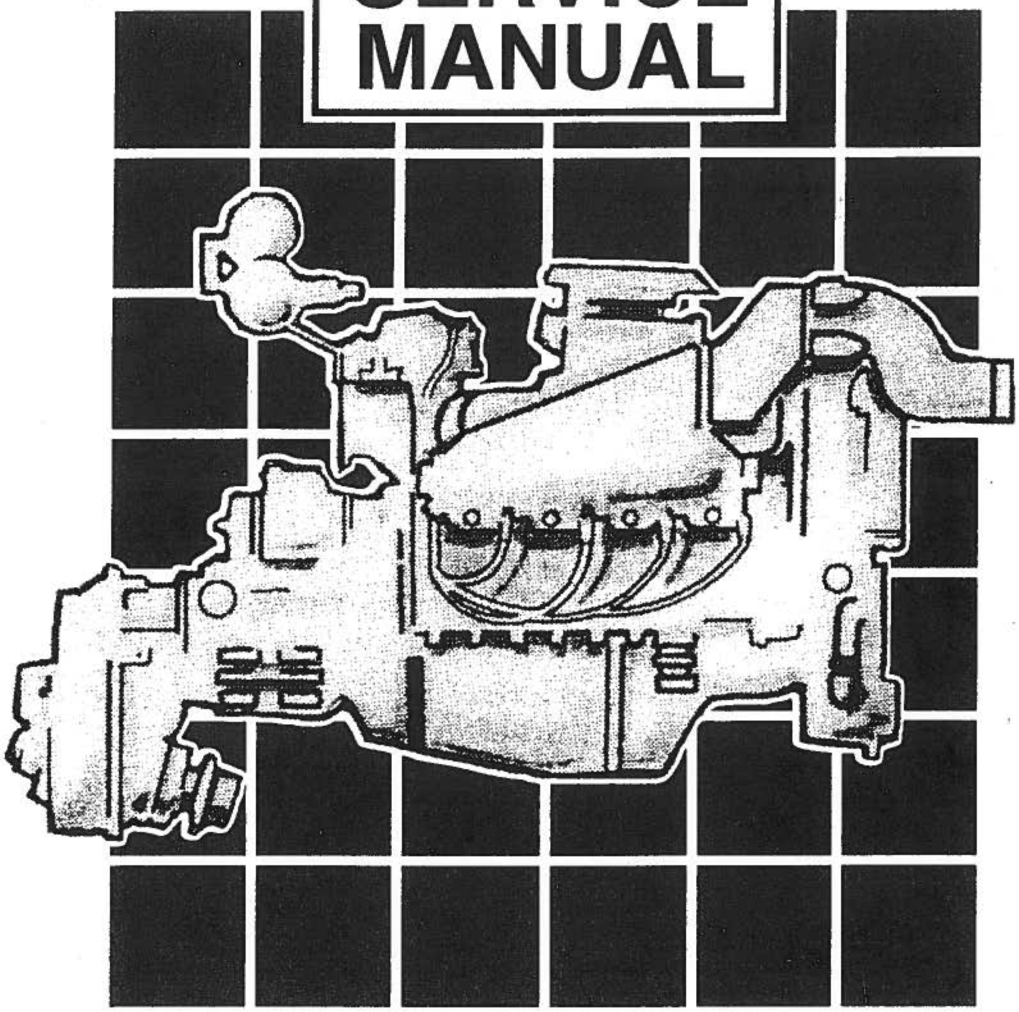
Crusader

ENGINES

SERVICE MANUAL



GASOLINE INBOARD ENGINES

1980 THRU 1992

TECM 596

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FOREWORD

The publication and distribution of this manual by Crusader Engines does not constitute a warranty or guarantee of any kind. This service manual is written for the use of qualified and experienced mechanics and is not intended as a "do-it-yourself" guide for persons with little or no marine engine repair experience.

This service manual includes comprehensive maintenance instructions for the following Crusader marine engines:

Model 229, V-6
Model 262, V-6
Model 305, V-8
Model 350, V-8
Model 454, V-8
Model 502, V-8

This manual is divided into sections according to the type of information provided, and tailored to the type of maintenance required.

The **Introduction** explains the purpose of the manual and provides information on the break-in of the engine, various factors that affect boat performance, and engine identification.

Engine Removal and Installation gives detailed instructions on removal, installation, alignment, and throttle/transmission controls.

Maintenance presents a recommended maintenance schedule; fuel, oil, and coolant specifications; and other periodic maintenance instruction.

Tune-Up provides the various engine tune-up specifications.

Troubleshooting uses a two-column chart to guide the service technician from symptoms, through potential causes.

The sections on the **Electrical System, Fuel System, Engine Mechanical, Exhaust System, Cooling System** and **Drive System** contain instructions needed to disassemble, test, and reassemble engine components for replacement or repair.

IMPORTANT: Throughout this publication, Warnings and Cautions are used to alert the mechanic to special instructions concerning a particular service or operation that may be hazardous if performed incorrectly or carelessly – observe them carefully!

These "Safety Alerts" alone cannot eliminate the hazards that they signal. Strict compliance to these special instructions when performing the service, plus "common sense" operation, are major accident prevention measures.

⚠ WARNING
Hazards or unsafe practices which could result in severe personal injury or death.

⚠ CAUTION
Hazards or unsafe practices which could result in minor personal injury or product or property damage.

ACKNOWLEDGEMENT

Crusader Engines would like to thank the following firms for permission to use text and illustrations from their service literature:

- AE Clevite Engine Parts
- Borg-Warner
- Champion Spark Plugs
- CH Corporation
- Chevrolet-Pontiac-Canada Group
- General Motors Corporation
- Holley Carburetor
- Prestolite
- Rochester Product Division of General Motors Corporation
- Yamaha Motor Corporation, USA

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Section 1

Introduction

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1 INTRODUCTION

1.1 GENERAL INFORMATION

This comprehensive manual written by the Crusader Service Department provides information for dealers and service mechanics.

Because of the nature of repair work, Crusader Engines does not guarantee the results of any procedure outlined in this manual in any particular case. This manual is meant to be a general guide to the care, maintenance and repair of Crusader Engines for the assistance of experienced mechanics, and Crusader Engines makes no further representations.

Maintenance and repair procedures are written under the assumption that the technician has been trained in servicing Crusader products or in marine engine repair and the use of common mechanics' tools.

Before attempting maintenance and repair tasks, the appropriate procedure should be read thoroughly to gain knowledge of proper methods and tools and to become aware of any dangers.

Crusader Engines could not possibly know of and advise the service trade of all conceivable procedures by which a service might be performed, and of the possible hazards and/or results of each method. We have not undertaken any such wide evaluation. Therefore, anyone who uses a service procedure and/or tool which is not recommended by the manufacturer, first, must completely satisfy himself that neither his nor the product's safety will be endangered by the service procedure selected.

Crusader Engines assumes no responsibility for any loss occasioned by failure to follow accurately and completely the procedures set forth in this manual with respect to any of its products, and further assumes no responsibility or liability for any loss or damage caused by failure to follow the procedures outlined or to observe the foregoing precautions.

All information, illustrations and specifications contained in this manual are based on the latest product information available at time of publication.

Specifications, dimensions and product content are all subject to change without notice, and Crusader Engines assumes no responsibility with respect to notification. Persons using this manual should take care to ensure that the procedures followed are applicable to the product being serviced.

It should be kept in mind, while working on the product, that the electrical system and ignition system are capable of violent and damaging short circuits or inflicting severe electrical shocks. When performing any work where electrical terminals could possibly be grounded or touched by the mechanic, the battery cables should be disconnected at the battery.

Anytime the engine's intake or exhaust openings are exposed during service, they should be covered to protect against accidental entrance of foreign material which could enter the cylinders and cause extensive internal damage when the engine is started.

It is important to note that, during any maintenance procedure, replacement fasteners must have the same measurements and strength as those removed, whether metric or customary. Numbers on the heads of the metric bolts and on surfaces of metric nuts indicate their strength. Customary bolts use radial lines for this purpose, while most customary nuts do not have strength markings. Mismatched or incorrect fasteners can result in damage or malfunction, or possibly personal injury. Therefore, fasteners removed should be saved for reuse in the same locations whenever possible. Where the fasteners are not satisfactory for reuse, care should be taken to select a replacement that matches the original.

Replacement Parts:

> **⚠ WARNING**
>
> Electrical, ignition and fuel system components on Crusader Engines are designed and manufactured to comply with U.S. Coast Guard rules and regulations to minimize risks of fire or explosion. Use of replacement electrical, ignition or fuel system components which **do not** comply with these rules and regulation could result in a fire or explosion hazard and should be avoided.

> **⚠ WARNING**
>
> When servicing the electrical, ignition and fuel systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

Engine Mechanical Components:

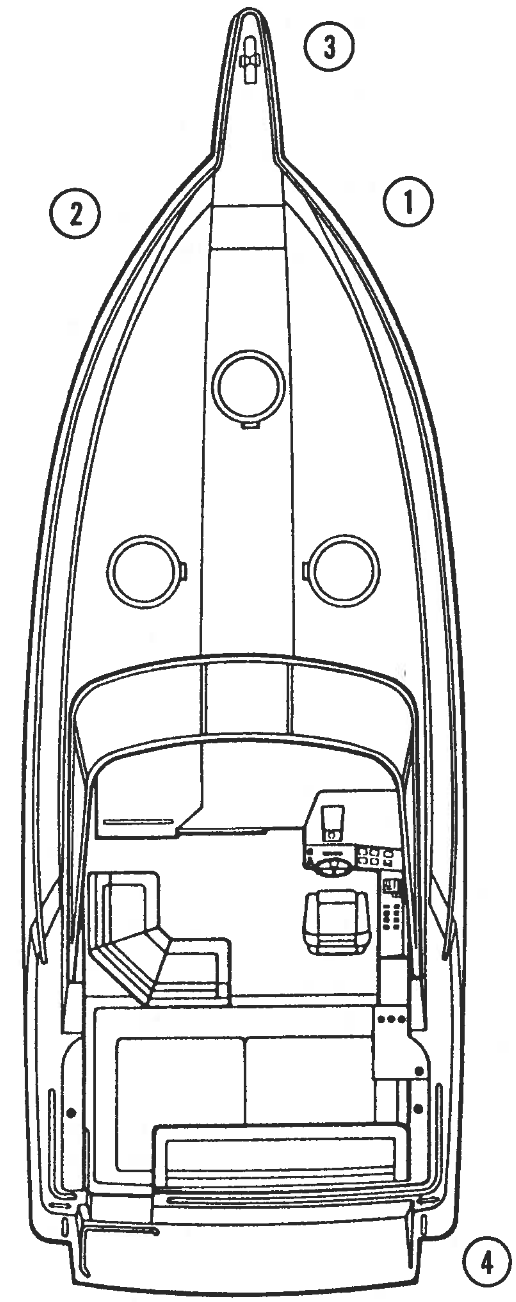
Many of the engine mechanical components are designed for marine application. Unlike automotive engines, marine engines are subjected to extended periods of heavy-load and wide-open-throttle operation, and therefore, require heavy-duty components. Special marine engine parts have design and manufacturing specifications which are required to provide long life and dependable performance. Marine engine parts also must be able to resist the corrosive action of salt or brackish water that will rust or corrode standard automotive parts within a short period of time.

Failure to use recommended Crusader service replacement parts can result in poor engine performance and/or durability, rapid corrosion of parts subjected to salt water and possibly complete failure of the engine.

Use of replacement parts other than those recommended by Crusader will void the warranty on any parts damaged as a result of the use of other than recommended parts.

Directional References:

The front of the boat is the bow and the rear is the stern. The starboard side is the right side, the port side is the left side. In this maintenance manual, all directional references are given as they appear when viewing boat from the stern, looking toward the bow.



1. Starboard
2. Port
3. Bow
4. Stern

Figure 1-1. Directional References

Engine Rotation:

Engine rotation is identified as "RH" (right-hand) or "LH" (left-hand) by the model number. Rotation always is determined from the flywheel end of the engine. In some instances, propeller shaft rotation may be opposite to that of the engine. Always refer to engine model number for engine rotation. When ordering a replacement engine, short blocks or parts for an engine, be certain to check engine rotation. Do not rely on propeller rotation in determining engine rotation.

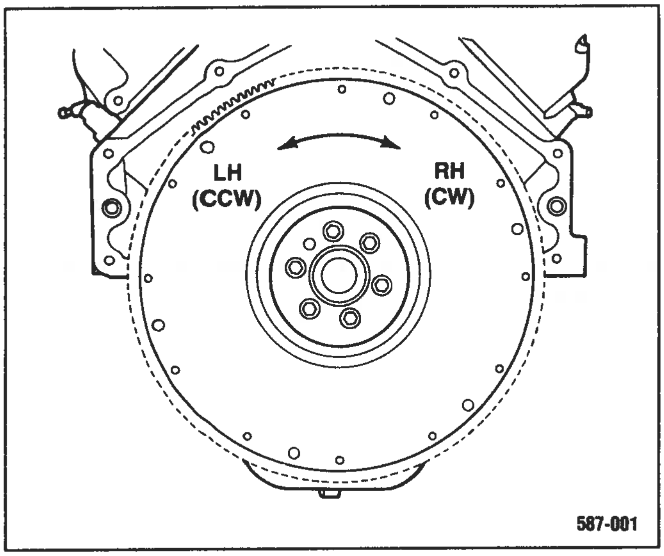


Figure 1-2. *Engine Rotation*

1.2 ENGINE BREAK-IN

IMPORTANT: Proper break-in is essential to obtain minimum oil consumption, maximum engine performance and good service life.

The first 25-hour period of operation, for a new or rebuilt engine, is called the engine break-in period. During this period, it is extremely important that the engine be operated as outlined below:

a. Do not operate the engine below 1500 rpm for extended periods of time during the first 10 hours. During this period, shift into gear as soon as possible after starting engine and advance throttle so that engine speed is above 1500 rpm (provided that conditions permit safe operation at this speed).

b. Do not operate at any one constant speed for extended periods of time.

c. Do not exceed 3/4 of full throttle during the first 10 hours of operation. During the next 15 hours, occasional operation at full throttle (5 minutes at a time maximum) is permissible.

d. Avoid full-throttle acceleration from the stopped position.

e. Do not operate at full throttle until engine reaches normal operating temperature.

f. Observe instrumentation carefully. If an abnormal reading occurs, stop engine immediately and determine cause.

g. Frequently check the crankcase oil level and add oil if necessary. It is normal for oil consumption to be somewhat high during the break-in period.

IMPORTANT: To check the transmission fluid level accurately, the engine must run at 1500 rpm for 2 minutes immediately prior to checking the level. Oil must be at normal operating temperature.

h. At the end of the 25-hour break-in period, drain break-in oil from the crankcase. Replace the oil filter and fill crankcase with oil of the correct grade and viscosity.

Use care during the first 25 hours of operation on new Crusader engines or engine failure may occur. If a new engine has to be water-tested at full throttle before the break-in period is complete, follow this procedure:

1. Start engine and run at 1200 rpm until normal operating temperature is reached.
2. Run boat up on plane.
3. Advance engine speed in 200 rpm increments until engine reaches its maximum rated rpm.

IMPORTANT: Do not run at maximum rpm for more than 2 minutes.

1.3 PERFORMANCE FACTORS

Propeller Design:

Changing the diameter or pitch of a propeller will affect engine rpm and boat performance. The blade configuration also will affect performance. Two similar propellers, with same pitch and diameter, from two different manufacturers will also perform differently.

It is the responsibility of the boat manufacturer and/or selling dealer to equip the boat with the correct propeller to allow the engine to operate within its specified rpm range at wide-open throttle (W.O.T.).

Because of the many variables of boat design and operation, only testing will determine the best propeller for a particular application.

To test for correct propeller, operate boat (with an average load on board) at W.O.T. and check rpm with an accurate tachometer. Engine rpm should be near the top of the specified range so that, under heavy load, engine speed will not fall below specifications.

- If engine exceeds the specified rpm, an increase in pitch and/or diameter is required.
- If engine is below rated rpm, a decrease in pitch and/or diameter is required.

Normally, a change of approximately 150 to 250 rpm will be achieved for each single pitch change of the propeller.

> **⚠ CAUTION**
>
> If a propeller is installed that does not allow engine rpm to reach the specified full-throttle rpm range, the engine will "labor" and will not produce full power. Operation under this condition will cause excessive fuel consumption, engine overheating and possible piston damage (due to detonation). On the other hand, installation of a propeller that allows engine to run above the specified rpm limit will cause excessive wear on internal engine parts which may lead to premature engine failure.

Boat Bottom Design:

For maximum speed, a boat bottom should be as flat as possible in a fore-and-aft direction (longitudinally) for approximately the last 5 ft. (1.5 m).

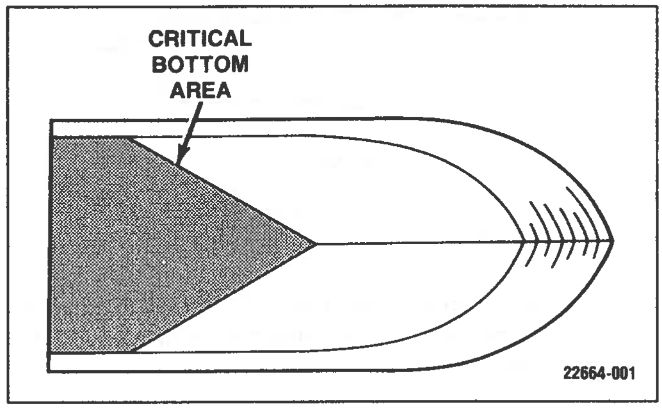


Figure 1-3. *Critical Bottom Area*

For best speed and minimum spray, the corner between the bottom and the transom should be sharp.

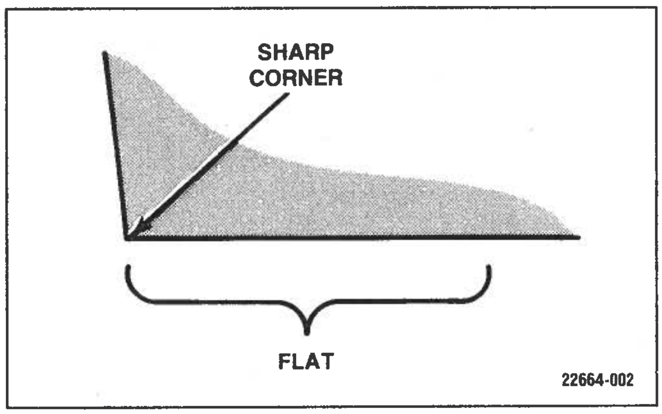


Figure 1-4. *Bottom Corner*

The bottom is referred to as having a "hook" if it is concave in the fore-and-aft direction. A hook causes more lift on the bottom near the transom and forces the bow to drop. This increases wetted surface and reduces boat speed.

A hook, however, aids in planing and reduces any porpoising (rhythmical bouncing) tendency. A slight hook is often built in by the manufacturer. A hook can also be caused by incorrect storing of the boat with support directly under the transom.

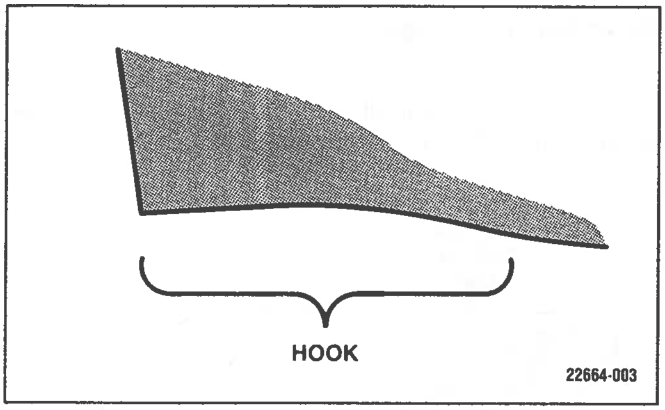


Figure 1-5. *Hook*

A "rocker" is the reverse of a hook. The bottom is convex or bulged in the fore-and-aft direction. it can cause the boat to porpoise.

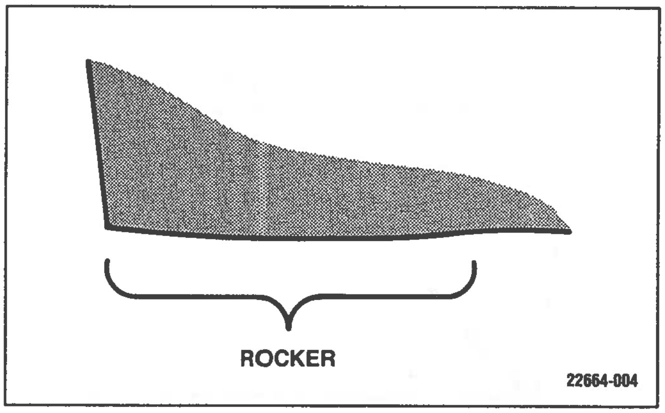


Figure 1-6. *Rocker*

Any hook, rocker or surface roughness on the boat bottom, particularly in the all-important center and aft portion, will have a negative effect on speed, often by several miles per hour on a fast boat.

Weight Distribution:

Weight distribution is extremely important; it affects a boat's running angle or attitude. For best top speed, all movable weight – cargo and passengers – should be as far aft as possible to allow the bow to come up to a more efficient angle (3° to 5°). On the negative side of this approach is the problem that, as weight is moved aft, some boats will begin an unacceptable porpoise.

Secondly, as the weight is moved aft, planing out becomes more difficult.

Finally, the ride in choppy water becomes more uncomfortable as the weight goes aft. With these factors in mind, each boater should seek out weight locations which best suit his/her needs.

Weight and passenger loading placed well forward increases the "wetted area" of the boat bottom and, in some cases, virtually destroys the good performance and handling characteristics of the boat. Operation in this configuration can produce an extremely wet ride from wind-blown spray, and could even be unsafe in certain weather conditions or where bow steering may occur.

Weight distribution is not confined strictly to fore and aft locations, but also applies to lateral weight distribution. Uneven weight concentration to port or starboard of the longitudinal centerline can produce a severe listing attitude that can adversely affect the boat's performance, handling ability and riding comfort. In extremely rough water, the safety of the boat and passengers may be in jeopardy.

Elevation and Climate Effects:

Elevation has a very noticeable effect on the wide-open throttle power of an engine. Since air (containing oxygen) gets thinner as elevation increases, the engine begins to starve for air. Humidity, barometric pressure and temperature do have a noticeable effect on the density of air. Heat and humidity thin the air. This phenomenon can become particularly annoying when an engine is propped out on a cool, dry day in spring, and later, on a hot, sultry day in August, the engine may not have its old zip (Figure 1-7).

Although some performance can be regained by dropping to a lower-pitch propeller, the basic problem still exists. The propeller is too large in diameter for the reduced power output. The experienced marine dealer can determine how much diameter to remove from a lower-pitch propeller for specific high-elevation locations. It is a known fact that weather conditions exert a profound effect on power output of internal combustion engines. Therefore, established horsepower ratings refer to the power that the engine will produce at its rated rpm under a specific combination of weather conditions.

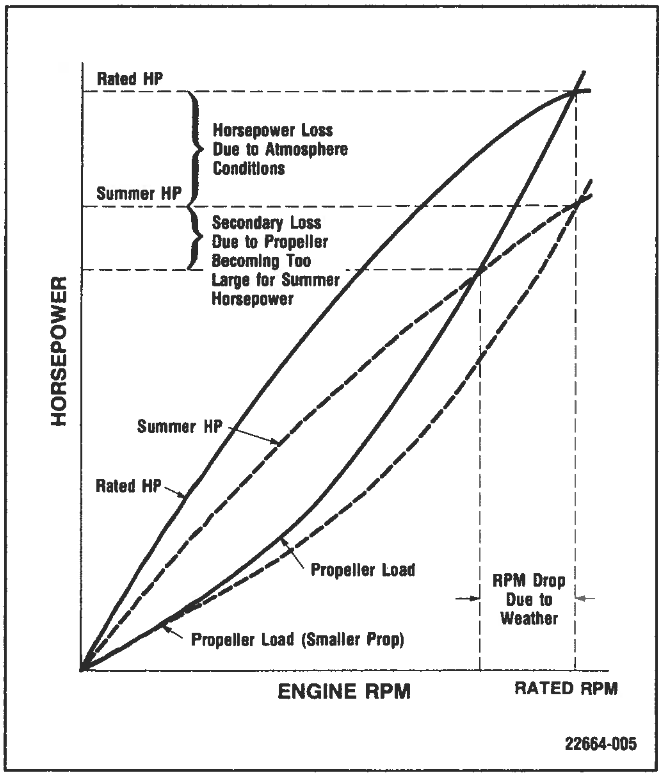


Figure 1-7. Effects Of Weather On Engine Power

Marine Fouling:

Fouling is an unwanted build-up (usually animal/vegetable-derived) occurring on the boat's bottom. Fouling adds to drag, which reduces boat performance. In fresh water, fouling results from dirt, vegetable matter, algae or slime, chemicals, minerals and other pollutants.

In salt water, barnacles, moss and other marine growth often produce dramatic build-up of material quickly. It is therefore important to keep the hull as clean as possible in all water conditions to maximize boat performance. Special hull treatments, such as antifouling paint, will reduce the rate of bottom fouling.

Water in Boat:

When a boat loses performance, check bilge for water. Water can add considerable weight to the boat, thereby decreasing the performance and handling.

Ensure that all drain passages are open for complete draining.

1.4 ENGINE IDENTIFICATION

When ordering spare parts or obtaining information, always include the engine model and serial number.

Figures 1-8 through 1-23 are photos of the engine models described in this manual:

Typical V-6 Engine
Figures 1-8 through 1-11

Typical Engine, Model 305/350 CID
Figures 1-12 through 1-13

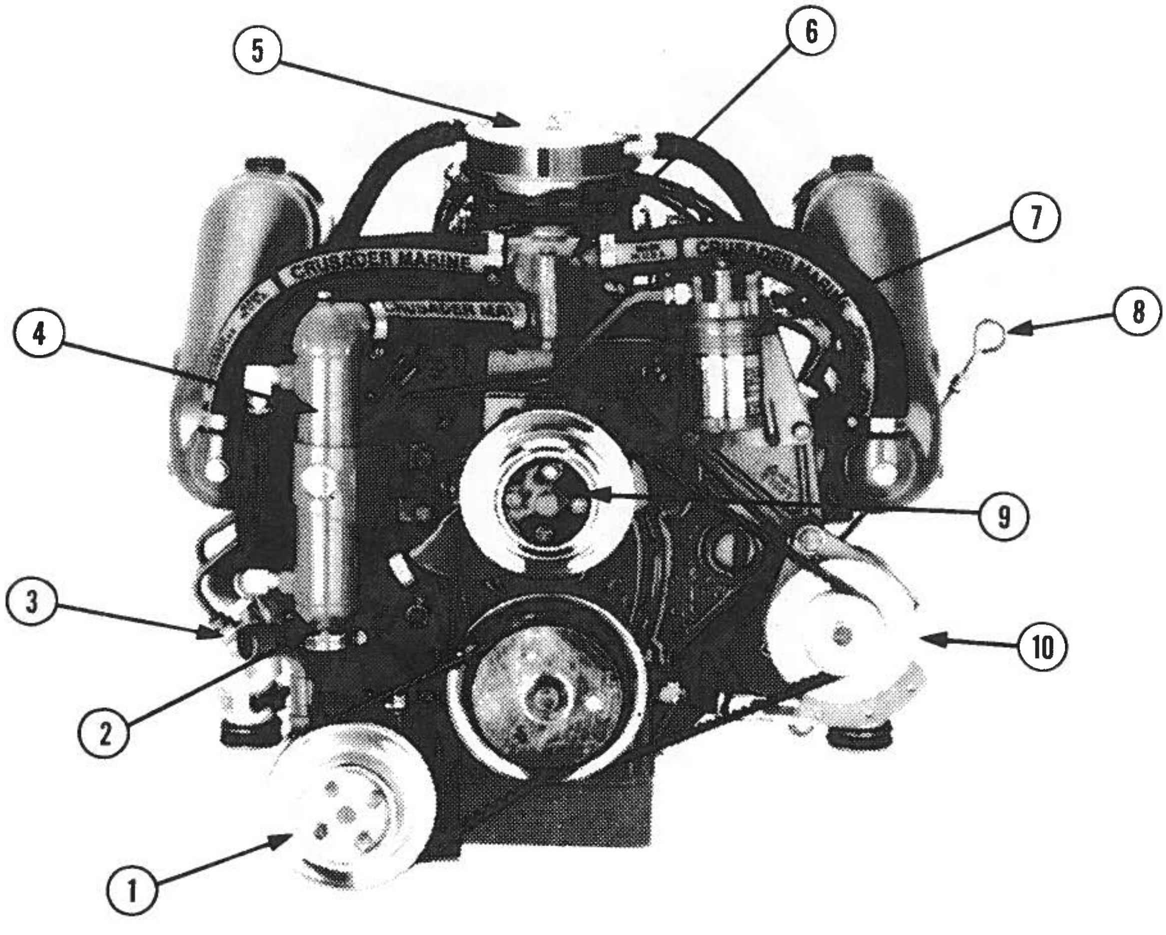
Typical Engine, Model 305/350 CID
(Freshwater-Cooled)
Figures 1-14 through 1-15

Typical Engine, Model 305/350 CID
(Seawater-Cooled)
Figures 1-16 through 1-19

Typical Engine, Model 454/502 CID
Figures 1-20 through 1-23

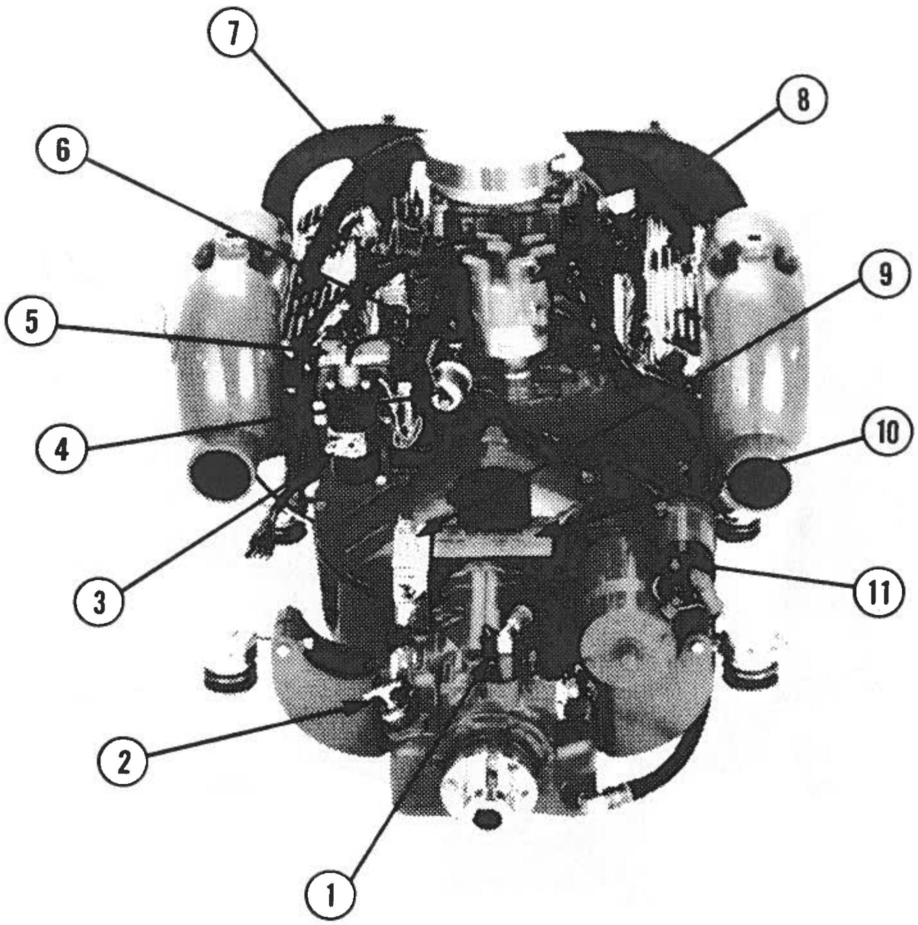
These photos will help the user to determine which engine model he/she is using. Also, each engine has a metal tag attached to the flywheel housing that contains the engine model and serial number.

All illustrations are for reference only, and in some instances, the parts shown may vary slightly.



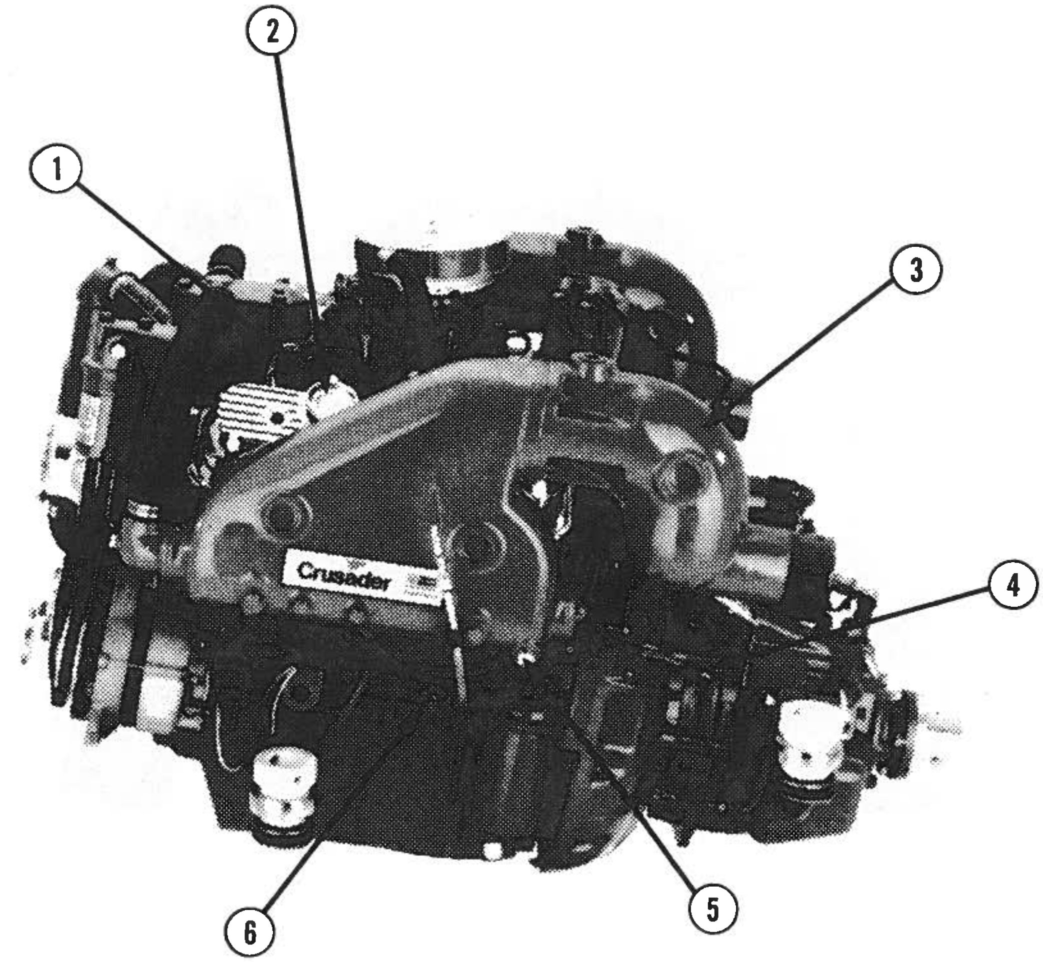
1. Raw-water pump
2. Drain plug (oil cooler)
3. Fuel pump
4. Oil cooler (transmission)
5. Flame arrestor (carburetor)
6. Thermostat housing
7. Fuel filter
8. Oil level dipstick (engine)
9. Engine water circulation pump
10. Alternator

Figure 1-8. *Typical V-6 Engine – Front View*



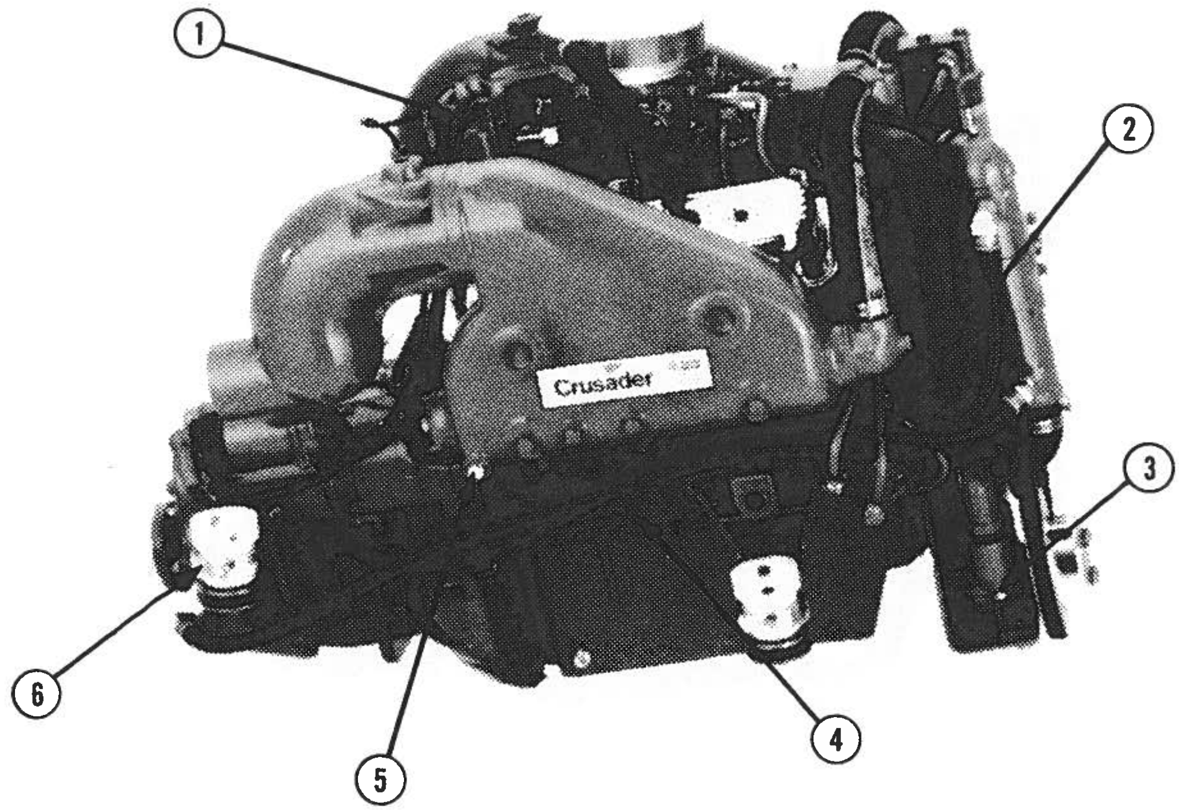
1. Alarm sender (transmission)
2. Oil level dipstick (transmission)
3. Ignition coil
4. Oil pressure sender
5. Circuit breaker
6. Alarm sender (oil)
7. Throttle lever bracket
8. Distributor
9. Shift bracket
10. Model and serial number plate
11. Starter motor

Figure 1-9. *Typical V-6 Engine – Rear View*



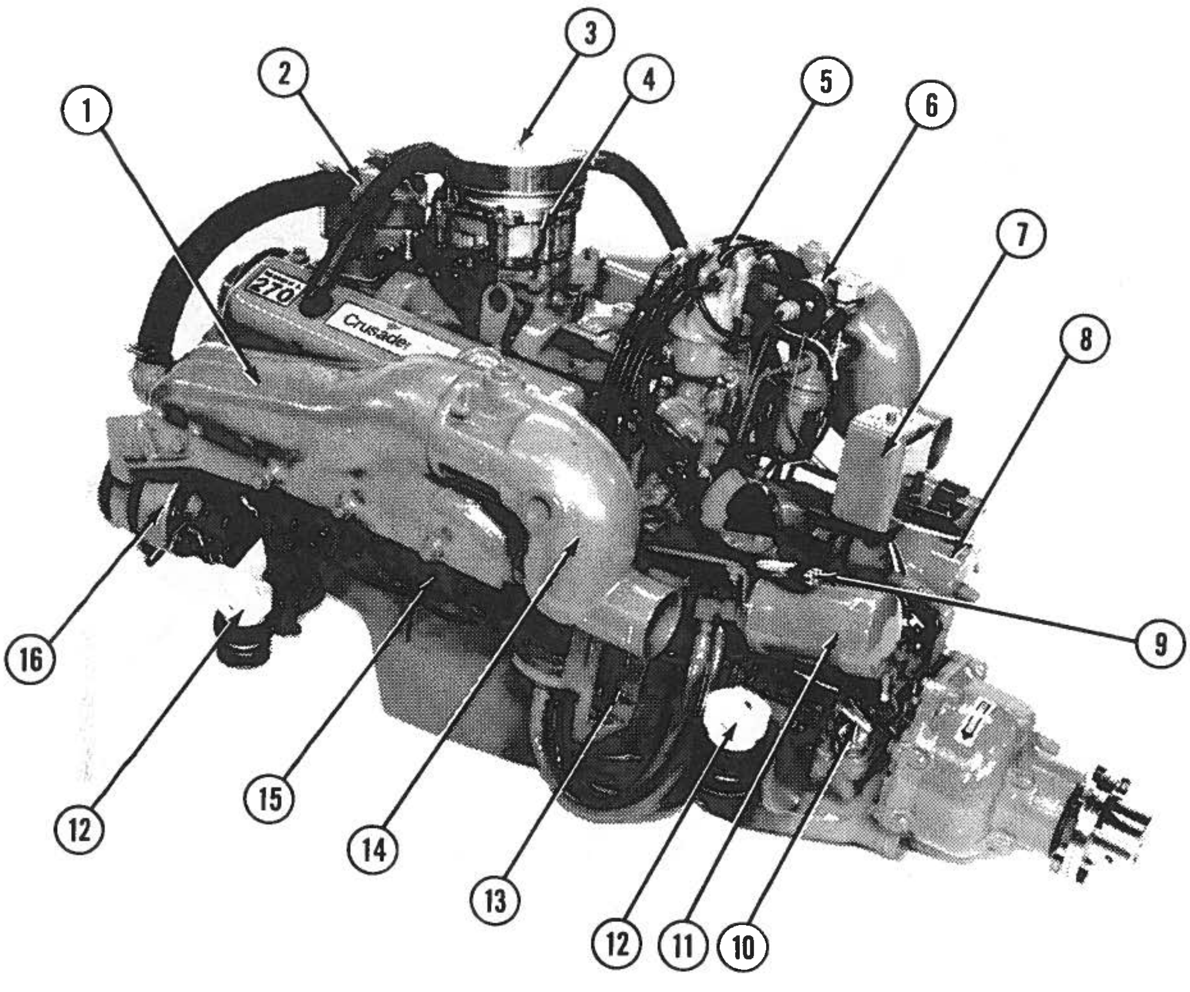
1. Alarm sender (temperature)
2. Motor oil fill cap
3. Exhaust elbow
4. Engine harness connector
5. Drain plug (manifold)
6. Drain plug (engine)

Figure 1-10. *Typical V-6 Engine – Port "Left" View*



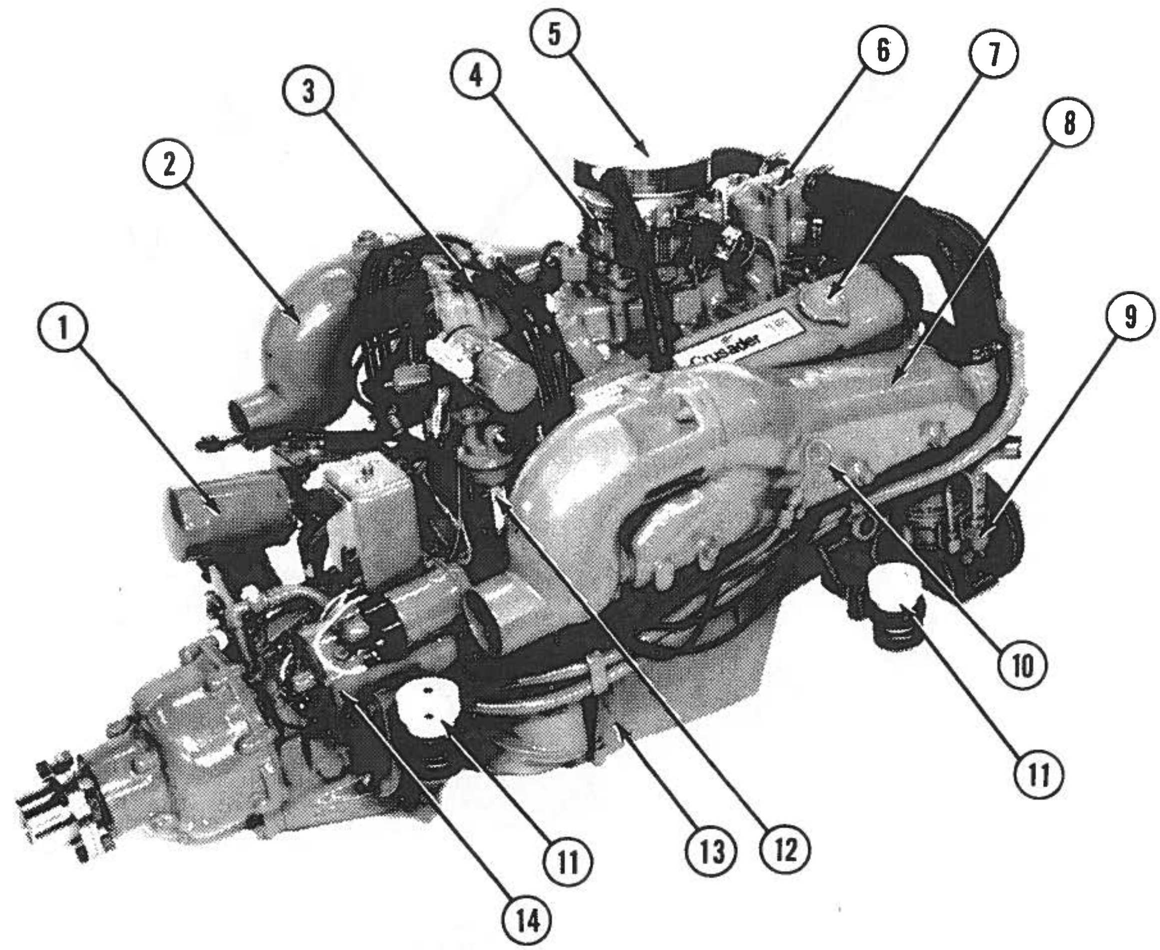
1. Distributor
2. Transparent fuel pump overflow hose
3. Drain plug (water pump)
4. Drain plug (engine)
5. Drain plug (manifold)
6. Motor mount

Figure 1-11. *Typical V-6 Engine – Starboard "Right" View*



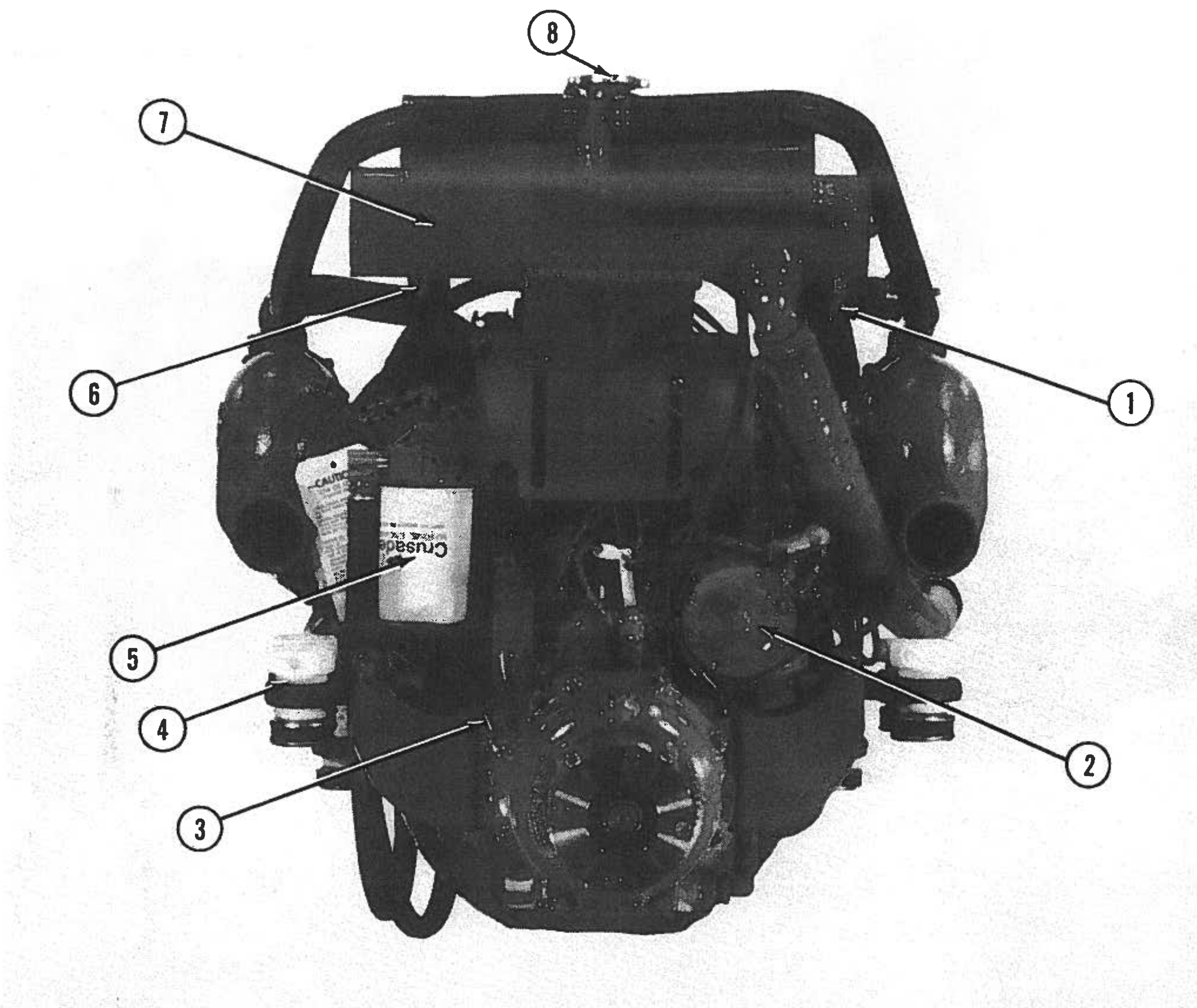
1. Exhaust manifold
2. Thermostat housing
3. Flame arrestor (carburetor)
4. Carburetor
5. Distributor
6. Ignition coil
7. Circuit breaker
8. Starter motor
9. Engine harness connector
10. Oil level dipstick (transmission)
11. Oil filter
12. Motor mount
13. Battery ground stud
14. Exhaust elbow
15. Drain plug (engine)
16. Alternator

Figure 1-12. *Typical Engine Model 305/350 CID – Port "Left" View*



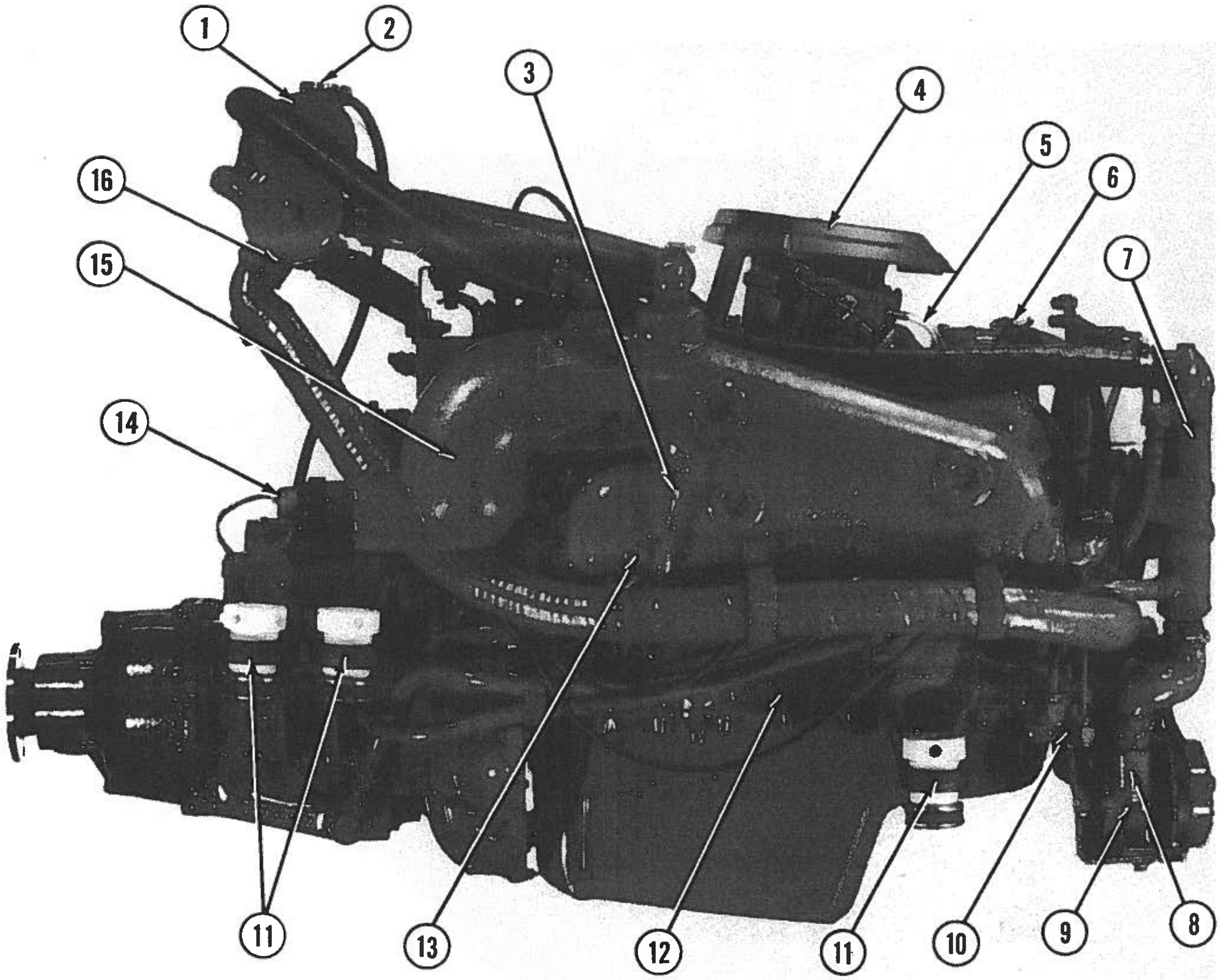
1. Oil filter
2. Exhaust elbow
3. Distributor
4. Carburetor
5. Flame arrestor
6. Thermostat housing
7. Motor oil fill cap
8. Exhaust manifold
9. Fuel pump
10. Oil level dipstick (engine)
11. Motor mount
12. Fuel filter
13. Oil pan
14. Starter motor

Figure 1-13. *Typical Engine Model 305/350 CID – Starboard "Right" View*



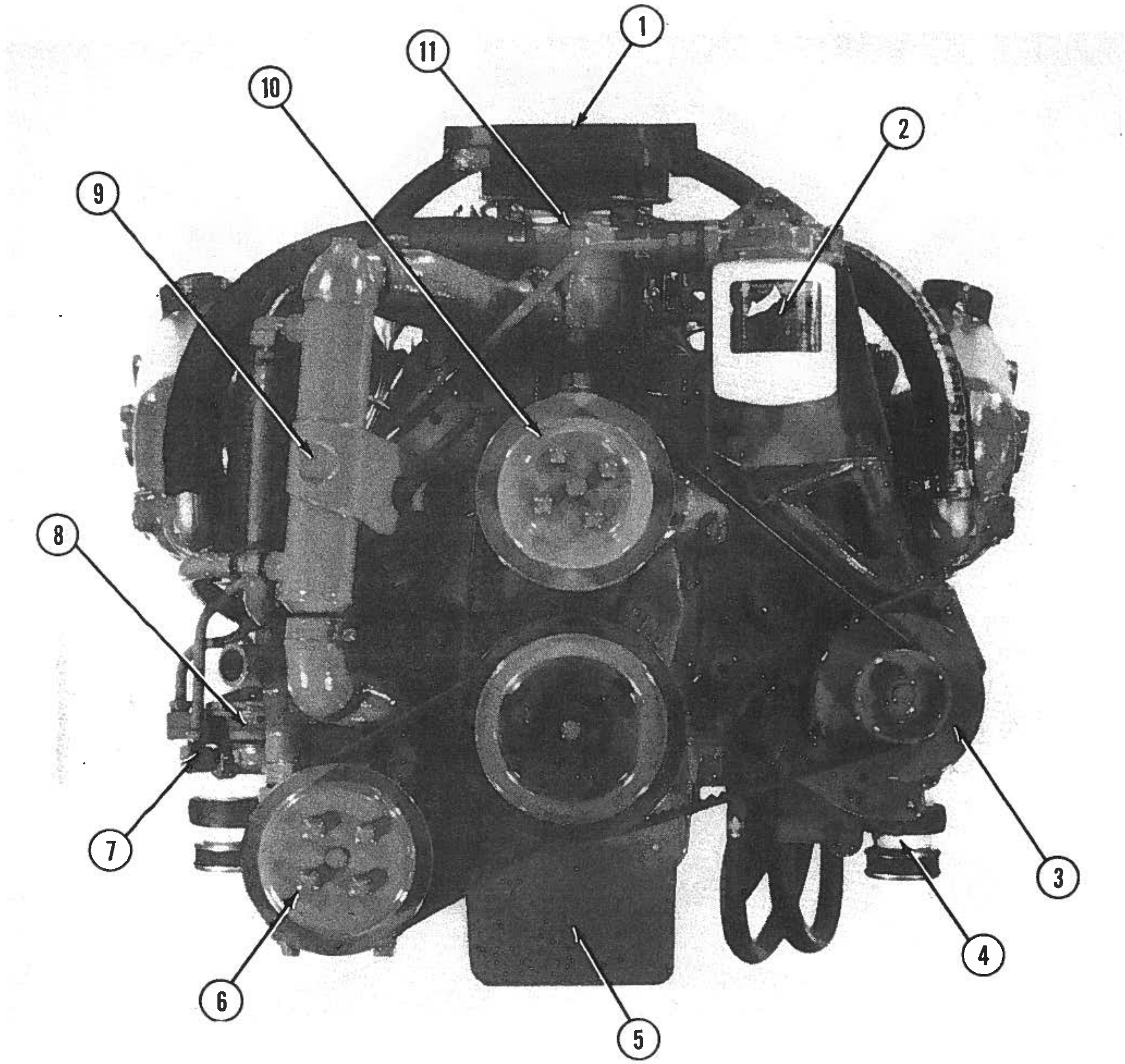
1. Zinc anodes
2. Starter motor
3. Oil level dipstick (transmission)
4. Motor mount
5. Oil filter
6. Drain plug (heat exchanger)
7. Heat exchanger (freshwater-cooled)
8. Fill cap (heat exchanger)

Figure 1-14. *Typical Engine Model 305/350 CID (Freshwater-Cooled) – Rear View*



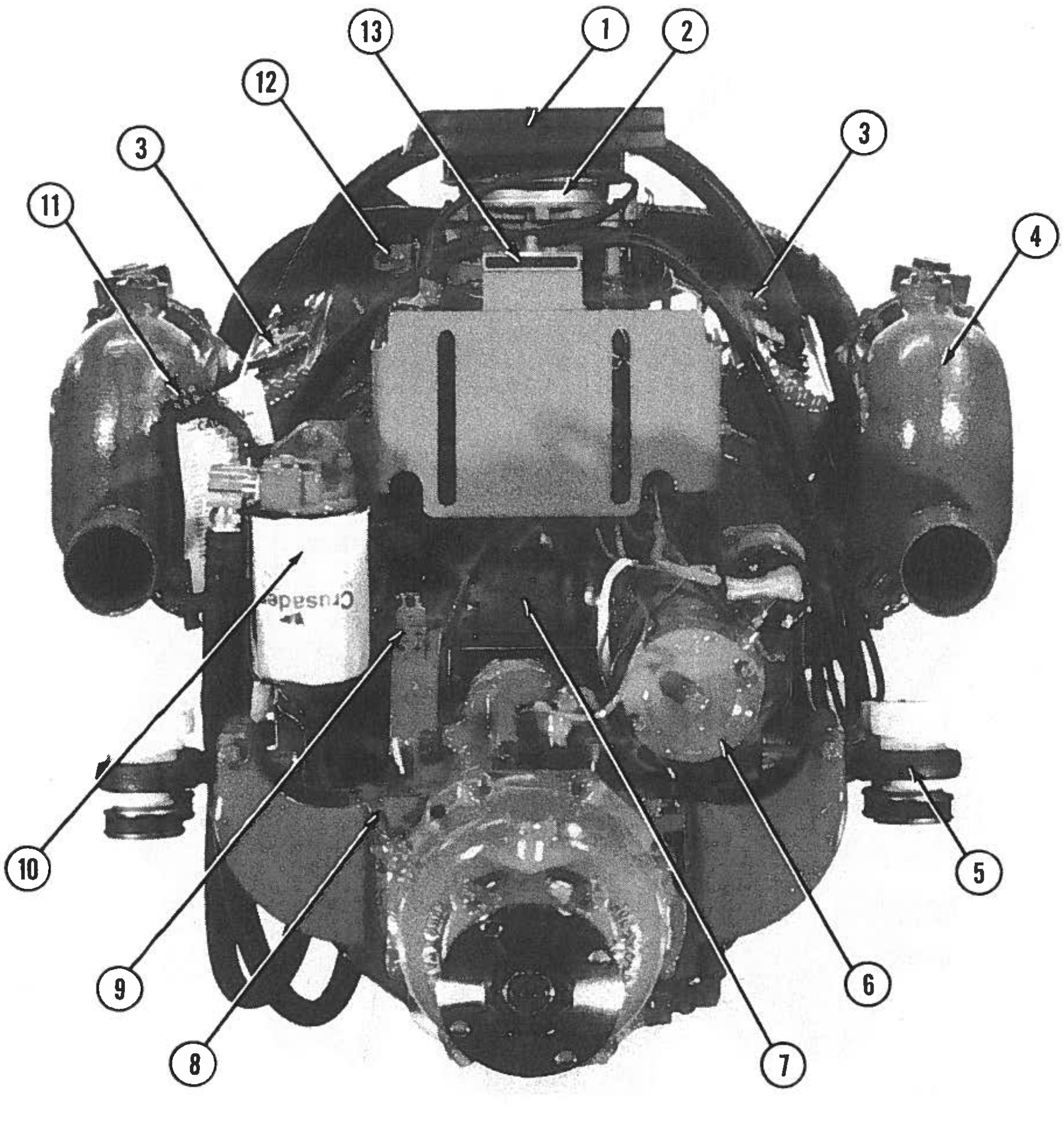
1. Heat exchanger (freshwater-cooled)
2. Fill cap (heat exchanger)
3. Oil level dipstick (engine)
4. Flame arrestor (carburetor)
5. Transparent fuel pump overflow hose
6. Thermostat
7. Oil cooler (transmission)
8. Raw-water pump
9. Drain plug (water pump)
10. Fuel pump
11. Motor mount
12. Drain plug (engine)
13. Drain plug (manifold)
14. Starter motor
15. Exhaust elbow
16. Zinc anodes

Figure 1-15. *Typical Engine Model 305/350 CID (Freshwater-Cooled) – Starboard "Right" View*



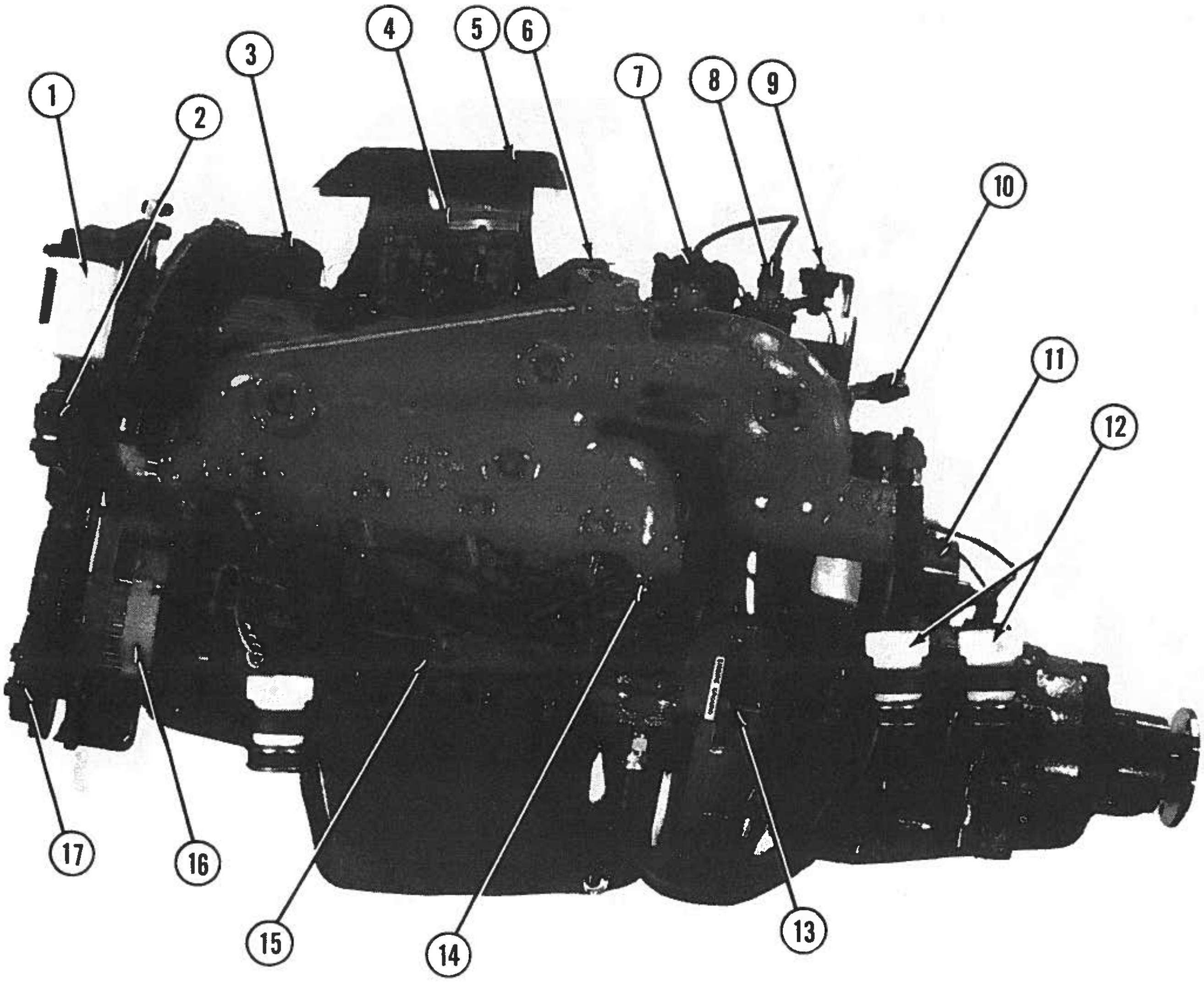
1. Flame arrestor (carburetor)
2. Fuel filter
3. Alternator
4. Motor mount
5. Oil pan
6. Raw-water pump
7. Fuel pump
8. Transparent fuel pump overflow hose
9. Oil cooler (transmission)
10. Engine water-circulation pump
11. Thermostat housing

Figure 1-16. *Typical Engine Model 305/350 CID (Seawater-Cooled) – Front View*



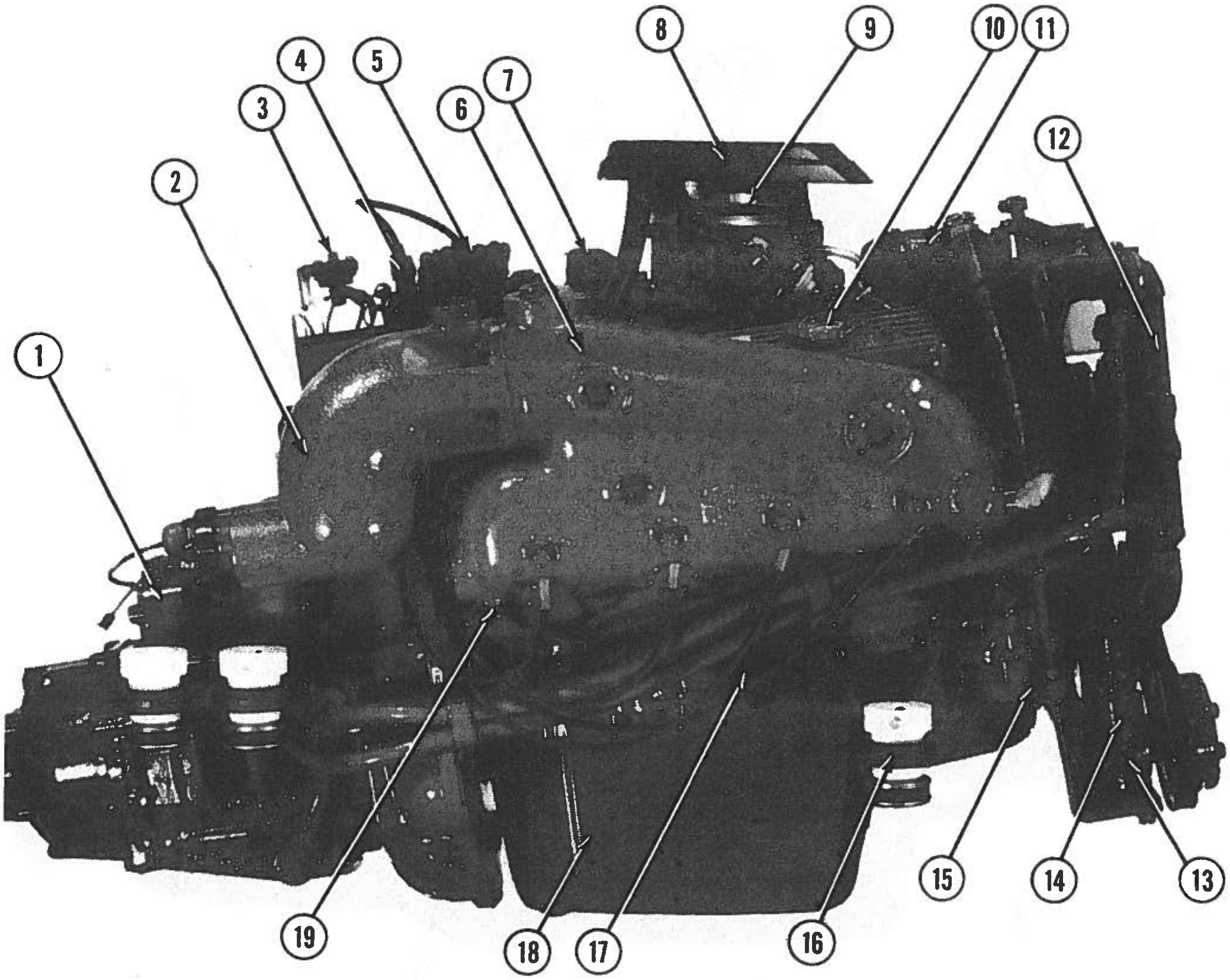
1. Flame arrestor (carburetor)
2. Carburetor
3. Motor oil fill cap
4. Exhaust elbow
5. Motor mount
6. Starter motor
7. Model and serial number plate
8. Oil level dipstick (transmission)
9. Shift lever bracket
10. Oil filter
11. Engine harness connector
12. Throttle cable bracket
13. Circuit breaker

Figure 1-17. *Typical Engine Model 305/350 CID (Seawater-Cooled) – Rear View*



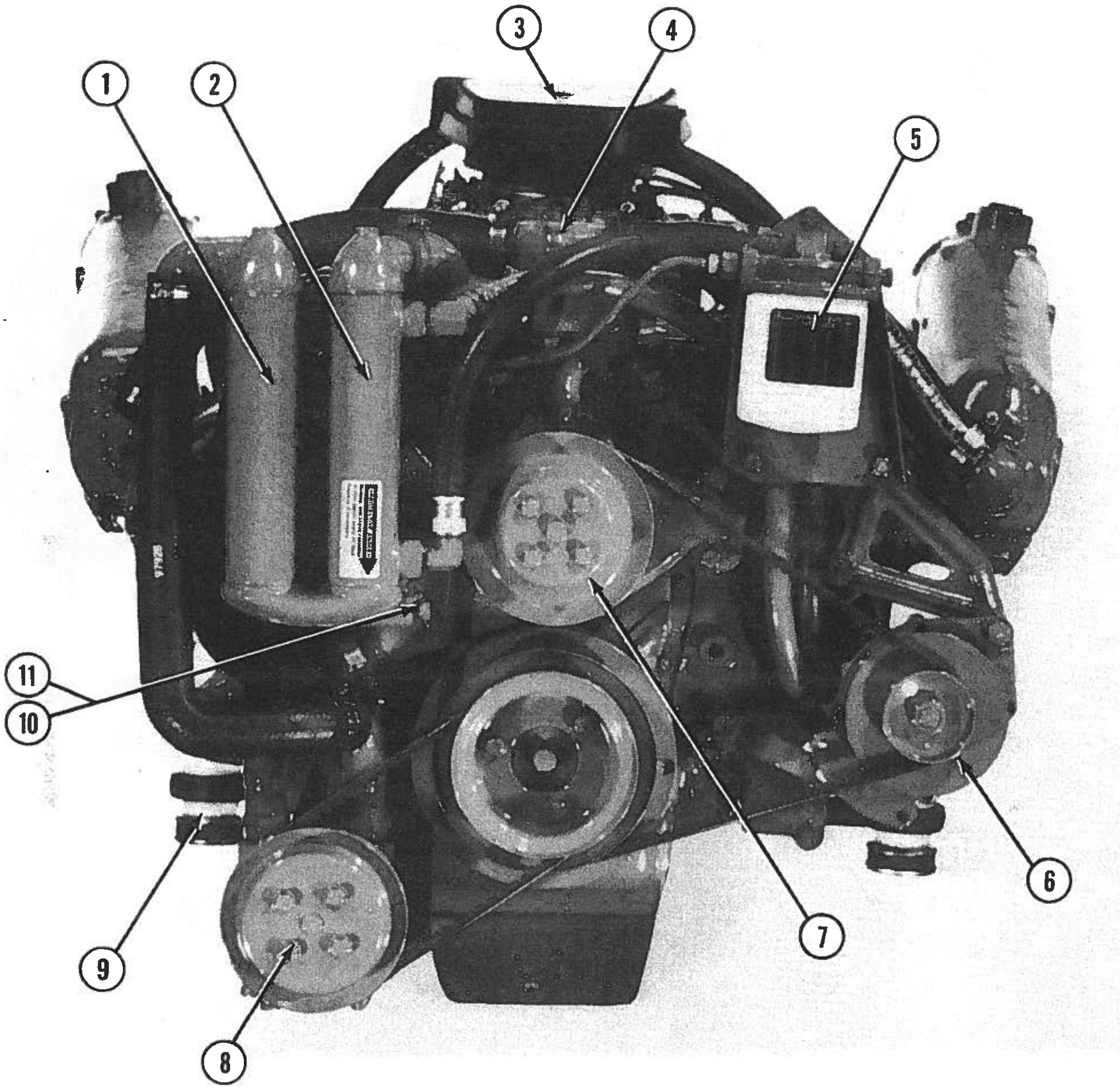
1. Fuel filter
2. Engine water-circulating pump
3. Thermostat housing
4. Carburetor
5. Flame arrestor (carburetor)
6. Throttle cable bracket
7. Distributor
8. Ignition coil
9. Circuit breaker
10. Engine harness connector
11. Starter motor
12. Motor mount
13. Battery ground stud
14. Drain plug (manifold)
15. Drain plug (engine)
16. Alternator
17. Raw-water pump

Figure 1-18. *Typical Engine Model 305/350 CID (Seawater-Cooled) – Port "Left" View*



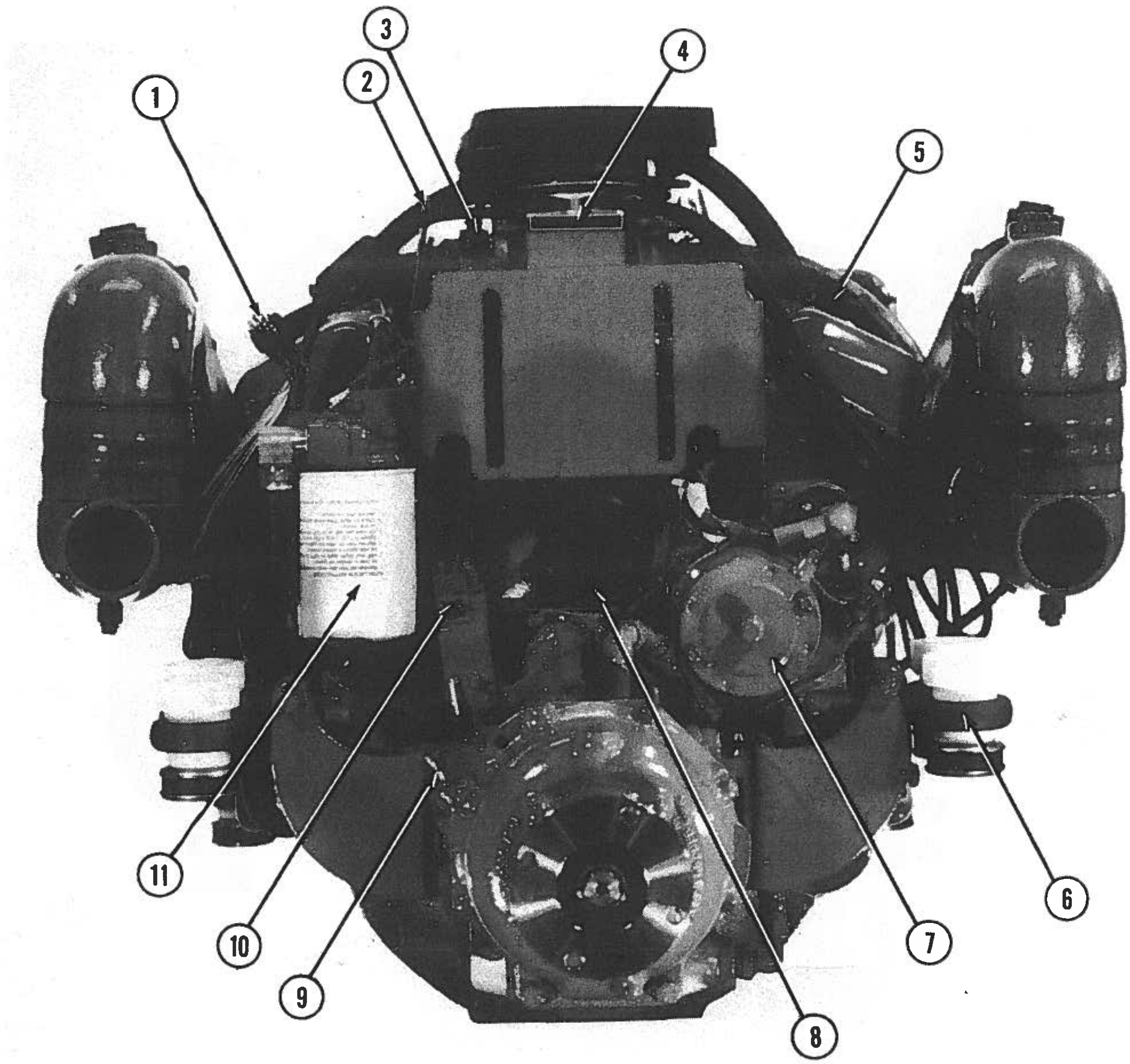
1. Starter motor
2. Exhaust elbow
3. Circuit breaker
4. Ignition coil
5. Distributor
6. Exhaust manifold
7. Throttle cable bracket
8. Flame arrestor (carburetor)
9. Carburetor
10. Motor oil fill cap
11. Thermostat housing
12. Oil cooler (transmission)
13. Drain plug (water pump)
14. Raw-water pump
15. Fuel filter
16. Motor mount
17. Drain plug (engine)
18. Oil pan
19. Drain plug (manifold)

Figure 1-19. *Typical Engine Model 305/350 CID (Seawater-Cooled) – Starboard "Right" View*



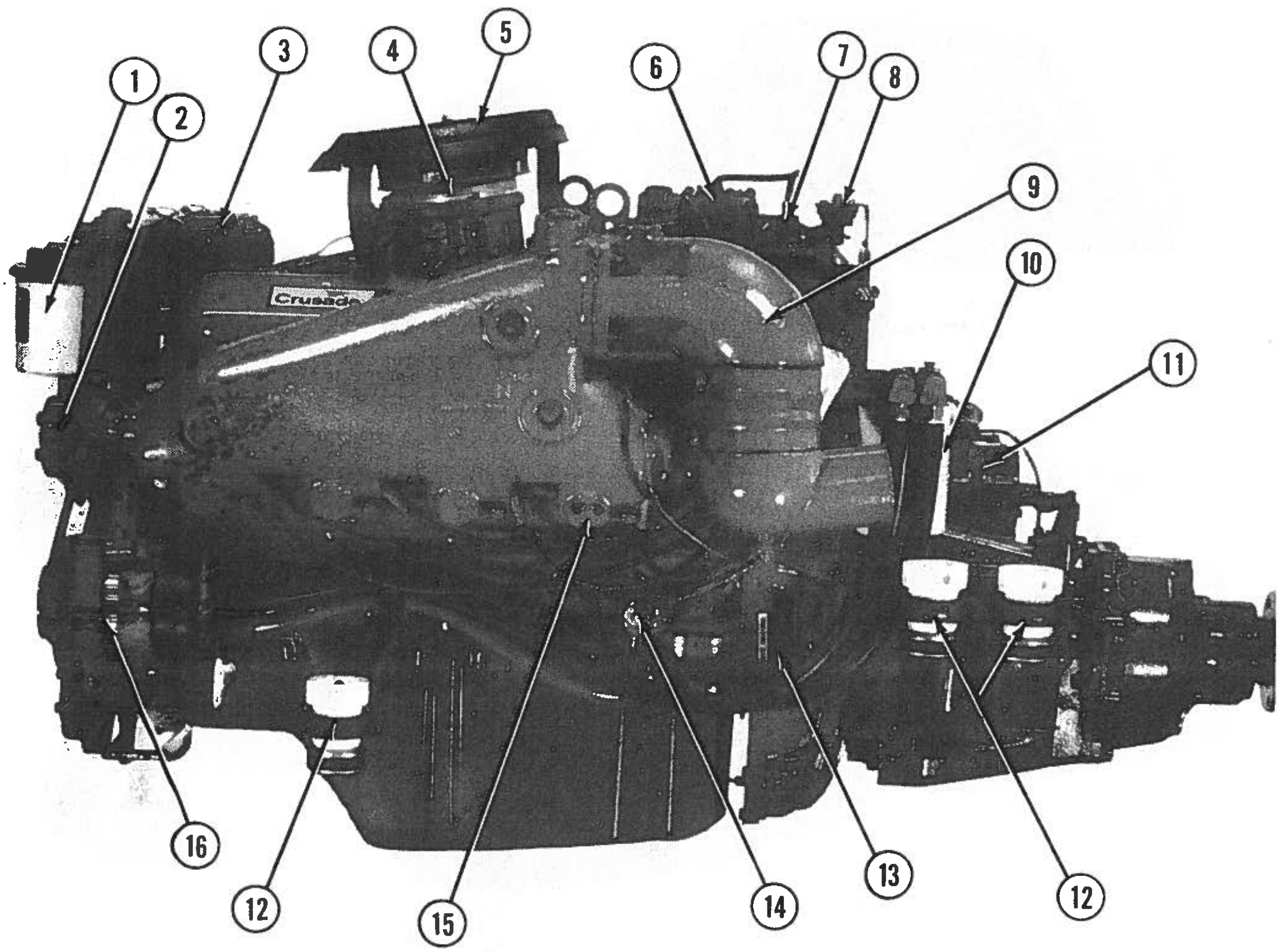
1. Oil cooler (transmission)
2. Oil cooler (engine)
3. Flame arrestor (carburetor)
4. Thermostat housing
5. Fuel filter
6. Alternator
7. Engine water-circulation pump
8. Raw-water pump
9. Motor mount
10. Drain plug (oil cooler)
11. Zinc anodes

Figure 1-20. *Typical Engine Model 454/502 CID – Front View*



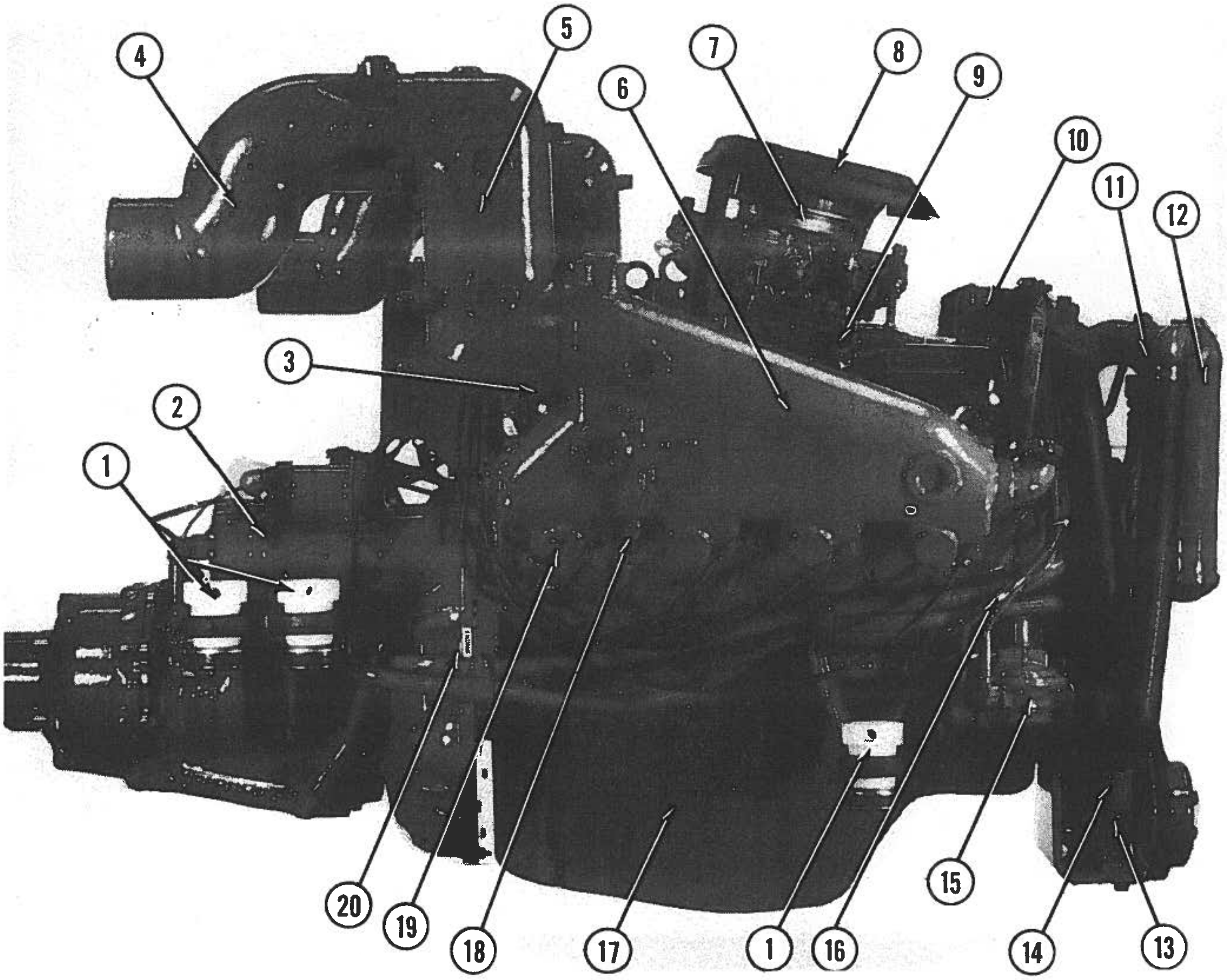
1. Engine harness connection
2. Throttle cable bracket
3. Ignition coil
4. Circuit breaker
5. Motor oil fill cap
6. Motor mount
7. Starter motor
8. Model and serial number plate
9. Oil level dipstick (transmisison)
10. Shift bracket
11. Oil filter

Figure 1-21. *Typical Engine Model 454/502 CID – Rear View*



1. Fuel filter
2. Engine water-circulation disk
3. Thermostat housing
4. Carburetor
5. Flame arrestor
6. Distributor
7. Ignition coil
8. Circuit breaker
9. Exhaust elbow
10. Oil filter
11. Starter motor
12. Motor mount
13. Battery ground stud
14. Oil pressure sender
15. Drain plug (manifold)
16. Alternator

Figure 1-22. *Typical Engine Model 454/502 CID – Port "Left" View*



1. Motor mount
2. Starter motor
3. Drain plug (riser)
4. Exhaust elbow
5. Exhaust riser
6. Exhaust manifold
7. Carburetor
8. Flame arrestor (carburetor)
9. Motor oil fill cap
10. Thermostat housing
11. Oil cooler (engine)
12. Oil cooler (transmission)
13. Drain plug (water pump)
14. Raw-water pump
15. Fuel pump
16. Transparent fuel pump overflow hose
17. Oil pan
18. Oil level dipstick (engine)
19. Drain plug (manifold)
20. Battery ground stud

Figure 1-23. *Typical Engine Model 454/502 CID – Starboard "Right" View*

Section 2

Engine Removal and Installation

BLANK

2 ENGINE REMOVAL AND INSTALLATION

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** working on fuel system to prevent fire or explosion.

WARNING

Be careful when changing fuel system components; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that ignition key is "OFF." **Do not** smoke or allow sources of spark or flame in the area. Wipe up any spilled fuel immediately.

CAUTION

If boat is in the water, be sure to close water inlet valve before removing inlet hose from pump to prevent water from draining into boat. If boat is not fitted with a valve, either plug inlet or raise it above water level after removing.

CAUTION

Do not operate engine without cooling water being supplied to raw water pickup pump or the pump impeller will be damaged and subsequent overheating damage may result.

FASTENER TORQUE REQUIREMENTS

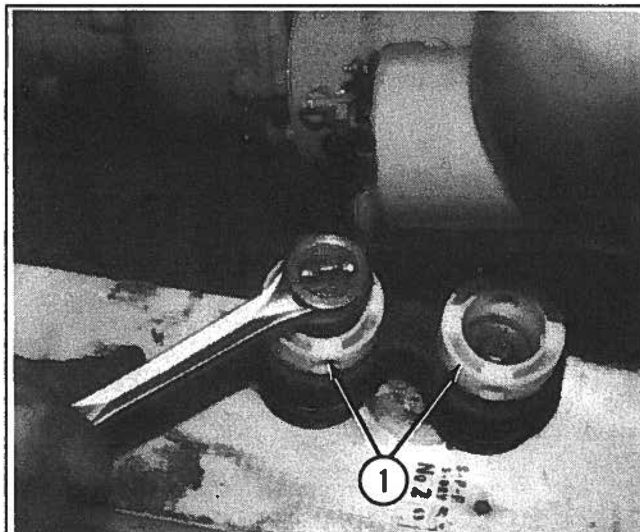
Fastener Location	lb-ft (N•m)
Battery cables	Securely
Engine mount to stringer	Securely
Hose clamps	Securely
Propeller shaft coupling	50 (68)
Trunnion bolts	45 (61)

Tools
22165 Mount adjusting tool

2.1 ENGINE REMOVAL

If the engine needs to be replaced or requires maintenance on parts where access is restricted by the boat's hull, the following procedure should be followed:

1. Disconnect the battery cables from the battery and remove the instrument panel harness connector plug from the engine harness receptacle.
2. Disconnect the fuel line.
3. Disconnect the transmission shift cable and throttle cable in the reverse sequence outlined in Section 2.4, Control Cables.
4. Disconnect the water inlet hose and exhaust system.
5. Disconnect any ground wires or accessories that are connected to the engine.
6. Disconnect the propeller shaft coupling from the transmission coupling.
7. Support the engine with a suitable sling through the lifting eyes on the engine, and remove the front and rear engine mounting bolts (Figure 2-1).
8. Carefully remove engine.



1. Engine mounting bolts

Figure 2-1. *Engine Mounting Bolts*

2.2 ENGINE INSTALLATION

To reinstall the engine after performing the required maintenance, or to install a new engine, the following procedure should be followed:

1. Ensure that all engine mounts (Figure 2-2):
   a. Are in the center of their up and down adjustment.
   b. Have the large diameter of the trunnion extended as shown in Figure 2-2.
   c. Have the mounting base facing downward.

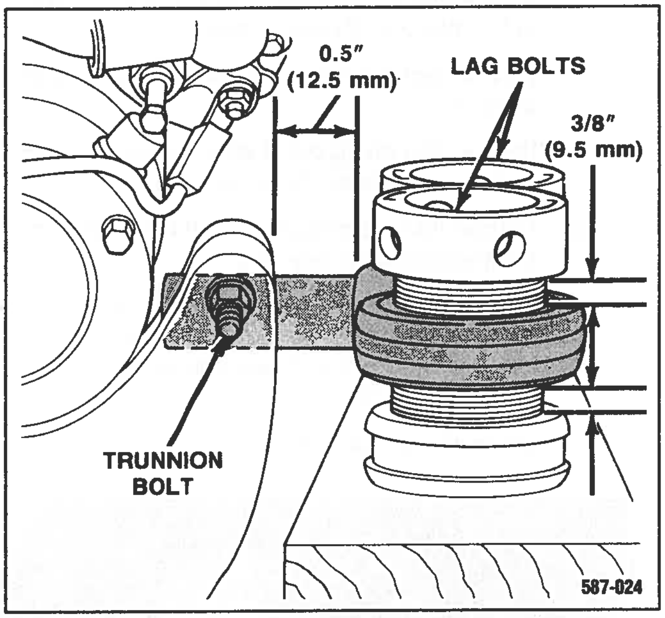


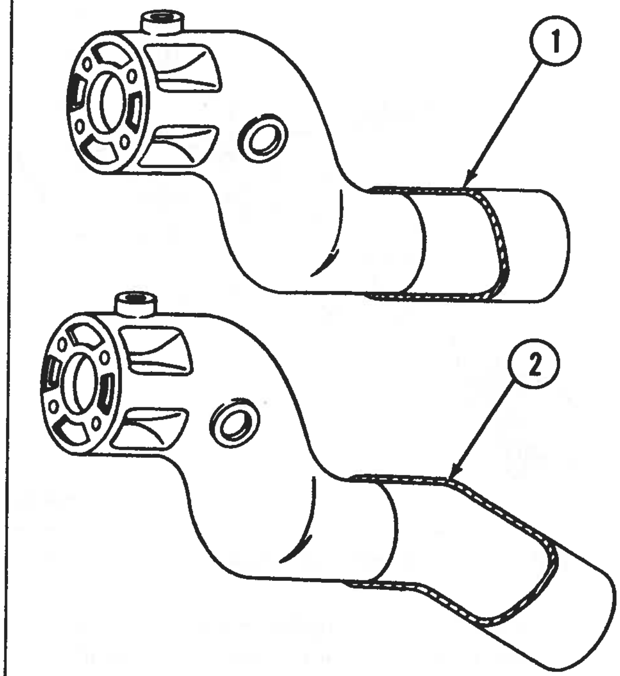
Figure 2-2. *Preliminary Engine Mount Adjustment*

2. Tighten the trunnion clamp nuts and screws just enough so that the trunnion cannot move in or out of the clamp, but still is able to pivot.
3. Lift the engine into the boat and position it on the engine bed so the transmission and propeller shaft couplings are visibly aligned (no gap can be seen between coupling faces when butted together).
4. Adjust the engine bed height, if necessary, to obtain the proper alignment. At this time do not use the mount adjustment to adjust the engine's position.

NOTE: The engine bed must position the engine so that a minimum up-and-down adjustment of 0.25 in. (6 mm) still exists on all four mounts after performing the final alignment. This is necessary to allow for future engine re-alignment.

5. Check all four mounts to ensure that they are still positioned properly, then fasten the mounts to the engine bed with lag bolts and tighten securely.
6. Disconnect and remove the sling.
7. Connect the fuel line and check for leaks.
8. Connect the seawater inlet hose and tighten the clamps securely.
9. Connect the exhaust system and tighten the clamps securely.
10. Before completing the installation, align the engine as outlined in Section 2.3, Engine Alignment.
11. After the alignment is correct, connect the propeller shaft coupling to the transmission coupling and torque the bolts and nuts to specifications.

IMPORTANT: Exhaust hoses must be connected to exhaust elbows without restricting the flow of discharge water from the elbow (Figure 2-3). If the hoses are connected incorrectly, discharge water from the elbow will not flow around the entire inside diameter of the hose. This will cause a hot spot in the hose which may eventually burn through.



1. Correct hose installation
2. Incorrect hose installation

Figure 2-3. Exhaust Hose Installation

12. Connect the instrument harness plug to the engine harness receptacle.
13. Connect the transmission shift cable and throttle cable as outlined in Section 2.4, Control Cables.
14. Reconnect any ground wire and accessories that may have been disconnected.
15. Connect the battery cables to the battery and tighten securely.

2.3 ENGINE ALIGNMENT

> **CAUTION**
>
> Engine must be properly aligned or vibration, noise and damage to the transmission output shaft oil seal and bearings may result.

IMPORTANT: On boats with remote V-Drives, refer to the V-Drive manufacturer's instructions for the correct alignment of the driveshaft between the V-Drive and the transmission.

IMPORTANT: Engine alignment must be checked with the boat in the water, fuel tanks filled and with a normal load on board.

The engine must be aligned so that the transmission and propeller shaft coupling centerlines are aligned and their coupling faces are parallel. This applies to installations with solid couplings, as well as installations with flexible couplings.

Perform the following procedure to correctly align and connect the propeller shaft to the engine:

1. Check the mating faces on the transmission and propeller shaft couplings to make sure they are clean and flat.
2. Center the propeller shaft in the shaft log as follows (Figure 2-4):
   a. Push down and then lift the propeller shaft as far as it will move. Then place the shaft in the middle of the movement.
   b. Move the shaft to port and then to starboard as far as the shaft will move. Then place the shaft in the middle of the movement.
   c. With the shaft in the center of the shaft log, align the engine to the shaft.

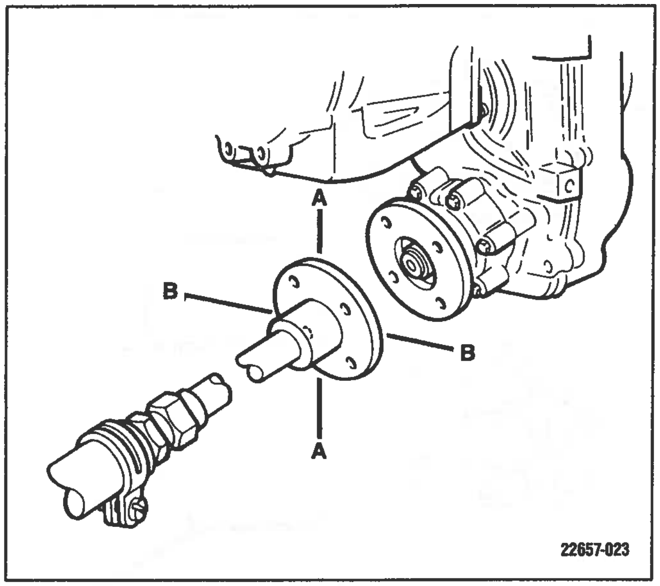


Figure 2-4. Propeller Shaft Alignment To Engine

3. Check that the coupling flange centerlines align by butting the propeller shaft coupling against the transmission flange (see Figure 2-5). The shoulder on the propeller shaft coupling face should engage the recess on the transmission flange with no resistance.

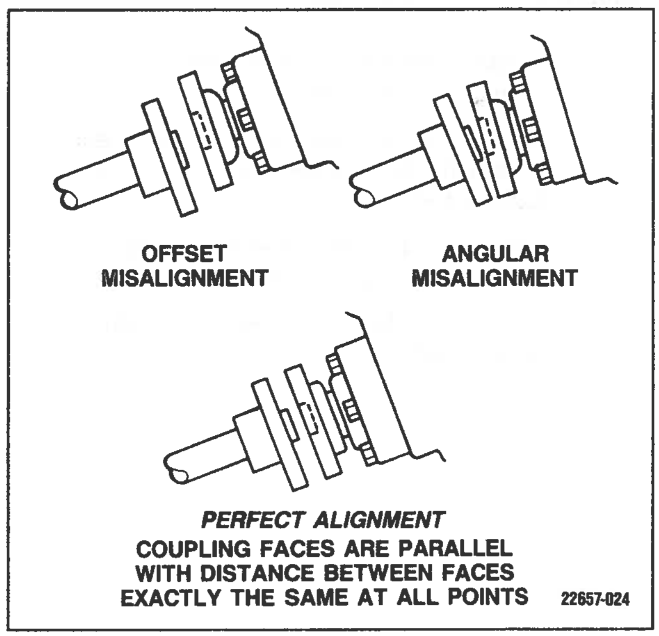


Figure 2-5. Coupling Face Alignment

4. Check for any angular misalignment. Hold the coupling faces tightly together by hand and check for a gap between the coupling faces with a 0.003 in. (0.07 mm) feeler gauge at 90° intervals (see Figure 2-6).

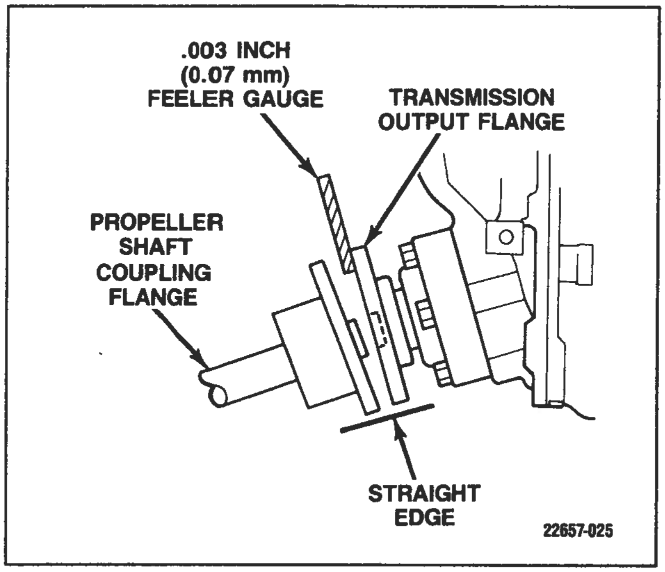


Figure 2-6. Angular Misalignment Check

5. If the coupling centerlines are not aligned or if the coupling faces are more than 0.003 in. (0.07 mm) out of parallel, adjust the engine mounts as follows:
   a. To adjust the engine up or down (Figure 2-7), loosen the lag screw only 1/4 of a turn. Use mount adjusting tool or a 1/2 in. or 3/8 in. diameter rod through both sides of the adjusting sleeve to turn. After the adjustment is complete, retighten the lag screw.

IMPORTANT: Both front mounts must be adjusted equally and both rear mounts must be adjusted equally to keep engine level from side to side.

   b. To move the engine to the left or right, loosen the clamping screw and the nut on all four mounting brackets and move the engine to the left or right, as necessary, to obtain the proper alignment.

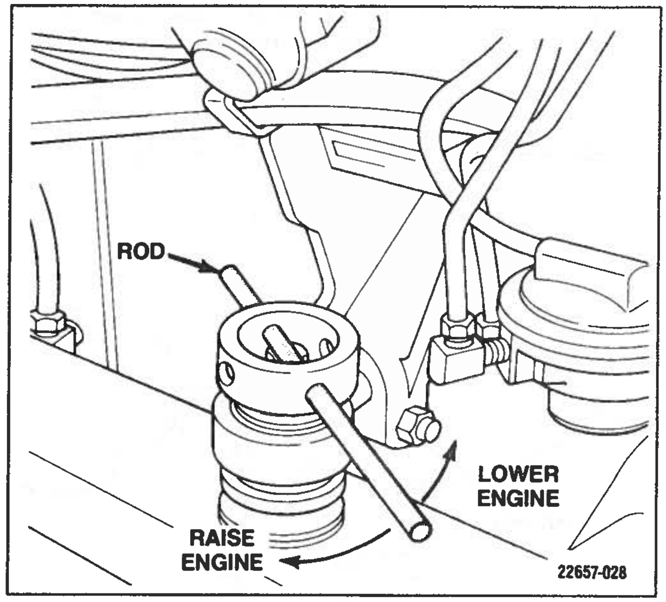


Figure 2-7. Engine Mount Adjustment

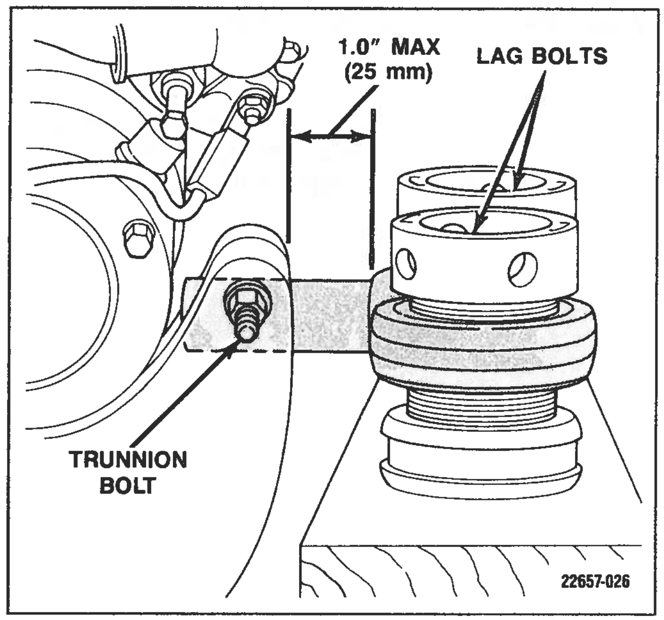


Figure 2-8. Engine Mount Extension

IMPORTANT: The large diameter of the mount trunnion must not extend over 1.0 in. (25 mm) from the mounting brackets on any of the mounts.

6. After the engine has been properly aligned, secure the engine mounts (Figure 2-9).

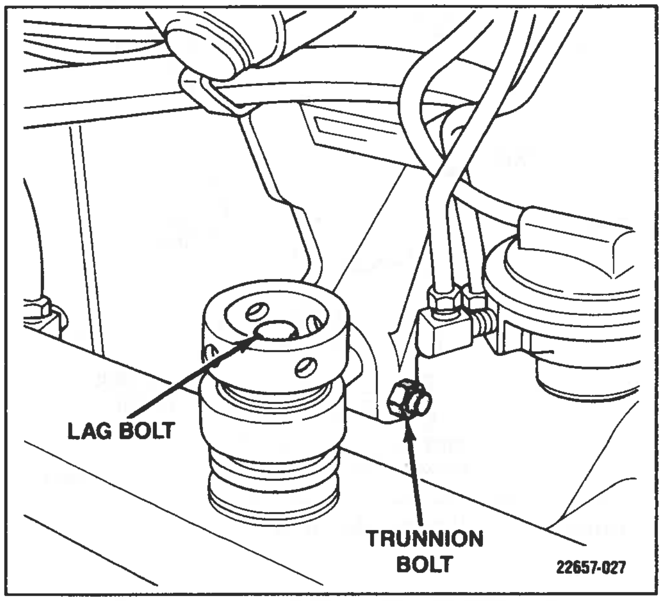


Figure 2-9. *Securing Engine Mount*

7. Connect the propeller shaft coupling to the transmission coupling. Torque the coupling, attaching the screws and nuts to the correct specifications as listed in the table.

2.4 CONTROL CABLES

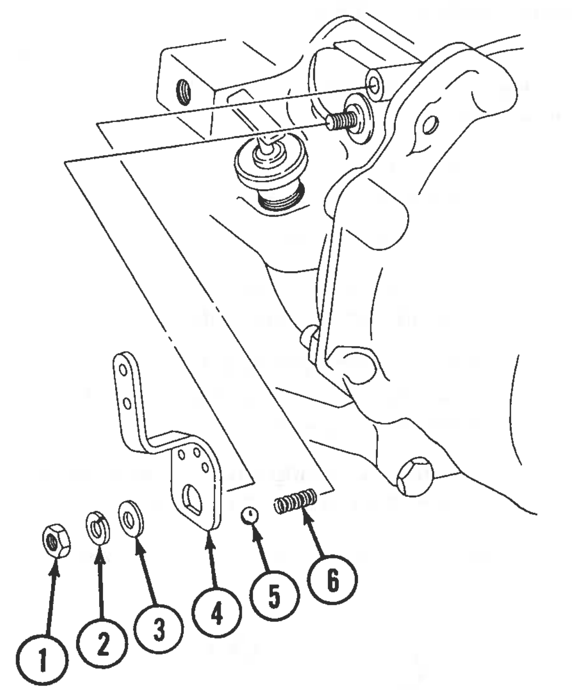
IMPORTANT: The remote control lever must provide a total shift cable travel (transmission end) of at least 2.75 in. (70 mm). This is necessary to position the transmission shift lever fully in the forward and reverse gear positions. Insufficient shift cable travel will cause the transmission to slip and eventually fail.

Transmission Shift Lever Installation:

IMPORTANT: The Warner Gear warranty is jeopardized if the shift lever poppet spring and/or ball is permanently removed; if the shift lever is changed or repositioned in any manner; or if the linkage between the remote control and the transmission shift lever does not have sufficient travel in both directions.

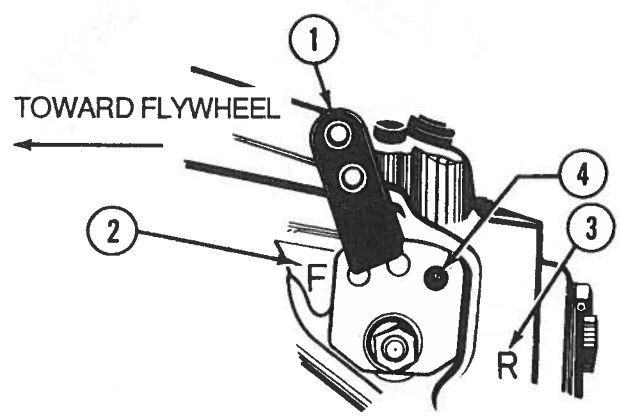
The transmission shift lever and related parts must be assembled as shown in Figure 2-10.

1. Lubricate poppet ball, spring and holes in the transmission shift lever with a high-temperature grease.
2. Torque the nut from 96-132 lb-in (11-15 N•m).
3. After installation, move the transmission shift lever through the forward, neutral and reverse positions (Figure 2-11). No more than fingertip effort should be required. If the valve binds, the cause for binding must be found and corrected.



1. Nut
2. Lockwasher
3. Flat washer
4. Shift lever
5. Poppet ball
6. Poppet spring

__Figure 2-10.__ Transmission Shift Lever Assembly



1. Transmission shift lever
2. Shift lever must be over this letter when propelling boat FORWARD
3. Shift lever must be over this letter when propelling boat in REVERSE
4. Poppet ball must be centered in detent hole for each F-N-R position (Forward gear position shown)

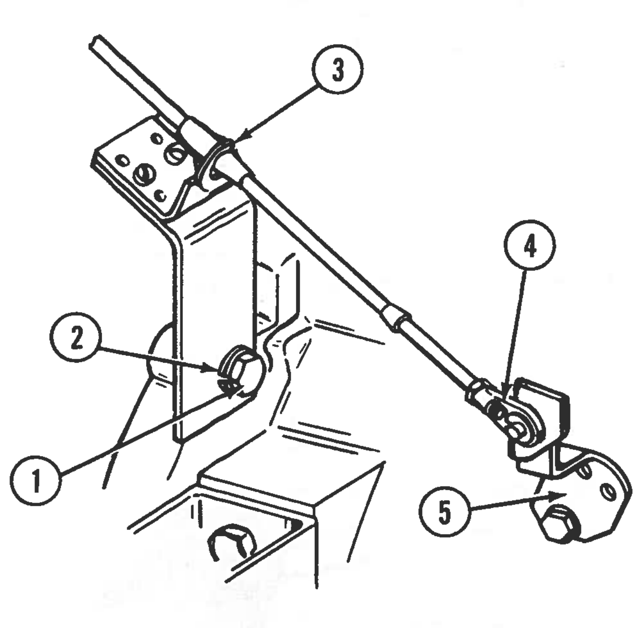
__Figure 2-11.__ Transmission Shift Lever

Attaching/Adjusting Transmission Cable:

Single-Station Control

Use the following procedure to properly attach and adjust the transmission shift (Figures 2-11 and 2-12) for a single-station mount:

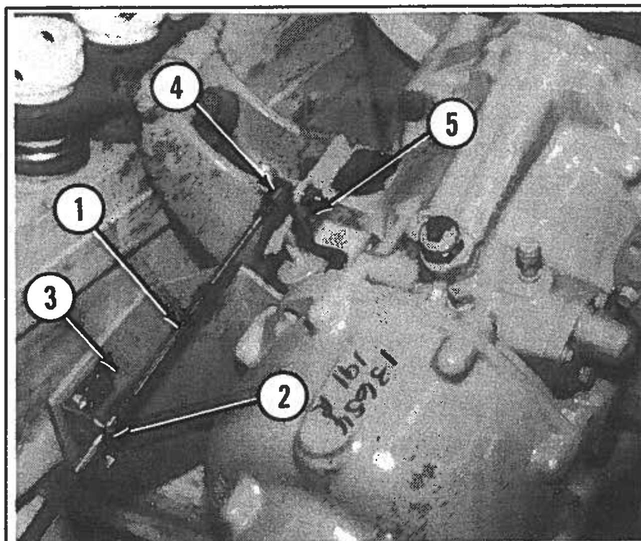
1. Place the remote control shift lever in the neutral position.
2. Place the transmission shift lever in neutral.
3. Install the shift cable hub into the shift cable bracket and lock the cable clip.
4. Install a clevis pin onto the cable rod until the hole lines up with the ball joint stud, then tighten the locknut.
5. Retract the spring lock on the clevis pin and attach the cable to the ball joint stud.



1. Mounting bolt
2. Lockwasher
3. Cable anchor clip
4. Clevis pin assembly
5. Shift lever

Figure 2-11. *Single-Station Shift Cable Assembly – Front Mount*

6. Place the remote control shift lever in the full forward gear position. Check the position of the transmission shift lever for full engagement.
7. Place the remote control shift lever in the full reverse gear position. Check the position of the transmission shift lever for full engagement.
8. If the transmission shift lever is positioned properly in one gear, but not in the other, recheck the shift cable adjustment. If the transmission shift lever is not positioned properly in either gear, move the shift lever ball joint stud to the bottom hole in the shift lever, readjust the cable and recheck for correct engagement. If correct positioning is still not achieved, the remote control does not provide sufficient shift cable travel and must be replaced.

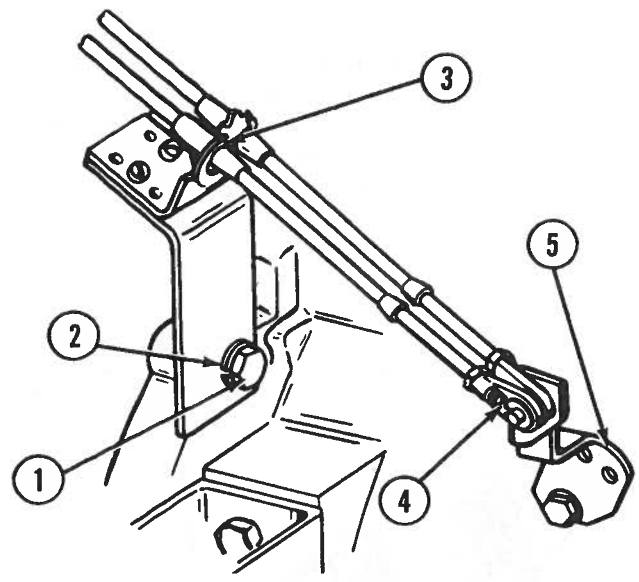


1. Throttle cable
2. Cable anchor clip
3. Bracket
4. Cable ball joint
5. Shift lever

Figure 2-12. *Single-Station Shift Cable Assembly – Rear Mount*

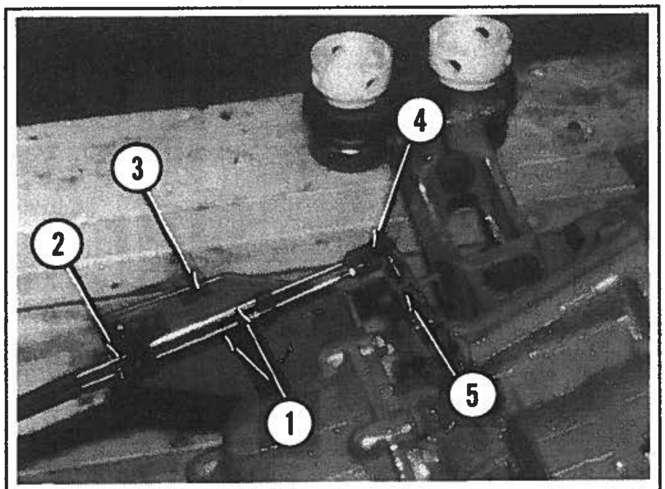
Dual-Station Control

Use the following procedure to attach and adjust a dual-station shift cable properly (Figure 2-13 and 2-14) for a dual-station mount:



1. Mounting bolt
2. Lockwasher
3. Cable anchor clip
4. Cable terminal
5. Shift lever

Figure 2-13. Dual-Station Shift Cable Assembly – Front Mount



1. Throttle cable
2. Cable anchor clip
3. Bracket
4. Cable ball joint
5. Shift lever

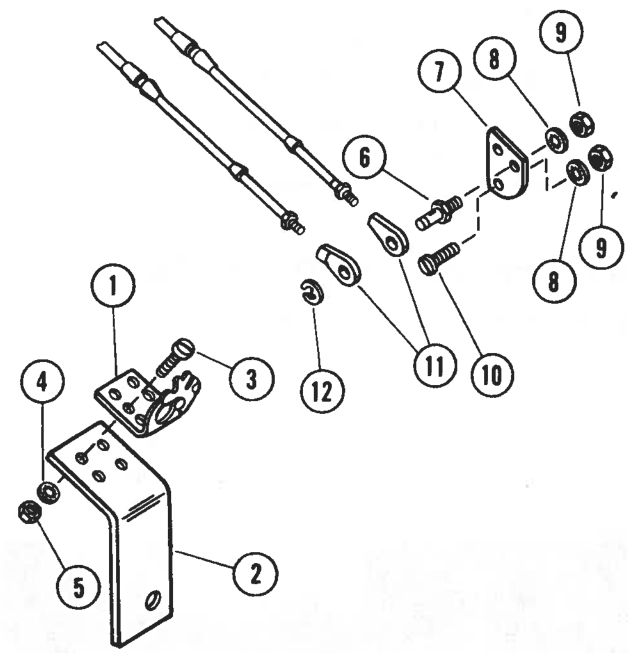
Figure 2-14. Dual-Station Shift Cable Assembly – Rear Mount

NOTE: The following instructions refer to Crusader attaching kit number 22435.

1. Place the remote control shift lever and the transmission shift lever in the neutral position.

IMPORTANT: The remote control lever must provide a total shift cable travel of at least 2.75 in. (70 mm). Insufficient travel will cause the transmission to slip and eventually fail.

2. Referring to Figure 2-15, attach the cable clip to the bracket using screws, lockwashers and nuts.



1. Cable clip
2. Bracket
3. Mach. screw, flat head 10-32x1/2 in. lg.
4. #10 lockwasher
5. 10-32 hex nut
6. Pivot pin
7. Adaptor plate
8. 1/4 in. lockwasher
9. 1/4-28 hex nut
10. Mach. screw, flat head 1/4-28x5/8 in. lg.
11. Cable terminal
12. 5/16 in. E-ring

Figure 2-15. Dual-Station Shift Cable Assembly

3. Remove the top transmission mounting bolt and lockwasher from the left (valve) side of transmission; position bracket and replace bolt and lockwasher.
4. Fasten the pivot pin securely through hole in the adaptor plate using a lockwasher and a nut.
5. Insert the cable hubs into the cable clip and screw the terminals onto the cable rods until the holes in the terminals line up with the pivot

pin. Hold each terminal securely to prevent it from turning and tighten the cable nut against the terminal.

NOTE: Be sure the transmission shift lever and the remote control shift lever are in the neutral position during the above installation.

6. Place terminals on the pivot pin and secure with a 5/16 in. E-ring.

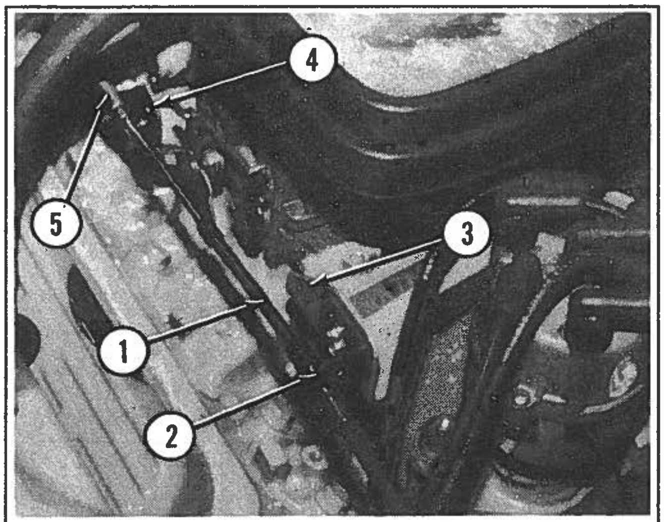
NOTE: Shift the control box by hand and be sure it operates freely with no binding.

7. Place the remote-control shift lever in the forward gear position and check position of transmission shift lever. Shift lever must be positioned as shown in Figure 2-11.
8. Place remote control lever in the reverse gear position and again check the transmission shift lever position. Shift lever must be positioned as shown in Figure 2-11.

Attaching/Adjusting Throttle Cable:

Single-Station Throttle Cable Control

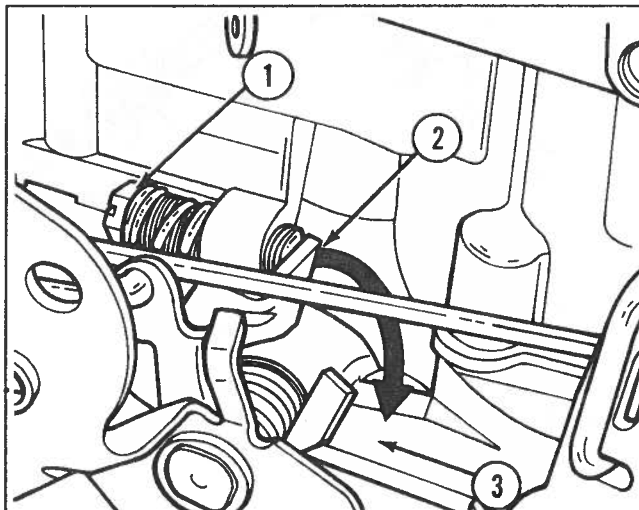
1. Place the remote control throttle lever in the neutral or idle position.
2. Install throttle cable hub into the throttle cable mounting clip and secure with cable clip.



1. Throttle cable
2. Cable anchor clip
3. Bracket
4. Throttle lever
5. Cable ball joint

Figure 2-17. Throttle Cable Adjustment – Single Station

3. Thread the ball joint clevis onto the throttle cable in order to line up the ball joint stud mounted on carburetor throttle arm. Tighten clevis jam nut when positioned correctly.
4. Retract the spring lock on the clevis pin and attach the throttle cable to the ball joint stud.
5. Place the remote-control throttle lever in the full-throttle position, and check that the carburetor throttle plates open fully and the throttle lever contacts the control stops. Check the throttle cable and carburetor linkage for any binding. Return the throttle lever to the neutral or idle position and check that the throttle plates are closed.

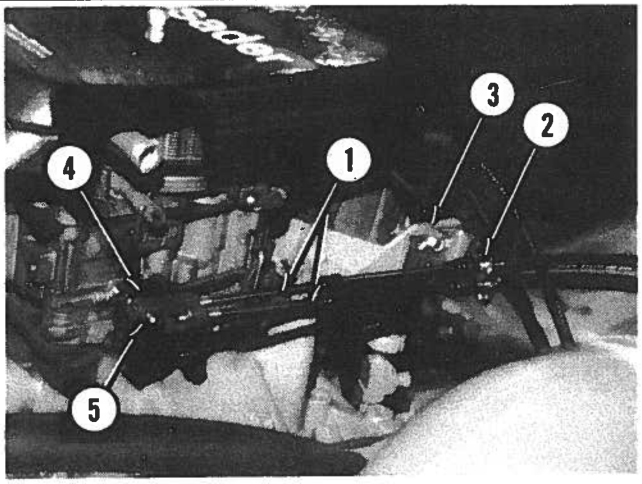


1. Idle-adjusting screw
2. Idle position
3. Wide-open throttle position

Figure 2-18. Remote-Control Throttle Cable Positioning

Dual-Station Throttle Cable Control

1. Place the remote-control throttle lever in the neutral or idle position.
2. Install throttle cable pivot pin on the carburetor throttle arm.



1. Throttle cable
2. Cable anchor clip
3. Bracket
4. Throttle lever
5. Cable ball joint

Figure 2-18. *Throttle Cable Adjustment – Dual Station*

3. Install the throttle cable hubs into the throttle cable mounting clip and secure with cable clips.
4. Thread the cable attaching terminal onto the throttle cable until it lines up with the pivot pin on the carburetor throttle arm. Tighten cable terminal end by holding the terminal to prevent it from turning and tightening the jam nut.
5. Place the cable terminal ends over the throttle pivot pin and secure with retaining clip.
6. Place the remote-control lever in the full throttle position. Make sure that the carburetor throttle plates are in the full open position and that the throttle lever contacts the control stops. Check cables and carburetor linkage for any binding. Return the throttle levers to the neutral or idle position and make sure that the carburetor throttle arm is contacting the idle stop, and the throttle plates are fully closed. Adjust as needed.

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Section 3

Maintenance

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3 MAINTENANCE

All Crusader engines require a certain amount of maintenance. Suggested maintenance requirements are contained in this section. The owner should, however, develop his own maintenance schedule using the requirements listed in this manual and any other necessary requirements resulting from optional additions to the engine system.

3.1 DRIVE BELTS

Alternator Belt Tension Adjustment:

IMPORTANT: When adjusting the alternator belt tension, do not apply pressure to the alternator's rear end-frame, as this may damage the alternator.

1. Check belt tension by depressing belt with thumb at midway point (4) (Figure 3-1). Belt should depress 1/2 in. (12 mm).
2. If adjustment or replacement is necessary, loosen alternator brace attaching bolts and alternator mounting bolt.
3. Pivot alternator inward to replace drive belt.
4. Pivot alternator outward, as required, to obtain correct belt tension. Apply pressure to alternator front end-frame only. Set new belts at the high-tension reading.
5. Retighten alternator brace attaching bolts and alternator mounting bolt securely.
6. Recheck alternator belt tension. If a new drive belt has been installed, recheck belt tension after running for 5 minutes.

Raw-water Pickup Pump Belt Tension Adjustment:

1. Check belt tension by depressing belt with thumb at midway point (2) (Figure 3-1). Belt should depress 1/4 in. (6 mm).
2. If adjustment or replacement is necessary, loosen the pickup pump attaching bolts.
3. Slide pump away from engine, as required, until correct tension is obtained.
4. After obtaining correct tension, securely retighten pump mounting bolts.
5. Recheck pickup pump belt tension. If a new drive belt has been installed, recheck belt tension after running for 5 minutes.

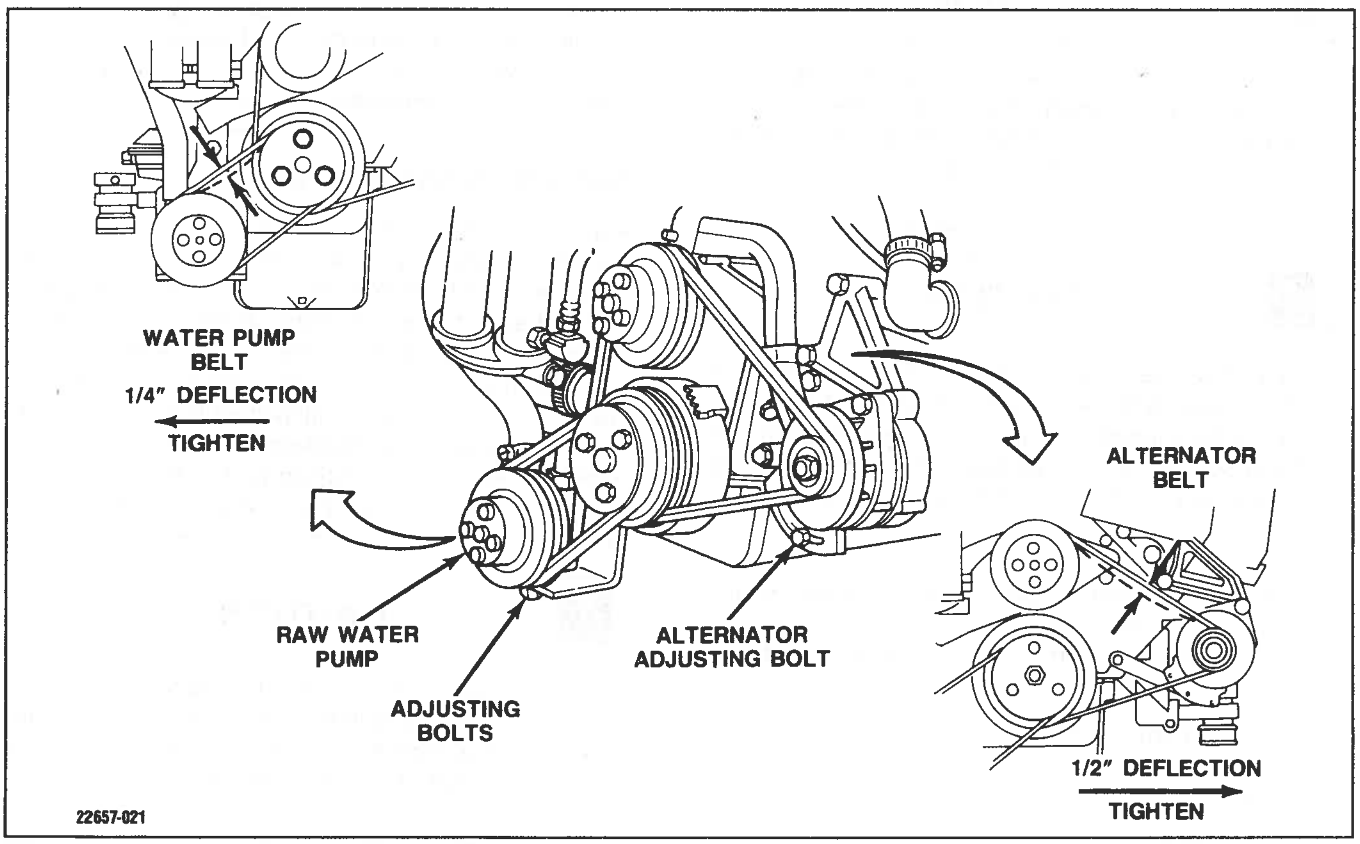


Figure 3-1. *Drive Belt Deflection*

3.2 FUELS AND LUBRICANTS

FUEL RECOMMENDATIONS

The ignition timing set by the factory requires the use of lead-free or leaded gasoline with the following minimum or higher octane specification:

- Anti-Knock Index Number (AKI) – 87
- Research Octane Number (RON) – 91

If 87 AKI (91 RON) octane is not available, a gasoline (regular leaded, premium, low-lead or lead-free) with an average octane rating as low as 86 AKI (RON 90) octane may be used. Ignition timing, however, must be retarded 4° to prevent harmful detonation.

Recent regulations by the U.S. Environmental Protection Agency (EPA) and the Canadian government have required the removal of lead (antiknock compound) from all gasoline by 1988, due to health hazards from lead emission generated by the exhaust.

Detonation or spark knock in a marine engine is not necessarily audible. Overheating is an indication of detonation in a marine engine. If you suspect detonation or spark knock and the engine is properly tuned, change to a higher octane fuel.

CAUTION

Use of incorrect gasoline can damage the engine seriously. Engine damage that results from use of incorrect gasoline is considered misuse of the engine and is not covered under Crusader Engines' warranty.

CAUTION

If the engine is to be operated in a foreign country, or if the above recommended gasoline is not available, the ignition timing will have to be retarded so that lower octane fuels can be used. When ignition timing is retarded, a slight decrease in power can be expected.

In order to maintain octane ratings, many gasoline manufacturers are adding ethyl alcohol (ethanol) or methyl alcohol (methanol) to the gasoline to replace the lead.

Gasolines containing alcohol, either methyl alcohol (methanol) or ethyl alcohol (ethanol), may cause increased:

- Corrosion of metal parts.
- Deterioration of elastomer and plastic parts.
- Fuel permeation through flexible fuel lines.
- Wear and damage of internal engine parts.
- Starting and operating difficulties.

Some of these adverse effects are due to the tendency of gasolines containing alcohol to absorb moisture from the air, resulting in a phase of water and alcohol separating from the gasoline in the fuel tank.

The adverse effects of alcohol are more severe with methanol and are heightened with increased alcohol content.

WARNING

Fire and explosion hazard: Fuel leakage from any part of the fuel system can be a fire and explosion hazard which can cause serious bodily injury or death. Careful periodic inspection of the entire fuel system is mandatory, particularly after storage. All fuel components including fuel tanks, whether plastic, metal or fiberglass, fuel lines, fittings, fuel filters, fuel pumps and carburetors should be inspected for leakage, softening, hardening, swelling or corrosion. Any sign of leakage or deterioration necessitates replacement before further engine operation.

Because of the possible adverse effects of alcohol in gasoline, it is recommended that only alcohol-free gasoline be used where possible. If only alcohol-containing fuel is available, or if the presence of alcohol is unknown, then more frequent inspection for leaks and abnormalities is required.

Gasoline/Alcohol Blends:

Many new motor vehicle owner's manuals warn about the potential damage from using gasoline containing alcohol, especially **methanol**. They cite possible fuel system damage and performance problems. These are just two of the hazards that may be caused by alcohol. These same problems, as well as the additional safety risk of fire and explosion from fuel system leaks, apply to marine inboard engines. **Methanol** is more severe in its harmful effect than is **ethanol**. Alcohol is also more harmful in older engines since newer engines have materials which are more resistant to alcohol.

CAUTION

Performance problems, or other damage resulting from the use of gasoline/alcohol-blended fuels, are not the responsibility of Crusader Engines and will not be covered under our warranty.

Corrosion of metals may result from the use of alcohol-gasoline blends. Portable or permanently installed fuel tanks of metal or fiberglass, fuel filters, fuel lines and float bowls may be affected by alcohol-blended fuels. Many fiberglass fuel tanks are slowly dissolved by alcohol, leading immediately to filter- and carburetor-plugging and, eventually, to tank failure.

Alcohol-containing fuels will absorb moisture from the air. At first, this moisture will remain in solution, but once the water content of the fuel has built up to about one-half of one percent, it will separate (phase separation), bringing the alcohol with it. This alcohol-water mixture settles to the bottom of the fuel tank, and, if this mixture gets into the engine, engines can be seriously damaged internally, as it may wash the protective film of oil off the bore of any cylinder that it enters. Before the engine can be restarted, it is necessary to remove the separated alcohol and water layer, flush out the fuel system with clean fuel, and remove and dry the spark plugs.

The effects of gasoline blended with ethanol or methanol are still being evaluated by the United States Coast Guard, the National Marine Manufacturing Association (NMMA), Crusader Engines, and other engine and boat manufacturers.

Crusader Engines has recommended pump-posting of the alcohol content of all gasoline. Crusader Engines recommends using gasoline known to contain no methanol or ethanol when possible.

Gasoline/Alcohol Content Test:

The following is an acceptable and widely used field procedure for the detection of alcohol in gasoline. Use any small transparent bottle or tube that can be capped and can be provided with graduations or a mark at about 1/3 full. A pencil mark on a piece of adhesive tape may be used.

1. Fill the container with water to the mark.
2. Add fuel almost to fill the container, leaving some air space, then cap the container. The proportions of fuel to water are not critical, but there should be 2-3 times as much fuel as water.
3. Shake container vigorously and allow it to sit upright for about 3-5 minutes. If the volume of water appears to have increased, alcohol is present. If you are not sure, there is no need for concern. If the dividing line between water and fuel becomes cloudy, use the middle of the cloudy band, or use a Kent-Moore #J 34353 Alcohol Detection Kit.

ENGINE OIL

After the 25-hour break-in oil has been drained, select a crankcase oil based on the prevailing daytime temperature in the area in which the boat is operated.

The table below is a guide to selecting the proper crankcase oil and shows recommended change intervals. When changing the oil, always change the oil filter.

IMPORTANT: The use of multi-viscosity oils is not recommended for use in Crusader engines. Oils containing "solid" additives, nondetergent oils, or low-quality oils specifically are not recommended.

Prevailing Ambient Temperature	Recommended A.P.I. Classification and Viscosity
Above 50°F (10°C)	SAE 40 "SG/CC"
32-50°F (0-10°C)	SAE 30 "SG/CC"
Below 32°F (0°C)	SAE 20 "SG/CC"

Care must be taken when checking engine oil level. Oil level must be maintained between the "ADD" mark and the "FULL" mark on the dipstick. To ensure that you are not getting a false reading, make sure the following steps are taken before checking the oil level.

Checking/Filling Engine Oil Level:

1. Stop engine if in use, and allow boat to come to a rest.
2. Allow sufficient time (approximately 5 minutes) for the oil to drain back into the oil pan.
3. Remove dipstick. Wipe clean and reinstall. Push dipstick all the way into the dipstick tube.
4. Remove dipstick and note the oil level.
5. Oil level must be between the "FULL" and "ADD" marks.
6. If the oil level is below the "ADD" mark, proceed to Steps 7 and 8, or reinstall dipstick into the dipstick tube.
7. Remove oil filler cap from the valve rocker arm cover.
8. Add required amount of oil to bring level up to, but not over, the "FULL" mark on dipstick.

Overfilled crankcases (oil level being too high) can cause a fluctuation or drop in oil pressure and rocker arm "clatter" on engines. The overfill condition results in the engine crankshaft splashing and agitating the oil, causing it to foam (become aerated). The aerated oil causes the hydraulic valve lifters to "bleed down." This, in turn, results in rocker arm "clatter" and loss of engine performance due to the valves not opening properly.

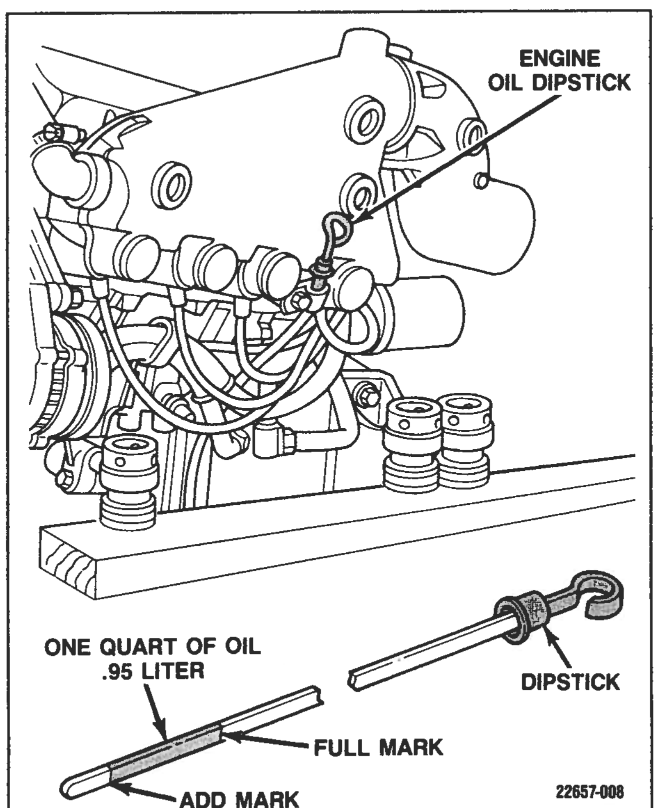


Figure 3-2. *Dipstick – Engine Oil*

Changing Engine Oil and Filter:

1. Start engine and run until it reaches normal operating temperatures.

IMPORTANT: Change oil when engine is warm from operation as it flows more freely, carrying away more impurities.

2. Stop engine.
3. Remove engine oil dipstick.
4. Using a pump, suck engine oil from the engine through the dipstick tube. (See directions on pump used.) (Figure 3-3)
5. Remove and discard oil filter and its sealing ring.
6. Coat sealing ring on new filter with clean engine oil, and install new filter. Tighten filter securely (following filter manufacturer's instructions). Do not overtighten.

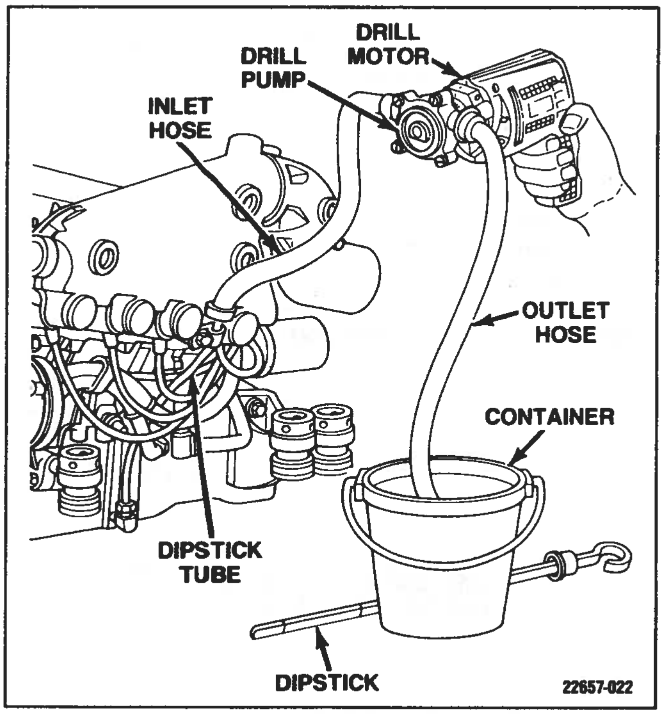


Figure 3-3. *Oil Removal*

7. Fill crankcase with oil.
8. Start engine and check for oil leaks.

TRANSMISSION OIL

Dexron II or other hydraulic transmission oils which meet the Detroit Diesel Allison Type C3 specifications are recommended for use in all Velvet Drive® (Borg-Warner) marine transmissions.

Checking/Filling Transmission Oil Level:

1. Remove dipstick. Check to ensure that the oil is indicated on the dipstick (Figure 3-4). The oil level may be somewhat over the full mark, as some of the oil from transmission fluid cooler and hoses may have drained back into the transmission. If the level is low, add automatic transmission fluid (ATF) until the level comes up to the "FULL" mark on the dipstick.

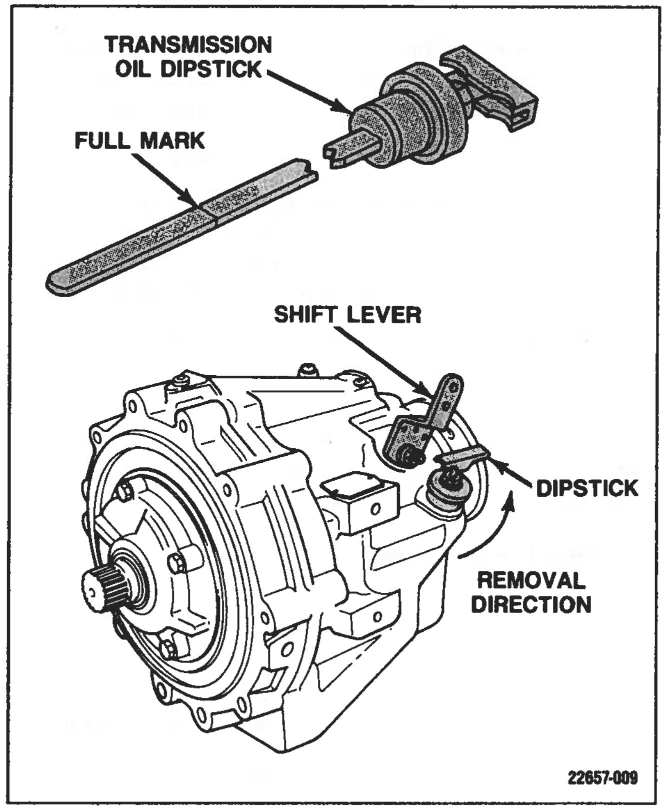


Figure 3-4. *Transmission Oil Fill*

2. Start the engine and run at 1500 rpm for 2 minutes to allow the oil to fill all the hydraulic circuits.

IMPORTANT: To accurately check the oil level, the engine must be run at 1500 rpm for two minutes immediately prior to checking level.

3. Stop the engine and quickly check the oil level. Add transmission fluid, if necessary, to bring the level up to the "FULL" mark on the dipstick.

IMPORTANT: Be sure to push dipstick all the way down into dipstick tube when checking oil level.

4. Reinstall dipstick. Be sure to tighten the T-handle securely.
5. If the transmission oil level was extremely low, carefully check transmission, oil cooler and hoses for leaks.

Changing Transmission Oil:

NOTE: When servicing or repairing transmissions equipped with a charge tube and strainer or models equipped with an oil shield, it is recommended to replace these components with a new tube screen PT # 25526.

In-Line Transmissions

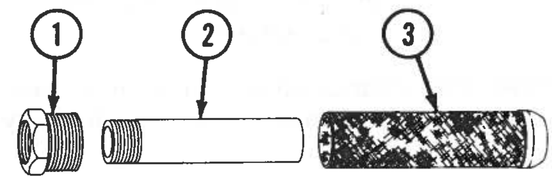
1. Disconnect the return hose from bushing (lower hose on transmission).
2. Remove the components shown in Figures 3-5 through 3-7, depending on model type, and allow transmission to drain completely.
3. Clean or replace the tube screen.
4. Coat threads of bushing with Perfect Seal. Install components in the order shown in the corresponding model (Figures 3-5 through 3-7). Torque bushing to 25 lb-ft (33.9 N•m).
5. Reconnect hose and tighten fitting securely.
6. Refill transmission with the correct oil (Dexron II or equivalent).

NOTE: See Checking/Filling Transmission Oil Level procedure.

V-Drive Transmissions

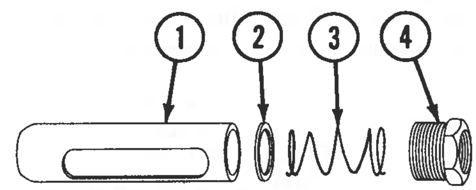
1. Disconnect the return hose (lower hose at bottom of V-Drive).
2. Allow V-Drive to drain completely.
3. Reconnect hose and tighten fitting securely.
4. Refill V-Drive with the correct oil.

NOTE: See Checking/Filling Transmission Oil Level procedure.



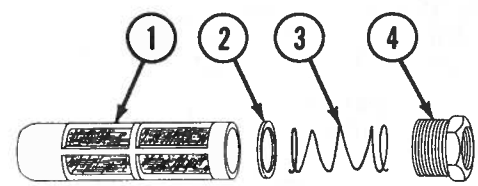
1. Bushing
2. Charge tube (not used on all models)
3. Strainer (installed approximately 1/2 in. [13 mm] below surface of case)

Figure 3-5. Strainer Models



1. Oil shield PT # 25511 (slot toward bottom of transmission)
2. Washer PT #25512
3. Spring PT # 25513
4. Bushing

Figure 3-6. Oil Shield Models



1. Tube screen PT # 25526 (slot toward bottom of transmission)
2. Washer PT # 25512
3. Spring PT # 25513
4. Bushing

Figure 3-7. Tube Screen Models

3.3 SCHEDULED MAINTENANCE

The following table displays a proposed schedule of required maintenance checks:

MAINTENANCE SCHEDULE					
Location and Service	**When Starting Engine Each Day**	**After First 25 Hours of Operation**	**Every 50 Hours of Operation**	**Every 100 Hours of Operation**	**At Least Once Each Year**
Check coolant level (freshwater-cooled models only).	X				
Check engine crankcase oil level.	X				
Observe entire power package for obvious leaks (water, fuel, oil, exhaust, etc.).	X				
Check remote control and steering system for proper operation.	X				
Check transmission oil level (A).	X				
Check sea strainer – if equipped.	X				
Check tightness of cooling system hose clamps.		X		X[1]	X
Inspect condition and check tension of all drive belts.		X		X	X
Inspect exhaust system condition. Check hose clamps for adequate tightness.		X		X[1]	X
Clean and inspect ignition system.		X		X[1]	X
Check entire power package for loose, missing, or damaged parts (especially engine mount fasteners, starter and alternator mounting fasteners).		X		X	X
Change crankcase oil and oil filter.		X	X		X
Check engine alignment.		X			X
Check ignition system timing and, if necessary, adjust.		X			X

MAINTENANCE SCHEDULE (continued)					
Location and Service	**When Starting Engine Each Day**	**After First 25 Hours of Operation**	**Every 50 Hours of Operation**	**Every 100 Hours of Operation**	**At Least Once Each Year**
Check battery electrolyte level and specific gravity. Inspect case for damage.			X		X
Check entire electrical system for loose or dirty connections, or damaged wiring (especially battery cables).			X[2]		X
Check fuel pump sight tube for evidence of fuel.			X		X
Clean and inspect flame arrestor and crankcase ventilation system.				X	X
Inspect all hoses for cracks, swelling, weather checking or other signs of deterioration. Check connections for adequate tightness.				X	X
Lubricate and inspect the shift cable, throttle cable and linkage (B).				X	X
Replace fuel filters.					X[1]
Adjust carburetor.	As required				
Clean freshwater section of the freshwater-cooled system.	As required[3]				
Check coolant for alkalinity (closed-cooling models only).	At least once a year				
Spray power package exterior surfaces with rust preventive.	Freshwater areas – every 60 days Saltwater areas – every 30 days				
Flush raw-water cooling system (saltwater areas only).	After use each day				
Check zinc anodes, heat exchangers, and U-cooler.	Every 30 days[3]				

(A) Use Automatic Transmission Fluid (ATF), Dexron or Dexron II.
(B) Use SAE 30 engine oil.

NOTES: [1] In freshwater areas, every 100 hours of operation or 120 days (whichever comes first). In saltwater areas, every 50 hours of operation or 60 days (whichever comes first).

[2] In freshwater areas, every 50 hours of operation or 60 days (whichever comes first). In saltwater areas, every 25 hours of operation or 30 days (whichever comes first).

[3] Requires more frequent attention if used in extremely salty, polluted or mineral-laden waters.

3.4 COOLING SYSTEM MAINTENANCE

CAUTION

Alcohol- or methanol-based antifreeze or plain water are not recommended for use in the freshwater section of the cooling system at any time.

Crusader Engines recommends that the freshwater cooling system be filled with a 30/70 mixture of ethylene glycol antifreeze and water. In areas where the possibility of freezing **does not** exist, it is permissible to use a solution of rust inhibitor and water (mixed to the manufacturer's recommendations).

Crusader engines can use any type of permanent antifreeze or any brand antifreeze solution that meets GM Specification 6038-M.

Maintaining Coolant Level:

WARNING

Allow engine to cool down before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled down, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

The coolant level in the heat exchanger should be within 1 in. (25 mm) from the bottom of the filler neck.

IMPORTANT: When reinstalling the pressure cap, be sure to tighten it until the contacts stop on the filler neck.

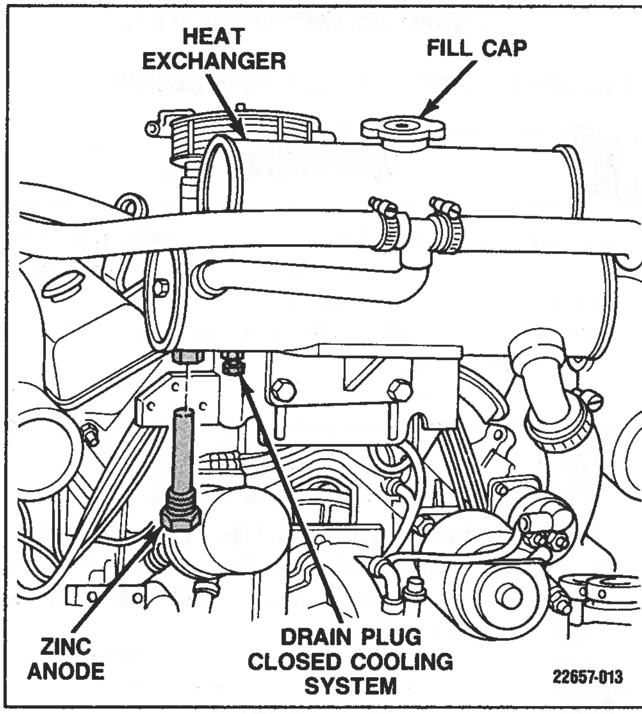


Figure 3-8. *Checking F.W.C. Coolant Level*

Freshwater Cooling System Alkalinity Test:

WARNING

Allow engine to cool down before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled down, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

To check the coolant for alkalinity, use the following procedure:

1. Obtain pink litmus paper from a local supplier (drugstore, pet shop, etc.).
2. Remove the pressure cap from the heat exchanger and insert one end of the litmus paper into the coolant.
3. If pink litmus paper turns blue, coolant is alkaline and need not be replaced.
4. If pink litmus paper remains pink, coolant is not alkaline and must be replaced.

Changing Coolant:

If draining or flushing of the cooling system is required due to contamination or before storage, see Section 10, Cooling System.

3.5 STORAGE INFORMATION

Out-of-Season Storage Precautions:

WARNING

Be careful while working on the fuel system; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that ignition key is "OFF." Do not smoke or allow sources of spark and/or open flame in the area.

WARNING

To prevent the possibility of a **FIRE**, be sure that engine compartment is well ventilated and that there are no gasoline vapors present during starting or fogging of the engine.

CAUTION

A discharged battery can be damaged by freezing.

CAUTION

Do not operate engine without cooling water being supplied to the raw-water pickup pump, or the pump impeller will be damaged and subsequent overheating damage to the engine may result.

CAUTION

Cooling system must be completely drained for storage or trapped water may freeze and/or cause corrosion damage to the engine. If the engine has been exposed to freezing temperatures, the boat should be placed in a warm area before attempting to run the engine or drain the cooling system.

CAUTION

If the engine is equipped with a freshwater-cooled system, the freshwater section must be kept filled with a solution of ethylene glycol antifreeze and water (mix antifreeze at manufacturer's recommended proportions to protect engine to lowest temperature to which it will be exposed). The raw-water section, however, must be drained completely.

Storage Procedure (Winterizing):

NOTE: Refer to the "Out-of-Season Storage Precautions" in this section **before** commencing with the following procedure:

1. Fill the permanent fuel tank(s) with fresh gasoline that does not contain alcohol. Add a sufficient amount of gasoline stabilizer (STA-BIL® or equivalent) to treat the gasoline and prevent the formation of fuel gum and varnish.

IMPORTANT: If a boat is to be placed in storage (with fuel containing alcohol in the fuel tanks), carburetors must be run dry at idle rpm. Permanent fuel tanks should be drained completely and STA-BIL® or equivalent added to any fuel remaining in the tank.

NOTE: Long periods of storage, common to boats, create unique problems. In cars, gasoline/alcohol-blended fuels normally are consumed before they can absorb enough moisture to cause trouble, but boats often sit idle long enough for phase separation to take place. In addition, internal corrosion may take place during storage if alcohol has washed protective oil films from internal components.

2. Replace all fuel filters.
3. Start engine and check for fuel leaks.
4. Run engine sufficiently to bring it up to normal operating temperature; shut off engine and change oil and filter.
5. Test coolant on engines equipped with a freshwater cooling system to ensure that it will withstand the lowest temperature expected during storage.
6. If boat has been operated in salty, polluted or mineral-laden waters, flush the raw-water section of the freshwater cooling system or the raw-water cooling system (see Section 10, Cooling System).
7. Remove the flame-arrestor assembly and restart the engine. While operating the engine at fast idle (1000-1500 rpm), fog internal surfaces of induction system and combustion chambers by squirting approximately 8 ounces (226 grams) of Rust Preventive Oil or SAE 20 "SF" or "SG" engine oil into the carburetor bores. Turn ignition OFF.
8. Close the fuel shut-off valve (if so equipped).
9. Clean the flame arrestor and crankcase ventilation hoses and reinstall.

10. Drain the cooling system with the following procedure appropriate to the system equipped on the engine:

CAUTION

Cooling system must be completely drained for storage or trapped water may freeze and/or cause corrosion damage to engine.

CAUTION

If boat is in the water, the water inlet valve (if so equipped) must be left closed until the engine is recommissioned to prevent water from flowing back into the cooling system. If the boat is not fitted with a valve, the water inlet hose must be left disconnected and plugged to prevent water from flowing into the cooling system and/or boat.

WARNING

As a precautionary measure, attach a tag to the ignition switch or steering wheel with the warning that the valve must be opened or the water inlet hose reconnected prior to starting the engine.

IMPORTANT: To prevent the threads in manifolds, elbows and cylinder blocks from rusting out during storage, reinstall plugs using Perfect Seal on threads. Never leave drain plugs out during storage.

Raw-Water Cooled Models

IMPORTANT: After removing the drain plugs, insert a wire into the drain hole to remove any obstruction which could prevent water from draining completely. (See Water Flow Diagrams.)

a. Close seacock if boat is to remain in water when draining cooling system.
b. Remove exhaust manifold plugs (one on each manifold).
c. Remove drain plugs from exhaust risers (if equipped).
d. Remove drain plugs from engine block, one on each side of block.
e. Remove drain plug from bottom of oil cooler (Engine Models 454 and 502 CID only).
f. Remove drain plugs (2) from raw-water pump.
g. Remove large hose from engine circulating pump and allow water to drain.
h. Crank engine over once to purge any trapped water in raw-water pump. Do not allow engine to start.
i. After water has completely drained, coat threads of drain plugs with Perfect Seal (or equivalent), and reinstall in proper locations.
j. Reinstall engine circulating pump hose and tighten clamp securely.

NOTE: For additional protection against freezing and corrosion, you may wish to fill the engine with antifreeze. If ethylene glycol base antifreeze is used, check with local environmental agencies about the proper disposal of antifreeze. It may be necessary to drain system prior to recommissioning the boat.

k. Remove thermostat housing from intake manifold. Fill engine with a mixture of antifreeze solution properly mixed to protect engine to the lowest temperature it will be exposed to.
l. Remove hoses between thermostat housing and exhaust manifolds. Fill exhaust manifolds with antifreeze solution.
m. Reinstall thermostat housing using a new gasket. Reattach hoses to exhaust manifolds.

Freshwater-Cooled Models

IMPORTANT: The freshwater section of the cooling system must be kept filled year-round with recommended coolant. Make certain the cooling system is protected with antifreeze properly mixed to protect engine to the lowest temperature it will be exposed to.

IMPORTANT: After removing drain plugs, insert a wire into hole to remove any obstruction which would prevent water from draining completely.

IMPORTANT: Drain raw-water section of cooling system only. (See Water Flow Diagrams.)

n. Close seacock if boat is to remain in water when draining cooling system.
o. Remove drain plugs (2) from raw-water pump.
p. Remove drain plug from bottom of oil cooler (Engine Models 454 and 502 CID only).
q. Remove drain plug from raw-water section of heat exchanger.
r. If equipped with exhaust risers, remove drain plugs from underside of riser or remove overboard water hose connected to bottom of riser.

s. Crank engine over once to purge any trapped water in raw-water pump. **Do not** allow engine to start.

t. After water has completely drained, coat threads of drain plugs with Perfect Seal (or equivalent) and reinstall in proper locations. Reattach hoses to risers if removed and securely tighten clamps.

11. Service the batteries with the following procedure:
    a. Remove battery and clean exterior.
    b. Check fluid level and fill if low.
    c. Cover terminals and bolts with a light coat of grease.
    d. Set battery on wood or in carton and store in cool, dry place.
    e. Check every 30 days for fluid level and slow charge.

IMPORTANT: A discharged battery can be damaged by freezing.

12. Clean outside of engine and repaint any areas as required. After paint has dried, spray with rust-preventive oil, or wipe down with SAE 20 engine oil.

Recommissioning:

NOTE: Refer to the "Out-of-Season Storage Precautions" in this subsection, before proceeding.

1. Check that all cooling system hoses are connected and tight, and drain plugs are in and tight.
2. Inspect all drive belts.
3. Check the engine belts.
4. Perform all lubrication and maintenance at least once each year as specified in appropriate column in the Scheduled Maintenance table in Section 3.3, Scheduled Maintenance, except tasks which were performed at time of engine layup.

CAUTION

When installing battery (in next step), be sure to connect first, the positive battery cable to (+) battery terminal and then negative battery cable to negative (–) terminal. If battery cables are reversed, damage to electrical system will result.

5. Install fully charged battery. Clean battery cable clamps and terminals and reconnect cables. Be sure to tighten clamps securely. Apply a thin coat of petroleum-based grease to clamps and terminals to help retard corrosion.
6. Start the engine and closely observe the instrumentation to ensure that all systems are functioning properly.
7. Carefully inspect the entire engine for fuel, oil, water and exhaust leaks.
8. Check fuel pump sight tube for fuel level.
9. Check steering system, transmission shift and throttle control for proper operation.

Section 4

Tune-Up

BLANK

4 TUNE-UP

Periodically the engine should be tuned. This is necessary after retrieving the boat from storage or when engine performance is not up to normal operating standards.

4.1 GENERAL INFORMATION

Spark Plugs:

Spark-plug maintenance is essential in controlling engine performance and gas consumption. A regular service interval is specified in Section 3.3, Scheduled Maintenance, and is required at every 100 hours of operation, or once a year.

Perform plug service only on those plugs suitable for additional service using the following procedure:

1. Remove and inspect each plug (Figure 4-1) individually for badly worn electrodes, glazed, broken or blistered porcelain, and replace where necessary. Check Section 5, Troubleshooting, for help in determining the reusability of each spark plug.
2. Remove any oil deposits with solvent and dry plugs thoroughly.
3. Inspect each spark plug for make and heat range. All plugs must be the same make, number and heat range. Refer to Section 4.2, Tune-Up Specifications, for spark plug numbers.
4. Remove combustion deposits from the firing end of spark plug with a plug cleaner. Blow off spark plug with compressed air to remove abrasives.
5. File electrode surfaces to restore clean, sharp edges. Again remove filings with compressed air.
6. Reset spark plug gaps with a round feeler gauge. Refer to Section 4.2, Tune-Up Specifications, for the proper spark plug gap.

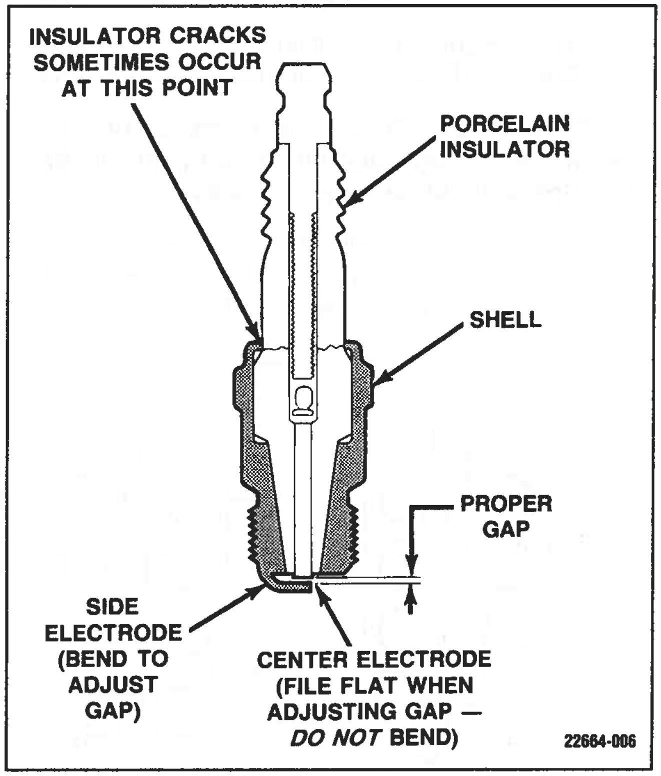


Figure 4-1. *Spark Plug*

IMPORTANT: Never bend the center electrode to adjust gap. Always adjust by bending ground or side electrode.

7. Clean spark plug seating area. Do not use gaskets on tapered-seat plugs. Install spark plugs and torque to specifications. Where used, gasket must be fully compressed to complete heat transfer and provide a gas-tight seal in cylinder. For this reason, as well as the necessity of maintaining the correct plug gap, correct torque (15 lb-ft or 20 N•m) is very important during installation.

IMPORTANT: Tapered-seat spark plugs are not interchangeable with nontapered spark plugs (with gasket).

Ignition Timing – Conventional Systems:

To check and adjust the ignition timing for the Mallory and both Prestolite Distributors, use the following procedure:

IMPORTANT: Dwell must be set to the correct specification before adjusting timing (only for the Mallory and Prestolite breaker-type distributor).

1. Connect the timing light to the No. 1 spark plug (see Figure 4-2). Connect power supply leads on light to the 12 V battery.

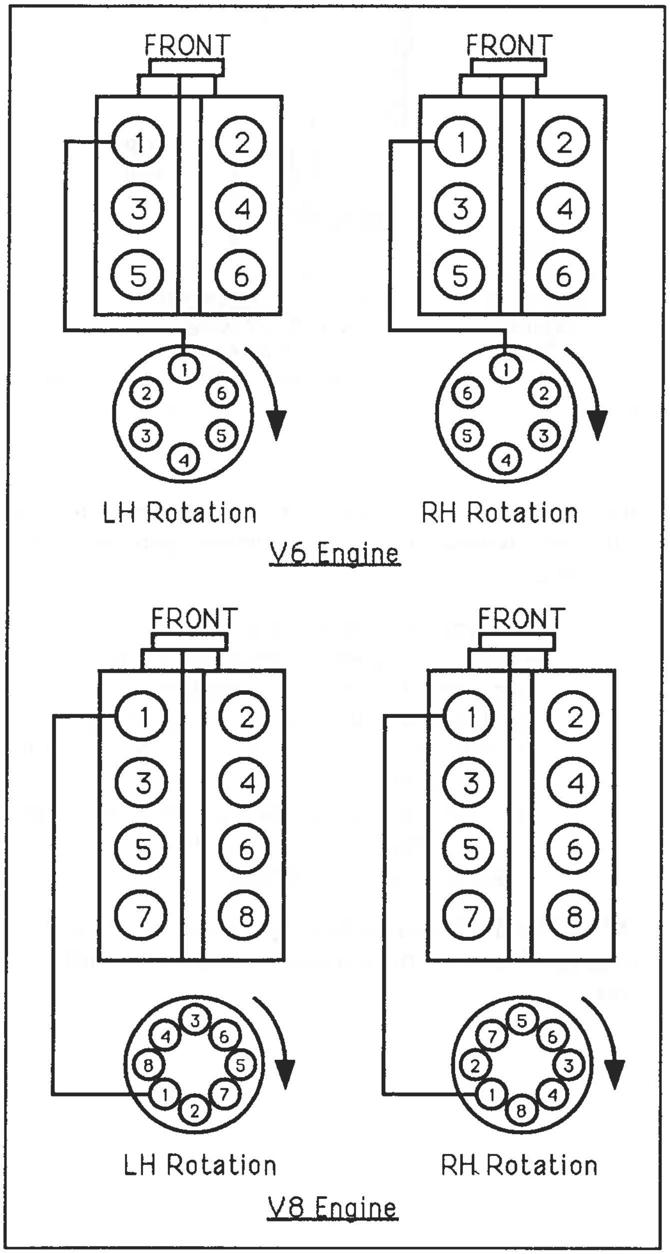


Figure 4-2. Spark Plug Order

2. Connect the tachometer to the engine.
3. Start the engine and run at normal idle speed.
4. Aim the timing light at the timing tab located on the timing gear cover and at the crankshaft harmonic balancer (Figure 4-3).

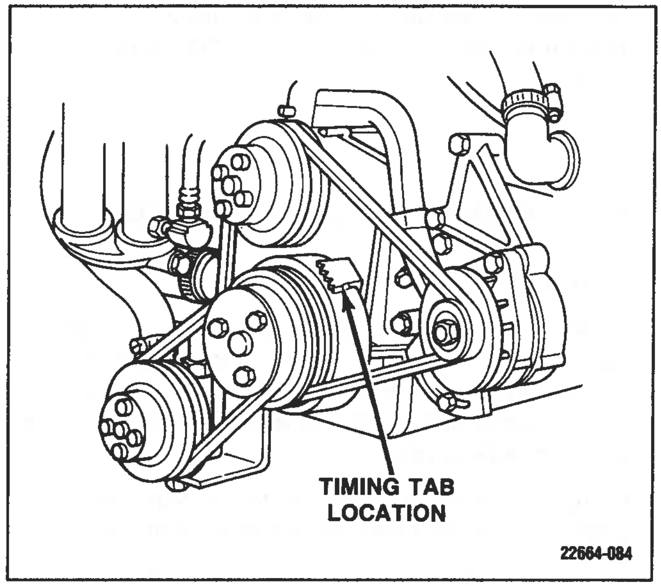


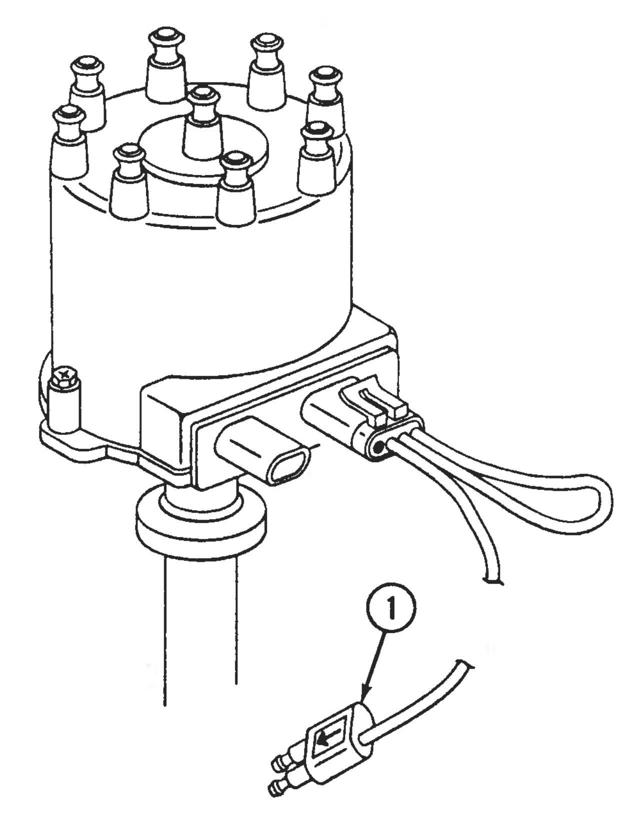
Figure 4-3. Engine Timing Tab

5. Adjust the timing by loosening the distributor hold-down clamp and rotating the distributor body as required until the timing mark on the balancer, or pulley, lines up with the mark on the timing tab as specified in Section 4.2, Tune-Up Specifications. Tighten clamp and recheck timing.
6. Stop engine and remove timing light.

Ignition Timing – Delco E.S.T. Systems:

The following procedure is used to check and adjust ignition timing for the Delco E.S.T. Distributor:

In order to set the timing correctly, it is necessary to lock out the automatic electronic spark advance feature. This is done using the timing connector plug which is attached to the distributor. This two-pronged connection is marked as shown.



1. Connector plug

Figure 4-4. *Delco E.S.T. Distributor Timing Connector Plug*

1. Connect the timing light to the No. 1 spark plug (Figure 4-2). Connect the power supply leads of the light to 12 V battery.
2. Change the timing plug to the "TIME" position (see Figure 4-5).

NOTE: When the BROWN lead from plug connected to distributor housing is in line with the PINK or PURPLE/WHITE (T) lead or with the label (TIME), the electronic spark advance is disabled and the initial spark timing can be checked and adjusted at this point if necessary.

3. Start engine and run at normal idle speed.

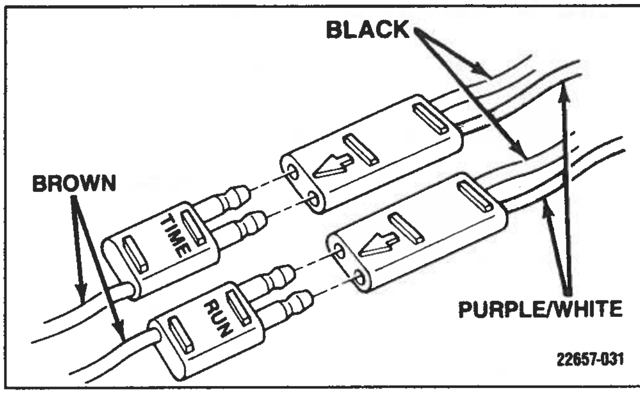


Figure 4-5. *Timing Plug Positions*

4. Aim timing light at timing tab, located on timing gear cover (Figure 4-3).
5. Adjust the timing by loosening the distributor hold-down clamp and rotating the distributor body as required, until the timing mark on the balancer, or pulley, lines up with the mark on the timing tab as specified in Section 4.2, Tune-Up Specifications. Tighten clamp and recheck timing.
6. Stop the engine and remove the timing light.
7. Switch the timing plug to the "RUN" position (see Figure 4-5).

NOTE: When the BROWN lead from plug connected to distributor housing is in line with the WHITE or BLACK (R) lead or with the label (RUN), the electronic spark advance is functioning and this is the normal operating mode.

Engine Compression Check:

1. Disconnect the primary lead from the distributor.
2. Remove all spark plugs.
3. Block the throttle plate and choke plate into the wide-open position.
4. Make sure the battery is fully charged.
5. Starting with the compression gauge at zero, crank the engine through four compression strokes (four "puffs").
6. Make the compression check at each cylinder and record each reading.
7. If some cylinders have low compression, inject about 15 ml (one tablespoon or about three squirts from a pump-type oil can) of engine oil into the combustion chamber through the spark-plug hole. Recheck compression.
8. Minimum compression recorded in any one cylinder should not be less than 70% of the highest cylinder, and no cylinder should read less than 100 psi (690 kPa). For example, if the highest pressure in any one cylinder is 150 psi (1035 kPa), the lowest allowable pressure for any other cylinder would be 105 psi (725 kPa), since 150 x 70% = 105 (1035 x 70% = 725).

- Normal condition – compression builds up quickly and evenly to the compression specified on each cylinder.
- Piston rings leaking – low compression on first stroke tends to build up on following strokes but does not reach normal. Improves considerably with addition of oil.
- Valves leaking – low compression on first stroke. Does not tend to build up on following strokes. Does not improve much with addition of oil.
- If two adjacent cylinders have lower than normal compression, and injecting oil into cylinders does not increase the compression, the cause may be a head gasket leak between the cylinders.

4.2 TUNE-UP SPECIFICATIONS

The following tables list all of the tune-up specifications for each engine model:

229/262 CID TUNE-UP SPECIFICATIONS		
Engine Model	**229 CID**	**262 CID**
Number of cylinders	V-6	
Displacement	3.8 L	4.3 L
Bore/stroke	3.736/3.48 in. (94.9/88.4 mm)	4.0/3.48 in. (101.6/88.4 mm)
Compression ratio	8.6:1	9.3:1
Compression pressure	140-160 psi (965-1,103 kPa)	
Idle rpm in forward gear	650-700 rpm	
Max. rpm at W.O.T.	4200-4600 rpm	
Oil pressure at 2000 rpm	30-60 psi (206.8-413.7 kPa)	
Min. oil pressure at idle	10 psi (68.9 kPa)	
Fuel pump pressure at 1800 rpm	5.25-6.0 psi (36.2-41.4 kPa)	
Electrical system	12 V negative (–) ground	
Min. battery cold cranking amps	400 A	
Firing order	LH Rot. 1-6-5-4-3-2 RH Rot. 1-2-3-4-5-6	
Spark plug type	AC-MR43T AC-MR44T Champion RV8C	
Spark plug gap	0.035 in. (0.9 mm)	
Timing at idle rpm	10° BTDC	6° BTDC
Preliminary idle mixture	2-3 turns	
Thermostat	143° F (62° C) R.W.C./160° F (71° C) F.W.C.	
Breaker-point gap (Prestolite)	0.020 in. (0.5 mm)	
Point dwell	36-41°	
Breaker-point spring tension	25-30 oz. (7.0-8.3 N)	

305/350/454 CID TUNE-UP SPECIFICATIONS USING A MALLORY OR PRESTOLITE BREAKER-TYPE DISTRIBUTOR			
Engine Model	**305 CID**	**350 CID**	**454 CID**
Number of cylinders	V-8		
Displacement	5.0 L	5.7 L	7.4 L
Bore/stroke	3.74/3.48 in. (94.9/88.4 mm)	4.00/3.48 in. (101.6/88.4 mm)	4.25/4.00 in. (108.0/101.6 mm)
Compression ratio	9.3:1		8.2:1
Compression pressure	140-160 psi (965-1,103 kPa)		130-145 psi (896-1,000 kPa)
Idle rpm in forward gear	650-700 rpm		
Max. rpm at W.O.T.	4000-4400 rpm		
Oil pressure at 2000 rpm	30-60 psi (206.8-413.7 kPa)		
Min. oil pressure at idle	10 psi (68.9 kPa)		
Fuel pump pressure at 1800 rpm	5.25-6.0 psi (36.2-41.4 kPa)		
Electrical system	12 V negative (–) ground		
Min. battery cold cranking amps	400 A		450 A
Firing order	LH Rot. 1-8-4-3-6-5-7-2 RH Rot. 1-2-7-5-6-3-4-8		
Spark plug type	AC-MR43T AC-MR44T Champion RV8C		
Spark plug gap	0.035 in. (0.9 mm)		
Timing at idle rpm	10° BTDC		
Preliminary idle mixture	2-3 turns		
Thermostat	143° F (62° C) R.W.C./160° F (71° C) F.W.C.		
Breaker-point gap (Prestolite)	0.016 in. (0.41 mm)		
Breaker-point gap (Mallory)	0.016-0.018 in. (0.41-0.46 mm)		
Point dwell	28-31°		
Breaker-point spring tension	25-30 oz. (7.0-8.3 N)		

305/350/454 CID TUNE-UP SPECIFICATIONS USING A PRESTOLITE B.I.D. DISTRIBUTOR			
Engine Model	**305 CID**	**350 CID**	**454 CID**
Number of cylinders	V-8		
Displacement	5.0 L	5.7 L	7.4 L
Bore/stroke	3.74/3.48 in. (94.9/88.4 mm)	4.00/3.48 in. (101.6/88.4 mm)	4.25/4.00 in. (108.0/101.6 mm)
Compression ratio	9.3:1		8.12:1
Compression pressure	140-160 psi (965-1,103 kPa)		130-145 psi (896-1,000 kPa)
Idle rpm in forward gear	650-700 rpm		
Max. rpm at W.O.T.	4000-4400 rpm		
Oil pressure at 2000 rpm	30-60 psi (206.8-413.7 kPa)		
Min. oil pressure at idle	10 psi (68.9 kPa)		
Fuel pump pressure at 1800 rpm	5.25-6.0 psi (36.2-41.4 kPa)		
Electrical system	12 V negative (–) ground		
Min. battery cold cranking amps	400 A		450 A
Firing order	LH Rot. 1-8-4-3-6-5-7-2	RH Rot. 1-2-7-5-6-3-4-8	
Spark plug type	AC-MR43T	AC-MR44T	Champion RV8C
Spark plug gap	0.035 in. (0.9 mm)		
Timing at idle rpm	10° BTDC		
Preliminary idle mixture	2-3 turns		
Thermostat	143° F (62° C) R.W.C./160° F (71° C) F.W.C.		
Prestolite B.I.D.* sensor air gap	0.008 in. (0.20 mm)		

* B.I.D. – Breakerless Ignition Distributor

305/350/454 CID TUNE-UP SPECIFICATIONS USING A DELCO E.S.T. DISTRIBUTOR			
Engine Model	**305 CID**	**350 CID**	**454 CID**
Number of cylinders	V-8		
Displacement	5.0 L	5.7 L	7.4 L
Bore/stroke	3.74/3.48 in. (94.9/88.4 mm)	4.00/3.48 in. (101.6/88.4 mm)	4.25/4.00 in. (108.0/101.6 mm)
Compression ratio	9.3:1		8.12:1
Compression pressure	140-160 psi (965-1,103 kPa)		130-145 psi (896-1,000 kPa)
Idle rpm in forward gear	650-700 rpm		
Max. rpm at W.O.T.	4000-4400 rpm		
Oil pressure at 2000 rpm	30-60 psi (206.8-413.7 kPa)		
Min. oil pressure at idle	10 psi (68.9 kPa)		
Fuel pump pressure at 1800 rpm	5.25-6.0 psi (36.2-41.4 kPa)		
Electrical system	12 V negative (–) ground		
Min. battery cold cranking amps	400 A		450 A
Firing order	LH Rot. 1-8-4-3-6-5-7-2 RH Rot. 1-2-7-5-6-3-4-8		
Spark plug type	AC-MR43T	AC-MR44T	Champion RV8C
Spark plug gap	0.045 in. (1.14 mm)		
Timing at idle rpm	10° BTDC		
Preliminary idle mixture	2-3 turns		
Thermostat	143° F (62° C) R.W.C./160° F (71° C) F.W.C.		

502 CID TUNE-UP SPECIFICATIONS			
Engine Model	**502 CID Prestolite B.I.D.**		**502 CID Delco E.S.T.**
Number of cylinders	V-8		
Displacement	8.2 L		
Bore/stroke	4.47/4.0 in. (113.5/101.6 mm)		
Compression ratio	9.0:1 [1]		
Compression pressure	130-150 psi (896-1,034 kPa)		
Idle rpm in forward gear	650-700 rpm		
Max. rpm at W.O.T.	4200-4600 rpm		
Oil pressure at 2000 rpm	30-60 psi (206.8-413.7 kPa)		
Min. oil pressure at idle	10 psi (68.9 kPa)		
Fuel pump pressure at 1800 rpm	5.25-6.0 psi (36.2-41.4 kPa)		
Electrical system	12 V negative (–) ground		
Min. battery cold cranking amps	450 A		
Firing order	LH Rot. 1-8-4-3-6-5-7-2		RH Rot. 1-2-7-5-6-3-4-8
Spark plug type	AC-MR43T	AC-MR44T	Champion RV8C
Spark plug gap	0.035 in. (0.9 mm)		0.045 in. (1.14 mm)
Timing at idle rpm	2° BTDC		8° BTDC
Preliminary idle mixture	1-2 turns		
Thermostat	143° F (62° C) R.W.C./160° F (71° C) F.W.C.		
Prestolite B.I.D.* sensor air gap	0.008 in. (0.20 mm)		N/A

* B.I.D. – Breakerless Ignition Distributor

NOTE: [1] Later engines had 8.75:1 compression ratio.

BLANK

Section 5

Troubleshooting

BLANK

5 TROUBLESHOOTING

5.1 PRECAUTIONS

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** working on fuel system to prevent fire or explosion.

WARNING

Be careful when changing fuel system components; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that ignition key is "OFF." **Do not** smoke or allow sources of spark and/or flame in the area while changing fuel filter. Wipe up any spilled fuel immediately.

WARNING

Make sure no fuel leaks exist before closing engine hatch.

WARNING

To prevent the possibility of a **FIRE**, be sure that engine compartment is well ventilated and that there are no gasoline vapors present.

CAUTION

Do not operate engine without cooling water being supplied to the raw-water pickup pump. The pump impeller may be damaged and subsequent overheating damage to the engine may result.

CAUTION

Models with a belt-driven, raw-water pickup pump must be in the water when running the engine over 1500 rpm, because a garden hose will not supply enough water to the system.

WARNING

When running engine with boat out of water, be certain that the area in the vicinity of the propeller is clear and that no person is standing nearby. As a precautionary measure, it is recommended that the propeller be removed.

CAUTION

If boat is in the water, be sure to close water inlet valve before removing inlet hose from pump to prevent water from draining into boat. If boat is not fitted with a valve, either plug inlet or raise it above water level after removing.

CAUTION

Allow engine to cool down before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled down, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

WARNING

Do not leave helm unattended while performing idle speed adjustment.

5.2 USED SPARK PLUG ANALYSIS

Use the following descriptions and illustrations for determining the serviceability of a used spark plug. Spark-plug conditions can also suggest a variety of possible engine malfunctions and, therefore, can indicate needed engine repairs. When old plugs are replaced, replace entire set.

IMPORTANT: When working on engine, spark-plug holes and carburetor throat should be kept covered to prevent foreign objects from entering combustion chamber.

Perform plug service only on those plugs suitable for additional service, using the following procedures:

1. Remove any oil deposits with solvent and dry plugs thoroughly.
2. Open electrode gap wide enough to permit cleaning and filing.
3. Remove combustion deposits from firing end of spark plug with a plug cleaner.
4. Blow off with compressed air to remove abrasives.
5. File electrode surfaces to restore clean, sharp edges. Again remove filings with compressed air.
6. Reset gap to specifications by bending only side electrode with proper tool.

Normal Condition:

Few deposits are present in a normal plug, and the plug is probably light-tan or gray in color. The plug in Figure 5-1 shows that the heat range is compatible with the engine, and the engine is electrically and mechanically in good running condition. With proper servicing (clean, file and regap), this plug can be reinstalled with good results.

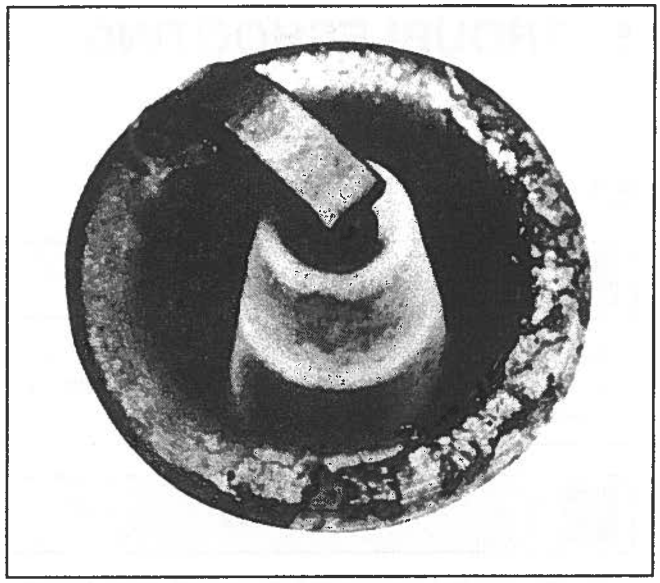


Figure 5-1. *Normal Plug*

Chipped Insulator:

A chipped insulator (Figure 5-2) usually results from careless plug regapping. Under certain conditions, severe detonation also can split insulator firing ends. Plug must be replaced.

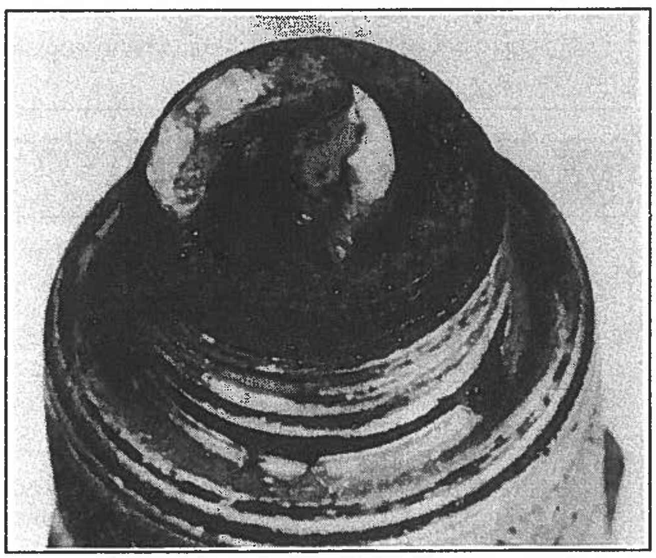


Figure 5-2. *Chipped Insulator*

Wet-Fouling (Oil Deposits):

A plug becomes shorted by excessive oil entering the combustion chamber (Figure 5-3), usually in engines with many hours of operation. Worn piston rings, cylinder walls, valve guides or valve stem seals are causes of oil entering the combustion chamber. Only engine repairs will permanently relieve oil wet-fouling.

IMPORTANT: New engines or recently overhauled engines may wet-foul plugs before normal oil control is achieved with the proper break-in procedures. Such fouled plugs may be serviced (clean, file and regap) and reinstalled.

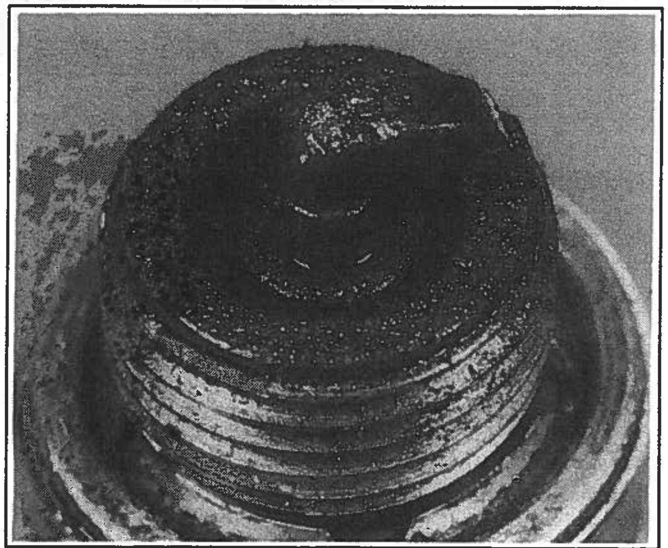


Figure 5-3. *Wet-Fouled Plug*

Cold-Fouling:

Dry, black deposits indicate a rich fuel mixture or weak ignition (Figure 5-4). Clogged flame arrestor, flooding carburetor, sticky choke or weak ignition components all are probable causes. If, however, only one or two plugs in a set are fouled, check for sticking valves or bad ignition leads. After correcting the problem, service (clean, file and regap) plugs and reinstall.

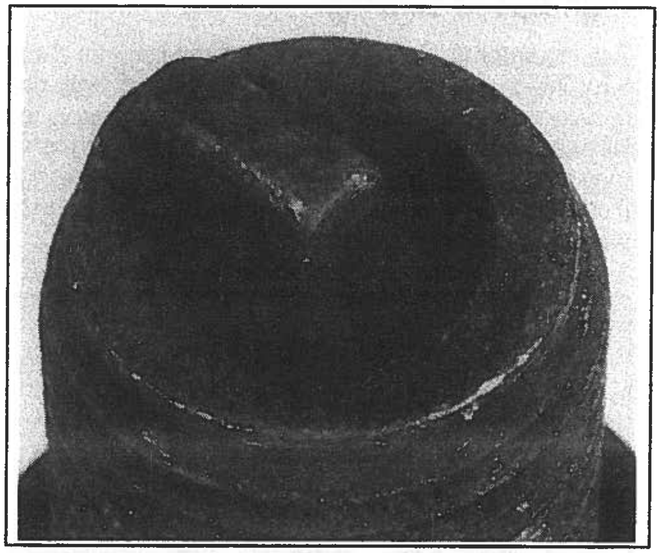


Figure 5-4. *Cold-Fouled Plug*

Overheating:

The insulator is a dull white or gray color and appears blistered (Figure 5-5). Electrodes are eroded and there is an absence of deposits. Check that correct plug heat range is being used. Also check for overadvanced ignition timing, cooling system malfunction, lean fuel/air mixtures, leaking intake manifold or sticking valves. Replace spark plugs.

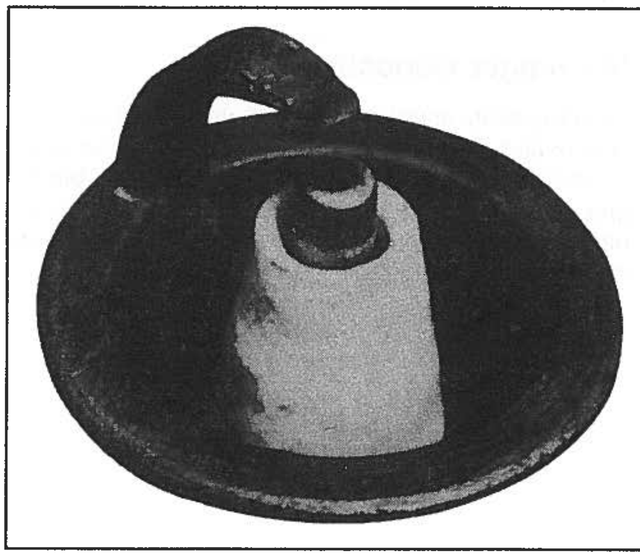


Figure 5-5. *Overheated Plug*

High-Speed Glazing:

The insulator has a yellowish, varnish-like color (Figure 5-6), indicating that temperatures have suddenly risen, usually during hard, fast acceleration under heavy load. Normal deposits do not get a chance to blow off. Instead, they melt and form a conductive coating. Replace plugs. If condition recurs, use a colder heat range plug and service the plugs more frequently.

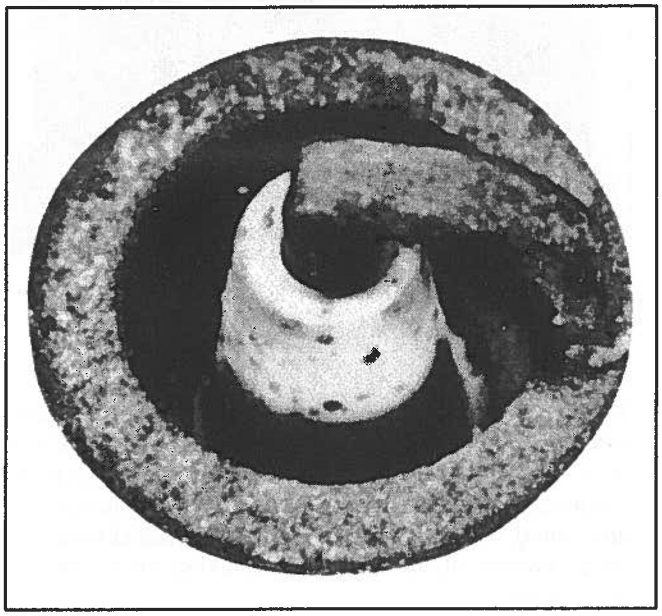


Figure 5-6. *Glazed Plug*

Scavenger Deposits:

Powdery white or yellow deposits are built up on shell, insulator and electrodes (Figure 5-7). This is a normal appearance with certain brands of fuel. Accumulation on ground electrode and shell areas may be unusually heavy, but may be easily chipped off. Plugs can be serviced (clean, file and regap) and reinstalled.

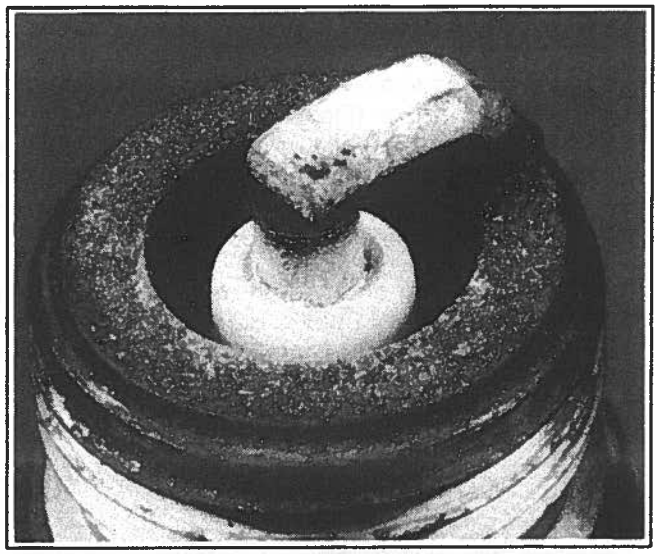


Figure 5-7. *Scavenger-Deposited Plug*

Preignition Damage:

Preignition damage is caused by excessively high temperatures. The center electrode melts first, followed by the ground electrode (Figure 5-8). Normally, insulators are white but may be dirty if plug has been misfiring. Check for correct plug heat range, advanced ignition timing, lean fuel mixture, incorrect fuel used, malfunctioning cooling system, leaking intake manifold or lack of lubrication.

