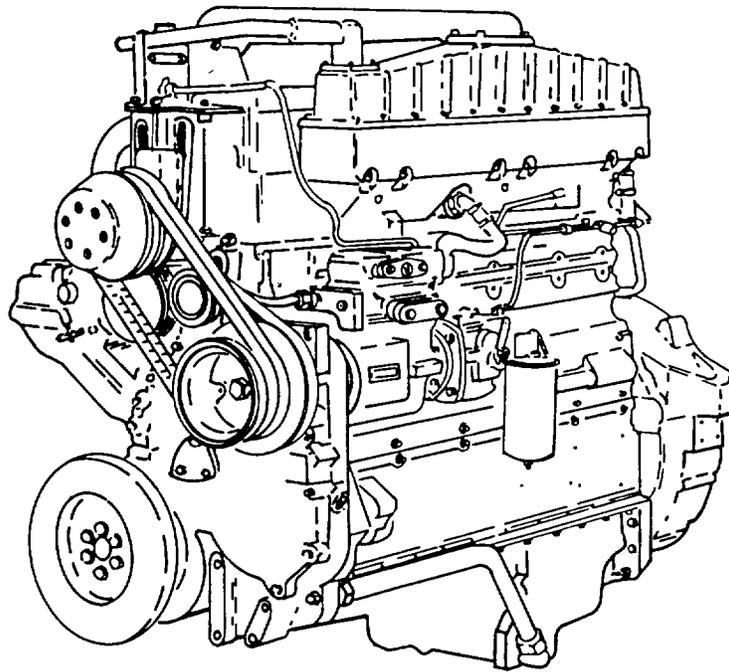


This copy is a reprint which includes current pages from Change i.

**DIRECT SUPPORT AND GENERAL SUPPORT  
MAINTENANCE MANUAL  
FOR**



**ENGINE, DIESEL, 6 CYLINDER  
INLINE, TURBOCHARGED,  
CUMMINS MODEL NTC-400 BC2  
NSN 2815-01-156-6210**

**HEADQUARTERS, DEPARTMENT OF THE ARMY**

**SEPTEMBER 1985**

CHANGE  
NO. 1

HEADQUARTERS  
DEPARTMENT OF THE ARMY  
WASHINGTON, D.C.  
10 APRIL 1987

Direct Support and General Support  
Maintenance Manual

**ENGINE, DIESEL, 6 CYLINDER  
INLINE, TURBOCHARGED  
CUMMINS MODEL NTC-400 BC 2**

(2815-01-156-6210)

TM 9-2815-226-34, September 1985 is changed as follows:

1. Remove old pages and insert new pages as indicated below.
2. New or changed material is indicated by a vertical bar in the margin of the page.
3. Added or revised illustrations are indicated by a vertical bar adjacent to the illustration identification number.
4. The purpose of Change 1 to this manual is to identify configuration differences between the 1980, 1982, and 1984 models. Model designators can be determined by viewing the data plate on your truck chassis.

Remove Pages	Insert Pages	Remove Pages	Insert Pages
i	i	3-139 and 3-140	3-139 and 3-140
ii	ii	3-151 and 3-152	3-151 and 3-152
1-1 thru 1-4	1-1 thru 1-4	3-155 and 3-156	3-155 and 3-156
1-5/(1-6 blank)	1-5 and 1-6	3-177 thru 3-180	3-177 thru 3-180
3-29 thru 3-34	3-29 and 3-34	INDEX-1 and INDEX-2	INDEX-1 and INDEX-2
3-37 and 3-38	3-37 and 3-38		
3-53 thru 3-56	3-53 thru 3-56		
3-65 thru 3-68	3-65 thru 3-68.1/ (3-68.2 blank)		
3-133 and 3-134	3-133 and 3-134		

File this change sheet in front of the publication for reference purposes.

By Order of the Secretary of the Army:

Official:

JOHN A. WICKHAM, JR.  
*General, United States Army*  
*Chief of Staff*

R.L. DILWORTH  
*Brigadier General, United States Army*  
*The Adjutant General*

Distribution:

To be distributed in accordance with DA Form 12-38 (block 0128), direct and general support maintenance requirements for Truck Chassis, Direct Support Section, RC25-64.

**WARNING**

**EXHAUST FUMES**

**The following precautions must be observed to ensure the safety of personnel when the engine of any vehicle is operated:**

1. DO NOT operate personnel heater or engine of vehicle in a closed place unless the place has a lot of moving air.
2. DO NOT idle engine for long periods without ventilator blower operation. If tactical situation permits, open hatches.
3. DO NOT drive any vehicle with inspection plates, cover plates, or engine compartment doors removed unless necessary for maintenance purposes.
4. BE ALERT at all times during vehicle operation for exhaust odors and exposure symptoms. If either are present, IMMEDIATELY VENTILATE personnel compartment. If symptoms persist, remove affected crew to fresh air; keep warm; DO NOT PERMIT PHYSICAL EXERCISE; if necessary, give artificial respiration and get immediate medical attention.
5. BE AWARE; neither the gas particulate filter unit nor the field protection mask for nuclear-biological-chemical protection will protect you from carbon monoxide poisoning.

**WARNING**

**COMPRESSED AIR**

**Compressed air used for cleaning purposes will not exceed 30 PSI (207 KPA). Use only with effective chip guarding and personal protective equipment (goggles, shield, gloves, etc.).**

**WARNING**

**FIRE AND EXPLOSION**

Do not use gasoline for cleaning or as fuel.

Do not get battery electrolyte on your skin, clothing, or in your eyes. It is an acid which can cause injury. Keep all sparks and flames away from batteries. The battery gas is explosive.

When disconnecting battery terminals, always disconnect the ground terminal first.

When reconnecting battery terminals, always connect the ground terminal last.

Methyl alcohol is highly flammable and poisonous, and can be absorbed through the skin. Do not drink or breathe it. If you spill any on your skin, wash it off immediately with water. Keep it away from sparks or flames.

Ether quick-start is explosive and poisonous. Do not permit canisters to be subjected to excessive heat. Do not attempt to start vehicle if ether line to engine is broken or disconnected.

When filling fuel tank with diesel fuel, be sure hose nozzle on container contacts filler tube on fuel tank to carry off static electricity. Do not smoke, permit open flame or uncovered battery compartments while you are servicing the diesel fuel system.

Dry cleaning solvent P-D-680 is toxic and flammable. Wear protective goggles and gloves and use only in well ventilated area. Avoid contact with skin, eyes, and clothes, and do not breathe vapors. Do not use near open flame or excessive heat.

**WARNING**

**EXHAUST PIPE AND MUFFLER**

During normal operation, the exhaust pipe and muffler can become very hot. Do not touch these components with your bare hands.

**WARNING**

**ENGINE COOLANT**

Take extreme care when removing engine coolant tank fill cap if temperature gage reads above 195°F (91°C), to prevent burns or serious injury.

**WARNING**

**JACKING UP TRUCK**

Hydraulic jack is intended for lifting the truck, not for supporting the vehicle when performing maintenance. To prevent serious injury, do not get under truck unless it is properly supported with blocks or jack stands.

**WARNING**

**COOLING FAN**

When working in engine compartment with the engine running, stay clear of the cooling fan. The fan may engage automatically at any time and can cause serious injury.

**WARNING**

**HOISTING TRUCK**

Direct personnel to stand clear during hoisting operation. Failure to do this may cause injury to personnel.

**DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE MANUAL  
ENGINE, DIESEL, 6 CYLINDER INLINE, TURBOCHARGED,  
CUMMINS MODEL NTC-400 BC2**

**REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS**

You can help improve this manual. If you find any mistakes or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual directly to: Commander, US Army Tank-Automotive command, ATTN: AMSTA-MBS, Warren, MI 48397-5000. A reply will be furnished to you.

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**CHAPTER 1****INTRODUCTION****Section I. GENERAL INFORMATION****1-1. SCOPE.**

- a. Type of Manual: Direct Support and General Support Maintenance.
- b. Model Number and Equipment Name: Cummins Model NTC-400 BC2, Six-Cylinder Inline, Turbocharged Diesel Engine.
- c. Purpose of Equipment: Engine for Truck Chassis, Direct Support Section, Topographic Support System (TSS).

**1-2. MAINTENANCE FORMS, RECORDS, AND REPORTS.** Department of the Army forms and procedures used for equipment maintenance will be those prescribed by DA Pam 738-750, The Army Maintenance Management System (TAMMS).

**1-3. DESTRUCTION OF ARMY MATERIAL TO PREVENT ENEMY USE.** Procedures outlined in TM 750-244-6 (Procedures for Destruction of Tank-Automotive Equipment to Prevent Enemy Use) are applicable to this equipment.

**1-4. PREPARATION FOR STORAGE OR SHIPMENT.** Instructions concerning storage or shipment of engine are found in Chapter 3, Section XXXIII of this manual.

**1-5. REPORTING EQUIPMENT IMPROVEMENT RECOMMENDATIONS (EIR).** EIR can and must be submitted by anyone who is aware of an unsatisfactory condition with the equipment design or use. It is not necessary to show a new design or list a better way to perform a procedure. Just simply tell why the design is unfavorable or why a procedure is difficult. EIR may be submitted on SF 368 (Quality Deficiency Report). Mail directly to: Commander, U.S. Army Tank - Automotive Command, ATTN: AMSTA-QR, Warren, Michigan 48397-5000. A reply will be furnished to you.

**Section II. EQUIPMENT DESCRIPTION AND DATA**

**1-6. EQUIPMENT CHARACTERISTICS, CAPABILITIES, AND FEATURES.** The following information describes engine characteristics and features:

Camshaft: 2-1/2 inch diameter gear driven camshaft which controls all valve and injector movement. Made of induction hardened alloy steel. Camshaft followers are roller type.

Connecting Rods: Drop forged, rifle drilled for pressure lubrication.

Crankshaft: High tensile strength steel forging. Bearing journals and fillets induction hardened. Fully counterweighted.

Cylinder Block: Alloy cast iron with removable, wet liners.

Cylinder Head: Each head serves two cylinders. Drilled fuel supply and return lines. High temperature inserts on exhaust valve seats.

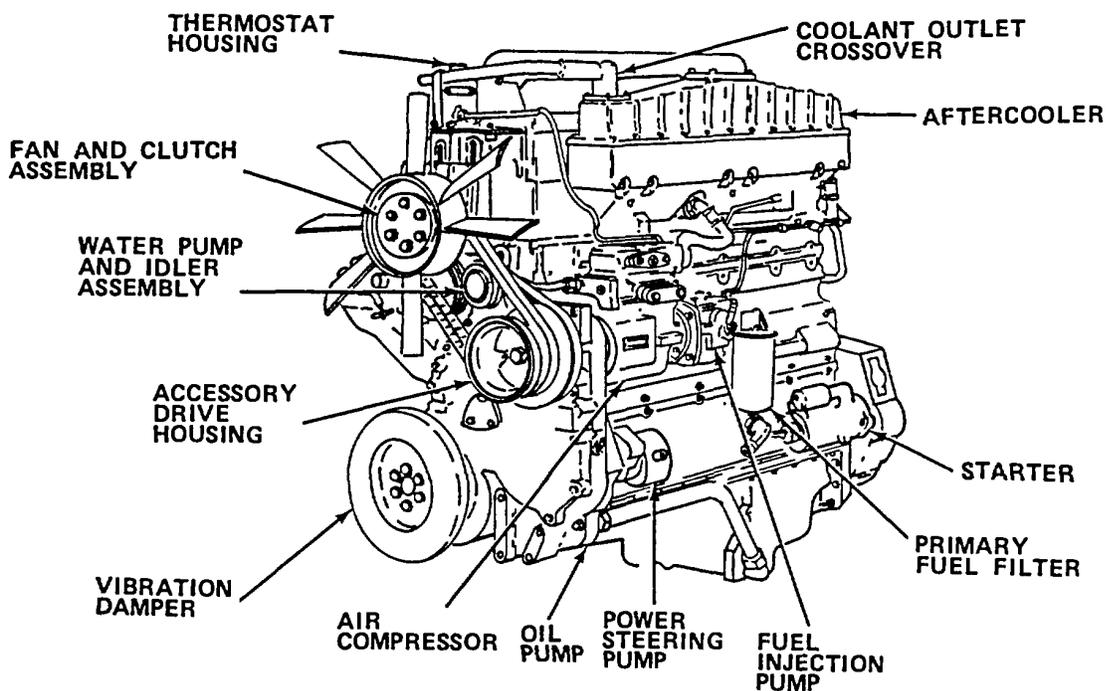
Fuel System: Integral flyweight type governor.

Injectors: Camshaft actuated top stop type.

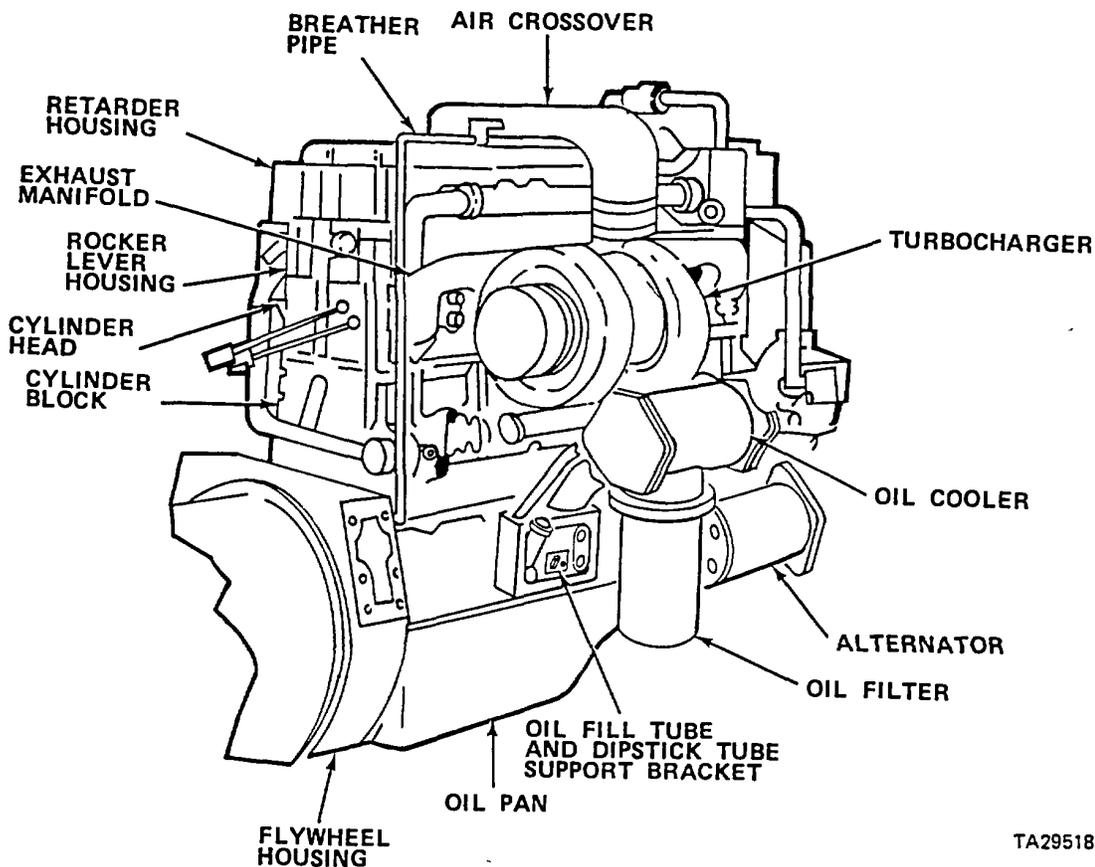
Intake Manifold: Single pass water aftercooler.

Lubricating Oil Cooler: Demand flow.

1-7. LOCATION AND DESCRIPTION OF MAJOR COMPONENTS. The illustrations below show the location of the major engine components.



TA295181



TA295182

**1-8. DIFFERENCES BETWEEN MODELS.** Configuration differences have been identified by model years. Actual manufactured dates may differ from model year date as stamped on your vehicle's data plate. To avoid confusion, Usable-on-Codes have been cross-referenced to U.S. Registration Numbers (stenciled on vehicle chassis) as shown below:

<u>U.S. Registration Number</u>	<u>Model Year</u>	<u>Usable-on-Codes</u>
NPO 8AO	1980	RCS
NPO 89Z	1980	RCS
NPO 89X	1980	RCS
NPO 8AI	1980	RCS
NPO 89W	1980	RCS
NPO 89Y	1980	RCS
NPO 89V	1980	RCS
NPO 62L	1982	RCT
NPO 62M	1982	RCT
NPO 62N	1982	RCT
NPO 62P	1982	RCT
NPO 62Q	1982	RCT
NPO 62R	1982	RCT
NPO 62S	1982	RCT
NPO 62T	1982	RCT
NPO 62U	1982	RCT
NPO 62V	1982	RCT
NPO 62W	1982	RCT
NPO 62X	1982	RCT
NPO 62Y	1982	RCT
NPO 89S	1984	RCV
NPO 89R	1984	RCV
NPO 633	1984	RCV
NPO 89Q	1984	RCV
NPO 632	1984	RCV
NPO 631	1984	RCV
NPO 630	1984	RCV
NPO 62Z	1984	RCV
NPO 89T	1984	RCV
NPO 89U	1984	RCV

**1-9. EQUIPMENT DATA**

Manufacturer	Cummins Engine Company, Inc.
Model	NTC-400 Big Cam 2 (BC2)
Type	4 stroke, turbocharged diesel, compression ignition
Dimensions:	
Length	58.88 in. (1495.55 mm)
Width	33.61 in. (853.69 mm)
Height	50.91 in. (1293.11 mm)
Net Weight, Dry	2680 lbs (1216.7 kg)
Cylinders:	
Number	6
Arrangement	Inline
Firing Order	1 - 5 - 3 - 6 - 2 - 4
Bore	5.5 in. (139.7 mm)
Stroke	6 in. (152.4 mm)
Displacement	855 cu. in. (14 l)
Compression Ratio	14:1
Fuel Consumption	150 pph @ maximum torque
Rated Speed and Power:	
Maximum Torque	1150 ft lbs @ 1500 rpm
Full Load Horsepower at Rated Speed	400 hp @ 2100 rpm
Blow-By (Breather Pressure) Maximum	12 in. (304.8 mm) water
Maximum No Load Speed	2400 rpm
Maximum Full Load Speed	2150 rpm
Idle Speed	580 - 620 rpm
Lubrication System:	
Type	Demand Flow Cooling
Operating Pressures:	
Rated Speed	35 - 45 psi (241.5 - 310.5 kPa)
Peak Torque (Minimum Pressure)	30 psi (207 kPa)
Idle Speed	10 - 32 psi (69 - 220 kPa)
Oil Temperature Maximum	250°F (121°C)

Cooling System: Type	Liquid with fan and radiator
Water Temperatures: Minimum	160 F° (71°C)
Maximum	205 F°(96°C)
Thermostat Temperature: Range (770C - 880C)	170°F - 190°F
Fan Operating Range: Engages	Above 190°F (88°C)
Disengages	Below 182 F (83°C)
Shutters Operating Range: Open	Above 190°F (88°C)
Close	Below 177°F°(81°C)
Fuel System: Manufacturer	Cummins Engine Company
Type Fuel Pump	Pressure-time, governor (PT Type G)
Type Fuel Injectors	PT (Type D) Top Stop
Engine Brake: Manufacturer	Jacobs Brake Company
Model	Model 30E

**CHAPTER 2****MAINTENANCE INSTRUCTIONS****Section I. REPAIR PARTS, SPECIAL TOOLS, TMDE, AND SUPPORT EQUIPMENT**

**2-1. COMMON TOOLS AND EQUIPMENT.** For authorized common tools and equipment, refer to Modified Table of Organization and Equipment (MTOE) applicable to your unit.

**2-2. SPECIAL TOOLS, TMDE, AND SUPPORT EQUIPMENT.** Special tools, TMDE, and Support Equipment for this equipment are listed and illustrated in TM 9-2815-226-34P.

**2-3. REPAIR PARTS.** Repair parts are listed and illustrated in the repair parts and special tools list TM 9-2815-226-34P covering direct support and general support maintenance for this equipment.

**Section II. TROUBLESHOOTING**

**2-4. GENERAL.** Information in this chapter is for use of supporting maintenance personnel in conjunction with, and as a supplement to, the troubleshooting procedures in TM 9-2320-281-20. This section provides continuation of instructions given in TM 9-2320-281-20.

**WARNING**

**OPERATION OF A DEADLINED VEHICLE WITHOUT A PRELIMINARY EXAMINATION CAN CAUSE FURTHER DAMAGE TO A DISABLED COMPONENT AND POSSIBLE INJURY TO PERSONNEL. BY CAREFUL INSPECTION AND TROUBLESHOOTING, SUCH DAMAGE AND INJURY CAN BE AVOIDED. IN ADDITION, THE CAUSES OF FAULTY OPERATION OF A VEHICLE OR COMPONENT CAN OFTEN BE DETERMINED WITHOUT EXTENSIVE DISASSEMBLY.**

**2-5. GENERAL INSTRUCTIONS AND PROCEDURES**

a. This section contains troubleshooting information for locating and correcting most of the operating troubles which may develop in the Cummins NTC-400 Big Cam 2 engine. Each malfunction for an individual component, unit or system is followed by a list of tests or inspections which will help you to determine corrective actions to take. You should perform the tests/inspections and corrective actions in the order listed. The troubleshooting chart will consider the engine to be mounted on a maintenance stand with the use of various test equipment.

b. Inspection after the engine is removed from the vehicle or maintenance stand is described in specific sections for removal and installation, and disassembly and assembly of the various components and subassemblies.

c. Table 2-1 lists possible malfunctions that may be experienced during the operations of the component on the maintenance stand. Each malfunction is followed by a list of probable causes that may be considered in determining their corrective action. You should perform the tests/inspections and corrective actions in the order listed.

Table 2-1. TROUBLESHOOTING PROCEDURES

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

1. ENGINE WILL NOT CRANK. BATTERIES ARE FULLY CHARGED.

Step 1. Check for hydraulic seizure.

- a. Remove fuel injectors (para 3-6).
- b. Rotate engine crankshaft several times (if possible).
- c. If engine now turns, reinstall injectors and start engine.
- d. If engine does not turn with injectors out, proceed to next step.

Step 2. Check for mechanical seizure.

Disassemble engine (para 3-6) and check for bound rod or main bearing, broken piston rings, or seized piston.

2. ENGINE WILL CRANK, BUT WILL NOT START OR STARTS HARD.

Step 1. Check fuel tank quantity.

Service fuel tank with proper grade fuel (TM 9-2320-281-10).

Step 2. Check for defective fuel pump shutoff valve.

- a. Listen for shutoff valve opening (click) when ignition switch is placed to RUN position.
- b. If opening (click) not heard, check for 12 vdc at switch terminal with ignition switch placed to RUN position.
- c. If no voltage present, troubleshoot truck electrical system (TM 9-2320-281-20).
- d. If voltage present, manually open shutoff valve and attempt start (TM 9-2320-281-20).
- e. If engine starts, replace fuel shutoff valve (para 3-77c).
- f. If engine does not start, proceed to next step.

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

## 2. (Cont)

Step 3. Check for dirty filter elements.

- a. Drain dirty fuel from fuel filter assembly (TM 9-2320-281-10).
- b. Replace filter element (TM 9-2320-281-20).
- c. Replace main fuel filter element (TM 9-2320-281-20).

Step 4. Check fuel tank for contamination.

Drain fuel tank and fill with clean fuel (TM 9-2320-281-20).

Step 5. Check for leaks in fuel supply (suction) lines to fuel pump.

Tighten all line connectors.

Step 6. Check no-air adjustment screw in fuel pump for proper opening or setting.

- a. Disconnect AFC input line from fitting on fuel pump.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC). CAUTION TOO MUCH PRESSURE WILL DAMAGE AFC BELLOWS.**

- b. Apply 25 psi (172 kPa) air pressure to AFC unit and attempt start.
- c. If engine starts, reset no-air adjustment screw (para 3-84).
- d. If engine does not start, remove pump and set AFC plunger adjustment; then no-air adjustment screw (para 3-84).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

## 2. (Cont)

Step 7. Check valves and injectors for proper timing.

Retime valves and injectors (para 3-94).

Step 8. Check valves and injectors for proper adjustment.

Adjust valves (para 3-94).

Step 9. Check for scored gear pump or worn gears.

Replace gear pump (para 3-80).

Step 10. Check for broken gear pump drive shaft.

Replace defective pump (para 3-80).

Step 11. Check for cracked injector body or cup.

Replace defective injector (para 3-6 and 3-94).

Step 12. Check for broken or worn piston rings.

Replace defective piston rings (para 3-19).

3. ENGINE STOPS, BUT IS NOT SEIZED.

Step 1. Check fuel tank quantity.

Service tank with proper grade fuel (TM 9-2320-281-10).

Step 2. Check for broken wire to fuel pump shutoff valve.

Troubleshoot electrical system (TM 9-2320-281-20). Repair as necessary.

Step 3. Check for air leaks in fuel supply (suction) lines to fuel pump.

Tighten all line connections.

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

## 3. (Cont)

Step 4. Check fuel tank for contamination.

Drain tank and reservice (TM 9-2320-281-10).

Step 5. Check for broken stand pipe inside tank.

Replace stand pipe (TM 9-2320-281-20).

Step 6. Check for seized governor plunger.

Repair governor assembly (para 3-82).

Step 7. Check for broken (sheared) gear pump shaft.

Remove gear pump and repair as necessary (para 3-80).

Step 8. Engine overheated.

Check cooling system (TM 9-2320-281-20).

4. ENGINE SUDDENLY STOPS AND IS SEIZED.

Step 1. Check for seized bearing on crankshaft.

Repair or replace crankshaft as necessary (para 3-14).

Step 2. Check for seized piston in cylinder liner.

Replace defective piston and liner (para 3-6).

Step 3. Check for broken connecting rod.

Replace defective rod (para 3-6).

Step 4. Check for cracked or broken liner.

Replace defective liner (para 3-6).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

5. ENGINE MISSES.

Step 1. Check for leaks in supply (suction) lines to fuel pump.

Tighten all line connectors.

Step 2. Check for water in fuel system.

a. Drain fuel filter assembly bowl (TM 9-2320-281-10).

b. Drain fuel tank (TM 9-2320-281-20).

c. Reservice fuel tank (TM 9-2320-281-10).

Step 3. Check engine valves for proper adjustment.

Adjust valves (para 3-94).

Step 4. Check for plugged injector spray holes.

Clean injector (para 3-73).

Step 5. Check for cracked injector body or cup.

Replace defective injector (para 3-6 and 3-94).

Step 6. Check for defective injector O-rings.

Replace O-rings (para 3-72).

Step 7. Check for improper injector flow adjustments.

Test and adjust injector (para 3-75).

Step 8. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 9. Check for broken or worn piston rings.

Replace defective rings (para 3-20).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

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**MALFUNCTION****TEST OR INSPECTION**

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**CORRECTIVE ACTION**

---

**6. EXCESSIVE BLACK SMOKE AT IDLE.**

Step 1. Check for restricted fuel lines.

Remove and purge fuel lines (TM 9-2320-281-20).

Step 2. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective head gasket(s) (para 3-6 and 3-94).

Step 3. Check for plugged injector spray holes.

Clean injector (para 3-73).

Step 4. Check for cracked injector body or cup.

Replace defective injector (para 3-6 and 3-94).

Step 5. Check for improper injector flow adjustments.

Test and adjust injectors (para 3-75).

Step 6. Check for worn or scored governor plunger.

Replace defective plunger (para 3-82).

Step 7. Check for improper weight assist setting.

Set weight assist (para 3-82).

Step 8. Check for worn or scored cylinder liners or pistons.

Replace defective cylinder liners or pistons (para 3-6 and 3-94).

Step 9. Check for broken or worn piston rings.

Replace defective rings (para 3-20).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

7. EXCESSIVE WHITE SMOKE AT IDLE.

Step 1. Check for stuck open thermostat.

Replace thermostat (TM 9-2320-281-20).

Step 2. Check for incorrect valve and injector timing.

Time valves and injectors (para 3-94).

Step 3. Check for cracked injector body or cup.

Replace defective injector (para 3-6 and 3-94).

Step 4. Check injectors for proper flow adjustments.

Test and adjust injectors (para 3-75).

8. EXCESSIVE SMOKE UNDER LOAD.

Step 1. Check for defective baffles in muffler or severely distorted exhaust piping creating high back pressure.

Replace muffler or defective piping (TM 9-2320-281-20).

Step 2. Check for dirty turbocharger compressor.

Clean compressor (para 3-86).

Step 3. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 4. Check for plugged injector spray holes.

Clean injector (para 3-73).

Step 5. Check for cracked injector body or cup.

Replace defective injector (para 3-6 and 3-94).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

## 8. (Cont)

Step 6. Check for proper injector flow adjustments.

Test and adjust injector (para 3-75).

Step 7. Check engine valves for proper adjustment.

Adjust valves (para 3-94).

Step 8. Check for incorrect valve and injector timing.

Time valves and injector (para 3-94).

Step 9. Check for defective or maladjusted fuel pump.

Test and calibrate pump (para 3-84).

Step 10. Check for broken or worn piston rings.

Replace defective piston rings (para 3-6).

9. EXCESSIVE SMOKE WHILE ACCELERATING.

Step 1. Check for defective baffles in muffler or severely distorted exhaust

pipings creating high back pressure.

Replace muffler or defective piping (TM 9-2320-281-20).

Step 2. Check for dirty turbocharger compressor.

Clean compressor (para 3-86).

Step 3. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

9. (Cont)

Step 4. Check for plugged injector spray holes.

Clean injector (para 3-73).

Step 5. Check for cracked injector body or cup.

Replace defective injector (para 3-6 and 3-94).

Step 6. Check for proper injector flow adjustments.

Test and adjust injector (para 3-75).

Step 7. Check engine valves for proper adjustment.

Adjust valves (para 3-94).

Step 8. Check for incorrect valve and injector timing.

Time valves and injector (para 3-94).

Step 9. Check for incorrect AFC or fuel pump calibration.

Test and calibrate AFC and fuel pump (para 3-84).

Step 10. Check for broken camshaft lobes.

Replace defective camshaft (para 3-6 and 3-94).

Step 11. Check for bent or broken push rods.

Replace defective rods (para 3-6 and 3-94).

Step 12. Check for defective cam follower(s).

Replace defective follower(s) (para 3-6 and 3-94).

Step 13. Check for worn liners or pistons.

Replace defective liner or pistons (para 3-6 and 3-94).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

10. LOW POWER OR LOSS OF POWER.

Step 1. Check for defective baffles in muffler or severely distorted exhaust piping creating high back pressure.

Replace muffler or defective piping (TM 9-2320-281-20).

Step 2. Check for dirty turbocharger compressor.

Clean compressor (para 3-86).

Step 3. Check for leaks in supply (suction) fuel lines to pump.

Tighten all line connectors.

Step 4. Check for restricted fuel lines.

Purge all lines.

Step 5. Check all fuel filters for contamination.

Replace or clean filters (including fuel pump screen) (TM 9-2320-281-20).

Step 6. Check for plugged injector(s) spray holes.

Clean injector(s) spray holes (para 3-73).

Step 7. Check for plugged breather tube and breather assembly.

Clean tube and breather assembly (TM 9-2320-281-20).

Step 8. Check for plugged ASA on fuel pump.

Replace ASA (para 3-83).

Step 9. Check for plugged injector(s) spray holes.

Clean injector(s) spray holes (para 3-73).

Step 10. Check for cracked injector body or cup.

Replace defective injectors (para 3-6 and 3-94).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

10. (Cont)

Step 11. Check for damaged injector O-rings.

Replace O-rings (para 3-72).

Step 12. Check for improper injector flow adjustments.

Test and adjust injector (para 3-75).

Step 13. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 14. Check engine valves for proper adjustment.

Adjust valves (para 3-94).

Step 15. Check for incorrect valve and injector timing.

Time valves and injector (para 3-94).

Step 16. Check for defective or miscalibrated fuel pump.

Test and calibrate pump (para 3-84).

Step 17. Check for scored liners and pistons.

Replace defective liners and pistons (para 3-6).

Step 18. Check for broken or worn piston rings.

Replace defective piston-rings (para 3-5).

Step 19. Check for incorrect main bearing clearances.

Replace defective bearings and recondition crankshaft as necessary (para 3-6).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

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**MALFUNCTION****TEST OR INSPECTION****CORRECTIVE ACTION**

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11. CANNOT REACH GOVERNED RPM.

Step 1. Check for defective or maladjusted throttle linkage.

Adjust or replace defective linkage (TM 9-2320-281-20).

Step 2. Check all fuel filters for contamination.

Replace or clean filters (including fuel pump screen) (TM 9-2320-281-20).

Step 3. Check high-speed governor setting.

Adjust governor setting (para 3-84).

Step 4. Check for improper injector flow adjustments.

Test and adjust injector (para 3-75).

Step 5. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 6. Check for defective or miscalibrated fuel pump.

Test and calibrate pump (para 3-84).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

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**MALFUNCTION****TEST OR INSPECTION****CORRECTIVE ACTION**

---

12. ENGINE ACCELERATES SLOWLY.

Step 1. Check for leaks in supply (suction) fuel lines to pump.

Tighten all line connectors.

Step 2. Check for restricted fuel lines.

Purge all lines.

Step 3. Check for water in fuel.

Drain fuel tank and reservice (TM 9-2320-281-10).

Step 4. Check for improper injector flow adjustments.

Test and adjust injector (para 3-84).

Step 5. Check for blown or leaking head gasket(s).

a. Retorque head bolts (Table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 6. Check for plugged ASA on fuel pump.

Replace defective ASA (para 3-83).

Step 7. Check for defective or maladjusted fuel pump.

Test and calibrate pump (para 3-84).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

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**MALFUNCTION****TEST OR INSPECTION****CORRECTIVE ACTION**

---

13. EXCESSIVE FUEL CONSUMPTION.

Step 1. Check air intake and exhaust for restrictions.

Remove restrictions (TM 9-2320-281-20).

Step 2. Check for external fuel leaks.

Repair as necessary.

Step 3. Check for improper injector flow adjustments.

Test and adjust injector (para 3-75).

Step 4. Check for cracked injector body or cup.

Replace defective injector (para 3-6 and 3-94).

Step 5. Check for damaged injector O-rings.

Replace O-rings (para 3-73).

Step 6. Check for incorrect valve and injector timing.

Time valves and injectors (para 3-94).

Step 7. Check for defective or miscalibrated fuel pump.

Test and calibrate pump (para 3-84).

Step 8. Check for excessive main bearing clearances.

Replace defective bearings and recondition crankshaft as necessary (para 3-6).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

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**MALFUNCTION****TEST OR INSPECTION****CORRECTIVE ACTION**

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**14. POOR ENGINE DECELERATION.**

Step 1. Check for leaks in supply (suction) fuel lines to pump.

Tighten all line connectors.

Step 2. Check for restricted fuel lines.

Purge all lines.

Step 3. Check for damaged injector O-rings.

Replace O-rings (para 3-73).

Step 4. Check for excessive internal injector leakage.

Test and repair injector as necessary (para 3-75).

Step 5. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 6. Check for defective or miscalibrated fuel pump (excessive throttle leakage).

Test and calibrate pump (para 3-84).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

15. ERRATIC IDLE SPEED.

Step 1. Check for leaks in supply (suction) fuel lines to pump.

Tighten all line connectors.

Step 2. Check for binding or hanging-up throttle input linkage.

Lubricate or repair as necessary (LO 9-2320-281-12 and TM 9-2320-281-20).

Step 3. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 4. Check for defective or miscalibrated fuel pump (excessive throttle leakage).

Test and calibrate pump (para 3-84).

16. ENGINE DIES.

Step 1. Check for defective fuel pump shutoff valve.

Perform steps 2a thru 2f of MALFUNCTION 2 to determine status of shutoff valve.

Step 2. Check for leaks in supply (suction) lines to fuel pump.

Tighten all line connectors.

Step 3. Check for fuel blockage in engine fuel lines.

Purge all lines.

Step 4. Check for external fuel leaks.

Repair as necessary.

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

## 16. (Cont)

Step 5. Check for blown or leaking head gasket(s).

- a. Retorque head bolts (table 3-3).
- b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 6. Check for broken fuel pump drive shaft.

Replace pump (para 3-77).

Step 7. Check for defective fuel pump.

Test, repair, and calibrate fuel pump as necessary (para 3-84).

17. ENGINE SURGES AT GOVERNED RPM.

Step 1. Check for leaks in supply (suction) fuel lines to fuel pump.

Tighten all line connectors.

Step 2. Check for blown or leaking head gasket(s).

- a. Retorque head bolts (table 3-3).
- b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 3. Check for defective governor weights.

- a. Remove fuel pump and governor (TM 9-2320-281-34).
- b. Disassemble and repair governor as necessary (para 3-82).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

MALFUNCTION	TEST OR INSPECTION	CORRECTIVE ACTION
18. <u>EXCESSIVE OIL CONSUMPTION.</u>	Step 1. Check for external oil leaks.	Tighten all connectors.
	Step 2. Check for blown or leaking head gasket(s).	<ul style="list-style-type: none"> <li>a. Retorque head bolts (table 3-3).</li> <li>b. Replace defective gasket(s) (para 3-6 and 3-94).</li> </ul>
	Step 3. Check for broken or worn piston rings.	Replace defective piston rings (para 3-6).
	Step 4. Check for worn or scored liners and pistons.	Replace defective liners or pistons (para 3-6).
19. <u>CRANKCASE SLUDGE.</u>	Step 1. Check for dirty oil filter.	Replace oil filter (TM 9-2320-281-20).
	Step 2. Check for defective thermostat (coolant temperature too low).	Replace defective thermostat (TM 9-2320-281-20).
	Step 3. Check for internal water leaks.	Disassemble engine and repair as necessary (para 3-6 and 3-94).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

20. LUBRICATING OIL DILUTION.

Step 1. Check for blown or leaking head gasket(s).

a. Retorque head bolts (table 3-3).

b. Replace defective gasket(s) (para 3-6 and 3-94).

Step 2. Check for clogged breather tube and breather assembly.

Clean tube and breather assembly (TM 9-2320-281-20).

Step 3. Check for cracked injector body or cups.

Replace injector (para 3-6 and 3-94).

Step 4. Check for defective injector O-rings.

Replace O-rings (para 3-73).

Step 5. Check for internal fuel leaks.

Disassemble heads and repair as necessary (para 3-30).

Step 6. Check for defective liner O-rings and crevice seals.

Replace defective O-rings and crevice seals (para 3-6 and 3-94).

21. COOLANT TEMPERATURE TOO LOW.

Step 1. Check for defective thermostat.

Replace defective thermostat (TM 9-2320-281-20).

Step 2. Check for deteriorated thermostat seal lip.

Replace seal (TM 9-2320-281-20).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

MALFUNCTION	TEST OR INSPECTION	CORRECTIVE ACTION
22. <u>COOLANT TEMPERATURE TOO HIGH (ENGINE OVERHEATING).</u>	Step 1. Check for excessive oil in crankcase (crankshaft oil dipping creating increased friction and parasitic drag on engine).	Drain oil to proper level (LO 9-2320-281-12).
	Step 2. Check exterior of engine for excessive dirt and grease hindering normal heat dissipation.	Steam clean engine.
	Step 3. Check for leaking water pump, hoses, oil cooler, aftercooler, and all external lines.	Repair or replace defective parts (TM 9-2320-281-20).
	Step 4. Check for blown or leaking engine and air compressor head gaskets.	<ul style="list-style-type: none"> <li>a. Replace engine head gasket(s) (para 3-6 and 3-94).</li> <li>b. Replace air compressor head gasket (TM 9-2320-281-34).</li> </ul>
	Step 5. Check for defective thermostat.	Replace defective thermostat (TM 9-2320-281-20).
	Step 6. Check for defective water pump.	Replace defective pump (TM 9-2320-281-20).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

## MALFUNCTION

## TEST OR INSPECTION

## CORRECTIVE ACTION

23. LOW IDLE OIL PRESSURE (LESS THAN 10 PSI, [69 KPA]).

Step 1. Check for oil dilution.

Refer to MALFUNCTION 20 for corrective action.

Step 2. Check for coolant overheating.

Refer to MALFUNCTION 22 for corrective action.

Step 3. Check for low oil level in crankcase.

Service crankcase (LO 9-2320-281-12).

Step 4. Check for leaks on suction line and fittings.

Tighten line or replace gaskets (para 3-54).

Step 5. Check oil cooler for restricted coolant flow

Remove and clean cooler (para 3-56).

Step 6. Check for defective oil pump high pressure limit valve.

Remove pump and replace defective limit valve (para 3-51).

Step 7. Check for defective oil pump pressure regulator.

Remove pump and replace defective regulator (para 3-51).

Step 8. Check oil pump for defective bushing and gears.

Replace defective pump. Repair as necessary (para 3-51).

Step 9. Check for broken piston cooling nozzle.

Replace defective nozzle (para 3-6).

Step 10. Check for worn main and rod bearings.

Replace defective main and rod bearings (para 3-6).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

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**MALFUNCTION****TEST OR INSPECTION****CORRECTIVE ACTION**

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24. LOW OIL PRESSURE AT TORQUE PEAK (LESS THAN 30 PSI, [207 KPA]).**NOTE**

**Perform steps 1 thru 9 in MALFUNCTION 23 before proceeding with the following steps.**

Step 1. Check for clogged oil filter.

Replace filter element (TM 9-2320-281-20).

Step 2. Check for kinked or clogged or leaking oil pressure signal tube to oil pump.

a. Tighten tube connector.

b. Clean tube.

c. Replace if defective (para 3-6).

Step 3. Check for oil leaks on suction line and fittings.

Tighten line or replace gaskets (para 3-54).

Step 4. Check for worn main and rod bearings.

Replace defective main and rod bearings (para 3-6).

Table 2-1. TROUBLESHOOTING PROCEDURES (Cont)

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**MALFUNCTION****TEST OR INSPECTION****CORRECTIVE ACTION**

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**25. HIGH OIL PRESSURE AT RATED ENGINE RPM (HIGHER THAN 45 PSI, [311 KPA]).**

Step 1. Check that proper oil viscosity is being used.

Drain and service oil system (LO 9-2320-281-12).

Step 2. Check for stuck closed pressure regulator plunger.

Remove pump and replace regulator (para 3-51).

**26. NO OIL PRESSURE.**

Step 1. Check for broken oil pump drive shaft or gear turning on shaft.

Replace defective pump (para 3-6) and repair as necessary (para. 3-51).

Step 2. Check for defective (stuck open) or weak spring in pump pressure regulator.

Remove pump and replace regulator (para 3-51).

**27. EXCESSIVE CRANKCASE PRESSURE.**

Step 1. Check for worn or scored liners or pistons.

Replace defective liners or pistons (para 3-6).

Step 2. Check for broken or worn piston rings.

Replace defective rings (para 3-6).

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## CHAPTER 3

### REPAIR OF ENGINE ASSEMBLY

#### Section I. GENERAL

**3-1. PURPOSE** The purpose of this chapter is to provide complete instructions for the repair of engine subassemblies. General procedures are provided which are applicable to all operations, followed by detailed instructions for each subassembly. General procedures for cleaning, inspection, repair, and assembly are outlined below.

#### 3-2. CLEANING

- a. General. The procedures for cleaning will be the same for most parts and components which comprise the engine subassemblies. To avoid repetition of instructions, the general procedures for cleaning are detailed in b thru f below. Any cleaning procedures which are peculiar to a specific part or component are covered in the section or paragraph relating to the item.
- b. Cleaning Instructions. The importance of cleaning must be thoroughly understood by maintenance personnel. Great care and conscientious effort are required in all cleaning operations. The presence of dirt or foreign substances is a constant threat to satisfactory engine operation and maintenance. The following should apply to all cleaning operations:

#### CAUTION

**DO NOT ALLOW DRY CLEANING SOLVENTS TO COME IN CONTACT WITH SEALS OR FLEXIBLE HOSES. THESE CLEANERS CAUSE LEATHER, RUBBER AND SYNTHETIC MATERIALS TO DRY OUT, ROT, AND LOSE PLIABILITY.**

- (1) Clean all parts before inspection, after repair, and before assembly.
  - (2) Hands should be kept free of any accumulation of grease which can collect dust and grit.
  - (3) After cleaning, all parts should be covered or wrapped in plastic or suitable paper to protect them from dust and dirt.
- c. Castings.
- (1) Clean inner and outer surfaces of castings and all areas subject to oil and grease, with dry cleaning solvent.
  - (2) Remove sludge and gum deposits from castings, using a stiff brush.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA) USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES/SHIELD, GLOVES, ETC.).**

- (3) Use clean, dry, compressed air to blow out and dry all tapped holes in castings.
- d. Oil Passages. Particular attention must be given to all oil passages in castings and machine parts. All oil passages must be clean and free of obstructions.

- (1) Clean passages with wire or a probe to break up any sludge or gum deposits.

**CAUTION**

**DO NOT ALLOW DRY CLEANING SOLVENTS TO COME IN CONTACT WITH SEALS OR FLEXIBLE HOSES. THESE CLEANERS CAUSE LEATHER, RUBBER AND SYNTHETIC MATERIALS TO DRY OUT, ROT, AND LOSE PLIABILITY.**

- (2) Wash passages by flushing with dry cleaning solvent.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- (3) Dry passages by blowing them out with compressed air.
- e. Oil Seals and Flexible Hoses. Clean seals and flexible hoses with soap and water.
- f. Ball Bearings.

Refer to TM 9-214 for information on care and maintenance of antifriction bearings.

### 3-3. INSPECTION

- a. General. Procedures for inspection will be the same for most parts and components which comprise the engine subassemblies. To avoid repetition of instructions, the general procedures for inspection are detailed in b thru h below. Any inspection procedures which are peculiar to a specific part or component are covered in the section or paragraph relating to the item.
- b. Castings.
  - (1) Inspect all ferrous and nonferrous castings for cracks using a magnifying glass and strong light. Particularly check the areas adjacent to studs, pipe plugs, threaded inserts, and in sharp corners and fillets.
  - (2) Inspect machined surfaces of castings for nicks, burrs, and raised metal. Mark damaged areas for repair.
  - (3) Check all mating flanges on housings and supports for warpage with a straightedge or on a surface plate. Inspect mating flanges for discoloration which may indicate persistent oil leakage.
  - (4) Inspect all pipe plug and capscrew-tapped openings for damaged or stripped threads.
  - (5) Check all castings for conformance to applicable repair standards (table 3-1).
- c. Ball Bearings.
  - (1) Refer to TM 9-214 for inspection of bearings. Check all bearings for conformance to applicable repair standards (table 3-1).

Table 3-1. REPAIR AND REPLACEMENT STANDARDS

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
<b>CYLINDER BLOCK</b>			
Camshaft Bushing Inside Diameter	2.5023 in. (63.5584 mm)	2.4983 in. (63.4568 mm)	2.4998 in. (63.4949 mm)
Camshaft Bushing Bore Inside Diameter	2.6265 in. (66.7131 mm)	2.6245 in. (66.6623 mm)	2.6255 in. (66.6877 mm)
Cylinder Liner Counterbore Inside Diameter		6.5615 in. (166.6621 mm)	6.5635 in. (166.729 mm)
Depth	0.412 in. (10.465 mm)	0.350 in. (8.890 mm)	0.352 in. (8.941 mm)
Liner-to-Block Clearance Lower Bore		0.002 in. (0.050 mm)	0.006 in. (0.152 mm)
Lower Liner Bore Inside Diameter		6.124 in. (155.550 mm)	6.126 in. (155.600 mm)
Main Bearing Bore Inside Diameter	4.7505 in. (120.6627 mm)	4.7485 in. (120.6119 mm)	4.750 in. (120.650 mm)
<b>Block</b>			
Height from Main Bearing Center Line	18.994 in. (482.448 mm)	19.003 in. (482.676 mm)	19.007 in. (4.82778 mm)
Height from Installed Alinement Bar	16.619 in. (422.123 mm)	16.628 in. (422.351 mm)	16.632 in. (422.453 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Cylinder Liner Inside Diameter	5.505 in. (139.827 mm)	5.4995 in. (139.687 mm)	5.01 in. (139.725 mm)
<b>NOTE</b>			
<b>New cylinder liners inside diameter dimensions at 60°F - 70°F (16°C - 21°C) may be 0.0002 0.0006 in. (0.0050 0.0152 mm) smaller than indicated due to lubrite coating.</b>			
Protrusion Above Block		0.003 in. (0.076 mm)	0.006 in. (0.152 mm)
Crankshaft			
Connecting Rod Journal Outside Diameter	3.122 in. (79.299 mm)	3.1235 in. (79.336 mm)	3.125 in. (79.3875 mm)
Main Bearing Journal			
Outside Diameter	4.4975 in. (114.2365 mm)	4.4985 in. (114.2619 mm)	4.50 in. (114.300 mm)
Thrust Bearing Surface- to-Rear Counterweight	3.006 in. (76.352 mm)	3.001 in. (76.225 mm)	3.003 in. (76.276 mm)
Main Rod Journals Out-of- Round, Total Indicated Runout	0.002 in. (0.051 mm)		
Main and Rod Journal Taper (Length of Journal)	0.0005 in. (0.0127 mm)		

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
<b>Main Bearings</b>			
Shell Thickness	0.1215 in. (3.0861 mm)	0.123 in. (3.1242 mm)	0.1238 in. (3.1445 mm)
Journal Clearance	0.007 in. (0.178 mm)	0.0015 in. (0.0381 mm)	0.005 in. (0.127 mm)
<b>Rod Bearings</b>			
Shell Thickness	0.093 in. (2.362 mm)	0.0942 in. (2.3927 mm)	0.0947 in. (2.4054 mm)
Number of Undersizes			4
Each Undersize			0.010 in. (0.254 mm)
<b>Crankshaft Thrust Rings</b>			
Standard Thickness		0.245 in. (6.223 mm)	0.247 in. (6.274 mm)
1st Oversize Thickness		0.255 in. (6.477 mm)	0.257 in. (6.528 mm)
2nd Oversize Thickness		0.265 in. (6.731 mm)	0.267 in. (6.782 mm)
Crankshaft End Clearance	0.022 in. (0.559 mm)	0.007 in. (0.178 mm)	0.017 in. (0.432 mm)
<b>Connecting Rod</b>			
Crankpin Bore Inside Diameter		3.3157 in. (84.2187 mm)	3.3167 in. (84.24418 mm)
Center-to-Center Length		11.998 in. (304.750 mm)	12.00 in. (304.800 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Piston Pin Bushing Inside Diameter	2.0022 in. (50.8558 mm)	2.0010 in. (50.8254 mm)	2.0015 in. (50.8381 mm)
Connecting Rod			
Bend Without Bushing	0.010 in. (0.254 mm)		0.010 in. (0.254 mm)
Bend With Bushing	0.004 in. (0.102 mm)		0.004 in. (0.102 mm)
Twist Without Bushing	0.020 in. (0.508 mm)		0.020 in. (0.508 mm)
Twist With Bushing	0.010 in. (0.254 mm)		0.010 in. (0.254 mm)
Connecting Rod Capscrew			
Minimum Outside Diameter	0.583 in. (14.808 mm)	0.584 in. (14.833 mm)	0.590 in. (14.986 mm)
Pilot Outside Diameter	0.637 in. (16.179 mm)	0.638 in. (16.205 mm)	0.643 in. (16.103 mm)
Bolt Hole Pilot (Two Bolt Rods)			
Rod	0.6249 in. (15.8725 mm)	0.6243 in. (15.8572 mm)	0.6248 in. (15.8699 mm)
Cap	0.6252 in. (15.8800 mm)	0.6246 in. (15.8648 mm)	0.6251 in. (15.8775 mm)
Dowel and Hole			
Dowel Diameter		0.3127 in. (7.9425 mm)	
Rod Dowel Hole		0.3128 in. (7.9451 mm)	0.3133 in. (7.9578 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Dowel Protrusion		0.220 in. (5.588 mm)	0.250 in. (6.350 mm)
Dowel Press-Fit in Cap		0.0001 in. (0.0025 mm)	0.0006 in. (0.0152 mm)
Piston			
Skirt Diameter at 70°F (21 °C)	5.483 in. (139.268 mm)	5.487 in. (139.369 mm)	5.488 in. (139.395 mm)
Piston Pin Bore			
Inside Diameter at 70°F (21 °C)	2.000 in. (50.800 mm)	1.9985 in. (50.7620 mm)	1.998 in. (50.7746 mm)
Piston Pin			
Outside Diameter	1.9985 in. (50.7619 mm)	1.9987 in. (50.7682 mm)	1.9990 in. (50.7746 mm)
Piston Ring Gap in Travel Area of Liner			
No. 1 Gap		0.023 in. (0.584 mm)	0.033 in. (0.838 mm)
No. 2 Gap		0.019 in. (0.482 mm)	0.029 in. (0.736 mm)
No. 3 Gap		0.019 in. (0.482 mm)	0.029 in. (0.736 mm)
No. 4 (Oil Ring) Gap		0.010 in. (0.254 mm)	0.025 in. (0.635 mm)

**NOTE**

**Add 0.003 in. (0.076 mm) ring gap to new maximum for each 0.001 in. (0.025 mm) wear in cylinder liner wall inside diameter.**

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Camshaft Journal Outside Diameter	2.495 in. (63.373 mm)	2.496 in. (63.398 mm)	2.497 in. (63.424 mm)
Thrust Bearing Shell Thickness	0.083 in. (2.108 mm)	0.093 in. (2.362 mm)	0.098 in. (2.489 mm)
Camshaft Support Inside Diameter	1.757 in. (44.627 mm)	1.751 in. (44.475 mm)	1.754 in. (44.552 mm)
Gear Case Cover Accessory			
Drive Bushing Inside Diameter	1.571 in. (39.903 mm)	1.565 in. (39.751 mm)	1.569 in. (39.852 mm)
CYLINDER HEAD			
Cylinder Head Height	4.340 in. (110.236 mm)	4.370 in. (111.998 mm)	4.380 in. (111.252 mm)
Valve Stem			
Outside Diameter	0.449 in. (11.405 mm)	0.450 in. (11.430 mm)	0.451 in. (11.455 mm)
Face Angle		30°	30°
Valve Guide			
Inside Diameter	0.445 in. (11.303 mm)	0.4525 in. (11.494 mm)	0.4532 in. (11.5113 mm)
Assembled Height		1.270 in. (32.258 mm)	1.280 in. (32.512 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Valve Seat Insert			
Outside Diameter		2.0025 in. (50.8635 mm)	2.0035 in. (50.8889 mm)
Number of Oversizes			5
Each Oversize (See table 3-2 for specific sizes) Diameter Increase			0.005 in. (0.127 mm)
Cylinder Head Insert			
Bore Diameter		2.0025 in. (50.8635 mm)	2.0035 in. (50.8889 mm)
Insert Height		0.278 in. (7.061 mm)	0.282 in. (7.163 mm)
Run-Out (360 Degrees)	0.002 in. (0.051 mm)		
Refaced Seat Width		0.063 in. (1.600 mm)	0.125 in. (3.175 mm)
Valve Spring			
Assembled Height			2.250 in. (57.150 mm)
Free Length			2.685 in. (68.119 mm)
Number of Coils			9
Wire Diameter			0.177 in. (4.495 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Load Length			1.724 in. (43.79 mm)
Required Load	143 lb (636 N)	147.25 lb (655 N)	162.75 lb (724 N)
Crosshead Guide			
Outside Diameter	0.432 in. (10.973 mm)	0.433 in. (10.998 mm)	0.4335 in. (11.0109 mm)
Assembled Height		1.860 in. (47.244 mm)	1.880 in. (47.752 mm)
Crosshead Bore	0.440 in. (11.176 mm)	0.434 in. (11.024 mm)	0.436 in. (11.074 mm)
Injector Sleeve		0.060 in. (1.524 mm)	0.070 in. (1.778 mm)
ROCKER LEVER			
Bushing			
Inside Diameter	1.1286 in. (28.6664 mm)	1.1245 in. (28.5623 mm)	1.1275 in. (28.6385 mm)
Shaft			
Outside Diameter	1.122 in. (28.500 mm)	1.123 in. (28.524 mm)	1.124 in. (28.550 mm)
Cam Follower			
Shaft			
Outside Diameter	0.748 in. (19.000 mm)	0.7485 in. (19.0119 mm)	0.749 in. (19.025 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Cam Follower Lever			
Bushing Inside Diameter	0.752 in. (19.101 mm)	0.7501 in. (19.0525 mm)	0.7511 in. (19.0779 mm)
Injector Cam Roller			
Inside Diameter	0.705 in. (17.907 mm)	0.703 in. (17.856 mm)	0.704 in. (17.882 mm)
Outside Diameter	1.2485 in. (31.7119 mm)	1.2495 in. (31.7373 mm)	1.2505 in. (31.7627 mm)
Valve Cam Rollers			
Inside Diameter	0.503 in. (12.776 mm)	0.5005 in. (12.7127 mm)	0.5015 in. (12.7381 mm)
Outside Diameter	1.2485 in. (31.7119 mm)	1.2495 in. (31.7373 mm)	1.2505 in. (31.7627 mm)
Cam Roller Pin Diameter			
Valve	0.497 in. (12.624 mm)	0.4995 in. (12.6873 mm)	0.500 in. (12.700 mm)
Injector	0.697 in. (17.704 mm)	0.6995 in. (17.7673 mm)	0.700 in. (17.780 mm)
Push Tubes Length			
Injector		17.775 in. (451.485 mm)	17.805 in. (452.247 mm)
Valve		17.880 in. (454.152 mm)	18.910 in. (480.314 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
<b>WATER PUMP</b>			
<b>Impeller</b>			
Impeller-to-Shaft Press Fit	0.001 in. (0.025 mm)		
Impeller-to-Body Clearance		0.020 in. (0.508 mm)	0.040 in. (1.016 mm)
<b>Housing</b>			
Housing Bearing Bores	2.4494 in. (62.2147 mm)	2.4408 in. (61.9963 mm)	2.4418 in. (62.0217 mm)
Carbon Face Seal Bore in Housing		1.500 in. (38.100 mm)	1.520 in. (38.608 mm)
<b>Shaft</b>			
Impeller Location Diameter		0.6262 in. (15.9055 mm)	0.6267 in. (15.918 mm)
Seat Location Diameter		0.6262 in. (15.9055 mm)	0.6267 in. (15.9182 mm)
Inner and Outer Bearing Location Diameters		0.9843 in. (25.0012 mm)	0.9847 in. (25.0114 mm)
Pulley End Shaft Diameter		0.6693 in. (17.0002 mm)	0.6696 in. (17.0078 mm)
Minimum Press Fit Between Shaft and Pulley		0.001 in. (0.025 mm)	
Impeller Bore Diameter		0.624 in. (15.849 mm)	0.625 in. (15.875 mm)
<b>Pulley</b>			
Bore Diameter		0.6663 in. (16.9240 mm)	0.6673 in. (16.9494 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
Accessory Drive End Clearance		0.002 in. (0.051 mm)	0.012 in. (0.304 mm)
LUBRICATING OIL PUMP			
Bushings Inside Diameter	0.6185 in. (15.7099 mm)	0.6165 in. (15.6591 mm)	0.6175 in. (15.6845 mm)
Idler and Drive Shaft Outside Diameter	0.6145 in. (15.6083 mm)	0.615 in. (15.621 mm)	0.6155 in. (15.6337 mm)
Drive Gear to Body Clearance	0.012 in. (0.305 mm)		
Drive Shaft End Play		0.002 in. (0.051 mm)	0.005 in. 0.127 mm)
Idler Shaft Protrusion		0.720 in. (18.288 mm)	0.740 in. (18.796 mm)
Driven Gear/Drive Shaft Shaft Protrusion		0.855 in. (21.717 mm)	0.875 in. (22.225 mm)

Table 3-1. REPAIR AND REPLACEMENT STANDARDS (Cont)

COMPONENT	WEAR LIMIT	NEW MINIMUM	NEW MAXIMUM
FINAL ASSEMBLY			
Main Bearing Journal Clearance	0.007 in. (0.178 mm)	0.0015 in. (.0381 mm)	0.005 in. (.127 mm)
Connecting Rod Bearing Journal Clearance	0.007 in. (0.178 mm)	0.0015 in. (0.0381 mm)	0.0045 in. (0.1143 mm)
Crankshaft End Clearance	0.022 in. (0.559 mm)	0.007 in. (0.178 mm)	0.017 in. (0.432 mm)
Cylinder Liner			
Protrusion		0.003 in. (0.076 mm)	0.006 in. (0.152 mm)
Out-of-Round, Top One Inch (25.4 mm)			0.003 in. (0.076 mm)
Out-of-Round, Packing Ring (Lower) Area			0.002 in. (0.051 mm)
Connecting Rod Side Clearance		0.0045 in. (0.1143 mm)	0.0130 in. (0.3300 mm)
Gear Train (Gear-to-Gear) Crankshaft, Camshaft, Accessory Drive, and Lube Oil Pump			
Backlash	0.020 in. (0.508 mm)	0.0045 in. (0.1143 mm)	0.0105 in. (0.2667 mm)
Camshaft Support End Clearance		0.008 in. (0.203 mm)	0.013 in. (0.330 mm)

Table 3-2. VALVE SEAT INSERTS

VALVE SEAT INSERT PART NO.	OVERSIZE DIAMETER in. (mm)	OVERSIZE DEPTH in. (mm)	INSERT OD in. (mm)	CYLINDER HEAD ID in. (mm)	INSERT THICKNESS in. (mm)
127935	0.005 in. (0.127 mm)	STD	2.0075/2.0085 (50.9905/51.0159)	2.0045/2.0055 (50.9143/50.9397)	0.278/0.282 (7.061/7.163)
127931	0.010 in. (0.254 mm)	STD	2.0125/2.0135 (51.1175/51.1429)	2.0095/2.0105 (51.0413/51.0667)	0.278/0.282 (7.061/7.163)
127932	0.020 in. (0.501 mm)	0.005 in. (0.127 mm)	2.0225/2.0235 (51.3715/51.3969)	2.0195/2.0205 (51.2953/51.3207)	0.283/0.287 (7.188/7.290)
127933	0.030 in. (0.762 mm)	0.010 in. (0.254 mm)	2.0325/2.0335 (51.6255/51.6509)	2.0295/2.0305 (51.5493/51.5747)	0.288/0.292 (7.320/7.420)
127934	0.040 in. (1.016 mm)	0.015 in. (0.381 mm)	2.0425/2.0435 (51.8795/51.9049)	2.0395/2.0405 (51.8033/51.8287)	0.293/0.297 (7.442/7.544)

**NOTE**

**Be sure to measure insert before matching or installing insert in head.**

- d. Studs. Inspect all studs for stripped or damaged threads, bent or loose condition, and evidence of stretching.
- e. Gears.
  - (1) Inspect all gears for cracks, using a magnifying glass and a strong light.
  - (2) Inspect all gear teeth for wear, sharp fins, burrs, and galled or pitted surfaces.
  - (3) Check all gears for conformance to applicable repair standards (Table 3-1).

- f. Bushings and Bushing-Type Bearings.
  - (1) Check all bushing and bushing-type bearings for secure fit in their respective casting or mating part, and for evidence of heating which may be indicated by discoloration of bushing or bearing surface.
  - (2) Inspect bushings and bushing-type bearings for wear, burrs, nicks, and out-of-round condition.
  - (3) Check for dirt in lubrication holes or grooves of bushings or bushing-type bearings. Holes and grooves must be clean and free from damage to insure proper lubrication.
  - (4) Check all bushings and bushing-type bearings for conformance to applicable repair standards (Table 3-1).
- g. Oil Seals. Metal-encased oil seals should not be replaced unless inspection indicates damage.
  - (1) Inspect feather edge of oil seal for damage.
  - (2) Check seal for loss of pliability and resiliency.
- h. Core Hole Plugs. Inspect core hole plugs for evidence of leakage. Replace seals if they are damaged or if leakage is evident.

### 3-4. REPAIR

- a. General. Procedures for repair will be the same for most parts and components which comprise the engine subassemblies. To avoid repetition of instructions, general procedures for repair are detailed in b through g below. Any repair procedures which are peculiar to a specific part or component are covered in the section or paragraph relating to that item. After repair, clean all parts thoroughly to prevent metal chips or abrasives used in repair operations from entering working parts of the engine.
- b. Castings.
  - (1) Replace all cracked castings.
  - (2) Replace all castings which do not conform to tolerances specified in repair standards in Table 3-1.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (3) Repair minor damage to machined surfaces with a fine file, emery cloth, or crocus cloth dipped in dry cleaning solvent. Replace all castings on which machined surfaces are burred or nicked to the point of impairing subsequent assembly or operation.
- (4) Repair minor warpage of mounting flanges and gasket surfaces by working the surface across a sheet of emery cloth held tightly on a surface plate or a similar flat surface. Finish similarly with crocus cloth. Replace castings having flanges which are warped to the point of impairing assembly or operation.
- (5) Repair damaged pipe or capscrew threads in tapped holes with a tap.

**NOTE**

**Pipe plug threads in castings must be in good condition to prevent oil or water leakage.**

## c. Ball Bearings.

- (1) Replace all galled, pitted, or damaged ball bearings.
- (2) Replace all ball bearings which do not conform to tolerances specified in repair standards (Table 3-1).
- (3) Refer to TM 9-214 for maintenance of antifriction bearings.

## d. Studs. Replace all bent or loose studs and studs showing evidence of stretching. Repair minor thread damage with a thread chaser. Replace all studs having stripped or damaged threads. Remove and replace studs as outlined in (1) and (2), below.

- (1) Removal. Using a stud extractor, back the studs out slowly to avoid heating and possible seizure. When the studs are broken off too short to use a stud extractor, drill the stud and extract it with an easy out. Another method of removal is to use a welding torch and heat stud. Apply a wax stick to stud allowing melted wax to flow into threads. While stud is still hot, use vise grips and carefully turn stud until it comes out. Take care not to break stud.
- (2) Replacement. Only standard studs are supplied for replacement. If threaded openings are damaged and retapping will not clean up threads, drill and tap opening in casting and install a threaded insert.

**NOTE**

All replacement studs have a special coating and must have a small amount of mica-base antiseize compound (MIL-A-13881) applied on the threads before the stud is installed in the casting.

## e. Gears.

- (1) Replace all cracked gears.
- (2) Replace all gears which do not conform to tolerances specified in the repair standards in table 3-1.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (3) Replace gears having worn, pitted, or galled teeth. Remove sharp fins and burrs from gear teeth with crocus cloth dipped in dry cleaning solvent.
- f. Bushings and Bushing-Type Bearings. When bushings and bushing-type bearings are damaged or worn beyond specified limits, the associated parts with which they are used must also be replaced.
- g. Oil Seals. Oil seals must be replaced when the thin feather edge is damaged or when the seal material has become hard or brittle.
- (1) Removal. Press a damaged oil seal from the casting or adapter, being careful not to damage the bore in the casting or adapter.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (2) Repair. When a casting oil seal bore or adapter is burred to a point where an oil-tight seal is impossible, replace the casting or adapter. Remove slight nicks, burrs, and scratches from the casting bore or adapter with crocus cloth dipped in dry cleaning solvent.
- (3) Installation. Install a new oil seal in the bore of the casting or adapter, using a proper oil seal replacer tool.

