfaces.

   Check control lever for condition and for proper operation.

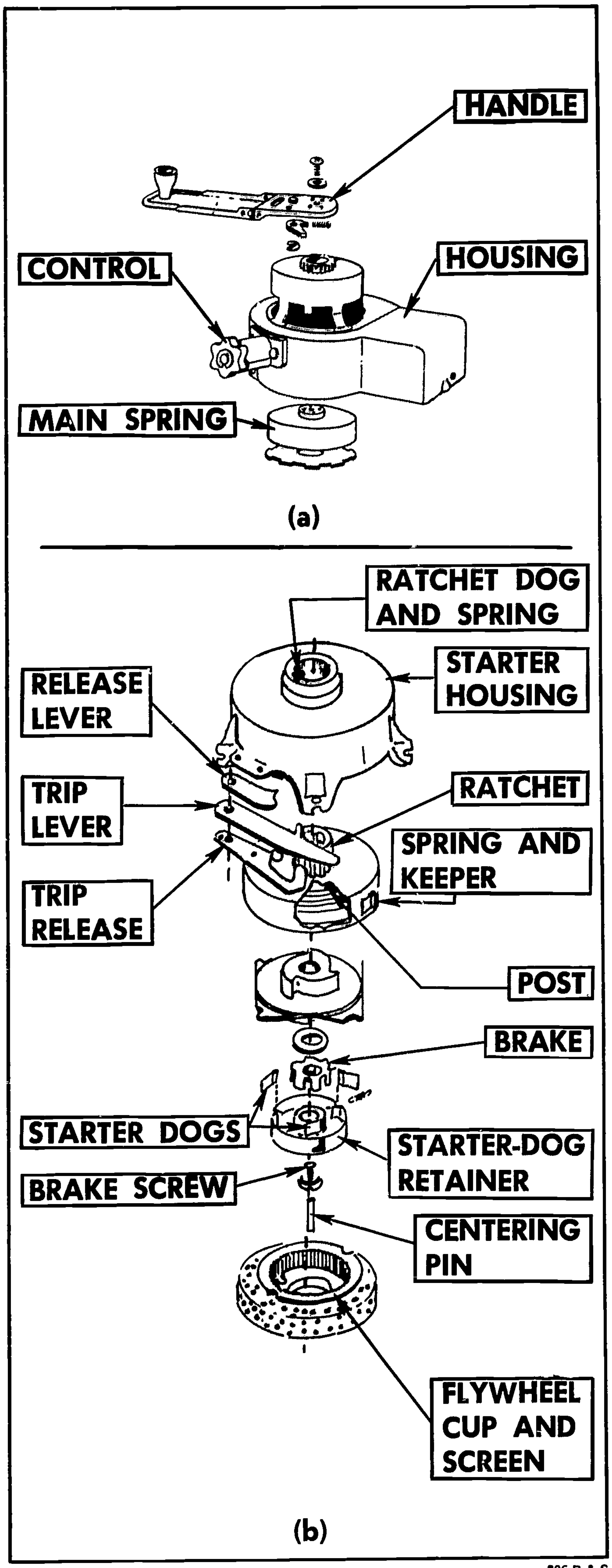


FIGURE 44. (a) A typical windup starter of the type that must be disassembled from the handle end. (b) One from which the drive mechanism is first removed.

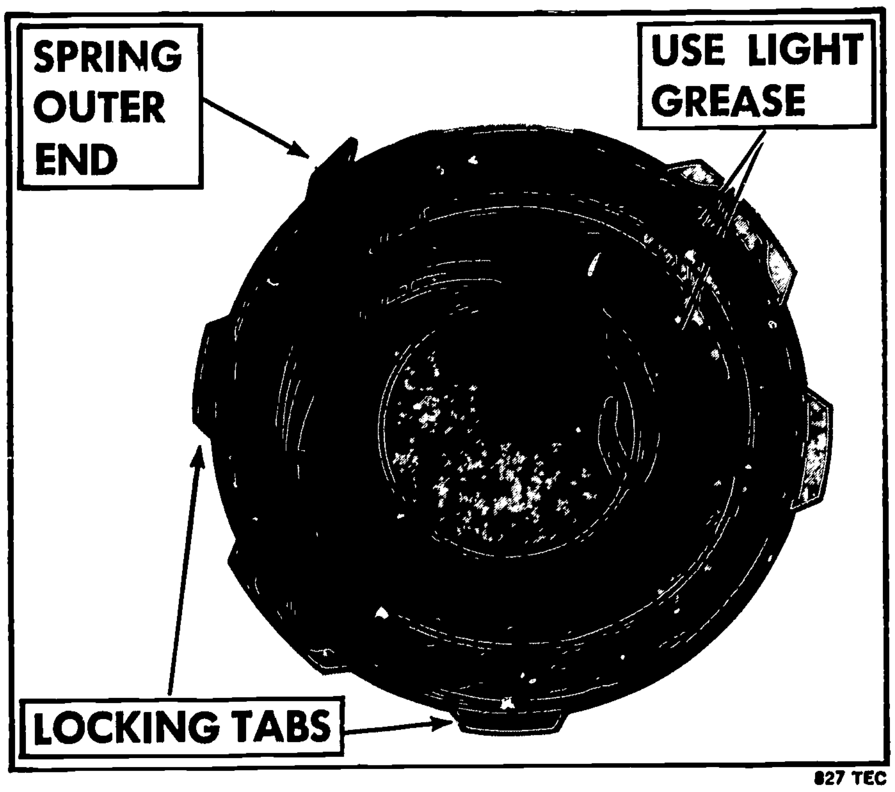


FIGURE 45. A main spring assembly.

7. *Reassemble parts in reverse order.*

   Replace badly worn or broken parts.

   The main spring will most likely be in a retainer housing.

8. *Destroy the old main spring so that no one will be likely to tamper with it.*

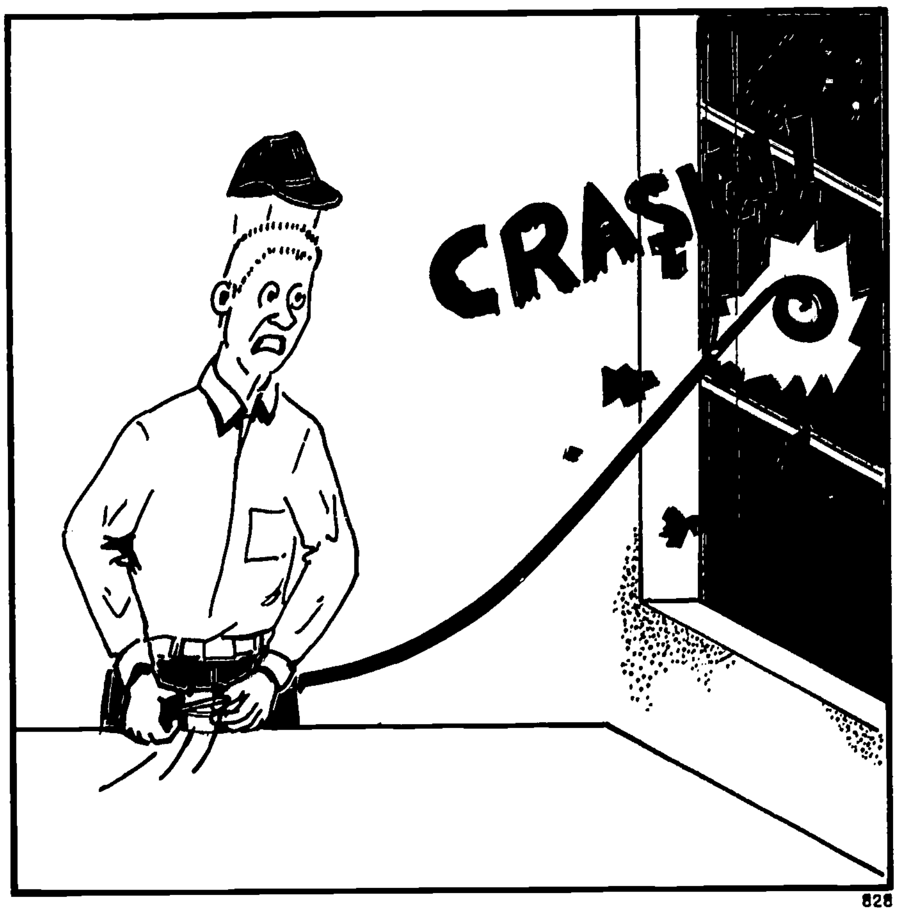
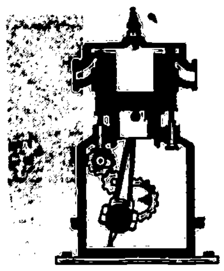


FIGURE 46. Never remove a main spring from its retainer unless you are specifically instructed to do so by the manufacturer.

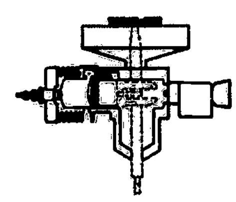
   A good policy is to heat it with a torch. This will remove the tension.

9. *Reinstall the starter on the engine.*

10. *Recheck the starter for proper operation.*



D. REPAIRING 120-VOLT ALTERNATING-CURRENT STARTERS



Alternating-current starters are operated on 120-volt current from your home wiring system. An extension cord is used to connect the starter to a convenience outlet.

Although most manufacturers offer alternating-current starters for small engines, these types of starters have not become very popular. The number in use is limited. For this reason, repair procedures are not given here. Only the two following topics are discussed.

1. Principles of operation.

2. Checking for proper operation.

PRINCIPLES OF OPERATION

The 120-volt alternating-current starting system consists primarily of the following:

- **An electric motor**—power to operate the starter.
- **A control switch.**
- **An extension cord** to reach the power source.
- **A starter-drive mechanism**—to engage the starter with the flywheel for cranking and for disengaging when the engine starts.

Basically, alternating-current starters can be classified according to the type of drive (engaging and disengaging) mechanism.

Three types are described here: (1) **cone-**

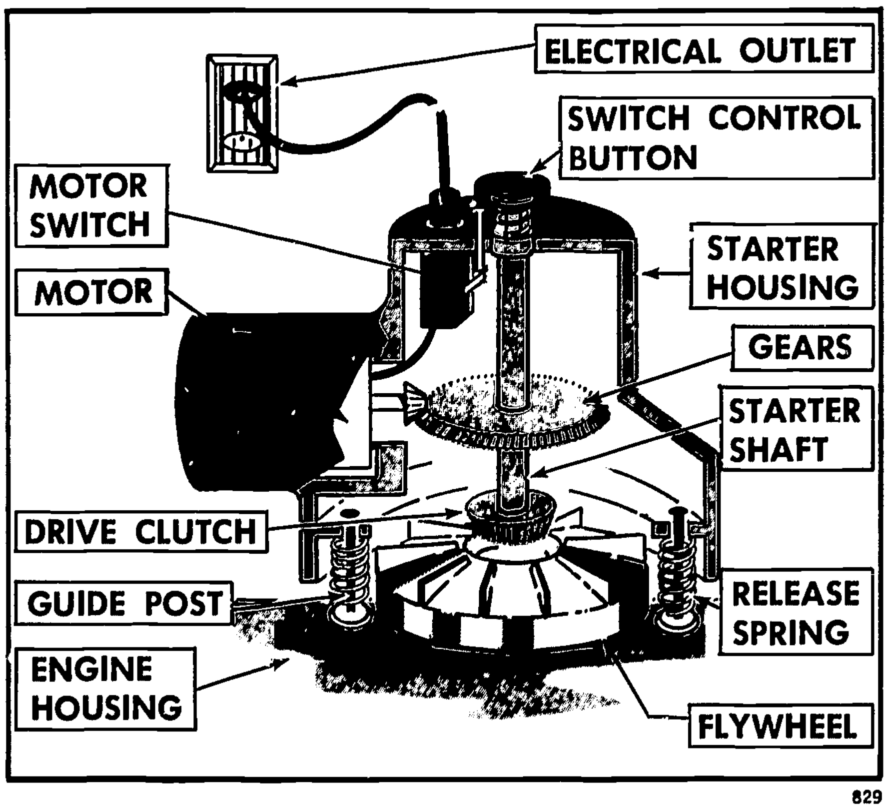


FIGURE 47. An alternating-current starter with a manually operated cone-shaped friction-clutch drive mechanism.

shaped friction-clutch, (2) **split-pulley clutch** and (3) **bendix.**

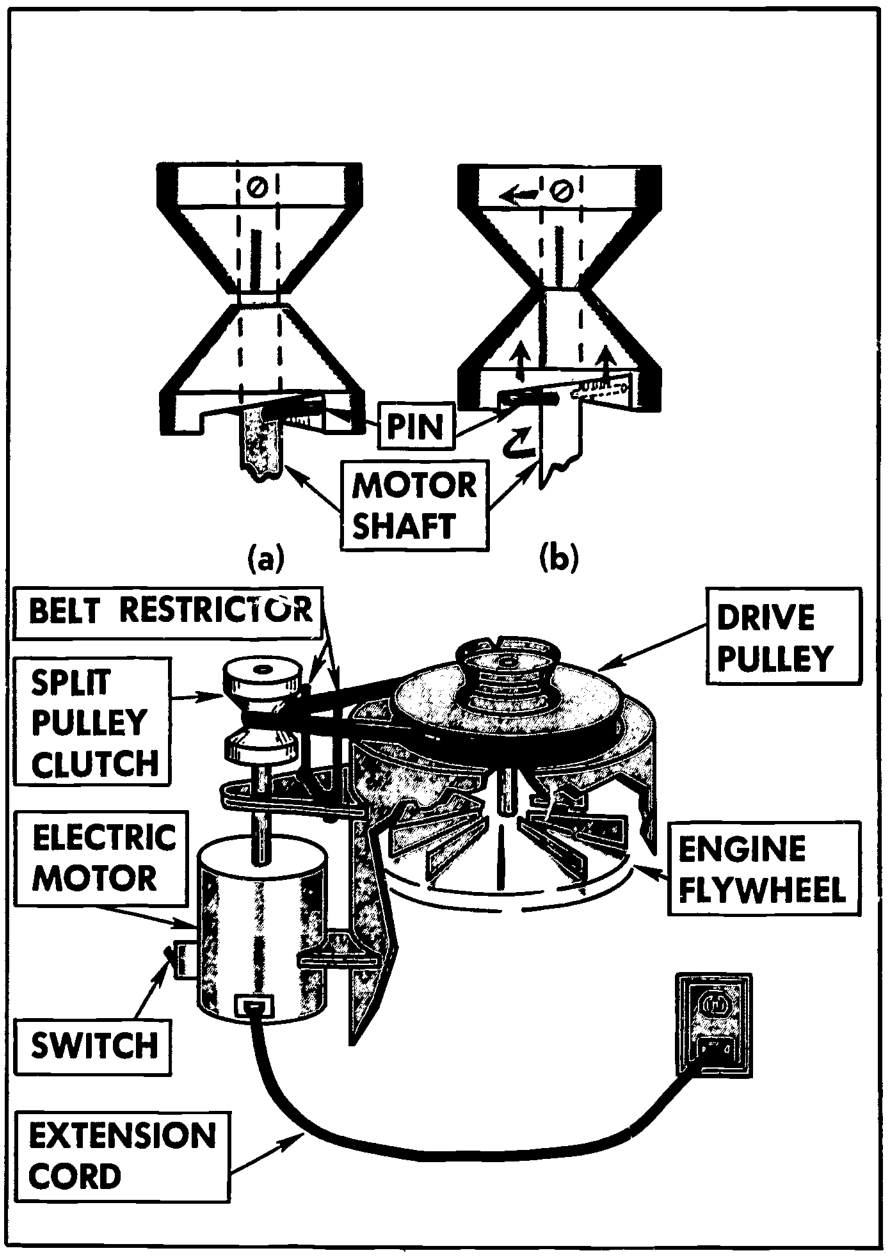


FIGURE 48. An alternating-current electric starter with a split-pulley-clutch drive mechanism.

A starter with the **cone-shaped friction clutch** is shown in Figure 47. To operate this type of starter, press the switch-control button down until the electric motor starts. Hold it in this position until the electric motor gains speed; then push the entire starter housing down until the cone-shaped clutch is engaged. This engages the starter to the flywheel and cranks the engine.

When the engine starts, release the control knob. The starter housing is lifted by the starter-release spring, and the switch is turned off by the switch release spring.

The **split-pulley type clutch** (Figure 48) is also engaged by friction, but it is done automatically. The pulley halves are separated when the starter is not engaged (Figure 48 inset a). They close when the starter is engaged (Figure 48 inset b).

When you turn on the switch, the electric motor starts. The upper half of the pulley turns with the motor shaft. The motor shaft turns inside the lower half of the split pulley (Figure 48 inset a). The lower half does not turn momentarily because of inertia (resistance to changing position). As a result, the pin in the starter shaft pushes against the incline on the pulley and forces the lower pulley half upward. This closes the gap between the pulley halves (Figure 48 inset b). When this happens, the belt tension is increased; and friction is developed between the pulley flanges. The drive pulley rotates. The starter is engaged and cranks the engine.

When the engine starts and the starter switch is turned off, the electric motor stops. With the engine running, belt tension applied to the split pulley forces the movable (lower) half back down, thus releasing the belt tension and the starter. The belt rides loose in the open split pulley while the engine is running. A **belt restrictor** holds the belt in place when the starter is not operating.

The **bendix-type starter drive** (Figure 49) is a common type used on direct-current starters on all types of automobile and tractor engines. It is called "bendix" from the name of the inventor. Here is how it works. When you turn the switch on, the electric motor starts (Figure 49a). The pinion gear does not turn because of inertia (similar to the split-pulley type previously described). As a result, it moves endwise on the threaded shaft (Figure 49b) until it engages the flywheel gear. When this happens, the endwise motion stops and the pinion gear rotates

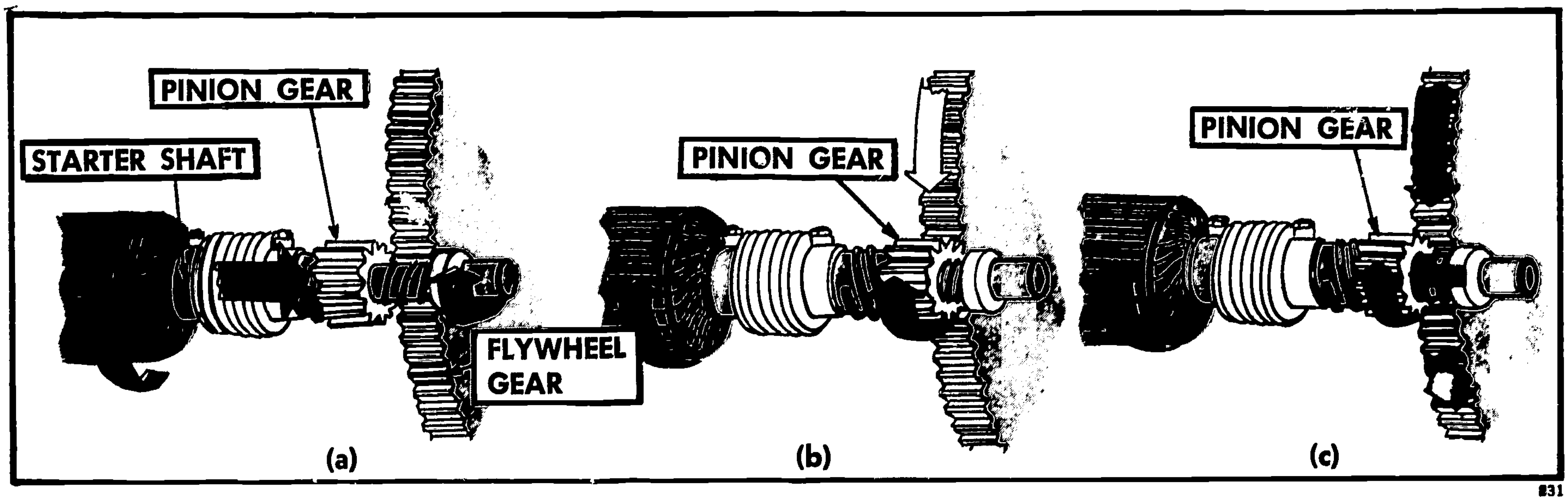


FIGURE 49. A bendix-type starter-drive mechanism. (a) Starter motor turned on, pinion gear moves endwise on threaded shaft. (b) Starter operating, pinion gear engaged in flywheel. (c) Starter turned off, pinion gear disengages.

with the shaft. The starter is engaged. The flywheel turns and cranks the engine.

When the engine starts, the starter switch is turned off. The pinion gear rotates faster than the starter shaft because it is now being driven by the flywheel. It spins back on the threaded shaft, away from the flywheel gear, thus disengaging itself (Figure 49c). The heavy spring on the starter shaft is used to help relieve the shock on the starter parts as the starter cranks the engine.

CHECKING FOR PROPER OPERATION

1. *Remove the load from the engine, if one is engaged. Disengage the clutch.*
2. *Disconnect the spark-plug wire to prevent the engine from starting.*
3. *Plug the extension cord into the starter motor.*

   CAUTION! Always plug the extension cord into the starter motor first. It is possible to get an external spark at the engine if you connect the extension cord to the convenience outlet first. This could start a fire.

   CAUTION! Use a three-wire extension if possible. The third wire is for grounding the equipment in case of a short circuit.
4. *Plug the extension cord into a 120-volt convenience outlet.*
5. *Turn on the starter switch.*

   If your starter is similar to the one in Figure 47, allow the starter motor to come up to speed; then press further down on the starter switch to engage the starter drive clutch. Other starter drives engage automatically.

   If the starter does not operate, the trouble may be in the source of electric power, in the electric motor and connections, or it may be in the drive mechanism. Proceed to step 7.

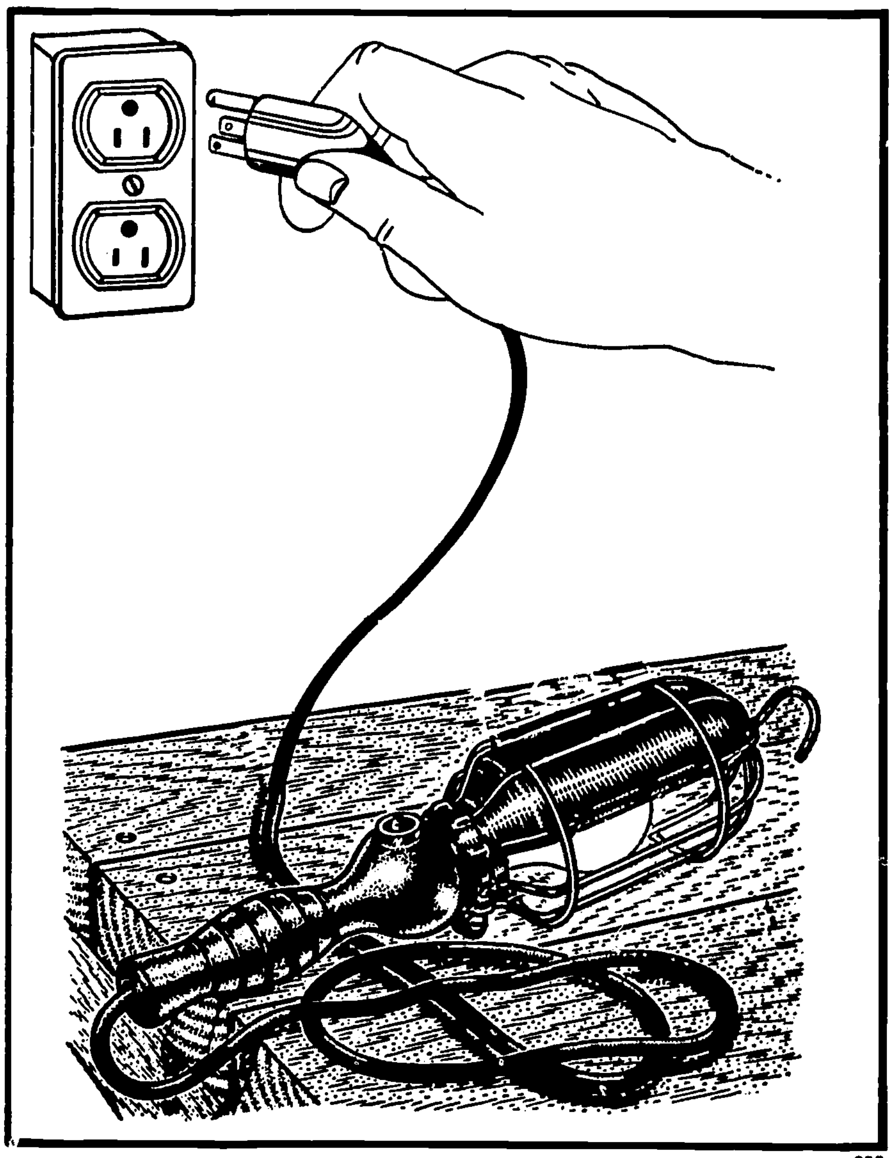


FIGURE 50. Checking the electric power source.

6. *Check starter operation.*

   Do not operate more than 10 seconds at a time.

   This is to prevent overheating the electric motor. Wait 30 seconds for the motor to cool before operating the starter again.

7. *Check the source of electric power (Figure 50).*

   Connect a portable lamp to the convenience outlet. If the *light does not burn*—and the bulb is good—you have no power available. The trouble is not in the starter.

   If the *light burns,* you know you have a source of power. Proceeed to step 8.

8. *Check the electric motor and connections.*

   If the piston in the engine happens to be on compression stroke when the starter is engaged, the starter will be sluggish because it has trouble overcoming the resistance of compression at this point. Turn the flywheel by hand until the piston is off the compression stroke; then try the electric starter.

   If the electric motor still does not work and there is a hum in the motor, the trouble may be in worn brushes, worn bearings, or a short in the motor wiring.

   If there is no noise, the trouble may be a burned-out motor, worn brushes, or an open circuit—most likely in the extension cord.

   Procedures for replacing the brushes on direct-current starters are given under "Repairing Direct-Current Starting and Generating Systems," page 33.

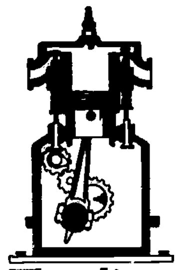
   The same procedures may be used for the brushes in your alternating-current starter since they are of similar design. Or, refer to your service manual.

   If the starter motor **runs but does not engage,** proceed to step 9.

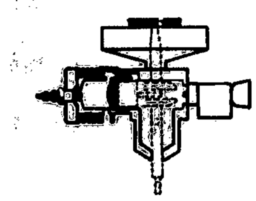
9. *Check the starter-drive mechanism.*

   Check the engaging mechanism for wear, broken parts and proper adjustment.

   See your service manual for procedures.



E. REPAIRING DIRECT-CURRENT STARTING AND GENERATING SYSTEMS



The direct-current starter on your small engine is similar to the one you have on your tractor, truck or automobile. It operates on power supplied by a storage battery (6 or 12 volts). The charge on the storage battery is maintained by an engine-driven generator. The **generator** may be (1) a *separate direct-current* unit, (2) a *separate alternating-current* unit—with a means for converting the alternating current to a direct current—or (3) it may be a *combination starter-generator* unit.

The combination unit is by far the most popular for small engines. It is more compact and self-contained, and does not require a disengaging mechanism.

Procedures for maintaining and repairing direct-current starting and generating systems are discussed under the following headings:

1. Principles of operation.
2. Importance of proper repair.
3. Tools and materials needed.
4. Checking for proper operation.
5. Checking and repairing the (12-volt direct-current) starting circuit.
6. Checking the generator control circuit (12-volt).
7. Repairing the direct-current starter and generator.

PRINCIPLES OF OPERATION

The direct-current starter-generator system consists of the following:

- A **direct-current starter** or a **combination starter-generator.**
- A **storage battery.**

*A good reference on the subject of starters and generators is "Tractor Electrical Systems," AAAE & VA. It deals with (1) electrical theory; (2) measuring and computing electrical current, voltage and resistance; (3) batteries and generators; and (4) starters and starter controls.

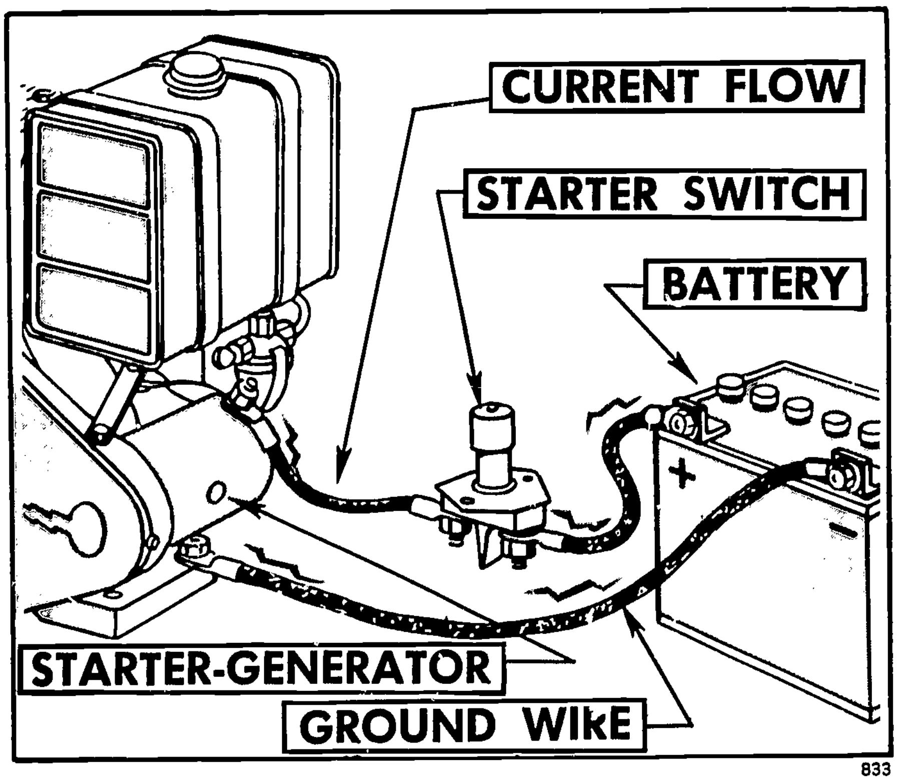


FIGURE 51. A 12-volt direct-current starter-generator system.

- A **direct-current generator** and **voltage regulator,** or an **alternating-current genrator** and **rectifier** for changing the alternating current to direct current.
- A **starter switch.**
- An **ignition switch.**
- A generator **warning light, or an ammeter** (most systems).
- A **starter-drive mechanism**—a belt is used on the **starter-generator combination,** and it is never disengaged from the engine. **Direct-current starters**—without a built-in generator—normally have a bendix type of drive mechanism for engaging and disengaging the starter and the flywheel. It is described under "Principles of Operation," page 30.
- **Connecting wires.**

A **12-volt combination direct-current starter-generator** (Figure 51) is the most common type of electric starter used on small engines. When the starter switch is closed, the electric circuit is completed between the starter-generator and the battery. Current flows from the battery (negative to positive) through the ground wire to the starter-generator. The starter-generator acts as an electric motor. It turns the engine crankshaft through a belt drive.

When the engine starts, the starter switch is released. The starter-generator is *not* disengaged as with other starters. Instead, the engine drives the starter-generator. Then the starter-generator acts as a generator and produces electrical energy for the ignition system, for the lights—if installed—and for recharging the battery. The amount and the rate of charge to the battery is controlled by a current-voltage regulator (Figure 52).

Here is how it works.

A **voltage regulator** controls the amount of current going from the generator while the engine is operating. The regulator protects the generator from

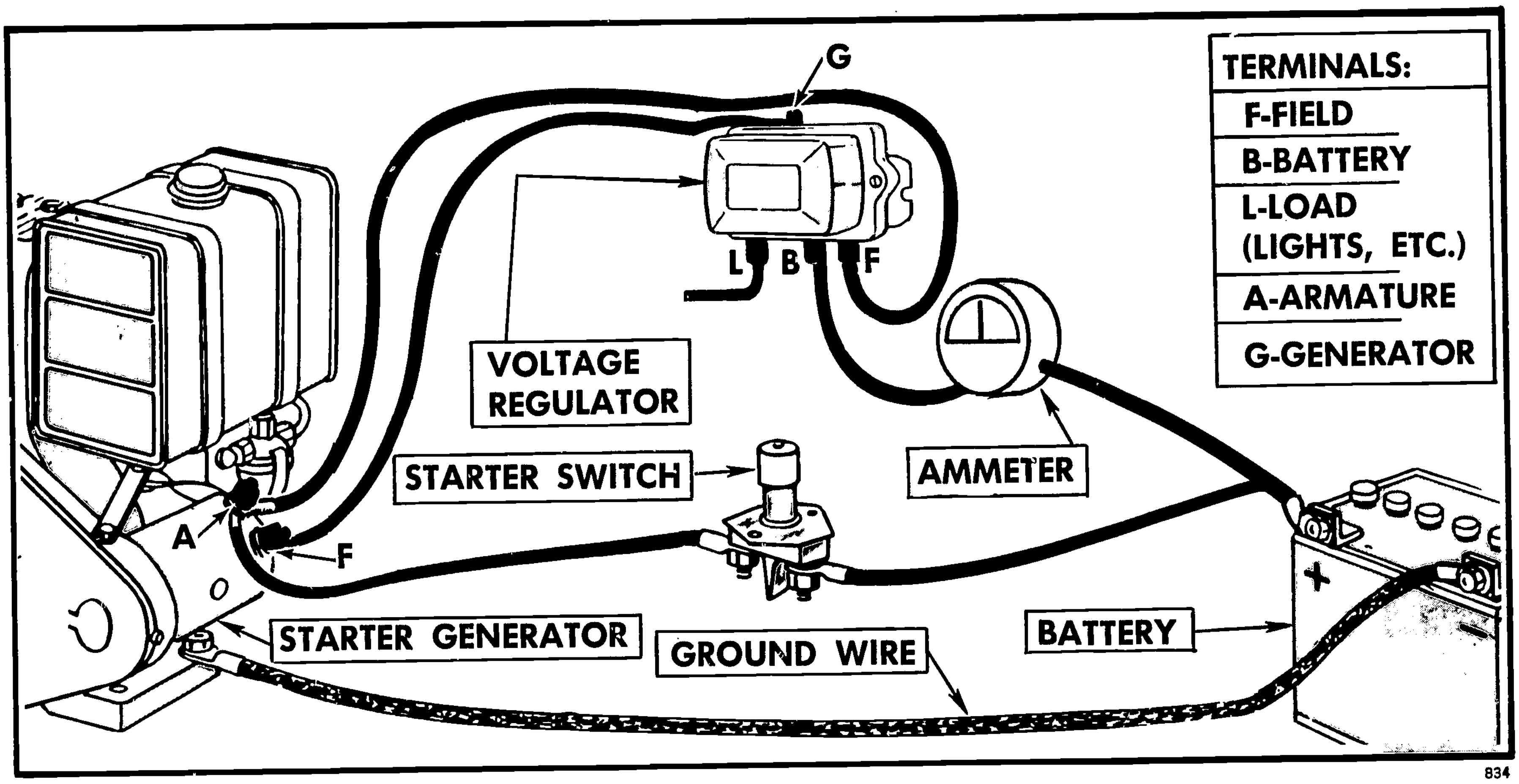


FIGURE 52. A 12-volt starter generator system showing the voltage regulator circuit.

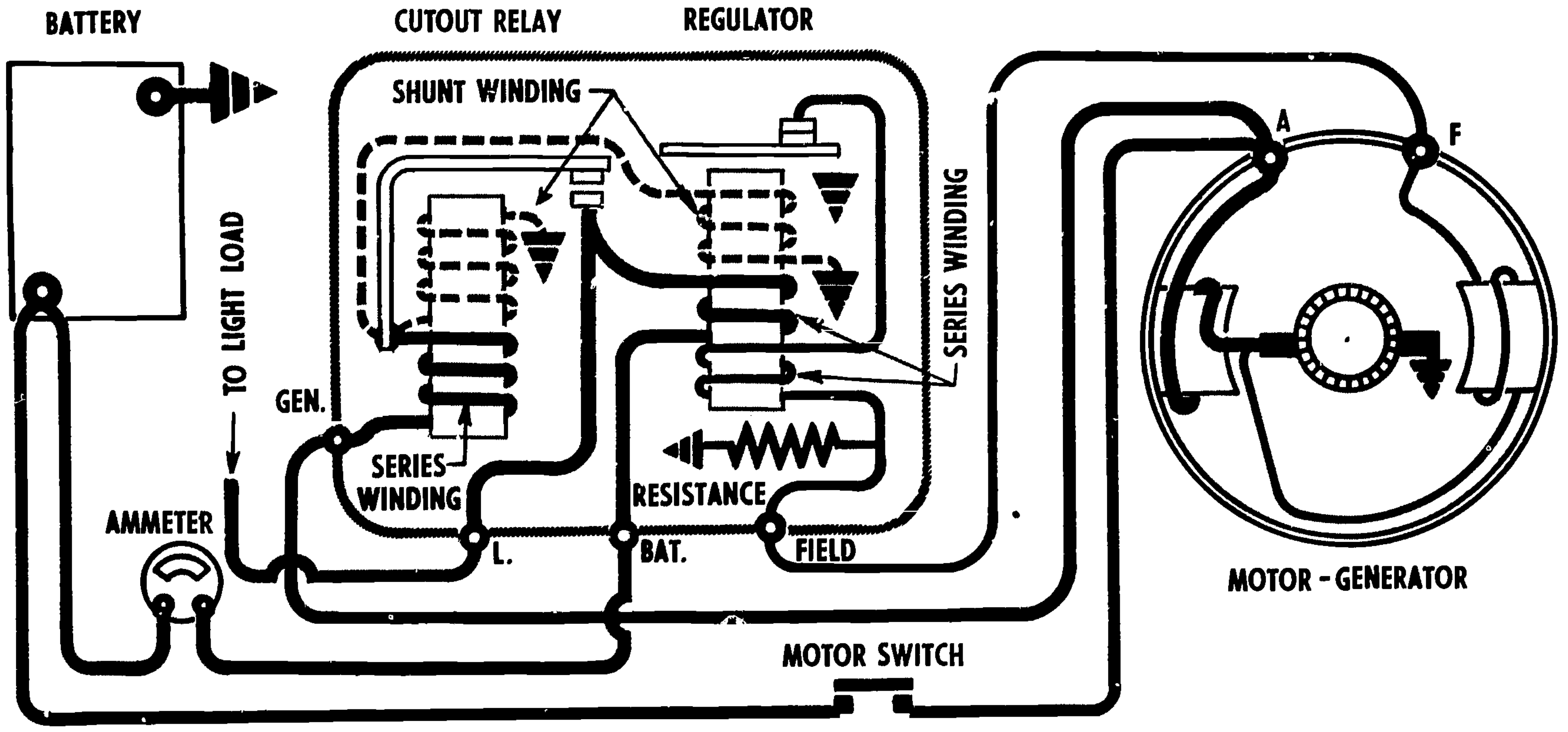


FIGURE 53. Diagram of a tractor-type, starter-generator system used on small engines, showing the current-voltage regulator circuit.

excessive output and possible failure. It also prevents the battery from becoming overcharged. Without some means of control, overcharging could cause the battery to get too hot, and the water in the electrolyte would boil away.

Wiring diagrams of voltage regulators used on direct-current generator systems are shown in Figures 53 and 54.

The first (Figure 53) is a **tractor-type, current-voltage regulator.** It is designed for light electrical loads and for normal operating conditions —moderate climate and infrequent starting. This type is most frequently used on small engines.

The second (Figure 54) is the type used on automobiles. It is designed for heavy electrical loads. The current regulator and voltage regulator are separate. This type of regulator allows the generator output to increase, or decrease, according to the demand (electrical load, or need for charging the battery).

The **tractor-type current-voltage regulator** operates as follows:

When the starter switch is closed, current flows from the battery to the starter, thus causing the starter to turn.

After the engine starts and comes up to 800-1000 r.p.m., with the starter switch off, current is generated. It flows from the generator armature through the shunt and series winding in the cutout relay of the regulator. This causes the cutout relay points to close and allows current to flow through the points to the battery, thus charging the battery. Increased current flow through the points and the series winding holds the points tightly closed.

As the generator voltage builds up, sufficient current goes through the series winding in the regulator to open the regulator points. The combination of currents through the series winding and the shunt-winding, act together to open the points. Therefore, high output of generator current and voltage are both controlled.

As soon as the regulator points open, the generator output (voltage) drops, thus allowing the regulator points to close again. The opening and the closing of the points continue at a rapid rate, thus regulating the generator output and voltage to match the requirements of the battery.

When the battery becomes fully charged, the regulator points remain open most of the time until the battery needs charging again. This prevents overcharging the battery.

The field current is directed through the resistor to ground. The resistor reduces arcing at the points and decreases the current flow from the generator.

The **automotive-type current-voltage regulator** operates as follows (Figure 54):

When the starter switch is closed, current flows from the battery to the starter, thus causing the starter to turn.

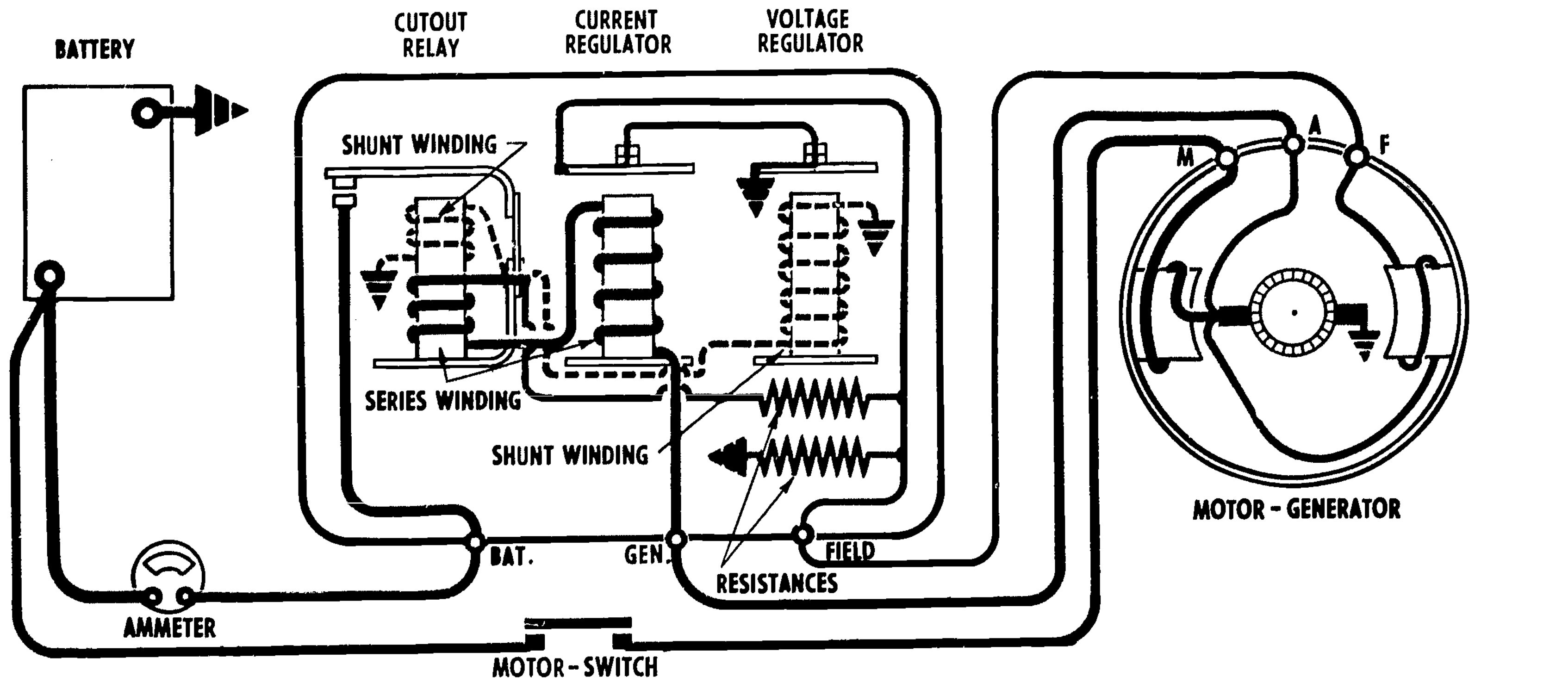


FIGURE 54. Diagram of an automotive-type, starter-generator system used on small engines showing the current voltage regulator circuit.

After the engine starts and comes up to 800 to 1,000 r.p.m., with the starter off, current is generated by the generator.

Current from the generator flows from the armature through the current-regulating coil and the cutout-relay coil. The cutout relay points close, thus allowing generator current to flow to the battery and to the electrical loads. The current regulator points do not open until the current flow is built up to a pre-set limit.

The generator voltage increases until it reaches the amount for which the two units of the regulator are set; then the points open.

If there is a **high current flow** to supply both the battery and various other uses, there is often not sufficient voltage to operate the voltage regulator coil. Then the current regulator limits generator output by making and breaking the field circuit.

If the electrical load is reduced, or if the battery comes up to charge, the system voltage will increase to the pre-set regulating voltage and open the voltage-regulator points. With the voltage regulator points open, the generator output is not sufficient to hold the current regulator points open, and they close. The voltage regulator points then open. The field current flows through the resistor to ground. The generator output decreases, thus allowing the regulator points to close again.

The cycle is repeated approximately 75 times per second, thus regulating the voltage.

Some engines generate **alternating current** by means of a **magneto on the flywheel.** This supplies direct current to the starter motor and battery.

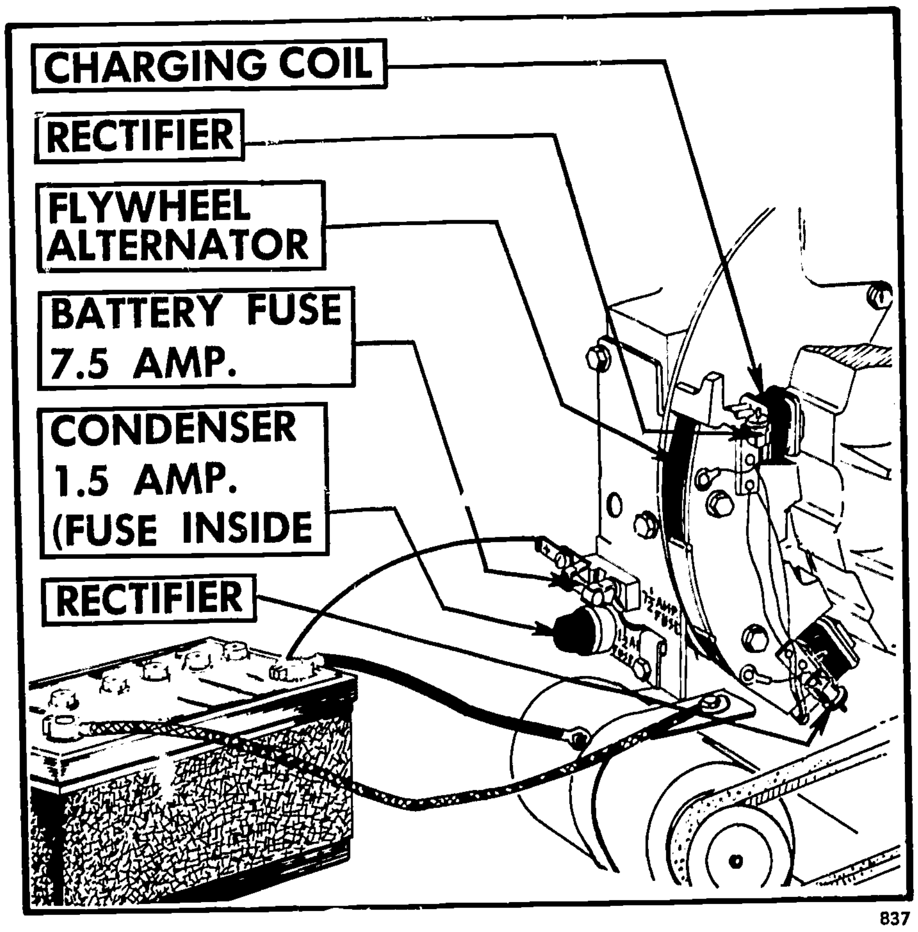


FIGURE 55. An alternating-current generator and starter system. Current is produced by the coils being passed by magnets in the flywheel. It is changed to direct current by the rectifiers.

Alternating current differs, as the name implies, from direct current in that the direction of flow completely reverses itself at regular intervals. Alternating current cannot be used to recharge a storage battery. It is necessary to change it to direct current. This is done by rectifiers (or diodes) in this system (Figure 55). Figure 85 explains the principle of a diode rectifier.

This system is good for engines in intermittent service. But there is a danger of overcharging the battery when the engine operates too long at a time. It is sometimes necessary to remove one fuse to prevent overcharging of the battery. An overcharged battery gets too hot and the water in the electrolyte evaporates.

IMPORTANCE OF PROPER REPAIR

If you expect your starter to operate when you need it, there are a few maintenance and repair jobs you should do to the starter and generator system regularly. They are as follows:

- *Checking and servicing the battery*—for procedures refer to "Checking and Servicing Batteries," Volume I.
- *Lubricating the starter and generator bearings if needed*—some have factory sealed bearings and require no additional lubrication. If the bearings become worn, there is a danger of the starter or generator shorting out (grounding).
- *Checking and repairing the starter circuit*—much starter trouble is due to loose connections in the wiring circuit. The full charge of the battery never gets to the starter motor.
- *Replacing the brushes in the starter and generator*—occasionally brushes wear out in electric motors and generators. If you do not replace them in time, the starter or direct-current generator will be less effective. The segments in the commutator will become worn and pitted.

TOOLS AND MATERIALS NEEDED

1. 0-20 range voltmeter
2. 0-30 range ammeter
3. Slot-head screwdriver—8″
4. Open-end wrenches—7/16″, 1/2″, and 9/16″
5. Brush-seating stone, or sandpaper (No. 00) and a small wooden block with a 1/2″ square end
6. A clean cloth
7. Tachometer
8. Petroleum solvent (mineral spirits, kerosene or diesel fuel)

CHECKING FOR PROPER OPERATION

1. *Disconnect all driven equipment from the engine.*
2. *Turn on the ignition switch.*
3. *Check to see if the generator warning light comes on, or if the ammeter shows a discharge when the ignition switch is turned on.*

   If so, the instruments are working, and current is available from the battery.
4. *Shift power transmission into neutral if installed.*
5. Engage the starter switch.
6. *Turn the starter switch off as soon as the engine starts.*

   When the engine starts and picks up speed, look to see if the generator warning light goes out.

   If the warning **light does not go out,** the trouble is in the generator circuit. Follow procedures under the next heading.

   If you have an ammeter, check to see if the battery is charging (Figure 56).

   If the ammeter **does not indicate a charge,** the trouble is in the generator circuit. Follow procedures under the next heading.

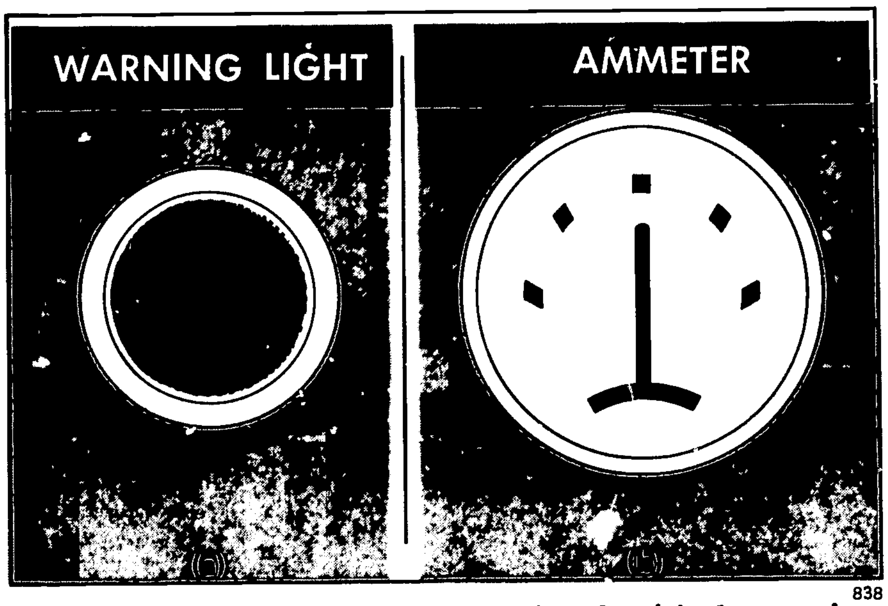


FIGURE 56. Generator warning signals. (a) A warning light indicates that the generator is not generating current. (b) An ammeter indicates the rate of charge going to the battery.

The **ammeter** indicates if the generator is working properly. The **warning light** comes on when the current is being supplied by the battery instead of the generator. This indicates the generator is not in good working order.

If the starter does not work or if it is sluggish, it is most likely due to low battery voltage or a faulty connection in the circuit. Check the battery first. Refer to "Checking and Servicing the Battery," Volume I.

If the battery is satisfactory, proceed with checking the starter circuit.

CHECKING AND REPAIRING THE 12-VOLT DIRECT-CURRENT STARTING CIRCUIT

Each step must be done in sequence and the condition corrected for this check to work. Otherwise, you will not be able to isolate the trouble.

1. *Check for proper ground connections at the starter-generator or at the battery (Figure 57).*

   (1) *Connect the negative lead of the voltmeter to the starter-generator mounting frame, and the positive lead to the negative battery post.*

   NOTE: This connection is for negatively grounded systems. If the starter circuit has the positive ground, the connections would be opposite.

   (2) *Close the starter switch and check the voltage.*

   The voltmeter should read approximately 10 volts, proceed with step 2.

   If the **voltage drops below 10 volts,** this indicates you have a poor ground connection in the system. Check for loose and/or corroded ground connections.

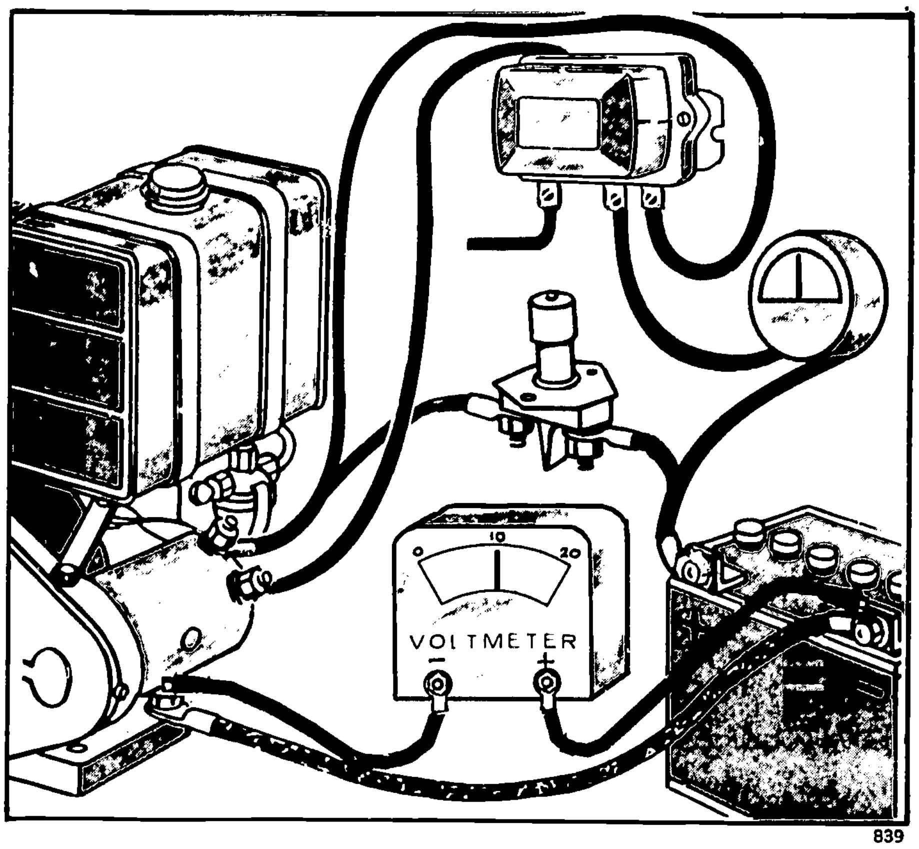


FIGURE 57. Checking the battery and ground connections with the voltmeter.

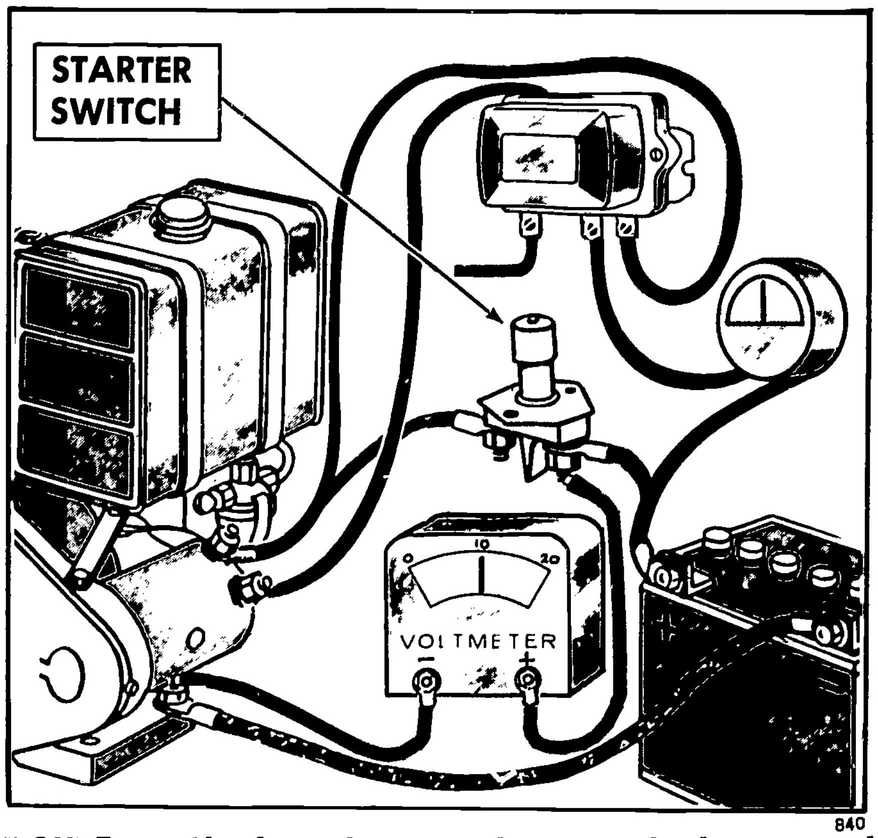


FIGURE 58. Checking the circuit between the battery and the starter switch with a voltmeter.

   (3) *Clean and tighten ground connections or replace ground cable if it is worn or corroded.*

   (4) *Close starter switch and recheck.*

   If the **voltage is still low,** proceed to step 2.

2. *Check the circuit between the battery and the starter switch (Figure 58).*

   (1) *Leave the negative lead grounded to the generator mounting frame and connect the positive lead of the voltmeter to the switch terminal nearest the battery.*

   (2) *Close the starter switch and check voltage.*

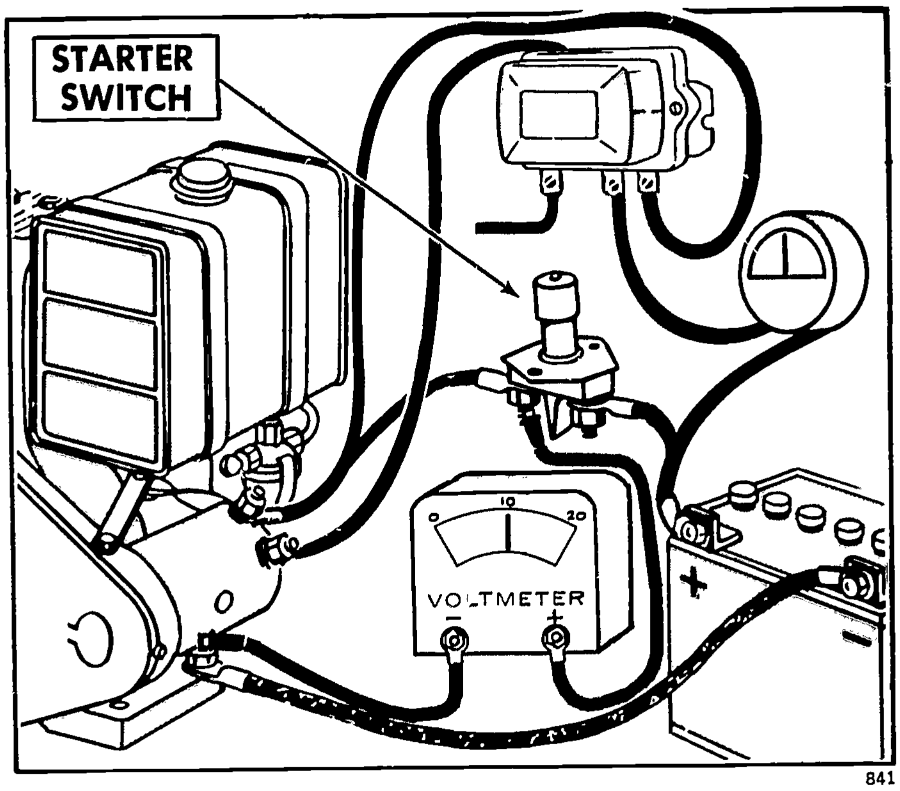


FIGURE 59. Checking the starter switch with a voltmeter.

Low voltage reading indicates a poor connection between the battery and the starter switch.

If the starter does not crank the engine, proceed to step 3.

(3) *Check for a loose connection or a worn battery cable.*

(4) *Clean and tighten the cable connections.*

(5) *Close starter switch and recheck the voltmeter.*

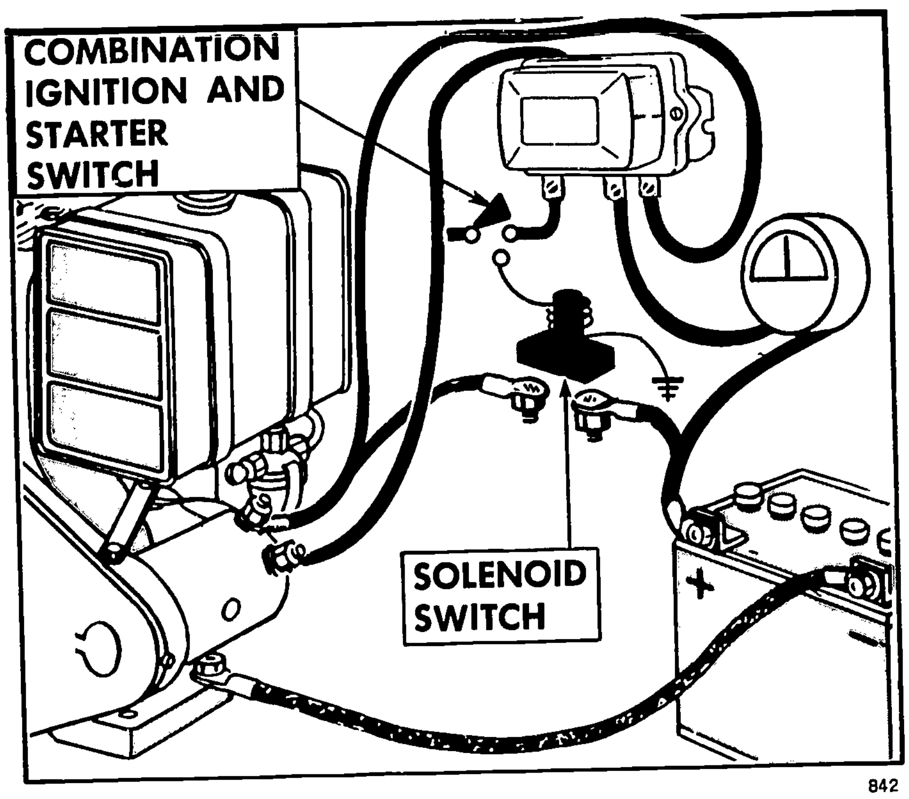


FIGURE 60. A solenoid starter switch. The solenoid is energized by a small amount of current from the battery when the starter switch is turned on. It becomes an electromagnet and closes the main starter switch.

3. *Check the operation of the starter switch (Figure 59).*

(1) *Leave the negative test lead connected to the starter-generator mounting frame; connect the positive lead to the switch terminal nearest the starter-generator.*

(2) *Close the starter switch.*

If you have **very little voltage or no voltage,** the starter switch is not closing the circuit properly. This would be true with either a plain switch as shown in Figure 59, or a solenoid switch (Figure 60).

(3) *Repair or replace the starter switch.*

(4) *Close the starter switch and recheck voltage.*

If the voltage is still low, proceed to step 4.

4. *Check the circuit between the starter switch and the starter (Figure 61).*

(1) *Connect the negative lead of the voltmeter to the generator frame (ground) and the positive lead to the "A" (armature) post on the starter-generator.*

The starter motor should turn satisfactorily and the meter reading should be nearly 11 volts.

(2) *Close the starter switch.*

If the starter motor **does not work and battery voltage is satisfactory,** this in-

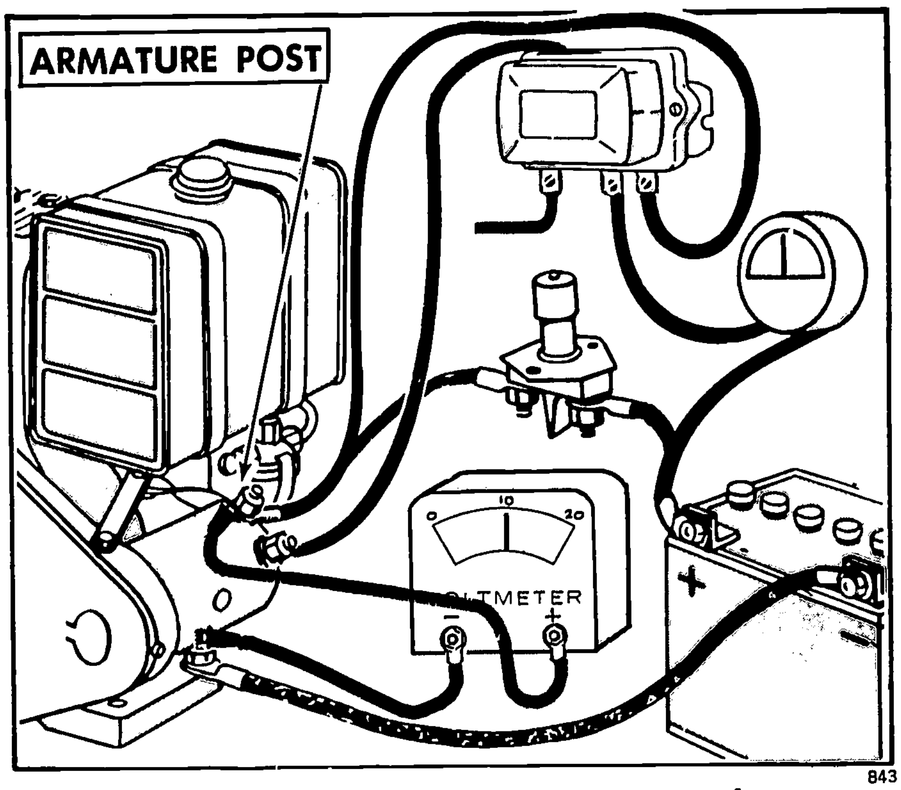


FIGURE 61. Checking the circuit between the starter switch and the starter with a voltmeter.

dicates the starter motor is at fault. Refer to "Repairing Direct Current Startering and Generating Systems," page 33.

If the starter motor **does not work and there is little or no voltage,** this indicates that there is a loose or broken connection between the starter switch and the starter-generator connection.

(3) *Clean, tighten, and inspect or replace the wiring.*

(4) *Recheck with the voltmeter.*

CHECKING THE GENERATOR CONTROL CIRCUIT (12-VOLT)

If you have a **generator warning light or an ammeter,** you can tell at a glance if the generator system is working. But if the warning light comes on or the ammeter shows no charge while the engine is operating, you need to be able to determine if the trouble is in the generator or in the regulator.

Only the procedures for checking the tractor-type regulator (Figure 62) are given, since it is this type you are most likely to have on your small engine.

1. *Check the "A" and "B" leads to make certain they are not interchanged (Figure 62).*

   Sometimes this is done to bypass the regulator and get a quicker battery charge. The "A" lead should connect to the starter switch. The "B" lead should be connected to the positive terminal of the battery.

2. *Disconnect the "B" lead from the voltage regulator (Figure 62).*

3. *Connect one lead of the ammeter to the "B" lead on the voltage regulator and the other lead to the positive battery post.*

   Use an ammeter with a 0.30 amperage range.

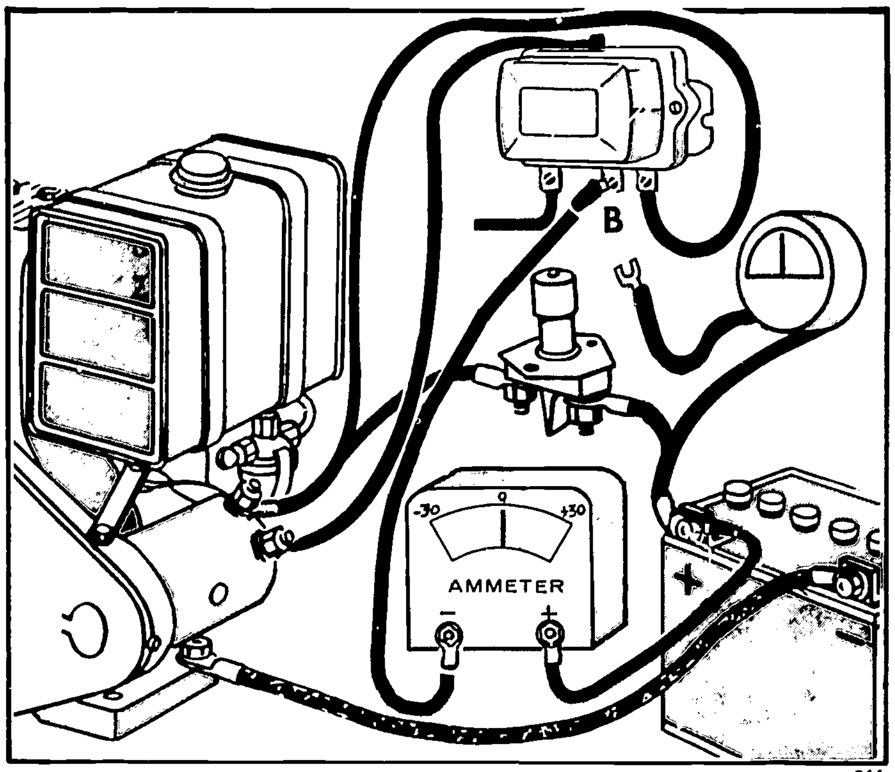


FIGURE 62. Checking the generator circuit with an ammeter on a tractor-type regulator.

4. *Start the engine and operate it at approximately 2,000 r.p.m. (fast idle).*

5. *Read the ammeter.*

   If the generator output is **too much** (10 amps *or more), proceed to step 6.*

   If the generator output is **too low** (5 amps or less—depending on the state of charge of the battery), the trouble is most likely in the regulator. A slipping drive belt or loose wiring connection might give the same indications. Check and correct these conditions first if they exist.

   Replace the regulator.

6. *Disconnect the "F" terminal on the regulator.*

   This opens the generator field circuit and should prevent generator output from building up.

   If the output **remains high,** the generator is defective. There is likely an internal short in the field winding. Refer to the next heading, "Repairing the Direct-Current Starter and Generator."

   If the generator output is **zero,** the regulator is defective. The regulator points do not close or there is an open circuit. Further checks are given in steps 7 and 8.

7. *Short the "F" terminal to ground.*

   This completes the generator field circuit and the output should be excessive.

8. *Read the ammeter.*

   It should show 10 amperes, or more, because there is no control.

   If no charge is shown, you have a bad generator. Refer to the next heading, "Repairing the Direct-Current Starter and Generator," page 41.

   If you have **some charge but it is low,** the regulator needs adjusting.

NOTE. Do not tamper with a current-voltage regulator unless you know what you are doing. You can easily damage it beyond repair. Some service manuals give procedures for adjusting voltage regulators. But if you do not have procedures or if you are not thoroughly familiar with adjusting voltage regulators, it is advisable for you to see your service dealer.

REPAIRING THE DIRECT-CURRENT STARTER AND GENERATOR

Direct-current starters and generators are equipped with **commutators** and **brushes** that require occasional maintenance (Figure 63).

1. *Wipe dirt from starter or generator housing.*

   If it is covered with an oily film, use cloth dampened with petroleum solvent.

2. *Check for worn bearings.*

   Bearings are located at both ends of the armature shaft. You can check them for excessive play by moving the shaft up and down by hand. Usually worn bearings in a generator are noisy during operation.

   Another check for worn bearings is to look at the armature after it has been removed to see if it has been touching the field windings. Worn bearings will allow this to happen.

3. *Remove cover band (Figure 64a).*

   Some *generators* have no cover band. If yours is of this type, you will need to remove the through bolts and pull off the end frame on the commutator end (Figure 64b).

4. *Inspect for thrown solder (Figure 65).*

   If a starter or generator has been **overheated,** you can tell by the ring of solder that has been thrown against the band (Figure 65) or against the inside of the housing, if of the type without a band. If it appears that the starter or generator has been overheated, take it to a service shop. It may require expert repair.

5. *Check brushes for wear and binding action.*

   NOTE: When checking a brush for wear, do not pull on the wire that connects to the brush while it is being held under spring tension. This may loosen the wire connection to the brush. Remove the tension clip from the brush first. Avoid snapping the clips down on the brushes. This causes them to chip and crack.

   If you are checking a **generator,** look for either two or three brushes.

   If you have a **starter-generator combination,** look for two brushes. If the *old brushes are worn (Figure 66)* until the clips are pressing on the brush holders instead of the

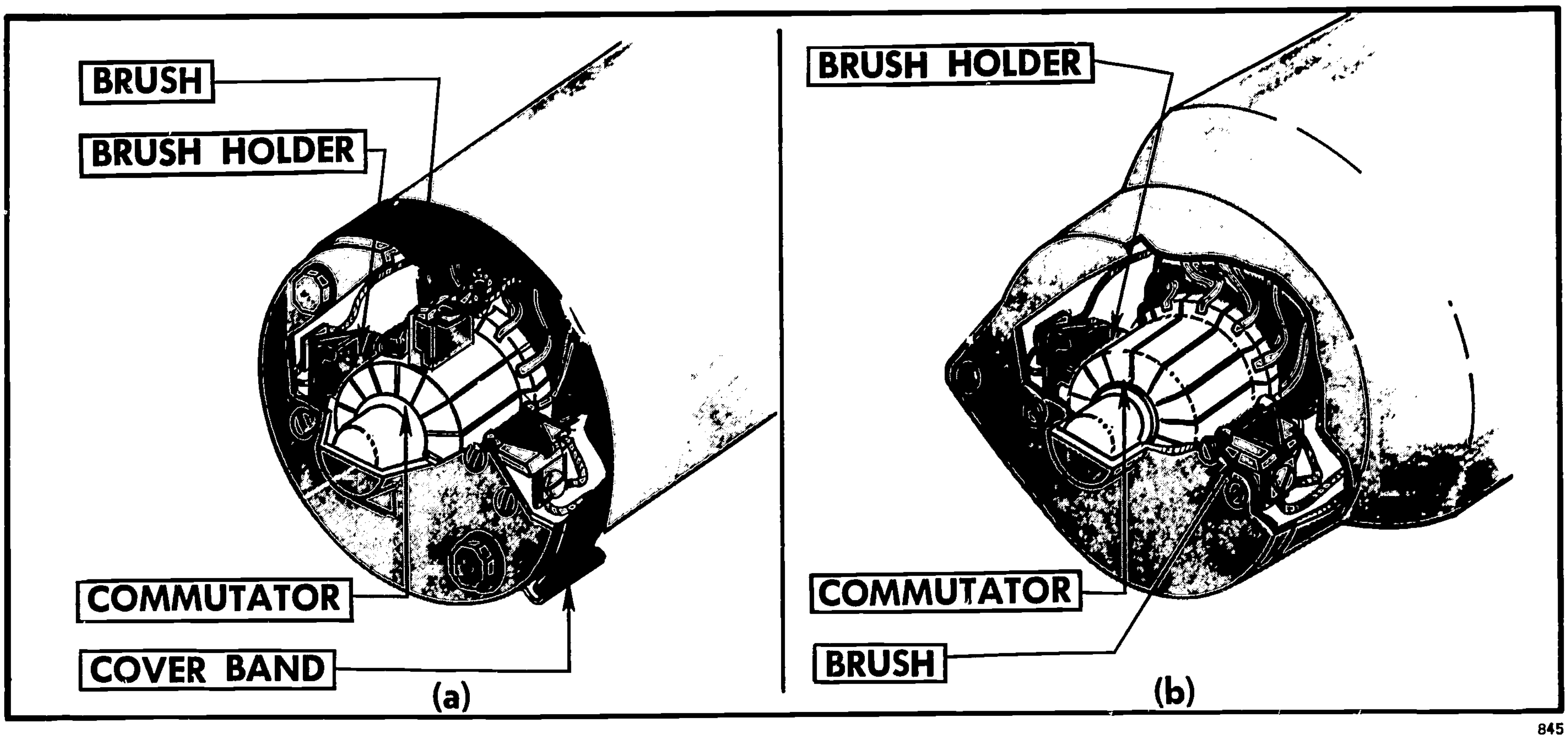


FIGURE 63. (a) The starter is equipped with a commutator, 4 brushes and 4 brush holders that require occasional maintenance. (b) The generator is equipped with a commutator and either 2 or 3 brushes and brush holders. Starter-generator combinations have 2 brushes.

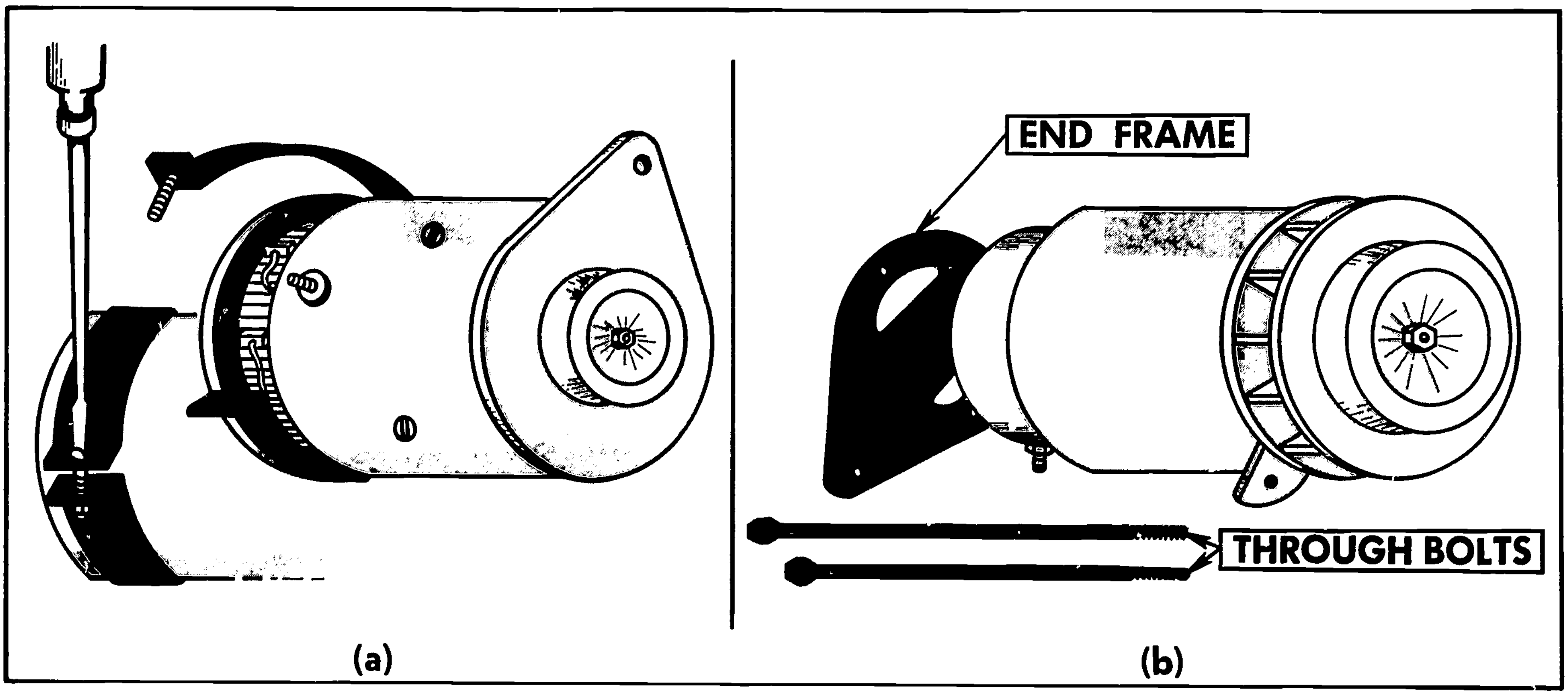


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FIGURE 64. (a) Cover bands are generally held in position with a clamp screw. Unscrew and remove band. (b) Generators without cover bands must have through bolts removed and commutator end frame pulled from main frame.

brushes, or if they are worn to less than half their original length, replace them with new ones. Follow the procedure in step 6.

If you are checking a **generator** that has the end frame removed, the brushes are usually attached to it.

Disconnect the brush-wire lead wire where it fastens to the brush holder (Figure 67), lift brush tension clip, remove old brush and slip new one into place. Reconnect wire lead to brush holder.

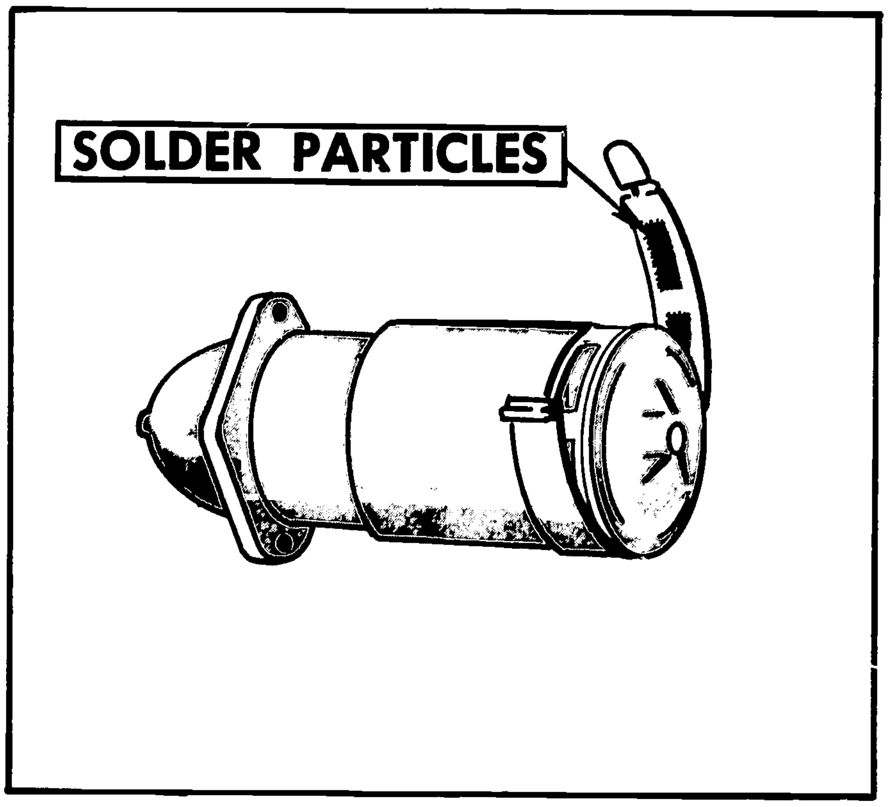

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FIGURE 65. Thrown solder on cover band indicates starter or generator has been overheated.

6. *Replace worn brushes.*

   Install brushes with the beveled edge toward the direction of rotation. Otherwise, the brush edges will lock in the low segments of the commutator and break.

7. *Check brushes for binding action in holder.*

   If brush *tends to bind* in the brush holder, remove and wipe brush holder with a clean cloth. Do not use a petroleum solvent. It tends to soften the insulation on the wires.

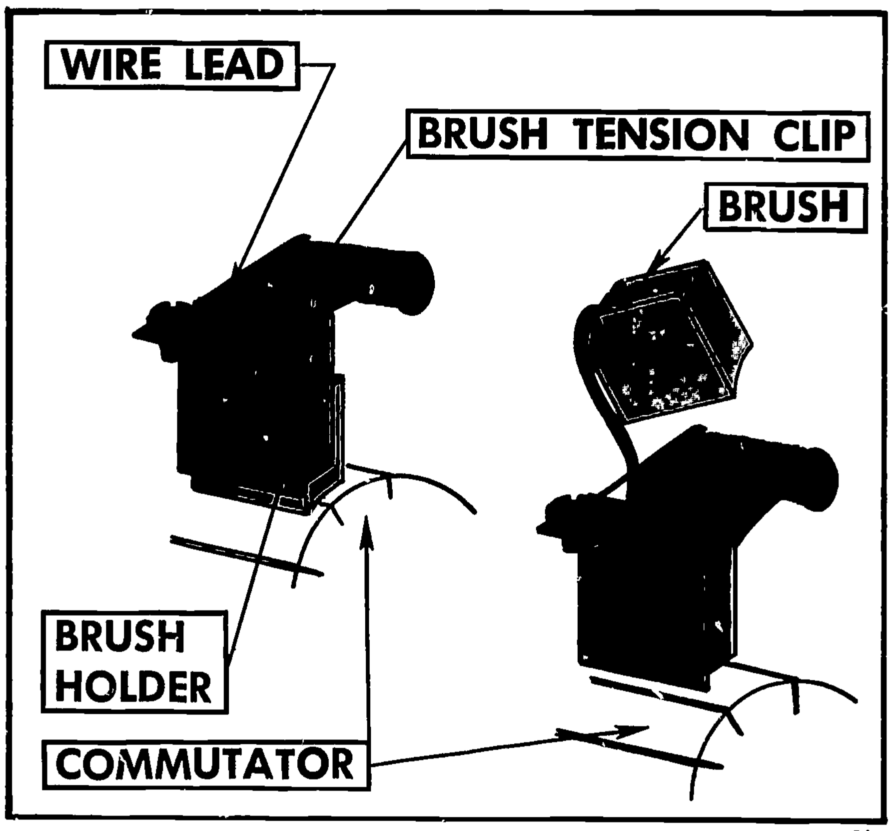

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FIGURE 66. (a) Brush, brush holder and tension clip. (b) Brush removed from holder.

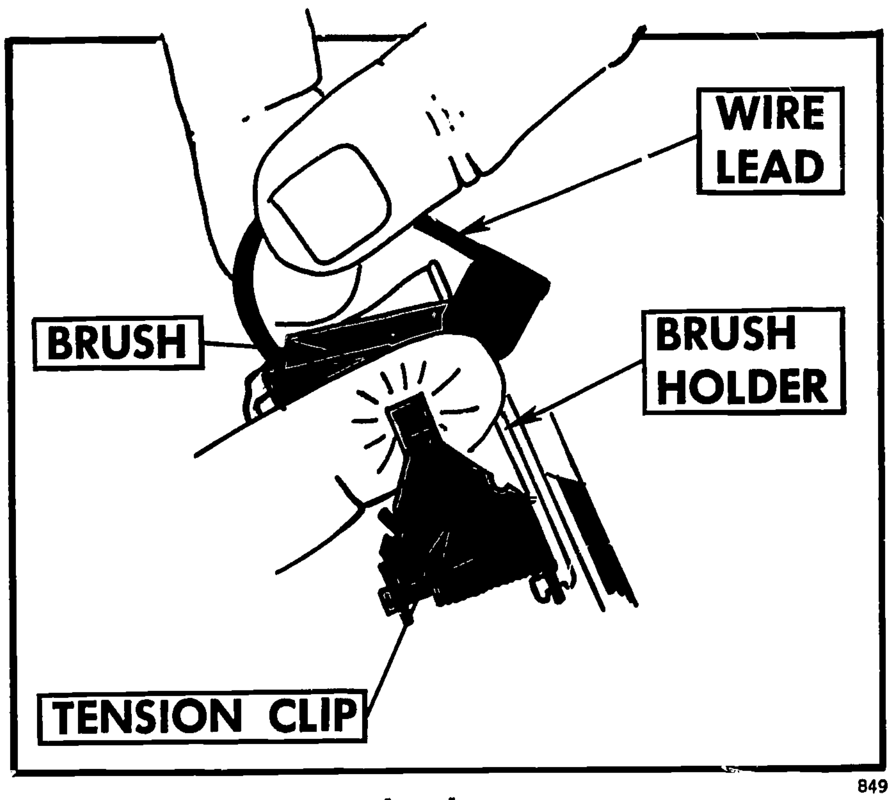


FIGURE 67. Removing a brush.

8. *Check electrical connections for tightness.*
9. *Inspect commutator for wear and roughness.*

If the commutator is **rough or out-of-round,** it will have to be machined in a lathe. This must be done by an experienced service man.

If the commutator **appears to have only dirt and a glaze** on the surface (Figure 68), proceed with step 10. (Replace end frame if it has been removed.)

10. *Remove dirt and glaze from commutator surface (Figure 69).*

Clean the commutator on a **generator** while the engine is running slowly if possible. If for any reason you have disconnected a wire lead on your generator, reconnect it before starting engine. If left disconnected, the generator will burn out.

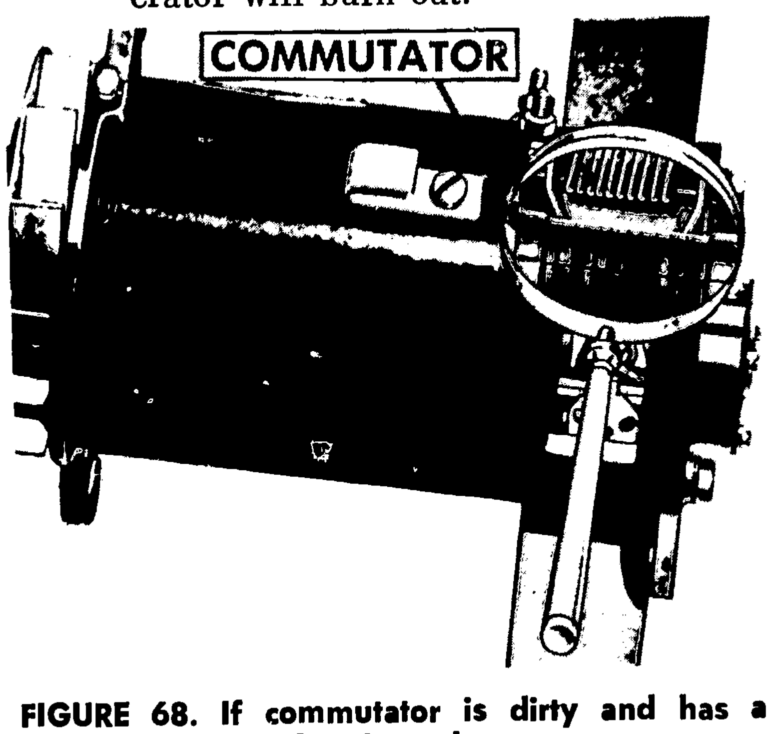


FIGURE 68. If commutator is dirty and has a glazed surface, it should be cleaned.

Use No. 00 sandpaper on a stick with a square end, moving the stick back and forth on the commutator until all gum and dirt have been removed (Figure 69b). You can also use a **brush-seating stone** (Figure 69a) for the same purpose.

NOTE: Do not use emery cloth. Remaining particles will cause arcing, burning and rapid wear. Do not use a solvent. It damages the wire insulation.

Clean the commutator on your **starter** while the starter is turning the engine. Disconnect the spark-plug wire to prevent the engine from starting.

11. *Seat new brushes on commutator.*

In cleaning the commutator, there has prob-

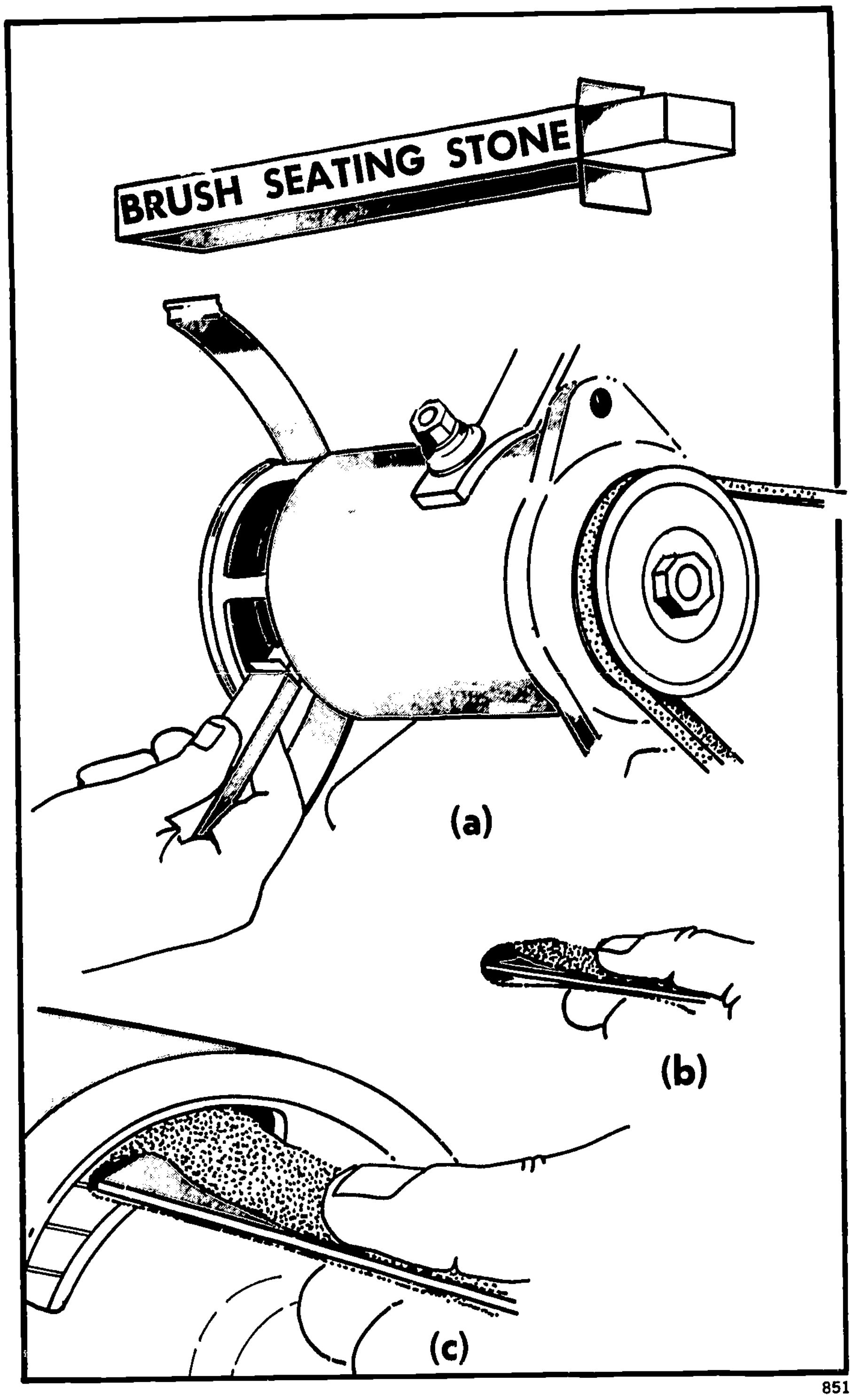


FIGURE 69. (a) Brush-seating stone used for cleaning commutators and seating new brushes. (b) No. 00 sandpaper used for cleaning a commutator. (c) Commutator cleaned through opening in end plate if generator has no cover band.

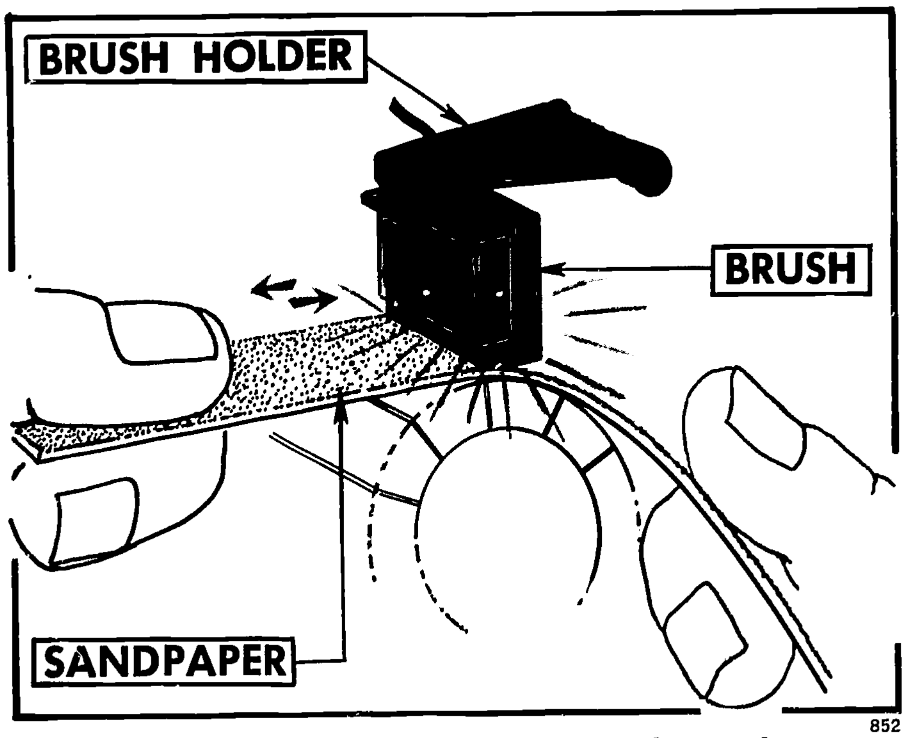


FIGURE 70. Pulling a strip of No. 00 sandpaper between the commutator and brush (with the abrasive side next to the brush) and in a direction that will push the brush against the brush holder is one method of seating new brushes.

ably been enough abrasive action on the brushes so that they are already seated and fitting squarely on the commutator surface. If not, continue to use the brush-seating stone on the commutator until the brushes are seated; or place a strip of sandpaper between the brushes and commutator with the abrasive side against the brush. Pull sandpaper strip in the direction that will cause the brush to fit the curvature of the commutator (Figure 70).

12. *Blow dust from commutator, brush holders and casing.*

    Removing the dust particles prevents further abrasive action on the brushes and commutator.

13. *Replace band if one is used.*

14. *Polarize the generator before starting the engine (Figure 71).*

    If any of the wire leads were disconnected while the starter or generator was being serviced, **polarize the generator.** Reconnect the wires and touch a short jumper wire momentarily between the two posts on the regulator marked "BAT" and "GEN" (sometimes marked "ARM").

    This procedure establishes correct polarity of the generator. *If you do not polarize the generator* and it has become reversed, you may run down the battery, burn out the generator or burn out the cutout relay points in the regulator.

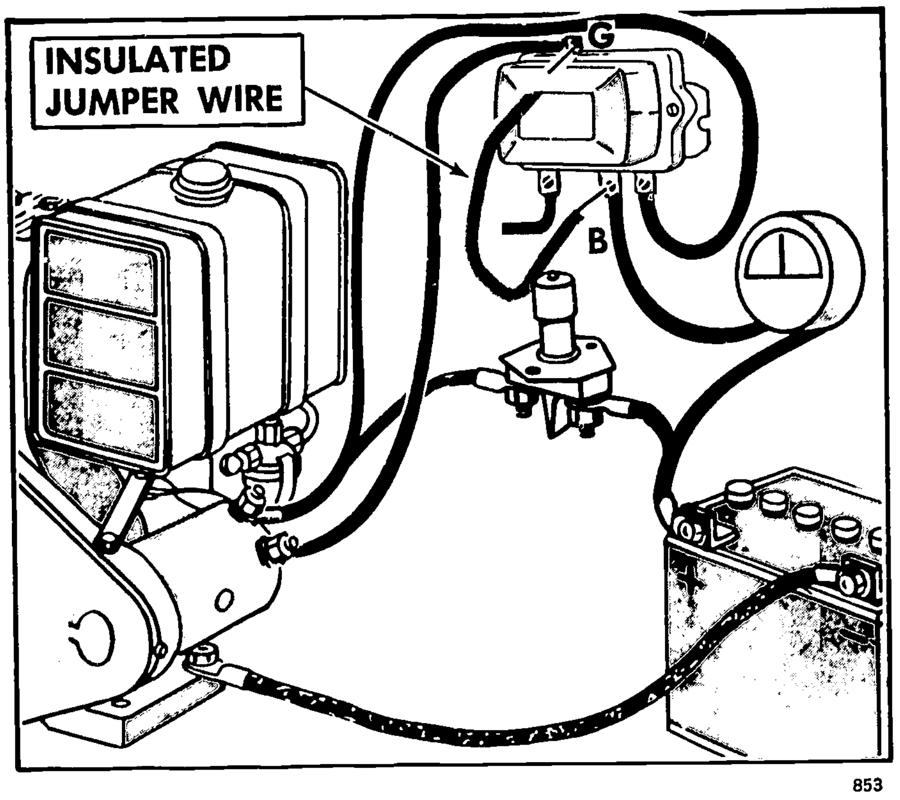
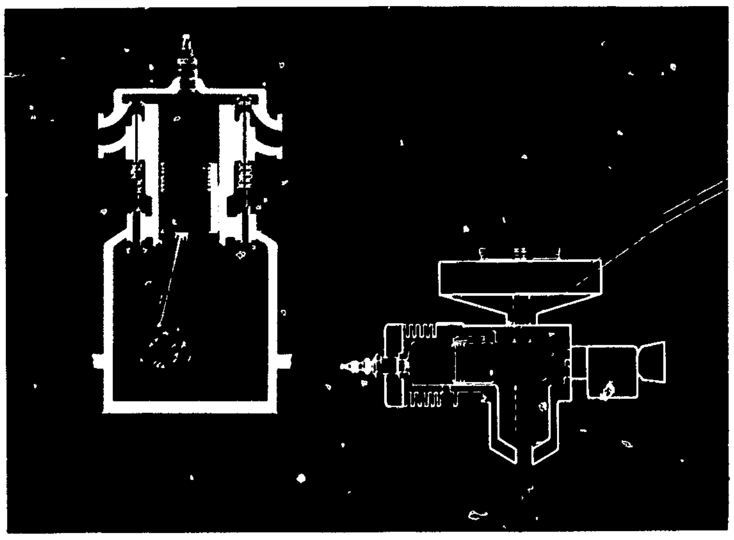


FIGURE 71. To polarize the generator, touch a short jumper wire to the "BAT" and "GEN" (or "ARM") posts of the regulator momentarily.



II. MAINTAINING AND REPAIRING IGNITION SYSTEMS

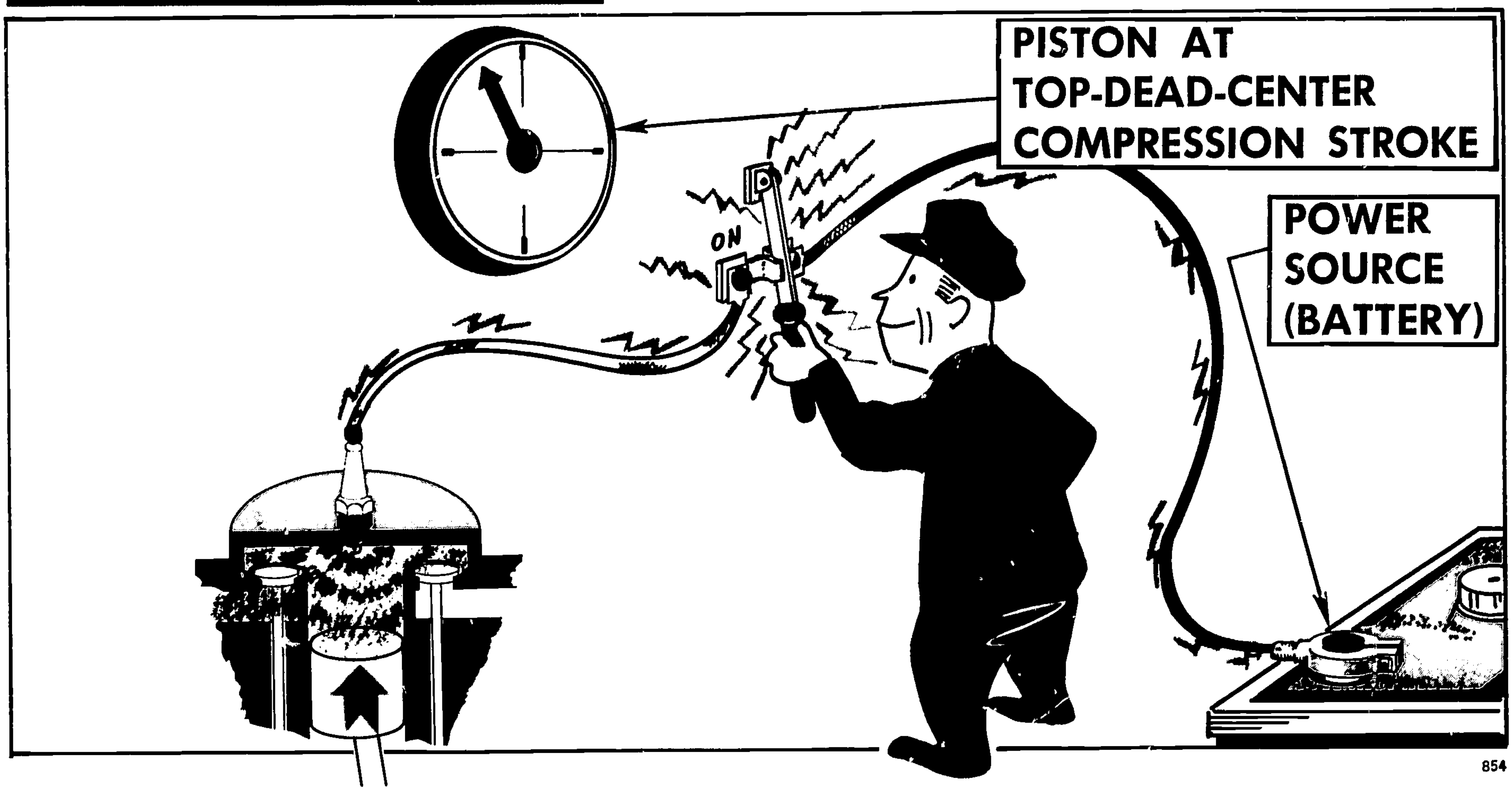


FIGURE 72. The ignition system, when working properly, provides the proper size spark, and at exactly the right moment—just before the piston reaches top-dead-center on the compression stroke.

The purpose of the ignition system on your small engine — and on all spark-ignition engines — is to provide a strong spark in the combustion chamber at the proper time for igniting the fuel-air mixture (Figure 72).

The spark has two important requirements:

- **The spark must be of the proper strength.**

  It must be "hot" enough to ignite the fuel-air mixture in the combustion chamber.

  If the spark is too weak, the fuel will not ignite.

  If the spark is too strong, the spark-plug electrodes will burn.

- **The spark must take place at exactly the proper time.**

  The best time for the spark to occur on most engines is just before the piston reaches top-dead-center on the compression stroke. This gives the burning process a head start so the expanding gases (due to combustion) will be most effective in pushing the piston down. See Figure 5, Volume I.

TYPES OF IGNITION SYSTEMS

There are two types of ignition systems commonly used on small gasoline engines:

- **Magneto-ignition systems (Figure 73).**
- **Battery-ignition systems (Figure 74).**

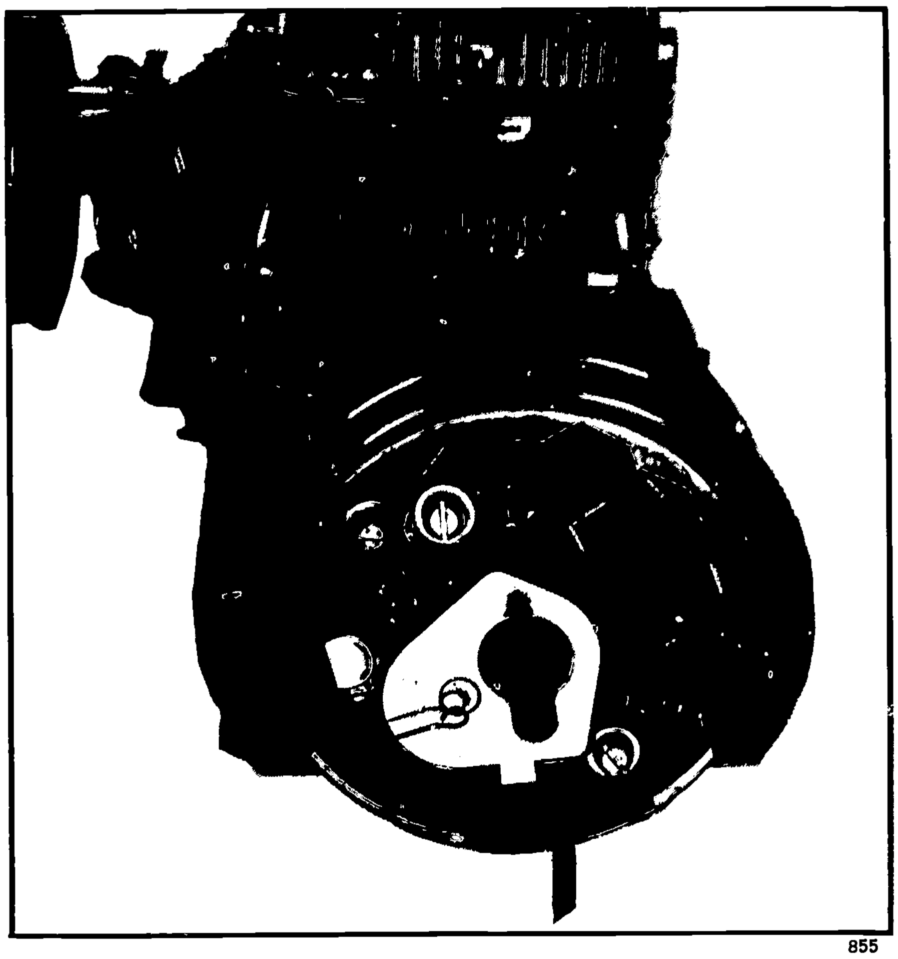


FIGURE 73. Most magneto-ignition systems on small gasoline engines are located behind the flywheel shroud and are hard to reach.

A third type system, **solid state** (Figure 84), is now being used on a limited scale.

Magneto-ignition systems are easily adaptable to small engines, especially those with no electrical load other than that of igniting the fuel in the combustion chamber.

The magneto produces its own electricity without the aid of a battery or generator. Magneto-ignition systems are simple and economical. They give very little trouble and are easy to maintain.

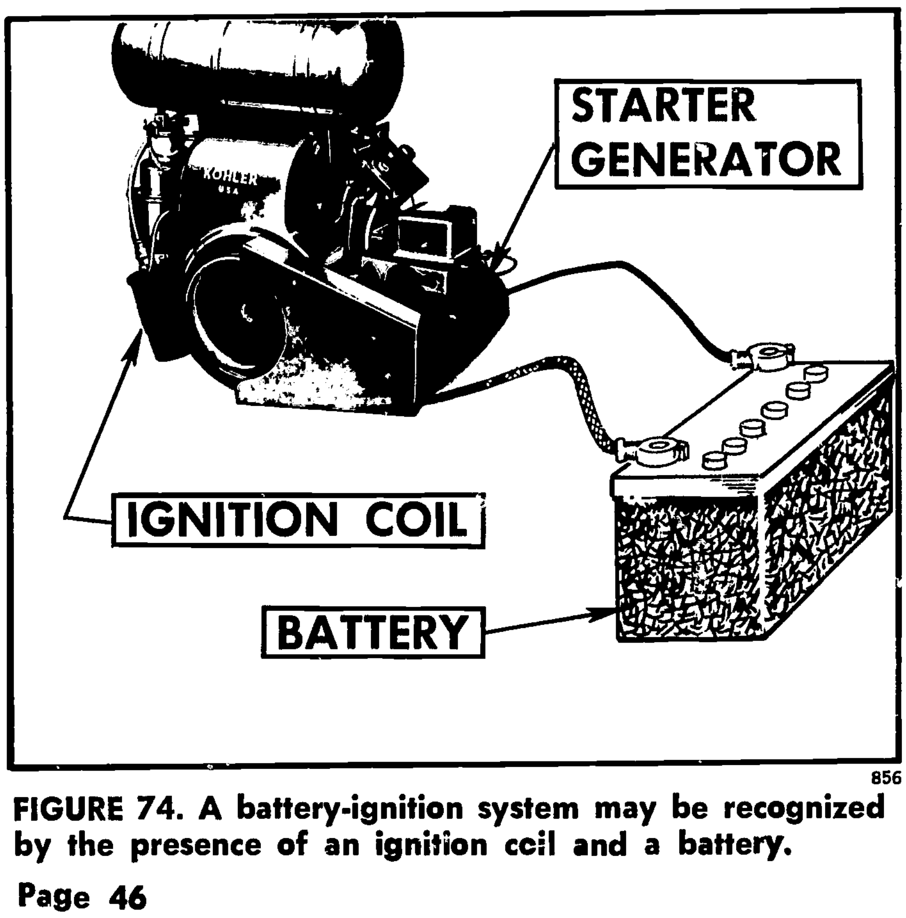


FIGURE 74. A battery-ignition system may be recognized by the presence of an ignition coil and a battery.

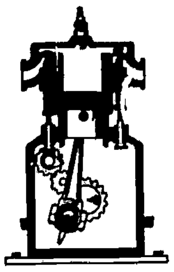
Solid-state-ignition systems have no mechanical means for breaking the circuit. The ones used in small engines receive electric power from a magneto-type generator. Therefore, they are discussed under "Maintaining and Repairing Magneto and Solid State-Ignition Systems," page 47.

Battery-ignition systems are common on automobiles, trucks and tractors. They are also used on small engines where additional electrical loads are needed. Small garden-type tractors, with starter and lights, usually have a battery-ignition system. The presence of a battery and generator, however, does not necessarily mean you have a battery-ignition system. Some manufacturers continue to equip their engines with a magneto ignition but add a battery and a generator for starting and lights. You can recognize the battery-ignition system by the presence of a can-shaped **ignition coil,** in addition to the battery and the generator (Figure 74).

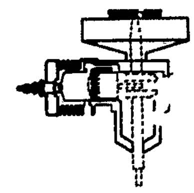
Maintaining and repairing ignition systems are discussed under the following headings:

A. Maintaining and repairing magneto and solid-state ignition systems.

B. Maintaining and repairing battery-ignition systems.



A. MAINTAINING AND REPAIRING MAGNETO AND SOLID STATE IGNITION SYSTEMS



Magnetos are used on most small engines to supply the electrical power for the spark at the spark plug which ignites the fuel-air mixture in the combustion chamber. If the magneto on your engine is not functioning properly, your engine will be hard to start, and it will not develop maximum power.

Maintaining and repairing magneto-ignition systems are discussed under the following headings:

1. Types of magnetos.
2. Principles of operation.
3. Importance of proper maintenance.
4. Tools and materials needed.
5. Checking the magneto for proper operation.
6. Removing and checking the flywheel.
7. Checking and conditioning the breaker-point assembly.
8. Checking the condenser.
9. Adjusting the breaker-point gap.
10. Removing and replacing breaker points.
11. Timing the magneto to the engine.
12. Timing the breaker points to the magneto.
13. Checking and adjusting the stator-plate (armature) air gap.
14. Checking the magneto coil.
15. Removing and replacing the stator plate and coil.
16. Installing the flywheel.

TYPES OF MAGNETOS

There are two types of magnetos used on small engines. They are (1) a **flywheel-type** magneto, which is not visible from the outside of the engine but is built in and around the flywheel (Figure 75); and (2) an **external type,** which is a self-contained unit mounted on the side of the engine (Figure 76).

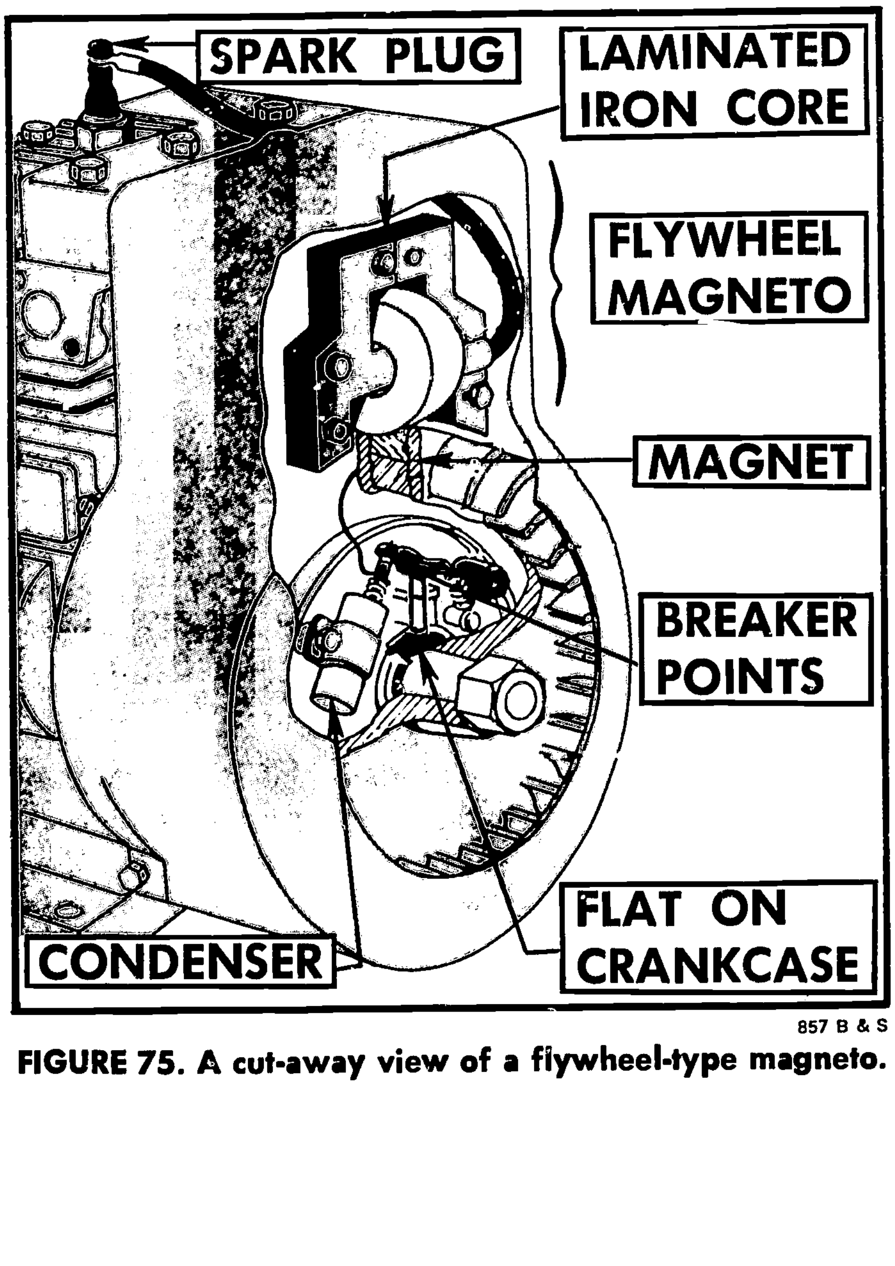


FIGURE 75. A cut-away view of a flywheel-type magneto.

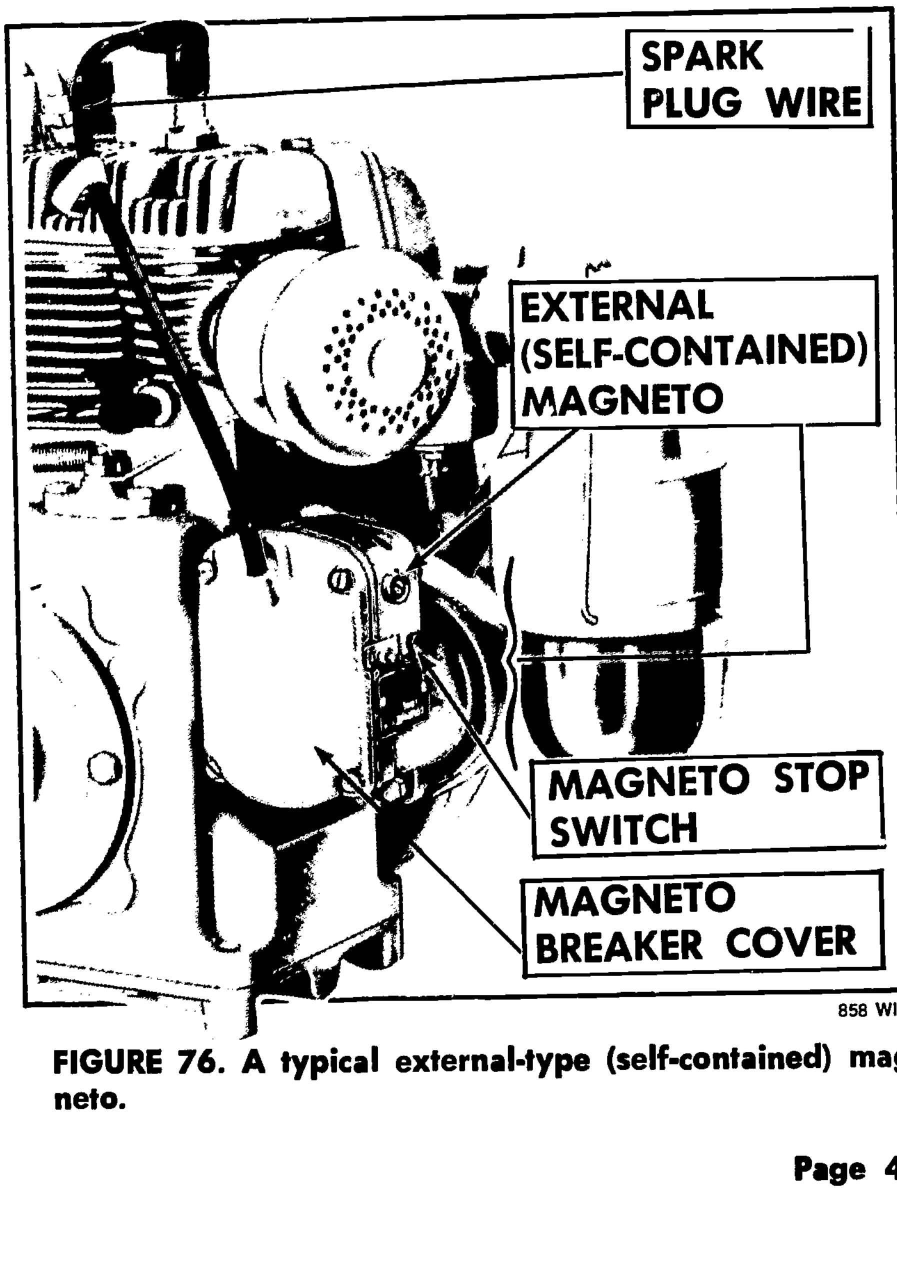


FIGURE 76. A typical external-type (self-contained) magneto.

PRINCIPLES OF OPERATION

Before you can understand the magneto-ignition system, you need to know how the magneto generates electricity.

To understand this, you need to know two basic principles of how electricity is generated and how voltage can be changed to meet different needs.

When magnetic lines of force are cut by a closed conductor, voltage (electrical pressure) is induced and current flows in the conductor. Magnetic lines of force are supplied by a permanent magnet (Figure 77). In Figure 78 the coil is stationary. The lines of force from the magnet are cut by the coil as the magnet rotates past it. This action induces voltage into the coil, thus causing current to flow. This is how current is generated. The mechanism is called a generator.

The amount of current flow is determined by three conditions:

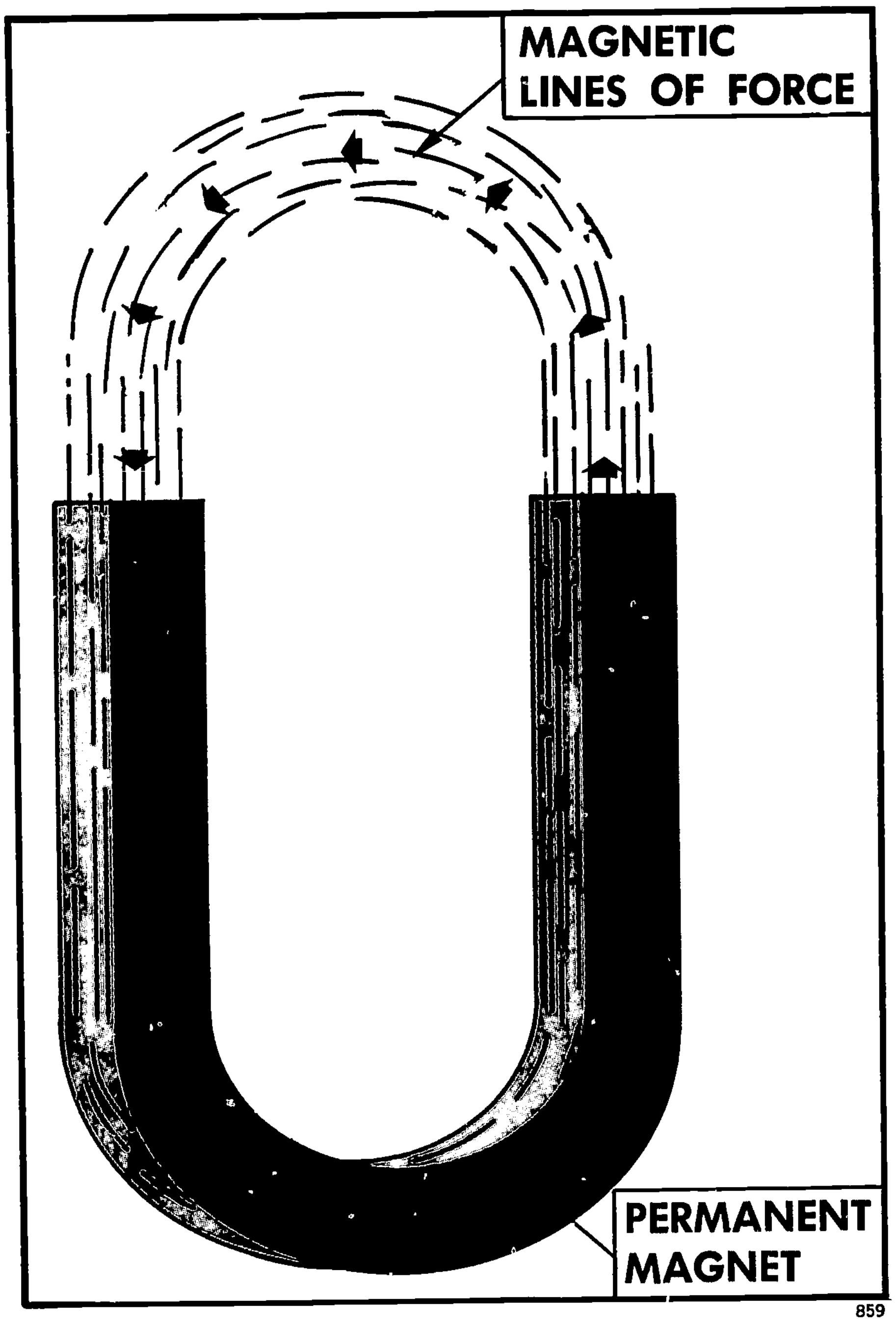


FIGURE 77. A permanent magnet has imaginary lines of force extending from the N (north) pole to the S (south) pole and through the length of the magnet.

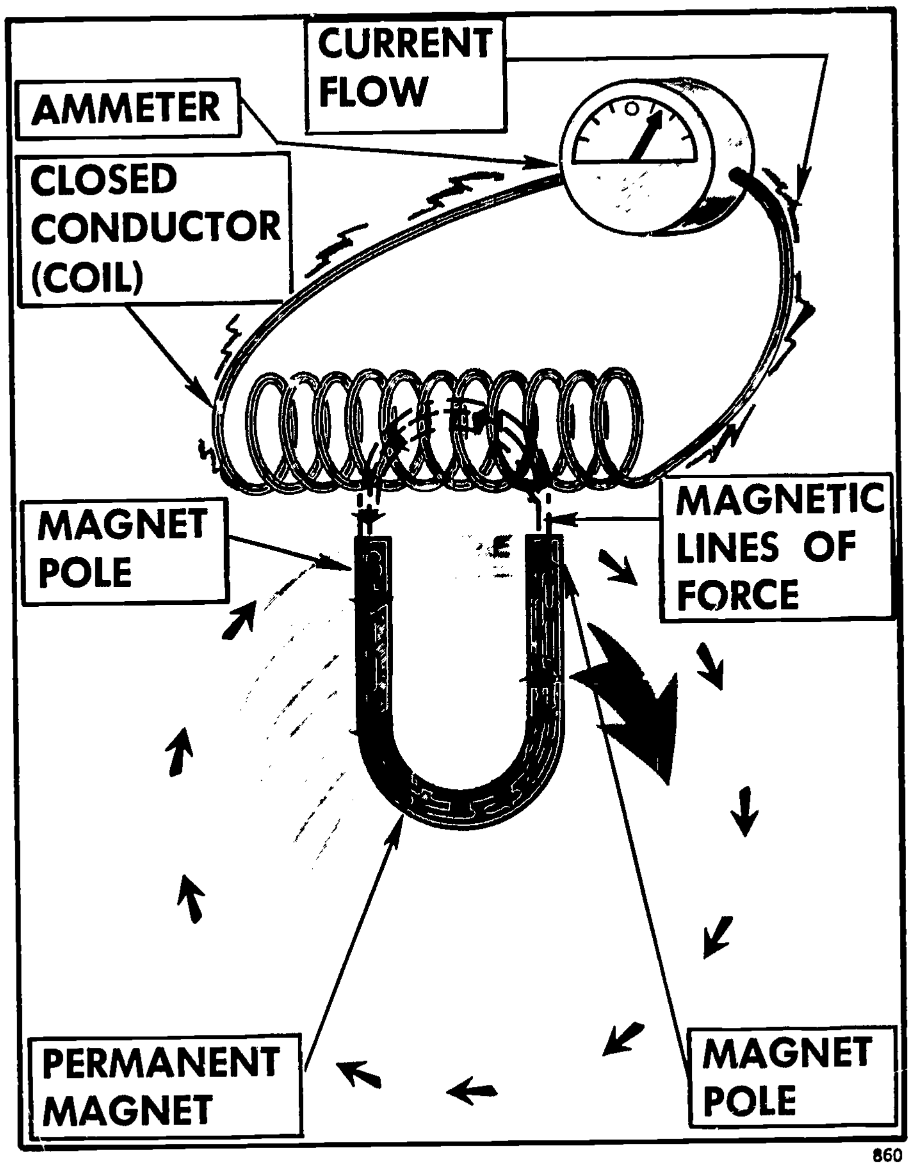


FIGURE 78. A simple generator. When these magnetic lines of force are cut by a closed conductor, current flows in the conductor.

- The *number of turns of wire in the coil.*
- The *intensity of the magnetic field.*
- The *speed at which the magnetic lines of force are cut.*

To develop the necessary voltage to jump the gap at the spark plug, a *second principle* is involved. It is that of a **transformer.** It consists of two coils wound together (one over the other) as shown in Figure 79. One coil is called a "primary" coil and the other, a "secondary" coil. The transformer primary coil is supplied with current by the generator (Figure 79). The current from the generator also flows through the primary coil. This causes a magnetic field to be developed around the coil. The iron core in the center becomes magnetized and establishes additional lines of force.

As the magnetic lines of force build up around the magnetized iron core, they are cut by the windings of the secondary coil. Voltage is induced in the secondary coil. Current flows momentarily. When the current flow in the primary coil is interrupted, the magnetic field collapses. Lines of force are cut by the windings of the secondary coil, and voltage is again induced in the secondary coil.

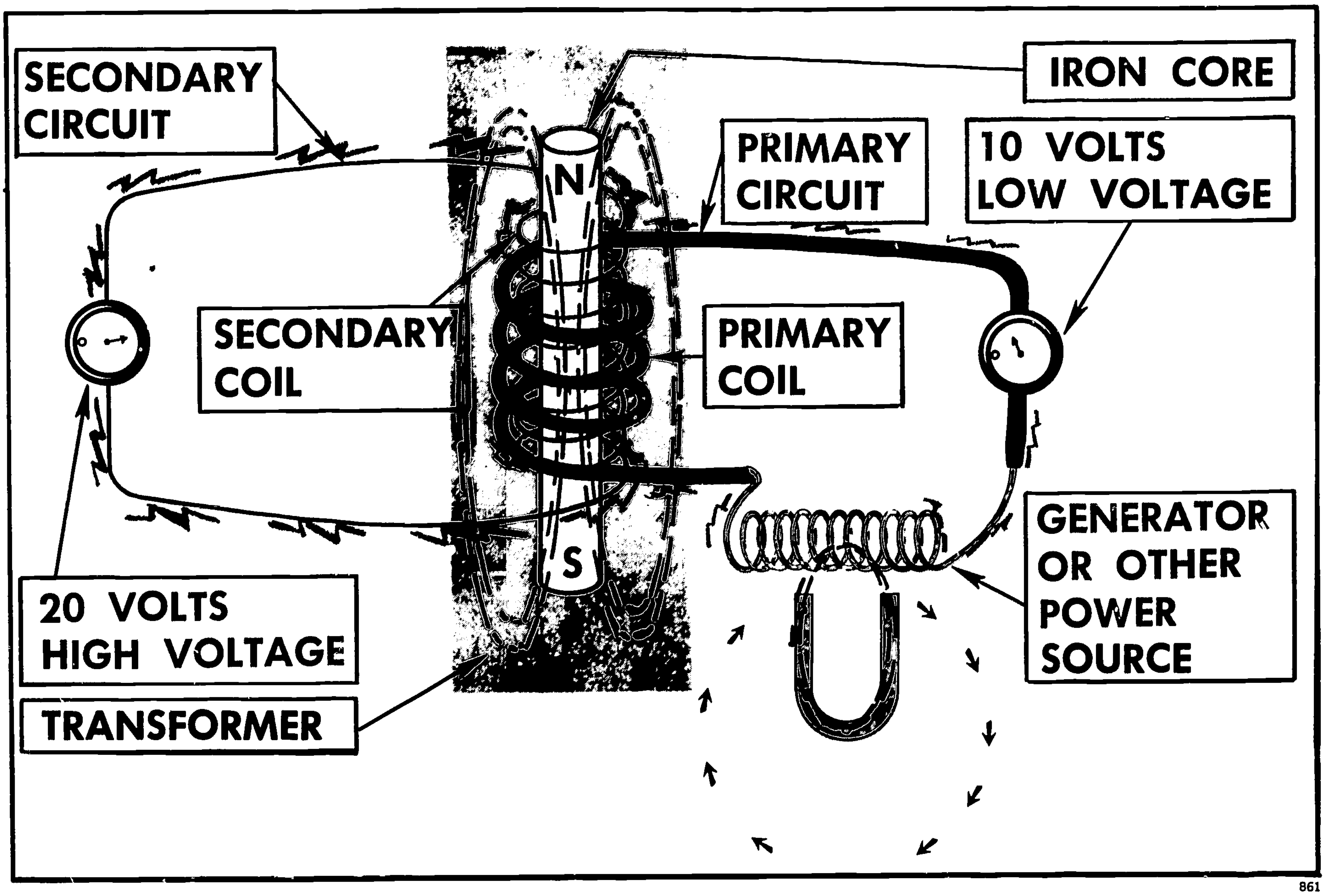


FIGURE 79. Principle of the transformer. When voltage is induced in the primary coil, it is also induced in the secondary coil. The amount is proportional to the ratio of the number of turns in the primary.

The amount of voltage induced in the secondary coil is directly related to the number of turns it contains in relation to the number of turns in the primary coil. If the secondary coil has twice the number of turns as the primary coil, the voltage induced will be twice that in the primary. For example, if the primary coil has 10 turns and 10 volts and the secondary coil has 20 turns, the voltage in the secondary will be 20 volts. If the secondary coil has 30 turns, the induced voltage will be 30 volts. This is transformer action.

Transformer coils used in ignition systems provide high voltage to assure a good spark at the spark plug. They are often called "induction coils," "spark coils" or "ignition coils." The voltage for small engines is stepped up from approximately 200 volts to approximately 12,000 volts. This means there are 60 times more turns of wire in the secondary circuit than in the primary (12,000 volts ÷ 200 volts = 60 turns).

The principles of the generator and the transformer apply to a magneto (Figure 80). A permanent magnet rotates past a coil. The coil consists of a stationary primary and secondary circuit. Both are wound around the center leg of a three-pronged soft-iron "core" called an armature or yoke. In a magneto the **primary serves as a primary coil and a generating coil.**

At the point where the 2 poles of the magnet start to align—one with the left-hand prong of the armature and the other with the center prong of the armature—magnetic lines of force flow through the center and left-hand prongs of the armature. Lines of force are cut by the spark coil (Figure 80a).

Voltage is induced in the primary coil and current flows in the primary circuit because the breaker points are closed and the circuit is complete. No current flows through the secondary circuit at this time because it is open at the spark-plug electrode, and there is not enough voltage generated to cause the current to jump the gap.

Current flow in the primary increases the strength of the magnetic field by adding more lines of force.

As the magnet continues to rotate to a position where the N pole of the magnet is a little to the right of center of the middle prong, the lines of force start to flow in the right prong and the center prong of the

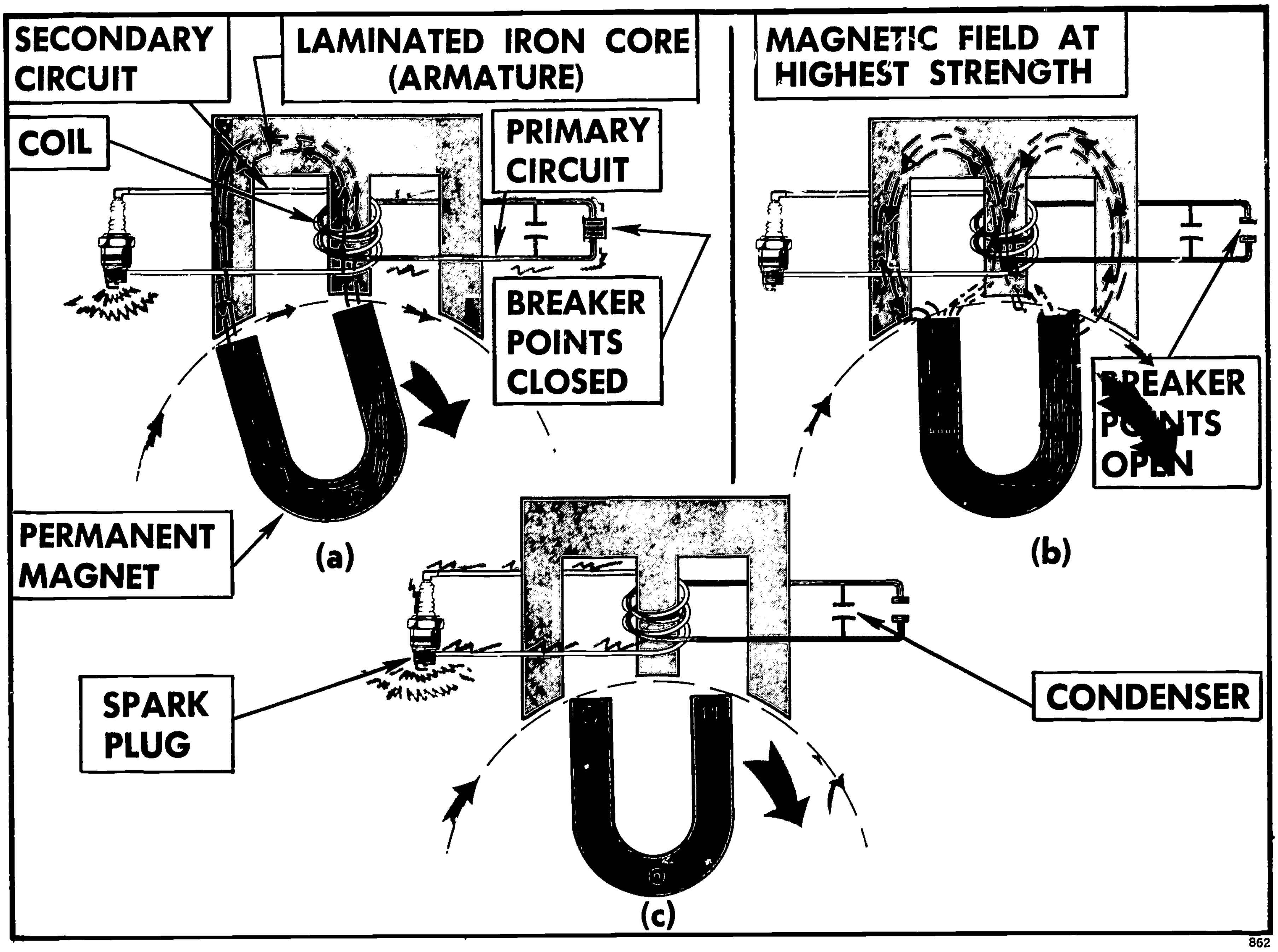


FIGURE 80. Principles of a magneto. (a) Magnetic lines of force build up when the poles of a permanent magnet, which is embedded in the flywheel, approach alignment with the left-hand prong and center prong of the armature. As the magnet continues to rotate, lines of force are cut and voltage is induced. Current flows in the primary circuit so long as the breaker points are closed. The magnetic field is strengthened. (b) A point is reached when the magnetic field is strongest. The breaker points open. Current flow stops in the primary. (c) The sudden collapse and reversal of the magnetic field induces enough voltage in the secondary coil to force current across the spark-plug electrode gap, thus causing a spark.

armature. When this happens, the lines of force change direction. *The magnetic field is strongest at this point. Therefore, the breaker points are timed to open at this instant (Figure 80b).* The flow of current stops in the primary circuit. The strong magnetic field collapses. This sudden collapse of the strong magnetic field induces enough voltage in the secondary coil to cause the current to jump the gap at the spark plug (Figure 80c).

One reason current does not jump the gap at the breaker points is that the voltage is not so great in the primary as it is in the secondary circuit. Another reason is that there is a **condenser** in the primary circuit (Figure 81).

FLYWHEEL MAGNETO. The principles just explained apply to a flywheel magneto. Figure 82 shows one method by which the magneto parts may be arranged on a flywheel magneto.

The permanent magnet is embedded in the flywheel or in the flywheel rotor. It rotates past a coil which is wound around the center prong of a laminated iron core called the "armature" (Figure 82a).

To stop a magneto-equipped engine, the ignition switch is closed (grounded), or the secondary circuit is grounded at the spark-plug terminal. This bleeds off the electrical charge from the primary circuit so that no spark can develop. The engine stops.

EXTERNAL MAGNETO. **The operating principle of the external (self-contained) magneto** is the same as that of the flywheel magneto (Figure 83), except it looks different.

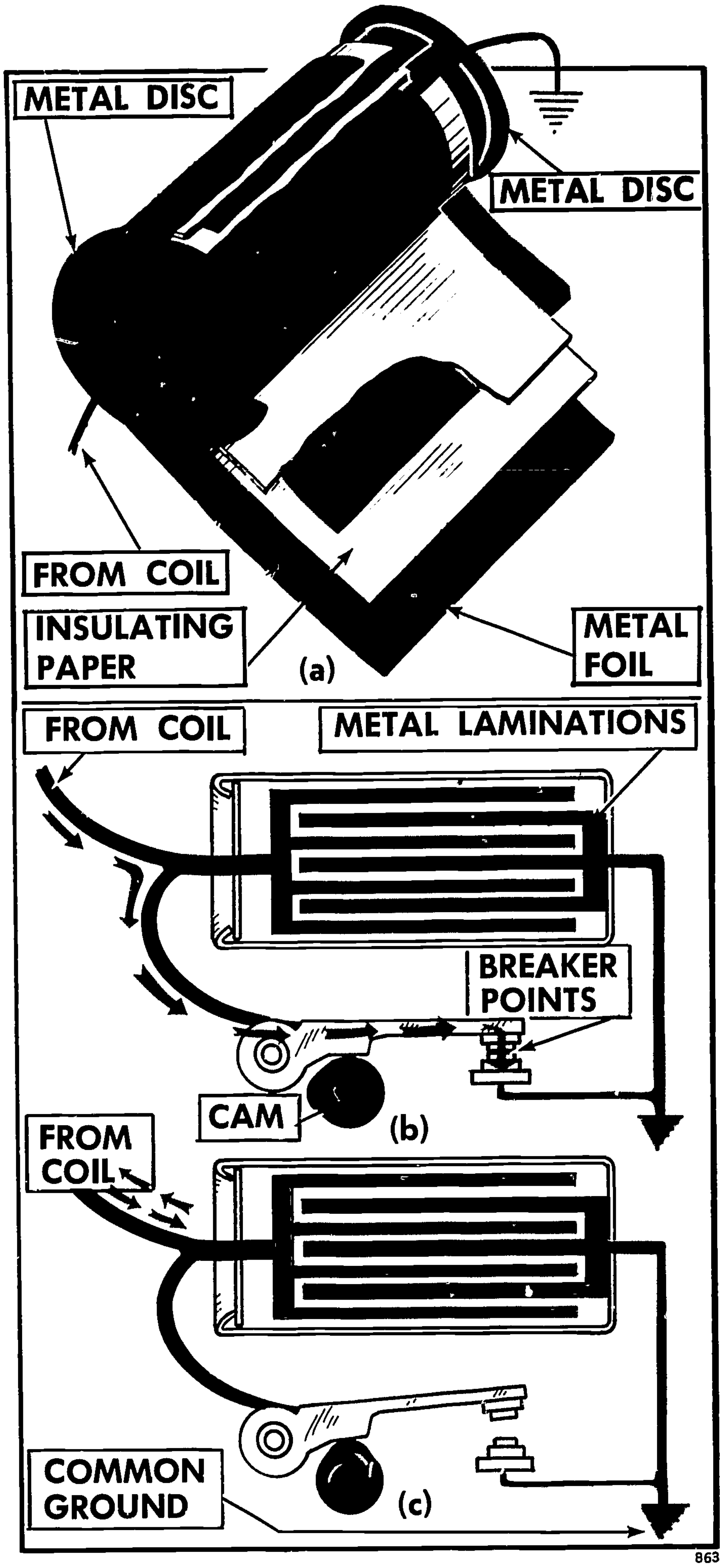


FIGURE 81. A condenser is a reservoir, or a "surge chamber," for electric current. (a) It consists of metal laminations (sheets) separated by insulating paper. (b) When the breaker points are closed, current flows into the condenser. The condenser absorbs most of the excess current, thus preventing arcing at the breaker points. Some flows back into the primary circuit and helps in the reversal (breaking down) of the magnetic field in the iron core which makes the spark stronger. Without the condenser the breaker points would soon burn up.

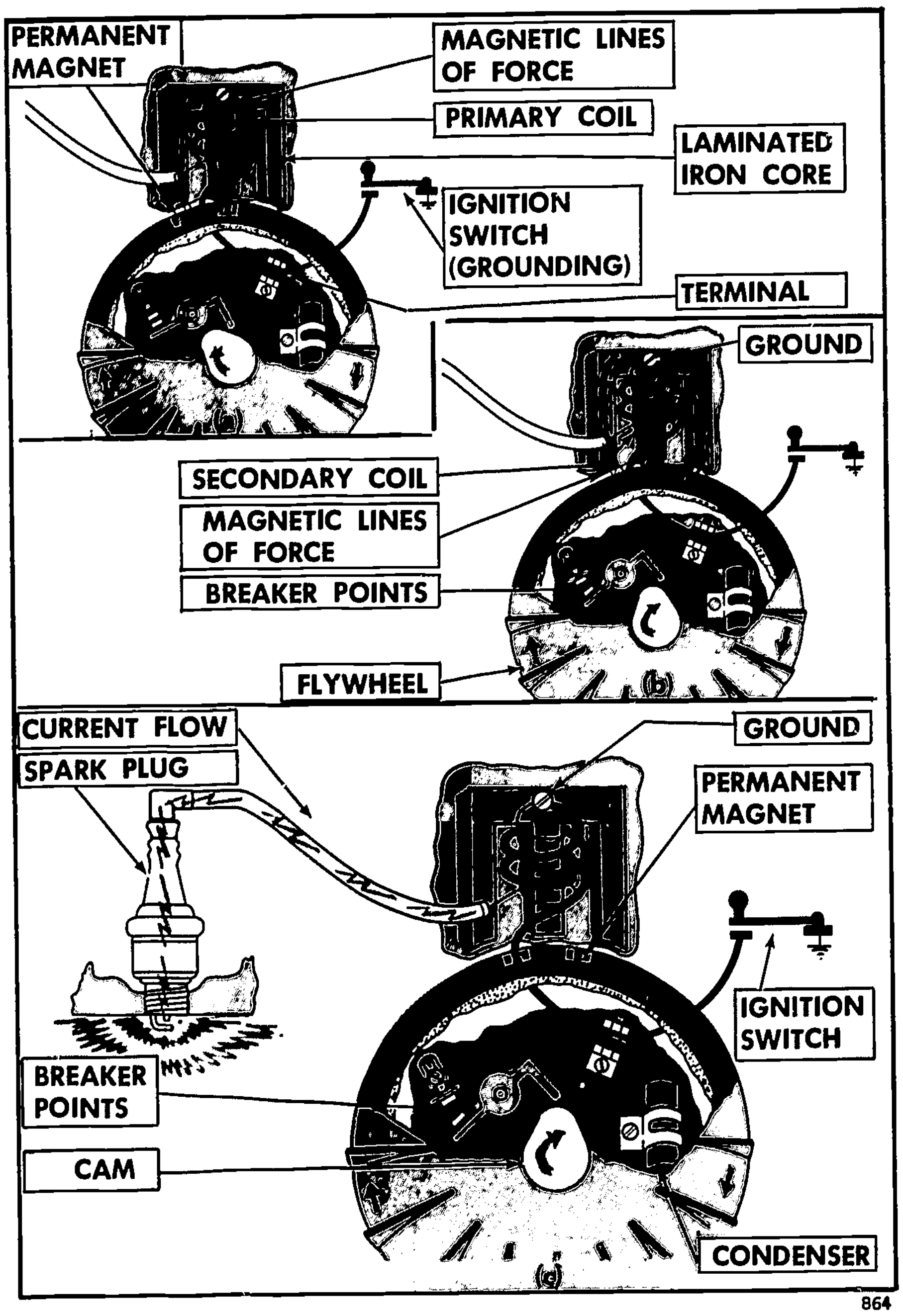


FIGURE 82. Principles of the flywheel magneto-ignition system. (a) Magnetic lines of force are built up around a coil by the movement of a permanent magnet past the armature. (b) As the permanent magnet passes the armature, the lines of force break down, thus causing a high voltage to be induced in the secondary circuit of the coil. (c) The high voltage causes a spark at the spark plug.