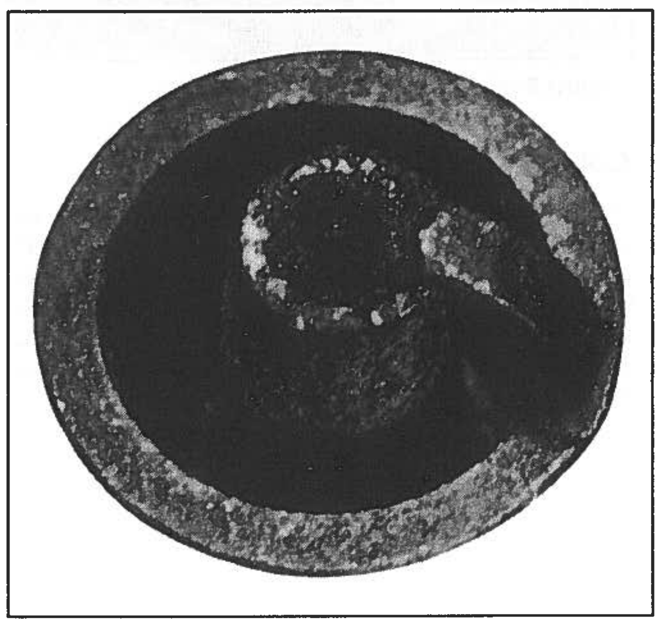


Figure 5-8. *Preignition-Damaged Plug*

Reversed-Coil Polarity:

Concave erosion of the ground electrode (Figure 5-9) is an indication of reversed polarity. The center electrode will show only normal wear. The engine will misfire and idle rough. To correct, reverse the primary coil leads and replace the spark plugs.

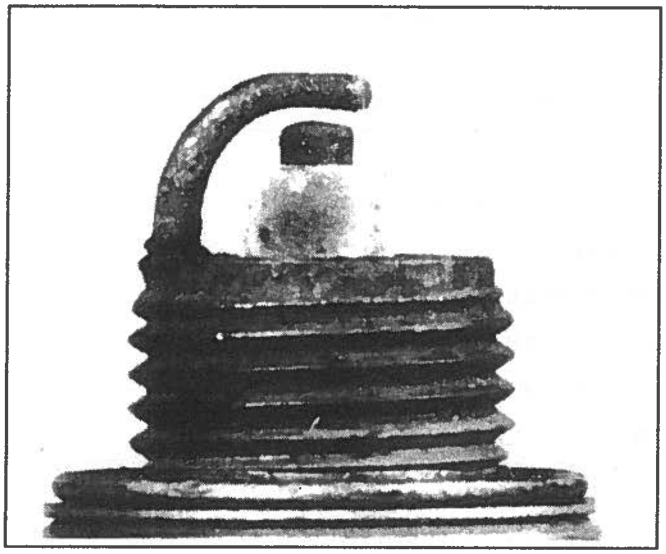


Figure 5-9. *Reversed-Polarity Damaged Plug*

Splashed Deposits:

Spotted deposits, which sometimes occur after a long-delayed tune-up, accumulate after a long period of misfiring (Figure 5-10). When normal combustion temperatures are restored, upon installation of new plugs, deposits loosen from top of piston and head and are thrown against hot insulator. Clean and service plugs and reinstall.

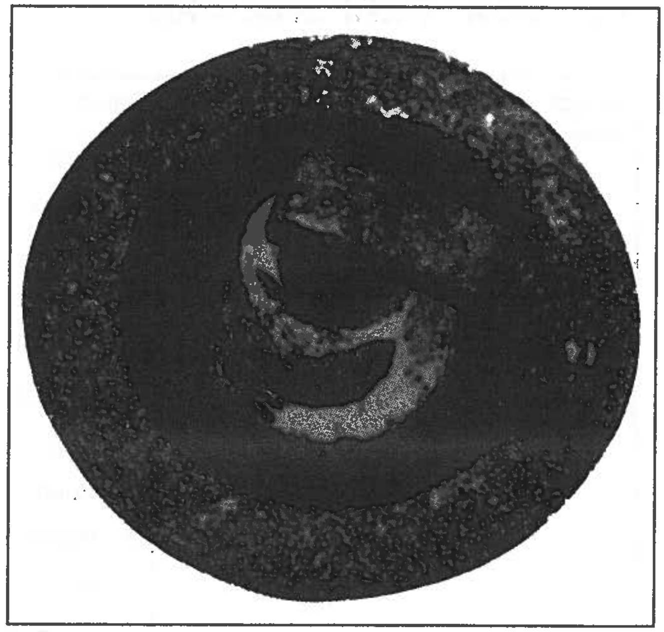


Figure 5-10. *Deposit-Damaged Plug*

Mechanical Damage:

Mechanical damage to the spark plug firing end (Figure 5-11) is caused by a foreign object in the combustion chamber. Because of valve overlap, small objects can travel from one cylinder to another. Check all cylinders, intake manifold and exhaust manifold for foreign objects to prevent further damage.

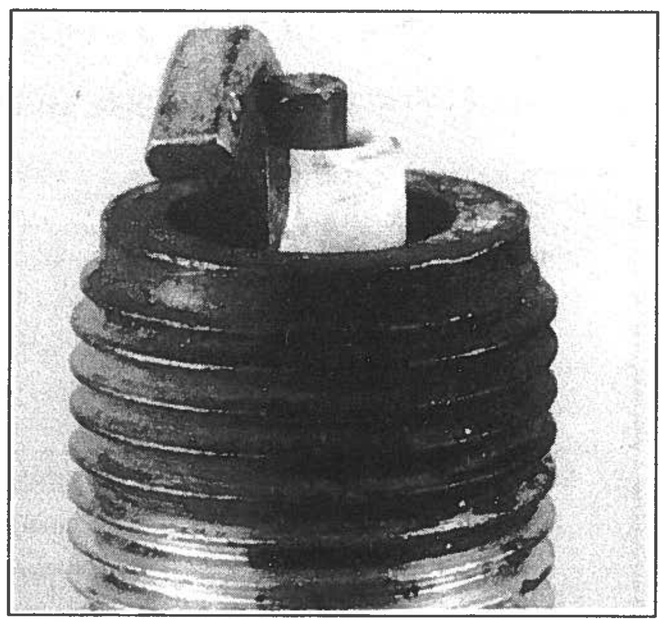


Figure 5-11. *Mechanically-Damaged Plug*

5.3 BOAT PERFORMANCE

Symptom	Cause
1. Bow too low.	A. Improper weight distribution. B. Boat is underpowered. C. Permanent or power hook in boat bottom. D. False bottom full of water. E. Improperly adjusted trim tabs (after boat planes out).
2. Bow too high.	A. Propeller pitch too great. B. Dirty boat bottom (marine growth). C. Poorly running engine. D. Improper weight distribution. E. Permanent or rocker in boat bottom. F. False bottom full of water. G. Improperly adjusted trim tabs (after boat planes out).
3. Propeller ventilating.	A. Dirty or rough boat bottom. B. Damaged propeller; pitch too small; diameter too small. C. Water pickup or accessories located too close to propeller. D. Power hook in boat bottom. E. Propeller plugged up with weeds.

5.4 FULL-THROTTLE ENGINE RPM PROBLEMS

Symptom	Cause
1. Engine rpm too high.	A. Propeller damaged. B. Propeller pitch too low. C. Propeller diameter too small. D. Water pickup or accessories mounted too close to propeller (ventilation).
2. Engine rpm too low.	A. Propeller damaged. B. Propeller pitch too great. C. Propeller diameter too great. D. Dirty or damaged boat bottom. E. Permanent or power hook in boat bottom. F. False bottom full of water.

5.5 ENGINE PERFORMANCE PROBLEMS

Symptom	Cause
1. Poor engine idle.	A. Clogged flame arrestor. B. Improper idle-fuel mixture adjustment. C. Cap or spark plug wires arcing. D. Water in fuel. E. Low grade or stale fuel. F. Incorrect ignition timing. G. Automatic choke. H. Spark plugs (fouled, burned, cracked porcelain). I. Incorrect point gap, burned or pitted points. J. Spark plug wires broken or faulty insulation. K. Defective coil or condenser. L. Cracked or dirty distributor cap. M. Incorrect float level. N. Dirty carburetor. O. Leak at intake manifold or carburetor base. P. Incorrect fuel pump pressure (too low – can't supply the carburetor; too high – unseats the needle and seat). Q. Low compression. (Check for blown head gasket.) R. Loose or worn distributor. S. Head gasket, exhaust manifold, cracked head or valve seat allowing water to leak into cylinders.
2. Poor engine acceleration.	A. Idle mixture screws. B. Air-valve spring out of adjustment (Rochester 4-barrel carburetor only). C. Incorrect ignition timing. D. Incorrect distributor advance curve. E. Accelerator pump. (Check for fuel flowing into the carburetor.) F. Cracked or dirty distributor cap or rotor. G. Vacuum leak on the intake manifold or carburetor base. H. Spark plugs (fouled, burned, wrong heat range, cracked porcelain). I. Incorrect point gap, dirty or burned points. J. Float adjustment. K. Dirty carburetor. L. Low compression. M. Refer to Section 1.3, Performance Factors.

ENGINE PERFORMANCE PROBLEMS (continued)

Symptom	Cause
3. Engine runs poorly at high rpm.	A. Crankcase overfilled with oil. B. Antisiphon valve (if equipped) restricting fuel supply. C. Plugged fuel tank vent. D. Fuel supply. E. Ignition timing. F. Low grade of fuel, or water in the fuel. G. Spark plugs fouled, burned, cracked porcelain or incorrect heat range. H. Spark plug wires are broken or have poor insulation. I. Distributor cap or rotor, dirty or cracked. J. Coil tower cracked. K. Distributor points, condenser, worn cam or excessive play in shaft. L. Engine overheating. M. Low compression caused by worn valves, cylinders, etc. N. Restricted exhaust. O. Poor boat performance.

5.6 ENGINE STARTING PROBLEMS

The following information will help to locate the starting problem:

1. Determine which engine system is causing the problem. To make an engine run, basic components – fuel, spark (ignition) and compression – are required. If all three components are present, the engine should run. If any one of the three is missing, weak or arriving at the wrong time, the engine will not run.
2. Determine if there is fuel present by looking down the carburetor venturi while actuating the throttle. There should be a stream of fuel coming out of the accelerator pump nozzles if the carburetor venturi has fuel.
3. Check ignition system operation. Remove coil wire from tower on distributor cap. Hold coil wire near ground and check for spark while cranking engine over. Repeat procedure with spark plug wires. If there is a spark at the spark plug wires, remove the spark plugs and make sure the plugs are of correct type and heat range, and not fouled or burned.
4. Run a compression check on the engine to make sure the engine is mechanically OK.

Symptom	**Cause**
1. No spark (conventional ignition).	A. Distributor cap or spark plug leads arcing.
	B. Spark plugs fouled, burned or cracked porcelain.
	C. Spark plug wires are broken or have faulty insulation.
	D. Battery, electrical connections, damaged wiring.
	E. Ignition switch. (May run in START position and lose spark in the RUN position.)
	F. Ignition timing. (May crank over hard, backfire or try to run backwards.)
	G. Faulty ignition resistor.
	H. Ignition points improperly gapped, burned or dirty.
	I. Cracked or dirty distributor cap or rotor.
	J. Coil.
	K. Condenser.
2. No spark (breakerless ignition).	A. Distributor cap or spark plug leads arcing.
	B. Spark plugs fouled, burned or cracked porcelain.
	C. Spark plug wires are broken or have faulty insulation.
	D. Battery, electrical connections, damaged wiring.
	E. Ignition switch.
	F. Ignition timing.
	G. Faulty ignition components.
	H. Cracked or dirty distributor cap.
	I. Shorted tachometer. (Disconnect tachometer and try again.)

ENGINE STARTING PROBLEMS (continued)

Symptom	Cause
3. Engine will not crank over.	A. Control lever not in neutral position. B. Battery charge low; damaged wiring; loose electrical connections. C. Circuit breaker tripped. D. Bad ignition switch. E. Bad slave solenoid. F. Faulty neutral-start safety switch (open circuit). G. Bad starter solenoid. H. Defective starter motor.
4. Fuel system too rich.	A. Fuel boils out of float bowl when shut off and warm. Floods intake manifold. B. Clogged flame arrestor. C. Automatic choke not opening. D. Float adjustment incorrect. E. Float leaks or is saturated with fuel. F. Needle and seat leaking. G. Carburetor gaskets leaking. H. Excessive fuel pump pressure (unseats needle and seat). I. Cracked or porous carburetor body.
5. Fuel system too lean.	A. Empty fuel tank. B. Fuel shut-off valve closed (if equipped). C. Antisiphon valve stuck closed (if equipped). D. Vapor lock (engine will not start after shutting down the warm engine). E. Automatic choke stuck open or adjusted wrong. F. Fuel tank vent plugged. (The engine will run for a short period of time, then stall and not restart for a period of time. Verify this by loosening the filler cap, thus creating a vent.) G. Air leak on suction side of fuel system. H. Plugged or pinched fuel line. I. Low fuel pump pressure.
6. Miscellaneous.	A. Low grade or stale fuel. B. Water in fuel. C. Vacuum leak. D. Low compression (worn valves, rings, cylinder or head gasket). E. Valve timing incorrect (timing chain or gears jumped or improperly installed).

5.7 FUEL ECONOMY

Symptom	Cause
1. Poor fuel economy.	A. Fuel leaks. B. Operator habits – prolonged idling, slow acceleration, failure to cut back on throttle once boat is on plane, boat overloaded, uneven weight distribution. C. Engine laboring because of bent, damaged or incorrect propeller. D. Clogged flame arrestor. E. Inadequate air ventilation. F. Boat bottom – dirty (marine growth), hook or rocker built in. G. Carburetor – idle mixture settings, accelerator pump adjustment, linkage binding, choke adjustment, carburetor flooding, main fuel jets. H. Improper fuel. I. Crankcase ventilation system not working. J. Engine needs tune-up. K. Engine running too cold or too hot. L. Plugged or restricted exhaust. M. Low engine compression.

5.8 CARBURETOR MALFUNCTIONS

Symptom	Cause
1. Carburetor flooding.	A. Needles and seat. B. Float adjustment. C. Saturated float. D. Gaskets leaking. E. Cracked fuel line. F. Fuel percolation. G. Automatic choke.
2. Rough engine idle.	A. Idle rpm too low. B. Idle mixture screws. C. Idle passages dirty. D. Throttle valves not closing. E. Engine flooding. F. Vacuum leak. G. Throttle-body heat passages plugged.

CARBURETOR MALFUNCTIONS (continued)

Symptom	Cause
3. Hesitation or acceleration flatness.	A. Accelerator pump. B. Leaking gaskets. C. Automatic choke. D. Power piston or power valve. E. Throttle valves. F. Throttle-body heat passages plugged. G. Main metering jets. H. Float adjustment. I. Secondary air-valve wind-up.
4. Engine surges.	A. Main metering jets. B. Leaking gaskets. C. Float adjustment. D. Saturated float. E. Power piston or valve. F. Throttle valves.
5. Lack of power or low top rpm.	A. Power piston or valve. B. Float adjustment. C. Main metering jets. D. Leaking gaskets.
6. Poor cold-engine operation.	A. Idle rpm too low. B. Idle mixture screws. C. Throttle valves. D. Automatic choke. E. Engine flooding.
7. Stalling engine.	A. Idle rpm too low. B. Idle mixture screws. C. Engine flooding. D. Automatic choke. E. Dirt in carburetor. F. Accelerator pump. G. Leaking gaskets.

5.9 CHARGING SYSTEM PROBLEMS

Symptom	Cause
1. Gauges indicate no battery charge.	A. Loose or broken drive belt. B. Loose or corroded electrical connections. C. Faulty ammeter or battery gauge. D. Battery will not accept charge. E. Faulty alternator or regulator.
2. Noisy alternator.	A. Loose mounting bolts. B. Worn, frayed or loose drive belt. C. Loose drive pulley. D. Worn or dirty bearings. E. Faulty diode trio or stator.

5.10 INSTRUMENT PROBLEMS

Symptom	Cause
1. Malfunctioning instruments or gauges.	A. Faulty wiring, loose or corroded terminals. B. Bad key switch (see Section 6.5, Instrumentation). C. Faulty gauge (see Section 6.5, Instrumentation). D. Faulty sender (see Section 6.5, Instrumentation).

5.11 RADIO NOISE

Symptom	Cause
1. "Popping" noise that increases with engine rpm.	A. Wrong spark plugs. B. Cracked distributor cap. C. Cracked coil tower. D. Leaking spark plug wires. E. Moisture on ignition components.
2. High-pitched "whine" in the radio.	A. Poor brush contact on the slip rings in the alternator.
3. A "hissing" or "crackling" radio noise when instruments are jarred with ignition on.	A. Instrumentation – loose connections, or antenna wire routed too close to instruments.
4. Various unexplained radio noises.	A. Bilge pump. B. Bilge blower. C. Fish finder. D. Depth locator. E. Cabin heater motor.

5.12 ENGINE NOISE

No definite rule or test will positively determine source of engine noise, therefore, use the following information only as a general guide to engine noise diagnosis.

1. Set a timing light to determine if noise is timed with engine rpm or one-half engine rpm. Noises timed with engine rpm are related to crankshaft, rods, pistons, piston pins and flywheel. Noises timed to one-half engine rpm are valve-train related.
2. The use of a stethoscope can aid in locating a noise source. However, because noise will travel to other metal parts not involved in the problem, caution must be exercised.
3. If noise is believed to be confined to one particular cylinder, ground the spark-plug leads, one at a time. If noise lessens noticeably or disappears, it is isolated to that particular cylinder.
4. Try to isolate the noise to location in engine, front to back, top to bottom. This can help determine which components are at fault.
5. Sometimes noises can be caused by moving parts coming in contact with other components. Examples are: flywheel, crankshaft striking (pan and pan baffle), rocker arm striking valve cover and loose flywheel cover. In many cases, if this is found to be the problem, a complete engine teardown is not necessary.
6. When noise is isolated to a certain area and component, removal and inspection will be required. Refer to proper sections of service manual for pertinent information.

Symptom	Cause
1. Noise around the valve cover area.	A. Rocker arm striking valve cover. B. Rocker arm out of adjustment. C. Worn rocker arm. D. Bent push rod. E. Collapsed lifter.
2. Noise around the cylinder area.	A. Sticking valve. B. Carbon build-up. C. Connecting rod installed wrong. D. Bent connecting rod. E. Piston. F. Piston rings. G. Piston pin. H. Cylinder worn.
3. Noise around camshaft area (throughout engine).	A. Loss of oil pressure. B. Valve lifters. C. Cam bearings.
4. Noise in camshaft area (front of engine).	A. Camshaft timing gear. B. Timing chain. C. Fuel pump. D. Valve lifter. E. Cam bearings.

ENGINE NOISE (continued)

Symptom	Cause
5. Noise in camshaft area (center of engine).	A. Fuel pump. B. Valve lifter. C. Cam bearings.
6. Noise in camshaft area (rear of engine).	A. Distributor gear. B. Valve lifter. C. Cam bearings.
7. Noise in crankshaft area (throughout engine).	A. Loss of oil pressure. B. Main bearings. C. Rod bearings.
8. Noise in crankshaft area (front of engine).	A. Crankshaft timing gear. B. Timing chain. C. Main bearing. D. Rod bearing.
9. Noise in crankshaft area (center of engine).	A. Crankshaft striking pan or pan baffle. B. Main bearing. C. Rod bearing.
10. Noise in crankshaft area (rear of engine).	A. Loose flywheel cover. B. Loose flywheel. C. Drive plate. D. Main bearing. E. Rod bearing.
11. Engine spark knock.	A. Advanced timing. B. Low-octane fuel. C. Engine running hot. D. Carbon deposits in engine.
12. Popping through carburetor.	A. Wrong ignition timing. B. Carburetor set too lean. C. Faulty accelerator pump. D. Vacuum leak. E. Valve adjustment. F. Valve timing. G. Burned or stuck valve.

ENGINE NOISE (continued)

Symptom	Cause
13. Hissing.	A. Vacuum leak. B. Fuel pump (hissing in sight tube). C. Leaking exhaust (manifolds or pipes). D. Loose cylinder heads. E. Blown head gasket.
14. Whistle.	A. Vacuum leak. B. Dry or tight bearing in an accessory.
15. Sparks jumping.	A. Defective high-tension cables. B. Cracked coil tower. C. Cracked distributor cap.
16. Squeaks or squeals.	A. Drive belt slipping. B. Dry or tight bearing in an accessory. C. Parts rubbing together.

5.13 OIL PRESSURE DIAGNOSTICS

The following table contains important information for the checking of oil pressure.

Condition	Information
1. Measuring oil pressure.	A. Use a good automotive oil pressure test gauge. Do not rely on the oil pressure gauge in the boat.
2. Check engine oil level with boat at rest in the water.	A. Oil level should be between the "ADD" and "FULL" marks.
3. Oil level in crankcase above "FULL" mark.	A. May cause loss of engine speed, oil pressure gauge fluctuation, drop in oil pressure and hydraulic valve lifter noise at high rpm.
4. Oil level in crankcase below "ADD" mark.	A. Low oil pressure, oil pressure gauge fluctuation, internal engine noise and/or damage.
5. Change in oil pressure.	A. This may be a normal condition. Oil pressure may read high in the cooler times of the day and when engine is not up to operating temperature. As the air temperature warms up and the engine is running at normal operating temperature, it is normal for oil pressure to drop off slightly.
6. Low engine oil pressure at idle or high rpm.	A. With modern engines and engine oils, low oil pressure readings at idle do not necessarily mean there is a problem. If valve lifters do not "clatter" (at idle), there is a sufficient volume of oil to lubricate all internal moving parts properly. The reason for the drop in oil pressure is that engine heat causes an expansion of the internal tolerances in the engine and, also, the oil will thin out somewhat from heat.
7. Boats with dual engines.	A. It is not uncommon to see different oil pressure readings between the two engines, as long as both engines fall within specifications. Differences in oil pressure can be attributed to differences in engine tolerances, gauges, wiring, senders, etc.

5.14 OIL PRESSURE PROBLEMS

Symptom	Cause
1. Low oil pressure.	A. Low oil level in crankcase. B. Defective oil pressure gauge and/or sender. C. Oil broken down, contains water or gas, wrong viscosity, engine running too hot or too cold, excessive idling in cold water (condensation). D. Relief valve stuck open, pickup tube restricted, worn parts in oil pump, air leak on suction side of oil pump or pickup tube. E. Oil passage plugs leaking, cracked or porous cylinder block. F. Excessive bearing clearance.
2. High oil pressure.	A. Wrong viscosity, oil full of sludge or tar. B. Defective oil pressure gauge and/or sender. **IMPORTANT: Oil pressure slightly higher than normal does not always indicate a problem. Tolerance stack-up in the engine, oil viscosity, and weather conditions could cause high oil pressure.** C. Clogged or restricted oil passage. D. Oil pump relief valve stuck closed.
3. Excessive oil consumption. **NOTE:** Normal consumption is approximately one quart of oil in 5-15 hours of operation at W.O.T.	A. Oil leaks. B. Oil diluted or of the wrong viscosity. C. Oil level too high. D. Drain holes in cylinder head plugged causing flooding of valve guides. E. Defective valve seals. F. Intake manifold gasket leaking, worn valve stem or valve guides. G. Defective oil cooler (if so equipped). H. Glazed, scuffed, worn, stuck, improperly installed; ring grooves worn; improper break-in; wrong end gap. I. Piston out-of-round, scored, tapered, glazed; excessive piston-to-cylinder clearance; cracked piston. J. Excessive bearing clearance.

5.15 WATER IN ENGINE

Determine location of water in engine. This information is necessary to determine where the water came from and how it got into the engine. The most common problems are water on top of pistons and/or water in crankcase oil.

1. After locating the water, remove all the water from the engine by removing all spark plugs and pump cylinders by cranking engine over. Next change oil and filter. Start engine and see if problem can be duplicated. If so, there is more than likely a mechanical problem. If problem cannot be duplicated, it is either an operator error or a problem that exists only under certain environmental conditions.
2. If water is confined to cylinder(s), it is usually entering through the intake system, exhaust system or head gasket.
3. If the water is confined to crankcase, it is usually caused by a cracked or porous block, a flooded bilge or condensation.
4. If the water is located in both the cylinder(s) and the crankcase, it is usually caused by water in the cylinders getting past the rings and valves, or complete submersion.
5. Checking for rust in the intake manifold or exhaust manifolds is a good idea. Rust in these areas will give clues if the water entered through these areas.

Symptom	**Cause**
1. Water found on top of the pistons.	A. Operator shut engine off at high rpm. B. Engine "diesels" or tries to run backwards (engine out of tune, poor fuel, high idle rpm, timing set too high). C. Rainwater running into flame arrestor (loose hatch cover). D. Spark plugs misfiring. E. Backwash through the exhaust system. F. Improper engine or exhaust hose installation. G. Cracked exhaust manifold. H. Improper manifold-to-elbow gasket installation. I. Loose cylinder head bolts. J. Blown cylinder head gasket. (Check for warped cylinder head or cylinder block.) K. Cracked valve seat. L. Porous or cracked casting. (Check engine.)
2. Water found in the crankcase oil.	A. Water in boat bilge. B. Water seeping past piston rings or valves. C. Engine running cold (defective thermostat). D. Intake manifold leaking near a water passage. E. Cracked or porous casting.

5.16 ENGINE OVERHEATING

Symptom	Cause
1. Mechanically related.	A. Engine rpm below specification for W.O.T. (engine laboring). B. Wrong ignition timing. C. Sticking distributor advance weights. D. Spark plug wires crossed (wrong firing order). E. Lean fuel mixture. F. Wrong heat-range spark plugs. G. Exhaust restriction. H. Valve timing off, caused by a jumped or improperly installed timing chain and/or gears. I. Blown head gasket(s). J. Insufficient lubrication to moving parts of engine.
2. Cooling system-related.	A. Loose or broken drive belt. B. Raw-water shut-off valve partially or fully closed (if equipped). C. Clogged or improperly installed raw-water strainer. D. Loose hose connections between raw-water pickup and raw-water pump inlet. E. Raw-water inlet hose kinked or collapsed. F. Raw-water pickup clogged. G. Obstruction on boat bottom causing water turbulence. H. Defective thermostat. I. Exhaust elbow water outlet holes plugged. J. Insufficient raw-water pump operation caused by worn pump impeller. K. Obstruction in cooling system such as casting flash, sand, rust, salt, etc. L. Engine circulating pump defective. M. Low coolant level. N. Antifreeze not mixed properly. O. Heat exchanger cores plugged.

ENGINE OVERHEATING (continued)

Symptom	Cause
3. Insufficient water flow – raw-water pickup pump.	A. Loose or broken drive belt. B. Raw-water shut-off valve partially or fully closed. C. Clogged or improperly installed raw-water strainer. D. Loose hose connections between raw-water pickup and raw-water pump inlet. Allows pump to suck air bubbles into the cooling system. E. Raw-water inlet hose kinked or collapsed. F. Raw-water pickup clogged. G. Obstruction in front of raw-water pickup causing water turbulence and forcing air bubbles into the cooling system. H. Faulty raw-water pump.

5.17 VACUUM GAUGE DIAGNOSTICS

Gauge Reading	Probable Cause
1. Steady reading ranging between 15-21 in. at idle rpm.	A. Normal.
2. Extremely low reading but steady at idle rpm.	A. Vacuum leak. B. Incorrect timing. C. Underpowered boat. D. Faulty boat bottom.
3. Fluctuates between high and low at idle rpm.	A. Blown head gasket between two adjacent cylinders.
4. Fluctuates 4 or 5 in. very slowly at idle rpm.	A. Carburetor needs adjustment. B. Spark plug gap too narrow. C. Valves are sticking.
5. Fluctuates rapidly at idle rpm and steadies as the rpm is increased.	A. Valve guides are worn.
6. Continuously fluctuates between low and normal reading at regular intervals at idle rpm.	A. Burned or leaking valve.

Section 6

Electrical System

BLANK

6 ELECTRICAL SYSTEM

6.1 GENERAL INFORMATION

Observe the following Warnings and Cautions whenever working on the engine:

> **⚠ WARNING**
>
> **Always** disconnect the battery cables from battery, negative terminal first, **before** performing engine disassembly/reassembly procedures.

> **⚠ WARNING**
>
> Electrical and ignition components on your Crusader marine engines are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.
>
> Use of replacement electrical or ignition system components which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

> **⚠ WARNING**
>
> When servicing the electrical and ignition systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

> **⚠ WARNING**
>
> To prevent the possibility of a **FIRE**, be sure that the engine compartment is well ventilated and that there are no gasoline vapors present.

> **⚠ WARNING**
>
> Make sure that no fuel leaks exist before closing engine hatch.

Battery Maintenance:

IMPORTANT: Boating industry standards (BIA, ABYC, etc.), Federal standards and Coast Guard regulations must be adhered to when installing a battery. Be sure battery cable installation meets the pull-test requirements and that the positive battery terminal is properly insulated in accordance with standards and regulations.

IMPORTANT: Engine electrical system is negatively (–) grounded. It is recommended (required in some states) that the battery be installed in an enclosed case. Refer to regulations for your area.

Select a battery that meets all of the following specifications:

1. 12 V marine type.
2. Tapered post connector or side terminal connectors (do not use a battery with wing-nut connectors).
3. Reserve capacity rating of at least 100 minutes.

MINIMUM COLD CRANKING AMPERAGE	
Engine Model	**Amperage**
229/262 CID	400
305/350 CID	400
454/502 CID	450

Battery Cables:

For safety purposes, and to provide the proper electrical flow from the battery to the engine's electrical components, the battery cables must meet specifications in the following table:

BATTERY CABLE SPECIFICATIONS	
Cable Length	**Cable Gauge**
Up to 3-1/2 ft. (1.1 m)	4 (19 mm^2)
3-1/2 – 6 ft. (1.1 – 1.8 m)	2 (32 mm^2)
6 – 7-1/2 ft. (1.8 – 2.3 m)	1 (40 mm^2)
7-1/2 – 9-1/2 ft. (2.3 – 2.9 m)	0 (50 mm^2)
9-1/2 – 12 ft. (2.9 – 3.7 m)	00 (62 mm^2)
12 – 15 ft. (3.7 – 4.6 m)	000 (81 mm^2)
15 – 19 ft. (4.6 – 5.8 m)	0000 (103 mm^2)
Both positive (+) and negative (–) cables	

IMPORTANT: Terminals must be soldered to cable ends to ensure good electrical contact. Use electrical-grade resin-flux solder only. Do not use acid-flux solder as it may cause corrosion and failure.

Check battery condition periodically.

Make sure that battery leads are kept clean and tight.

Battery Testing:

WARNING

Test battery in well-ventilated area as gases given off by battery are hazardous.

WARNING

Hydrogen gases that escape from the battery during charging are explosive. Be sure that the battery area is well ventilated and that the bilge blower is in operation when charging. Do not smoke or allow sources of spark or open flame in area when charging battery.

WARNING

Battery electrolyte is a corrosive acid and should be handled with extreme care. If electrolyte is spilled or splashed on any part of the body, immediately flush the exposed area with liberal amounts of water and obtain medical aid as soon as possible. Safety glasses and rubber gloves are recommended when handling batteries.

CAUTION

To prevent damage to the electrical system be sure to adhere to the following:

When installing the battery, be sure to connect first the positive (+) battery cable to the positive (+) battery terminal, and the negative (–) battery cable to the grounded (–) battery terminal. Never disconnect the battery cables while the engine is running.

If a charger or booster is to be used, be sure to connect it in parallel with the existing battery (positive to positive and negative to negative).

When applying a booster charge to battery, disconnect both cables from battery to prevent damage to voltage regulator.

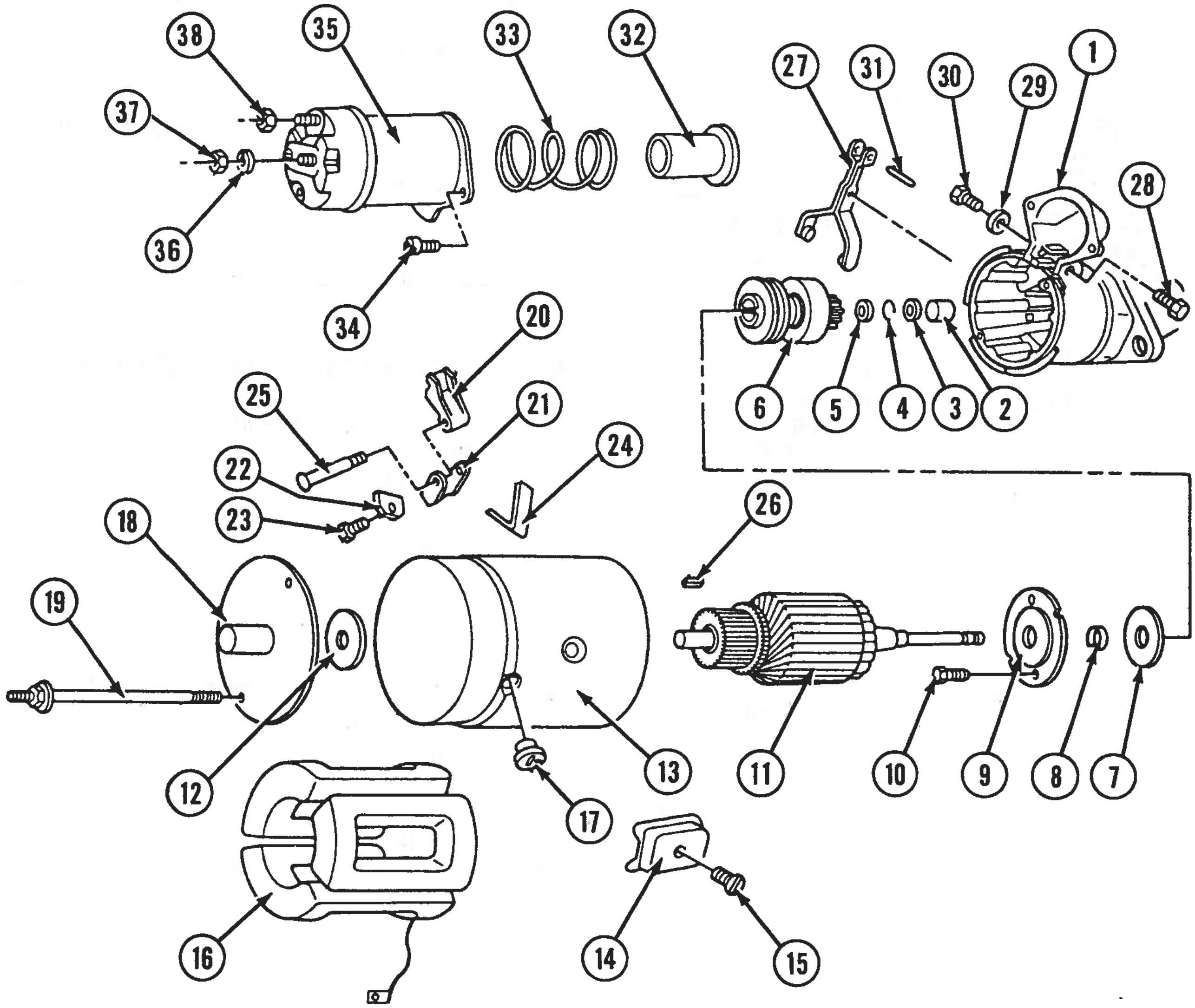
Certain conditions must be met before testing:

1. The battery must be within a temperature range of 60° F (16° C) to 100° F (38° C).
2. The electrolyte level must be correct in all cells.
3. The battery must be at least half-charged.
4. The battery must have no obvious defects.

If these conditions are met, then use the following procedure to test the battery:

1. Place battery under a heavy load (as during engine cranking or with a variable resistor tester) and test battery voltage while under load.
2. Compare the voltage obtained against the manufacturer's specifications.
3. If the voltage readings are low, recharge and retest.
4. If voltage readings remain low, the battery should be replaced.

6.2 STARTER MOTOR



1. Housing	14. Shoe	27. Shift lever
2. Bushing	15. Screw	28. Shift lever bolt
3. Thrust collar	16. Field coil assembly	29. Washer
4. Retaining ring	17. Grommet	30. Shift lever bolt
5. Collar	18. Commutator end cap	31. Pin
6. Drive assembly	19. Through-bolt	32. Plunger
7. Washer	20. Insulated brush holder	33. Spring
8. Bushing	21. Grounded brush holder	34. Screw
9. Bearing plate	22. Field frame brush	35. Solenoid assembly
10. Screw	23. Brush lead screw	36. Lockwasher
11. Armature	24. Spring	37. Nut
12. Washer	25. Brush holder support kit	38. Nut
13. Field frame	26. Dowel pin	

Figure 6-1. *Starter Motor*

IDENTIFICATION

The starter identification number is located as shown in Figure 6-2.

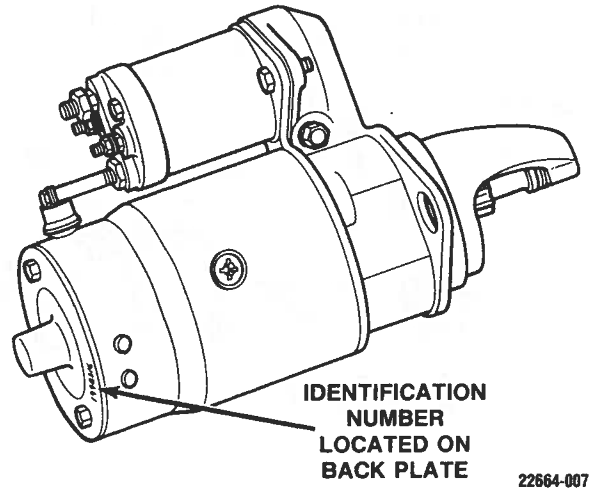


Figure 6-2. *Starter Motor I.D. Number*

STARTER BOLT TORQUE SPECIFICATIONS		
Fastener Location	**lb-ft (N•m)**	**lb-in (N•m)**
Starter motor to flywheel housing	50 (68)	600 (68)

STARTER LUBRICANTS AND SEALANTS
Liquid neoprene
SAE 10W Oil
SAE 20W Oil

STARTER MOTOR MAINTENANCE

The starter motor and solenoid are completely enclosed in the drive housing to prevent entrance of moisture and dirt. Periodic inspection, however, is required as follows:

1. Inspect terminals for corrosion and loose connections.
2. Inspect wiring for frayed and worn insulation.
3. Check the mounting bolts for tightness.

STARTER MOTOR SPECIFICATIONS							
			No-Load Test				
Delco I.D. Number	**Engine Rotation**	**Volts**	**Min. Amps**	**Max. Amps**	**Min. rpm**	**Max. rpm**	**Brush Spring Tension**
1998315 1109484	RH	10.0	70	110	6,500	10,700	56-105 oz. (15.57-29.19 N)
1998316 1109485	LH	10.0	70	110	6,500	10,700	56-105 oz. (15.57-29.19 N)
Pinion clearance			0.010-0.140 in. (0.254-3.56 mm)				
Commutator end-frame gap			0.025 in. max. (0.635 mm max.)				

LH = Left-Hand Engine Rotation
RH = Right-Hand Engine Rotation

ELECTRIC CURRENT FLOW

The following is a general description of the positive current flow from the battery through the system, until the starter motor cranks:

1. Twelve (12) volts of power flow from the battery (positive red battery cable) to the starter solenoid switch.
2. The current flows from the starter solenoid switch through the red wire to the circuit breaker.
3. The current flows from the circuit breaker, through the red wire, to terminal No. 8 in the wiring harness plug.
4. The current flows from the wiring harness plug, through the red wire, to the 20 A fuse connected on the instrument panel.
5. The current flows from the 20 A fuse through a red/purple wire, to the "BAT" terminal on the ignition switch.
6. When the ignition switch is in the "START" position, the current flows from the ignition switch "BAT" terminal to the "SOL" terminal.
7. The current flows from the ignition switch "SOL" terminal, through a yellow/red wire, to the wiring harness plug, terminal No. 3.
8. The current flows from the wire harness plug, through a yellow/red wire, to the neutral start switch. The neutral start switch must be in a neutral position.
9. The current flows through the neutral start switch, through a yellow/red wire, to the starter relay.
10. The current flows from the starter relay (large terminal), through a yellow/red wire, to the starter solenoid ("S" terminal). The starter solenoid is now "closed," completing the circuit, causing the starter motor to crank.

STARTER MOTOR REMOVAL

WARNING

Disconnect battery cables at battery before removing starter.

1. Disconnect battery cables from battery.
2. Disconnect wires from starter solenoid terminals.
3. Remove starter mounting nuts.
4. Pull starter assembly away from flywheel and remove from engine.

STARTER MOTOR DISASSEMBLY

1. Remove solenoid switch and mounting screws (2).

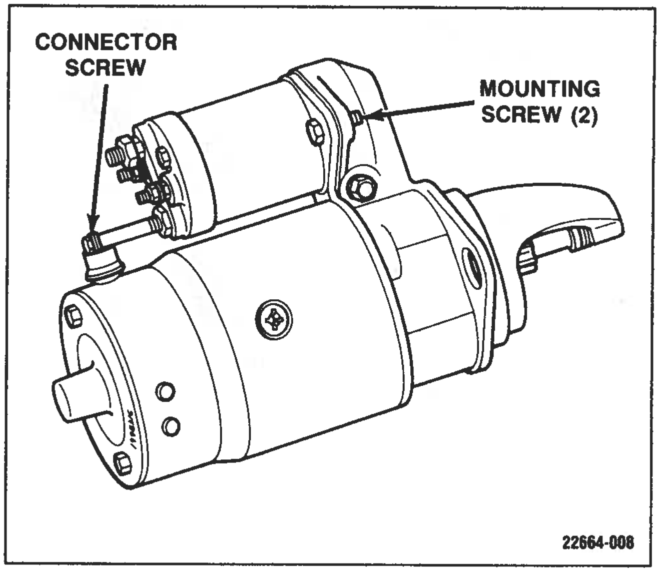


Figure 6-3. *Solenoid Screw Removal*

2. Remove screw from solenoid connector.
3. Rotate solenoid housing and remove solenoid and plunger spring.
4. Remove end-cap through-bolts, end-cap, washer and field frame (Figure 6-4).
5. Remove center bearing plate screws and remove armature from housing (Figure 6-5).
6. Slide thrust collar off armature shaft (see Figure 6-1).
7. Drive retainer ring collar toward armature.
8. Remove snap ring, retaining collar, clutch assembly and bearing plate.

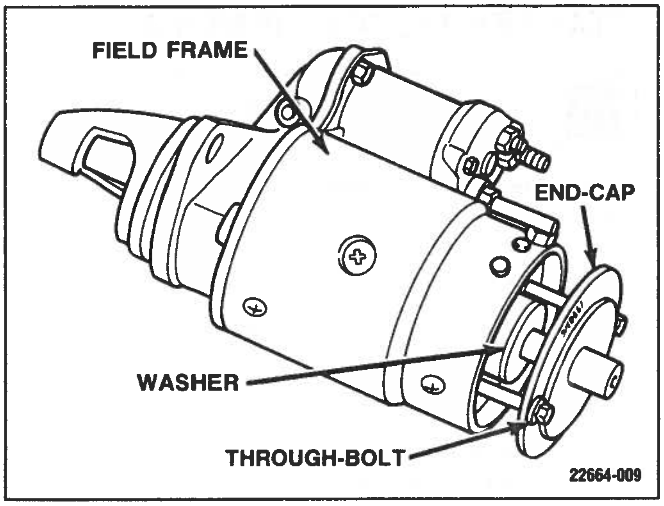


Figure 6-4. *End-Frame Removal*

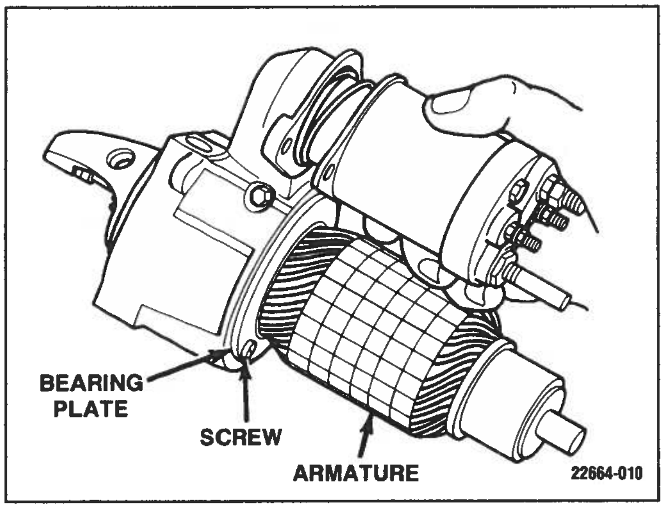


Figure 6-5. *Bearing Plate And Armature*

CLEANING AND INSPECTION

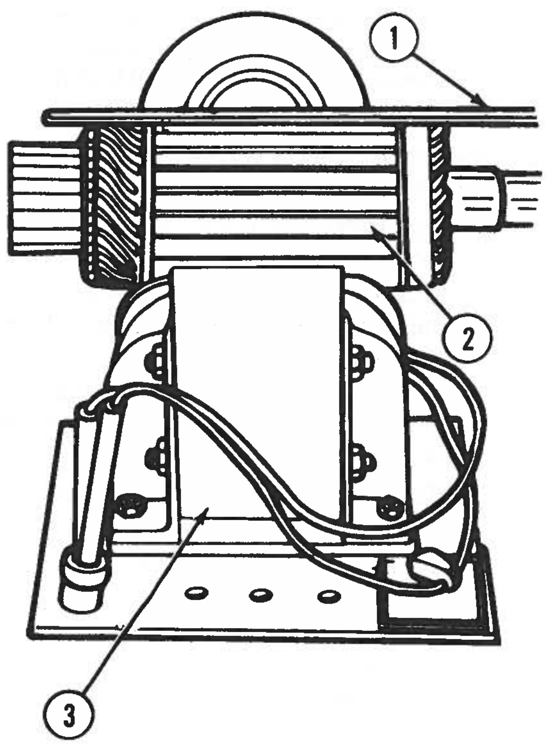
With the starting motor completely disassembled, except for removal of field coils, component parts should be cleaned and inspected. Field coils should be removed only when defects are indicated by tests. Defective parts should be replaced or repaired.

1. Clean all starting motor parts. **Do not** use dissolving agents for cleaning overrunning clutch, armature and field coils. Such a solvent would dissolve grease packed in clutch mechanism and damage armature and field-coil insulation.
2. Test overrunning clutch action. Pinion should turn freely in overrunning direction and must not slip in cranking direction. Check pinion teeth. Check spring for tension and drive collar for wear. Replace if necessary.
3. Check that brush holders are not damaged or bent and will hold brushes against commutator.
4. Check brushes. Replace if pitted or worn to one-half their original length (5/16 in. [8 mm] or less).
5. Check fit of armature shaft in bushing of drive housing. Shaft should fit snugly. Replace bushing if worn. Apply SAE 20 oil to bushing before reassembly. Avoid excessive lubrication.
6. Check fit of bushing in commutator end-cap. If bushing is damaged or worn excessively, replace end-cap assembly. Apply SAE 20 oil to bushing before reassembly. Avoid excessive lubrication.
7. Inspect armature commutator. If rough or out-of-round, turn down and undercut. Inspect points where armature conductors join commutator bars for good, firm connection. Burned commutator bar usually is evidence of poor connection.

ARMATURE TESTS

Test For Short Circuits:

Check armature for short circuits by placing on growler and holding hacksaw blade over armature core while rotating armature. If saw blade vibrates, armature is shorted. After cleaning between commutator bars, recheck. If saw blade still vibrates, replace armature.



1. Saw blade
2. Armature
3. Growler

Figure 6-6. *Testing Armature For Short Circuits*

Test For Grounded Circuit:

1. With continuity meter, place one lead on armature core or shaft and other lead on commutator.
2. If meter needle moves, armature is grounded and must be replaced.

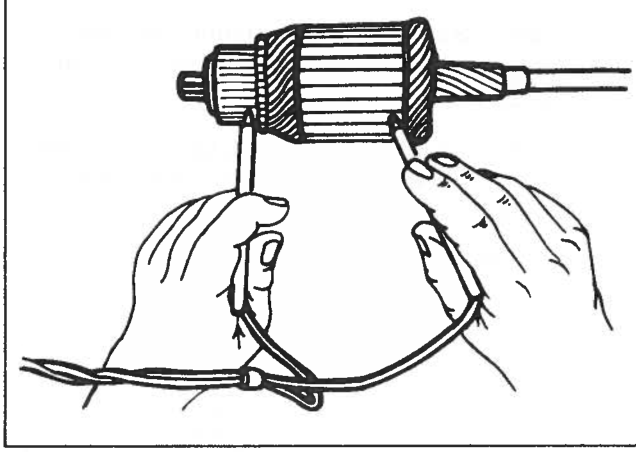


Figure 6-7. *Testing Armature For Grounded Circuit*

FIELD COIL TESTS

Test For Open Circuit:

1. With continuity meter, place one lead on each end of field coils (insulated brush and field connector bar).
2. If meter does not move, field coils are open and must be replaced.

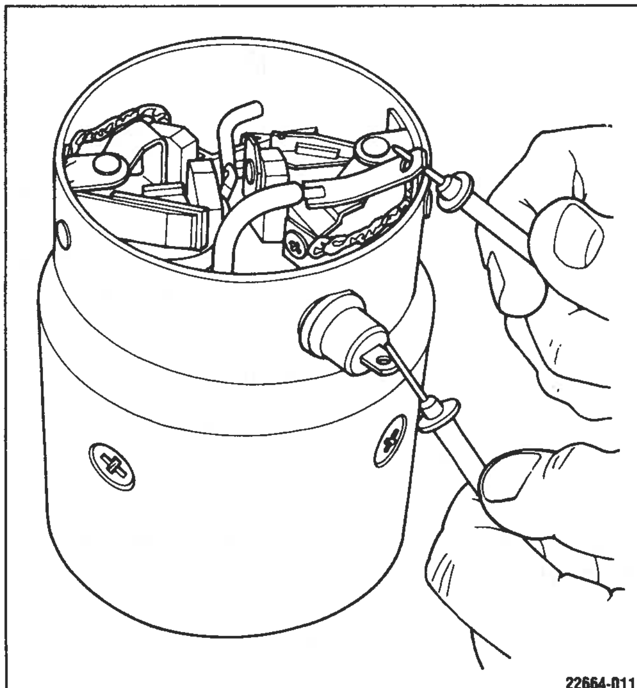


Figure 6-8. *Testing Field Coils For Open Circuit*

Test For Ground:

IMPORTANT: Be sure that positive brushes and leads do not contact field frame assembly during test, or false reading will result.

1. With continuity meter, place one lead on field connector bar and other lead on grounded brush.
2. If meter needle moves, field coils are grounded and must be replaced.

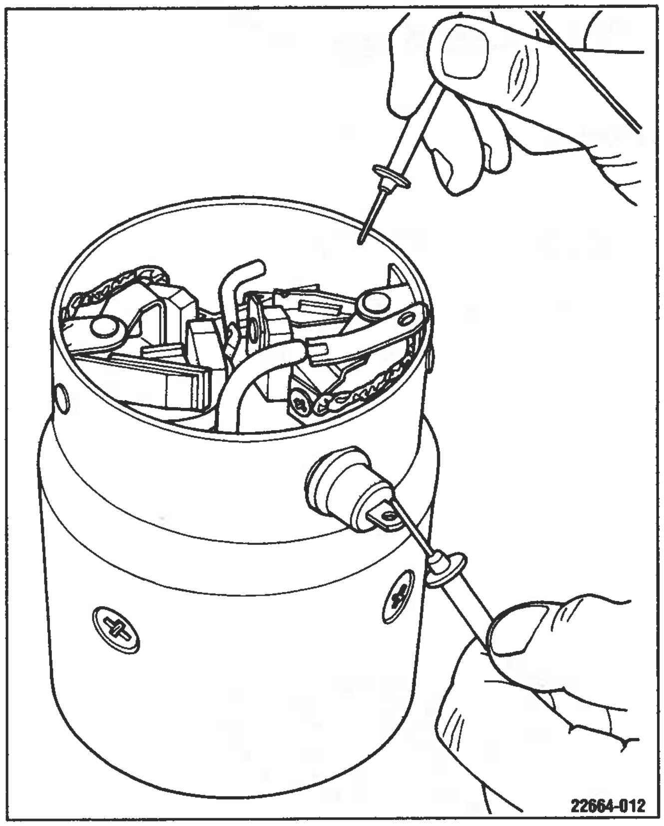


Figure 6-9. *Testing Field Coil For Grounded Circuit*

Loose Electrical Connections:

If an open-soldered connection of armature-to-commutator leads is found during inspection, resolder it with resin flux.

IMPORTANT: Never use acid flux on electrical connections.

Turning the Commutator:

When inspection shows commutator roughness, clean as follows:

1. Turn down commutator in a lathe until thoroughly cleaned.
2. Recheck armature for shorts as outlined.

STARTER MOTOR REASSEMBLY

After all parts are thoroughly tested and inspected, and worn or damaged parts replaced, reassemble starter as follows:

1. Assemble brushes and related parts to field frame as follows:
   a. Assemble brushes to brush holders. Attach ground wire to grounded brush and field lead wire to insulated brush.
   b. Assemble insulated and grounded brush holders together with V-spring. Position as a unit and install support pin. Push holders and spring to bottom of support and rotate spring to engage center of V-spring in slot of support.
2. Assemble overrunning clutch assembly to armature shaft as follows:
   a. Lubricate drive end of armature shaft with SAE 10 oil.
   b. Install bearing plate, washer and clutch assembly onto armature shaft with pinion outward.
   c. Slide retaining collar onto shaft with cupped surface facing end of shaft away from pinion.
   d. Drive snap ring onto shaft and slide down into groove.
   e. Assemble the thrust collar on shaft with shoulder next to snap ring.
   f. Place thrust collar and retaining collar next to snap ring. Using two pliers, squeeze both until snap ring is forced into retainer.
3. Place four or five drops of light engine oil in drive housing bushing. Slide armature and clutch assembly into place while engaging shift lever with clutch. Install center bearing attaching screws and tighten securely.
4. Position field frame over armature. Carefully apply liquid neoprene between frame and drive housing. Use caution to prevent damage to brushes.

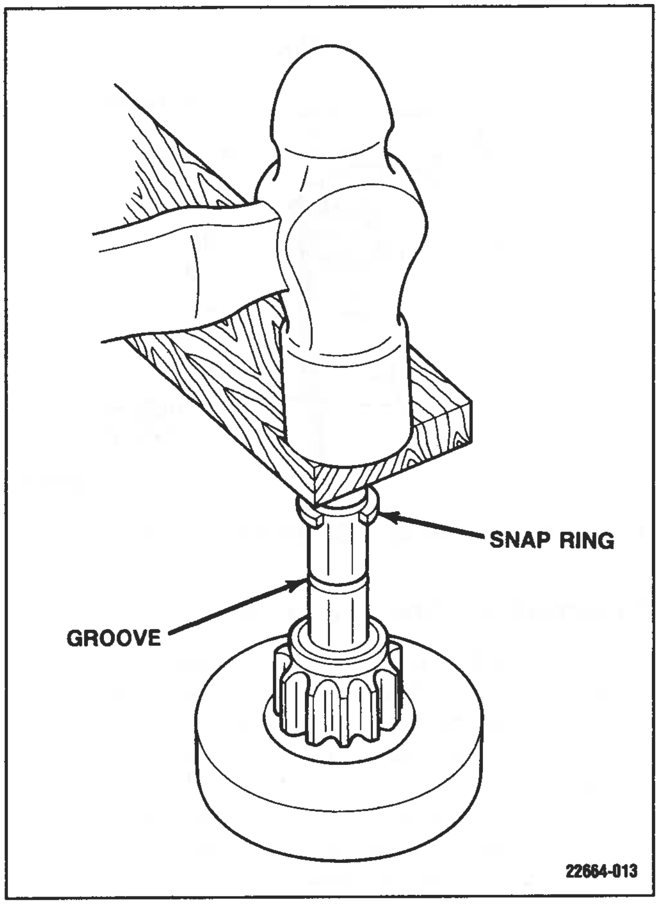


Figure 6-10. *Assembling Overrunning Clutch To Armature*

5. Place four or five drops of light engine oil in bushing in commutator end-frame. Place washer and commutator end-frame onto shaft.
6. Install through-bolts and tighten securely.
7. Install solenoid return spring on plunger.
8. Position solenoid assembly to starter motor end-frame and turn solenoid to engage flange in slot.
9. Install screws which hold solenoid assembly to end-frame and tighten securely.
10. Install field coil screw and tighten securely.

STARTER MOTOR ADJUSTMENTS

Pinion Clearance:

Pinion clearance must be checked as follows after reassembly of motor to insure proper adjustment:

1. Disconnect motor field coil connection from solenoid motor terminal and insulate it carefully.

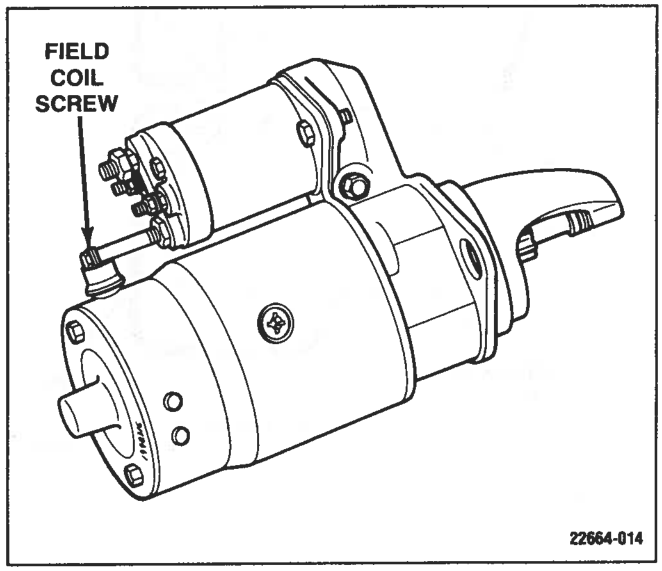


Figure 6-11. *Disconnecting Field Coil From Solenoid Strap*

2. Connect 12-volt battery from solenoid switch terminal to solenoid frame.
3. Momentarily touch a jumper lead from solenoid motor terminal to starter motor frame. This shifts pinion into cranking position where it will remain until battery is disconnected.

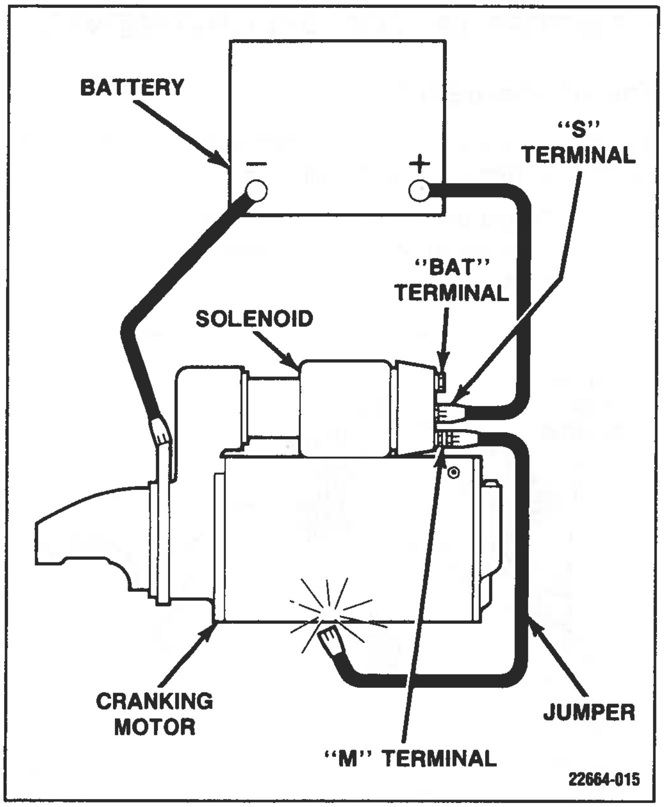


Figure 6-12. *Shifting Starter Pinion To Check Clearance*

4. Push pinion back toward commutator end to eliminate slack (Figure 6-13).
5. Measure distance between pinion and pinion retainer.
6. If clearance is not within specified limits, it may indicate excessive wear of solenoid linkage shift-lever yoke buttons or improper assembly of shift-lever mechanism. Check for proper assembly and recheck gap. If still excessive, replace worn or defective parts since no provision is made for adjusting pinion clearance.

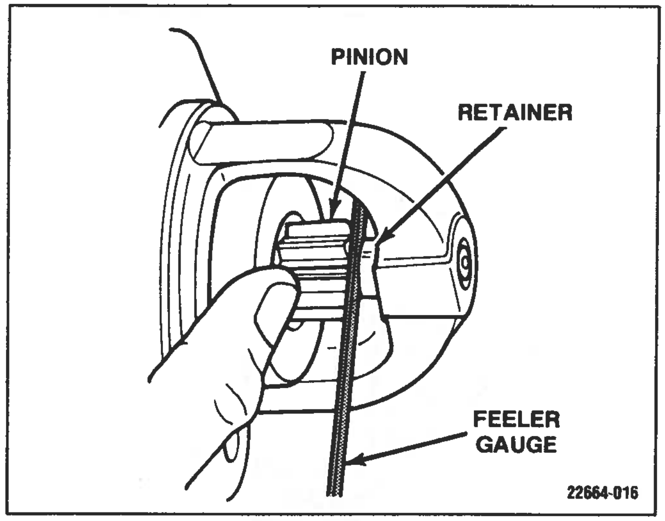


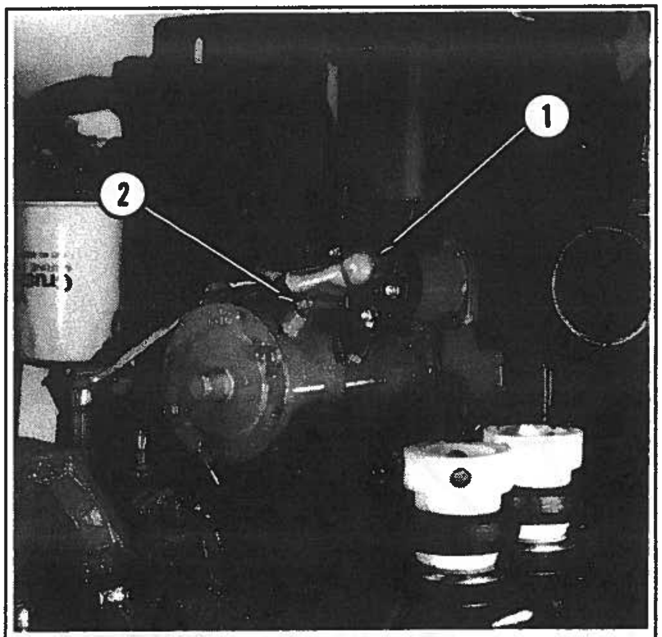
Figure 6-13. *Checking Starter Pinion Clearance*

Commutator End-Frame Gap:

To keep the starter ignition-proof and able to meet safety requirements, the gap between the commutator end-frame and field-coil housing must be checked. See specifications. If the gap exceeds measurement when checked with a feeler gauge, the end-frame should be checked for proper seating on the field-coil housing. If properly seated and still found to have excessive gap, the end-frame must be replaced.

STARTER MOTOR INSTALLATION

1. Place starter motor and solenoid assembly in position and install attaching nuts. Torque to specifications.
2. Fasten wires as outlined in wiring diagram.
3. Coat solenoid terminal connections with liquid neoprene.
4. Place rubber boot over positive battery cable connection.



1. Positive battery cable connection w/rubber boot
2. Mounting nuts

Figure 6-14. *Starter Installation*

SOLENOID SWITCH REMOVAL

1. Disconnect battery cables from battery.
2. Disconnect wires from solenoid terminals.
3. Remove screw from field-coil connector and solenoid-attaching screws.
4. Twist solenoid to disengage tab and remove.

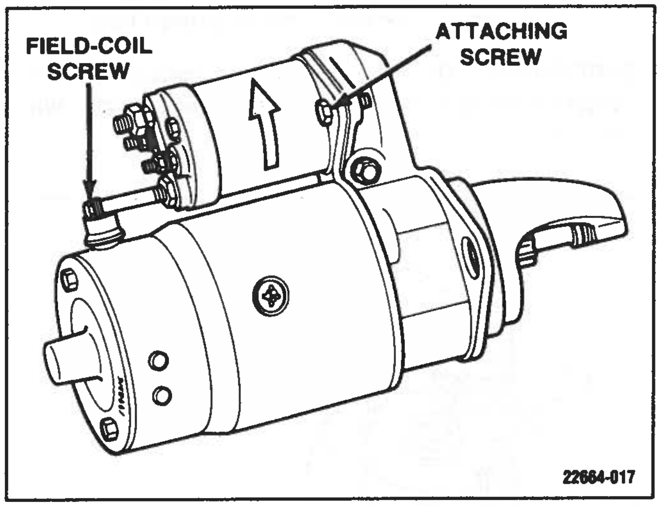
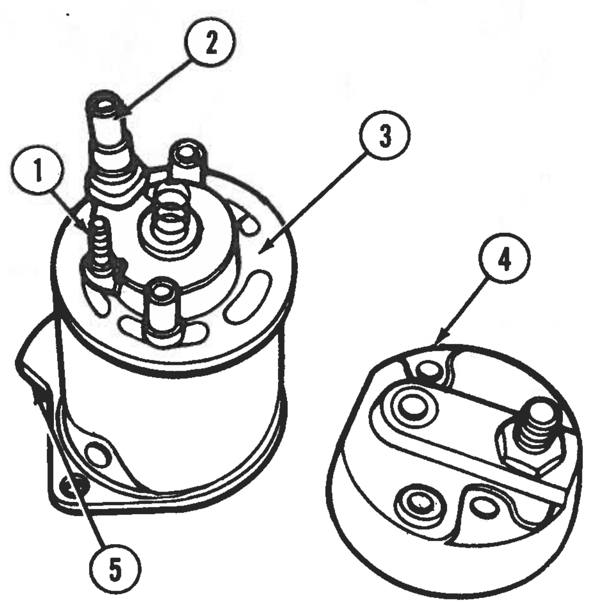


Figure 6-15. *Field-Coil-To-Solenoid Strap Removal*

REPLACEMENT OF CONTACTS

1. With solenoid removed from motor, remove nuts and washers from switch ("S") terminal and starter motor connector strap terminal.
2. Remove solenoid end-cover retaining screws and washers, and remove end cover from solenoid body.
3. Remove nut and washer from battery terminal on end-cover and remove battery terminal.

IMPORTANT: Do not cut starter motor connector strap terminal wire to remove terminal; wire will be too short.



1. "S" terminal
2. Motor terminal
3. Contact disc assembly
4. Cover
5. Lock tab

Figure 6-16. *Replacement Contacts*

4. Remove motor connector strap terminal and solder new terminal in position.
5. Remove and install new battery terminal, washer and retaining nut to end cover.
6. Place new contact ring and push rod assembly in solenoid housing.
7. Position end-cover over switch and motor terminals and install end-cover retaining screws. Also install washers and nuts on solenoid switch and starting motor terminals.

SOLENOID SWITCH INSTALLATION

1. Place plunger spring over plunger. Install solenoid onto plunger.
2. Twist solenoid to engage lock tab.
3. Install attaching screws and tighten securely.
4. Install field-coil connector screw and tighten securely.
5. Connect solenoid wires and battery cables.

SOLENOID SWITCH TESTING

1. Using continuity meter, connect test leads as shown in Figure 6-17, and connect 12-volt battery with jumper leads as shown.

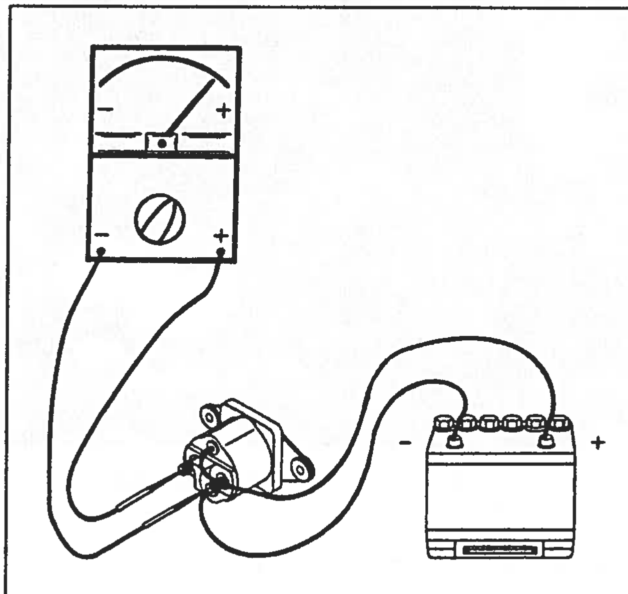


Figure 6-17. *Testing Standard Solenoid, Four-Connection Type*

2. If no meter movement is present, replace solenoid.

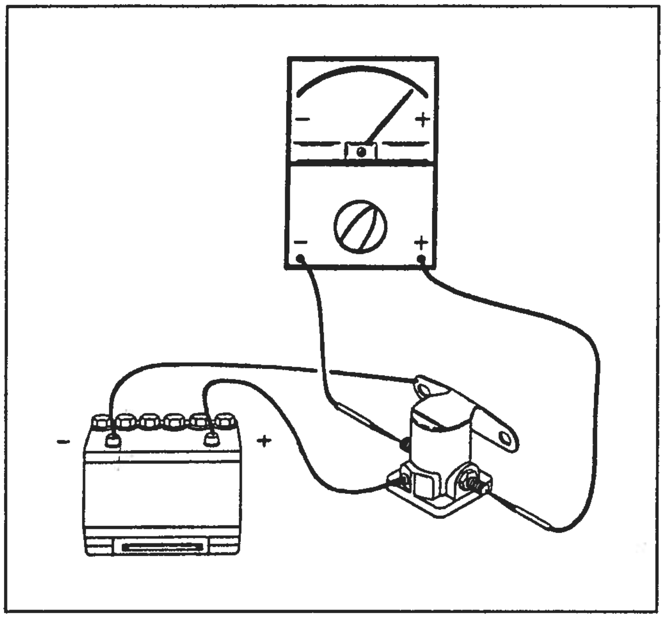
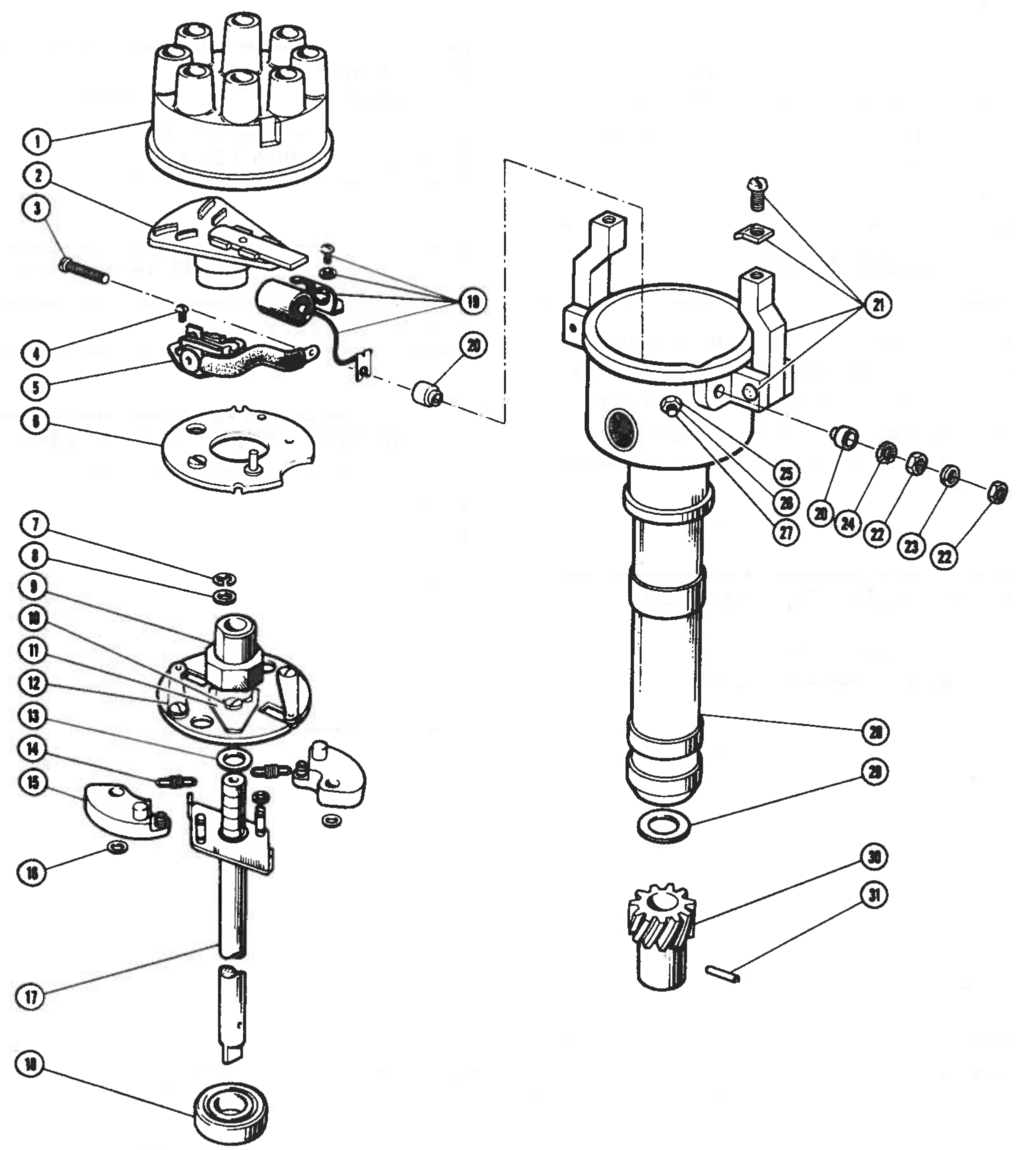


Figure 6-18. *Testing Standard Solenoid, Three-Connection Type*

BLANK

6.3 DISTRIBUTORS

SYSTEMS WITH MALLORY DISTRIBUTOR



1. Distributor cap
2. Rotor
3. Primary terminal screw
4. Contact set screw
5. Contact set
6. Armature plate assembly
7. Clip
8. Washer
9. Cam, advance plate assembly
10. Screw
11. Clamp
12. Advance plate assembly
13. Washer
14. Spring
15. Weight
16. Shim
17. Shaft assembly
18. Bearing or bushing assembly
19. Condenser assembly
20. Insulator
21. Clamp set
22. Nut
23. Lockwasher
24. External tooth lockwasher
25. Lockwasher
26. Nut
27. Screw
28. Housing assembly
29. Drive gear shim
30. Gear
31. Roll pin

Figure 6-19. *Mallory Distributor*

WARNING

Electrical and ignition system components on your Crusader marine engines are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement electrical or ignition system components which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

When servicing the electrical, ignition and fuel systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

MALLORY BREAKER-TYPE DISTRIBUTOR	
Item	**Specification**
Type	Y L624 AV
Used on	305, 350, 454 Engines
Rotation	Right-hand
Point gap	0.016-0.018 in. (0.4-0.46 mm)
Dwell angle	28°-30°
Contact spring tension	25-30 oz. (7.0-8.34 N)
Condenser	0.26-0.30 µF

DISTRIBUTOR LUBRICANTS
Distributor cam lubricant
Moisture-absorbing penetrating oil
Silicone grease

Distributor Fastener Location	Bolt Torque
Distributor clamp 3/8-16	20 lb-ft (27 N•m)

DISTRIBUTOR SEALANTS
Liquid neoprene

DISTRIBUTOR TOOLS OBTAINED LOCALLY
Dwell meter
Magneto analyzer
Remote starter switch
Timing light
Volt/ohmmeter
Spring tension gauge

IGNITION COIL AND COIL RESISTOR SPECIFICATIONS (OHMS)		
	Crusader Coil Part No.	
Type	**41080 Prestolite CAH**	**41062 Prestolite CAH**
Primary resistance	1.25-1.4	1.25-1.4
Secondary resistance	9,400-11,700	9,400-11,700
Coil resistor	0.5-0.6	0.5-0.6

NOTE: These values are affected by the temperature of the coil and the coil resistor. Readings should, however, be checked at room temperature.

ELECTRIC CURRENT FLOW

The following is a method for tracing the positive current flow from the battery through the ignition system to the spark plugs. See Section 5.6, Wiring Diagrams, for a diagram of the electrical connections.

1. Twelve (12) volts of power flow from the battery to the starter solenoid.
2. The current flows from the starter solenoid, through the red wire, to the circuit breaker.
3. The current flows from the circuit breaker, through the red wire, to the terminal (No. 8) in the plug connector.
4. The current flows from terminal (No. 8) through the red wire, to a 20-amp fuse in the instrument panel.
5. The current flows from the 20-amp fuse, through a red/purple wire, to the "BAT" terminal on the ignition switch.
6. If the ignition switch is in the "RUN" or "START" position, the current flows from the "BAT" terminal to the "IGN" terminal.
7. The current flows from the "IGN" terminal, through a purple wire, to the plug connector terminal (No. 7).
8. The current flows from the terminal (No. 7) plug connector, through the purple wire, to the coil resistor.
9. The current flows from the coil resistor, through the purple wire, to the coil's positive (+) terminal.
10. The breaker points in the distributor are connected to the coil's negative terminal.
11. The breaker points open, causing high voltage to be discharged from the coil tower to the center lower of the distributor and through the rotor to the spark plugs.
12. The ignition bypass system supplies full battery voltage to the ignition coil. The starter solenoid's "R" terminal has 12 volts during cranking only. Current passes from the "R" terminal, to the coil's terminal, through a purple wire.

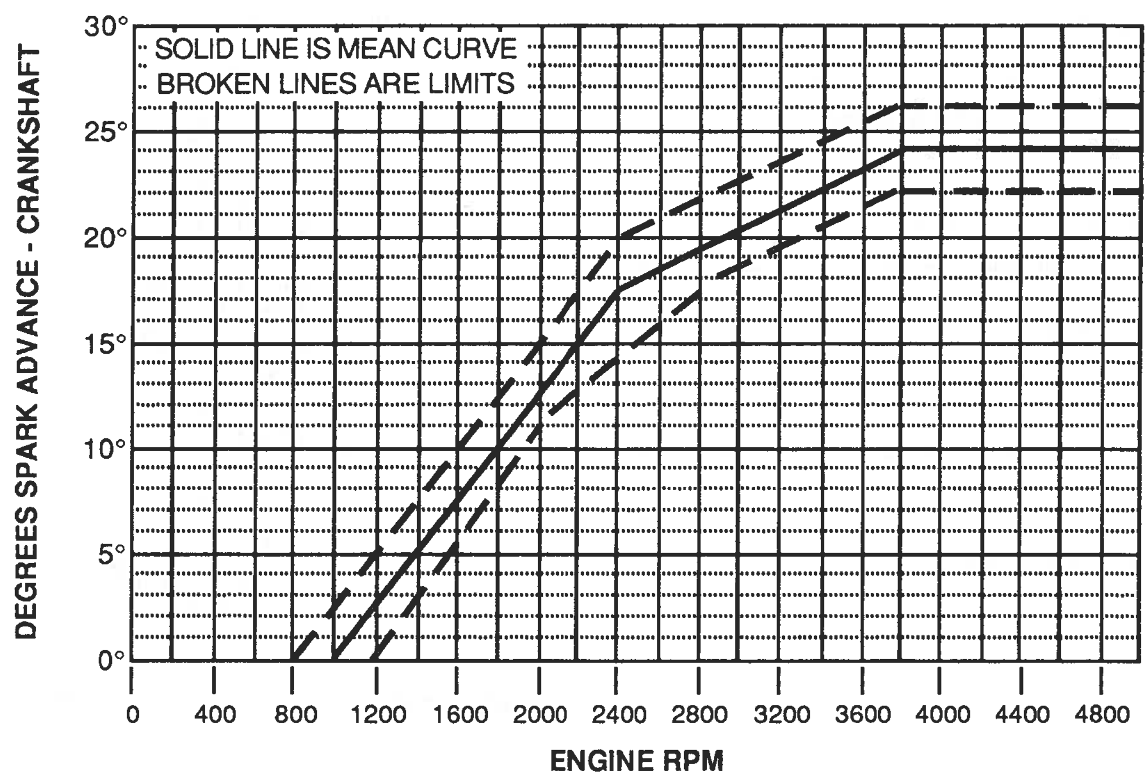


Figure 6-20. *Mallory Breaker-Type Distributor Spark-Advance Curve*

COIL TESTING

Using a magneto tester, test the coil for the following:

1. Coil power.
2. Coil surface insulation.
3. Coil continuity.
4. Primary resistance.
5. Secondary resistance.

Replace coil if test results are not within the specifications shown in the Ignition Coil and Coil Resistor Specifications Table.

COIL RESISTOR TESTING

1. Disconnect wires from the coil resistor.
2. Connect the ohmmeter leads to each end of the coil resistor.
3. Replace resistor if reading is not within specifications shown in the Ignition Coil and Coil Resistor Specifications Table.
4. Reconnect wires to the coil resistor.

MALLORY DISTRIBUTOR MAINTENANCE

WARNING

When performing the procedures in this section, be sure to observe the following:

Be sure that engine compartment is well ventilated and that no gasoline vapors are present to avoid the possibility of fire.

Be sure to keep hands, feet and clothing clear of the engine's moving parts.

Do not touch or disconnect any ignition system parts while engine is running.

Do not reverse the battery cable connections. The system uses negative (–) ground.

To check and adjust the Mallory distributor, use the following procedure:

1. Loosen the distributor cap's clamp-retaining screws.
2. Remove the distributor cap.
3. Clean the cap with warm soap and water, and blow off any particles with compressed air.
4. Check the cap contacts for excessive burning or corrosion. Check the center contact for deterioration.

IMPORTANT: Most distributor caps for marine use should have brass contacts.

5. Check the cap for cracks or carbon tracks.
6. Lift the rotor up off the distributor shaft.
7. Check the rotor for a burned or corroded center contact and electrode tip.
8. Check the rotor for cracks and carbon tracks.
9. Install rotor onto the shaft. Make sure to line up the rotor with the keyway on the distributor shaft. Be sure the rotor is completely seated on the distributor shaft.
10. Place cap on the distributor. Make sure the notch on the bottom edge lines up with the notch in the distributor, allowing the cap to be firmly seated.
11. Tighten the clamp-retaining screws.
12. Install spark plug wires (if removed) as shown in Figures 6-21 and 6-22.

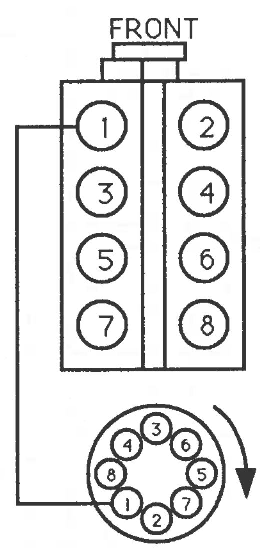


Figure 6-21. *Ignition Wiring (Left-Hand Rotating Engine)*

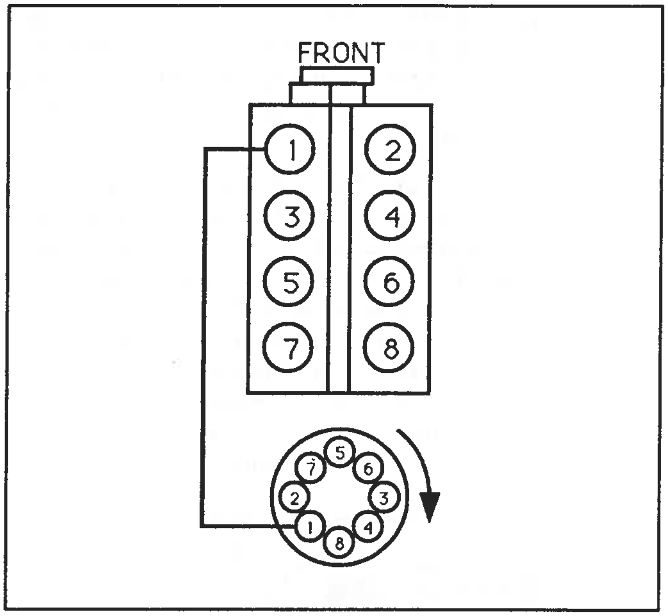


Figure 6-22. *Ignition Wiring (Right-Hand Rotating Engine)*

Contact Points:

Examine the contact points for dirt, wear, pitting and misalignment. Dirty points should be cleaned. Normal point condition exists when an overall grey color appears on the contact surface.

Check for point resistance with a sensitive voltmeter or point-resistance meter. A voltage drop of less than 0.125 V across the points should exist.

Abnormal Point Wear:

Points which have been operating for a period of time have a rough surface, but this does not mean that the points are worn out.

If the points burn or pit, they soon will become unsatisfactory for further operation. Not only must they be replaced, but the ignition system and engine must be checked to determine the cause. Unless this condition is corrected, new points will provide no better service than the old points.

Cleaning of Points:

To clean the contact points, use the following procedure:

1. Dirty contact points should be dressed with a few strokes of clean, fine-cut contact file. File should not have been used on other metals and should not be greasy or dirty.

IMPORTANT: Never use emery cloth to clean contact points.

2. Contact surfaces, after considerable use, may not appear bright and smooth, but this is not necessarily an indication that they are functioning unsatisfactorily. Do not attempt to remove all roughness nor dress point surfaces down smoothly. Merely remove scale or dirt.
3. Badly burned or pitted contact points should be replaced and the cause of trouble determined and corrected.

Burning of Points:

Contact-point burning results from high voltage, presence of oil or other foreign material, defective condenser or improper point adjustment.

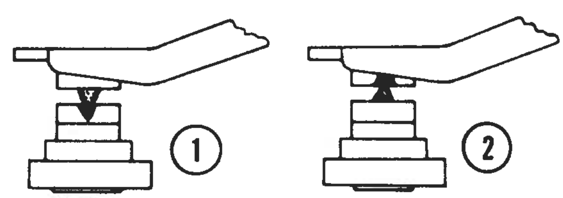
High voltage causes excessively high current flow through the contact points which causes them to burn rapidly. High voltage can result from an improperly adjusted or inoperative voltage regulator.

Oil or crankcase vapors, which work up into the distributor and become deposited on the point surfaces, also cause them to burn rapidly.

If a contact point opening is too small (cam angle too large), points will be closed too long. The average current flow through the points will be too high, thus causing the points to burn rapidly and allowing the existence of arcing between points.

Pitting of Points:

Contact-point pitting results from an out-of-balance condition in the ignition system. This causes the transfer of material from one point to another so that a tip builds up on one point while a pit forms in the other (See Figure 6-23).



1. Negative to positive 2. Positive to negative

Figure 6-23. *Contact-Point Pitting*

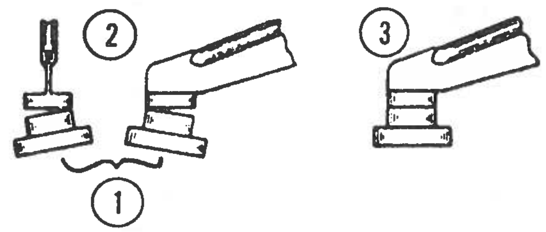
If the points are pitted (See Figure 6-23), the condenser should be checked for proper capacity

Points Replacement:

1. Remove the primary lead from the primary terminal on the distributor. Remove the primary-terminal screw and nut from distributor. (Use care not to lose the two insulator bushings in the distributor housing.) Remove the condenser lead and point from the primary-terminal screw.
2. Remove the contact-set-attaching screw and lift the contact-point set from the breaker plate.
3. Clean any oil and dirt from the breaker plate.

IMPORTANT: Carefully wipe any protective film from point set prior to installation.

4. Place a small amount of distributor cam lubricant on the distributor cam. Place two or three drops of engine oil on the wick in the top of the distributor shaft.
5. Place a new contact-point assembly in position on the breaker plate and install the attaching screw.
6. Place the primary terminal screw through the condenser and point leads. Install the primary screw through the two insulator bushings in the distributor housing. Install the primary-terminal locknut, primary lead and primary-lead-retaining nut to the primary-terminal screw.
7. Check the points for proper alignment (See Figure 6-24). If the points do not align properly, replace with another set of points, or bend the fixed contact supports. Never bend the breaker point.



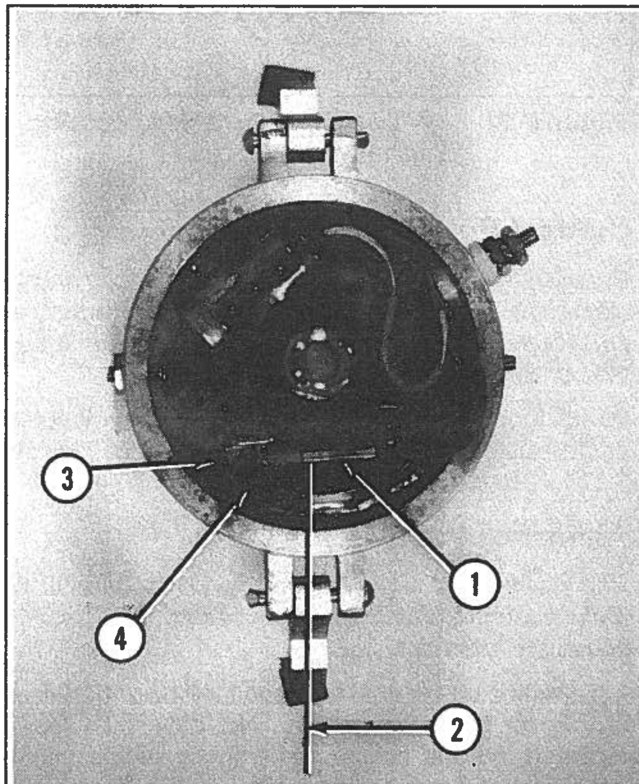
1. Fixed contact supports
2. Lateral misalignment
3. Proper lateral alignment

Figure 6-24. *Contact-Point Alignment*

8. Check point-spring tension.

   The contact-point-spring tension must fall within the specified limits. Weak tension will cause chatter, resulting in pitting and burning of points and ignition miss at high speeds, while excessive tension will cause undue wear of the contact points, cam and rubbing block. Contact-point tension should be checked with a spring gauge (Figure 6-25).

   A scale should be hooked to the breaker lever and a pull exerted at 900 to the breaker lever. The reading should be taken just as the points separate. The tension can be adjusted by bending the breaker-lever spring. If the tension is excessive, it can be decreased by pinching the spring carefully. To increase tension, remove the lever from the distributor so that the spring can be bent away from the lever. Avoid any excessive spring distortion.



1. Movable contact
2. Spring-tension gauge
3. Adjustment notch
4. Locking screw

Figure 6-25. *Contact-Lever Spring-Tension Check*

Optional Tach-Drive Lubrication Procedure:

On engines equipped with the optional Mallory tach-drive distributor, lubrication is required once a year.

1. With a **hand-operated grease gun only**, grease the fitting which is installed on the mechanical drive adapter with silicone grease or distributor cam lubricant.

2. **Stop** at the slightest amount of back-pressure.

At the beginning of each boating season only:

3. Remove tach-drive cable.
4. Remove the distributor tach-drive gear mechanism by removing the large hex nut with a suitable wrench.
5. Remove the drive gear and clean it with solvent.
6. Inspect for signs of excessive wear. If gear is in good condition, coat with grease and reinstall in distributor housing.
7. Tighten hex nut and grease fitting as required.
8. Reattach tachometer-drive cable and start engine to check operation.

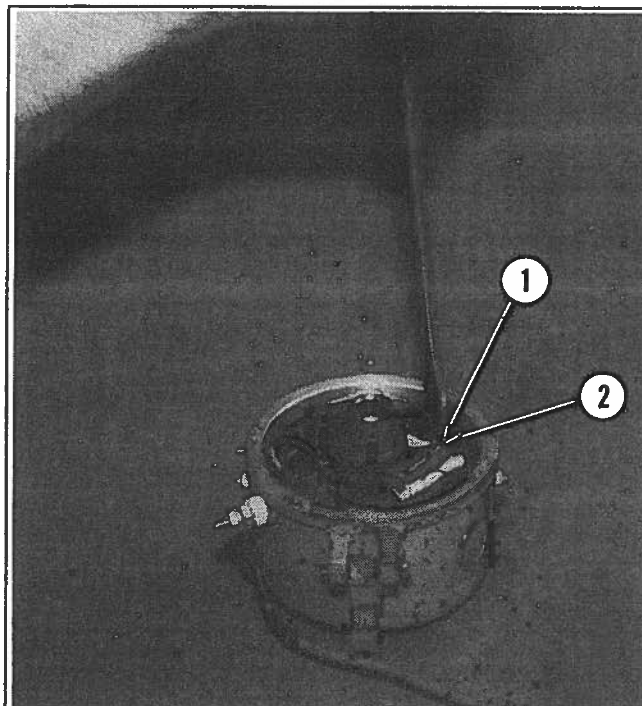
CONDENSER TESTING

1. Remove distributor cap.
2. Lift rotor off distributor shaft.
3. Remove condenser and breaker points and, using a magneto tester, test condenser for the following:
   a. Condenser capacity.
   b. Condenser leakage and for a short.
4. Replace condenser if test results are not within the specifications.
5. Replace the condenser and breaker points.
6. Replace the rotor onto the distributor shaft.

BREAKER-POINT ADJUSTMENT WITH FEELER GAUGE

IMPORTANT: The point gap (dwell) can be adjusted by two methods. It is preferred that the points be first adjusted with a feeler gauge, then checked with a dwell meter. Points, however, can also be adjusted as well as checked with a dwell meter. The dwell angle should be checked with the engine running.

1. Rotate the distributor until the breaker-lever rubbing block rests on the peak of the cam lobe, which will provide a maximum breaker-point opening.
2. Insert the correct feeler gauge between the breaker points.
3. Loosen the lockscrew and adjust the points to specifications (Figure 6-26).



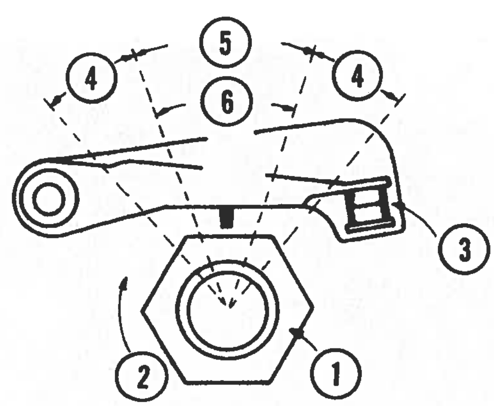
1. Adjustment screw 2. Locking screw

Figure 6-26. *Adjusting Point Gap*

DWELL ADJUSTMENT

1. Remove the distributor cap and rotor.
2. Connect the positive (+) dwell meter lead to the negative (–) side of the coil. Connect the negative (–) meter lead to ground.
3. Loosen point lockscrew slightly.
4. While cranking the engine, adjust the breaker point setting with a screwdriver to obtain the specified reading on the dwell meter and retighten the lockscrew. The dwell reading will be unsteady using this method.

IMPORTANT: The dwell angle increases as the point opening is decreased and vice versa (see Figure 6-27).



1. Cam
2. Direction of rotation
3. Breaker points
4. Open points
5. Points close
6. Dwell angle

Figure 6-27. Adjusting Dwell Angle

5. Install the rotor and distributor cap and recheck the dwell with the engine running.

IMPORTANT: The dwell should be checked between idle speed and 1750 engine rpm. Any dwell reading variations of more than 3° between idle and 1750 rpm would indicate that wear is occurring in the distributor.

Cam angle readings, taken at speeds above 1750 rpm, may prove unreliable on some dwell meters.

SPARK PLUG WIRES

1. Inspect the spark plug wires for damage.
2. Check the spark plug wires for continuity.
3. Replace any wires that are cracked, cut or have damaged spark plug boots.
4. Replace any wires that do not show continuity from end to end.
5. Reinstall the spark plug wires in the proper order.

IMPORTANT: Proper positioning of the spark plug wires is important to prevent crossfiring.

MALLORY DISTRIBUTOR REMOVAL

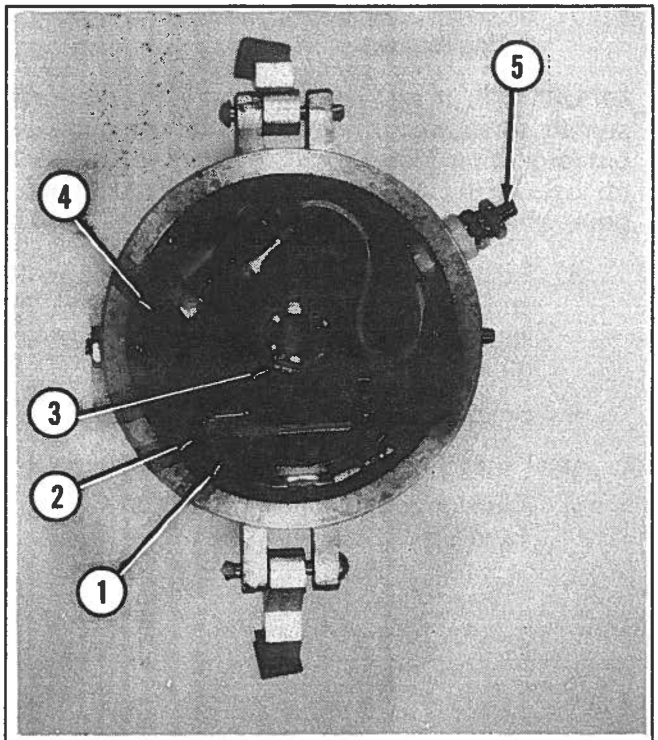
1. Remove distributor cap (two screws) and gasket. Do not remove plug wires from cap unless necessary.
2. Disconnect coil primary lead from distributor.
3. Crank or turn engine slowly. Align timing marks when rotor is pointing to the No. 1 terminal of distributor cap. If same distributor is to be reinstalled in the engine, mark the position of the distributor housing in relation to the engine so the distributor may be installed in the same position.
4. Remove distributor-retaining clamp.
5. Remove distributor.

IMPORTANT: To simplify distributor installation, do not turn crankshaft with distributor removed from engine.

MALLORY DISTRIBUTOR DISASSEMBLY

IMPORTANT: Do not disassemble distributor any further than required to complete repairs.

1. Lift rotor off distributor shaft.
2. Remove condenser and breaker points and test using a magneto tester.
3. Mark breaker plate location and remove the two retaining screws. Remove breaker plate.



1. Locking screw
2. Adjusting notch
3. Rotor alignment notch
4. Breaker plate
5. Primary terminal

Figure 6-28. *Distributor Components*

4. Remove pin from driving gear and shaft, and remove gear from shaft.
5. Remove washer(s) from shaft. (If there are two washers, the steel washer goes toward the housing and the brass washer toward the gear.)

IMPORTANT: Housing bushings are not serviced separately.

6. Check for side play between shaft and housing bushings. Maximum side play is 0.002 in. (0.05 mm).
7. Remove and check shaft for straightness by placing it in V-blocks and checking the run-out of the shaft with a dial indicator. Maximum run-out allowed is 0.002 in. (0.05 mm). Retain washer between advance mechanism and distributor housing.
8. Check cam lobes for wear. Cam and advance plate should fit tightly on shaft.

IMPORTANT: Shaft, advance mechanism and cam are serviced as an assembly and should not be disassembled (refer to parts manual).

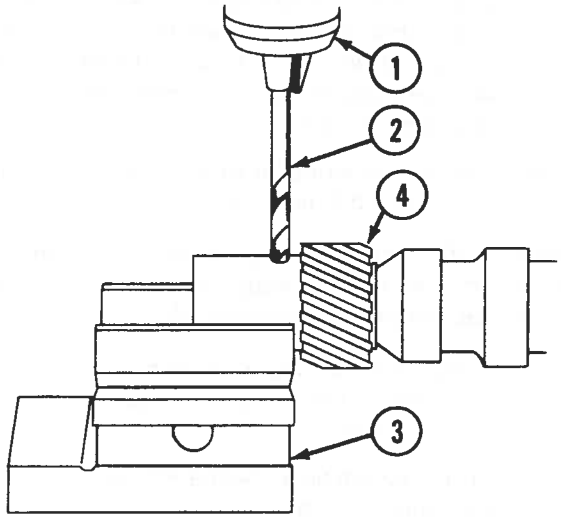
9. Check advance mechanism for free movement. Mechanism should return freely when released.
10. Lubricate advance mechanism with moisture-absorbing penetrating oil such as WD-40 or equivalent.

MALLORY DISTRIBUTOR REASSEMBLY

1. Install washer on shaft assembly and lubricate shaft with engine oil. Install shaft in housing.
2. Install washer(s) on shaft between housing and gear (if there are two washers, steel goes toward housing and brass goes toward gear).
3. If installing original driven gear, slide it onto the shaft and install roll pin.

IMPORTANT: The holes in the distributor-driven gear and distributor shaft are offset. The driven gear will fit on only one way so the holes line up. New driven gears come either with only one hole drilled or a dimple stamped in one side. It is recommended that a machine shop complete drilling of the new driven gear to install it. If new driven gear is the type with one hole, you may be able to drill the hole all the way through using Step 4.

4. If driven gear has one hole, put gear on shaft. Turn gear so hole in gear lines up with hole in shaft. Using drill press and 3/16-in. carbide-tipped bit, finish drilling through the other side of the gear.



1. Drill press
2. 3/26-in. carbide-tipped drill
3. V-block
4. New gear

Figure 6-29. *Drilling Of Distributor-Driven Gear*

5. Once hole is drilled, install roll pin to secure gear to shaft.
6. Install breaker plate using alignment mark to locate it properly.
7. Install points, condenser and primary terminal screw.

MALLORY DISTRIBUTOR INSTALLATION

Engine Not Disturbed:

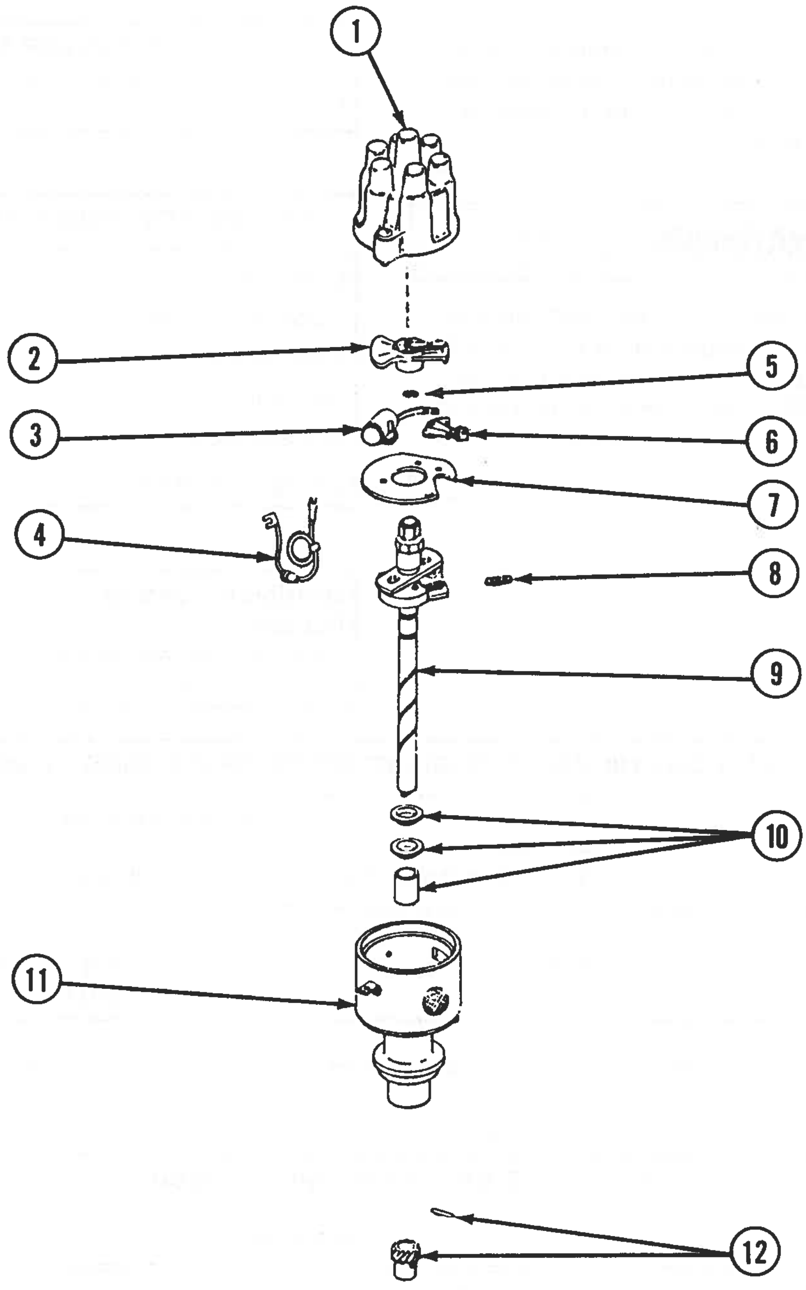
Distributor installation for an undisturbed engine crankshaft is as follows:

1. Install new gasket on distributor housing.
2. Turn rotor approximately 1/8 turn in a counterclockwise direction, past the mark previously scratched on distributor housing.
3. Work distributor down into position in engine block with distributor positioned as noted during removal.

IMPORTANT: It may be necessary to move rotor slightly to start gear into mesh with camshaft gear, but rotor should line up with the mark when distributor is down in place. Distributor shaft must enter oil pump shaft for complete installation.

4. Replace and tighten distributor hold-down bolt and clamp. Connect primary lead to coil. Also install spark plug and coil secondary wires if removed.
5. Set point gap and dwell.
6. Install rotor and cap.
7. Time ignition as outlined in Section 4, Tune-Up.

SYSTEMS WITH PRESTOLITE BREAKER-TYPE DISTRIBUTOR



1. Distributor cap
2. Rotor
3. Condenser
4. Lead assembly
5. Washer
6. Points
7. Plate
8. Spring
9. Shaft
10. Bearing package
11. Body
12. Gear package

Figure 6-30. *Prestolite Breaker-Type Distributor*

WARNING

Electrical and ignition system components on your Crusader marine engines are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement electrical or ignition system components which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

When servicing the electrical, ignition and fuel systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

DISTRIBUTOR LUBRICANTS
Distributor cam lubricant
Moisture-absorbing penetrating oil
Silicone grease

DISTRIBUTOR SEALANTS
Liquid neoprene

DISTRIBUTOR TOOLS OBTAINED LOCALLY
Dwell meter
Magneto analyzer
Remote starter switch
Timing light
Volt/ohmmeter
Spring-tension gauge

Distributor Fastener Location	Bolt Torque
Distributor clamp 3/8-16	20 lb-ft (27 N•m)

IGNITION COIL AND COIL RESISTOR SPECIFICATIONS (OHMS)		
	Crusader Coil Part No.	
Type	41080 Prestolite CAH	41062 Prestolite CAH
Primary resistance Secondary resistance Coil resistor	1.25-1.4 9,400-11,700 0.5-0.6	1.25-1.4 9,400-11,700 0.5-0.6

NOTE: These values are affected by the temperature of the coil and the coil resistor. Readings should, however, be checked at room temperature.

PRESTOLITE BREAKER-TYPE DISTRIBUTOR			
Item	Specification		
Type Used on Rotation Point gap Dwell angle	IBM - 7018 229 CID (3.8l) Right-hand (CW) 0.020 in. (0.51 mm) 36-41°	IBM - 7021 262 CID (4.3l) Right-hand (CW) 0.020 in. (0.51 mm) 36-41°	IBM - 7011 305, 350, and 454 CID Right-hand (CW) 0.016 in. (0.41 mm) 28-31°
Contact-spring tension	20-27 oz. (5.55-7.50 N)	20-27 oz. (5.55-7.50 N)	20-27 oz. (5.55-7.50 N)
Condenser	0.18-0.25 µF	0.18-0.25 µF	0.25-0.28 µF

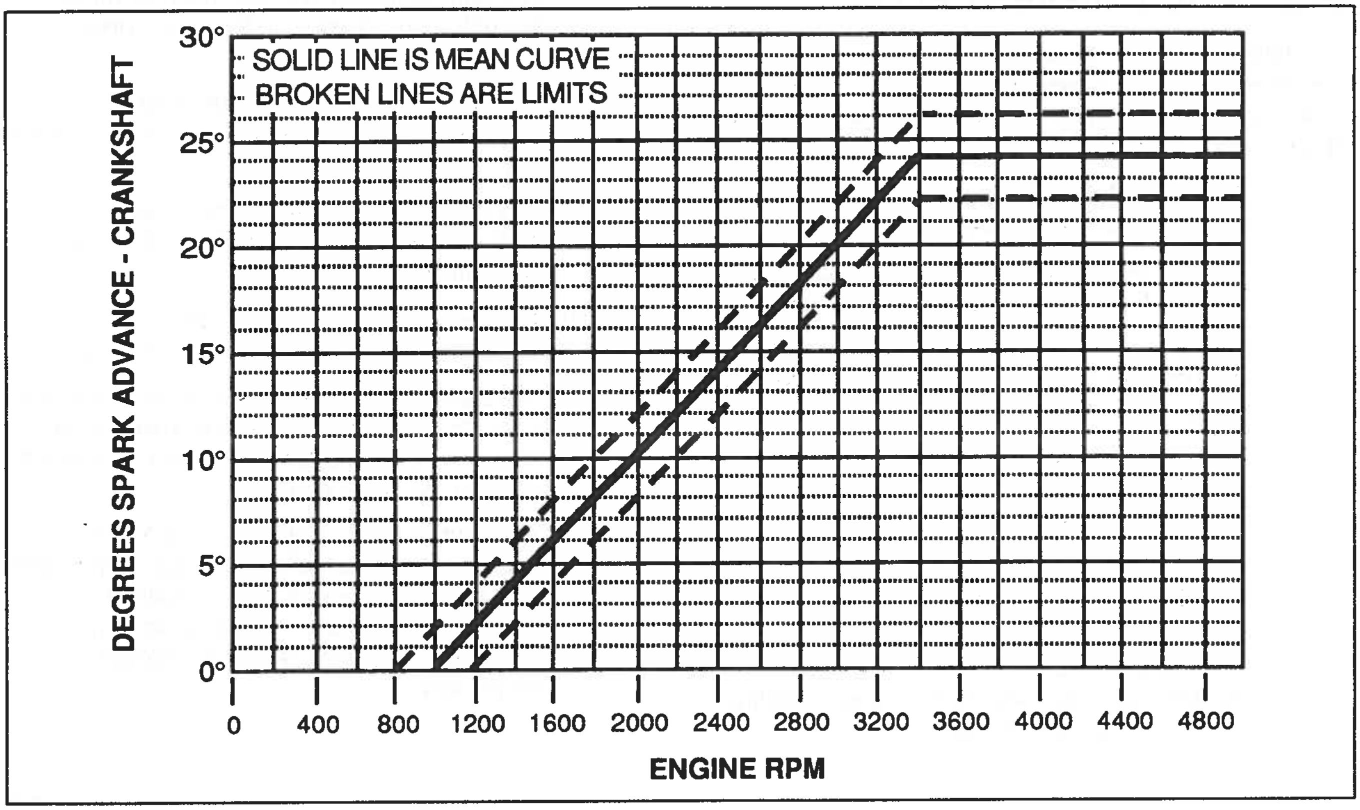


Figure 6-31. *Prestolite Breaker-Type Distributor Spark-Advance Curve For 229 CID Engine*

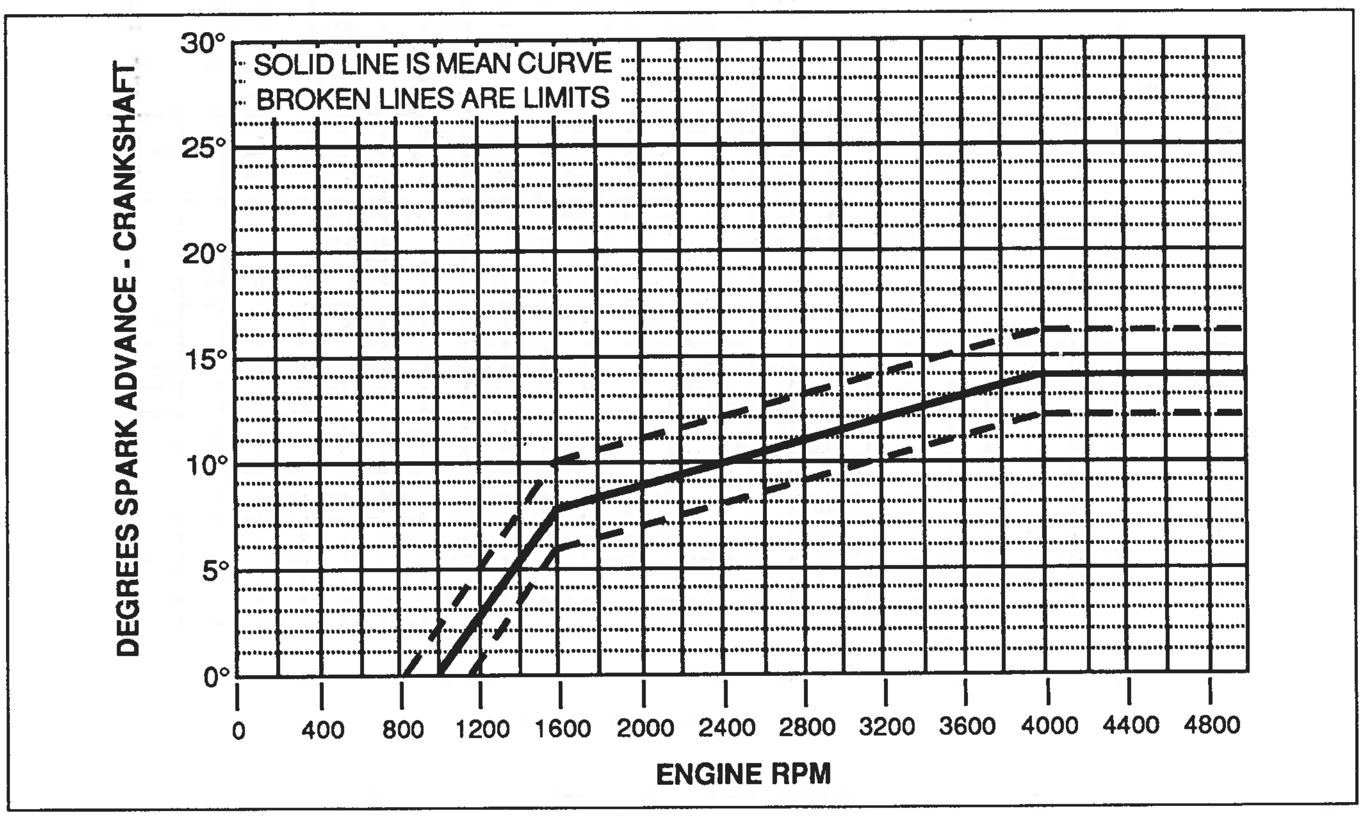


Figure 6-32. *Prestolite Breaker-Type Distributor Spark-Advance Curve For 262 CID Engine*

ELECTRIC CURRENT FLOW

The following is a method for tracing the positive current flow from the battery through the ignition system to the spark plugs. See Section 6.6, Wiring Diagrams, for a diagram of the electrical connections.

1. Twelve (12) volts of power flow from the battery to the starter solenoid.
2. The current flows from the starter solenoid, through the red wire, to the circuit breaker.
3. The current flows from the circuit breaker, through the red wire, to the terminal (No. 8) in the plug connector.
4. The current flows from terminal (No. 8), through the red wire, to a 20-amp fuse in the instrument panel.
5. The current flows from the 20-amp fuse, through a red/purple wire, to the "BAT" terminal on the ignition switch.
6. If the ignition switch is in the "RUN" or "START" position, the current flows from the "BAT" terminal to the "IGN" terminal.
7. The current flows from the "IGN" terminal, through a purple wire, to the plug connector terminal (No. 7).
8. The current flows from the terminal (No. 7) plug connector, through the purple wire, to the coil resistor.
9. The current flows from the coil resistor, through the purple wire, to the coil's positive (+) terminal.
10. The breaker points in the distributor are connected to the coil's negative terminal.
11. The breaker points open, causing high voltage to be discharged from the coil tower, to the center tower of the distributor, and through the rotor, to the spark plugs.
12. The ignition bypass system supplies full battery voltage to the ignition coil. The starter solenoid's "R" terminal has 12 volts during cranking only. Current passes from the "R" terminal, to the coil's terminal, through a purple wire.

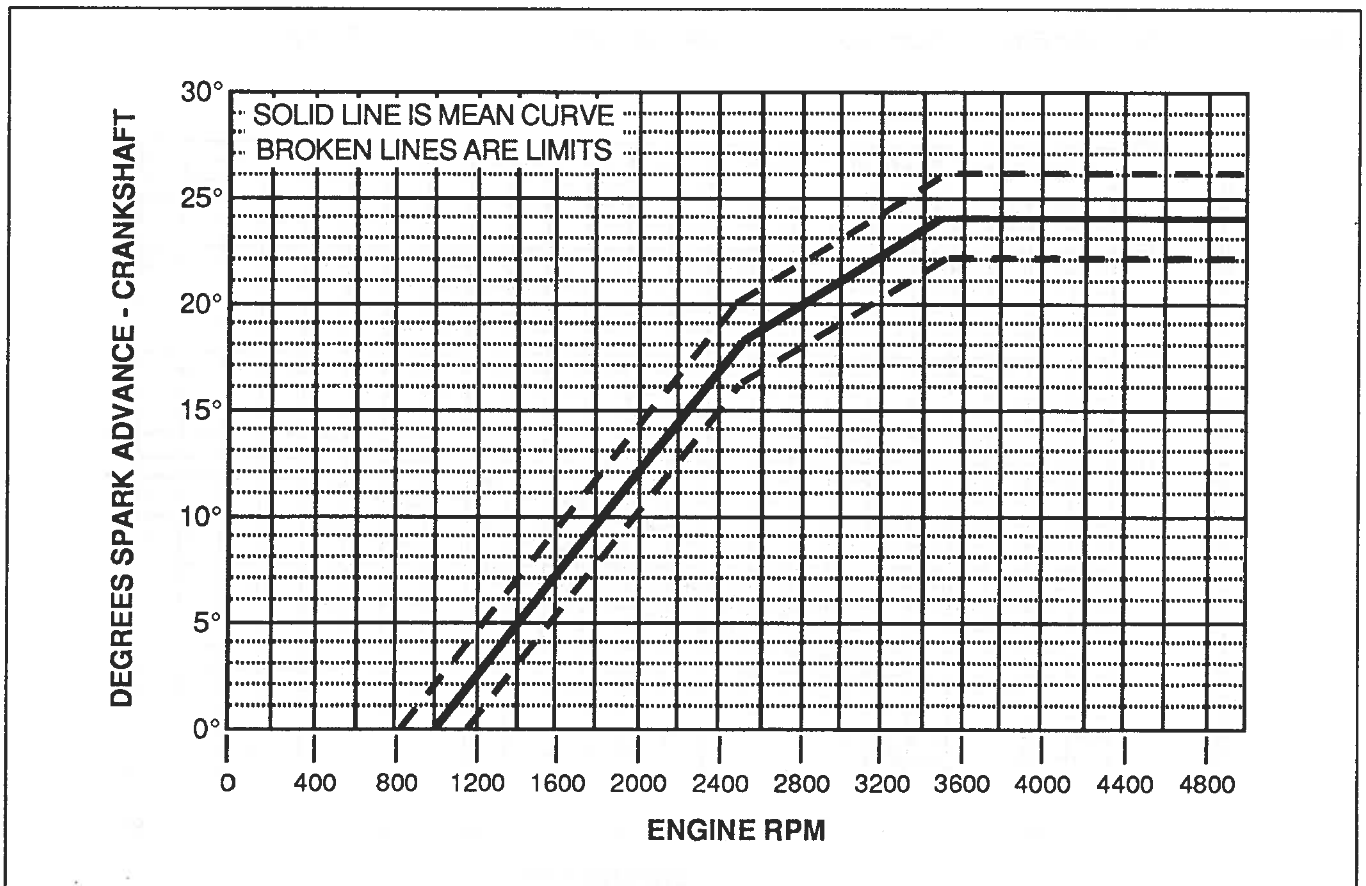


Figure 6-33. *Prestolite Breaker-Type Distributor Spark-Advance Curve For 305, 350, And 454 CID Engines*

COIL TESTING

Using a magneto tester, test the coil for the following:

1. Coil power.
2. Coil surface insulation.
3. Coil continuity.
4. Primary resistance.
5. Secondary resistance.

Replace coil if test results are not within the specifications shown in the Ignition Coil and Coil Resistor Specifications Table.

COIL RESISTOR TESTING

1. Disconnect wires from the coil resistor.
2. Connect the ohmmeter leads to each end of the coil resistor.
3. Replace resistor if reading is not within specifications shown in the Ignition Coil and Coil Resistor Specifications Table.
4. Reconnect wires to the coil resistor.

INSPECTION ON ENGINE

1. Remove distributor cap and inspect for cracks and marks of crossfiring. Replace if necessary.
2. Make sure that all distributor wire terminals are clean and tight.
3. Clean and inspect rotor and breaker assembly. Replace if necessary.
4. Check distributor bushings for wear. Attach dial indicator to distributor housing. Position registering point of dial indicator to rest on distributor shaft. Shaft must not have more than 0.002 in. (0.05 mm) side play with bushings when shaft is pushed back and forth by hand.
5. Check for sticking centrifugal weights. Grip distributor shaft (or rotor) and twist in direction of rotation, then release. Shaft should snap back to its original position. If it hangs up, returns sluggishly or slowly, shaft assembly must be replaced or rebuilt.

PRESTOLITE DISTRIBUTOR MAINTENANCE

WARNING

When performing the procedures of this section, be sure to observe the following:

Be sure that engine compartment is well ventilated and that no gasoline vapors are present, to avoid the possibility of fire.

Be sure to keep hands, feet and clothing clear of the engine's moving parts.

Do not touch or disconnect any ignition system parts while engine is running.

Do not reverse the battery cable connections. The system uses negative (–) ground.

To check and adjust the Prestolite Breaker-Type Distributor, use the following procedure:

1. Loosen the distributor cap's clamp-retaining screws.
2. Remove the distributor cap.
3. Clean the cap with warm soap and water and blow off any particles with compressed air.
4. Check the cap contacts for excessive burning or corrosion. Check the center contact for deterioration.

IMPORTANT: Most distributor caps for marine use should have brass contacts.

5. Check the cap for cracks or carbon tracks.
6. Lift the rotor up off the distributor shaft.
7. Check the rotor for a burned or corroded center contact and electrode tip.
8. Check the rotor for cracks and carbon tracks.
9. Install rotor onto the shaft. Make sure to line up the rotor with the keyway on the distributor shaft. Be sure the rotor is completely seated on the distributor shaft.
10. Place cap on the distributor. Make sure the notch on the bottom edge lines up with the notch in the distributor, allowing the cap to be firmly seated.
11. Tighten the clamp-retaining screws.
12. Install spark plug wires (if removed) as shown in Figures 6-34 and 6-35.

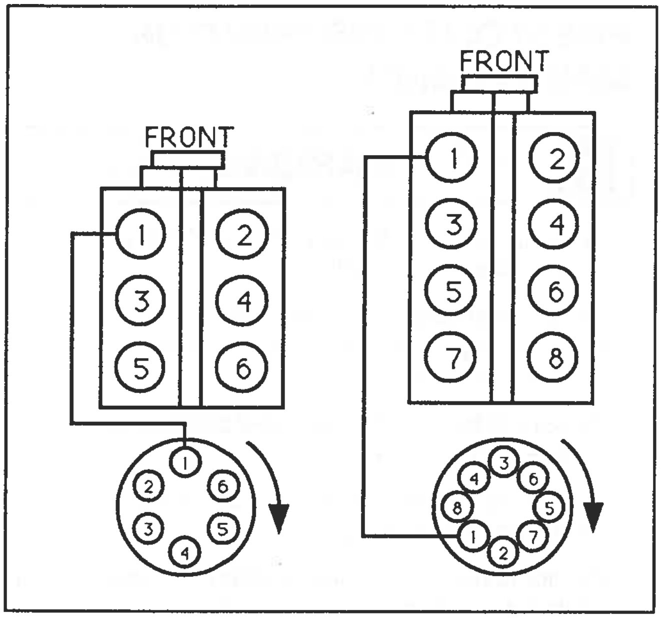


Figure 6-34. *Ignition Wiring (Left-Hand Rotation Engine)*

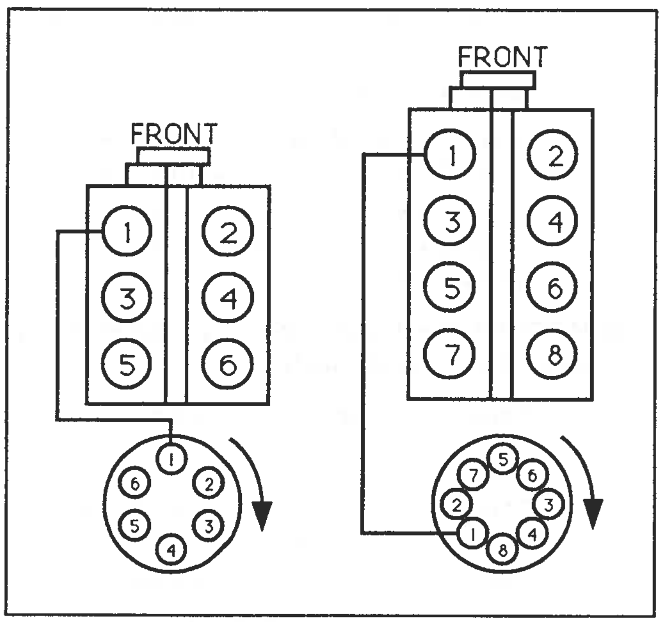


Figure 6-35. *Ignition Wiring (Right-Hand Rotation Engine)*

Contact Points:

Examine the contact points for dirt, wear, pitting, and misalignment. Dirty points should be cleaned. Normal point condition exists when an overall grey color appears on the contact surface.

Check for point resistance with a sensitive voltmeter or point-resistance meter. A voltage drop of less than 0.125 V across the points should exist.

Abnormal Point Wear:

Points which have been operating for a period of time have a rough surface, but this does not mean that the points are worn out.

If the points burn or pit, they soon will become unsatisfactory for further operation. Not only must they be replaced, but the ignition system and engine must be checked to determine the cause. Unless this condition is corrected, new points will provide no better service than the old points.

Cleaning of Points:

To clean the contact points, use the following procedure:

1. Dirty contact points should be dressed with a few strokes of clean, fine-cut contact file. File should not have been used on other metals and should not be greasy or dirty.

IMPORTANT: Never use emery cloth to clean contact points.

2. Contact surfaces, after considerable use, may not appear bright and smooth, but this is not necessarily an indication that they are functioning unsatisfactorily. Do not attempt to remove all roughness nor dress point surfaces down smoothly. Merely remove scale or dirt.
3. Badly burned or pitted contact points should be replaced and the cause of the trouble determined and corrected.

Burning of Points:

Contact-point burning results from high voltage, presence of oil or other foreign material, defective condenser or improper point adjustment.

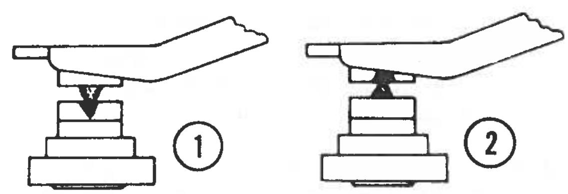
High voltage causes excessively high current flow through the contact points which causes them to burn rapidly. High voltage can result from an improperly adjusted or inoperative voltage regulator.

Oil or crankcase vapors, which work up into the distributor and become deposited on the point surfaces, also cause them to burn rapidly.

If a contact-point opening is too small (cam angle to large), points will be closed too long. The average current flow through the points will be too high, thus causing the points to burn rapidly and allowing the existence of arcing between points.

Pitting of Points:

Contact point pitting results from an out-of-balance condition in the ignition system. This causes the transfer of material from one point to other so that a tip builds up on one point while a pit forms in the other (see Figure 6-36).



1. Negative to positive 2. Positive to negative

Figure 6-36. *Contact-Point Pitting*

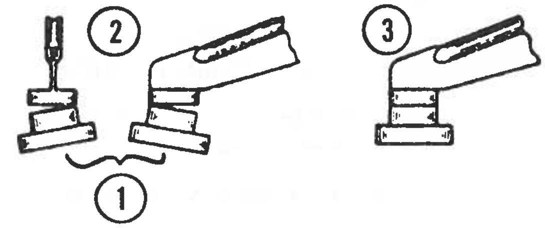
If the points are pitted (see Figure 6-36), the condenser should be checked for proper capacity.

Points Replacement:

1. Remove the primary lead from the primary terminal on the distributor. Remove the primary-terminal screw and nut from the distributor. (Use care not to lose the two insulator bushings in the distributor housing.) Remove the condenser lead and point from the primary-terminal screw.
2. Remove the contact-set-attaching screw and lift the contact point set from the breaker plate.
3. Clean any oil and dirt from the breaker plate.

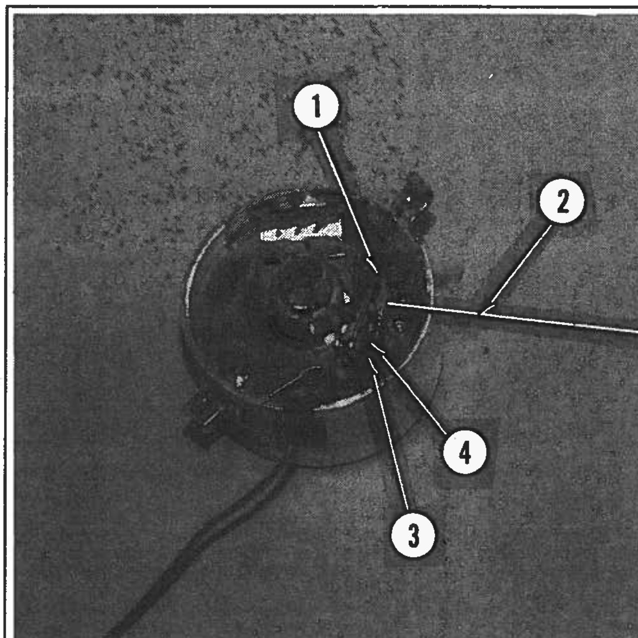
IMPORTANT: Carefully wipe any protective film from point set prior to installation.

4. Place a small amount of distributor cam lubricant on the distributor cam. Place two or three drops of engine oil on the wick in the top of the distributor shaft.
5. Place a new contact-point assembly in position on the breaker plate and install the attaching screw.
6. Place the primary terminal screw through the condenser and point leads. Install the primary screw through the two insulator bushings in the distributor housing. Install the primary-terminal locknut, primary lead, and primary-lead retaining nut to the primary-terminal screw.
7. Check the points from proper alignment (see Figure 6-37). If the points do not align properly, replace with another set of points, or bend the fixed contact supports. Never bend the breaker point.



1. Fixed contact supports
2. Lateral misalignment
3. Proper lateral alignment

Figure 6-37. *Contact-Point Alignment*



1. Movable contact 3. Adjustment notch
2. Spring-tension gauge 4. Locking screw

Figure 6-38. *Contact-Lever Spring-Tension Check*

CONDENSER TESTING

1. Remove distributor cap.
2. Lift rotor off distributor shaft.
3. Remove condenser and breaker points and, using a magneto tester, test condenser for the following:
   a. Condenser capacity.
   b. Condenser leakage and a short.
4. Replace condenser if test results are not within the specifications.
5. Replace the condenser and breaker points.
6. Replace the rotor onto the distributor shaft.

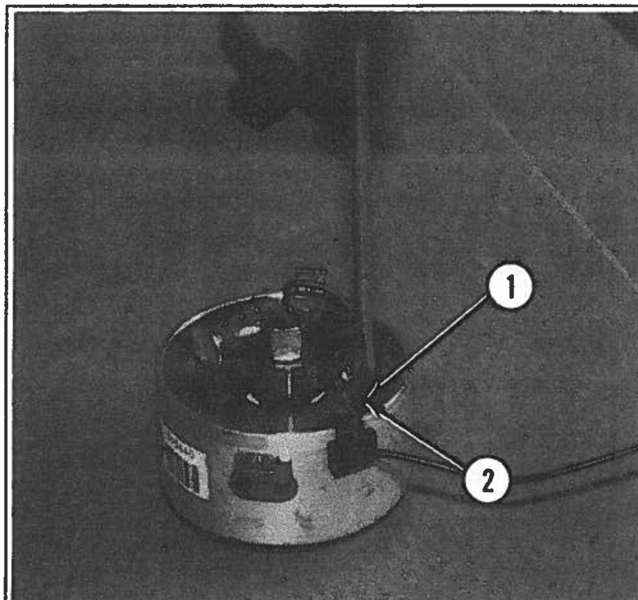
BREAKER-POINT ADJUSTMENT WITH FEELER GAUGE

IMPORTANT: The point gap (dwell) can be adjusted by two methods. It is preferred that the points be first adjusted with a feeler gauge, then checked with a dwell meter. Points can also be adjusted as well as checked with a dwell meter. The dwell angle should be checked with the engine running.

1. Rotate the distributor until the breaker lever rubbing block rests on the peak of the cam lobe, which will provide a maximum breaker-point opening.

NOTE: On the engine model 229 CID V-6 with LH rotation, a rounded lobe must be aligned with the rubbing block. On a RH rotation engine, a sharp lobe is aligned with the rubbing block.

2. Insert the correct feeler gauge between the breaker points.
3. Loosen the lockscrew and adjust the points to specifications (Figure 6-39).



1. Adjustment screw 2. Locking screw

Figure 6-39. *Adjusting Point Gap*

DWELL ADJUSTMENT

1. Remove the distributor cap and rotor.
2. Connect the positive (+) dwell meter lead to the negative (–) side of the coil. Connect the negative (–) meter lead to ground.
3. Loosen point lockscrew slightly.
4. While cranking the engine, adjust the breaker-point setting with a screwdriver to obtain the specified reading on the dwell meter and retighten the lockscrew. The dwell reading will be unsteady using this method.

IMPORTANT: The dwell angle increases as the point opening is decreased and vice versa (see Figure 6-40).

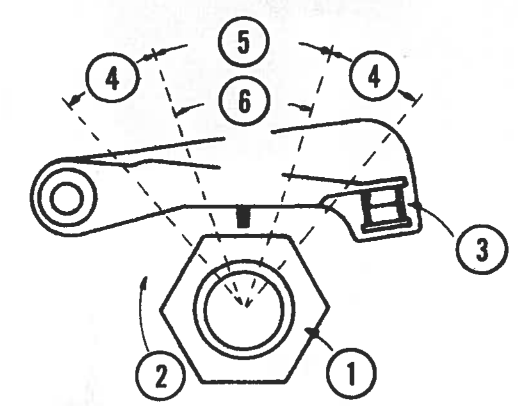


Figure 6-40. Adjusting Dwell Angle

5. Install the rotor and distributor cap and recheck the dwell with the engine running.

IMPORTANT: The dwell should be checked between idle speed and 1750 engine rpm. Any dwell reading variations of more than 3° between idle and 1750 rpm would indicate that wear is occurring in the distributor.

Cam-angle readings, taken at speeds above 1750 rpm, may prove unreliable on some dwell meters.

SPARK PLUG WIRES

1. Inspect the spark plug wires for damage.
2. Check the spark plug wires for continuity.
3. Replace any wires that are cracked, cut or have damaged spark plug boots.
4. Replace any wires that do not show continuity from end to end.
5. Reinstall the spark plug wires in the proper order.

IMPORTANT: Proper positioning of the spark plug wires is important to prevent crossfiring.

PRESTOLITE DISTRIBUTOR REMOVAL

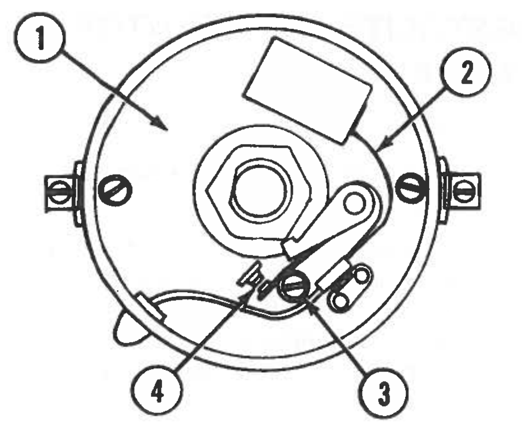
1. Disconnect coil primary lead from coil.
2. Remove distributor cap, leaving all wires in place.
3. Crank engine slowly to align timing marks and position rotor so it is pointing to the No. 1 terminal of distributor cap. If same distributor is to be reinstalled in engine, mark position of distributor housing in relation to engine so that distributor may be installed in same position.
4. Remove distributor and its retaining clamp.

IMPORTANT: To simplify reinstallation, DO NOT turn crankshaft with distributor removed.

PRESTOLITE DISTRIBUTOR DISASSEMBLY

IMPORTANT: DO NOT disassemble distributor unless necessary. When checking for worn parts, refer to "Inspection on Engine," preceding. When disassembling distributor, use soft wood blocks to hold it in a vise.

1. Lift rotor off.
2. Remove breaker plate and lift from housing.
3. Remove primary-terminal screw and washer. Remove condenser and contact points from plate.

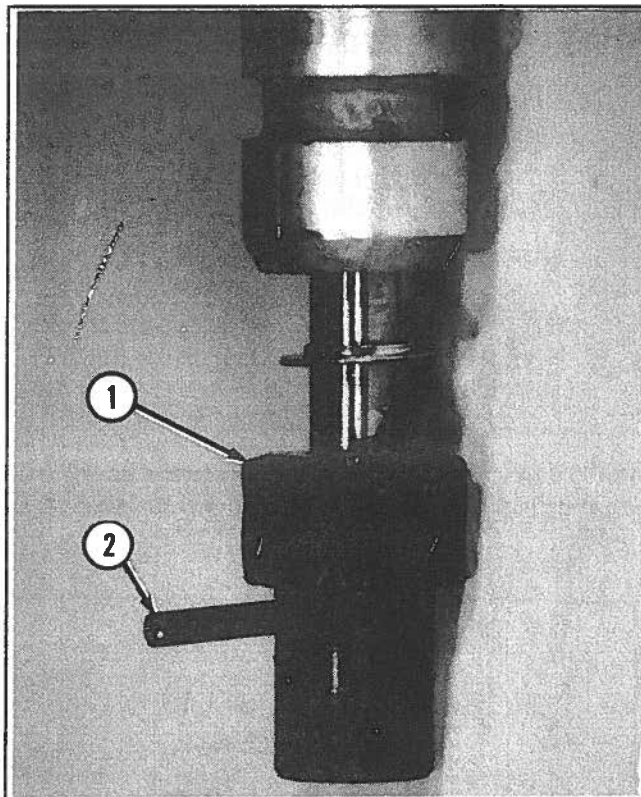


1. Breaker plate
2. Condenser lead strap
3. Primary terminal screw
4. Breaker points

Figure 6-41. *Removing Contact Points And Condenser From Distributor*

NOTE: Proceed with steps 4, 5, 6 and 7 ONLY if shaft assembly or shaft bushings in housing are to be replaced.

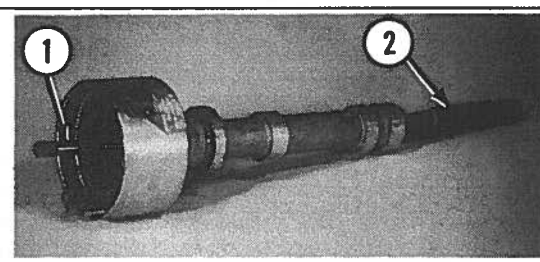
4. Drive pin from gear and remove gear.



1. Gear 2. Pin

Figure 6-42. *Removing Distributor-Driven Gear From Distributor*

5. Remove shaft assembly.
6. Thread a 1/2 in. x 13 or 1/2 in. x 20 tap into the upper shaft bushing. Using a punch, drive tap and bushing out of housing (Figure 6-43).
7. Repeat Step 6 for lower bushing.



1. Tap 2. Punch

Figure 6-43. *Removing Upper Bushing From Prestolite Distributor*

CLEANING AND INSPECTION

1. Wash breaker plate, gear, collar and all washers and fasteners in cleaning solvent. If bushings are removed, wash housing in solvent after removing coil lead wire. Do not wash points, condenser or any nonmetal parts in solvent.
2. Inspect contact points. Replace if necessary.
3. Inspect advance weights for wear or burrs and free fit on their pins. If worn, replace distributor shaft assembly.
4. Inspect cam for wear or roughness. Check cam fit on end of shaft. It should be free but not loose. If worn, replace distributor.

PRESTOLITE DISTRIBUTOR REASSEMBLY

1. If bushings were removed from housing, drive in new bushings, using appropriate bushing driver. Upper bushing will seat; lower bushing should be driven slightly beyond the point of being flush.
2. Replace shaft assembly.
3. Place washer on shaft (lip away from gear).
4. Place drive gear on shaft and install new roll pin.
5. Install breaker points and condenser. Attach point spring, condenser strap and coil lead to primary terminal, and install screw.
6. Install breaker plate.
7. Set point gap and point-spring tension as outlined.
8. Place rotor on shaft, aligning flat side of shaft with flat surface in rotor.
9. Install cap.

PRESTOLITE DISTRIBUTOR INSTALLATION

NOTE: The following procedure applies to engine models 262 CID (V-6) and all V-8.

Engine Not Disturbed:

Distributor installation for an undisturbed engine crankshaft is as follows:

1. Install new gasket on distributor housing.
2. Turn rotor approximately 1/8 turn in a counterclockwise direction, past the mark previously scratched on distributor housing.
3. Work distributor down into position in engine block with distributor positioned as noted during removal.

IMPORTANT: It may be necessary to move rotor slightly to start gear into mesh with camshaft gear, but rotor should line up with the mark when distributor is down in place. Distributor shaft must enter oil pump shaft for complete installation.

4. Replace and tighten distributor-hold-down bolt and clamp. Connect primary lead to coil. Also install spark plug and coil secondary wires if removed.
5. Set point gap and dwell.
6. Install rotor and cap.
7. Time ignition as outlined in Section 4, Tune-Up.

Engine Disturbed:

Distributor installation for a disturbed engine crankshaft is as follows:

1. Locate No. 1 piston in firing position by either of two methods:
   a. Remove No. 1 spark plug and, with finger on plug hole, crank engine until compression is felt in No. 1 cylinder. Continue cranking until pointer lines up with timing mark on crankshaft pulley, or
   b. Remove rocker cover and crank engine until No. 1 intake valve closes, continuing to crank slowly until pointer lines up with timing mark on crankshaft pulley.
2. Position distributor in its opening in the block.
3. Position rotor to point toward No. 1 cylinder on cap, then turn rotor counterclockwise approximately 1/8 turn more and push distributor down to engage camshaft. It may

be necessary to rotate rotor slightly until camshaft engagement is felt.

4. While pressing down firmly on distributor housing, engage starter a few times to make sure oil pump shaft is engaged. Install hold-down clamp and bolt, and snug up bolt.
5. Turn distributor body slightly until points just open and tighten distributor clamp bolt.
6. Place distributor cap in position and check that rotor lines up with terminal for No. 1 spark plug.
7. Install cap and distributor primary lead to the coil. Check all high-tension wire connections and connect spark plug wires if they have been removed. Wires must be installed in their proper location.
8. Set point gap and dwell.
9. Time ignition as outlined in Section 4, Tune-Up.

PRESTOLITE DISTRIBUTOR INSTALLATION

NOTE: The following procedure applies only to the engine model 229 CID:

Engine Not Disturbed:

1. Install distributor shaft into engine. Make certain that a rounded lobe is aligned with rubbing block on 229 V-6 LH rotation, or a sharp lobe is aligned with rubbing block on Engine Model 229 CID V-6 RH rotation.
2. Align marks made at time of removal, and tighten clamp to specifications.
3. Set engine timing with timing light.

Engine Disturbed:

1. Rotate engine (in normal direction of rotation) until timing mark on torsional damper lines up with (TDC-0) on timing tab and engine is in No. 1 firing position.
2. Look closely at the cam in the distributor. You will notice that three of the lobes have a sharper profile than the other three. They are situated sharp-round-sharp-round, etc., (engine model 229 V-6 only).

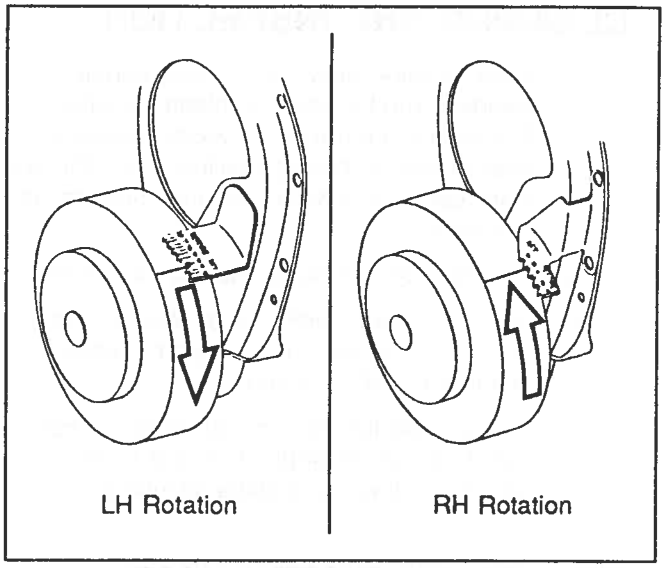
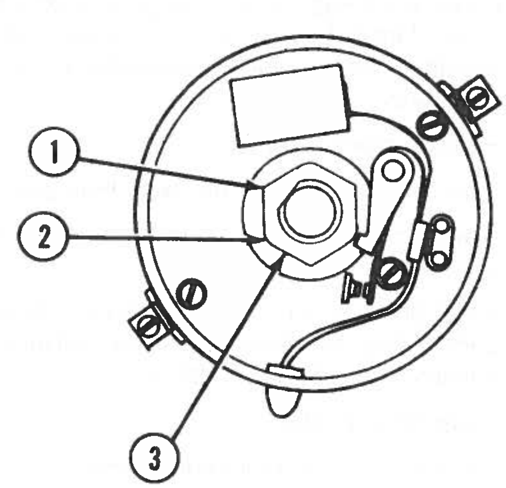


Figure 6-44. *Engine Timing Marks*

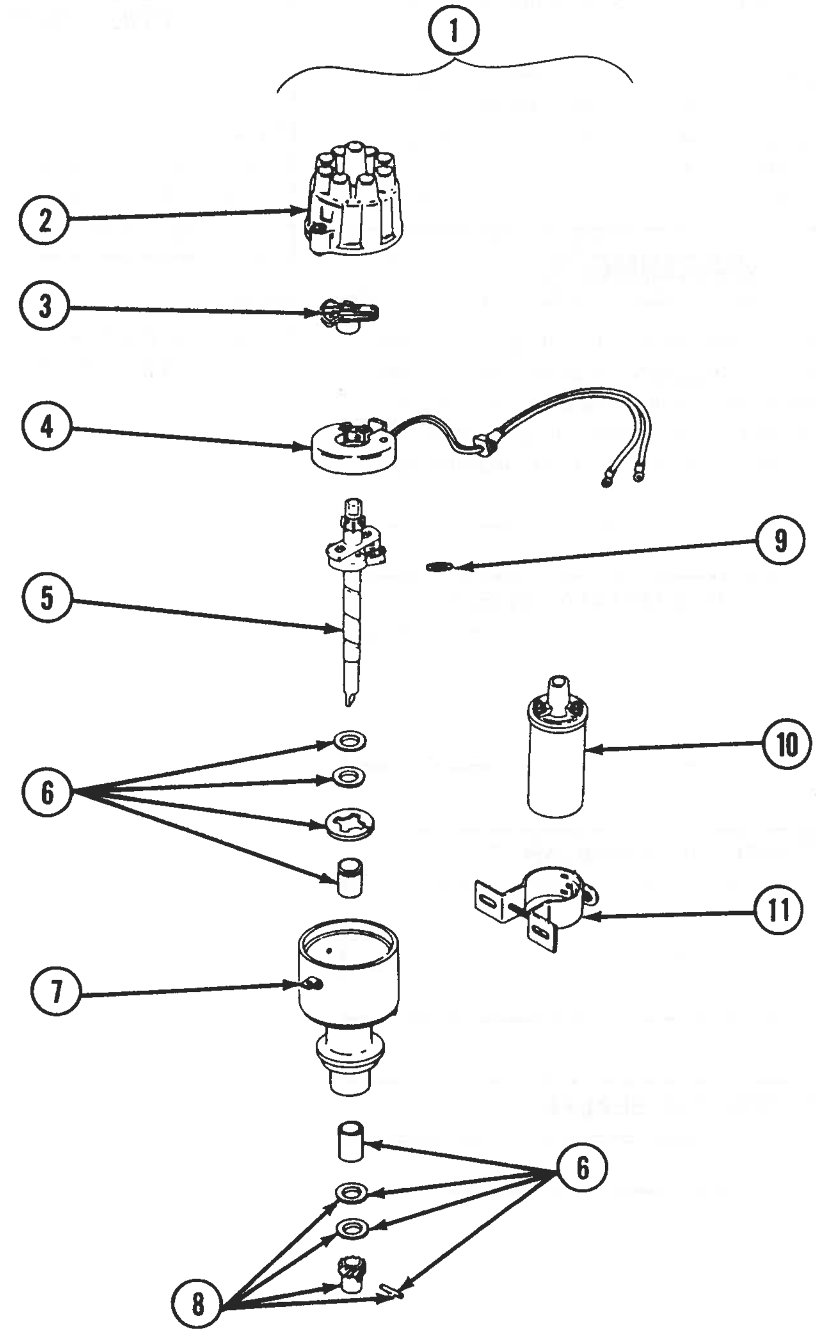


1. Sharp lobe
2. Rounded lobe
3. Cam

Figure 6-45. *Distributor Cam*

3. Install distributor into engine so that the rotor is aligned with the No. 1 spark plug tower. On engine model 229 CID V-6 LH rotation, a rounded lobe must be aligned with rubbing block of breaker points. On engine model 229 CID V-6 RH rotation, a sharp lobe must be aligned with rubbing block of breaker points.
4. Secure distributor with clamp and check engine timing with timing light.

SYSTEMS WITH PRESTOLITE BREAKERLESS DISTRIBUTOR



1. Distributor assembly
2. Distributor cap
3. Rotor
4. Circuit board and plate assembly sensor
5. Shaft and cam
6. Bearing package
7. Body
8. Gear package
9. Spring
10. High output, B.I.D. coil
11. Ignition coil bracket

Figure 6-46. *Prestolite Breakerless Distributor*

⚠ WARNING

Electrical and ignition system components on your Crusader marine engines are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement electrical or ignition system components which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

⚠ WARNING

When servicing the electrical, ignition and fuel systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

DISTRIBUTOR TOOLS OBTAINED LOCALLY
Remote starter switch
Timing light
Volt/ohmmeter

DISTRIBUTOR LUBRICANTS
Distributor cam lubricant
Moisture-absorbing penetrating oil
Silicone grease

DISTRIBUTOR SEALANTS
Liquid neoprene

Distributor Fastener Location	Bolt Torque
Distributor clamp 3/8-16	20 lb-ft (27 N•m)

COIL SPECIFICATIONS (OHMS)	
	Crusader Coil Part No.
Type	37068 Prestolite - CCB
Primary resistance	1.25-1.4
Secondary resistance	9,400-11,700

NOTE: These values are affected by the temperature of the coil and the coil resistor. Readings should, however, be checked at room temperature.

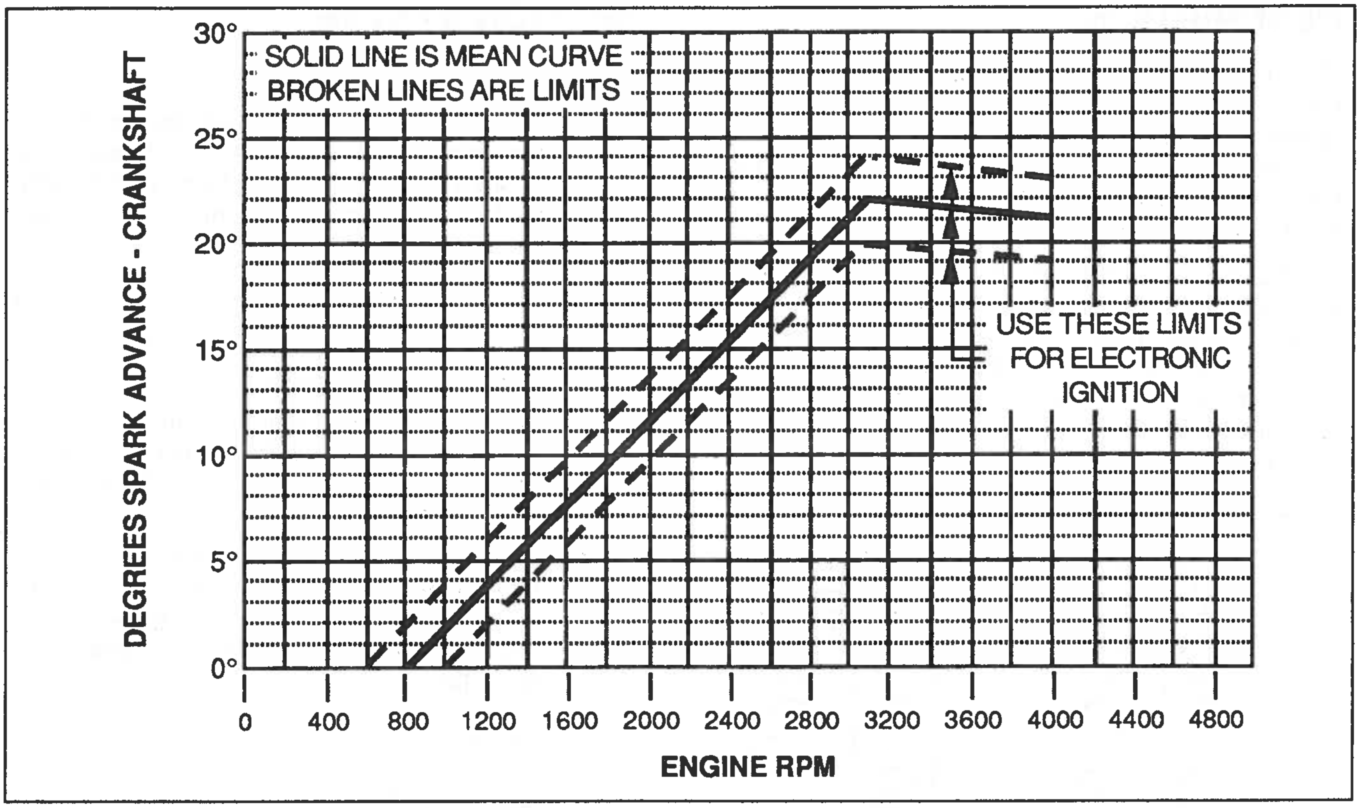


Figure 6-47. *Prestolite Breakerless Distributor Spark-Advance Curve For 305, 350, And 454 CID Engines*

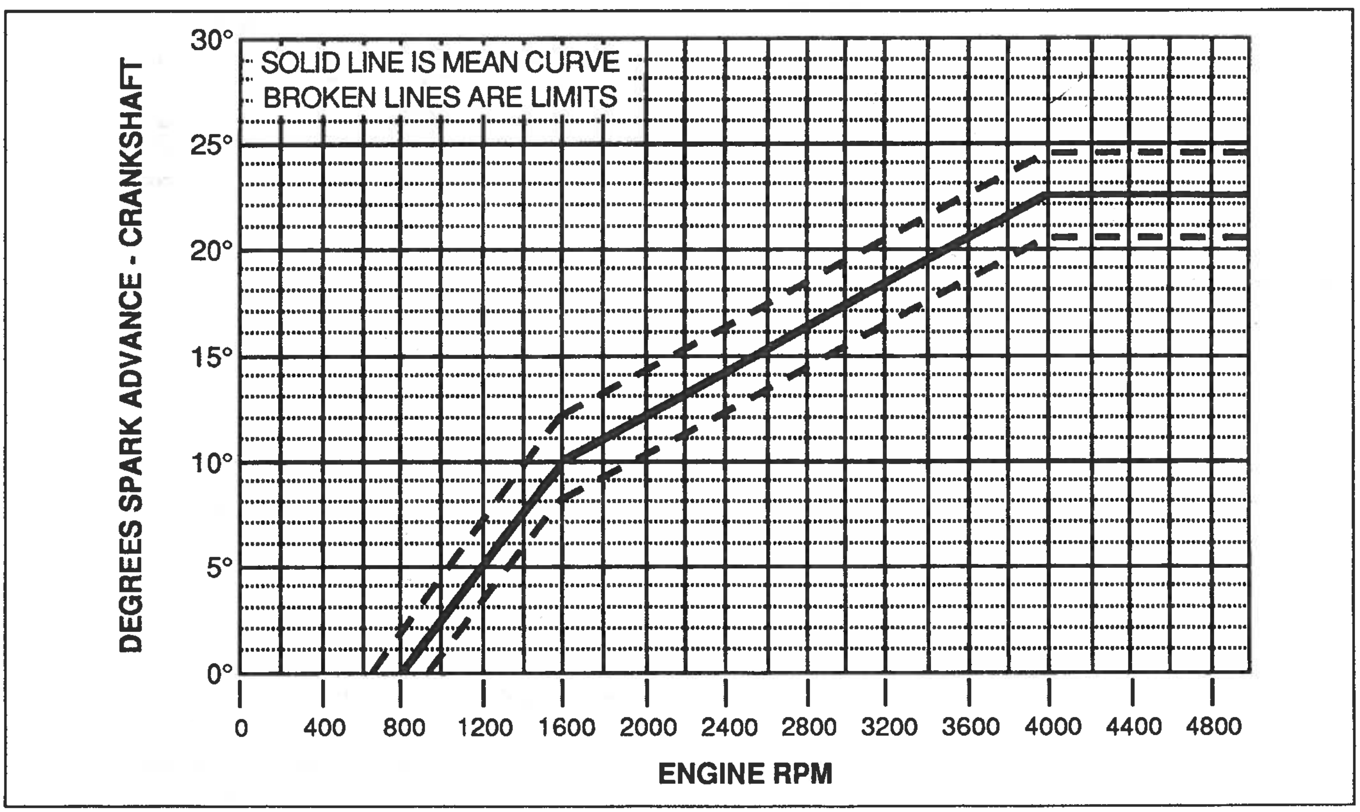


Figure 6-48. *Prestolite Breakerless Distributor Spark-Advance Curve For 502 CID Engine*

DESCRIPTION

The Prestolite Breakerless Ignition Distributor (B.I.D.) is basically of conventional design using a centrifugal advance mechanism to control timing. A sensor and trigger wheel, however, replace the points and condenser in the distributor and control the precise timing needed to fire the spark plugs.

The Electronic Control Unit controls timing and dwell by accurately making and breaking the ignition coil primary circuit. The electronic control unit is a self-contained solid-state device which is encapsulated with potting compound to provide a vibration- and moisture-proof barrier. It is not repairable and, if necessary, must be replaced as a complete assembly.

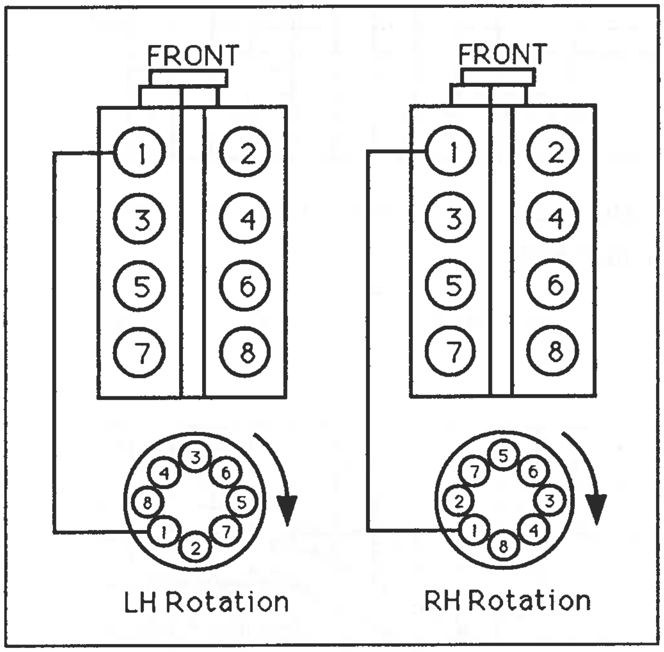


Figure 6-49. *Ignition Wiring*

IGNITION SYSTEM CIRCUITRY TEST

NOTE: Most no-start problems will be the result of one faulty component. Ignition systems, however, may develop more than one problem. Complete the entire troubleshooting procedure before returning the boat to service.

Perform the following tests using a 0-20 VDC voltmeter.

1. Position the trigger wheel so the sensor is located between two teeth.
2. Turn on the ignition switch. Connect a voltmeter (V1) across the battery terminals. The reading should be 12-13 V. If the battery is low, charge it.
3. Connect the voltmeter (V2) between the coil (positive terminal) and ground. The reading should be within one volt of the battery voltage. If reading is low, perform Voltage Drop Test.

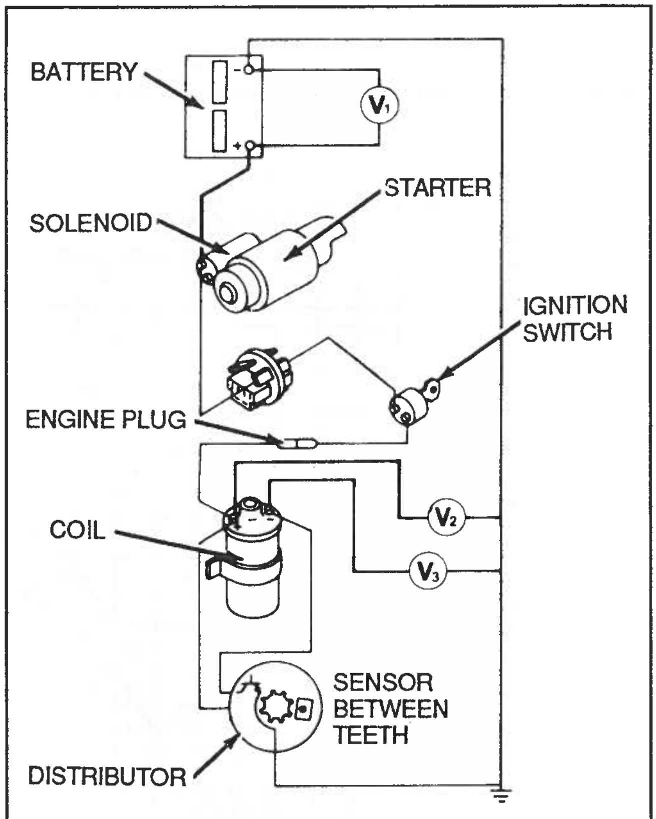


Figure 6-50. *Ignition Wiring*

4. Connect the voltmeter (V3) between the coil (negative terminal) and ground. Reading should be 4-8 V. If reading is 4- 8 V, proceed to Step 8.

5. If reading is less than 4 V, remove the wires from the coil (negative terminal). Recheck voltage reading. If the reading is now 12-13 V, it is an indication that the coil primary winding has continuity and the electronic sensor is shorted. Replace the electronic sensor in the distributor.
6. If the reading did not change (still reads low), it is an indication of an open primary winding in the coil. Replace the coil.
7. If the voltage reading in Step 4 is greater than 8 V, this indicates an open ground circuit (see Voltage Drop Test), open transistor or shorted coil (primary). Check distributor for good ground. If OK, replace the electronic sensor in the distributor.
8. Place a screwdriver in front of the sensor face. A spark should occur between the coil negative terminal and ground with the voltage now reading 12-13 V. If neither occurs, either the coil or the electronic sensor is faulty.
9. Test the coil, or replace it with a good coil. Repeat screwdriver test. if no spark occurs, replace the electronic sensor.
10. When installing the new electronic sensor, adjust sensor to trigger-wheel air gap to 0.008 in. (0.20 mm).

VOLTAGE DROP TEST

1. Position sensor between two trigger wheel teeth. Connect voltmeter positive lead to battery positive post and voltmeter negative lead to ignition-coil positive terminal.
2. Turn ignition switch to ON position. Voltmeter (V4) should read less than one volt.
3. Check for poor circuit conditions by flexing (moving) the connectors at the following points:
   a. Positive battery cable.
   b. Starter motor solenoid.
   c. Engine plug.
   d. Ignition switch.
4. If any of the conditions in Step 3 causes a fluctuation or an upscale voltmeter indication, a poor connection exists and must be corrected.

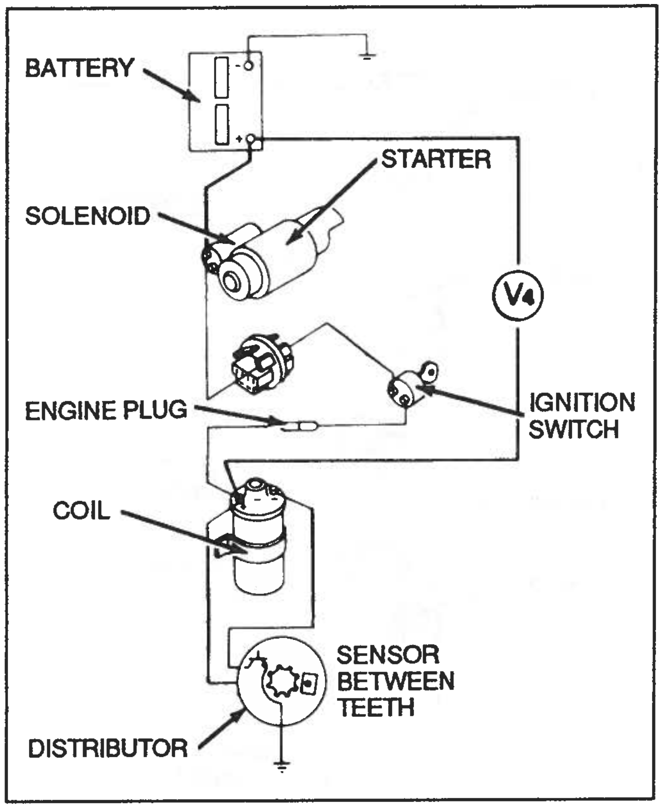


Figure 6-51. *Voltage Drop Test – Battery-Feed Circuit Connections*

5. Connect voltmeter negative lead to battery negative post and voltmeter positive lead to module case. With ignition switch on, voltmeter (V5) should read less than one volt.
6. Check for poor circuit conditions by:
   a. Securing system ground connections.
   b. Inspecting battery ground cable.
   c. Checking sensor mounting screws.

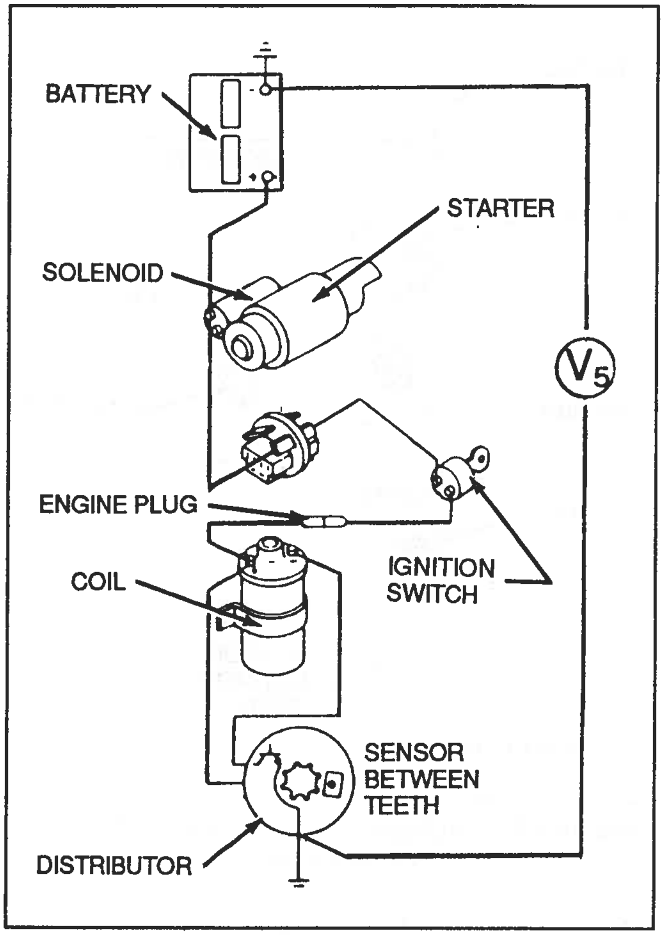


Figure 6-52. *Voltage Drop Test – Battery-Feed Circuit Connections*

ELECTRONIC SENSOR

Removal:

1. Remove distributor cap and rotor.
2. Remove primary wires from coil positive and negative terminals.
3. Remove two sensor-attaching screws.
4. Remove sensor from distributor body.

NOTE: Electronic sensor is not repairable. The sensor must be replaced as an assembly if faulty.

Installation:

1. Install new sensor into distributor body and install the two attaching screws.
2. Position trigger wheel so that one tooth is in line with sensor face. Loosen sensor-attaching screw and adjust air gap to 0.008 in. (0.20 mm) using a feeler gauge. Tighten sensor-attaching screw. Recheck air gap.
3. Install primary wires to coil positive and negative terminals.
4. Install rotor and distributor cap.
5. Start engine and adjust ignition timing to specification.

INSPECTION ON ENGINE

1. Remove distributor cap and rotor and inspect. Replace if necessary.
2. Make sure that all distributor wire terminals are clean and tight.
3. Check distributor bushings for wear. Attach a dial indicator to distributor housing. Position registering point of dial indicator to rest on distributor shaft. Shaft must not have more than 0.002 in. (0.05 mm) side play within bushing when shaft is pushed back and forth by hand.
4. Check for sticking centrifugal weights. Grip distributor shaft or rotor and twist in direction of rotation and then release. Shaft should snap back to its original position. If it hangs up, returns slowly or sluggishly, shaft assembly must be repaired, or distributor assembly must be replaced.

PRESTOLITE B.I.D. DISTRIBUTOR REMOVAL

1. Disconnect coil primary wires from coil.
2. Remove distributor cap, leaving all wires in place.
3. Crank engine slowly to align timing marks when rotor is pointing to the No. 1 terminal of distributor cap. If same distributor is to be reinstalled in engine, mark position of distributor housing in relation to engine so that distributor may be installed in same position.
4. Remove distributor-retaining clamp and distributor.

NOTE: To simplify reinstallation, do not turn crankshaft with distributor removed.

PRESTOLITE B.I.D. DISTRIBUTOR DISASSEMBLY

NOTE: Do not disassemble distributor unless necessary. When disassembling distributor, use soft wood blocks to hold it in vise.

1. Remove rotor from distributor shaft.
2. Remove sensor assembly.

NOTE: Proceed with Steps 3-6 only if shaft bushings in housing are to be replaced.

3. Drive roll pin from gear and remove gear.
4. Remove shaft assembly.
5. Thread 1/2 in. x 13 or 1/2 in. x 20 tap into upper shaft bushing. Using a punch, drive tap and bushing out of housing.
6. Repeat Step 5 for lower bushing.

CLEANING AND INSPECTION

1. Wash housing, gear, and shaft in cleaning solvent.
2. Inspect advance weights for wear or burrs and free fit on their pins. If worn, replace distributor.
3. Inspect shaft for wear. Check cam fit on end of shaft. It should be free but not loose. If worn, replace distributor.

PRESTOLITE B.I.D. DISTRIBUTOR REASSEMBLY

Engine Not Disturbed:

1. Install distributor shaft into engine, aligning marks made at time of removal. Ensure that shaft engages oil pump.
2. Install clamp.
3. Install distributor cap.
4. Set engine timing with timing light.

Engine Disturbed:

1. Rotate engine (in normal direction of rotation) until timing mark on torsional damper (or flywheel) lines up with TDC-0 on timing tab and engine is in No. 1 firing position.
2. Install distributor into engine so that the rotor is aligned with No. 1 spark plug tower on distributor cap.
3. Secure distributor with clamp and check engine timing with timing light.

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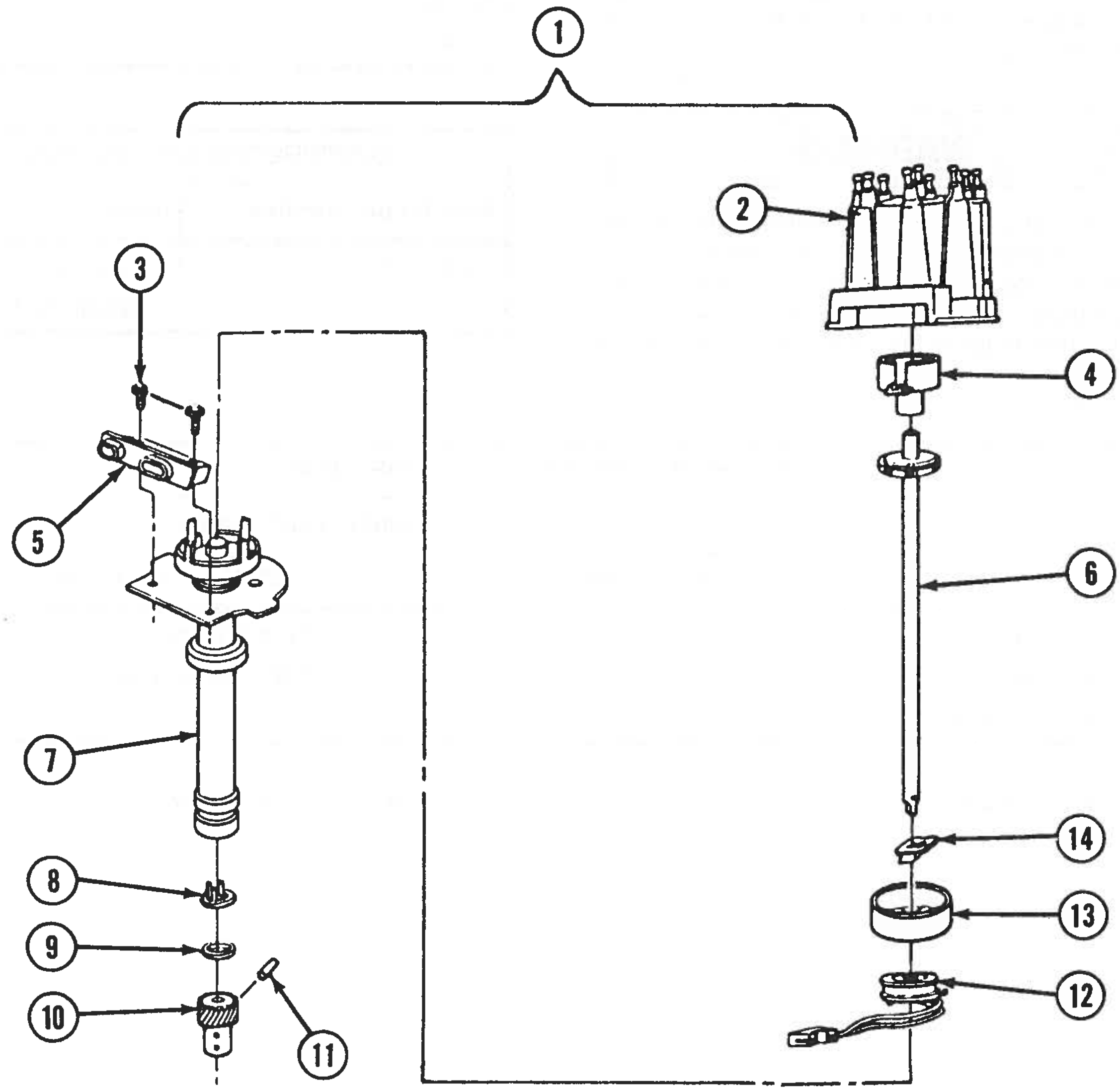
SYSTEMS WITH DELCO ELECTRONIC SPARK TIMING (E.S.T.) DISTRIBUTOR



1. Distributor assembly
2. Distributor cap
3. Ignition-module-attaching screw
4. Ignition rotor
5. Ignition module
6. Shaft assembly
7. Distributor housing
8. Tang washer
9. Thrustwasher
10. Driven gear
11. Driven gear pin
12. Pickup coil assembly
13. Pickup coil shield
14. Retainer

Figure 6-53. *Delco Electronic Spark Timing (E.S.T.) Distributor*

> **⚠ WARNING**
>
> Electrical and ignition system components on your Crusader marine engines are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.
>
> Use of replacement electrical or ignition system components which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

> **⚠ WARNING**
>
> When servicing the electrical, ignition and fuel systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

Distributor Fastener Location	Bolt Torque
Distributor clamp 3/8-16	20 lb-ft (27 N•m)

DISTRIBUTOR TOOLS OBTAINED LOCALLY
Remote starter switch
Timing light
Volt/ohmmeter

DISTRIBUTOR SPECIAL TOOLS	
Kent-Moore Number	**Name**
J-24642-F	Module tester
J-26792	Spark tester (E.S.T.)

COIL RESISTOR SPECIFICATIONS (OHMS)		
	Crusader Coil Part No.	
Type	**38075 - Pickup Coil**	**38066 - Ignition Coil**
Primary resistance		0.4-0.5 ohms
Secondary resistance		8000-9000 ohms
Pickup coil resistance	500-1500 ohms	

NOTE: These values are affected by the temperature of the coil. Readings should, however, be checked at room temperature.

DESCRIPTION

The Delco E.S.T. ignition system consists of the distributor, ignition coil, wiring and spark plugs. The distributor contains a module, pickup coil and conventional cap and rotor. There are no points or condenser to adjust or change and no moving parts except for the distributor shaft and rotor. Spark advance and dwell are controlled by the distributor module. The distributor module and pickup coil are self-contained solid-state devices which are not repairable. If necessary, they may be replaced separately but must be serviced as a complete unit.

DELCO DISTRIBUTOR COMPONENT TESTING

NOTE: In the test procedures that follow, check the ignition coil and each component of the distributor separately to identify defective or good components. These tests can be made with the distributor and coil mounted on the engine or on the repair bench.

DELCO DISTRIBUTOR MODULE TESTING

An approved module tester must be used in order to check the module. Use a Kent-Moore Module Tester, Part No. J24642 F or equivalent.

1. Remove module from distributor.
2. Connect red battery-cable clamp to positive (+) terminal and black battery-cable clamp to negative (–) terminal of a fully charged 12 V battery.
3. Connect J 24642-85 (detail 201) adapter to yellow 2-way terminal connector, and J 24642-85 (detail 200) adapter to black 3-way connector of the tester.
4. Connect black 4-way and 2-way connectors of detail 200 to module terminals. Connect yellow 2-way connector of detail 201 to yellow module terminals and engage locking tabs. See Figure 6-55.

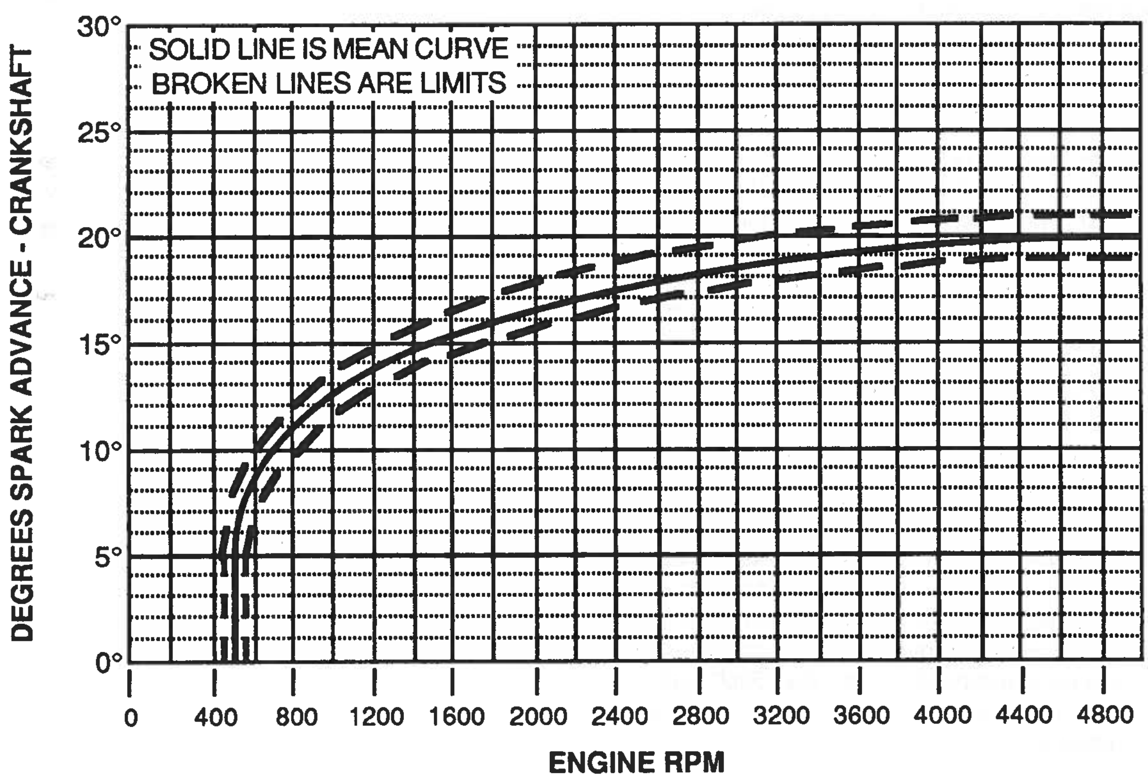


Figure 6-54. *Delco E.S.T. Distributor Spark-Advance Curve*

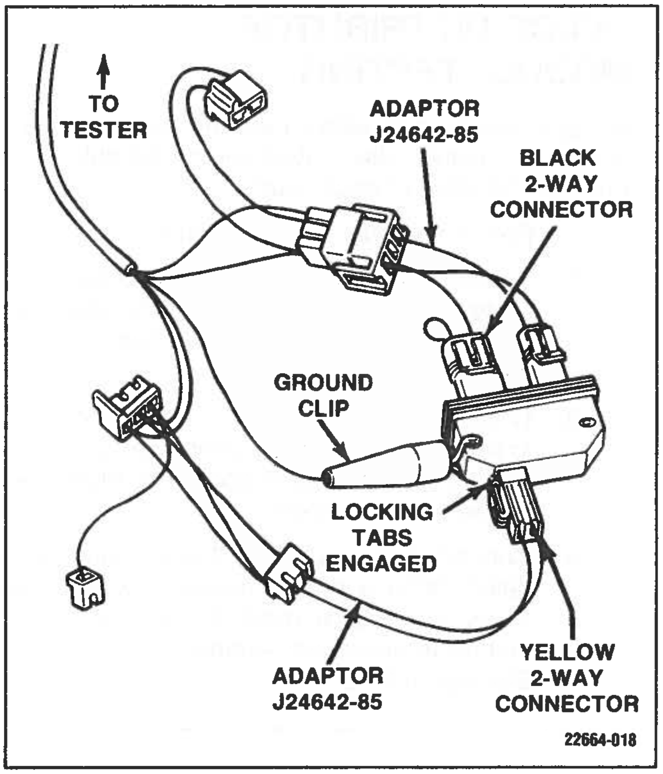


Figure 6-55. *Test 1 Tester Connections*

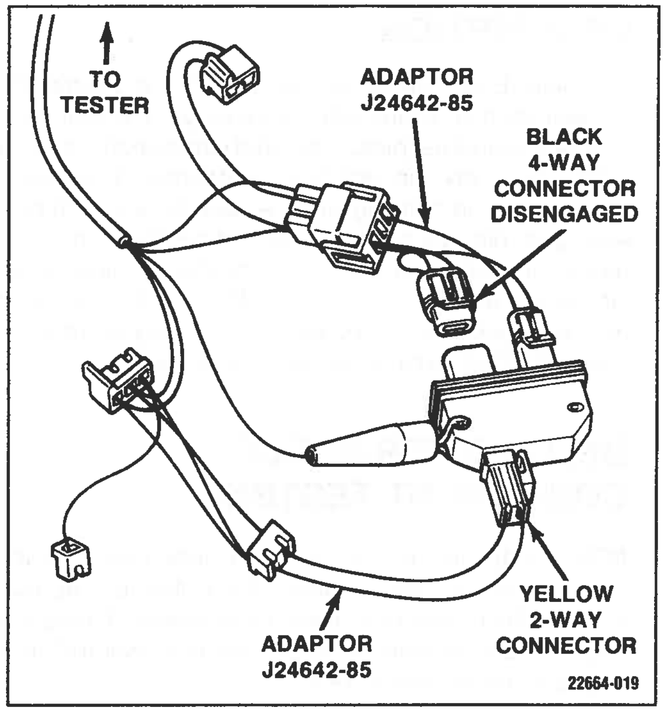
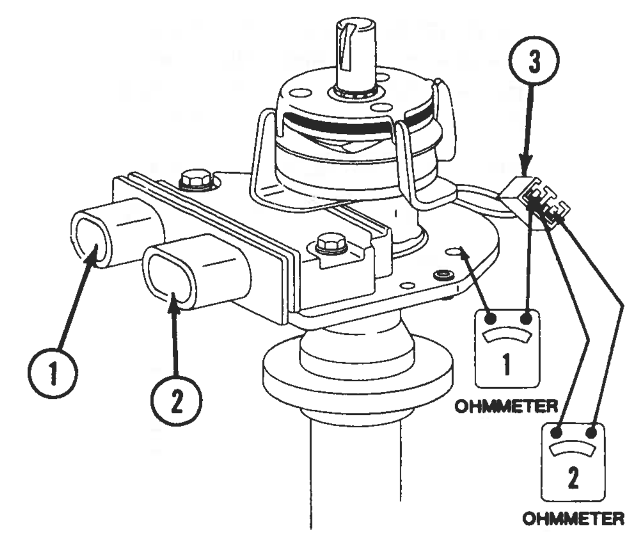


Figure 6-56. *Test 2 Tester Connections*

5. Connect module ground clip of the tester to the metal base plate of the module.
6. Hold the toggle switch in the 3-terminal test position. If a momentary indication of the red "Fail" light and then a steady indication of the green "Pass" light occurs, go on to the next step. If a steady indication of the red "Fail" light occurs, the module is defective and should be replaced.
7. Disconnect black 4-way connector from module. Disconnect yellow 2-way connector, rotate it 180 degrees so the lock and tab are opposite each other, and reconnect it to the module terminals. See Figure 6-56.
8. Hold the toggle switch in the 3-terminal test position. A momentary indication of the red "Fail" light and then a steady indication of the green "Pass" light means the module is good. A steady indication of the red "Fail" light means the module is defective and should be replaced.

PICKUP COIL TESTING

1. Remove the distributor cap and rotor.
2. Disconnect the pickup coil leads from the module.
3. Connect an ohmmeter between the pickup coil lead and housing (Test 1 in Figure 6-57). Reading should be infinite (no continuity). If not, replace pickup coil.
4. Connect an ohmmeter to both pickup coil leads (Test 2 in Figure 6-57). Reading should be a constant, unchanging value between 500-1500 ohms. Flex leads by hand at coil and connector to locate intermittent opens. Replace pickup coil if not within specifications.



1. B+ and C- terminals
2. 4-terminal connector
3. Pickup coil leads disconnected from module

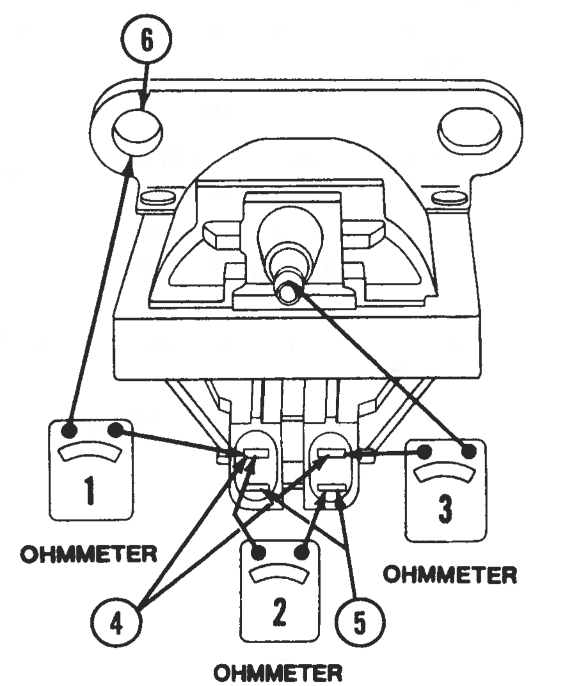
Figure 6-57. Testing Pickup Coil

IGNITION COIL TESTING

1. Connect ohmmeter between "B+" or "C-" terminals and ground (coil-mounting bracket). On high scale, reading should be infinite (Test 1). See Figure 6-58.
2. Connect ohmmeter between "B+" and "C-" terminals. On low scale, reading should be nearly zero (approximately 0.4 ohm) (Test 2). See Figure 6-58.
3. Connect ohmmeter between "B+" or "C-" terminals and coil high-voltage tower. On high scale, reading should be approximately 8000 ohms. Reading should not be infinite. See Figure 6-58.

NOTE: On Tests 2 and 3, reading may vary slightly depending on coil temperature.

4. If reading is not within specifications, replace coil.



1. Ohmmeter test 1
2. Ohmmeter test 2
3. Ohmmeter test 3
4. B+ terminals
5. C- and TAC terminals
6. Scrape clean metal ground

Figure 6-58. Testing Ignition Coil

DELCO DISTRIBUTOR REMOVAL

1. Remove distributor cap (2 screws). Do not remove plug wires from cap unless necessary.
2. Disconnect distributor primary leads at coil.
3. Crank or turn engine slowly. Align timing marks when rotor is pointing to No. 1 terminal of distributor cap. If same distributor is to be reinstalled in engine, mark position of distributor housing in relation to engine so that distributor may be installed in same position.
4. Remove distributor retaining clamp.
5. Remove distributor.

NOTE: To simplify distributor installation, do not turn crankshaft with distributor removed from engine.

DELCO DISTRIBUTOR DISASSEMBLY

NOTE: Do not disassemble distributor unless necessary. When disassembling distributor, use soft wood blocks to hold it in vise.

1. Remove rotor from distributor shaft.
2. Remove module by detaching leads and removing two mounting screws.
3. Place a mark on the distributor gear in line with rotor segment so reassembly can be made in same location.
4. Drive pin from gear. Remove gear and shaft assembly.
5. Pry off upper retainer and remove pickup coil.

CLEANING AND INSPECTION

1. Wash housing, gear and shaft in cleaning solvent.
2. Inspect housing, gear and shaft for wear. Replace if worn.
3. Inspect wires and connector on pickup coil. Replace if damaged.

DELCO DISTRIBUTOR REASSEMBLY

1. Install pickup coil and retainer.
2. Install shaft assembly, two thrustwashers and gear. Install roll pin.
3. Spin shaft to insure that teeth do not touch.
4. Clean module mounting surfaces of old silicone grease. Apply clean silicone grease between housing and module. Silicone grease is necessary for proper heat dissipation.
5. Install module and two mounting screws.
6. Attach wires from pickup coil to module.
7. Install rotor onto shaft.

DELCO DISTRIBUTOR INSTALLATION

Engine Not Disturbed:

1. Install distributor shaft into engine, aligning marks made at time of removal. Be sure that shaft engages oil pump.
2. Install clamp.
3. Install distributor cap.

IMPORTANT: Set engine timing with timing light. See Timing procedure in Section 4, Tune-Up.

Engine Disturbed:

1. Rotate engine (in normal direction of rotation) until timing mark on torsional damper (or flywheel) lines up with TDC on timing tab and engine is in No. 1 firing position.
2. Install distributor into engine so that the rotor is aligned with No. 1 spark plug tower on distributor cap.
3. Secure distributor with clamp.

IMPORTANT: Set engine timing with timing light. See Timing procedure in Section 4, Tune-Up.

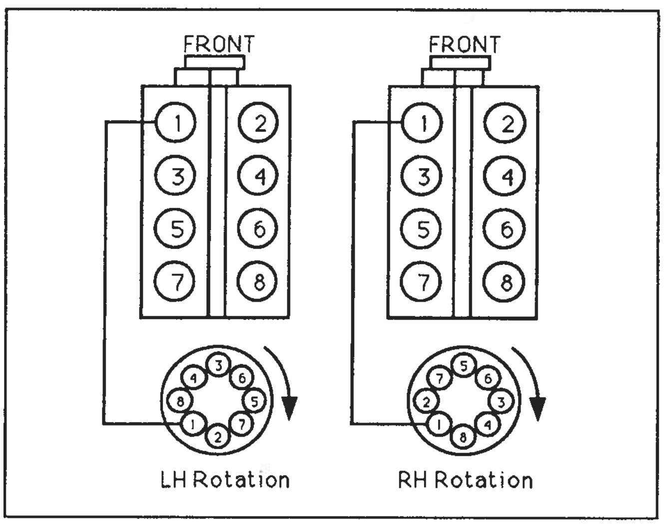


Figure 6-59. *Spark Plug And Distributor Order*

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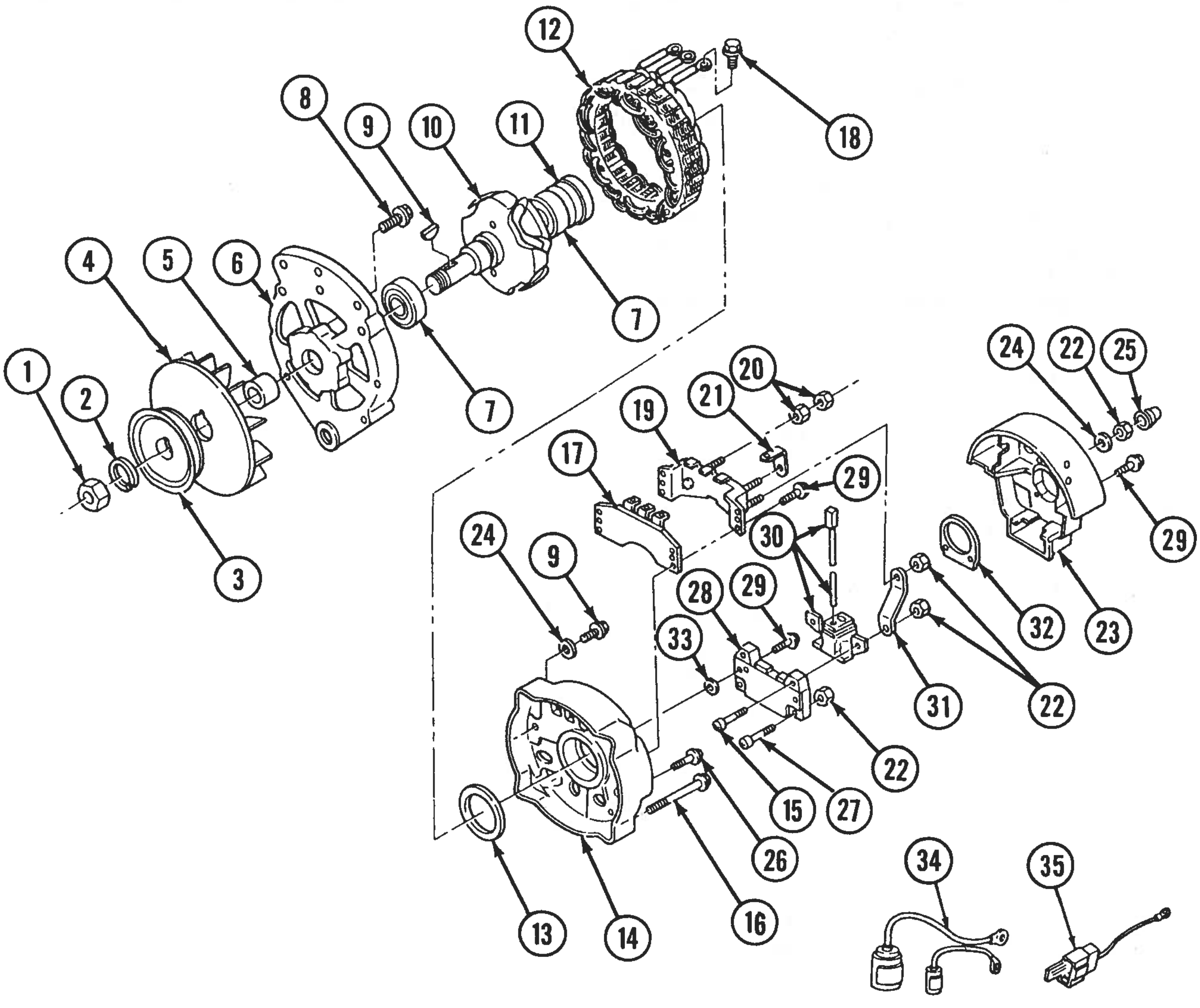
SYSTEMS WITH PRESTOLITE 8E SERIES ALTERNATOR



1. Nut
2. Lockwasher
3. Pulley
4. Cooling fan
5. Spacer
6. Front housing
7. Rotor bearing
8. Screw
9. Key
10. Rotor assembly
11. Slip ring
12. Stator assembly
13. Retainer
14. Rear housing
15. Screw
16. Housing assembly bolt
17. Rectifier
18. Screw
19. Diode trio
20. Nut
21. Strap
22. Nut
23. Rear cover
24. Washer
25. Cap
26. Screw
27. Screw
28. Voltage regulator
29. Screw
30. Brush assembly
31. D+ strap
32. Gasket
33. Washer
34. Alternator suppression kit
35. Adapter

Figure 6-60. *8E Series Alternator*

Description:

The alternator employs a rotor, which is supported between two end-frames by ball bearings. The alternator is driven by the crankshaft by means of a V-belt and two pulleys at approximately twice the engine speed. The rotor contains a field winding that is enclosed between two multiple-finger pole pieces. The ends of the field winding are connected to two slip rings which are in continuous sliding contact with two brushes mounted in the rear end-frame. The current flowing through the field winding creates a magnetic field that causes the adjacent fingers of the pole pieces to become alternate north and south magnetic poles.