**3-5. ASSEMBLY INSTRUCTIONS.**

- a. General. Extreme care must be exercised in all component assembly operations to ensure satisfactory engine performance. Precautionary rules for assembly are outlined below. Step-by-step procedures for assembly or various components are covered in the paragraph relating to the specific component.
- b. Precautionary Rules.
  - (1) Cleanliness is essential in all component assembly operations. Dirt and dust, even in minute quantities, are abrasive. Parts must be cleaned, as specified, and kept clean. Wrap or cover parts and components when assembly procedures are not immediately completed.
  - (2) Coat all bearings and contact surfaces with engine oil OE/HDO-10 (MIL-L-2104) to insure lubrication of parts during initial engine starting.
  - (3) Replace all gaskets and preformed packings during assembly.
- c. Teflon-Wrapped Pipe Plugs. Certain pipe plugs have a thin strip of teflon tape or liquid sealant applied to the pipe threads before installation of the plug. This is done to provide a better seal and also to permit easier removal of the pipe plug. Those pipe plugs requiring teflon wrapping or sealant are identified in the particular assembly procedure calling for the installation of such plugs. The method of teflon wrapping these particular plugs is as follows:
  - (1) Be sure that the pipe plug is thoroughly clean and dry before applying teflon tape. All dirt, grease, oil, and scale must be removed.
  - (2) Start the tape one or two threads from the small or leading edge of the plug, joining the tape together with an overlap of approximately 1/8 inch (3.175 mm).
  - (3) Wrap the tape tightly in the same direction as you would turn a nut. Press the tape into the minor diameter of threads without cutting or ripping the tape.

**CAUTION****DO NOT USE POWER TOOLS; DAMAGE TO EQUIPMENT MAY RESULT.**

- (4) Torque the pipe plugs to their specified torque. Torque values of engine parts are provided in table 3-3.

Table 3-3. TORQUE CHART

PART NAME OR LOCATION	FT LB (N•m)
*Denotes inch-pounds	
<b>Cylinder Block</b>	
Oil Gallery Pipe Plugs	60 - 70 (81 - 95)
<b>Main Bearing Bolts</b>	
Step 1 Torque To	145 - 155 (197 - 210)
Step 2 Advance To	300 - 310 (407 - 420)
Step 3 Loosen All	Minimum of 3 Turns
Step 4 Torque To	140 - 145 (190 - 197)
Step 5 Advance To	300 - 310 (407 - 420)
<b>Connecting Rod Capscrews</b>	
Step 1 Torque To	70 - 75 (95 - 102)
Step 2 Advance To	140 - 150 (190 - 203)
Step 3 Loosen All	Completely
Step 4 Torque To	25 - 30 (34 - 41)
Step 5 Advance To	70 - 75 (95 - 102)
Step 6 Advance To	140 - 150 (190 - 203)
<b>Cylinder Head Bolts</b>	
Step 1 Torque To	25 (34)
Step 2 Advance To	80 - 100 (108 - 136)
Step 3 Advance To	180 - 200 (244 - 271)
Step 4 Advance To	280 - 300 (380 - 407)
<b>Fuel Cross-Overs</b>	
Slotted Head Screws	*34 - 38 (3.8 - 4.3)
<b>Cam Follower and Housing Assembly Bolts</b>	
Step 1	15 - 20 (20 - 27)
Step 2	30 - 35 (41 - 47)

TABLE 3-3. TORQUE CHART (Cont)

PART NAME OR LOCATION	FT LB (N•m)
Lube Oil Pump	
Capscrews	25 - 35 (34 - 47)
Gear Case Cover	
Capscrews	45 - 50 (61 - 68)
Air Compressor	
Capscrews	40 - 45 (54 - 61)
Accessory Drive Pulley	
Retaining Nut	300 - 310 (407 - 420)
Coupling Capscrew	30 - 35 (41 - 47)
Front Engine Support	
Capscrews	55 (75)
Vibration Damper Pulley to Vibration Damper	
Capscrews	85 (115)
Vibration Damper	
Capscrews	85 (115)
Water Pump Capscrews	
Step 1 Torque To	10 (14)
Step 2 Advance To	20 (27)
Step 3 Advance To	30 (41)
Water Pump Idler Pulley	
Capscrew	50 (68)

TABLE 3-3. TORQUE CHART (Cont)

PART NAME OR LOCATION	FT LB (Nm)
Fan Drive Housing Assembly	
Capscrews	50 (68)
Crankshaft Rear Cover Plate	
Capscrews	24 - 29 (33 - 39)
Flywheel Housing	
Capscrews	150 (203)
Flex Drive Assembly to Crankshaft	
Capscrews	200 - 220 (271 - 298)
Flywheel to Flex Disk Assembly	50 - 60 (68 - 81)
Oil Pan (All Except to Rear Cover)	
Capscrews	28 - 40 (38 - 54)
Oil Pan to Rear Cover	
Capscrews	15 - 20 (20 - 27)
Fuel Injectors	
Cup Retainers	50 (68)
Hold-Down Capscrews	
Step 1 Torque To	4 (5)
Step 2 Advance To	8 (11)
Step 3 Advance To	12 (16)

TABLE 3-3. TORQUE CHART (Cont)

PART NAME OR LOCATION	FT LB (N•m)
Valve Crossovers	
Adjusting Screw Locknuts (Without ST-669 Torque Wrench Adapter)	25 - 30 (34 - 41)
Adjusting Screw Locknuts (With ST-669 Torque Wrench Adapter)	22 - 26 (30 - 35)
Rocker Lever Housing	
Capscrews	65 - 75 (88 - 102)
Engine Brake Housing	
Retaining Nuts	55 - 60 (75 - 81)
Rocker Lever Injector	
Adjusting Screw Locknut (Without ST-669 Torque Wrench Adapter)	40 - 45 (54 - 61)
Adjusting Screw Locknut (With ST-669 Torque Wrench Adapter)	30 - 35 (41 - 47)
Rocker Lever Valve	
Adjusting Screw Locknut (Without ST-669 Torque Wrench Adapter)	40 - 45 (54 - 61)
Adjusting Screw Locknut (With ST-669 Torque Wrench Adapter)	30 - 35 (41 - 47)
Rocker Housing Covers	
Capscrews	10 - 15 (14 - 21)

TABLE 3-3. TORQUE CHART (Cont)

PART NAME OR LOCATION	FT LB (Nm)
Aftercooler	
Mounting Capscrews	22 - 27 (30 - 37)
Crossbolts	
Step 1 Torque To	15 (21)
Step 2 Advance To	25 (34)
Water Inlet Connection	
Capscrews	27 - 32 (37 - 43)
Water Outlet Connection	
Capscrews	15 - 20 (21 - 27)
Cover to Housing	
Capscrews	25 (34)
Fuel Filter	
Inlet Fitting	30 - 40 (41 - 54)
Exhaust Manifold	
Capscrews	25 (34)
Oil Cooler	
Cooler Support Brace to Block	
Capscrews	30 (41)
Cover to Cooler	
Capscrews	30 - 35 (41 - 47)

TABLE 3-3. TORQUE CHART (Cont)

PART NAME OR LOCATION	FT LB (N•m)
Cooler to Cooler Support	
Capscrews	30 - 35 (41 - 47)
Mounting Capscrews	30 (41)
Center Bolt	25 - 35 (34 - 47)
Water Transfer Connection to Water Pump	
Capscrews	30 (41)
Alternator to Mount Bracket	
Bolt	77 - 80 (104 - 108)
Oil Spray Nozzles	
Capscrews	10 (14)
Turbocharger	
V-Band Clamp	*32 - 36 (3.6 - 4.1)
Rotor Assembly Locknut	20 - 24 (276 - 33)
Lube Oil Drain Fitting	50 (68)
Lube Oil Inlet Fitting	20 - 25 (27 - 34)
Diffuser Plate Capscrews	5 - 7 (7 - 10)
Air Crossover Connection to Turbocharger V-Clamp	
T-Bolt Lock Nuts	*65 - 75 (7.4 - 8.5)

TABLE 3-3. TORQUE CHART (Cont)

PART NAME OR LOCATION	FT LB (Nm)
<b>Fuel Pump</b>	
Filter Screen Cover	8 - 12 ( 11 - 16)
Governor Spring Pack Cover Capscrews	9 - 11 ( 12 - 15)
AFC Throttle Stop Set Screws	* 70 - 90 ( 8 - 10)
Front Cover to Main Housing Capscrews	9 - 11 ( 12 - 15)
Gear Pump to Main Housing Capscrews	11 - 13 ( 15 - 18)
Damper and Head Assembly to Gear Pump Capscrews	11 - 13 ( 15 - 18)
Shut-Off Valve to Main Housing Capscrews	11 - 13 ( 15 - 18)
Shut-Off Valve Coil to Valve Housing Capscrews	* 25 - 30 (2.8 - 3.4)
<b>Air Compressor</b>	
Mounting Capscrews	40 - 45 (54 - 61)
Cylinder Block to Crankcase Capscrews	* 150 - 180 (17 - 20)
Piston Rod Cap Bolts	* 125 - 140 (14 - 16)
Cylinder Head Capscrews	
Step 1 Torque To	* 100 (11)
Step 2 Advance To	* 175 - 225 (20 - 25)
Crankcase Cover Capscrews	* 95 - 125 (11 - 14)

**Section II. ENGINE DISASSEMBLY****3-6. ENGINE DISASSEMBLY**

- a. Drain Engine Oil (LO 9-2320-281-12).
- b. Drain Coolant (TM 9-2320-281-20).
- c. Prepare Engine for Steam Cleaning.
  - (1) Remove power steering cooler (TM 9-2320-281-20).
  - (2) Remove Fan Drive Belts and Fan Clutch Assembly (TM 9-2320-281-20).
  - (3) Remove Alternator Drive Belts and Alternator (TM 9-2320-281-20).
  - (4) Remove Dipstick Tube and Filler Tube Bracket (TM 9-2320-281-20).
  - (5) Remove Water Pump Drive Belt (TM 9-2320-281-20).
  - (6) Remove Starter (TM 9-2320-281-20).
  - (7) Remove Water Filter and Mount Bracket (TM 9-2320-281-20).
  - (8) Remove all heater water lines, associated clamps, brackets, and shut-off valves (TM 9-2320-281-20).
  - (9) Plug all open fittings and ports.
- d. Clean Engine Exterior.

**WARNING**

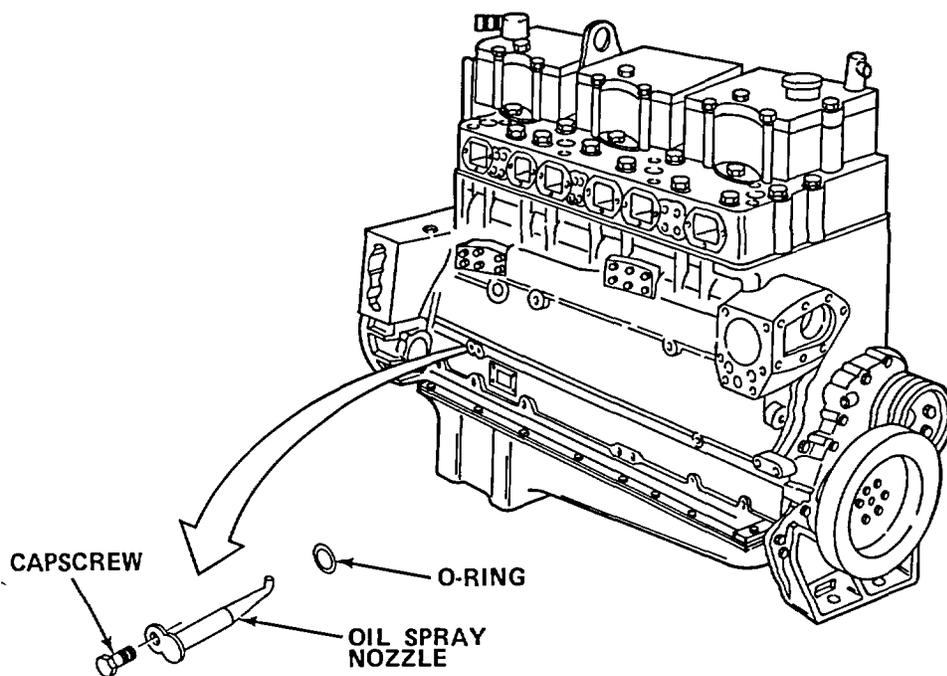
**WEAR PROTECTIVE CLOTHING AND GOGGLES WHEN STEAM CLEANING TO PREVENT POSSIBLE PERSONAL INJURY.**

- (1) Thoroughly steam clean engine exterior.
  - (2) Allow engine to thoroughly dry.
- e. Perform Preliminary Inspection.

Inspect external components for breaks, kinks, dents, deterioration, and any other damage.

f. Remove Remaining Engine Components.

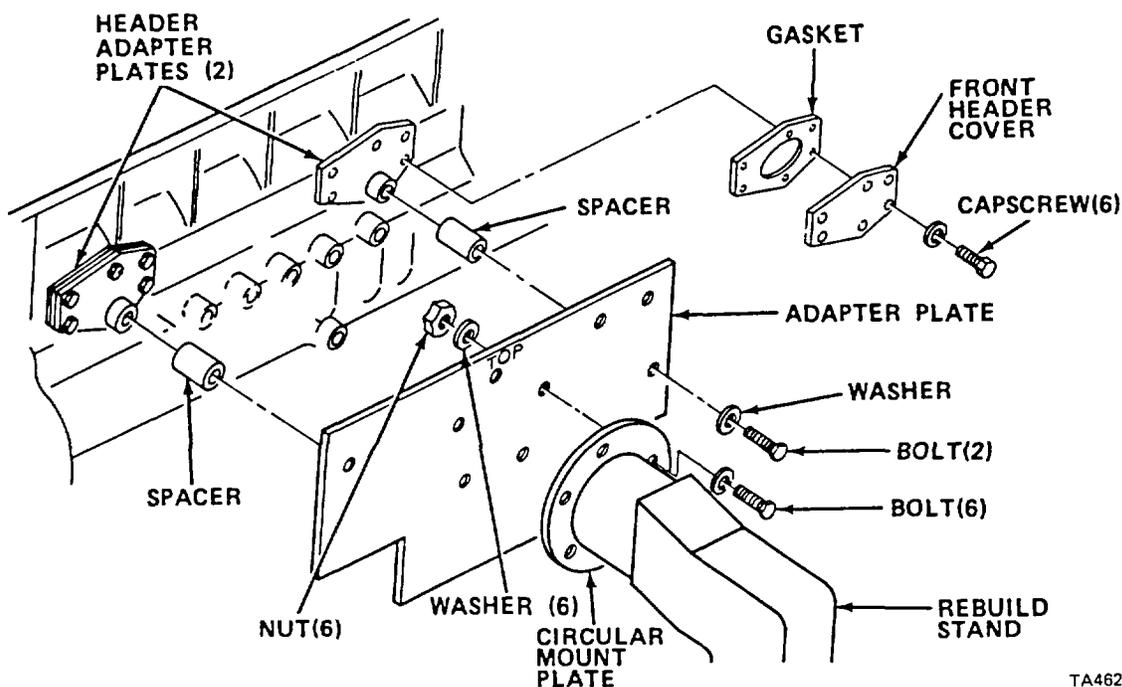
- (1) Remove Fuel Pump (TM 9-2320-281-34).
- (2) Remove Air Governor (TM 9-2320-281-20).
- (3) Remove Air Compressor (TM 9-2320-281-34).
- (4) Remove Power Steering Pump (TM 9-2320-281-20).
- (5) Remove Alcohol Evaporator (TM 9-2320-281-20).
- (6) Remove Water Inlet Assembly (TM 9-2320-281-20).
- (7) Remove Oil Spray Nozzles.



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- (a) Remove capscrews securing six oil spray nozzles to engine block.
- (b) Remove nozzles and O-rings. Discard O-rings.
- (8) Remove Turbocharger (TM 9-2320-281-20).
- (9) Remove Breather Tube (TM 9-2330-281-20).
- (10) Remove Oil Cooler and Water Header Connection (TM 9-2320-281-34).
- (11) Remove Aftercooler (TM 9-2320-281-34).

(12) Mount Engine in Engine Rebuild Stand.



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- (a) Remove capscrews and lockwashers securing forward water header cover to cylinder block, and remove cover and gasket. Discard gasket.
- (b) Secure both header plate adapters to header ports on right side of engine.

**NOTE**

**Adapter plate must be installed with word "TOP" facing up.**

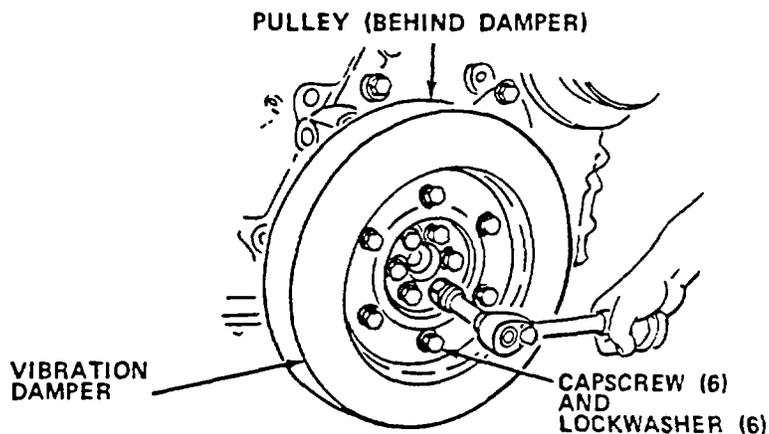
- (c) Position engine-to-rebuild stand adapter plate with spacers over water header adapter plates, and secure in position with capscrews and lockwashers.

**WARNING**

**DIRECT PERSONNEL TO STAND CLEAR DURING HOISTING OPERATION.  
FAILURE TO DO THIS MAY CAUSE INJURY TO PERSONNEL.**

- (d) Lift engine and mate adapter plate with circular mount plate on engine rebuild stand.
- (e) Bolt adapter plate and circular mount plate together with bolts, washers, and nuts.
- (f) Remove lifting device.

(13) Remove Vibration Damper.



TA295185

(a) Remove capscrews and lockwashers securing vibration damper to crankshaft.

**WARNING**

**MAINTAIN FIRM HOLD OF DAMPER WHEN REMOVING TO KEEP FROM DROPPING TO FLOOR. KEEP FEET CLEAR OF DAMPER TO PREVENT PERSONAL INJURY.**

**CAUTION**

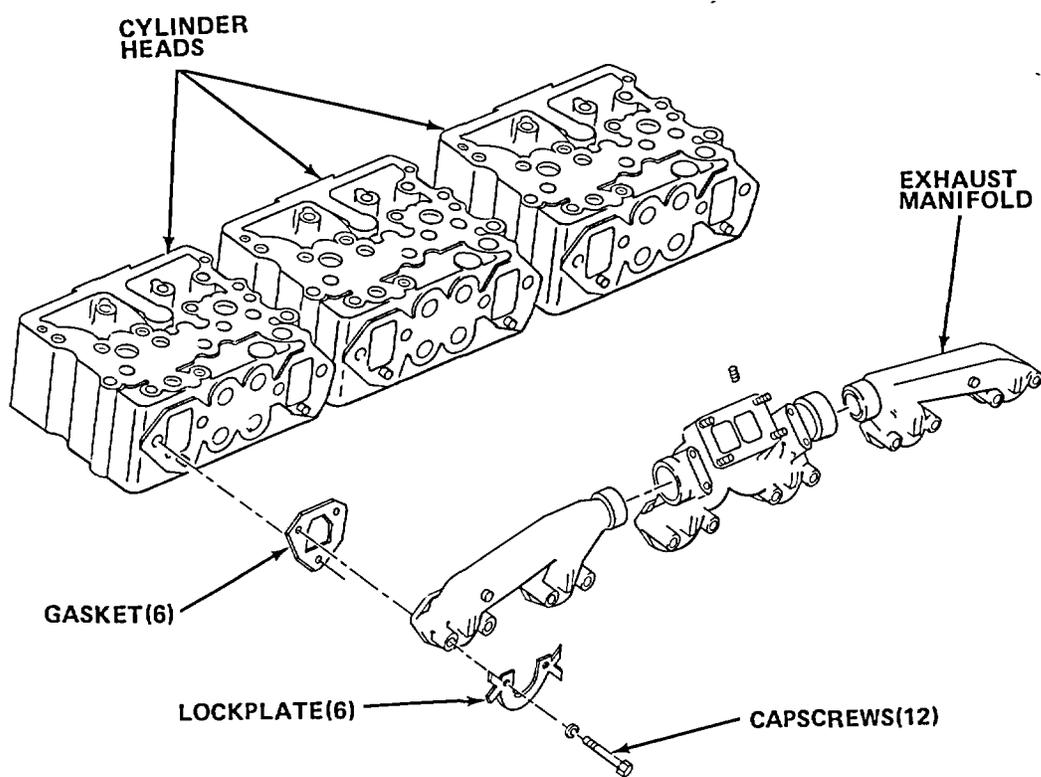
**DO NOT POUND OR PRY ON DAMPER TO FREE FROM CRANKSHAFT. DENTING OUTER SHELL MAY ELIMINATE ITS EFFECTIVENESS.**

(b) Firmly grasp damper and pull off crankshaft. If tight, tap on pulley with softhead mallet to free.

- (14) Remove Accessory Drive Housing Assembly (TM 9-2320-281-34).
- (15) Remove Power Steering Cooler Mount Bracket and Fan Clutch Mount Bracket , Brace (TM 9-2320-281-20).
- (16) Remove Water Pump and Idler Assembly (TM 9-2320-281-20).
- (17) Remove Exhaust Manifold.

**NOTE**

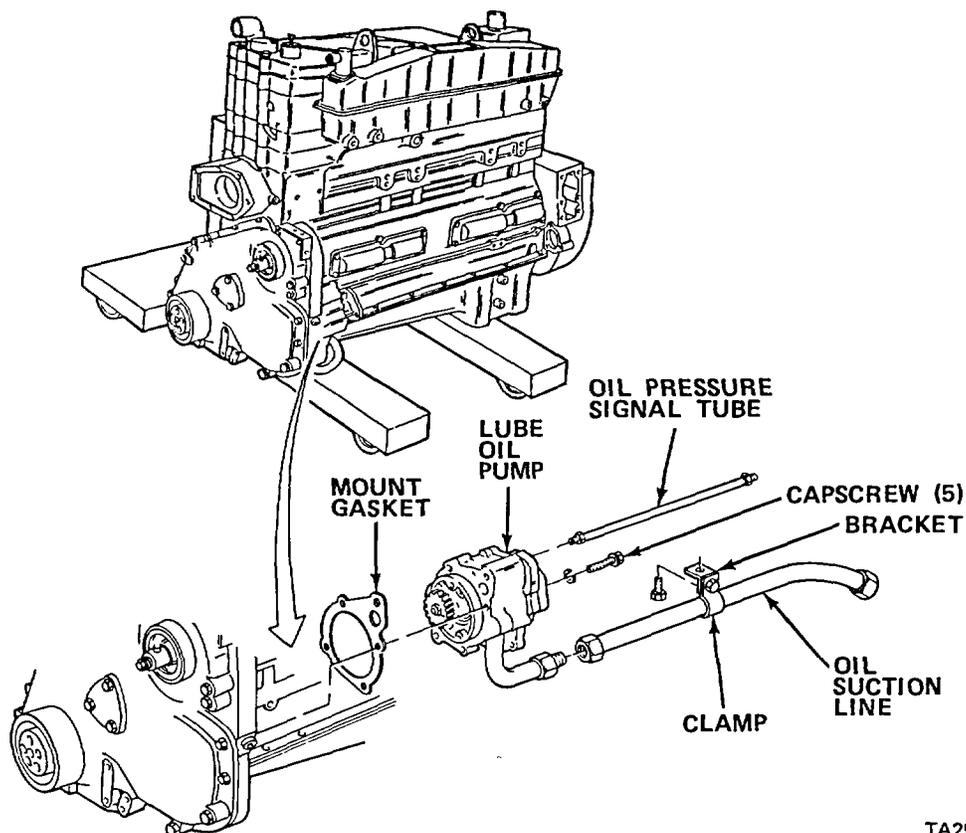
**Remove exhaust manifold as one assembly.**



TA295186

- (a) Bend back tabs on exhaust manifold capscrew lockplates.
- (b) Remove capscrews, washers, and lockplates. Discard plates.
- (c) Remove exhaust manifold and gaskets. Discard gaskets.

(18) Remove Lube Oil Pump.



TA295187

**NOTE**

**Oil pressure signal tube must be disconnected from engine block first.**

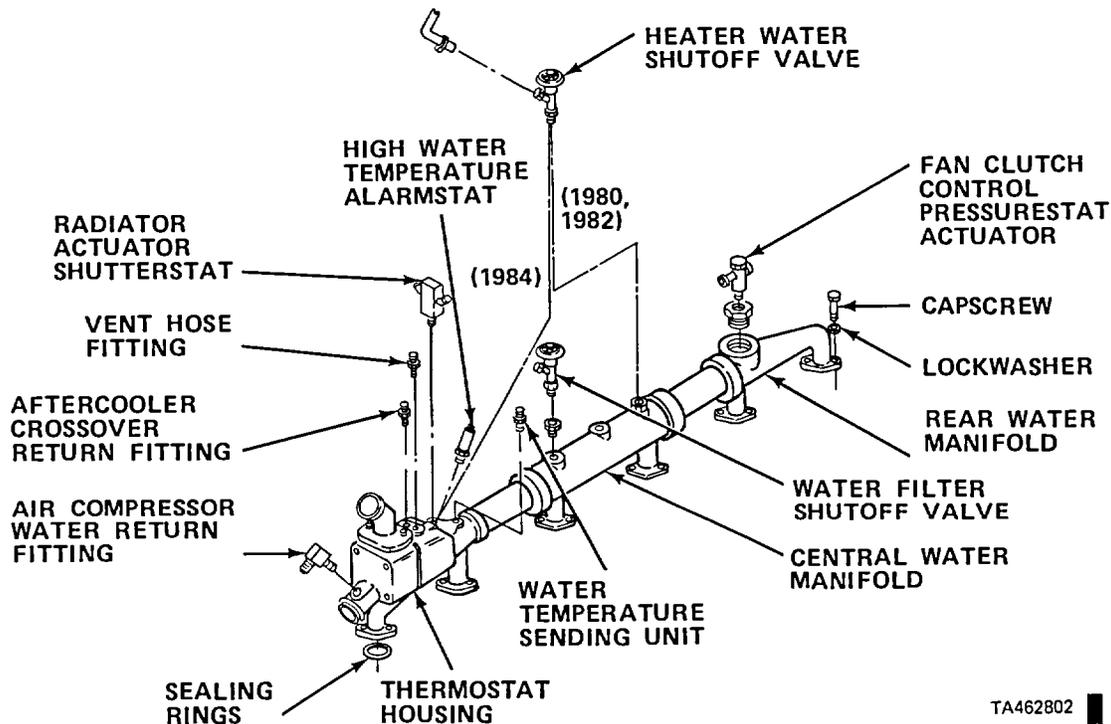
- (a) Disconnect oil pressure signal tube from pump and engine block and remove tube.
- (b) Disconnect oil suction line clamp and bracket from oil pan.
- (c) Disconnect oil suction line from oil pan fitting and oil pump inlet fitting and remove line.

**NOTE**

**Note lengths of pump mount capscrews to ensure proper reassembly.**

- (d) Remove capscrews and lockwashers securing pump to engine block.
- (e) Support pump and tap on pump housing with softhead mallet until free from engine block. Discard mount gasket.

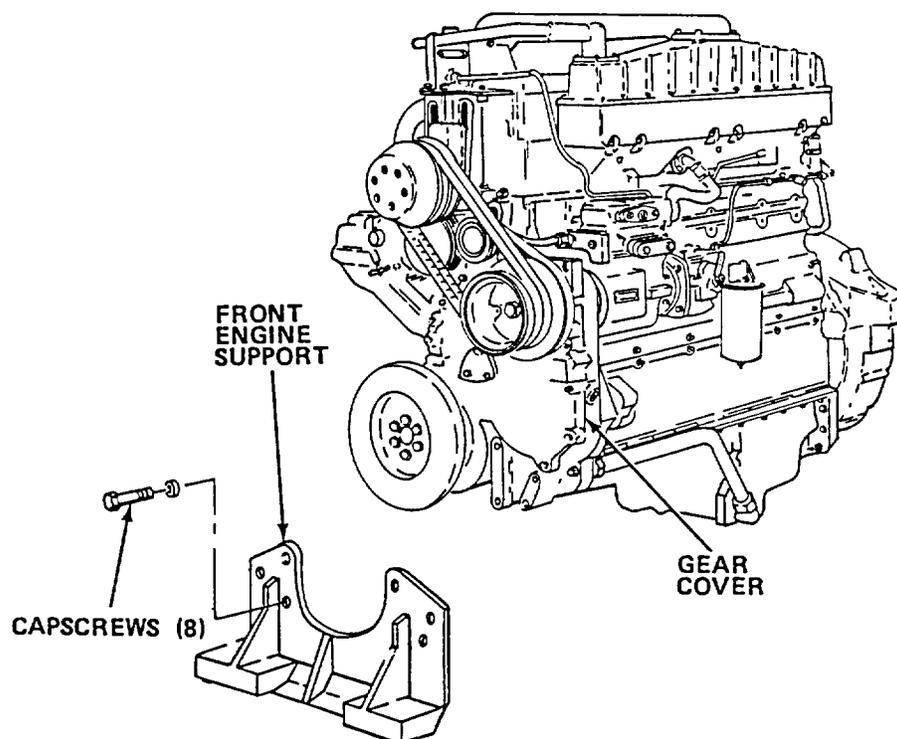
(19) Remove Water Manifolds and Thermostat Housing.



TA462802

- (a) Remove radiator actuator shutterstat (TM 9-2320-231-20).
- (b) Remove high water temperature alarmstat (TM 9-2320-281-20).
- (c) Remove water temperature sending unit (TM 9-2320-281-20).
- (d) Remove water filter shut-off valve (TM 9-2320-281-20).
- (e) Remove heater water shut-off valve (TM 9-2320-281-20).
- (f) Remove fan clutch pressurestat (TM 9-2320-281-20).
- (g) Remove capscrews and lockwashers securing water manifold to cylinder heads.
- (h) Remove thermostat housing, front, center, and rear water manifolds as an assembly.
- (i) Remove all remaining bushings and fittings from thermostat housing and manifolds.
- (j) Remove and discard sealing rings.

(20) Remove Front Engine Support.



TA295189

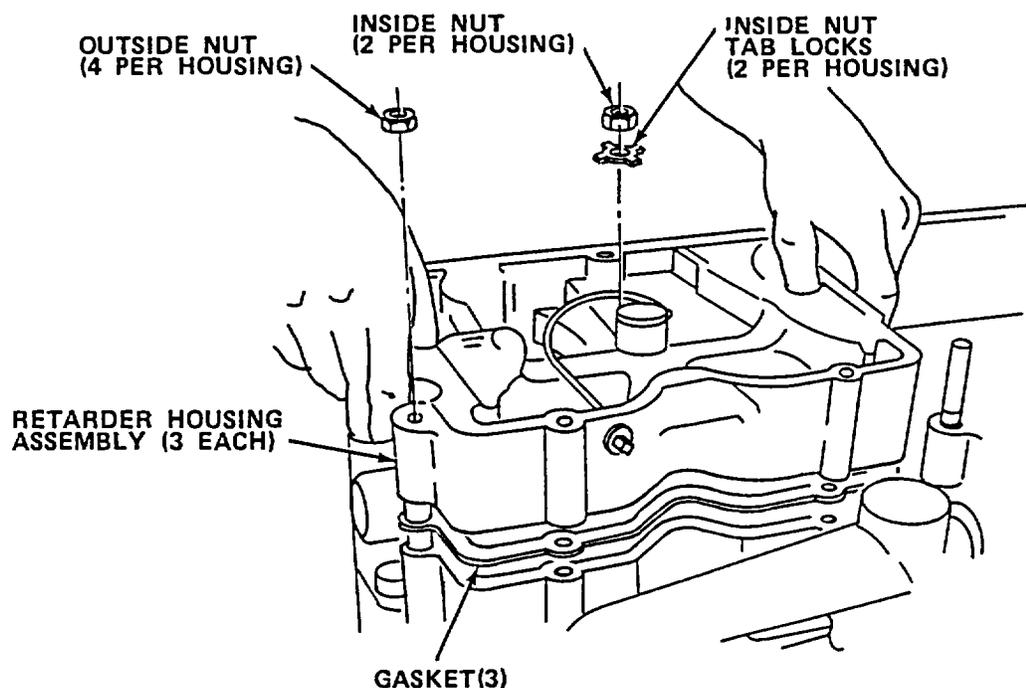
**NOTE**

**Note different lengths of cap screws and placement of washers to ensure proper reassembly.**

- (a) Remove cap screws, flat washers, and lockwashers securing front engine support to engine block.
- (b) Remove front engine support.

(21) Remove Rocker Housing Covers (TM 9-2320-281-20).

(22) Remove Engine Retarder Housing Assemblies.



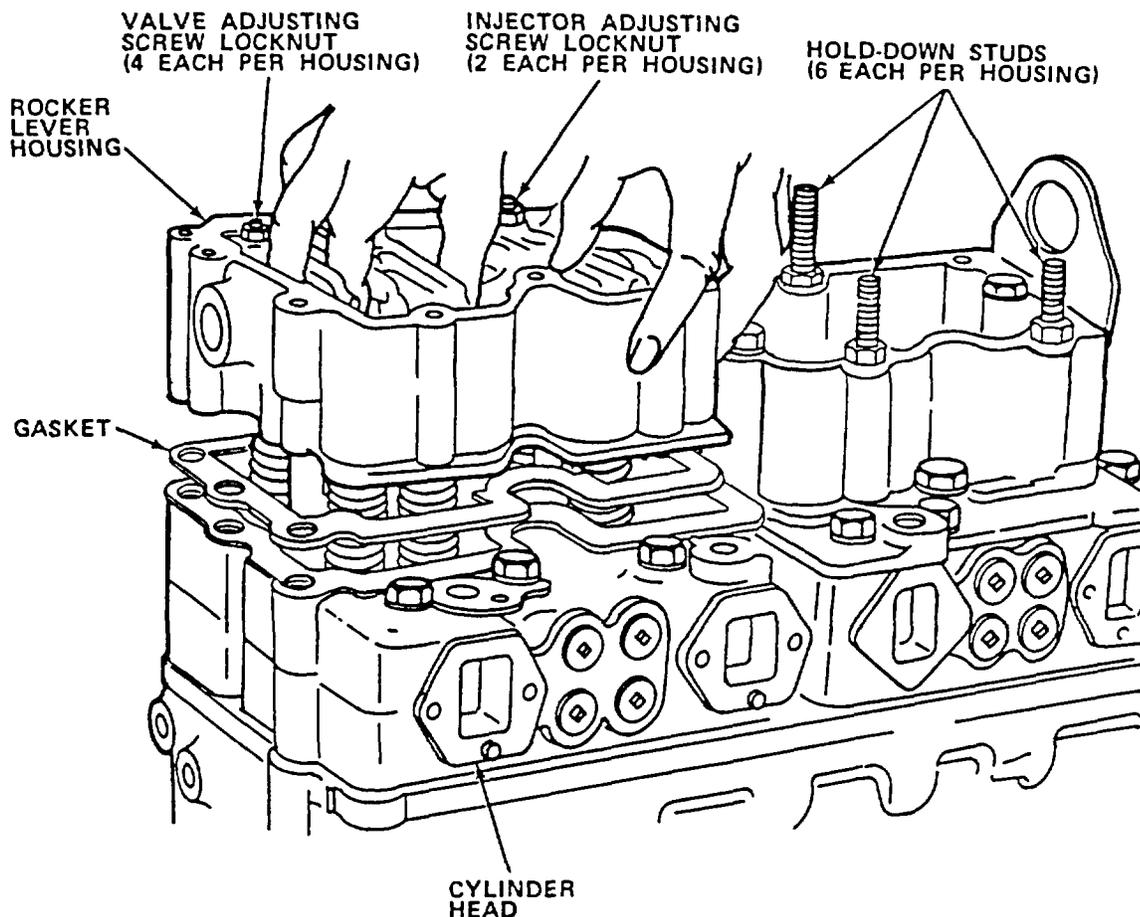
TA295190

#### NOTE

Note location of rear lift bracket and air intake tube center support bracket and associated spacers before removing engine retarder housings to ensure proper reassembly.

- (a) Mark engine retarder housing position (No. 1, 2, and 3, from front to rear).
- (b) Bend down tablocks on two inside nuts of each retarder housing.
- (c) Remove all nuts, washers, spacers, rear engine lift support, and air intake center support bracket.
- (d) Lift three engine retarder housings from rocker lever housings.
- (e) Remove and discard gaskets.

(23) Remove Rocker Lever Housing.



TA295191

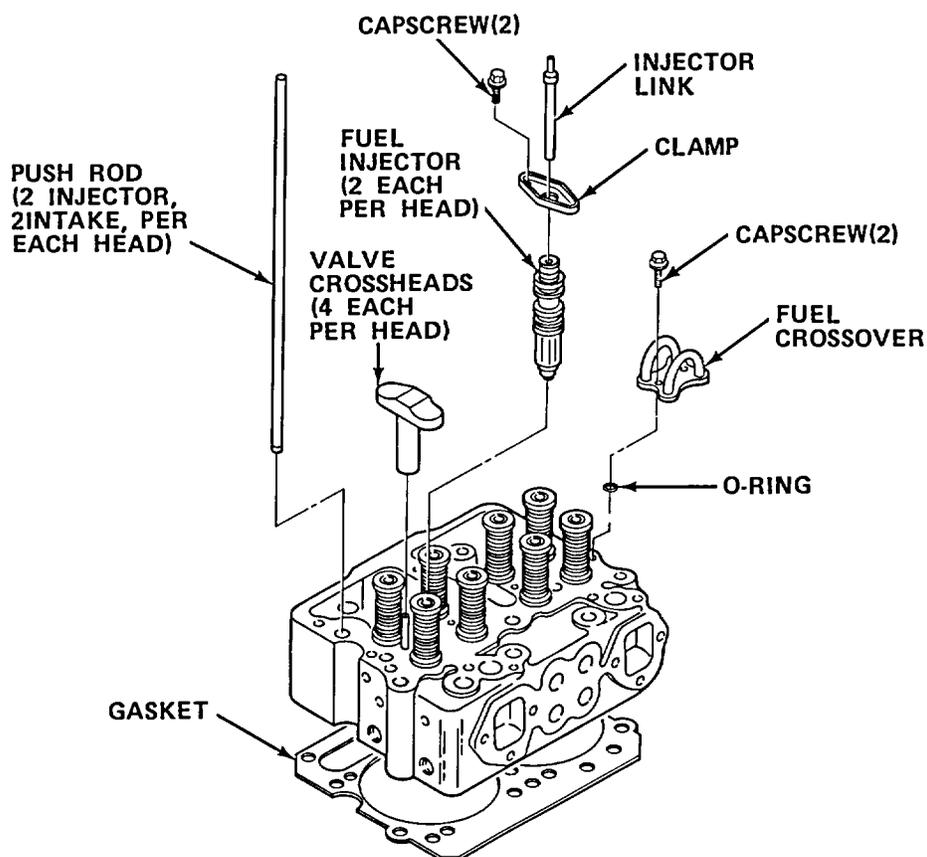
- (a) Mark housing positions (No. 1, 2, and 3, from front to rear).
- (b) Loosen valve adjusting screw locknuts and injector adjusting screw locknuts and back out, turning to left until tension is released.

**NOTE**

If aluminum rocker housing is used, special steel washers are used with housing hold-down studs. If steel rocker housing is used, no washers are installed. Note various lengths and locations of hold-down studs to ensure proper reassembly. Three different lengths are used.

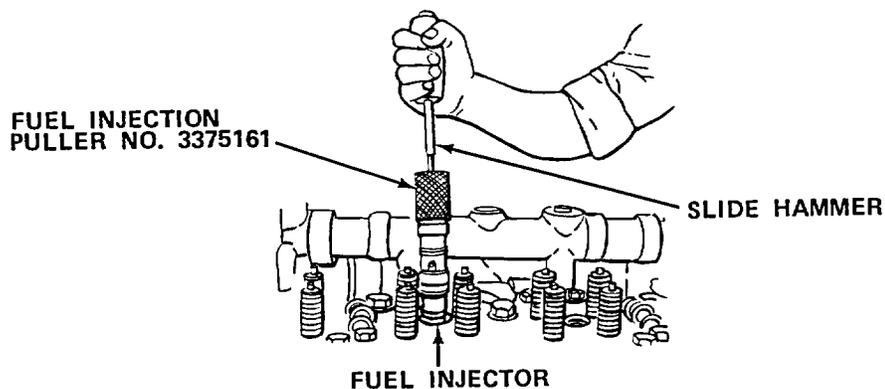
- (c) Remove hold-down studs and washers (if used) securing housings to cylinder heads.
- (d) Lift and remove housings and gaskets. Discard gaskets.

(24) Remove Cylinder Heads.



TA295192

- Mark push rods for position and remove rods.
- Mark valve crossheads for position and remove crossheads.
- Mark injector links for position and remove links.
- Remove capscrews securing injector hold-down clamps to cylinder head and remove clamps.



TA295193

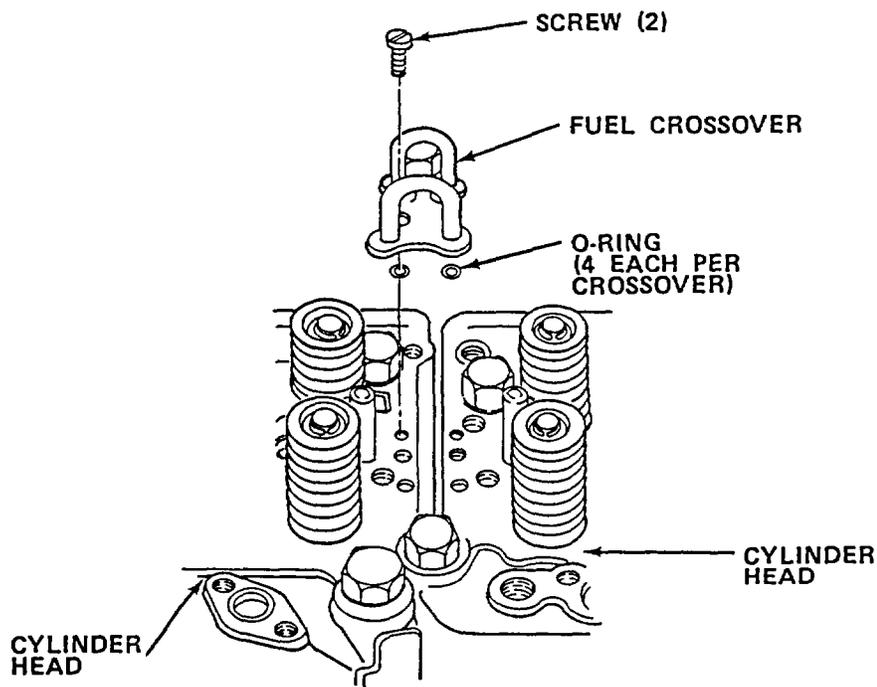
- Slide tool no. 3375161 over each injector and rotate tool to secure in place.

- (f) Carefully tap each injector out of head using slide hammer on tool.

**CAUTION**

**TO PREVENT PLUNGER FROM DROPPING OUT OF INJECTOR, DO NOT TURN INJECTOR UPSIDE-DOWN. DAMAGE CAN RESULT TO PLUNGER IF DROPPED.**

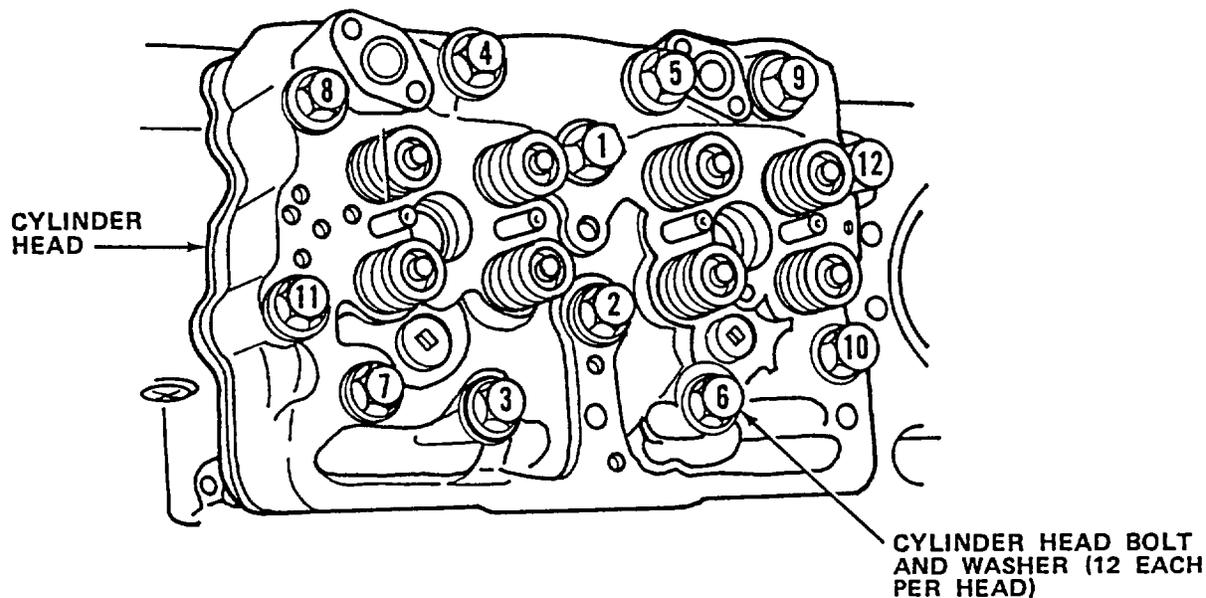
- (g) As each injector is removed, number its position and wrap in protective paper. Set injector straight up in holding rack.



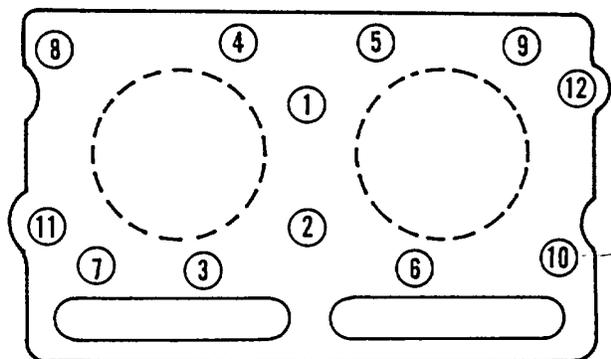
TA295194

- (h) Remove screws securing fuel crossovers to cylinder heads.
- (i) Remove fuel crossovers and O-rings. Discard O-rings.

(j) Mark each cylinder head for position. (No. 1, 2, and 3, from front to rear).



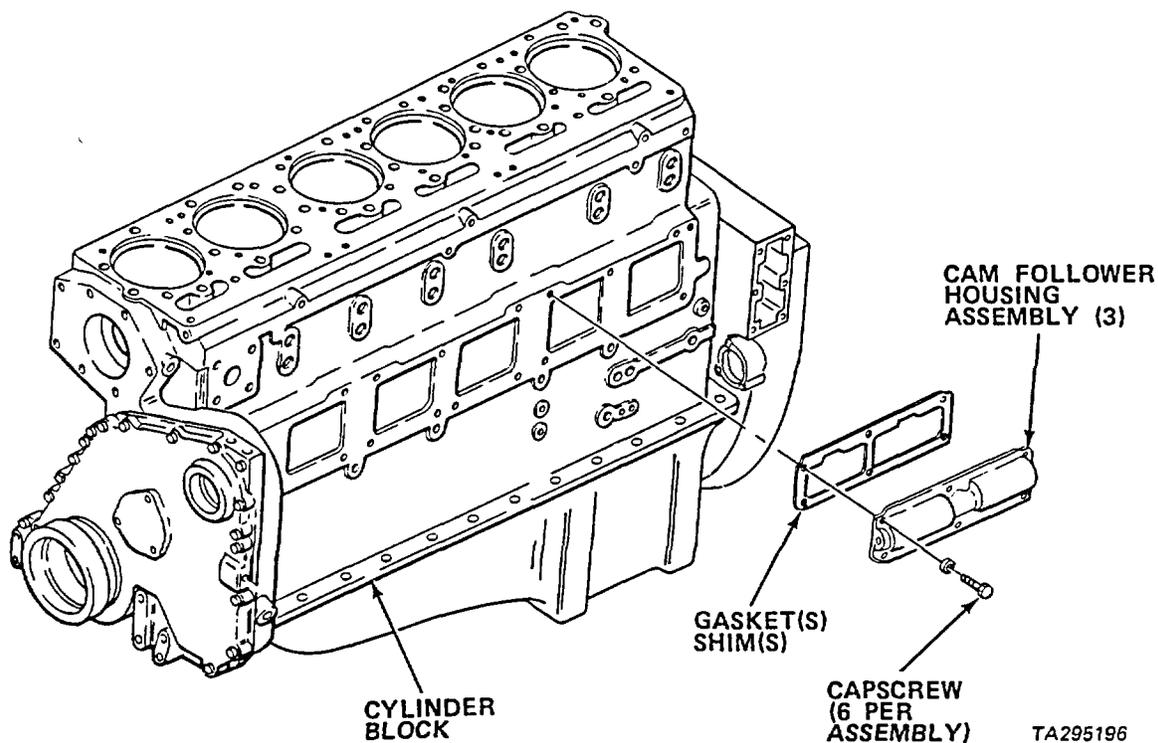
**NOTE:**  
**WHEN REMOVING HEAD**  
**LOOSEN NO. 12 CYLINDER**  
**HEAD BOLT FIRST, THEN WORK**  
**BACKWARDS TOWARD NO. 1**



TA295195

- (k) Remove cylinder head bolts and washers in opposite order to torquing sequence as shown above.
- (l) Remove cylinder heads and gaskets. Discard gaskets.

(25) Remove Cam Follower Housing Assemblies.



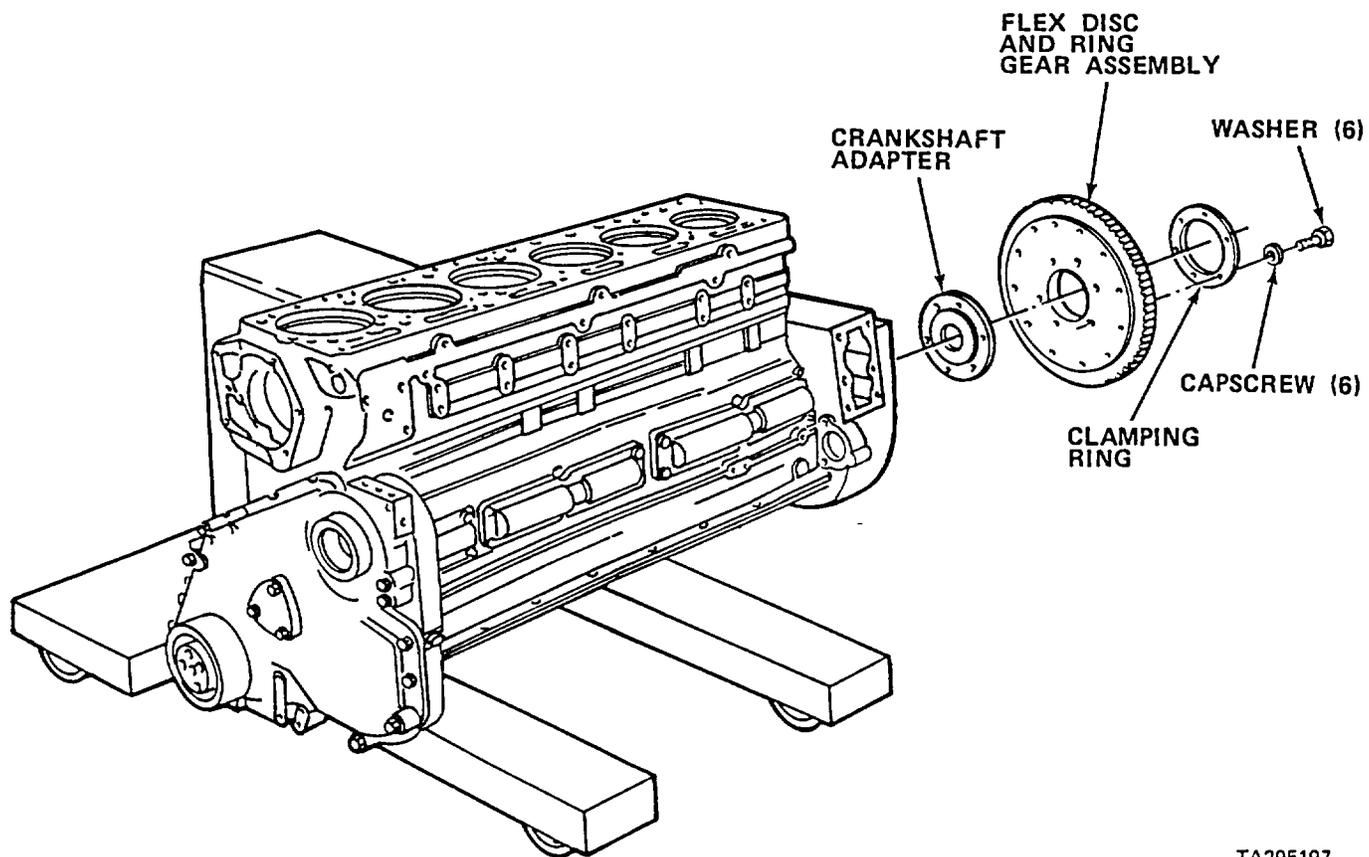
- (a) Mark position of each cam follower housing assembly to ensure proper reassembly.
- (b) Remove capscrews and lockwashers securing cam follower housing assemblies to cylinder block.
- (c) Carefully tap on assemblies with softhead mallet to break free from assembly-positioning dowels.
- (d) Remove cam follower housing assemblies.

**NOTE**

**Measuring and recording of total thickness of gaskets (shims) for each housing is necessary to establish proper injector timing. Thickness variations occur due to differences in housing castings.**

- (e) Remove old shim(s), measure, and record thickness for each housing. After recording, discard shim(s).

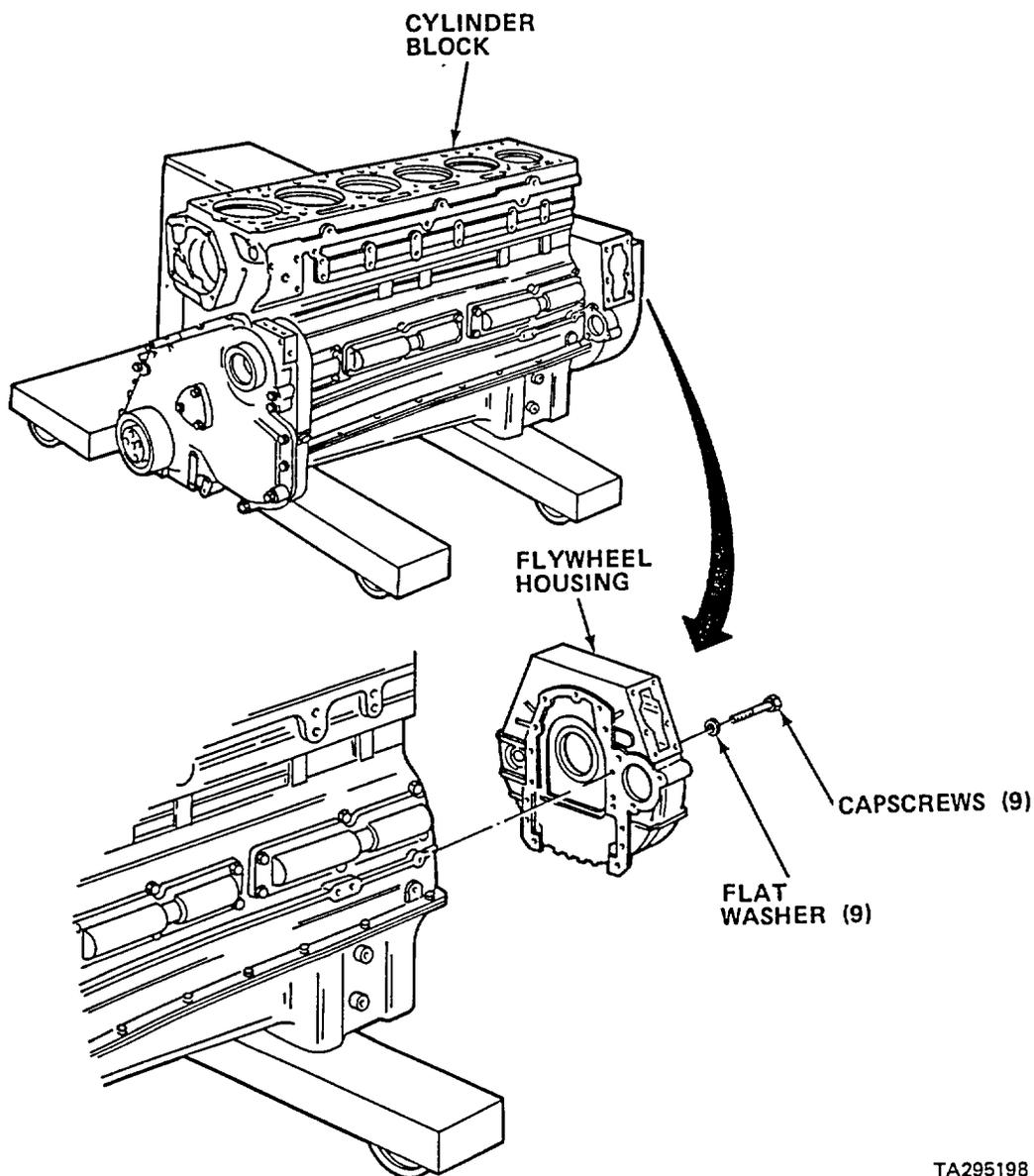
(26) Remove Flex Disk and Ring Gear Assembly.



TA295197

- (a) Remove capscrews and washers securing flex disk and ring gear assembly, clamping ring, and crankshaft adapter.
- (b) Remove clamping ring, flex disk and ring gear assembly, and crankshaft adapter.

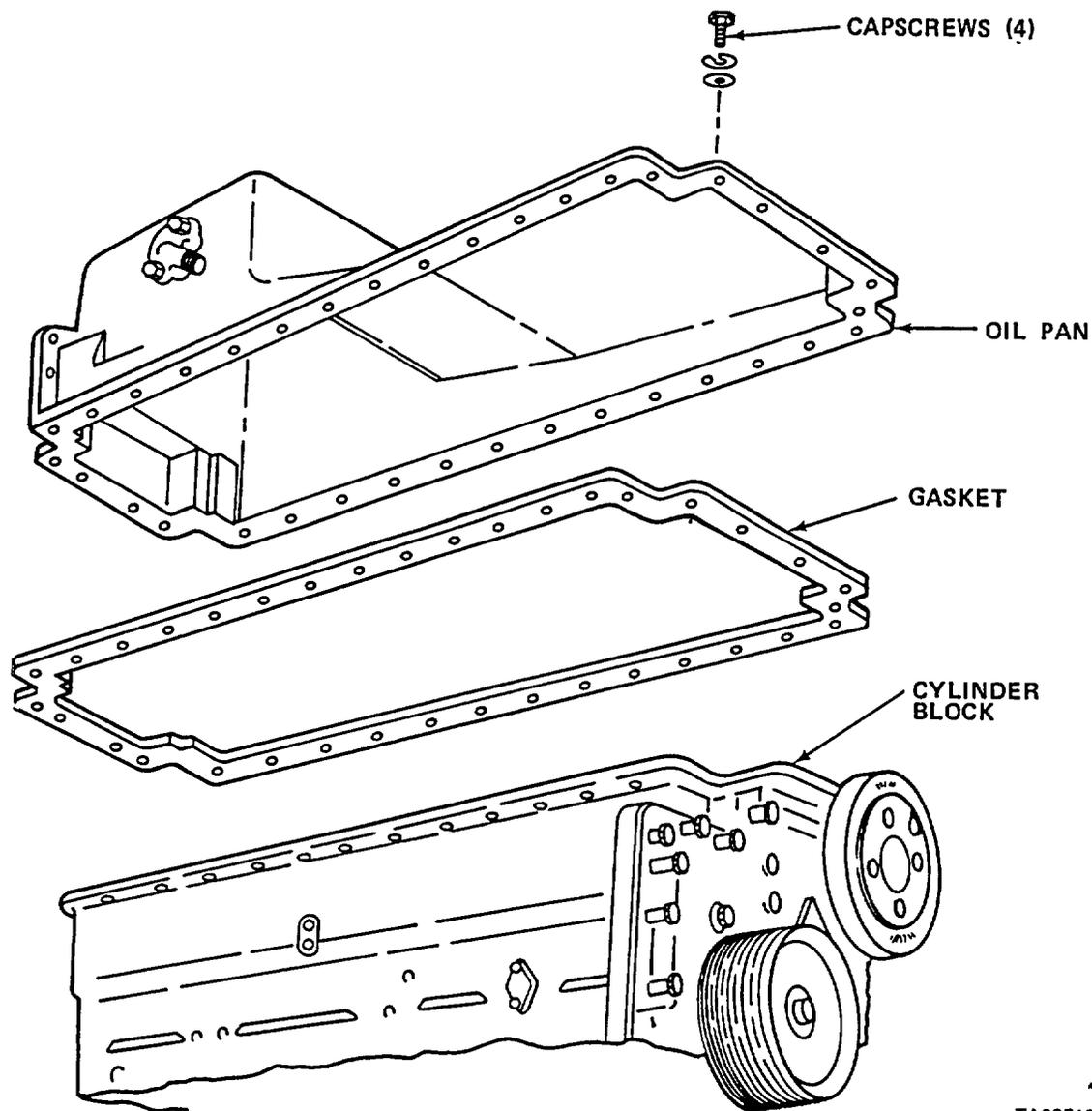
(27) Remove Flywheel Housing.



TA295198

- (a) While supporting flywheel housing, remove capscrews and flat washers securing flywheel housing to cylinder block.
- (b) Remove flywheel housing from positioning dowels. Use rubberfaced mallet to assist in removal if needed.

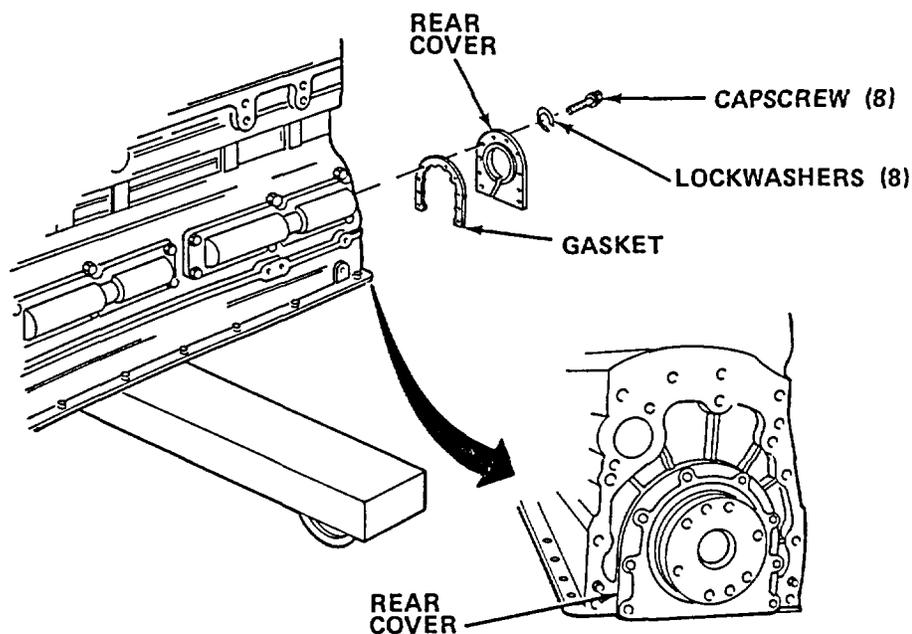
(28) Remove Oil Pan.



TA295199

- (a) Rotate engine until it is upside down.
- (b) Remove capscrews, flat washers and lockwashers securing oil pan to rear cover.
- (c) Remove capscrews securing oil pan to cylinder block.
- (d) Remove capscrews, flat washers, and lockwashers securing oil pan to front gear cover.
- (e) Remove oil pan and gasket. Discard gasket.

(29) Remove Rear Cover.

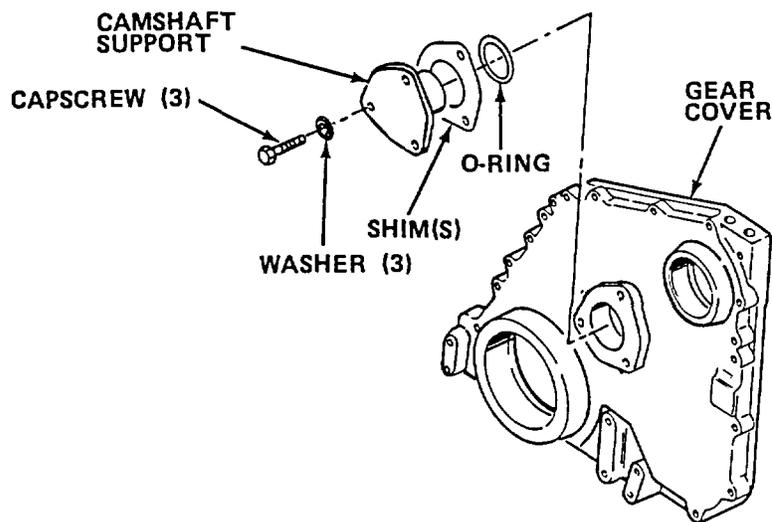


TA295200

(a) Remove capscrews and lockwashers securing rear cover to cylinder block.

(b) Remove rear cover and gasket. Discard gasket.

(30) Remove Front Gear Cover.