As the *magneto rotor rotates*, magnetic flux lines are established in the laminated iron frame (armature) (Figure 83a). The magnetic lines of force develop and collapse with each half turn of the rotor. The expanding and collapsing of the lines of force induce voltage into the primary winding, thus causing current to flow in the primary winding while the breaker points are closed.

When the current in the primary winding is greatest (Figure 83b), the breaker points open. The lines of force collapse and induce high voltage into the secondary coil. This is enough to cause a spark when it reaches the spark plug.

The **condenser** serves the same purpose here as in the flywheel magneto.

The **impulse coupling** on the rotor shaft is for starting. It has two functions: (1) It retards the

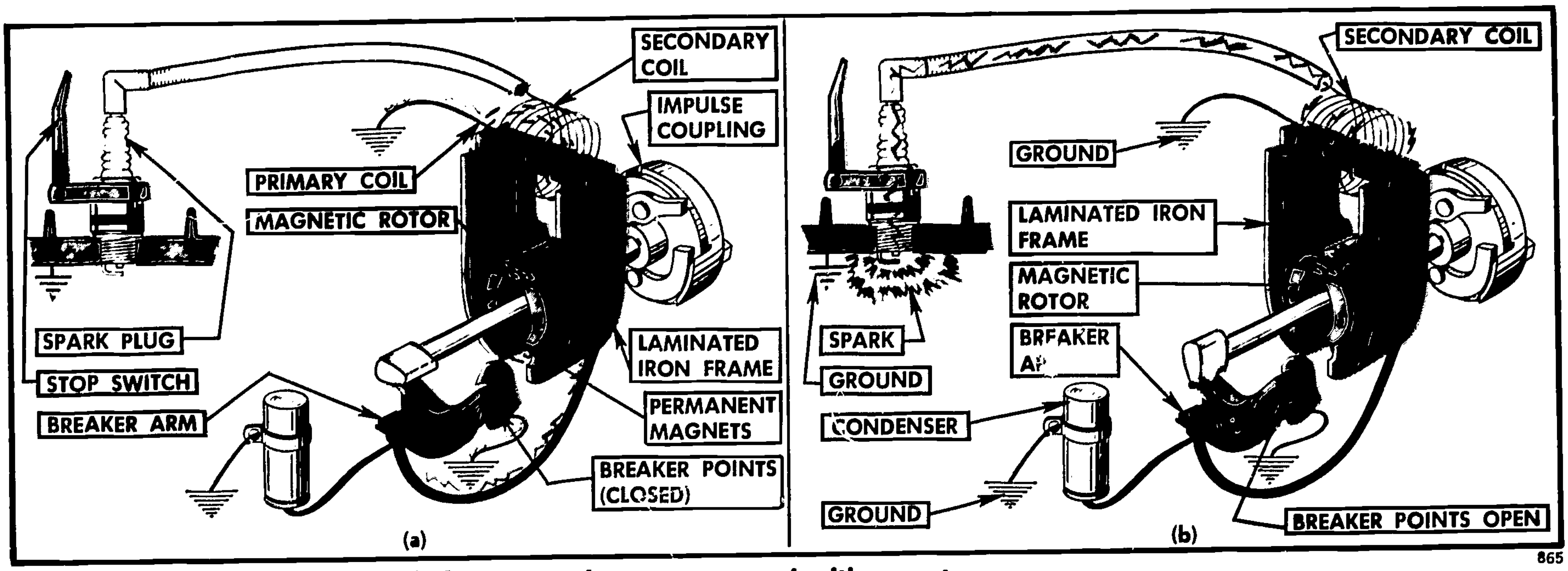


FIGURE 83. Schematic view of the external-type magneto-ignition system.

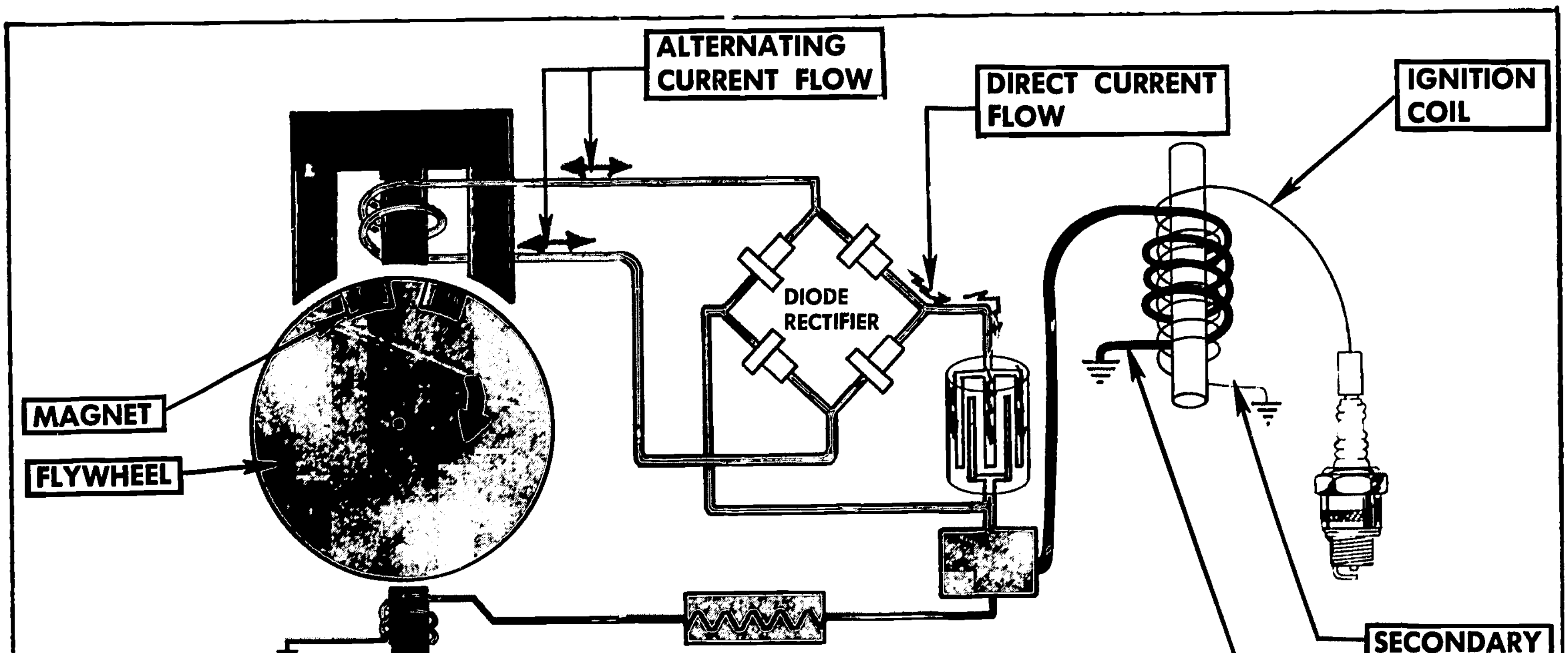


FIGURE 84. Principal parts of the solid-state ignition system.

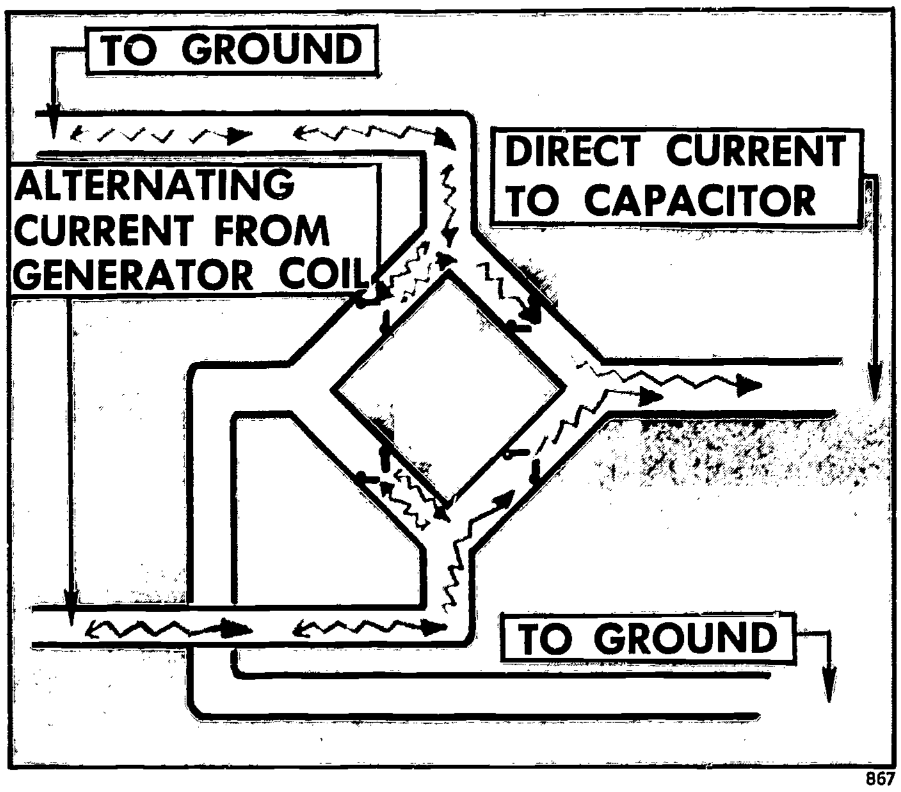


FIGURE 85. A diode rectifier is an electrical device that will allow current to pass in one direction only.

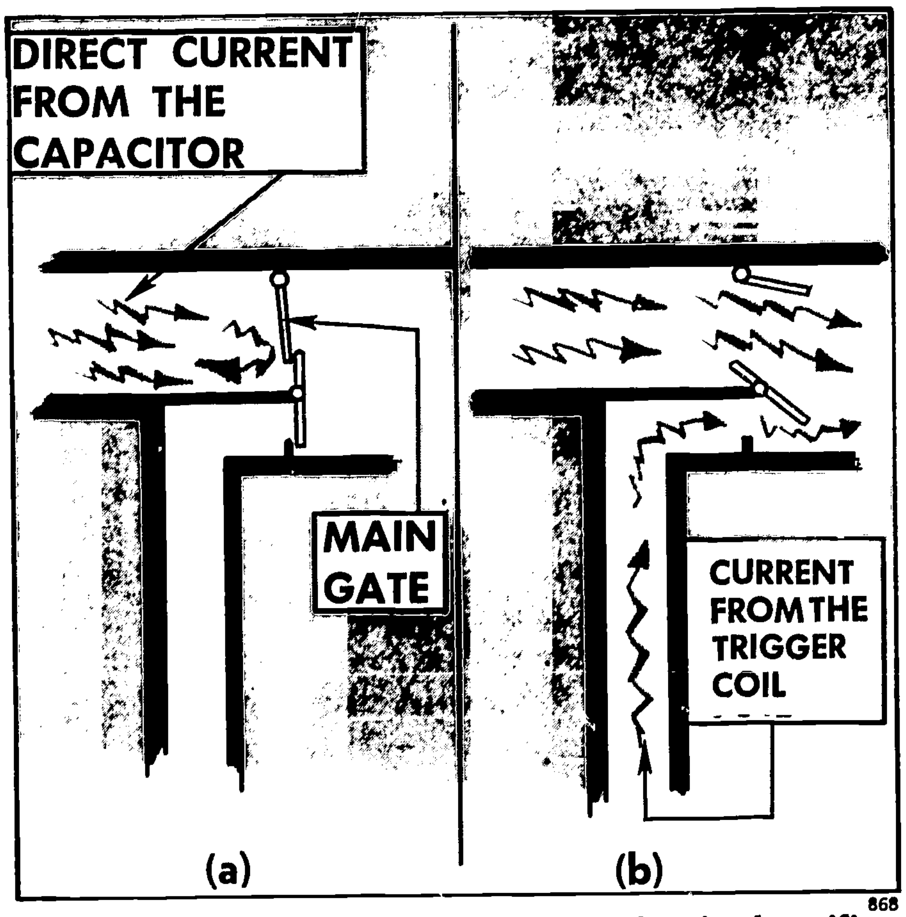


FIGURE 86. The trigger coil and the transistorized rectifier (solid-state switch) serve the same purpose as the breaker points on the conventional system, but there is no mechanical movement. (a) A high resistance (gate) in the transistor prevents current flow until the resistance is reduced (opened) by (b) a small current flow from the trigger coil.

spark for cranking, and (2) it flips the magnetic rotor at the proper time to produce a stronger spark through delayed spring action. After the engine starts, the impulse coupling automatically disengages.

SOLID-STATE IGNITION. The solid-state ignition system (Figure 84) used on small engines is similar in one respect to the flywheel magneto. That is, the initial current is generated in a coil by a magnet on the flywheel (Figure 82). But how the current gets to the spark plug at the proper time is different.

Current from the generator (input) coil is directed through a **diode rectifier** where it is changed from alternating current to direct current (Figure 85).

A transistor is an electrical device which can be used to control the flow of current in a circuit. It is a resistor whose resistance is changed by a small amount of current supplied to a third part of the transistor.

When explained electrically, a transistor is often difficult to understand. To help you develop an image of what happens, study Figure 86. If a transistor were a mechanical device, it would block the current from the capacitor with a main gate until it is needed. When needed, a second gate would be opened by a small current flow—enough to unlatch the main gate so the capacitor charge would be released. Once the charge is spent, the gates return to the original positions.

Direct current flows from the diode rectifier to a **capacitor** where it is stored momentarily (Figure 84a). A capacitor works on the same principle as a condenser (Figure 81).

The current remains stored in the capacitor until the flywheel rotates one half turn. At this point the piston is in the proper position for combustion to take place—just before top-dead-center, compression stroke. As the **magnet** on the flywheel passes the **trigger coil,** a small amount of current is generated in the trigger coil. This current flows through the **resistor** and the **transistorized switch.** This small current flow through the transistorized switch creates a path for the current from the capacitor (Figure 86). It goes through the ignition coil where it is stepped up enough to jump the gap at the spark plug (Figure 84b).

IMPORTANCE OF PROPER MAINTENANCE

It is important that the ignition system on your engine be electrically sound and in good mechanical condition for your engine to function properly.

The breaker points must be clean and in good condition. Dirty, pitted or corroded points will slow the original build-up of current in the pri-

mary circuit because they make a poor electrical connection and resist current flow. When the points open, there will not be a sharp, clean-cut break to speed the breakdown of the primary current which results in a weak spark at the spark plug.

The breaker points must be adjusted properly. *Points that are too close together* will retard (slow) the timing because the cam must move farther to open the points. Retarded timing causes the spark to occur late, and the piston passes the point where the most effective ignition should occur. The engine loses power. *Points that are too far apart* (timing over advanced) will cause the spark to occur too soon before the piston reaches the optimum position for maximum compression. Again the engine will lose power. It will require a faster cranking speed and may cause the engine to "kick" — rotate backwards — when cranked. If the engine starts, it will run at a high temperature because the burned gases will remain in the combustion chamber longer. It will also "knock."

Either of the above conditions will cause the breaker points to open before or after the time when the magnetic field is at its highest intensity. A weaker spark will occur at the spark plug.

The condenser must be in good condition and of the proper capacity. If it is not, arcing will occur at the points; and they will burn. The magnetic field will not collapse fast enough in the primary to induce enough voltage in the secondary for a strong, hot spark at the spark plug.

Other difficulties, such as a partially shorted spark-plug wire, a partially grounded stop switch, or a fouled spark plug, can contribute to a weak spark. A weak spark results in poor combustion.

Continued operation with the ignition system out of order and improper combustion will eventually cause pre-ignition and knock, which results in overheating, valve burning, valve sticking and other complications.

If you know how to look for ignition trouble and how to recognize it when you find it, correcting the trouble is relatively simple.

TOOLS AND MATERIALS NEEDED

1. Socket-wrench set—1/4″ through 13/16″, 3/8″ drive
2. Flywheel puller(s)
3. Open-end wrenches—1/4″ through 1/2″
4. Slot-head screwdriver—6″
5. Phillips-head screwdriver—6″
6. Needle-nose pliers—7″
7. Tag-card stock or postal card for measuring air gap
8. Ignition tools
9. Feeler gage
10. Permate, for sealing around spark-plug wire at the coil
11. Ohmmeter
12. Flywheel holder
13. Coil tester
14. Continuity test light
15. Neon timing light
16. Clean rags
17. Cleaning solvent (denatured alcohol, mineral spirits, kerosene, or diesel fuel)

CHECKING THE MAGNETO FOR PROPER OPERATION

If your engine will not start, follow procedures given under "Starting Engines," Volume I.

If your engine runs but does not run properly, see "Operating Engines," Volume I.

If, after making these checks, you suspect the trouble is in the ignition system, proceed as follows:

1. *Check the spark plug.*

   Follow procedures under "Checking the Spark Plug for Proper Operation," Volume I.

2. *Check all visible wiring for looseness and the possibility of shorting.*

   Loose connections retard or disrupt current flow.

   Shorted circuits, caused from worn insulation and exposed wire touching some part of the engine, allow the current to flow directly to ground instead of going to the spark plug. Replace frayed, cracked or oil-soaked insulation, which may cause a short circuit

in the spark-plug wire.

If the **ignition switch is grounded,** current from the primary winding goes through it to ground, and it is never interrupted when the points open. Therefore, no spark is developed (Figure 82).

3. *Disconnect the spark-plug wire from the spark plug but leave it loosely attached or touching.*

4. *Start the engine.*

5. *Remove the spark-plug wire and hold it 1/16″ away from the spark-plug terminal.*

6. *Operate the engine at various speeds: 1,000, 2,000 and 3,000 r.p.m.*

   Do not prolong the test or hold the connector more than 1/16″ away from the plug as it is possible to damage the magneto coil. Current may have a tendency to jump the windings inside the coil and short the coil wires. The spark will occur at each revolution of the crankshaft on all 2-cycle engines and on some 4-cycle engines. If the breaker points are opened by a **cam on the crankshaft,** the spark will occur at each revolution of the crankshaft. This is always true on 2-cycle engines which fire each revolution. Single cylinder 4-cycle engines, however, use the spark only at every other revolution.

   The breaker points on many 4-cycle engines are opened by a *cam on the camshaft.* They open and close every other revolution because the camshaft turns one half the speed of the crankshaft.

   If a good spark occurs regularly, it is likely that the magneto is good.

   If the engine runs better with the spark-plug wire loosely connected, the spark plug may be fouled. The 1/16″ air gap which you have provided in the test acts as a resistor-type plug and increases the spark intensity in the plug. This might cause a bad plug to fire. Here is the reason. The extra resistance causes a slight delay in the jump, and more voltage builds up. Then there is less time for the voltage to leak away before jumping the gap. Refer to "Servicing Spark Plugs," Volume I.

   If the engine backfires, or kicks, when starting, the breaker-point gap may be too wide. Too wide a gap also causes a spark knock while the engine is operating.

   If there is no spark or the spark is weak, proceed to step 7.

7. *Check the breaker points for condition and adjustment.*

   It may be necessary to remove the flywheel on some flywheel magnetos to get to the points. Procedures are given under the next heading for removing the flywheel.

   Checking the breaker points is discussed under "Checking and Conditioning the Breaker-Point Assembly," page 58.

8. *Check for a partially sheared flywheel key.*

   See step 3 under "Removing and Checking the Flywheel," next heading.

9. *Check the condenser.*

   See "Checking the Condenser," page 61.

10. *Check the ignition timing.*

    See "Timing the Magneto to the Engine," page 65.

11. *Check the stator-plate air gap for proper space.*

    See "Checking and Adjusting the Stator-Plate (Armature) Air Gap," page 69.

12. *Check the magneto edge gap (some flywheel magnetos).*

    See "Timing the Magneto to the Engine," page 65.

13. *Check the permanent magnet for strength.*

    See step 7, next heading.

14. *Check the magneto coil for continuity and strength.*

    See "Checking the Magneto Coil," page 71.

REMOVING AND CHECKING THE FLYWHEEL

If your breaker points are located underneath the flywheel, proceed as follows:

1. *Disconnect the spark-plug wire.*

2. *Remove the starter if one is installed.*

   If your engine has a **rope rewind** or a **windup starter,** it will be necessary to re-

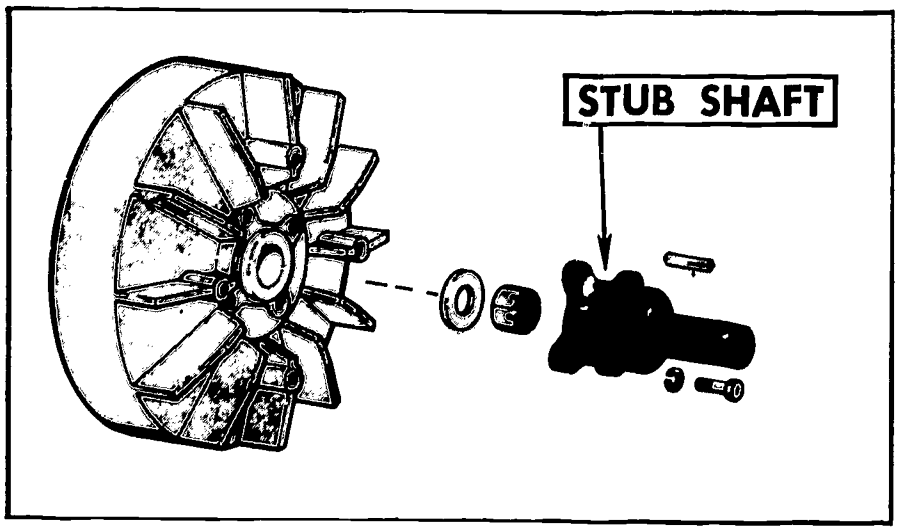


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FIGURE 87. Stub-shaft for starter-generator drive pulley.

move it first. See "Repairing Starters," page 8.

If it has an **electric starter-generator,** it will have a stub-shaft, which must be removed (Figure 87).

3. *Remove the flywheel shroud (Figure 88).*

4. *Remove the flywheel nut (Figure 89).*

A sharp blow on the wrench handle with a mallet will help break the flywheel nut loose (Figure 89a). Use a special flywheel holding tool (Figure 89b) to protect the crankshaft bearing while you are loosening the nut.

Remember flywheel nuts have right-hand threads for clockwise rotating engines (viewing the engine from the flywheel side). They have left-hand threads for counter-clockwise rotating engines.

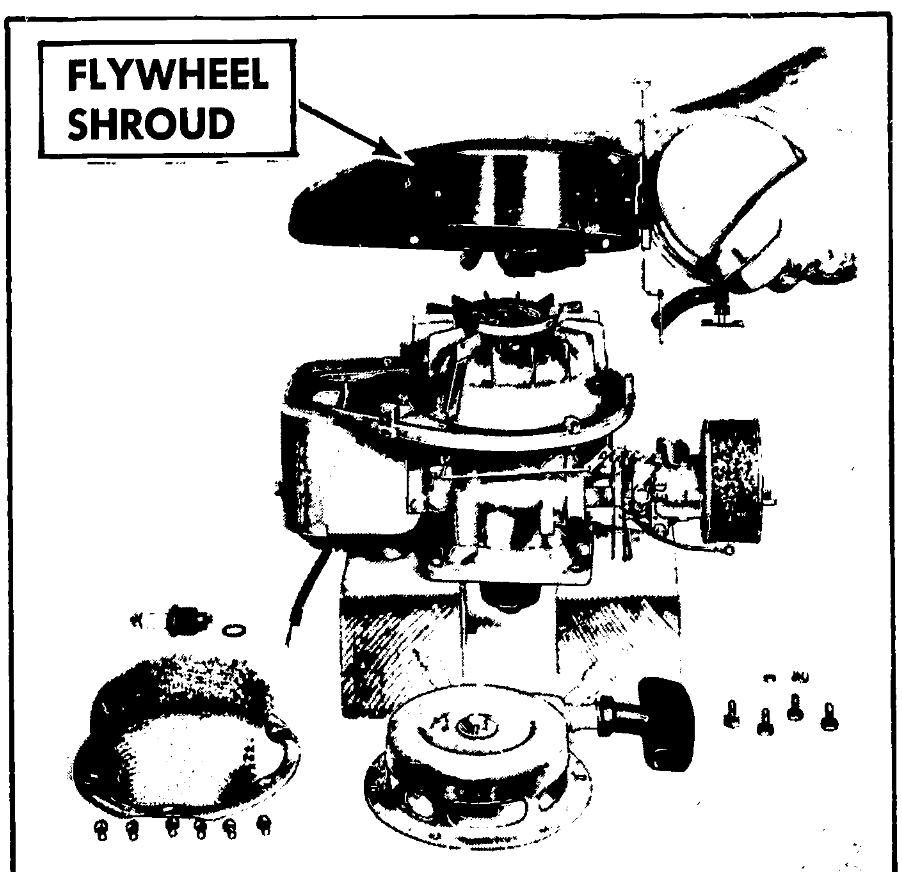

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FIGURE 88. Removing the flywheel shroud.

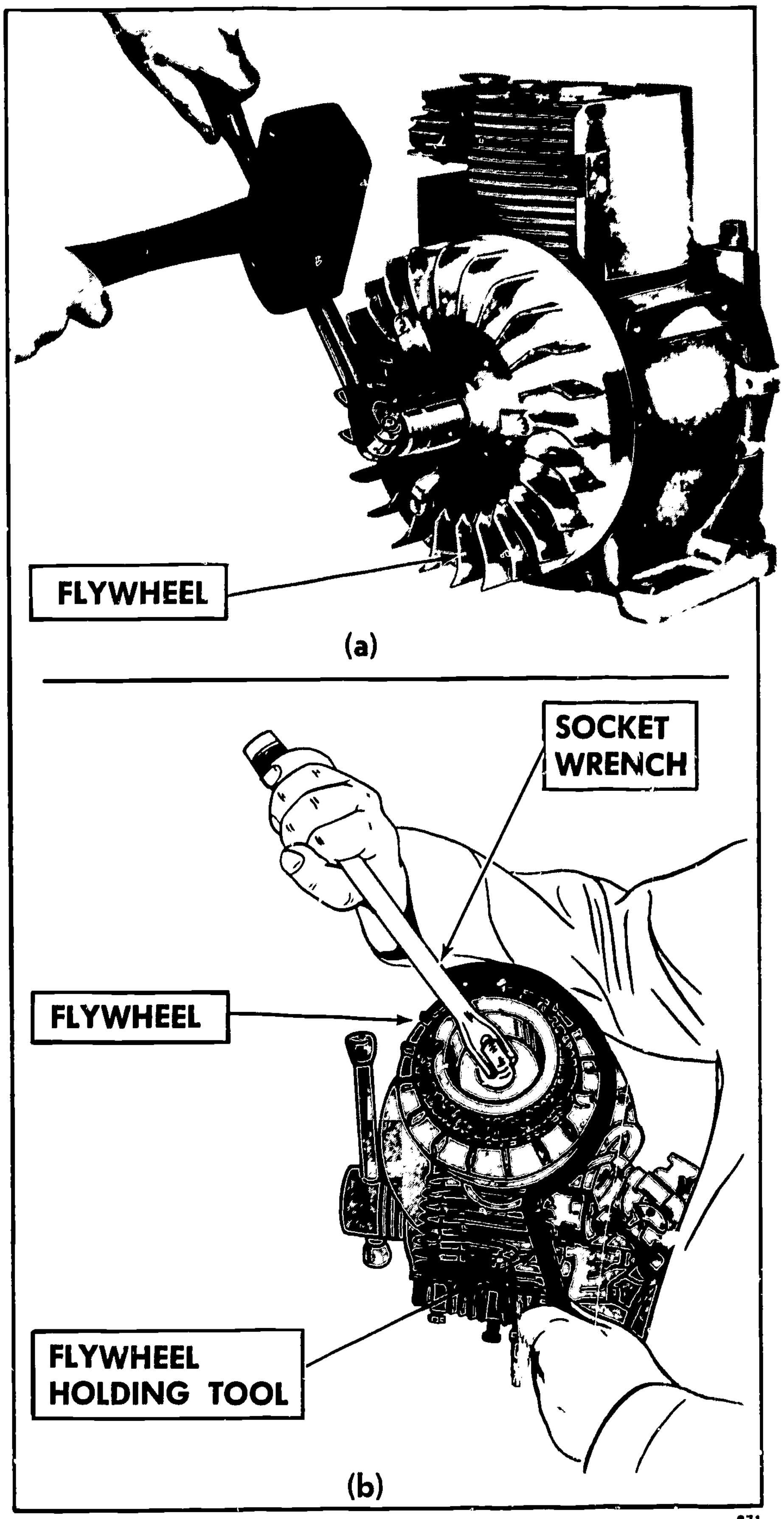

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FIGURE 89. Removing the flywheel nut. (a) A sharp blow may break the nut loose. (b) A special flywheel holding tool should be used, if available.

5. *Remove the flywheel.*

There are two methods for removing the flywheel. The method used depends on whether it is mounted on a tapered or a standard shaft.

(a) **If the flywheel is mounted on a tapered shaft,** remove it as follows:

(1) *Place an impact nut on the end of the crankshaft to prevent damage to the threads (Figure 90).*

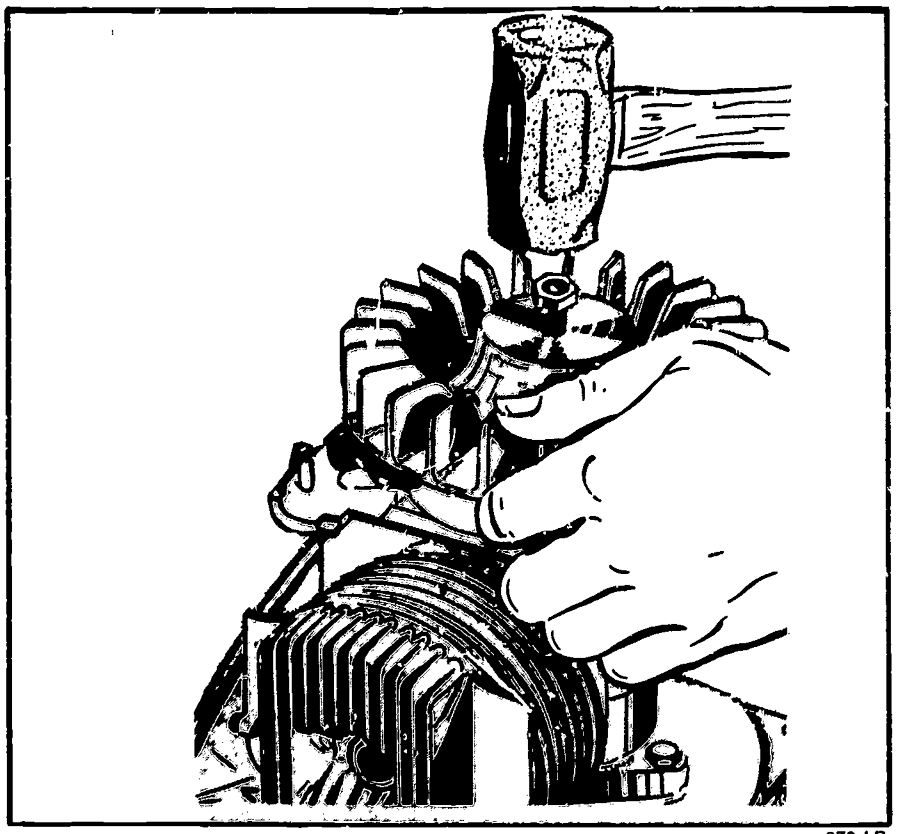

FIGURE 90. Removing the flywheel from a tapered crankshaft.

(2) *Hold the flywheel by hand.*

(3) *Strike the end of the shaft with a sharp blow.*

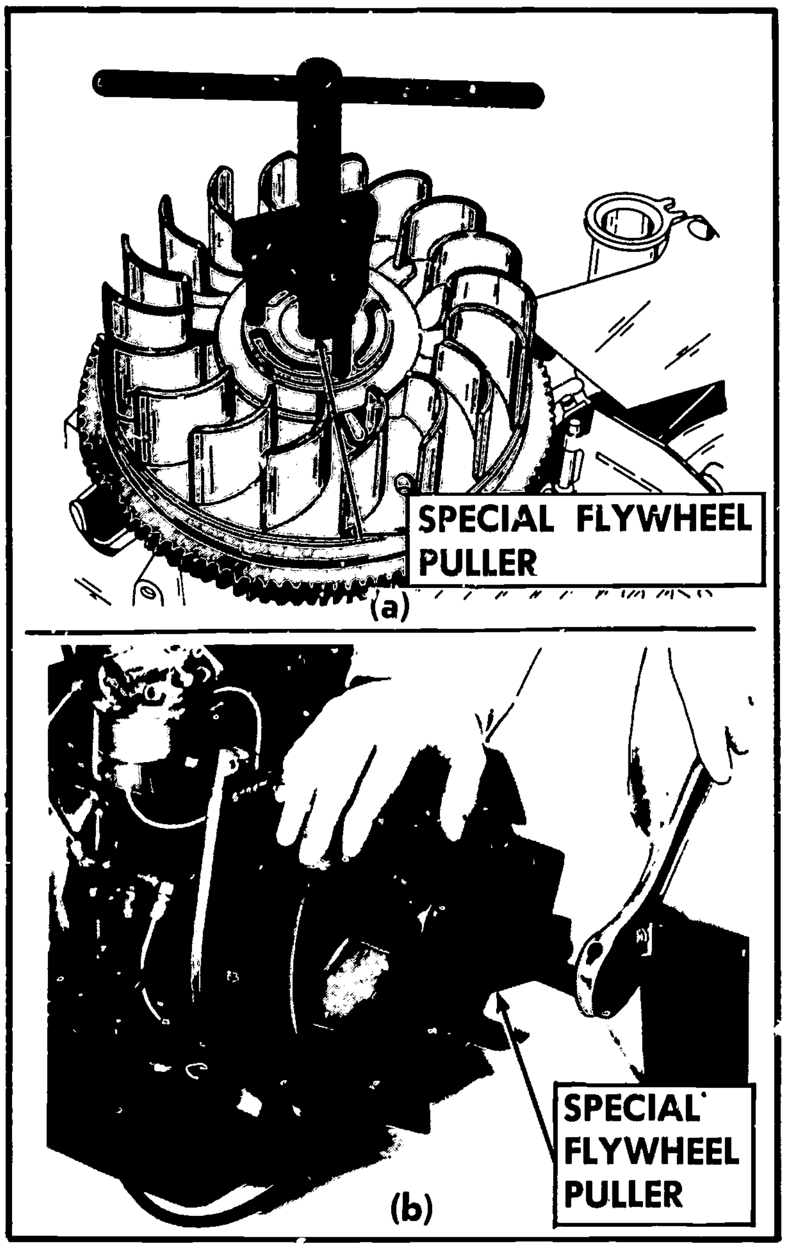

FIGURE 91. Special flywheel pullers. (a) A T-handle type. (b) A puller to be turned with a wrench.

Use a lead or plastic hammer. If the flywheel does not break loose after two or three tries, use a puller (Figure 91). Too much hammering will jar the magnetism out of the flywheel magneto and may damage the crankshaft bearings.

(b) **If your flywheel is not on a tapered shaft,** it will be necessary to use a puller. All of them are equipped for a special puller. Proceed as follows:

(1) *Attach special puller to the flywheel (Figure 91).*

Be careful not to damage the crankshaft threads and do not drop the flywheel. Dropping the flywheel

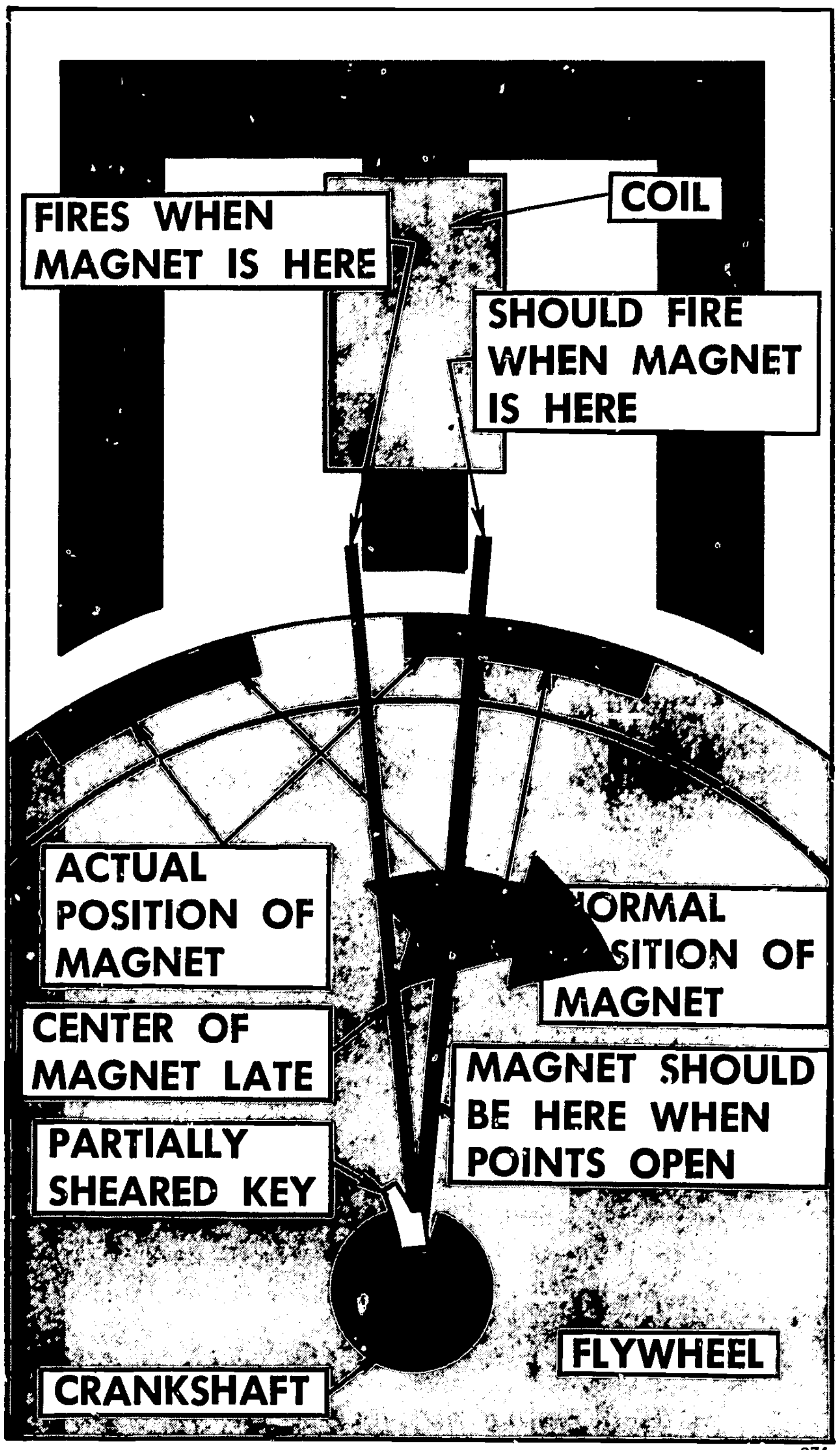

FIGURE 92. A partially sheared flywheel key can cause the ignition timing to be off. The points open before the magnet reaches the point where the maximum magnetic-field intensity is developed.

will jar the magnetism from the magnets. Do not store it near iron or steel.

(2) *Turn puller screw with a wrench until flywheel is loosened.*

6. *Check for a partially sheared flywheel key (Figure 92).*
7. *Check strength of the magnets.*

Hold a steel tool near the magneto. There should be a strong magnetic pull. There is no accurate measurement given by manufacturers for measuring the intensity of the magnetic field. One method suggested is to dangle a 6″ screwdriver with the blade 1″ from the magnet. The magnet should pull the blade against itself.

8. *Proceed with checking the breaker-point assembly.*

CHECKING AND CONDITIONING THE BREAKER-POINT ASSEMBLY

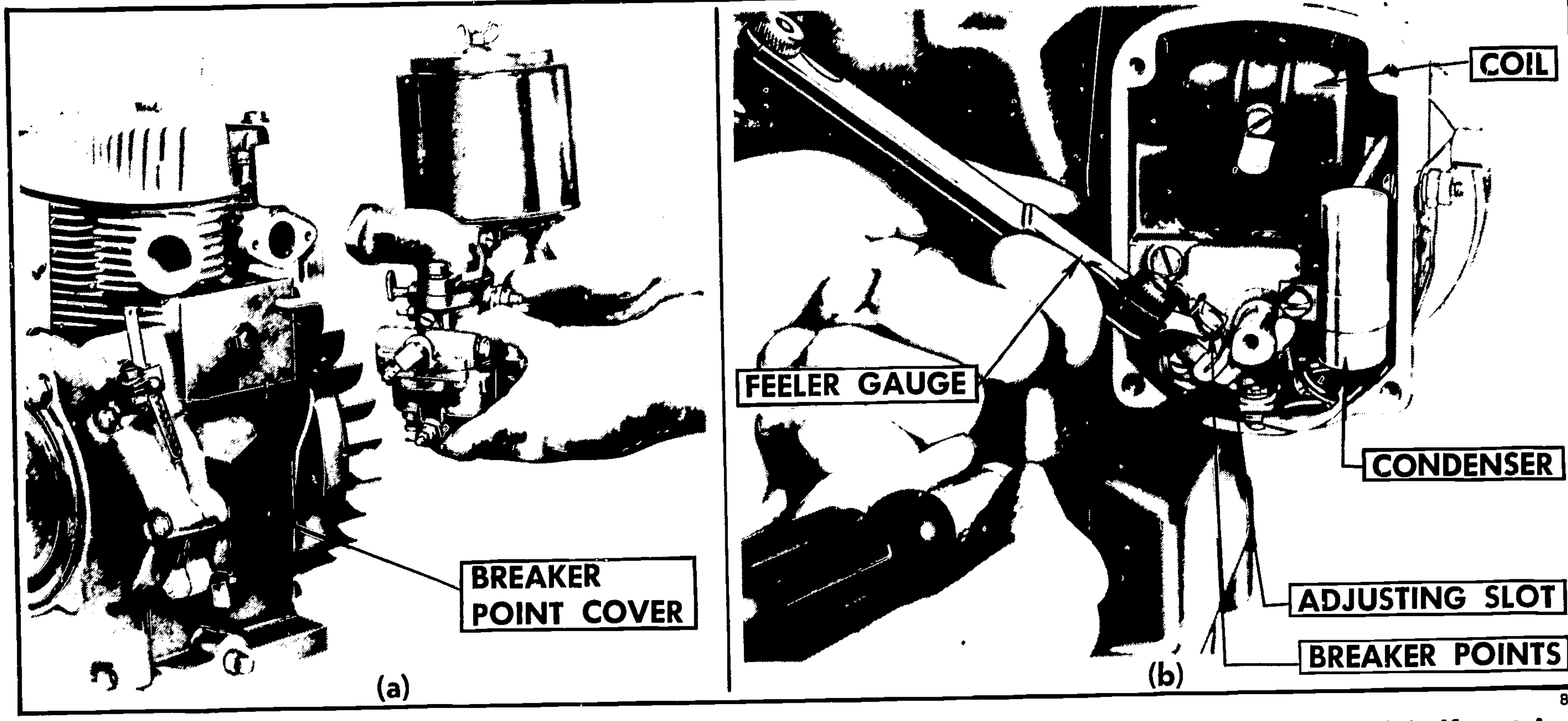

FIGURE 93. Some breaker points are located on the side of the engine. (a) Engine with a flywheel magneto but an external breaker box. (b) An external (self-contained) magneto showing breaker points.

1. *Locate the breaker-point assembly (Figures 93 and 94).*

   Some breaker points are easily accessible. They are **located on the side of the engine** and may be reached by removing a protective cover (Figure 93).

   Other breaker points (on flywheel magnetos) are **located underneath the flywheel,** and and it is necessary to remove the flywheel to gain access to them (Figure 94). Most of those located underneath the flywheel are also protected by a dust cover, which must be removed.

2. *Gain access to the breaker-point assembly.*

   If your points are located on the **outside of the engine,** remove the protective cover. Before removal, wipe the dust from the cover with a clean rag to prevent dirt from getting into the breaker box.

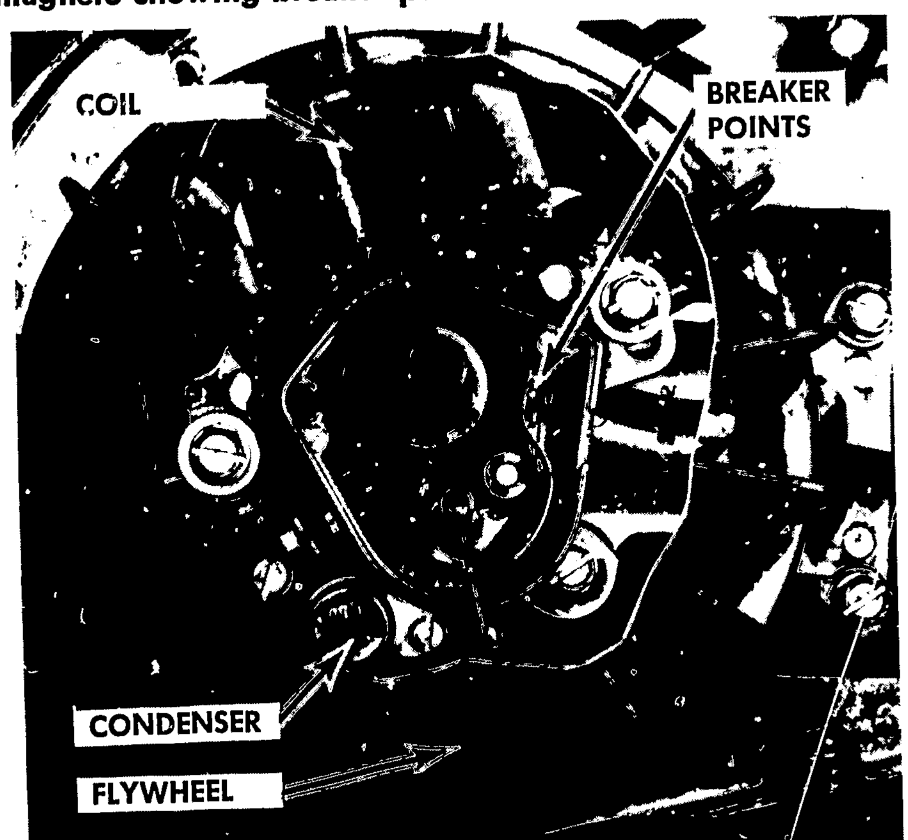

FIGURE 94. A cut-a-way view of a flywheel magneto showing the breaker points.

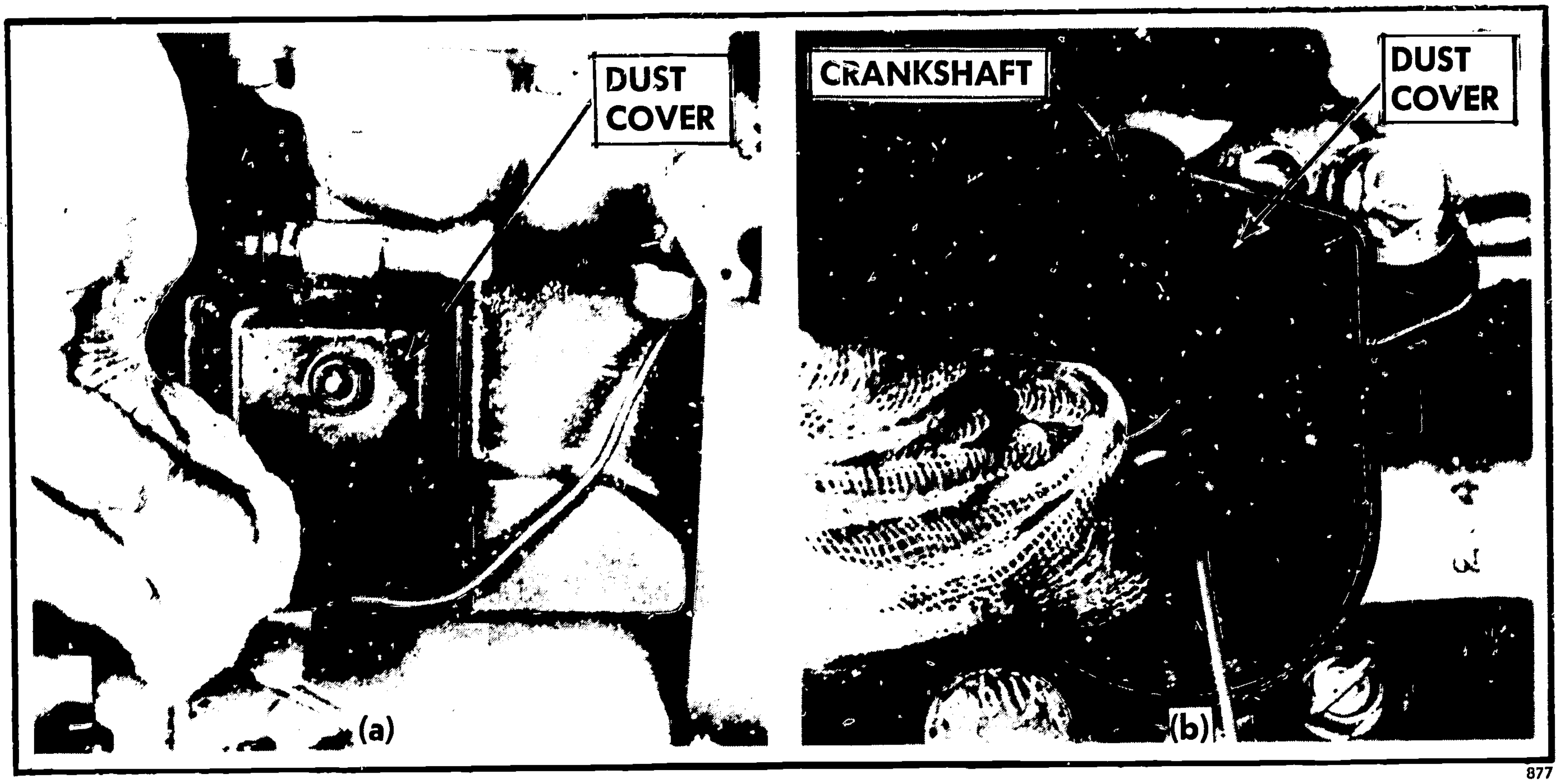

FIGURE 95. Wipe away dirt, dust and grime before removing the breaker-box cover. (a) Outside cover. (b) Cover under the flywheel.

Use a clean cloth with a small amount of petroleum solvent to remove grease. Do not use water. It may cause short circuiting (Figure 95).

If the points are located **underneath the flywheel**, remove it.

3. *Check and remove, if necessary, the centrifugal spark-advance mechanism (Figure 96) if installed.*

4. *Check and recondition or replace the breaker points.*

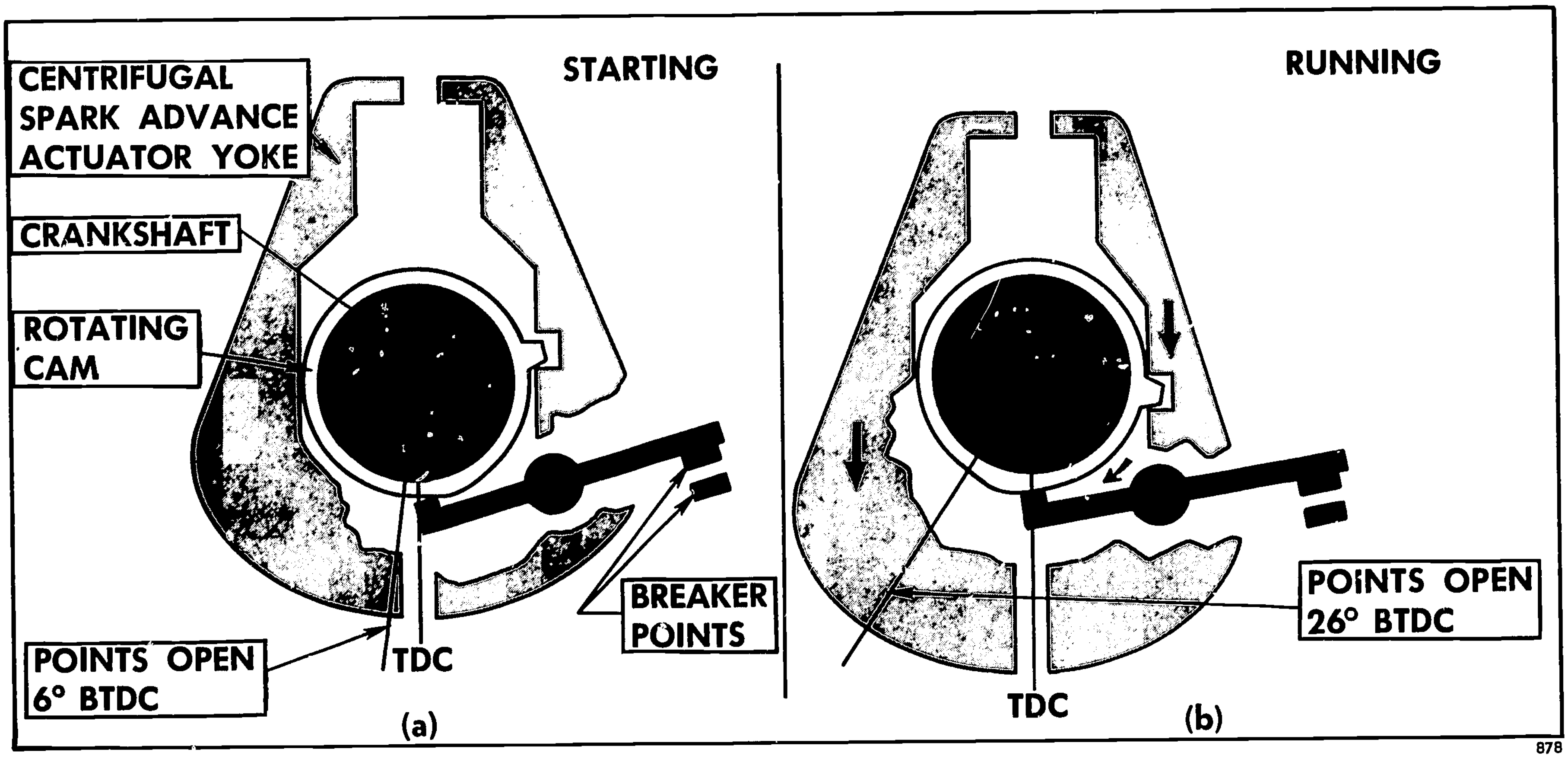

FIGURE 96. One type of centrifugal spark-advance mechanism moves the cam, which opens the points earlier when the engine is running above 1,000, to 1,500 r.p.m. (a) For starting, the rotating cam remains stationary and opens the points when the piston is near top dead center.

(b) When the engine speed increases, the yoke moves because of centrifugal force. When it moves, it rotates the cam in the direction of the crankshaft rotation. Then the points are opened earlier.

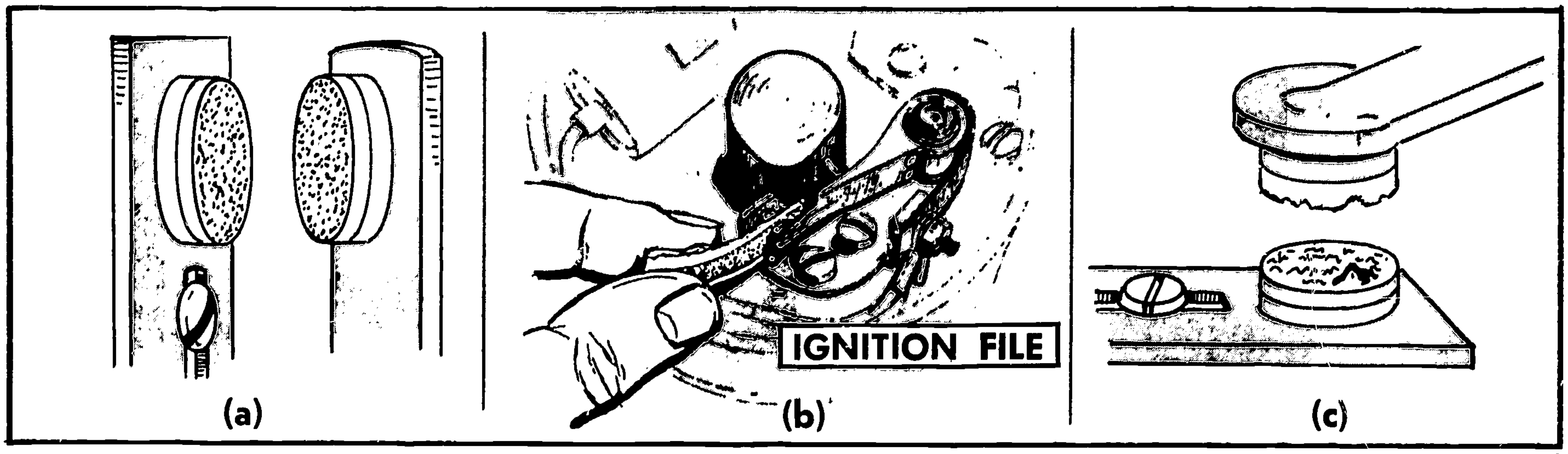

FIGURE 97. (a) Unplated contact points that are slightly burned or pitted may be (b) smoothed with an ignition file. (c) Badly pitted points should be replaced with new ones.

If the contact points are rough but show only a **slight pitting and metal deposits** (Figure 97a), they can be smoothed with an ignition file (Figure 97b). It is not necessary to have the points completely smooth with all pits removed. Just remove the high spots. When the engine is operating properly, there is a small amount of pitting and metal deposits. Make certain a large area of contact is still being maintained.

Blow out the dust after you have completed the filing.

Do not use sandpaper or emery cloth. The particles may embed in the contact surface and cause the points to burn.

Some points are plated with a high-melting-point metal, like tungsten. They are so hard there is little you can do to them if they are worn or damaged. They must be replaced. If points are **badly pitted and/or worn,** (Figure 97c), replace them with a new set. Follow procedures under "Removing and Replacing Breaker Points," page 64.

Badly burned points may be due to (1) oil or foreign material on the contact surfaces, (2) a defective condenser, (3) contact-point gap out of adjustment, or (4) points out of alignment.

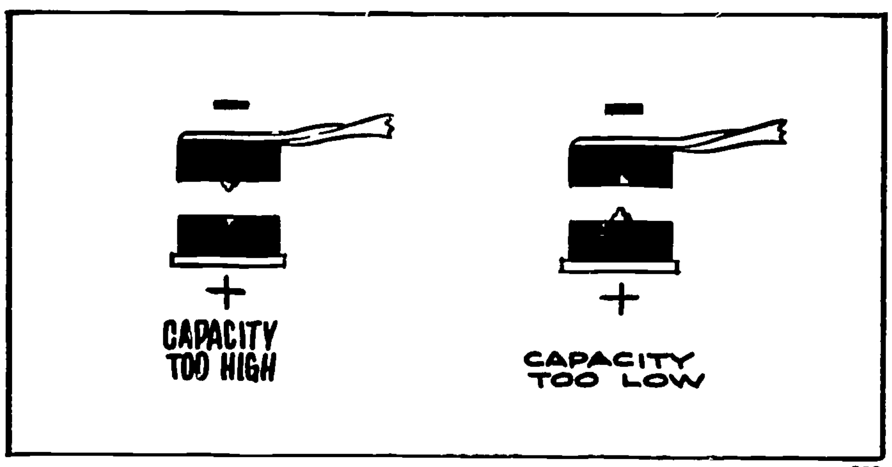

FIGURE 98. Effect on contact points when condenser is of improper capacity.

5. *Check the condenser.*

   See next heading.

   If the **condenser is not working properly,** or if it is not of the proper capacity for your

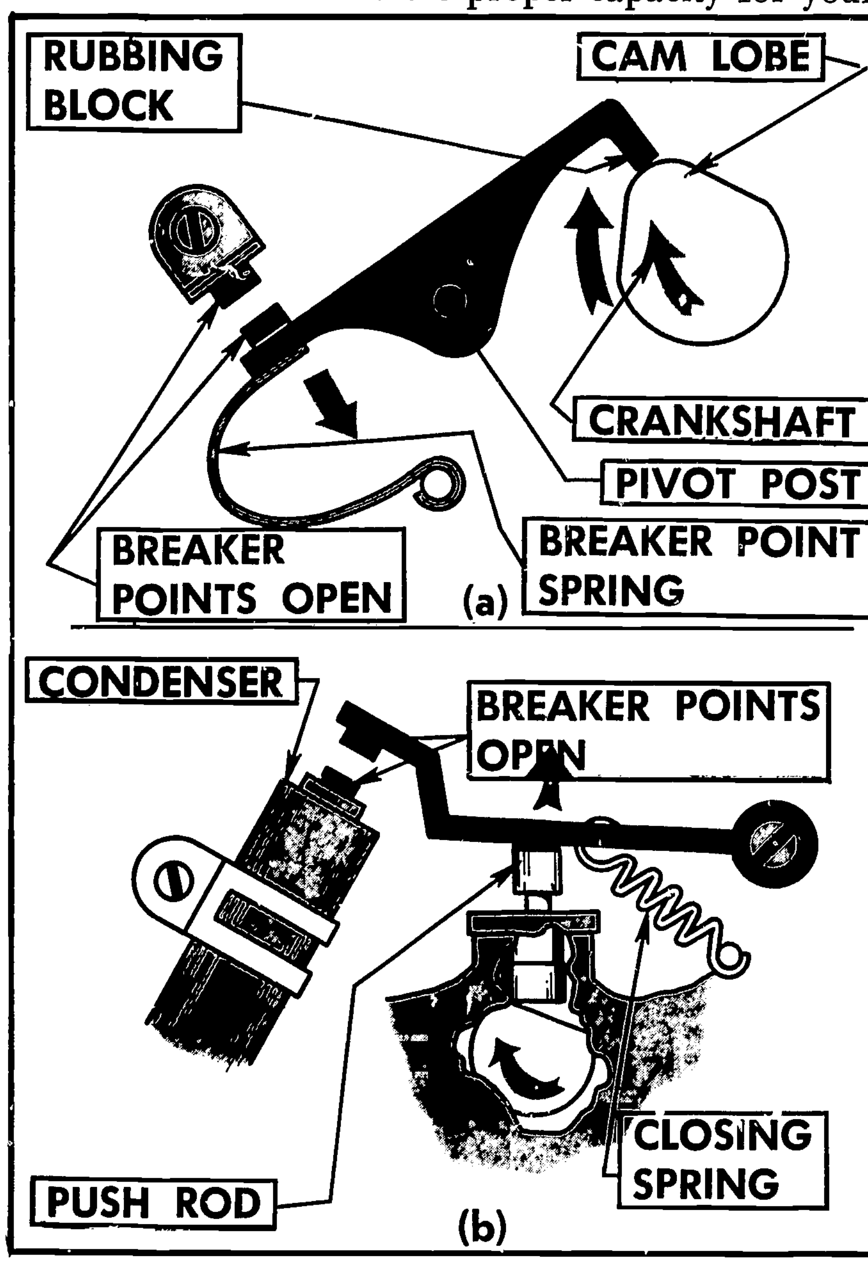

FIGURE 99. (a) Breaker points opened by a cam on the crankshaft and closed by a spring. (b) Breaker points closed by a spring and a flat spot on the crankshaft and then opened at the proper time by the crankshaft and push rod.

6. *Check the breaker cam for wear.*

   Some breaker points are opened by a cam on the crankshaft (Figure 99a). The cam may be machined on the crankshaft, or it may be a separate collar locked by a key on the crankshaft. With the latter type, it is possible to install it up-side-down. If you do, the points will open 180° ahead of time. Other breaker points are opened by push rods which are operated by the crankshaft (Figure 99b). A flat space on the crankshaft closes the points in time for the induction coil to build up a charge and then opens them for the spark discharge.

   Check push rod for wear and for freedom of movement.

   Some are operated from a cam on the camshaft which trips a lever arm on the breaker arm shaft (Figure 100).

7. *Check rubbing block for wear.*

   When wear takes place on the rubbing block, this changes both the point gap and the timing. This is one of the main reasons for an engine getting out of time.

8. *Check for a leaking crankshaft seal.*

   This may allow oil to get on the points of flywheel type magnetos and ground them out.

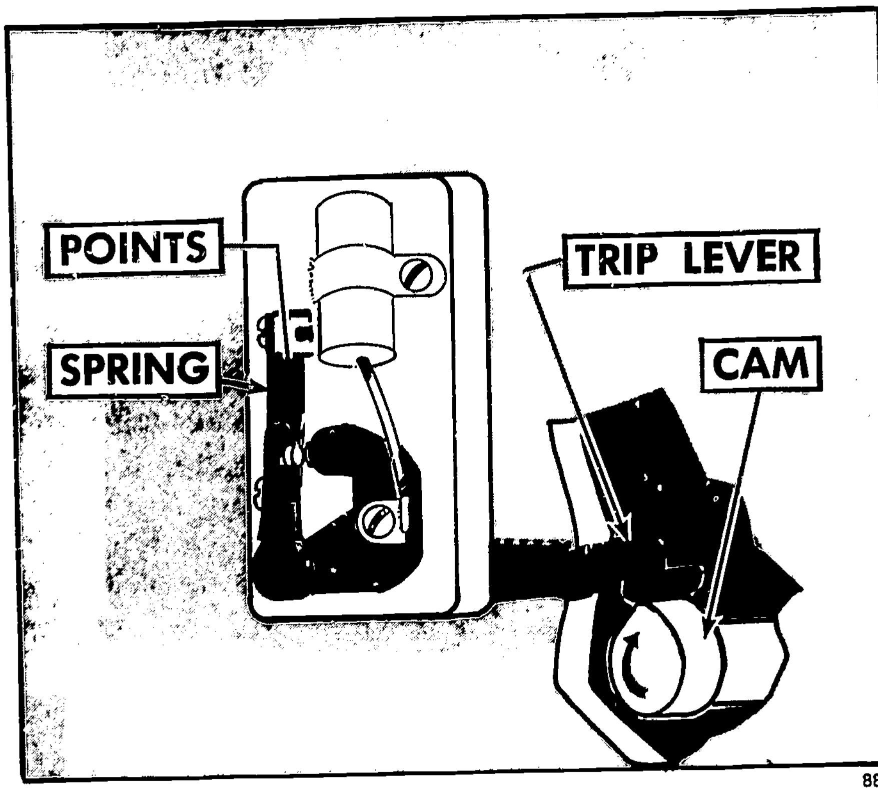

FIGURE 100. Some breaker points are opened by a trip lever which is tripped by a cam on the camshaft.

9. *Check condition of wiring and tightness of connections.*

   Look for frayed insulation and loose connections.

10. *Check point assembly for tightness.*

11. *Check and adjust the breaker-point gap.*

CHECKING THE CONDENSER

Some manufacturers recommend changing the condenser every time you change points. They say the price of a condenser is not worth the risk of burning up a new set of points.

Other manufacturers say the odds of a condenser going bad are 1,000 to 1, and you are better off to use the old condenser. Some points, however, are attached to the condenser, and you are forced to replace condenser when you replace points (Figure 101).

Badly pitted breaker points indicate the condenser is bad or is of the improper capacity.

1. *Remove and check condenser for capacitance (.10 to .30) microfarads, depending on your type of magneto).*

   Follow procedures given with the particular instrument you use and the manufacturer's specifications.

   Check the old condenser first. If it is not good, replace it — but also check the new one.

   Condensers should be checked for capacity, shortage (or leakage) and resistance (Figure

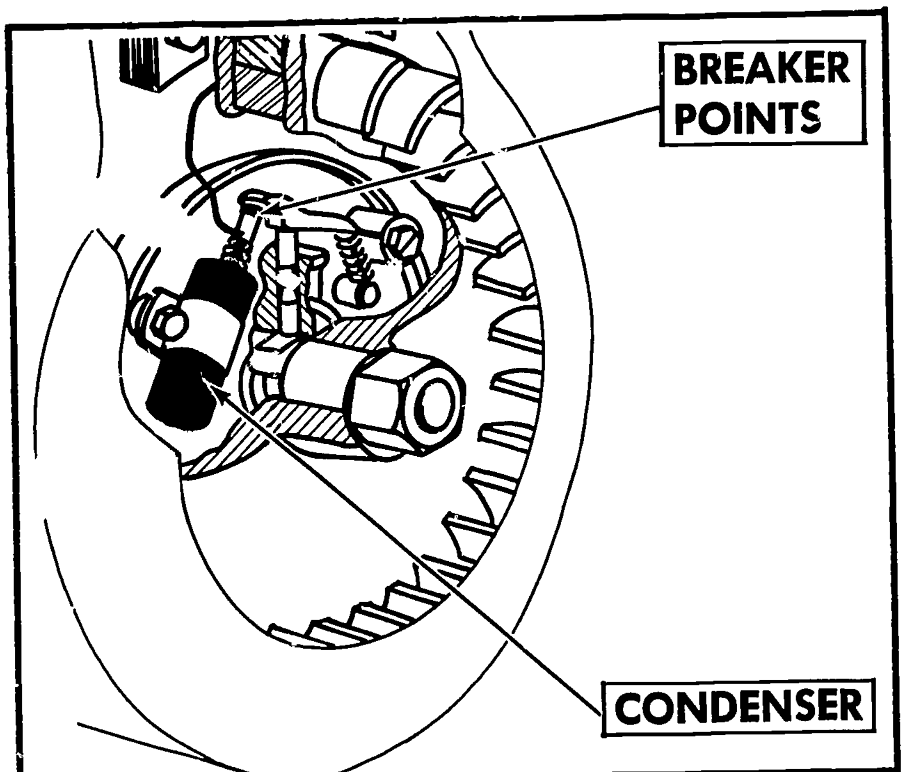

FIGURE 101. Some breaker points and the condenser are assembled as one unit. It is necessary to replace one when you replace the other.

102). Heat the condenser to approximately 100° F. before testing. This is more nearly operating temperature. A condenser that checks out good when cold may not when heated. For example, if it has a leak, the short will show up better at higher temperatures. Do not overheat. The expansion may crack some of the insulation. Hold it in the palm of your hand for a couple of minutes, or put it in an oven with a thermometer control.

If you are not equipped to check the condenser, have it checked at your dealer's or replace it with a new one.

2. *Replace the condenser if it is bad.*

3. *Check the tightness of the clamp that holds the condenser.*

   The clamp is also a ground connection for the condenser. It must be tight to provide a good electrical connection. This helps prevent arcing at the points.

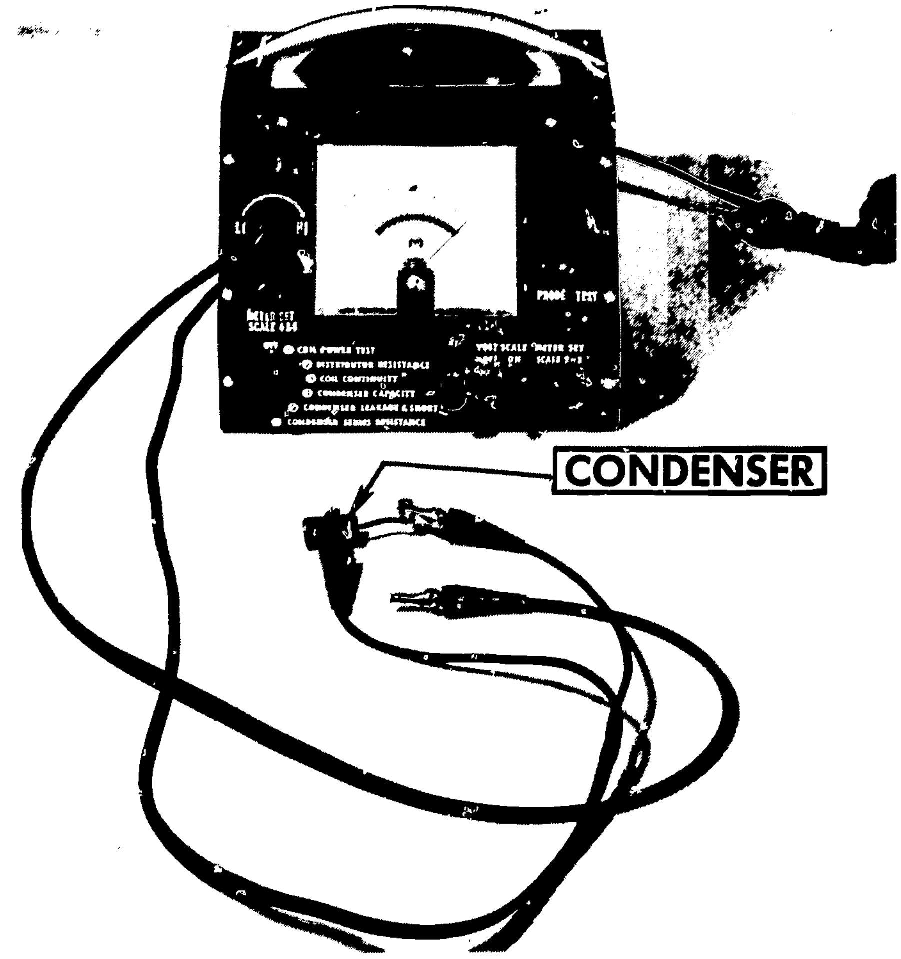

FIGURE 102. A typical instrument for testing coils and condensers.

ADJUSTING THE BREAKER-POINT GAP

1. *Turn the crankshaft in direction of normal rotation until cam opens breaker points to the widest position (Figures 99 and 100).*

2. *Check points for proper gap spacing (Figure 103).*

   Use a clean feeler gage of the thickness recommended for your engine. This may vary from .015 to .020 inch. Usually the point gap can be found on the engine nameplate and/or on the breaker-point dust cover. If not it will be given in your operator's manual. The proper width gap is provided when there is a slight drag on the thickness gage as you pull it between the contact points. If adjustments are needed, proceed to step 3.

3. *Loosen locking screw on bracket that provides for the point adjustment (Figure 106).*

4. *Tighten snugly but not completely.*

   Tighten just snug enough so that the adjusting plate and breaker cam will remain in place when the stationary point is moved.

5. *Adjust points for proper spacing and alignment (Figure 103).*

   Four different means are provided for adjusting breaker point gap. The one used depends on the design of the point assembly: (1) a **slot** for moving the back plate, or stationary points (Figure 103) with a screwdriver, (2) a **screw** with a cam for moving the back plate with a screwdriver, (3) a **slot in the back plate with no special provision for moving the back plate,** and (4) a **clamp** on the condenser if the points are part of the condenser (Figure 103c).

   If the gap width recommended for your engine provides for a width range such as .015 to .018 inch, use the wider recommendation. As the cam and rubbing block wear, the points will gradually decrease in gap width.

   Be sure the breaker point faces fit together squarely (Figure 104a). If they fit as shown in Figure 104b and c, the points will burn, pit and wear unevenly. It is possible to bend some metal-arm breaker points into position to get the points to fit squarely. This action, however, is not generally recommended.

6. *Lock breaker points into position with locking screw (Figure 103).*

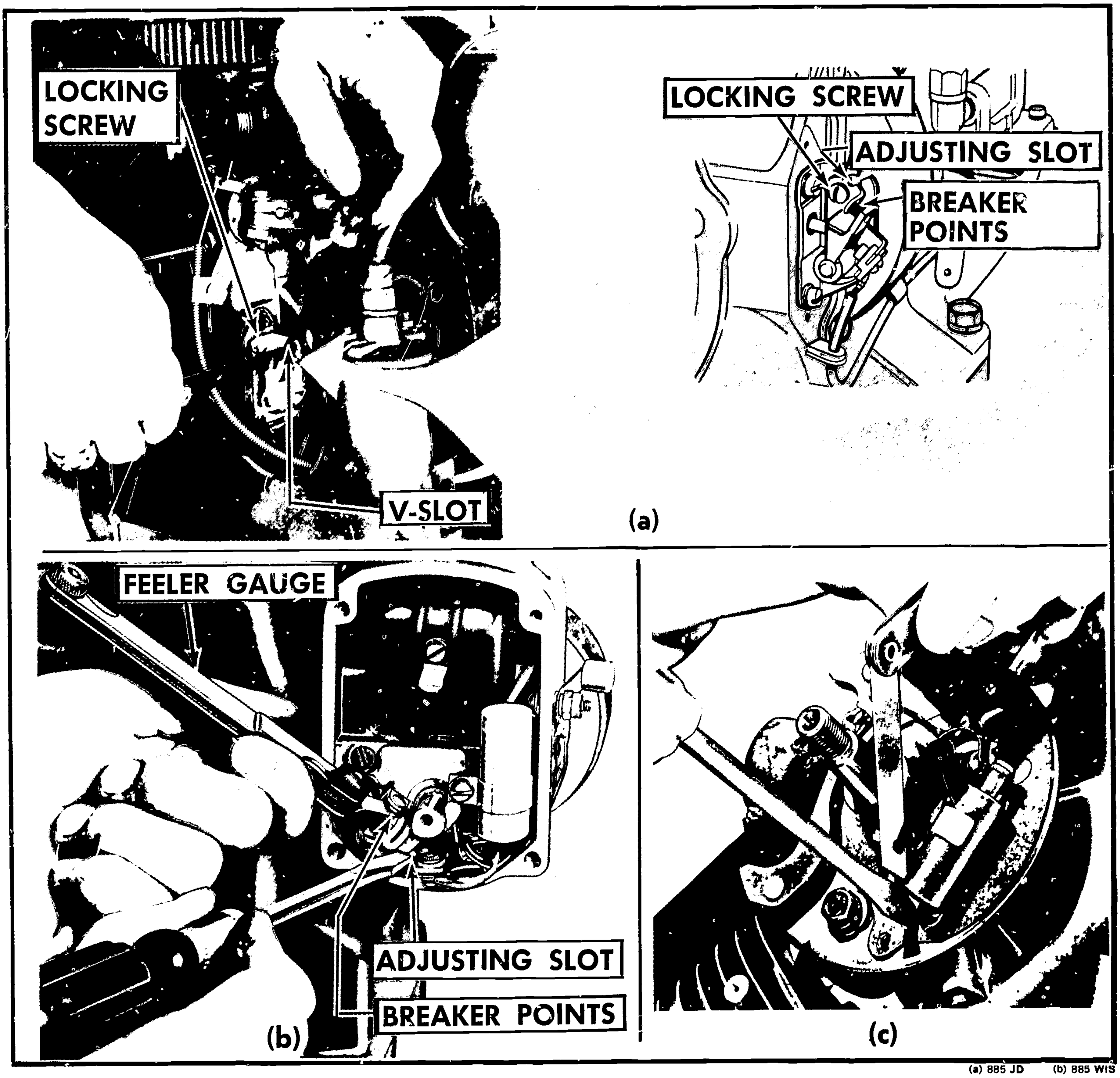

FIGURE 103. Adjusting breaker points. (a) Points adjusted by loosening the stationary point and shifting it with a screwdriver at the adjusting slot. (b) Similar adjustment on external magneto. (c) Similar adjustment on a flywheel magneto.

7. *Recheck gap between points and wipe points clean.*

Rechecking the gap insures that no change was made in the gap setting when you tightened the lock screw.

Running a strip of paper between the contacts will remove dirt particles. Do not use cloth because it may leave enough lint to provide insulating "fuzz."

If points are oily, clean them with a small amount of petroleum solvent.

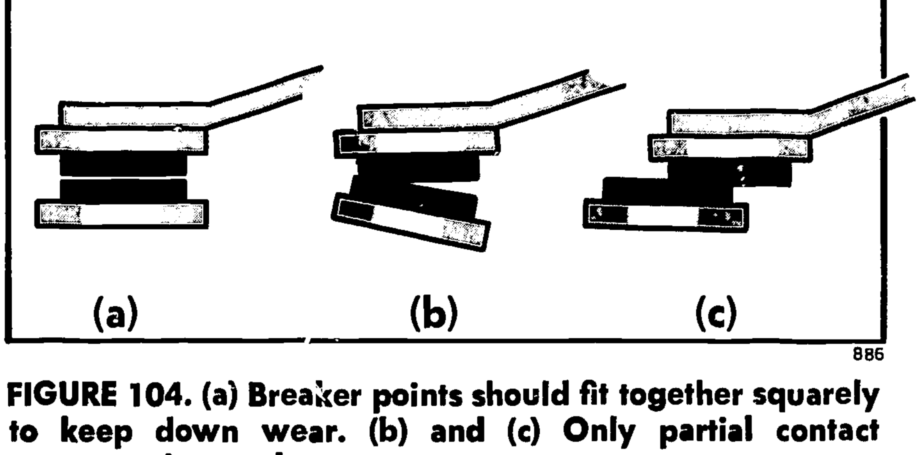

FIGURE 104. (a) Breaker points should fit together squarely to keep down wear. (b) and (c) Only partial contact causes arcing and uneven wear.

8. *Clean and lubricate cam with a grease of high melting point.*

   If the breaker-point assembly has a **cam lubricating wick**, replace it with a new one. If the assembly has **no wick**, use *only* enough grease to provide a thin film on the cam lobe. This avoids getting it on the breaker points, thus causing them to burn.

   A very small amount greatly reduces wear on the rubbing block and cam.

REMOVING AND REPLACING BREAKER POINTS

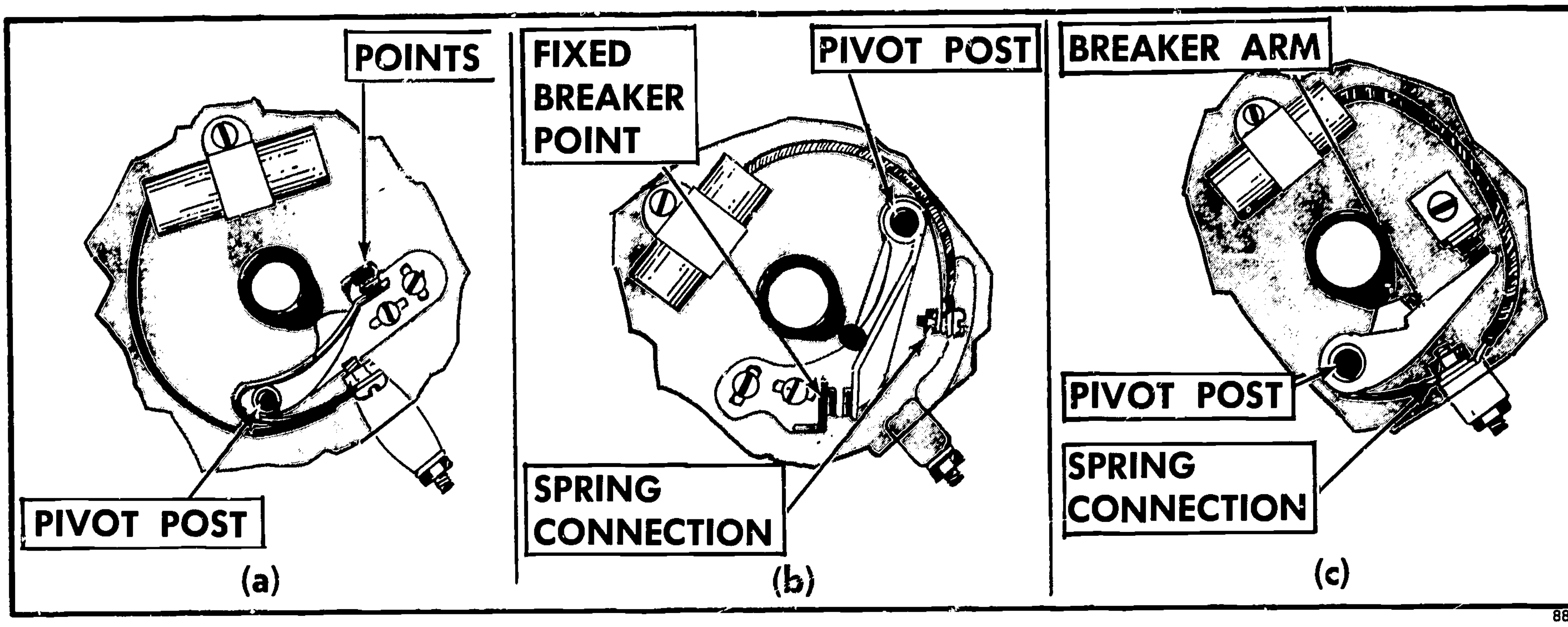

FIGURE 105. Typical mounting arrangements for removable breaker arms on different magnetos. In all three types — (a), (b) and (c) — the breaker arm is removed by loosening a spring connection at the primary terminal and lifting the arm from the pivot post.

1. *Open the breaker points.*

   Turn the flywheel by the starter. This prevents scratching the new points when installing them.

2. *Remove breaker arm and spring.*

   The exact procedure you use depends on the type of installation. Figure 105 shows three common assemblies. Study the installation before taking the assembly apart.

3. *Remove stationary breaker point and bracket (Figure 106).*

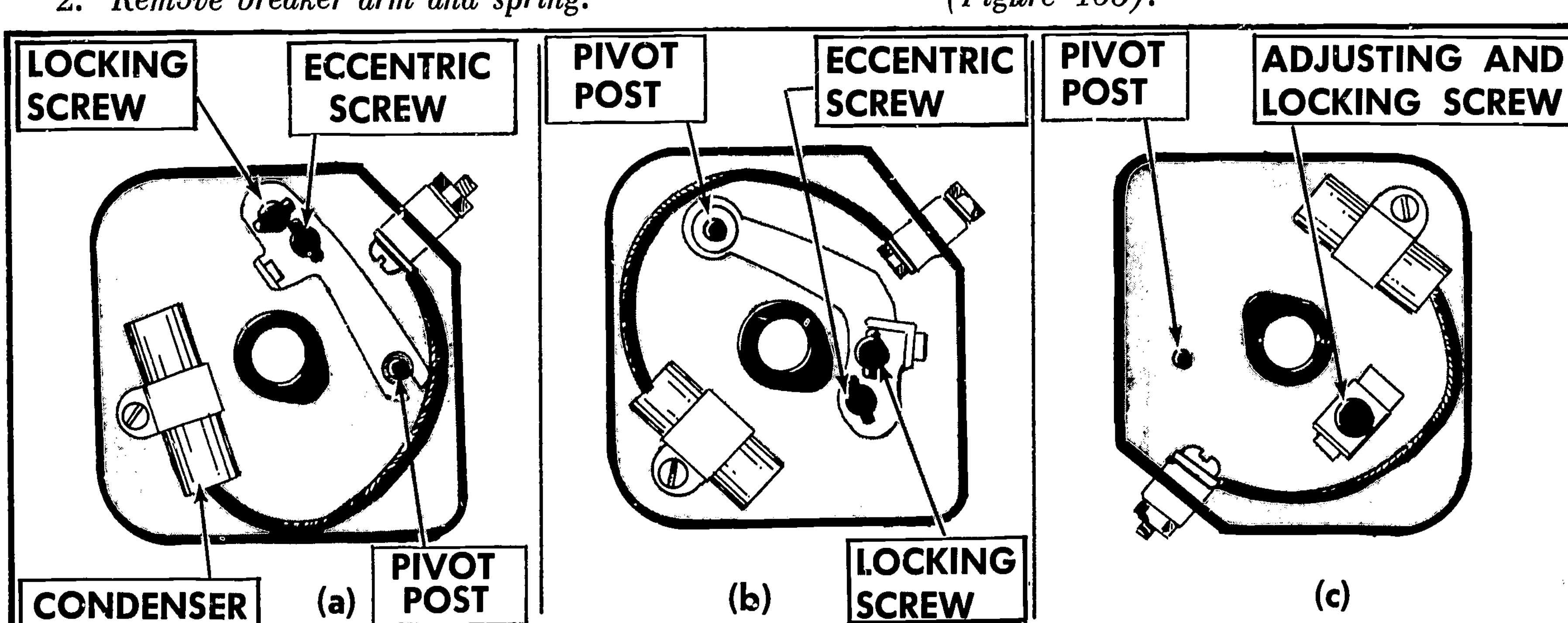

FIGURE 106. (a) and (b) Stationary breaker point and bracket are removed by loosening the locking screw and lifting out the bracket. The adjusting or eccentric screw remains in position. (c) Loosen the adjusting-and-locking screw to remove bracket.

On most installations, one end of the breaker-point bracket is held by the same pivot pin that holds the breaker arm. The other end is held by a locking screw (Figure 106a and b). The second screw is for adjusting the position of the points and is called an "eccentric screw," or "adjusting screw." On others the bracket and adjustable point are held by one screw (Figure 106c). With this type, the hole in the bracket is slotted so that the breaker point can be adjusted to the proper position.

There are some installations (Figure 101) that have one point attached to the condenser. Loosen the retaining clamp and remove the condenser.

4. *Install new points in reverse order.*

   Be sure electrical connections are tight.

   It is important on most installations that the breaker-arm spring be connected next to the retaining nut to give proper spring tension.

5. *Adjust point clearance.*

   Refer to "Adjusting the Breaker-Point Gap," page 62.

TIMING THE MAGNETO TO THE ENGINE

Very seldom will your magneto get out of time. But *if your engine is running rough* and the spark plug and breaker points are in good condition, check the timing. Or, if you replace the coil or have moved the stator plate, it will be necessary to adjust the timing.

Timing the magneto to the engine consists of adjusting the position of the stator plate (coil and laminated yoke, or armature). The center line of the rotating magnet should be just past the center line of the stator plate, when the piston is at the desired position for ignition to take place — on or before top-dead-center on the compression stroke. This position is set by the manufacturer.

The distance between the center lines is known as the **"edge distance"** because it can only be measured at the edges of the armature and magnet (Figure 107). It is at this point that the spark is greatest. Only a few manuals give this measurement because the edge distance is preset at the factory; and when the engine is in proper condition, the edge distance will be right.

There are several reasons why **the edge distance may be off.** Some of them are a *worn flywheel key and/or key way, partially sheared flywheel key, or twisted crankshaft.* But the most probable one is the magneto being out-of-time.

For **checking and adjusting the magneto timing** on your engine, proceed as follows:

1. *Determine what provisions are made for adjustment.*

   On **flywheel-type magnetos** the stator plate (laminated iron yoke and coil, or armature) may be (1) *stationary* with no provisions for adjustment Figure 108a); (2) it may have *straight adjusting slots* for adjusting the armature air gap (Figure 108b) — which does not affect the timing; or (3) it may have *curved slots,* or slots on the mounting flange, for adjusting the timing (Figure 108c).

   External-type magnetos (self-contained types) may or may not have adjusting slots in the mounting flange.

   If your magneto stator plate has **curved slots for rotational adjustment,** proceed to step 2.

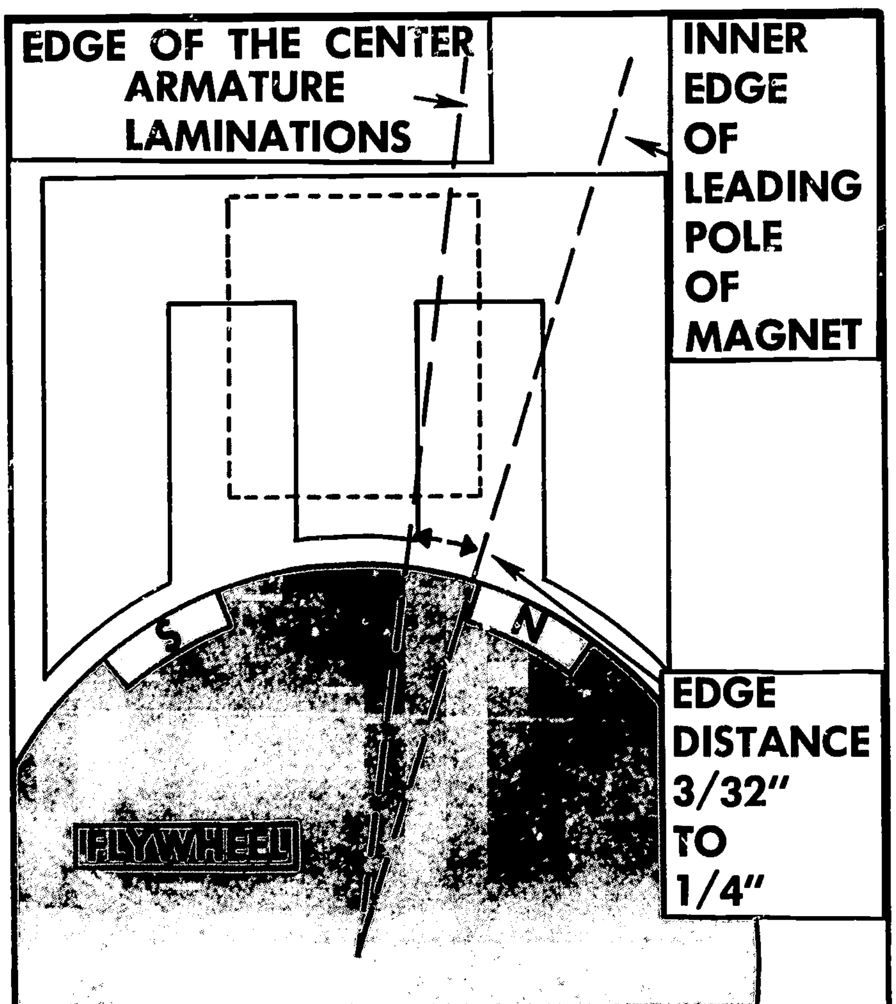

FIGURE 107. The spark is greatest if the points open when the center of the magnet is just past the center line of the coil. This distance is known as "edge distance."

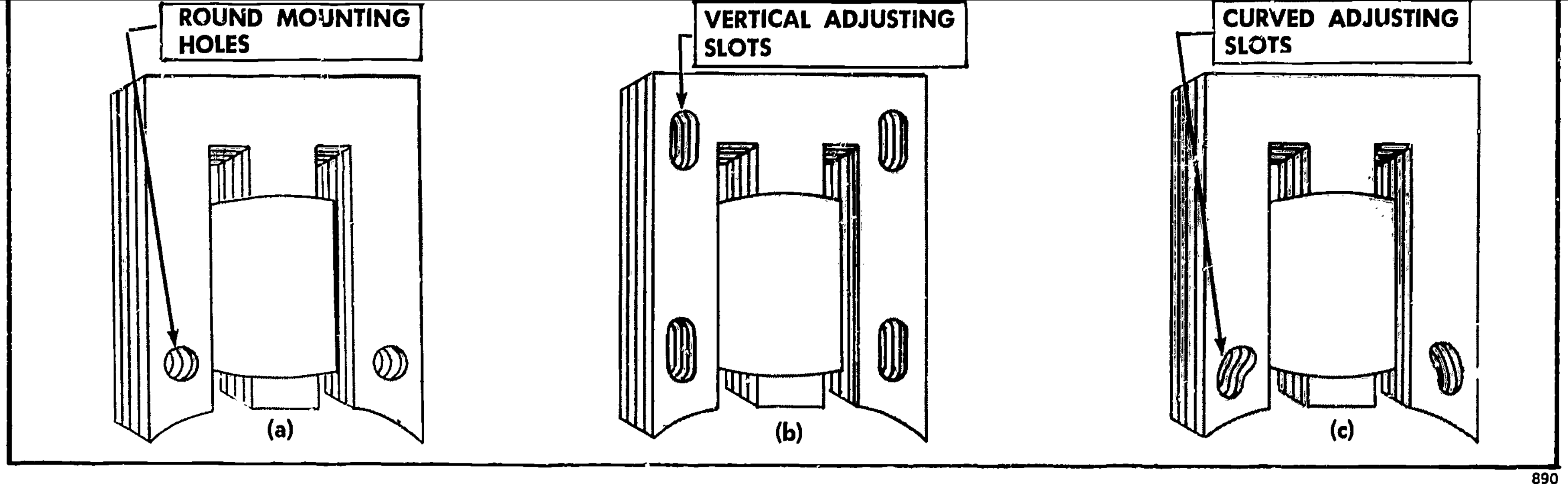

FIGURE 108. The stator plate (laminated iron yoke and coil or armature) on your flywheel magneto may be (a) stationary with no means for adjustment, (b) designed for vertical adjustment, which does not affect timing, or (c) slotted for rotational timing adjustment.

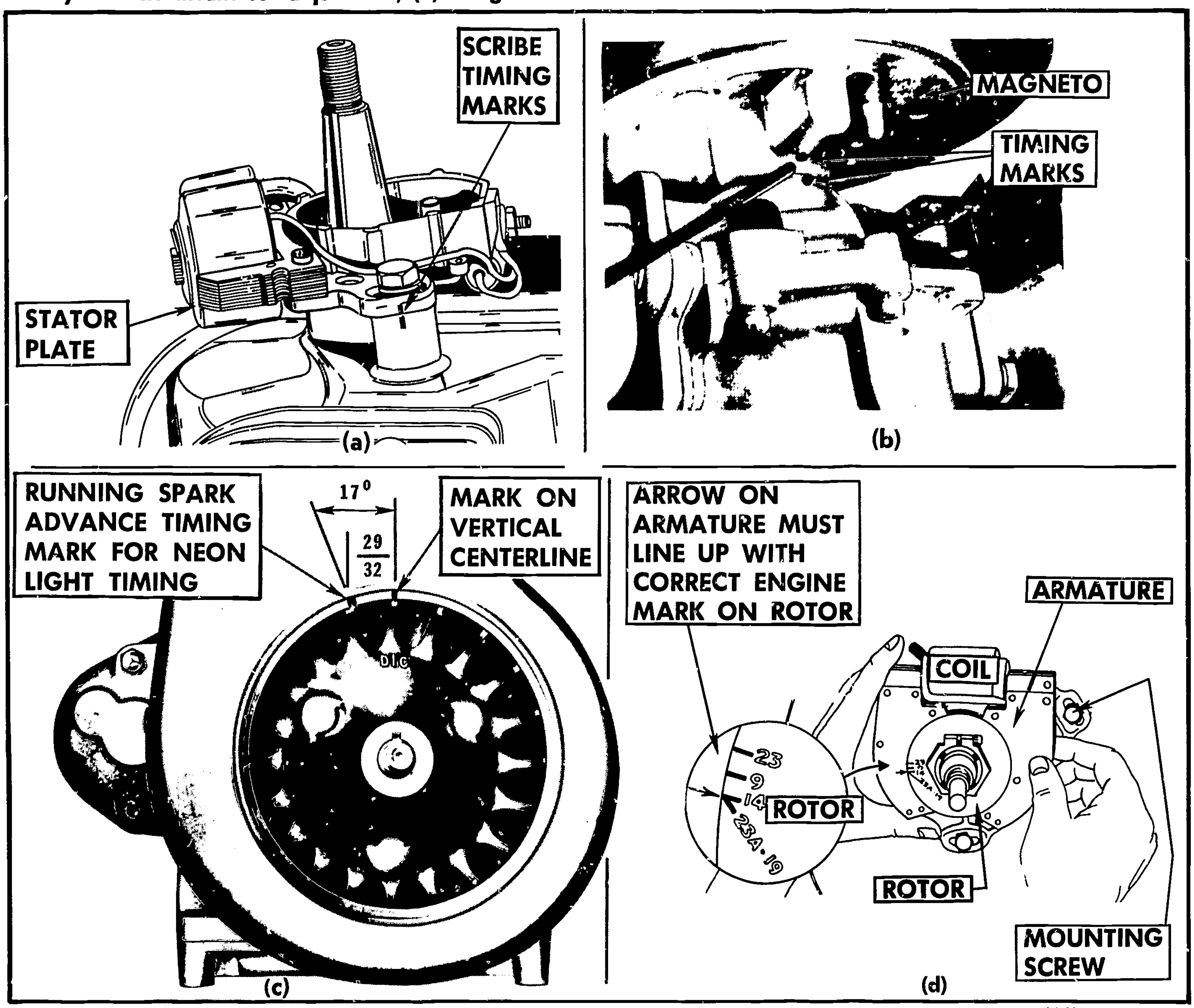

FIGURE 109. Some engines have timing marks which tell you the proper relative positions of the rotating magnet and the stator plate. (a) The timing marks may be scribed marks matching up the stator plate with a point on the engine block. (b) Timing marks may be drilled holes. (c) Timing marks may be scribed marks on the blower housing and on the flywheel. (d) Some magnetos are used on different engine models, and the different timing for each model is indicated.

2. *Locate the timing marks (Figure 109).*

   Timing marks on flywheel magnetos are on the stator plate and the engine block. They may be in the form of scribe marks (Figure 109a) or drilled holes (Figure 109b). Some have no timing marks.

   Timing marks are also located on the flywheel and flywheel housing (Figure 109c). More than one timing mark may be present. One for static timing and one for timing with the engine running. In some cases multiple timing marks are provided for magneto's which are used on different engine models (Figure 109d).

3. *Time the magneto.*

   If your engine **has timing marks,** loosen the capscrews which hold the stator plate and rotate it until the timing marks are aligned. If there are **no timing marks,** and your stator plate is adjustable, proceed as follows:

   (1) *Remove the spark plug.*

   (2) *Adjust the breaker-point gap.*

   See "Adjusting the Breaker-Point Gap," page 62.

   (3) *Set the piston at the recommended position for firing.*

   Check your service manual for the distance in inches or degrees from top-dead-center on the compression stroke. Measure with a ruler or dial indicator if given in inches. Measure with a disk indicator if given in degrees of crankshaft travel.

   (4) *Adjust the magneto stator plate so the points start to open at this point.*

   Check with a continuity timing light. See next heading for procedures.

TIMING THE BREAKER POINTS TO THE MAGNETO

Timing the breaker points is adjusting them so they will open at the exact time the magnet is aligned with the coil for the greatest spark, when the piston is at the desired position.

There are two types of lights used for timing the breaker points: (1) **a continuity light** and (2) **a neon timing light.**

A continuity light (Figure 110) is a light similar to a flash light. It is wired so that when the circuit is broken, the light will go out. When the light is connected to the breaker points, you can tell when they first open. It must be used when the engine is stopped.

A neon timing light (Figure 111) is a specially designed neon light which flashes when the points open. With the flash directed to the timing marks you can tell if the points are opening at the proper time when the engine is running.

a. If you adjust the breaker-point timing with a **continuity light** (Figure 110), proceed as follows:

1. *Rotate the crankshaft by hand until timing marks are aligned (Figures 109 and 110a, inset).*

   Piston is at or near top-dead-center, compression stroke.

2. *Disconnect primary-coil lead wire at the terminal stud (Figure 110a).*

3. *Connect one alligator clip of the continuity light to ground—any convenient place on the crankcase.*

4. *Connect the other lead to the breaker-point terminal stud (Figure 110a).*

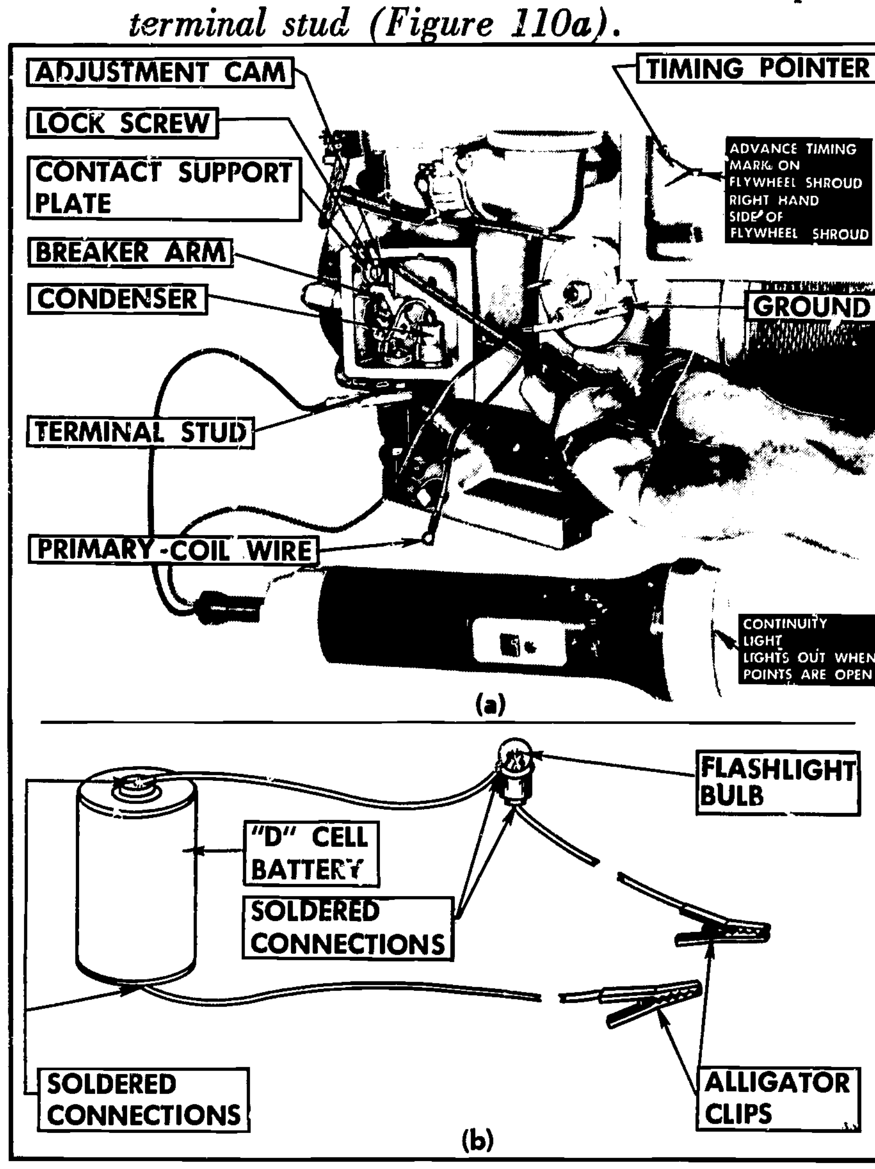

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FIGURE 110. Timing the magneto-ignition system with a timing light. (a) Static timing with a continuity light. (b) You can make a continuity light from a flash light battery and bulb.

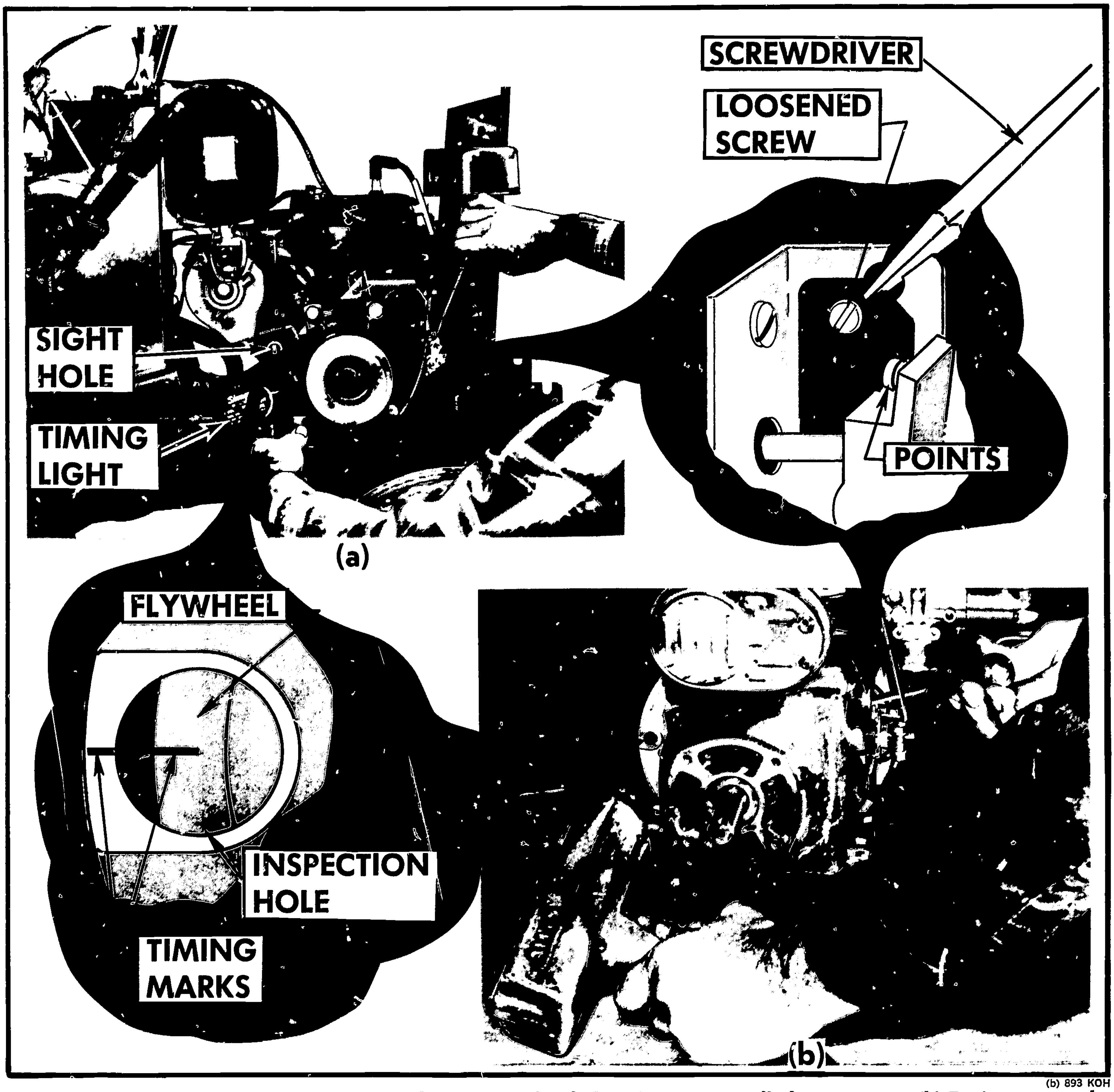


FIGURE 111. Checking the ignition timing with a neon timing light. (a) Engine installed on a tractor. (b) Engine mounted on a test stand.

5. *Loosen breaker-point lock screw and retighten snugly.*

   Tighten enough so the plate can be moved for adjustment but will still hold without slipping.

6. *Adjust points so that the light will just go out.*

7. *Tighten points.*

8. *Check adjustment.*

   This is done by rotating the flywheel backwards—opposite from normal direction of rotation—until the light comes on again. Then rotate the flywheel forward until the light goes out. The timing marks should be aligned. If they are not, readjust the points and recheck.

9. *Remove continuity light and reconnect primary lead.*

b. If you adjust the breaker-point timing with a **neon timing light** (Figure 111), proceed as follows:

1. *Adjust points to recommended gap at full open position.*

   Refer to "Adjusting the Breaker-Point Gap," page 62.

2. *Remove inspection plug or the flywheel shroud, if necessary, to see the timing mark on the flywheel (Figure 109c).*

   Remember this check will be made while the engine is operating. Most engines have a spark-advance mechanism. If so, there will be two timing marks: one for static timing—when the engine is not running—and one for timing while the engine is running. This is called the advance timing mark.

3. *Accent the advance timing mark with chalk so that it may be seen easily.*

   Refer to your service manual.

4. *Connect the neon timing light.*

   Connect one lead to ground and the other lead to the spark-plug terminal. Do not disconnect the spark plug.

5. *Start engine and operate it above 1,000* r.p.m.

6. *Direct the timing light on the timing mark of the flywheel.*

7. *Loosen and adjust the points until the timing mark on the flywheel and the one on the engine frame appear to be exactly in line when the light flashes.*

8. *Stop the engine.*

9. *Disconnect timing light.*

CHECKING AND ADJUSTING THE STATOR-PLATE (ARMATURE) AIR GAP

The stator-plate air gap is a space between the laminated-iron arms (yoke) of the coil and the rotating magnet (Figure 112). Since the yoke is known as "armature," "yoke heels" and "pole shoes," the air gap is sometimes referred to as "armature heel space," or "pole-shoe clearance." The closer the spacing (without the two members touching), the stronger the spark — more magnetic lines of force are cut.

Some engines have no provision for adjustment of the gap spacing (Figures 108a and 108c). While others do (Figure 108b).

There are three different types of armatures that can be adjusted: (1) the type which is located **outside the flywheel** (Figure 112a), (2) the type which is located **under the flywheel**, and (3) the type which is located **under the flywheel, but with a magnet in a rotor** which turns inside the stator plate.

Only stator plates with straight elongated mounting slots provide for air-gap adjustment. Those with curved (timing) slots provide for timing adjustment only.

When those without adjustment provisions get out of adjustment, it is usually caused by worn crankshaft bearings or a bent crankshaft.

a. If your **stator plate is located outside the flywheel (Figure 112a)**, proceed as follows:

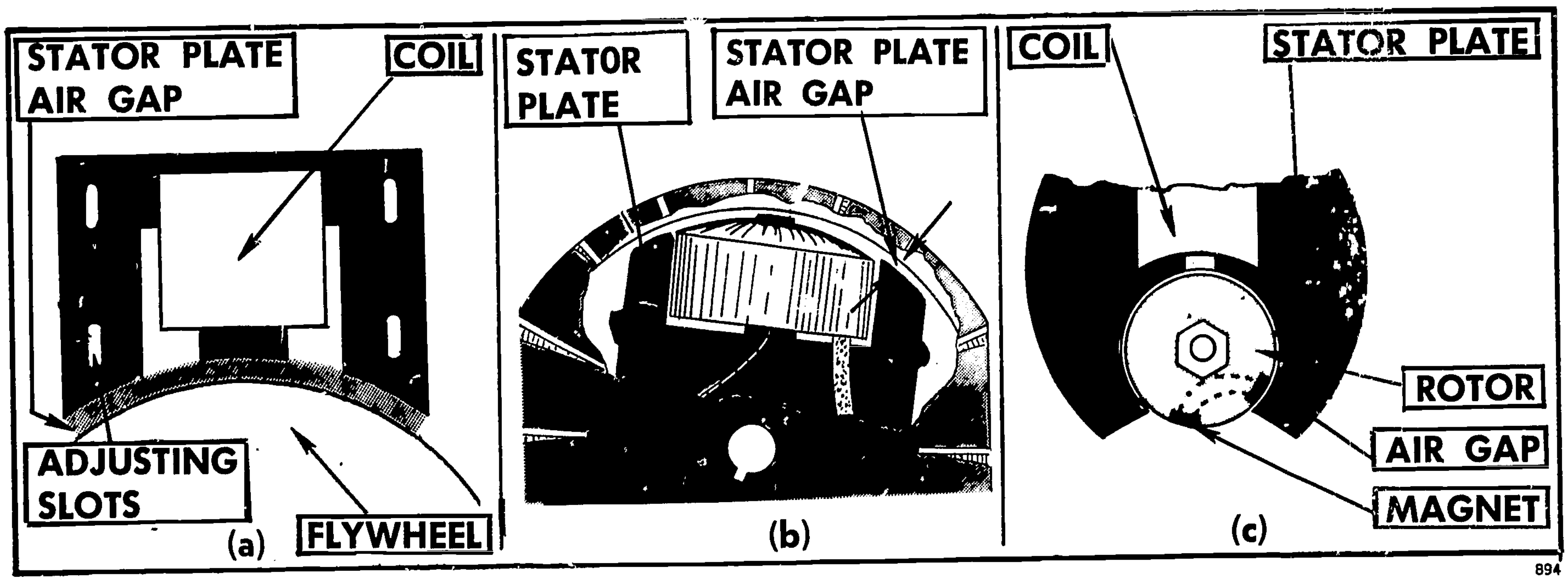


FIGURE 112. The stator-plate (armature) air gap is the clearance between the laminated iron arms and the rotating magnet. (a) Stator plate outside the flywheel. (b) Stator plate under the flywheel. (c) Stator plate under the flywheel with the magnets in a rotor which turns inside the stator plate.

1. *Check the clearance.*

   Use a feeler gage or postal card. The thickness of a postal card is within the range of .007″ to .012″, which is the recommended gap width.

   Rotate the flywheel as you check the clearance to make sure it is clear on all sides.

   If you use a **metal feeler gage,** check clearance at points away from the magnet. Otherwise, the magnet will attract the gage and give you a sense of binding when it is not.

   If the **air gap is correct,** proceed to checking the coil described under the next heading.

   If the clearance is **too little or too much and the stator plate is adjustable,** proceed to step 2.

   If the **air-gap clearance is not adjustable,** check the crankshaft and bearings.

2. *Adjust the clearance if possible.*

   (1) *Put a postal card, or a tag card, between the stator plate and the flywheel.*

   (2) *Turn flywheel by hand until magnet aligns with the armature.*

   (3) *Loosen the stator plate.*

   The magnetism will pull the stator plate against the magnets, thus closing the gap to the thickness of the card.

   (4) *Tighten the stator plate (Figure 113).*

3. *Remove the card.*

4. *Recheck the clearance.*

   The clearance should be accurate.

b. If your **stator plate is under the flywheel** (Figure 112b), proceed as follows:

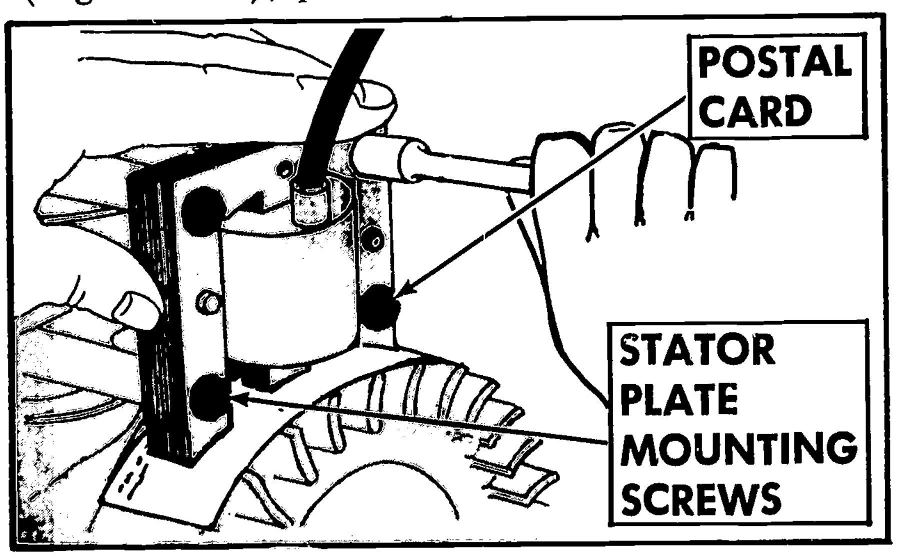


FIGURE 113. Adjusting the stator-plate air gap.

1. *Remove the flywheel if it is not already removed.*

   Refer to "Removing and Checking the Flywheel," page 55.

2. *Place a piece of electrician's tape on the inner rim of the flywheel.*

3. *Reinstall the flywheel.*

4. *Rotate the flywheel 10 or 12 times by hand to check for scuffing on the tape.*

5. *Remove the flywheel.*

6. *Check to see if the tape is scuffed.*

   If tape is scuffed, the clearance is too small. Adjust if possible.

   If tape is not scuffed, proceed to step 7.

7. *Add a second piece of tape to the rim of the flywheel.*

8. *Replace the flywheel.*

9. *Turn the flywheel 10 or 12 times by hand.*

10. *Remove the flywheel.*

11. *Check to see if the tape is scuffed.*

    If it is not scuffed, the clearance is too great. Adjust if possible as described in step 12. If not possible, check the crankshaft bearings.

12. *Adjust the stator plate.*

    Loosen the mounting screw and shift the stator plate up or down as needed.

13. *Recheck the clearance.*

c. If your **stator plate is located under the flywheel and the magnet is on a separate rotor** (Figure 112c), proceed as follows:

1. *Remove the flywheel if not already removed.*

   Refer to "Removing and Checking the Fly-

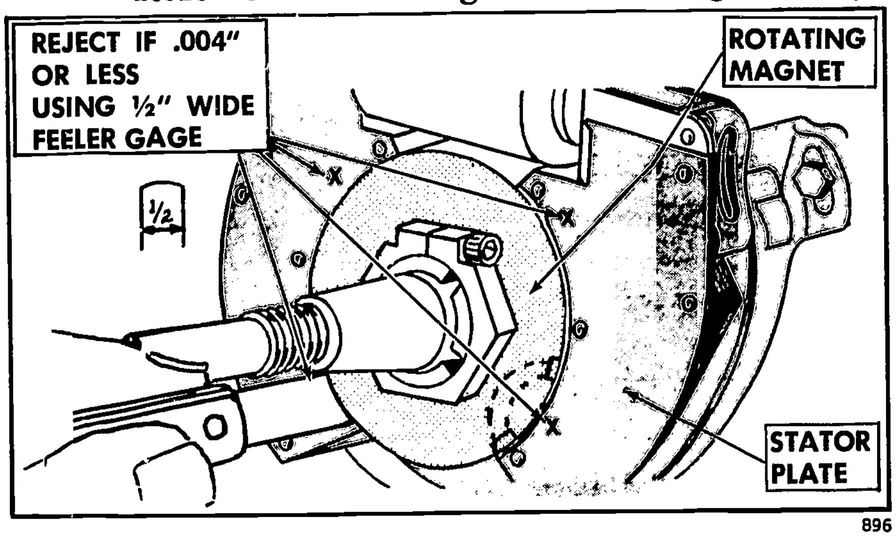


FIGURE 114. Check the stator-plate air gap in four places.

2. *Check the clearance (Figure 114).*

   Check in four different places as shown in Figure 114. Move the magnets away from the gage when checking. This is done by turning the crankshaft by hand. Removing the spark plug will make the crankshaft easier to t n because it relieves the compression.

   If the clearance is **too small** or **too large,** check the crankshaft and bearings. There is no adjustment on this type of stator plate.

CHECKING THE MAGNETO COIL

Magneto coils seldom give trouble. Consequently, you should make a thorough check of the remainder of the system before you decide to replace one. A weak spark, or no spark, at the spark plug may be due to a damaged or defective coil. The coil can usually be checked and tested without removing it.

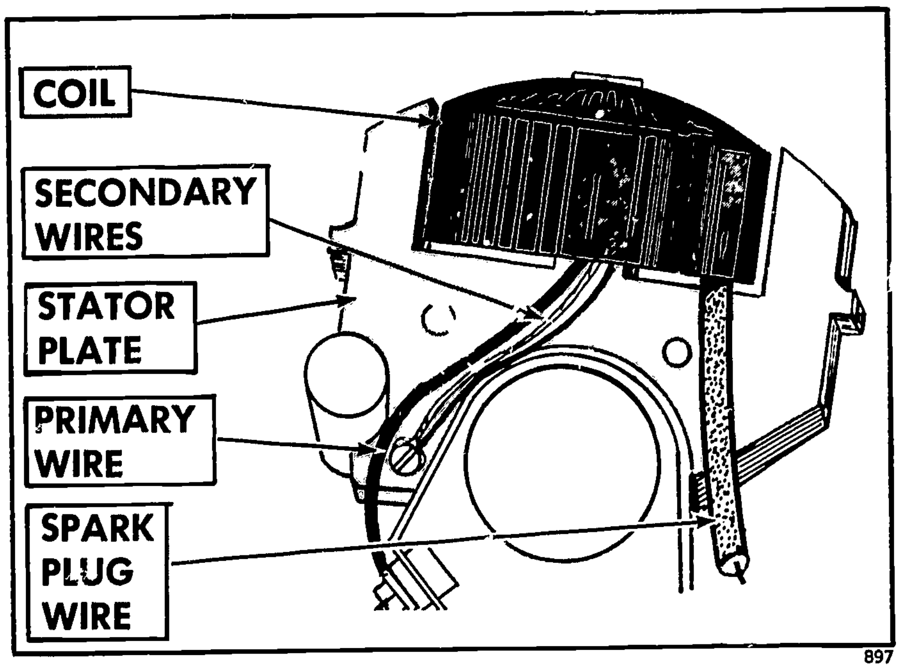


FIGURE 115. Make a thorough check of the coil, coil wires and connections before deciding to replace it.

1. *Inspect coil assembly for damage (Figure 115).*

   Look for cracks or gouges in the insulation, evidence of overheating or other damage. Make sure the electrical leads are intact, not shorted, and are tightly connected.

2. *Check coil spark.*

   a. If you have an **approved coil tester,** follow instructions given by the tester manufacturer and the specifications given for your coil. Examples of approved testers are shown in Figure 116. Check with the coil assembly installed on the yoke. If the coil fails to check out properly, it should be replaced.

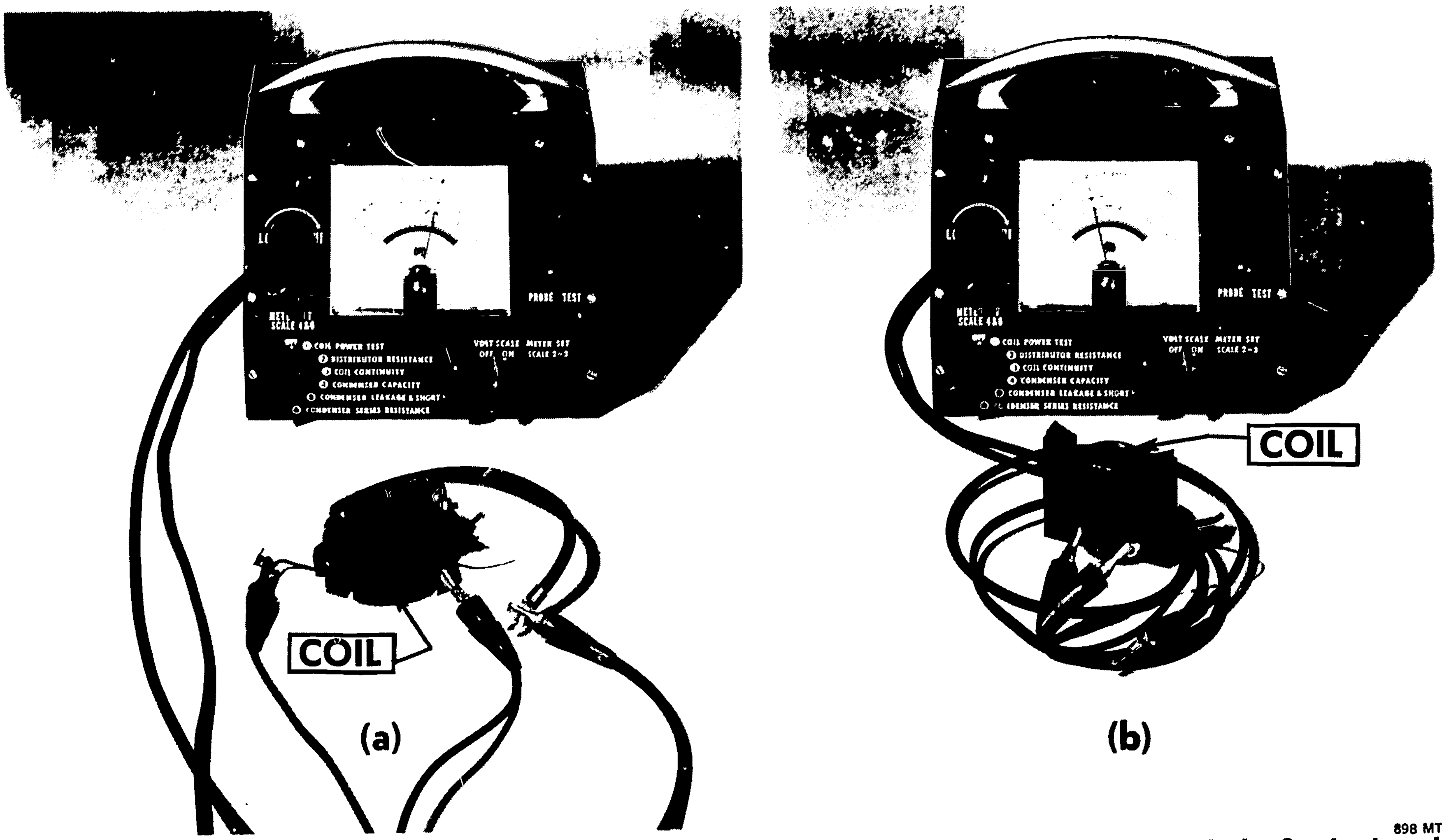


FIGURE 116. Testing coils. Hook up for testing a coil that is is designed for mounting (a) underneath the flywheel, and (b) outside the flywheel.

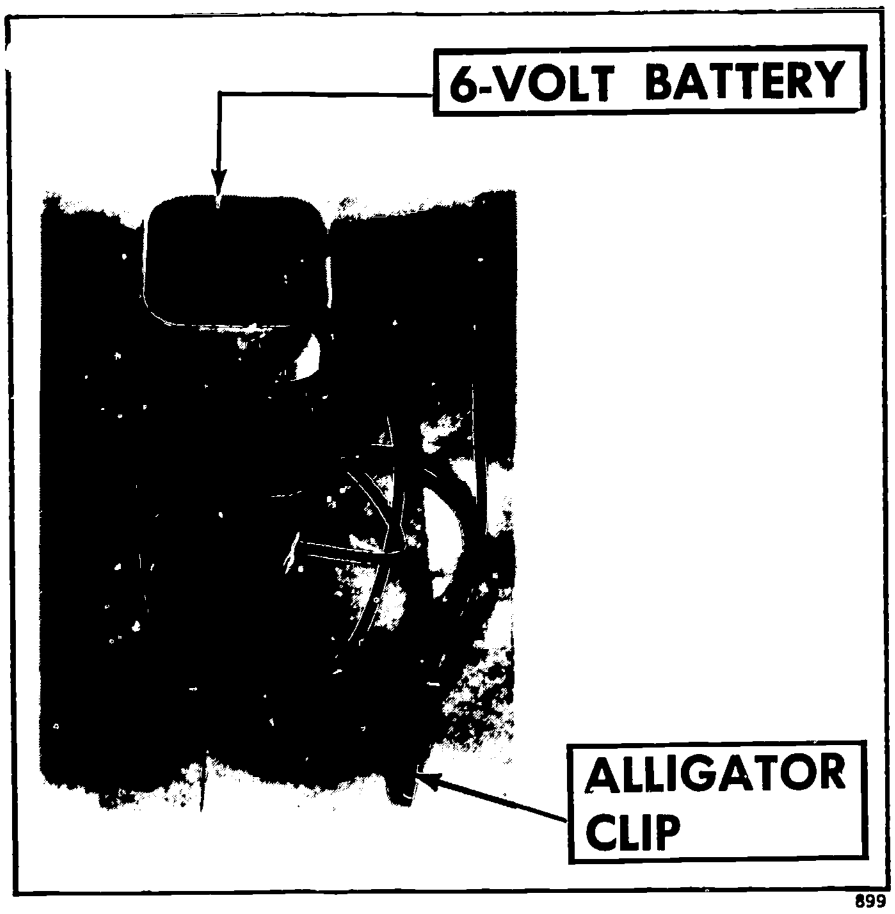


FIGURE 117. A 6-volt lantern battery rigged for checking coils.

CAUTION! Do not use a coil tester on a metal workbench. There is a danger of your getting shocked by the high voltage from the secondary coil carried by the metal in the bench.

b. If you **do not have a tester available,** the coil and ignition circuit can be tested with a **6-volt lantern battery** as shown in Figure 117. It is convenient to have an alligator clip on the end of one battery wire and a test prod on the end of the other wire. Continue with step 3.

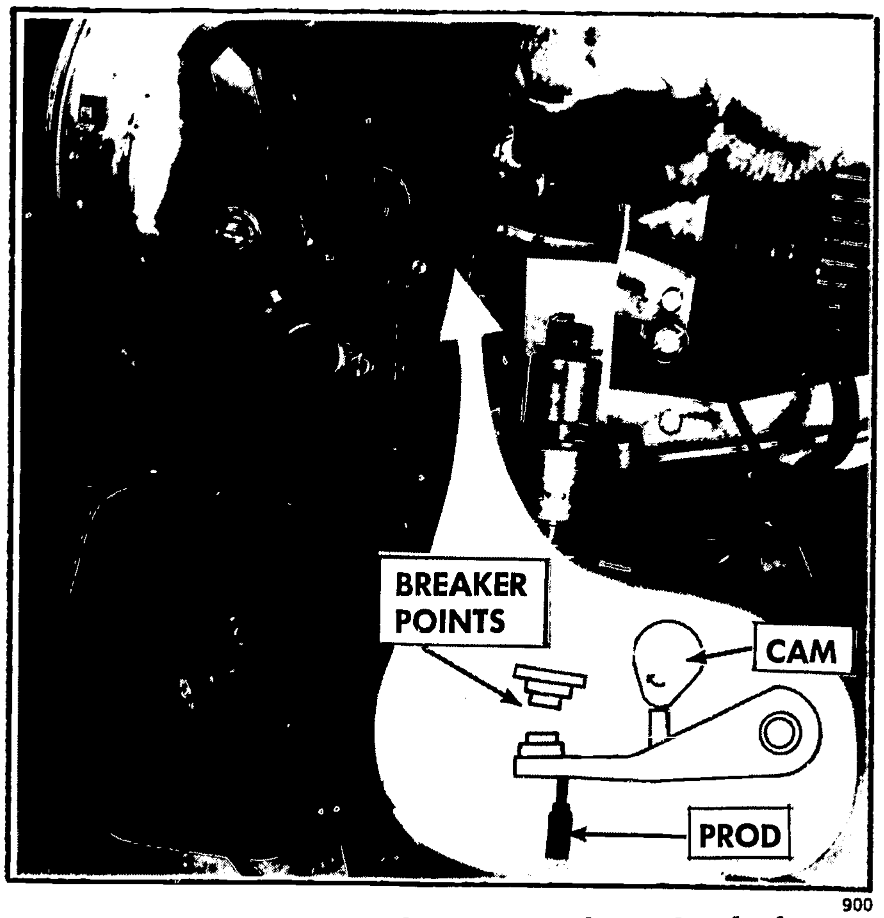


FIGURE 118. Checking the coil with a 6-volt lantern battery tester.

3. *Remove the spark plug and ground it on the engine as shown in Figure 118.*
4. *Connect the spark-plug wire to the spark plug.*
5. *Clip one battery wire to the engine frame.*
6. *Turn the engine until the points are fully open.*
7. *Strike the movable breaker-point arm with the test prod (Figure 118).*

You should get a strong spark at the prod. The spark is most intense when you touch the prod to the insulated point for a moment and then break the contact quickly. This is the same action as that when the engine is running.

What you are doing is energizing the primary circuit and building up a magnetic field in the coil. When you break this circuit by suddenly removing the prod, the primary field collapses. This induces a high voltage in the secondary and provides a spark at the spark plug. It also gives a momentary surge of current back through the primary circuit, thus causing a bright blue spark at the prod.

If you **get a good spark at the spark plug** when you scratch the prod on the insulated breaker point, with the points open, both the primary and secondary coil circuits are functioning properly. If you do not get a good spark at the spark plug, then examine the spark at the prod in an effort to pinpoint the trouble.

If you get **a bright blue spark at the prod,** this generally indicates that the primary circuit is all right, whether or not you get a spark at the plug. A bright spark at the prod means you are getting perhaps 200 volts there by self-inductance from the primary coil winding.

If you get **no spark at the spark plug,** do not conclude immediately that the coil is defective. It merely means that current is not going through the primary ignition circuit. There is an open circuit somewhere in the primary circuit.

Do not overlook the shorting wire that may be used to stop the engine. This wire may be grounded and shorting out the points continuously. The trouble may be in the electrical leads to the coil, such as in the **primary wire** leading from the points to the coil, in the

coil grounding wire, or in the **secondary wire** leading from the coil to the spark plug. Look for a poor connection or a break in the wire leading from the point assembly to the coil. A loose connection at the points where the coil winding is grounded will also prevent the current from flowing in the primary.

If *after rechecking the connections* you still get **no spark,** you may assume that the coil is bad. Have it checked at your dealer's before replacing it. Proceed with the steps under the next heading.

If you get a **weak spark at the spark plug,** most likely the insulated breaker-point assembly is grounded somewhere. This may be due to the lug on the wire, attached to the insulated breaker point, touching the frame, or to a break in the insulation on the wire leading from the point to the coil.

If you get a **weak spark at the prod**—one comparable to what you get by scratching the two battery leads together—it generally means that the insulated breaker point is grounded or there is a high-resistance ground somewhere in the primary circuit.

REMOVING AND REPLACING THE STATOR PLATE AND COIL

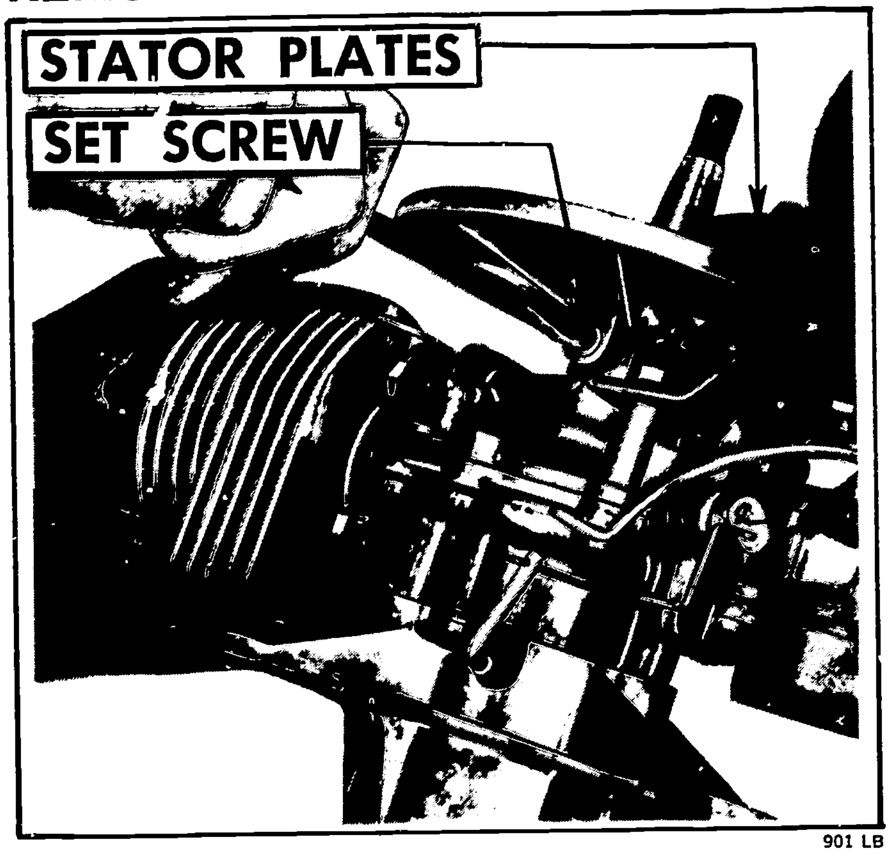


FIGURE 119. Some stator plates are held by a set screw.

1. *Mark the position of the stator plate on the crankcase (Figure 109) if it is not already marked.*

   Use a sharp chisel and mark both the stator plate and engine block. This is very important. It will save you from having to locate its proper timing position when replacing it.

2. *Disconnect the spark-plug wire at the spark plug.*

3. *Remove the spark-plug wire frame clamp if attached.*

   This is a clamp which holds the wire to the engine frame.

4. *Disconnect the primary-ground wire if attached.*

   This wire goes to the ignition switch.

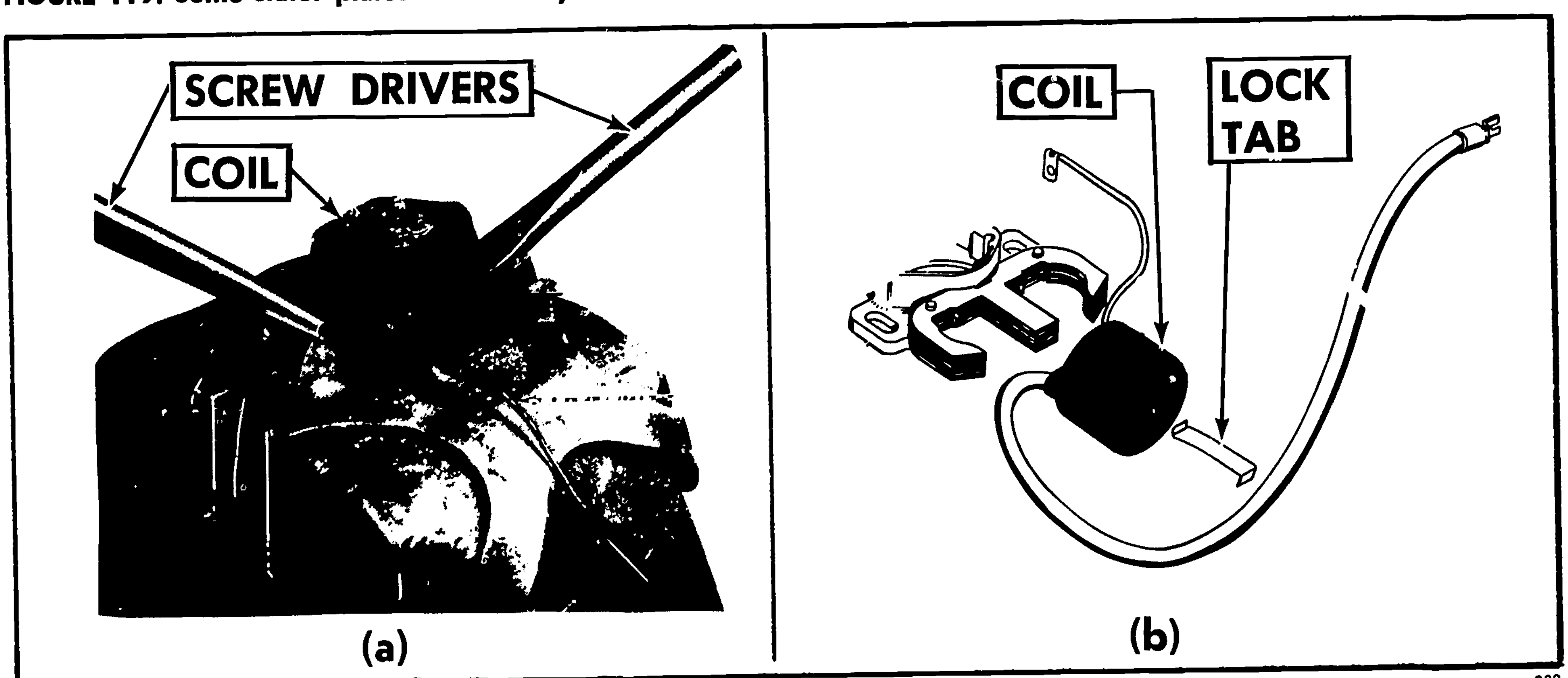


FIGURE 120. Most coils are removable from the iron core. (a) Removing a coil. (b) A coil removed.

5. *Loosen or remove the screws holding stator plate (Figures 108 and 119).*

6. *Remove magneto coil.*

   Most coils are removable from the iron core (Figure 120).

7. *Replace coil and stator plate, using reverse procedures.*

INSTALLING THE FLYWHEEL

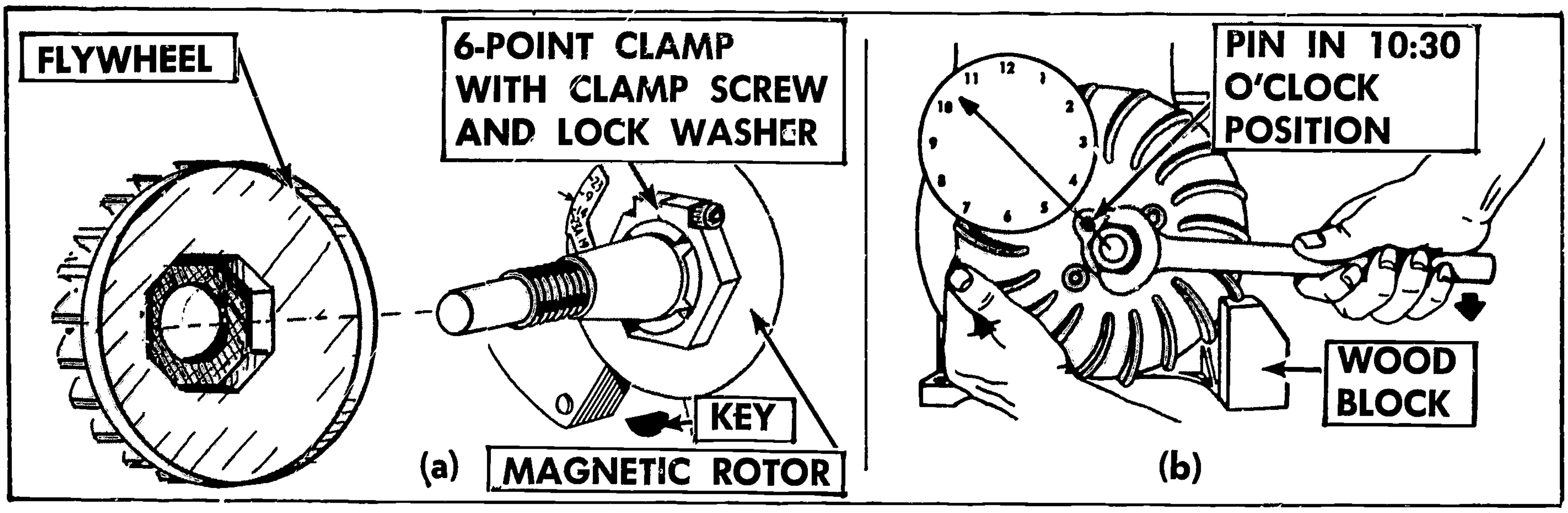


FIGURE 121. A flywheel that is not keyed directly to the shaft. (a) Six-point clamp acts as a flywheel locking device, and (b) starter pin is aligned to the 10:30 o'clock position.

1. *Check all electrical connections.*

   Make sure no wires are pinched and that connections are tight.

2. *Recheck to see that all nuts, screws and bolts under the flywheel are tight.*

3. *Remove all dust, grease and foreign particles from inside the magneto and breaker points.*

   Use denatured alcohol to clean the points. It will clean oil from the contacts.

4. *Install washer if applicable.*

   Some have a spacer washer.

   Some have a concave washer. If the nut is not tight, the key will shear.

5. *Install flywheel.*

   Most flywheels are keyed onto the crankshaft, and there is only one way to put them on.

   If your engine has a **magnetic rotor** under the flywheel (Figure 121a), there may be several positions in which the flywheel will fit. If your engine is of this design (Figure 121a), check the service manual before installing the flywheel. Some specify aligning the starter pin to the 10:30 o'clock position (Figure 121b).

7. *Install starter pulley if applicable.*

   Refer to "Repairing Starters," page 8.

8. *Install lock washer.*

9. *Install retainer bolt and tighten.*

   See your service manual for the proper torque. Do not tighten too much.

   If you use a **lock washer,** turn the nut until the lock washer flattens.

10. *Check crankshaft end play (Figure 122).*

    Correct end play varies from .002″ to .019″. You can get some idea if it is too little or too

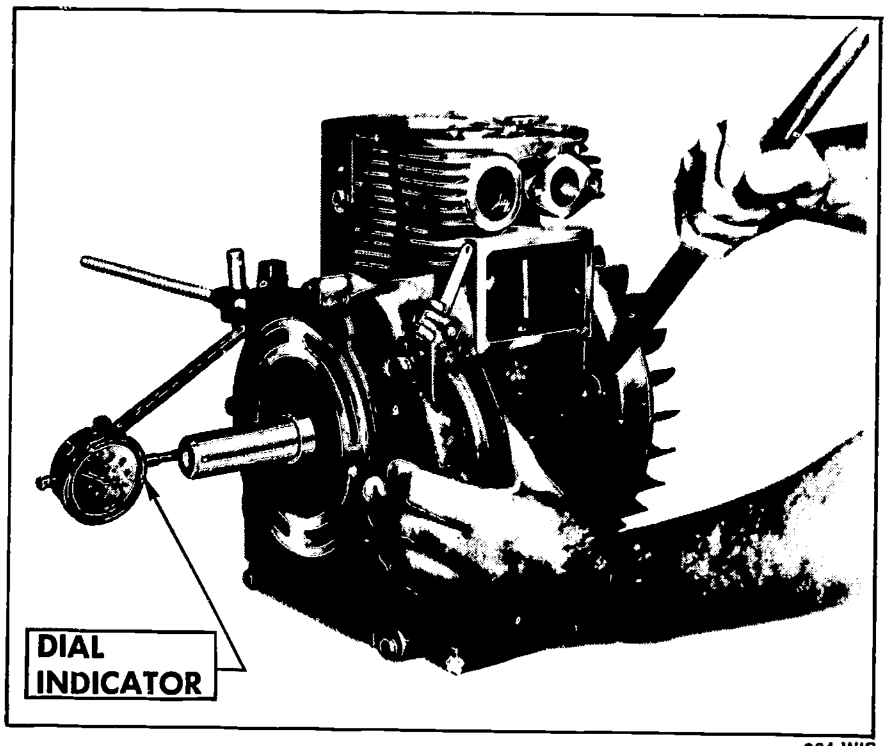
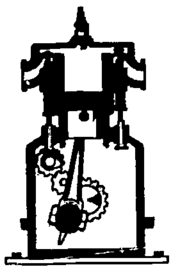


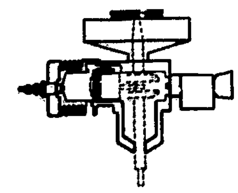
FIGURE 122. Checking the crankshaft end play with a dial indicator.

much by feel, but the best way to check it is by the use of a dial indicator as shown in Figure 122.