A 3-phase stator is mounted directly over the rotor pole pieces and between the two end-frames. It consists of three windings arranged at 120° electrically out-of-phase on the inside of a laminated core. The windings are all connected together on one end, while the other ends are connected to a full-wave rectifier bridge.

The rectifier bridge contains six diodes which are arranged to allow current to flow from ground, through the stator and to the output terminal, but not in the opposite direction.

When current is supplied to the rotor field winding, and the rotor is turned, the movement of the magnetic fields induces an alternating current into the stator windings. The rectifier bridge then changes this alternating current to direct current which appears at the output terminal. A diode trio also is connected to the rotor windings to supply current to the regulator and the rotor field windings during operation.

Voltage output of the alternator is controlled by regulating the current supplied to the rotor field windings. This is accomplished by a transistorized voltage regulator that senses the voltage at the battery and regulates the field current to maintain the alternator voltage within prescribed limits for properly charging the battery. The current output of the alternator does not require regulation, as maximum current output is self-limited by the design of the alternator. As long as the voltage is regulated within the prescribed limits, the alternator cannot produce excessive current. A cutout relay in the voltage regulator is not required either, as the rectifier diodes, which allow current to flow in one direction only, prevent the battery from discharging back through the stator.

Due to the lack of residual magnetism in the rotor pole pieces, a small amount of current must be supplied to the rotor field to initially start the alternator charging. This is accomplished by means of an excitation circuit in the regulator which is connected to the ignition switch. Once the alternator begins to produce output, the field is then supplied solely by the diode trio.

The alternator is also equipped with a fan, mounted on the rotor shaft, which induces airflow through the alternator to remove the heat created by the rectifier and stator.

A capacitor is utilized to protect the rectifier system from high voltages and to suppress radio noise.

Two models of alternator have been used on Crusader marine engines, Prestolite 8E (Figure 6-60) and Motorola 8MR (Figure 6-93). The 8MR is the earlier model and has been replaced by the 8E. Both alternators have integral regulators and the same current and voltage output specifications. The 8E has a more compact regulator than the 8MR and has plug-in instead of soldered diode assemblies.

WARNING

Electrical and ignition system components on the Crusader engine are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize the risks of fire and explosion.

Use of electrical or ignition system component replacements which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

When servicing the electrical and ignition systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

WARNING

Be sure that engine compartment is well ventilated and that there is no gasoline vapor present, to prevent the possibility of an explosion and/or fire, should a spark occur.

CAUTION

Always remove negative (–) battery cable from battery before working on the alternator system.

When installing battery, be sure to connect the negative (–) (grounded) battery cable to negative (–) battery terminal and the positive (+) battery cable to positive (+) battery terminal.

If a charger or booster battery is to be used, be sure to connect it in parallel with existing battery (positive to positive, negative to negative).

CAUTION

Do not attempt to polarize the alternator.

Do not short across or ground any of the terminals on the alternator, except as specifically instructed.

Never disconnect the alternator output lead or battery cables when the alternator is being driven by the engine.

Never disconnect the regulator lead from alternator regulator terminal when the alternator is being driven by the engine.

WARNING

Keep fingers, clothing, etc., from alternator belts, fan and pulley; severe bodily harm can occur.

ALTERNATOR TOOLS

Kent-Moore Number	Name
J-22912-01	Bearing remover

ALTERNATOR TOOLS OBTAINED LOCALLY
Volt/ohmmeter

ALTERNATOR ELECTRICAL SPECIFICATIONS

Category	Specification
Current output	50 A maximum
Voltage output	13.8-14.8 V
Condenser capacity	0.5 µf

The alternator is mounted using various brackets, screws and nuts. The following table contains torque specifications for each type of mounting and connector.

TORQUE SPECIFICATIONS		
Fastener Location	**lb-ft N•m**	**lb-in N•m**
End-frame screws		50-60 (5.6-6.8)
Brush-set screws		16-20 (1.8-2.3)
Regulator mounting screws		40-45 (4.5-5.0)
Regulator leads		20-30 (2.3-3.9)
Ground terminal nut		20-30 (2.3-3.9)
Pulley nut	35-50 (47-68)	
Alternator brace to alternator		192 (22)
Alternator brace to block	30 (41)	
Alternator to mounting bracket	35 (47)	
Alternator mounting bracket	30 (41)	

Before proceeding with any alternator tests, perform the following checks to eliminate possible problem areas.

1. If the problem is an undercharged battery, check to ensure that undercharged condition has not been caused by excessive accessory current draw or by accessories which have accidentally been left on. Also, check that the undercharged condition has not been caused by running the engine at too low a speed for extended periods of time.
2. Check the state of charge and physical condition of the battery. The battery must be at least 75% (1.230 specific gravity) of a full charge to obtain valid results in the following tests. If not, charge battery before testing system.
3. Inspect the entire alternator wiring system for defects. Check all connections for tightness and cleanliness, particularly battery-cable clamps and battery terminals.
4. Check the alternator drive belt and replace if necessary. Also, check tension and adjust if necessary, as outlined in Section 3.1, Drive Belts.

8E SERIES ALTERNATOR TEST

> **CAUTION**
>
> Observe the Cautions and Warnings at the beginning of this section before performing the following tests.

1. Connect a voltmeter to the output (+) terminal and the ground (–) terminal as shown in Figure 6-61.

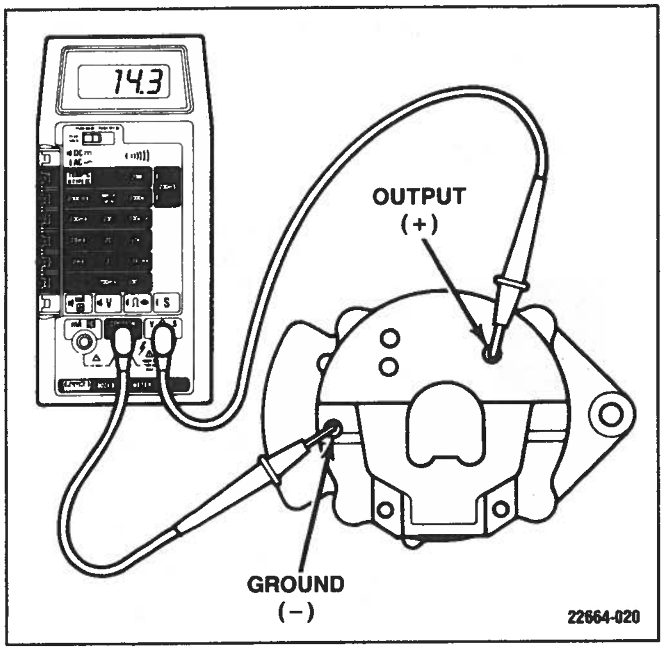


Figure 6-61. *Voltmeter Connection To Alternator*

2. Start the engine and operate at approximately 1500 rpm.
3. Turn on electrical accessories.
4. Observe the voltmeter reading. Voltage should range between 13.8-14.8 V for a properly operating alternator.

NOTE: Voltage may vary a few tenths of a volt, higher or lower, due to temperature variations.

5. If the voltage output is more than 14.8 V, the regulator is shorted. Replace regulator. If the voltage output is less than 13.8 V, check the diode trio and then the regulator for proper operation. Refer to the Alternator Diode Trio and Alternator Regulator Test procedures in this section.

8E SERIES ALTERNATOR DIODE TRIO TEST

1. With the engine stopped, turn the ignition switch to ON. Do not start engine. Connect a voltmeter to the output (+) terminal and the ground (–) terminal (Figure 6-61). This step will check the battery voltage.
2. With the ignition ON, connect the voltmeter to the indicator light (D+) terminal and ground (–) terminal (Figure 6-62). This will check voltage at the regulator. Voltage should measure between 1.5-3.0 V.

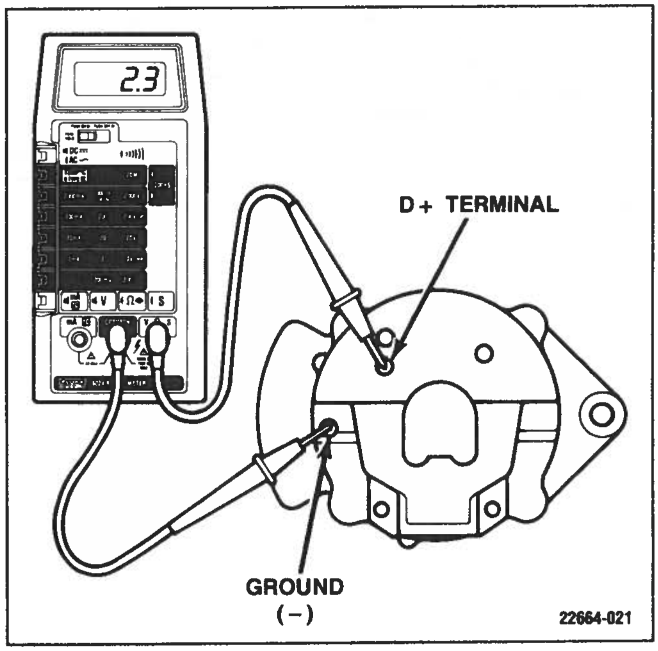


Figure 6-62. *Regulator Voltage Check*

3. Turn the ignition switch OFF. Connect a jumper wire between the output (+) terminal and the indicator light (D+) terminal (Figure 6-63).
4. Start and operate the engine at idle speed.
5. Connect a voltmeter to output (+) terminal and ground (–) terminal (Figure 6-63). If a reading ranging from 13.5-15.0 V is obtained, the diode trio is defective (open). Remove alternator for repair.

   If 13.5-15.0 V is not indicated, remove the jumper wire and test the regulator.

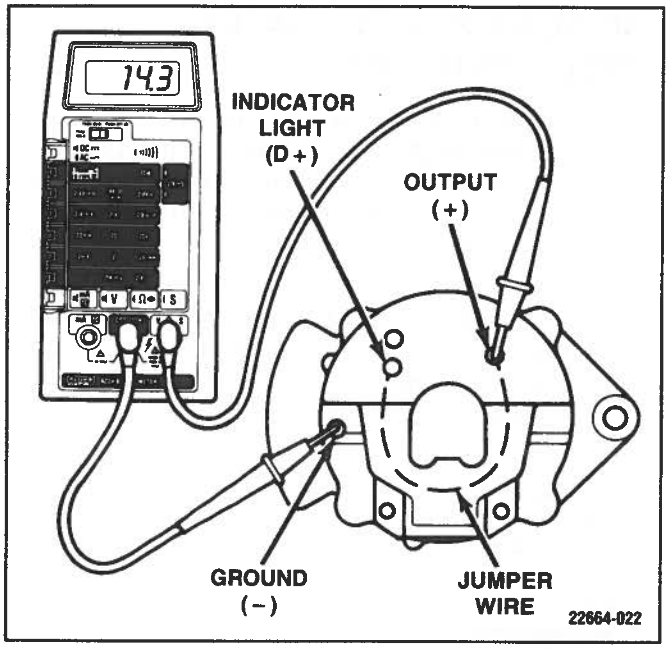


Figure 6-63. Diode-Trio Voltage Check

8E SERIES ALTERNATOR REGULATOR TEST

1. Disconnect the wires from the alternator and remove back cover. Connect wires to the proper terminals on the alternator.
2. Turn the ignition switch to ON. Do not start engine. Connect a voltmeter to the output (+) terminal and the ground (–) terminal (Figure 6-61). This will check the battery voltage.
3. With the ignition switch still ON, connect a voltmeter to the indicator light (D+) terminal and the ground (–) terminal (Figure 6-64). An open regulator can indicate battery voltage at terminal (D+).

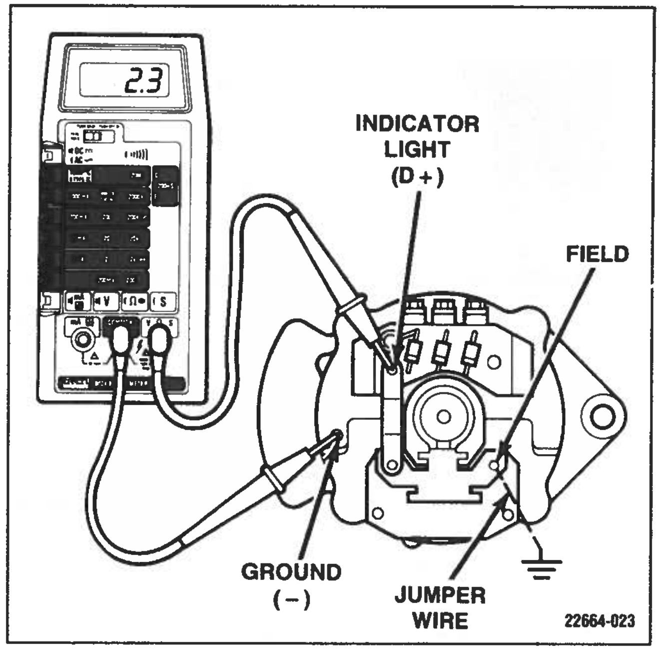
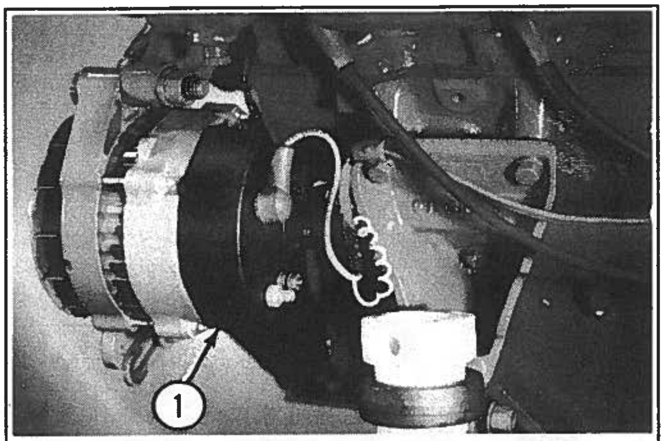


Figure 6-64. Open Field Circuit – Battery Voltage Check

4. Turn the ignition switch OFF. Connect a jumper wire between the field terminal and the ground (–) terminal.
5. Turn the ignition switch to ON. Connect a voltmeter to the indicator light (D+) terminal and ground (–) terminal (Figure 6-64). If 1.5-3.0 V is measured, a defective (open) regulator is indicated. If battery voltage is present at the (D+) terminal, a defective (open) field circuit is indicated. Repair the alternator, check for bad rotor, brushes, slip rings, etc.

8E SERIES ALTERNATOR REMOVAL

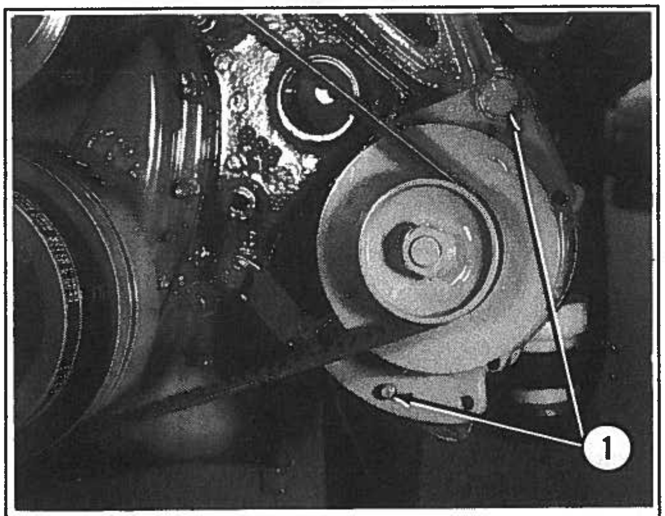
1. Disconnect negative (–) battery ground cable.
2. Disconnect wiring leads (Figure 6-65).



1. Wire leads

Figure 6-65. *Disconnecting Alternator Leads*

3. Loosen cap screws (Figure 6-66). Move alternator towards engine and lift belts off the pulley.



1. Cap screws

Figure 6-66. *Removing Alternator-Mounting Screws*

4. Remove cap screws and washers to remove alternator.

8E SERIES ALTERNATOR DISASSEMBLY

NOTE: The following instructions are for complete disassembly and overhaul of the alternator. In many cases, complete disassembly is not required. Perform only the operations required to repair or replace the faulty part.

1. Remove terminal nuts (1) and two mounting screws (2) to remove the back cover.

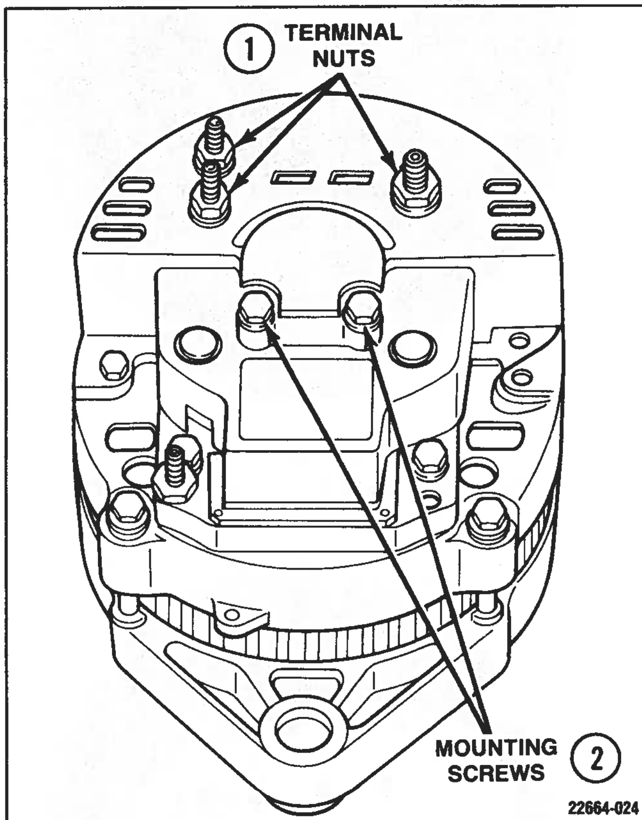
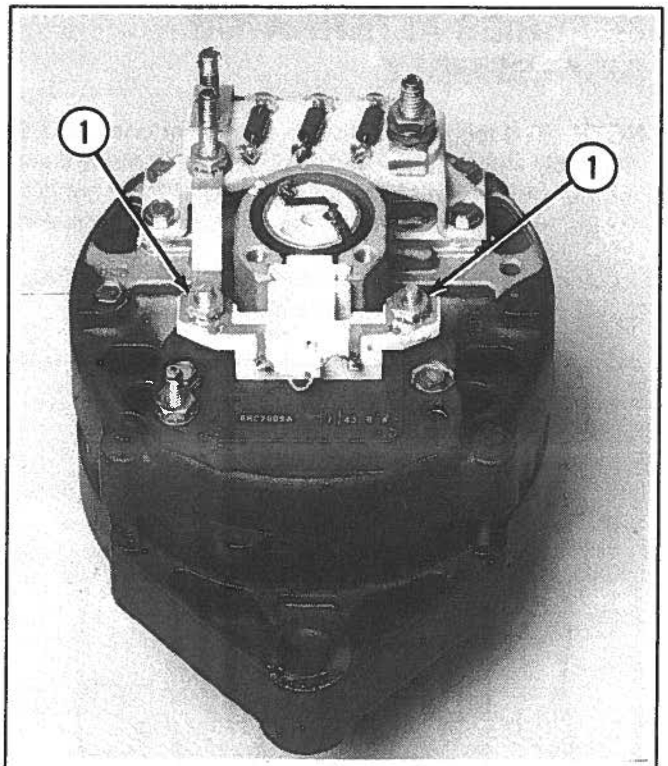


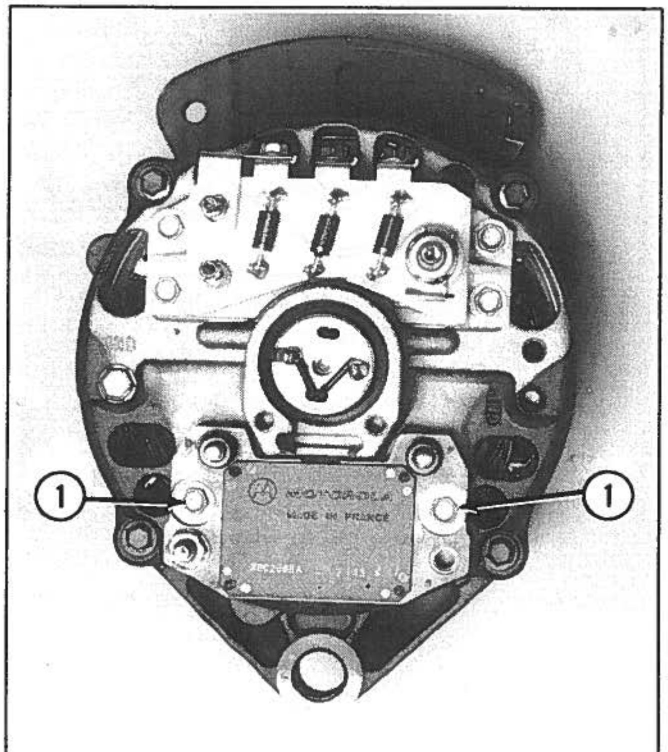
Figure 6-67. *Removing Terminal Nuts And Back Cover Screws*

2. Remove two nuts (1) to remove the brush-holder assembly (Figure 6-68).
3. Remove two mounting screws (1) (Figure 6-69) to remove the voltage regulator and two washers under the regulator.



1. Nuts

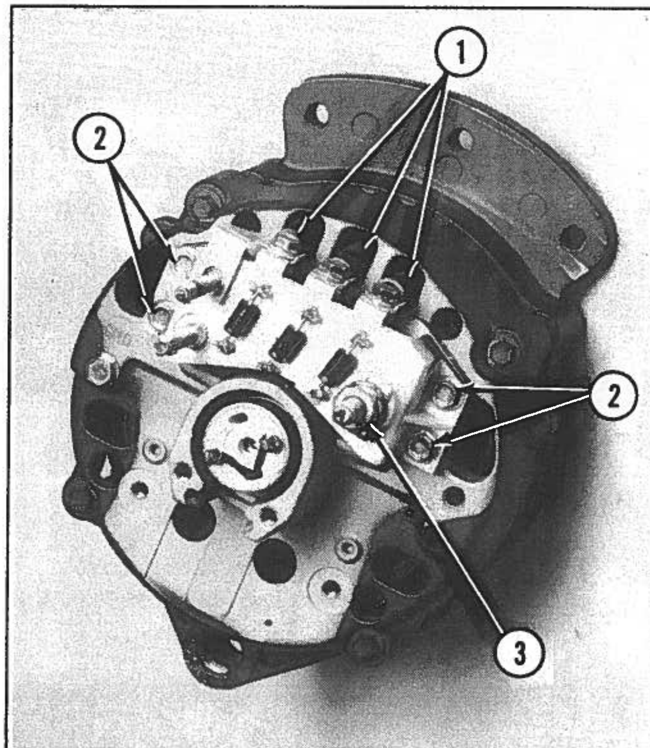
Figure 6-68. *Removing Brushholder Assembly*



1. Mounting screws

Figure 6-69. *Voltage Regulator Removal*

4. The diode trio and rectifier-diode bridge are removed as an assembly. Remove three terminal screws (1) (Figure 6-70) and four mounting screws (2). Remove locknut (3) on the output (B+) terminal. Remove assembly and separate the diode trio from the diode bridge.



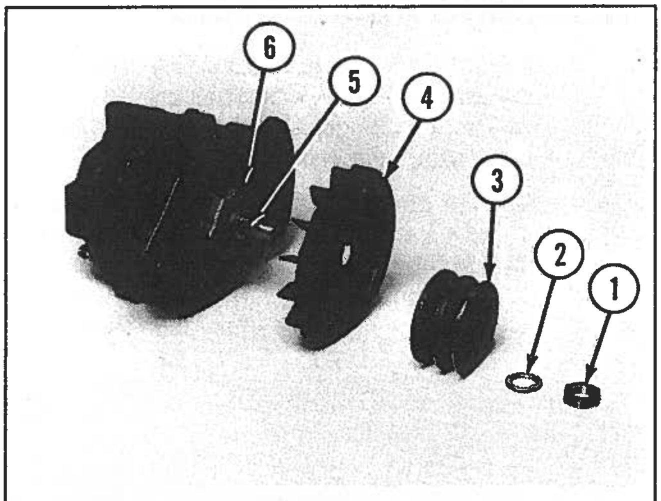
1. Terminal screws
2. Mounting screws
3. Locknut

Figure 6-70. *Diode Trio And Rectifier Bridge Removal*

5. Remove the pulley nut (1) (Figure 6-71) and lockwasher (2). Remove the pulley (3), fan (4) and spacer off the rotor shaft, and the pulley key (5) and spacer (6) from the shaft.

CAUTION

Do not insert screwdriver blades more than 1/16 in. (1.6 mm). Damage to the stator winding could result from deeper penetration.



1. Nut
2. Lockwasher
3. Pulley
4. Fan
5. Key
6. Spacer

Figure 6-71. *Pulley Removal*

6. Remove four through-bolts. Using two screwdrivers, carefully pry the rear housing away from the front housing.

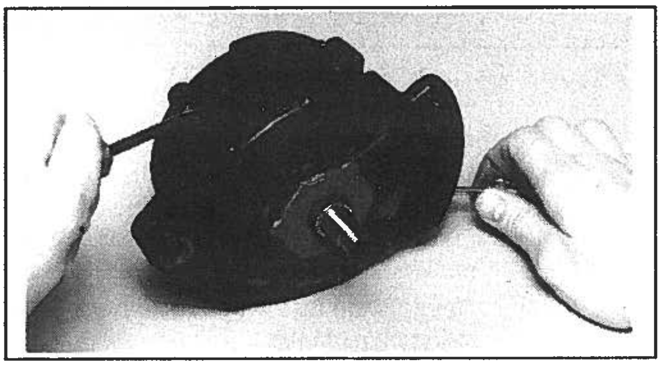


Figure 6-72. *Removing Rear Housing*

7. Carefully push the rotor assembly out of the front housing (Figure 6-73).

NOTE: If bearing is removed from housing, a new bearing must be installed.

8. After removing the three bearing locking screws (1), carefully press the front bearing (2) from the housing. Press against the inner face (3) of the bearing as shown (Figure 6-74).
9. Test rotor assembly before proceeding with Steps 10 and 11.

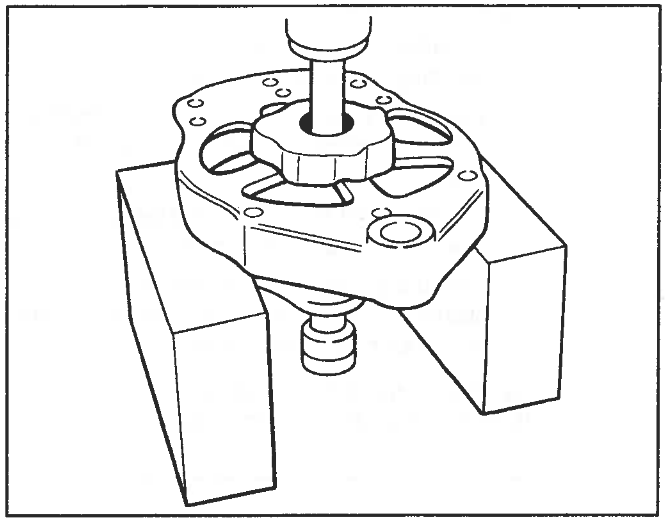
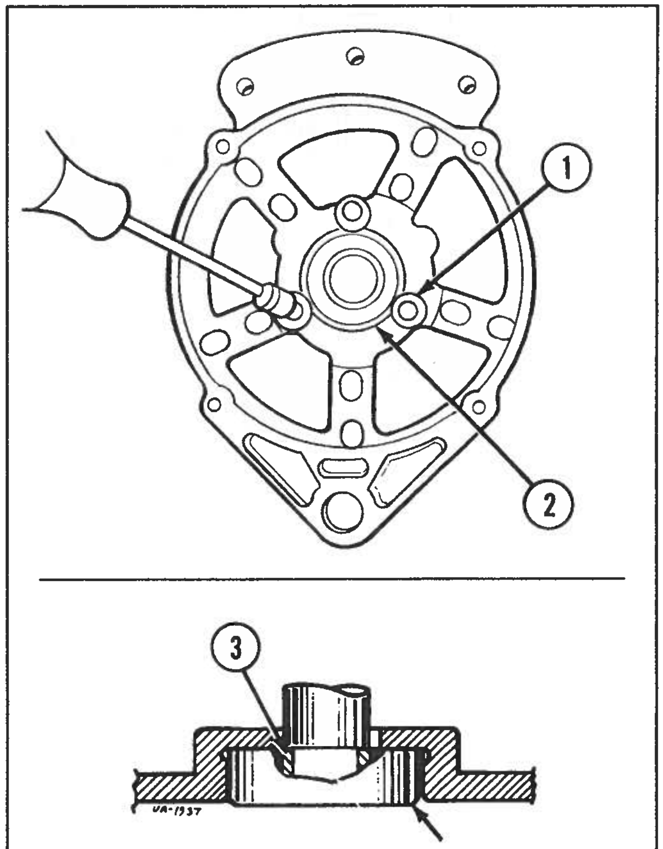


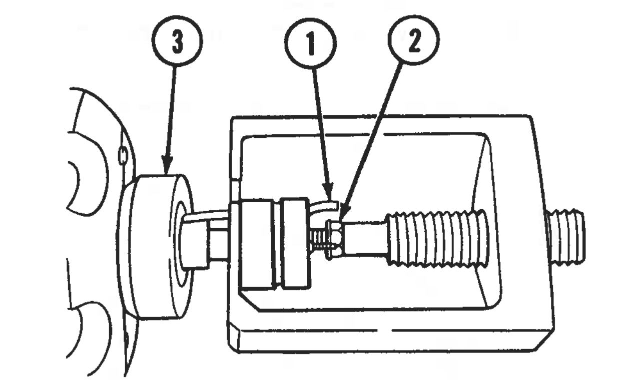
Figure 6-73. *Removing Rotor From Housing*



1. Bearing locking screws
2. Front bearing
3. Inner face

Figure 6-74. *Removing Front Bearing From Housing*

10. Remove the slip rings as follows:
    a. Unsolder the rotor leads (1) from the slip-ring terminals (Figure 6-75).
    b. Carefully unwind the rotor leads from the slip-ring terminals and straighten the rotor leads.
    c. Install a #10 x 1 in. cap screw (2) into the opening in the center of the slip ring.
    d. Using a puller, remove the slip-ring assembly from the rotor shaft. Use care not to damage rotor leads.
11. Use the same puller to remove the rear bearing (3) from the rotor shaft.



1. Rotor leads
2. #10 x 1" cap screw
3. Rear bearing

Figure 6-75. *Removing Slip Rings*

CLEANING AND TESTING

1. Inspect and test brush assembly. Brush set may be reused if brushes are 3/16 in. (4.7 mm) or longer. Brushes must not be oil-soaked, cracked or grooved.

   Test for continuity from points 1 to 2 and 3 to 4 using a test lamp or an ohmmeter (Figure 6-76). Test for no continuity from points 1 or 2 to 3 or 4. These checks will indicate a good brush assembly. Replace complete assembly if necessary.

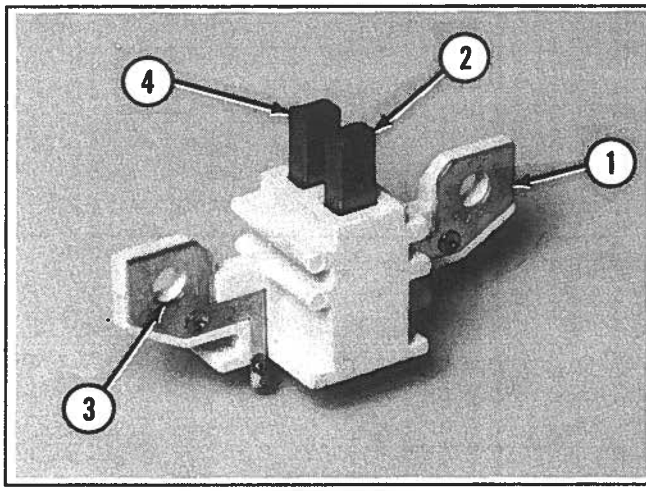
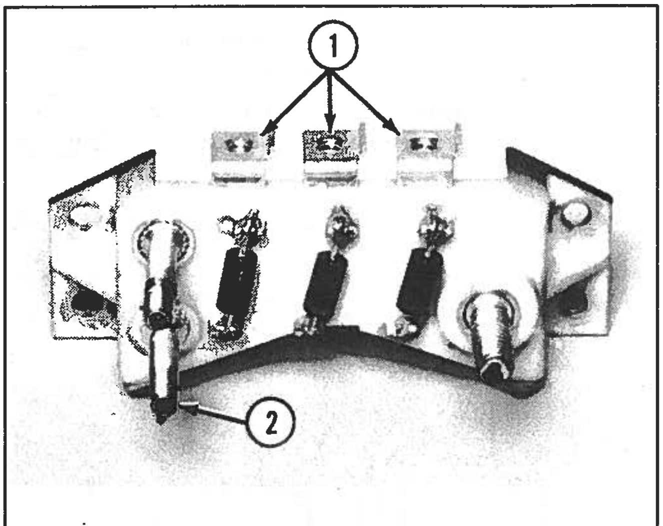


Figure 6-76. *Testing Brush Assembly*

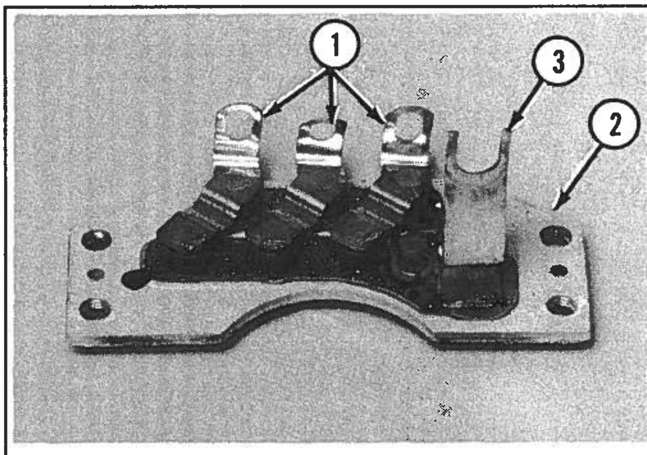
2. Inspect and test diode trio assembly.
    a. Using an ohmmeter, check the resistance between each of the three diode terminals (1) (Figure 6-77) and the D+ stud (2) as shown.
    b. Reverse the tester leads and repeat the resistance checks.
    c. If the diodes are normal, a very low resistance should be indicated in one direction and a very high resistance should be indicated in the other direction.
    d. If any diode appears to be defective, replace the complete assembly. Do not attempt to replace an individual diode.



1. Diode terminals 2. D+ stud

Figure 6-77. Testing Diode Trio

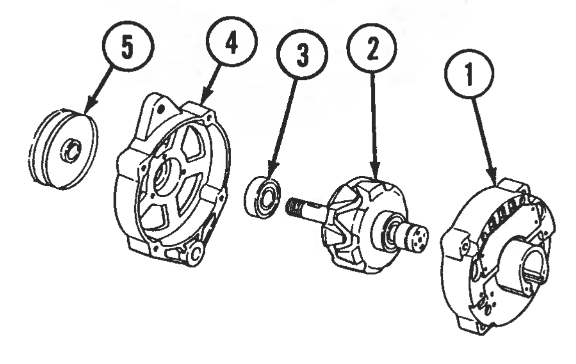
3. Test diode-rectifier bridge as follows:
   a. Using an ohmmeter, check for continuity from each of three terminals (1) (Figure 6-78) to plate (2).
   b. Reverse the tester leads and repeat Step a.
   c. Continuity should exist in only one direction and all diodes should check alike.



1. Diode terminals 3. B+ strap
2. Plate

Figure 6-78. Testing Rectifier Bridge

   d. Perform the same continuity checks between the three terminals and strap B+ (3). This should show continuity in only one direction through the diodes and all diodes should check alike.
   e. If any diode appears to be defective, replace the rectifier assembly.
4. Clean and inspect front (4) and rear (1) housings (Figure 6-79):
   a. Inspect the rear housing for cracks or breaks in the casting, stripped threads or damaged bearing bore. Replace the housing if any of these conditions exist.
   b. Inspect the front housing for cracks, stripped or damaged threads in the adjusting ear or an out-of-round bore in the mounting foot. If possible, correct slightly damaged threads using a tap. Replace the housing if necessary.
   c. If the housings are to be reused, clean them in solvent and dry with compressed air.
5. Clean and inspect rotor shaft bearing (Figure 6-79):
   a. Bearing should be wiped clean with a lint-free cloth containing a moderate amount of commercial solvent. Do not immerse the bearing in solvent or use pressurized solvent or air.

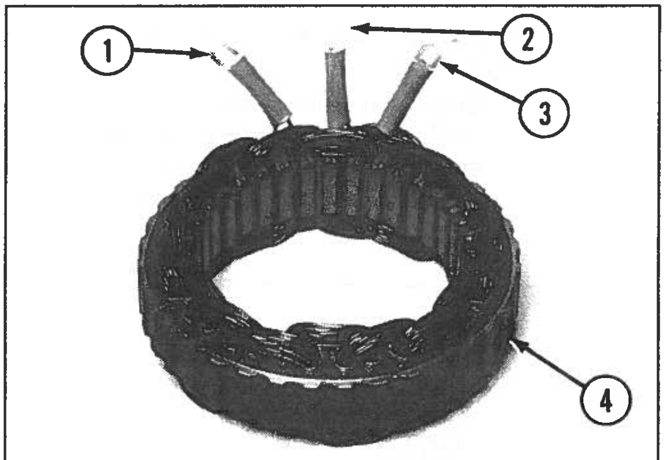


1. Rear housing 4. Front housing
2. Rotor 5. Pulley
3. Front bearing

Figure 6-79. Alternator Subassemblies Inspection

   b. Check the bearing for obvious damage, looseness or rough rotation. Replace the bearing if any doubt exists as to its condition.
6. Inspect the pulley (5) (Figure 6-79) for rough or badly worn belt grooves or keyway and for cracks and breaks. Remove minor burrs and correct minor surface damage; replace a badly worn or damaged pulley.

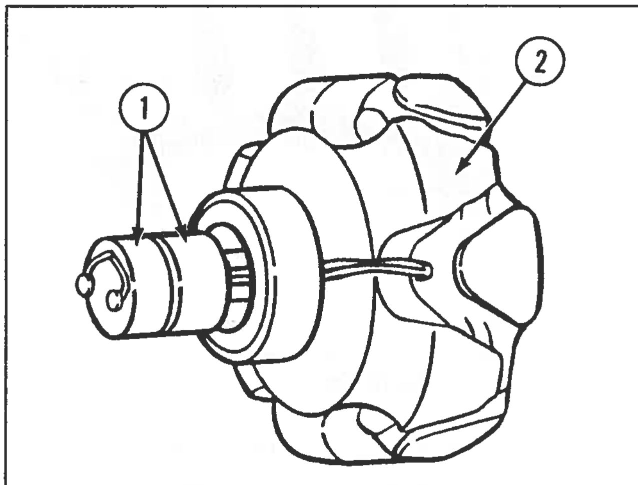
7. Test stator windings as follows (Figure 6-80):
   a. Using an ohmmeter or test lamp, check for continuity between all three leads (1, 2, and 3). A low ohm reading or lit test lamp should be observed.
   b. Check resistance from each lead (1, 2, and 3) to the laminations (4). There should be no continuity if the insulation is good.
   c. Inspect the stator windings for signs of discoloration. A discolored winding should be replaced.
   d. If a winding shows a high resistance or an open circuit between any two of the three winding terminals or indicates poor insulation between the windings and the laminations, the stator must be replaced.



1. Stator winding leads
2. Stator winding leads
3. Stator winding leads
4. Stator winding laminations

Figure 6-80. *Testing Stator Windings*

8. Check rotor assembly as follows (Figure 6-81):
   a. Visually inspect for physical defects such as damaged shaft threads, damaged pulley key slot, worn or damaged bearing areas, burned or pitted slip rings (1) and scuffed pole fingers (2).
   b. Measure winding resistance across the slip rings. Place the ohmmeter leads on the edges of the slip rings, not on the brush-contact surfaces. The correct winding resistance at 70-80° F (21-27° C) is 4.1-4.7 ohms.
   c. Minor burning or pitting of the slip-ring surfaces can be removed using crocus cloth. Thoroughly wipe the slip rings clean after polishing, removing all grit and dust.
   d. Check for a grounded slip or rotor winding by measuring resistance from each slip ring (1) to the rotor body or pole finger (2). An open circuit should be indicated in both cases for a good rotor.
   e. If windings are defective or physical damage cannot be corrected, replace the rotor assembly.

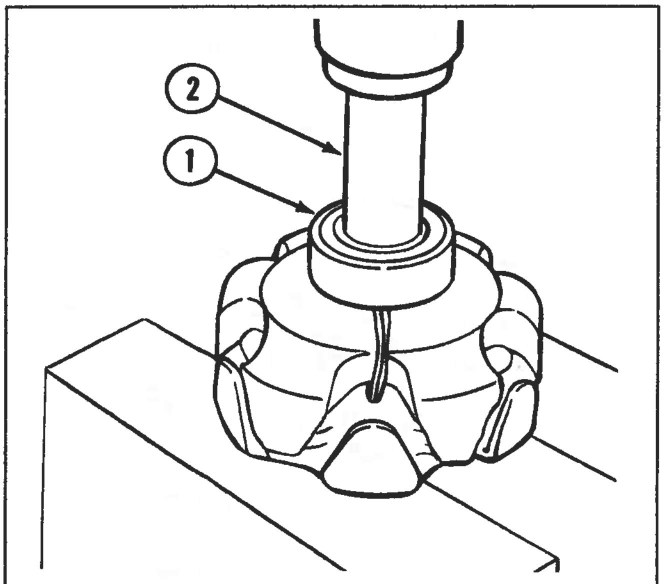


1. Slip rings
2. Pole fingers

Figure 6-81. *Testing Rotor*

8E SERIES ALTERNATOR REASSEMBLY

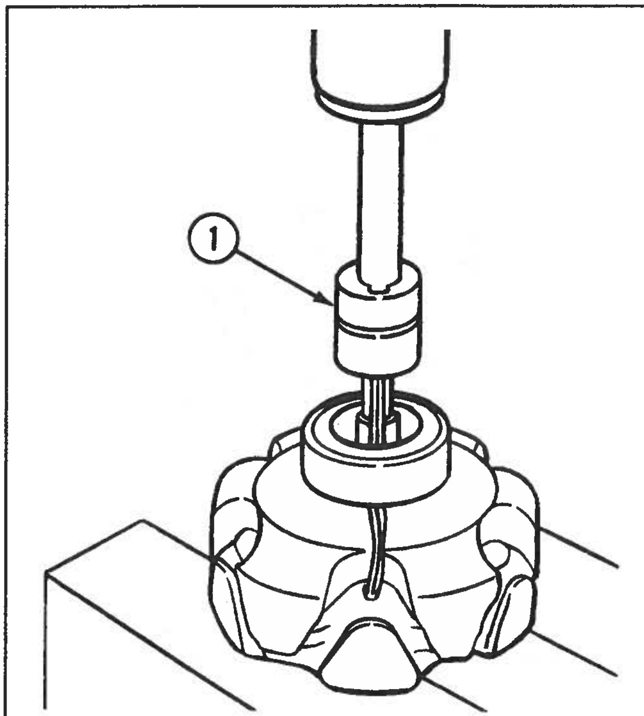
1. Place the rotor assembly on suitable blocks (Figure 6-82). Make sure wire leads are in the groove of the shaft. Press the rear bearing onto the shaft using a driver sleeve, pressing against the inner race only. Seat the bearing firmly against the shaft shoulder.



1. Rear bearing 2. Driver sleeve

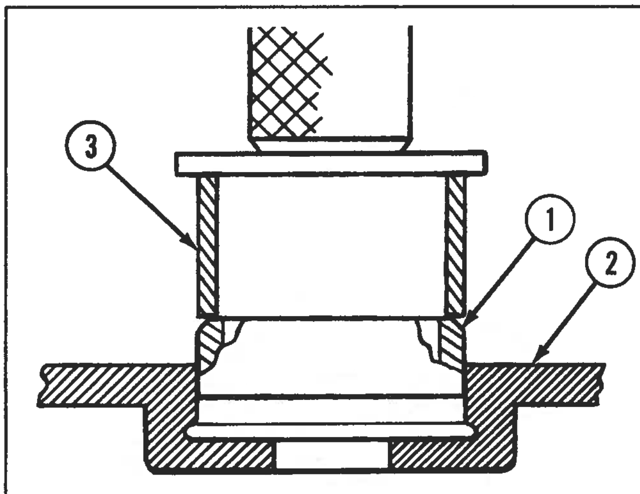
Figure 6-82. Installing Rear Bearing On Rotor

2. Guide the rotor leads through one of the oval passages in the slip-ring assembly. Align this oval passage with the groove in the shaft and make sure that the driver sleeve used will clear the rotor leads. Carefully press the slip-ring assembly onto the shaft. See Figure 6-83.
3. Solder the rotor leads to the leads on the slip ring. Trim any excess leads that may extend above the solder connections.
4. Carefully press the front bearing into the front housing, pushing against the bearing outer race with a sleeve driver (See Figure 6-84). Lock the bearing in place with screws (Figure 6-85). Torque screws to 25-35 lb-in (2.8-4.0 N•m).



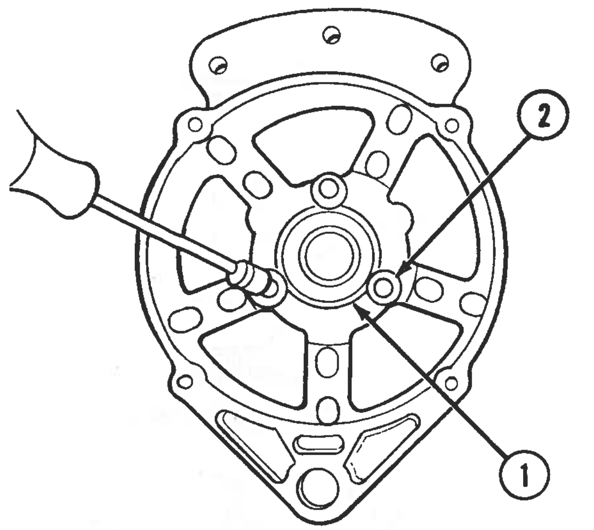
1. Slip-ring assembly

Figure 6-83. Installing Slip Rings On Rotor



1. Front bearing
2. Front housing
3. Sleeve driver

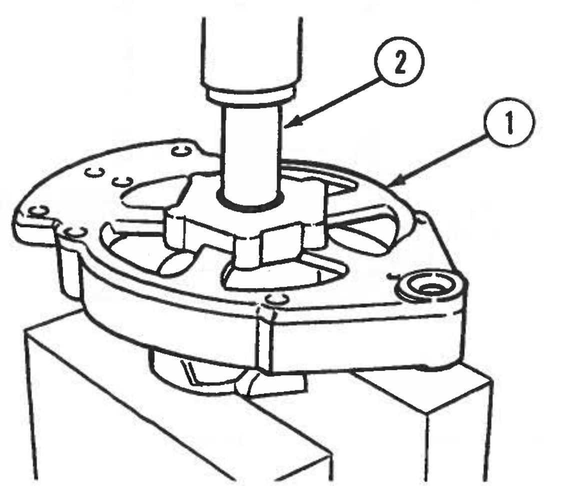
Figure 6-84. Pressing Front Bearing Into Front Housing



1. Front bearing
2. Screws

Figure 6-85. *Tightening Alternator Front-Housing Screws*

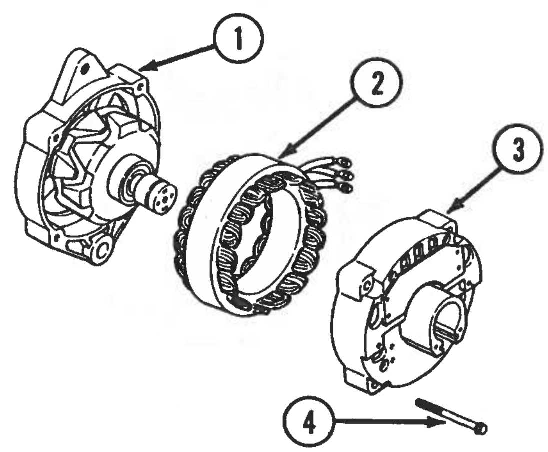
5. Place the rotor (pulley end up) on the bed of an arbor press, on two steel blocks (Figure 6-86).
6. Press the front housing and bearing assembly down onto the rotor shaft. Press against the bearing inner race only. Take care to ensure that the rotor leads clear the steel blocks.



1. Front housing and bearing assembly
2. Driver

Figure 6-86. *Pressing Front Housing And Bearing Onto Rotor*

7. Assemble the front and rear housings as follows (Figure 6-87):
   a. Put the stator winding in the front housing with the stator leads away from the front housing and the notches in the stator laminations aligned with the four through-bolt holes in the housing.
   b. Slip the rear housing into place over the rotor shaft. Align the mounting holes and put the stator leads through the holes at the top of the rear housing.
   c. Install four bolts and torque to 35-65 lb-in (4.0-7.3 N•m).

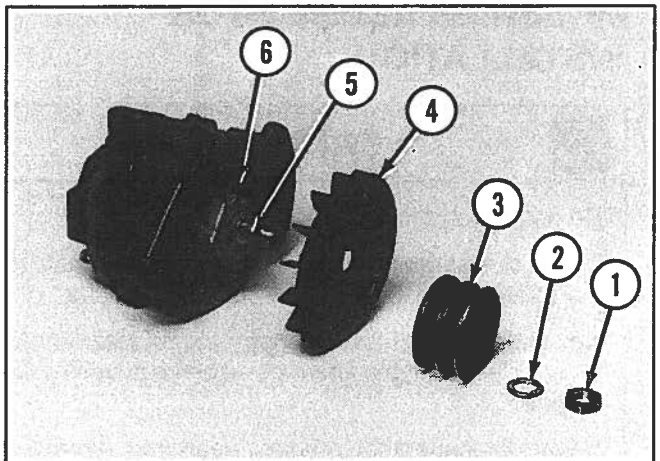


1. Front housing
2. Stator winding
3. Rear housing
4. Bolt

Figure 6-87. *Assembling Front Housing, Stator And Rear Housing*

NOTE: If the front housing is new, the through-bolt holes will not be tapped.

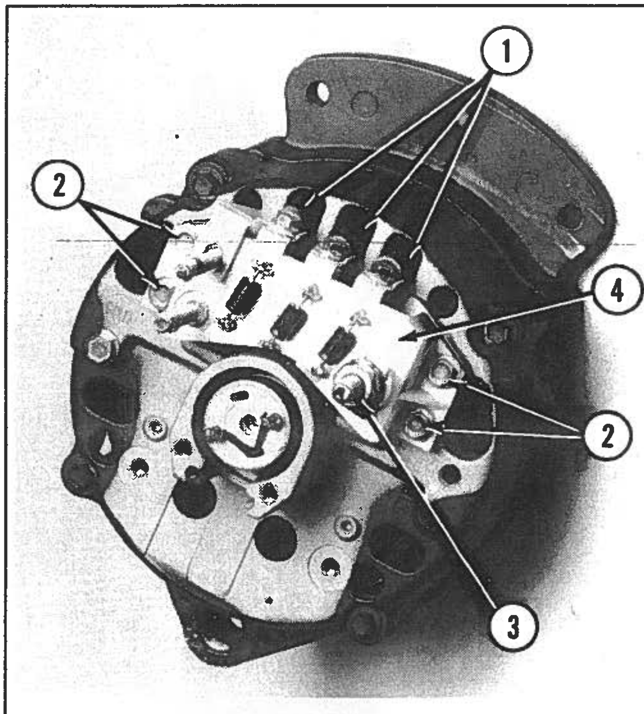
8. Install the spacer, pulley key, and the fan. Then push the pulley, lockwasher and nut onto the shaft (Figure 6-88). Tighten alternator pulley nut to 35-50 lb-ft (47-68 N•m) torque.



1. Nut
2. Lockwasher
3. Pulley
4. Fan
5. Pulley key
6. Spacer

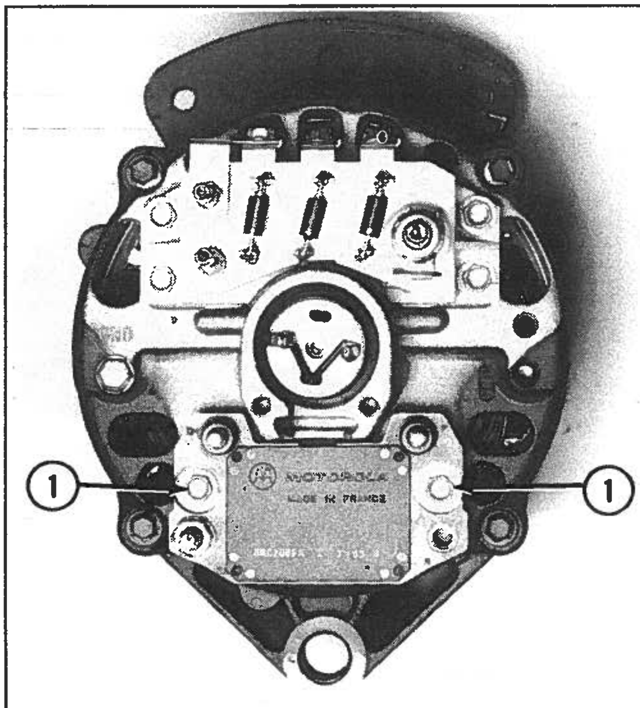
Figure 6-88. *Installing Pulley*

9. Install the diode trio/rectifier assembly as follows (Figure 6-89):
   a. Apply a thin film of heat-sink compound to the back of the rectifier bridge and to its mating surface on the rear housing.
   b. Assemble the rectifier bridge to the diode trio. Bend the strap over the B+ terminal and secure with locknut.
   c. Place the assembly on the rear housing and install the four mounting screws.
   d. Position the strap for the AC-tap terminal and connect the three stator leads to the terminals on the diode trio.
10. Install the regulator assembly (Figure 6-90) on the rear housing with the two mounting screws. Tighten to 25-45 lb-in (2.8-5.1 N•m) torque.
11. Carefully insert the brushholder assembly into the grooves in the rear housing hub (Figure 6-91). Place one end of the (D+) strap on the brushholder mounting stud. Install both attaching nuts (See Figure 6-91). Secure the other end of the (D+N) strap to lower terminal on the diode trio.



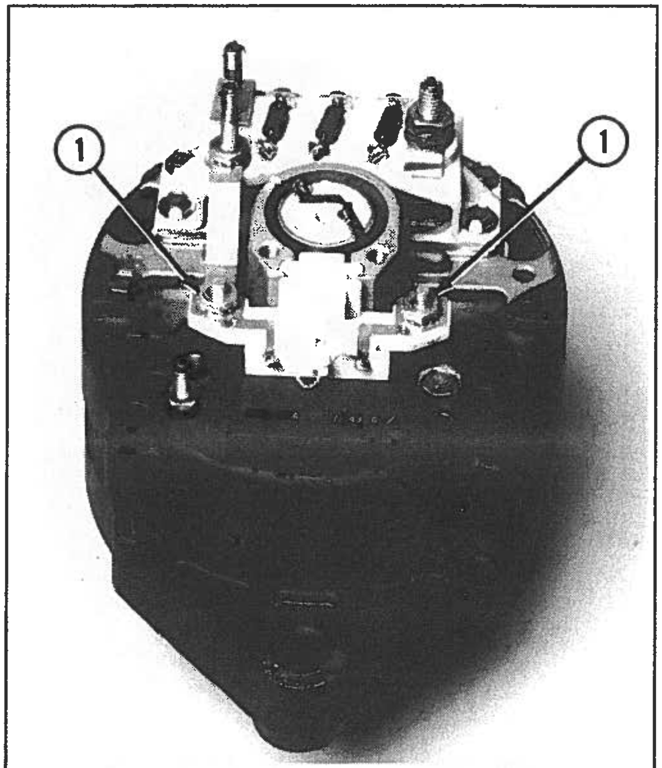
1. Stator leads
2. Mounting screw
3. Locknut
4. Diode trio/rectifier bridge

Figure 6-89. *Installing Diode Trio/Rectifier Bridge*



1. Mounting screw

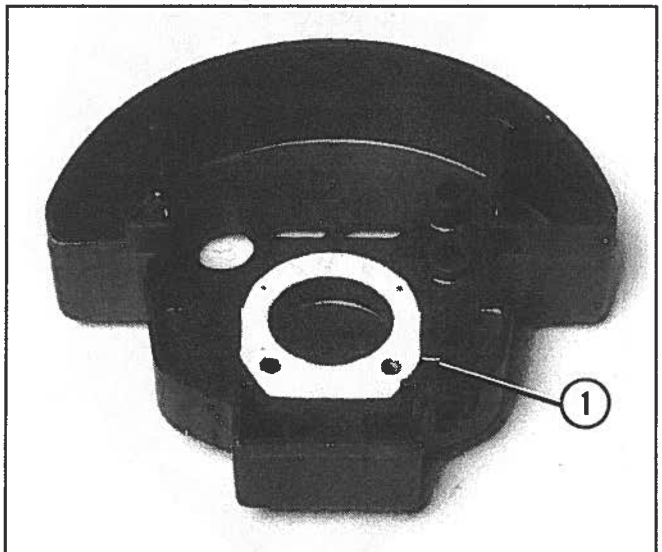
Figure 6-90. *Installing Regulator Assembly*



1. Attaching nuts

Figure 6-91. *Installing Brushholder Assembly*

12. Make sure the felt gasket (Figure 6-92) is on the inside of the rear cover and install the rear cover. Secure the rear cover with two screws.



1. Felt gasket

Figure 6-92. *Installing Rear Cover*

8E SERIES ALTERNATOR INSTALLATION

CAUTION

Do not attempt to polarize the alternator.

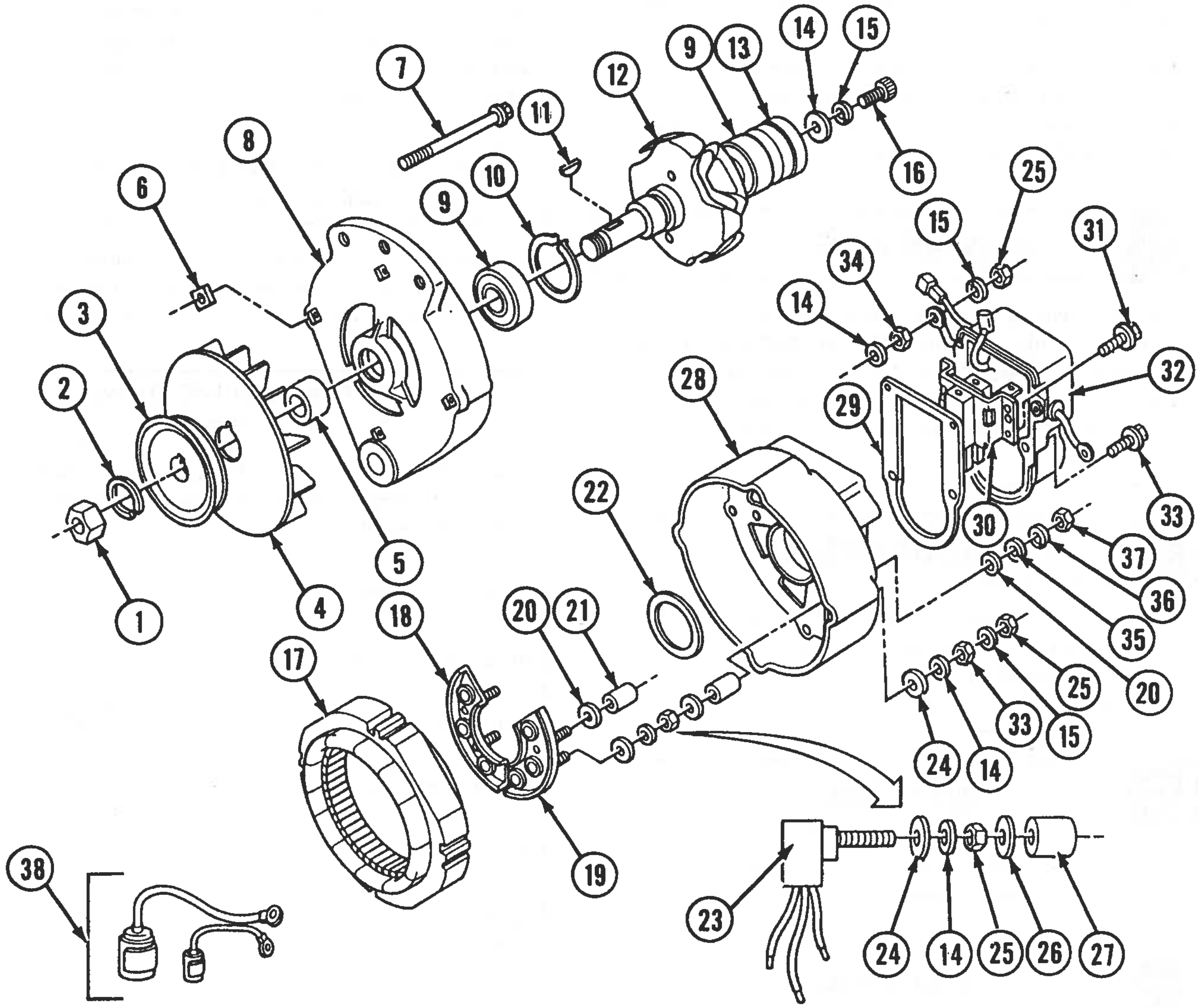
Do not short across or ground any of the terminals on the alternator, except as specifically instructed.

Never disconnect the alternator output lead or battery cables when the alternator is being driven by the engine.

Never disconnect the regulator lead from alternator regulator terminal when the alternator is being driven by the engine.

1. Position alternator in mounting bracket and install mounting bolt, washers (if used), spacer and nut. Place washers (if used) on each side of spacer. Do not tighten nut securely at this time.
2. Fasten alternator brace to alternator with bolt, washers and spacer (if used). Do not tighten bolt securely at this time.
3. Position alternator drive belt on pulleys and adjust tension as explained under Section 3.1, Drive Belts.
4. Reconnect wiring harness to alternator and negative battery cable to battery.

SYSTEMS WITH MOTOROLA 8MR SERIES ALTERNATOR



1. Nut
2. Lockwasher
3. Drive pulley
4. Cooling fan
5. Spacer
6. Nut
7. Through-bolt
8. Front housing
9. Rotor bearing
10. Retainer
11. Key
12. Rotor assembly
13. Slip ring assembly
14. Washer
15. Lockwasher
16. Screw
17. Stator assembly
18. Diode assembly
19. Heat sink
20. Washer
21. Insulating sleeve
22. Retainer
23. Diode trio
24. Washer
25. Nut
26. Washer
27. Insulating sleeve
28. Housing
29. Gasket
30. Brush holder assembly
31. Screw
32. Voltage regulator assembly
33. Screw
34. Nut
35. Washer
36. Lockwasher
37. Nut
38. Alternator suppression kit

Figure 6-93. *Motorola 8MR Series Alternator*

WARNING

Electrical and ignition system components on the Crusader engine are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize the risks of fire and explosion.

Use of electrical or ignition system component replacements which do not comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

When servicing the electrical and ignition systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel s stem leaks.

WARNING

Be sure that engine compartment is well ventilated and that there is no gasoline vapor present, to prevent the possibility of an explosion and/or fire, should a spark occur.

WARNING

Keep fingers, clothing, etc., from alternator belts, fan and pulley; severe bodily harm can occur.

CAUTION

Do not attempt to polarize the alternator.

Do not short across or ground any of the terminals on the alternator, except as specifically instructed.

Never disconnect the alternator-output lead or battery cables when the alternator is being driven by the engine.

Never disconnect the regulator lead from alternator-regulator terminal when the alternator is being driven by the engine.

CAUTION

Always remove negative (–) battery cable from battery before working on the alternator system.

When installing battery, be sure to connect the negative (–) (grounded) battery cable to negative (–) battery terminal and the positive (+) battery cable to positive (+) battery terminal.

If a charger or booster battery is to be used, be sure to connect it in parallel with existing battery (positive to positive, negative to negative).

The alternator is mounted using various brackets, screws and nuts. The following table contains torque specifications for each type of mounting and connector:

TORQUE SPECIFICATIONS

Fastener Location	lb-ft (N•m)	lb-in (N•m)
End-frame screws		50-60 (5.6-6.8)
Brush-set screws		16-20 (1.8-2.3)
Regulator-mounting screws		40-45 (4.5-5.0)
Regulator leads		20-30 (2.3-3.9)
Ground-terminal nut		20-30 (2.3-3.9)
Pulley nut	35-50 (47-68)	
Alternator brace to alternator		192 (22)
Alternator brace to block	30 (41)	
Alternator to mounting bracket	35 (47)	
Alternator mounting bracket	30 (41)	

ALTERNATOR ELECTRICAL SPECIFICATIONS	
Category	**Specification**
Current output	50 A maximum
Voltage output	13.8 V to 14.8 V
Condenser capacity	0.5 µF

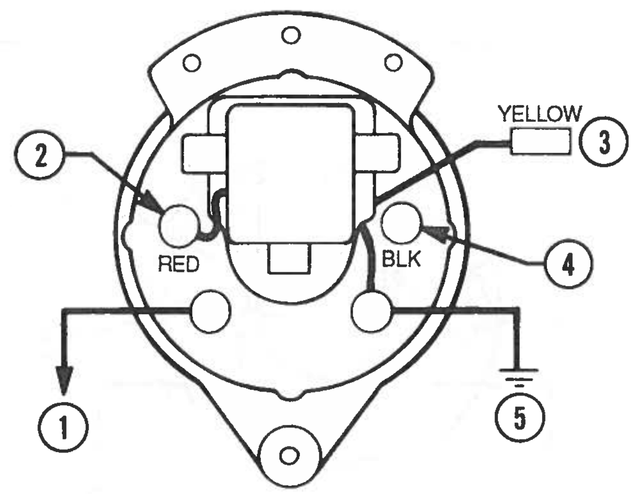
The following two tables list the various special tools that are needed to disassemble/reassemble the alternators.

ALTERNATOR TOOLS	
Kent-Moore Number	**Name**
J-22912-01	Bearing remover

ALTERNATOR TOOLS OBTAINED LOCALLY
Volt/ohmmeter

8MR SERIES ALTERNATOR TEST

1. Connect a voltmeter to the output (+) terminal and the ground terminal as shown in Figure 6-91.



1. Battery (+12 V) terminal
2. Regulator
3. To ignition (+12 V) terminal
4. Stator terminal
5. Ground (–) terminal

Figure 6-94. *Voltmeter Connection to Alternator*

2. Start the engine and operate at approximately 1500 rpm.
3. Turn on electrical accessories.
4. Observe the voltmeter reading. Voltage should range between 13.8-14.8 V for a properly operating alternator.

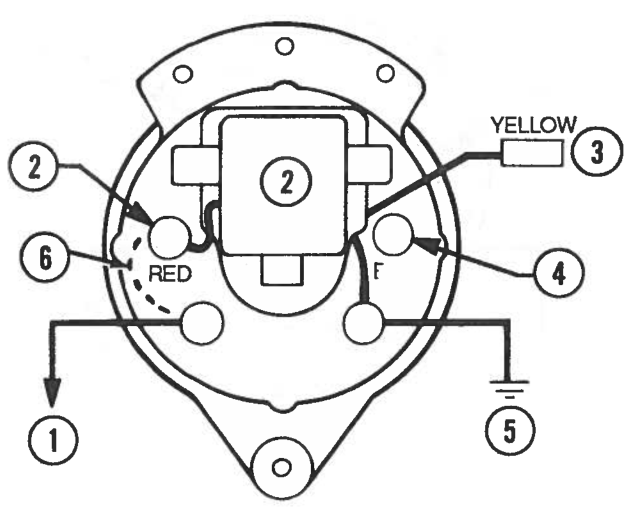
NOTE: Voltage may vary a few tenths of a volt, higher or lower, due to temperature variations.

5. If the voltage output is more than 14.8 V, the regulator is shorted. Replace regulator.

If the voltage output is less than 13.8 V, check the diode trio and then the regulator for proper operation. Refer to the "Diode Trio Test" and "Regulator Test" procedures in this section.

8MR SERIES ALTERNATOR DIODE-TRIO TEST

1. With the engine stopped, turn the ignition switch to ON. Connect a voltmeter to the output (+) terminal and the ground (–) terminal (Figure 6-95). This will check battery voltage.



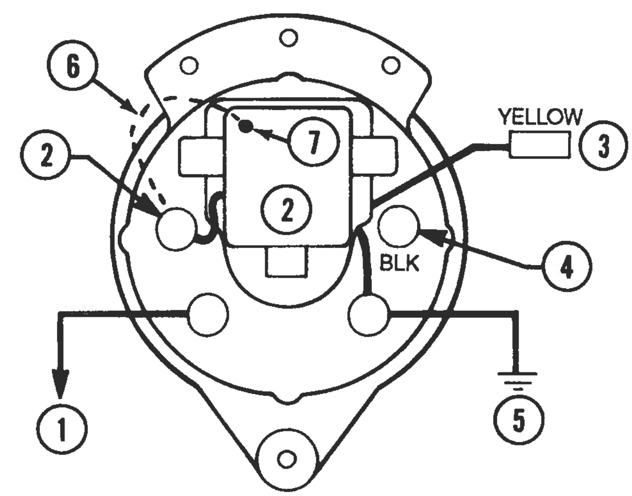
1. Battery (+12 V) terminal
2. Regulator
3. To ignition (+12 V)
4. Stator terminal
5. Ground (–) terminal
6. Jumper

Figure 6-95. *Battery Voltage Check*

2. With the ignition switch still ON, connect the voltmeter to the regulator terminal and ground (–) terminal (Figure 6-95). Regulator voltage should range between 1.5-3.0 V.
3. Connect a jumper wire between the regulator terminal and the output (+) terminal.
4. Start and operate engine at idle speed.
5. Connect a voltmeter to output (+) terminal and ground (–) terminal (Figure 6-95). If a reading ranging from 13.5-15.0 V is obtained, the diode trio is defective (open). Remove alternator for repair. If 13.5-15.0 V is not indicated, remove the jumper wire and test regulator.

8MR SERIES ALTERNATOR REGULATOR TEST

1. Turn the ignition switch to ON. Connect a voltmeter to the output (+) terminal and the ground (–) terminal (Figure 6-96). This will check battery voltage.
2. With the ignition switch ON, connect a voltmeter to the regulator terminal and the ground (–) terminal. An open regulator will indicate battery voltage at the regulator terminal. Turn ignition switch to OFF.
3. Remove the regulator-mounting screws to gain access to the field terminal. Connect a jumper wire between the regulator terminal and field terminal (Figure 6-96).
4. With the ignition switch ON, connect a voltmeter to the regulator terminal and ground. If the voltmeter does not indicate 1.5-3.0 V, the regulator is defective. If battery voltage is still present at the regulator terminal, a defective (open) field circuit is indicated. Repair the alternator, check for bad rotor, brushes, slip rings, etc.



1. Battery (+12 V) terminal
2. Regulator
3. To ignition (+12 V)
4. Stator
5. Battery (–) terminal
6. Jumper
7. Field terminal

Figure 6-96. *Open Regulator-Battery Voltage Check*

8MR SERIES ALTERNATOR REMOVAL

1. Disconnect battery cables from battery.
2. Disconnect wiring harness from alternator.
3. Remove alternator brace to alternator-attaching bolt, washer(s) and spacer (if used).
4. Loosen alternator brace to engine-attaching bolt and alternator-mounting bolt, then pivot alternator inward and remove alternator drive belt.
5. Remove alternator-mounting bolt, washers (if used), spacer and nut, and remove alternator.

8MR SERIES ALTERNATOR DISASSEMBLY

The following instructions are for complete disassembly and overhaul of the alternator. In many cases, however, complete disassembly is not required and, in those cases, it is necessary only to perform the operations required to repair or replace the faulty part.

1. Mount alternator in a vise.
2. Disconnect regulator leads from terminals on rear end-frame. Remove regulator-attaching screws, then pull regulator away from rear end-frame and disconnect regulator field leads. Remove seal.
3. Remove brush-set-attaching screws and brush set.
4. Scribe a mark on rear end-frame, stator and front end-frame to ensure proper reassembly.
5. Remove end-frame screws.

CAUTION
Do not insert screwdrivers more than 1/16 in. (1.6 mm) into openings as stator windings may be damaged.

6. Using two screwdrivers in slots shown, separate rear end-frame and stator assembly from front end-frame and rotor assembly (Figure 6-97).

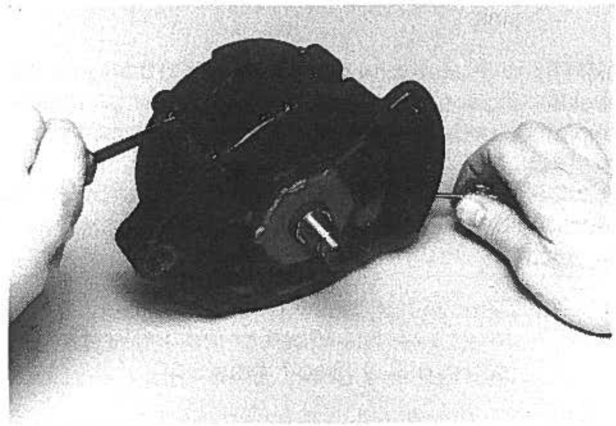
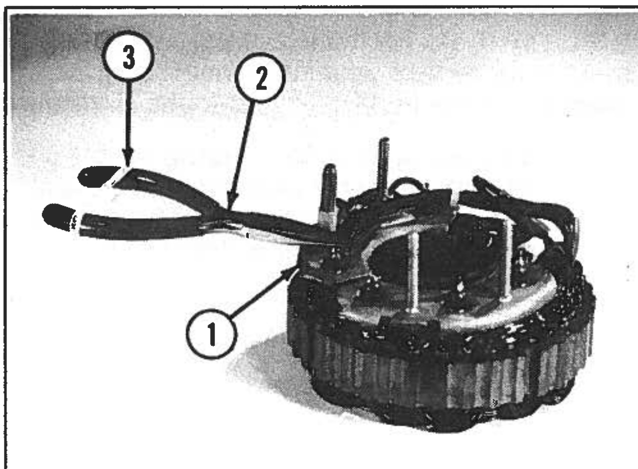


Figure 6-97. *Separating Rear End-Frame From Stator*

7. Remove (and discard) bearing retaining ring from rear end-frame.
8. Place rear end-frame and stator assembly on the bench, stator downward. Remove nuts, washers, insulators and condenser from rectifier-mounting studs and lift rear end-frame from studs. Remove insulating sleeves and washers from rectifier studs.
9. Unsolder stator and diode trio leads from rectifier diode terminals. Place needlenose pliers on diode terminal between solder joint and diode body (Figure 6-98) to help prevent heat damage to diodes. Unsolder joints as quickly as possible and allow diode terminal to cool before removing pliers.



1. Diode terminal
2. Needlenose pliers
3. Rubber band

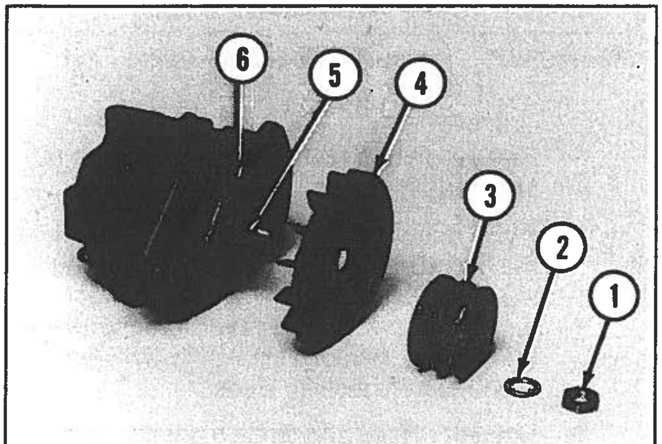
Figure 6-98. *Unsoldering Diode Connections*

10. Remove diode trio from positive rectifier heat sink.

NOTE: With alternator disassembled to this point, stator, rectifier diodes, diode trio and rotor may be tested, as explained under "Component Testing" following.

IMPORTANT: Do not clamp vise on rotor-pole pieces when removing pulley nut, as pole pieces may be distorted.

11. Remove nut, lockwasher, pulley and fan. Use an old oversize V-belt or protective jaws to protect pulley (See Figure 6-99).



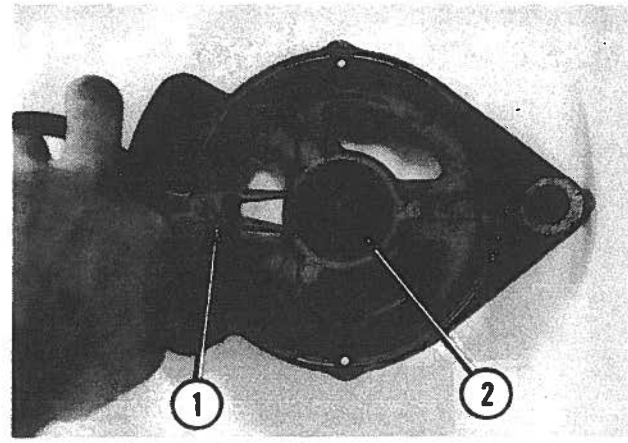
1. Nut	4. Fan
2. Lockwasher	5. Key
3. Pulley	6. Spacer

Figure 6-99. *Removing Pulley*

12. Remove key and spacer.

IMPORTANT: Do not remove front end-frame from rotor shaft, unless absolutely necessary, as front bearing must be replaced if end-frame is removed.

13. Compress ears of front-bearing retainer and lift retainer free of recess in front end-frame. Tap pulley end of rotor shaft with a rawhide mallet to remove rotor and front bearing assembly. See Figure 6-100.



1. Needlenose pliers
2. Front bearing retainer

Figure 6-100. *Removing Front Bearing Retainer*

14. Remove front bearing from shaft with Universal Puller Plate and an arbor press, as shown in Figure 6-101. Discard bearing.

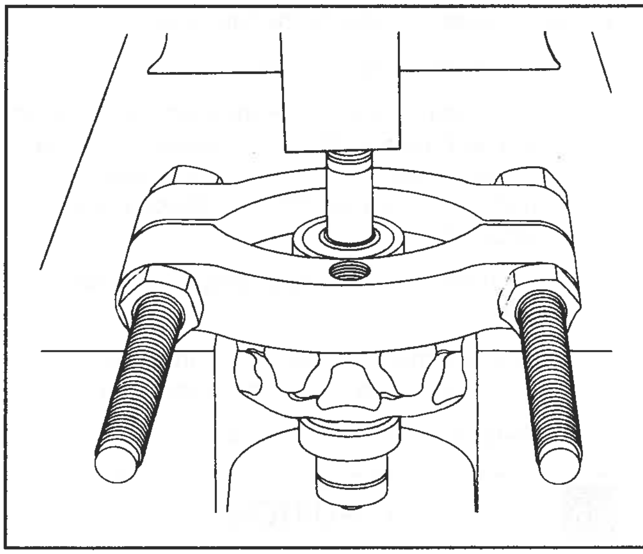


Figure 6-101. *Removing Front Bearing From Rotor*

15. If rotor-slip rings or rear bearing require replacement, unsolder rotor-field-winding leads from slip-ring terminals and unwind end of leads. Remove slip-ring-attaching screw, lockwasher, flat washer and slip rings.

16. If rear bearing requires replacement, remove with Universal Puller Plate and arbor press. Bearing must be replaced, if removed.

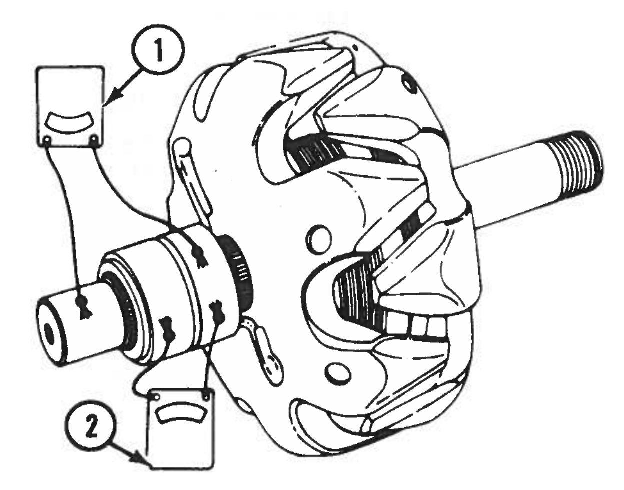
CLEANING AND INSPECTION

1. Clean all parts with a clean, soft cloth. Do not use solvent which may damage electrical components.
2. Inspect the following parts:
   a. **Brush set** – inspect for cracked porcelain casing, damaged brush leads, poor brush-lead solder connections, weak or broken brush springs or worn brushes. Replace brush set if brushes are less than 1/4 in. (6.4 mm) long.
   b. **Rotor** – inspect for stripped threads, worn keyway, scuffed pole-piece fingers or damaged bearing surfaces caused by bearing turning on shaft.
   c. **Rotor slip rings** – clean slip rings with 400-grain (or finer) polishing cloth while spinning rotor in a lathe. Blow off dust with compressed air. Inspect slip rings for grooves, pits, flat spots or out-of-round (0.002 in. [0.05 mm] maximum) and replace, if required.
   d. **Rotor-shaft bearings** – inspect for damaged seals, discoloration (from overheating) or excessive side or end play. Hold inner race of bearings while turning outer race. Bearing should turn freely without binding or showing evidence of rough spots.
   e. **Stator** – inspect for damaged insulation or wires; also inspect insulating enamel for heat discoloration as this is usually a sign of a shorted or grounded winding or a shorted diode.
   f. **Regulator** – inspect leads for damaged insulation.
   g. **Front and rear end-frames** – inspect for cracks, distortion, stripped threads or wear in bearing bore (from bearing outer race spinning in bore). End-frame must be replaced if bearing has spun. Also, inspect bearing-retainer recess in front end-frame for damage.
   h. **Fan** – inspect for cracked or bent fins, broken welds (bidirectional fan only) or worn mounting hole caused by fan spinning on shaft.
   i. **Pulley** – inspect pulley-mounting bore and key groove for wear. Inspect drive surface of pulley sheaves for trueness, excessive wear or corrosion. Repair, if possible, with a fine file and a wire brush or replace pulley. Drive surfaces must be true and smooth, or drive-belt wear will be greatly accelerated.
   j. **Alternator** – if alternator has output at low speeds, but no output at high speeds, rotor-field winding may be shorting or grounding out because of centrifugal force. Replace rotor if all other electrical components test good.

COMPONENT TESTING

Rotor:

1. Test rotor-field circuit for grounds, using an ohmmeter set on Rx1 scale as follows (see Figure 6-102):
   a. Connect one lead of ohmmeter to either slip ring and the other lead to rotor shaft or pole pieces.
   b. Meter should indicate no continuity (meter should not move).
   c. If continuity does exist, rotor-field circuit is grounded. Inspect slip-ring terminals to be sure that they are not bent and touching rotor shaft. Also be sure that excess solder is not grounding terminals to rotor shaft. If cause for ground cannot be found, unsolder field-winding leads from slip-ring terminals and connect ohmmeter between one of the leads and rotor shaft or pole pieces. If continuity still exists, replace rotor assembly. If continuity is eliminated, replace slip rings.



1. Step 1 connections 2. Step 2 connections

Figure 6-102. *Testing Rotor*

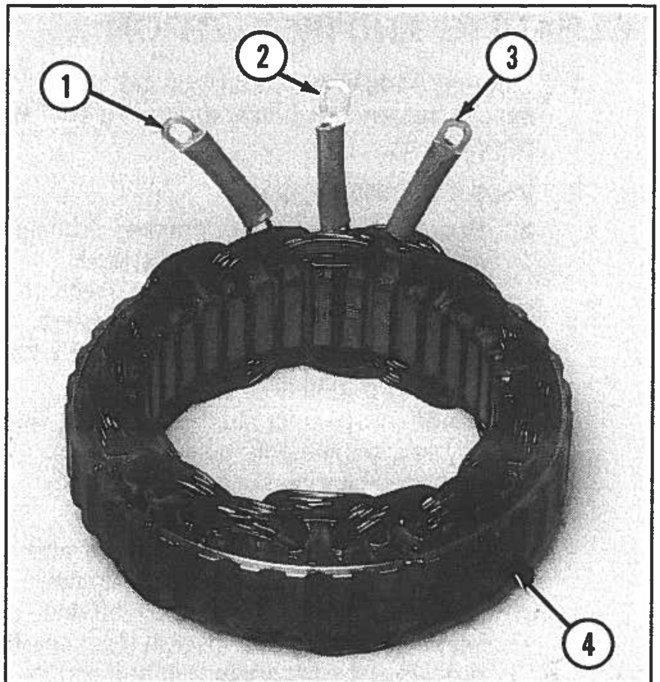
2. Test rotor field circuit for opens, shorts or high resistance using an ohmmeter set on Rx1 scale as follows:
   a. Connect one ohmmeter lead to each slip ring.
   b. Ohmmeter reading should be 4.2-5.5 ohms with rotor at room temperature (70-80° F [21-27° C]).
   c. If reading is high or infinite (no meter movement), high resistance or an open exists in the field circuit. Check for poor connections between field-winding leads and slip-ring terminals. If cause for open or high resistance cannot be found, connect ohmmeter directly to slip-ring terminals. If correct reading is now obtained, replace slip rings. If reading is still high or infinite, replace complete rotor assembly.
   d. If reading is low, a short exists in the field circuit. Inspect slip rings to be sure that they are not bent and touching outer slip ring. Also be sure that excess solder is not shorting terminals to aft slip ring. If cause for short cannot be found, unsolder field-winding leads from slip-ring terminals and connect ohmmeter directly to leads. If correct reading is now obtained, slip rings are shorted and must be replaced. If reading is still low, rotor-field windings are shorted, and complete rotor assembly must be replaced.

Stator:

IMPORTANT: Stator leads must be disconnected from rectifier diodes and diode trio for this test

1. Test stator (Figure 6-103) for grounds using ohmmeter set on Rx1 scale as follows:
   a. Connect one lead of ohmmeter or test lamp to one of the stator leads (1, 2 or 3) and the other lead to stator frame (4). Be sure that lead makes good contact with frame.

      Meter should indicate no continuity (meter should not move). If continuity does exist, stator is grounded and must be replaced.



1. Stator-winding leads
2. Stator-winding leads
3. Stator-winding leads
4. Stator-winding laminations

Figure 6-103. *Testing Stator*

2. Test for opens in stator using an ohmmeter set on Rx1 scale as follows:
   a. Connect ohmmeter or test lamp between each pair of stator windings (three different ways). Either of the two leads (1, 2 or 3) coming from each stator winding may be used

      Continuity should be present in all three cases (meter should move). If it does not, one or more of the windings are open and stator must be replaced.
3. A short in the stator is difficult to detect without special equipment, because of the windings' low resistance. If all other electrical components test out all right, and alternator fails to produce rated output, stator probably is shorted and should be replaced. Also, examine stator for heat discolorations as this is usually a sign of a short.

Negative (–) Rectifier Diodes:

IMPORTANT: Rectifier diodes must be disconnected from stator for this test.

> **⚠ CAUTION**
>
> Do not use a test instrument with more than a 12-V source as rectifier diodes may be damaged.

1. Connect one lead of an ohmmeter set on Rx1 scale to negative (–) rectifier-diode heat sink and the other lead to one of the rectifier-diode terminals (Figure 6-104). Note the reading.

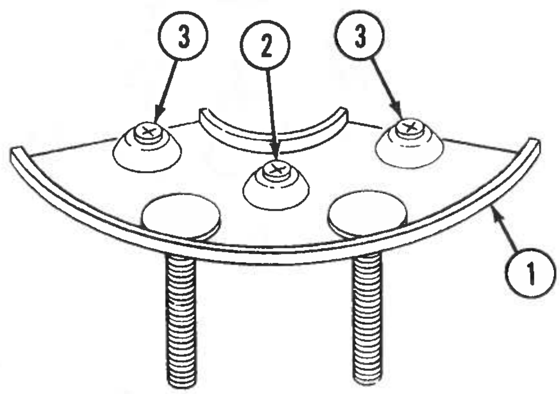


Figure 6-104. *Testing Negative Diodes*

2. Reverse leads and again note reading.
3. Meter should indicate a high or infinite resistance (no meter movement) when connected one way and a low reading when connected the other. If both readings are low, diode is shorted.
4. Repeat Steps 1 through 3 for two other rectifier diodes in heat sink.
5. Replace complete rectifier set, if any one of the diodes is shorted or open.

Positive (+) Rectifier Diodes and Diode Trio:

> **⚠ CAUTION**
>
> Do not use a test instrument with more than a 12-V source as rectifier diodes may be damaged.

1. Connect one lead of an ohmmeter set on Rx1 scale to stud on positive (+) rectifier heat sink and the other lead to one of the rectifier-diode terminals (Figure 6-105). Note the meter reading.

NOTE: Two of the diode terminals come up the diode-trio circuit board.

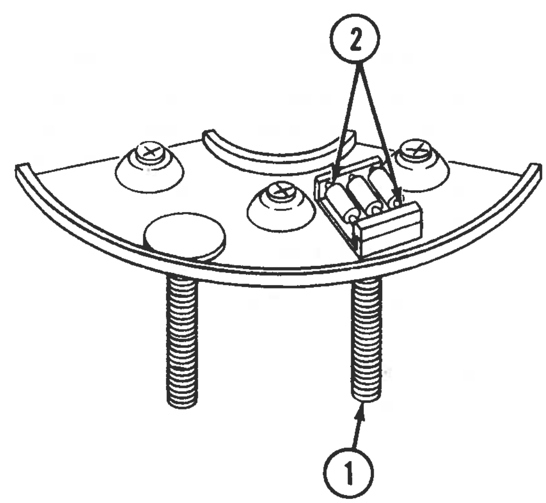
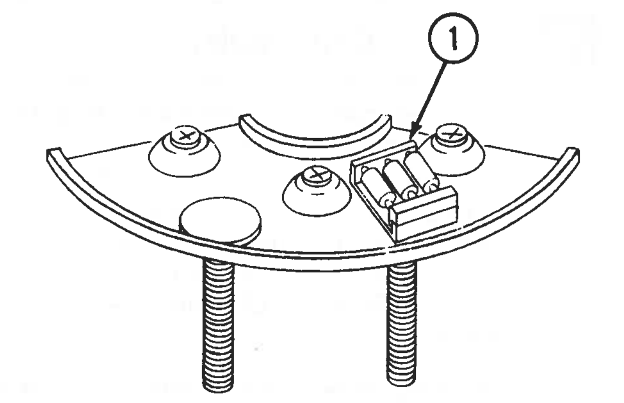


Figure 6-105. *Testing Positive Diodes*

2. Reverse leads and again note reading.
3. Meter should indicate a high or infinite resistance (no meter movement) when connected one way and a low reading when connected the other. If both readings are high or infinite, diode is open. If both readings are low, diode is shorted.
4. Repeat Steps 1 through 3 for two other rectifier diodes in heat sink.
5. Replace complete rectifier set if any one of the diodes is shorted or open.
6. Connect one lead of an ohmmeter set on Rx1 scale to the common side on the diode trio circuit board and the other lead to the other

side of one of the three trio diodes (Figure 6-106). Note the reading.



1. Common side of double trio circuit board

***Figure 6-106.** Testing Diode Trio*

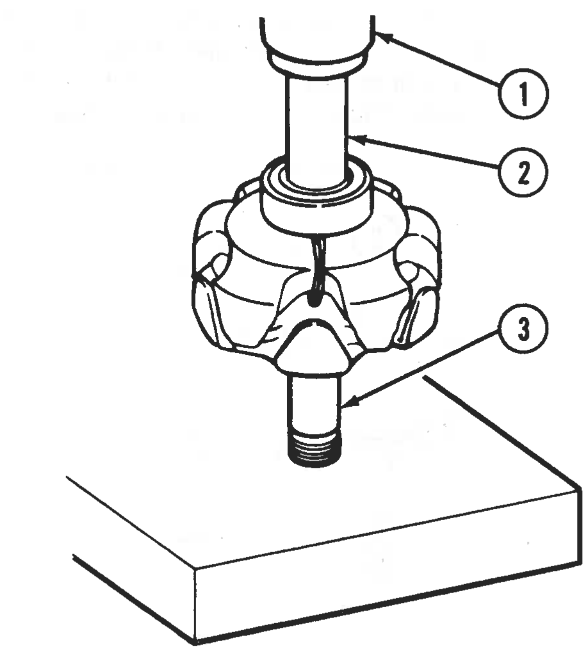
7. Reverse leads and again note reading.
8. Meter should indicate a high or infinite resistance (no meter movement) when connected one way and a low reading when connected the other. If both readings are high or infinite, diode trio is open. If both readings are low, diode trio is shorted.
9. Repeat Steps 6 through 8 for the other two diodes.
10. Replace positive (+) rectifier and diode-trio assembly if any one of the diodes is shorted or open.

Condenser:

1. Using Magneto Analyzer 91-76032 and accompanying instructions, perform the following condenser tests:
   a. Condenser Capacity Test (must be 0.5 µF)
   b. Condenser Short or Leakage Test
   c. Condenser Series Resistance Test
2. Replace condenser if test results are not within specifications.

8MR SERIES ALTERNATOR REASSEMBLY

1. Press new rear bearing all the way onto rotor shaft until inner race contacts shoulder. Use an arbor press and a bearing driver that contacts inner bearing race only. Use extreme care to prevent damage to field-winding leads. See Figure 6-107.



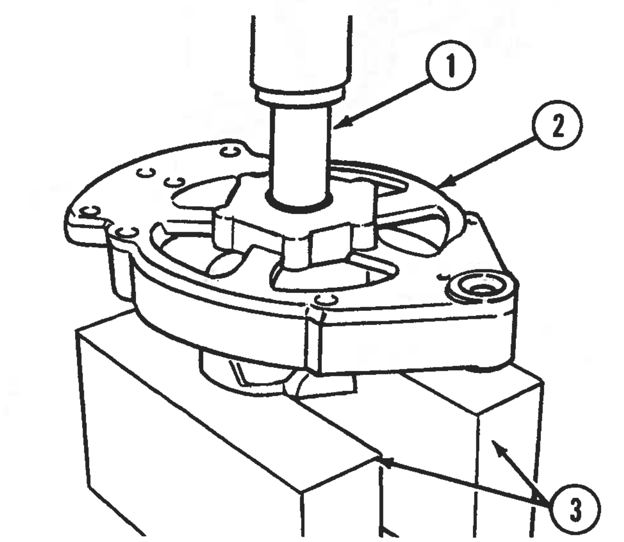
1. Arbor press
2. Bearing driver (must contact inner bearing race only)
3. Support pulley end of shaft on arbor press base (DO NOT support rotor on pole pieces)

***Figure 6-107.** Pressing Bearing Onto Rotor*

IMPORTANT: Be sure to support rotor on end of shaft and not on pole pieces, as pole pieces are only press-fit onto shaft.

2. Insert field-winding leads through passage in slip-ring hub, then hand-press slip rings onto shaft while maintaining proper alignment with leads and passage. Install cap screw, lockwasher and flat washer. Torque screw to specifications.
3. Wrap ends of field-winding leads around slip-ring terminals and solder with resin-core solder. Do not use excessive solder. Do not use excessive heat which may damage insulation on field-winding leads.

4. Press new front bearing into front end-frame bearing bore. If necessary, use a bearing driver that contacts outer race only. Install bearing retainer into recess in end-frame (with ears outward and aligned with opening), using long-nose pliers and a punch. Use extreme care to prevent damage to front-bearing seal. Be sure that retainer is fully seated in groove. Its ears should touch both sides of recess.
5. Press front end-frame and bearing assembly onto rotor shaft until inner bearing race contacts shoulder. Use an arbor press and a bearing driver that fits over shaft and contacts inner bearing race only, as shown. Be sure to support rotor on pole pieces only. See Figure 6-108.



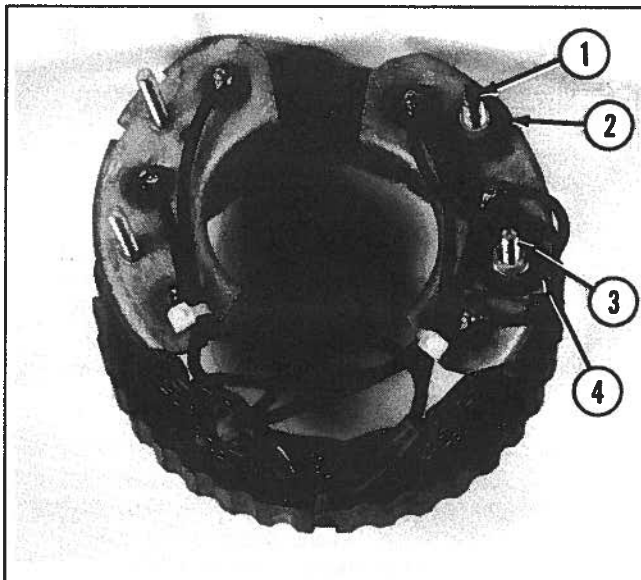
1. Arbor press with bearing driver (must contact inner-bearing race only)
2. Front end-housing
3. Supports for rotor

Figure 6-108. *Pressing Bearing Into Front End-Frame*

CAUTION

Do not clamp vise on rotor-pole pieces when tightening pulley nut or pole pieces may be distorted.

6. Slide fan spacer onto rotor shaft. Install new woodruff key, then install fan, pulley, lockwasher and nut on shaft. Use protective jaws or an old oversize V-belt to protect pulley and clamp pulley in a vise. Tighten vise only enough to allow tightening of nut, as excessive tightening may distort pulley. Torque nut to specifications.
7. Position diode trio in positive-rectifier-set heat sink. Using resin-core solder, resolder stator and diode trio leads to rectifier diodes, as shown. Use long-nose pliers to prevent heat damage to diodes. Solder connection as quickly as possible and allow it to cool before removing pliers.
8. Place insulating washers and sleeves on diode-trio stud and positive-rectifier-set stud, as shown in Figure 6-109.



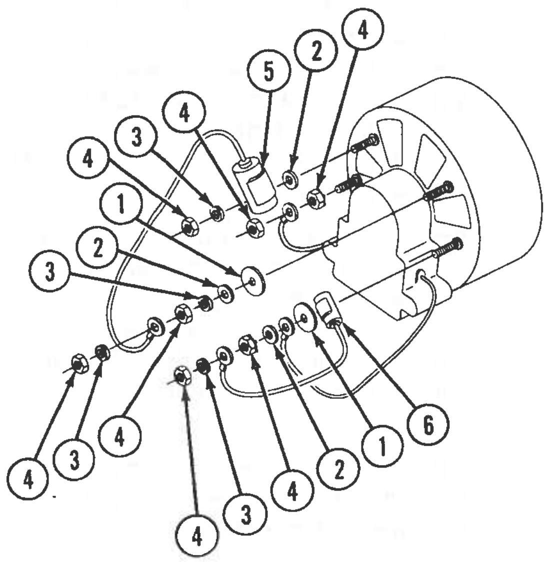
1. Diode trio stud
2. Small insulating washer and sleeve
3. Positive rectifier set stud
4. Large insulating washer and sleeve

Figure 6-109. *Insulating Washer Installation*

CAUTION

The insulating washers must be installed as shown or damage to the alternator will result.

9. Guide rear end-frame onto diode trio and rectifier-diode-set studs, then install condenser, insulating washers, flat washers, lockwashers and nuts (Figure 6-110). Tighten nuts to specifications.



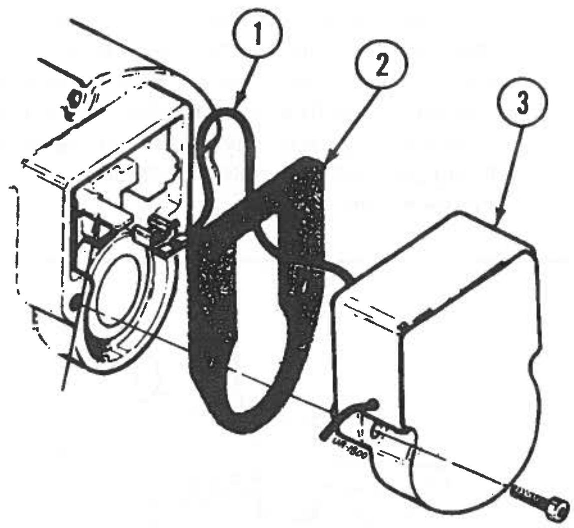
1. Fiber washer
2. Washer
3. Lockwasher
4. Nut
5. Large capacitor
6. Small capacitor

Figure 6-110. Rear End-Frame Fasteners

10. Install new rear bearing retainer in recess of rear end-frame bearing bore. Lubricate exposed surface of retainer with a small amount of hydraulic brake fluid to ease assembly over the rear bearing. Do not use oil or grease.
11. Position rear end-frame and stator assembly over front end-frame and rotor assembly and align scribe marks on each (scribed during disassembly). Hand-press end-frames together, then install through-bolts and nuts. Torque bolts evenly to specifications.
12. Place brush set in rear end-frame cavity and secure with mounting screws. Be sure to use outermost mounting holes. Torque screws to specifications.
13. Position felt seal on regulator-mounting surface (See Figure 6-108). Connect regulator-field lead to brush terminal, then mount regulator with screws. Torque screws to specifications. Connect regulator leads to regulator terminal and ground terminal, and secure with lockwashers and nuts. Torque nuts to specifications.

CAUTION

Regulator-field lead must be connected as shown or lead may be damaged by rotor slip rings during operation.



1. Regulator brush lead
2. Felt synthetics
3. Regulator

Figure 6-111. Regulator Installation

8MR SERIES ALTERNATOR INSTALLATION

CAUTION

Do not attempt to polarize the alternator.

Do not short across or ground any of the terminals on the alternator, except as specifically instructed.

Never disconnect the alternator output lead or battery cables when the alternator is being driven by the engine.

Never disconnect the regulator lead from alternator regulator terminal when the alternator is being driven by the engine.

1. Position alternator in mounting bracket and install mounting bolt, washers (if used), spacer and nut. Place washers (if used) on each side of spacer. Do not tighten nut securely at this time.
2. Fasten alternator brace to alternator with bolt, washers and spacer (if used). Do not tighten bolt at this time.
3. Position alternator drive belt on pulleys and adjust tension as explained under Section 3.1, Drive Belts.
4. Reconnect wiring harness to alternator and negative battery cable to battery.

BLANK

MANDO ALTERNATOR

PRECAUTIONS FOR TESTING ALTERNATOR

WARNING

Be sure that engine compartment is well-ventilated and that there is no gasoline vapor present to prevent the possibility of an explosion and/or fire should a spark occur.

WARNING

Keep fingers, clothing, etc., from alternator belts, fan and pulley; severe bodily harm can occur.

CAUTION

1. DO NOT attempt to polarize the alternator.
2. DO NOT short across or ground any of the terminals on the alternator, except as specifically instructed in the "Troubleshooting Tests."
3. NEVER disconnect the alternator-output lead or battery cables when the alternator is being driven by the engine.
4. NEVER disconnect regulator lead from alternator-regulator terminal when the alternator is being driven by the engine.
5. ALWAYS remove negative (–) battery cable from battery before working on alternator system.
6. When installing battery, BE SURE to connect the negative (–) (grounded) battery cable to the negative (–) battery terminal and the positive (+) battery cable to the positive (+) battery terminal.
7. If a charger or booster battery is to be used, BE SURE to connect it in parallel with existing battery (positive to positive; negative to negative).

TORQUE SPECIFICATIONS

Fastener Location	lb-ft N•m	lb-in N•m
Alternator Front Housing Screws		25-35 lb-in (2.8-4.0 N•m)
Alternator End Frame Screws		35-65 lb-in (4.0-7.3 N•m)
Alternator Pulley Nut	35-50 lb-ft (47-68 N•m)	
Regulator Mounting Screws		25-45 lb-in (2.8-5.1 N•m)

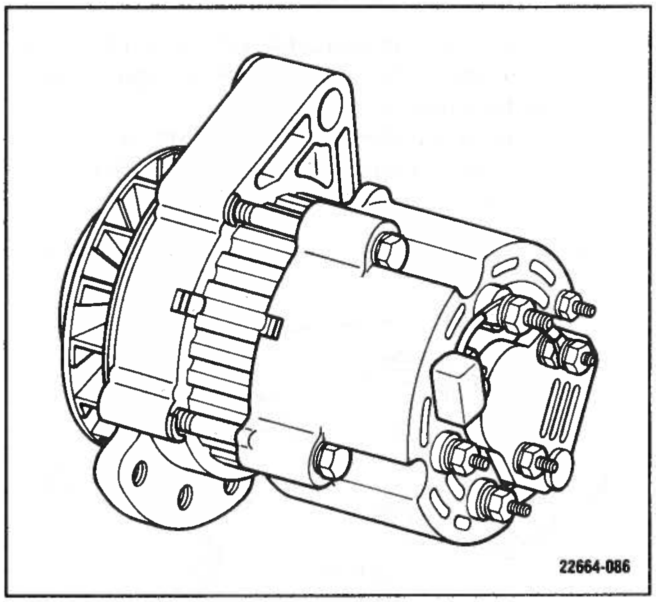


Figure 6-112. *Mando Alternator*

PREPARING TO CHECK ALTERNATOR

Before you start alternator tests, check these items:

1. If problem is an undercharged battery, check to ensure that undercharged condition has not been caused by excessive accessory current draw or by accessories which have accidentally been left on. Also, check that undercharged condition has not been caused by running engine at too low a speed for extended periods of time.
2. Check physical condition and state of charge of battery, as outlined under "Battery

Hydrometer Test" in this chapter. Battery MUST BE fully charged to obtain valid results in the following tests. If not, charge battery before testing system.

3. Inspect entire alternator system wiring for defects. Check all connections for tightness and cleanliness, particularly battery cable clamps and battery terminals.
4. Check alternator drive belt for excessive wear, cracks, fraying and glazed surfaces, and replace, if necessary. Also, check drive belt tension and adjust, if necessary, as outlined under "Adjust Alternator Belt" in this chapter.

TEST OUTPUT CIRCUIT

1. Connect positive voltmeter lead to alternator output terminal and negative lead to ground terminal on alternator. (Figure 6-114)
2. Wiggle engine wiring harness while observing voltmeter. Meter should indicate approximate battery voltage and should not vary. If no reading is obtained, or if reading varies, check alternator-output circuit for loose or dirty connections or damaged wiring.

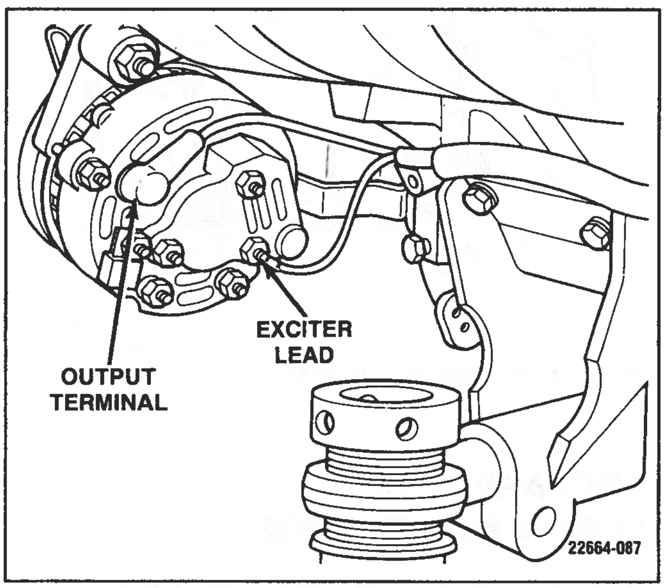


Figure 6-113. *Alternator Wiring Connections*

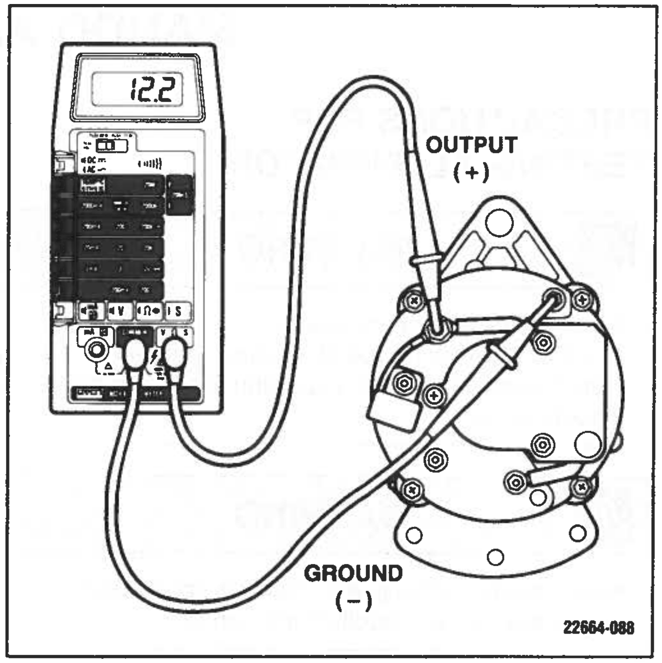


Figure 6-114. *Testing Alternator Output Circuit*

TEST EXCITATION CIRCUIT

1. Connect positive (+) voltmeter lead to excitation terminal on alternator and negative (–) lead to ground terminal on alternator.
2. Turn ignition switch to "On" position and note voltmeter reading. Reading should be 1.3 to 2.5 volts. (Figure 6-115)
3. **If reading is between .75 and 1.1 volts**, rotor field circuit probably is shorted or grounded. Disassemble alternator and test rotor as outlined under "Clean and Test Alternator Components" in this chapter.
4. **If reading is between 6.0 and 7.0 volts**, rotor field circuit probably is open. Remove regulator and inspect for worn brushes or dirty slip rings. Replace brushes if less than 1/4" (6 mm) long. If brushes and slip rings are in good condition, disassemble alternator and test rotor, as outlined under "Clean and Test Alternator Components" in this chapter.

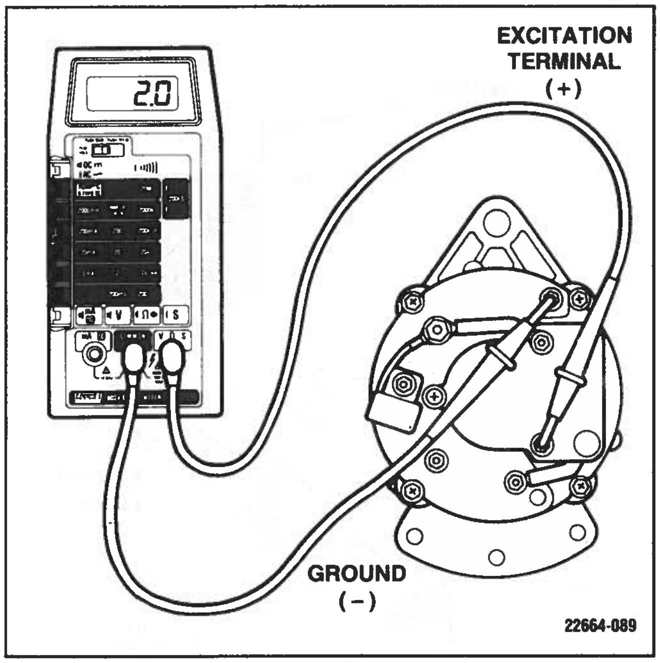


Figure 6-115. Testing Exciter Circuit

5. **If no reading is obtained**, an opening exists in alternator-excitation lead or in excitation circuit of regulator. Disconnect yellow lead from regulator. Connect positive voltmeter lead to yellow lead and negative voltmeter lead to ground. If voltmeter now indicates approximate battery voltage, voltage regulator is defective and must be replaced. If no voltage is indicated, check excitation circuit for loose or dirty connections or damaged wiring. (Figure 6-116)

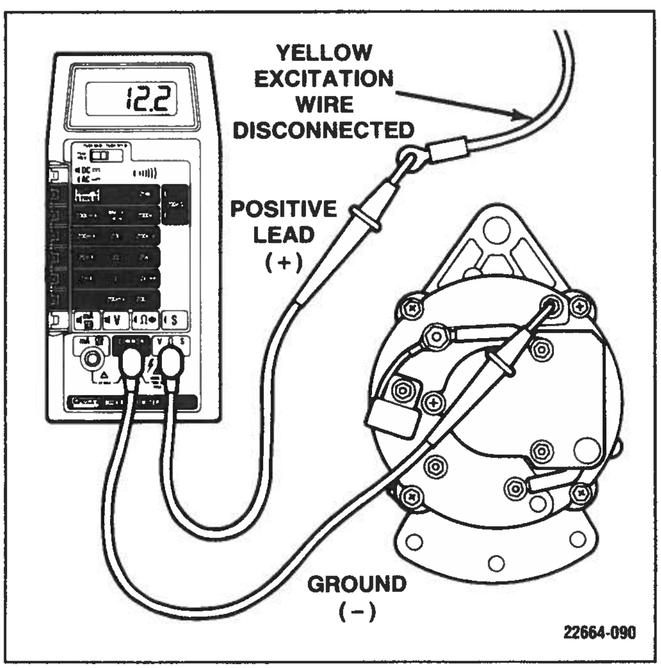


Figure 6-116. Testing Exciter Lead

TEST ALTERNATOR CURRENT OUTPUT

Perform this test to check if alternator is capable of producing rated current output, using a 0-50 amp DC ammeter.

1. Disconnect negative (–) battery cable from battery.
2. Disconnect orange lead from alternator-output terminal and connect ammeter in series between lead and output terminal. Connect positive side of ammeter toward output terminal.
3. Reconnect negative battery cable.
4. Remove coil high-tension lead from distributor cap tower and ground it to block. Turn on all accessories and crank engine over with starter motor for 15-20 seconds.
5. Turn off accessories and reinstall coil-high-tension lead. Start engine and adjust engine speed to 1500-2000 rpm. Quickly observe ammeter. Reading should be at least 30 amps. (Figure 6-117)

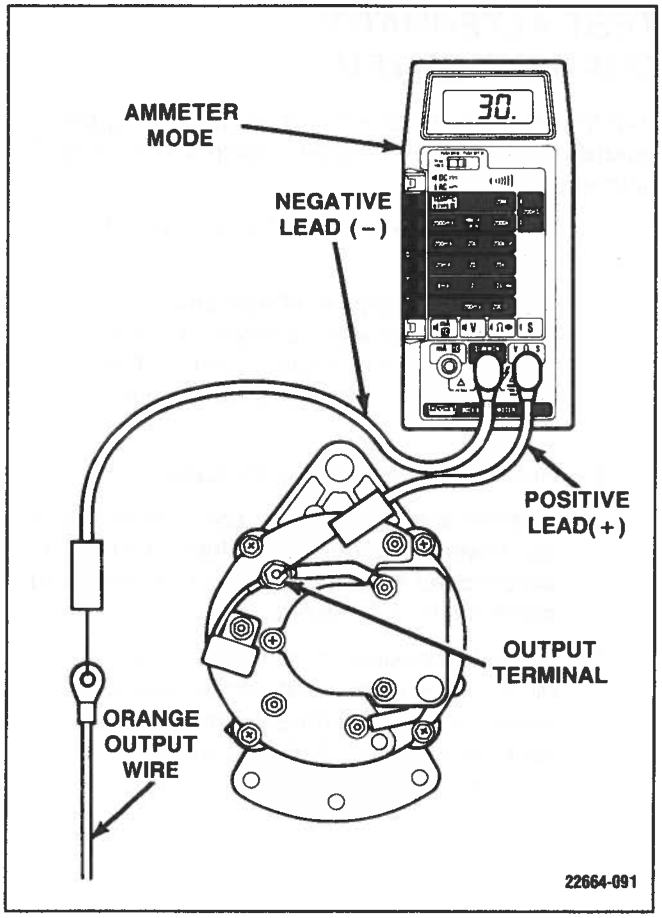


Figure 6-117. Alternator-Output Test 1

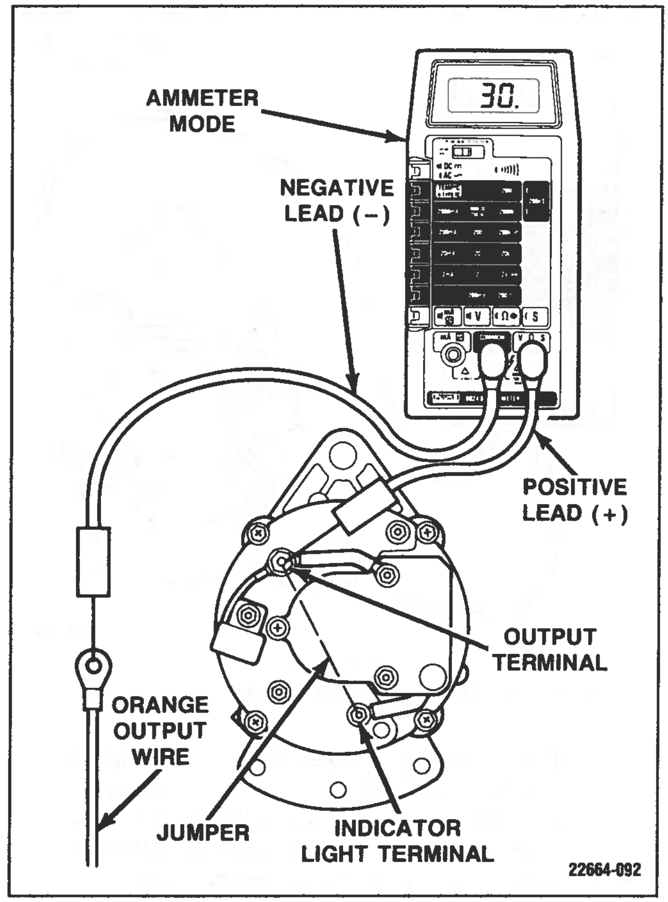


Figure 6-118. Alternator-Output Test 2

6. If reading is low, stop engine and connect a jumper lead between alternator-output terminal and indicator light terminal. Repeat Steps 4 and 5. (Figure 6-118)
7. If reading is now within specifications, diode trio is faulty. Disassemble alternator and replace diode trio, as explained in this chapter.
8. If reading is still low with jumper lead connected, perform Voltage Regulator Test to determine if fault is in regulator or alternator.

TEST VOLTAGE REGULATOR

Perform this test to determine if voltage regulator is operating correctly, using a 0-20 volt DC voltmeter.

IMPORTANT: Battery MUST BE fully charged, 1.265 or above specific gravity, to obtain proper voltage reading in this test. If necessary, charge battery with a battery charger or allow engine to run a sufficient length of time to fully charge battery before taking reading.

1. Connect positive (+) voltmeter lead to positive battery terminal and negative (–) voltmeter lead to negative terminal. (Figure 6-119)
2. Start engine and run at fast idle until engine reaches normal operating temperature. Adjust engine speed to 1,500-2,000 rpm and observe voltmeter for highest reading. Reading should be between 13.7 and 14.7 volts.
3. If reading is high, check for a loose or dirty regulator ground lead connection. If connection is good, voltage regulator is faulty and must be replaced. Be sure to disconnect battery cables before attempting to remove regulator.
4. If reading is low:
   a. Stop the engine.
   b. Remove Phillips cover screw from regulator cover. (Figure 6-120)
   c. Remove nut from output terminal and nut from sensing terminal, and remove jumper (A).
   d. Remove another nut from sensing terminal and nut from excitation terminal.
   e. Remove regulator cover.
   f. Temporarily install jumper (A) and all associated nuts. Leave jumper (B) installed.

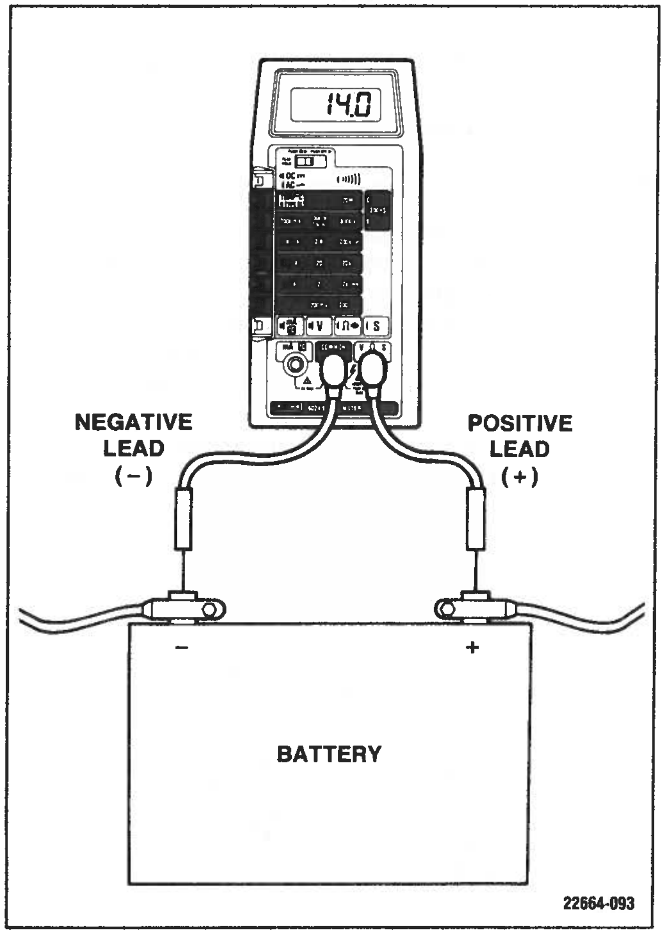


Figure 6-119. *System-Voltage Check*

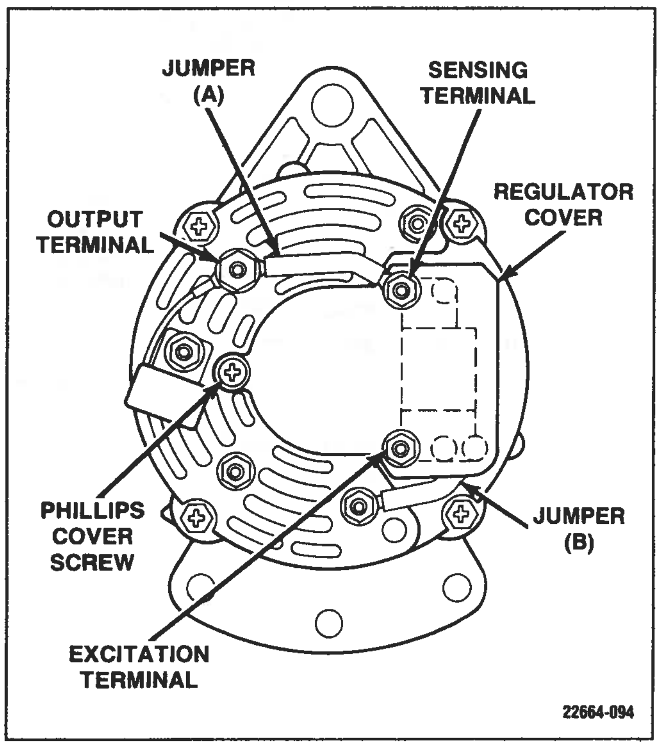


Figure 6-120. *Regulator-Cover Removal*

g. Remove plastic plug from side of regulator.

h. Connect a jumper between top brush lead from brush and ground. (Figure 6-121)

i. Repeat steps 1 and 2.

NOTE: DO NOT let voltage exceed 16 volts.

j. If a voltmeter reading of 14.5 volts or above is now obtained, voltage regulator is faulty and must be replaced. If voltmeter reading is below 14.5 volts, inspect brushes and slip rings for wear, dirt or damage. If brushes and slip rings are good, alternator is faulty internally. Disassemble alternator and test components, as outlined in this chapter.

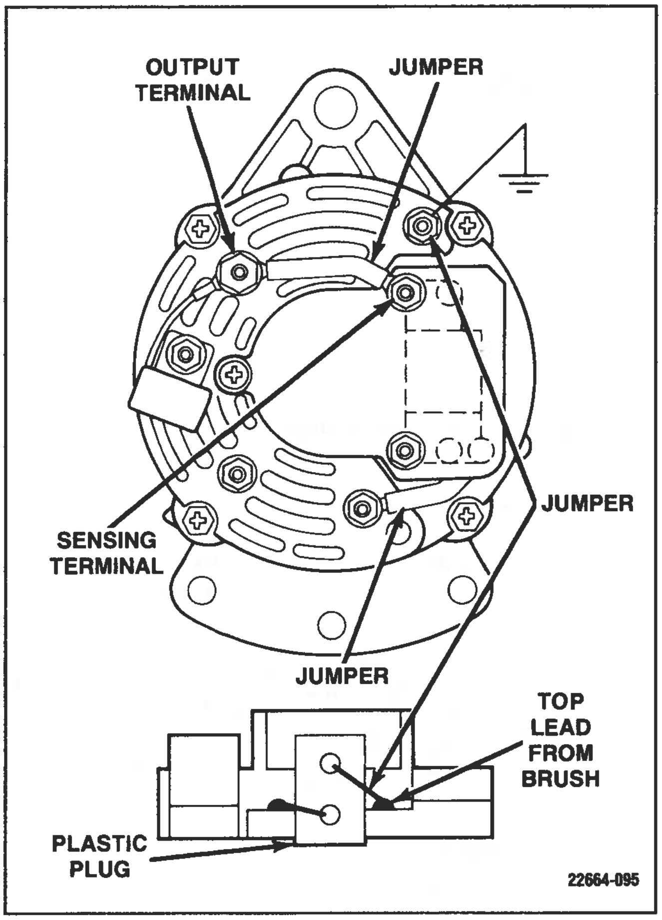


Figure 6-121. End View Of Regulator With Cover Removed

REMOVE ALTERNATOR

1. Disconnect negative (–) battery ground cable.
2. Disconnect wiring leads.
3. Loosen screws. Holding alternator, rotate alternator towards engine and lift belt off the pulley.
4. Remove screws and washers to remove alternator. (Figure 6-122)

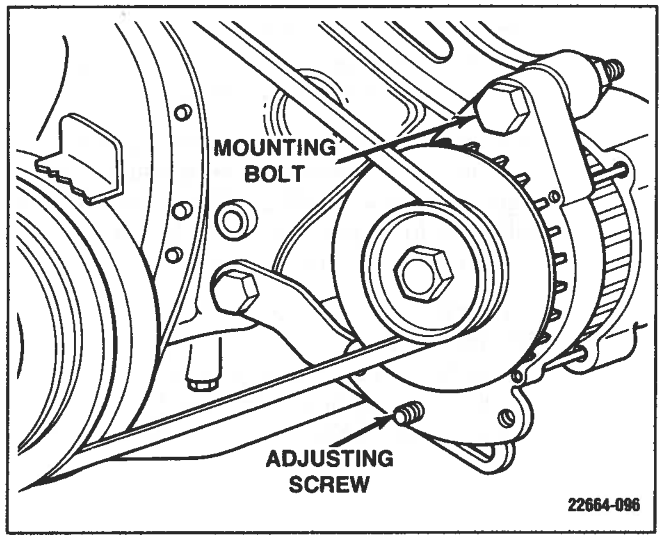


Figure 6-122. Alternator Mounting

DISASSEMBLE ALTERNATOR

1. Remove terminal nuts to remove jumper. (Figure 6-123)
2. Remove remaining terminal nuts.
3. Remove capacitor.
4. Remove Phillips screw from regulator cover.
5. Remove brush/regulator-assembly cover.
6. Remove nut from terminal.
7. Remove jumper.
8. Remove terminal insulators.
9. Remove two Phillips screws and remove brush/regulator assembly.

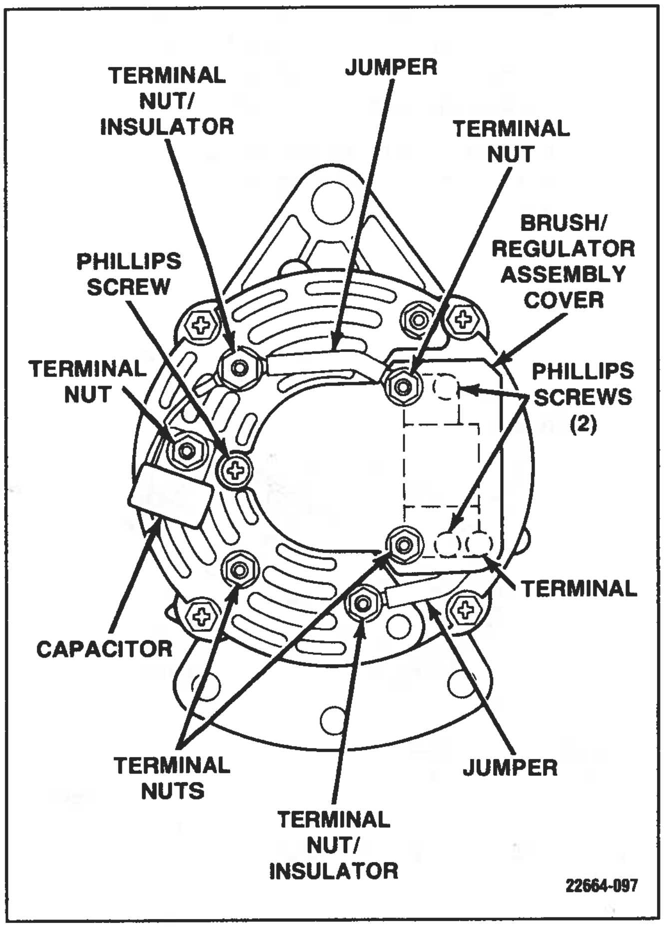


Figure 6-123. *Alternator Disassembly*

10. Place an oversized V-belt around pulley and fasten pulley in a vise. (Figure 6-124)
11. Use a 7/8" box wrench to loosen and remove pulley nut.

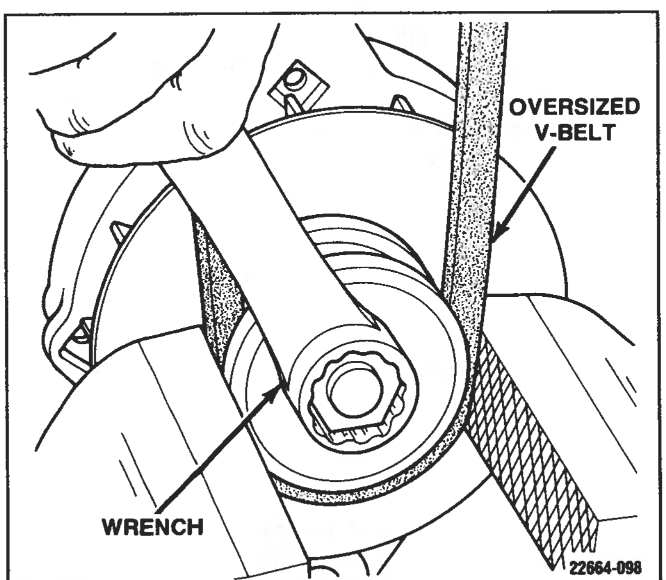


Figure 6-124. *Pulley Removal*

12. Remove the pulley nut, lockwasher, pulley, fan, and spacer. (Figure 6-125)

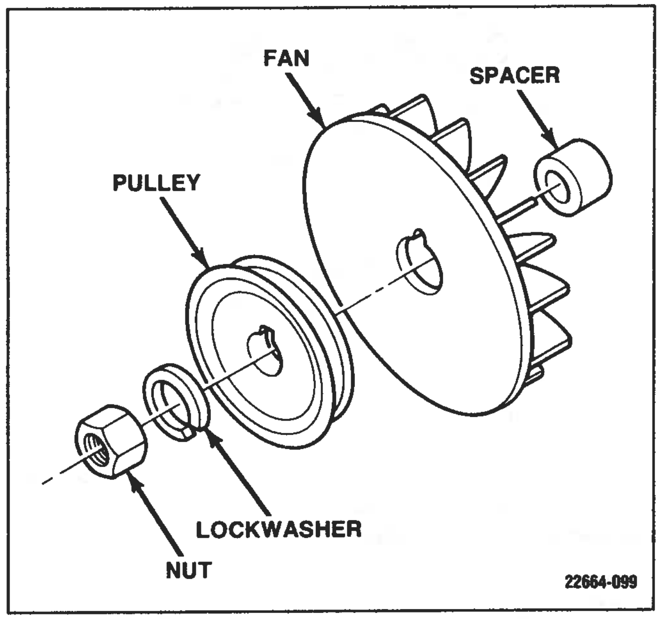


Figure 6-125. *Pulley And Fan Components*

CAUTION

DO NOT insert screwdriver blades more than 1/16 in. (1.6 mm). Damage to the stator winding could result from deeper penetration.

NOTE: Score the stator, front and rear housings so the unit may be reassembled correctly.

13. Remove four through-bolts and carefully pry the front housing away from the rear housing using two screwdrivers. (Figure 6-126)

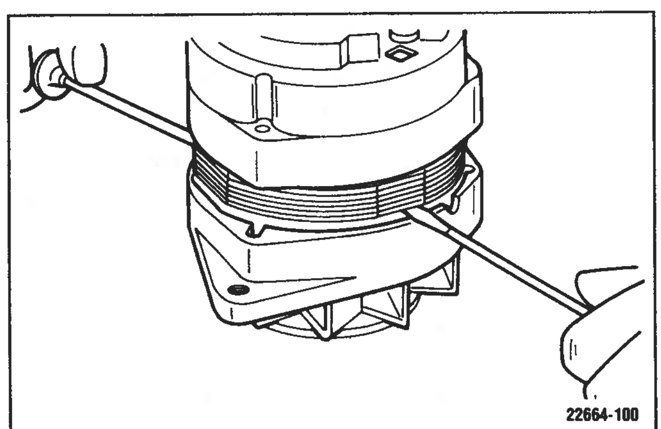


Figure 6-126. *Housing And Stator Removal*

14. Carefully push the rotor assembly out of the front housing and rear housing. (Figure 6-127)

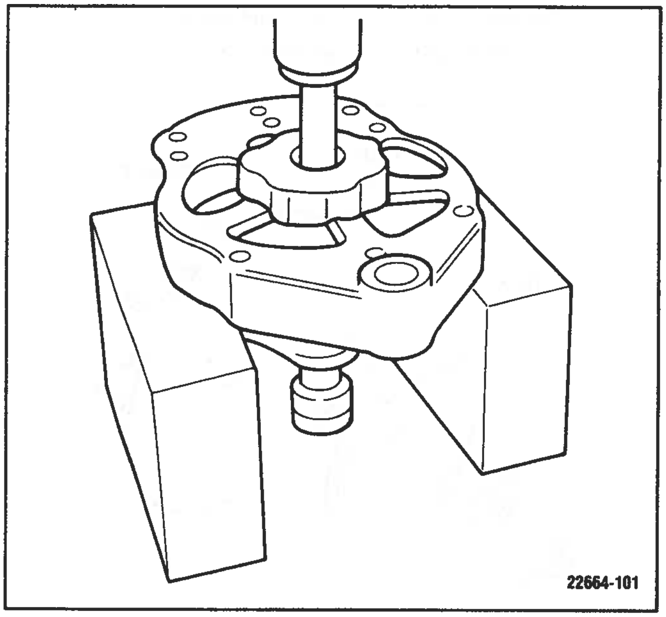


Figure 6-127. *Rotor Removal*

NOTE: If bearing is removed from housing, a new bearing must be installed.

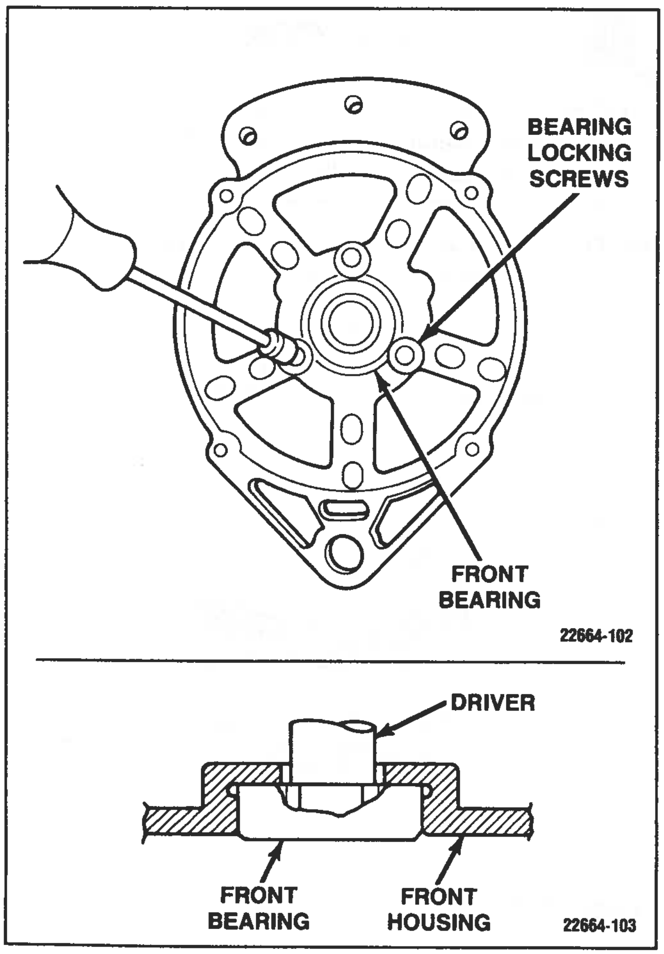


Figure 6-128. *Front-Housing Bearing Removal*

15. After removing the three bearing-locking screws, carefully press the front bearing from the housing. Press against the inner race of the bearing as shown. (Figure 6-128)
16. Remove rectifier assembly by removing Phillips screw and lifting out assembly. (Figure 6-129)

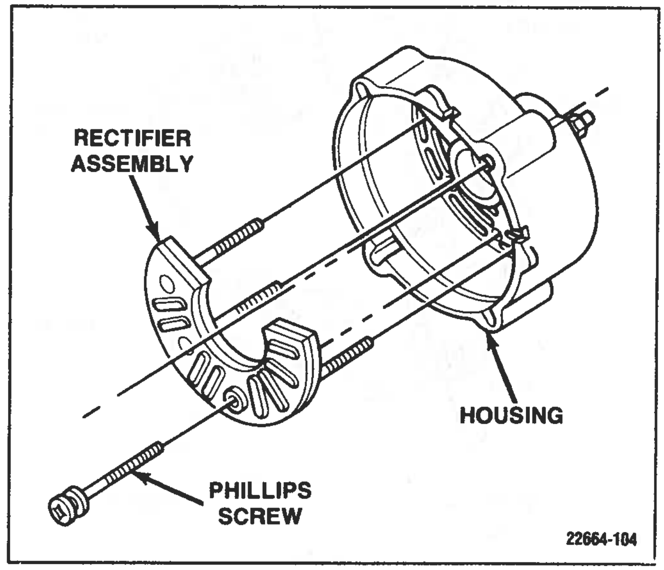


Figure 6-129. *Rectifier Removal*

CLEAN AND TEST ALTERNATOR COMPONENTS

1. Inspect and test brush/regulator assembly. Brush set may be reused if brushes are 1/4 in. (6 mm) or longer. Brushes must not be oil soaked, cracked or grooved.

   Test for continuity between 1 and 2, and 3 and 4 using a test lamp or an ohmmeter. These checks will indicate a good brush/regulator assembly; replace complete assembly, if necessary. (Figure 6-130)

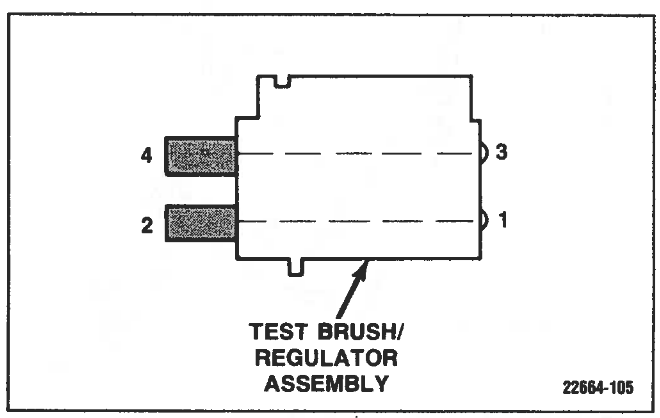


Figure 6-130. *Testing Brush/Regulator Assembly*

2. Inspect and test diode-trio assembly.
   a. Using a commercial diode tester, a 12-volt DC test lamp or an ohmmeter, check the resistance between each of the three diode terminals and the indicator-light stud as shown. (Figure 6-131)
   b. Reverse the tester leads and repeat the resistance checks.
   c. A very low resistance should be indicated in one direction and a very high resistance should be indicated in the other direction if the diodes are normal.
   d. If any diode appears to be defective, replace the complete assembly. Do not attempt to replace an individual diode.
3. Test diode-rectifier bridge as follows:
   a. Using a commercial diode tester, check for continuity from each of three terminals to output terminal. (Figure 6-132)

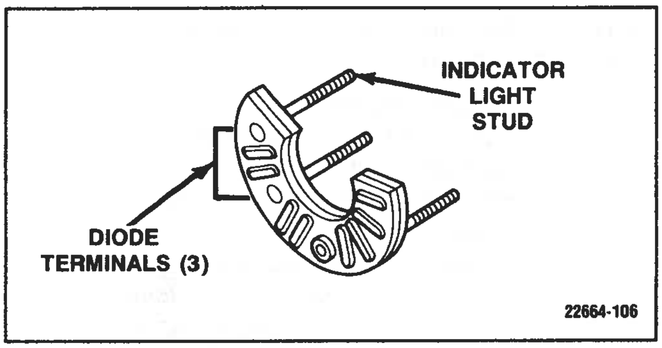


Figure 6-131. *Diode-Trio Assembly*

   b. Reverse the tester leads and repeat Step a.
   c. Continuity should exist in only one direction and all diodes should check alike.
   d. Perform the same continuity checks between the three terminals and strap ground terminal. This should show continuity in only one direction through the diodes and all diodes should check alike.
   e. If any diode appears to be defective, replace the rectifier assembly.

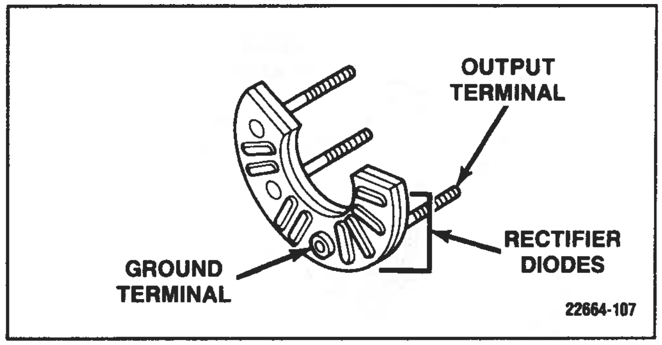


Figure 6-132. *Diode-Rectifier Bridge*

4. Clean and inspect front and rear housings:
   a. Inspect the rear housing for cracks or breaks in the casting, stripped threads or a damaged bearing bore. Replace the housing if any of these conditions exist.
   b. Inspect the front housing for cracks, stripped or damaged threads in the adjusting ear, or an out-of-round bore in the mounting foot. If possible, correct slightly damaged threads using a tap. Replace the housing, if necessary.
   c. If the housings are to be reused, clean them in solvent and dry with compressed air.
5. Clean and inspect rotor shaft bearings:

NOTE: DO NOT use a solvent on rear rotor bearing since it is serviced as a unit with the rotor.

   a. Bearings should be wiped clean with a lint-free cloth containing a moderate amount of commercial solvent. Do not immerse a bearing in solvent, or use pressurized solvent or air.
   b. Check the bearings for obvious damage, looseness or rough rotation. Replace a bearing if any doubt exists as to its condition.

NOTE: If the rear rotor bearing needs replacement, replace the entire rotor.

6. Inspect the belt pulley for rough or badly worn belt grooves or keyway and for cracks or breaks. Remove minor burrs and correct minor surface damage; replace a badly worn or damaged pulley.

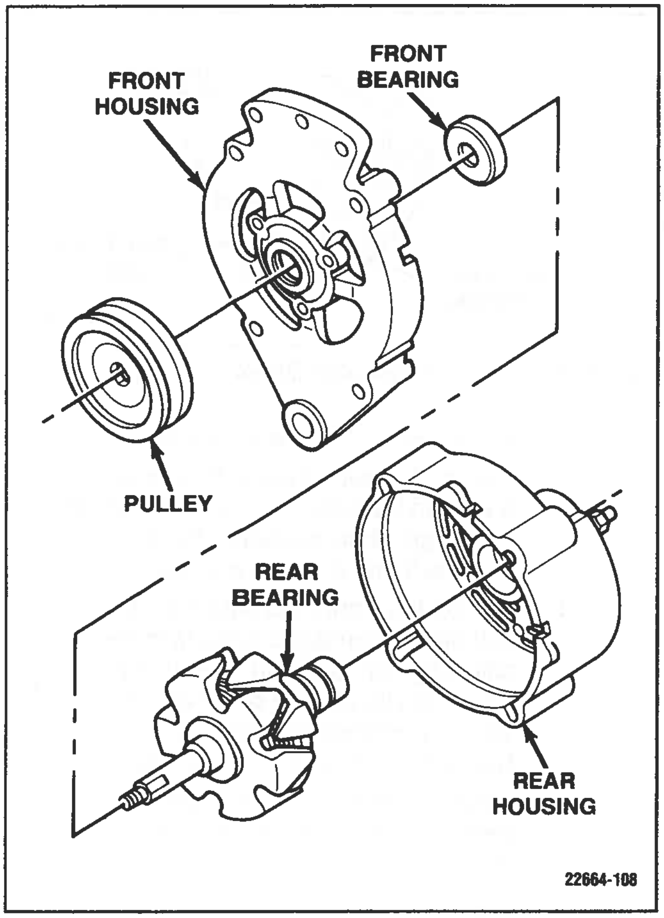


Figure 6-133. Alternator Bearings

7. Test stator windings as follows:
   a. Using an ohmmeter or test lamp, check for continuity between all three leads (1, 2, and 3). A low ohm reading or lit test lamp should be observed. (Figure 6-134)
   b. Check resistance from each lead (1, 2, and 3) to the laminations (4). There should be no continuity if the insulation is good.
   c. Inspect the stator windings for signs of discoloration. A discolored winding should be replaced.
   d. If a winding shows a high resistance or an open circuit between any two of the three winding terminals or indicates poor insulation between the windings and the laminations, the stator must be replaced.

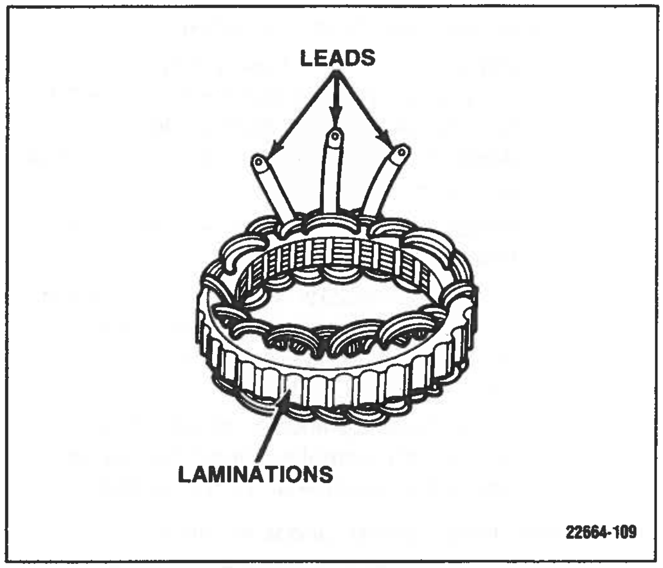


Figure 6-134. Stator Windings

8. Check rotor assembly as follows:

NOTE: If slip rings need to be replaced, you must replace the entire rotor.

   a. Visually inspect for physical defects such as damaged shaft threads, worn or damaged bearing areas, burned or pitted slip rings or scuffed pole fingers. (Figure 6-135)
   b. Measure winding resistance across the slip rings (A). Place the ohmmeter leads on the edges of the slip rings, not on the brush contact surfaces. The correct winding resistance at 70-80° F (21-27° C) is 4.1 to 4.7 ohms. (Figure 6-135)
   c. Minor burning or pitting of the slip ring surfaces can be removed using crocus cloth. Thoroughly wipe the slip rings clean after polishing, removing all grit and dust.
   d. Check for a grounded slip ring or rotor winding by measuring resistance from each slip ring to the rotor body or pole finger (B). An open circuit should be indicated in both cases for a good rotor. (Figure 6-135)
   e. If windings are defective or physical damage cannot be corrected, replace the rotor assembly.

9. Use a commercial capacitor checker to test capacitor for capacity, shorts, leakage, and series resistance.

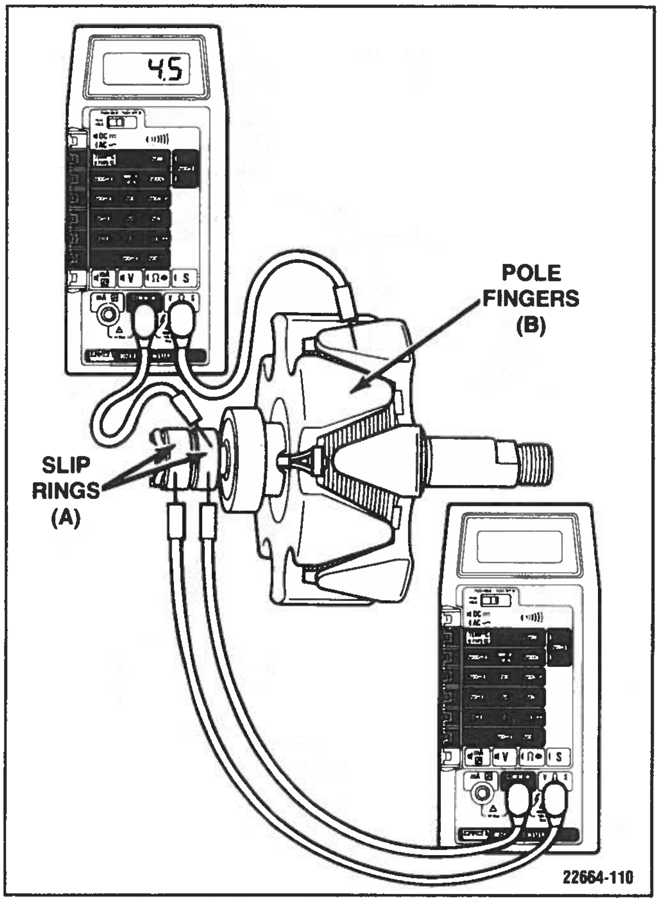


Figure 6-135. Testing Rotor

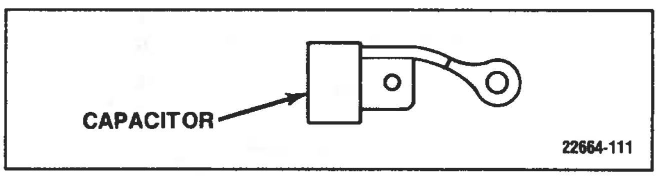


Figure 6-136. Capacitor

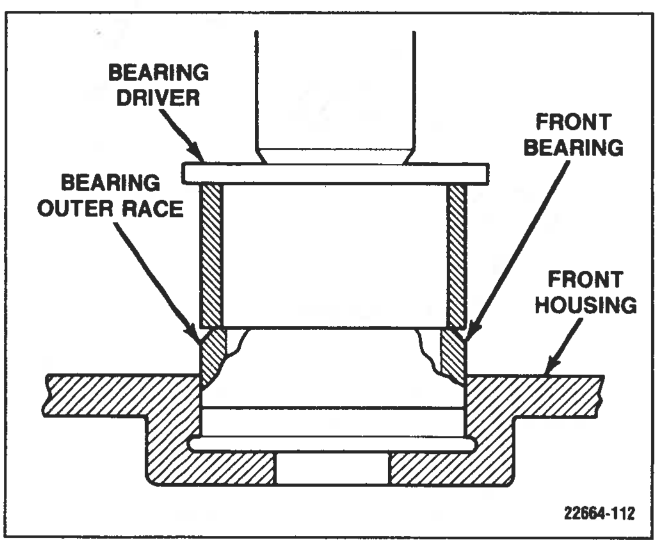


Figure 6-137. Front-Bearing Installation

ASSEMBLE ALTERNATOR

1. Carefully press the front bearing into the front housing, pushing against the bearing outer race using a bearing driver. Lock the bearing in place with screws. (Figure 6-137)

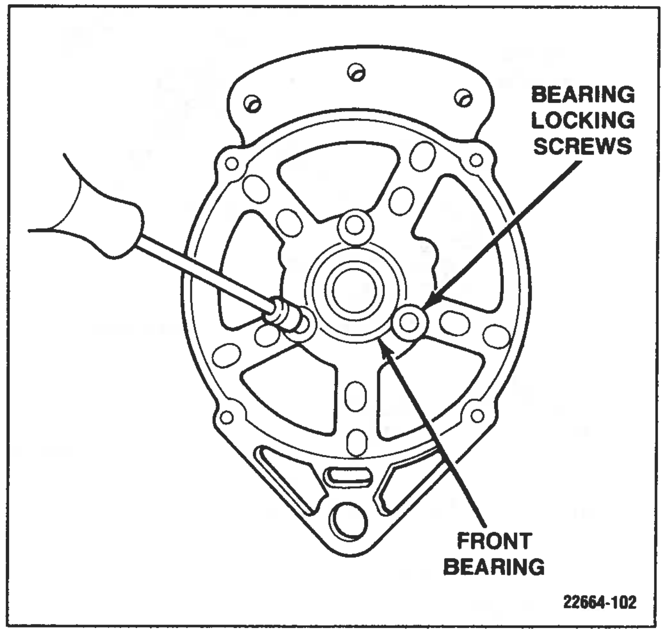


Figure 6-138. Installing Bearing Retainers

2. Place the rotor (pulley end up) on the bed of an arbor press, on two steel blocks.
3. Press the front housing and bearing assembly down onto the rotor shaft. Press against the bearing inner race only, using a sleeve driver. Take care to insure that the rotor leads clear the steel blocks. (Figure 6-139)

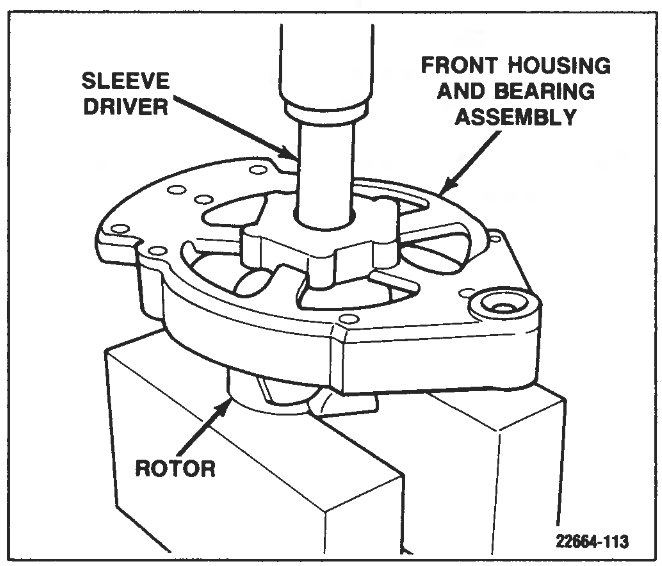


Figure 6-139. Installing Front Housing On Rotor Assembly

4. Install rectifier assembly into rear housing.
5. Insert Phillips screw and tighten. (Figure 6-140)

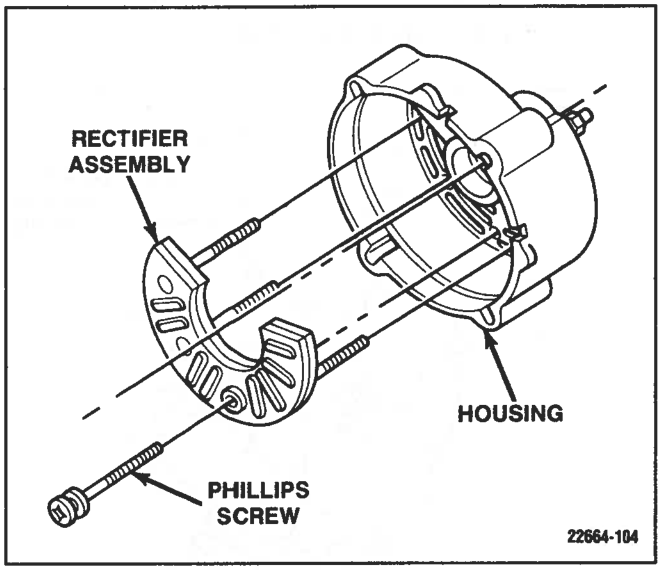


Figure 6-140. Installing Rectifier Assembly

6. Assemble the front and rear housings as follows:
   a. Put the stator winding in the front housing with the stator leads away from the front housing and the notches in the stator laminations aligned with the four through-bolt holes in the housing.
   b. Align the scribe marks you made in the stator, front, and rear housings during disassembly.
   c. Slip the rear housing into place over the rotor shaft. Align the mounting holes and put the stator leads through the holes at the top of the rear housing.
   d. Install the four bolts and tighten. (Figure 6-141)

NOTE: If the front housing is new, the through-bolt will not be tapped.

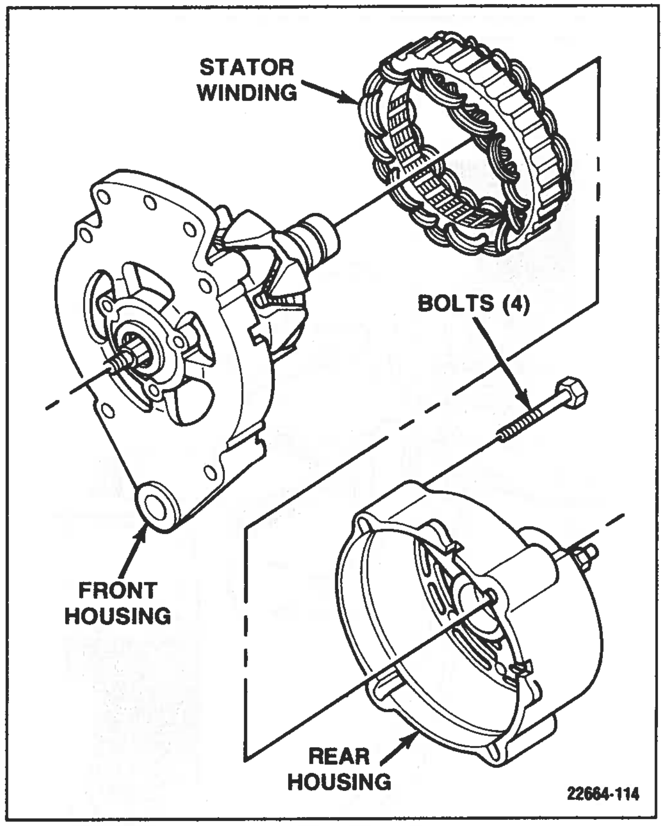


Figure 6-141. Assembling Housings

7. Install the spacer and the fan. Then push the pulley, lockwasher and nut onto the shaft. Turn nut a few turns.

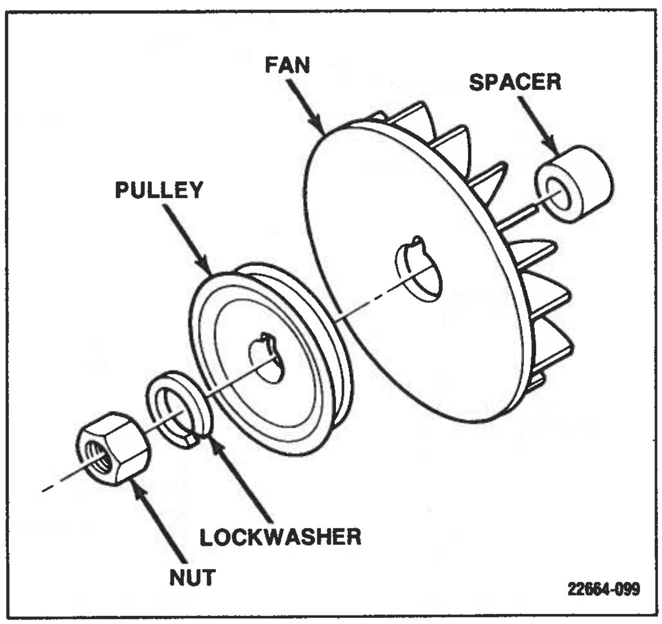


Figure 6-142. Pulley And Fan Components

8. Place an oversized V-belt around pulley and fasten pulley in a vise. (Figure 6-143)
9. Use a torque wrench to tighten nut.

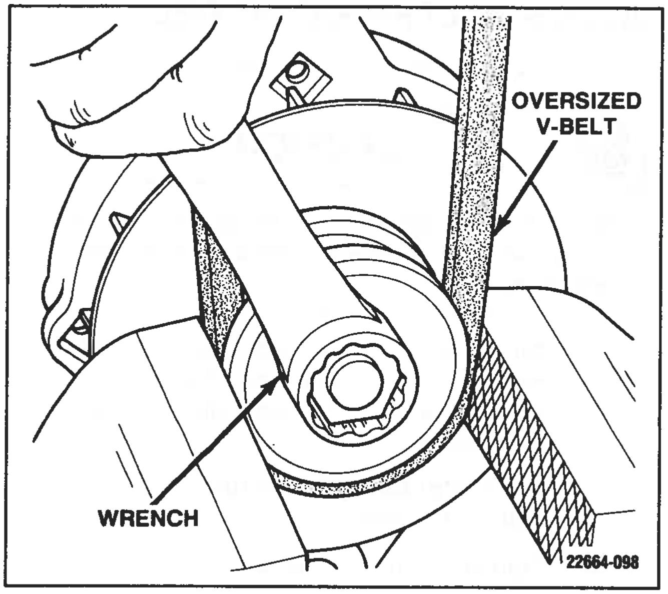


Figure 6-143. Installing Pulley And Fan Nut

10. Carefully install the brush/regulator assembly on the rear housing with the two mounting screws.
11. Install small terminal insulators.
12. Install large terminal insulator.
13. Install jumper.
14. Install nut on terminal.
15. Install brush/regulator assembly cover.
16. Install Phillips screw for brush/regulator assembly cover.
17. Install capacitor.
18. Install terminal nuts.
19. Install jumper.
20. Install last terminal nut.

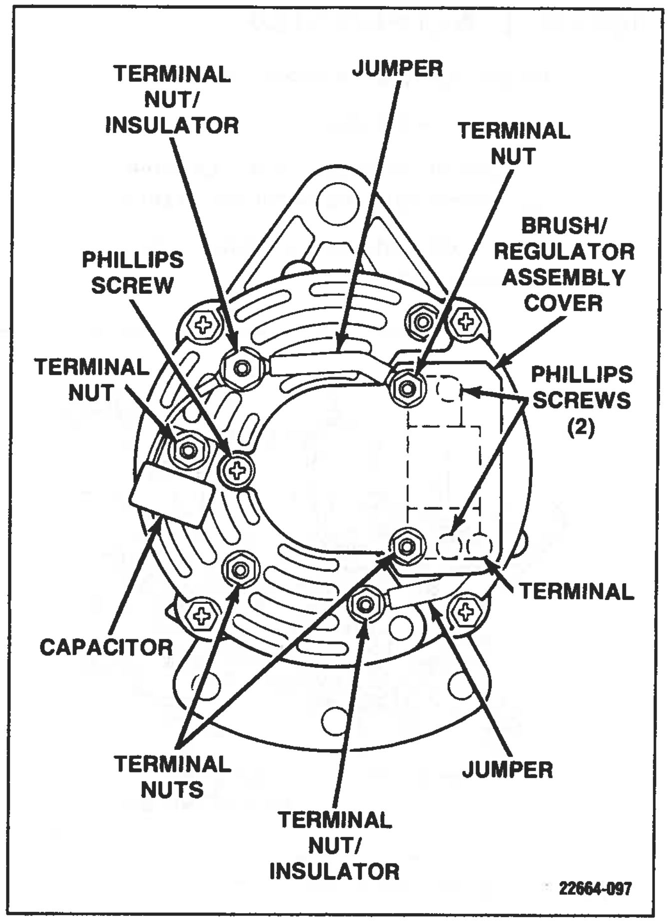


Figure 6-144. Alternator Assembly

INSTALL ALTERNATOR

1. Install alternator, screws and washers.
2. Connect wiring leads.
3. Put belt on alternator, water circulator, crankshaft and sea water pump pulleys.
4. Adjust alternator belt's tension. (See procedure in this chapter.)

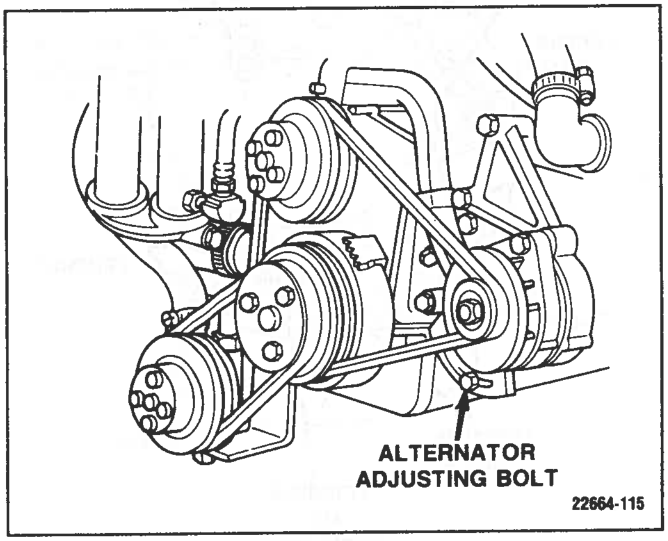


Figure 6-145. Installing Alternator

ADJUST ALTERNATOR BELT

1. Loosen mounting cap screws.

CAUTION
Force must be applied to front alternator housing only to prevent damaging alternator when belt tension is adjusted.

2. Pull alternator away from engine to adjust belt's tension to specification at a point halfway between engine water pump and alternator.

   Alternator Belt's Deflection:
   0.50 in. (13 mm)

3. Tighten mounting-cap screws securely.
4. If new drive belt is installed, check belt tension again after operating for 5 minutes.

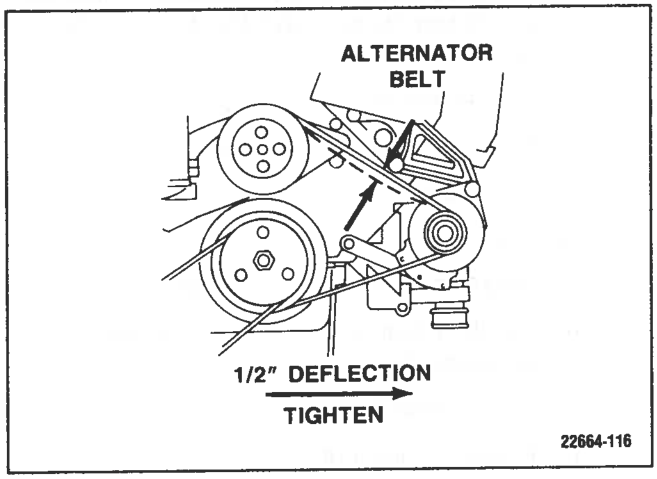


Figure 6-146. Adjusting Alternator Belt

6.5 INSTRUMENTATION

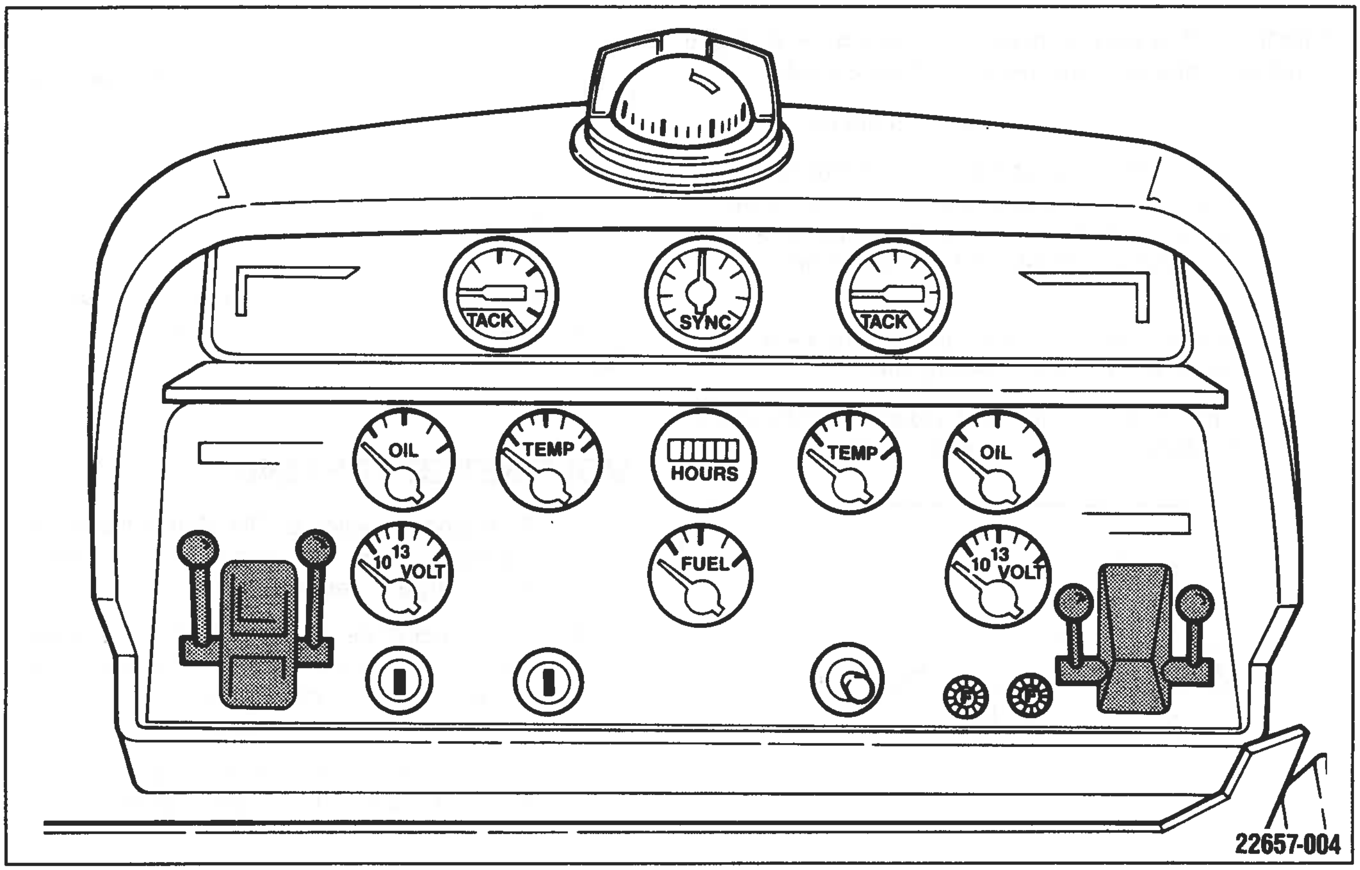


Figure 6-112. *Instrument Panel*

See Figure 6-124 in Section 6.6, Wiring Diagrams, for the instrument panel wiring diagram.

GAUGE REMOVAL

NOTE: The following steps apply to the removal and installation of the oil and temperature gauges, voltmeter and tachometer.

1. Disconnect battery cables from battery.
2. Remove wires from back of gauge.
3. Remove holding strap and remove gauge.

GAUGE INSTALLATION

1. Position gauge assembly in appropriate mounting hole.
2. Install holding strap and nuts. Tighten nuts evenly and securely.

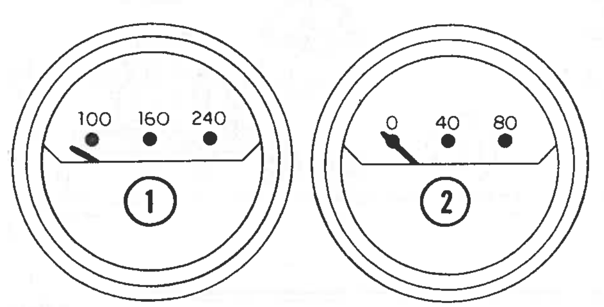
IMPORTANT: Do not distort case or bracket by overtightening.

3. Connect ground (black) wire to ground terminal.
4. Connect purple wire to ignition terminal and blue wire to light terminal.
5. Connect appropriate sender wire to terminal.
6. Coat all terminals with liquid neoprene.
7. Reconnect battery cables to battery.

OIL PRESSURE AND TEMPERATURE GAUGES TESTING

IMPORTANT: If testing proves a gauge to be faulty, it must be replaced. Gauges are not repairable.

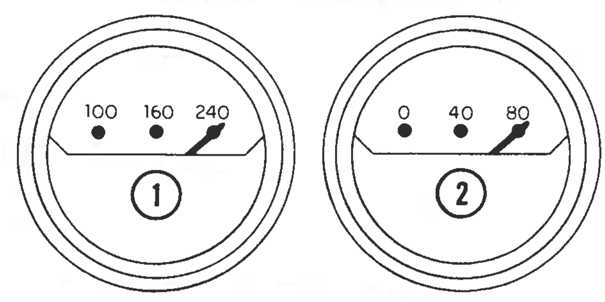
1. Gain access to rear of instrument panel.
2. Turn ignition switch ON (see "Ignition Switch Testing"). With a voltmeter, check the voltage reading between terminal "I" and terminal "G." Reading should be 12-13 V. Turn ignition switch OFF.
3. Remove wire from the oil-pressure and/or water-temperature sending unit.
4. Turn ignition switch ON. Gauge must be at the "A" position. If OK, proceed to Step 6.



1. Temperature gauge 2. Oil-pressure gauge

Figure 6-113. *Gauge Position "A"*

5. If gauge shows an upscale reading, remove wire from terminal "S" on gauge. If gauge indicates no upscale reading, sending unit wire is grounded. Repair as necessary. If gauge still shows an upscale reading, replace gauge.
6. Connect sending unit wire to ground. Turn ignition switch ON.
7. Indication needle must read at "B" position.
8. If gauge did not read upscale, connect a jumper wire from terminal "G" to terminal "S" on rear of gauge. If gauge reads upscale, sender wire is open. Repair as necessary. If gauge did not read upscale, replace gauge.



1. Temperature gauge 2. Oil-pressure gauge

Figure 6-114. *Gauge Position "B"*

VOLTMETER TESTING

1. Turn ignition switch to ON. With a hand-held voltmeter, check the voltage at the battery and fully charge, if necessary.
2. At the rear of the gauge, check the voltage at terminal "I" and terminal "G." Reading should be within one volt of reading at battery. If not, check wiring and connections.
3. Check indication on front of gauge. Gauge should indicate same reading as hand-held voltmeter. If not, replace gauge.

TACHOMETER TESTING

1. On rear of gauge check "CYL" selection. Select appropriate cylinder number (6 or 8 cyl.).
2. Connect a service tachometer to engine and compare readings at various engine speeds.
3. If not within specifications in the table, try adjusting calibration on rear of gauge.

TACHOMETER SPECIFICATIONS	
Tachometer	**Allowable Range**
4000 rpm	± 150 rpm

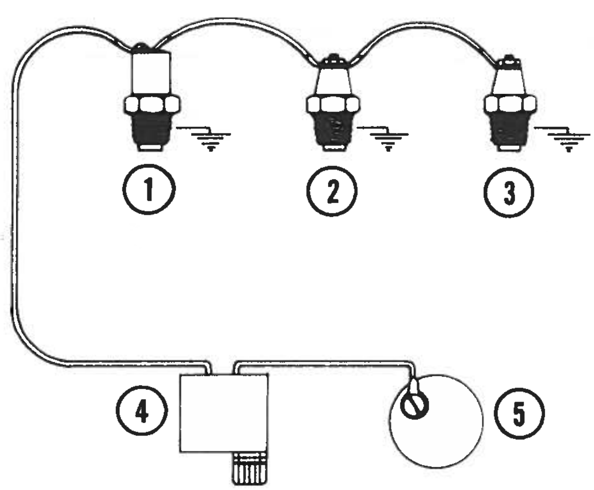
4. If unable to adjust tachometer within specifications, replace tachometer.

ENGINE ALARM SYSTEM

Engine Alarm Circuit Testing:

NOTE: Some boatbuilders may install their own alarm system. It is recommended to check with the dealer for an explanation of the particular alarm system installed and how it functions if different from that shown (See Figure 6-115).

1. Turn ignition switch to ON position but do not start engine.
2. Alarm should sound.
3. If alarm does not sound, check for 12 V at the positive (+) terminal of alarm buzzer. If 12 V is not present, check wiring for an open circuit.
4. If 12 V is present, connect a jumper wire from negative (–) terminal to ground. If alarm buzzer does not sound, replace it. If alarm sounds, the problem is in light blue/tan wire back to engine or alarm senders on engine.



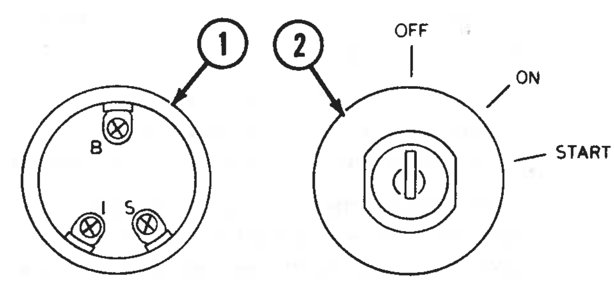
1. Water temp. switch – 210°F
2. Oil pressure switch – 9 lb
3. Transmission oil temp. switch – 235°F
4. Alarm buzzer (mount near control station)
5. Ignition switch (connect to ACC terminal or to IGN terminal)

Figure 6-115. *Standard Engine Alarm System*

Ignition Switch Testing:

CAUTION

Disconnect battery cables from battery before testing ignition switch with wires still connected to switch.



1. Back view
2. Front view

Figure 6-116. *Testing Ignition Switch*

1. Before testing ignition switch, check fuses and/or circuit breakers. Bad fuses and/or circuit breakers could prevent operation of the starter. Also, check operation of neutral safety switch.
2. With ignition switch in the OFF position, there should be no continuity between switch terminals.
3. With ignition switch in the ON position, there should be continuity between the "BAT" and "IGN" terminals. There should be no continuity between the "SOL" terminal and the other terminals.
4. With ignition switch in the START position, there should be continuity between the "BAT" and "IGN" terminals, and the "BAT" and "SOL" terminals.
5. If ignition switch tests bad, remove wires from switch and remove switch from panel. Repeat ignition switch test. If switch tests good, the wiring in harness is bad. There should be no continuity between any harness wires with switch removed.

Oil-Pressure Alarm Switch Testing:

At no or low oil pressure, the switch is closed (or grounded).

Oil pressure switch will open after oil pressure reaches 5.0 psi (34.5 kPa). A meter will indicate infinity or a test lamp will not light.

Water-Temperature Alarm Switch Testing:

1. Remove switch from engine.
2. Connect an ohmmeter or test light to switch terminal and base.
3. Immerse switch and a thermometer in a container of oil. Carefully heat oil over a flameless source and watch the thermometer.
4. Meter should show infinity or test lamp remains unlit until the temperature reaches 203° F (95° C). At this temperature and above, the meter should show continuity or the test lamp must be lit.

Transmission-Fluid-Temperature Alarm Switch Testing:

1. Remove switch from transmission.
2. Connect an ohmmeter or test light to switch terminals.
3. Immerse switch and a thermometer in a container of oil. Carefully heat oil over a flameless source and watch the thermometer.
4. Meter should show infinity or test lamp remains unlit until the temperature reaches 230° F (110° C). At this temperature and above, the meter should show continuity or the test lamp must be lit.

Oil-Pressure Sender Testing:

IMPORTANT: Use following test procedure for checking accuracy of oil-pressure sender only. If oil pressure gauge indicates zero oil pressure, refer to "Troubleshooting" section.

1. Remove wire from sender terminal.
2. Connect ohmmeter between sender terminal and sender case. Check ohms reading without engine running (zero pressure), then check reading with engine running. Compare oil pressure and ohms reading as shown in following chart:

CHECKING OIL PRESSURE SENDER

Oil Pressure (psi)	Ohms Reading	
	Single	Dual
0	227-257	113.5-128.5
20	142-162	71-81
40	92-114	46-57
80	22-49	11-24.5

NOTE: Dual-station sender will have 02504-1 stamped on hex of sender.

Water-Temperature Sender Testing:

1. Remove sender from engine.
2. Connect a digital ohmmeter to sender.
3. Immerse sender and a thermometer in a container of oil. Carefully heat oil over a flameless source and watch thermometer.
4. Meter should show the correct ohms for the corresponding temperature. Replace sender if not within 7.5% of specification.

CHECKING WATER TEMPERATURE SENDER		
Water Temperature	Ohms Reading	
	Single	Dual
100° F (37.8° C)	404-495	202-247.5
130° F (54.5° C)	158-202	79-101
160° F (71.1° C)	119-140	59.5-70
200° F (93.3° C)	63-79	31.5-39.5
220° F (104.4° C)	44-49	22-24.5

NOTE: Dual-station sender will have 02032 stamped on hex of sender.

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6.6 WIRING DIAGRAMS

The following figures (6-152 through 6-156) depict wiring diagrams for various electrical systems used on Crusader Engines. The variations in these systems occur by using one of four different distributors.

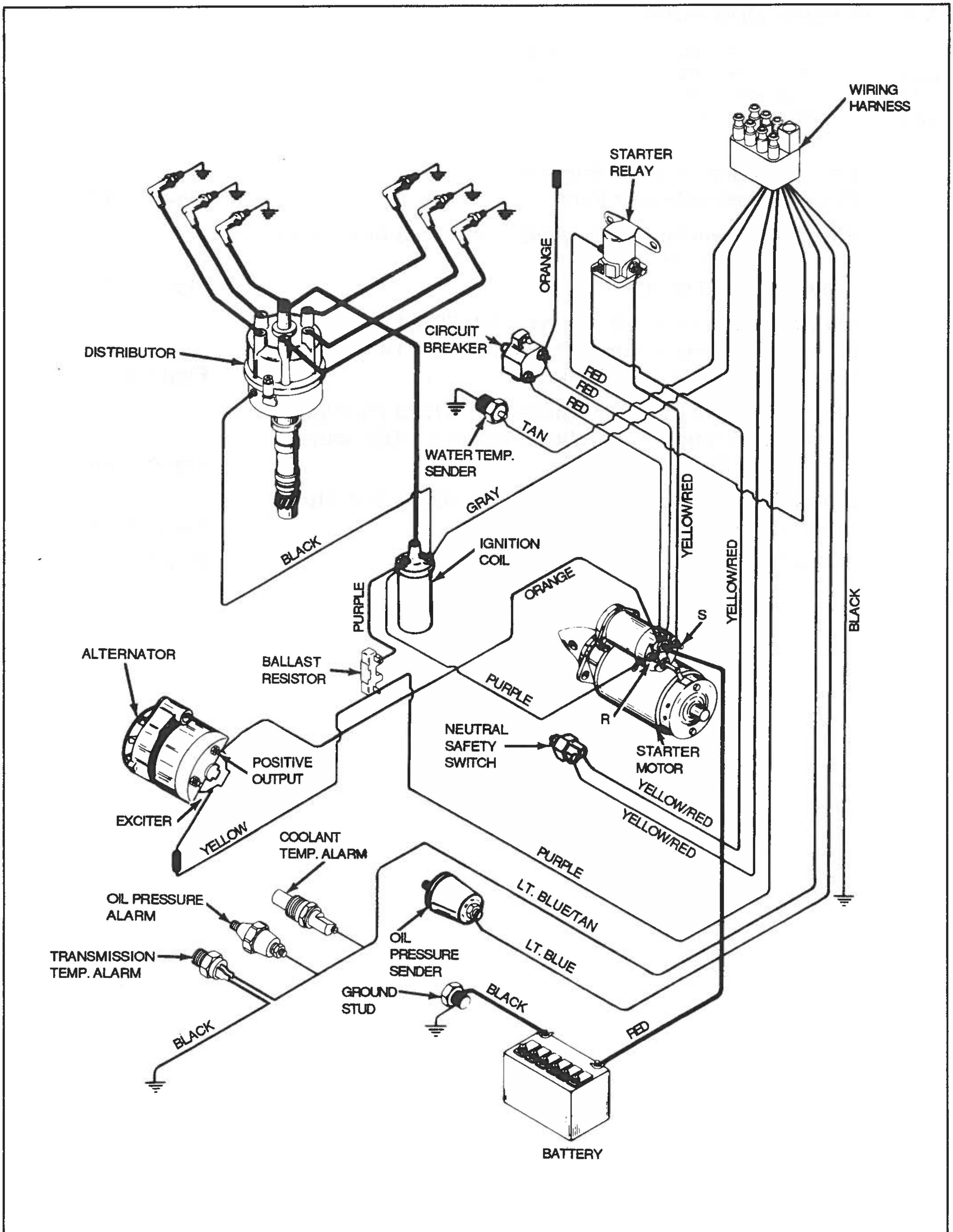


Figure 6-152. *Wiring Diagram For V-6 Engines Using A Prestolite Distributor*

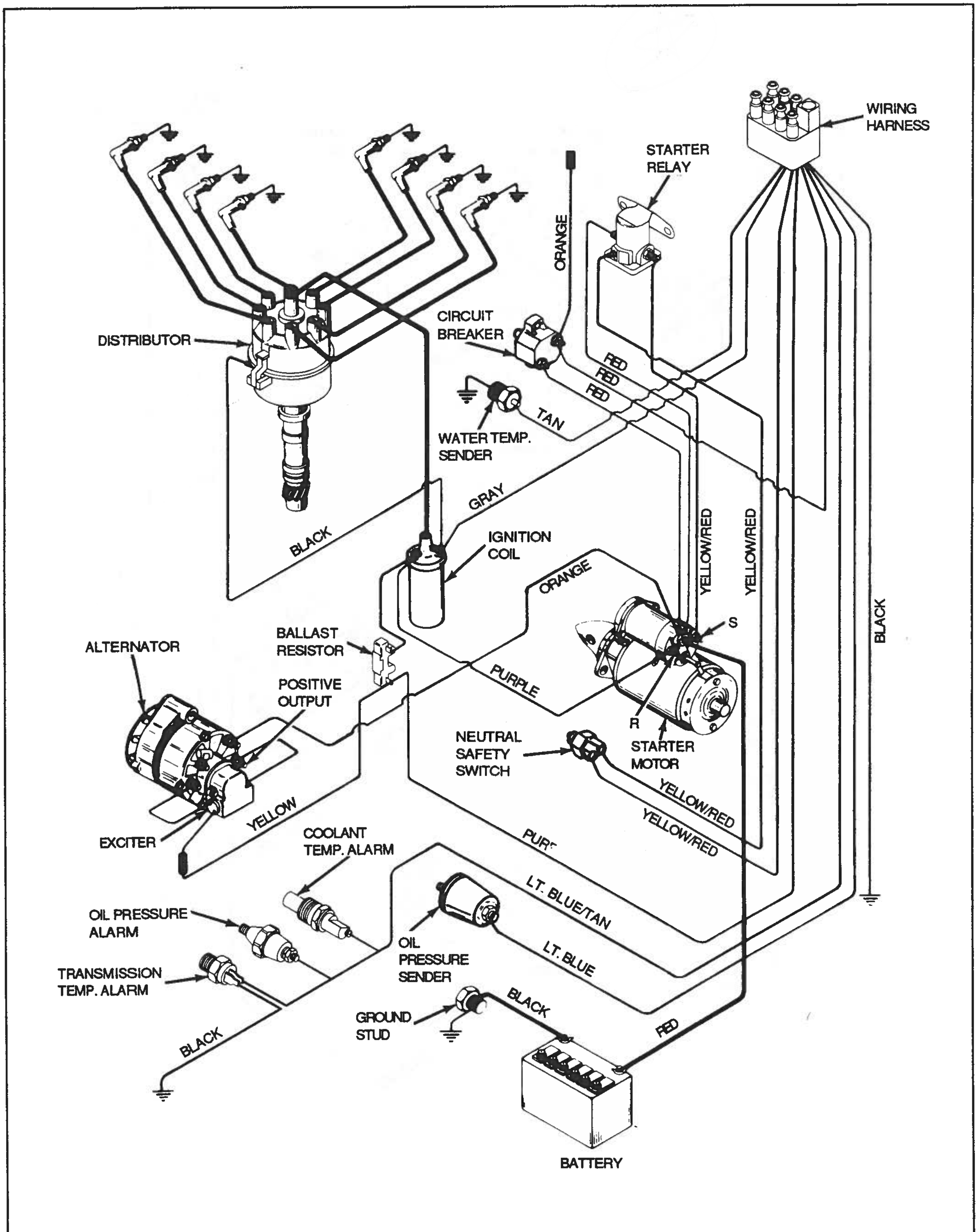


Figure 6-153. *Wiring Diagram For V-8 Engines (S/N 69063 And Below) Using A Mallory Or Prestolite Breaker-Type Distributor*

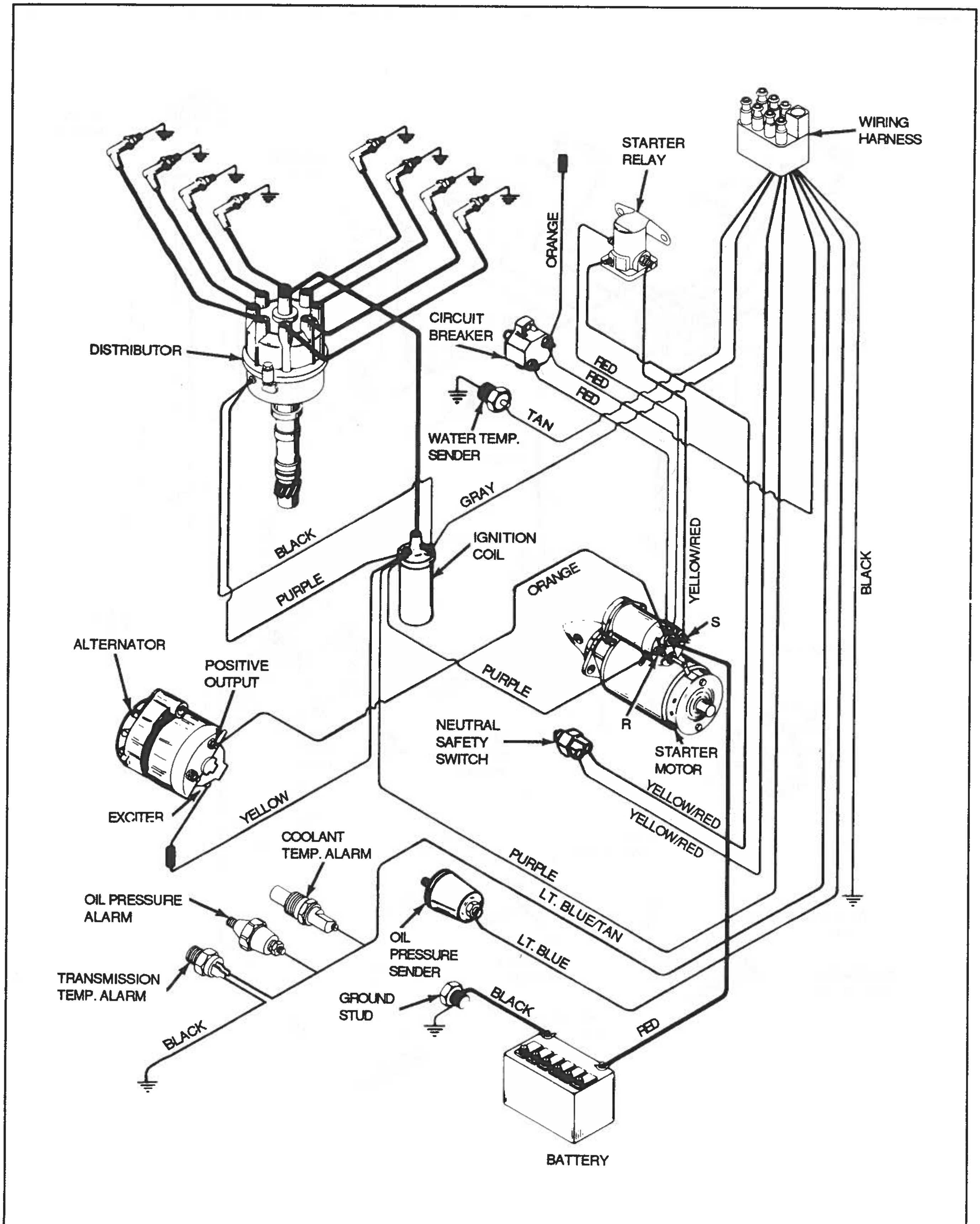


Figure 6-154. *Wiring Diagram For V-8 Engines (S/N 69064 Through S/N 81322) Using A Prestolite Breakerless Distributor And Starter Relay (S/N 9006320)*

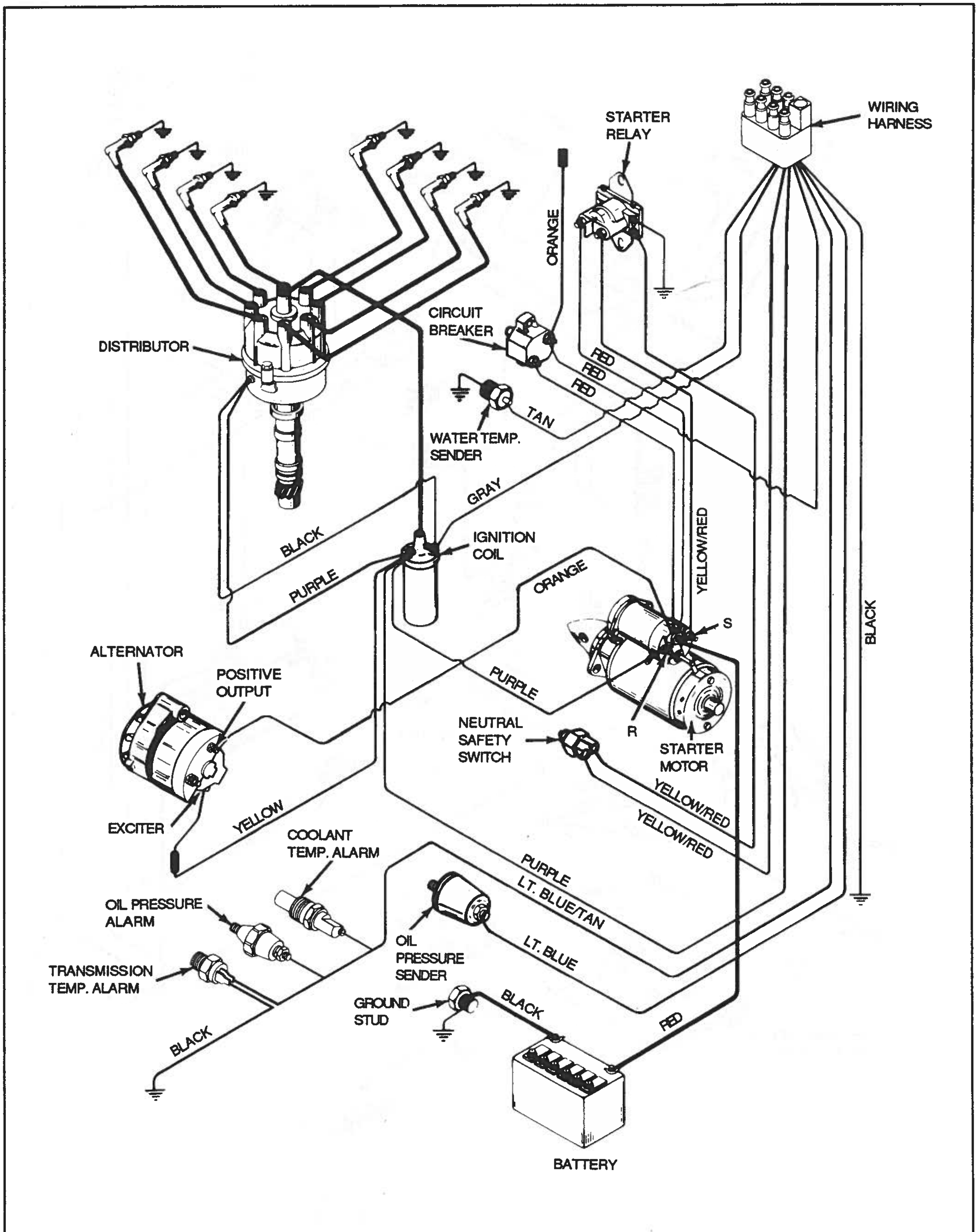


Figure 6-155. Wiring Diagram For V-8 Engines (S/N 81323 Through S/N 83807) Using A Prestolite Breakerless Distributor And Starter Relay (S/N 22611)

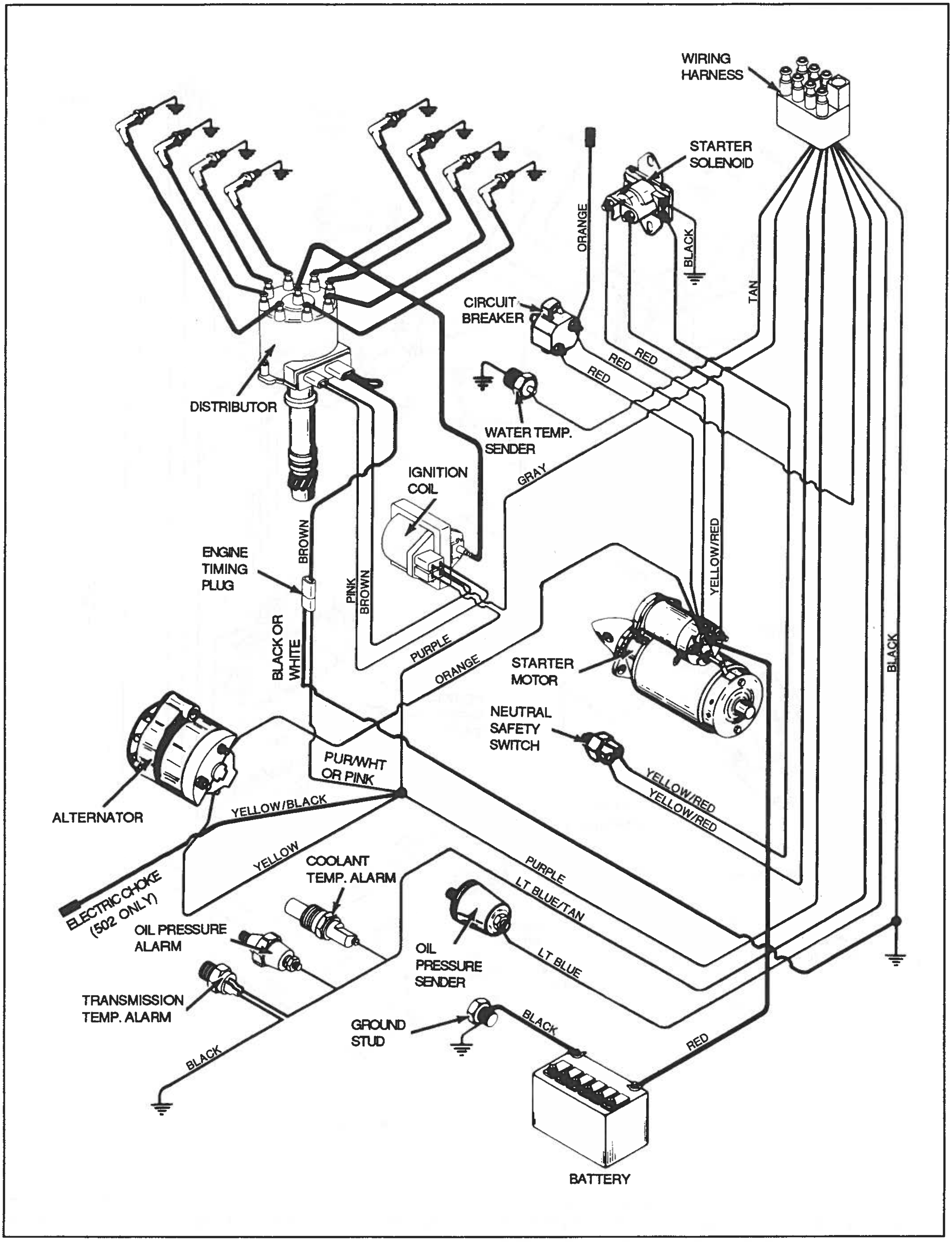
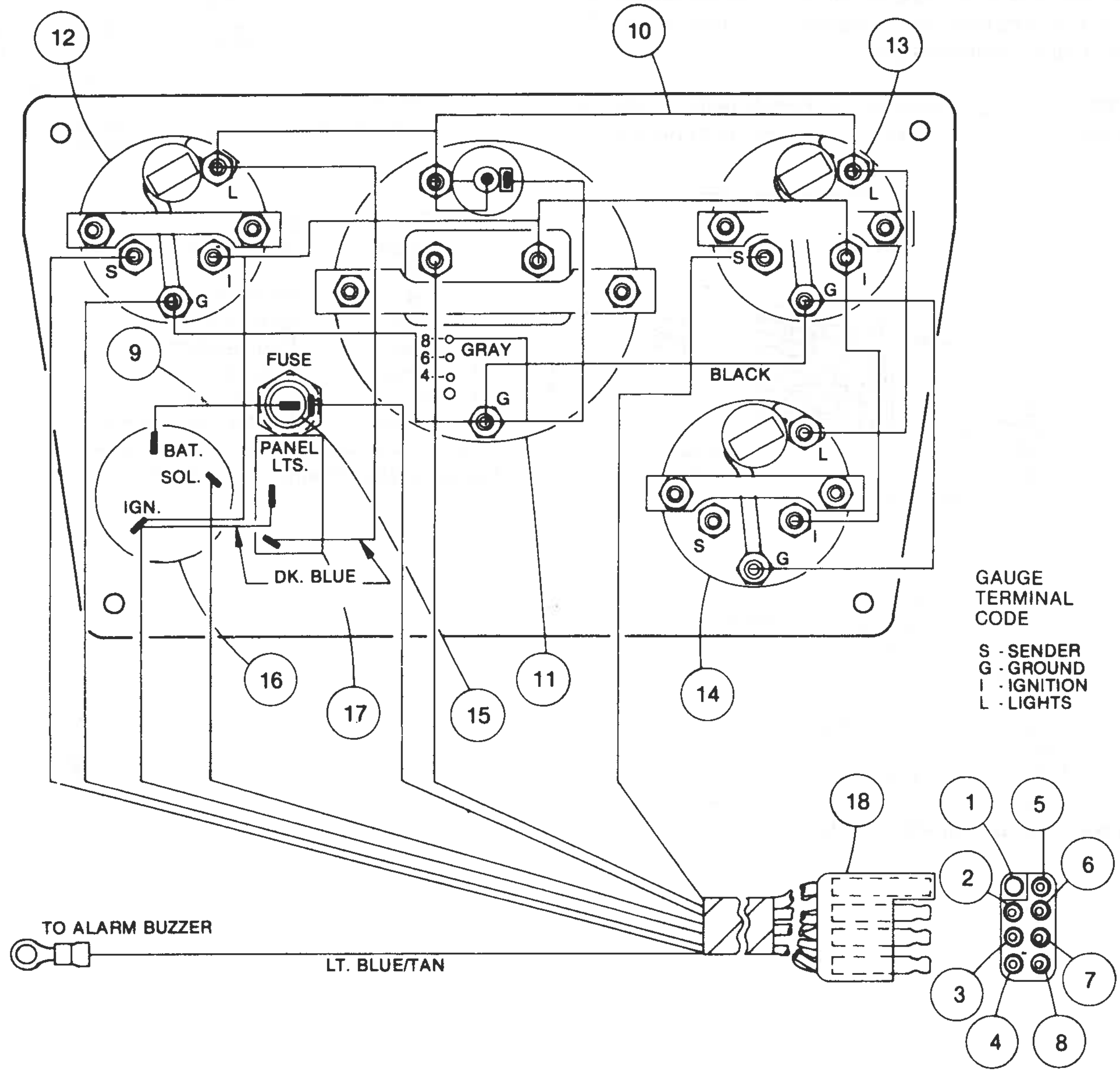


Figure 6-156. *Wiring Diagram For V-8 Engines (S/N 83808 And Above) Using A Delco E.S.T. Ignition*

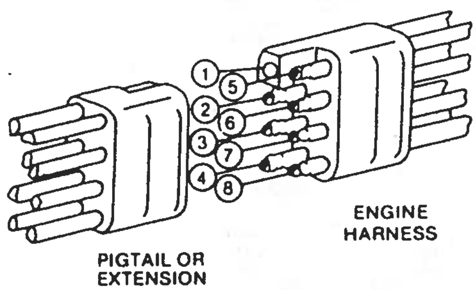


1.	Black	7.	Purple	13.	Water temp. gauge
2.	Gray	8.	Red	14.	Voltmeter
3.	Yellow/red	9.	Red/purple	15.	Fuse holder assembly
4.	Light blue/tan	10.	Dark blue	16.	Ignition switch
5.	Tan	11.	Tachometer	17.	Panel lights switch
6.	Light blue	12.	Oil pressure gauge	18.	Pigtail

Figure 6-157. *Instrument Panel Wiring Diagram*

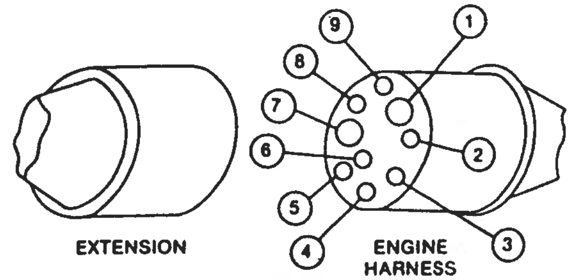
NOTE: An orange wire is supplied as an overcurrent-protected source for an accessory power panel which is operated at 12 ± 1 VDC, 0 to 10 A continuous or peaks up to 30 A for durations less than 100 milliseconds during accessory start-ups. If such a source is not required, do not tamper with the end connector or its insulation; simply restrain its free-end movement by taping to wire harness using electrical tape.