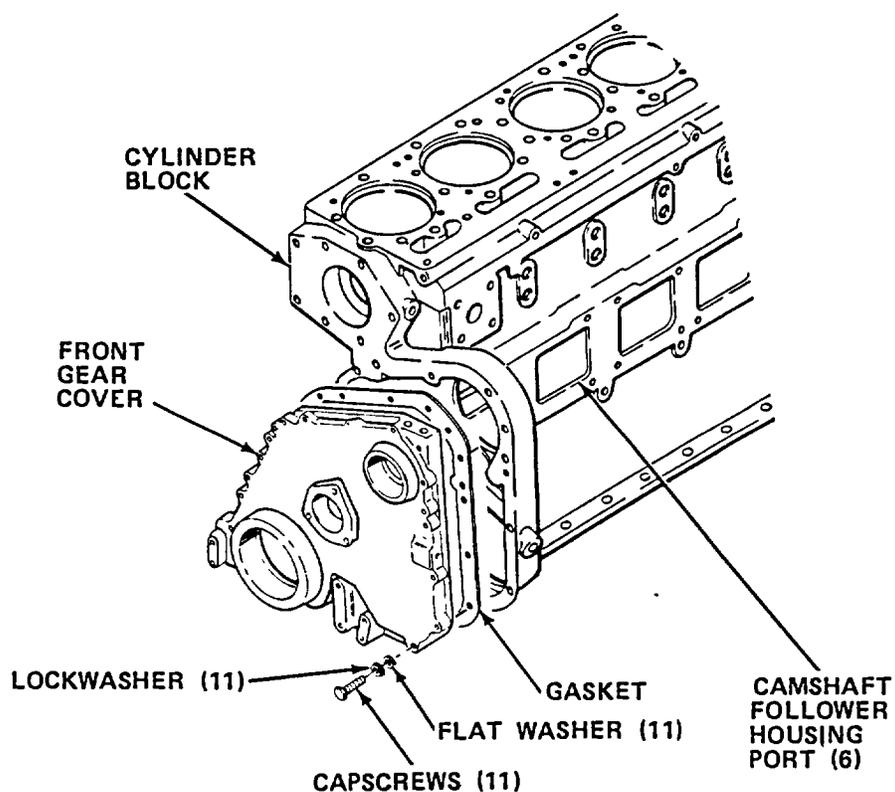
TA295201

**NOTE**

**Take note of different length capscrews to ensure proper reassembly.**

(a) Remove capscrews and flat washers, securing camshaft support to gear cover.

- (b) Remove camshaft support, shim(s), and O-ring. Discard O-ring.

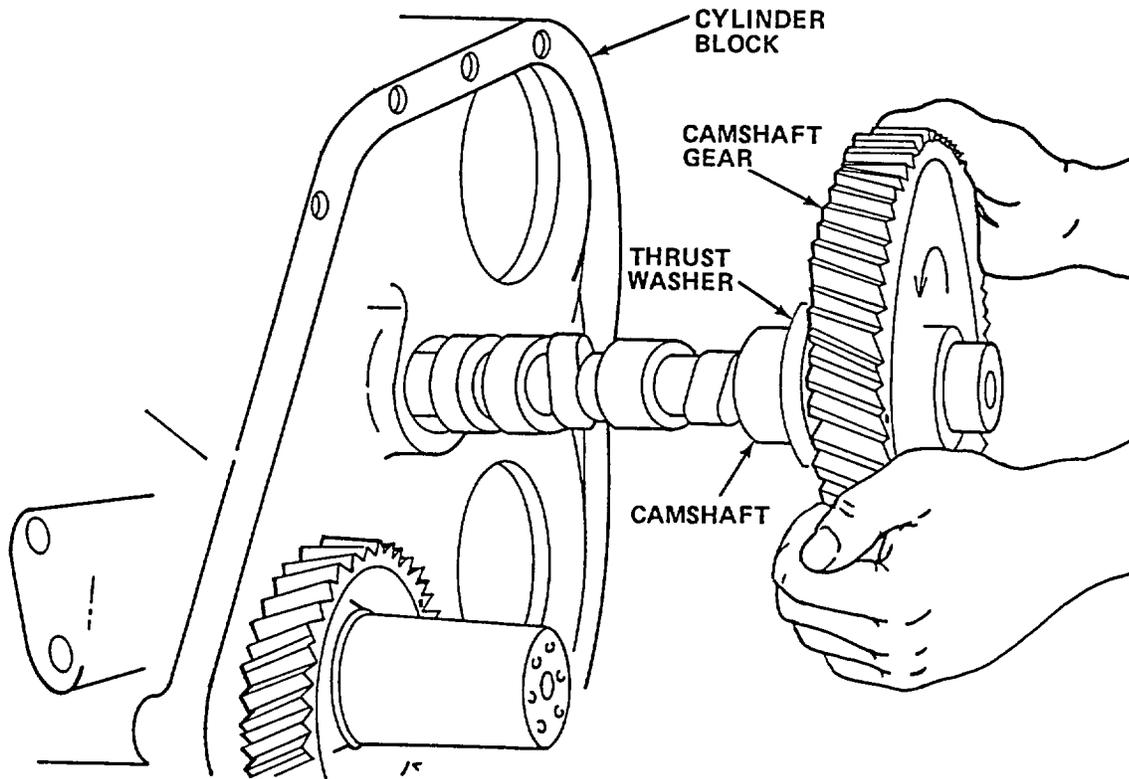


TA295202

- (c) Remove capscrews and flat washers securing gear cover to cylinder block.
- (d) Screw two 4-in. (101.6 mm) long guide studs into cylinder block at two places across from each other.
- (e) Tap on gear cover with softhead mallet to free from gasket and dowel positioning pins.
- (f) Remove front gear cover and gasket. Discard gasket.

(31) Remove Camshaft and Gear.

- (a) Have assistant work through cam follower housing ports to assist in guiding camshaft out of cylinder block while removing camshaft.



TA295203

- (b) Rotate camshaft slightly while carefully pulling camshaft out of cylinder block.
- (c) Remove and discard thrust washer from camshaft.
- (d) Tap out cup plug at rear of camshaft bore. Discard plug.

(32) Connecting Rod and Piston Assemblies.

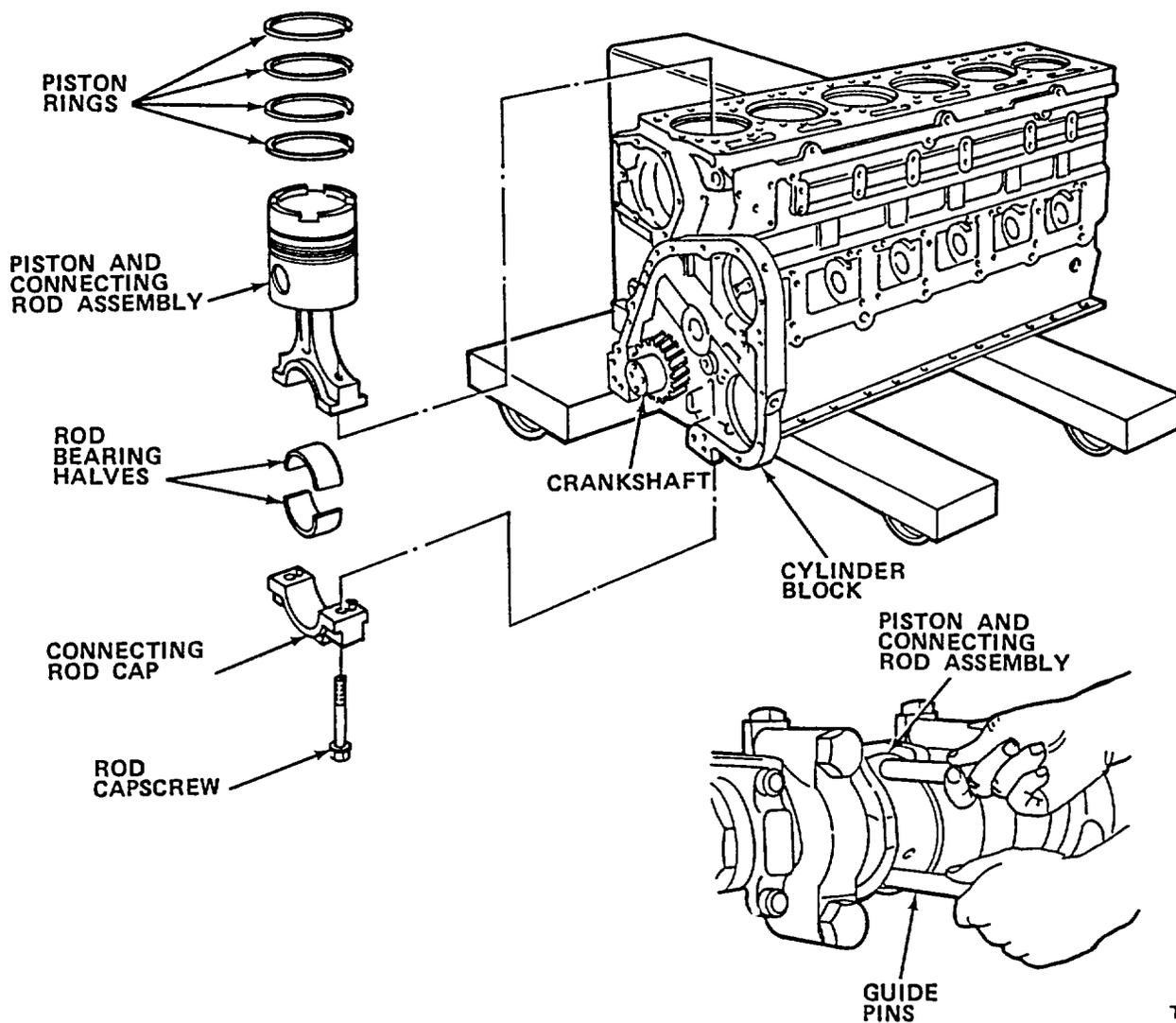
- (a) Rotate engine so that it is right side up.

**CAUTION**

**TAKE CARE NOT TO DAMAGE LINER FINISH WHEN REMOVING CARBON.**

- (b) Carefully remove carbon from upper inside walls of liners. Polish with fine emery cloth.

- (c) Thoroughly wipe area clean.
- (d) Rotate engine to vertical position with front-end up.
- (e) Rotate crankshaft so that rod bearing cap is accessible.



TA295204

- (f) Loosen connecting rod capscrews approximately 3/8 in. (9.52 mm).

**CAUTION**

**DO NOT PRY OR HAMMER ON CONNECTING ROD CAPS. DAMAGE TO CAPS OR RODS MAY RESULT.**

- (g) Tap on connecting rod capscrew heads with softhead mallet to pull caps away from dowel alignment pins.

**NOTE**

**Keep rod caps and mating rods together. Do not intermix parts. Caps and rods are matched assemblies.**

- (h) Remove capscrews and rod caps with lower bearing half.
- (i) Install two connecting rod guide pins.

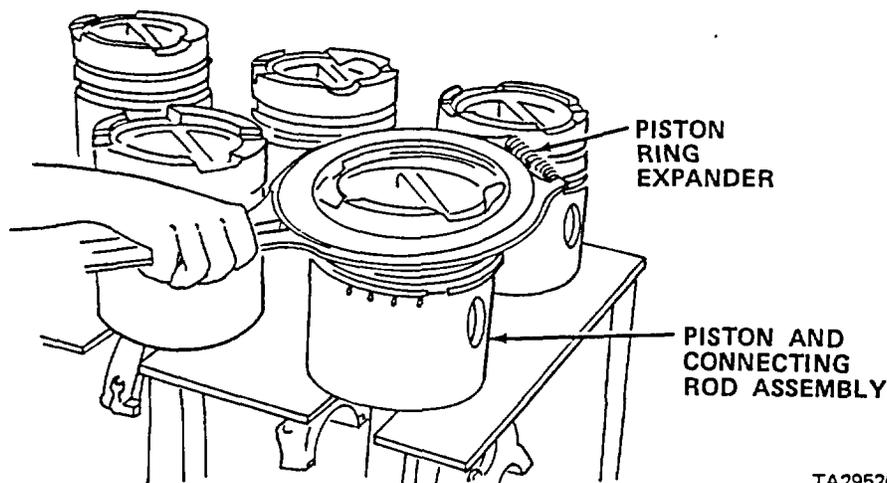
**CAUTION**

**CAREFULLY PUSH CONNECTING ROD AND PISTON ASSEMBLIES FROM LINERS TAKING CARE NOT TO SCORE OR GOUGE LINER WALLS.**

**NOTE**

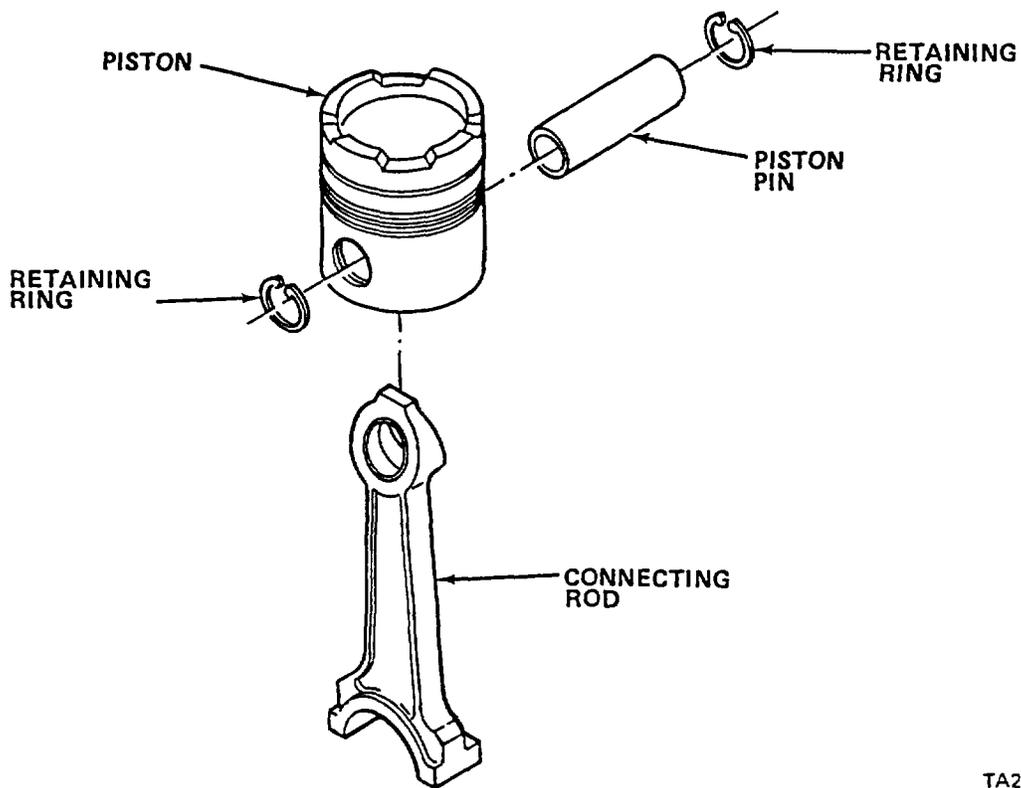
**ASSISTANT SHOULD BE USED IN REMOVAL OF PISTON AND CONNECTING ROD ASSEMBLY.**

- (j) Carefully push connecting rod and piston assemblies from cylinder liners, holding pistons so they will not drop.
- (k) Check each rod and cap to ensure it is stamped and labeled.
- (l) Remove rod upper bearing half and assemble each connecting rod to its mating rod cap.
- (m) Tape mating connecting rod bearing halves together and label each pair by cylinder.



TA295205

- (n) Using piston ring expander, remove and discard piston rings.



TA295206

- (o) Remove and discard piston pin retaining rings.

**WARNING**

**USE PROTECTIVE GLOVES WHEN HANDLING HOT PISTONS TO PREVENT SKIN BURNS.**

- (p) Heat piston in boiling water for two minutes.

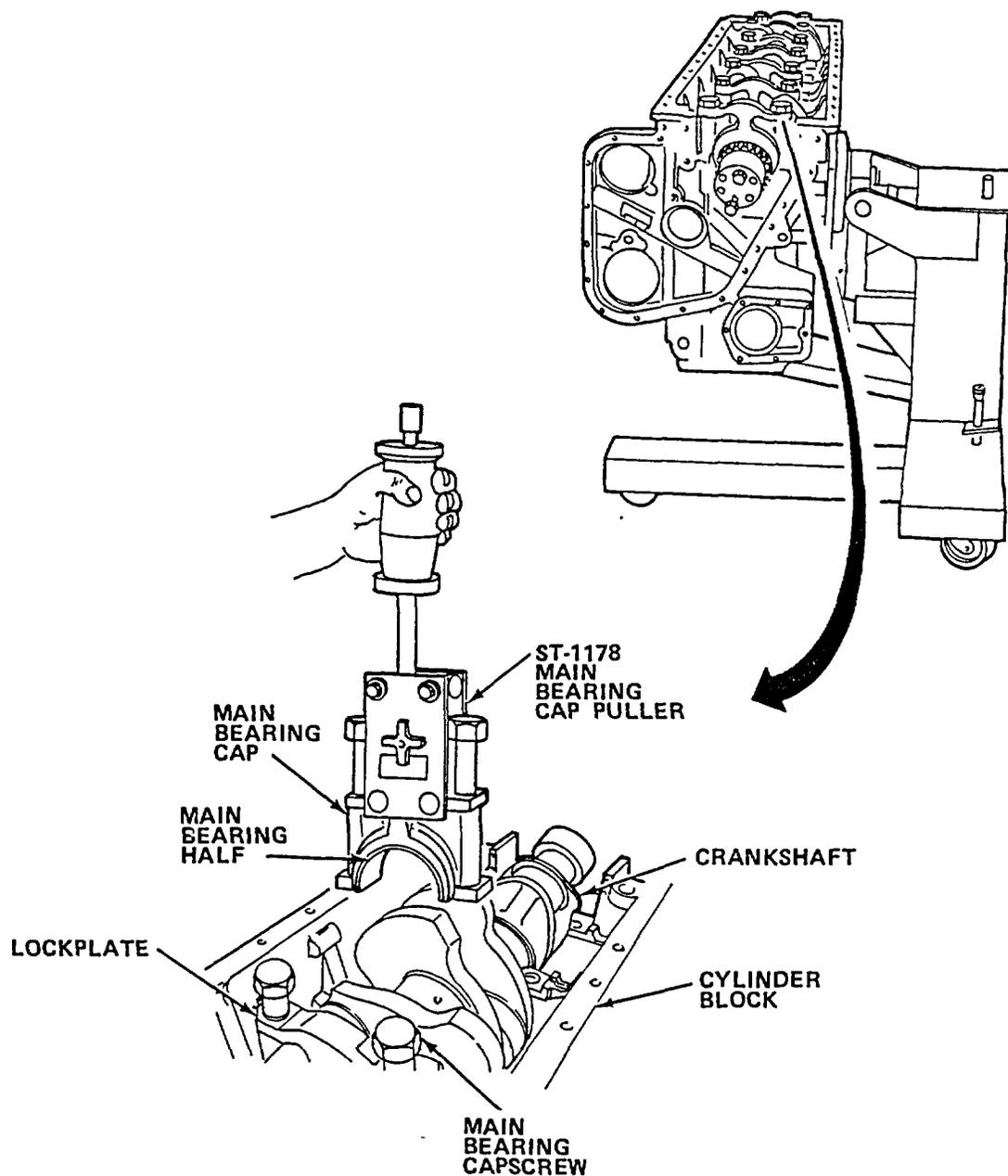
**CAUTION**

**DO NOT DRIVE AGAINST PIN OR USE EXCESSIVE FORCE WHEN REMOVING PIN FROM PISTON.**

- (q) Push piston pin from piston using finger pressure or wood or plast drift.  
 (r) Separate piston from connecting rod.  
 (s) Tag piston by cylinder position, if not previously stamped.

(33) Crankshaft and Main Bearings.

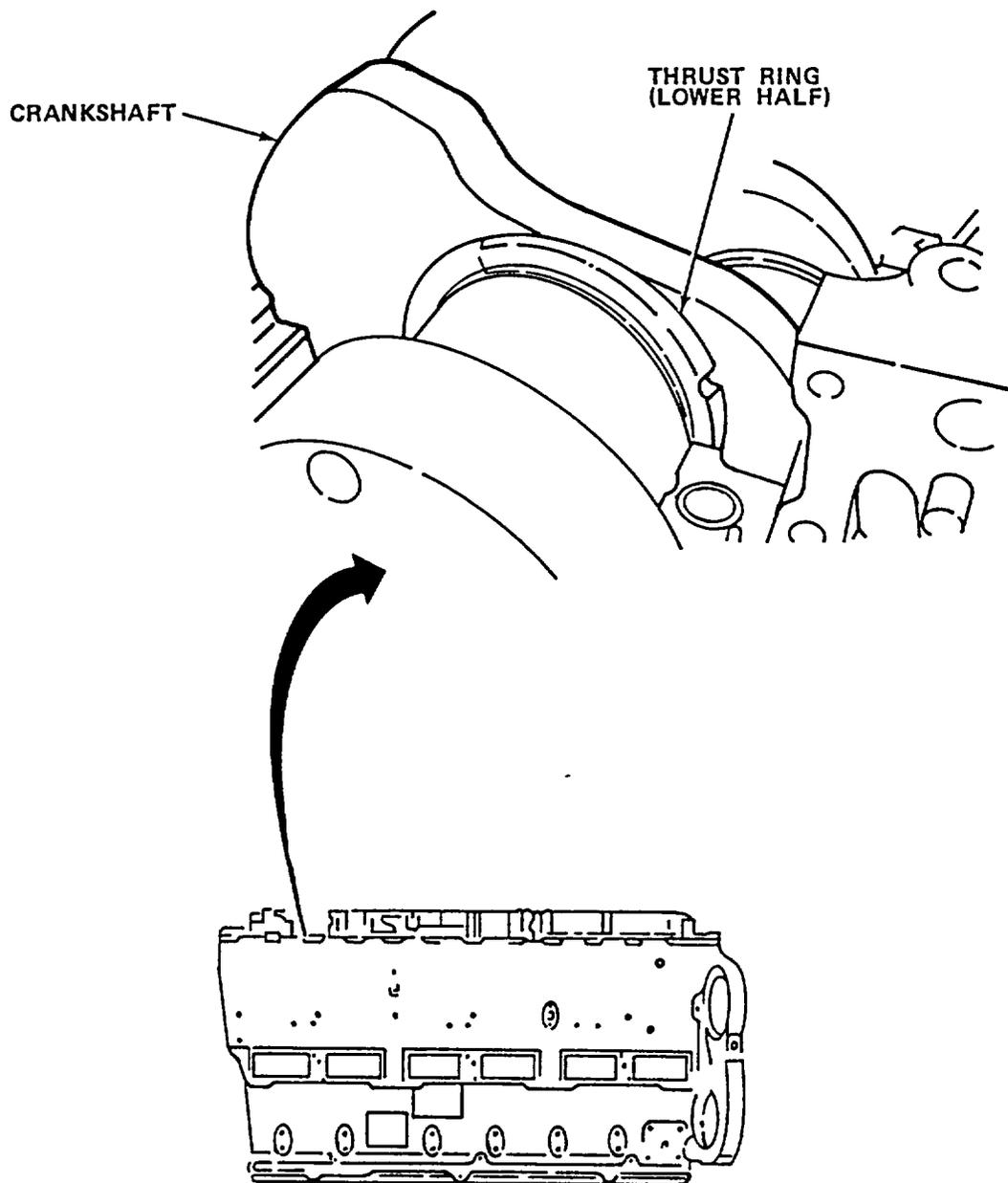
- (a) Rotate engine to upside down position.
- (b) Mark bearing caps to their journal position with No. 1 starting at vibration damper end.



TA295207

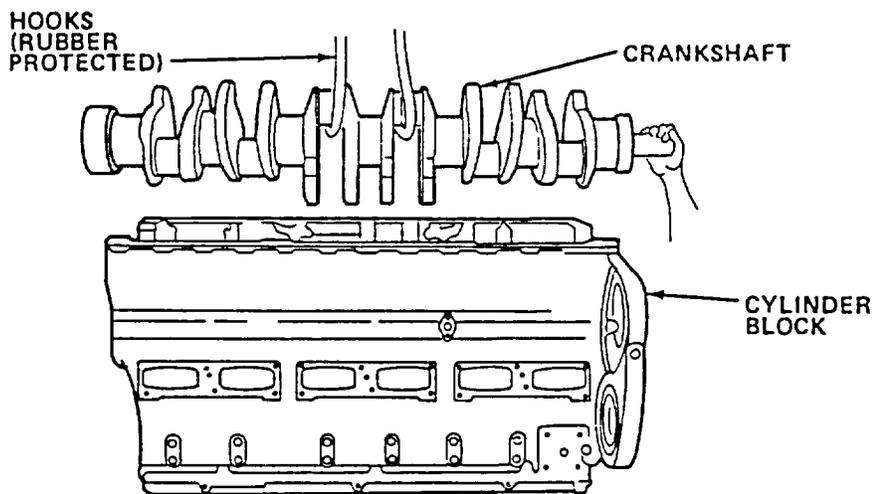
- (c) Bend lockplate tabs and remove cap screws and lockplates from main bearing caps. Discard lockplates.

- (d) With ST-1178 main bearing cap puller, remove main bearing caps and lower bearing halves.



TA295208

- (e) Remove lower half of rear main bearing thrust rings.
- (f) Remove main bearing lower halves from crankshaft if not previously removed.

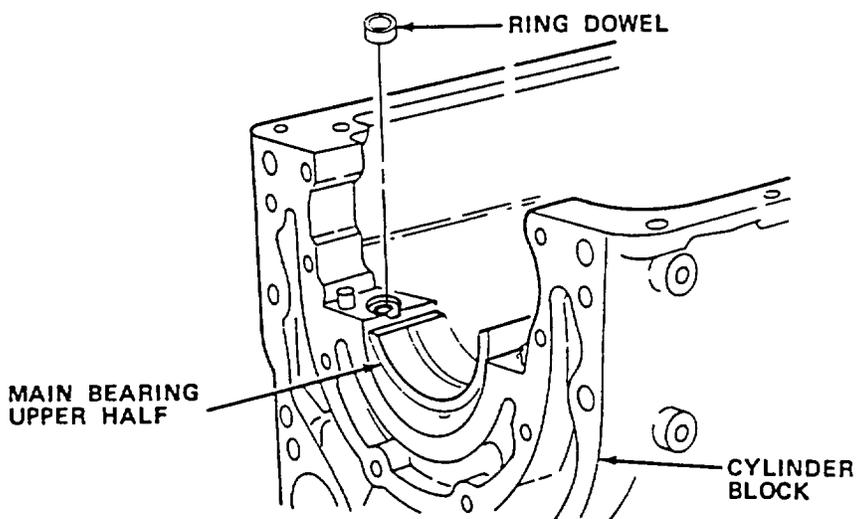


TA295209

**CAUTION**

**HANDLE CRANKSHAFT WITH CARE TO PREVENT DAMAGE TO FINISHED SURFACES. CRANKSHAFT IS VERY HEAVY.**

- (g) Place nylon lifting sling or rubber protected hooks around rod journals 3 and 4.
- (h) Use lifting device to lift crankshaft clear of cylinder block.

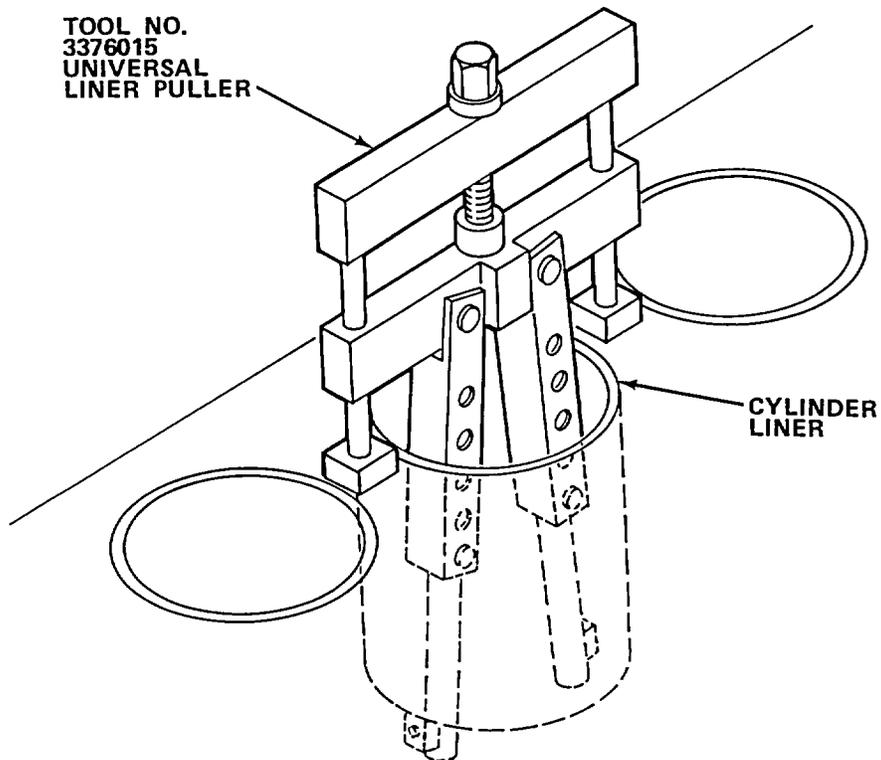


TA295210

- (i) Remove main bearing upper halves, ring dowels and upper half of thrust rings. Discard ring dowels.
- (j) Tape mating bearing halves and thrust rings together and label each pair of main bearings by journal number.

(34) Remove Cylinder Liners.

- (a) Rotate engine to upright position.



TA295211

**NOTE**

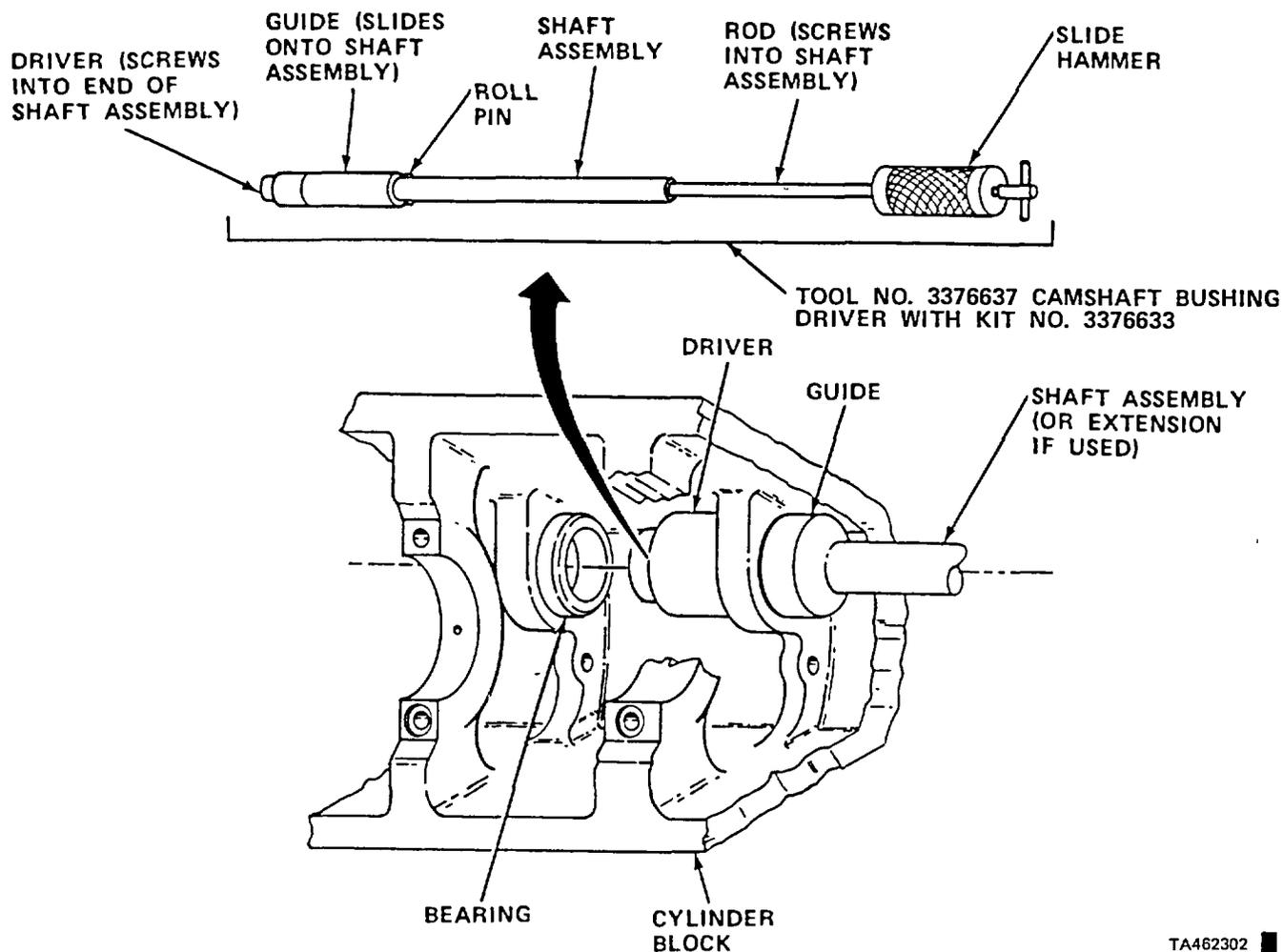
**Tool no. 3376015 universal liner puller must be initially adjusted to fit length of liner.**

- (b) Adjust tool lifting bolt to allow for lifting of puller legs.
- (c) Place tool over liner with tool legs engaged with bottom of liner.
- (d) Turn lifting bolt and withdraw liner from block.
- (e) Tag liner by cylinder position.
- (f) Remove puller from liner.
- (g) Remove and discard crevice seal and two O-rings.

(35) Remove and Discard Camshaft Bearings.

**NOTE**

Camshaft bearings installed in engines with high mileage (300,000 to 600,000 miles) should be replaced during overhaul. Bearings installed in engines with less accumulated mileage can be reused, providing original camshaft is used and bearing inside diameter does not exceed 2.5008 in. (63.5203 mm). Anytime the camshaft is replaced, the bearings must also be replaced, regardless of their condition.



- (a) Slip slide hammer onto rod.
- (b) Screw rod into shaft assembly. Ensure rod is tight in shaft assembly.
- (c) Slide guide on shaft assembly against roll pin.

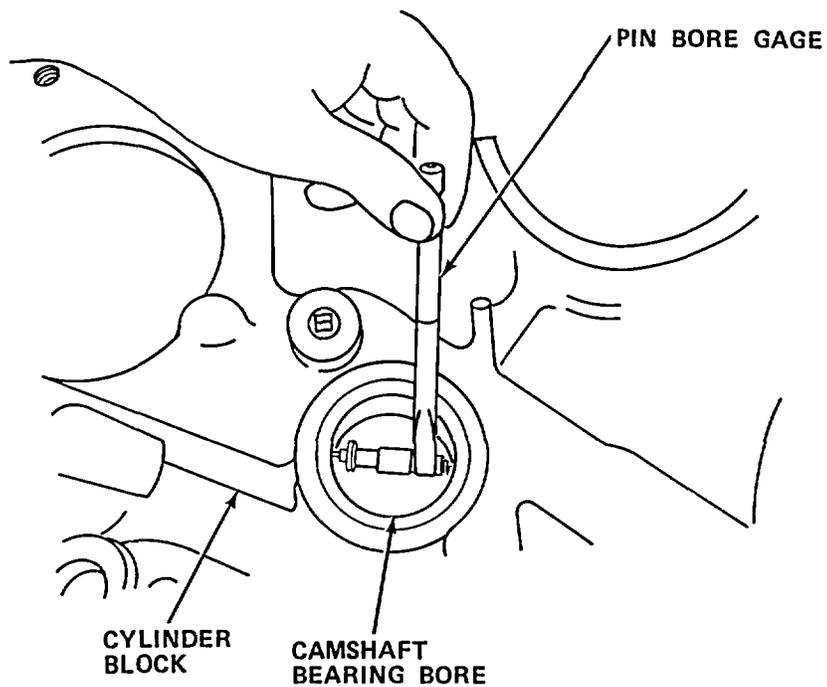
TA462302

- (d) Screw driver into end of shaft assembly.
- (e) Insert driver end of tool into camshaft bearing.
- (f) Using slide hammer, tap bearing out of bore.

**NOTE**

**An extension to shaft assembly is available to provide extended reach into block.**

- (g) Drive remaining bearings out of bore in same manner.

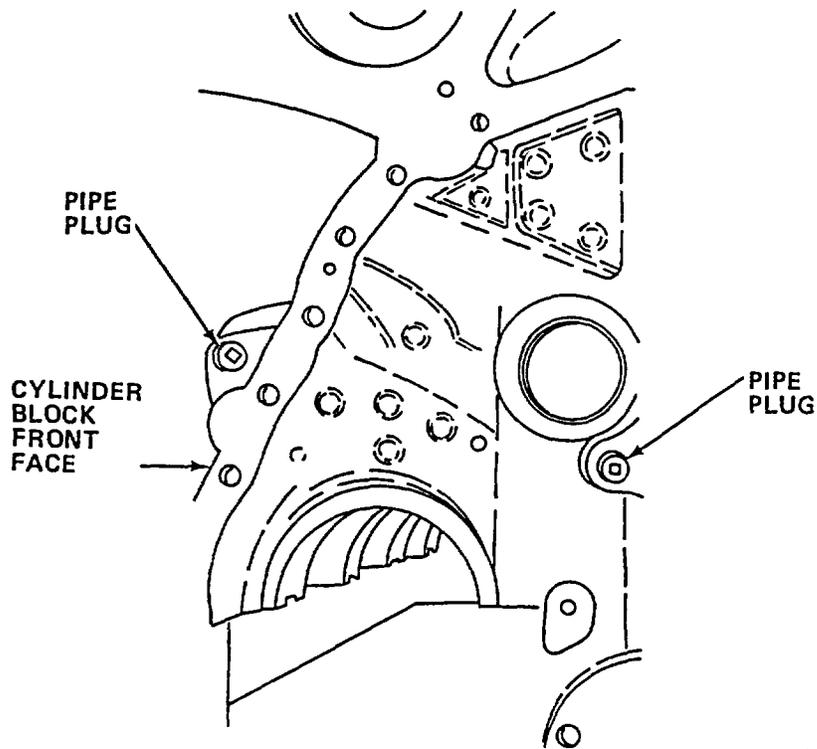


TA295213

- (h) Measure inside diameter of each bearing bore in block. Discard block if any diameter exceeds 2.6265 in. (66.7131 mm).

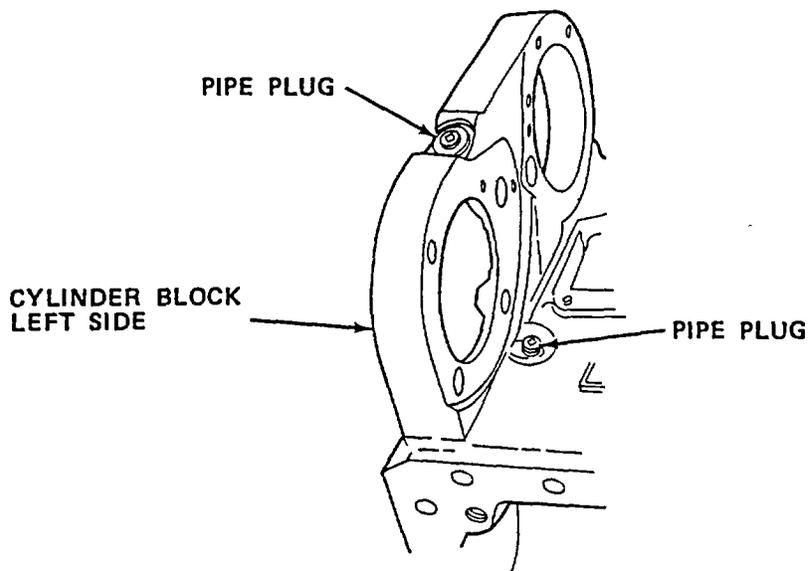
Section III. CYLINDER BLOCK REPAIR

3-7. CLEAN CYLINDER BLOCK



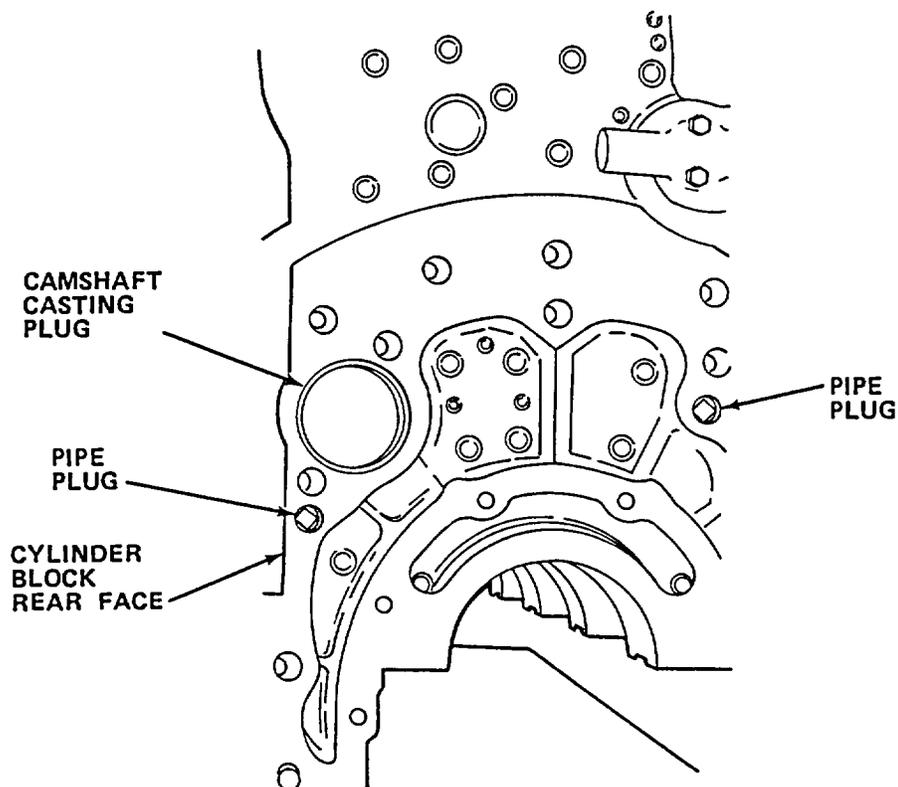
TA295214

- a. Remove pipe plugs from front face of cylinder block.



TA295215

- b. Remove pipe plugs from left side of cylinder block.



TA295216

- c. Remove pipe plugs from rear face of cylinder block.
- d. Remove camshaft casting plug from cylinder block.
- e. Remove all remaining plugs from cylinder block.
- f. Carefully scrape off any gasket material from gasket mounting surfaces.
- g. Remove deposits of sludge, carbon, etc with wire brush or scraper.

**WARNING**

**WEAR PROTECTIVE CLOTHING AND GOGGLES WHEN STEAM CLEANING TO PREVENT PERSONAL INJURY.**

- h. Steam clean entire cylinder block.

**WARNING**

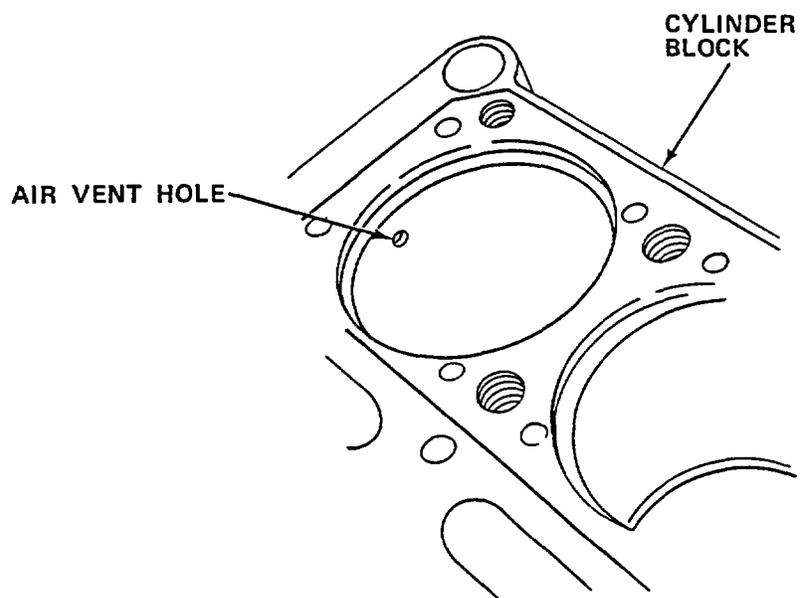
**HOT TANK CLEANING SOLVENTS ARE POTENTIALLY DANGEROUS. WEAR PROTECTIVE CLOTHING AND GOGGLES TO PREVENT SERIOUS PERSONAL INJURY.**

- i. Submerge cylinder block in hot agitation tank with water and cleaning solvent solution heated to 180°F-200°F (82°C-93°C). Leave in tank for 12 hours.
- j. Remove block from hot tank and steam clean to remove loose sludge and deposits.
- k. Run rods with brushes or swabs through all passages.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- l. Blow shop air through all passages, ports, and capscrew holes to remove debris.

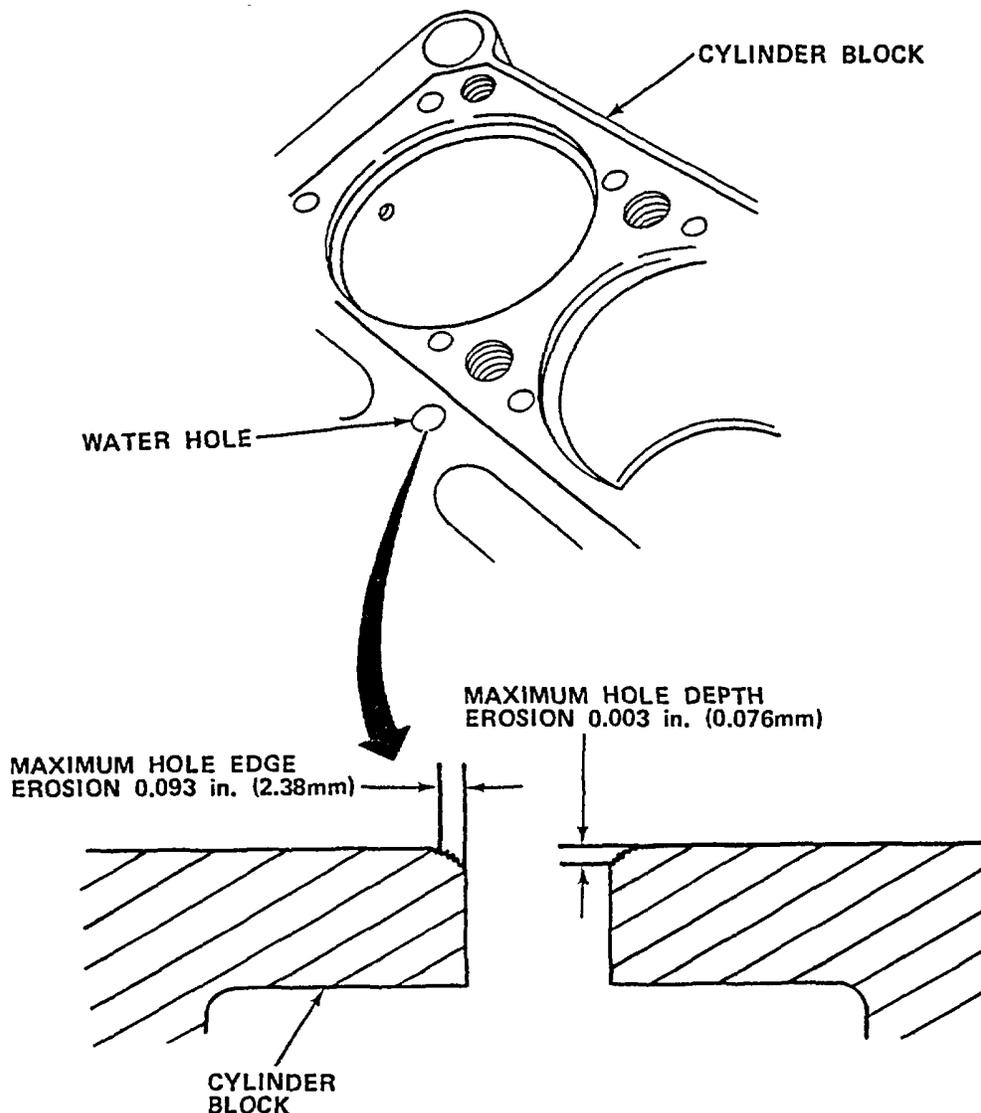


TA295217

- m. Direct shop air through no. 1 cylinder air vent hole which opens to water pump cavity.
- n. With emery cloth, remove any nicks and burrs from liner upper and lower counterbores.

**3-8. INSPECT CYLINDER BLOCK**

- a. Inspect cylinder block surfaces for cracks or any other defects.
- b. If crack is suspected, apply dye penetrant to surface allowing approximately 15 minutes for dye to dissolve or penetrate defect.
- c. Remove excess penetrant and apply developer.
- d. If crack detected, discard block.

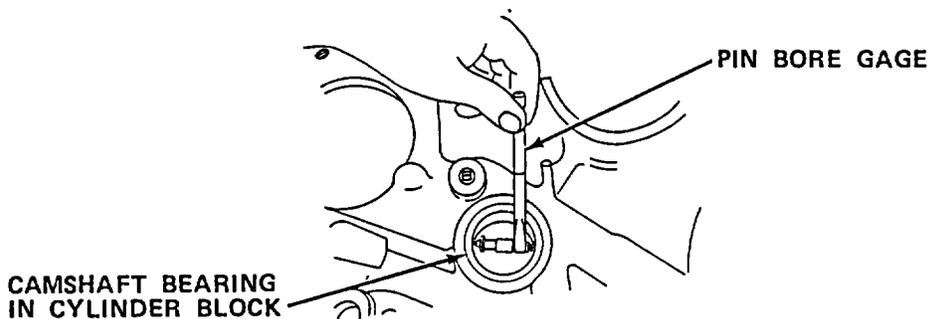


TA295218

- e. If corrosion (pitting) is found on top of block near liner bores, top surface can be refinished by removing maximum of 0.010 in. (0.254 mm) of material (para 3-9a).
- f. Check water holes to ensure they are open and free from erosion. Maximum erosion from edge of hole is 3/32 in. (2.38 mm) to maximum depth of 0.003 in. (0.076 mm). Refer to para 3-9k for water hole repair.

g. Check camshaft bearings:

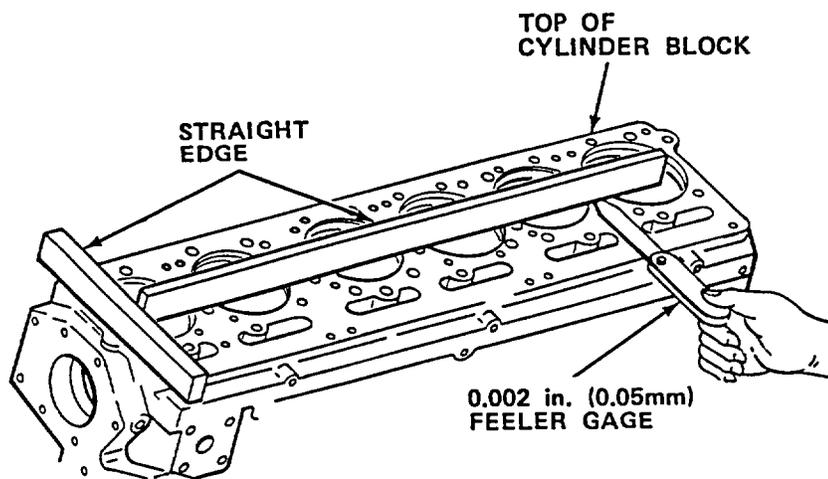
- (1) Inspect camshaft bearings for chips, scoring, or cracks. If defective, mark for replacement.



TA295219

- (2) Measure inside diameter of each camshaft bearing to determine amount of wear.
- (3) Mark for replacement if diameter is greater than 2.5008 in. (63.5203 mm).
- (4) If bearing has turned in block bore (oil hole in bearing not alined with hole in block bore) measure inside diameter of bore with bushing removed. Refer to para 3-6f(35) for bearing removal.
- (5) Replace cylinder block if inside diameter is greater than 2.6265 in. (66.7131 mm).

h. Check block top flatness.

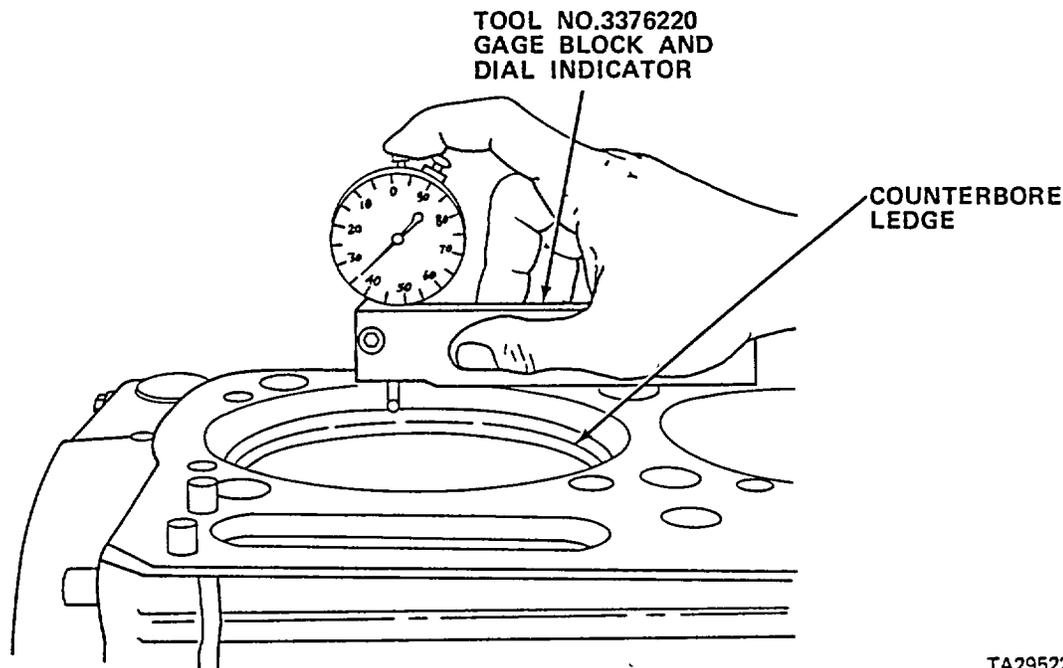


TA295220

- (1) Place straightedge on top of block to check flatness from front to rear and left to right.
- (2) Using a 0.002 in. (0.050 mm) feeler gage, try to insert gage between straightedge and block. If clearance greater than 0.002 in., top surface must be resurfaced (para 3-9a).

## i. Check cylinder liner upper counterbore.

- (1) Check counterbore and remove any loose scale, dirt, nicks, and burrs.



TA295221

**NOTE**

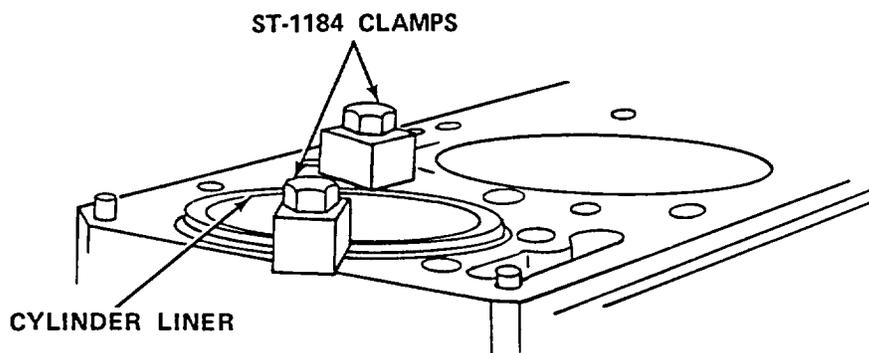
**First measure counterbore depth on ledge at edge of liner bore.**

- (2) Measure counterbore depth at four places 90 degrees apart on counterbore ledge with tool no. 3376220 gage block and dial indicator. Mark location of gage block on top of cylinder block.
- (3) Record readings for comparison.
- (4) Move gage block and gage on ledge at point closest to counterbore wall.
- (5) Measure depth at same four 90 degree locations as marked on top of block.
- (6) Record readings for comparison.
- (7) If difference between any one outer edge reading and its inner reading is greater than 0.0014 in. (0.0355 mm), counterbore ledge must be resurfaced (para 3-9b). This indicates that ledge is slanted beyond specifications.
- (8) Compare four inner edge readings. If variation between readings exceeds 0.001 in. (0.025 mm), counterbore ledge must be resurfaced. This indicates that ledge surface is not perpendicular to counterbore linebore.

- (9) If any one inner edge reading exceeds 0.412 in. (10.464 mm), bore must be machined to accept a replacement sleeve (para 3-9c).
- (10) Measure liner upper counterbore inside diameter. Install replacement sleeve if diameter exceeds 6.5635 in. (166.7129 mm) (para 3-9c).
- (11) Measure liner lower counterbore inside diameter. Install replacement sleeve if diameter exceeds 6.126 in. (155.600 mm) (para 3-9f).

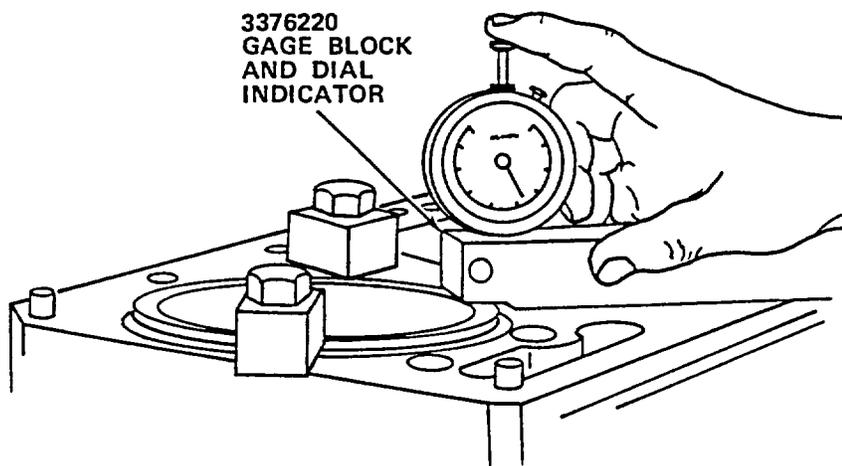
j. Check cylinder liner protrusion.

- (1) Carefully install liner into cylinder block without shims and lower seals in place.



TA295222

- (2) Install ST-1184 cylinder liner clamps at two locations approximately 180 degrees apart. Torque capscrews to 50 ft lbs (68 N•m).



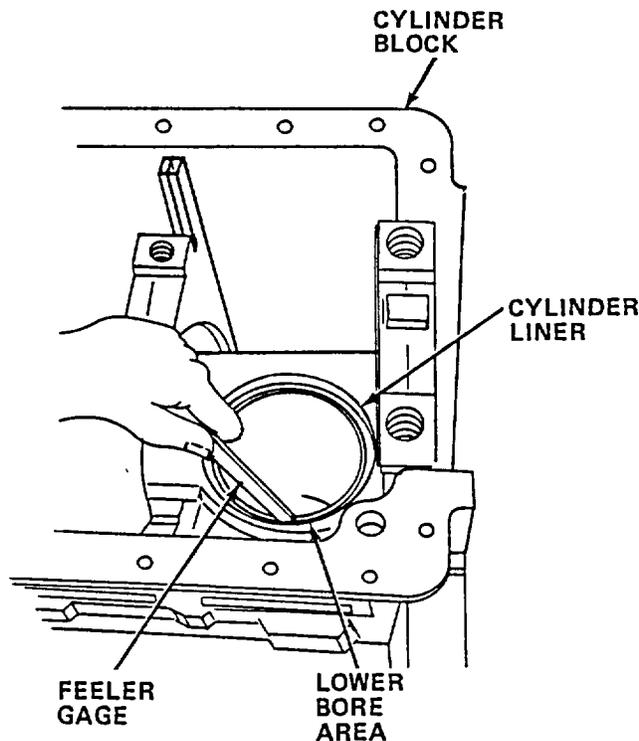
TA295223

- (3) Using tool no. 3376220 gage block and dial indicator, measure liner protrusion at four points 90 degrees apart. Dial indicator pin must rest on outer edge of liner and not on raised bead. Record readings.
- (4) Remove gage block, dial indicator, clamps, and liner.

- (5) Add shim(s) beneath liner flange as needed to establish a 0.003 in. (0.076 mm) minimum to 0.006 in. (0.152 mm) maximum protrusion. Shims are available in 0.007, 0.008, 0.009, 0.020, 0.030, and 0.062 in. (0.177, 0.203, 0.228, 0.508, 0.762, and 1.574 mm) sizes.
- (6) Reinstall liner with appropriate size shims.
- (7) Reclamp liner and retorque clamp capscrews to 50 ft lbs (68 N•m). Remeasure protrusion to insure dimensions are within specifications.
- (8) Remove gage block and dial indicator, clamps, and liner.

k. Check cylinder liner lower counterbore.

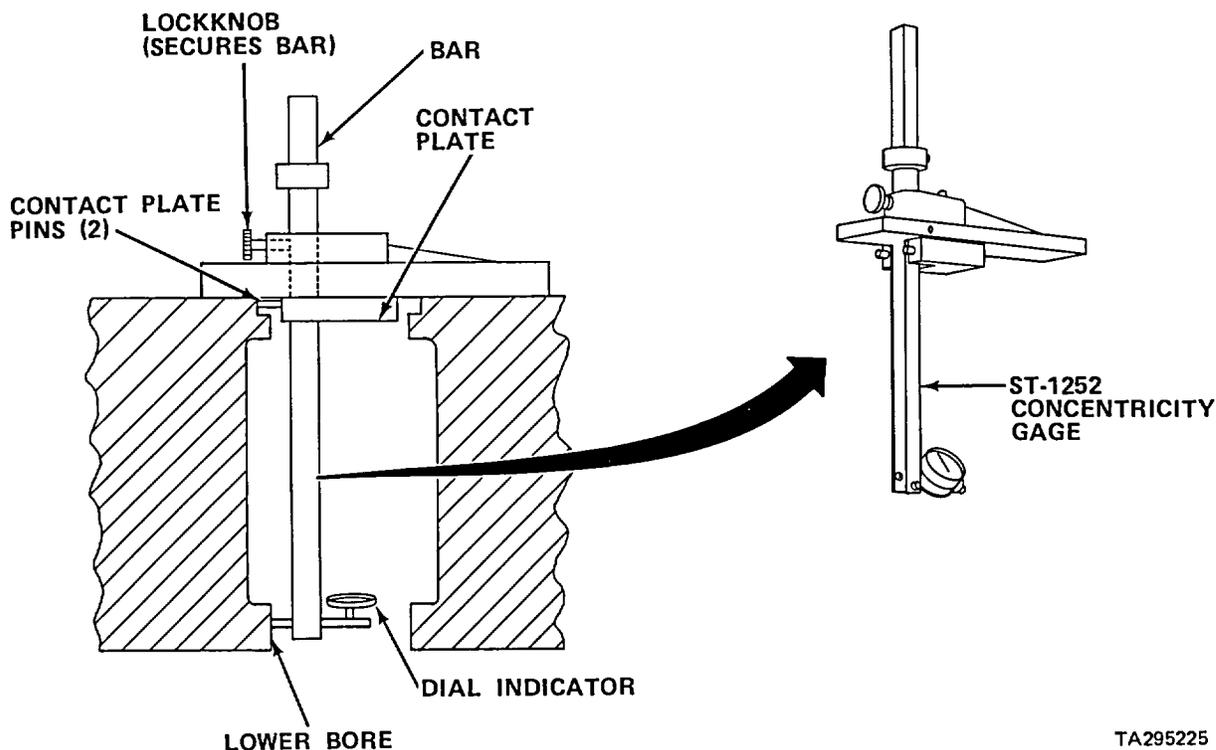
- (1) Install new liner without shims or seals into cylinder block and clamp liner in position. Torque clamp capscrews to 50 ft lbs (68 N•m).



TA295224

- (2) Measure clearance between cylinder block and liner lower counterbore with narrow leaf feeler gage. Liner contact with block is permitted providing it does not cause liner out-of-round.
- (3) If clearance exceeds 0.006 in. (0.152 mm), remove liner and measure inside diameter of lower counterbore.
- (4) If lower counterbore diameter exceeds 6.126 in. (155.600 mm), counterbore must be machined to accept replacement sleeve. Sleeve is available in two sizes; 6.2555 in. (158.889 mm) and 6.3055 in. (160.1597 mm).

- (5) If liner to block contact is made, check liner for out-of-round.
  - (a) Measure inside diameter of liner at several points within range of piston travel.
  - (b) If liner is more than 0.002 in. (0.050 mm) out-of-round in seal area, remove liner and check alinement of upper counterbore to lower counterbore.



TA295225

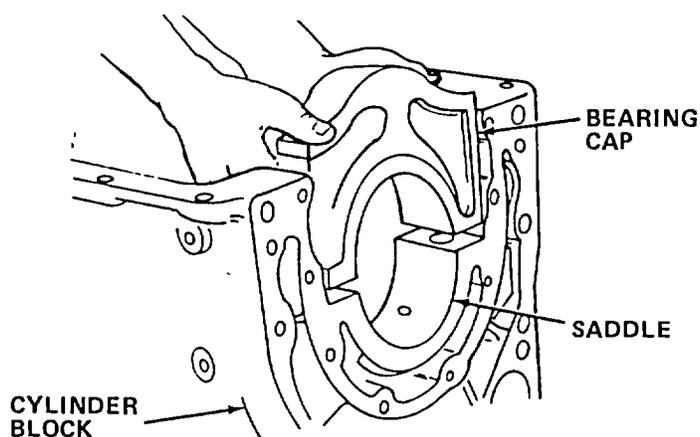
- (6) Place ST-1252 concentricity (alinement) gage flat on top surface of cylinder block with tool contact plate pins against counterbore inside diameter.
- (7) Loosen lockknob on tool and lower bar until dial indicator is located midway of lower counterbore. Tighten lockknob.
- (8) Push on contact plate so that pins are firmly against top counterbore inside diameter.
- (9) Zero dial indicator.
- (10) Release pressure on contact plate.
- (11) Reapply pressure to contact plate and check for zero on indicator. Rezero indicator if necessary.
- (12) Place gage 180 degrees from original setting position.

- (13) Apply pressure to contact plate to firmly position contact pins against counterbore inside diameter.
- (14) Record indicator reading.
- (15) Move gage 90 degrees and repeat procedure.
- (16) Move gage 180 degrees and repeat procedure.
- (17) Compare readings. Maximum out-of-alinement is 0.005 in. (0.127 mm) total indicator reading.
- (18) If out-of-alinement exceeds specification, a replacement sleeve must be installed (para 3-9f).

I. Check main bearing caps.

**NOTE**

- Main bearing caps on 1980 and 1982 models have 1 in. diameter bolts with a lock plate; 1984 models have 3/4 in. bolts with washers.
- Bearing cap positions are marked on caps.