See your service manual for directions on adjusting end play. Some use shims or gaskets under the bearing plate. Some are not adjustable. Adjustments are described under "Repairing Crankshaft Assemblies," page 174.



B. MAINTAINING AND REPAIRING BATTERY-IGNITION SYSTEMS



Many small engines come equipped with a battery ignition instead of a magneto ignition. Since a battery and generator are necessary for self-contained electric starting, it is a simple matter to equip the engine with an ignition powered by the battery and generator. This is accomplished by the installation of a few additional parts (Figure 123) to the battery-generator system.

PRINCIPLES OF OPERATION

The battery-ignition system differs from the magneto-ignition system in two ways. They are as follows: (1) **current is supplied** to a spark coil *from the battery and/or the generator rather than a magneto,* and (2) the **ignition switch must be closed** in the battery system for current to flow through the coil. (The switch must be open in the magneto system.) The function of the ignition system is the same — to produce a hot spark at the plug, and at the right time for igniting the fuel. See "Maintaining and Repairing Magneto and Solid State Ignition Systems," page 47.

Here is how the battery-ignition system works (Figure 123.)

- With the ignition switch closed (Figure 123a), *current flows from the battery or generator to the primary winding* of the coil, and through the closed breaker points to ground.
- At the right moment, when the piston is just before top-dead-center (compression stroke), the breaker points are opened by a cam, or push rod.
- When the points are opened (Figure 123b), the primary *electric circuit is broken* and the magnetic field breaks down.
- *The magnetic lines of force cut across the conductor (coil) and a high voltage is induced in the secondary winding* because it has many more turns of wire than the primary.
- *A spark occurs at the spark plug* which is in the secondary circuit. The high voltage developed in the secondary coil causes the current to jump across the spark-plug electrode gap, thus making the spark.
- *The residual current in the primary winding is taken up by the condenser (Figure 82).* It eliminates arcing at the points and aids in producing a stronger spark at the spark plug.

Maintaining the battery-ignition system is very much the same as maintaining the magneto-ignition system. For procedures, refer to the appropriate heading under batteries, generators and magneto-ignition systems.

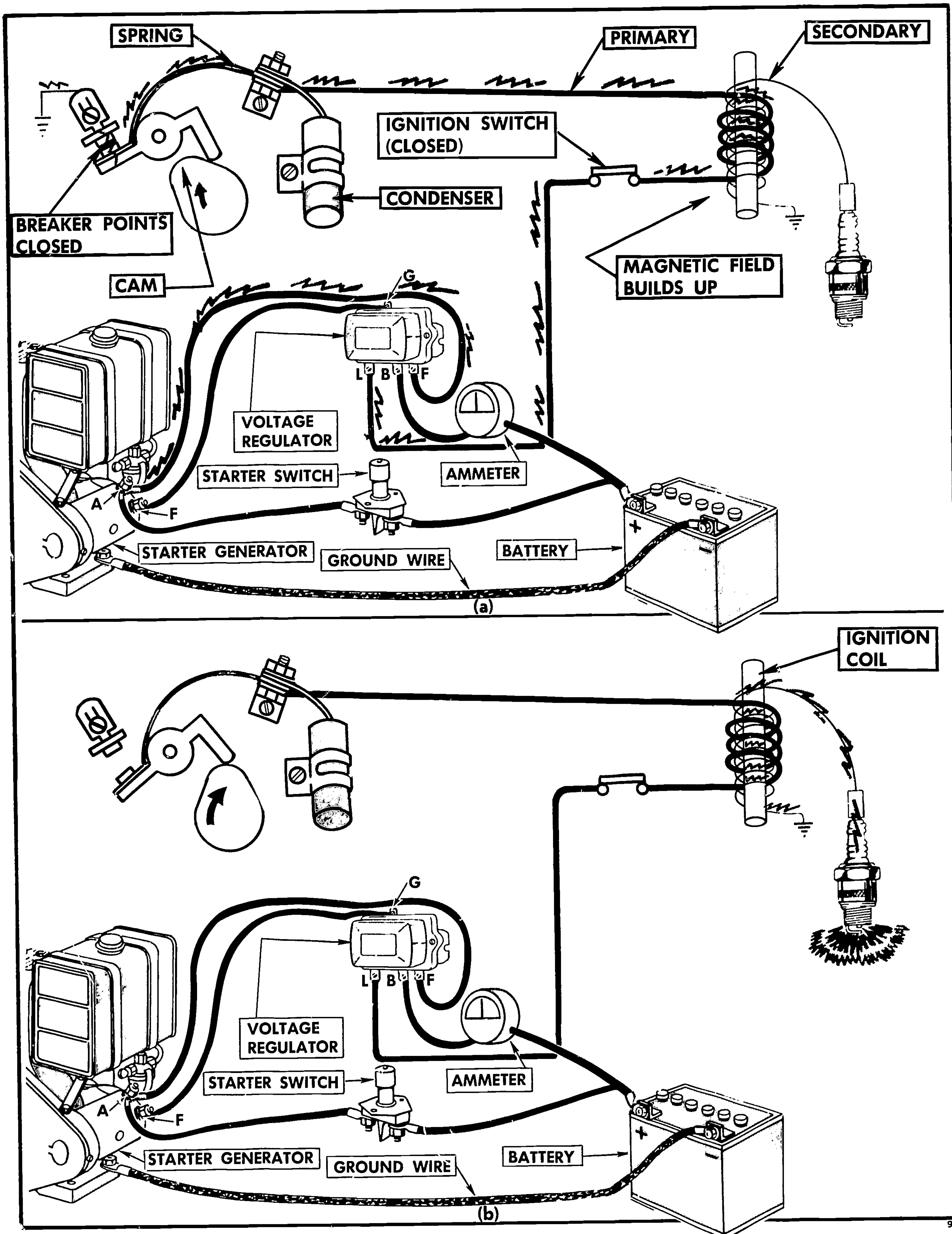
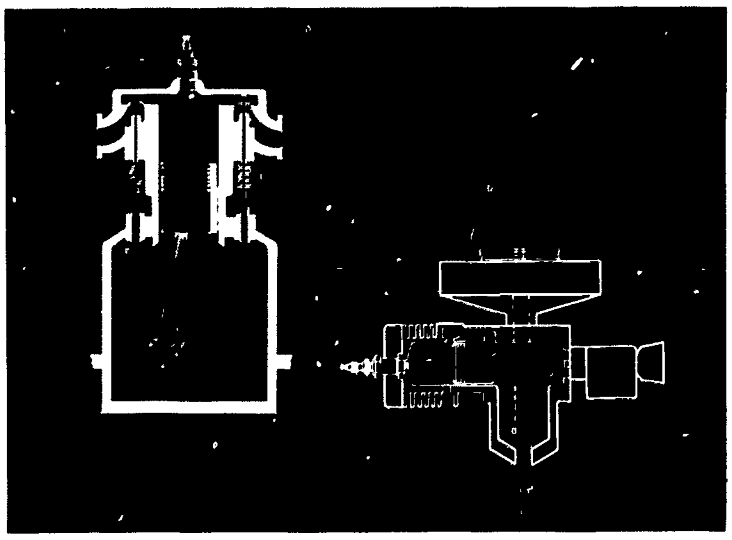


FIGURE 123. Operating principle of a battery-ignition system. (a) Breaker points closed. Current flows from battery through points to ground. Electromagnetic lines of force develop around the ignition coil. (b) Points open. Magnetic lines of force collapse. High-voltage current, induced in the secondary coil, jumps the gap at the plug, thus causing a spark.



III. REPAIRING FUEL SYSTEMS

You will probably experience more trouble with the fuel system than with any other system on your small engine. But most of the trouble is minor and can be corrected easily. For example, a common problem is attempting to start the engine without fuel in the tank. Another one is failing to open the fuel shut-off valve in the supply line. Such troubles are the fault of the operator and are easily corrected.

Failure to perform some maintenance jobs, however, can result in more serious troubles. For example, **trash, flakes of rust or gum** in the fuel tank and supply lines restrict the flow of fuel. This causes intermittent operation, such as popping and skipping of your engine. Or, it may cause the engine to stop. **An air leak on the suction side of the fuel line may also cause it to stop.**

If the *carburetor is out of adjustment,* it may result in either **too rich or too lean a mixture of fuel.** *Too rich a mixture* (too much fuel for the amount of air) allows liquid gasoline to wash down the cylinder walls, thus resulting in poor lubrication. The fuel-air mixture also fails to burn completely and leaves carbon deposits in your engine. These carbon deposits develop "hot spots." These hot spots will cause preignition — fuel ignited before the piston reaches the desired position during the compression stroke (Figure 124a). This can cause knock, loss of power, scoring and scuffing of the cylinder

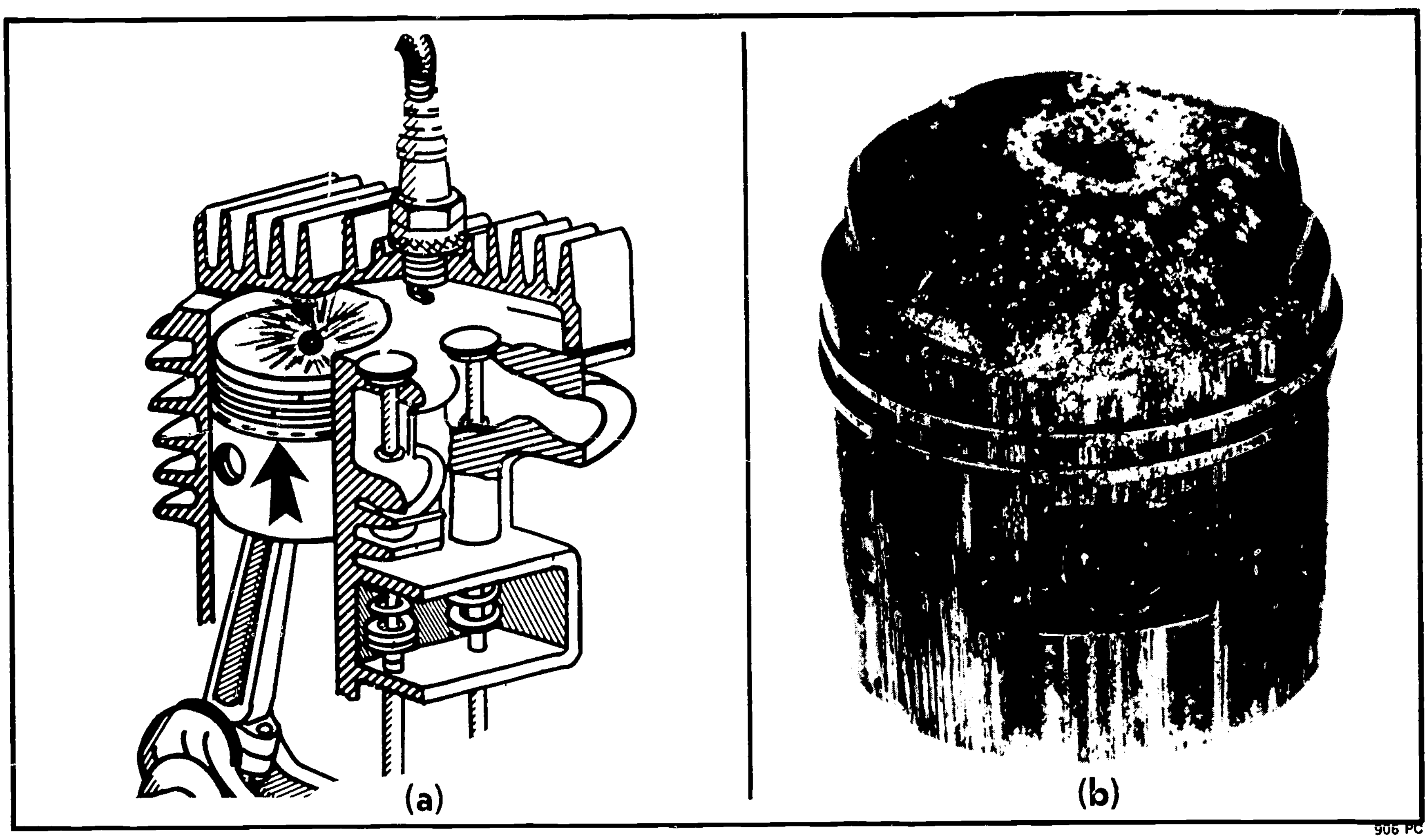


FIGURE 124. (a) Preignition is ignition taking place before time for the spark plug to fire. One cause is glowing carbon spots or high temperature buildup in the combustion chamber. (b) Piston damage caused by preignition knock.

and piston walls, and damage to the piston (Figure 124b).

Too lean a mixture (too little fuel for the amount of air) burns more slowly and at a higher temperature. This high temperature raises the temperature of the pistons, rings and valves. The oil may break down on the cylinder wall, and scuffing and scoring will occur (Figure 125). Valve stems stick, and valve faces and seats burn.

FIGURE 125. Piston scored by continued operation with too lean a fuel mixture.

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FUNCTIONS OF THE FUEL SYSTEM

The purpose of the fuel system **is to provide a constant supply of clean fuel and air to the combustion chamber.** The fuel-air mixture must be of *sufficient quantity* and of the *proper proportion* to meet the demands of your particular engine under all conditions. The proportion of fuel-to-air varies with the load being put on the engine.

The fuel system must perform its functions, regardless of constantly changing atmospheric pressure, humidity (moisture in the air) and the outdoor temperature.

The *principal parts of the fuel system and their functions* are as follows:

- A **fuel tank assembly,** which serves as a fuel reservoir.
- A **carburetor,** which provides the proper mixture of fuel and air.
- A **fuel pump,** on some engines, which provides fuel under pressure (higher than atmospheric) to the carburetor. On most small engines fuel is provided to the carburetor by gravity feed.
- **Screens and strainers** in the fuel tank, between the tank and the carburetor, which help provide clean fuel.
- The **carburetor air cleaner,** which cleans the air going into the carburetor. See "Servicing Carburetor Air Cleaners," Volume I, for complete explanation.

TYPES OF FUEL SYSTEMS AND HOW THEY WORK

There are *three types of fuel systems* used on small engines: (1) **gravity-feed** (Figure 126), (2) **pressure-feed** (Figure 127), and (3) **suction-feed** (Figure 128).

The **gravity-feed fuel system** has the fuel tank mounted above the carburetor, and fuel flows by gravity to the carburetor (Figure 126).

The **pressure-feed fuel system** may have the fuel tank mounted either above or below the carburetor. A **fuel pump** is installed between the tank and the carburetor to supply fuel to the carburetor under pressure — above atmospheric pressure (Figure 127). A mechanically driven diaphragm-type pump is used. It is the same type that is used on automobiles and tractors. Figure 127 shows how it works.

A *differential-pressure-driven diaphragm-type fuel pump* is used on engines that may be operated at extreme angles, such as on chain saws. This type pump is usually incorporated in the carburetor. It is explained under "Types of Carburetors and How They Work," Volume I.

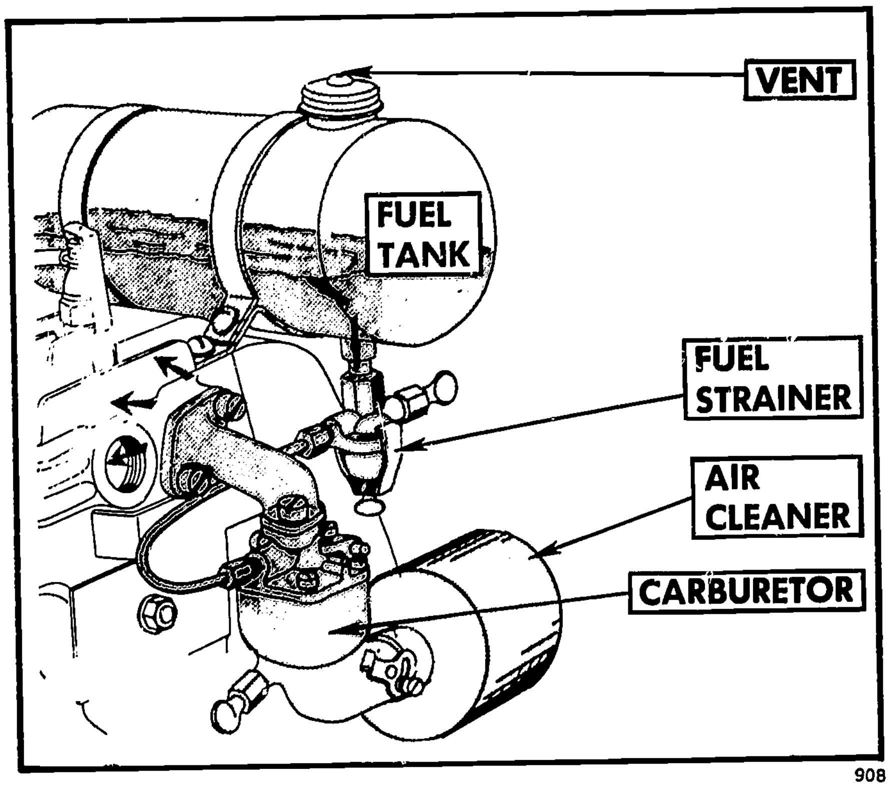


FIGURE 126. A gravity-feed fuel system. Fuel flows by gravity — its own weight — to the carburetor.

In the **suction-feed fuel system** fuel is drawn directly from the fuel tank into the low-pressure area (suction) developed in the carburetor (Figure 128). How the low-pressure area is developed is described under "Repairing Carburetors," page 86. Air is drawn through the carburetor by the engine suction — the partial vacuum created by the downward movement of the piston. As the air passes the venturi section of the carburetor, a suction is created that draws the fuel from the fuel tank.

The *fuel tank* is mounted below the carburetor. Sometimes it is attached to the carburetor and takes the place of the carburetor storage bowl.

A *foot valve* in the bottom of the tube keeps the fuel from running back. This keeps the tube full of fuel at all times.

Maintaining and repairing fuel systems are discussed under the following headings:

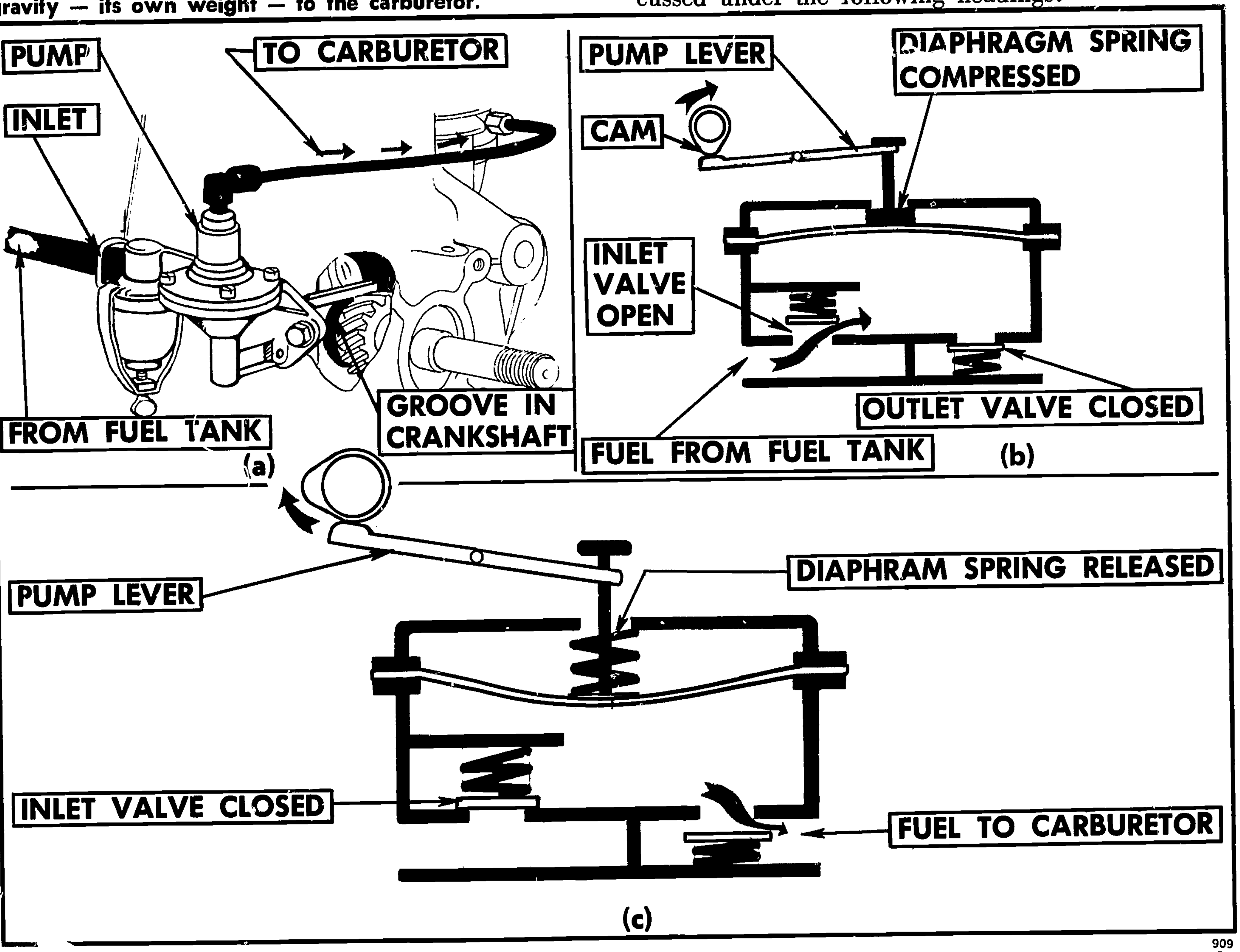


FIGURE 127. A pressure-feed fuel system. (a) A diaphragm-type fuel pump is operated from a cam on either the crankshaft or the camshaft. (b) and (c) Cut-a-way of a diaphragm fuel pump showing how it operates. (b) When the cam turns, it presses the pump lever. The lever raises the diaphragm. A partial vacuum is created in the pump chamber. The inlet valve opens and fuel flows into the pump chamber from the fuel tank. (c) When the cam releases the pump lever, spring tension forces the diaphragm in the opposite direction. The inlet valve closes and the outlet valve opens. Fuel is pumped to the carburetor.

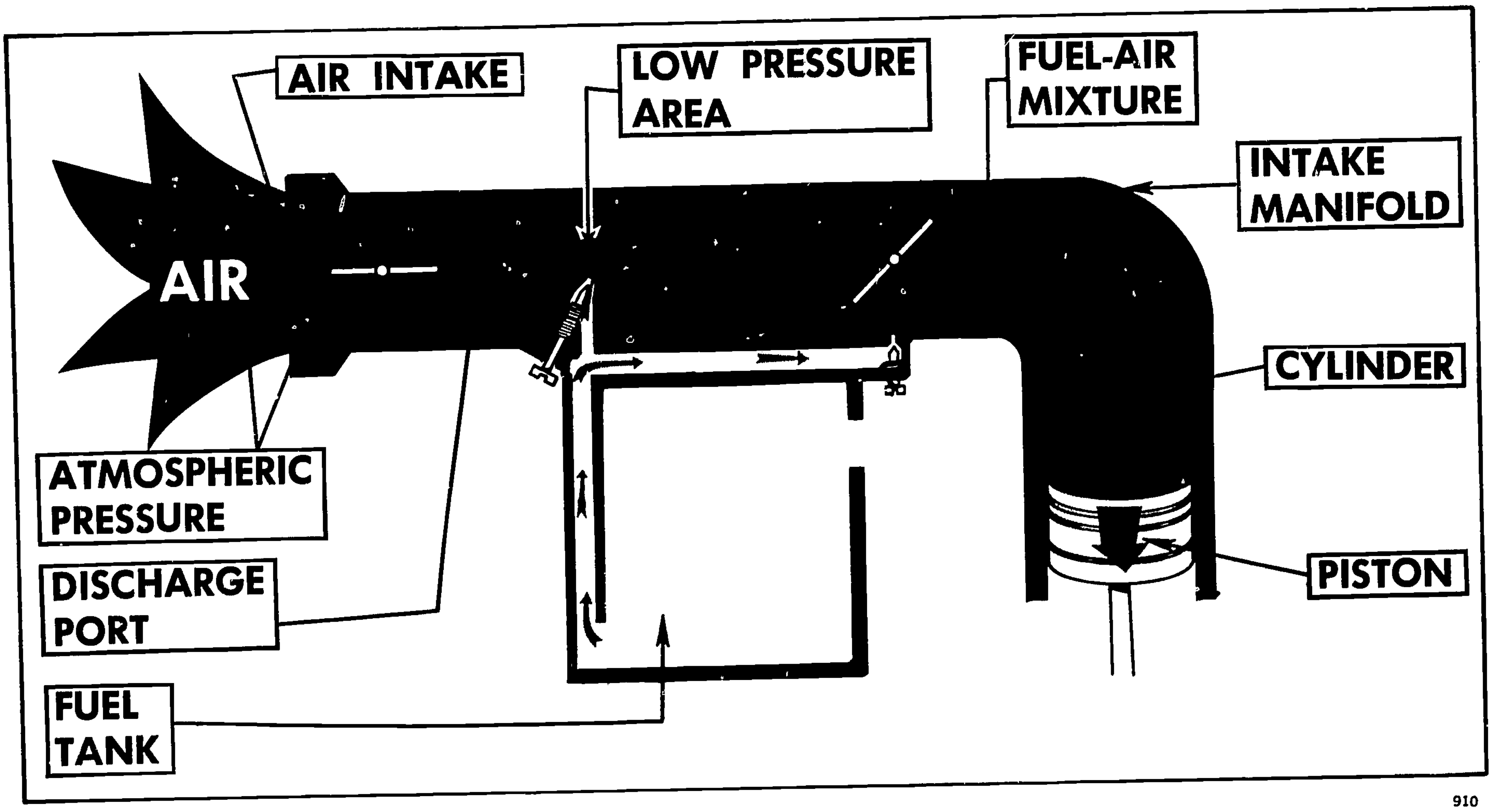
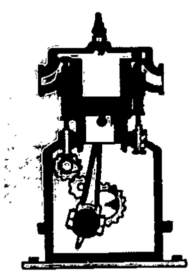


FIGURE 128. Principle (schematic) of a suction-feed fuel system. As the engine piston moves down, a vacuum tends to develop in the cylinder. Atmospheric pressure forces air through the air intake, past the fuel port and through the intake manifold to the engine cylinder (combustion chamber). As the air passes the fuel port, fuel is drawn in and mixed with the air.

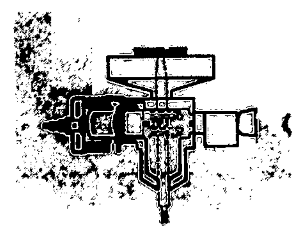
A. Repairing fuel-tank assemblies.

B. Repairing fuel pumps.

C. Repairing carburetors.



A. REPAIRING FUEL TANK ASSEMBLIES



The fuel tank on your small engine serves other functions in addition to providing a readily available source of fuel (Figure 129).

Fuel tank assemblies provide for:

- A *fuel reservoir* — some are separately mounted, while others are connected directly to the carburetor (Figure 130).
- *Venting the fuel tank* to atmospheric pressure.
- *Fuel strainers* for filtering out trash and dirt.
- *A fuel shut-off valve* — on most assemblies.

The primary function of the **fuel tank** is to *provide a reservoir of gasoline on or near the engine.* The *size of the tank* is determined by the size and use of the engine. For example, the average lawn can be mowed with a quart of gasoline. Therefore, a large tank is not necessary on a small lawn mower, while a small tractor can use a tank of several quarts capacity to advantage.

The *shape of the tank* may be determined by the design of the equipment. It may be molded for compactness, appearance and convenience.

Tanks are made from untreated steel, galvanized steel, annodized steel, nylon, plastic and other materials. Rust is a problem in non-treated steel tanks.

All tanks have a **vent** — usually the vent is in the cap (Figure 129b). This is to provide for atmospheric pressure to enter the tank and push the fuel through the carburetor into the engine. Otherwise, a partial vacuum would form in the tank and fuel would not flow.

Here is how it works. As a vacuum is developed in the tank, the poppet valve is forced down, and air enters the tank as shown in Figure 129b. If the tank is tilted or turned upside down, gravity plus the pressure of the fuel against the poppet valve closes it. This prevents fuel from leaking through the vent.

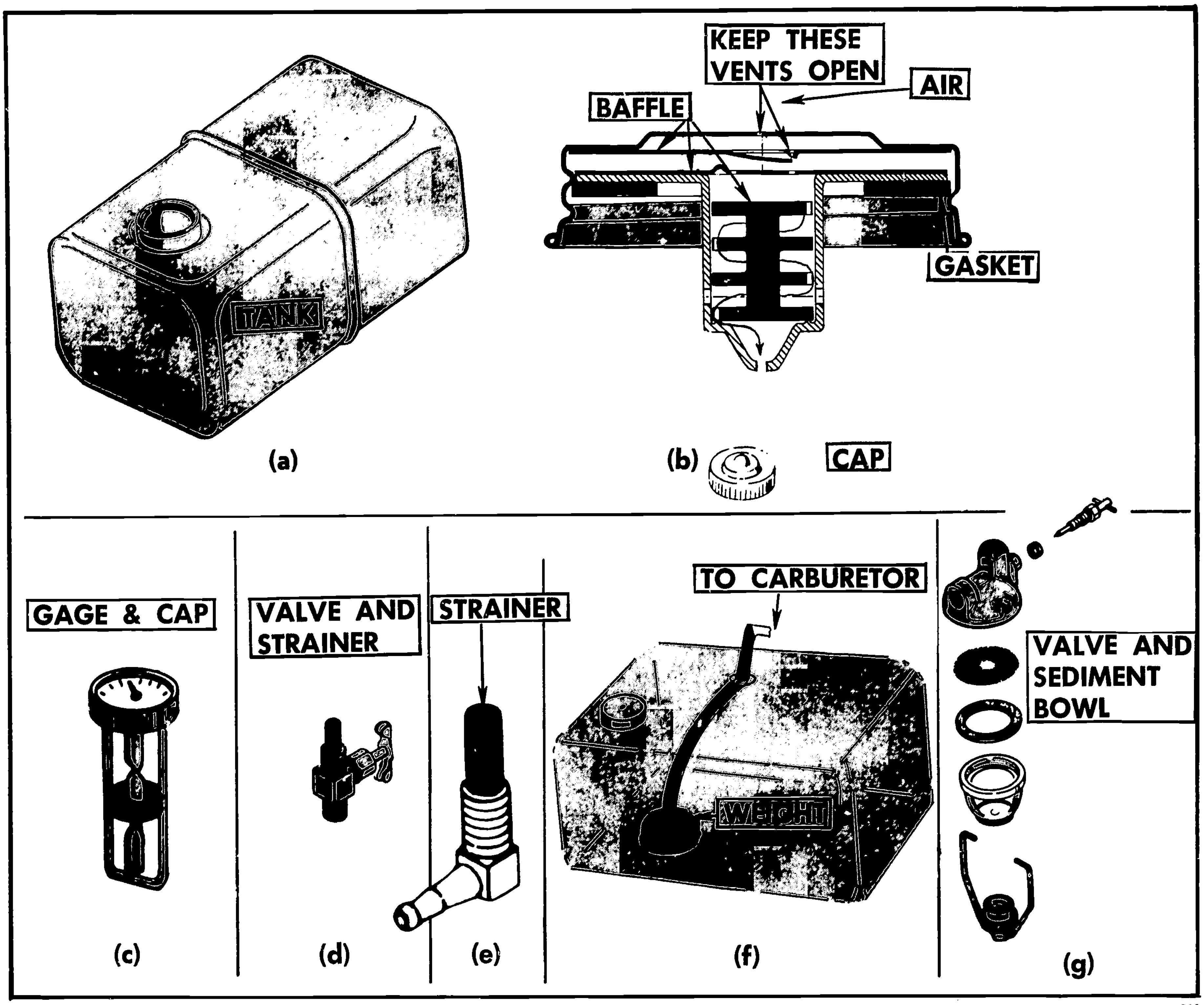


FIGURE 129. A typical fuel tank and accessories. (a) Tank. Supply line accessories may consist of (b) vented cap, (c) combination cap and gage, (d) combination shut-off valve and fuel strainer, (e) fuel strainer and fitting, (f) fuel strainer mounted on the end of a flexible hose, or (g) combination fuel shut-off valve, fuel strainer and glass sediment bowl.

Tanks on chain saws, and other applications of extreme angle operation, have a flexible fuel pick-up line (Figure 129f) with a weight on the end. It shifts to the low side of the tank, as the position of the engine is changed, and remains submerged in the fuel.

Some tank caps are equipped with a quantity gage in addition to the vent (Figure 129c).

Most gravity-feed and pressure-feed fuel tanks have a **strainer** at the bottom (Figure 129d and 129e). It collects dirt and trash. One tiny speck of dirt can clog a carburetor adjusting valve.

As part of the strainer assembly, most tanks have a **fuel shut-off valve** (Figure 129d). This provides for draining the fuel from the carburetor and supply line.

A combination fuel strainer, shut-off valve and sediment bowl is used on many small engines. This combination provides the surest method for preventing trash, dirt and water from entering the carburetor. Water, being heavier than gasoline, settles to the bottom of the sediment bowl along with dirt particles.

Maintaining and repairing fuel tanks is discussed under the following headings:

1. Tools and materials needed.
2. Checking and cleaning the fuel tank.
3. Repairing leaks in the fuel tank.

TOOLS AND MATERIALS NEEDED

1. Open-end wrenches — 7/16″ through 9/16″
2. Slot-head screwdriver — 6″ regular
3. Clean rags
4. Petroleum solvent (mineral spirits, kerosene, or diesel fuel)
5. One-foot length of wire — approximately 14 gage
6. Fuel container

CHECKING AND CLEANING THE FUEL TANK

1. *Determine if carburetor must be removed with tank.*

   If your carburetor is **mounted directly on the fuel tank,** as the one in Figure 130, you will have to remove the carburetor. See "Removing the Carburetor," page 86.

2. *Drain the fuel from the tank.*

   If the tank **has no fuel shut-off valve,** tilt the engine and pour the fuel out the filler hole.

   If the tank **has a fuel shut-off valve,** close it. Disconnect the fuel line from below the fuel shut-off valve, and drain the fuel from the tank. Large engines, and those mounted on heavy equipment, have fuel shut-off valves.

3. *Remove the fuel strainer.*

   If the strainer is **similar to the ones in Figure 129d and 129e,** unscrew the fitting from the tank.

   If the strainer is **on the end of a flexible pipe** fish it out with a wire hook.

   If you have a **sediment bowl and strainer,** see "Servicing the Sediment Bowl Type of Fuel Strainer," Volume I.

   Refer to "Servicing Fuel Strainers," Volume I, for more information on fuel strainers.

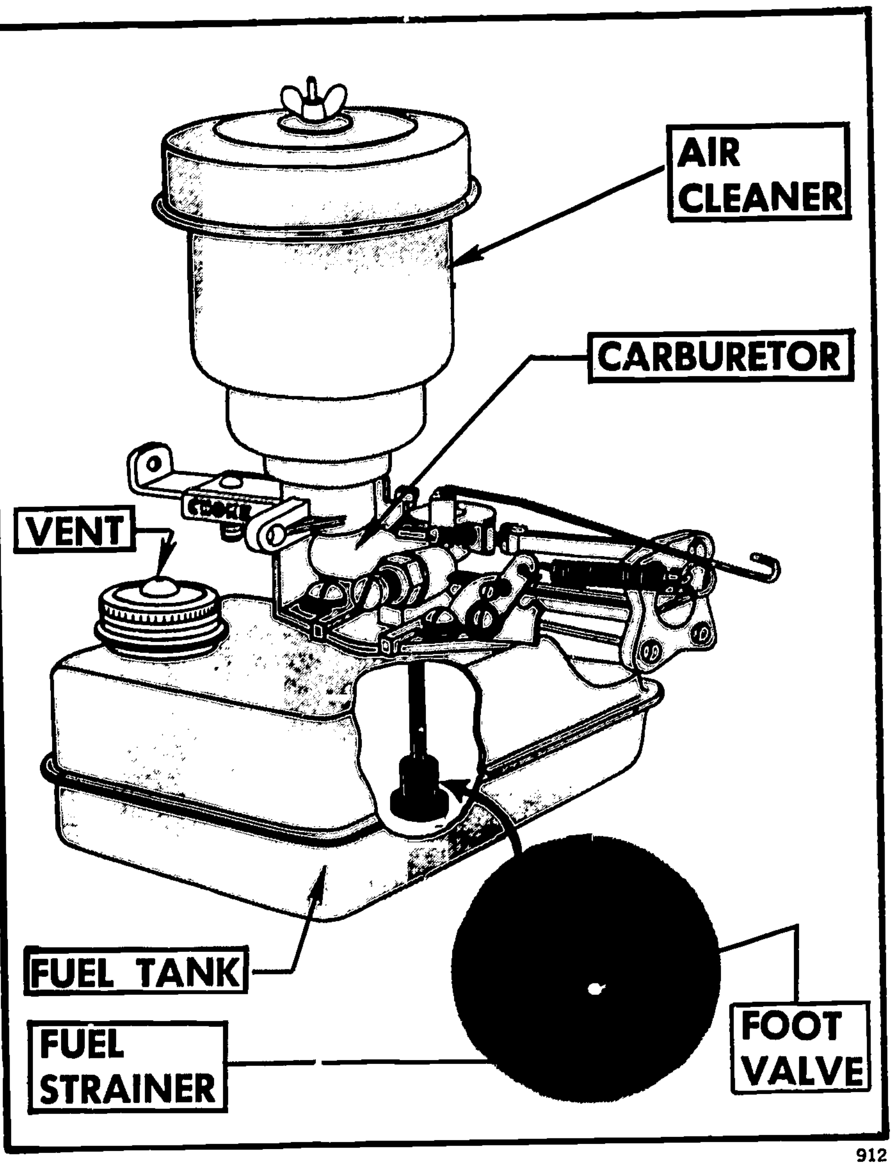


FIGURE 130. A fuel tank serving as a carburetor fuel reservoir.

4. *Remove the tank.*

   Most tanks are held by capscrews.

5. *Clean the tank strainer and fuel lines in petroleum solvent.*

6. *Inspect tank for damage and wear.*

   If you have a **steel tank,** small leaks can be soldered. See next heading for procedures.

   But usually if the leak is due to rust, the tank is too corroded to repair. Replace it with a new one. There is little you can do to repair **aluminum** and **plastic** tanks.

7. *Reinstall the strainer.*

   If your tank is to be repaired for leaks, leave the strainer out until the leak has been repaired.

REPAIRING LEAKS IN THE FUEL TANK

If you have a **steel tank,** you can solder it.

1. *Remove the tank (if not already removed).*
2. *Soak the tank in water to remove liquid fuel and gas fumes.*

   Fill the tank with water and let it stand a few minutes.

   CAUTION! Never apply heat to a tank that has gas fumes inside it. It will explode.

3. *Clean and solder the hole.*

   Use a 40 - 60 lead solder.

4. *Fill tank with water and recheck for leaks.*

5. *Drain tank and dry as soon as possible to prevent rust.*

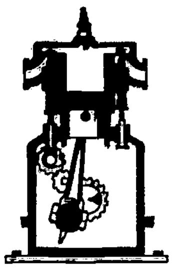
   Use forced air if available. Keep tank in a place where dirt and trash will not get inside it.

6. *Repaint outside of tank.*

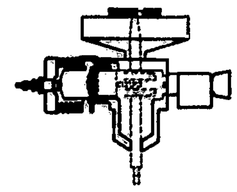
7. *Reinstall strainer.*

8. *Reinstall tank on engine.*

9. *Connect fuel lines and replace cap.*



B. REPAIRING FUEL PUMPS



Fuel pumps are generally used on installations where the fuel tank is located beneath the carburetor. Their purpose is to supply fuel to the carburetor at a constant pressure. They are also used on multi-position equipment such as chain saws.

Most fuel pumps have a **flexible diaphragm** for a pumping element. This is the part that is likely to cause the most trouble. If the diaphragm leaks, the pump will not function properly, and fuel will not be supplied to the carburetor.

Maintaining and repairing fuel pumps are discussed under the following headings:

1. Types of fuel pumps and how they work.
2. Tools an materials needed.
3. Checking the fuel pump for proper operation.
4. Repairing the fuel pump.
5. Installing the fuel pump.

TYPES OF FUEL PUMPS AND HOW THEY WORK

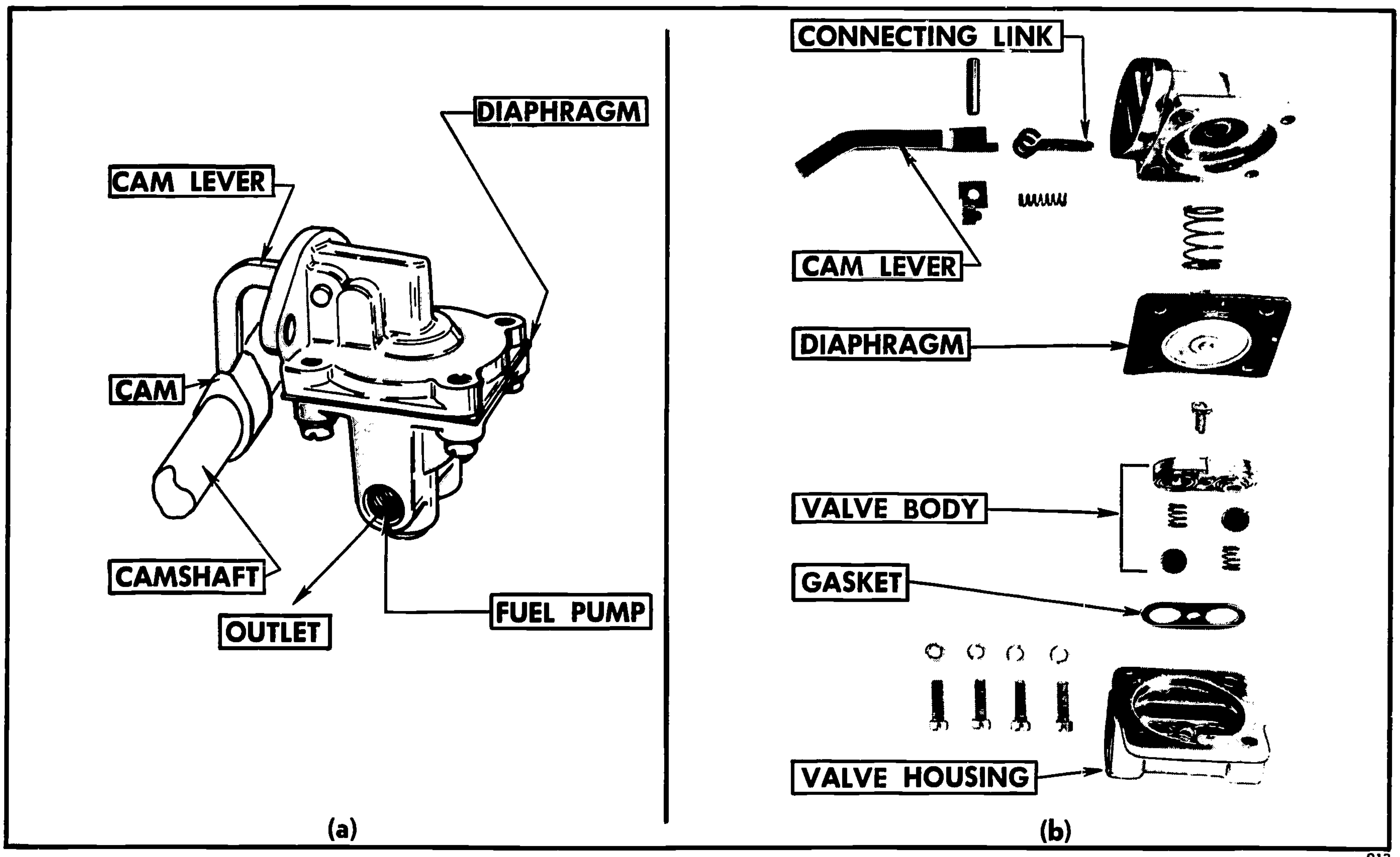


FIGURE 131. Typical mechanically driven fuel pumps. (a) Outside view. (b) Exploded view.

Fuel pumps on small engines have a diaphragm pumping element. The diaphragm may be driven by either (1) **mechanical** means (Figure 127a and 131) or (2) **differential pressure** (Figure 132).

Either type of pump has two check valves: an inlet and an outlet valve. Some are spring-loaded steel balls. Some are floating discs and some are flapper-type valves. The *mechanically driven type* is explained in Figure 127.

The **differential-pressure type** works in much the same manner. The difference is in the way force is applied to the diaphragm. With this type, the differential (changing) pressure is developed from the alternating (partial) vacuum and pressure in the crankcase of 2-cycle engines (Figure 132). When the piston moves away from the crankshaft, a partial vacuum develops in the crankcase. As it moves toward the crankshaft, pressure develops.

When a partial vacuum develops on the diaphragm, the diaphragm moves in the direction of least pressure (Figure 132a). A partial vacuum develops in the fuel chamber. This causes the inlet valve to open and the outlet valve to close. Fuel rushes into the fuel chamber. Atmospheric pressure on the fuel in the fuel tank forces the fuel into the fuel chamber.

When the diaphragm is moved in the opposite direction by crankcase pressure, the outlet valve opens and the inlet valve closes. Fuel is forced out of the pump to the carburetor by the pressure exerted on the diaphragm.

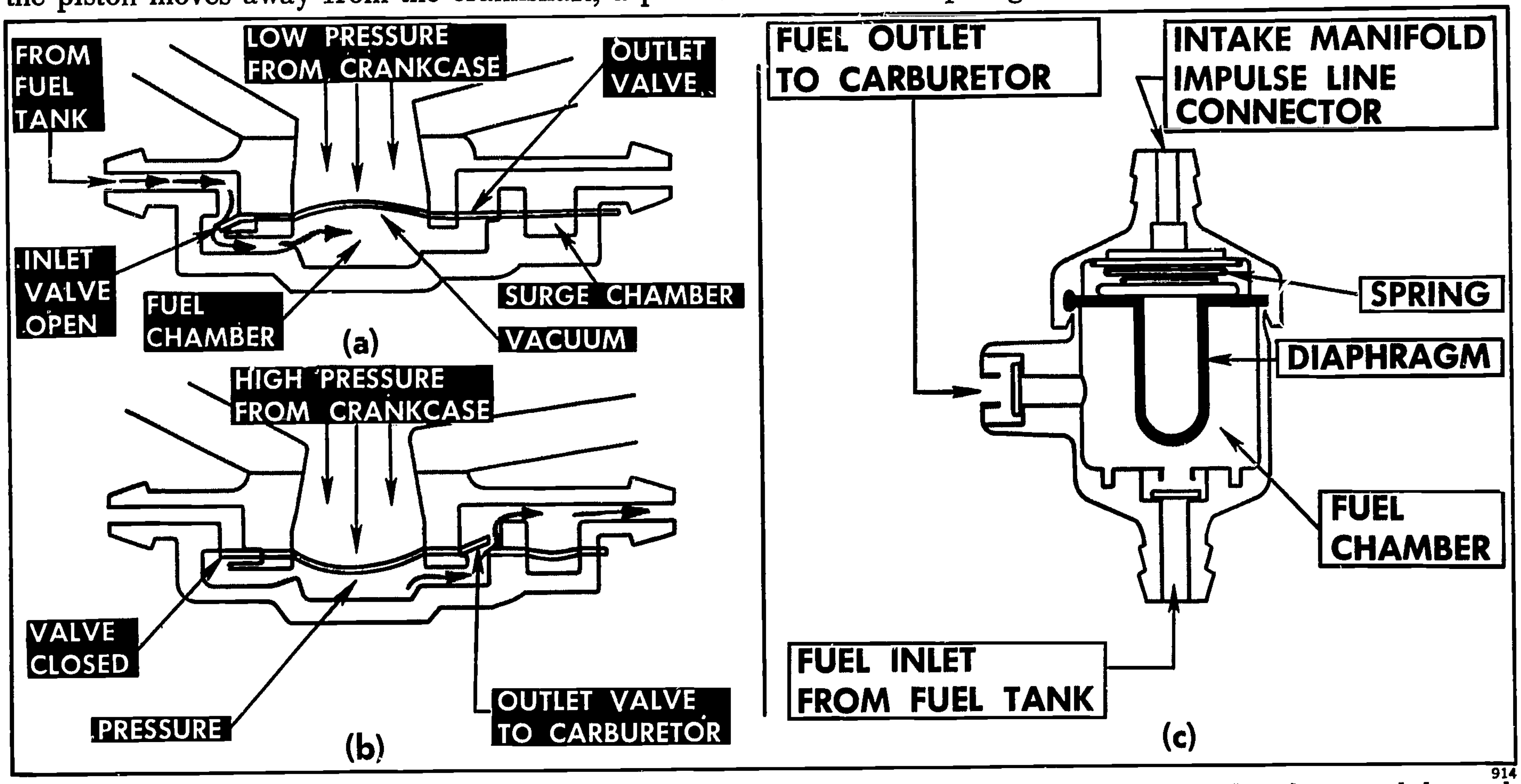


FIGURE 132. Cross section of typical differential-pressure driven fuel pumps used on 2-cycle engines. (a) Low pressure from the crankcase (2-cycle engines) allows the diaphragm to be forced upward. Fuel from the tank enters the pump chamber through the inlet valve. (b) High pressure from the crankcase (2-cycle engines) forces the diaphragm down. The inlet valve closes and the outlet valve opens. Fuel goes to the carburetor. (c) A pump which is similar in principle to the one shown in (a) and (b), except the diaphragm is returned to normal by a spring.

TOOLS AND MATERIALS NEEDED

1. Open-end wrenches — 7/16″ to 9/16″
2. Slot-head screwdriver — 6″
3. Phillips-head screwdriver — 6″
4. Petroleum solvent (mineral spirits, kerosene or diesel fuel)
5. Clean rags
6. Wire brush

CHECKING THE FUEL PUMP FOR PROPER OPERATION

1. *Disconnect the spark-plug wire.*
2. *Disconnect the fuel line at the carburetor.*
3. *Rotate the engine crankshaft with the starter 15 to 20 revolutions.*
4. *Observe the fuel flow.*

Fuel from the pump should flow strongly and in regular squirts.

If **fuel does not flow, or if** the **flow is weak and/or erratic,** the trouble is most likely a leak in the fuel pump diaphragm. You can get repair kits for most pumps. There are some, however, for which no repair parts are available, and the entire pump must be replaced. See your dealer.

Procedures for repairing the two types of fuel pumps are given under the next heading.

REPAIRING THE FUEL PUMP

Procedures for rebuilding are approximately the same for all types. But if your pump is different, follow instructions given in your service manual.

1. *Close the fuel shut-off valve.*
2. *Disconnect fuel lines from each side of pump.*
3. *Remove screws holding the pump to the engine block.*
4. *Remove the pump.*
5. *Clean the fuel pump unit in petroleum solvent.*
6. *Mark the alignment of the two main sections of the pump housing with a file or a center punch.*

   Some mechanically driven pumps are built so that the fuel inlet-and-outlet section may be rotated $\frac{1}{4}$ turn, in relation to the cam-lever section, to fit different installations. After disassembly you may not remember in which position yours was installed. The alignment marks will serve to remind you.
7. *Remove the screws that hold the pump together.*
8. *Separate the two sections.*

   Remember when disassembling a unit, such as the fuel pump, always lay the parts out in the order they came apart. This will help you remember how to put them back together again.
9. *Remove pin from pump lever on mechanical driven pumps.*

   Use a small pin punch.
10. *Remove the diaphragm.*

    If your pump is **similar to the one shown in Figure 131,** hold the connecting link steady with the thumb of the left hand. With the heel of your right hand, press down on the diaphragm. Turn it clockwise one quarter turn. This should unhook the diaphragm from the link so it can be removed.
11. *Clean and inspect parts.*

    Check parts for damage and excessive wear. Lay them out in a clean, well-protected place.
12. *Install new diaphragm, spring (if used) and gasket.*

    Diaphragm spring should fit into the cup under the diaphragm.
13. *Align the two housing sections by the alignment marks you made before disassembly.*

    Tighten screws loosely.
14. *Insert the pump lever on mechanically driven pumps (Figure 133a).*

    Hold diaphragm down while inserting the pump lever.

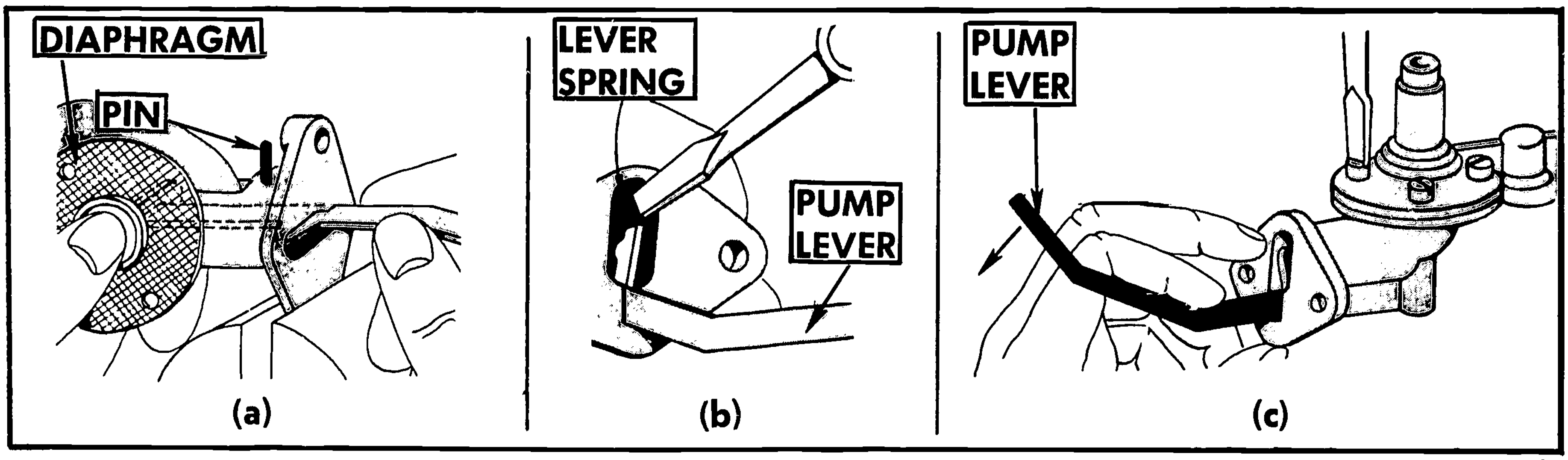


FIGURE 133. Reassembling one design of a mechanically driven fuel pump. (a) Installing the pump drive lever. (b) Installing the drive-lever spring. (c) Installing the pump housing.

15. *Install drive-lever pin on mechanically driven pumps (Figure 133a).*

16. *Install drive-lever spring (Figure 133b) on mechanically driven pumps.*

17. *Reassemble pump housing.*

18. *Press down on lever as far as possible on mechanically driven pumps (Figure 133c).*

    The purpose of this is to give the diaphragm flexibility.

INSTALLING THE FUEL PUMP

1. *Lubricate the part of the lever arm that contacts the cam on mechanically driven pumps.*

   Use multi-purpose grease.

2. *Attach the pump to the engine.*

   Use a new gasket.

   Keep mounting face of pump parallel to mounting face of engine. This is to make sure the drive arm seats properly on the drive cam.

3. *Crank engine to a position where there is pressure on the diaphragm.*

4. *Tighten the assembly screws securely.*

   This gives the diaphragm maximum flexibility.

5. *Turn crankshaft and check to see if drive arm is properly seated on the cam before tightening pump.*

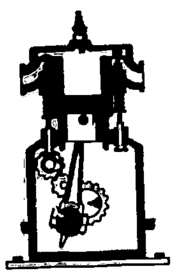
   Put your thumb and finger over the intake and discharge ports and observe pressure and suction.

6. *Secure pump to engine.*

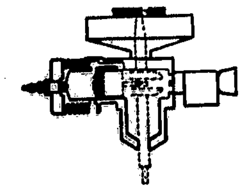
7. *Attach fuel lines coming from fuel tank.*

8. *Recheck pump for operation.*

9. *Attach fuel line to carburetor.*



C. REPAIRING CARBURETORS



The different types of carburetors and their principles of operation are described in Volume I. If you have forgotten how they work, it would be well to review the operating principles before proceeding with repairing a carburetor.

Repairing carburetors is discussed under the following headings:

1. Removing the carburetor.
2. Repairing the float- and diaphragm-type carburetor.
3. Repairing the suction-lift carburetor.
4. Installing the carburetor.

TOOLS AND MATERIALS NEEDED

1. Slot-head screwdriver — 6″
2. Phillips-head screwdriver — 6″
3. Open-end wrenches — 1/4″ through 1/2″
4. Needle-nose pliers — 7″

REMOVING THE CARBURETOR

1. *Close fuel shut-off valve.*

2. *Remove carburetor air cleaner.*

3. *Disconnect governor linkage (Figure 134).*

   Remember how the governor is connected. Usually there are several holes in the governor linkage. You must reconnect it to the same hole. Sometimes it is easier to disconnect the linkage after disconnecting the carburetor.

4. *Disconnect the throttle linkage.*

   Sometimes the ignition grounding switch is also connected to the throttle-control linkage so that when the throttle is closed, the switch is off (Figure 135)—magneto is grounded. Disconnect linkage to it also.

5. *Remove cowling if necessary.*

6. *Disconnect fuel line.*

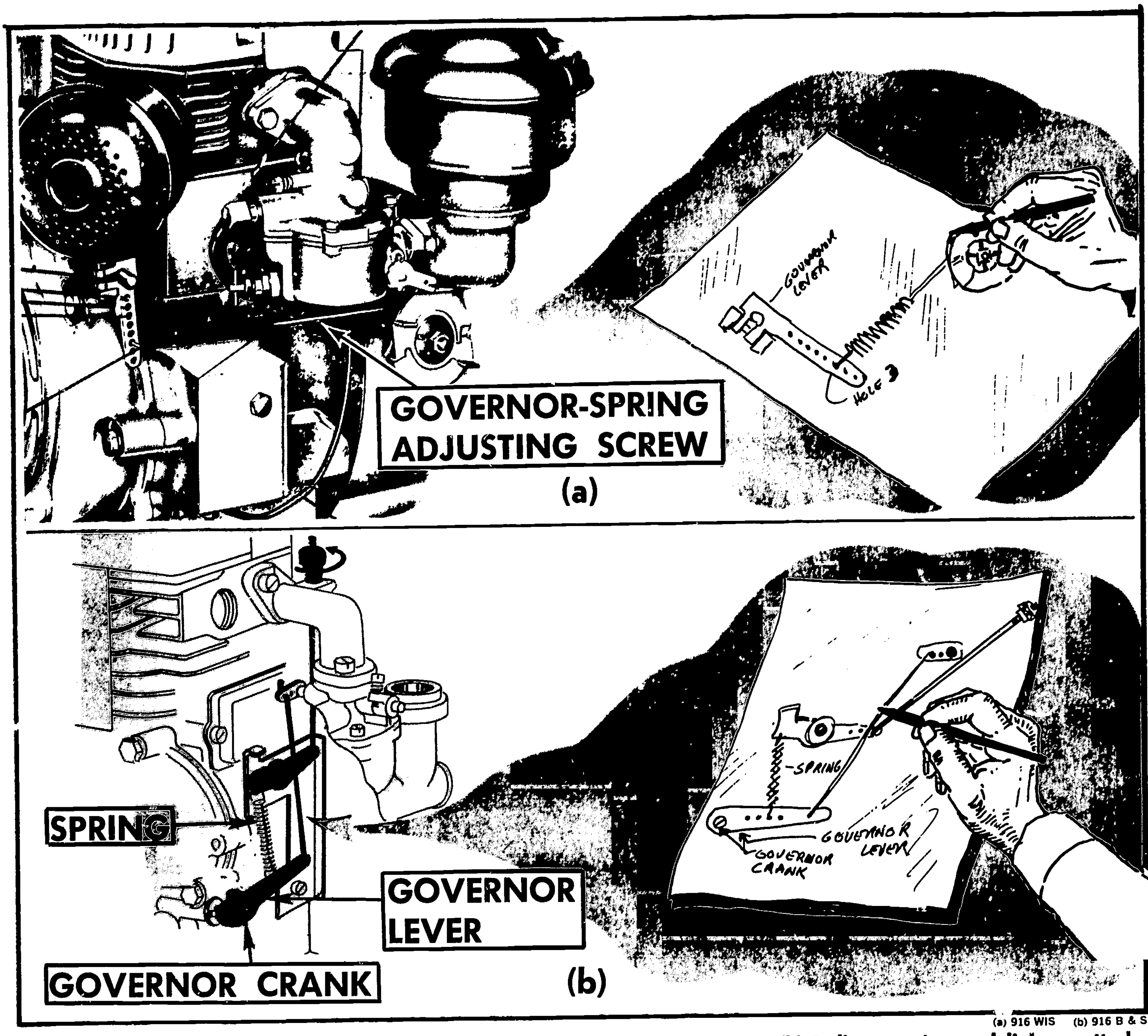


FIGURE 134. Make a note of how your governor and throttle are connected so that you can reconnect them properly. (a) Indicate at what point the spring attaches to the lever arm. (b) Indicate spring and linkage attachment points.

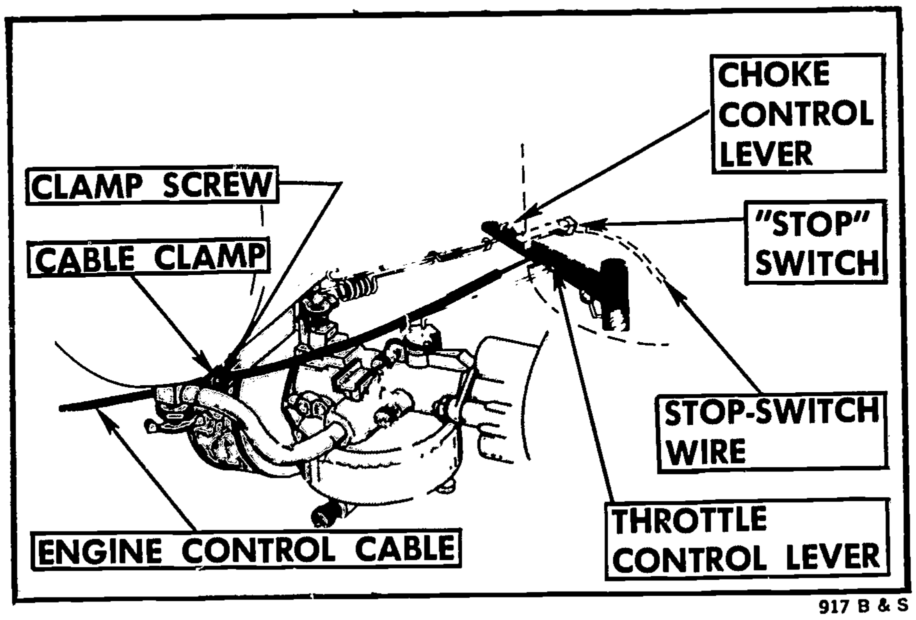


FIGURE 135. Throttle linkage combined with an ignition-grounding switch.

If the fuel lines are made of **neoprene,** they are usually pressed onto hose nipples. Pull hose from nipple.

Check for deterioration, cracks and breaks. Do not replace neoprene hose with rubber hose. Gasoline will soften rubber.

Metal tubing is attached with a flange nut. Use two open-end wrenches to prevent twisting the tubing. Hold the fitting with one while loosening the jam nut with the other.

7. *Remove breather return line, if installed (Figure 136).*

FIGURE 136. Breather return line on a two-piece float-type carburetor.

8. *Remove carburetor.*

Disconnect any control linkage which was not disconnected before. The carburetor may be attached directly to the engine (Figure 137a), or to an intake manifold (Figure 137b). With the latter, it is usually easier to disconnect the manifold from the engine and separate it from the carburetor later.

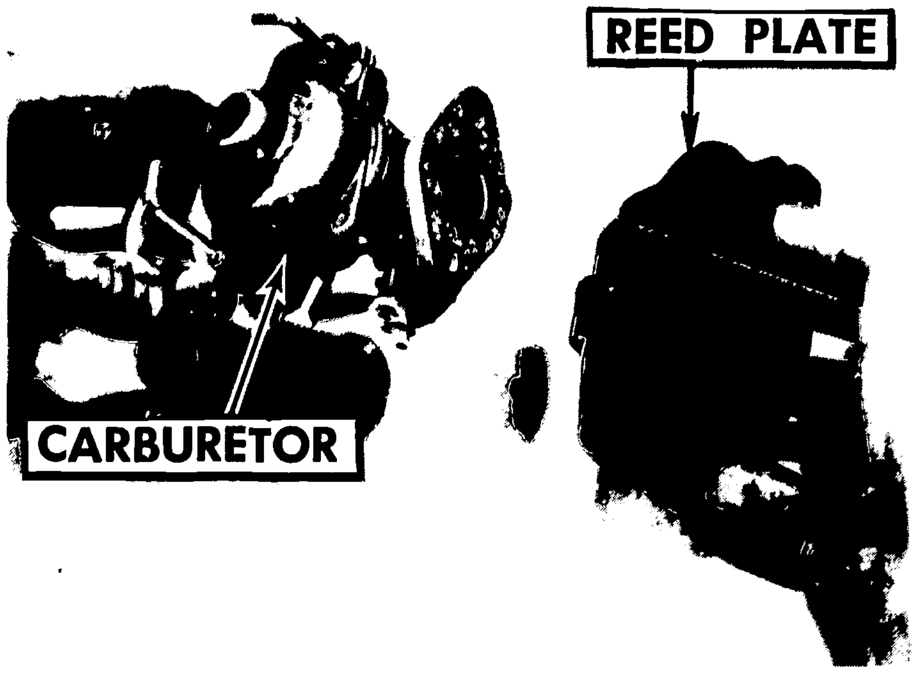


FIGURE 138. Carburetor separated from a reed plate (2-cycle engine).

On 2-cycle engines, it may be attached to the intake-valve plate on the crankcase, or to the reed plate. On some, the reed plate must be removed first with the carburetor attached; then separate the two (Figure 138).

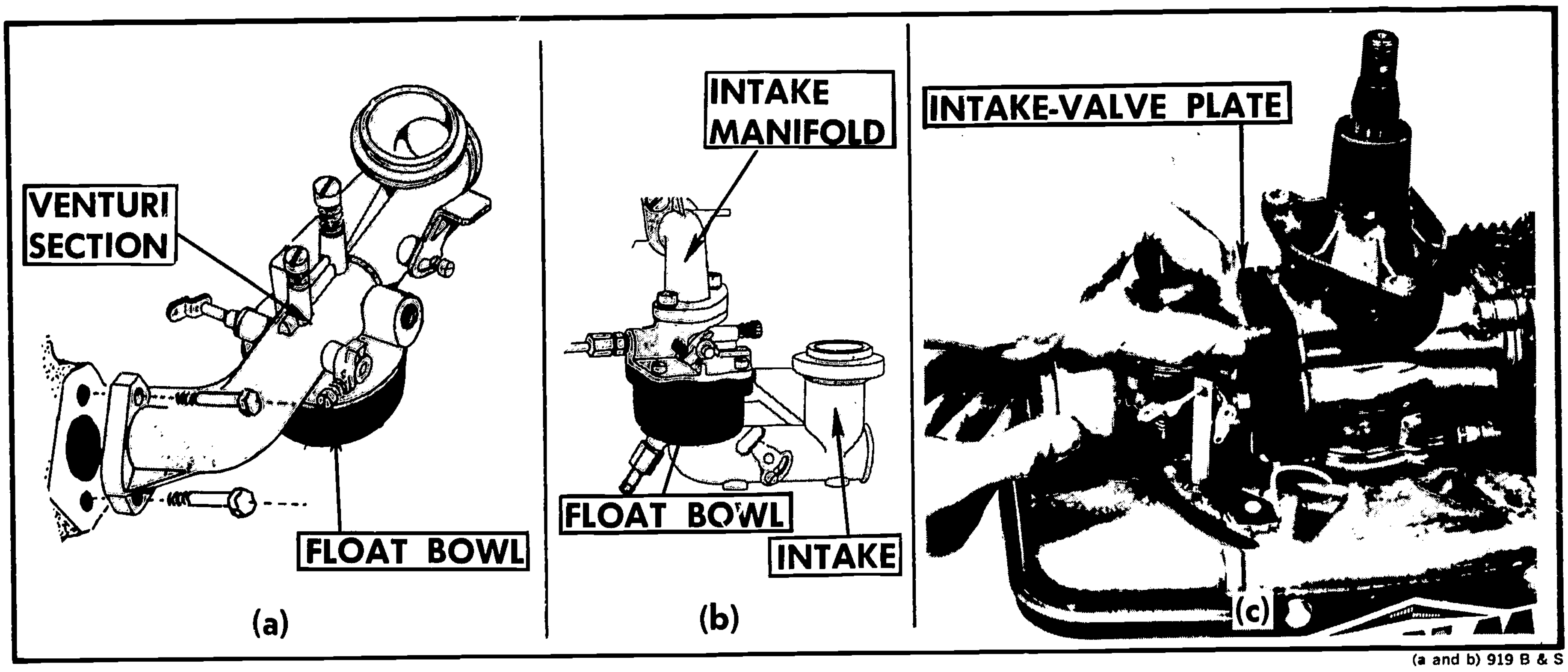


FIGURE 137. Most carburetors are attached by two cap screws. (a) Carburetor mounted directly to the engine. (b) Carburetor mounted to an intake manifold. (c) Carburetor mounted to the crankcase intake-valve plate (2-cycle engine).

REPAIRING THE FLOAT- AND DIAPHRAGM-TYPE CARBURETOR

The designs of carburetors vary so much that it is impossible to give specific steps and illustrations for all types and models. For this reason follow procedures given in your service manual for your particular carburetor, if you have a manual. The following steps, however, will give you a general idea

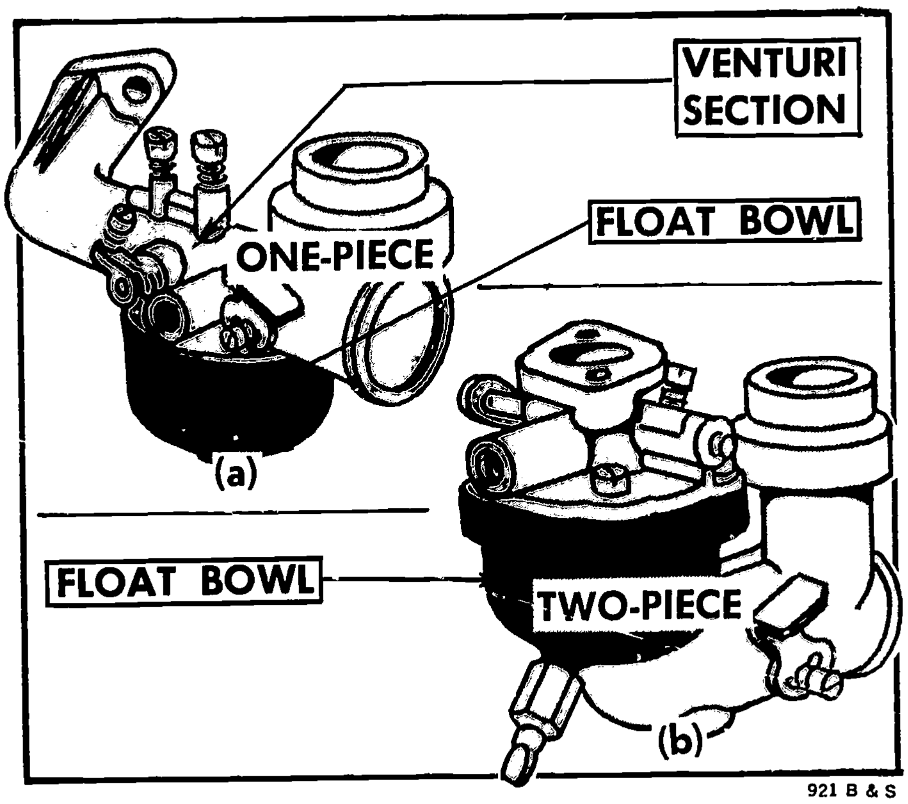


FIGURE 139. Typical float-type carburetors. (a) One-piece float type. Bowl can be removed from the bottom. (b) Two-piece float type. The venturi section is surrounded by the float. The housing can be separated into two parts.

of how to repair your carburetor even though the carburetor may not be exactly like either of the ones described here.

You may have a **1-piece float-type** carburetor (Figure 139a), or a **2-piece float-type** carburetor (Figure 139b), or a **diaphragm-type** (with or without a built-in fuel pump) carburetor (Figure 140).

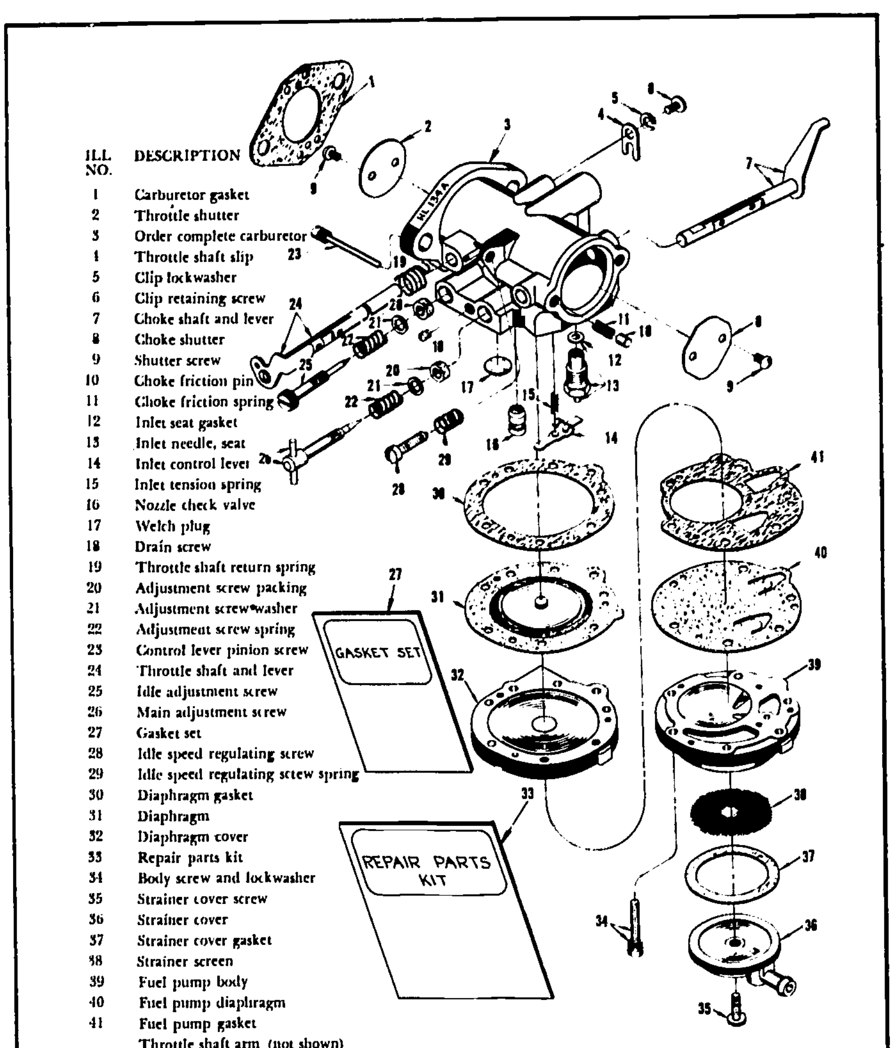


FIGURE 140. Parts of a diaphragm-type carburetor with a built-in fuel pump.

With few exceptions repair procedures are similar for either of the *float-types* (Figure 139) and for the *diaphragm type* (Figure 140) carburetors.

a. If your carburetor is a **float-type or diaphragm-type (without a built-in fuel pump)**, proceed as follows:

1. *Check throttle shaft for wear (Figure 141).*

   Place a metal block on the carburetor adjacent to the throttle shaft.

   Check play in **throttle shaft** with a feeler gage. If the wear is more than .010 inch, replace the bushing. That is, if it has a bushing and the remainder of the carburetor is reparable. See step 11.

   If the carburetor **has no throttle-shaft bushing** and the hole is worn excessively, it will be necessary to replace the top housing of the carburetor. Before replacing the carburetor housing, check the rest of the carburetor to see if it is worth repairing. A worn shaft and/or bushing in either type will allow air to enter the carburetor.

   This will provide too lean a mixture and make the engine run roughly.

2. *Remove and check the condition of the needle valves (Figure 142).*

   Normally there are two needle valve adjustments—one for high speed and one for idle speed. You may or may not have an idle-mixture adjustment.

   Needles become worn thin from damage and wear. A worn rim on the needle will occur, and you cannot adjust the needle properly. If valves are **worn or damaged**, replace with new ones.

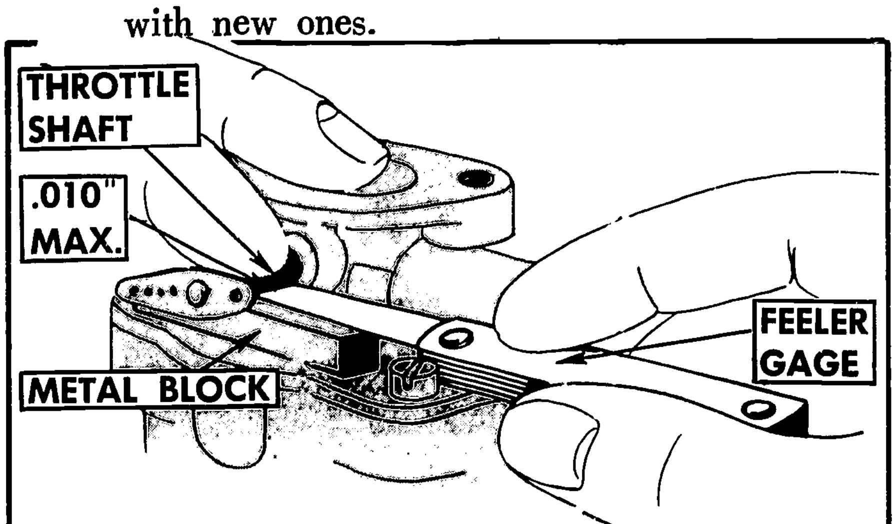


FIGURE 141. Checking the throttle shaft and/or bushing for wear.

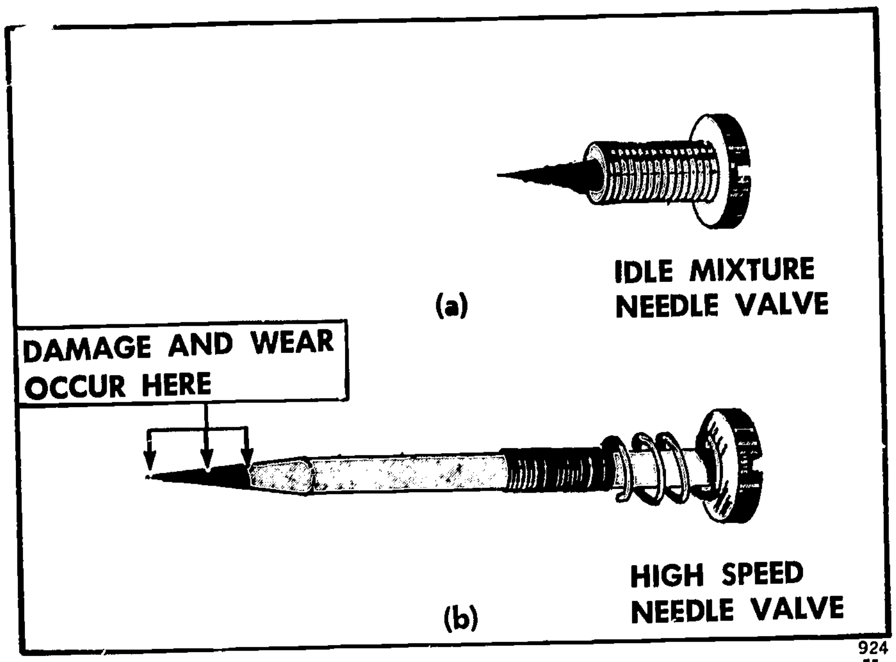


FIGURE 142. Where damage or wear occurs on needle valves.

If you have a **2-piece float-type carburetor and the main fuel nozzle is diagonally installed,** remove and check main fuel nozzle (Figure 143). Do this before separating the two halves to prevent damage to the diagonally inserted nozzle.

Be sure to use the proper size screwdriver. If you do not, threads and brass fittings will be damaged. Check for gum, dirt and mechanical damage. Make sure openings and passageways are clear.

3. *Remove fuel bowl (1-piece carburetor), or disassemble carburetor.*

If you have a **2-piece float-type carburetor,** separate the two pieces of the carburetor

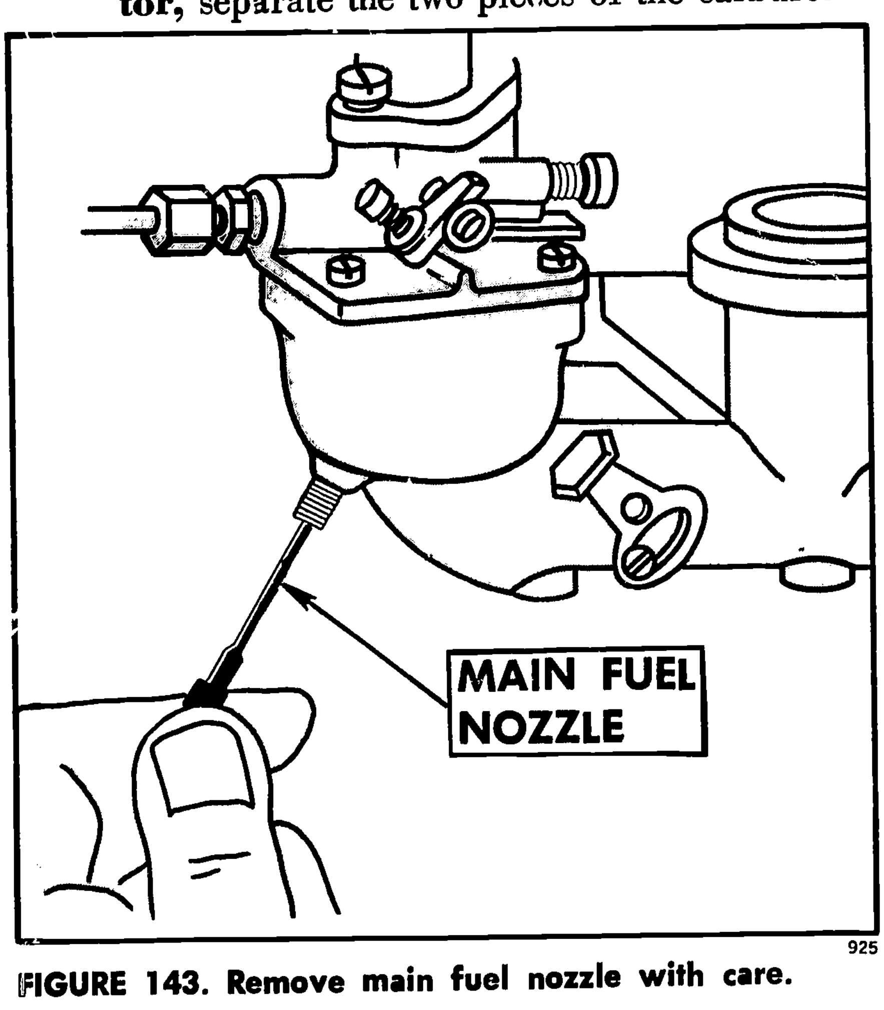


FIGURE 143. Remove main fuel nozzle with care.

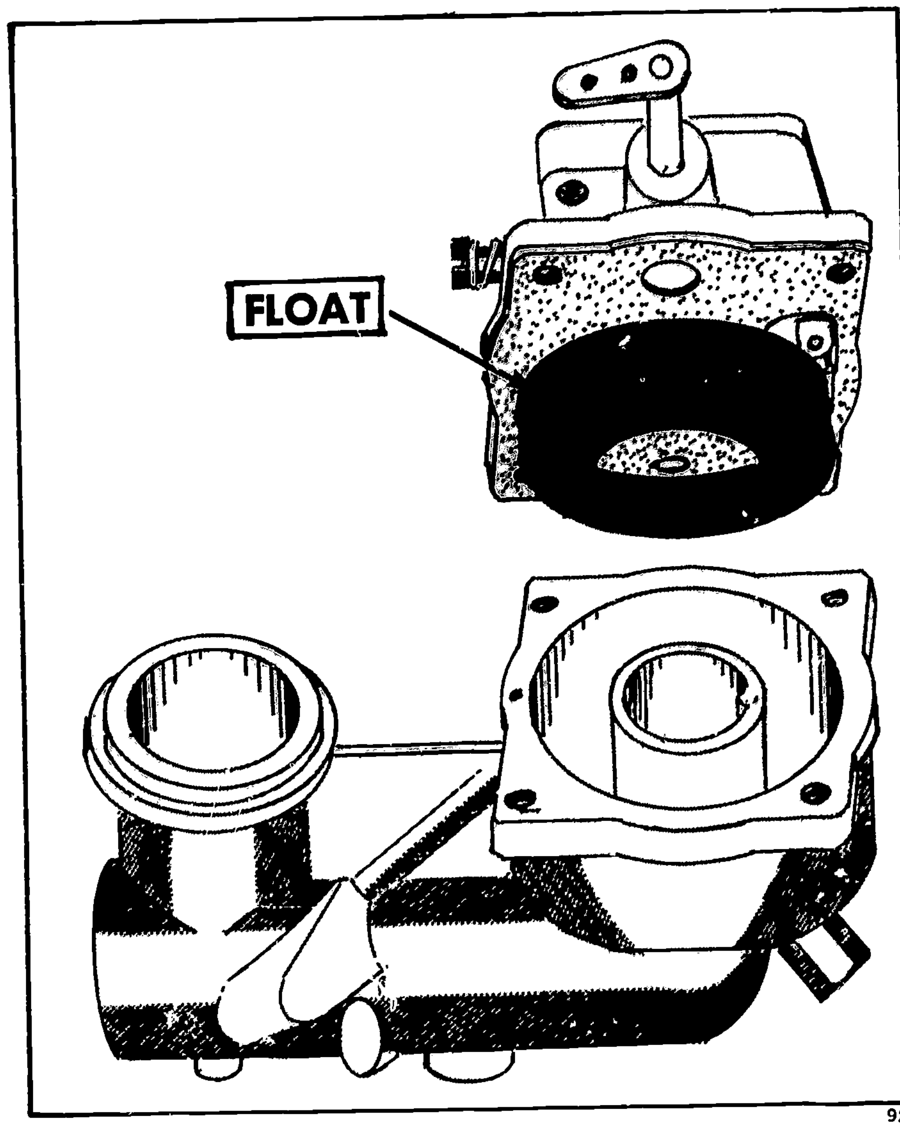


FIGURE 144. The two sections of a two-piece float-type carburetor.

body (Figure 144). Take care not to lose the needle valve. It may fall free.

4. *Remove the gasket (s).*

Be sure to notice how the gasket(s) fit(s) and how the holes in the gasket(s) are aligned with the holes in the carburetor. If you install the gasket wrong, you will restrict some vital passageways.

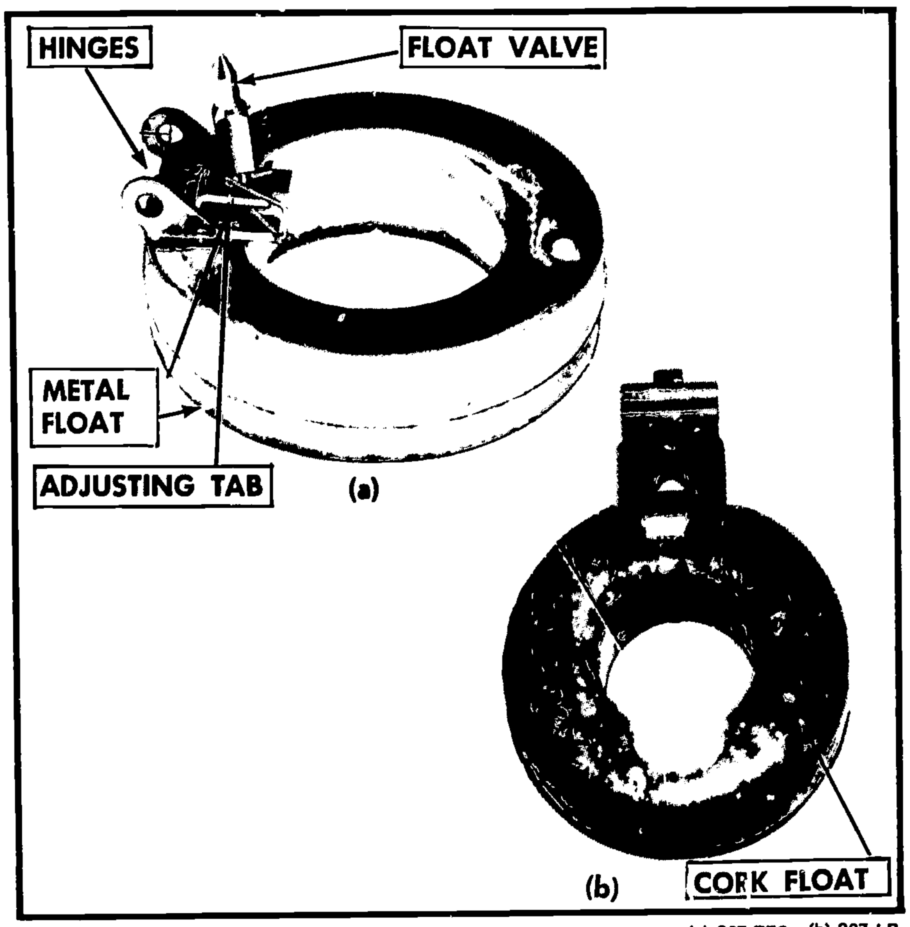
If the **float-chamber vent is clogged or restricted,** the mixture will be too lean.

If the **internal air bleed is restricted,** you will get a rich mixture.

5. *Remove float or diaphragm, and check condition (Figure 145).*

If you have a **float-type carburetor,** pull pin from float hinge. Check float valve and hinges for wear and check float for mechanical condition and leaks. Most floats are **air-tight metal capsules** (Figure 145a). If this type float contains gasoline or if it is crushed, it must be replaced with a new one.

Some floats are **varnished cork** (Figure 145b). Check to see if the varnish coating is good. Do not puncture the protective coating



(a) 927 TEC (b) 927 LB

FIGURE 145. Types of floats. (a) Metal float with needle valve and adjusting tab. (b) Cork float.

or soak it in strong solvents. If you do, it will break the coating so that the float will absorb gasoline.

If you have a **diaphragm carburetor,** remove and check the diaphragm. Inspect the diaphragm for condition and leaks.

6. *Determine if float or diaphragm needs adjustment or replacement.*

   Figure 146 shows three methods for checking different *float adjustments*. Specifications vary for different carburetors. Each manufacturer supplies the measurements that are needed to determine when your carburetor float is in proper adjustment.

   If the float is **set too high,** the valve will not close completely and the carburetor will flood.

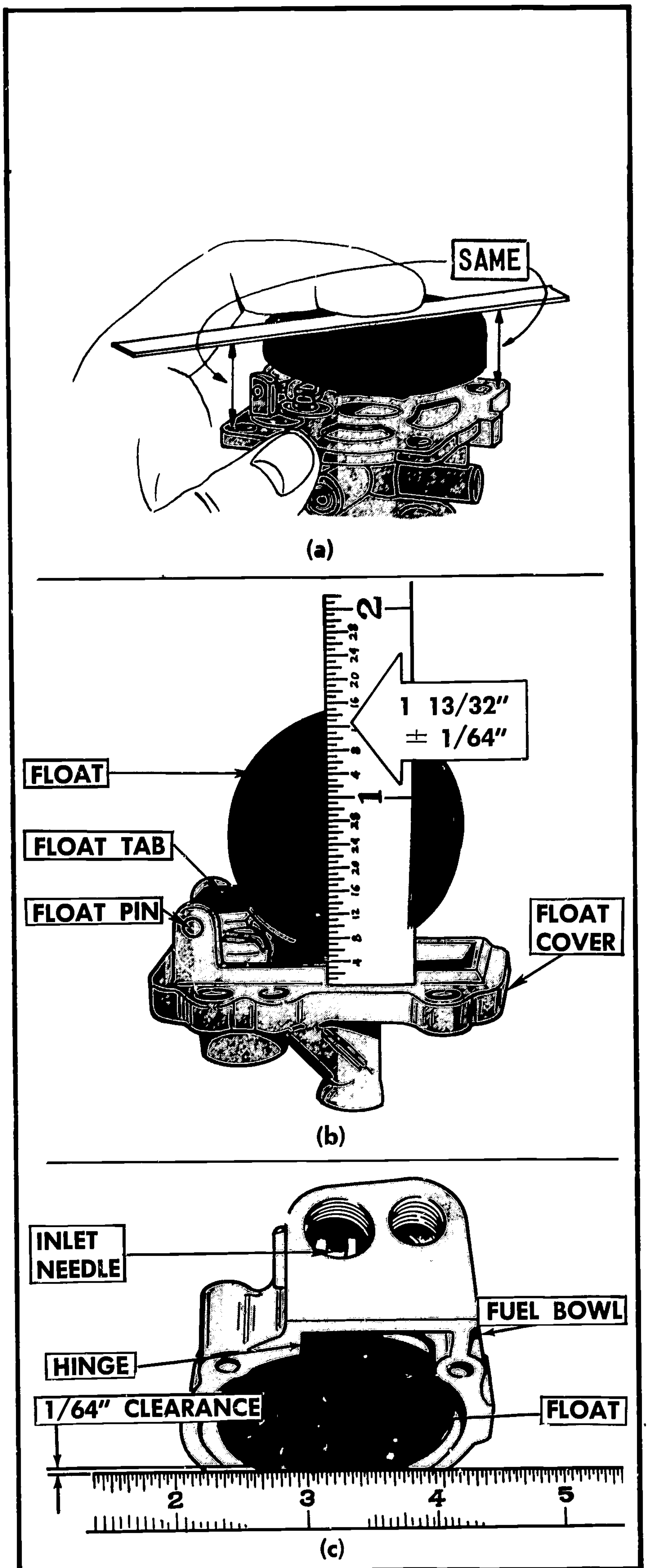
   If float is **set too low,** the valve will close too early and the carburetor will starve. (*High* and *low* refer to the assembled carburetor).

   If the float **valve sticks open,** the carburetor will flood.

7. *Adjust tab (tang) on float, or diaphragm control lever, if necessary.*

   Bend tab under float needle. You may have to remove the hinge pin to reach the tab.

   If you have a **diaphragm-type carburetor,** check the diaphragm inlet valve to see if it



(a) 928 B & S (b and c) 928 TEC

FIGURE 146. Checking floats for adjustment. (a) Checking distance from carburetor housing to top of horizontal float to determine if it is the same on both sides. (b) Checking distance on a vertical float from housing to top side. (c) Checking bottom of float for proper clearance in relation to float housing.

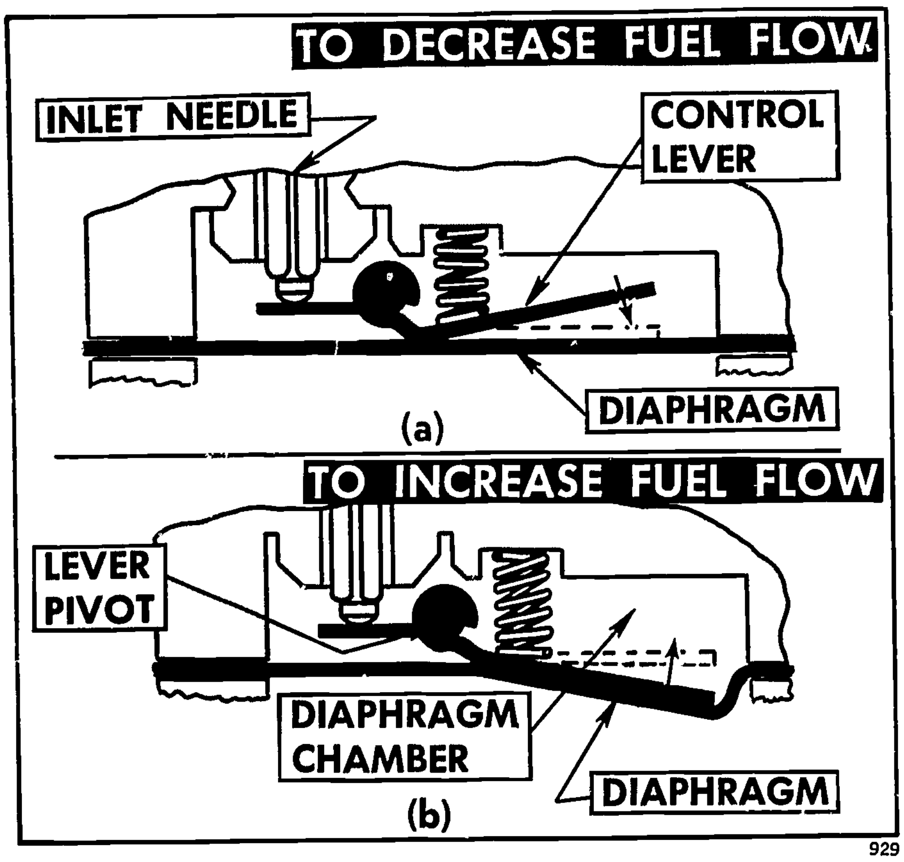


FIGURE 147. Adjustment of the control lever position on a diaphragm-type carburetor. Tab and control lever should be parallel.

opens and closes properly (Figure 147). If necessary, bend inlet control lever until the ends of lever are parallel.

8. *Remove and check main discharge nozzle and valve seats, if not already removed.*

   Be sure to use the proper size screwdriver. The brass fittings are easily damaged. Inspect for wear and damage. Replace with new ones if needed.

9. *Remove primer pump if installed (Figure 148).*

   Remove cotter pin from primer-pump shaft and remove shaft from the bottom.

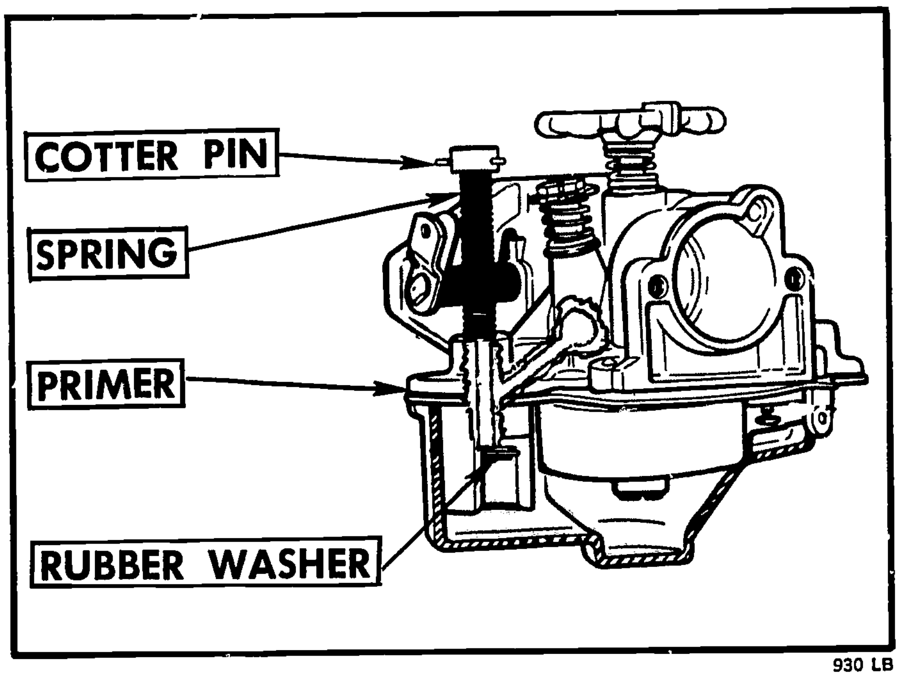


FIGURE 148. A one-piece float-type carburetor with primer pump.

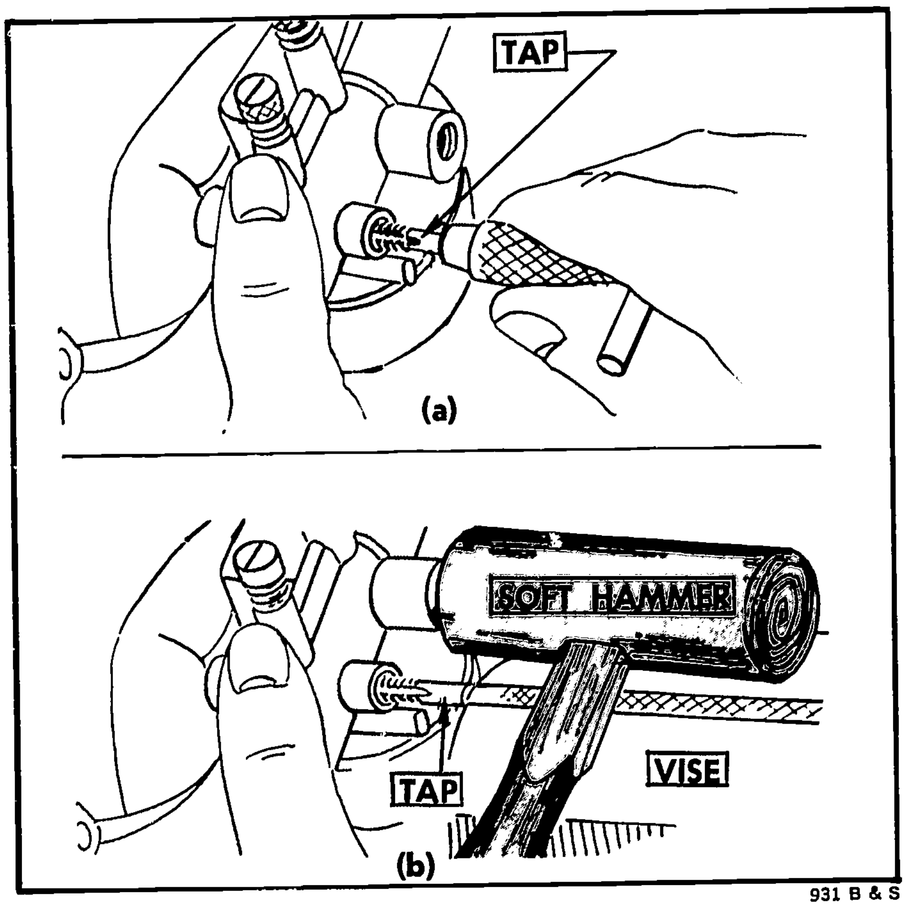


FIGURE 149. Removing the carburetor throttle-shaft bushing. (a) Inserting a tap in the bushing. (b) Driving the carburetor from the bushing.

10. *Remove and replace throttle-shaft bushing if necessary (Figure 149).*

    To remove the throttle-shaft bushing, thread a tap of the proper size into the worn bushing. Hold tap in vise and drive carburetor off with a soft hammer. Press new bushing into place. Ream to size if necessary. Be sure to use the proper size drill for reaming. Use a drill .001″ larger than the new shaft.

11. *Remove choke valve and throttle valve if necessary.*

    If your carburetor has a **welch plug** on the elbow like the one shown in Figure 150a, push it out with a screwdriver to get to the choke valve.

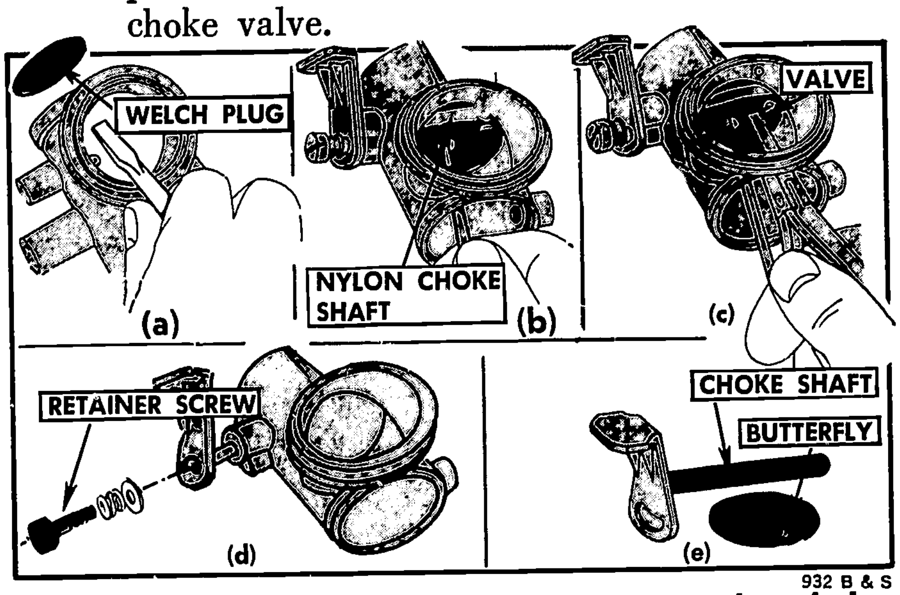


FIGURE 150. Removing choke valve from a nylon choke valve shaft. (a) Pry out welch plug. (b) Insert sharp tool under choke valve. (c) Pull out choke butterfly with long nose pliers. (d) Remove retainer screw, spring and washer. (e) Remove shaft.

Some choke valves have a **nylon shaft.** The valve is wedged in a slot in the shaft. Remove them in the manner shown in Figure 150.

12. *Soak carburetor parts.*

    Use Bendix Cleaner, Petisol or other recommended commercial carburetor cleaners.

    Nylon and other plastic parts may be washed in the same carburetor solvent, and soaked for *not more than 30 minutes.* If left for longer periods, the chemical may soften them.

13. *Rinse in petroleum solvent.*

14. *Reassemble carburetor in reverse order of disassembly.*

    Use new gaskets.

    Be sure to install the gaskets properly (Figure 151).

15. *Adjust carburetor for initial setting.*

    For procedures refer to "Adjusting Carburetors," Volume I.

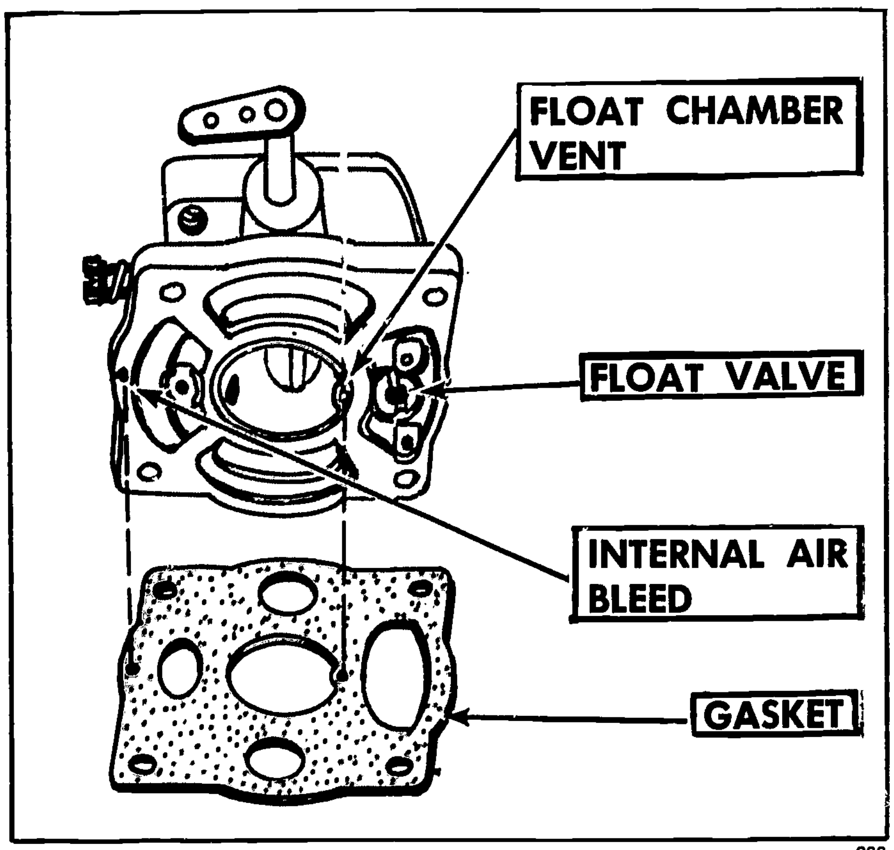


FIGURE 151. When replacing the gasket, be sure it does not restrict vital passageways.

16. *Install the carburetor.*

    See "Installing the Carburetor," page 96.

REPAIRING THE SUCTION-LIFT CARBURETOR

Some simple suction-lift types carburetors — those with only one fuel lift tube — have no means for adjusting either fuel mixture. Some have a high speed adjustment but no idle mixture adjustment. About all you can do for these types of carburetors is to clean them and inspect the high-speed, load needle valve and seat, if installed. They usually have the fuel tank mounted directly beneath the carburetor.

A suction-lift carburetor with a diaphragm pump and fuel chamber is a little more complicated (has more parts).

Repair procedures vary for different suction-lift carburetors (Figure 152). Check your service manual for those that apply to your particular carburetor.

1. *Remove the carburetor from fuel tank.*

   Lift the carburetor straight from the tank to avoid damaging the suction tube.

2. *Check throttle-valve shaft for wear (Figure 141).*

3. *Remove throttle valve (Figure 153).*

   Valves such as those in Figure 153a and 153b are removed by turning them until the flange

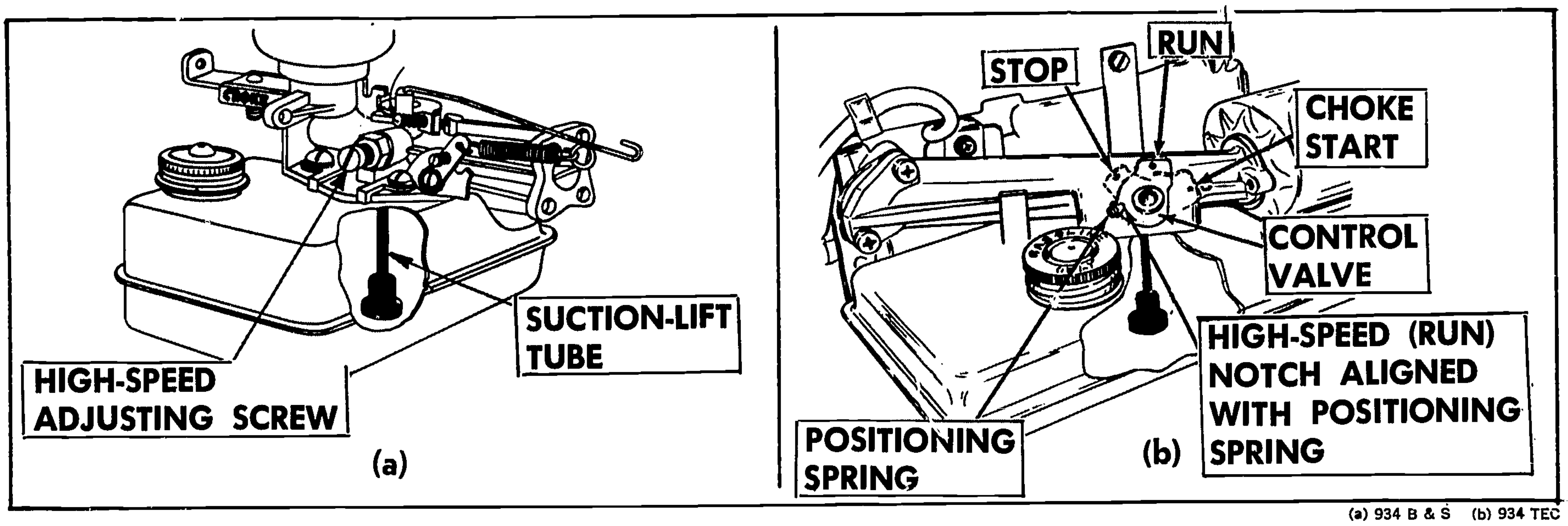


FIGURE 152. Examples of one-tube suction-lift carburetors. (a) Carburetor equipped with a high-speed mixture adjustment and separate choke control. (b) Carburetor with a single control valve for choke, run and stop.

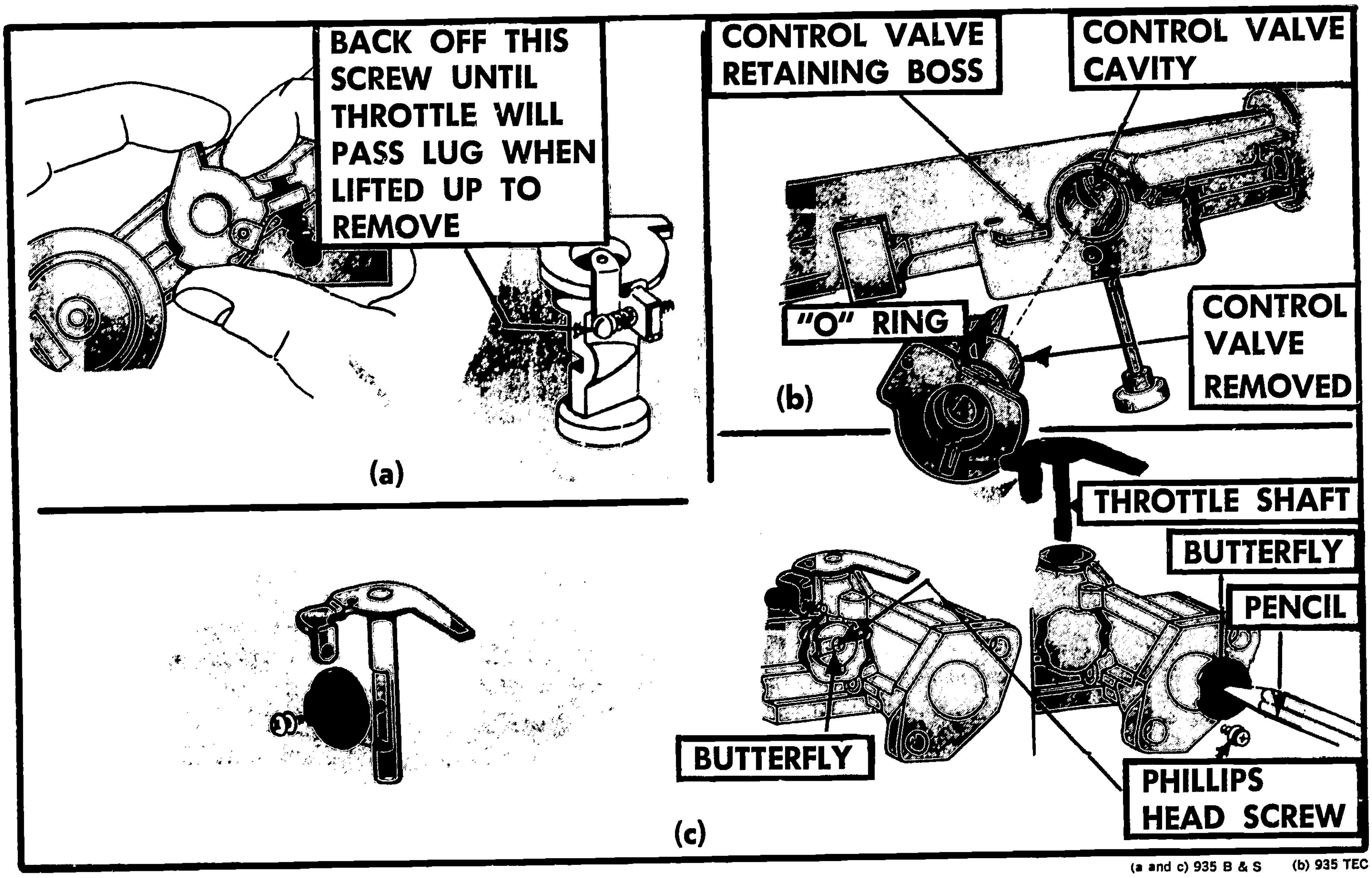


FIGURE 153. Types of throttle valves on suction-lift types of carburetors. (a) Rectangular valves. (b) Notched cylindrical valve used for choking, running and shutting off fuel for stopping. (c) Butterfly-type valve.

clears the retaining boss. Remove butterfly valve from shaft if your throttle valve is like the one shown in Figure 153c.

4. *Inspect "O" ring if installed (Figure 154b).*

5. *Inspect and clean air valves.*

6. *Remove fuel strainer(s) and pipe(s) (Figure 154).*

   Nylon pipes are one piece and are screwed into the carburetor body (Figure 154a).

   Brass pipes (Figures 154b and 154c) may be one or two pieces. They are usually pressed into the carburetor body. The foot valve is pressed onto the pipe.

   Be sure to **check the length of the pipe** before removing it. The length of the pipe can be varied. It is adjustable by the amount inserted into the carburetor. *If it is too long,* it will jam on the bottom of the fuel tank. *If it is too short,* it will not reach into the fuel sufficiently, and there is also danger of restricting the inlet valve in the carburetor.

7. *Clean and inspect pipe and strainer.*

   Do not soak nylon and other synthetic carburetor parts in carburetor cleaner more than 30 minutes. If you cannot clean the screen, replace it with a new one.

   Check foot valve for freedom of operation.

8. *Remove pump assembly if installed (Figure 155).*

   If your carburetor has **two suction pipes (Figure 155a)**, it is equipped with a diaphragm pump. Refer to "Repairing Fuel Pumps," page 83.

   If the **diaphragm is exposed to atmosphere on one side and it is punctured,** you will get a lean mixture.

   If the **diaphragm is exposed to fuel on both sides and is punctured,** you will get a rich mixture.

9. *Remove and inspect the adjusting needles and seats.*

   Some suction-lift carburetors have neither adjusting needle. Some have only the high-speed adjusting needle.

   Some manufacturers do not recommend cleaning carburetor jets with a wire. There is

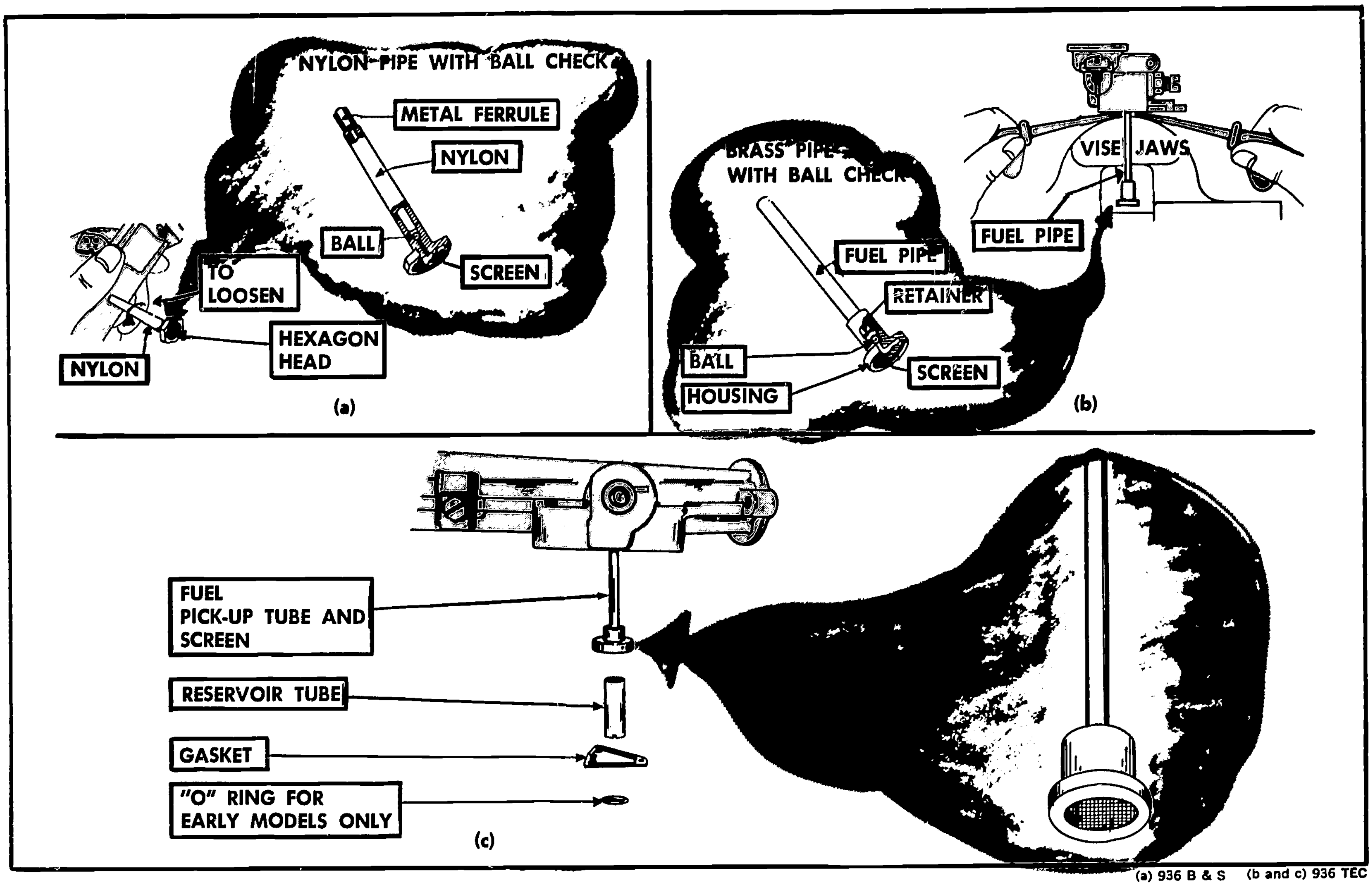


FIGURE 154. Types of fuel strainers and pipes on suction-lift type carburetors. (a) Nylon pipe. (b) and (c) Metal pipes and strainers.

danger of enlarging the hole in the jet. Some manufacturers, however, recommend using a small copper wire to clean clogged jets. Usually, soaking in carburetor solvent for several hours and blowing out with compressed air will clean them adequately.

10. *Clean and inspect the carburetor body.*

    Soak the carburetor body and metal parts in Bendix, Petisol or other recommended carburetor solvent. After several hours remove the carburetor and blow it out with compressed air.

11. *Reassemble carburetor.*

    Replace all gaskets, and worn and damaged parts, with new ones. Be careful about installing the fuel-strainer pipe. The length is critical (Figure 156). On some carburetors you can restrict the fuel flow by pressing the pipe too far into the carburetor. See your operator's manual for proper length.

    If you have a suction-lift carburetor with a pump, replace the diaphragm also.

12. *Readjust high-speed needle valve to setting recommended by the manufacturer.*

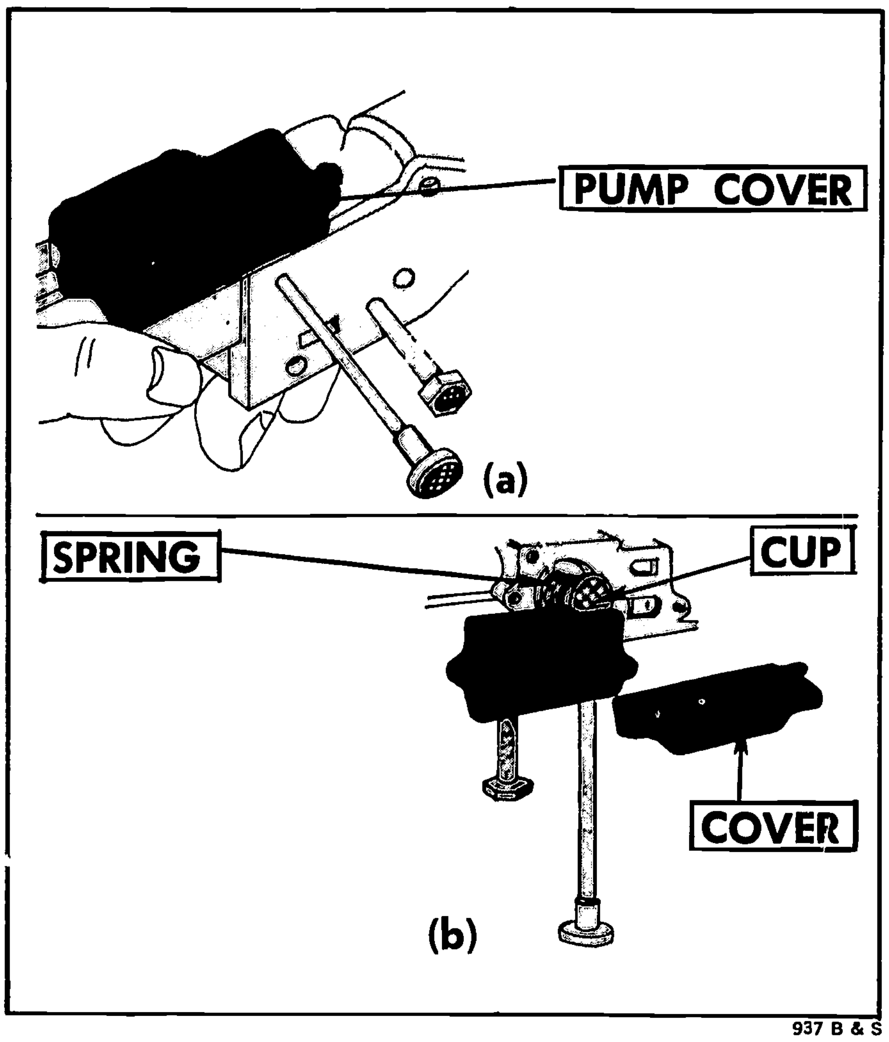


FIGURE 155. Removing the fuel pump assembly on a suction-lift carburetor. (a) Carburetor with diaphragm pump. (b) Pump disassembled.

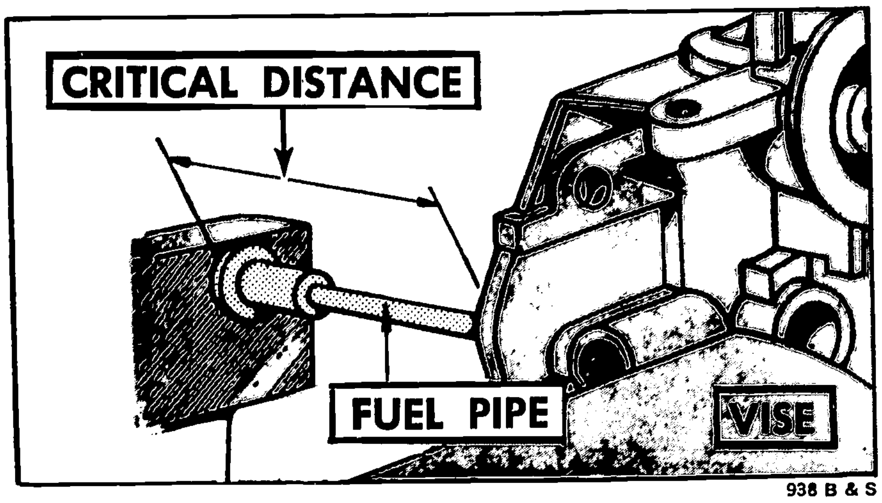


FIGURE 156. The length of the brass fuel pipe is critical.

13. *Adjust throttle setting (single-control carburetor) (Figure 157).*

    Set the throttle to high-speed run position. On some models this is done when the mark on the face of the valve is aligned with the retaining boss on the carburetor body. On other models there is a high-speed notch that aligns with a positioning spring.

    If you are not sure, remove the throttle valve and observe its position when the throttle is open.

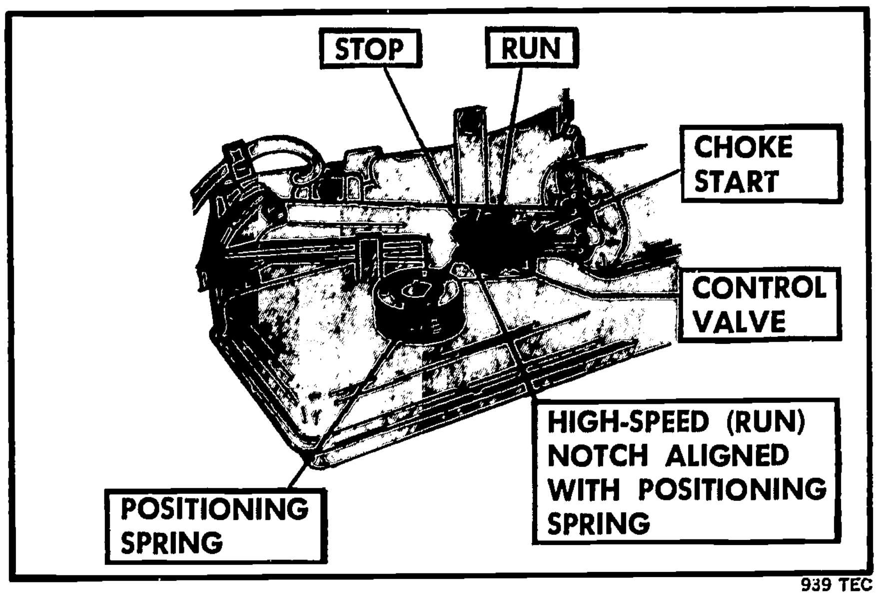


FIGURE 157. Aligning the single control type carburetor valve for the correct positions of choke, run and stop.

With the throttle valve in run position, set the remote control lever (if installed) in run position, and fasten the control wire to the throttle-valve lever.

14. *Install the carburetor.*

    See "Installing the Carburetor," next heading.

INSTALLING THE CARBURETOR

1. *Install gasket between carburetor and engine.*

   Coat both sides of a new gasket with a recommended gasket sealant.

2. *Install carburetor.*

   It may be easier, or even necessary in many cases, to connect some of the control linkages, breather return line and fuel line before securing the carburetor to the engine.

3. *Connect the governor linkage.*

   See your preliminary sketch of how to connect the governor linkage. If you are not sure

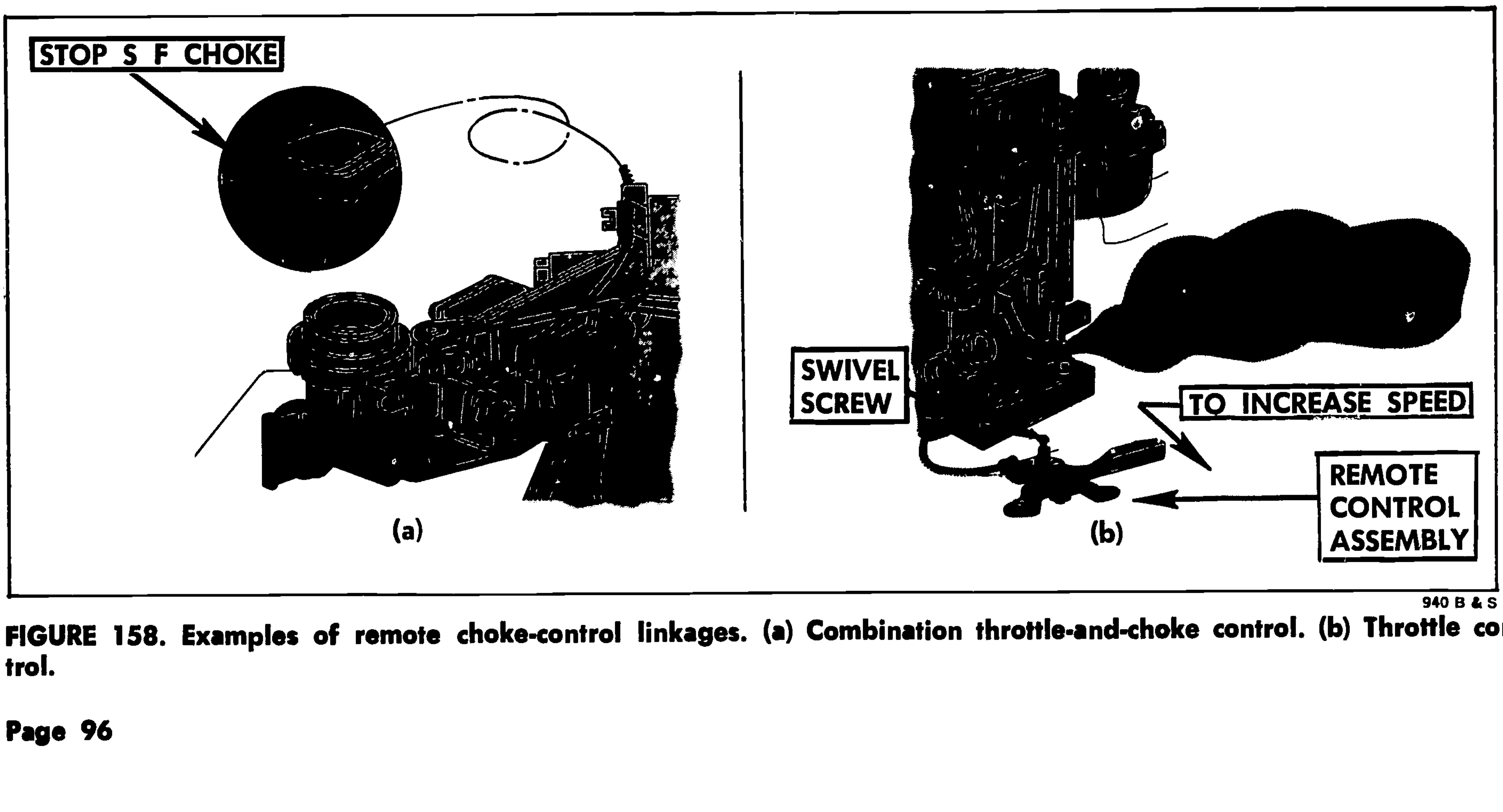


FIGURE 158. Examples of remote choke-control linkages. (a) Combination throttle-and-choke control. (b) Throttle control.

of this, consult your service manual or follow procedures given under "Adjusting the Governor," page 102.

4. *Connect the choke and throttle linkage (Figure 158).*

   If your engine is equipped with a **hand-operated remote throttle-and-choke control,** check the position of the remote-control lever before attaching the linkage, or control wire, to the carburetor. Proceed as follows: For the **choke,** set the choke lever on the carburetor in closed position. Set the remote choke control to a closed position. Tighten the choke-control linkage to the carburetor linkage.

   For connecting the **throttle** control, set the remote throttle-control lever in a closed position. Set the throttle-valve control on the carburetor to be closed. Tighten the control linkage to the carburetor linkage.

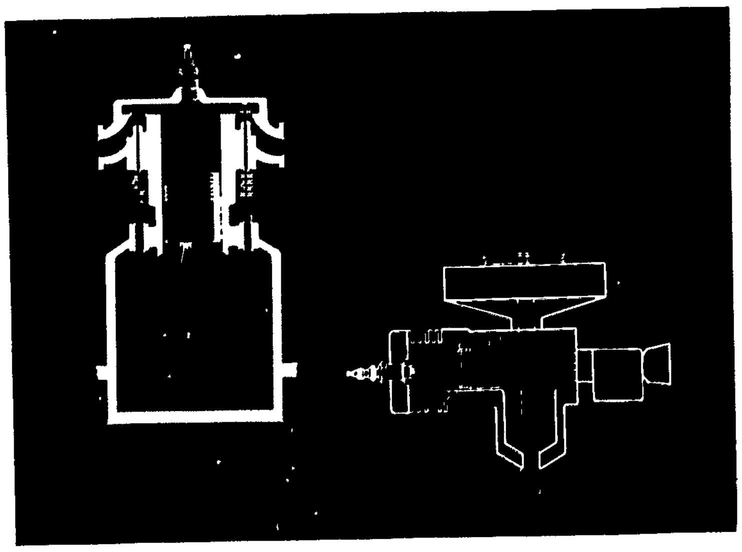
   There are many variations in the carburetor linkage. No attempt is made to show all of them in this publication. If you have not made a sketch and cannot remember how your linkage should be attached, it will be necessary for you to consult the service manual for your particular engine.

5. *Connect ground ignition wire if installed.*

6. *Install the carburetor air cleaner.*

7. *Recheck for proper operation.*

   See "Checking the Carburetor for Proper Operation," Volume I.



IV. REPAIRING GOVERNORS

The governor automatically regulates the speed of your engine at whatever setting you select on the speed control (throttle). Many people think the primary purpose of the governor is to prevent an engine from overspeeding. Most governors, however, used on small engines prevent the engine from underspeeding as well, thus maintaining a constant engine speed.

If your engine had no governor, it would choke down as load is applied. With the governor functioning properly, the engine speed remains fairly constant at variable loads as long as the load is within the horsepower capacity of the engine.

The governor regulates the engine speed by adjusting the amount of fuel-air mixture fed through the carburetor. As the load increases, the governor opens the throttle valve to provide enough more fuel so that the engine can increase its power output and maintain a constant speed. If the load decreases, the governor closes the throttle valve enough to provide less fuel to the engine, thus reducing the horsepower output and still maintaining a constant speed (Figure 159).

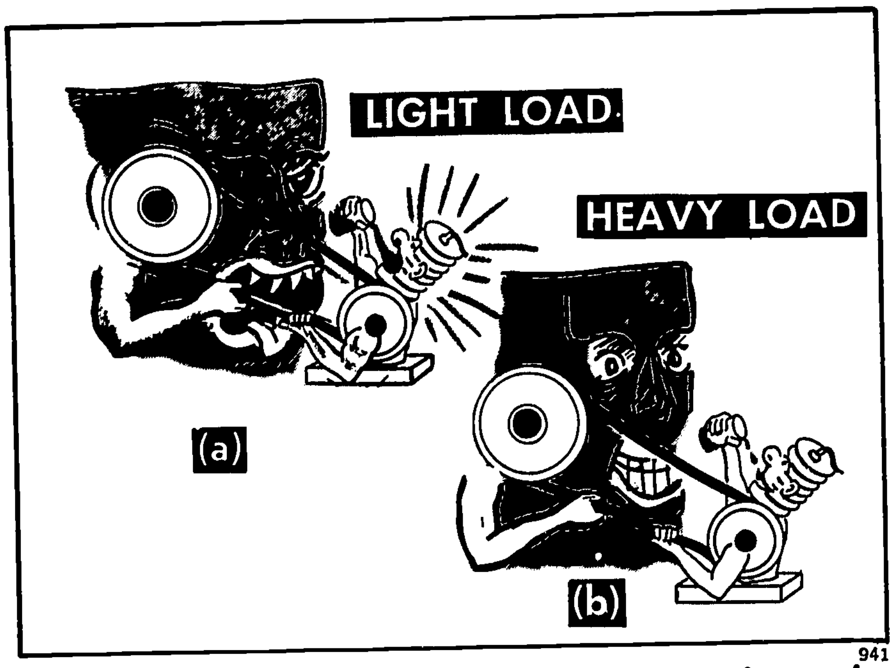


FIGURE 159. The governor on your small engine maintains a constant speed. (a) If load is applied, the governor opens the throttle and supplies enough more fuel-air mixture to maintain engine speed. (b) If the load decreases, the governor reduces the amount of fuel-air mixture and prevents the engine from overspeeding.

Maintaining and repairing governors are discussed under the following headings:

1. Types of governors and how they work.
2. Importance of proper repair.
3. Tools and materials needed.
4. Checking the governor for proper operation.
5. Adjusting the governor.
6. Repairing the governor.

TYPES OF GOVERNORS AND HOW THEY WORK

Generally there are two types of governors used on small engines: They are (1) **air-vane type,** or "pneumatic" (Figure 160); and (2) **centrifugal-type,** or "mechanical" (Figure 161). The names are derived from the speed-sensing elements.

Here is *how the air-vane governor (Figure 160) works.* The **air-vane,** located under the flywheel shroud, is in the path of the air coming from the flywheel fan. The air vane is *connected by linkage to the throttle valve* (Figure 160) in such a way that when it moves, the throttle valve opens or closes. The air vane is also connected by a spring to the throttle control. When the engine is stopped, the throttle valve is open by spring tension.

As the engine runs, air from the flywheel is directed against the air vane. The faster the flywheel turns, the greater the quantity of air directed against the air vane. This air pressure moves the air vane in the direction of air flow. **As the air vane moves,** the throttle valve closes accordingly, bringing the

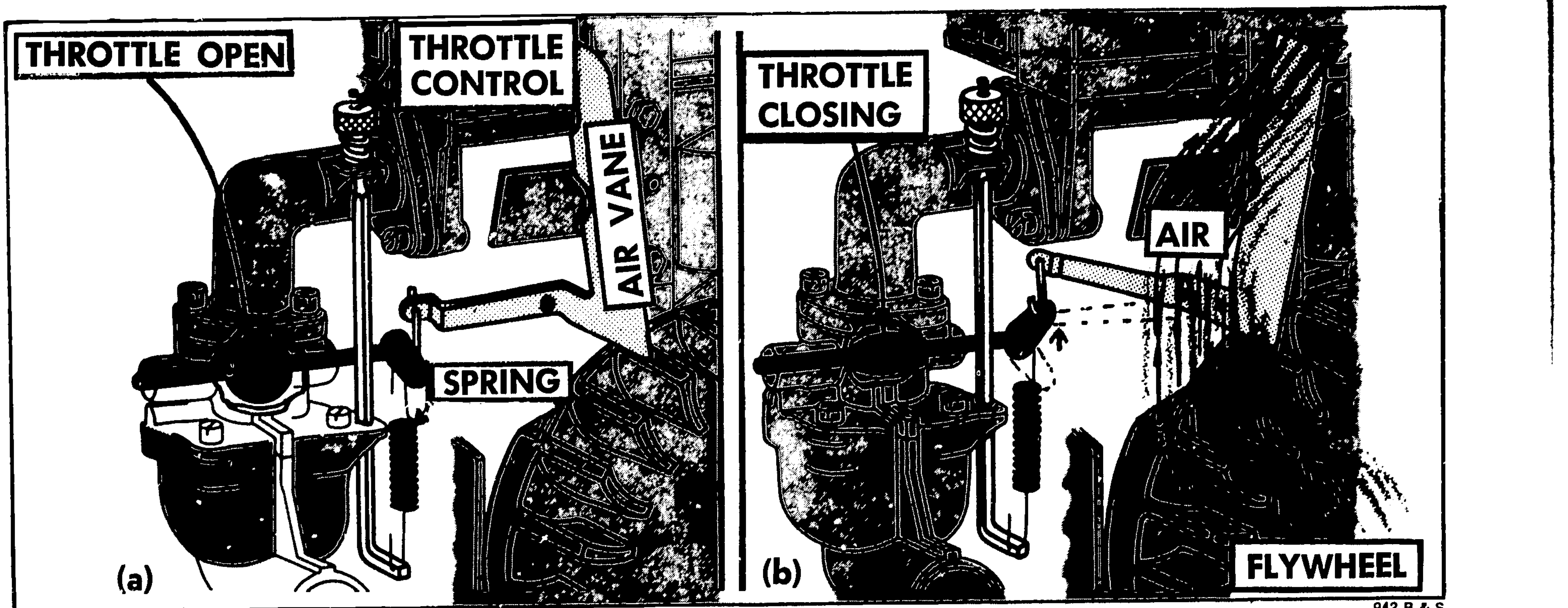


FIGURE 160. Principles of the air-vane governor. (a) With engine stopped, spring tension opens the throttle. (b) With engine running, air from the flywheel deflects the air vane and the throttle closes until the spring tension is equal to the amount of force applied to the air vane. The throttle then remains at this position unless the load changes or unless you change the throttle setting.

engine speed back in line with the speed selected by the throttle setting. At this point, the air force against the vane equals the spring tension pulling against it at the throttle. It remains in this position until you change the speed control, or the load on the engine changes.

Here is how a *centrifugal governor* (Figure 161) works. **When you adjust the throttle control** for increased speed, additional tension is exerted

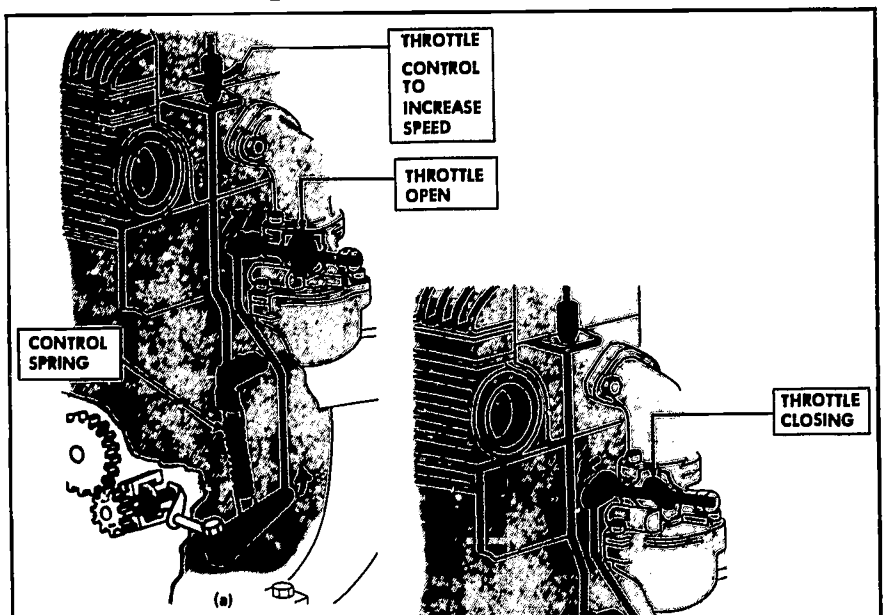


FIGURE 161. Principles of the centrifugal-type governor. (a) With engine stopped, spring tension opens the throttle. (b) With engine running, fly weights extend by centrifugal force and push the governor spool outward. This action rotates the governor arm against the spring tension and has a tendency to close the throttle.

on the governor-control spring. The spring tension opens the throttle valve (Figure 161a) and the engine speeds up.

As the engine **speeds up,** centrifugal force causes the flyweights or flyballs (Figure 162), to extend outward. As the flyweights move outward (Figure 161b), they push against a governor spool (or plate) which in turn rotates the governor arm. The rotation of the governor arm overcomes some of the spring tension and closes the throttle valve until the force against the throttle linkage equals the tension in the

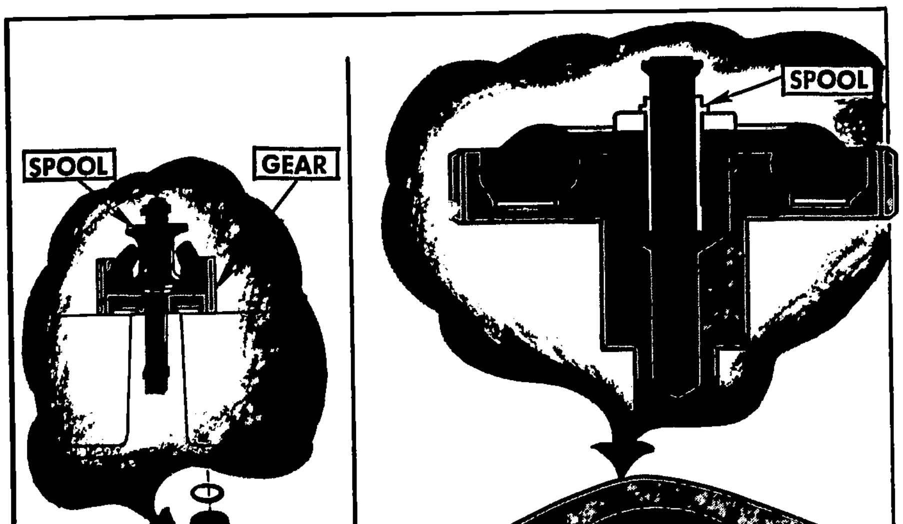


FIGURE 162. Two types of centrifugal governors. (a) Flyweights and spool. (b) Flyballs and spool.