NOTE: This harness wired for panels using voltmeters. Harness must be changed if ammeter is to be used.



1. Black – Ground
2. Grey – Electronic tachometer
3. Yellow/red – Start switch
4. Lt. blue/tan – Engine alarm
5. Tan – W/temperature
6. Lt. blue – Oil temperature
7. Purple – Ignition coil
8. Red – Battery

Figure 6-158. *Standard Wiring Harness*



1. Red – Battery
2. Purple – Start switch
3. Blank
4. Tan – W/temperature
5. Grey – Ignition coil
6. Black – Engine alarm
7. White – Ground
8. Blue – Oil pressure
9. Yellow – Neutral safety switch

Figure 6-159. *Optional O.E.M. Wiring Harness*

Section 7

Fuel System

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7 FUEL SYSTEM

7.1 GENERAL INFORMATION

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** working on fuel system to prevent fire or explosion.

WARNING

Be careful when changing fuel system components; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that ignition key is "OFF." **Do not** smoke or allow sources of spark and/or flame in the area while changing fuel filters. Wipe up any spilled fuel immediately.

WARNING

Fuel system components on your Crusader Engine are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement fuel system components which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

When servicing the electrical, ignition and fuel systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

WARNING

Make sure that no fuel leaks exist before closing engine hatch.

WARNING

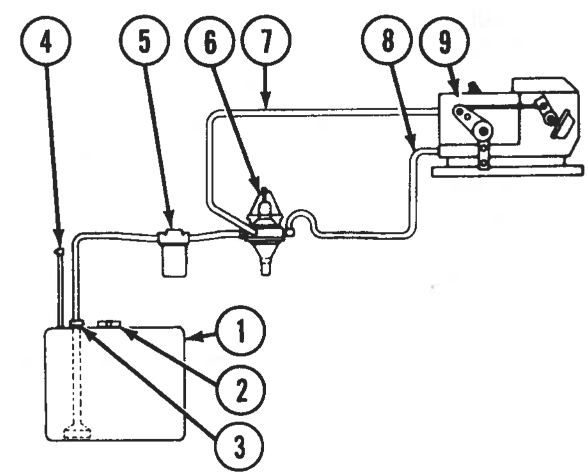
To prevent the possibility of a **FIRE**, be sure that engine compartment is well ventilated and that there are no gasoline vapors present.

CAUTION

Do not operate engine without cooling water being supplied to raw-water pickup pump or the pump impeller will be damaged and subsequent overheating damage to the engine may result.

Description:

The fuel system consists of fuel tank(s), fuel filter, a fuel pump and carburetor as shown in Figure 7-1.



1. Fuel tank
2. Fuel filler
3. Antisiphon valve
4. Vent hose
5. Fuel filter
6. Fuel pump
7. Sight tube
8. Fuel line
9. Carburetor

Figure 7-1. *Fuel System*

NOTE: The "Fire Prevention Standard for Motor Craft (Pleasure and Commercial)" is available from the National Fire Protection Association, 470 Atlantic Avenue, Boston, Massachusetts 02110. Designated NFPA 302, this standard indicates current good practice toward making gasoline and diesel-powered boats as free as possible from the hazards of fire and explosion.

The fuel is stored in the fuel tank(s). Fuel is drawn from the tank(s) through a fuel filter by a mechanically operated fuel pump. The fuel is pushed from the fuel pump to the carburetor where it is metered and fed into the engine.

Design Constraints:

WARNING

The fuel system should be in accordance with the standards of all industry associations (BIA, ABYC, etc.) and all applicable Federal standards. U.S. Coast Guard regulations must also be adhered to when installing the fuel system.

When designing and installing a fuel delivery system, the following guidelines **must be** followed:

1. The fuel tank should be mounted below carburetor level, if possible. If tank is mounted above carburetor level, gravity feed may cause carburetor-fuel-inlet needle to unseat, resulting in flooding.
2. Fuel pickup should be at least 1 in. (25 mm) from the bottom of the fuel tank to prevent picking up water or other impurities.
3. Fuel lines used **must be** Coast-Guard-approved (USCG type A) and **must not be smaller than** 3/8 in. (9.5 mm) I.D. On installations where long lines or numerous fittings are required, larger-size lines should be used.
4. The fuel line should be installed free of stress and firmly secured to prevent vibration and/or chafing.
5. Sharp bends in fuel line should be avoided.
6. A flexible fuel line must be used to connect the fuel line to the engine to absorb deflection when engine is running.

7.2 FUEL DELIVERY SYSTEM

Specifications:

TORQUE SPECIFICATIONS		
Fastener Location	**AC Pump**	**Carter Pump**
Inlet fitting*	10-18 lb-ft (14-25 N•m)	10-18 lb-ft (14-25 N•m)
Fuel line to fuel inlet fitting	Securely	Securely
Fuel line to fuel outlet fitting	Securely	Securely
Fuel outlet fitting*	10-18 lb-ft (14-25 N•m)	10-18 lb-ft (14-25 N•m)
Fuel pump to block	20 lb-ft (27 N•m)	20 lb-ft (27 N•m)

NOTE: Coat fuel-line inlet and outlet fitting threads using Loctite Pipe Sealant with Teflon (**do not** use Teflon tape). Torque to specifications.

FUEL PUMP SPECIFICATIONS		
Item	**AC Pump**	**Carter Pump**
Pump pressure @ 1800 rpm	5.25-6.25 psi (36-43 kPa)	5.25-6.25 psi (36-43 kPa)
V-6 engine push-rod length	5.0 in. (127 mm)	5.0 in. (127 mm)
V-8 engine push-rod length	5.76 in. (146 mm)	5.76 in. (146 mm)
V-6 and V-8 push-rod movement	0.344 in. (8.7 mm)	0.344 in. (8.7 mm)

TOOLS OBTAINED LOCALLY
Fuel pressure gauge

LUBRICANTS/SEALANTS OBTAINED LOCALLY
Perfect Seal
Loctite Pipe Sealant with Teflon

Fuel Filters:

There are three different types of fuel filters used with Crusader marine engines:

1. Water-separating type with a screw-on replaceable cartridge.
2. Remote with replaceable internal cartridge, made by AC.
3. On-the-carburetor fuel filter. This type is retained by a nut in the fuel inlet and comes in two types, Holley and Rochester. They are covered in Section 7.5, Carburetor.

Water-Separating Fuel Filter:

WARNING

Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

The water-separating fuel filter is standard on some engines and can also be purchased as an option for engines not equipped with it. The water-separating fuel filter consists of the fuel-filler header, sealing rings and filter element (Figure 7-2).

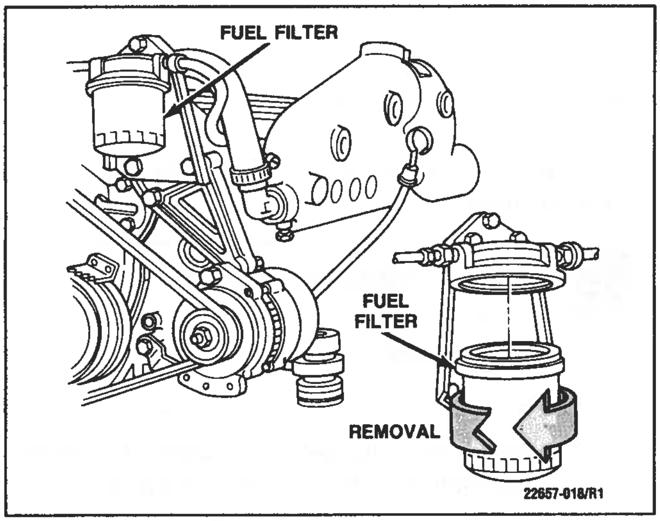
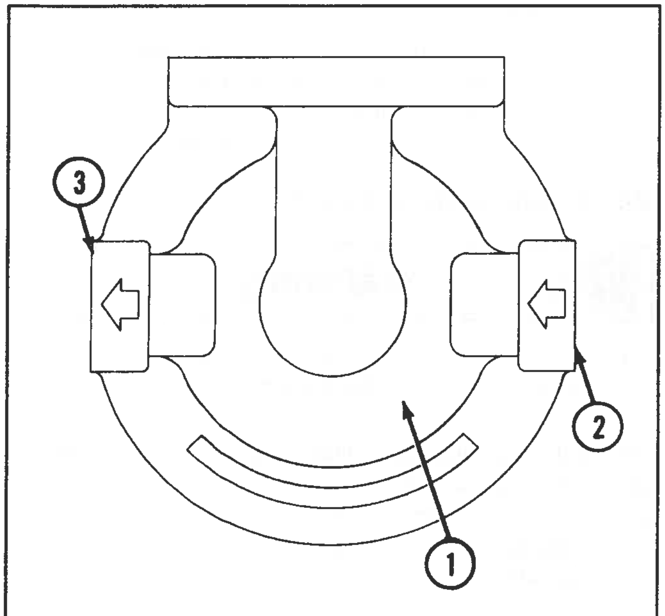


Figure 7-2. *Water-Separating Fuel Filter*

IMPORTANT: If installing a water-separating fuel filter as an option, filter should be located between fuel tank and fuel pump. Fuel inlet and outlet lines must also be connected correctly for filter to work properly (Figure 7-3). Follow instructions supplied with water-separating fuel filter.

> **CAUTION**
>
> Coat fuel-line fitting threads using Loctite Pipe Sealant with Teflon (do not use Teflon tape). Torque to specifications.



1. Fuel filter header
2. Inlet – from fuel tank
3. Outlet – to fuel pump

Figure 7-3. *Fuel Filter Base*

To replace the water-separating fuel filter, perform the following procedure:

> **WARNING**
>
> Turn OFF fuel supply before servicing the fuel system.

1. Remove filter element from header by turning counterclockwise. You may need a filter wrench to break element loose.

IMPORTANT: Element cannot be cleaned and reused. It must be replaced.

2. Lubricate sealing rings with engine oil.
3. Install new element. Tighten securely by hand.
4. Start engine (making sure water is supplied to cooling system) and check for fuel leaks.

AC Remote Fuel Filter:

SPECIAL TOOLS	
Snap-On Tool Number	**Name**
YA 997	Fuel filter wrench

> **WARNING**
>
> Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

To replace the AC remote fuel filter (Figure 7-4), perform the following procedure:

1. Turn OFF fuel supply.
2. Using Snap-On Tool YA 997 strap wrench or equivalent, remove fuel-filter canister.

NOTE: Place strap at bottom of the canister.

3. Remove gasket and discard.
4. Remove filter element from canister and discard element.

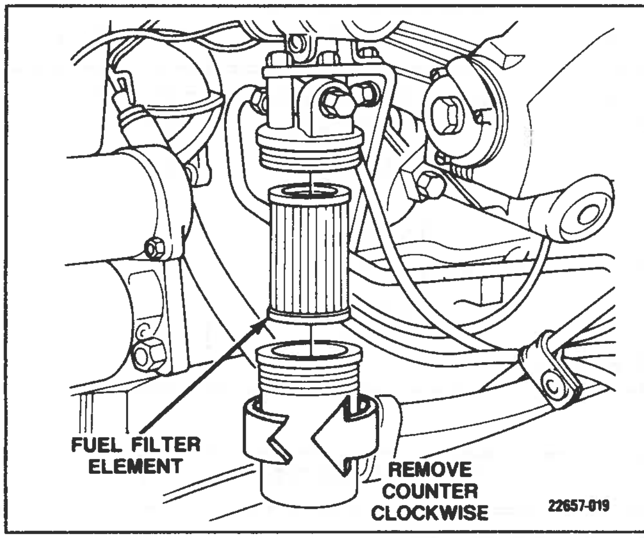


Figure 7-4. *AC Remote Fuel-Filter Assembly*

5. Clean fuel-filter canister.
6. Inspect internal surface of canister for rust or corrosion. Replace complete filter if heavily rusted or pitted.

7. Install new filter element in canister.
8. Apply a small amount of engine oil on gasket and place in housing.
9. Screw canister onto housing hand-tight.
10. Start engine and check for leaks.

Fuel Pump:

One of two makes of fuel pumps is used on Crusader marine engines, AC and Carter (Figures 7-5 and 7-6). Testing, removal and installation are the same for both pumps. Neither can be repaired and must be replaced if defective.

1. Remove the inspection plug to check for a ruptured diaphragm (AC pump only).

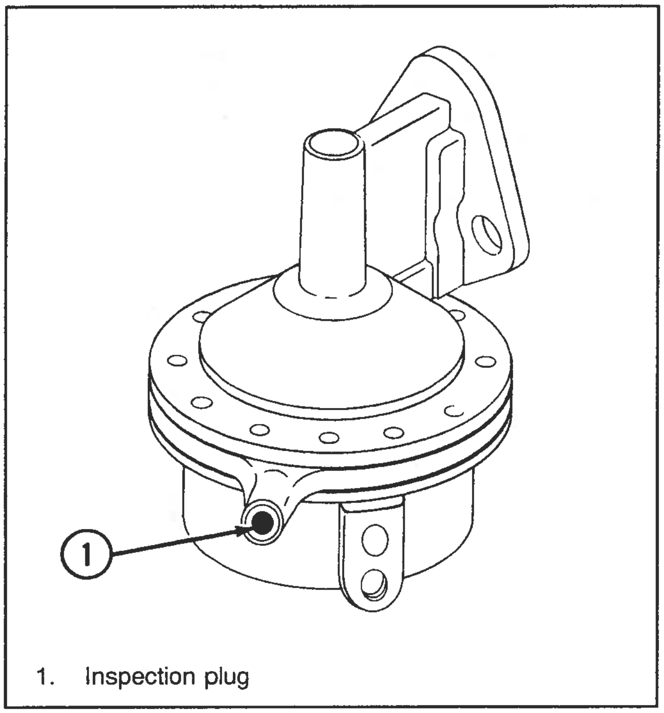


Figure 7-5. *AC Dual-Diaphragm Fuel Pump*

The tygon tube (Carter pump only) between the fuel pump and the carburetor is made of clear plastic and also serves as a sight tube (Figure 7-7). Evidence of fuel in the sight tube indicates a ruptured diaphragm, and fuel pump must be replaced immediately

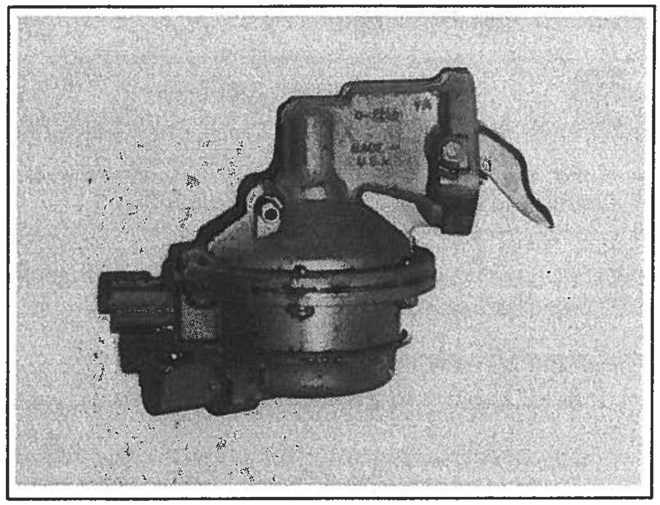


Figure 7-6. *Carter Fuel Pump*

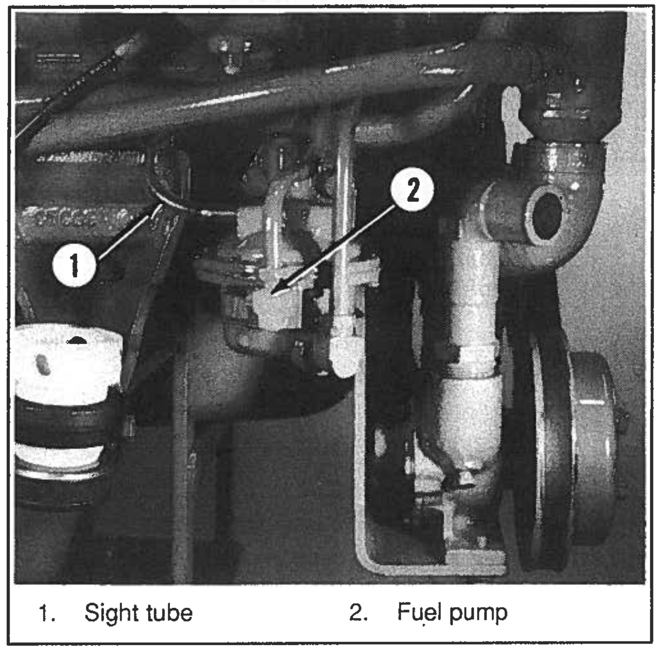


Figure 7-7. *Fuel-Pump Sight Tube*

Fuel Pump Testing:

WARNING

Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

NOTE: See specifications at the beginning of Section 7.2, Fuel Delivery System.

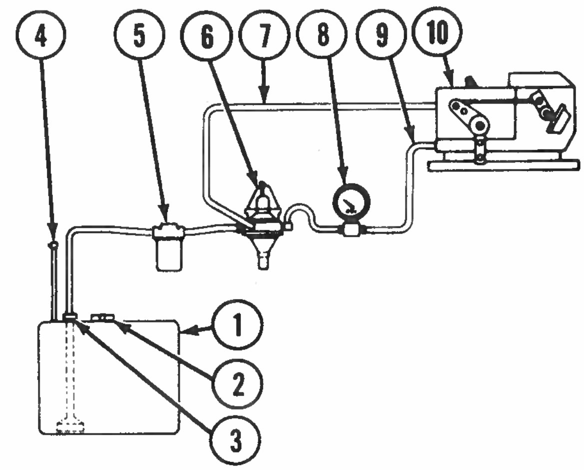
Refer to Figure 7-8 throughout procedure.

1. Remove fuel line from outlet side of fuel pump.
2. Install fuel pressure test gauge to outlet side of fuel pump using T-fitting and appropriate adapters.

CAUTION

Coat fuel-line inlet-fitting threads using Loctite Pipe Sealant with Teflon (do not use Teflon tape). Torque to specifications.

3. Connect fuel line (previously removed from pump) to other side of T-fitting on fuel pressure test gauge using appropriate adapters.
4. Start engine and run at the speed listed in specifications.
5. Fuel pressure should be within specifications. If it is not, replace fuel pump.
6. Remove fuel-pressure gauge and adapters. Reconnect fuel line to fuel pump. Tighten to specifications.



1. Fuel tank
2. Fuel filler
3. Antisiphon valve
4. Vent hose
5. Fuel filter
6. Fuel pump
7. Sight (vent) tube
8. Pressure-test gauge
9. Fuel line
10. Carburetor

Figure 7-8. Testing Fuel Pump

Fuel Pump Replacement:

> **WARNING**
>
> Refer to Cautions and Warning under Section 7.1, General Information, **before** proceeding.

NOTE: Removal, inspection and installation steps are the same for both AC and Carter fuel pumps.

Removal

1. Disconnect fuel inlet and outlet lines at fuel pump.

> **CAUTION**
>
> Plug fuel lines after disconnecting from fuel pump to eliminate any chance of fuel siphoning into bilge.

2. Remove sight tube.
3. Remove two fuel-pump-mounting screws, pump and gasket.
4. Remove mounting plate bolts, mounting plate, gasket and push rod.

Inspection

1. Check push-rod length. See Specifications.
2. Check push-rod movement by installing push rod in engine. Install a dial indicator against end of push rod and turn engine over two complete revolutions. Push rod should have total movement as shown in specifications.

Installation

1. Coat push rod with high-temperature bearing grease and install in engine.
2. Apply Perfect Seal to both sides of mounting plate gasket. Then install gasket, plate and mounting bolts. Tighten securely.
3. Apply Perfect Seal to both sides of fuel pump gasket.
4. Install gasket, fuel pump and mounting bolts. Torque bolts to specifications.

> **CAUTION**
>
> Coat fuel-line inlet-fitting threads using Loctite Pipe Sealant with Teflon (do not use Teflon tape). Torque to specifications.

5. Install fuel inlet and outlet fittings to fuel pump. Torque fittings to specifications. Tighten flare fittings securely.
6. Install sight tube.
7. Start engine and check for fuel leaks.

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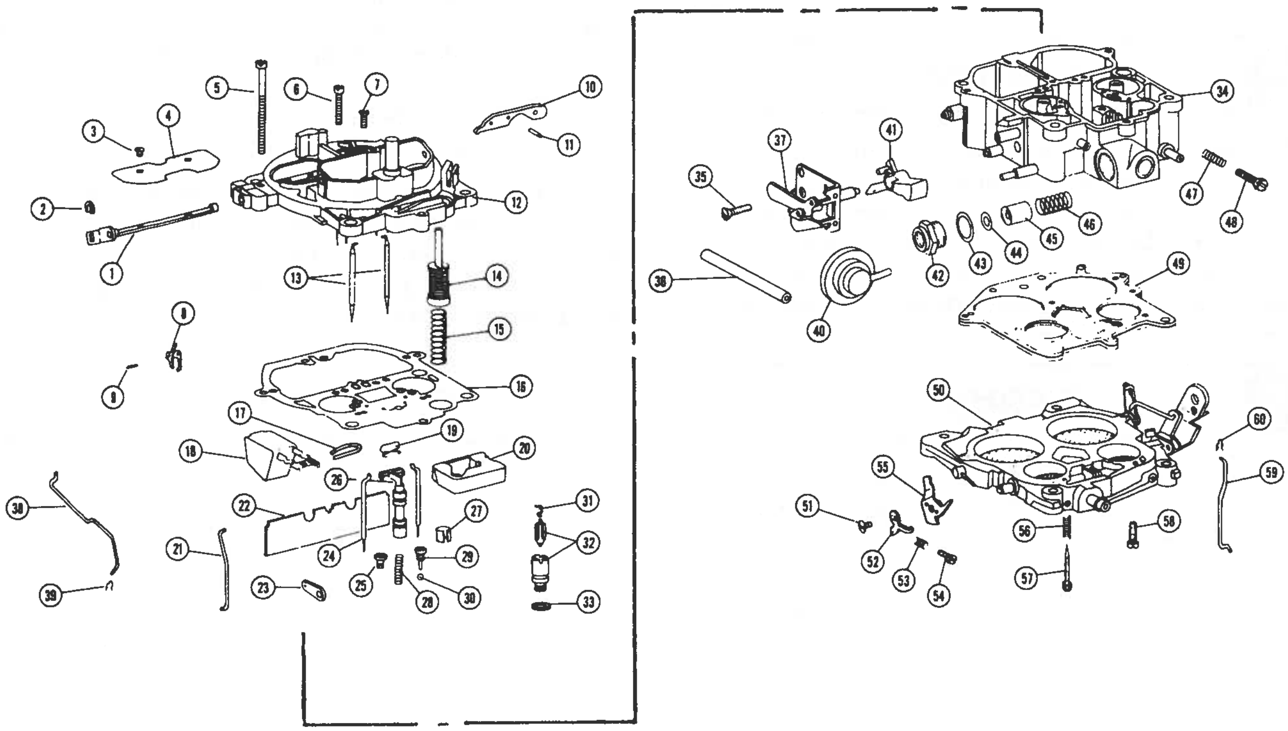
7.3 ROCHESTER 4-BARREL QUADRAJET CARBURETOR



1. Choke shaft and lever assembly
2. Clip, choke rod (horseshoe)
3. Screw, choke valve
4. Choke valve
5. Screw, air horn (long)
6. Screw, air horn (intermediate)
7. Screw, air horn (short)
8. Lever, air valve lockout
9. Roll pin, lever hinge
10. Lever, pump-actuating
11. Roll pin, lever hinge
12. Air-horn assembly
13. Metering rod, secondary
14. Pump assembly
15. Spring, pump-return
16. Gasket, air-horn
17. Hinge pin, float assembly
18. Float assembly
19. Spring, metering rod, primary
20. Insert, float bowl
21. Rod, choke
22. Baffle, float bowl
23. Lever, intermediate choke
24. Metering rod, primary
25. Jet, primary
26. Primary power-piston assembly
27. Retainer, power-piston
28. Spring, power-piston
29. Retainer, pump-discharge ball
30. Ball, pump-discharge
31. Pull clip, float needle
32. Float needle and seat assembly
33. Gasket, float-needle seat
34. Float-bowl assembly
35. Screw, control-attaching
36. Hose, vacuum
37. Vacuum break-control bracket assembly
38. Rod, vacuum-break
39. Clip, vacuum-break-rod
40. Vacuum break-control assembly
41. Cam, fast-idle
42. Filter nut, fuel-inlet
43. Filter nut, fuel-inlet gasket
44. Gasket, filter
45. Filter, fuel-inlet
46. Spring, fuel-filter
47. Spring, idle-stop-screw
48. Screw, idle-stop
49. Gasket, throttle-body
50. Throttle-body assembly
51. Screw, cam and fast-idle lever
52. Lever, fast-idle
53. Spring, fast-idle screw
54. Screw, fast-idle adjusting
55. Lever, cam
56. Spring, idle-needle
57. Needle, idle
58. Screw, throttle
59. Rod, pump
60. Clip, pump-rod (hairpin)

Figure 7-9. *Rochester 4MV 4-Barrel Quadrajet Carburetor Assembly*

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** working on the fuel system, to prevent fire or explosion.

WARNING

Be careful when changing fuel system components; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that ignition key is OFF. **Do not** smoke or allow sources of spark and/or flame in the area while changing fuel system components. Wipe up any spilled fuel immediately.

WARNING

Fuel system components on your Crusader are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement fuel system components which do not comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

To prevent the possibility of a **FIRE**, be sure that engine compartment is well ventilated and that there are no gasoline vapors present.

WARNING

Make sure no fuel leaks exist before closing engine hatch.

CAUTION

Do not operate engine without cooling water being supplied to water pickup; water pump impeller will be damaged and subsequent overheating damage to the engine may result.

DESCRIPTION

The Quadrajet carburetor operates in two stages. The primary (fuel inlet) side has small bores with a venturi setup equipped with plain-tube nozzles. Its metering principles are similar to most plain-tube carburetors which use the venturi principle. The triple venturi stack-up, plus smaller primary bores, give a more stable and finer fuel control in idle and economy ranges. Fuel metering in the primary side is accomplished with tapered metering rods positioned by a manifold vacuum-responsive piston.

The secondary side has two very large bores which have greatly increased air capacity to meet present-day and future engine demands. The air-valve principle is used in the secondary side for metering control, and supplements fuel flow from primary bores.

Using the air-valve principle, fuel is metered in direct proportion to air passing through secondary bores.

The fuel reservoir is centrally located to avoid problems of fuel slosh causing engine-turn cutout and delayed fuel to carburetor bores. The float system uses a single-float pontoon for ease in servicing the unit.

ROCHESTER 4MV CARBURETOR SPECIFICATIONS					
Item	**Rochester 4MV**				
Carburetor manufacturer number	1728282	17082403	17059293	17080560	17080561
Primary jet size	0.069 in. (1.75 mm)	0.070 in. (1.78 mm)	0.069 in. (1.75 mm)	0.069 in. (1.75 mm)	0.068 in. (1.73 mm)
Primary (secondary) metering rods	0.035 in. (0.89 mm) [AV]	0.043 in. (1.09 mm) [CL]	0.043 in. (1.09 mm) [AV]	0.042 in. (1.07 mm) [CL]	0.041 in. (1.04 mm) [DW-DE]
Float level	1/4 in. (6.4 mm)	9/32 in. (7.1 mm)	3/8 in. (9.5 mm)	15/64 in. (6.0 mm)	15/64 in. (6.0 mm)
Pump rod hole location	Inner	Inner	Inner	Inner	Inner
Accelerator pump[2]	13/32 in. (10.3 mm)	23/64 in. (9.1 mm)	23/64 in. (9.1 mm)	23/64 in. (9.1 mm)	23/64 in. (9.1 mm)
Air-valve dashpot (Air-valve rod)	0.025 in. (0.64 mm)	0.025 in. (0.64 mm)	0.025 in. (0.64 mm)	0.025 in. (0.64 mm)	0.025 in. (0.64 mm)
Vacuum break	0.100 in. (2.4 mm)	0.080 in. (2.0 mm)	0.080 in. (2.0 mm)	0.080 in. (2.0 mm)	0.080 in. (2.0 mm)
Air-valve spring wind up	5/8 turn (70-90 g)	3/4 turn (80-95 g)	5/8 turn (70-90 g)	3/4 turn (80-95 g)	1/2 turn (60-75 g)
Choke coil rod[3]	Top of rod even with bottom of hole	Top of rod even with bottom of hole	Top of rod even with bottom of hole	Top of rod even with bottom of hole	Top of rod even with bottom of hole
Idle-mixture screw preliminary setting	2-3 turns	2-3 turns	2-3 turns	2-3 turns	2-3 turns
Float weight (max.)	9.88 g	9.88 g	9.88 g	9.88 g	9.88 g

NOTE:

[1] All measurements are ±1/64 in. (0.4 mm).

[2] Accelerator pump measurement taken from flame arrestor surface to pump stem with throttle plates closed.

[3] Choke valve must be closed, choke rod in bottom of choke lever slot and choke coil rod pushed down to end of travel.

ROCHESTER CARBURETOR TORQUE SPECIFICATIONS	
Fastener Location	**lb-ft (N•m)**
Carburetor to manifold	11 (15)
Fuel line to carburetor	18 (24)
Fuel-inlet filter nut	18 (24)

TOOLS OBTAINED LOCALLY
Test tachometer

SPECIAL TOOLS	
Kent-Moore Number	**Name**
J8789-118	Carburetor stand
J34935-130	Float-level gauge
13T-8128-13	Float scale
J22769	Needle-valve seat remover
J9789-D	Universal carburetor gauge

SPECIAL TOOLS	
Wagner Number	**Name**
Model G.D. 150	Gram scale (with round tip)

TORX® SCREWDRIVERS

Later Rochester Quadrajet carburetors will have a star-shaped socket in the head of the screw. A Torx® screwdriver must be used on this type of screw. The three sizes used are No. 9, No. 20 and No. 25.

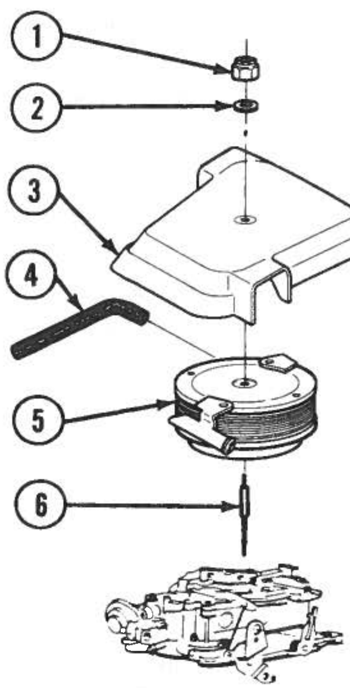
FLAME ARRESTOR

WARNING

Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

Refer to Figure 7-10.

1. Remove (in the following order):
   a. nut.
   b. sealing washer.
   c. carburetor cover (if equipped).
   d. crankcase-ventilation hoses from flame arrestor and rocker-arm covers.
   e. flame arrestor – lift from carburetor.



1. Locknut
2. Washer
3. Flame arrestor
4. Crankcase-ventilation hose
5. Flame arrestor
6. Flame-arrestor-mounting stud

Figure 7-10. *Flame Arrestor Assembly*

WARNING

Be careful when cleaning flame arrestor and crankcase ventilation hose; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that ignition key is OFF. Do not smoke or allow sources of spark or open flame in area when cleaning flame arrestor and crankcase ventilation hose.

2. Clean and inspect:
   a. Clean flame arrestor in solvent and blow dry with compressed air.
   b. Clean crankcase-ventilation hoses.
   c. Inspect crankcase-ventilation hose for cracks or deterioration. Replace if necessary.
3. Install (in the following order):
   a. flame arrestor on carburetor.
   b. crankcase-ventilation hoses to flame arrestor and rocker-arm covers.
   c. carburetor cover (if equipped).
   d. sealing washer.
   e. nut – tighten securely.

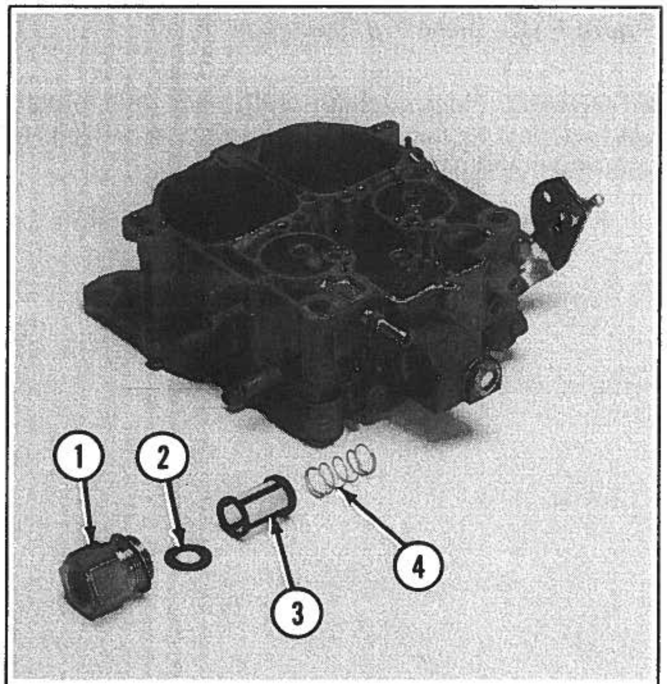
FUEL FILTER ON CARBURETOR

WARNING

Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

Refer to Figure 7-11.

1. Remove (in the following order):
   a. fuel line from fuel-inlet-filter nut.
   b. fuel-inlet-filter nut.
   c. large gasket.
   d. filter using fuel-filter wrench.
   e. spring.
   f. small gasket from inside filter nut.
2. Clean filter nut and spring.



1. Fuel-inlet-filter nut	3. Filter
2. Gasket	4. Spring

Figure 7-11. *Changing Rochester Fuel Filter*

3. Install (in the following order):
   a. spring – place in carburetor body.
   b. small gasket – place inside filter nut.
   c. filter with open end to inlet filter nut.
   d. large gasket – place over filter nut.
   e. fuel inlet filter nut – tighten to specifications.
   f. fuel line – tighten to specifications.

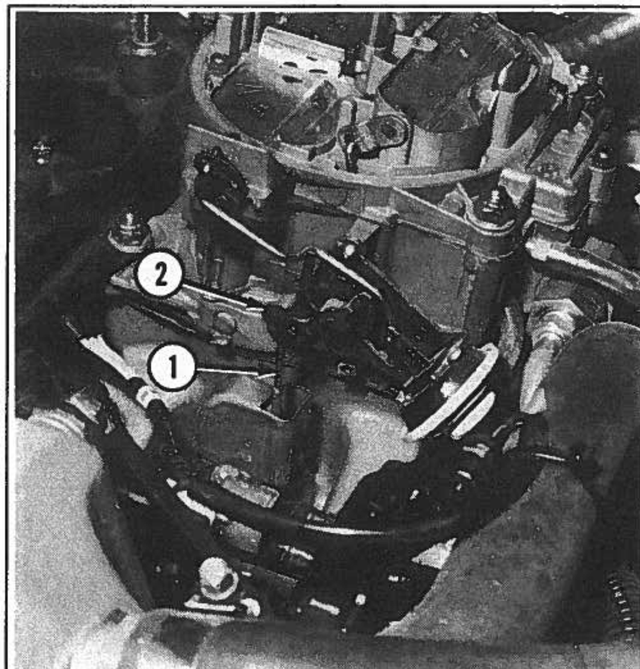
ROCHESTER CARBURETOR REMOVAL

WARNING

Refer to Cautions and Warnings under Section 7.1, General information, **before** proceeding.

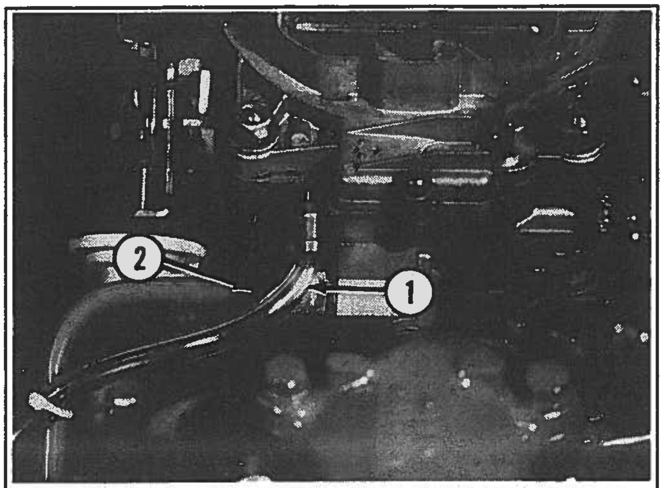
IMPORTANT: Carburetor malfunctions are, in many cases, caused by the presence of dirt, water or other foreign matter in carburetor. To aid in diagnosis, carefully remove carburetor from engine without draining fuel from bowl. Contents of fuel bowl may then be inspected for contamination as the carburetor is disassembled.

1. Remove flame arrestor.
2. Disconnect choke rod.
3. Disconnect sight tube.



1. Choke rod	2. Choke-rod clip

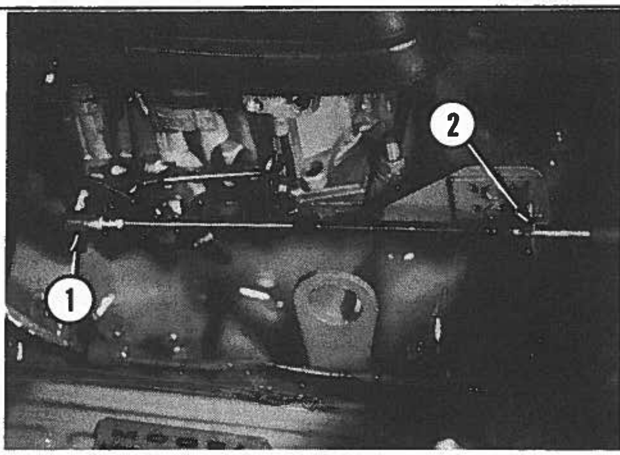
Figure 7-12. *Removing Choke-Spring Rod*



1. Sight tube 2. Fuel line

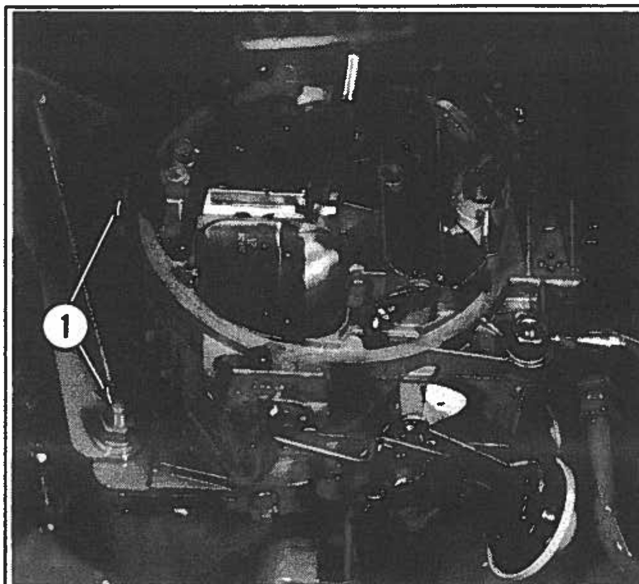
Figure 7-13. *Removing Sight Tube And Fuel Line*

4. Turn off fuel supply at the fuel tank.
5. Disconnect fuel line (Figure 7-13).
6. Disconnect throttle cable (Figure 7-14).
7. Remove retaining nuts and bolts, then remove carburetor and cable bracket.



1. Throttle-cable ball joint 2. Throttle-cable clip

Figure 7-14. *Removing Throttle Cable*



1. Mounting bolts and nuts

Figure 7-15. *Removing Carburetor*

IMPORTANT: Place a clean cloth over intake-manifold opening to prevent dirt or foreign material from entering manifold.

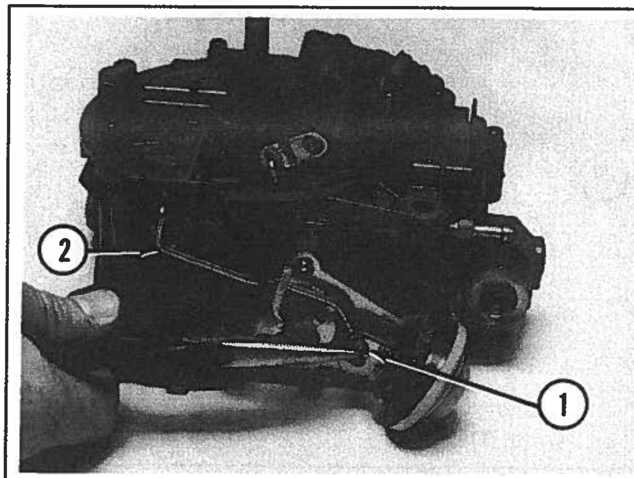
8. Remove old gasket from carburetor and manifold.

ROCHESTER CARBURETOR DISASSEMBLY

IMPORTANT: Place carburetor on a holding fixture to prevent throttle-valve damage.

Air Horn:

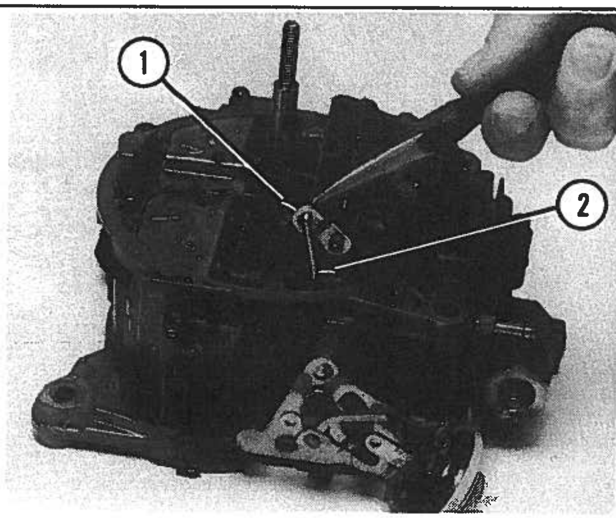
1. Remove vacuum-pump clip and rod.



1. Rod clip 2. Rod

Figure 7-16. *Removing Vacuum-Pump Rod Clip*

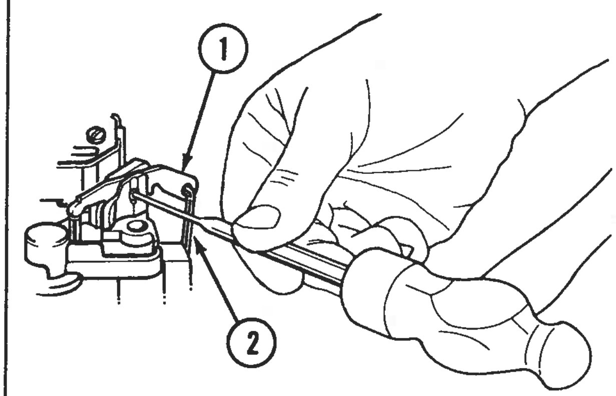
2. Remove choke-shutter clip and rod.



1. Clip 2. Rod

Figure 7-17. *Removing Choke Rod And Clip*

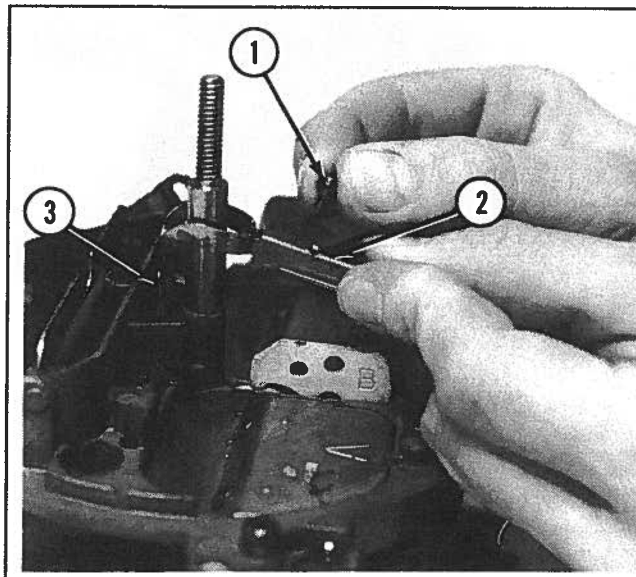
3. Drive roll pin back and remove accelerator pump lever and rod.



1. Accelerator-pump lever 2. Rod

Figure 7-18. *Removing Accelerator Pump Lever*

4. Remove screw, secondary metering rods and hanger.



1. Screw
2. Hanger
3. Metering rods

Figure 7-19. *Removing Metering Rods And Hanger*

5. Remove air-horn screws and air horn (Figure 7-20 and 7-21).

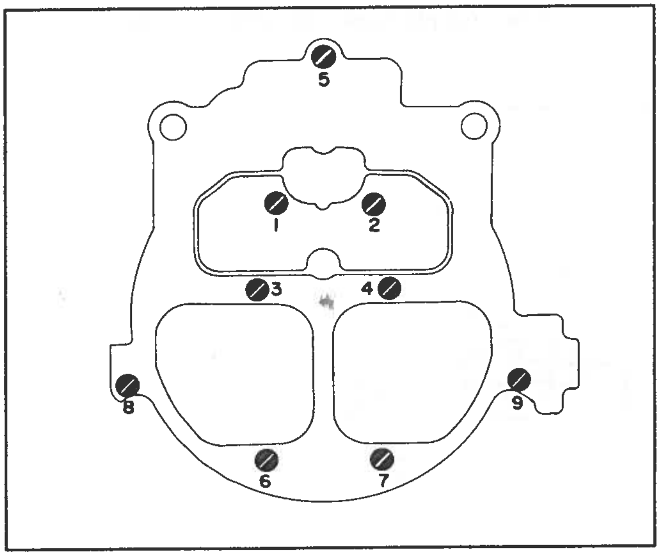
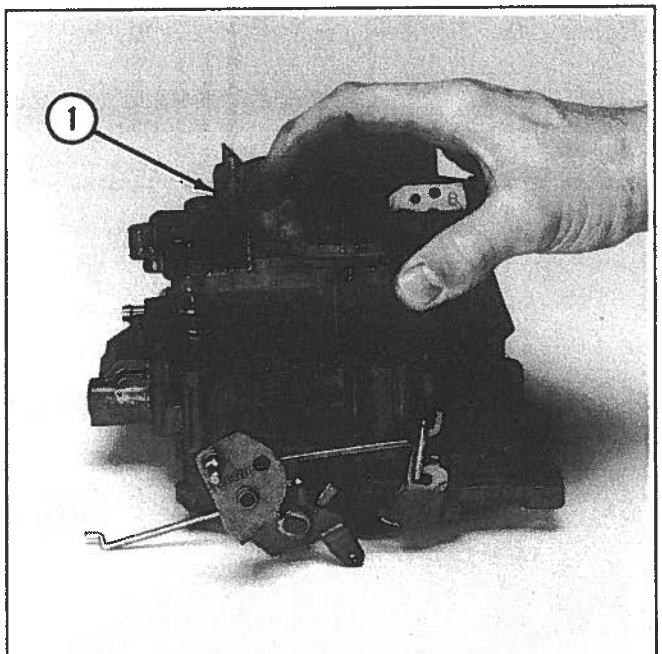


Figure 7-20. Air-Horn Screws

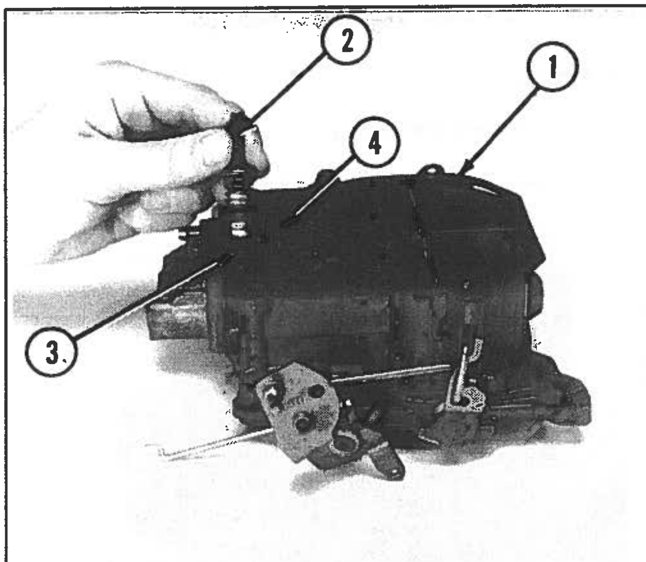


1. Air horn

Figure 7-21. Removing Air Horn

Float Bowl:

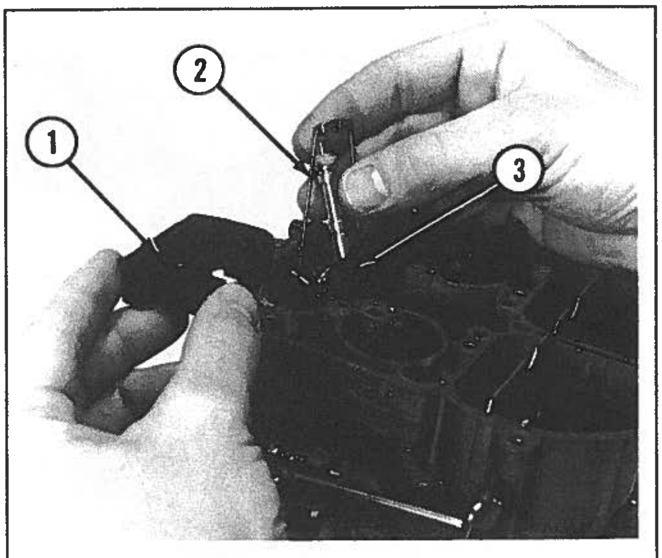
1. Remove pump plunger, return spring and gasket.



1. Gasket
2. Pump plunger
3. Return spring
4. Power piston hanger

Figure 7-22. Removing Gasket And Accelerator Pump

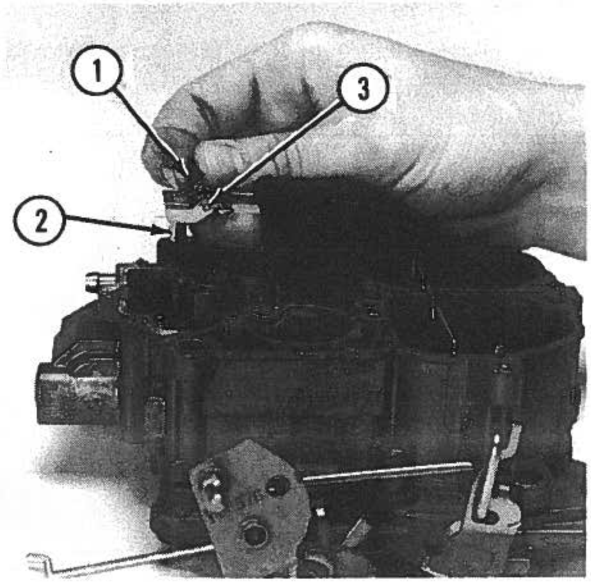
2. Remove insert block, power piston and spring.



1. Insert block
2. Power piston
3. Spring

Figure 7-23. Removing Insert Block And Power Piston

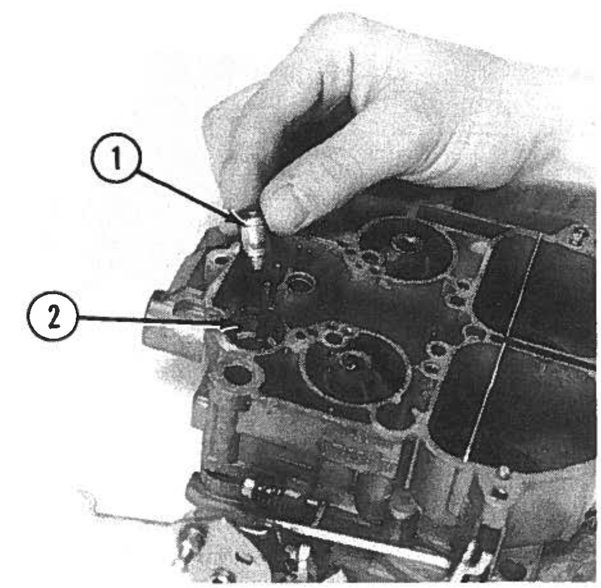
3. Remove float assembly, needle and retaining pin.



1. Float assembly
2. Needle
3. Retaining pin

Figure 7-24. *Removing Float And Inlet Needle*

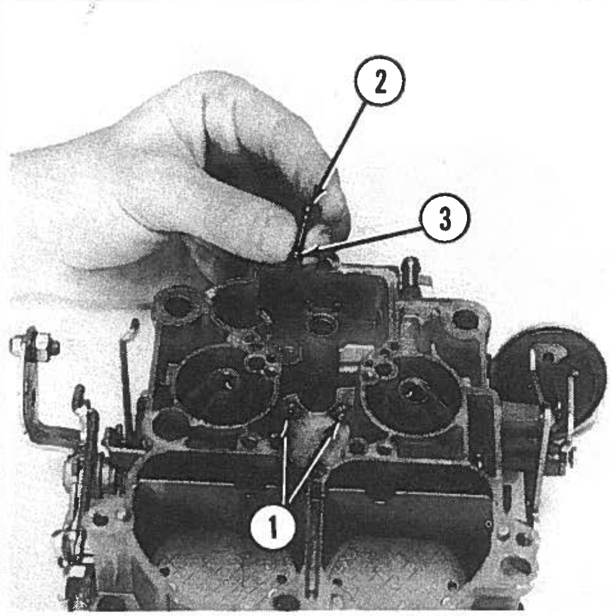
4. Remove fuel-inlet seat and gasket.



1. Fuel-inlet seat
2. Gasket

Figure 7-25. *Removing Inlet Seat*

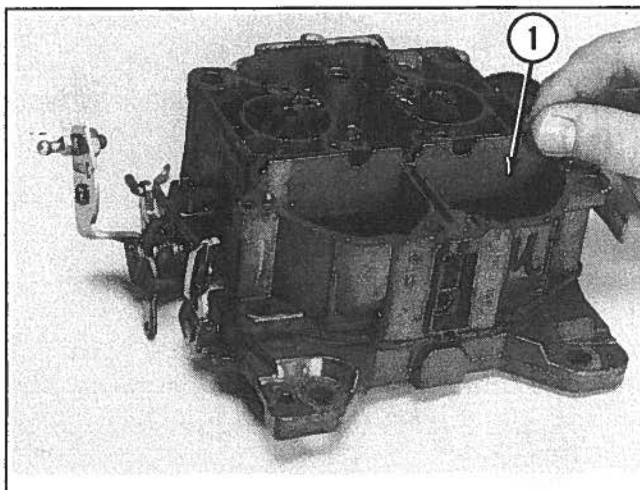
5. Remove primary metering jets, pump-discharge check-ball retainer and check ball.



1. Primary metering jets
2. Quick-discharge retainer
3. Check ball

Figure 7-26. *Removing Primary Jets, Retainer And Check Ball*

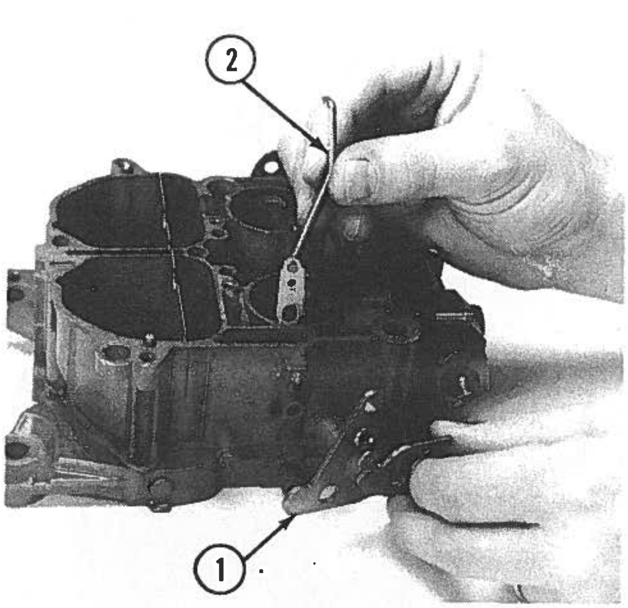
6. Remove baffle.



1. Baffle

Figure 7-27. *Removing Baffle*

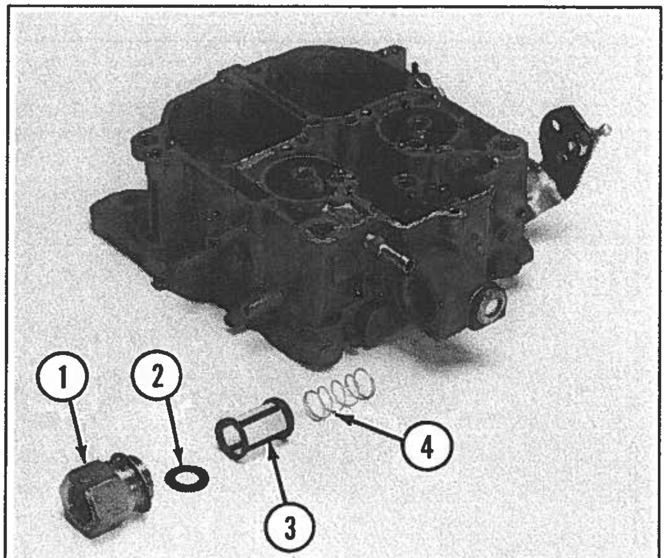
7. Remove vacuum-control assembly and hose.



1. Vacuum-control assembly
2. Inner choke rod

Figure 7-28. *Removing Vacuum Control*

8. Remove fuel-inlet-filter nut, gasket, filter and spring.

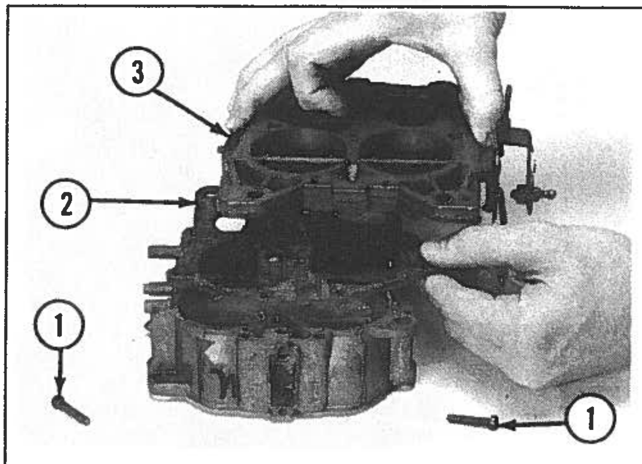


1. Nut
2. Gasket
3. Fuel filter
4. Spring

Figure 7-29. *Removing Fuel-Inlet Filter Assembly*

Throttle Body:

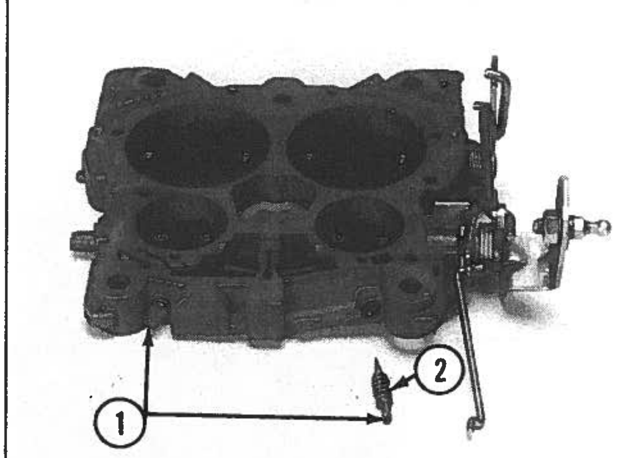
1. Separate throttle body from float bowl and remove gasket.



1. Attaching screws
2. Gasket
3. Throttle body

Figure 7-30. *Removing Throttle Body*

2. Remove idle mixture screws and springs.



1. Screw
2. Spring

Figure 7-31. *Removing Idle-Mixture Screws*

IMPORTANT: Throttle body should not be disassembled any further than shown. Throttle body is serviced as an assembly.

CLEANING AND INSPECTION

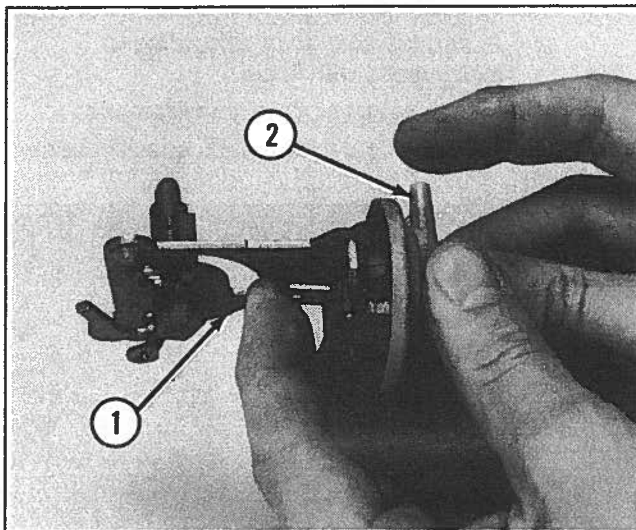
> **CAUTION**
>
> Rubber, or plastic parts, pump plungers or diaphragms cannot be immersed in carburetor cleaner. The Delrin air-valve cam will withstand normal carburetor cleaner.

1. Clean carburetor in immersion-type cleaner.

> **CAUTION**
>
> Do not leave carburetor in cleaner for more than two hours.

2. Blow out passages with compressed air. Do not drill through passages.
3. Inspect for wear:
   a. idle-mixture needles
   b. float needle and seat
   c. casting surfaces
   d. all levers
   e. power piston
   f. accelerator-pump seal
4. Check all valves for binding.
5. Check vacuum-break unit for leaks.
   a. Depress plunger and seal hose connection (Figure 7-32).
   b. Maintain seal on hose connection; plunger must remain seated. If plunger extends, replace unit.

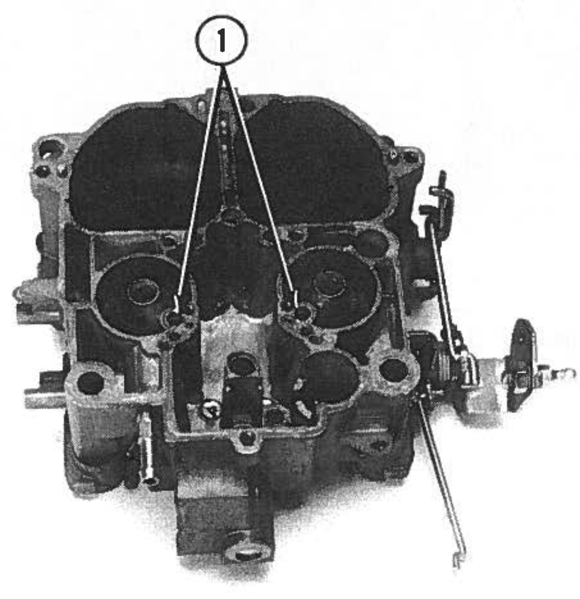
IMPORTANT: The idle-fuel pickup tubes have a smaller I.D. at the bottom than the top. Do not drill.



1. Plunger 2. Hose connection

Figure 7-32. *Seating Plunger And Hose Connection Sealed*

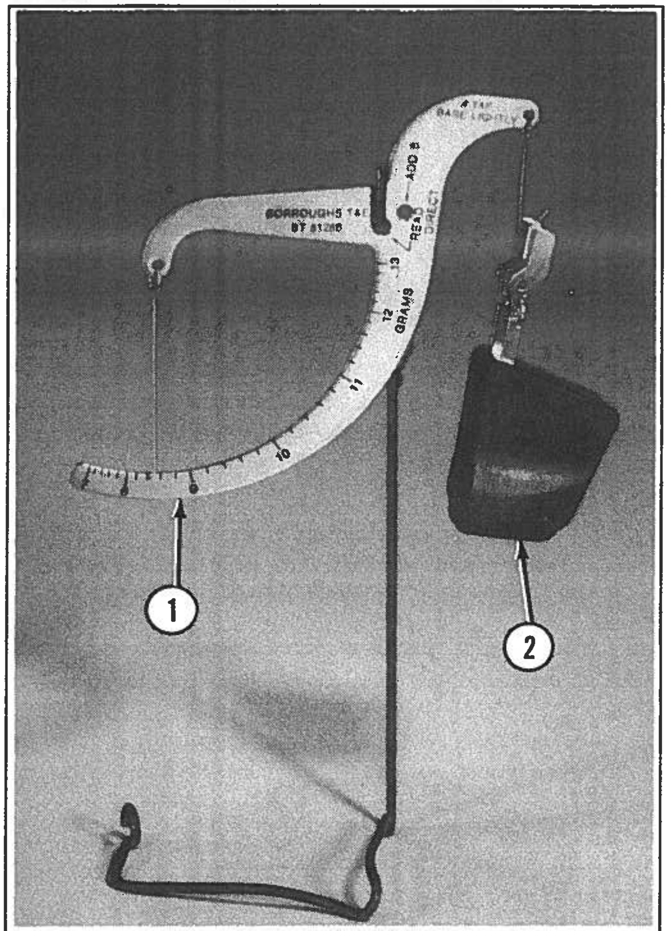
6. Clean idle-fuel pickup tubes with a fine wire (approximately 0.020 in. [0.5 mm] O.D.) and blow out all channels with compressed air.



1. Idle-fuel-pickup tubes

Figure 7-33. *Cleaning Idle Passages*

7. Check float weight.
   a. Assemble float scale according to instructions with scale.
   b. Check float weight to specifications.
   c. Replace float if it exceeds specifications.



1. Float scale 2. Float

Figure 7-34. *Checking Float Weight*

ROCHESTER CARBURETOR REASSEMBLY

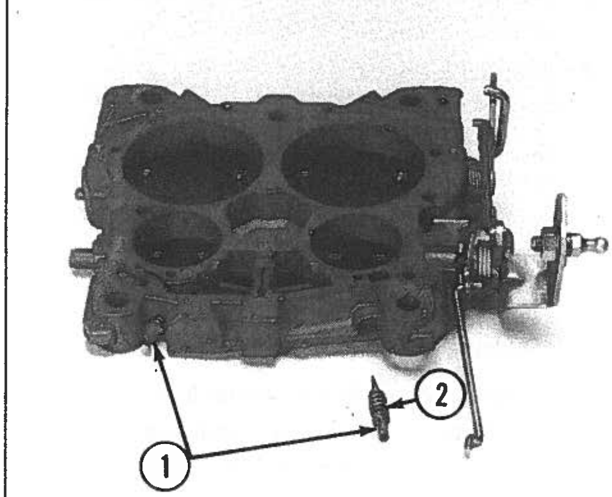
Throttle Body:

NOTE: Refer to "Rochester Carburetor Adjustments" in this Section for all adjustment procedures.

CAUTION

Seat idle-mixture screws lightly to avoid damage to needles and seats.

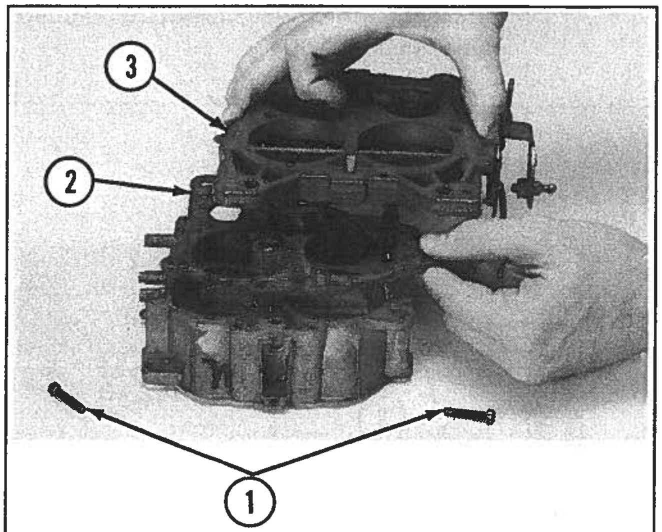
1. Install idle mixture needles and springs until lightly seated, then back out two to three turns.



1. Idle-mixture screw 2. Springs

Figure 7-35. *Installing Idle-Mixture Needles*

2. Install new gasket and assemble throttle body to float bowl. Tighten securely.



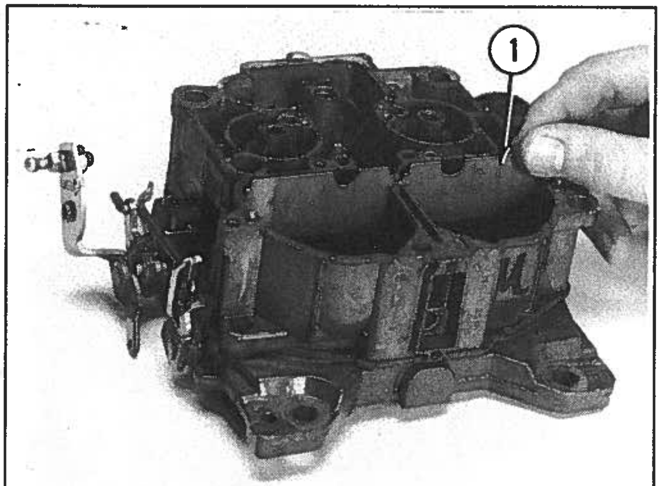
1. Attaching screws
2. Gasket
3. Throttle body

Figure 7-36. Installing Throttle Body

Float Bowl:

IMPORTANT: Place carburetor on a holding fixture to prevent damage to throttle valve.

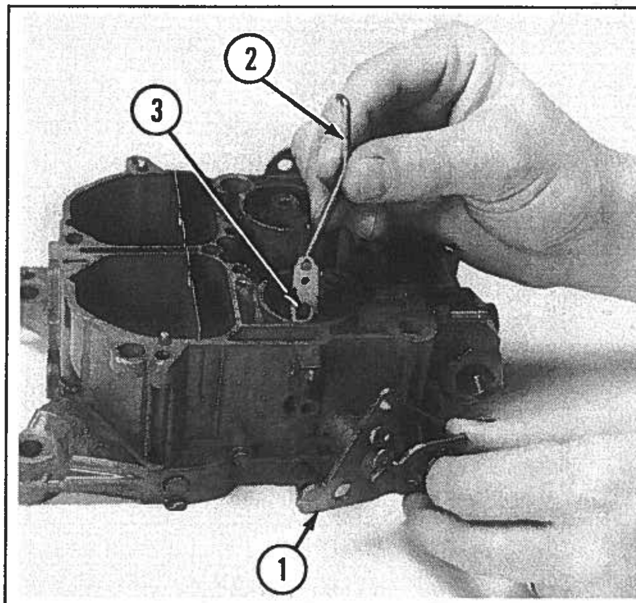
1. Install baffle plate.



1. Baffle plate

Figure 7-37. Installing Baffle Plate

2. Install intermediate choke lever and vacuum-break control bracket assembly.

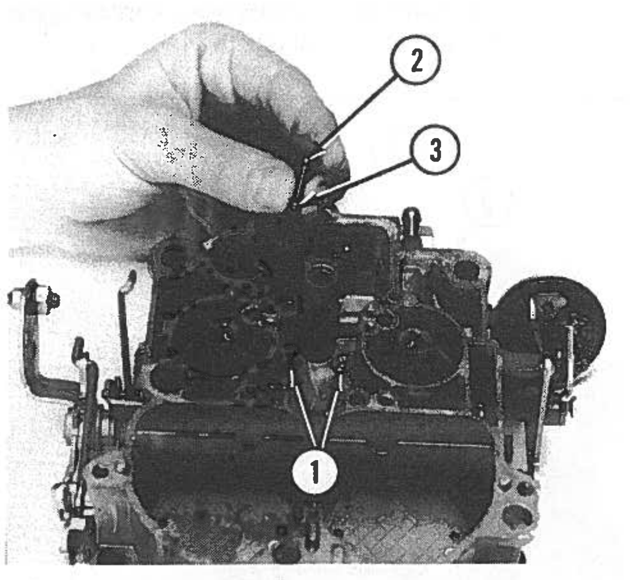


1. Choke lever
2. Choke
3. Flat-sided hole

Figure 7-38. Installing Choke Rod And Lever To Vacuum Break

a. Using choke rod, suspend intermediate choke lever in float bowl cavity so that flat-sided hole aligns with hole in side of float bowl.
b. Insert choke shaft on vacuum-break control assembly to engage flat-sided hole of choke lever and secure with screw. Tighten securely.

3. Install pump-discharge check-ball retainer. Install primary metering jets and tighten securely.

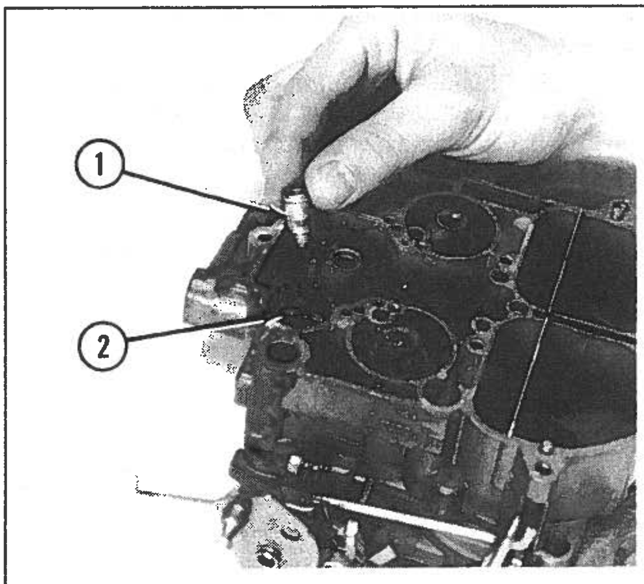


1. Primary metering jets
2. Pump discharge retainer
3. Check ball

Figure 7-39. *Installing Check Ball, Retainer And Primary Jets*

IMPORTANT: Float needle and seat should be replaced as a set only.

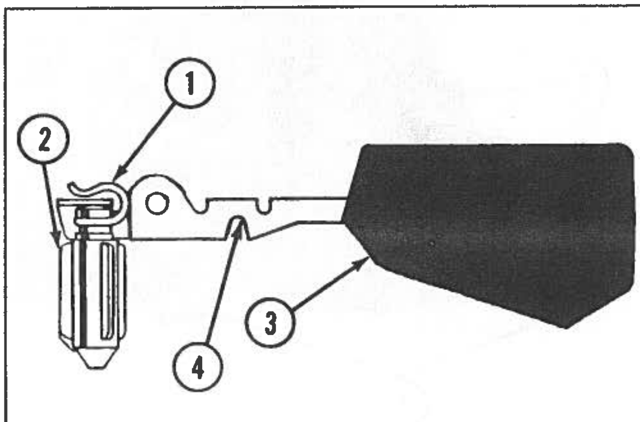
4. Install float needle seat and gasket.



1. Float-needle seat
2. Gasket

Figure 7-40. *Installing Needle Seat And Gasket*

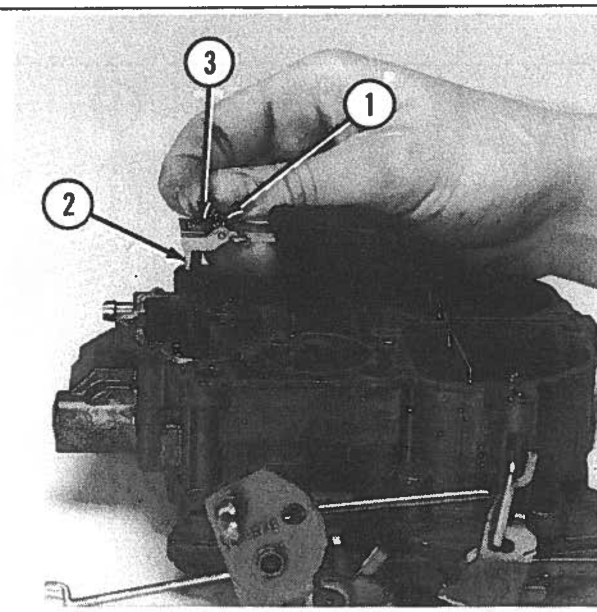
5. Install float needle and float assembly.
   a. Install pull-clip onto needle.
   b. If a new float or needle and seat are used, bend float arm slightly upward at notch for easier adjustment.



1. Pull-clip
2. Float needle
3. Float
4. Float-arm notch

Figure 7-41. *Installing Float Needle And Float Assembly*

   c. Hook needle with pull-clip over edge of float arm closest to end of pontoon.
   d. Install retaining pin into float arm and install float and needle into bowl.



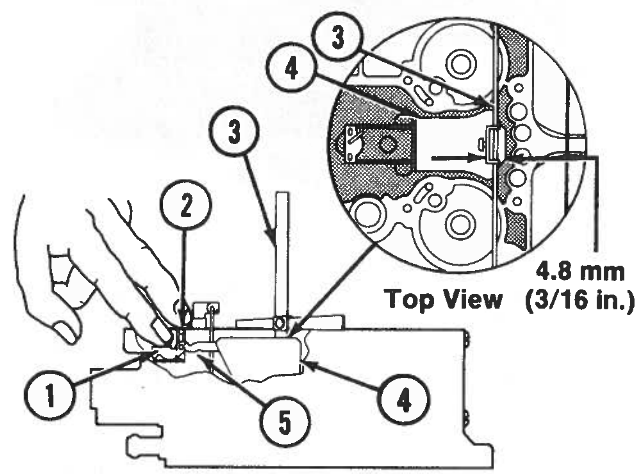
1. Float assembly
2. Needle
3. Retaining pin

Figure 7-42. *Installing Float And Needle*

IMPORTANT: Top of hinge pin must extend above casting by 0.010 in. (0.3 mm) for good pin retention.

e. Check float adjustment. (See "Rochester Carburetor Adjustments" in this section.)

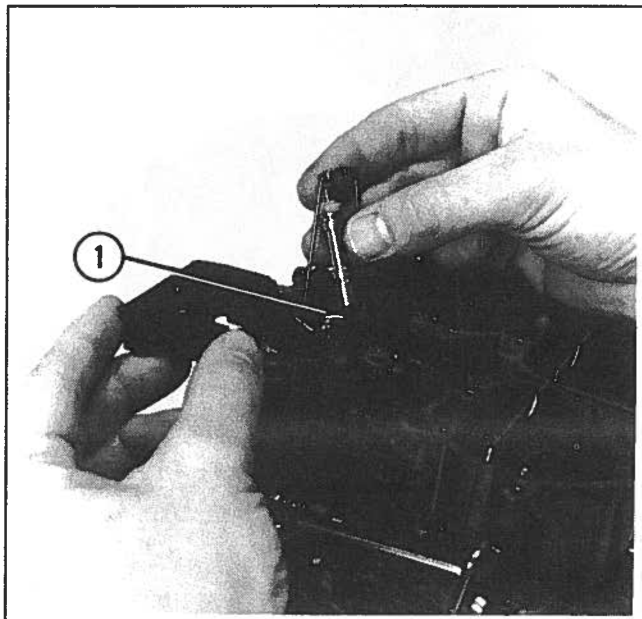
6. Hold hinge pin firmly. Turn carburetor upside down and measure from casting surface to toe of float with Universal carburetor gauge. Check specifications.
7. Bend at float-arm notch for adjustment to specifications.



1. Float lever
2. Retainer
3. J-9789-90 Scale
4. Float
5. Notch

Figure 7-43. *Adjusting Float*

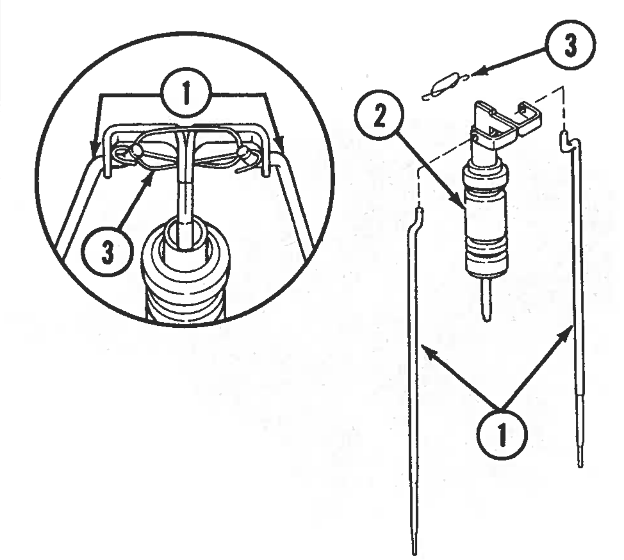
8. Install power-piston spring.



1. Power piston spring

Figure 7-44. *Installing Power-Piston Spring*

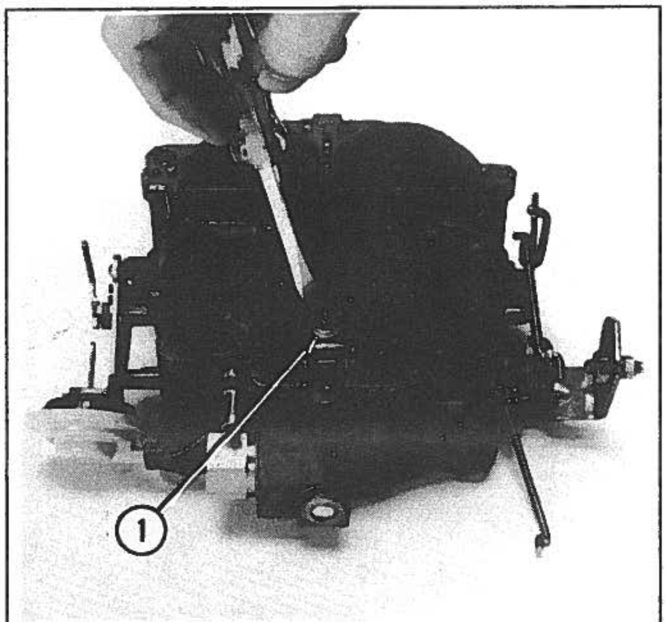
9. Install primary main-metering rods in power-piston hanger and connect spring as shown.



1. Metering rods
2. Power piston
3. Tension spring

Figure 7-45. *Installing Primary Metering Rods*

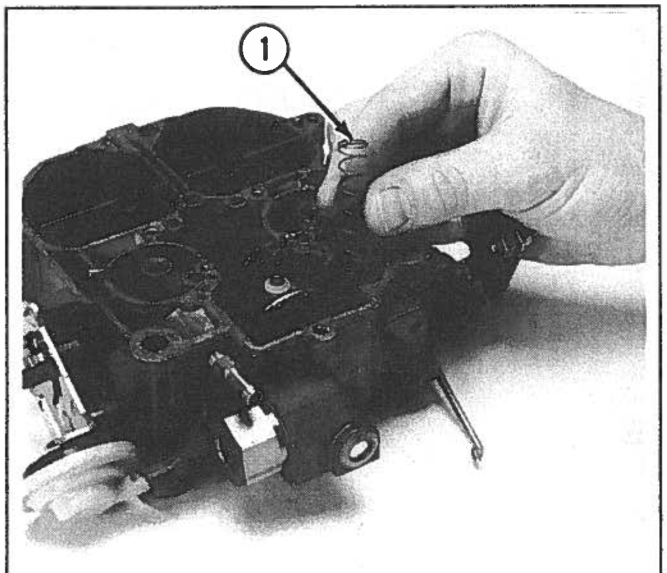
10. Install power-piston assembly, guiding metering-rod tips into main metering jets.
11. Push power-piston retainer down until flush with casting.



1. Power piston retainer

Figure 7-46. Installing Power-Piston Assembly

12. Install filler block.
13. Install accelerator-pump return spring.

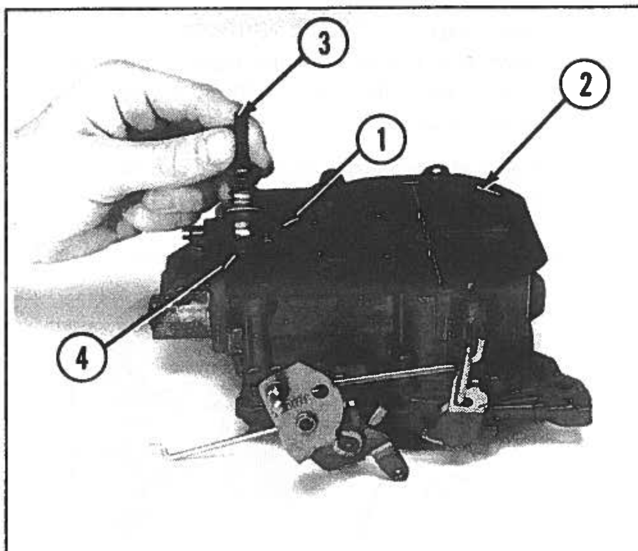


1. Return spring

Figure 7-47. Installing Pump-Return Spring

Air Horn:

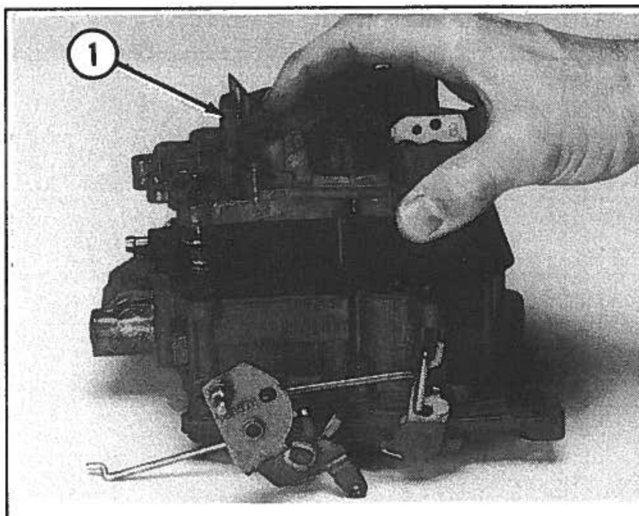
1. Install new gasket and slide tab under power-piston hanger.



1. Power piston hanger
2. Gasket
3. Pump plunger
4. Return spring

Figure 7-48. Installation Of Gasket And Accelerator Pump

2. Install accelerator-pump plunger (Figure 7-48).
3. Install air horn.



1. Air horn

Figure 7-49. Installing Air Horn

4. Install nine attaching screws. Tighten screws with Torx® screwdriver securely in sequence as numbered.

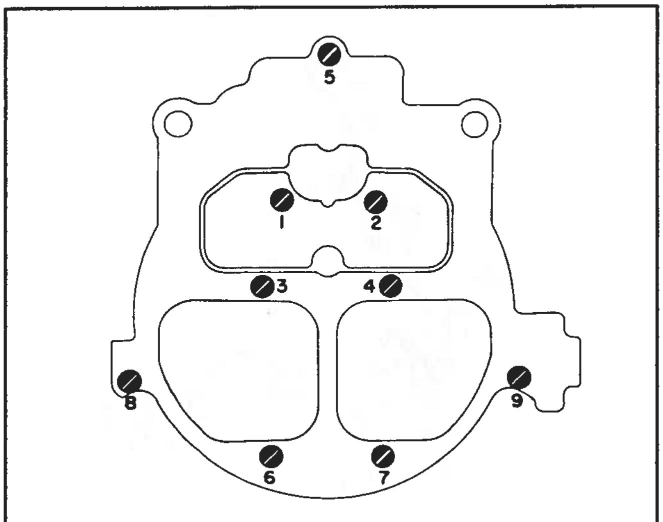
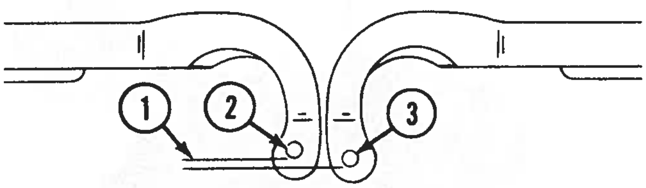


Figure 7-50. Attaching Screw Installation

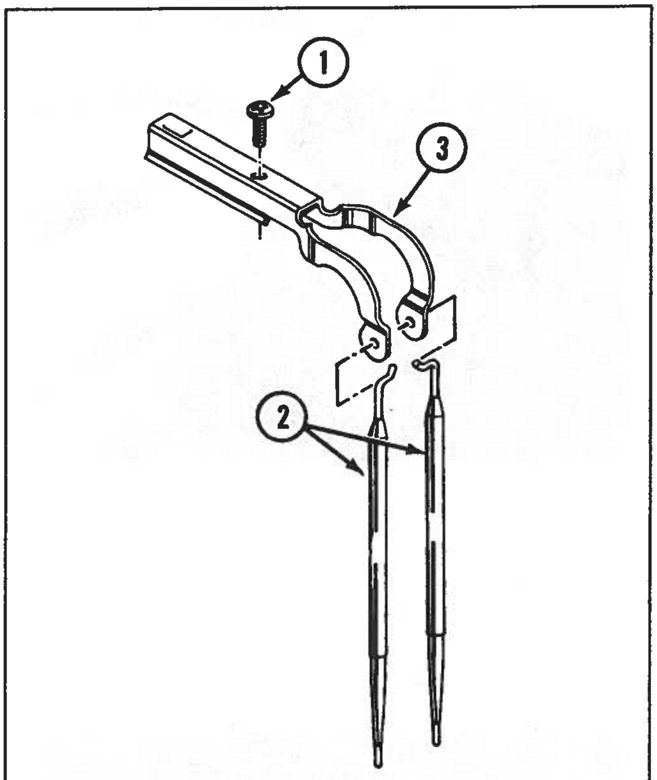
IMPORTANT: Hanger size may vary from specification chart. Manufacturer varies hanger size to compensate for differences in carburetor castings. Always install the same-size hanger as was removed from the carburetor. The difference in hangers is in the hole location which affects secondary fuel metering.



1. Hole location changes fuel metering
2. Richer
3. Leaner

Figure 7-51. Hanger Size

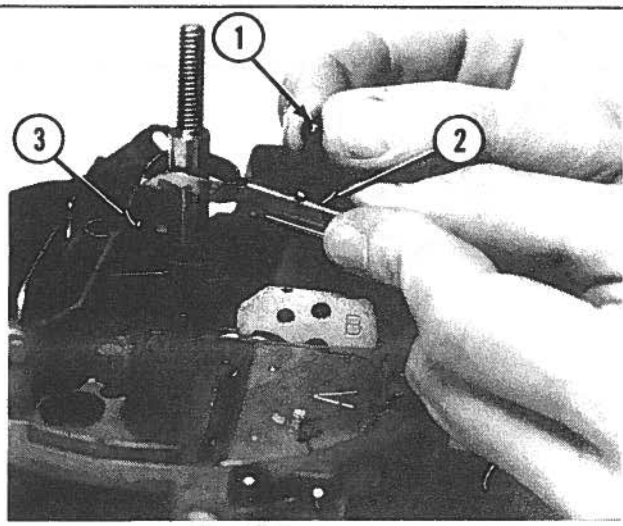
5. Install secondary metering rods into hanger with upper ends toward each other as shown. Install same-size hanger as was removed from the carburetor.



1. Screw
2. Secondary metering rods
3. Hanger

Figure 7-52. Installing Metering Rods

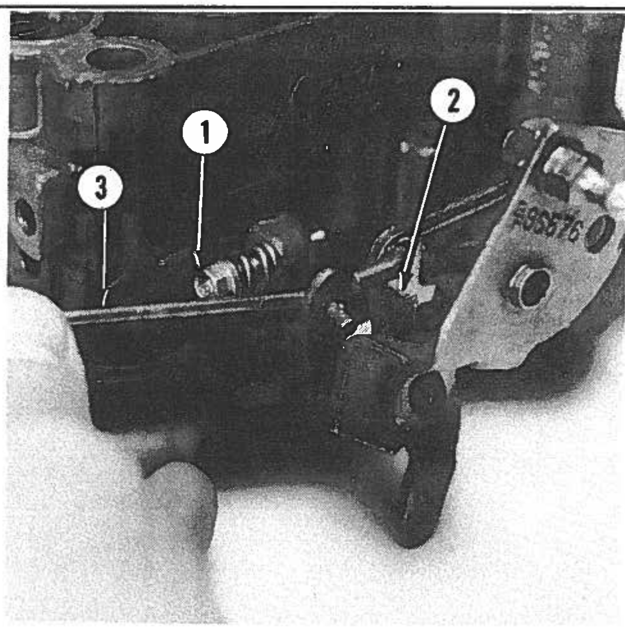
6. Install metering rods and hanger and secure with screw. Tighten securely.



1. Screw
2. Hanger
3. Metering rods

Figure 7-53. Installing Hanger Assembly

7. Install pump-lever rod.

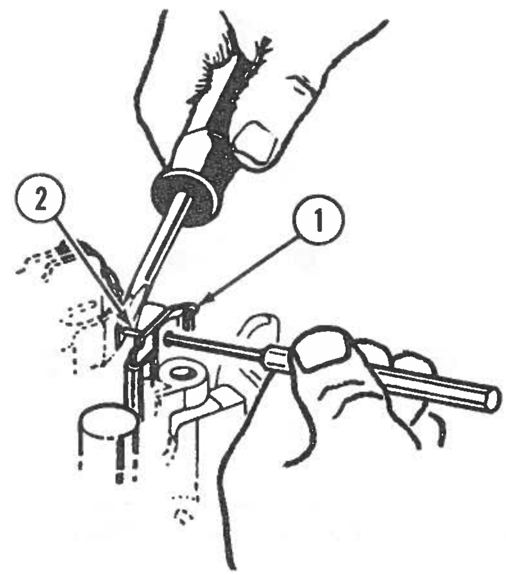


1. Idle-stop screw
2. Throttle lever
3. Pump-lever rod

Figure 7-54. Installing Pump-Lever Rod

8. Install rod into lever inner hole and place lever into casting mount.

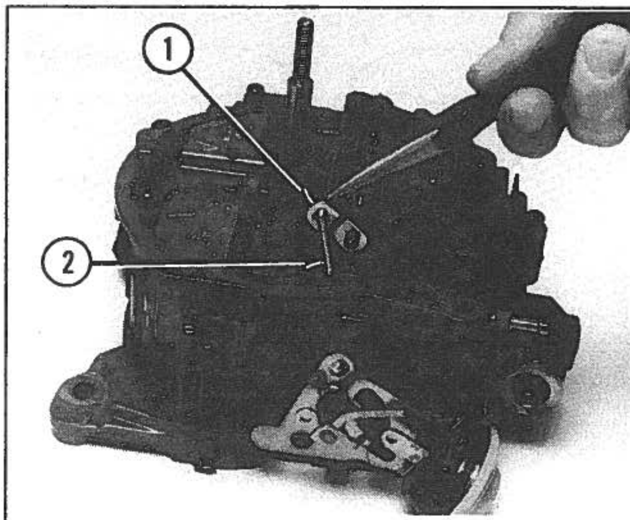
9. Press roll pin into place using a screwdriver.



1. Accelerator-pump lever
2. Roll pin

Figure 7-55. Locating Pump-Lever Rod And Roll Pin

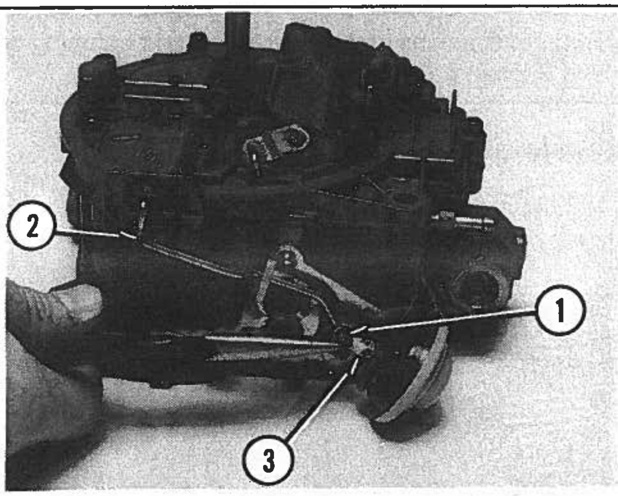
10. Install bottom end of choke-shutter rod into intermediate choke lever in float bowl.



1. Clip
2. Rod

Figure 7-56. Installing Choke-Shutter Rod

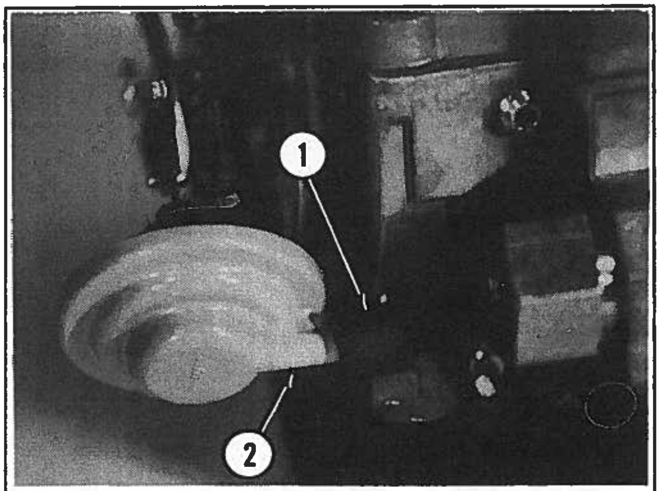
11. Install upper end of choke-shutter rod into the choke-blade lever. Install clip onto choke-shutter rod.
12. Install rod into air-valve lever.



1. Rod clip
2. Rod
3. Air-valve lever

Figure 7-57. *Installing Air-Valve Rod*

13. Install rod into vacuum-break arm and install clip.
14. Install vacuum-break hose onto carburetor fitting.
15. Install vacuum-break hose onto vacuum-dashpot fitting.

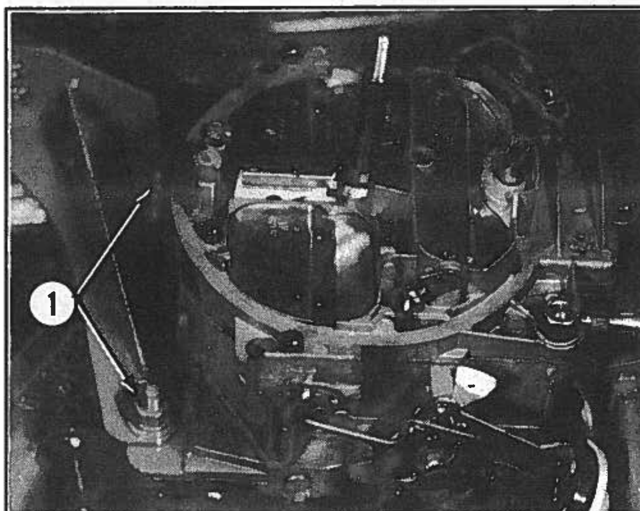


1. Hose
2. Dashpot fitting

Figure 7-58. *Installing Vacuum Hose*

ROCHESTER CARBURETOR INSTALLATION

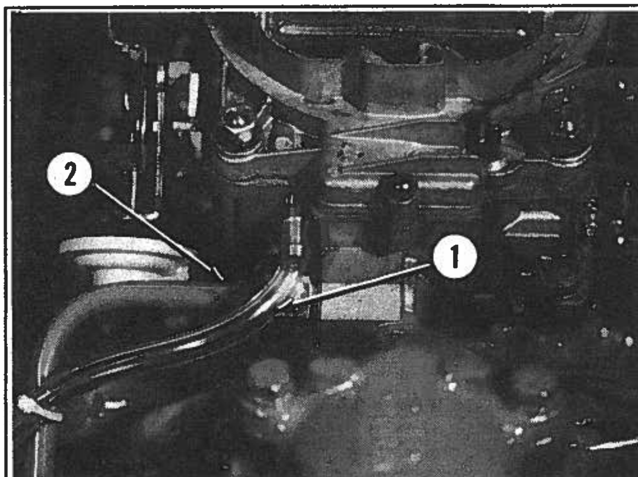
1. Install new gasket onto manifold.
2. Install carburetor and throttle bracket, and torque bolts to specifications.



1. Mounting bolts and nuts

Figure 7-59. *Installing Carburetor*

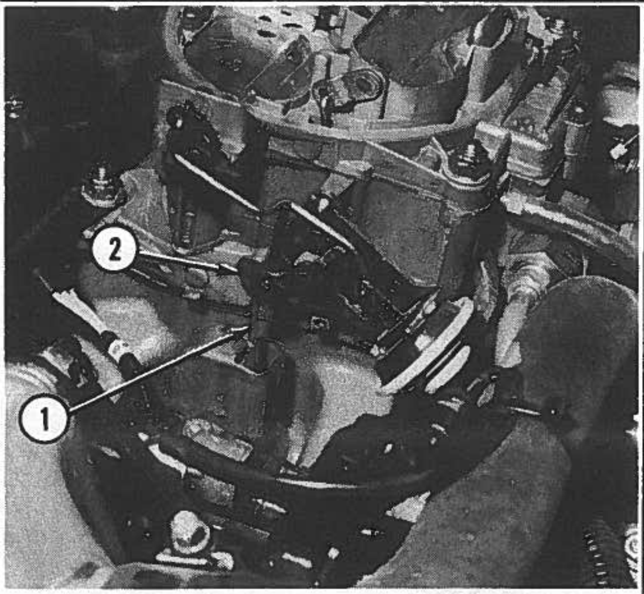
3. Connect fuel line and torque to specifications.



1. Sight tube
2. Fuel line

Figure 7-60. *Connecting Fuel Line and Sight Tube*

4. Connect fuel-sight tube (Figure 7-60).
5. Connect choke link and install retaining clip.



1. Choke link 2. Clip

Figure 7-61. Connecting Choke-Spring Rod

6. Install throttle cable.
7. Install flame arrestor and tighten securely.
8. Reconnect battery cables to battery.
9. Start engine and check for gasoline leaks. If leaks exist, STOP ENGINE IMMEDIATELY and recheck connections.
10. Adjust idle speed and idle mixture as outlined under "Rochester Carburetor Adjustments" in this Section.

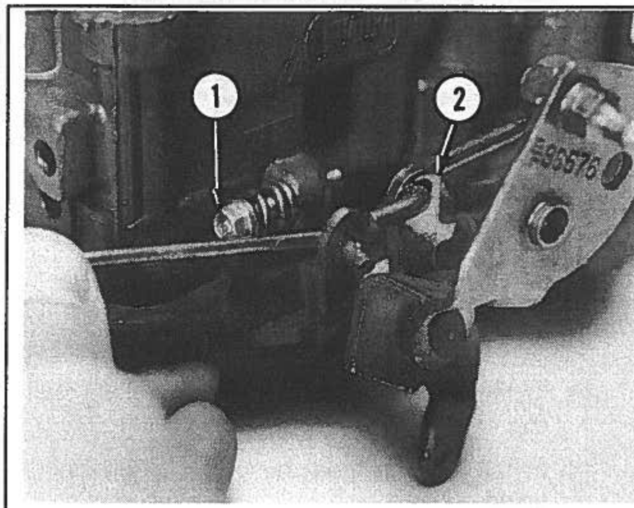
ROCHESTER CARBURETOR ADJUSTMENTS

WARNING

Refer to Cautions and Warnings at the beginning of this Section **before** proceeding.

Accelerator Pump:

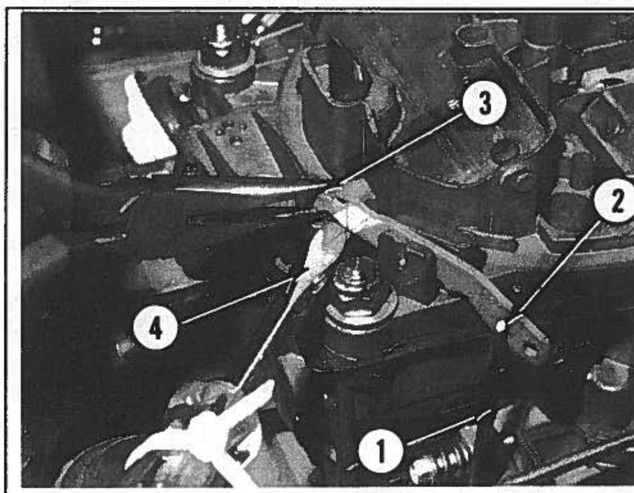
1. Back out idle-stop screw until it no longer contacts throttle lever.



1. Idle-stop screw 2. Throttle lever

Figure 7-62. Backing Out Idle-Stop Screw

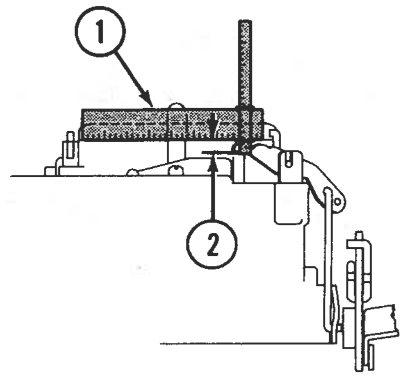
2. Pump rod must be in inner hole of lever.



1. Pump rod
2. Inner hold
3. Tip of pump lever
4. Support as shown

Figure 7-63. Pump Rod Location

3. Close throttle valves completely and measure from flame-arrestor-mounting surface to top of pump-plunger stem.



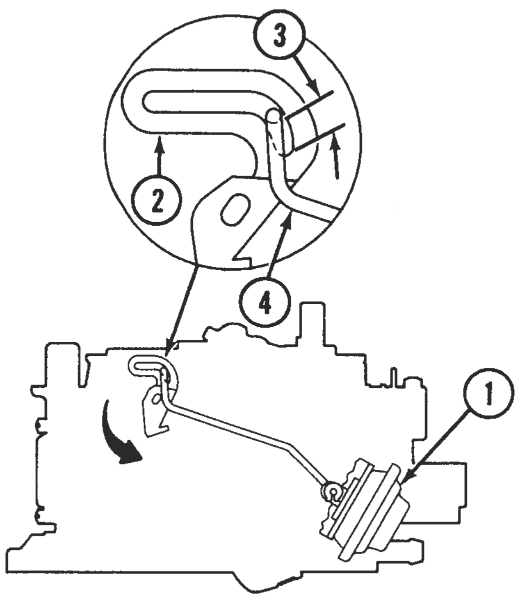
1. J-9789-96 Universal carburetor gauge
2. Flame-arrestor-mounting surface

Figure 7-64. *Measuring Pump-Plunger Height*

4. While supporting lever, bend tip of pump lever to obtain specified dimension.

Air-Valve Dashpot:

1. Seat vacuum-break diaphragm and close air valve completely. Bend rod to adjust gap to specifications.

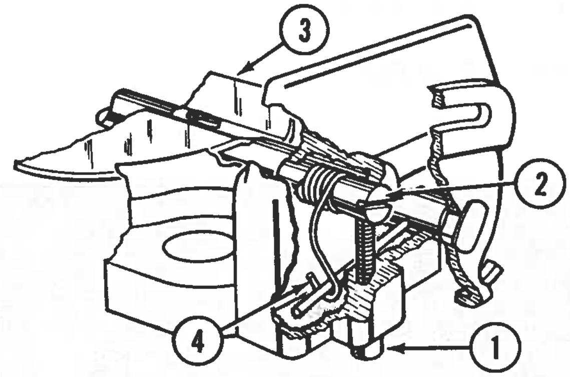


1. Push in completely
2. Fully closed
3. Specified gap
4. Bend here to adjust

Figure 7-65. *Adjusting Dashpot-Link Rod*

Air-Valve Spring Windup:

1. Rotate gram scale until air valve begins to open. Check scale reading.



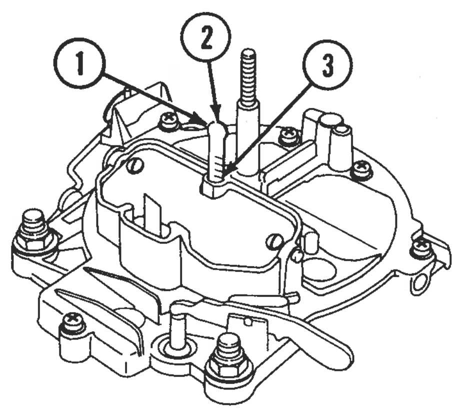
1. Lockscrew
2. Tension-adjusting screw
3. Air valve
4. Spring

Figure 7-66. *Checking/Adjusting Air Valve*

2. To adjust spring windup, hold tension-spring screw and loosen Allen-head screw.
3. Adjust tension and retighten Allen-head screw securely.

Float Level:

1. Start engine to fill float bowl, run at idle and insert float gauge into hole next to flame-arrestor stud.



1. Float gauge
2. Tap gauge here
3. Read here

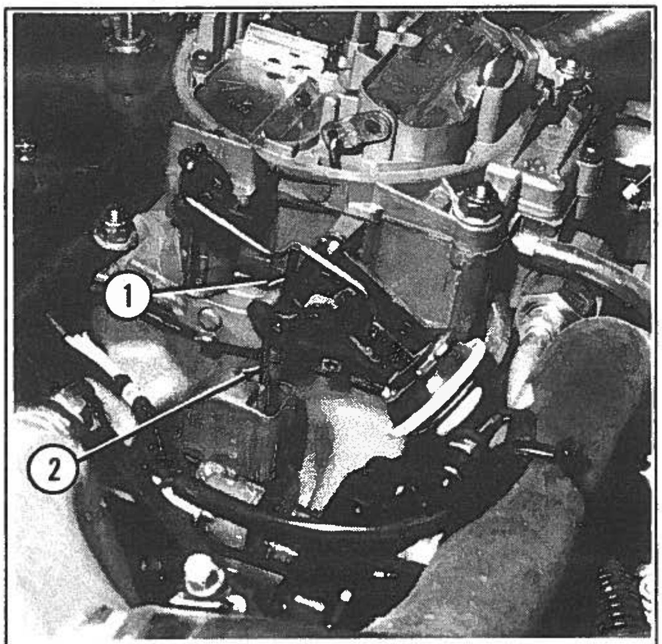
Figure 7-67. *Float Gauge*

2. Tap float gauge down lightly to enable free movement.
3. Take gauge reading at top of carburetor casting.

NOTE: If float requires adjustment, air horn must be removed from carburetor.

Choke-Coil Rod:

1. Push choke-coil rod down.



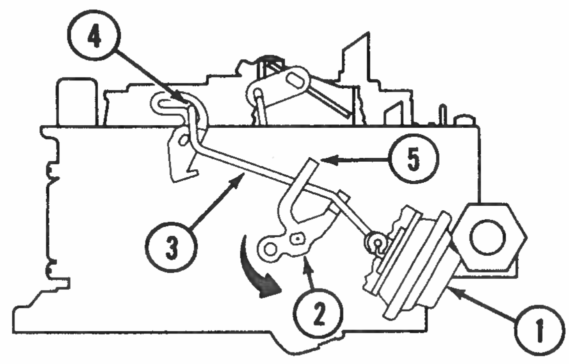
1. Vacuum-break choke lever
2. Choke-coil rod

Figure 7-68. *Pushing Choke Rod Down*

2. Choke-coil-rod top must be even with bottom of hole in vacuum-break choke lever.
3. Bend rod to adjust.

Vacuum Break:

1. Seat vacuum-break-control diaphragm.



1. Vacuum break
2. Vacuum-break lever
3. Vacuum-break rod
4. Choke-lever slot
5. Arm

Figure 7-69. *Vacuum Break*

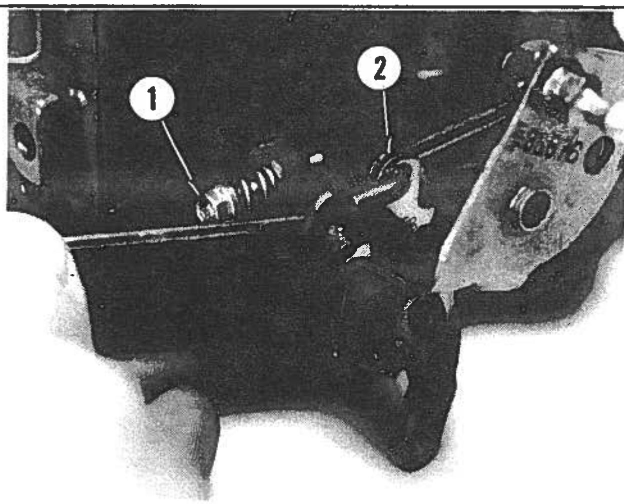
2. Rotate vacuum-break choke lever (2) counterclockwise until tang contacts vacuum-break rod. Choke rod must be at bottom of choke-shaft lever slot.
3. Bend tang as necessary to obtain specified choke valve gap.

Preliminary Idle Speed and Mixture:

Initial start setting.

NOTE: Make final adjustments with engine running.

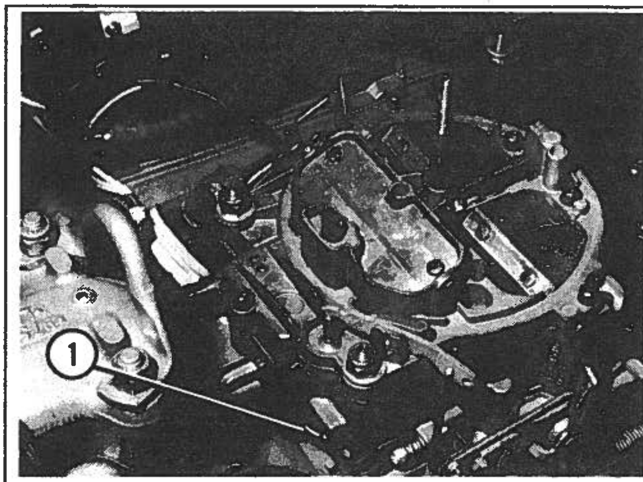
1. Turn idle-stop screw until contact is made with throttle lever.



1. Idle-stop screw 2. Throttle lever

Figure 7-70. *Idle-Stop Screw and Throttle*

2. Turn idle screw until lightly seated, then back out 2 to 3 turns.



1. Idle-mixture screw

Figure 7-71. *Idle-Mixture Screw*

Final Idle Speed and Mixture:

CAUTION

Do not turn idle-mixture screws tightly against seat, as damage to seat and/or needle may result.

IMPORTANT: Boat must be in the water and engine at normal operating temperature to accurately check and adjust idle speed and mixture.

IMPORTANT: Do not attempt to compensate for other engine problems (incorrect ignition timing, faulty ignition components, low compression, vacuum leaks, etc.) with carburetor adjustments. This will only mask the problem, which must be corrected if engine is to achieve maximum fuel economy and performance.

Carburetor should be set so that engine idles smoothly with boat in the water, engine at normal operating temperature and transmission in forward gear. To adjust idle speed and mixture, proceed as follows:

1. Connect a shop tachometer to engine.

IMPORTANT: Do not turn idle-mixture needles tightly into seat as damage to needle and/or seat may result.

2. If a new or rebuilt carburetor has been installed, turn each idle-mixture needle until it lightly contacts seat, then back out 2 to 3 turns. This will provide a sufficient setting to allow starting the engine.
3. Start engine and run at 1500 rpm until engine reaches normal operating temperature.

WARNING

Do not leave the helm unoccupied while performing idle speed and mixture adjustments. Be careful not to accidentally accelerate engine while performing adjustments.

4. With boat in water, place remote control in forward gear, idle position.

IMPORTANT: Refer to Section 2.4, Control Cables, for throttle cable installation and adjustment procedures.

5. Disconnect throttle cable from the anchor clip.
6. Adjust idle-speed-adjustment screw to obtain specified rpm.

7. With engine running at specified rpm, adjust idle-mixture needles as follows:
   a. Turn idle-mixture needle inward (clockwise) until the engine speed begins to drop due to lean mixture.
   b. Turn idle-mixture needle outward (counterclockwise) until the speed begins to drop due to a rich mixture.
   c. Turn idle-mixture needle inward to a point between these two extremes to obtain maximum engine rpm and smoothness.
   d. Repeat procedure with other needle.
   e. Readjust idle-speed-adjusting screw, if necessary, to obtain specified rpm.
8. Reattach throttle cable.

7.4 HOLLEY 4-BARREL CARBURETOR 4150 SERIES (EARLY)

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** working on the fuel system to prevent fire or explosion.

WARNING

Be careful when changing fuel system components; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that the ignition key is OFF. **Do not** smoke or allow sources of spark and/or flame in the area while changing fuel system components. Wipe up any spilled fuel immediately.

WARNING

Fuel system components on your Crusader Engine are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement fuel system components which do not comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

To prevent the possibility of a **FIRE**, be sure that the engine compartment is well ventilated and that there are no gasoline vapors present.

WARNING

Make sure no fuel leaks exist before closing engine hatch.

CAUTION

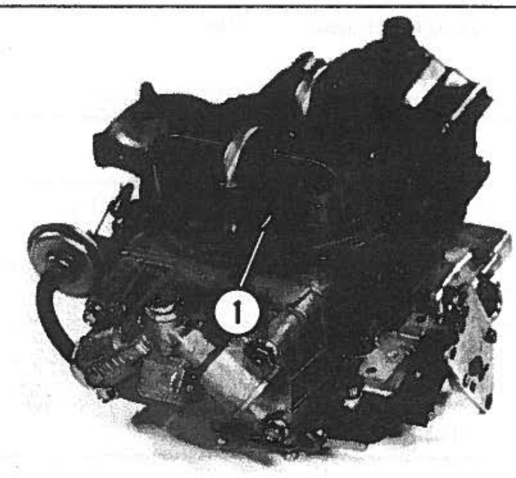
Do not operate engine without cooling water being supplied to water pickup; water pump impeller will be damaged and subsequent overheating damage to the engine may result.

DESCRIPTION

A Holley Model 4150 4-Barrel Carburetor is used on Crusader 502 CID engines. The Holley is easily identified by its two fuel bowls, one on each end. The Holley's flame arrestor and internal fuel filters are also different from those used on the Rochester Carburetors.

The Holley Model 4150 is a dual-feed, single-pump carburetor. This means each fuel bowl has a separate fuel inlet and one accelerator pump.

Metering bodies are located between the fuel bowls and the carburetor body. The metering bodies contain the main jets, power valve and the majority of the metered passages in the carburetor. Both the primary and secondary floats have an external float adjustment.



1. Part number

Figure 7-72. *Holley Part Number Location*

HOLLEY CARBURETOR SPECIFICATIONS	
Item	**Holley 4150**
Holley part number	80180
Main primary jets	0.092 in. (2.33 mm)
Main secondary jets	0.092 in. (2.33 mm)
Accelerator pump	0.015 in. (0.4 mm)
Accelerator-pump check ball	0.015 in. (0.4 mm)
Float adjustment	Bottom of sight-plug hole ± 1/32 in. (0.08 mm)
Float weight	15.6 g max.
Vacuum-kick adjust	0.350 in. (8.89 mm)
Unloader adjust	0.350 in. (8.89 mm)
Preliminary idle-mixture setting	2 turns
Choke setting	See procedure

HOLLEY CARBURETOR TORQUE SPECIFICATIONS	
Fastener Location	**lb-ft (N•m)**
Carburetor to manifold	20 (27)
Fuel line to carburetor	18 (24)
Fuel-inlet-filter nut	Securely

TOOLS OBTAINED LOCALLY
Test tachometer

SPECIAL TOOLS	
Kent-Moore Number	**Name**
J9789-D	Universal carburetor gauge
BT8128B	Float gram scale

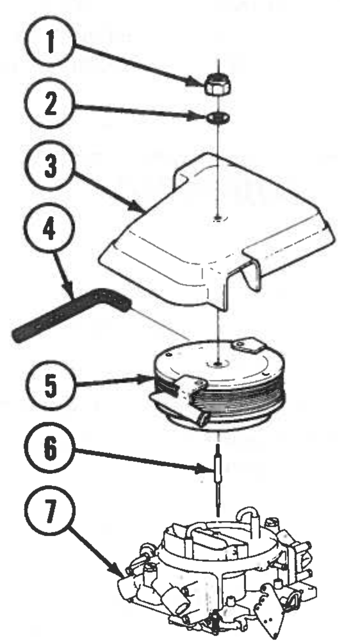
FLAME ARRESTOR

WARNING

Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

Refer to Figure 7-73.

1. Remove (in the following order):
   a. nut.
   b. washer.
   c. carburetor cover.
   d. crankcase-ventilation hoses – from flame arrestor and rocker-arm covers.
   e. flame arrestor – lift from carburetor.



1. Nut
2. Washer
3. Flame-arrestor cover
4. Crankcase breather hoses
5. Flame arrestor
6. Stud
7. Carburetor

Figure 7-73. Flame Arrestor Assembly

2. Clean and inspect:
   a. Clean flame arrestor with solvent and blow dry using compressed air.
   b. Clean crankcase-ventilation hoses.
   c. Inspect crankcase-ventilation hose for cracks or deterioration. Replace if necessary.

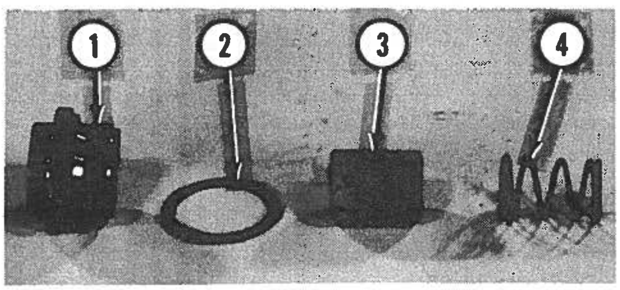
3. Install (in the following order):
    a. flame arrestor on carburetor.
    b. crankcase-ventilation hoses to flame arrestor and rocker-arm covers.
    c. carburetor cover.
    d. washer.
    e. nut – tighten securely. Do not overtighten.

FUEL FILTER ON CARBURETOR

WARNING

Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

Carburetor-inlet filters are located in float chamber assemblies behind fuel-inlet fittings.



1. Fuel-filter nut
2. Filter-nut gasket
3. Filter
4. Spring

Figure 7-74. *Fuel Inlet Filter*

To replace filters, proceed as follows:

1. Remove fuel line from fuel-inlet-filter nuts.
2. Remove fuel-inlet-filter nut, gasket, filter and spring from each float chamber assembly. (Discard gasket and filter.)
3. Clean nuts and springs in solvent and dry with compressed air.
4. Install spring, new filter (with open end outward), gasket and fuel-inlet-filter nut into each float chamber assembly (in that order). Tighten nut securely.
5. Reconnect fuel line and tighten securely.
6. Run engine and check for gasoline leaks.

AUTOMATIC CHOKE

The choke does not require any periodic maintenance; however, if a choke malfunction is suspected, do the following:

1. With engine off, remove flame arrestor.
2. Open and close choke several times. Check for binding, loose or disconnected linkages, or other signs of damage.
3. If choke or linkage binds, sticks or works sluggishly, clean with carburetor choke cleaner. Carefully follow directions on can.

HOLLEY CARBURETOR REMOVAL

IMPORTANT: Carburetor malfunctions are, in many cases, caused by the presence of dirt, water, or other foreign matter in carburetor. To aid in diagnosis, carefully remove carburetor from engine without draining fuel from bowl. Contents of fuel bowl may then be inspected for contamination as carburetor is disassembled.

1. Remove crankcase-ventilation hoses from flame arrestor; then remove flame arrestor.
2. Turn fuel supply off at fuel tank.
3. Disconnect throttle cable from carburetor.
4. Remove fuel lines.
5. Remove fuel-pump sight tube.
6. Disconnect choke linkage.
7. Remove carburetor-attaching nuts and washers, and remove carburetor.

IMPORTANT: Place a clean cloth over intake manifold opening to prevent dirt or foreign material from entering manifold.

8. Remove and discard gaskets.

HOLLEY CARBURETOR DISASSEMBLY

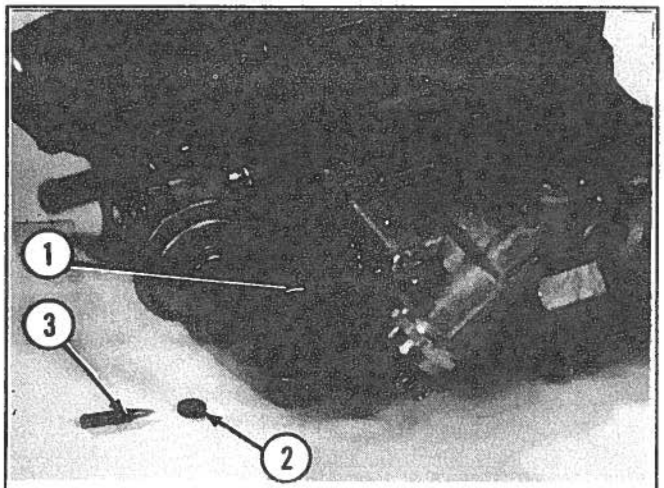
The following is a step-by-step procedure for completely overhauling carburetor after it has been removed from the engine. In many cases, however, complete overhaul is not necessary. In these cases, only the steps required to repair the carburetor malfunction should be performed. Read the instructions carefully to avoid doing any unnecessary steps.

IMPORTANT: Before performing any service on carburetor, it is essential that carburetor be placed in a holding fixture to prevent possible damage to throttle valves.

Fuel Bowls and Metering Bodies:

IMPORTANT: As the rest of the carburetor is disassembled, all of the parts from the primary side of the carburetor should be kept separated from secondary side parts. This will ensure that all of the parts are installed properly upon reassembly.

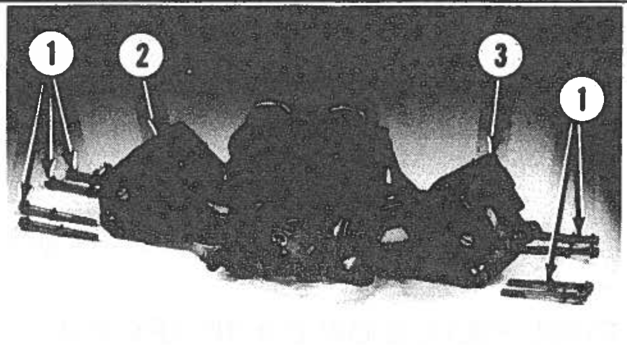
1. Remove fuel-inlet-filter nuts, gaskets, filters, and springs.
2. Remove idle-mixture screws and gaskets.



1. Idle-mixture chamber (only one shown)
2. Gasket
3. Idle-mixture screw

Figure 7-75. Removing Idle-Mixture Screws

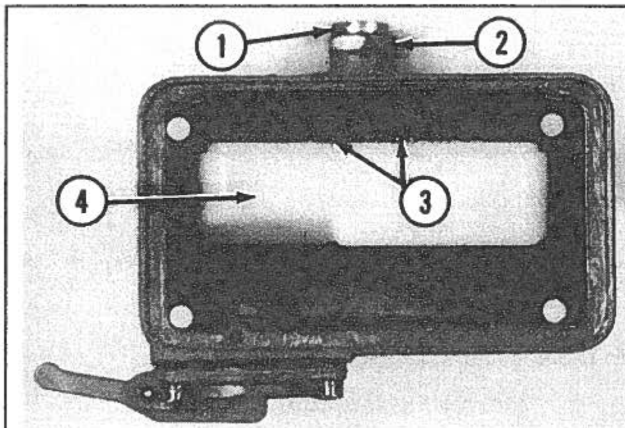
3. Remove primary and secondary fuel bowls.



1. Through-bolts
2. Primary fuel bowl
3. Secondary fuel bowl

Figure 7-76. Removing Fuel Bowls

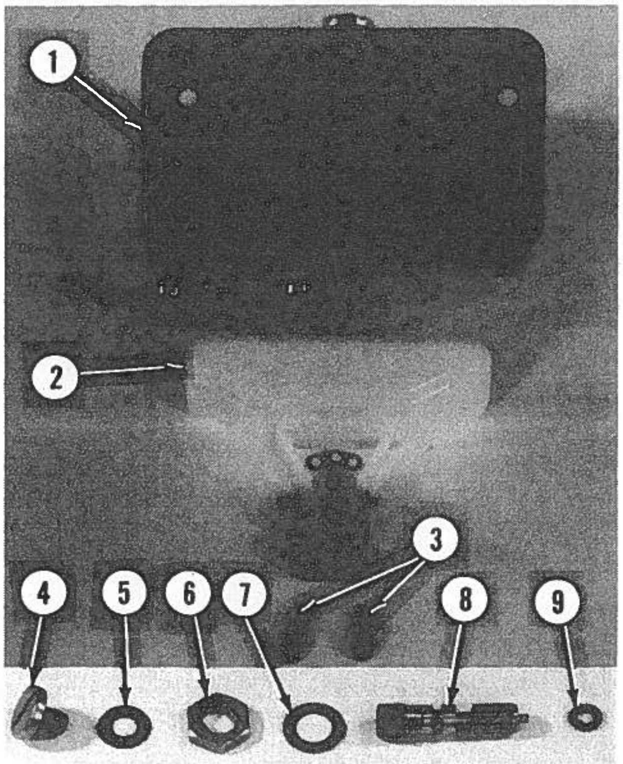
4. Remove needle seat and float assembly from fuel bowls.
   a. Loosen locking screw.
   b. Turn adjustment nut counterclockwise to remove needle-seat assembly.
   c. Remove float-retaining screws and remove float.



1. Locking screw
2. Adjustment nut
3. Float-retaining screws
4. Float

Figure 7-77. Removing Needle Seat And Float

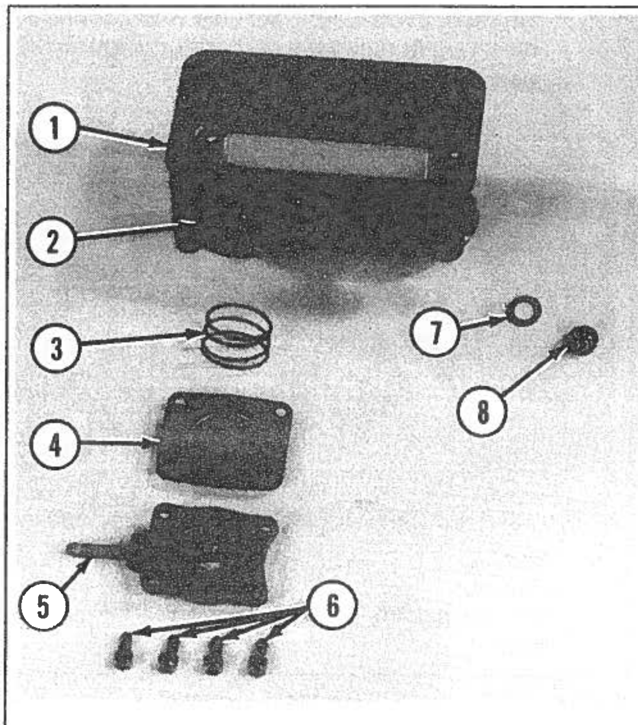
IMPORTANT: Needle seat and needle are factory-assembled and must be serviced as an assembly.



1. Fuel bowl
2. Float
3. Float-retaining screws
4. Locking screw
5. Gasket
6. Adjustment nut
7. Gasket
8. Needle and seat assembly
9. O-ring

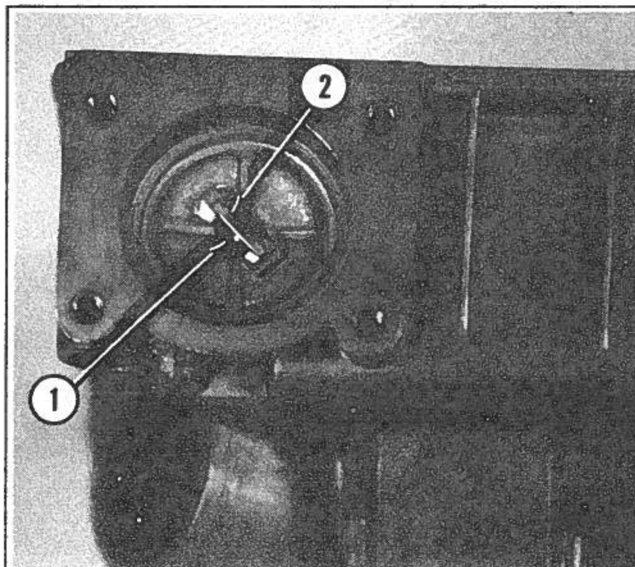
Figure 7-78. *Needle, Seat, And Float Assembly Removed*

5. Remove accelerator pump assembly, sight plug and gasket.
6. Accelerator-pump check balls are not removable. Check for clearance between ball and retainer. Check ball must be free to move.



1. Fuel bowl
2. Pump-check valve – NOT REMOVABLE
3. Pump-return spring
4. Pump diaphragm
5. Pump housing
6. Pump-housing-retaining screws
7. Gasket
8. Sight plug

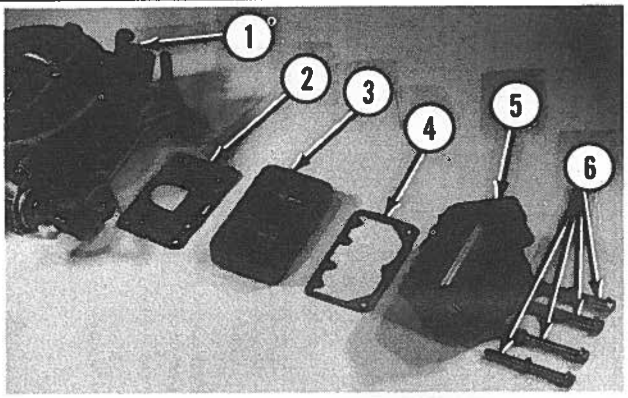
Figure 7-79. *Accelerator-Pump Removal*



1. Check ball
2. Retainer

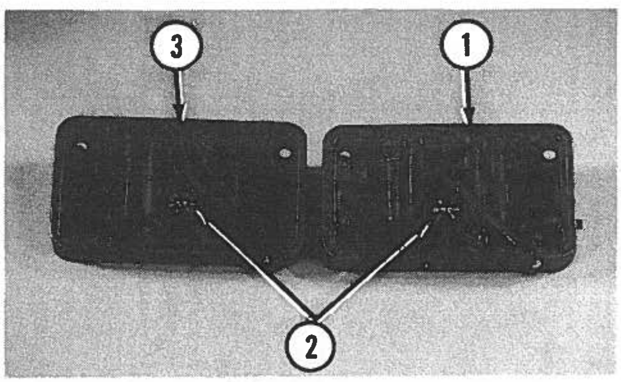
Figure 7-80. *Accelerator-Pump Check Ball*

7. Remove gaskets and primary and secondary metering bodies from carburetor (Figure 7-81 and 7-82).



1. Body
2. Gasket
3. Primary metering body
4. Gasket
5. Fuel bowl
6. Attaching bolts

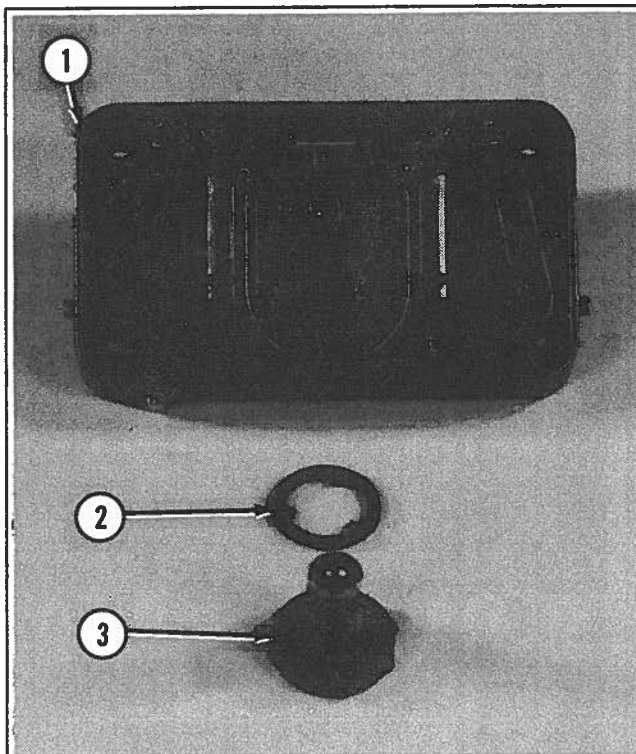
Figure 7-81. *Removing Metering Bodies*



1. Primary metering body
2. Power valves
3. Secondary metering body

Figure 7-82. *Metering Body Identification*

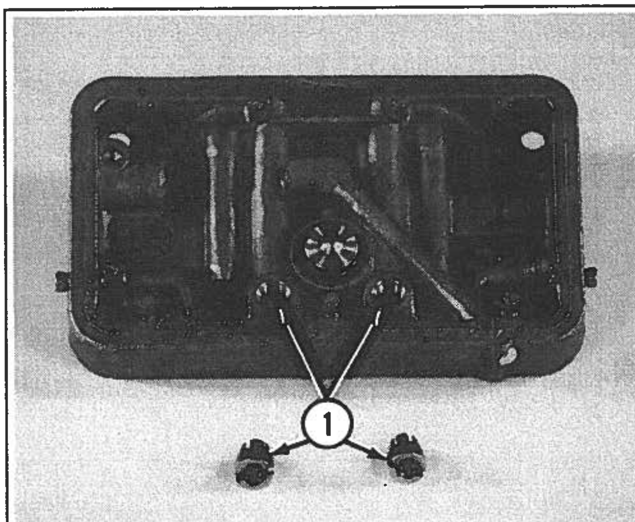
8. Remove power valve from primary metering body. Power valve cannot be serviced separately. If defective, it must be replaced.



1. Primary metering body
2. Gasket
3. Power valve

Figure 7-83. *Power Valve Removal*

9. Remove main fuel jets from primary and secondary metering bodies.

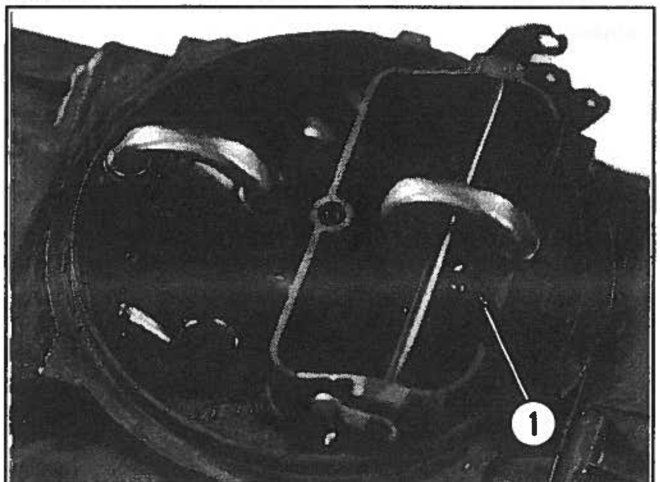


1. Main fuel jets

Figure 7-84. *Main Fuel Jets Removal*

Carburetor Body:

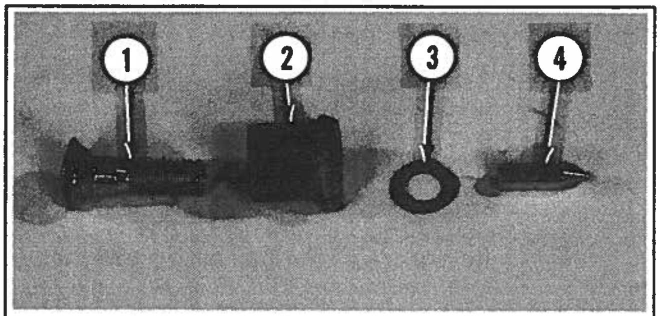
1. Remove two screws which hold accelerator-pump discharge needles in place.



1. Screw

Figure 7-85. Accelerator-Pump Discharge-Needle-Retaining Screws

2. Remove pump-discharge needles and components.



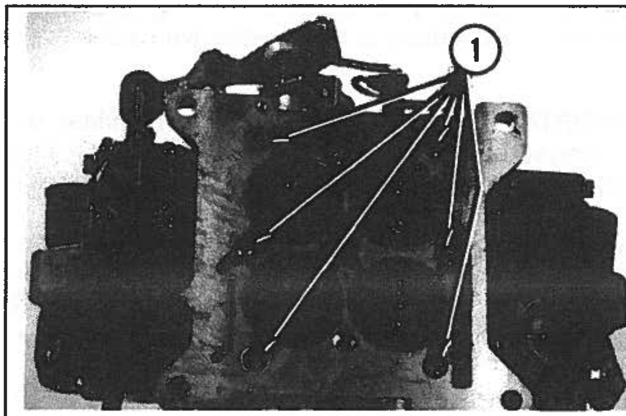
1. Screw	3. Gasket
2. Nozzle	4. Needle

Figure 7-86. Pump-Discharge Needle Removed

IMPORTANT: Choke valves should not be removed from carburetor body. If damaged, carburetor body should be replaced.

Throttle Body:

1. Remove six screws which hold throttle body to carburetor body.

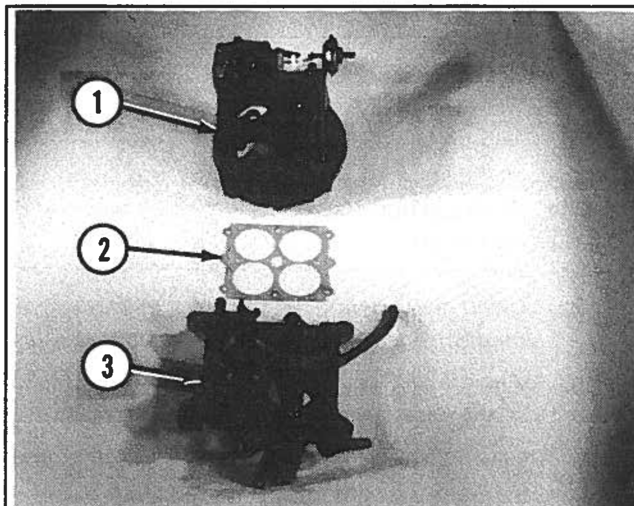


1. Screws

Figure 7-87. Removing Throttle Body

2. Remove carburetor body and gasket from throttle body.

IMPORTANT: Further disassembly of the throttle body is normally not required. Throttle valves should not be removed. If throttle valves are damaged, throttle body should be replaced.



1. Carburetor body	3. Throttle body
2. Gasket	

Figure 7-88. Throttle Body Removed From Carburetor Body

CLEANING AND INSPECTION

Carbon, varnish, gum, dirt, and water contaminants in the carburetor or on exterior moving parts of the carburetor often are responsible for carburetor malfunctions. Therefore, carefully observe the following cleaning and inspection procedure to obtain effective carburetor repair.

IMPORTANT: Do not use a wire or drill to clean jets, passages, or tubes in carburetor as this may enlarge orifices and seriously affect carburetor calibration.

IMPORTANT: Do not clean float-bowl-gasket surfaces with a gasket scraper or knife as sealing bead will be damaged and component replacement will be necessary.

IMPORTANT: All gaskets, O-rings and seals should be replaced during carburetor repair.

1. Thoroughly clean all metal parts in a commercial carburetor cleaner until all deposits have been removed. Follow the cleaner manufacturer's instructions for the proper cleaning and rinsing procedure. Dry the parts with compressed air.

CAUTION

Do not leave carburetor in carburetor cleaner for more than two hours.

CAUTION

Any plastic, rubber, or neoprene parts should not be immersed in carburetor cleaner as they will swell, harden, or distort.

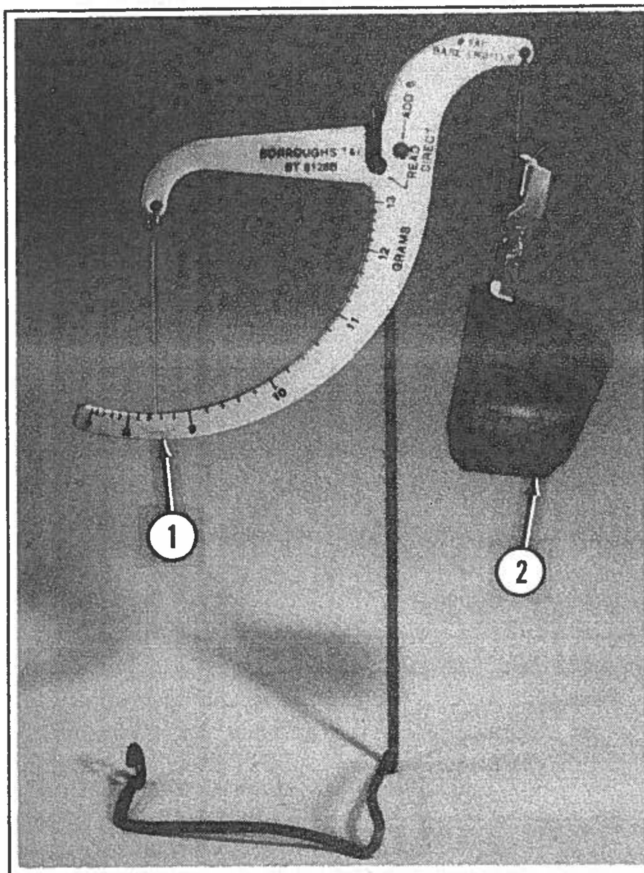
2. Using compressed air, blow out all passages in carburetor to remove any foreign material.
3. Wipe off all parts that cannot be cleaned in carburetor cleaner with a clean, dry cloth.
4. Carefully inspect all carburetor parts for wear and damage; pay particular attention to the following:

a. Float needle and seat: If either is worn or damaged, replace with a new needle and seat assembly.

IMPORTANT: Float needle and seat are factory-assembled. Needle and seat cannot be serviced separately.

b. Float assembly and hinge pin: Inspect float pontoon for deterioration and porosity. Check pontoon density (to see if it is saturated with fuel) by comparing weight of float with specifications. If pontoon weight is high, float assembly **must be** replaced. Shake float. If float contains fuel inside, float is leaking and must be replaced. Check hinge pin and holes for wear.
c. Fuel and air passages: Passages **must be** perfectly clean for proper carburetor operation.
d. Accelerator pump diaphragm and return spring: Inspect pump diaphragm, check ball, discharge needles and return spring for proper operation.
e. Power-piston spring: Check power-piston spring for weakness or distortion.
f. Idle-mixture needles: Inspect and, if damaged, needles **must be** replaced.
g. Levers and linkages: Check levers, links and rods for wear.
h. Throttle valve and shaft: Check throttle shaft for excessive looseness in throttle body. Check throttle valve and shaft for binding through entire operating range, making sure valve opens and closes completely. Throttle body assembly **must be** replaced if throttle valve and shaft are worn or damaged.
i. Choke valve, shaft, and lever assembly: Check shaft and lever assembly for excessive looseness in air horn assembly. Check choke valve and shaft and lever assembly for binding through entire operating range, making sure valve opens and closes completely. Carburetor body assembly **must be** replaced if choke valve and shaft and lever assembly are worn or damaged.

j. Inspect casting for visible damage. Inspect gasket surfaces.



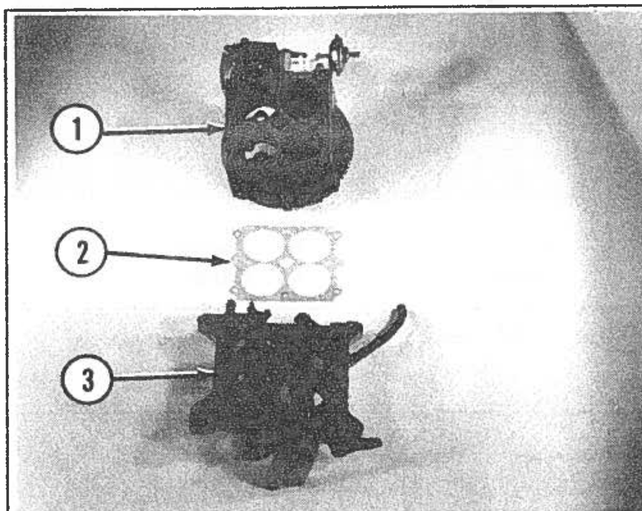
1. Float scale
2. Float

Figure 7-89. *Checking Float Weight*

HOLLEY CARBURETOR REASSEMBLY

Throttle Body:

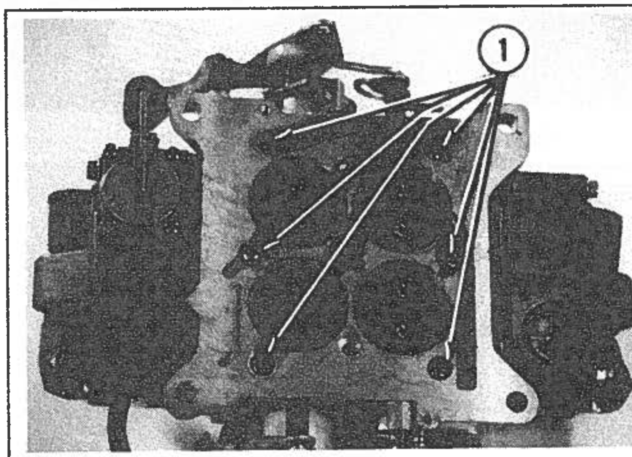
1. Using new gasket, assemble throttle body to carburetor body, taking care to line up gasket and carburetor body with throttle-body locating pins.



1. Carburetor
2. Gasket
3. Throttle body

Figure 7-90. *Installing Throttle Body*

2. Install throttle-body attaching screws and tighten evenly and securely.

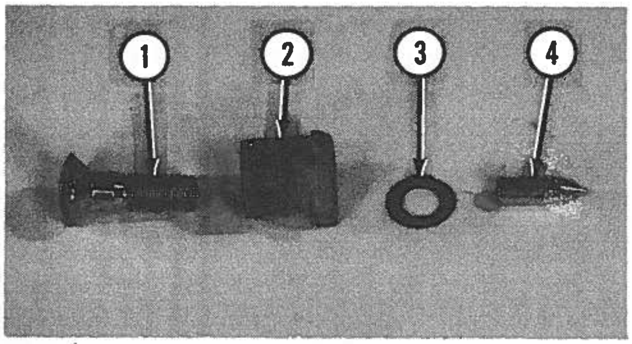


1. Screws

Figure 7-91. *Installing Attaching Screws*

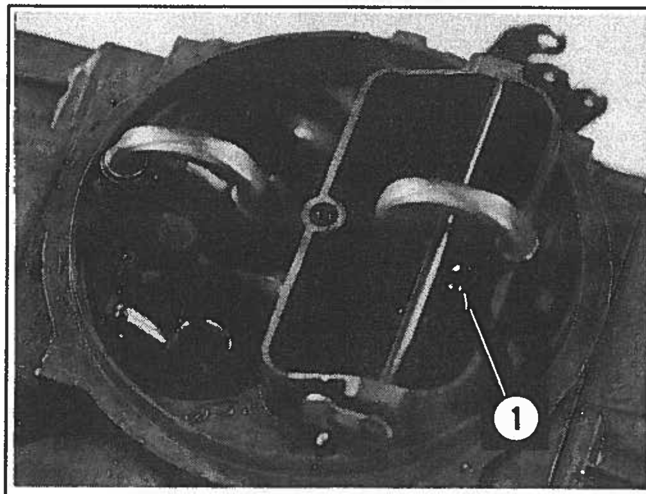
Carburetor Body:

1. Install pump-discharge needles into carburetor body in order shown. Tighten screws securely.



1. Screw
2. Nozzle
3. Gasket
4. Needle

Figure 7-92. Installing Pump-Discharge Needle

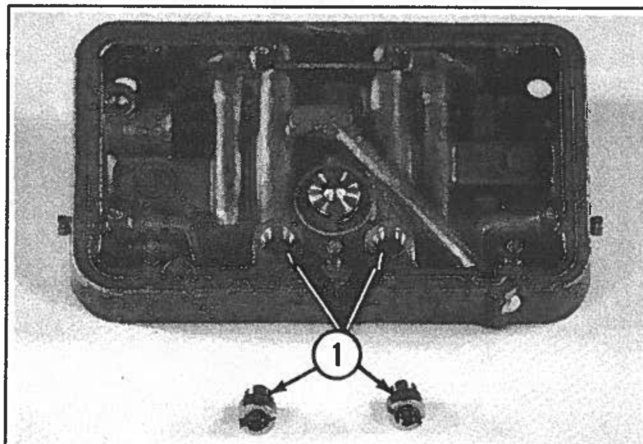


1. Pump-discharge-needle-retaining screw

Figure 7-93. Install Retaining Screw

Fuel Bowls and Metering Bodies:

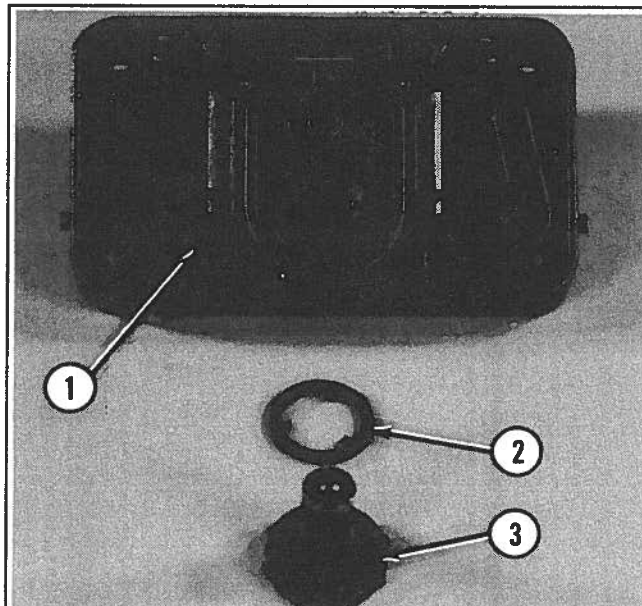
1. Install fuel-bowl vent tubes into metering bodies. Vent tube must be pushed in far enough to lock into locating pin.
2. Install primary and secondary main-fuel jets.



1. Main fuel jets

Figure 7-94. Installing Main Jets

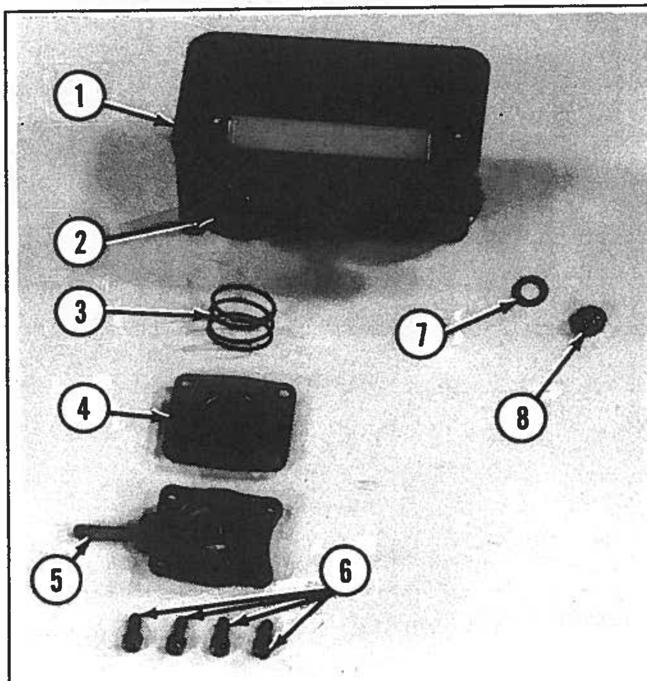
3. Install power valve and new gasket in primary metering body.



1. Primary metering body
2. Gasket
3. Power valve

Figure 7-95. Installing Power Valve

4. Install accelerator pump assembly as shown.

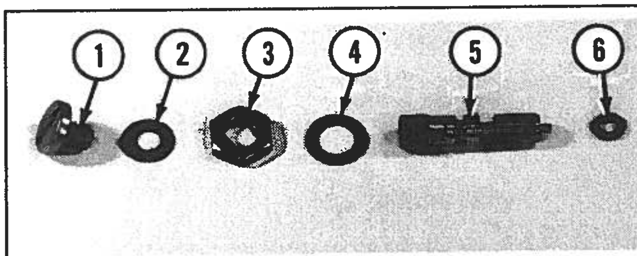


1. Fuel bowl
2. Pump-check valve – NOT REMOVABLE
3. Spring
4. Pump diaphragm
5. Pump housing
6. Retaining screws
7. Gasket
8. Sight plug

Figure 7-96. *Installing Accelerator Pump*

5. Install sight plug and gasket. Tighten screws securely.

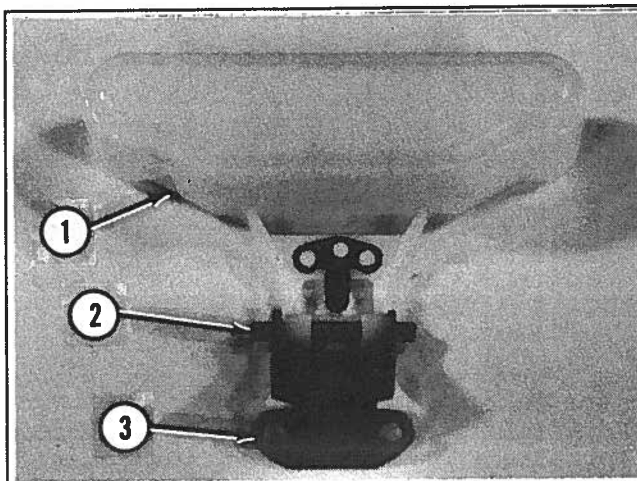
6. Assembly needle and seat as shown.



1. Locking screw
2. Gasket
3. Adjusting nut
4. Gasket
5. Needle and seat assembly
6. O-ring

Figure 7-97. *Needle And Seat Assembly*

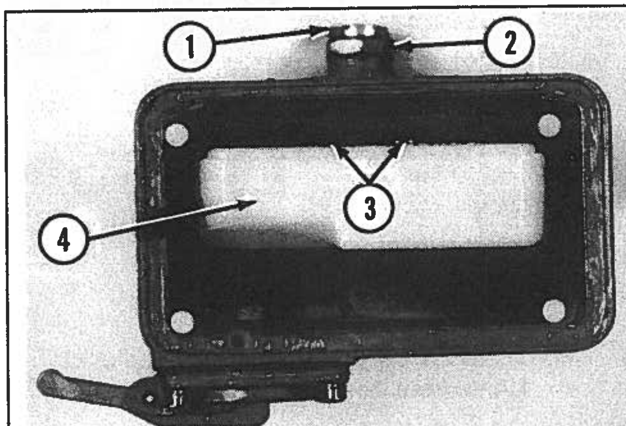
7. Assemble float, spring, hinge, and hinge pin as shown.



1. Float
2. Hinge pin
3. Hinge

Figure 7-98. *Assembling Float*

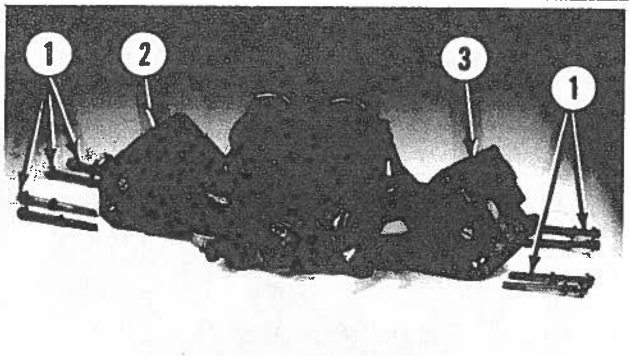
8. Install float and float-retaining screws. Tighten screws securely. Install needle seat assembly. Adjust float to specifications. See "Adjustments" in this Section.



1. Locking screw
2. Adjustment nut
3. Float-retaining screws
4. Float

Figure 7-99. *Installing Float And Needle Seat*

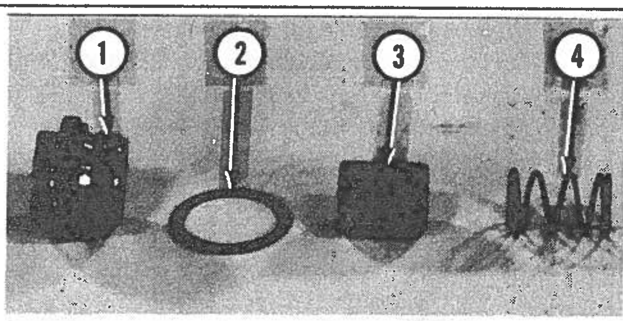
9. Install fuel bowls and metering bolt with through-bolts as shown. Tighten screws securely.



1. Through-bolts
2. Primary fuel bowl
3. Secondary fuel bowl

Figure 7-100. *Installing Fuel Bowls*

10. Install fuel-inlet-filter components, fuel-inlet gasket, and nut as shown. Tighten nut securely.

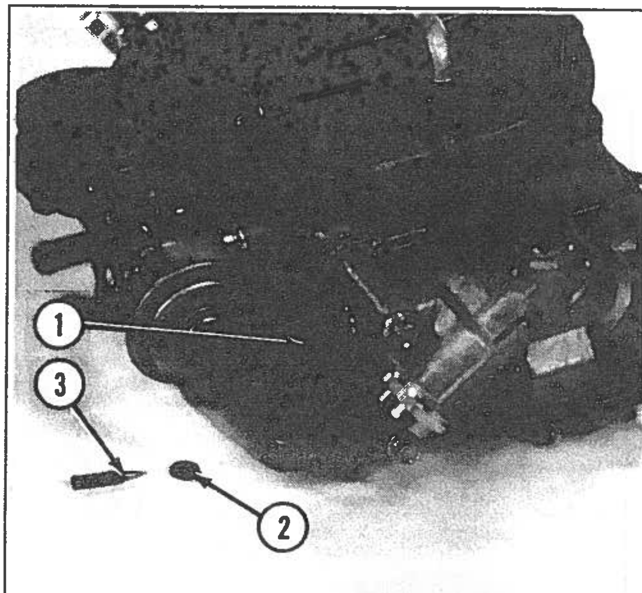


1. Fuel-filter nut
2. Filter-nut gasket
3. Filter (open end towards nut)
4. Spring

Figure 7-101. *Installing Filter And Inlet Nut*

11. Install idle-mixture screws and gaskets. Lightly seat needle, then back out two turns.

IMPORTANT: Do not tighten idle-mixture needles against seats; damage to needle and/or seat may result.



1. Idle-mixture hole (only one shown)
2. Gasket
3. Needle

Figure 7-102. *Installing Idle-Mixture Screws*

HOLLEY CARBURETOR INSTALLATION

1. Thoroughly clean gasket surfaces. Use care to prevent gasket material from entering intake manifold.
2. Place new carburetor-base gasket on intake manifold. Install carburetor and secure with nuts and washers. Torque to specifications.
3. Connect fuel lines to fuel-inlet nuts and torque to specifications.
4. Connect fuel-pump sight tube.
5. Connect choke.
6. Move throttle lever back and forth, and check for binding in throttle linkage.
7. Install throttle cable.
8. Install flame arrestor and crankcase-ventilation hoses.
9. Reconnect battery cables to battery.
10. Start engine and check for gasoline leaks. If leaks exist, **STOP ENGINE IMMEDIATELY** and recheck connections.
11. Adjust idle speed and idle mixture as outlined under “Holley Carburetor Adjustments.”

HOLLEY CARBURETOR ADJUSTMENTS

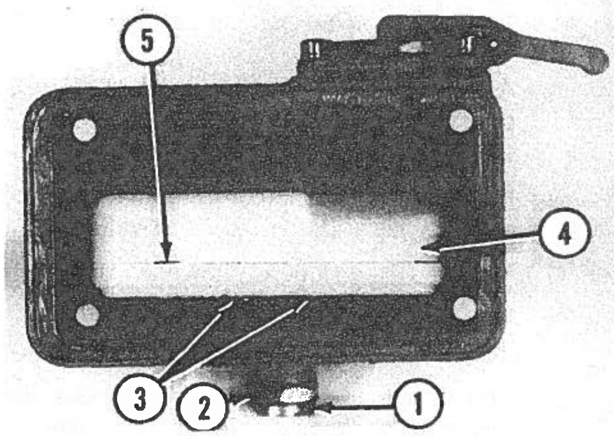
WARNING

Refer to Cautions and Warnings under Section 7.1, General Information, **before** proceeding.

Preliminary Float Adjustment:

IMPORTANT: The preliminary float adjustment will provide a sufficient setting for starting the engine. Final float adjustments must be made with engine running.

1. Invert float bowl as shown.



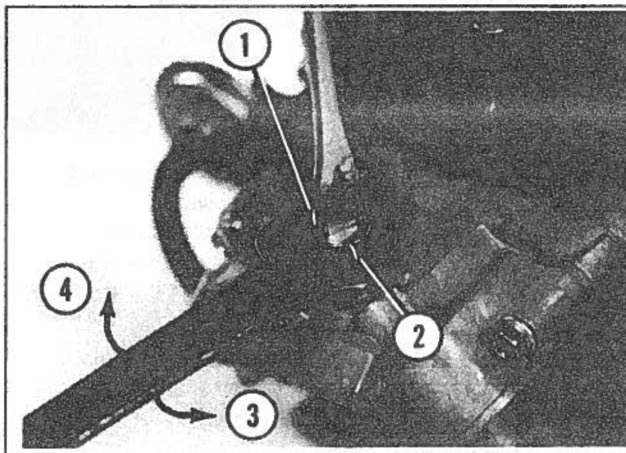
1. Locking screw
2. Adjustment nut
3. Float-retaining screws
4. Float
5. Float-parting line

Figure 7-103. *Adjusting Float Level*

2. Loosen locking screw and turn float adjustment nut to adjust float.
3. Proper float adjustment is achieved when parting line on float is parallel with fuel bowl (Figure 7-103). Parting line must be parallel all the way around float.
4. Repeat this procedure for both floats.

Final Float Adjustment:

1. With carburetor mounted on engine, start engine and let it run for several minutes.
2. While engine is running, remove sight plug on primary fuel bowl.
3. Loosen locking screw and turn adjustment nut slowly until fuel can be seen to be level with the bottom of the sight-plug hole.



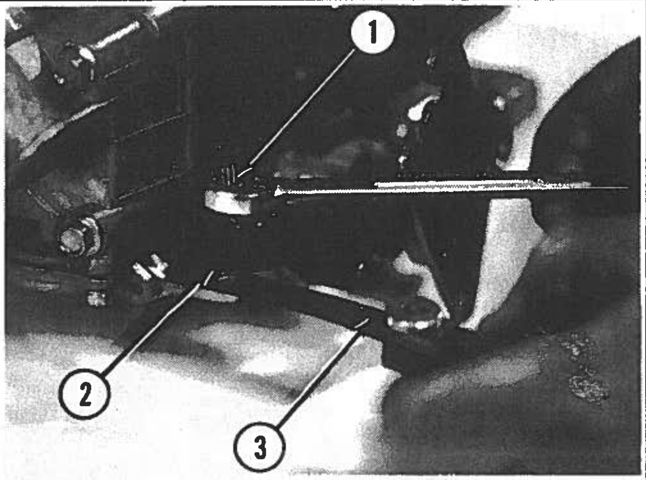
1. Adjustment nut
2. Locking screw
3. Lowers fuel level
4. Raises fuel level

Figure 7-104. *Final Float Adjustment*

4. Tighten locking screw securely, being careful not to let adjustment nut turn.
5. Reinstall sight plug and gasket.
6. Repeat this procedure for secondary side of carburetor.

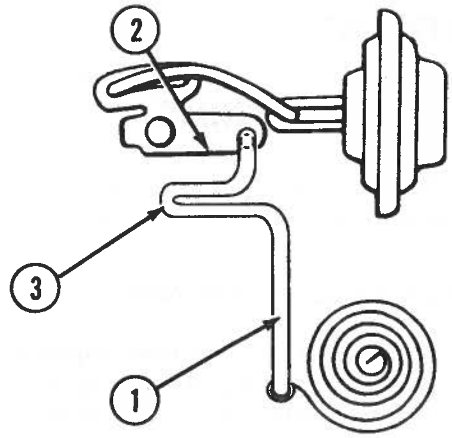
Accelerator Pump:

1. With engine shut off, move throttle arm to wide-open throttle (W.O.T.) position.
2. While holding throttle arm in W.O.T. position, push down on primary accelerator-pump lever.



1. Adjustment screw and nut
2. Pump lever (push down)
3. Feeler gauge

Figure 7-105. *Primary Accelerator-Pump Adjustment*



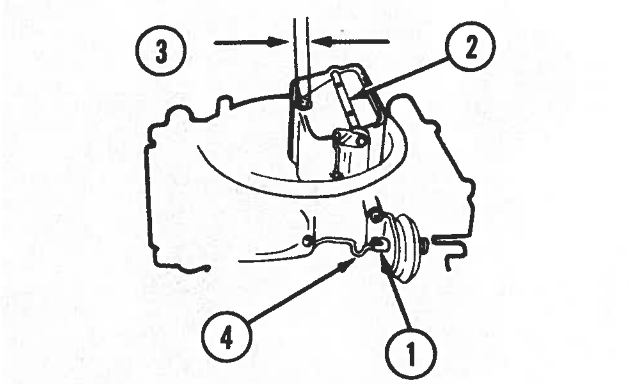
1. Rod
2. Choke lever
3. To adjust, bend rod here

Figure 7-106. *Choke Rod Adjustment*

3. With a feeler gauge, check for clearance between adjustment screw and accelerator-pump lever. Adjust screw and nut to specifications (1/64 in. [0.4 mm]).

Choke Adjustment:

1. Pull rod up.
2. Choke lever is now in closed choke position.
3. To adjust, bend rod here.
4. Apply a light closing pressure on choke plate, depressing diaphragm and stem to limit of its travel.
5. Measure the distance between the lower edge of the choke plate and air horn wall.
6. To adjust, bend link as shown (Figure 7-107).
7. With the choke rod properly adjusted, the throttle plates are in a wide-open position.
8. Apply a light closing pressure on choke plate. Measure the distance between the lower edge of the choke plate and air horn wall.
9. To adjust, bend throttle-lever unloader tang.



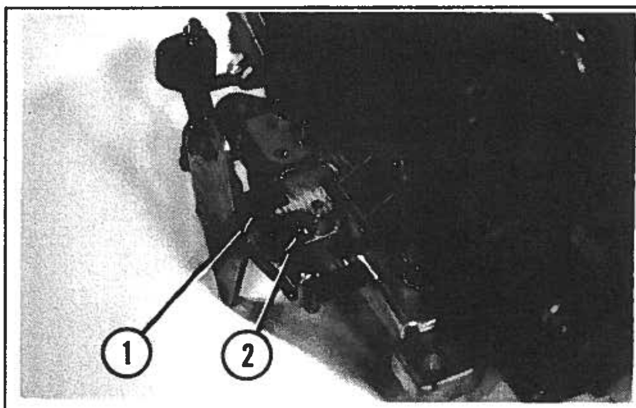
1. Diaphragm stem
2. Choke plate
3. Distance horn wall to lower choke-plate edge
4. To adjust, bend link here

Figure 7-107. *Vacuum Kick Adjustment*

Preliminary Idle Speed and Mixture:

IMPORTANT: The following adjustments will provide a sufficient setting to start engine. Final adjustments must be made with engine running.

1. Turn idle-speed screw in until it just contacts idle cam, then turn screw in one additional turn.

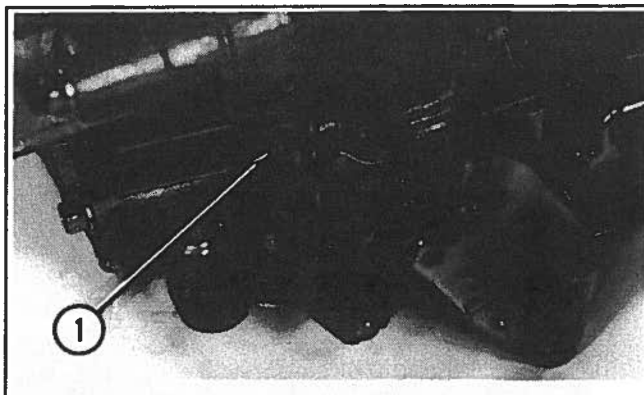


1. Idle cam
2. Idle-speed screw

Figure 7-108. *Idle-Speed Screw*

IMPORTANT: Do not turn idle-mixture screw tightly against seat (in the following step) as damage to seat and/or needle may result.

2. Turn idle-mixture screw in until it **lightly seats**; then back out two turns.



1. Idle-mixture screw

Figure 7-109. *Idle-Mixture Screw*

Final Idle Speed and Mixture:

IMPORTANT: Boat must be in the water and engine at normal operating temperature to accurately check and adjust idle speed and mixture.

IMPORTANT: Do not attempt to compensate for other engine problems (incorrect ignition timing, faulty ignition components, low compression, vacuum leaks, etc) with carburetor adjustments. This will only mask the problem, which must be corrected if engine is to achieve maximum fuel economy and performance.

Carburetor should be set so that engine idles smoothly with boat in the water, engine at normal operating temperature, and transmission in forward gear. To adjust idle speed and mixture, proceed as follows:

1. Connect a shop tachometer to engine.

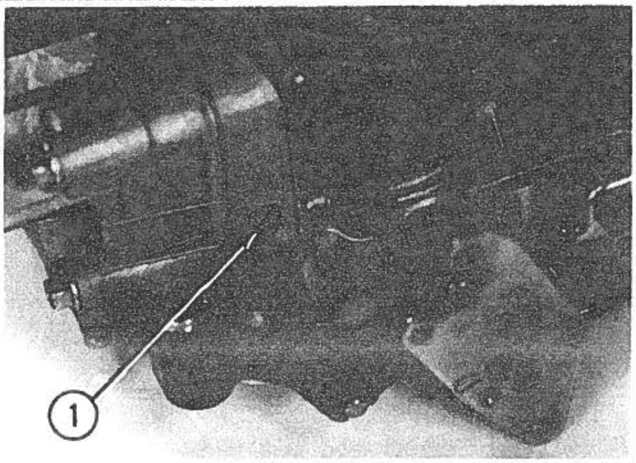
IMPORTANT: Do not turn idle-mixture screw tightly into seat (in next step) as damage to needle and/or seat may result.

2. If a new or rebuilt carburetor has been installed, turn idle-mixture screw in (clockwise) until it **lightly** contacts seat; then, back out needle two turns. This will provide a sufficient setting to allow starting engine.
3. Start engine and run at 1500 rpm until engine reaches normal operating temperature.

⚠ WARNING

Do not leave the helm unoccupied while performing the following idle speed and mixture adjustments. Be careful not to accidentally accelerate engine while performing adjustments.

4. With boat in water, place remote control in forward gear, idle position.



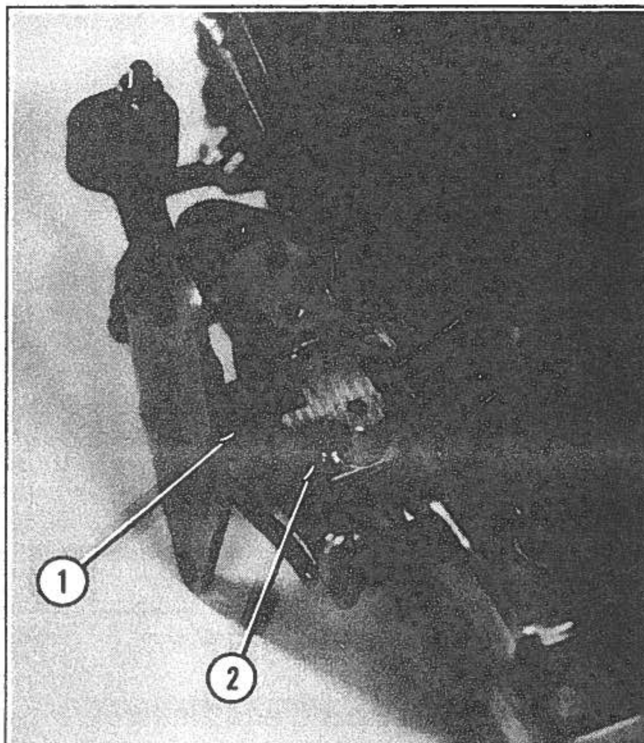
1. Idle-mixture screw

Figure 7-110. Mixture Adjustment

5. Disconnect throttle cable from anchor clip.

IMPORTANT: Refer to Section 2.4, Control Cables, for throttle cable installation and adjustment procedures.

6. Adjust idle-speed-adjustment screw to obtain specified rpm.
7. With engine running at specified rpm, adjust mixture needle as follows:
   a. Turn idle-mixture needle inward (clockwise) until the engine speed begins to drop due to **lean** mixture.
   b. Turn idle-mixture screw outward (counterclockwise) until the speed begins to drop due to rich mixture.
   c. Turn idle-mixture needle inward to a point between these two extremes to obtain maximum engine rpm and smoothness.
   d. Repeat procedure with other needle.
   e. Readjust idle-speed-adjusting screw, if necessary, to obtain specified rpm.



1. Idle cam 2. Idle-speed screw

Figure 7-111. Idle-Speed Adjustment

8. Reattach throttle cable.

7.5 HOLLEY 4-BARREL CARBURETOR 4010 SERIES

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** working on the fuel system to prevent fire or explosion.

WARNING

Be careful when changing fuel system components; gasoline is extremely flammable and highly explosive under certain conditions. Be sure that ignition key is OFF. **Do not** smoke or allow sources of spark and/or flame in the area while changing fuel system components. Wipe up any spilled fuel immediately.

WARNING

Fuel system components on your Crusader Engine are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement fuel system components which do not comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

To prevent the possibility of a **FIRE**, be sure that engine compartment is well ventilated and that there are no gasoline vapors present.

WARNING

Make sure no fuel leaks exist before closing engine hatch.

CAUTION

Do not operate engine without cooling water being supplied to water pickup; water pump impeller will be damaged and subsequent overheating damage to the engine may result.

HOLLEY CARBURETOR TORQUE SPECIFICATIONS	
Fastener Location	**lb-ft (N•m)**
Carburetor to manifold	20 (27)
Fuel line to carburetor	18 (24)
Fuel-inlet-filter nut	Securely

TOOLS OBTAINED LOCALLY
Test tachometer

SPECIAL TOOLS	
Kent-Moore Number	**Name**
J9789-D	Universal carburetor gauge

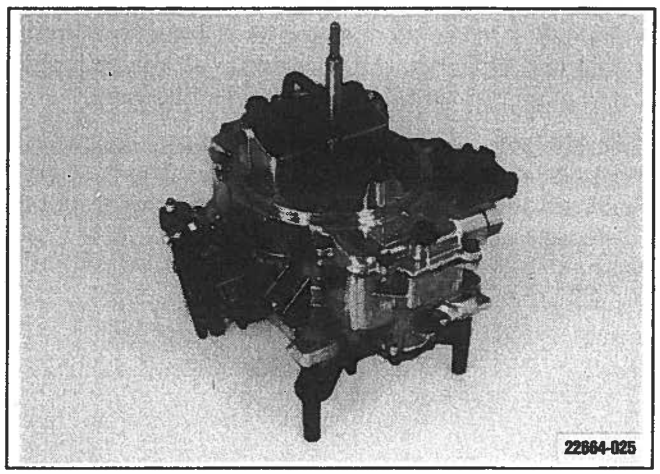


Figure 7-112. Carburetor

HOLLEY OVERHAUL PROCEDURES FOR 4010 SERIES CARBURETORS

Description:

The Holley 4010 series carburetor are used on Crusader 502 CID engines. The design of these carburetors is the essence of simplicity. The main body and throttle body are combined into one aluminum casting containing the fuel bowls, venturis, throttle bores and mounting surfaces for the booster-venturi clusters. The air horn acts as a cover for the float bowls. Fuel inlets, needle and seal assemblies, and the float mounting are also included in the air horn.

Fuel levels are externally adjustable for greater convenience. The primary and secondary float bowls have their own fuel inlets.

Annular-discharge boost venturis provide a stronger metering signal at lower airflows and better prepare the mixture for combustion. Cylinder-to-cylinder distribution is also improved.

The carburetor has three basic functions: First, it controls fuel/air input which controls engine power output. Second, it mixes the fuel and air in the correct proportions to satisfy engine requirements. Thirdly, it vaporizes and atomizes the fuel to prepare it for burning.

For the carburetor to perform properly, the following fuel circuits must operate as designed. The fuel circuits utilized are the idle, main, power, and accelerator-pump circuits.

Idle Circuit:

The idle-fuel flow is induced by intake-manifold vacuum and controlled by the idle-mixture screws. Fuel is drawn up the idle tube where it meets air from the first idle-air bleed. This mixture is then metered by the idle-feed restrictor. More air is added by the second idle-air bleed. When the throttle plates are opened, they expose the idle-transfer holes which increases fuel flow through the idle circuit.

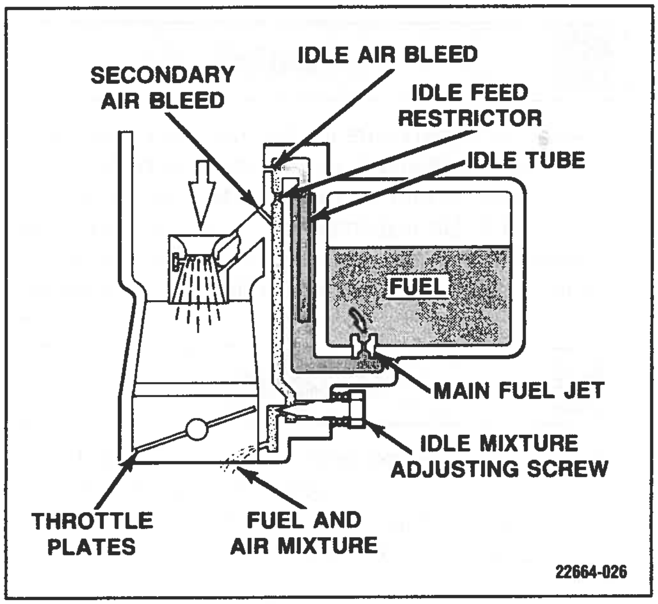


Figure 7-113. *Idle Circuit*

Accelerator-Pump Circuit:

When the throttle is opened suddenly, the rush of air into the intake causes the manifold vacuum to drop quickly. The accelerator pump adds a small amount of fuel under pressure to eliminate engine lag or hesitation during the transition of fuel flow to the main fuel circuit.

Movement of the throttle lever moves the intermediate lever which in turn activates the accelerator pump lever. This movement compresses the accelerator pump diaphragm. This closes the inlet check valve and opens the outlet discharge-check valve. Fuel is then forced into the airstream through the pump discharge restrictors. When the throttle closes, the diaphragm-return spring forces the accelerator-pump diaphragm down and fuel is drawn into the chamber through the inlet check valve. The outlet check valve is closed during this process so air is not drawn in. The pump is not charged.

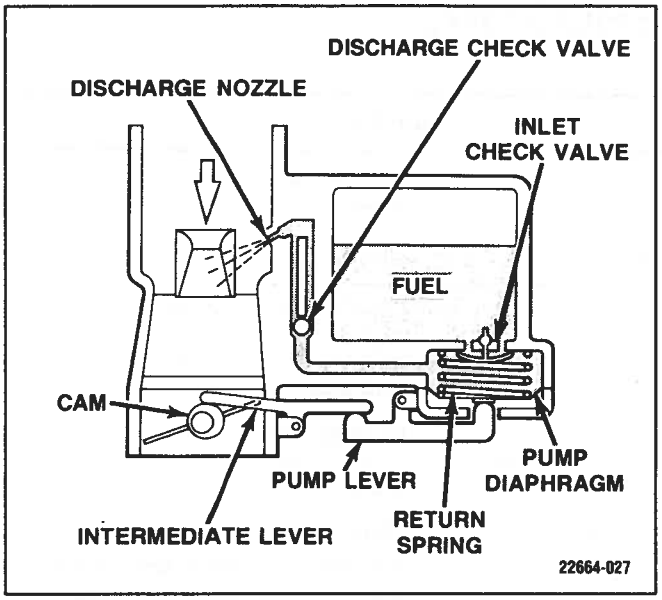


Figure 7-114. Accelerator-Pump Circuit

Main Fuel Circuit:

For normal cruising speeds, the fuel/air mixture is controlled by the main fuel circuit. Fuel enters the main circuit through the main jets. It then moves up the emulsion tubes and joins air from the main air bleeds. The fuel/air combination continues to the boost venturis where it joins the incoming air. Low pressure in the boost venturi creates a pressure drop necessary to induce fuel flow. Flow of the incoming air is controlled by the throttle-valve opening.

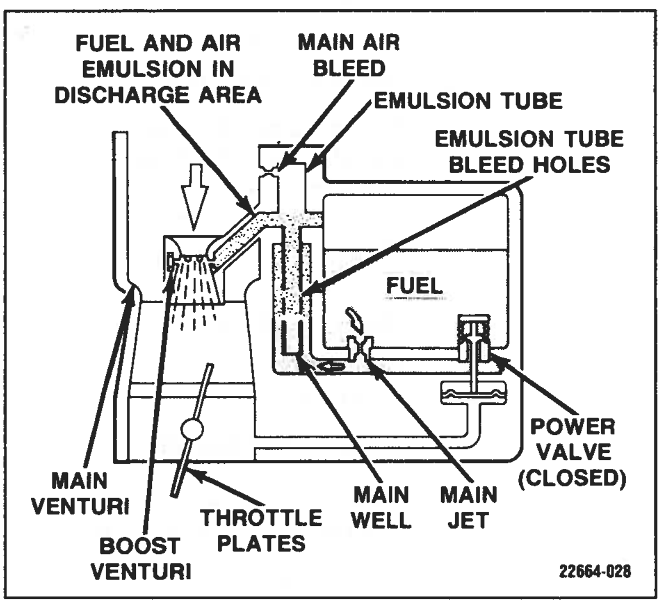


Figure 7-115. Main Fuel Circuit

Power Circuit:

When engine load increases at higher rpm levels and during hard acceleration, intake-manifold-vacuum drops. At a predetermined intake manifold vacuum setting, the power-valve spring will open the power valve. Fuel then enters the main circuit and is metered by the power-valve-channel restrictor. This fuel is supplemental to the fuel supplied by the main jets and enriches the fuel/air mixture. The power valve is a gate valve that permits fuel flow. The power-valve-channel restrictor determines the amount of extra fuel added when the power valve opens.