TA462803

- (1) Reinstall and seat main bearing caps on their respective saddles.
- (2) Check for cap movement.

**NOTE**

**Replacement No. 7 bearing cap is provided without dowel pin holes. Dowel pin holes must be drilled into cap (para 3-9).**

- (3) Discard loose caps.

m. Check main bearing bore diameter.

(1) Assemble main bearing caps in their proper positions and secure with capscrews.

(2) Alternately torque capscrews in following sequence:

(a) 1980 and 1982 models.

1 Tighten to 100-110 ft lbs (136-149 N•m).

2 Tighten to 200-210 ft lbs (271-285 N•m).

3 Tighten to 300-310 ft lbs (407-420 N•m).

4 Loosen all capscrews.

5 Tighten to 100-110 ft lbs (136-149 N•m).

6 Tighten to 200-210 ft lbs (271-285 N•m).

7 Tighten to 300-310 ft lbs (407-420 N•m).

(b) 1984 model.

1 Tighten to 80-90 ft lbs (108-122 N•m).

2 Tighten to 160-170 ft lbs (217-230 N•m).

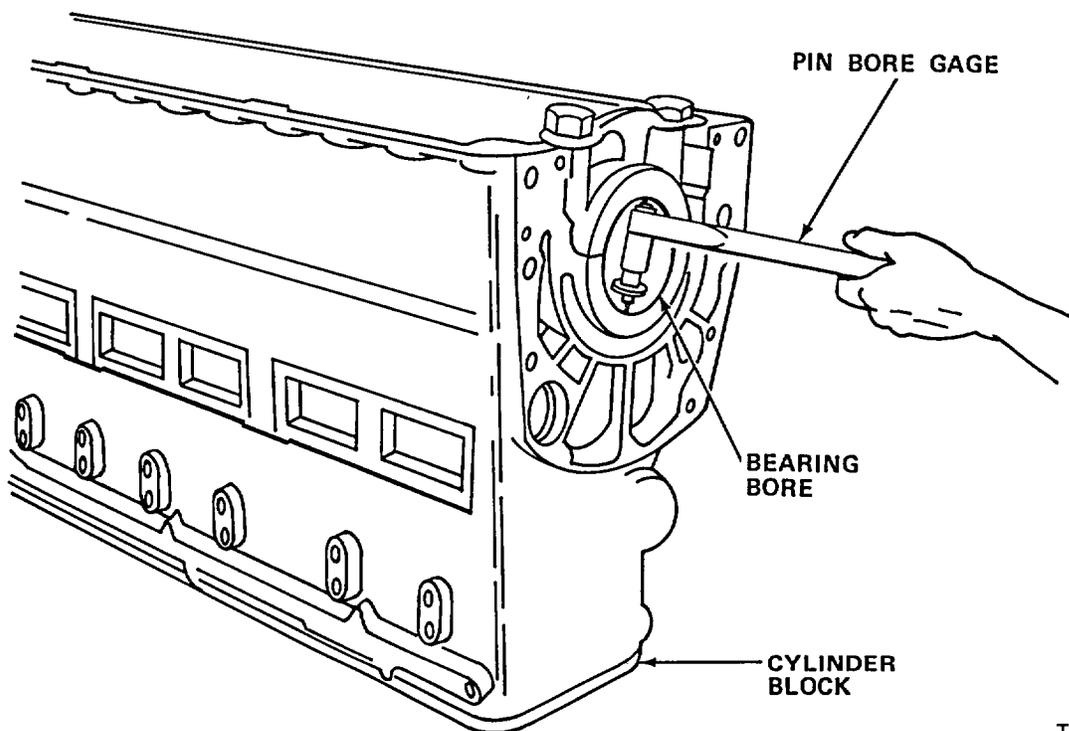
3 Tighten to 250-260 ft lbs (339-353 N•m).

4 Loosen all capscrews.

5 Tighten to 80-90 ft lbs (108-122 N•m).

6 Tighten to 160-170 ft lbs (217-230 N•m).

7 Tighten to 250-260 ft lbs (339-353 N•m).



TA295227

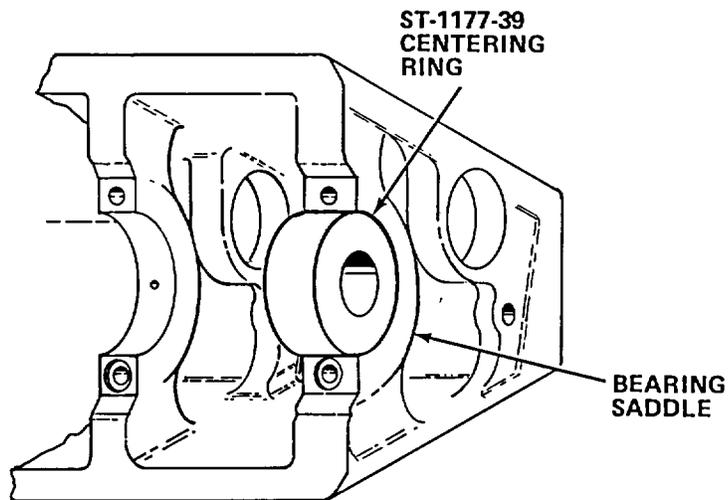
- (3) Measure inside diameter of all bearing bores vertically, horizontally, and diagonally. Mark specific bores for oversize boring if diameters exceed 4.7505 in. (120.6627 mm) or bore is out-of-round. Refer to para 3-9g for boring procedures.

n. Check main bearing bore alignment.

#### NOTE

**ST-1177 is both a bore alignment checking tool and boring tool. Allow tool and block to stabilize to room temperature before using.**

- (1) Remove no. 1 and no. 7 main bearing caps. If those caps are damaged, remove two undamaged caps preferably one from each end of block or as far apart as possible.



TA295228

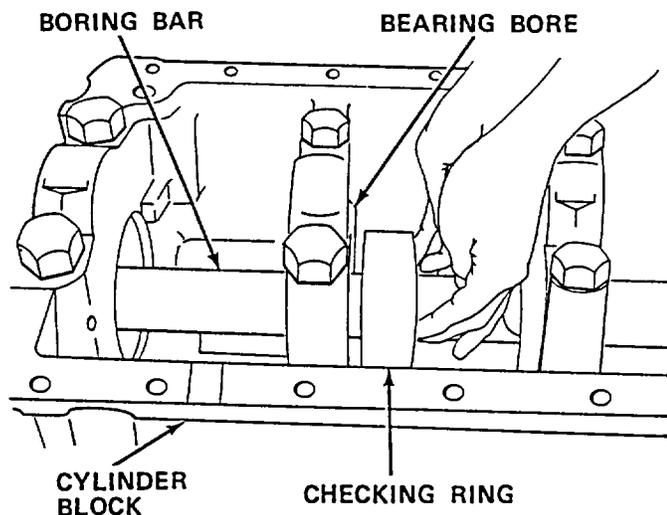
- (2) Install ST-1177-39 centering rings in center of bearing saddles. Tap in position with soft head hammer.

**NOTE**

**Caps fit tightly to provide proper sealing.**

- (3) Assemble main bearing caps to saddles and torque capscrews as specified in para m(2) above.
- (4) Lubricate centering ring bores and ST-1177-16 boring bar with engine oil.
- (5) While rotating boring bar, slowly slide bar through both centering rings.
- (6) Spin boring bar; it should spin freely.

- (7) Slide bar out until ST-1177-13 checking ring can be installed on bar.
- (8) Lubricate outside diameter of checking ring with engine oil.



TA295229

- (9) Apply light finger pressure against checking ring while rotating boring bar, and push checking ring through each bearing bore.
- (10) If checking ring will not pass through bore, check bore for burrs. Remove burrs with emery cloth.
- (11) Attempt to insert a 0.003 in. (0.076 mm) narrow blade feeler gage (not over 1/2 in. [12.7 mm] wide) between checking ring and bore. Run gage completely around checking ring and bore on each side of bore.
- (12) Evaluate results:
  - (a) Gage does not enter at any point and bar rotates freely. Bore is serviceable.
  - (b) Gage enters on one side and not on opposite side. There is slight misalignment but bar rotates freely. Bore is serviceable.
  - (c) Gage does not enter top (saddle) half of bore but enters bottom half. Cap must be replaced and new cap rebores (para 3-9g).
  - (d) Gage is loose. Remeasure bore diameter for maximum of 4.7505 in. (120.6627 mm). If larger than specification, bore will require machining to accept saddle repair sleeve (para 3-9g).
  - (e) Gage enters in front and not in rear. Bore is tapered and will require machining to accept saddle repair sleeve.
- (13) Mark bores to be machined and caps to be replaced.
- (14) Remove boring bar, checking ring, and centering rings.

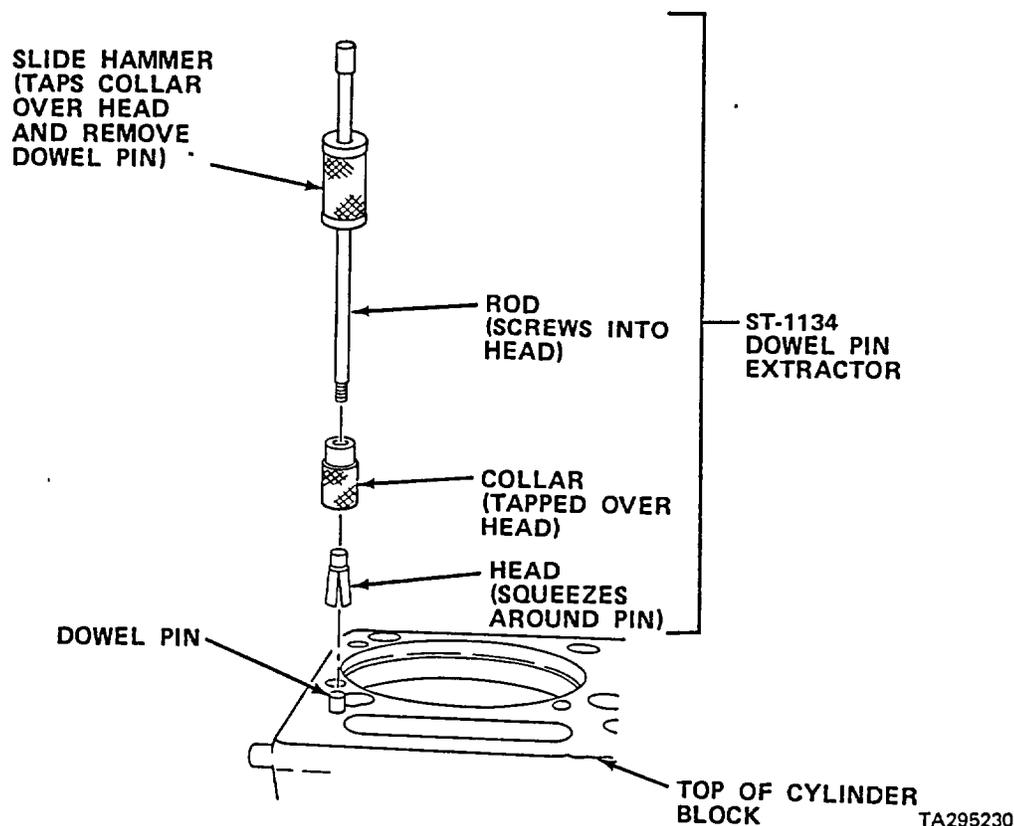
o. Check cylinder head bolt threads.

(1) Inspect cylinder head bolt threads for damage.

(2) Mark damaged threads for installation of solid bushing-type threaded inserts (para 3-9j).

### 3-9. REPAIR CYLINDER BLOCK

a. Top surface refinishing.



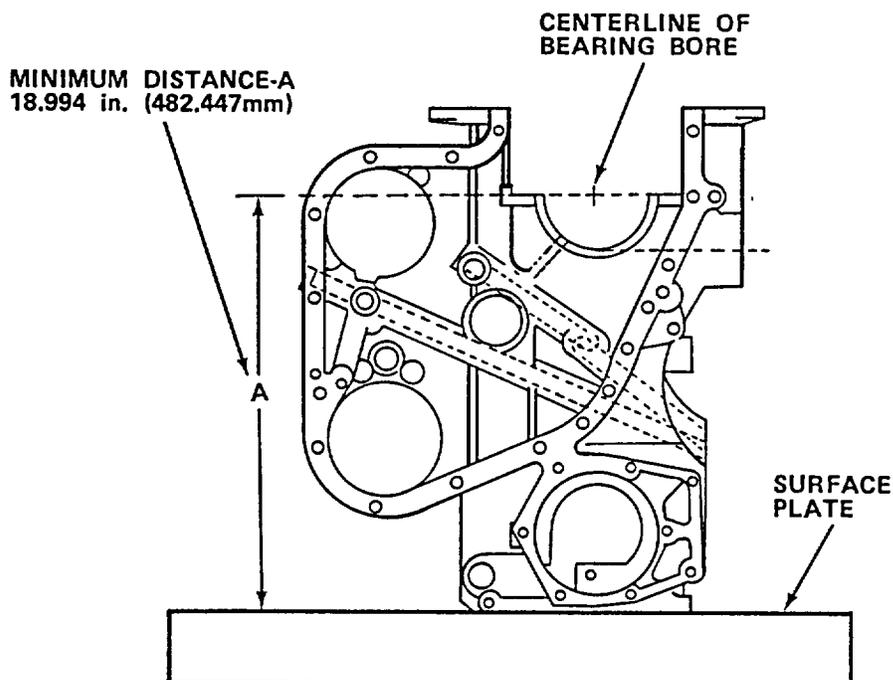
- (1) Remove all dowel pins from top of block using ST-1134 dowel pin extractor. Extractor has several size heads to fit various size dowel pins.
- (2) Using large surface grinder, set up cylinder block using main bearing saddle pads for surface alignment.

#### CAUTION

**DO NOT USE DISC SANDER. MAY RESULT IN UNEVEN GASKET SEALING SURFACE.**

- (3) Make light cuts of 0.001 to 0.003 in. (0.025 to 0.076 mm) deep removing only enough material to make block serviceable. Maximum material that can be removed is 0.010 in. (0.254 mm). Finish material with orbital sander to 125 microfinish.

- (4) After resurfacing is completed, check distance from centerline of main bearing bore to top of block.



TA295231

- (a) Place cylinder block, top down, on surface plate.
- (b) Measure distance (dimension A) from each main bearing bore centerline to surface plate. Record distances.
- (c) Minimum distance for any one measurement is 18.994 in. (482.447 mm). Discard block if distance less than specified.
- (d) Note variations between distances. If distances vary more than 0.002 in. (0.050 mm), block can be further refinished providing no more than 0.010 in. (0.254 mm) of total material is removed.
- (e) After additional refinning (if required), remeasure bore centerline to surface plate. If distance is less than specified, discard block.

#### NOTE

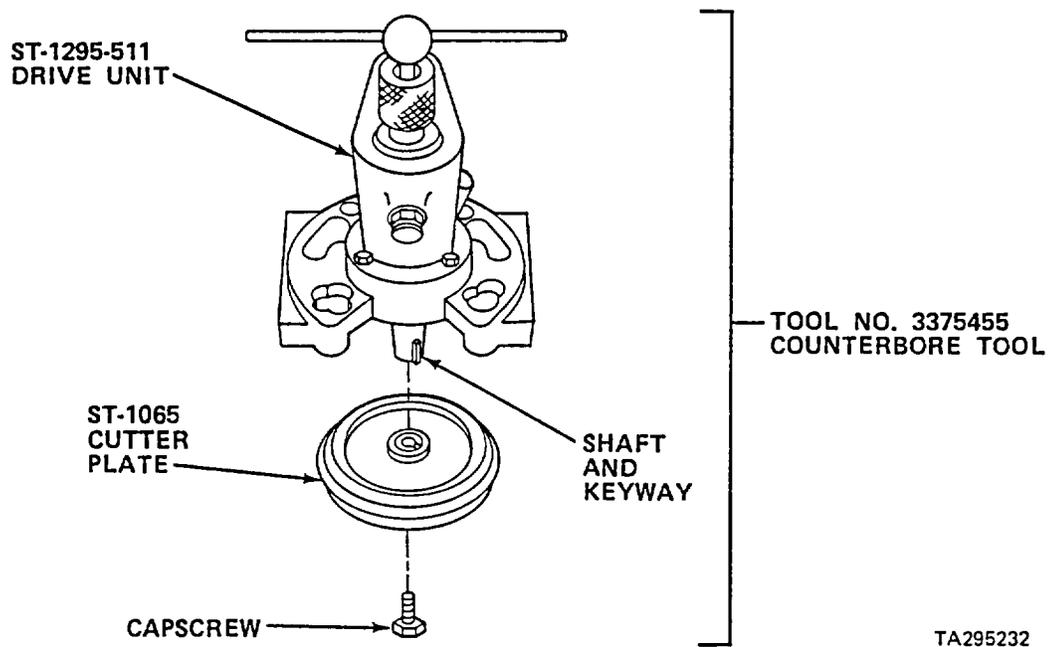
**If top surface refinished, liner protrusion must be rechecked (para 3-8j).**

b. Cylinder liner upper counterbore resurfacing.

**NOTE**

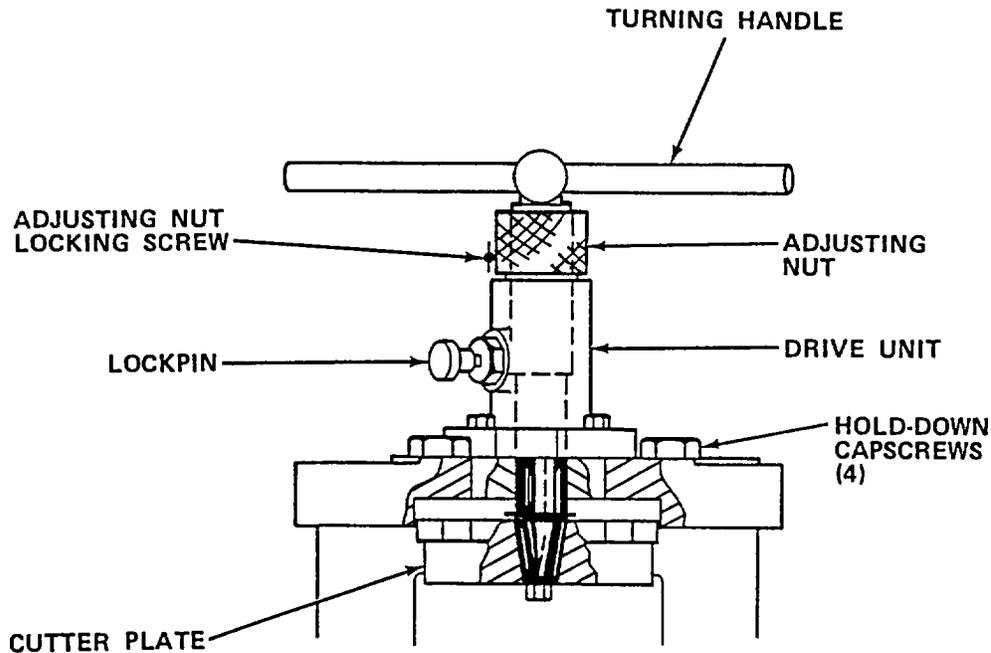
**Resurface cylinder liner upper counterbore if cylinder block top surface has been resurfaced or if ledge is uneven, cracked, or liner protrudes more than 0.006 in. (0.152 mm).**

- (1) Assemble tool no. 3375455 cylinder block counterbore tool:



- (a) Aline keyway and position ST-1065 cutter plate on shaft of ST-1295-511 drive unit.
- (b) Secure cutter plate with capscrew.
- (2) Preset tool bit as specified on data sheet that comes with the tool.

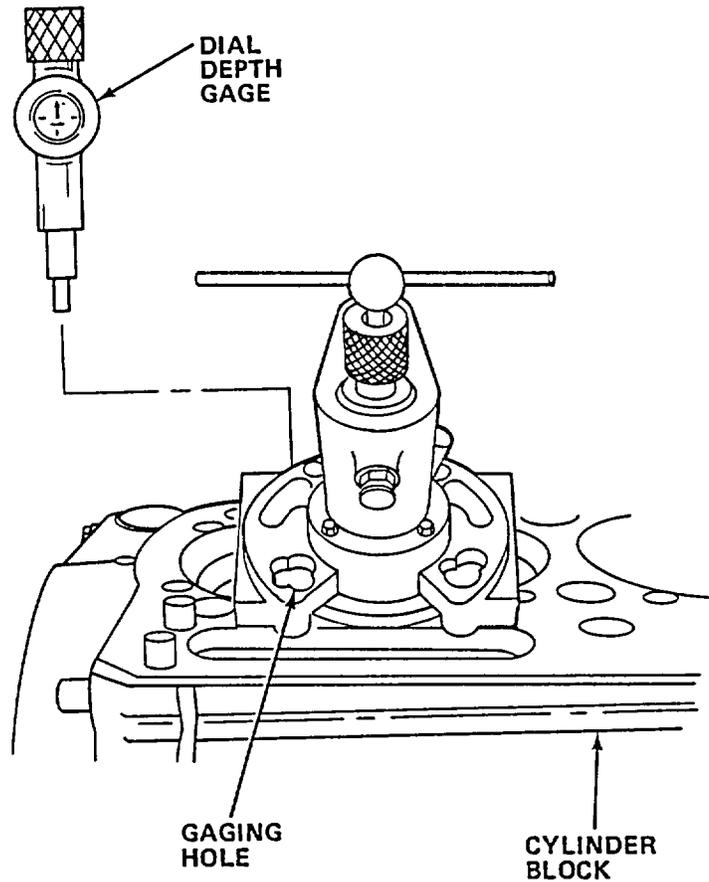
(3) Install tool and cut counterbore:



TA295233

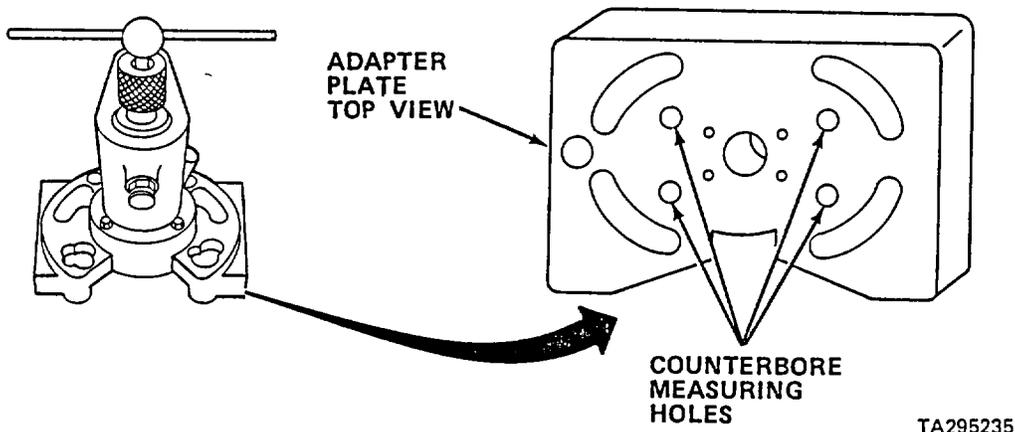
- (a) Pull out on handle and push lockpin in. Lockpin holds cutter plate in up position.
- (b) Place tool on cylinder block with hold-down holes alined with holes in cylinder block. Do not install hold-down capscrews at this time.
- (c) Hold onto handle and pull lockpin out.
- (d) With large diameter of cutter plate acting as a pilot, slowly lower cutter plate into counterbore until tool bit rests on counterbore ledge.
- (e) Loosen adjusting nut locking screw and slowly turn adjusting nut clockwise until tool bit lifts off of counterbore ledge.
- (f) Tighten adjusting nut locking screw.
- (g) Install hold-down capscrews and washers through adapter plate.
- (h) Tighten screws finger tight.

- (i) Rotate cutter plate wth handle. Plate should rotate freely. If binding occurs, tap lightly on tool adapter plate to reposition tool -allowing free rotation.
- (j) Torque hold-down capscrews to 50 75 ft lbs (68 102 Nom).
- (k) Recheck for free rotation.



TA295234

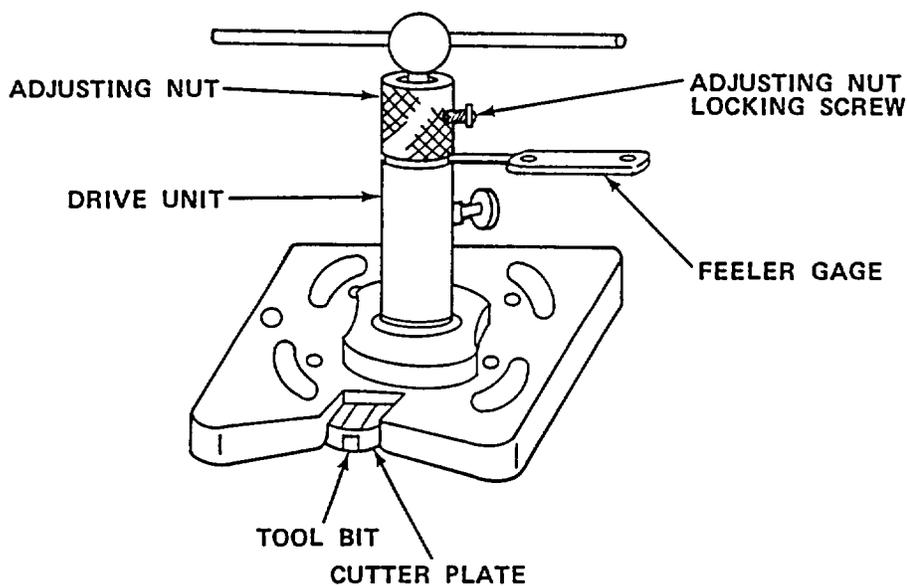
- (l) Insert dial depth gage through gaging hole in adapter plate.
- (m) Push down on dial indicator until plunger moves to its end of travel (bottoms out).
- (n) Pull dial indicator 0.020 in. (0.508 mm) off bottom and zero indicator.
- (o) Rotate cutter plate until red indicator line on plate alines with line on adapter plate.



**NOTE:**

**DRIVE UNIT NOT SHOWN INSTALLED ON TOP VIEW OF PLATE FOR CLARITY**

- (p) Place depth gage through counterbore measuring holes in adapter plate.
- (q) Take four depth readings. Average of four readings will represent present depth of counterbore.
- (r) Loosen adjusting nut locking screw.
- (s) Rotate adjusting nut in counterclockwise direction until tool bit is resting on counterbore ledge.



- (t) To set depth of cut, continue rotating adjusting nut until feeler gage of required thickness can be inserted between nut and top of drive unit. For example, if 0.005 in. (0.127 mm) of material is to be removed from counterbore ledge, use 0.005 in. (0.127 mm) feeler gage. Ensure that there is no grease or dirt between adjusting nut and top of drive unit.

- (u) Rotate adjusting nut until feeler gage is just held between nut and drive unit.)
- (v) Tighten adjusting nut locking screw. Remove gage.
- (w) Apply oil to tool bit.
- (x) Rotate handle clockwise while applying pressure to cutter plate.
- (y) Stop rotating handle when adjusting nut bottoms out against top of drive unit (handle turns freely).
- (z) Lift up on handle and engage lockpin.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

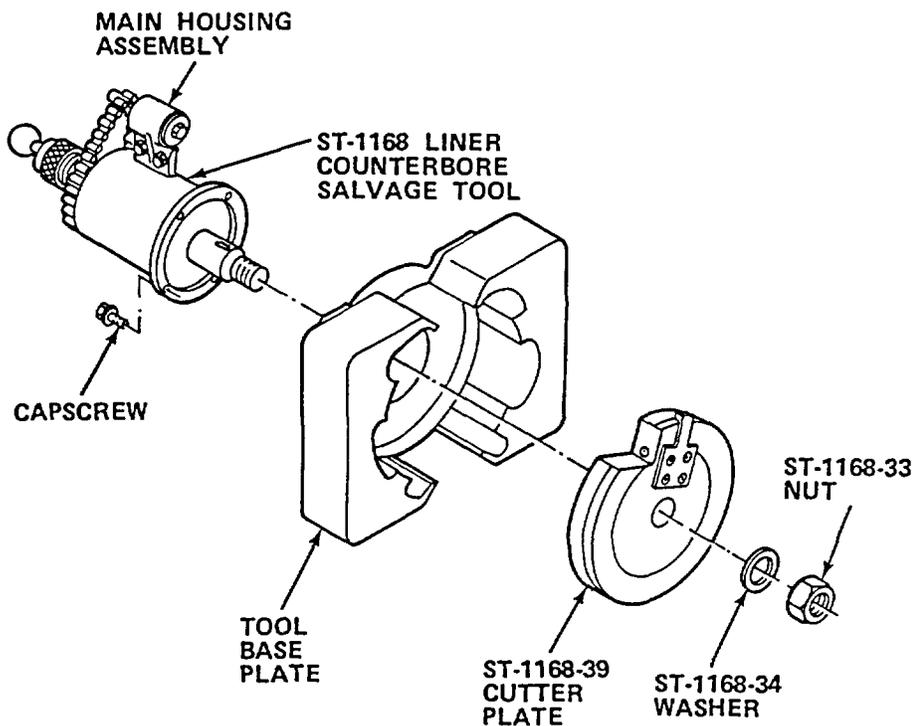
- (aa) Direct shop air onto counterbore ledge to remove metal shavings.
- (ab) Remeasure counterbore depth as previously described. If depth exceeds 0.412 in. (10.46 mm), ledge must be enlarged to accept replacement sleeve (para 3-9c).
- (ac) Remove counterbore tool.
- (ad) Deburr bore with emery cloth.
- (ae) Wipe counterbore clean.

c. Cylinder liner upper counterbore enlarging.

**NOTE**

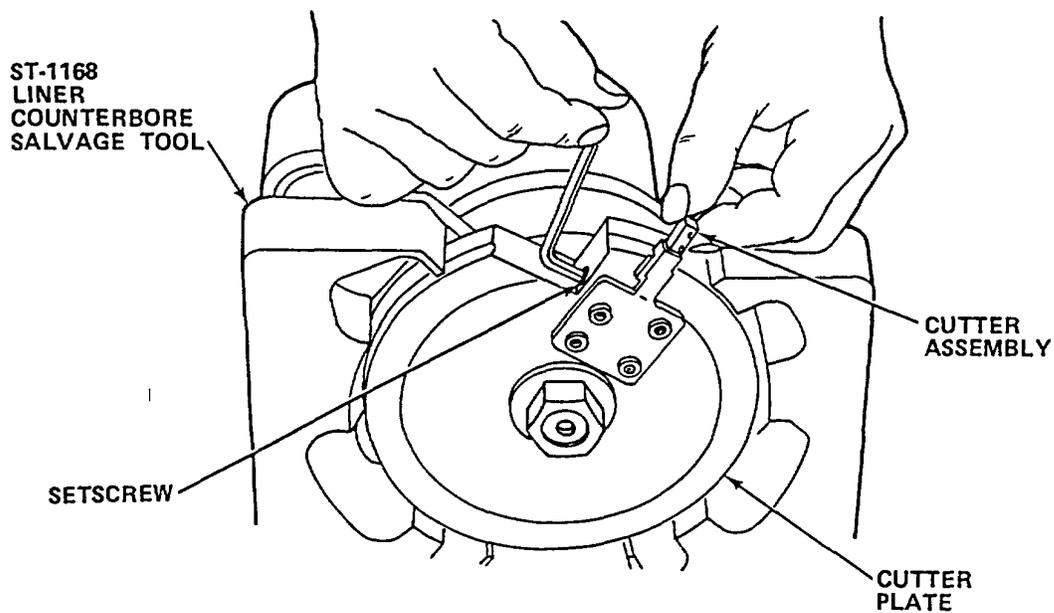
**Enlarging of an upper counterbore is required to repair a cylinder block if any one of the following conditions exists: its upper liner counterbore ledge area is damaged; its upper liner counterbore ledge has been resurfaced beyond maximum depth; or its upper liner counterbore ledge diameter has been exceeded. Counterbore is enlarged to accept a replacement sleeve which forms a new watertight seal.**

- (1) Assemble and install ST-1168 liner counterbore salvage tool.



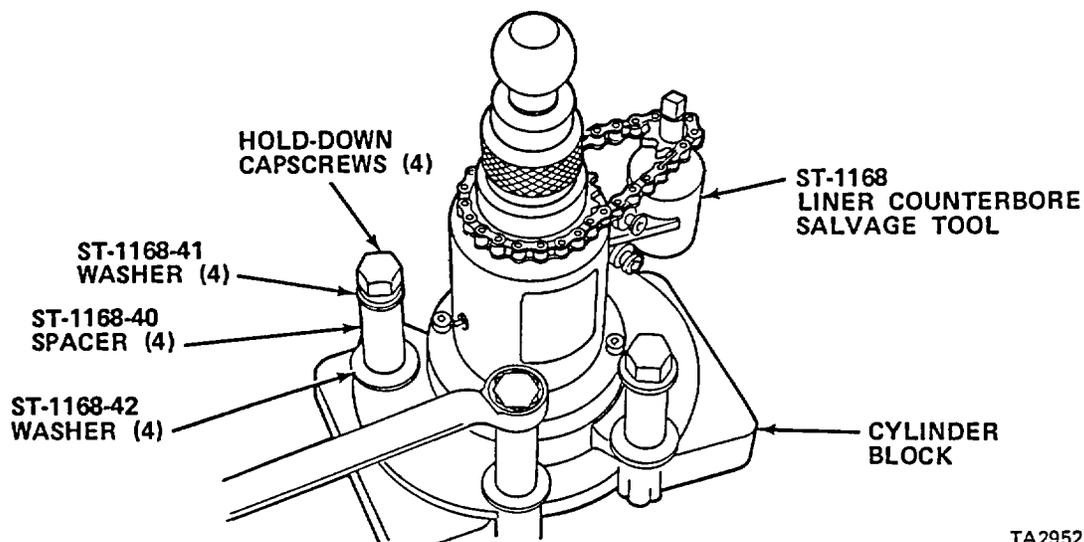
TA295237

- (a) Secure base plate to main housing assembly with capscrews.
- (b) Secure ST-1168-39 cutter plate to main housing shaft with ST-1168-34 washer and ST-1168-33 nut.

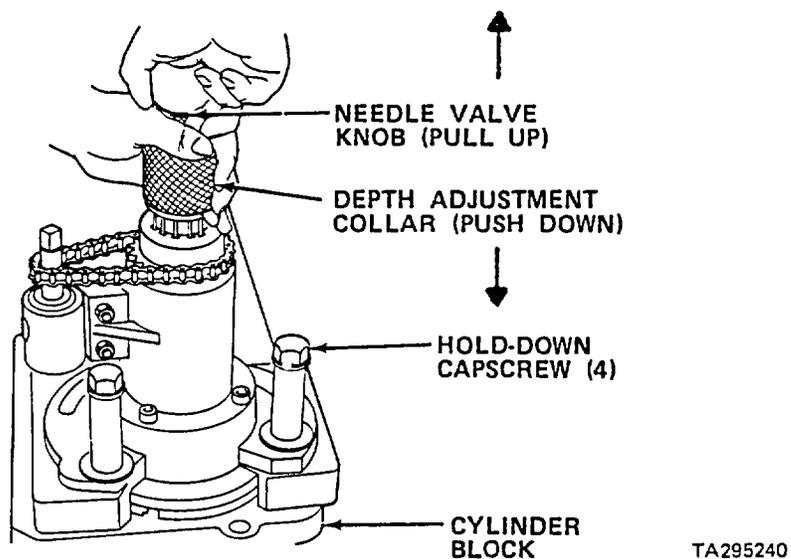


TA295238

- (c) Loosen setscrew on tool holder plate of cutter plate and remove cutter assembly.

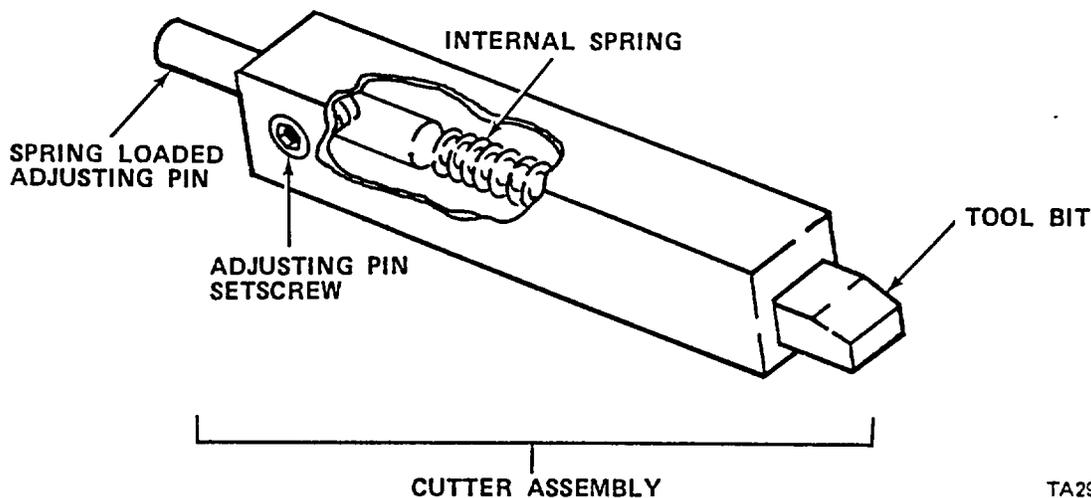


- (d) Place salvage tool on cylinder block bore to be cut.
- (e) Place ST-1168-41 washers, ST-1168-40 spacers, and ST-1168-42 washers on hold-down cap screws and install cap screws securing salvage tool to cylinder block. Tighten finger tight.



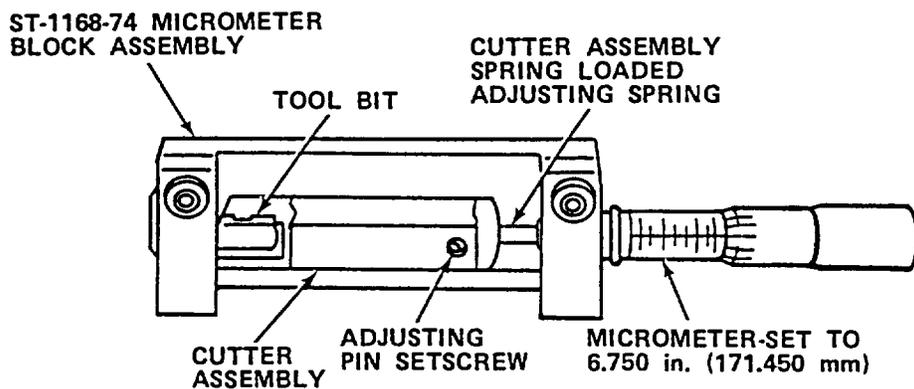
- (f) Pull up on needle valve knob while pushing down on depth adjustment collar. This will lower cutter plate into cylinder counterbore. Cutter plate lower diameter is used to center salvage tool assembly in counterbore inside diameter.
- (g) Tighten hold-down cap screws and torque to 25 35 ft lbs (34 47 Nm).
- (h) Raise cutter plate out of counterbore by pulling up on needle valve knob.

(2) Preset and install cutter assembly.



TA295241

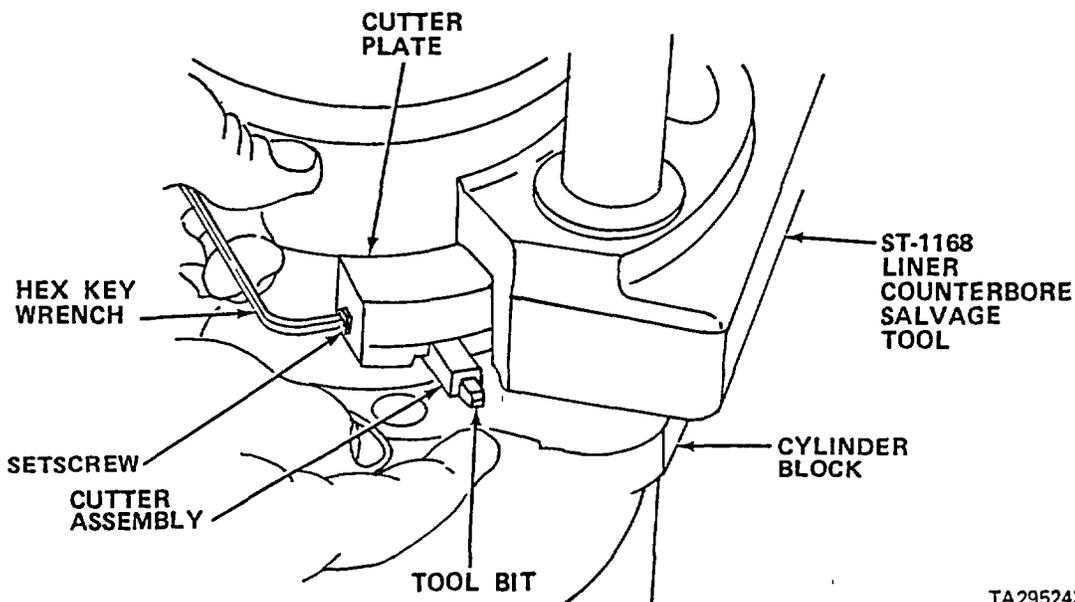
- (a) Loosen adjusting pin setscrew at rear of cutter assembly and push cutter adjusting pin all the way in. Tighten setscrew.
- (b) Adjust micrometer on ST-1168-74 micrometer block assembly to 6.750 in. (171.450 mm).
- (c) Place tool bit end of cutter assembly against pad on micrometer block assembly.



TA295242

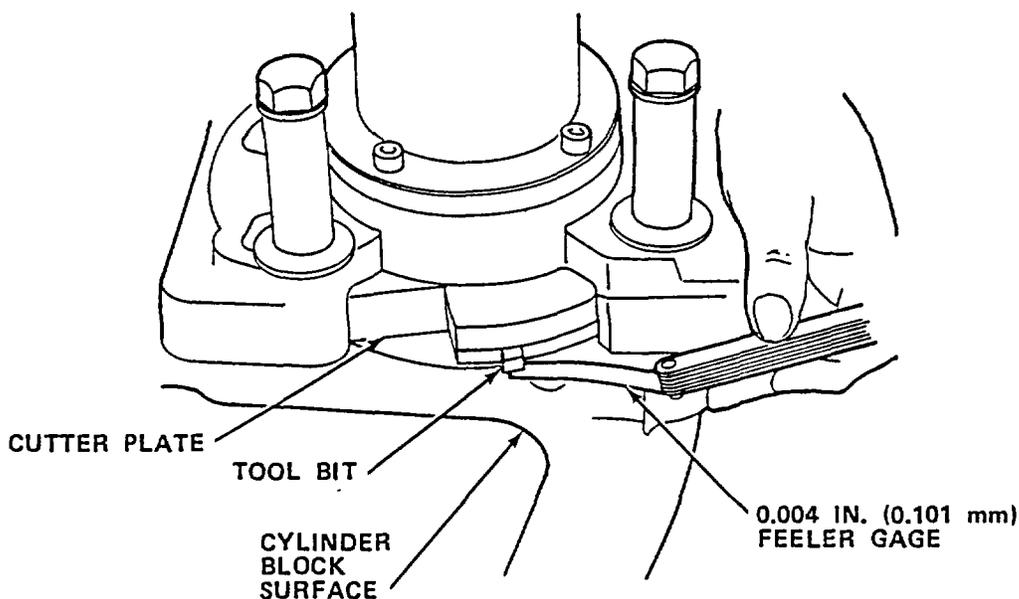
- (d) While holding cutter assembly against pad, loosen adjusting pin setscrew on cutter assembly. Internal spring will push adjusting pin against micrometer spindle.
- (e) Tighten adjusting pin setscrew.

- (f) Back off thimble on micrometer to retract spindle and recheck cutter assembly length. Length must be set for 6.750 in. (171.450 mm) micrometer reading.
- (g) Rotate cutter plate until plate tool bit recess is at large opening in base plate.



TA295243

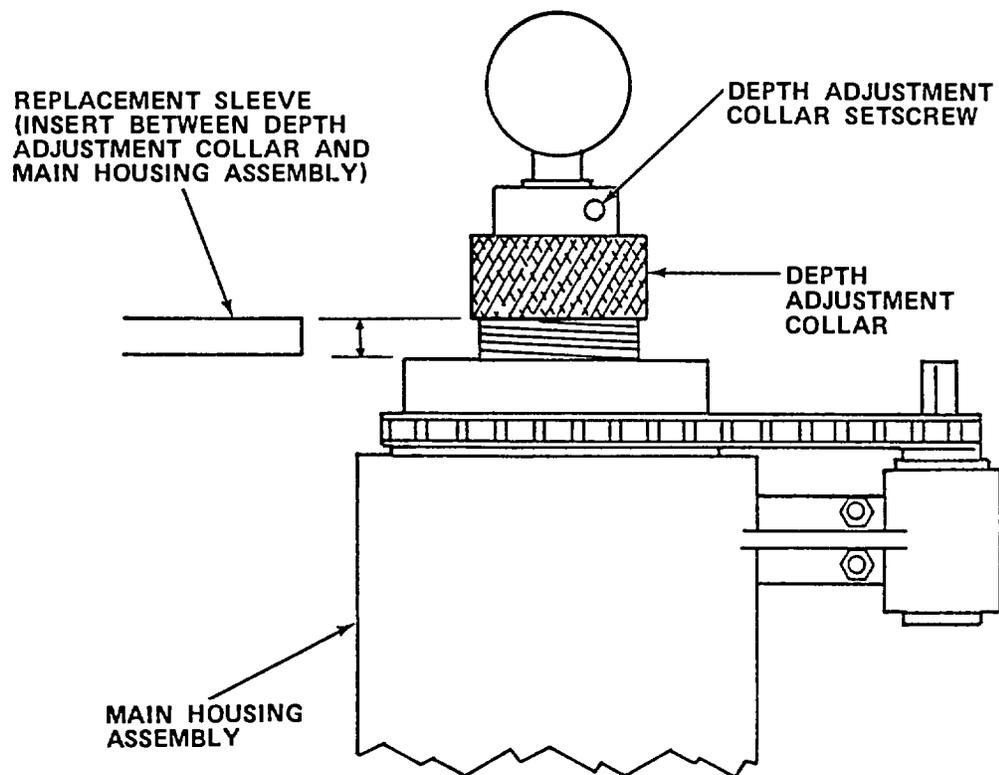
- (h) Insert cutter assembly all the way into cutter plate. While holding tip of tool bit, tighten setscrew with hex key wrench.



TA295244

- (i) Place a 0.004 in. (0.101 mm) feeler gage between cylinder block and tool bit and lower cutter plate until tool rests on feeler gage.

- (j) Loosen setscrew on depth adjustment collar.



TA295245

- (k) Rotate depth adjustment collar counterclockwise until replacement sleeve can be placed between collar and top of main housing assembly. This procedure establishes depth of cut using replacement sleeve (to be installed) as a depth gage.
- (l) Tighten depth adjusting collar setscrew.
- (m) Remove feeler gage and replacement sleeve.

- (3) Cut counterbore to accept replacement sleeve:

**CAUTION**

**DO NOT USE DRILL RATED AT LESS THAN 10 AMPERES OR OVER 450 RPM. USE OF HIGH SPEED AND/OR LOW AMPERE RATED DRILL COULD DAMAGE DRILL DUE TO HEAVY LOAD.**

- (a) Place ST-1168-48, a 1/2 in. (12.7 mm) universal driver, in 3/4 in. (19.05 mm) heavy duty hand drill.
- (b) Engage universal driver with main housing assembly.

**WARNING**

**APPROXIMATELY HALF WAY DOWN DURING CUT, TOOL BIT WILL BEGIN CUTTING OUT OLD COUNTERBORE LEDGE. ENSURE THAT YOU HAVE A FIRM GRIP ON DRILL TO PREVENT SLIPPAGE AND POSSIBLE PERSONAL INJURY.**

**CAUTION**

**KEEP TOOL BIT WELL OILED TO PREVENT BIT WEAR AND UNEVEN CUT.**

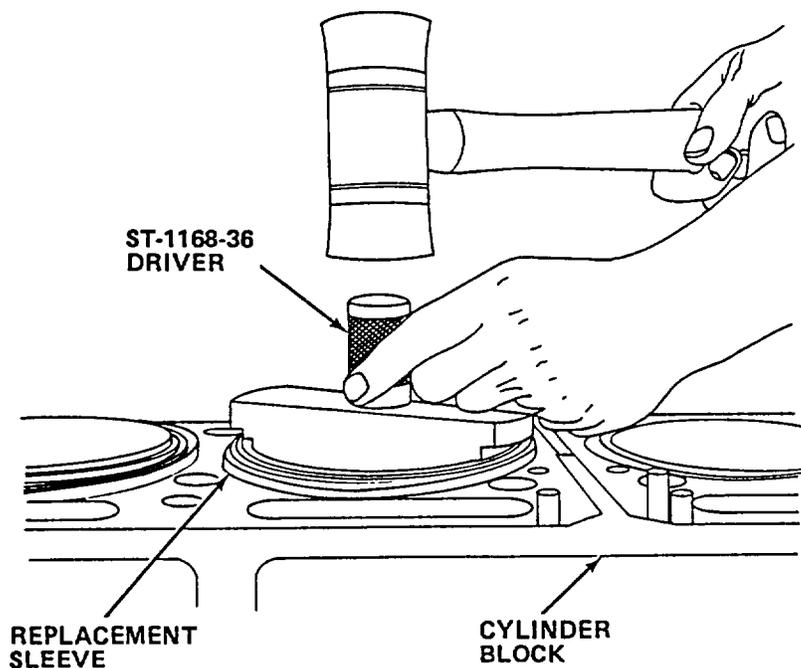
- (c) Keep a firm grip on drill and bore hole until drill free wheels. Immediately stop drill.
- (d) Disconnect drill from boring tool.
- (e) Pull up on needle valve knob to retract cutter plate from bore.
- (f) Remove capscrews, spacers, and washers securing counterbore salvage tool to cylinder block.
- (g) Remove salvage tool.
- (h) Clean away all metal shavings.
- (i) Deburr bore with emery cloth.
- (j) Wipe counterbore clean.

- d. Cylinder liner upper counterbore replacement sleeve installation.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (1) Clean bore thoroughly with solvent.
- (2) Coat outside of replacement sleeve with high temperature retaining compound.



TA295246

- (3) With ST-1168-36 driver, drive replacement sleeve into bore until it bottoms. Remove driver.

**NOTE**

**Sleeve will protrude 0.004 in. (0.101 mm) above top of block.**

- (4) Carefully file protruding sleeve until sleeve is even with top of block.
- (5) Remove all burrs with emery cloth.
- (6) Clean away all filings.

**NOTE**

Replacement sleeve is designed to be 0.005 to 0.010 in. (0.127 to 0.254 mm) above required counterbore depth.

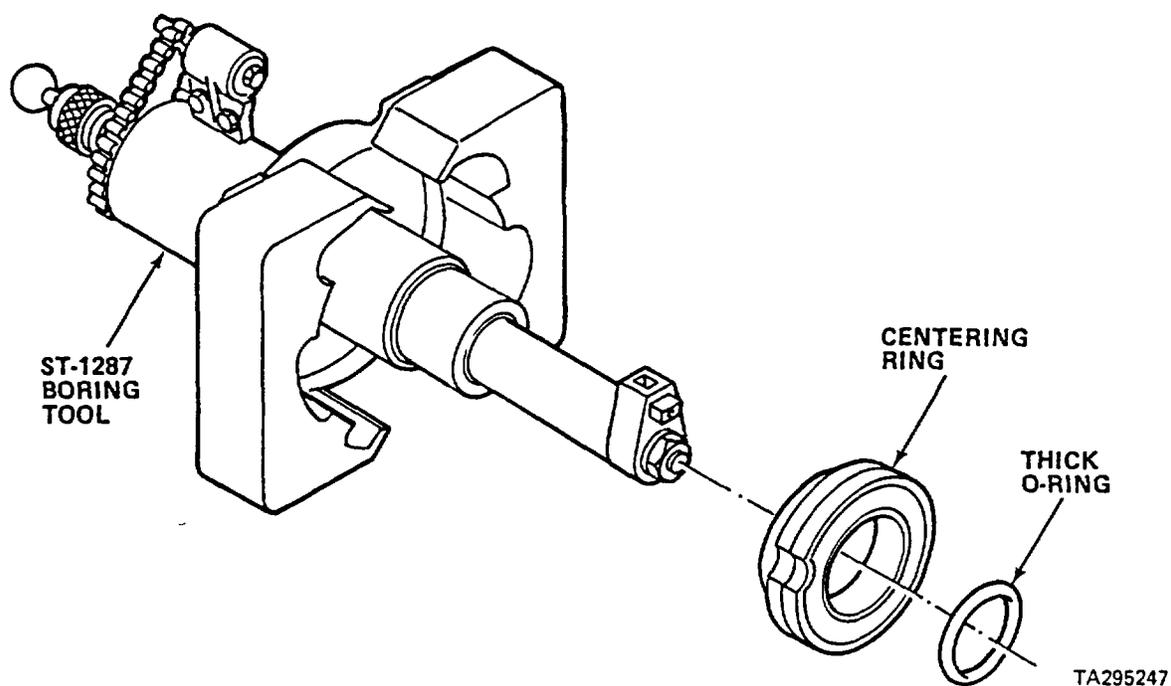
(7) Check depth of counterbore ledge and cut to specifications.

e. Cylinder liner lower counterbore enlarging.

**NOTE**

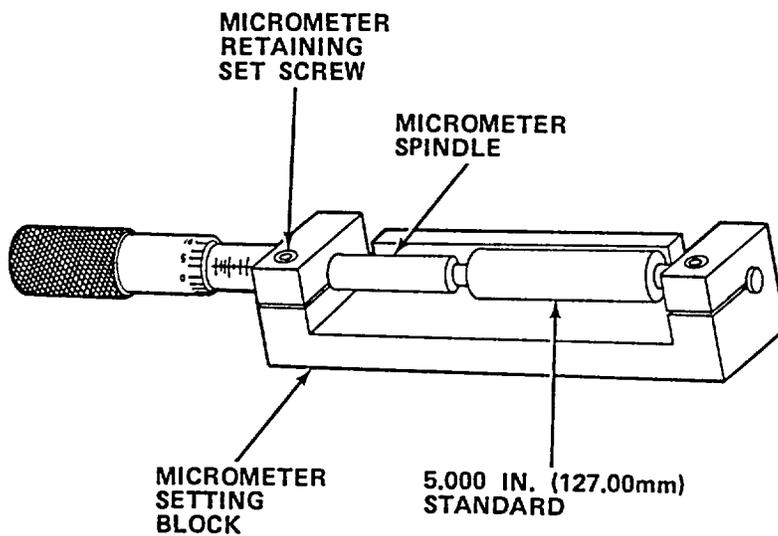
Enlarging of lower counterbore is required to repair a cylinder block when counterbore has been damaged, misaligned, or its diameter has exceeded specifications. Counterbore is enlarged to accept a replacement sleeve which will provide liner seals with tight sealing surface.

(1) Assemble ST-1287 lower cylinder liner counterbore salvage boring tool:



- (a) Remove thick O-ring from bottom of boring tool.
- (b) Slide 5-1/2 in. (768.35 mm) centering ring onto boring tool with taper on ring toward cutter.
- (c) Reinstall O-ring to retain centering ring.

- (2) Preset and install tool bit assembly.



TA295248

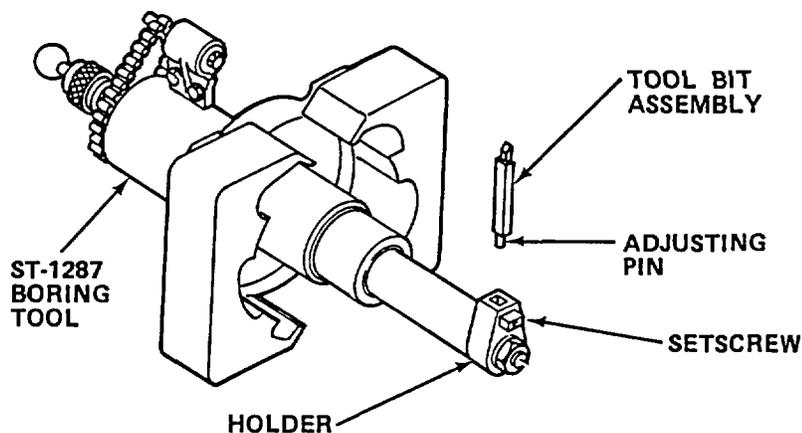
- (a) Place special "standard" in micrometer setting block.
- (b) Set micrometer to read length of "standard". Micrometer must read 5.000 in. (127.000 mm).
- (c) If micrometer does not read as specified, loosen micrometer retaining setscrew and move micrometer in or out as required.
- (d) Place tool bit assembly in micrometer block with tool bit placed against pad of block.
- (e) Loosen adjusting pin setscrew and allow internal spring to move spring loaded adjusting pin against micrometer spindle (see Fig. 3-60).

#### NOTE

Lower salvage sleeves are available in two sizes; 6.2555 in. (158.8897 mm) outside diameter and 6.3055 in. (160.1597 mm) outside diameter. Instruction sheet which comes with sleeve, provides cutter assembly setting dimension.

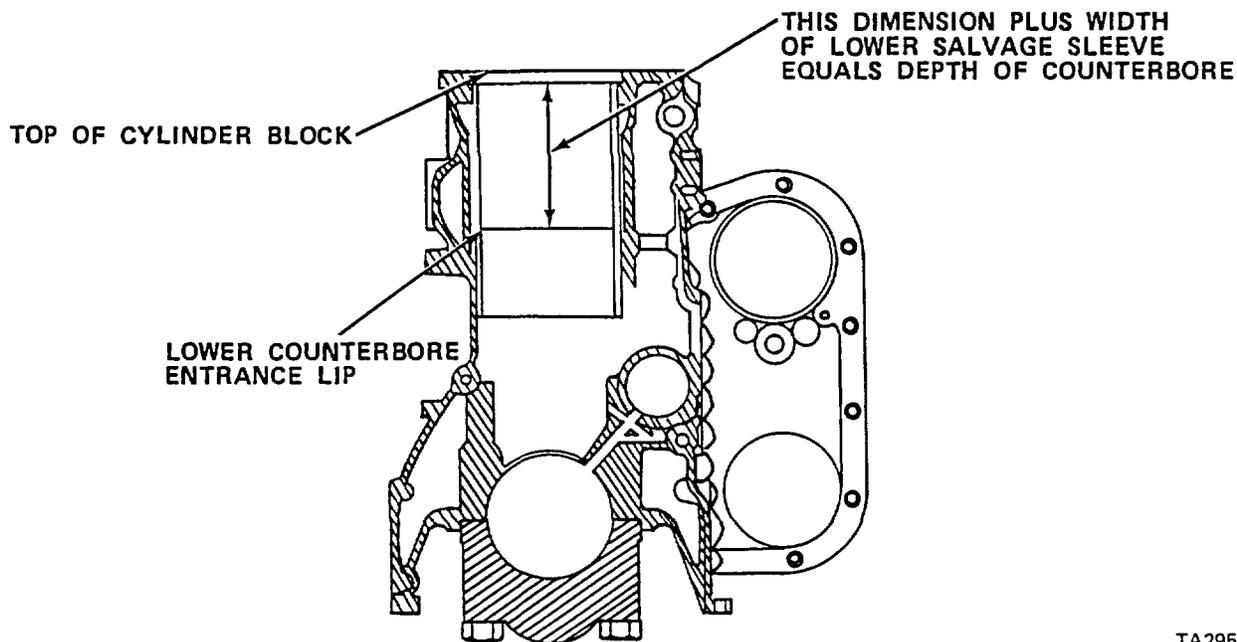
- (f) Set micrometer to read dimension as indicated on sleeve instruction sheet.

- (g) Tighten adjusting pin setscrew.
- (h) Back off micrometer thimble and recheck value. Readjust as necessary.



TA295249

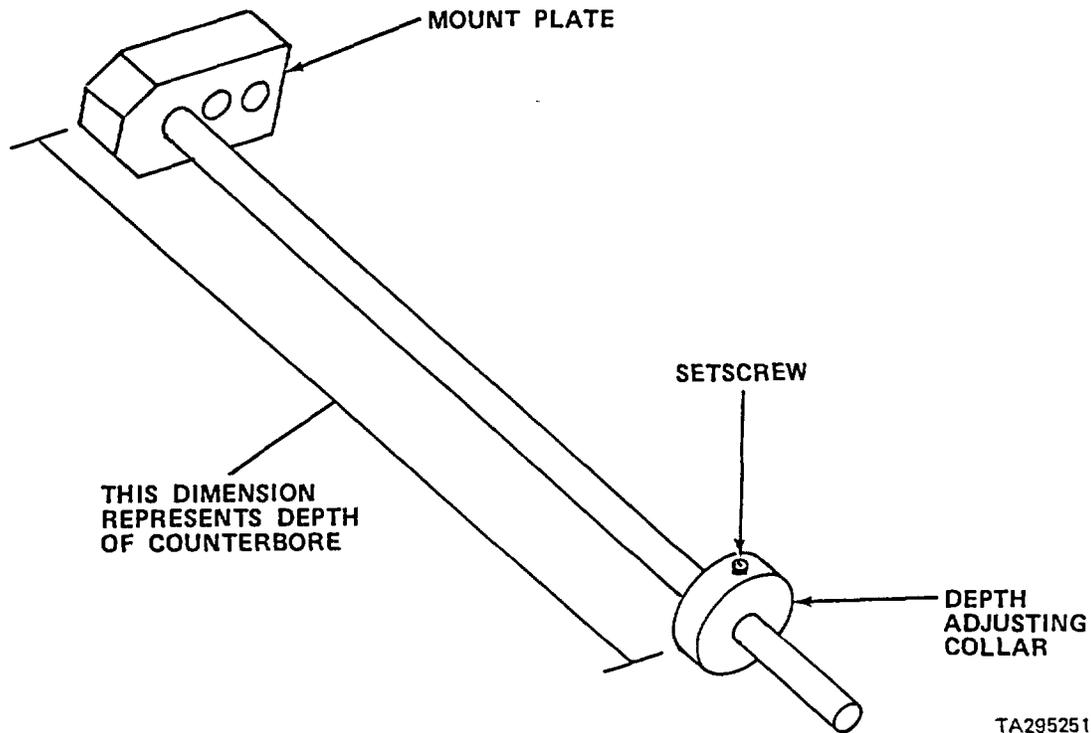
- (i) Place tool bit assembly into holder until pin bottoms against drive shaft.
  - (j) Tighten setscrew securing tool bit assembly.
- (3) Adjust tool boring depth.



TA295250

- (a) Measure distance from top of block to lower counterbore entrance lip.
- (b) Measure thickness of replacement sleeve to be installed.

- (c) Add both dimensions. This represents depth of counterbore.

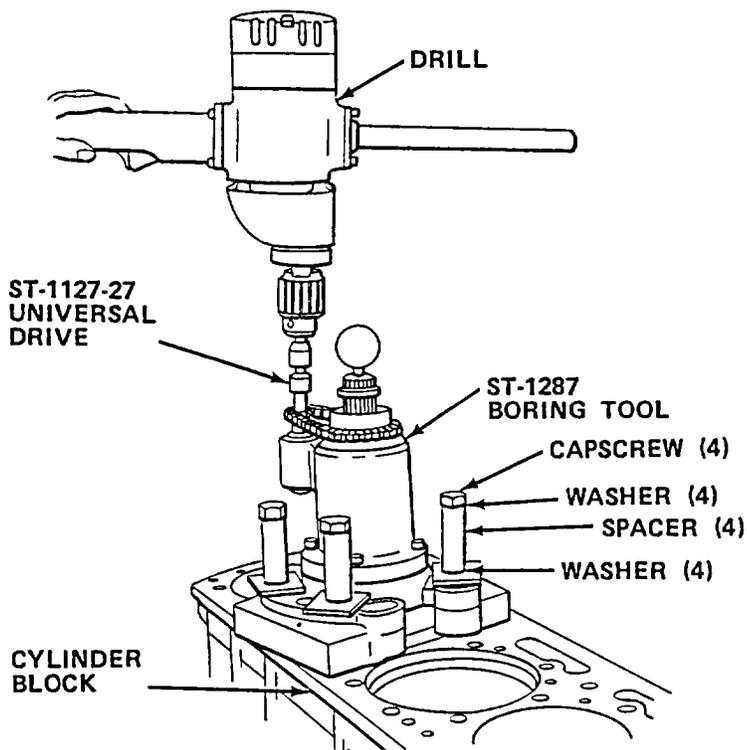


TA295251

- (d) Loosen setscrew on depth adjusting collar of gage rod.
- (e) Slide adjusting collar to point where distance from rod mount plate to top of collar equals depth of counterbore dimension determined in (c) above.
- (f) Attach gage rod assembly mount plate to bottom of boring tool base plate with capscrew.
- (g) Loosen round knob on top of tool and push drive shaft down until tool bit barely touches preset depth collar on gage rod.
- (h) Loosen setscrew on depth adjusting collar and turn collar clockwise until it contacts top of tool housing. This establishes boring depth.
- (i) Tighten adjusting collar setscrew.
- (j) Remove gage rod from base plate.
- (k) Pull upward on round knob and raise drive shaft all the way up.

(4) Install counterbore salvage boring tool.

- (a) Remove all nicks or burrs from upper counterbore with emery cloth.
- (b) Clean upper bore thoroughly to ensure smooth counterbore surface. This is necessary to provide boring tool with proper alignment between upper and lower bores.



TA295252

- (c) Place boring tool on top of cylinder block over bore to be machined. Tapered centering ring will engage with upper counterbore to center tool.
- (d) Secure boring tool base plate to block with capscrews, washers, and spacers.
- (e) Torque capscrews to 50 ft lbs. (68 N•m).
- (f) Slowly push downward on round knob until tool bit touches lower bore area.
- (g) With round knob, raise drive shaft approximately 1.0 in. (25.4 mm).
- (h) Turn round knob clockwise to tighten. This engages automatic feed (, mechanism.
- (i) Rotate shaft by hand to ensure free rotation.

- (5) Cut counterbore to accept replacement sleeve.