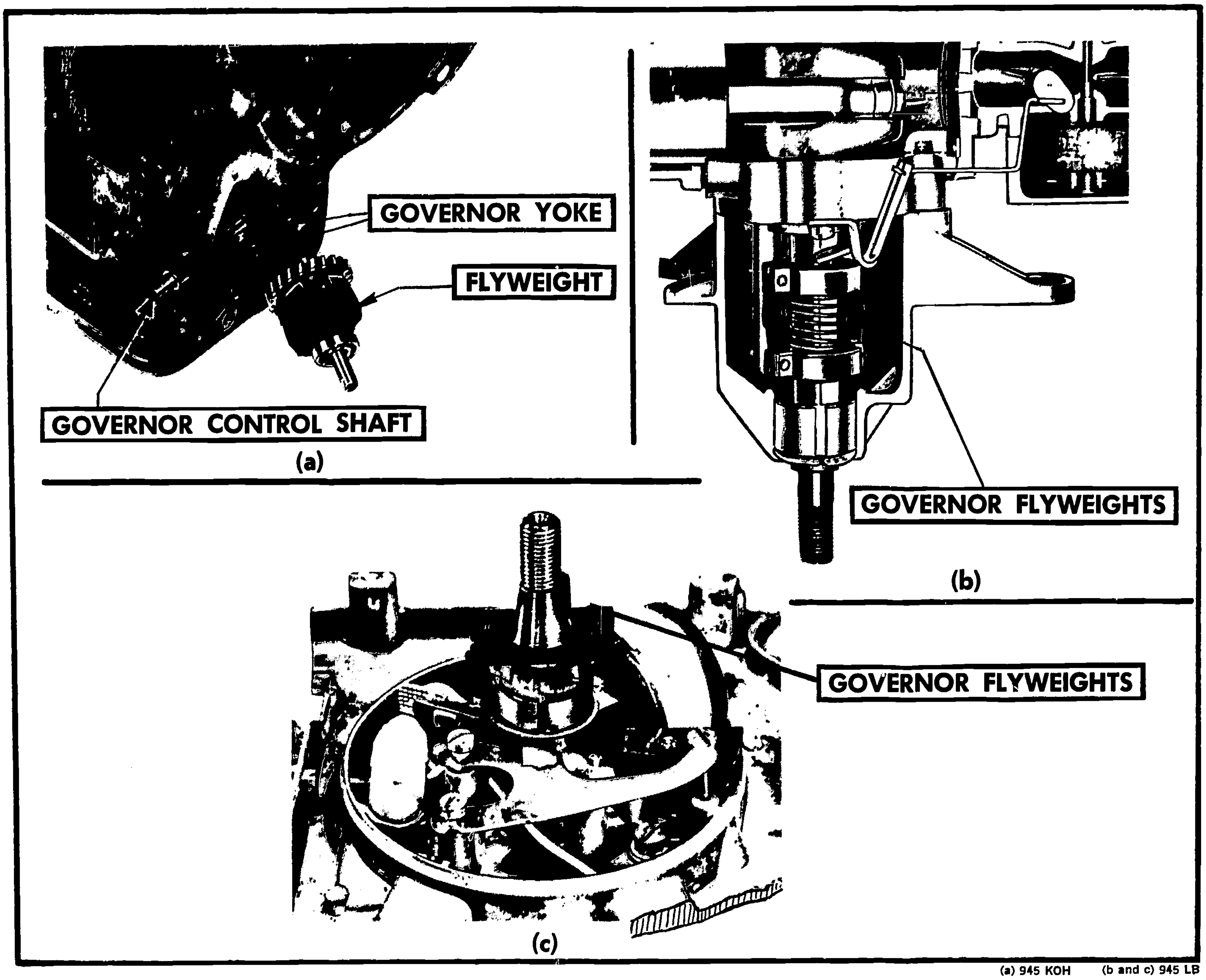


FIGURE 163. Centrifugal governors may be located (a) inside the crankcase. (b) on the drive end of the crankshaft, and (c) on the flywheel end of the crankshaft.

governor spring (Figure 161b). The amount of fuel-air mixture is reduced. In this way, the speed remains constant under variable loads, unless you change the throttle setting.

If more load is added to the engine, the engine tends to run more slowly. Centrifugal force is reduced on the flyweights and they recede. This reduces the force on the governor linkage. There is less tension in the spring, and the throttle valve opens proportionately. More fuel-air mixture then enters the engine and increases the horsepower output without reducing the engine speed.

Most centrifugal governors are located inside the crankcase (Figure 163a). They may be driven by the camshaft gear, or from the crankshaft. But some centrifugal governors are located on the drive end of the crankshaft (Figure 163b), while others are located on the flywheel end of the crankshaft (Figure 163c).

Most small engines should be operated in the high-speed range. At the high speed, your engine has the capacity to adjust to a wide range of power demands.

If the throttle setting is high enough, your engine is ready to start lugging the instant the governor action takes place. If the throttle setting is too low, there is not enough tension on the governor spring to allow the engine to adjust to full power quickly.

IMPORTANCE OF PROPER REPAIR

Engine manufacturers test their engines and select a maximum speed for each model — one that provides satisfactory power in relation to fuel consumption, wear and other factors. The speed selected varies

with different makes of engines and with different models of the same make.

The *maximum idle speed* recommended for your engine is given in your operator's manual. It is the one you normally use for checking your governor.

You may find that your engine is operating either too rapidly or too slowly. *If your engine is operating too rapidly,* wear increases rapidly. *If it operates too slowly,* less power is available. The engine overloads, chokes down and overheats.

TOOLS AND MATERIALS NEEDED

1. Combination pliers — 7″
2. Long-nose pliers — 7″
3. Open-end wrenches — 3/8″ through 1/2″
4. Cleaning solvents (mineral spirits, kerosene or diesel fuel)
5. Rags

CHECKING THE GOVERNOR FOR PROPER OPERATION

The governor, when in proper condition and adjustment, will respond quickly to any change in load. It will maintain the correct engine speed without hunting (surging). There is a delicate balance between the **governor control spring** and the governor **air vane, flyballs,** or **flyweights.** If the spring loses its tension, if the governor parts wear, or if any of the control linkages become damaged or worn, the governor will not work properly.

The governor often gets blamed for poor performance when the difficulty is in the fuel system, ignition system or in the compression. Clogged cooling fins will restrict the flow of air to an air-vane type governor and cause the engine to overspeed. Before checking your governor for proper operation, see that all these components of your engine are functioning properly.

1. *Check the condition of the governor linkage.*

   Check for bent links and worn connections. Check for freedom of operation of the linkage. Check the air-vane condition and the mechanical linkage for freedom of movement.

2. *Check to see if the throttle valve is open when the engine is stopped.*

   It should be completely open when the engine is stopped.

3. *Check the speed-sensing element.*

   You will not be able to check most **centrifugal-type governor** mechanisms without removing the flywheel or disassembling the engine. Usually these parts give little trouble. But if you have checked all the other sources of trouble and still suspect the governor, follow procedures for getting to your type governor. Refer to "Removing and Checking the Flywheel," page 55, and "Removing the Crankshaft," page 180.

   If your engine has an **air-vane type of governor,** you may have to remove the engine shroud to inspect the air vane. Check to see if the air vane is parallel to the crankshaft.

4. *Find the recommended speeds for your engine in your operator's manual.*

   There are three speeds with which you are concerned when checking your engine governor. They are (1) **idle speed,** (2) **high-idle, no-load speed,** and (3) **high-idle, full-load speed.**

   Manufacturers recommended that *idle speeds* range from *800* to *2,000 r.p.m.,* usually 1,800 r.p.m.

   High-idle speeds for 4-cycle engines vary from 2,000 to 3,600 r.p.m.; for 2-cycle engines, from 2,000 to 5,000 r.p.m. Engines on chain saws and go-karts may operate as high as 9,000 r.p.m.

   Full-load speed is usually 200 to 300 r.p.m., less than the high-idle, no-load speed. Your operator's manual does not always give a *full-load speed.* It will be less, however, than the high-idle speed, even though the speed-control lever is in the same position. This decrease occurs because there is some loss of engine speed at full load that the governor does not recover. For example, an engine that has a maximum no-load speed of 3,600 r.p.m. may have a full-load speed of 3,400 r.p.m. The amount of speed loss is different with different engines.

   Some manuals will indicate a speed range such as 3,000 to 3,200 r.p.m. In this case the governor is considered to be in proper adjustment if the high-idle speed is within this range. If only one high-idle speed is

given in your operator's manual, the governor is usually considered as being in satisfactory adjustment if the top engine speed is within 20 r.p.m. — faster or slower — than that speed.

5. *Start your engine and allow it to warm up.*

6. *Check the no-load, idle speed.*

   Check with the throttle control in the closed position. Use a tachometer for measuring your engine speed. Adjust the no-load idle speed by adjusting the idle stop screw. See "Adjusting the Carburetor," Volume I.

7. *Check the no-load, high-idle engine speed.*

   Move the throttle control to open fully and check the engine r.p.m. with a tachometer. The engine speed should come up to that recommended in your operator's manual. It should remain constant.

   If the **engine does not come up to speed,** or overspeeds, proceed to "Adjusting the Governor." Your governor could be worn, sticking or out of adjustment. The governor spring may be too loose. The spring may have lost its tension. If so, replace it.

   A worn-wear block on some governors will cause a reduction in r.p.m. Adjustment for a worn-wear block is shown in Figure 163c.

   If surging occurs on changing from one load to another, the spring is too tight. If you get a substantial drop in r.p.m. when load is increased, the spring is too loose.

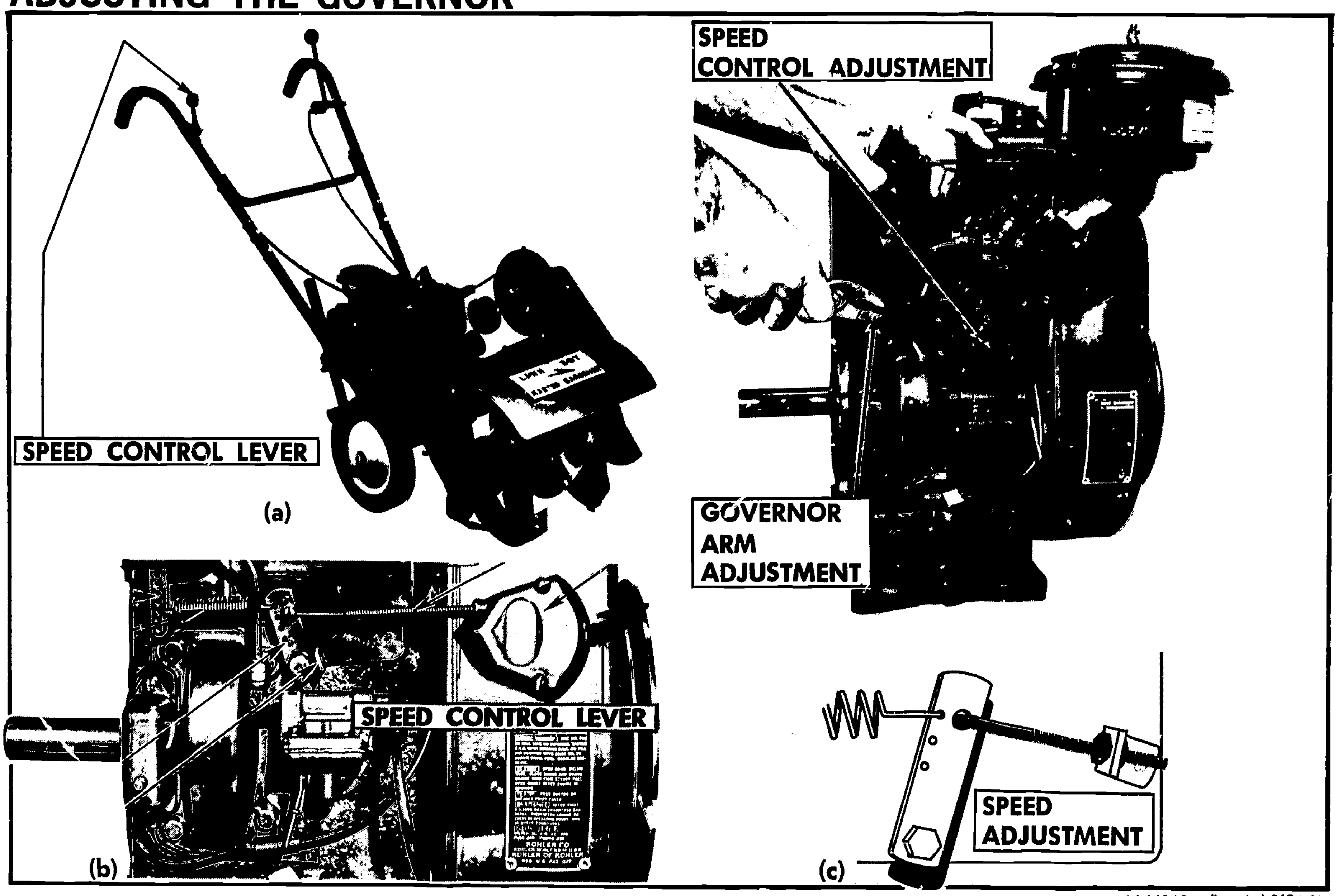
   If your **engine overspeeds,** the spring tension is too tight. It may be connected wrong; it may be binding or out of adjustment.

8. *Check the high-speed, full-load engine speed.*

   Use a dynamometer if possible.

   The governor should maintain the high-speed, full-load r.p.m. without fluctuating. Anything that restricts the movement of the governor mechanism and linkage can cause engine surging.

ADJUSTING THE GOVERNOR



(a) 946 LB (b and c) 946 KOH

FIGURE 164. On an engine with a constant-speed governor the speed-control lever is attached to the governor spring and not the throttle valve. (a) Engine equipped with a remote speed-control lever. (b) Speed-control lever on engine. (c) Adjustment for constant speed.

Adjusting the governor consists of adjusting the tension on the governor spring. Actually that is what you do when you change the speed of your engine.

You may have a remote (throttle) control lever (Figure 164a), or the control may be mounted on the engine (Figure 164b and c).

There are many different ways provided for adjusting governors (Figure 165), but regardless of

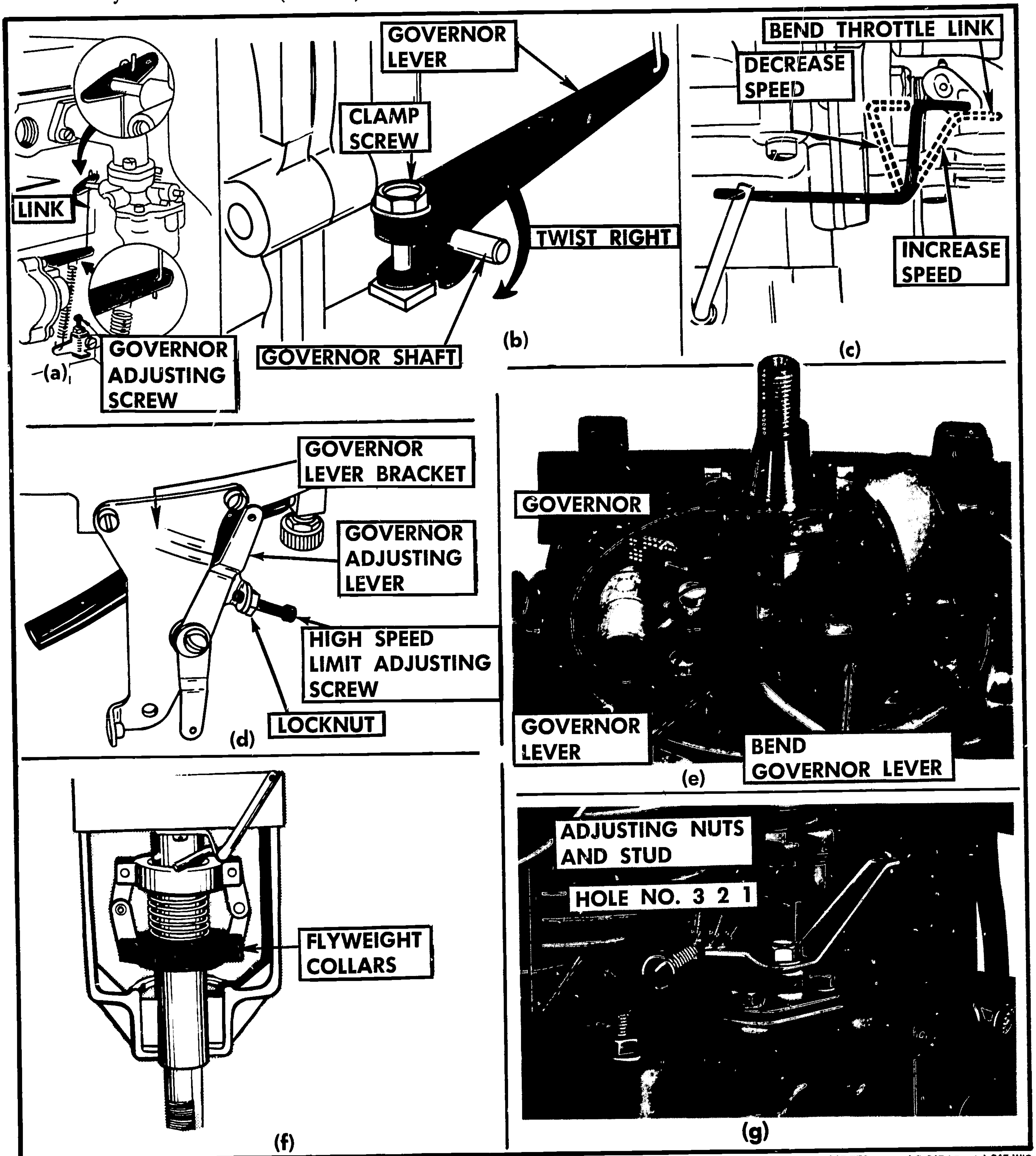


FIGURE 165. Different means for adjusting governors. (a) Changing the effective length of the throttle link. (b) Loosening clamp and rotating the governor lever. (c) Bending the throttle link. (d) Adjusting the high-speed limiting screw. (e) Bending the governor lever. (f) Repositioning the flywheel collars. (g) Changing the effective length of the governor adjusting stud.

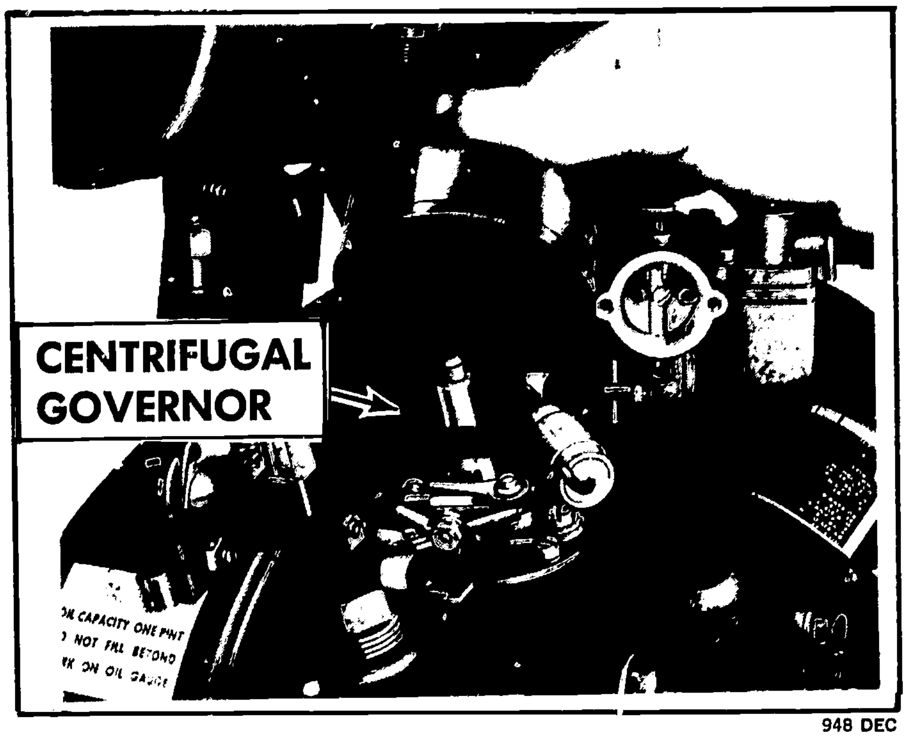


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FIGURE 166. Centrifugal governor mounted on a special shaft inside the breaker box.

the method the object is to increase or decrease tension on the governor spring.

Procedures for adjusting some governors are more complicated than others (Figure 166). But the principle is the same. It may be necessary to follow procedures in your service manual, but, in general, the following procedures will apply.

1. *Adjust the governor so that the throttle valve is closed when the engine is stopped.*

   Spring tension closes the throttle valve.

2. *Start engine and operate at full speed.*

3. *Adjust the spring tension so the engine will operate steadily at the maximum recommended r.p.m.*

   If you cannot get your engine to operate properly by adjusting the spring, replace the spring with a new one. Just any spring will not do. Use the spring designed for your engine.

4. *Check and adjust high-speed stop screw if installed.*

   This should be done each time a change is made in the governor spring tension.

   On some engines a safety override stop is installed. It is a mechanical stop which limits the amount of tension you can apply to the governor spring.

REPAIRING THE GOVERNOR

From a repair standpoint there are three kinds of governors: (1) the air-vane type, (2) the centrifugal type mounted inside the crankcase, and (3) the centrifugal type mounted outside of the crankcase.

a. If your governor is the **air-vane type** (Figure 160), proceed as follows:

1. *Remove the flywheel shroud.*

   Refer to "Cleaning Engines," Volume I. Check the air vane for condition and position.

2. *Straighten air vane if it is bent.*

   It should be parallel to the crankshaft.

3. *Replace worn or damaged parts.*

b. If your governor is the **centrifugal type (Figure 161) and located inside the crankcase,** proceed as follows:

1. *Check and repair, or replace spring and/or linkage.*

2. *Gain access to the sensing element.*

   If the governor is **located on the flywheel end of the crankshaft (Figure 163c),** it will be necessary to remove the flywheel. Refer to "Removing and Checking the Flywheel," page 55.

   If the **governor is located inside the crankcase** (Figure 167), it likely cannot be removed without disassembling the engine. If it becomes necessary for you to get to the governor inside the crankcase, see procedures under "Removing the Crankshaft," page 180. Remember when disassembling your governor to make sure you note how to put it back together. Either draw a sketch or lay the parts out in order of their reassembly.

3. *Remove the flyweight assembly and other governor mechanisms.*

4. *Clean governor parts.*

   Use petroleum solvent.

5. *Inspect governor parts for damage and/or wear.*

6. *Reassemble governor, replace in reverse order of disassembly.*

7. *Adjust governor.*

   Follow procedures under "Adjusting the Governor" page 102.

8. *Recheck for proper operation.*

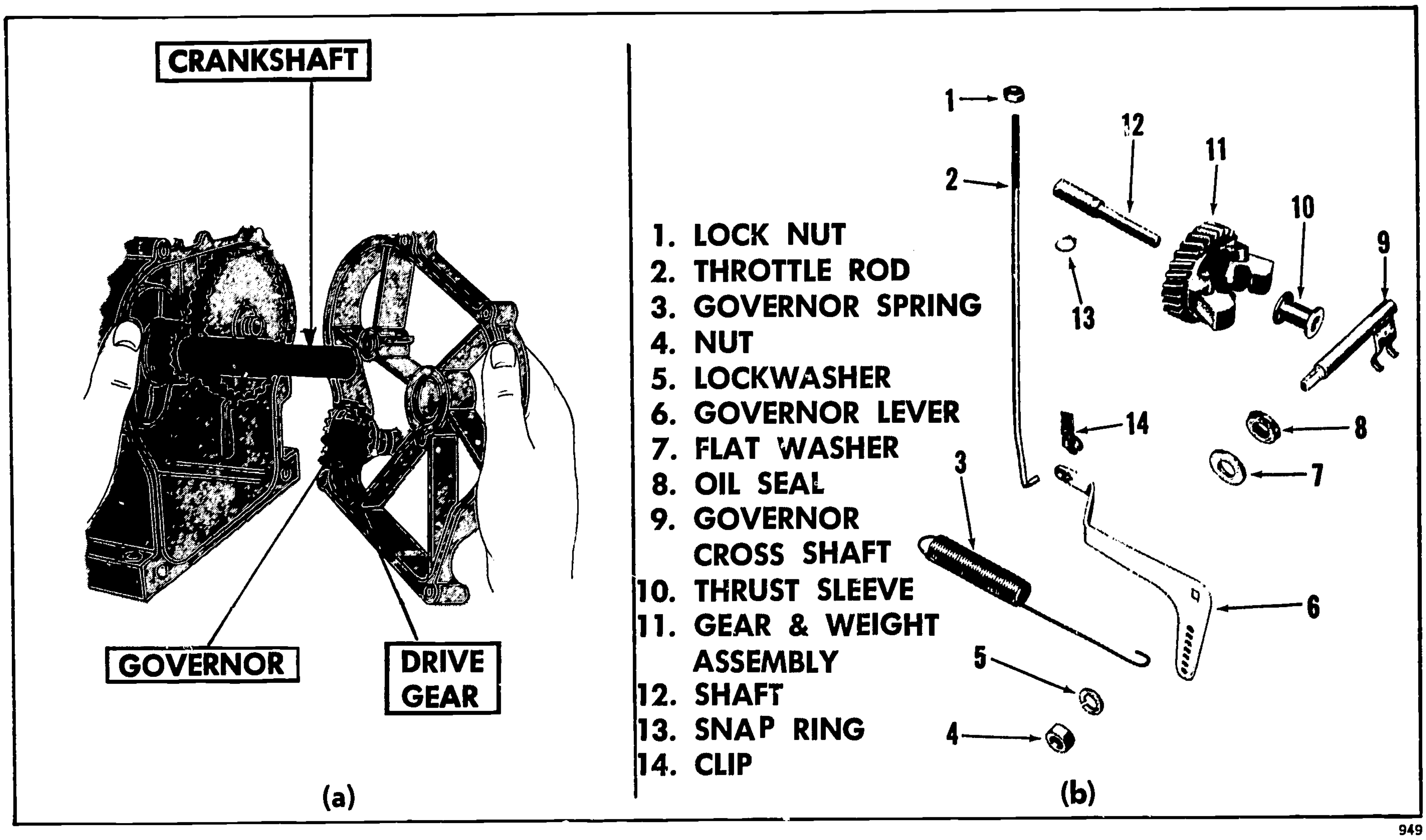


FIGURE 167. (a) Removing a crankcase type of centrifugal governor. (b) Clean and inspect governor parts for damage or wear. Lay them out in order of disassembly so you can tell how to put them back together.

c. If the governor is the **centrifugal type mounted outside of the crankcase** (Figure 168), use the procedures that follow. There are several variations of this type of governor. If the procedures given here are not sufficient for your engine, consult your service manual.

1. *Remove the flywheel.*

   Refer to "Removing and Checking the Flywheel," page 55.

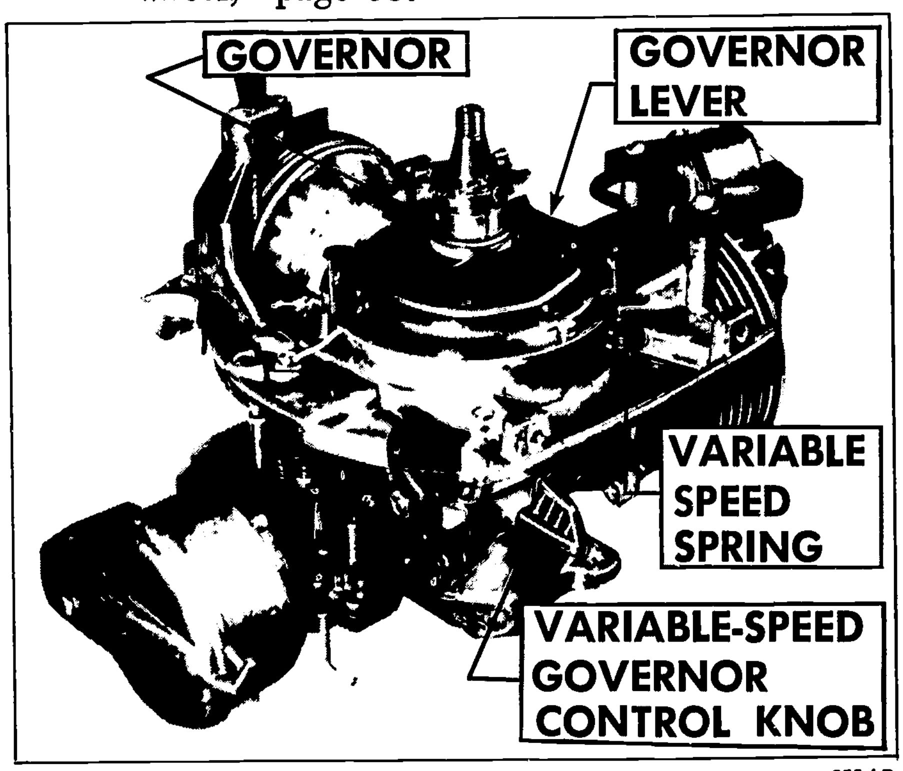


FIGURE 168. One type of centrifugal governor mounted on the flywheel end of the crankshaft outside of the crankcase.

2. *Disconnect the variable-speed spring attached to the governor lever (Figure 168).*

3. *Remove the flyweight assembly (Figure 169).*

4. *Remove the nylon thrust collar and governor lever from the crankshaft (Figure 170).*

   Look for worn or damaged parts. Replace them with new ones. Parts of this type governor are shown in Figure 171.

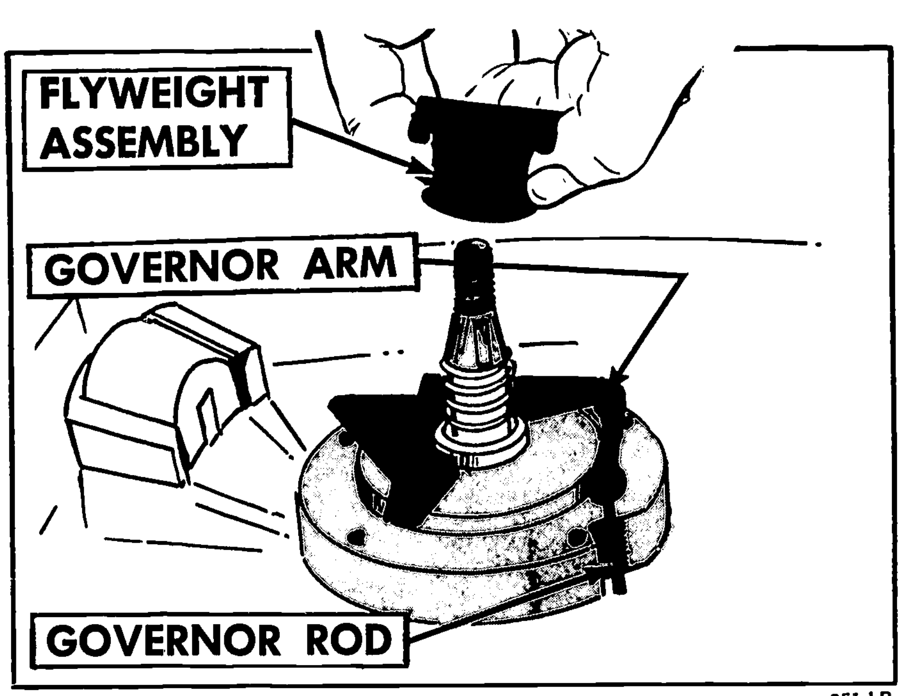


FIGURE 169. Removing governor flyweight assembly.

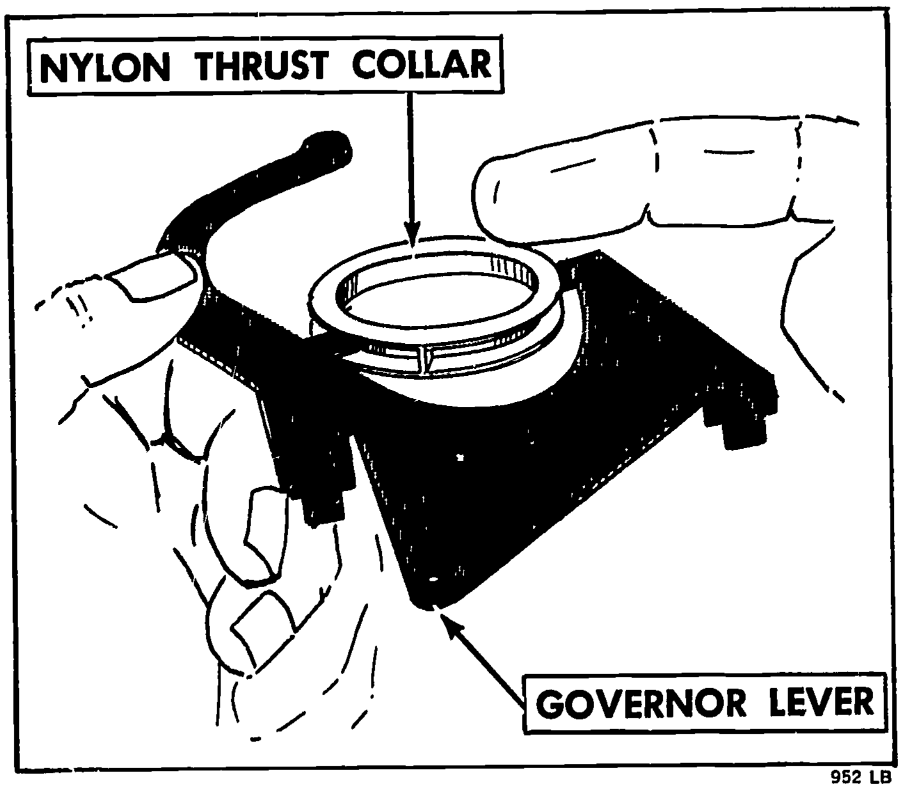


FIGURE 170. Removing the governor arm and nylon thrust collar.

5. *Install governor lever and thrust washer assembly (Figure 172a).*

   Hook the governor lever-arm hinge into slots on the breaker-box dust cover and connect the spring (Figure 172b).

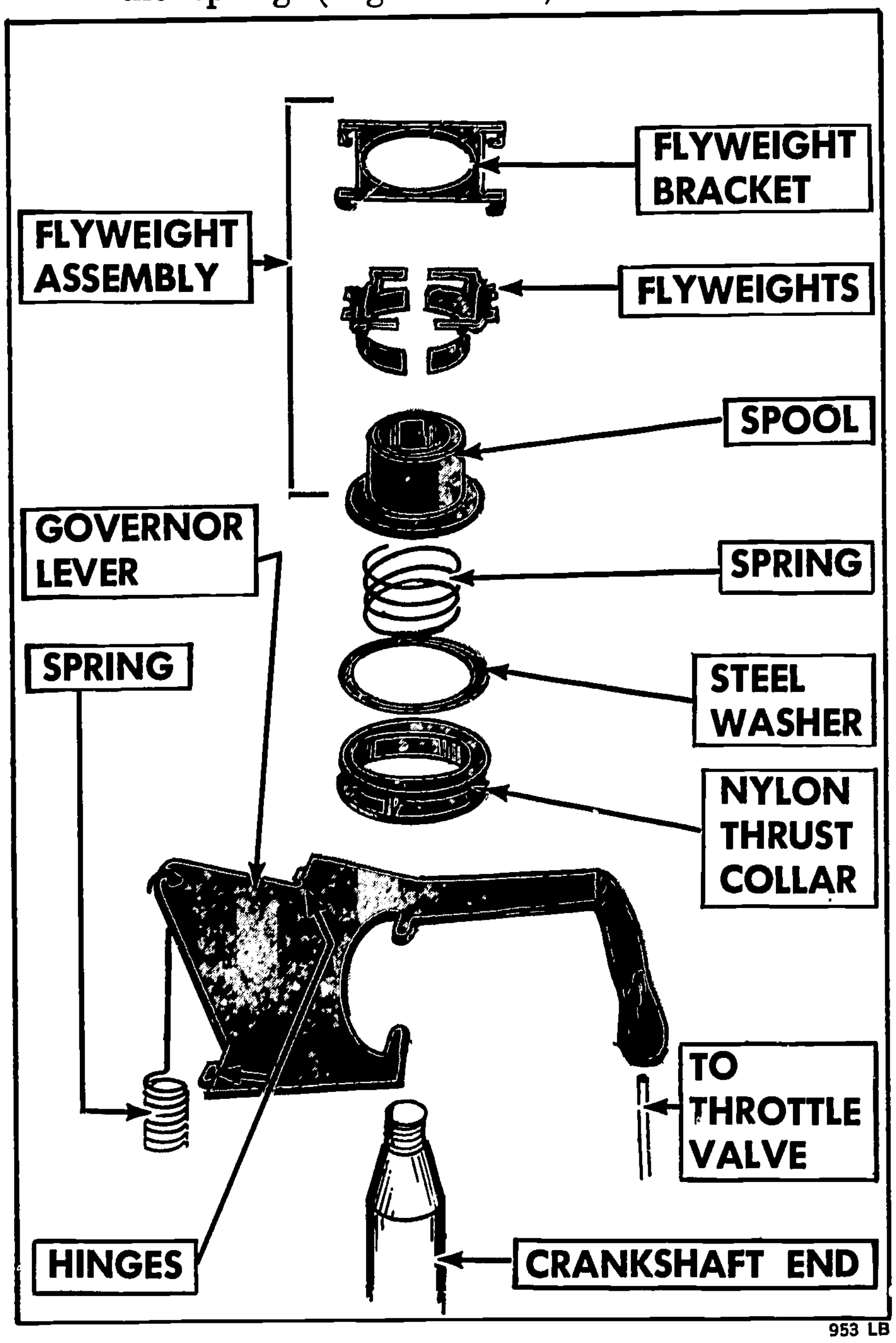


FIGURE 171. Parts of a centrifugal governor mounted on the flywheel-end of the crankshaft.

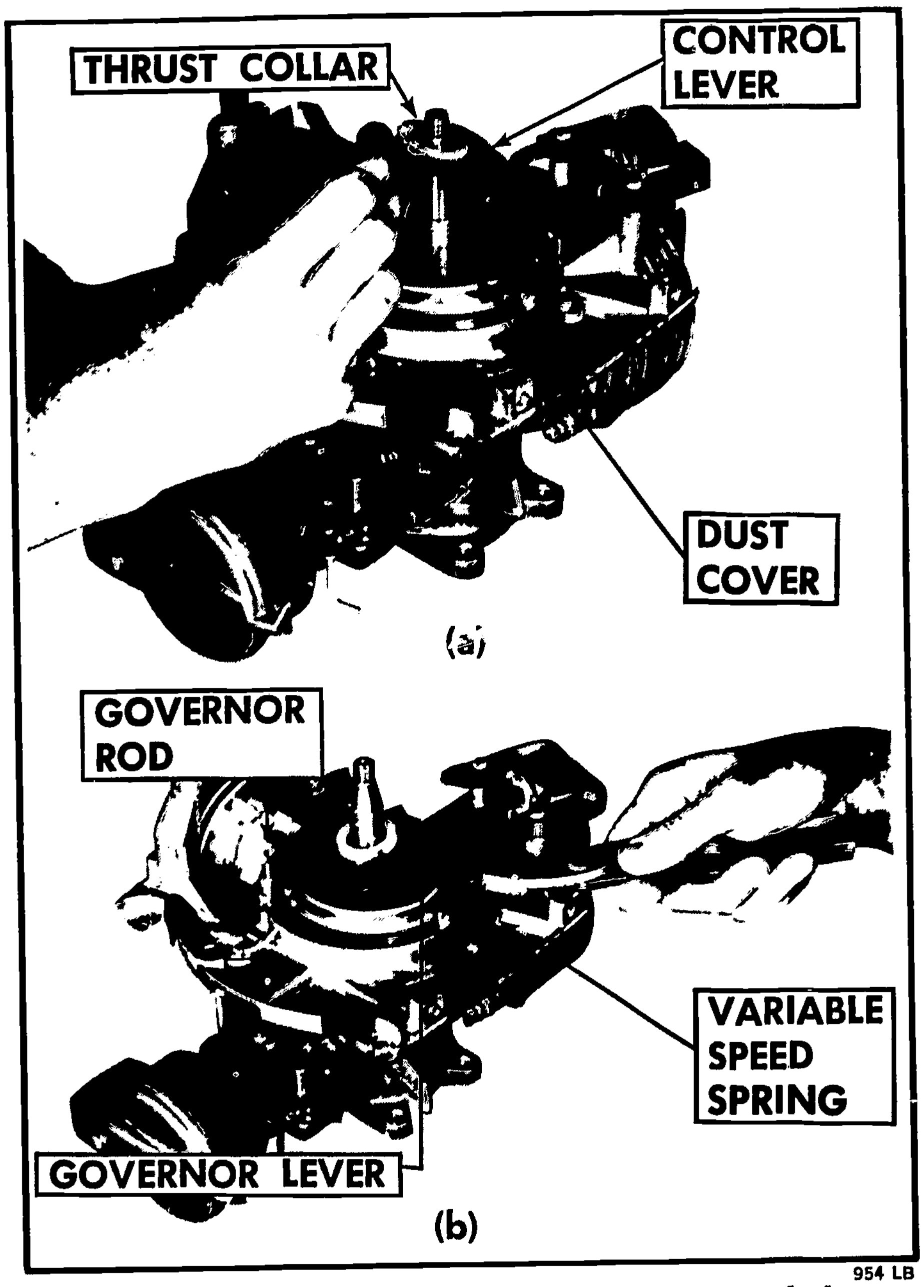


FIGURE 172. (a) Installing the governor arm and thrust collar assembly. (b) Fastening the governor spring.

6. *Install the flyweights, spring and fly-weight assembly.*

7. *Check governor lever adjustment (Figure 173).*

   Hold flyweights down with a pipe nipple. At the same time close the throttle by hand. Measure the clearance between the governor lever and the governor rod (Figure 173). It should be approximately 1/16 inch. Note in Figure 173a how the governor arm extends over the end of the governor rod. Adjust by bending the governor lever at the crease (Figure 173b).

8. *Install flywheel key.*

9. *Install flywheel (Figure 174).*

   When installing the flywheel, clean tapered end and the taper inside the flywheel with a clean cloth.

   Align the governor flyweight assembly so that it will clear the governor drive lug on the flywheel. If it does not clear, the flyweight assembly will be jammed when you tighten

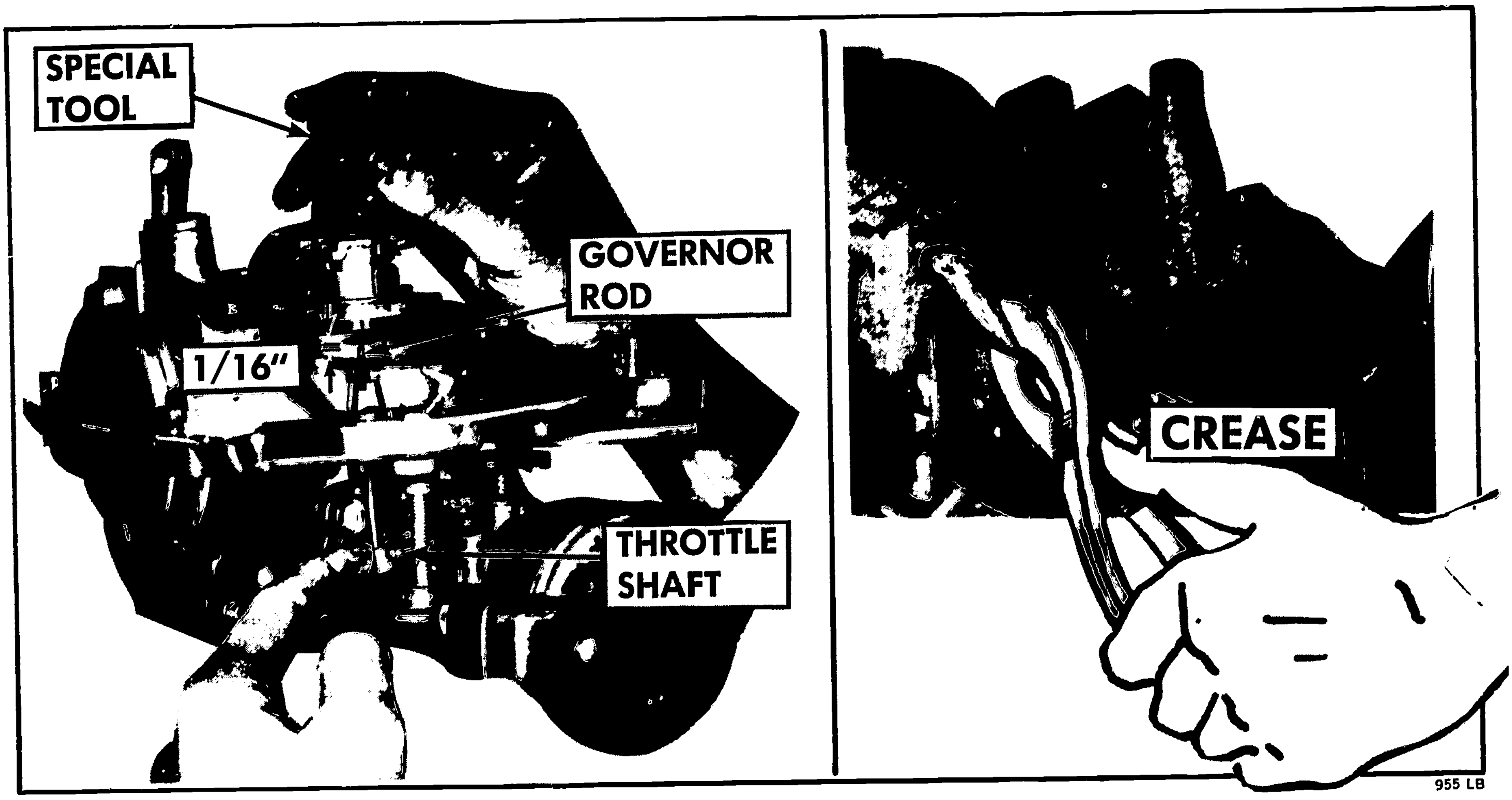


FIGURE 173. (a) Checking the governor-lever adjustment. (b) Adjusting the governor lever for clearance between it and the governor rod.

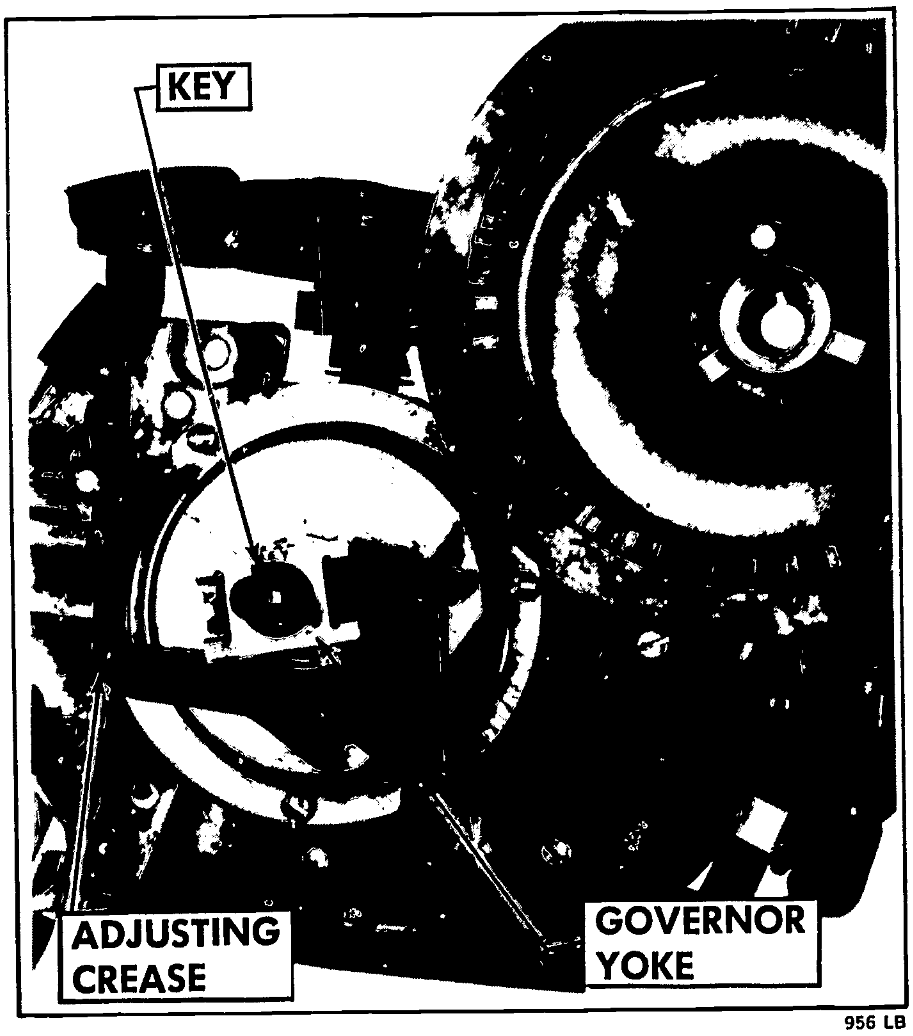
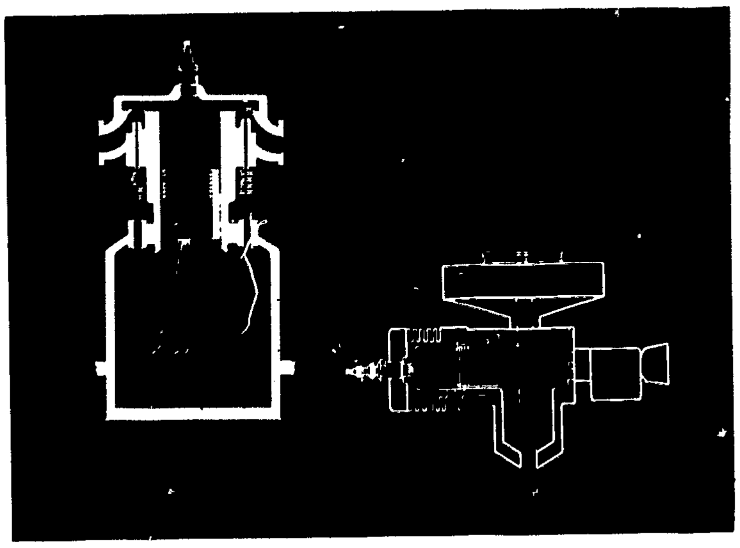


FIGURE 174. Align one of the straight edges of the governor with the flywheel key way.

the flywheel nut. To avoid this, some flyweight assemblies are marked "key" to indicate where the governor should be mounted in relation to the crankshaft key.



V. REPAIRING VALVES

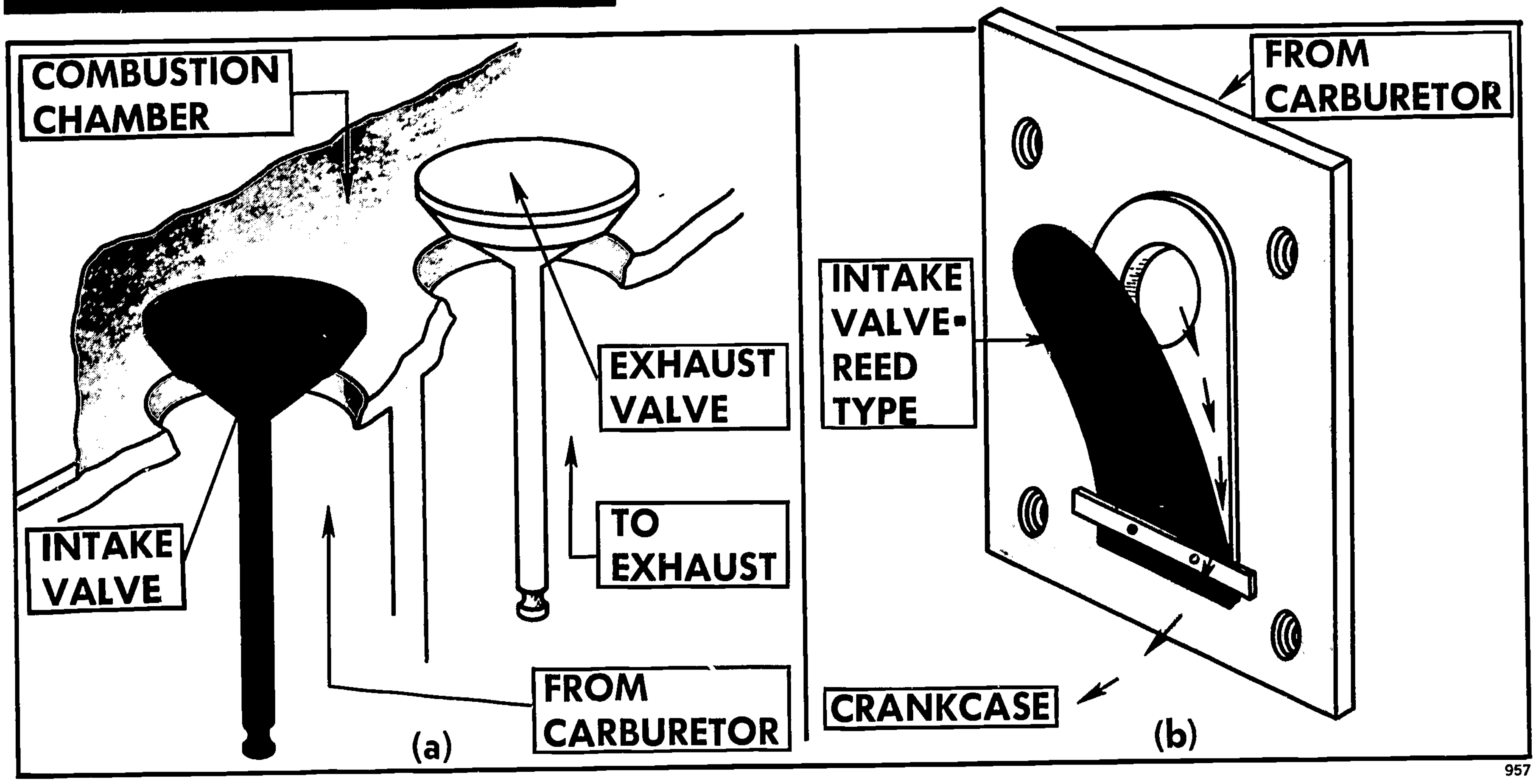


FIGURE 175. Valves on 4-cycle and 2-cycle engines. (a) Four-cycle engines have both an intake poppet valve and an exhaust poppet valve opening into the combustion chamber. (b) Two-cycle engines have only an intake valve which opens into the crankcase. It is usually a reed-type valve.

Four-cycle and 2-cycle engines are similar in many respects; but when it comes to valves, they are very different (Figure 175).

IMPORTANCE OF PROPER REPAIR

There is little preventive maintenance you can do directly to your valves. Valves, however, are seriously affected by the condition of your fuel and/or ignition system. Failure to maintain these systems properly result in valve failure.

Anything that affects valve operation will reduce the compression of your engine and result in hard starting, loss of power, and in eventual engine failure.

On **4-cycle engines,** valve failures consist of valves burning, sticking, dishing and necking (Figure 176).

Valve burning is caused by burning gases escap-

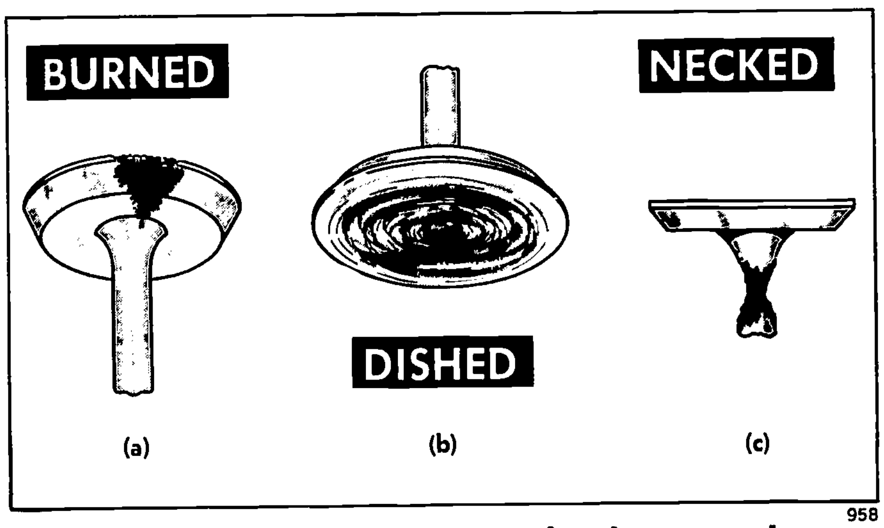


Figure 176. Improperly maintained valves may become (a) burned, (b) dished or (c) necked.

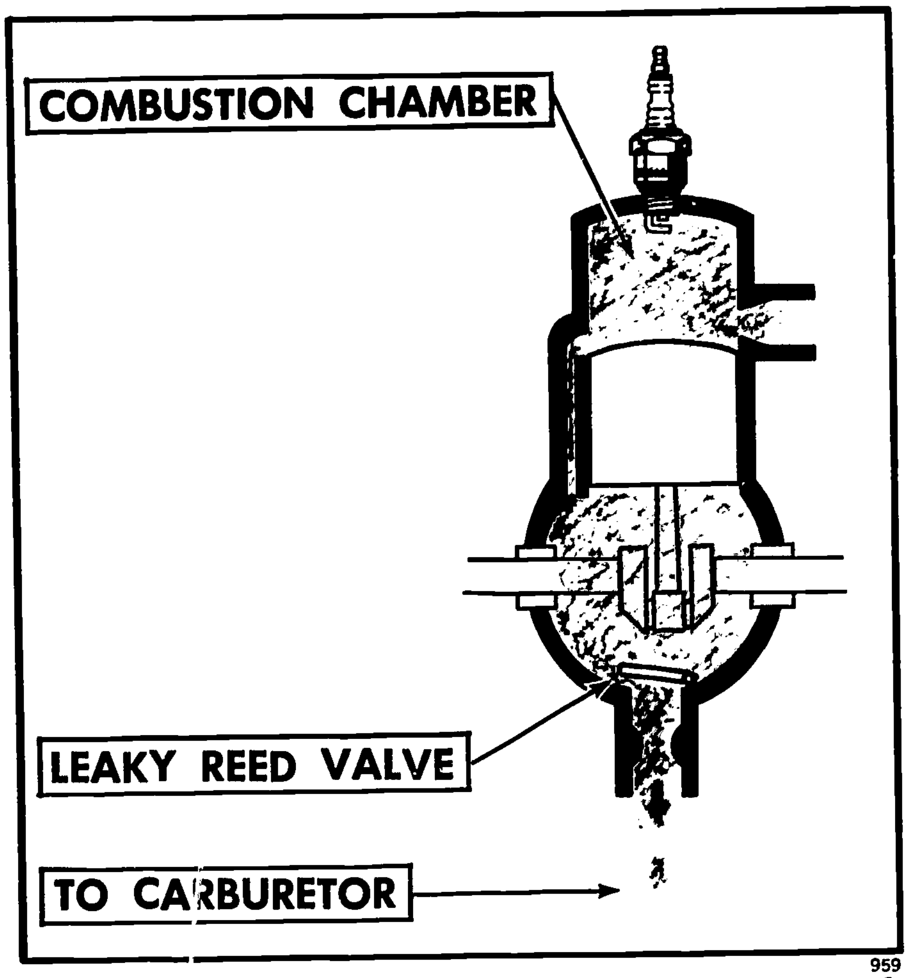


FIGURE 177. A leaky reed valve will result in loss of power.

ing by the valve. This happens when valve clearance is too small, or if the valve does not seat properly.

Valve sticking is failure of the valve to close because of the stem binding in the valve-stem guide. This sticking occurs most frequently on exhaust valves. It is caused by carbon, lead, gum and varnish. This is what happens. The hot gases escaping from the combustion chamber overheat the valve stem and guide. This overheating causes the oil on the valve stem to oxidize into varnish which holds the valve partially open. Continued operation with the valve partially open results in valve burning.

Intake-valve sticking may be caused by an excessive amount of gum in stale gasoline.

Valve dishing develops when the valve get so hot that it is cupped when it strikes the valve seat (Figure 176b). *Valve necking* results from the same conditions. The valve neck becomes red hot and elongates on impact with the valve seat (Figure 176c).

Proper valve-tappet clearance on 4-cycle engines is also essential to good engine operation. Since valve clearance on most small engines cannot be adjusted without removing them, there is not much need for checking clearance unless you are prepared to do a valve repair job.

Reed valves on **2-cycle engines** are located between the carburetor and the crankcase. They seldom give trouble; but when you suspect trouble, it is not difficult to clean, check and adjust them.

The term "reed" valve may be misleading. Reed valves are not made of bamboo, as in reed-type musical instruments. They are made of thin spring steel, plastic or phenolic materials.

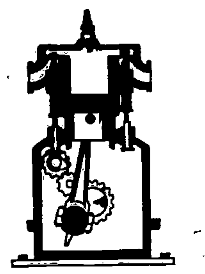
A leaky reed valve will allow the fuel, air and oil mixture to be forced back into the carburetor (Figure 177), an action which decreases pressure in the crankcase. As a result of this pressure loss, the fuel charge entering the combustion chamber is lessened. The result is a loss of power.

Three common failures that result from improper engine care of reed valves are (1) **carbon build up under the reeds,** (2) **broken reeds,** and (3) **reeds out of adjustment.**

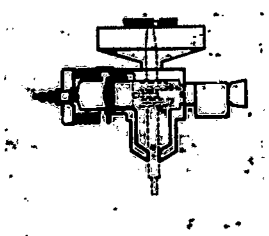
Maintaining and repairing valves are discussed under the following headings.

A. Repairing valves on 4-cycle engines.

B. Repairing valves on 2-cycle engines.



A. REPAIRING VALVES ON 4-CYCLE ENGINES



Valves on 4-cycle engines have three functions: (1) **to provide an inlet for the fuel-and-air mixture to enter the combustion chamber (Figure 178a),** (2) **to seal the combustion chamber during the compression and power strokes (Figure 178b),** and (3) **to allow burned gases to escape (Figure 178c).**

Maintaining and repairing valves on 4-cycle engines are discussed under the following headings:

1. Types of valves and how they work.
2. Tools and materials needed.
3. Checking valve operation by compression test.
4. Checking the valve-tappet clearance.

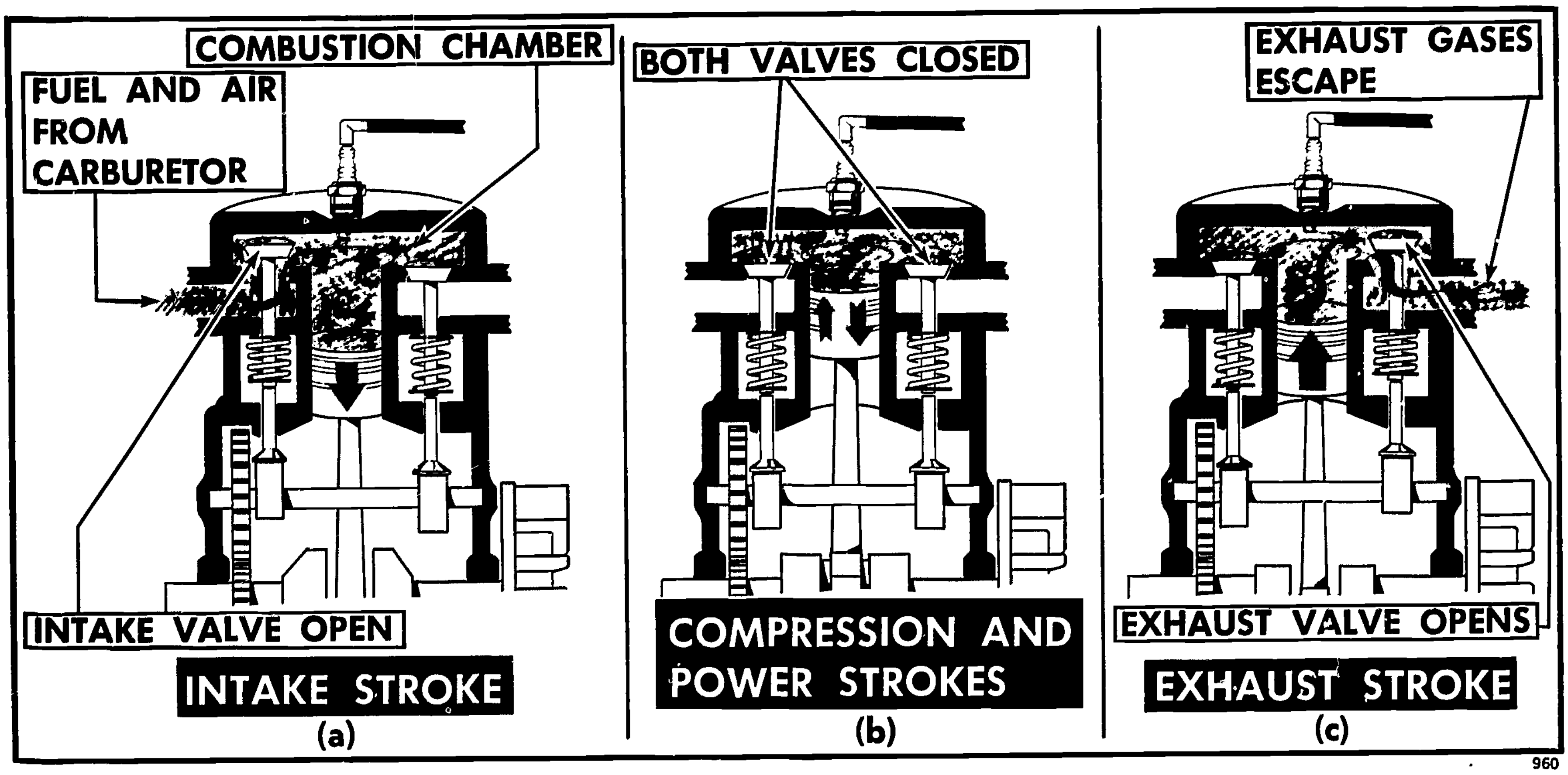


FIGURE 178. Functions of valves on 4-cycle engines. (a) Intake valve opens for fuel and air to enter the combustion chamber. (b) Both valves closed to seal the combustion chamber during the compression and power strokes. (c) Exhaust valve opens to allow burned gases to escape.

5. Removing the cylinder head.
6. Removing the valves.
7. Inspecting the valves and valve accessories.
8. Repairing valve guides.
9. Grinding (refacing) the valves.
10. Grinding (refacing) the valve seats.
11. Replacing the valve seats.
12. Lapping the valves.
13. Adjusting the valve tappet clearance.
14. Installing the cylinder head.

TYPES OF VALVES AND HOW THEY WORK

All 4-cycle engine valves are of the **poppet-type** (Figure 175a).

On 4-cycle engines there are two valves, an **intake valve** and an **exhaust valve.** *Exhaust valves*

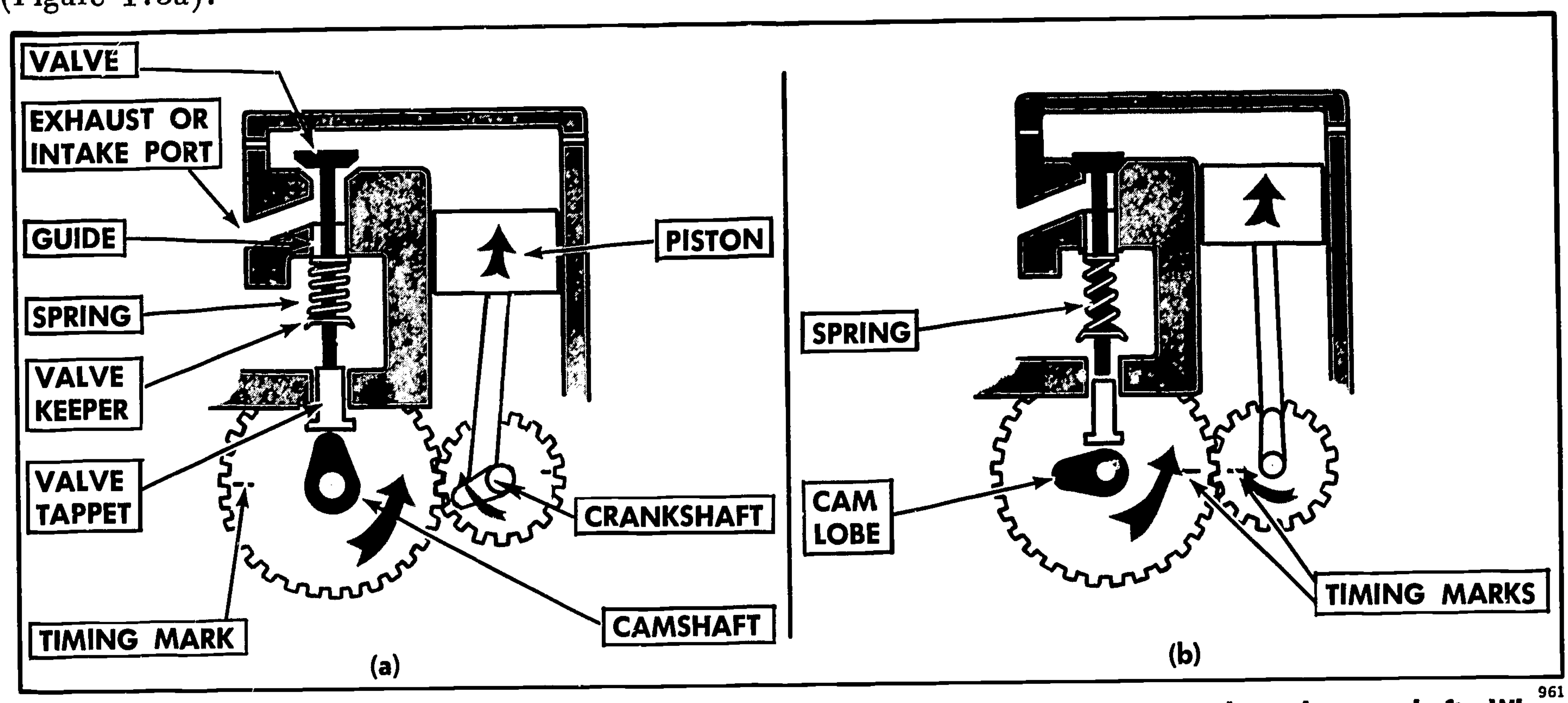


FIGURE 179. How a valve works on a 4-cycle engine. (a) Lobe on camshaft pushes valve tappet up, which opens the valve. (b) The crankshaft gear drives the camshaft gear which is connected to the camshaft. When the cam lobe moves past the valve tappet, spring compression causes the valve to close.

are made of special heat-resistant steel, and sometimes the stems are filled with a liquifying metal, such as sodium, to help them to cool faster by dissipating heat.

Here is how the valves work. Poppet valves are opened at the proper time by tappets which are driven from lobes on the camshaft (Figure 179a). They are closed by spring tension (Figure 179b). Some engines, designed for continuous operation, have *rotators* that cause the valves to turn as they operate. This helps reduce valve burning.

The **camshaft** is driven from a gear on the crankshaft (Figure 179). Note that the camshaft has twice the number of teeth as the gear on the crankshaft. This proportion enables the camshaft to turn at one half the speed of the crankshaft, since the 4-cycle engine has only one power stroke in two revolutions of the crankshaft. Refer to Figure 5, Volume I.

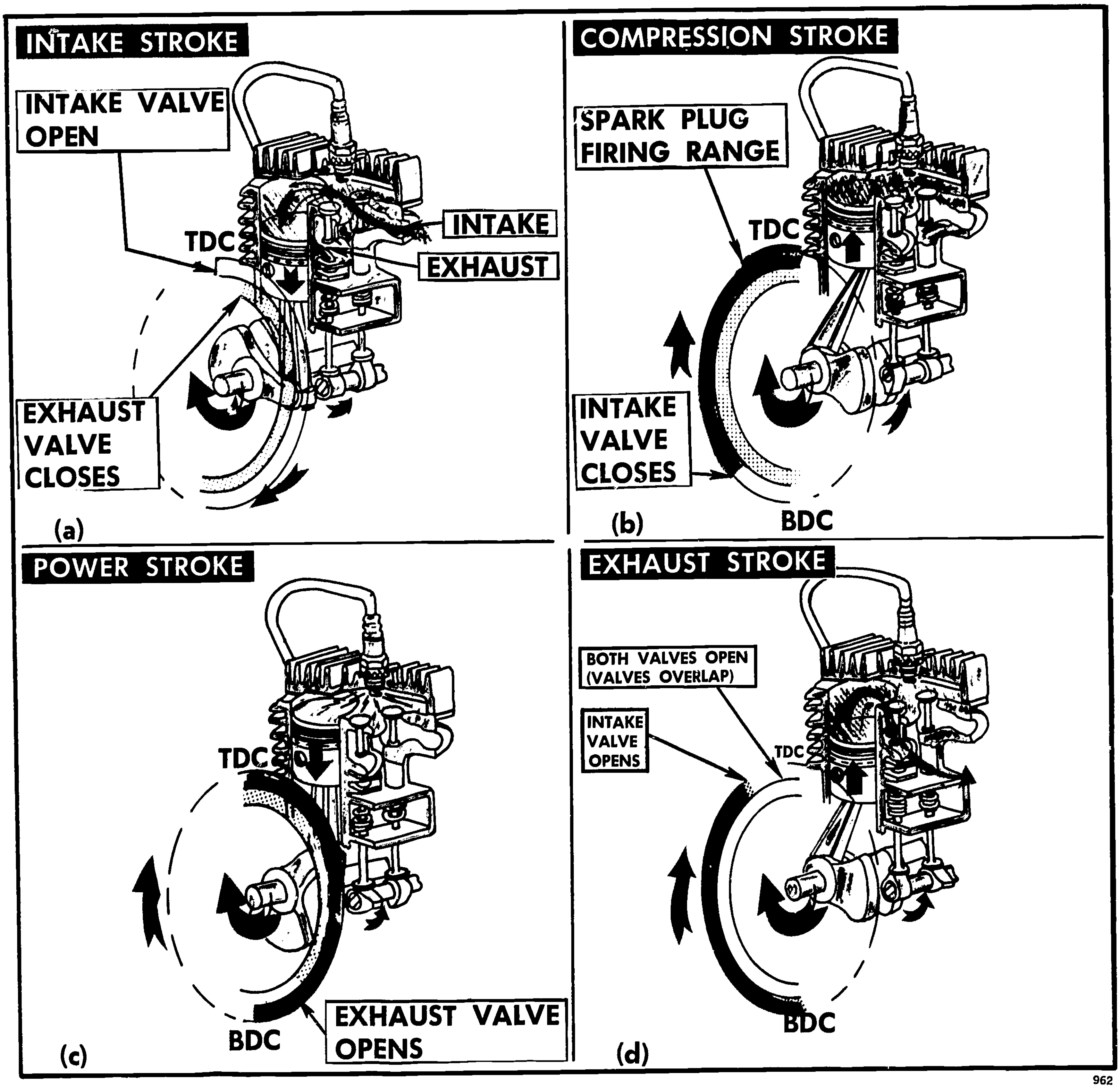


FIGURE 180. Typical positions of the crankshaft when the valves open and close. (a) Both valves are slightly open at the beginning of the intake stroke. This is called "valve overlap." Shortly afterwards the exhaust valve closes. (b) The spark plug fires at the beginning of the power stroke, or just before. The intake valve closes approximately 20° past bottom-dead-center (BDC), compression stroke, and both valves remain closed until near the end of the power stroke. (c) At approximately 35° before bottom-dead-center (BBDC) power stroke, the exhaust valve opens and remains open throughout the exhaust stroke. (d) The intake valve begins to open approximately 20° BTDC.

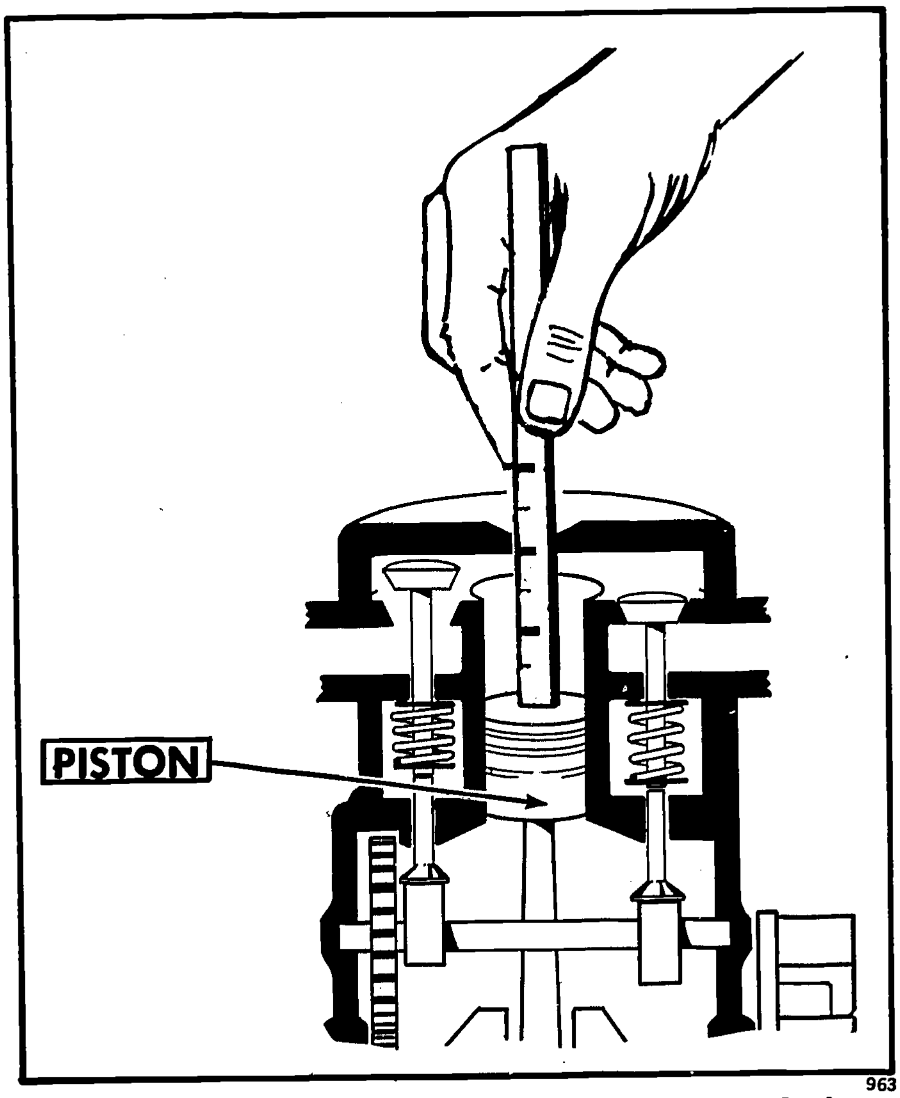


FIGURE 181. Measuring valve timing in inches of piston travel before TDC.

With your engine turning at 3,000 r.p.m., each valve must open and close in approximately 1/15 of a second. This is fast for a poppet valve, and there is not much time for the fuel charge to enter. Neither is there much time for the burned gases to escape. For this reason the cams are designed to hold the valves open as long as possible. They open a little ahead of time and close a little late (Figure 180). The time the valves are to open and to close is established by the manufacturer for each engine model. "Timing marks" are made on the camshaft gear and the crankshaft gear (Figure 179) for aligning the gears properly.

Note that the *spark-plug firing range* is also indicated in Figure 180. It ranges from 25° BTDC compression stroke to 4° ATDC. When the spark occurs before TDC, it is called "advanced-ignition timing." When the spark occurs after TDC, it is called "retarded-ignition timing."

The position of the crankshaft at which the valves open and close varies with different engines. This may be measured in degrees of turn by the crankshaft (Figure 180a), or by the measured distance of the piston from TDC (Figure 181). Manufacturers who give their timing specifications in their service manuals, may give them either in degrees of crankshaft travel or in inches or piston travel.

TOOLS AND MATERIALS NEEDED

1. Socket wrenches — 1/4″ through 9/16″
2. Wire brush
3. Valve spring compressor
4. Valve lapping tool
5. Valve seat insert remover
6. Valve grinder
7. Feeler gage
8. Torque wrench and socket set — 3/8″ through 9/16″ - 3/8″ drive, and a 3/4″ or 11/16″ spark-plug socket
9. Slot-head screwdriver — 6″ regular
10. Phillips-head screwdriver — 6″
11. Air pressure gage — 0 to 100 psi
12. Air-operating valve adapter
13. Pocket knife
14. Micrometer — 0″ to 2″ and 0″ to 6″
15. Clean rags
16. Emery cloth

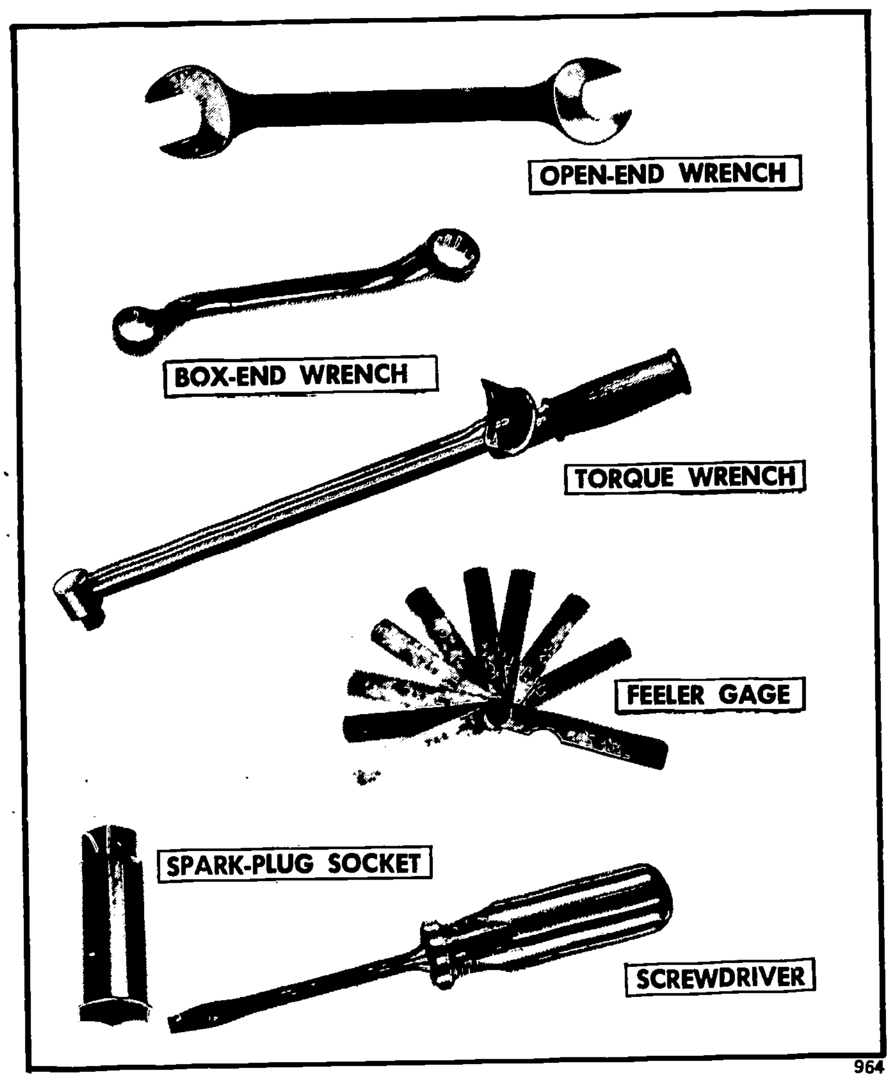


FIGURE 182. Some examples of tools needed for maintaining and repairing valves.

17. Bucket and petroleum solvent (mineral spirits, kerosene or diesel fuel)
18. Container for nuts, bolts and screws
19. Valve-lapping compound
20. Prussian blue

CHECKING VALVE OPERATION BY COMPRESSION TEST

Hard starting, rough running and loss of power are signs of poor valve operation.

Engine backfiring through the carburetor is a sign of a bad intake valve.

If you suspect valve trouble, check the compression. Improper valve operation can cause poor compression, but several other conditions can also cause it. They are as follows:

- *A dry cylinder on an engine that has not been used for some time* — the oil drains away from the rings, thus allowing air to bypass.
- *Piston rings stuck because of carbon deposits.*
- *Worn piston rings and worn cylinder.*
- *Loose or broken spark plug.*
- *Damaged cylinder head, gasket or loose cylinder head.*
- *Sticking, burned or warped valves, and/or valves out of adjustment.*

There are four methods for checking compression.

a. Turning the *crankshaft* by hand without removing the spark plug and feeling the amount of compression resistance to turning.

b. Turning the crankshaft with the starter (wind-up type) with the spark plug removed and feeling the compression.

c. Forcing compressed air into the spark-plug hole.

d. Using a compression gage in the spark-plug hole.

a. The first method **(cranking the engine by hand)** is described under "Checking Compression," Volume I. According to some manufacturers, it is sufficient.

b. The second method is a simple test **for engines with wind-up starters.** Proceed as follows:

1. *Remove the spark plug.*
2. *Wind the starter.*
3. *Place your finger over the spark-plug hole.*
4. *Release the starter.*

   Your finger should be blown away with a strong force.

c. If you use the **compressed-air method,** proceed as follows:

1. *Remove the spark plug.*
2. *Insert an "air operative valve tool" into spark-plug hole.*

   This is a special adapter for connecting an air hose to the spark-plug hole (Figure 183).

3. *Rotate the engine crankshaft to TDC, compression stroke.*

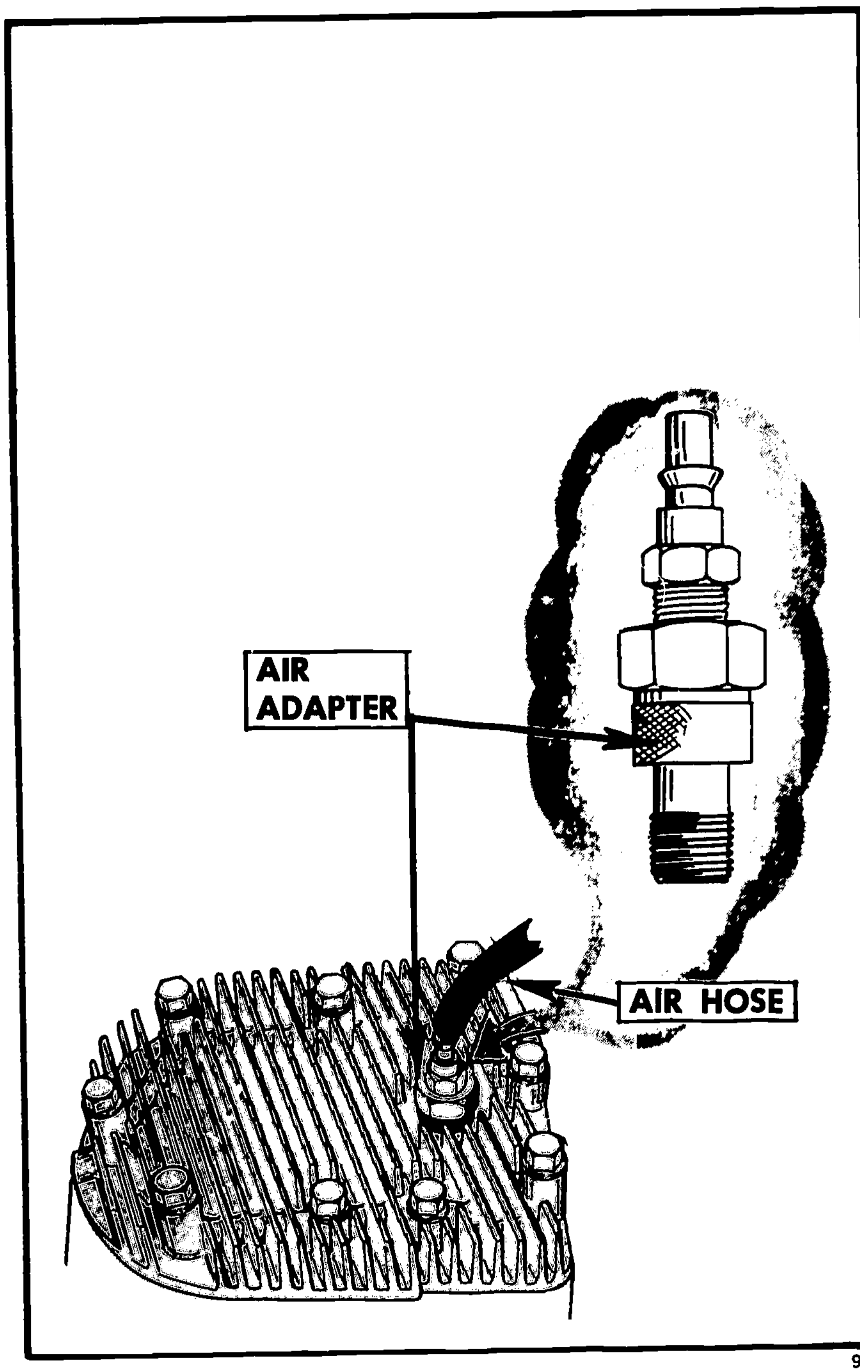


FIGURE 183. An air operative tool for connecting an air hose to the spark-plug hole.

4. *Remove the oil-filler plug.*

   Place a clean cloth over the oil-filler hole. In case there is a leak in or around the piston, this will prevent oil from being blown out.

5. *Set air compressor to supply 60 pounds maximum pressure.*

6. *Connect air hose to valve tool.*

7. *Listen for air leakage.*

   If you hear air through the muffler, this indicates a leak in your exhaust valve.

   If you hear air through the carburetor, this indicates a leak in the intake valve.

   If you hear air at the oil-filler hole, this indicates worn or damaged cylinder, piston or rings.

   If you find compression is low but you still are not certain of the cause, proceed with step 8.

8. *Squirt a teaspoon of oil into the cylinder through the spark-plug hole and crank the engine several times for the oil to be distributed around the piston rings.*

9. *Recheck compression.*

   If compression improves, the trouble is worn or damaged piston rings. The oil helps provide a seal which causes the compression pressure to increase.

d. The fourth method **(use of a compression gage)** is somewhat controversial. One manufacturer states:

> On single cylinder engines we think of good compression, not in terms of pounds of pressure per square inch, but in terms of horsepower output. If the engine produces the power for which it was designed, we believe the compression must be good. It is extremely difficult to make an accurate compression test on a small one cylinder engine without expensive machinery. The reasons for this are the lack of a starter to crank the engine at a constant speed and the small displacement of the cylinder. Therefore we do not publish any compression pressure figures. As a simple compression test, give the flywheel a quick spin. If the flywheel rebounds on the compression stroke, the compression is at least good enough to start the engine. *Briggs & Stratton Engine Corporation.*

If you check compression with a **compression gage,** proceed as follows:

1. *Remove the spark plug.*

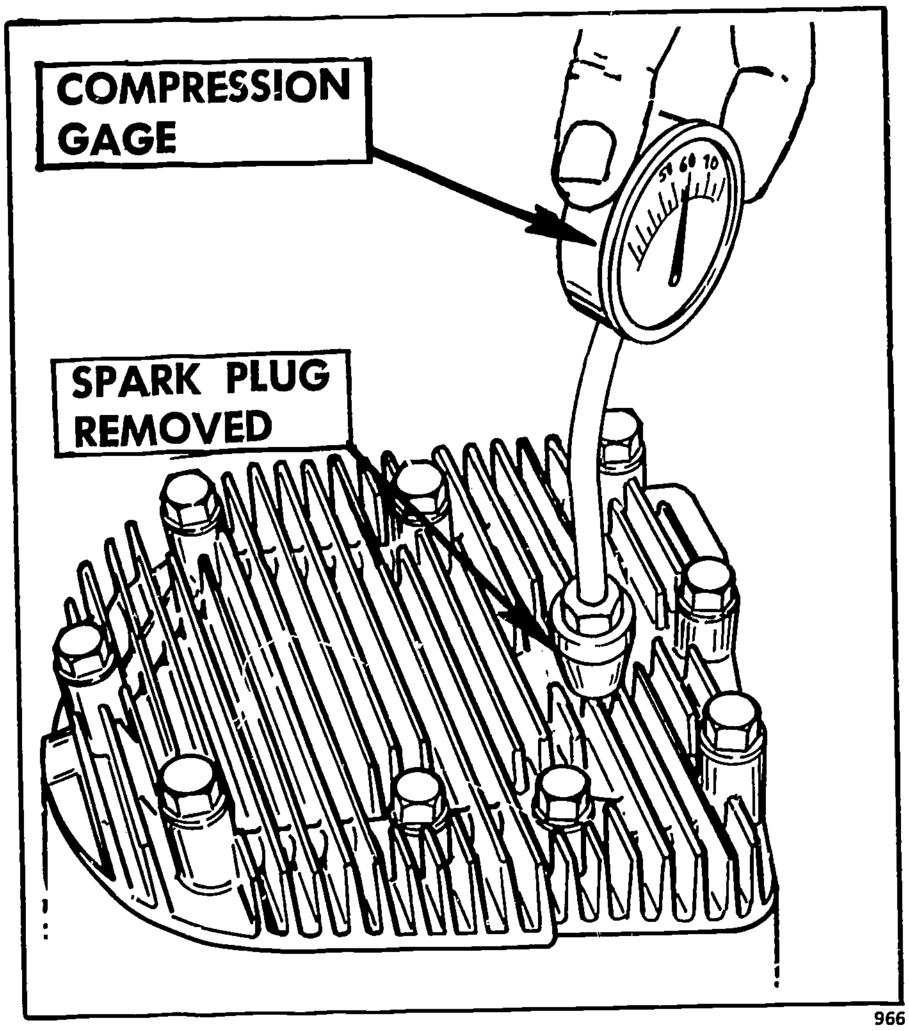


FIGURE 184. Checking the cylinder compression with a compression gage.

2. *Insert compression gage in spark-plug hole (Figure 184).*

3. *Turn engine at least 6 to 8 revolutions at cranking speed.*

   If you have an **electric starter,** be sure the battery is fully charged. Press pressure gage tightly against spark-plug hole.

   The throttle should be fully open when making the test so as much air as possible can reach the cylinder.

4. *Observe the compression reading.*

   Compare the reading with that given in your operator's manual. For satisfactory operation the minimum gage reading should read above 60 pounds per square inch on most engines.

   If the pressure is **10 per cent less** than that given in your engine specifications, check for compression leaks.

If, after following one or more of the foregoing procedures, you find the compression is low, it is probably in the valves. Proceed with "Checking the Valve-Tappet Clearance," next heading.

CHECKING THE VALVE-TAPPET CLEARANCE

Proper valve-clearance adjustment is important for the following reasons:

- *Valves give longer service.*
- *Fuel is used more efficiently.*
- *Engine starting is easier.*
- *Maximum power is produced.*
- *Overheating is less probable.*
- *Engine operation is smoother.*

When a valve is properly adjusted, there is clearance between the end of the valve stem and the valve tappet when the valve is closed (Figure 185). This clearance is very small, varying from approximately .005″ to .012″, but it is extremely important. Each manufacturer recommends the proper clearance for each model of engine. Recommendations vary depending on (1) whether the engine is hot or cold at the time of adjustment, and (2) the design of the engine — some are designed to run hotter than others.

If valves are adjusted so that there is **little or no clearance,** they are thrown out of time. This causes them to *open too early* and *close too late*. Also, the valve stems may lengthen enough from heating so that the valves do not seat completely (Figure 185). This allows hot combustion gases to leak past the valve seats, thus causing the valves, seats, stems and guides to overheat. The valves seat too briefly, too poorly or not at all. This causes loss of compression, overheating, sticking and burning of the valves.

If there is **too much valve clearance,** there is a noisy lag in valve timing which throws the engine out of balance. The fuel-air mixture is late entering the cylinder during the intake stroke. The exhaust valve closes early and prevents waste gases from being completely removed. The valves themselves become damaged because they close with heavy impact. They crack and break. (When valve clearances are correct, the camshaft lobe slows the speed of valve movement just as it closes. With too much clearance the slowing action is lost.)

To **check the valve-tappet clearance,** proceed as follows:

1. *Remove the valve cover plate (Figure 186).*

   It may be necessary to remove the carburetor to get to the valve access well. Refer to "Removing the Carburetor," page 86.

2. *Remove the crankcase breather, if necessary.*

   Some are located in the cover plate and some are located in the valve access well. Be careful not to damage the breather or drop anything into the crankcase. Refer to "Servicing Crankcase Breathers (4-cycle engines)," Volume I.

3. *Check the valves for sticking.*

   Turn the crankshaft by hand and look to see if the valves travel all the way up and down.

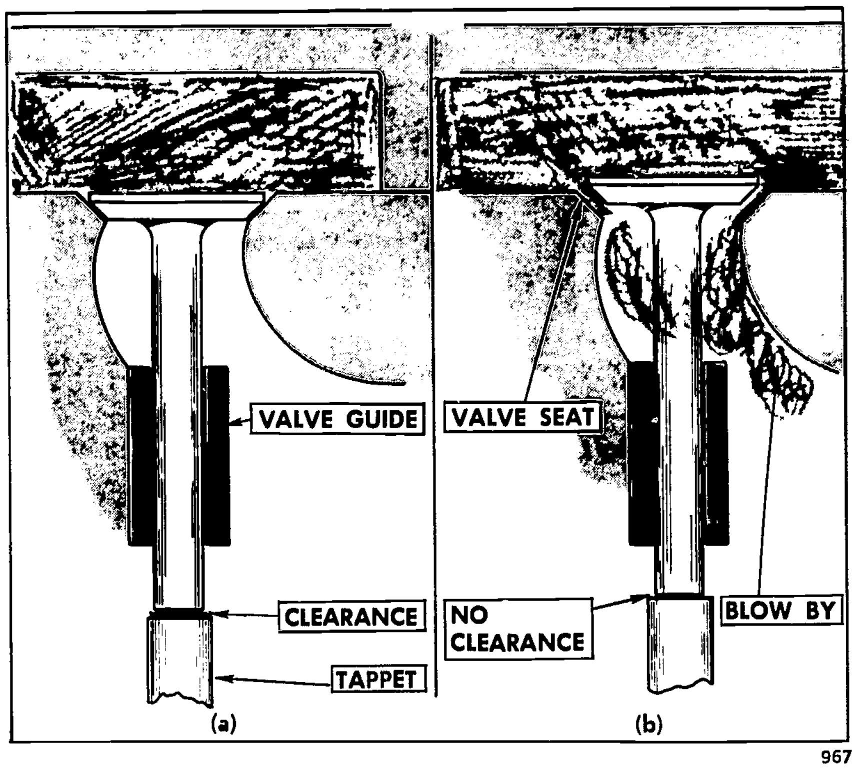


FIGURE 185. Importance of proper valve adjustment. (a) If valve-tappet clearance is correct, valve closes tightly. (b) If valve-tappet clearance is too little, valve fails to close. Exhaust gases leak by the valve seat.

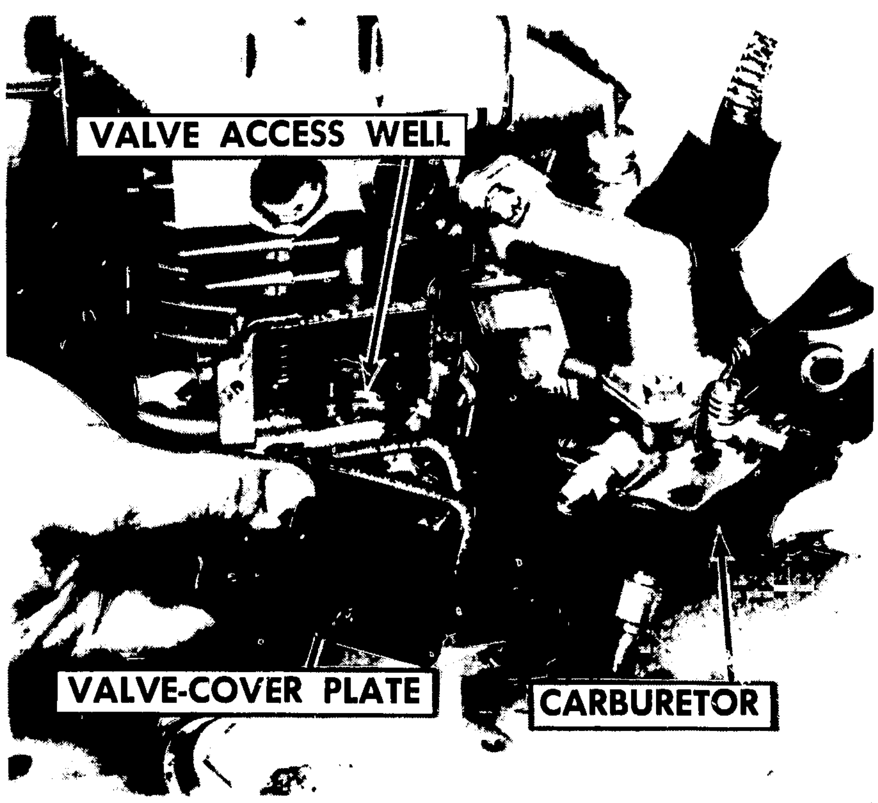


FIGURE 186. The valve access well may be located behind the carburetor.

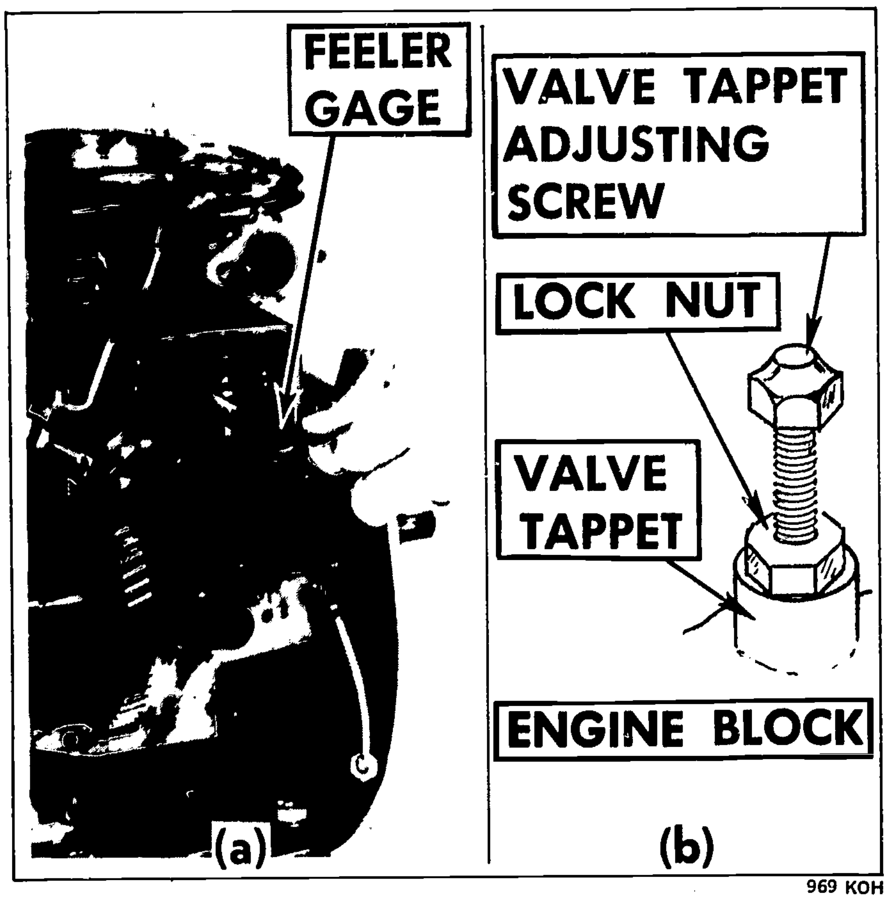


FIGURE 187. (a) Checking valve-tappet clearance with a feeler gage. (b) An adjustable tappet.

4. *Turn the crankshaft until the valve you are going to check is fully open.*
5. *Rotate the crankshaft one complete revolution.*

   This is to make sure the valve is completely closed.

   If your engine has **timing marks,** both valves will be closed when the timing marks are aligned and the piston is at TDC, compression stroke. Refer to "Timing the Magneto to the Engine," page 65.
6. *Check your operator's manual for the proper valve-tappet clearance for your engine.*

   The specifications are usually given for checking when the engine is cold.

   Intake valve-tappet clearances vary from .005″ to .012″.

   Exhaust valve-tappet clearances vary from .009″ to .012″.
7. *Check the valve-tappet clearance with a feeler gage (Figure 187).*

   There should be a slight drag as you move the feeler gage between the valve stem and tappet.

   If the clearance is not correct and you have **adjustable tappets,** adjust the valve clearance. Loosen the tappet with an open-end wrench, and turn it up or down until the clearance is correct (Figure 187b). Then tighten tappet.

   If the clearance is not correct and you have **no adjustable tappets,** it will be necessary for you to remove the cylinder head to correct it. Follow procedures under the next heading. Usually when you have to remove the valves for adjusting, it will be necessary to recondition them also.

   Too small a clearance is corrected by shortening the valve stem. Too much clearance is corrected by replacing the valve with a new one, then adjusting it.

REMOVING THE CYLINDER HEAD

1. *Remove the spark-plug wire from the spark plug.*
2. *Remove the spark plug.*

   Use a spark-plug wrench to avoid breaking the spark plug.
3. *Remove the carburetor if not already removed (Figure 188).*

   See "Removing the Carburetor," page 86.
4. *Remove the cowling if necessary to get to the cylinder head (Figure 189).*
5. *Remove the valve-cover plate if it is not already removed (Figure 186).*
6. *Clean and inspect all of the removed parts.*

   Use a petroleum solvent.
7. *Loosen and remove cylinder-head bolts (Figure 190).*

   Use a socket wrench with a ratchet handle or "T" handle. Sometimes the bolts are of different lengths. Note any difference in the lengths so you can properly reassemble them in the right positions.

   If you should use a **bolt which is too short,** it may not reach enough threads to hold; and it will strip out.

   If you use a **bolt that is too long,** it may

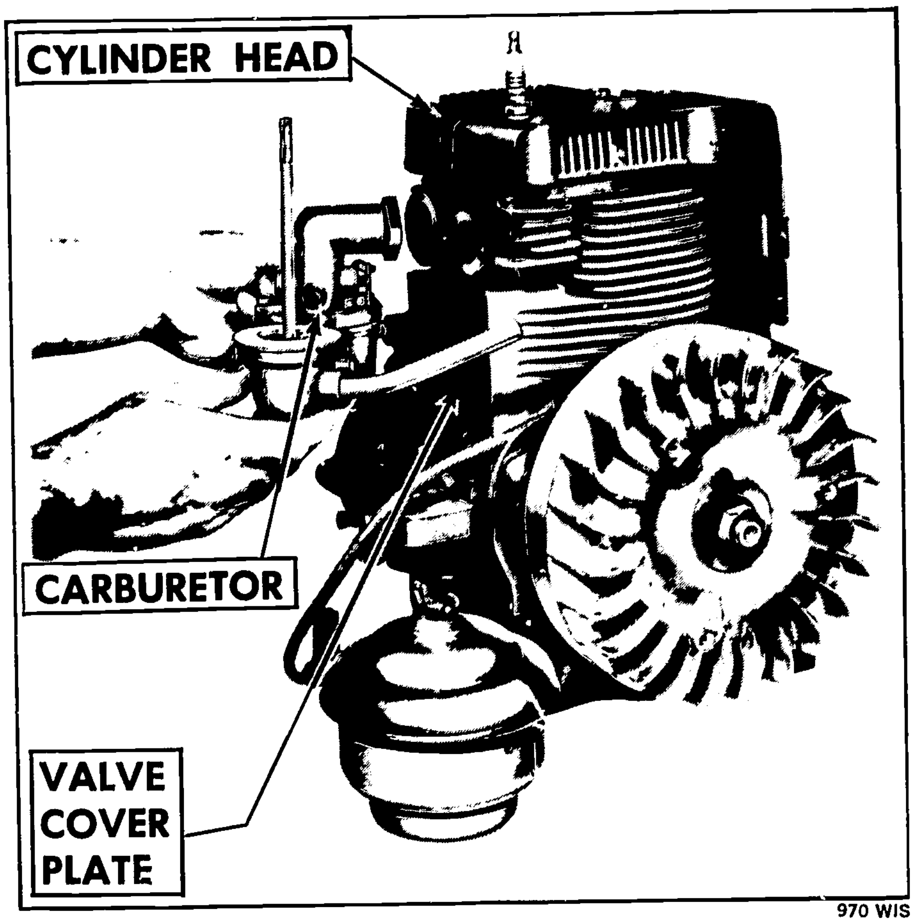


FIGURE 188. It may be necessary to remove the carburetor to get to the valve-cover plate.

bottom on a cooling fin and break the fin; or it may not tighten the head sufficiently.

Some bolts are long because braces, supports and/or brackets are anchored to them.

8. *Remove the cylinder head and cylinder-head gasket.*

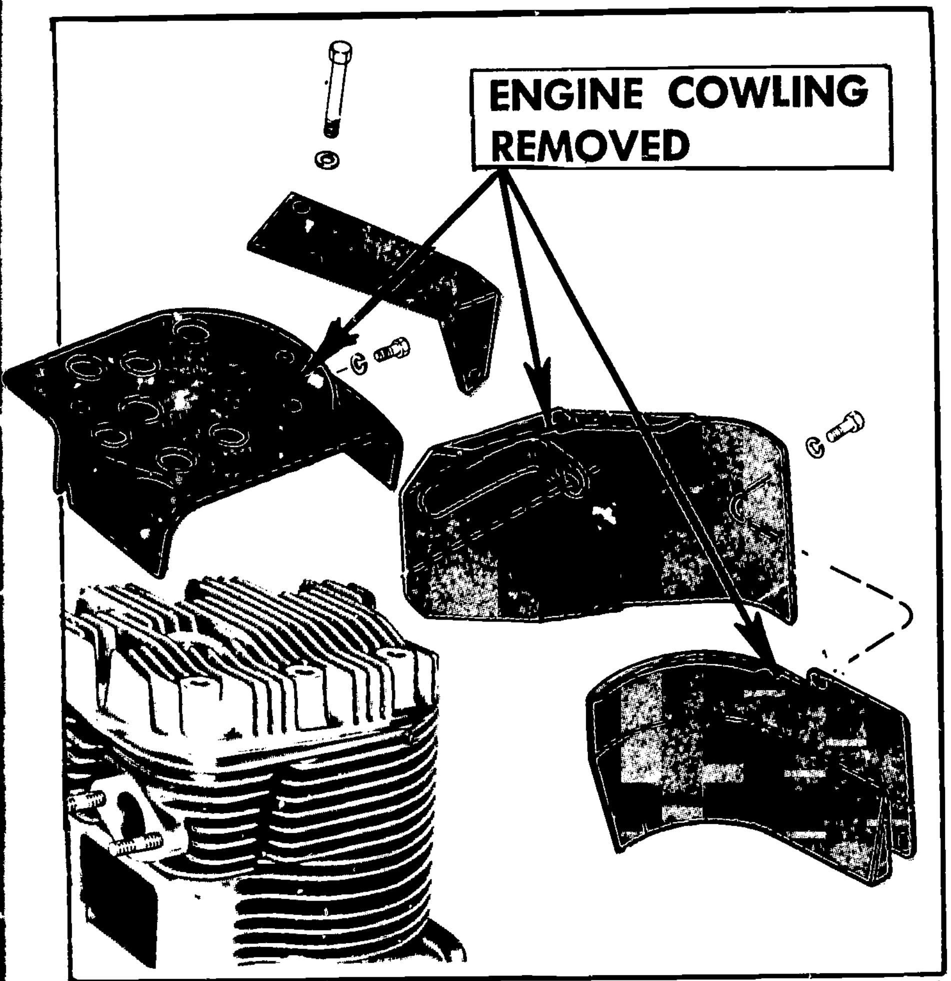


FIGURE 189. Remove cowling from around the cylinder and cylinder head.

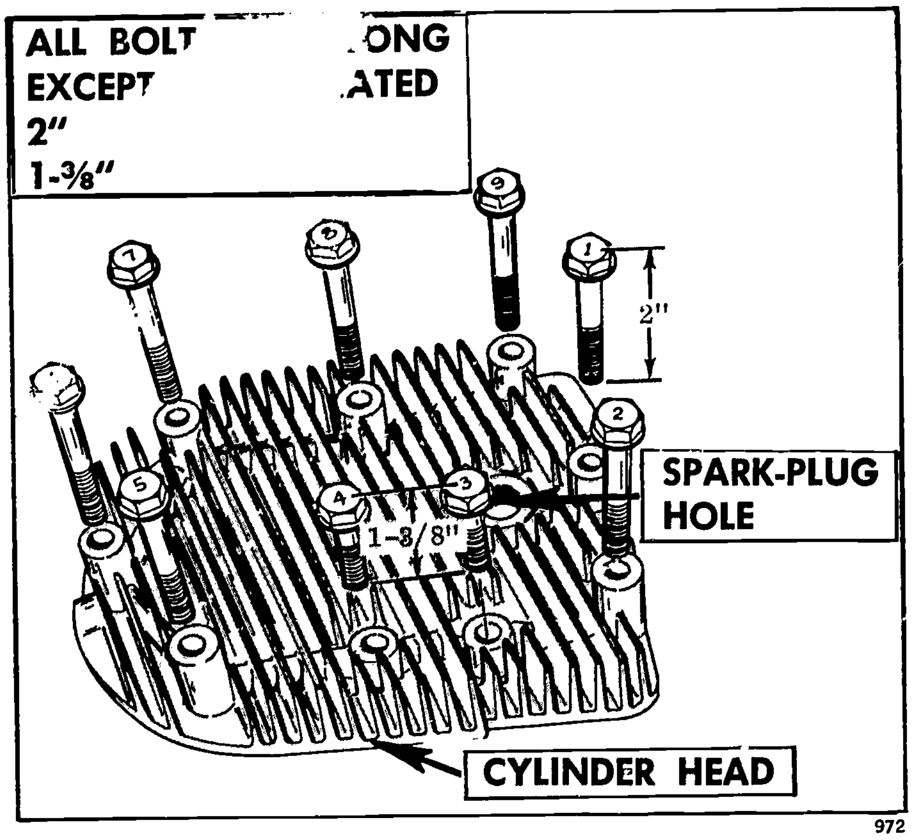


FIGURE 190. Cylinder-head bolts may be of different lengths for different positions.

To loosen the cylinder head, tap it sharply on the edge with a soft hammer.

The gasket may stick to either the cylinder head or the engine block or both.

Generally the gasket needs to be replaced with a new one.

9. *Clean the head, the piston and the area around the valve seats (Figure 191).*

Remove carbon and any gasket material that may remain. Use a metal scraper. If the

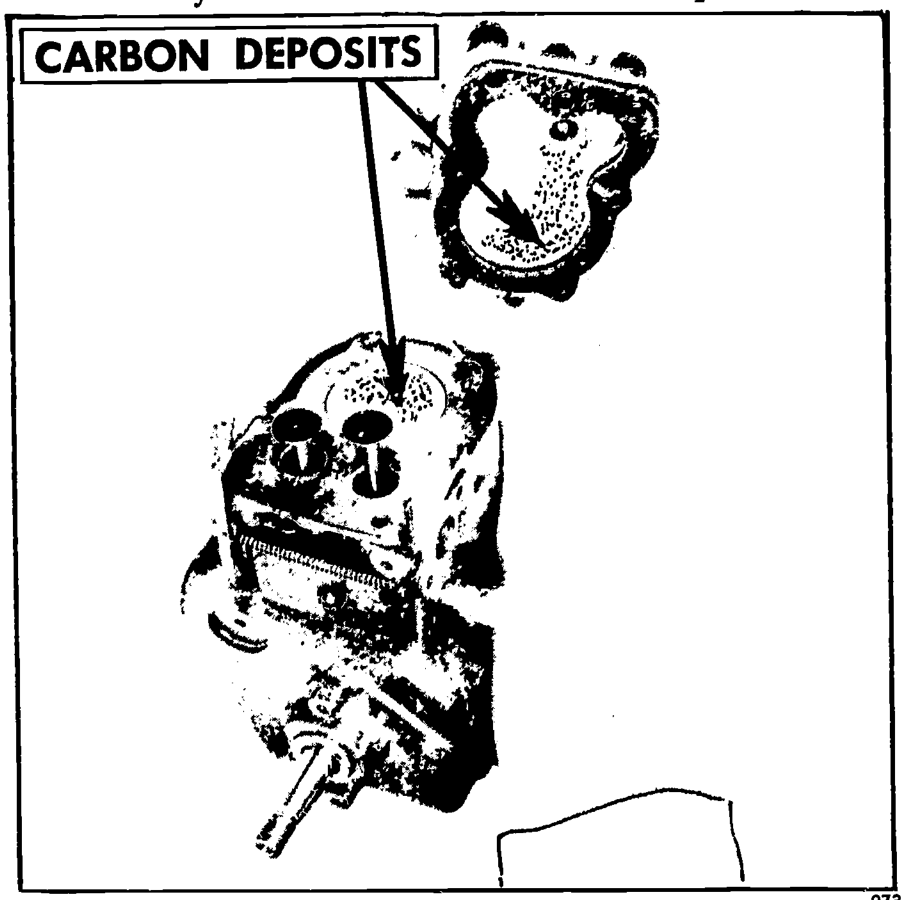


FIGURE 191. Clean the carbon from the cylinder head, from the piston and from around the valve seats.

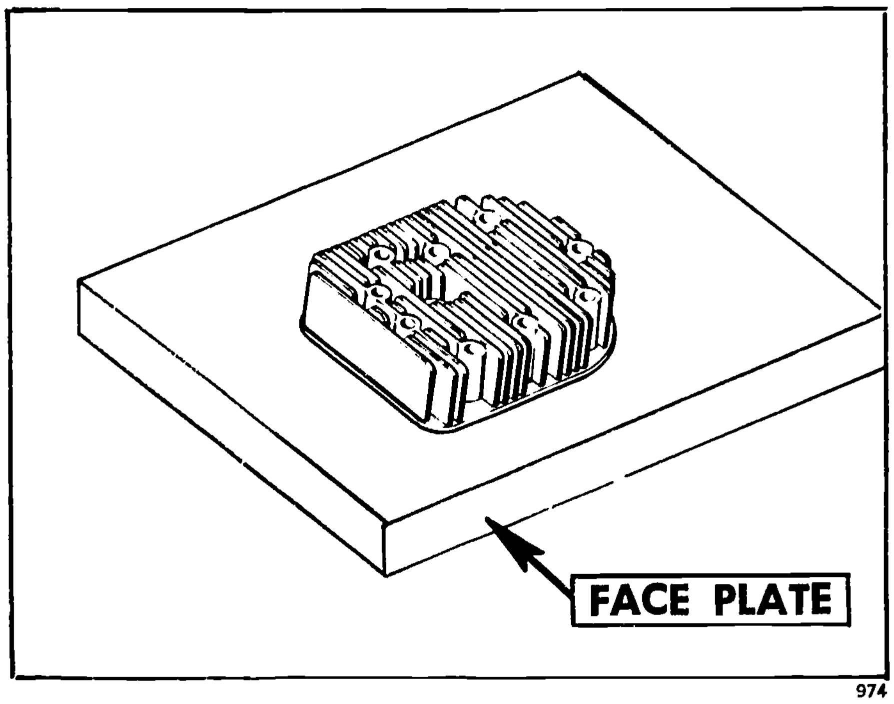


FIGURE 192. Checking the cylinder head for warpage.

metal you are cleaning is soft, like aluminum, be careful to avoid scratching it.

10. *Check the cylinder head for warpage (Figure 192).*

    Use a face plate. A face plate is a thick metal plate with a perfectly flat surface. Apply thin layer of prussian blue to the face plate, and lay the head (gasket-side) down on the face plate. Slide the head back and forth a couple of times. Then remove it and check to see that bluing has transferred to all contact surfaces of the cylinder head. If not, the cylinder head is warped and must be replaced with a new one.

11. *Remove prussian blue from head and face plate.*

    Use a clean dry cloth.

12. *Place the parts in a clean, well-protected place and in an orderly manner.*

REMOVING THE VALVES

1. *Compress the valve spring (Figure 193).*

A valve-spring compressor is almost essential

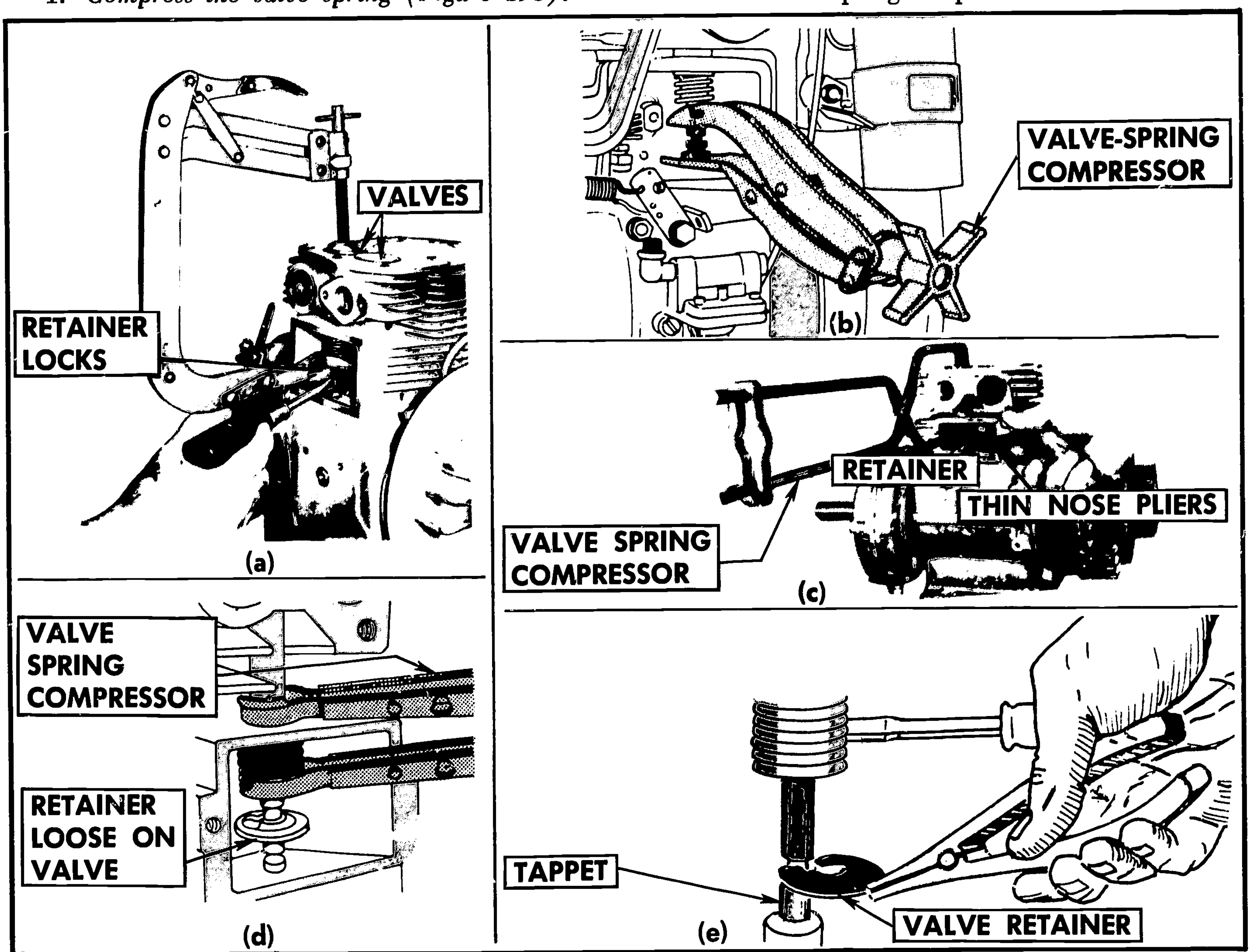


FIGURE 193. Compressing the valve springs. (a, b, c and d) Types of commercial valve-spring compressors. (e) Using a screwdriver for compressing the valve spring.

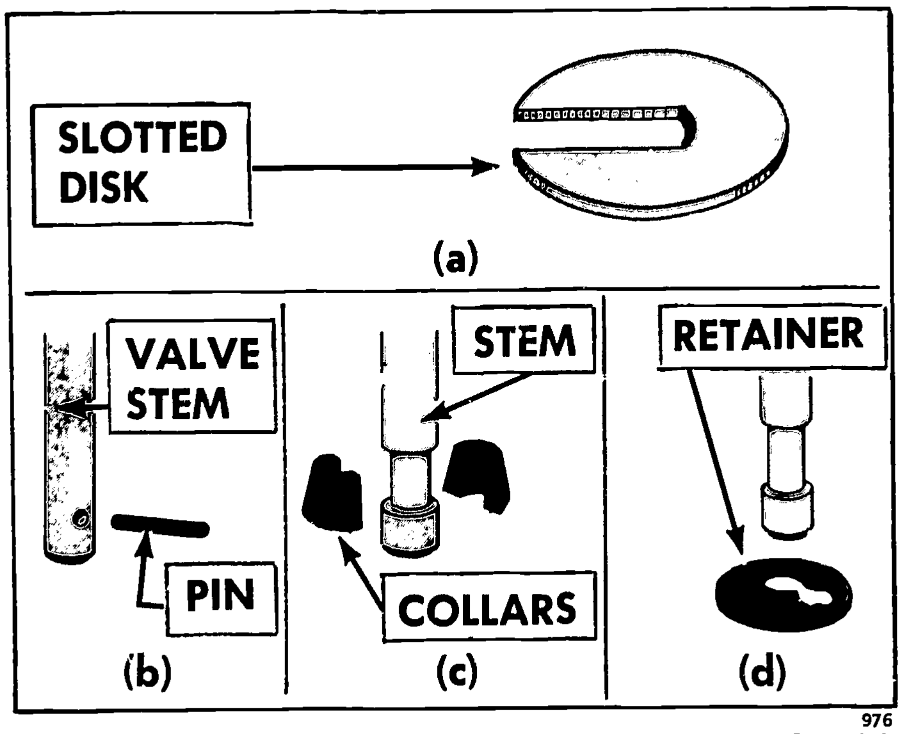


FIGURE 194. Types of valve spring retainer locks: (a) slotted disc, (b) pin, (c) split collar and (d) combination retainer and lock.

to releasing the valve. It is possible, however, to compress the spring with a screwdriver enough to remove the valve spring and retainer lock (Figure 193e).

2. *Hold the valve closed with your thumb, if the valve is not held by valve compressor.*

3. *Remove the valve-spring retainer and/or retainer lock (Figure 194).*

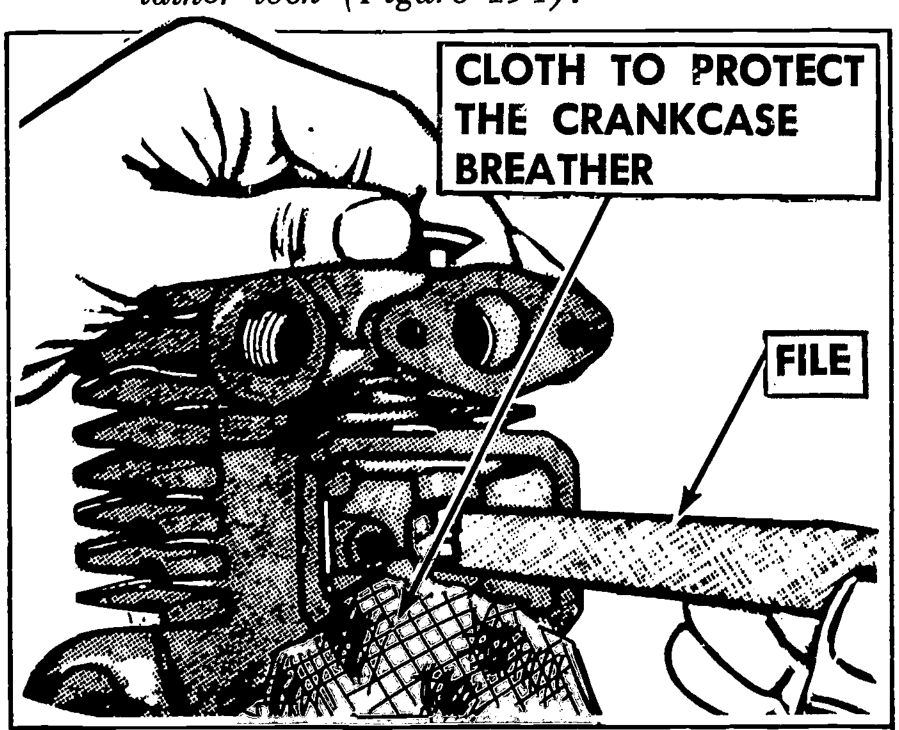


FIGURE 195. Filing away burrs from a valve stem before removal of the valve.

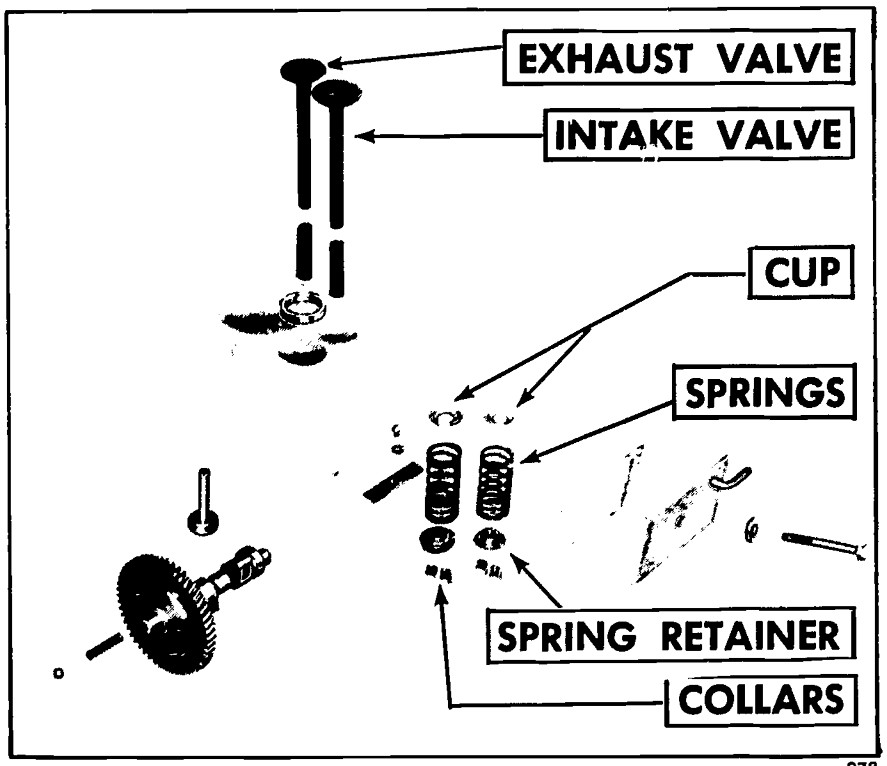


FIGURE 196. Valve assembly removed from the engine.

4. *Remove the valves.*

   It may be necessary to file away burrs that have developed on the valve-stem lock and groove, before removing the valve, to prevent damage to the valve guide (Figure 195). Use a fine, flat file. Do not over file.

   Do not let the filings drop into the crankcase breather hole, unless you plan to do a complete engine overhaul. Stuff a rag in the valve access well.

   Be careful not to damage the crankcase breather plate in the bottom of the valve access well, if it is installed.

   Tag the valves and the springs so you will know how to replace them in the same positions. On some engines the exhaust spring is heavier than the intake spring.

5. *Remove the valve springs and cups (Figure 196).*

6. *Clean valves and accessories.*

   Carburetor cleaner, such as Petisol or Bendix, may be used to remove gum. For normal cleaning, use petroleum solvent.

INSPECTING THE VALVES AND VALVE ACCESSORIES

Before going too far with valve repair, check the cylinder and bearings. The engine may be worn too much to repair. See "Repairing Cylinders and Piston-and-Rod Assemblies," page 138. Also see "Repairing Crankshaft Assemblies," page 174.

The condition of the valves tell you much about the condition of your engine.

Intake valves are cooled by the fuel-and-air mixture going into the cylinder. Therefore, intake valve trouble is usually caused by the use of stale

gasoline or a poor grade of gasoline. Gum builds up on the valve neck and burns, thus leaving a hard deposit of carbon material under the valve head. This deposit causes the valve to stick and/or burn.

Another cause of intake valve sticking and burning is leaking valve guides — guides that are worn and out of round. Oil seeps into the ports — the upper ends of the valve guides — and builds up a soft oily deposit under the valve head.

Exhaust valves operate under extremely high temperatures (red hot) under normal engine operation. For cooling they depend upon heat dissipation through the valve seat and the valve guides and then out onto the cooling fins. So anything that causes the engine to run only slightly hotter than normal will affect the exhaust-valve life. For this reason exhaust valves are more likely to fail than intake valves. This is the reason most of them are made of a heat-resistant steel.

You can tell by looking at the condition of the valves what may have caused the failure. Examine the valves; determine their condition; then refer to the following guide to find out what caused the trouble. The guide indicates what steps to take to prevent the reoccurrence of the trouble.

VALVE CONDITIONS AND PROBABLE CAUSE:

Gum and Varnish Deposits:

Use of stale or low quality gasoline

Use of poor quality oil, or insufficient lubrication

Worn valve guides

Loose guide, or guide extending too far into the exhaust port

Dirty cooling fins

Overspeeding or overloading the engine

Operating with an excessively rich fuel-air mixture

Poor crankcase ventilation (clogged crankcase breather)

Evidence of Valve Burning:

Sticking valve stem

Leaking valve seat

Insufficient valve-tappet clearance

Weak valve spring

Excessive exhaust back pressure (clogged muffler)

Excessively lean fuel-air mixture

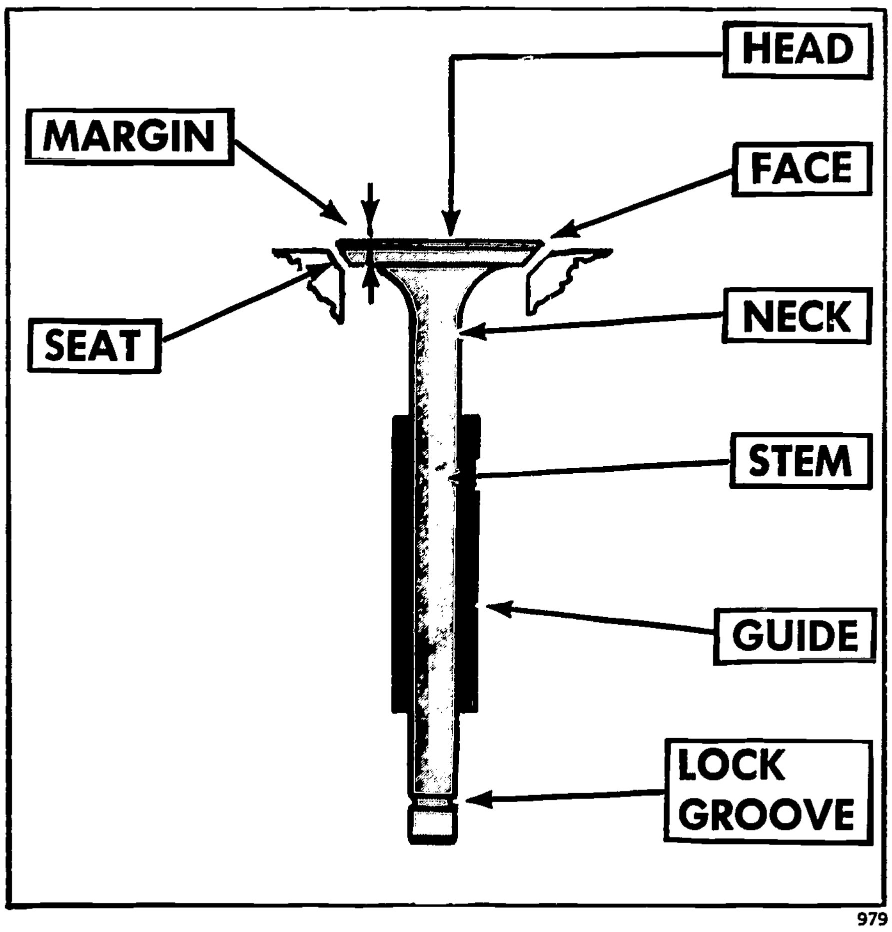


FIGURE 197. Wearing parts of a valve.

Warped valve

Deposits on the valve face

Necked (stretched) valve stem

Loose valve seat insert or warped valve seat

Carbon Deposits on the Valve Face:

High seating impact from excessive valve-tappet clearance

Excessive spring tension

Worn valve retainers and retainer grooves

To **inspect the valves and valve accessories,** proceed as follows:

1. *Inspect the valve head (Figure 197).*

   Look for warped valve heads; bent, necked or worn stems; valve face burned, cracked or out of round.

   You seldom know whether a valve is reusable until you see how much grinding it is going to require to smooth the face. This is discussed under "Grinding (Refacing) the Valves," page 124.

2. *Check condition of valve stem (Figure 198).*

   Polish the stem with an emery cloth; then check the stem diameter with a micrometer.*

*If you do not know how to use a micrometer, get a copy of "Micrometers and Related Measuring Tools," a publication available from Vocational Agriculture Service, University of Illinois, Urbana, Illinois.

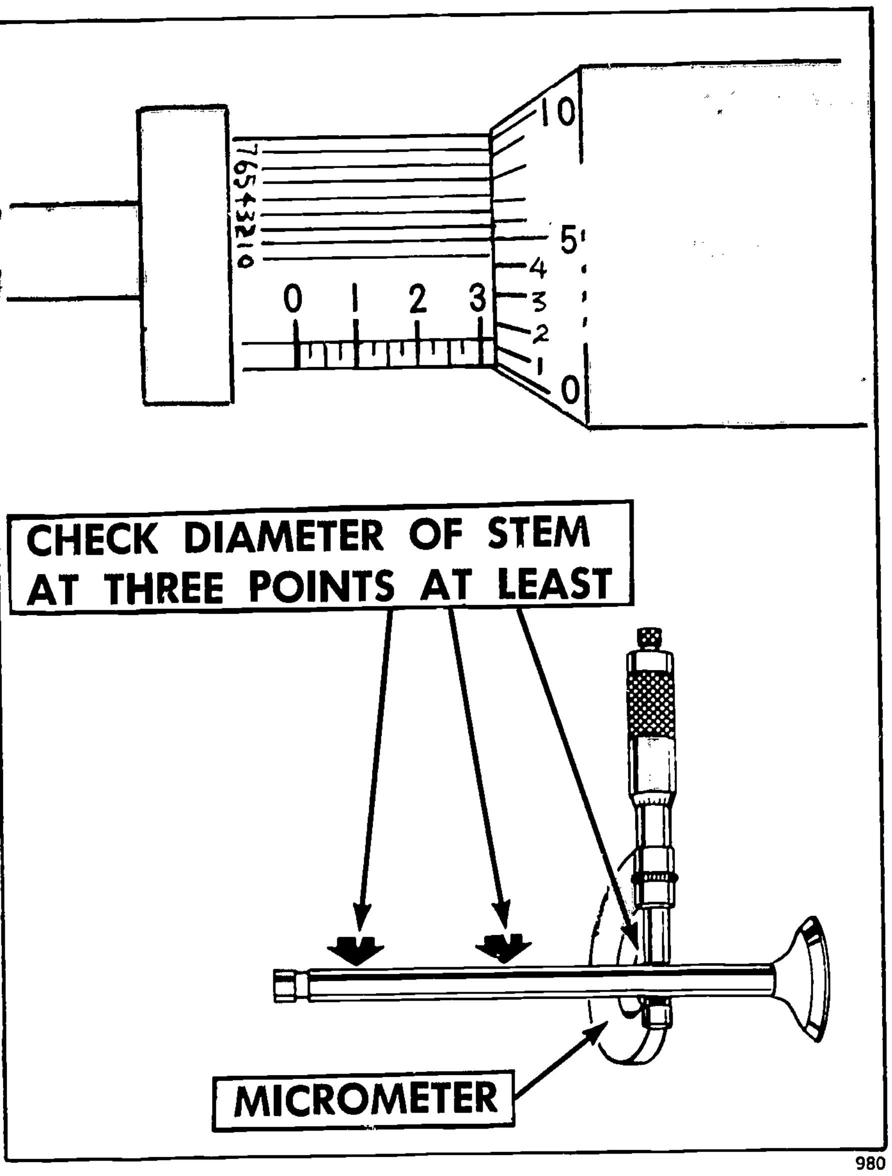


FIGURE 198. Checking the valve-stem diameter with a micrometer.

If the stem is worn more than .005″, replace the valve. See your service manual for the original diameter of the valve-stem.

3. *Inspect the valve springs (Figure 199).*

Inspect valve spring for squareness at the top and bottom. Also inspect for distortion and for pits or cracks.

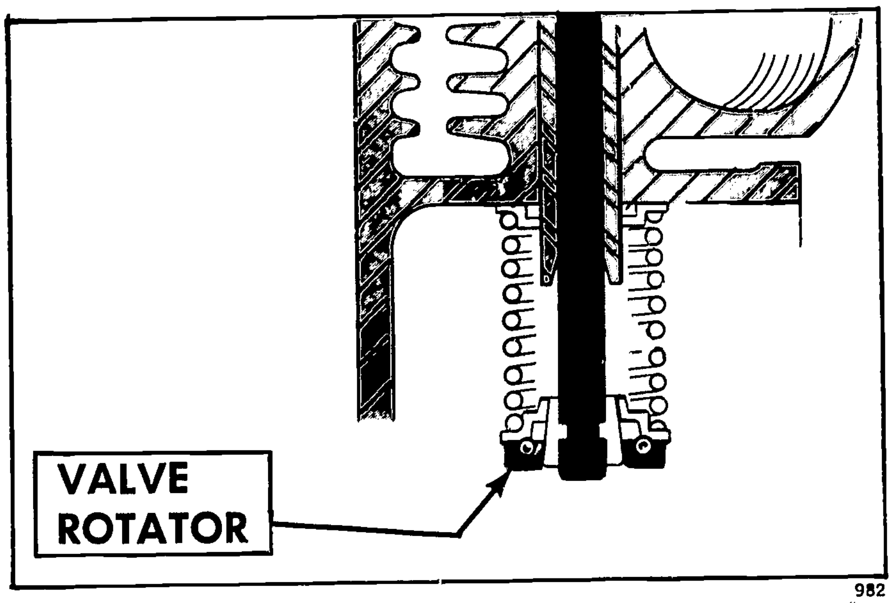


FIGURE 200. Valve rotators are used on engines under constant use, to rotate the valves as the engine runs. This helps prevent valve burning.

Some manufacturers give specifications for the expanded length of the valve spring so you can measure them (Figure 199a). Others give the required spring tension. This is measured with a spring tension tester (Figure 199b).

4. *Check valve-spring retainer and retainer locks for wear (Figure 196).*

Also check valve rotator if installed. They are installed in the valve-spring retainer (Figure 200).

5. *Check the valve seats for cracking and pitting.*

On some engines you can replace the valve seats with a new insert (Figure 206b).

Some have only the exhaust valve seat replaceable. On others, neither valve seat is replaceable (Figure 206a).

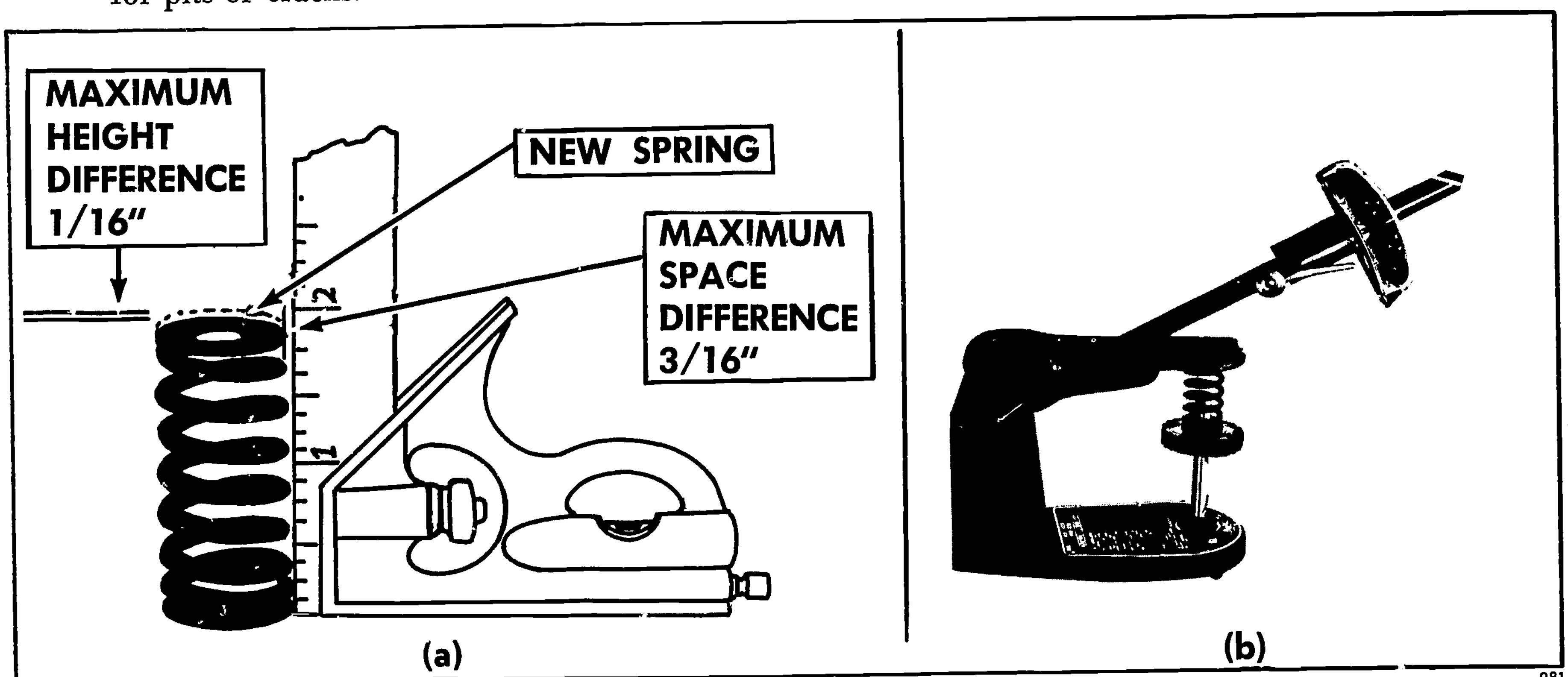


FIGURE 199. Checking the valve-tension. (a) Measuring the expanded length. (b) Checking with a tension tester.

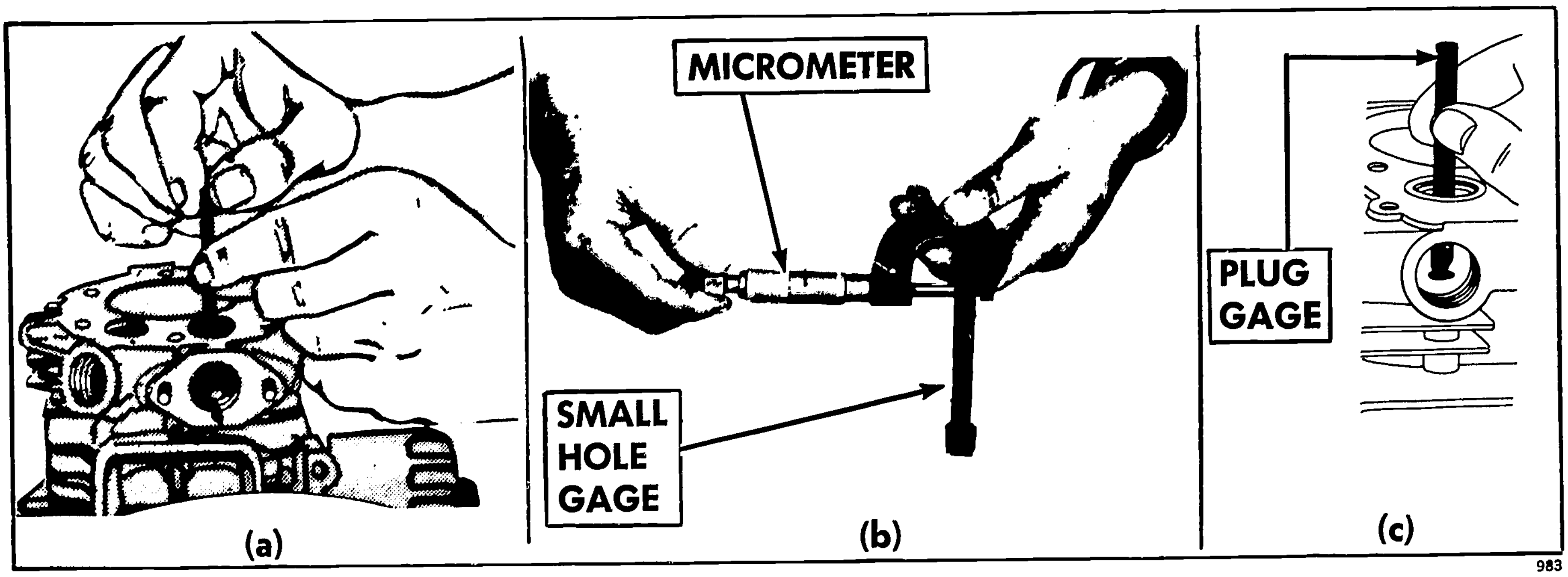


FIGURE 201. Check the valve guide for wear. (a and b) Use a small-hole gage and micrometer, or (c) Use a special go and no-go gage supplied by your manufacturer.

If the valve seat in your engine is damaged and is not replacable, it will need to be refaced. If it can not be refaced properly, it will be necessary to replace the engine block.

6. *Checking the valve-guide bushings (Figure 201).*

Clean valve guides thoroughly and check for wear. Use a small-hole gage and a micrometer (Figure 201a and b). Or you may use a special go and no-go gage (Figure 201c).

Check the bushing at the top and at the bottom. Turn the gage 1/4 turn and recheck.

See your service manual for specifications.

As a rule, there should be no more than .005″ difference in the valve stem and bushing diameter. Clearance greater than this allows the valve to move about on the seat and not seal properly.

On some engines you can get over-sized valve stems which will allow you to ream worn guides to oversize. If you are replacing the valve anyway, get a new standard-size valve guide.