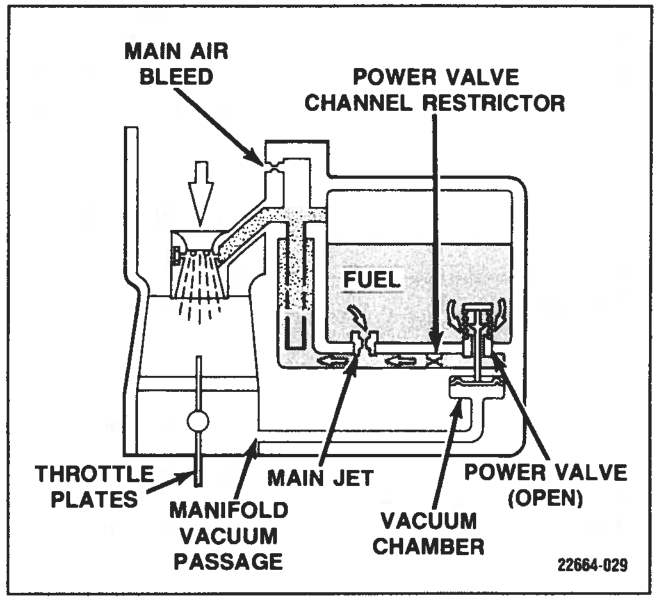


Figure 7-116. Power-Valve Circuit

TROUBLESHOOTING

Problem	Probable Cause	Solution
Hard Starting – Cold	1. Choke sticking 2. Electric choke not working	– Check choke linkage for binding. – Check 12-volt power supply.
Hard Starting – Hot	1. Improper float adjustment 2. Flooding 3. Vapor lock	– Check float adjustments. – Check for dirt in inlet needle and seat. – Change fuel brands.
Loss of Power	1. Dirty flame arrestor 2. Secondaries not opening 3. Water/dirt in fuel	– Clean. – Check throttle linkage for movement. Check secondary vacuum-diaphragm operation. – Clean carburetor and fuel system.
Rough Idle	1. Vacuum leak 2. Leaking power valve 3. Improper float adjustment 4. Improper idle mixture	– Check carburetor-base gaskets and MAP-sensor-vacuum hose. – Replace power valve. – Check and adjust float level. – Adjust idle-mixture screws.
Stalling	1. Idle speed too low 2. Improper idle mixture 3. Improper float adjustment 4. Leaking power valve 5. Vacuum leak	– Raise idle speed to specifications. – Adjust idle-mixture screws. – Check and adjust float level. – Replace power valve. – Check carburetor, intake manifold, and MAP-sensor-vacuum hose.
Hesitation on Acceleration	1. Clogged accelerator-pump passage 2. Accelerator-pump linkage adjustments off 3. Improper float level 4. Accelerator-pump diaphragm damaged	– Clean carburetor. – Set to specifications. – Check and adjust float level. – Replace pump diaphragm.
Missing at Sustained Speed or Load	1. Improper fuel level 2. Insufficient fuel 3. Contaminated fuel 4. Spark plugs	– Check and adjust float level. – Check fuel filters. – Check fuel for water/dirt. Clean fuel system. – Replace spark plugs.

CARBURETOR SPECIFICATIONS

Engine Model:	C502
Crusader Part Number:	46090
Holley Identification Number:	84028
Size (CFM):	750
Inlet Seat – Primary (in.):	0.110"
Inlet Seat – Secondary (in.):	0.110"
Primary Main Jet:	86
Secondary Main Jet:	90
Power Valve – Primary (in.):	6.5
Power Valve – Secondary (in.):	6.5
Primary-Pump Shooter (in.):	0.035"
Diaphragm-Spring Color:	Red
Primary Bore:	1.686
Secondary Bore:	1.686
Accelerator-Pump Cam:	Pink – 330

CARBURETOR MAINTENANCE

WARNING

Refer to Cautions and Warnings, under Section 7.1, General Information, **before** proceeding.

Flame Arrestor:

1. Remove in the following order:
   a. Nut.
   b. Washer.
   c. Carburetor cover.
   d. Crankcase-ventilation hoses – from flame arrestor and rocker-arm covers.
   e. Flame arrestor – lift from carburetor.
2. Clean and inspect:
   a. Clean flame arrestor with solvent and blow dry with compressed air.
   b. Clean crankcase-ventilation hoses.
   c. Inspect crankcase-ventilation hoses for cracks or deterioration. Replace if necessary.
3. Install in the following order:
   a. Flame arrestor – place on carburetor.
   b. Crankcase-ventilation hoses to flame arrestor and rocker-arm covers.
   c. Carburetor cover.
   d. Washer.
   e. Nut – tighten securely. DO NOT overtighten.

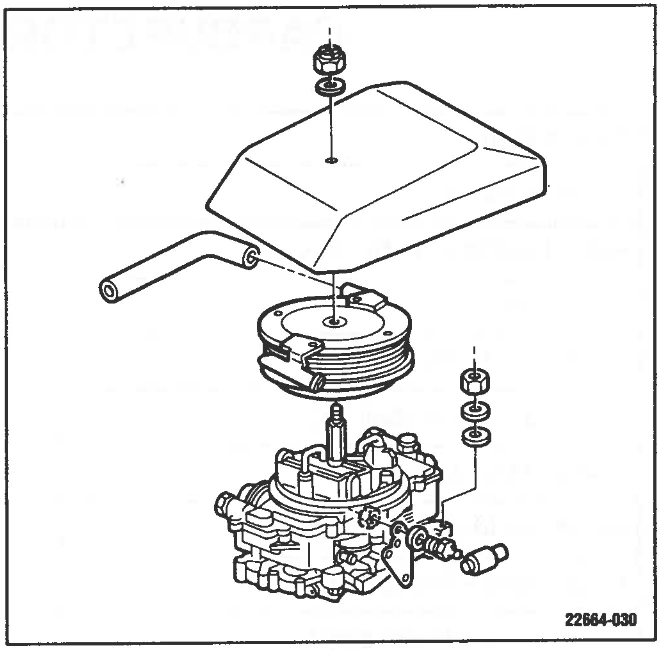


Figure 7-117. *Carburetor And Flame Arrestor Assembly*

Carburetor Fuel Filters:

WARNING

Refer to Cautions and Warnings, under Section 7.1, General Information, **before** proceeding.

Carburetor fuel-inlet filters are located in air horn assembly behind the fuel-inlet fittings. To replace or clean filters, proceed as follows:

1. Remove fuel line from fuel-inlet nuts.
2. Remove fuel-inlet nut, gasket, and filter from each float chamber. (Discard filter and gasket.)
3. Clean nuts with solvent and dry with compressed air.
4. Install new filter, with open end into fuel inlet nut, gasket and fuel-inlet nut into air horn assembly. Tighten nut securely.
5. Reconnect fuel line and tighten securely.
6. Run engine and check for gasoline leaks.

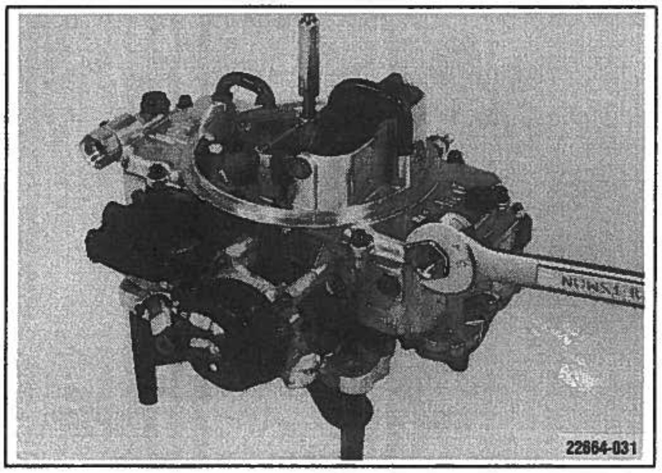


Figure 7-118. *Fuel Filter Assembly*

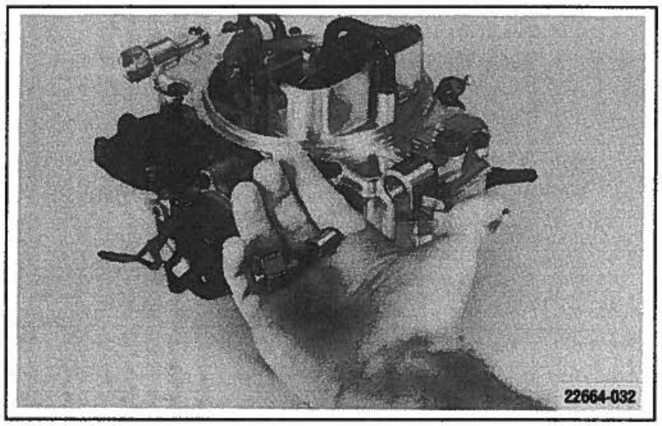


Figure 7-119. *Fuel Filter Assembly*

Choke Inspection:

The automatic choke does not require any periodic maintenance. If a choke malfunction is suspected, the following should be done:

1. With engine off, remove the flame arrestor.
2. Open and close the choke several times to check for binding, loose or disconnected linkages, or other signs of damage.
3. If choke or linkage binds, sticks or works sluggishly, clean with carburetor-choke cleaner. Carefully follow instructions on can.
4. Check power supply to electric choke. With key "ON," electrical connection should show 12 volts.

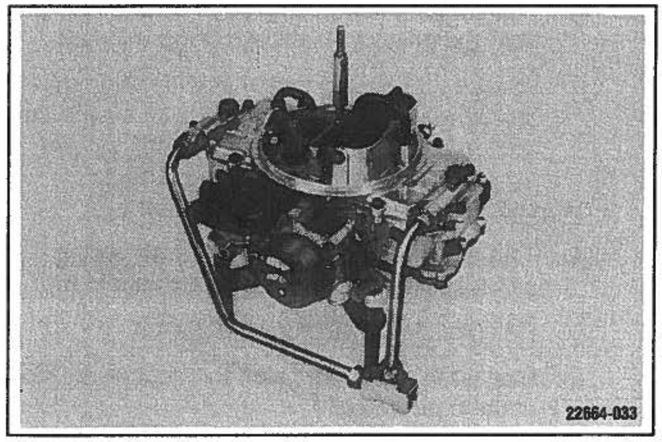


Figure 7-120. *Fuel Lines And Choke Assembly*

Carburetor Adjustments:

WARNING

Refer to Cautions and Warnings, under Section 7.1, General Information, **before** proceeding.

Preliminary Float Adjustment:

IMPORTANT: The preliminary float adjustment will provide a sufficient setting for starting the engine. Final adjustments must be made with the carburetor installed and engine running.

1. Invert carburetor air horn as shown (Figure 7-121).
2. Loosen locking screw and turn float-adjustment nut to adjust float level.
3. Adjust float level until floats are slightly up from a parallel position with the air horn as shown.

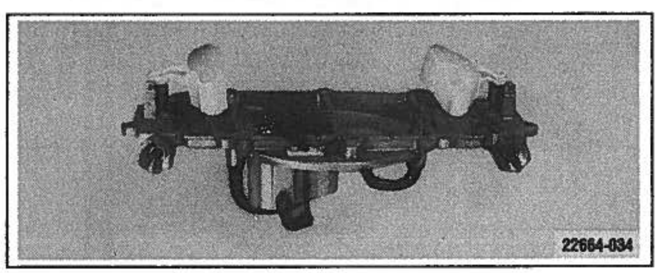


Figure 7-121. *Preliminary Float Adjustment*

Final Float Adjustment:

1. With carburetor mounted on the engine, start engine and allow to run several minutes.
2. While engine is running, remove the sight plug from the primary float bowl (Figure 7-122).
3. Loosen the locking screw slightly and turn adjusting nut slowly until fuel is level with the bottom of the sight hole. (Turn adjustment nut clockwise to lower the float and counterclockwise to raise the float.)
4. Tighten the locking screw securely, being careful not to allow the adjusting nut to turn.
5. Reinstall the sight plug and gasket.
6. Repeat this procedure on the secondary side of the carburetor.

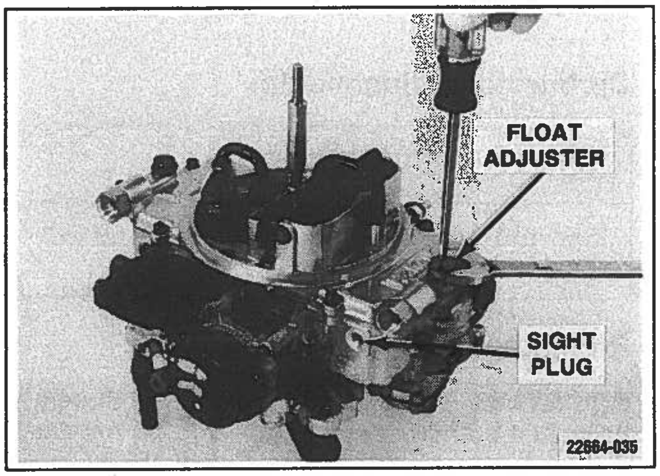


Figure 7-122. Final Float Adjustment

Accelerator-Pump Adjustment:

1. With engine shut off, move the throttle lever to wide-open throttle (W.O.T.) position.
2. While holding throttle arm in the W.O.T. position, push down on the primary accelerator-pump lever.
3. With a feeler gauge, check for clearance between adjustment screw and accelerator-pump lever. Adjust screw and nut to specifications (0.010 to 0.015 inch) (Figure 7-123).

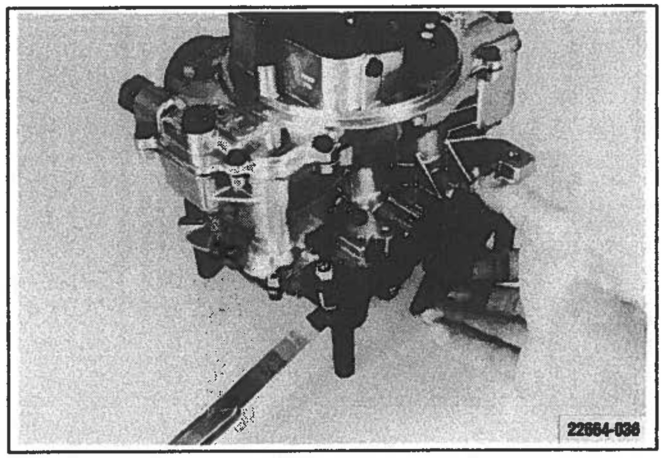


Figure 7-123. Pump-Adjustment Procedure

Choke Adjustment:

1. Normal choke setting is such that the scribed mark on the choke housing is lined up with the last mark to the right (clockwise) on the choke housing.
2. If choke adjustment is necessary, loosen the three (3) choke-cover-retaining screws and adjust as necessary.
3. Tighten choke-cover-retaining screws securely.

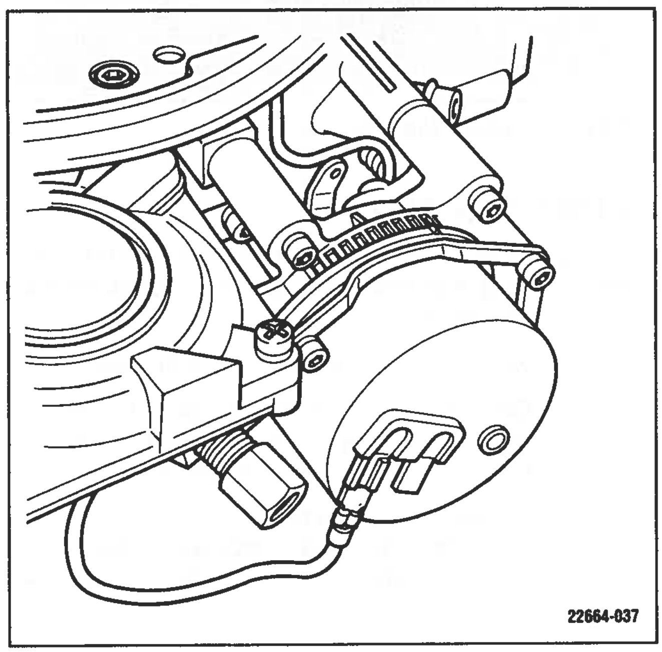


Figure 7-124. Choke Assembly

Preliminary Idle Speed and Mixture:

IMPORTANT: The preliminary float adjustment will provide a sufficient setting for starting the engine. Final adjustments must be made with the carburetor installed and engine running.

1. Turn the idle-speed screw in until it just contacts the idle cam, then turn screw in one additional turn.

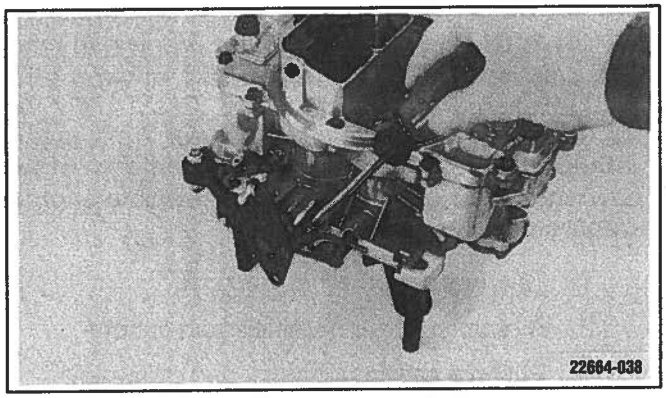


Figure 7-125. *Idle-Speed Screw Location*

IMPORTANT: DO NOT turn the idle mixture screws tightly against seat (in the next step) as damage to seat and/or mixture screw may result.

2. Turn idle-mixture screws in until they LIGHTLY SEAT; then back out (2) turns.

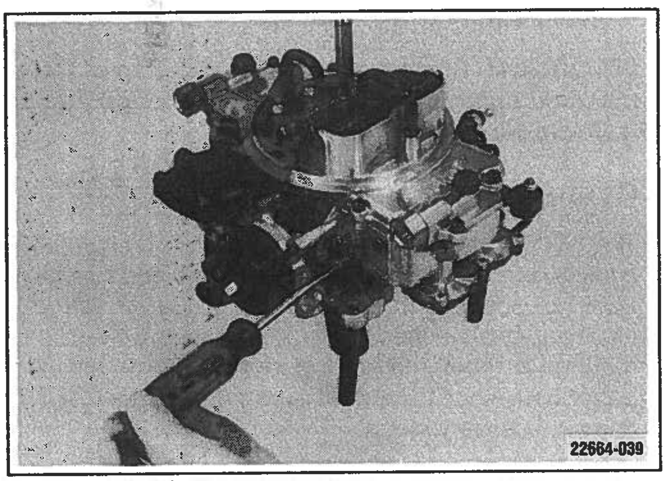


Figure 7-126. *Idle-Mixture Screw Location*

Final Idle Speed and Mixture Adjustments:

IMPORTANT: Boat must be in the water and engine at normal operating temperature to accurately check and adjust idle speed and mixture.

IMPORTANT: DO NOT attempt to compensate for other engine problems (incorrect ignition timing, faulty ignition components, low compression, vacuum leaks, etc.) with carburetor adjustments. This will only mask the problem, which must be corrected if engine is to achieve maximum fuel economy and performance.

Carburetor should be set so the engine idles smoothly with the boat in the water, engine at normal operating temperature, and transmission in forward gear. To adjust idle speed and mixture, proceed as follows:

1. Connect a shop tachometer to the engine.

IMPORTANT: DO NOT turn the idle-mixture screws tightly against seat (in the next step) as damage to seat and/or mixture screw may result.

2. If a new or rebuilt carburetor has been installed, turn idle mixture screw in (clockwise) until it LIGHTLY contacts the seat; then, back out screw two turns. This will allow a sufficient setting to start the engine.
3. Start engine and run at 1500 rpm until engine reaches normal operating temperature.

> **⚠ WARNING**
>
> Do not leave the helm unoccupied while performing the following idle speed and mixture adjustments. Be careful not to accidentally accelerate engine while performing adjustments.

4. With boat in open water, place remote control in forward gear, idle position.
5. Disconnect throttle cable from anchor clip.

IMPORTANT: Refer to Section 2.2, Engine Installation, for throttle cable installation and adjustment procedures.

6. Adjust idle-speed adjustment screw to obtain specified idle rpm.
7. With engine running at specified rpm, adjust idle-mixture screws as follows:
   a. Turn idle-mixture screw inward (clockwise) until engine speed begins to drop due to **lean** mixture.
   b. Turn idle-mixture screw outward (counterclockwise) until engine speed begins to drop due to **rich** mixture.

c. Turn idle-mixture screw inward to a point between these two extremes to obtain maximum engine rpm and smoothness.
d. Repeat procedure with other mixture screw.

8. Readjust idle-speed-adjustment screw, if necessary, to obtain the specified idle rpm.

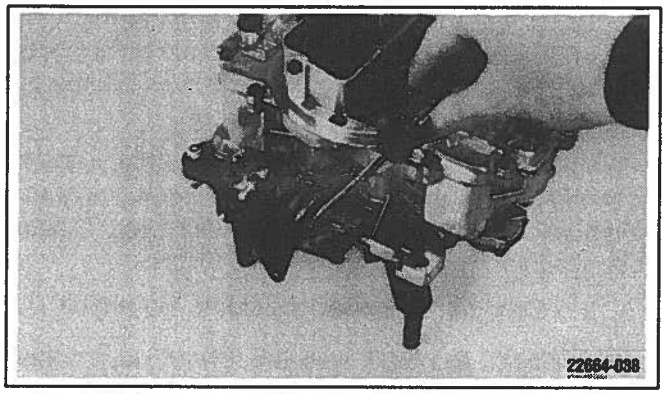


Figure 7-127. *Idle-Speed Screw Location*

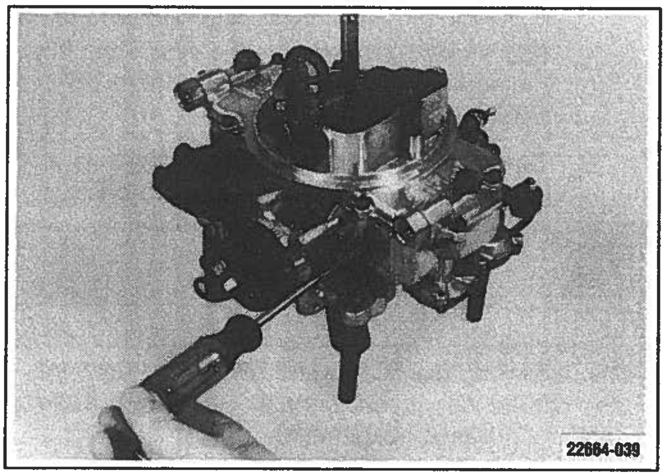


Figure 7-128. *Idle-Mixture Screw Location*

CARBURETOR OVERHAUL PROCEDURES

WARNING

Refer to Cautions and Warnings, under Section 7.1, General Information, **before** proceeding.

Carburetor Removal:

IMPORTANT: Carburetor malfunctions are, in many cases, caused by the presence of dirt, water, or other foreign material in the carburetor. To aid in diagnosis, carefully remove the carburetor from engine without draining fuel from bowl. Contents of fuel bowl may then be inspected for contamination as carburetor is disassembled.

1. Turn fuel supply off at fuel tank.
2. Disconnect battery cables from battery.
3. Remove carburetor cover and crankcase-ventilation hoses from flame arrestor, then remove flame arrestor.
4. Disconnect throttle cable from carburetor.
5. Remove fuel lines.
6. Disconnect choke-power lead.
7. Remove carburetor-attaching nuts and washers; remove carburetor.
8. Remove discard gaskets.

IMPORTANT: Place a clean cloth in bores of intake-manifold opening to prevent dirt or foreign material from entering intake manifold.

Carburetor Disassembly:

The following is a step-by-step procedure for completely overhauling the carburetor after it has been removed from the engine. In many cases, however, complete overhaul is not necessary. In these cases, only the steps required to repair the carburetor malfunction should be performed. Read the instructions carefully to avoid doing any unnecessary steps.

IMPORTANT: Before performing any service on carburetor, it is essential that carburetor be placed in a holding fixture to prevent possible damage to throttle valves.

1. Remove two (2) fuel-inlet fittings, gaskets, and filters.

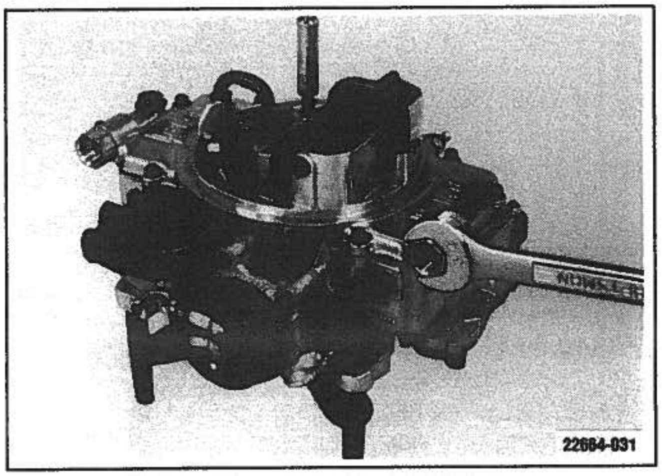


Figure 7-129. *Fuel Filter Removal*

2. Remove flame arrestor mounting stud.

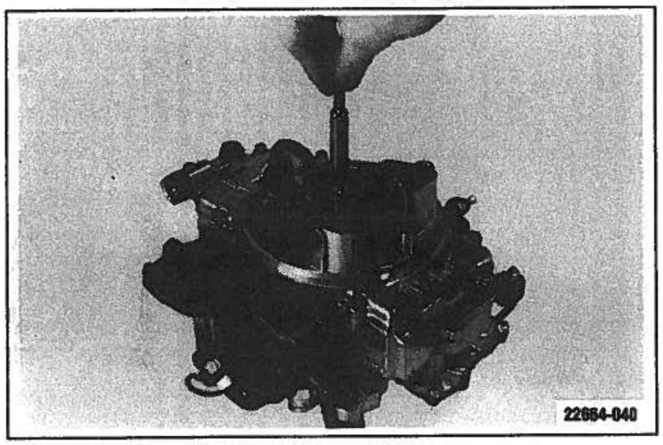


Figure 7-130. *Flame-Arrestor-Mounting Stud*

3. Remove screws that attach air horn to main body.

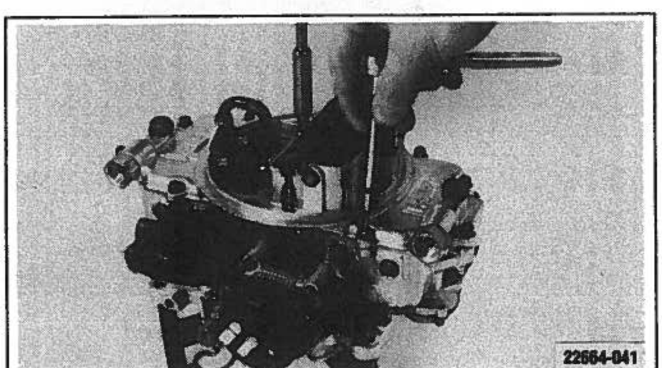


Figure 7-131. *Air-Horn-Attaching Screws*

4. Remove wire clip or C-clip from choke link.

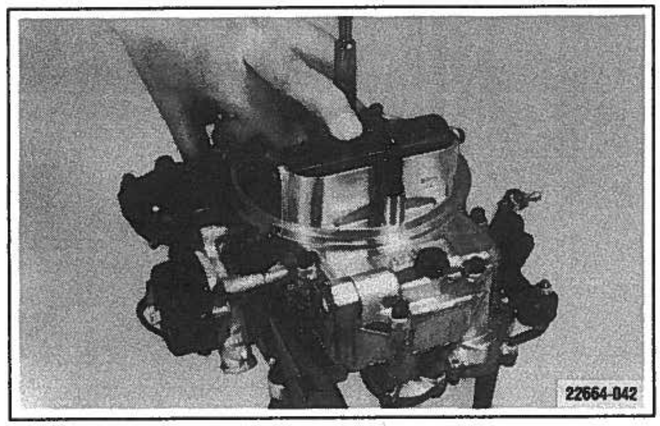


Figure 7-132. *Choke Link*

5. Carefully remove air-horn assembly from main body.

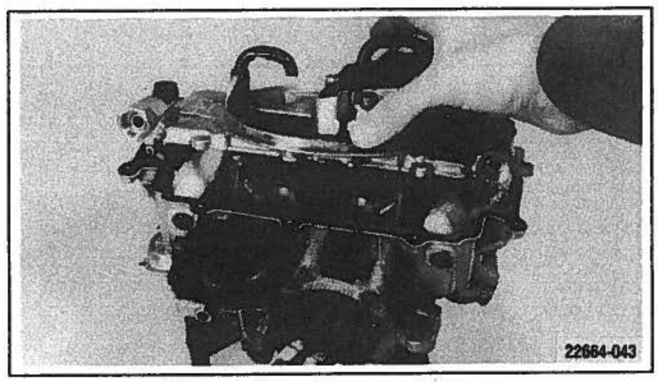


Figure 7-133. *Air-Horn-Assembly Removal*

6. Remove idle-mixture screws.

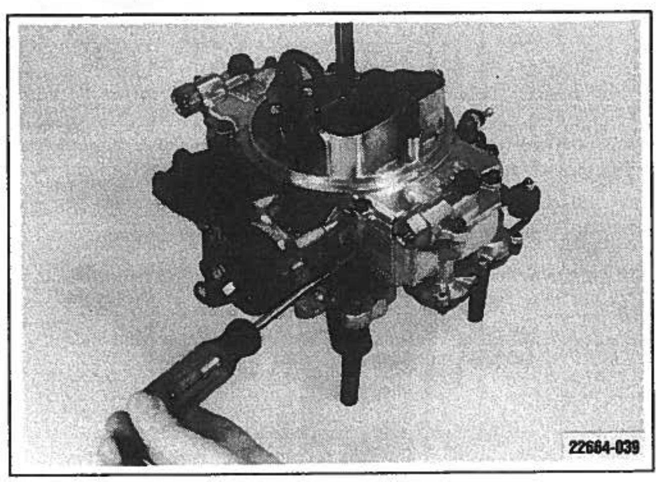


Figure 7-134. *Idle-Mixture Screw Location*

7. Remove float-hinge pins from primary and secondary floats.

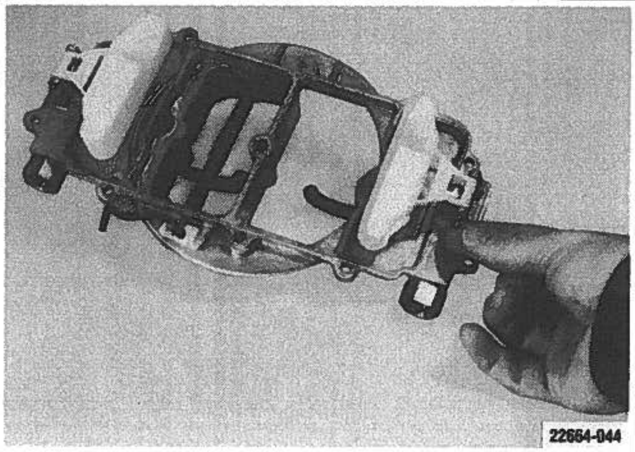


Figure 7-135. Float-Hinge Pins

8. Remove lock screws and adjusting nuts, then turn needle and seat assembly counterclockwise to remove from air horn.

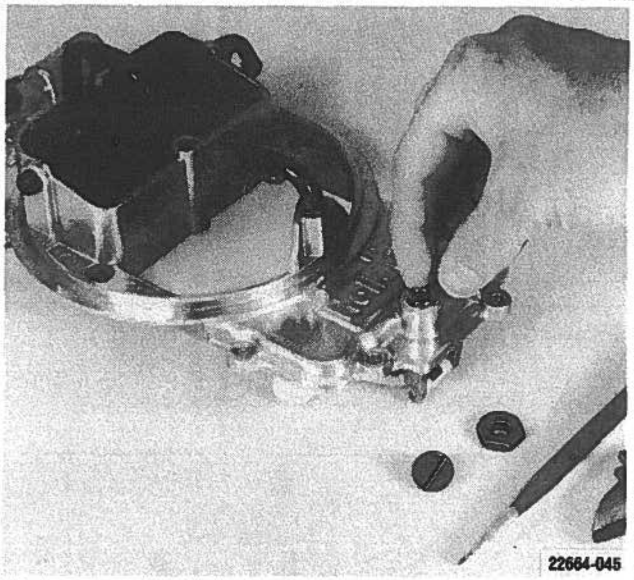


Figure 7-136. Needle And Seat Removal

9. Remove single-screw-retaining primary and secondary clusters. Primary cluster is retained with hollow screw. Keep parts segregated. (Do not lose spring ball under primary cluster screw.)

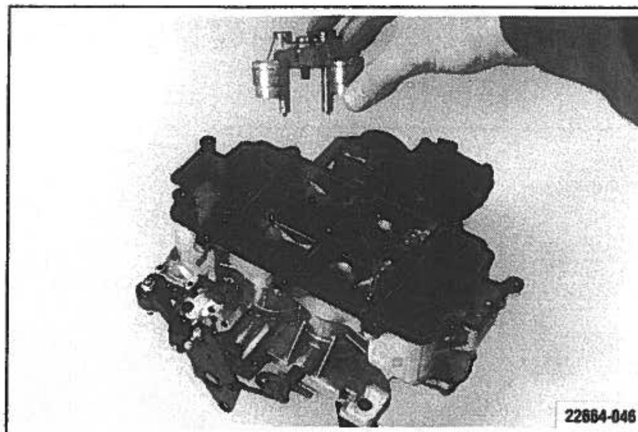


Figure 7-137. Screw Removal

10. Remove main jets from bowls. Use screwdriver wide enough to span slot in jet. Keep primary and secondary jets separated.

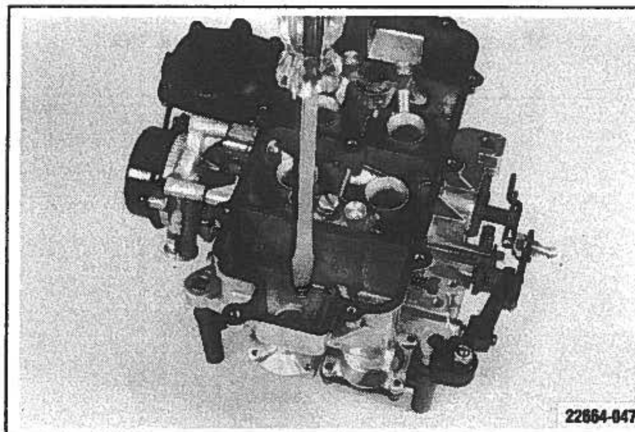


Figure 7-138. Main Jet Removal

11. Remove screws from power-valve cover and remove.

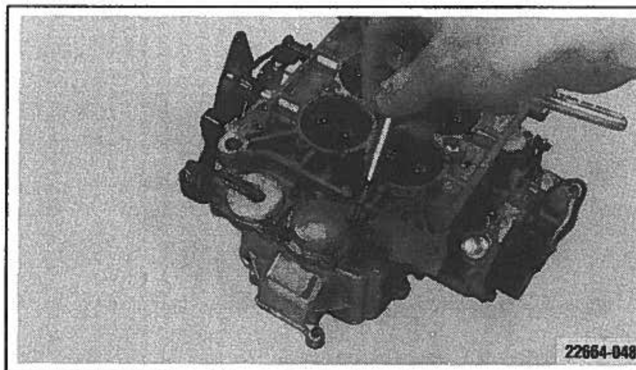


Figure 7-139. Power-Valve Cover Removal

12. Remove power valves from main body using 1" socket.

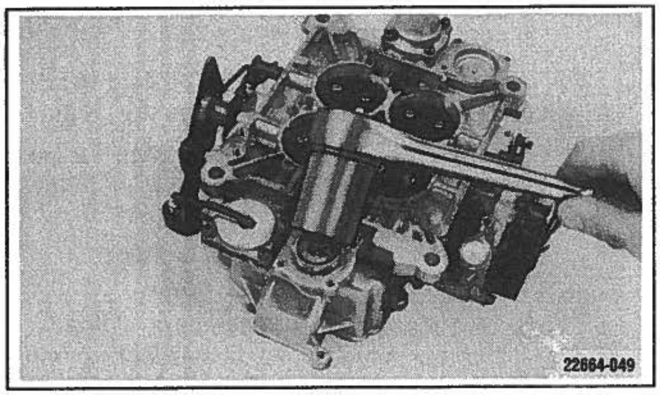


Figure 7-140. Power Valves

13. Remove screws retaining accelerator-pump cover, and remove diaphragm and spring.

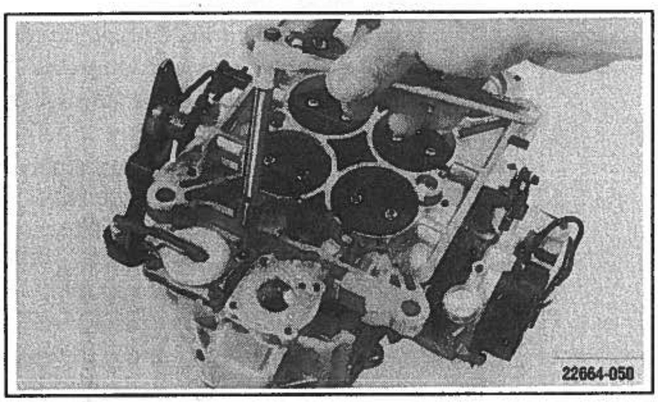


Figure 7-141. Accelerator-Pump Cover

14. Remove rubber check valve from accelerator-pump housing.

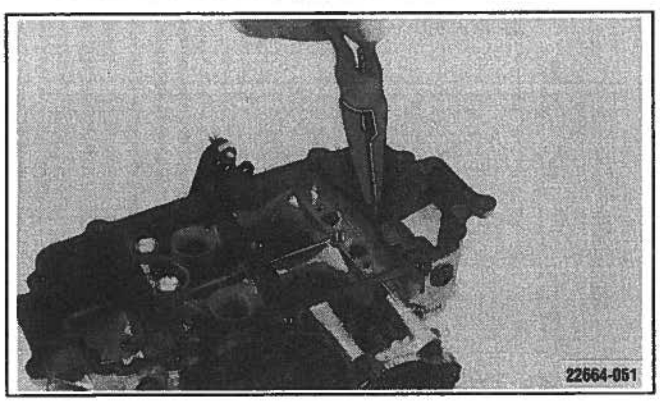


Figure 7-142. Accelerator-Pump Housing

15. Remove three (3) screws retaining electric choke cap.

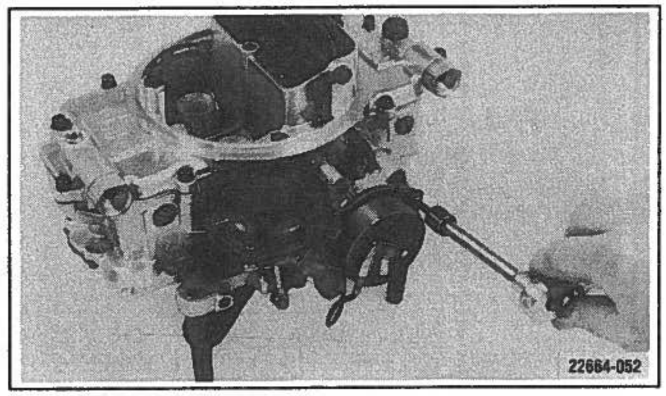


Figure 7-143. Electric Choke Cap

16. Remove three (3) screws holding choke housing to main body.

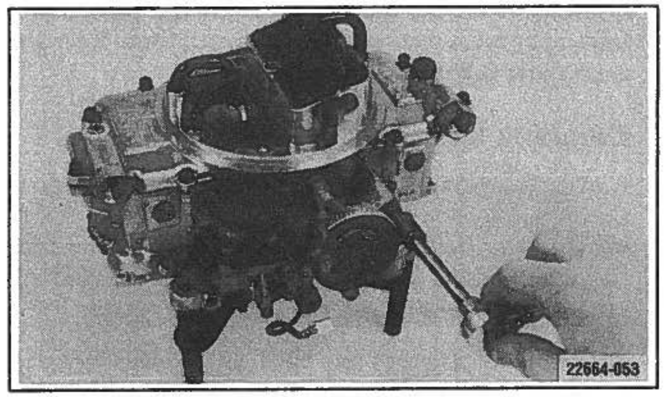


Figure 7-144. Choke Housing

17. Remove three (3) screws holding secondary diaphragm housing to main body.

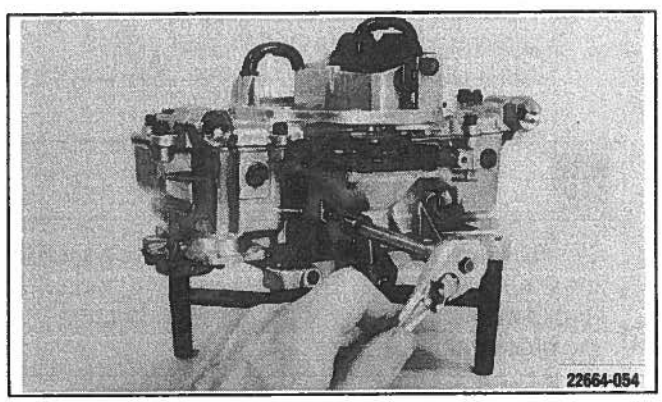


Figure 7-145. Secondary Diaphragm Housing

18. Remove four (4) screws retaining cover on secondary housing.

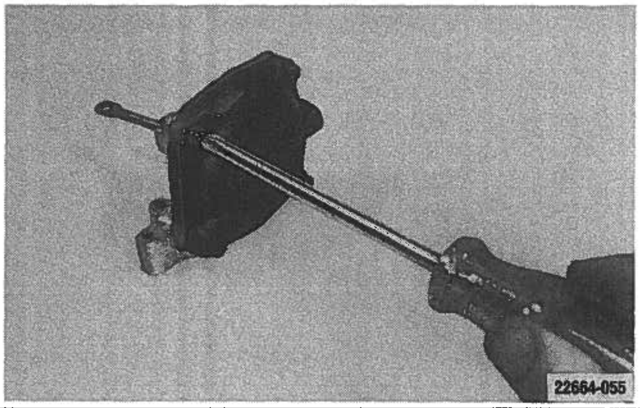


Figure 7-146. Secondary Diaphragm

IMPORTANT: It should not be necessary to go any further with disassembly of main body/throttle body combination. Do not remove throttle plates as retaining screws are staked to prevent them from loosening and falling into engine.

Cleaning and Inspection:

Carbon, varnish, gum, dirt, and water contaminants in the carburetor or on exterior moving parts of the carburetor are often responsible for carburetor malfunctions. Carefully observe the following cleaning and inspection procedure to obtain effective carburetor repair.

IMPORTANT: Do not use wire or drills to clean jets, passages, or tubes in carburetor as this may enlarge orifices and seriously affect carburetor calibration.

IMPORTANT: All gaskets, O-rings, and seals should be replaced during carburetor repair.

1. Thoroughly clean all metal parts in a commercial carburetor cleaner until all deposits have been removed. Dry parts with compressed air.

> **CAUTION**
>
> Do not leave carburetor in carburetor cleaner for more than two hours. Follow the cleaner manufacturer's instructions for the proper cleaning and rinsing procedure.

> **CAUTION**
>
> Any plastic, rubber, or neoprene parts should not be immersed in carburetor cleaner as they will swell, harden, or distort.

2. Using compressed air, blow out all passages in carburetor to remove any foreign material.
3. Wipe off all parts that cannot be cleaned in carburetor cleaner with a clean, dry cloth.
4. Carefully inspect all carburetor parts for wear and damage; pay particular attention to the following:
   a. Inlet needle and seat: If worn or damaged, replace with new.
   b. Float assembly: Shake float. If float contains fuel inside, float is leaking and must be replaced. Check hinge pins and holes for wear.
   c. Fuel and air passages: Passages MUST be perfectly clean for proper operation.
   d. Idle-mixture screws: Inspect, and if damaged, MUST be replaced.
   e. Throttle valves and shaft: Check throttle valve and shaft for binding through the entire operating range. Make sure valve opens and closes completely.
   f. Choke valve, shaft, and lever assembly: Check shaft and linkage for excessive looseness in air horn. Check choke valve and lever for binding through entire operating range. Make sure valve opens and closes completely.
   g. Check casting for visible damage. Inspect all gasket surfaces.

Carburetor Reassembly:

1. Using new secondary diaphragm supplied with overhaul kit, assemble secondary diaphragm unit. Make sure ball check is inserted in hole as shown.

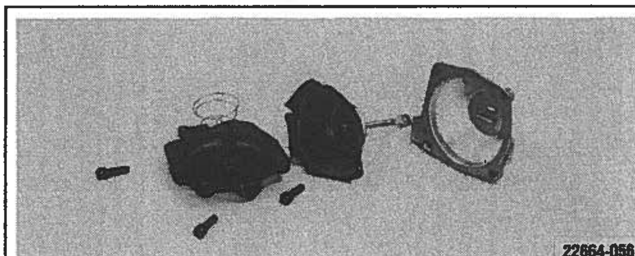


Figure 7-147. Secondary Diaphragm Unit

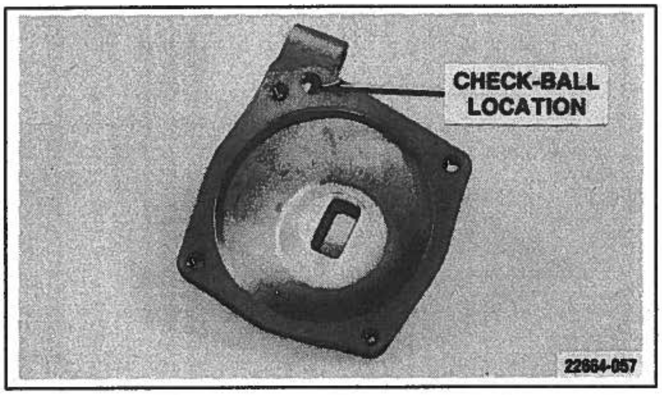


Figure 7-148. Ball Check

2. Check operation of secondary diaphragm after assembly by pushing diaphragm stem all the way in and placing your thumb over vacuum passage. Release stem. If it moves, there is a leak.

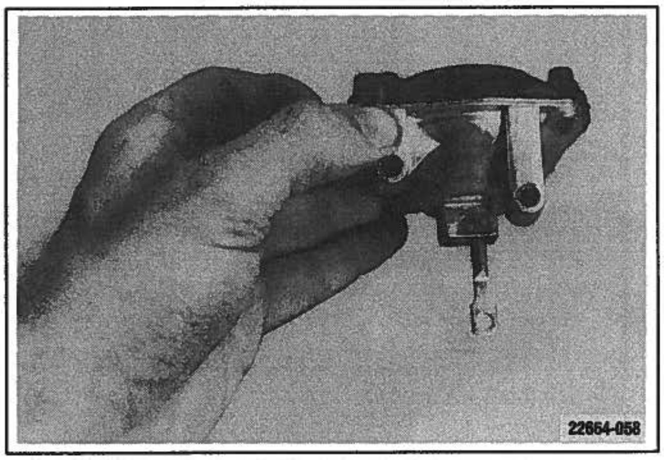


Figure 7-149. Secondary Diaphragm

3. Reattach secondary diaphragm to main housing with three (3) screws.

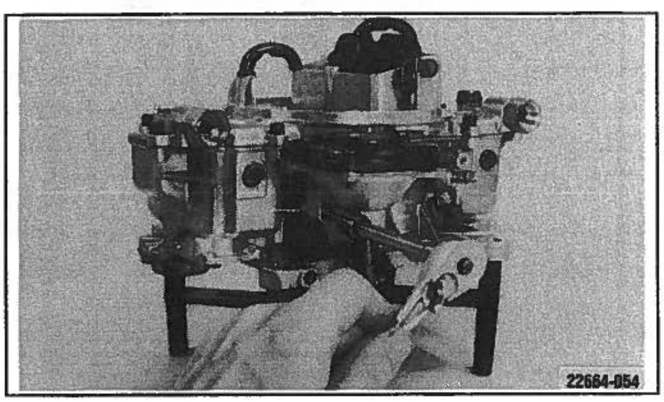


Figure 7-150. Attaching Secondary Diaphragm

4. Replace rubber inlet valve in accelerator-pump housing. Pull stem through from bottom until ball section pops through opening.

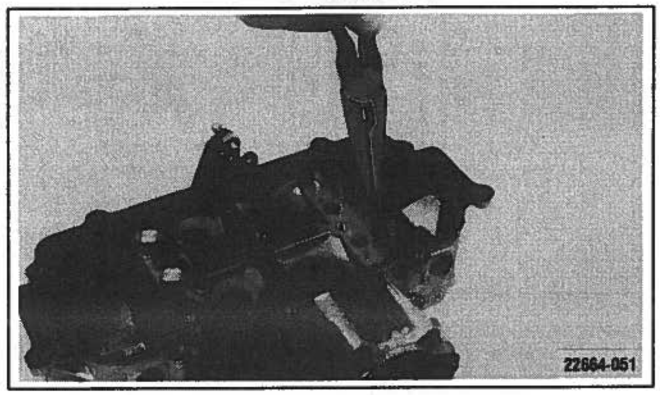


Figure 7-151. Installing Accelerator-Pump Valve

5. Using new pump diaphragm, reassemble accelerator pump and reattach cover using four (4) screws.

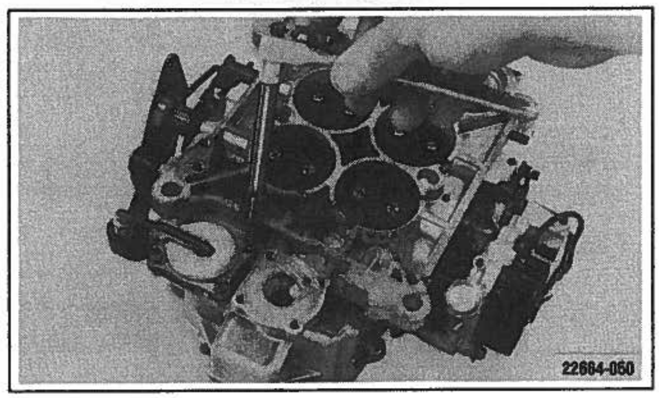


Figure 7-152. Accelerator Pump Cover

6. Place new gasket on power valves and reinstall in main body.

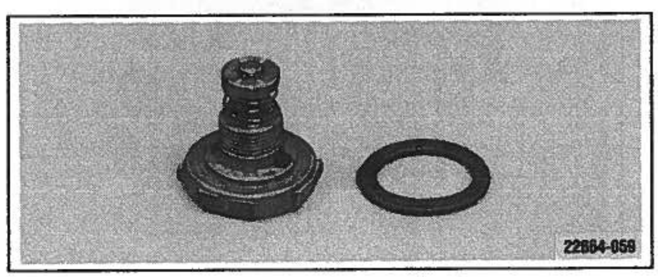


Figure 7-153. Power Valves And Gasket

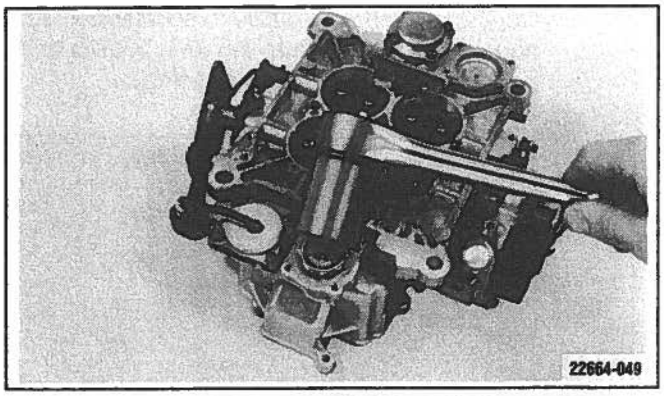


Figure 7-154. Power Valves Reinstallation

7. Place gasket and cover in position over power valves and tighten screws securely.

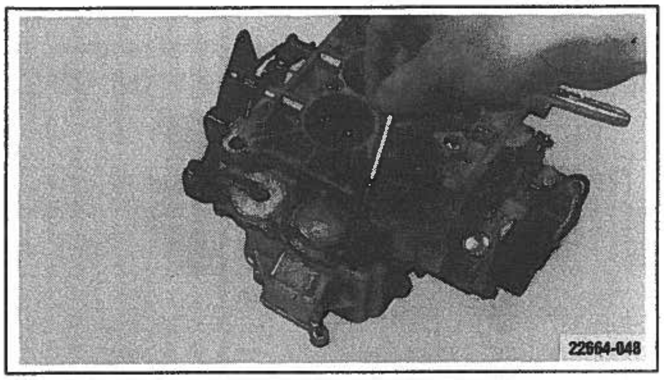


Figure 7-155. Power-Valves Cover

8. Install main jets into main body. Make sure jets are reinstalled in proper location. Do not intermix primary and secondary jets.

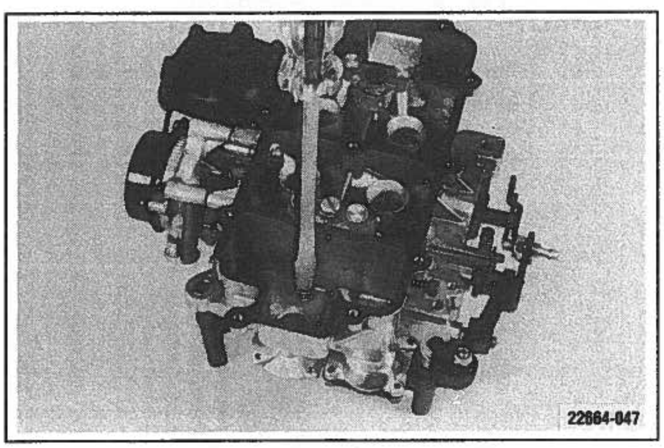


Figure 7-156. Main Jets Installation

9. Assemble primary cluster as shown. Make sure spring and ball are installed in proper order.

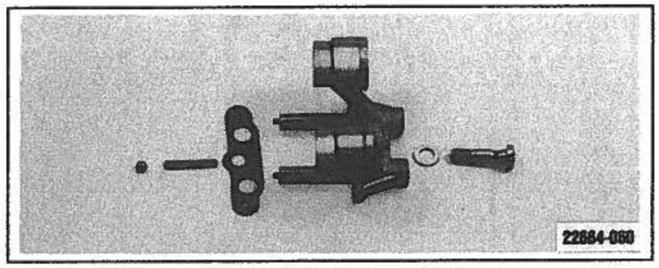


Figure 7-157. Primary Cluster Assembly

10. Using new gaskets, install primary and secondary clusters on main body. Primary side uses hollow screw for accelerator-pump circuit.

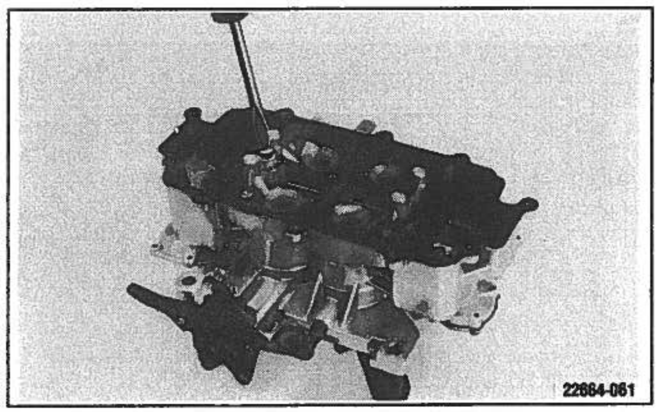


Figure 7-158. Gaskets

11. Using new gasket, install choke housing on main body with three (3) screws. Choke-actuating rod should be above fast-idle cam.

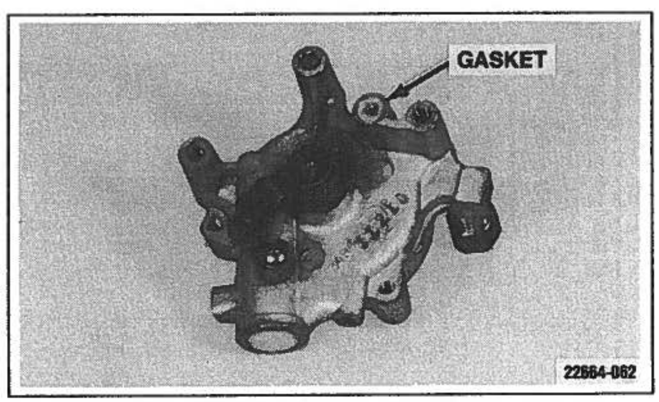


Figure 7-159. Choke Housing

12. Install new needle and seat assemblies into air horn as shown.

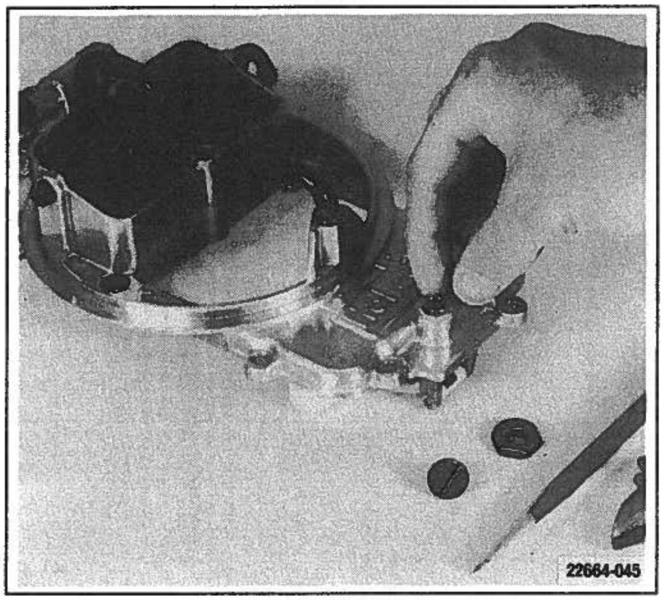


Figure 7-160. *Needle And Seat Assemblies*

13. Install floats onto air horn. Screw needle and seat in and out as needed to set float level as shown. Final adjustment is made on the engine.

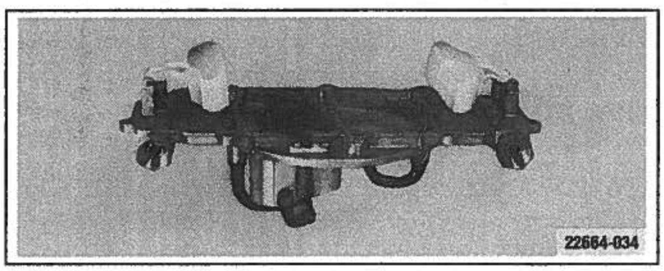


Figure 7-161. *Inverted Air Horn*

14. Carefully set the air horn onto the main body to avoid damaging the floats. Use new gasket.

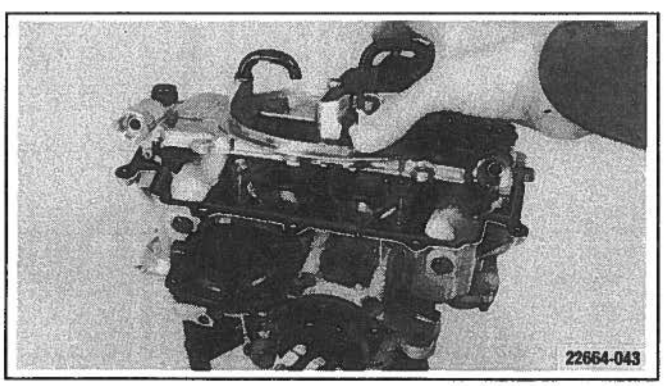


Figure 7-162. *Air-Horn Installation*

15. Insert choke-link rod into lower choke lever. Install attaching clip.

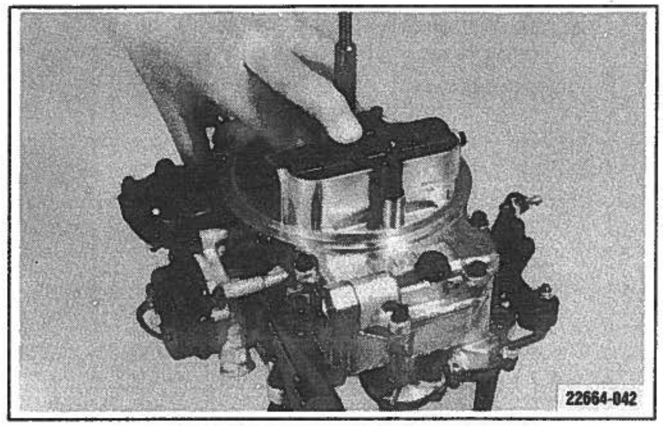


Figure 7-163. *Choke-Link Rod*

16. Install air-horn-attaching screws and tighten securely.

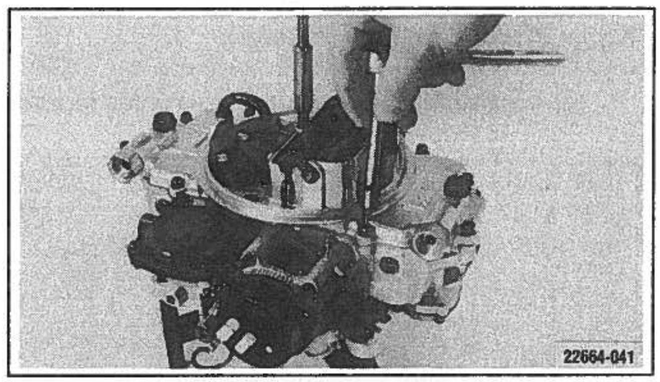


Figure 7-164. *Air-Horn-Attaching Screws*

17. Install idle-mixture screws.

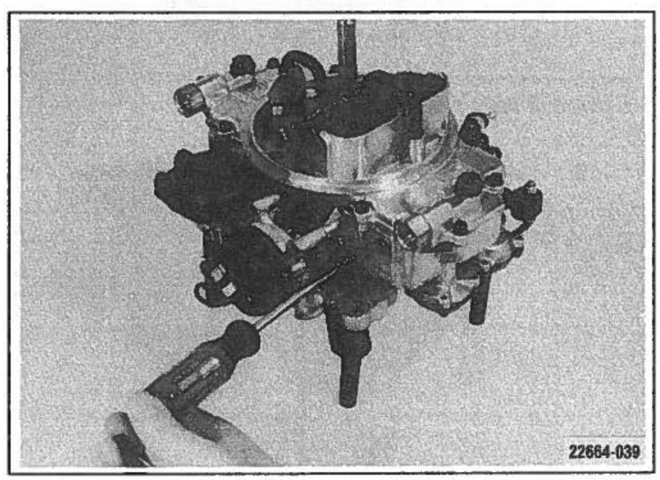


Figure 7-165. *Idle-Mixture Screw Location*

IMPORTANT: Do not tighten idle-mixture screws against seats; damage to screw and/or seat may result.

18. Install fuel-inlet-filter screens into air horn. Using new gasket, screw in fuel-inlet fittings and tighten.

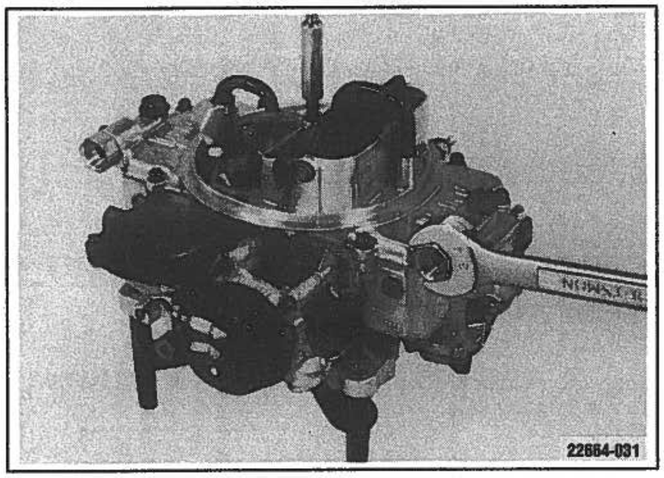


Figure 7-166. *Fuel Filter Installation*

19. Install flame-arrestor stud and tighten securely.

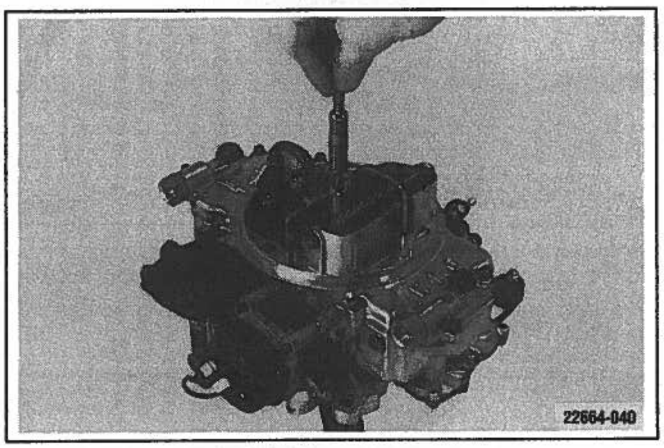


Figure 7-167. *Flame Arrestor Stud*

20. Install choke cap. Be sure bimetal loop engages tang on lever.

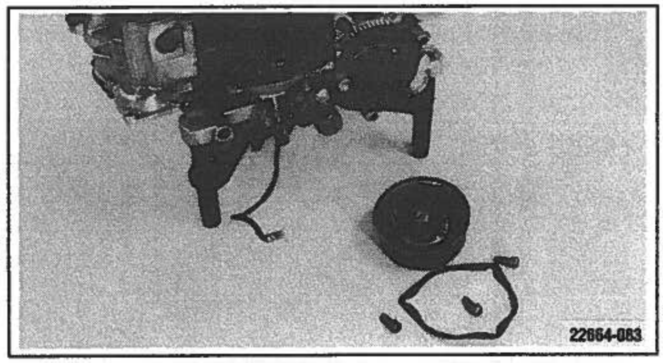


Figure 7-168. *Choke Cap*

21. Install screws holding choke-cap retainer. Tighten securely.

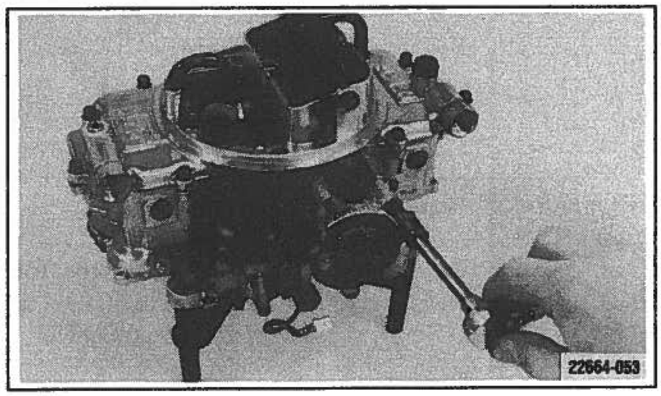


Figure 7-169. *Choke-Cap Retainer*

Carburetor Installation:

1. Thoroughly clean intake-manifold-gasket surfaces. Use care to prevent gasket material from entering intake manifold.
2. Place new carburetor-base gasket(s) as required on intake manifold. Install carburetor and secure with nuts and washers. Torque to specification.
3. Connect fuel lines to fuel-inlet fittings. Tighten securely.
4. Attach 12-volt power lead to choke housing.
5. Move carburetor throttle lever back and forth, checking for binding in throttle linkage.
6. Install throttle cable.
7. Install flame arrestor and crankcase-ventilation hoses.
8. Reconnect battery cables to battery.
9. Start engine and check for gasoline leaks. If leaks exist, STOP ENGINE IMMEDIATELY and recheck all connects. Repair as needed.
10. Make all carburetor adjustments required as outlined under "Carburetor Adjustments" in this Section.

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Section 8

Engine Mechanical

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8 ENGINE MECHANICAL

8.1 GENERAL INFORMATION

WARNING

Always disconnect the battery cables from battery, negative terminal first, **before** performing any disassembly/reassembly procedures on the engine.

WARNING

Electrical, ignition and fuel system components on your Crusader marine engines are designed and manufactured to comply with U.S. Coast Guard Rules and Regulations to minimize risks of fire and explosion.

Use of replacement electrical, ignition or fuel system components which **do not** comply with these rules and regulations could result in a fire or explosion hazard and should be avoided.

WARNING

When servicing the electrical and ignition systems, it is extremely important that all components are properly installed and tightened. If they are not, any electrical or ignition component opening would permit sparks to ignite fuel vapors from possible fuel system leaks.

WARNING

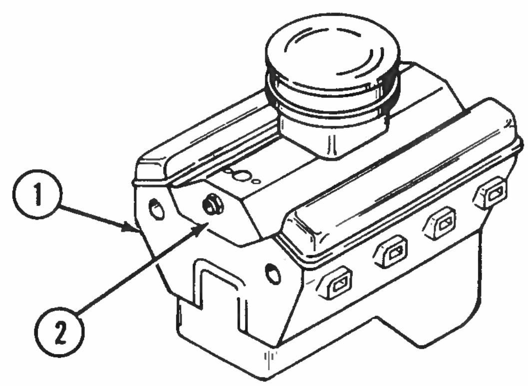
To prevent the possibility of a **FIRE**, be sure that the engine compartment is well ventilated and that there are no gasoline vapors present.

WARNING

Make sure that no fuel leaks exist before closing engine hatch.

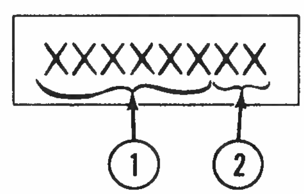
Engine Identification:

The Crusader engine model number (Figures 8-1 and 8-2) can be determined by examining the last two letters of the engine code. This code number is stamped into the cylinder block on all Crusader Engine packages and partial-replacement engines.



1. Engine code numbers located on front, starboard side, near cylinder-head-mating surfaces (229, 262, 305, and 350 CID)
2. Engine code numbers located on front, in the center below the intake-manifold-mating surface (454 and 502 CID)

Figure 8-1. *Engine Code Numbers*



1. Engine code
2. Model code

Figure 8-2. *Engine Code*

If the engine serial number and/or model decals are missing, the engine code letters or Figures in Section 1.4, Engine Identification, may help in determining the engine model. The following is a list of engine models and their respective code letters:

Engine Displacement	Engine Rotation	Block Code
229 CID	LH	JB — JM
229 CID	RH	JC — JN
262 CID	LH	KF
262 CID	RH	KH
305 CID	LH	PF — MA
305 CID	RH	PH — MB
350 CID	LH	AN — WN
350 CID	RH	AR — WR
454 CID	LH	XN
454 CID	RH	XR
502 CID	LH	FA — FC
502 CID	RH	FB — FD

Cylinder Head Identification:

For each cylinder head there is an identification mark, as shown in Figures 8-3 through 8-6.

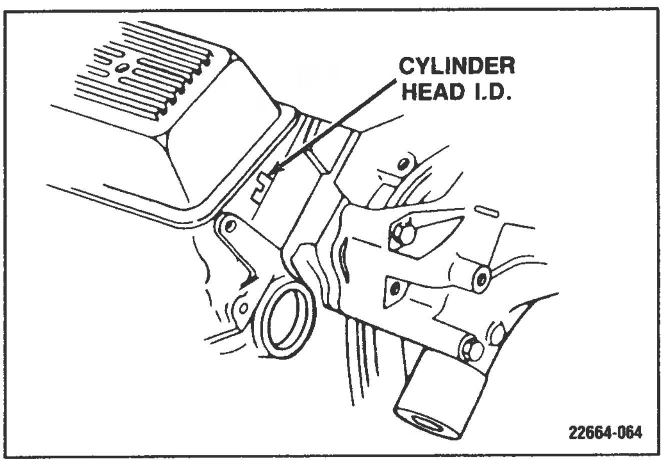


Figure 8-3. *305 CID Cylinder-Head Code*

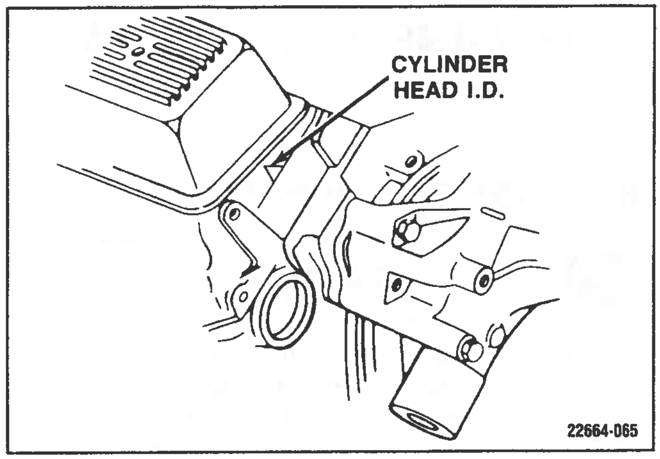


Figure 8-4. *350 CID Cylinder-Head Code*

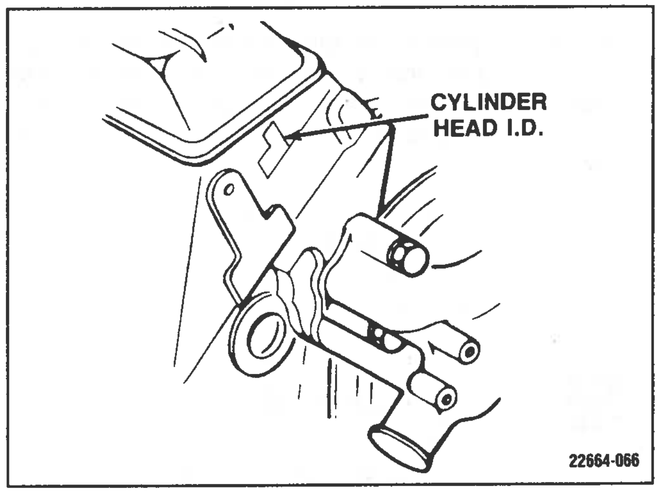


Figure 8-5. *454 CID Cylinder-Head Code*

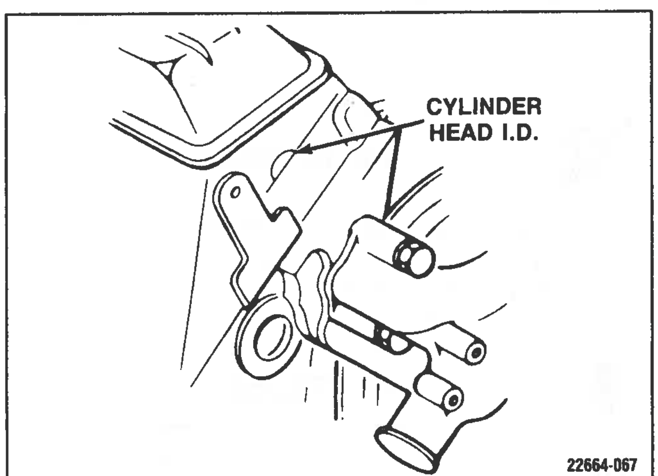


Figure 8-6. *502 CID Cylinder-Head Code*

Engine Rotation:

Engine rotation is determined by observing the flywheel rotation from the rear (flywheel end) of the engine (Figure 8-7) looking forward (water-pump end).

Propeller rotation is not necessarily the same as engine rotation.

When ordering replacement engines, production blocks or parts for engines, be certain to check engine rotation. Do not rely on propeller rotation in determining engine rotation.

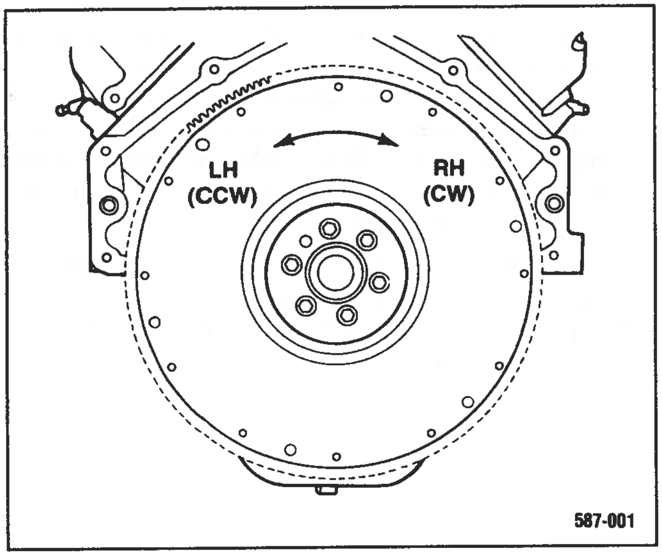


Figure 8-7. *Engine Rotation*

Working Principles:

Crankshaft

The crankshaft is supported in the block by insert-type bearings. The crankshaft-end thrust is controlled by flanges on the end bearing. A torsional damper on the forward end of the crankshaft serves to help dampen any engine-torsional vibration.

Pistons and Connecting Rods

The piston pins are offset slightly toward the thrust side of the pistons to provide a gradual change in thrust pressure against the cylinder wall as the piston travels its path. Pins have a floating fit in the piston and a press fit into the connecting rod to hold them in place.

The connecting rods are made of forged steel and are connected to the crankshaft through insert-type bearings.

Camshaft and Drive

The camshaft is supported by four bearings for the V-6, or five bearings for the V-8 engines. The bearings are pressed into the block. The camshaft is driven at one-half the crankshaft speed by a timing chain and gears (LH rotation engines), or by timing gears.

The taper on the lobes coupled with the spherical foot on the hydraulic valve lifters cause the valve lifters to rotate, thus reducing wear. A helical gear on the shaft end of the camshaft drives the distributor and oil pump while an eccentric cam on the front of the camshaft actuates the fuel pump.

Cylinder Head

The cylinder heads are made of cast iron and have individual intake and exhaust ports for each cylinder.

Stainless-steel or composition-head gaskets are used to retard corrosion.

Valve Train

The valves and valve springs are of a heavy-duty design to withstand the high engine speeds encountered. Valve tips have been hardened to extend valve life. Exhaust valve rotators are used on engines (except the Model 454 CID engine) to help extend valve life.

Hydraulic valve lifters ride directly on the camshaft lobes and transmit the thrust of the lobes to the push rods which in turn actuate the valves through the rocker arm.

In addition to transmitting the thrust of the cam lobes, the hydraulic lifters also serve to remove any clearance from the valve train to keep all parts in constant contact.

The valve lifters are also used to lubricate the valve-train-bearing surfaces.

Lubrication System

The engine lubrication system is of the force-feed type in which oil is supplied under full pressure to the crankshaft, connecting rods, camshaft bearings and valve lifters, and is supplied under controlled volume to the push rods and rocker arms. All other moving parts are lubricated by gravity flow or splash.

A positive-displacement, gear-type oil pump is mounted on the rear main bearing cap and is driven by an extension shaft from the distributor (which is driven by the camshaft). Oil from the bottom of the pump in the rear of the oil pan is drawn into the oil pump through an oil-pickup screen and pipe assembly.

The pump then forces the oil through the lubrication system. A spring-loaded relief valve in the pump limits the maximum pump-output pressure.

After leaving the pump, the pressurized oil flows through a full-flow oil filter. On engines with an engine oil cooler, the oil also flows through the cooler before returning to the block.

V-6 Engine

Some of the oil, after leaving the oil cooler and/or filter, is routed to the crankshaft's No. 4 main bearing. The remainder of the oil is routed to the main oil gallery, which is located above the camshaft, and runs the entire length of the block. From the main oil gallery, the oil is routed through individual oil passages into an annular groove in each camshaft-bearing bore. Some of the oil is then used to lubricate camshaft bearings. The remainder of the oil is routed to the valve-lifter oil galleries and the crankshaft's No. 1, 2 and 3 main bearings by means of individual oil passages which intersect the annular grooves.

V-8 Engine

Some of the oil, after leaving the oil cooler and/or filter, is routed to the main oil gallery which supplies oil through individual passages to the No. 1, 2, 3 and 4 crankshaft main bearings and the No. 1, 2, 3 and 4 camshaft bearings. The remainder of the oil is routed to the No. 5 crankshaft main bearing and to an annular groove in the No. 5 camshaft-bearing bore. Some of the oil is then used to lubricate the camshaft bearing while the remainder is routed to both valve-lifter oil galleries through oil passages which intersect the annular groove.

The camshaft bearings have holes which align with the oil passages or annular grooves in the block and allow the oil to flow in-between the bearings and the camshaft journals. The oil that is forced out the front end of the camshaft's No. 1 bearing drains down onto the camshaft drive and keeps it lubricated.

The oil which reaches the crankshaft main bearings is forced through a hole in the upper half of each bearing and flows in between the bearings and the crankshaft journals. Some of the oil is then routed to the connecting-rod bearings through grooves in the upper half of the crankshaft main bearings and oil passages in the crankshaft. Oil which is forced out the ends of the connecting-rod bearings and crankshaft main bearings is splashed onto the camshaft, cylinder walls, pistons and piston pins, thus keeping them lubricated. Oil which is forced out the front end of the crankshaft's No. 1 main bearing also assists in lubricating the camshaft drive. A baffle plate, mounted on the bottom of the main bearings or in the oil pan, prevents oil thrown from the crankshaft and connecting rods from aerating the oil in the oil pan.

Oil which reaches the valve-lifter oil galleries is forced into each hydraulic valve lifter through holes in the side of the lifter. From here, the oil is forced through the metering valve in each of the lifters (which controls the volume of oil flow) and then up through the push rods to the rocker arms. A hole in each rocker-arm push-rod seat allows the oil to pass through the rocker arm and lubricate the valve-train-bearing surfaces. After lubricating the valve train, oil drains back to the oil pan through oil-return holes in the cylinder head and block.

The distributor shaft and gear also are lubricated by the oil flowing through the right valve-lifter oil gallery. The fuel-pump push rod is lubricated by oil thrown off from the camshaft eccentric.

Bearing Failures:

Figures 8-8 through 8-13 describe how to analyze bearing failure conditions found during repairs of all Crusader marine engine models.

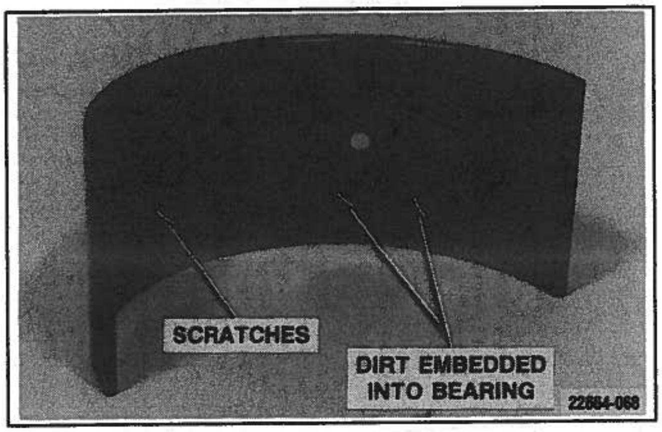


Figure 8-8. *Scratched By Dirt*

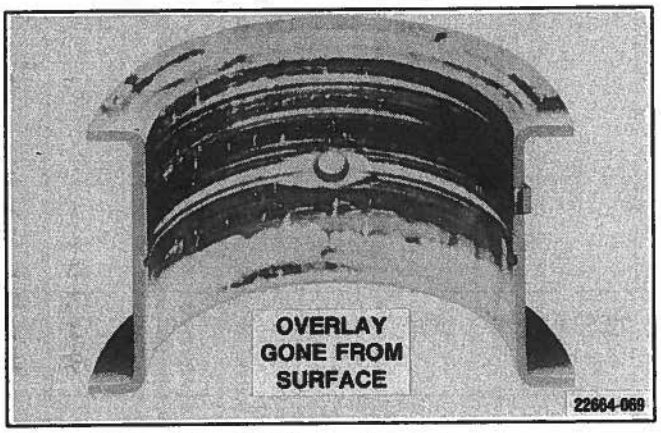


Figure 8-9. *Out-Of-Shape Journal*

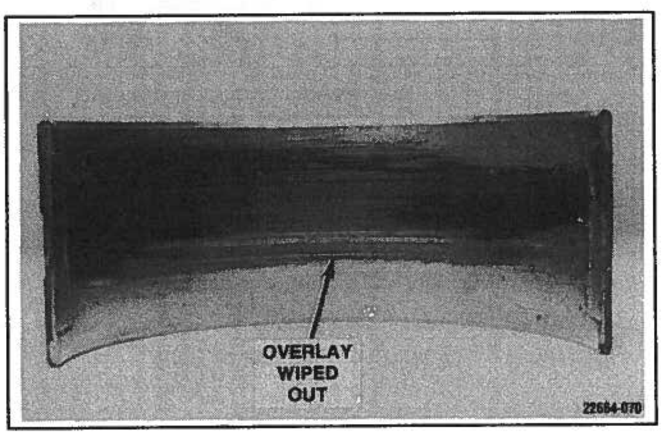


Figure 8-10. *Lack Of Oil*

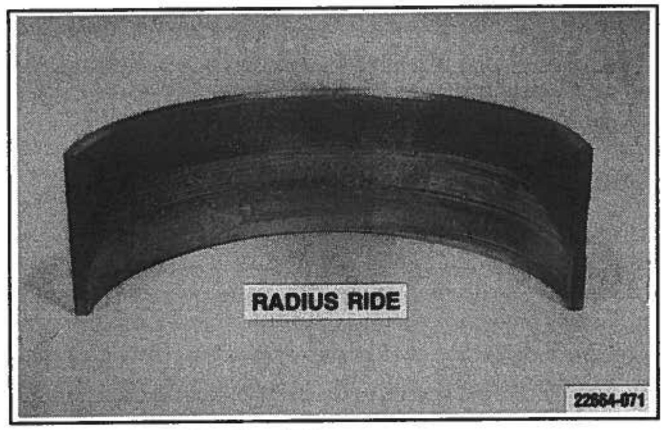


Figure 8-11. *Radius Ride*

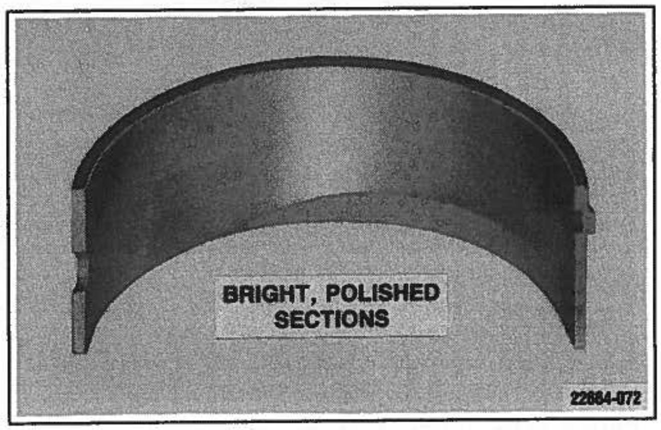


Figure 8-12. *Bent Or Twisted Connecting Rod*

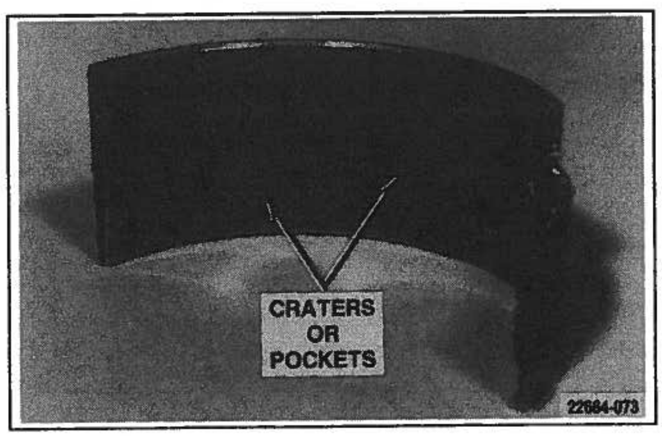


Figure 8-13. *Fatigue Failure*

Piston Failures:

The following instructions and illustrations describe how to analyze piston failure conditions found during repairs of all Crusader marine engine models.

Preignition:

Preignition is abnormal fuel ignition caused by combustion-chamber hot spots. Control of the start of ignition is lost as combustion pressure rises too early, causing power loss and rough running. The upward motion of the piston is opposed by the pressure rise. This can result in extensive damage to the internal parts from the high increase in combustion-chamber temperature (Figure 8-14).

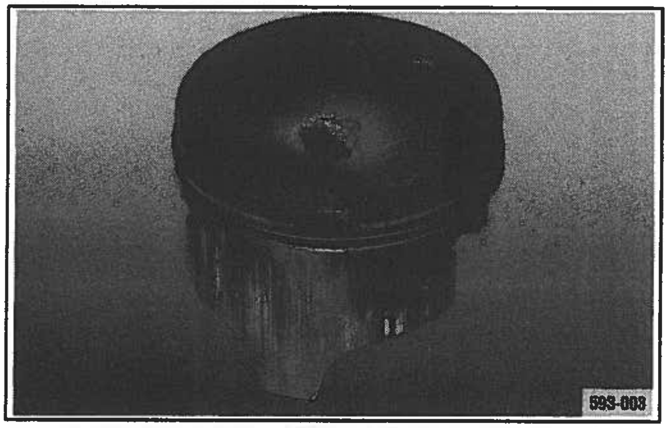


Figure 8-14. *Preignition Damage*

Preignition is caused by the following:

1. Hot spots in the combustion chamber from glowing deposits (due in turn to the use of improper oils and/or fuels).

   Figures 8-15 through 8-18 illustrate how hot spots react inside the combustion chamber.
2. Overheated spark plug electrodes (improper heat range or defective plug).
3. Anything projecting into the combustion chamber, such as an overhanging piece of gasket, an improperly seated valve or any other inadequately cooled section of material which can serve as an igniter.

IMPORTANT: Engine failures, which result from the foregoing conditions, are beyond the control of Crusader Engines. Therefore, no warranty will apply to failures which occur under these conditions.

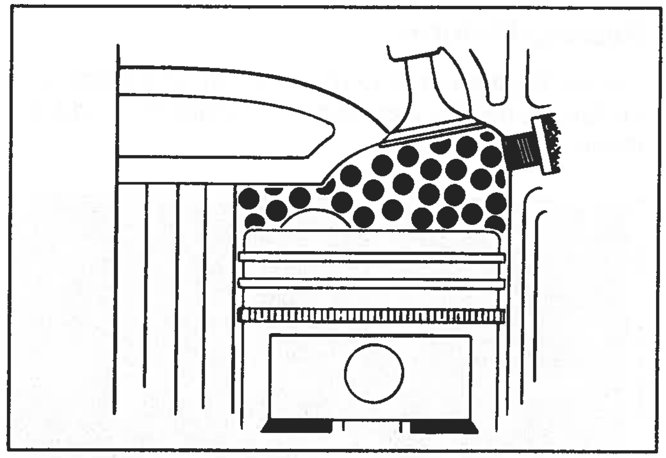


Figure 8-15. *Ignition By Hot Spot*

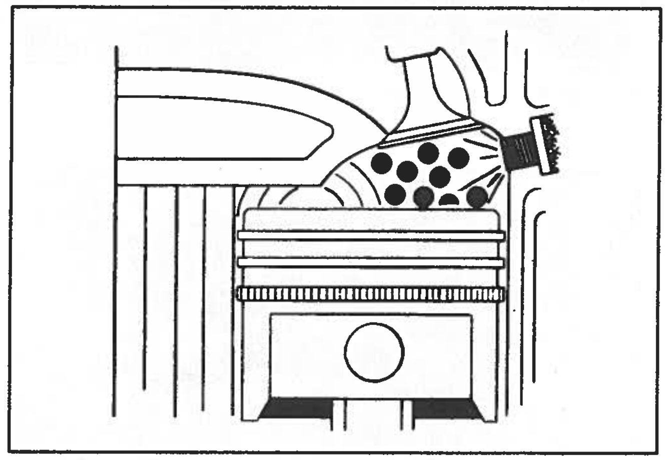


Figure 8-16. *Regular Ignition Spark*

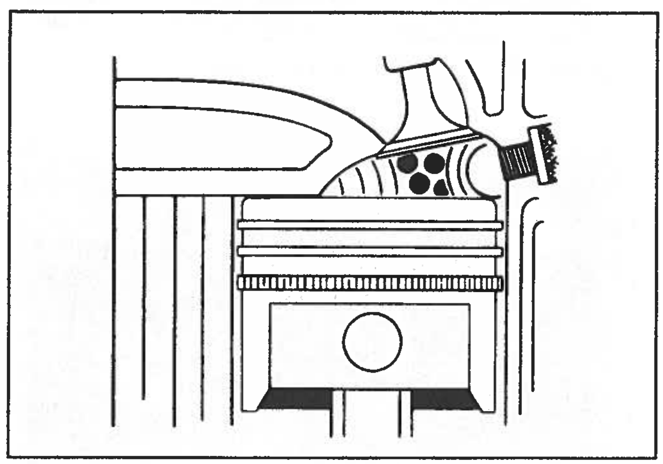


Figure 8-17. *Ignition Of Remaining Fuel*

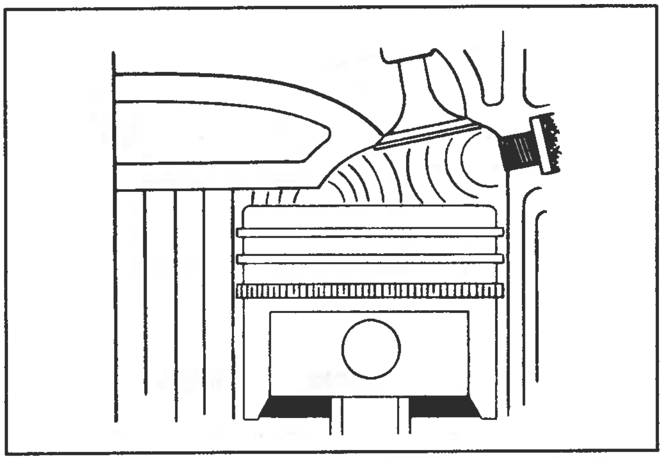


Figure 8-18. *Flame Fronts Collide*

Detonation:

Detonation, commonly called "fuel knock," "spark knock," or "carbon knock," is abnormal combustion of the fuel which causes the fuel to explode violently. The explosion, in turn, causes overheating or damage to the spark plugs, pistons, valves and, in severe cases, results in preignition (Figure 8-19).

Use of low-octane gasoline is one of the most common causes of detonation. Even with high-octane gasoline, detonation could occur if engine maintenance is neglected.

IMPORTANT: Use of improper fuels will cause engine damage and poor performance.

Other causes of detonation are:

1. Overadvanced ignition timing.
2. Lean fuel mixture at or near full throttle (could be caused by carburetor or leaking intake manifold).
3. Crossfiring spark plugs.

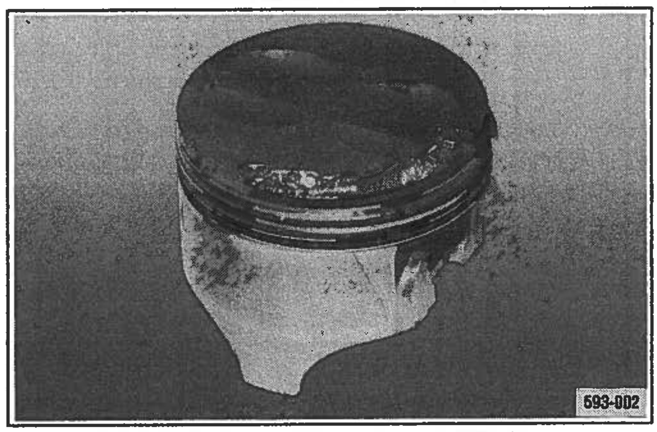


Figure 8-19. *Detonation Damage*

4. Excess accumulation of deposits on piston and/or combustion chamber (results in higher compression ratio).
5. Inadequate cooling of engine by deterioration of cooling system.
6. Improper propeller selection.
7. Wrong transmission-gear-reduction selection.

Figures 8-20 through 8-23 illustrate how abnormal fuel combustion reacts inside the combustion chamber.

IMPORTANT: Engine failures, which result from the foregoing conditions, are beyond the control of Crusader Engines. Therefore, no warranty will apply to failures which occur under these conditions.

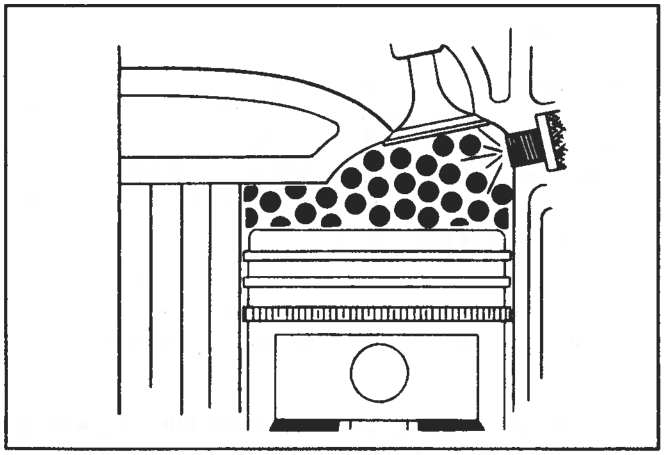


Figure 8-20. Spark Occurs

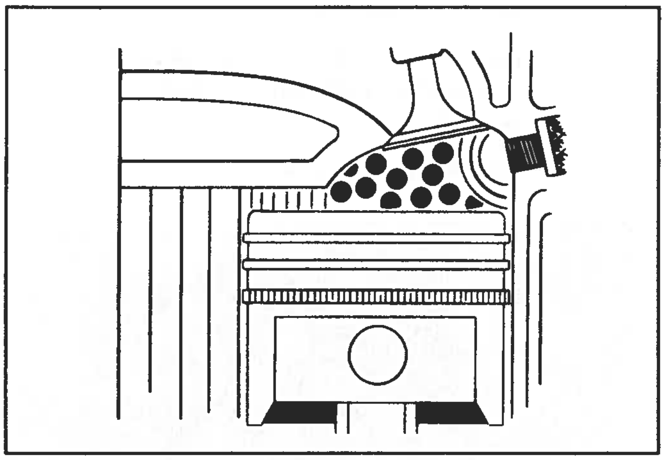


Figure 8-21. Combustion Begins

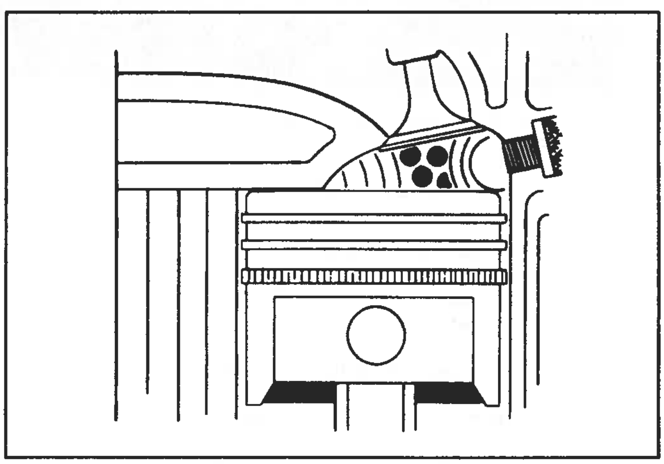


Figure 8-22. Continued Combustion

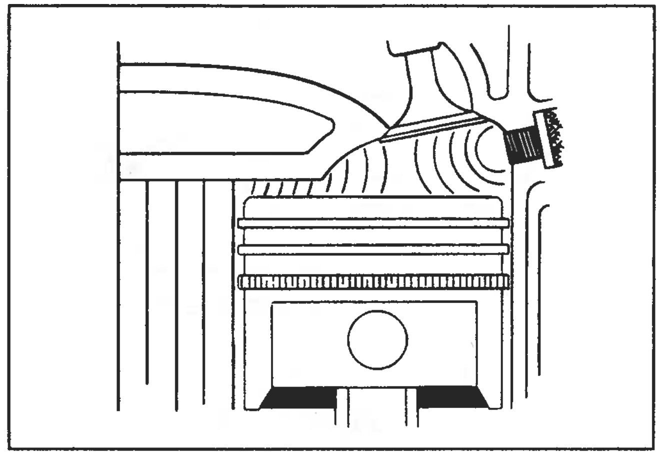


Figure 8-23. Detonation

8.2 V-6 ENGINE

Special Tools:

SPECIAL TOOLS	
Kent-Moore Number	**Item**
J-8062	Valve-spring compressor (cylinder head off)
J-8101	Valve-guide bore-cleaning brush
J-8358	Valve seat and valve-face cleaning brush
J-5830-1	Oversized valve-guide reamer (0.003 in.)
J-5830-6	Oversized valve-guide reamer (0.006 in.)
J-9345-1	Oversized valve-guide reamer (0.010 in.)
J-8080	Crankshaft upper bearing-shell remover and installer
J-8369	Oil-suction-pipe installer
J-5825	Crankshaft gear remover (LH engine rotation)
J-1619	Crankshaft gear remover (RH engine rotation)
J-5239	Connecting-rod guide set for cap-screw rods
J-5802-01	Rocker-arm stud remover
J-6880	Rocker-arm stud installer
J-5590	Crankshaft-gear installer
J-24420-B	Crankshaft-gear installer
J-8037	Piston-ring compressor
J-25087	Oil-pressure gauge
J-3049	Valve-lifter remover
J-5790	Hydraulic valve-lifter leakdown tester
J-23394	Front intake-manifold-bolt wrench
J-5250	Timing-chain-cover oil-seal installer
J-4160-A	Hydraulic valve-lifter-plunger remover
J-5892	Valve-spring compressor (cylinder head on block)
J-8089	Carbon-removing brush
J-6098	Camshaft-bearing remover and installer
J-8056	Valve-spring tester
J-23994	Valve-seal leak tester
J-8520	Cam-lobe lift indicator
J-24086-B	Piston-pin remover and replacer set
J-22509	Intake-valve seal installer
J-23590	Air adapter

Available from:

Kent-Moore Tools
29784 Little Mack
Roseville, MI 48066-2298
Phone: (800) 345-2233
(313) 574-2332

Specifications:

CID MODEL FASTENER TORQUE SPECIFICATIONS						
Model	**229 CID**			**262 CID**		
Units	**N•m**	**lb-ft**	**lb-in**	**N•m**	**lb-ft**	**lb-in**
Rocker-arm-cover bolts	10.2	–	90	10.2	–	90
Intake-manifold bolts	41	30	–	48	35	–
Exhaust-manifold bolts	27	20	–	48	35	–
Cylinder-head bolts	90	65	–	90	65	–
Torsional damper bolt	81	60	–	95	70	–
Crankcase-front-cover bolts	9	–	80	13.6	–	120
Oil-pan nuts	–	–	–	22.6	–	200
Oil-pan bolts	9	–	80	11.3	–	100
Oil-pump bolt	90	65	–	90	65	–
Rear crankshaft oil-seal-retainer screws and nuts	–	–	–	15.3	–	135
Camshaft gear bolts	28	21	–	28	21	–
Connecting-rod-cap nuts	61	45	–	61	45	–
Oil-filter-adapter bolts	33.9	25	–	20	15	–
Main bearing-cap bolts	95	70	–	110	80	–
Oil-pump-cover bolts	9.0	–	80	9.0	–	80
Flywheel bolts	54	40	–	102	75	–
Spark plugs	20	–	180	20	–	180
Water-outlet bolts	28	21	–	28	21	–
Water-pump bolts	41	30	–	41	30	–
Flywheel-housing bolts	43	32	–	43	32	–
Camshaft-thrust-plate screws	–	–	–	11.9	–	105
Hydraulic lifter-restrictor-retainer bolts	–	–	–	16.4	–	145
Oil-pan studs to oil-seal retainer or crankcase	18.6	–	165	1.7	–	15
Flywheel-damper plate	47	35	–	47	35	–

CYLINDER BORE SPECIFICATIONS				
Model			**229 CID**	**262 CID**
Diameter			3.7350-3.7385 in. (90.8690-94.9579 mm)	3.9995-4.0025 in. (101.587-101.663)
Out-of-round		Production	0.001 in (0.025 mm) max.	
		Service	0.002 in. (0.051 mm) max.	
Taper	Production	Thrust side	0.0005 in. (0.0127 mm) max.	
		Relief side	0.001 in. (0.025 mm) max.	
	Service		0.001 in. (0.025 mm) max.	

229/262 PISTON SPECIFICATIONS		
Clearance	Production	0.0007-0.0017 in. (0.018-0.043 mm)
	Service	0.0027 in. (0.069 mm) max.

229/262 PISTON RING SPECIFICATIONS				
Com-pression	Groove-side clearance	Production	Top	0.0012-0.0032 in. (0.031-0.081 mm)
			2nd	0.0012-0.0032 in. (0.031-0.081 mm)
		Service		(1) + 0.001 in. (0.025 mm)
	Gap	Production	Top	0.010-0.020 in. (0.254-0.508 mm)
			2nd	0.010-0.025 in. (0.254-0.635 mm)
		Service		(1) + 0.010 in. (0.254 mm)
Oil	Groove-side clearance	Production		0.002-0.007 in. (0.051-0.178 mm)
		Service		(1) + 0.001 in. (0.025 mm)
	Gap	Production		0.015-0.055 in. (0.381-1.397 mm)
		Service		(1) + 0.010 in. (0.254 mm)

CID PISTON PIN SPECIFICATIONS			
Model		**229 CID**	**262 CID**
Diameter		0.9270-0.9273 in. (23.546-23.553 mm)	
Clearance	Production	0.00025-0.00035 in (0.00635-0.00889 mm)	0.00025-0.0007 in. (0.00635-0.01778 mm)
	Service	0.001 in. (0.025 mm) max.	
Fit in rod		0.0008-0.0016 in. (0.0203-0.0406 mm) interference	

229/262 CID CAMSHAFT AND DRIVE SPECIFICATIONS		
Lobe lift	Intake	0.269 ± 0.002 in. (6.833 ± 0.051 mm)
	Exhaust	0.273 ± 0.002 in. (6.943 ± 0.051 mm)
Journal diameter		1.8682-1.8692 in. (47.452-47.478 mm)
Journal out-of-round		0.001 in. (0.025 mm) max.
Camshaft end play		0.004-0.012 in. (0.102-0.305 mm)
Timing-chain deflection		3/8 in. (9.5 mm) from taut position (3/4 in. [19.1 mm] total)

229/262 CRANKSHAFT SPECIFICATIONS			
Main journal	Diameter	No. 1	2.4484-2.4493 in. (62.1894-62.2122 mm)
		No. 2, 3	2.4481-2.4490 in. (62.1817-62.2046 mm)
		No. 4	2.4479-2.4488 in. (62.1767-62.1995 mm)
	Taper	Production	0.0002 in. (0.0051 mm) max.
		Service	0.001 in. (0.025 mm) max.
	Out-of-round	Production	0.0002 in. (0.0051 mm) max.
		Service	0.001 in. (0.025 mm) max.
Main bearing clearance	Production	No. 1	0.0008-0.0020 in. (0.0203-0.0508 mm)
		No. 2, 3	0.0011-0.0023 in. (0.0279-0.0584 mm)
		No. 4	0.0017-0.0032 in. (0.0432-0.0813 mm)
	Service	No. 1	0.001-0.0015 in. (0.0254-0.0381 mm)
		No. 2, 3	0.001-0.0025 in. (0.0254-0.635 mm)
		No. 4	0.0025-0.0035 in. (0.0635-0.0889 mm)
Crankshaft end play			0.002-0.006 in. (0.051-0.152 mm)
Connecting-rod journal	Diameter		2.0986-2.0998 in. (53.3044-53.3349 mm)
	Taper	Production	0.0005 in. (0.0127 mm) max.
		Service	0.001 in. (0.025 mm) max.
	Out-of-round	Production	0.0013-0.0035 in. (0.0330-0.0889 mm)
		Service	0.003 in. (0.0762 mm) max.
Rod-bearing clearance		Production	0.0013-0.0035 in. (0.0330-0.0889 mm)
		Service	0.003 in. (0.0762 mm) max.
Rod-side clearance			0.008-0.014 in. (0.203-0.356 mm)
Crankshaft run-out			0.0015 in. (0.0381 mm) max.

229/262 CID CYLINDER HEAD SPECIFICATIONS	
Gasket-surface flatness	0.030 in. (0.076 mm) in a 6.00 in. (152 mm) area
	Overall maximum out-of-flat 0.007 in. (0.18 mm)

229/262 CID FLYWHEEL SPECIFICATIONS	
Run-out	0.008 in. (0.203 mm) max.

229/262 CID VALVE SYSTEM SPECIFICATIONS			
Lifter type			Hydraulic
Rocker-arm ratio			1.50 to 1
Valve lash (intake and exhaust)			3/4 turn down from zero lash
Face angle (intake and exhaust)			45°
Seat angle (intake and exhaust)			46°
Seat run-out (intake and exhaust)			0.002 in. (0.051 mm) max.
Seat width		Intake	1/32-1/16 in. (0.79-1.59 mm)
		Exhaust	1/16-3/32 (1.59-2.38 mm)
Stem clearance	Production	Intake	0.0010-0.0027 in. (0.0254-0.0686 mm)
		Exhaust	0.0010-0.0027 in. (0.0254-0.0686 mm)
	Service	Intake	0.0037 in. (0.0940 mm)
		Exhaust	0.0047 in. (0.1194 mm)
Valve spring	Free length		2.03 in. (51.6 mm)
	Pressure	Closed	76-84 lb. @ 1.70 in. (338-374 N @ 43.18 mm)
		Open	194-206 lb. @ 1.25 in. (863-916 N @ 31.75 mm)
	Installed height		1-23/32 in. (43.7 mm)
Damper	Free length		1.86 in. (47.24 mm)
	Approximate no. of coils		4

ROCKER-ARM COVER

Removal:

It may be necessary to remove the exhaust manifold before removing the rocker-arm cover. Also remove any component that will interfere with the removal of the manifold or rocker-arm cover.

1. Remove rocker-arm-cover-attaching hardware.

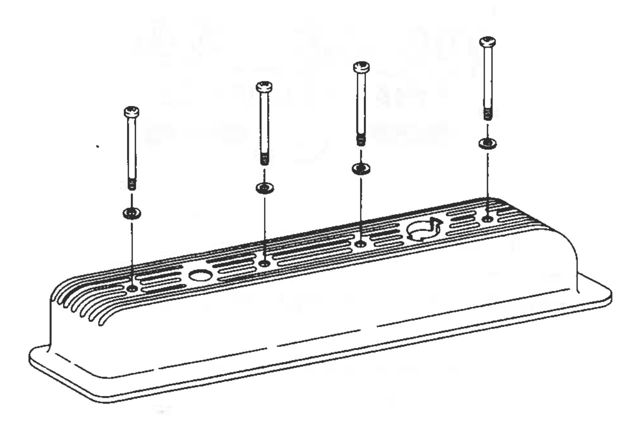


Figure 8-24. *Typical Rocker-Arm Cover*

2. Disconnect crankcase-ventilation hoses.

IMPORTANT: Do not pry rocker-arm cover loose. Gaskets, which adhere to cylinder head and rocker-arm cover, may be sheared by bumping end of rocker-arm cover from the rear with palm of hand or a rubber mallet.

3. Remove rocker-arm cover.

Installation:

1. Clean sealing surfaces on cylinder head and rocker-arm cover with degreaser.
2. Install rocker-arm covers, as follows:
   a. Position new rocker-arm-cover gasket on rocker-arm cover.
   b. Install rocker-arm cover and secure with screws. Torque to specifications.
3. Connect crankcase-ventilation hoses to rocker-arm covers.
4. Install exhaust manifolds.
5. Start engine and check for leaks.

INTAKE MANIFOLD

Removal:

1. Drain engine cooling system (see Section 10, Cooling System).
2. Disconnect hoses from thermostat housing.
3. Disconnect crankcase-ventilation hoses from rocker-arm covers.
4. Disconnect throttle cable from carburetor. Remove fuel line running between fuel pump and carburetor.

IMPORTANT: Do not crank engine over after distributor has been removed.

5. Remove distributor cap and mark position of rotor on distributor housing. Also, mark position of distributor housing on intake manifold. Remove distributor.
6. Remove other ignition components, if necessary.
7. Disconnect wire from water-temperature sending unit and alarm sender.
8. Disconnect any other items that might prevent removal of manifold.

IMPORTANT: It may be necessary to pry intake manifold away from cylinder heads and block in next step. Use extreme care to prevent damage to sealing surfaces.

9. Remove intake manifold screws, then remove intake manifold and carburetor assembly.

NOTE: If intake manifold requires replacement, transfer carburetor and other related parts to new manifold.

Cleaning and Inspection:

1. Clean gasket material from all mating surfaces.

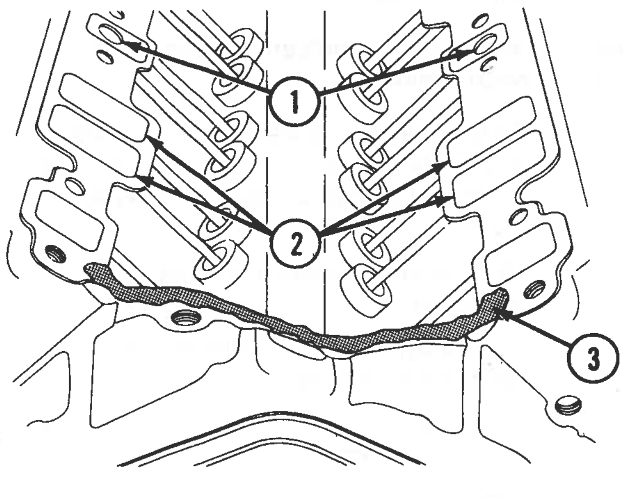
IMPORTANT: When cleaning cylinder-head-mating surface, do not allow gasket material to enter engine crankcase.

2. Inspect manifold for cracks or scratches. Machined surfaces must be clean and free of all marks and deep scratches or leaks may result.
3. Check intake passages for varnish build-up or other foreign material. Clean as necessary.

Installation:

IMPORTANT: Install intake-manifold gaskets with marked side up. Both gaskets are identical.

1. Apply Perfect Seal to intake-manifold gaskets and install gaskets on cylinder heads.
2. Place a 3/16-in.-wide (5 mm) bead of RTV Sealer on block. Extend the bead 1/2 in. (13 mm) on each gasket to seal corners.



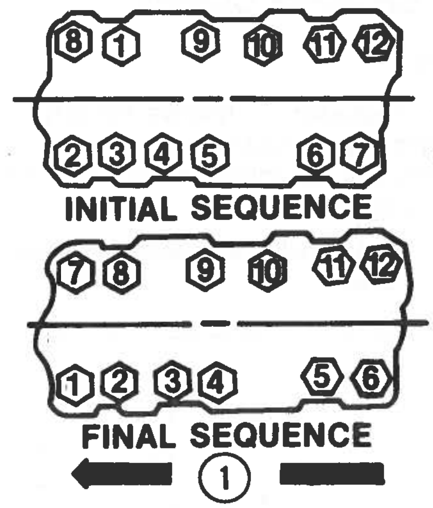
1. Exhaust-crossover-port opening in gasket
2. Intake-valve ports
3. RTV Sealer (typical both ends)

Figure 8-25. *Applying Sealer For Intake Manifold Installation*

IMPORTANT: All Crusader V-6 engines that have automatic carburetor chokes must use an intake gasket that has an opening for the exhaust cross-over port in the intake manifold.

Without this opening, the automatic choke will not operate properly. The choke will remain ON longer causing rough engine operation and wasted fuel.

3. Carefully install manifold assembly and torque bolts in sequence to specifications (see Figure 8-26).



1. Front
2. Initial sequence
3. Final sequence

Figure 8-26. *Intake-Manifold Torquing Sequence*

4. Connect wire to water-temperature sending unit and alarm sender.
5. Reconnect hoses to thermostat housing. Tighten securely.
6. Install fuel line to carburetor and fuel pump. Torque to 18 lb-ft (24 N•m).
7. Connect throttle cable to carburetor.
8. Connect crankcase-ventilation hoses to rocker-arm covers.
9. Install distributor. Position the rotor and the housing to align with marks made during removal. Tighten securely, then install distributor cap.
10. Install other ignition components, as necessary, and reconnect wires.
11. Reconnect any other items which were disconnected from manifold during the removal.
12. Start engine. Adjust ignition timing and carburetor. Check hose connections, gaskets and seals for leaks.
13. Inspect fuel line connections for fuel leaks.

ROCKER ARM/PUSH ROD

Removal:

1. Remove rocker-arm covers.
2. Remove rocker-arm components, rocker arms and push rods.

IMPORTANT: Place rocker arms, rocker-arm components and push rods in a rack for reinstallation in the same locations.

Cleaning and Inspection:

1. Clean parts with solvent and dry with compressed air.
2. Inspect all contact surfaces for wear. Replace all damaged parts.

Installation:

IMPORTANT: When installing rocker arms and rocker-arm balls, coat bearing surfaces of rocker arms and rocker-arm balls with engine oil.

1. Install push rods. Be sure push rods seat in lifter socket.
2. Install rocker arms, rocker-arm balls and rocker-arm nuts. Tighten rocker-arm nuts until all lash is eliminated.
3. Valve lash can be adjusted either with engine stopped or running.

Adjustment - Engine Stopped:

With valve cover removed, adjust valves when lifter is on low part of camshaft lobe as follows:

1. Crank engine with starter, or turn over in normal direction of rotation until mark on torsional damper lines up with "TDC" mark on timing tab, and engine is in No. 1 firing position. This may be determined by placing fingers on No. 1 valve as mark on damper comes near "TDC" mark on timing mark. If valves move as mark comes up to timing tab, engine is in No. 4 firing position and should be turned over once more to reach the No. 1 position.

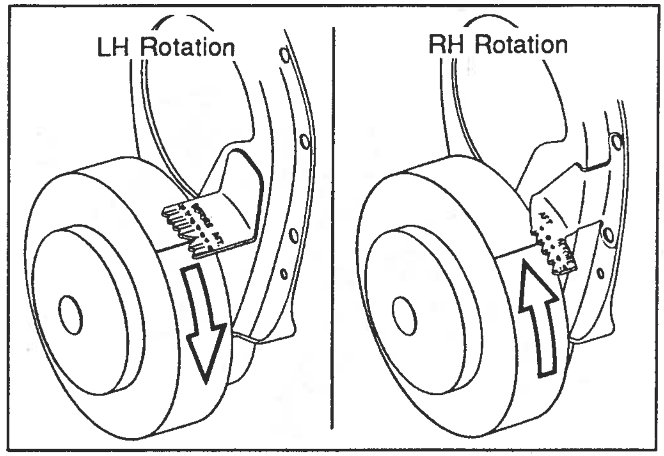
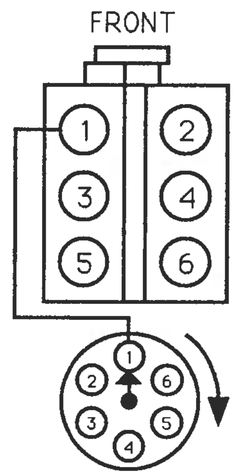


Figure 8-27. Engine In No. 1 Firing Position

2. With engine in No. 1 firing position, as determined above, the following valves may be adjusted (see Figure 8-28):



With number one cylinder at TDC of compression stroke, adjust the following rocker arms.	
Left-hand (normal) rotation engine	Right-hand rotation engine
Exhaust 1, 5, 6	Exhaust 1, 2, 3
Intake 1, 2, 3	Intake 1, 5, 6

Figure 8-28. Adjusting Rocker Arms With No. 1 Piston At TDC Of Compression Stroke

3. Back out adjusting nut until lash is felt at push rod, then turn in adjusting nut until all lash is removed. This can be determined by moving push rod up and down while turning adjusting nut until all play is removed.

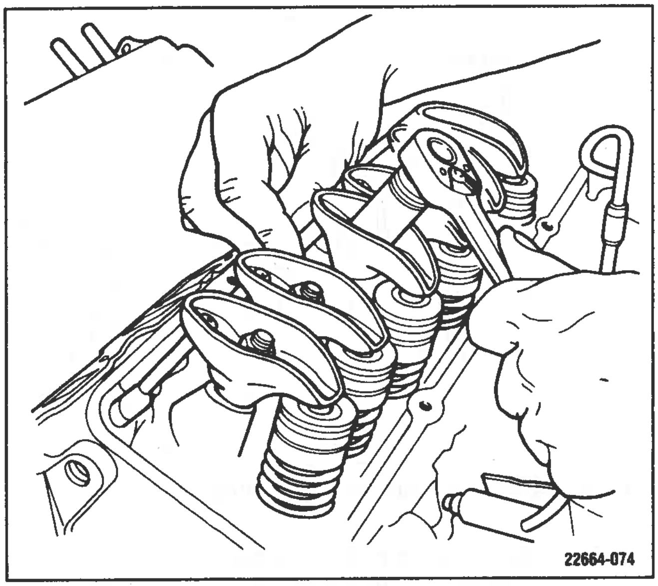
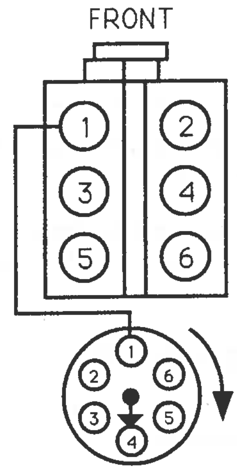


Figure 8-29. *Adjusting Lifter With Engine Not Running*

4. Hydraulic lifters now can be adjusted by tightening adjustment nut 3/4 of an additional turn. No other adjustment is required.
5. Crank engine one revolution until "TDC" pointer mark and torsional damper mark are again in alignment. This is No. 4 firing position. With engine in this position, the following valves may be adjusted (see Figure 8-30).
6. Install rocker-arm covers.



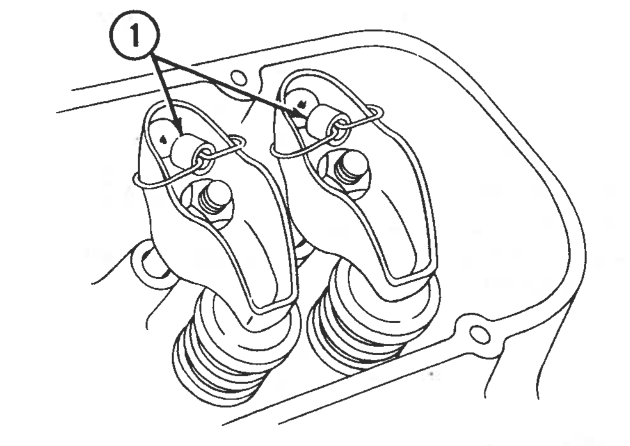
With number four cylinder at TDC of compression stroke, adjust the following rocker arms.	
Left-hand (normal) rotation engine	Right-hand rotation engine
Exhaust 2, 3, 4	Exhaust 4, 5, 6
Intake 4, 5, 6	Intake 2, 3, 4

Figure 8-30. *Adjusting Rocker Arms With No. 4 Piston At TDC Of Compression Stroke*

Adjustment – Engine Running:

1. After engine has reached normal operating temperature, remove valve covers and install rocker stoppers to prevent oil from squirting all over engine.
2. With engine running at idle, back rocker-arm nuts off (one at a time) until valve-rocker arm starts to clatter.
3. Turn rocker-arm nut down until clatter just stops.
4. Turn nut down 1/4 additional turn and pause 10 seconds until engine runs smoothly. Repeat until nut has been turned down 3/4 of a turn from the zero lash position.

IMPORTANT: This 3/4-turn preload adjustment must be done slowly to allow lifter to adjust itself, thus preventing possibility of interference between valve head and top of piston which might result in internal damage and/or bent push rods.



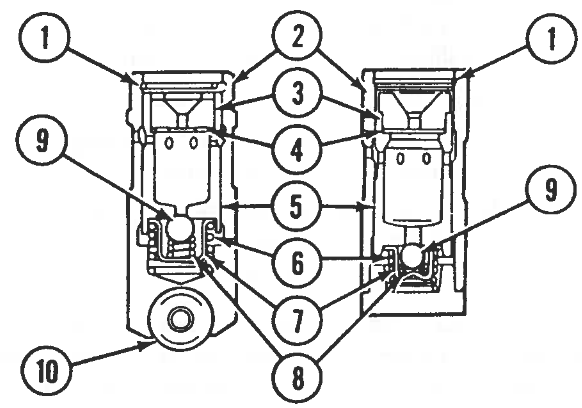
1. Rocker stoppers

Figure 8-31. *Adjusting Lifters With Engine Running*

5. Repeat Steps 2, 3 and 4 to adjust other valves.
6. Remove rocker stoppers after all valves are adjusted.
7. After valves have been adjusted, complete the following:
   a. Install new gasket and install covers. Torque to specifications.
   b. Adjust carburetor-idle speed and mixture.
   c. Start engine and check for leaks.

HYDRAULIC VALVE LIFTERS

Hydraulic valve lifters (Figure 8-34) require little attention. Lifters are extremely simple in design. Normally, readjustments are not necessary and servicing requires only that care and cleanliness be exercised in the handling of parts.



1. Retainer
2. Lifter body
3. Push rod seat
4. Metering valve
5. Plunger
6. Plunger spring
7. Check ball retainer
8. Check ball spring
9. Check ball
10. Roller (262 CID only)

Figure 8-32. *Typical Hydraulic Valve Lifter Assemblies*

Locating Noisy Lifters:

Locate a noisy valve lifter by using a piece of garden hose approximately 4 ft. (1.2 m) in length. Place one end of hose near end of each intake and exhaust valve, with other end of hose to the ear. In this manner, sound is localized, making it easy to determine which lifter is at fault.

Another method is to place a finger on face of valve-spring retainer. If the lifter is not functioning properly, a distinct shock will be felt when valve returns to its seat.

General types of valve lifter noise are as follows:

1. Hard rapping noise - usually caused by plunger becoming tight in bore of lifter body so that the return spring cannot push plunger back up to working position.

   Probable causes are:

   a. Excessive varnish or carbon deposits, causing abnormal stickiness.
   b. Galling or "pickup" between plunger and bore of lifter body - usually caused by an

abrasive piece of dirt or metal wedged between plunger and lifter body.

2. Moderate rapping noise – probable causes are:
   a. Excessively high leakdown rate.
   b. Leaky check-valve seat.
   c. Improper adjustment.
3. General noise throughout valve train – this will, in most cases, be a definite indication of insufficient oil supply or improper adjustment.
4. Intermittent clicking – probable causes are:
   a. A piece of dirt momentarily caught between ball seat and check-valve ball.
   b. In rare cases, ball itself may be out-of-round or have a flat spot.
   c. Improper adjustment.

In most cases, where noise exists in one or more lifters, all lifter units should be removed, disassembled, cleaned in solvent, reassembled and reinstalled in engine. If dirt, corrosion, carbon, etc., exist in one unit, they probably exist in all the units. Thus, it would only be a matter of time before all lifters caused trouble.

Removal:

Conventional Lifters

On models with conventional lifters:

1. Drain cooling system (see Section 10, Cooling System).
2. Remove intake manifold.
3. Remove rocker-arm cover and rocker arms.
4. Remove valve mechanism.
5. Remove valve lifters.

IMPORTANT: Keep push rod and hydraulic valve lifter from each valve together as a matched set and mark them so they can be reinstalled in the same location later.

NOTE: If the hydraulic lifter is stuck, use a valve lifter remover tool (J-3049) to remove lifter.

⚠ CAUTION

Install all new hydraulic lifters when a new camshaft is installed.

Change the engine oil and filter if any new hydraulic lifter is installed.

6. Inspect the hydraulic lifters:
   a. For a scored or scuffed lifter body. If marks are present, inspect the mating bore of the cylinder block for damage. Replace parts as necessary.
   b. For a scuffed or worn lifter-push-rod seat. If marks are present, inspect the push rod's mating end for damage. Replace parts as necessary.
   c. For clearance between the lifter and its mating bore. If excessive clearance is found, try a new lifter or replace the cylinder block.
   d. For a smooth and slightly convex surface on the lifter foot. If the foot is scored, pitted or extremely worn, check the mating camshaft lobe. Replace parts as necessary.

Roller Lifters Only

On models with roller lifters:

1. Drain cooling system (see Section 10, Cooling System).
2. Remove intake manifold.
3. Remove rocker-arm cover and rocker arms.
4. Remove valve mechanism.
5. Remove retainer (2 screws) and restrictors before removing lifter.

IMPORTANT: Keep push rod and hydraulic valve lifter from each valve together as a matched set and mark them so they can be reinstalled in the same location later.

NOTE: If the hydraulic lifter is stuck, use a valve-lifter. remover tool (J-3049) to remove lifter.

⚠ CAUTION

Install all new hydraulic lifters when a new camshaft is installed.

Change the engine oil and filter if any new hydraulic lifter is installed.

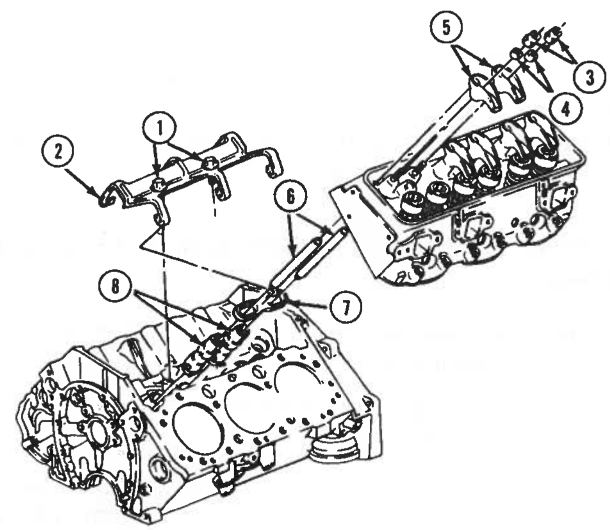
6. Inspect the hydraulic lifters:
   a. For a scored or scuffed lifter body. If marks are present, inspect the mating bore of the cylinder block for damage. Replace parts as necessary.
   b. For a scuffed or worn lifter-push-rod seat. If marks are present, inspect the push rod's mating end for damage. Replace parts as necessary.

c. For clearance between the lifter and its mating bore. If excessive clearance is found, try a new lifter or replace the cylinder block.

d. For flat spots, rough rotation or damaged needle bearing on the check roller. If the roller is damaged check the mating camshaft lobe. Replace parts as necessary.

7. Check roller for freedom of movement.

8. Check roller for flat spots, pits and missing or broken needle bearings. If worn, pitted or damaged, the mating camshaft lobe should also be checked.



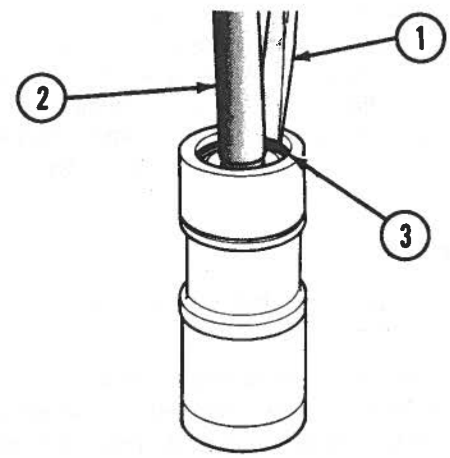
1. Bolt	5. Rocker arms
2. Retainer	6. Push rods
3. Nuts	7. Restrictor
4. Balls	8. Hydraulic lifter

Figure 8-33. *Roller Lifter Removal*

Disassembly:

IMPORTANT: The internal parts of each hydraulic lifter assembly are matched sets. DO NOT intermix the parts. Replace the complete lifter if any wear or damage is noted.

1. Hold plunger down with a push rod and remove push-rod-seat retainer with the blade of a small screwdriver.



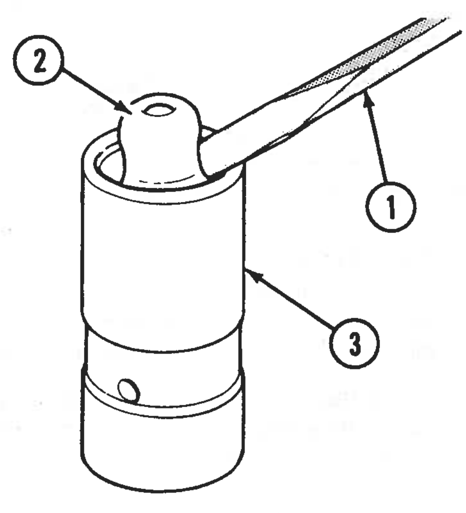
1. Screwdriver	3. Retainer
2. Push rod	

Figure 8-34. *Lifter-Seat Retainer Removal*

2. Remove push-rod seat and metering valve.

3. Remove the plunger and the plunger spring using the hydraulic valve-lifter plunger remover (J-4160-A).

4. Remove the valve check-ball and spring by prying the ball retainer loose from the plunger with the blade of a small screwdriver.



1. Screwdriver	3. Plunger
2. Check-ball retainer	

Figure 8-35. *Lifter Check-Ball Removal*

Cleaning and Inspection:

Thoroughly clean all parts in cleaning solvent and inspect them carefully. If any parts are damaged or worn, entire lifter assembly should be replaced. If outer lifter-body wall is scuffed or worn, inspect cylinder-block lifter bore. If bottom of lifter is scuffed or worn, inspect camshaft lobe. If push rod seat is scuffed or worn, inspect push rod.

Reassembly:

1. Place the check ball in small hole at bottom of the plunger.
2. Insert check-ball spring on seat in ball retainer and place retainer over ball so that spring rests on the ball. Carefully press the retainer into position in the plunger with the blade of a small screwdriver.

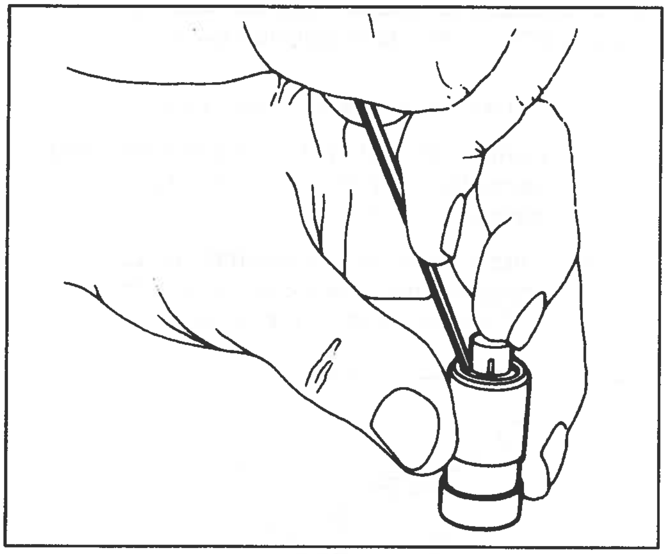
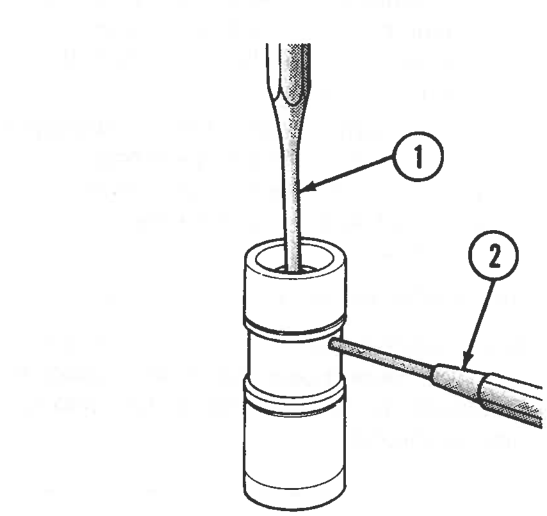


Figure 8-36. *Lifter Check-Ball Installation*

3. Place the plunger spring over the check-ball retainer and slide the lifter body over the spring and plunger. Be careful to line up the oil-feed hole in the lifter body and plunger.
4. Fill the assembly with oil (see Specifications). Insert the end of a 1/8-in. (3.2 mm) drift pin into the plunger and press down on check ball until hole in lifter body aligns with hole in plunger.
5. Insert a 1/16-in. (1.6 mm) drift pin through both oil holes to hold the plunger down against the lifter-spring tension.



1. 1/8-in. (3 mm) drift
2. 1/16-in. (1.5 mm) drift inserted in oil-feed hole

Figure 8-37. *Preparing to Install Metering Valve And Push-Rod Seat*

IMPORTANT: Do not attempt to force or pump the plunger.

6. Remove the 1/8-in. (3.2 mm) drift pin and refill assembly with oil.
7. Install the metering valve, push-rod seat and push-rod seat retainer.
8. Press down on the push rod seat with a push rod and remove the 1/16-in. (1.6 mm) drift pin from lifter.

Installation:

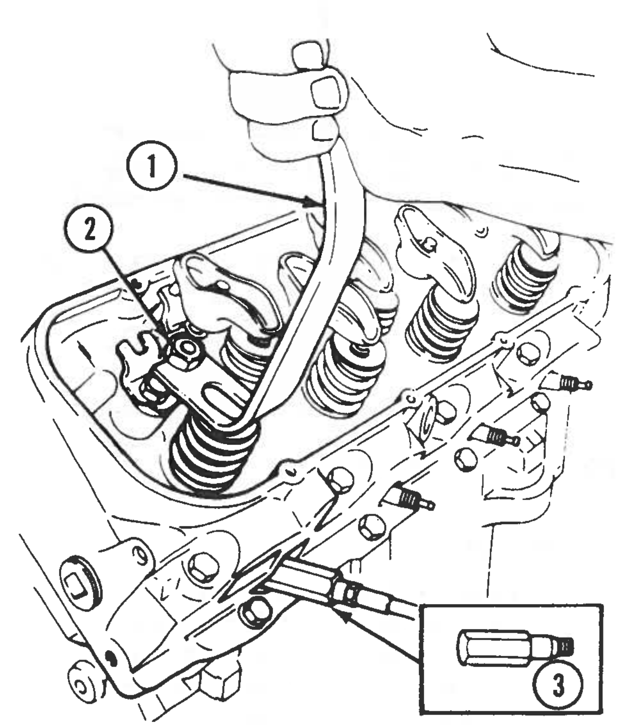
IMPORTANT: Before installing lifters, coat the bottom of the lifter with engine oil. If new lifters or a new camshaft have been installed, an additive containing EP lubricant should be poured over camshaft lobes before installing lifters.

1. Install hydraulic valve lifters into the same bore from which they were removed.
2. Install restrictors and retainer if roller lifters are used. Torque restrictor-retainer bolts to specifications.
3. Install intake manifold.
4. Install and adjust valve mechanism as outlined.
5. Install rocker-arm cover.
6. Fill cooling system (see Section 10, Cooling System).
7. Start engine and check for leaks.

VALVE-STEM OIL SEAL AND VALVE SPRING

Removal:

1. Remove rocker-arm cover.
2. Remove spark plug, rocker arm and push rod on cylinder to be serviced.
3. Position piston in cylinder to be serviced at TDC to prevent valve from dropping out of valve guide.
4. Install the J-23590 air-adapter tool into spark plug hole. Apply air pressure to the cylinder to hold the valves in place.
5. Compress valve spring with J-5892 tool. Remove valve locks and all other components.



1. J-5892 tool
2. Rocker-arm nut
3. Air-adapter tool (J-23590)

Figure 8-38. Compressing Valve Spring With Cylinder Head Installed

Installation:

1. If removed, install damper in valve spring.
2. If engine has an additional valve-stem seal, install the intake valve seal over the valve stem and seat it against the cylinder head.
3. Set valve spring, damper, valve shield and cap in place. Be sure to install valve cap with rotator on exhaust valve. Compress spring with tool J-5892 and install O-ring seal into lower groove of valve stem.

IMPORTANT: A light film of oil will help prevent twisting of the seal.

4. Install valve locks and release pressure of tool while making sure that locks are in place. Grease may be used to help hold locks while removing pressure from tool.

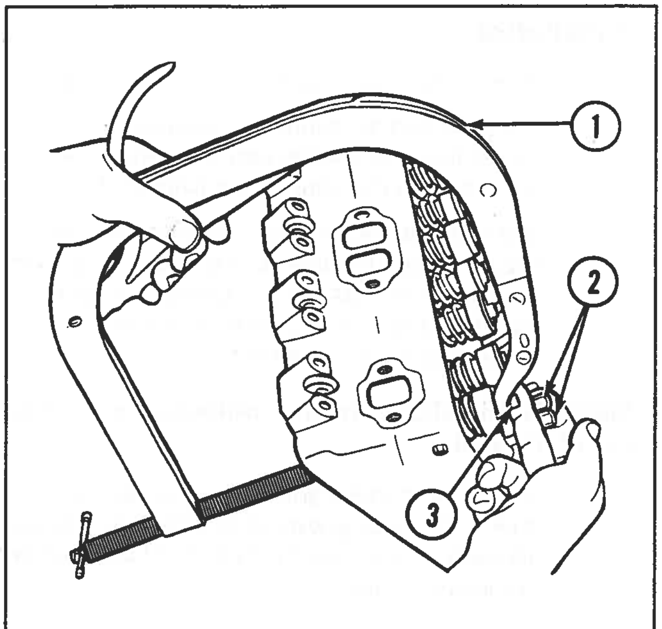
CYLINDER HEAD ASSEMBLY

Removal:

1. Drain engine cooling system.
2. Remove exhaust manifolds.
3. Remove intake manifold.
4. Remove valve mechanism.
5. Remove any component attached to front or aft end of cylinder head.
6. Remove spark plugs.
7. Remove spark-plug-wire retainers from the cylinder head.
8. Remove cylinder-head bolts, cylinder head and gasket.
9. Place cylinder head on two blocks of wood to prevent damage.

Disassembly:

1. With cylinder head removed, remove rocker arms and components (if not previously done).
2. Compress valve springs with J-8062 tool and remove valve retainers. Release compressor tool and remove all valve components.
3. Remove valves from cylinder head and place valves and components in a rack in their proper sequence for reassembly in their original positions.

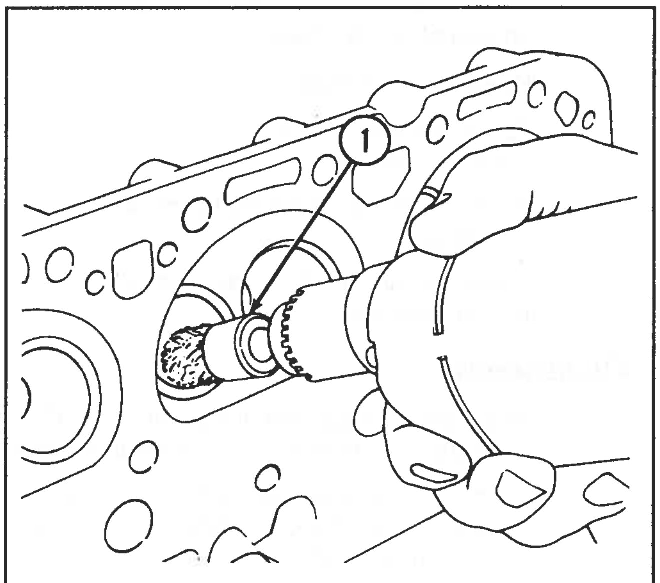


1. J-8062 spring-compressor tool
2. Valve retainers
3. O-ring

Figure 8-39. *Compressing Valve Spring With Cylinder Head Removed*

Cleaning:

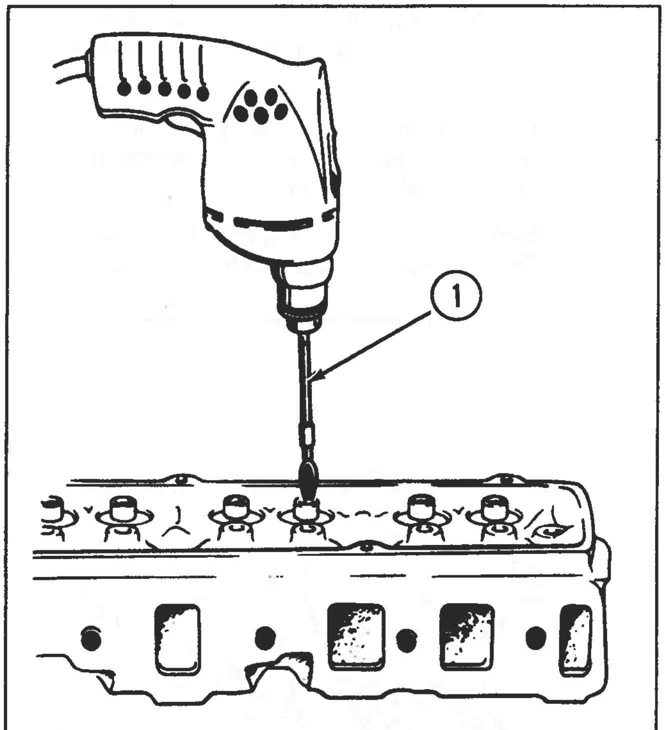
1. Clean all carbon from combustion chambers and valve ports with J-8089 tool.



1. J-8089 wire-brush tool

Figure 8-40. *Cleaning Carbon From Combustion Chamber*

2. Thoroughly clean valve guides with J-8101 tool.
3. Clean all push rods, rocker arms and push-rod guides.
4. Clean carbon from valves on a buffing wheel.
5. Clean carbon deposits and gasket material from cylinder-head-mating surfaces.



1. J-8101 valve-guide cleaning tool

Figure 8-41. *Cleaning Valve Guides*

Inspection:

1. Inspect cylinder head for cracks in the exhaust ports, combustion chambers (especially around spark plug holes and valve seats) and for cracks in external surface of water jacket. Replace head, if cracked.
2. Inspect cylinder head gasket surface for burrs, nicks, erosion or other damage. Also, check flatness of cylinder-head gasket surface, using a machinist's straightedge and feeler gauges as shown. Refer to 'Specifications."

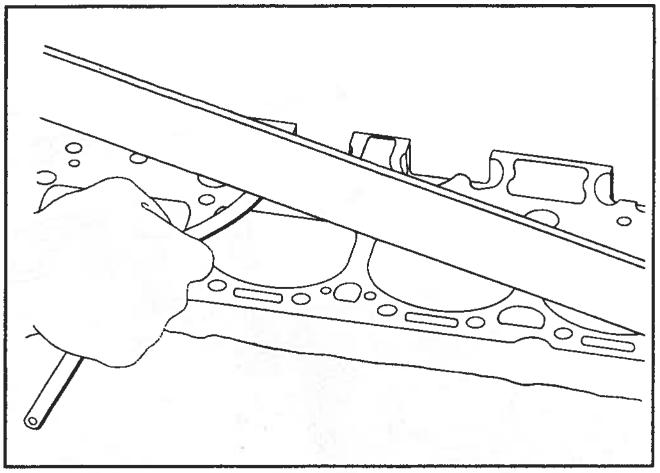


Figure 8-42. *Checking Cylinder-Head Flatness*

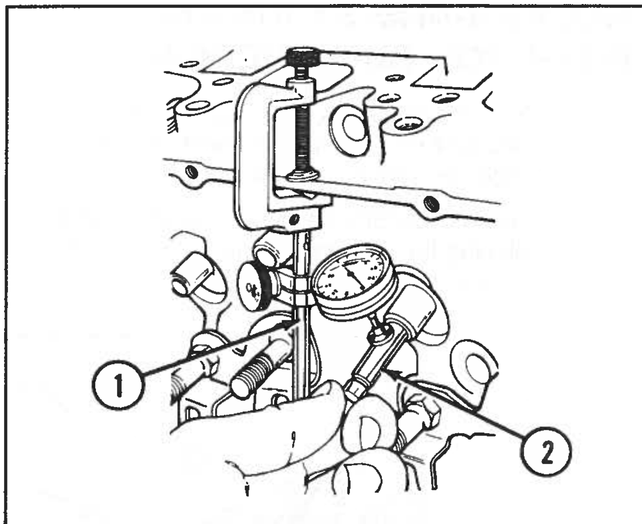
IMPORTANT: Cylinder-head-to-block gasket surface should be resurfaced if out-of-flat more than specified. When resurfacing, cylinder-head-to-intake-manifold gasket surface also must be milled to provide proper alignment between manifold and head.

3. Inspect valves for burned heads, cracked faces or damaged stems.

IMPORTANT: Excessive valve-stem-to-guide clearance will cause excessive oil consumption and possible valve breakage. Insufficient clearance will result in noisy and sticky functioning of valves and disturb engine smoothness.

4. Measure valve stem clearance as follows:

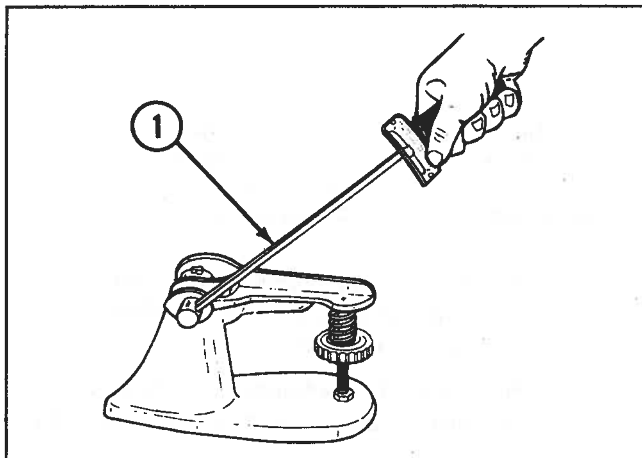
   Clamp a dial indicator on one side of cylinder-head rocker-arm-cover gasket rail, locating indicator so that movement of valve stem from side to side (crosswise to the head) will cause a direct movement of indicator stem. Indicator stem must contact side of valve stem just above valve guide. With valve head dropped about 1/16 in. (1.6 mm) off valve seat, move valve stem from side to side, using light pressure to obtain a clearance reading. If clearance exceeds specifications, it will be necessary to ream valve guides for oversized valves as outlined under "Valve Guide Bore Repair."



1. Valve guide 2. Valve stem

Figure 8-43. *Measuring Valve-Stem Clearance*

5. Check valve spring tension with J-8056 spring tester.



1. J-8056 tool

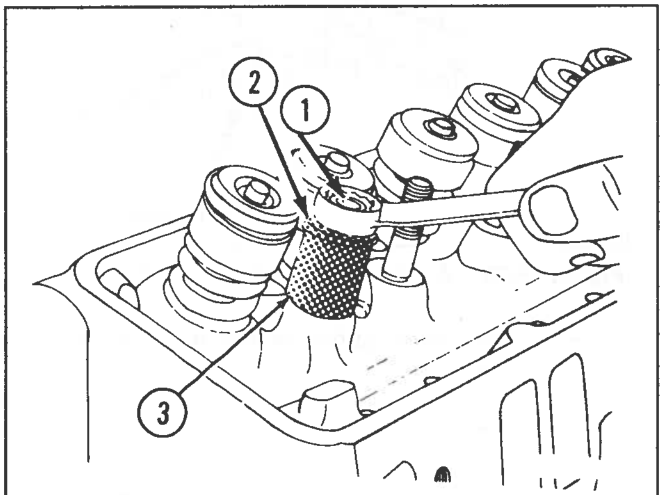
Figure 8-44. *Checking Valve-Spring Tension*

IMPORTANT: Springs should be compressed to specified height and checked against specification. Springs should be replaced if not within 10 lb-ft of specified load.

6. Inspect rocker-arm studs for wear or damage. Inspect push-rod guides for wear or damage.

ROCKER-ARM STUDS AND PUSH-ROD GUIDE REPAIRS

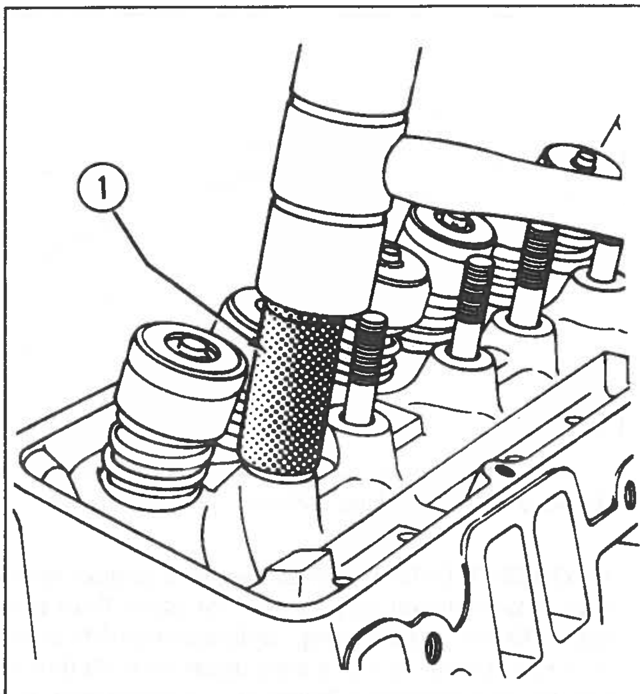
1. Rocker-arm studs, which are replaced because of wear or looseness, should be replaced with oversized studs.
2. Use tool J-5802-01 to remove old stud by placing flat washer and nut over stud, then turning nut.



1. Nut
2. Flat washer
3. J-5802-01 rocker arm stud remover

Figure 8-45. *Removing Rocker-Arm Stud*

3. Remove nut and washer and install second short spacer, washer and nut. Retighten nut until stud is removed.
4. Ream stud hole whenever installing an oversize stud using appropriate reaming tool.
5. Install new stud with tool J-6880 or similar stud-installing tool made for press-in-type studs. Follow instructions with tool.



1. J-6880 stud installing tool

Figure 8-46. *Installing Rocker-Arm Stud*

VALVE GUIDE BORE REPAIR

IMPORTANT: Be sure to measure valve stem diameter of both the intake and exhaust valve, as valve stem diameter may or may not be the same for both valves.

If 0.015-in. (0.38 mm) oversized valves are required, ream valve-guide bores for oversized valves as follows:

1. Measure valve stem diameter of old valve being replaced and select proper size Valve Guide Reamer from Set J-7049-S.
2. Ream valve-guide bores as shown.
3. Remove the sharp corner created by reamer at top of valve guide.

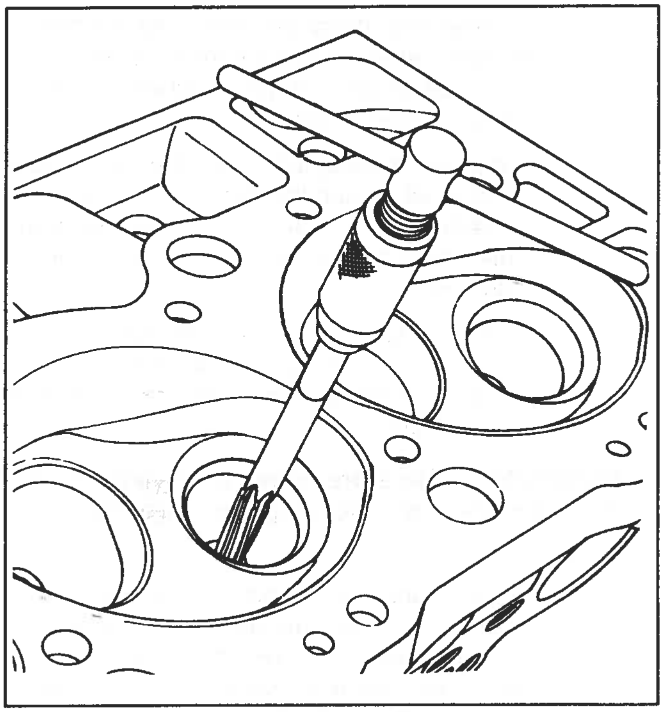


Figure 8-47. *Reaming Valve Guide*

VALVE SEAT REPAIR

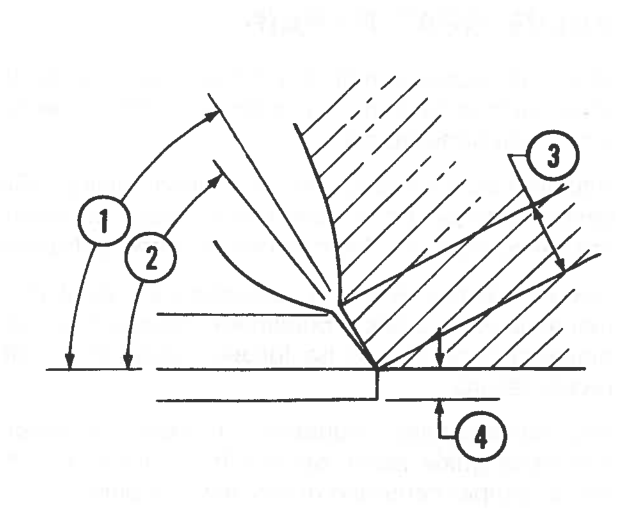
Valve seat reconditioning is very important, since seating of valves must be perfect for engine to deliver maximum power and performance.

Another important factor is valve head cooling. Good contact between each valve and its seat is important to ensure that heat in valve head will be properly dispersed.

Several different types of equipment are available for reseating valve seats. Equipment manufacturer's recommendations should be followed carefully to attain proper results.

Regardless of type of equipment, however, it is essential that valve guide bores be free from carbon or dirt to ensure proper centering of pilot in valve guide.

1. Install expanding pilot in valve-guide bore and expand pilot.
2. Place roughing stone or forming stone over pilot and clean up valve seat only. Use a stone that is cut to specifications.
3. Remove roughing stone or forming stone from pilot, place finishing stone (cut to specifications) over pilot and cut just enough metal from seat to provide a smooth finish. Refer to "Specifications."
4. Narrow down valve seats to specified width by grinding with a 300 stone to lower the seat and a 60 stone to raise the seat.
5. Remove expanding pilot, and clean cylinder head carefully to remove all chips and grindings from above operations.
6. Measure valve seat width. See "Specifications."
7. Measure valve seat out-of-round. See "Specifications."



1. Valve-seat angle
2. Valve-face angle
3. Valve-seat width
4. Valve-edge thickness

Figure 8-48. *Valve-Seat Grinding Angles*

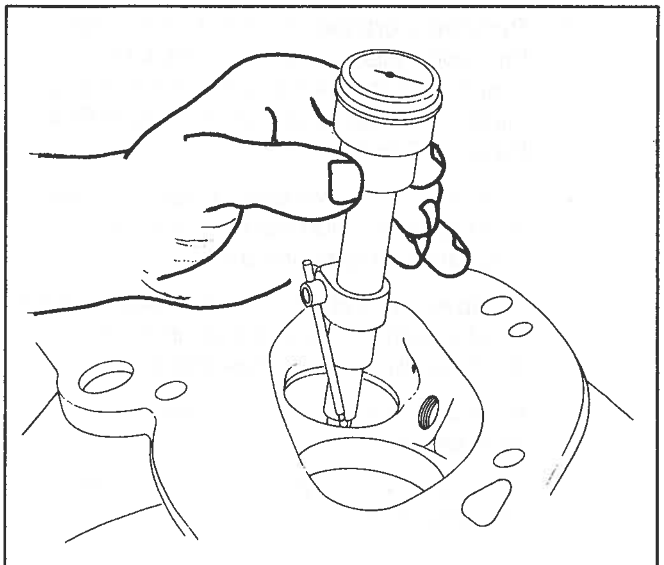


Figure 8-49. *Measuring Valve Seat*

VALVE REPAIR

Pitted valves can be refaced to proper angle on a valve grinder, thus insuring correct relation between cylinder-head seat and valve-mating surface. Replace valves with excessive wear on stems or valves which are over-used.

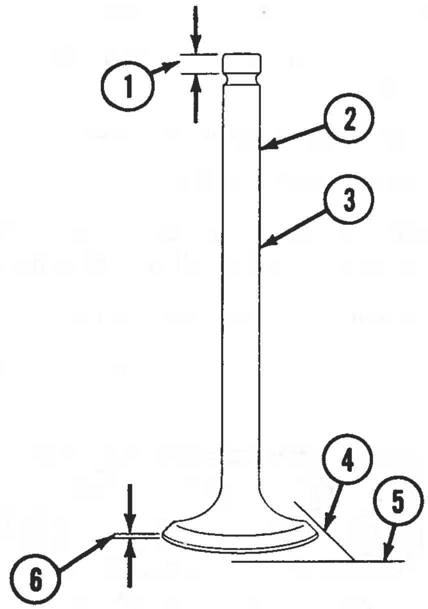
When an excessively warped valve head is refaced, a knife edge will be ground on part or all of the valve head due to amount of metal that must be removed to completely reface. Knife edges lead to breakage, burning or preignition caused by heat localizing in this knife edge. If edge of valve head is less than 1/32 in. (0.8 mm) after grinding, replace the valve.

Various equipment is available for refacing valves. Manufacturer's recommendations should be carefully followed to attain proper results.

1. If necessary, dress the valve-refacing-machine grinding wheel to make sure it is smooth and true. Set chuck at angle specified for valve. Refer to "Specifications."
2. Continue grinding until valve face is true and smooth all around the valve. If this makes valve head thin (1/32 in. [0.8 mm] minimum), valve must be replaced or valve will overheat and burn.
3. Remove valve from chuck and place stem in V-block. Feed valve squarely against grinding wheel to grind any pit from rocker-arm end of stem.

IMPORTANT: Only extreme end of valve stem is hardened to resist wear. Do not grind end of stem excessively.

4. After cleaning valve face and cylinder-head valve seat of grinding particles, make pencil marks about 1/4 in. (6 mm) across the valve face, place valve in cylinder head and give valve 1/2 turn in each direction while exerting firm pressure on its head.
5. Remove valve and check face carefully. If all pencil marks have not been removed at point of contact with valve seat, repeat refacing operation and again recheck for proper seating.

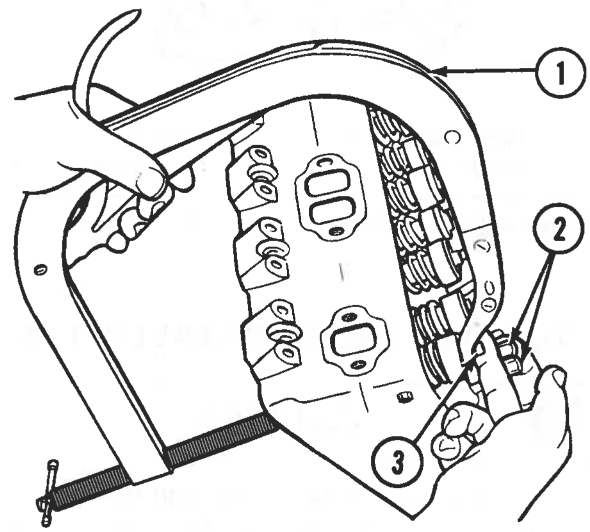


1. Refer to specifications for min. dimensions
2. Check for bent stem
3. Diameter
4. Valve-face angle
5. This line parallel with valve head
6. 1/32 in. minimum

Figure 8-50. *Critical Valve Dimensions*

VALVE REASSEMBLY

1. Lubricate valve guides and valve stems with engine oil.
2. Install each valve in the port from which it was removed or to which it was fitted.
3. Install valve-stem oil seal, spring(s) and related parts on each valve as explained under "Valve-Stem Oil Seal and/or Valve Spring."
4. Compress valve spring with tool J-8062.



1. J-8062 spring-compressor tool
2. Valve retainers
3. O-ring

Figure 8-51. *Compressing Valve Spring With Cylinder Head Removed*

5. Check installed height of the valve springs with a narrow, thin scale. A cutaway scale will help.

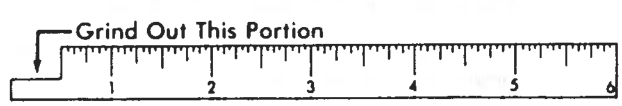
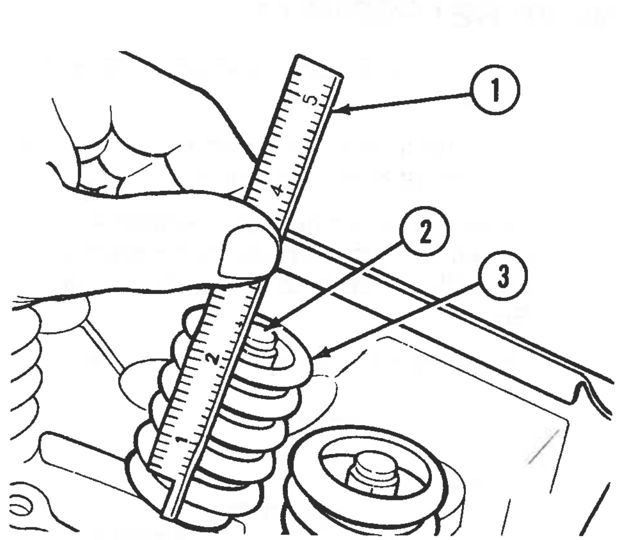


Figure 8-52. *Installed Valve-Height Measuring Tool*

6. Measure from top of spacer (spring seat) to top of valve spring. If measurement exceeds specified height, install a valve-spring seat shim approximately 1/16 in. (1.6 mm) thick. The spring should never be shimmed to give an installed height under the minimum specified.



1. Valve-installed-height gauge
2. Valve tip
3. Valve spring

Figure 8-53. Checking Installed Valve Height

CYLINDER HEAD INSTALLATION

CAUTION

Gasket surfaces on both head and block must be clean of any foreign matter and free of nicks or deep scratches. Cylinder-bolt threads in block and threads on cylinder-head bolts must be clean. Dirt will affect bolt torque.

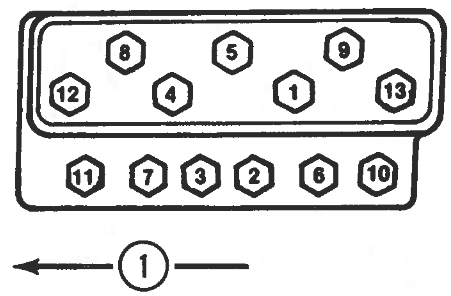
1. When using a stainless-steel gasket, coat both sides of new gasket with Perfect Seal. Spread sealer thin and even. Too much sealer may hold gasket away from head or block. If a fiber gasket is used, no sealer is required.

IMPORTANT: Do not use a carbon-steel gasket.

2. Place gasket in position over dowel pins.
3. Carefully guide cylinder head into place over dowel pins and gasket.
4. Coat threads of cylinder-head bolts with Perfect Seal and install bolts finger-tight.
5. Tighten each cylinder-head bolt a little at a time in sequence shown. Torque to specifications.
6. Install intake manifold as described.
7. Install and adjust valve mechanism as outlined in this Section.
8. Install valve covers as outlined.
9. Install spark plugs. Torque to 180 lb-in (20.3 N•m).
10. Install spark plug wire retainers.
11. Install exhaust manifolds.

IMPORTANT: Install any component that was removed from the front or aft end of cylinder head.

12. Run engine, adjust timing and check for leaks.



1. Forward

Figure 8-54. Cylinder-Head Tightening Sequence

OIL PAN

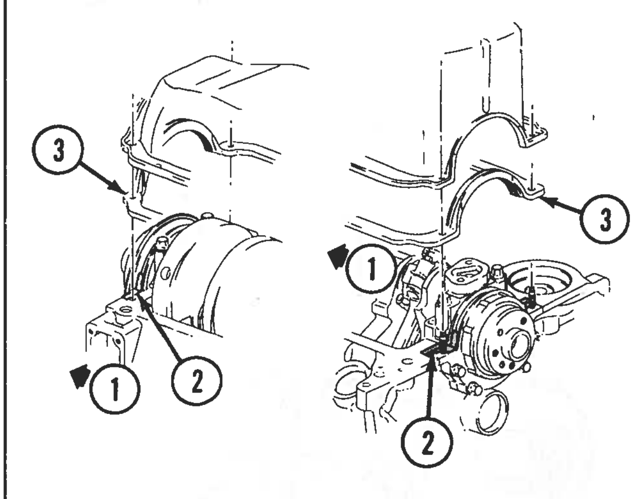
Removal:

1. Drain coolant.
2. Drain crankcase oil.
3. Remove oil dipstick and tube, if required.
4. Remove oil pan and discard gaskets.

Installation:

1. Thoroughly clean gasket and seal surfaces on oil pan, cylinder block, rear main bearing cap and crankcase front cover.
2. Coat both sides of oil pan side gaskets with Perfect Seal and place gaskets in position on each side of cylinder block.
3. Apply a 1/8-in. (3 mm) bead of RTV Sealer to front and rear seal-mating surfaces on cylinder-block rear main-bearing cap, front cover and gaskets.

IMPORTANT: RTV Sealer sets up in about 15 minutes. Be sure to complete assembly promptly.



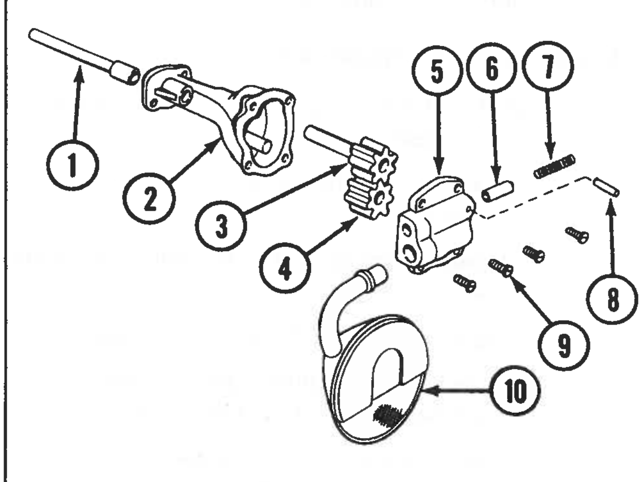
1. Forward
2. Sealant
3. Gasket

Figure 8-55. *Applying RTV Sealer For Oil Pan*

4. Install new front and rear seals, being sure ends of seals are butted properly against side gaskets.
5. Apply a 1/8-in. (3 mm) bead of RTV Sealer to outer surface of seals. This is extremely important on engines which have aluminum oil pans.
6. Carefully position oil pan against the block, being careful not to disturb gaskets and seals. Install oil-pan-attaching screws and washers. Torque screws to specifications, starting from center and working outward in each direction.
7. Install oil dipstick tube and dipstick.
8. Install engine in boat. Fill engine with oil, start engine and check for leaks.

OIL PUMP

The oil pump consists of two gears and a pressure regulator valve enclosed in a two-piece housing. The oil pump is driven by the distributor shaft which is driven by a helical ear on the camshaft.



1. Extension shaft
2. Pump body
3. Drive gear
4. Idler gear
5. Pump cover
6. Pressure regulator valve
7. Spring
8. Pin
9. Screw (4 used)
10. Pickup screen and pipe assembly

Figure 8-56. *Oil Pump Disassembled*

To eliminate pressure loss, a baffle is incorporated on the pickup screen and engine-oil-pump tubes are bent at special angles.

Removal:

1. Remove oil pan.
2. Remove pump to rear main bearing-cap bolt and remove pump and extension shaft.

Disassembly:

1. Remove pump-cover-attaching screws and pump cover.

IMPORTANT: Mark gear teeth so that pump can be reassembled with the same gear teeth indexed.

2. Remove idler gear, drive gear and shaft from pump body.
3. Remove retaining pin, pressure regulator valve and related parts.

IMPORTANT: Do not remove pickup screen and pipe assembly unless replacement is necessary. Loss of

press fit could result in an air leak and loss of oil pressure.

IMPORTANT: Do not disturb pickup screen on pipe. This is serviced as an assembly.

4. If pickup screen and pipe assembly require replacement, mount pump in a soft-jawed vise and extract pipe from pump.

Cleaning and Inspection:

1. Wash all parts in cleaning solvent and dry with compressed air.
2. Inspect pump body and cover for cracks or excessive wear.
3. Inspect pump gears for damage or excessive wear.
4. Check pump body for loose drive-gear shaft.
5. Inspect inside of pump cover for wear that would permit oil to leak past ends of gears.
6. Inspect pickup screen and pipe assembly for damage to screen or pipe.
7. Check pressure-regulator valve for fit.

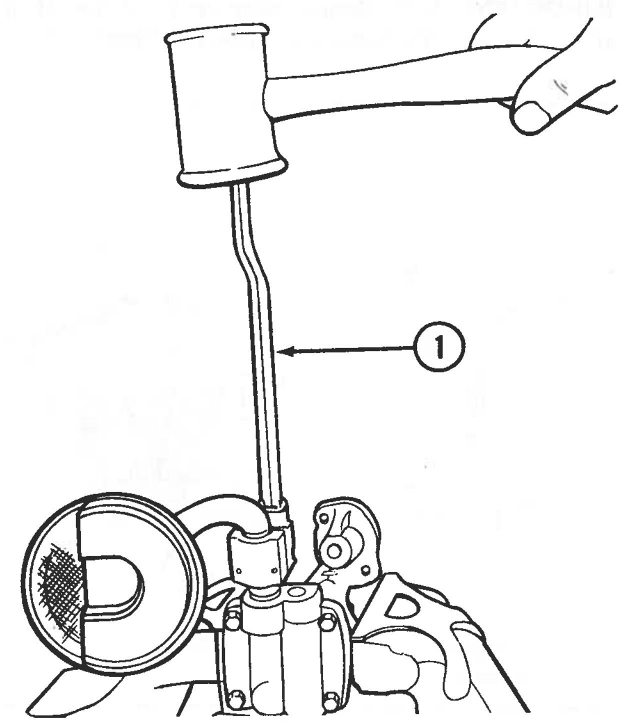
IMPORTANT: Pump gears and body are not serviced separately. If pump gears or body are damaged or worn, replacement of entire oil pump assembly is necessary.

Reassembly:

CAUTION

Be careful of twisting, shearing or collapsing pipe while installing in pump. Pickup screen must be parallel to oil-pan rails when oil pump is installed.

If the pump screen and pipe assembly were removed, secure pump in a soft-jawed vise, apply Perfect Seal to end of new pipe and, using tool (J-8369), tap the pipe in place with a hammer.



1. J-8369 tool

Figure 8-57. *Seating Oil-Pickup Tube*

IMPORTANT: Oil internal parts liberally before installation.

1. Install pressure regulator valve and related parts.
2. Install drive gear and shaft in pump body.
3. Install idler gear in pump body with smooth side of gear toward pump-cover opening. Align marks made in disassembly.
4. Install pump cover and torque attaching screws to specifications.
5. Turn drive shaft by hand to check for smooth operation.

Installation:

1. Assemble pump and extension shaft to rear main bearing cap, aligning slot on top end of extension shaft with drive tang on lower end of distributor drive shaft.
2. Install pump to rear main bearing cap and torque to specifications.

IMPORTANT: Oil-pump screen is installed with bottom edge parallel to the oil pan.

3. Install oil pan as outlined.

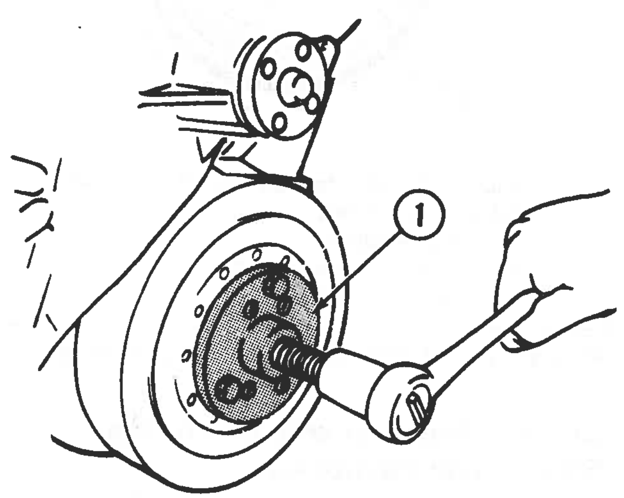
TORSIONAL DAMPER

Removal:

1. Remove drive belts.
2. Remove drive pulley, then remove damper retaining bolt.

IMPORTANT: Do not use a Universal claw-type puller to remove torsional damper as outside ring of damper is bonded in rubber to the hub and use of claw-type puller may break the bond.

3. Remove damper with tool J-23523-E.



1. J-23523-E torsional damper-puller tool

Figure 8-58. *Pulling Torsional Damper*

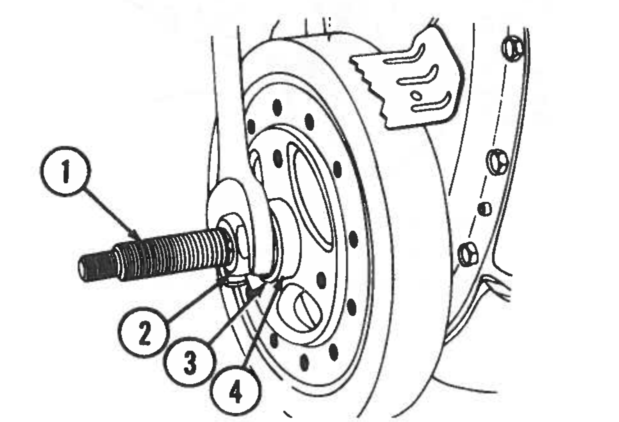
Installation:

IMPORTANT: The inertia weight section of the torsional damper is assembled to the hub with a rubber-type material. The installation procedure (with proper tool) must be followed or movement of the inertia weight on the hub will destroy the tuning of the torsional damper.

1. Coat front-cover seal-contact area on damper with engine oil.
2. Pull damper onto crankshaft, using tool J-23523-E as follows:
   a. Install appropriate end of threaded rod into crankshaft.

IMPORTANT: Be sure to install threaded rod in crankshaft so that at least 1/2 in. (13 mm) of thread engagement is obtained to prevent damage to threads.

   b. Install plate, thrust bearing, washer and nut on rod.
   c. Pull damper onto crankshaft by turning nut until it bottoms out.



1. Stud
2. Nut
3. Washer
4. Bearing

Figure 8-59. *Installing Torsional Damper*

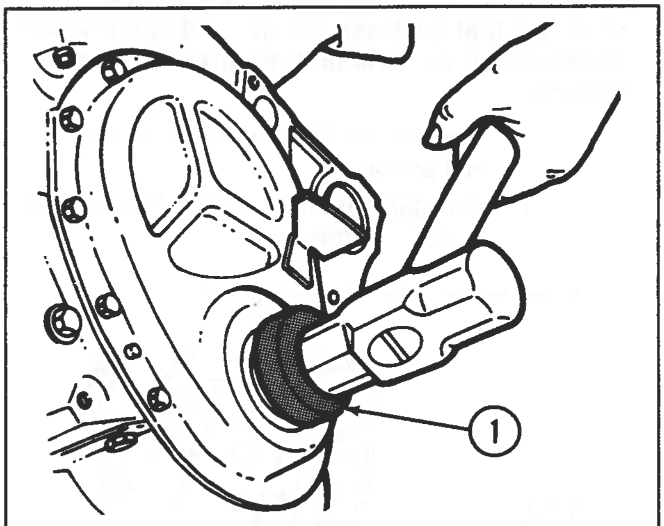
   d. Remove tool from crankshaft, then install damper-retaining bolt and torque to specifications.

3. Install drive pulley(s).
4. Install and adjust drive belts.

CRANKCASE FRONT COVER/OIL SEAL

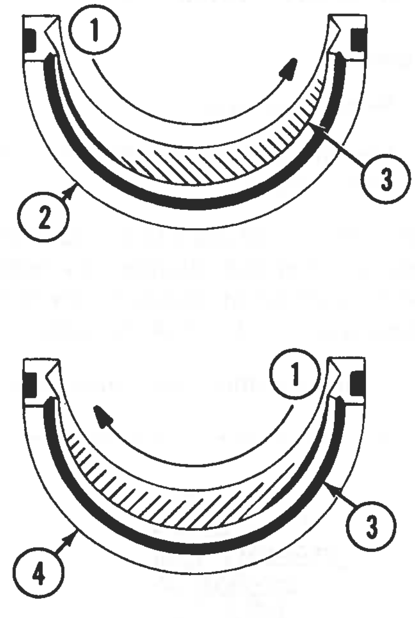
Oil Seal Replacement without Removing Crankcase Front Cover:

1. Remove torsional damper.
2. Pry seal out of cover from the front with a large screwdriver, being careful not to distort front cover or damage crankshaft-seal surface.
3. Install new seal with open end of seal inward using tool J-35468. Drive seal in until it just bottoms out. Do not use excessive force.
4. Reinstall torsional damper.



1. J-35468 seal installer tool

Figure 8-60. *Installing Front-Cover Oil Seal*



1. Rotation of crankshaft as viewed from flywheel end looking forward
2. LH rotation engines
3. Seal lip toward inside of engine
4. RH rotation engines

Figure 8-61. *Front Seals With Helical Grooves*

Oil Seal Removal with Crankcase Front Cover Removed:

1. Remove engine from boat.
2. Remove torsional damper and oil pan.
3. Remove water-circulating pump.
4. Remove crankcase front-cover-attaching screws and remove cover. Remove and discard cover gasket.
5. If damaged, drive oil seal out of front cover (from the rear) with a punch.

Oil Seal Installation with Crankcase Front Cover Removed:

IMPORTANT: The correct rotation oil seal must be used to prevent oil leak.

1. Clean front cover in solvent and dry with compressed air. Clean old gasket material and sealer from mating surfaces on cover and cylinder block. Check gasket surface on front cover for distortion and true if necessary. Surfaces must be clean and flat or oil leakage may result.
2. Install oil seal in cover with lip of seal toward the inside of the engine, using tool J-35468. Support cover around seal area with appropriate tool as shown.

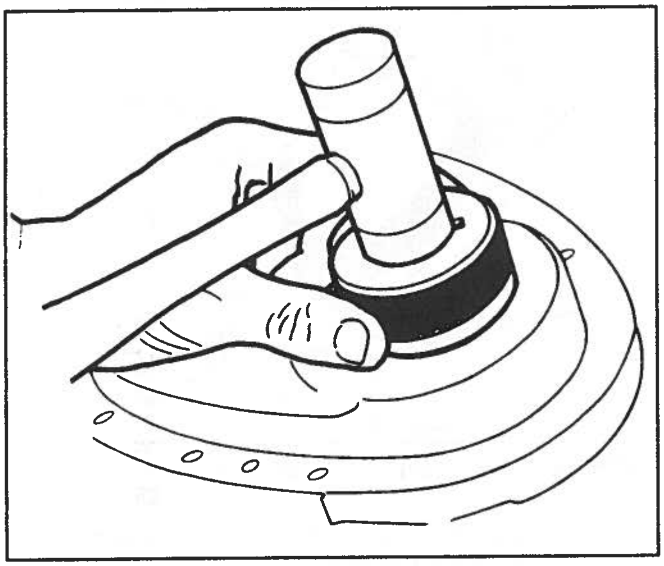


Figure 8-62. Installing Front Cover Oil Seal

3. Coat both sides of front cover gasket with Perfect Seal and place in position on engine.
4. Install front cover, making sure holes in cover align with dowel pins in block. Torque front cover to specifications.
5. Install oil pan and torsional damper as outlined.
6. Install water-circulating pump. Torque to specifications.
7. Reinstall engine in boat.
8. Fill crankcase with engine oil.
9. Start engine and check for water and oil leaks.

FLYWHEEL

Removal:

1. Remove transmission.
2. Remove flywheel housing and related parts.
3. Remove drive-damper-attaching screws and washers, and remove drive damper.
4. Remove flywheel-attaching screws and washers, and remove flywheel.

Inspection:

1. Check flywheel ring gear for worn or missing teeth.
2. Inspect drive damper for worn splines.

Installation:

1. Clean mating surfaces of flywheel and crankshaft.
2. Align dowel hole in flywheel with dowel hole in crankshaft flange and install flywheel.

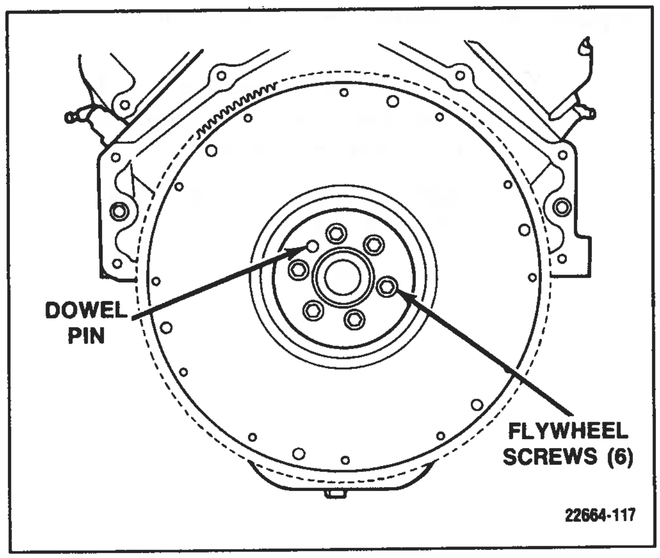
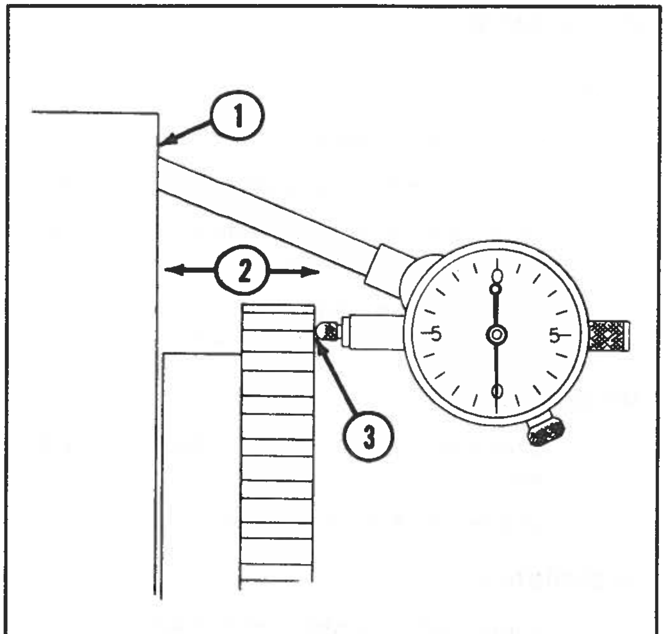


Figure 8-63. Installing Flywheel

3. Secure flywheel with screws and lock-washers. Torque to specifications.
4. Install drive damper and torque to specifications.
5. Check flywheel run-out by mounting dial indicator against machined surface of flywheel.



1. Rear of engine
2. Hold flywheel and crankshaft forward or rearward as far as they will go when taking reading.
3. 0.008 in. (0.203 mm) max. run-out

Figure 8-64. *Checking Flywheel Run-Out*

6. Run-out should not exceed 0.008 in. (0.203 mm). If excessive, remove flywheel and check for burrs, or replace flywheel.
7. Install flywheel housing and related parts. Torque bolts to specifications.
8. Install transmission.

REAR MAIN OIL SEAL

Two-Piece Rear Main Seal Removal:

Both halves of rear main-bearing oil seal can be replaced without removing crankshaft.

IMPORTANT: Always replace upper and lower seal as a unit. Install with lip facing toward inside of engine.

1. Remove oil pan and oil pump.
2. Remove rear main bearing cap.
3. Remove lower half of oil seal from the bearing cap by prying from the bottom with a small screwdriver. Be careful not to damage seal seating surface.

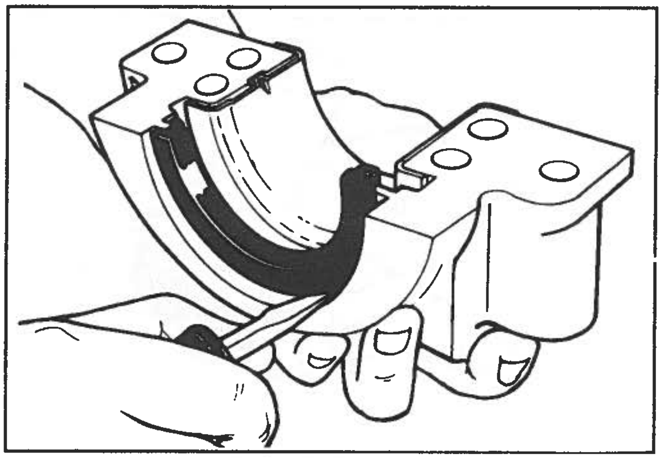


Figure 8-65. *Prying Out Rear Main Seal*

4. Using a hammer and a soft metal punch, tap upper half of oil seal on one end until it protrudes far enough on the other end to remove it with pliers.
5. Clean rear main bearing cap, cylinder block and crankshaft with solvent and blow dry with compressed air. Be sure all of the old sealer is removed from bearing cap and cylinder-block mating surfaces.

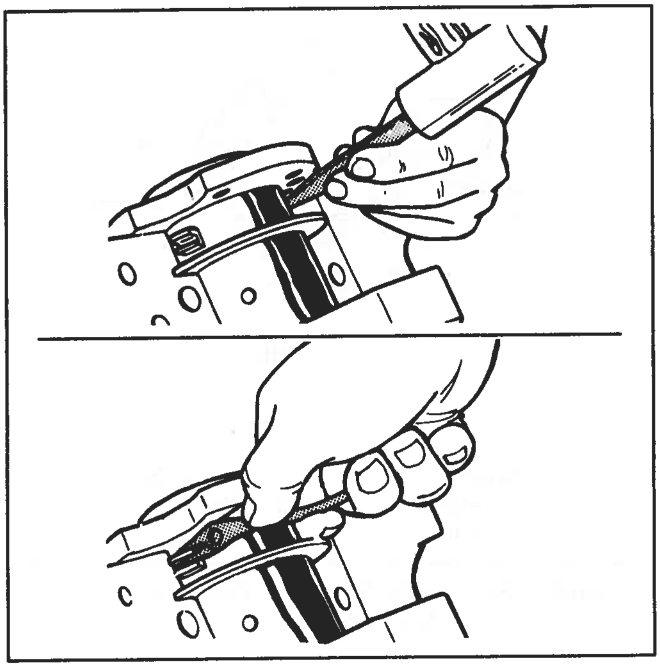
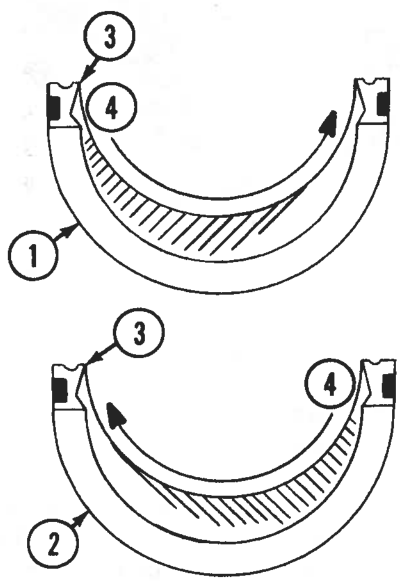


Figure 8-66. Removing Upper Rear Main Seal

Two-Piece Rear Main Seal Installation:



1. LH rotation engines
2. RH rotation engines
3. Seal lip toward inside of engine
4. Rotation of crankshaft as viewed from flywheel end looking forward

Figure 8-67. Rear Seals With Helical Grooves

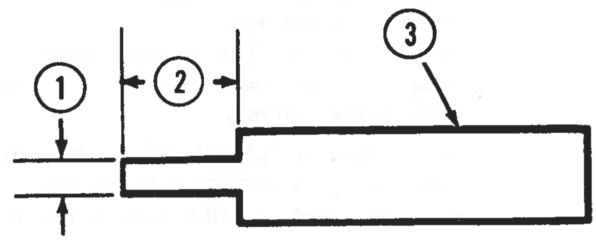
IMPORTANT: The correct rotation oil seal must be used to prevent oil leak.

Extreme care must be exercised when installing seal to prevent damage to sealing bead located in the channel on outside diameter of the seal. To protect this bead, installation tool must be used. Construct tool using 0.004 in. (0.1 mm) shim stock if tool is not supplied with seal.

1. Coat lips and sealing bead on new rear oil seal with engine oil. Keep oil off the seal-parting surfaces.

IMPORTANT: Be sure to install oil seal with lip facing toward inside of engine.

2. Install upper half of oil seal:
   a. Position tip of installation tool between crankshaft and seal-seating surface in cylinder block.
   b. Position upper half of seal between crankshaft and tip of installation tool so that seal bead contacts tips of tool.



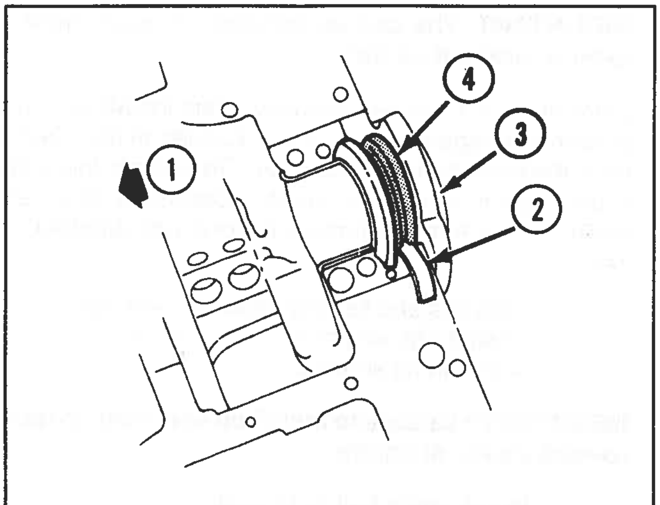
1. 11/64 in. (4 mm)
2. 1/2 in. (13 mm)
3. 0.004 in. (0.10 mm) shim-stock

Figure 8-68. Rear Main Seal Installation Tool

   c. Roll upper half of seal around crankshaft using installation tool as a shoehorn to protect seal bead from sharp corner of seal-seating surface.

IMPORTANT: Installation tool must remain in position until seal is properly positioned with both ends flush with block.

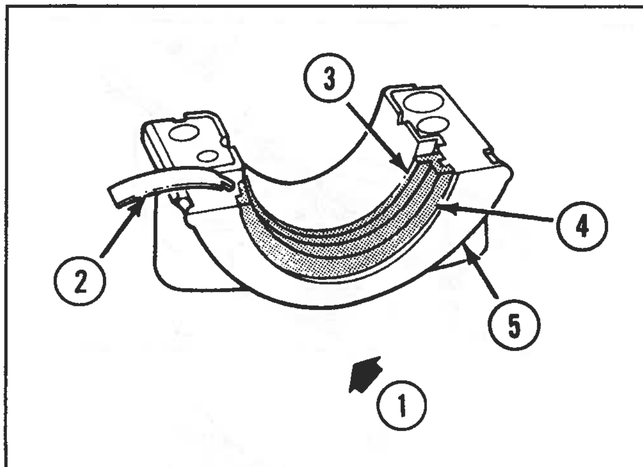
   d. After both ends of seal half are flush with block, remove installation tool.



1. Forward
2. Fabricated tool
3. Crankshaft
4. Upper seal half

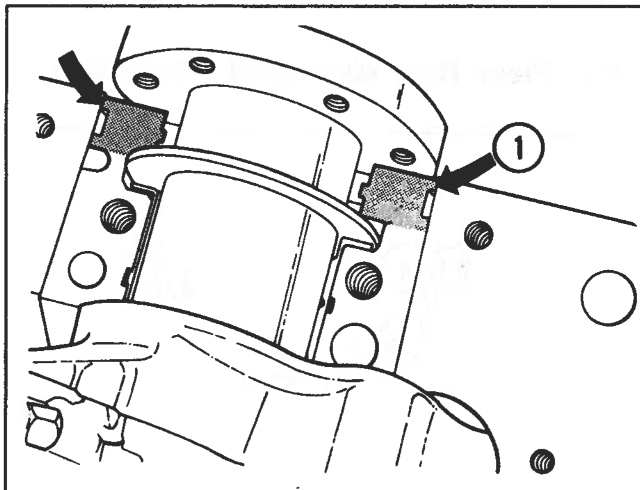
Figure 8-69. *Using Rear Main Seal Installation Tool On Upper Seal*

3. Install lower half of oil seal:
   a. Position oil-seal half in rear main bearing cap so that one end is slightly below mating surface and seal lip is facing toward bearing. Do not allow sealing bead on other end of seal half to contact seal-seating surface.
   b. Insert the installation tool between sealing bead and seal-seating surface; then, using installation tool as a shoehorn to protect sealing bead from sharp corner of seal-seating surface, roll seal into place. Seal is properly positioned when both ends are flush with cap.
   c. Remove installation tool.
4. Make sure that bearing cap and cylinder-block mating surfaces and oil-seal parting surfaces are clean and free of oil, then apply Perfect Seal to block at locations shown. Do not get sealer on seal-parting surfaces or on surfaces adjacent to main bearing inserts.