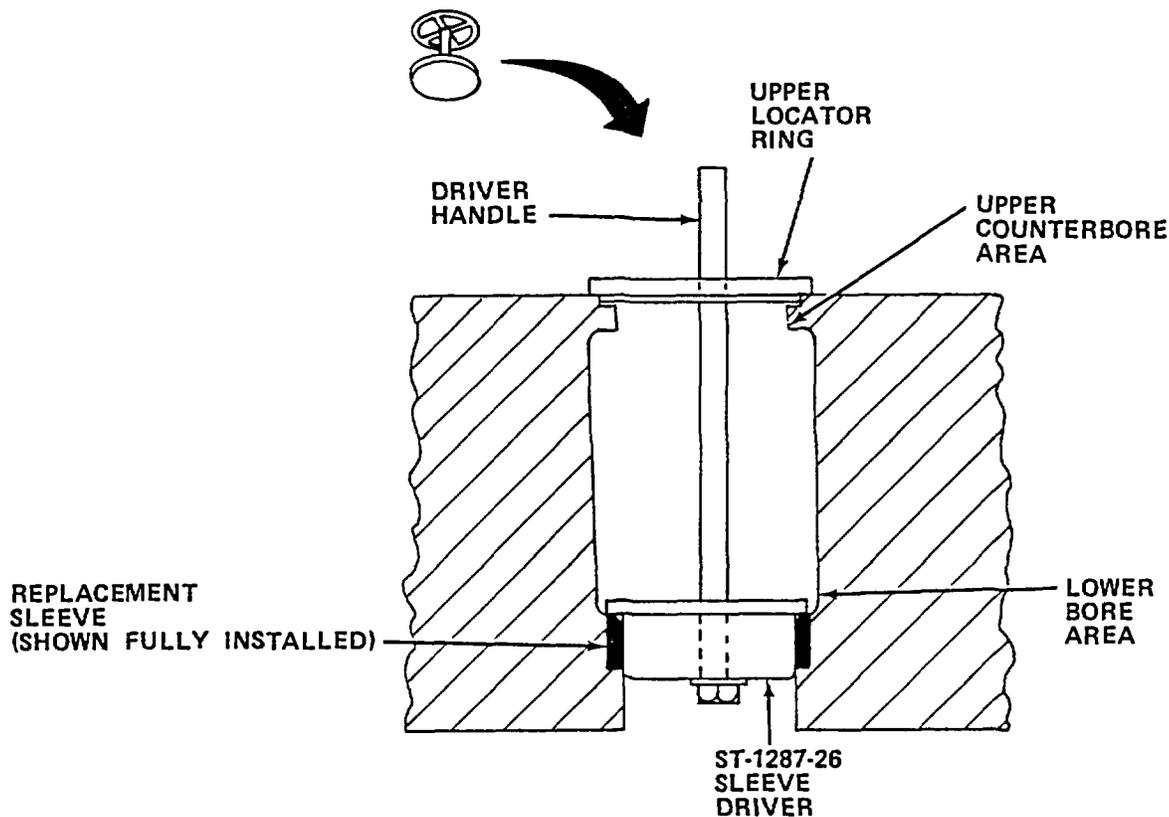
**CAUTION**

**DO NOT USE DRILL RATED AT LESS THAN 10 AMPERES OR OVER 450 RPM. USE OF HIGH SPEED AND/OR LOW AMPERE RATED DRILL COULD DAMAGE DRILL DUE TO HEAVY LOAD.**

- (a) Place ST-1127-27, 1/2 in. (12.7 mm) universal drive, in 3/4 in. (19.05 mm) heavy duty hand drill.
- (b) Engage universal drive with tool housing assembly.
- (c) Start drill and bore until depth adjusting collar contacts boring tool housing. A noticeable change in drill speed will be observed.
- (d) Stop drill.
- (e) Loosen round knob on tool housing, and pull drive shaft all the way up.
- (f) Tighten knob.
- (g) Remove drill.
- (h) Remove boring tool.
- (i) Clean bore and remove any rough edges or burrs with emery cloth.
- (j) Measure bore diameter to ensure proper sleeve fit.

f. Cylinder liner lower counterbore replacement sleeve installation.

- (1) Clean counterbore and outside diameter of sleeve with solvent.
- (2) Coat outside diameter of sleeve with high temperature retaining compound.
- (3) With inside diameter chamfer of sleeve facing upward, push sleeve through upper counterbore.



TA295253

- (4) Insert ST-1287-26 sleeve driver (without upper locator ring) into sleeve.
- (5) Slide upper locator ring onto driver handle and seat locator ring in upper counterbore.
- (6) With rawhide mallet, tap on driver handle and drive sleeve into place.
- (7) When sleeve is positioned, driver should rotate freely.
- (8) Remove sleeve driver assembly.
- (9) Wipe clean excess compound from around sleeve entrance.

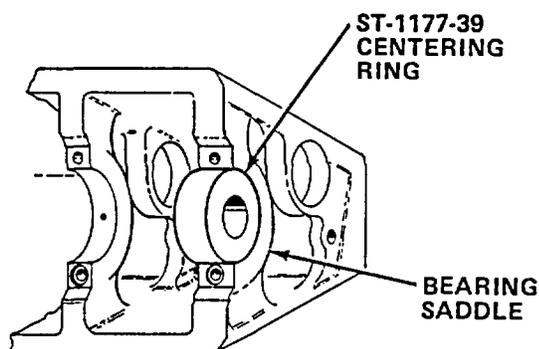
## g. Main bearing line boring.

**NOTE**

Replacement main bearing caps are not machine finished. They are furnished with 0.015 in. (0.381 mm) excess material in bore. They must be machined to their respective bearing saddles to ensure proper bearing shell fit. Line boring is also required if bearing saddle is damaged, misaligned, excessively tapered, or exceeds maximum diameter. Rebored saddles are then fit with salvage sleeves. Sleeves are then bored to accept standard bearing shells.

## (1) Install boring bar.

- (a) Remove two main bearing caps which do not require boring. Select two caps which are at each end of cylinder block or as far apart as possible.
- (b) If two caps cannot be selected which are far apart from each other, bridges must be installed to provide boring bar with required support and stability (para 3-9i).



TA295254

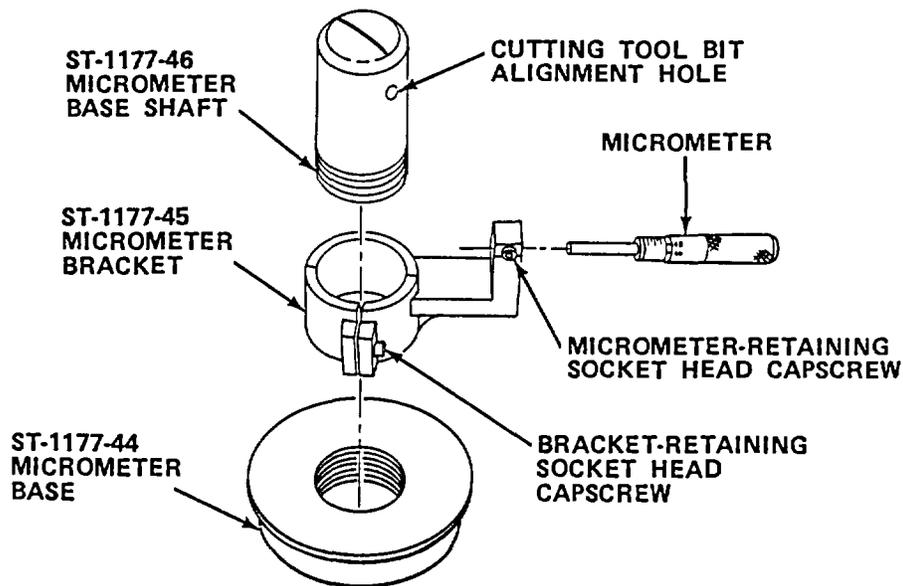
- (c) Install ST-1177-39 centering rings in center of bearing saddles. Tap in position with soft head hammer.

**NOTE**

**Caps fit tightly to provide proper seating.**

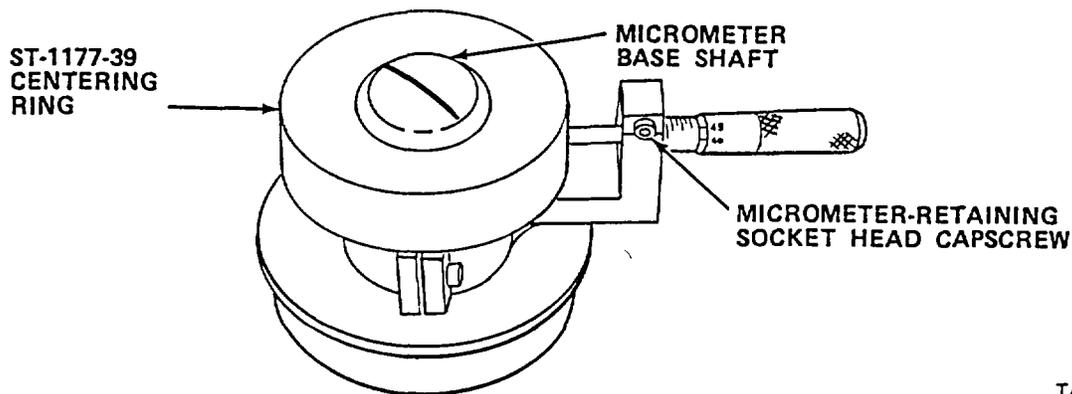
- (d) Assemble two main bearing caps with centering rings in saddles and torque capscrews as specified in para 3-94e.
- (e) Assemble new caps as required and torque to specifications.
- (f) Lubricate centering rings and boring bar with engine oil.
- (g) Slide boring bar through centering rings in block.

(2) Assemble micrometer tool bit setting gage.



TA295255

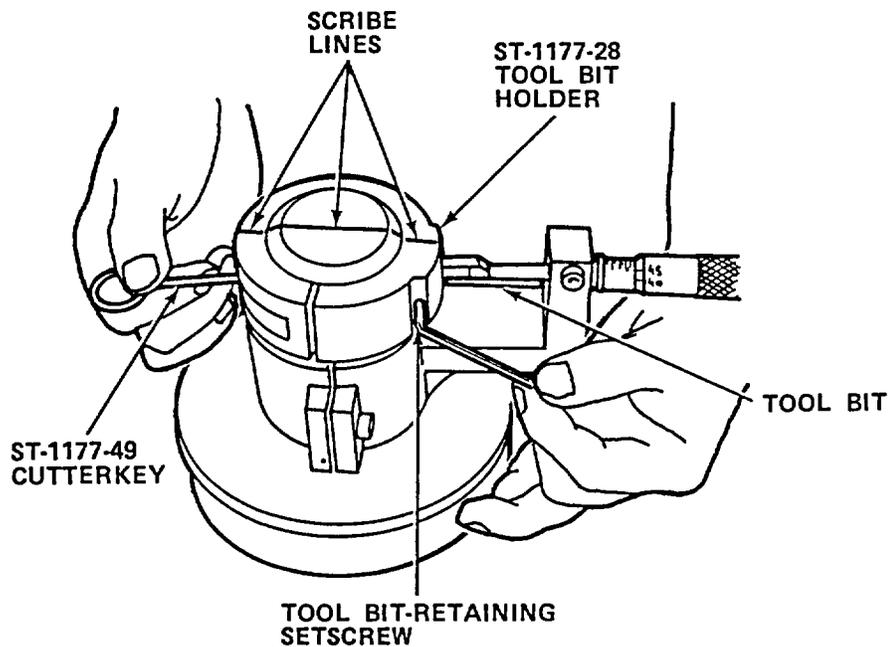
- (a) Place ST-1177-46 micrometer base shaft through ST-1177-45 micrometer bracket and screw shaft into ST-1177-44 micrometer base. Tighten securely.
- (b) Aline cutting tool bit alinement hole in micrometer base shaft with hole in micrometer bracket.
- (c) Secure bracket to base shaft with socket head capscrew.



TA295256

- (d) Slide ST-1177-39 centering ring over micrometer base shaft.
- (e) Install micrometer in micrometer bracket. Leave micrometer retaining socket head capscrew loose.
- (f) Adjust micrometer thimble to 4.750 in. (120.650 mm).
- (g) Hold micrometer spindle against centering ring and tighten micrometer retaining socket head capscrew.

- (h) Back off micrometer thimble then recheck dimension.
- (i) Remove centering ring.



TA295257

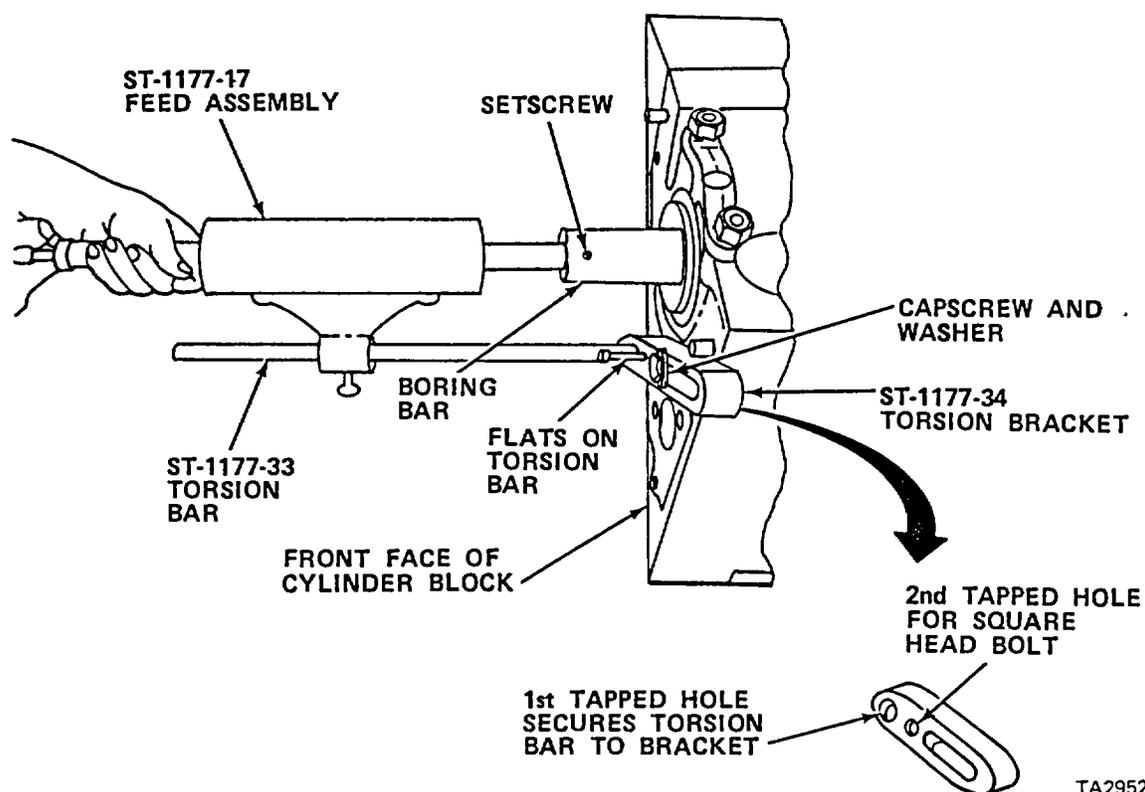
- (j) Slide ST-1177-28 tool bit holder onto micrometer base shaft.
- (k) Aline scribe line on tool bit holder with scribe line on base shaft. This alines through-hole in base shaft with tool bit hole in holder.
- (l) Select tool bit holder which is short enough so it does not extend into bore of tool holder.
- (m) Insert tool bit into bit holder.

**CAUTION**

**TO PREVENT CHIPPING OF BIT, DO NOT TIGHTEN MICROMETER SPINDLE AGAINST TOOL BIT POINT.**

- (n) Set micrometer to 4.750 in. (120.650 mm).
- (o) With ST-1177-49 cutter key inserted in through hole of base shaft, carefully push tool bit tip against micrometer spindle. Tighten tool bit retaining setscrew in tool bit holder.
- (p) Back off micrometer then recheck dimension. Tool bit is now set at proper length for boring of new rod caps to standard size.
- (q) Back off micrometer and remove cutter holder from micrometer base.

(3) Feed assembly and cutter holder assembly installation.



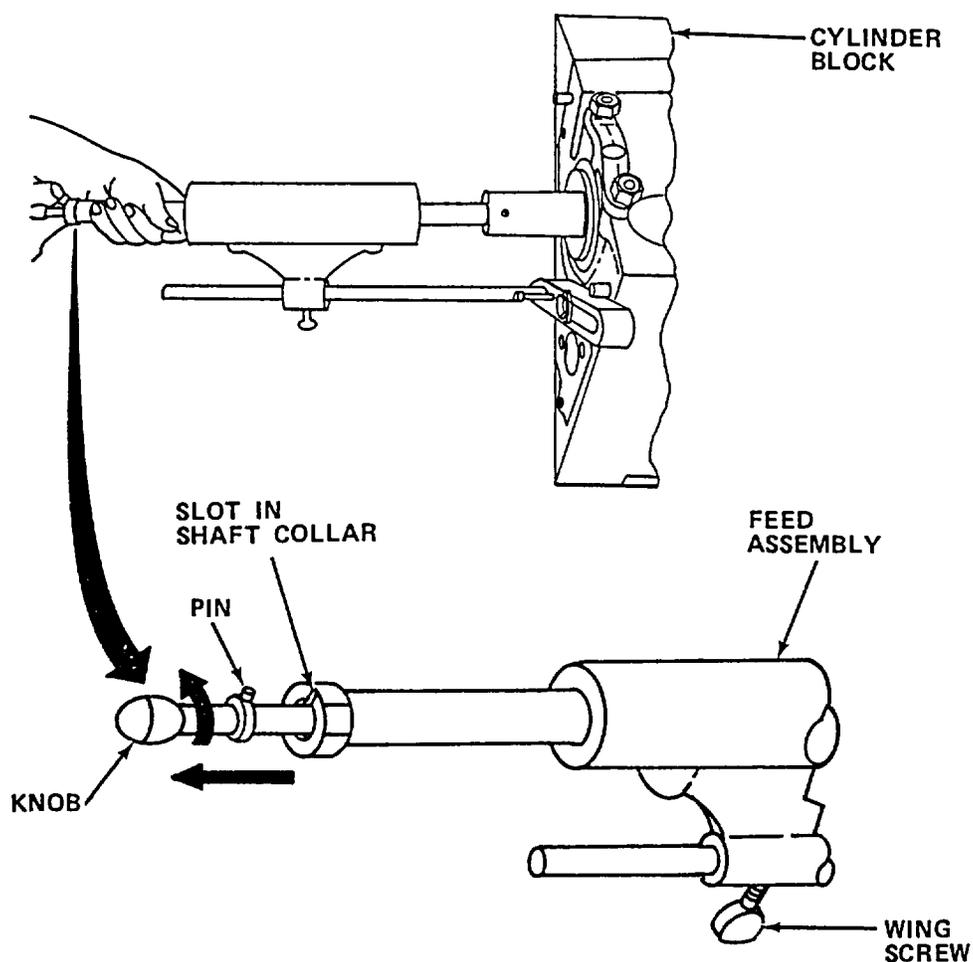
TA295258

- (a) Insert ST-1177-17 feed assembly into front end of boring bar.
- (b) Secure to bar with setscrew.
- (c) Install ST-1177-33 torsion bar, threaded end first, through hole in feed assembly.
- (d) Thread torsion bar into end hole of ST-1177-34 torsion bracket. Engage open-end wrench with flats on torsion bar and tighten bar.

**NOTE**

**Torsion bracket has slot for securing of bracket to cylinder block.**

- (e) Locate tapped hole in end face of block and secure torsion bracket to block with capcrew and washer.



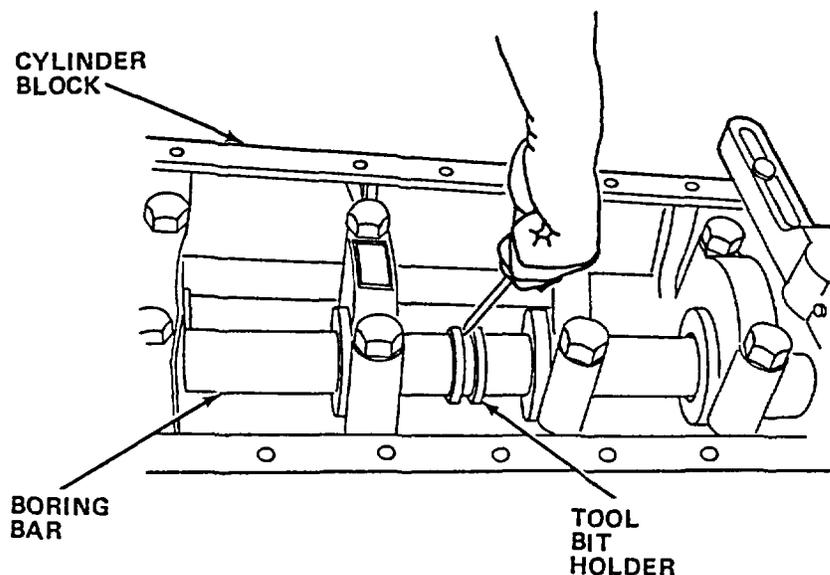
TA295259

**NOTE:**

**TO DISENGAGE AUTO FEED:**

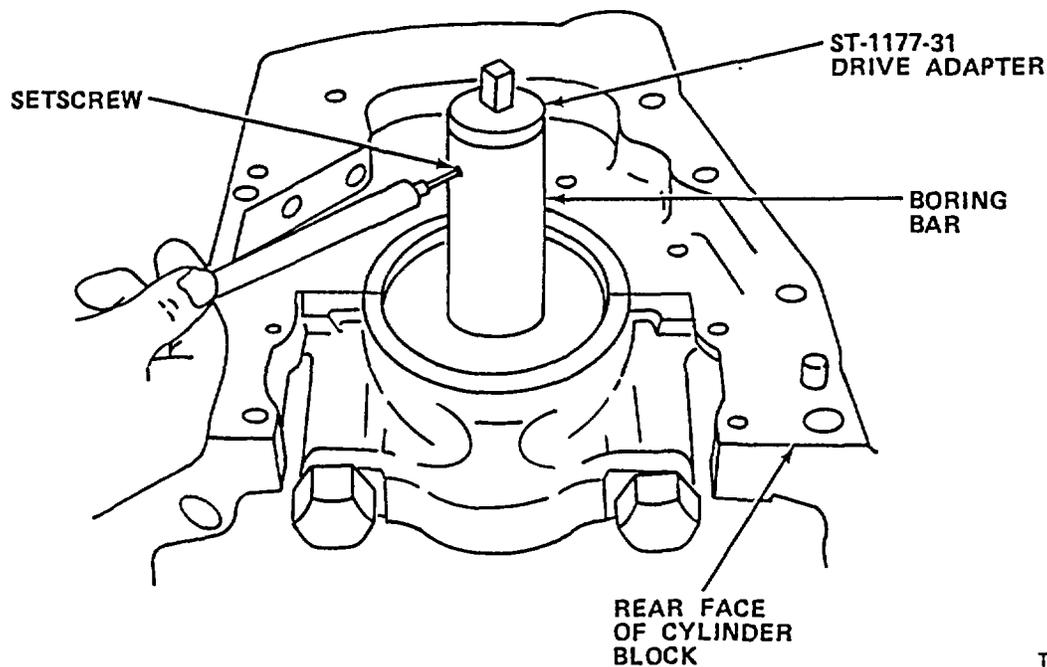
- 1. PULL KNOB OUT**
- 2. ROTATE KNOB 1/4 TURN**

- (f) Pull out on round knob on feed assembly until pin in knob shaft is free of slot in collar.
- (g) Rotate knob 1/4 turn. This disengages automatic feed.
- (h) Pull complete feed assembly all the way back to knob.
- (i) Tighten wing screw securing torsion rod to feed assembly.
- (j) Turn knob 1/4 turn to seat pin in slot. This reengages automatic feed.



TA295260

- (k) Install tool bit holder on boring bar next to bore to be cut. Ensure that tool bit cutting edge is turned in direction of drill rotation. Boring bar will automatically feed toward feed assembly.
- (l) Install square head bolt in second threaded hole in torsion bracket. Tighten snug against cylinder block to stabilize torsion bracket and rod.



TA295261

- (m) Install ST-1177-31 drive adapter in other end of boring bar. Lock to bar with setscrew.

- (4) Cut bore and bearing cap.

**CAUTION**

**DO NOT USE DRILL RATED AT LESS THAN 10 AMPERES OR OVER 450 RPM. USE OF HIGH SPEED AND/OR LOW AMPERE RATED DRILL COULD DAMAGE DRILL DUE TO HEAVY LOAD.**

- (a) Secure universal driver to 3/4 in. (19.05 mm) heavy duty hand drill and engage driver with drive adapter on end of boring bar.

**CAUTION**

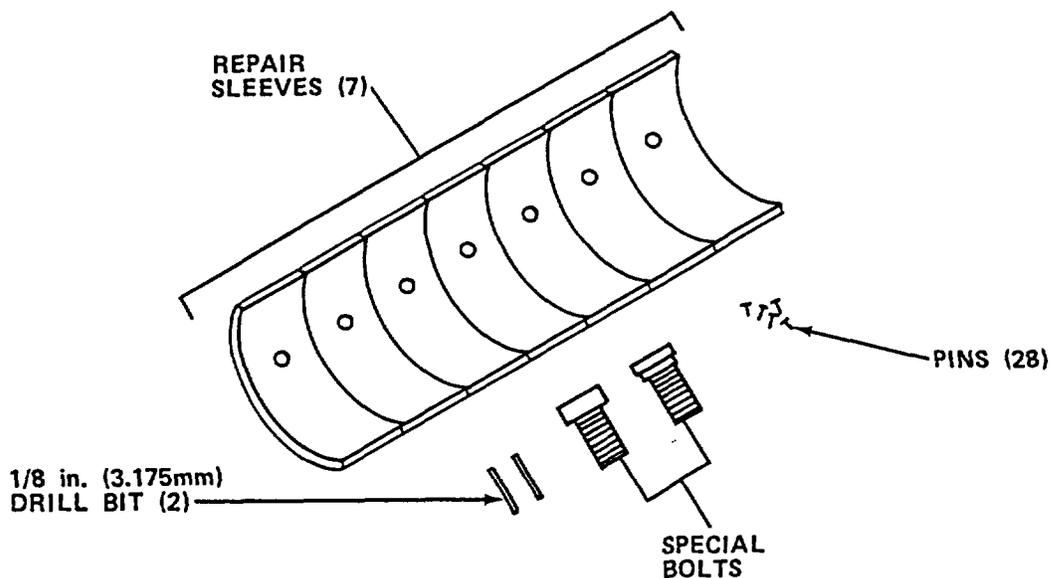
**TO PREVENT DAMAGE TO TOOL BIT OR BORE, KEEP TOOL BIT WELL OILED WHILE BORING.**

- (b) Apply cutting oil to tool bit and start drill.
- (c) Stop drill when tool bit holder passes completely through bore.
- (d) To cut next journal (if necessary), remove tool bit holder from boring bar.
- (e) Pull out knob on feed assembly and turn 1/4 turn.
- (f) Push in on knob until it stops against feed assembly. This places boring bar in start position.
- (g) Turn knob 1/4 turn until pin seats in slot. Automatic feed is now reengaged.
- (h) Install tool bit holder on boring bar next to face to be cut. Ensure that tool bit cutting edge is turned in direction of drill rotation. Boring bar will automatically feed toward feed assembly.
- (i) Proceed with boring operation following steps (a), (b), and (c) above.
- (j) Remove drill, drive adapter cutter holder, and feed assembly from end of boring bar.
- (k) Pull boring bar out far enough to slip on checking ring.
- (l) Lubricate checking ring with engine oil and slide ring through newly cut bore(s) to check alinement.
- (m) Remove checking ring and boring bar.
- (n) Measure bore(s) with dial bore gage to ensure bore does not exceed 4.7505 in. (120.6627 mm).
- (o) If a bore is found out of alinement or is larger than specified, it will have to be enlarged to accept a repair sleeve.

(5) Main bearing saddle salvage sleeve installation.

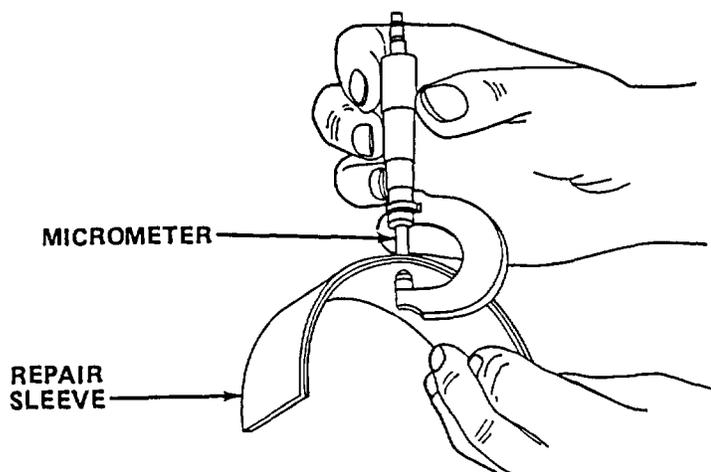
**NOTE**

Tool no. 3375168 main bearing saddle repair kit contains seven repair sleeves. Sleeves have undersized bores which have to be machined to standard size after sleeves are installed. A new bearing cap will have to be installed when sleeve is machined to standard size. Saddle sleeve numbers 1, 3, and 5 are identical (P/N 3375169). Sleeve numbers 2, 4, and 6 are identical (P/N 3375170). Sleeve number 7 differs from the rest (P/N 3375171).



TA295262

(a) Select sleeve, by location and part number, to be installed.



TA295263

(b) Measure thickness of sleeve with ball pin micrometer. Record thickness.

- (c) Remeasure diameter of bore to be machined and record dimension.
- (d) Determine how large bore is to be cut to accept sleeve using following example:

Diameter of bore before machining	4.752 in.	(120.70 mm)
Thickness of sleeve	<u>+ 0.150 in.</u>	(3.81-mm)
Total of both dimensions	4.902 in.	(124.51 mm)
Subtract 0.025 in. (2.54 mm)	<u>- 0.025 in.</u>	(0.635 mm)
New bore diameter	4.877 in.	(123.88 mm)

**NOTE**

**When new sleeve is installed, ends of sleeve must protrude slightly over saddle-to-cap surface. In example above, approximately 0.025 in. (0.635 mm) of sleeve will protrude over that surface.**

- (e) Set tool bit using micrometer tool bit setting gage (para 3-9g(2) above). Setting gage establishes a 4.750 in. (120.650 mm) diameter.
- (f) Set micrometer to read 4.877 in. (123.875 mm) and set tool bit length accordingly.
- (g) Install boring bar feed assembly and cutter holder (para 3-9g(3) above).

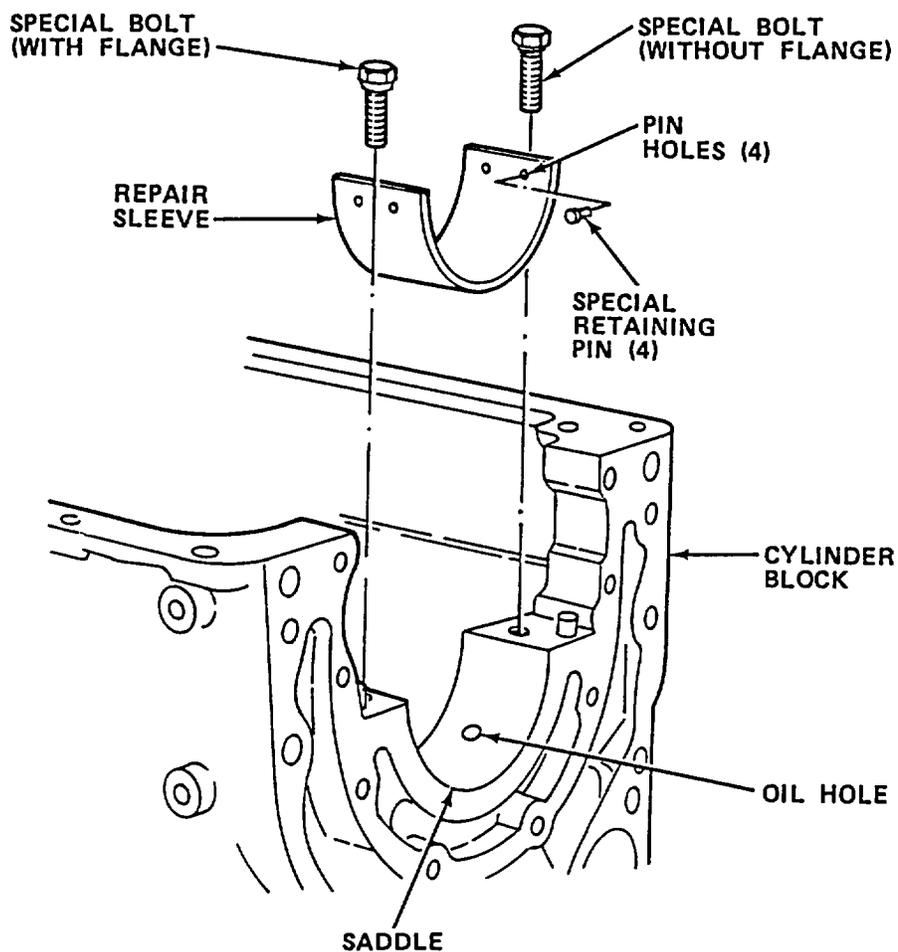
**NOTE**

**Bearing cap is not installed on saddle being bored.**

- (h) Cut bore (para 3-9g(4) above).
- (i) Remove tool bit holder, feed assembly, and boring bar.
- (j) Clean bored surface with lintfree cloth.
- (k) Place repair sleeve in saddle and check that sleeve oil hole alines with hole in saddle.
- (l) Carefully file protruding end of sleeve to be flush with saddle-to-cap surface.

**NOTE**

Special locking bolt has flange under head which fits into counterbore in saddle.



TA295264

- (m) Secure sleeve to saddle with two special large head bolts that come with repair kit.

**NOTE**

Sleeve has four 1/8 in. (3.175 mm) pre-drilled holes, one hole near each corner.

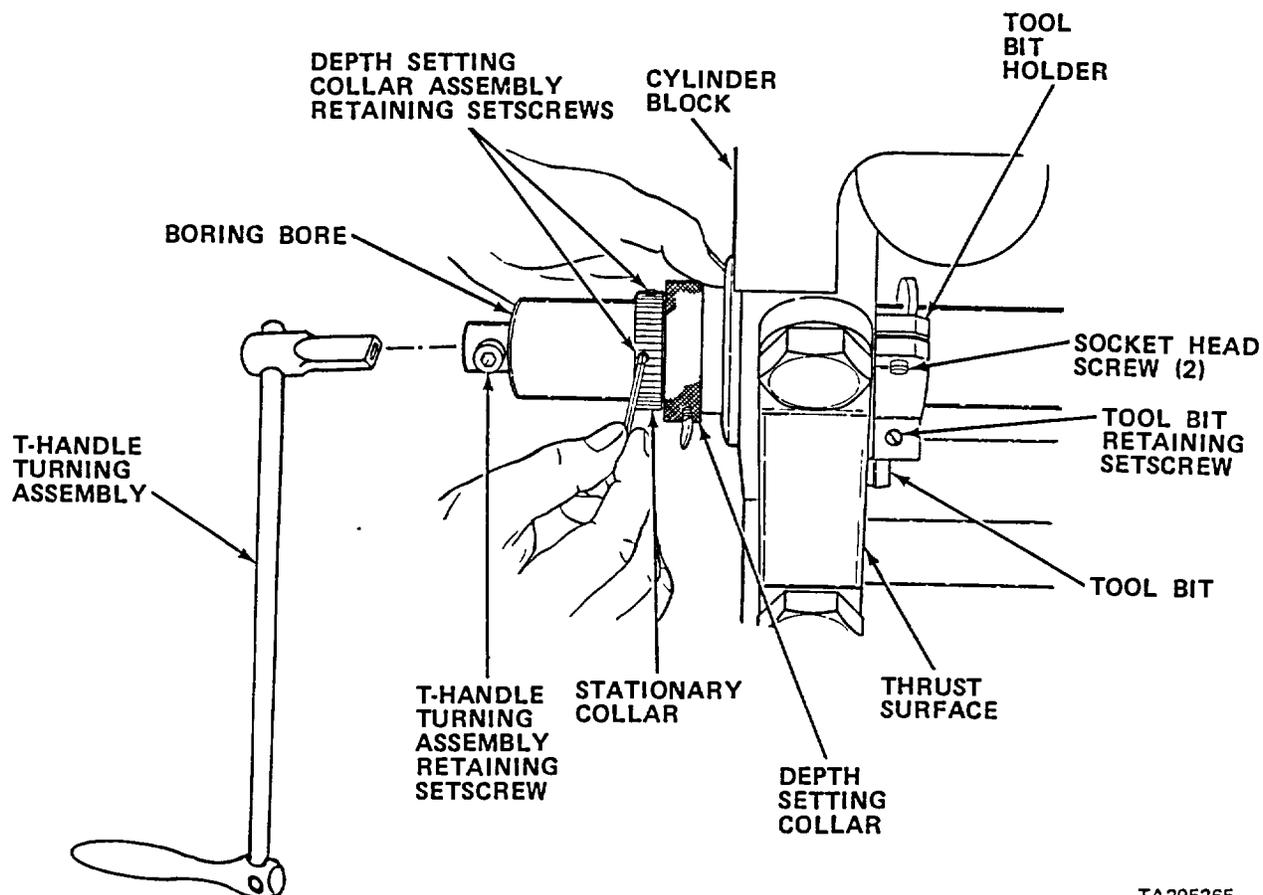
- (n) Measure shank length (minus head) on one special retaining pin that comes with kit. Record length.

- (o) Place 1/8 in. (3.175 mm) drill bit in hand drill.
  - (p) Set length of bit so that the pin is installed through sleeve into saddle, pin bottoms out in hole before head seats in sleeve.
  - (q) Carefully drill four holes into saddle using pre-drilled holes in sleeve as guides.
  - (r) Install special pins and carefully peen heads to insure tight fit of sleeve.
  - (s) Remove special sleeve retaining bolts.
  - (t) Wipe area clean.
  - (u) Install new bearing cap and torque to specifications in table 3-3.
  - (v) Rebore sleeve and cap to standard size (para 3-9g(2), g(3), and g(4)).
  - (w) If sleeve protrudes on sides of saddle, remove excess with thrust surface cutter.
- h. Main bearing (no. 7) thrust surface repair.
- (1) Install thrust surface cutter.

#### NOTE

**Tool no. 3375053 thrust surface cutter is used with ST-1117 main bearing bore tool to restore thrust surface of block and no. 7 main bearing cap. Grooves, uneven wear, and galled surfaces are machined away to provide smooth surface.**

- (a) Install centering rings in center of no. 1 and no. 7 bearing saddles. Ensure ring is centered in thrust saddle to clear tool holder when cutting thrust bearing surface. Use softhead hammer to tap rings into place.
- (b) Install main bearing caps over centering rings and torque capscrews to specifications in table 3-3.
- (c) Slide boring bar through centering rings.



TA295265

- (d) Slide depth setting collar assembly on boring bar. Do not secure at this time.
- (e) Install T-handle turning assembly into end of boring bar. Secure to bar with setscrew.
- (f) Install tool bit holder halves around boring bar behind thrust surface and secure halves with socket head screws.
- (g) Adjust tool bit with setscrew to cut full thrust bearing surface when boring bar turned in clockwise direction. Tighten setscrew securely.
- (h) Set depth collar assembly so that tool bit makes light contact with surface to be cut.
- (i) Tighten two setscrews on stationary collar, securing depth setting collar assembly to boring bar.

- (j) Apply cutting oil to thrust surface and tool bit.

**CAUTION**  
**ROTATE T-HANDLE DRIVE VERY SLOWLY TO AVOID CHATTER AND UNEVEN THRUST SURFACE.**

**NOTE**

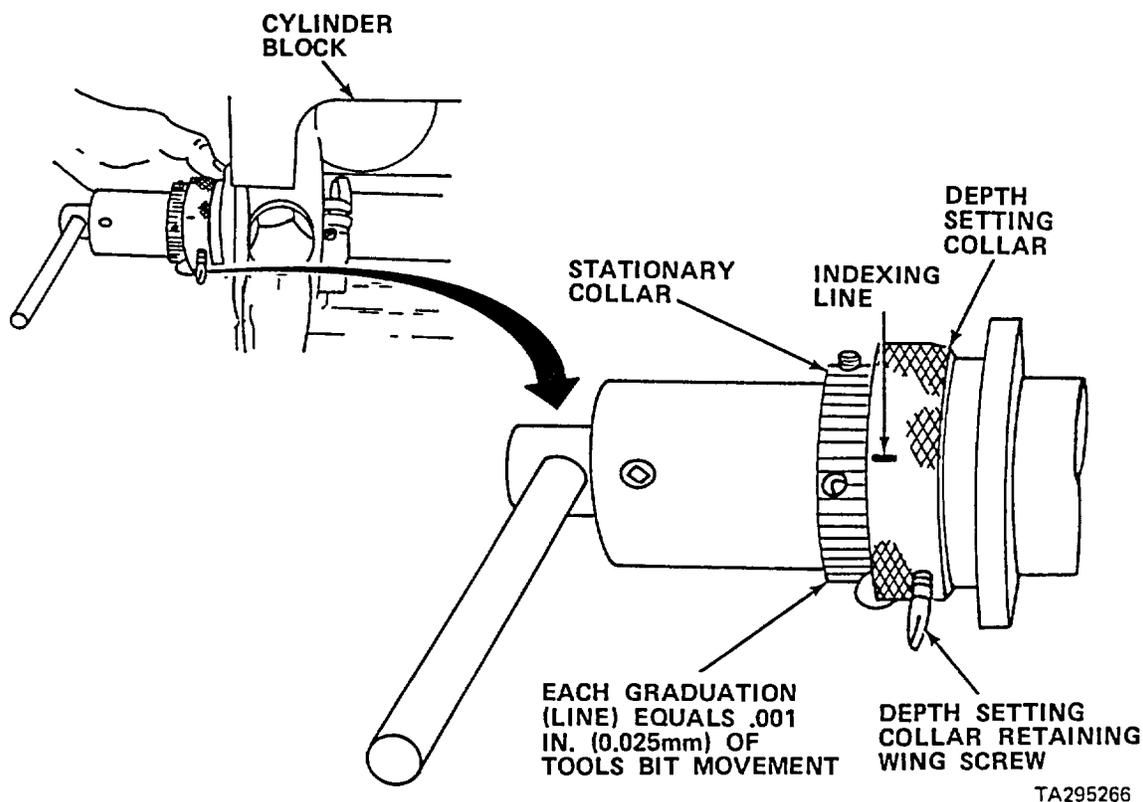
**Keep tool bit well oiled while cutting.**

- (k) Turn boring bar clockwise one full revolution to check tool bit cutting depth and pattern.

**CAUTION**  
**REMOVE ONLY AMOUNT OF MATERIAL NECESSARY TO PROVIDE SMOOTH, EVEN THRUST SURFACE.**

**NOTE**

**Each graduation line on stationary collar is 0.001 in. (0.025 mm).**



- (l) Loosen wingscrew on depth setting collar and turn collar to right until indexing line moves one graduation. Tighten wingscrew.

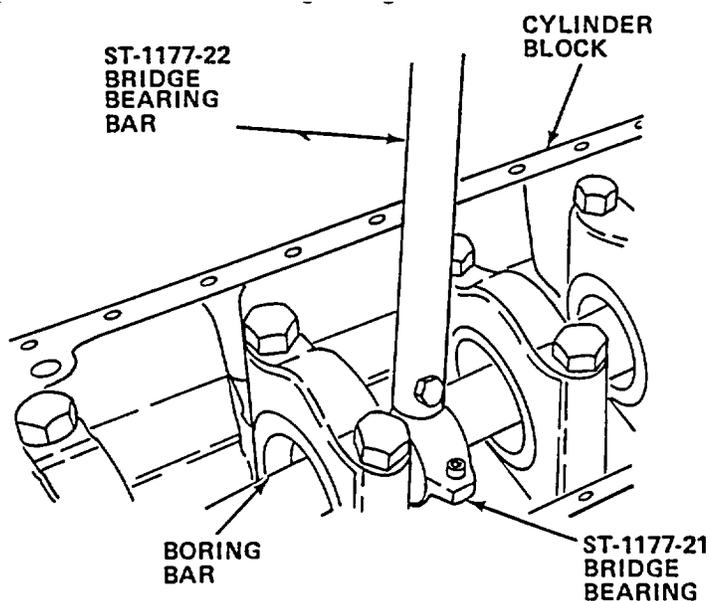
- (m) Check thrust surface after each cut to ensure proper finish is attained.
- (n) Remove T-handle drive assembly.
- (o) Remove depth setting collar assembly.
- (p) Remove tool bit holder.
- (q) Remove boring bar and centering rings.
- (r) Clean thrust bearing area.

i. Boring bar bridges installation.

**NOTE**

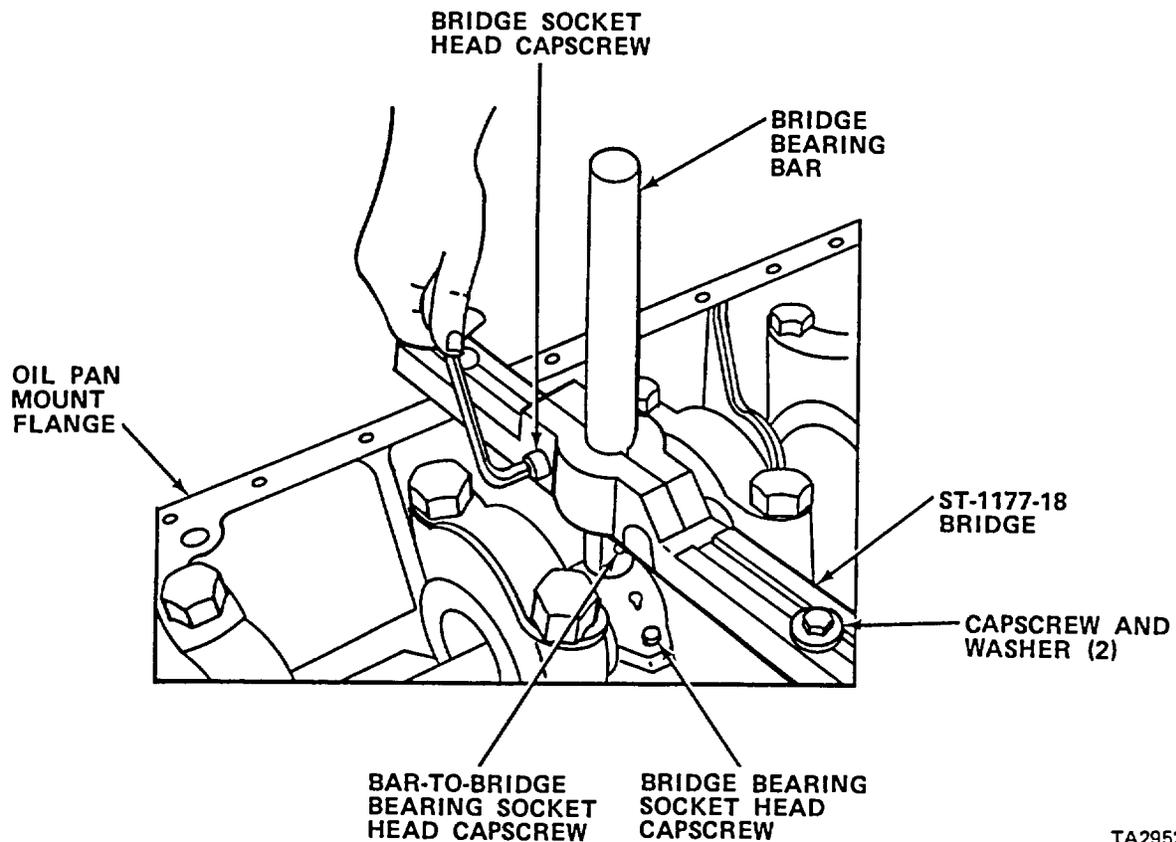
**If centering rings cannot be placed equally apart because of main bearing saddle damage, bridges are available. These bridges support boring bar while saddle bores are checked and/or machined.**

- (1) Install centering rings in undamaged main bearing saddles as far apart as possible.
- (2) Install main bearing caps and torque capscrews to specifications in table 3-3.
- (3) Slide boring bar into centering rings.



TA295267

- (4) Slide ST-1177-21 bridge bearing with ST-1177-22 bridge bearing bar over boring bar. Stop at point where support is needed. Allow room for cutter holder if bridge bearing is next to journal to be cut.



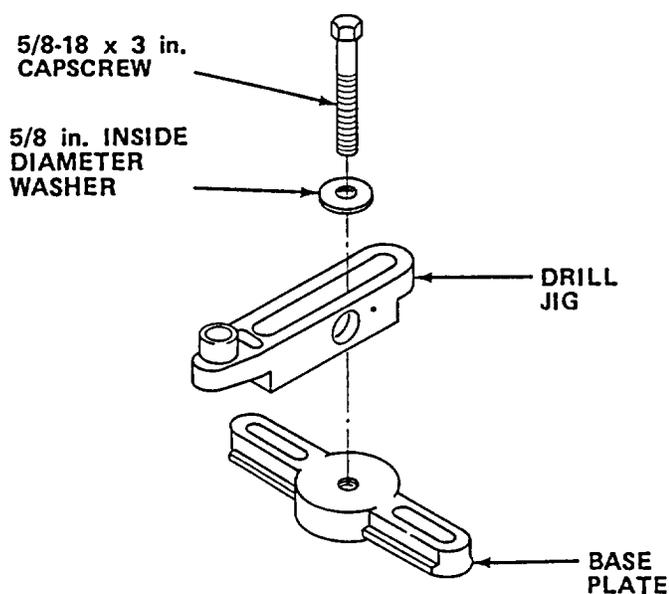
TA295268

- (5) Slide St-1177-18 line bore bridge over bridge bearing bar. Secure bridge to oil pan rail.
- (6) Tighten socket head capscREW in bridge bearing until bearing is snug around boring bar.
- (7) Turn boring bar to ensure free rotation.
- (8) Tighten socket head capscREW in bridge.
- (9) Ensure that capscREW securing bridge bearing bar to bridge bearing is tight.
- (10) Recheck boring bar freedom of rotation.
- (11) Continue setting up for boring operation.
- (12) After boring and checking operation are complete, remove bore bridge, bridge bearing, and bar.

j. Cylinder Block Cylinder Head Bolt Thread Repair.

**NOTE**

If cylinder head bolts are stripped or distorted or threads in cylinder block are damaged, block can be repaired by installing special inserts. Inserts are threaded internally and externally with one end having counterbore same as bolt hole in block. The insert internal threads are same size as original threads in block. Tool nos. 3376208 and 3376005 capscrew thread repair tool kits are used to perform task.

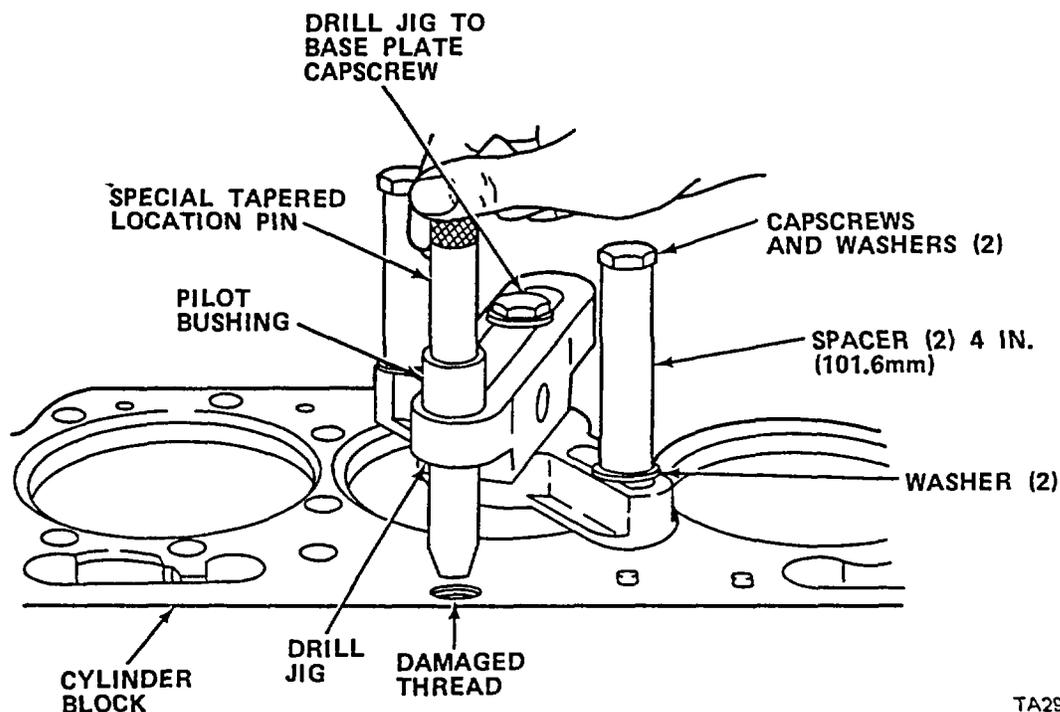


TA295269

**NOTE**

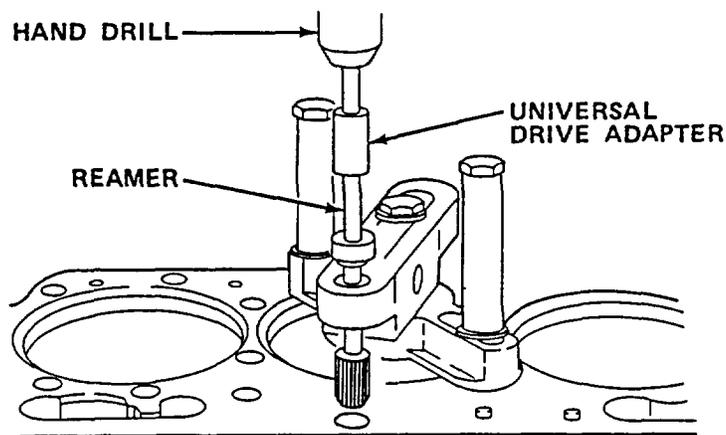
5/8 18 X 3 in. capscrew, 5/8 in. inside diameter washer and two 4-in. long spacers are not part of thread repair tool kit.

- (1) Secure drill jig to base plate with 5/8 - 18 X 3-in. capscrew and washer. Leave capscrew loose.
- (2) Secure base plate to block with cylinder head bolts and 4 in. (101.6 mm) spacers and washers.



TA295270

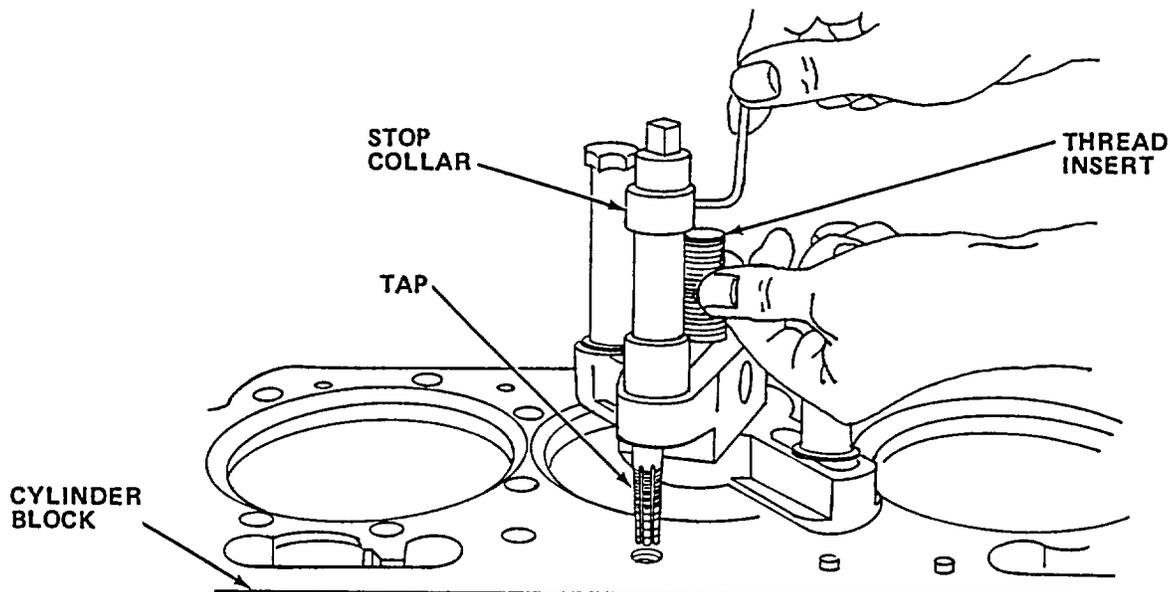
- (3) Place special tapered location pin through drill jig pilot bushing into hole to be repaired.
- (4) While holding location pin in place, tighten drill jig to base plate cap screw.
- (5) Remove special tapered location pin.



TA295271

- (6) Install tool no. 3376006 reamer in pilot bushing.
- (7) Install universal drive adapter into heavy duty 1/2 in. (12.7 mm) hand drill.

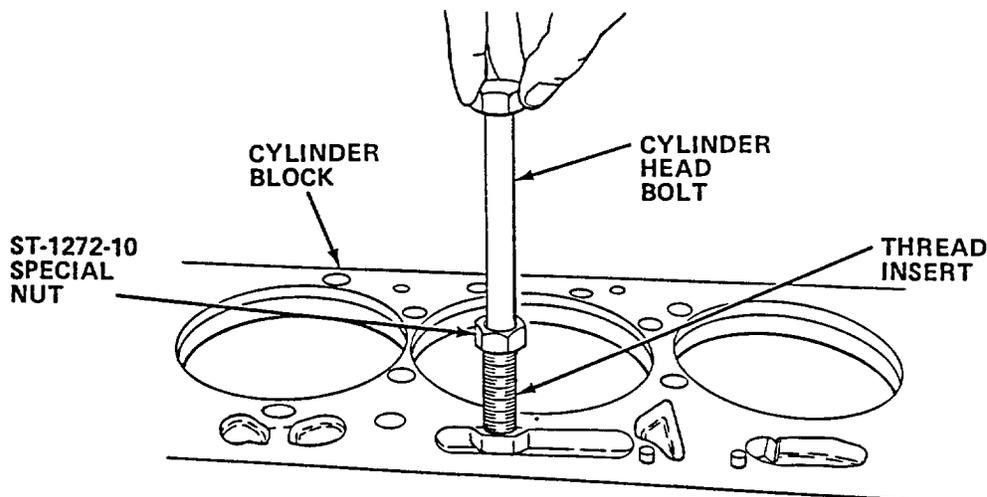
- (8) Apply cutting oil to reamer and ream hole until reamer bottoms out in bore.
- (9) Remove reamer.
- (10) Remove shavings with ST-1271-11 chip remover.
- (11) Reinstall reamer and reream to ensure bore is completely reamed.
- (12) Remove reamer.
- (13) Insert tool no. 3376007 tap in pilot bushing.



TA295272

- (14) Slide stop collar over tap.
- (15) Place thread insert to be installed, between top of pilot bushing and bottom of stop collar on tap.
- (16) Adjust stop collar to rest on top of insert.
- (17) Tighten setscrew in stop collar.
- (18) Install drive adapter on tap and secure adapter to 3/4 in. (19.05 mm) hand drill.
- (19) Apply cutting oil to tap and start drill.
- (20) Carefully tap hole until stop collar is within 1/8 in. to 1/4 in. (3.175 to 6.350 mm) from pilot bushing.
- (21) Remove drill drive adapter and tap.
- (22) Clean shavings from hole with chip remover.

- (23) Reinstall tap.
- (24) Secure tap to tap handle.
- (25) Turn tap into hole until stop collar mates with pilot bushing.
- (26) Remove tap, drill jig and base plate.
- (27) Thoroughly clean out hole.



TA295273

- (28) Install ST-1272-10 special nut on standard cylinder head retaining bolt.
- (29) Install thread insert on head bolt until it contacts special nut.

### **WARNING**

**WHEN USING PAINT THINNER, MINERAL SPIRITS, AND SIMILAR SOLVENTS, AVOID SKIN CONTACT, INHALATION, OR CONDITIONS THAT MAY CAUSE FIRE HAZARDS.**

- (30) Clean insert external threads with ST-1272-13 primer cleaner. Allow to dry.
- (31) Apply light coat of ST-1272-12 sealing compound to insert external threads.
- (32) Screw insert into cylinder block until flush with top of block.
- (33) Hold head bolt and back off special nut 1/4 turn.
- (34) Remove head bolt from insert.
- (35) Remove special nut from head bolt.

**CAUTION**

**TAKE CARE NOT TO MAR TOP BLOCK GASKET SEALING SURFACE WHEN FILING. IMPROPER GASKET SEALING COULD CAUSE LEAKAGE.**

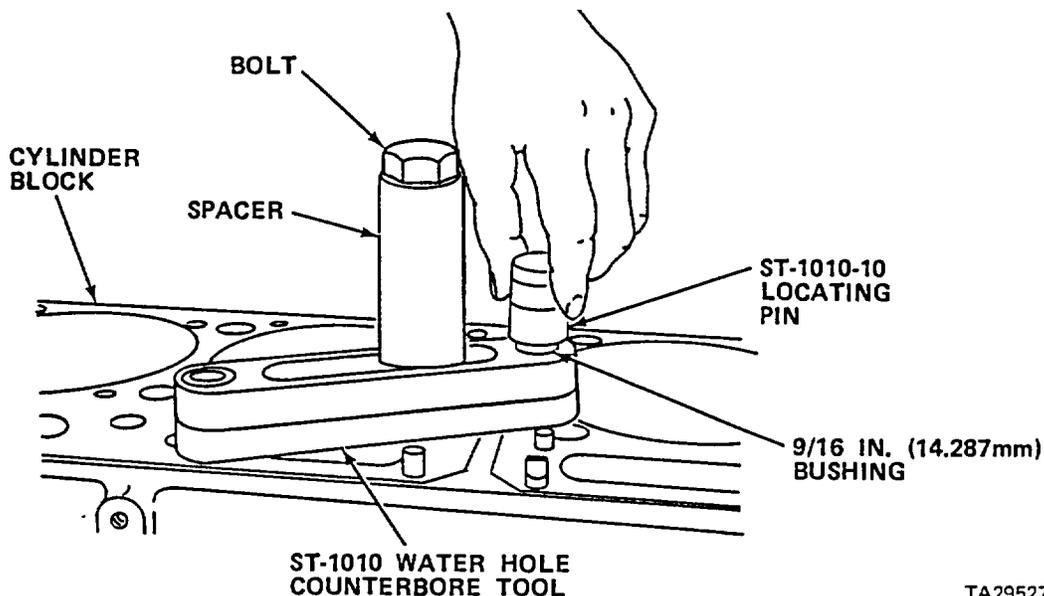
(36) If insert protrudes above cylinder block, carefully file excess stock until insert is flush with block.

k. Eroded water hole repair.

**NOTE**

**Eroded water holes are enlarged to accept a repair sleeve. ST-1010 water hole counterbore tool is used to perform task. Bushing plate has 5/8-in. (15.875 mm) bushing in one end and 9/16-in. (14.287 mm) bushing on other end.**

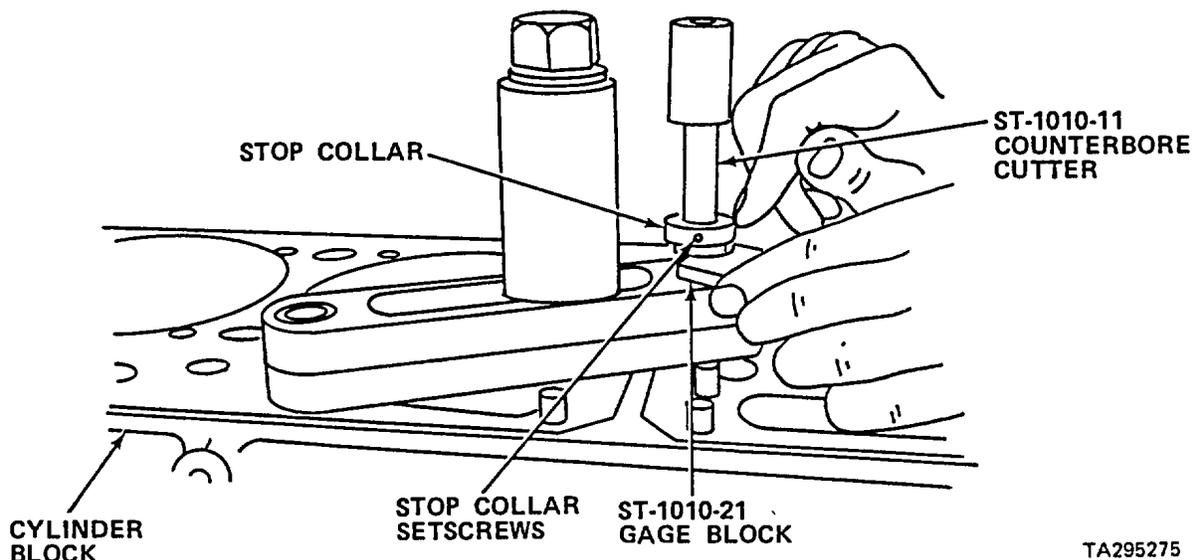
- (1) Place counterbore tool on top of cylinder block with 9/16-in. (14.287 mm) bushing located above hole to be machined.
- (2) Secure tool to block using cylinder head bolt and spacer. Leave bolt hand tight.



TA295274

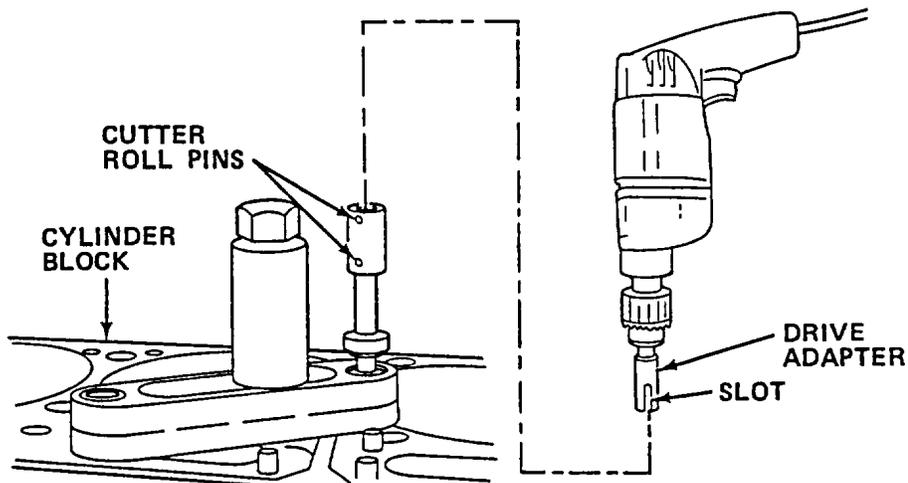
- (3) Insert ST-1010-10 locating pin through 9/16-in. bushing and into hole to be machined.
- (4) With locating pin held in position, tighten bolt and torque to 50 ft lbs. (68 N•m).

- (5) Adjust ST-1010-11 counterbore cutter depth.