REPAIRING THE VALVE GUIDES

Before repairing the valve guides, you will have to determine the type of valve guide you have and determine which method to use for repairing it (Figure 202). There are three alternatives:

a. Some aluminum engines **have no guide bushing inserts.** If the guide is worn, rebore the valve guide and install replacement inserts (Figure 202a

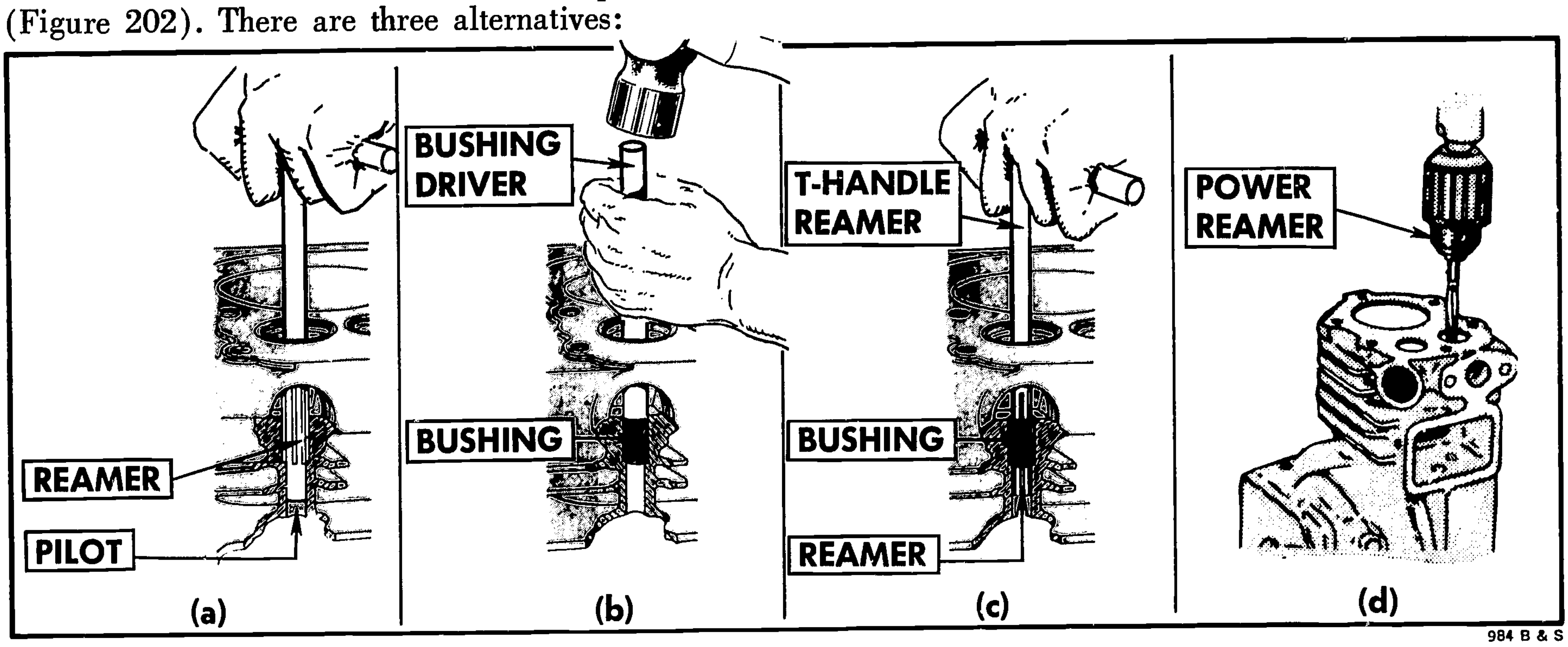


FIGURE 202. Methods of repairing valve guides. (a) Reaming the cylinder block where no bushings are used. (b) Installing new bushings. (c) Reaming the bushing with a T-handle reamer. (d) Reaming bushing with a power-driven reamer.

and b). Then ream the insert to fit standard-size valve stems (Figure 202c and d).

b. If your engine comes equipped **with guide bushing inserts,** they can be replaced when they become worn. Remove the old guide, install a new one, and ream it to fit standard-size valve stems.

c. If your engine is equipped **with or without guide bushing inserts,** it is possible to ream the valve guide bushing to *oversize* and install new valves with oversize stems to fit.

a. If the engine **has no guide bushing and you elect to install a bushing,** proceed as follows:

1. *Protect the engine from metal cuttings.*

   Unless you plan to disassemble completely and clean the engine, do not allow metal chips to fall into the crankcase. Place a *clean cloth* in the valve access well to catch the cuttings.

2. *Select the proper size reamer.*

   Follow the manufacturer's recommendation. Most manufacturers supply a special reamer already sized. They may be purchased by part number.

   The bushing is a press fit, so the hole in the engine block should be .001″ smaller than the bushing.

3. *Check to see how valve-guide bushing is mounted in the block.*

   On some engines the hole for the valve guide is reamed all the way through to the valve access well. On other engines there is a limit to the depth you should rebore for the valve-guide bushing (Figure 202b). Check your service manual and be sure not to bore further than recommended. The cylinder block wall may get thin below a certain point.

4. *Ream the cylinder block to accommodate the valve-guide bushing (Figure 202a).*

   Make a positive stroke with the reamer. Rotate reamer clockwise with each up and down stroke. Never turn the reamer backwards — you will score the cylinder block. Continue to turn it in a clockwise direction as you remove it. Do not cut any more than necessary when removing the reamer.

5. *Remove metal clippings.*

   Use compressed air and then remove cloth.

CAUTION! Wear protective goggles when you use compressed air on the engine. There is a danger of blowing metal and dirt into your eyes.

6. *Chill the guide bushing in a home-type freezer for an hour.*

   This contracts the size of the guide so it is more easily inserted in the cylinder block. It will become tight when it reaches the temperature of the block.

7. *Drive new guide bushing into cylinder block.*

   Use a brass rod as a punch and guide. If the engine has a flat base and the valve guide is at a right angle to the base, use an arbor press. Otherwise, drive the bushing out with a hammer.

8. *Ream new valve-guide bushings to fit valve stem (Figure 202c and d).*

   Use a reamer that will provide .002″ to .004″ clearance between the valve stem and the valve guide.

   Make only one cut through with the reamer. Otherwise, you will cut too much.

   If you use a power reamer, operate it no faster than 600 r.p.m. There is danger of overheating.

9. *Check the dimension and the condition of the newly reamed guide (Figure 201).*

   See that there are no burrs or pieces of metal left.

10. *Lubricate the valve-guide bushing with crankcase oil.*

b. If the engine comes **equipped with guide bushings and you wish to replace them,** proceed as follows:

1. *Remove old valve-guide bushings (Figure 203).*

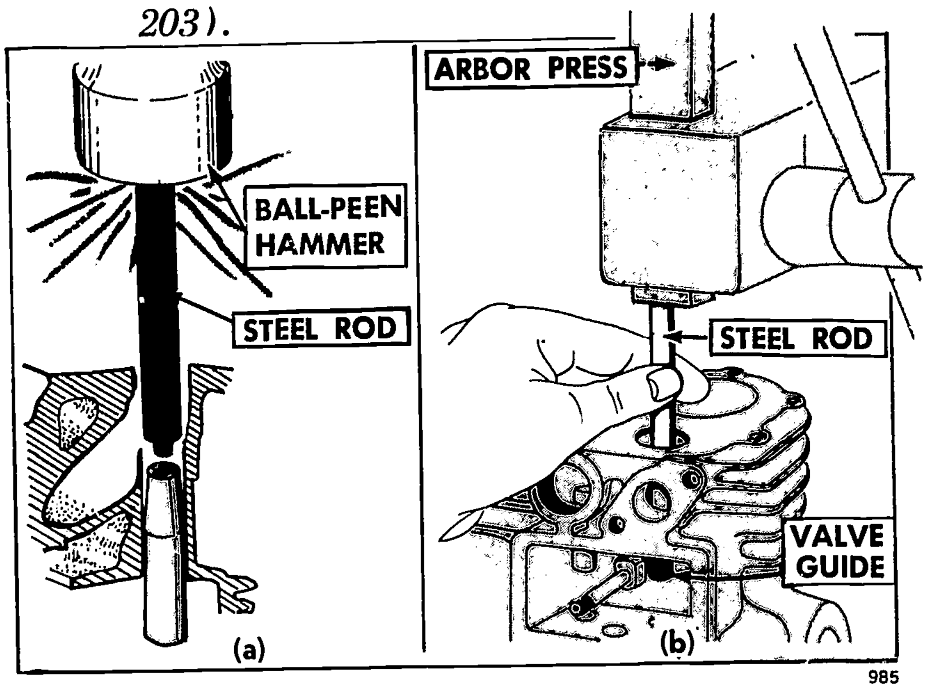


FIGURE 203. Removing valve-guide bushings. (a) Driving valve-guide bushing out with a special punch. (b) Pressing valve-guide bushing out with an arbor press and steel rod.

You may use a steel rod as shown in Figure 203a or an arbor press if your engine has a flat base and if the valve guide is at a right angle to the base (Figure 203b).

Some valve guides are too long to be removed in one piece through the valve access well. In this case, use a press designed to press the bushing toward the cylinder head.

Or, if you have a **cast-iron engine,** you can drive the bushing down part way and break it off. Use a sharp cold chisel to aid in breaking the bushing. Be careful not to damage the cylinder block.

2. *Install new bushings.*

   Follow procedures given in steps 4 through 10, under "a" preceding.

c. If you elect to **ream your old valve guides, or valve-guide bushings, to oversize and install valves with oversize stems,** proceed as follows:

1. *Select reamer of proper size for the oversize valve you have selected.*
2. *Follow steps 8 through 10 in "a" preceding.*

GRINDING (REFACING) THE VALVES

With old valve, first grind and then lap both the valve faces and valve seats (Figure 204). With new valves only lapping is necessary. Lapping is matching the valve face to the valve seat by rubbing the two together with a grinding paste.

1. *Dress the valve grinding wheel if needed.*

   If the grinding wheel is glazed or irregular, dress it according to directions by the grinder manufacturer.

2. *Adjust the valve grinder for grinding the proper face angle (Figure 205).*

   Most valves on small engines are ground at a 45° angle. Some older engines had valves which were ground at a 30° angle. Check the engine specifications before doing any machine work.

3. *Place the valve in the grinder chuck and tighten it securely.*

   Make sure it is straight and does not wobble.

4. *Check to see that the valve face is in proper position to contact the grinding wheel.*

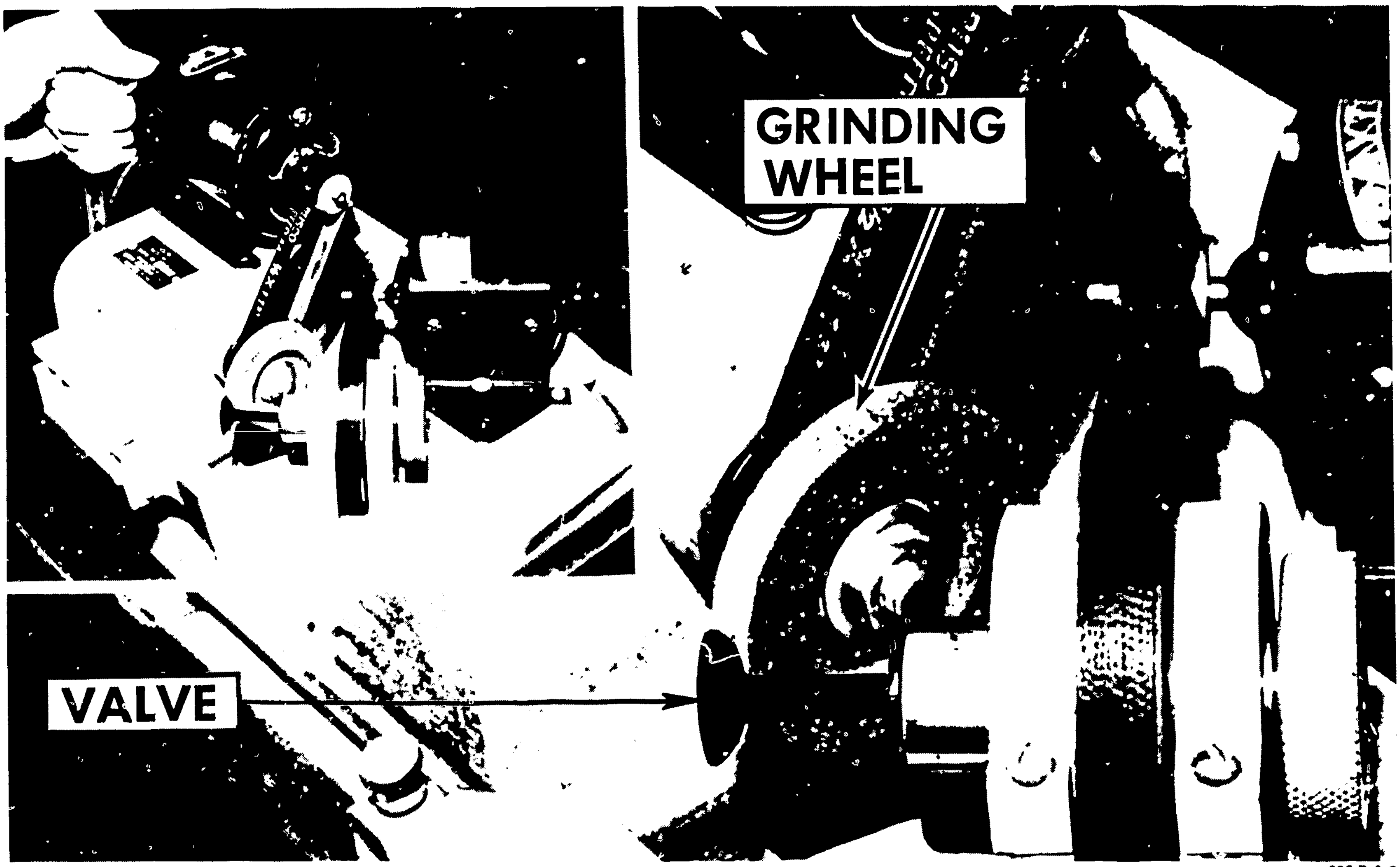


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FIGURE 204. Valve grinding is done with a special valve-grinding machine.

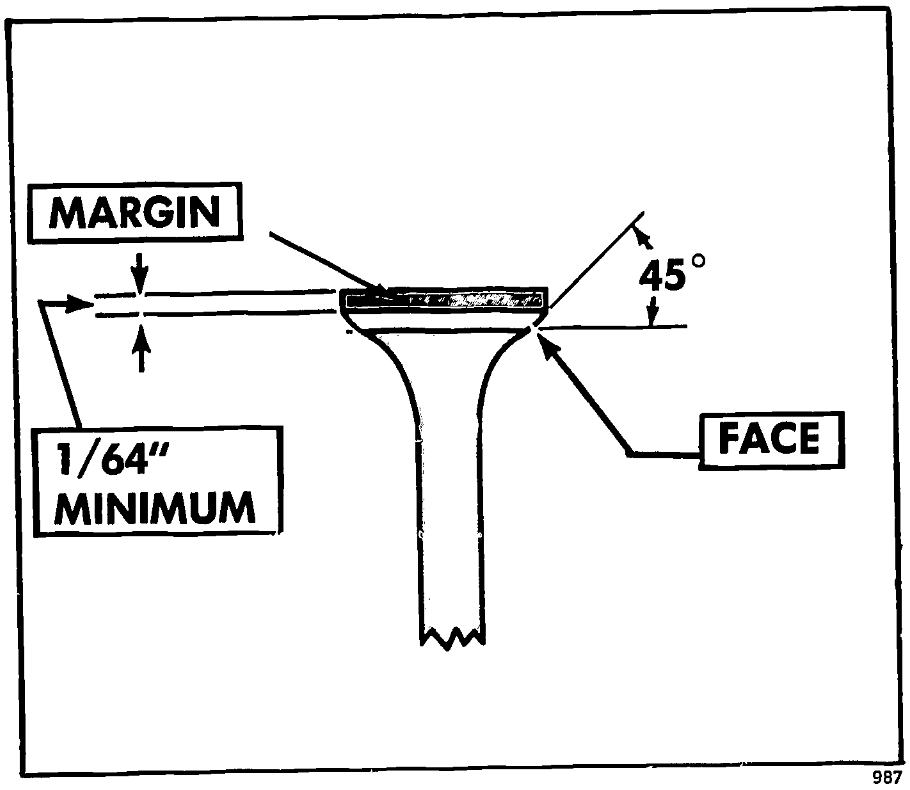

FIGURE 205. Typical specifications for grinding a valve.

Move the valve in and out before starting the grinder while observing its position. Set the machine so the wheel will not contact the valve stem.

5. *Start grinder.*

   Make sure the cutting oil is flowing properly.

6. *Move the valve face up to the wheel and start grinding lightly.*

   Take light cuts and continue until the grinding sound is regular. Do not try to finish the grinding without checking your progress often.

7. *Remove the valve from the grinding wheel.*
8. *Stop the grinder.*
9. *Check the valve face width (Figure 205).*

   You may not be able to grind the valve face adequately before grinding the margin too thin. If the margin (Figure 205) is less than 1/64", or less than 1/2 the thickness of a new valve margin, discard the valve.

   Check your manufacturer's specifications. If you use a refaced valve with the margin too thin, it is likely to crack and burn.

10. *Clean valve with petroleum solvent.*

GRINDING (REFACING) THE VALVE SEATS

To insure a *tight seal between the valve and valve seat,* it is necessary to grind (or reface) the valve seats whenever you grind the valves. Some valve seats are machined in the cylinder block (Figure 206a) and others are separate inserts (Figure 206b).

If you have a **cast-iron cylinder block,** you may find the *intake-valve* seat is machined in the cylinder block and the *exhaust-valve* seat is a moly-nickel, chrome-steel (Stellite) insert.

It is possible on some cast-iron engines without inserts to install them if the seats become badly worn.

When the *valves and valve seats have been reworked a number of times,* the valve rests too deeply in the block. This condition requires that too much metal be removed from the end of valve stem to get the proper valve-tappet clearance. Also the valve spring tension is weakened by the lengthening of the stem. A good gage of when a valve seat has been cut too

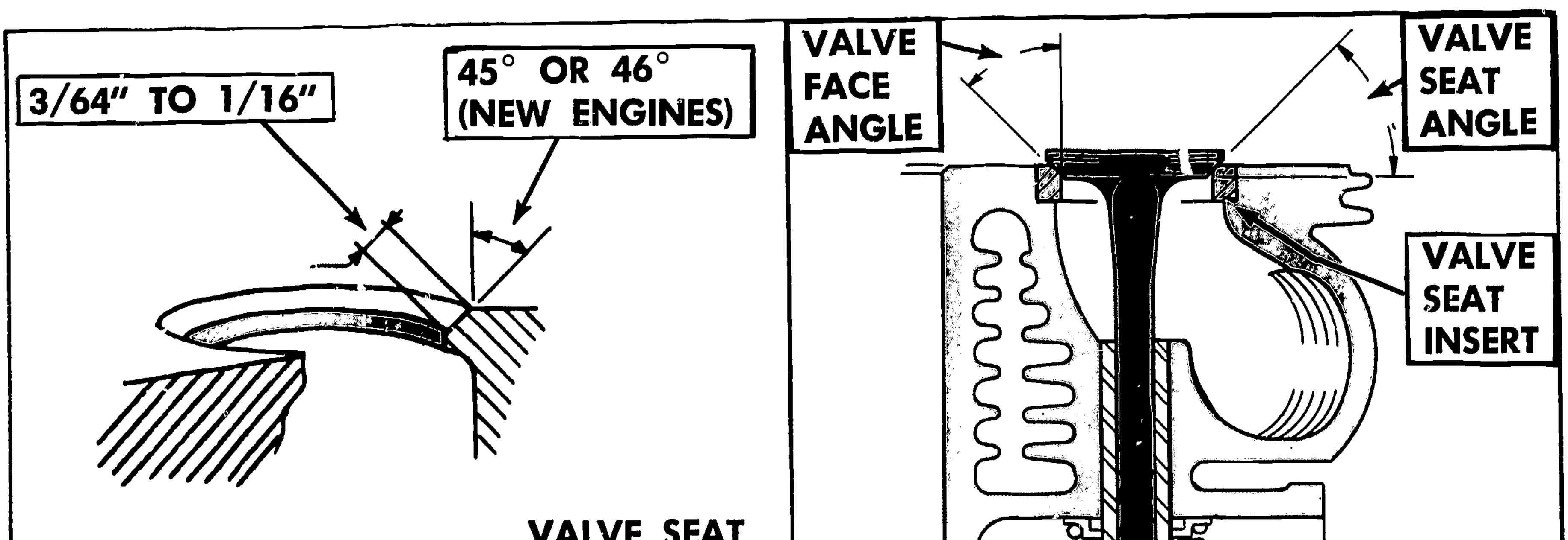

FIGURE 206. (a) Some valve seats are machined in the cylinder block. (b) Others are separate inserts.

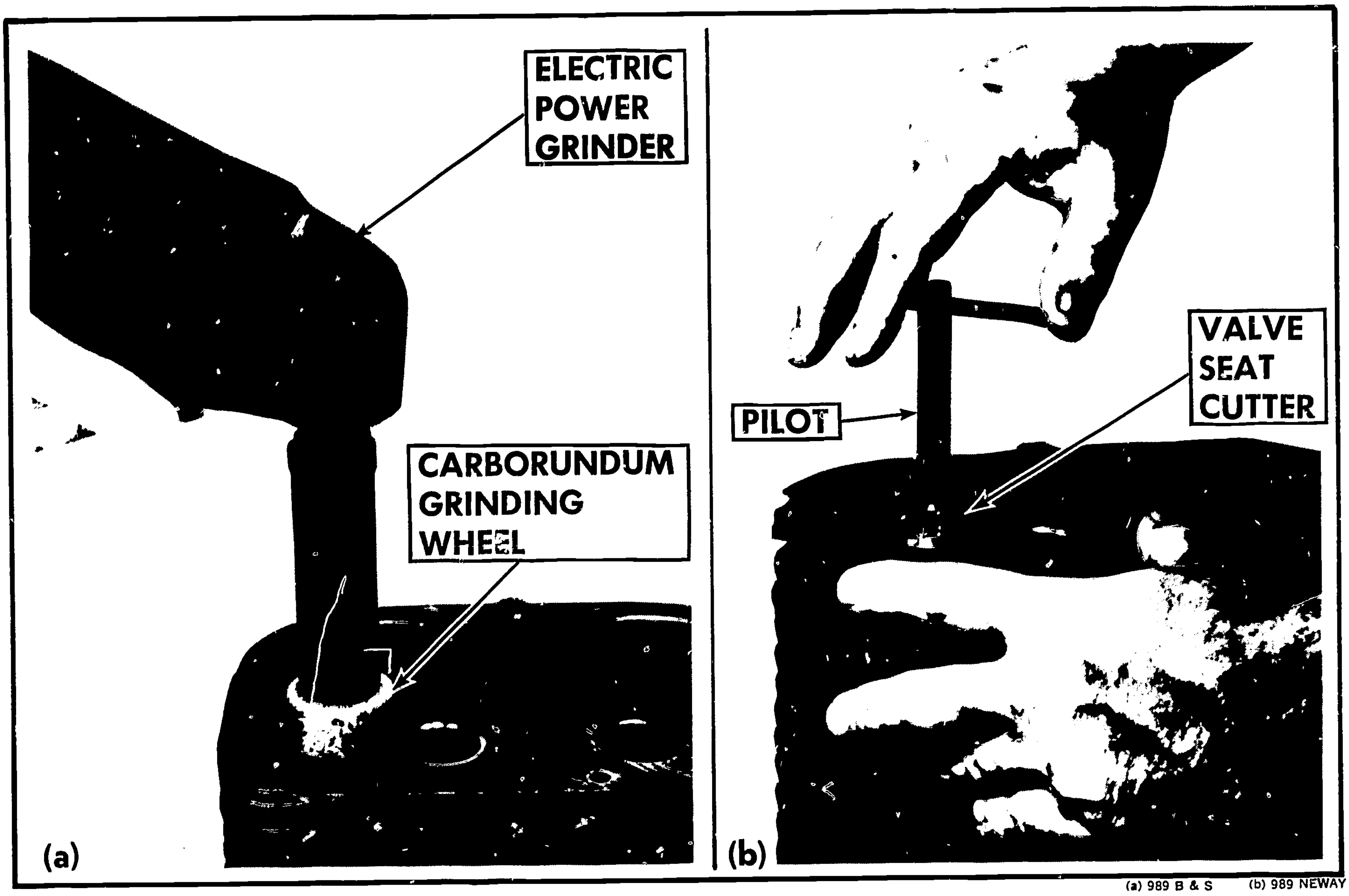

FIGURE 207. Two methods for refacing valve seats. (a) Portable electric grinder equipped with carborundum grinding wheel and pilot. (b) Special valve-seat cutter, pilot and T-handle.

deeply into the block is to compare the length of the valve stem with a new one. If over half of the metal from the lock groove to the end of the valve has been removed to get the proper clearance between the tappet and the valve stem, install a new valve-seat insert.

There are two tools used for servicing valve seats. They are (1) **electric-power grinder** with a carborundum grinding wheel (Figure 207a), and (2) a **special valve-seat cutter** (Figure 207b).

a. If you use the **electric-power grinder**, proceed as follows:

1. *Select a grinding wheel with the proper angle.*

   Most valve seats are ground at a 45° angle. Some 44°; some 46°. Others vary. Some older engines are ground at 30°. Check the specifications in your engine manual.

2. *Be sure the wheel is dressed properly.*

3. *Install the pilot in the valve guide.*

   This is why it is important that the valve guides be serviced before grinding the valve seats.

4. *Grind the valve seats.*

   Cut away all oxidized (discolored) metal. Grinding action is fast; so be careful not to do too much. Keep the grinder straight.

5. *Check width of valve seat (Figure 208).*

   It should not be over 1/16-inch wide, or the

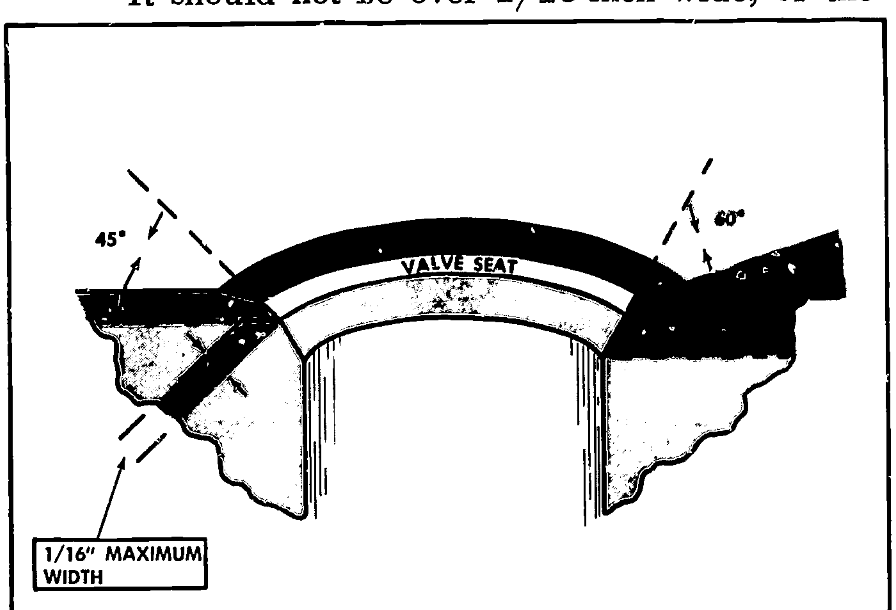

FIGURE 208. The seat width can be reduced by grinding both at the top and the bottom with the proper type grinding wheels.

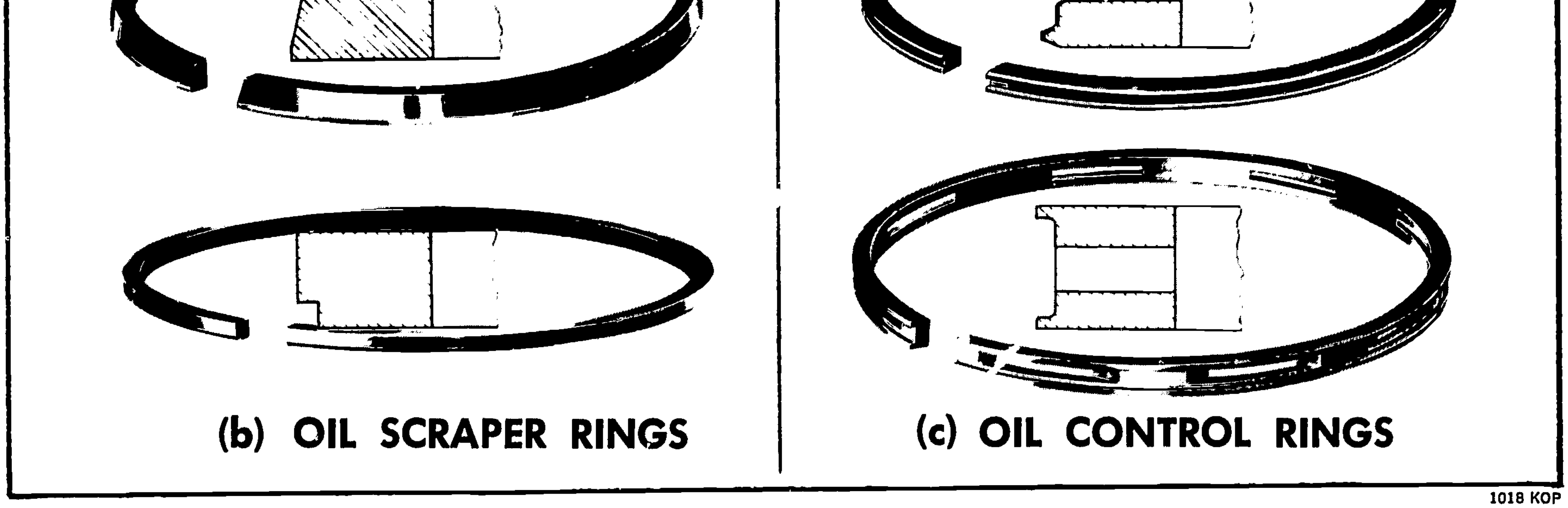

FIGURE 236. Types of piston rings used on small gasoline engines. (a) Compression rings. (b) Oil-wiper rings. (c) Oil-control rings. These types shown in (b) and (c) are used only on 4-cycle engines.

- **Oil-control rings** (Figure 236c). These are located below the compress.on rings. They regulate the amount of oil going to the compression rings and cylinder walls. Sometimes an additional expander spring is placed under the oil-control ring to help maintain its tension as it wears (Figure 237). The expander spring also helps the oil ring to take the shape of a slightly distorted cylinder wall.

  Two-cycle engines have no oil-control rings since the oil is mixed with the fuel.

Most piston rings are made of cast iron. Some have a chrome-plated face, or are specially heat treated, to harden the surface and reduce the wear. Oil rings do not run so hot as compression rings; consequently, they can be made of steel without annealing while running. Therefore, many oil rings

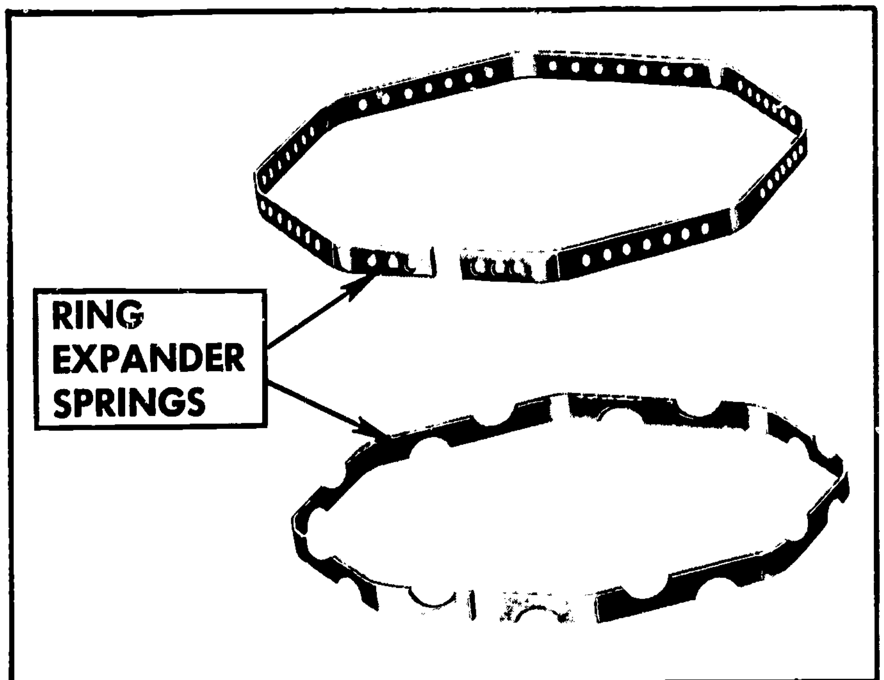

FIGURE 237. Expander springs can be placed under oil-control rings.

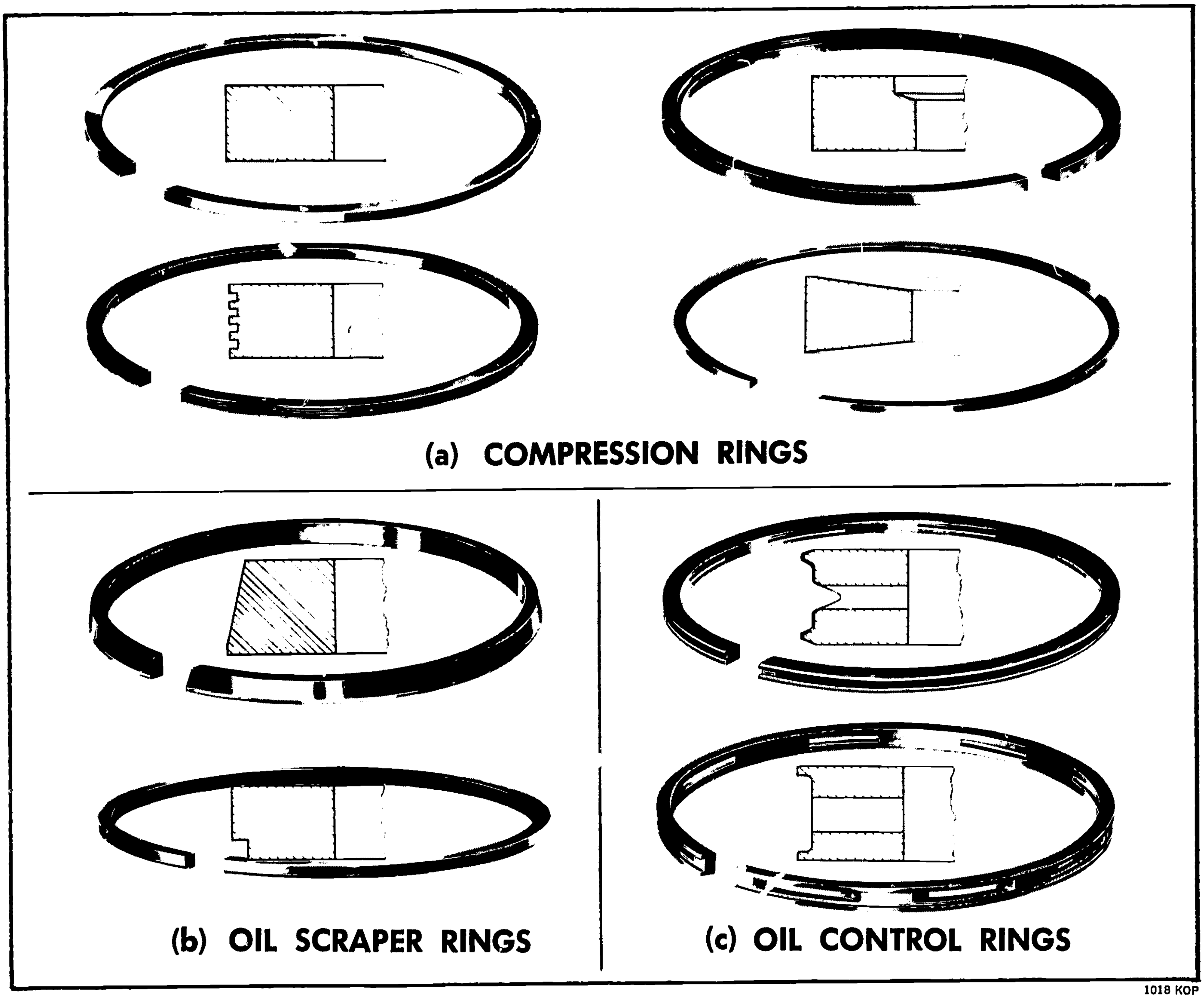

FIGURE 236. Types of piston rings used on small gasoline engines. (a) Compression rings. (b) Oil-wiper rings. (c) Oil-control rings. These types shown in (b) and (c) are used only on 4-cycle engines.

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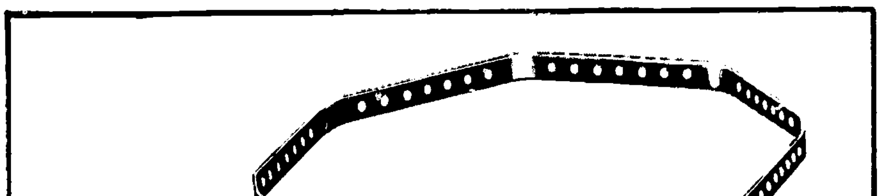

FIGURE 237. Expander springs can be placed under oil-control rings.

connecting the rod (Figure 238) from the crankshaft. Most of them are pushed out through the top of the cylinder (Figure 239a). Some (on 2-cycle engines) are removed from the bottom of the cylinder (Figure 239b).

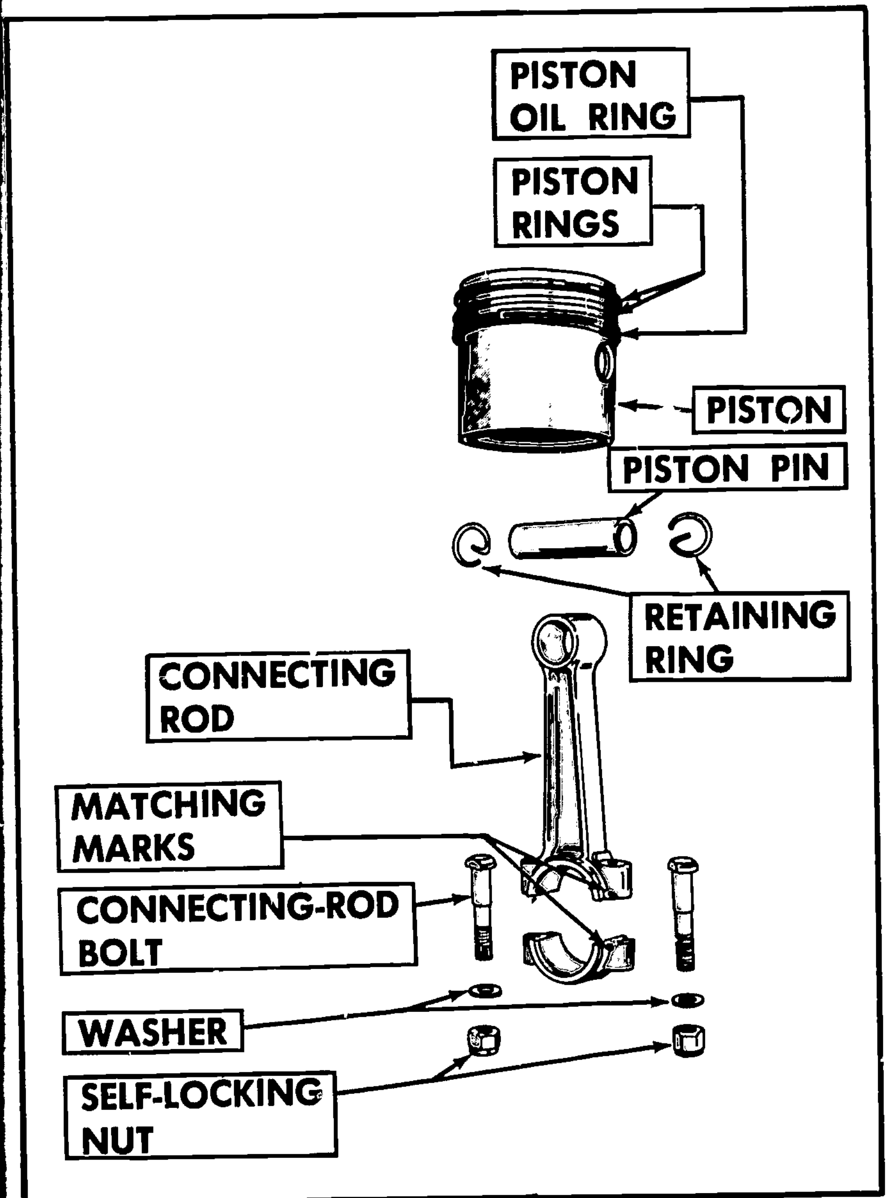

FIGURE 238. Parts of the piston-and-rod assembly.

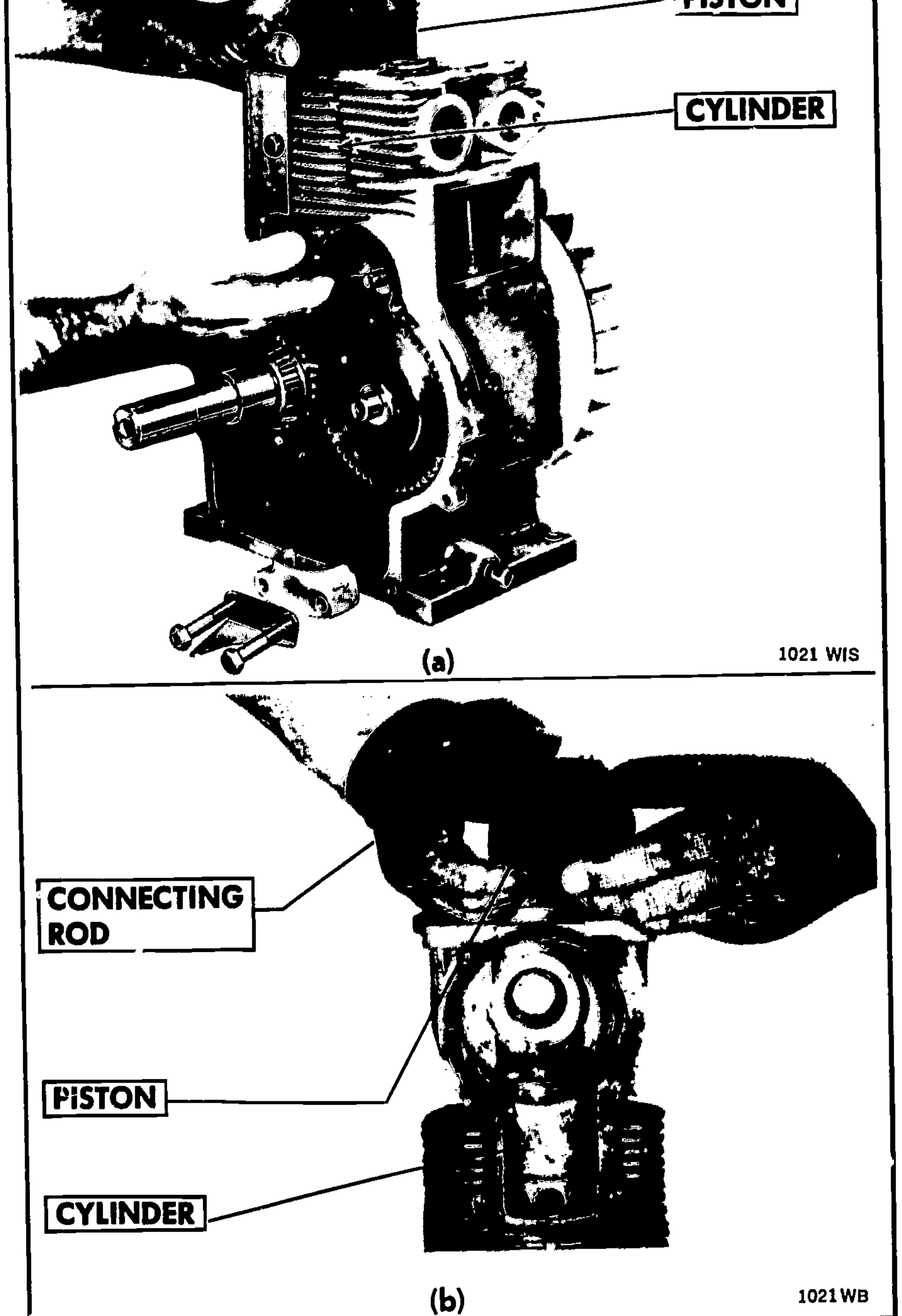

FIGURE 239. Removing the piston-and-rod assembly. (a) Most piston-and-rod assemblies are removed from the top of the cylinder. (b) Some are removed from the bottom of the cylinder.

are designed with two narrow steel rails that contact the cylinder wall.

Some manufacturers now have a replaceable ring which tney claim will take the shape of a worn, uneven or out-of-round cylinder. You can use them in cylinders that have not worn to the extent that they must be rebored.

All piston rings provide enough spring action to press against the cylinder wall. This spring action provides a seal between the piston and the cylinder.

TOOLS AND MATERIALS NEEDED

1. Long-nose pliers — 7″
2. Piston ring expander
3. Reamer for piston pin
4. Micrometer (outside and inside)
5. Ring-groove gage
6. Open-end wrenches — 3/8″ through 9/16″
7. Sockets, ratchet handle — 3/8″ through 9/16″ — 3/8″ drive
8. Brass punch — 1/2″ x 6″
9. Piston solvent — John Deere, Stoddard or equivalent
10. Clean rags
11. Crankcase oil

PREPARING TO REMOVE THE PISTON-AND-ROD ASSEMBLY

All piston-rod assemblies are removed by disconnecting the rod (Figure 238) from the crankshaft. Most of them are pushed out through the top of the cylinder (Figure 239a). Some (on 2-cycle engines) are removed from the bottom of the cylinder (Figure 239b).

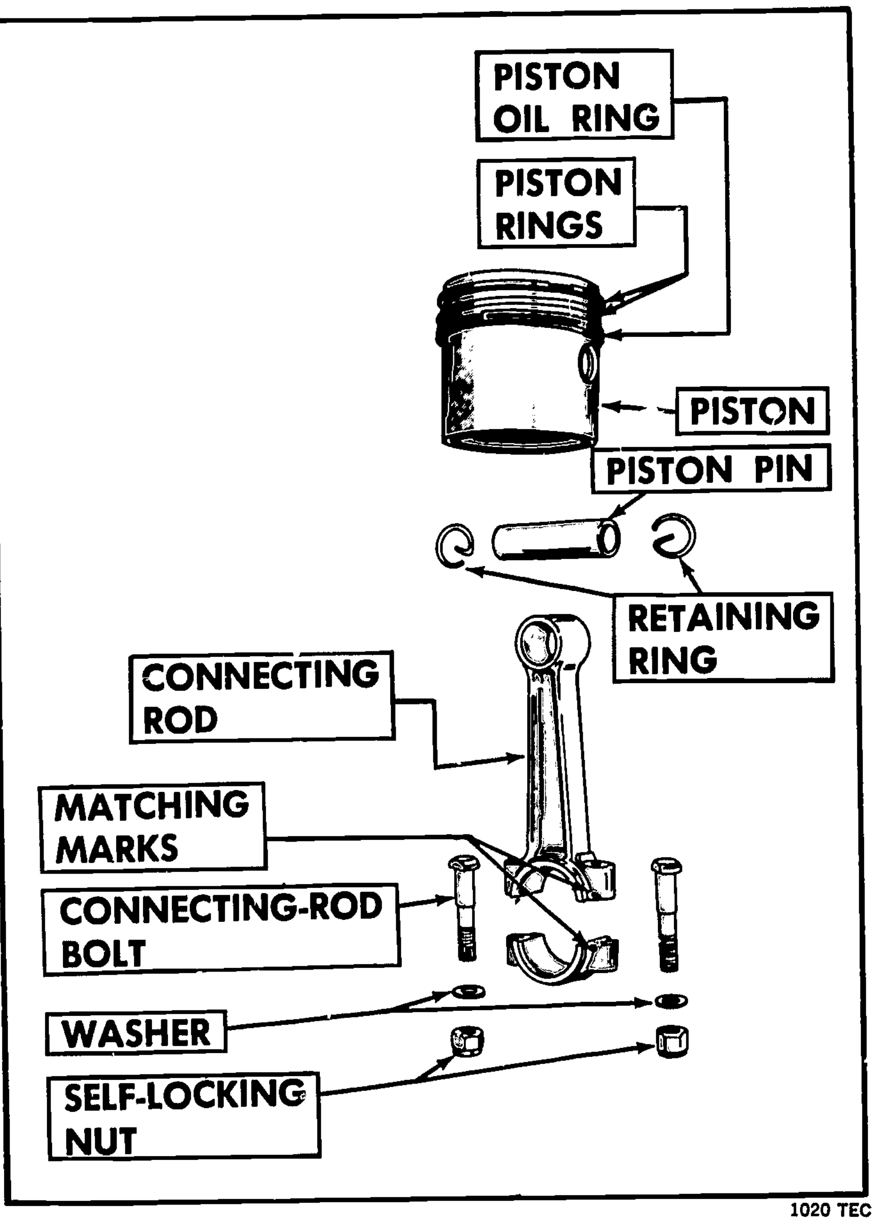

FIGURE 238. Parts of the piston-and-rod assembly.

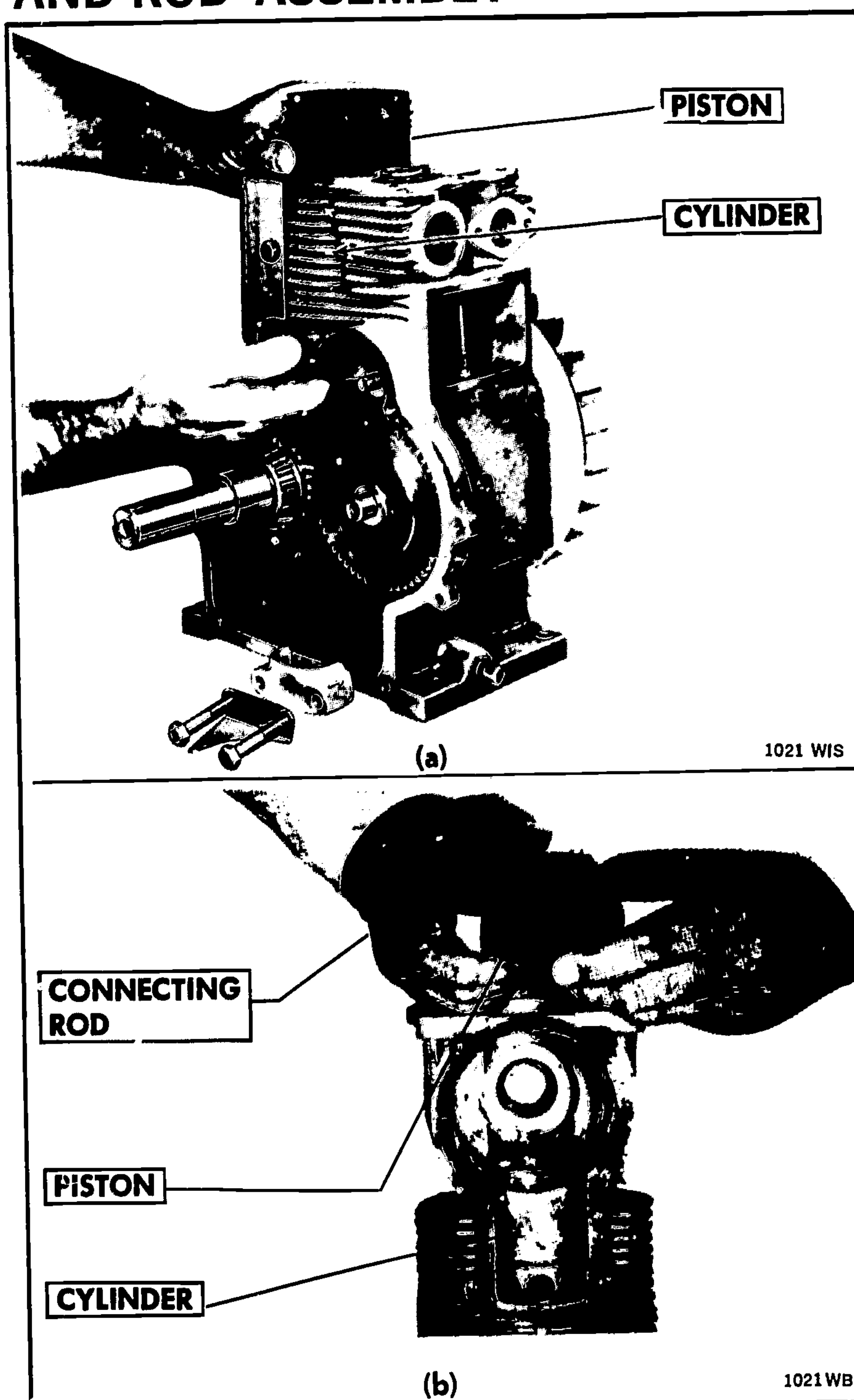

FIGURE 239. Removing the piston-and-rod assembly. (a) Most piston-and-rod assemblies are removed from the top of the cylinder. (b) Some are removed from the bottom of the cylinder.

80.

5. *Remove the starter (if one is installed).*

   See "Repairing Starters," page 8.

6. *Remove the flywheel shroud and cylinder baffles.*

haul the engine.

See "Removing the Cylinder Head," page 116.

13. *Remove the valves if they are to be serviced.*

    See "Removing the Valves," page 118.

REMOVING THE PISTON-AND-ROD ASSEMBLY

The piston rod is attached to the crankshaft by a **rod-bearing cap** (Figure 240). To remove the piston-and-rod assembly, you must remove the rod-bearing cap which is located inside the crankcase. Proceed as follows:

1. *Remove the cylinder head — if it is removable.*

   If your **cylinder head is bolted on to the cylinder block,** the piston-and-rod assembly is removed from the top, or cylinder-head end of the cylinder.

   If the **cylinder head and cylinder are cast in one piece** and bolted to the crankcase (Figure 249), proceed to step 2.

   If the **cylinder head, cylinder and crankcase are cast in one piece** (Figure 250), proceed to step 2.

2. *Gain access to the rod-bearing cap.*

   This is a matter of removing some part of the crankcase. On **4-cycle engines** remove the oil sump (Figure 241a) or a PTO bearing plate (Figure 241b and c).

   On **2-cycle engines** remove the carburetor and reed plate (Figure 242a) or a rod-bearing access plate (Figure 242b).

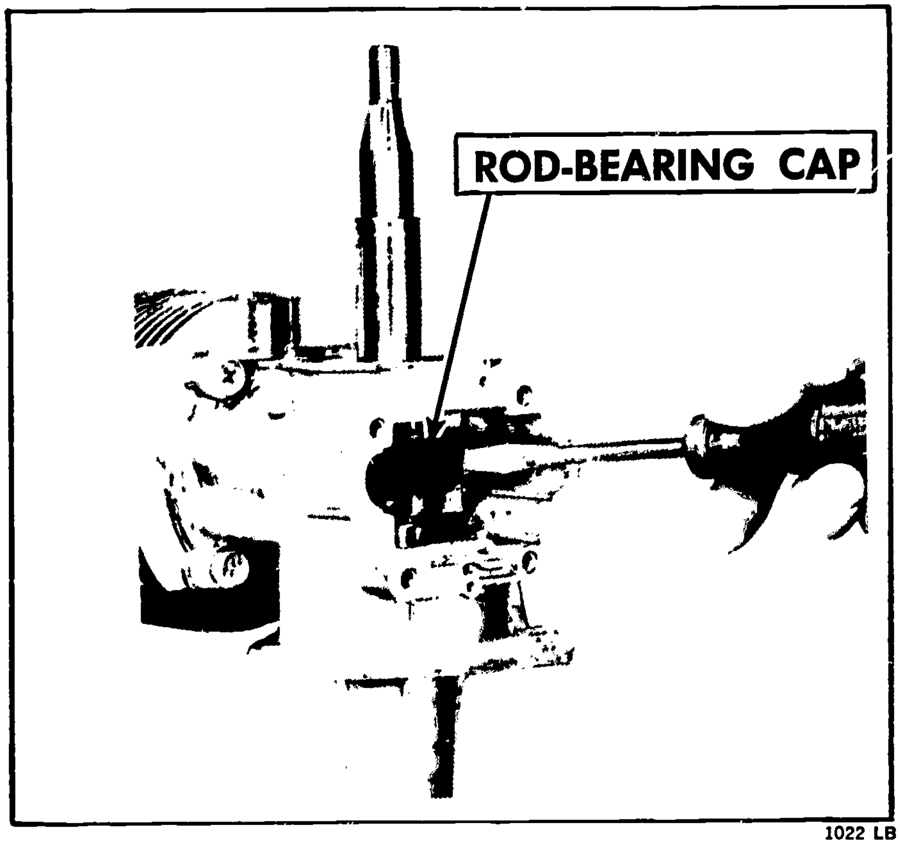

FIGURE 240. Removing the rod-bearing cap.

There are several steps you have to complete before removing the piston assembly, since it is connected inside the crankcase. Proceed as follows:

1. *Clean the engine and equipment.*

   See "Cleaning Small Engines," Volume I.

2. *Drain the oil (4-cycle engines).*

   See "Changing the Crankcase Oil (4-Cycle Engines)," Volume I.

3. *Remove the engine from the equipment if convenient.*

   A major job of repairing your engine will be easier if you can remove it from the tractor, mower, chain saw or the equipment to which it may be attached.

4. *Remove the fuel tank.*

   See "Repairing Fuel Tank Assemblies," page 80.

5. *Remove the starter (if one is installed).*

   See "Repairing Starters," page 8.

6. *Remove the flywheel shroud and cylinder baffles.*

   See "Removing and Checking the Flywheel," page 55.

7. *Remove the flywheel if necessary.*

   On some engines it is not necessary to remove the flywheel, unless you are going to remove the crankshaft.

8. *Remove the spark plug.*

   See "Servicing Spark Plugs," Volume I.

9. *Remove the carburetor air cleaner.*

   See "Servicing Carburetor Air Cleaners," Volume I.

10. *Remove the carburetor.*

    See "Repairing Carburetors," page 86.

11. *Remove the muffler (if one is installed.)*

    See "Cleaning Small Engines," Volume I.

12. *Remove the cylinder head if you plan to overhaul the engine.*

    See "Removing the Cylinder Head," page 116.

13. *Remove the valves if they are to be serviced.*

    See "Removing the Valves," page 118.

REMOVING THE PISTON-AND-ROD ASSEMBLY

The piston rod is attached to the crankshaft by a **rod-bearing cap** (Figure 240). To remove the piston-and-rod assembly, you must remove the rod-bearing cap which is located inside the crankcase. Proceed as follows:

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   On **2-cycle engines** remove the carburetor and reed plate (Figure 242a) or a rod-bearing access plate (Figure 242b).

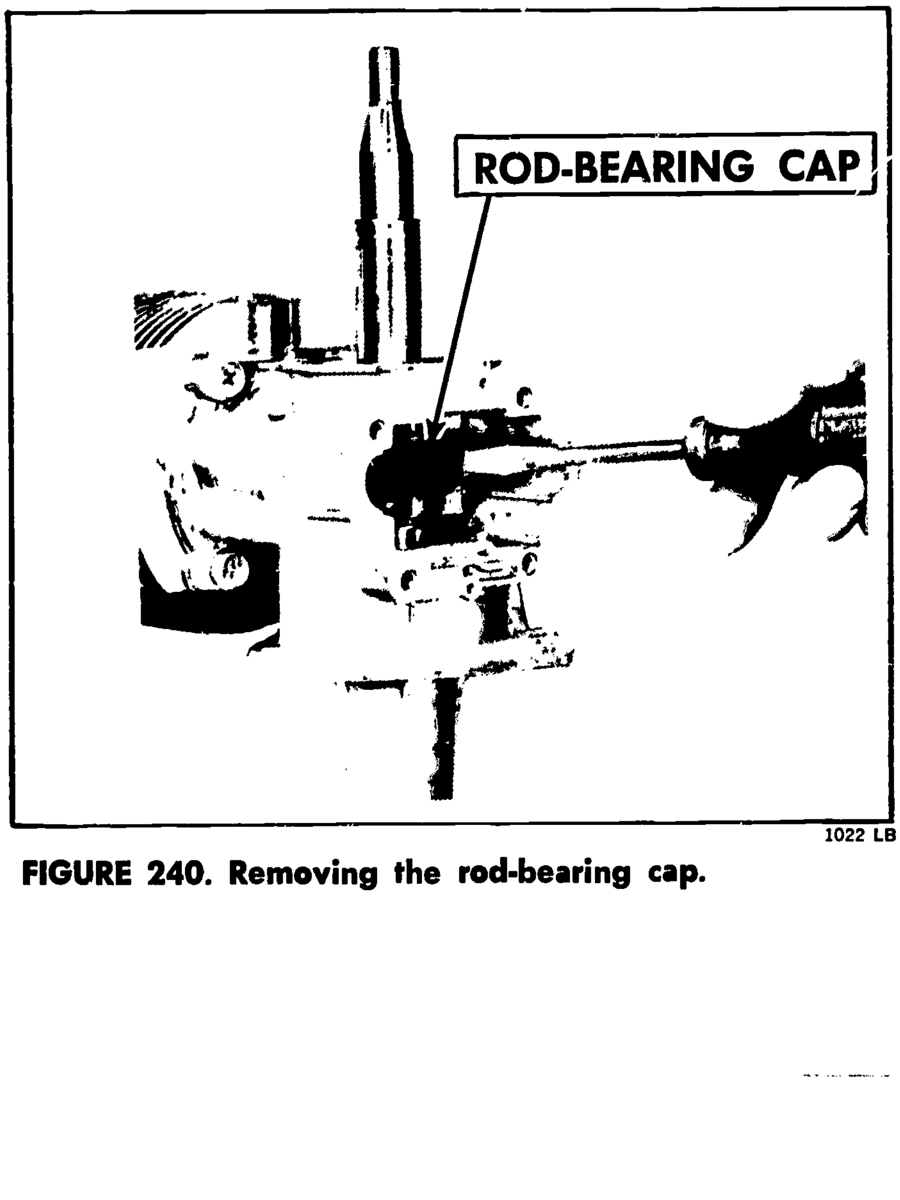
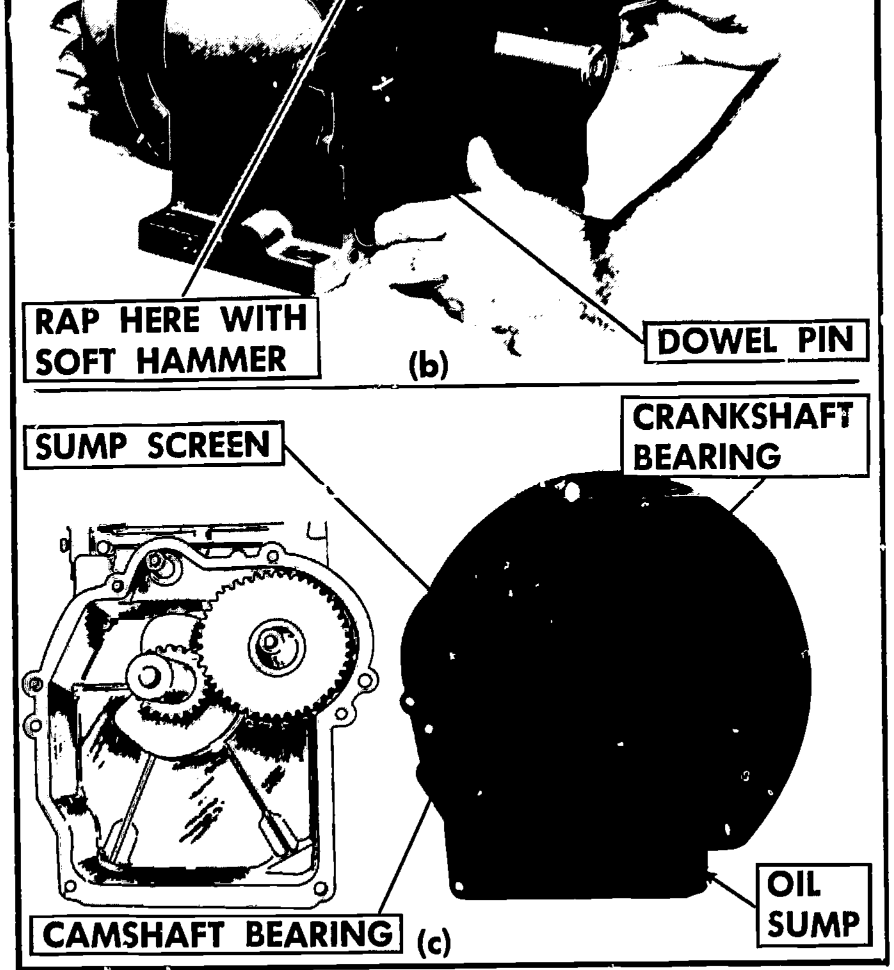


FIGURE 240. Removing the rod-bearing cap.

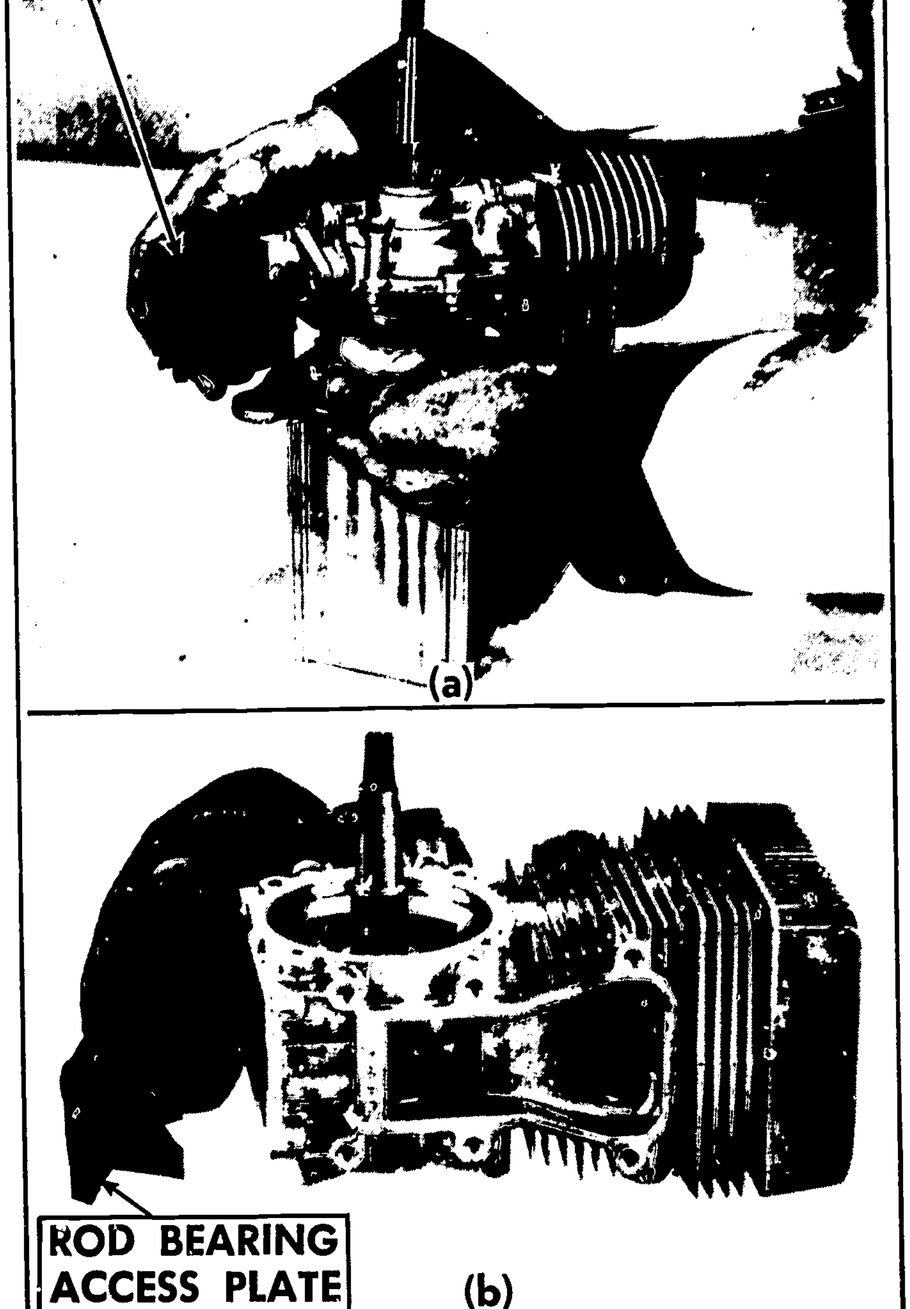


(a) 1023 KOH (b) 1023 WIS (c) 1023 TEC

FIGURE 241. Gaining access to the rod-bearing cap on the crankshaft of different types of 4-cyle engines. (a) Removing the oil sump. (b) Removing the bearing plate. (c) Removing the oil sump and bearing plate.

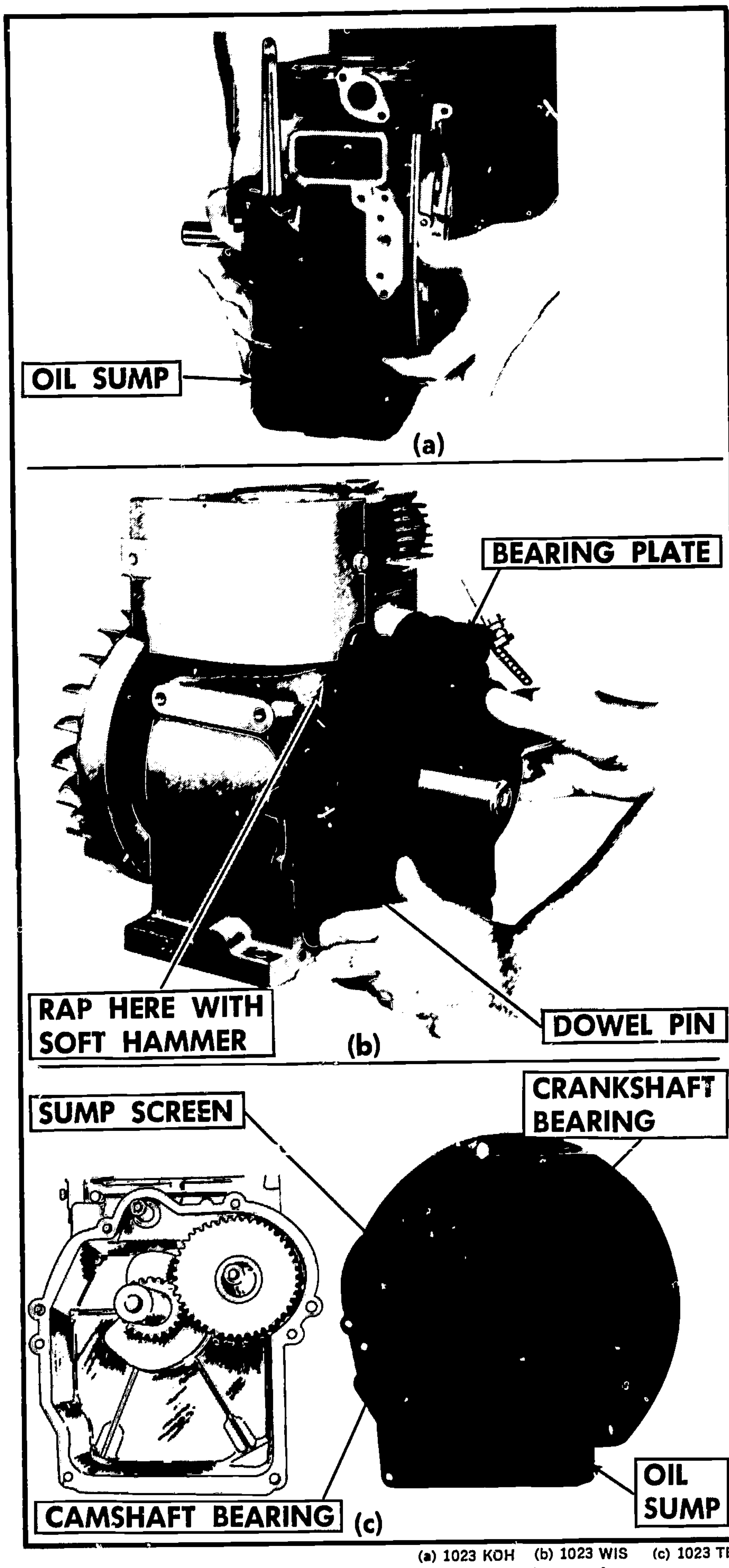
a. If you are removing from the crankcase **a part which does not serve as a bearing support,** such as an oil sump (Figure 241a), or a carburetor and reed plate (Figure 242a), or a rod-bearing access plate (Figure 242b), proceed as follows:

(1) *Remove nuts, or capscrews, that hold*



(a) 1024 LB (b) 1024 WB

FIGURE 242. Two methods for gaining access to the rod-bearing cap on 2-cycle engines. (a) Removing the carburetor and reed plate. (b) Removing a special rod-bearing access plate.



(a) 1023 KOH (b) 1023 WIS (c) 1023 TEC

FIGURE 241. Gaining access to the rod-bearing cap on the crankshaft of different types of 4-cyle engines. (a) Removing the oil sump. (b) Removing the bearing plate. (c) Removing the oil sump and bearing plate.

a. If you are removing from the crankcase **a part which does not serve as a bearing support,** such as an oil sump (Figure 241a), or a carburetor and reed plate (Figure 242a), or a rod-bearing access plate (Figure 242b), proceed as follows:

(1) *Remove nuts, or capscrews, that hold the part to be removed from the crankcase.*

Some parts have alignment dowels that must be removed also.

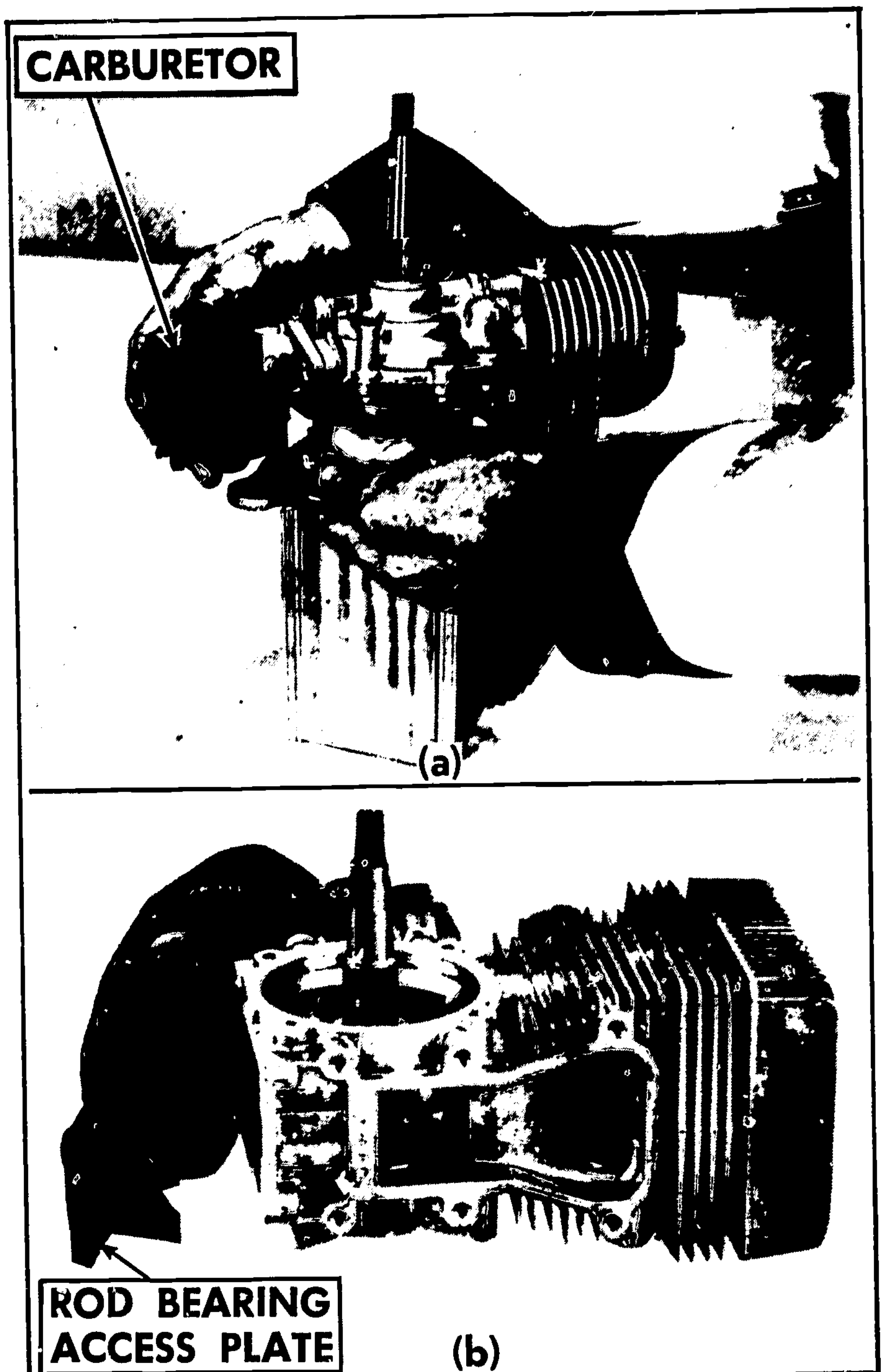
If you are removing the carburetor, refer to "Removing the Carburetor," page 86, for procedures.

(2) *Jar the part loose with a soft hammer*

(3) *Remove the part from the crankcase.*

b. If you must remove a **part that supports a bearing,** such as a base plate on a horizontal cylinder engine (Figure 241b), or a bearing plate on a vertical cylinder engine (Figure 241c), proceed as follows:

(1) *Clean rust and burrs from the power*



(a) 1024 LB (b) 1024 WB

FIGURE 242. Two methods for gaining access to the rod-bearing cap on 2-cycle engines. (a) Removing the carburetor and reed plate. (b) Removing a special rod-bearing access plate.

take-off (PTO) end of the crank-shaft.

This is to prevent damage to the main bearing and oil seal when the bearing plate is removed.

On engines with clutch or speed-reduction units, these must be removed first.

(2) *Remove dust cover if installed and Tru Arc lock ring on engines with ball bearings (Figure 243).*

(3) *Remove alignment dowels if they are the removable type.*

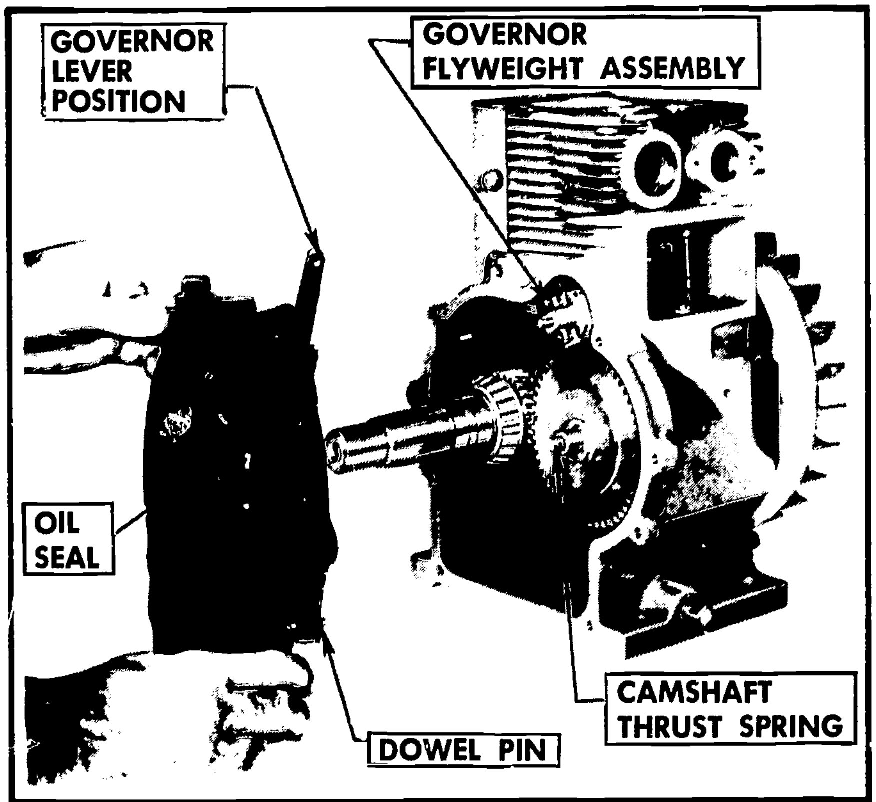


FIGURE 244. Removing the bearing plate.

get to the rod-bearing cap.

Turn the crankshaft until the valve-timing marks are aligned. This relieves the cam pressure on the valve tappets.

The valve tappets will fall out when the camshaft is removed. Mark them so you will be able to install them in the original location.

3. *Inspect the crankshaft bearings that are removed.*

Refer to "Cleaning and Inspecting the Crankshaft Bearings," page 183. This check will help you determine whether to repair the engine or buy a new "short block."

4. *Scrape the carbon ring from around the top of the cylinder and/or remove the metal ridge from top of cylinder on removable-head engines (Figure 245).*

This is to avoid breaking the piston rings and/or damaging the piston when removing the piston-and-rod assembly from the top. If left, it may also break the new rings.

Remove carbon deposits with a pocket knife (Figure 245a). Remove metal ridge with a "ridge reamer" (Figure 245b).

5. *Turn the crankshaft so the piston will be at bottom-dead-center.*

The rod-bearing cap will be at its lowest point so that you will have better access to it.

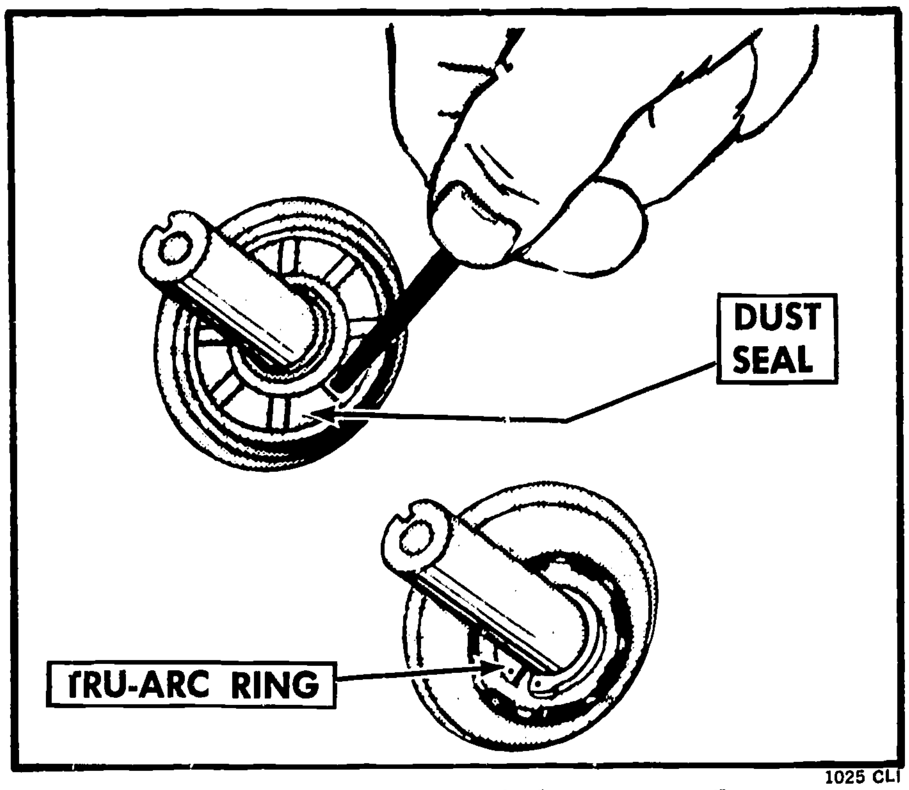


FIGURE 243. (a) Removing metal dust cover. (b) Tru Arc lock ring.

take-off (PTO) end of the crankshaft.

This is to prevent damage to the main bearing and oil seal when the bearing plate is removed.

On engines with clutch or speed-reduction units, these must be removed first.

(2) *Remove dust cover if installed and Tru Arc lock ring on engines with ball bearings (Figure 243).*

(3) *Remove alignment dowels if they are the removable type.*

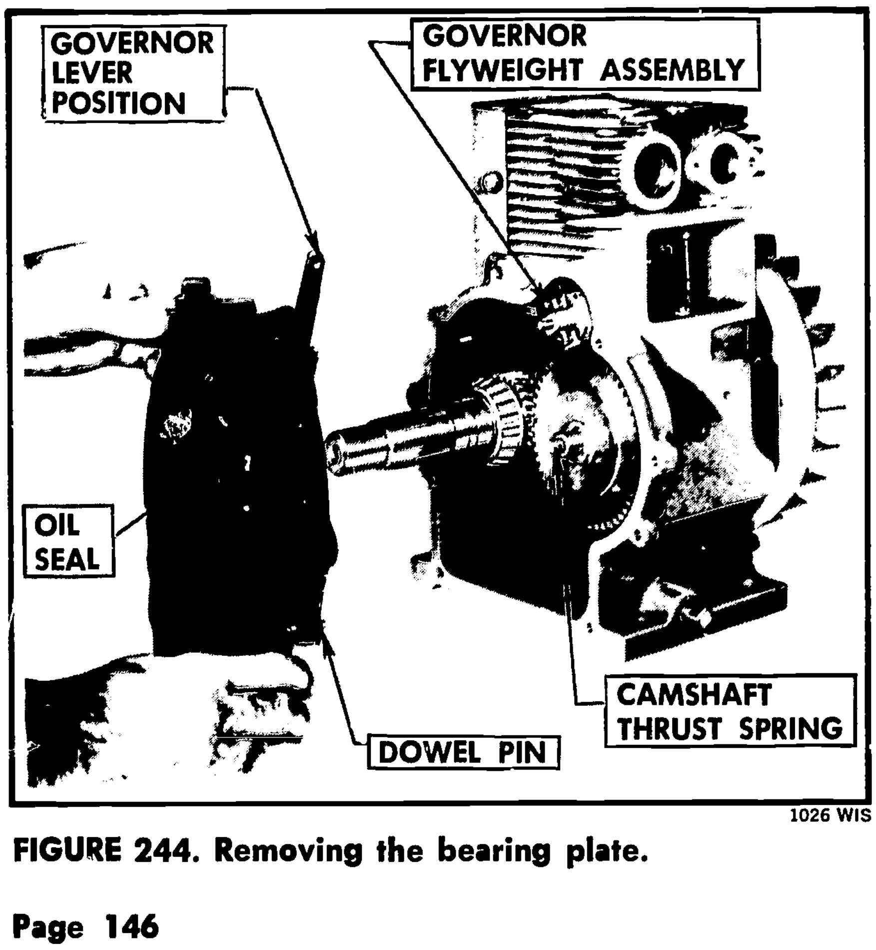


FIGURE 244. Removing the bearing plate.

(4) *Remove base plate, or bearing plate (Figure 244).*

Tap with a soft hammer to loosen. Be careful not to damage oil seal and bearings.

Some engines have a *steel ball for end thrust* at the end of the camshaft. Watch for this because it may fall out when you remove the bearing plate. There is also an end-thrust spring on the end of the camshaft on this type.

(5) *Remove the governor and oil pump assembly if installed.*

Note how they are assembled so you can reassemble them properly.

(6) *Remove the camshaft if necessary to get to the rod-bearing cap.*

Turn the crankshaft until the valve-timing marks are aligned. This relieves the cam pressure on the valve tappets.

The valve tappets will fall out when the camshaft is removed. Mark them so you will be able to install them in the original location.

3. *Inspect the crankshaft bearings that are removed.*

Refer to "Cleaning and Inspecting the Crankshaft Bearings," page 183. This check will help you determine whether to repair the engine or buy a new "short block."

4. *Scrape the carbon ring from around the top of the cylinder and/or remove the metal ridge from top of cylinder on removable-head engines (Figure 245).*

This is to avoid breaking the piston rings and/or damaging the piston when removing the piston-and-rod assembly from the top. If left, it may also break the new rings.

Remove carbon deposits with a pocket knife (Figure 245a). Remove metal ridge with a "ridge reamer" (Figure 245b).

5. *Turn the crankshaft so the piston will be at bottom-dead-center.*

The rod-bearing cap will be at its lowest point so that you will have better access to it.

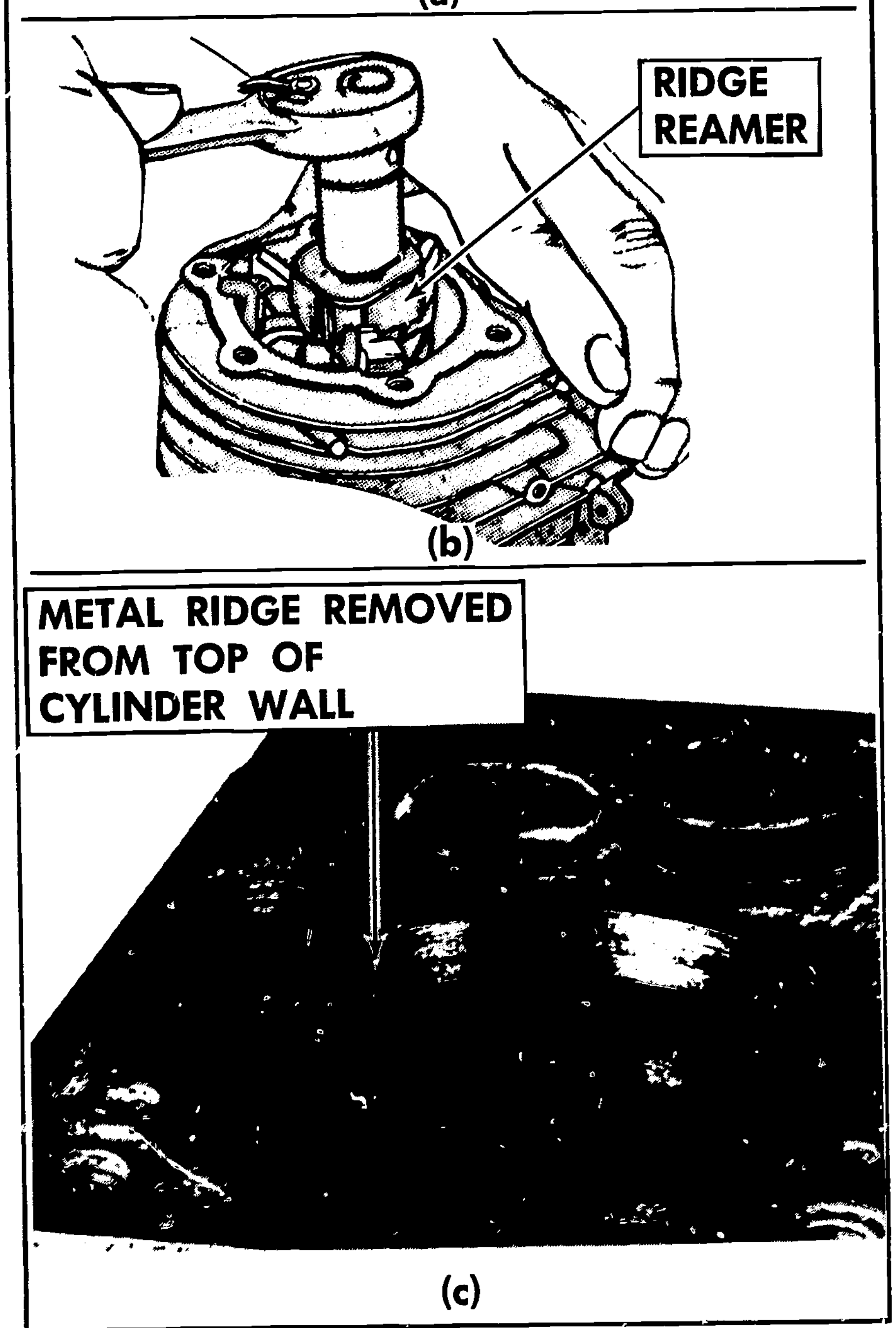


FIGURE 245. (a) Scraping the carbon ring from around the top of the cylinder. (b) Removing the metal ridge from the top of the cylinder with a ridge reamer. (c) Ridge removed.

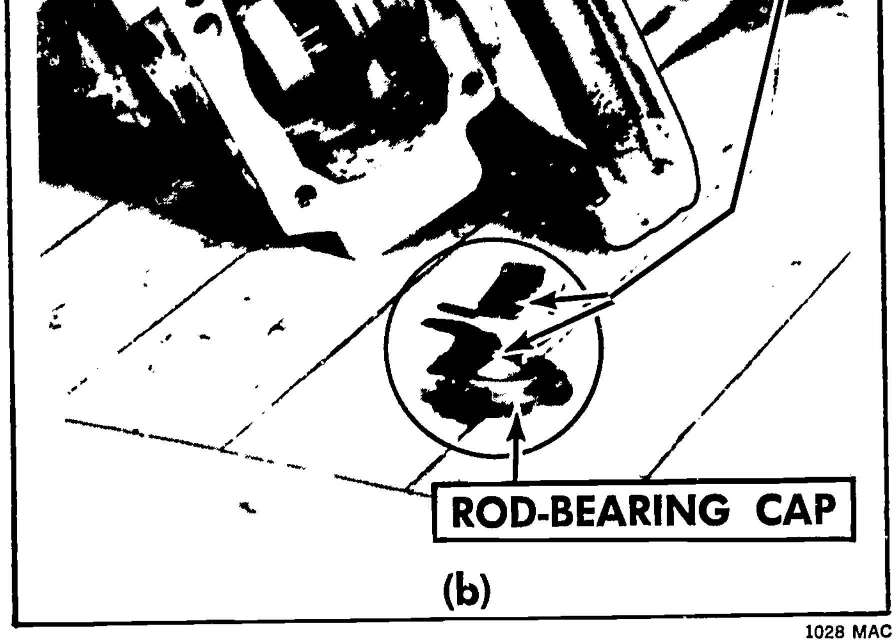


FIGURE 246. Take special care when removing needle bearings. (a) Removing needle bearings. (b) Needle bearings and rod-bearing cap removed.

This provides better access to the rod-bearing cap.

7. *Remove the nut or capscrews from the rod-bearing cap.*

   Some capscrews are held by a lock which is bent along the edge of the screw head. If so, it must be flattened first. Use a 5/16″ punch.

8. *Note positions of cap and rod.*

   Before removing the rod-bearing cap, take note of its position. It is usually marked with matching notches or bosses so that you can replace them in the same position. The bearings have been fitted with the cap in this position. If you turn the cap around when you reinstall it, you may not get a good fit.

6. *Turn the engine upside down or on its side (Figure 246).*

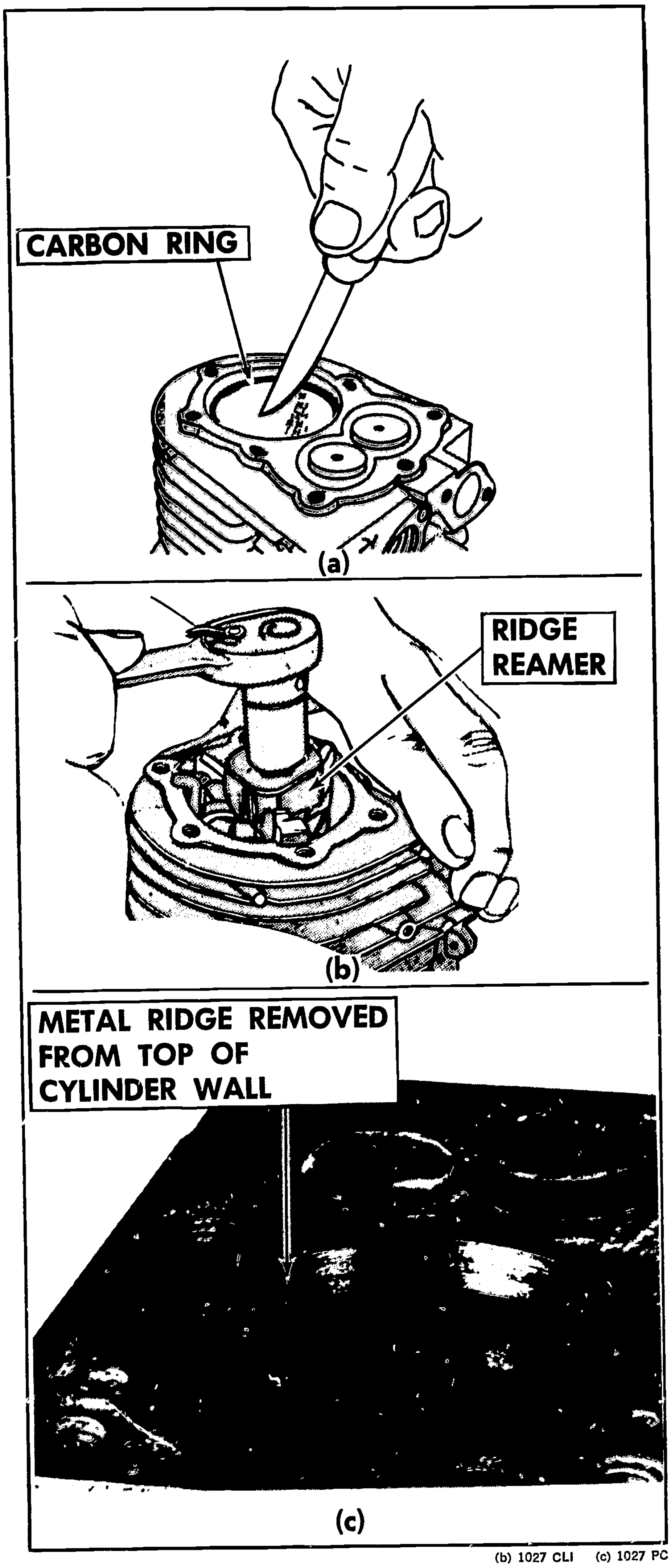


FIGURE 245. (a) Scraping the carbon ring from around the top of the cylinder. (b) Removing the metal ridge from the top of the cylinder with a ridge reamer. (c) Ridge removed.

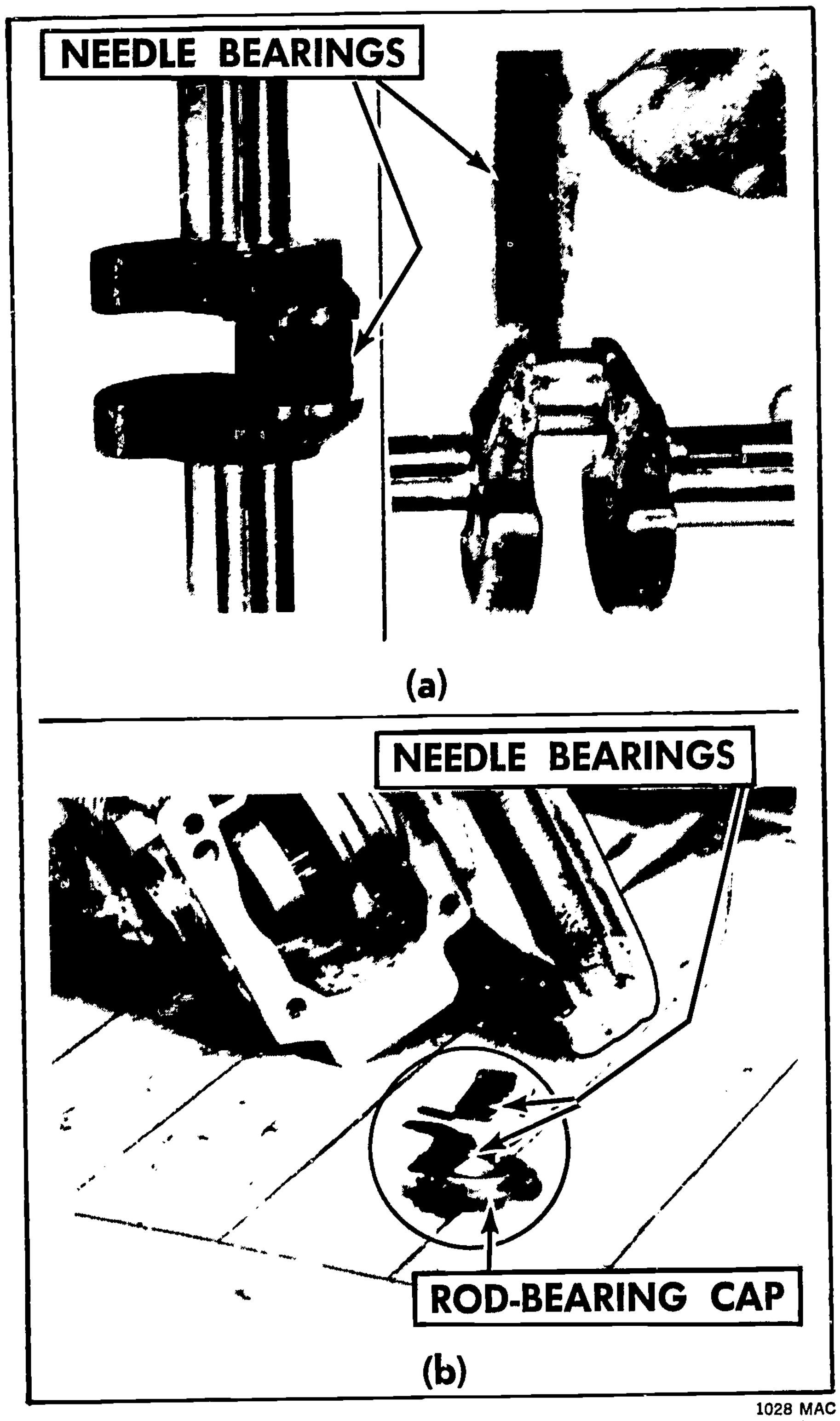


FIGURE 246. Take special care when removing needle bearings. (a) Removing needle bearings. (b) Needle bearings and rod-bearing cap removed.

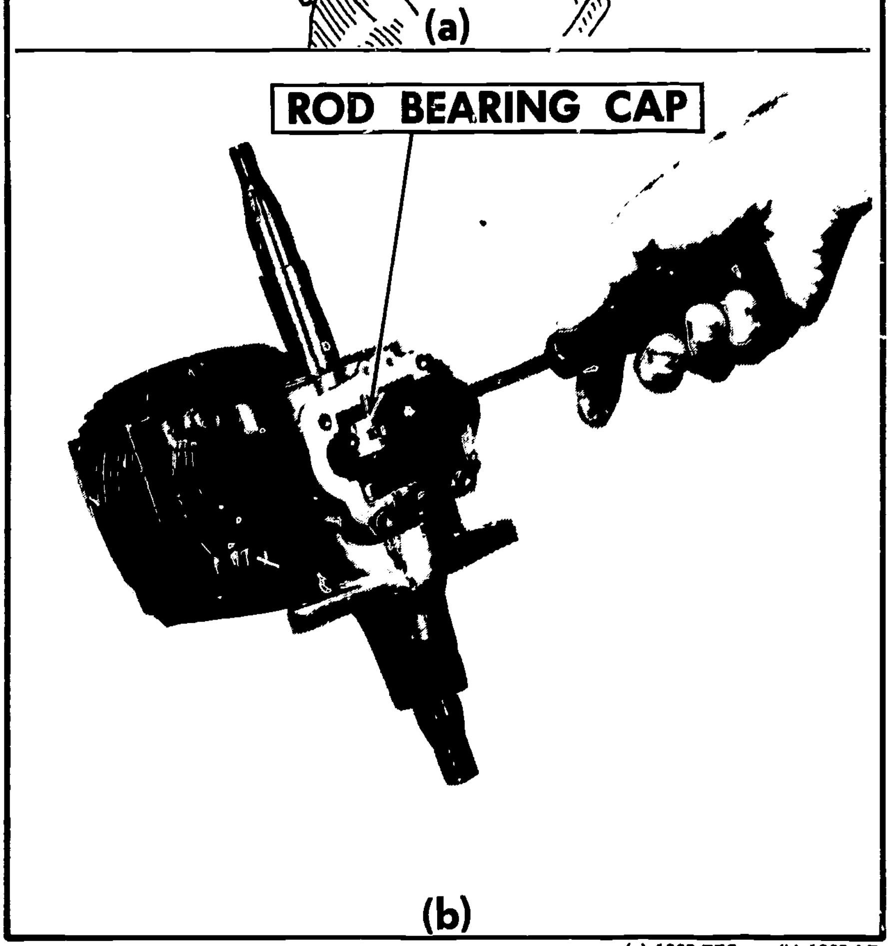
This provides better access to the rod-bearing cap.

7. *Remove the nut or capscrews from the rod-bearing cap.*

   Some capscrews are held by a lock which is bent along the edge of the screw head. If so, it must be flattened first. Use a 5/16″ punch.

8. *Note positions of cap and rod.*

   Before removing the rod-bearing cap, take note of its position. It is usually marked with matching notches or bosses so that you can replace them in the same position. The bearings have been fitted with the cap in this position. If you turn the cap around when you reinstall it, you may not get a good fit.



(a) 1029 TEC (b) 1029 LB

FIGURE 247. Removing the rod-bearing cap from (a) a 4-cycle engine, and (b) a 2-cycle engine.

Another reason for noting the position of the cap is that some **caps have an oil dipper** which must be positioned a certain way to sling oil over the crankcase.

Also **note the position of the connecting rod.** Some rods work satisfactorily in either position, but most of them will not. If the cap is not marked, mark it and the rod with a center punch. Some rods have needle bear-

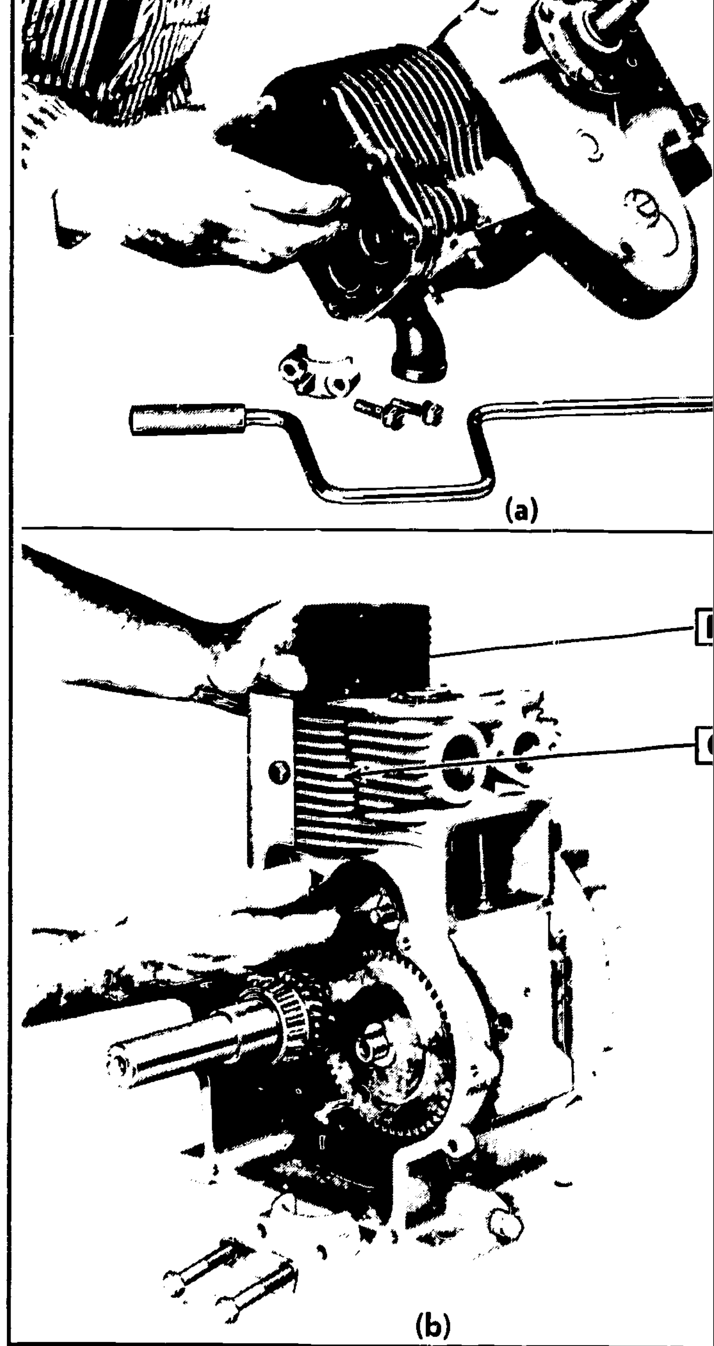


FIGURE 248. Removing the piston-and-rod asse the cylinder (a) with the oil sump removed an the bearing plate removed.

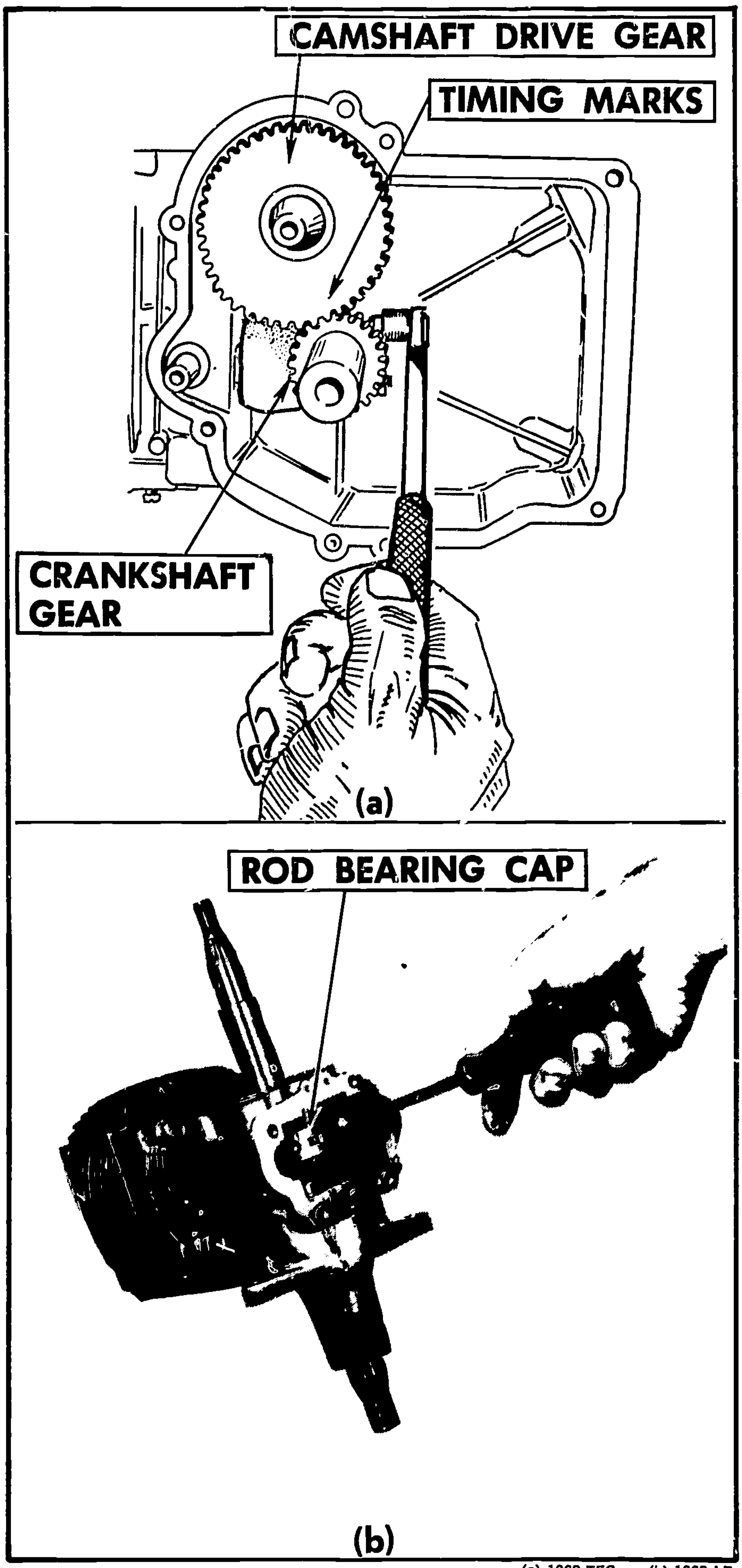


FIGURE 247. Removing the rod-bearing cap from (a) a 4-cycle engine, and (b) a 2-cycle engine.

Another reason for noting the position of the cap is that some **caps have an oil dipper** which must be positioned a certain way to sling oil over the crankcase.

Also **note the position of the connecting rod.** Some rods work satisfactorily in either position, but most of them will not. If the cap is not marked, mark it and the rod with a center punch. Some rods have needle bear- ings. If so, these bearings may fall you remove the rod-bearing cap. Ta care not to lose the bearings an races (Figure 246.)

9. *Remove the rod-bearing cap and b installed (Figure 247).*

10. *Remove the piston-and-rod assem the cylinder.*

    If your engine has a **removable** piston is to be removed from the the piston out with a wooden stic 248).

    If the **cylinder and cylinder head in one piece** and the casting is r

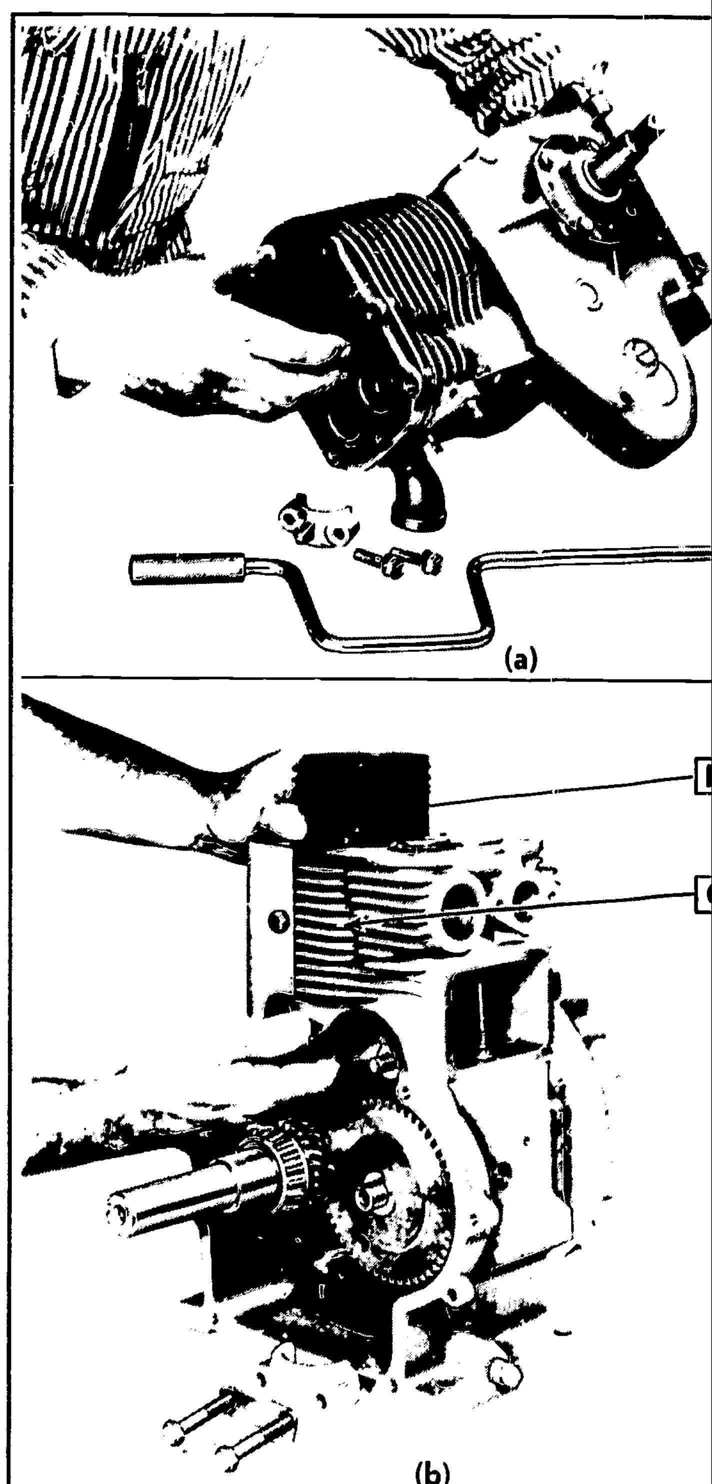


FIGURE 248. Removing the piston-and-rod asse the cylinder (a) with the oil sump removed a the bearing plate removed.

"Plastigage" is a plastic ribbon that is designed to expand in proportion to the amount of pressure applied to it.

5. *Install the rod and cap on the crankshaft.*
6. *Tighten the cap nuts or screws to the torque given in your repair manual.*
7. *Remove the rod cap and measure the flattened plastigage at its widest point with the plastigage scale (Figure 260b).*

   The number corresponding to the width of the flattened plastigage is the bearing clearance in thousandths of an inch. If the **clearance is more than allowed** in your repair manual, replace the rod or rod bearing. Some manufacturers, however, recommend filing away some of the rod-bearing-cap flange. If you do, be sure to take the same amount off of both sides. Very little filing will be needed.

   Too much filing will cause the bearing to be out of round and will result in very rapid wear.

INSTALLING THE PISTON RINGS

1. *Check the end gap of each new ring (Figure 259b).*

   If the **end gap is too small,** file the end of the ring squarely to the proper gap. If the **end gap is too large** and the cylinder is the proper size, discard the ring.

2. *Apply crankcase oil to the rings and pistons.*
3. *Install the rings on the piston (Figures 259 and 261).*

   Begin with the bottom ring. If you use expander springs under the lower oil ring, install them first.

   Use a piston ring expander if available. If not available, you can install them by hand. Start open end of ring in slot first; then push it over top of piston into position.

   Be sure you install them right side up. Some are marked "top"; others are not marked. If not labeled, you cannot tell by looking at the rings how they should go. Refer to the notes you made when removing the rings and/or to your operator's manual. Most manuals give specific instructions (Figure 262).

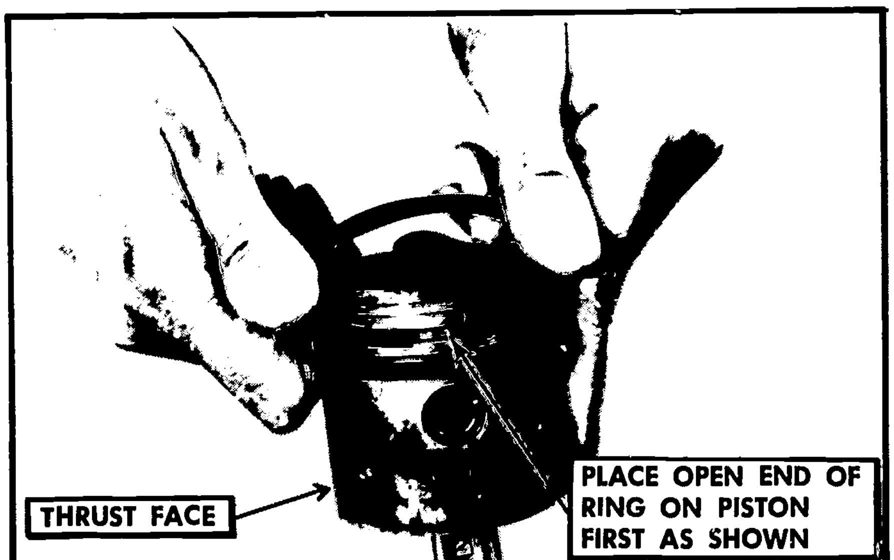


FIGURE 261. Installing rings without a ring expander.

4. *Check the rings for freedom of movement in the grooves.*

   If they are not free to move in the grooves, there is a danger of their scoring the cylinder wall and breaking.

5. *Stagger the ring gaps.*

   Some claim that if the ring gaps are in line on a 4-cycle engine, the engine will lose compression and use oil. Others dispute this claim.

   With **2-cycle engines,** however, it is agreed you should have the ring gaps on any two adjacent rings 180° apart. Some have stops at the ring-gap position to insure this.

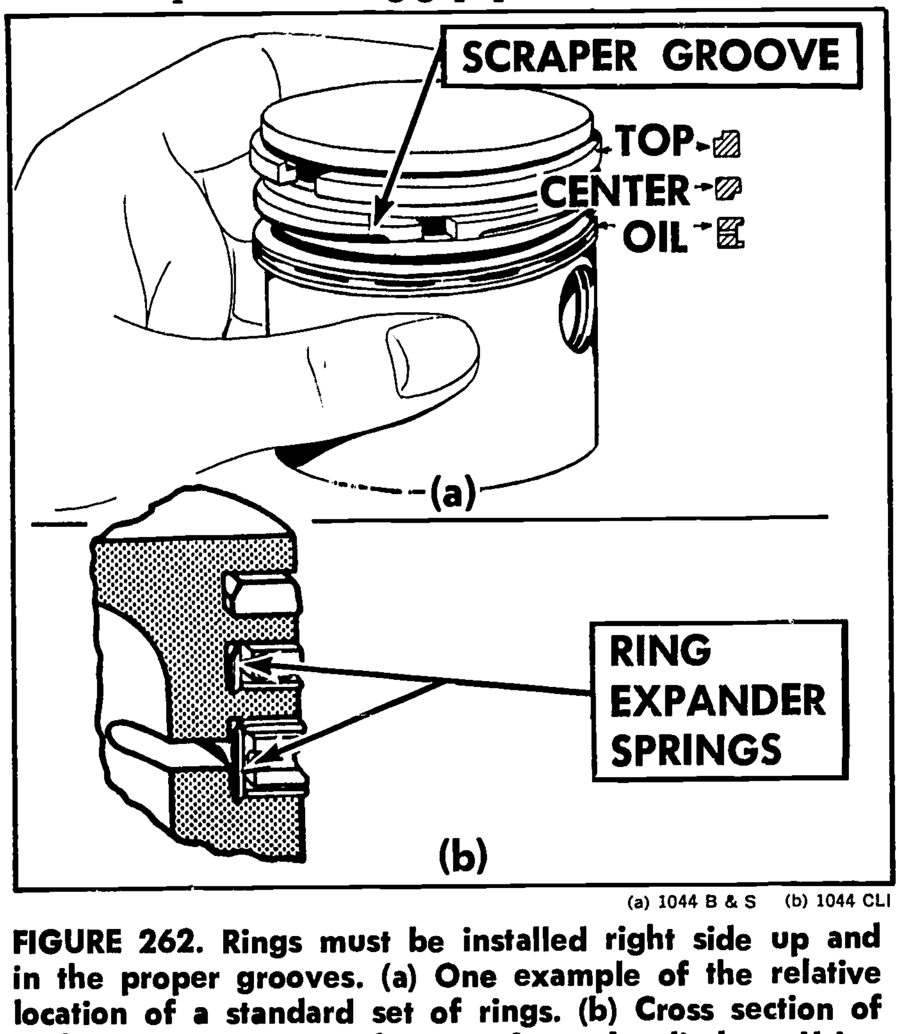


FIGURE 262. Rings must be installed right side up and in the proper grooves. (a) One example of the relative location of a standard set of rings. (b) Cross section of a chrome re-ring set for out-of-round cylinders. Using expander springs back of the two lower rings.

INSTALLING THE PISTON PIN

1. *Install the needle bearings if used.*

   Coat them with multi-purpose grease so they will stay in place.

2. *Install a lock ring on one side of the piston.*

3. *Apply oil to the rod bearing and piston bore.*

4. *Align the rod bearing with the piston bore and insert the piston pin.*

   Insert solid ends first on hollow pins. Some are easy to install with a handpress fit. Others are "sweat fitted."

   If the *pin appears to be too large,* it probably requires sweat fitting. You will have to heat the piston to expand the hole, and shrink the pin by cooling with dry ice before installation.

   Pistons on cross-scavenged, **2-cycle engines** must have the abrupt side of the piston head facing the fuel intake.

   Some pistons have hollow pins with one closed end. With these the closed end should be turned toward the exhaust port.

5. *Install the second piston-pin lock ring.*

INSTALLING THE PISTON-AND-ROD ASSEMBLY

If you are doing a complete overhaul job, before installing the piston and rod, proceed with the steps under "Repairing Crankshaft Assemblies," page 174.

To install the piston-and-rod assembly, proceed as follows:

1. *Oil the piston rings and cylinder.*

   Oiling makes the installation easier and supplies lubrication when the engine is started — before normal lubrication can be supplied.

2. *Install ring compressor on rings (Figure 263).*

   Compress the rings completely; then release slightly.

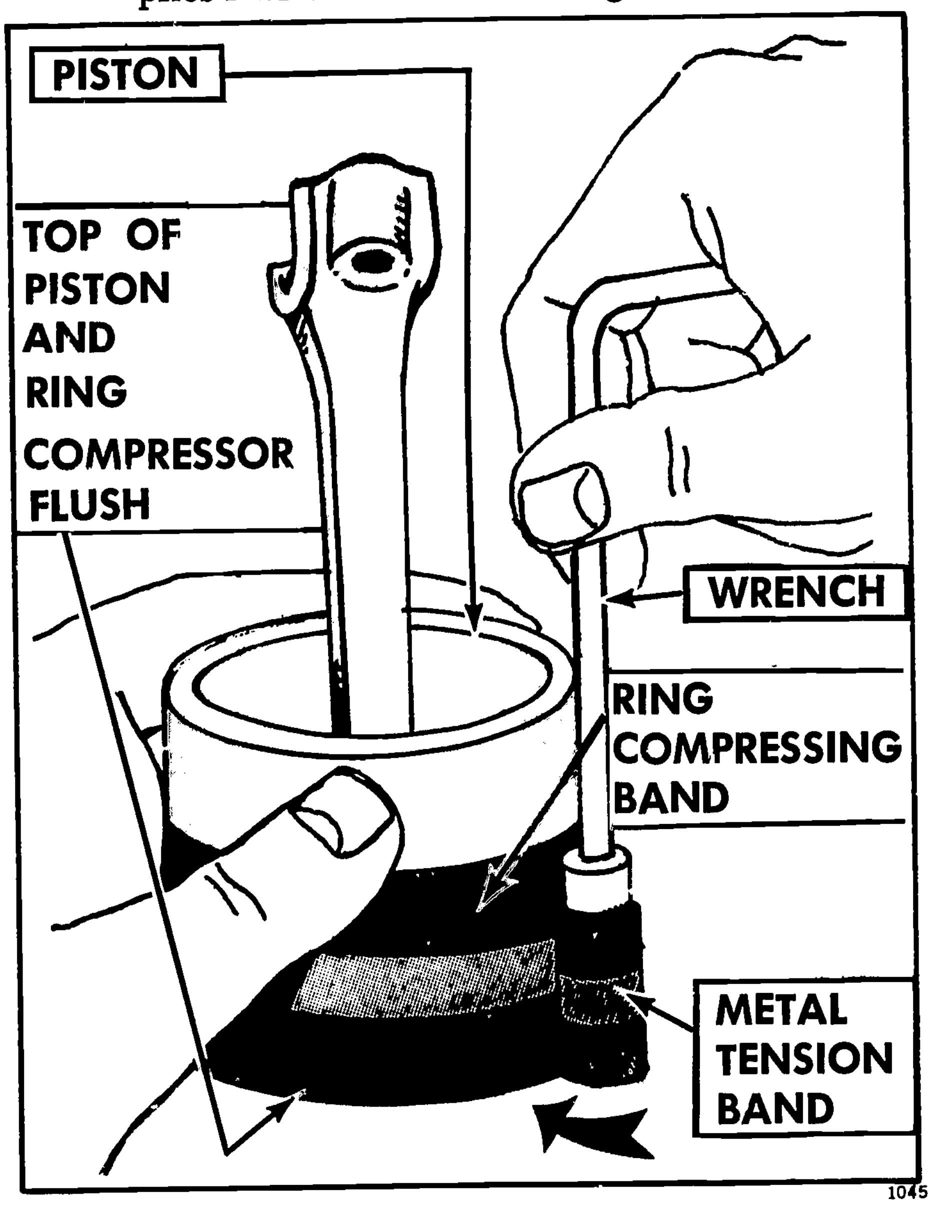


FIGURE 263. Attaching a piston-ring compressor.

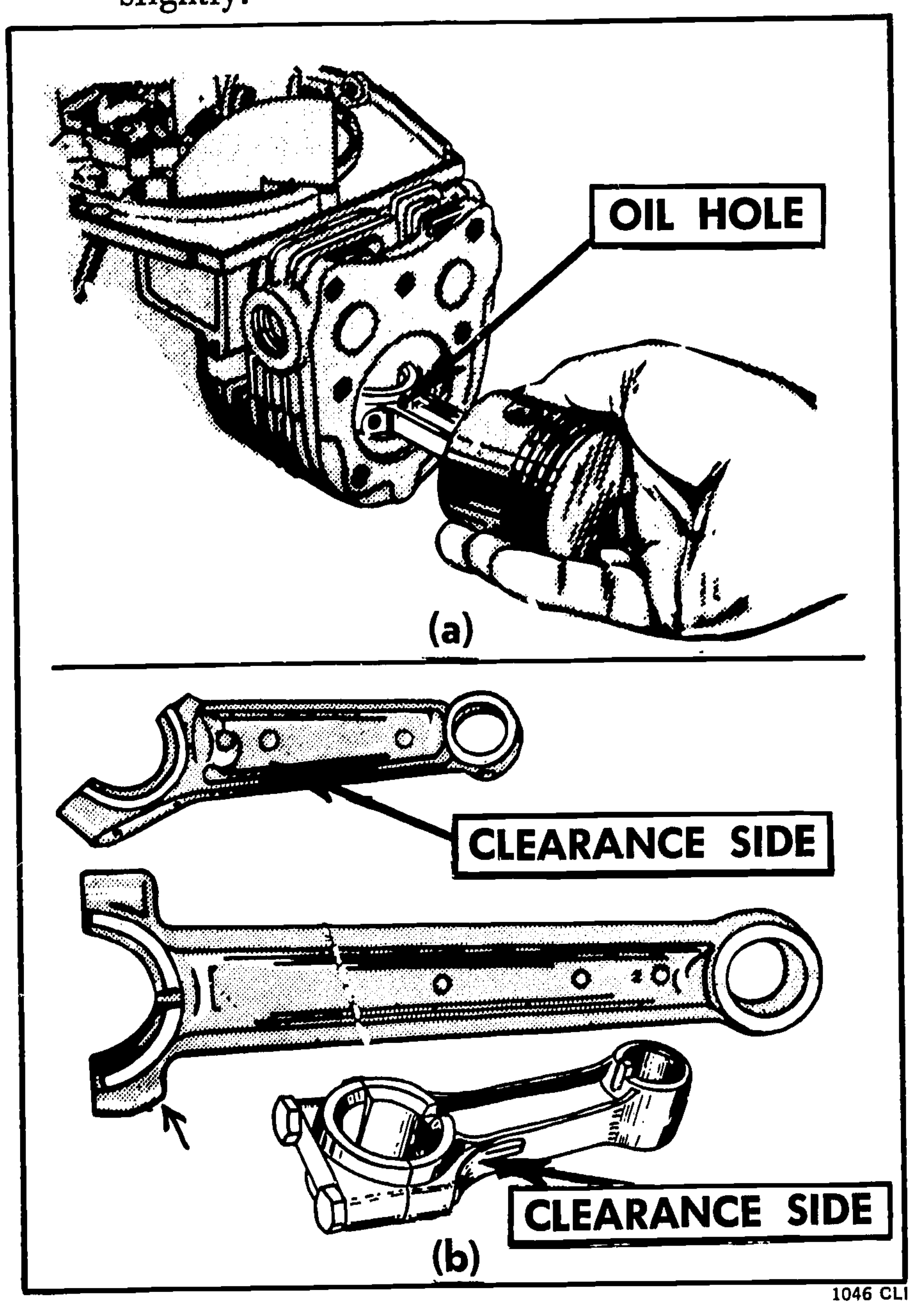


FIGURE 264. Some rods must be installed in a certain position. (a) Rod with a special oil hole. (b) Special-clearance rods.

1047 KOH

FIGURE 265. Tapping the piston into the cylinder.

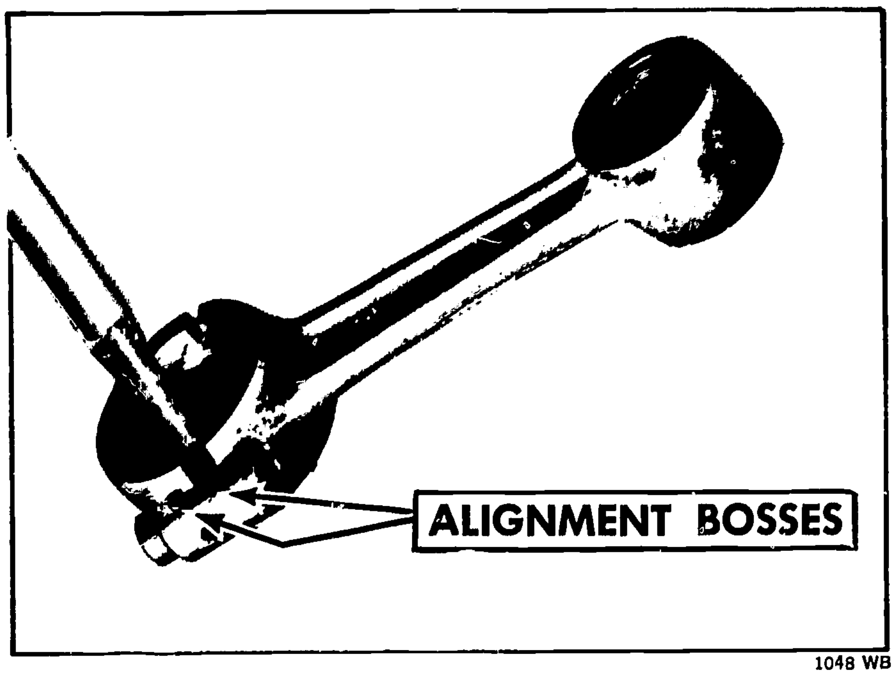
3. *Place the piston and rod over the cylinder (Figure 264a).*

   Some engines have a certain way the rod fits on the crankshaft (Figure 264).

   For example, some engines with horizontal cylinders have a special oil hole in the rod aligned with the crankshaft. This oil hole must be on the top side so that oil will flow to the bearing (Figure 264a). Others have a special clearance provision to bypass the bottom edge of the cylinder as the crankshaft turns (Figure 264b).

4. *Center ring compressor over the cylinder, and tap the piston and rings into the cylinder (Figure 265).*

5. *Install the rod-bearing cap.*



1048 WB

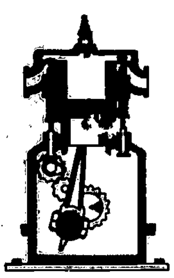
FIGURE 266. Match marks embossed on rod and rod-bearing cap.

   Install the oil dipper if it is attached to the rod-bearing cap. There should be a boss or some marking for aligning the cap to the rod (Figure 266). If not, refer to the notes you made during removal. The rod and cap are made in two separate pieces and then tightened together and bored. If you turn the cap around, you may change the bore alignment.

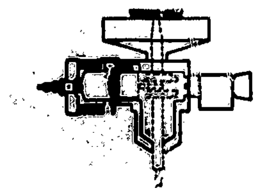
6. *Install the nuts or cap screws and apply the proper torque.*

   Use a torque wrench and tighten to specifications given in your repair manual. These specifications vary with the size of the engine. They range from 35 inch-pounds to over 400 inch-pounds.

   When the rod bearing was bored, the cap was tightened to a certain torque. This is why it is necessary for you to apply the same torque that was applied when the rod was bored so that the bearing will not be distorted.



A. CHECKING AND REPAIRING CYLINDERS



There are three types of cylinders used on small engines. They are as follows: (1) **cast iron** — the cylinder is part of the cast-iron block; (2) **aluminum** — the cylinder is part of the aluminum cylinder block; and (3) **steel sleeves** in an aluminum cylinder block.

Even though aluminum is soft, compared to cast iron or steel, satisfactory wear has been experienced by using aluminum cylinders when proper rings are used. One experiment showed only a .004″ total ring-and-bore wear after 1,000 hours of operation.

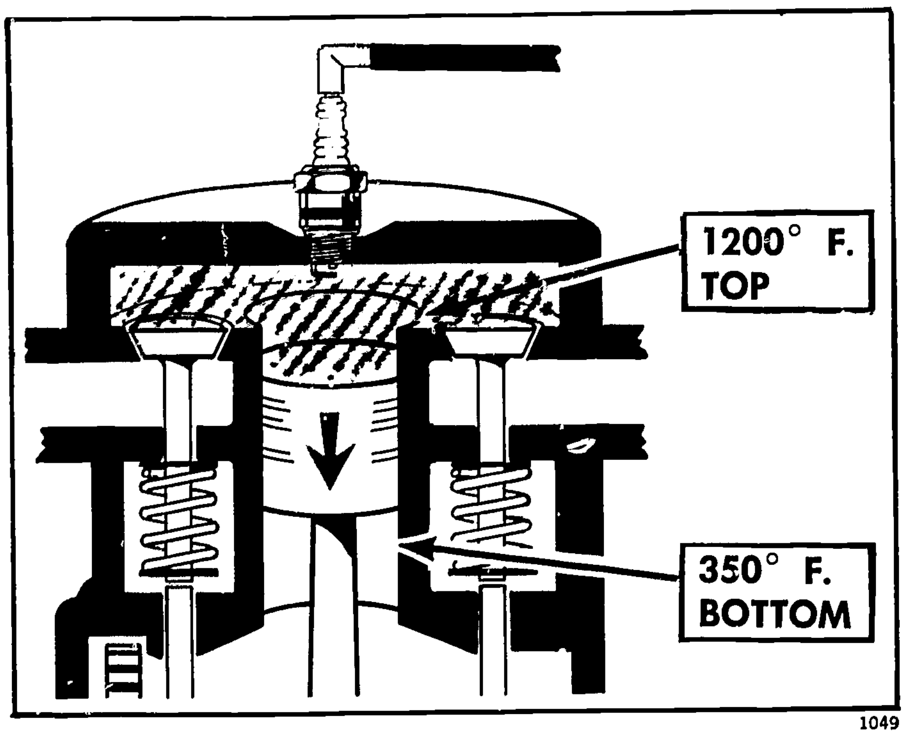


FIGURE 267. The cylinder is subjected to extreme temperature differences.

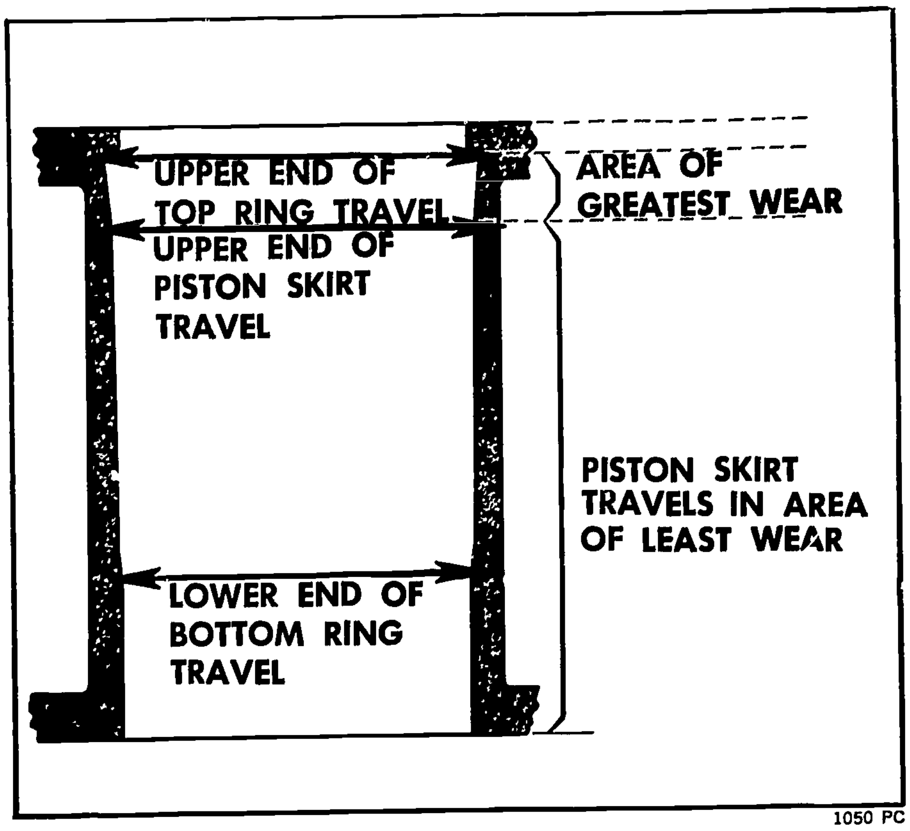


FIGURE 268. Cylinder cross-section showing the area of greatest wear.

Cylinders are subjected to extreme temperature differentials. The top of the cylinder is next to the combustion chamber, where the temperature may reach 1200° F. The bottom of the cylinder is in the crankcase (Figure 267) where temperatures are comparatively cool. The cylinder walls on all air-cooled engines take the heat from the piston and rings and conduct it to the cooling fins. This is why you should always keep the cooling fins free of dust, trash and oil.

Cylinders wear mostly at the top (Figure 268). This is the point of maximum stress, where the greatest force is exerted against the piston because of combustion. If the cylinder is worn very much, there is a ridge left at the top of the cylinder which should be removed before you attempt to remove the piston. Otherwise, there is a danger of breaking the rings and damaging the piston. See Figure 245. Of course, if you rebore the cylinder, this will be bored out.

Repairing cylinders is discussed under the following headings:

1. Tools and materials needed.
2. Inspecting the cylinder.
3. Reboring the cylinder.

TOOLS AND MATERIALS NEEDED

1. Inside micrometer or cylinder gage
2. Hone and/or boring bar (coarse and fine honing stones)
3. Clean rags
4. Cleaning solvent (mineral spirits, kerosene or diesel fuel)
5. Soap and water
6. Paper and pencil
7. Cutting fluid

INSPECTING THE CYLINDER

There are three reasons for measuring the cylinder diameter: (1) to determine if it is **worn too much for a new standard ring** to seat properly — tolerances range from .003 to .008 inch; (2) to determine if the cylinder is **warped or out of round** — tolerances range from .0015 to .003 inch; (3) to determine if the cylinder has **too much taper** — tolerances range from .004 to .008 inch.

If you are unable to repair the cylinder by reboring without exceeding any of these tolerances, you will have to replace the cylinder block.

1. *Clean the cylinder inside and out with petroleum solvent.*

   Clean all dirt from the cooling fins and all carbon from the cylinder head.

2. *Inspect the cylinder block for cracks, stripped bolts threads, broken fins and scored cylinder walls.*

   Scored cylinder walls are a sign of overheating and/or lack of proper lubrication.

1 CYLINDER DIMENSION	2 Actual Size (Present)	3 Standard Size (New)	4 Actual Wear	5 Maximum Wear Allowed	6 Reboring Required	7 Minimum Oversize	8 Rebore to Oversize Dimension
Top	2.0050	2.0000	.0050	.0030	Yes	.0100	2.0100
Center	2.0030	2.0000	.0030	.0030	No		2.0100
Bottom	2.0010	2.0000	.0010	.0030	No		2.0100
ROTATE 90° TO ABOVE MEASUREMENTS							
Top	2.0070	2.0000		.0030			
Center		2.0000		.0030			
Bottom		2.0000		.0030			

1051

FIGURE 269. Chart for determining cylinder wear. The figures shown are examples only.

Dirt causes uniform wear, not scoring.

3. *Prepare chart similar to the one shown in Figure 269.*

   Record the standard size dimension of your cylinder in column 2 and the maximum wear allowable in column 5 from your repair manual.

4. *Measure and record the diameter of the cylinder for wear (Figure 270).*

   Take *measurements* in six places (Figure 271) and record in column 2 (Figure 269). (1) Start *at the top* of the piston-ring travel, then (2) *at the center* of the piston-ring travel, and then (3) *at the bottom* of the piston-ring travel. Rotate gage 90 degrees and repeat measurements.

5. *Determine the amount of cylinder wear for each position.*

   Subtract the "Standard Size" dimensions (Column 3) from the "Actual Size" dimensions (Column 2). This gives the amount of actual wear. Record the amount of wear in column 4.

   $$\text{Example: } \underset{\text{(col. 2)}}{2.0050''} - \underset{\text{(col. 3)}}{2.000''} = \underset{\text{(col. 4)}}{.0050''}$$

6. *Compare the amount of "Actual Wear" (column 4) with "Maximum Wear Allowed," column 5 (Figure 269).*

   If the actual wear is greater than the maximum wear allowed at any of the six positions, rebore the cylinder and get a new oversize piston and rings to fit it. Cylinders that cannot be rebored within the oversize limits must be replaced. Most manufacturers make oversize pistons and rings in increments of .010″, .020″, and .030″ oversize.

   If the actual wear in column 4 is less than the maximum wear allowed in column 5, in all positions, proceed to step 8.

7. *Determine the oversize dimensions of the cylinder and record them in the chart.*

   $$\text{Example: } \underset{\text{(col. 3)}}{2.000''} + \underset{\text{(col. 7)}}{.010''} = \underset{\text{(col. 8)}}{2.0100''}$$

   Bore to the smallest oversize that will even up the cylinder. See column 8, Figure 262.

8. *Check to see if the cylinder is out of round.*

   Prepare a chart similar to the one shown in Figure 272 and record the measurements from columns 2 and 3 (Figure 269) into column 2 (Figure 272).

   Subtract the dimensions at each of 3 measurements from the measurements taken at 90° at the same location in the cylinder.

   $$\text{Example: } \underset{\text{(col. 3)}}{2.0070''} - \underset{\text{(col. 2)}}{2.0050''} = \underset{\text{(col. 4)}}{.0020''}$$

   If the difference at any of the three locations is greater than the maximum allowable out-of-round dimensions, you must replace the block or rebore the cylinder. **If the actual out-of-round in column 4**

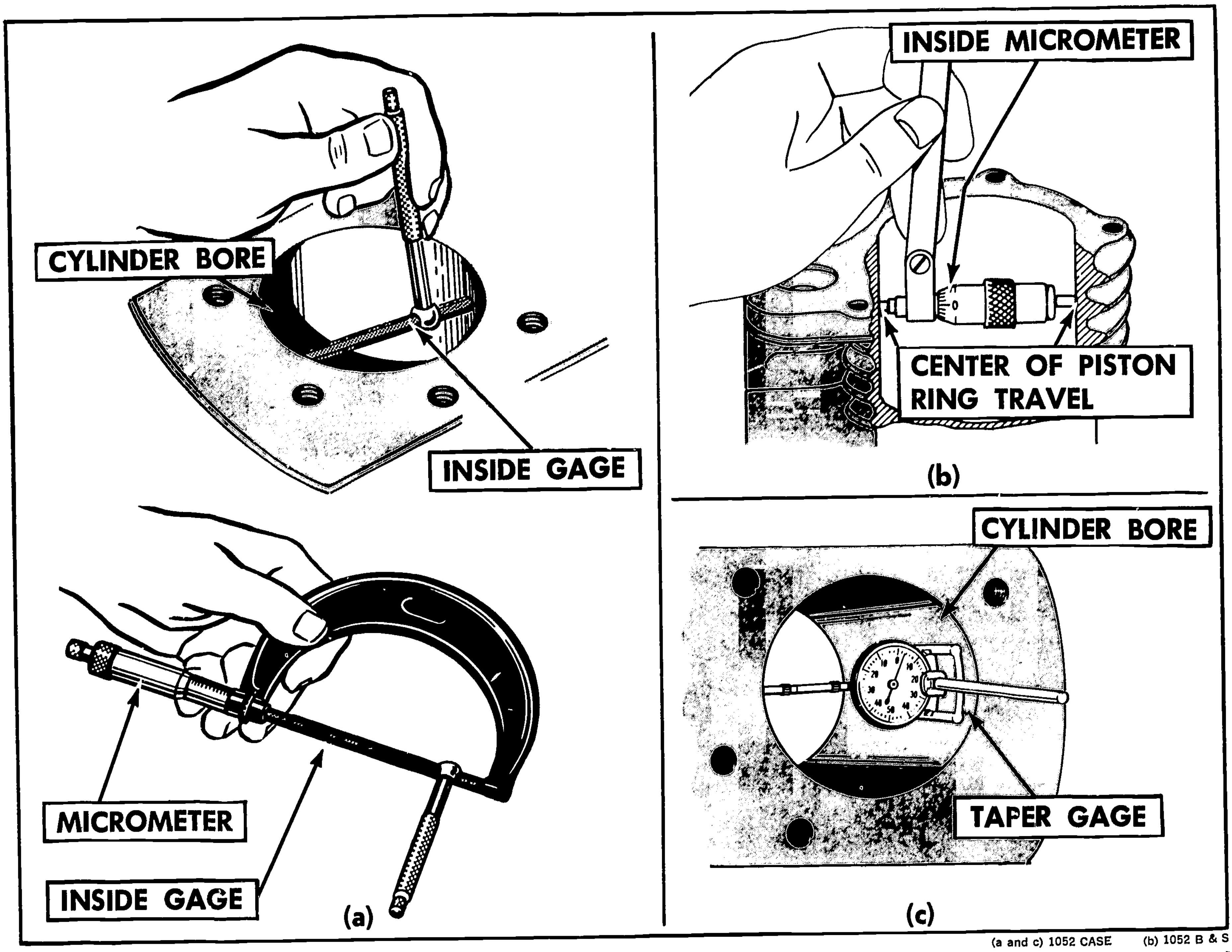


FIGURE 270. Methods for measuring the diameter of a cylinder. (a) Adjustable inside gage and micrometer for measuring gage length. (b) Inside micrometer, (c) Special gage and dial indicator for measuring cylinder taper.

is less than the maximum out-of-round allowance in column 5, proceed to step 9.

9. *Check the cylinder for taper.*

Subtract the measured dimensions at the bottom of the cylinder from the measured dimensions at the top (Figure 272).

If the difference exceeds the maximum allowable given in your repair manual, replace the block or rebore the cylinder.