1. Forward
2. Fabricated tool
3. Oil-seal lip
4. Lower seal half
5. Main bearing cap

Figure 8-70. *Using Rear Main Seal Installation Tool On Lower Seal*



1. Apply Perfect Seal to outlined area only

Figure 8-71. *Applying Sealer To Block At Rear Main Seal*

5. Install rear main bearing cap and torque attaching bolts to 10-12 lb-ft (13-16 N•m). Tap crankshaft first rearward and then forward with a lead hammer to line up rear main bearing-thrust surfaces. With crankshaft in forward position, torque rear main bearing-cap-attaching bolts evenly (alternating from side to side).
6. Install oil pump and oil pan as outlined above.

One-Piece Rear Main Seal Removal:

The one-piece rear crankshaft-oil seal can be replaced without removing the oil pan or rear main bearing cap from engine. Transmission and flywheel removal is required.

NOTE: Care should be taken when removing the rear crankshaft-oil seal so as not to nick the crankshaft-sealing surface.

1. Insert a screwdriver into the notches provided in the seal retainer and pry the seal out. Take care not to damage the crankshaft-sealing surface.

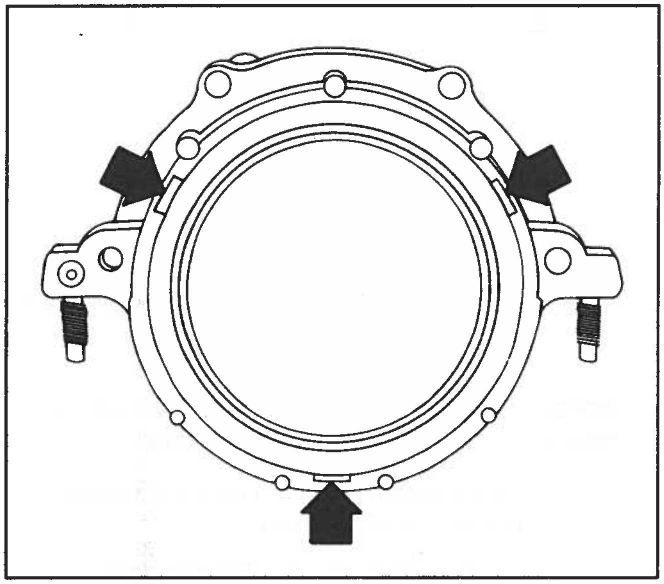
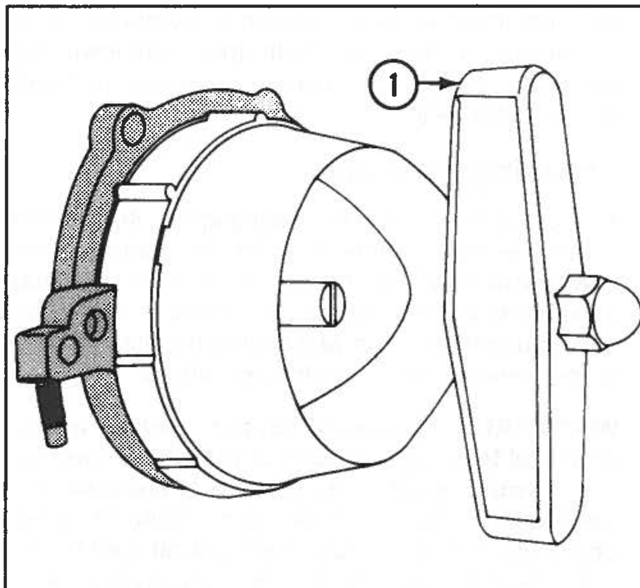


Figure 8-72. *Removing One-Piece Rear Main Oil Seal*

2. Clean crankshaft-seal running surface and seal retainer.

One-Piece Rear Main Seal Installation:

1. Lubricate the inner and outer diameter of the seal with engine oil.
2. Install the seal using the J-35621 tool.



1. J-35621 Rear-main-seal installer tool

Figure 8-73. *Installing One-Piece Rear Main-Oil Seal*

3. Position the J-35621 tool against the crankshaft. Thread the attaching screws into the tapped holes in the crankshaft.
4. Tighten the screws securely with a screwdriver. This will ensure that the seal is installed squarely over the crankshaft.
5. Turn the handle until it bottoms.
6. Remove the J-35621 tool.

MAIN BEARINGS

Inspection:

In general (except No. 1 bearing), lower half of bearing shows a greater wear and most distress from fatigue. After inspection, if lower half is suitable for use, it can be assumed that the upper half also is satisfactory. If lower half is worn or damaged, both upper and lower halves should be replaced. Never replace one half without replacing the other.

Checking Clearance:

To obtain best results, use Plastigage (or its equivalent), a wax-like plastic material which will compress evenly between bearing and journal surfaces without damaging either surface. With engine upside down, crankshaft will rest on upper bearings, and total clearance can be measured between lower bearing and journal.

IMPORTANT: To assure proper seating of crankshaft, all bearing-cap bolts should be at their specified torque. In addition, surface of crankshaft journal and bearing should be wiped clean of oil before checking fit of bearings. Remove oil seal from rear main bearing cap prior to checking clearance.

1. With oil pan and oil pump removed (starting with rear main bearing), remove bearing cap and wipe oil from journal and bearing cap.

Main bearings are precision-insert-type and do not utilize shims for adjustment. If clearances are excessive, a new bearing (both upper and lower halves) will be required. Bearings are available in standard size and undersize. Selective fitting of both rod and main bearing inserts is necessary in production to obtain close tolerances. Consequently, one half of a standard insert may have one half of a 0.001-in. (0.025 mm) undersized insert which will decrease clearance 0.0005 in. (0.013 mm) from using a full standard bearing.

When a production crankshaft cannot be precision-fitted by this method, it then is ground 0.009 in. (0.23 mm) undersize on main journals only. A 0.009-in. (0.23 mm) undersized bearing and a 0.010 in. (0.25 mm) undersized bearing may be used for precision fitting in the same manner as previously described. Any engine fitted with a 0.009-in. (0.23 mm) undersized crankshaft will be identified by the following markings:

Number 0.009 will be stamped on crankshaft counterweight forward of center main journal.

A figure 9 will be stamped on block at left front oil-pan rail.

A crankshaft with an undersized journal will be painted light green on each side of the affected journal.

IMPORTANT: If crankshaft has an undersized journal and a new bearing is required, journal must be reconditioned to accept a 0.010 in. (0.25 mm) or a 0.020 in. (0.51 mm) undersized bearing as 0.009 in. (0.23 mm) undersized bearings are not available for service.

2. Place a piece of gauging plastic full width of bearing (parallel to crankshaft) on journal.

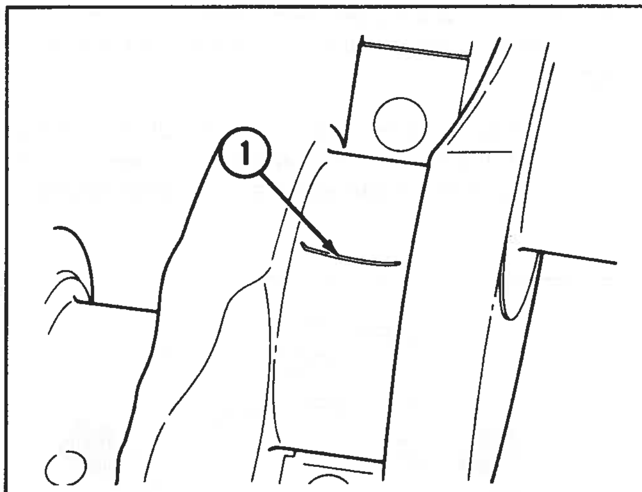
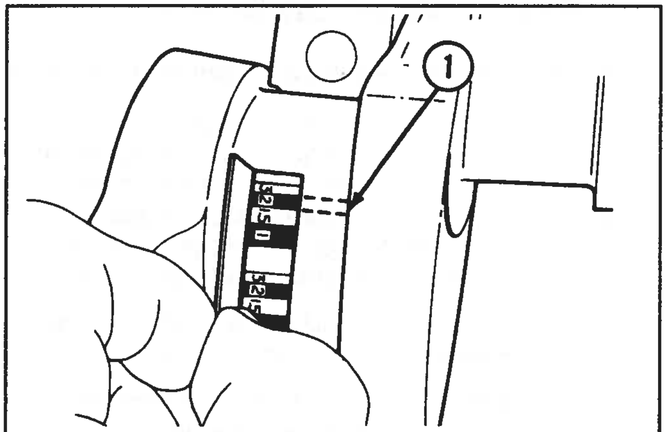


Figure 8-74. Placing Plastic Gauging Material On Journal

IMPORTANT: Do not rotate crankshaft while gauging plastic is between bearing and journal.

3. Install bearing cap and torque retaining bolts evenly to specifications.
4. Remove bearing cap. Flattened gauging plastic will be found adhering to either bearing shell or journal.
5. Use graduated scale (marked in thousandths of an inch) on edge of gauging plastic envelope. Without removing plastic, measure its compressed width (at widest point) with graduated scale.

IMPORTANT: Main bearing journals usually wear evenly and are not out- of-round. If a bearing is being fitted into an out-of-round journal (0.001 in. [0.025 mm] maximum), however, be sure to fit bearing to the maximum diameter of the journal. If bearing is fitted to minimum diameter, and journal is out-of-round (0.001 In. [0.025 m m]), interference between bearing and journal will result in rapid bearing failure. If flattened gauging plastic tapers toward middle or ends, there is a difference in clearance indicating taper, low spot or other irregularity of bearing or journal. Be sure to measure journal with a micrometer if flattened gauging plastic indicates more than 0.001 in. (0.025 mm) difference.



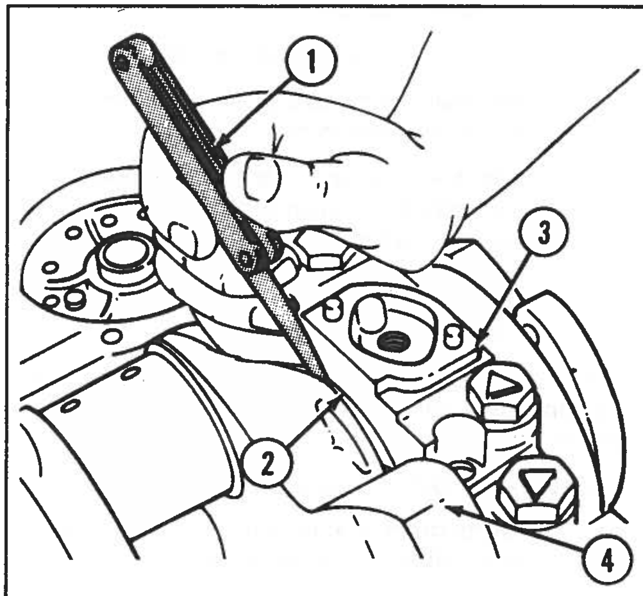
1. Measuring gauging plastic

Figure 8-75. Measuring Bearing Clearance With Plastic Gauging Material

6. If bearing clearance is within specifications, bearing insert is satisfactory. If clearance is not within specifications, replace the insert. Always replace both upper and lower insert as a unit.

IMPORTANT: If a new bearing cap is being installed and clearance is less than 0.001 in. (0.025 mm), inspect for burrs or nicks.

7. A standard 0.001-in. (0.025 mm) or 0.002-in. (0.050 mm) undersized bearing may produce proper clearance. If not, regrind crankshaft journal for use with next undersized bearing.
8. Proceed to next bearing. After all bearings have been checked, rotate crankshaft to see that excessive drag does not exist.
9. Install front three main bearing caps and torque evenly to specifications.
10. Install rear main bearing cap and torque attaching bolts to specifications. Tap end of crankshaft, first rearward and then forward, with a hammer to align rear main bearing-thrust surfaces. With crankshaft in forward position, torque rear main bearing-attaching bolts evenly (alternating from side to side) to specifications.
11. Measure crankshaft end-play with a feeler gauge by forcing crankshaft forward and measuring clearance between the front of the rear main bearing and the crankshaft. If clearance is excessive, rear main bearing and/or crankshaft must be replaced.
12. Install a new rear main bearing-oil seal in cylinder block and main bearing cap, as outlined above.



1. Feeler gauge
2. Main bearing thrust surface
3. Rear main bearing cap
4. Crankshaft

Figure 8-76. Measuring Crankshaft End-Play

Replacement:

IMPORTANT: Main bearings may be replaced with or without removing crankshaft.

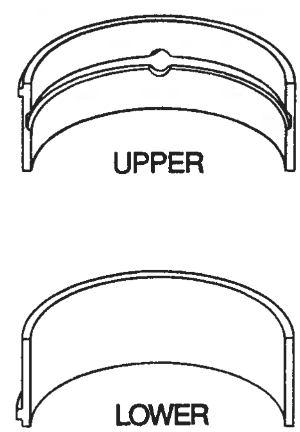


Figure 8-77. Identifying Upper And Lower Main Bearing Inserts

With Crankshaft Removed

1. Remove and inspect crankshaft.
2. Remove main bearings from cylinder block and main bearing caps.
3. Coat the bearing surfaces of the new, correctly-sized main bearings with oil and install in cylinder block and main bearing caps.
4. Install crankshaft.

Without Crankshaft Removed

With oil pan, oil pump and spark plugs removed, remove cap on main bearing requiring replacement and remove bearing from cap.

Replace main bearing upper half as follows:

1. Install main bearing removing and installing tool J-8080 in crankshaft-journal oil hole.

IMPORTANT: If tool is not available, bend a cotter pin.

2. Rotate crankshaft clockwise (as viewed from front of engine). This will roll upper bearing out of block.
3. Oil new (selected-size) upper bearing. Insert plain (unnotched) end between crankshaft and notched side of block. Rotate bearing into place and remove tool from oil hole in crankshaft journal.
4. Oil new lower bearing and install in bearing cap.
5. Install main bearing cap with arrows pointing toward front of engine.
6. Torque main bearing-cap bolts to specifications.

CONNECTING-ROD BEARINGS

Inspection and Replacement of Bearings:

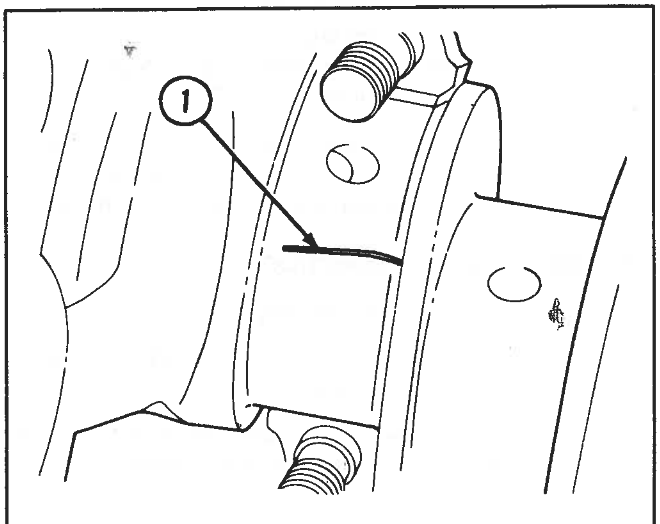
Connecting-rod bearings are precision-insert-type and do not require shims for adjustment. Do not file rods or rod caps. If clearances are found to be excessive, a new bearing will be required. Bearings are available in standard size and undersized for new and used standard-size crankshafts and reconditioned crankshafts.

1. With oil pan and oil pump removed, remove connecting-rod cap and bearing.
2. Inspect bearing for wear or damage and replace unsatisfactory bearings.
3. Wipe bearings and crankpin clean of oil.
4. Measure crankpin for out-of-round or taper with a micrometer. If not within specifications, replace or recondition crankshaft. If within specifications, and a new bearing is to be installed, measure maximum diameter of crankpin to determine new bearing size required.
5. Measure new or used bearing clearances with Plastigage or equivalent.

IMPORTANT: If a bearing Is being fitted to an out-of-round crankpin, be sure to fit to maximum diameter of crankpin. If bearing is fitted to minimum diameter, and crankpin is out-of-round 0.001 (0.025 mm) or more, interference between bearing and crankpin will result in rapid bearing failure.

a. Install bearing in connecting rod and cap.
b. Place a piece of gauging plastic the full width of crankpin (parallel to crankshaft).
c. Install bearing cap and torque nuts evenly to specifications.

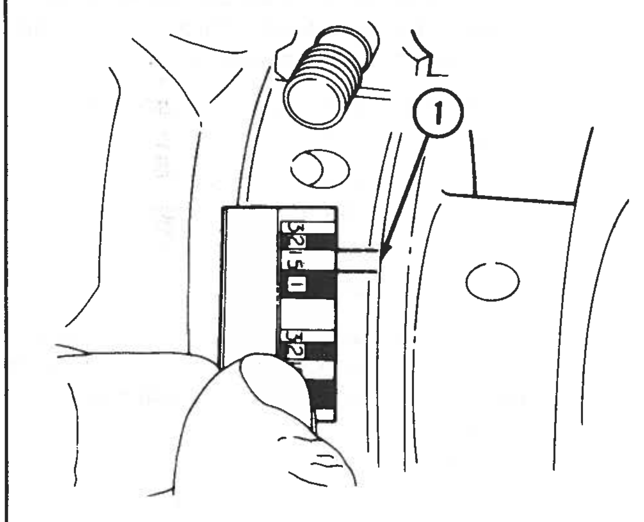
IMPORTANT: Do not turn crankshaft with gauging plastic installed.



1. Gauging plastic

Figure 8-78. Gauging Plastic on Crankpin

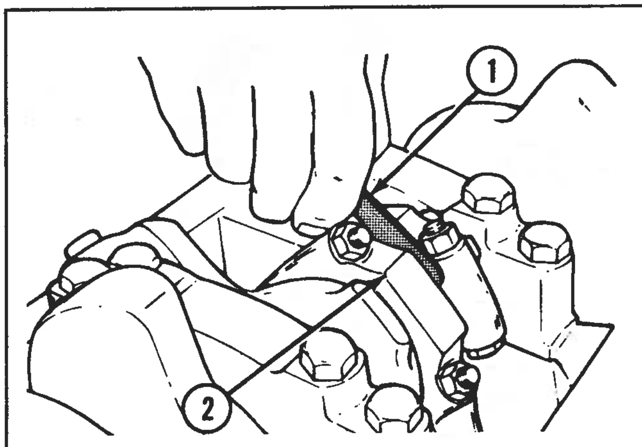
d. Remove bearing cap. Using scale on gauging plastic envelope, measure gauging plastic width at the widest point.



1. Gauging plastic
2. Chart from gauging-plastic package

Figure 8-79. Measuring Bearing Clearance With Plastic Gauging Material

6. If clearance exceeds specifications, select a new, correctly-sized bearing and recheck clearance.
7. Coat bearing surface with oil, install rod cap and torque nuts to specifications.
8. When all connecting-rod bearings have been installed, tap each rod lightly (parallel to crankpin) to make sure they have clearance.
9. Measure all connecting-rod side clearances (see "Specifications") between connecting rod caps.



1. Feeler gauge
2. Connecting rods

Figure 8-80. Measuring Connecting-Rod Side Clearance

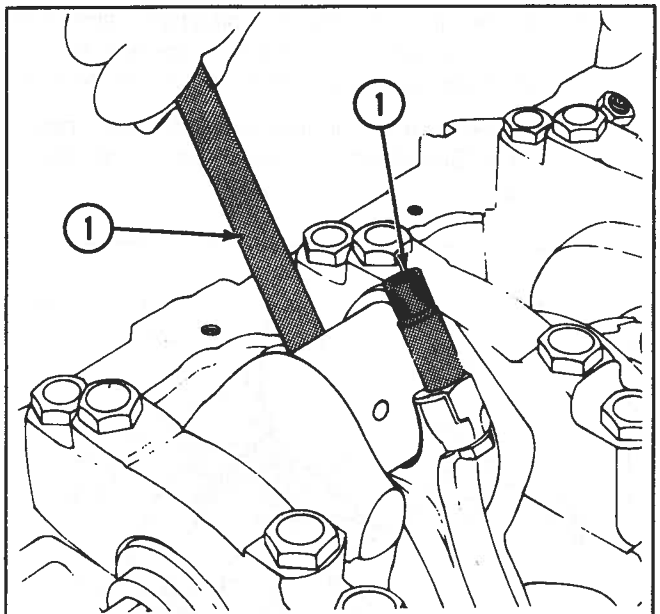
PISTON ASSEMBLY

Removal:

IMPORTANT: Before ridge and/or deposits are removed, turn crankshaft until piston is at bottom of stroke and place a cloth on top of piston to collect cuttings. After ridge and/or deposits are removed, turn crankshaft until piston is at top of stroke, then remove cloth and cuttings.

1. With oil pan, oil pump and cylinder head removed, use a ridge reamer to remove any ridge and/or deposits from upper end of cylinder bore.
2. Mark connecting rod and bearing caps; left bank 1, 3, 5, and right bank 2, 4, 6, from front to rear on same side as piston thrust.
3. Remove connecting-rod cap and install tool J-5239 (3/8 in. [9.4 mm]) on bolts. Push connecting rod and piston assembly out of top of cylinder block.

NOTE: It will be necessary to turn crankshaft slightly to disconnect and remove some connecting rod and piston assemblies.

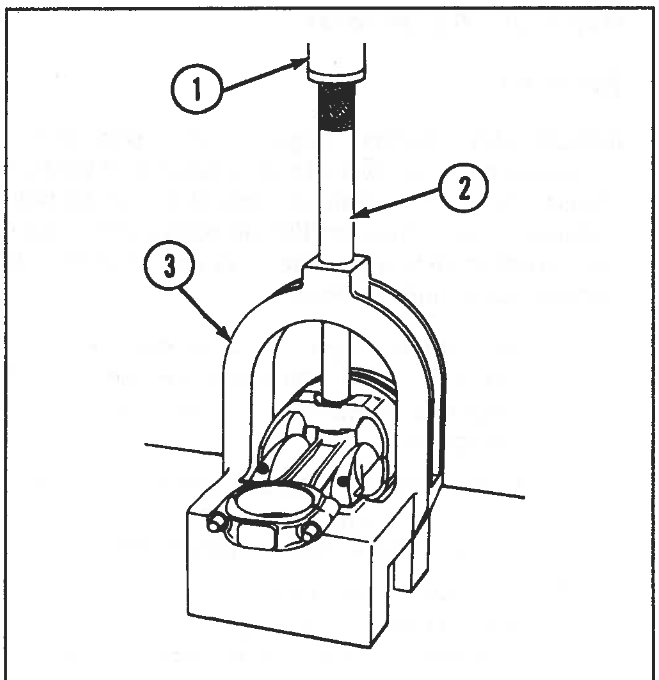


1. J-5239 tool

Figure 8-81. *Pushing Out Connecting Rod and Piston Assembly*

Disassembly:

1. Use Tool Kit J-24086-B.



1. Ram
2. J-24086-8A Tool
3. J-24086-20A Tool

Figure 8-82. *Tool Kit J-24086-B*

2. Position connecting rod onto tool-rod support with rod support inserted between connecting-rod end and piston. Align piston pin with hole located in top of arched base.
3. Insert pin remover through the hole located in top of arched base and into piston pin hole. Press on pin remover to remove piston pin.

Cleaning and Inspection:

To clean and inspect connecting rods:

1. Wash connecting rods in cleaning solvent and dry with compressed air.
2. Check for twisted or bent rods and inspect for nicks or cracks. Replace damaged connecting rods.

To clean and inspect pistons:

1. Clean varnish from piston skirts and pins with a cleaning solvent. Do not wire-brush any part of piston. Clean ring grooves with a groove cleaner and make sure oil-ring holes and slots are clean.
2. Inspect piston for cracked ring lands, skirts or pin bosses, wavy or worn ring lands, scuffed or damaged skirts, or eroded areas at top of piston. Replace pistons which are damaged or show signs of excessive wear.
3. Inspect grooves for nicks or burrs that might cause rings to hang up.
4. Measure piston skirt and check clearance as outlined under "Cylinder Block – Piston Selection."

To clean and inspect piston pins:

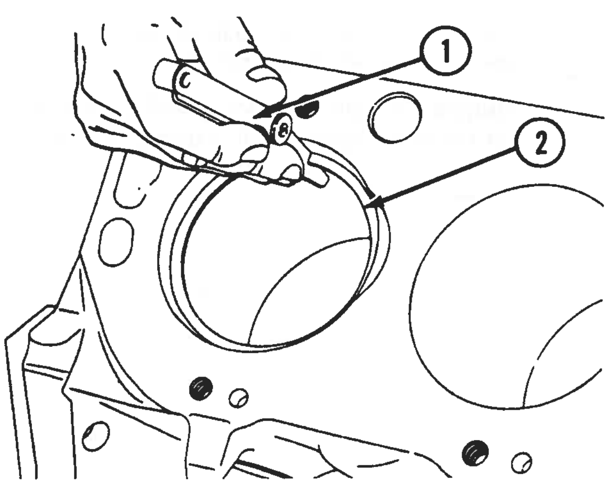
1. Piston pin clearance is designed to maintain adequate clearance under all engine-operating conditions. Because of this, piston and piston pin are a matched set and not serviced separately.
2. Inspect piston-pin bores and piston pins for wear. Piston-pin bores and piston pins must be free of varnish or scuffing when measured. Measure piston pin with a micrometer and piston-pin bore with a dial-bore gauge or inside micrometer. If clearance is in excess of the 0.001-in. (0.025 mm) wear limit, replace piston and piston pin assembly.

To fit piston rings:

All compression rings are marked on upper side of ring. When installing compression rings, make sure that marked side is toward top of piston.

Oil-control rings are three-piece-type, consisting of two segments (rails) and a spacer.

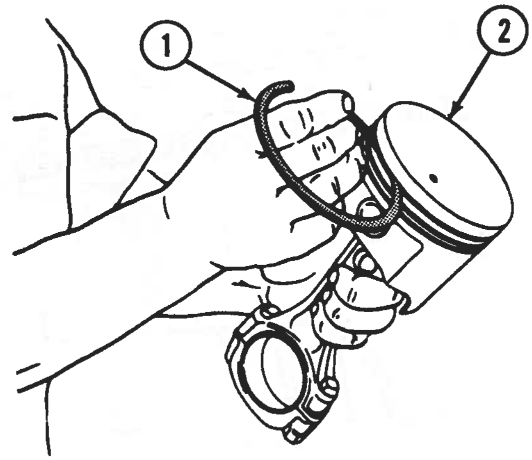
1. Select rings appropriate in size to piston being used.
2. Slip compression ring into cylinder bore, then press ring down into cylinder bore approximately 1/4 in. (6 mm) (below ring travel). Be sure that ring is square with cylinder wall.
3. Measure gap between ends of ring with a feeler gauge.



1. Feeler gauge 2. Piston ring

Figure 8-83. *Measuring Piston Ring End-Gap*

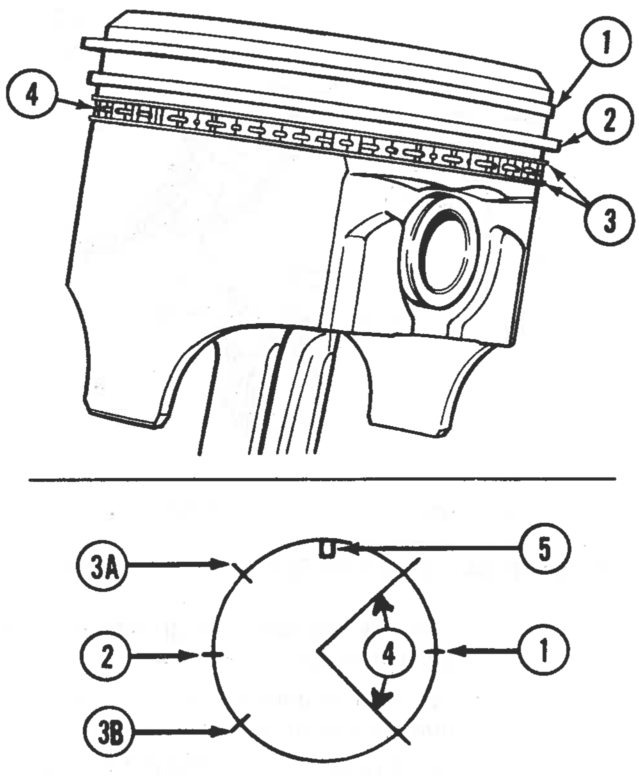
4. If gap between ends of ring is below specifications, remove ring and try another for fit.
5. Fit each compression ring to a cylinder in which it is going to be used.
6. Clean and inspect pistons, if not previously done.
7. Slip outer surface of top and second compression ring into respective piston-ring groove and roll the ring entirely around the groove to make sure that the ring is free. If binding occurs at any point, determine cause. If caused by ring groove, remove by dressing with a fine cut file. If binding is caused by a distorted ring, use a new ring.
8. Install piston ring as shown. Use piston-ring expanders for compression ring installation.



1. Piston ring 2. Piston

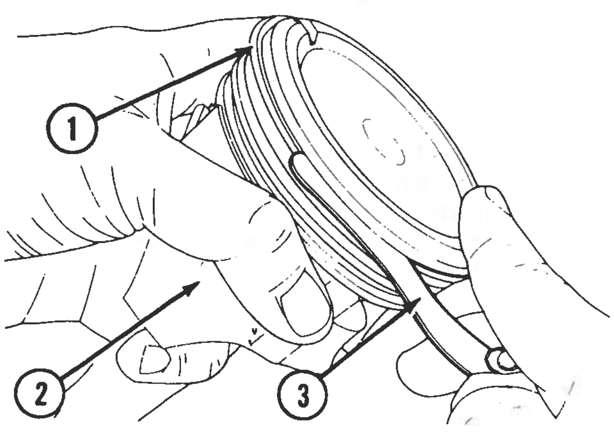
Figure 8-84. *Checking Piston Ring Fit In Groove*

   a. Install oil-ring spacer in groove and insert antirotation tang in oil hole.
   b. Hold spacer ends butted and install lower steel oil-ring rail with gap properly located.
   c. Install upper steel oil-ring rail with gap properly located.
   d. Flex the oil-ring assembly to make sure ring is free. If binding occurs at any point, the cause should be determined and, if caused by ring groove, remove by dressing groove with a fine cut file. If binding is caused by a distorted ring, use a new ring.
   e. Install lower compression ring, using ring expander and check location of gap.
   f. Install top compression ring with gap properly located.
9. Proper clearance of piston ring in its piston-ring groove is very important to provide proper ring action and reduce wear. Therefore, when fitting new rings, clearances between ring and groove surfaces should be measured. See "Specifications."



1. Top compression ring and gap location
2. Second compression ring and gap location
3. A and B oil ring rails and gap location
4. Oil ring spacer and ends location
5. Piston notch

Figure 8-85. *Piston-Ring Gap Alignment*



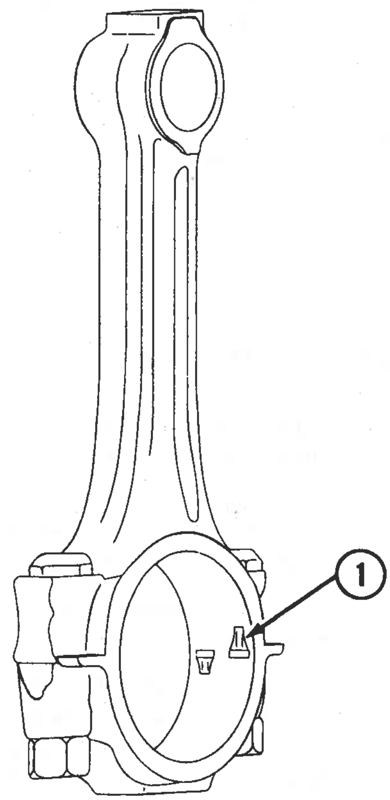
1. Piston ring
2. Piston
3. Feeler gauge

Figure 8-86. *Measuring Piston-Ring Clearance*

Reassembly:

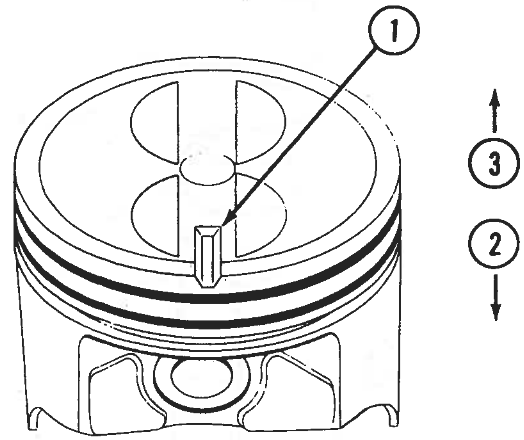
IMPORTANT: When reassembling pistons and connecting rods, the following must be kept in mind:

- Piston and pin are machine-fitted to each other and must remain together as a matched set. Do not intermix pistons and pins.
- If original pistons and/or connecting rods are being used, be sure to assemble pistons and connecting rods so they can be reinstalled in same cylinder from which they were removed.
- Connecting-rod bearing tangs are always toward outside of cylinder block.
- Reference mark on piston must be positioned correctly for engine that is being repaired.



1. Connecting-rod-bearing tang

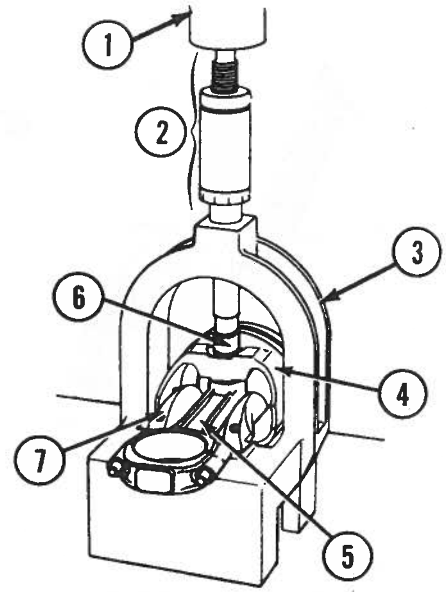
Figure 8-87. *Connecting-Rod-Bearing Tangs Orientation*



1. Notch
2. Notch goes toward front of engine on LH rotation engines
3. Notch goes toward rear of engine on RH rotation engines

Figure 8-88. *Piston Orientation*

1. Install piston pin with Tool Kit J-24086-B. Refer to chart (furnished with tool) and select proper-size piston-pin guide for specific engine being worked on.
2. Lubricate piston pin, piston-pin hole and hole in rod end with a light coat of engine oil.
3. Position rod onto rod support and piston onto rod end. Insert piston-pin guide through bottom of piston-pin hole and into connecting rod. Place piston pin through top side of piston.
4. Adjust installer to setting specified on chart which came with tool for particular piston installation. Lock adjustable installer with jam nut.
5. Insert adjustable installer through hole located on top of arched base and into piston-pin hole. Carefully press on adjustable installer until installer bottoms out on arched base to install piston pin.



1. Press ram
2. Adjustable installer J-24086-9
3. Support fixture J-24086-20
4. Piston
5. Connecting rod
6. Piston pin
7. Connecting-rod support

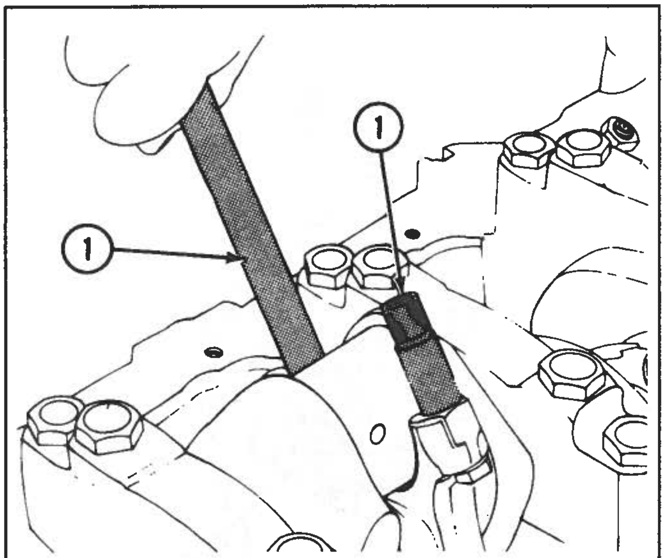
Figure 8-89. *Installing Piston Pin*

6. Check piston for freedom of movement in piston-pin bore by moving connecting rod back and forth and up and down. Connecting rod should move freely (with no resistance) in both directions. If it does not, piston pin is tight in piston-pin bore, and piston and pin assembly must be replaced.
7. If a new connecting rod has been installed, mark connecting rod and cap (on side of rod and cap with slots for connecting-rod bearing tangs) with cylinder number in which it will be installed.

Installation:

IMPORTANT: Cylinder bores must be clean before piston installation. Clean with a light honing, as necessary, then clean with hot water and detergent wash. After cleaning, swab bores several times with light engine oil and a clean cloth, then wipe with a clean, dry cloth.

1. Lubricate connecting-rod bearings and install in rods and rod caps.
2. Lightly coat pistons, rings and cylinder walls with light engine oil.
3. With bearing caps removed, install tool J-5239 (3/8 in. [9.4 mm]) on connecting-rod bolts.



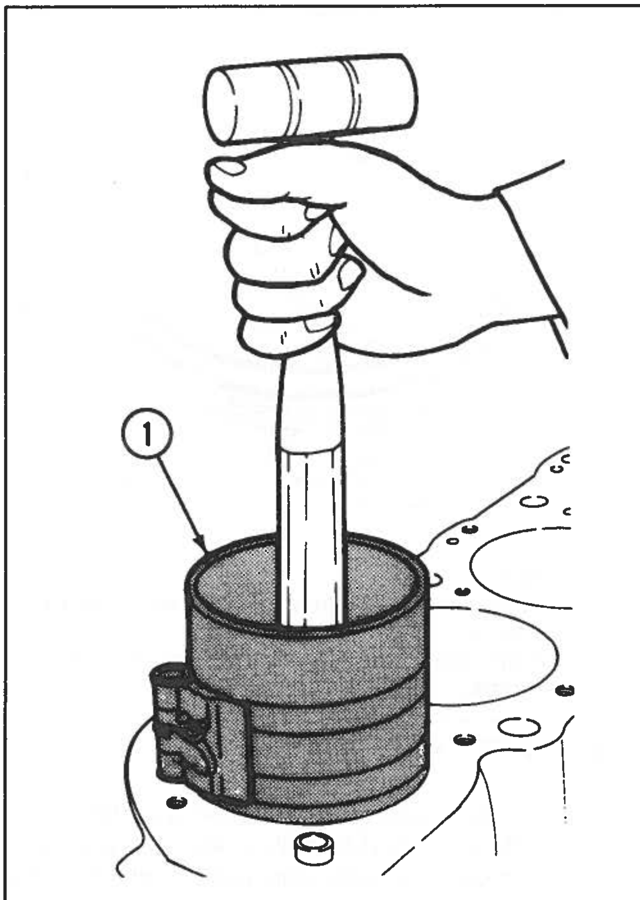
1. J-5239 tool

Figure 8-90. *Pulling Assembled Piston And Connecting Rod Into Place*

IMPORTANT: Be sure ring gaps are properly positioned as previously outlined.

4. Install each connecting rod and piston assembly in its respective bore. Install with connecting-rod bearing tangs toward outside of cylinder block. Use tool J-8037 to compress rings. Guide connecting rod into place on crankshaft journal with tool J-5239. Using a hammer handle, tap with light blows to install piston into bore. Hold ring compressor firmly against cylinder block until all piston rings have entered cylinder bore.

IMPORTANT: Be sure to install new pistons in same cylinders for which they were fitted, and used pistons in same cylinder from which they were removed. Each connecting rod and bearing cap should be marked, beginning at front of engine (1, 3, 5 in left bank and 2, 4, 6 in right bank). Numbers on connecting rod and bearing cap must be on same side when installed in cylinder bore. If a connecting rod is ever transposed from one block or cylinder to another, new bearings should be fitted and connecting rod should be numbered to correspond with new cylinder number.



1. Piston ring compressor

Figure 8-91. *Tapping Piston Into Cylinder*

5. Remove tool J-5239.
6. Install bearing caps and torque nuts to 45 lb-ft (61 N•m).
7. Check connecting-rod side clearance.

IMPORTANT: If bearing replacement is required, refer to "Connecting-Rod Bearings."

8. Install the following items:
   a. oil pump.
   b. oil pan.
   c. cylinder head.
9. Install engine in boat.
10. Fill crankcase with oil.
11. Start engine, adjust timing and check for leaks.

CRANKSHAFT

Removal:

1. Remove engine from boat.
2. Drain coolant and crankcase oil. Disconnect all hoses.
3. Remove transmission starter motor, flywheel housing and flywheel. Place engine in repair stand.
4. Remove belts, crankshaft pulley and water pump.
5. Remove torsional damper and crankcase front cover.
6. Remove spark plugs.
7. Remove camshaft gear and timing chain on LH-rotation engines.
8. Remove oil pan and oil pump.
9. Mark all bearing caps (main and connecting rods) so they can be installed in their original locations.
10. Remove connecting-rod bearing caps, then push piston and rod assemblies toward heads.
11. Remove main bearing caps and carefully lift crankshaft out of cylinder block. Remove rear main bearing-oil seal from cylinder block and rear main bearing cap.

NOTE: If new main and/or connecting-rod bearings are to be installed, remove main bearing inserts from cylinder block and bearing caps, and/or connecting-rod bearing inserts from connecting rod and caps. Install new bearings following procedures outlined above.

Cleaning and Inspection:

1. Wash crankshaft in solvent and dry with compressed air.
2. Measure main bearing journals and crankpin dimensions with a micrometer for out-of-round, taper or undersize (see "Specifications").
3. Check crankshaft for run-out (by supporting at front and rear main bearings journals in V-blocks) and check at front and rear intermediate journals with a dial indicator (see "Specifications").
4. Replace or recondition crankshaft if not meeting specifications.

Installation:

1. If a new crankshaft is being installed, remove timing gear from old crankshaft and reinstall on new crankshaft.

IMPORTANT: Be sure that all bearings and crankshaft journals are clean.

2. Install a new rear main bearing-oil seal in cylinder block and rear main bearing cap.
3. Carefully lower crankshaft into place. Be careful not to damage bearing surface.
4. Check clearance of each main bearing, following procedure outlined under "Main Bearings." If bearing clearances are satisfactory, apply a light coat of engine oil to journals and bearings.
5. Install all bearing caps and bolts. Torque all main bearing-cap bolts to specifications. When tightening rear main bearing cap, follow procedure outlined under "Main Bearing."
6. Check clearance for each connecting-rod bearing, following procedure under "Connecting-Rod Bearings." If bearing clearances are satisfactory, apply a light coat of engine oil to journals and bearings.
7. Install all rod caps and torque nuts to 45 lb-ft (61 N•m).
8. Check crankshaft end-play. Follow procedure outlined under "Main Bearings."
9. Install oil pump and pan as outlined.
10. Install camshaft gear and timing chain (LH-rotation engines only).
11. Install crankcase front cover and torsional damper.
12. Remove engine from repair stand and install water pump, flywheel, flywheel housing and starter motor.
13. Install transmission.
14. Install crankshaft pulley and belts.
15. Install spark plugs.
16. Install engine in boat, fill crankcase and install hoses.

TIMING CHAIN AND/OR GEARS

NOTE: Timing chain is used on left-hand-rotation engines and timing gears on right-hand-rotation engines.

Crankshaft Gear Removal:

1. Remove torsional damper and crankcase front cover as outlined.
2. Remove camshaft-timing chain as outlined.
3. Using tool J-5825-A or tool J-1619 (RH-rotation engines), remove gear.

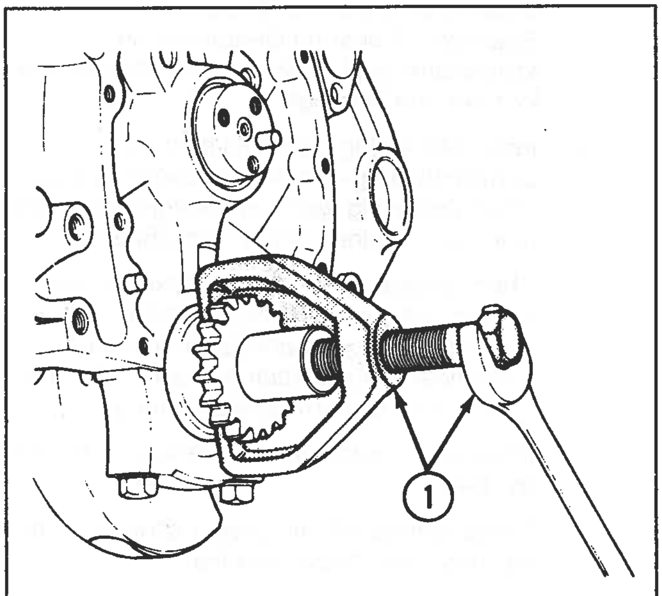


Figure 8-92. *Removing Crankshaft-Timing Gear*

Crankshaft Gear Installation:

1. Using tool J-5590 as shown, install gear.
2. Install camshaft-timing chain as outlined.
3. Install crankcase front cover and torsional damper as outlined above.

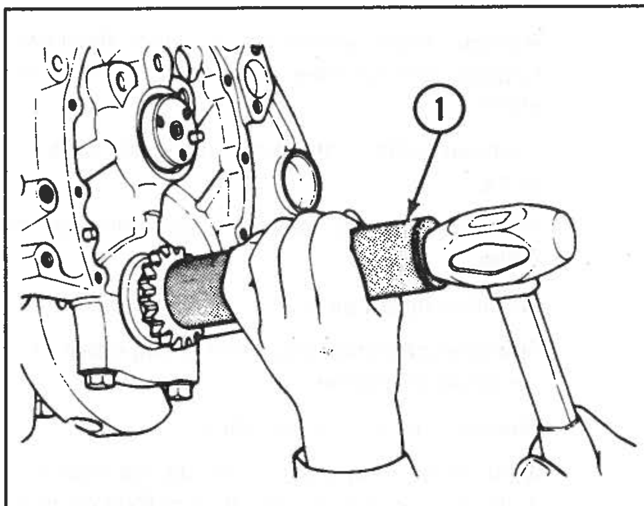
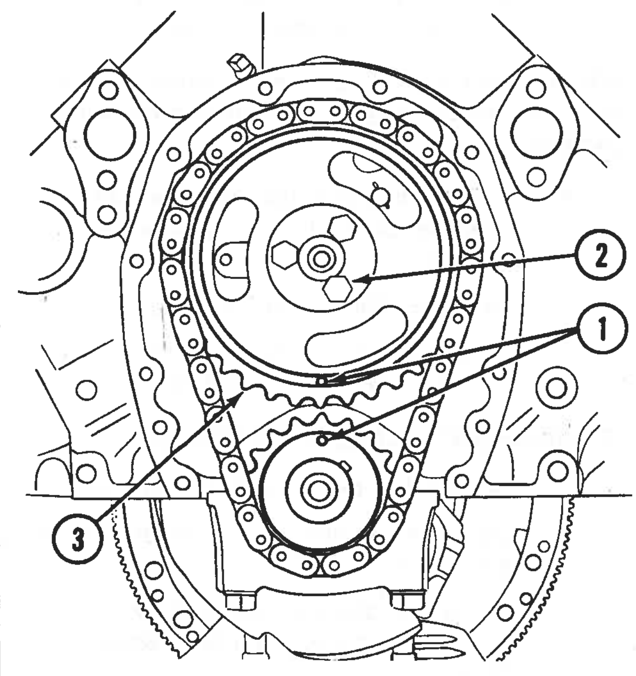


Figure 8-93. *Installing Crankshaft-Timing Gear*

CAMSHAFT GEAR AND TIMING CHAIN (LH-ROTATION ENGINE)

Removal:

1. Remove torsional damper and crankcase front cover as outlined.
2. Crank engine until marks on camshaft and crankshaft gears are in alignment.



1. Timing marks
2. Gear-cap screw
3. Gear

Figure 8-94. Timing-Gear Alignment Marks

3. Remove camshaft gear to camshaft bolts.
4. Remove camshaft gear and timing chain together. Gear is mounted with a light press-fit on camshaft. If gear does not come off easily, a light blow on lower edge of gear with a plastic mallet should dislodge the gear.
5. If crankshaft gear has to be replaced, remove as outlined in "Crankshaft Gear."

Cleaning and Inspection:

1. Clean all parts in solvent and dry with compressed air.
2. Inspect timing chain for wear or damage.
3. Inspect gears for wear or damage.

Installation:

1. If crankshaft gear was removed, install as outlined in "Crankshaft Gear."
2. Install timing chain on camshaft gear. Hold gear vertical with chain hanging down and orientate to align marks on camshaft and crankshaft gear.

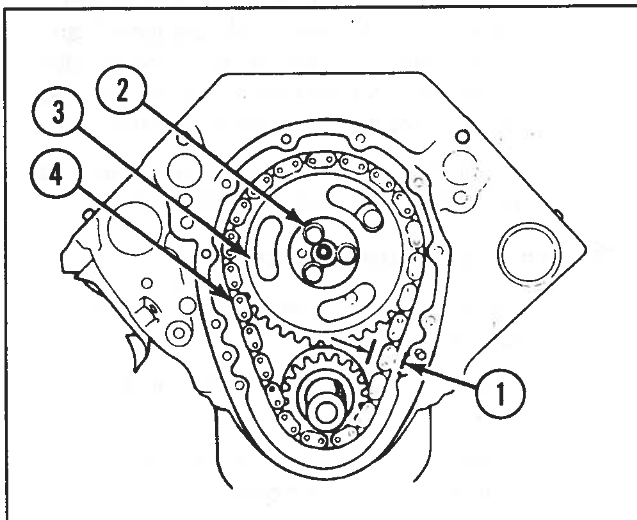
IMPORTANT: Do not attempt to drive gear on camshaft as welsh plug at rear of engine can be dislodged.

3. Draw camshaft gear onto camshaft, using the three mounting bolts. Torque to specifications.
4. Lubricate timing chain with engine oil. Install crankcase front cover and torsional damper as outlined.

Checking Timing-Chain Deflection:

With timing chain and gears installed, check timing-chain deflection as follows:

1. Rotate camshaft (in either direction) to place tension on one side of the chain.
2. Establish a reference point on the block (on taut side of chain) and measure from this point to the chain.
3. Rotate camshaft in the opposite direction to slacken the chain, then force chain out with fingers and again measure the distance between reference point and timing chain.
4. The deflection is the difference between these two measurements. If the deflection exceeds specifications, timing chain should be replaced.



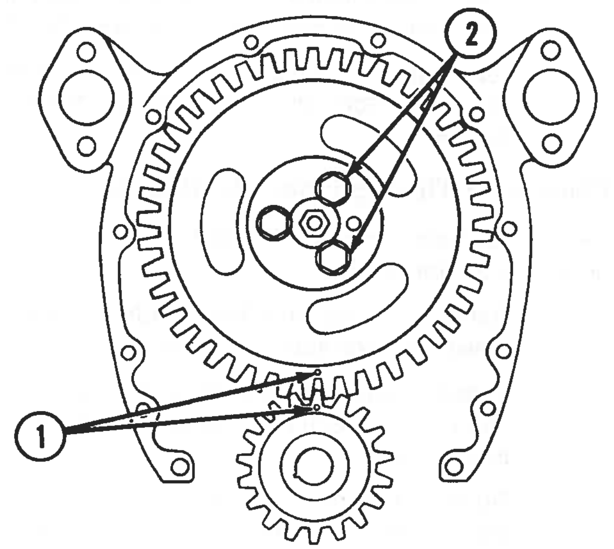
1. 5/8 in. (16 mm) max.
2. Bolt
3. Camshaft gear
4. Timing chain

Figure 8-95. Checking Timing-Chain Deflection

TIMING GEAR (RH-ROTATION ENGINES)

Removal:

1. Remove oil pan, torsional damper and crankcase front cover as outlined.
2. Crank engine over until timing mark on camshaft-timing gear aligns with timing mark on crankshaft-timing gear.



1. Timing marks 2. Cam-gear bolts

Figure 8-96. *Timing-Gear Alignment Marks – Right-Hand Rotation*

3. Remove camshaft-timing-gear-attaching screws (and washers if so equipped) and remove gear. If gear does not come off easily, a light blow on the lower edge of the gear with a plastic mallet should dislodge the gear.
4. If crankshaft-timing gear requires replacement, remove as outlined in "Crankshaft Gear."

Cleaning and Inspection:

1. Clean all parts in solvent and dry with compressed air.
2. Inspect timing gears for worn or damaged teeth.
3. Inspect camshaft-gear-to-cylinder-block contact surfaces for damage.

Installation:

1. If removed, install crankshaft timing gear as outlined in "Crankshaft Gear."
2. Position camshaft timing gear so that timing mark aligns with timing mark on crankshaft timing gear, then align camshaft dowel with hole in camshaft gear and install gear on camshaft.
3. Install three camshaft-timing-gear-attaching screws (and washers if so equipped) and draw gear onto camshaft. After gear is in place, torque screws to specifications.

IMPORTANT: Do not attempt to drive gear on camshaft as welsh plug at rear of engine can be dislodged.

4. Check timing-gear backlash and run-out as explained under "Checking Backlash and Run-out."
5. Lubricate timing gears with engine oil.
6. Install crankcase front cover, oil pan and torsional damper as explained.

Checking Backlash and Run-out:

1. Remove fuel pump and fuel-pump push rod.
2. Loosen rocker-arm nuts (to relieve tension on hydraulic valve lifters).
3. With timing gears installed, check camshaft-to-crankshaft-gear backlash as follows:
   a. Mount a dial indicator on engine so that indicator stem contacts one of the teeth on camshaft gear. Indicator stem should be as perpendicular to gear-tooth surface as possible.
   b. Check the backlash between the camshaft gear and crankshaft gear while applying inward pressure on camshaft gear.
   c. If backlash is not within specifications, check for improperly machined parts or for worn camshaft or crankshaft bearings. If bearings check out OK, replace both timing gears.

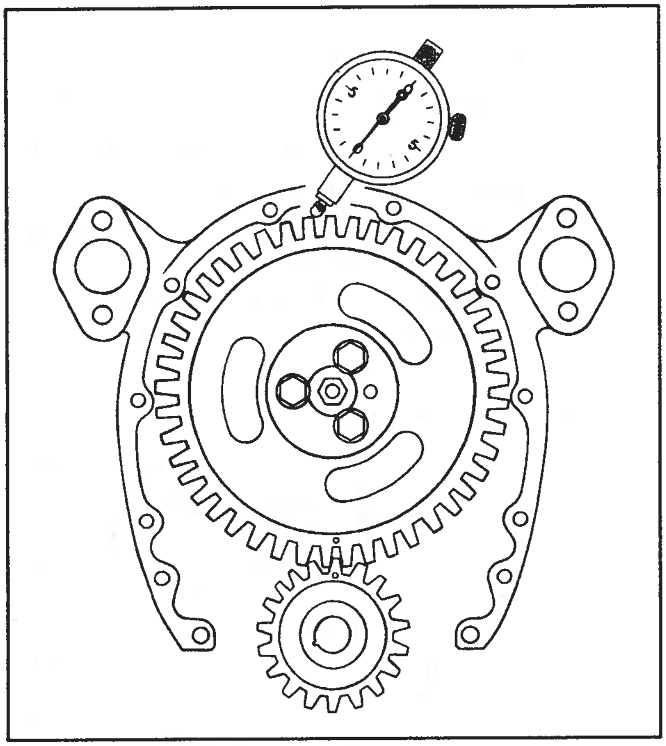


Figure 8-97. Checking Timing-Gear Backlash

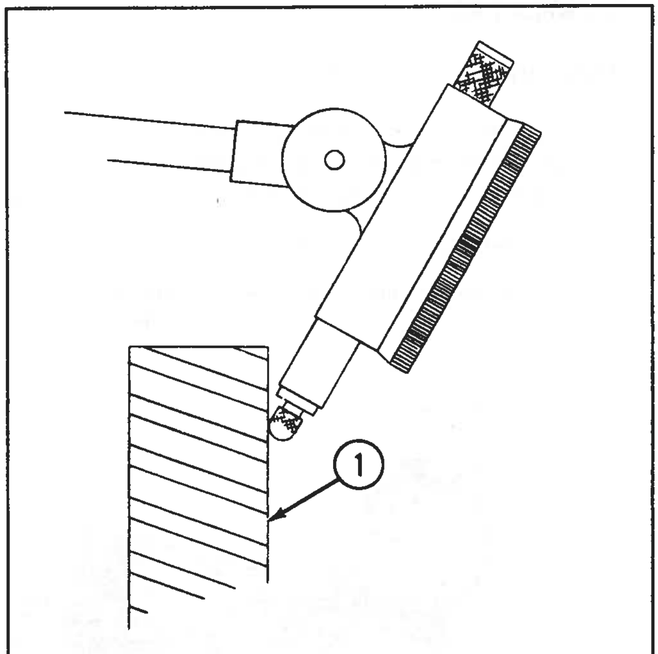


Figure 8-98. Checking Timing-Gear Run-Out

4. With timing gear installed, check camshaft and crankshaft timing gear run-out as follows:
   a. Mount dial indicator on block so that indicator stem is perpendicular to camshaft-timing gear and contacts gear surface just adjacent to teeth.
   b. Apply inward pressure on timing gear and zero indicator, then turn crankshaft. Check gear run-out through one complete revolution of camshaft gear.
   c. If not within specifications, check for burrs or foreign material between gear and camshaft-joining surfaces. If none is found, replace both timing gears.
   d. Check crankshaft-timing gear run-out in same manner. Run-out should not exceed specifications. Replace both gears if run-out is excessive.
5. Adjust rocker-arm nuts.
6. Install fuel-pump push rod and fuel pump.

CAMSHAFT

Measuring Lobe Lift:

NOTE: Procedure is similar to checking valve timing. If improper valve operation is indicated, measure lift of each push rod in consecutive order and record readings.

1. Remove rocker arms as outlined.
2. Position indicator with ball-socket adapter tool J-8520-1 on push rod. Be sure that push rod is in lifter socket.

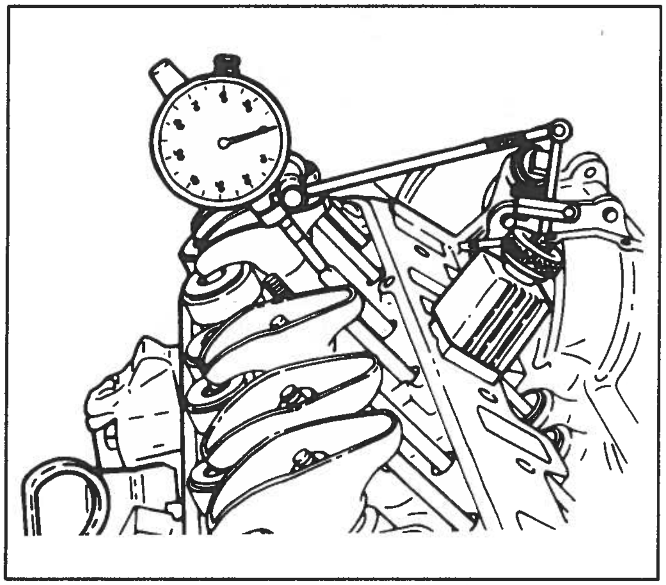


Figure 8-99. *Measuring Camshaft-Lobe Lift*

3. Rotate crankshaft damper slowly in direction of rotation until lifter is on heel of cam lobe. At this point, push rod will be in its lowest position.
4. Set dial indicator on zero, then rotate balancer slowly (or attach an auxiliary starter switch and "bump" engine over) until push rod is in fully raised position.
5. Compare total lift recorded from dial indicator with "Specifications."
6. Continue to rotate engine until indicator reads zero. This will be a check on accuracy of original indicator reading.
7. If camshaft readings for all lobes are within specifications, remove dial indicator assembly.
8. Install and adjust valve mechanism as outlined.

Removal:

1. Remove valve lifters as outlined.
2. Remove crankcase front cover as outlined.
3. Remove fuel pump and fuel-pump push rod.
4. Remove camshaft as follows:
   a. Refer to "Timing Chain and/or Gears" to remove chain and gear.
   b. Install two 5/16-18 bolts in camshaft gear-bolt holes and carefully remove camshaft.

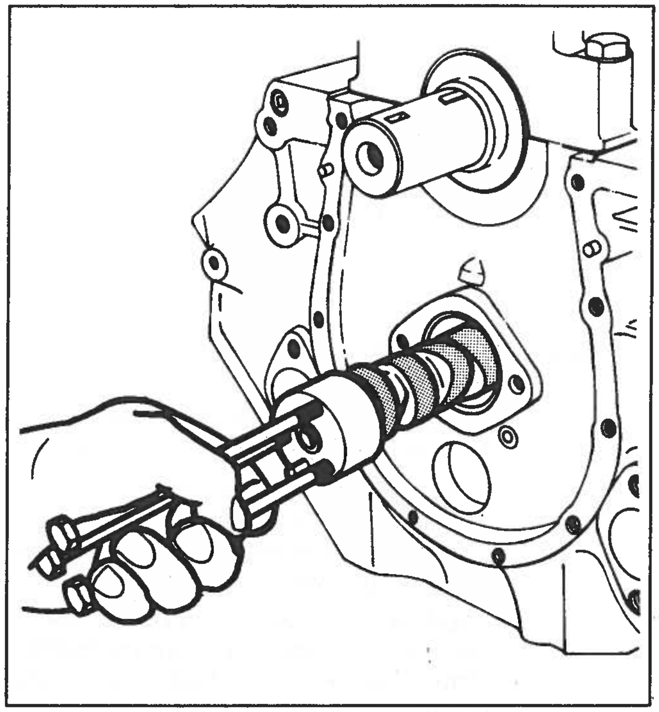
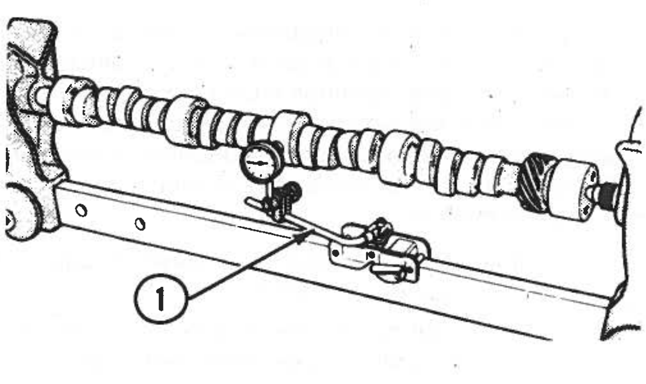


Figure 8-100. *Removing Camshaft*

Inspection:

Measure camshaft-bearing journals with a micrometer for out-of-round condition. if journals exceed 0.001 in. (0.025 mm) out- of-round, camshaft should be replaced.

Also check camshaft for alignment with V-blocks and dial indicator which indicates exact amount camshaft is out-of-true. It out more than 0.002 in. (0.051 mm) (dial indicator reading), camshaft should be replaced.



1. J-7872 dial indicator

***Figure 8-101.** Checking Camshaft For Straightness*

Installation:

1. Install camshaft as follows:
   a. Install two 5/16-18 bolts in camshaft-bolt holes, then lubricate camshaft journals with engine oil and install camshaft, being careful not to damage bearings. Remove the two 5/16-18 bolts.
   b. Install timing chain and gear as outlined in "Timing Chain and/or Gears."

CAMSHAFT BEARINGS

Removal:

Camshaft bearings can be replaced while engine is disassembled for overhaul or without complete disassembly. To replace bearings without complete disassembly, remove camshaft and crankshaft, leaving cylinder heads attached and pistons in place. Before removing crankshaft, tape threads of connecting-rod bolts to prevent damage to crankshaft. Fasten connecting rod against sides of engine so that they will not interfere while replacing camshaft bearings.

1. With camshaft and crankshaft removed, drive camshaft rear plug from cylinder block.

IMPORTANT: This procedure is based on the removal of center bearings from the engine first, thus requiring a minimum amount of turns to remove all bearings.

2. Using Tool Set J-6098-01 (with nut and thrust washer installed to end of threads), position pilot in front camshaft bearing and install puller screw through pilot.
3. Install tool with shoulder toward bearing. Be sure a sufficient amount of threads is engaged.
4. Using two wrenches, hold puller screw while turning nut. When bearing has been pulled from bore, remove tool and bearing from puller screw.
5. Remove remaining bearings (except front and rear) in same manner. It will be necessary to position pilot in rear camshaft bearing to remove rear intermediate bearing.
6. Assemble remover tool on driver handle and remove front and rear camshaft bearings by driving toward center of cylinder block.

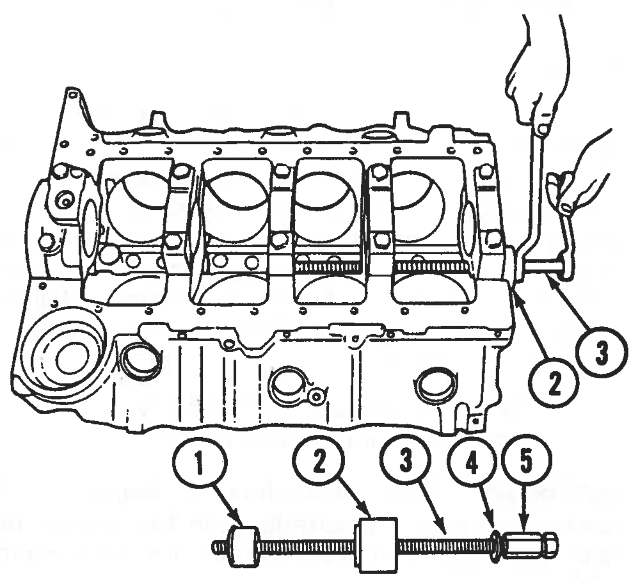


Figure 8-102. *Removing Center Camshaft Bearings*

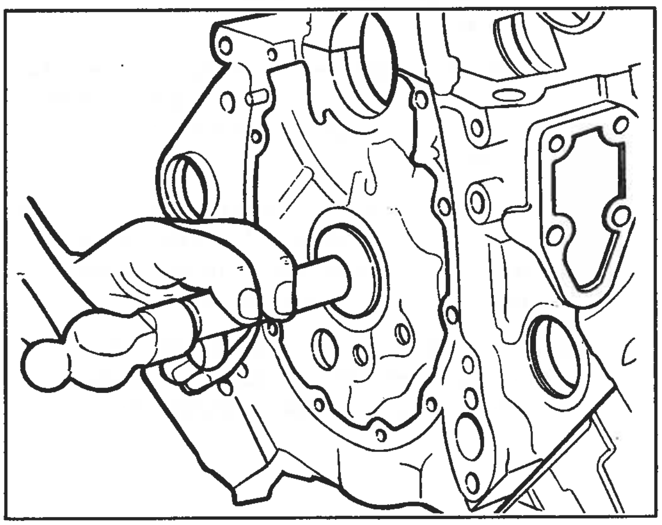


Figure 8-103. *Removing Front and Rear Camshaft Bearings*

Inspection:

Clean camshaft-bearing bores in cylinder block with solvent and blow out with compressed air. Be sure grooves and drilled oil passages are clean.

Installation:

Front and rear bearings must be installed last as pilot will not fit into bearing bores if bearings are installed.

Lubricate outer surface of new camshaft bearings with engine oil to ease installation.

IMPORTANT: All camshaft bearings are not the same. Be sure to install bearing in proper location (indicated by bearing manufacturer) and to position bearings as follows (directional references apply to engine in its normal operating position):

Front bearing must be positioned so that oil holes are equidistant from 6-o'clock position in the block. Intermediate and center bearings must be positioned so that oil holes are at the 5-o'clock position (toward left side of block and at a position even with bottom of cylinder bore). Rear bearing must be positioned so that oil hole is at the 12-o'clock position.

1. Installing intermediate and center bearings (see Figure 8-107 for reference):
   a. Install nut and thrust washer all the way onto puller screw, then position pilot in front camshaft bearing bore and insert screw through pilot.
   b. Index center camshaft bearing, then position appropriately sized remover and installer tool in bearing and thread puller screw into tool. Be sure at least 1/2 in. (13 mm) of threads are engaged.
   c. Using two wrenches, hold puller screw and turn nut until bearing has been pulled into position. Remove the removal and installer tool and check to ensure that oil holes in bearing are positioned correctly.
   d. Install intermediate bearings in same manner, being sure to index bearings correctly. It will be necessary to position pilot in rear camshaft bearing bore to install rear intermediate bearing.
2. Installing front and rear bearings:
   a. Install appropriately sized removal and installer tool on drive handle.
   b. Index front bearing (as explained in "Important"), and drive it into position with tool. Check position of oil hole(s) in bearing to ensure bearing is positioned correctly.
   c. Install rear bearing in same manner, being sure to index bearing correctly.

3. Install a new camshaft rear plug.

IMPORTANT: Plug must be installed flush to 1/32 in. (0.8 mm) deep and must be parallel with rear surface of cylinder block.

4. Install crankshaft and camshaft as outlined.

CYLINDER BLOCK

Cleaning and Inspection:

1. Remove all engine components as previously outlined.
2. Wash cylinder block thoroughly in cleaning solvent and clean all gasket surfaces.
3. Remove oil gallery plugs and clean all oil passages.

NOTE: These plugs may be removed with a sharp punch or they may be drilled and pried out.

4. Clean and inspect water passages in cylinder block.
5. Inspect cylinder block for cracks in cylinder walls, water jacket, valve-lifter bores and main bearing webs.
6. Measure cylinder walls for taper, out-of-round or excessive ridge at top of ring travel. This should be done with a dial indicator or inside micrometer. Carefully work gauge up and down cylinder to determine taper and turn it to different points around cylinder wall to determine out-of-round condition. If cylinders exceed specifications, boring and/or honing will be necessary.

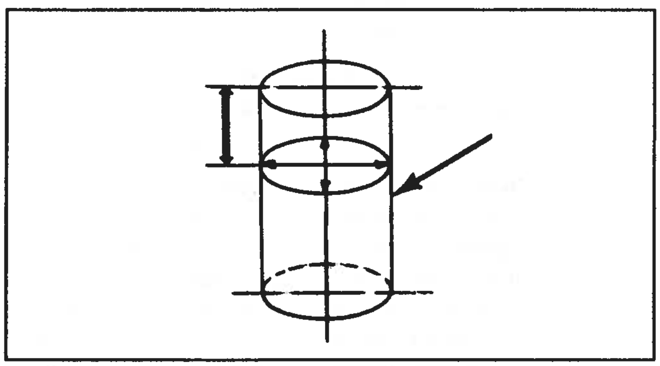


Figure 8-104. *Measuring Points For Cylinder Bore Out-of-Round*

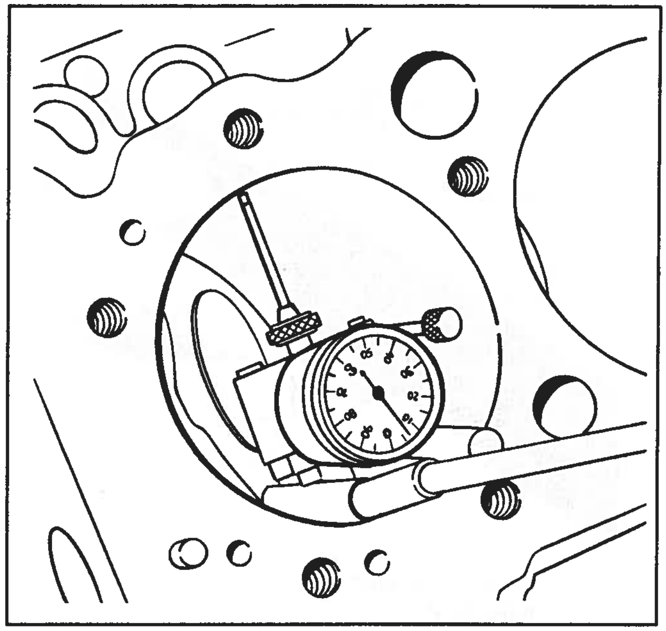


Figure 8-105. *Using Dial Indicator To Check Cylinder For Taper And Out-of-Round*

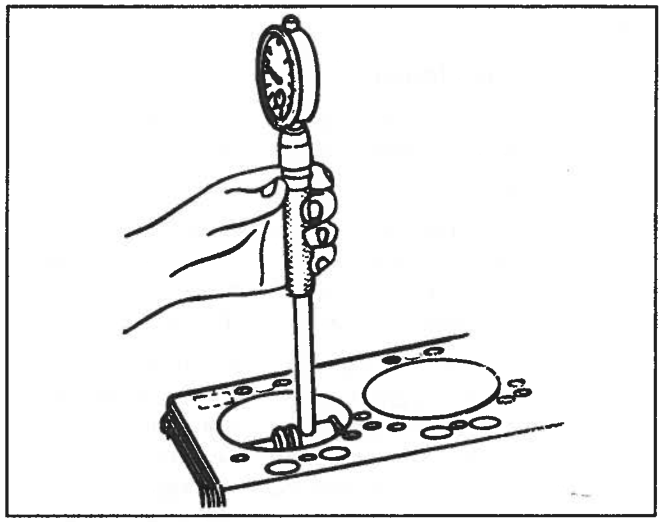
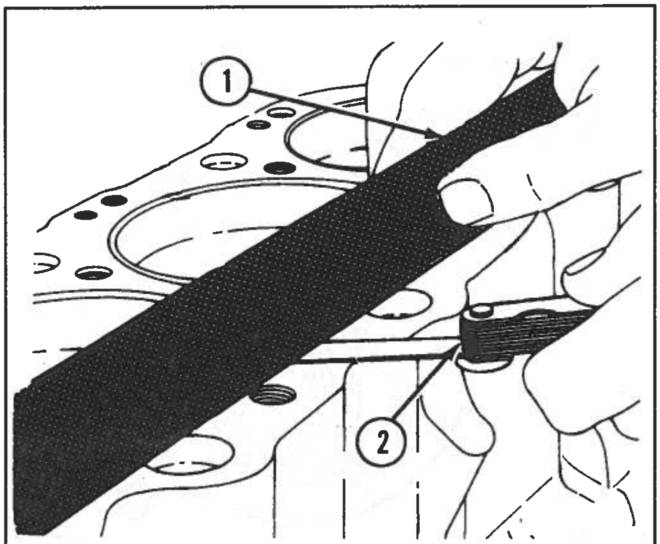


Figure 8-106. *Using Telescoping Gauge To Check Cylinder For Taper And Out-of-Round*

7. Check cylinder head gasket surfaces for warping with a machinist's straightedge and a feeler gauge, as shown. Take measurements diagonally across surfaces (both ways) and straight down center. If surfaces are out-of-flat more than 0.003 in. (0.08 mm) in a 6-in. area or 0.007 in. (0.18 mm) overall, block must be resurfaced by an automotive machine shop.



1. Machinist's straightedge
2. Feeler gauge

Figure 8-107. Checking Engine-Block Head-Gasket Deck For Flatness

Repairs:

Cylinder Conditioning

1. Performance of the following operation depends upon engine condition at time of repair.
2. If cylinder block inspection indicates that block is suitable for continued use (except for out-of-round or tapered cylinders), it can be conditioned by honing or boring.
3. If cylinders have less than 0.005-in. (0.13 mm) taper or wear, they can be conditioned with a hone and fitted with a high-limit, standard-sized piston. A cylinder bore of more than 0.005-in. (0.13 mm) wear or taper may not clean up entirely when fitted to a high-limit piston. To entirely clean up the bore, it will be necessary to rebore for an oversize piston. If more than 0.005-in. (0.13 mm) taper or wear, bore and hone to smallest oversize that will permit complete resurfacing of all cylinders.
4. When pistons are being fitted and honing is not necessary, cylinder bores may be cleaned with a hot water and detergent wash. After cleaning, swab cylinder bores several times with light engine oil and a clean cloth, then wipe with a clean dry cloth.

Cylinder Boring

1. Before using any type boring bar, clean off top of cylinder block to remove dirt or burrs. This is very important to prevent boring bar tilt, with result that rebored cylinder wall is not at right angles to crankshaft.
2. Measure piston to be fitted with a micrometer, measuring at center of piston skirt and at right angles to piston pin. Bore cylinder to same diameter as piston and hone to give specified clearance.

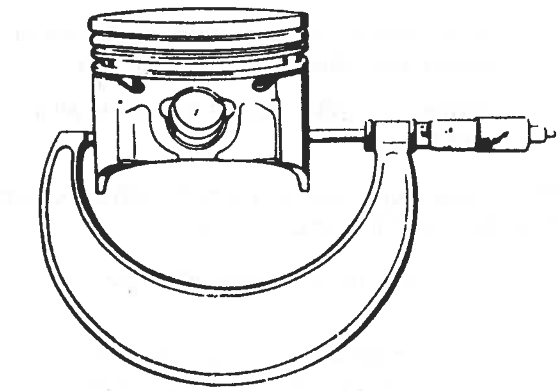


Figure 8-108. Measuring Piston Diameter

IMPORTANT: Hone cylinders as outlined under "Cylinder Honing" and "Piston Selection," following.

3. Carefully observe instructions furnished by manufacturer of equipment being used.

Cylinder Honing

1. Follow hone manufacturer's recommendations for use of hone, cleaning, and lubrication during honing.
2. Occasionally, during the honing operation, thoroughly clean cylinder bore and check piston for correct fit in cylinder.
3. When finish-honing a cylinder bore to fit a piston, move hone up and down at a sufficient speed to obtain very fine, uniform-surface finish marks in a crosshatch pattern of approximately 30° to cylinder bore. Finish marks should be clean but not sharp, free from imbedded particles and torn or folded metal.
4. Permanently mark piston (for cylinder to which it has been fitted) and proceed to hone cylinders and fit remaining pistons.

IMPORTANT: Handle pistons with care and do not attempt to force them through cylinder, as this type piston can be distorted by careless handling.

5. Thoroughly clean cylinder bores with hot water and detergent. Scrub well with a stiff-bristle brush and rinse thoroughly with hot water. It is essential that a good cleaning operation be performed. If any abrasive material remains in cylinder bores, it will rapidly wear new rings and cylinder bores, in addition to bearings lubricated by the contaminated oil. Swab bores several times with light engine oil on a clean cloth, then wipe with a clean, dry cloth. Cylinder should not be cleaned with kerosene or gasoline. Clean remainder of cylinder block to remove excess material spread during honing operation.

Piston Selection

1. Check used piston-to-cylinder bore clearance as follows:
   a. Measure cylinder-bore diameter with a telescope gauge 2-1/2 in. (64 mm) from top of cylinder bore (Figure 8-107).
   b. Measure piston diameter at skirt across centerline of piston pin (Figure 8-108).
   c. Subtract piston diameter from cylinder bore diameter to determine piston-to-bore clearance.
   d. Determine if piston-to-bore clearance is in acceptable range shown in "Specifications."
2. If used piston is not satisfactory, determine if a new piston can be selected to fit cylinder bore within acceptable range.
3. If cylinder bore must be reconditioned, measure new piston diameter (across centerline of piston pin), then hone cylinder bore to correct clearance (preferable range).
4. Mark piston to identify cylinder for which it was fitted.

BLANK

8.3 SMALL V-8 ENGINES

Special Tools:

SPECIAL TOOLS	
Kent-Moore Number	**Item**
J-8062	Valve-spring compressor (cylinder head off)
J-8101	Valve-guide-bore cleaning brush
J-8358	Valve seat and valve-face cleaning brush
J-5830-1	Oversized valve-guide reamer (0.003 in.)
J-5830-6	Oversized valve-guide reamer (0.006 in.)
J-9345-1	Oversized valve-guide reamer (0.010 in.)
J-8080	Crankshaft upper bearing-shell remover and installer
J-8369	Oil-suction-pipe installer
J-5825	Crankshaft-gear remover (LH-engine rotation)
J-1619	Crankshaft-gear remover (RH-engine rotation)
J-5239	Connecting-rod guide set for cap-screw rods
J-5802-01	Rocker-arm stud remover
J-6880	Rocker-arm stud installer
J-5590	Crankshaft-gear installer
J-24420-B	Crankshaft-gear installer
J-8037	Piston-ring compressor
J-25087	Oil-pressure gauge
J-3049	Valve-lifter remover
J-5790	Hydraulic valve-lifter leakdown tester
J-23394	Front intake-manifold-bolt wrench
J-5250	Timing-chain-cover-oil-seal installer
J-4160-A	Hydraulic valve-lifter-plunger remover
J-5892	Valve-spring compressor (cylinder head on block)
J-8089	Carbon-removing brush
J-6098	Camshaft-bearing remover and installer
J-8056	Valve-spring tester
J-23994	Valve-seal leak tester
J-8520	Cam-lobe lift indicator
J-24086-B	Piston-pin remover and replacer set
J-22509	Intake-valve-seal installer
J-23590	Air adapter

Available from:

Kent-Moore Tools
29784 Little Mack
Roseville, MI 48066-2298
Phone: (800) 345-2233
(313) 574-2332

Specifications:

305/350 CID MODEL FASTENER TORQUE SPECIFICATIONS			
Units	**N•m**	**lb-ft**	**lb-in**
Rocker-arm-cover bolts	10	–	90
Intake-manifold bolts	47	35	–
Exhaust-manifold bolts	47	35	–
Cylinder-head bolts	88	65	–
Torsional-damper bolt	95	70	–
Crankcase-front-cover bolts	11.3	–	100
Oil-pan nuts	22.6	–	200
Oil-pan bolts	11.3	–	100
Oil-pump bolt	88	65	–
Rear crankshaft-oil-seal-retainer screws and nuts	15.3	–	135
Camshaft-gear bolts	28	21	–
Connecting-rod-cap nuts	61	45	–
Oil-filter-adapter bolts	26	20	–
Main bearing-cap bolts	110	80	–
Oil-pump-cover bolts	9.0	–	80
Flywheel bolts	102	75	–
Spark plugs	30	22	–
Water-outlet bolts	28	21	–
Water-pump bolts	41	30	–
Flywheel-housing bolts	43	32	–
Camshaft-thrust-plate screws	11.9	–	105
Oil-pan studs to oil-seal retainer or crankcase	1.7	–	15
Flywheel-damper plate	47	35	–

<table>
<tr><th colspan="3">ENGINE SPECIFICATIONS</th></tr>
<tr><th>Model</th><th>305 CID</th><th>350 CID</th></tr>
<tr><td>Bore</td><td>3.74 in. (95.0 mm)</td><td>4.00 in. (101.6 mm)</td></tr>
<tr><td>Stroke</td><td>3.48 in. (88.4 mm)</td><td>3.48 in. (88.4 mm)</td></tr>
<tr><td>Displacement</td><td>305 in^3 (5.0 L)</td><td>350 in^3 (5.7 L)</td></tr>
<tr><td>Compression ratio</td><td>8.5:1 or 9.3:1[1]</td><td>9.0:1 or 9.3:1[1]</td></tr>
<tr><td>Heads</td><td colspan="2">Cast iron</td></tr>
<tr><td>Intake manifold</td><td colspan="2">Cast iron</td></tr>
<tr><td>Block</td><td colspan="2">Cast iron (2-bolt main bearing caps)</td></tr>
<tr><td>Rods</td><td colspan="2">Forged steel</td></tr>
<tr><td>Pistons</td><td colspan="2">Cast aluminum</td></tr>
<tr><td>Crankshaft</td><td colspan="2">Nodular iron</td></tr>
</table>

NOTE: [1] Compression ratio increased in 1987 model engine.

<table>
<tr><th colspan="5">CYLINDER BORE SPECIFICATIONS</th></tr>
<tr><th colspan="3">Model</th><th>305 CID</th><th>350 CID</th></tr>
<tr><td colspan="3">Diameter</td><td>3.7360-3.7381 in.
(94.894-94.948 mm)</td><td>4.0000-4.0021 in.
(101.600-101.653 mm)</td></tr>
<tr><td colspan="2" rowspan="2">Out-of-round</td><td>Production</td><td colspan="2">0.001 in (0.025 mm) max.</td></tr>
<tr><td>Service</td><td colspan="2">0.002 in. (0.051 mm) max.</td></tr>
<tr><td rowspan="3">Taper</td><td rowspan="2">Production</td><td>Thrust side</td><td colspan="2">0.0005 in. (0.0127 mm) max.</td></tr>
<tr><td>Relief side</td><td colspan="2">0.001 in. (0.025 mm) max.</td></tr>
<tr><td colspan="2">Service</td><td colspan="2">0.001 in. (0.025 mm) max.</td></tr>
</table>

<table>
<tr><th colspan="3">305/350 CID PISTON SPECIFICATIONS</th></tr>
<tr><td rowspan="2">Clearance</td><td>Production</td><td>0.0007-0.0021 in. (0.018-0.053 mm)</td></tr>
<tr><td>Service</td><td>0.0027 in. (0.069 mm) max.</td></tr>
</table>

<table>
<tr><th colspan="3">305/350 CID PISTON PIN SPECIFICATIONS</th></tr>
<tr><td colspan="2">Diameter</td><td>0.9270-0.9271 in. (23.546-23.548 mm)</td></tr>
<tr><td rowspan="2">Clearance</td><td>Production</td><td>0.00025-0.0006 in. (0.00635-0.0152 mm)</td></tr>
<tr><td>Service</td><td>0.001 in. (0.025 mm) max.</td></tr>
<tr><td colspan="2">Fit in rod</td><td>0.0008-0.0016 in. (0.0203-0.0406 mm) interference</td></tr>
</table>

305/350 PISTON RING SPECIFICATIONS				
Com-pression	Groove-side clearance	Production	Top	0.0012-0.0032 in. (0.031-0.081 mm)
			2nd	0.0012-0.0032 in. (0.031-0.081 mm)
		Service		Hi-Limit Production + 0.001 in. (0.025 mm)
	Gap	Production	Top	0.010-0.020 in. (0.254-0.508 mm)
			2nd	0.013-0.025 in. (0.330-0.635 mm)
		Service		Hi-Limit Production + 0.010 in. (0.254 mm)
Oil	Groove-side clearance	Production		0.002-0.007 in. (0.051-0.178 mm)
		Service		Hi-Limit Production + 0.001 in. (0.025 mm)
	Gap	Production		0.010-0.030 in. (0.254-0.762 mm)
		Service		Hi-Limit Production + 0.010 in. (0.254 mm)

305/350 CID CAMSHAFT AND DRIVE SPECIFICATIONS		
Lobe lift	Intake	0.269 ± 0.002 in. (6.833 ± 0.051 mm)
	Exhaust	0.273 ± 0.002 in. (6.943 ± 0.051 mm)
Duration @ 0.020 in. (0.508 mm) cam lift	Intake	230°
	Exhaust	243°
Journal diameter		1.8682-1.8692 in. (47.452-47.478 mm)
Journal out-of-round		0.001 in. (0.025 mm) max.
Camshaft run-out		0.002 in. (0.051 mm) max.
Timing-chain deflection (LH [standard] rotation engines only)		0.38 in. (10 mm) from taut position (0.75 in. [19 mm] total)
Camshaft-timing-gear run-out (RH [opposite] rotation engines only)		0.004 in. (0.102 mm) max.
Camshaft-timing-gear run-out (RH [opposite] rotation engines only)		0.003 in. (0.076 mm) max.
Camshaft to crankshaft-timing-gear backlash (RH [opposite] rotation engines only)		New gears: 0.004-0.006 in. (0.102-0.152 mm) Used gears: 0.004-0.008 in. (0.102-0.203 mm)

305/350 CID CRANKSHAFT SPECIFICATIONS			
Main journal	Diameter	No. 1	2.4484-2.4493 in. (62.1894-62.2122 mm)
		No. 2, 3, 4	2.4481-2.4490 in. (62.1817-62.2046 mm)
		No. 5	2.4479-2.4488 in. (62.1767-62.1995 mm)
	Taper	Production	No. 1 through 4: 0.0002 in. (0.0051 mm) max. No. 5: 0.0003 in. (0.0076 max.)
		Service	0.001 in. (0.025 mm) max.
	Out-of-round	Production	0.0002 in. (0.0051 mm) max.
		Service	0.001 in. (0.025 mm) max.
Main bearing clearance	Production	No. 1	0.0008-0.0020 in. (0.0203-0.0508 mm)
		No. 2, 3, 4	0.0011-0.0023 in. (0.0279-0.0584 mm)
		No. 5	0.0017-0.0032 in. (0.0432-0.0813 mm)
	Service	No. 1	0.001-0.0015 in. (0.0254-0.0381 mm)
		No. 2, 3, 4	0.001-0.0025 in. (0.0254-0.635 mm)
		No. 5	0.0025-0.0035 in. (0.0635-0.0889 mm)
Crankshaft end-play			0.002-0.006 in. (0.051-0.152 mm)
Connecting-rod journal	Diameter		2.0986-2.0998 in. (53.3044-53.3349 mm)
	Taper	Production	0.0005 in. (0.0127 mm) max.
		Service	0.001 in. (0.025 mm) max.
	Out-of-round	Production	0.0002 in. (0.0051 mm) max.
		Service	0.001 in. (0.025 mm) max.
Rod-bearing clearance		Production	0.0013-0.0035 in. (0.0330-0.0889 mm)
		Service	0.003 in. (0.0762 mm) max.
Rod-side clearance			0.008-0.014 in. (0.203-0.356 mm)
Crankshaft run-out			0.0015 in. (0.0381 mm) max.

305/350 CID CYLINDER HEAD SPECIFICATIONS	
Gasket-surface flatness	0.003 in. (0.076 mm) in a 6.00 in. (152 mm) area
	Overall maximum out-of-flat 0.007 in. (0.178 mm)

305/350 CID FLYWHEEL SPECIFICATIONS	
Run-out	0.008 in. (0.203 mm) max.

305/350 CID VALVE SPECIFICATIONS			
Lifter type			Hydraulic
Rocker-arm ratio			1.50 to 1
Valve lift		Intake	0.400 in. (10.16 mm)
		Exhaust	0.410 in. (10.41 mm)
Valve lash (intake and exhaust)			3/4 turn down from zero lash
Face angle (intake and exhaust)			45°
Seat angle (intake and exhaust)			46°
Seat run-out (intake and exhaust)			0.002 in. (0.051 mm) max.
Seat width		Intake	0.031-0.063 in. (0.79-1.60 mm)
		Exhaust	1/16-3/32 in. (1.59-2.39 mm)
Stem clearance	Production	Intake	0.0010-0.0027 in. (0.0254-0.0686 mm)
		Exhaust	0.0010-0.0027 in. (0.0254-0.0686 mm)
	Service	Intake	0.0037 in. (0.0940 mm)
		Exhaust	0.004 in. (0.119 mm)

305/350 CID VALVE SPRING SPECIFICATIONS				
Valve spring[1]	Spring (with two light-green stripes)	Free length		21.91 in. (48.5 mm)
		Pressure[2]	Closed	76-84 lb. @ 1.61 in. (103-114 N @ 40.89 mm)
			Open	194-206 lb. @ 1.16 in. (263-279 N @ 29.46 mm)
		Installed height		1.718 in. (43.7 mm)
	Spring (with one lavender stripe)	Free length		2.03 in. (51.6 mm)
		Pressure[2]	Closed	76-84 lb. @ 1.70 in. (103-114 N @ 43.18 mm)
			Open	194-206 lb. @ 1.25 in. (263-279 N @ 31.75 mm)
		Installed height		1.563-1.623 in. (39.7-41.3 mm)
Damper	Free length			1.859 in. (47.2 mm)
	Approximate no. of coils			4

NOTES: [1] Refer to information under "Cylinder Heads" to determine which valve spring is being used.

[2] Test spring pressure with damper removed.

ROCKER ARM COVER

Removal:

1. Remove rocker-arm-cover-attaching hardware.
2. Disconnect crankcase-ventilation hoses.

IMPORTANT: Do not pry rocker-arm cover loose. Gaskets which adhere to cylinder head and rocker-arm cover may be sheared by bumping end of rocker-arm cover from the rear with palm of hand or a rubber mallet.

3. Remove rocker-arm cover.

Installation:

1. Clean sealing surfaces on cylinder head and rocker-arm cover with degreaser.
2. Install rocker-arm covers, as follows:

Rocker-Arm Covers Using Gaskets

1. Place new rocker-arm cover gasket in position in rocker-arm cover.
2. Install rocker-arm cover and secure with reinforcements and attaching screws or nuts. Torque to specifications.

Rocker-Arm Covers Using RTV Sealer

1. Replace RTV Sealer with a gasket.
2. Install a new cover gasket in position in rocker-arm cover.
3. Install rocker-arm cover and secure with attaching screws or nuts. Torque to specifications.
4. Reinstall any items which were removed to allow removal of rocker-arm covers.
5. Connect crankcase-ventilation hoses to valve rocker-arm covers.
6. Start engine and check for oil leaks.

INTAKE MANIFOLD

Removal:

1. Drain engine cooling system.
2. Disconnect hoses from thermostat housing.
3. Disconnect all electrical leads.
4. Disconnect crankcase-ventilation hoses from rocker-arm covers.
5. Disconnect throttle cable. Remove fuel line running between fuel pump and carburetor.

IMPORTANT: Do not crank engine over after distributor has been removed.

6. Remove distributor cap and mark position of rotor on distributor housing. Also, mark position of distributor housing on intake manifold. Remove distributor.
7. Remove other ignition components, if necessary.
8. Disconnect any other miscellaneous items that will prevent removal of manifold.

IMPORTANT: It may be necessary to pry intake manifold away from cylinder heads and block in the next step. Use extreme care to prevent damage to sealing surfaces.

9. Remove intake-manifold screws, then remove intake manifold.

NOTE: If intake manifold requires replacement, transfer other related parts to new manifold.

Cleaning and Inspection:

1. Clean gasket material from all mating surfaces.

IMPORTANT: When cleaning cylinder-head mating surface, do not allow gasket material to enter engine crankcase.

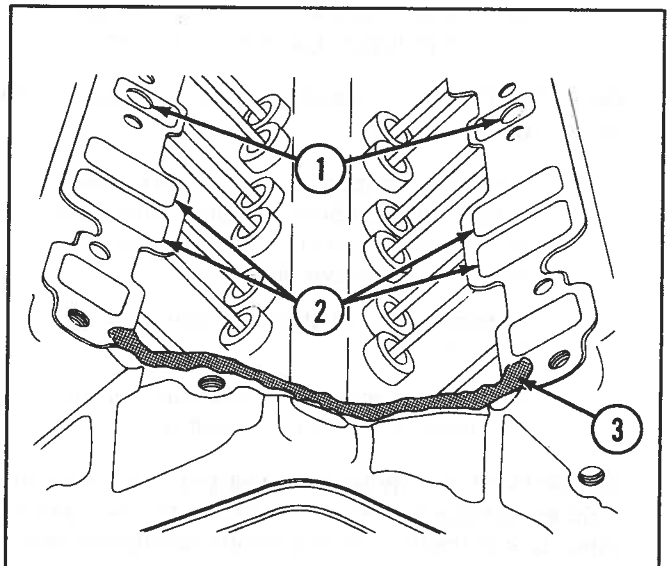
2. Inspect manifold for cracks or scratches. Machined surfaces must be clean and free of all marks, or deep scratches or leaks may result.
3. Check intake passages for varnish build-up or other foreign material. Clean as necessary.

Installation:

1. Apply Perfect Seal to intake-manifold gaskets and install gaskets on cylinder heads.
2. Install front and rear end seals on cylinder block and apply Perfect Seal to areas where seals butt against gaskets.

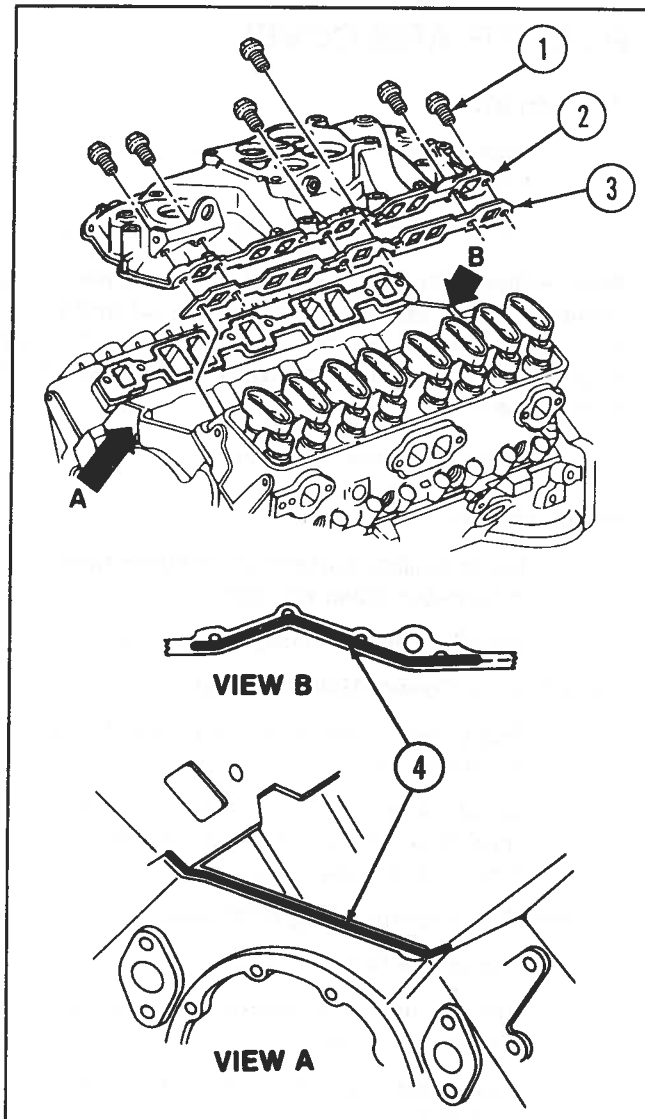
NOTE: Install gasket with marked side up. Both gaskets are identical.

IMPORTANT: All Crusader V-8 GM engines that have automatic carburetor chokes must use an intake gasket that has an opening for the exhaust-crossover port in the intake manifold. Without this opening, the automatic carburetor choke will not operate properly. The choke will remain ON longer causing rough engine operation and wasted fuel.



1. Exhaust-crossover-port opening in gasket
2. Intake-valve ports
3. RTV Sealer (typical both ends)

Figure 8-109. *Crossover-Port Opening*



1. Bolts
2. Intake manifold
3. Gasket
4. Seal (typical both ends)

Figure 8-110. *Applying Sealer And Gasket To Heads For Intake Manifold*

IMPORTANT: If cylinder-block rails do not have holes for locating pins on end seals, RTV Sealer must be used instead of seals. Apply a 3/16-in. (5 mm) wide bead of RTV Sealer. Extend the bead 1/2 in. (13 mm) up each gasket to seal and retain gaskets. RTV Sealer can be used instead of end seals on all engines if desired.

3. Carefully install the manifold assembly, and torque bolts to specifications in sequence indicated in Figure 8-111.

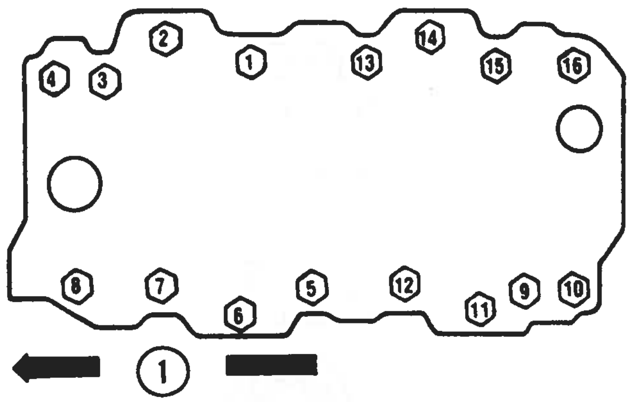


Figure 8-111. Intake-Manifold Torque Sequence

4. Connect all electrical leads.
5. Reconnect hoses to thermostat housing. Tighten securely.
6. Install fuel line to carburetor and fuel pump.
7. Connect crankcase-ventilation hoses to rocker-arm covers.
8. Install the distributor. Position the rotor and housing to align with marks made during removal, then install distributor cap.
9. Install other ignition components, as necessary, and reconnect wires.
10. Reconnect any other items which were disconnected from manifold during the removal.
11. Start engine. Adjust ignition timing and carburetor. Check hose connections, gaskets and seals for leaks.
12. Inspect fuel line connections for fuel leaks.

ROCKER ARM/PUSH ROD

Removal:

1. Remove rocker-arm covers.
2. Remove rocker-arm components, rocker arms and push rods.

IMPORTANT: Place rocker arms, rocker-arm components and push rods in a rack for reinstallation in the same locations.

Cleaning and Inspection:

1. Clean parts with solvent and dry with compressed air.
2. Inspect all contact surfaces for wear. Replace all damaged parts.

Installation:

IMPORTANT: Push rods with a hardened-tip end must be installed with the hardened tip toward rocker arm. Push rods without hardened tips must be installed with large oil-hole end toward rocker arms. Hardened-tip end or large-hole end is marked with a blue stripe.

IMPORTANT: When installing rocker arms and rocker-arm balls, coat bearing surfaces of rocker arms and rocker arm balls with engine oil.

1. Install push rods. Be sure push rods seat in lifter socket.
2. Install rocker arms, rocker-arm balls and rocker-arm nuts. Tighten rocker-arm nuts until all lash is eliminated.
3. Valve lash can be adjusted either with engine stopped or running.

Adjustment - Engine Stopped:

With valve cover removed, adjust valves when lifter is on low part of camshaft lobe, as follows:

1. Crank engine with starter, or turn over in normal direction of rotation until mark on torsional damper lines up with "TDC" mark on timing tab and engine is in No. 1 firing position. This may be determined by placing fingers on No. 1 valve as mark on damper comes near the "TDC" mark on timing mark. If valves move as mark comes up to timing tab, engine is in No. 6 firing position and should be turned over one more time to reach No. 1 position.

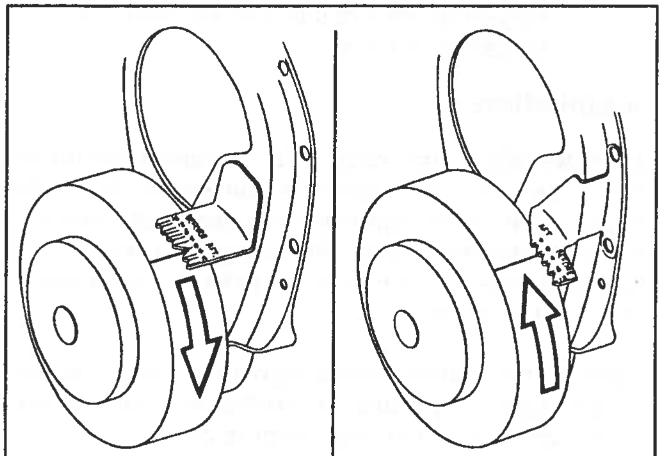
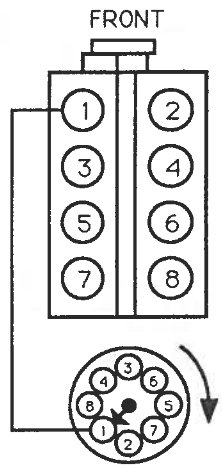


Figure 8-112. *Engine In No. 1 Firing Position*

2. With engine in No. 1 firing position as determined above, see Figure 8-119 for information on which valves may be adjusted.
3. Back out adjusting nut until lash is felt at push rod, then turn (Figure 8-120) adjusting nut until all lash is removed. This can be determined by moving push rod up and down while turning adjusting nut until all play is removed.
4. Hydraulic lifters can now be adjusted by tightening adjustment nut an additional 3/4 turn. No other adjustment is required.



With number one cylinder at TDC of compression stroke, adjust the following rocker arms.	
Left-hand (normal) rotation engine	Right-hand rotation engine
Exhaust 1, 3, 4, 8	Exhaust 1, 2, 5, 7
Intake 1, 2, 5, 7	Intake 1, 3, 4, 8

Figure 8-113. *Adjusting Rocker Arms With No. 1 Piston At TDC Of Compression Stroke*

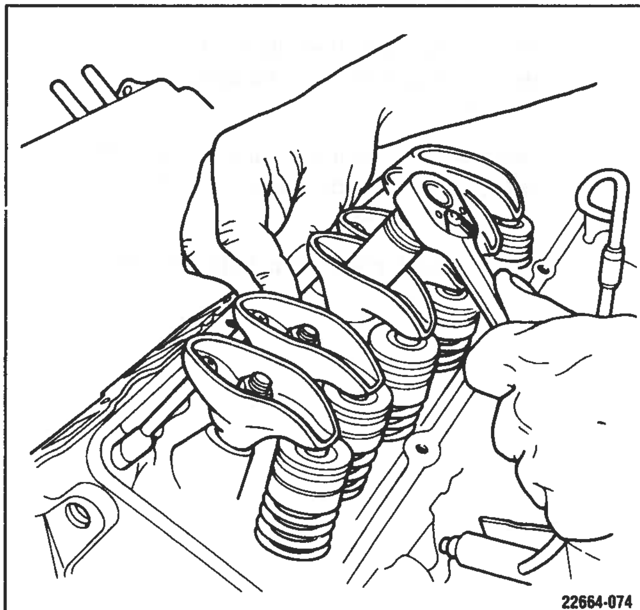
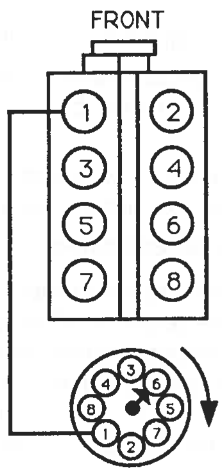


Figure 8-114. *Adjusting Rocker Arms With Engine Not Running*

5. Crank engine one revolution until pointer "TDC" mark and torsional-damper mark are again in alignment. This is No. 6 firing position. With engine in this position, see Figure 8-115 for information on which valves may be adjusted.



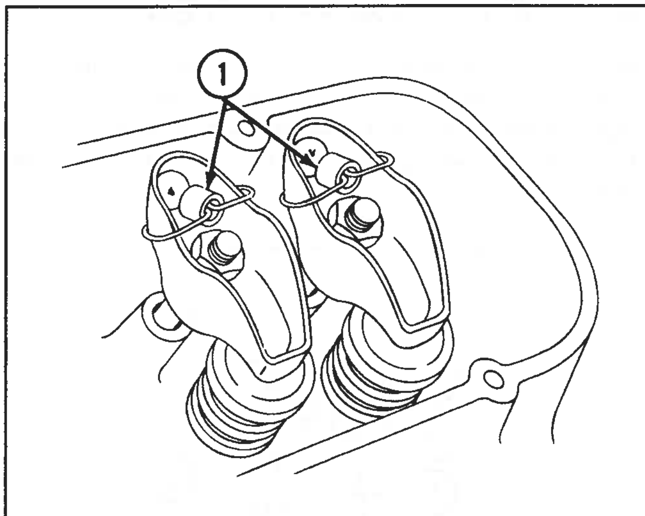
With number one cylinder at TDC of compression stroke, adjust the following rocker arms.	
Left-hand (normal) rotation engine	Right-hand rotation engine
Exhaust 2, 5, 6, 7	Exhaust 3, 4, 6, 8
Intake 3, 4, 6, 8	Intake 2, 5, 6, 7

Figure 8-115. *Adjusting Rocker Arms With No. 6 Piston At TDC Of Compression Stroke*

Adjustment - Engine Running:

Perform the following procedure with engine running:

1. After engine has been rechecked for normal operating temperature, remove valve covers and install rocker stoppers.
2. With engine running at idle, back valve-rocker-arm nuts off (one at a time) until valve-rocker arm starts to clatter.



1. Rocker stoppers

Figure 8-116. *Rocker Stoppers Installed*

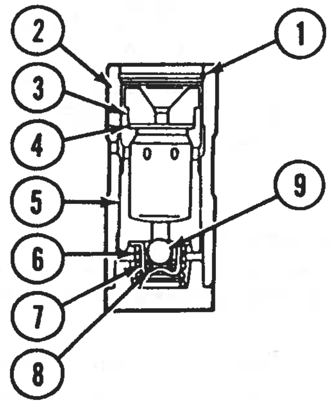
3. Turn rocker-arm nut down until clatter just stops. This is zero-lash position.
4. Turn nut down 1/4 additional turn and pause 10 seconds until engine runs smoothly. Repeat until nut has been turned down 3/4 of a turn from the zero-lash position.

IMPORTANT: This preload adjustment must be done slowly to allow lifter to adjust itself, thus preventing possibility of interference between valve head and top of piston which might result in internal damage and/or bent push rods.

5. Repeat Steps 2, 3 and 4 to adjust other valves.
6. Remove rocker stoppers after all valves are adjusted.
7. After valves have been adjusted, complete the following:
   a. Install new gasket and install covers. Torque to specifications.
   b. Start engine and check for leaks.
   c. Adjust carburetor idle speed and mixture.

HYDRAULIC VALVE LIFTERS

Hydraulic valve lifters (Figure 8-117) require little attention. Lifters are extremely simple in design. Normally, readjustments are not necessary and servicing requires only that care and cleanliness be exercised in the handling of parts.



1.	Retainer	6.	Plunger spring
2.	Lifter body	7.	Ball-check retainer
3.	Push rod seat	8.	Ball-check spring
4.	Oil-metering valve	9.	Ball check
5.	Plunger		

Figure 8-117. *Hydraulic Valve Lifter Assembly*

Locating Noisy Lifters:

Locate a noisy valve lifter by using a piece of garden hose approximately 4 ft (1.2 m) in length. Place one end of hose near end of each intake and exhaust valve, with another end of hose to the ear. In this manner, sound is localized, making it easy to determine which lifter is at fault.

Another method is to place a finger on the face of a valve spring retainer. If lifter is not functioning properly, a distinct shock will be felt when valve returns to its seat.

General types of valve lifter noise are as follows:

1. Hard rapping noise – usually caused by plunger becoming tight in bore of lifter body so that return spring cannot push plunger back up to working position. Probable causes are:
   a. excessive varnish or carbon deposit causing abnormal stickiness
   b. galling or "pickup" between plunger and bore of lifter body, usually caused by an abrasive piece of dirt or metal wedged between plunger and lifter body.
2. Moderate rapping noise – probable causes are:
   a. excessively high leakdown rate.
   b. leaky check-valve seat.
   c. improper adjustment.
3. General noise throughout valve train – this will, in most cases, be a definite indication of insufficient oil supply or improper adjustment.
4. Intermittent clicking probable causes are:
   a. a microscopic piece of dirt momentarily caught between ball seat and check valve ball.
   b. in rare cases, ball itself may be out-of-round or have a flat spot.
   c. improper adjustment.

In most cases, where noise exists in one or more lifters, all lifter units should be removed, disassembled, cleaned in solvent, reassembled and reinstalled in engine. If dirt, corrosion, carbon, etc., is shown to exist in one unit, it most likely exists in all the units, thus it would only be a matter of time before all lifters caused trouble.

Removal:

1. Drain cooling system (See Section 10, Cooling System).
2. Remove intake manifold.
3. Remove rocker-arm cover and rocker arms.
4. Remove push rod(s).
5. Remove valve lifters.

IMPORTANT: Keep push rod and hydraulic valve lifter from each valve together as a matched set and mark them so they can be reinstalled in the same location later.

NOTE: If the hydraulic lifter is stuck, use a valve lifter remover tool (J-3049) to remove lifter.

> ⚠ **CAUTION**
>
> Install all new hydraulic lifters when a new camshaft is installed.
>
> Change the engine oil and filter if any new hydraulic lifter is installed.

6. Inspect the hydraulic lifters for:
   a. scored or scuffed lifter body. If marks are present, inspect the mating bore of the cylinder block for damage. Replace parts as necessary.

b. scuffed or worn lifter-push-rod seat. If marks are present, inspect the push rod's mating end for damage. Replace parts as necessary.

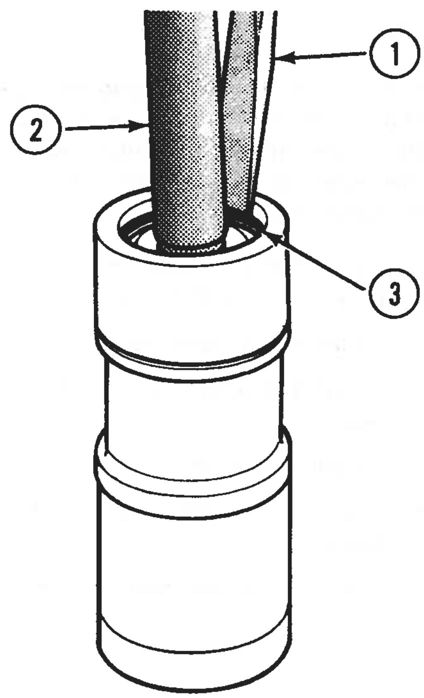
c. clearance between the lifter and its mating bore. If excessive clearance is found, try a new lifter or replace the cylinder block.

d. smooth and slightly convex surface on the lifter foot. If the foot is scored, pitted or extremely worn, check the mating camshaft lobe. Replace parts as necessary.

Disassembly:

IMPORTANT: The internal parts of each hydraulic lifter assembly are matched sets. Do not intermix the parts. Replace the complete lifter if any wear or damage is noted.

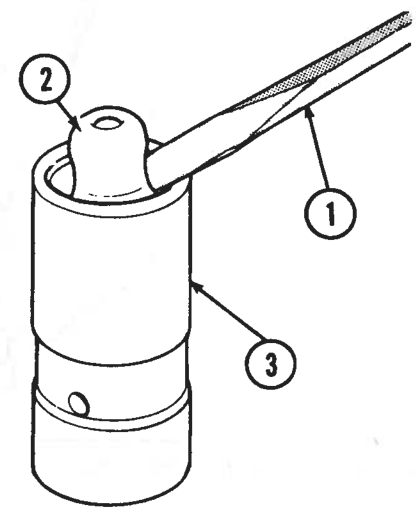
1. Hold plunger down with a push rod and remove push-rod-seat retainer with the blade of a small screwdriver.
2. Remove push-rod seat and metering valve.



1. Screwdriver
2. Push rod
3. Retainer

Figure 8-118. *Lifter-Seat Retainer Removal*

3. Remove the plunger and the plunger spring using the hydraulic valve-lifter-plunger remover (J-4160-A).
4. Remove the check-ball valve and spring by prying the ball retainer loose from the plunger with the blade of a small screwdriver.



1. Screwdriver
2. Check-ball retainer
3. Plunger

Figure 8-119. *Removing Check-Ball Valve*

Cleaning and Inspection:

Thoroughly clean all parts in cleaning solvent and inspect them carefully. If any parts are damaged or worn, entire lifter assembly should be replaced. If outer lifter-body wall is scuffed or worn, inspect cylinder-block-lifter bore. If bottom of lifter is scuffed or worn, inspect camshaft lobe. If push rod seat is scuffed or worn, inspect push rod.

Reassembly:

1. Place the check ball in small hole in bottom of the plunger.
2. Insert check-ball spring on seat in ball retainer and place retainer over ball so that spring rests on the ball. Carefully press the retainer into position in plunger with the blade of a small screwdriver.
3. Place the plunger spring over the check-ball retainer and slide the lifter body over the spring and plunger, being careful to line up the oil-feed hole in the lifter body and plunger.

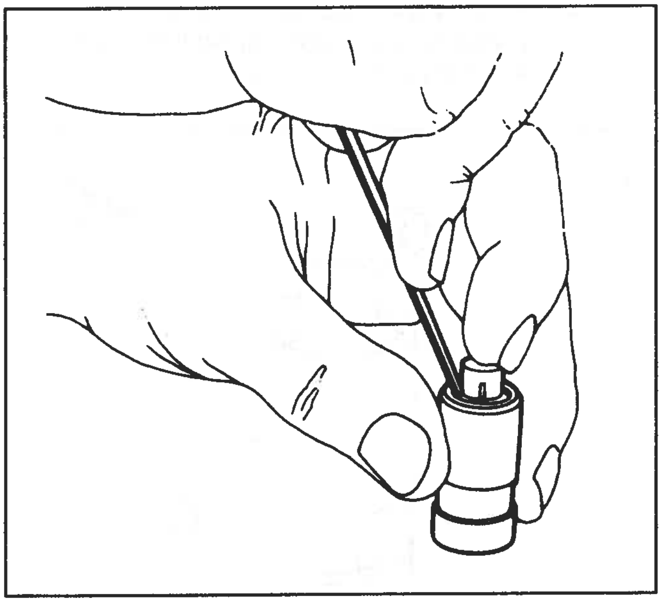
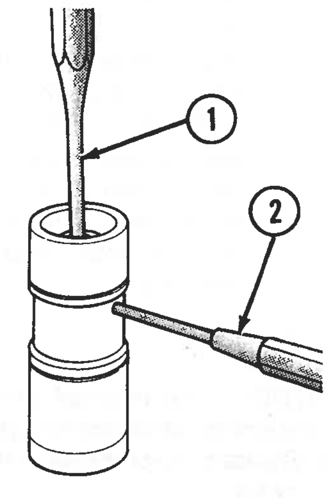


Figure 8-120. *Lifter Check-Ball Installation*

4. Fill the assembly with oil (see specifications). Insert the end of a 1/8-in. (3 mm) drift pin into the plunger and press down on check ball until hole in lifter body aligns with hole in plunger.
5. Insert a 1/16-in. (1.6 mm) drift pin through both oil holes to hold the plunger down against the lifter-spring tension.

IMPORTANT: Do not attempt to force or pump the plunger.

6. Remove the 1/8-in. (3 mm) drift pin and refill assembly with the oil.
7. Install the metering valve, push-rod seat and push-rod-seat retainer.
8. Press down on the push-rod seat with a push rod and remove the 1/16-in. (1.6 mm) drift pin from lifter. The lifter is now completely assembled, filled with oil and ready for installation.



1. 1/8-in. (3 mm) drift pin
2. 1/16-in. (1.5 mm) drift inserted in oil-feed hole

Figure 8-121. *Oil-Feed Holes Aligned And Drift Pin Installed*

Installation:

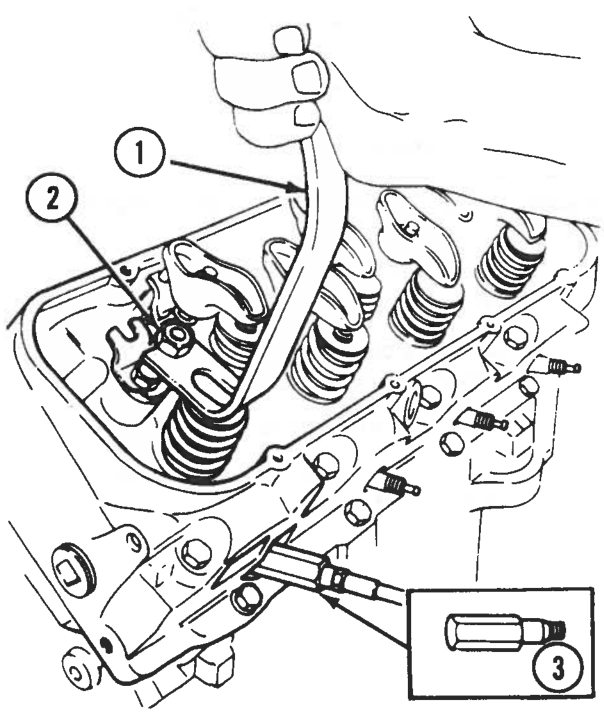
IMPORTANT: Before installing lifters, coat the bottom of the lifter with engine oil. If new lifters or a new camshaft have been installed, an additive containing EP lube should be poured over camshaft lobes before installing lifters.

1. Install hydraulic valve lifters into the same bore from which they were removed.
2. Install intake manifold.
3. Install and adjust valve mechanism as outlined.
4. Install rocker-arm cover.
5. Fill cooling system (see Section 10, Cooling System).
6. Start engine and check for leaks.

VALVE-STEM OIL SEAL/ VALVE SPRING

Removal:

1. Remove rocker-arm cover.
2. Remove spark plug, rocker arm and push rod on cylinder lo be serviced.
3. Position piston in cylinder to be serviced at TDC to prevent valve from dropping out of valve guide.
4. Install the J-23590 tool, air adapter, into spark plug hole. Apply air pressure to the cylinder.
5. Compress valve spring with J-5892 tool. Remove valve locks and all other components.



1. J-5892 tool
2. Rocker-arm nut
3. Air-adapter tool (J-23590)

Figure 8-122. Compressing Valve Spring With Cylinder Head Installed

Installation:

1. If removed, install damper in valve spring.
2. If engine has an additional valve-stem seal, install the intake-valve seal over the valve stem and seat it against the cylinder head.

NOTE: A light film of oil will help prevent twisting of the seal.

3. Set valve spring, damper, valve shield and cap in place. Be sure to install valve cap with rotator on exhaust valve. Compress spring with tool J-5892 and install O-ring seal into lower groove of valve stem.

IMPORTANT: Compress valve spring only enough to install valve locks in next step. Excessive compression could cause damage to seal.

4. Install valve locks and release pressure of tool, being sure that locks are in place. Grease may be used to help hold locks while removing pressure from tool.
5. Install spark plug(s) and torque to specifications.
6. Install and adjust valve mechanism.
7. Install rocker-arm cover and torque to specifications.
8. Start engine and check for leaks.

CYLINDER HEAD ASSEMBLY

Removal:

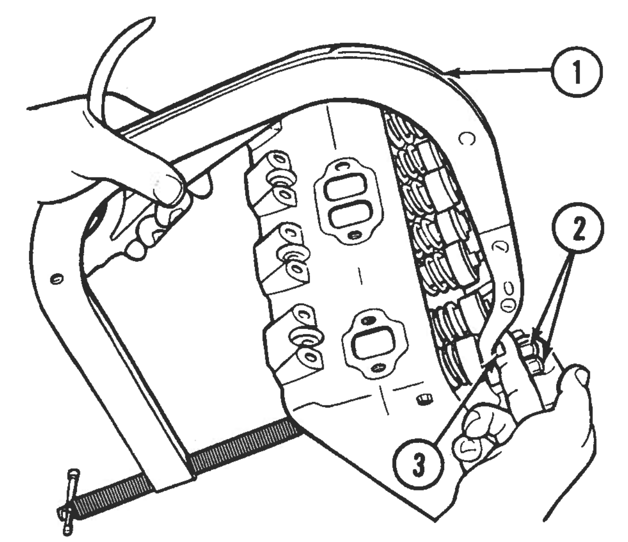
1. Drain engine cooling system.
2. Remove exhaust manifolds.
3. Remove intake manifold.
4. Remove valve mechanism.

NOTE: Remove any component attached to front or aft end of cylinder head to be removed.

5. Remove spark plugs.
6. Remove spark-plug-wire retainers from cylinder head.
7. Remove cylinder-head bolts, cylinder head and gasket.
8. Place cylinder head on two blocks of wood to prevent damage.

Disassembly:

1. With cylinder head removed, remove rocker arms and components (if not previously done).
2. Compress valve springs with J-8062 tool and remove valve retainers. Release compressor tool and remove all components.
3. Remove valves from cylinder head and place valves in a rack in their proper sequence for reassembly in their original positions.

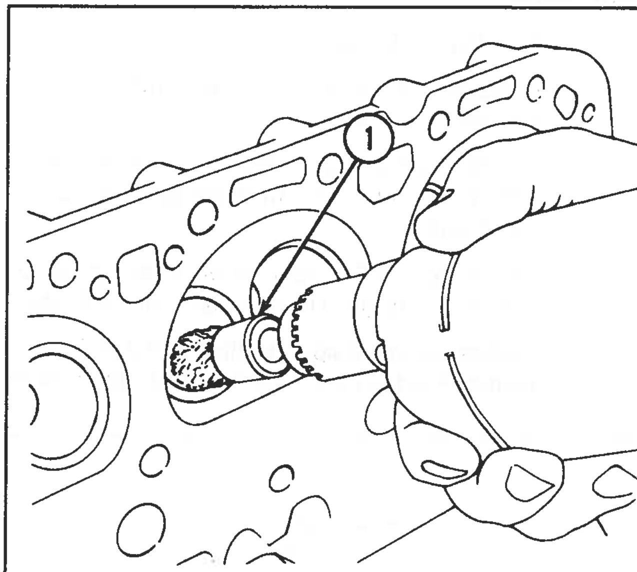


1. J-8062 spring-compression tool
2. Valve retainers
3. O-ring

***Figure 8-123.** Compressing Valve Spring With Cylinder Head Removed*

Cleaning:

1. Clean all carbon from combustion chambers and valve ports with J-8089 tool.



1. J-8089 wire-brush tool

***Figure 8-124.** Cleaning Combustion Chambers*

2. Thoroughly clean valve guides with J-8101 tool.
3. Clean all carbon and sludge from push rods, rocker arms and push-rod guides.
4. Clean carbon from valves on a buffing wheel.
5. Clean carbon deposits and gasket material from cylinder head.

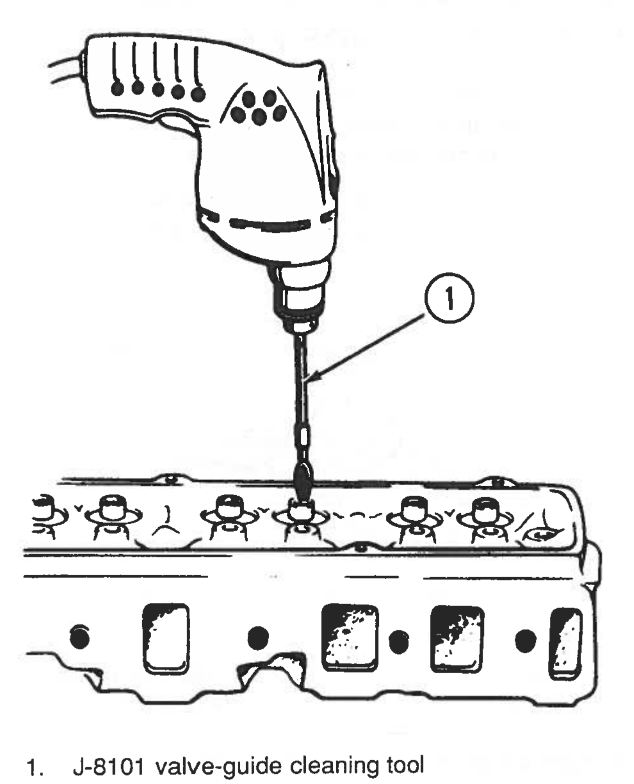


Figure 8-125. Cleaning Valve Guides

Inspection:

1. Inspect cylinder head for cracks in the exhaust ports, combustion chambers (especially around spark-plug holes and valve seats) and for cracks in external surface of water jacket. Replace head if cracked.
2. Inspect cylinder head gasket surface for burrs, nicks, erosion or other damage. Also, check flatness of cylinder-head-gasket surface, using a machinist's straightedge and feeler gauges as shown. Refer to "Specifications."

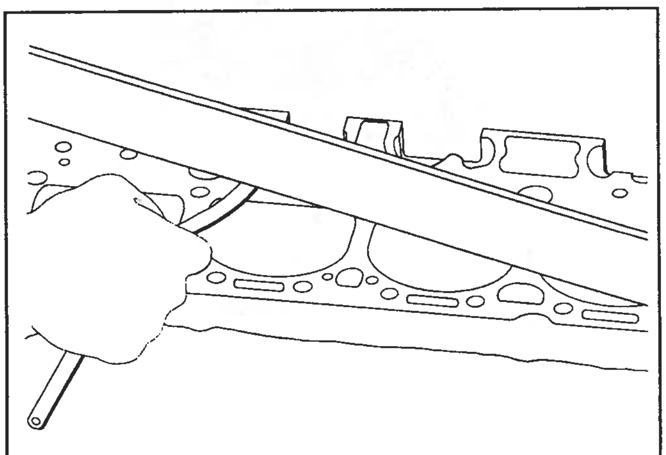


Figure 8-126. Checking Cylinder Head Flatness

IMPORTANT: Cylinder-head-to-block-gasket surface should be resurfaced if out-of-flat more than specified. When resurfacing gasket surface, cylinder-head-to-intake-manifold-gasket surface also must be milled to provide proper alignment between manifold and head.

3. Inspect valves for burned heads, cracked faces or damaged stems.

IMPORTANT: Excessive valve-stem-to-bore clearance will cause excessive oil consumption and possible valve breakage. insufficient clearance will result in noisy and sticky functioning of valve and disturb engine smoothness.

4. Measure valve stem clearance as follows: Clamp a dial indicator on one side of cylinder-head-rocker-arm-cover-gasket rail, locating indicator so that movement of valve stem from side to side (crosswise to the head) will cause a direct movement of indicator stem. Indicator stem must contact side of valve stem just above valve guide. With valve head dropped about 1/1 6 in. (2 mm) off valve seat, move valve stem from side to side, using light pressure to obtain a clearance reading. If clearance exceeds specifications, it will be necessary to ream valve guides for oversized valves as outlined under "Valve Guide Bores."

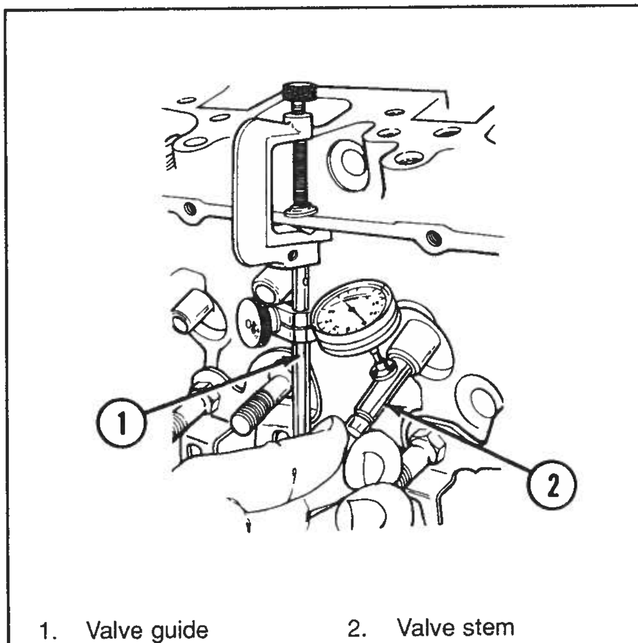
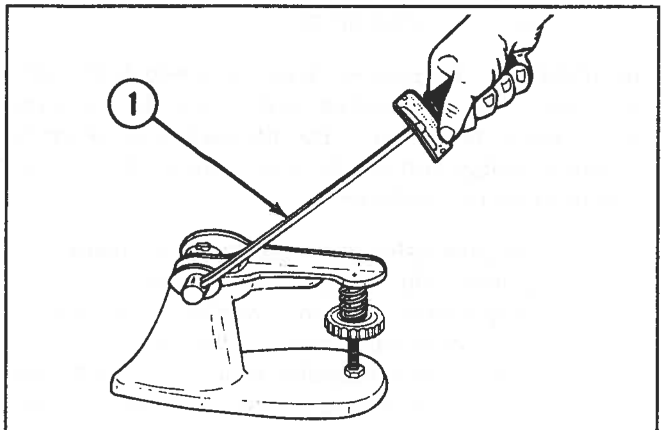


Figure 8-127. Measuring Valve Stem Clearance

5. Check valve spring tension with J-8056 spring tester.

IMPORTANT: Springs should be compressed to specified height and checked against specification. Springs should be replaced if not within 10 lb. (44 N) of specified load.

6. Inspect rocker-arm studs for wear or damage. Inspect push-rod guides for wear or damage.

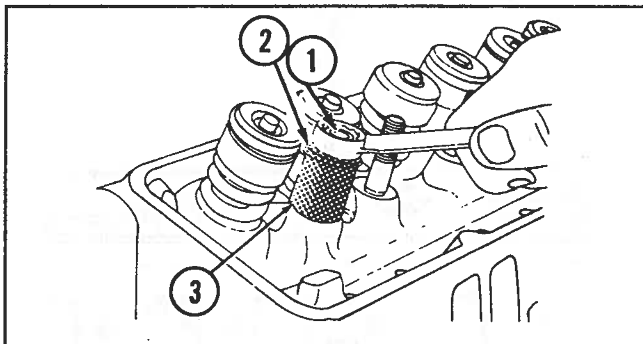


1. J-8056 tool

Figure 8-128. *Checking Valve-Spring Tension*

ROCKER-ARM STUDS AND PUSH-ROD GUIDE REPAIR

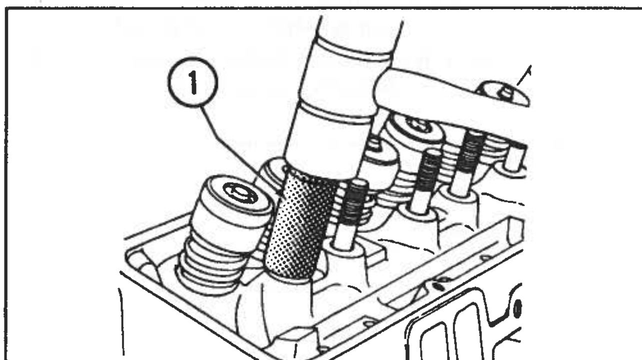
1. Rocker-arm studs, which are replaced because of wear or looseness, should be replaced with oversized studs.
2. Use tool J-5802-01 to remove old stud by placing tool, flat washer and nut over stud, then turning nut.



1. Nut
2. Flat washer
3. J-5802-01 rocker-arm stud remover

Figure 8-129. *Remove Rocker-Arm Stud*

3. Remove nut and washer. Place short spacer, washer and nut over stud. Retighten nut until stud is removed.
4. Ream stud hole whenever installing an oversized stud, using appropriate reaming tool.
5. Install new stud with tool J-6880 or similar stud-installing tool made for press-in-type studs. Follow instructions with tool.



1. J-6880 stud-installing tool

Figure 8-130. *Installing Rocker-Arm Stud*

VALVE-GUIDE BORE REPAIR

IMPORTANT: Be sure to measure valve stem diameter of both the intake and exhaust valve, as valve stem diameter may or may not be the same for both valves.

If 0.015-in. (0.38 mm) oversized valves are required, ream valve-guide bores for oversized valves as follows:

1. Measure valve-stem diameter of old valve being replaced and select proper-size Valve Guide Reamer from Set J-7049-5.
2. Ream valve-guide bores as shown.
3. Remove the sharp corner created by reamer at top of valve guide.

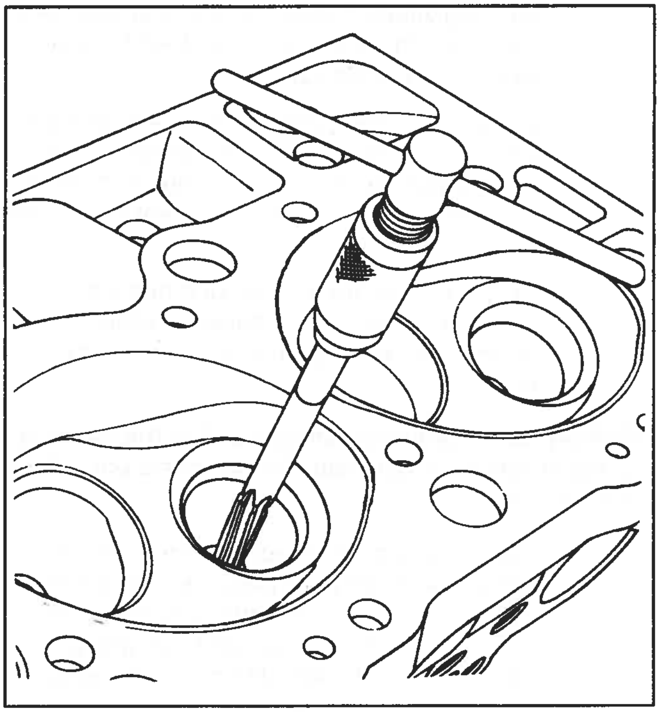


Figure 8-131. *Reaming Valve Guides*

VALVE SEAT REPAIR

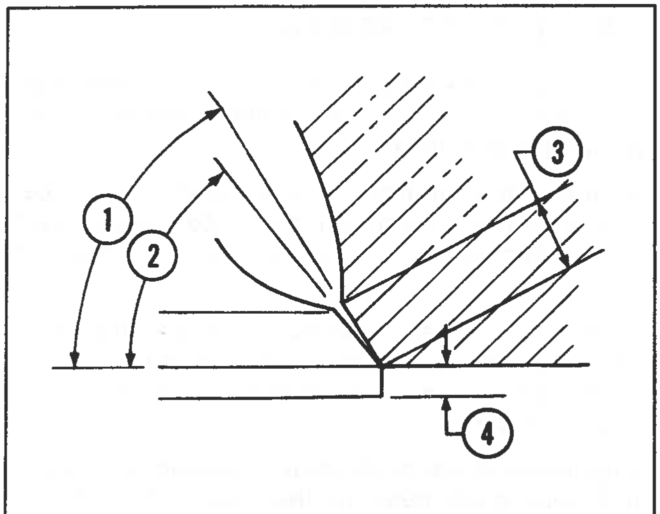
Valve seat reconditioning is very important, since seating of valves must be perfect for engine to deliver maximum power and performance.

Another important factor is valve-head cooling. Good contact between each valve and its seat is important to ensure that heat in the valve head will be properly dispersed.

Several different types of equipment are available for reseating valve seats. Equipment manufacturer's recommendations should be followed carefully to attain proper results.

Regardless of type of equipment, however, it is essential that valve-guide bores be free from carbon or dirt to ensure proper centering of pilot in valve guide.

1. Install expanding pilot in valve-guide bore and expand pilot.
2. Place roughing stone or forming stone over pilot and clean up valve seat only. Use a stone that is cut to specifications.
3. Remove roughing stone or forming stone from pilot, place finishing stone (cut to specifications) over pilot and cut just enough metal from seat to provide a smooth finish. Refer to "Specifications."
4. Narrow down valve seats to specified width by grinding with a 300 stone to lower seat and a 600 stone to raise seat.
5. Remove expanding pilot and clean cylinder head carefully to remove all chips and grindings from above operations.
6. Measure valve-seat width. See "Specifications."
7. Measure valve seat out-of-round. See "Specifications."



1. Valve-seat angle
2. Valve-face angle
3. Valve-seat width
4. Valve-edge thickness

Figure 8-132. *Valve-Seat-Grinding Angles*

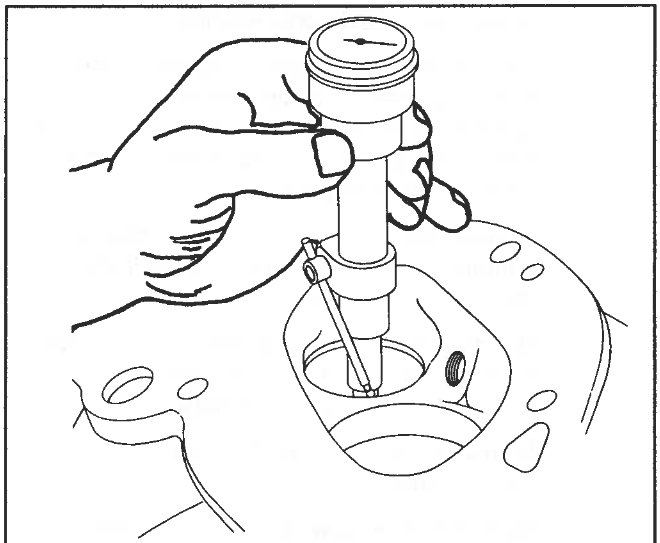


Figure 8-133. *Measuring Valve-Seat Concentricity*

VALVE REPAIR

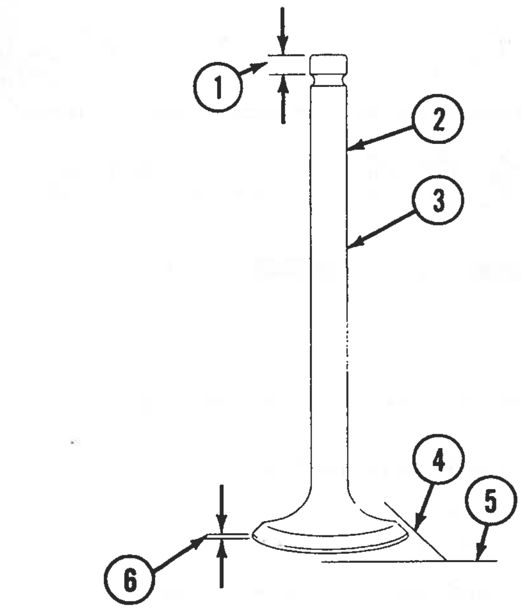
Pitted valves can be refaced to the proper angle on a valve grinder, thus ensuring correct relation between cylinder-head seat and valve-mating surface. Replace valves with excessive wear on stems or valves which are overly warped. When an excessively warped valve head is refaced, a knife edge will be ground on part or all of the valve head, due to amount of metal that must be removed to completely reface. Knife edges lead to breakage, burning or preignition caused by heat localizing in this knife edge. If edge of valve head is less than 1/32 in. (0.8 mm) thick after grinding, replace the valve.

Various equipment is available for refacing valves. Manufacturer's recommendations should be carefully followed to attain proper results.

1. If necessary, dress the valve-refacing-machine grinding wheel to make sure it is smooth and true. Set chuck at angle specified for valve. Refer to "Specifications."
2. Continue grinding until valve face is true and smooth all around the valve. If this makes valve head thin (1/32 in. [0.8 mm] minimum), valve must be replaced, or valve will overheat and burn.
3. Remove valve from chuck and place stem in V-block. Feed valve squarely against grinding wheel to grind any pit from rocker-arm end of stem.

IMPORTANT: Only the extreme end of the valve stem Is hardened to resist wear. Do not grind end of stem excessively.

4. After cleaning valve face and cylinder-head-valve seat of grinding particles, make pencil marks about 1/4 in. (6 mm) across the valve face, place valve in cylinder head and give valve 1/2 turn in each direction while exerting firm pressure on head of valve.
5. Remove valve and check face carefully. If all pencil marks have not been removed at point of contact with valve seat, repeat refacing operation and again recheck for proper seating.

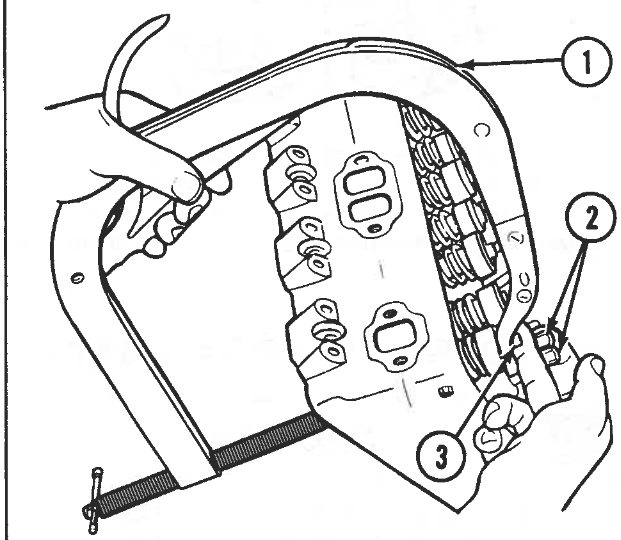


1. Refer to Specifications for min. dimensions
2. Check for bent stem
3. Diameter
4. Valve-face angle
5. This line parallel with valve head
6. 1/32 in. minimum

Figure 8-134. *Critical Valve Dimensions*

VALVE REASSEMBLY

1. Lubricate valve guides and valve stems with engine oil.
2. Install each valve in the port from which it was removed or to which it was fitted.
3. Install valve-stem-oil seal, valve spring(s) and related parts on each valve as explained under "Valve-Stem-Oil Seal/Valve Spring."
4. Compress valve spring with tool J-8062.



1. J-8062 spring-compressor tool
2. Valve retainers
3. O-ring

Figure 8-135. *Compressing Valve Spring With Cylinder Head Removed*

5. Check installed height of the valve springs with a narrow, thin scale. A cutaway scale will help. Measure from top of spacer (spring seat) to top of valve spring. If this exceeds specified height, install a valve-spring-seat shim approximately 1/16 in. (1.6 mm) thick. At no time should spring be shimmed to give an installed height under minimum specified.

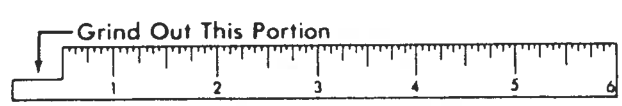
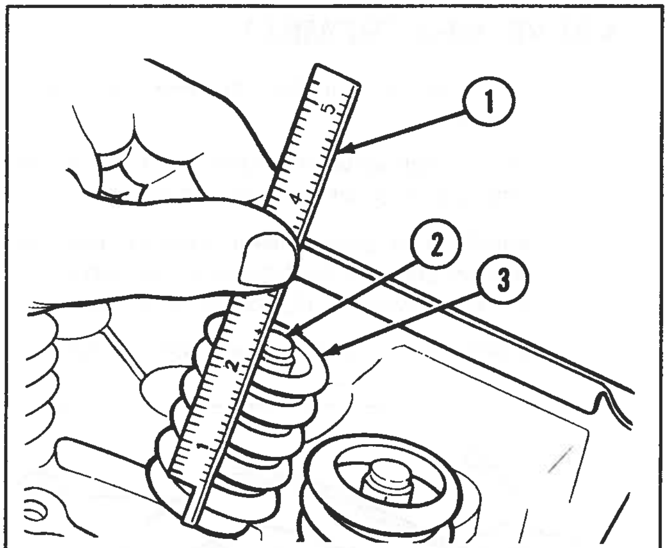


Figure 8-136. *Cutaway Scale*



1. Valve-installed height gauge
2. Valve tip
3. Valve spring

Figure 8-137. *Measuring Valve-Spring Installed Height*

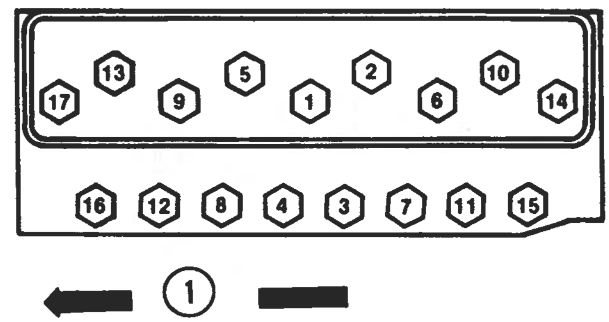
CYLINDER HEAD INSTALLATION

> **CAUTION**
>
> Gasket surfaces on both head and block must be clean of any foreign matter and free of nicks or deep scratches. Cylinder-bolt threads in block and threads on cylinder-head bolts must be clean. Dirt will affect bolt torque.

1. On engines using a stainless-steel gasket, coat both sides of new gasket with Perfect Seal. Spread sealer thin and even. Too much sealer may hold gasket away from head or block.

> **CAUTION**
>
> Use no sealer on engines which have a composition steel-asbestos gasket.

2. Place gasket in position over dowel pins.
3. Carefully guide cylinder head into place over dowel pins and gasket.
4. Coat threads of cylinder-head bolts with Perfect Seal and install bolts finger-tight.
5. Tighten each cylinder-head bolt a little at a time in sequence shown in Figure 8-138 until specified torque is reached.



1. Front

Figure 8-138. *Cylinder-Head Tightening Sequence*

6. Install intake manifold.
7. Install and adjust valve mechanism as outlined in this Section.
8. Install valve covers as outlined.
9. Install spark plugs. Torque spark plugs to specifications.
10. Install spark-plug-wire retainers.
11. Install exhaust manifolds as outlined.

NOTE: Install any component that was removed from the front or aft end of cylinder head.

12. Run engine, adjust timing and check for leaks.

OIL PAN

Removal:

1. Drain coolant.
2. Drain crankcase oil.
3. Remove oil dipstick and tube, if required.
4. Remove oil pan and discard gaskets.

Installation:

1. Thoroughly clean gasket and seal surfaces on oil pan, cylinder block, rear main bearing cap and crankcase front cover.
2. Coat both sides of oil-pan-side gaskets with Perfect Seal and place gaskets in position on each side of cylinder block.
3. Apply 1/8-in. (3 mm) bead of RTV Sealer to front and rear seal-mating surfaces on cylinder-block-rear-main-bearing cap, front cover and gaskets.

IMPORTANT: RTV Sealer sets up in about 15 minutes. Be sure to complete assembly promptly.

4. Install new front and rear seals, being sure ends of seals are butted properly against side gaskets.
5. Apply a 1/8-in. (3 mm) bead of RTV Sealer to outer surface of seals. This is extremely important on engines which have aluminum oil pans.

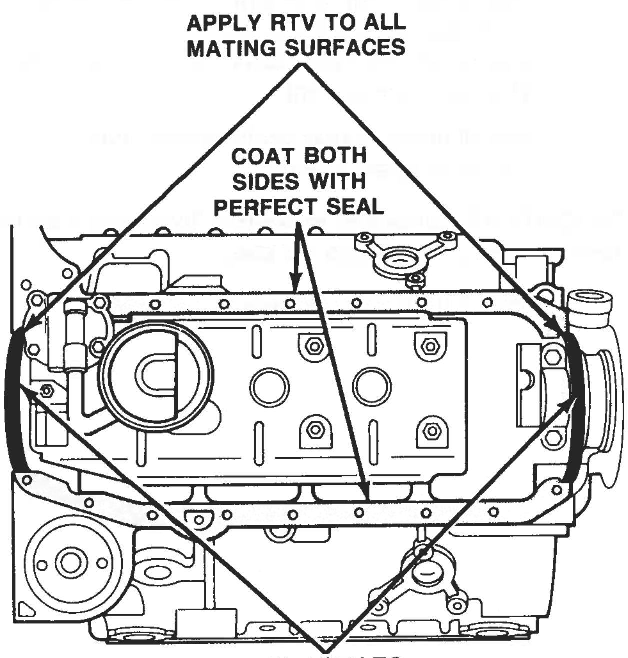
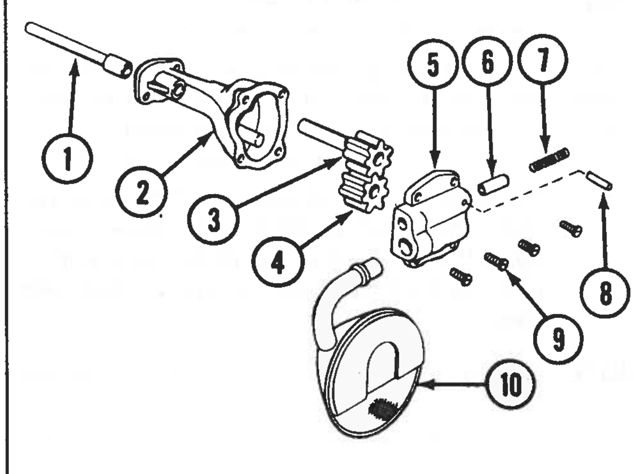


Figure 8-139. Applying RTV Sealer For Oil Pan

6. Carefully position oil pan against the block, being careful not to disturb gaskets and seals. Install oil-pan-attaching screws and washers. Torque screws to specifications, starting from center and working outward in each direction.
7. Install oil dipstick tube and dipstick.
8. Install engine in boat. Fill engine with oil, start engine and check for leaks.

OIL PUMP

The oil pump consists of two gears and a pressure-regulator valve enclosed in a two-piece housing (Figure 8-140). The oil pump is driven by the distributor shaft which is driven by a helical gear on the camshaft.



1. Extension shaft
2. Pump body
3. Drive gear
4. Idler gear
5. Pump cover
6. Pressure-regulator valve
7. Spring
8. Pin
9. Screw (4 used)
10. Pickup screen and pipe assembly

Figure 8-140. Oil Pump Assembly

To eliminate pressure loss, a baffle is incorporated on the pickup screen and engine-oil-pump lubes are bent at special angles.

Removal:

1. Remove oil pan.
2. Remove pump to rear main bearing-cap bolt and remove pump and extension shaft.

Disassembly:

1. Remove pump-cover-attaching screws and pump cover.

IMPORTANT: Mark gear teeth so that pump can be reassembled with the same gear teeth indexed.

2. Remove idler gear, drive gear and shaft from pump body.
3. Remove retaining pin, pressure-regulator valve and related parts.

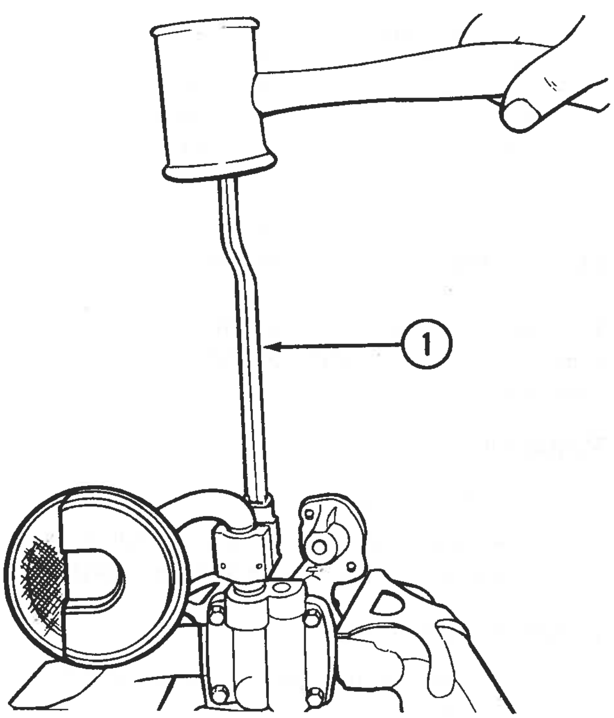
IMPORTANT: Do not remove pickup screen and pipe assembly unless replacement is necessary. Loss of press-fit could result in an air leak and loss of oil pressure.

Reassembly:

> **CAUTION**
>
> Be careful of twisting, shearing or collapsing pipe while installing in pump. Pickup screen must be parallel to oil-pan rails when oil pump is installed.

1. If pickup screen and pipe assembly have been removed, mount pump in a soft-jawed vise, apply Perfect Seal to end of new pipe and, using tool J-21882, tap the pipe in place with a hammer.

NOTE: Tool will have to be modified to fit later engines.



1. J-8369 tool

Figure 8-141. *Installing New Pickup Screen And Pipe Assembly*

IMPORTANT: Oil internal parts liberally before installation.

2. Install pressure-regulator valve and related parts.
3. Install drive gear and shaft in pump body.
4. Install idler gear in pump body with smooth side of gear toward pump-cover opening. Align marks made during disassembly.
5. Install pump cover and torque attaching screws to specifications.
6. Turn drive shaft by hand to check for smooth operation.

Installation:

1. Assemble pump and extension shaft to rear main bearing, aligning slot on top end of extension shaft with drive tang on lower end of distributor-drive shaft.
2. Install pump to rear main bearing cap and torque to specifications.

IMPORTANT: Oil-pump screen is installed with bottom edge parallel to the oil pan.

3. Install oil pan as outlined.

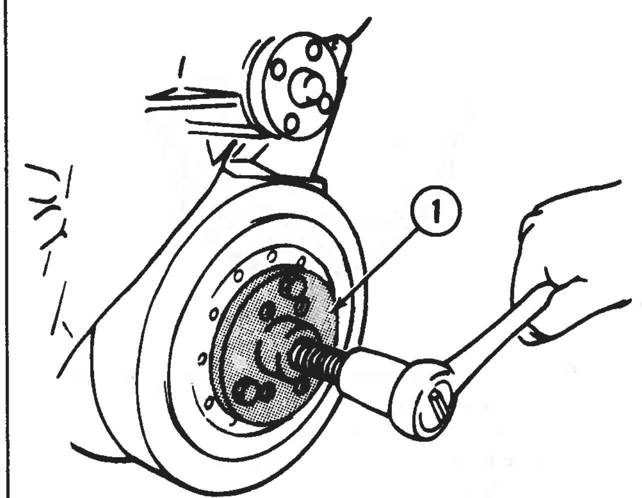
TORSIONAL DAMPER

Removal:

1. Remove drive belts.
2. Remove drive pulley, then remove damper-retaining bolt.

IMPORTANT: Do not use a Universal claw-type puller to remove torsional damper (in next step) as outside ring of damper is bonded in rubber to the hub, and use of claw-type puller may break the bond.

3. Remove damper with tool J-23523-E.



1. J-23523-E torsional damper-puller tool

Figure 8-142. Removing Torsional Damper

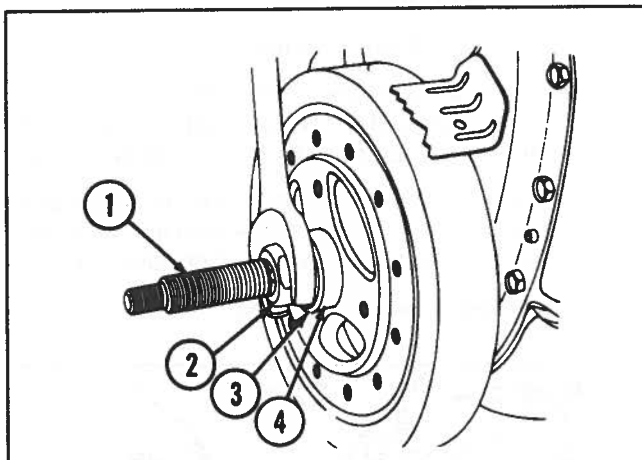
Installation:

IMPORTANT: The inertia weight section of the torsional damper is assembled to the hub with a rubber-type material. The installation procedure (with proper tool) must be followed or movement of the inertia weight on the hub will destroy the tuning of the torsional damper.

1. Coat front-cover-seal-contact area (on damper) with engine oil.
2. Pull damper onto crankshaft, using tool J-23523-E, as follows:
   a. Install appropriate end of threaded rod into crankshaft.

IMPORTANT: Be sure to install threaded rod in crankshaft so that at least 1/2 in. (13 mm) of thread engagement is obtained to prevent damage to threads.

   b. Install plate, thrust bearing, washer and nut on rod.
   c. Pull damper onto crankshaft (by turning nut) until it bottoms out.



1. Stud
2. Nut
3. Washer
4. Bearing

Figure 8-143. Installing Torsional Damper

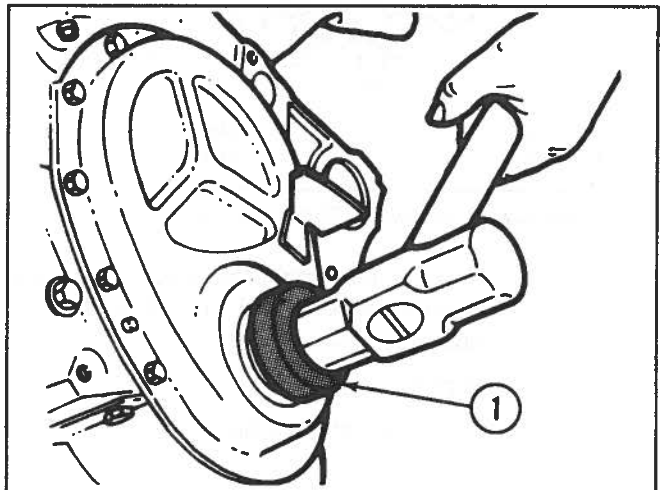
   d. Remove tool from crankshaft, then install damper-retaining bolt and torque to specifications.

3. Install drive pulley(s).
4. Install and adjust drive belts.

CRANKCASE-FRONT COVER/OIL SEAL

Oil Seal Replacement Without Removing Crankcase-Front Cover:

1. Remove torsional damper.
2. Pry seal out of cover from the front with a large screwdriver, being careful not to distort front cover or damage crankshaft-seal surface.
3. Install new seal with open end of seal inward, using tool J-35468. Drive seal in until it just bottoms out. Do not use excessive force.
4. Reinstall torsional damper.



1. J-35468 seal-installer tool

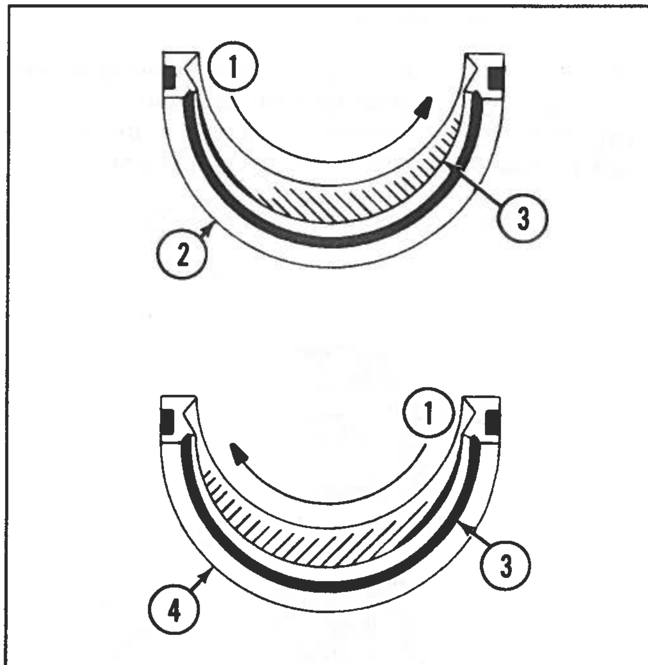
Figure 8-144. *Installing Front-Cover Oil Seal – Cover Installed*

Oil Seal Removal With Crankcase-Front Cover Removed:

1. Remove engine from boat.
2. Remove torsional damper and oil pan.
3. Remove water-circulating pump.
4. Remove crankcase-front-cover-attaching screws and remove cover. Remove and discard cover gasket.
5. If damaged, drive oil seal out of front cover (from the rear) with a punch.

Oil Seal Installed With Crankcase-Front Cover Removed:

IMPORTANT: Correct-rotation oil seal must be used to prevent oil leak.



1. Rotation of crankshaft as viewed from flywheel end looking forward
2. LH rotation engines
3. Seal lip toward inside of engine
4. RH rotation engines

Figure 8-145. *Front Seals With Helical Grooves*

1. Clean front cover in solvent and dry with compressed air. Clean old gasket material and sealer from mating surfaces on cover and cylinder block. Check gasket surface on front cover for distortion and true if necessary. Surfaces must be clean and flat or oil leakage may result.
2. Using tool J-35468, install oil seal in cover with lip of seal toward inside of engine. Support cover around seal area with appropriate tool as shown in Figure 8-146.

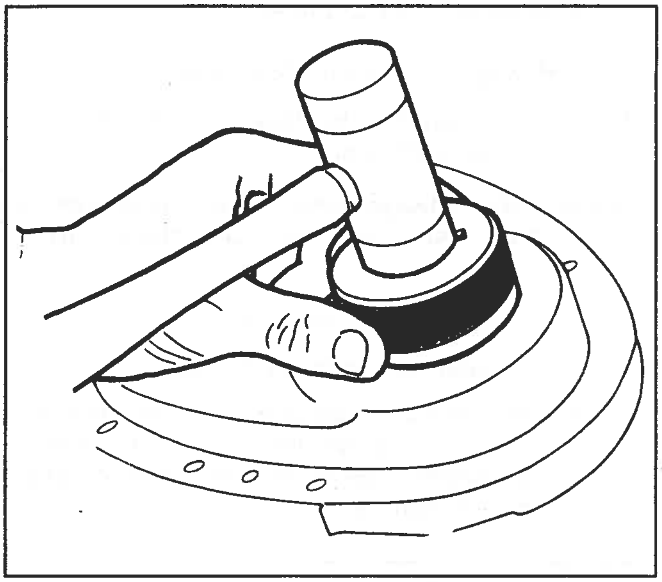


Figure 8-146. *Installing Front-Cover Oil Seal With Cover Removed*

3. Coat both sides of front cover gasket with Perfect Seal and place in position on engine.
4. Install front cover, making sure holes in cover align with dowel pins in block. Torque front-cover-attaching screws to specifications.
5. Install oil pan and torsional damper as outlined.
6. Install water-circulating pump.
7. Reinstall engine in boat.
8. Fill crankcase with engine oil.
9. Start engine and check for water and oil leaks.

FLYWHEEL

Removal:

1. Remove transmission.
2. Remove flywheel housing and related parts.
3. Remove drive-damper-attaching screws and washers and remove drive damper. Remove flywheel-attaching screws and washers and remove flywheel.

Inspection:

1. Inspect drive damper for worn splines.
2. Check flywheel-ring gear for worn or missing teeth.

Installation:

1. Clean mating surfaces of flywheel and crankshaft.

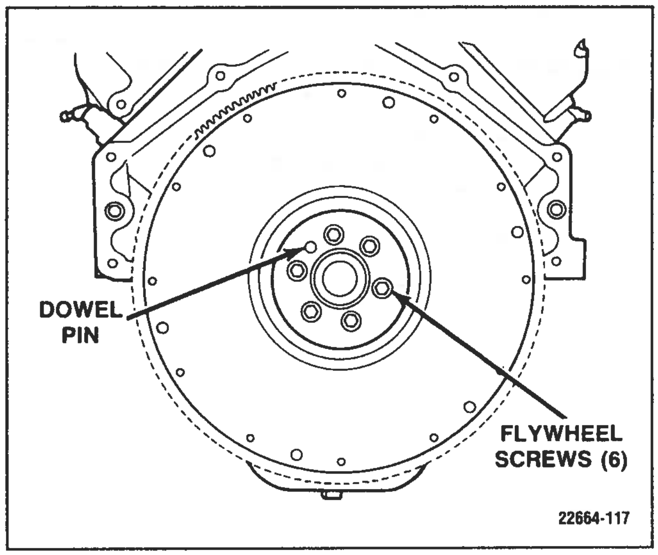
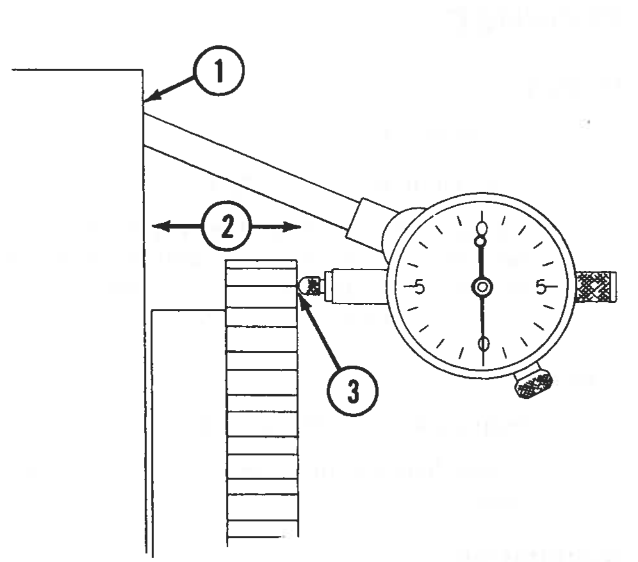


Figure 8-147. *Installing Flywheel*

2. Align dowel hole in flywheel with dowel or dowel hole in crankshaft flange and place flywheel in position on flange.
3. Secure flywheel with screws and lock-washers. Torque screws to specifications.
4. Install drive plate and torque to specifications.
5. Check flywheel run-out by mounting dial indicator on machined surface of flywheel.
6. Run-out should not exceed 0.008 in. (0.203 mm). If excessive, remove flywheel and check for burrs or replace flywheel.



1. Rear of engine
2. Hold flywheel and crankshaft forward or rearward as far as they will go when taking reading
3. 0.008 in. (0.203 mm) max. run-out

Figure 8-148. *Checking Flywheel Run-Out*

7. Install flywheel housing and related parts. Torque flywheel-housing screws to specifications.
8. Install transmission.

REAR MAIN OIL SEAL

Two-Piece Rear Main Seal Removal:

Both halves of rear main bearing-oil seal can be replaced without removing crankshaft.

IMPORTANT: Always replace upper and lower seal as a unit. Install with lip facing toward front of engine.

1. Remove oil pan and oil pump.
2. Remove rear main bearing cap.
3. Remove lower half of oil seal from the bearing cap by prying from the bottom with a small screwdriver. Be careful not to damage seal seating surface.

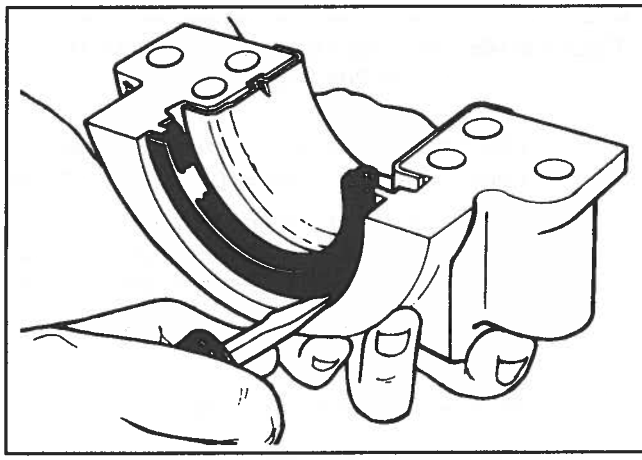


Figure 8-149. *Removing Lower Half Of Oil Seal*

4. Using a hammer and a soft metal pin punch, tap upper half of oil seal on one end until it protrudes far enough on the other end to remove it with pliers.
5. Clean rear main bearing cap, cylinder block and crankshaft with solvent and blowdry with compressed air. Be sure all of the old sealer is removed from bearing cap and cylinder-block-mating surfaces.

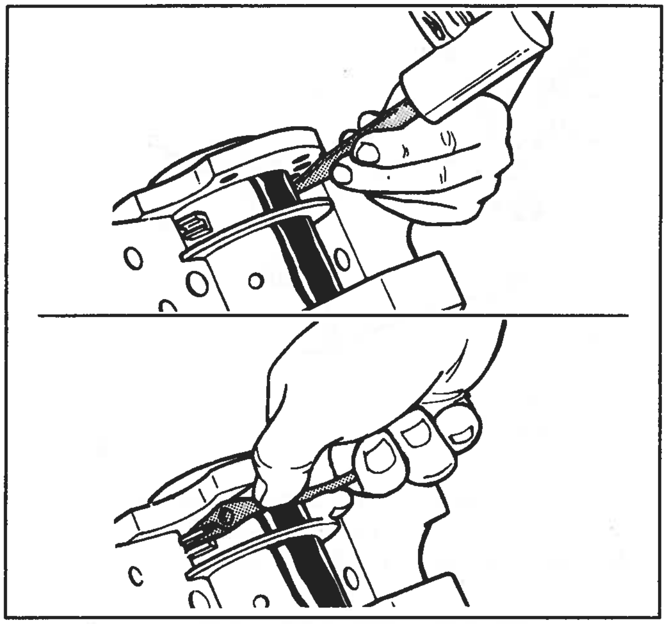
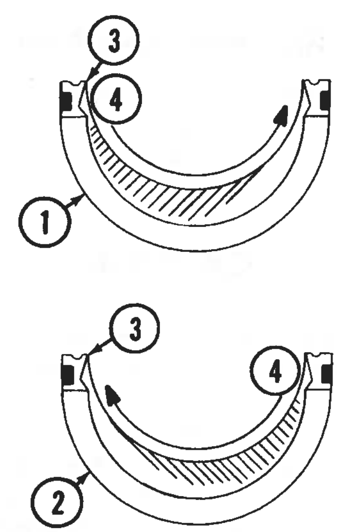


Figure 8-150. Removing Upper Half Of Oil Seal

Two-Piece Rear Main Seal Installation:

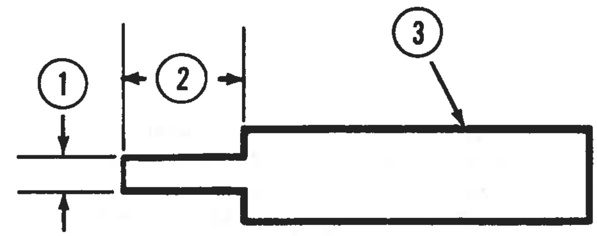
IMPORTANT: Correct-rotation oil seal must be used to prevent oil leak.



1. LH rotation engines
2. RH rotation engines
3. Seal lip toward inside of engine
4. Rotation of crankshaft as viewed from flywheel end looking forward

Figure 8-151. Rear Seals With Helical Grooves

Extreme care must be exercised when installing seal to prevent damage to sealing bead, located in the channel on outside diameter of the seal. To protect this bead, installation tool must be used. Construct tool using 0.004-in. (0.1 mm) shim stock if tool is not supplied with seal.



1. 11/64 in. (4 mm)
2. 1/2 in. (13 mm)
3. 0.004 in. (0.10 mm) shim stock

Figure 8-152. Installing Rear Main Seal – Cylinder Block Inverted

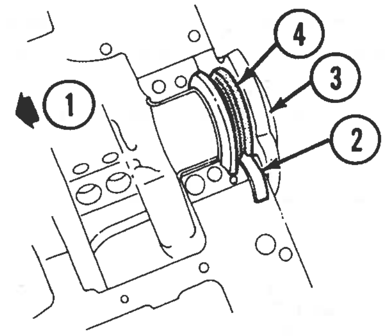
1. Coat lips and sealing bead on new rear oil seal with engine oil. Keep oil off seal-parting surfaces.

IMPORTANT: Be sure to install oil seal with lip facing toward inside of engine.

2. Install upper half of oil seal:
   a. Position tip of installation tool between crankshaft and seal-seating surface in cylinder block.
   b. Position upper half of seal between crankshaft and tip of installation tool so that seal bead contacts tip of tool.
   c. Roll upper half of seal around crankshaft using installation tool as a “shoehorn” to protect seal bead from sharp corner of seal-seating surface.

IMPORTANT: Installation tool must remain in position until seal is properly positioned with both ends flush with block.

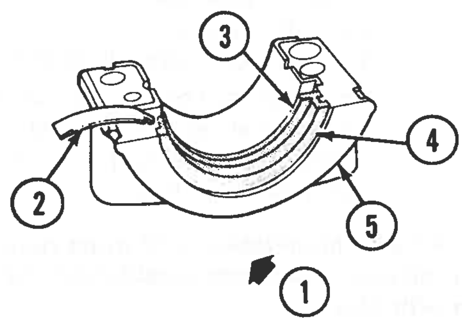
   d. After both ends of seal half are flush with block, remove installation tool.



1. Forward
2. Fabricated tool
3. Crankshaft
4. Upper seal half

Figure 8-153. *Installing Upper Half Of Oil Seal*

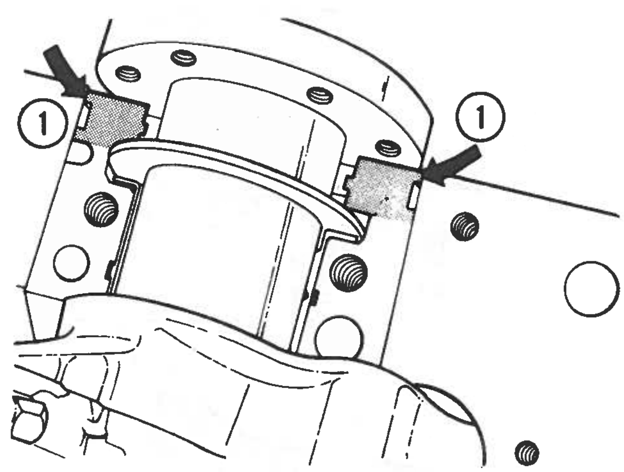
3. Install lower half of oil seal:
   a. Position oil-seal half in rear main bearing cap so that one end is slightly below mating surface and seal lip is facing toward bearing. Do not allow sealing bead on other end of seal half to contact seal-seating surface.
   b. Insert installation tool between sealing bead and seal-seating surface, then, using tool as a "shoehorn" to protect sealing bead from sharp corner of seal-seating surface, roll seal into place. Seal is properly positioned when both ends are flush with cap.
   c. Remove installation tool.



1. Forward
2. Fabricated tool
3. Oil-seal lip
4. Lower seal half
5. Main bearing gap

Figure 8-154. *Installing Lower Half Of Oil Seal*

4. Make sure that bearing cap and cylinder-block-mating surfaces and oil-seal-parting surfaces are clean and free of oil, then apply Perfect Seal to block at locations shown. Do not get sealer on seal-parting surfaces or on surfaces adjacent to main bearing inserts.



1. Apply Perfect Seal to outlined area only

Figure 8-155. *Applying Sealer to Block*

5. Install rear main bearing cap and torque attaching bolts to 10-12 lb-ft (13.6-16.3 N•m). Tap crankshaft, first backward and then forward, with a lead hammer to line up rear main bearing-thrust surfaces. With crankshaft in forward position, torque rear main bearing-cap-attaching bolts evenly (alternating from side to side) to specifications.
6. Install oil pump and oil pan as outlined.

One-Piece Rear Main Seal Removal:

The one-piece rear crankshaft oil seal can be replaced without removing the oil pan or rear main bearing cap from engine. Transmission and flywheel must be removed.

CAUTION

Care should be taken when removing the rear crankshaft oil seal so as not to nick the crankshaft sealing surface.

1. Insert a screwdriver into the notches provided in the seal retainer and pry the seal out. Take care not to damage the crankshaft-sealing surface.

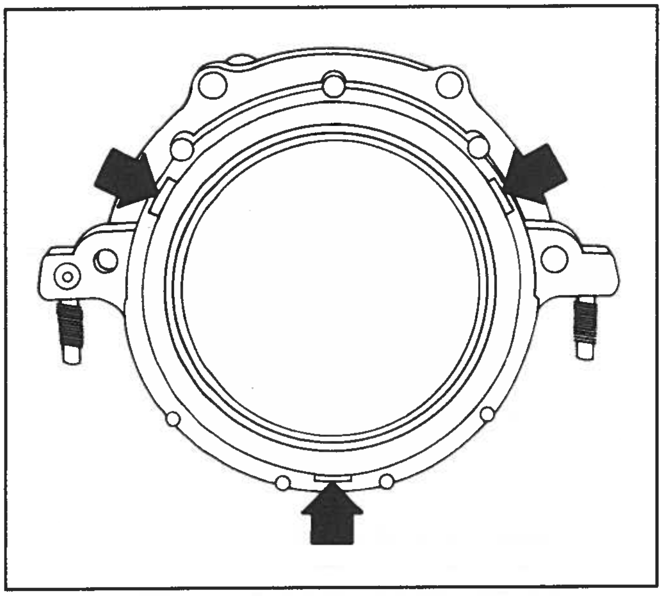
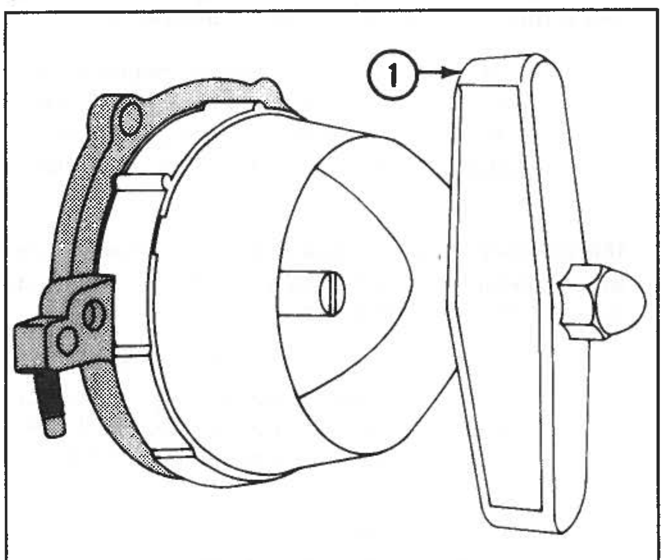


Figure 8-156. Removing Rear Crankshaft Seal

2. Clean crankshaft-seal-running surface and seal retainer.

One-Piece Rear Main Seal Installation:

1. Lubricate the inner and outer diameter of the seal with engine oil.
2. Install the seal on J-35621.
3. Position the tool J-35621 against the crankshaft. Thread the attaching screws into the tapped holes in the crankshaft.



1. J-35621 rear main seal-installer tool

Figure 8-157. Installing Rear Crankshaft-Oil Seal

4. Tighten the screws securely with a screwdriver. This will ensure that the seal is installed squarely over the crankshaft.
5. Turn the handle until it bottoms.
6. Remove J-35621.

MAIN BEARINGS

Main bearings are precision-insert-type and do not use shims for adjustment. If clearances are excessive, a new bearing (both upper and lower halves) will be required. Bearings are available in standard size and undersize. Selective fitting of both the rod and the main bearing inserts is necessary in production to obtain close tolerances. Consequently, one half of a standard insert may have one half of a 0.001-in. (0.025 mm) undersized insert which will decrease clearance 0.0005 in. (0.013 mm) from using a full standard bearing.

When a production crankshaft cannot be precision-fitted by this method, it then is ground 0.009-in. (0.229 mm) undersize on main journals only. A 0.009-in. (0.229 mm) undersized bearing and 0.010-in. (0.25 mm) undersized bearing may be used for precision-fitting in the same manner as previously described. Any engine fitted with a 0.009-in. (0.229 mm) undersized crankshaft will be identified by the following markings:

- The number 0.009 will be stamped on the crankshaft counterweight, forward of the center main journal.
- A figure 9 will be stamped on the block at left front oil-pan rail.
- A crankshaft with an undersized journal will be painted with light green on each side of the affected journal.

IMPORTANT: If the crankshaft has an undersized journal and a new bearing is required, journal must be reconditioned to accept a 0.010 in. (0.25 mm) or a 0.020 in. (0.51 mm) undersized bearing, as 0.009-in. (0.229 mm) undersized bearings are not available for service.

Inspection:

In general (except No. 2 bearing), lower half of bearing shows greater wear and more distress from fatigue. After inspection, if lower half is suitable for use, it can be assumed that the upper half also is satisfactory. If lower half is worn or damaged, both upper and lower halves should be replaced. Never replace one half without replacing the other.

Checking Clearance

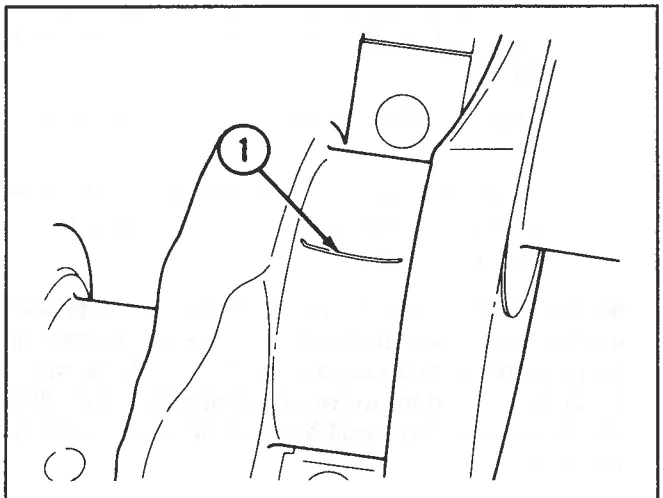
To obtain best results, use Plastigage (or its equivalent), a wax-like plastic material which will compress evenly between bearing and journal surfaces without damaging either surface. With engine upside down, the crankshaft will rest on upper bearings, and total clearance can be measured between lower bearing and journal.

IMPORTANT: To ensure proper seating of crankshaft, all bearing-cap bolts should be at their specified torque. In addition, surface of crankshaft journal and bearing should be wiped clean of oil before checking fit of bearings. Remove oil seal from rear main bearing cap prior to checking clearance.

1. With oil pan, baffle (some engines) and oil pump removed (starting with rear main bearing), remove bearing cap and wipe oil from journal and bearing cap.
2. Place a piece of the gauging plastic full width of the bearing (parallel to the crankshaft) on journal.

IMPORTANT: Do not rotate crankshaft while gauging plastic is between bearing and journal.

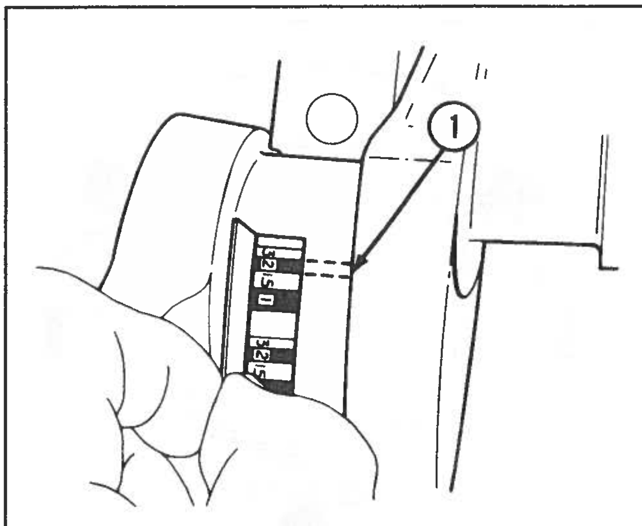
3. Install bearing cap and torque retaining bolts evenly to specifications.



1. Gauging plastic on journal

Figure 8-158. *Gauging Plastic on Journal*

4. Remove bearing cap. Flattened gauging plastic will be found adhering to either bearing shell or journal.
5. Use scale, graduated in thousandths of an inch, on edge of gauging-plastic envelope. Without removing gauging plastic, measure its compressed width (at widest point) with graduations on gauging-plastic envelope.



1. Measuring gauging plastic

Figure 8-159. *Measuring Gauging Plastic*

IMPORTANT: Main bearing journals usually wear evenly and are not out-of-round. If a bearing is being fitted to an out-of-round journal (0.001 in. [0.025 mm] maximum), however, be sure to fit bearing to the maximum diameter of the journal. If bearing is fitted to the minimum diameter, and journal is out-of-round 0.001 in. (0.025 mm), interference between the bearing and the journal will result in rapid bearing failure. If flattened gauging plastic tapers toward middle or ends, there is a difference in clearance indicating taper, low spot or other irregularity of bearing or journal. Be sure to measure journal with a micrometer if flattened gauging plastic indicates more than 0.001 in. (0.025 mm) difference.

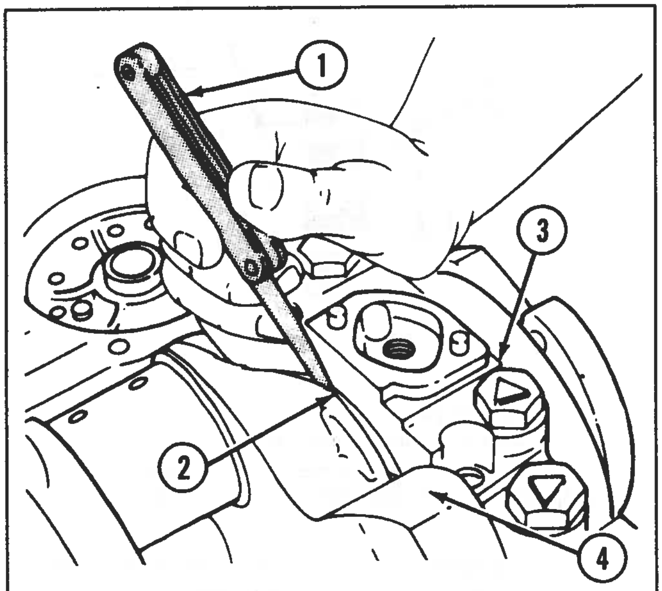
6. If bearing clearance is within specifications, bearing insert is satisfactory. If clearance is not within specifications, replace the insert. Always replace both upper and lower insert as a unit.

IMPORTANT: If a new bearing cap is being installed and clearance is less than 0.001 in. (0.025 mm), inspect for burrs or nicks.

7. A standard 0.001-in. (0.025 mm) or 0.002-in. (0.051 mm) undersized bearing may produce proper clearance. If not, regrind crankshaft journal for use with next undersized bearing.
8. Proceed to next bearing. After all bearings have been checked, rotate crankshaft to see that excessive drag does not exist.
9. Install front four main bearing caps and torque evenly to specifications.
10. Install rear main bearing cap and torque attaching bolts to 10-12 lb-ft (13.6-16.3 N•m).

Tap end of crankshaft, first backward and then forward, with a hammer to align rear main bearing-thrust surfaces. With crankshaft in forward position, torque rear main bearing-attaching bolts evenly (alternating from side to side) to specifications.

11. Measure crankshaft end-play with a feeler gauge by forcing crankshaft forward and measuring clearance between the front of the rear main bearing and the crankshaft. If clearance is excessive, rear main bearing and/or crankshaft must be replaced.



1. Feeler gauge
2. Main bearing-thrust surface
3. Rear main bearing cap
4. Crankshaft

Figure 8-160. *Measuring Crankshaft End-Play*

12. Install a new rear main bearing-oil seal in cylinder block and main bearing cap as outlined.

Replacement:

NOTE: Main bearings may be replaced with or without removing crankshaft.

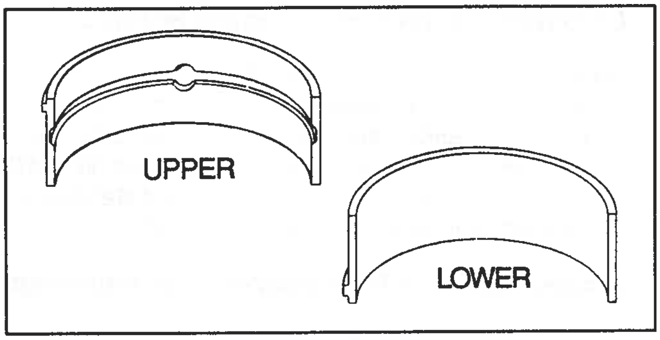


Figure 8-161. *Main Bearing Inserts*

With Crankshaft Removed

1. Remove and inspect crankshaft.
2. Remove main bearings from cylinder block and main bearing caps.
3. Coat bearing surfaces of new, correctly sized, main bearings with oil and install in cylinder block and main bearing caps.
4. Install crankshaft.

Without Crankshaft Removed

1. With oil pan, baffle (some engines), oil pump and spark plugs removed, remove cap on main bearing requiring replacement, and remove bearing from cap.
2. Replace main bearing upper half as follows:
   a. Install main bearing removing and installing tool in crankshaft-journal-oil hole.

NOTE: If tool is not available, bend a cotter pin.

   b. Rotate crankshaft clockwise (as viewed from front of engine). This will roll upper bearing out of block.
   c. Oil new selected-size upper bearing and insert plain (unnotched) end between crankshaft and notched side of block. Rotate bearing into place and remove tool from oil hole in crankshaft journal.
3. Oil new lower bearing and install in bearing cap.
4. Install main bearing cap with arrows pointing toward front of engine.
5. Torque main bearing-cap bolts to specifications.

CONNECTING-ROD BEARINGS

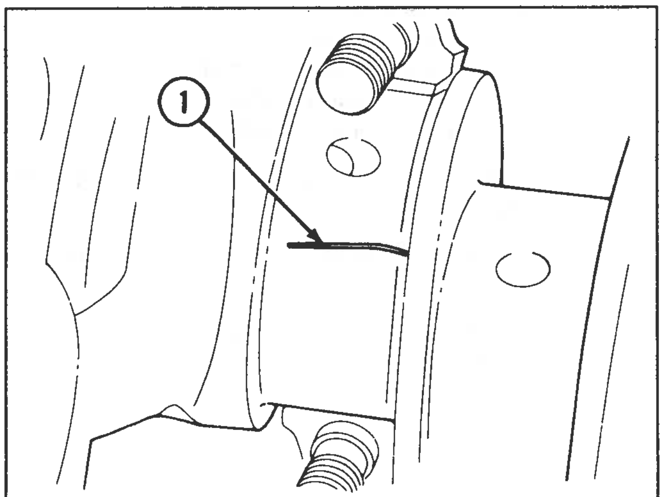
Connecting-rod bearings are precision-insert-type and do not use shims for adjustment. Do not file rods or rod caps. If clearances are found to be excessive, a new bearing will be required. Bearings are available in standard size and undersize for new and used standard-size crankshafts and reconditioned crankshafts.

Inspection and Replacement of Bearings:

1. With oil pan and oil pump removed, remove connecting-rod cap and bearing.
2. Inspect bearings for wear or damage and replace unsatisfactory bearings.
3. Wipe bearings and crankpin clean of oil.
4. Measure crankpin for out-of-round or taper with a micrometer. If not within specifications, replace or recondition crankshaft. If within specifications, and a new bearing is to be installed, measure maximum diameter of crankpin to determine new bearing size required.
5. Measure new or used bearing clearances with Plastigage or its equivalent.

IMPORTANT: If a bearing is being fitted to an out-of-round crankpin, be sure to fit bearing to maximum diameter of crankpin. If bearing is fitted to minimum diameter, and crankpin is out-of-round 0.001 in. (0.025 mm) or more, interference between bearing and crankpin will result in rapid bearing failure.

   a. Install bearing in connecting rod and cap.
   b. Place a piece of gauging plastic the full width of the crankpin (parallel to the crankshaft).



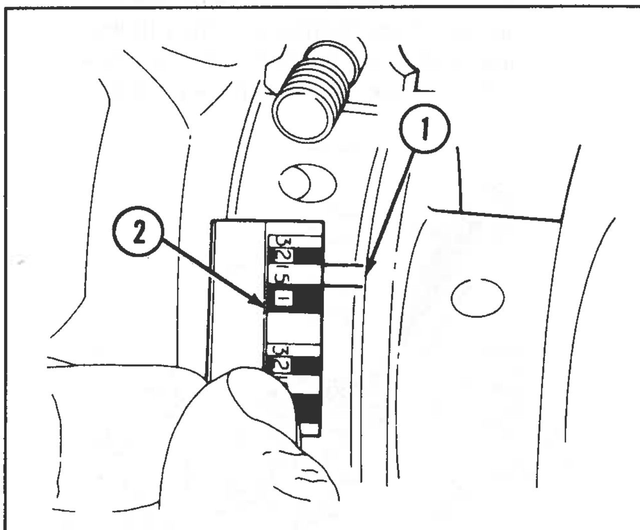
1. Gauging plastic

Figure 8-162. *Gauging Plastic On Crankpin*

   c. Install bearing cap and torque nuts evenly to specifications.

IMPORTANT: Do not turn crankshaft with gauging plastic installed.

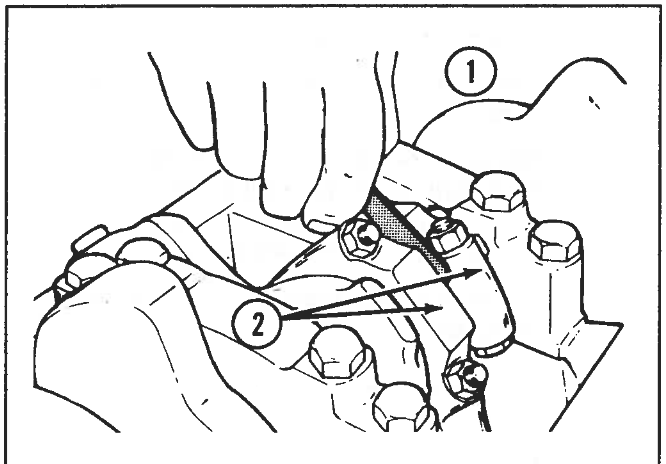
   d. Remove bearing cap, and using scale on gauging-plastic envelope, measure gauging-plastic width at the widest point.



1. Gauging plastic
2. Chart from gauging plastic package

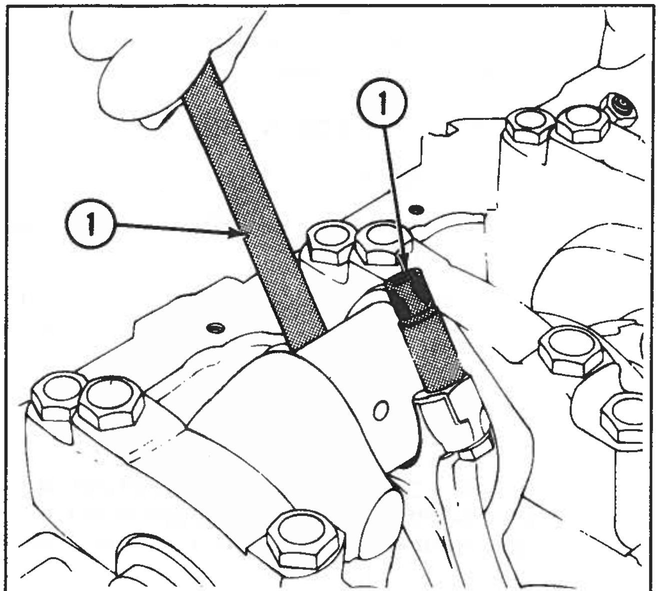
Figure 8-163. *Measuring Gauging Plastic*

6. If clearance exceeds specifications, select a new, correctly sized bearing and recheck clearance.
7. Coat bearing surface with oil, install rod cap and torque nuts to specifications.
8. When all connecting-rod bearings have been installed, tap each rod lightly (parallel to crankpin) to make sure they have clearance.
9. Measure all connecting-rod-side clearances (see "Specifications") between connecting-rod caps.



1. Feeler gauge 2. Connecting rods

Figure 8-164. *Measuring Connecting-Rod-Side Clearance*



1. J-5239 tool

Figure 8-165. *Removing Piston Assembly*

PISTON ASSEMBLY

Removal:

1. With oil pan, battle (some engines), oil pump and cylinder head removed, use a ridge reamer to remove any ridge and/or deposits from upper end of cylinder bore.