TA295275

- (a) Loosen setscrew in stop collar on cutter.
  - (b) Place ST-1010-21 gage block on top of 9/16-in. (14.287 mm) bushing in bushing plate. Line up arc on gage block with hole in bushing.
  - (c) Insert cutter into bushing until it bottoms on cylinder block.
  - (d) Slide stop collar down until it rests on top of gage block.
  - (e) Tighten collar setscrew.
  - (f) Remove gage block.
- (6) Secure drive adapter to hand drill chuck.



TA295276

- (7) Insert drive adapter into top of cutter. Ensure that slot in drive adapter straddles roll pin in top of cutter.

- (8) Apply cutting oil to cutter.
- (9) With light pressure on drill, bore hole until stop collar contacts counterbore tool.
- (10) Remove drill and cutter.
- (11) Remove counterbore tool.
- (12) Slide repair sleeve onto bushing driver.
- (13) Coat bushing with retaining compound.
- (14) Aline sleeve with water hole and drive sleeve into hole. Sleeve will protrude above surface of block.

**CAUTION**

**TAKE CARE WHEN FILING NOT TO MAR CYLINDER HEAD GASKET SURFACE.  
IMPROPER GASKET SEALING COULD CAUSE LEAKAGE.**

- (15) If block is to be resurfaced (para 3-9a), excess material will then be removed. If not to be resurfaced, file bushing flush with top of block.

**WARNING**

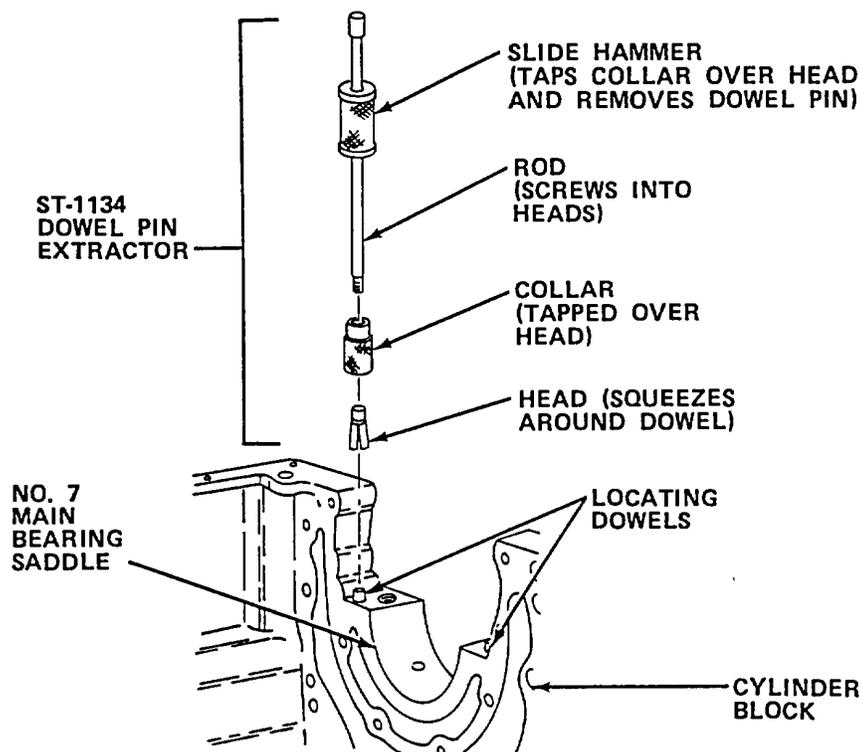
**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI  
(207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL  
PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- (16) Blow shavings and oil from hole and top of block with compressed air.
- (17) Wipe area clean.

I. No. 7 Main Bearing Cap Machining.

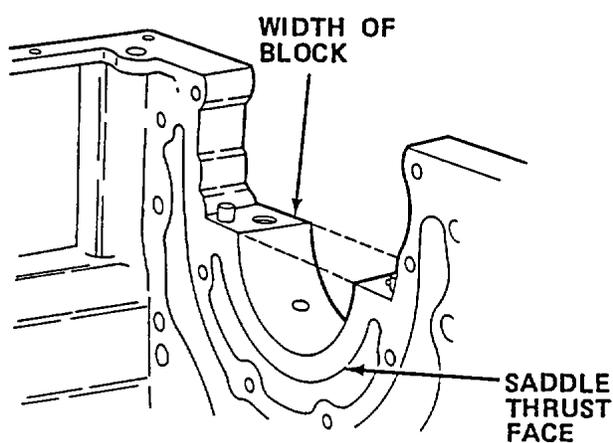
**NOTE**

A new replacement No. 7 main bearing cap does not have cap-to-block locating dowel holes. Cap dowel holes must be machined to match dowel pins in block.



TA295277

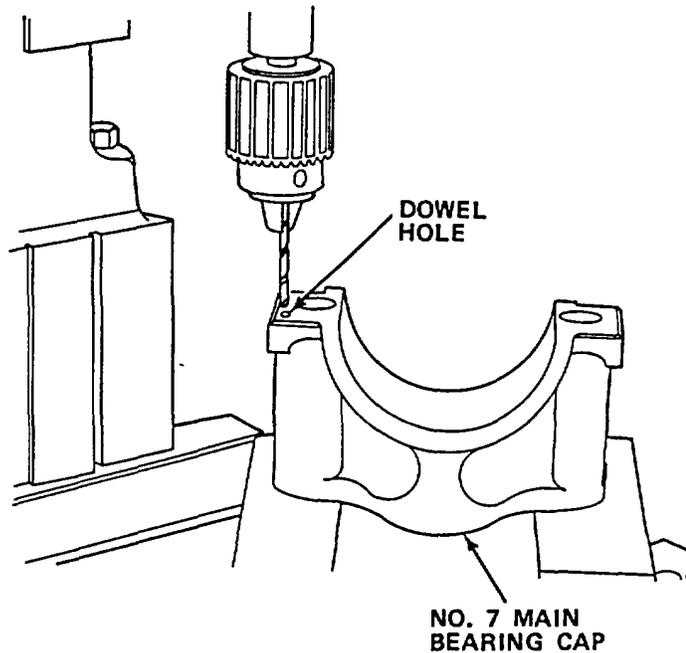
- (1) Remove locating dowel pins in block with ST-1134 dowel pin extractor.



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- (2) Measure width of block across saddle thrust face.

- (3) With surface grinder, remove material from thrust (inside) face of new cap to equal width of saddle. Thrust faces of cap and block must be flush.
- (4) Apply Prussian bluing to block surface.
- (5) Place bearing cap in position so that bluing will make dowel pin location impressions on cap.
- (6) Remove cap.
- (7) Measure depth of dowel pin hole in discarded cap.



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- (8) Drill holes in new cap to required depth and smallest available oversize diameter.
- (9) Ream holes in block to smallest permissible oversize.
- (10) Clean block and cap with lint free cloth.
- (11) Install cap and recheck thrust faces to ensure they are flush.

**Section IV. CYLINDER LINERS INSPECTION****3-10. CLEAN LINERS****CAUTION**

**STAY CLEAR OF SEAL RING GROOVES WITH WIRE BRUSH. MAY DAMAGE GROOVES.**

**NOTE**

**Cylinder liners are in direct contact with coolant for efficient cooling. Coolant is sealed in block by machined surfaces at liner flange and by O-rings and crevice seal at lower end of liner.**

- a. Remove rust and scale from exterior of liner. Stay clear of seal grooves.
- b. Clean exterior of liner with bristle (not wire) scrub brush and warm water and detergent soap.
- c. Wash interior with detergent soap and warm water using bristle (not wire) scrub brush.

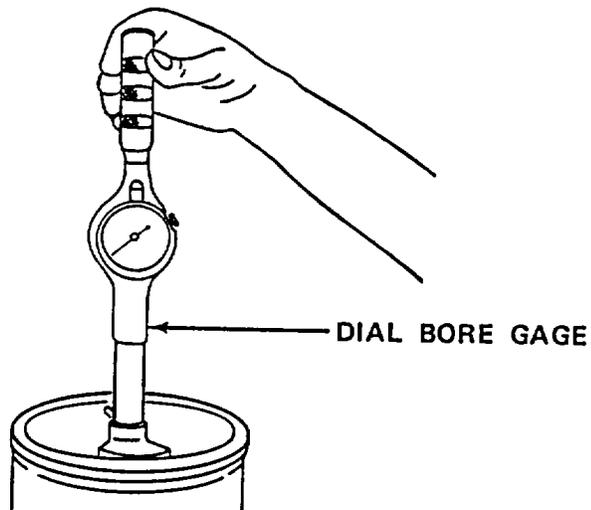
**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- d. Rinse liners thoroughly and dry with compressed air.
- e. Coat liner interior with engine oil and let stand for 5 to 10 minutes.
- f. Use white paper towels to wipe oil from inside of liners. Note gray or black residue that appears with oil on white towels.
- g. Repeat application of engine oil and wipe off with towels until residue no longer shows.

**3-11. INSPECT LINERS**

- a. Using magnetic particle method, inspect liner just under top flange, bottom of liner, and above top seal ring groove for cracks. Discard cracked liners.
- b. Check exterior of liner for excessive corrosion or erosion and pits 1/16 in. (1.59 mm) deep or more. Discard if defective.
- c. Check liners for dents, pitting, or fretting on underside of top flange. Discard if defective.

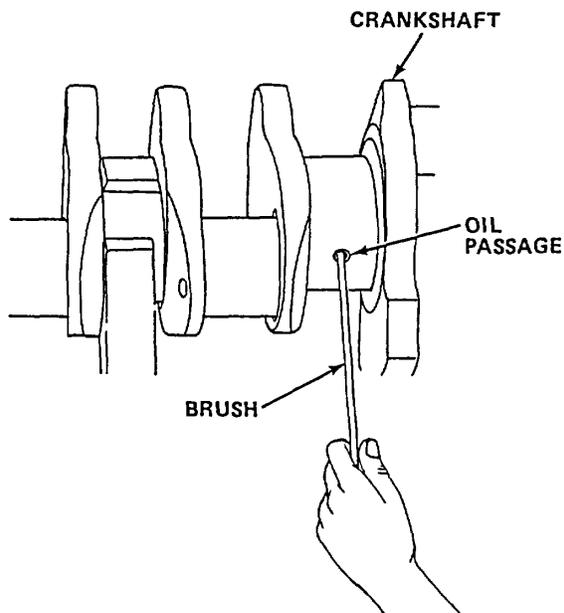


TA295280

- d. Check liners for wear with dial bore gage. Discard liner if inside diameter exceeds 5.505 in. (139.827 mm).

## Section V. CRANKSHAFT ASSEMBLY REPAIR

## 3-12. CLEAN CRANKSHAFT



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**WARNING**

P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.

- a. Clean all drilled oil passages with stiff nylon bristle brush and solvent.

**WARNING**

COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).

- b. Flush passages with solvent and dry with compressed air.
- c. Clean remainder of crankshaft with solvent and dry with compressed air.

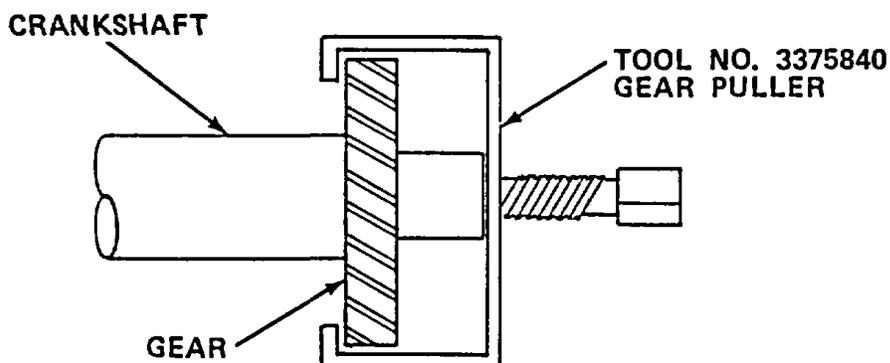
**3-13. INSPECT CRANKSHAFT**

- a. Check gear for chips, cracks, broken or worn teeth.

**NOTE**

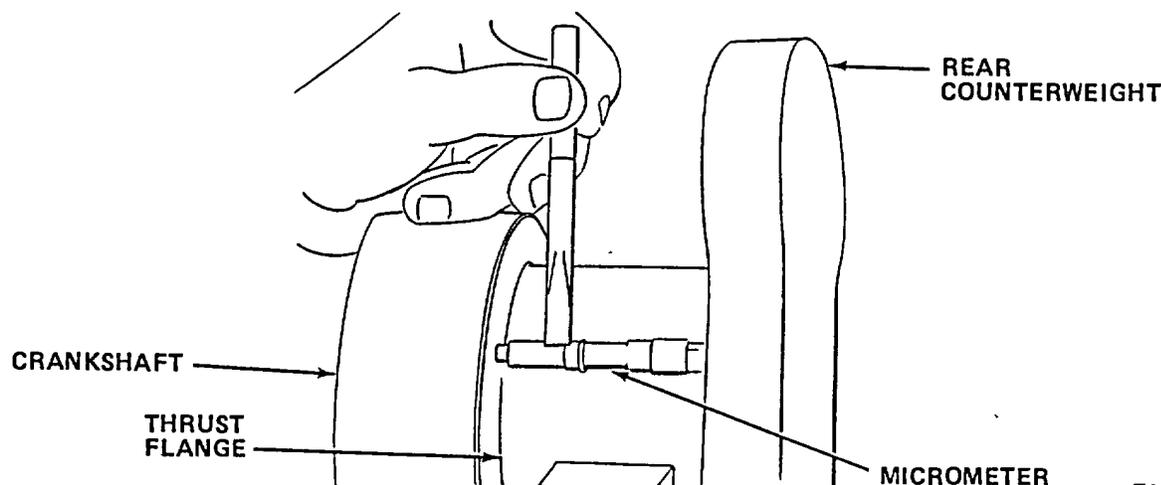
**It is not necessary to remove gear unless it is found defective.**

- b. If defective, remove gear.



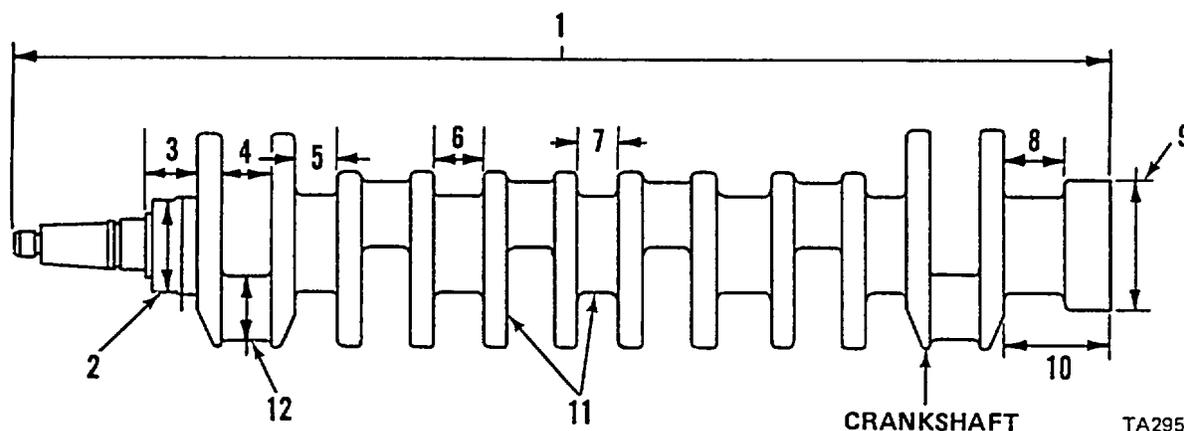
TA295282

- (1) Position tool no. 3375840 gear puller jaws around gear and pin jaws together.
  - (2) With pneumatic impact tool engaged with puller, remove gear.
  - (3) Remove gear key from crankshaft.
- c. Visually inspect crankshaft journals for scoring, scratches, nicks, and wear patterns. If journals are scored, scratched, or nicked, shaft must be reground to accept undersize main bearings and rod bearings. Undersize main and rod bearing sets are available in 0.010, 0.020, 0.030, and 0.040 in. (0.254, 0.508, 0.762, and 1.016 mm).
- d. Check crankshaft thrust flange at No. 7 bearing for scoring, scratches, and nicks. If defects found, flange must be reground. Oversize thrust rings are, available in 0.010 and 0.020 in. (0.254 and 0.508 mm).



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- e. Measure thrust flange wear at four points 90 degrees apart. If distance between thrust flange and rear counterweight does not exceed 3.006 in. (76.352 mm), flange wear is acceptable.
- f. If wear exceeds 3.006 in. (76.352 mm), shaft must be ground to restore flatness.
- g. If after grinding, dimension does not exceed 3.008 in. (76.403 mm), standard thrust rings may be used.
- h. If dimension exceeds 3.008 in. (76.403 mm), flange must be reground to accept 0.010 or 0.020 in. (0.254 or 0.508 mm) oversize thrust rings, i. Regrinding must clean up a minimum of 90 percent of thrust surface and result in maintaining installed crankshaft end clearance below 0.015 in. (0.381 mm).

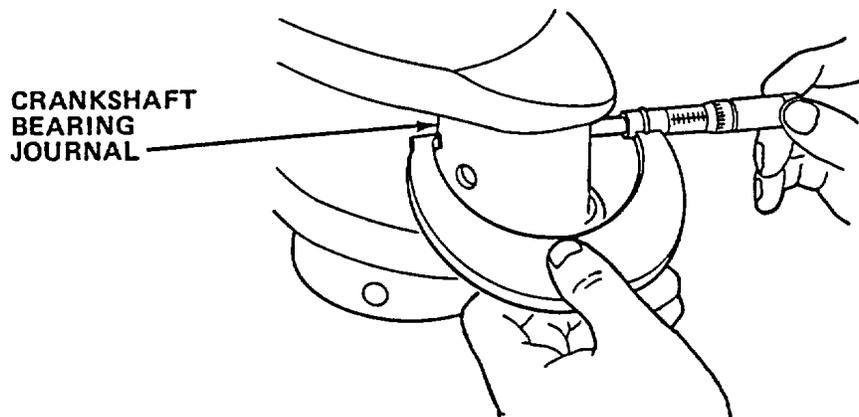


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LEGEND:

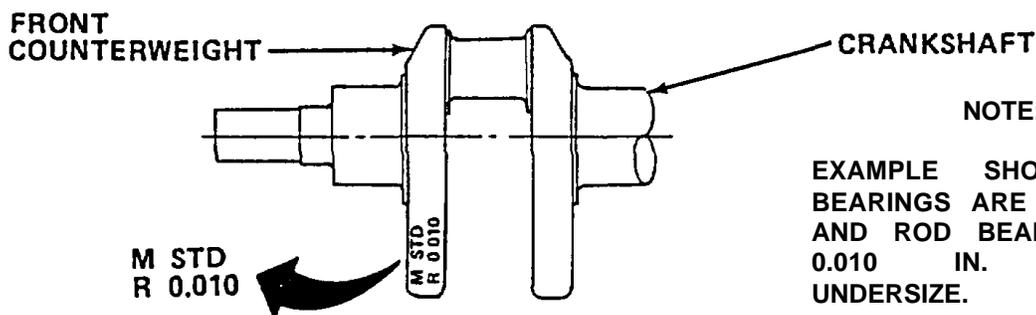
- |   |   |  |
|---|---|--|
| 1. 51.8125 INCHES<br>(1316.0375 MM)                 | 5. 2.000 INCHES<br>(50.8 MM)                        | 9. 5.998 TO 6.000 INCHES<br>(76.2762 TO 152.4 MM)      |
| 2. 4.499 TO 4.500 INCHES<br>(114.2746 TO 114.3 MM)  | 6. 2.500 INCHES<br>(63.5 MM)                        | 10. 5.151 TO 5.163 INCHES<br>(130.8354 TO 131.1402 MM) |
| 3. 2.4375 INCHES<br>(61.9125 MM)                    | 7. 2.000 INCHES<br>(50.8 MM)                        | 11. 0.172R TO 0.195R INCHES<br>(4.3688 TO 4.953 MM)    |
| 4. 2.126 TO 2.128 INCHES<br>(54.0004 TO 54.0512 MM) | 8. 3.001 TO 3.003 INCHES<br>(76.2254 TO 76.2762 MM) | 12. 3.1235 TO 3.12505 INCHES<br>(79.3369 TO 79.375 MM) |

- j. Measure crankshaft journals and other points of measurement and compare to illustration.



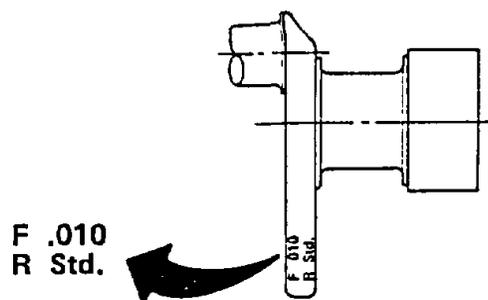
TA295285

- k. Measure crankshaft bearing journals for wear, out-of-round, or taper. If wear exceeds 4.4975 in. (114.2365 mm) or journal out-of-round more than 0.002 in. (0.050 mm) or tapered more than 0.0005 in. (0.0127 mm), crankshaft must be ground to accept undersize bearings.
- l. Measure crankshaft rod bearing journals for wear, out-of-round, or taper. If wear exceeds 3.122 in. (80.30 mm) or journal out-of-round more than 0.002 in. (0.05 mm) or taper more than 0.0015 in. (0.013 mm), crankshaft must be ground to accept undersize rod bearings. Oversizes are available in 0.010, 0.020, 0.030, and 0.040 in. (0.254, 0.508, 0.764, and 1.016 mm).



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- m. If undersize main bearings and/or undersize rod bearings are to be installed, steel stamp the size of main and rod bearings on front counterweight. Stamp characters 1/8 in. (3.175 mm) high.



TA295287

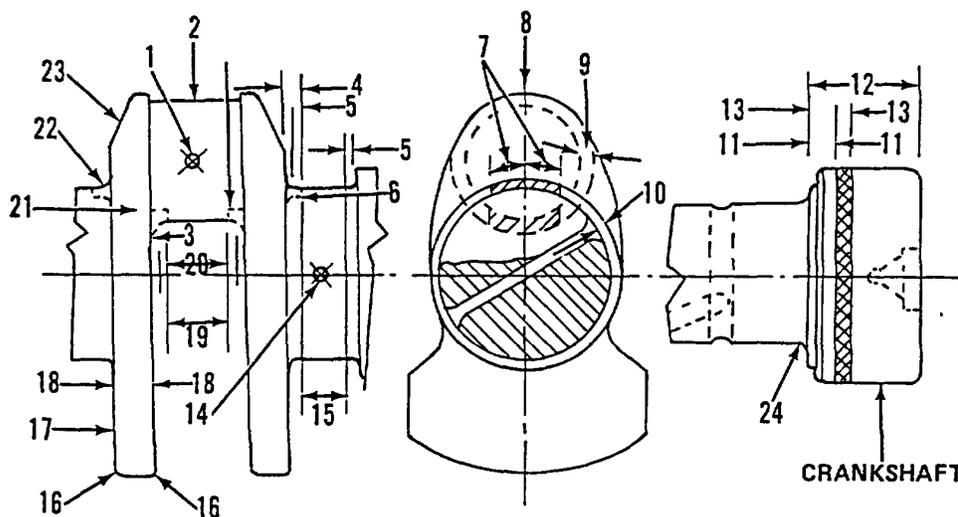
- n. Steel stamp the size and location of thrust rings on rear counterweight. For example, front thrust ring may be 0.010 in. (0.254 mm) oversize so stamp F0.010. Rear thrust ring may be standard so stamp R STD. Stamp characters 1/8 in. (3.175 mm) high.

- o. Limits listed in the following steps must be maintained within Critical Region. Dimensional value of Critical Region is the vertical distance measured downward from the crankpin centerline and extending longitudinally for all crank webs between region (3) on the crankpin and crankpin hole (1) on the journal.

**CAUTION**

**WHENEVER STRUCTURAL DAMAGE HAS OCCURRED TO AN ENGINE SUCH AS PISTON OR VALVE BREAKAGE, THROWN ROD, ETC., A MAGNAFLUX INSPECTION MUST BE ACCOMPLISHED TO DETECT POSSIBLE RUPTURES AND CRACKS. FAILURE TO ACCOMPLISH THIS INSPECTION COULD LEAD TO EARLY ENGINE FAILURE AND SERIOUS DAMAGE.**

- (1) Indications located less than 1 in. (25.4 mm) from the major axis of centerline (8) adjacent web (measure circumferentially) must not exceed the following limits:



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**LEGEND:**

- |                                |  |
|--------------------------------|--|
| 1. CRANKPIN HOLE               | 13. KNURLING   |
| 2. CRANKPINS                   | 14. CHAMBER OF MAIN BEARING OIL HOLE                   |
| 3. CRANKPIN WALL               | 15. MAIN BEARING JOURNAL SURFACES                      |
| 4. FILLETS-MAIN JOURNAL-DEEP   | 16. COUNTERWEIGHT CORNERS                              |
| 5. MAIN JOURNAL FILLETS        | 17. WEBS   |
| 6. CRITICAL REGION             | 18. WEB SURFACES                                       |
| 7. MAJOR JOURNAL WALLS         | 19. CONNECTING ROD BEARING CRANKSHAFT JOURNAL SURFACES |
| 8. MAJOR AXIS OR CENTERLINE OF | 20. CONNECTING ROD BEARING CRANKSHAFT                  |
| 9. JOURNAL SURFACE DEPTH       | 21. WEB PERIPHERY                                      |
| 10. JOURNAL SURFACE THICKNESS  | 22. MAIN JOURNAL WALLS                                 |
| 11. REAR SEAL SURFACE FACES    | 23. FLANK CHEEK  |
| 12. SEAL AREA                  | 24. THRUST FLANGE FILLET                               |

- (a) Light indications in or entering fillets (5) are acceptable if not more than 1/8 in. long (open) or 1/4 in. long (subsurface).
- (b) Light open indications on crankpin (2) and main journal walls (18) or bearing surface that extend closer than 1/8 in. to fillets (5), but do not enter fillets, are acceptable if 3/16 in. long or less. Light subsurface indications are acceptable.

- (2) Indications located more than 1 in. from major axis on centerline (8) of adjacent web (measured circumferentially) must not exceed following limits:
- (a) Light open indication in or entering fillets (5) are acceptable if 3/16 in. long or less. Light subsurface indications are acceptable.
  - (b) Light open indications on crankpin (2) and main journal walls (7) or bearing surfaces that extend closer than 1/8 in. to fillet (5) but do not enter fillet, are acceptable if 1/4 in. or less. Light subsurface indications are acceptable.
  - (c) Nicks on corners (16) of webs (17) are not acceptable. The part will be acceptable if the nick can be removed by grinding a 1/8 in. radius on the corner.
  - (d) Imperfections on web periphery (21) may be ground out to a depth of 1/8 in. maximum using a 1-1/2 in. minimum radius grinding wheel, provided balance limits are maintained.
  - (e) Light open indications that pass within 3/16 in. of a crankpin hole (1) are acceptable if 1/2 in. long or less and does not enter oil hole chamfer or intersect  $45^\circ + 10^\circ$  diagonal. Only those subsurface indications that lay closer than 1/16 in. to the surface (measured at the chamfer at  $45^\circ + 10^\circ$  diagonal) are not acceptable. All other subsurface indications are acceptable.
- (3) Light open indications that enter chamfer of any main bearing oil hole (14) are acceptable if they are 3/8 in. or less. Subsurface indications ending in a main bearing oil hole (14) are acceptable.
- (4) Fine subsurface salt and pepper type indications are permitted on upper and lower sides of crankpins (2) on the trimming line.
- (5) Open longitudinal indications within region (15) which are less than 1-1/8 in. on main journal surfaces (15), and 7/8 in. long on crankpin surfaces (19) are acceptable after the sharp edges have been honed 0.002 - 0.004 in. below journal surface.
- (6) Longitudinal subsurface indications within area (15) or (19) are acceptable.
- (7) Parallel open indications that met requirements of (4) above, and other requirements on length and frequency, are acceptable.
- (8) Parallel subsurface indications are acceptable.

- (9) Indications that contain loose or foreign particles or voids left by such particles are not acceptable.
- (10) Not more than three open indications are to appear on any one journal (15) or crankpin (2). Scattered small, open, or subsurface indications, four per crankpin (2), and six per main bearing (15), 1/8 in. long or less, if not forming part of a long intermittent indication or entering an oil hole (1) or (14), or fillet (4), will not be counted as indications in arriving at the total number permitted. However, if in addition to showing the maximum number of acceptable indications for the whole crankshaft, the-part also shows many widely scattered short indications, it must be rejected.
- (11) An inclusion which is intermittently open and subsurface shall be considered and measured as an open indication after the original indication has been wiped off. The entire modification must first meet the requirements for subsurface limits.
- (12) Open and subsurface indications on counterweights and crankthrow bevel outside the critical region are acceptable.
- (13) Open seams on web periphery that show depth on crankpin wall (10) may be removed from web periphery with a 1/2 in. radius wheel, provided at least 1/16 in. remains above crankpin fillet (6) after repair and balance limits are maintained.
- (14) Seams or indications outside the critical region that extend over crank web periphery (21) but are not visible on the crankpin wall are acceptable.
- (15) Indications due to weld defects are not acceptable in the counterweight welds. Indications at flank cheek corner (23) may be ground out and blended to a depth not exceeding 1/4 X 5/8 in. long.
- (16) Open longitudinal indications in the thrust flange fillets (24) longer than 3/8 in. are not acceptable.
- (17) Limits of indications on the oil seal surface (11) (which, when wiped clean do not show sharp edges) are acceptable.
- (18) After inspection where coil shot is used, give crankshaft head shot to put magnetic poles at ends of crank, not throws. The residual magnetic field should not exceed two units on the Magna Flux Field Indication or equal.

p. Perform magnetic crack inspection of crankshaft.

- (1) Wet the complete surface with magnetic particle suspension before applying currents.
- (2) The following directional magnetizing currents are to be used for crankshaft magnetic inspection or Magnaflux inspection:

	Direction of Defect	
	Longitudinal	Circumferential
DC or Rectified AC	1200 Amp	3600-4000 amp turns
AC Equipment	1400 Amp	4200-4700 amp turns
Magnetizing Method	Head Shot	Coil Shot

**NOTE**

**Ampere turns in amperage flowing through coil is multiplied by number of turns in coil; above is for 4 turn coil.**

- (3) Flow magnetic particle suspension over the part before placing part through coil. Turn current on the coil and move the coil the full length of the part.
- (4) If shaft parts are within 2 or 3 in. of the coil inside diameter ample magnetism will be obtained if 3 shots of current are passed through coil while it is at each end and the center of part length.
- (5) The limits of acceptability, unless otherwise stated, apply only to light slag or oxide stringers usually defined as inherent inclusions, obvious cracks and circumferential or transverse defects.

**3-14. REPAIR CRANKSHAFT**

- a. Buff all minor nicks and scratches with crocus cloth.
- b. If inspection shows crankshaft is worn to a point where it must be reground and magnetic inspection shows it suitable for regrinding, grind shaft to next standard undersize (table 3-1).
- c. If crankshaft thrust face is worn, grind as necessary to accept larger thrust rings.
- d. Fillets add strength to crankshaft. Reducing fillet radii or undercutting subtracts material from that strength. If fillets are larger than those specified, bearing shells may be squeezed and will quickly fail.
- e. Grind width of journals to clean up basic face surface.
  - (1) If there are deep interruptions such as gouges or nicks that do not extend into fillets, smooth the edges with crocus cloth.
  - (2) Maintain a limit of 0.030 in. (0.762 mm) over the maximum new crankshaft main bearing width specification (table 3-1).
  - (3) The journal wall heights are not to be lowered to less than 0.010 in. (0.254 mm) from journal cheeks in regrinding journal bearing widths.
  - (4) All fillet and bearing surfaces should have the same finish as a new crankshaft.
- f. Crankshafts requiring "off-stroke" grinding to clean up an unusually bad out-of-round crankpin can be ground off-stroke a maximum of 0.020 in. (0.508 mm) over or under mean stroke dimension of new crankshaft specifications. All crankpins must be reground to the degree of "off-stroke" required by the most out-of-round crankpin.
- g. Install the crankshaft gear.

**WARNING**

**USE GLOVES TO PROTECTED HANDS. HANDLE GEAR WITH CARE.**

**CAUTION**

**DO NOT USE CUTTING TORCH TO HEAT GEAR. OVERHEATING OF GEAR WILL REMOVE HARDNESS CAUSING EARLY FAILURE.**

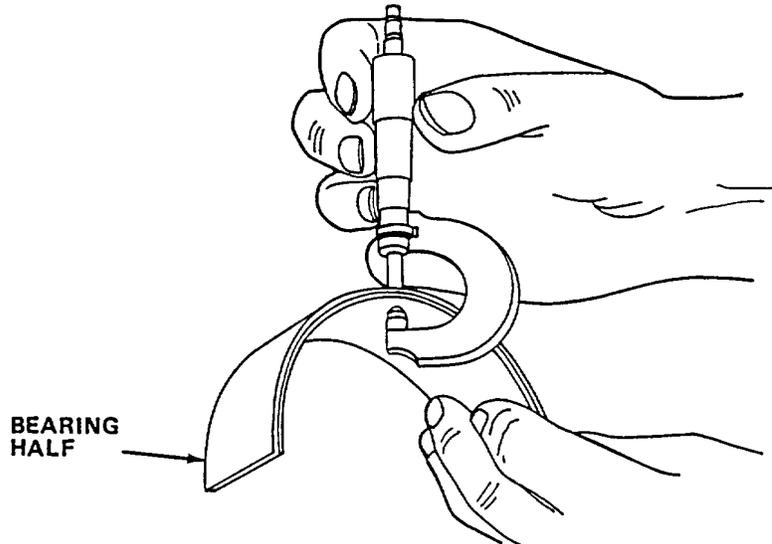
- (1) Heat the gear with heating torch (not a cutting torch) to 400° F (204 C) for minimum of 1 hour.
- (2) Lubricate the flange with grease and drive the gear onto the shaft with a piece of tubing.

## Section VI. BEARING HALVES INSPECTION

## 3-15. INSPECT BEARING HALVES

## NOTE

Main bearings are two-piece halves with upper half containing an oil hole for passage of lubricating oil.



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- a. Measure bearing half thickness with ball point micrometer.
- b. Discard bearing half if thickness less than 0.1215 in. (3.086 mm).

## NOTE

A properly fit bearing will appear dull gray after a reasonable period of service. This indicates bearing is running on an oil film. Bright spots indicate metal-to-metal contact. Black spots indicate excessive clearance.

- c. Inspect bearing for chips, flaking, or scoring. Replace if defective.

**CAUTION**

**UNDER NO CIRCUMSTANCES SHOULD AN ATTEMPT BE MADE TO SCRAPE, LAP, OR FILE BEARING HALVES TO INCREASE OIL CLEARANCE. RAPID ENGINE FAILURE MAY RESULT.**

- d. Total worn maximum clearance should not vary more than 0.002 in. (0.050 mm) between adjacent main bearings.
- e. If crankshaft is reground to accept undersize bearings, new undersize bearings must be used. Bearings are available in 0.010, 0.020, 0.030, and 0.040 in. (0.254, 0.508, 0.762, and 1.016 mm) undersizes.

**Section VII. CONNECTING ROD REPAIR****3-16. CLEAN CONNECTING ROD****WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- a. Submerge rods in cleaning solvent for two hours.

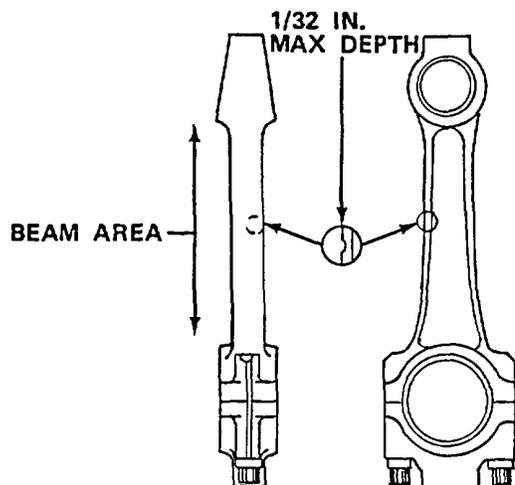
**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- b. Remove rods and wipe clean. Dry with compressed air.

**3-17. INSPECT CONNECTING RODS**

- a. Magnaflux all rods, caps, and cap bolts.
- b. Discard cracked components.

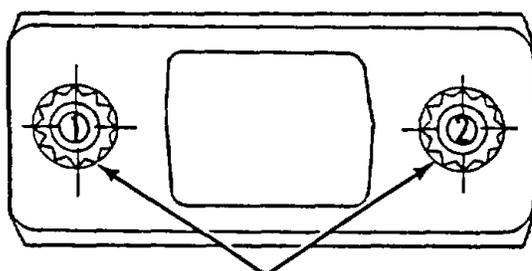


TA295290

- c. Discard rod if nicked or dented in excess of 1/32 in. (0.80 mm) deep in beam area.

**NOTE**

**Ensure that rod and cap are kept mated at all times.**

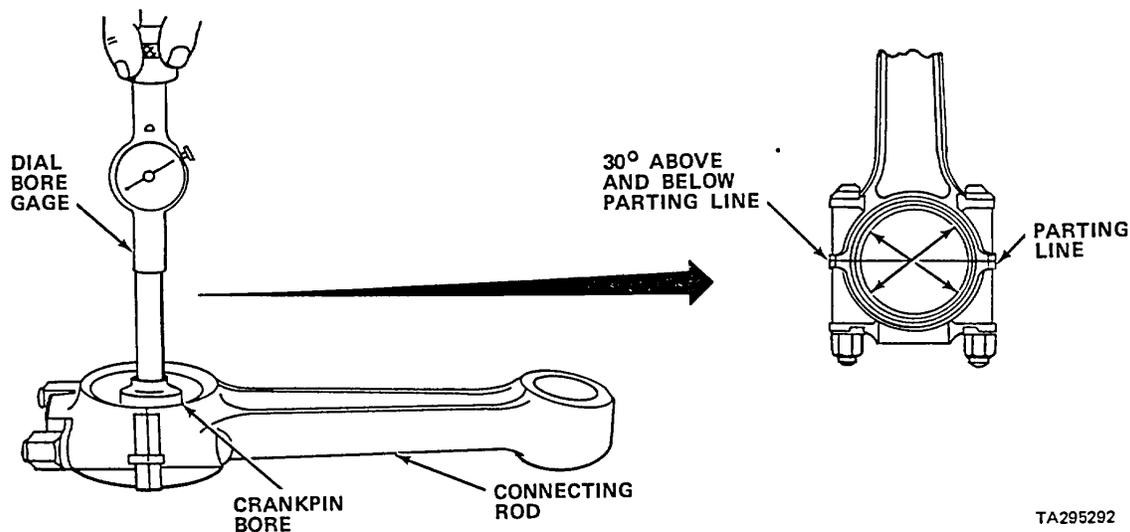


**CAP BOLTS  
(BOTTOM VIEW  
OF ROD CAP)**

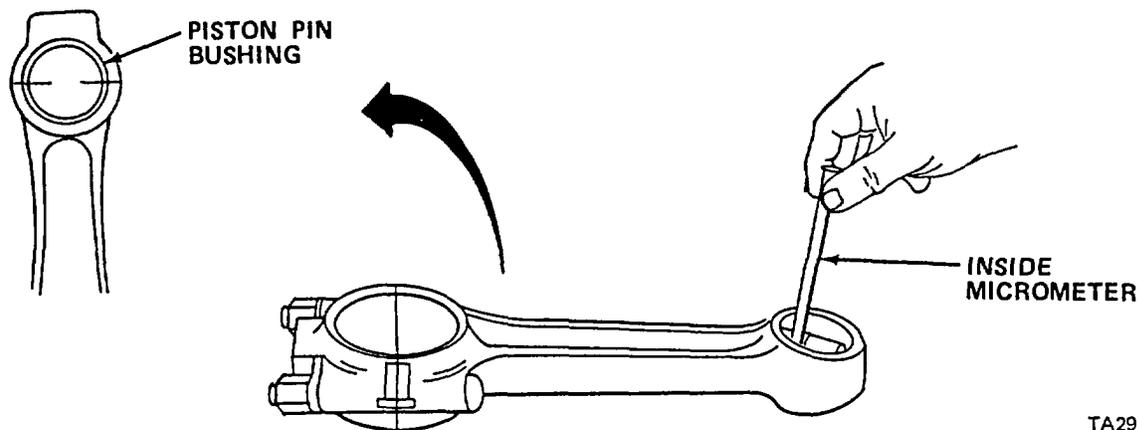
TA295291

- d. Secure cap to rod with cap bolts. Alternately torque cap bolts in following sequence:

- |                |                                  |
|----------------|----------------------------------|
| (1) Tighten To | 70 - 75 ft lbs (95 - 102 N•m)    |
| (2) Advance To | 140 - 150 ft lbs (190 - 203 N•m) |
| (3) Loosen All | Completely                       |
| (4) Tighten To | 25 - 30 ft lbs (34 - 41 N•m)     |
| (5) Advance To | 70 - 75 ft lbs (95 - 102 N•m)    |
| (6) Advance To | 140 - 150 ft lbs (190 - 203 N•m) |



- e. Measure crankpin bore and piston pin bushing inside diameter using dial bore gage or inside micrometer.
- f. Crankpin bore must be within 3.3157 and 3.3167 in. (84.2187 and 84.2441 mm) beyond 30 degrees on either side of parting line.
- g. Resize rod if either specification is not met (para 3-18).



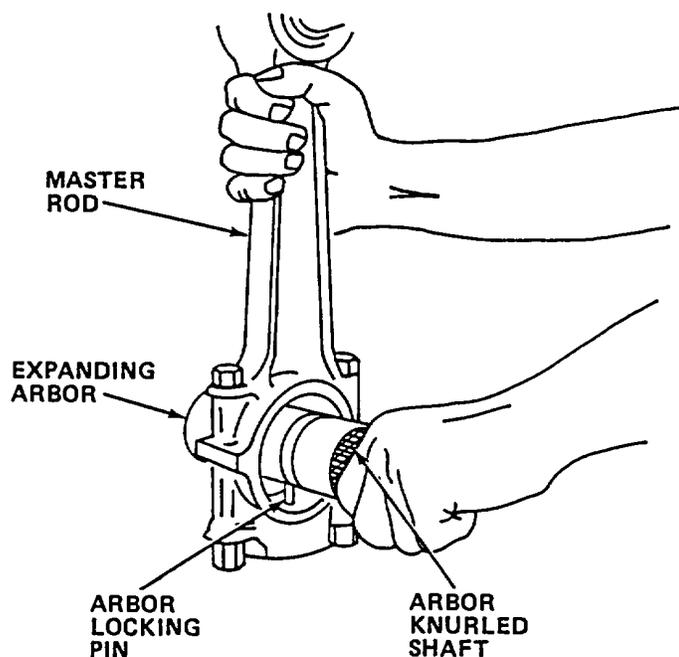
- h. Measure piston pin bushing diameter.
- i. If diameter exceeds 2.0022 in. (50.8558 mm), mark rod for bushing replacement.

**NOTE**

**Check connecting rod length and alignment with ST-561 connecting rod checking fixture-and ST-563 locating mandrel set.**

j. Adjust checking fixture for rod size.

- (1) Select new rod that has been checked for absolute length of 12 in. (304.80 mm) from center of bushing bore to center of crankpin bore. Production rods may vary from 11.998 to 12.000 in. (304.749 to 304.800 mm).
- (2) Secure rod to cap and torque as specified in paragraph d above.



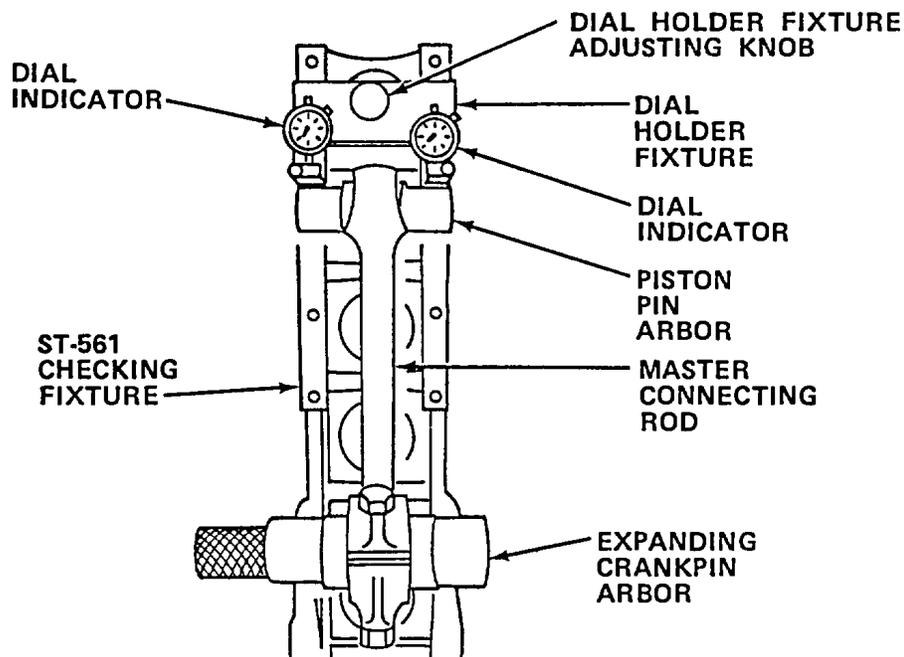
TA295294

- (3) Insert and center expanding arbor into crankpin end of rod.
- (4) With locking pin of arbor facing straight down (aligned with center line of rod), turn knurled shaft of arbor to expand arbor in crankpin bore.
- (5) Tighten arbor so that it fits snugly.

**NOTE**

**Two piston pin bushing arbors are available; one if bushing is installed and other if bushing is removed.**

- (6) Insert piston pin arbor into rod piston pin bore.



TA295295

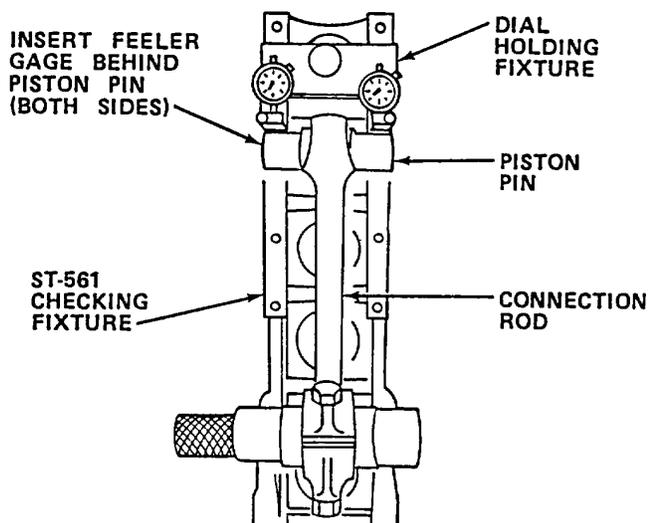
- (7) Set master rod in fixture.
  - (8) Position dial holder fixture so that indicator pins are in contact with piston pin arbor.
  - (9) Zero dial indicators.
  - (10) Lift rod assembly from fixture and turn rod 180 degrees.
  - (11) Set rod back into fixture.
  - (12) Readjust dial indicators to divide difference between first reading (zero) and second reading. Checking fixture is now calibrated.
  - (13) Remove rod from fixture.
  - (14) Remove arbors from rod.
- k. Check rod bend, twist, and length.

**NOTE**

**Measurements read from dial indicators indicate length and misalignment of bores.  
Measurements apply with or without piston pin bushing installed.**

- (1) Assemble arbors to rod to be checked. Ensure that pin in arbor faces down and is in center line with rod.
- (2) Set rod in fixture.

- (3) To determine length, add right and left dial indicators (noting plus and minus readings) and divide by two. This gives amount that rod is shorter or longer than master rod.
- (4) Length must be no longer than master rod or no more than 0.002 in. (0.050 mm) shorter.
- (5) To determine bend, subtract smaller indicator reading from larger (again noting plus and minus readings).
- (6) Bend must not exceed 0.004 in. (0.101 mm) without bushing  $\sigma$  0.0015 in. (0.0381 mm) with bushing installed.



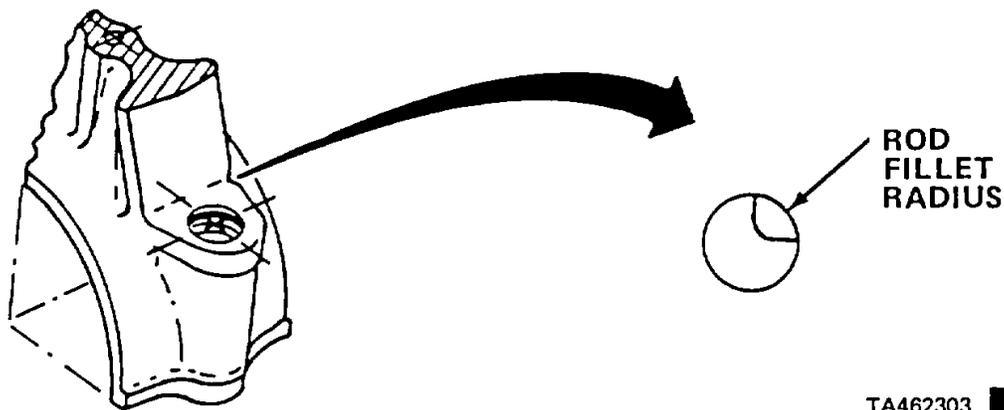
TA295295

- (7) Measure rod twist with a feeler gage between piston pin and dial holding fixture.
  - (8) If rod does not contain piston pin bushing, twist must not exceed 0.007 in. (0.177 mm).
  - (9) If bushing is installed, twist must not exceed 0.004 in. (0.101 mm).
  - (10) Discard rods which do not meet length, bend, and twist specifications.
- I. Check bolts, bolt holes, and bolt pads.
- (1) Measure rod cap bolts diameter and pilot diameter.
  - (2) Discard bolt(s) if smallest diameter is less than 0.540 in. (13.716 mm).
  - (3) Discard bolt(s) if pilot diameter of bolt is less than 0.6242 in. (15.846 mm).
  - (4) Discard bolts with distorted threads.
  - (5) Check rod bolt hole pilot inside diameter in rod and cap.

**NOTE**

**A rod and its cap are a matched set. Must be replaced as an assembly.**

- (6) If diameter exceeds 0.6249 in. (15.872 mm) in rod or 0.6252 in. (15.880 mm) in cap, discard rod and cap.



TA462303 ■

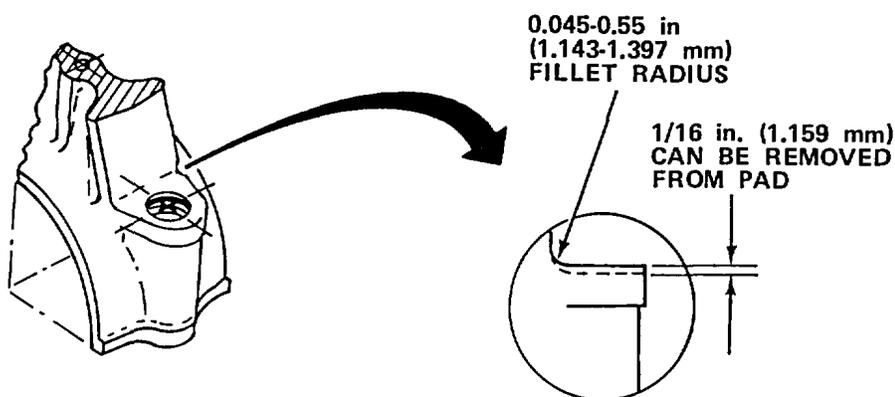
- (7) Check bolt pad radius for dents or nicks. If defects found, mark rod for radius repair.
- (8) Check radius of fillets. Must be 0.045 to 0.055 in. (1.143 to 1.397 mm). If radius incorrect, mark rod for radius restoration.
- (9) Check rod-to-cap alignment dowels.
- Measure dowel outside diameter. Must not be less than 0.3127 in. (7.9425 mm).
  - Measure hole depth in rod. Must not exceed 0.3133 in. (7.9578 mm) or be less than 0.3128 in. (7.945 mm).
  - Measure dowel protrusion from cap. Must not exceed 0.250 in. (6.350 mm) or be less than 0.220 in. (5.588 mm).
  - Check that dowel pins are tight.
  - If above specifications for dowels are not met, discard rod and cap.

m. Measure rod bearings (shells).

- With ball micrometer, measure thickness of rod bearings to determine wear.
- Discard bearings which are less than 0.093 in. (2.362 mm) thick. If crankshaft reground, bearings are available in undersizes of 0.010, 0.020, 0.030, and 0.040 in. (0.254, 0.508, 0.762, and 1.016 mm).

### 3-18. REPAIR CONNECTING RODS

a. Restore fillets.



- (1) Mill rod pads to restore fillet radius of 0.045 0.055 in. (1.143 1.397 mm). Maximum of 1/16 in. (1.59 mm) depth of metal may be milled off pad to restore radius.
- (2) Break sharp edges around pad.
- (3) Polish fillet to 16 microfinish.

b. Resize crankpin bore.

#### NOTE

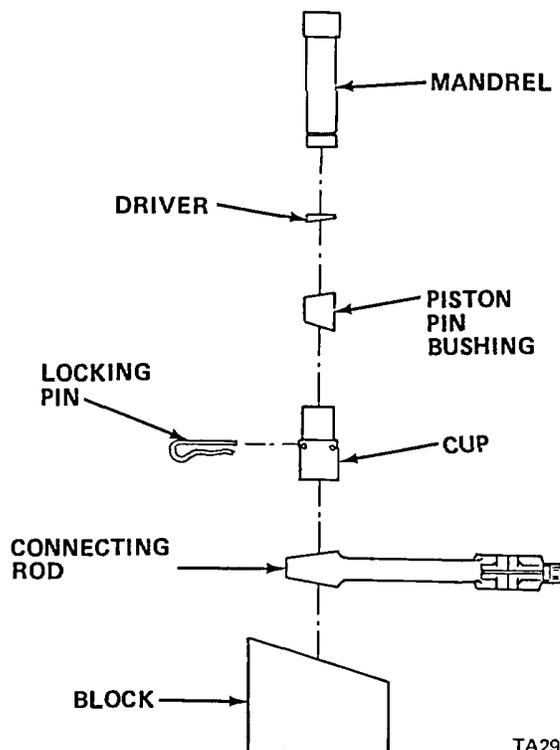
If crankpin bore specifications were exceeded as determined in para 3-17, rod-to-cap mating surface and cap must be reground and crankpin bore resized.

- (1) Remove old piston pin bushing.

#### NOTE

ST-1242 connecting rod bushing driver is used to remove and install piston pin bushing.

- (a) Lay rod horizontally on press with pin bushing with hole in tool alined block.
- (b) Place knockout ring on mandrel and insert mandrel through pin bushing.
- (c) Press piston pin bushing out of rod.



- (2) Install rod cap and torque to specifications in table 3-3.
- (3) Place rod in checking fixture and check length. If rod length is 11.991 in. (304.571 mm) or less, rod cannot be resized and must be discarded.

**NOTE**

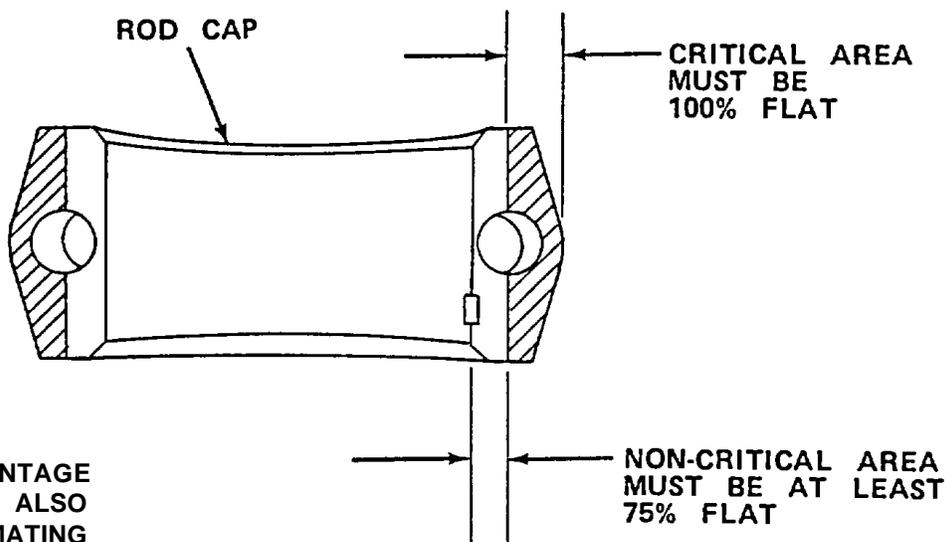
**Maximum of 0.009 in. (0.228 mm) may be machined from cap and rod. Equal stock must be removed from cap and rod. Rod must measure 12.000 in. (304.800 mm) in length to remove 0.009 in. (0.228 mm) from mating surfaces. Center-to-center length must be 11.991 in. (304.571 mm) after grinding and lapping.**

- (4) Remove rod from checking fixture and remove cap.

**WARNING**

**WEAR PROTECTIVE CLOTHING AND GOGGLES WHILE GRINDING TO PREVENT PERSONAL INJURY FROM FLYING PARTICLES.**

- (5) Mount rod in grinding machine and remove material as required.
- (6) Mount cap in grinding machine and remove material as required.
- (7) Lap rod and cap mating surfaces.
- (8) After lapping, apply Prussian bluing to machined surfaces.
- (9) Seating and flatness pattern must show minimum of 75 percent contact with surface plate.



- (10) Non-contact area must not be in critical area outside bolt centerline (area furthest from bore centerline). That area must indicate 100 percent contact.
- (11) Secure rod cap to rod and torque bolts to specifications in table 3-3.

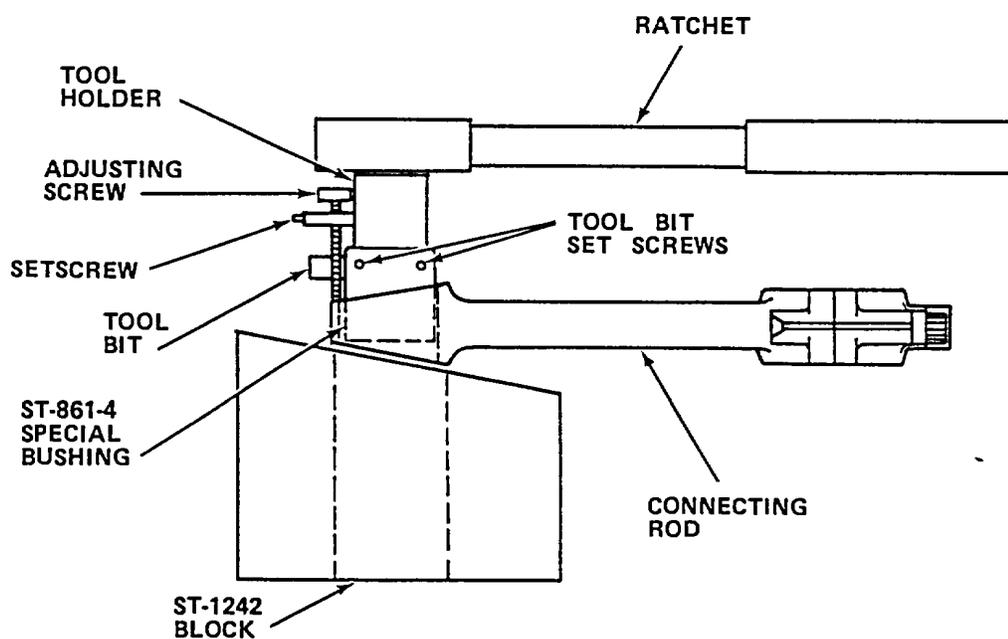
## NOTE

**Boring machine 3375115 is used to resize connecting rod bore and bore oversize (thick wall) piston pin bushing (if required).**

- (12) Mount rod on boring machine. Instruction book furnished with machine provides machine operating procedures.
  - (13) Line bore crankpin bore to 3.3160 to 3.3165 in. (84.2264 to 84.2391 mm).
  - (14) Finished surface must be to 75 microfinish or better to ensure proper contact with connecting rod bearing shells.
  - (15) Remove rod from machine.
- c. Chamfer piston pin bore.

## NOTE

**ST-861 chamfering tool is only used on rods which do not have chamfers on piston pin bushing bores. Piston pin bushing must be removed in order to chamfer bore.**



TA295300

- (1) Place rod on ST-1242 block and secure rod in horizontal position.
- (2) Place ST-861-4 special bushing into rod bore.
- (3) Loosen two setscrews retaining tool bit to holder.

- (4) Adjust tool bit until point just clears end of guide screw. Tighten setscrews.
- (5) Place tool bit holder into special bushing in rod bore.
- (6) Rotate adjusting screw up or down until tool bit just engages bore.
- (7) Tighten setscrew in end of guide screw holder to secure guide screw.
- (8) Insert ratchet into top of tool holder and rotate holder one complete turn.
- (9) Loosen guide setscrew and back out screw one turn.
- (10) Rotate tool holder one more complete turn.
- (11) Remove ratchet and tool holder.
- (12) Measure chamfer depth. Must be uniform to 0.020 0.030 in. (0.508 0.762 mm).
- (13) Continue process until proper depth is reached.
- (14) Remove tool holder.
- (15) Turn rod over and chamfer other side of bore to same depth.
- (16) Remove tool holder and special bushing.
- (17) Remove any sharp edges with emery cloth.

**WARNING**

**MINERAL SPIRITS ARE POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (18) Wash rod in mineral spirits before installing piston pin bushing.

- d. Install piston pin bushing.

**NOTE**

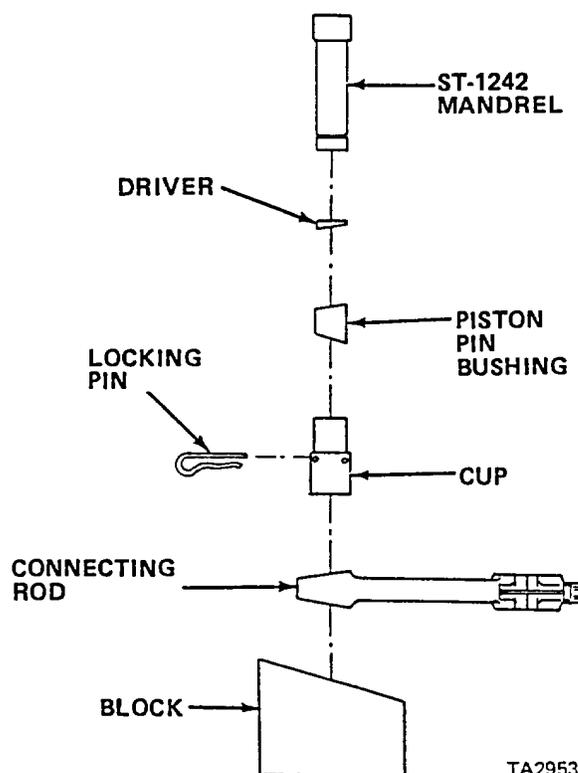
**Standard size and oversize (thick wall) bushings are installed with same tool.**

- (1) Slide new bushing onto ST-1242 mandrel.
- (2) Position driver then cup on mandrel.
- (3) Secure cup to mandrel with locking pin.
- (4) Place rod on block and support in horizontal position.
- (5) Insert mandrel in bushing bore.
- (6) Aline driver with middle of boss on rod.

**CAUTION**

**ENSURE THAT OIL HOLE IN BUSHING ALINES WITH HOLE IN ROD. MISALINEMENT CAN CAUSE LITTLE OR NO OIL FLOW RESULTING IN RAPID BUSHING WEAR AND FAILURE.**

- (7) Press bushing in rod until driver seats against rod boss.
- (8) Check oil hole alinement by passing 1/8 in. (3.175 mm) rod through bushing into rod.



TA295301

- e. Bore rod piston pin bushing.

#### NOTE

**This procedure only applies to boring of oversize (thick wall) bushings. Standard size bushings are not reamed or bored after installation.**

- (1) Fill oil hole in bushing with bar soap to keep out metal shavings.
- (2) Mount connecting rod in No. 3375115 boring machine, following instructions which are furnished with machine.
- (3) Bore bushing off center to restore rod to original 11.998 to 12.000 in. (304.749 to 304.800 mm) length.
- (4) Bore inside diameter to 2.001 to 2.0015 in. (50.825 to 50.8381 mm).
- (5) Remove rod from machine.
- (6) Check diameter with dial bore gage.
- (7) Remove sharp edge with a scraper.
- (8) Remove shavings and soap.

#### WARNING

- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
- **MINERAL SPIRITS ARE POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (9) Wash rod in mineral spirits and dry with compressed air.

#### CAUTION

**ALL CONNECTING RODS SHOULD BE SAME PART NUMBER. DO NOT ATTEMPT TO INTERCHANGE CAPS.**

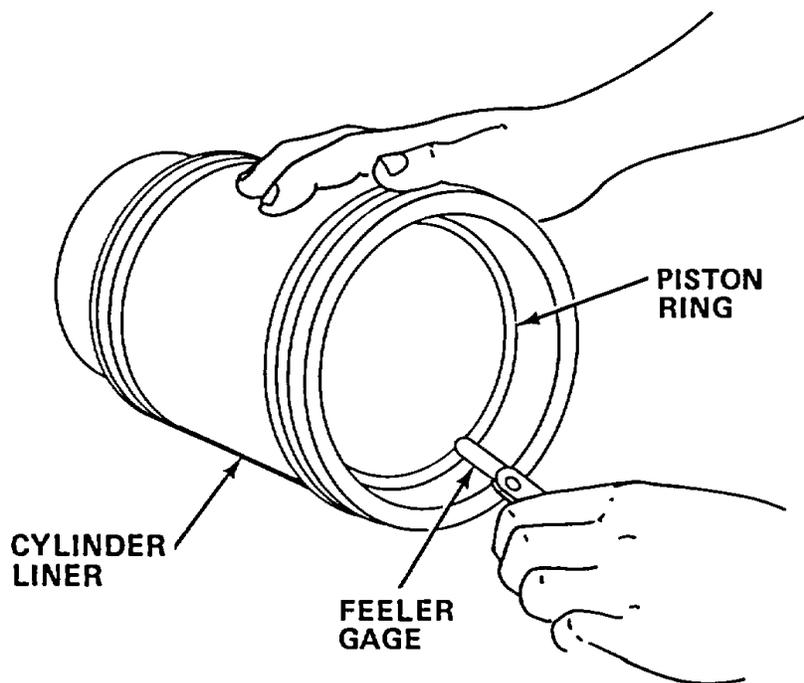
- (10) Recheck all dimensions on rebuilt and rebored rod on checking fixture. Ensure that all specifications are met (table 3-3).