NOTE: If any one dimension in the cylinder exceeds the factory allowance, the cylinder will require resizing; and there is no need to measure all the other dimensions.

If the taper is within allowable tolerance, hone the cylinder lightly and reinstall your standard-size piston with new standard-size rings.

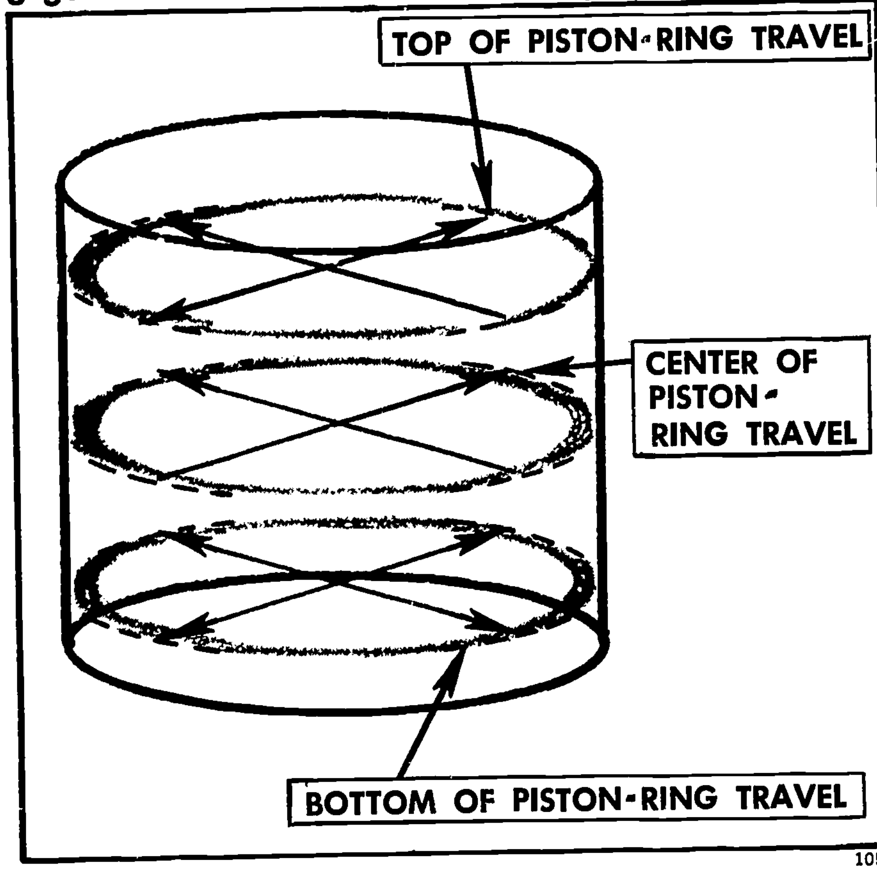


FIGURE 271. Measure the cylinder diameter in six different positions.

1	2 Cylinder Dimension	3 Cylinder Dimension at 90°	4 Actual Out of Round Computed	5 Maximum Allowance Out of Round	6 Maximum Allowance for Taper	Reb Req
[illegible]	2.0050	2.0070	.0020	.0013		Ye
[illegible]						
[illegible]						

FIGURE 272. A chart for determining the amount of cylinder is out-of-round. The figures are examples on

REBORING THE CYLINDER

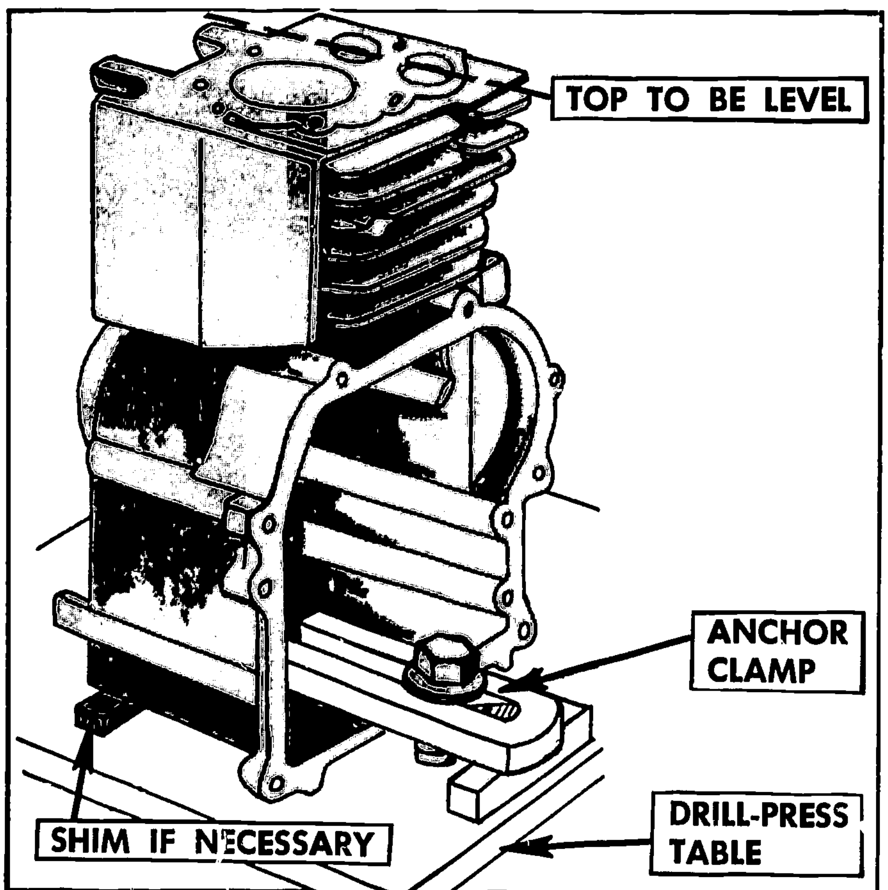
1. *Anchor the cylinder block (Figure 273).*
2. *Select the proper boring tools (Figure 274).*

   Hones for aluminum are different from those of cast iron or steel.

   A boring bar uses a high carbon steel cutting tool. Procedures given here apply only to the use of a hone.

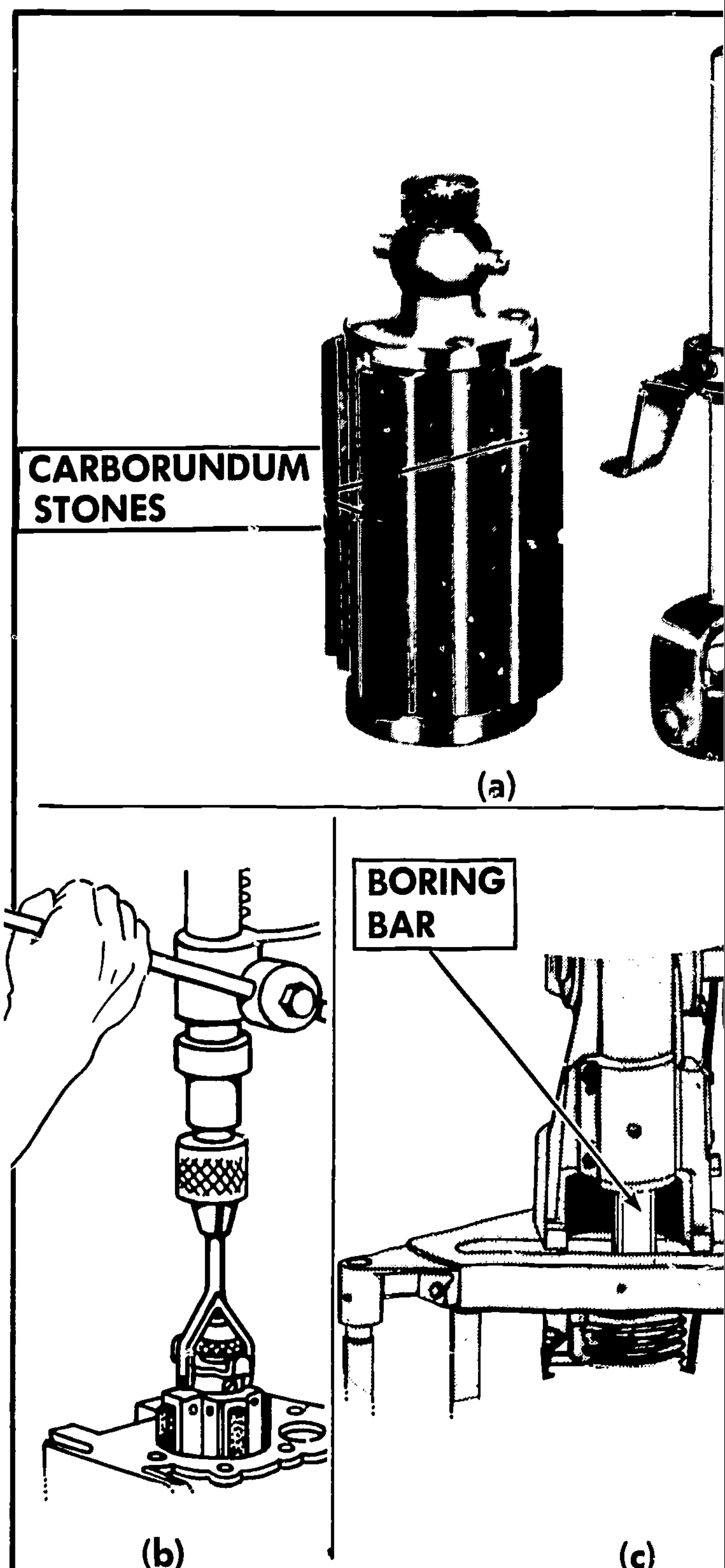
   Most manufacturers recommend a "**hone**" for reboring small engines. This machine uses coarse honing stones for removing most of the bore and fine honing stones for finishing.

   A **boring bar** (Figure 274c) is necessary



1055 B & S

FIGURE 273. Anchor the cylinder block before reboring the cylinder.



(a) 1056 AMMC

FIGURE 274. Two methods for reboring cylind follows: (a and b) hone with carborundum st (c) boring bar with a cutting tool.

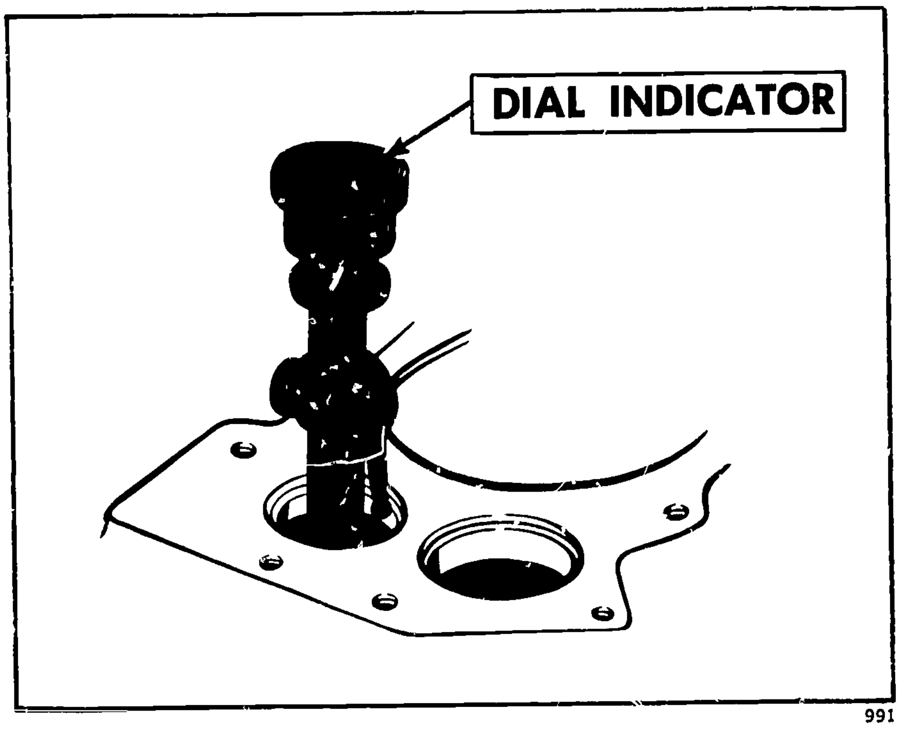


FIGURE 209. Checking the valve-seat trueness with a dial indicator.

valve will not seat properly. The minimum seat width is from 1/32 inch to 3/64 inch. If the seat angle is 45° and the seat width is over 1/16 of an inch wide, narrow it down with a 15° to 30° angle wheel at the top, and a 60° to 75° angle wheel at the bottom (Figure 208).

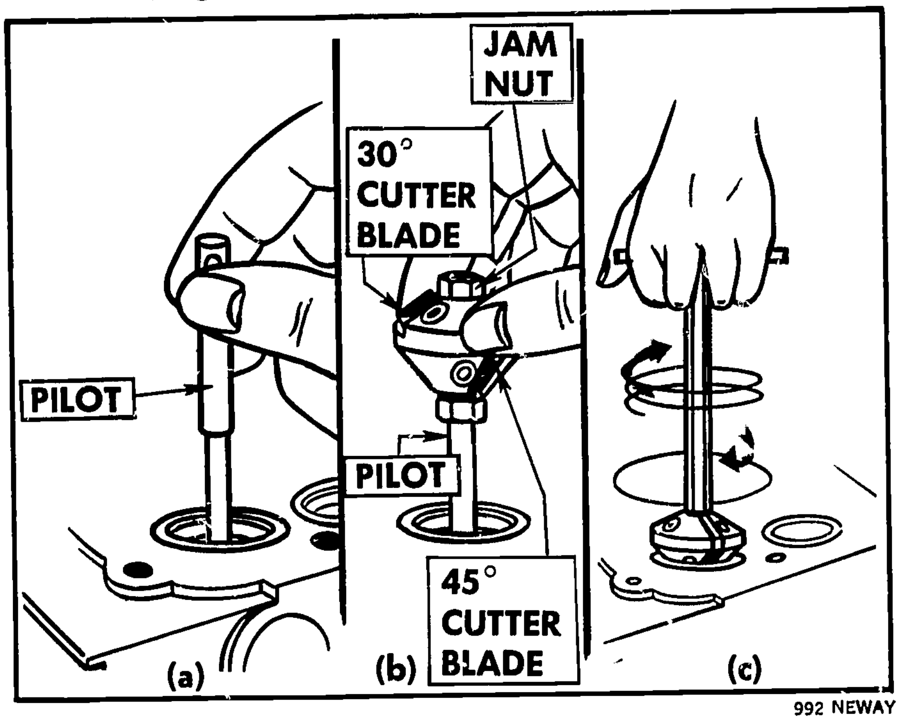


FIGURE 210. Refacing valve seats with a special cutter. (a) Installing the cutter pilot in the valve guide. (b) Installing the cutter head on the pilot. It is held by a jam nut. (c) Cutting the valve seat.

6. *Smooth burred edge with the original seat-grinder wheel.*
7. *Check the valve in the seat.*

   Apply prussian blue to the valve, and insert it in the engine. Turn the valve with a slight pressure of your thumb on the valve head. Remove the valve, and check to see if the blue has transferred to all areas of the valve seat. A *slight imperfection* may be taken out by lapping.

   If you are not able to shape the seat properly, replace the valve seat with a new insert if possible. See "Replacing Valve Seats," next heading, for procedures.

   It is possible to check trueness of the valve seat with a dial indicator (Figure 209).
8. *Lap the valve to the seat.*

   Refer to "Lapping the Valves," page 130.

b. If you use a **valve-seat cutter**, proceed as follows:

1. *Determine the angle of your valve seat.*

   See the engine specifications.
2. *Install the pilot in the valve guide (Figure 210a).*
3. *Install the cutter head on the pilot (Figure 210b).*
4. *Install the T-handle on the cutter head and cut the valve seat (Figure 210c).*

   Press down on T-handle and turn in clockwise direction.
5. *Check valve seat for condition and width.*

   If it requires over 1/16 of an inch width (Figure 208) to recondition the valve seat, turn the valve cutter over and trim the width with the 30° angle cutter (45° seats). The minimum seat width is from 1/32 to 3/64 inches.
6. *Lap the valve to the seat.*

   Refer to "Lapping the Valves," page 130.

REPLACING THE VALVE SEATS

If your engine is aluminum and you plan to rebore the cylinder, do it after replacing the valve-seat inserts. There is a danger of distorting the rebored cylinder wall when installing the valve-seat insert.

Most engines have provisions for replacing valve seats if they cannot be reground properly. All **aluminum engines** have **valve-seat inserts.**

Cast-iron engines that do not have inserts can be counterbored (bored larger) and inserts installed. Some cast-iron engines have an exhaust-valve seat insert, and the intake-valve seat machined in the cylinder block.

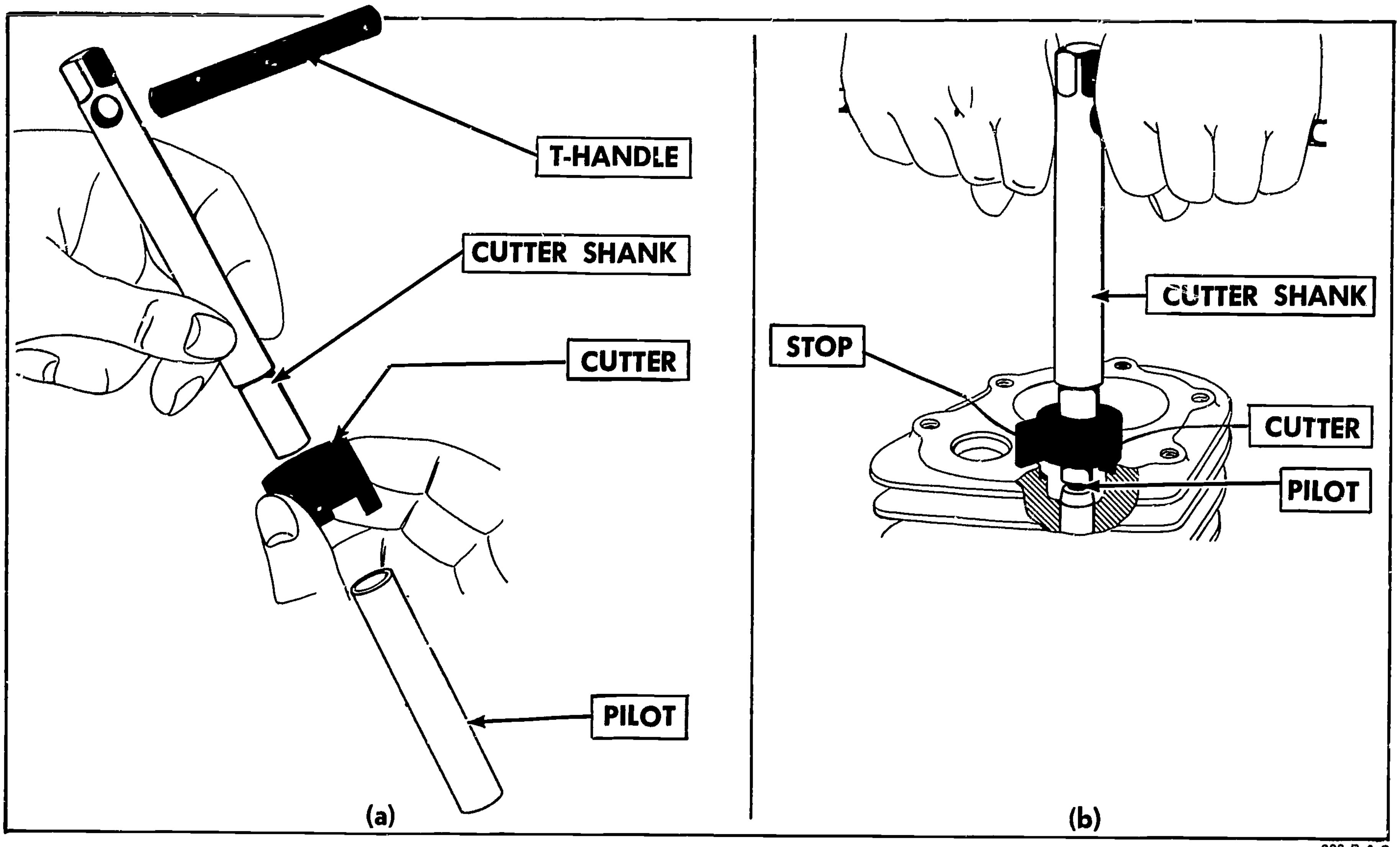


FIGURE 211. Counterboring for installing cast iron engine valve-seat inserts. (a) Tools required. (b) Counterboring.

a. If the **valve seat is machined in the cylinder block** (cast-iron engine), proceed as follows:

1. *Select the proper size of seat insert, cutter shank, cutter and pilot for your engine (Figure 211a).*

   Special tools are prescribed by your manufacturer. The counterbored hole is slightly smaller (.001″ to .002″) than the outside diameter of the new insert.

2. *Insert the pilot in the valve guide.*

   The pilot must be snug in the guide or the cutter will cut oversize.

3. *Protect the engine from metal cuttings.*

   Place cloth in valve-access well. Be certain openings to crankcase are covered.

4. *Counterbore to the depth of the stop on the cutter or according to specifications for your engine.*

   There is a critical boring depth for the new insert. You will have to get this from the engine specifications.

   If a drill press or a hand drill is used, keep the speed down to 300 r.p.m. for proper cutting and to prevent overheating.

   Be very careful not to allow the cutter to wobble, or the hole will be too large for the insert.

5. *Clean away all metal cuttings.*

   Use compressed air. If cleaning is done before removing the pilot, this will prevent metal chips from getting into the valve guide.

6. *Remove boring tools.*

7. *Measure counterbore depth.*

   Compare depth with the depth of the valve seat.

   The top of the valve insert should seat just below the cylinder-head gasket level.

8. *Chill the insert in a freezer for an hour.*

   This chilling is to reduce the insert size for ease of installation and to help insure a tight fit when both the cylinder block and valve insert reach the same temperature.

9. *Install the insert.*

   Install with a valve-seat insert driver (Figure 212a).

   Be sure the seat is right side up.

   Do not pound heavily on the insert. There is danger of damaging the block.

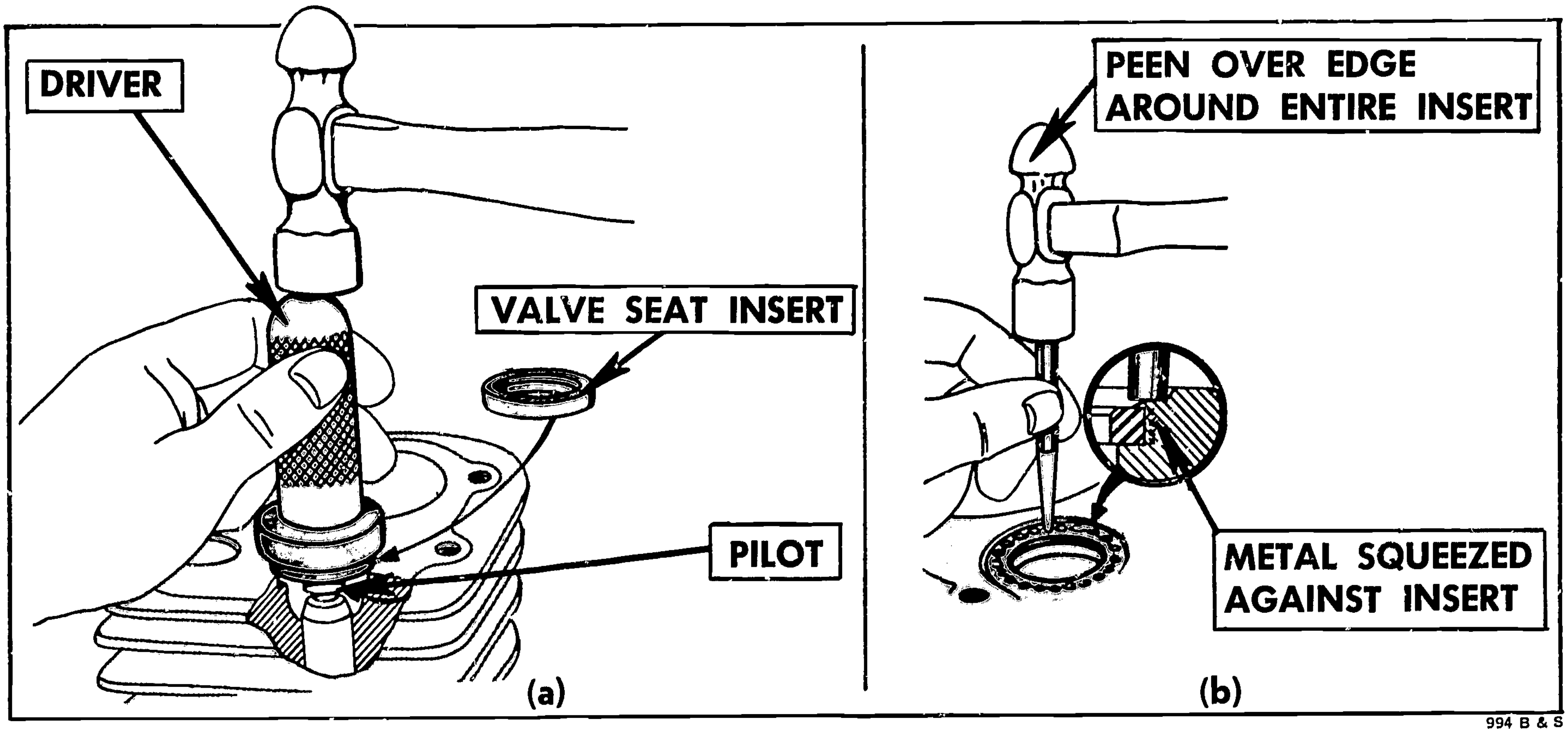


FIGURE 212. Installing valve-seat inserts. (a) Driving the insert into the cylinder block. (b) Peening the cylinder block over the valve-seat insert.

Do not pound the pilot onto the valve tappet. You can damage the camshaft gear.

10. *Peen the metal over the insert (Figure 212b).*

    This is to wedge the insert so as to further tighten it. Alternate from side to side when peening to prevent shifting the insert to one side.

    NOTE: This procedure is not recommended by some manufacturers. They say that peening pushes the seat away from the block and causes it to overheat.

11. *Grind insert lightly.*

    Refer to "Grinding (Refacing) the Valve Seats," page 125.

b. If your **engine already has valve-seat inserts** and they must be replaced, proceed as follows:

1. *Remove the peened or rolled metal lip from over the top of the insert if necessary.*

   Use counterbore cutter (Figure 211).

2. *Remove the old insert.*

   Note three methods shown in Figure 213.

   Take care not to damage the cylinder block.

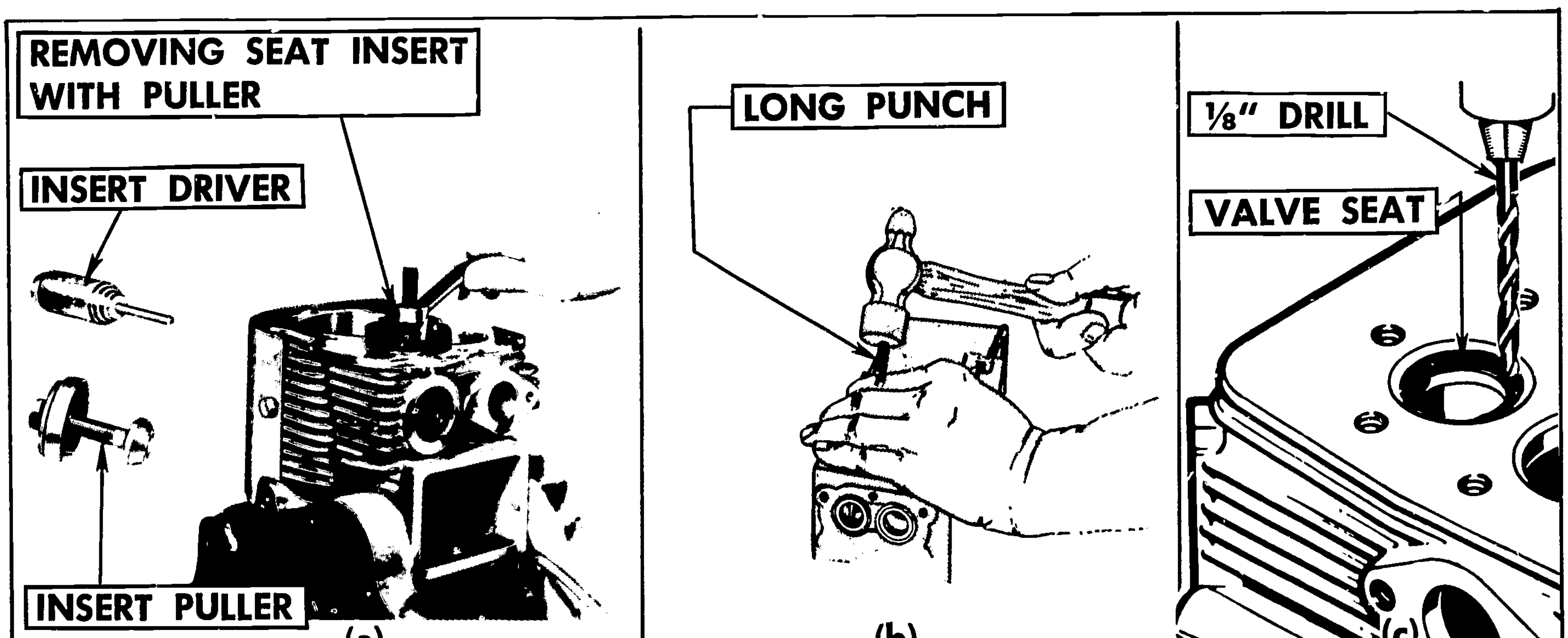


FIGURE 213. Removing old valve-seat inserts. (a) Using a special puller. (b) Using a punch. (c) Drilling holes in insert for breaking it out.

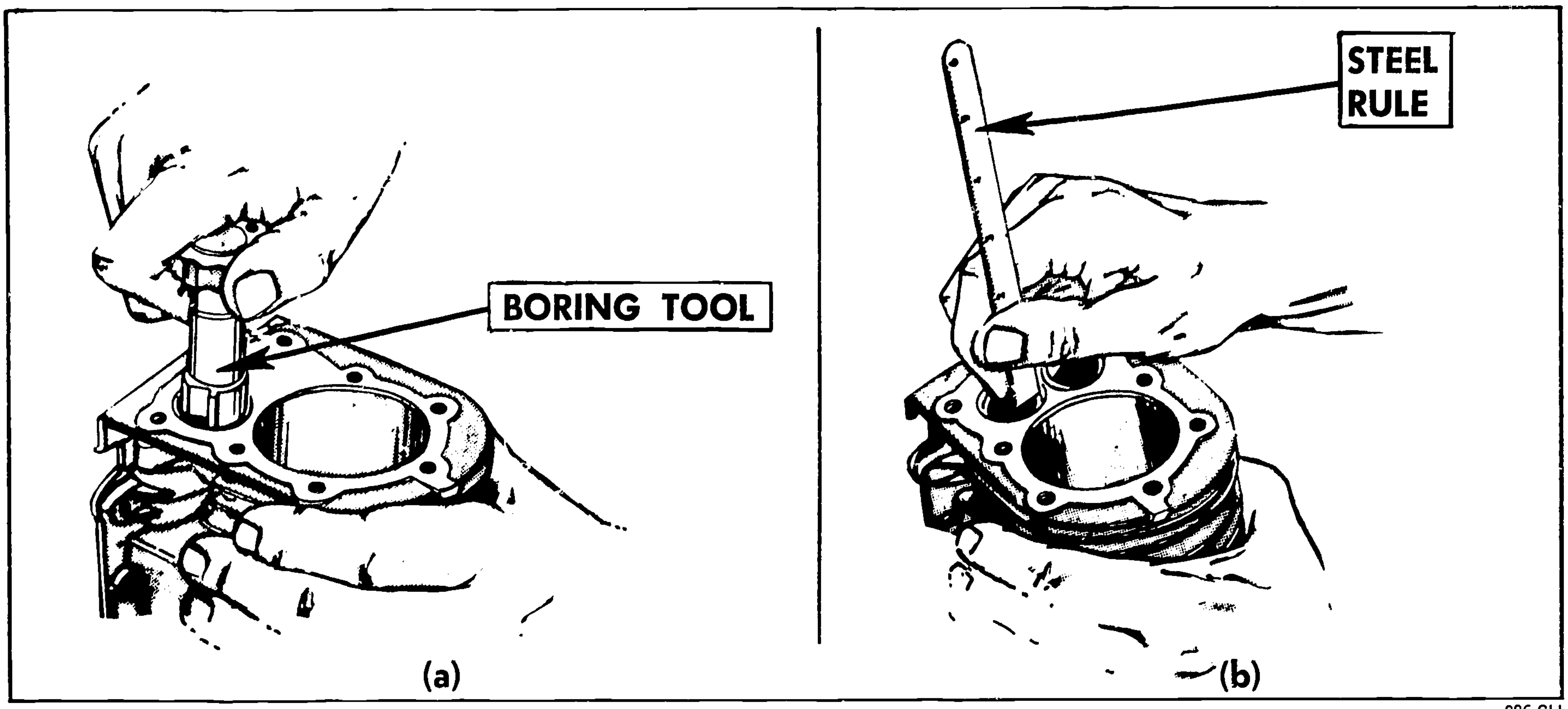


FIGURE 214. Preparing cylinder block for installing of a new valve-seat insert. (a) Counterboring oversize hole (b) Measuring the depth of the counterbore.

3. *Clean counterbore.*

   Remove dirt and metal chips. Use rag dampened with petroleum solvent. Scrape away deposits with a knife.

4. *Check hole diameter.*

   It should be .001″ to .002″ smaller than the outside diameter of the insert.

   Some engines require counterboring deeper than the original insert in order to accommodate the new insert (Figure 214). Oversize inserts are available.

5. *Rebore oversize hole if necessary.*

6. *Install new insert.*

   Follow steps 8 through 11, under "a" preceding.

LAPPING THE VALVES

Some manufacturers recommend that you "lap" the valves to the seats anytime you have the valves out of your engine. To assure a good fit, lapping is recommended by some for new valves and seats and even for valves that appear to be in good condition. Proceed as follows:

1. *Apply thin coat of lapping compound (carborundum paste) to the valve face.*

   If you *have serviced the valve seats,* or if you *are installing new valves,* use **coarse-grain lapping compound** for fast action; then finish with a **fine-grain paste.** Wipe away the coarse compound before finishing with the fine-grained paste.

2. *Insert valve into the cylinder block.*

   Be sure to use the proper valve. Intake and exhaust valves are of different sizes. The intake valve is usually larger than the exhaust valve.

3. *Attach special valve-lapping tool.*

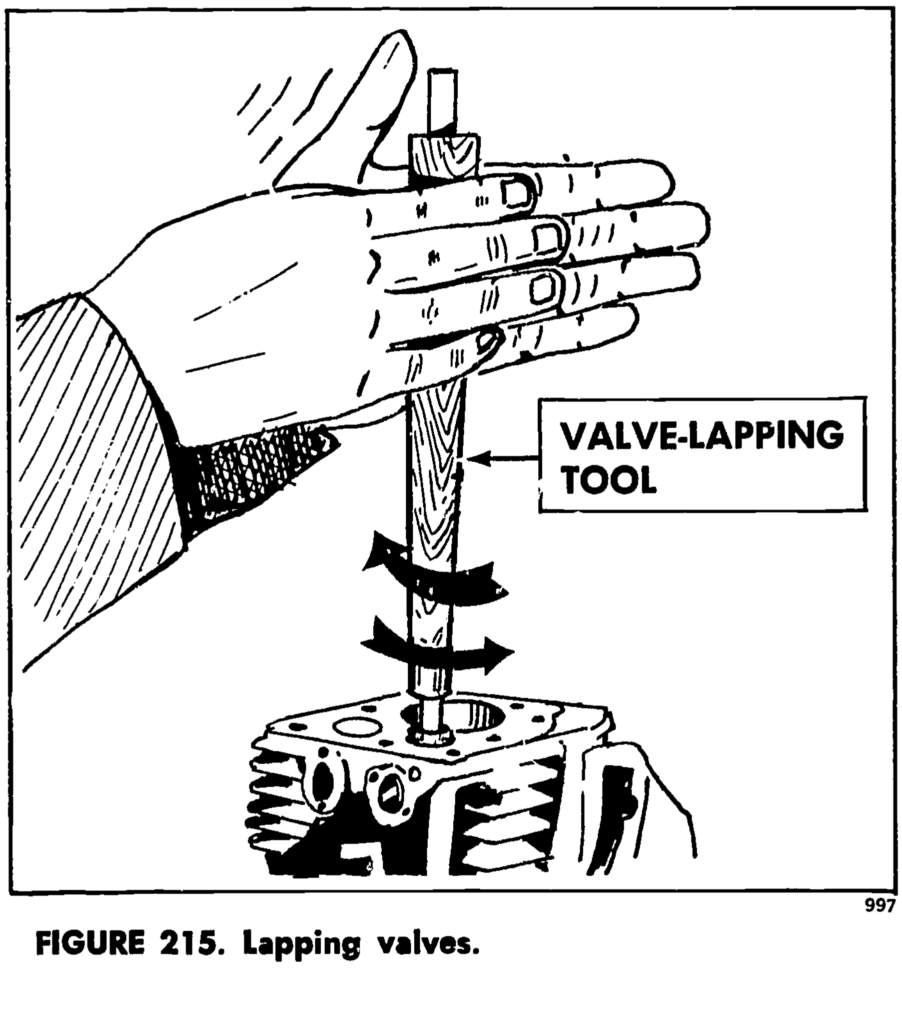


FIGURE 215. Lapping valves.

It has a suction cup to hold the valve and a spring-loaded cap; so you can apply constant and uniform pressure.

4. *Rotate valve while applying pressure (Figure 215).*

5. *Check seating of the valve (Figure 216).*

   Clean away all lapping compound with petroleum solvent. Apply prussian blue to the valve face.

   Install the valve and turn it on the seat with your thumb. Remove the valve and observe how the bluing is distributed on the valve seat. When properly lapped, the prussian blue should be distributed evenly around the center of the valve seat. This means the valve is seating at all points.

   An alternate method for checking the valve seat for an unmounted engine is as follows: (1) Install the valve and valve spring. (2) Adjust the valve-tappet clearance. (3) Turn the cylinder block upside down, pour gasoline into the valve port, and see if any gasoline leaks out. (4) If the valve leaks, remove and relap.

6. *Clean all compound from the valve and the engine.*

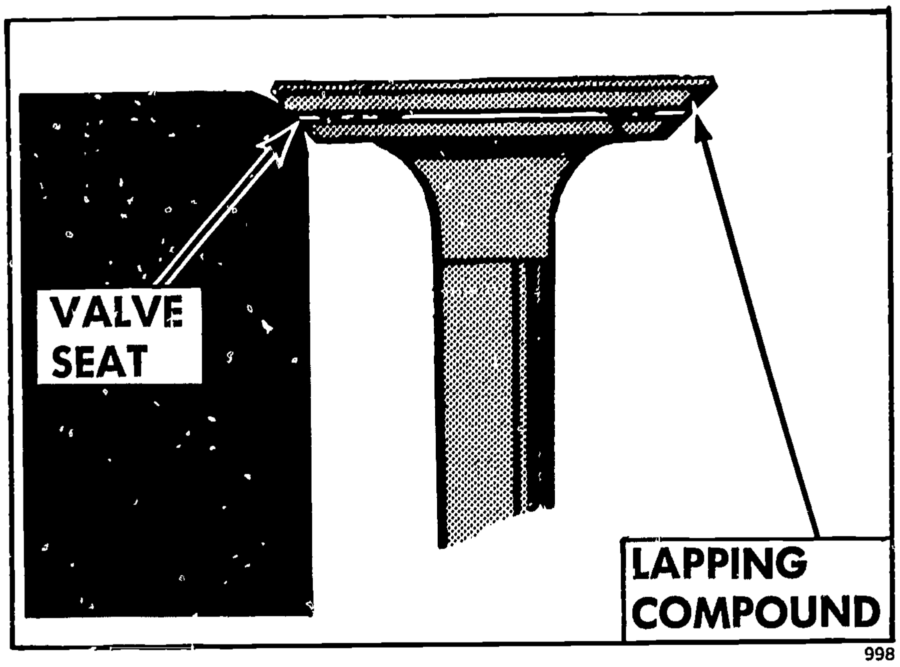


FIGURE 216. Valve face should contact the seat evenly and at the center.

   If the lapping compound is a **petroleum-solvent base,** clean with petroleum solvent.

   If the lapping compound is **water base,** use water.

   Only a small amount of lapping compound left in your engine will get into the lubricating oil and grind away vital parts.

7. *Install valve.*

   See procedures under next heading.

ADJUSTING THE VALVE-TAPPET CLEARANCE

There are two methods for checking and adjusting the valve clearance: (1) Grinding a small amount from the end of the valve stem, or (2) using adjustable tappets.

Some manufacturers recommend that you adjust the valves before installing the valve springs. Others object because they say you cannot get an accurate check without spring tension on the valve.

a. If your engine has **no valve-tappet adjusting screw,** proceed as follows:

1. *Apply crankcase oil to the valve stems, valve guides, springs and spring retainers.*

   Be sure they are clean and have no dirt or grinding compound on them. The oil makes installation easier, and provides lubrication when the engine is started.

2. *Place the valve in the cylinder block.*

3. *Turn the crankshaft to top-dead-center, compression stroke (piston at the top and both valves closed.)*

   You may turn the crankshaft until the valve in its highest position (open); then make one complete revolution.

4. *Check for the recommended valve-tappet clearance in your operator's manual.*

   See "Checking the Valve-Tappet Clearance," page 115.

5. *Install valve spring.*

   If the manufacturer of your engine recommends installing the valve spring before checking the tappet clearance, add these steps:

   (1) *Place the valve spring, valve-spring seat and retainer in the valve access well.*

   On some engines the exhaust-valve spring is heavier than the intake-valve spring. Be sure to install the proper spring.

   (2) *Insert the proper valve in its position.*

   (3) *Compress the valve spring (Figure 217).*

   See Figure 193 for other types of valve-spring compressors.

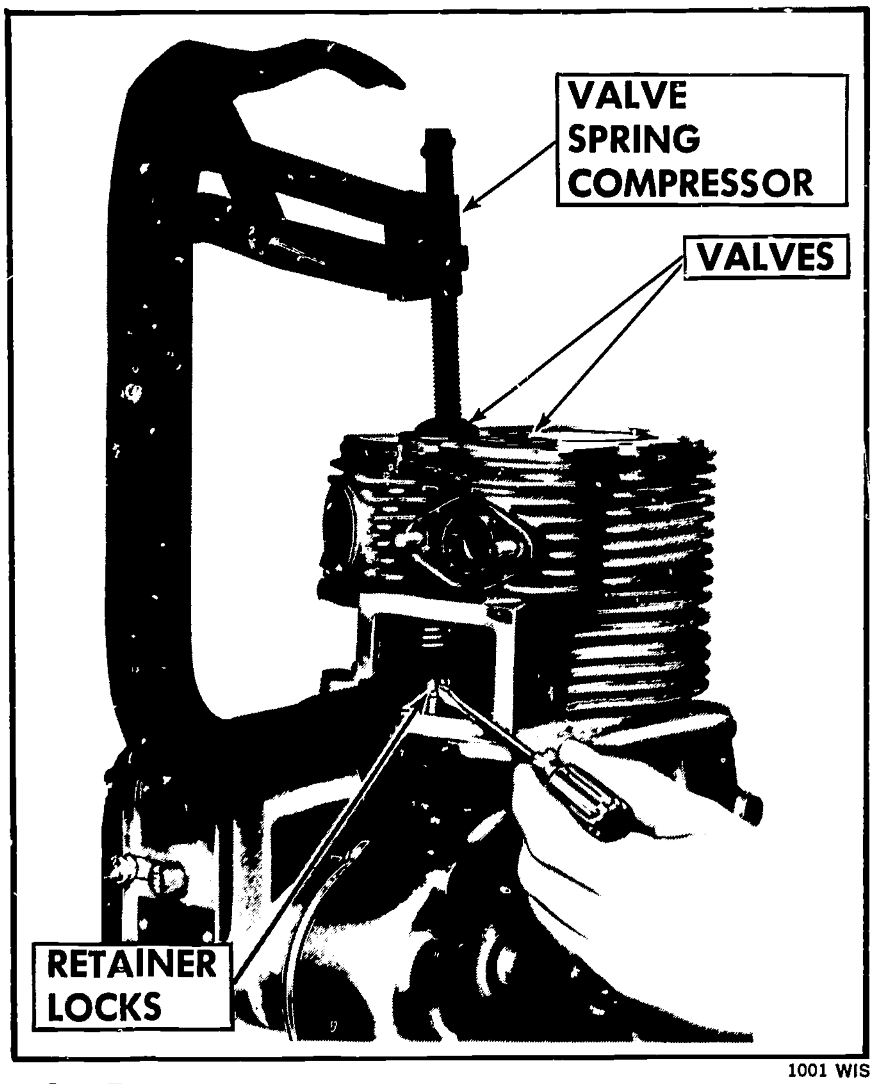


FIGURE 217. Installing a valve with a valve-spring compressor.

(4) *Install the valve-spring retainer locks.*

Use needle-nose pliers to install pin-type locks (Figure 194b). A little multi-purpose grease applied to split-type (Figure 194c) retainer locks will help you install them.

Be sure the retainer-combination lock (Figure 194d) is centered on the valve if you have this type.

6. *Check valve-tappet clearance (Figure 218a).*

Use the proper thickness gage. Press the valve down firmly and insert the gage.

You can get a thickness gage with a step which provides a .002-inch tolerance (Figure 219). The difference between the thickness of the thinner gage and the heavier gage is .002 of an inch, which is the usual allowable tolerance. This is called a "go, no-go gage." With this type of gage, adjust the valve-tappet clearance so that the minimum thickness will clear and the maximum thickness will not clear.

Note the amount needed to be removed from the valve stem before removing the valve. For example, if you have .002″ clearance and you need .007″ clearance, you will need to remove .005″ from the valve stem.

7. *Remove the valve.*

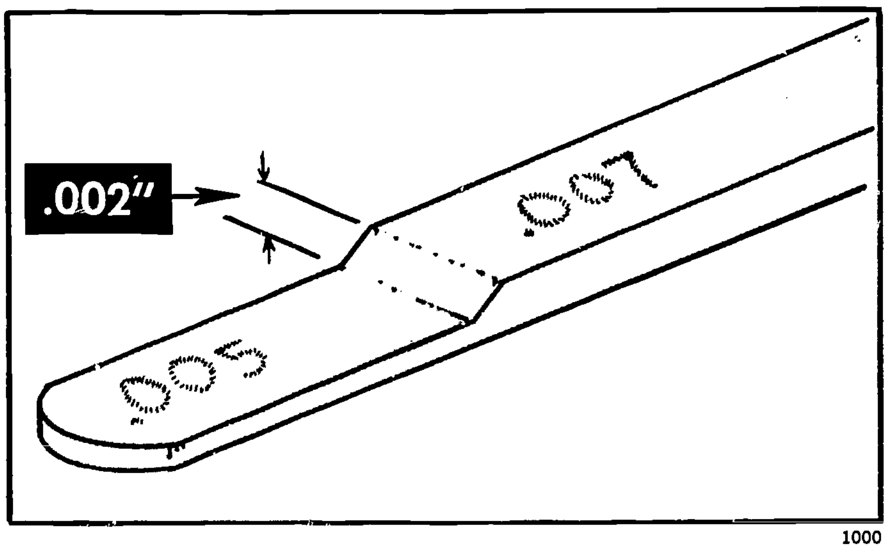


FIGURE 219. A "go, no-go" thickness gage for adjusting valve-tappet clearance.

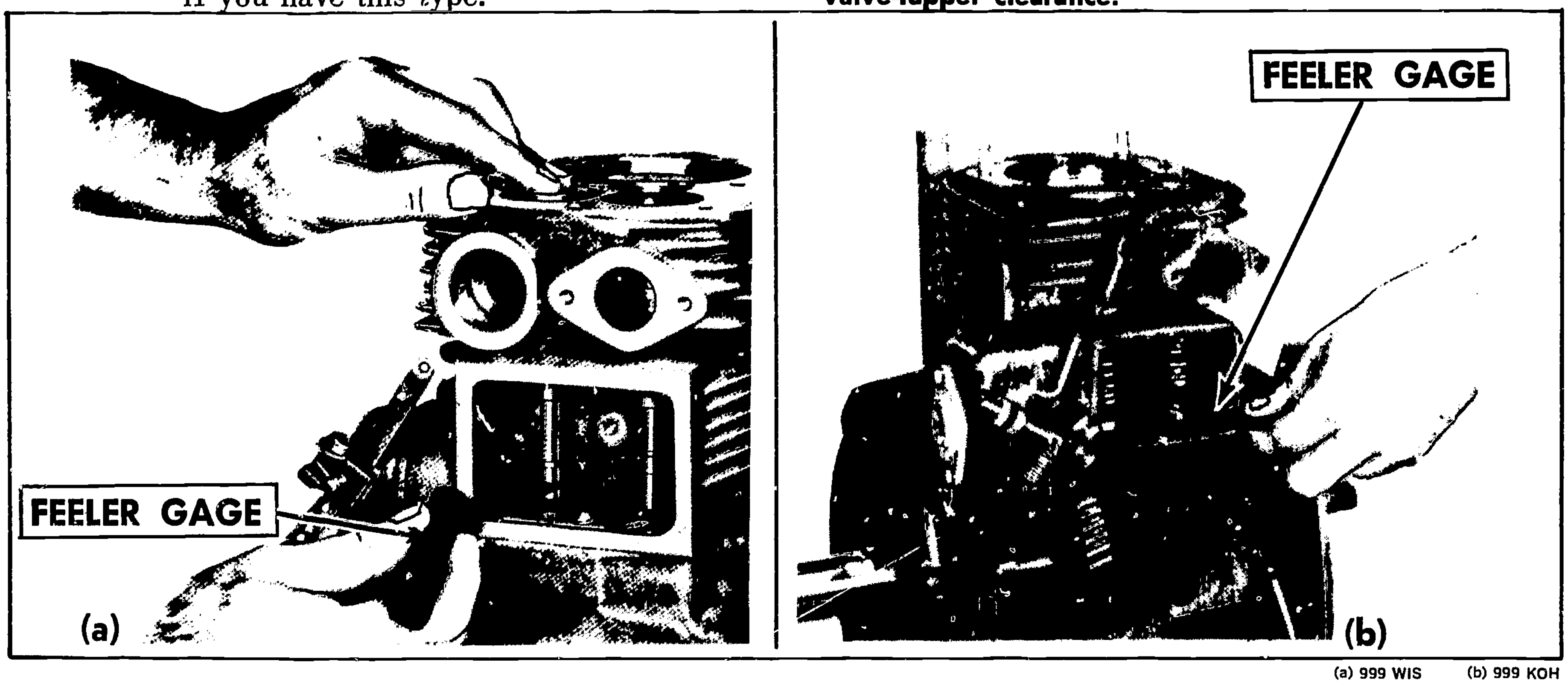


FIGURE 218. Checking the valve-tappet clearance. (a) Checking the clearance before installing the valve spring. (b) Checking the clearance after installing the valve spring.

FIGURE 220. Measuring valve length with a micrometer.

8. *Measure the length of the valve with a large micrometer (Figure 220).*

   With the micrometer you can determine how much to grind away without replacing the valve assembly each time for a measurement. If your valve is 3.010″ and you need to remove .005″, the final length of the valve should be 3.005″.

9. *Grind required amount from valve stem.*

   Grind it square and remove all burrs.

10. *Reinstall valve assembly in cylinder block.*

    Note steps 2 through 5.

11. *Recheck clearance.*

b. If your engine has **valve-tappet adjusting screws**, proceed as follows:

1. *Position the camshaft for valve adjustment.*

   Follow steps 1 through 3 under "a" preceding.

2. *Install valve-tappet adjusting screws (Figure 187b).*

3. *Install the valve assembly.*

   Follow steps 2 through 5 under "a" preceding.

4. *Adjust valve-tappet clearance by turning the valve-tappet adjusting screws.*

5. *Tighten jam nuts.*

INSTALLING THE CYLINDER HEAD

There are two points to keep in mind when tightening the cylinder-head cap screws. They are (1) **the sequence in which the cap screws are to be tightened,** and (2) **the amount of torque to apply.** The recommendations vary so much among different makes and models of engines that it is impossible to give a general recommendation.

The recommended *sequence of cap screw tightening* is given to prevent warping the cylinder head by uneven tightening. Usually you are directed to tighten alternate cap screws back and forth across the cylinder head (Figure 221).

The *amount of torque to apply* depends primarily on the size of cylinder-head cap screws, the metal composition of the cylinder block (aluminum or cast iron), the depth of the threads, and the number of cap screws used. Most manufacturers give torque in inch-pounds (Figure 222). The torque may be as low

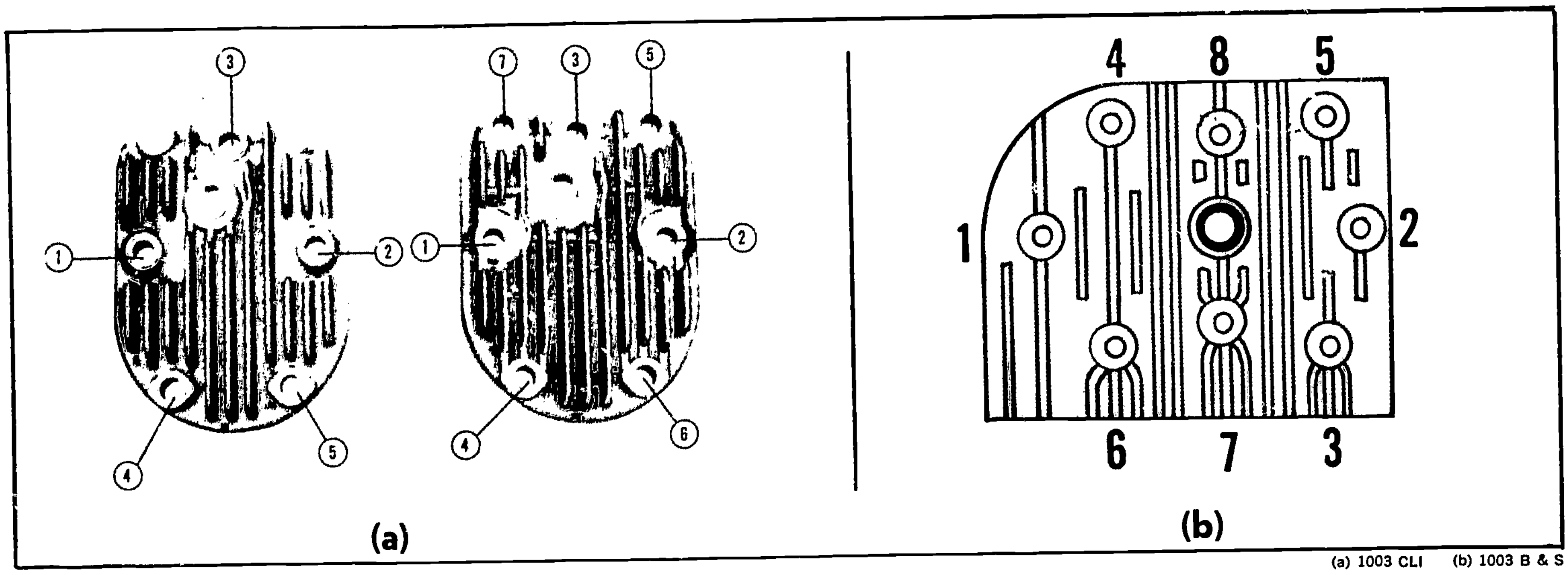


FIGURE 221. Three examples of recommended sequence for tightening cap screws on cylinder heads.

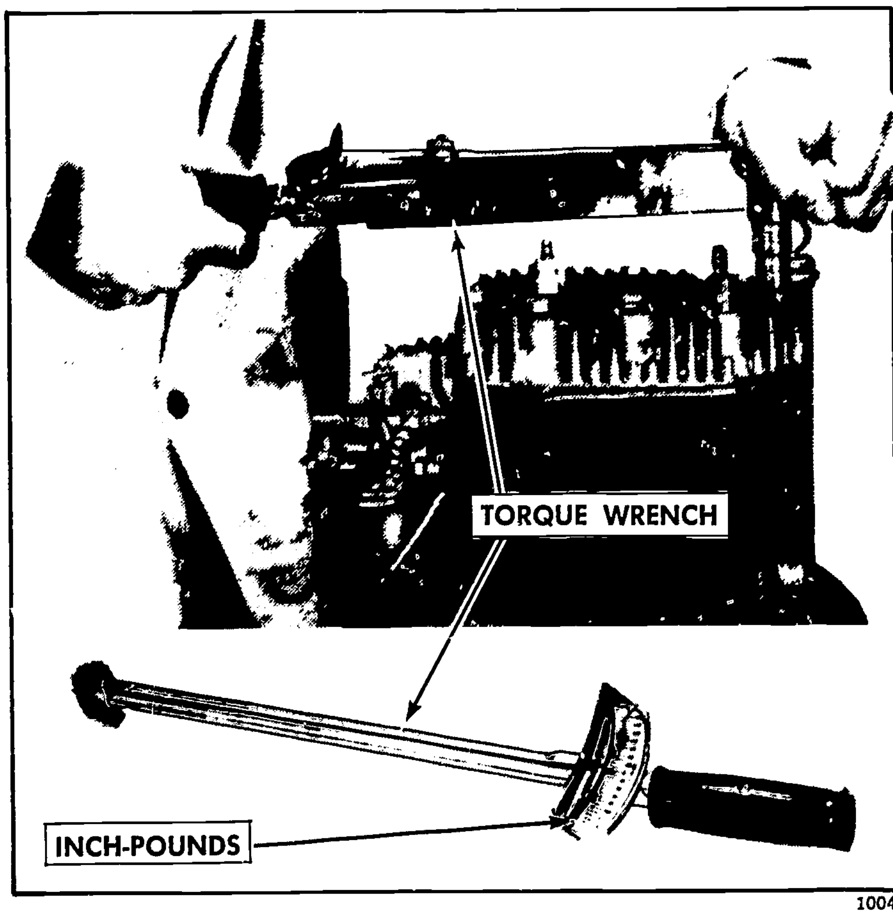


FIGURE 222. Use a torque wrench when tightening the cylinder-head screws.

as 50 inch-pounds on some 2-cycle engines and 150 to 480 inch-pounds on 4-cycle engines. When you use a torque wrench, tighten the cap screws in at least three stages.

Some manufacturers do not give torque recommendations but instead recommend tightening the cap screws by feel. For example, tighten the cap screws finger tight; then turn each ¼th turn in the recommended sequence. The general procedure is as follows:

1. *Check piston, cylinder, valves and cylinder head for cleanliness.*
2. *Install new head gasket.*

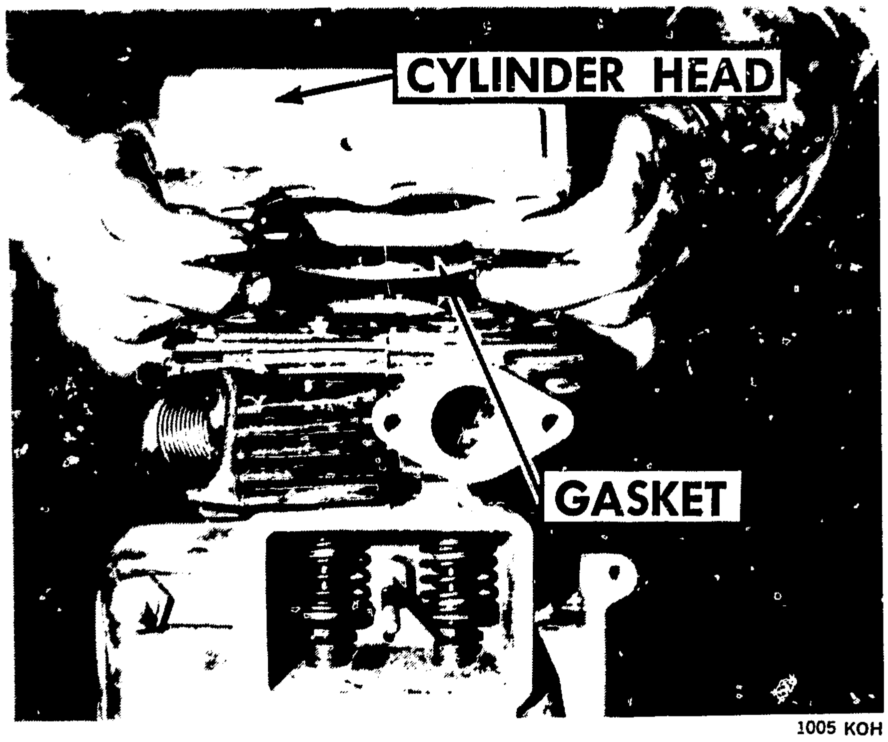


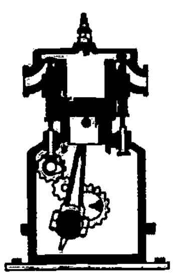
FIGURE 223. Installing the cylinder head and gasket.

Be sure the gasket is the proper one for your engine.

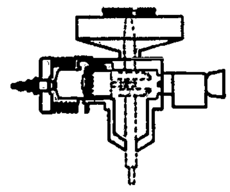
3. *Place cylinder head on cylinder block (Figure 223).*
4. *Install all cylinder-head cap screws snugly. Do not tighten!*

   Remember that some cylinder-head cap screws are longer than others. Replace them in their original positions.
5. *Tighten the cap screws according to procedures given by your manufacturer.*
6. *Operate the engine for a few minutes; then retighten cap screws.*

   This tends to equalize the pressure from the cap screws.



B. REPAIRING VALVES ON 2-CYCLE ENGINES



Two-cycle engines have no valves in the combustion chamber. The intake and exhaust ports are located in the cylinder wall, and their opening and closing are controlled by the piston.

There is a valve between the carburetor and the crankcase. It has two purposes: (1) **to allow the fuel-air-and-oil mixture to enter the crankcase (Figure 224a)**, and (2) **to seal the crankcase on the downward stroke of the piston (Figure 224b)**.

The fuel mixture that is displaced by the piston on the downward stroke enters the combustion chamber under pressure.

Maintaining and repairing valves on 2-cycle engines are discussed under the following headings:

1. Types of valves and how they work.
2. Tool and materials required.
3. Checking the reed valve for proper operation.
4. Removing and replacing the reed-valve assembly.

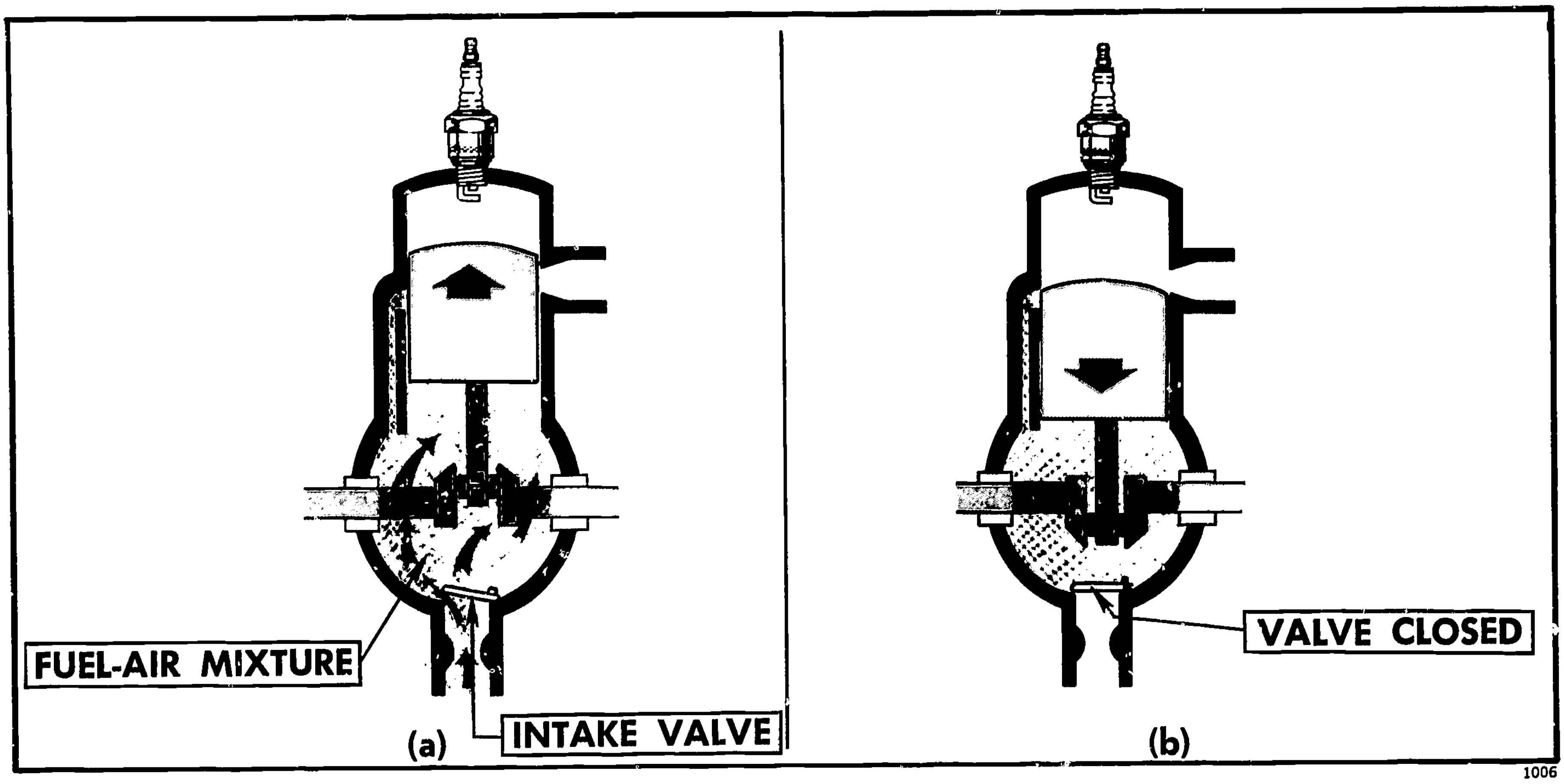


FIGURE 224. Functions of a fuel valve on a 2-cycle engine. (a) Valve opens to allow fuel-air-and-oil mixture to enter the crankcase. (b) Valve closes on the downward stroke of the piston to seal the crankcase.

TYPES OF VALVES AND HOW THEY WORK

Most valves used on small, 2-cycle engines are of the **reed type** (Figure 225). They are made of **spring steel, phenolic or plastic.**

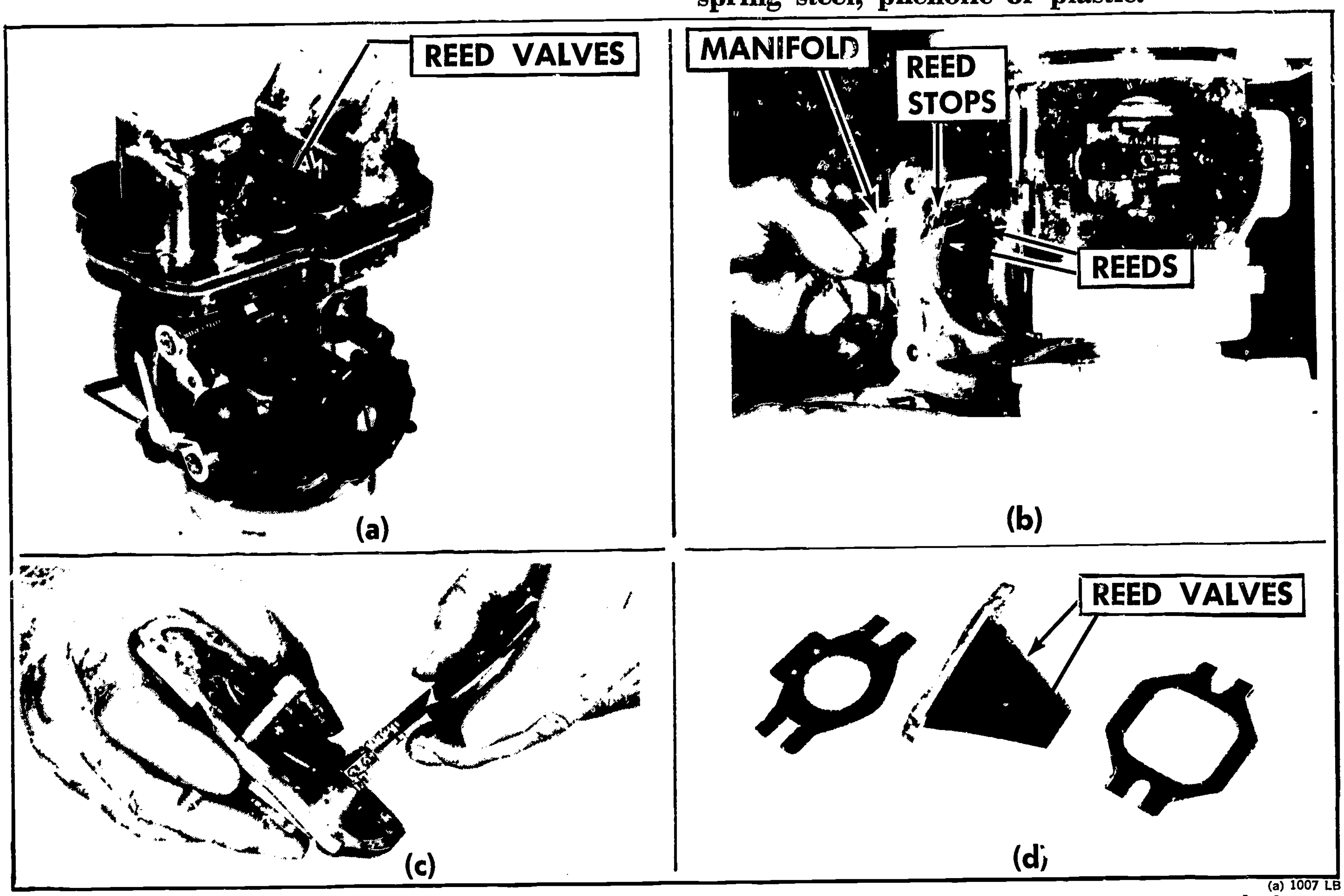


FIGURE 225. Types of reed-valve arrangements used on 2-cycle engines. (a anb b) Twin reeds. (c) A 4-reed cluster. (d) Pyramid-type 4-reed cluster.

The valves are opened by the partial vacuum created in the crankcase on the upward stroke of the piston (Figure 224a). They are closed by the built-in spring tension in the reed and also by the pressure the crankcase developed by the downward stroke of the piston.

TOOLS AND MATERIALS NEEDED

1. Open-end wrenches — 3/8″ to 9/16″
2. Steel rule — 6″
3. Slot-head screwdriver — 6″
4. Punch — 5/16″
5. Carburetor cleaning solvent
6. Clean rags
7. Wooden scraper

CHECKING THE REED VALVE FOR PROPER OPERATION

If your engine is **hard to start and spits back through the carburetor when starting,** check the reed valve. Proceed as follows:

1. *Remove the carburetor air cleaner.*

   Check for signs of blowback in the carburetor. This will show as carbon deposits in the carburetor manifold.

2. *Turn the engine by hand quickly and listen to the carburetor.*

   The engine must be turning at cranking speed or above for enough compression to build up in the crankcase to close the reed valves. If you hear air passing backwards through the carburetor, it indicates a leaking valve. The reed may be bent, broken or out of adjustment, or the reed-valve seat may need cleaning.

REMOVING AND REPLACING THE REED-VALVE ASSEMBLY

1. *Remove the reed plate.*

   On some engines it is a simple matter to get to the reed plate. All you have to do is to remove it along with the carburetor (Figure 226a).

   On others it is necessary to remove the carburetor first (Figure 226b).

2. *Disassemble the reed-valve assembly (Figure 227).*

   Check reed for cracks and smoothness.

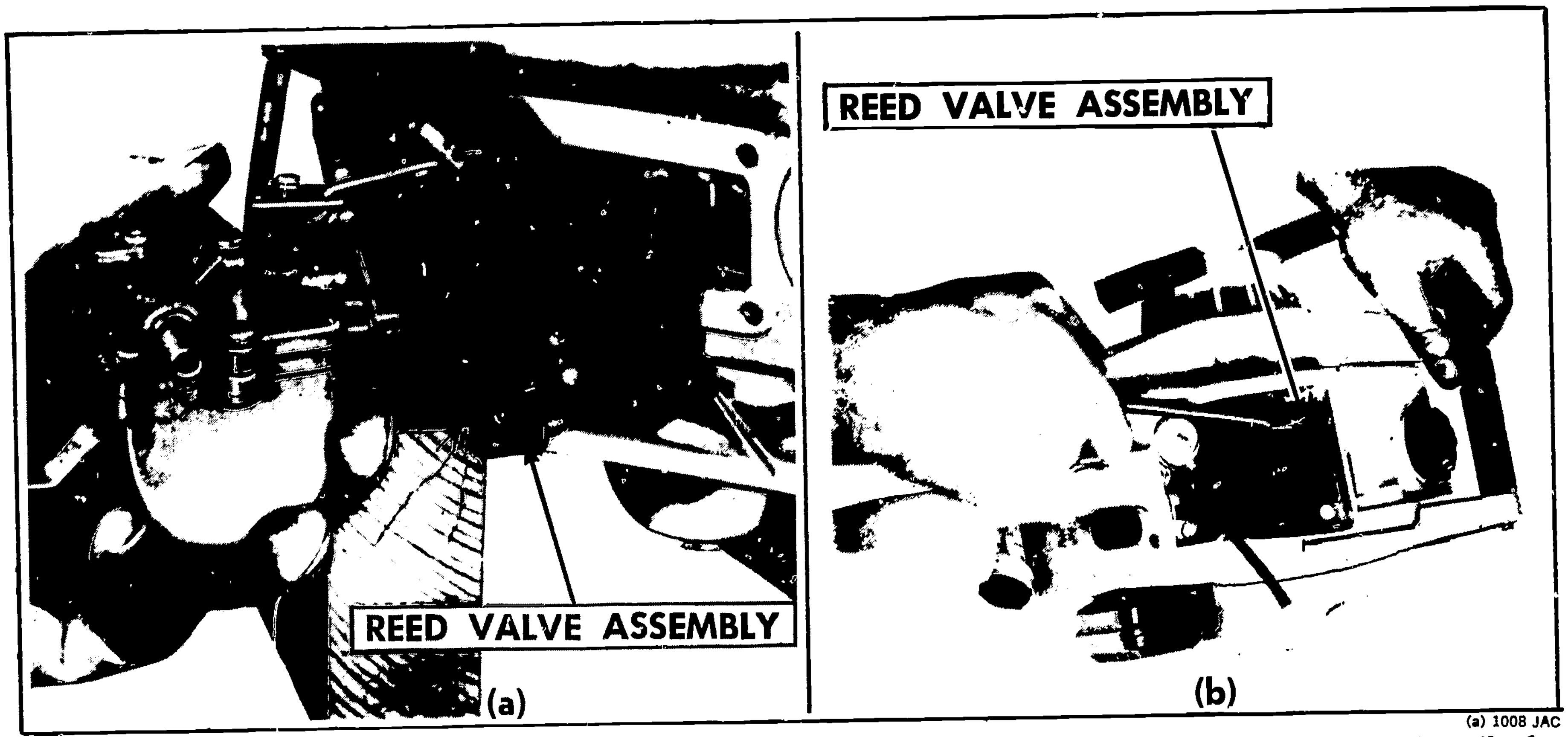


FIGURE 226. (a) Some reed plates are removed along with the carburetor. (b) Others cannot be removed until after the carburetor is removed.

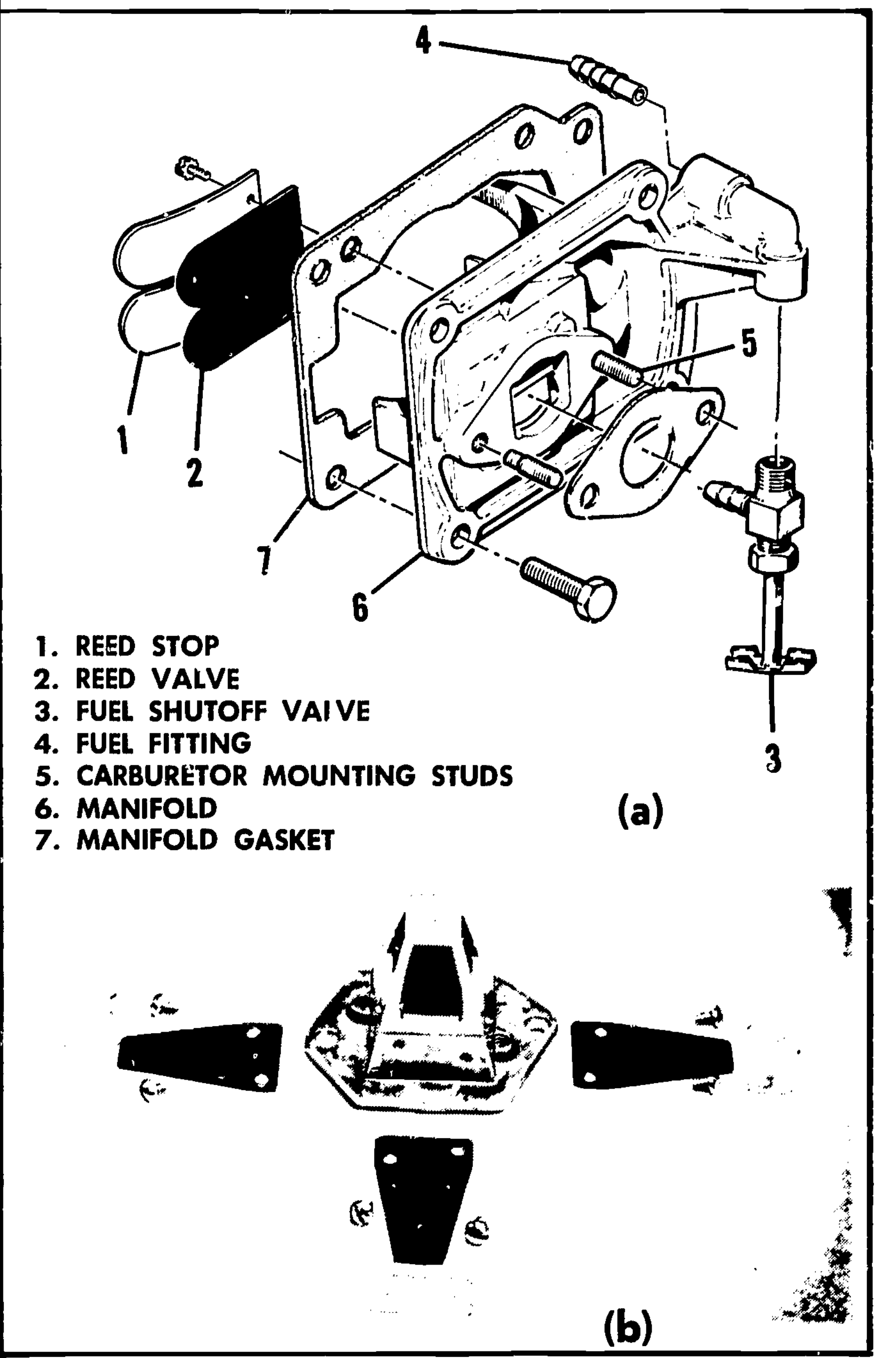


FIGURE 227. Reed valves disassembled. (a) Twin reeds. (b) Four-reed cluster.

3. *Clean and inspect parts (Figure 228).*

4. *Check reed-stop plate adjustment if installed (Figure 229).*

   Some leaf-type reeds have a stop plate to prevent the reed from opening too far. If they are bent or distorted, they should be replaced.

5. *Reassemble reed-valve assembly.*

6. *Install reed plate.*

   Use new gasket.

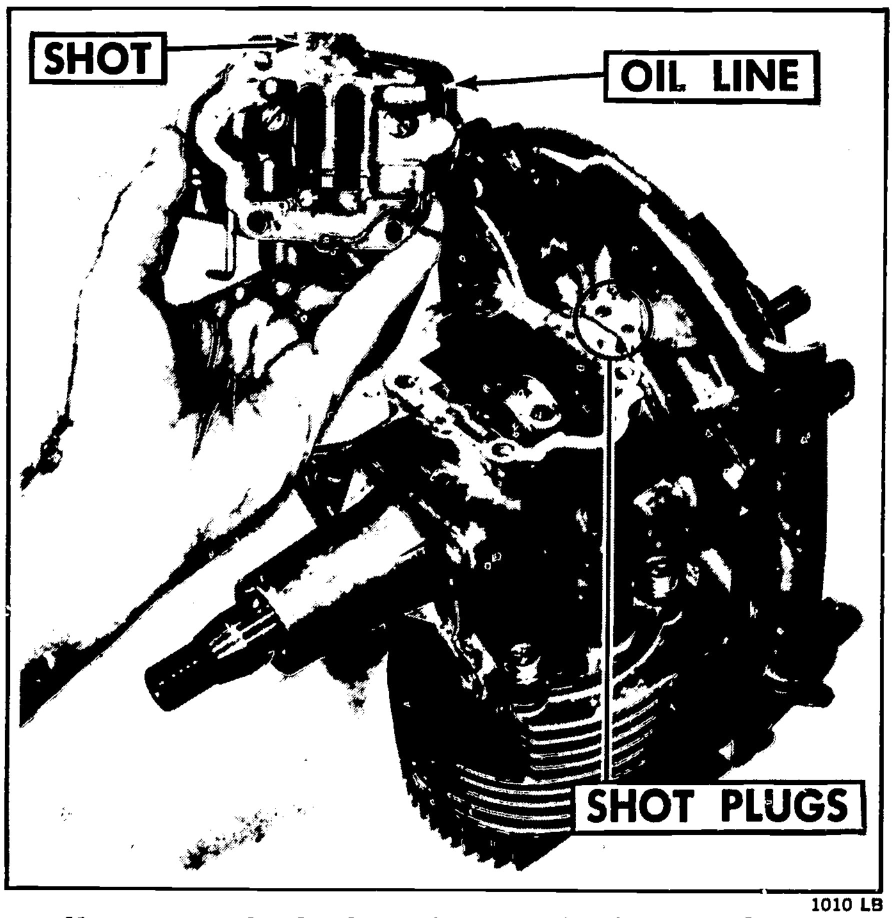


FIGURE 228. Check shot plugs and oil lines if present on your assembly.

7. *Install carburetor.*

8. *Check for proper operation.*

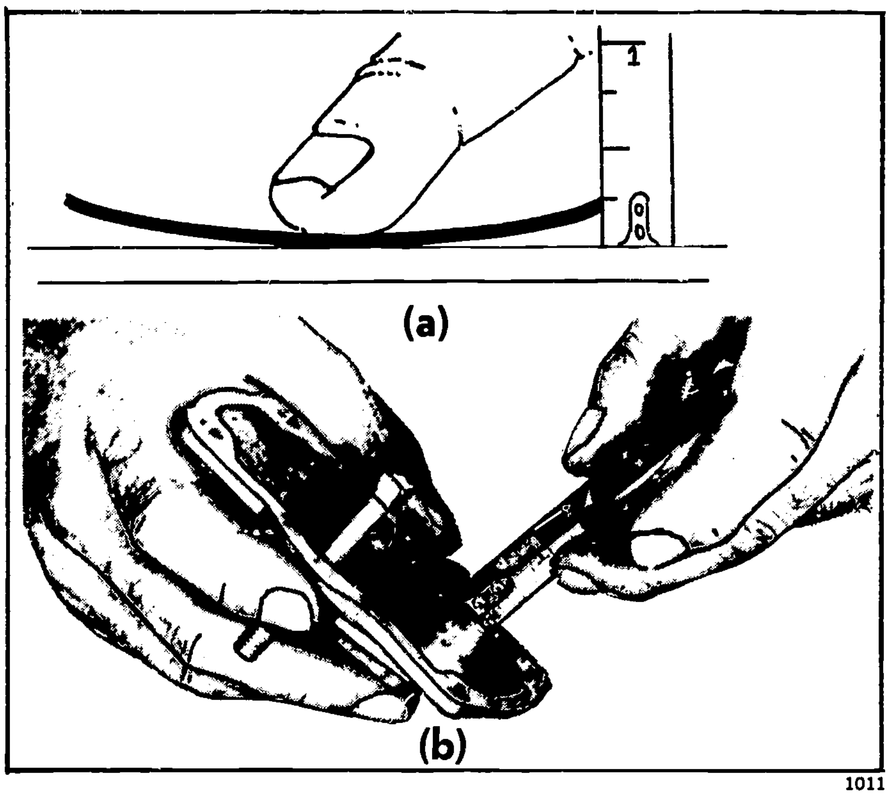
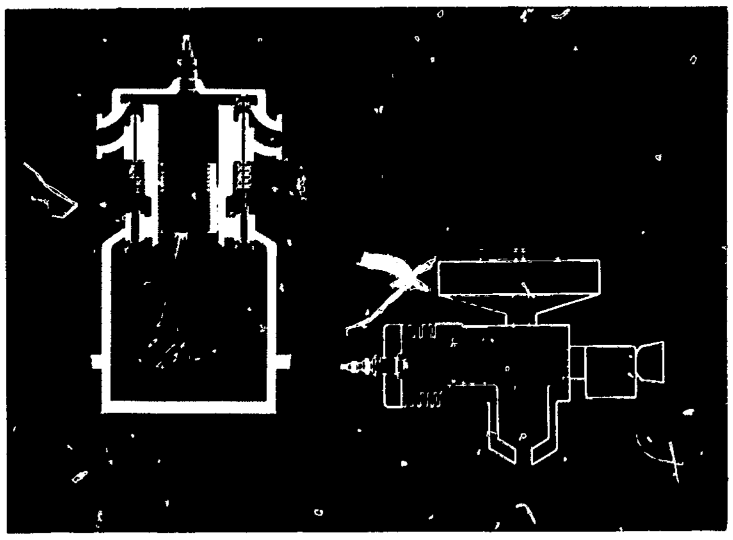


FIGURE 229. Checking reed-stop plate adjustment. (a) Some reed-stop plates are removed for checking. (b) Others may be checked while assembled.



VI. REPAIRING CYLINDERS, AND PISTON-AND-ROD ASSEMBLIES

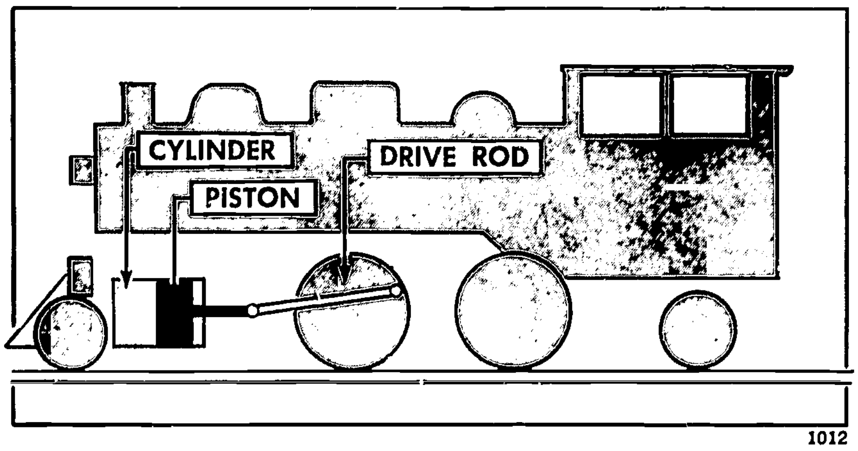


FIGURE 230. The drive rod transfers power from the pist-n and cylinder to the drive wheel on a steam locomotive.

The function of the **cylinder and piston-and-rod assembly** in a small engine is similar to that of the cylinder, piston and drive rod on steam locomotives (Figure 230).

It is through the action of the engine piston-and-rod assembly that chemical energy of the gasoline is converted to mechanical energy. The rod and crankshaft change the motion of the energy from reciprocating motion (back and forth) to rotating motion.

Figure 231a illustrates how the power is transferred from the piston to the crankshaft in your engine. Power is developed in the cylinder and transferred through the piston and piston rod to the crankshaft. The piston acts as a pump on the intake, compression and exhaust strokes. On the power stroke, however, the piston is driven by the rapidly expanding gases that developed when the fuel burned in the combustion chamber. This is how the power is developed. For each complete cycle (up and down motion) of the piston, the crankshaft makes one revolution.

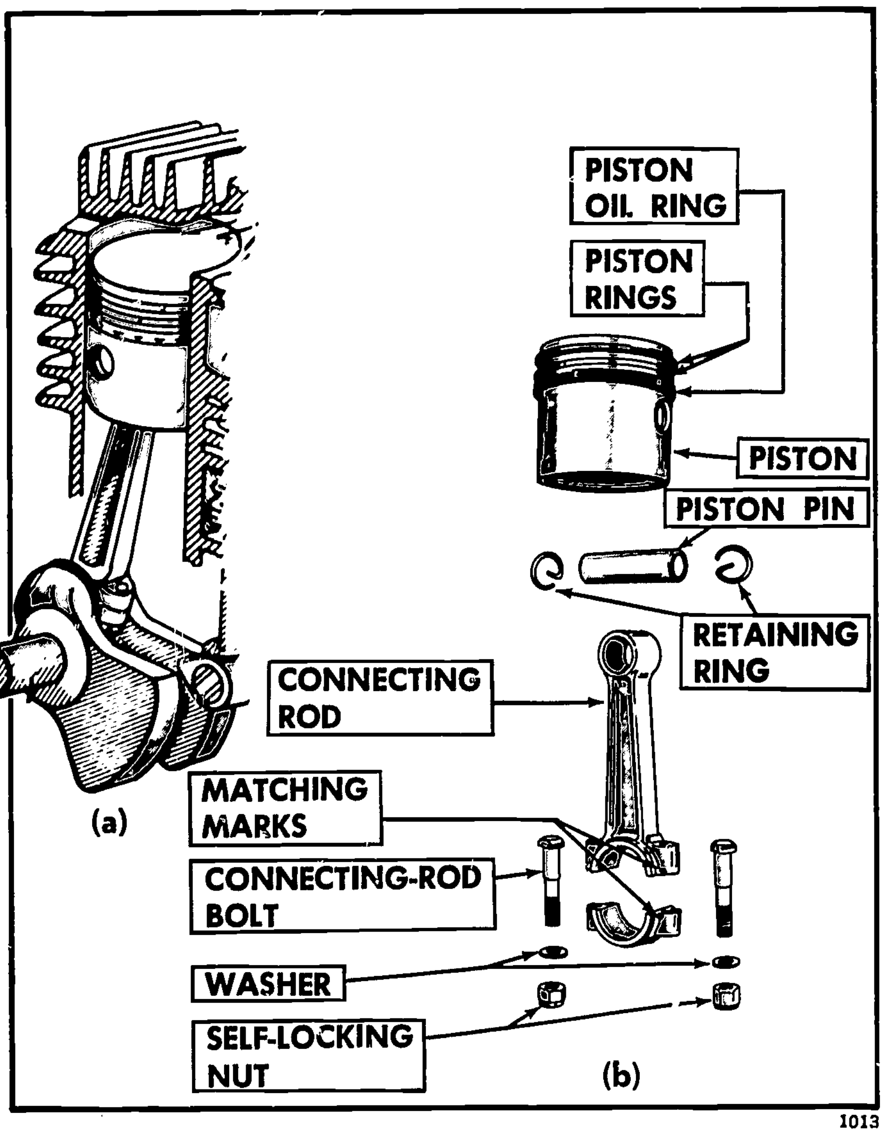


FIGURE 231. (a) Power is transferred from the piston to the crankshaft. (b) The cylinder and piston-and-rod assembly consist of a cylinder, piston, piston rings and a connecting rod.

Again you will note that on **4-cycle engines** each second downward stroke of the piston is a power stroke—or, every second revolution of the crankshaft. On **2-cycle engines** each downward stroke, or every revolution of the crankshaft, is a power stroke.

IMPORTANCE OF PROPER REPAIR

If the cylinder and piston-and-rod assembly are to perform effectively, there are some critical conditions and tolerances which must be met. The rings must be fitted properly. The compression rings must seal combustion gases out of the crankcase, thus preventing blow-by. The oil ring must prevent the

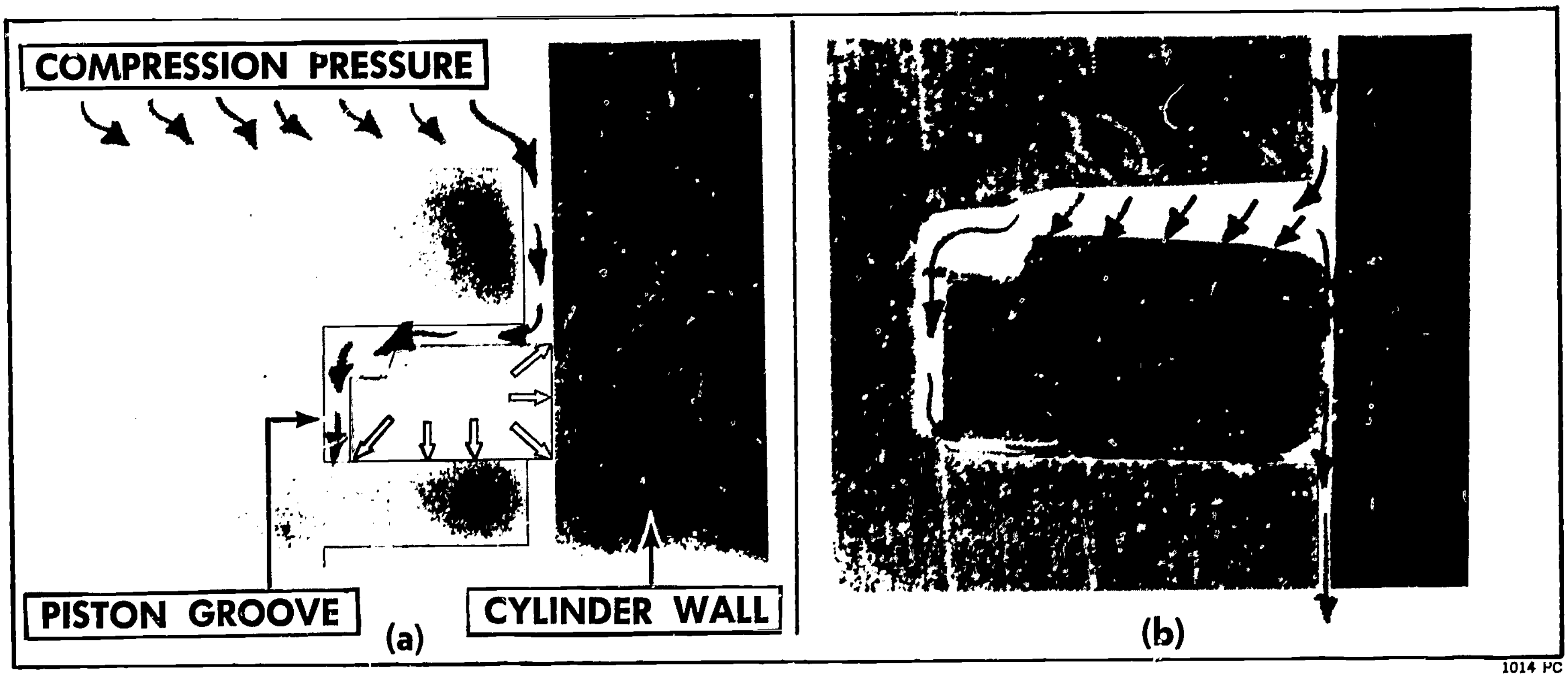


FIGURE 232. (a) On compression stroke the compression ring seats against the cylinder wall and the bottom of the piston-ring groove. (b) A ring cannot seal properly in a worn ring groove.

oil in the crankcase from entering the combustion chamber, thus preventing oil consumption.

The seal between the piston ring and the cylinder wall takes place at two areas of contact (Figure 232): (1) **the cylinder wall** and (2) the **piston groove** (either top or bottom depending upon the direction of pressure). When the piston is being forced downward, the contact points are as shown in Figure 232. When the piston is moving downward on the intake stroke, the seal shifts to the top of the piston groove.

There is a top and a bottom to most piston rings. If you install them upside down, the engine will use oil. New rings cannot seat properly if the ring grooves are worn badly (Figure 232b). Also, they are likely to develop a fluttering and break.

Rings which are **too tight** in the cylinder will *overheat, score* and eventually *seize.*

Rings which are **too loose** in the grooves will *not seat properly* and the ring *may break* during operation.

Other critical areas in the repair of your cylinder, and piston-and-rod assembly are the bearing surfaces between the rod and piston pin, and the bearing surfaces between rod and crankshaft. The bearing surfaces must have smooth finishes and proper clearances.

There is a **critical clearance between the piston and the cylinder wall.** If there is *too little clearance,* the parts will overheat and score — and perhaps seize because of friction. If there is *too much clearance,* it will wear unevenly in the cylinder and the rings cannot perform properly.

Cylinders which are worn excessively may be rebored, and oversized pistons and rings may be installed. But if the cylinder walls are not honed (ground slightly) properly, the rings will not seat properly, and the engine will use oil (Figure 276).

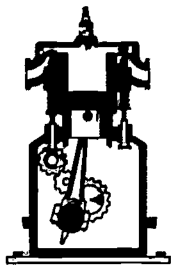
It is most important that you **keep the parts clean** when repairing your engine. Clean all the parts to be reused, and protect your engine from dirt and dust when repairing it. A small amount of dirt left in the engine will wear out bearings and rings in a very short time. Your efforts at repair will have been wasted.

Checking and repairing the cylinder and piston-and-rod assemblies are discussed under the following headings:

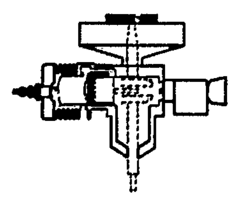
A. Checking the cylinder and piston-and-rod assembly for proper operation.

B. Repairing pistons, rods and rings.

C. Repairing cylinders.



A. CHECKING THE CYLINDER AND PISTON-AND-ROD ASSEMBLY FOR PROPER OPERATION



Indications of improper operation of the cylinder and piston-and-rod assembly are (1) poor compression, (2) excessive oil consumption and (3) noisy operation.

It is difficult to tell just what may be causing the trouble until you disassemble the piston-and-rod assembly and inspect the parts. Inspection of the parts will give you a clue as to what caused the trouble. The following procedures for checking before disassembly, however, may give you an indication as to the source of your trouble.

1. *Check the compression.*

   For procedures see "Checking the Valve Operation by Compression Test," page 113. This will give you an indication as to the condition of the cylinder and piston rings.

2. *Check for oil consumption.*

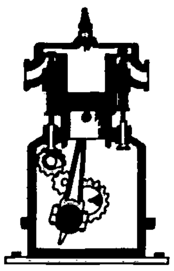
   Puffs of blue smoke from the exhaust indicate oil consumption which may be due to worn or seized piston rings. Another indication, of course, is necessity for adding oil frequently.

3. *Check for noisy operation.*

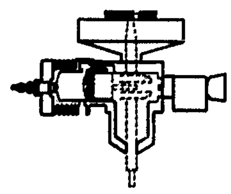
   Noisy operation may be due to worn piston-rod bearings — either at the piston pin or at the crankshaft.

Before repairing the cylinder and piston-and-rod assembly, it is a good idea to check the crankshaft, bearings and valves. If they are worn also, you may decide to purchase a "short block" assembly rather than to overhaul the engine. "Short blocks" consist of a cylinder block, crankcase, crankshaft, camshaft assembly, piston assembly and valves.

The cost is approximately one half of the cost of a new engine.



B. REPAIRING PISTONS, RODS AND RINGS



Repairing pistons, rods and rings is discussed under the following headings.

1. Types of pistons and how they work.
2. Types of piston rings and how they work.
3. Tools and materials needed.
4. Preparing to remove the piston-and-rod assembly.
5. Removing the piston-and-rod assembly.
6. Disassembling the piston-and-rod assembly.
7. Cleaning and inspecting the piston and rings.
8. Inspecting the piston rod and bearings.
9. Installing the piston rings.
10. Installing the piston pin.
11. Installing the piston-and-rod assembly.

TYPES OF PISTONS AND HOW THEY WORK

Pistons in **4-cyle engines** appear to be the same diameter from top to bottom (Figure 233). If you check them closely, you will usually find they are tapered slightly toward the top. The piston top is flat.

Pistons on **2-cycle engines** may be tapered or they may have the same diameter from top to bottom. Some may have an odd-shaped piston top, depending on the scavenging system for which it is designed (Figure 234).

Pistons may be made of aluminum alloy or steel. The piston is drilled for a **piston pin.** The pin connects the piston to the connecting rod. During operation the piston floats — moves from side to side — on the piston pin. This reduces the possibility of the piston binding against the cylinder wall.

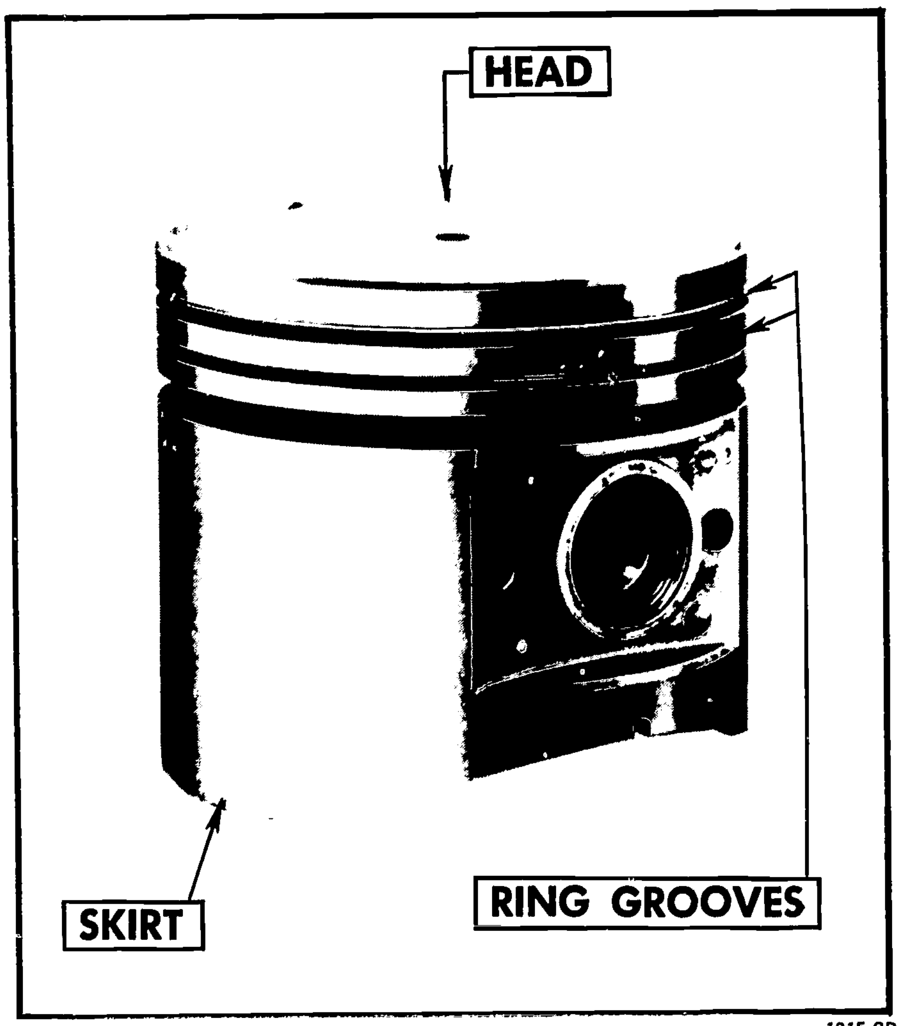


FIGURE 233. A typical piston used in small 4-cycle gasoline engines. Some are slightly tapered from bottom to top.

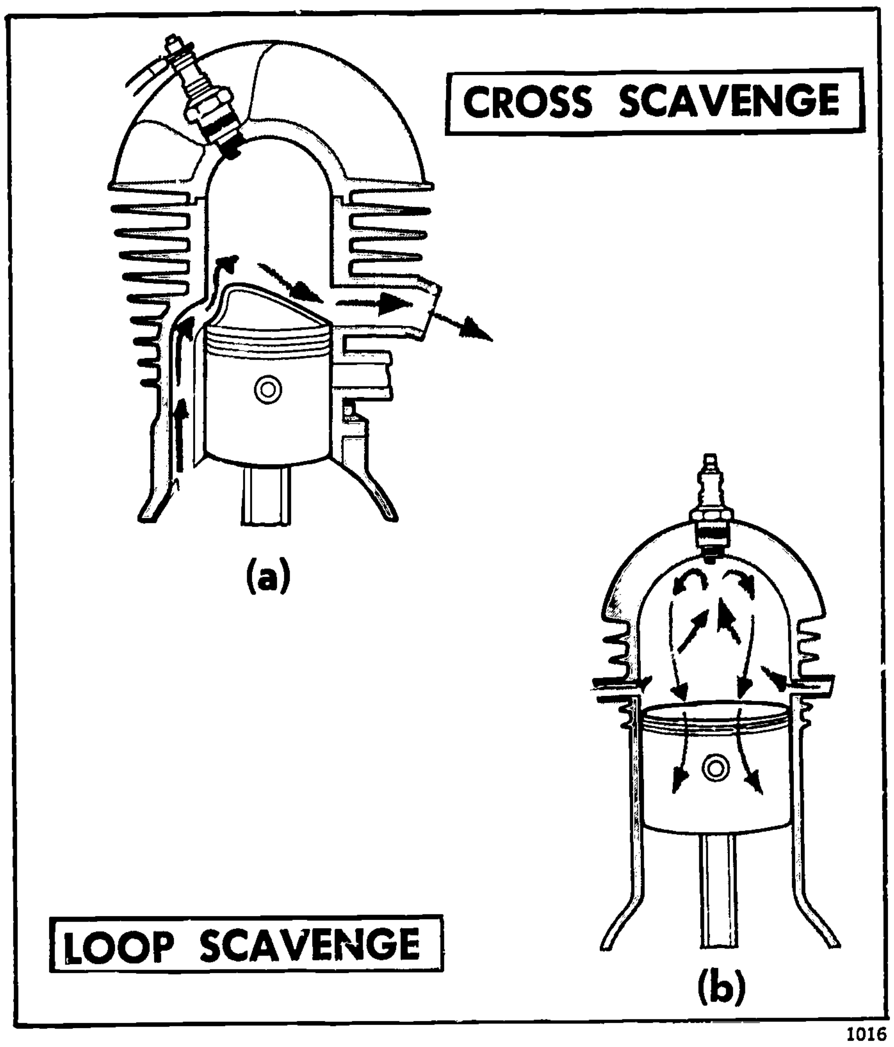


FIGURE 234. Two types of pistons used on 2-cycle engines. (a) A piston with a baffle on top for deflecting the fuel-air mixture going into the cylinder. This reduces the amount of unburned fuel mixture escaping through the exhaust port. (b) A flat-top piston used for loop scavenging. The fuel-air mixture enters through two intake ports on opposite sides of the cylinder. It is directed up and over by the dome-shaped combustion chamber and out through the exhaust ports which are located between the intake ports.

Pistons are slightly smaller than the cylinder (.005″ to .010″). After being sized and installed properly, they barely touch the cylinder walls when operating.

TYPES OF PISTON RINGS AND HOW THEY WORK

All pistons are grooved for **rings** (Figure 235). Most pistons on **4-cycle engines** have three rings. Pistons on **2-cycle engines** generally have two rings.

FIGURE 235. Typical piston and piston rings.

Each ring is designed for a specific purpose. They are described as follows:

- **Compression rings** (Figure 236a). These rings are designed to make a tight seal against the cylinder wall. This is particularly important during the power stroke to prevent combustion gases from being forced by the piston, thus resulting in a loss of power.

  Compression ring(s) are always placed in the top groove(s) of the piston on **4-cycle engines.** On **2-cycle engines** compression rings are the only ones used.

- **Oil-wiper rings** (Figure 236b). These are designed to wipe the excess oil off the cylinder wall as the piston moves down. This prevents the oil from bypassing the ring, entering the combustion chamber and being burned. Compression rings also provide for some oil wiping.

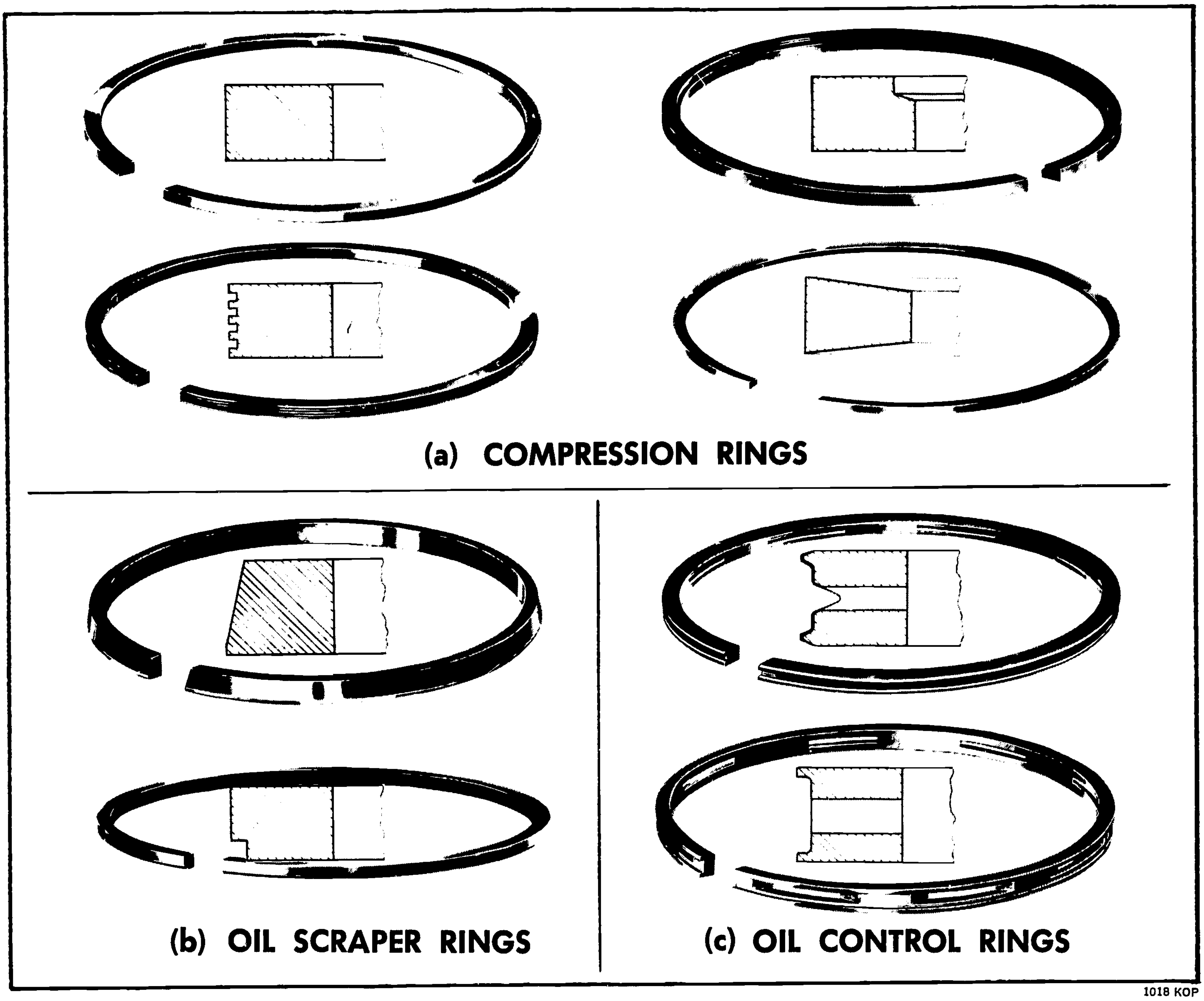


FIGURE 236. Types of piston rings used on small gasoline engines. (a) Compression rings. (b) Oil-wiper rings. (c) Oil-control rings. These types shown in (b) and (c) are used only on 4-cycle engines.

- **Oil-control rings** (Figure 236c). These are located below the compression rings. They regulate the amount of oil going to the compression rings and cylinder walls. Sometimes an additional expander spring is placed under the oil-control ring to help maintain its tension as it wears (Figure 237). The expander spring also helps the oil ring to take the shape of a slightly distorted cylinder wall.

  Two-cycle engines have no oil-control rings since the oil is mixed with the fuel.

Most piston rings are made of cast iron. Some have a chrome-plated face, or are specially heat treated, to harden the surface and reduce the wear. Oil rings do not run so hot as compression rings; consequently, they can be made of steel without annealing while running. Therefore, many oil rings

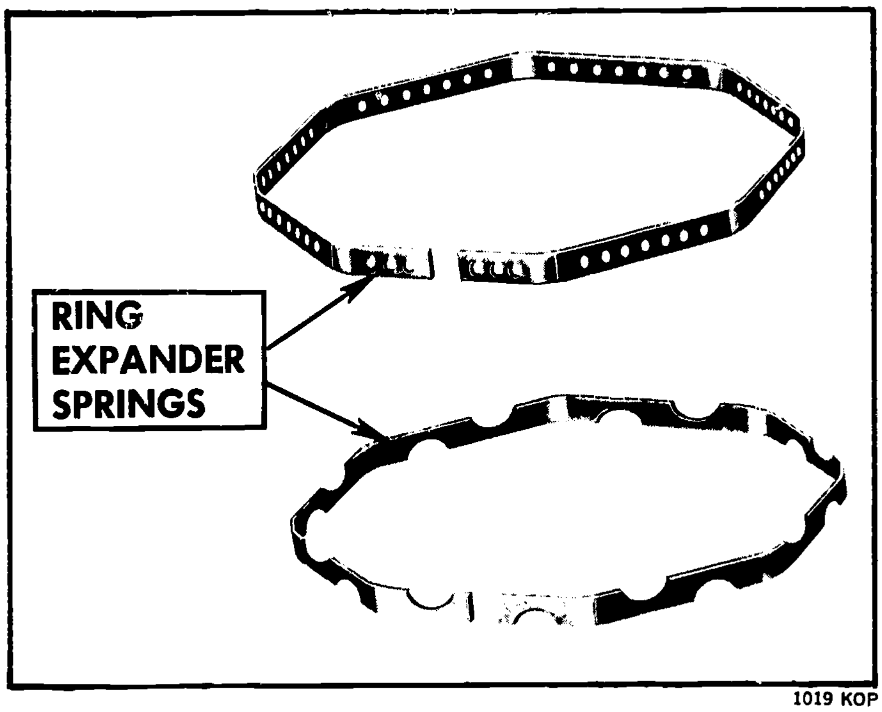


FIGURE 237. Expander springs can be placed under oil-control rings.

are designed with two narrow steel rails that contact the cylinder wall.

Some manufacturers now have a replaceable ring which they claim will take the shape of a worn, uneven or out-of-round cylinder. You can use them in cylinders that have not worn to the extent that they must be rebored.

All piston rings provide enough spring action to press against the cylinder wall. This spring action provides a seal between the piston and the cylinder.

TOOLS AND MATERIALS NEEDED

1. Long-nose pliers — 7″
2. Piston ring expander
3. Reamer for piston pin
4. Micrometer (outside and inside)
5. Ring-groove gage
6. Open-end wrenches — 3/8″ through 9/16″
7. Sockets, ratchet handle — 3/8″ through 9/16″ — 3/8″ drive
8. Brass punch — 1/2″ x 6″
9. Piston solvent — John Deere, Stoddard or equivalent
10. Clean rags
11. Crankcase oil

PREPARING TO REMOVE THE PISTON-AND-ROD ASSEMBLY

All piston-rod assemblies are removed by disconnecting the rod (Figure 238) from the crankshaft. Most of them are pushed out through the top of the cylinder (Figure 239a). Some (on 2-cycle engines) are removed from the bottom of the cylinder (Figure 239b).

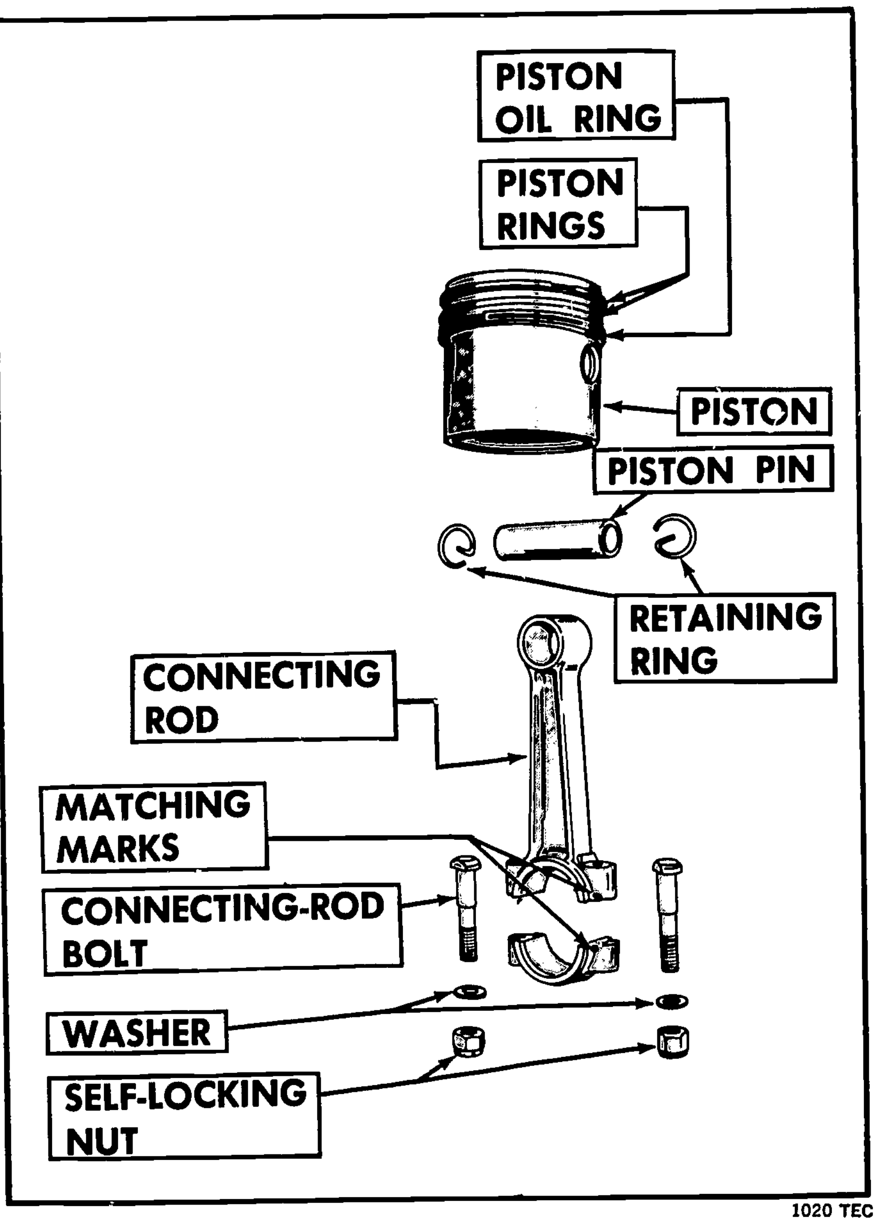


FIGURE 238. Parts of the piston-and-rod assembly.

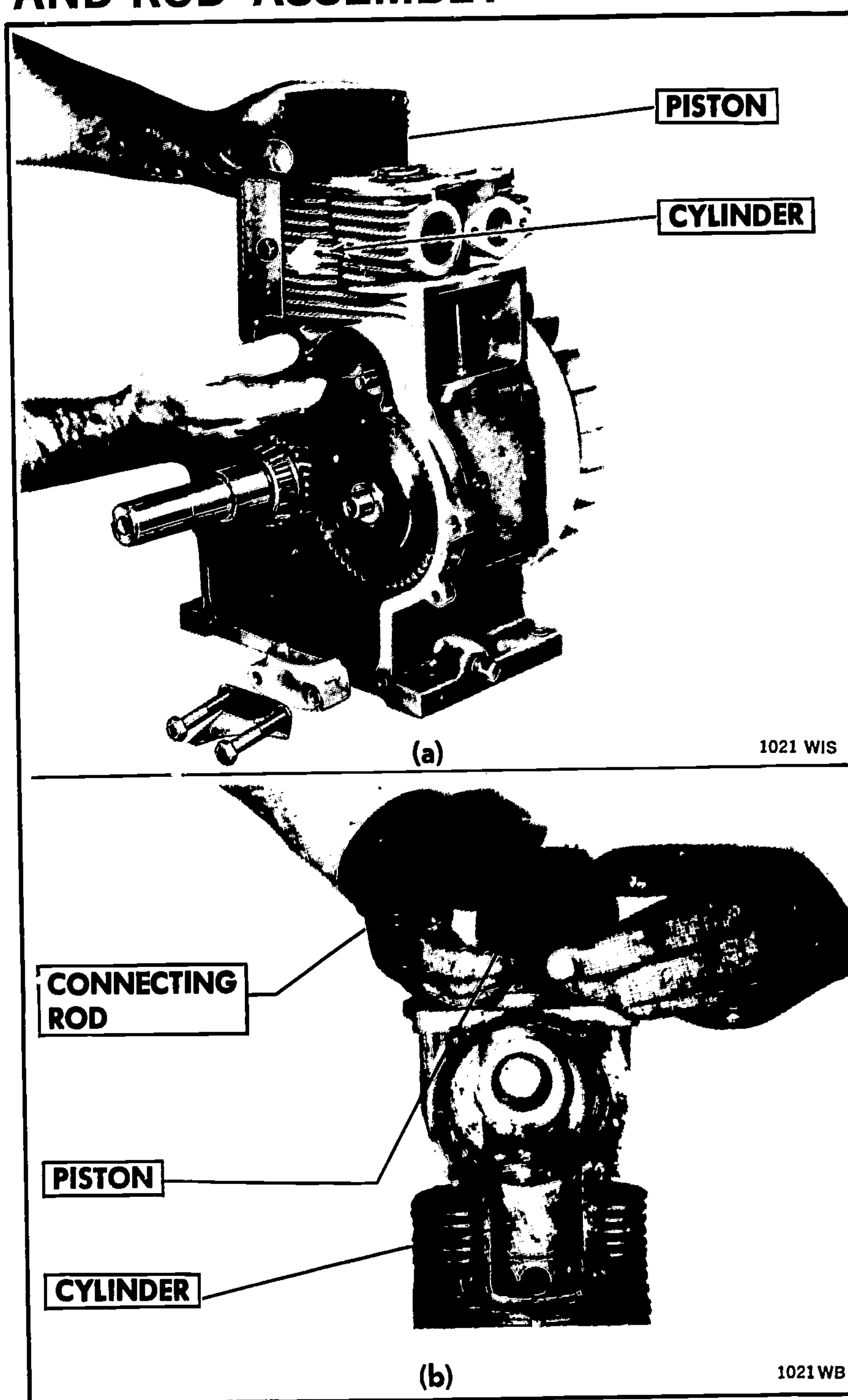


FIGURE 239. Removing the piston-and-rod assembly. (a) Most piston-and-rod assemblies are removed from the top of the cylinder. (b) Some are removed from the bottom of the cylinder.

There are several steps you have to complete before removing the piston assembly, since it is connected inside the crankcase. Proceed as follows:

1. *Clean the engine and equipment.*

   See "Cleaning Small Engines," Volume I.

2. *Drain the oil (4-cycle engines).*

   See "Changing the Crankcase Oil (4-Cycle Engines)," Volume I.

3. *Remove the engine from the equipment if convenient.*

   A major job of repairing your engine will be easier if you can remove it from the tractor, mower, chain saw or the equipment to which it may be attached.

4. *Remove the fuel tank.*

   See "Repairing Fuel Tank Assemblies," page 80.

5. *Remove the starter (if one is installed).*

   See "Repairing Starters," page 8.

6. *Remove the flywheel shroud and cylinder baffles.*

   See "Removing and Checking the Flywheel," page 55.

7. *Remove the flywheel if necessary.*

   On some engines it is not necessary to remove the flywheel, unless you are going to remove the crankshaft.

8. *Remove the spark plug.*

   See "Servicing Spark Plugs," Volume I.

9. *Remove the carburetor air cleaner.*

   See "Servicing Carburetor Air Cleaners," Volume I.

10. *Remove the carburetor.*

    See "Repairing Carburetors," page 86.

11. *Remove the muffler (if one is installed.)*

    See "Cleaning Small Engines," Volume I.

12. *Remove the cylinder head if you plan to overhaul the engine.*

    See "Removing the Cylinder Head," page 116.

13. *Remove the valves if they are to be serviced.*

    See "Removing the Valves," page 118.

REMOVING THE PISTON-AND-ROD ASSEMBLY

The piston rod is attached to the crankshaft by a **rod-bearing cap** (Figure 240). To remove the piston-and-rod assembly, you must remove the rod-bearing cap which is located inside the crankcase. Proceed as follows:

1. *Remove the cylinder head — if it is removable.*

   If your **cylinder head is bolted on to the cylinder block,** the piston-and-rod assembly is removed from the top, or cylinder-head end of the cylinder.

   If the **cylinder head and cylinder are cast in one piece** and bolted to the crankcase (Figure 249), proceed to step 2.

   If the **cylinder head, cylinder and crankcase are cast in one piece** (Figure 250), proceed to step 2.

2. *Gain access to the rod-bearing cap.*

   This is a matter of removing some part of the crankcase. On **4-cycle engines** remove the oil sump (Figure 241a) or a PTO bearing plate (Figure 241b and c).

   On **2-cycle engines** remove the carburetor and reed plate (Figure 242a) or a rod-bearing access plate (Figure 242b).

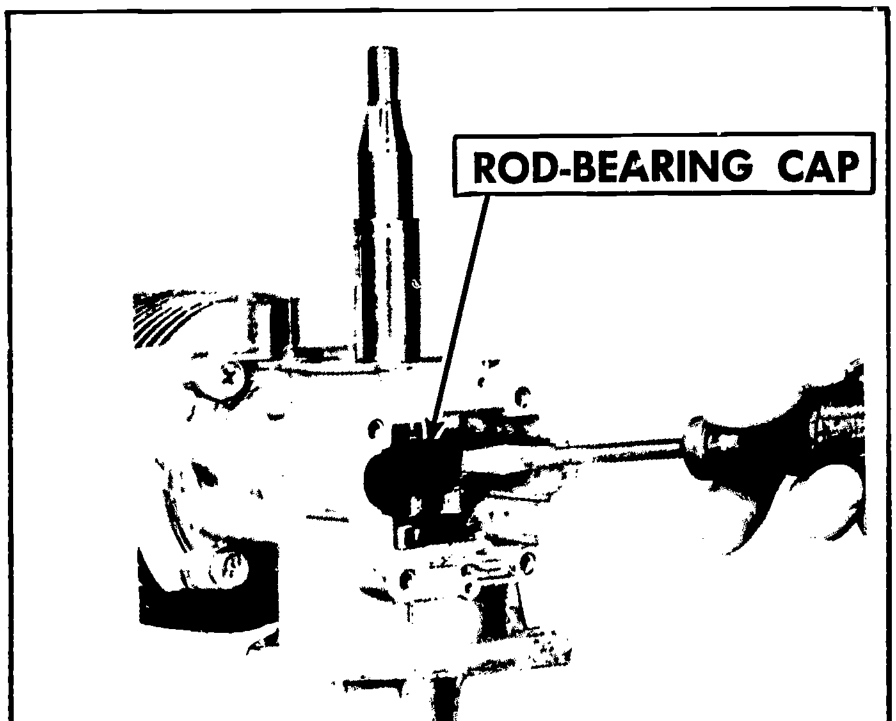
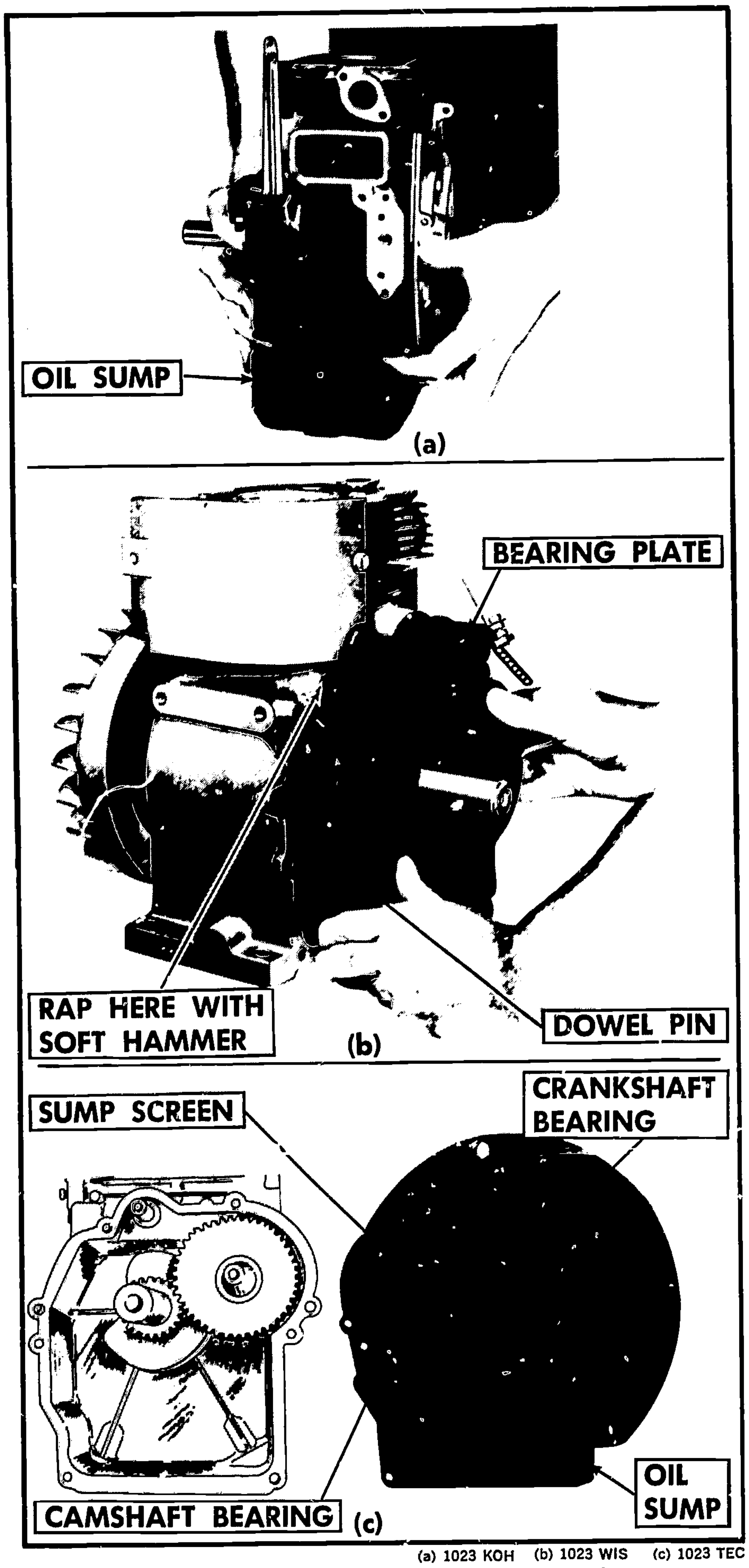


FIGURE 240. Removing the rod-bearing cap.



(a) 1023 KOH (b) 1023 WIS (c) 1023 TEC

FIGURE 241. Gaining access to the rod-bearing cap on the crankshaft of different types of 4-cyle engines. (a) Removing the oil sump. (b) Removing the bearing plate. (c) Removing the oil sump and bearing plate.

a. If you are removing from the crankcase **a part which does not serve as a bearing support,** such as an oil sump (Figure 241a), or a carburetor and reed plate (Figure 242a), or a rod-bearing access plate (Figure 242b), proceed as follows:

(1) *Remove nuts, or capscrews, that hold the part to be removed from the crankcase.*

Some parts have alignment dowels that must be removed also.

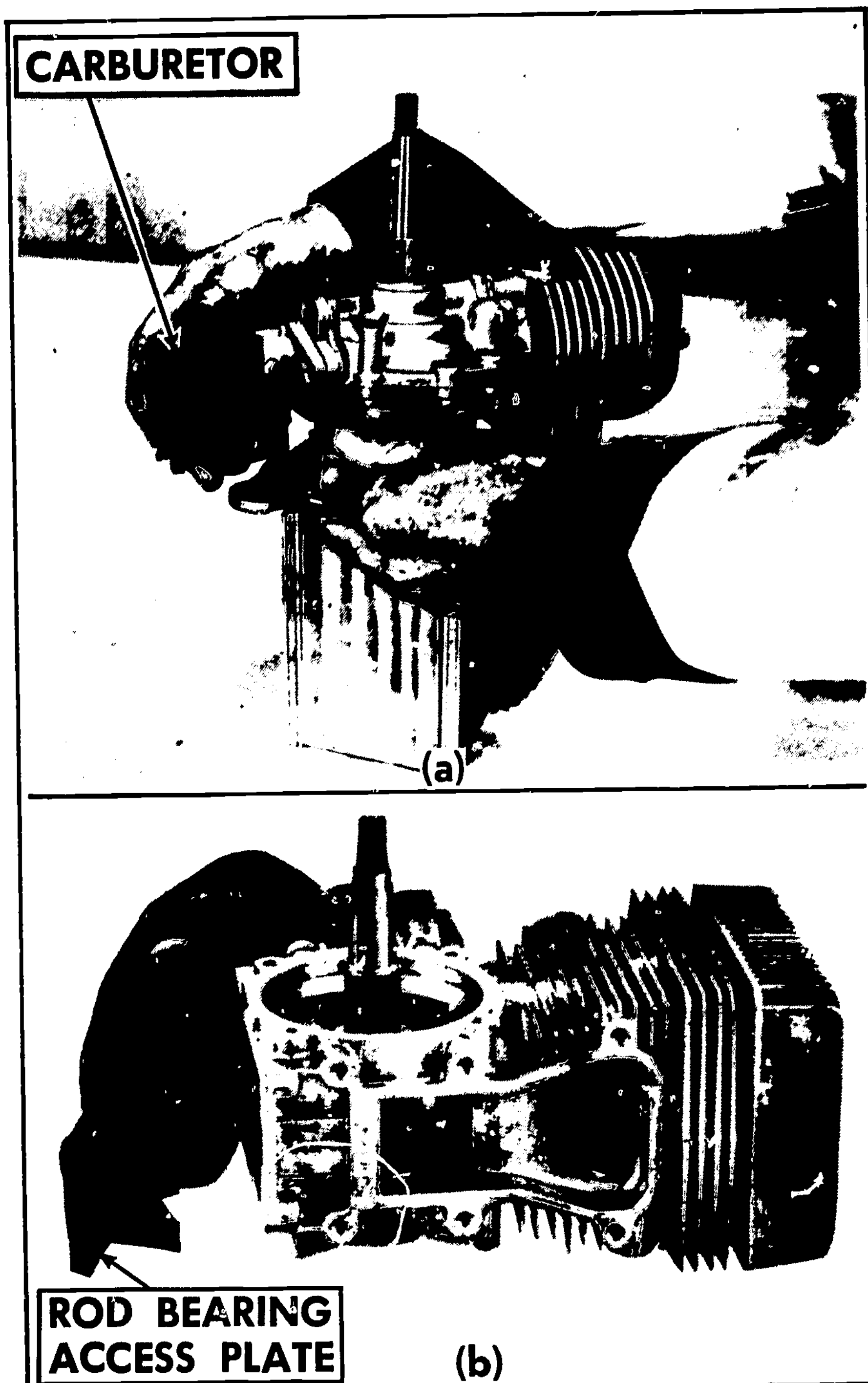
If you are removing the carburetor, refer to "Removing the Carburetor," page 86, for procedures.

(2) *Jar the part loose with a soft hammer*

(3) *Remove the part from the crankcase.*

b. If you must remove a **part that supports a bearing,** such as a base plate on a horizontal cylinder engine (Figure 241b), or a bearing plate on a vertical cylinder engine (Figure 241c), proceed as follows:

(1) *Clean rust and burrs from the power*



(a) 1024 LB (b) 1024 WB

FIGURE 242. Two methods for gaining access to the rod-bearing cap on 2-cycle engines. (a) Removing the carburetor and reed plate. (b) Removing a special rod-bearing access plate.

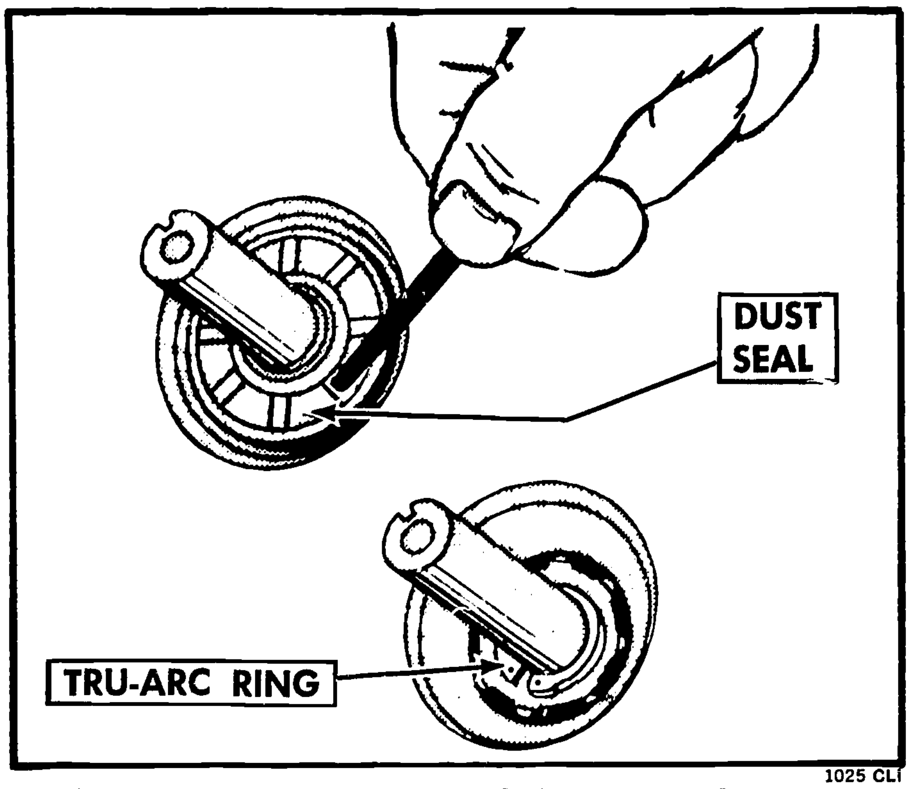


FIGURE 243. (a) Removing metal dust cover. (b) Tru Arc lock ring.

take-off (PTO) end of the crankshaft.

This is to prevent damage to the main bearing and oil seal when the bearing plate is removed.

On engines with clutch or speed-reduction units, these must be removed first.

(2) *Remove dust cover if installed and Tru Arc lock ring on engines with ball bearings (Figure 243).*

(3) *Remove alignment dowels if they are the removable type.*

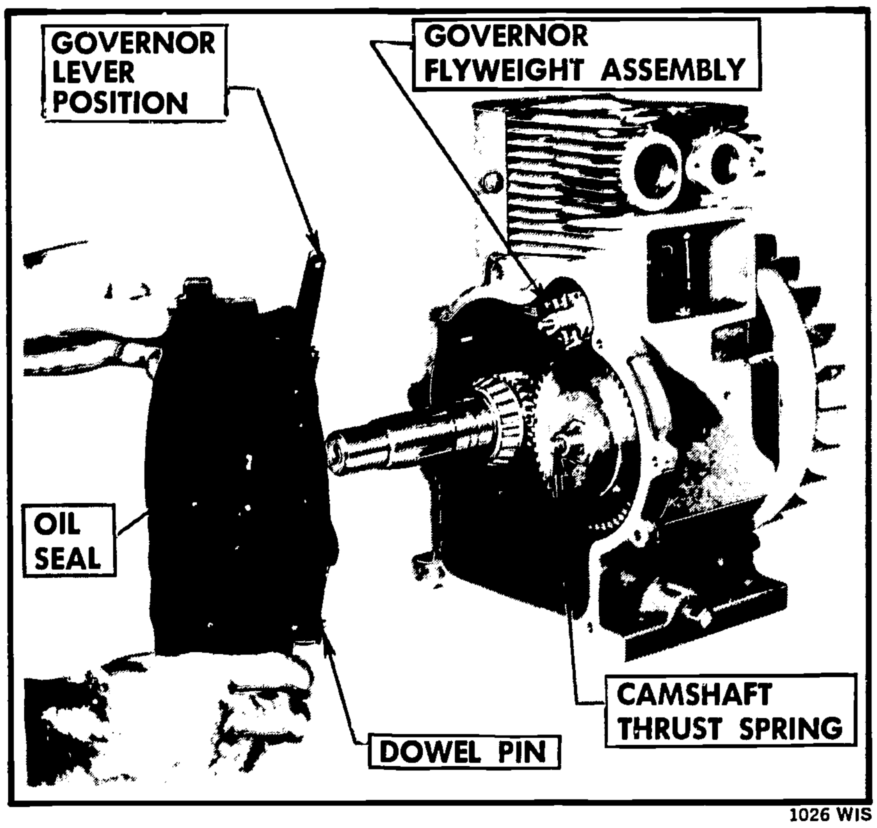


FIGURE 244. Removing the bearing plate.

(4) *Remove base plate, or bearing plate (Figure 244).*

Tap with a soft hammer to loosen. Be careful not to damage oil seal and bearings.

Some engines have a *steel ball for end thrust* at the end of the camshaft. Watch for this because it may fall out when you remove the bearing plate. There is also an end-thrust spring on the end of the camshaft on this type.

(5) *Remove the governor and oil pump assembly if installed.*

Note how they are assembled so you can reassemble them properly.

(6) *Remove the camshaft if necessary to get to the rod-bearing cap.*

Turn the crankshaft until the valve-timing marks are aligned. This relieves the cam pressure on the valve tappets.

The valve tappets will fall out when the camshaft is removed. Mark them so you will be able to install them in the original location.

3. *Inspect the crankshaft bearings that are removed.*

   Refer to "Cleaning and Inspecting the Crankshaft Bearings," page 183. This check will help you determine whether to repair the engine or buy a new "short block."

4. *Scrape the carbon ring from around the top of the cylinder and/or remove the metal ridge from top of cylinder on removable-head engines (Figure 245).*

   This is to avoid breaking the piston rings and/or damaging the piston when removing the piston-and-rod assembly from the top. If left, it may also break the new rings.

   Remove carbon deposits with a pocket knife (Figure 245a). Remove metal ridge with a "ridge reamer" (Figure 245b).

5. *Turn the crankshaft so the piston will be at bottom-dead-center.*

   The rod-bearing cap will be at its lowest point so that you will have better access to it.

6. *Turn the engine upside down or on its side (Figure 246).*

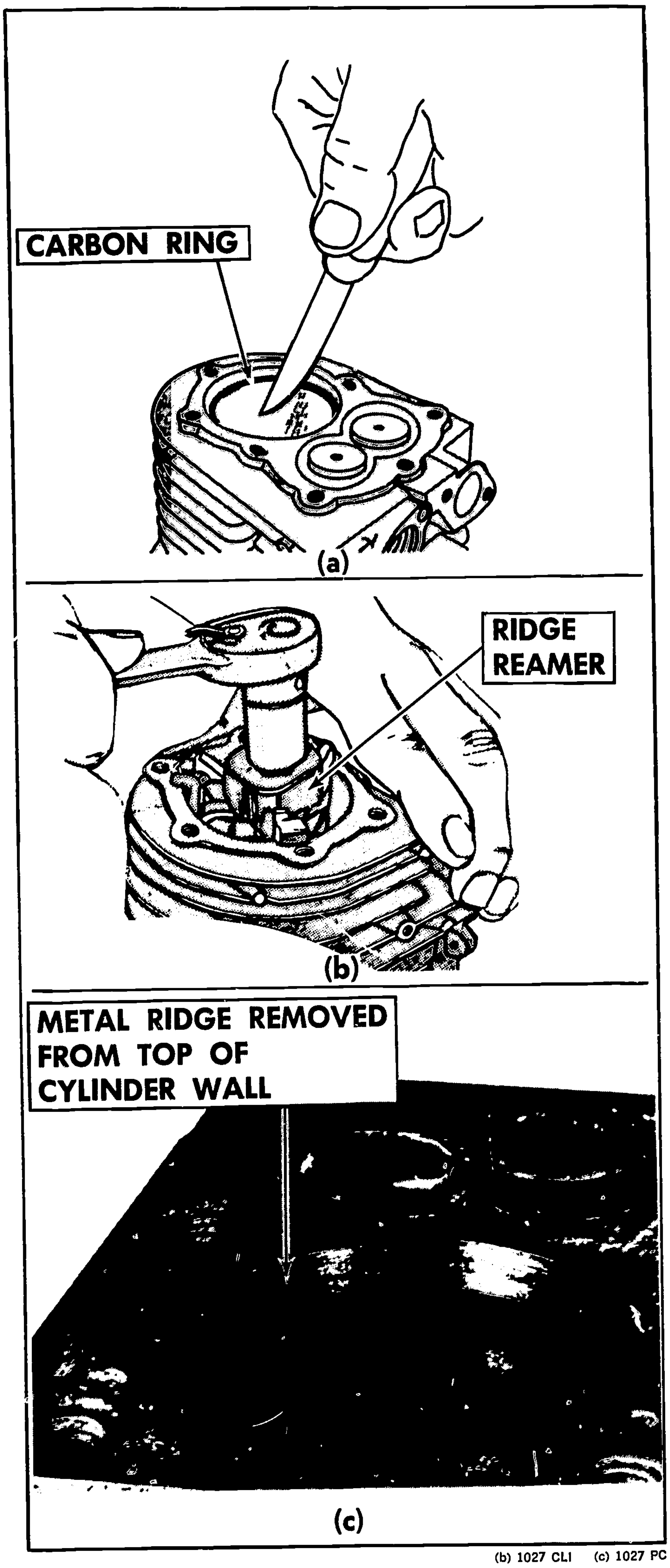


FIGURE 245. (a) Scraping the carbon ring from around the top of the cylinder. (b) Removing the metal ridge from the top of the cylinder with a ridge reamer. (c) Ridge removed.

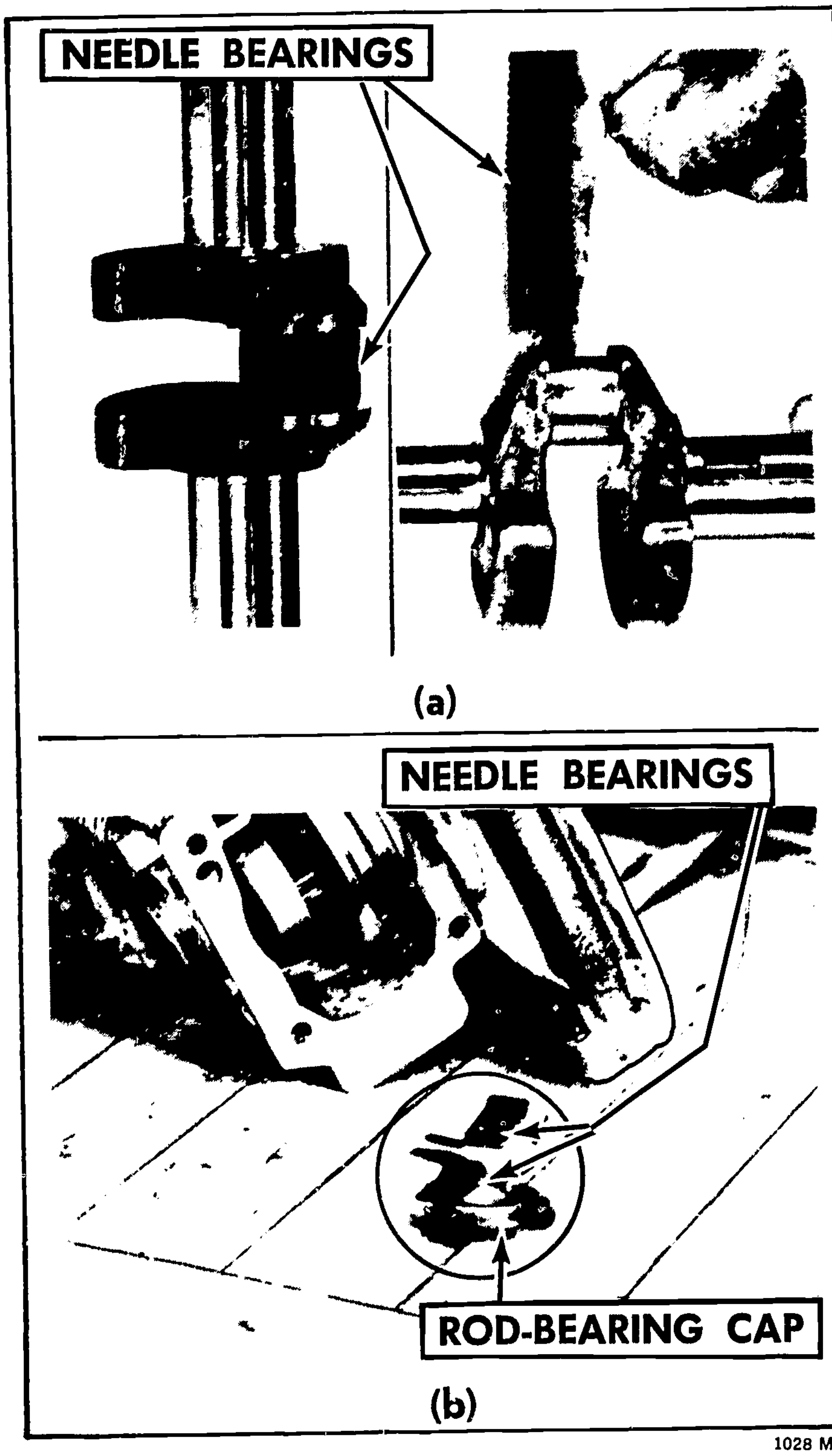


FIGURE 246. Take special care when removing needle bearings. (a) Removing needle bearings. (b) Needle bearings and rod-bearing cap removed.