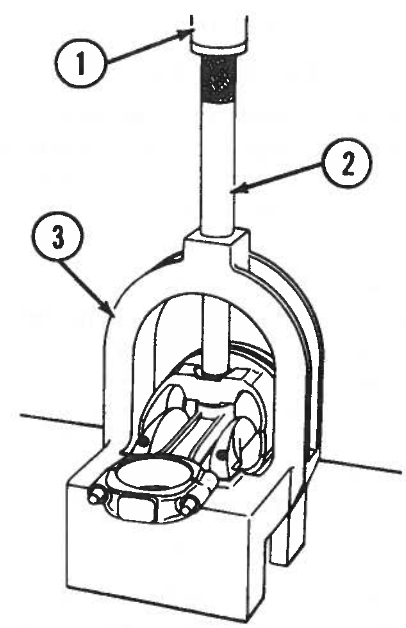
IMPORTANT: Before ridge and/or deposits are removed, turn crankshaft until piston is at bottom of stroke and place a cloth on top of piston to collect cuttings. After ridge and/or deposits are removed, turn crankshaft until piston is at top of stroke, then remove cloth and cuttings.

2. Mark connecting rod and bearing caps left bank 1, 3, 5 and 7; right bank 2, 4, 6 and 8 from front to rear on same side as piston thrust.
3. Remove connecting-rod cap and install tool J-5239 (3/8 in. [9.5 mm]) on bolts. Push connecting rod and piston assembly out of top of cylinder block.

NOTE: It will be necessary to turn crankshaft slightly to disconnect and remove some connecting rod and piston assemblies.

Disassembly:

1. Use Tool Kit J-24086-B as shown.



1. Press ram
2. J-24086-8-A tool
3. J-24086-20-A tool

Figure 8-166. *Tool Kit J-24086-B*

2. Position connecting rod onto tool-rod support with rod support inserted between connecting-rod end and piston. Align piston pin with hole located in top of arched base.

3. Insert pin remover through hole located in top of arched base and into piston-pin hole. Press on pin remover to remove piston pin.

Cleaning and Inspection:

To clean and inspect connecting rods:

1. Wash connecting rods in cleaning solvent and dry with compressed air.
2. Check for twisted or bent rods and inspect for nicks or cracks. Replace damaged connecting rods.

To clean and inspect pistons:

1. Clean varnish from piston skirts and pins with a cleaning solvent. **Do not wire-brush any part of piston.** Clean ring grooves with a groove cleaner and make sure oil-ring holes and slots are clean.
2. Inspect piston for cracked ring lands, skirts or pin bosses, wavy or worn ring lands, scuffed or damaged skirts or eroded areas at top of piston. Replace pistons which are damaged or show signs of excessive wear.
3. Inspect grooves for nicks or burrs that might cause rings to hang up.
4. Measure piston skirt and check clearance as outlined under "Cylinder Block."

To clean and inspect piston pins:

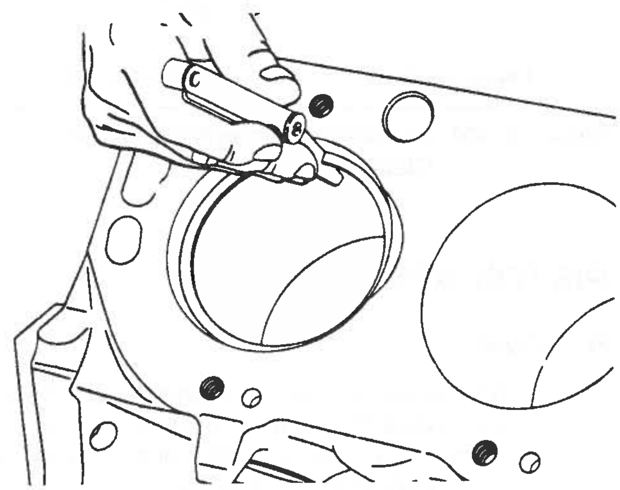
1. Piston-pin clearance is designed to maintain adequate clearance under all engine-operating conditions. Because of this, piston and piston pin are a matched set and not serviced separately.
2. Inspect piston-pin bores and piston pins for wear. Piston-pin bores and piston pins must be free of varnish or scuffing when measured. Measure piston pin with a micrometer and piston-pin bore with a dial bore gauge or inside micrometer. If clearance is in excess of the 0.001-in. (0.025 mm) wear limit, replace piston and piston-pin assembly.

To clean and inspect piston rings:

All compression rings are marked on upper side of ring. When installing compression rings, make sure that marked side is toward top of piston.

Oil-control rings are a 3-piece type, consisting of two segments (rails) and a spacer.

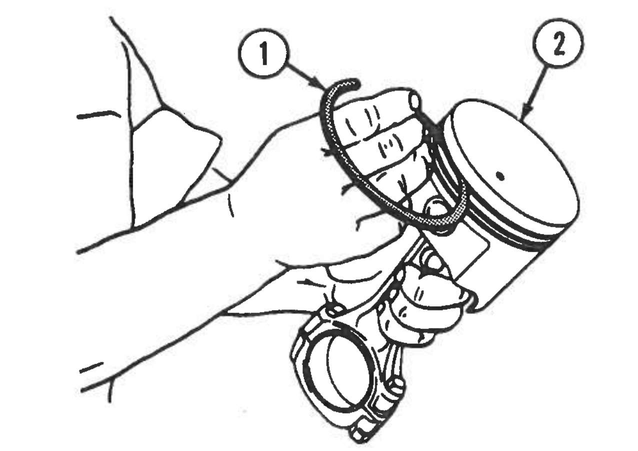
1. Select rings comparable in size to piston being used.
2. Slip compression ring into cylinder bore, then press ring down into cylinder bore about 1/4 in. (6 mm) (below ring travel). Be sure that ring is square with cylinder wall.
3. Measure gap between ends of ring with a feeler gauge.



1. Feeler gauge 2. Piston ring

Figure 8-167. *Checking Ring Gap*

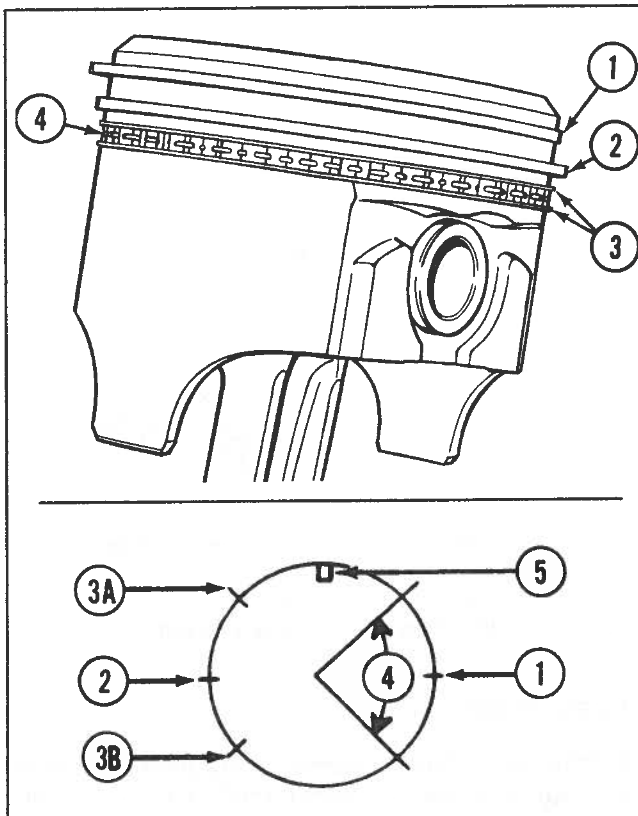
4. If gap between ends of ring is below specifications, remove ring and try another for fit.
5. Fit each compression ring to cylinder in which it is going to be used.
6. Clean and inspect pistons, if not previously done.
7. Slip outer surface of top and second compression ring into respective piston-ring groove and roll the ring entirely around the groove to make sure that ring is free. If binding occurs at any point, determine cause. if caused by ring groove, remove by dressing with a fine cut file. If binding is caused by a distorted ring, use a new ring.



1. Piston ring 2. Piston

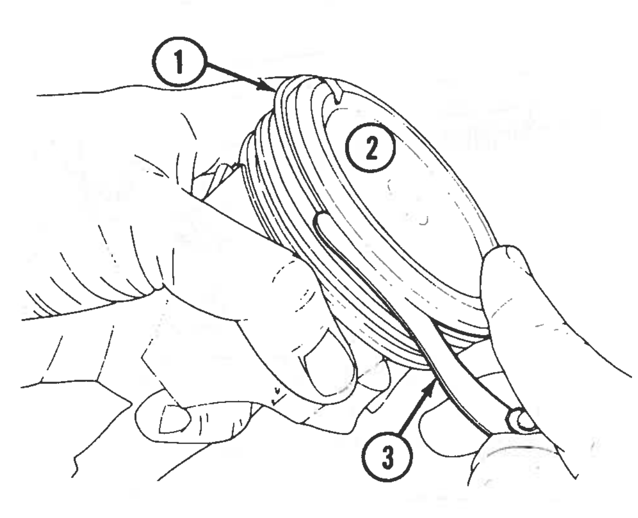
Figure 8-168. Rolling Ring In Groove

8. Install piston ring as shown. Use piston-ring expanders for compression-ring installation.
   a. Install oil-ring spacer in groove and insert antirotation tang in oil hole.
   b. Hold spacer ends butted and install lower steel oil-ring rail with gap properly located.
   c. Install upper steel oil-ring rail with gap properly located.
   d. Flex the oil-ring assembly to make sure ring is free. If binding occurs at any point, the cause should be determined and, if caused by ring groove, remove by dressing groove with a fine cut file. If binding is caused by a distorted ring, use a new ring.
   e. Install lower compression ring, using ring expander, and check location of gap.
   f. Install top compression ring with gap properly located.
9. Proper clearance of piston ring in its piston-ring groove is very important to provide proper ring action and reduce wear. Therefore, when fitting new rings, clearances between ring and groove surfaces should be measured. See "Specifications."



1. Top compression ring and gap location
2. Second compression ring and gap
3. A and B oil-ring rails and gap location
4. Oil-ring spacer and ends location
5. Piston notch

Figure 8-169. Ring Gap Location



1. Piston ring
2. Piston
3. Feeler gauge

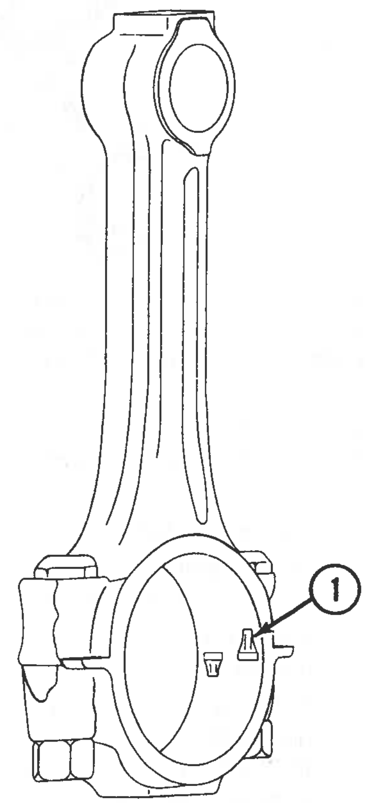
Figure 8-170. *Checking Groove Clearance*

Reassembly:

IMPORTANT: When reassembling pistons and connecting rods, the following must be kept in mind:

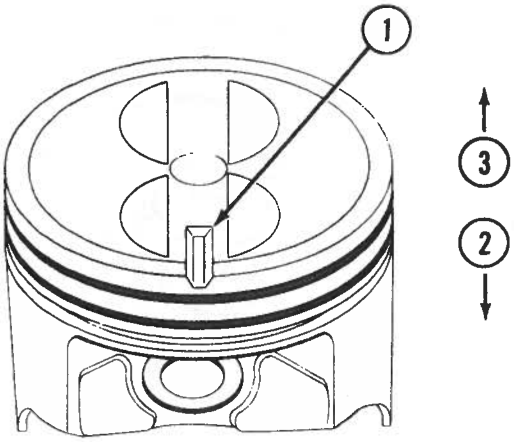
- Piston and pin are machine-fitted to each other and must remain together as a matched set. Do not intermix pistons and pins.
- If original pistons and/or connecting rods are being used, be sure to assemble pistons and connecting rods so they can be reinstalled in same cylinder from which they were removed.
- Connecting-rod-bearing tangs are always toward outside of cylinder block.
- Reference mark on piston must be positioned correctly for engine being repaired.
- To determine if engine is left-hand (standard) rotation or right-hand (opposite) rotation, inspect camshaft drive. If engine has a timing chain, engine is left-hand rotation. If engine has timing gears, engine is right-hand rotation.

1. Install piston pin with Tool Kit J- 24086-B. Refer to chart (furnished with tool) and select proper-size piston-pin guide for specific engine being worked on.
2. Lubricate piston pin, piston-pin hole in piston and hole in rod end with a light coat of engine oil.
3. Position connecting rod onto rod support and piston onto rod end. Insert piston-pin guide through bottom piston-pin hole and into connecting rod. Place piston pin through top side of piston.
4. Adjust installer to the setting specified on chart which came with the tool for particular piston installation. Lock adjustable installer with jam nut.



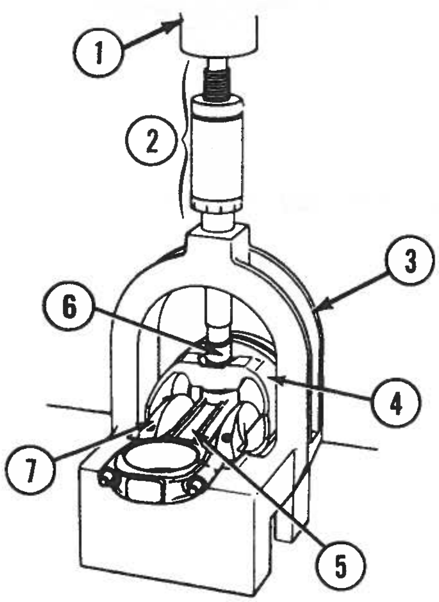
1. Connecting-rod-bearing tang

Figure 8-171. *Connecting-Rod-Bearing-Tangs Orientation*



1. Notch
2. LH rotation engines – notch goes toward front of engine
3. RH rotation engines – notch goes toward rear of engine

Figure 8-172. *Engine-Piston Orientation*



1. Press ram
2. Adjustable installer J-24086-9
3. Support fixture J-24086-20A
4. Piston
5. Connecting rod
6. Piston pin
7. Connecting rod support

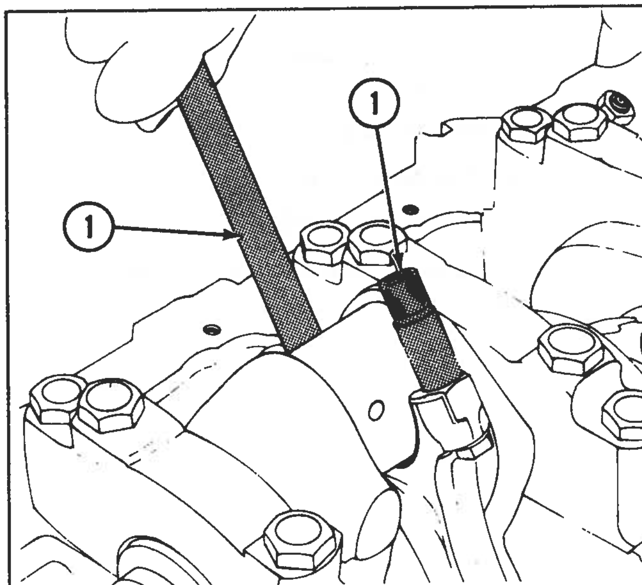
Figure 8-173. *Installing Piston Pin*

5. Insert adjustable installer through hole (located on top of arched base) and into piston-pin hole. Carefully press on adjustable installer until installer bottoms out on arched base to install piston pin.
6. Check piston for freedom of movement in piston-pin bores by moving connecting-rod back and forth and up and down. Connecting rod should move freely (with no resistance) in both directions. If it does not, piston pin is tight in piston-pin bores and piston and pin assembly must be replaced.
7. If a new connecting rod has been installed, mark connecting rod and cap with cylinder number in which it will be installed. Mark rod and cap on the side with slots for connecting-rod-bearing tangs.

Installation:

IMPORTANT: Cylinder bores must be clean before piston installation. Clean with light honing, as necessary. Then clean with hot water and detergent wash. After cleaning, swab bores several times with light engine oil and a clean cloth, then wipe with a clean dry cloth.

1. Lubricate connecting-rod bearings and install in rods and rod caps.
2. Lightly coat pistons, rings and cylinder walls with light engine oil.
3. With bearing caps removed, install tool J-5239 (3/8 in. [9.5 mm]) on connecting-rod bolts.



1. J-5239 tool

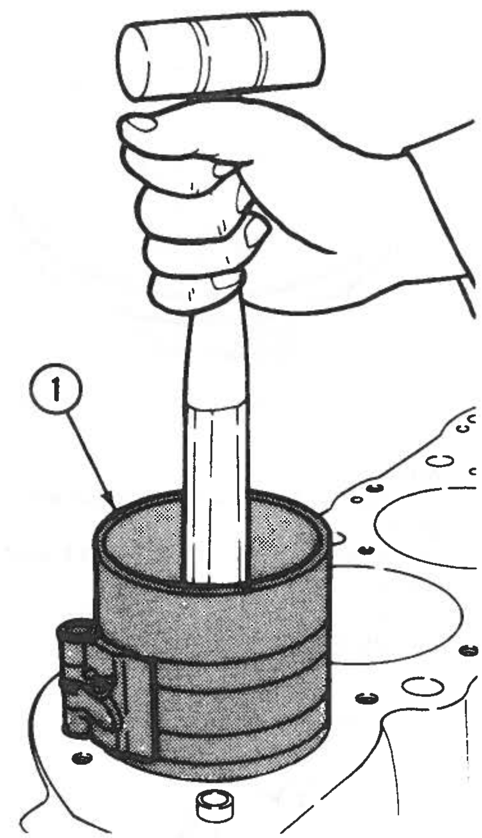
Figure 8-174. *Pulling Piston And Connecting Rod Into Place*

IMPORTANT: Be sure ring gaps are properly positioned as previously outlined.

4. Install each connecting rod and piston assembly in its respective bore. Install with connecting-rod-bearing tangs toward outside of cylinder block. Use tool J-8037 to compress rings. Guide connecting rod into place on crankshaft journal with tool J-5239. Using a hammer handle, tap with light blows to install piston into bore. Hold ring compressor firmly against cylinder block until all piston rings have entered cylinder bore.

IMPORTANT: Be sure to install new pistons in same cylinders for which they were fitted, and used pistons in same cylinder from which they were removed. Each connecting rod and bearing cap should be marked, beginning at front of engine (1, 3, 5 and 7 in left bank; and 2, 4, 6 and 8 in right bank). Numbers on connecting rod and bearing cap must be on same side when installed in cylinder bore. If a connecting rod is transposed from one block or cylinder to another, new bearings should be fitted and connecting rod should be numbered to correspond with new cylinder number.

5. Remove tool J-5239.
6. Install bearing caps and torque nuts to specifications.
7. Check connecting-rod-side clearance.
8. Install the following items:
   a. oil pump.
   b. baffle (if equipped).
   c. oil pan.
   d. cylinder head.
9. Install engine in boat.
10. Fill crankcase with oil.
11. Start engine, adjust timing and check for leaks.



1. Piston-ring compressor

Figure 8-175. *Tapping Piston Into Cylinder*

CRANKSHAFT

Removal:

1. Remove engine from boat.
2. Drain coolant and crankcase oil. Disconnect all hoses.
3. Remove starter motor, transmission, flywheel housing and flywheel. Place engine in repair stand.
4. Remove belts, crankshaft pulley and water pump.
5. Remove torsional damper and crankcase-front cover.
6. Remove spark plugs.
7. Remove camshaft gear and timing chain (LH-rotation engines only).
8. Remove oil pan and oil pump.
9. Make sure all bearing caps (main and connecting rods) are marked so they can be installed in their original locations.
10. Remove connecting-rod-bearing caps, then push piston and rod assemblies toward heads.
11. Remove main bearing caps and carefully lift crankshaft out of cylinder block. Remove rear main bearing oil seal from cylinder block and rear main bearing cap.
12. If new main and/or connecting-rod bearings are to be installed, remove main bearing inserts from cylinder block and bearing caps, and/or connecting-rod-bearing insert from connecting rod and caps. Install new bearings following the procedures outlined.

Cleaning and Inspection:

1. Wash crankshaft in solvent and dry with compressed air.
2. Measure main bearing journals and crankpin dimensions with a micrometer for out-of-round, taper or undersize (see "Specifications").
3. Check crankshaft for run-out (by supporting at front and rear main bearings journals in V-blocks) and check at front and rear intermediate journals with a dial indicator (see "Specifications").
4. Replace or recondition crankshaft if not meeting specifications.

Installation:

1. If a new crankshaft is being installed, remove timing gear from old crankshaft and reinstall on new crankshaft.

IMPORTANT: Be sure that all bearings and crankshaft journals are clean.

2. Install a new rear main bearing oil seal in cylinder block and rear main bearing cap.
3. Carefully lower crankshaft into place. Be careful not to damage bearing surface.
4. Check clearance of each main bearing, following procedure outlined under "Main Bearings." If bearing clearances are satisfactory, apply a light coat of engine oil to journals and bearings.
5. Install all bearing caps and bolts. Torque all main bearing cap bolts to specifications. When tightening rear main bearing cap, follow procedure outlined under "Main Bearings."
6. Check clearance for each connecting-rod bearing, following procedure under "Connecting Rod Bearings." If bearing clearances are satisfactory, apply a light coat of engine oil to journals and bearings.
7. Install all rod caps and torque nuts to specifications.
8. Check crankshaft end-play. Follow procedure outlined under "Main Bearings."
9. Install oil pump and pan as outlined.
10. Install camshaft gear and timing chain (LH-rotation engines only).
11. Install crankcase-front cover and torsional damper.
12. Remove engine from repair stand and install water pump, flywheel, flywheel housing, transmission and starter motor.
13. Install crankshaft pulley and belts.
14. Install spark plugs.
15. Install engine in boat, fill crankcase and install hoses.

TIMING CHAIN AND/OR GEARS

NOTE: Left-hand-rotation engines use a timing chain. Right-hand-rotation engines use timing gears. Except for timing chain removal, the steps for the gear and the chain are the same.

Crankshaft Gear Removal:

1. Remove torsional damper and crankcase-front cover as previously outlined.
2. Remove camshaft-timing chain.
3. Using tool J-5825-A (or J-1619 for RH-rotation engines), remove crankshaft gear.

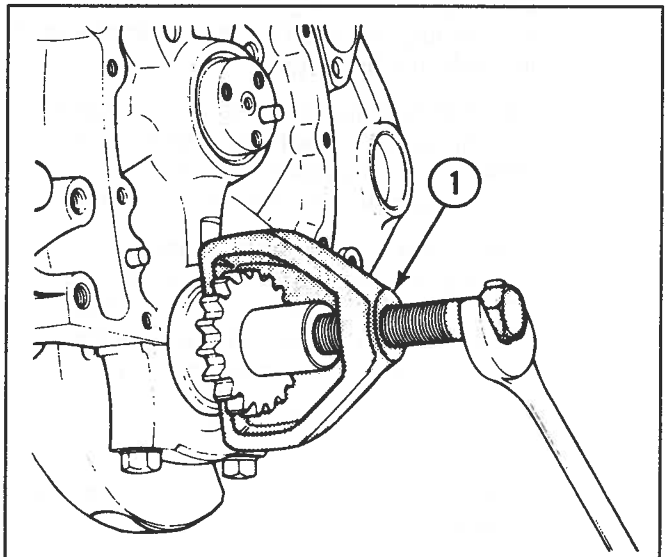


Figure 8-176. *Removing Crankshaft-Timing Gear*

Crankshaft Gear Installation:

1. Using correct tool as shown, install gear.
2. Install camshaft-timing chain as outlined.
3. Install crankcase-front cover and torsional damper as outlined.

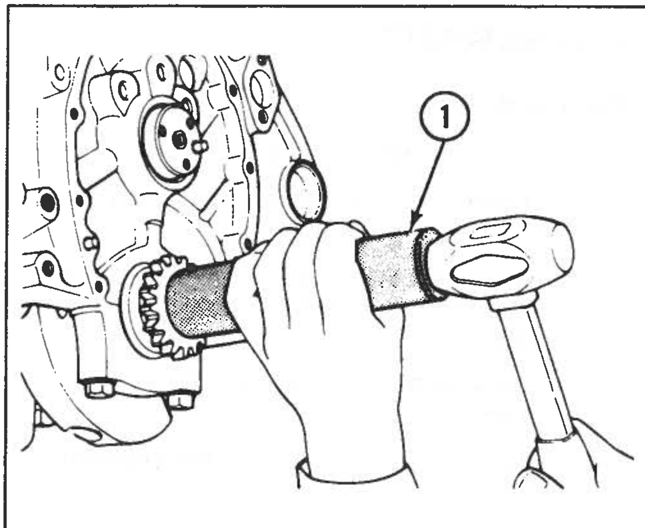
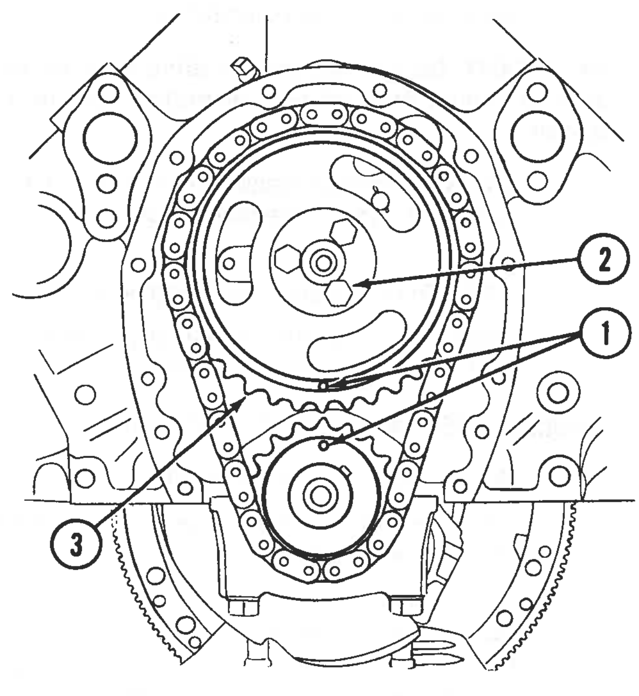


Figure 8-177. *Installing Crankshaft-Timing Gear*

CAMSHAFT GEAR AND TIMING CHAIN (LH-ROTATION ENGINES)

Removal:

1. Remove torsional damper and crankcase-front cover as outlined.
2. Crank engine until marks on camshaft and crankshaft gears are in alignment.



1. Timing marks
2. Gear-cap screw
3. Cam gear

Figure 8-178. *Timing-Gear Alignment Marks*

3. Remove camshaft gear-to-camshaft bolts.
4. Remove camshaft gear and timing chain together. Gear is mounted with a light press-fit on camshaft. If gear does not come off easily, a light blow on its lower edge with a plastic mallet should dislodge it.
5. If crankshaft gear has to be replaced, remove as outlined under "Crankshaft Gear."

Cleaning and Inspection:

1. Clean all parts in solvent and dry with compressed air.
2. Inspect timing chain for wear or damage.
3. Inspect gears for wear or damage.

Installation:

1. If crankshaft gear was removed, install as outlined under "Crankshaft Gear."
2. Install timing chain on camshaft gear. Hold gear vertical with chain hanging down and orientate to align marks on camshaft and crankshaft gear.

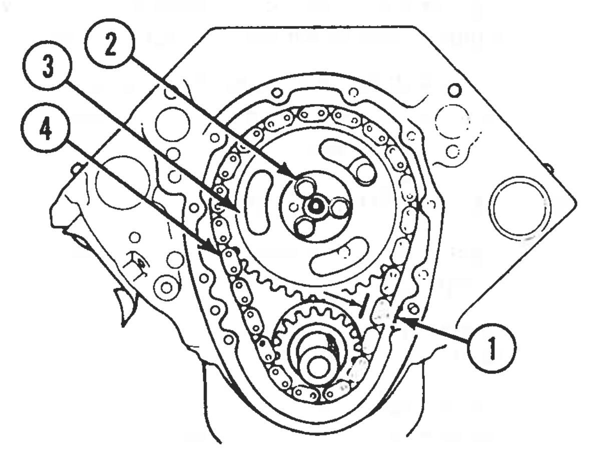
IMPORTANT: Do not attempt to drive gear on camshaft as welsh plug at rear of engine can be dislodged.

3. Draw camshaft gear onto camshaft, using the three mounting bolts. Torque to specifications.
4. Lubricate timing chain with engine oil. Install crankcase-front cover and torsional damper as outlined.

Checking Chain Deflection:

With timing chain and gears installed, check timing-chain deflection, as follows:

1. Rotate camshaft (in either direction) to place tension on one side of the chain.
2. Establish a reference point on the block (on taut side of chain) and measure from this point to the chain.
3. Rotate camshaft in the opposite direction to slacken the chain, then force chain out with fingers and again measure the distance between reference point and timing chain.
4. The deflection is the difference between these two measurements. If the deflection exceeds specification, timing chain should be replaced.



1. 5/8 in. (16 mm) max.
2. Bolt
3. Camshaft gear
4. Timing chain

Figure 8-179. *Checking Timing-Chain Deflection*

TIMING GEARS (RH-ROTATION ENGINES)

Removal:

1. Remove oil pan, torsional damper and crankcase-front cover.
2. Crank engine over until timing mark on camshaft-timing-gear aligns with timing mark on crankshaft-timing gear.

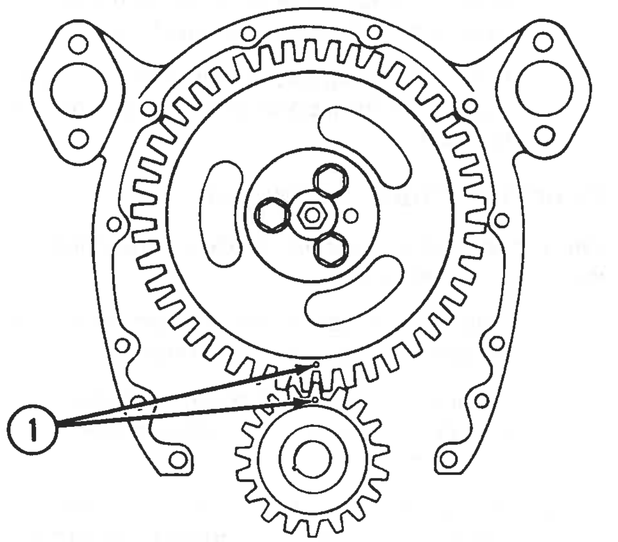


__Figure 8-180.__ Timing Marks Aligned – RH-Rotation

3. Remove camshaft-timing-gear-attaching screws (and washers if so equipped) and remove gear. If gear does not come off easily, a light blow on the lower edge of the gear with a plastic mallet should dislodge the gear.
4. If crankshaft-timing gear requires replacement, remove as outlined under "Crankshaft Gear."

Cleaning and Inspection:

1. Clean all parts in solvent and dry with compressed air.
2. Inspect timing gears for worn or damaged teeth.
3. Inspect camshaft-gear-to-cylinder-block contact surfaces for damage.

Installation:

1. If removed, install crankshaft-timing gear as outlined under "Crankshaft Gear."
2. Position camshaft-timing gear so that timing mark aligns with timing mark on crankshaft-timing gear, then align camshaft dowel with hole in camshaft gear and install gear on camshaft.
3. Install three camshaft-timing-gear-attaching screws (and washers if so equipped) and draw gear onto camshaft. After gear is in place, torque screws to specifications.

IMPORTANT: Do not attempt to drive gear on camshaft as welsh plug at rear of engine can be dislodged.

4. Check timing-gear backlash and run-out as explained under "Checking Backlash and Run-out."
5. Lubricate timing gears with engine oil.
6. Install crankcase-front cover, oil pan and torsional damper as explained.

Checking Backlash and Run-out:

1. Remove fuel pump and fuel-pump-push rod.
2. Loosen rocker-arm nuts to relieve tension on hydraulic valve lifters.
3. With timing gears installed, check camshaft-to-crankshaft-gear backlash, as follows:
   a. Mount a dial indicator on engine so that indicator stem contacts one of the teeth on camshaft gear. Indicator stem should be as perpendicular to gear-tooth surface as possible.
   b. Check the backlash between the camshaft gear and crankshaft gear while applying inward pressure on camshaft gear.
   c. If backlash is not within specifications, check for improperly machined parts or for worn camshaft or crankshaft bearings. If bearings are within specifications, replace both timing gears.

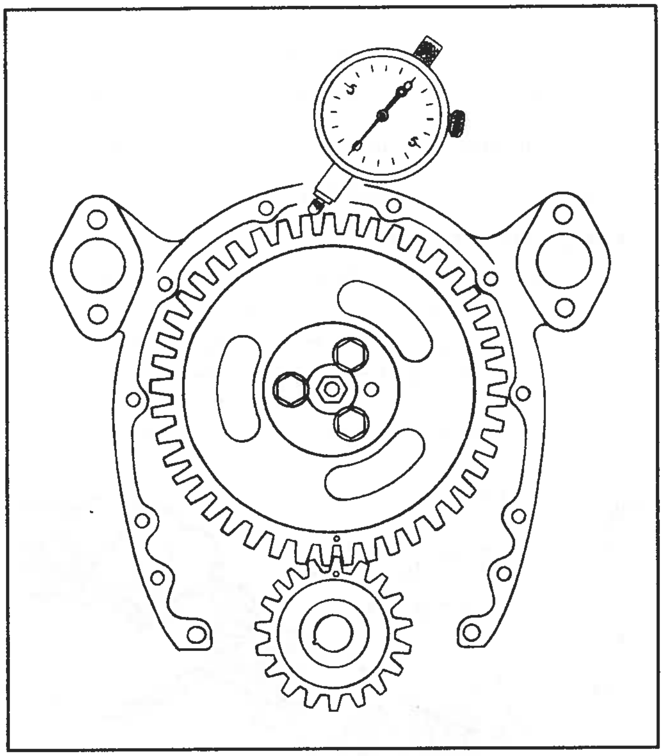
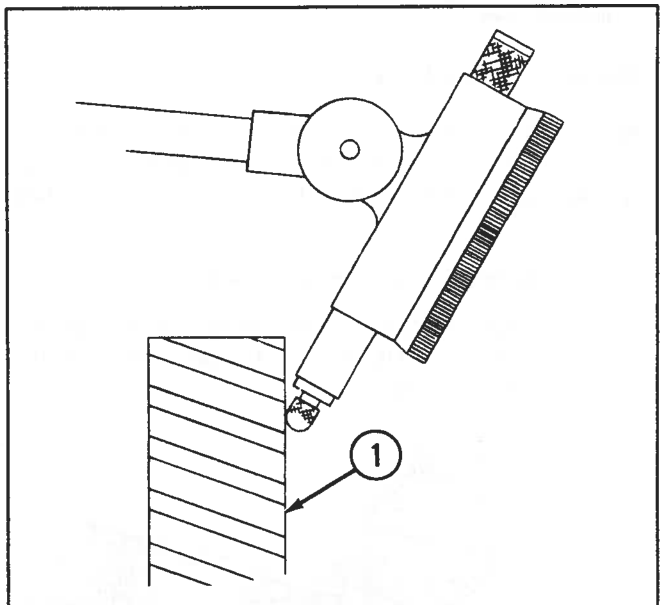


Figure 8-181. *Checking Timing-Gear Backlash*

4. With timing gear installed, check camshaft and crankshaft-timing-gear run-out, as follows:
   a. Mount dial indicator on block so that indicator stem is perpendicular to camshaft-timing gear and contacts gear surface just adjacent to teeth.
   b. Apply inward pressure on timing gear and zero indicator, then turn crankshaft. Check gear run-out through one complete revolution of camshaft gear.
   c. If not within specifications, check for burrs or foreign material between a gear and camshaft-joining surfaces. If none is found, replace both timing gears.
   d. Check crankshaft-timing-gear run-out in same manner. Run-out should not exceed specifications. Replace both gears if run-out is excessive.



1. Camshaft gear

Figure 8-182. *Checking Timing-Gear Run-out*

5. Adjust rocker-arm nuts.
6. Install fuel-pump-push rod and fuel pump.

CAMSHAFT

Measuring Lobe Lift:

NOTE: This procedure is similar to checking valve timing. If improper valve operation is indicated, measure lift of each push rod in consecutive order and record readings.

1. Remove rocker arms as outlined.
2. Position indicator with ball-socket adapter tool J-8520-1 on push rod. Be sure that push rod is in lifter socket.

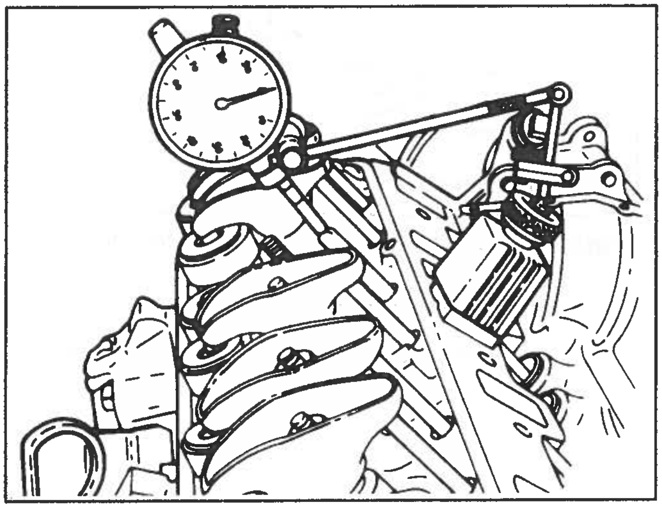


Figure 8-183. *Measuring Camshaft-Lobe Lift*

3. Rotate crankshaft-torsional damper slowly in direction of rotation until lifter is on heel of cam lobe. At this point, push rod will be in its lowest position.
4. Set dial indicator on zero, then rotate damper slowly (or attach an auxiliary starter switch and "bump" engine over) until push rod is in fully raised position.
5. Compare total lift recorded from dial indicator with "Specifications."
6. Continue to rotate engine until indicator reads zero. This will be a check on accuracy of original indicator reading.
7. If camshaft readings for all lobes are within specifications, remove dial indicator assembly.
8. Install and adjust valve mechanism as outlined under "Rocker Arm/Push Rod".

Removal:

1. Remove valve lifters as outlined.
2. Remove crankcase-front cover as outlined.
3. Remove fuel pump and fuel-pump-push rod.
4. Remove camshaft as follows:

LH-Rotation Engines

a. Refer to "Timing Chain and/or Gears" to remove chain and gear

b. Install 5/16-18 bolts in camshaft-gear-bolt holes and carefully remove camshaft.

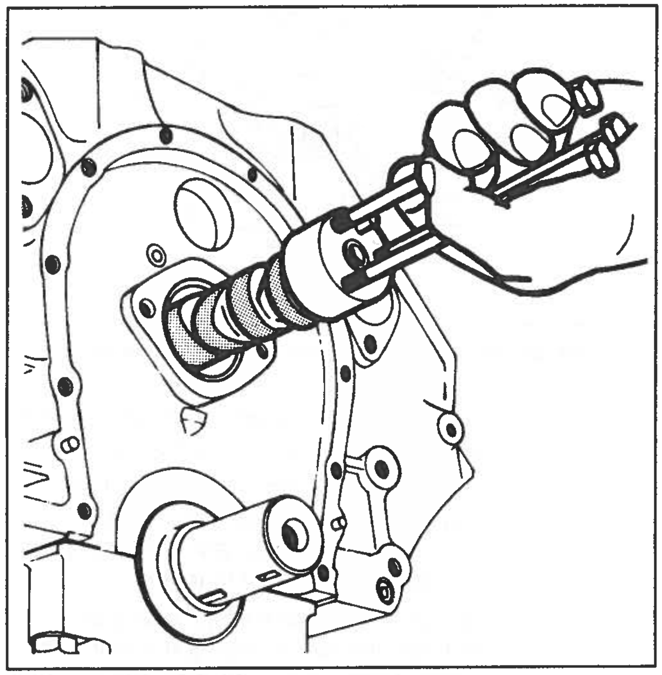


Figure 8-184. *Removing Camshaft*

RH-Rotation Engines

a. Refer to "Timing Chain and/or Gears" to remove timing gear.

b. Install 5/16-18 bolts in camshaft-gear-bolt holes and carefully remove camshaft.

Inspection:

Measure camshaft-bearing journals with a micrometer for out-of-round condition. If journals exceed 0.001 in. (0.025 mm) out-of-round, camshaft should be replaced.

Also check camshaft for alignment with V-blocks and dial indicator which indicates exact amount that camshaft is out-of-true. If it is out more than 0.002 in. (0.051 mm) (dial indicator reading), camshaft should be replaced.

On engines with timing gears, inspect camshaft gear and thrust plate for wear or damage.

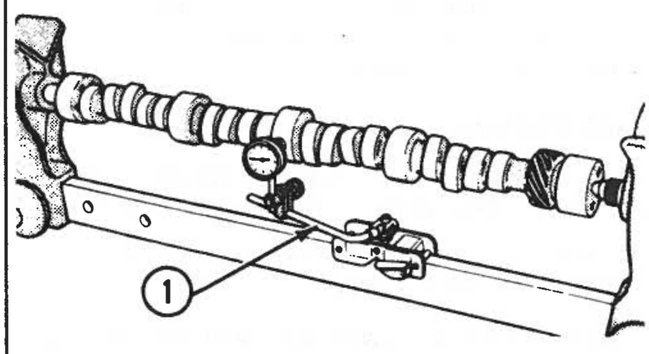


Figure 8-185. *Checking Camshaft Alignment*

Installation:

1. Install camshaft as follows:

LH-Rotation Engines

a. Install 5/16-18 bolts in camshaft-bolt holes, then lubricate camshaft journals with engine oil and install camshaft, being careful not to damage bearings. Remove installation bolts.

b. Install timing chain and gear as outlined in "Timing Chain and/or Gears."

RH-Rotation Engines

a. Install 5/16-18 bolts in camshaft-bolt holes, then lubricate camshaft journals with engine oil and install camshaft, being careful not to damage bearings. Remove installation bolts.

b. Install timing gear as outlined in "Timing Chain and/or Gears."

2. Lubricate camshaft-drive system with engine oil.
3. Install fuel-pump-push rod and fuel pump.
4. Install crankcase-front cover and valve lifters as outlined.

CAMSHAFT BEARINGS

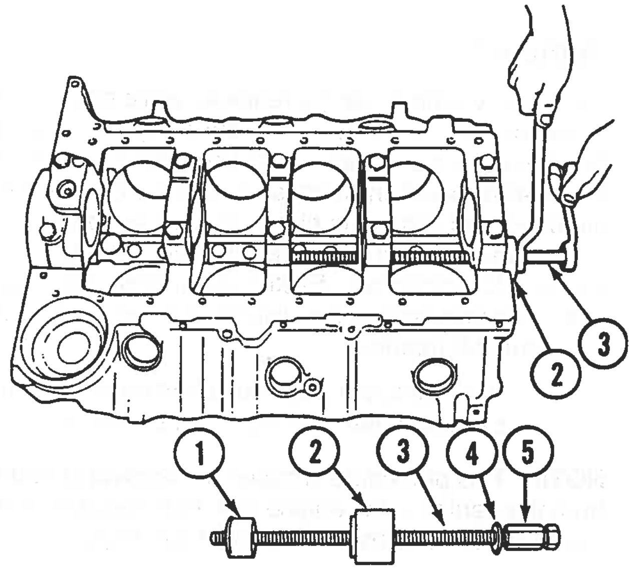
Removal:

Camshaft bearings can be replaced while engine is disassembled for overhaul or without complete disassembly. To replace bearings without complete disassembly, remove camshaft and crankshaft, leaving cylinder heads attached and pistons in place. Before removing crankshaft, tape threads of connecting-rod bolts to prevent damage to crankshaft. Fasten connecting rods against sides of engine so that they will not interfere while replacing camshaft bearings.

1. With camshaft and crankshaft removed, drive camshaft rear plug from cylinder block.

NOTE: This procedure is based on removal of bearings from the center of the engine first, thus requiring a minimum amount of turns to remove all bearings.

2. Using Tool Set J-6098-01 (with nut and thrust-washer installed to end of threads), position pilot in front camshaft bearing and install puller screw through pilot.
3. Install tool with shoulder toward bearing. Be sure a sufficient amount of threads are engaged.
4. Using two wrenches, hold puller screw while turning nut. When bearing has been pulled from bore, remove tool and bearing from puller screw.
5. Remove remaining bearings (except front and rear) in the same manner. It will be necessary to position pilot in rear camshaft bearing to remove rear intermediate bearing.



1. Puller disk
2. Pilot bushing
3. Puller screw
4. Washer
5. Puller nut

Figure 8-186. *Removing Center Camshaft Bearings*

6. Assemble remover tool on driver handle and remove front and rear camshaft bearings by driving toward center of cylinder block.

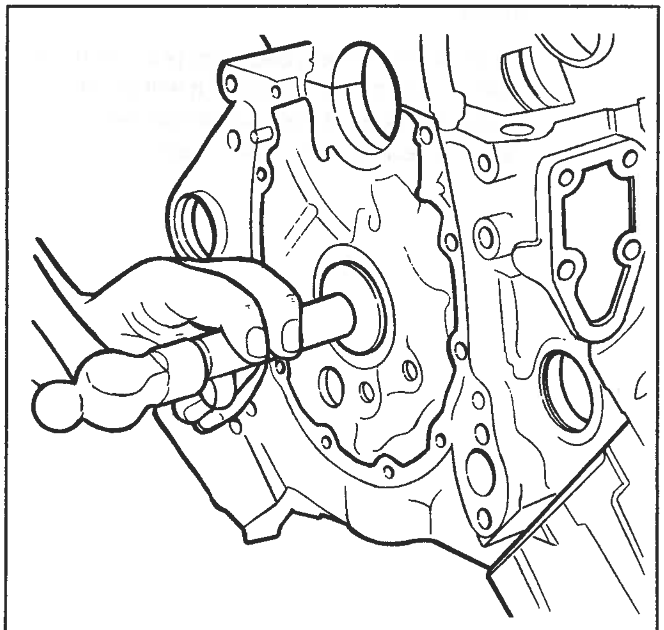


Figure 8-187. *Removing Front And Rear Camshaft Bearings*

Inspection:

Clean camshaft bearing bores in cylinder block with solvent and blow out with compressed air. Be sure grooves and drilled oil passages are clean.

Installation:

Front and rear bearings must be installed last, as pilot will not fit into bearing bores if bearings are installed.

Lubricate outer surface of new camshaft bearings with engine oil to ease installation.

IMPORTANT: All camshaft bearings are not the same. Directional references are in reference to engine in its normal operating position. Be sure to install bearing in proper location (indicated by bearing manufacturer) and to position bearings as follows:

Front bearing must be positioned so that oil holes are equidistant from 6-o'clock position in the block. Intermediate and center bearings must be positioned so that oil holes are at the 5-o'clock position (toward left side of block and at a position even with bottom of cylinder bore). Rear bearing must be positioned so that oil hole is at the 12-o'clock position.

1. Installing intermediate and center bearings:
   a. Install nut and thrustwasher all the way onto puller screw, then position pilot in front camshaft-bearing bore and insert screw through pilot.
   b. Index center camshaft bearing, then position appropriately sized remover and installer tool in bearing and thread puller screw into tool. Be sure at least 1/2 in. (13 mm) of threads are engaged.
   c. Using two wrenches, hold puller screw and turn nut until bearing has been pulled into position. Remove the remover and installer tool and check to ensure that oil hole(s) in bearing is (are) positioned correctly.
   d. Install intermediate bearings in the same manner, being sure to index bearings correctly. It will be necessary to position pilot in rear camshaft bearing bore to install rear intermediate bearing.
2. Installing front and rear bearings:
   a. Install appropriately sized remover and installer tool on drive handle.
   b. Index front bearing (as explained in "Important"), and drive it into position with tool. Check position of oil hole(s) in bearing to ensure bearing is positioned correctly.

c. Install rear bearing in same manner, being sure to index bearing correctly.

3. Install a new camshaft rear plug.

IMPORTANT: Plug must be installed flush to 1/32 in. (0.8 mm) deep and must be parallel with rear surface of cylinder block.

4. Install crankshaft and camshaft as outlined.

CYLINDER BLOCK

Cleaning and Inspection:

1. Remove all engine components as previously outlined.
2. Wash cylinder block thoroughly in cleaning solvent and clean all gasket surfaces.
3. Remove oil-gallery plugs and clean all oil passages.

NOTE: These plugs may be removed with a sharp punch or they may be drilled and pried out.

4. Clean and inspect water passages in cylinder block.
5. Inspect cylinder block for cracks in cylinder walls, water jacket, valve-lifter bores and main bearing webs.
6. Measure cylinder walls for taper, out-of-round or excessive ridge at top of ring travel. This should be done with a dial indicator or inside micrometer. Carefully work gauge up and down cylinder to determine taper, and turn it to different points around cylinder wall to determine out-of-round condition. If the cylinders exceed specifications, boring and/or honing will be necessary.

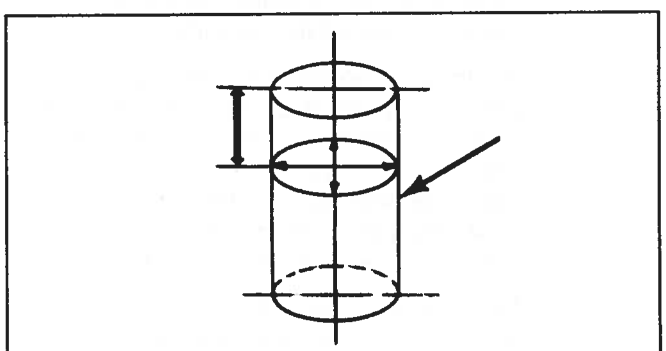


Figure 8-188. *Measuring Point For Cylinder Bore Out-Of-Round*

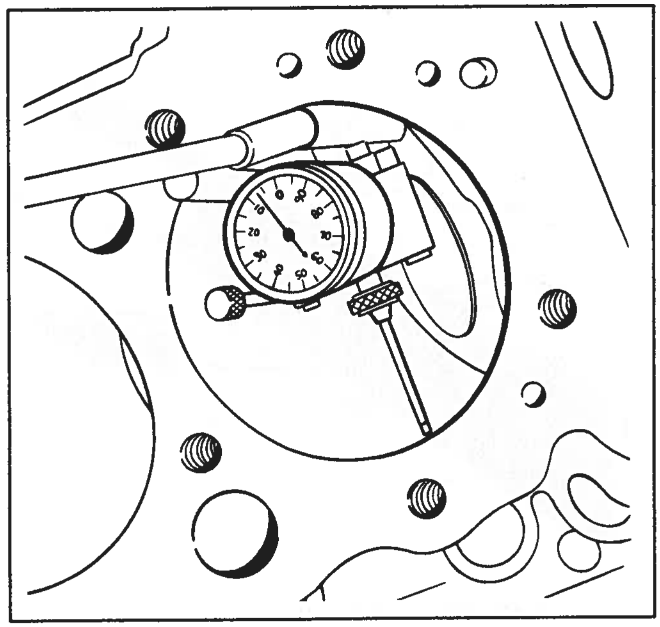


Figure 8-189. *Using Dial Indicator To Check For Cylinder Taper And Out-Of-Round*

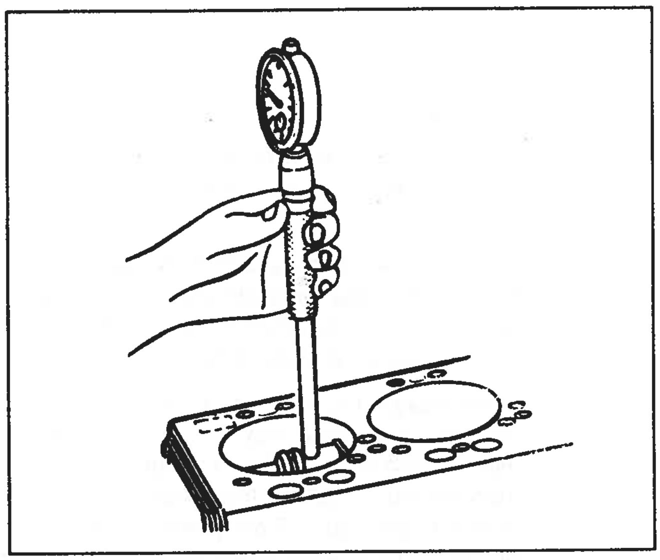


Figure 8-190. *Using Telescoping Gauge To Check For Cylinder Taper And Out-Of-Round*

7. Check cylinder-head-gasket surfaces for warping with a machinist's straightedge and a feeler gauge. Take measurements diagonally across surfaces (both ways) and straight down center. If surfaces are out-of-flat more than 0.003 in. (0.076 mm) in a 6-in. (152 mm) area or 0.007 in. (0.178 mm) overall, block must be resurfaced by an automotive machine shop.

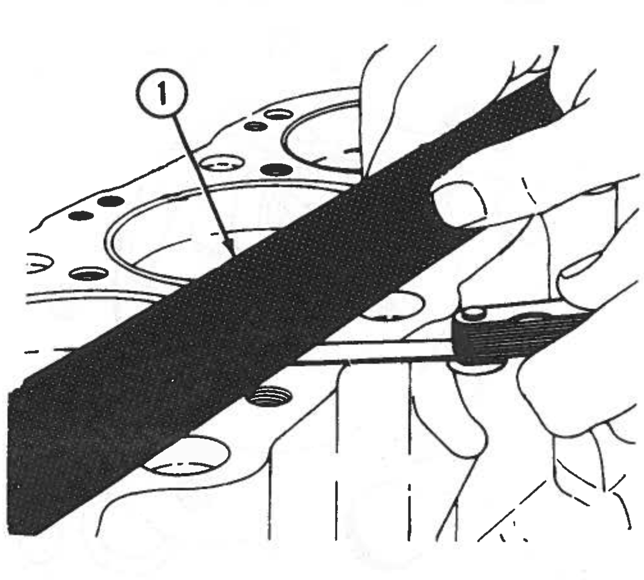


Figure 8-191. Checking Cylinder-Head-Gasket Surfaces For Warping

Repairs:

Cylinder Conditioning

1. Performance of the following operation depends upon engine condition at time of repair.
2. If cylinder-block inspection indicates that block is suitable for continued use (except for out-of-round or tapered cylinders), they can be conditioned by honing or boring.
3. If cylinders have less than 0.005-in. (0.127 mm) taper or wear, they can be conditioned with a hone and fitted with a high-limit, standard-size piston. A cylinder bore of more than 0.005-in. (0.127 mm) wear or taper may not clean up entirely when fitted to a high-limit piston. To clean up the bore entirely, it will be necessary to rebore for an oversized piston. If there is more than 0.005-in. (0.127 mm) taper or wear, bore and hone to smallest oversize that will permit complete resurfacing of all cylinders.
4. When pistons are being fitted and honing is not necessary, cylinder bores may be cleaned with a hot-water and detergent wash. After cleaning, swab cylinder bores several times with light engine oil and a clean cloth, then wipe with a clean, dry cloth.

Cylinder Boring

1. Before using any type of boring bar, file off top of cylinder block to remove dirt or burrs. This is very important to prevent boring-bar tilt, which results in a rebored cylinder wall that is not at right angles to the crankshaft.
2. Measure piston to be fitted with a micrometer, at center of piston skirt and at right angles to piston pin. Bore cylinder to same diameter as piston and hone to give specified clearance.

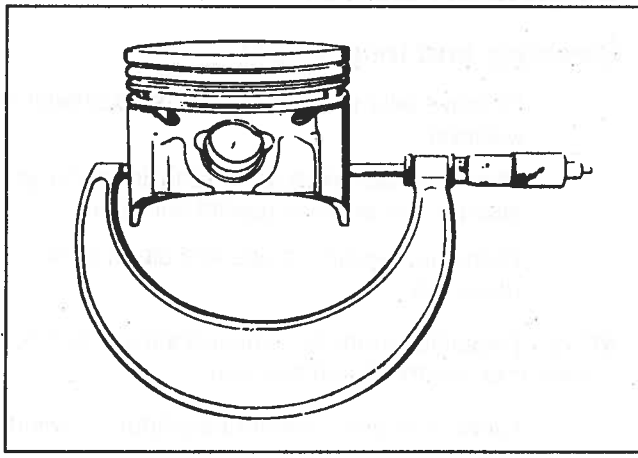


Figure 8-192. Measuring Piston

3. Carefully observe instructions furnished by manufacturer of equipment being used.

IMPORTANT: Hone cylinders as outlined under "Cylinder Honing" and "Piston Selection," following:

Cylinder Honing

1. Follow hone manufacturer's recommendations for use of hone, and cleaning and lubrication during honing.
2. Occasionally, during the honing operation, thoroughly clean cylinder bore and check piston for correct fit in cylinder.
3. When finish-honing a cylinder bore to fit a piston, move hone up and down at a sufficient speed to obtain very fine, uniform surface-finish marks in a crosshatch pattern of approximately 300 to cylinder bore. Finish marks should be clean but not sharp, free from imbedded particles and torn or folded metal.
4. Permanently mark piston (for cylinder to which it has been fitted) and proceed to hone cylinders and fit remaining pistons.

IMPORTANT: Handle pistons with care and do not attempt to force them through cylinder until cylinder is honed to correct size, as this type of piston can be distorted by careless handling.

5. Thoroughly clean cylinder bores with hot water and detergent. Scrub well with a stiff-bristle brush and rinse thoroughly with hot water. It is essential that a good cleaning operation be performed. If any abrasive material remains in cylinder bores, it will rapidly wear new rings and cylinder bores in addition to bearings lubricated by the contaminated oil. Swab bores several times with light engine oil on a clean cloth, then wipe with a dry cloth. Cylinder should not be cleaned with kerosene or gasoline. Clean remainder of cylinder block to remove excess material spread during honing operation.

Piston Selection

1. Check used piston-to-cylinder-bore clearance as follows:
   a. Measure cylinder bore diameter with a telescope gauge 2-1/2 in. (64 mm) from top of cylinder bore (Figure 8-190).
   b. Measure piston diameter at skirt across centerline of piston pin (Figure 8-192).
   c. Subtract piston diameter from cylinder-bore diameter to determine piston-to-bore clearance.
   d. Determine if the piston-to-bore clearance is in the acceptable range shown in "Specifications."
2. If used piston is not satisfactory, determine if a new piston can be selected to fit cylinder bore within acceptable range.
3. If cylinder bore must be reconditioned, measure new piston diameter (across centerline of piston pin), then hone cylinder bore to correct clearance (preferable range).
4. Mark piston to identify cylinder for which it was fitted.

BLANK

8.4 LARGE V-8 ENGINES

Special Tools:

SPECIAL TOOLS	
Kent-Moore Number	**Item**
J-8062	Valve-spring compressor (cylinder head off)
J-8101	Valve-guide-bore cleaning brush
J-8358	Valve-seat and valve-face cleaning brush
J-5830-1	Oversized valve-guide reamer (0.003 in.)
J-5830-6	Oversized valve-guide reamer (0.006 in.)
J-9345-1	Oversized valve-guide reamer (0.010 in.)
J-8080	Crankshaft upper bearing-shell remover and installer
J-8369	Oil-suction-pipe installer
J-24420-B	Crankshaft-gear remover (LH-engine rotation)
J-1619	Crankshaft-gear remover (RH-engine rotation)
J-5239	Connecting-rod-guide set for cap-screw rods
J-5802-01	Rocker-arm stud remover
J-6880	Rocker-arm stud installer
J-22102	Crankshaft gear installer
J-8037	Piston-ring compressor
J-25087	Oil-pressure gauge
J-3049	Valve-lifter remover
J-5790	Hydraulic valve-lifter leakdown tester
J-23394	Front intake-manifold-bolt wrench
J-5250	Timing-chain-cover-oil seal installer
J-4160-A	Hydraulic valve-lifter-plunger remover
J-5892	Valve-spring compressor (cylinder head on block)
J-8089	Carbon-removing brush
J-6098	Camshaft-bearing remover and installer
J-8056	Valve-spring tester
J-23994	Valve-seal-leak tester
J-8520	Cam-lobe-lift indicator
J-24086-B	Piston-pin remover and installer set
J-22509	Intake-valve-seal installer
J-23590	Air adapter

Available from:

Kent-Moore Tools
29784 Little Mack
Roseville, MI 48066-2298
Phone: (800) 345-2233
(313) 574-2332

Specifications:

454/502 CID FASTENER TORQUE SPECIFICATIONS			
Units	**N•m**	**lb-ft**	**lb-in**
Rocker-arm-cover nuts	13.0	–	115
Intake-manifold bolts	40	30	–
Rocker-arm studs	68	50	–
Exhaust-manifold bolts	47	35	–
Cylinder-head bolts	108	80	–
Torsional-damper bolts	115	85	–
Front cover-to-block bolts	10.8	–	96
Oil-pan-to-front-cover bolts	7.9	–	70
Oil-pan-to-block bolts	18.1	–	160
Oil-pump bolt	88	65	–
Main bearing caps	150	110	–
Camshaft-gear bolts	27	20	–
Connecting-rod-cap nuts	65	48	–
Oil-filter-adapter bolts	27	20	–
Flywheel bolts	88	65	–
Oil-pump-cover bolts	9.0	–	80
Flywheel-housing bolts	40	30	–
Water-pump bolts	40	30	–
Water-outlet bolts	40	30	–
Spark plugs	30	22	–
Flywheel-damper plate	47	35	–

ENGINE SPECIFICATIONS		
Model	**454 CID**	**502 CID**
Bore	4.25 in. (107.95 mm)	4.47 in. (113.5 mm)
Stroke	4.00 in. (101.6 mm)	4.00 in. (101.6 mm)
Displacement	454 in^3 (Standard) (7.4 L)	502 in^3 (Standard) (8.2 L)
Compression ratio	8.12:1	8.75:1 or 9.0:1[2]
Heads	Cast iron	Cast iron
Intake manifold	Cast iron	Aluminum high-rise
Block	Cast iron[1] (4-bolt main bearing caps)	Cast iron (4-bolt main bearing caps)
Rods	Forged steel	Forged steel
Pistons	Cast aluminum	Forged aluminum
Crankshaft	Nodular iron	Forged steel
Rocker arms	Stamped steel	Stamped steel

NOTES: [1] Early 454 blocks will have two-bolt main bearing caps.
[2] 502 CID engines changed compression to 8.75:1 in 1990 engines.

CYLINDER BORE SPECIFICATIONS				
Model			**454 CID**	**502 CID**
Diameter			4.2595-4.2525 in. (107.937-108.0135 mm)	4.4655-4.4662 in. (113.424-113.386)
Out-of-round		Production	0.001 in. (0.025 mm) max.	
		Service	0.002 in. (0.051 mm) max.	
Taper	Production	Thrust side	0.0005 in. (0.013 mm) max.	
		Relief side	0.001 in. (0.025 mm) max.	
	Service		0.001 in. (0.025 mm) max.	

PISTON SPECIFICATIONS			
Model		**454 CID**	**502 CID**
Out-of-round	Production	0.003-0.004 in. (0.08-0.10 mm)	0.0055-0.0065 in. (0.140-0.165 mm)
	Service	0.005 in. (0.13 mm) max.	0.0065 in. (0.165 mm) max.

PISTON RING SPECIFICATIONS					
Model				**454 CID**	**502 CID**
Com-pression	Groove-side clearance	Production	Top	0.0017-0.0032 in. (0.043-0.081 mm)	0.0025-0.0035 in. (0.0635-0.0889 mm)
			2nd	0.0012-0.0032 in. (0.043-0.081 mm)	0.0025-0.0035 in. (0.0635-0.0889 mm)
		Service		Hi-Limit Production + 0.001 in. (0.025 mm)	
	Gap	Production	Top	0.010-0.020 in. (0.254-0.508 mm)	0.011-0.0211 in. (0.279-0.533 mm)
			2nd	0.010-0.025 in. (0.254-0.635 mm)	0.016-0.026 in. (0.406-0.660 mm)
		Service		Hi-Limit Production + 0.010 in. (0.254 mm)	
Oil	Groove-side clearance	Production		0.005-0.0065 in. (0.127-0.165 mm)	0.0025-0.0045 in. (0.0635-0.0889 mm)
		Service		Hi-Limit Production + 0.0075 in. (0.191 mm)	0.005 in. (0.127 mm) max.
	Gap	Production		0.015-0.055 in. (0.38-1.40 mm)	0.010-0.030 in. (0.254-0.762 mm)
		Service		Hi-Limit Production + 0.010 in. (0.254 mm)	0.010-0.055 in. (0.254-1.397 mm)

PISTON PIN SPECIFICATIONS			
Model		**454 CID**	**502 CID**
Diameter		0.8985-0.9898 in. (25.1333-25.1409 mm)	
Clearance	Production	0.00025-0.00035 in (0.00635-0.00889 mm)	0.00045-0.00065 in. (0.0114-0.0165 mm)
	Service	0.001 in. (0.025 mm) max.	
Fit in rod		0.0013-0.0021 in. (0.033-0.053 mm) interference	0.0008-0.0021 in. (0.0203-0.0533) interference

CRANKSHAFT SPECIFICATIONS				
Model			**454 CID**	**502 CID**
Main journal	Diameter	No. 1, 2, 3, 4	2.7481-2.7490 in. (69.8017-69.8246 mm)	2.7481-2.7490 in. (69.8017-69.8246 mm)
		No. 5	2.7476-2.7486 in. (69.7890-69.8144 mm)	2.7476-2.7486 in. (69.7890-69.8144 mm)
	Taper	Production	0.0002 in. (0.0051 mm) max.	0.0002 in. (0.0051 mm) max.
		Service	0.001 in. (0.025 mm) max.	0.001 in. (0.025 mm) max.
	Out-of-round	Production	0.002 in. (0.0051 mm) max.	0.002 in. (0.0051 mm) max.
		Service	0.001 in. (0.025 mm) max.	0.001 in. (0.025 mm) max.
Main bearing clearance	Production	No. 1, 2, 3, 4	0.0013-0.0025 in. (0.0330-0.0635 mm)	0.0013-0.0025 in. (0.0330-0.0635 mm)
		No. 5	0.0024-0.0040 in. (0.0610-0.1016 mm)	0.0024-0.0040 in. (0.0610-0.1016 mm)
	Service	No. 1, 2, 3, 4	0.001-0.0025 in. (0.025-0.635 mm)	0.001-0.0025 in. (0.025-0.635 mm)
		No. 5	0.0025-0.0035 in. (0.064-0.089 mm)	0.0025-0.0035 in. (0.064-0.089 mm)
Crankshaft end-play			0.006-0.010 in. (0.15-0.25)	0.006-0.010 in. (0.15-0.25)
Connecting-rod journal	Diameter		2.1990-2.2000 in. (55.855-55.880 mm)	2.1990-2.2000 in. (55.855-55.880 mm)
	Taper	Production	0.0005 in. (0.0127 mm) max.	0.0005 in. (0.0127 mm) max.
		Service	0.001 in. (0.025 mm) max.	0.001 in. (0.025 mm) max.
	Out-of-round	Production	0.0005 in. (0.0127 mm) max.	0.0005 in. (0.0127 mm) max.
		Service	0.001 in. (0.025 mm) max.	0.001 in. (0.025 mm) max.
Rod-bearing clearance		Production	0.0009-0.0025 in. (0.0229-0.0635 mm)	0.0009-0.0025 in. (0.0229-0.0635 mm)
		Service	0.003 in. (0.076 mm) max.	0.003 in. (0.076 mm) max.
Rod-side clearance			0.013-0.023 in. (0.33-0.58 mm)	0.013-0.023 in. (0.33-0.58 mm)
Crankshaft run-out (#3 main bearing)			0.0015 in. (0.0381 mm) max.	0.003 in. (0.0762 mm) max.

CRANKSHAFT AND DRIVE SPECIFICATIONS			
Model		**454 CID**	**502 CID**
Lobe lift	Intake	0.2694-0.2734 in. (6.832-6.934 mm)	0.300 in. (7.62 mm)
	Exhaust	0.2804-0.2844 in. (7.112-7.214 mm)	0.300 in. (7.62 mm)
Duration	Intake	289°	293°
	Exhaust	302°	293°
Journal diameter		1.9482-1.9492 in. (49.484-49.510 mm)	1.9477-1.9497 in. (49.472-49.522 mm)
Journal out-of-round		0.001 in. (0.025 mm) max.	0.001 in. (0.025 mm) max.
Camshaft run-out		0.005 in. (0.127 mm) max.	0.005 in. (0.127 mm) max.
Timing-chain deflection (LH [standard] rotation engines only)		0.38 in. (10 mm) from taut position (0.75 in. [19 mm] total)	0.5 in. (12.7 mm) from taut position
Camshaft end-play (RH [opposite] rotation engines only)		0.001-0.005 in. (0.03-0.13 mm)	0.002-0.006 in. (0.051-0.152 mm)
Camshaft-timing-gear run-out (RH [opposite] rotation engines only)		0.004 in. (0.102 mm) max.	0.004 in. (0.102 mm) max.
Crankshaft-timing-gear run-out (RH [opposite] rotation engines only)		0.003 in. (0.076 mm) max.	0.003 in. (0.076 mm) max.
Camshaft-to-crankshaft-timing-gear backlash (RH [opposite] rotation engines only)		New gears: 0.004-0.006 in. (0.102-0.152 mm) Used gears: 0.004-0.008 in. (0.102-0.203 mm)	New gears: 0.004-0.006 in. (0.102-0.152 mm) Used gears: 0.004-0.008 in. (0.102-0.203 mm)

VALVE SPECIFICATIONS					
Model				**454 CID**	**502 CID**
Lifter type				Hydraulic	Hydraulic
Rocker-arm ratio				1.70:1	1.70:1
Valve lift			Intake	0.461 in. (11.71 mm)	0.510 in. (12.954 mm)
			Exhaust	0.479 in. (12.17 mm)	0.510 in. (12.954 mm)
Valve lash (intake and exhaust)				3/4 turn down from zero lash	3/4 turn down from zero lash
Face angle (intake and exhaust)				45°	45°
Seat angle (intake and exhaust)				46°	46°
Seat run-out (intake and exhaust)				0.02 in. (0.051 mm) max.	0.002 in. (0.051 mm) max.
Seat width			Intake	0.037-0.062 in. (0.79-1.57 mm)	0.060-0.090 in. (1.524-2.286 mm)
			Exhaust	0.062-0.093 in. (1.57-2.39 mm)	0.060-0.090 in. (1.524-2.286 mm)
Stem clearance	Production		Intake	0.0010-0.0027 in. (0.025-0.069 mm)	0.0010-0.0027 in. (0.025-0.069 mm)
			Exhaust	0.0012-0.0029 in. (0.030-0.074 mm)	0.0012-0.0029 in. (0.030-0.074 mm)
	Service		Intake	0.001-0.0037 in. (0.0254-0.0940 mm)	0.001-0.0037 in. (0.0254-0.0940 mm)
			Exhaust	0.001-0.0039 in. (0.0254-0.0991 mm)	0.001-0.0039 in. (0.0254-0.0991 mm)

<table>
<tr><th colspan="6">VALVE SPRING SPECIFICATIONS</th></tr>
<tr><th colspan="4">Model</th><th>454 CID</th><th>502 CID</th></tr>
<tr><td rowspan="14">Valve spring</td><td colspan="3">Outer spring O.D.</td><td colspan="2">1.46 in. (37.08 mm)</td></tr>
<tr><td colspan="3">Inner spring O.D.</td><td colspan="2">1.00 in. (25.4 mm)</td></tr>
<tr><td rowspan="4">Spring assembly (with 2 springs)</td><td colspan="2">Free length</td><td colspan="2">2.21 in. (56.13 mm)</td></tr>
<tr><td rowspan="2">Pressure</td><td>Closed at</td><td>80 lb. (356 N)</td><td>110 lb. (489 N)</td></tr>
<tr><td>Open at</td><td>215 lb. (957 N)</td><td>316 lb. (1406 N)</td></tr>
<tr><td colspan="2">Installed height</td><td>1.79 in. (45.457 mm)</td><td>1.88 in. (47.75 mm)</td></tr>
<tr><td rowspan="4">Inner spring</td><td colspan="2">Free length</td><td colspan="2">2.12 in. (58.85 mm)</td></tr>
<tr><td rowspan="2">Pressure</td><td>Closed at</td><td rowspan="2">Not used</td><td>40 lb. (178 N)</td></tr>
<tr><td>Open at</td><td>107 lb. (476 N)</td></tr>
<tr><td colspan="2">Installed height</td><td colspan="2">1.88 in. (47.75 mm)</td></tr>
<tr><td rowspan="4">Outer spring</td><td colspan="2">Free length</td><td colspan="2">2.21 in. (56.13 mm)</td></tr>
<tr><td rowspan="2">Pressure</td><td>Closed at</td><td colspan="2">70 lb. (312 N)</td></tr>
<tr><td>Open at</td><td colspan="2">209 lb. (930 N)</td></tr>
<tr><td colspan="2">Installed height</td><td colspan="2">1.88 in. (47.75 mm)</td></tr>
<tr><td rowspan="2">Damper</td><td colspan="3">Free length</td><td>External with rotator</td><td>Not used</td></tr>
<tr><td colspan="3">Approximate no. of coils</td><td></td><td></td></tr>
</table>

<table>
<tr><th colspan="3">CYLINDER HEAD SPECIFICATIONS</th></tr>
<tr><th>Model</th><th>454 CID</th><th>502 CID</th></tr>
<tr><td rowspan="2">Gasket-surface flatness</td><td>0.03 in. (0.08 mm) over 6.00 in. (152 mm) distance</td><td>0.03 in. (0.08 mm) over 6.00 in. (152 mm) distance</td></tr>
<tr><td>Overall maximum out-of-flat 0.007 in. (0.18 mm)</td><td>0.010 in. (0.254 mm) max.</td></tr>
</table>

<table>
<tr><th colspan="3">FLYWHEEL SPECIFICATIONS</th></tr>
<tr><th>Model</th><th>454 CID</th><th>502 CID</th></tr>
<tr><td>Run-out (face area)</td><td>0.009 in. (0.229 mm) max.</td><td>0.010 in. (0.254 mm) max.</td></tr>
</table>

ROCKER-ARM COVER

Removal:

1. Remove rocker-arm-cover-attaching hardware.
2. Disconnect crankcase-ventilation hoses.

IMPORTANT: Do not pry rocker-arm cover loose. Gaskets which adhere to cylinder head and rocker-arm cover may be sheared by bumping end of rocker-arm cover from the rear with palm of hand or a rubber mallet.

3. Remove rocker-arm cover.

Installation:

1. Clean sealing surfaces on cylinder head and rocker-arm cover with degreaser.
2. Install rocker-arm covers as follows:

Rocker-Arm Covers Using Gaskets

a. Place new rocker-arm-cover gasket in position on rocker-arm cover.
b. Install rocker-arm cover and secure with reinforcements and attaching screws or nuts. Torque to specifications.

Rocker-Arm Covers Using RTV Sealer

It is recommended that RTV Sealer be replaced with a gasket.

c. Install a new cover gasket in position in rocker-arm cover.
d. Install rocker-arm cover and secure with attaching screws or nuts. Torque to specifications.

3. Reinstall any items which were removed to allow removal of rocker-arm covers.
4. Connect crankcase-ventilation hose to valve-rocker-arm covers.
5. Start engine and check for oil leaks.

INTAKE MANIFOLD

Removal:

1. Drain engine-cooling system.
2. Disconnect hoses from thermostat housing.
3. Disconnect intake-manifold-to-circulating-pump-bypass hose from circulating pump.
4. Disconnect wire from water-temperature sending unit and water-temperature alarm sender. It may be necessary to remove sending unit to allow removal of manifold-attaching screw.
5. Disconnect crankcase-ventilation hoses from rocker-arm covers.
6. Disconnect throttle cable from carburetor.
7. Remove fuel line running between fuel pump and carburetor.

IMPORTANT: Do not crank engine over after distributor has been removed.

8. Remove distributor cap and mark position of rotor on distributor housing. Also mark position of distributor housing on intake manifold. Remove distributor.
9. Remove other ignition components, if necessary.
10. Disconnect any other items that will prevent removal of manifold.

IMPORTANT: It may be necessary to pry intake manifold away from cylinder heads and block in next step. Use extreme care to prevent damage to sealing surfaces.

11. Remove intake-manifold screws, then remove intake manifold and carburetor assembly.

NOTE: If intake manifold requires replacement, transfer carburetor and other related parts to new manifold.

Cleaning and Inspection:

1. Clean gasket material from all mating surfaces.

IMPORTANT: When cleaning cylinder-head-mating surface, do not allow gasket material to enter engine crankcase.

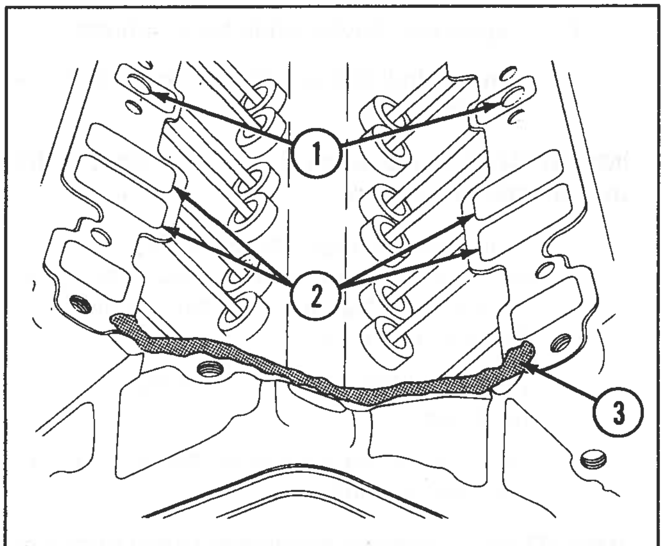
2. Inspect manifold for cracks or scratches. Machined surfaces must be clean and free of all marks or deep scratches, otherwise leaks may result.
3. Check intake passages for varnish build-up or other foreign material. Clean as necessary.

Installation:

IMPORTANT: When installing intake-manifold gaskets in next step, be sure to do the following:

1. Install gasket marked "Right Side Only" on the starboard (right) cylinder head and unmarked gasket on the port (left) cylinder head.

IMPORTANT: All Crusader engines which have automatic carburetor chokes must use an intake gasket that has an opening for the exhaust-crossover port in the intake manifold. Without this opening, the automatic carburetor choke will not operate properly. The choke will remain ON longer, causing rough engine operation and wasted fuel.

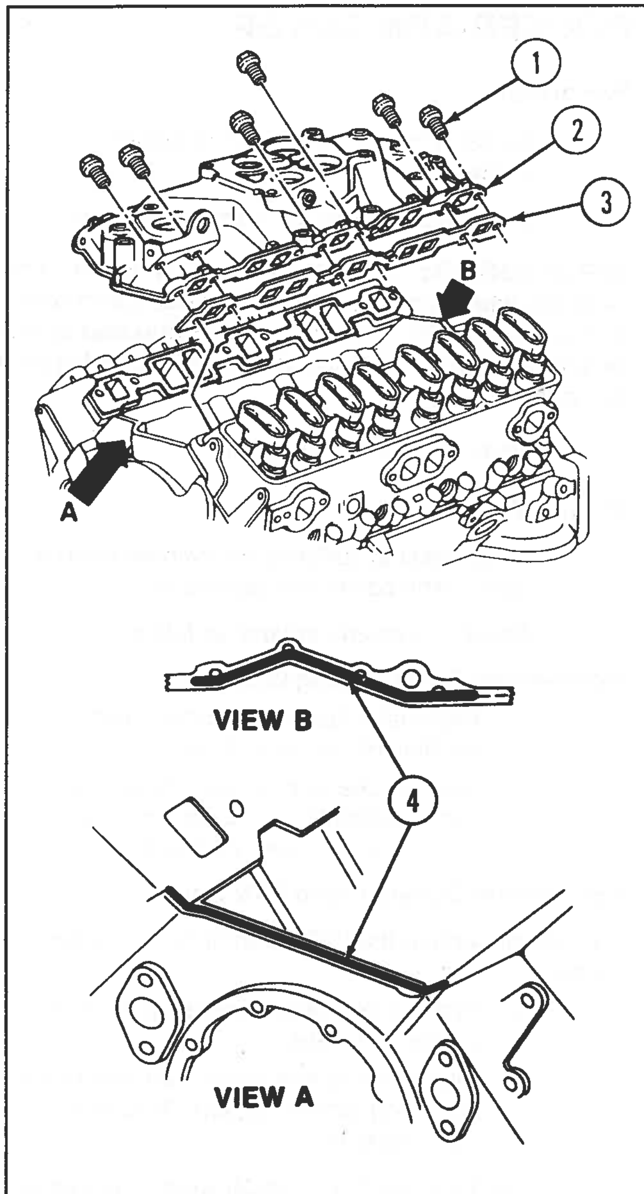


1. Exhaust-crossover-port opening in gasket
2. Intake-valve ports
3. RTV Sealer (typical both ends)

Figure 8-193. *Crossover-Port Opening*

2. Apply Perfect Seal to intake-manifold gaskets and install gaskets on cylinder heads. Install front and rear end seals on cylinder block and apply Perfect Seal to areas where seals butt against gaskets.

IMPORTANT: If cylinder-block rails do not have holes for locating pins on end seals, RTV Sealer must be used instead of seals. Apply a 3/16-in. (5 mm) wide bead of RTV Sealer. Extend the bead 1/2 in. (13 mm) up each gasket to seal and retain gaskets. RTV Sealer can be used instead of end seals on all engines.



1. Bolt/stud
2. Intake manifold
3. Gasket
4. Sealant

Figure 8-194. *Applying Sealer And Gaskets To Heads For Intake Manifold*

3. Carefully install manifold assembly and torque bolts in sequence displayed in Figure 8-195 to specifications.

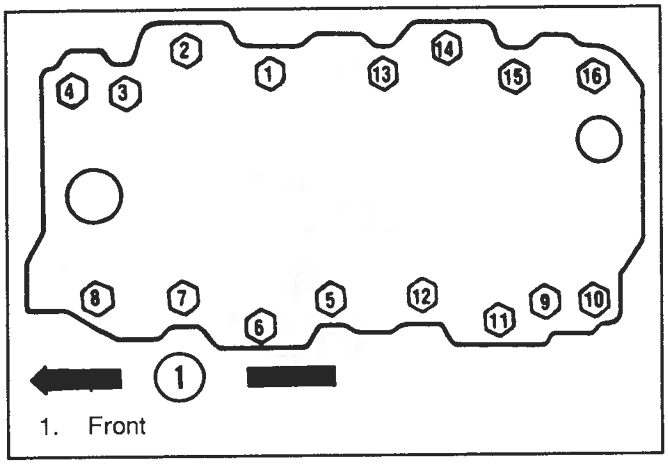


***Figure 8-195.** Intake-Manifold-Tightening Sequence*

4. Connect intake manifold to circulating-pump-bypass hose.
5. Connect wire to water-temperature-sending unit and water-temperature-alarm sender.
6. Reconnect hoses to thermostat housing.
7. Install fuel line to carburetor and fuel pump. Connect throttle cable to carburetor.
8. Connect crankcase-ventilation hoses to rocker-arm covers.
9. Install distributor. Position rotor and housing to align with marks made during removal, then install distributor cap.
10. Install other ignition components and reconnect wires.
11. Reconnect any other items which were disconnected from manifold during the removal.
12. Start engine. Adjust ignition timing and carburetor. Check hose connections, gaskets and seals for leaks.
13. Inspect fuel-line connections for fuel leaks.

ROCKER ARM/PUSH ROD

Removal:

1. Remove rocker-arm covers.
2. Remove rocker-arm components, rocker arms and push rods.

IMPORTANT: Place rocker arms, rocker-arm components and push rods in a rack for reinstallation in the same locations.

Cleaning and Inspection:

1. Clean parts with solvent and dry with compressed air.
2. Inspect all contact surfaces for wear. Replace all damaged parts.

Installation:

IMPORTANT: Push rods with a hardened-tip end must be installed with the hardened tips toward rocker arm. Push rods without hardened tips must be installed with large oil-hole end toward rocker arms. Hardened-tip end or large hole end is marked with a blue stripe.

IMPORTANT: When installing rocker arms and rocker-arm balls, coat bearing surfaces of rocker arms and rocker-arm balls with engine oil.

1. Install push rods. Be sure push rods seat in lifter socket.
2. Install rocker arms, rocker-arm balls and rocker-arm nuts. Tighten rocker-arm nuts until all lash is eliminated.
3. Valve lash can be adjusted either with engine stopped or running.

Adjustment – Engine Stopped:

With valve cover removed, adjust valves when lifter is on low part of camshaft lobe as follows:

1. Crank engine with starter or turn over in normal direction of rotation until mark on torsional damper lines up with center “0” mark on timing tab, and engine is in No. 1-firing position. This may be determined by placing fingers on No. 1-valve as mark on damper comes near “0” mark on timing mark. If valves move as mark comes up to timing tab, engine is in No. 6-firing position and should be turned over one more time to reach No. 1-position.

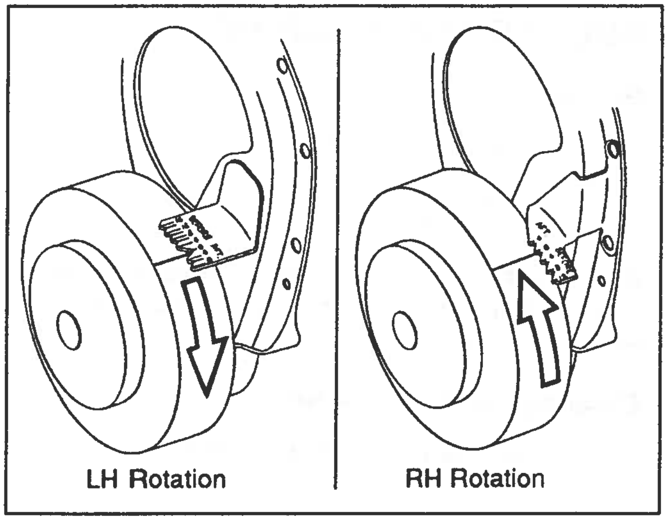
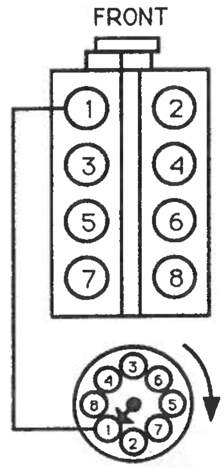


Figure 8-196. Engine In No. 1 Firing Position

2. With engine in No. 1 firing position as determined above, the valves indicated in Figure 8-196 may be adjusted.
3. Back out adjusting nut until lash is felt at push rod, then turn in adjusting nut until all lash is removed. This can be determined by moving push rod up and down while turning adjusting nut until all play is removed.



With number one cylinder at TDC of compression stroke, adjust the following rocker arms.	
Left-hand (normal) rotation engine	Right-hand rotation engine
Exhaust 1, 3, 4, 8	Exhaust 1, 2, 5, 7
Intake 1, 2, 5, 7	Intake 1, 3, 4, 8

Figure 8-197. Adjusting Rocker Arms With No. 1 Piston At TDC Of Compression Stroke

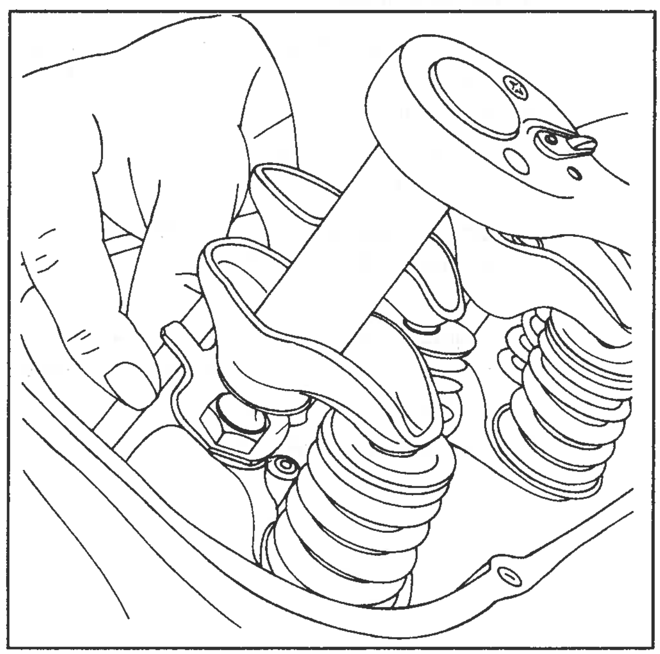
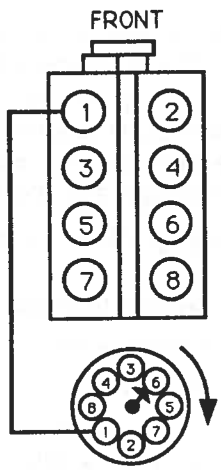


Figure 8-198. Adjusting Rocker Arms With Engine Stopped

4. Hydraulic lifters now can be adjusted by tightening adjustment nut 3/4 additional turn. No other adjustment is required.
5. Crank engine one revolution until pointer "0" mark and torsional damper mark are again in alignment. This is No. 6-firing position. With engine in this position, the valves indicated in Figure 8-199 may be adjusted as previously outlined.



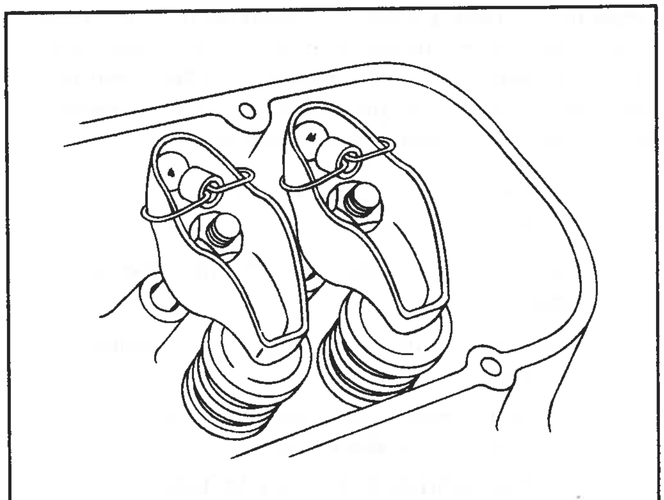
With number six cylinder at TDC of compression stroke, adjust the following rocker arms.	
Left-hand (normal) rotation engine	Right-hand rotation engine
Exhaust 2, 5, 6, 7	Exhaust 3, 4, 6, 8
Intake 3, 4, 6, 8	Intake 2, 5, 6, 7

Figure 8-199. *Adjusting Rocker Arms With No. 6 Piston At TDC Of Compression Stroke*

Adjustment – Engine Running:

The following procedure is performed with engine running:

1. After engine has been rechecked for normal operating temperature, remove valve covers and install rocker stoppers to prevent oil from squirting all over the engine.



1. Rocker stoppers

Figure 8-200. *Rocker Stoppers Installed*

2. With engine running at idle, back valve-rocker-arm nuts off (one at a time) until valve-rocker arm starts to clatter.
3. Turn rocker-arm nut down until clatter just stops. This is zero-lash position.
4. Turn nut down 1/4 additional turn and pause 10 seconds until engine runs smoothly. Repeat until nut has been turned down one turn from the zero-lash position.

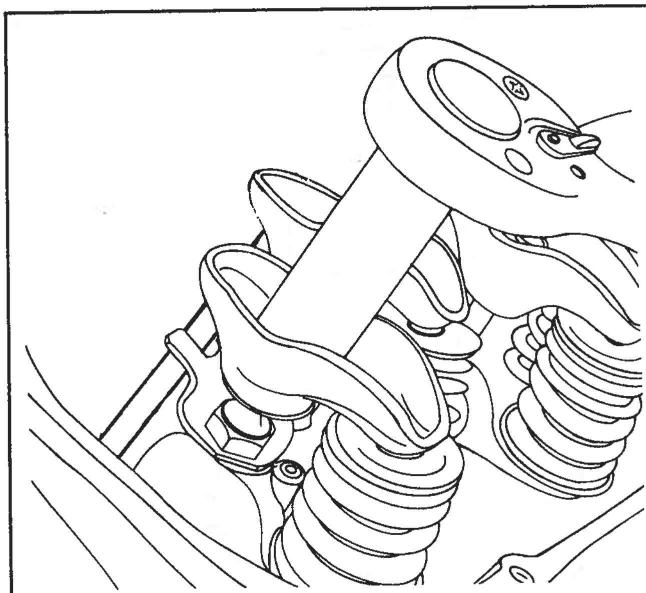


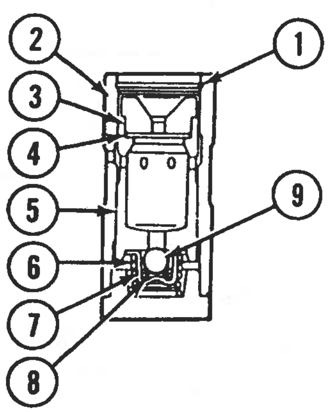
Figure 8-201. *Adjusting Rocker Arms With Engine Running*

IMPORTANT: This 3/4-turn preload adjustment must be done slowly to allow lifter to adjust itself, thus preventing possibility of interference between inlet valve head and top of piston, which might result in internal damage and/or bent push rods.

5. Repeat Steps 2, 3 and 4 to adjust other valves.
6. Remove rocker stoppers after all valves are adjusted.
7. After valves have been adjusted, complete the following:
   a. Install new gasket and install covers. Torque to specifications.
   b. Start engine and check for leaks.
   c. Adjust carburetor-idle speed and mixture.

HYDRAULIC VALVE LIFTERS

Hydraulic valve lifters (Figure 8-202) require little attention. Lifters are extremely simple in design. Normally, readjustments are not necessary and servicing requires only that care and cleanliness be exercised in the handling of parts.



1. Retainer
2. Lifter body
3. Push-rod seat
4. Oil-metering valve
5. Plunger
6. Plunger spring
7. Check-ball retainer
8. Check-ball spring
9. Check-ball

Figure 8-202. *Hydraulic Valve Lifter Assembly*

Locating Noisy Lifters:

Locate a noisy valve lifter by using a piece of garden hose approximately 4 ft (1.2 m) in length. Place one end of hose near end of each intake and exhaust valve, with other end of hose to the ear. In this manner, sound is localized, making it easy to determine which lifter is at fault.

Another method is to place a finger on the face of a valve-spring retainer. If lifter is not functioning properly, a distinct shock will be felt when valve returns to its seat.

General types of valve-lifter noise are as follows:

1. Hard rapping noise – usually caused by plunger becoming tight in bore of lifter body so that return spring cannot push plunger back up to working position.

Probable causes are:

   a. Excessive varnish or carbon deposits causing abnormal stickiness.
   b. Galling or pickup between plunger and bore of lifter body, usually caused by an abrasive piece of dirt or metal wedged between plunger and lifter body.

2. Moderate rapping noise – probable causes are:
   a. Excessively high leakdown rate.
   b. Leaky check-valve seat.
   c. Improper adjustment.
3. General noise throughout valve train – this will, in most cases, be a definite indication of insufficient oil supply or improper adjustment.
4. Intermittent clicking – probable causes are:
   a. A microscopic piece of dirt momentarily caught between ball seat and check-ball valve.
   b. In rare cases, ball itself may be out-of-round or have a flat spot.
   c. Improper adjustment.

In most cases, where noise exists in one or more lifters, all lifter units should be removed, disassembled, cleaned in solvent, reassembled and reinstalled in engine. If dirt, corrosion, carbon, etc., is shown to exist in one unit, it probably exists in all the units, thus it would only be a matter of time before all lifters caused trouble.

Removal:

1. Drain cooling system (See Section 10, Cooling System).
2. Remove intake manifold.
3. Remove rocker-arm cover and rocker arms.
4. Remove valve mechanism.
5. Remove valve lifters.

IMPORTANT: Keep push rod and hydraulic valve lifter from each valve together as a matched set and mark them so they can later be reinstalled in the same location.

NOTE: If the hydraulic lifter is stuck, use a valve lifter remover tool (J-3049) to remove lifter.

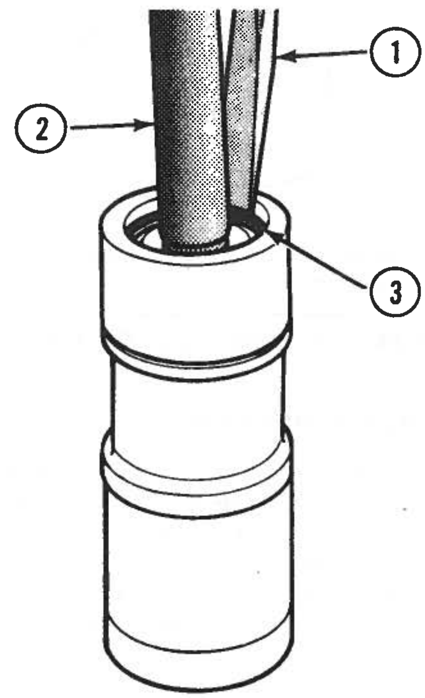
> ⚠ **CAUTION**
>
> Install all new hydraulic lifters when a new camshaft is installed.
>
> Change the engine oil and filter if any new hydraulic lifter is installed.

6. Inspect the hydraulic lifters for:
   a. scored or scuffed lifter body. If marks are present, inspect the mating bore of the cylinder block for damage. Replace parts as necessary.
   b. scuffed or worn lifter-push-rod seat. If marks are present, inspect the push rod's mating end for damage. Replace parts as necessary.
   c. clearance between the lifter and its mating bore. If excessive clearance is found, try a new lifter or replace the cylinder block.
   d. smooth and slightly convex surface on the lifter foot. If the foot is scored, pitted or extremely worn, check the mating-camshaft lobe. Replace parts as necessary.

Disassembly:

IMPORTANT: The internal parts of each hydraulic lifter assembly are matched sets. Do not intermix the parts. Replace the complete lifter if any wear or damage is noted.

1. Hold plunger down with a push rod and remove push-rod-seat retainer with the blade of a small screwdriver.



1. Screwdriver
2. Push rod
3. Retainer

Figure 8-203. *Lifter-Seat-Retainer Removal*

2. Remove push-rod seat and metering valve.
3. Remove the plunger assembly and the plunger spring using the hydraulic valve-lifter-plunger remover (J-4160-A).
4. Remove the check-ball valve and spring by prying the ball retainer loose from the plunger with the blade of a small screwdriver.

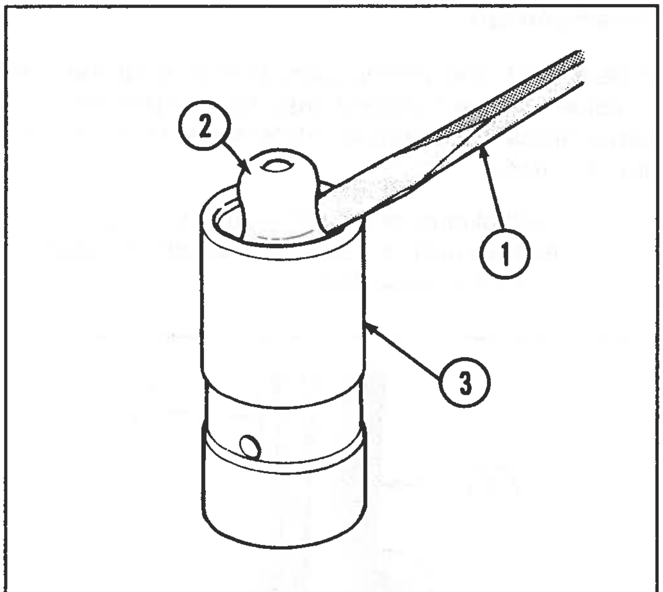


Figure 8-204. Removing Check-Ball Valve

Cleaning and Inspection:

Thoroughly clean all parts in cleaning solvent and inspect them carefully. If any parts are damaged or worn, entire lifter assembly should be replaced. If outer body wall is scuffed or worn, inspect cylinder-block-lifter bore. If bottom of lifter is scuffed or worn, inspect camshaft lobe. If push-rod seat is scuffed or worn, inspect push rod.

Reassembly:

1. Place the check ball in small hole in bottom of the plunger.
2. Insert check-ball spring on seat in ball retainer and place retainer over ball so that spring rests on the ball. Carefully press the retainer into position in plunger with the blade of a small screwdriver.

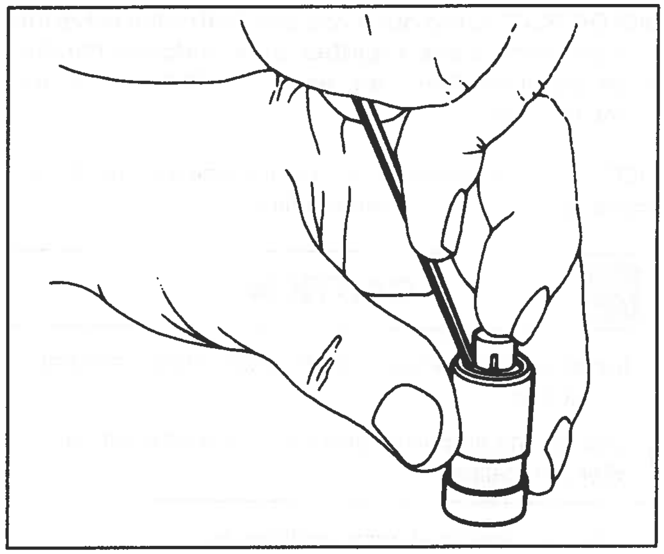
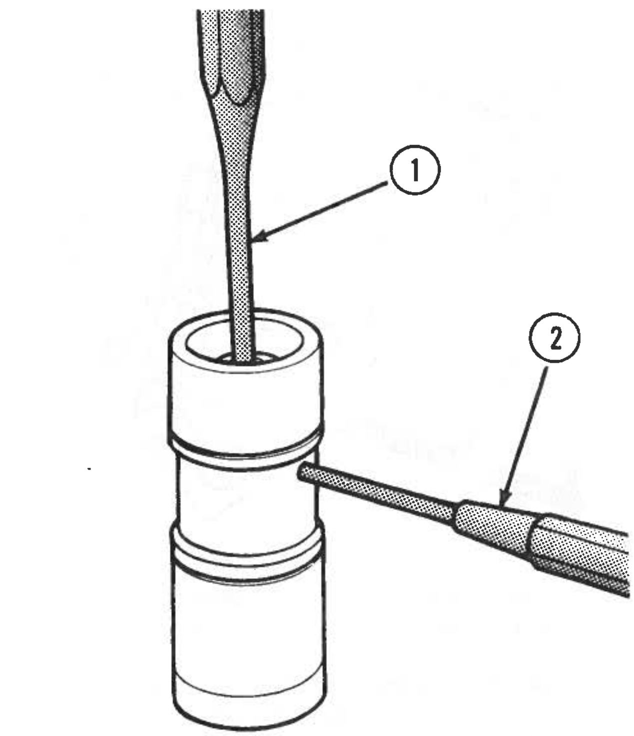


Figure 8-205. Check-Ball Valve Installation

3. Place the plunger spring over the check-ball retainer and slide the lifter body over the spring and plunger, being careful to line up the oil-feed hole in the lifter body and plunger.
4. Fill the assembly with oil (see Specifications), then insert the end of a 1/8-in. (3 mm) drift pin into the plunger and press down on check ball until hole in lifter body aligns with hole in plunger.
5. Insert a 1/16-in. (1.6 mm) drift pin through both oil holes to hold the plunger down against the lifter-spring tension.

IMPORTANT: Do not attempt to force or pump the plunger.

6. Remove the 1/8-in. (3 mm) drift pin and refill assembly with oil.
7. Install the metering valve, push-rod seat and push-rod-seat retainer.
8. Press down on the push rod seat with a push rod and remove the 1/16-in. (1.6 mm) drift pin from lifter. The lifter is now completely assembled, filled with oil and ready for installation.



1. 1/8-in. (3 mm) drift pin
2. 1/16-in. (1.5 mm) drift pin inserted in oil-feed hole

Figure 8-206. *Oil-Feed Holes Aligned and Drift Pin Installed*

Installation:

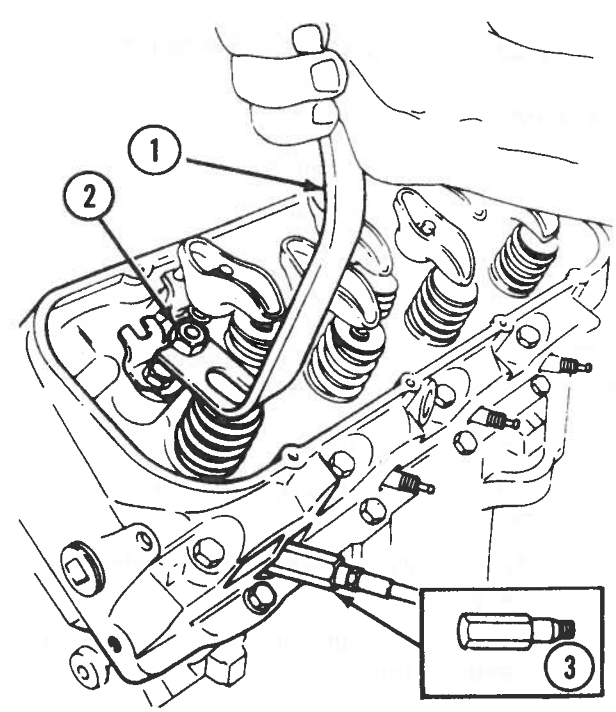
IMPORTANT: Before installing lifters, coat the bottom of the lifter with engine oil. If new lifters or a new camshaft have been installed, an additive containing EP lubricant should be poured over camshaft lobes before installing lifters.

1. Install hydraulic valve lifters into the same bore from which they were removed.
2. Install intake manifold.
3. Install and adjust valve mechanism as outlined.
4. Install rocker-arm cover.
5. Fill cooling system (see Section 10, Cooling System).
6. Start engine and check for leaks.

VALVE-STEM-OIL SEAL AND VALVE SPRING

Removal:

1. Remove rocker-arm cover.
2. Remove spark plug, rocker arm and push rod on cylinder to be serviced.
3. Position piston (in cylinder to be serviced) at TDC to prevent valve from dropping out of valve guide.
4. Install the J-23590 air-adapter tool into spark-plug hole. Apply air pressure to the cylinder to hold the valves in place.
5. Compress valve spring with J-5892 tool. Remove valve locks and all other components.
6. Remove valve-stem oil seal(s) from valve.



1. J-5892 tool
2. Rocker-arm nut
3. Air-adapter tool (J-23590)

Figure 8-207. *Compressing Valve Spring With Cylinder Head Installed*

Installation:

1. Install valve rotator or shim in position on valve-spring seat (rotator is used on exhaust valve, shim is used on intake valve).

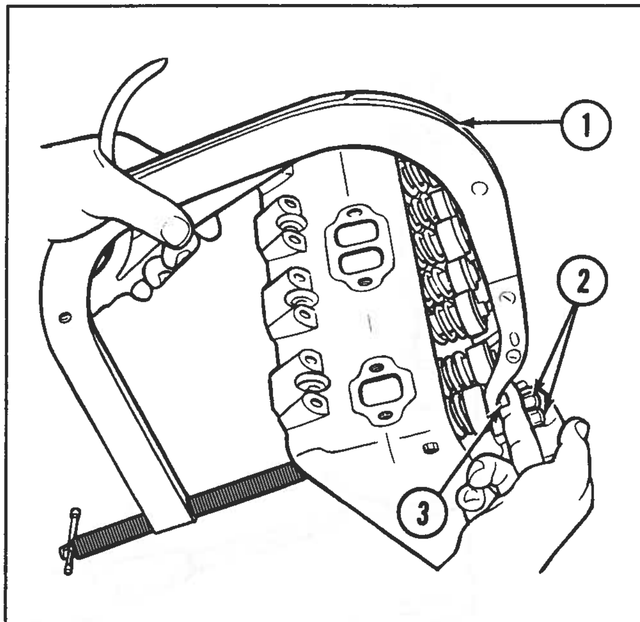
2. Coat valve-stem-oil seal with engine oil and install over valve stem.

IMPORTANT: If new pressed-on-type intake valve-stem-oil seals are to be used, install seals in accordance with instructions which accompany them.

3. If removed, install damper in valve spring.
4. Set valve spring and damper assembly and valve-spring cap in position over valve stem.
5. Compress spring with J-5892 tool and install valve locks. Then release compressor tool, making sure that locks seat properly in groove of valve stem.

NOTE: Grease may be used to hold locks in place while releasing compressor tool.

IMPORTANT: Compress valve spring only enough to install valve locks in next step. Excessive compression could cause valve-spring cap to damage seal.



1. J-8062 spring-compression tool
2. Valve retainers
3. O-ring

Figure 8-208. *Compressing Valve Spring With Cylinder Head Removed*

CYLINDER HEAD ASSEMBLY

Removal:

1. Drain engine cooling system.
2. Remove exhaust manifolds.
3. Remove intake manifold.
4. Remove valve mechanism.

NOTE: Remove any component attached to front or aft end of cylinder head to be removed.

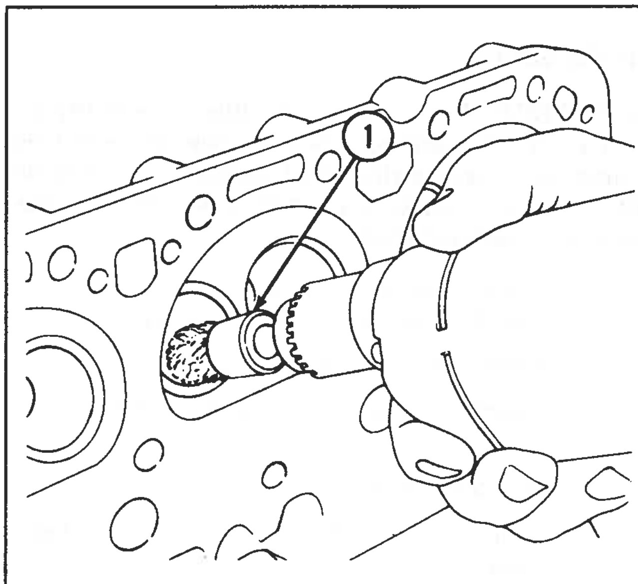
5. Remove spark plugs.
6. Remove spark-plug-wire retainers from cylinder head.
7. Remove cylinder-head bolts, cylinder head and gasket.
8. Place cylinder head on two blocks of wood to prevent damage.

Disassembly:

1. With cylinder head removed, remove rocker arms and components (if not previously done).
2. Compress valve springs with J-8062 tool and remove valve retainers. Release compressor tool and remove all valve components.
3. Remove valves from cylinder head and place valves in a rack in their proper sequence for reassembly in their original positions.

Cleaning:

1. Clean all carbon from combustion chambers and valve ports with J-8089 tool.

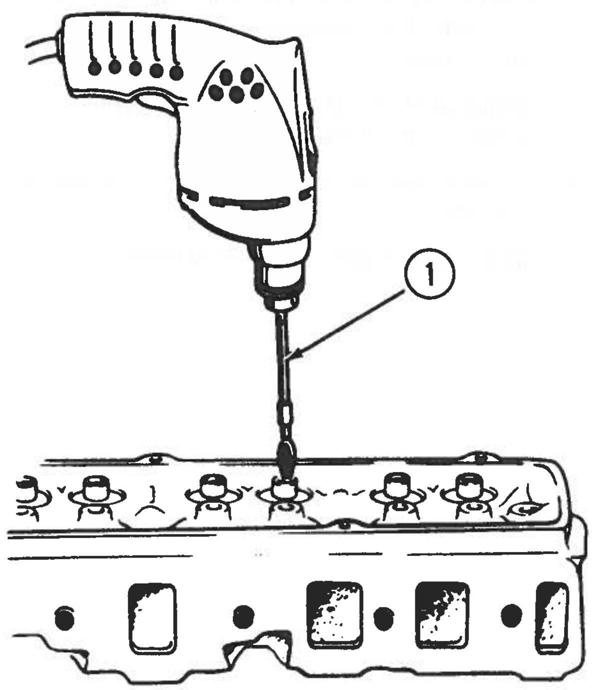


1. J-8089 wire-brush tool

Figure 8-209. *Cleaning Combustion Chambers*

2. Thoroughly clean valve guides with J-8101 tool.

3. Clean all push rods, rocker arms and push-rod guides.
4. Clean carbon from valves on a buffing wheel.
5. Clean carbon deposits and gasket material from cylinder-head-mating surfaces.



1. J-8101 valve-guide cleaning tool

***Figure 8-210.** Cleaning Valve Guides*

Inspection:

1. Inspect cylinder head for cracks in the exhaust ports, combustion chambers (especially around spark plug holes and valve seats) and for cracks in external surface of water jacket. Replace head if cracked.
2. Inspect cylinder-head-gasket surface for burrs, nicks, erosion or other damage. Also, check flatness of cylinder-head-gasket surface, using a machinist's straightedge and feeler gauges as shown. Refer to "Specifications."

IMPORTANT: Cylinder head-to-block-gasket surface should be resurfaced if out-of-flat more than specified. When resurfacing gasket surface, cylinder-head-to-intake-manifold-gasket surface also must be milled to provide proper alignment between manifold and head.

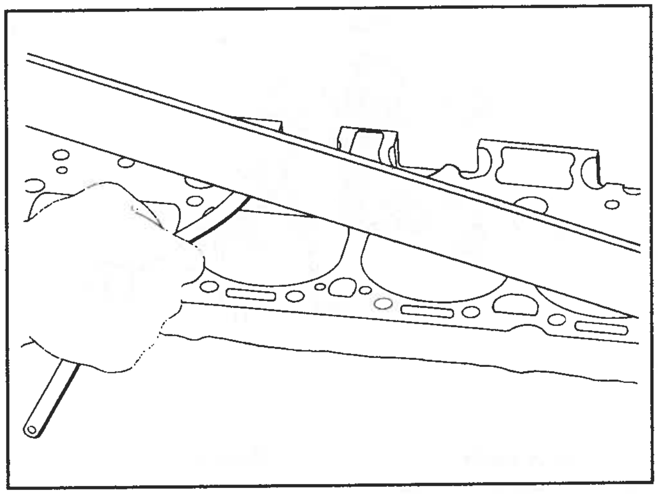


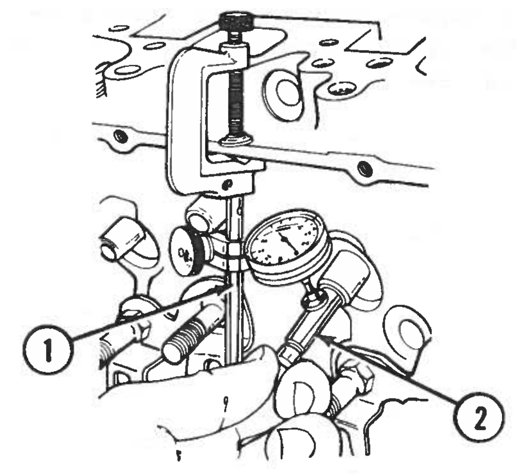
***Figure 8-211.** Checking Gasket Surface Of Cylinder Head For Flatness*

3. Inspect valves for burned heads, cracked faces or damaged stems.

IMPORTANT: Excessive valve-stem-to-bore clearance will cause excessive oil consumption and possible valve breakage. Insufficient clearance will result in noisy and sticky functioning of valve and disturb engine smoothness.

4. Measure valve stem clearance as follows:

   Clamp a dial indicator on one side of cylinder-head-rocker-arm-cover-gasket rail, locating indicator so that movement of valve stem from side to side (crosswise to the head) will cause a direct movement of indicator stem. Indicator stem must contact side of valve stem just above valve guide. With valve head dropped about 0.06 in. (1.5 mm) off valve seat, move valve stem from side to side, using light pressure to obtain a clearance reading. If clearance exceeds specifications, it will be necessary to ream valve guides for oversized valves, as outlined under "Valve-Guide-Bore Repair."



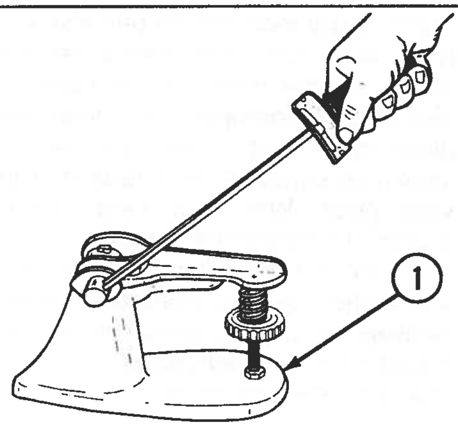
1. Valve guide 2. Valve stem

Figure 8-212. *Measuring Valve-Stem Clearance*

5. Check valve-spring tension with J-9666 spring tester.

IMPORTANT: Springs should be compressed to specified height and checked against specification. Springs should be replaced if not within 10 lb-ft (13.6 N•m) of specified load.

6. Inspect rocker-arm studs for wear or damage. Inspect push-rod guides for wear or damage.



1. J-8056 tool

Figure 8-213. *Checking Valve-Spring Tension*

ROCKER-ARM STUDS AND PUSH-ROD GUIDE REPAIR

1. Remove rocker-arm cover and rocker arms as outlined.
2. Using a deep socket, remove rocker-arm stud and push-rod guide.
3. Inspect rocker-arm stud and push-rod guide for wear. If components show any sign of wear, replace.
4. Install push-rod guide and rocker-arm studs. Torque to specifications.
5. Install rocker arms and push rods. Adjust as outlined.
6. Install rocker-arm cover as outlined.

VALVE-GUIDE-BORE REPAIR

If oversized valves are required, ream valve-guide bores for oversized valves, as follows:

1. Measure valve-stem diameter of old valve being replaced and select proper-size Valve Guide Reamer from J-7049-5 Kit.
2. Ream valve guide bores, as shown.
3. Remove the sharp corner created by reamer at top of valve guide.

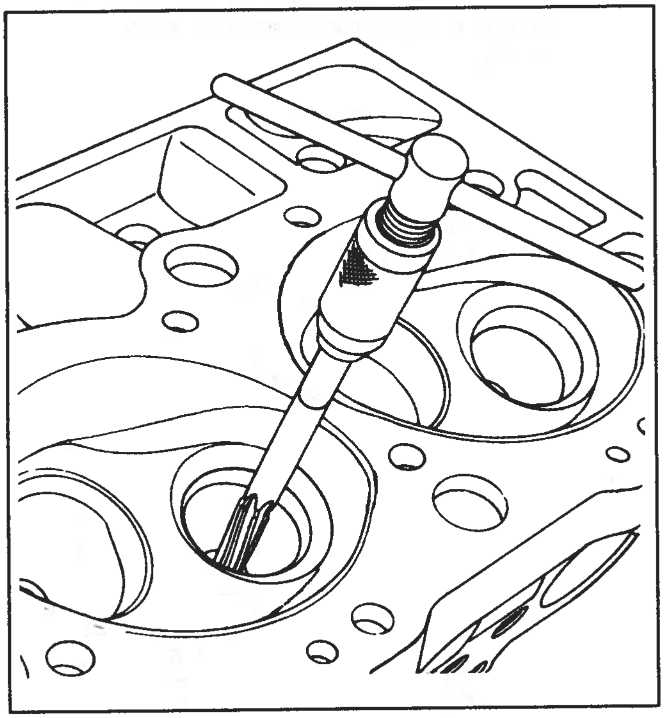


Figure 8-214. *Reaming Valve Guides*

VALVE-SEAT REPAIR

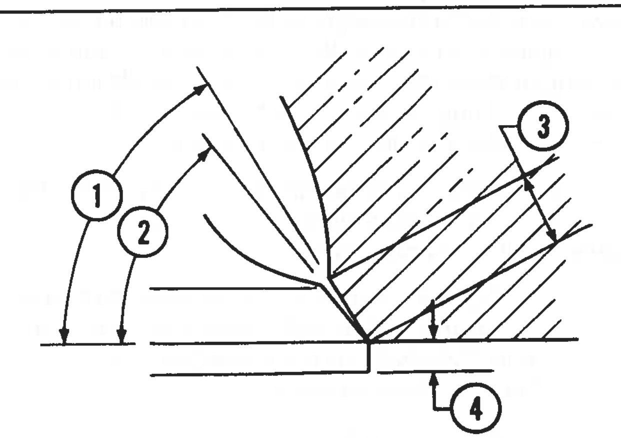
Valve-seat reconditioning is very important, since seating of valves must be perfect for engine to deliver maximum power and performance.

Another important factor is valve-head cooling. Good contact between each valve and its seat in the head is important to ensure that heat in the valve head will be properly dispersed.

Several different types of equipment are available for reseating valve seats. Equipment manufacturer's recommendations should be followed carefully to attain proper results.

Regardless of type of equipment, however, it is essential that valve guide bores be free from carbon or dirt to ensure proper centering of pilot in valve guide.

1. Install expanding pilot in valve-guide bore and expand pilot.
2. Place roughing stone or forming stone over pilot and clean up valve seat only. Use a stone that is cut to specifications.
3. Remove roughing stone or forming stone from pilot. Place finishing stone (cut to specifications) over pilot and cut just enough metal from seat to provide a smooth finish. Refer to "Specifications."
4. Narrow down valve seats to specified width by grinding with a 30° stone to lower seat and a 60° stone to raise seat.



1. Valve-seat angle
2. Valve-face angle
3. Valve-seat width
4. Valve-edge thickness

Figure 8-215. *Valve-Seat Grinding Angles*

5. Remove expanding pilot and clean cylinder head carefully to remove all chips and grindings from above operations.
6. Measure valve seat width. See "Specifications."

7. Measure valve seat run-out. See "Specifications."

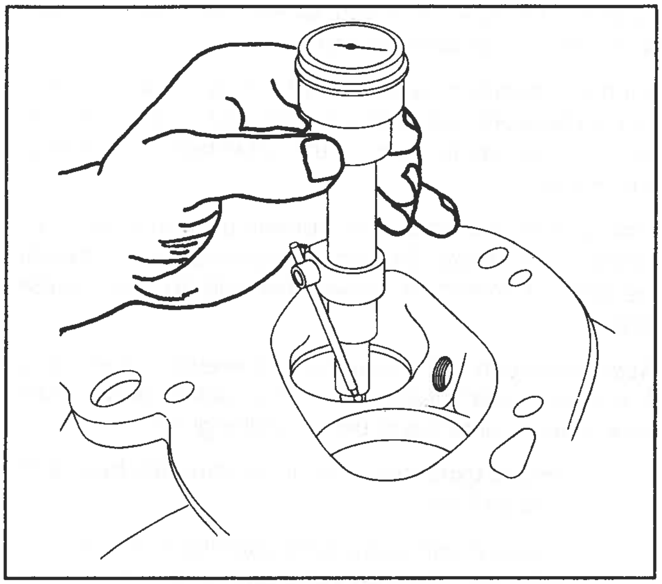


Figure 8-216. Measuring Valve-Seat Run-out

VALVE REPAIR

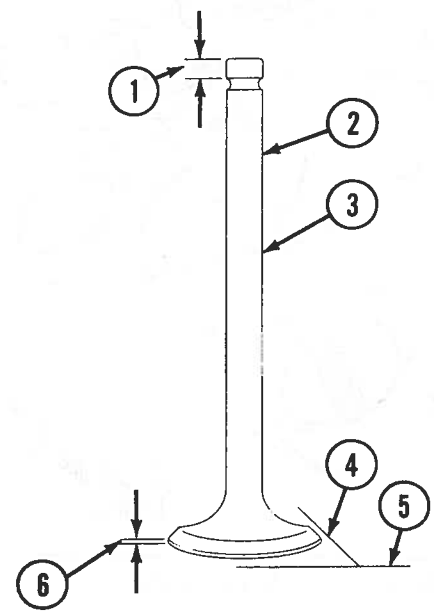
Pitted valves can be refaced to proper angle on a valve grinder, thus insuring correct relation between cylinder-head seat and valve-mating surface. Replace valves with excessive wear on stems or valves which are overly warped. When an excessively warped valve head is refaced, a knife edge will be ground on part or all of the valve head due to amount of metal that must be removed to completely reface. Knife edges lead to breakage, burning or preignition caused by heat localizing in this knife edge. If edge of valve head is less than 0.03 in. (0.8 mm) thick after grinding, replace the valve.

Various equipment is available for refacing valves. Manufacturer's recommendations should be carefully followed to attain proper results.

1. If necessary, dress the valve-refacing-machine grinding wheel to make sure it is smooth and true. Set chuck at angle specified for valve. Refer to "Specifications."
2. Continue grinding until valve face is true and smooth all around the valve. If this makes valve head thin (0.03 in. [0.8 mm] minimum), valve must be replaced or valve will overheat and burn.
3. Remove valve from chuck and place stem in V-block. Feed valve squarely against grinding wheel to grind any pit from rocker-arm end of stem.

IMPORTANT: Only extreme end of valve stem is hardened to resist wear. Do not grind end of stem excessively.

4. After cleaning valve face and cylinder-head-valve seat of grinding particles, make pencil marks about 0.25 in. (6 mm) across the valve face, place valve in cylinder head and give valve a 1/2 turn in each direction while exerting firm pressure on head of valve.
5. Remove valve and check face carefully. If all pencil marks have not been removed at point of contact with valve seat, repeat refacing operation and again recheck for proper seating.

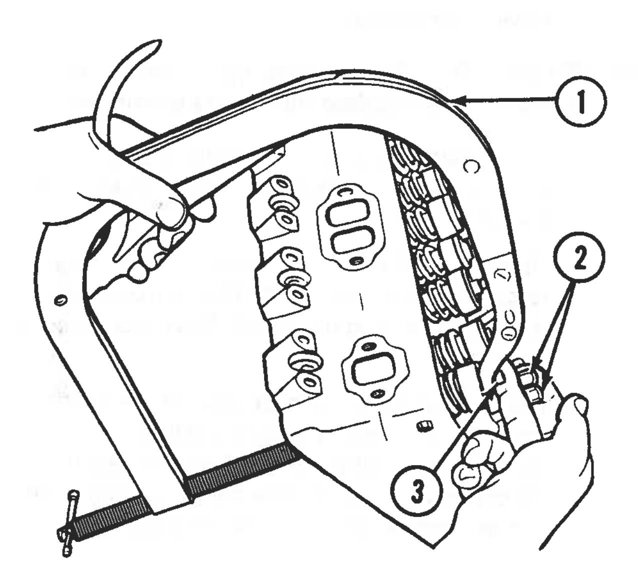


1. Refer to specifications for min. dimension
2. Check for bent stem
3. Diameter
4. Valve-face angle
5. This line parallel with valve head
6. 0.03 in. (0.8 mm) minimum

Figure 8-217. Critical Valve Dimensions

Reassembly:

1. Lubricate valve guides and valve stems with engine oil.
2. Install each valve in the port from which it was removed or to which it was fitted.
3. Install valve-stem-oil seal, valve spring(s) and related parts on each valve as explained under "Valve-Stem-Oil Seal/Valve Spring."
4. Compress valve spring with tool J-8062.
5. Check installed height of the valve springs with a narrow, thin scale. A cutaway scale will help. Measure from top of spacer (spring seat) to top of valve spring. If this exceeds specified height, install a valve-spring-seat shim approximately 0.06 in. (1.6 mm) thick. At no time should spring be shimmed to give an installed height under minimum specified.



1. J-8062 spring-compressor tool
2. Valve retainers
3. O-ring

Figure 8-218. *Compressing Valve Spring With Cylinder Head Removed*

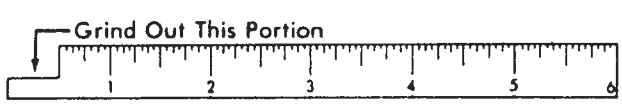
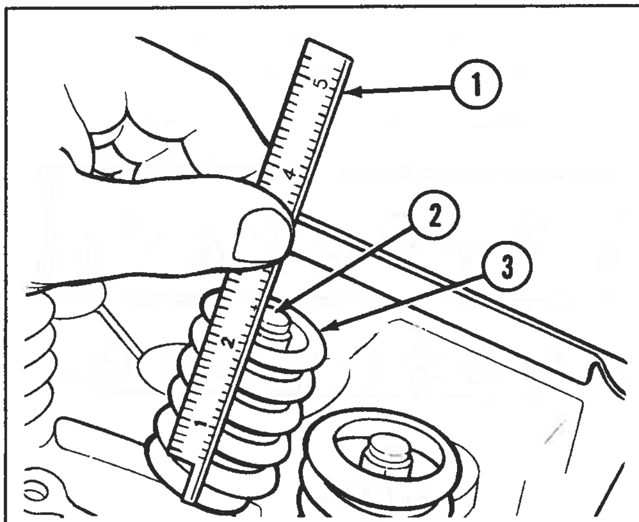


Figure 8-219. *Valve-Installed Height Gauge*



1. Valve-installed-height gauge
2. Valve tip
3. Valve spring

Figure 8-220. *Measuring Valve-Spring Installed Height*

CYLINDER HEAD INSTALLATION

CAUTION

Gasket surfaces on both head and block must be clean of any foreign matter and free of nicks or deep scratches. Cylinder-bolt threads in block and threads on cylinder-head bolts must be clean. Dirt will affect bolt torque.

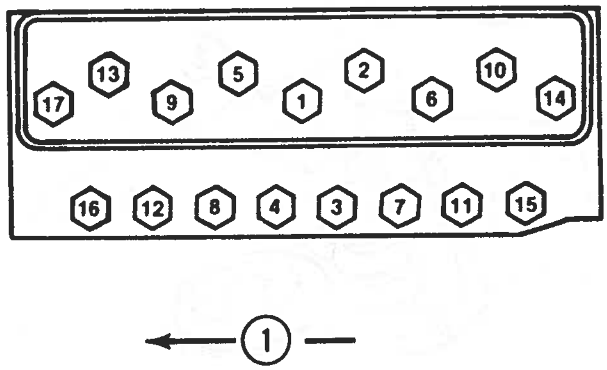
1. On engines using a stainless-steel gasket, coat both sides of new gasket with Perfect Seal. Spread sealer thin and even. Too much sealer may hold gasket away from head or block.

CAUTION

Use no sealer on engines which have a composition steel-asbestos gasket.

2. Place gasket in position over dowel pins.
3. Carefully guide cylinder head into place over dowel pins and gasket.
4. Coat threads of cylinder-head bolts with Perfect Seal and install bolts finger-tight.

5. Tighten each cylinder-head bolt a little at a time, in sequence shown in Figure 8-221, until specified torque is reached.



1. Forward

Figure 8-221. *Cylinder-Head Torque Sequence*

6. Install intake manifold as described.
7. Install and adjust valve mechanism as outlined.
8. Install valve covers.
9. Install spark plugs. Torque spark plugs to specifications.
10. Install spark-plug-wire retainers.
11. Install exhaust manifolds as outlined.

NOTE: Install any component that was removed from the front or aft end of cylinder head.

12. Run engine, adjust timing and check for leaks.

OIL PAN

Removal:

1. Drain coolant.
2. Drain crankcase oil.
3. Remove oil dipstick and tube, if required.
4. Remove oil pan and discard gaskets.

Installation:

1. Thoroughly clean gasket and seal surfaces on oil pan, cylinder block, rear main bearing cap and crankcase-front cover.
2. Coat both sides of oil-pan-side gaskets with Perfect Seal and place gaskets in position on each side of cylinder block.
3. Apply a 0.13-in. (3 mm) bead of RTV Sealer to front and rear seal-mating surfaces on cylinder-block rear main bearing cap, front cover and gaskets.

IMPORTANT: RTV Sealer sets up in about 15 minutes. Be sure to complete assembly promptly.

4. Install new front and rear seals, being sure ends of seals are butted properly against side gaskets.
5. Apply a 0.13-in. (3 mm) bead of RTV Sealer to outer surface of seals. This is extremely important on engines which have aluminum oil pans.
6. Carefully position oil pan against the block, being careful not to disturb gaskets and seals. Install oil-pan-attaching screws and washers. Torque screws to specifications, starting from center and working outward in each direction.
7. Install oil-dipstick tube and dipstick.
8. Install engine in boat.
9. Fill engine with oil, start engine and check for leaks.

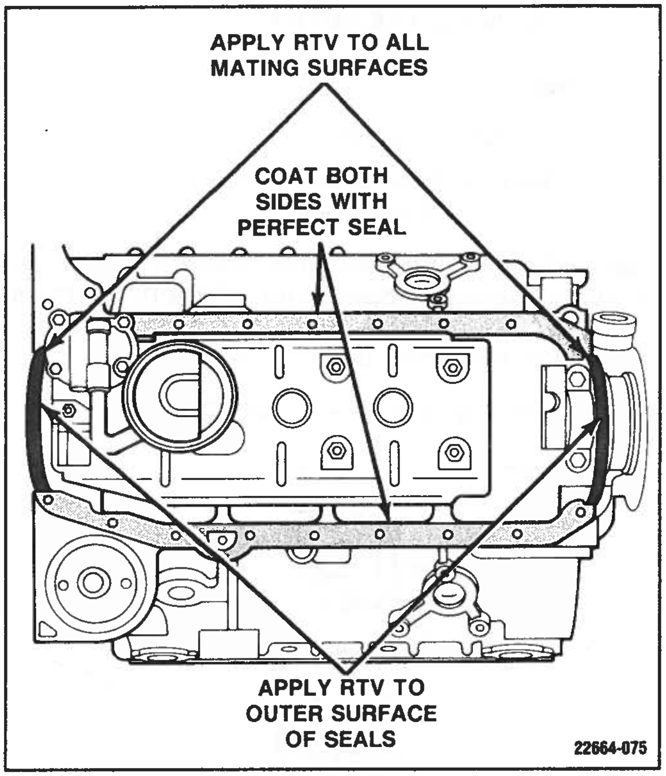
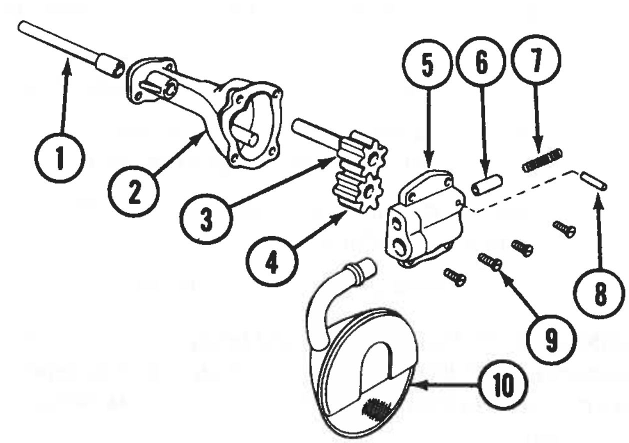


Figure 8-222. Applying RTV Sealer For Oil Pan

OIL PUMP

The oil pump consists of two gears and a pressure-regulator valve enclosed in a two-piece housing. The oil pump is driven by the distributor shaft which is driven by a helical gear on the camshaft.

A baffle is incorporated on the pickup screen and engine-oil-pump tubes are bent at special angles to eliminate pressure loss.



1. Shaft extension
2. Pump body
3. Drive gear
4. Idler gear
5. Pump cover
6. Pressure-regulator valve
7. Spring
8. Pin
9. Screw (4 used)
10. Pickup screen and pipe assembly

Figure 8-223. Oil Pump Disassembled

Removal:

1. Remove oil pan.
2. Remove pump-to-rear main bearing-cap bolt and remove pump and extension shaft.

Disassembly:

1. Remove pump-cover-attaching screws and pump cover.

IMPORTANT: Mark gear teeth so that pump can be reassembled with the same gear teeth indexed.

2. Remove idler gear, drive gear and shaft from pump body.
3. Remove retaining pin, pressure-regulator valve and related parts.

IMPORTANT: Pickup screen and pipe assembly cannot be removed from pump.

IMPORTANT: Do not disturb pickup screen on pipe. Pump and pickup screen are serviced as an assembly.

Cleaning and Inspection:

1. Wash all parts in cleaning solvent and dry with compressed air.
2. Inspect pump body and cover for cracks or excessive wear.
3. Inspect pump gears for damage or excessive wear.
4. Check for loose drive-gear shaft in pump body.
5. Inspect inside of pump cover for wear that would permit oil to leak past ends of gears.
6. Inspect pickup screen and pipe assembly for damage to screen or pipe.
7. Check pressure-regulator valve for fit.

IMPORTANT: Pump gears and body are not serviced separately. If pump gears or body are damaged or worn, replacement of entire oil pump assembly is necessary.

Reassembly:

IMPORTANT: Oil internal parts liberally before installation.

1. Install pressure-regulator valve and related parts.
2. Install drive gear and shaft in pump body.
3. Install idler gear in pump body with smooth side of gear toward pump-cover opening. Align marks made in disassembly.
4. Install pump cover and torque attaching screws to specifications.
5. Turn drive shaft by hand to check for smooth operation.

Installation:

1. Assemble pump and extension shaft to rear main bearing cap, aligning slot on top end of extension shaft with drive tang on lower end of distributor-drive shaft.
2. Install pump to rear main bearing cap and torque to specifications.
3. Install oil pan.

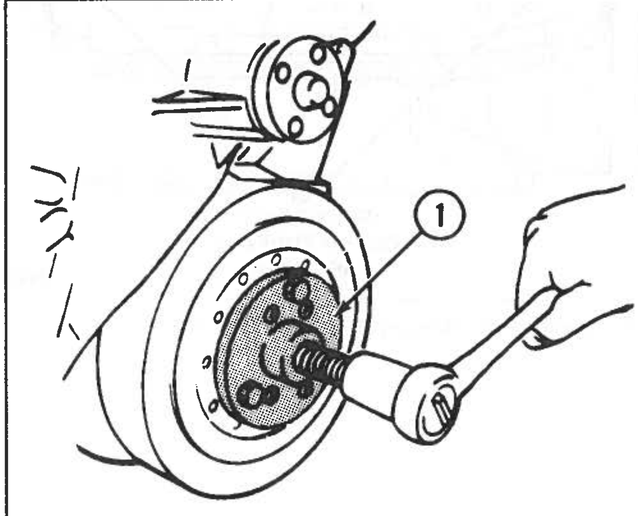
TORSIONAL DAMPER

Removal:

1. Remove drive belts.
2. Remove drive pulley, then remove damper-retaining bolt.

IMPORTANT: Do not use a Universal claw-type puller to remove torsional damper as outside ring of damper is bonded in rubber to the hub and the use of a claw-type puller may break the bond.

3. Remove damper with tool J-23523-E.



1. J-23523-E tool

Figure 8-224. *Removing Torsional Damper*

Installation:

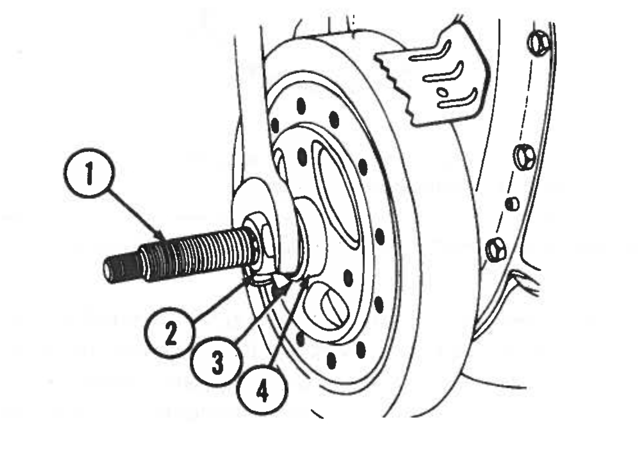
IMPORTANT: The inertia weight section of torsional damper is assembled to the hub with a rubber-type material. The installation procedure, with proper tool, must be followed or movement of the inertial weight on the hub will destroy the tuning of the torsional damper.

1. Coat front-cover-seal contact area (on damper) with engine oil.
2. Pull damper onto crankshaft, using tool J-23523-E as follows:
   a. Install appropriate end of threaded rod into crankshaft.

IMPORTANT: Be sure to install threaded rod in crankshaft so that at least 0.5 in. (13 mm) of thread engagement is obtained to prevent damage to threads.

b. Install plate, thrust bearing, washer and nut on rod.

c. Pull damper onto crankshaft by turning nut until it bottoms out.



1. Stud
2. Nut
3. Washer
4. Bearing

Figure 8-225. *Installing Torsional Damper*

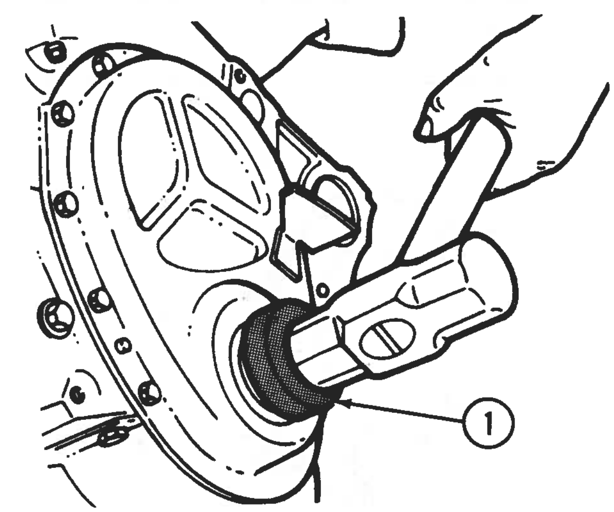
d. Remove tool from crankshaft, then install damper retaining bolt and torque to specifications.

3. Install drive pulleys.
4. Install drive belts.

CRANKCASE-FRONT COVER/OIL SEAL

Oil Seal Replacement (Without Removing Front Cover):

1. Remove torsional damper.
2. Pry seal out of cover from the front with a large screwdriver, being careful not to distort front cover or damage crankshaft seal surface.
3. Using tool J-22102, install new seal with open end of seal inward. Drive seal in until it just bottoms out. Do not use excessive force.
4. Reinstall torsional damper.



1. J-22102 tool

Figure 8-226. *Installing Oil Seal – With Cover Installed*

Crankcase-Front Cover Removal:

NOTE: The following instructions outline removal of the front cover without removing oil pan. If oil pan must be removed for other engine service, remove oil pan and disregard Steps 3, 4 and 5.

1. Remove torsional damper.
2. Remove water-circulating pump.
3. Remove two screws attaching oil pan to front cover.
4. Remove crankcase-front-cover-attaching screws and timing pointer, then pull cover slightly forward (only enough to permit cutting of oil-pan-front seal).
5. Using a sharp knife, cut oil-pan-front-cover seal flush with cylinder block on both sides of cover.

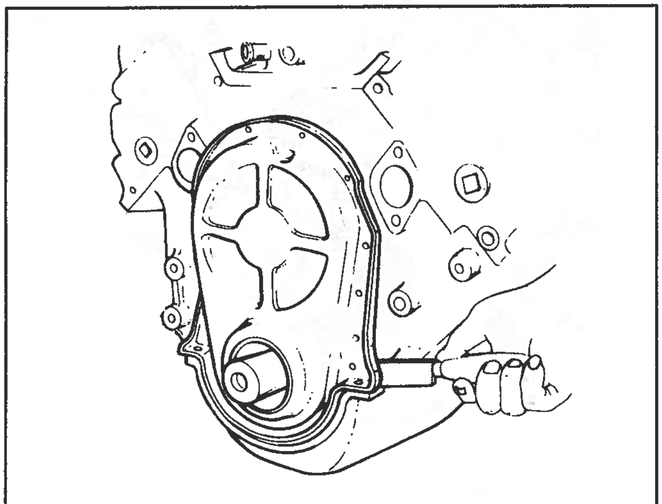
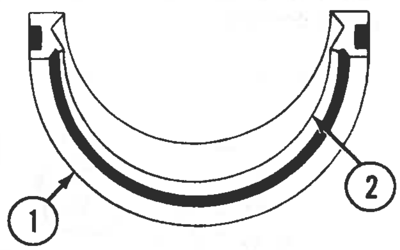


Figure 8-227. *Cutting Oil-Pan-Front Seal*

6. Remove front cover and attached portion of oil-pan-front seal. Remove and discard oil-pan-front seal and front cover gasket.
7. If damaged, drive oil seal out of front cover (from the rear) with a punch.

Crankcase-Front Cover Installation:

NOTE: Crankcase-front-cover oil seals for the 454/502 CID engine are birotational. The same seals can be used on both right-hand and left-hand-rotation engines.

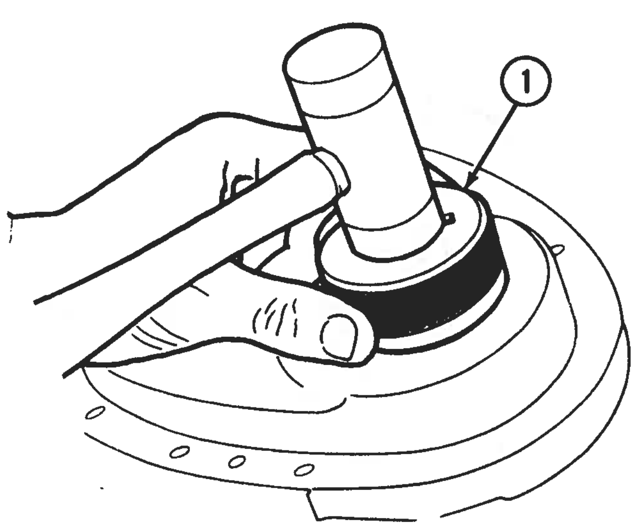


1. Can be used on any rotation engine
2. Seal lip toward inside of engine

Figure 8-228. *Front Seal Without Helical Grooves*

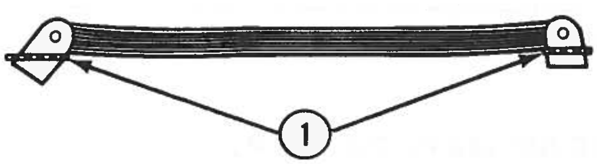
NOTE: The following instructions outline installation of front cover with oil pan installed. If oil pan has been removed for other engine service, disregard Steps 3, 4, 6, 8 and 10 and install oil pan after front cover has been installed.

1. Clean front cover in solvent and dry with compressed air. Clean old gasket material and sealer from mating surfaces on cover and cylinder block. Check gasket surface on front cover for distortion.
2. Using tool J-22102, install oil seal in cover with lip of seal toward inside of engine. Support cover around seal area with appropriate tool as shown.
3. Coat both sides of front-cover gasket with Perfect Seal and place in position on engine. Be sure to position gasket over dowel pins.
4. Cut tabs from the new oil-pan front seal.
5. Apply a 0.13-in. (3 mm) wide bead of RTV Sealer across entire length of seal surface on front cover. Install seal to front cover, pressing tips into holes provided in cover. After seal is installed, place a 0.13-in. (3 mm) wide bead of RTV Sealer across entire length of outer seal surface.



1. J-22102 tool
2. Support (to prevent distorting cover [hidden])

Figure 8-229. Installing Front-Cover-Oil Seal with Cover Removed

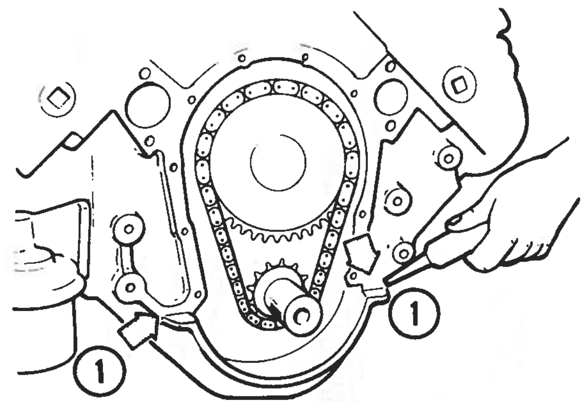


1. Cut this portion from new seal

Figure 8-230. Oil-Pan-Front-Seal Modification (Without Oil Pan Removed)

IMPORTANT: Use of RTV Sealer on outer surface of seal is essential on engines which have aluminum oil pans.

6. Apply a 0.13-in. (3 mm) bead of RTV Sealer to the joints formed where oil pan mates against cylinder block.
7. Position the crankcase-front cover over the crankshaft.
8. Press front cover downward against oil pan until holes in cover align with dowel pins on block and push cover over pins. Install and partially tighten the two oil-pan-to-front-cover-attaching screws to retain cover.



1. 0.13-in. (3 mm) wide bead of RTV sealer

Figure 8-231. RTV Sealer Application To Oil-Pan-To-Cylinder-Block Joints

9. Install front-cover-attaching screws and timing pointer (if removable). Torque screws to specifications.
10. Torque two oil-pan-to-front-cover-attaching screws (installed in Step 8) to specifications.
11. Install torsional damper.
12. Install water-circulating pump.
13. Start engine and check for water and oil leaks.

FLYWHEEL

Removal:

1. Remove transmission.
2. Remove flywheel housing and related parts if applicable.
3. Remove drive-damper-attaching screws and washers and remove drive damper, then remove flywheel-attaching screws and washers and remove flywheel.

Inspection:

1. Inspect drive damper for worn splines or broken springs.
2. Check the flywheel-ring gear for worn or missing teeth.

Installation:

1. Clean mating surfaces of flywheel and crankshaft.

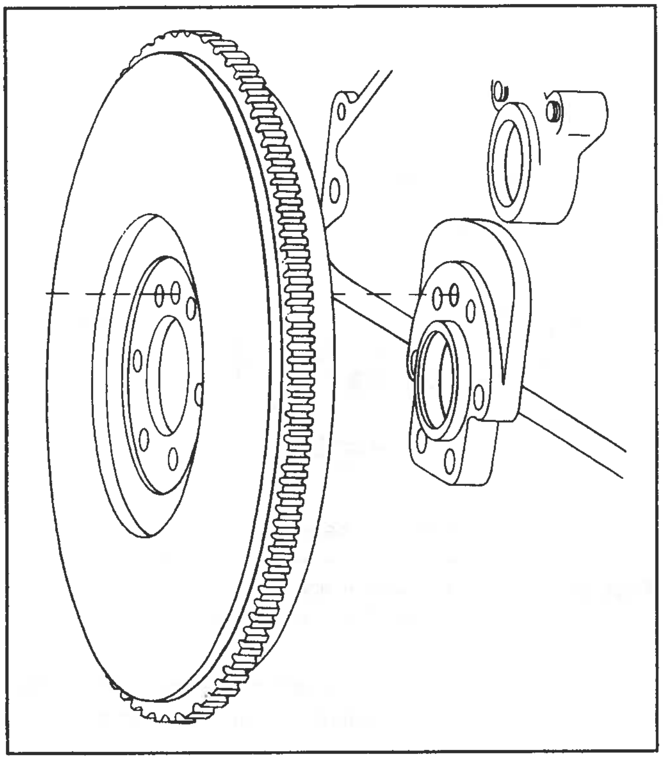
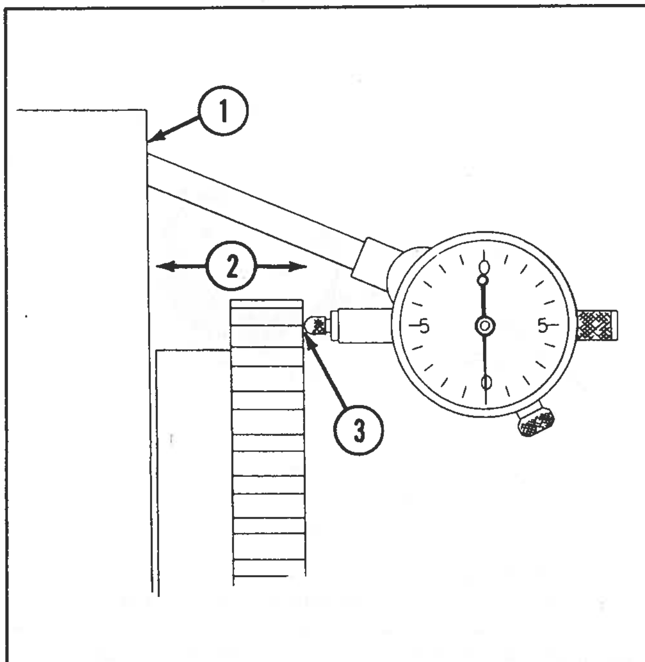


Figure 8-232. Flywheel Installation

2. Align dowel hole in flywheel with dowel or dowel hole in crankshaft flange and place flywheel in position on flange.
3. Secure flywheel with screws and lockwashers. Torque screws to specifications.
4. Install drive damper and torque to specifications.
5. Check flywheel run-out by mounting dial indicator on machined surface of flywheel.
6. Run-out should not exceed 0.008 in. (0.203 mm). If excessive, remove flywheel and check for burrs or replace flywheel.
7. Install flywheel housing and related parts. Torque flywheel-housing screws to specifications.
8. Torque flywheel-housing-cover screws to specifications.
9. Install transmission.



1. Rear of engine
2. Hold flywheel and crankshaft forward or rearward as far as possible when taking reading
3. 0.008 in. (0.203 mm) max. run-out

Figure 8-233. Checking Flywheel Run-Out

REAR MAIN OIL SEAL

Removal:

Both halves of the main bearing oil seal can be replaced without removing crankshaft.

IMPORTANT: Always replace both the upper and lower seal as a unit. Install with lip facing toward inside of engine.

1. Remove oil pan and oil pump.
2. Remove rear main bearing cap.
3. Remove lower half of oil seal from the bearing cap by prying from the bottom with a small screwdriver. Be careful not to damage seal-seating surface.

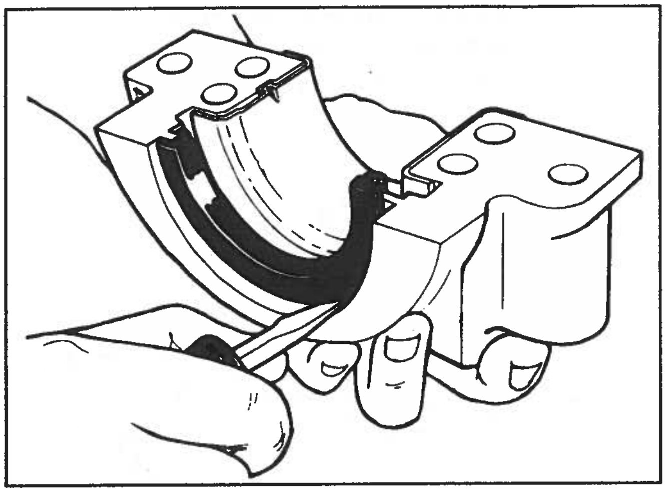
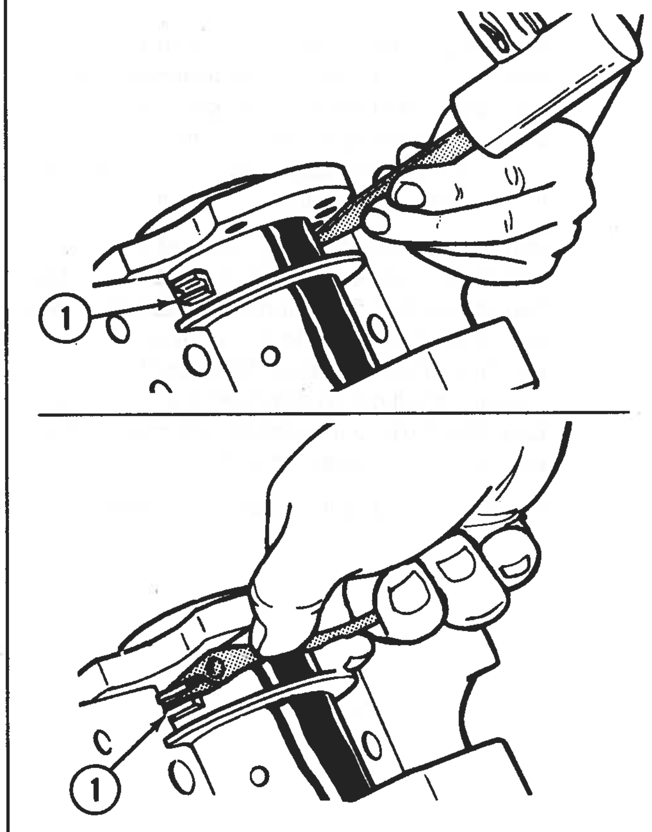


Figure 8-234. Removing Lower Half Of Oil Seal

4. Using a hammer and a soft, metal pin punch, tap upper half of oil seal on one end until it protrudes far enough on the other end to be removed with pliers.



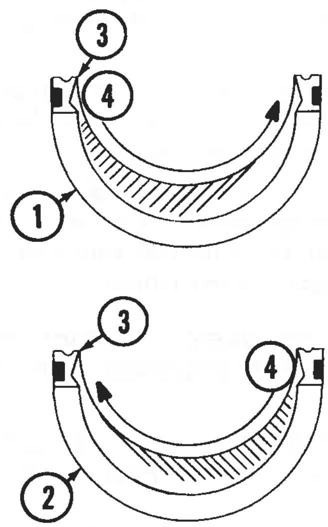
1. Oil seal upper half

Figure 8-235. Removing Upper Half Of Oil Seal

5. Clean rear main bearing cap, cylinder block and crankshaft with solvent and blow dry with compressed air. Be sure all of the old sealer is removed from bearing cap and cylinder-block-mating surfaces.

Installation:

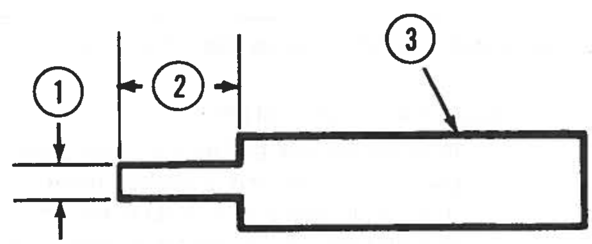
IMPORTANT: The correct-rotation-oil seal must be used to prevent an oil leak.



1. LH rotation engines
2. RH rotation engines
3. Seal lip toward inside of engine
4. Rotation of crankshaft as viewed from flywheel end looking forward

Figure 8-236. Rear Seals With Helical Grooves

Extreme care must be exercised when installing seal to prevent damage to sealing bead, located in the channel on outside diameter of the seal. To protect this bead, installation tool must be used. Construct tool using 0.004-in. (0.1 mm) shim stock if tool is not supplied with seal.



1. 11/64 in. (4 mm)
2. 0.5 in. (13 mm)
3. Tool made from 0.004-in. (0.10 mm) shim stock

Figure 8-237. Oil-Seal Installation Tool

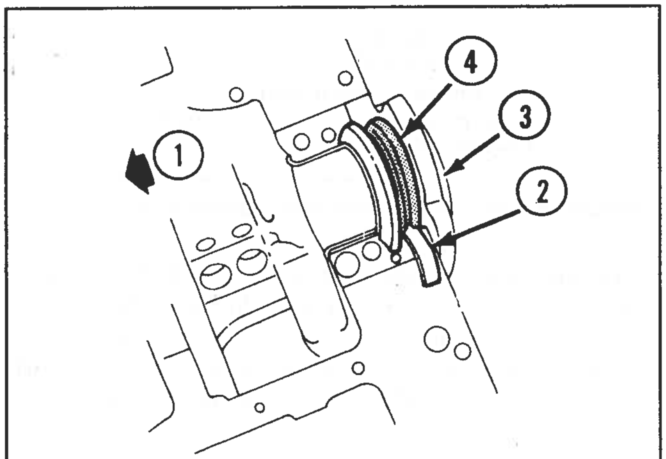
1. Coat lips and sealing bead on new rear oil seal with engine oil. Keep oil off seal-parting surfaces.

IMPORTANT: Be sure to install oil seal with lip facing toward inside of engine.

2. Install upper half of oil seal:
   a. Position tip of installation tool between crankshaft and seal-seating surface in cylinder block.
   b. Position upper half of seal between crankshaft and tip of installation tool so that seal bead contacts tip of tool.
   c. Roll upper half of seal around crankshaft using installation tool as a "shoehorn" to protect seal bead from sharp corner of seal-seating surface.

IMPORTANT: Installation tool must remain in position until seal is properly positioned, with both ends flush with block.

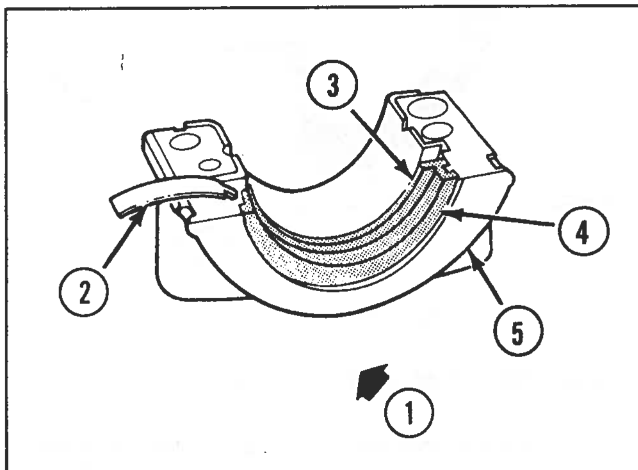
   d. After both ends of seal half are flush with block, remove installation tool.



1. Forward
2. Fabricated tool
3. Crankshaft
4. Upper seal half

Figure 8-238. *Installing Upper Half Of Oil Seal*

3. Install lower half of oil seal:
   a. Position oil-seal half in rear main bearing cap so that one end is slightly below mating surface and seal lip is facing toward bearing. Do not allow sealing bead on other end of seal half to contact seal-seating surface.
   b. Insert installation tool in between sealing bead and seal-seating surface. Then, using tool as a "shoehorn" to protect sealing bead from sharp corner of seal-seating surface, roll seal into place. Seal is properly positioned when both ends are flush with cap.
   c. Remove installation tool.



1. Forward
2. Fabricated tool
3. Oil-seal lip
4. Lower seal half
5. Main bearing cap

Figure 8-239. *Installing Lower Half Of Oil Seal*

4. Make sure that bearing cap, cylinder-block-mating surfaces, and oil-seal-parting surfaces are clean and free of oil. Apply Perfect Seal to block at locations shown. Do not get sealer on seal-parting surfaces or on surfaces adjacent to main bearing inserts.
5. Install rear main bearing cap and torque attaching bolts to 10-12 lb-ft (13.6-16.3 N•m). Tap crankshaft first rearward and then forward with a lead hammer to line up rear main bearing-thrust surfaces. With crankshaft in forward position, torque rear main bearing cap, attaching bolts evenly (alternating from side to side) to specifications.
6. Install oil pump and oil pan as outlined.

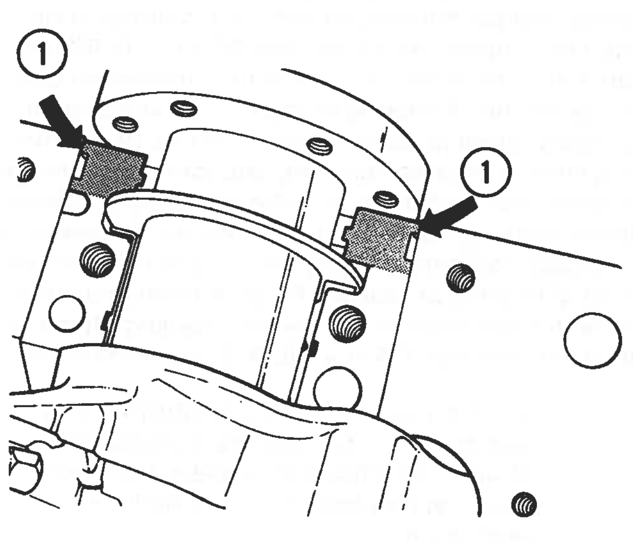


Figure 8-240. Applying Sealer To Block

MAIN BEARINGS

Main bearings are precision-insert-type and do not utilize shims for adjustment. If clearances are excessive, a new bearing (both upper and lower halves) will be required. Bearings are available in standard size and undersize. Selective fitting of both rod and main bearing inserts is necessary in production to obtain close tolerances. Consequently, one half of a standard insert may have one half of a 0.001-in. (0.025 mm) undersized insert which will decrease clearance 0.0005 in. (0.013 mm) from a full standard bearing.

When a production crankshaft cannot be precision-fitted by this method, it then is ground 0.009 in. (0.229 mm) undersize on main journals only. A 0.009-in. (0.229 mm) undersized bearing and 0.010-in. (0.25 mm) undersized bearing may be used for precision-fitting in the same manner as previously described. Any engine fitted with a 0.009-in. (0.25 mm) undersized crankshaft will be identified by the following markings:

- The numbers 0.009 will be stamped on crankshaft counterweight forward of center main journal.
- A figure 9 will be stamped on the block at left front oil-pan rail.
- A crankshaft with an undersized journal will be painted with light green on each side of the affected journal.

IMPORTANT: If the crankshaft has an undersized journal and a new bearing is required, the journal must be reconditioned to accept a 0.010-in. (0.25 mm) or a 0.020-in. (0.51 mm) undersized bearing, as 0.009-in. (0.229 mm) undersized bearings are not available for service.

Inspection:

In general (except No. 2 bearing), lower half of bearings show greater wear and more fatigue. After inspection, if lower half is suitable for use, it can be assumed that the upper half also is satisfactory. If lower half is worn or damaged, both upper and lower halves should be replaced. Never replace one half without replacing the other.

Checking Main Bearing Clearance:

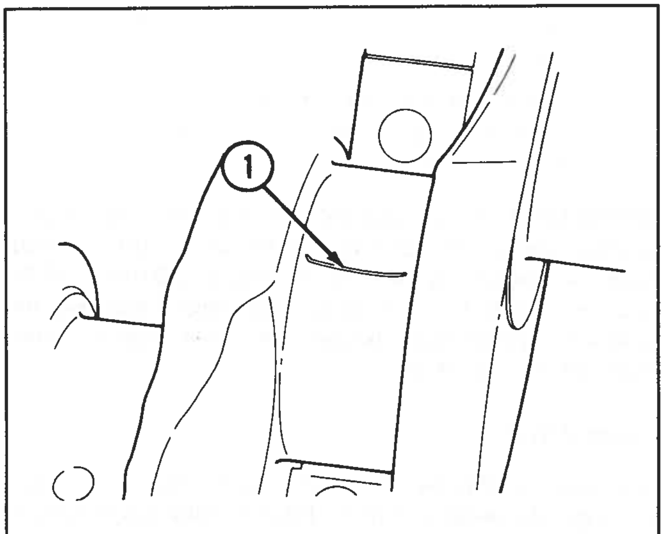
To obtain best results, use Plastigage (or its equivalent), a wax-like, plastic material which will compress evenly between bearing and journal surfaces without damaging either surface. With engine upside down, crankshaft will rest on upper bearings, and total clearance can be measured between lower bearing and journal.

IMPORTANT: To assure proper seating of crankshaft, all bearing cap bolts should be at their specified torque. In addition, surface of crankshaft journal and bearing should be wiped clean of oil before checking fit of bearings. Remove oil seal from rear main bearing cap prior to checking clearance.

1. With oil pan, baffle and oil pump removed (starting with rear main bearing), remove bearing cap and wipe oil from journal and bearing cap.
2. Place a piece of gauging plastic, full width of bearing (parallel to crankshaft), on journal.

IMPORTANT: Do not rotate crankshaft while gauging plastic is between bearing and journal.

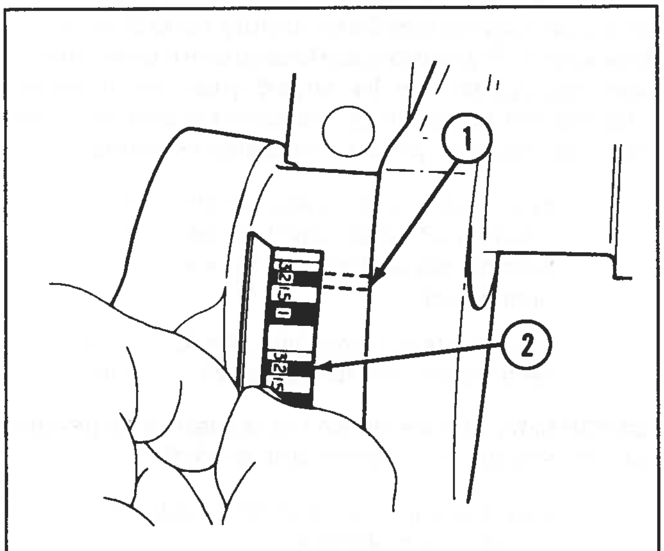
3. Install bearing cap and torque retaining bolts evenly to specifications.



1. Gauging plastic

Figure 8-241. Gauging Plastic on Journal

4. Remove bearing cap. Flattened gauging plastic will be found adhering to either bearing shell or journal.
5. Use a scale graduated in thousandths of an inch on edge of gauging-plastic envelope. Without removing gauging plastic, measure its compressed width (at widest point) with graduations on gauging-plastic envelope.



1. Gauging plastic
2. Chart from gauging plastic package

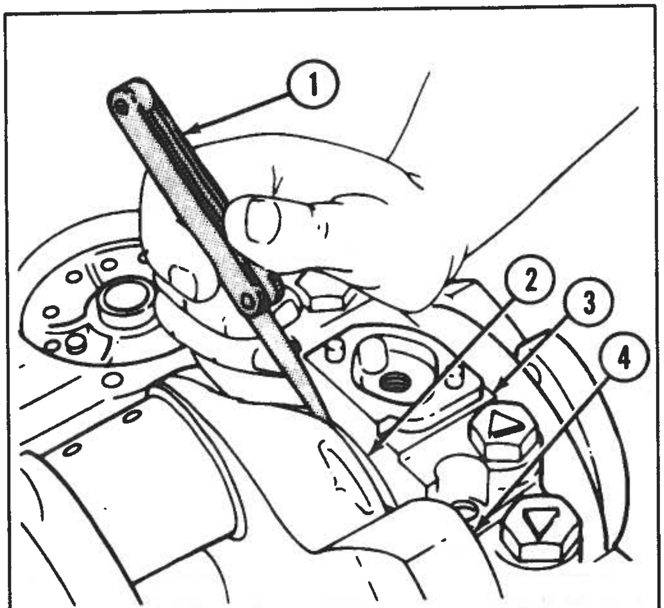
Figure 8-242. Measuring Gauging Plastic

IMPORTANT: Main bearing journals usually wear evenly and are not out-of-round. If a bearing is being fitted to an out-of-round journal (0.001 in. [0.025 mm] maximum), however, be sure to fit to maximum diameter of journal. If bearing is fitted to minimum diameter, and journal is out-of-round 0.001 in. (0.025 mm), interference between bearing and journal will result in rapid bearing failure. If flattened gauging plastic tapers toward middle or ends, there is a difference in clearance, indicating taper, low spot or other irregularity of bearing or journal. Be sure to measure journal with a micrometer if flattened gauging plastic indicates more than 0.001 in. (0.025 mm) difference.

6. If bearing clearance is within specifications, bearing insert is satisfactory. If clearance is not within specifications, replace the insert. Always replace both the upper and lower insert as a unit.

IMPORTANT: If a new bearing cap is being installed and clearance is less than 0.001 in. (0.025 mm), inspect for burrs or nicks.

7. A standard 0.001-in. (0.025 mm) or 0.002-in. (0.51 mm) undersized bearing may produce proper clearance. If not, regrind crankshaft journal for use with next undersized bearing.
8. Proceed to next bearing. After all bearings have been checked, rotate crankshaft to see that excessive drag does not exist.
9. Install front four main bearing caps and torque evenly to specifications.
10. Install rear main bearing cap and torque attaching bolts to 10-12 lb-ft (13.6-16.3 N•m). Tap end of crankshaft, first rearward and then forward, with a hammer to align rear main bearing thrust surfaces. With crankshaft in forward position, torque rear main bearing attaching bolts evenly (alternating from side to side) to specifications.
11. Measure crankshaft end play with a feeler gauge by forcing crankshaft forward and measuring clearance between the front of the rear main bearing and the crankshaft. If clearance is excessive, rear main bearing and/or crankshaft must be replaced.
12. Install a new rear main bearing oil seal in cylinder block and main bearing cap, as outlined.



1. Feeler gauge
2. Main bearing-thrust surface
3. Rear main bearing cap
4. Crankshaft

Figure 8-243. *Measuring Crankshaft End-Play*

Replacement:

NOTE: Main bearings may be replaced with or without removing crankshaft.

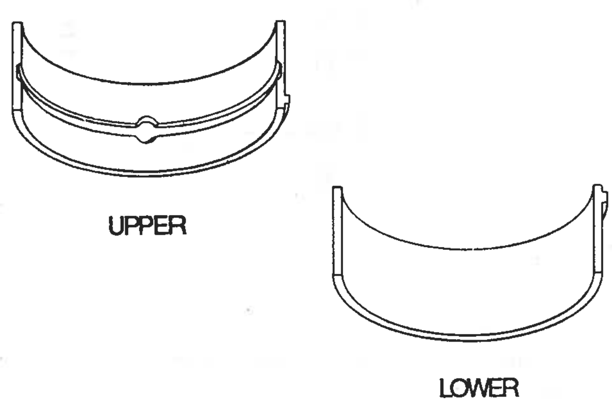


Figure 8-244. *Main Bearing Inserts*

With Crankshaft Removed

1. Remove and inspect crankshaft.
2. Remove main bearings from cylinder block and main bearing caps.
3. Coat bearing surfaces of new, correctly sized main bearings with oil and install in cylinder block and main bearing caps.
4. Install crankshaft.

Without Crankshaft Removed

1. With oil pan, baffle (some engines), oil pump and spark plugs removed, remove cap on main bearing requiring replacement and remove bearing from cap.
2. Replace main bearing upper half as follows:
   a. Install main bearing, removing and installing tool in crankshaft-journal-oil hole.

NOTE: If tool is not available, bend a cotter pin.

   b. Rotate crankshaft clockwise as viewed from front of engine. This will roll upper bearing out of block.
   c. Oil new (selected size) upper bearing and insert plain (unnotched) end between crankshaft and notched side of block. Rotate bearing into place and remove tool from oil hole in crankshaft journal.
3. Oil new lower bearing and install in bearing cap.
4. Install main bearing cap with arrows pointing toward front of engine.
5. Torque main bearing-cap bolts to specifications.

CONNECTING-ROD BEARINGS

Connecting-rod bearings are precision-insert-type and do not use shims for adjustment. Do not file rods or rod caps. If clearances are found to be excessive, a new bearing will be required. Bearings are available in standard size and undersize for new and used standard-size crankshafts and reconditioned crankshafts.

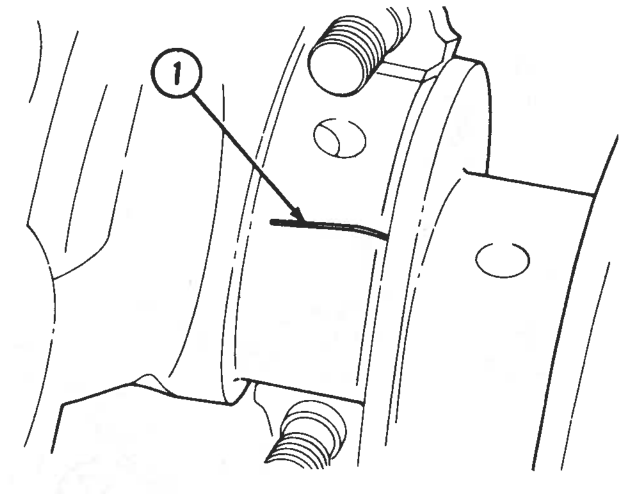
Inspection and Replacement of Bearings:

1. With oil pan and oil pump removed, remove connecting-rod cap and bearing.
2. Inspect bearing for wear or damage and replace unsatisfactory bearings.
3. Wipe bearings and crankpin clean of oil.
4. Measure crankpin for out-of-round or taper with a micrometer. If not within specifications, replace or recondition crankshaft. If within specifications, and a new bearing is to be installed, measure maximum diameter of crankpin to determine new bearing size required.
5. Measure new or used bearing clearances with Plastigage or its equivalent.

IMPORTANT: If a bearing is being fitted to an out-of-round crankpin, be sure to fit to maximum diameter of crankpin. If bearing is fitted to minimum diameter, and crankpin is out-of-round 0.001 in. (0.025 mm) or more, interference between bearing and crankpin will result in rapid bearing failure.

a. Install bearing in connecting rod and cap.
b. Place a piece of gauging plastic the full width of crankpin (parallel to crankshaft).
c. Install bearing cap and torque nuts evenly to specifications.

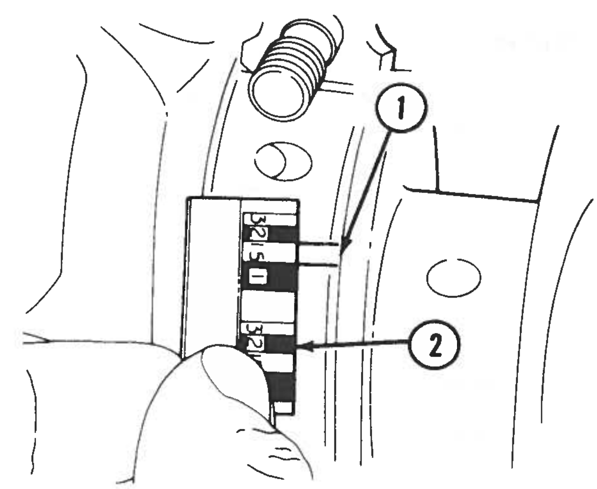
IMPORTANT: Do not turn crankshaft with gauging plastic installed.



1. Gauging plastic

Figure 8-245. *Gauging Plastic On Crankpin*

d. Remove bearing cap, and using scale on gauging-plastic envelope, measure gauging-plastic width at the widest point.

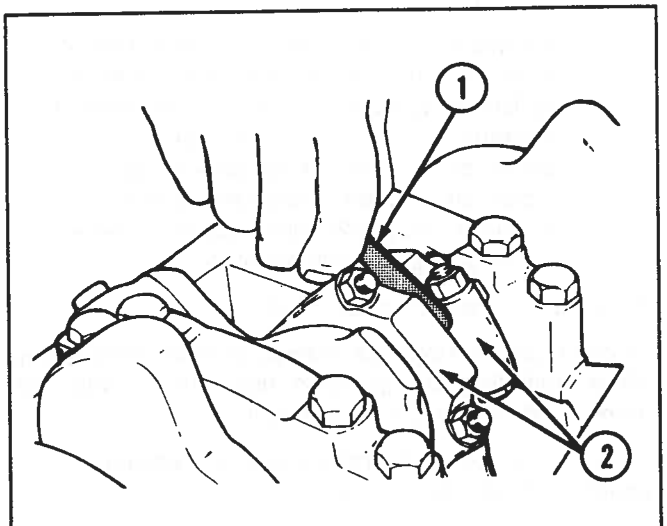


1. Gauging plastic
2. Chart from gauging-plastic package

Figure 8-246. *Measuring Gauging Plastic*

6. If clearance exceeds specifications, select a new, correctly sized bearing and recheck clearance.
7. Coat bearing surface with oil, install rod cap and torque nuts to specifications.
8. When all connecting-rod bearings have been installed, tap each rod lightly (parallel to crankpin) to make sure they have clearance.

9. Measure all connecting-rod-side clearances between connecting rod caps. (See "Specifications.")



1. Feeler gauge 2. Connecting rods

Figure 8-247. Measuring Connecting-Rod Side Clearance

PISTON ASSEMBLY

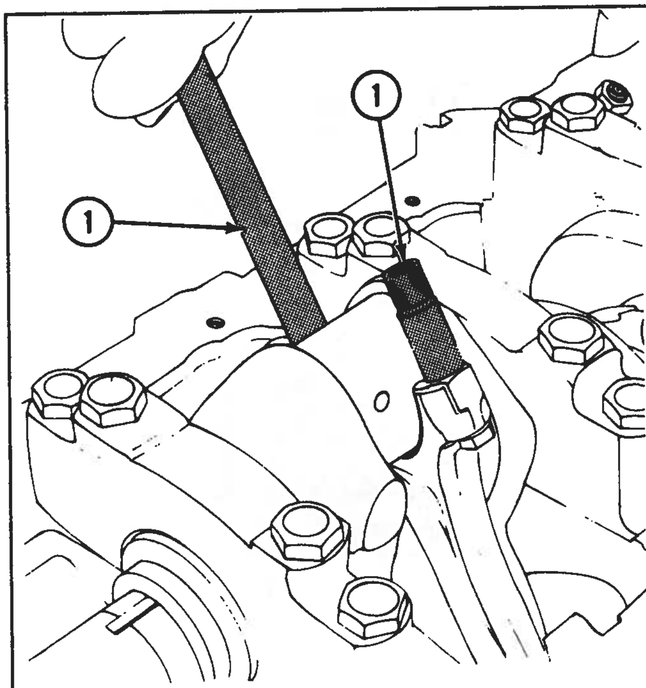
Removal:

1. With oil pan, baffle, oil pump and cylinder head removed, use a ridge reamer to remove any ridge and/or deposits from upper end of cylinder bore.

IMPORTANT: Before ridge and/or deposits are removed, turn crankshaft until piston is at bottom of stroke and place a cloth on top of piston to collect cuttings. After ridge and/or deposits are removed, turn crankshaft until piston is at top of stroke, then remove cloth and cuttings.

2. Mark connecting rod and bearing caps (left bank 1, 3, 5 and 7; right bank 2, 4, 6 and 8) from front to rear on same side as piston thrust.
3. Remove connecting-rod cap and install tool J-5239 on bolts. Push connecting rod and piston assembly out of top of cylinder block.

NOTE: It will be necessary to turn crankshaft slightly to disconnect and remove some connecting rod and piston assemblies.

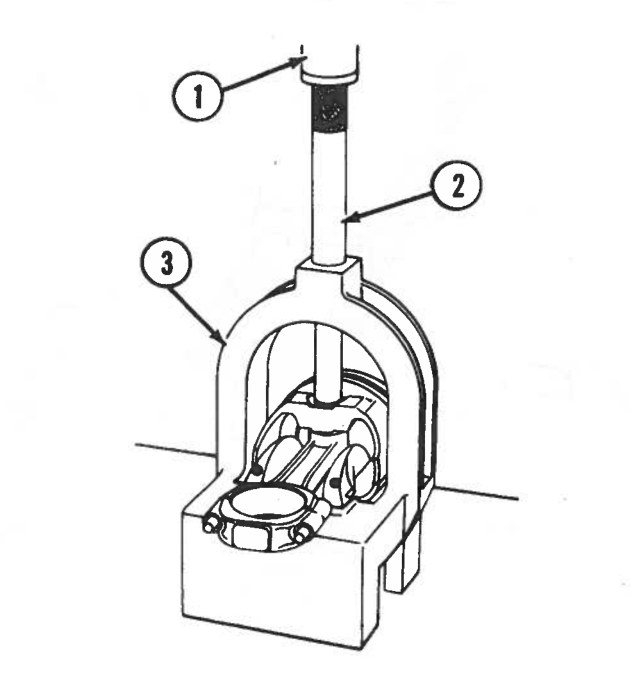


1. Tool J-5239

Figure 8-248. Removing Piston Assembly

Disassembly:

1. Use Tool Kit (J-24086-B).
2. Position connecting rod onto tool-rod support, with rod support inserted between connecting-rod end and piston. Align piston pin with hole located in top of arched base.
3. Insert pin remover through hole (located in top of arched base) and into piston-pin hole. Press on pin remover to remove piston pin.



1. Press ram
2. J-24086-8A tool
3. J-24086-20A tool

Figure 8-249. *Tool Kit J-24086-B Parts Identification*

Cleaning and Inspection:

To clean and inspect connecting rods:

1. Wash connecting rods in cleaning solvent and dry with compressed air.
2. Check for twisted or bent rods and inspect for nicks or cracks. Replace damaged connecting rods.

To clean and inspect pistons:

1. Clean varnish from piston skirts and pins with a cleaning solvent. Do not wire-brush any part of piston. Clean ring grooves with a groove cleaner and make sure oil-ring holes and slots are clean.
2. Inspect piston for cracked ring lands, skirts or pin bosses, wavy or worn ring lands, scuffed or damaged skirts, or eroded areas at top of piston. Replace pistons which are damaged or show signs of excessive wear.
3. Inspect grooves for nicks or burrs that might cause rings to hang up.
4. Measure piston skirt and check clearance as outlined under "Cylinder Block" in this subsection.

To clean and inspect piston pins:

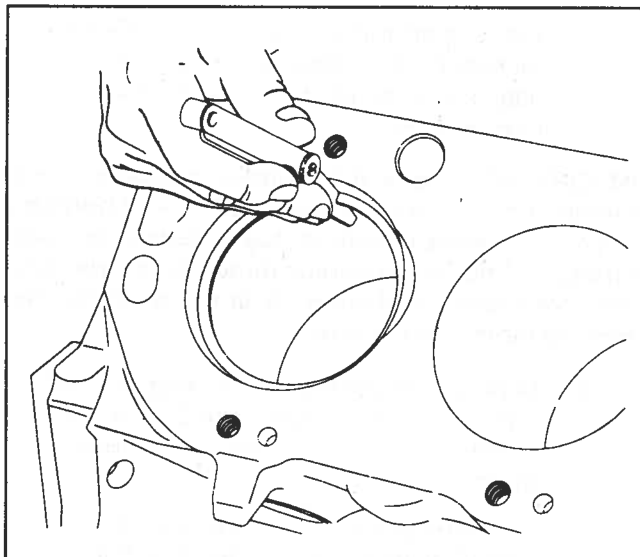
1. Piston-pin clearance is designed to maintain adequate clearance under all engine-operating conditions. Because of this, piston and piston pin are a matched set and not serviced separately.
2. Inspect piston-pin bores and piston pins for wear. Piston-pin bores and piston pins must be free of varnish or scuffing when measured. Measure piston pin with a micrometer and piston-pin bore with a dial-bore gauge or inside micrometer. If clearance is in excess of the 0.001-in. (0.025 mm) wear limit, replace piston and piston-pin assembly.

To clean and inspect piston rings:

All compression rings are marked on upper side of ring. When installing compression rings, make sure that marked side is toward top of piston.

Oil-control rings are a three-piece type, consisting of two segments (rails) and a spacer.

1. Select rings comparable in size to piston being used.
2. Slip compression ring in cylinder bore, then press ring down into cylinder bore about 0.25 in. (6 mm) below ring travel. Be sure that ring is square with cylinder wall.
3. Measure space or gap between ends of ring with a feeler gauge.

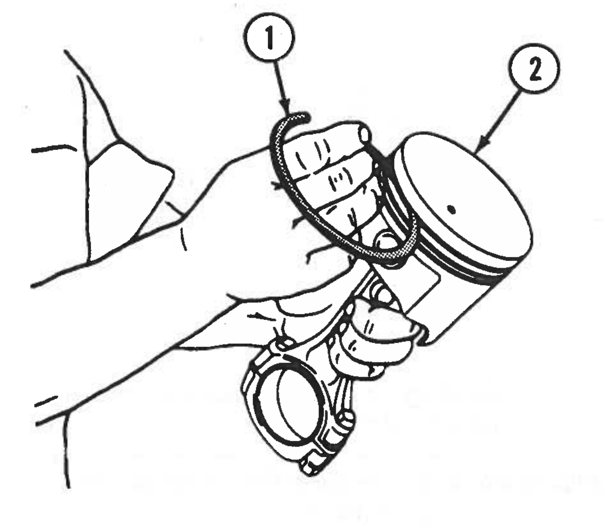


1. Feeler gauge
2. Piston ring

Figure 8-250. *Checking Ring Gap*

4. If gap between ends of ring is below specifications, remove ring and try another for fit.

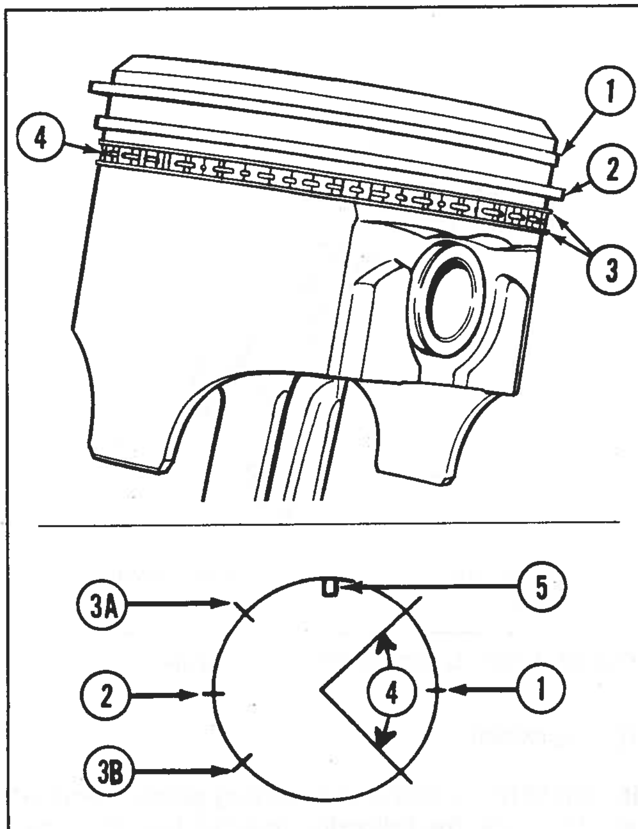
5. Fit each compression ring to cylinder in which it is going to be used.
6. Clean and inspect pistons if not previously done.
7. Slip outer surface of top and second compression ring into respective piston-ring groove and roll the ring entirely around the groove to make sure that ring is free. if binding occurs at any point, determine cause. If caused by ring groove, remove by dressing with a fine cut file. If binding is caused by a distorted ring, replace with a new ring.



1. Piston ring 2. Piston

Figure 8-251. Rolling Ring In Ring Groove

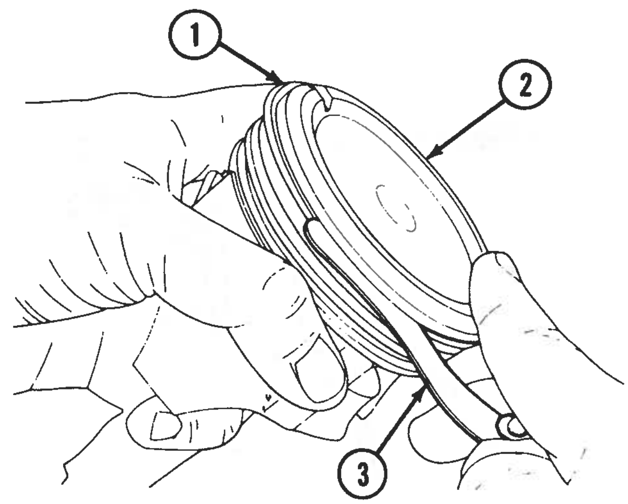
8. Install piston ring. Use piston-ring expanders for compression-ring installation.
   a. Install oil-ring spacer in groove and insert antirotation tang in oil hole.
   b. Hold spacer ends butted and install lower steel oil-ring rail with gap properly located.
   c. Install upper steel oil-ring rail with gap properly located.
   d. Flex each oil-ring assembly to make sure each ring is free. If binding occurs at any point, the cause should be determined and, if caused by ring groove, remove by dressing groove with a fine cut file. If binding is caused by a distorted ring, replace with a new ring.
   e. Install lower compression ring using ring expander, and check location of gap.
   f. Install top compression ring with gap properly located.



1. Top compression ring and gap location
2. Second compression ring and gap location
3. A and B oil-ring rails and gap location
4. Oil-ring spacer and ends location
5. Piston notch

Figure 8-252. Ring-Gap Location

9. Proper clearance of piston ring in its piston-ring groove is very important to provide proper ring action and reduce wear. Therefore, when fitting new rings, clearances between ring and groove surfaces should be measured. See "Specifications."



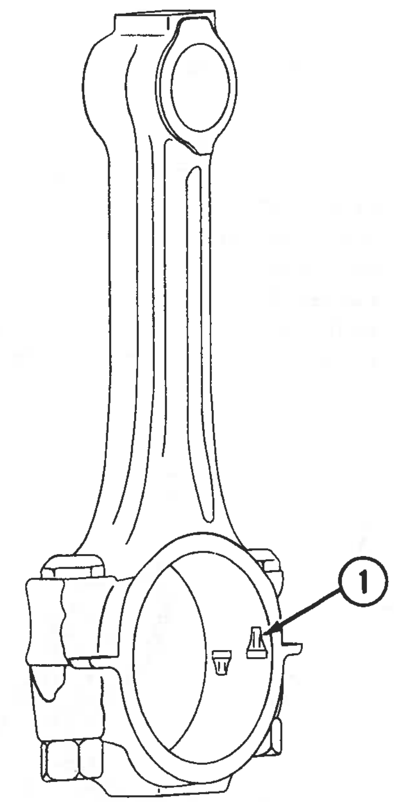
1. Piston ring
2. Piston
3. Feeler gauge

Figure 8-253. *Checking Groove Clearance*

Reassembly:

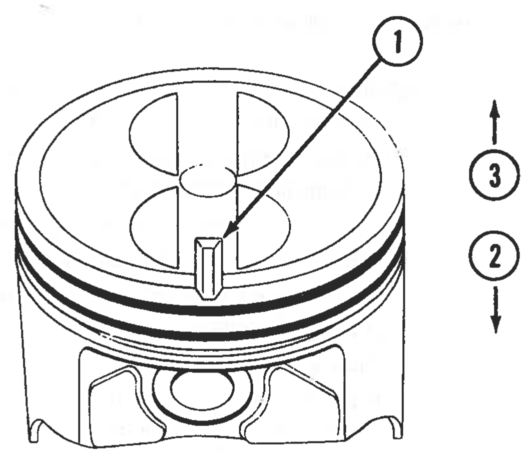
IMPORTANT: When reassembling pistons and connecting rods, the following must be kept in mind:

- Piston and pin are machine-fitted to each other and must remain together as a matched set. Do not intermix pistons and pins.
- If original pistons and/or connecting rods are being used, be sure to assemble pistons and connecting rods so they can be reinstalled in same cylinder from which they were removed.
- Connecting-rod-bearing tangs are always toward outside of cylinder block.
- Reference mark on piston must be positioned correctly for engine that is being repaired.
- To determine if engine is left-hand (standard) rotation or right-hand (opposite) rotation, inspect camshaft drive. If engine has a timing chain, engine is left-hand rotation. If engine has timing gears, engine has right-hand rotation.



1. Connecting-rod-bearing tangs must face toward outside of cylinder block

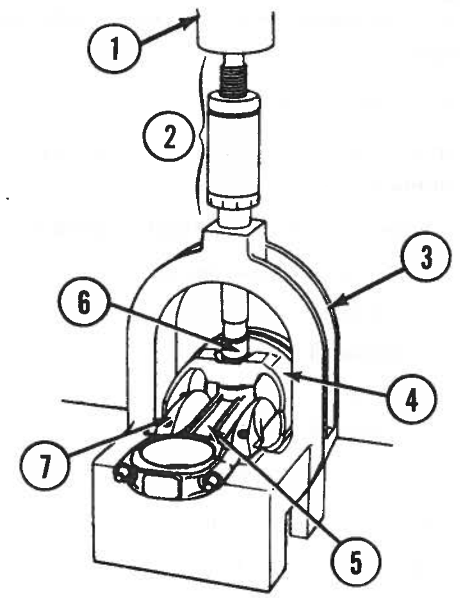
Figure 8-254. *Connecting-Rod-Bearing Tang Orientation*



1. Notch
2. Notch goes toward front of engine on LH rotation engines
3. Notch goes toward rear of engine on RH rotation engines

Figure 8-255. *Standard Piston Orientation*

1. Install piston pin with Tool Kit J-24086-B. Refer to chart furnished with tool, and select proper-size piston-pin guide for specific engine being worked on.
2. Lubricate piston pin, piston-pin hole in piston and hole in rod end with a light coat of engine oil.



1. Press ram
2. Adjustable installer tool J-24086-9
3. Support fixture J-24086-20
4. Piston
5. Connecting rod
6. Piston pin
7. Connecting-rod support

Figure 8-256. *Installing Piston Pin*

3. Position rod onto rod support and piston onto rod end. Insert piston-pin guide through bottom piston-pin hole and into connecting rod. Insert piston pin through top side of piston.
4. Set adjustable installer, as specified on chart which came with tool, for particular piston installation. Lock adjustable installer with jam nut.
5. Insert adjustable installer through hole located on top of arched base and into piston-pin hole. Carefully press on adjustable installer until installer bottoms out on arched base to install piston pin.
6. Check piston for freedom of movement in piston-pin bores by moving connecting rod back and forth, and up and down. Connecting rod should move freely (with no resistance) in both directions. If it does not, piston pin is tight in piston-pin bores, and piston and pin assembly must be replaced.
7. If a new connecting rod has been installed, mark connecting rod and cap on side of rod and cap with slots for connecting-rod bearing tangs with number of cylinder in which it will be installed.