## Section VIII. PISTON ASSEMBLY REPAIR

## 3-19. INSPECT PISTON RINGS

## NOTE

New rings should be checked in cylinder liner in which they are to be used to ensure gaps are correct.



TA295302

- a. Insert each ring in its mating cylinder liner. Seat ring squarely in ring travel area of liner.

## CAUTION

**DO NOT FILE CHROME-PLATED RINGS OR USE CHROME-PLATED RINGS IN CHROME-PLATED LINERS. RAPID ENGINE FAILURE CAN OCCUR.**

## NOTE

When used, chrome-plated compression ring is always installed in top piston ring groove.

- b. Measure ring gap with feeler gage. Gap must fall within following limits:

**NOTE**

**Add 0.003 in. (0.076 mm) ring gap to new maximum limit for each 0.001 in. (0.025 mm) wear in cylinder liner wall.**

Location Ring No.	New Minimum	GAP	New Maximum
1. (top)	0.023 in. (0.584 mm)		0.033 in. (0.838 mm)
2.	0.019 in. (0.482 mm)		0.029 in. (0.736 mm)
3.	0.019 in. (0.482 mm)		0.029 in. (0.736 mm)
4.	0.010 in. (0.254 mm)		0.025 in. (0.635 mm)

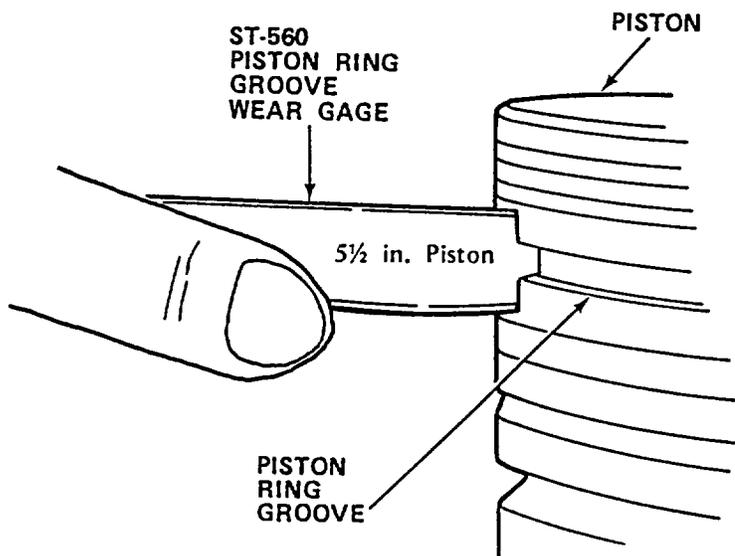
- c. If gap is not correct, try another ring.  
 d. If ring is not chrome-plated, file end of ring to meet new minimum specification (if required).

## 3-20. INSPECT PISTONS

**WARNING**

- COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).
- P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.

- a. Clean pistons in solvent and blow dry with compressed air.
- b. Check the piston for cracks, breaks, scoring, galling, and scratches.
- c. Inspect all ring grooves for missing sections, breaks, cracks, distortion, and galling.



TA295303

**NOTE**

ST-560 ring groove gage consists of four different size gages. Use gage marked for NTC 400 engine, 5-1/2-in. piston.

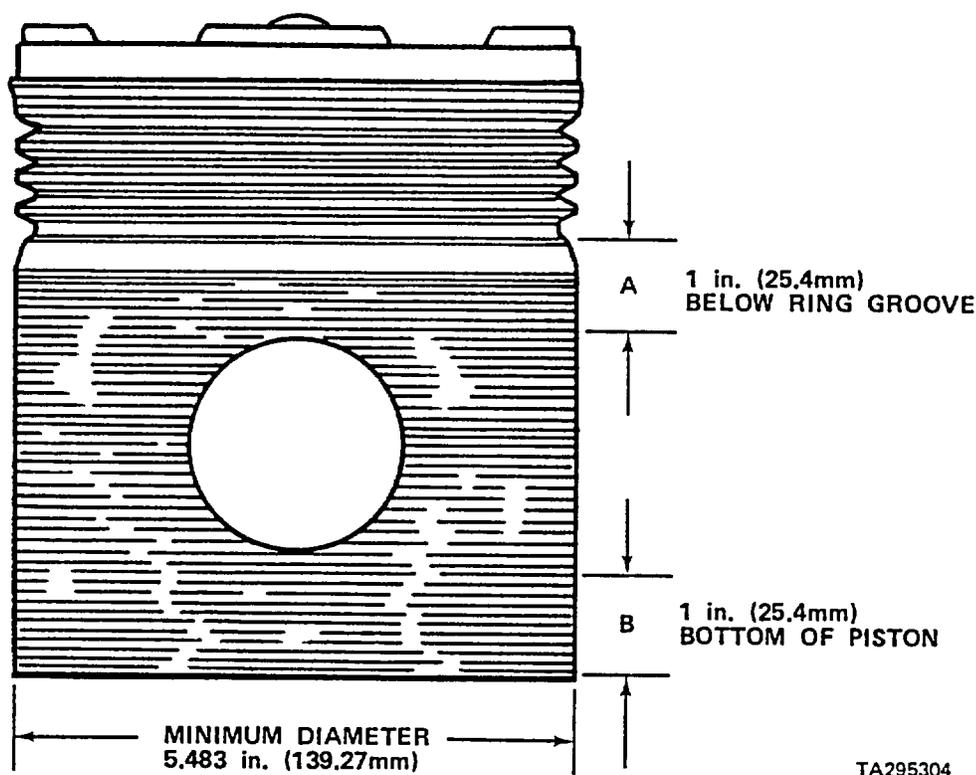
- d. Check the top and second ring grooves with ST-560 ring groove gage. Shoulders of gage must not touch ring groove lands. If shoulders of gage touch, discard piston.

e. The ring groove width can also be checked by the following method:

- (1) Check ring groove wear using a segment of a new ring and feeler gage.
- (2) Hold ring in groove, flush with ring land.
- (3) Try to insert 0.006 in. (0.152 mm) feeler gage between ring and groove land.
- (4) If gage enters groove without forcing or disengaging ring, wear is excessive and piston must be discarded.

**NOTE**

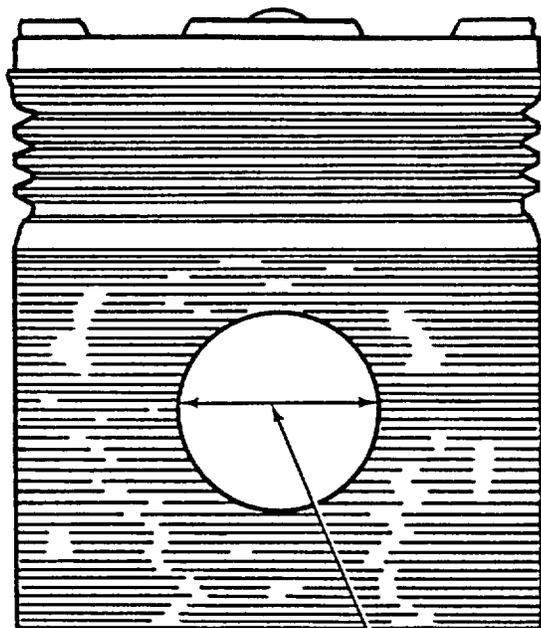
Piston diameter should be checked at temperature of 70°F - 90°F (21°C - 32°C). Piston to cylinder liner clearance may be determined after measuring piston and comparing with liner inside diameter.



TA295304

f. Check measurement of piston skirt diameter using a micrometer at right angle to piston pin bore. A and B of above illustration points out measurements.

- g. Discard piston if diameter exceeds 5.483 in. (139.268 mm).



**PIN BORE MAXIMUM  
DIAMETER (AT 70°F  
[21.1°C] ) 1.999 in.  
950.775mm)**

TA295305

**NOTE**

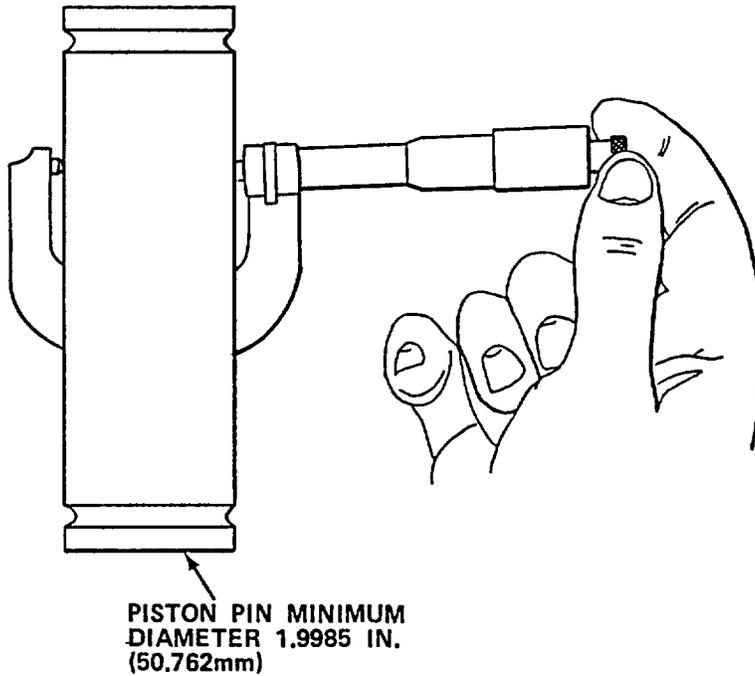
Specification applies to pin bore check at 70°F (21°C). Add 0.005 in. (0.013 mm) for every 10°F (-12°C) over 70°F (21°C) up to 90°F (32°C).

- h. Measure piston pin bore inside diameter.

**CAUTION**

**REBORING OF PISTON PIN BORE AND USE OF OVERSIZE PIN IS NOT PRACTICAL. MISALINEMENT WHICH COULD RESULT FROM SUCH PRACTICE WILL CAUSE SEIZURE OF PISTON OR FAILURE OF CONNECTING ROD BEARING.**

- i. Discard piston if diameter exceeds 1.999 in. (50.775 mm).



TA295306

- j. Measure piston pin diameter at several points along its length.
- k. Discard pin if diameter is less than 1.9985 in. (50.762 mm) or pin is more than 0.001 in. (0.025 mm) out-of-round.

### 3-21. REPAIR PISTONS

- a. Remove any small nicks or scratches from piston with crocus cloth.
- b. Use small fine dressing file to remove any sharp edges or burrs.

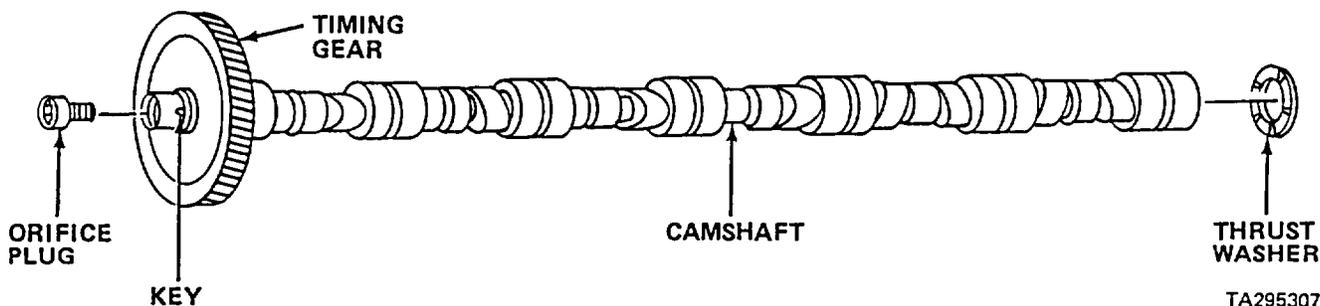
## Section IX. CAMSHAFT REPAIR

## 3-22. CLEAN CAMSHAFT

**WARNING**

**WEAR PROTECTIVE CLOTHING AND GOGGLES WHILE STEAM CLEANING TO PREVENT PERSONAL INJURY.**

- a. Steam clean camshaft. Dry thoroughly.



- b. Remove orifice plug from front of camshaft.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- c. With nylon bristle brush and solvent, clean oil passage.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

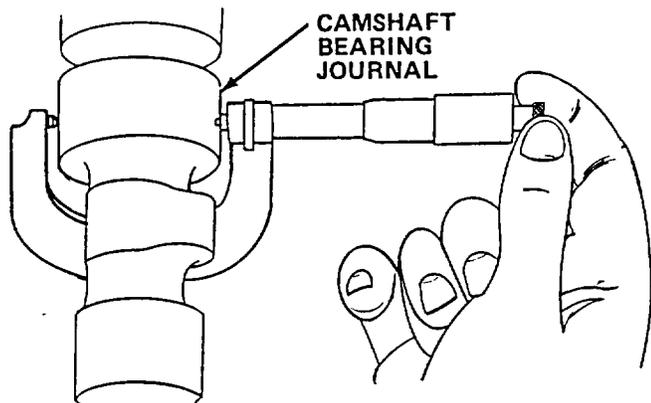
- d. Flush passage with clean solvent and blow compressed air into passage to clear of particles.

**CAUTION**

**DO NOT INTERMIX ORIFICE PLUG WITH COMMON 1/8 IN. (3.175 MM) PLUG. ENSURE THAT ORIFICE PLUG IS CORRECT PART NUMBER. IMPROPER PLUG WILL CUT OFF OIL FLOW.**

- e. Reinstall orifice plug and torque to 5 - 10 ft lbs (7 - 14 N•m).

**3-23. INSPECT CAMSHAFT**



**NOTE:**

**MINIMUM JOURNAL  
DIAMETER IS  
2.495 IN. (63.373mm)**

TA295308

- a. Measure diameters of bearing journals.
- b. Discard camshaft if any one journal diameter is less than 2.495 in. (63.373 mm).

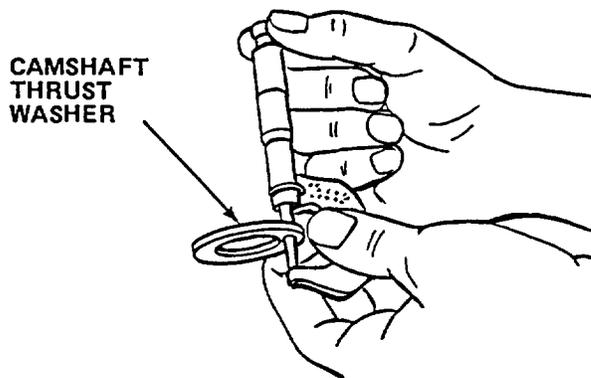
**NOTE**

**Camshaft lobes cannot be reground.**

- c. Discard camshaft that has scuffed or scored lobes.
- d. Check camshaft for cracks using magnetic inspection (Magnaflux) method..

**3-24. INSPECT CAMSHAFT TIMING GEAR AND THRUST WASHER**

- a. Check timing gear for chips, cracks, or visible wear.
- b. Mark gear for replacement if defects found.
- c. Inspect thrust washer for flaking, burrs, and distortion.



**NOTE:**

**MINIMUM RING THICKNESS  
0.083 IN. (2.108mm)**

TA295309

- d. Measure thrust washer thickness to determine wear.
- e. Discard if thickness less than 0.083 in. (2.108 mm).

### 3-25. REPAIR CAMSHAFT

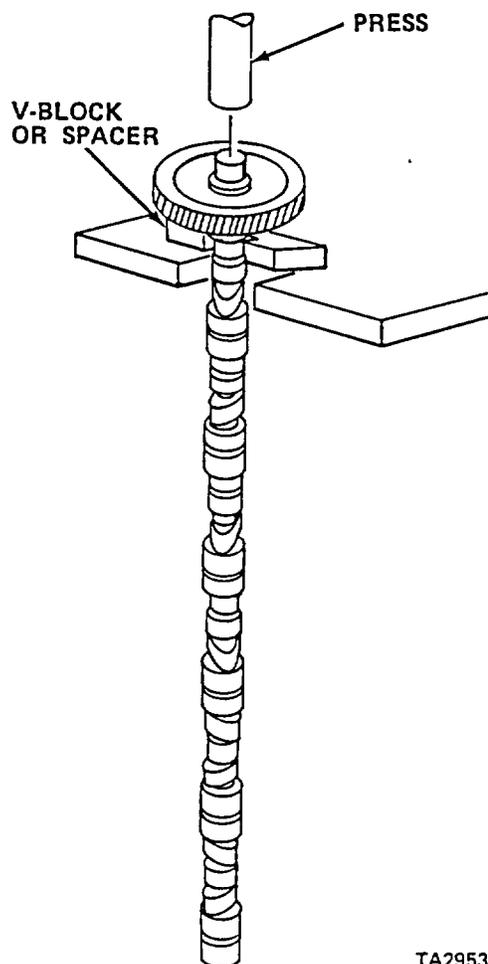
#### NOTE

Repair is limited to replacement of timing gear. Gear is press-fit on camshaft.

- a. Remove timing gear.

#### CAUTION

ANYTIME CAMSHAFT GEAR IS TO BE REUSED, DO NOT APPLY HEAT WITH A TORCH DURING REMOVAL OR INSTALLATION OF GEAR. IF HEATING TORCH IS-USED TO REMOVE GEAR, A NEW GEAR MUST BE INSTALLED TO PREVENT FUTURE GEAR FAILURE.



- (1) Place camshaft in press with V-blocks or spacers.
- (2) Ensure that hub area and not outer gear surface is supported.
- (3) Press camshaft from gear.
- (4) Remove and discard key.

TA295310

b. Install timing gear.

- (1) Preheat oven to 400°F (204°C).
- (2) Heat gear in oven for minimum of one hour before installing.
- (3) Place camshaft in press.
- (4) Install new gear-positioning key into camshaft groove.

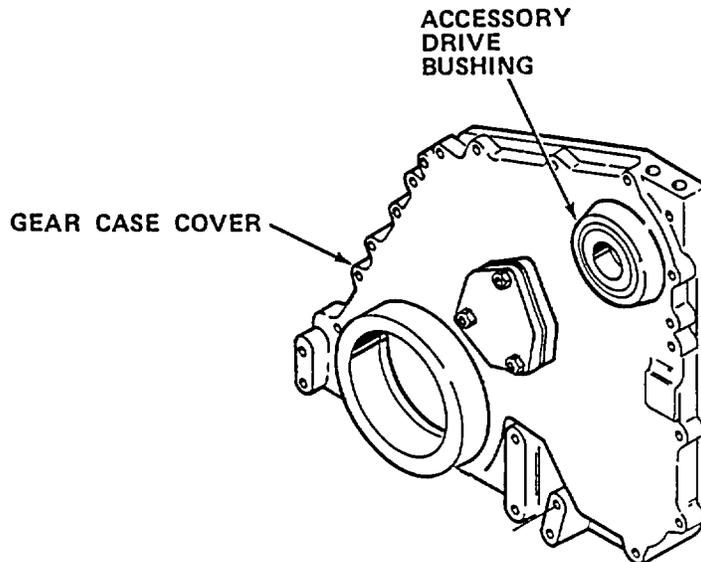
**WARNING**

**WEAR GLOVES TO PREVENT BURNS. HANDLE CAMSHAFT GEAR WITH CARE.**

- (5) While hot, press timing gear onto camshaft until seated against camshaft flange.
- (6) Check clearance between gear and camshaft flange. Must not exceed 0.0015 in. (0.0381 mm).
- (7) If clearance greater than specified, remove gear and check gear bore and camshaft for obstructions.
- (8) Reheat and reinstall gear.
- (9) Install orifice plug (if not previously installed) and torque plug to 5 - 10 ft lbs (7 - 14 Nom).
- (10) Remove from press and wipe assembly clean.

**Section X. GEAR CASE COVER ASSEMBLY REPAIR****3-26. CLEAN GEAR CASE COVER**

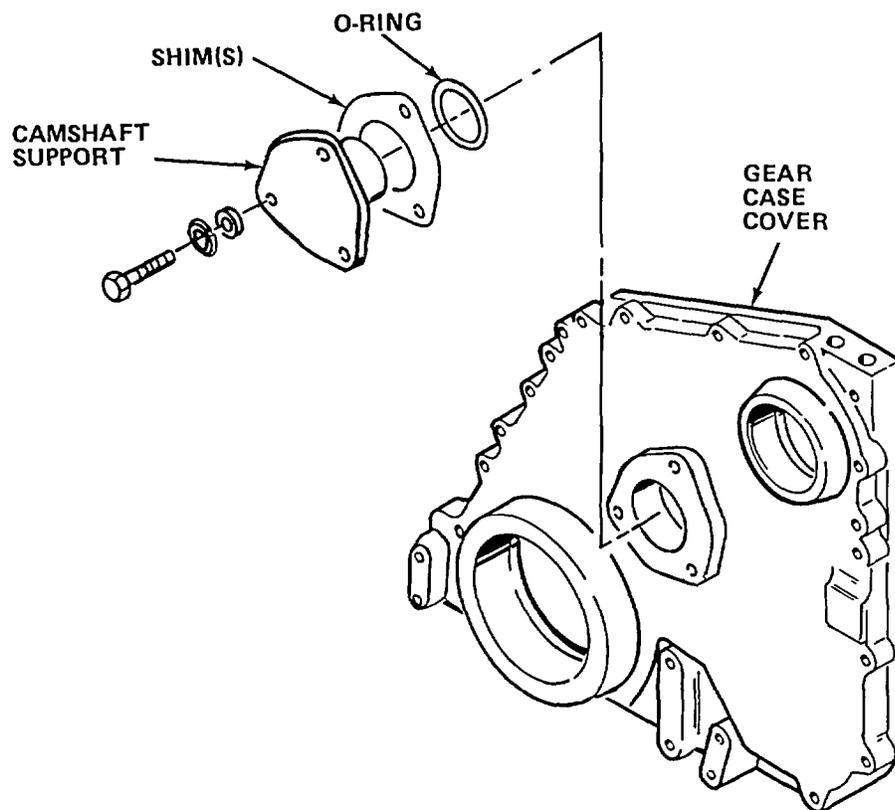
- a. Steam clean cover. Dry thoroughly.
- b. Remove stubborn tar and dirt with fine wire brush. Rinse with cleaning solvent.

**3-27. INSPECT GEAR CASE COVER**

TA295311

- a. Check cover for distortions, breaks, cracks, or broken out sections.
- b. Replace if defective.
- c. Measure accessory drive bushing inside diameter at several points.
- d. Mark bushing for replacement if diameter exceeds 1.7585 in. (44.6659 mm) or if out-of-round.

## 3-28. INSPECT CAMSHAFT SUPPORT



TA295312

- a. Remove capscrews and washers and remove camshaft support (if not removed during-engine disassembly).
- b. Remove and retain shims. Discard O-ring.
- c. Check support for scratches, cracks, breaks, and galling. Discard if defective.
- d. Measure inside diameter of cover bore to determine wear.

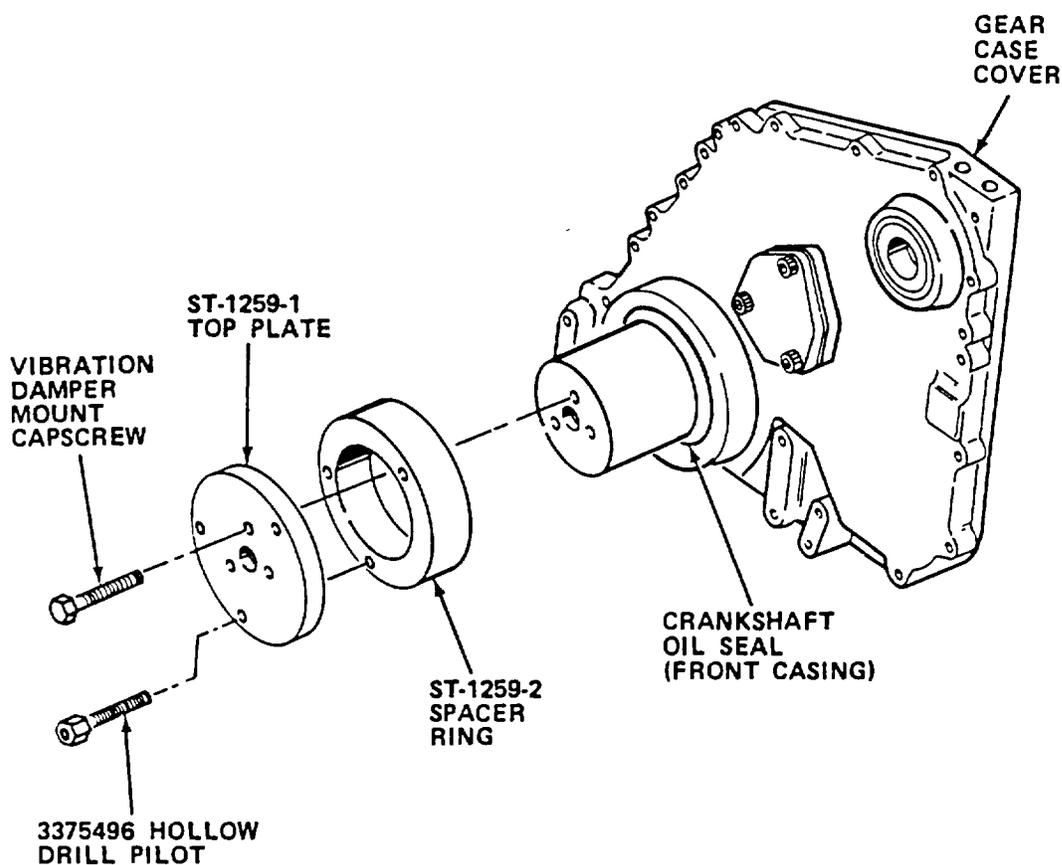
**NOTE**

**Support will be installed upon final engine assembly.**

- e. Discard support if diameter exceeds 1.757 in. (44.627 mm).

**3-29. REPAIR GEAR CASE COVER.**

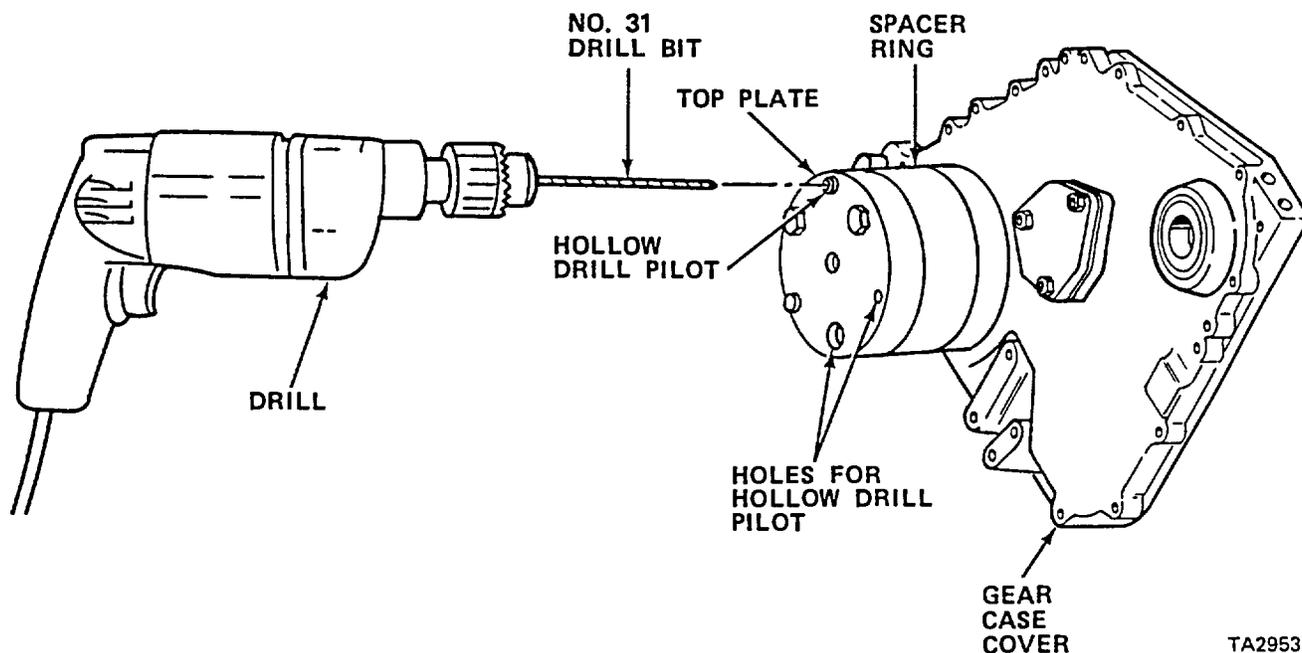
- a. Remove crankshaft oil seal.



TA295313

- (1) Slide ST-1259-2 spacer ring over crankshaft end and seat against gear case cover.
- (2) Secure ST-1259-1 top plate to end of crankshaft with three vibration damper mounting cap screws.
- (3) Screw hollow drill pilot of 3375496 oil seal puller drill pilot into any one of three holes in top plate until pilot is up against crankshaft oil seal casing.

**CAUTION**  
**DO NOT DRILL HOLE ALL THE WAY THROUGH OIL SEAL CASING. DRILLING HOLE THROUGH REAR FACE OF CASING CAN DAMAGE GEAR CASE COVER.**

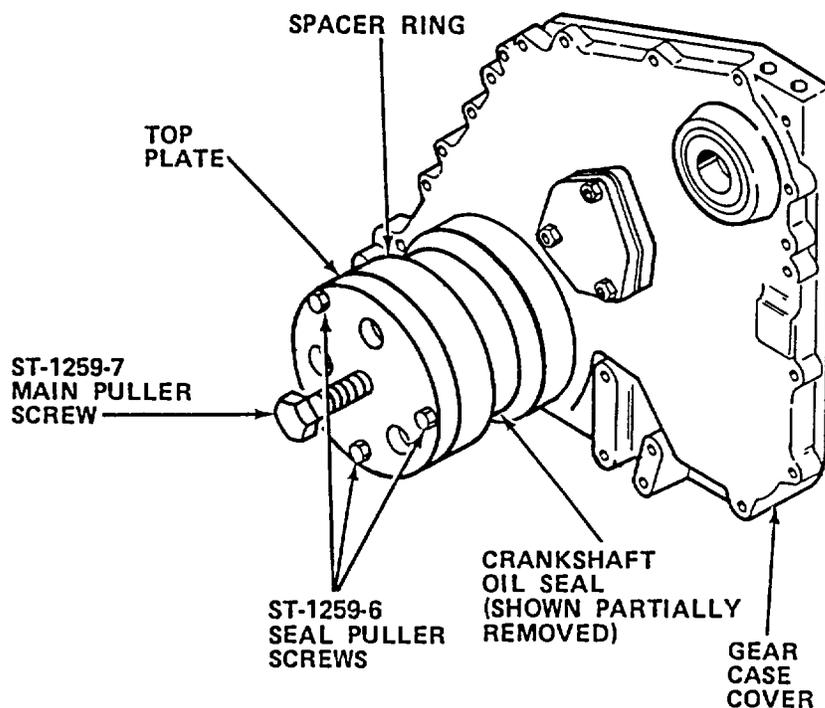


TA295314

- (4) Using a no. 31 drill bit (0.120 in. [3.048 mm]) and drill, insert drill bit into drill pilot and carefully drill hole through front face of oil seal casing.
- (5) Remove drill bit and drill pilot.
- (6) Install drill pilot in second and third holes of top plate and drill two more pilot holes in front face of oil seal casing.
- (7) Remove drill pilot.
- (8) Screw three ST-1259-6 seal puller screws into top plate until pointed tips of screws penetrate oil seal front casing.
- (9) Carefully turn seal puller screws into oil seal from casing. Pointed tips of screws are followed by no. 10-16 sheet metal screw threads which will thread themselves into oil seal front casing.

**CAUTION**  
**TAKE CARE WHEN BOTTOMING OUT SCREWS TO PREVENT THEIR DAMAGE.**

- (10) Continue turning screws until they bottom out in seal casing.
- (11) While holding top plate against crankshaft, remove vibration damper mounting capscrews which secure top plate to crankshaft.

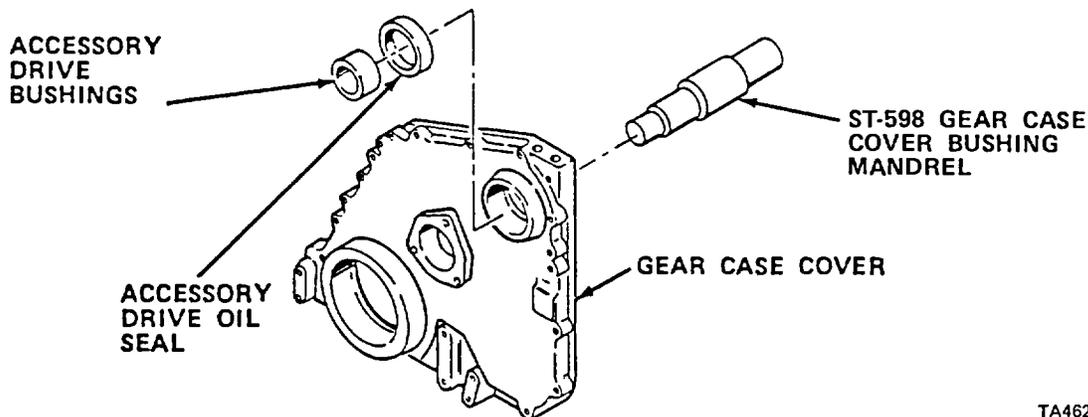


TA295315

- (12) Install ST-1259-7 main puller screw through center threaded hole of top plate.

**NOTE**  
**New crankshaft oil seal will be installed upon final assembly of engine.**

- (13) Turn main puller screw until crankshaft oil seal is removed from gear case cover. Discard seal.



TA462304 ■

b. Replace accessory drive oil seal.

- (1) Carefully pry out and discard accessory drive oil seal from gear case cover.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (2) Clean bore in cover with cleaning solvent and wipe dry with lint-free cloth.
- (3) Carefully tap new seal into cover until fully seated.

c. If accessory drive bushing is to be replaced, proceed as follows:

- (1) Using ST-598 gear cover bushing mandrel, insert mandrel through rear of bushing and drive bushing out of cover.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (2) Clean bore in cover with cleaning solvent and wipe dry with lint-free cloth.
- (3) Apply coat of bushing retaining compound to exterior of bushing.
- (4) Using ST-598 gear case cover bushing mandrel, carefully tap bushing into gear case cover from front until fully seated.
- (5) Remove mandrel and wipe area clean.

d. Using crocus cloth or fine file, remove minor scratches, nicks and burrs from gear case cover.

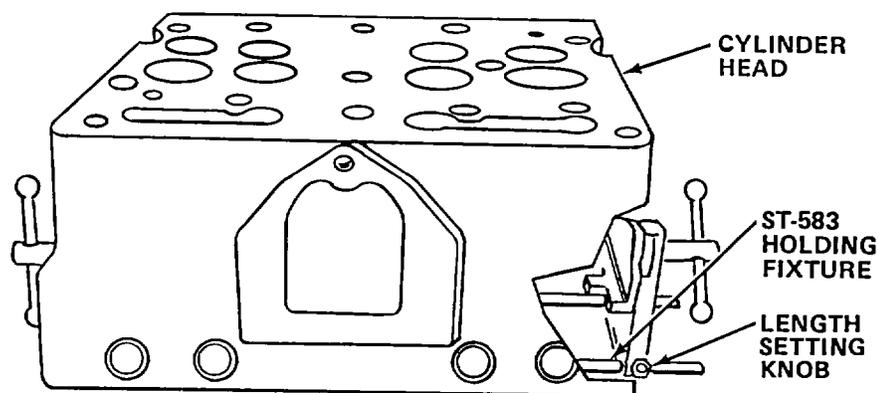
Section XI. CYLINDER HEAD ASSEMBLY REPAIR

3-30. DISASSEMBLE CYLINDER HEAD ASSEMBLY

**WARNING**

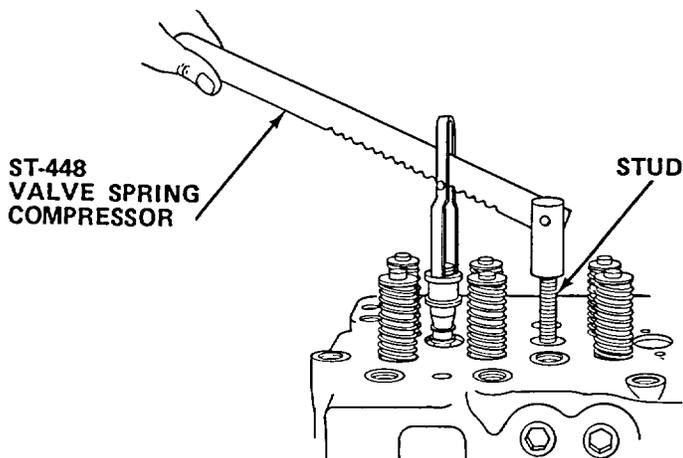
- COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).
- WEAR PROTECTIVE CLOTHING AND GOGGLES WHILE STEAM CLEANING TO PREVENT PERSONAL INJURY.

- a. Steam clean head assembly and dry with compressed air.



TA295317

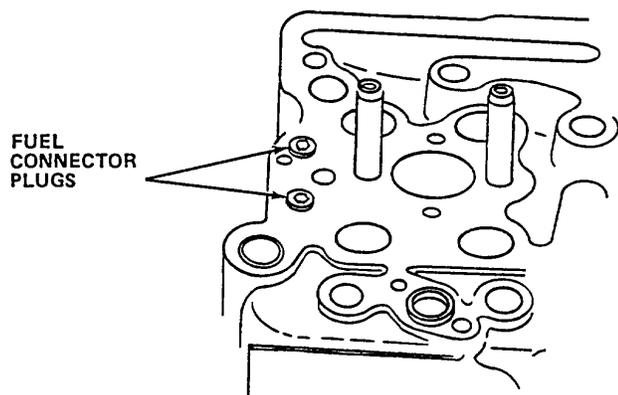
- b. Secure head to ST-583 holding fixture. Fixture provides 360 degrees rotation of head. Set knobs on fixture brackets for desired length.
- c. Remove valves:



TA295318

- (1) Screw ST-448 valve spring compressor stud into rocker lever housing mounting capscrew hole in cylinder head.
- (2) Compress one valve spring at a time.

- (3) Tap valve head lightly to loosen half collets.
- (4) With a magnet, remove and discard half collets.
- (5) Release spring tension and remove spring seats, springs, and valves.
- (6) Place valves on a numbered valve board for inspection.

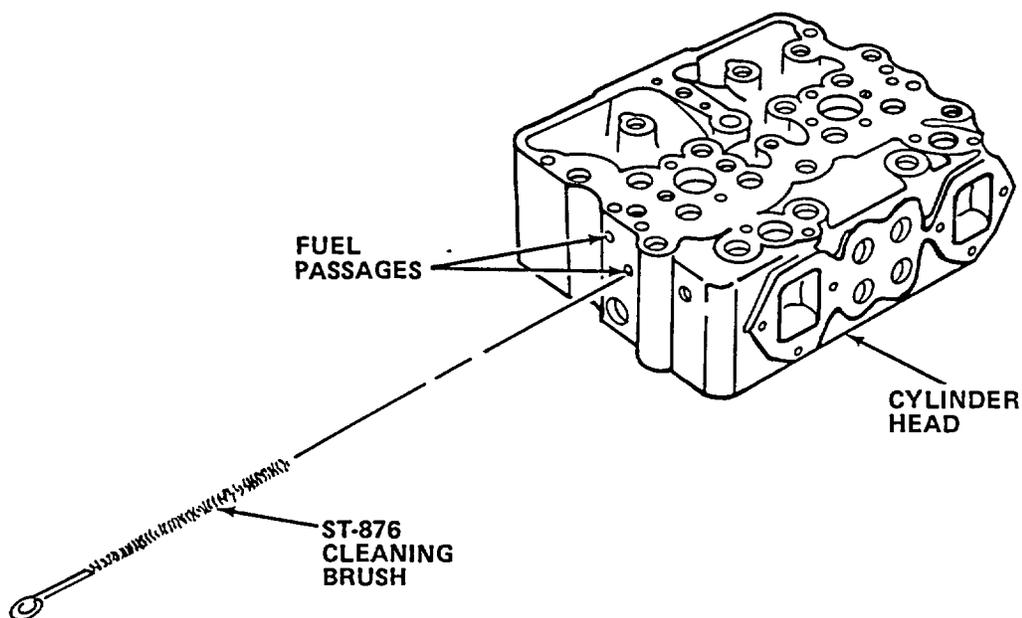


**NOTE:**

**TOP REAR OF NO. 3 HEAD AND TOP FRONT OF NO. 1 HEAD SHOWN**

TA295319

- d. Remove pipe plugs from fuel connector holes on top rear of number three cylinder head and top front of number one cylinder head.
- e. Remove pipe plugs from fuel passages in ends of each head.
- f. Place heads in hot tank for four hours to clean thoroughly.



TA295320

- g. Clean internal fuel passages with ST-876 fuel passage cleaning brush.

**WARNING**

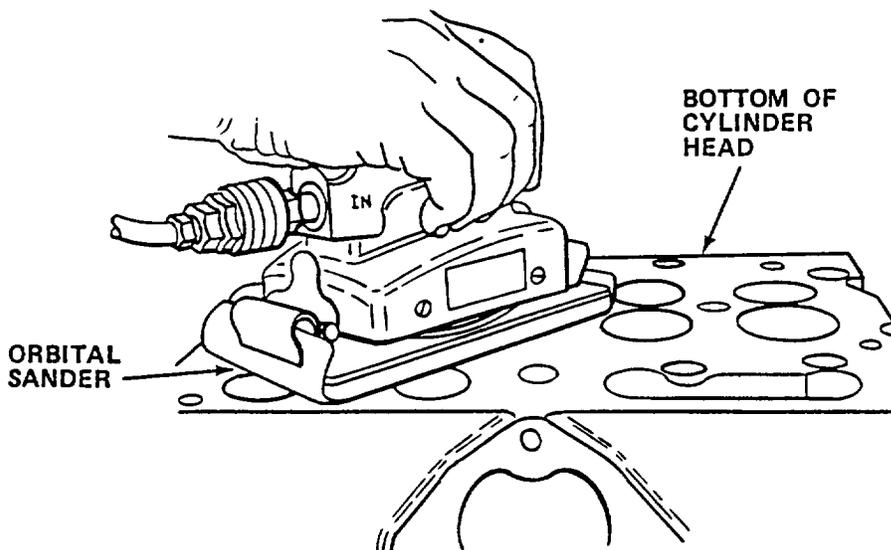
**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- h. Flush passages with cleaning solvent to remove deposits.
- i. Clean valves, springs, and spring seats in hot tank solvent.

**WARNING**

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- j. Direct shop air into all passages and ports to clear loose particles.



TA295321

**CAUTION**

**DO NOT USE DISC SANDER. MAY RESULT IN UNEVEN GASKET SEALING SURFACE.**

- k. Sand bottom surface of cylinder head with orbital sander to 125 R.M.S. finish. Keep sander from tilting or rocking to prevent rounding of edges.

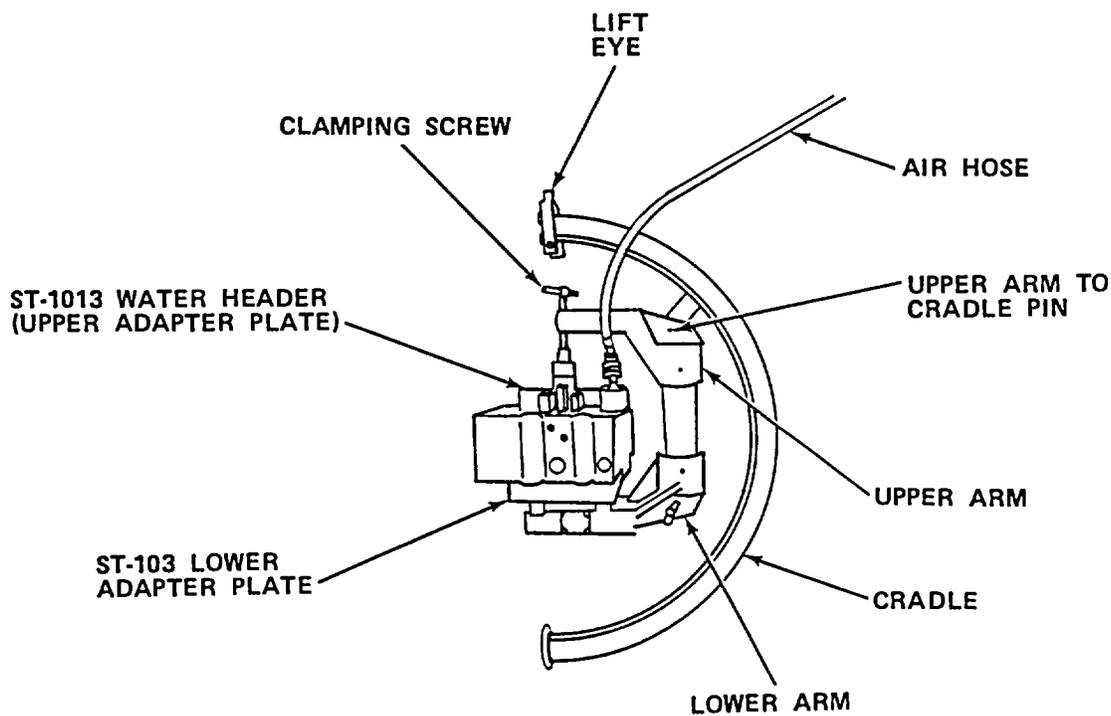
### 3-31. REPAIR CYLINDER HEAD

- a. Cylinder head air pressure test:

#### NOTE

**ST-1012 hydrostatic tester is used to check for coolant leaks in cylinder head. Head is sealed with adapter plates then submerged in water tank. Air pressure is applied to check for internal cracked passages and defective injector sleeves.**

- (1) Lay head on its side with intake manifold down.
- (2) Place a fuel injector in each sleeve and secure with capscrews.
- (3) Torque screws to 10 - 12 ft lbs (14 - 16 N•m).

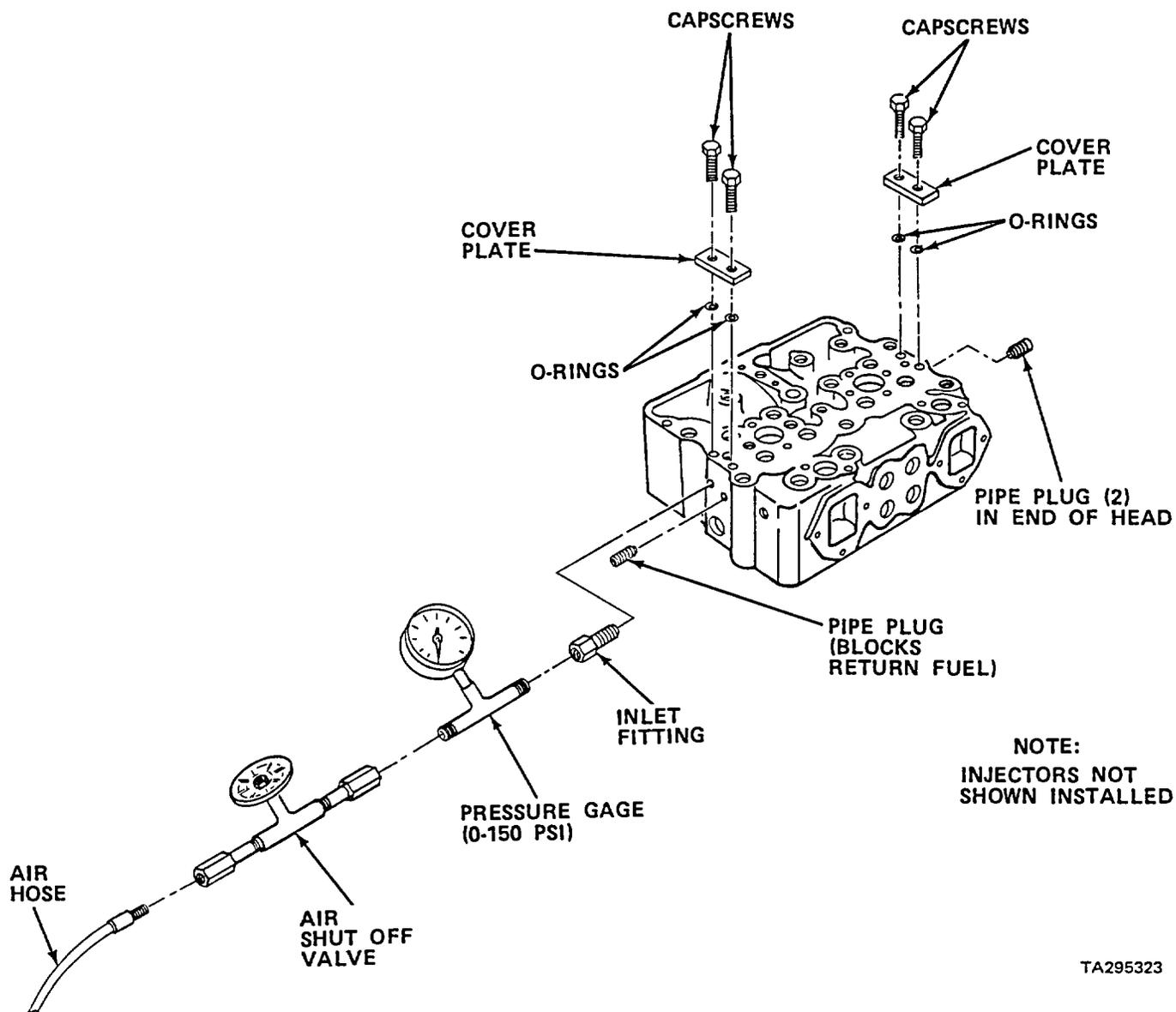


TA295322

- (4) Pin upper arm of ST-1012 to lift eye cradle.
- (5) Check that O-rings in ST-1013 lower adapter plate are installed and are in good condition. Replace O-rings as necessary.
- (6) Position lower adapter plate on head aligning locator pin in plate with hole in head.

- (7) Place head and lower plate on lower arm of tester alining locating pin on arm with plate hole.
- (8) Check that O-rings in ST-1013 water header (upper adapter plate) are installed and are in good condition. Replace O-rings as necessary.
- (9) Position water header on top of head alining water hole locators on heater with holes in head.
- (10) Tighten clamping screw against water header. Head is now secured to tester with all water ports sealed off.
- (11) Lift tester with head and position over water tank.
- (12) Connect air line to water header.
- (13) Apply 30 - 40 psi (207 - 276 kPa) to head.
- (14) Lower head into tank until top of head is 1/2 in. (12.70 mm) below water level.
- (15) Check exhaust ports for leaks. If leakage noted, discard head.
- (16) Remove pin from upper arm and rotate head 180 degrees.
- (17) Check lower injector sleeve area for leaks. If leakage noted, mark sleeve for replacement.
- (18) Rotate head back to upright position and pin upper arm in position. Check injector upper sleeve area for leaks. If leakage noted, discard sleeve.
- (19) Lift cylinder head from water tank.
- (20) Cut off air supply and disconnect air line from water heater.
- (21) Place tester and head on bench and remove head from tester.

b. Fuel line passages test:

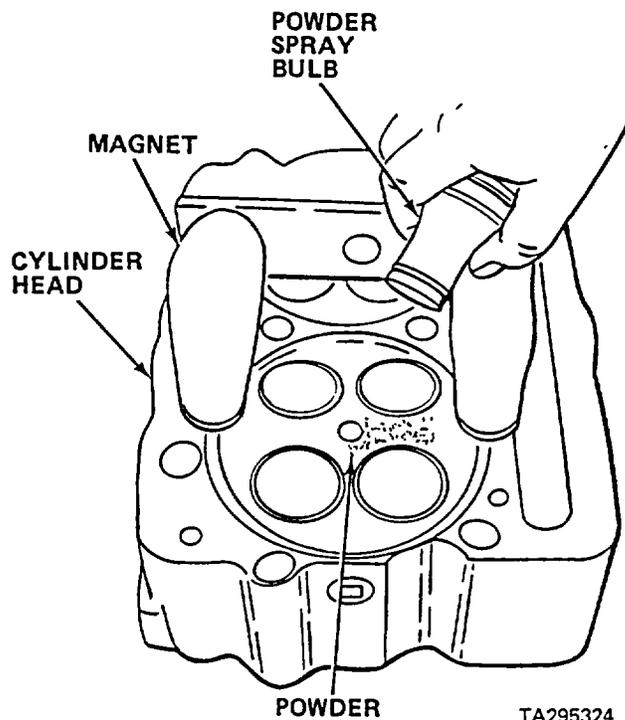


- (1) Install injectors in head with new O-ring seals. Torque capscrews to 10 - 12 ft lbs (14 - 16 N•m).
- (2) Install O-rings and cover plate at fuel crossover mount pad. Torque screws to 34 - 38 in. lbs (3.8 - 4.3 N•m).
- (3) Reinstall pipe plugs in fuel passages on one end of head.
- (4) Reinstall pipe plugs in top rear of no. 3 head. If No. 1 head is being tested, reinstall pipe plugs in top front of No. 1 head.
- (5) Install pipe plugs in fuel outlet passage of head.
- (6) Install fitting in fuel inlet passage.

- (7) With shut-off valve and 0 - 150 psi (0 - 1035 kPa) gage attached to air line, secure air line to inlet fitting.
- (8) Apply 80 - 100 psi (550 - 690 kPa) air pressure to head.
- (9) Close shut-off valve and watch gage for pressure drop.
- (10) Discard head if there is any pressure drop within 15 seconds after applied.

c. Magnetic particle inspection.

**NOTE**  
ST-1166 magnetic crack detector is used to check valve seats and injector ports for cracks.



- (1) Place magnet on area being inspected.

**NOTE**  
Hold thumb partially over spray cap of bulb to keep from blowing off.

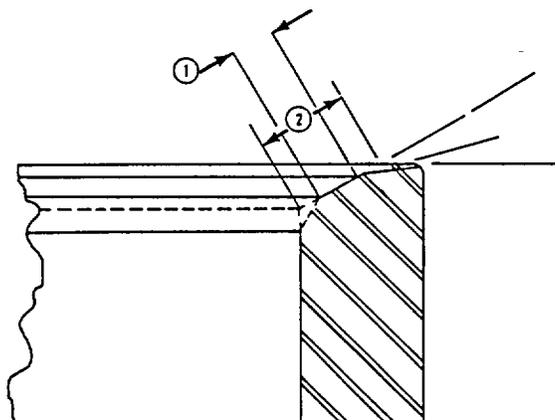
- (2) Spread moderate amount of powder with spray bulb on valve seats and injector ports.

**WARNING**  
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- (3) Blow off excess powder with low air pressure.
- (4) If crack exists, powder will fall into it and will show as a white line.
- (5) If valve seat insert(s) is cracked, mark for replacement.
- (6) Discard head if injector port is cracked or head area around valve seat is cracked.

d. Valve seat insert security and seat width check:

- (1) Tap lightly on cylinder head near seat insert.
- (2) If seat loose enough to bounce, mark it for replacement.
- (3) If slight looseness found, seat insert is serviceable.



1. MINIMUM SEAT WIDTH 0.063 INCH (1.600mm)
2. MAXIMUM SEAT WIDTH 0.125 INCH (3.175mm)

TA295325

- (4) Check insert seat area width. If width exceeds 0.125 in. (3.175 mm) at any point and cannot be narrowed sufficiently during grind, mark for replacement.

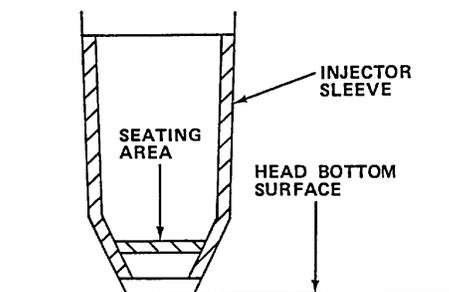
e. Injector sleeves inspection.

**NOTE**

**Injector sleeves marked for replacement due to failure of air pressure test are not checked further.**

**NOTE:**

**SEATING AREA IS APPROXIMATELY 1/16 IN. (1.58mm) WIDE.**



TA295326

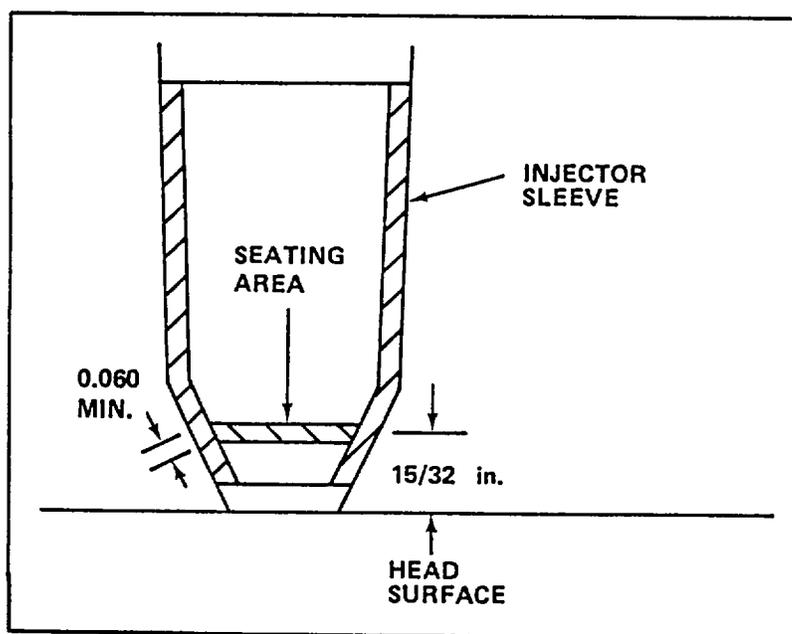
- (1) With bright light, check injector cup seat area of sleeve for scratches.
- (2) If scratched, mark for replacement.

- f. Injector sleeve seating area pattern and tip protrusion inspections.

**NOTE**

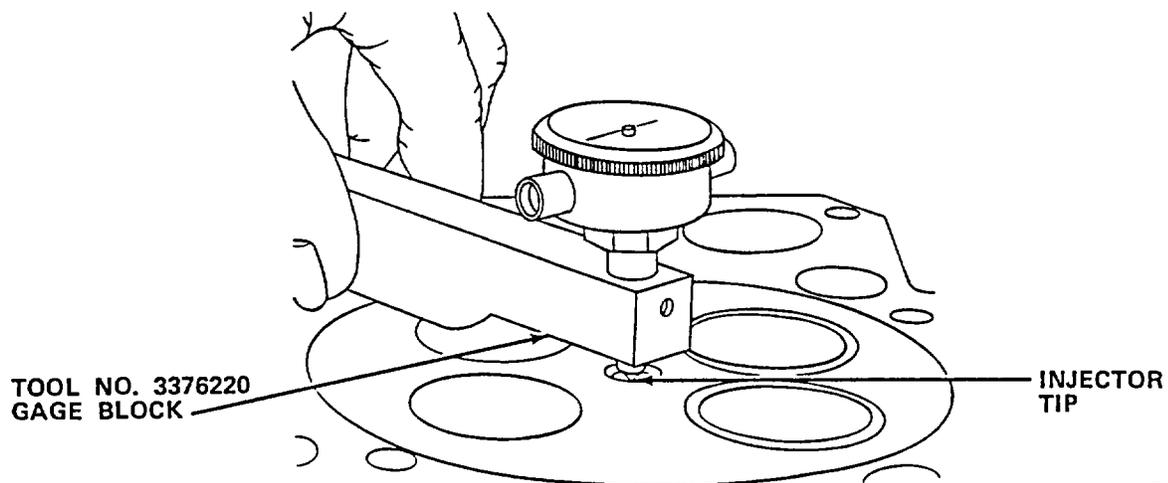
**Injector sleeves that have passed both air pressure test and seat area scratch inspection are further inspected for seating pattern and tip protrusion.**

- (1) Lightly coat new injector cup (on injector body) with Prussian bluing.
- (2) Install injector in sleeve. Torque capscrews to 10 - 12 ft lbs (14 - 16 N•m).



TA295327

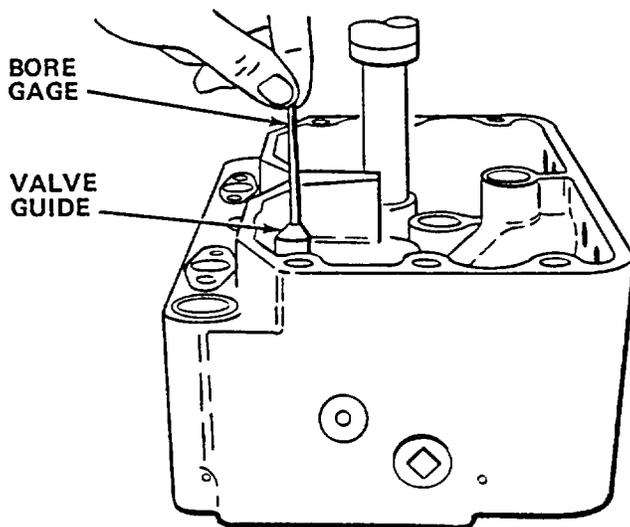
- (3) Remove injector and check seat pattern. Bluing band must be 0.060 in. (1.52 mm) minimum in width and located approximately 15/32 in. (11.91 mm) from bottom of head surface.
- (4) Mark sleeve for replacement if seat area does not meet specifications.
- (5) Reinstall injector and capscrews. Torque capcrews to 10 - 12 ft lbs (14 - 16 N•m).



TA295328

- (6) Measure tip protrusion above block surface with tool no. 3376220 gage block.
- (7) Mark sleeve for cutting if protrusion is less than 0.060 in. (1.524 mm).
- (8) Mark sleeve for replacement if protrusion exceeds 0.070 in. (1.778 mm).

g. Valve guides inspection.



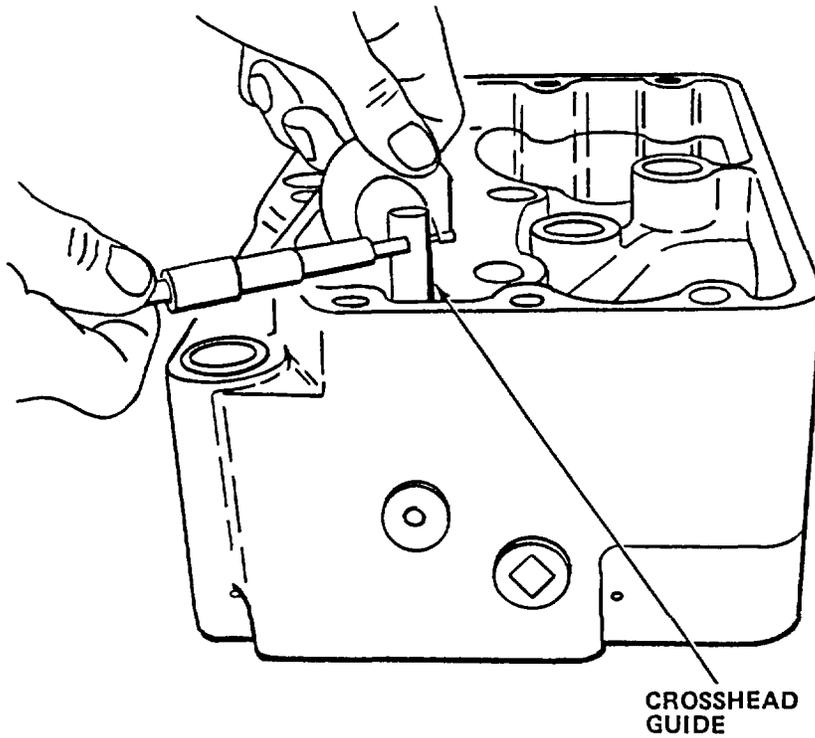
TA295329

**CAUTION**  
**DO NOT USE PLUG GAGE. PLUG GAGE WILL NOT DETECT OUT-OF-ROUND HOLE.**

- (1) Using a small bore gage set at 0.4552 in. (11.5620 mm), check inside diameter of valve guide. If gage enters hole, guide is excessively worn. Bore gage is used as "NO GO" gage.

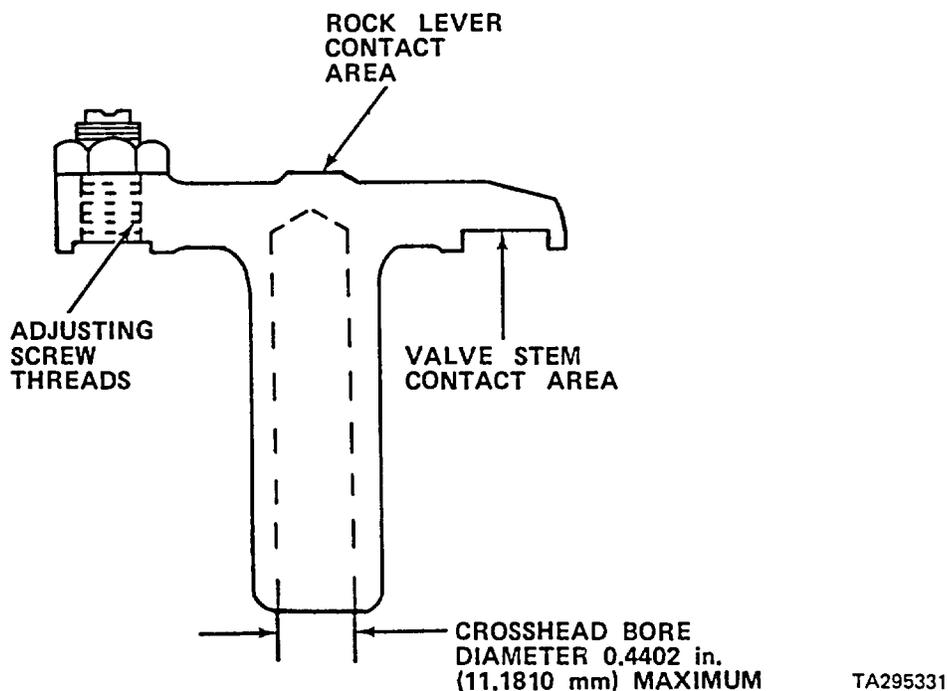
- (2) Gage at several points crosswise and endwise of head to check for out-of-round.
- (3) Mark guide for replacement if out-of-round or excessively worn.
- (4) Check guides for looseness, chips, cracks, or burrs. Mark for replacement if damaged.

h. Valve crosshead guides and crossheads inspection.



TA295330

- (1) Measure outside diameter of valve crosshead guide.
- (2) Mark guide for replacement if diameter exceeds 0.432 in. (10.97 mm).
- (3) Check guide for straightness.
- (4) Mark guide for replacement if not at right angle with milled surface of head.
- (5) Check crossheads for cracks using magnetic particle inspection method.
- (6) Mark crosshead(s) for replacement if cracked.