This provides better access to the rod-bearing cap.

7. *Remove the nut or capscrews from the rod-bearing cap.*

   Some capscrews are held by a lock which is bent along the edge of the screw head. If so, it must be flattened first. Use a 5/16″ punch.

8. *Note positions of cap and rod.*

   Before removing the rod-bearing cap, take note of its position. It is usually marked with matching notches or bosses so that you can replace them in the same position. The bearings have been fitted with the cap in this position. If you turn the cap around when you reinstall it, you may not get a good fit.

ings. If so, these bearings may fall out when you remove the rod-bearing cap. Take special care not to lose the bearings and bearing races (Figure 246.)

9. *Remove the rod-bearing cap and bearings, if installed (Figure 247).*

10. *Remove the piston-and-rod assembly from the cylinder.*

If your engine has a **removable head,** the piston is to be removed from the top. Push the piston out with a wooden stick (Figure 248).

If the **cylinder and cylinder head are cast in one piece** and the casting is removable,

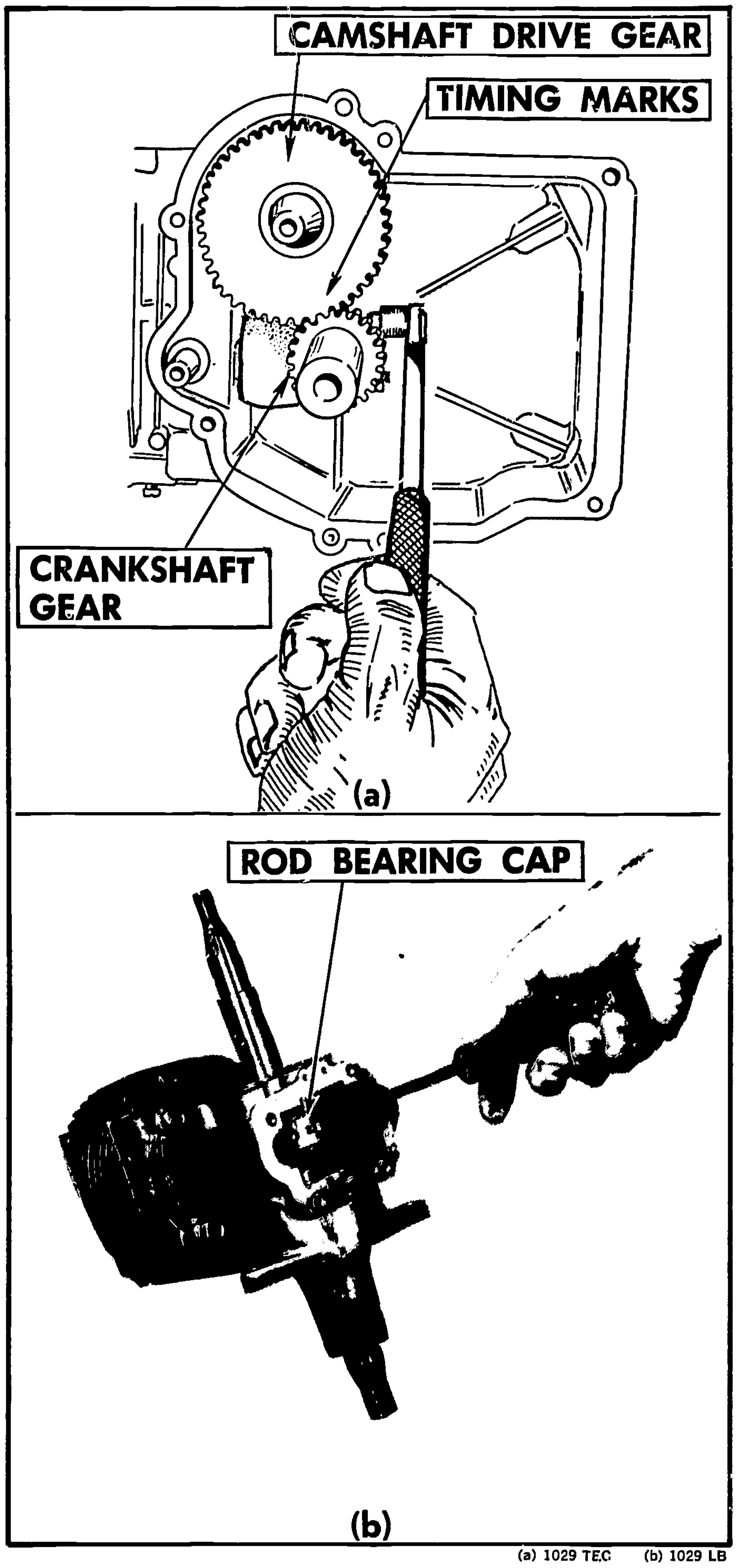


FIGURE 247. Removing the rod-bearing cap from (a) a 4-cycle engine, and (b) a 2-cycle engine.

Another reason for noting the position of the cap is that some **caps have an oil dipper** which must be positioned a certain way to sling oil over the crankcase.

Also **note the position of the connecting rod.** Some rods work satisfactorily in either position, but most of them will not. If the cap is not marked, mark it and the rod with a center punch. Some rods have needle bear-

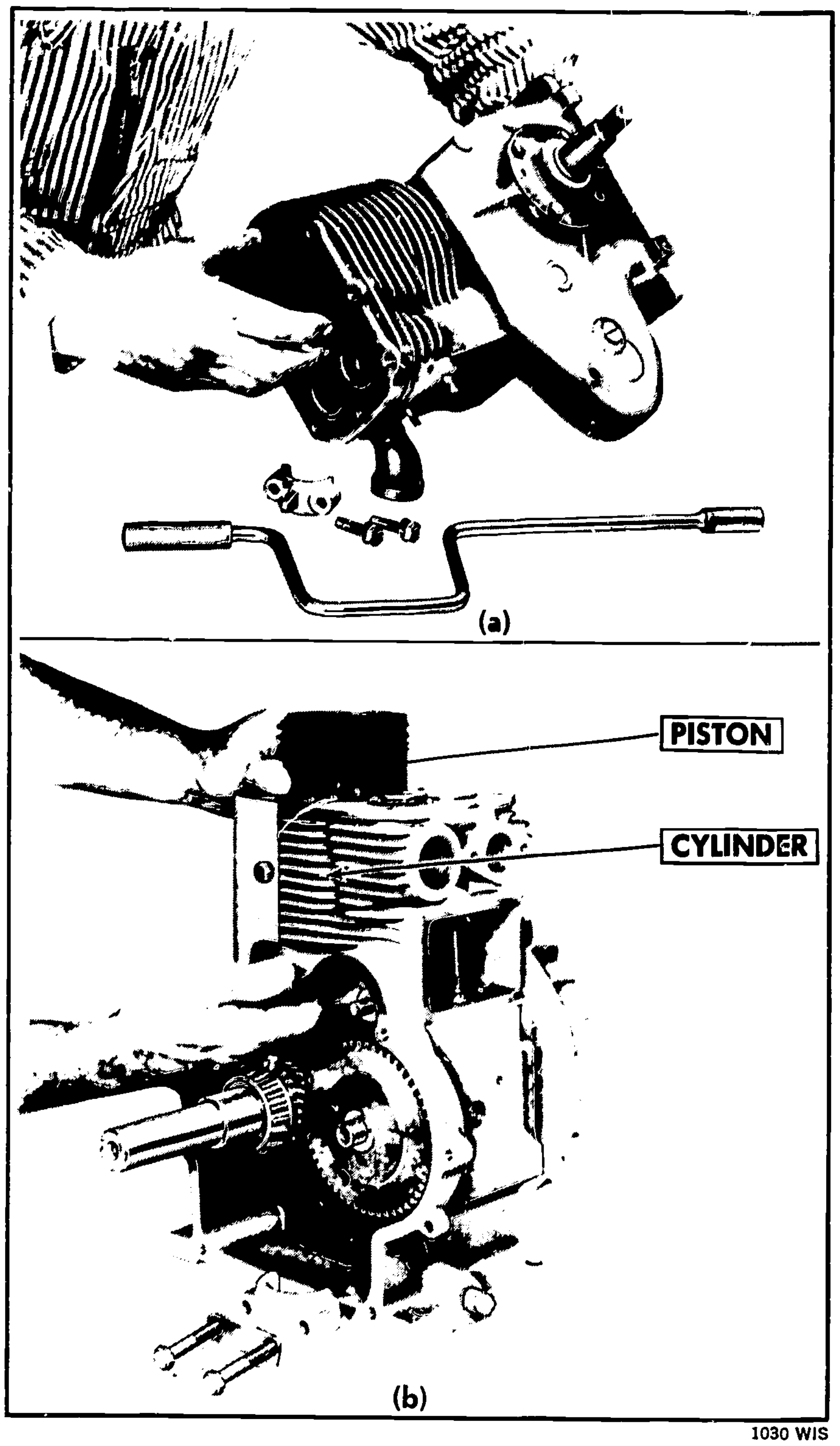


FIGURE 248. Removing the piston-and-rod assembly from the cylinder (a) with the oil sump removed and (b) with the bearing plate removed.

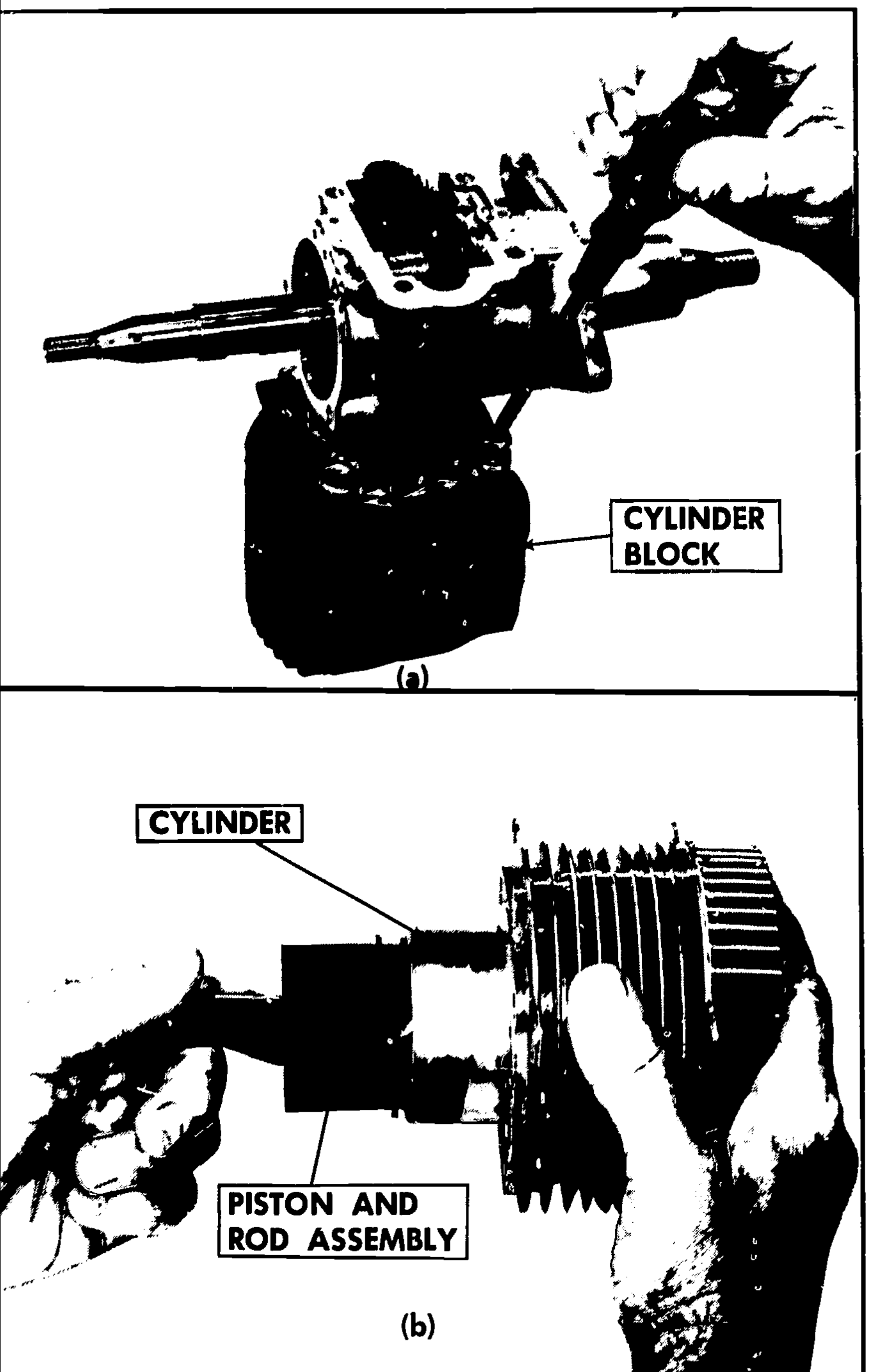


FIGURE 249. (a) Removing the 1-piece cylinder block and head from one model of 2-cycle engine. (b) Removing the piston-and-rod assembly from the cylinder.

it will be necessary to remove the casting from the crankcase (Figure 249a).

If the **cylinder, cylinder head and crankcase are cast in one piece** (Figure 242b), it will be necessary for you to remove the crankshaft and then remove the piston through the crankcase (Figure 250). Proceed as follows:

FIGURE 250. Removing the crankshaft from a 2-cycle engine that has the head, cylinder block and crankcase cast in one piece.

(1) *Push the piston up into the cylinder to provide for clearance for removing the crankshaft.*

(2) *Remove the crankshaft retaining ring if installed.*
Some require special tools.

(3) *Rotate the crankshaft so that the counterweights will clear the connecting rod.*

(4) *Remove the crankshaft (Figure 250).*

(5) *Remove the piston-and-rod assembly from the crankcase.*

Pull the piston out through the crankcase by the rod.

DISASSEMBLING THE PISTON-AND-ROD ASSEMBLY

Before going any further with piston repair, inspect the cylinder to determine if the engine is worth repairing. Refer to "Inspecting the Cylinder," page 157.

If the **cylinder must be rebored,** you will need a new, oversized piston.

If the **cylinder dimensions are all right,** proceed as follows:

1. *Remove the two retaining rings that hold the piston pin in the piston (Figure 251).*

   Special tools are available, or you can pry the ring out with a small screwdriver. Be careful not to damage the piston.

Mark the relative position of the piston and piston pin on the rod so that you can reassemble it in the same position.

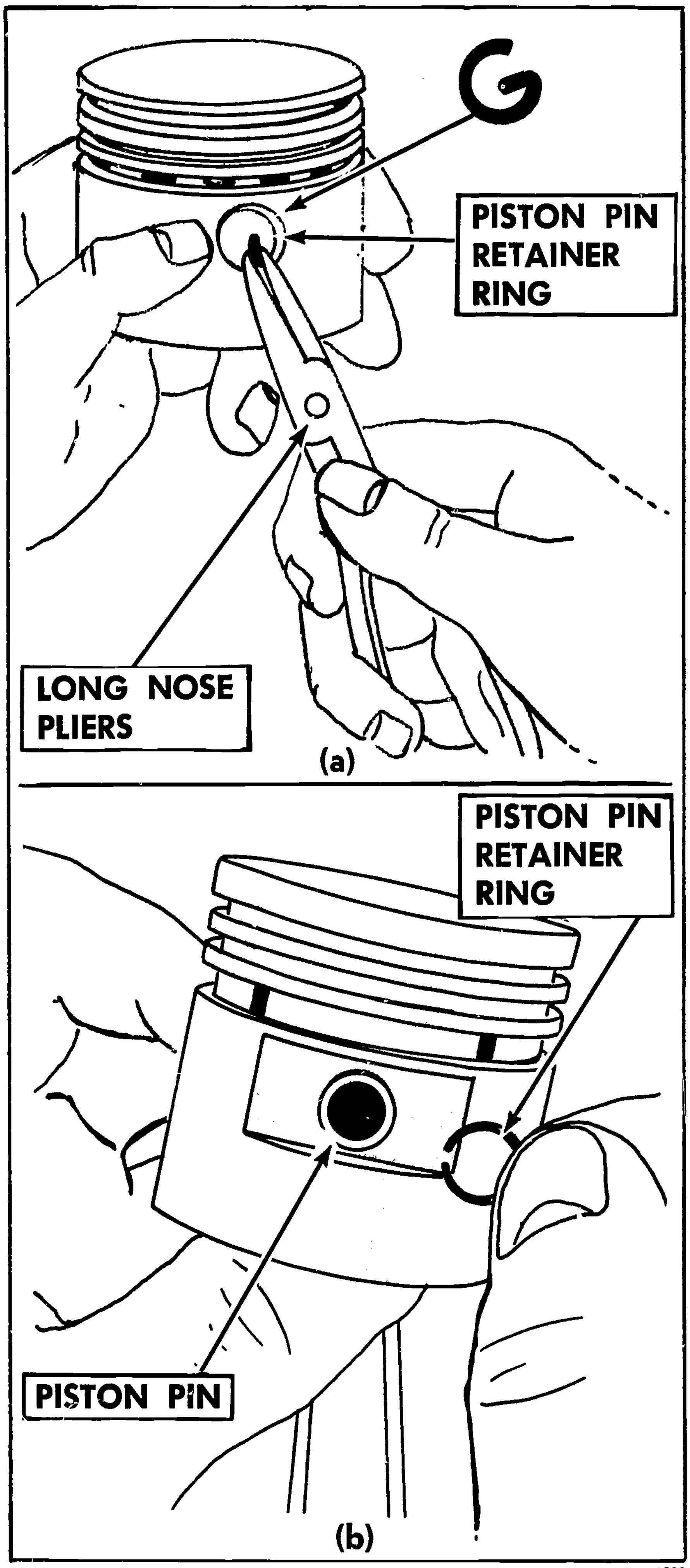


FIGURE 251. Removing piston retainer rings. (a) Some rings can be removed with long-nose pliers. (b) Others have no provision for removal with pliers and must be pried out with a special tool or a small screwdriver.

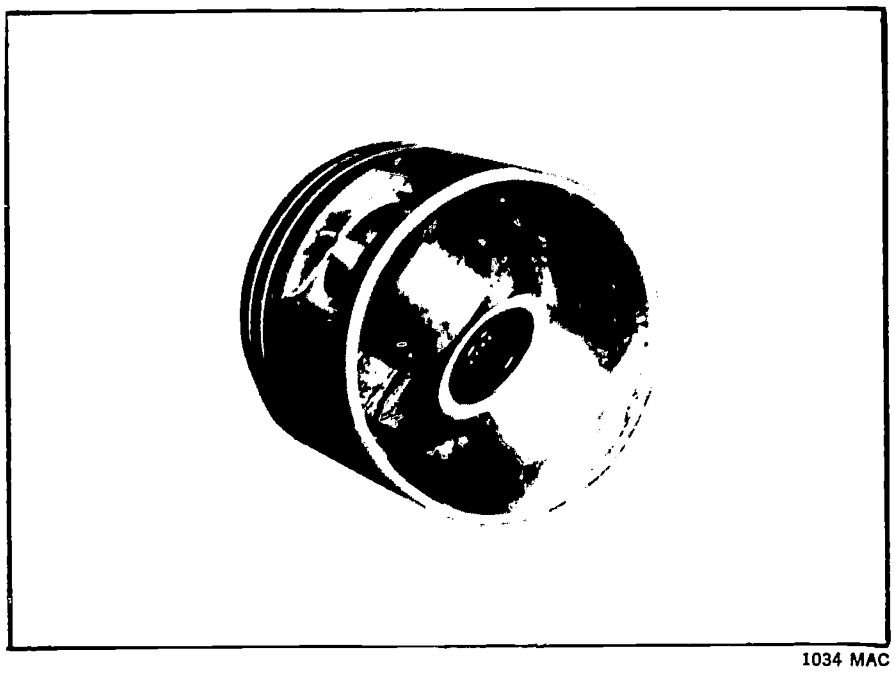


FIGURE 252. Piston with needle bearings between the pin and piston.

2. *Remove pin from piston.*

   On some 2-cycle engines there are needle bearings in the piston end of the rod also. Watch for these. Some have needle bearings between the rod and the pin. Others have needle bearings between the pin and the piston (Figure 252). Some piston pins are installed with a slight pressure fit. If yours is tight, heat the piston with a light bulb and drive the pin out with a punch (Figure 253).

3. *Remove the rings (Figure 254).*

   Use a piston-ring expander to avoid breaking

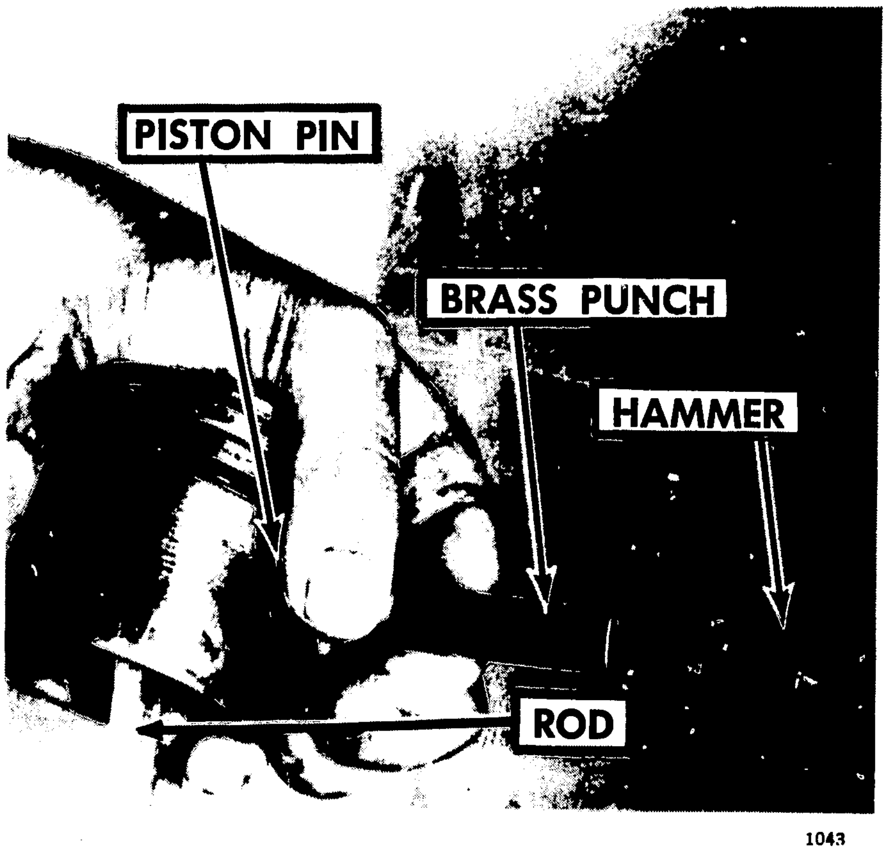


FIGURE 253. Removing the piston pin.

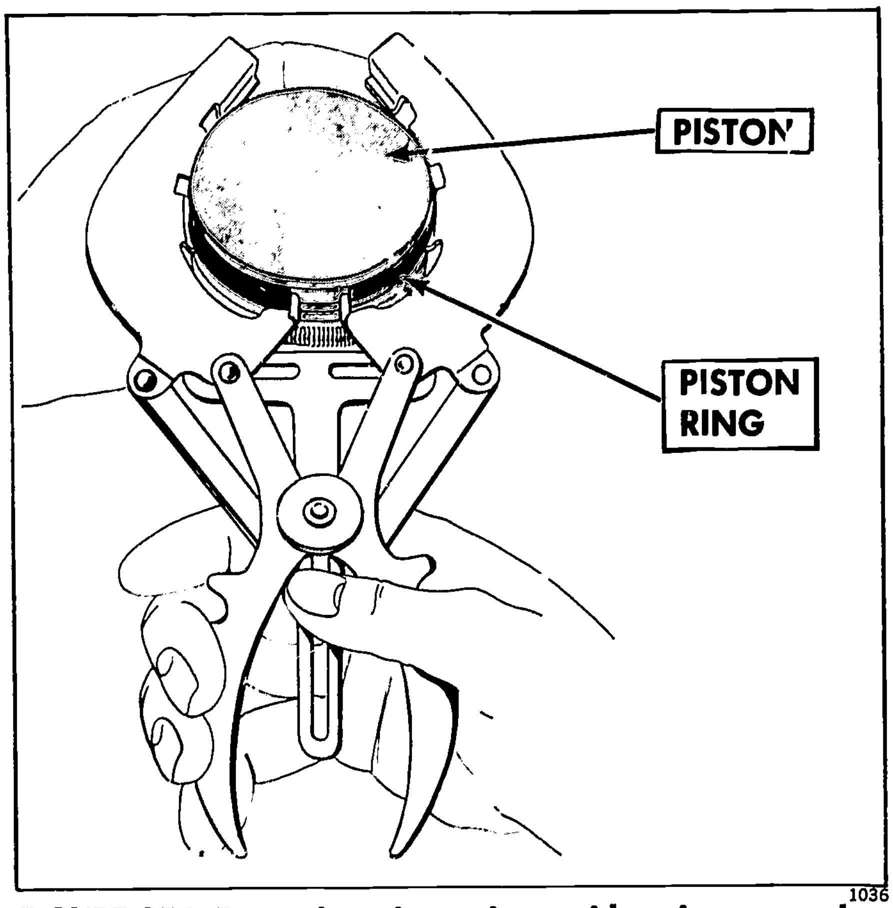


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FIGURE 254. Removing piston rings with a ring expander.

the rings. Make a note describing the position and the top and bottom of the piston rings.

Otherwise, you may not know how to reinstall them or to install new ones.

CLEANING AND INSPECTING THE PISTON AND RINGS

1. *Soak the piston in a special carbon solvent.*

   Some manufacturers supply special piston solvents. Commercial brands, such as John Deere and Stoddard solvents, are available for this purpose.

2. *Scrape the carbon from the ring groove with a broken piston ring if available.*

   The broken ring fits the ring groove. Do not scratch the piston. Special scraping tools are also available (Figure 255).

3. *Check the condition of the piston and rings (Figure 256).*

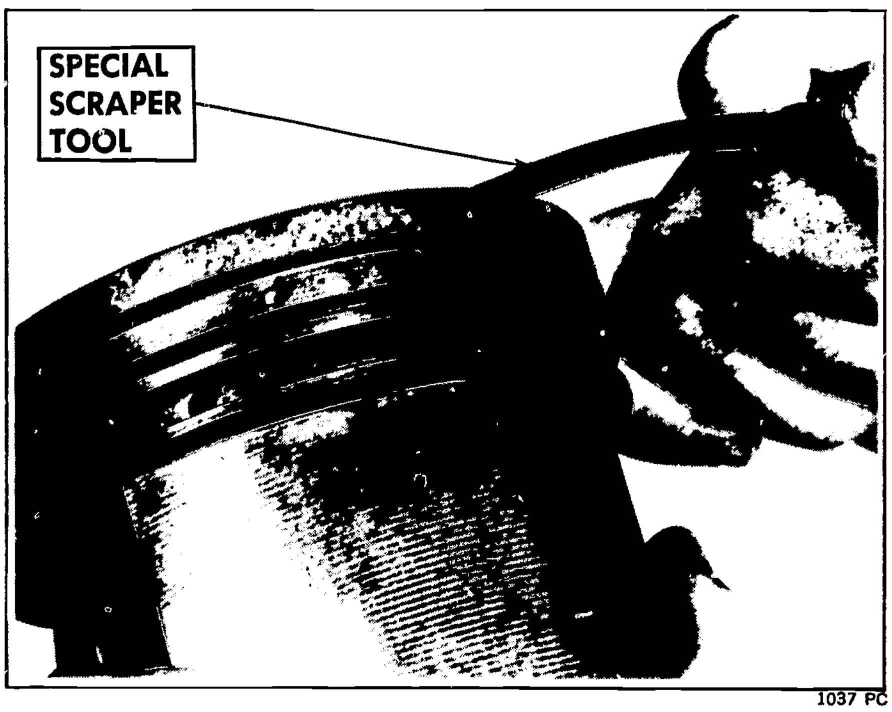

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FIGURE 255. Cleaning the ring grooves with a special tool.

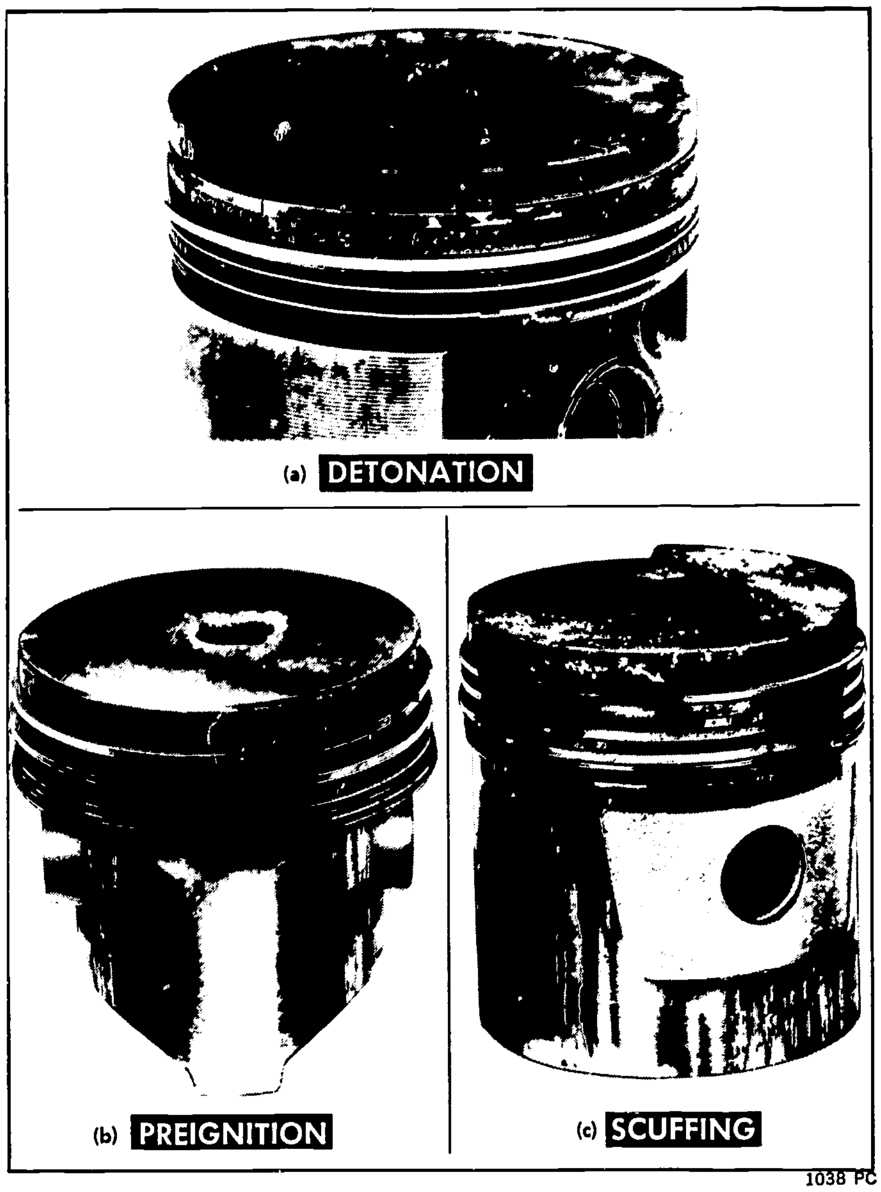

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FIGURE 256. Examples of piston failures. (a) Top land burned and melted away. (b) Hole blown in the top of the piston from preignition. (c) Piston scuffed because of lack of proper lubrication.

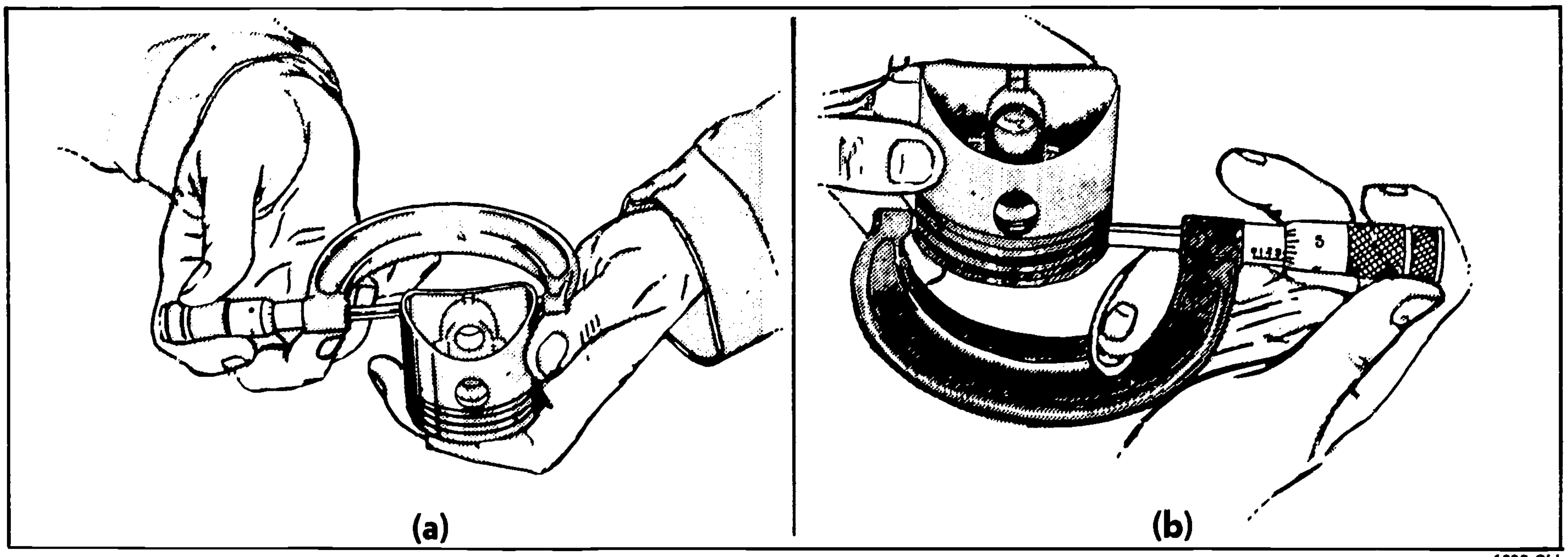


FIGURE 257. Measuring the diameter of the piston. (a) Measuring the skirt diameter. (b) Measuring the diameter at the lands.

Check for burning, top groove wear and broken or stuck rings. Such conditions are caused by detonation and preignition. Detonation causes extremely high pressure against the top ring which is resisted by the second land of the piston. As a result it is usually the second and sometimes lower lands that are broken by detonation. For an explanation of detonation and preignition, refer to "Refueling Small Engines," Volume I.

Check for scuffing and scoring. (Figure 256b and c). Scoring is the result of metals getting so hot because of lack of lubrication that they reach the melting point and tend to fuse. Scuffing is a lighter form of scoring.

Check for scratches on the piston and rings. Vertical scratches and excessive wear indicate that too much dirt and other abrasive materials are entering the engine. This is most likely the result of your letting dirt get into the engine through the air cleaner, intake manifold or the oil system. Abrasives from the use of a spark plug sand blast may also cause piston scratches.

4. *Measure the piston for wear (Figure 257).*

Refer to your repair manual for the maximum allowable wear. It gives the tolerances.

Whether or not you will be able to use your old piston may also depend on the diameter of the cylinder. There is a critical clearance between the piston and the cylinder. These clearances range from .005″ to .010″. If it is too much, the piston will "slap" against the cylinder wall and cause more wear. Note discussion under "Checking and Repairing Cylinders," page 156.

5. *Check the ring-groove wear (Figure 258).*

Use a ring-groove wear gage (Figure 258a),

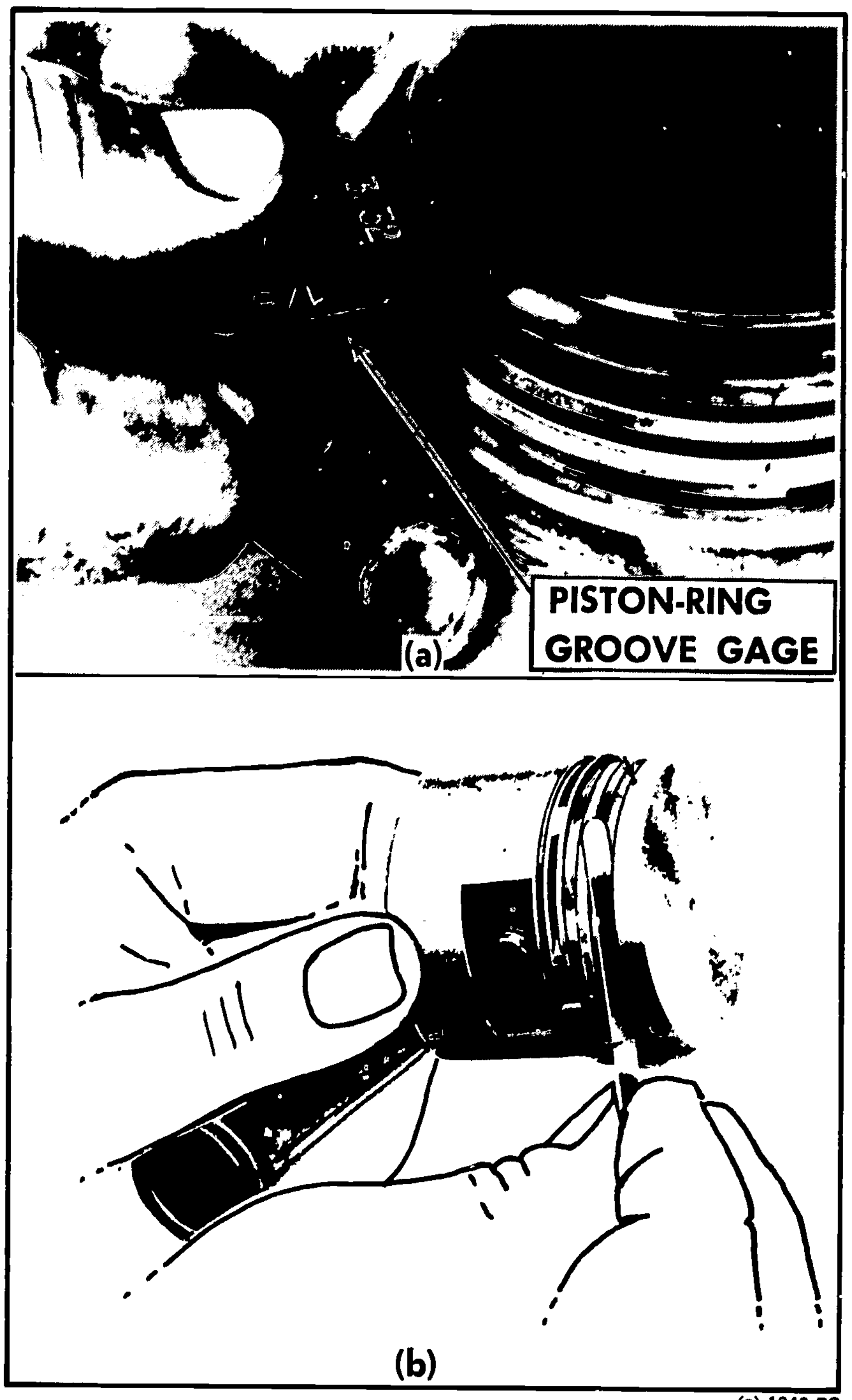


FIGURE 258. Checking the piston ring groove. (a) Checking the width, or (b) checking the clearance.

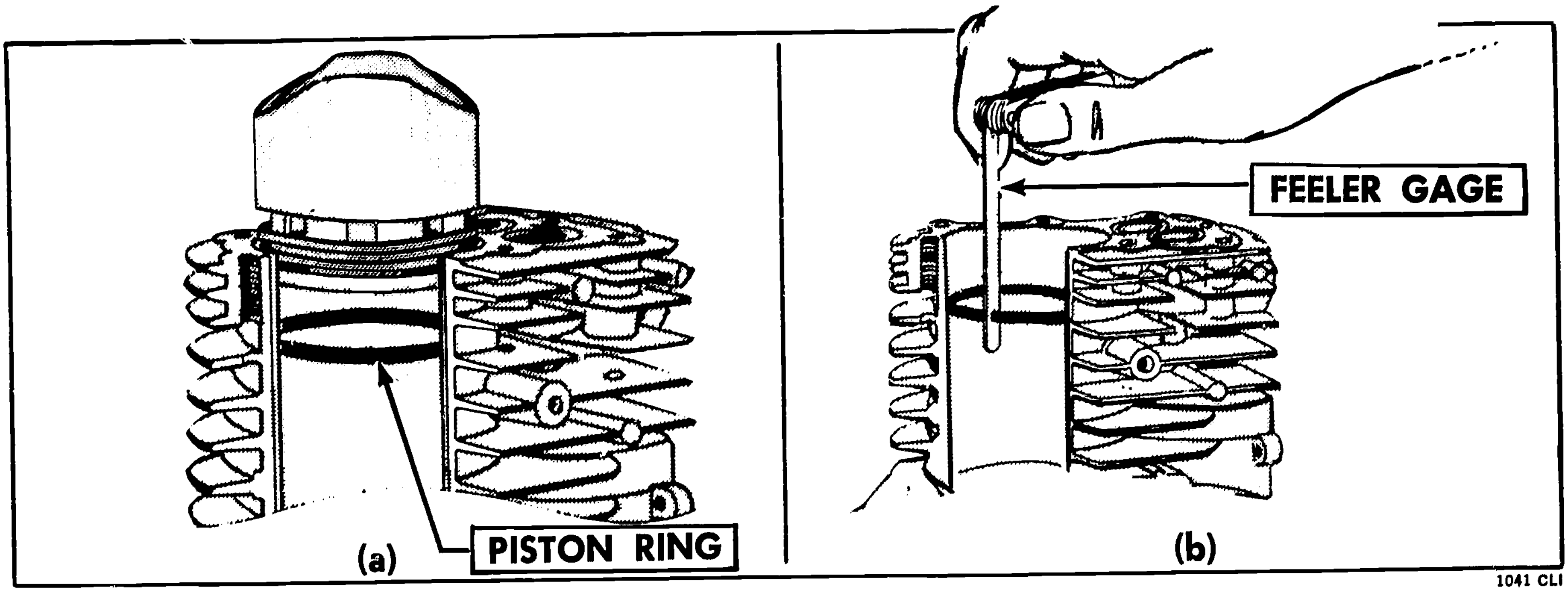


FIGURE 259. Checking the piston ring gap. (a) Insert the ring with a piston. (b) Check the gap with a feeler gage.

or install new rings and use a thickness gage (Figure 258b). See your repair manual for the proper clearance. It may range from .002 inches to .007 inches.

6. *Check the rings for wear (Figure 259a).*

   Insert the rings one at the time into the cylinder. Push the ring in with a piston (rings removed) so that it will be in its natural position in relation to the cylinder wall (Figure 259a). Measure the ring gap with a feeler gage (Figure 259b).

   Refer to your repair manual for the proper ring gap. It ranges from .007 inches to .045 inches. If the *ring gap is too much* and your cylinder is not worn too much, replace the rings with a new set of standard-size rings. Special chrome rings are available for warped cylinders.

INSPECTING THE PISTON ROD AND BEARINGS

1. *Check the condition of the rod.*

   Inspect for straightness and for cracks.

2. *Install rod temporarily and check for side clearance between the rod and the crankshaft.*

   Check with a feeler gage.

   Refer to your repair manual for the proper tolerance. Too much clearance indicates excessive wear. If left in that condition, the rod will "slap" during operation and increase the wear rate.

3. *Remove rod from crankshaft.*

4. *Place a piece of plastigage across the full width of the bearing cap (Figure 260a).*

7. *Check the piston pin and bore.*

   Refer to your repair manual for the proper dimensions. Use an inside gage and micrometer for the piston-pin bore and an outside micrometer for the pin.

   Some manufacturers make oversize piston pins. If they are available, you can rebore the piston and install the oversize pin. Others supply new connecting rods and bearings to use when the holes in the piston are worn. Then a standard-size pin can be used. Installing oversize pins and bearings is a delicate operation and should be done at a shop which is well equipped for this job.

   If your piston has **needle bearings** that show flat spots or do not fit snugly in position, replace them.

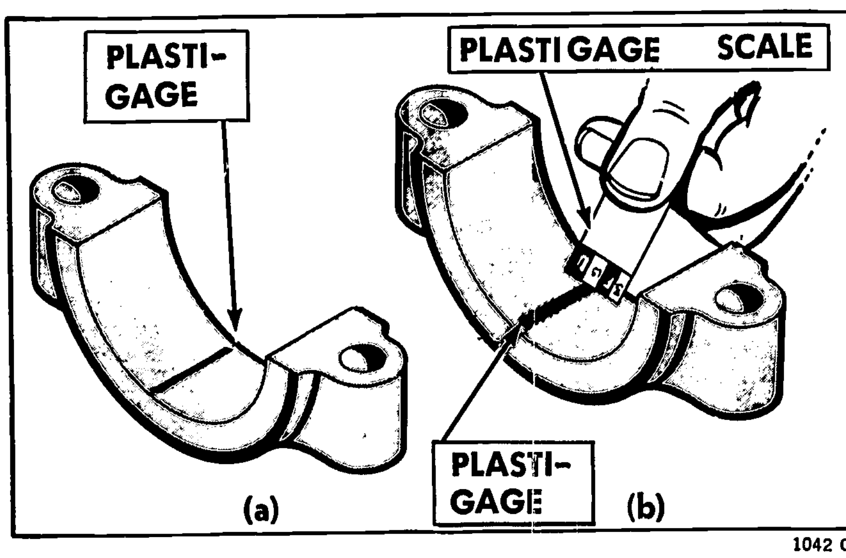


FIGURE 260. Checking rod-bearing clearance with plastigage. (a) Plastigage is placed in the bearing cap. (b) Checking the width of the expanded plastigage after the rod-bearing cap has been installed and tightened to the specified torque and then removed.

"Plastigage" is a plastic ribbon that is designed to expand in proportion to the amount of pressure applied to it.

5. *Install the rod and cap on the crankshaft.*
6. *Tighten the cap nuts or screws to the torque given in your repair manual.*
7. *Remove the rod cap and measure the flattened plastigage at its widest point with the plastigage scale (Figure 260b).*
   The number corresponding to the width of the flattened plastigage is the bearing clearance in thousandths of an inch. If the **clearance is more than allowed** in your repair manual, replace the rod or rod bearing. Some manufacturers, however, recommend filing away some of the rod-bearing-cap flange. If you do, be sure to take the same amount off of both sides. Very little filing will be needed.

   Too much filing will cause the bearing to be out of round and will result in very rapid wear.

INSTALLING THE PISTON RINGS

1. *Check the end gap of each new ring (Figure 259b).*

   If the **end gap is too small**, file the end of the ring squarely to the proper gap. If the **end gap is too large** and the cylinder is the proper size, discard the ring.

2. *Apply crankcase oil to the rings and pistons.*
3. *Install the rings on the piston (Figures 259 and 261).*

   Begin with the bottom ring. If you use expander springs under the lower oil ring, install them first.

   Use a piston ring expander if available. If not available, you can install them by hand. Start open end of ring in slot first; then push it over top of piston into position.

   Be sure you install them right side up. Some are marked "top"; others are not marked. If not labeled, you cannot tell by looking at the rings how they should go. Refer to the notes you made when removing the rings and/or to your operator's manual. Most manuals give specific instructions (Figure 262).

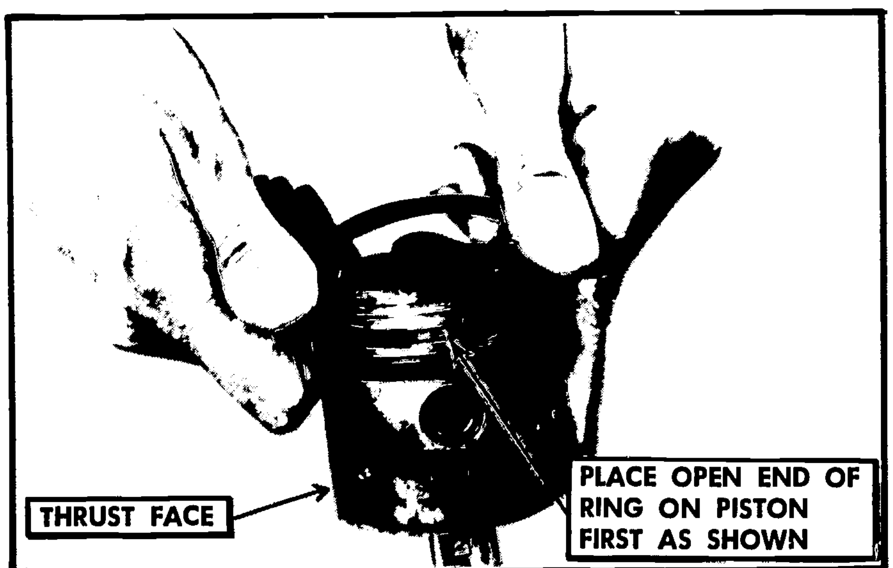


FIGURE 261. Installing rings without a ring expander.

4. *Check the rings for freedom of movement in the grooves.*

   If they are not free to move in the grooves, there is a danger of their scoring the cylinder wall and breaking.

5. *Stagger the ring gaps.*

   Some claim that if the ring gaps are in line on a 4-cycle engine, the engine will lose compression and use oil. Others dispute this claim.

   With **2-cycle engines**, however, it is agreed you should have the ring gaps on any two adjacent rings 180° apart. Some have stops at the ring-gap position to insure this.

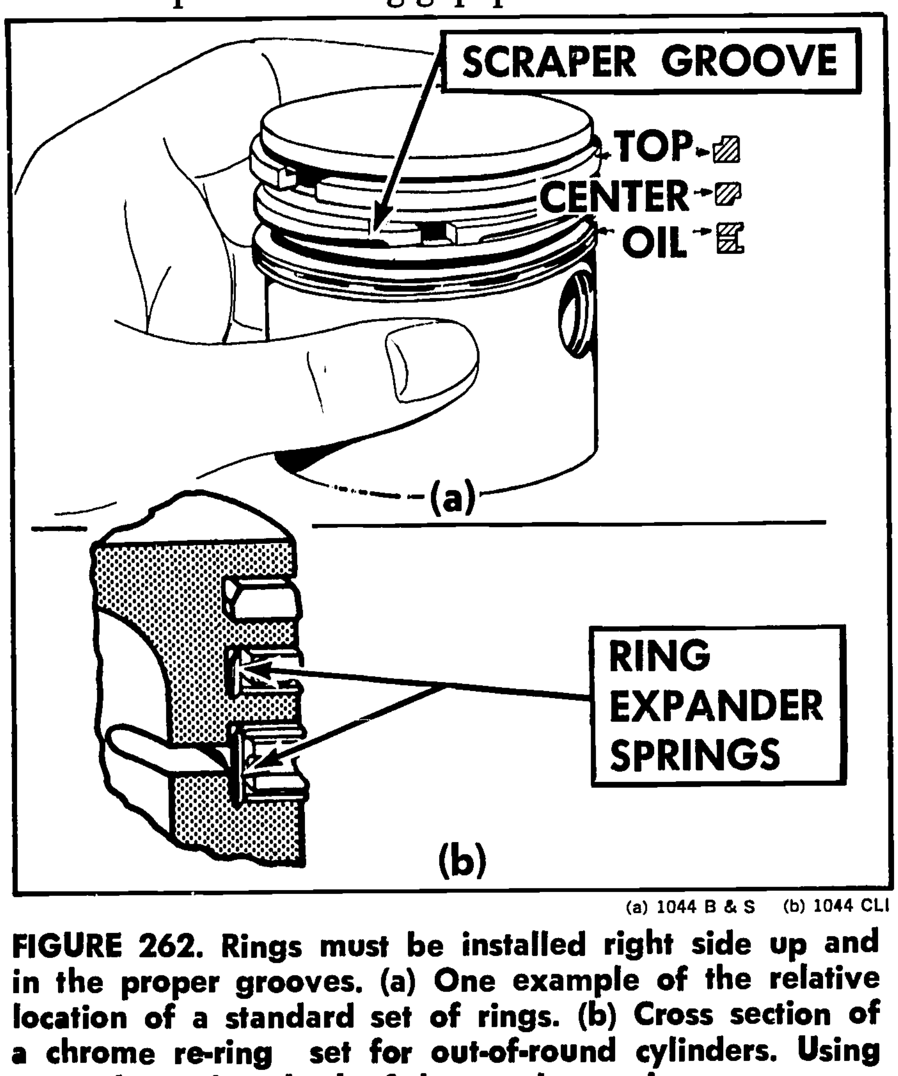


FIGURE 262. Rings must be installed right side up and in the proper grooves. (a) One example of the relative location of a standard set of rings. (b) Cross section of a chrome re-ring set for out-of-round cylinders. Using expander springs back of the two lower rings.

INSTALLING THE PISTON PIN

1. *Install the needle bearings if used.*

   Coat them with multi-purpose grease so they will stay in place.

2. *Install a lock ring on one side of the piston.*

3. *Apply oil to the rod bearing and piston bore.*

4. *Align the rod bearing with the piston bore and insert the piston pin.*

   Insert solid ends first on hollow pins. Some are easy to install with a handpress fit. Others are "sweat fitted."

   If the *pin appears to be too large,* it probably requires sweat fitting. You will have to heat the piston to expand the hole, and shrink the pin by cooling with dry ice before installation.

   Pistons on cross-scavenged, **2-cycle engines** must have the abrupt side of the piston head facing the fuel intake.

   Some pistons have hollow pins with one closed end. With these the closed end should be turned toward the exhaust port.

5. *Install the second piston-pin lock ring.*

INSTALLING THE PISTON-AND-ROD ASSEMBLY

If you are doing a complete overhaul job, before installing the piston and rod, proceed with the steps under "Repairing Crankshaft Assemblies," page 174.

To install the piston-and-rod assembly, proceed as follows:

1. *Oil the piston rings and cylinder.*

   Oiling makes the installation easier and supplies lubrication when the engine is started — before normal lubrication can be supplied.

2. *Install ring compressor on rings (Figure 263).*

   Compress the rings completely; then release slightly.

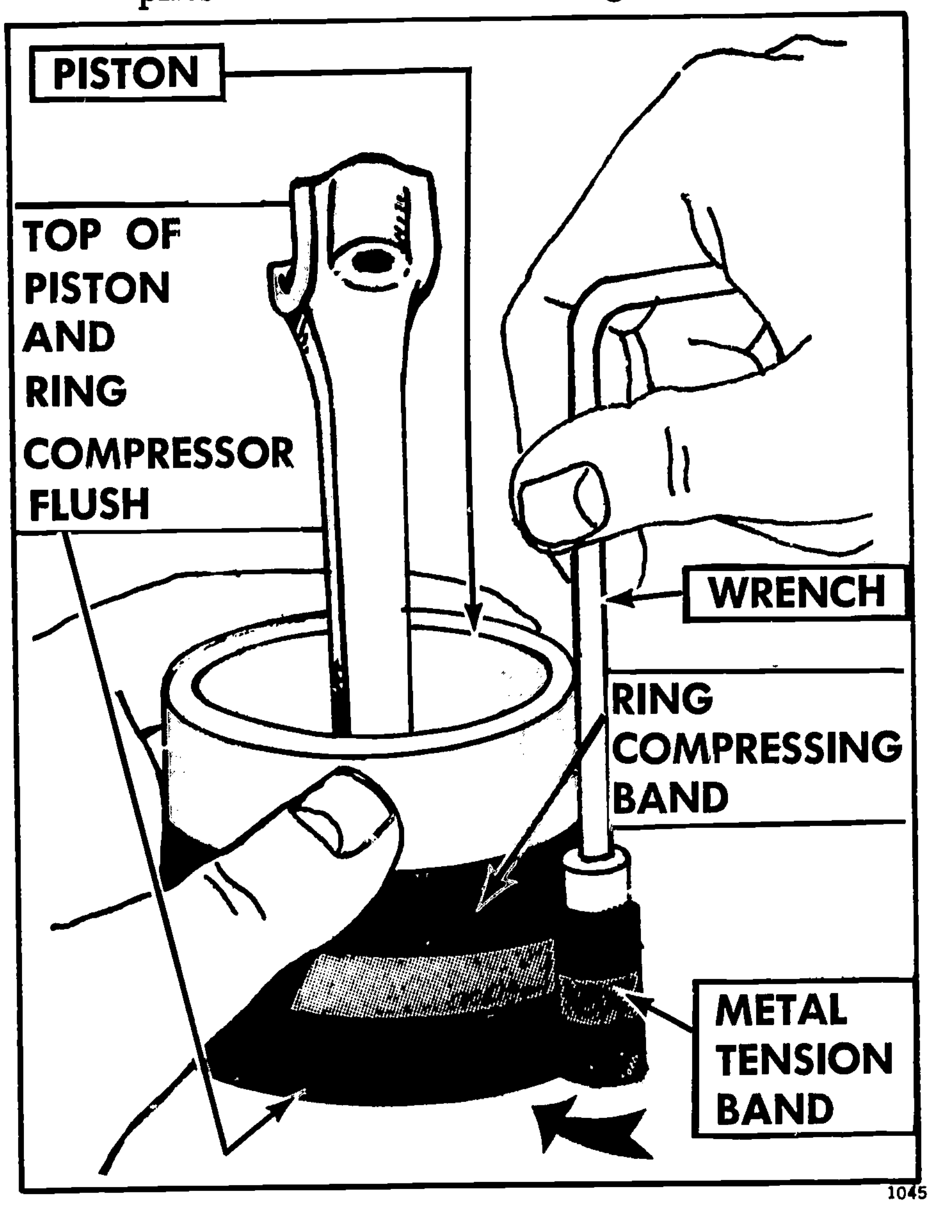


FIGURE 263. Attaching a piston-ring compressor.

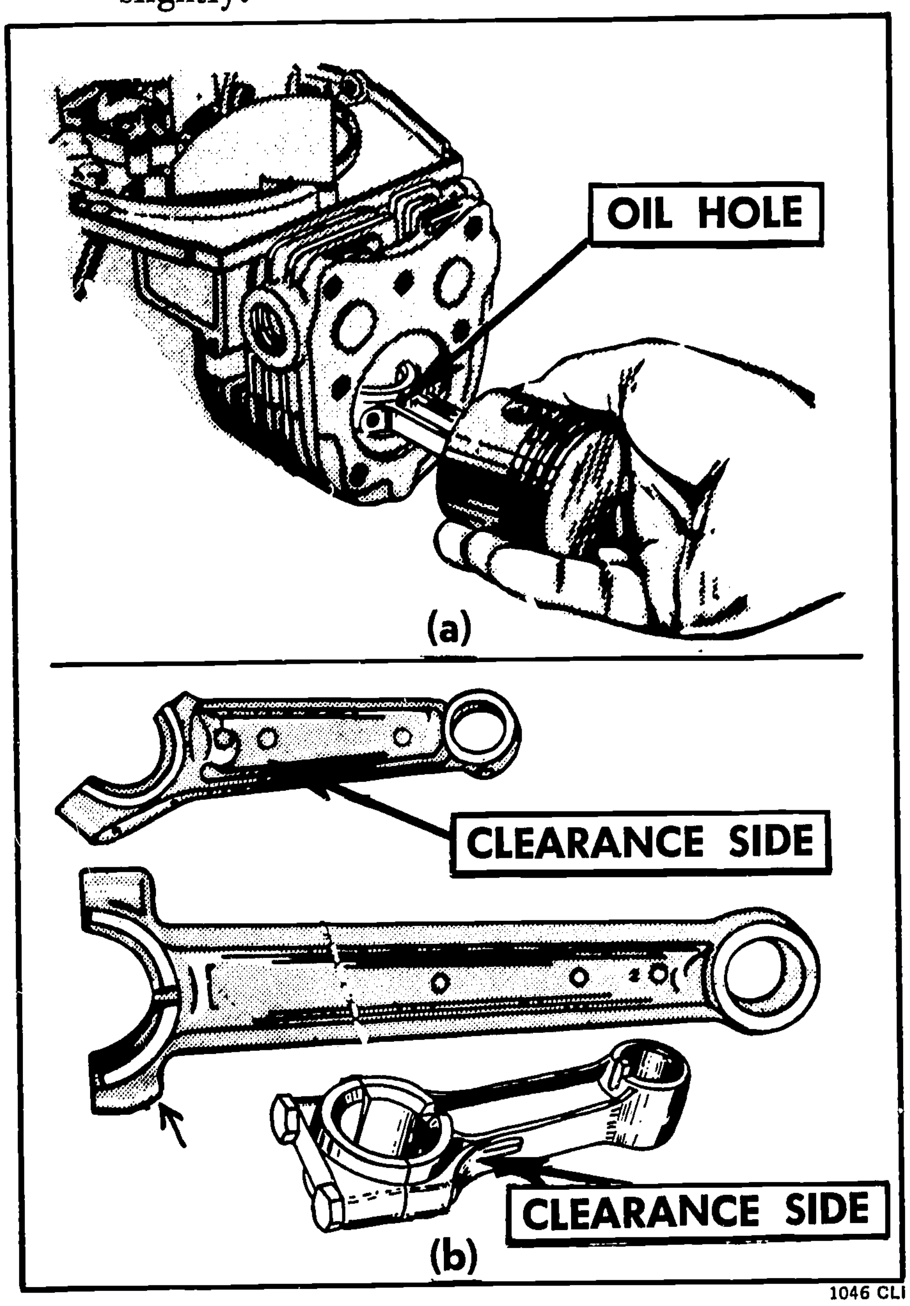


FIGURE 264. Some rods must be installed in a certain position. (a) Rod with a special oil hole. (b) Special-clearance rods.

1047 KOH

FIGURE 265. Tapping the piston into the cylinder.

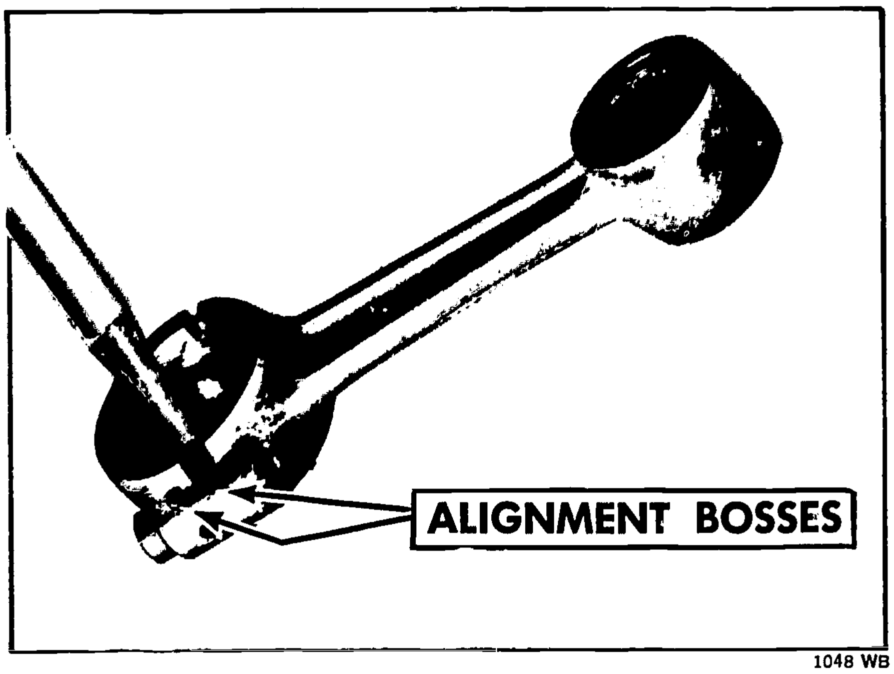
3. *Place the piston and rod over the cylinder (Figure 264a).*

   Some engines have a certain way the rod fits on the crankshaft (Figure 264).

   For example, some engines with horizontal cylinders have a special oil hole in the rod aligned with the crankshaft. This oil hole must be on the top side so that oil will flow to the bearing (Figure 264a). Others have a special clearance provision to bypass the bottom edge of the cylinder as the crankshaft turns (Figure 264b).

4. *Center ring compressor over the cylinder, and tap the piston and rings into the cylinder (Figure 265).*

5. *Install the rod-bearing cap.*



1048 WB

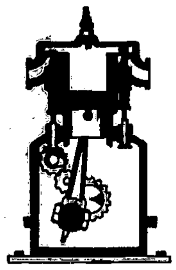
FIGURE 266. Match marks embossed on rod and rod-bearing cap.

   Install the oil dipper if it is attached to the rod-bearing cap. There should be a boss or some marking for aligning the cap to the rod (Figure 266). If not, refer to the notes you made during removal. The rod and cap are made in two separate pieces and then tightened together and bored. If you turn the cap around, you may change the bore alignment.

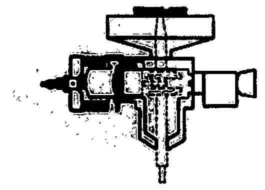
6. *Install the nuts or cap screws and apply the proper torque.*

   Use a torque wrench and tighten to specifications given in your repair manual. These specifications vary with the size of the engine. They range from 35 inch-pounds to over 400 inch-pounds.

   When the rod bearing was bored, the cap was tightened to a certain torque. This is why it is necessary for you to apply the same torque that was applied when the rod was bored so that the bearing will not be distorted.



A. CHECKING AND REPAIRING CYLINDERS



There are three types of cylinders used on small engines. They are as follows: (1) **cast iron** — the cylinder is part of the cast-iron block; (2) **aluminum** — the cylinder is part of the aluminum cylinder block; and (3) **steel sleeves** in an aluminum cylinder block.

Even though aluminum is soft, compared to cast iron or steel, satisfactory wear has been experienced by using aluminum cylinders when proper rings are used. One experiment showed only a .004″ total ring-and-bore wear after 1,000 hours of operation.

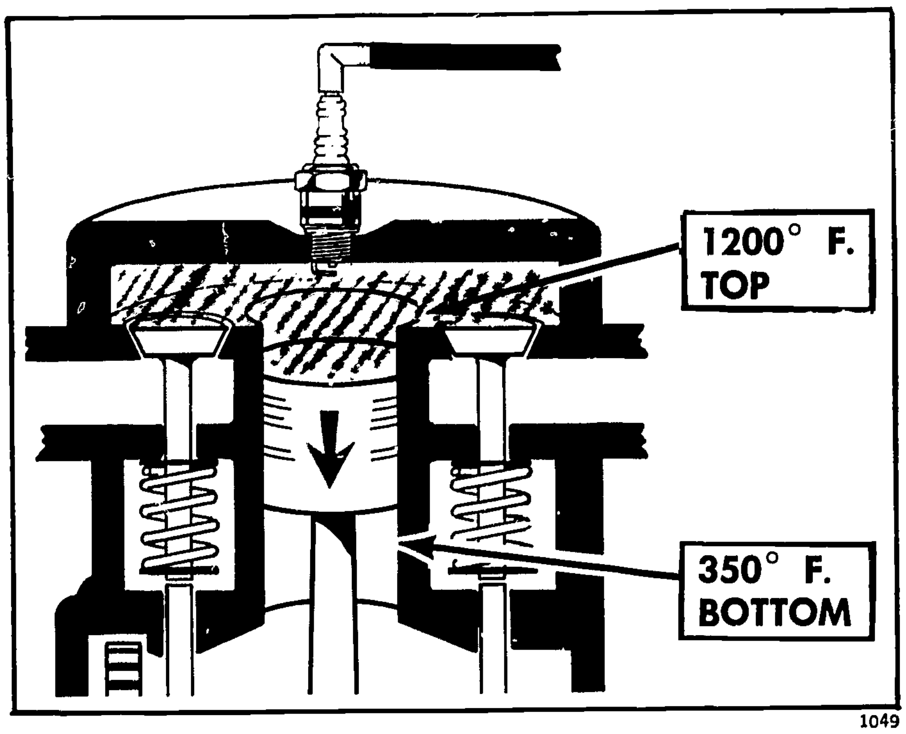


FIGURE 267. The cylinder is subjected to extreme temperature differences.

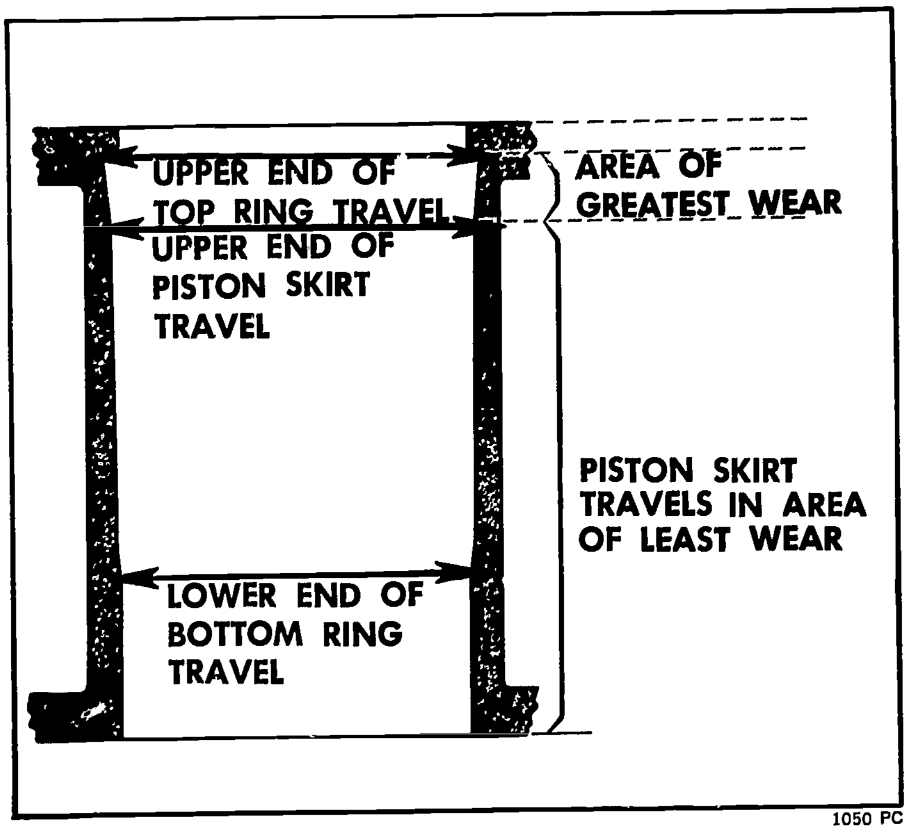


FIGURE 268. Cylinder cross-section showing the area of greatest wear.

Cylinders are subjected to extreme temperature differentials. The top of the cylinder is next to the combustion chamber, where the temperature may reach 1200° F. The bottom of the cylinder is in the crankcase (Figure 267) where temperatures are comparatively cool. The cylinder walls on all air-cooled engines take the heat from the piston and rings and conduct it to the cooling fins. This is why you should always keep the cooling fins free of dust, trash and oil.

Cylinders wear mostly at the top (Figure 268). This is the point of maximum stress, where the greatest force is exerted against the piston because of combustion. If the cylinder is worn very much, there is a ridge left at the top of the cylinder which should be removed before you attempt to remove the piston. Otherwise, there is a danger of breaking the rings and damaging the piston. See Figure 245. Of course, if you rebore the cylinder, this will be bored out.

Repairing cylinders is discussed under the following headings:

1. Tools and materials needed.
2. Inspecting the cylinder.
3. Reboring the cylinder.

TOOLS AND MATERIALS NEEDED

1. Inside micrometer or cylinder gage
2. Hone and/or boring bar (coarse and fine honing stones)
3. Clean rags
4. Cleaning solvent (mineral spirits, kerosene or diesel fuel)
5. Soap and water
6. Paper and pencil
7. Cutting fluid

INSPECTING THE CYLINDER

There are three reasons for measuring the cylinder diameter: (1) to determine if it is **worn too much for a new standard ring** to seat properly — tolerances range from .003 to .008 inch; (2) to determine if the cylinder is **warped or out of round** — tolerances range from .0015 to .003 inch; (3) to determine if the cylinder has **too much taper** — tolerances range from .004 to .008 inch.

If you are unable to repair the cylinder by reboring without exceeding any of these tolerances, you will have to replace the cylinder block.

1. *Clean the cylinder inside and out with petroleum solvent.*

   Clean all dirt from the cooling fins and all carbon from the cylinder head.

2. *Inspect the cylinder block for cracks, stripped bolts threads, broken fins and scored cylinder walls.*

   Scored cylinder walls are a sign of overheating and/or lack of proper lubrication.

1 CYLINDER DIMENSION	2 Actual Size (Present)	3 Standard Size (New)	4 Actual Wear	5 Maximum Wear Allowed	6 Reboring Required	7 Minimum Oversize	8 Rebore to Oversize Dimension
Top	2.0050	2.0000	.0050	.0030	Yes	.0100	2.0100
Center	2.0030	2.0000	.0030	.0030	No		2.0100
Bottom	2.0010	2.0000	.0010	.0030	No		2.0100
ROTATE 90° TO ABOVE MEASUREMENTS							
Top	2.0070	2.0000		.0030			
Center		2.0000		.0030			
Bottom		2.0000		.0030			

1051

FIGURE 269. Chart for determining cylinder wear. The figures shown are examples only.

Dirt causes uniform wear, not scoring.

3. *Prepare chart similar to the one shown in Figure 269.*

   Record the standard size dimension of your cylinder in column 2 and the maximum wear allowable in column 5 from your repair manual.

4. *Measure and record the diameter of the cylinder for wear (Figure 270).*

   Take *measurements* in six places (Figure 271) and record in column 2 (Figure 269). (1) Start *at the top* of the piston-ring travel, then (2) *at the center* of the piston-ring travel, and then (3) *at the bottom* of the piston-ring travel. Rotate gage 90 degrees and repeat measurements.

5. *Determine the amount of cylinder wear for each position.*

   Subtract the "Standard Size" dimensions (Column 3) from the "Actual Size" dimensions (Column 2). This gives the amount of actual wear. Record the amount of wear in column 4.

   $$\text{Example: } \underset{\text{(col. 2)}}{2.0050''} - \underset{\text{(col. 3)}}{2.000''} = \underset{\text{(col. 4)}}{.0050''}$$

6. *Compare the amount of "Actual Wear" (column 4) with "Maximum Wear Allowed," column 5 (Figure 269).*

   If the actual wear is greater than the maximum wear allowed at any of the six positions, rebore the cylinder and get a new oversize piston and rings to fit it. Cylinders that cannot be rebored within the oversize limits must be replaced. Most manufacturers make oversize pistons and rings in increments of .010″, .020″, and .030″ oversize.

   If the actual wear in column 4 is less than the maximum wear allowed in column 5, in all positions, proceed to step 8.

7. *Determine the oversize dimensions of the cylinder and record them in the chart.*

   $$\text{Example: } \underset{\text{(col. 3)}}{2.000''} + \underset{\text{(col. 7)}}{.010''} = \underset{\text{(col. 8)}}{2.0100''}$$

   Bore to the smallest oversize that will even up the cylinder. See column 8, Figure 262.

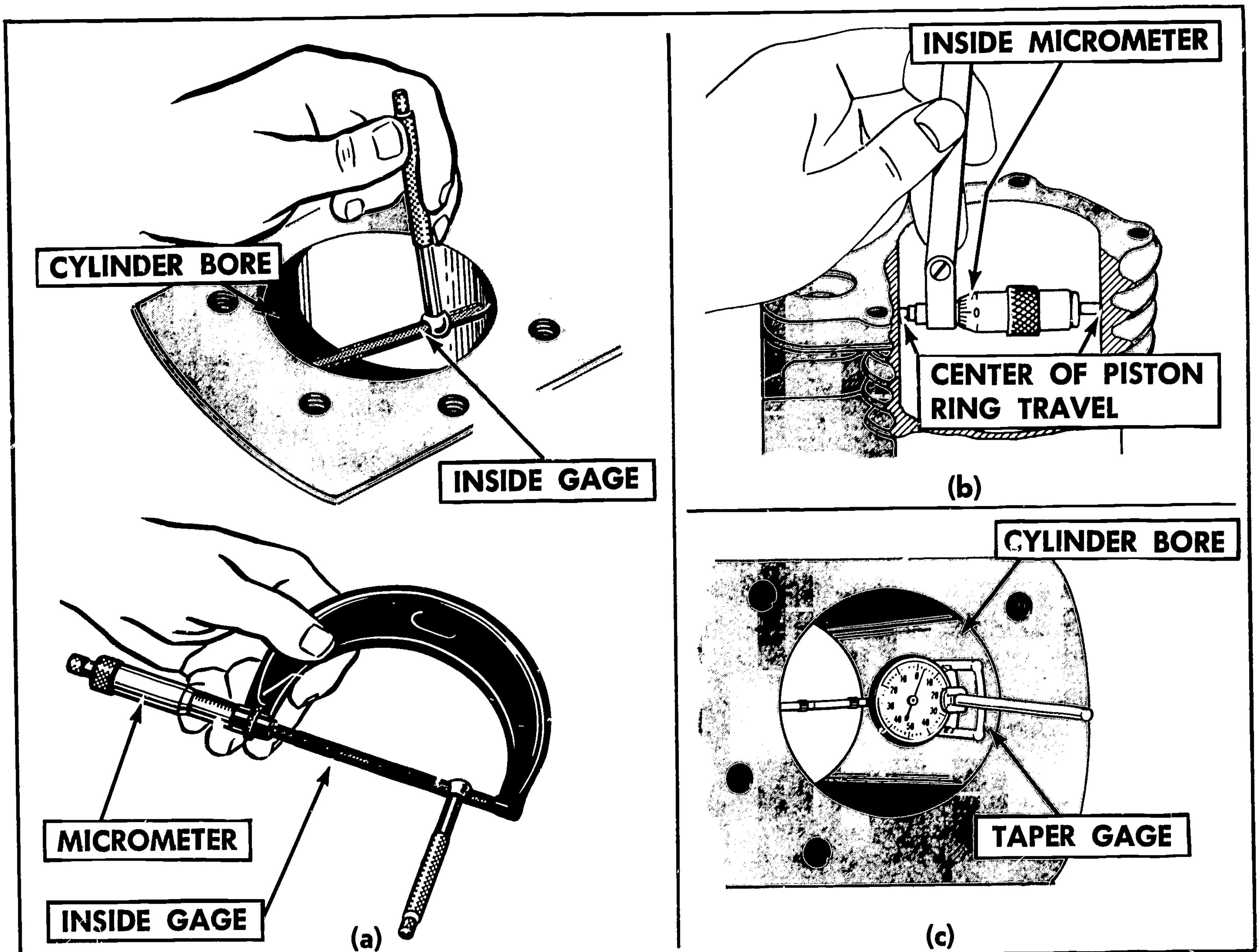
8. *Check to see if the cylinder is out of round.*

   Prepare a chart similar to the one shown in Figure 272 and record the measurements from columns 2 and 3 (Figure 269) into column 2 (Figure 272).

   Subtract the dimensions at each of 3 measurements from the measurements taken at 90° at the same location in the cylinder.

   $$\text{Example: } \underset{\text{(col. 3)}}{2.0070''} - \underset{\text{(col. 2)}}{2.0050''} = \underset{\text{(col. 4)}}{.0020''}$$

   If the difference at any of the three locations is greater than the maximum allowable out-of-round dimensions, you must replace the block or rebore the cylinder. **If the actual out-of-round in column 4**



(a and c) 1052 CASE (b) 1052 B & S

FIGURE 270. Methods for measuring the diameter of a cylinder. (a) Adjustable inside gage and micrometer for measuring gage length. (b) Inside micrometer, (c) Special gage and dial indicator for measuring cylinder taper.

is less than the maximum out-of-round allowance in column 5, proceed to step 9.

9. *Check the cylinder for taper.*

Subtract the measured dimensions at the bottom of the cylinder from the measured dimensions at the top (Figure 272).

If the difference exceeds the maximum allowable given in your repair manual, replace the block or rebore the cylinder.

NOTE: If any one dimension in the cylinder exceeds the factory allowance, the cylinder will require resizing; and there is no need to measure all the other dimensions.

If the taper is within allowable tolerance, hone the cylinder lightly and reinstall your standard-size piston with new standard-size rings.

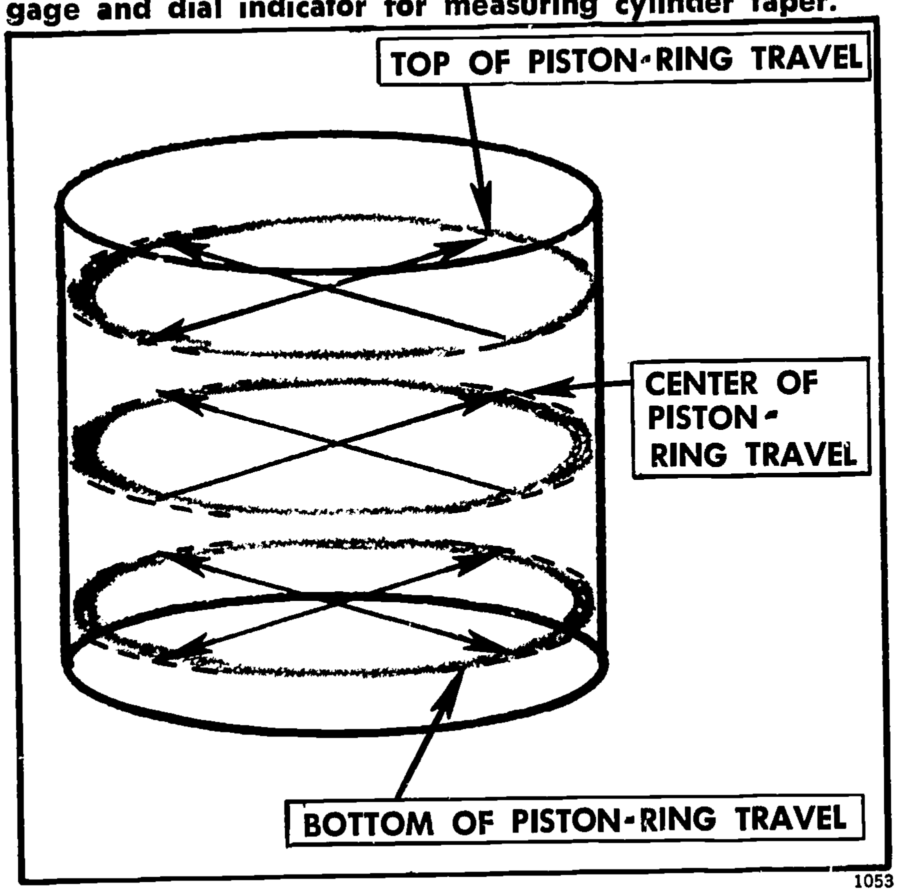


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FIGURE 271. Measure the cylinder diameter in six different positions.

1	2 Cylinder Dimension	3 Cylinder Dimension at 90°	4 Actual Out of Round Computed	5 Maximum Allowance Out of Round	6 Maximum Allowance for Taper	7 Reboring Required
Top	2.0050	2.0070	.0020	.0013		Yes
[illegible]						
[illegible]						

1054

FIGURE 272. A chart for determining the amount of cylinder is out-of-round. The figures are examples only.

REBORING THE CYLINDER

1. *Anchor the cylinder block (Figure 273).*
2. *Select the proper boring tools (Figure 274).*

   Hones for aluminum are different from those of cast iron or steel.

   A boring bar uses a high carbon steel cutting tool. Procedures given here apply only to the use of a hone.

   Most manufacturers recommend a "**hone**" for reboring small engines. This machine uses coarse honing stones for removing most of the bore and fine honing stones for finishing.

   A **boring bar** (Figure 274c) is necessary

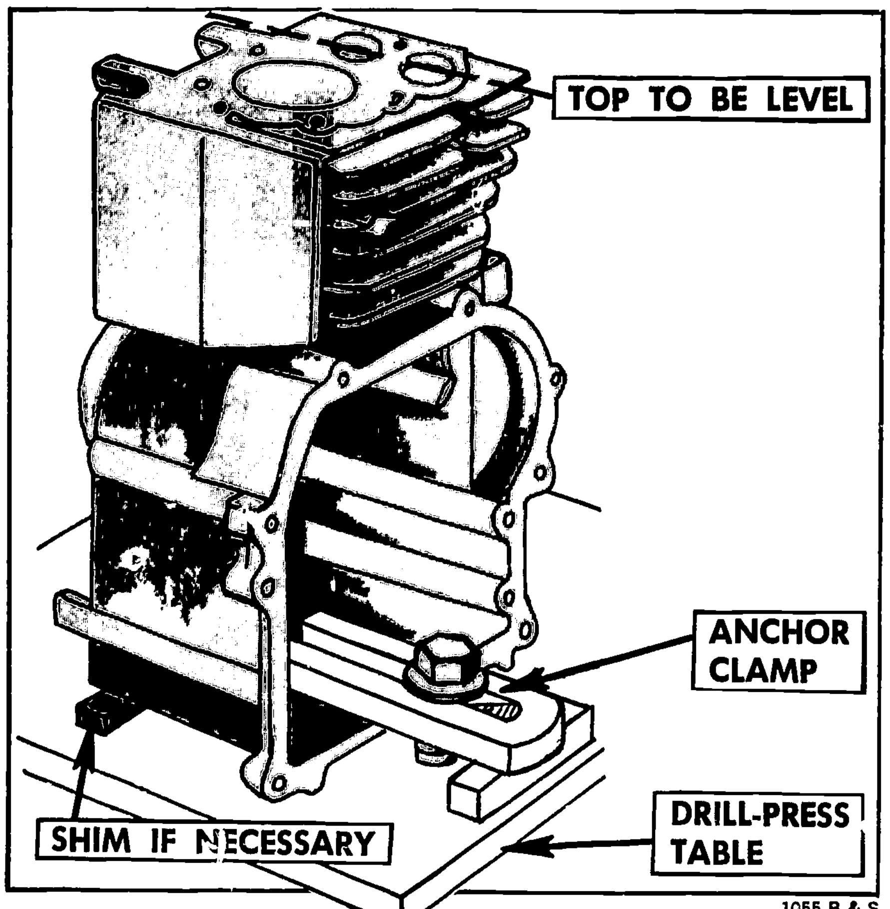


FIGURE 273. Anchor the cylinder block before reboring the cylinder.

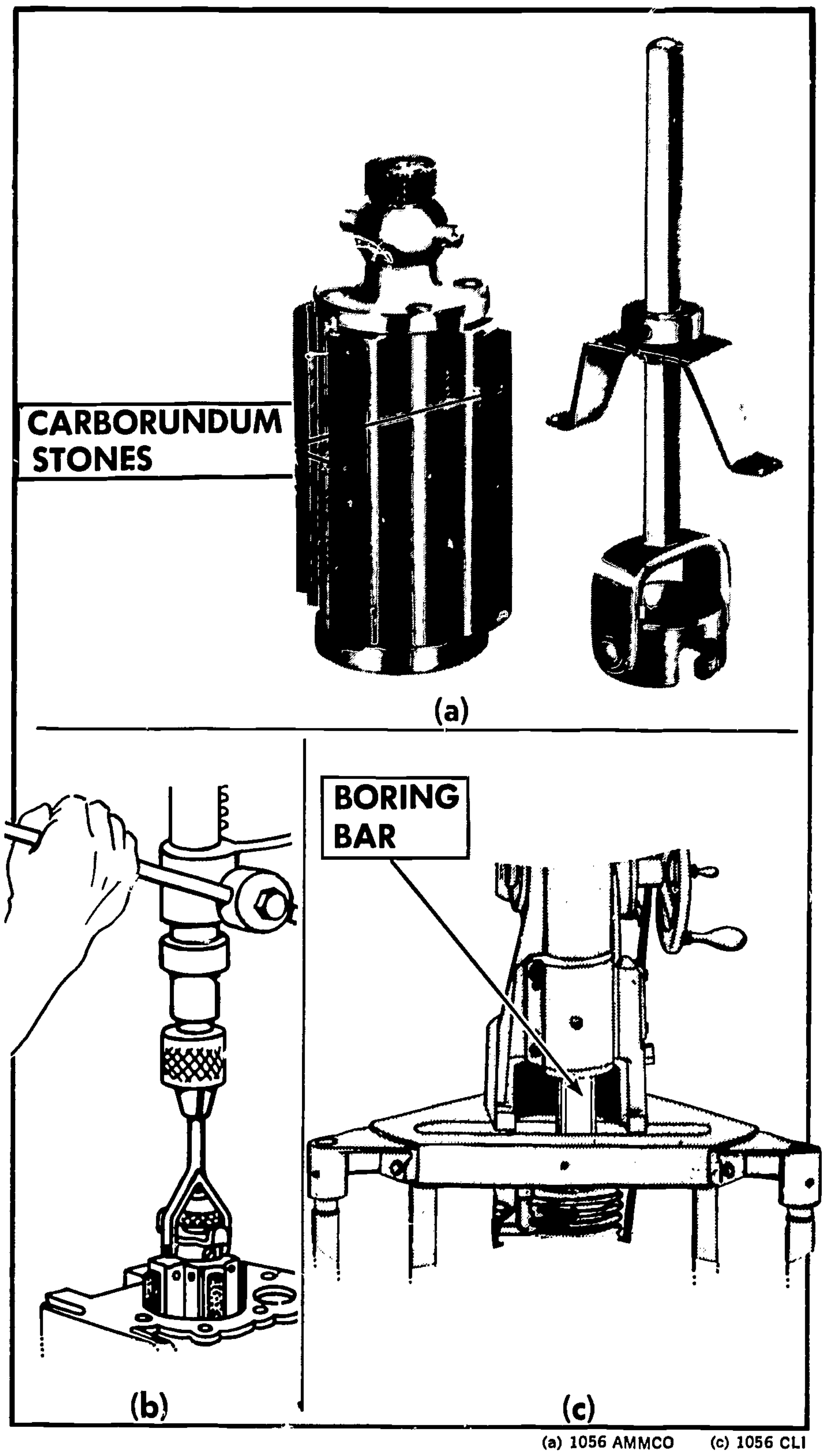
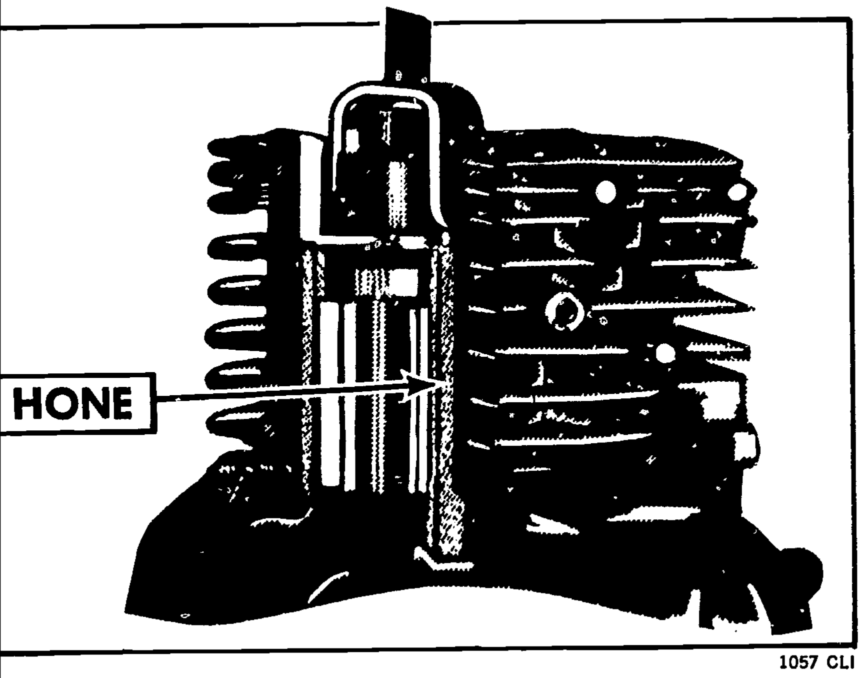


FIGURE 274. Two methods for reboring cylinders are as follows: (a and b) hone with carborundum stones, and (c) boring bar with a cutting tool.



GURE 275. Allow the stones to protrude ½ to 1 inch elow and above the cylinder when honing.

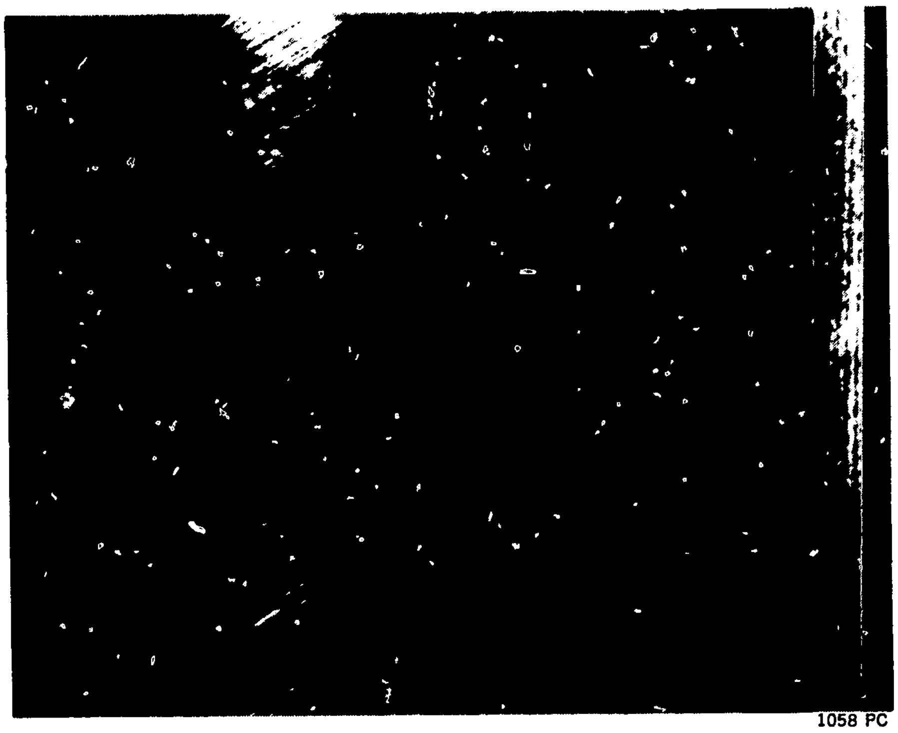


FIGURE 276. To aid in seating the new rings, the cylinder should have a cross-hatched surface.

for reboring some cylinders on 2-cycle engines — ones that do not have a removable head. It is difficult to rebore them with a hone without tapering the cylinder. Some manufacturers recommend replacing rather than reboring this type of cylinder.

Be sure the hone is in good condition and the stones are not worn to much.

3. *Set the drill press to operate from 450 to 700 r.p.m.*

4. *Lower the hone to the point where the lower end protrudes 1/2 to 3/4 inch past the end of the cylinder (Figure 275).*

5. *Rotate the adjusting nut on the hone until the stones come in contact with the cylinder wall at the narrowest point.*

   The narrowest point is normally on the crankcase end of the cylinder.

6. *Turn the hone by hand.*

   If you cannot turn it, it is too tight. Loosen it until it can be turned by hand.

7. *Start the drill.*

8. *Move the hone up and down in the cylinder approximately 40 cycles per minute.*

   Usually it is necessary to work out the bottom of the cylinder first because it is smaller. Then when the cylinder begins to take a uniform diameter, move the hone up and down all the way through the cylinder. Follow the hone manufacturer's recommendation. Some require oil, and some will not work with even a small amount of oil on the cylinder wall.

9. *Check the diameter of the cylinder regularly during honing.*

   Stop the drill before measuring, and remove the hone from the cylinder.

10. *Change the stone grit size.*

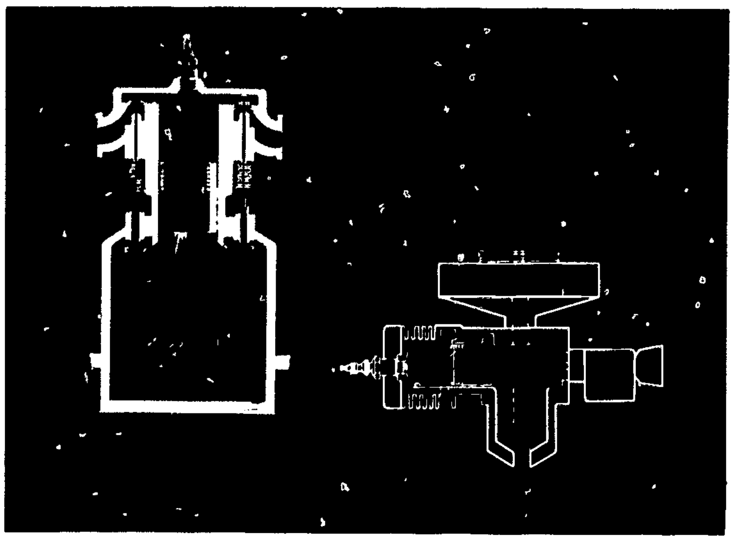
    When the cylinder is approximately .002 inch within the desired bore, change to fine stones and finish the bore. Finish should not be perfectly smooth. You should have a cross hatch pattern similar to the one illustrated in Figure 276.

11. *Clean the cylinder block thoroughly.*

    Use soap, water and clean rags. Clean the cylinder wall for a "white glove" inspection. You should not be able to soil a clean white rag on the cylinder wall. Do not use solvent or gasoline. They wash all the oil from the cylinder but do not remove metal particles produced during honing. These cause wear.

12. *Dry the cylinder and coat it with crankcase oil.*

    Cover the cylinder block if you are not ready to install a new piston and rings.



VII. REPAIRING, LUBRICATING, MECHANISMS IN 4-CYCLE ENGINES

Without oil, the metal rubbing parts of your engine would become overheated from friction and finally weld themselves together.

Wherever two metal parts move, one against the other, there must be some form of cushion between them. Petroleum companies have developed high-quality crankcase oils that provide this cushion as needed for different engines. (See "Lubricating Small Engines," Volume I.) The problem encountered by engine manufacturers is to design a mechanism that will furnish a **constant** and **adequate supply of oil** to all bearing surfaces.

Repairing lubricating mechanisms in 4-cycle engines is discussed under the following headings:

1. Types of lubricating mechanisms and how they work.
2. Importance of proper repair.
3. Tools and materials needed.
4. Removing and servicing the oil pump.

TYPES OF LUBRICATING MECHANISMS AND HOW THEY WORK

Lubrication is provided in **2-cycle engines** by the oil which is mixed with the gasoline. It is fed first into the crankcase and pressurized. Small droplets of oil suspended in the fuel mixture collect on the bearing journals and gradually feed into the bearing surfaces.

Four-cycle engine lubrication is different. Oil is supplied to the bearings by means of a dipper, scoop, slinger, gear pump or barrel-and-plunger type of pump (Figure 277).

How these five types of oil distribution mechanisms work is as follows:

- **The dipper type rotates with the crankshaft throw.** On the lower end of the stroke the dipper dips into oil, picks it up, and throws it against the sides of the crankcase. Some of it bounces off the crankcase walls and falls onto the crankshaft, thus lubricating the bearings. It is also splashed onto the cylinder walls and lubricates the piston and rings. Oil is splashed onto the cam gear, camshaft bearing and cam lobes. It is very important that you maintain the proper oil level in your engine for this type oiler. This is especially true if your engine does not have an oil trough. If the oil level gets too low, there will not be enough lubrication of the engine. The engine in Figure 277a has a plunger pump which is operated by an eccentric on the camshaft. It maintains a constant oil level for the dipper. Many small engines with splash-type systems have no such provision. An oil strainer is used wherever a pump is used.
- **An oil scoop type on the cam gear** (Figure 277b) operates in a similar manner to the dipper. It is used on vertical crankshaft engines. As the crankshaft turns, the scoop agitates the oil and throws it onto all parts requiring lubrication.
- **The oil slinger type** (Figure 277c) is partially submerged in the oil at all times. It picks up oil as it turns and slings it around inside the crankcase to supply lubrication to all parts.
- **The gear-type oil pump** (Figures 277d and 278) is different from the pumps previously mentioned. It is a positive acting type of pump and requires a relief valve. Some engines provide for regulating the oil pressure by adjusting the relief valve. Others have the desired oil pressure designed into the pump,

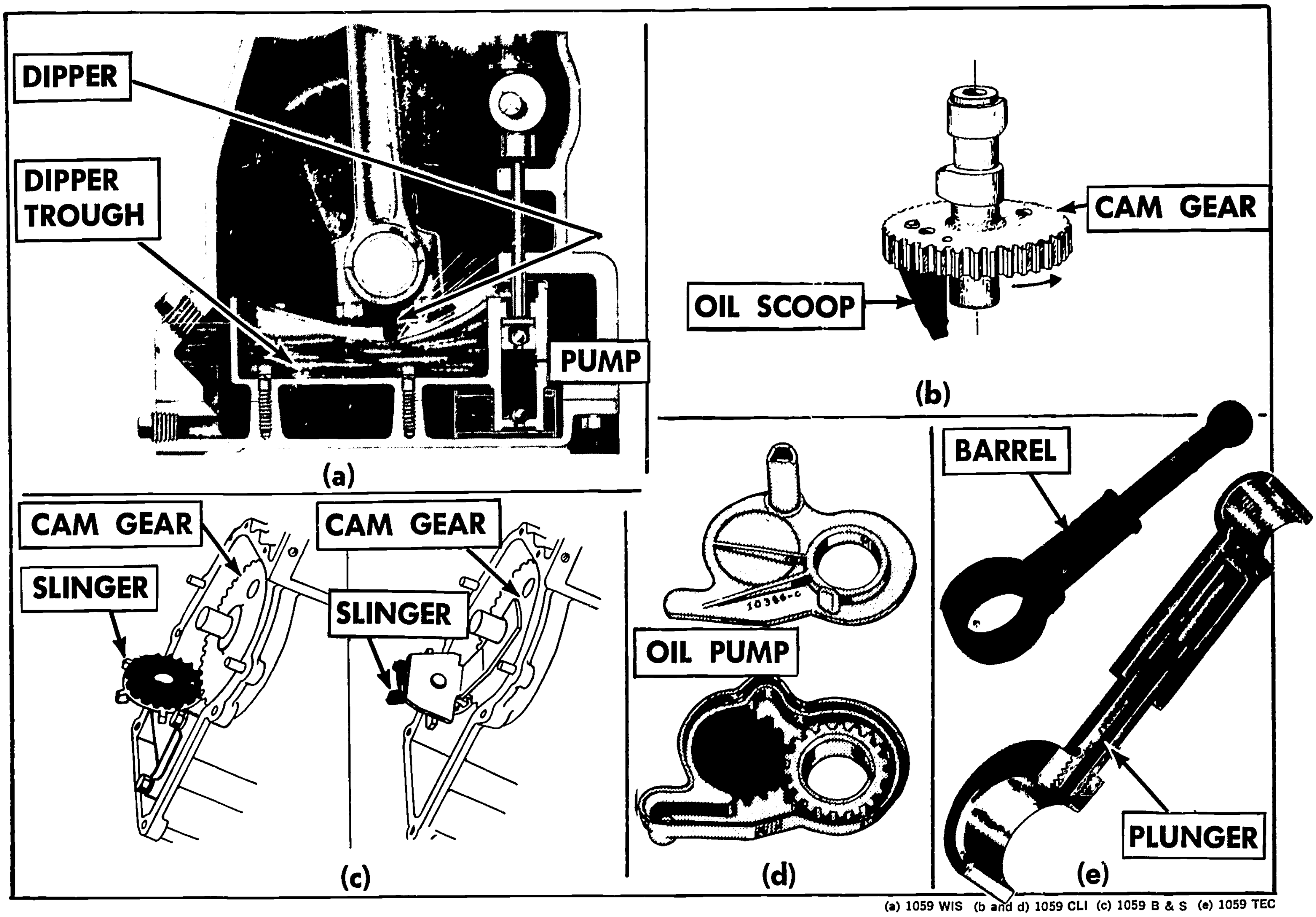


FIGURE 277. Types of oil distribution mechanisms used on 4-cycle engines. (a) Dipper on rod-bearing cap picks up oil and slings it over the crankcase. A pump is also supplied with this engine to maintain an oil level in the dipper trough. (b) A scoop on the cam gear. (c) A rotary oil slinger driven from the cam gear. (d) Gear-type pump driven from the cam gear. (e) Barrel-and-plunger type of pump operated from an eccentric drive located on the camshaft.

and the relief valve is only a safety measure in case something happens to cause the pressure to build up excessively in the crankcase. See Figure 280.

Oil is picked up from the oil sump and is either sprayed or pumped through drilled passageways to the bearings.

- **Barrel-and-plunger type of pump** (Figures 277e and 279) is located in the oil sump. This type is also a positive-acting pump. It picks up oil from the sump and pumps it into a drilled passageway through the camshaft and crankshaft and into the bearings. The piston and cylinder are lubricated by the oil splashed on the cylinder walls and on the piston by the splashing action from the crankshaft.

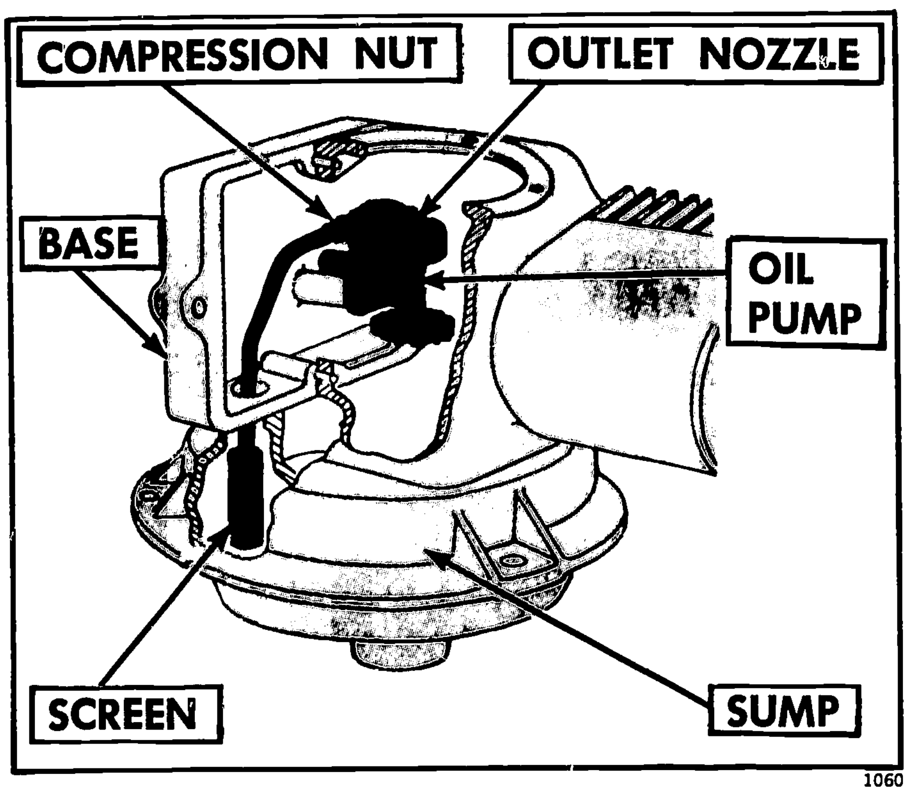


FIGURE 278. Gear-type oil pump.

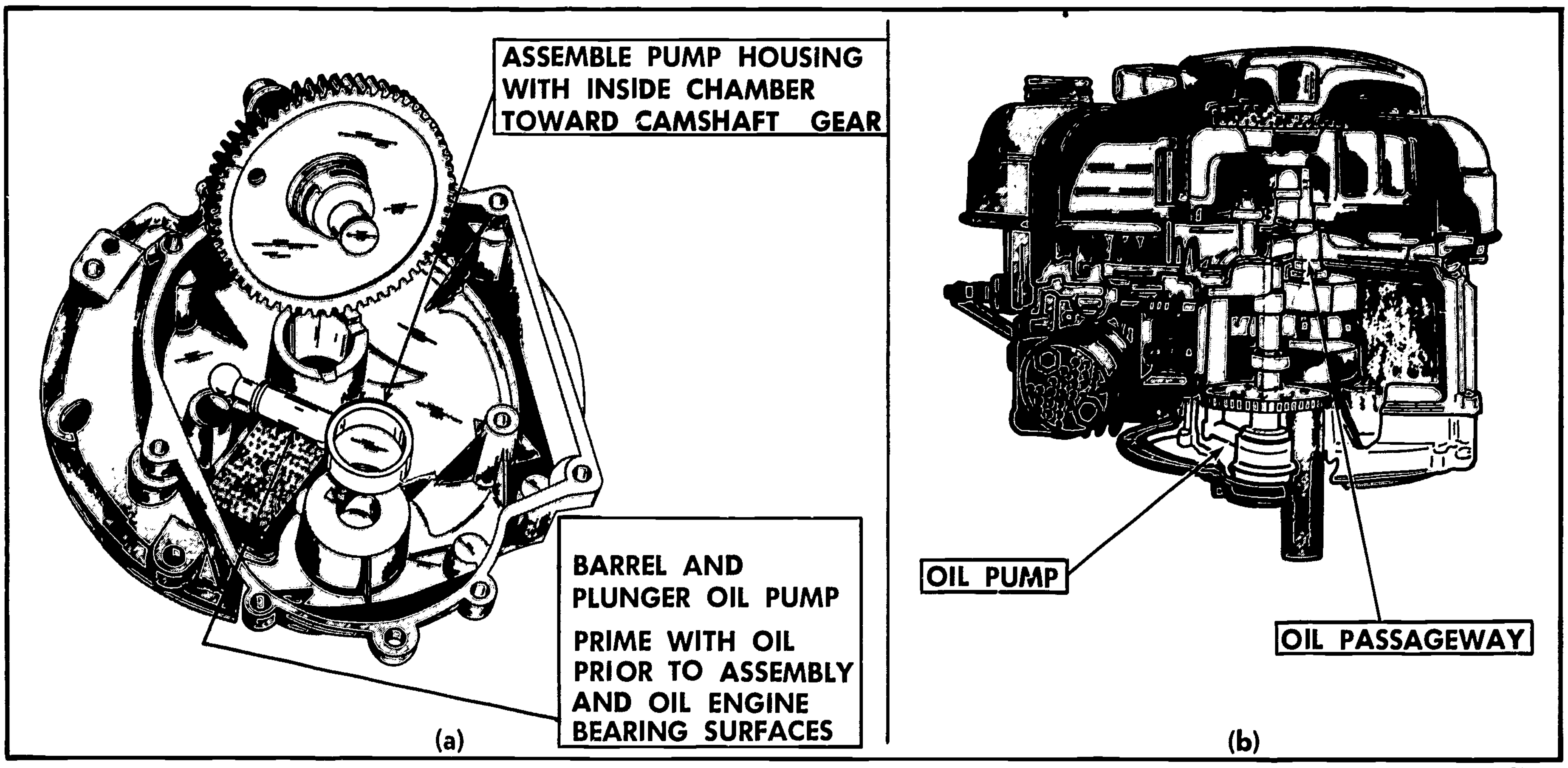


FIGURE 279. Barrel-and-plunger type of pump. (a) Pump is located on the oil sump. (b) It pumps oil through the camshaft and crankshaft to the camshaft and crankshaft bearings.

IMPORTANCE OF PROPER REPAIR

If your engine is equipped with a **dipper, scoop or slinger,** your main concern is to see that they are installed in the proper position for distributing oil. They require no further servicing.

Oil pumps and relief valves give little trouble and are not generally reparable.

You can check most pumps for proper operation by placing the suction end of the pump in oil and operating it.

A relief valve, provided on some engines for regulating the oil pressure, can usually be adjusted without removing the pump (Figure 280).

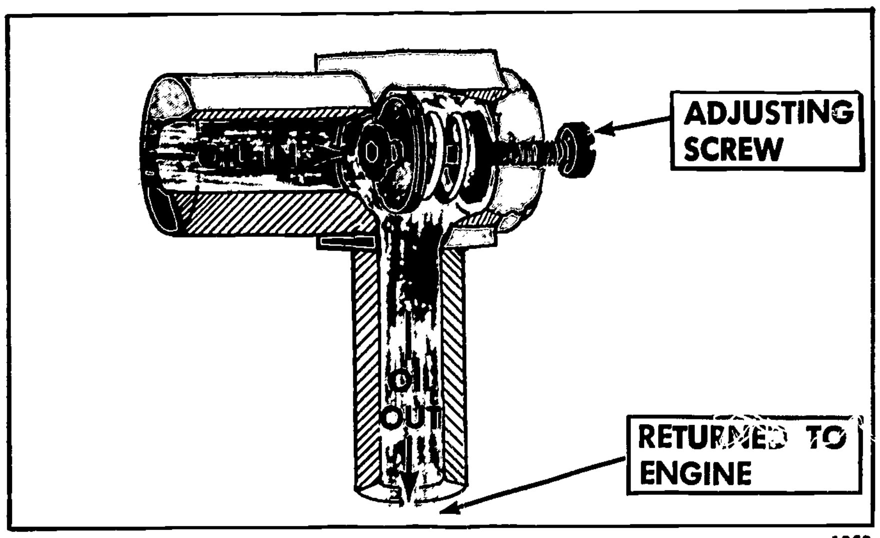


FIGURE 280. Principle of an oil-pressure regulating valve. Oil pressure pushes against the spring-loaded valve while the engine operates. When pressure becomes excessive, the valve lifts and oil discharges back into the crankcase.

TOOLS AND MATERIALS NEEDED

1. Open-end wrenches — 3/8" - 9/16"
2. Slot-head screwdrivers — 6"
3. Phillips-head screwdriver — 6"
4. Crankcase oil
5. Squirt can
6. Clean rags
7. Petroleum solvent (mineral spirits, kerosene or diesel fuel)

REMOVING AND SERVICING THE OIL PUMP

Figures 281, 282, 283, and 284 show different types of oil-pump assemblies. If you have an oil pump on your engine, it may look different from any of these; but the operating principle is the

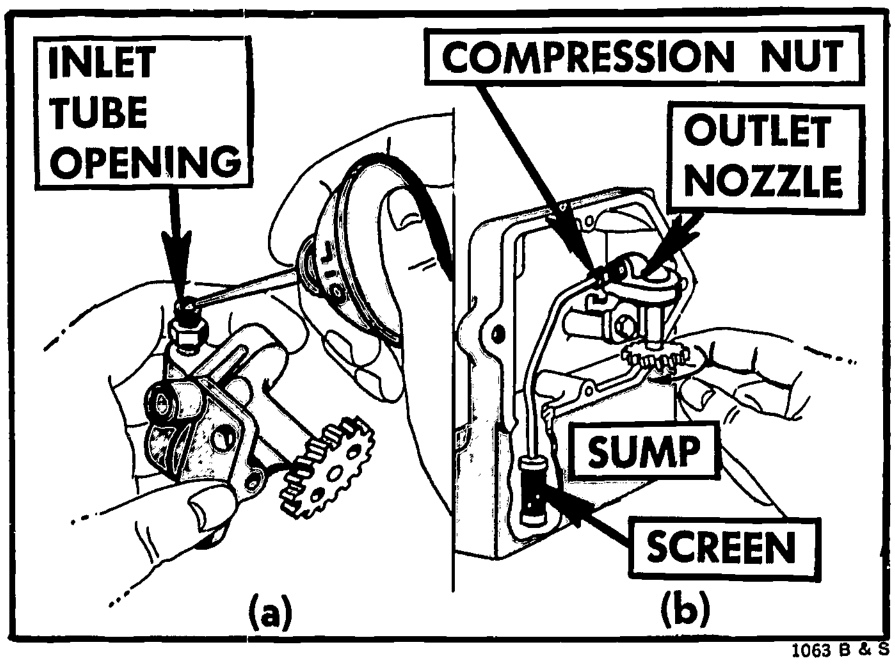


FIGURE 281. One type of removable gear pump. (a) Priming after cleaning. (b) Checking the pump for proper operation.

same for each one of them. Since you cannot see the oil pumps, it will be necessary for you to refer to your service manual to determine which type of oil pump is used in your engine.

a. If your oil-pump unit is the **removable gear type** (Figure 278), proceed as follows:

1. *Open the crankcase as explained under "Removing the Piston and Rod Assembly," page 144.*
2. *Remove the oil pump.*

   Most oil-pump housings are attached to the crankcase by capscrews. Observe carefully how the unit is assembled so you can reassemble it in the same way.
3. *Disconnect the pipe at the pump and remove the pipe and screen.*
4. *Flush the pump with a cleaning solvent.*

   Turn the pump while it is submerged in cleaning solvent; then blow solvent out with compressed air.
5. *Clean the screen and pipe with petroleum solvent.*
6. *Fill the pump with oil for priming (Figure 281a).*
7. *Connect the pipe to the pump but leave the nut loose.*

   This is for easy installation.
8. *Attach the pump to the housing.*

   Use cap screws.
9. *Center the oil pipe and strainer over the sump opening and tighten the compression unit.*
10. *Check the pump for proper operation (Figure 281b).*

    Place enough oil in the sump to cover the screen and spin the pump. Oil should flow freely.

b. If your oil pump unit is a **gear design of the non-removable type** — pump housing part of casting (Figure 282), — proceed as follows:

1. *Open the crankcase as explained under "Removing the Piston and Rod Assembly," page 144.*

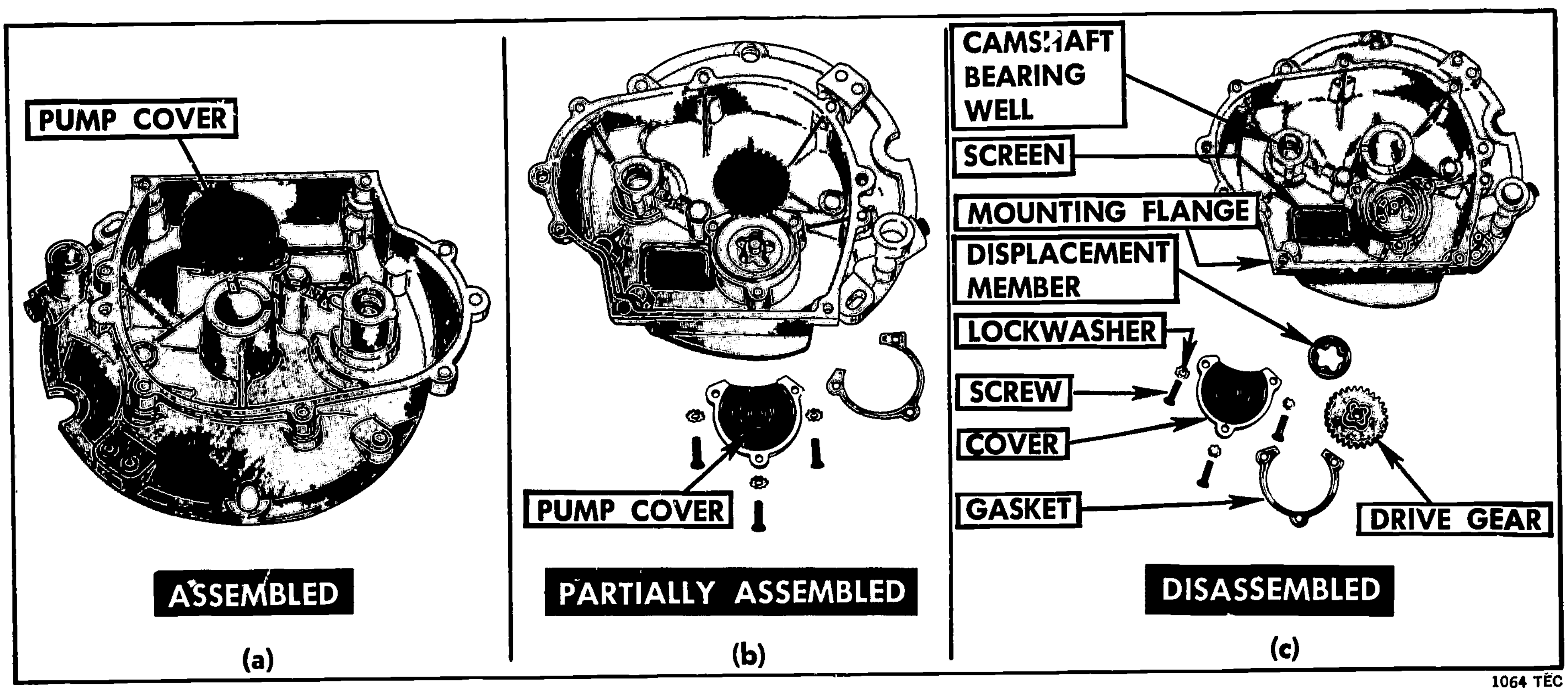


FIGURE 282. A gear pump located in the oil sump. (a) Pump with cover. (b) Pump partially disassembled. (c) Pump disassembled — except screen.

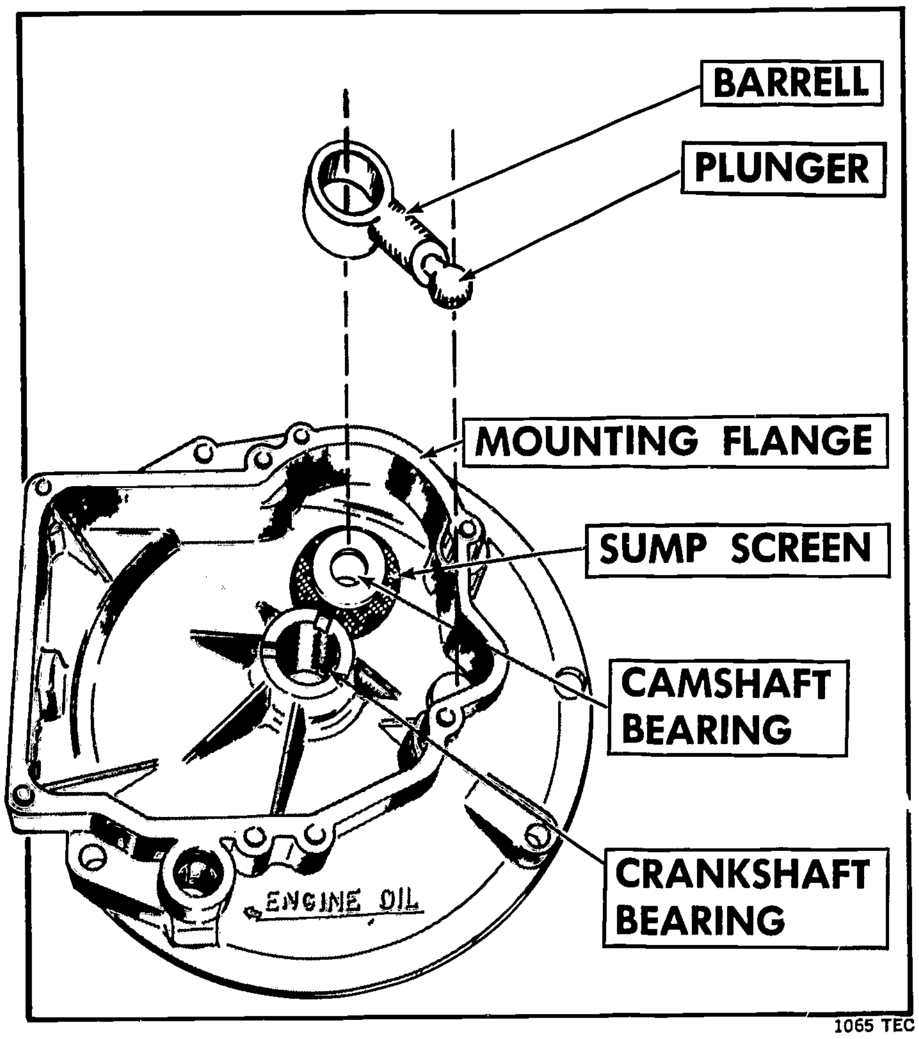


FIGURE 283. A removable barrel-and-plunger type of pump.

2. *Remove the cap screws that hold the pump cover.*
3. *Remove the cover (Figure 282a).*
4. *Lift out the drive gear and piston (Figure 282b and c).*
5. *Remove the oil screen.*
6. *Clean and inspect all the parts.*
7. *Reassemble the pump.*
8. *Put a new gasket on the pump cover and replace it.*
9. *Install the oil screen.*
10. *Check for proper operation.*

    Fill the oil sump (over the screen) with oil and spin the pump. Oil should flow freely into the camshaft-bearing well.

c. If your oil pump is a **removable barrel-and-plunger type** (Figure 283), proceed as follows:

1. *Open the crankcase as explained under "Removing the Piston and Rod Assembly," page 144.*
2. *Remove the pump (Figure 283).*

   This is a simple-type plunger pump. It is anchored to the camshaft by a ring and to the crankcase by a ball joint or a pivot post.

   When you remove the base plate from your engine, the pump will most likely remain on the camshaft. All you have to do is lift it off.

3. *Disassemble the pump.*

   Remove the plunger from barrel.

4. *Clean and inspect the parts, screen and sump.*

   Use petroleum solvent. It is difficult to remove the screen without damaging it. So try to clean it without removing it.

5. *Reassemble the pump.*
6. *Check for proper operation.*

   Submerge the pump in oil and operate. Place your finger over the pump outlet and observe operation.

7. *Install the pump properly.*

   Some have a bevel inside the camshaft ring on one side only. If yours is like this, put the bevel side next to the camshaft.

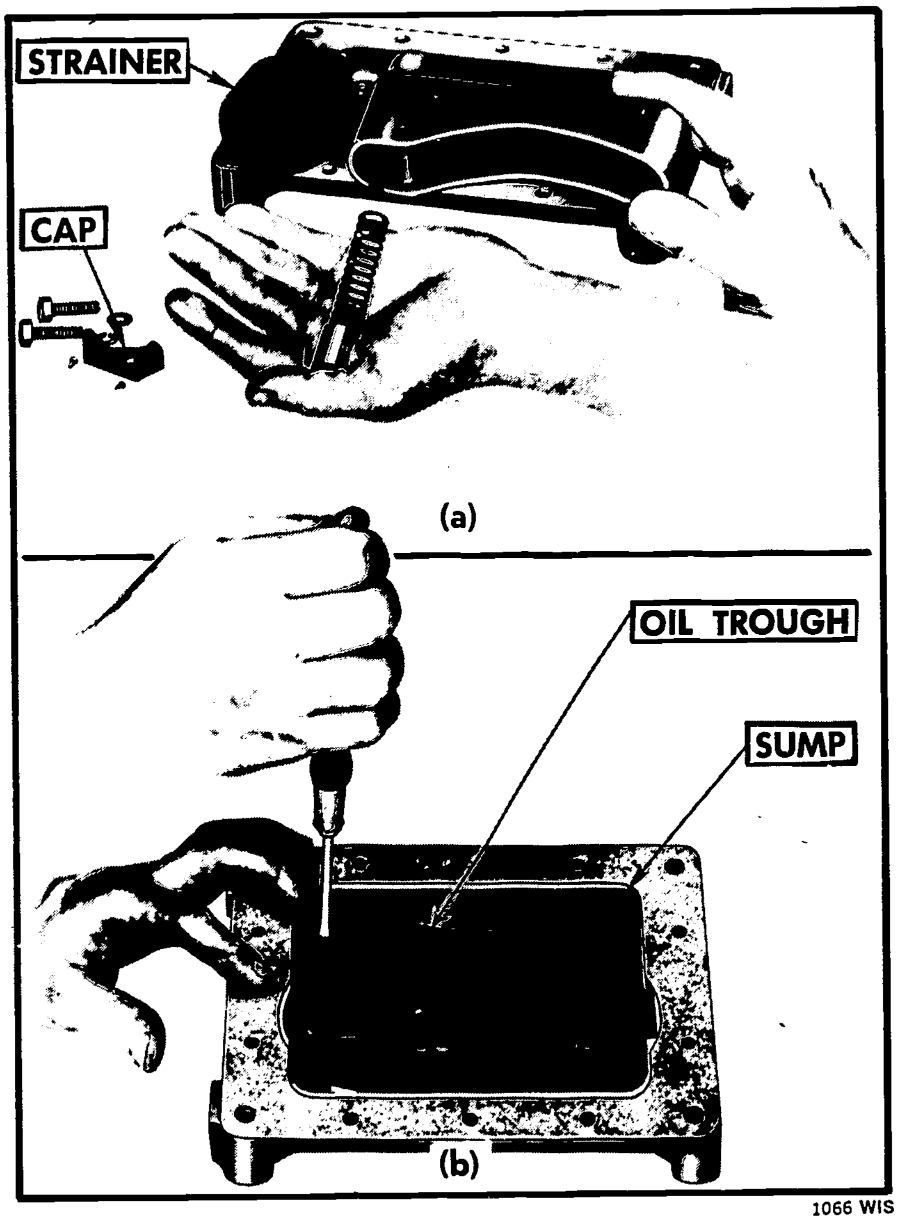


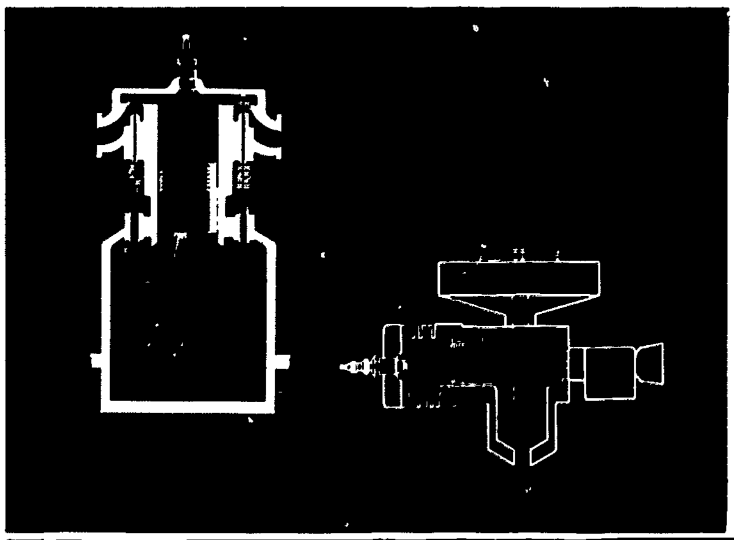
FIGURE 284. A combination oil trough for a dipper and plunger pump. (a) Pump disassembled. (b) Checking the pump for proper operation.

d. If your oil pump unit is a **non-removable barrel-and-plunger type** (Figure 284), proceed as follows:

1. *Open the crankcase as explained under "Removing the Piston and Rod Assembly," page 144.*
2. *Remove the oil trough and strainer from the engine base.*
3. *Remove the cap from the top of the oil pump (Figure 284).*
4. *Remove the pump parts.*
5. *Clean in petroleum solvent and inspect.*
6. *Reassemble in reverse order.*
7. *Check for proper operation (Figure 284b).*

   Fill the sump with oil over the screen. Use a small screwdriver and operate the plunger.

   The trough should fill with oil.



VIII. REPAIRING CAMSHAFT ASSEMBLIES IN 4-CYCLE ENGINES

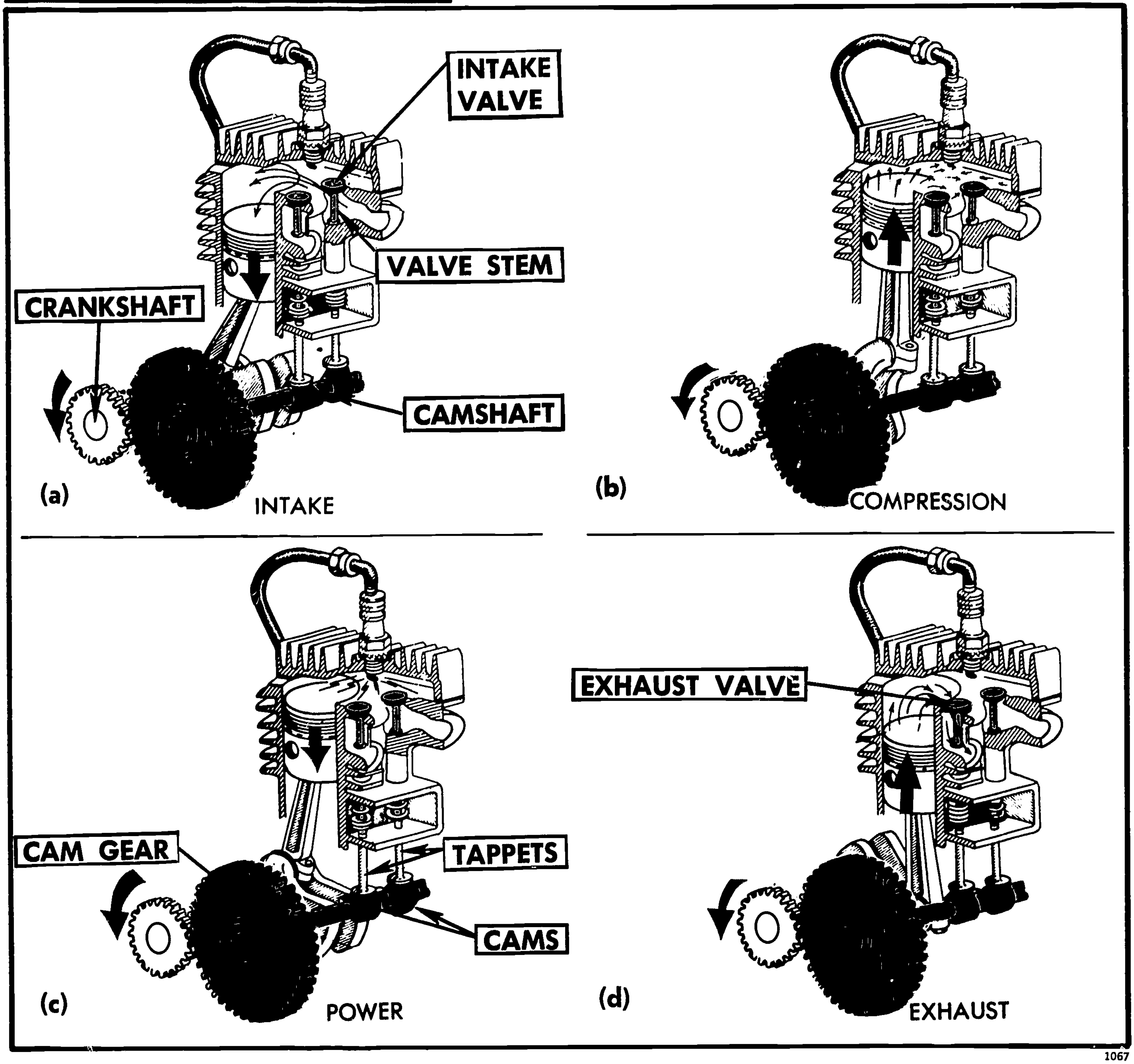
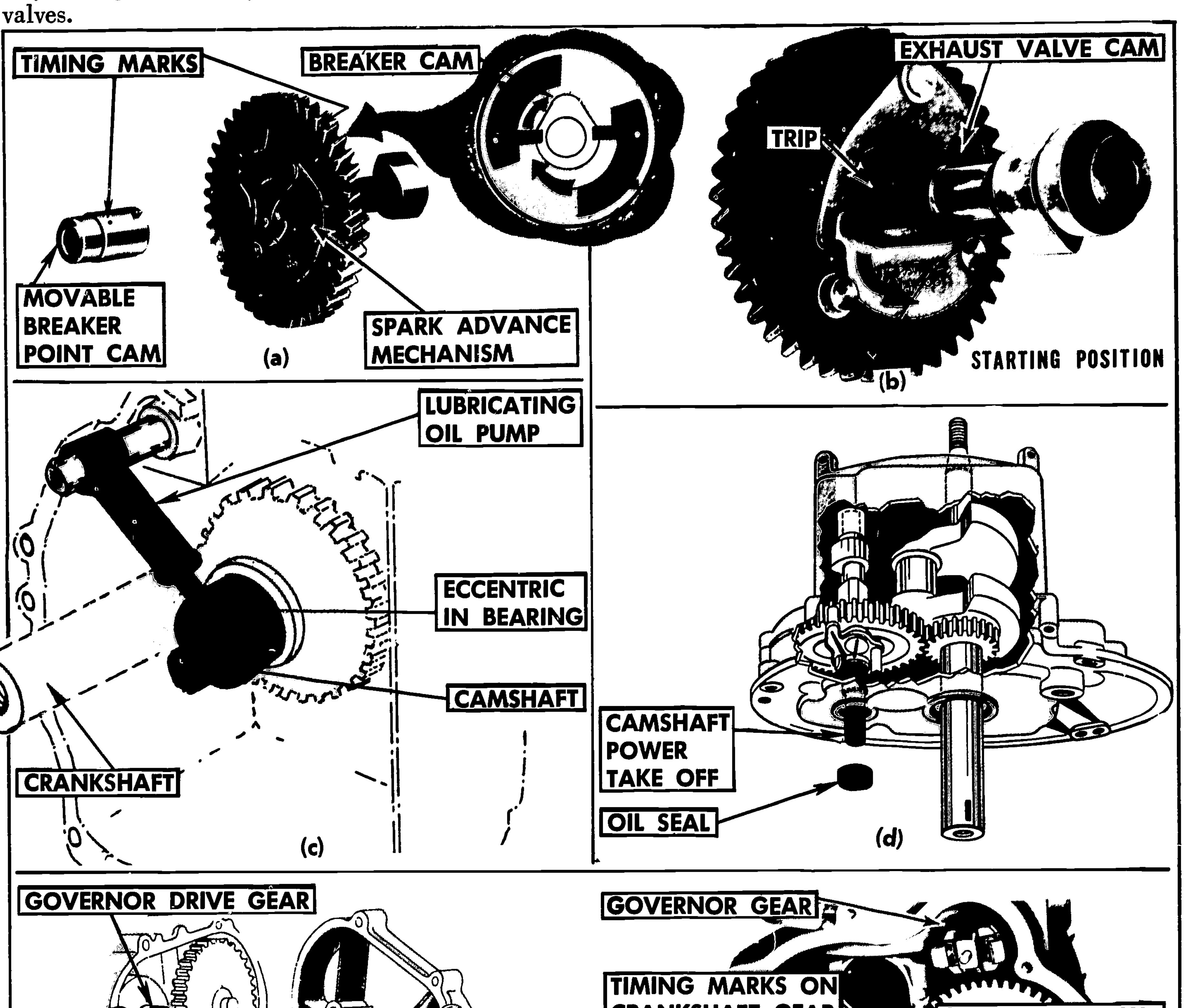


FIGURE 285. The primary function of the camshaft assembly is to open and close the valves at exactly the right time. (a) Intake stroke — cam pushes tappet against the valve stem and forces the intake valve open. There is no cam action against the exhaust valve tappet in this stroke. It remains closed. (b) Compression stroke — no cam action against either valve tappet. Both valves are closed. (c) Power stroke — both valves remain closed. (d) Exhaust stroke — cam pushes tappet against exhaust-valve stem and opens the exhaust valve.

The primary function of the camshaft assembly in your 4-cycle engine is to open and close the valves at the proper time (Figure 285) It is used only with 4-cycle engines. Two-cycle engines have no poppet valves.

The camshaft has two cams machined on the shaft. They are located so that when the shaft turns, the valves open and close at the proper time. The valves are closed by spring tension.



(a and b) 1068 KOH (c) 1068 TEC (d) 1068 WIS

FIGURE 286. The camshaft assembly, in addition to opening and closing valves may also have: (a) a breaker-point cam and a spark-advance mechanism, (b) an automatic compression-release mechanism for easier starting, (c) an extra cam for operating an oil pump, or a gear-type oil pump driven from the cam gear, (d) a camshaft extending through the housing to provide for additional source of power, and (e) a cam gear which turns a centrifugal-type speed-control governor.

The camshaft is driven by the crankshaft through gears (Figure 285). Since there is only one power stroke for each two revolutions of the crankshaft, the gear ratio is designed so that the camshaft will turn at only half the speed of the crankshaft. This is done by making twice the number of teeth in the camshaft as in the crankshaft (Figure 287).

For more information on valve operation refer to "Types of Valves and How They Work," page 110.

In addition to opening and closing the valve, the camshaft assembly may also operate:

- **An (ignition) breaker-point cam and spark-advance mechanism (Figure 286a).**

  The spark-advance mechanism is operated by a centrifugal device. It advances or retards the breaker point cam. When the engine is being cranked, the centrifugal device retards the breaker-point opening time and makes starting easier. As engine speed increases, the centrifugal device opens the breaker points earlier. This provides higher efficiency at high speeds.

- **A compression release mechanism (Figure 286b) for easy starting** — At slow speeds the flyweights remain closed and the exhaust-valve trip lifts the exhaust valve slightly on compression stroke to relieve the compression before starting. At high speeds the flyweights move out because of centrifugal force, thus allowing the trip to drop in the slot back of the exhaust valve cam for normal operation.

  Some engine manufacturers accomplish the same action by shaping the exhaust valve cam so that the exhaust valve closes late.

- **An oil-pump drive cam (Figure 286c).** An eccentric inside of the bearing journal provides pumping action to the plunger.

- **An external power source (Figure 286d).** On some engines, the camshaft is extended to provide a power connection for supplying power to operate equipment. It operates at ½ of crankshaft speed.

Repairing the camshaft assembly is discussed under the following headings:

1. Tools and materials needed.
2. Removing the camshaft assembly.
3. Inspecting the camshaft assembly.
4. Installing the camshaft assembly.

TOOLS AND MATERIALS NEEDED

1. Open-end wrenches — 3/8″ through 9/16″
2. Socket wrenches and handle — 3/8″ through 3/4″ — 3/8″ drive
3. Slot-head screwdrivers — 6″
4. Phillips-head screwdriver — 6″
5. Combination pliers — 7″
6. Needle-nose pliers — 7″
7. Micrometer — 1/2″ to 1″
8. Petroleum solvent (mineral spirits, kerosene or diesel fuel
9. Clean rags

REMOVING THE CAMSHAFT ASSEMBLY

There are one of two methods of removing the camshaft, depending on the design of the crankcase.

If your *engine has no separate oil sump, or base plate (Figure 241b),* or if it *has a vertical crankshaft (Figure 241c),* you can usually remove the camshaft by removing the base plate or gear cover (Figure 287a) because they are bearing supports. If your engine **has a base plate or oil sump and no removable bearing support** (Figure 287b), it will be necessary for you to remove the crankshaft before you can completely remove the camshaft.

a. If your engine has a **removable bearing support,** remove the camshaft as follows:

1. *Remove the gear cover or mounting base.*

   See procedures under "Removing the Piston Rod Assembly," page 144.

2. *Note the position of the timing marks on the camshaft and crankshaft gears (Figure 288).*

   Timing marks are made in several different ways — punch marks, bosses, slots. Some gears are not marked. If yours are not, mark both the camshaft gear and the crankshaft gear with a center punch before removing the camshaft.

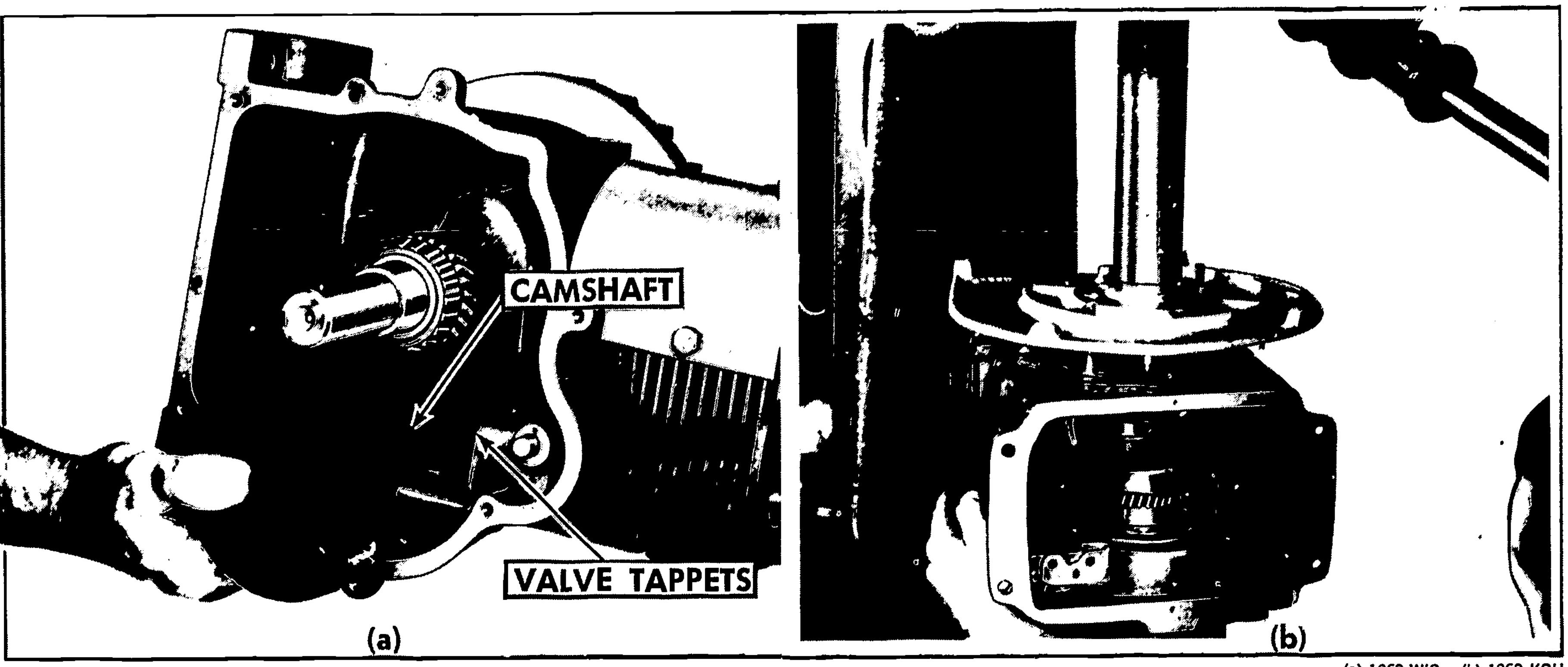


FIGURE 287. Removing the camshaft. (a) The camshaft is easily removed on some engines after you remove the gear cover or mounting base. (b) It is necessary to remove the crankshaft on some engines before you can completely remove the camshaft.

3. *Remove the thrust bearing and spring if installed.*

   Some engines have a camshaft end-thrust ball bearing and spring. Sometimes the ball will fall out when you remove the gear case. Most camshafts do not have this end-thrust bearing.

4. *Turn the crankshaft until the timing marks are aligned on compression stroke — both valves closed.*

   This action will relieve the pressure from the tappets and make removal of the camshaft easy.

5. *Turn the crankcase on its side or upside down.*

   This prevents the tappets from falling out.

6. *Remove the camshaft.*

   On some engines with ball bearings, both

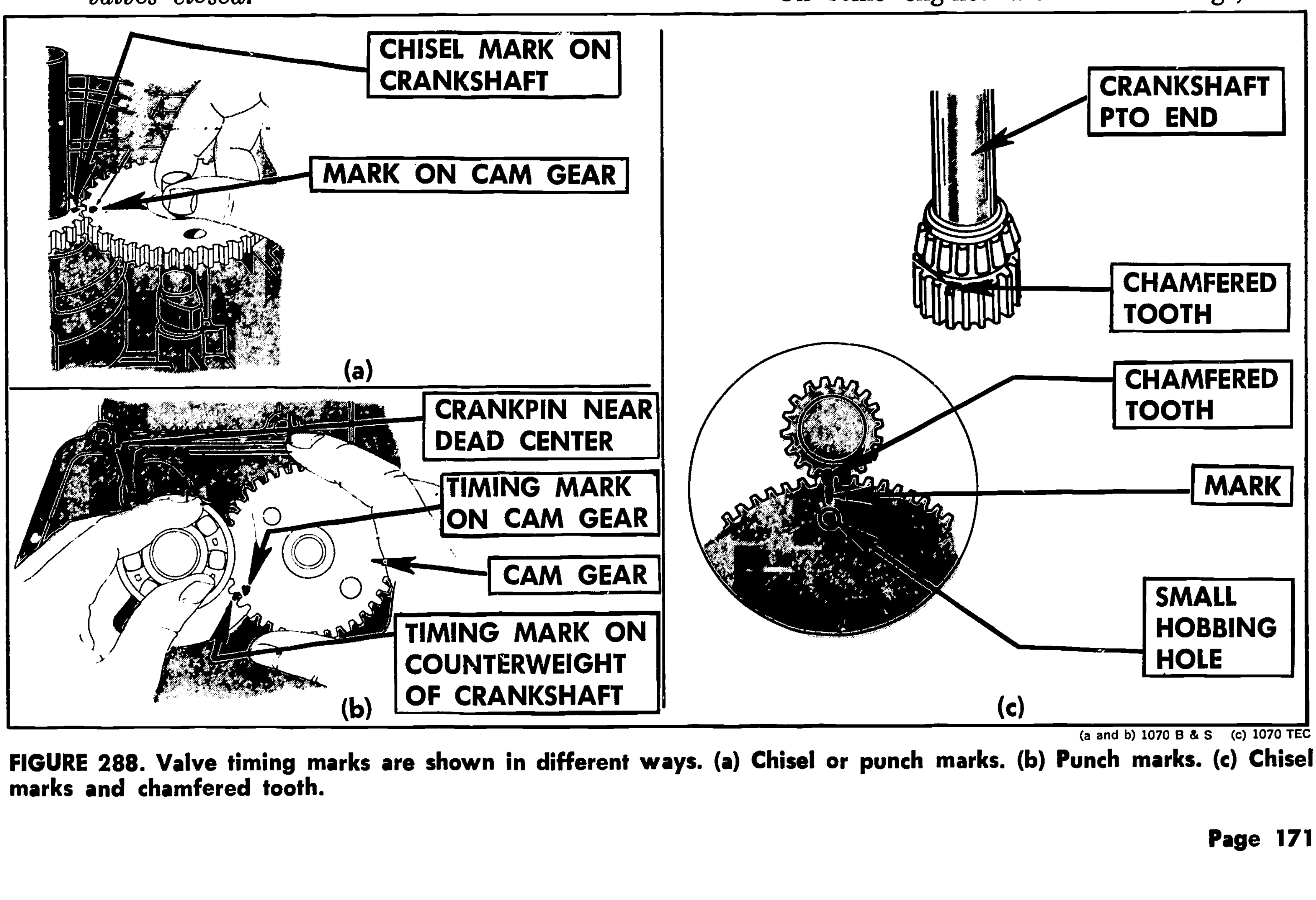


FIGURE 288. Valve timing marks are shown in different ways. (a) Chisel or punch marks. (b) Punch marks. (c) Chisel marks and chamfered tooth.

the camshaft and the crankshaft must be removed together.