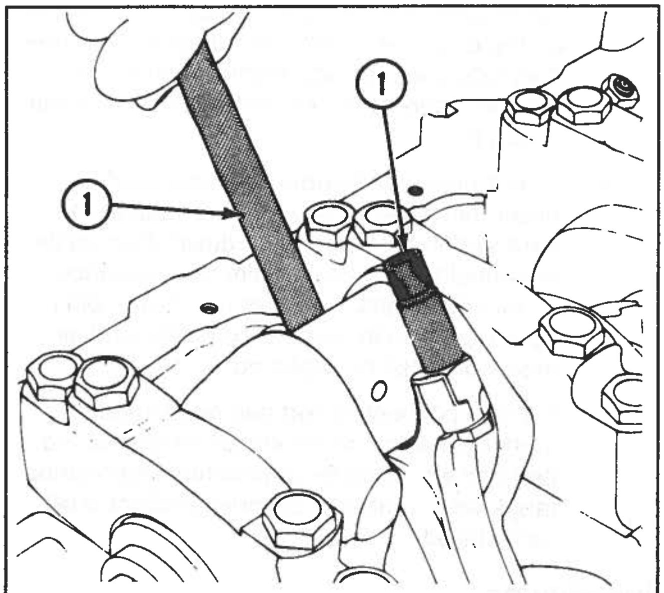
Installation:

IMPORTANT: Cylinder bores must be clean before piston installation. Clean with light honing as necessary. Then clean with hot water-and-detergent wash. After cleaning, swab bores several times with light engine oil and a clean cloth, then wipe with a clean dry cloth.

1. Lubricate connecting-rod bearings and install in rods and rod caps.
2. Lightly coat pistons, rings and cylinder walls with light engine oil.
3. With bearing caps removed, install tool J-5239 (3/8 in.) on connecting rod bolts.

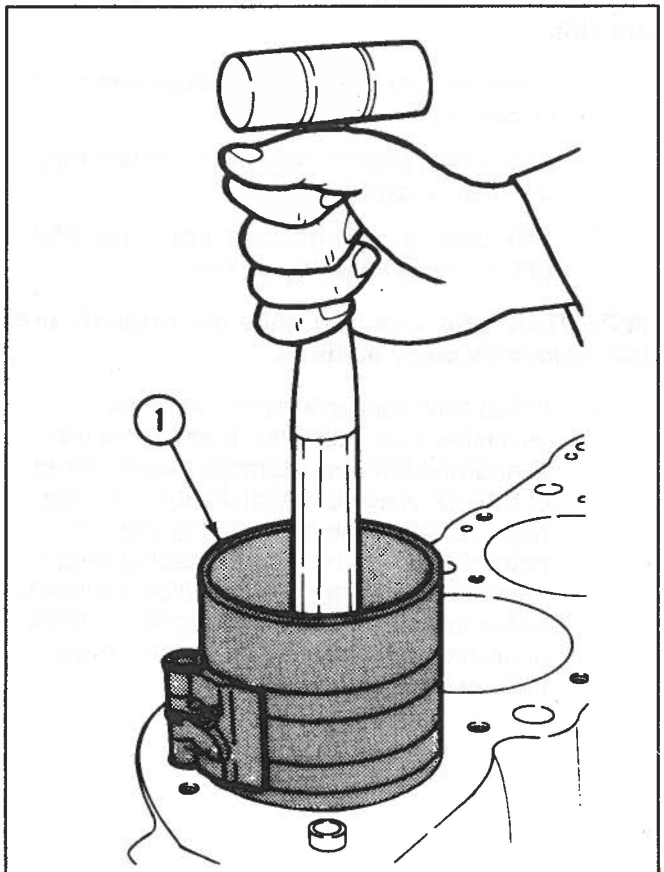
IMPORTANT: Be sure ring gaps are properly positioned as previously outlined.

4. Install each connecting rod and piston assembly in its respective bore. Install with connecting-rod-bearing tangs toward outside of cylinder block. Use tool J-8307 to compress rings. Guide connecting rod into place on crankshaft journal with tool J-5239. Using a hammer handle, tap with light blows to install piston into bore. Hold ring compressor firmly against cylinder block until all piston rings have entered cylinder bore.



1. J-5239 tool

Figure 8-257. *Pulling Piston And Connecting Rod Into Place*



1. Piston-ring compressor

Figure 8-258. *Tapping Piston Into Cylinder*

IMPORTANT: Be sure to install new pistons in the same cylinders for which they were fitted, used, and from which they were removed. Each connecting rod and bearing cap should be marked, beginning at front of engine (1, 3, 5 and 7 in left bank and 2, 4, 6 and 8 in right bank). Numbers on connecting rod and bearing cap must be on the same side when installed in cylinder bore. If a connecting rod is ever transposed from one block or cylinder to another, new bearings should be fitted and the connecting rod should be numbered to correspond with new cylinder number.

5. Remove tool J-5239.
6. Install bearing caps and torque nuts to specification.
7. Check connecting-rod-side clearance.
8. Install the following items:
   a. Oil pump.
   b. Baffle (if equipped).
   c. Oil pan.
   d. Cylinder head.
9. Install engine in boat.
10. Fill crankcase with oil.
11. Start engine, adjust timing and check for leaks.

CRANKSHAFT

Removal:

1. Remove engine from boat.
2. Drain coolant and crankcase oil. Disconnect all hoses.
3. Remove transmission, starter motor, flywheel housing and flywheel. Place engine in repair stand.
4. Remove belts, crankshaft pulley and water pump.
5. Remove torsional damper and crankcase front cover.
6. Remove spark plugs.
7. Remove camshaft gear and timing chain (LH-rotation engines only).
8. Remove oil pan and oil pump.
9. Make sure all bearing caps (main and connecting rods) are marked so they can be installed in their original locations.
10. Remove connecting-rod-bearing caps, then push piston and rod assemblies toward heads.

11. Remove main bearing caps and carefully lift crankshaft out of cylinder block. Remove rear main bearing-oil seal from cylinder block and rear main bearing cap.
12. If new main and/or connecting-rod bearings are to be installed, remove main bearing inserts from cylinder block and bearing caps, and/or connecting-rod-bearing inserts from connecting rod and caps. Install new bearings as outlined below.

Cleaning and Inspection:

1. Wash crankshaft in solvent and dry with compressed air.
2. Measure main bearing journals and crankpin dimensions with a micrometer for out-of-round, taper or undersize (see "Specifications").
3. Check crankshaft for run-out (by supporting at front and rear main bearings journals in V-blocks) and check at front and rear intermediate journals with a dial indicator (see "Specifications").
4. Replace or recondition crankshaft if not meeting specifications.

Installation:

1. If a new crankshaft is being installed, remove timing gear from old crankshaft and reinstall on new crankshaft.

IMPORTANT: Be sure that all bearings and crankshaft journals are clean.

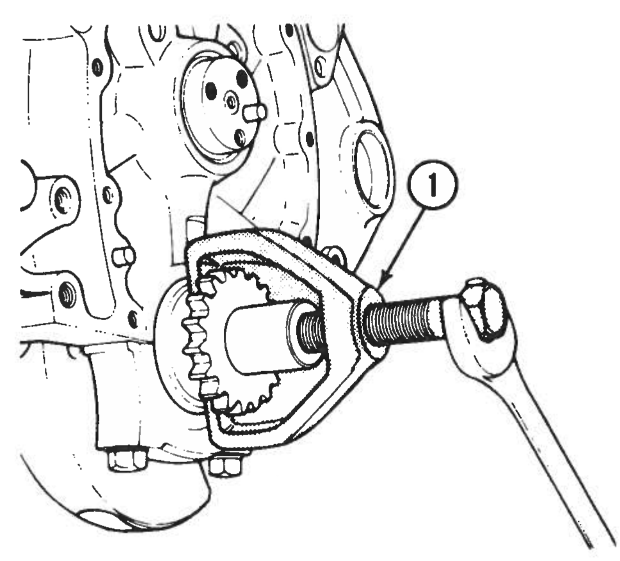
2. Install a new rear main bearing oil seal in cylinder block and rear main bearing cap.
3. Carefully lower crankshaft into place. Be careful not to damage bearing surface.
4. Check clearance of each main bearing, following procedure outlined under "Main Bearings." If bearing clearances are satisfactory, apply a light coat of engine oil to journals and bearings.
5. Install all bearing caps and bolts. Torque all main bearing cap bolts to specifications. When tightening rear main bearing cap, follow procedure outlined under "Main Bearings."
6. Check clearance for each connecting-rod bearing, following procedure under "Connecting Rod Bearings." If bearing clearances are satisfactory, apply a light coat of engine oil to journals and bearings.
7. Install all rod caps and torque nuts to specifications.
8. Check crankshaft end-play. Follow procedure outlined under "Main Bearings."
9. Install oil pump and pan as outlined.
10. Install camshaft gear and timing chain (LH-rotation engines only).
11. Install crankcase-front cover and torsional damper.
12. Remove engine from repair stand and install water pump, flywheel, flywheel housing, transmission and starter motor.
13. Install crankshaft pulley and belts.
14. Install spark plugs.
15. Install engine in boat, fill crankcase and install hoses.

TIMING CHAIN AND/OR GEARS:

NOTE: Timing chain is used on left-hand-rotation engines and timing gears on right-hand-rotation engines.

Camshaft Gear Removal:

1. Remove torsional damper and crankcase front cover as outlined.
2. Remove camshaft-timing chain as outlined.
3. Using tool J-1619 (or J-24420-B for LH-engine rotations), remove crankshaft gear.



1. J-1619 tool

Figure 8-259. Removing Crankshaft-Timing Gear

Camshaft Gear Installation:

1. Using tool J-22102, install gear.
2. Install camshaft-timing chain as outlined.
3. Install crankcase-front cover and torsional damper as outlined.

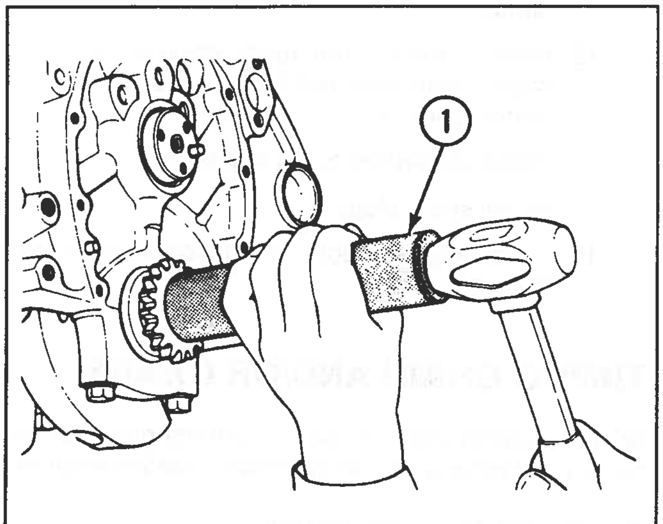


Figure 8-260. *Installing Crankshaft-Timing Gear*

CAMSHAFT GEAR AND TIMING CHAIN REMOVAL (LH-ROTATION ENGINES)

1. Remove torsional damper and crankcase front cover as outlined.
2. Crank engine until marks on camshaft and crankshaft gears are in alignment.

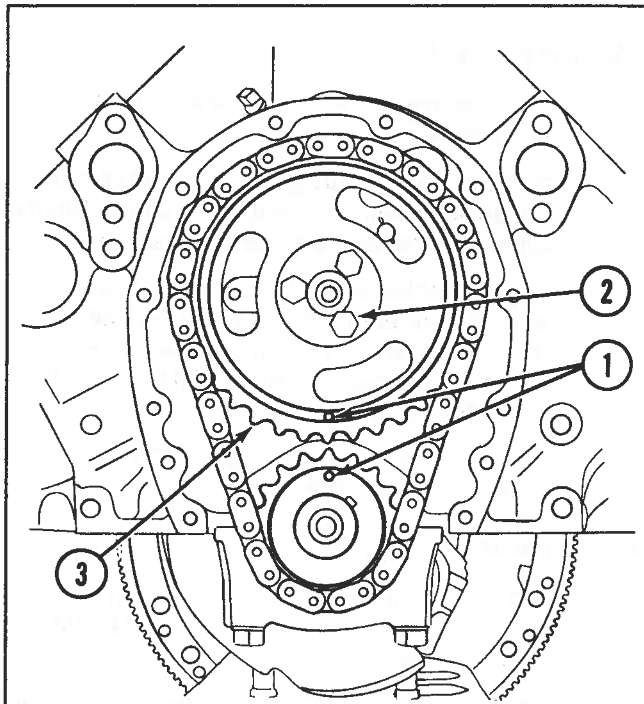


Figure 8-261. *Timing-Gear Alignment Marks*

3. Remove camshaft gear to camshaft bolts.
4. Remove camshaft gear and timing chain together. Gear is lightly press-fitted onto the camshaft. If gear does not come off easily, a light blow on its lower edge (with a plastic mallet) should dislodge it.
5. If crankshaft gear has to be replaced, remove as outlined in "Crankshaft Gear."

Cleaning and Inspection:

1. Clean all parts in solvent and dry with compressed air.
2. Inspect timing chain for wear or damage.
3. Inspect gears for wear or damage.

Installation:

1. If crankshaft gear was removed, install as outlined in "Crankshaft Gear."
2. Install timing chain on camshaft gear. Hold gear vertical with chain hanging down and orientate to align marks on camshaft and crankshaft gears.

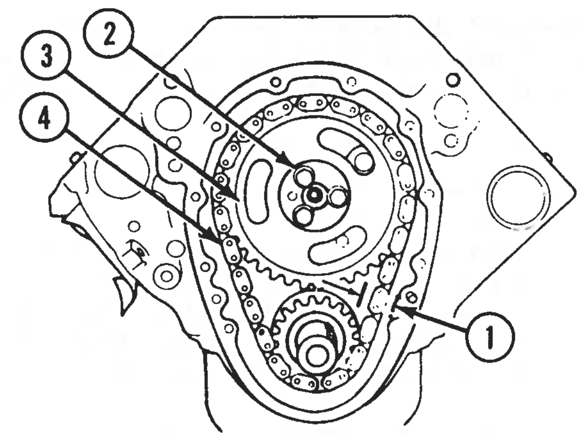
IMPORTANT: Do not attempt to drive gear on camshaft as welsh plug at rear of engine may be dislodged.

3. Draw camshaft gear onto camshaft using the three mounting bolts. Torque to specifications.
4. Lubricate timing chain with engine oil. Install crankcase-front cover and torsional damper as outlined.

Checking Timing-Chain Deflection:

With timing chain and gears installed, check timing-chain deflection as follows:

1. Rotate camshaft (in either direction) to place tension on one side of the chain.
2. Establish a reference point on the block (on taut side of chain) and measure from this point to the chain.
3. Rotate camshaft in the opposite direction to slacken the chain, then force chain out with fingers and again measure the distance between reference point and timing chain.
4. The deflection is the difference between these two measurements. If the deflection exceeds specifications, timing chain should be replaced.



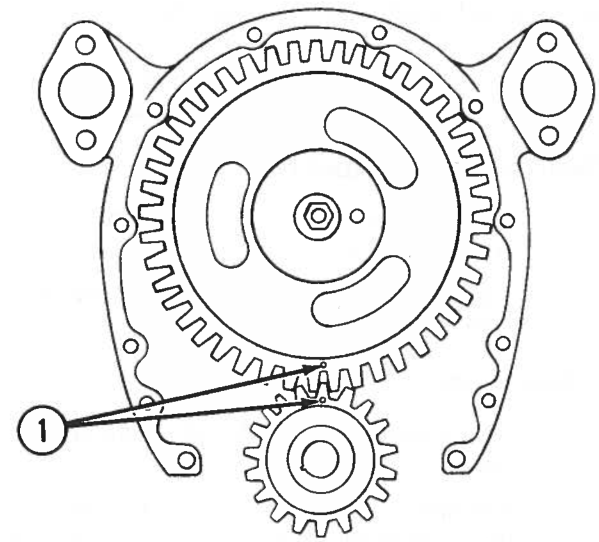
1. 5/8 in. (16 mm) max.
2. Bolt
3. Camshaft gear
4. Timing chain

***Figure 8-262.** Checking Timing-Chain Deflection*

TIMING GEAR (RH-ROTATION ENGINES)

Removal:

1. Remove crankcase front cover.
2. Crank engine over until mark on camshaft timing gear aligns with timing mark on crankshaft-timing gear.



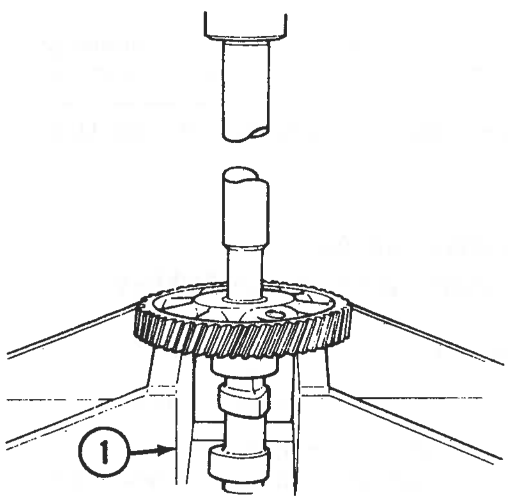
1. Timing marks

***Figure 8-263.** Timing Marks Aligned – RH-Rotation Engines*

3. Remove camshaft-thrust-plate-attaching screws through holes in timing gear.

IMPORTANT: Use extreme care when removing camshaft (in next step) to prevent damaging camshaft bearings. All camshaft journals are the same size.

4. Remove camshaft and gear as an assembly.
5. If either camshaft, timing gear or thrust plate requires replacement, press gear off camshaft using an arbor press and appropriate tools as shown. Be sure to use a support under gear to prevent pressing on thrust plate. If camshaft is to be replaced, remove and discard woodruff key from camshaft and remove spacer ring.



1. Support (must clear thrust plate)

Figure 8-264. *Removing Camshaft Gear*

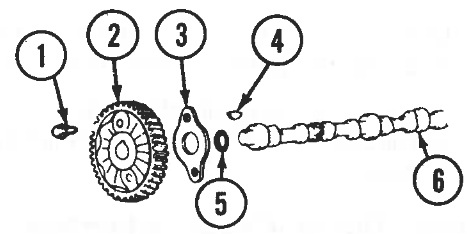
6. If crankshaft-timing gear requires replacement, remove as outlined in "Crankshaft Gear."

Cleaning and Inspection:

1. Clean all parts in solvent and dry with compressed air.
2. Inspect timing gears for worn or damaged teeth.

Installation:

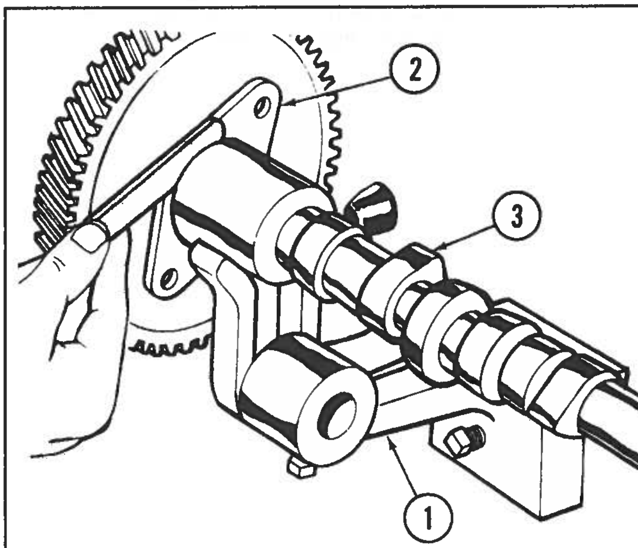
1. If removed, install crankshaft-timing gear as outlined in "Crankshaft Gear."
2. If removed, install spacer ring, woodruff key, thrust plate and timing gear on camshaft, as follows:
   a. Check mating surface on camshaft and timing gear to ensure that they are clean and free of burrs.
   b. Install spacer on camshaft with chamfered side toward camshaft.
   c. Install new woodruff key.
   d. Place thrust plate on end of camshaft with grooved side outward.
   e. Firmly support camshaft at back of front journal in an arbor press and press timing gear onto camshaft with timing mark outward.



1. Screw
2. Camshaft gear
3. Thrust plate
4. Key
5. Spacer
6. Camshaft

Figure 8-265. *Installing Camshaft-Timing Gear And Related Parts*

   f. Check camshaft front journal to thrust plate clearance (end play) with feeler gauge. If clearance is not as specified, make sure gear is pressed on all the way. Also check thrust plate and camshaft for excessive wear and replace as required.



1. Holding fixture
2. Thrust plate
3. Camshaft

Figure 8-266. *Checking Thrust-Plate-To-Camshaft Front Journal End-Play*

3. Lubricate camshaft journals with engine oil and install camshaft, being sure to align timing marks.
4. Install thrust-plate-attaching screws and torque to specifications.
5. Check timing-gear backlash and run-out as explained under "Checking Backlash and Run-out."
6. Lubricate timing gears with engine oil.
7. Install crankcase front cover and torsional damper, as explained.
8. Install hydraulic valve lifters, push rods, rocker arms and rocker-arm covers as previously explained.

Checking Backlash and Run-out:

1. Remove fuel pump and fuel-pump push rod.
2. Loosen rocker-arm nuts to relieve tension on hydraulic valve lifters.
3. With timing gears installed, check camshaft-to-crankshaft-gear backlash, as follows:
   a. Mount a dial indicator on engine so that stem contacts one of the teeth on camshaft gear. Indicator stem should be as perpendicular to gear-tooth surface as possible.
   b. Check the backlash between the camshaft gear and crankshaft gear while applying inward pressure on camshaft gear.
   c. If backlash is not within specifications, check for improperly machined parts or for worn camshaft or crankshaft bearings. If bearings are within specifications, replace both timing gears.
4. With timing gear installed, check camshaft and crankshaft-timing-gear run-out, as follows:
   a. Mount dial indicator on block so that indicator stem is perpendicular to camshaft-timing gear and contacts gear surface just adjacent to teeth.
   b. Apply outward pressure on timing gear and zero indicator, then turn crankshaft. Check gear run-out through one complete revolution of camshaft gear.
   c. If not within specifications, check for burrs or foreign material between gear and camshaft-joining surfaces. If none is found, replace both timing gears.
   d. Check crankshaft-timing gear run-out in same manner. Run-out should not exceed specifications. Replace both gears if run-out is excessive.
5. Adjust rocker-arm nuts.
6. Install fuel-pump-push rod and fuel pump.

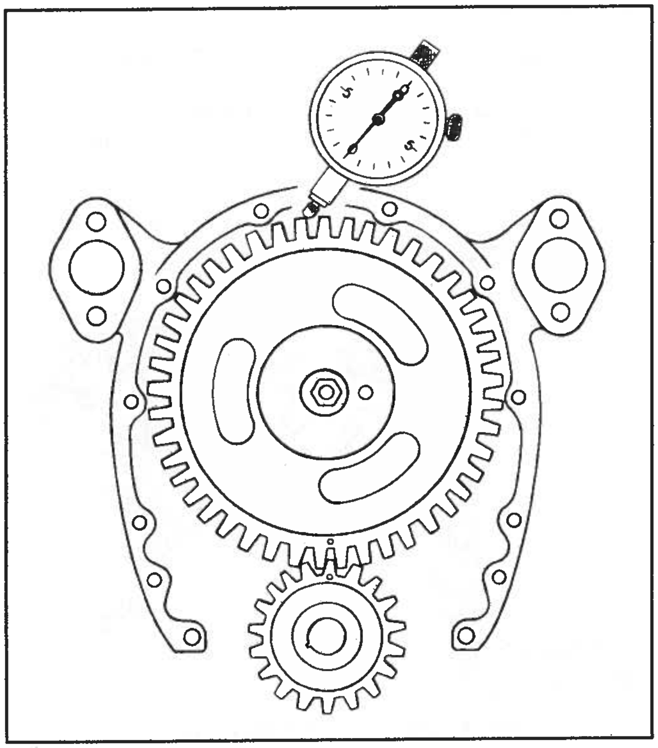
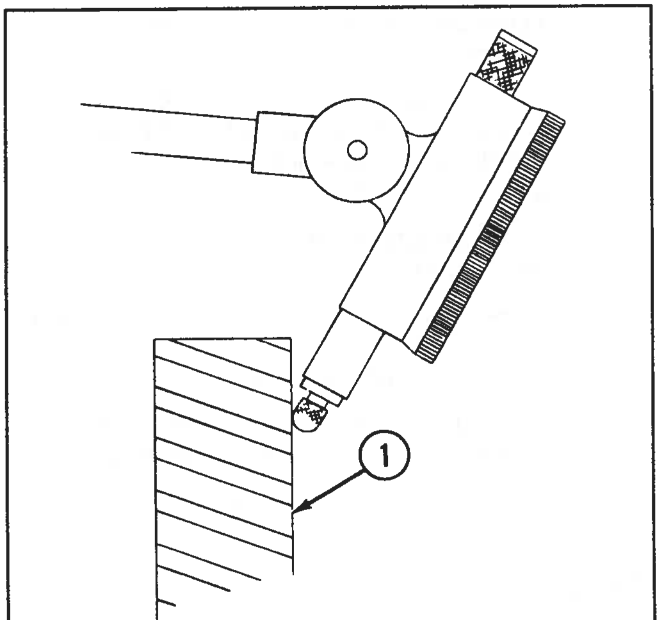


Figure 8-267. *Checking Timing-Gear Backlash*



1. Camshaft gear

Figure 8-268. *Checking Timing-Gear Run-out*

CAMSHAFT

Measuring Lobe Lift:

NOTE: Procedure is similar to checking valve timing. If improper valve operation is indicated, measure lift of each push rod in consecutive order and record readings.

1. Remove valve mechanism as outlined above.
2. Position indicator with ball-socket adapter tool J-8520-1 on push rod. Be sure that push rod is in lifter socket.

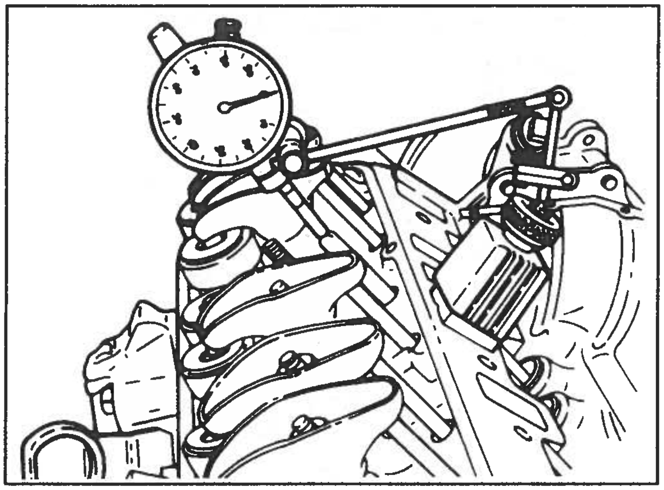


Figure 8-269. *Measuring Camshaft-Lobe Lift*

3. Rotate crankshaft damper slowly in direction of rotation until lifter is on heel of cam lobe. At this point, push rod will be in its lowest position.
4. Set dial indicator on zero, then rotate balancer slowly (or attach an auxiliary starter switch and "bump" engine over) until push rod is in fully raised position.
5. Compare total lift, recorded from dial indicator, with "Specifications."
6. Continue to rotate engine until indicator reads zero. This will be a check on accuracy of original indicator reading.
7. If camshaft readings for all lobes are within specifications, remove dial indicator assembly.
8. Install and adjust valve mechanism as outlined.

Removal:

1. Remove valve lifters as outlined.
2. Remove crankcase-front cover as outlined.
3. Remove fuel pump and fuel-pump-push rod.
4. Remove camshaft as follows:

   LH-Rotation Engines

   a. Refer to "Timing Chain and/or Gears" to remove chain and gear.

   b. Install two 5/16-18 bolts in camshaft-gear-bolt holes and carefully remove camshaft.

   RH-Rotation Engines:

   a. Remove camshaft-thrust-plate-attaching screws through holes in timing gear.

   b. Carefully remove camshaft and timing gear as an assembly.

   c. Remove timing gear as outlined in "Timing Chain and/or Gears."

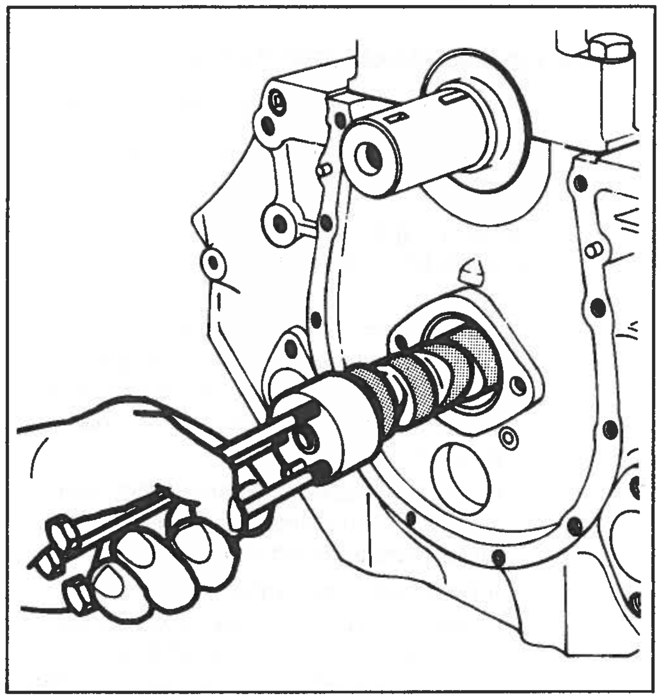


Figure 8-270. *Removing Camshaft*

Inspection:

1. Measure camshaft-bearing journals with a micrometer for out-of-round condition. If journals exceed 0.001 in. (0.025 mm) out-of-round, camshaft should be replaced.
2. Check camshaft for alignment with V-blocks and dial indicator which indicates exact amount camshaft is out-of-true. If out more than 0.002 in. (0.051 mm) dial indicator reading, camshaft should be replaced.
3. On engines with timing gears, inspect camshaft gear and thrust plate for wear or damage.

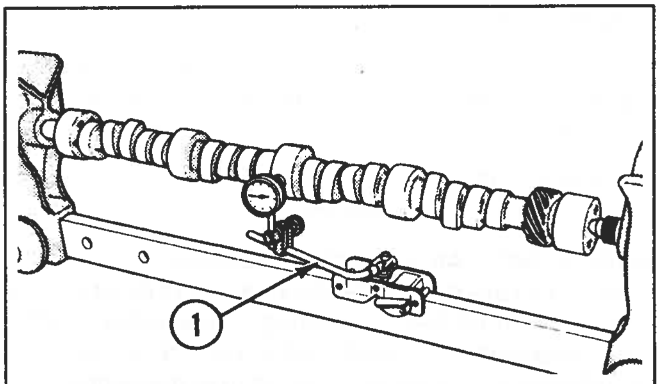


Figure 8-271. *Checking Camshaft Alignment*

Installation:

1. Install camshaft as follows:

   LH-Rotation Engines

   a. Install two 5/16-18 bolts in the camshaft bolt holes, then lubricate camshaft journals with engine oil and install camshaft, being careful not to damage bearings. Remove the two 5/16-18 bolts.
   b. Install timing chain and gear as outlined in "Timing Gears."

   RH-Rotation Engines

   a. Press timing gear onto camshaft as outlined "Timing Chain and/or Gears."
   b. Lubricate camshaft journals with engine oil and install camshaft and timing gear, being careful not to damage bearings.
2. Lubricate camshaft-drive system with engine oil.
3. Install fuel-pump-push rod and fuel pump.
4. Install crankcase-front cover and valve lifters as outlined.

CAMSHAFT BEARINGS

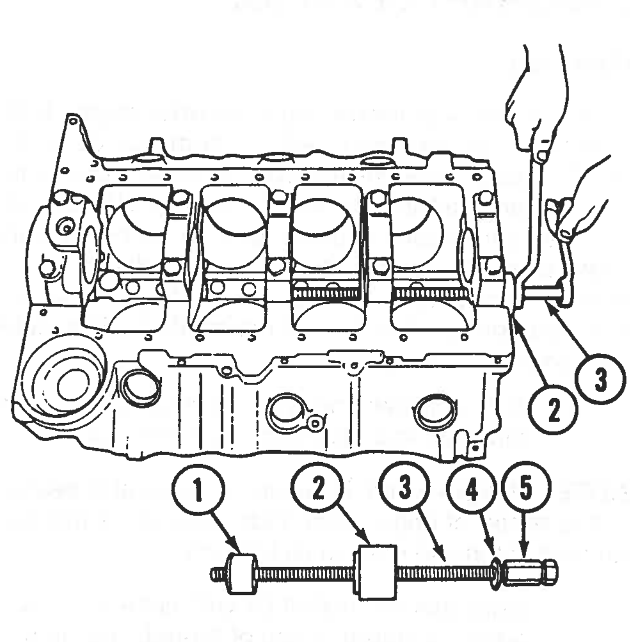
Removal:

Camshaft bearings can be replaced while engine is disassembled for overhaul or without complete disassembly. To replace bearings without complete disassembly, remove camshaft and crankshaft, leaving cylinder heads attached and pistons in place. Before removing crankshaft, tape threads of connecting-rod bolts to prevent damage to crankshaft. Fasten connecting rods against sides of engine so that they will not interfere while replacing camshaft bearings.

1. With camshaft and crankshaft removed, drive camshaft rear plug from cylinder block.

NOTE: This procedure is based on removal of bearings in the center of engine first, thus requiring a minimum amount of turns to remove all bearings.

2. Using tool set J-6098-01 with nut and thrust-washer installed to end of threads, position pilot in front camshaft bearing and install puller screw through pilot.
3. Install tool with shoulder toward bearing. Be sure a sufficient amount of threads is engaged.
4. Using two wrenches, hold puller screw while turning nut. When bearing has been pulled from bore, remove tool and bearing from puller screw.
5. Remove remaining bearings (except front and rear) in same manner. It will be necessary to position pilot in rear camshaft bearing to remove rear intermediate bearing.
6. Assemble remover tool on driver handle and remove front and rear camshaft bearings by driving toward center of cylinder block.



1. Puller disk
2. Pilot bushing
3. Puller screw
4. Washer
5. Puller nut

Figure 8-272. Replacing Center Camshaft Bearings

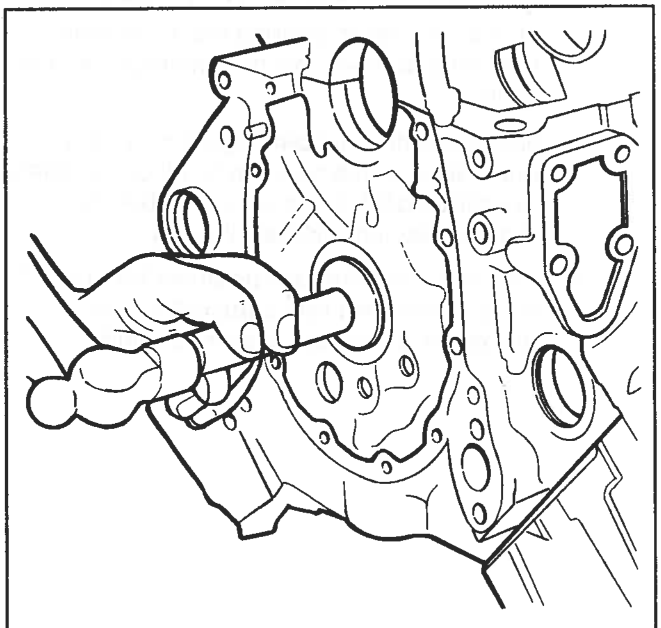


Figure 8-273. Replacing Front And Rear Camshaft Bearings

Inspection:

Clean camshaft bearing bores in cylinder block with solvent and blow out with compressed air. Be sure grooves and drilled oil passages are clean.

Installation:

Front and rear bearings should be installed first, to act as a guide to center pilot when installing center and intermediate bearings.

Lubricate outer surface of new camshaft bearings with engine oil to ease installation.

IMPORTANT: All camshaft bearings are not the same. Be sure to install each bearing in its proper location as indicated by bearing manufacturer. Position bearings as follows (directional references are in reference to engine in its normal operating position): front, intermediate and center camshaft bearings must be installed so that the oil hole in each aligns with the oil hole in block; rear bearing bore is grooved and bearing oil hole must be positioned at or near the 6-o'clock position.

1. Installing intermediate and center bearings:
   a. Install nut and thrustwasher all the way onto puller screw, then position pilot in front camshaft bearing bore and insert screw through pilot.
   b. Index center camshaft bearing, then position appropriate-size remover and installer tool in bearing and thread puller screw into tool. Be sure at least 0.5 in. (13 mm) of threads is engaged.
   c. Using two wrenches, hold puller screw and turn nut until bearing has been pulled into position. Remove the remover and installer tool and check to ensure that oil holes in bearings are positioned correctly.
   d. Install intermediate bearings in the same manner, being sure to index bearings correctly. It will be necessary to position pilot in rear camshaft bearing bore to install rear intermediate bearing.
2. Install front and rear bearings:
   a. Install appropriately sized remover and installer tool on drive handle.
   b. Align oil hole as explained above and drive it into position with tool. Check position of oil holes in bearings to ensure bearing is positioned correctly.
   c. Install rear bearing in same manner, being sure to index bearing correctly.
3. Install a new camshaft rear plug.

IMPORTANT: Plug must be installed flush to 0.03 in. (0.8 mm) deep and must be parallel with rear surface of block.

4. Install crankshaft and camshaft as outlined.

CYLINDER BLOCK

Cleaning and Inspection:

1. Remove all engine components as previously outlined.
2. Wash cylinder block thoroughly in cleaning solvent and clean all gasket surfaces.
3. Remove oil gallery plugs and clean oil passages.

NOTE: These plugs may be removed with a sharp punch or they may be drilled and pried out.

4. Clean and inspect water passages in cylinder block.
5. Inspect cylinder block for cracks in cylinder walls, water-jacket-valve-lifter bores and main bearing webs.
6. Measure cylinder walls for taper, out-of-round or excessive ridge at top of ring travel. This should be done with a dial indicator or inside micrometer. Carefully work gauge up and down cylinder to determine taper and turn it to different points around cylinder wall to determine out-of-round condition. If the cylinders exceed specifications, boring and/or honing will be necessary.

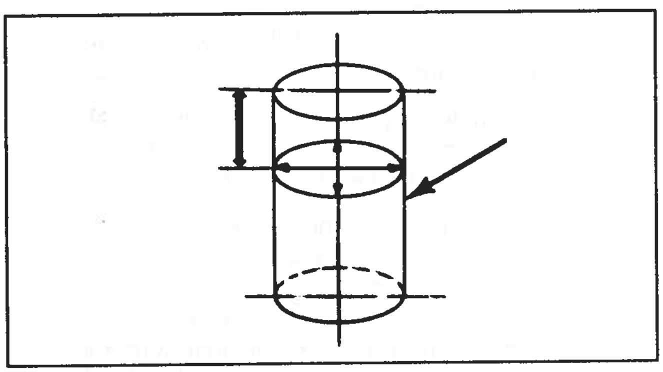


Figure 8-274. *Measuring Points For Cylinder Bore Out-Of-Round*

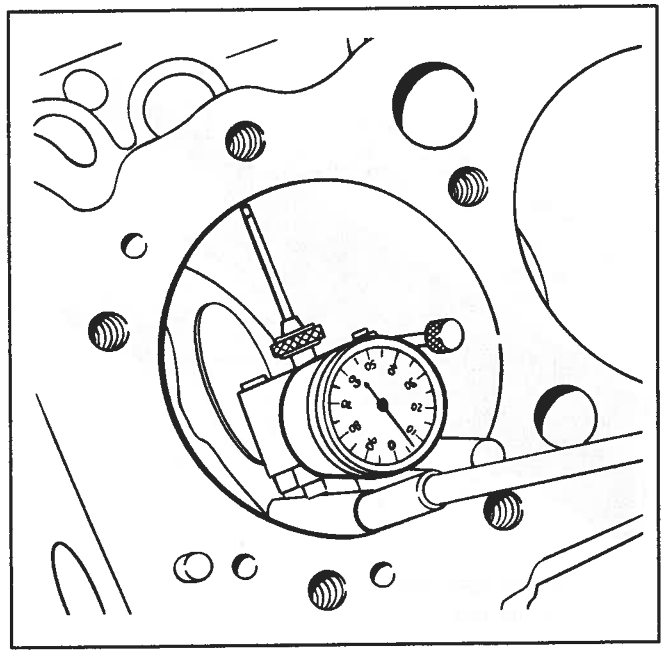


Figure 8-275. *Using Dial Indicator To Check For Cylinder Taper And Out-Of-Round*

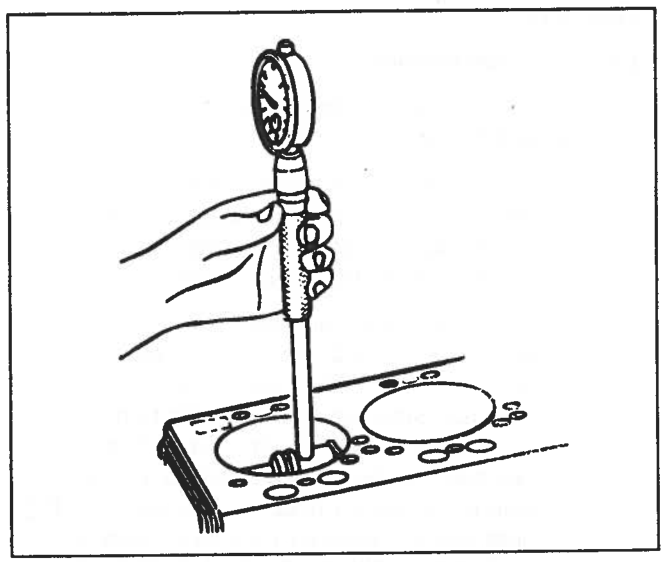
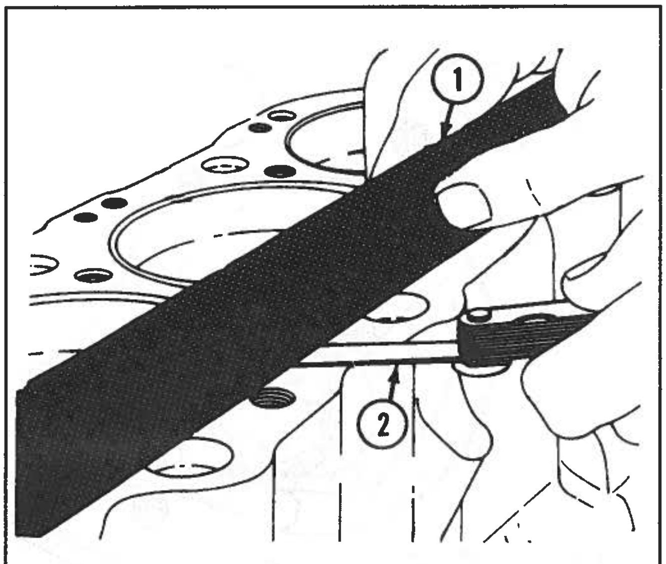


Figure 8-276. *Using Telescoping Gauge To Check For Cylinder Taper And Out-Of-Round*

7. Check cylinder-head-gasket surfaces for warping with a machinist's straightedge and a feeler gauge, as shown. Take measurements diagonally across surfaces (both ways) and straight down center. If surfaces are out-of-flat more than 0.003 in. (0.07 mm) in a 6.00-in. (152 mm) area or 0.007 in. (0.18 mm) overall, block must be resurfaced by an automotive machine shop.



1. Machinist's straightedge
2. Feeler gauge

Figure 8-277. *Checking Cylinder-Block-Gasket Surfaces For Warping*

Repairs:

Cylinder Conditioning

Performance of the following operation depends upon engine condition at time of repair:

1. If cylinder-block inspection indicates that block is suitable for continued use (except for out-of-round or tapered cylinders), it can be conditioned by honing or boring.
2. If cylinders have less than 0.005 in. (0.127 mm) taper or wear, they can be conditioned with a hone and fitted with a high-limit, standard-size piston. A cylinder bore of more than 0.005 in. (0.127 mm) wear or taper may not clean up entirely when fitted to a high-limit piston. To entirely clean up the bore, it will be necessary to rebore for an oversized piston. If more than 0.005 in. (0.127 mm) taper or wear, bore and hone to smallest oversize that will permit complete resurfacing of all cylinders.
3. When pistons are being fitted and honing is not necessary, cylinder bores may be cleaned with a hot water and detergent wash. After cleaning, swab cylinder bores several times with light engine oil and a clean cloth, then wipe with a clean, dry cloth.

Cylinder Boring

1. Carefully observe instructions furnished by manufacturer of equipment being used.
2. Before using any type boring bar, file off top of cylinder block to remove dirt or burrs. This is very important to prevent boring-bar tilt, with result that rebored cylinder wall is not at right angles to crankshaft.
3. Measure piston to be fitted with a micrometer, measuring at center of piston skirt and at right angles to piston pin. Bore cylinder to same diameter as piston and hone to give specified clearance. (See "Cylinder Honing" and "Piston Selection" following.)

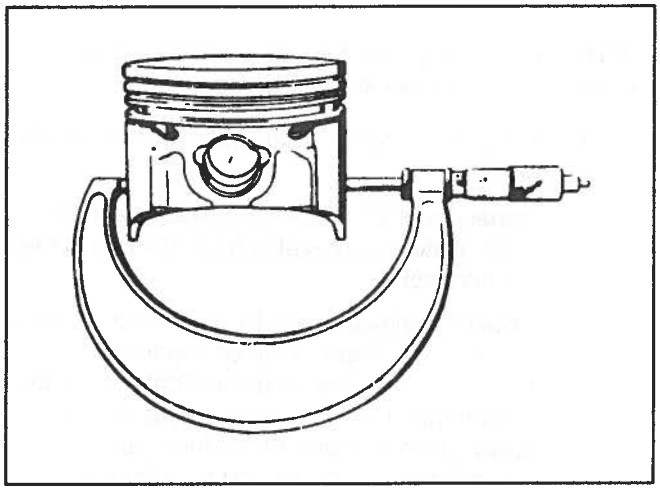


Figure 8-278. *Measuring Piston*

Cylinder Honing

1. Follow hone manufacturer's recommendations for use of hone, and cleaning and lubrication during honing.
2. Occasionally during the honing operation, thoroughly clean cylinder bore and check piston for correct fit in cylinder.
3. When finish-honing a cylinder bore to fit a piston, move hone up and down at a sufficient speed to obtain very fine uniform surface finish marks in a crosshatch pattern of approximately 300 to cylinder bore. Finish marks should be clean but not sharp, free from imbedded particles and torn or folded metal.
4. Permanently mark piston for cylinder to which it has been fitted, and proceed to hone cylinders and fit remaining pistons.

IMPORTANT: Handle pistons with care and do not attempt to force them through cylinder until cylinder is honed to correct size as this type of piston can be distorted by careless handling.

5. Thoroughly clean cylinder bores with hot water and detergent. Scrub well with a stiff-bristle brush and rinse thoroughly with hot water. It is essential that a good cleaning operation be performed. If any abrasive material remains in

cylinder bores, it will rapidly wear new rings and cylinder bores in addition to bearings lubricated by the contaminated oil. Swab bores several times with light engine oil on a clean cloth, then wipe with a clean dry cloth. Cylinder should not be cleaned with kerosene or gasoline. Clean remainder of cylinder block to remove excess material spread during honing operation.

Piston Selection

1. Check **used** piston-to-bore clearance as follows:
   a. Measure cylinder bore diameter with a telescope gauge 2.5 in. (64 mm) from top of cylinder bore.
   b. Measure piston diameter at skirt across centerline of piston pin.
   c. Subtract piston diameter from cylinder-bore diameter to determine piston-to-bore clearance.
   d. Determine if piston-to-bore clearance is in acceptable range shown in "Specifications."
2. If used piston is not satisfactory, determine if a new piston can be selected to fit cylinder bore within acceptable range.
3. If cylinder bore must be reconditioned, measure new piston diameter (across centerline of piston pin), then hone cylinder bore to correct clearance (preferable range).
4. Mark piston to identify cylinder for which it was fitted.

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Section 9

Exhaust System

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9 EXHAUST SYSTEM

Observe the following Warnings and Cautions whenever working on the engine.

⚠ WARNING

Always disconnect battery cables from battery, negative terminal first, **before** performing any disassembly/reassembly procedures on the engine.

⚠ WARNING

To prevent the possibility of a **FIRE**, be sure that the engine compartment is well ventilated and that there are no gasoline vapors present.

⚠ WARNING

Make sure that no fuel leaks exist before closing engine hatch.

SEALANTS
Perfect Seal

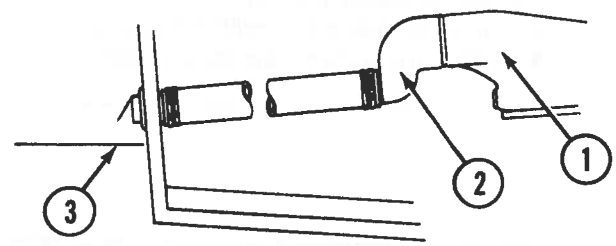
TORQUE SPECIFICATIONS	
Fastener Location	**lb-ft (N•m)**
Hose clamps	Securely
Exhaust elbow	25 (34)
Exhaust riser	25 (34)
Exhaust manifold and head	35 (47)

229, 262, 305, AND 350 CID ENGINES MINIMUM EXHAUST HOSE SIZES	
Dual exhaust	3 in. (76 mm)
Single exhaust	4 in. (102 mm)

454 AND 502 CID ENGINES MINIMUM EXHAUST HOSE SIZES	
Dual exhaust	4 in. (102 mm)
Single exhaust	5 in. (127 mm)

Installation:

The exhaust system consists of elbows connected to two exhaust manifolds which channel the exhaust out the back of the boat as illustrated in Figure 9-1.



1. Exhaust manifold
2. Elbow
3. Water line

Figure 9-1. Exhaust System

⚠ CAUTION

It is the responsibility of the boat manufacturer or installing dealer to properly locate the engine and install the exhaust system. Improper installation may allow water to enter the exhaust manifolds and combustion chambers and severely damage the engine. Damage caused by water in the engine will not be covered by Crusader Warranty, unless this damage is the result of a defective part(s).

1. System layout and construction must prevent cooling-system-discharge water from flowing back into engine and also must prevent seawater from entering the engine through the exhaust system. All cooling system water is discharged through openings which are located inside the exhaust elbows. To prevent discharge water from flowing back into the engine, the exhaust hoses and pipes must not be higher than the exhaust elbows at any point.

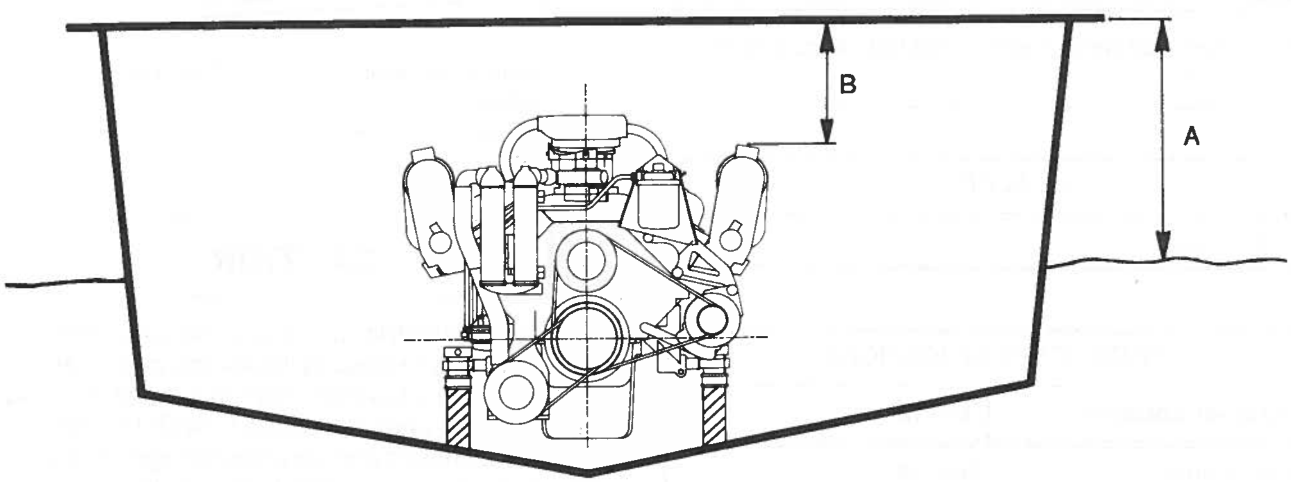
   The exhaust outlet (for routing exhaust outside of the boat) must be located so that a minimum of 1/2 in. (13 mm) per foot (30.5 cm) of downward pitch (drop) exists in the exhaust hose or pipe from the engine exhaust elbow to the outlet, with minimum drop of 4 in. (10 cm) overall. This is an American Boat and Yacht Council recommendation.

The drop must be constant so that a low spot does not exist at any point in the exhaust hose or pipe. The exhaust outlet must be slightly above the waterline with boat at rest in the water and with a full load aboard. The exhaust outlet should be equipped with a water shutter to prevent seawater from running back into the exhaust system. If thru-transom-exhaust outlets are used, an exhaust flapper on each outlet is also recommended.

2. Determine if exhaust elbows and/or risers are required by taking measurements "A" and "B," as shown in Figure 9-2, with the boat at rest in the water and a maximum load aboard. If "A" minus "B" is less than 12 in., select the appropriate-size exhaust-elbow riser that will correctly position the exhaust outlets.

3. The system must not cause excessive back-pressure. Back-pressure must not exceed 3 in. of Hg when measured with a manometer at the exhaust-elbow outlets. Minimum exhaust-hose sizes are given in the charts.

4. Exhaust hoses must be connected to the exhaust elbows so that restriction of discharge waterflow from the elbows does not occur. If the hoses are connected incorrectly, discharge water from the exhaust elbow will not flow around the entire inside diameter of the hose, thus causing a hot spot in the hose which may eventually burn through.



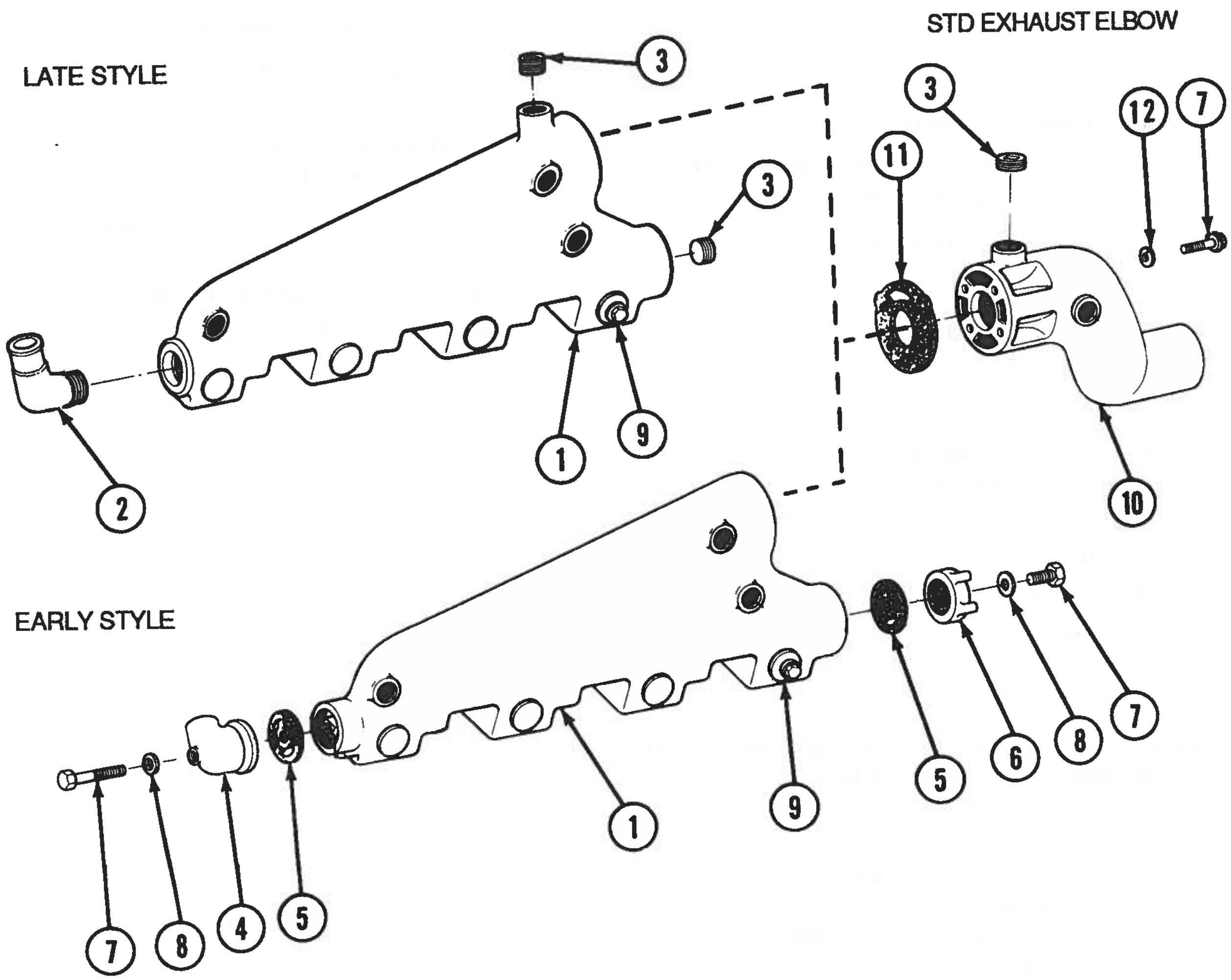
A. From waterline to reference point
B. From highest point on exhaust to same reference point

Figure 9-2. *Measuring Dimensions "A" And "B"*

9.1 EXHAUST MANIFOLD

Crusader Engine exhaust manifolds have undergone changes. The clean-out plate used on early-model manifolds has been replaced with a screw-in plug, and the water-inlet elbow has been simplified. Look at the manifolds to determine the type presently used.

The manifolds shown in Figure 9-3 are those used on the V-8 engines. The manifolds used on V-6 engines are similar and are maintained using the same steps.



1. Exhaust manifold
2. Brass elbow
3. Manifold plugs
4. Inlet cover
5. Gasket
6. Manifold-end cover
7. Bolt
8. Sealing washer
9. Manifold drain plug
10. Exhaust elbow
11. Exhaust gasket (1 hole)
12. Lockwasher

Figure 9-3. *Typical Exhaust Manifold Assembly*

Removal:

1. Disconnect battery cables from battery.
2. Drain water from manifold and elbow.
3. Disconnect exhaust hose and cooling hoses.
4. Port manifold of 305/350 CID engine:
    a. Remove alternator.
    b. Remove alternator mounting bracket (if equipped).
5. Remove outer exhaust-manifold-mounting bolts (2).
6. Install studs in place of bolts (3/8-in. 16 x 7-3/4 in., Part No. 22033) to aid in removal and installation of manifold.
7. Remove remaining bolts. Remove manifold assembly and discard gaskets.
8. Remove exhaust elbows and risers, if equipped.

Cleaning and Inspection:

1. Clean gasket material from all surfaces and wash parts in solvent.
2. Inspect all parts carefully. Machined surfaces must be clean and free of all marks and deep scratches to prevent water and exhaust leaks.
3. Check water passages for foreign material. Passages must be clean for efficient cooling.
4. If more thorough inspection is desired, pipe plugs may be removed from exhaust manifold and exhaust elbow.

IMPORTANT: If plugs are removed, coat the threads with Perfect Seal before reinstalling.

5. Check for cracks.
6. To test manifold body for leaks, block off plates, plugs or short hoses with plugged ends must be used. One block-off plate must have a threaded hole for attaching a compressed air hose. Use new gaskets when installing block-off plate(s). Apply 40 psi (276 kPa) of air pressure and submerge manifold in water. Air bubbles will indicate a leak.

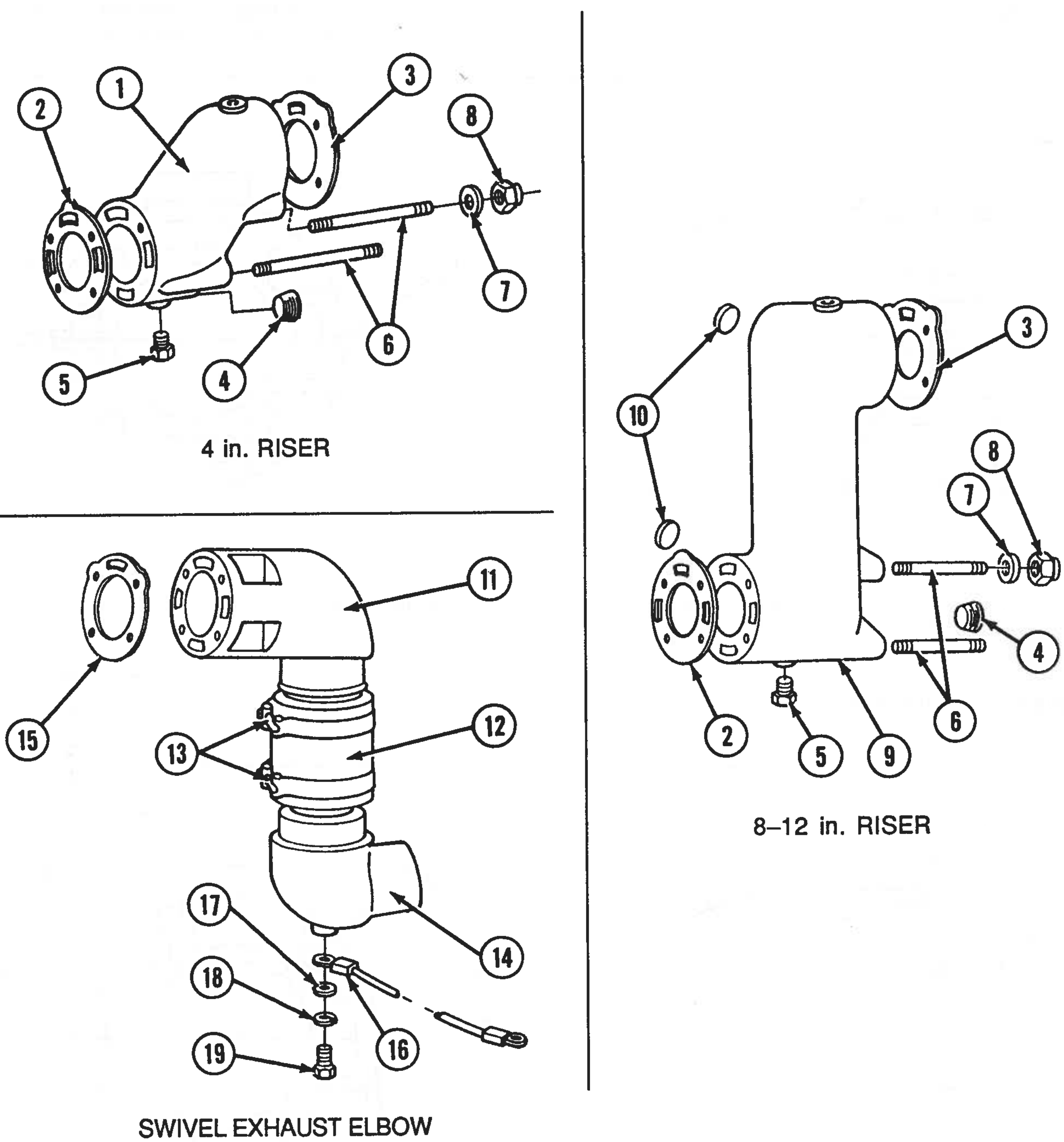
Installation:

1. Using a new gasket, install exhaust manifold to cylinder head.
2. Install center-attaching bolts. Remove alignment studs (2) and install bolts (2). Torque to specifications.
3. Port manifold of 305/350 CID engine:
    a. Install alternator mounting bracket (if equipped).
    b. Install alternator.
4. Using Perfect Seal on both sides of new gaskets, install riser (if used) and elbow.

IMPORTANT: On fresh-water-cooled engines, gaskets and stainless-steel separator plate must be installed as shown in Cooling Section (Figure 10-1).

5. Reconnect exhaust outlet hose and cooling hoses. Tighten clamps securely.
6. Reconnect battery cables to battery. Tighten securely.
7. On freshwater-cooled models, refill heat exchanger with coolant.
8. Start engine and check for exhaust and water leaks.
9. After warm-up, recheck coolant level. Fill to one inch below filler neck.

9.2 ELBOWS AND RISERS

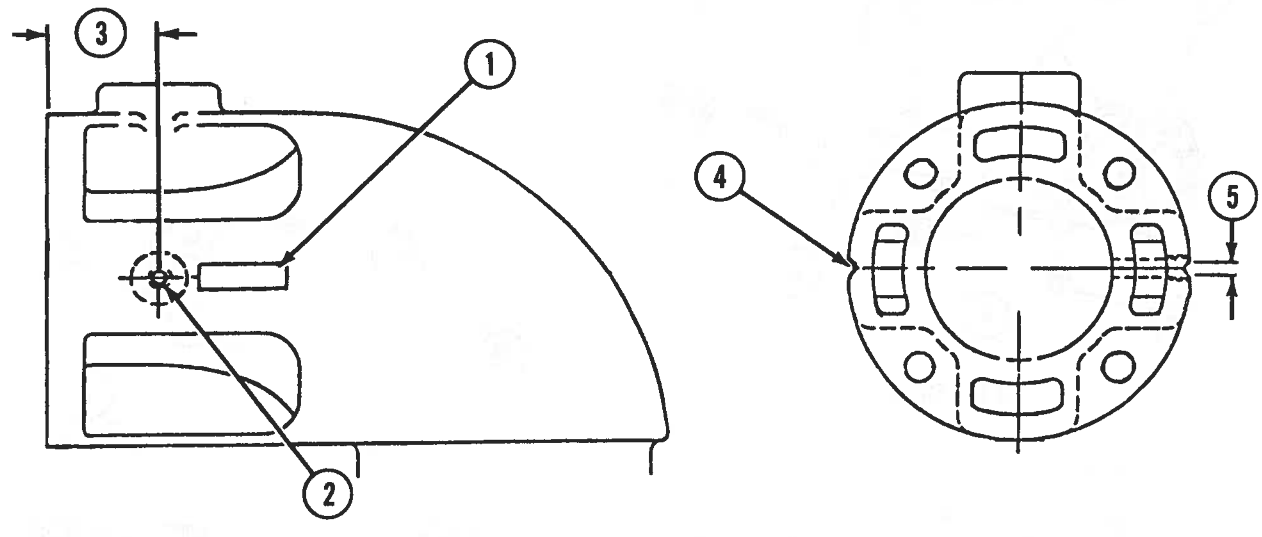


1. Four-inch exhaust riser
2. Three-hole exhaust-elbow gasket
3. One-hole exhaust-elbow gasket
4. Pipe plug
5. Drain plug
6. Mounting stud
7. Brass pipe plug
8. Stud
9. Eight-inch exhaust riser
10. Core plug
11. Upper exhaust elbow
12. Attaching hose
13. Hose-attaching clamp
14. Lower exhaust elbow
15. One-hole exhaust gasket
16. Ground wire assembly
17. Washer
18. Lockwasher
19. Ground-wire-attaching bolt

Figure 9-4. *Exhaust Elbows And Risers*

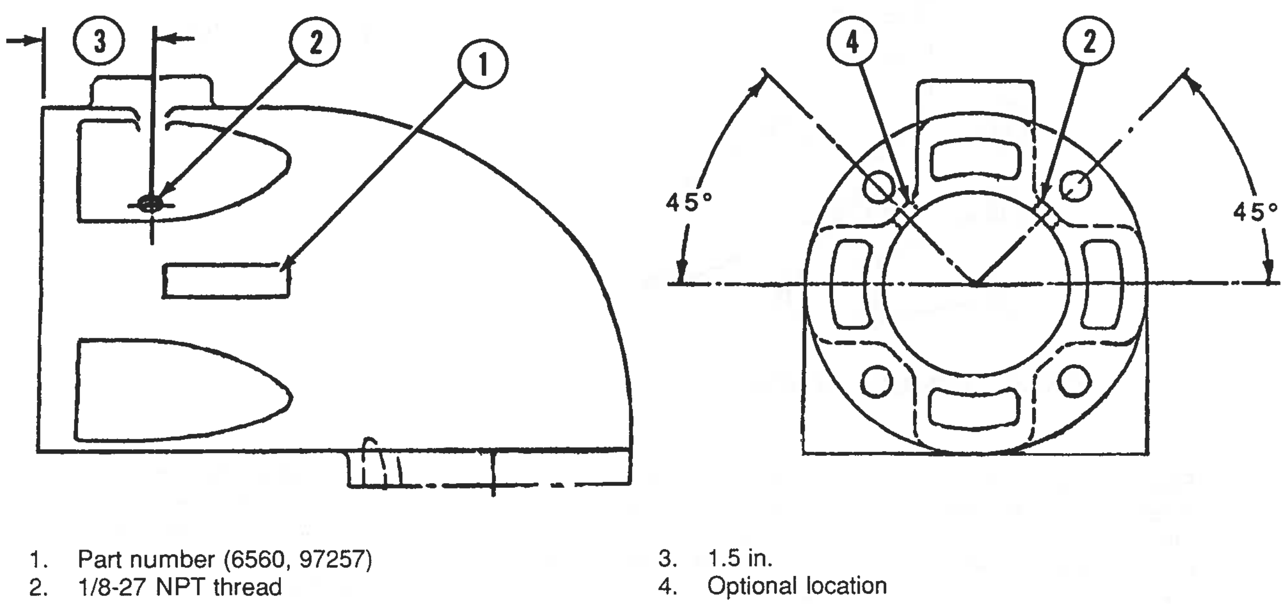
9.3 BACK-PRESSURE TESTING

1. Drill exhaust elbows with an "R" or 11/32 in.-diameter drill bit in location shown in Figures 9-5 or 9-6. Tap this hole with a 1/8-27 NPT tap.
2. Install the appropriate fitting into the elbow. Install a 2-ft. coil of 1/4 in. copper tubing onto the elbow. Attach a piece of flexible tubing or hose to the copper tubing and connect a mercury manometer or pressure gauge.



1. Part number (98040, 97924, 97386-B)
2. 1/8-27 NPT thread
3. 1.50 in.
4. Optional location
5. Dimple

Figure 9-5. Late-Model Elbow



1. Part number (6560, 97257)
2. 1/8-27 NPT thread
3. 1.5 in.
4. Optional location

Figure 9-6. Early-Model Elbow

3. Operate the boat at W.O.T. (at rated rpm) and record the system's back-pressure from the pressure gauge. The back-pressure must not exceed 3 in. of Hg when measured with a mercury manometer. If a pressure gauge is used, use the following conversion formula:

   ____ psi x 2.04 = _____ in. of Hg, based on the following conversion factors:

   1 psi = 2.04 in. of Hg
   1 in. of Hg = 0.49 psi

4. When test is completed, remove pressure gauge or manometer and fittings.

5. Install a 1/8-27 NPT plug into the exhaust elbow. Start engine and check for leaks.

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Section 10

Cooling System

BLANK

10 COOLING SYSTEM

Observe the following Warnings and Cautions whenever working on the engine.

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** performing any disassembly/reassembly procedures on the engine.

WARNING

To prevent the possibility of a **FIRE**, be sure that the engine compartment is well ventilated and that there are no gasoline vapors present.

CAUTION

Do not operate engine without cooling water being supplied to raw-water pickup pump or the pump impeller will be damaged and subsequent overheating damage to the engine may result.

CAUTION

If boat is in the water, be sure to close water inlet valve before removing inlet hose from pump to prevent water from draining into boat. If boat is not fitted with a valve, either plug inlet or raise it above water level after removing.

WARNING

Make sure that no fuel leaks exist before closing engine hatch.

SEALANTS
Perfect Seal

THERMOSTAT SPECIFICATIONS

Location	Specifications
Raw-water cooling	143° F (62° C)
Fresh-water cooling	160° F (71° C)

PRESSURE CAP SPECIFICATION

Location	Specifications
Fresh-water-cooling system	7 psi (48 kPa)

TORQUE SPECIFICATIONS

Fastener Location	Torque lb-ft (N•m)
Alternator brace to block	30 (41)
Alternator to mounting bracket	35 (48)
Alternator-mounting bracket	30 (41)
Drain plugs	Securely
Pulleys	Securely
Raw-water-pump bracket to block	30 (41)
Raw-water-pump to bracket	20 (27)
Raw-water-pump cover	10 (14)
Hose clamps	Securely
Thermostat housing	30 (41)
Water-circulating pump	30 (41)
Water-temperature sender	20 (27)

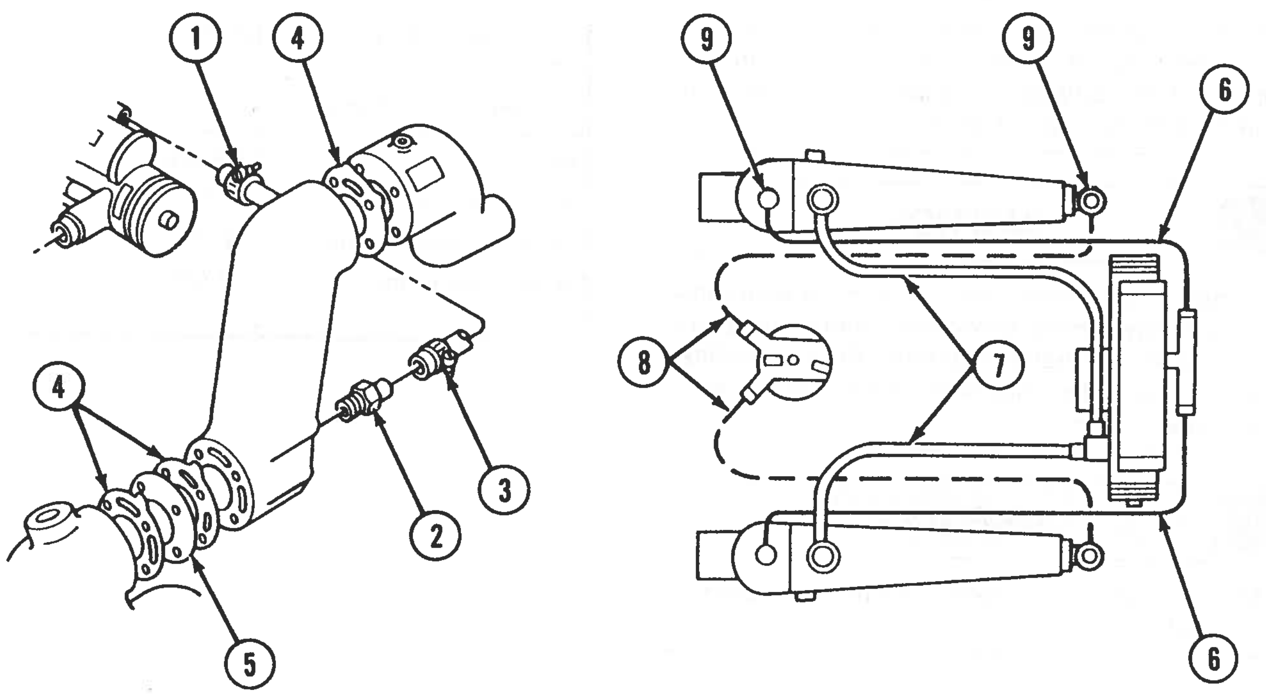
10.1 FRESH-WATER COOLING

There are several configurations of fresh-water-cooling systems (see Section 10.7, Flow Diagrams), but operation is essentially identical. Basically, the system is composed of two separate sections: the raw-water section (water in which the boat is being operated) and the fresh-water section. This allows the engine to be cooled with fresh (uncontaminated) water which is cooled in the heat exchanger by the raw water. The raw-water system absorbs heat from the fresh-water side of the heat exchanger as the raw water passes through the exchanger. After the raw water passes through the heat exchanger, it is dumped into the exhaust elbow where is mixes with the exhaust gases and is expelled overboard.

IMPORTANT: The fresh-water-system coolant (antifreeze) flows around the outside of the cooling tubes while the raw water flows through the inside of the tubes in the heat exchanger.

The fresh-water section is filled with a coolant, such as a solution of ethylene glycol (antifreeze) and water, or a solution of rust inhibitor and water. A centrifugal-type circulating pump, located on the front of the cylinder block, is used to circulate the coolant through the cylinder block, cylinder heads, and exhaust manifolds, removing the heat given off by these parts as the coolant passes. The heated coolant then travels to the heat exchanger where it is cooled by the raw water. After the coolant passes through the heat exchanger, it is routed back to the circulating pump where it is recirculated.

A thermostat is incorporated into the coolant side of the fresh-water system which provides fast engine warm-up and controlled engine-operating temperature.



RISER & BLOCK-OFF PLATE INSTALLATION

REVERSE MANIFOLD FLOW SCHEMATIC

1. Exchanger-to-riser hose
2. Hose-adapter fitting
3. Hose clamp
4. One-hole elbow-to-riser gasket
5. Water-block-off plate
6. Exchanger-to-elbow hose
7. Exchanger-to-manifold hose
8. Thermostat-to-manifold hose
9. Hose clamp

Figure 10-1. *Fresh-Water-Cooling-System Component Connections*

Draining Fresh-Water Section:

NOTE: To protect the environment, dispose of coolant properly. Check EPA and local restrictions applicable to proper disposal of removed coolant.

1. Remove heat-exchanger-pressure cap.
2. Remove exhaust-manifold-drain plugs.
3. Remove drain plugs from cylinder block (one located on each side of block).
4. Remove large hose from water-circulating pump.
5. Remove drain plug from heat-exchanger, fresh-water side (innermost plug). Do not allow coolant to drain directly onto starter motor.
6. After system has drained completely, coat all drain plugs with thread sealant and reinstall in proper locations. Reinstall large hose on circulating pump and tighten clamps securely.

Filling Fresh-Water Section:

Before filling the fresh-water-cooled system, see the following table for the approximate system capacity and coolant recommendations.

COOLING SYSTEM CAPACITY			
System	**229/262 CID**	**305/350 CID**	**454/502 CID**
Standard cooling system	14 qt. (53 L)	15 qt. (57 L)	20 qt. (76 L)
Fresh-water section	18.5 qt. (70 L)	23 qt. (87 L)	33 qt. (125 L)

CAUTION

The front of the engine should be higher than the rear. This will minimize the possibility of air being trapped in the fresh-water section during filling, which can cause the engine to overheat.

1. Fill fresh-water section with coolant as follows:

   Front-Mounted Tank

   a. Pour the coolant through the heat-exchanger-filler neck until coolant solution is 1 in. (25 mm) below filler neck.

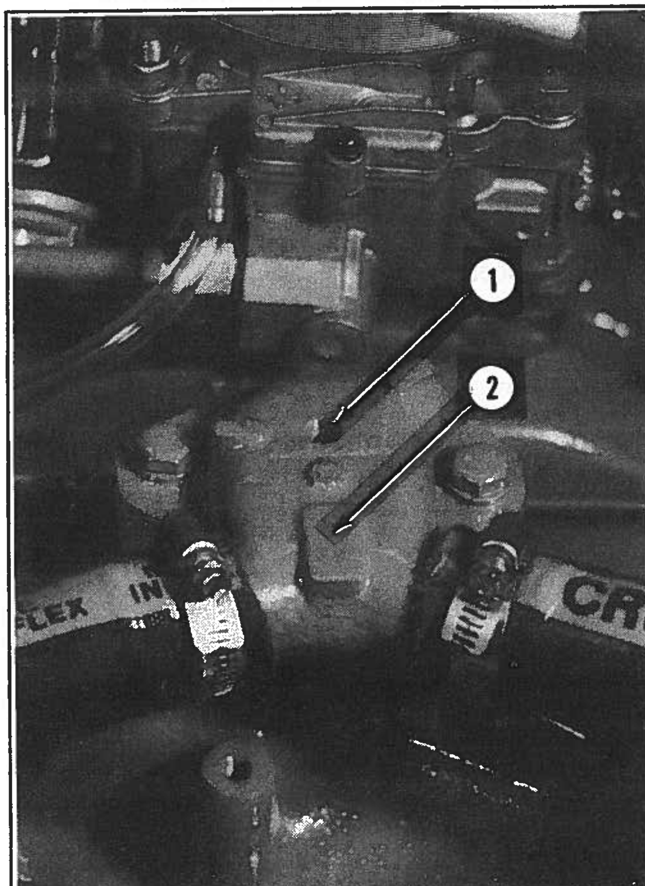
   Rear-Mounted Tank

   b. Remove the pipe plug from the top of the thermostat housing (Figure 10-2).

   c. Fill the fresh-water section with coolant through the heat-exchanger-filler neck until the coolant appears at the hold in the thermostat housing from which the pipe plug was removed.

   d. Coat threads of the pipe plug with Perfect Seal and reinstall.

   e. Continue filling the fresh-water section until the coolant level is 1 in. (25 mm) below the filler neck.



1. Vent 2. Thermostat housing

Figure 10-2. *Typical Fresh-Water Thermostat Housing*

CAUTION

Do not operate the engine without water flowing through the raw-water pickup pumps as pump impeller may be damaged, and subsequent overheating damage to the engine may result.

Models with a belt-driven, raw-water pickup pump must be in the water when running the engine over 1500 rpm because a garden hose will not supply enough water to the system.

2. With the pressure cap off, start the engine and run at a fast idle (1500-1800 rpm). Add coolant solution to the heat exchanger, as required, to maintain the coolant level at 1 in. (25 mm) below the filler neck.
3. After the engine has reached normal operating temperature (thermostat is fully open), and coolant level remains constant, fill heat exchanger to bottom of filler neck.
4. Observe engine-temperature gauge to make sure that engine-operating temperature is normal. If the gauge indicates a high temperature, stop engine immediately and examine for cause.
5. Install the pressure cap on the heat exchanger.
6. With engine still running, check hose connections, fittings, and gaskets for leaks. Repeat step 4.

IMPORTANT: Engine overheating is often due to air being trapped in the fresh-water section. Purge the air by running the engine at 2000 rpm for 10 minutes.

⚠ WARNING

Allow engine to cool down before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled down, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

7. Recheck coolant level after first open-throttle boat test and add coolant if necessary.

Fresh-Water-Section Pressure Test:

⚠ WARNING

Allow engine to cool down before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled down, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

If the fresh-water section of the fresh-water-cooled system is suspected of leaking or not holding sufficient pressure, and no visible signs of leakage can be found, perform the following test:

1. Remove the pressure cap from the heat exchanger or reservoir.
2. Clean, inspect, and test the pressure cap as outlined under "Pressure Cap Testing" in this Section to eliminate the possibility that the cap is not maintaining proper pressure in the system, allowing coolant to boil over.
3. Clean the inside of the filler neck to remove any deposits or debris. Examine the lower inside sealing surface for nicks or other damage. The surface must be perfectly smooth to achieve a good seal between it and the rubber seal on the cap. Also, check the locking cams on the sides of the filler neck to be sure that they are not bent or damaged. If the locking cams are bent or damaged, the pressure cap will not hold the proper pressure.
4. Adjust coolant level in fresh-water section to 1 in. (25 mm) below the filler neck.
5. Attach an automotive-type cooling system pressure tester to the filler neck, and pressurize the freshwater section to 14 psi (97 kPa).
6. Observe the gauge reading for approximately two minutes; pressure should not drop during this time. If pressure drops, proceed with Steps 7 through 13 until the leakage is found.
7. While maintaining a pressure of 14 psi (97 kPa) on the fresh-water section, visually inspect the external portion of the cooling system (hoses, gaskets, drain plugs, petcocks, core plugs, circulating-pump seal, etc.) for leakage. Also listen closely for bubbling or hissing as this usually is a sure indication of a leak.
8. Test the heat exchanger as outlined under "Heat Exchanger Test" in this Section.
9. If leakage could not be found in above steps, the engine is leaking internally and probably due to one or more of the following:
   a. Loose cylinder-head bolts or damaged gasket.
   b. Loose intake-manifold bolts or damaged gasket.
   c. Loose exhaust elbow.
   d. Cracked or porous cylinder-head block.
   e. Cracked or porous exhaust manifold.

Proceed as follows until internal leak is found:

10. Start engine. Repressurize system to 14 psi (97 kPa) and observe pressure gauge on tester. If needle in gauge vibrates, compression or combustion is leaking into the fresh-water section from a leak in the combustion chamber. Exact cylinders where leakage is taking place sometimes can be

found by removing spark-plug wires (one at a time) while observing the pressure gauge. Vibration will decrease or stop when a plug wire is removed from the leaking cylinder.

11. Remove spark plugs (one at a time) from cylinders and examine for presence of coolant. A spark plug that is perfectly clean or milky-appearing is a sure indication of a leak.
12. Drain oil from the engine and examine for the presence of coolant. Oil usually will be milky if coolant is present. If coolant is present, remove engine from boat and remove oil pan. With engine in the upright position, repressurize fresh-water section to 14 psi (97 kPa) and examine the internal surfaces of the engine to locate a leak.
13. If no leakage can be found, the entire engine must be disassembled and inspected for leaks (see Section 8, Engine Mechanical).

Pressure Cap Testing:

The pressure cap is designed to maintain a pressure of approximately 7 psi (48 kPa) in the fresh-water section once the engine has attained operating temperature. The cap should be cleaned, inspected, and pressure-tested at regular tune-up intervals or whenever the cap is suspected of not maintaining proper pressure.

> **⚠ WARNING**
>
> Allow engine to cool down before removing pressure cap. Sudden loss of pressure could cause hot coolant to boil and discharge violently. After engine has cooled down, turn cap 1/4 turn to allow any pressure to escape slowly, then push down and turn cap all the way off.

1. Carefully remove the pressure cap (Figure 10-3) from the reservoir or heat exchanger.

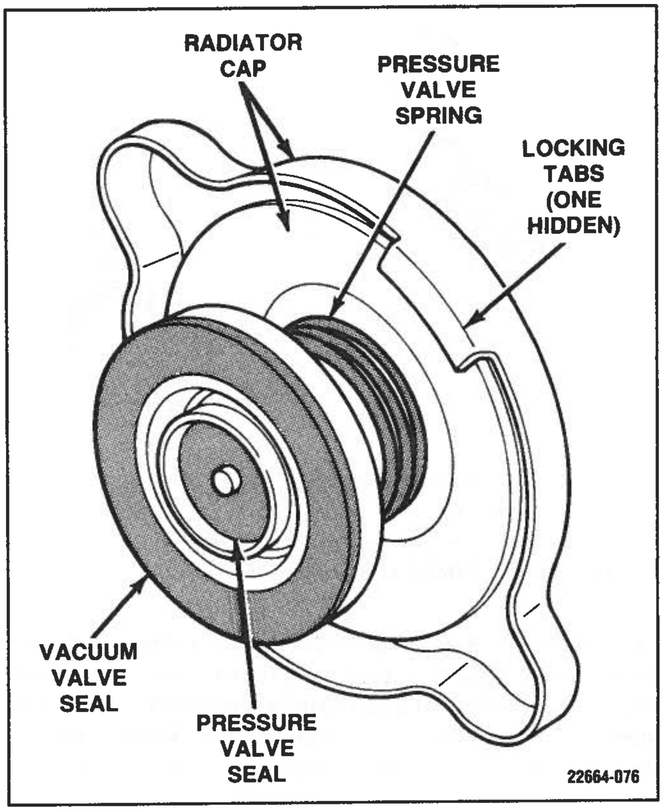
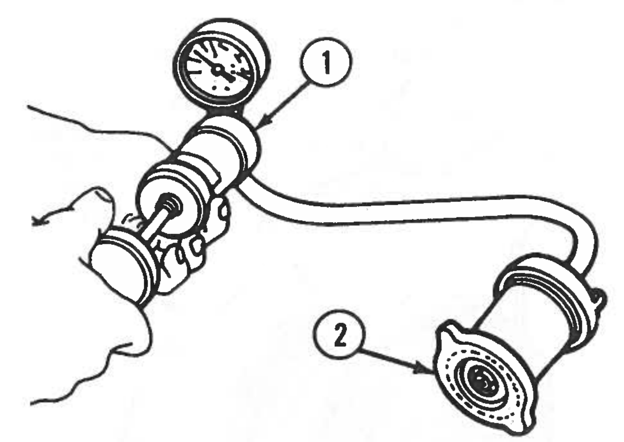


Figure 10-3. *Pressure Cap*

2. Wash the cap with clean water to remove any deposits or debris from the sealing surfaces.
3. Inspect gasket (if used) and rubber seal on the cap for tears, cuts, cracks, or other signs of deterioration. Replace gasket if damaged, or entire cap if rubber seal is damaged.
4. Check that the locking tabs on the cap are not bent or damaged.
5. Using a cooling-system-pressure tester (similar to the one shown in Figure 10-4), test cap to be sure that it releases at the proper pressure and does not leak. (Refer to instructions which accompany the tester for the correct test procedure.) The cap must relieve pressure at 7 psi (48 kPa) and must hold rated pressure for 30 seconds without going below 5 psi (34 kPa). Replace cap if it fails to fall within these limits.



1. J-24460-01 Pressure cap testing tool
2. Pressure cap

Figure 10-4. *Pressure-Cap Tester*

IMPORTANT: Before reinstalling cap in the next step, examine the lower inside sealing surface in the filler neck to ensure that it is perfectly smooth and free of debris. Also, inspect the cam-lock flanges on the sides of the filler neck to be sure that they are not bent.

6. Reinstall cap on reservoir or heat exchanger.

Heat Exchanger Test:

Internal Leaks

An internal leak will cause coolant to go into the raw-water system when pressure is put on the fresh-water section.

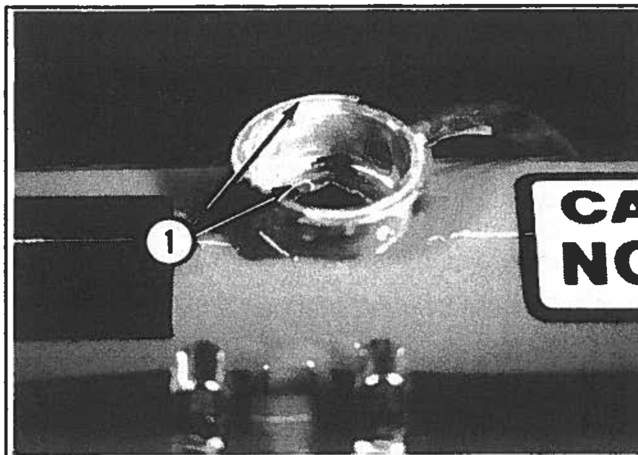
To check this, use the following test:

1. Remove a raw-water hose from the heat exchanger. Do not drain the heat exchanger.
2. Pressurize the fresh-water section at 14-20 psi (97-138 kPa) with a radiator tester.
3. If raw water begins to flow from the nipple, there is a leak.

Blockage

IMPORTANT: Raw water flows through the tubes in the heat exchanger. Fresh-water-section coolant flows around the tubes.

1. Remove end caps and inspect for any blockage in the raw-water section (broken impeller blades, weeds, etc.)
2. Remove fresh-water-section-circuit hoses and inspect the tubes just inside the nipples (Figure 10-5). Since the complete exchanger cannot be inspected, replace the heat exchanger if blockage is suspected.



1. Inspect for damage

Figure 10-5. *Heat Exchanger*

Cleaning Raw-Water Section:

Cooling efficiency of an engine with fresh water is greatly dependent upon heat transfer through the tubes within the heat exchanger. During engine operation, contaminants within the raw water (such as salt, silt, lime, etc.) collect on the inside of the tubes, thus reducing heat transfer and greatly decreasing heat-exchanger efficiency. It is therefore recommended that the raw-water section of the heat exchanger be cleaned at least once every two years, or whenever decreased cooling efficiency is suspected, as follows:

1. Remove the raw-water drain plug from the bottom of the heat exchanger and allow water to drain. After water has drained completely, coat the threads of the drain plug with Perfect Seal and reinstall.
2. Remove the bolts which secure the end plates to each end of the heat exchanger, then remove the end plates, seal washers, and gaskets. Clean gasket material from end plates and heat exchanger.
3. Clean water passages in heat exchanger by inserting a suitably sized wire brush into each passage. Use compressed air to blow loose particles out of the water passages.
4. Apply Perfect Seal to both sides of the new end-plate gaskets, then reinstall end plates using new gaskets and seal washers. (Be sure to install seal washers between end plates and gaskets.)
5. Start engine and inspect cooling system for leaks.

Cleaning Fresh-Water Section:

The fresh-water section of the fresh-water-cooling system should be cleaned at least once every two years, or whenever decreased cooling efficiency is experienced.

A good grade of automotive-cooling-system cleaning solution may be used to remove rust, scale, or other foreign material. Manufacturer's instructions, which accompany a particular cleaner, should always be followed.

If the fresh-water section is extremely dirty, a pressure-flushing device may be used to flush out the remaining deposits. The flushing should be done in a direction opposite the normal coolant flow to allow water to get behind deposits and force them out. Refer to instructions which accompany the flushing device for proper hookup and flushing procedure.

Cylinder-Head-Gasket Leak Test:

NOTE: This test may be performed only on engines equipped with a F.W.C. system.

A leaking head gasket will cause combustion gas to be forced into the cooling system. The mixture of coolant and tiny air bubbles is a poor heat conductor and will overheat an engine quickly. Compression tests or cooling-system-pressure checks normally will not detect the leak because the test pressure is far below the combustion pressures which cause the leak. An effective test is as follows:

IMPORTANT: Run boat in lake for this test. It is best to run the engine at or above cruising speed during this test. Usually a failed head gasket will not cause the engine to overheat below cruising speed.

1. Obtain a coolant-recovery bottle before running this test to allow recycling of the expelled coolant.
2. Install a clear, plastic hose between the reservoir and coolant recovery bottle. Use a 2-3 ft. (61-91 cm) long hose for this test.
3. Route this hose into a U-shape.
4. Put enough coolant into the hose to fill the center 4-5 in. (10-13 cm) of the U-shaped hose.
5. Observe the "U" while the engine is running.
   a. While idling and warming up the engine, some coolant and hot air will leave the reservoir.
   b. During cruising speed (2500-3500 rpm), coolant and/or air leaving the reservoir should stop after approximately five minutes of running at a given rpm. A leaking head gasket will produce air bubbles through the U-shaped hose going to the coolant recovery bottle. The frequency and size of the bubbles will depend on the size of the leak.
   c. At higher speeds (4000+ rpm), normal operation is the same as described in "b." A failed head gasket will cause bubbles to appear faster and may be accompanied by violent, intermittent bursts of coolant.

It is important not to confuse normal warm-up expansion with a failed head gasket. Normal warm-up produces an intermittent flow of coolant which will stop within approximately five minutes at a given rpm. A head-gasket leak will not stop. The one thing that marks a failed head gasket is the continued passage of air that may be accompanied by violent, intermittent bursts of coolant leaving the reservoir. If coolant continues to flow (not violent, intermittent bursts) from the reservoir at cruising speed, a component other than the head gasket is causing the engine to overhead.

10.2 RAW-WATER COOLING

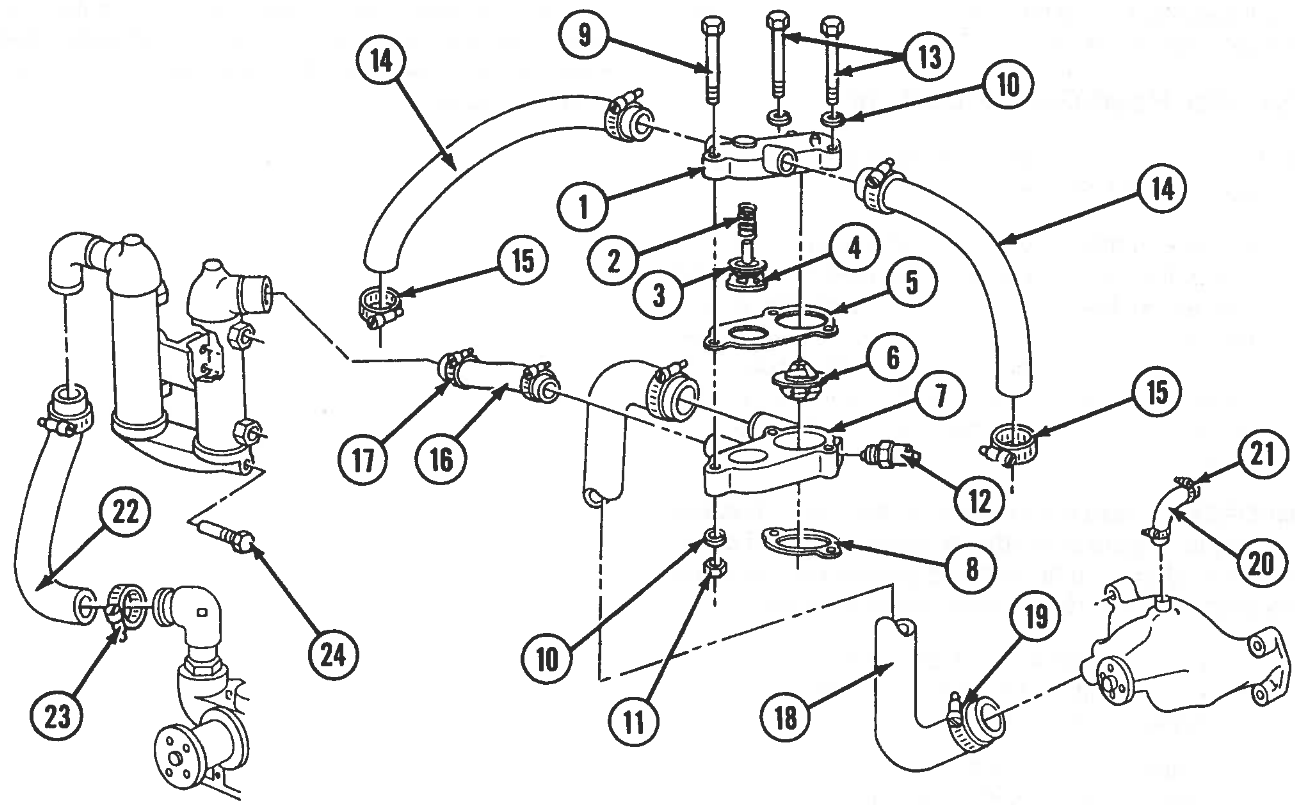
Crusader engines with standard cooling systems use raw water only (water in which the boat is being operated) to remove the heat given off by the engine.

The raw water is pumped to the cooling system by means of an impeller-type pickup pump which picks up raw water and delivers it to the centrifugal pump located over an opening on the front of the cylinder block. Raw water is pumped through an oil cooler before going to the circulating pump.

A centrifugal pump then circulates the raw water through the block, heads, and manifolds. The raw water removes the heat given off by these parts as it passes through.

After passing through the engine, the raw water is pumped into the exhaust elbow where it mixes with the exhaust gases and is expelled overboard.

A thermostat which controls circulation of the raw water is also incorporated into the system. It provides fast engine warm-up and controlled operating temperature.



1. Upper thermostat housing
2. Pressure-relief spring
3. Pressure-relief valve
4. Pressure-relief seat
5. Thermostat-housing gasket
6. Thermostat
7. Lower thermostat housing
8. Thermostat-housing gasket
9. Bolt
10. Lockwasher
11. Nut
12. Temperature-alarm sender
13. Bolt
14. Thermostat-housing-to-manifolds hose
15. Water-hose clamp
16. Oil-cooler-to-thermostat-housing hose
17. Water-hose clamp
18. Water-pump-to-thermostat-housing hose
19. Hose clamp
20. Water-pump-bypass hose
21. Hose clamp
22. Raw-water pump-to-cooler hose
23. Hose clamp
24. Zinc plug

Figure 10-6. *Raw-Water-Cooling-System Components*

Flushing Raw-Water-Cooling System:

If the engine is operating in salty, polluted, or mineral-laden waters, the cooling system should be flushed periodically (preferably after each use) to reduce corrosion and prevent the accumulation of deposits in the system. The cooling system also should be thoroughly flushed prior to storage.

> **CAUTION**
>
> **Do not** run engine above 1500 rpm, as suction created by the raw-water pickup pump may collapse the water supply hose and cause the engine to overheat.

> **CAUTION**
>
> If the cooling system is to be flushed with the boat in the water, the water inlet valve (if so equipped) must be closed, or the water inlet hose must be disconnected and plugged, to prevent water from flowing into the boat.

The following procedure should be used to flush the cooling system:

1. Disconnect the raw-water-inlet hose from the raw-water pump.
2. Using the appropriate connector, connect the fresh-water hose to the pump-inlet connection and partially open water tap (approximately 1/2 maximum capacity). Do not use full city-water pressure.

> **WARNING**
>
> When flushing cooling system with the boat out of water, be certain that the area in the vicinity of the propeller is clear and that no person is standing nearby. As a precautionary measure, it is recommended that the propeller be removed.

3. Start engine. Operate engine at idle speed in neutral gear for 10 minutes or until the discharge water is clear. Stop engine.

> **CAUTION**
>
> Watch temperature gauge at dash to ensure that engine does not overheat.

4. Shut off the water tap. Remove flushing connector from pump inlet and reconnect water-inlet hose. Tighten clamp securely.

IMPORTANT: If boat is in the water, do not open water-inlet valve until engine is to be restarted to prevent contaminated water from flowing back into engine.

10.3 WATER-CIRCULATING PUMP

Removal:

1. Drain water from cylinder block.
2. Break loose bolts attaching circulating-pump pulley. Do not remove bolts at this time.
3. Loosen alternator-brace-attaching bolts and alternator-mounting bolt, then pivot alternator inward and remove drive belt.
4. Remove pump-pulley-attaching bolts, lockwashers, and pulley.
5. Disconnect hoses from pump.
6. Remove bolts which secure pump to cylinder block, and remove pump and old gaskets. Discard gaskets.

Cleaning and Inspection:

1. Clean gasket surfaces on water pump and cylinder block.
2. Inspect water pump for blockage, cracks, sand holes, corrosion, or other damage. Inspect pump impeller for cracks and erosion. Replace complete pump if any damage exists.
3. Check impeller shaft and bearings for excessive side play. If play can be felt, replace complete pump.
4. Inspect pump pulley for bends, cracks, corrosion, or other physical damage. Inspect pulley for rotational trueness. Replace pulley if damaged or out-of-true.

Installation:

1. Coat both sides of new circulating-pump gasket with Perfect Seal, then position gasket and circulating pump on cylinder block. Coat threads of circulating-pump-attaching bolts with Perfect Seal and install bolts and alternator brace (if applicable). Torque bolts to specifications.
2. Reconnect hoses to pump.
3. Install pump pulley on pump hub and secure with bolts and lockwashers. Tighten bolts securely.
4. Install drive belts and adjust tension as outlined in Section 3.1, Drive Belts.
5. If engine is equipped with a fresh-water section, fill cooling system with coolant as outlined under "Filling Fresh-Water Section."
6. Start engine and check for leaks.

10.4 RAW-WATER-PICKUP PUMP

Raw-Water Pickup:

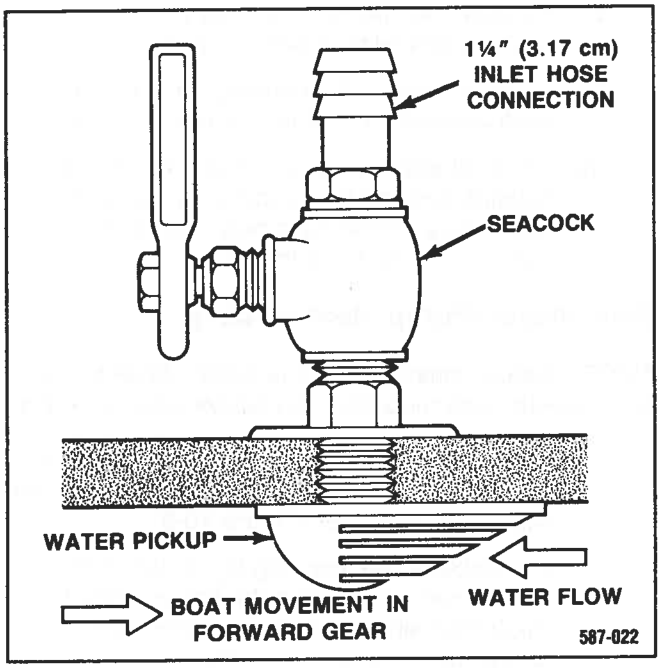


Figure 10-7. *Typical Through-Hull Raw-Water Pickup*

Raw-Water-Pump Removal:

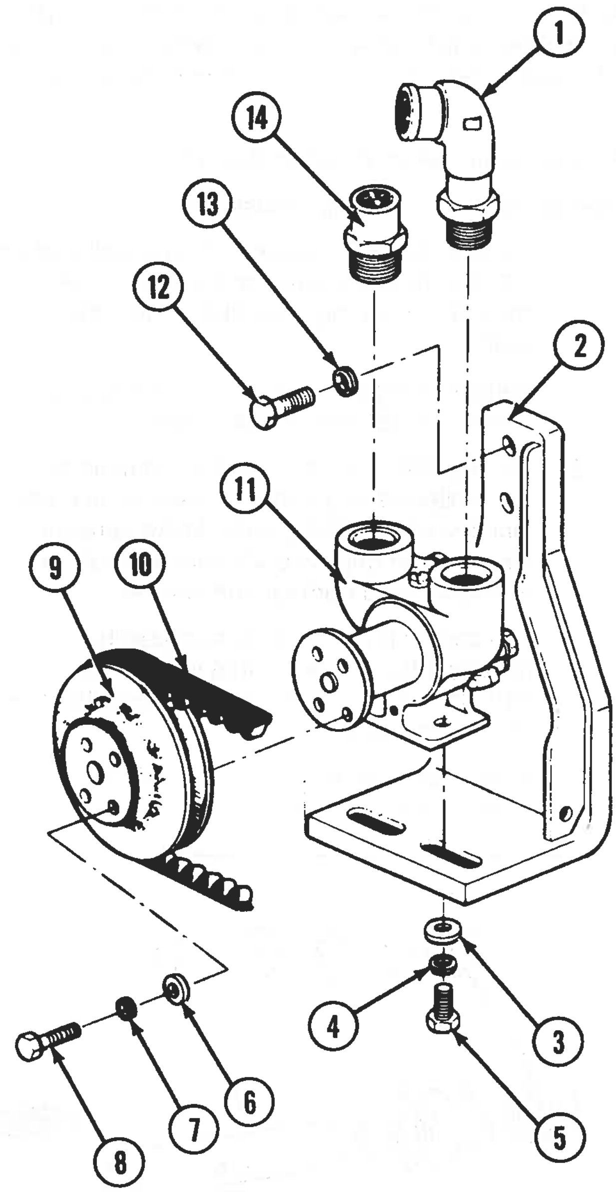
> **CAUTION**
>
> If boat is in the water, be sure to close water inlet valve before removing inlet hose from pump to prevent water from draining into boat. If boat is not fitted with a valve, either plug inlet or raise it above water level after removing.

Refer to Figure 10-8.

1. Disconnect water inlet and outlet hoses from pump.

NOTE: Make note of hose locations so that hoses are reinstalled in proper location.

2. If pump is to be disassembled, break loose four pump-pulley-attaching screws (8). Do not remove screws at this time.
3. Loosen two attaching screws from bottom of pump bracket.
4. Slide pump over and remove drive belt (10).
5. Remove attaching screws and remove pump (11) from bracket (2).
6. Remove four pump-pulley-attaching screws and remove pulley (9).



1. Elbow
2. Pump bracket
3. Washer
4. Lockwasher
5. Bolt
6. Washer
7. Lockwasher
8. Screw
9. Pulley
10. Belt
11. Raw-water pump
12. Bolt
13. Lockwasher
14. Adapter

Figure 10-8. *Raw-Water Pump Removal*

Raw-Water-Pump Disassembly

NOTE: It may not be necessary to completely disassemble the pump to repair it. Before performing overhaul of the pump, determine why it is not working satisfactorily.

Remove pump before disassembling it.

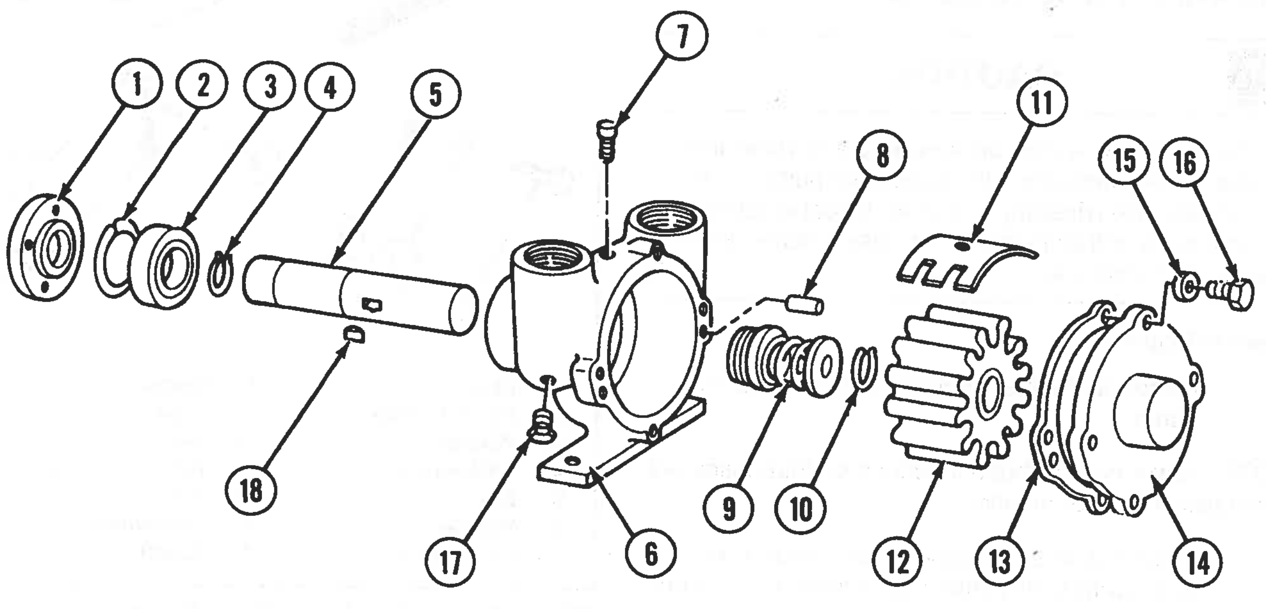
Refer to Figure 10-9 during disassembly.

1. Remove the four screws (16) and lockwashers (15) that hold the cover to the body. Pull the cover and bushing assembly off the drive shaft.
2. Remove the gasket (13) from the housing. Dowel pins (8) can remain in place.
3. The impeller (12) can now be removed by using pliers and grasping a vane on one side, then the other. Pull gently. Make sure you have a good grip on each vane so that pliers do not slip and damage the impeller.
4. The cam (11) can now be removed by removing the screw (7) that goes down through the top of the body between the intake and discharge ports.
5. Using a bearing puller, remove the hub (1) from the end of the shaft.
6. Remove the woodruff key (18) from the shaft.
7. Remove the external snap ring (4) from the impeller end of the housing (behind the mechanical seal).
8. Remove the internal snap ring (2) from the housing behind the sealed bearing.
9. Properly support the housing and press the shaft assembly out of the bearing housing.
10. The seal assembly is pressed into the bearing housing and can be removed by pushing a tool through the bearing end, against the rubber or backside of the seal.

Raw-Water-Pump Reassembly

NOTE: Before reassembling the pump, all parts should be inspected and replaced if excessive wear is noticed.

1. If the carbon bushing in the pump cover (14) needs replacing, it is serviced as an assembly with the pump cover (Figure 10-9).
2. Assemble a retaining ring (4) on the shaft into the second groove from the drive-shaft end. Push the ball bearing (3) over the shaft. Press on the inner race of the bearing. Push the bearing up against the snap ring.



1. Drive hub	7. Cam-retaining screw	13. Gasket
2. Bearing retainer	8. Dowel pin	14. Cover
3. Shaft bearing	9. Seal and seat assembly	15. Lockwasher
4. Shaft retainer	10. Shaft retainer	16. Screw
5. Shaft	11. Cam	17. Drain plug
6. Water-pump housing	12. Impeller	18. Woodruff key

Figure 10-9. *Raw-Water-Pump Assembly*

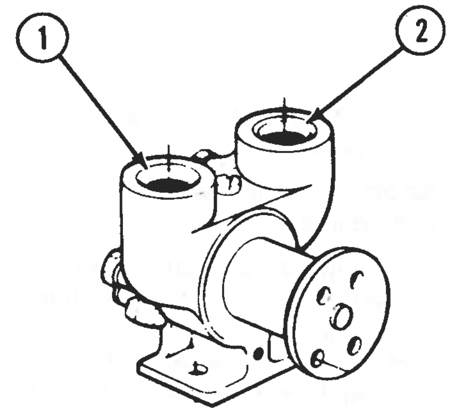
3. Push the bearing and shaft assembly into the pump body (6), using care not to cock the bearing. A tool that will give you uniform pressure on the bearing outer race is recommended. Lock the bearing in place with the large internal snap ring (2).
4. From the opposite end (woodruff-key end of the shaft), assemble the seal (9) over the shaft (5), rubber side first.

NOTE: When replacing the seal or seat, it is recommended that both are replaced at the same time.

5. Push the seal assembly (9) over the shaft and down against the seat. Do not damage the black carbon washer that rides against the ceramic.
6. Assemble the second snap ring (4) on the shaft. It will be necessary to compress the seal assembly to allow the retaining ring to enter the groove on the shaft.
7. Press the hub on the shaft. Take care to properly support the opposite shaft end to avoid placing any load on the bearings. The hub should be pressed flush against the ball bearing with 0.12 in. (3.0 mm) of shaft protruding through the hub face.
8. Press the woodruff key (18) into the keyway in the shaft.
9. Install the cam (11) and the cam screw (7).
10. Assemble the impeller (12) over the shaft. Line up the key in the shaft with the keyway in the impeller and push the impeller into the body.
11. Place the gasket (13) over the dowel pins (8) on the face of the pump. Secure the cover with the four screws (16) and the lockwasher (15) on to the housing.

Raw-Water Pump Installation:

1. Install pulley on hub and attach with bolts and lockwashers. Tighten bolts securely.
2. Place pump on bracket and install two pump-mounting bolts.
3. Install inlet and outlet hoses and tighten clamps (see Figure 10-10).



1. Inlet – RH rotation engine
2. Inlet – LH rotation engine

Figure 10-10. *Raw-Water-Pump-Flow Hookup*

4. Install drive belt and adjust tension as outlined in Section 3.1, Drive Belts.

CAUTION

To avoid damaging the impeller, **always** lubricate it with light grease or oil **before** starting the pump.

5. Start engine and check for leaks.

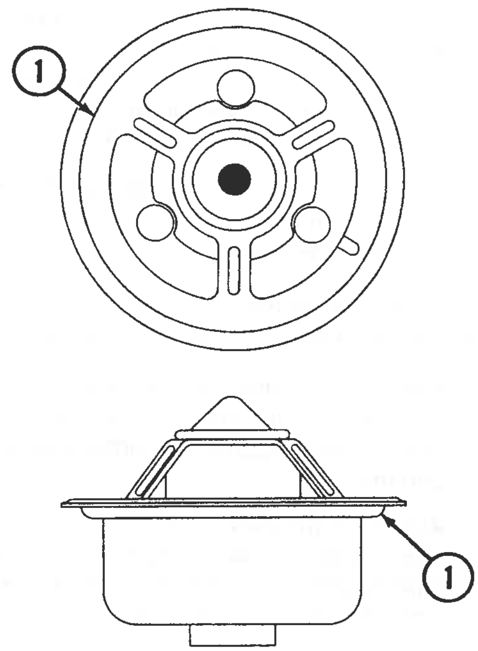
10.5 THERMOSTAT

Removal:

1. Drain water from cylinder block and exhaust manifolds.
2. Disconnect hoses form thermostat cover.
3. Remove thermostat-cover-attaching bolts and lockwashers, then remove cover and gasket.
4. Remove thermostat from thermostat housing or cover.

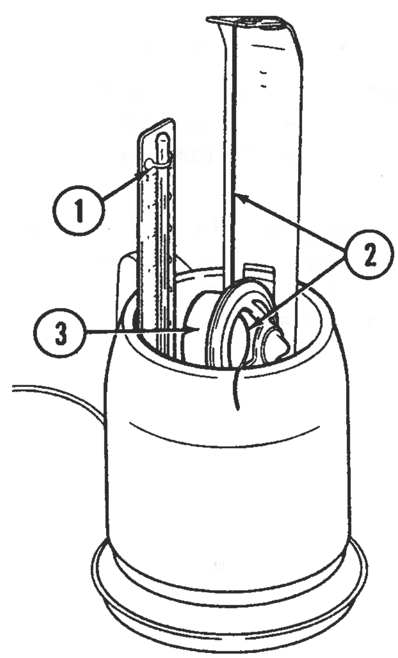
Testing:

1. Clean thermostat in soap and water to remove and deposits or debris.
2. Inspect thermostat for corrosion or other visible damage.
3. If thermostat is suspected of not regulating engine temperature, check thermostat for leakage by holding it up to a lighted background. Light leakage around the thermostat valve indicates that thermostat is not closing completely and should be replaced. A small amount of leakage at one or two points around the valve perimeter is acceptable (Figure 10-11).
4. Check opening and closing temperature of thermostat using a tester similar to the one shown in Figure 10-12. Proceed as follows:
   a. Fill tester to within 1 in. (25 mm) of top with tap water. Do not use distilled water.
   b. Open thermostat valve and insert nylon string. Position thermostat on string so that it will be just below water level when suspended, then allow valve to close. Suspend thermostat in water.
   c. Place thermometer in the container and position it so that bottom of thermometer is even with bottom of thermostat. Do not allow thermometer to touch container.



1. Check for light leakage around perimeter of thermostat valve

Figure 10-11. *Checking Thermostat For Leakage*



1. Thermometer
2. Nylon string
3. Thermostat

Figure 10-12. *Thermostat Tester*

IMPORTANT: When performing Steps d. through f., water must be agitated thoroughly to obtain accurate results.

d. Plug in tester and observe temperature at which thermostat opens (thermostat drops off thread). Thermostat must open at specified temperature stamped on thermostat.

e. Continue to heat water until a temperature of 25° F (14° C) above temperature specified on thermostat is obtained. Thermostat valve must be completely open at this temperature.

f. Unplug tester and allow water to cool to a temperature of 10° F (6° C) below specified temperature on thermostat. Thermostat must be completely closed at this temperature.

g. Replace a thermostat that fails to pass all of the preceding tests.

Installation:

1. Clean gasket surfaces on thermostat cover and thermostat housing.

IMPORTANT: Gasket has continuity rivets; do not coat with Perfect Seal. The temperature-alarm switch may not work properly.

2. If thermostat housing was disturbed during removal of thermostat, remove thermostat housing and replace thermostat housing to intake-manifold gasket.
3. Place thermostat in thermostat housing with thermostatic-element end toward engine. Be sure to position thermostat so that mounting flange fits into recess in thermostat housing (Figure 10-13).
4. Coat both sides of new thermostat cover-to-thermostat-housing gasket with Perfect Seal and position on thermostat housing. Reinstall thermostat cover and torque bolts to specifications.
5. Reconnect hose(s) to thermostat cover.

⚠ CAUTION
Operation of engine without cooling water being supplied to raw-water-pickup pump may result in damage to the pump impeller.

6. Start engine and inspect for leaks.

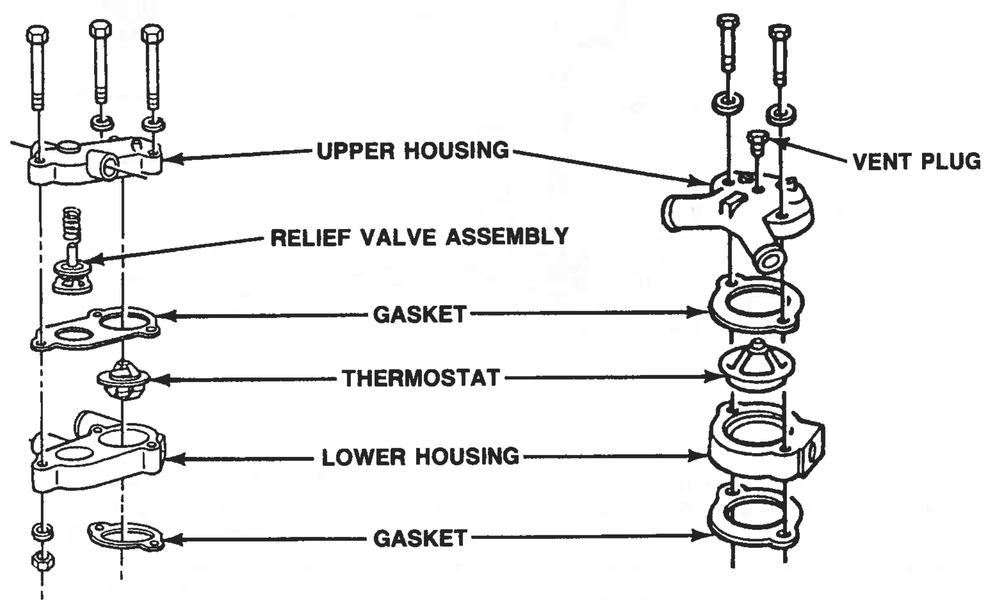
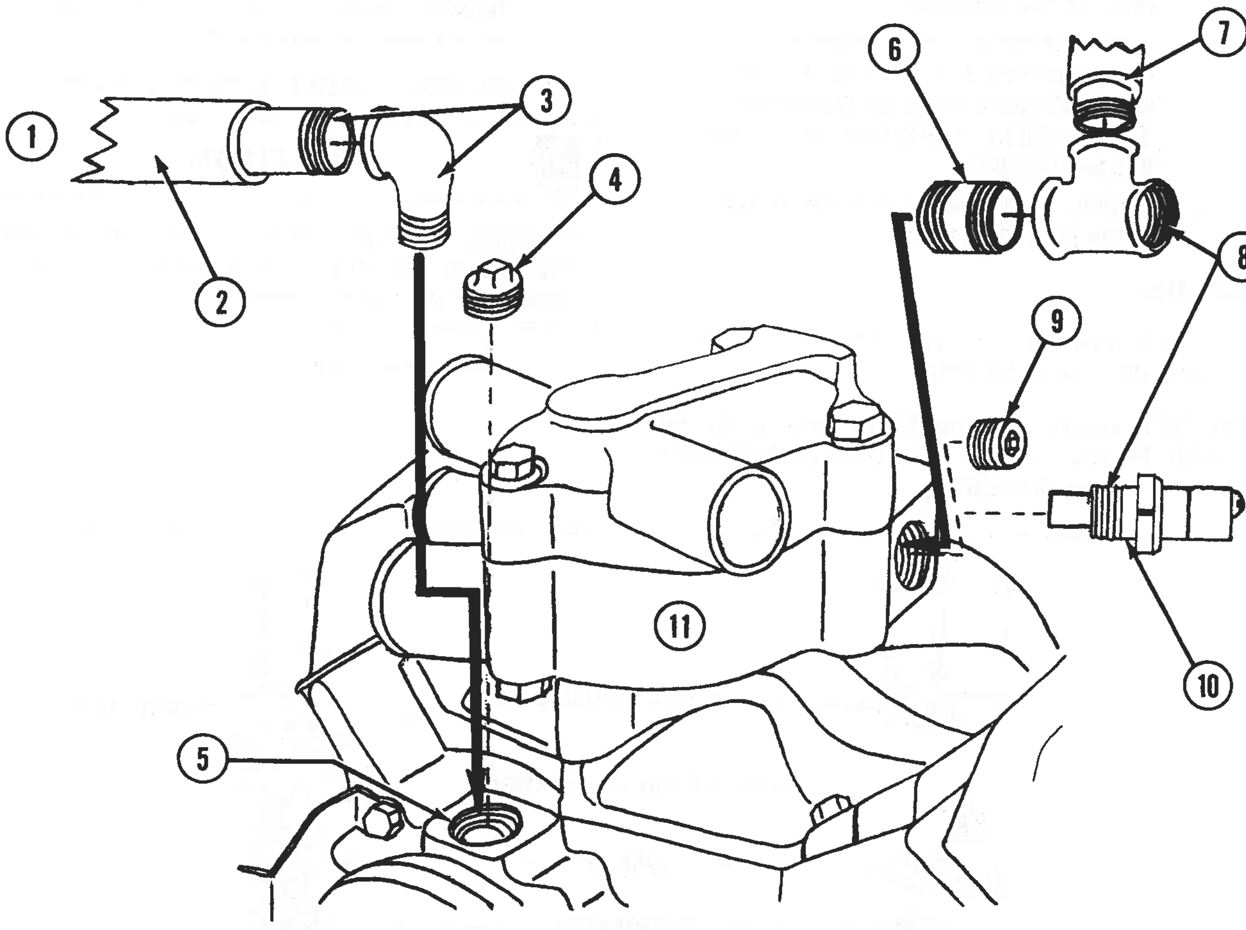


Figure 10-13. *Thermostat Installation – All Models*

10.6 WATER-HEATER INSTALLATION

When connecting a cabin heater or hot-water heater to a Crusader engine, the following requirements must be met:

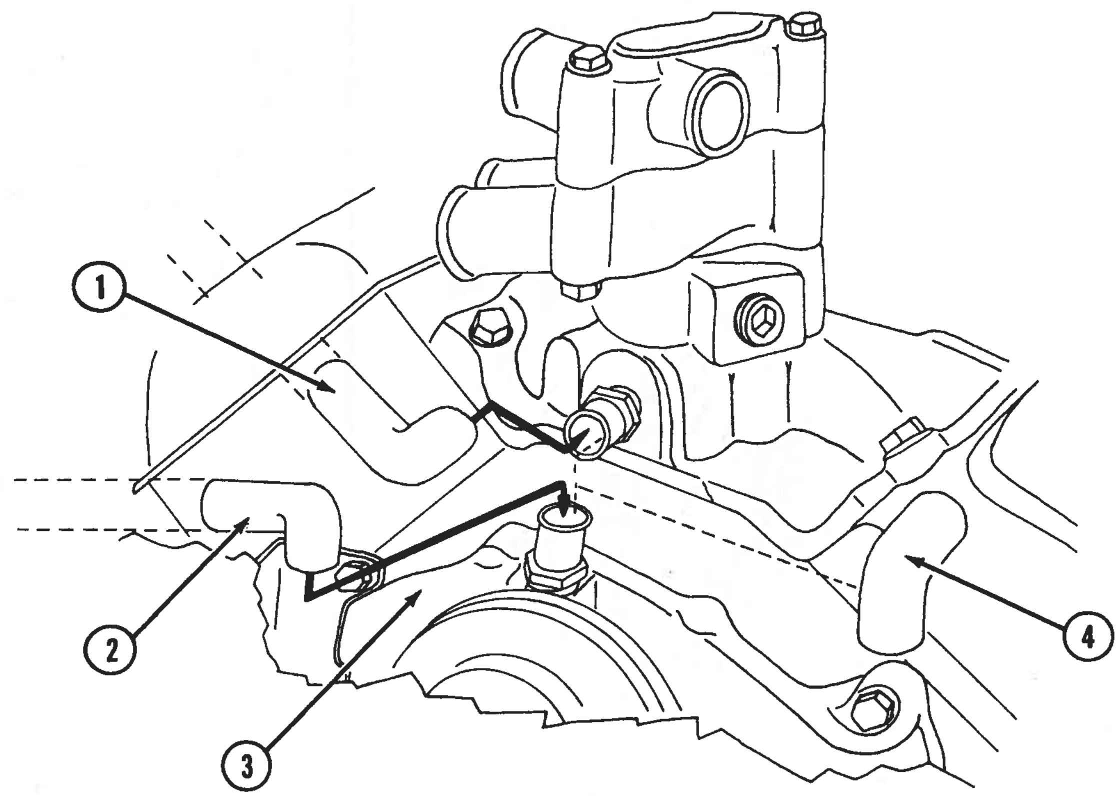
- The supply hose (from engine to heater) and the return hose (from heater to engine) must not exceed 5/8 in. (16 mm) inside diameter.
- On Crusader engines equipped with a fresh-water system, heater must be lower than the fill cap on the heat exchanger. If the heater is higher than the fill cap and coolant is lost in the system, and air pocket may form in the fresh-water system. This can cause the engine to overheat.
- Make heater connections to Crusader engines only at locations shown in Figures 10-14 and 10-15.



1. Water return from water heater
2. Hose from water heater to engine-circulation-water pump
3. Install 90° elbow in top of circulation water pump
4. Remove plug from top of circulation pump
5. Engine-circulation-water pump
6. Water outlet to water heater
7. Hose to water heater
8. Install water-alarm-sending unit
9. Remove plug
10. Water-alarm-sending unit
11. Thermostat housing

Figure 10-14. *Water-Heater Connection – Full Fresh-Water And Standard Water System – Engine Models 229, 262, 305, And 350 CID*

- Check complete system for leaks after heater is connected to the cooling system.
- Check for engine overheating after heater is connected to the cooling system.



1. Water outlet to water-heater hose
2. Water return from water hose
3. Circulation pump
4. Remove bypass-water hose

Figure 10-15. *Water-Heater Connection – Full Fresh-Water And Standard Water System – Engine Models 454 And 502 CID*

NOTE: If water fittings used are different from those received with engine, brass must be used.

10.7 FLOW DIAGRAMS

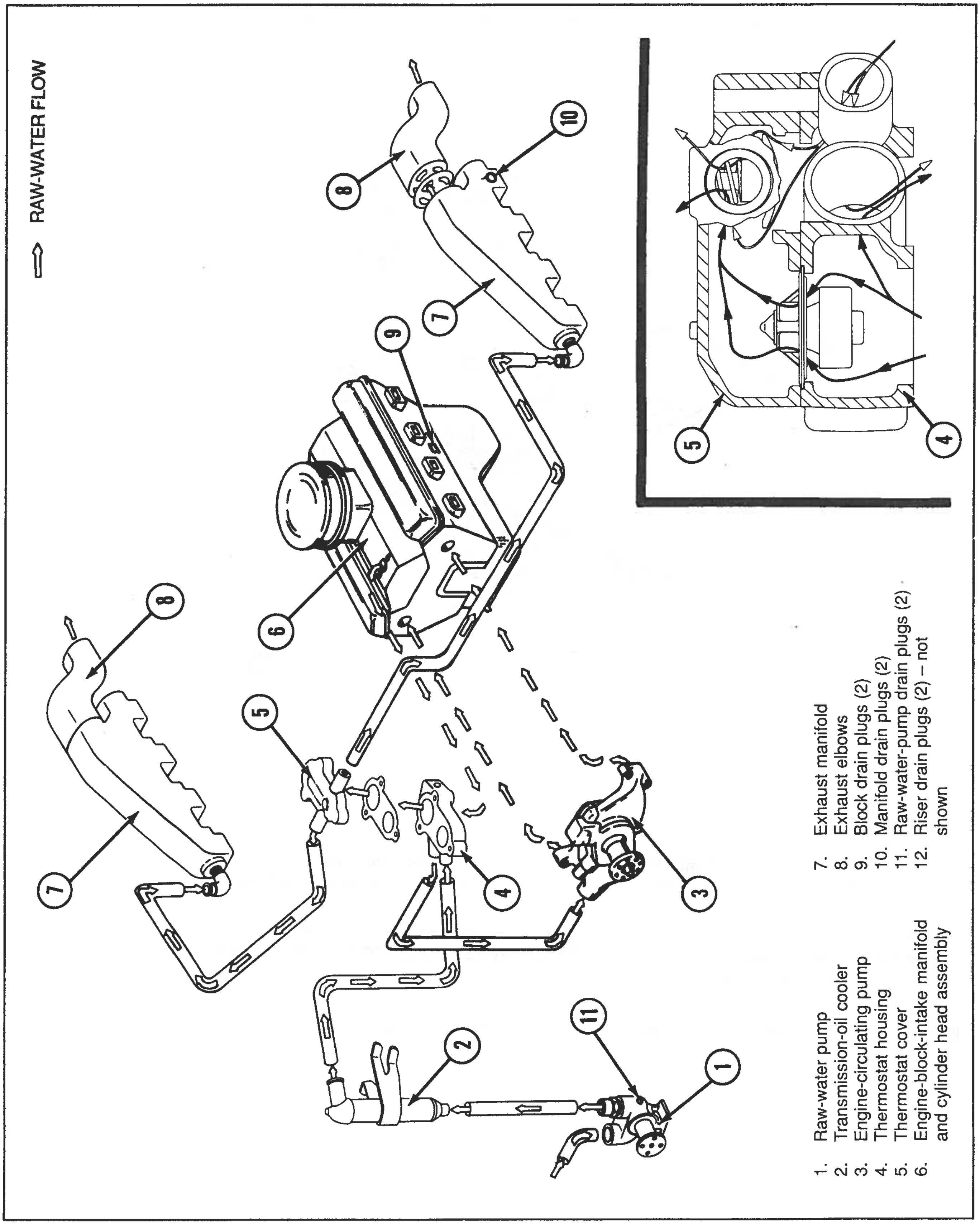


Figure 10-16. *Engine Models 229, 262, 305, And 350 CID Raw-Water-Cooled Systems*

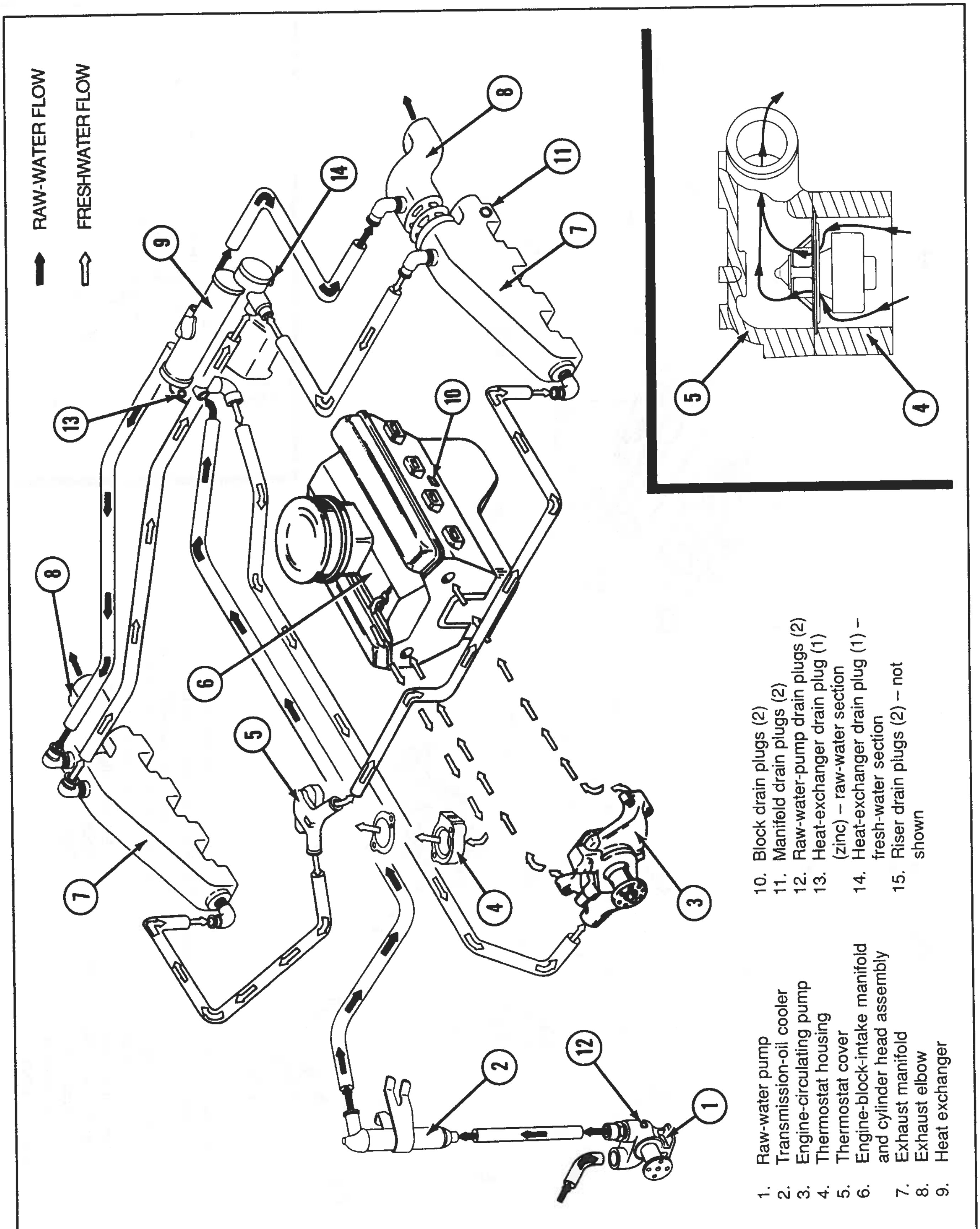


Figure 10-17. *Engine Models 229, 262, 305, And 350 CID Fresh-Water-Cooled Systems with Rear-Mounted Heat Exchanger*

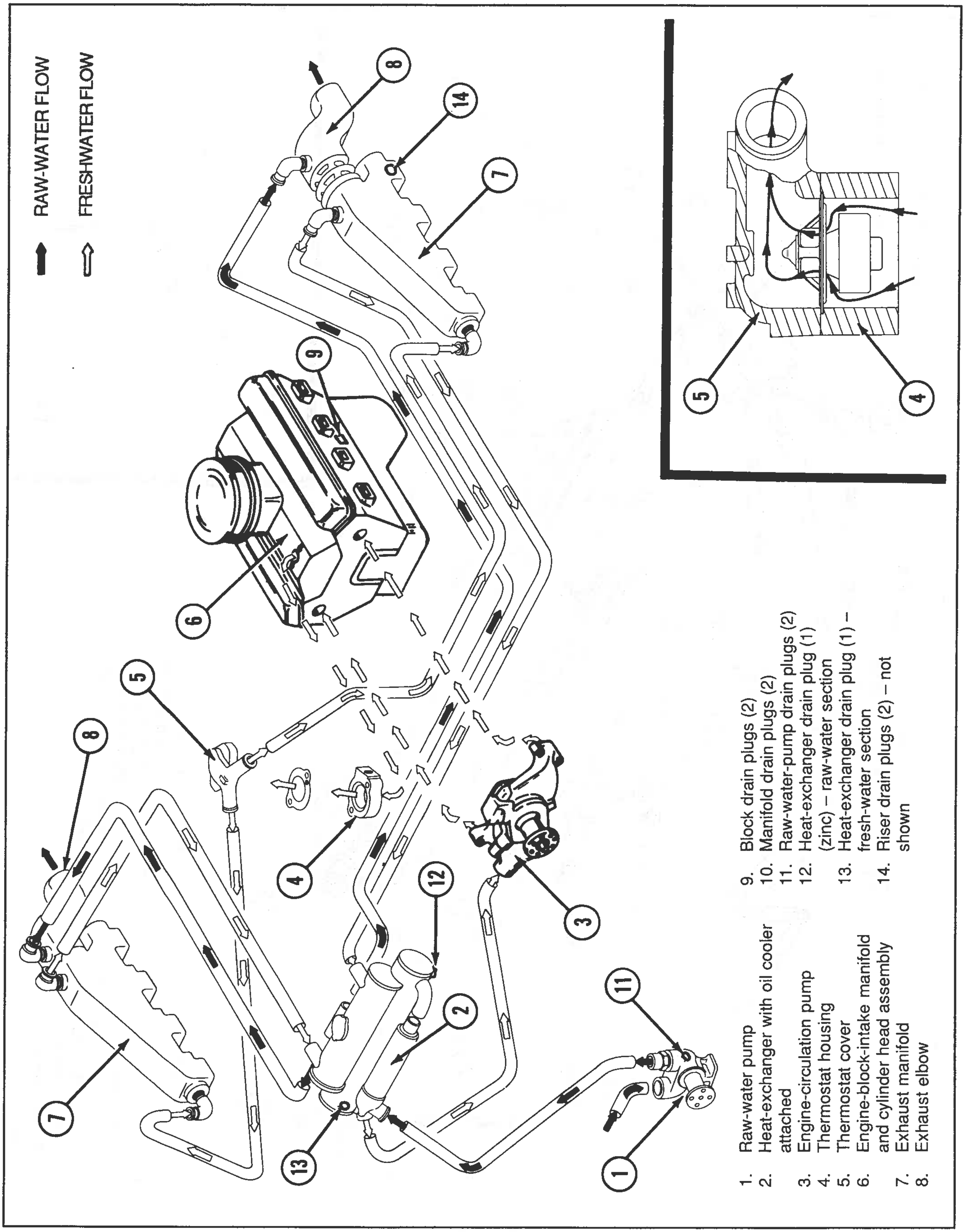


Figure 10-18. *Engine Models 262, 305, And 350 CID Fresh-Water-Cooled Systems With Front-Mounted Heat Exchanger*

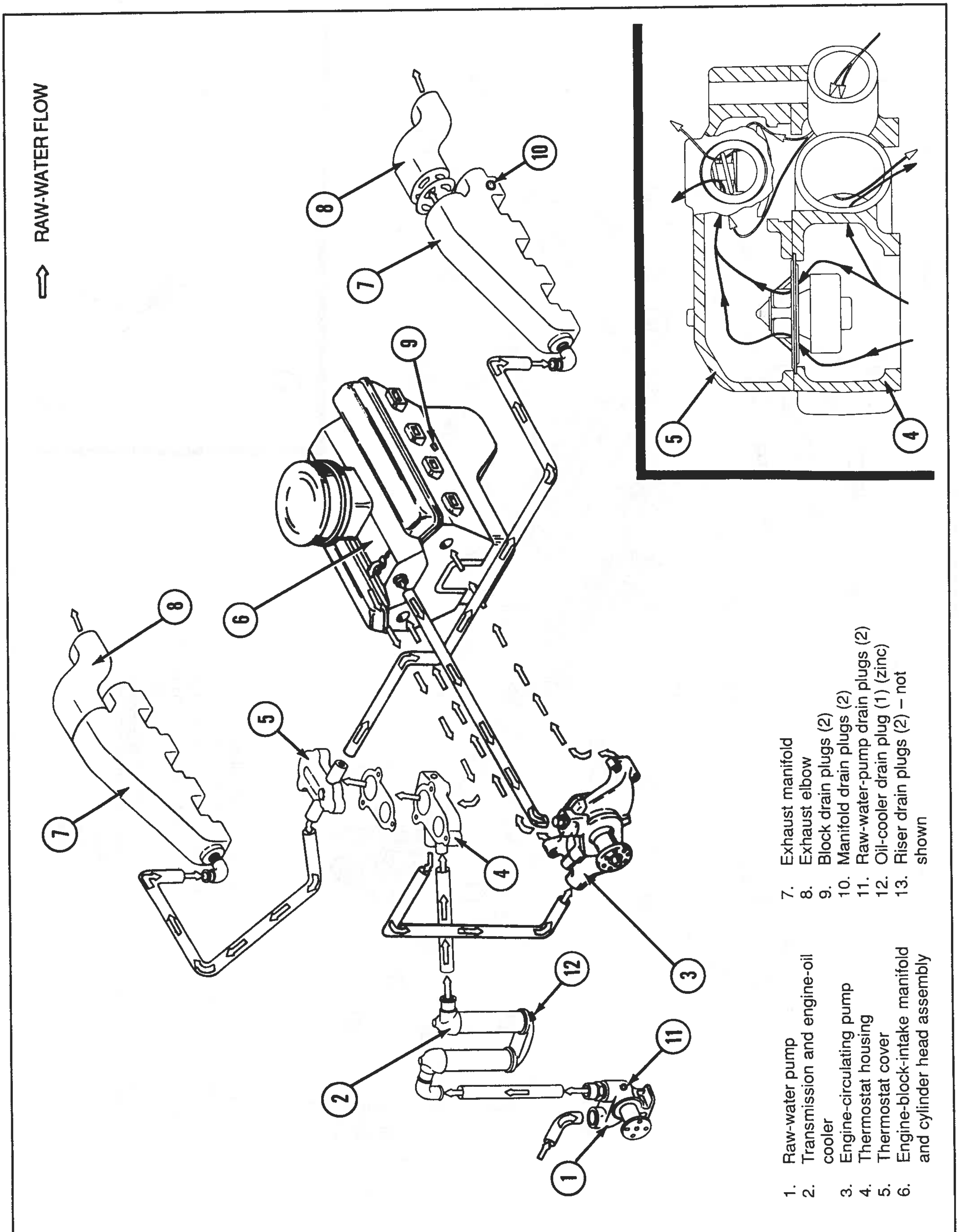


Figure 10-19. *Engine Models 454 And 502 CID Raw-Water-Cooled Systems*

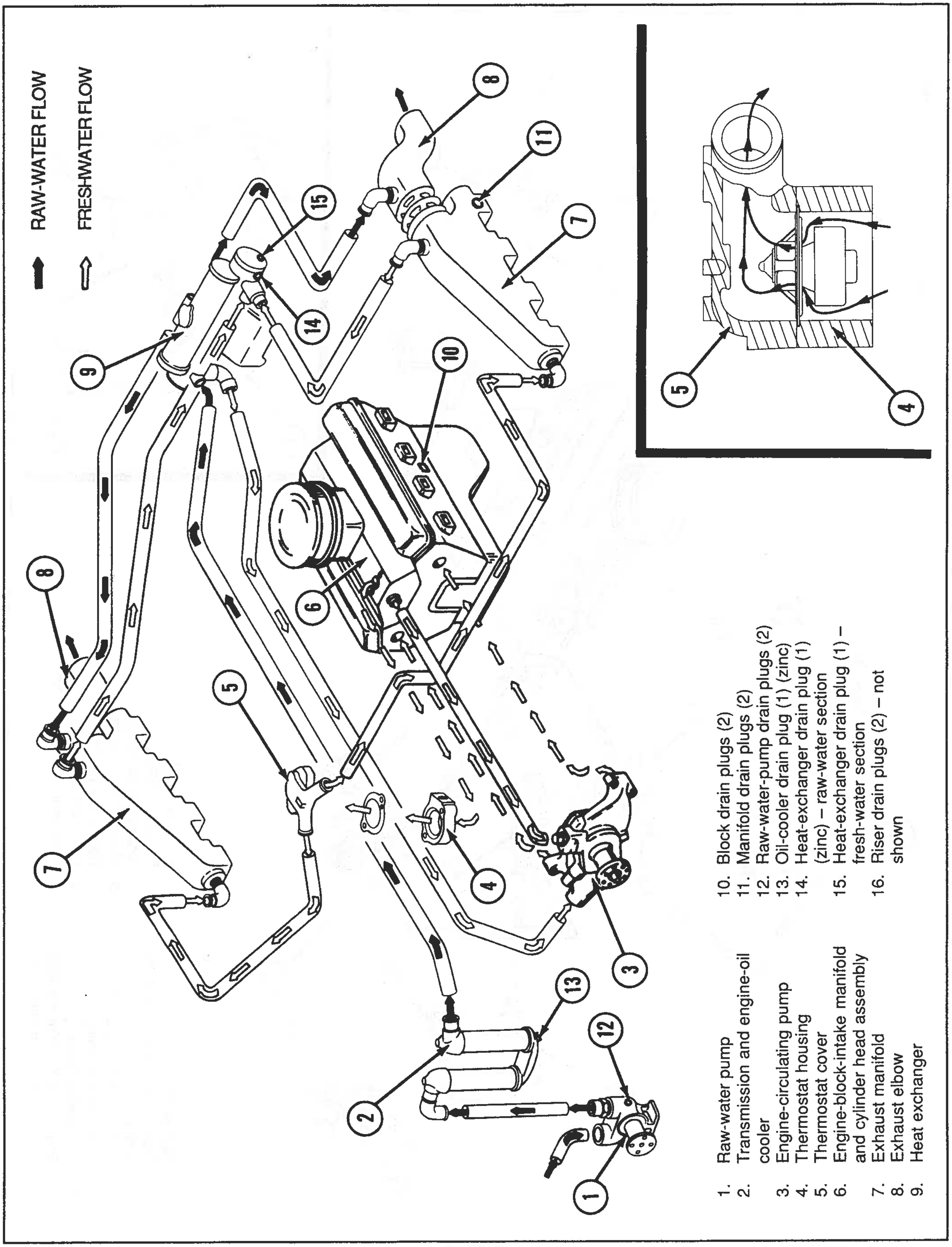


Figure 10-20. *Engine Models 454 And 502 CID Fresh-Water-Cooled Systems With Rear-Mounted Heat Exchanger*

Section 11

Drive System

BLANK

11 DRIVE SYSTEM

Observe the following Warnings and Cautions whenever working on the engine.

WARNING

Always disconnect battery cables from battery, negative terminal first, **before** performing any disassembly/reassembly procedures on the engine.

WARNING

To prevent the possibility of a **FIRE**, be sure that the engine compartment is well ventilated and that there are no gasoline vapors present.

WARNING

Make sure that no fuel leaks exist before closing engine hatch.

11.1 TRANSMISSION

CAUTION

Do not start or crank engine without fluid in transmission.

Freewheeling of one propeller (in a twin-engine boat) at trolling speeds, will not cause damage to the transmission. Avoid operation above trolling speed with one propeller freewheeling. Be sure proper fluid level exists before freewheeling propeller.

Use only recommended fluid in transmission.

CAUTION

Except in an emergency, never shift transmission at engine speeds above 1000 rpm.

CAUTION

Do not paint shift-lever-poppet ball and spring. An accumulation of paint here will prevent proper action of the detent.

CAUTION

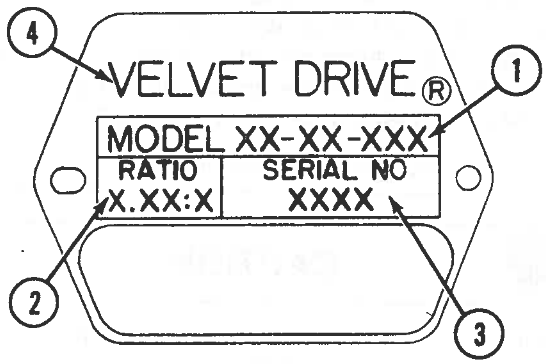
Always flush or replace oil cooler and hoses after a transmission failure or prior to installing a new or rebuilt transmission. Metallic particles from a failure tend to collect in the cooler and hoses and will gradually flow back into the fluid system and damage transmission.

CAUTION

Shift controller and shift cable must position transmission shift lever exactly as stated in Sections 2.1 and 2.2, Engine Installation and Removal. If transmission is damaged as a result of improper shift-lever positioning, it will not be covered by the Warner Gear warranty.

Identification:

The transmission-identification plate (Figure 11-1) is located on the top left side of the transmission. Refer to the following charts to determine engine and transmission combinations:



1. Model number
2. Ration (in forward)
3. Serial number
4. Identification-plate model-color code

Figure 11-1. *Transmission Identification Plate*

Transmission-output-shaft rotation and propeller rotation required is indicated on a decal on the transmission case. Transmission rotation is described when viewed from the rear of transmission with transmission in forward-gear-selector position.

Propeller rotation is described when observed from the rear of the boat (stern) looking forward (bow end). The term "left-hand" (LH) refers to rotation in the counterclockwise (CCW) direction. The term "right-hand" (RH) refers to rotation in the clockwise (CW) direction. A LH propeller will move the boat forward when rotated counterclockwise. Propeller rotation is not necessarily the same as engine rotation.

On engines which are equipped with V-drive transmissions, transmission-output-shaft rotation is the same as engine rotation with transmission in forward gear. Because of reversed engine-mounting positions, however, a RH propeller is required if engine has a (CCW) rotation. A LH-rotation propeller is required if engine has a (CW) rotation.

262/305/350 CID ENGINE MODELS AND WARNER TRANSMISSION COMBINATIONS			
Ratio in Forward Gear[1]	**Identification Plate Color Code**	**Warner Gear Model Number**	**Crusader Marine Part Number**
1:1	Red	10-17-000-004	25471
1.52:1	Red	10-17-000-006	9001545
1.88:1[2]	Red	10-17-000-108	25514
1.91:1[2]	Red	10-17-000-008	9001541
2.57:1	Red	10-17-000-012	1001512
2.91:1	Red	10-17-000-014	1001513

NOTES: [1] Ratio is shown on identification plate. Ratio may be rounded off in some cases.

[2] The propeller shaft will turn opposite to the engine rotation (when in forward gear) on this transmission.

262/305/350 CID ENGINE MODELS WITH WARNER V-DRIVE TRANSMISSION COMBINATIONS			
Ratio in Forward Gear[1]	**Identification Plate Color Code**	**Warner Gear Model Number**	**Crusader Marine Part Number**
1:1	Red	10-04-000-009	25448
1.51:1	Red	10-04-000-011	25447
1.99:1	Red	10-04-000-002	25450
2.49:1	Red	10-04-000-005	25451
3.14:1	Red	10-04-000-007	25452

NOTE: [1] Ratio is shown on identification plate. Ratio may be rounded off in some cases.

454/502 CID ENGINE MODELS AND WARNER TRANSMISSION COMBINATIONS			
Ratio in Forward Gear[1]	**Identification Plate Color Code**	**Warner Gear Model Number**	**Crusader Marine Part Number**
1:1	Green	10-18-000-002	9001517
1.52:1	Green	10-18-000-004	9001518
1.88:1[2]	Green	10-18-000-106	25515
1.91:1[2]	Green	10-18-000-006	9001519
2.57:1	Green	10-18-000-010	9001520
2.91:1	Green	10-18-000-012	9001521

NOTES: [1] Ratio is shown on identification plate. Ratio may be rounded off in some cases.
[2] The propeller shaft will turn opposite to the engine rotation (when in forward gear) on this transmission.

262/305/350 CID ENGINE MODELS WITH WARNER V-DRIVE TRANSMISSION COMBINATIONS			
Ratio in Forward Gear[1]	**Identification Plate Color Code**	**Warner Gear Model Number**	**Crusader Marine Part Number**
1:1	Green	10-05-000-009	25453
1.51:1	Green	10-05-000-011	25445
1.99:1	Green	10-05-000-002	25446
2.49:1	Green	10-05-000-005	25455
3.14:1	Green	10-05-000-007	25456

NOTE: [1] Ratio is shown on identification plate. Ratio may be rounded off in some cases.

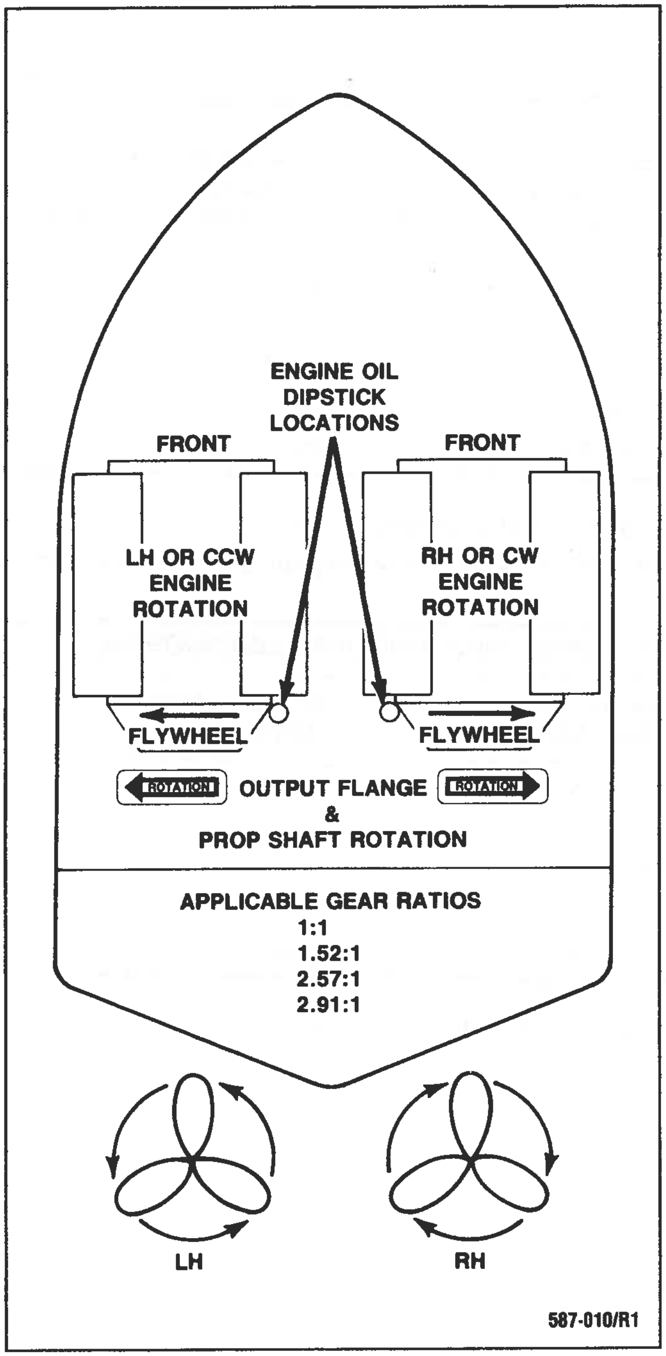


Figure 11-2. *Engine, Borg-Warner In-Line and Propeller Rotations*

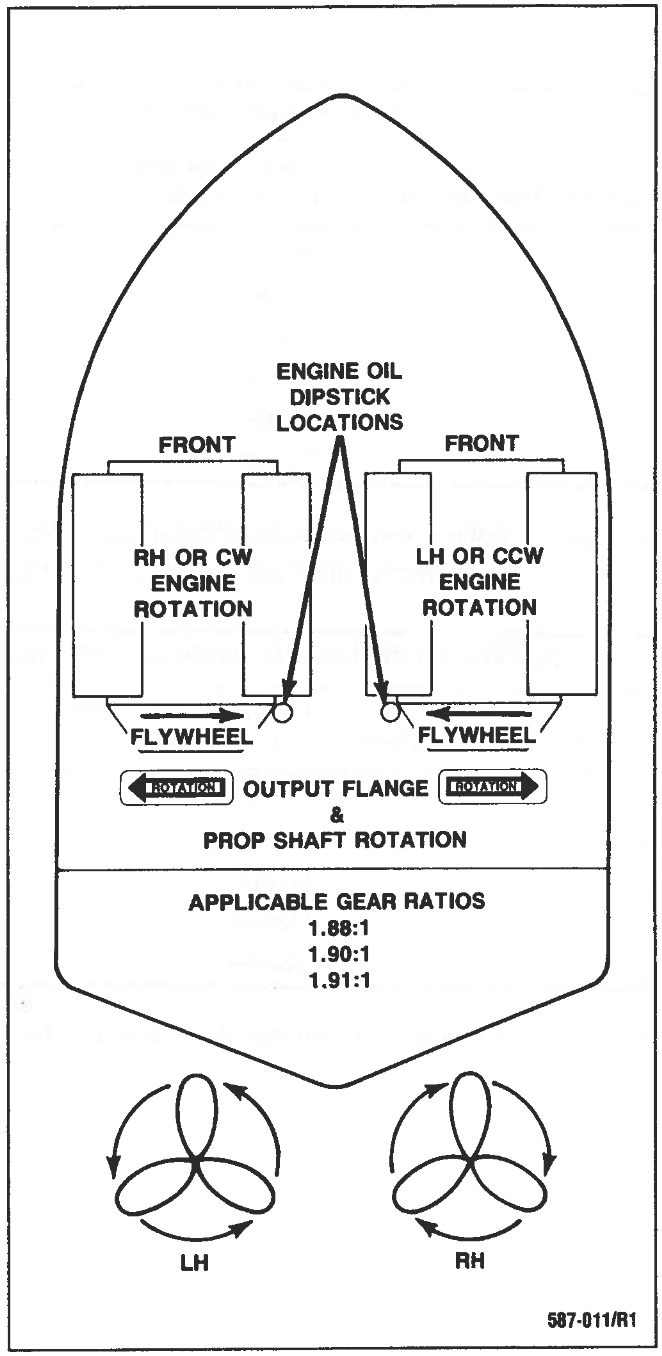


Figure 11-3. *Engine, Borg-Warner and Propeller Rotations*

Typical Borg-Warner In-line Installations:

On engines equipped with Borg-Warner In-line transmissions having 1:1, 1.52:1, 2.57:1, or 2.91:1 gear ratios, the engine rotation is the same as transmission output shaft rotation. A LH (CCW) rotation engine requires a LH propeller and a RH (CW) rotation engine requires a RH propeller.

On engines equipped with Borg-Warner In-line transmissions having 1.88:1, 1.90:1, or 1.91:1 gear ratios, the engine rotation is the opposite of the transmission output shaft rotation. A LH (CCW) rotation engine requires a RH propeller and a RH (CW) rotation engine requires a LH propeller.

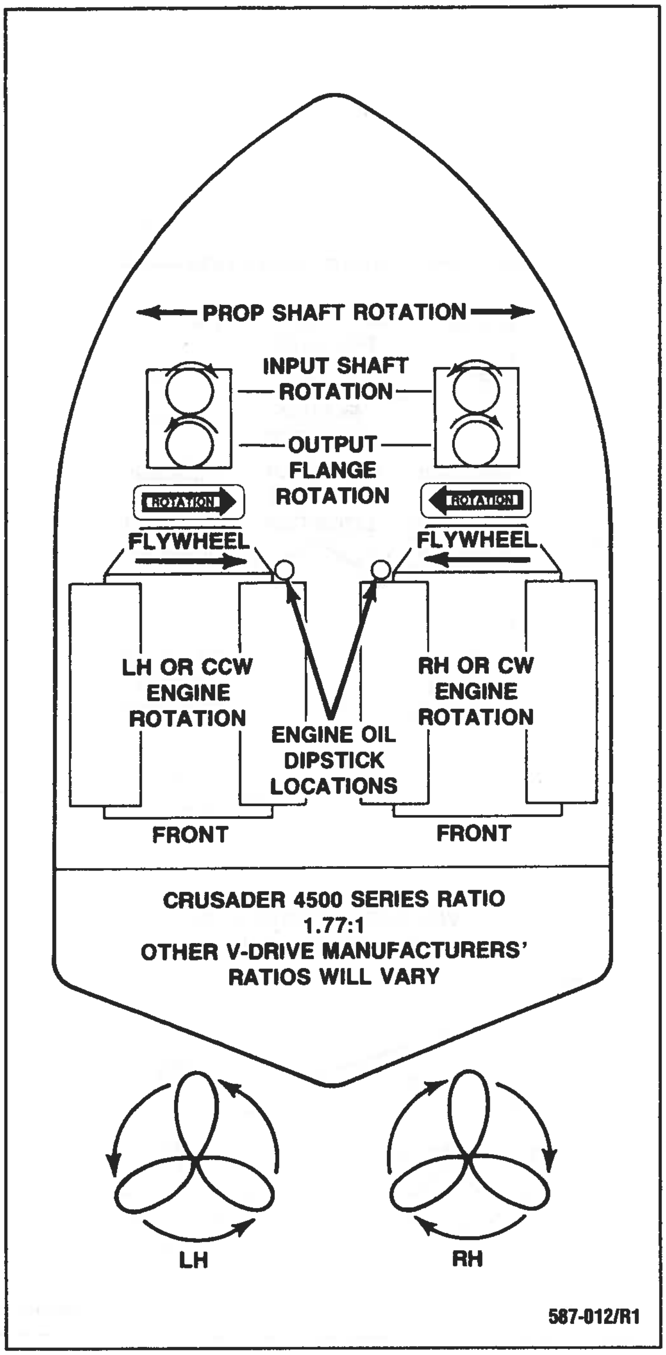


Figure 11-4. *Engine, Remote V-Drive and Propeller Rotations*

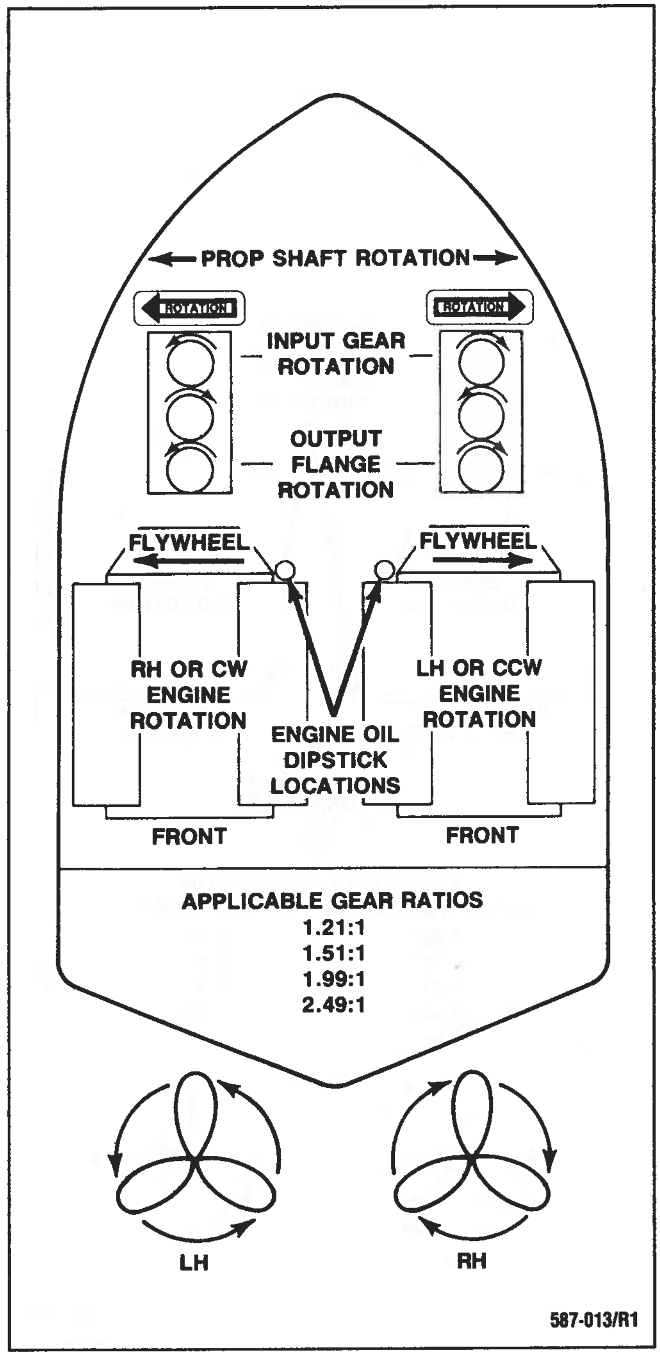


Figure 11-5. *Engine, Borg-Warner V-Drive and Propeller Rotations*

Typical Remote V-Drive Installation:

On engines equipped with Borg-Warner direct drive transmissions and driving a remotely mounted V-Drive, the engine rotation is opposite the remote V-Drive output flange rotation. However, the reversed engine mounting requires that a LH (CCW) rotation engine use a LH propeller and a RH (CW) rotation engine requires a RH propeller.

Typical Borg-Warner V-Drive Installation:

On engines equipped with Borg-Warner V-Drive transmissions having the following gear ratios, 1.21:1, 1.51:1, 1.99:1, and 2.49:1, the engine rotation is the same as transmission output shaft rotation. However, the reversed engine mounting requires a LH (CCW) rotation engine to use a RH propeller and a RH (CW) rotation engine requires a LH propeller.

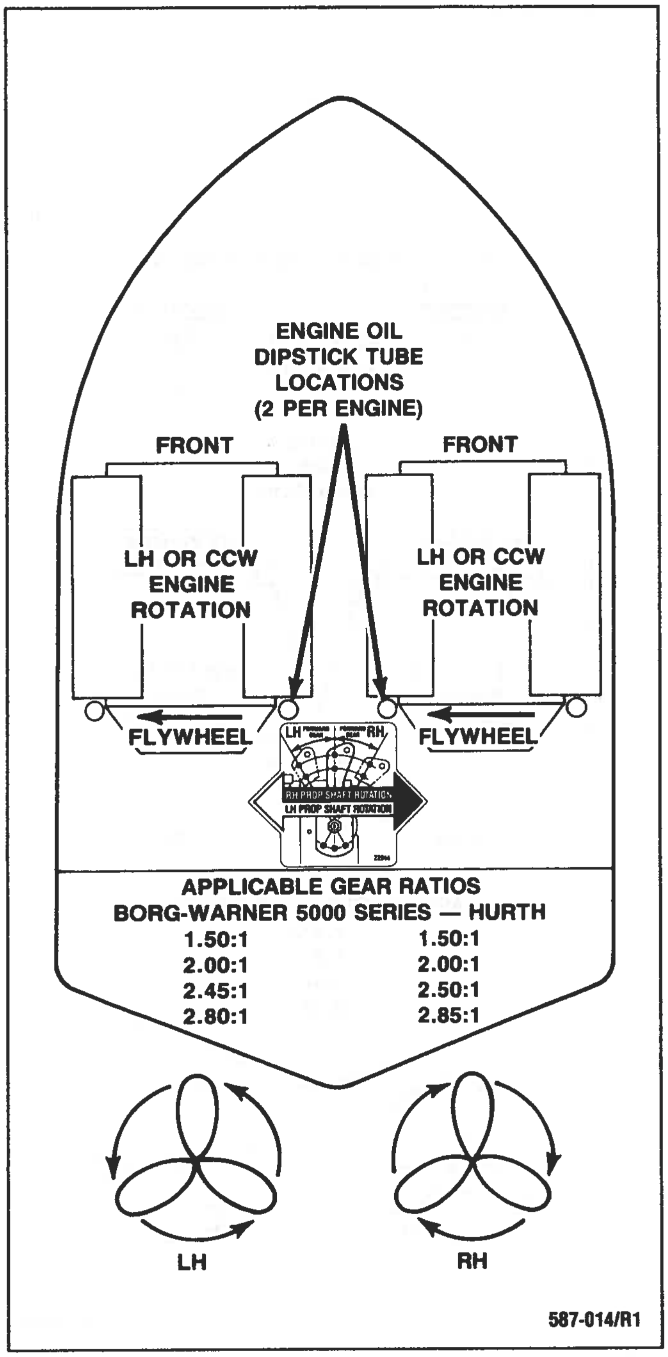


Figure 11-6. *Engine, Borg-Warner 5000 and Propeller Rotations*

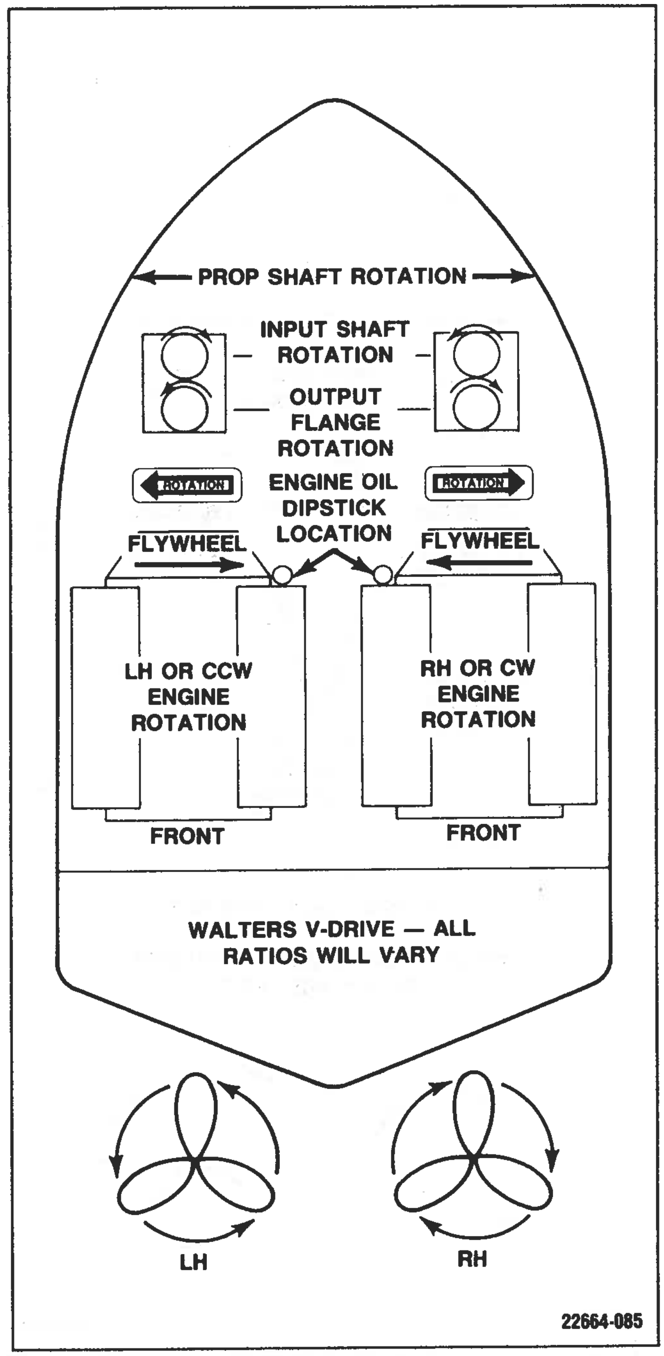


Figure 11-7. *Engine, Integral Walters V-Drive and Propeller Rotations*

Typical Borg-Warner 5000 Series and Hurth Installation:

On engines equipped with Borg-Warner 5000 series and Hurth transmissions, the engine rotations are the same (LH or CCW) and the output flange rotation is determined by shift cable attachment to remote control.

Typical Integral Walters V-Drive Installation:

On engines equipped with Borg-Warner direct drive transmissions and Walters V-Drive, the engine rotation is opposite the V-Drive output flange rotation. However, the reversed engine mounting requires that a LH (CCW) rotation engine use a LH propeller and a RH (CW) rotation engine requires a RH propeller.

Specifications:

TRANSMISSION FASTENERS TORQUE SPECIFICATIONS	
Fastener Location	**Torque lb-ft (N•m)**
Drain plug (bushing)	25 (34)
Fluid hose to bushing	25 (34)
Pump housing to adapter	17-22 (23-30)
Rear mounts to transmission	45 (61)
Shift lever to valve	8-11 (11-15)
Transmission to flywheel housing	50 (68)
Neutral-start switch	8-15 (11-20)

PRESSURE SPECIFICATIONS – TRANSMISSIONS USING BLACK SPRING (PART NO. 71-242)				
Engine rpm	**Neutral gear psi (kPa)**		**Forward or reverse gear psi (kPa)**	
	Min.	**Max.**	**Min.**	**Max.**
500	115 (793)	135 (931)	115 (793)	135 (931)
2000			125 (862)	160 (1103)

PROPELLER SHAFT FASTENERS TORQUE SPECIFICATIONS	
Fastener Location	**Torque lb-ft (N•m)**
Propeller-shaft coupling to transmission coupling	50 (68)

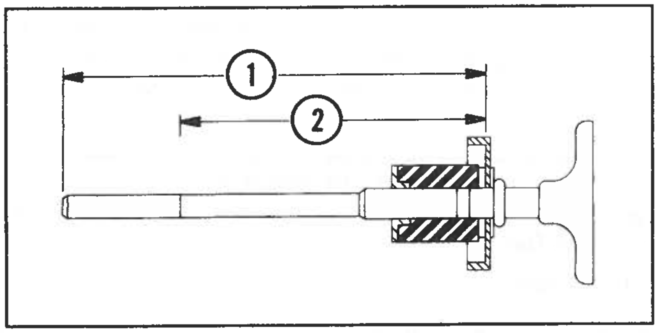


Figure 11-8. *Transmission Dipstick (See the Transmission Dipstick Specifications table below for number explanation.)*

TRANSMISSION DIPSTICK SPECIFICATIONS				
Transmission Model	**Dipstick Part No.**	**Dimension 1**	**Dimension 2**	**I.D. Color**
Units with prefix 10-17 and 10-18 and 1.51:1 through 2.49:1 reduction	25457	4.49 in. (114 mm)	3.24 in. (82 mm)	Plain
Units with prefix 10-17 and 10-18 and 1:1 reduction (Direct Drive)	25509	4.62 in. (117 mm)	3.50 in. (89 mm)	Yellow
V-drive units[1]	25461	5.50 in. (139 mm)	4.23 in. (107 mm)	Purple

NOTE: [1] When servicing or repairing any V-drive transmission which has the dipstick located in the V-drive case, check the dimensions of the dipstick and, if necessary, recalibrate as shown in Figure 11-8. New dipstick specifications were issued by Borg-Warner in 1987 to provide for additional oil capacity of V-drive transmissions.

TRANSMISSION FLUID CAPACITIES	
Transmission Type	**Capacity (approx.)**
Transmission 1:1	2 qt. (1.9 L)
Transmission 1.5:1-3.0:1	3 qt. (2.8 L)
Transmission V-drive	4.5 qt. (4.3 L)

NOTE: In all Velvet® Drive marine transmissions, use Dexron® II, or other hydraulic transmission fluids which meet the Detroit Diesel Allison Type C3 specifications.

SEALANTS/LUBRICANTS
Perfect Seal
RTV Sealer
High-temperature grease

TRANSMISSION REMOVAL

NOTE: The following procedure describes removal of transmission without removing engine. If engine must be removed, refer to Section 2, Engine Removal and Installation.

1. Drain transmission fluid.
2. Disconnect fluid-cooler hoses.
3. Disconnect shift cable.
4. Disconnect wires from neutral-start-safety switch.
5. Disconnect wire from transmission-alarm switch.
6. Disconnect propeller-shaft coupling.
7. Remove four rear mount-to-engine-bed bolts.
8. Support rear part of engine with either a hoist or by using wooden blocks under flywheel housing.
9. Remove transmission-attaching bolts and nuts.
10. Pull transmission straight back and off engine.

TRANSMISSION MAJOR REPAIR AND OVERHAUL

Complete overhaul manuals for Warner Transmissions and V-Drives may be obtained by writing to:

Borg-Warner
Marine and Industrial Transmissions
Theodore Rice Boulevard Industrial Park
New Bedford, Massachusetts 02745

Include transmission model and serial number.

PUMP INDEXING

Pump must be correctly indexed to correspond with engine rotation. If pump is not indexed correctly, it will not create oil pressure and transmission will not shift. Pump housing has two arrows, each pointing in a different direction. Pump must be positioned so that the arrow is at the top of transmission, pointing in the direction that the input shaft and pump will be turned by engine.

IMPORTANT: Some transmissions have letters "RH" and "LH" on pump housing. Letters do not indicate engine rotation.

If pump must be reindexed, proceed as follows:

1. Remove four pump-attaching bolts.
2. Loosen pump housing. A soft-tip mallet may be used to tap the fluid-passage boss. Do not strike the bolt bosses.

IMPORTANT: Do not remove the pump from the shaft unless a seal protector is used to prevent the shaft splines from cutting the pump seal. Care must be taken to ensure that seal, gasket, and seal and bolt bosses are kept in good condition to prevent leaks in those critical areas.

3. Make sure that pump gasket is not sticking to housing to avoid tearing or folding gasket when rotating pump.
4. Rotate pump until arrow indicating the proper direction of pump rotation is near the top of transmission.
5. Reinstall four pump-to-adapter-attaching bolts and torque to 204-264 lb-in (23-30 N•m).

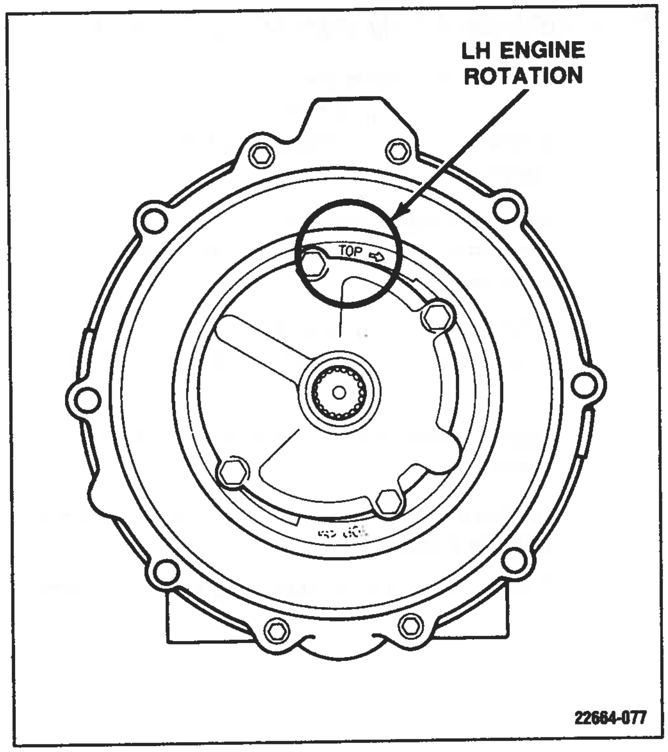


Figure 11-9. *Transmission Pump Indexing LH-(Standard) Rotation Engines*

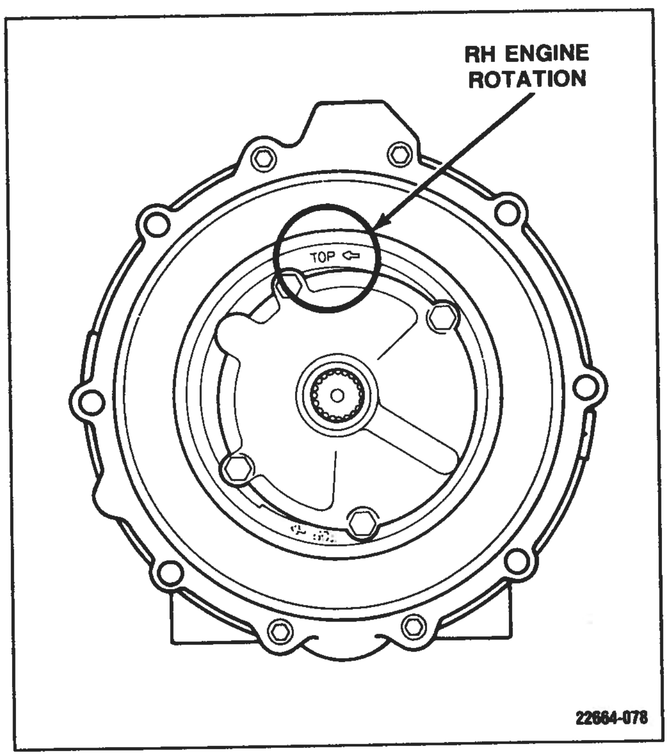


Figure 11-10. *Transmission Pump Indexing RH-(Opposite) Rotation Engines*

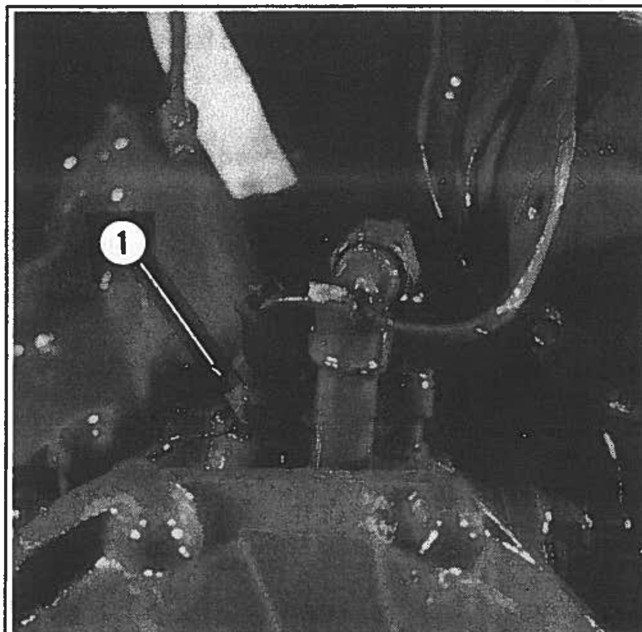
TRANSMISSION INSTALLATION

1. Before installing transmission, check transmission pump indexing for correct rotation. Refer to "Pump Indexing" in this section.
2. Apply high-temperature lubricant to transmission input shaft splines and engine drive-plate splines.
3. If removed, install rear engine-mounting brackets to transmission. Torque to 45 lb-ft (61 N•m).
4. Align transmission splines with drive-plate splines.
5. Slide transmission into place and secure with bolts and nuts.
6. Torque all nuts and bolts to 50 lb-ft (68 N•m).

PRESSURE TEST

1. Install pressure gauge as shown in Figure 11-11.

NOTE: Models with audio warning system remove temperature switch. Models without switch remove 3/8 in. pipe plug.



1. Main-line pressure tap

Figure 11-11. *Main-Line Pressure Tap*

2. With boat in water, start engine and run until normal operating temperature is reached.
3. Refer to "Specifications" at the beginning of this section for proper pressure readings.

11.2 VIBRATION PROBLEMS

NOTE: The following information can be used as a guide for determining vibration problems on boats powered by inboard engines.

For installation, alignment, and repairs to shafts, struts, shaft logs, and rudders, refer to boat manufacturer's service manual. If boat is equipped with a remote-mounted V-Drive, refer to V-Drive or boat manufacturer's service manual for all servicing and troubleshooting. For engine installation and alignment, refer to Sections 2.1 and 2.2, Engine Removal and Installation.

Checks Made While Boat Is In Water:

1. Disconnect propeller-shaft coupling from transmission coupling.
2. Check fit of coupling to propeller shaft.

   Straight-Bore Type

   a. Loosen set screws.
   b. Try to move coupling by hand. The bore of the coupling should be a semi-press fit to shaft.
   c. Check the shaft for wear. If it is worn, replacement of shaft may be necessary.
   d. If shaft is not worn, try another coupling.

   Tapered-Bore Type

   a. Check nut on shaft for tightness.
   b. If nut is loose, removing coupling and check for damage to taper on shaft or in coupling.
   c. Replace worn parts.
   d. Always make sure key is not sticking out of coupling.
   e. Install coupling on shaft without the key.
   f. Mark the shaft behind the coupling; then remove the coupling.
   g. Now install the key and coupling. Make sure coupling still lines up with the mark. This ensures that key is not oversized and holding the tapers apart.
3. Check out coupling flange of transmission (see Figures 11-12 and 11-13).
4. If there is movement in Step 3, replace output coupling.
5. Replace damaged parts and realign engine as described in Sections 2.1 and 2.2, Engine Removal and Installation.

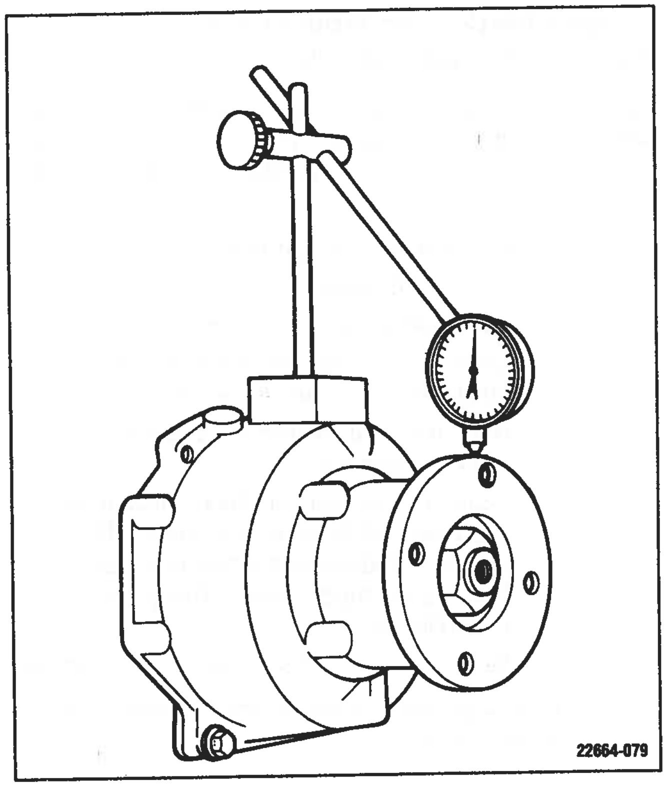


Figure 11-12. Checking Coupling Outside Diameter – Rotate One Complete Turn

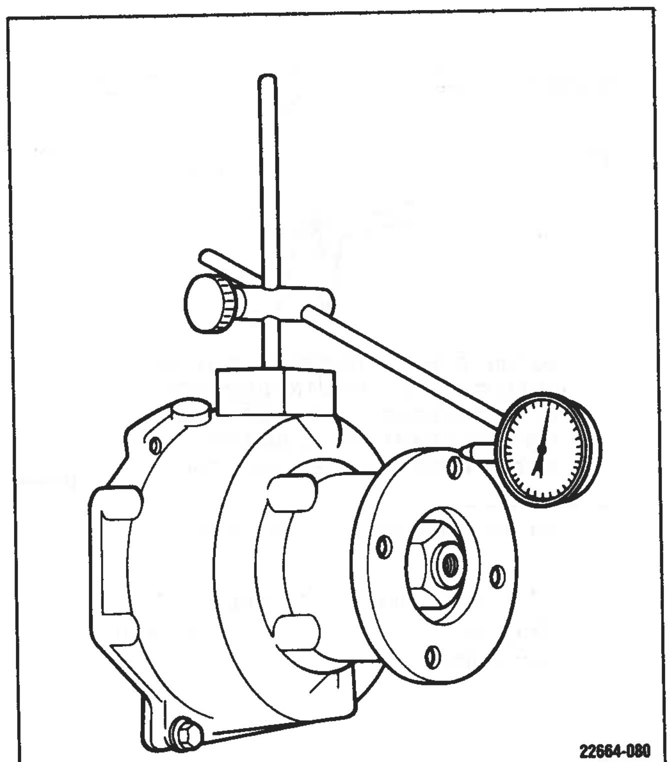


Figure 11-13. Checking Coupling Face – Rotate One Complete Turn

Checks Made with Boat Out of Water and Shaft Installed:

Possible causes for vibration may be propeller shaft, propeller-to-shaft fit, or propeller. All three can be checked by using the rudder, a strong metal straightedge and a C-clamp.

1. Check installation of propeller to shaft.
   a. Remove propeller.
   b. Install propeller on shaft without key.
   c. Check for chipped or cracked keyway in propeller and shaft without key.
   d. Mark the shaft behind the propeller; then remove propeller.
   e. Install the key and propeller. Make sure propeller still lines up with mark. This ensures that key is not oversized and holding the tapers apart. Retighten propeller nut.
   f. Be sure key is not sticking out of propeller.
2. Check propeller shaft being bent behind the strut (Figure 11-14).

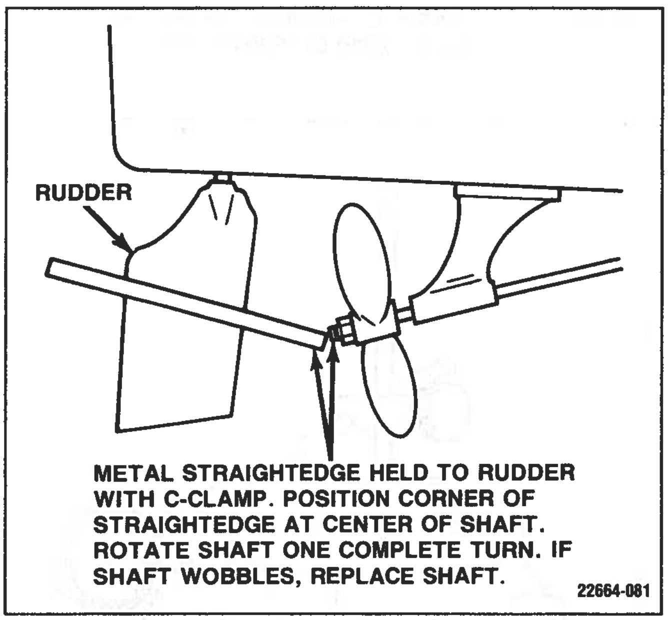


Figure 11-14. Checking For Bent Shaft

3. Check the radius of all propeller blades (Figure 11-15). If not the same, repair propeller.

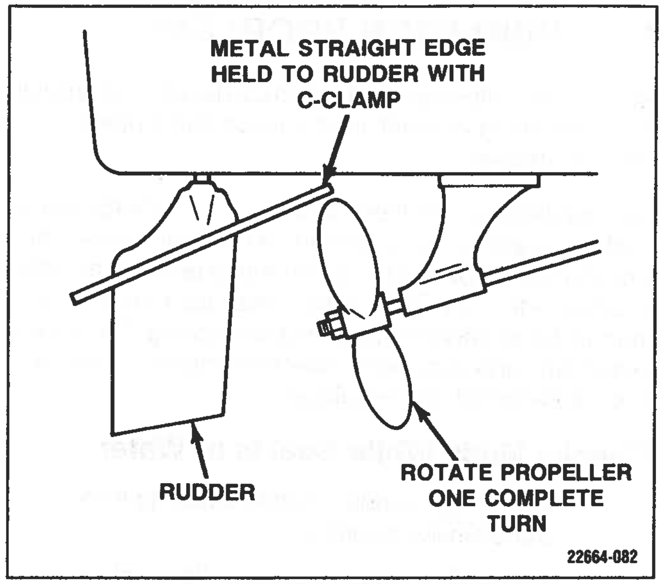


Figure 11-15. Checking Propeller Diameter

4. Check that all propeller blades are the same pitch and that propeller is properly seated on shaft (Figure 11-16). Repair or replace if necessary.

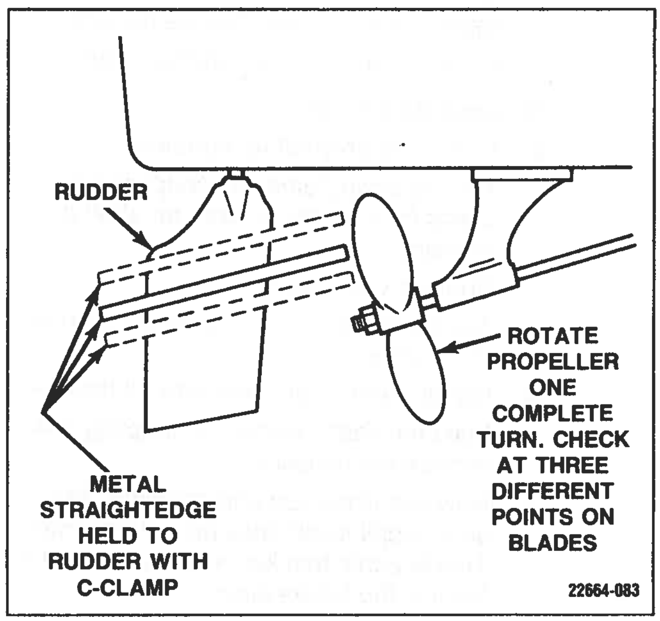
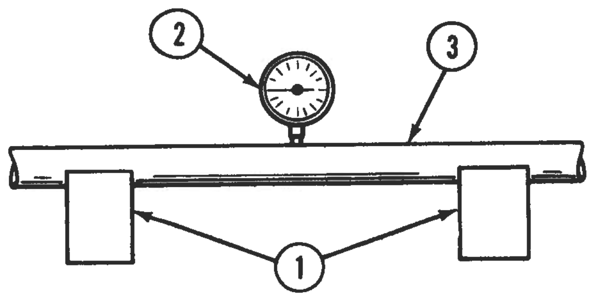


Figure 11-16. Checking Propeller Pitch And Seating

Checks Made with Propeller Shaft Removed:

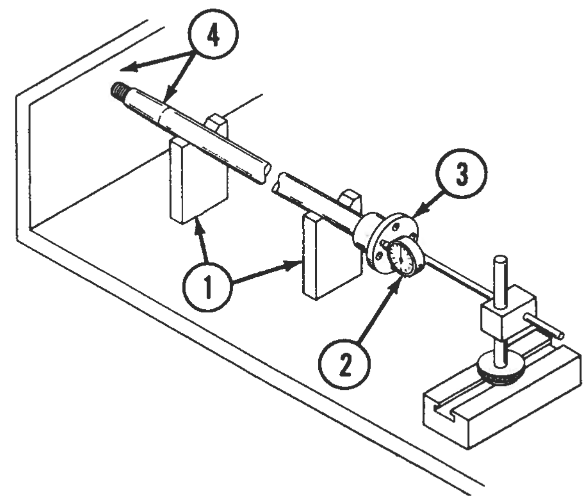
1. Check propeller shaft for straightness (Figure 11-17). Check at 3 or 4 places. Replace or straighten shaft if more than 0.04 in. (0.10 mm) from straight.



1. Vee blocks
2. Dial indicator
3. Shaft – rotate one complete turn

Figure 11-17. *Checking For Bent Shaft*

2. Check that the bore of the coupling is 90° from coupling flange (Figure 11-18). Replace coupling if needle moves.



1. V-blocks
2. Dial indicator
3. Coupling flange – rotate one complete turn
4. Shaft against block to prevent fore and aft movement

Figure 11-18. *Checking Coupling Bore*

Strut:

Refer to boat manufacturer's service manual for alignment and replacement. Normally, the shaft should be centered in the cutlass bearing. Shims placed between the strut and hull are used to align the strut to the shaft.

BLANK