7. *Remove the valve tappets one at a time.*

   Mark the tappets. They should go back in the same holes from which they came. On some engines with an automatic compression release, the exhaust tappet is shorter.

b. If your engine has **no removable bearing support,** proceed as follows:

1. *Remove the camshaft if possible (Figure 287).*

   On some engines this is not possible until you have performed steps 2 and 3.

2. *Remove the expansion plug from the crankcase (Figure 289a).*

   Some shafts are removed from the flywheel end and others from the power take-off end. For removal of the crankshaft see "Removing the Crankshaft," page 180.

3. *Drive the camshaft pin out (Figure 282b).*

   It will be easy after you have driven it past the housing.

4. *Remove the camshaft assembly.*

   Watch for endplay, adjusting washer if installed.

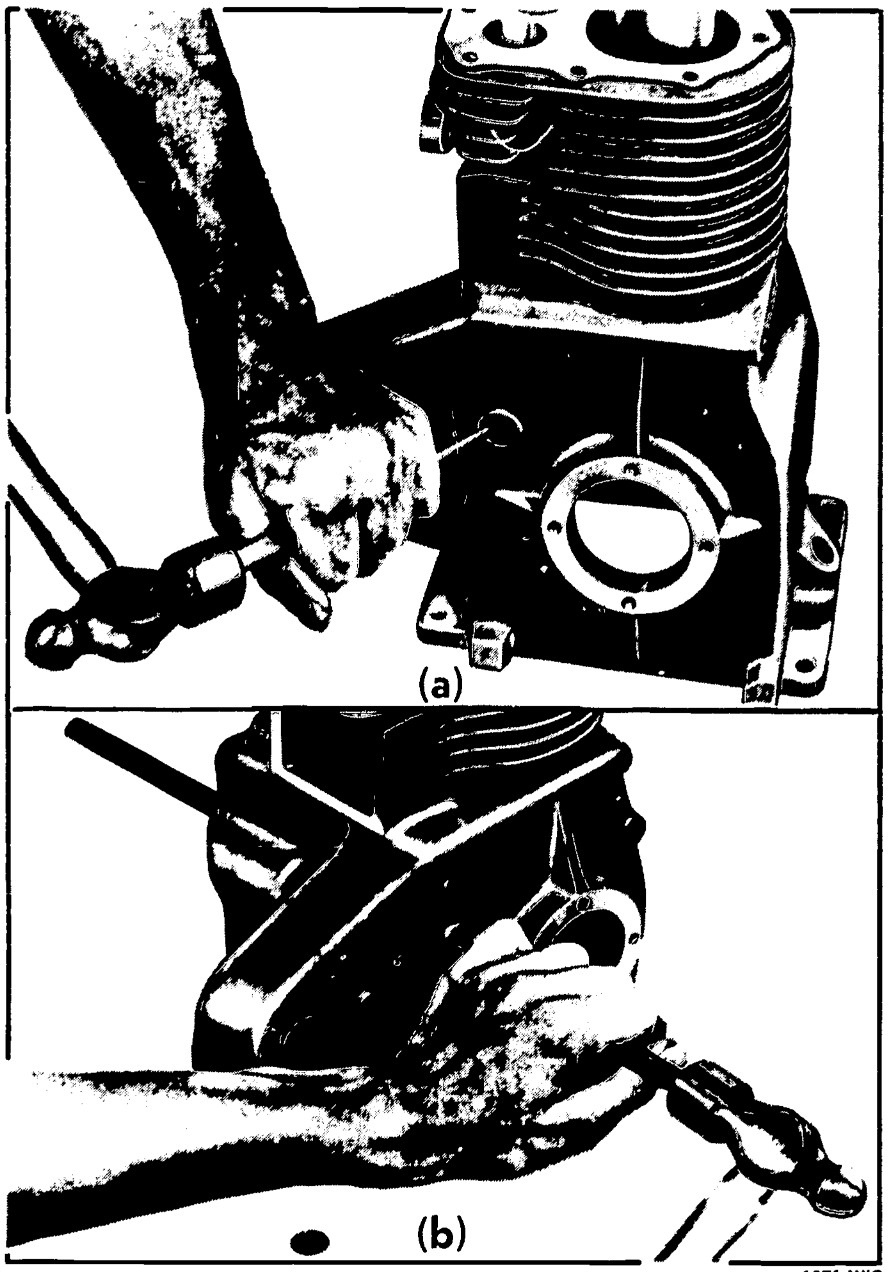


FIGURE 289. Removing the camshaft pin. (a) Remove the expansion plug. (b) Drive out the pin.

INSPECTING THE CAMSHAFT ASSEMBLY

1. *Clean the parts in petroleum solvent.*
2. *Inspect gear teeth for wear and nicks.*
3. *Check automatic spark advance if installed (Figure 286a).*

   Place the cam gear in normal position with the movable weight down. Press the weight down and release it. The spring should lift the weight. If it does not, check for binding. If the spring is weak, replace it.

   Some spark-advance assemblies do not have replaceable parts, The entire assembly has to be replaced.

4. *Check the tappets for wear.*
5. *Check the automatic compression-release mechanism for freedom of operation and excessive wear, if installed.*
6. *Clean out the oil passages, if the camshaft is drilled for oil passageways.*

   Use compressed air.

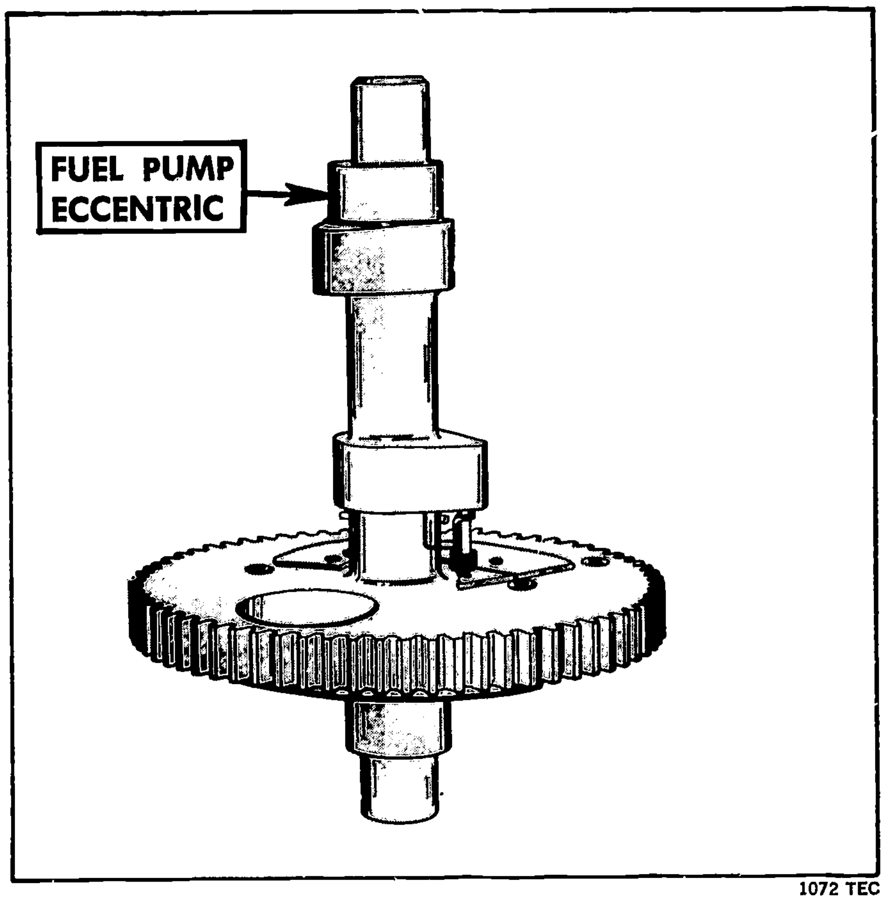


FIGURE 290. Points at which the camshaft should be measured.

7. *Measure the camshaft dimensions (Figure 290) and check against the tolerances given in your repair manual.*

   Use an outside micrometer.

8. *Measure the height of the cams with a micrometer.*

   Check the tolerances given in your repair manual.

NSTALLING THE CAMSHAFT ASSEMBLY

1. *Assemble the automatic compression-release and spark-advance mechanisms, if you have had them disassembled.*

2. *Oil all parts.*

   Make sure they are free from dirt.

3. *Turn the crankshaft so that the piston is at top-dead-center, compression stroke.*

4. *Turn the cylinder block upside down.*

5. *Install the valve tappets.*

   Be sure you install the tappets in the guides from which they came. If you do not, you may change the valve-tappet clearance. Also, the tappets in some engines are of different lengths.

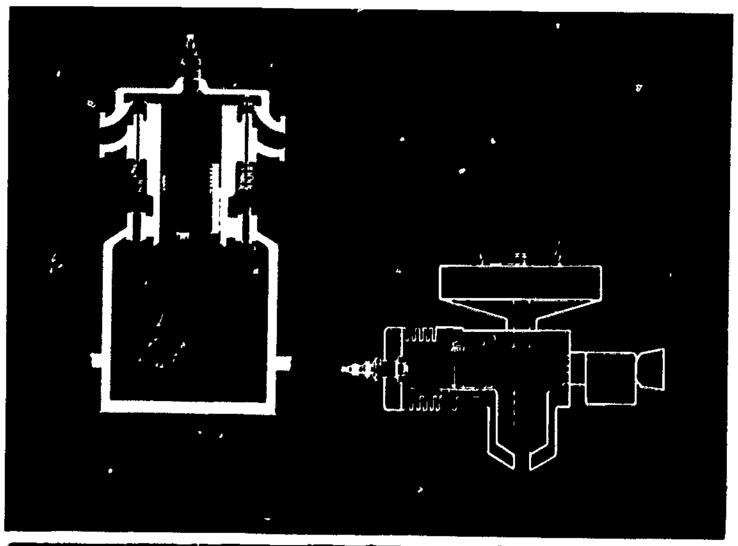
6. *Install the camshaft.*

   If your engine is similar to the one shown in Figure 287b, install the crankshaft before driving in the camshaft pin. This is so you can move the camshaft out of the way in order to install the crankshaft.

7. *Install the end-thrust spring and bearing, if applicable.*

   If you have an **external fuel pump, governor arm** or **breaker points operated by the camshaft assembly,** be sure the drive mechanisms are set in the proper position so that they will operate properly.

IX. REPAIRING CRANKSHAFT ASSEMBLIES



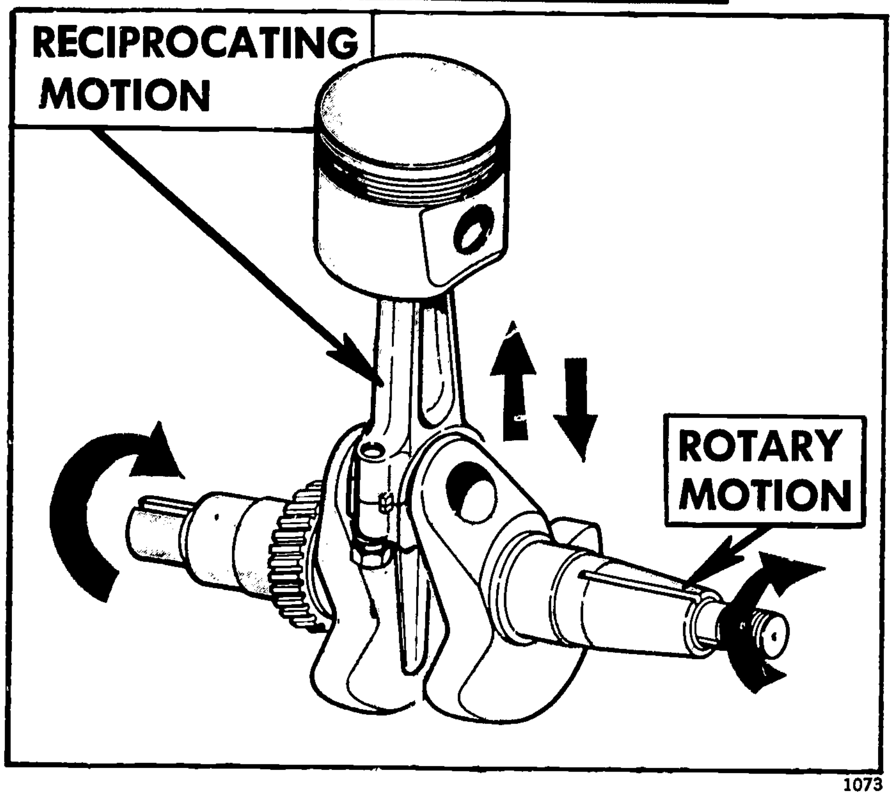


FIGURE 291. The crankshaft converts the reciprocating (up and down) motion of the piston to rotary motion.

The primary function of the crankshaft assembly is to convert the reciprocating motion of the piston to rotary motion (Figure 291). Other functions of the crankshaft include:

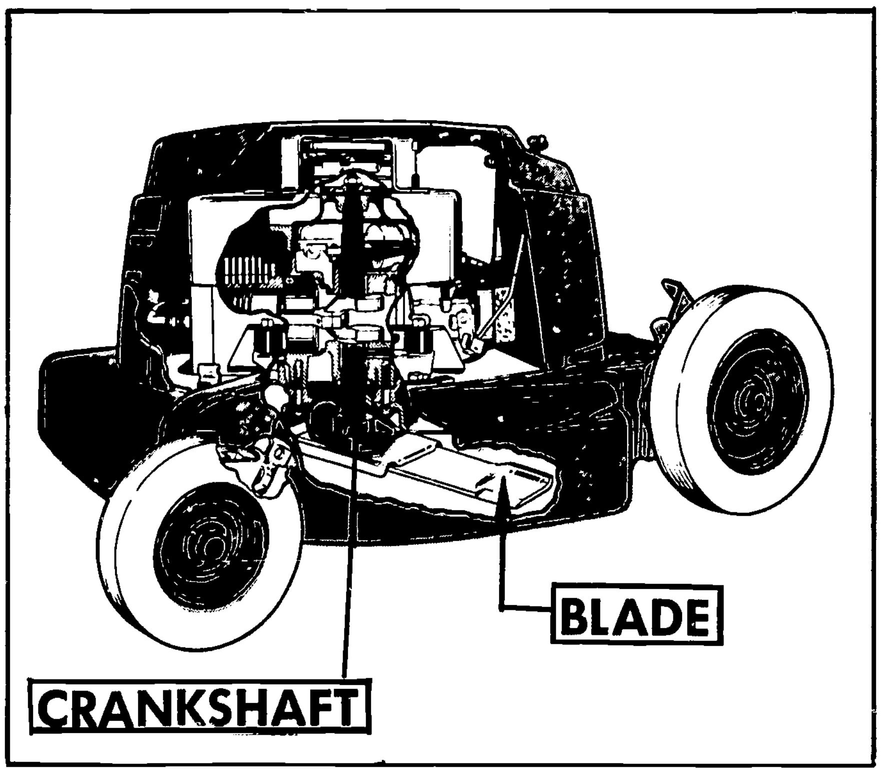


FIGURE 292. Mower blade attached to the end of a crankshaft.

- **Providing power for driving equipment such as a saw, mower blade, wheels on a self-propelled unit, pump or other units (Figure 292).**
- **Driving the camshaft (Figure 284e).**
- **Turning the flywheel (Figure 293).**

The flywheel gives balance and stability to the engine.

Some small engines are equipped with crankshaft balances. These are called "counter-

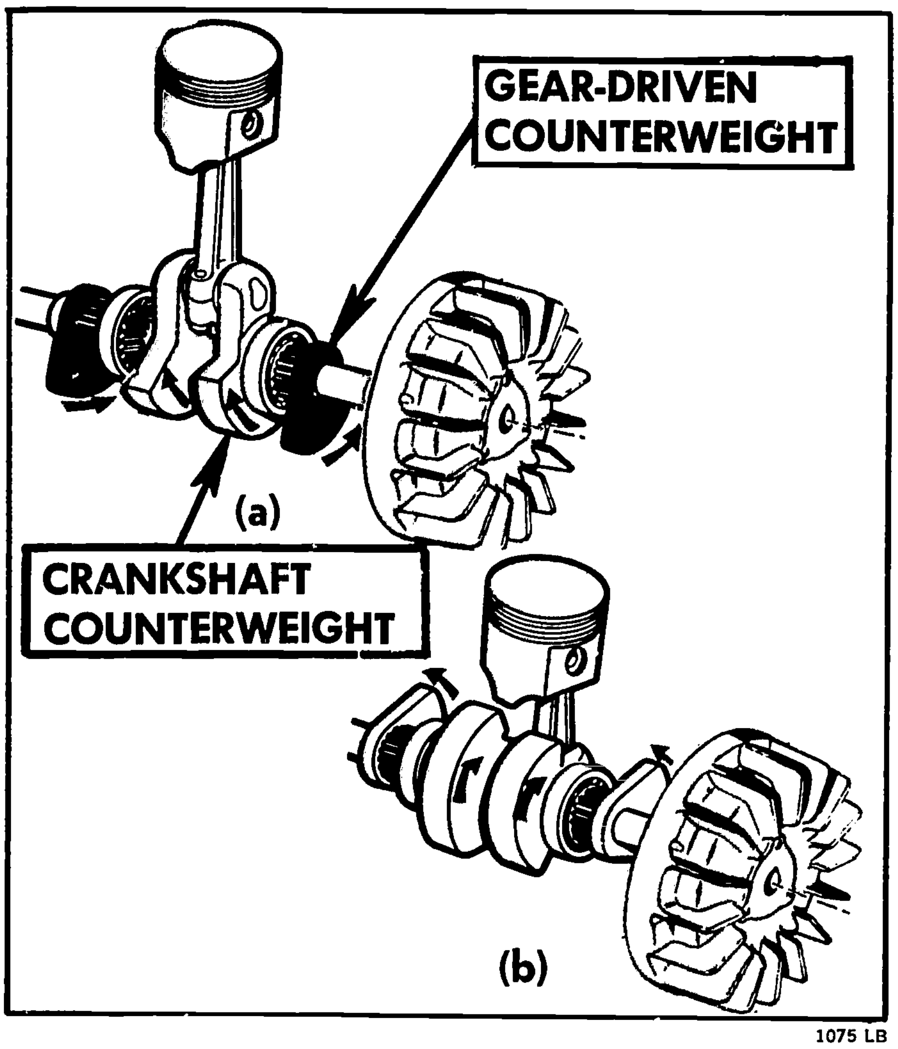


FIGURE 293. How counter-balanced crankshaft engines offset vibrations developed by the up-and-down motion of the piston. Counterbalances at each end of the crankshaft are geared to rotate in a direction opposite to that of the crankshaft counterweights. (a) In the horizontal position the counterbalances are positioned to offset the unbalanced weight at the crankshaft. (b) In the vertical position the synchronized counterbalances combine with the unbalanced weight of the crankshaft to balance the weight of the piston.

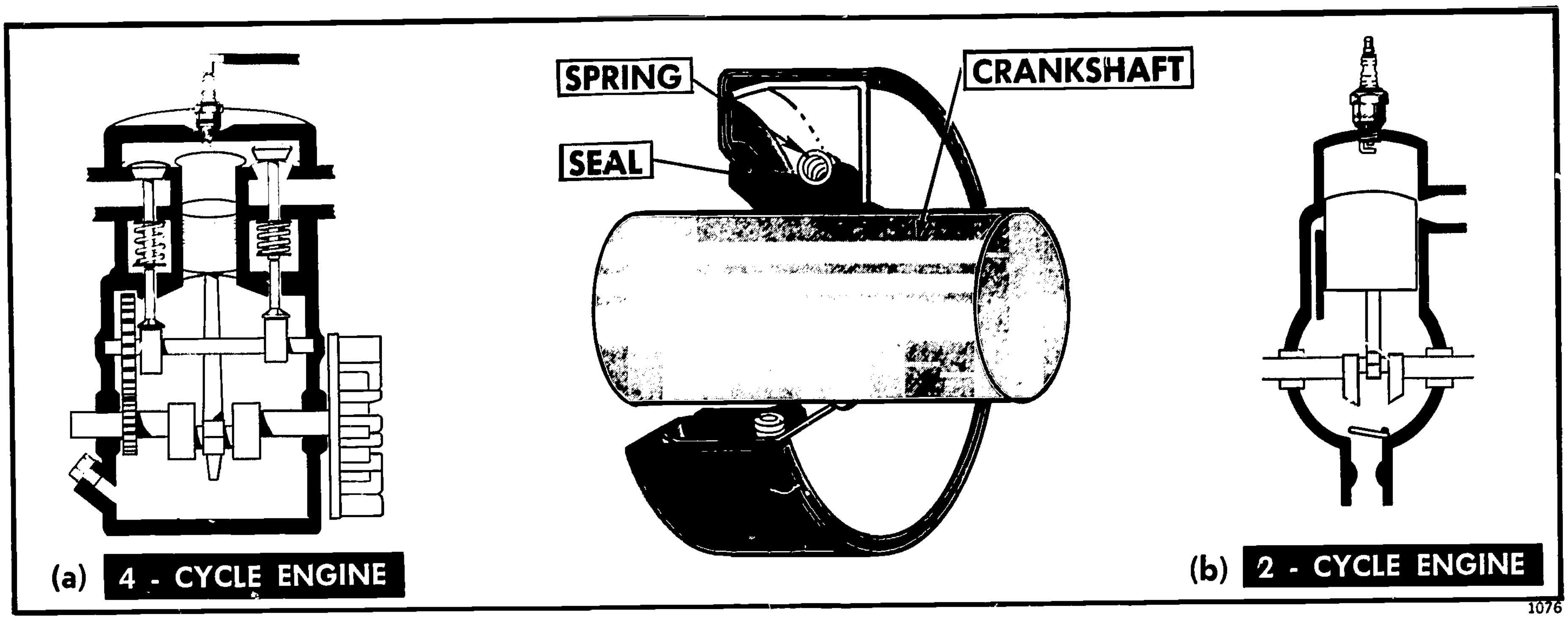


FIGURE 294. Seals are used at both ends of the crankshaft. (a) They prevent oil from leaking from the crankcase on 4-cycle engines. (b) They prevent fuel, air, oil and pressure leakage from the crankcase on 2-cycle engines.

balances." They overcome much of the vibration caused by the reciprocating motion of the piston and the unbalanced weight of the crankshaft. Figure 293 explains how they work.

- **Driving a cam for opening the breaker points on some engines.** On flywheel magnetos the spark occurs on each revolution of the crankshaft, even though with 4-cycle engines it is not needed except on every second revolution. On most 4-cycle engines, the points are operated from the camshaft. Since it operates only half as fast as the crankshaft, the spark occurs only on each compression stroke.
- Providing **seals to prevent leakage of pressure** from within the crankcase (2-cycle engines, Figure 294a) and oil from within the crankcase (4-cycle engines, Figure 294b).

Crankcases on 4-cycle engines may operate at either slightly negative pressure or at a slightly positive pressure. The seal is installed the same for either operating condition.

- Providing **power for the speed-control governor** on some engines (Figure 295).
- **Driving gear-type oil pump** on some engines (Figure 296).

Repairing crankshaft assemblies is discussed under the following headings:

1. Importance of proper repair.
2. Tools and materials needed.
3. Checking the crankshaft for proper operation.
4. Removing and replacing crankshaft oil seals (with shaft in place).

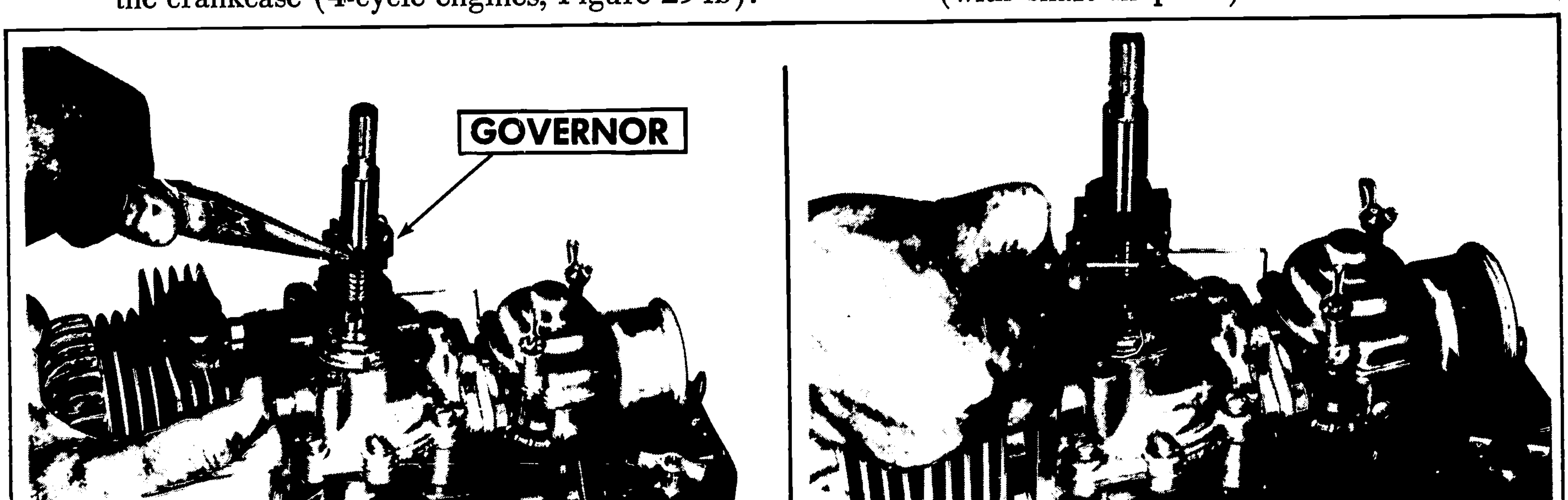


FIGURE 295. Governor attached directly to the crankshaft of a 2-cycle engine.

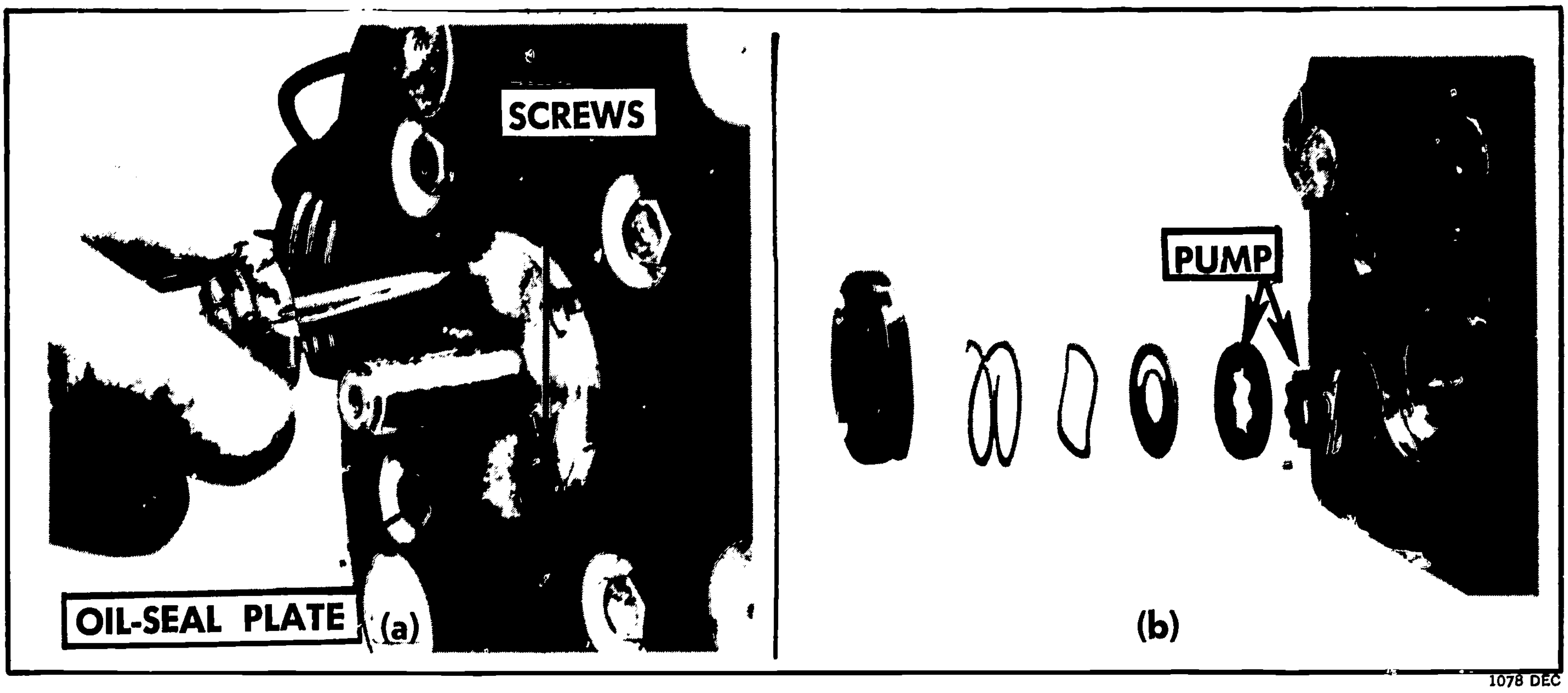


FIGURE 296. Oil-seal plate and crankshaft-driven gear-type oil pump. (a) Removing the oil seal. (b) Oil seal plate-and-pump assembly.

5. Removing the crankshaft.
6. Cleaning and inspecting the crankshaft.
7. Cleaning and inspecting crankshaft bearings.
8. Removing and replacing bearings.
9. Installing the crankshaft.

IMPORTANCE OF PROPER REPAIR

If you expect to get much service from your engine after overhaul, you will have to recognize crankshaft troubles and do the crankshaft repair job correctly. A **worn crankshaft will allow too much play** between the crankshaft and the bearings. The oil seal will leak. With **4-cycle engines,** which operate with a slight crankcase vacuum, dirt will be drawn inside the crankcase which increases bearing wear. With **2-cycle engines,** worn bearings and seals will prevent them from starting easily and running properly.

Since most spark-ignition breaker points operate from the crankshaft, **a worn crankshaft will cause the points to open and close at the wrong time.**

A partially sheared keyway or twisted shaft will also throw the timing off.

A bent crankshaft will cause the engine to vibrate excessively.

If you find very much crankshaft damage, it will be desirable to purchase a short block assembly which includes the cylinder block, crankcase assembly, pistons, rings and valves if one is available for your engine. A new shaft costs more than half as much as a new short-block assembly.

TOOLS AND MATERIALS NEEDED

1. Long nose pliers — 7″
2. Slot-head screwdriver — 8″
3. End wrenches — 3/8″ through 3/4″
4. Clean rags
5. Micrometers — inside and outside
6. Arbor press
7. Bearing puller
8. Special tools — gages and reamers
9. Petroleum solvent (mineral spirits, kerosene or diesel fuel)
10. Emery cloth
11. Gasket cement
12. Gaskets

CHECKING THE CRANKSHAFT FOR PROPER OPERATION

1. *Check for excessive vibration.*

Excessive vibration indicates a bent crankshaft. If you have a mower blade attached

to the crankshaft, remove it and check the blade for balance. An unbalanced mower blade will cause vibration.

A bent crankshaft also can cause excessive vibration.

2. *Check for noisy operation.*

Worn bearings, especially rod bearings, can be noisy and indicate trouble.

3. *Check for leaking crankshaft oil seals.*

Oil leaks in **4-cycle engines** indicate a bent crankshaft, bad oil seals, and/or worn bearings.

If you have an *oil leak and excessive vibration,* this indicates a bent crankshaft. See step 4.

If you have an *oil leak and there is no evidence of a bent crankshaft or worn bearings,* replace the oil seal. Follow procedures under "Removing and Replacing Crankshaft Oil Seals (With Shaft in Place)," page 178.

If you have a **2-cycle engine** and it is hard to start, it may be leaking at the crankshaft oil seals. Put some crankcase oil around the seal and observe to see if the oil is drawn into the crankcase as you turn the starter.

Another method is to use a special tool or kit for this purpose. The kit includes adapter plates that are bolted over the intake and exhaust ports to seal them off. A tube, in one adapter, accepts a hose to which is attached a pressure gage and a pump. A check valve is used in the hose to prevent leakage through the hose. Pressure is applied, by the pump, through the hose and into the engine and is registered on the pressure gage.

If there is a seal leak or other leak in the crankcase, this will show as the pressure reading on the gage drops. This same tool can be used to detect carburetor or fuel line leaks.

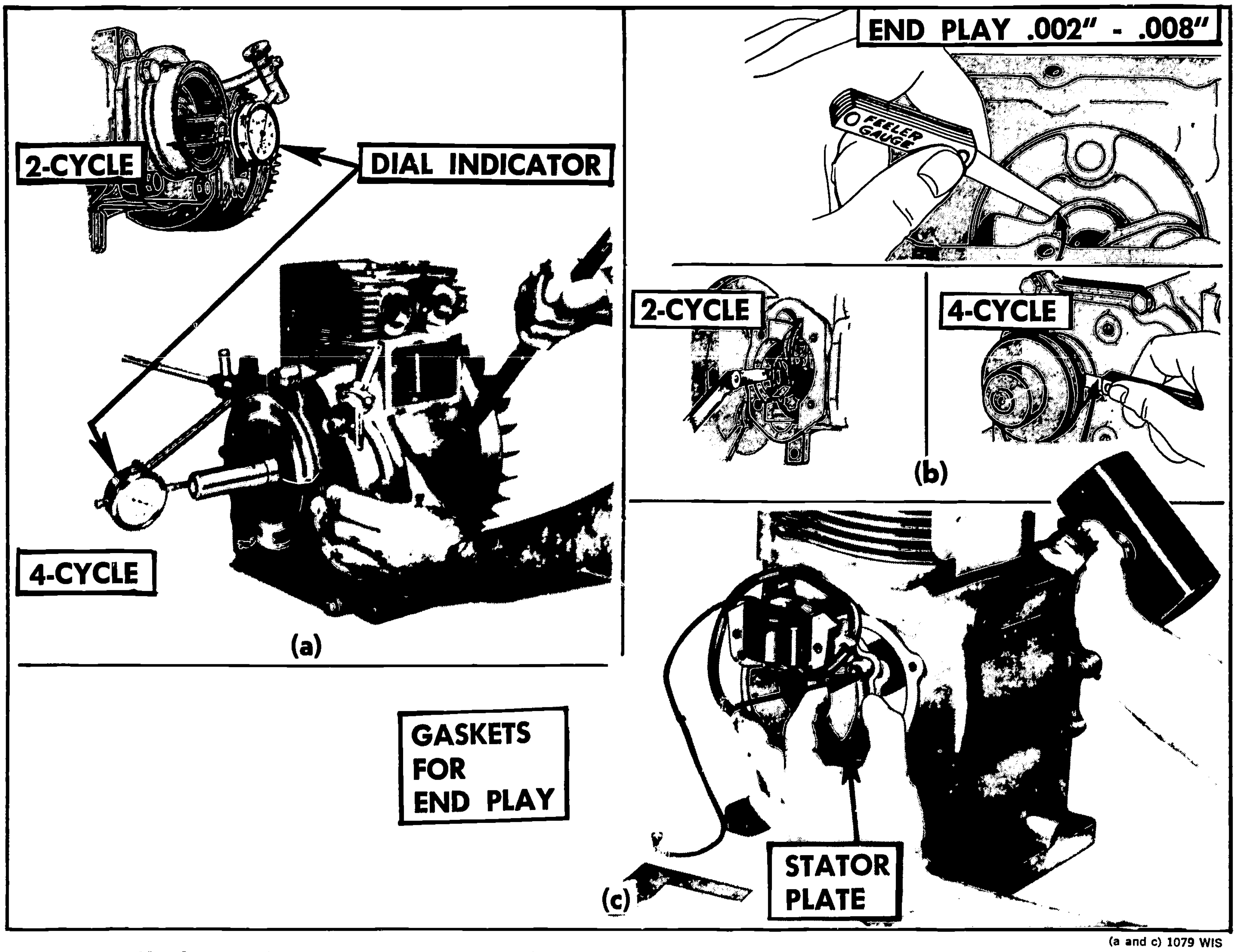


FIGURE 297. Checking and correcting crankshaft endplay. (a) Checking the crankshaft endplay with a dial indicator. (b) Checking the crankshaft endplay with a feeler gage. (c) One method for correcting crankshaft endplay is by inserting gaskets under the stator plate.

Hard starting may also be caused by a pin hole in the crankcase. Check it the same way.

4. *Check for bent crankshaft or warped housing.*

   If you cannot turn the shaft by hand either way, this binding indicates a bent crankshaft or seized bearing.

   If the crankshaft will turn, you can check with a dial indicator to see if it is bent before removing it from the engine.

   If you have already installed a new crankshaft and it still binds, this binding indicates the housing is warped.

5. *Check the crankshaft endplay (Figure 297).*

Before removing the crankshaft check the endplay so you will know how many, and what size gaskets to install to correct it when reassembling the crankcase. Move the crankshaft back and forth and check the amount of travel.

Too much endplay will allow the shaft to move back and forth, thus causing excessive pounding on the bearings.

Too little endplay will cause excessive pressure against the bearings.

Endplay is corrected by adding or removing the gaskets or shims under the bearing plate or stator plate (Figure 297c).

REMOVING AND REPLACING CRANKSHAFT OIL SEALS WITH SHAFT IN PLACE

If you have a leaking oil seal, you can usually replace it without removing the crankshaft or bearing support. Proceed as follows:

1. *Remove the flywheel if the seal is to be removed from the flywheel end.*

   Follow procedures under "Removing and Checking the Flywheel," page 55.

2. *Remove the dust cover if one is installed (Figure 298).*

3. *Determine if the oil seal can be removed without removing the crankshaft.*

   If the **seal is accessible,** it can be replaced without removing the crankshaft. Proceed to step 3.

4. *Remove the oil seal (Figure 299).*

   Some oil seals are **1-piece.** The neoprene seal is encased in a metal housing (Figure 294). This type is pressed into place around the crankshaft.

   Others are supplied in **3-piece sets** with the seal and retainer held by a lock ring (Figure 300).

   a. If you have the **1-piece type** (Figure 299), proceed as follows:

      (1) *Drill or punch two 1/8-inch holes in the seal on opposite sides.*

      Do not drill past the seal, or you will damage the crankcase or bearings.

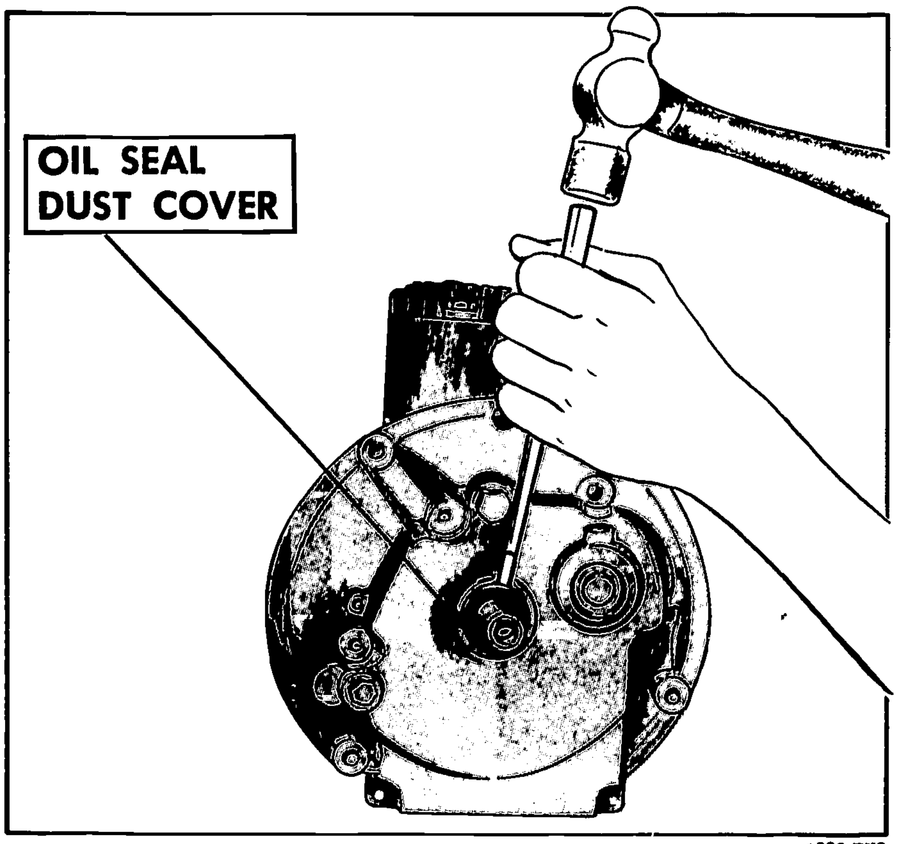


FIGURE 298. Removing the oil-seal dust cover.

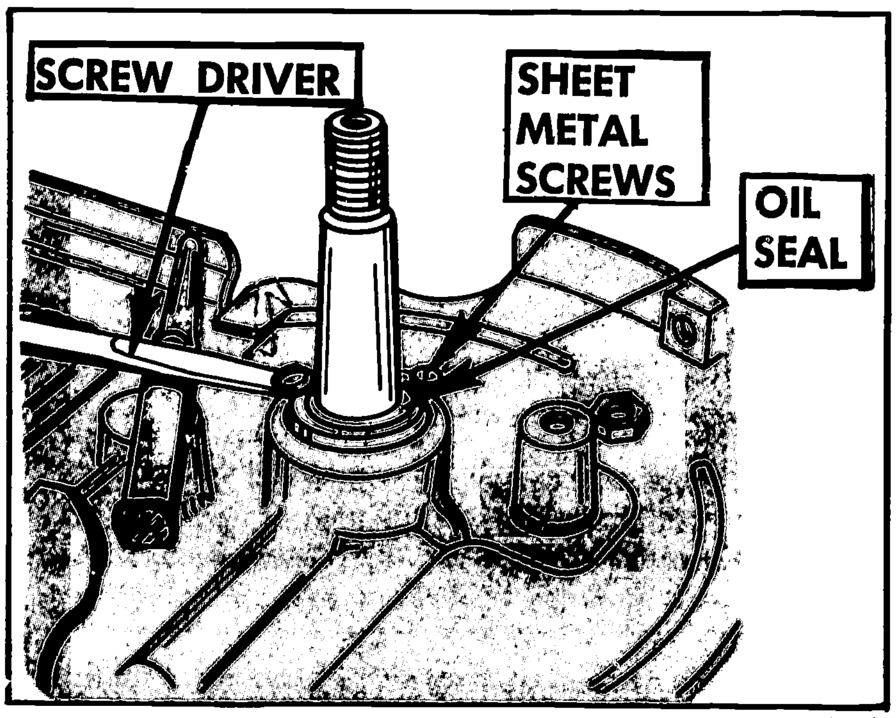


FIGURE 299. Removing a 1-piece oil seal.

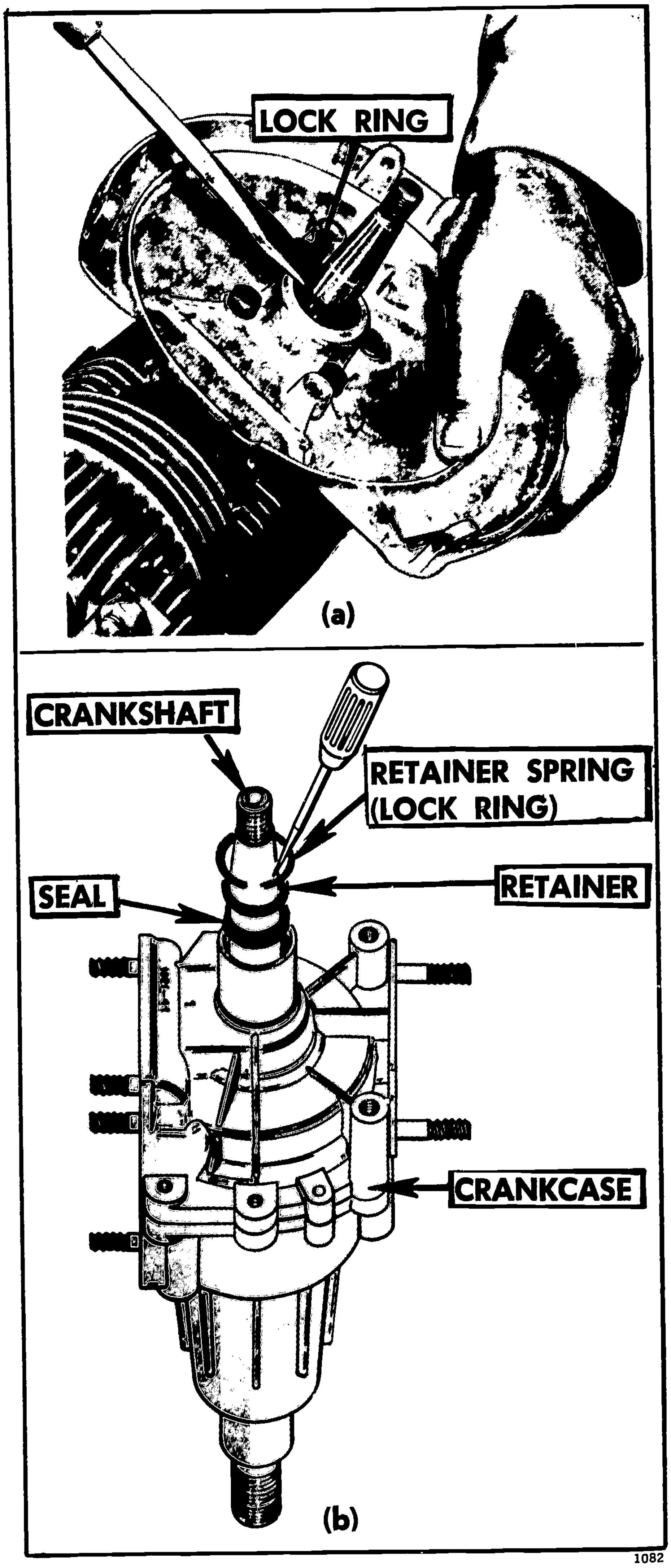


FIGURE 300. Removing a 3-piece oil seal. (a) Removing the lock ring. (b) Lock ring, retainer and seal removed.

(2) *Install 3/16″ sheet-metal screws in each hole part way.*

(3) *Pry the oil seal out with a screwdriver (Figure 299).*

A special tool is available for removing this type seal.

b. If yours is a **3-piece oil seal** (Figure 300), proceed as follows:

(1) *Remove the lock ring (Figure 300).*

Use a prick punch.

(2) *Remove the seal retainer.*

Turn the engine so the end of the crankshaft is down, and try to jar the retainer out by pounding the end of the crankshaft with a soft hammer. If the retainer does not fall out, follow procedures under "a" preceding; then proceed with step 3.

(3) *Remove the seal with a prick punch.*

(4) *Clean the oil-seal recess.*

Wipe dry with a clean cloth.

(5) *Apply gasket cement on the outside rim of the oil seal.*

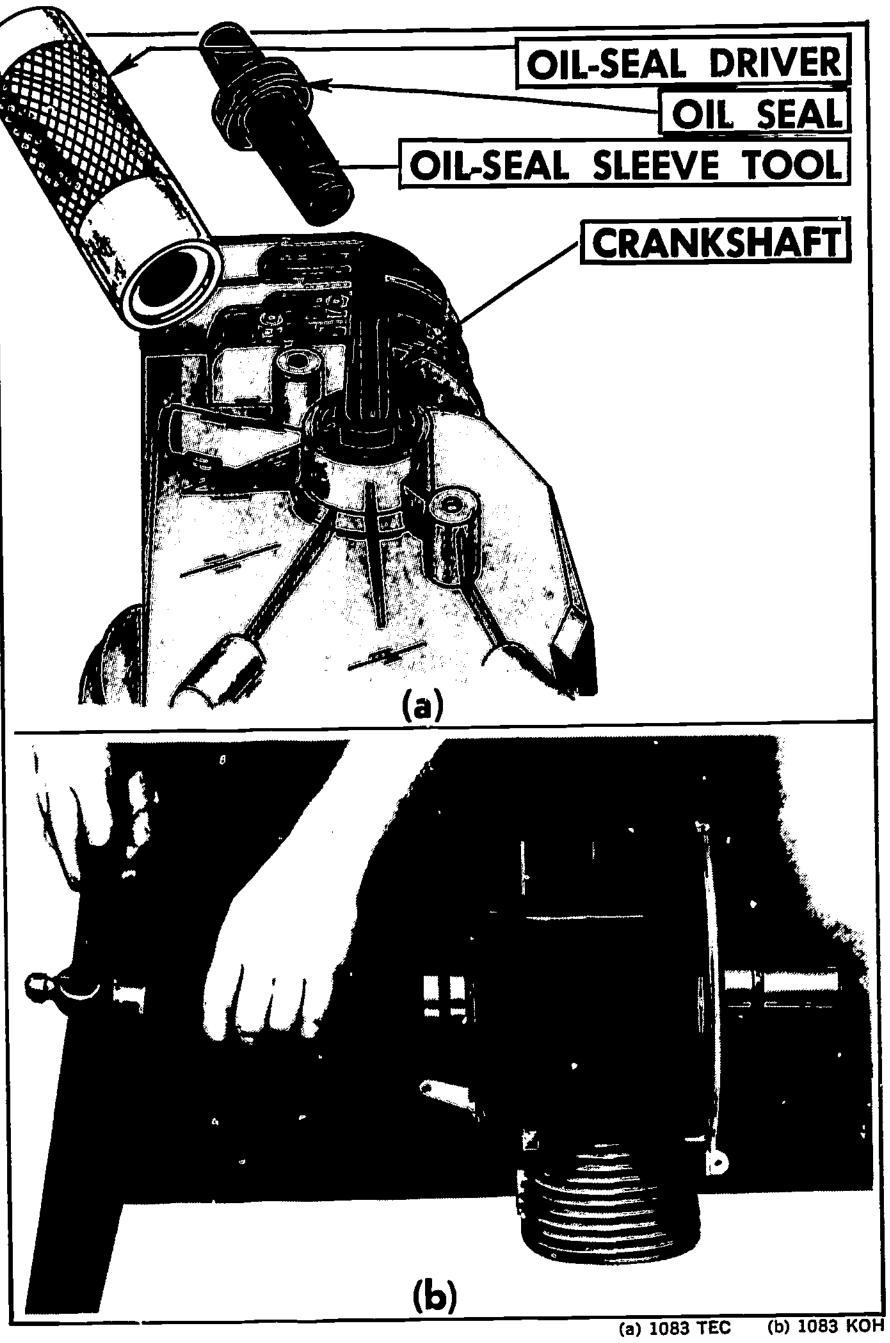


FIGURE 301. Installing the oil seal over the crankshaft. (a) Special oil-seal installation tools. (b) Installing the seal.

The cement seals the side next to the crankcase so that it is oil tight.

(6) *Apply crankcase oil to the inside of the seal and to the crankshaft.*

(7) *Install the oil seal over the oil-seal-sleeve tool (Figure 301a), or wrap the crankshaft with thin cardboard.*

This precaution protects the seal from being damaged while passing over the crankshaft.

(8) *Position the seal over the recess.*

(9) *Drive the seal in place (Figure 301b).*

(10) *Install dust cap if provided.*

REMOVING THE CRANKSHAFT

1. *Prepare the engine for removal of the crankshaft.*
   The parts to be removed are listed under "Preparing to Remove the Piston-and-Rod Assembly," page 143.

2. *Remove the flywheel.*

   For procedures refer to "Removing and Checking the Flywheel," page 55.

3. *Remove the magneto breaker-point assembly if installed.*

   Follow procedures under "Removing and Replacing the Stator Plate and/or Coil," page 73.

4. *Remove the magneto-bearing plate or PTO-bearing support and gear cover.*

   A bearing plate on the flywheel end, and/or a *bearing support on the PTO end* will have to be removed. The bearing plate on the flywheel end usually must be removed with a bearing puller (Figure 302a). Some bearing supports on the PTO end are removed along with the crankshaft, after the bearing plate on the opposite end is removed (Figure 302b).

5. *Release the ball bearing if it is held by cam locks (Figure 303).*
   Loosen lock nuts and turn one quarter turn with a screwdriver.

6. *Remove the oil pump, camshaft and governor from inside the engine if installed.*

7. *Remove crankshaft retaining ring from opposite end of crankshaft, if installed.*

   Some 2-cycle engines have a retainer ring inside the crankcase.

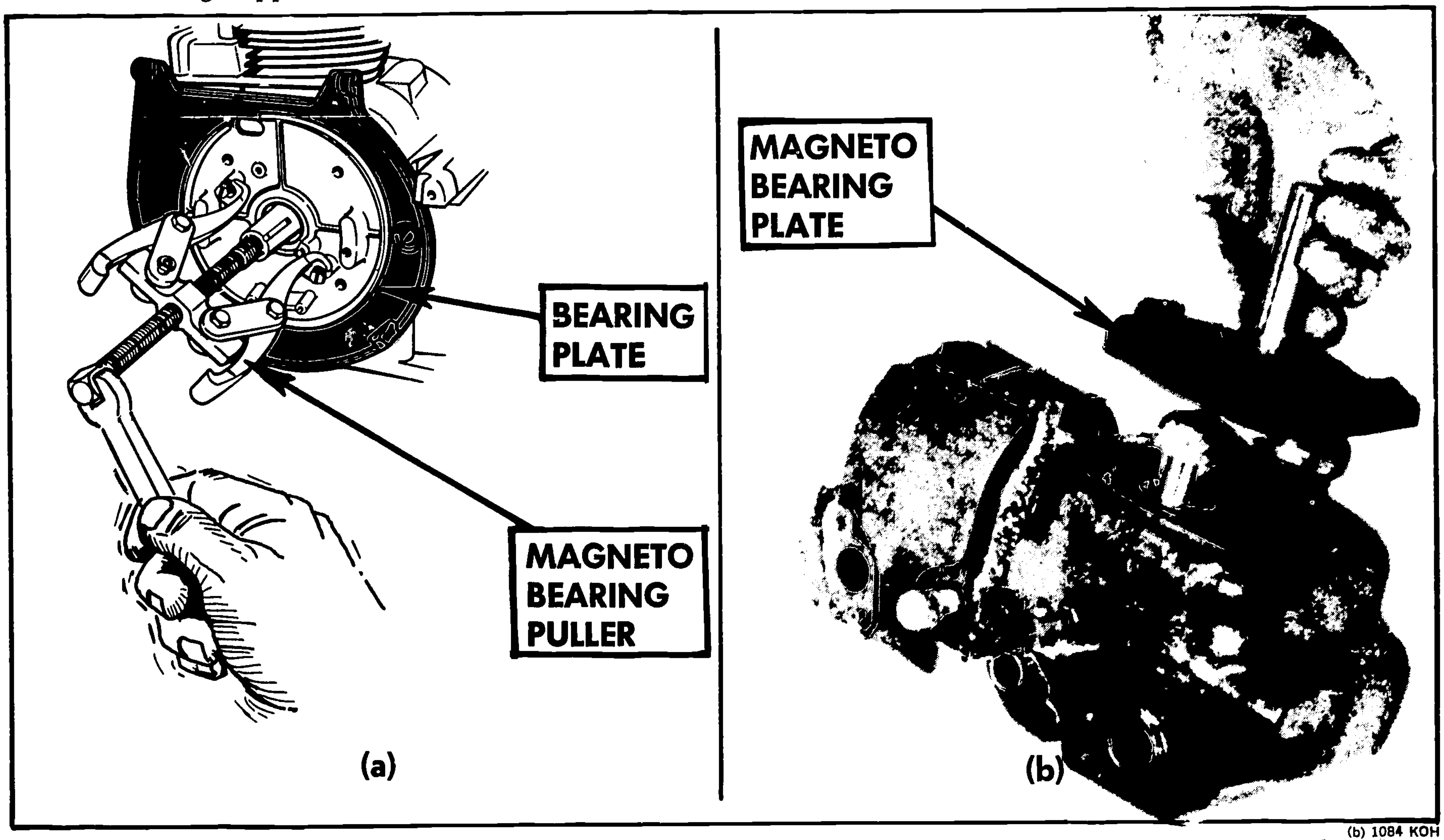


FIGURE 302. (a) Removing the bearing plate with a puller. (b) Removing the PTO-bearing support along with the crankshaft after the opposite bearing plate is removed.

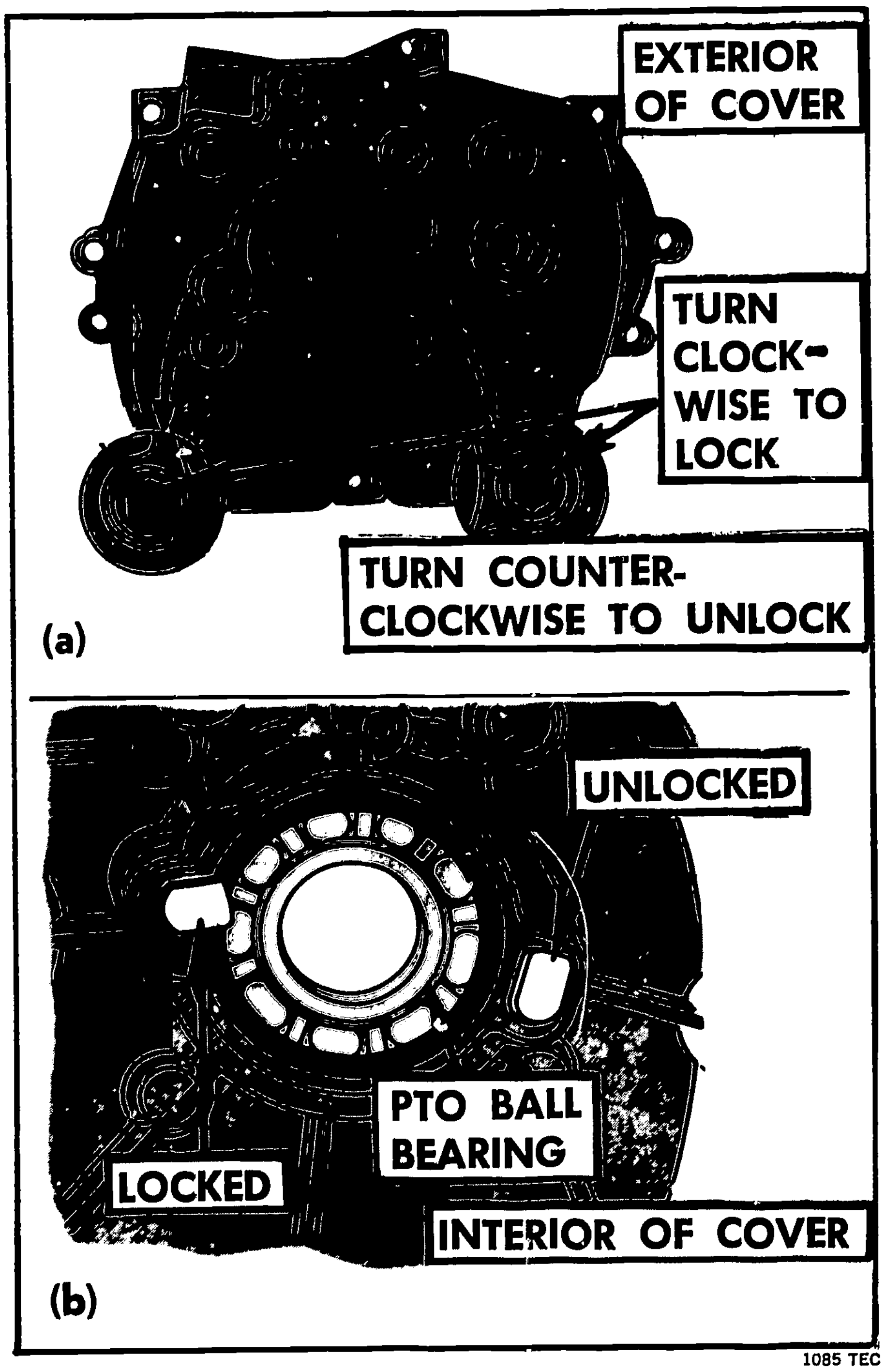


FIGURE 303. Cam locks for ball bearings. (a) Exterior view. Cam slots for turning with a screwdriver. (b) Interior view with one cam locked and one cam unlocked.

8. *Disconnect the connecting rod from the crankshaft.*

   Refer to "Removing the Piston-and-Rod Assembly," page 144.

   If the engine has **tapered-roller bearings** (Figure 304), remove the crankshaft by pulling gently by hand.

   If the engine has **ball or plain bearings,** tap (or press) the crankshaft out (Figure 305).

9. *Remove oil seals if not already removed.*

   Use a screwdriver or a special tool (Figure 306).

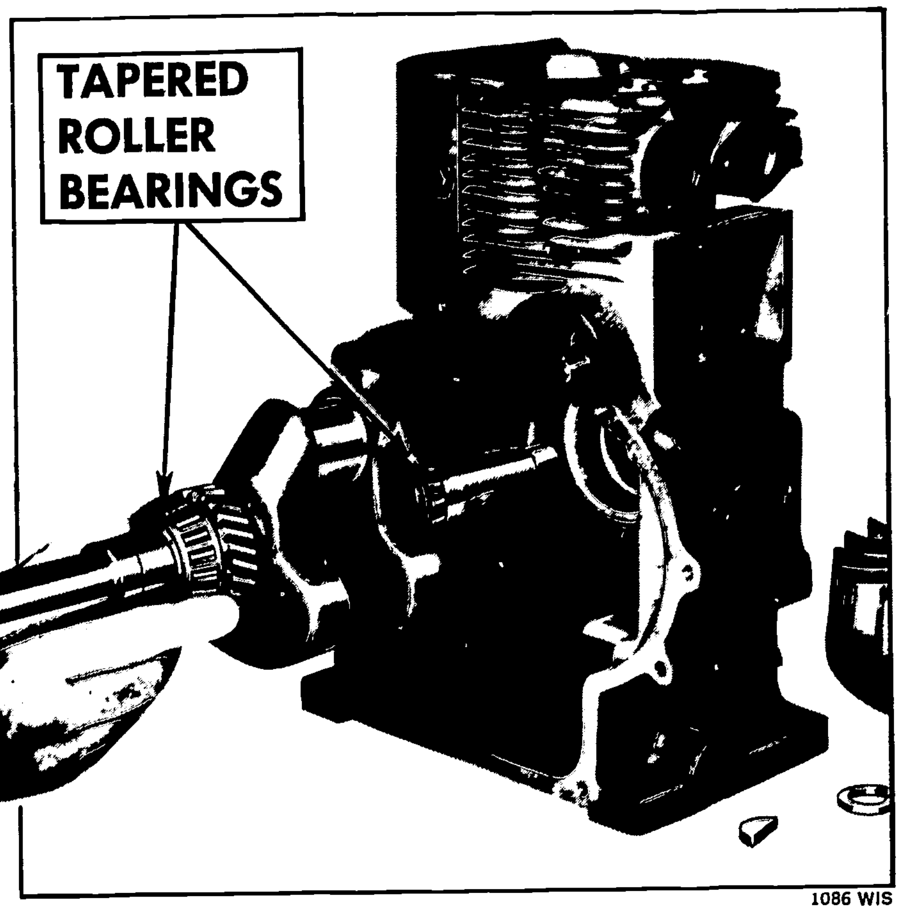


FIGURE 304. Removing a crankshaft which has tapered-roller bearings.

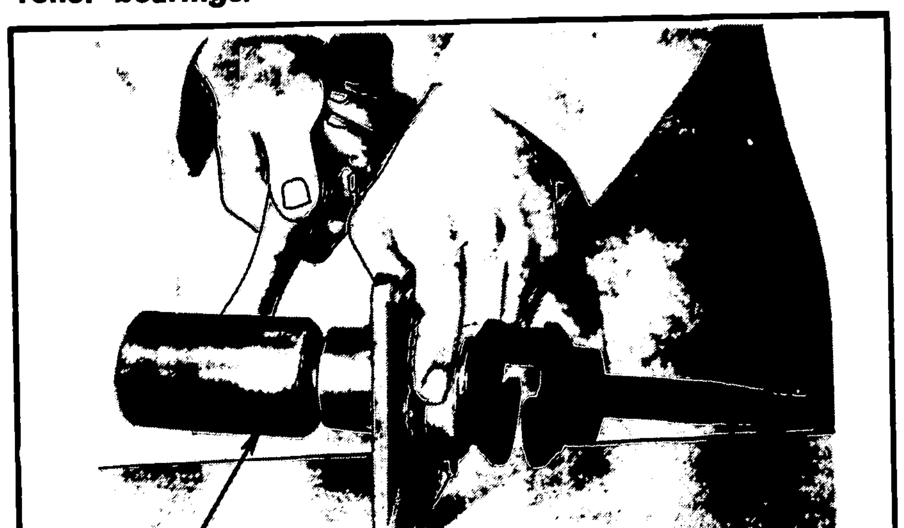


FIGURE 305. Removing a crankshaft equipped with ball or plain bearings from: (a) a removable bearing plate, and (b) the crankcase.

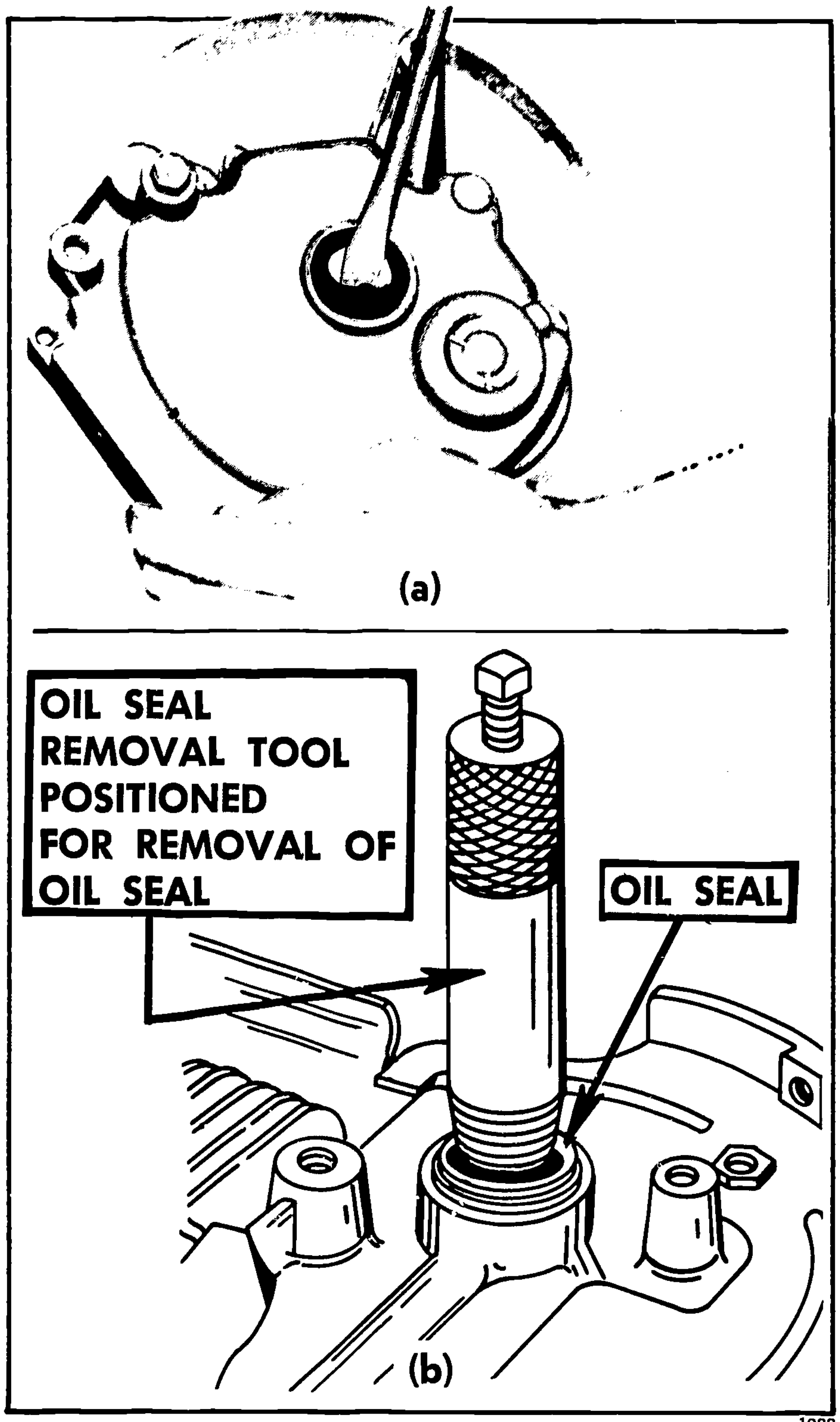


FIGURE 306. Removing the oil seal with (a) screwdriver, or (b) special tool for pulling the seal.

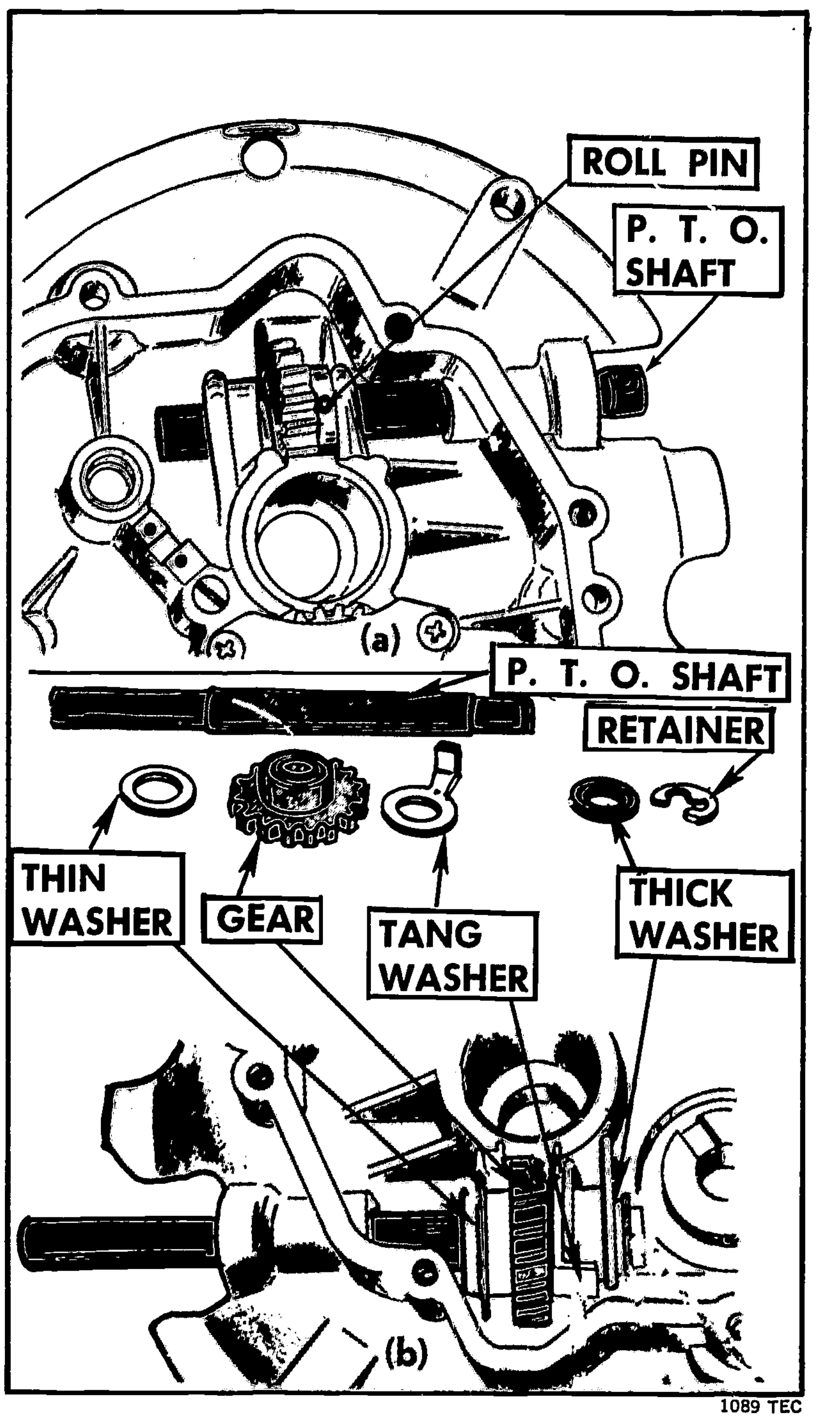


FIGURE 307. Two methods for removing a power take-off shaft are (a) punching out a roll pin, and (b) removing a shaft retainer.

10. *Remove the power take-off shaft, if installed (Figure 307).*

    Some engines have a secondary shaft for supplying power at slower speed. It is not the camshaft, as used on some engines. If you wish to service it, remove and check it while the crankshaft is removed.

CLEANING AND INSPECTING THE CRANKSHAFT

1. *Clean with petroleum solvent.*
2. *Check for wear (Figure 308).*

   Measure crankshaft journals for **out-of roundness.** Replace crankshaft if it is out-of-round more than .001″. The journals are the bearing surface of the crankshaft.

   Check **gear teeth** for chips and wear.

   Check **threads.** Threads can be reconditioned with a die.
3. *Check the crankshaft for straightness (Figure 309).*
4. *Check for score marks or roughness at bearing points.*

   Light scoring or roughness can be smoothed with an emery cloth.
5. *Check the crankshaft taper, if tapered.*

   If rust is present on the tapered portion which fits into the flywheel, this indicates

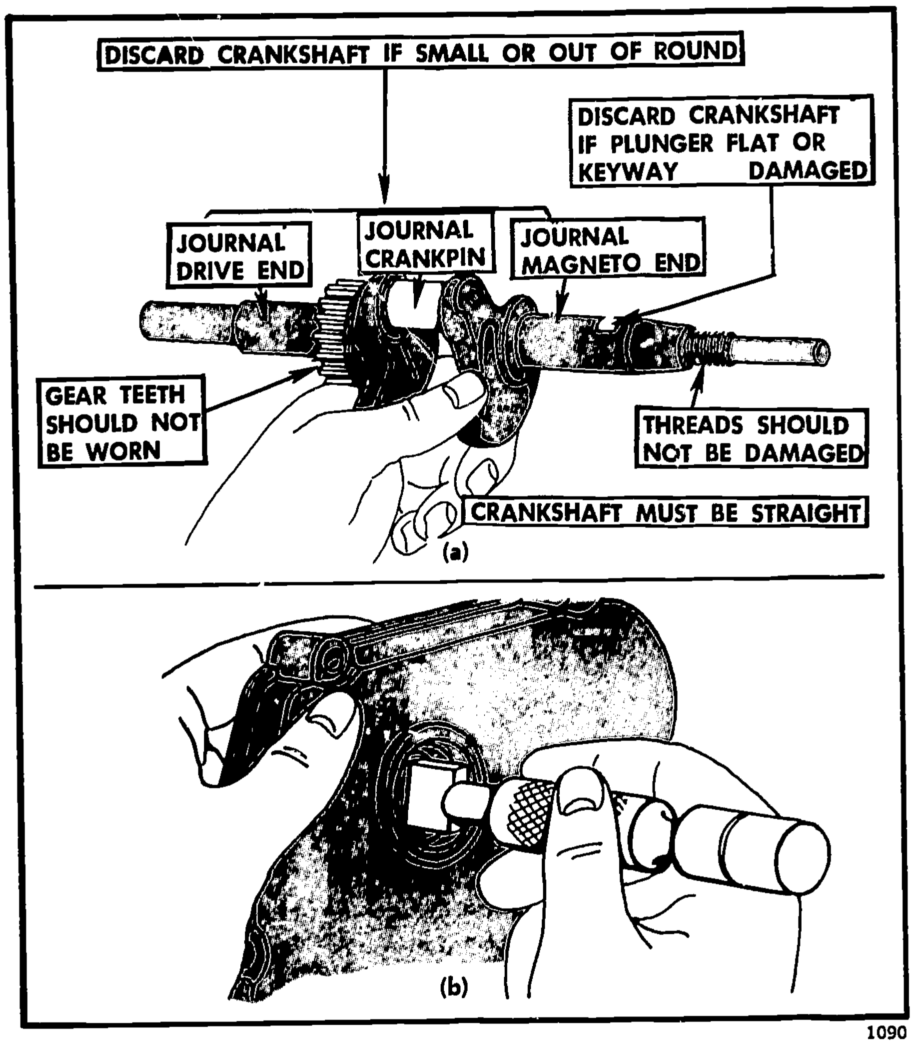


FIGURE 308. (a) Measuring the diameter, of the journals. Compare them with tolerances given in your repair manual. (b) Checking bearing with "go, no-go" gage.

the engine has been operating with a loose flywheel.

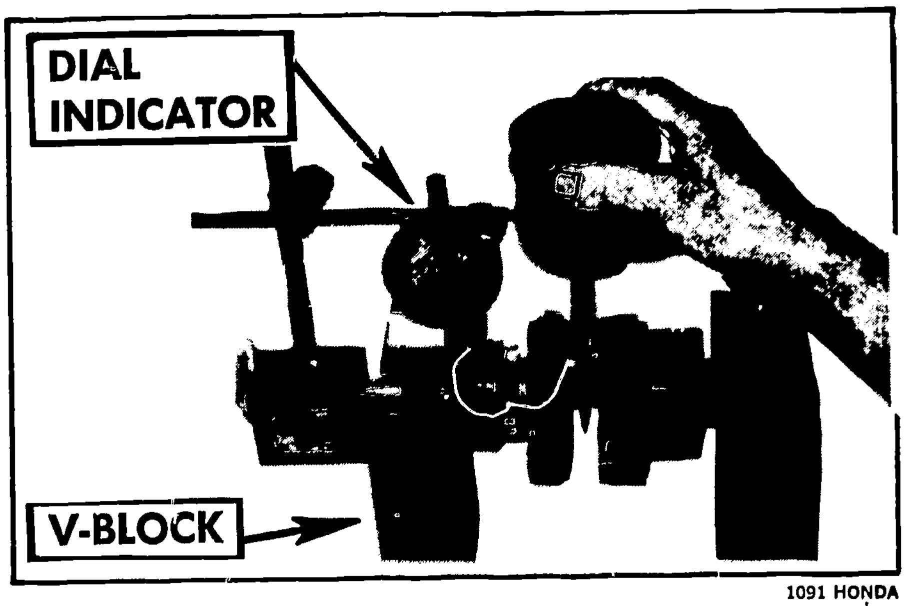


FIGURE 309. Checking the crankshaft for straightness with a dial indicator.

6. *Check the keyway.*

   If the keyway is worn excessively, replace the crankshaft. This worn keyway will cause the ignition timing to be off.

7. *Check the breaker-point plunger for wear, if installed (Figure 101).*

   This step is for engines that have the breaker points activated by a cam or trip on the crankshaft and/or camshaft. The plunger is not a part of the crankshaft, but the crankshaft must be removed in order for you to check it.

CLEANING AND INSPECTING THE CRANKSHAFT BEARINGS

Do not remove bearings from the crankcase unless you already know they are defective or unless it is necessary to remove them with the crankshaft.

1. *Clean the bearings in petroleum solvent.*

   Do not direct compressed air onto ball or roller bearings so they will spin. Spinning a dry bearing causes rapid wear and may ruin both the balls, or rollers, and the raceways.

2. *Check bearings for damage and wear.*

   Rotate **ball or roller bearings** by hand to check their condition. They should run smoothly. Balls and rollers should be true, with no flat sides or abrasions.

   Caged bearings should remain in the cage and not fall out.

   Check to see if the outer race is turning in the crankcase housing. If it is, peen the housing to tighten it.

   Replace ball, roller or needle bearings if damaged.

   Check **plain bearings** (Figure 310) for wear, scratches and scoring. Use an inside gage and an outside micrometer to measure the diameter of plain bearings, or use a special go, no-go gage (Figure 308b). Rebore and replace plain-bearing inserts when worn or damaged.

REMOVING AND REPLACING BEARINGS

Do not remove bearings unless there are indications that they are worn or damaged.

The removal method you use depends on the type of bearing and the material from which the crank-

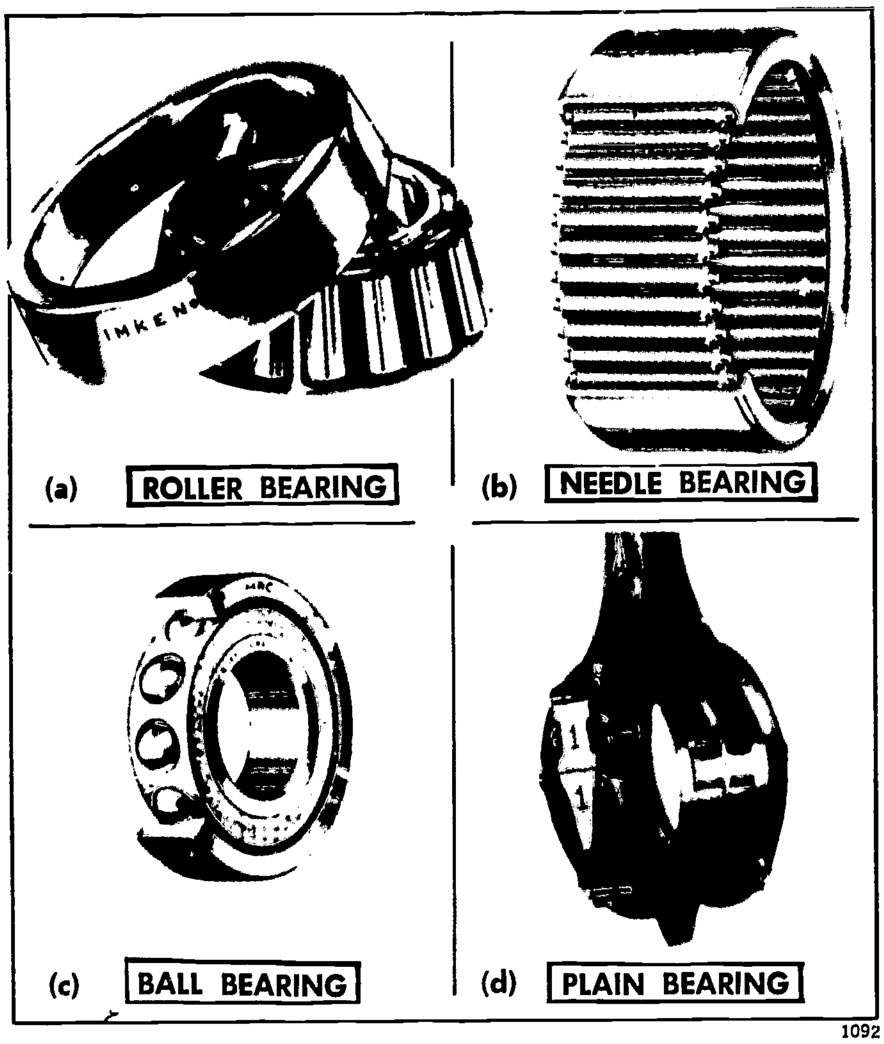


FIGURE 310. Types of bearings used on crankshaft assemblies. (a) Tapered-roller bearings withstand high speeds as well as heavy radial and thrust loads. They are used on heavy duty engines and engines of high horsepower. (b) Needle bearings take a heavy radial load. They are used in 2-cycle, high-speed engines. (c) Ball bearings withstand high speeds, moderate radial loads and moderate thrust. You will find ball bearings in all sizes of small engines. (d) Plain bearings are used in low-horsepower engines.

case is made. If the engine has **ball, needle or roller bearings** (Figure 310a, b and c), remove and replace them.

If the engine has a **cast-iron crankcase with plain-bearing inserts** (Figure 310d), they can also be removed and replaced; but the new inserts must be reamed.

If the engine has an **aluminum crankcase with plain bearings** which consists of a hole bored in the crankcase housing (no inserts), it may be possible to rebore and install an insert. The insert must be reamed to the shaft diameter.

Proceed as follows:

a. If the crankshaft has **ball, needle or roller bearings,** similar to the ones shown in Figure 310, proceed as follows:

1. *Install a bearing puller (Figure 311a), or place the crankshaft in an arbor press (Figure 311b).*

   Do not tighten the bearing separator against the crankshaft (Figure 311a). It will scratch the crankshaft bearing surface.

2. *Turn the removal screw with a wrench (Figure 311a).*

   Strike with a mallet occasionally.

3. *Install a new bearing on the crankshaft.*

   Ball bearings are press fitted. Cool the

FIGURE 311. Removing ball bearings from the crankshaft with (a) a bearing puller, or (b) an arbor press.

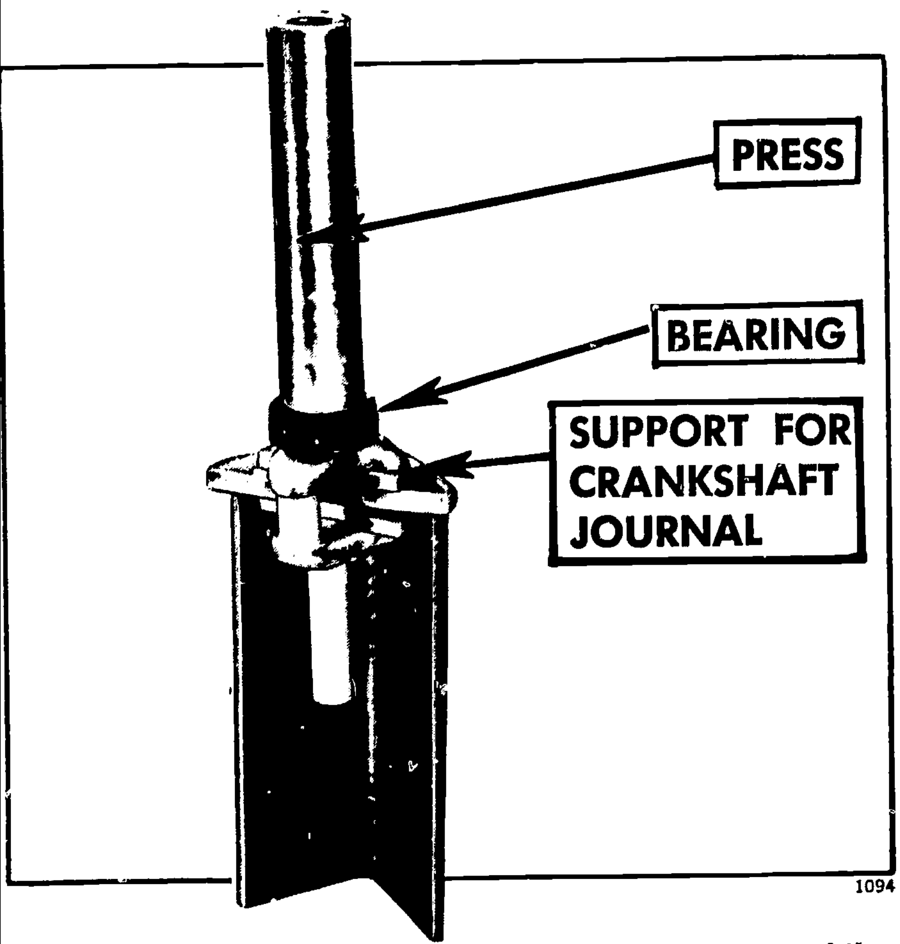


FIGURE 312. A jig supporting the crankshaft throw while bearing is fitted.

crankshaft and heat the bearing in hot oil — 325° F. maximum. Do not direct flame against the bearing as it may distort it. Press the bearing all the way to the shoulder of the crankshaft (Figure 312).

The ball bearing must be sweat fitted onto the shaft; then sweat fitted to the housing. Do not press or drive bearings onto the crankshaft without supporting the throw (Figure 312).

Install outer races for new **tapered-roller bearings** in the housing (Figure 313a).

This is done by cooling the race, heating the housing and pressing the bearings into the housing.

Place needle bearings in the outer race by hand. Pack with multi-purpose grease to hold them in place until the shaft is installed.

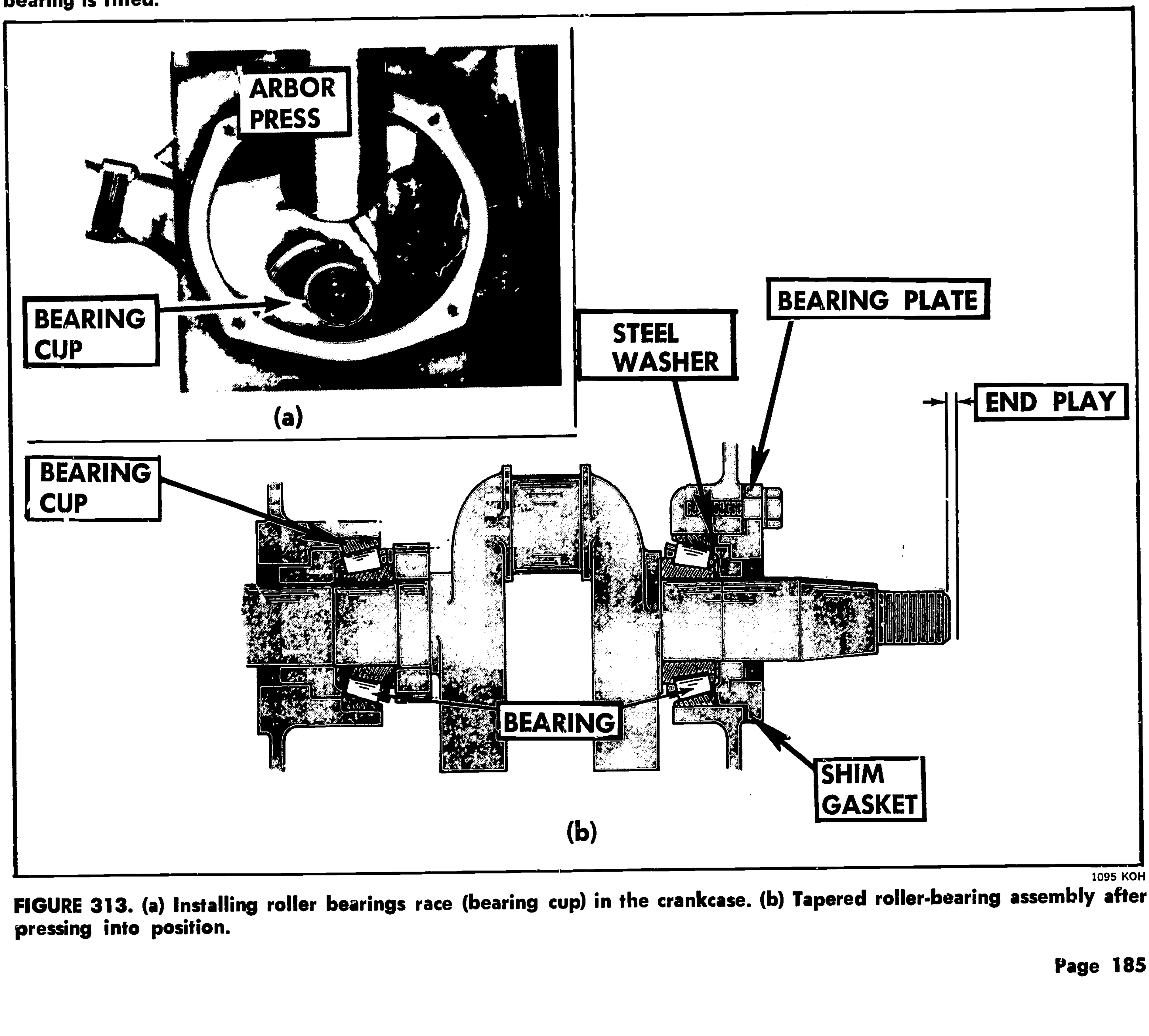


FIGURE 313. (a) Installing roller bearings race (bearing cup) in the crankcase. (b) Tapered roller-bearing assembly after pressing into position.

b. If the engine has a **cast-iron crankcase with plain-bearing inserts,** proceed as follows:

1. *Remove old bearings (Figure 314).*

   Remove bearing on PTO-end first. In these procedures you will remove, replace and ream one bearing before removing the opposite bearing. In this way you use one as a guide for reaming the other. When you are removing the bearing insert, always press it toward the inside of the crankcase. Use an arbor press.

2. *Press in a new bearing.*

   Install bearing toward the outside. Be sure you align the oil hole in the bearing with the oil hole in the crankcase.

   Make the outer end of the bearing flush with the outer end of the bearing hole in the crankcase to allow room for the oil seal.

3. *Select the proper reaming tools.*

   Special reaming tools are provided by each manufacturer. The size, design and procedures for their use vary; so check your service manual.

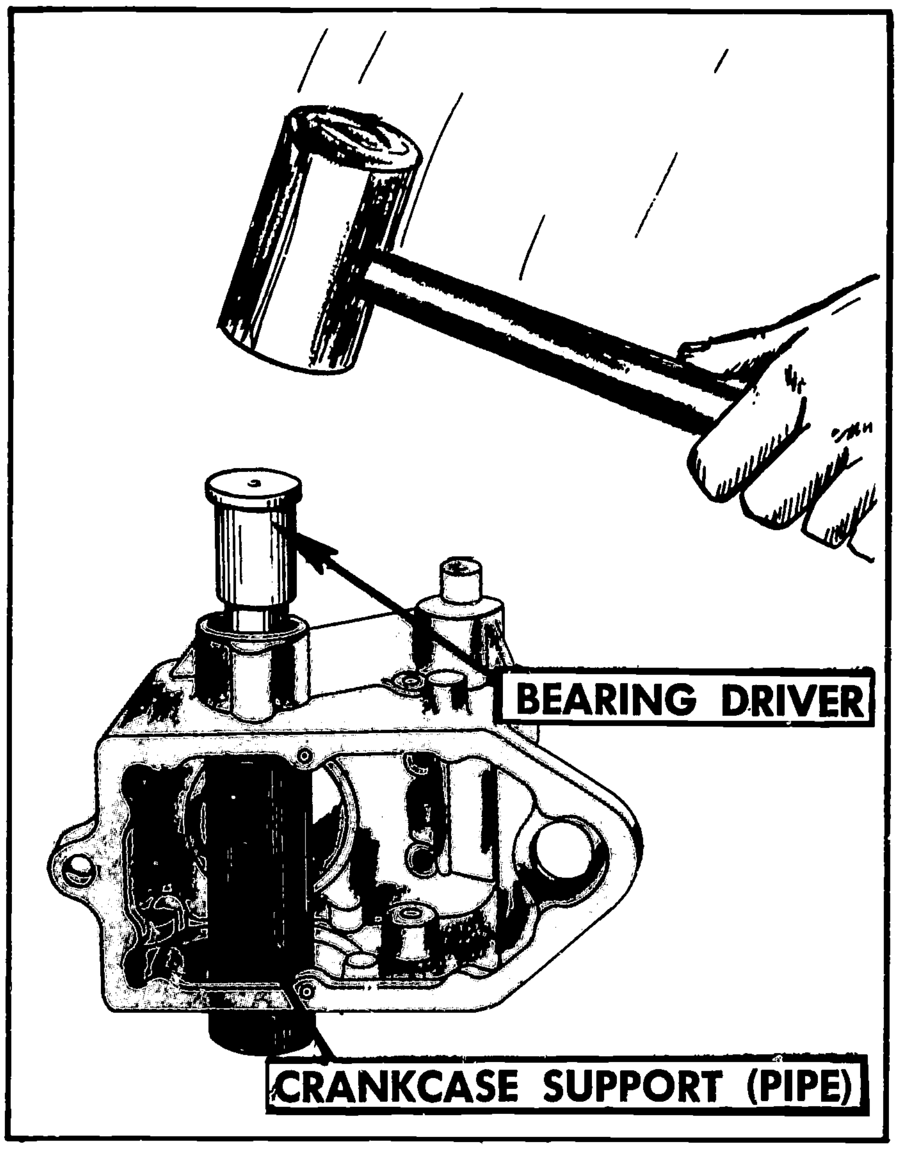


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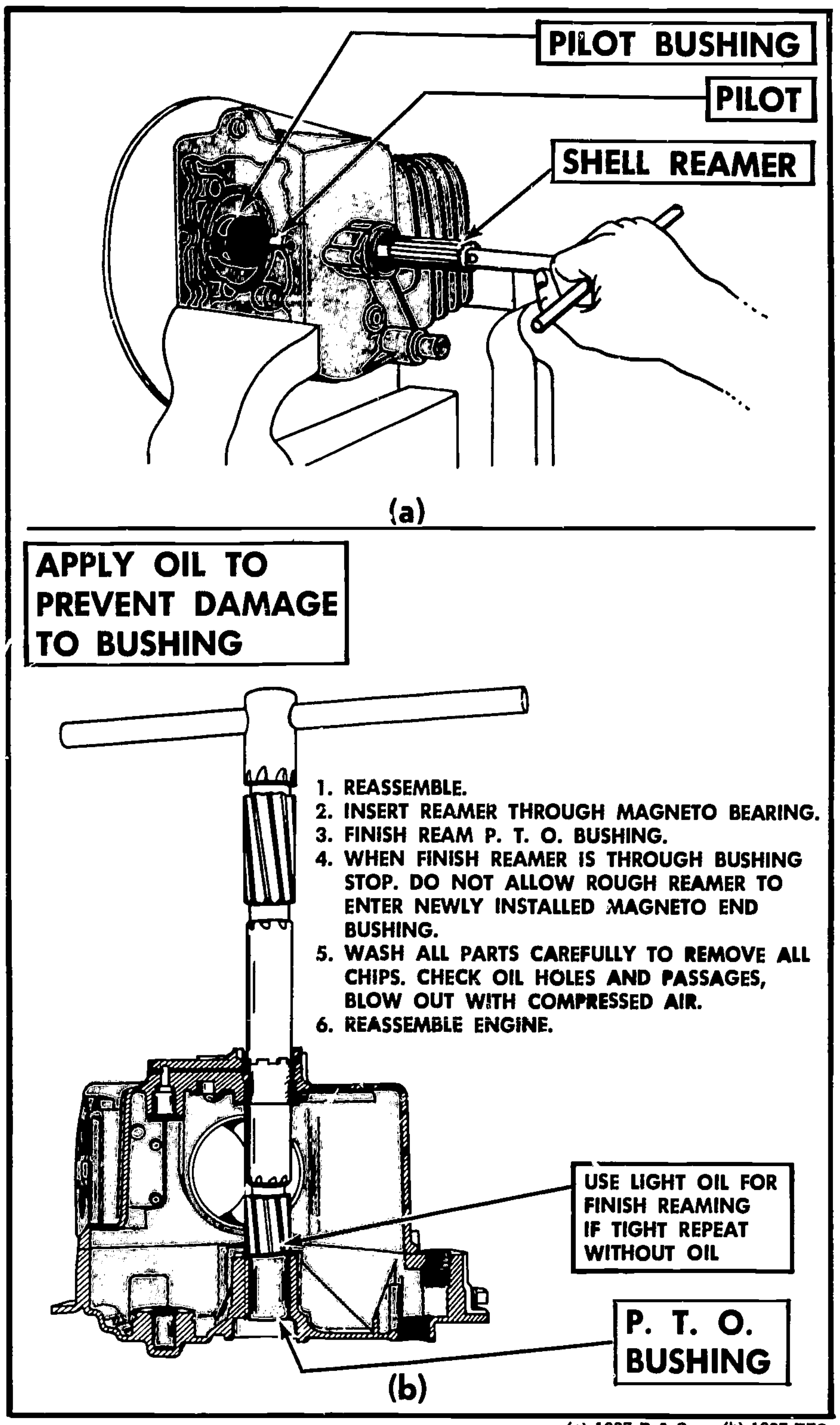
FIGURE 314. Removing a plain bearing. Crankcase is supported by large pipe in bearing area.

4. *Insert the reamer and pilot.*

   Procedures for two types of reamers are given here (Figure 315).

   If the reamer has a **pilot and guide bushing** (Figure 315a), place the guide bushing in the opposite bearing with the flange toward the inside; then reassemble the crankcase if separated.

   If the reamer is a **two-piece unit with the shank used as a pilot** (Figure 315b), assemble the crankcase — if disassembled — for alignment before you start. Then insert the reamer shank through the opposite bearing. With this type, the opposite bearing acts as the guide.



(a) 1097 B & S (b) 1097 TEC

FIGURE 315. Reaming a bearing insert with (a) a reamer which has a separate pilot and guide bushing or (b) a reamer with the reamer shank and opposite bearing used as a guide.

5. *Ream bearing to size (Figure 315).*

Turn reamer clockwise with a steady, even pressure until it is completely through the bearing. Follow instructions in your repair manual as to whether to use cutting oil or not. Cutting oil, kerosene or fuel oil will cause the reamer to cut a smaller hole than when it is cutting it dry. Some manufacturers recommend cutting wet; some, dry.

6. *Remove the magneto-bearing plate before attempting to remove the reamer.*

This removal is to prevent you from having to pull the reamer back through the bearing insert. Each time the reamer passes through the bearing, it is enlarged. It is well to make one pass through, if possible. On some engines one pass through is not possible. The reamer must be removed from the top. The reamer size is adjusted for this.

7. *Remove the reamer from the opposite end of the crankcase.*

Do not remove the reamer back through the bushing unless necessary. This removal will cut the bearing larger. Remove guide bushing (Figure 315a) if installed.

8. *Clean away all metal chips.*

Make certain metal chips do not get into the oil passageways.

CAUTION! Wear protective goggles when using compressed air to blow away metal chips.

9. *Check new bearing for size.*

10. *Remove and replace the other bearing in the same manner.*

Always replace both bearings — not just one. This will give you proper crankshaft bearing alignment.

c. If the engine has an **aluminum crankcase with plain bearings** (not inserts), proceed as follows:

1. *Determine if the bearing is reparable.*

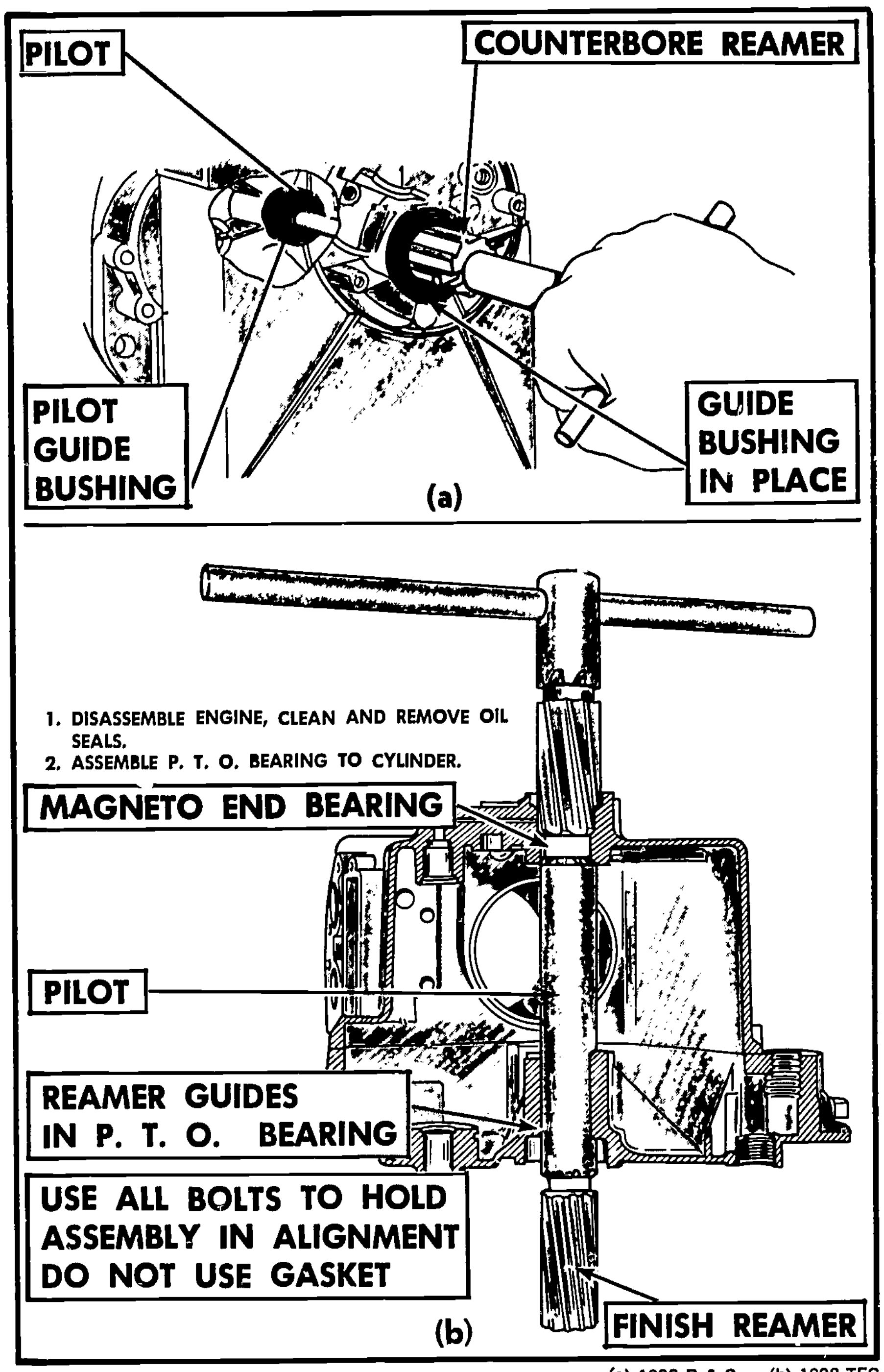
It is possible on some aluminum engines to counterbore the aluminum crankcase and install a bearing insert. If yours is reparable, proceed to step 2.

Some engines are not designed for having the bearing repaired, and no special tools or instructions are provided by the manufacturers. Some are designed for repairing only one of the bearings. The instructions in your service manual will provide this information.

2. *Sele… er counterboring tools.*
3. *C… ne crankcase for a new bearing in…*

If you do not know the difference between "counterboring" and "reaming," it is important that you understand the difference. The tools look the same and are used in the same manner, but the results are different. **Counterboring** consists of enlarging an existing hole with a rough cut. **Reaming** consists of sizing a hole to an exact dimension and finishing the surface with a fine finish.

Follow steps 4 through 8 under "b" preceding, except use the counterbore cutter instead of the finish reamer (Figure 316). When using the counterboring tool with the pilot-guide bushing, install a steel guide bushing in the oil-seal recess at the bearing which you are counterboring (Figure 315a). The guide bushing centers the reamer so that the



(a) 1098 B & S (b) 1098 TEC

FIGURE 316. Counterboring (a) with a counterboring tool equipped with a pilot and guide, and (b) with a tool which uses the shank and opposite bearing as a guide.

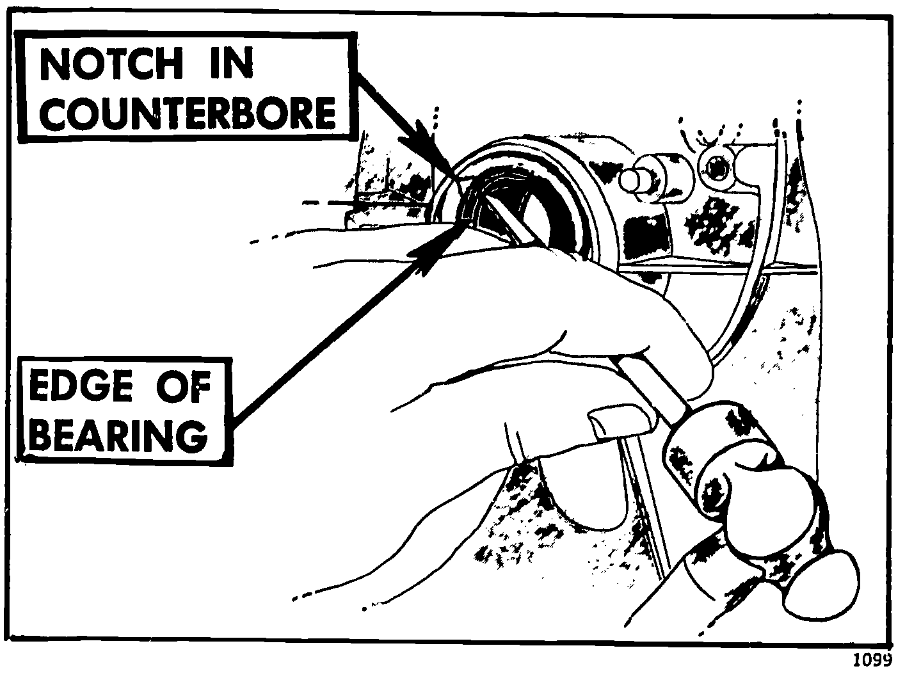


FIGURE 317. Staking (keying) the counterbore for anchoring the new bearing insert, in an aluminum crankcase.

enlarged hole is in line with the original bearing.

4. *Hold the new bearing insert against the outer end of the counterbore with the oil grooves aligned.*

5. *Mark the hub at a point opposite the split in the bearing insert.*

6. *Make a notch on the outer edge of a counterbore at the point marked (Figure 317).*

   One manufacturer recommends using a cold chisel to notch it at a 45° angle to the bearing surface. This notching is to stake (key) the bearing insert to the crankcase so that it will not turn during operation.

7. *Press in the new bearing.*

   Make sure oil passages are aligned. Make the bearing flush with the housing at the outer end.

INSTALLING THE CRANKSHAFT

Before installing your crankshaft be sure all parts are clean and well oiled. Do not handle steel parts with your fingers unless absolutely necessary. The acid from your fingers will cause them to corrode. Use a rag or gloves for handling.

1. *Install the oil seals (Figure 319).*

   Oil seals may be installed in the bearing plate before the plate is attached, or they may be installed after the crankshaft is installed. In either case, be careful not to damage the oil seals. If you install the seal before bearing plate is attached, proceed as follows:

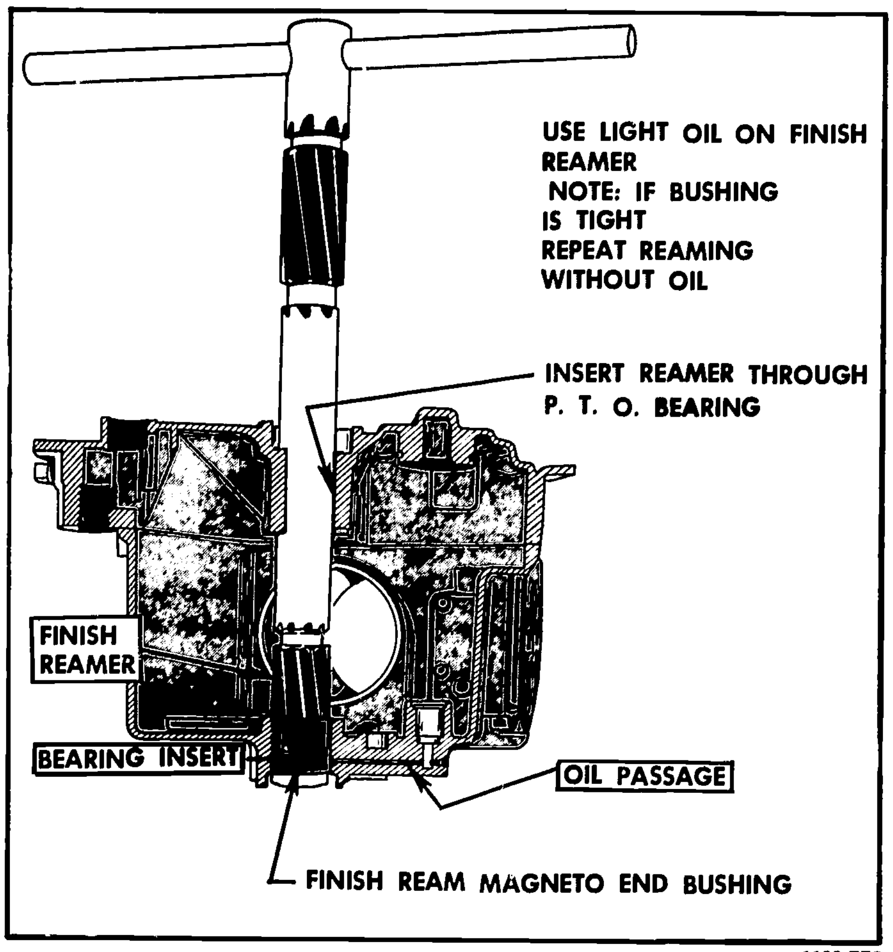


FIGURE 318. Reaming the front bearing.

8. *Stake the new bearing into the notch provided for in step 6, if recommended by your manufacturer.*

   Use a blunt chisel.

9. *Ream the new bearing insert (Figure 318).*

   Follow procedures in steps 3 through 10 under "b" preceding for reaming the new bearing.

10. *Check bearing for size.*

    Note procedures under "Cleaning and Inspecting Crankshaft Bearings," page 183.

11. *Repeat these procedures for the opposite crankshaft bearing if applicable.*

(1) *Apply gasket cement to the outside of the seal.*

As the oil seal bottoms when installed, the gasket cement will bond the outside of the seal to the crankcase.

(2) *Seat the seal flush with the receptacle (Figure 319b).*

(3) *Check to see that no gasket paste gets into the oil passageways.*

(4) *Lubricate the oil seal with crankcase oil.*

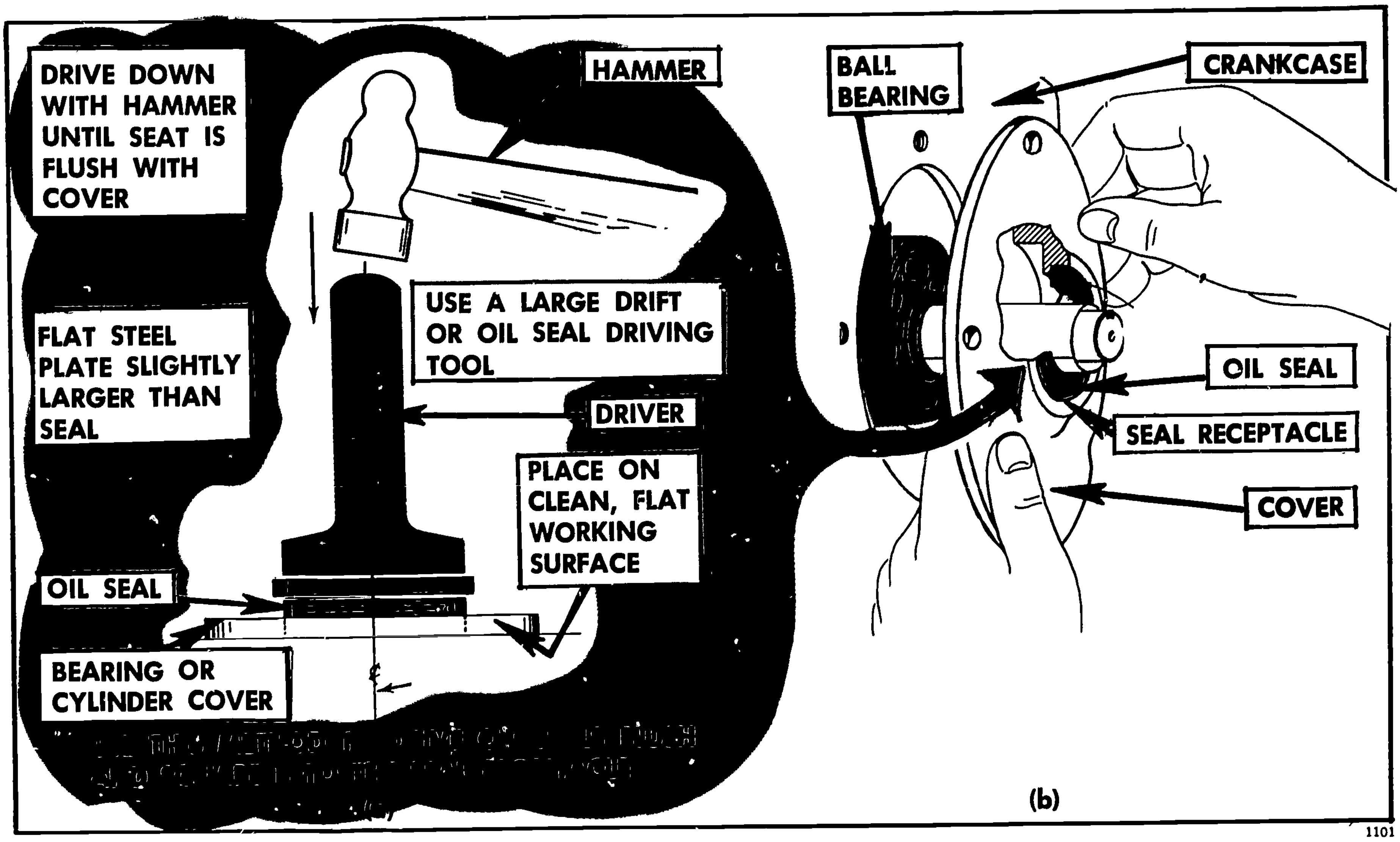


FIGURE 319. (a) Installing the oil seal before installing the crankshaft. (b) Installing the bearing plate and oil seal on the crankshaft.

2. *Install the camshaft assembly first, if it is the type that rotates on a pin (Figure 320a).*

   For procedures refer to "Installing the Camshaft Assembly," page 173. Unless you install the camshaft assembly first, you will not be able to get the camshaft and the valve tappets past the crankshaft after it is installed.

   The camshaft assembly should be installed loosely (not tightened securely) until the crankshaft can be installed on some engines.

   Lubricate all parts before installing them.

3. *Install the crankshaft in the crankcase.*

   If the crankshaft has a thrust washer, be sure it is installed.

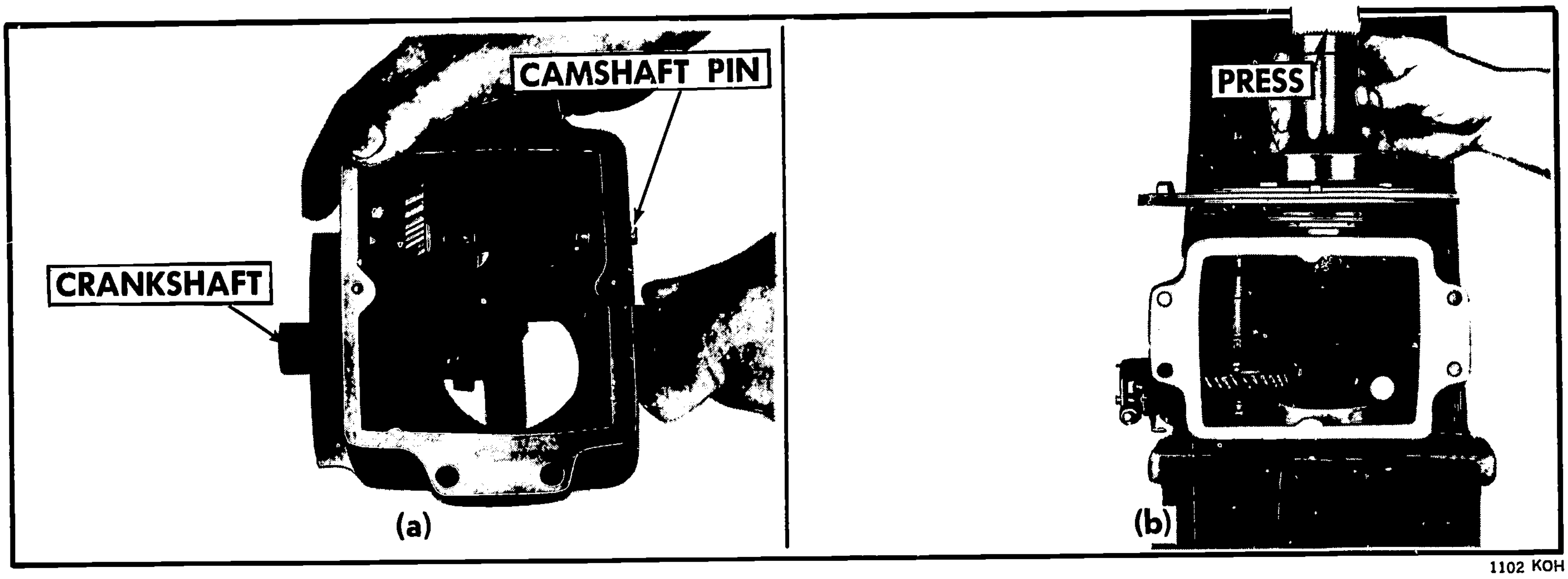


FIGURE 320. (a) Installing a crankshaft with ball bearings. (b) Pressing the bearings and crankshaft in place.

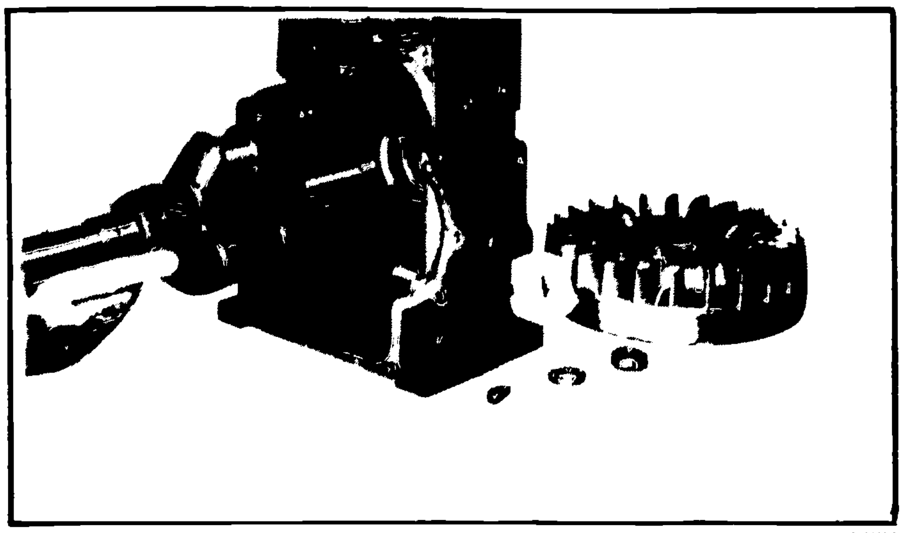


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FIGURE 321. Installing a crankshaft with tapered-roller bearings.

Watch for the breaker-point plunger, or the breaker-point actuating arm or the governor drive arm. These must be aligned properly. There is a danger of breaking them if you force the crankshaft into position.

If your engine has **ball bearings,** press the shaft and bearings in place (Figure 320).

If your engine has **tapered-roller, needle or plain bearings,** place the crankshaft in by hand (Figure 321).

4. *Connect the piston rod.*

   For procedures refer to "Installing the Piston-and-Rod Assembly," page 155.

5. *Install the camshaft assembly, if it has not already been installed (Figure 322).*

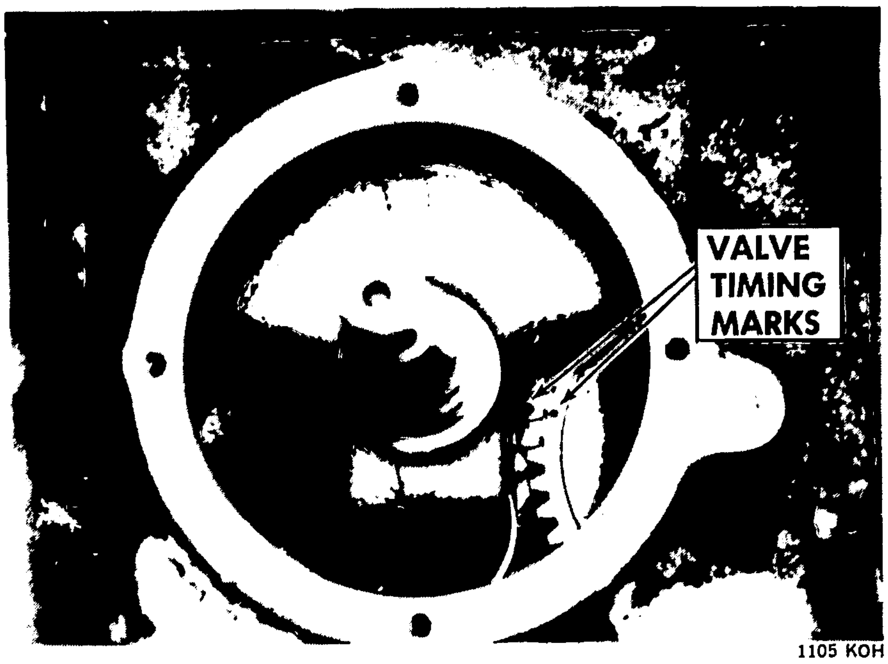

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FIGURE 323. Align the valve-timing marks on the crankshaft and camshaft gears before replacing the bearing plate.

   Refer to "Installing the Camshaft Assembly," page 173.

6. *Align the valve timing marks (Figure 323).*

   Refer to "Installing the Camshaft Assembly," page 173.

7. *Press in the camshaft pin if yours is the type that rotates on a pin (Figure 324).*
8. *Install the governor assembly if one is located inside the crankcase (Figure 322).*
9. *Install oil line from oil pump to upper main bearing if used (Figure 325).*

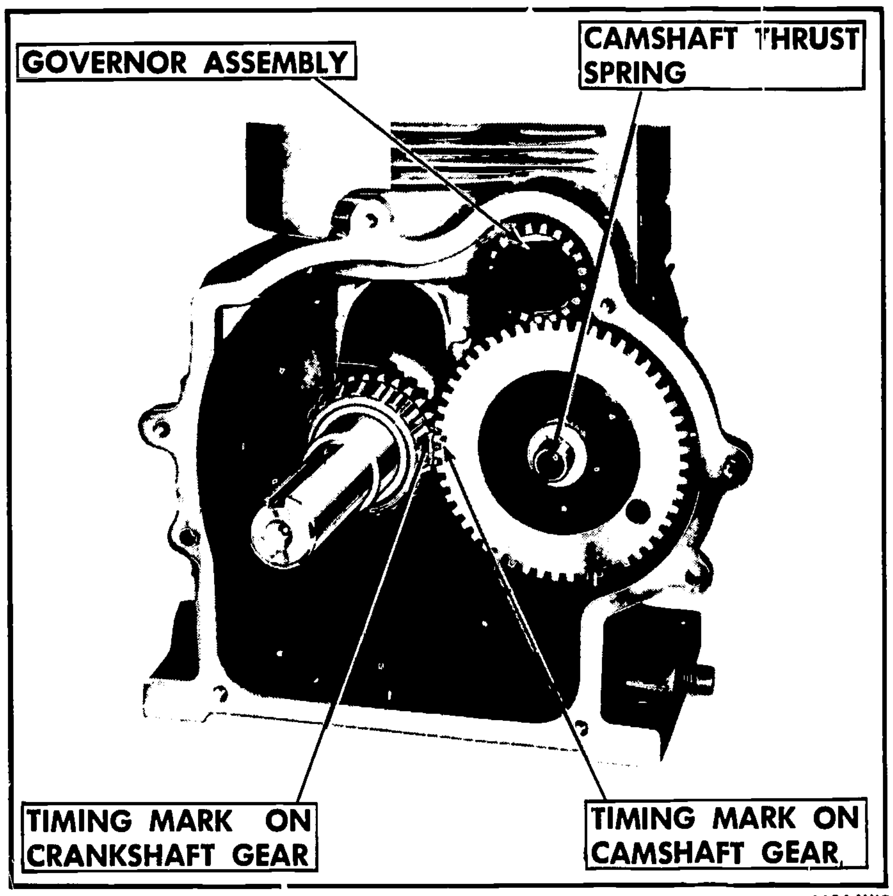

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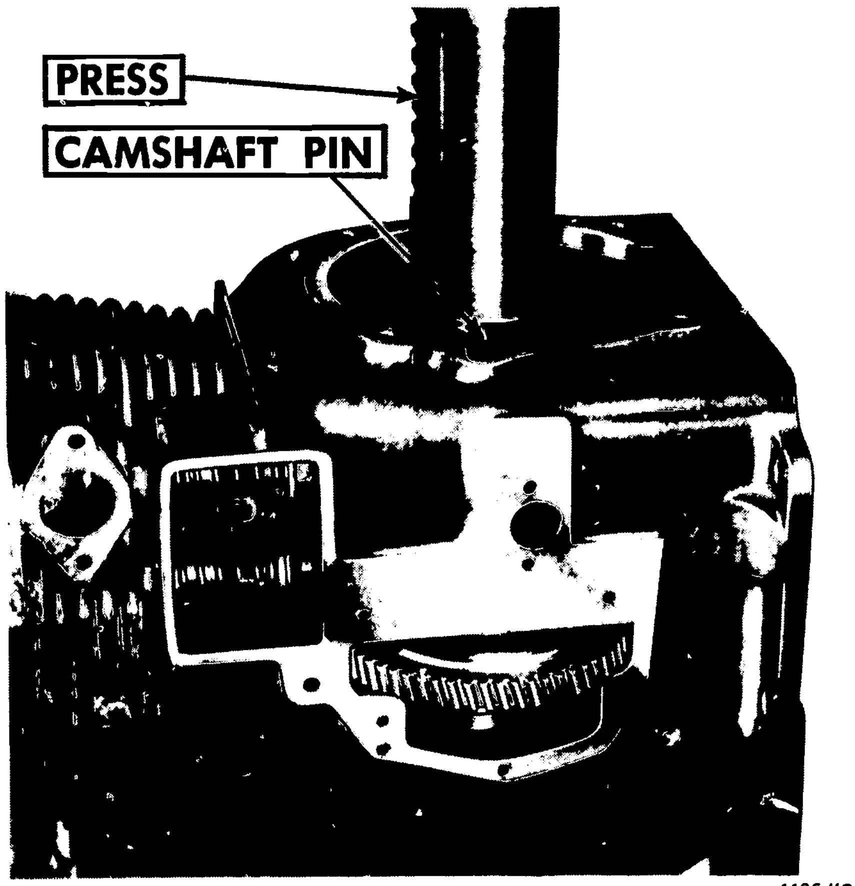
FIGURE 322. Camshaft, crankshaft and governor installed.



1106 KOH

FIGURE 324. Pressing in the camshaft pin.

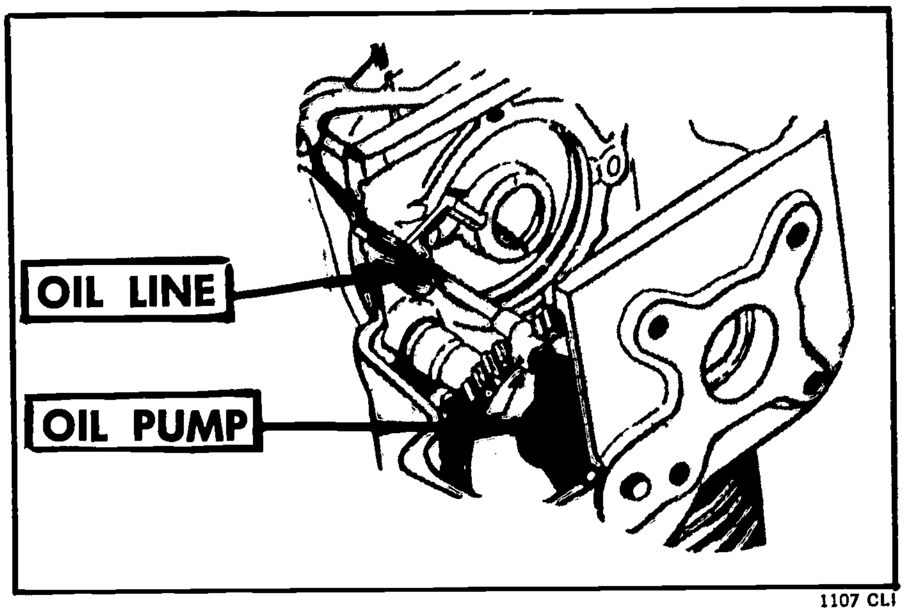


FIGURE 325. Some vertical-crankshaft engines have an oil line from the pump to the upper-main bearing.

10. *Install gasket(s) (Figure 326a).*

    On some engines the crankshaft endplay is controlled by the number of gaskets which are installed on the bearing plate, or bearing support.

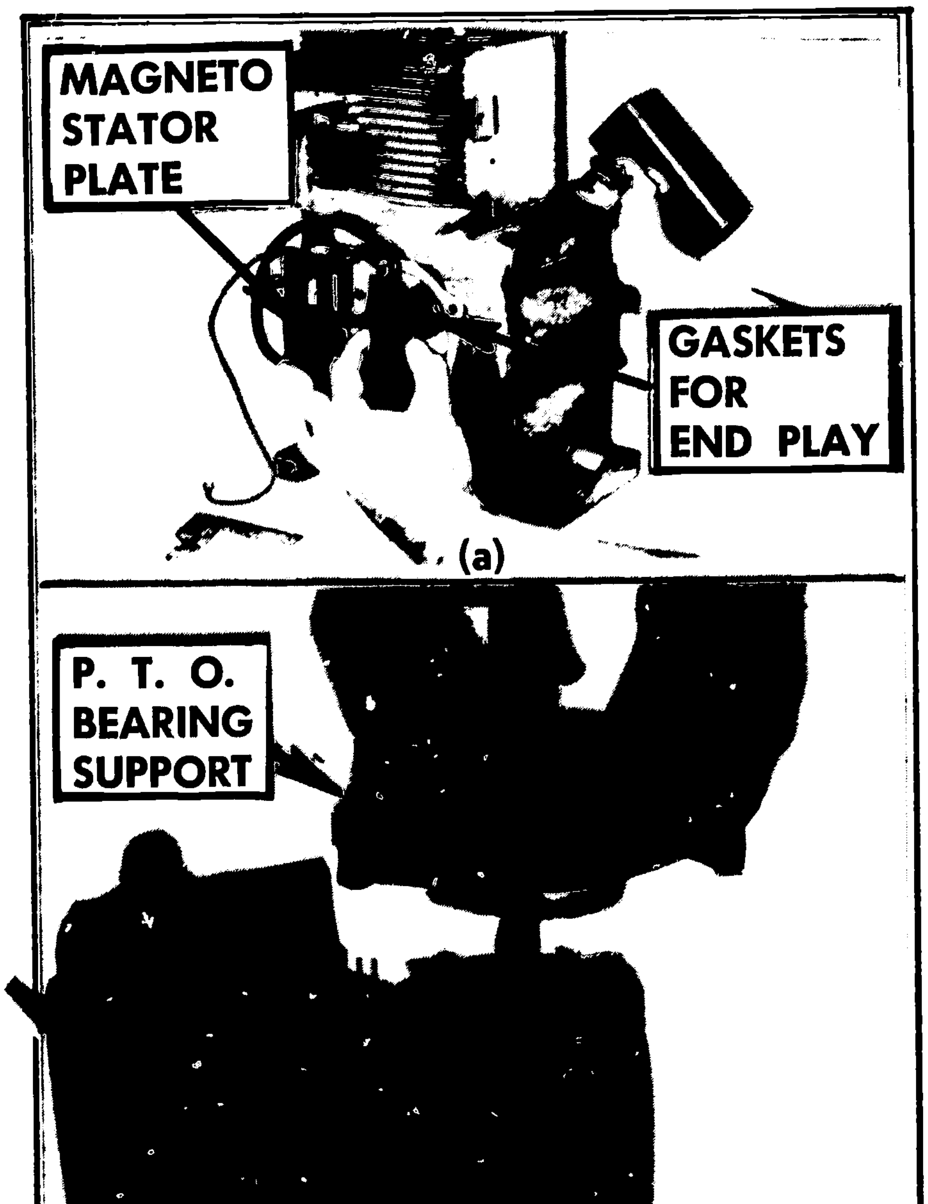


FIGURE 326. (a) Installing the magneto-bearing plate. (b) Installing the PTO-bearing support.

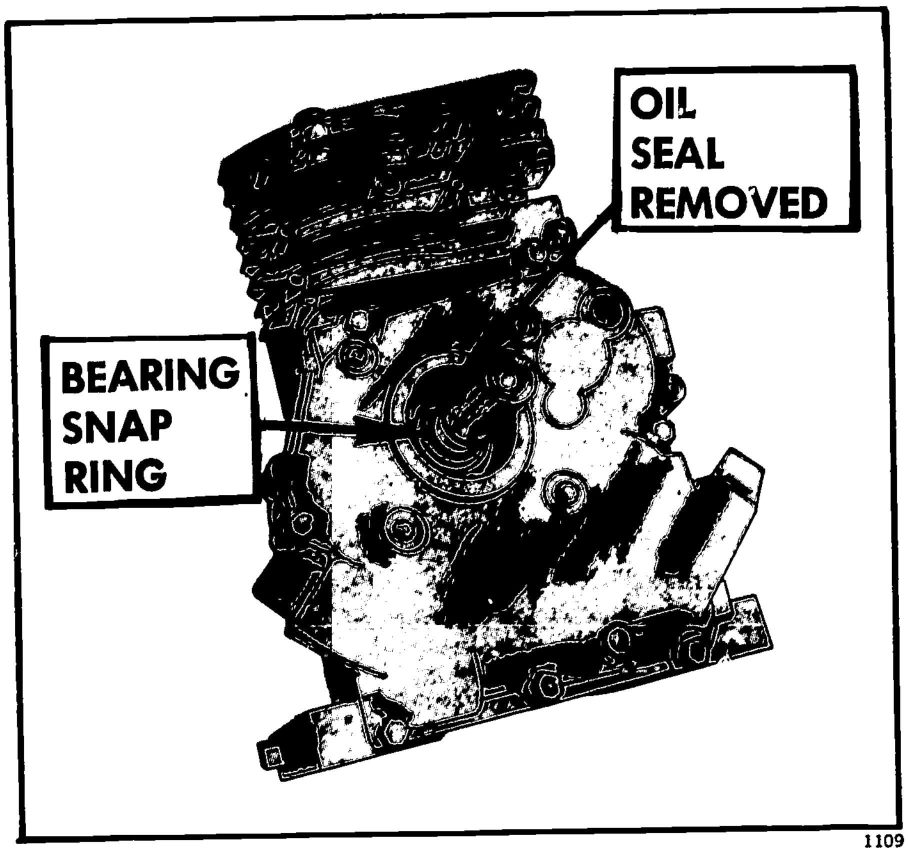


FIGURE 327. A crankshaft-bearing lock ring is installed on some engines.

11. *Install the magneto-bearing plate, or the PTO-bearing support (Figure 326).*

    Either of these plates contains the crankshaft bearing or provides for installing a bearing.

12. *Tighten magneto-bearing plate, or PTO-bearing support, with a torque wrench.*

    Torque recommendations vary from 75 to 100 pounds per square inch.

13. *Install crankshaft-bearing lock ring, if applicable (Figure 327).*

14. *Install oil seals if they are not already installed.*

    Refer to step 1.

15. *Check crankshaft endplay, if it is adjustable (Figure 328).*

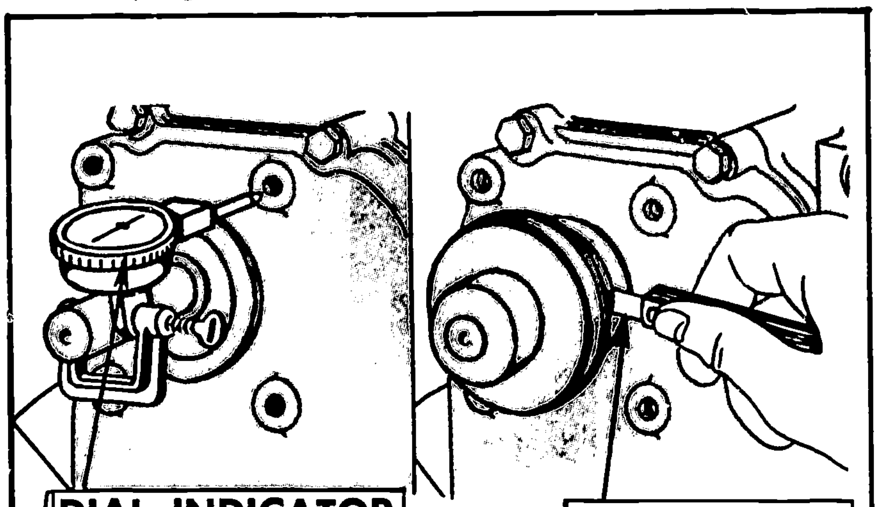


FIGURE 328. Checking the crankshaft endplay with a dial indicator.

OWNER'S ENGINE-INFORMATION FORM

GENERAL INFORMATION: ____________________

NAME OF EQUIPMENT (ON WHICH ENGINE IS MOUNTED) ____________________

NAME AND ADDRESS OF EQUIPMENT MANUFACTURER ____________________

____

NAME AND ADDRESS OF ENGINE MANUFACTURER ____________________

____

OPERATING POSITION OF CRANKSHAFT: VERTICAL ☐, HORIZONTAL ☐, MULTI-POSITION ☐.

ENGINE CYCLE: 2-Cycle ☐, 4-Cycle ☐.

MODEL NUMBER, OR NAME ____________________

SERIAL NUMBER ____________________

SPECIFICATION NUMBER ____________________

TYPE NUMBER ____________________

HORSEPOWER ____________________

TYPES OF ACCESSORIES AND MAJOR UNITS:

CARBURETOR AIR CLEANER: Oil bath☐, Oiled filter☐, Dry filter☐.

FUEL STRAINER: Combination screen and sediment bowl☐, Screen inside the fuel tank☐.

CRANKCASE BREATHER: Reed valve☐, Floating disk valve☐.

STARTER: Rope-wind☐, Rope-rewind☐, Wind up☐, Electric, AC☐, Electric, DC☐.

IGNITION SYSTEM: Flywheel magneto☐, External magnet☐, Battery☐.

FUEL PUMP: Mechanically driven☐, Differential pressure driven☐.

CARBURETOR: Float☐, Suction lift☐, Diaphragm☐.

GOVERNOR: Air vane☐, Centrifugal☐.

SERVICE AND MAINTENANCE SPECIFICATIONS:

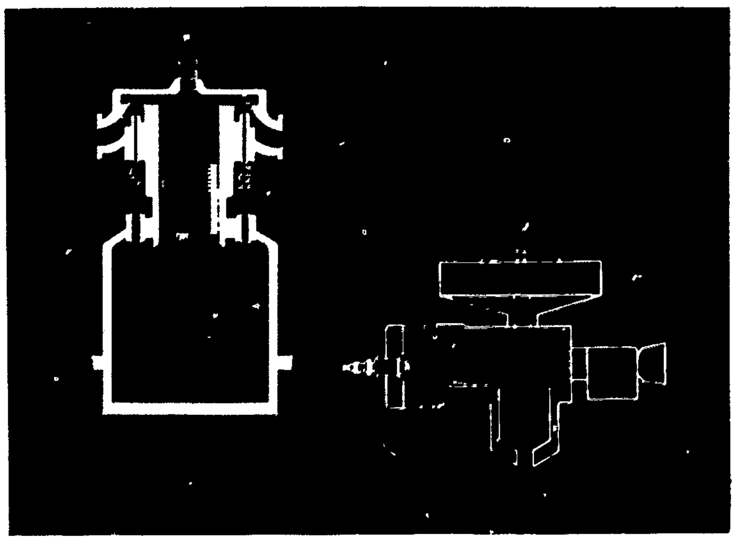
FUEL: Octane number ________. Mixture of oil and gasoline (2-cycle) (Amount of oil per gallon of gasoline): ¼ pint☐, ½ pint☐, other________.

OIL: SAE grade: 5 W☐, SAE 10 W☐, SAE 20 W☐, SAE 30☐, SAE 10 W-30☐. Classification: ML☐, MM☐, MS☐.

TYPE OF SPARK PLUG: ____________________

Gap setting: .020″, .025″, Other ________.

IGNITION BREAKER-POINT GAP: .012″☐, .015″☐, Other ________.



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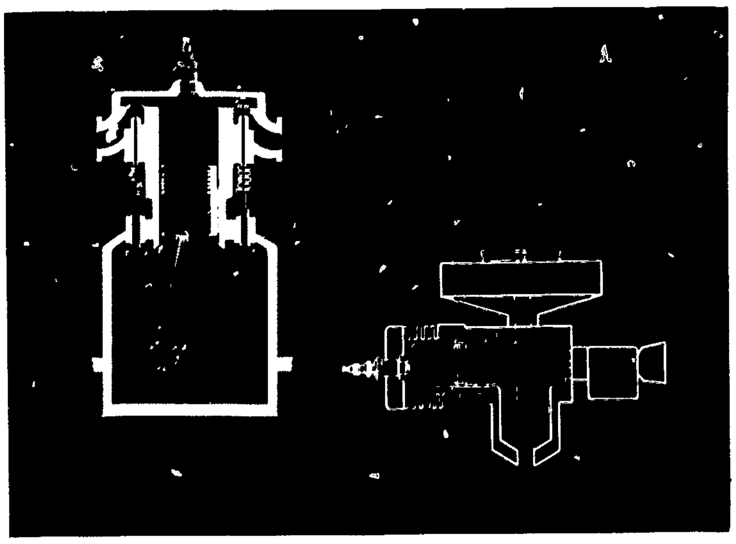

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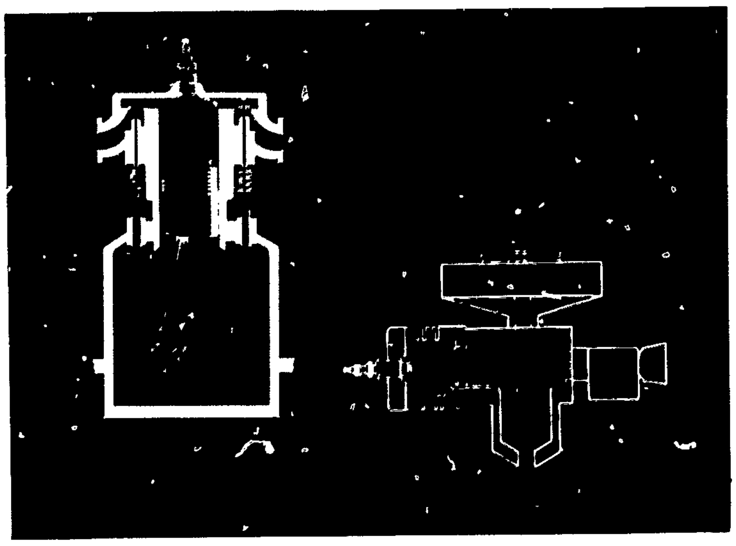

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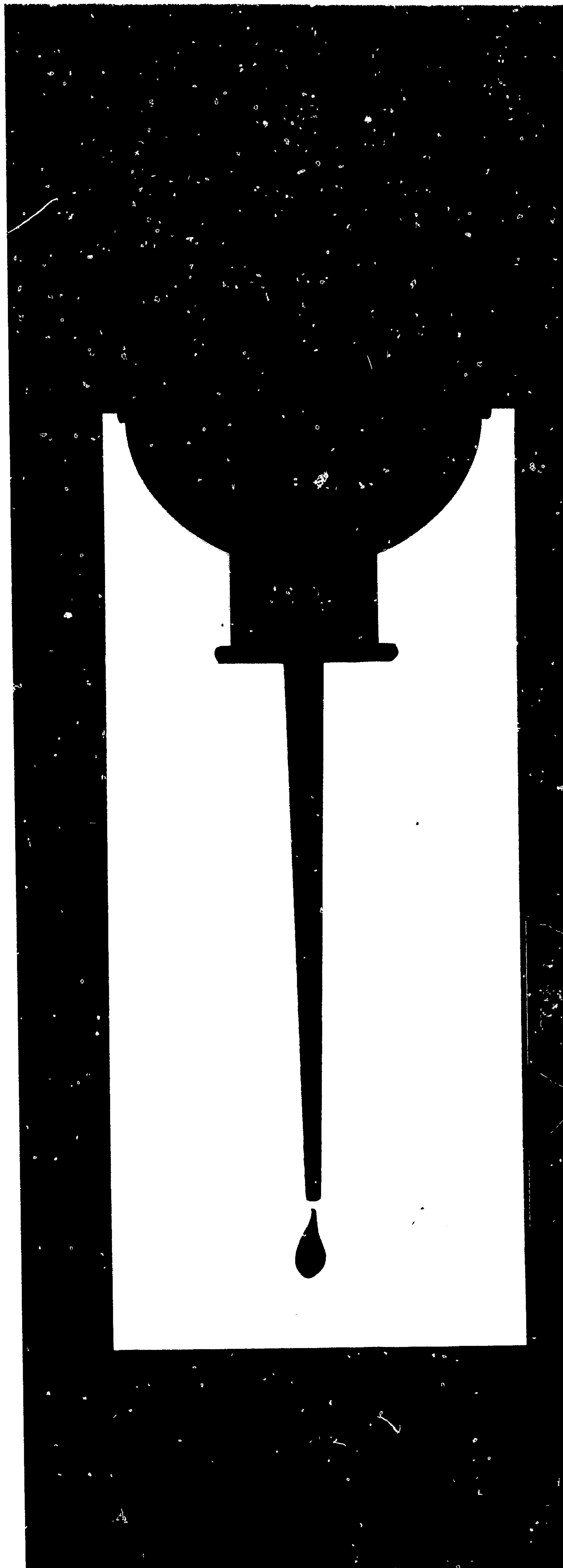

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