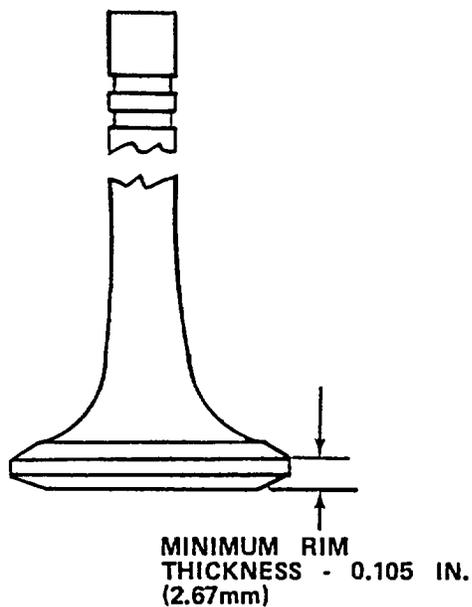
- (7) Measure inside diameter of crosshead bore using small bore gage set at 0.4402 in. (11.1810 mm).
- (8) If gage enters bore, crosshead must be marked for replacement.

**CAUTION**  
**DO NOT USE PLUG GAGE. PLUG GAGE CAN NOT MEASURE OUT-OF-ROUND OF HOLE.**

- (9) Check for out-of-round gaging at several points 90 degrees apart the full length of bore.
- (10) Mark out-of-round crossheads for replacement.
- (11) Check crossheads for excessive wear on rocker lever and valve stem contact surfaces.
- (12) Check adjusting screw and crosshead threads for wear distortion.
- (13) Mark screw and/or crosshead for replacement if threads distorted or contact surfaces are excessively worn.

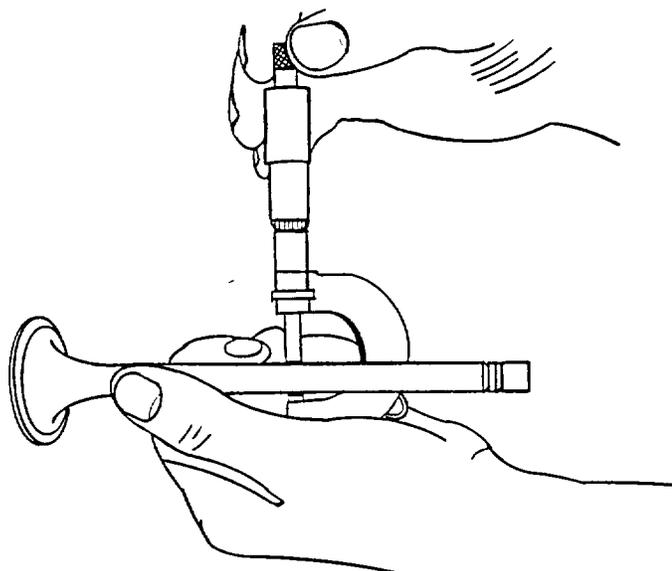
i. Valve inspection.

- (1) Clean valves with buffer and polish with crocus cloth.
- (2) Mark valve for replacement if:



TA295332

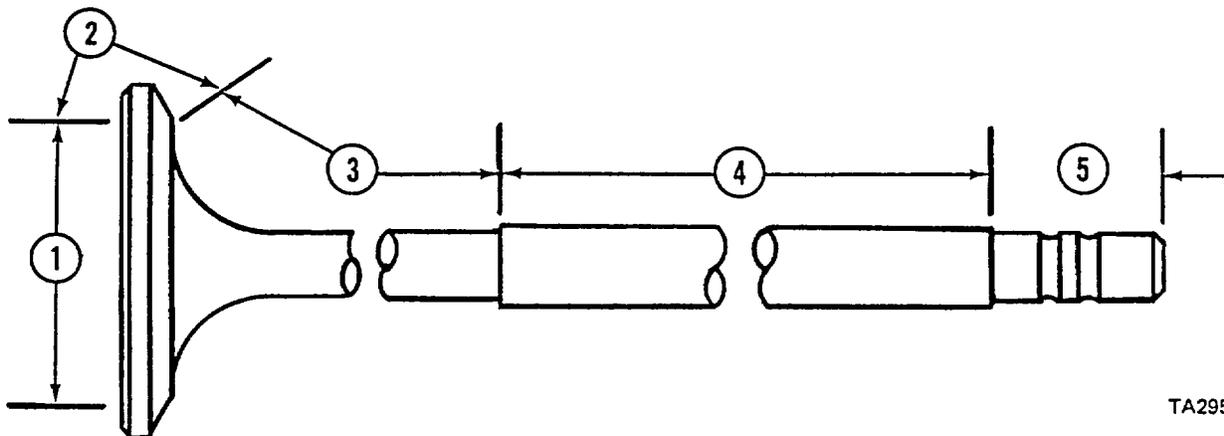
- (a) Head is cupped, obviously cracked, or pitted.
- (b) Rim worn too thin to regrind. Minimum rim thickness is 0.105 in. (2.67 mm).



TA295333

- (c) Stem scored or diameter worn to less than 0.449 in. (11.04 mm).
- (d) Collet recesses worn so new collets will not fit securely in recesses.

(3) Perform crack inspection of valve using Magnaglo method:



TA295334

(a) No magnetic indications over 1/2 in. (12.70 mm) in length or more than 5 indications spaced closer than 1/8 in. (3.18 mm) can be accepted in area 1.

**NOTE**

**Visible means indication can be seen with a 3 power magnifying glass after removing magnetic particle suspension.**

- (b) No visible or magnetic indication accepted in area 2.
- (c) No visible or circumferential magnetic indications are accepted in areas 3 and 4.
- (d) No visible or magnetic indication is accepted in area 5.

(4) Mark valves to be reground.

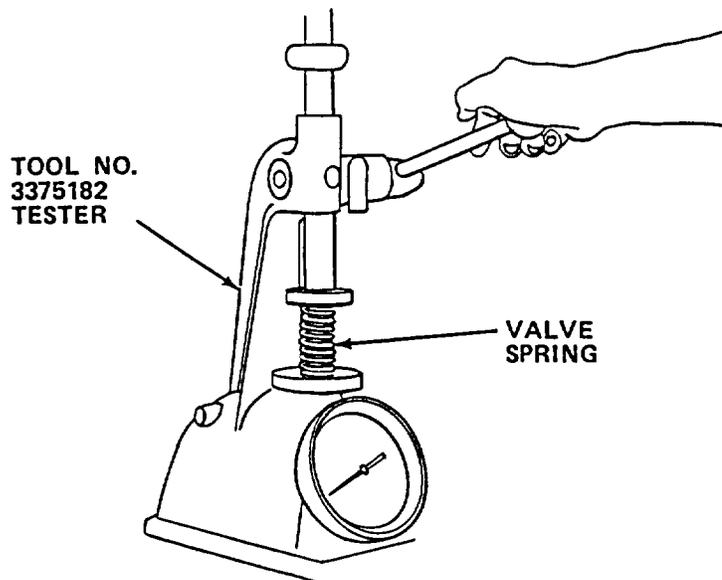
j. Cylinder head mounting surface and water holes inspection.

- (1) Check head for scratches, grooves, or unevenness at point where it contacts gasket sealing areas.
- (2) Mark head for surface refinishing if defects found.
- (3) Check water holes for maximum depth erosion of 0.003 in. (0.076 mm) up to 5/32 in. (3.97 mm) from edge of water hole.
- (4) Mark eroded holes for installation of salvage sleeves.

k. Valve springs inspection.

**NOTE**

Weak valve springs may cause valve flutter resulting in excessive wear of valves, seats and guides. Valve timing may also be affected causing valve to strike top of piston.



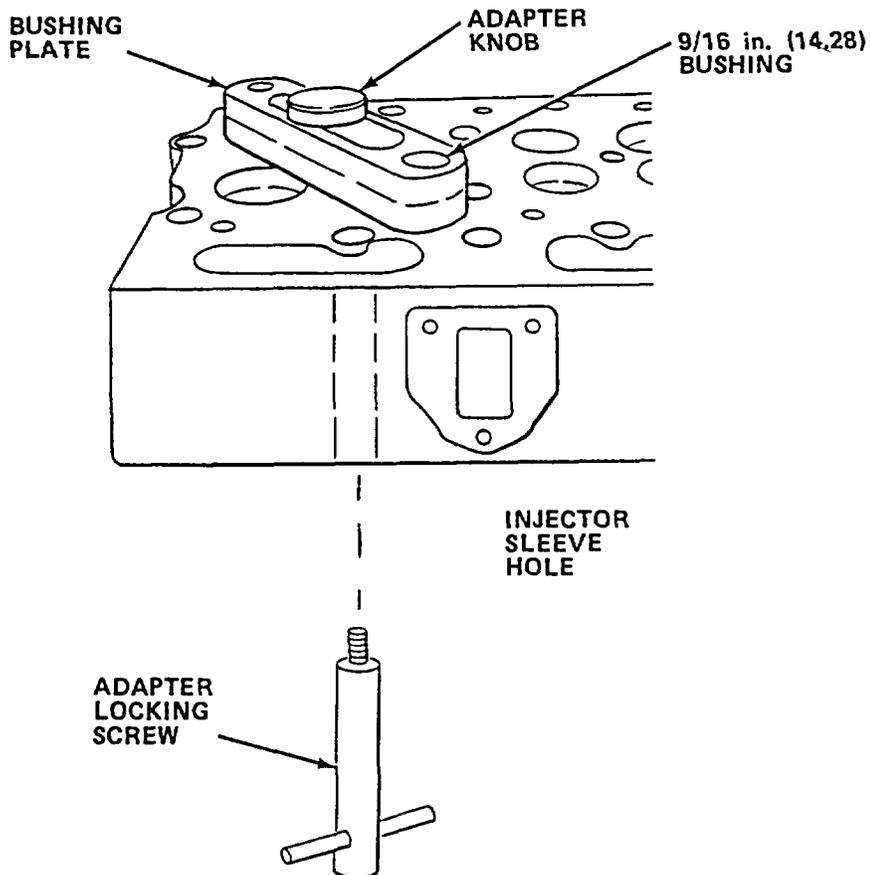
TA295335

- (1) Place valve spring to tool no. 3375182 valve spring tester.
- (2) Compress spring to 1/24 in. (43.79 mm) length.
- (3) Check load on tester gage.
- (4) Replace spring if load indicated is less than 143 lbs (636 N).

1. Repair eroded water holes.

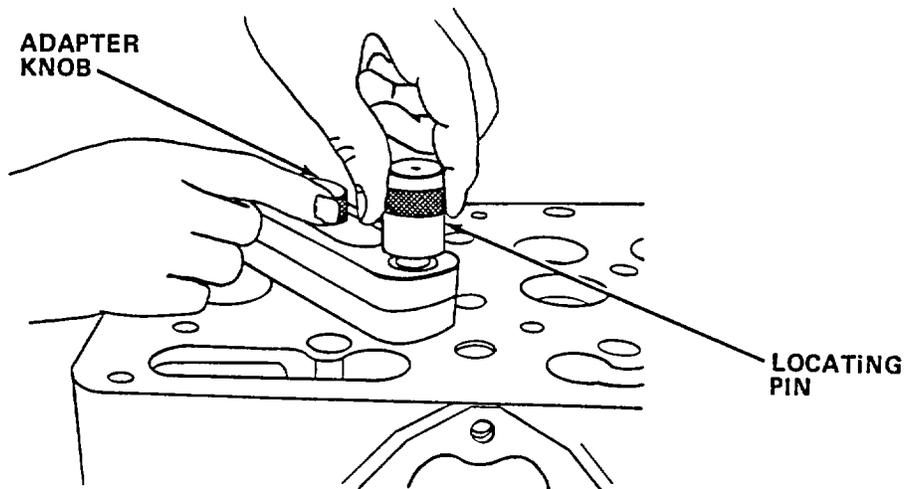
**NOTE**

ST-1010 water hole counterboring tool is used to enlarge eroded hole to accept a 9/16 in. (14.287 mm) salvage sleeve.



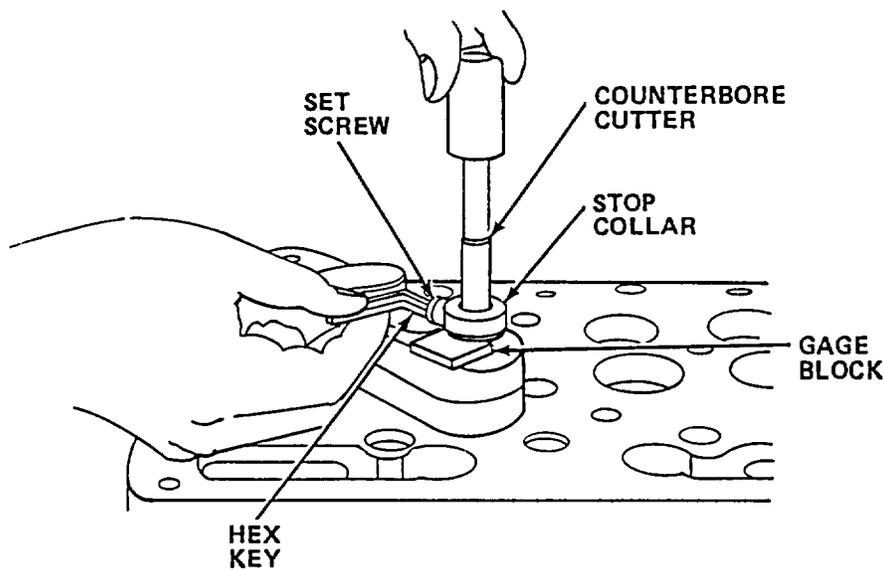
TA295336

- (1) Place bushing plate on cylinder head with slot in plate aligned with injector sleeve hole.
- (2) Reach under head and insert adapter locking screw into injector sleeve hole.
- (3) Screw adapter knob onto threads of adapter locking screw. Leave knob loose.
- (4) Position 9/16 in. (14.287 mm) bushing end of plate over hole to be repaired.



TA295337

- (5) Insert ST-1010-10 locating pin through 9/16 in. (14.287 mm) bushing plate and into hole to be repaired.
- (6) Tighten adapter knob while keeping adapter screw from turning.
- (7) Remove locating pin.



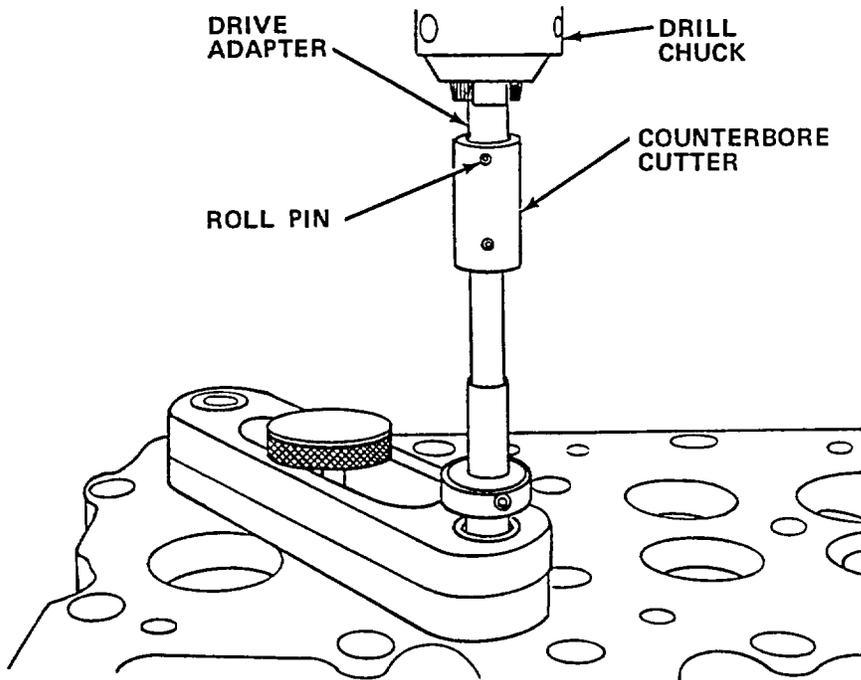
TA295338

- (8) Loosen stop collar setscrew on counterbore cutter.

**NOTE**  
Gage block established depth of bore.

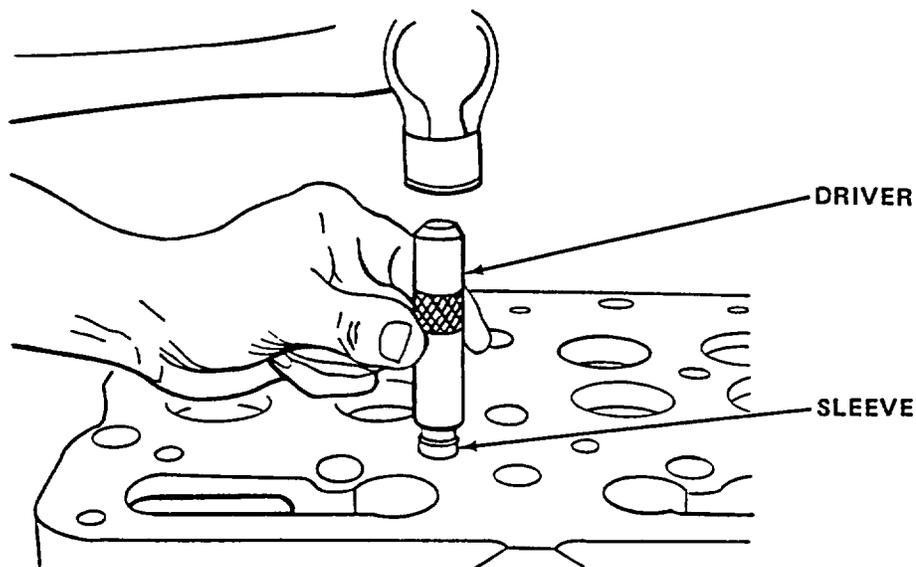
- (9) Set ST-1010-26 gage block on top of 9/16 in. bushing with arc on gage block aligned with hole in bushing.

- (10) Insert cutter into bushing until cutter bottoms on cylinder head.
- (11) Slide stop collar down until it sits on top of gage block.
- (12) Tighten collar setscrew.
- (13) Remove gage block.
- (14) Lock ST-1010-8 drive adapter in drill chuck.



TA295339

- (15) Insert drive adapter into top of cutter ensuring that slot in adapter straddles roll pin in cutter.
- (16) With light pressure on drill and oil applied to cutter, cut hole to depth. Cutter will free wheel when collar reaches bushing.
- (17) Remove drill, cutter, and counterbore tool.
- (18) Clean hole thoroughly with lintfree cloth.
- (19) Slide sleeve onto bushing driver.
- (20) Apply sealing compound to exterior of sleeve.



TA295340

- (21) Aline sleeve in top of water hole and carefully tap in sleeve with driver until it bottoms.

**NOTE**

**Salvage sleeve will protrude above surface of head.**

- (22) With flat mill file, carefully file sleeve flush with head surface. If proper sleeve is not available, heavy walled 7/16 in. (11.112 mm) inside diameter copper tubing may be used. Tuoning must provide 0.002 to 0.005 in. (0.050 to 0.127 mm) press fit. Overall length should be approximately 1/2 in. (12.70 mm).

**WARNING**

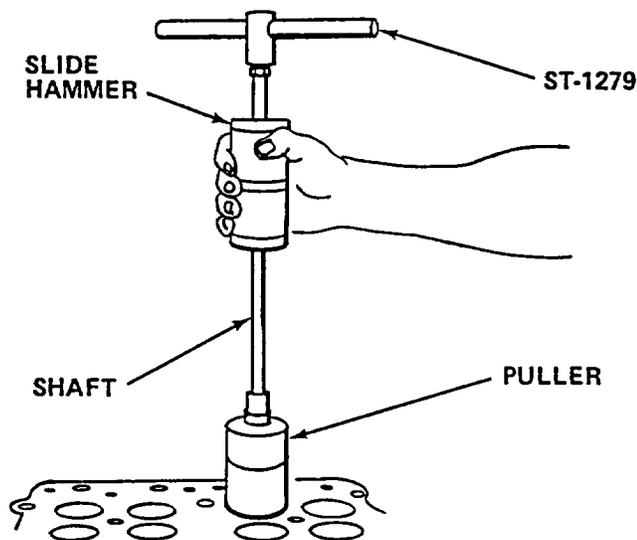
**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC).**

- (23) Thoroughly clean water passages with compressed air to remove cuttings and filings.

m. Cylinder head resurfacing.

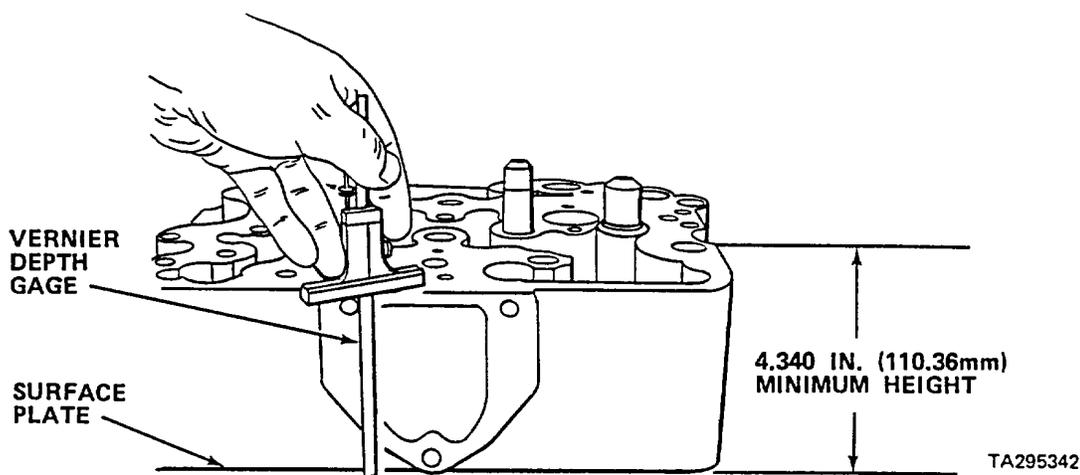
**NOTE**

If head is scratched, etched, or uneven at gasket contact area, head must be ground.



TA295341

- (1) Remove all valve seat inserts with ST-1279.
  - (a) Place puller on valve seat insert.
  - (b) Screw shaft into puller until shaft is tight. This expands puller in seat.
  - (c) With slide hammer, drive out seat insert.
- (2) Secure head on surface grinder.



TA295342

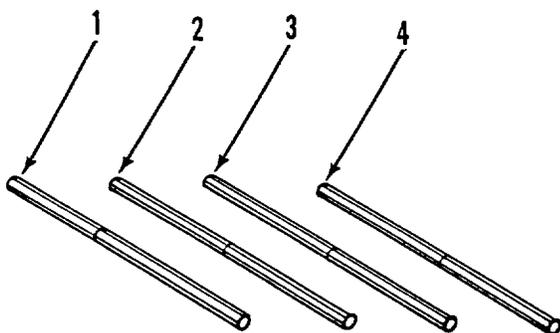
- (3) Measure head with vernier depth gage to determine height. Record height.
- (4) If head must be ground to a height less than 4.340 in. (110.236 mm) to remove damage or restore flatness, discard head.

- (5) Make light cuts of 0.001 to 0.003 in. (0.025 to 0.076 mm) deep, removing only enough material to make head serviceable.
- (6) Finish surface to 125 R.M.S. finish.
- (7) Remeasure head height to ensure it is not less than 4.340 in. (110.236 mm).
- (8) Rework valve seat insert counterbore by removing amount of stock equal to that removed during head resurfacing.

**n. Valve seat insert counterboring.**

**NOTE**

Two conditions will determine which size valve seat insert cutter (ST-662) will be used for counterboring. If head was refinished and same inserts are to be reinstalled, no oversize counterboring will be required. Since head material was removed, insert counterbores will only have to be deepened to amount equal to material removed. The second condition involves replacement of inserts which are found loose or their seating areas cannot be restored through regrinding. Those insert counterbores must be enlarged to accept oversize inserts. Inserts are available in 0.005, 0.010, 0.020, 0.030, and 0.040 in. (0.127, 0.254, 0.508, 0.762, and 1.016 mm) oversizes. The 0.020, 0.030 and 0.040 in. oversize inserts are 0.005, 0.010, and 0.015 in. (0.127, 0.254, and 0.381 mm) thicker respectively; therefore, their counterbores will also have to be deepened.



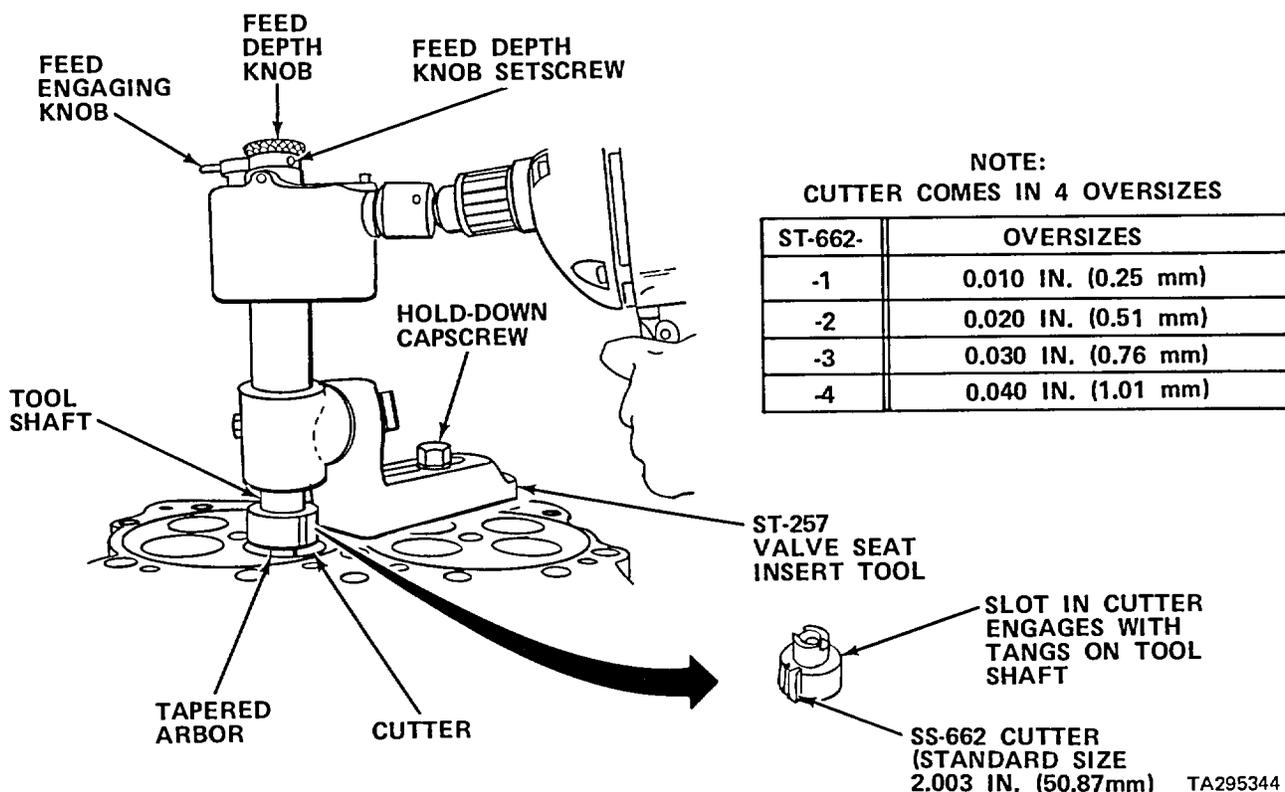
**TAPERED ARBORS**

NO.	SIZE
1	29/64 IN. (11.506mm)
2	29/64 IN. + .001 IN. (11.507mm)
3	29/64 IN. + .002 IN. (11.508mm)
4	29/64 IN. + .003 IN. (11.509mm)

TA295343

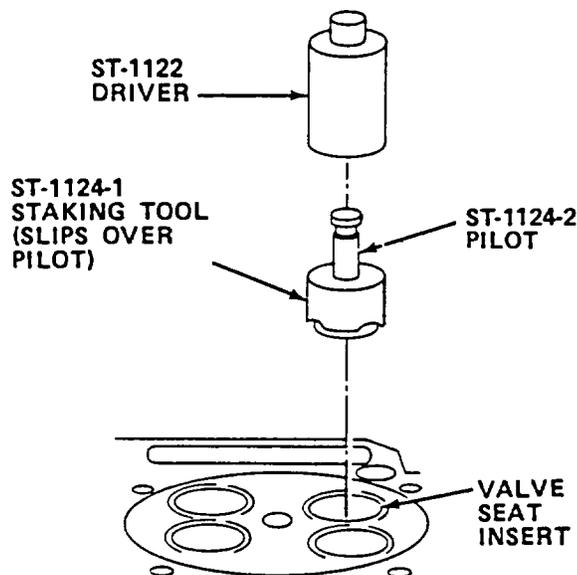
- (1) Select proper size ST-663 tapered arbor to fit valve guide.
- (2) Insert arbor into valve guide.

(3) Place proper size insert counterbore cutter on arbor.



- (4) Slide ST-257 valve seat insert tool cutter drive shaft over arbor and mate slot in cutter with tangs on shaft.
- (5) Secure insert tool to head with washer and capscrew.
- (6) Loosen feed engaging knob and loosen setscrew on feed depth knob.
- (7) Rotate feed depth knob to lower cutter drive shaft until shaft is fully engaged with slot in cutter.
- (8) Using new seat insert as depth gage, place insert and 0.006 in. (0.1524 mm) feeler gage between top of tool housing and feed depth knob.
- (9) This sets tool to bore to width of insert plus 0.006 in. (0.1524 mm) to permit staking of insert to head.
- (10) Tighten feed depth knob setscrew.
- (11) Remove insert and feeler gage.
- (12) Tighten feed engaging knob. Automatic feed is now engaged.
- (13) Apply cutting oil to cutter.
- (14) Secure insert tool drive shaft in drill chuck.
- (15) Start drill and cut counterbore.

- (16) Allow cutter to dwell for approximately 10 seconds upon reaching proper depth to ensure a flat seating surface.
- (17) Stop drill and disengage from drive shaft.
- (18) Loosen feed engaging knob.
- (19) Remove capscrew and washer securing insert tool to head.
- (20) Lubricate seat insert with engine oil and carefully tap insert into head.



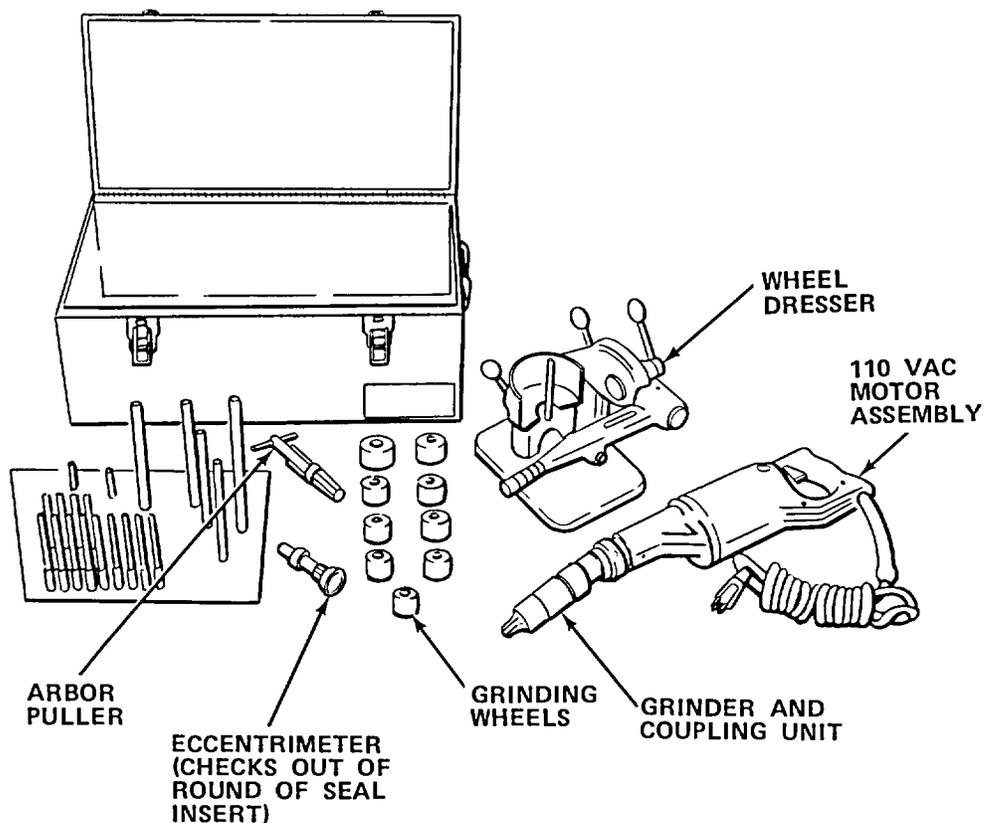
TA462305

**CAUTION**  
**OVER-PEENING WITH PUNCH MAY CRACK CYLINDER HEAD.**

**NOTE**  
**A 1/4 in. (6.35 mm) punch may be used topeen insert in place at four places.**

- (21) Place ST-1124-1 valve seat insert staking tool over pilot and set assembly on valve seat insert.
- (22) Place ST-1122 insert staking tool driver over shaft of staking tool.
- (23) Ensure that staking tool is even on face of cylinder head.
- (24) Strike driver one or two solid blows with ball-peen hammer.
- (25) Remove staking tool and driver.
- (26) Clean insert area thoroughly.

o. Valve seat grinding.



TA295346

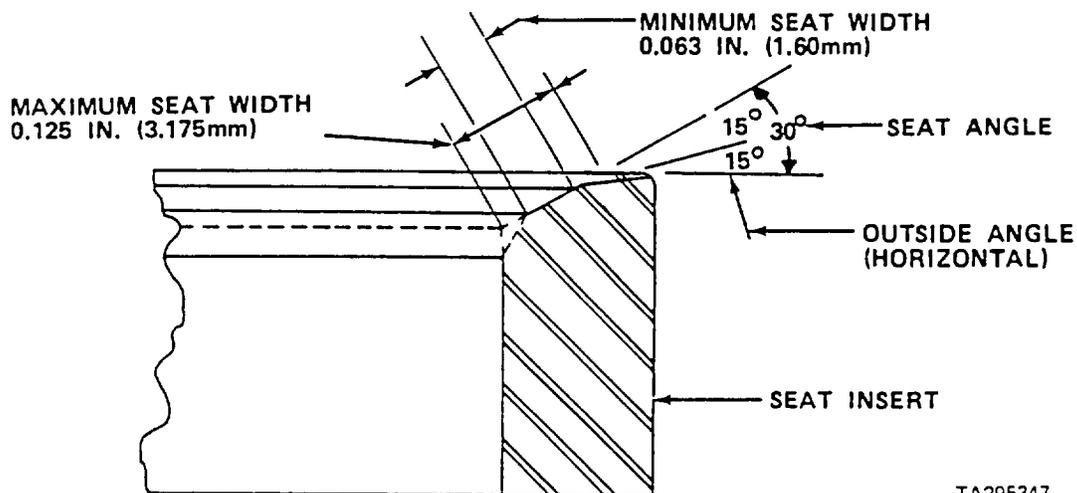
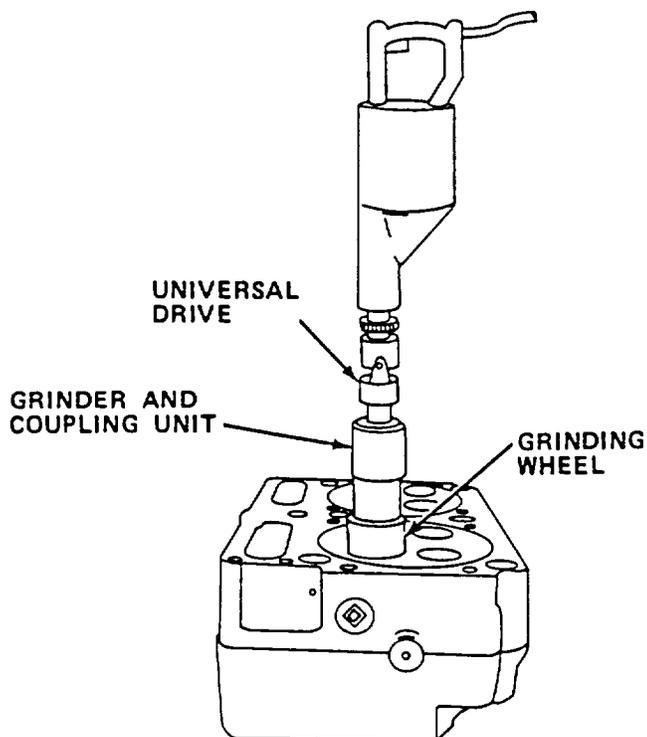
**WARNING**

**WEAR PROTECTIVE CLOTHING AND GOGGLES WHILE GRINDING TO PREVENT PERSONAL INJURY FROM FLYING PARTICLES.**

**NOTE**

**ST-685 valve seat grinding machine kit contains grinding wheels to refinishing insert seating area to 30° degrees from horizontal. Wheels are also included to dress inside angle to 30° degrees from vertical and outside angle to 15 degrees from horizontal.**

- (1) Place ST-663 tapered valve guide arbor in valve guide.
- (2) Dress seating area grinding wheel to 30° degrees from horizontal.



TA295347

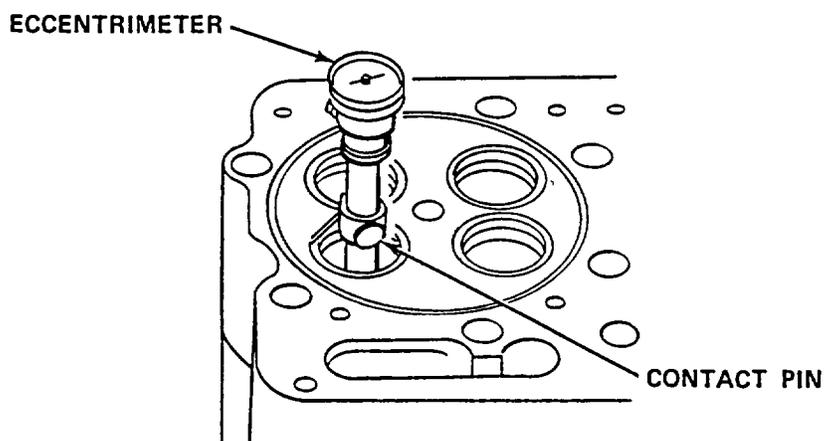
- (3) Engage ST-685-2 grinder motor assembly with grinding wheel and set wheel on valve guide arbor.

**CAUTION**

**KEEP MOTOR ASSEMBLY VERTICAL OR OUT-OF-TRUE ANGLE WILL RESULT.**

- (4) While holding grinder motor assembly in as near vertical position as possible, grind valve seats.

- (5) Remove motor, wheel, and arbor.
- (6) Check valve seat width of 0.063 in. (1.60 mm) minimum to 0.125 in. (3.175 mm) maximum.
- (7) If seating area is wider than 0.125 in. (3.175 mm), stock can be removed from inside angle (30 degrees from vertical) and outside angle (15 degrees from horizontal). Special grinding stones are provided in kit.
- (8) Finish grind with light touches of wheel against seating area face.



TA295348

- (9) With ST-685-4 eccentric meter inserted in valve guide, check concentricity of valve seat.
- (10) Total indicated runout is 0.002 in. (0.05 mm). Regrind seating area face or replace insert as required if runout exceeds specification.

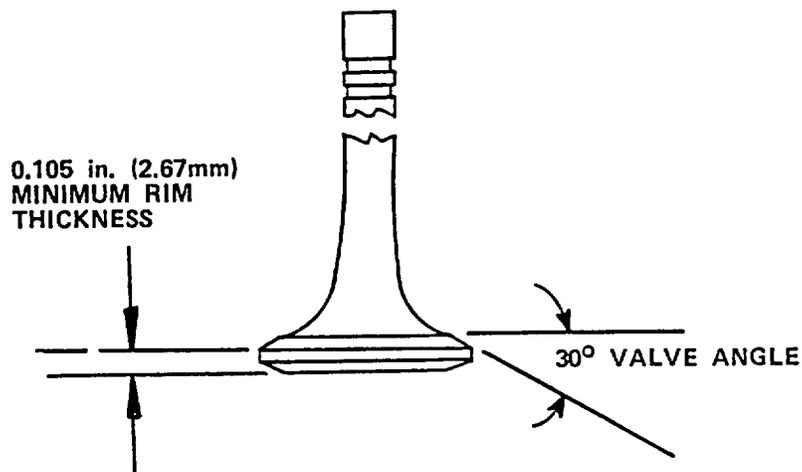
**p. Grind valves.**

**NOTE**

**Check valve grinder setting by using new valve and indicator gage:**

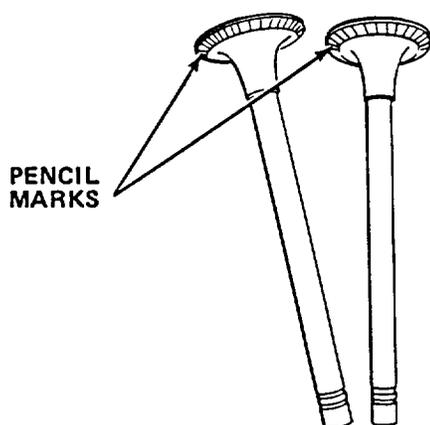
- (1) Chuck valve in grinder on guide area of stem.
- (2) Place indicator on round face of valve.
- (3) Rotate valve and mark high spots on head of valve.
- (4) Recheck valve 180 degrees from first position.
- (5) Repeat steps (2) and (3) above. If high spots are same for both (2) and (4) positions, valve is warped and must be discarded.

- (6) If high spots occur in different positions, chuck is out of alignment. Total indicated run-out should not exceed 0.001 in. (0.025 mm).



TA295349

- (7) Wet-grind valves to an exact 30 degrees angle from horizontal.  
 (8) Check rim thickness. Discard valve if thickness less than 0.105 in. (2.67 mm).

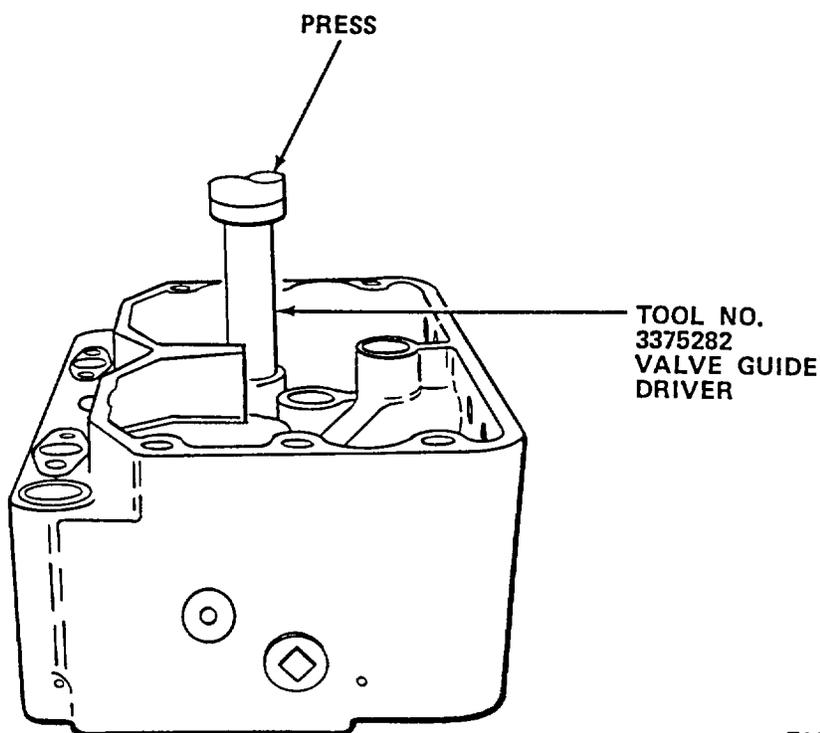


TA295350

- (9) Place pencil marks on valve face.  
 (10) Place valve in newly ground valve seat insert and rotate valve 10 degrees.  
 (11) Remove valve and check pencil marks. A good seat will be indicated if all pencil marks are broken.  
 (12) If pencil marks are not broken, seat insert grinding wheel and/or valve grinding wheel needs dressing or valve grinding machine chuck angle was not properly set up. Final check will be made with vacuum tester after assembly of head.

**q. Valve guide replacement.**

- (1) Using punch, carefully drive out worn or loose valve guides from underside of head.



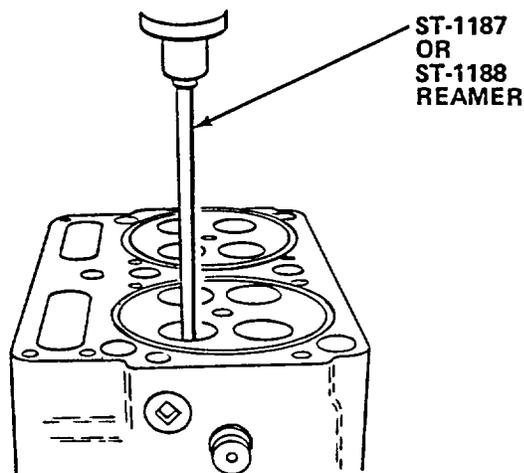
TA295351

- (2) With tool no. 3375282 valve guide driver, press guide into bore from top of head. Mandrel is designed to establish correct guide height. If special driver is not available, press guide into head to obtain 1.270 to 1.280 in. (32.258 to 32.512 mm) height.

**NOTE**

If valve guide is loose or bore in head is damaged, 0.010 and 0.015 in. (0.254 and 0.381 mm) outside diameter oversize guides are available.

- (3) Install oversize guides as follows:



TA295352

**NOTE**

**Tips of ST-1188 and ST-1187 reamers act as pilots.**

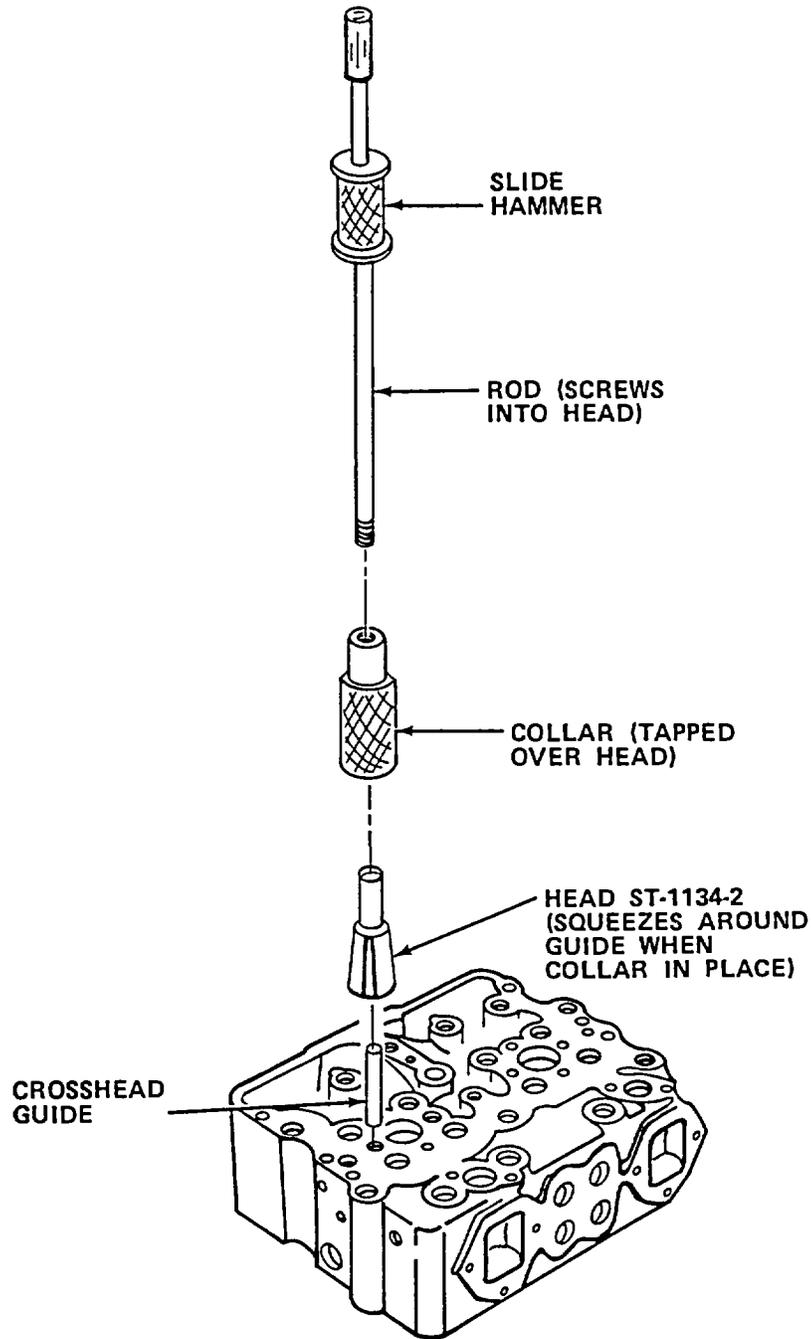
- (a) Lubricate ST-1187 reamer (0.010 in. [0.25 mm] oversize) with cutting oil.
  - (b) Using drill press with floating tool holder, ream out bore in head. Remove all burrs. Corner breaks should not exceed 0.015 in. (0.38 mm).
  - (c) Using ST-1217 driver, press oversize valve guide in head.
  - (d) If damaged valve bore does not clean up, use ST-1187 reamer (0.015 in. [0.381 mm] oversize).
  - (e) Repeat steps (a), (b), and (c) above.
- (4) Insert valve stem into guide and check for freedom of movement.

**CAUTION**

**HANDLE REAMER WITH CARE TO PREVENT DAMAGE TO CARBOLOY CUTTING EDGES.**

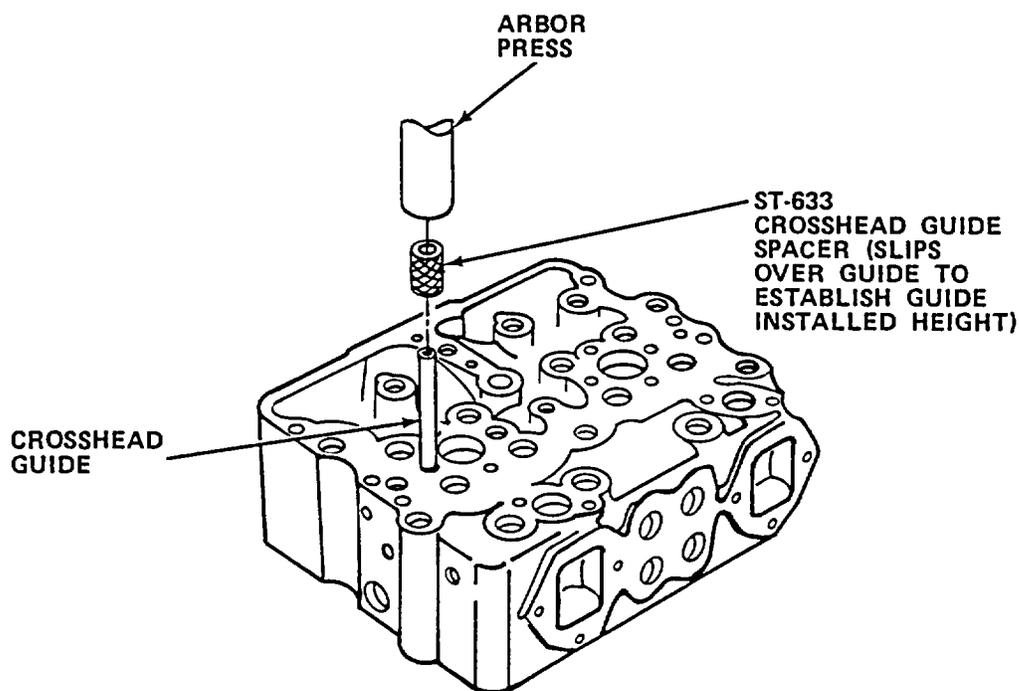
- (5) If movement is not smooth or some tightness is encountered, ream guide with tool no. 3376200 reamer. Use cutting oil for proper finish. Measure bore of guide after reaming. Bore diameter should not exceed 0.4532 in. (11.5112 mm).

r. Crosshead guides replacement.



TA295353

- (1) Remove crosshead guides marked for replacement using ST-1134 dowel pin extractor.
- (2) Lubricate new guide with engine oil and press guide into head approximately 1 in. (25.4 mm).



TA295354

- (3) Raise arbor press ram and slip ST-633 guide spacer over guide. Spacer establishes correct installed height of guide.
- (4) Continue pressing guide into head until ram bottoms against top of spacer.
- (5) Remove spacer.

**NOTE**

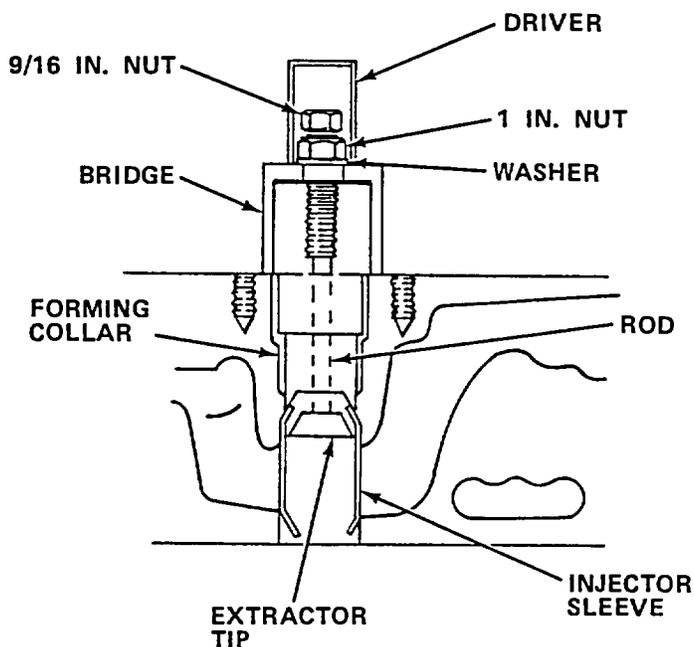
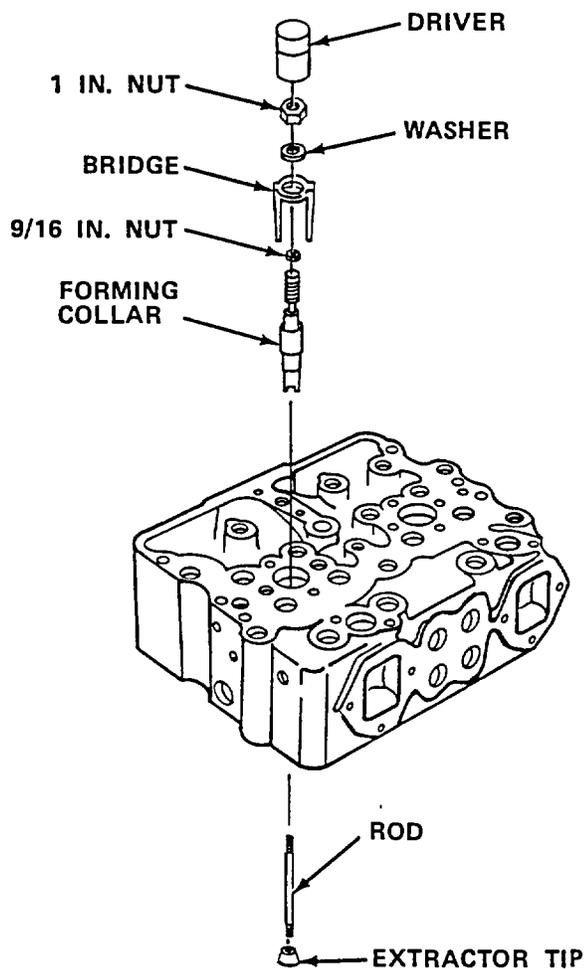
**A 0.030 in. (0.762 mm) oversize crosshead guide is available if guide is loose or bore is damaged.**

- (6) Install oversize guide as follows:
  - (a) Measure depth of guide bore in head.
  - (b) Drill bore to depth determined in (a) above with 29/64 in. (11.51 mm) drill.
  - (c) Apply cutting oil and ream bore with 15/32 in. (11.91 mm) reamer.
  - (d) Install oversize guide as per steps (2) thru (4) above.

**s. Injector sleeve replacement.**

(1) Remove injector sleeve with ST-1244 puller.

(a) Place head upside down.



**NOTE:  
TOOL SHOWN  
INSTALLED**

TA295355

(b) Screw extractor tip No. 3375825 onto rod.

(c) Slide rod into forming collar and secure with 9/16 in. nut.

(d) Place forming collar into injector bore.

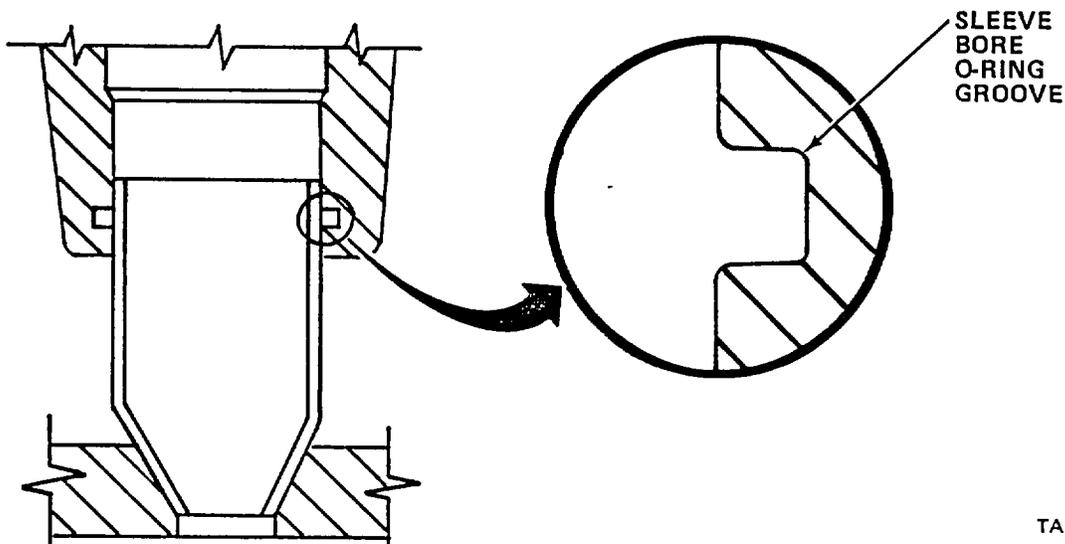
(e) Slide bridge over end of forming collar to provide support.

(f) Screw driver onto end of forming collar.

(g) Tap driver down until collar jaws bend top of injector sleeve over extractor tip.

(h) Tighten 9/16 in. nut to tightly draw extractor tip into injector sleeve. This secures sleeve to forming collar.

- (i) Remove driver and position washer over end of forming collar.
  - (j) Screw 1-in. nut onto forming collar.
  - (k) With air impact wrench, turn nut until forming collar loosens.
  - (l) Remove forming collar with injector sleeve from head.
  - (m) Remove 9/16 in. nut, rod with extractor tip, and injector sleeve.
  - (n) Discard sleeve.
- (2) Install injector sleeve.
- (a) Clean injector sleeve bore thoroughly.



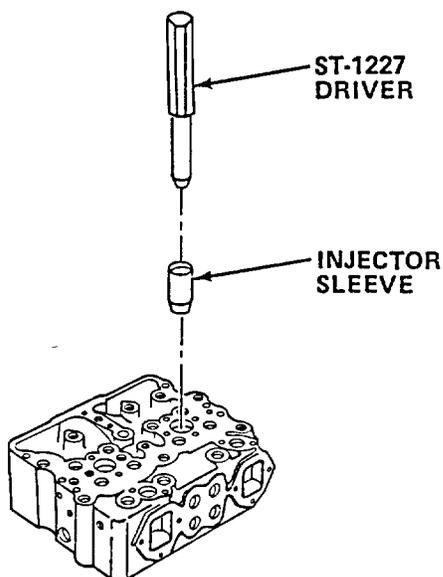
TA295356

- (b) Inspect sleeve bore O-ring groove for burrs and sharp edges. Remove defects with file.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC).**

- (c) Clean filings out of bore with compressed air.
- (d) Lubricate new O-ring with engine oil and install in groove.



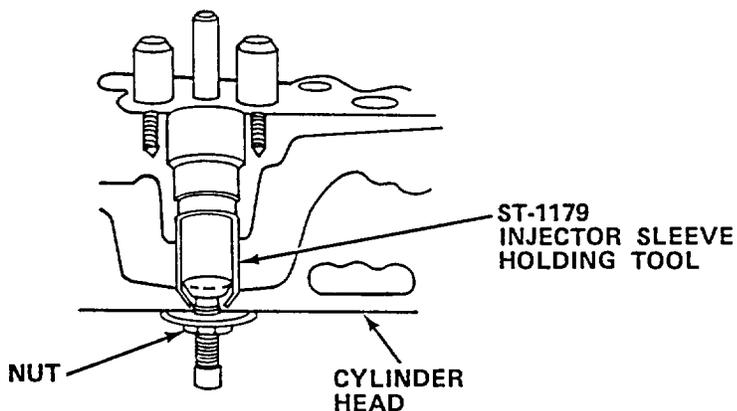
TA295357

- (e) Slide new sleeve onto ST-1227 injector sleeve driver.

**CAUTION**

**DO NOT STRIKE MANDREL WITH HAMMER WHILE INITIALLY INSTALLING SLEEVE. THIS MAY DAMAGE SLEEVE CAUSING IMPROPER SEATING.**

- (f) Push sleeve into head bore until it bottoms.



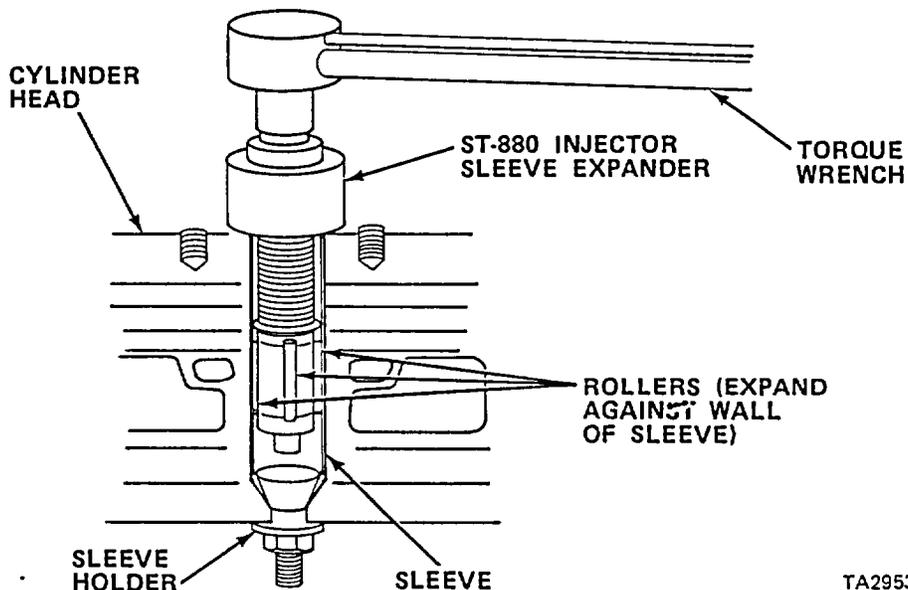
TA295358

- (g) Install ST-1179 injector sleeve holding tool and torque nut to 35 40 ft lbs (47 - 54 N•m).
- (h) Reinsert sleeve driver and apply two moderate blows to driver with hammer. This ensures sleeve is properly seated.
- (i) Retorque injector sleeve holding tool nut.

- (3) Expand injector sleeve.

**NOTE**

Top 1/2 in. (12.70 mm) of sleeve is expanded against top injector bore of head to form tight sealing area. O-ring in upper bore groove provides additional sealing.



TA295359

- (a) Insert ST-880 injector sleeve expander into injector bore.  
 (b) Set collar so that only top 1/2 in. (12.70 mm) of sleeve will be expanded.

**CAUTION**

**OVERROLLING OF INJECTOR SLEEVE WILL CAUSE DEFORMATION OF SLEEVE INTO O-RING GROOVE.**

**NOTE**

**End of mandrel will have to be ground to accept socket.**

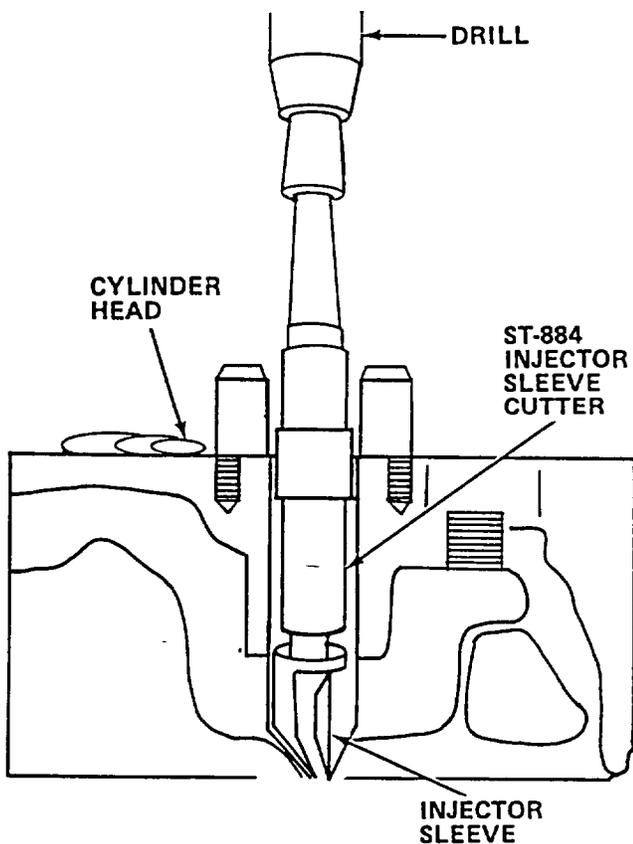
- (c) Using a torque wrench, turn mandrel until 6 ft lbs (8.1 N•m) maximum torque is obtained.  
 (d) Loosen mandrel.  
 (e) Remove torque wrench, sleeve expander, and sleeve holding tool.

(4) Injector seat cutting.

**NOTE**

**Fuel injector tip protrusion must be measured to establish 0.060 to 0.070 in. (1.524 to 1.778 mm) protrusion above milled face of cylinder head. Cutting of sleeve will provide proper injector seating and protrusion.**

- (a) Install fuel injector and secure with capscrews.
- (b) Torque capscrews to 10 12 ft lbs (14 16 Nm).
- (c) Using tool no. 3376220 gage block, measure tip protrusion.
- (d) Record dimension and compare to specification. Difference will represent depth of sleeve cut.
- (e) Remove fuel injector.



TA295360

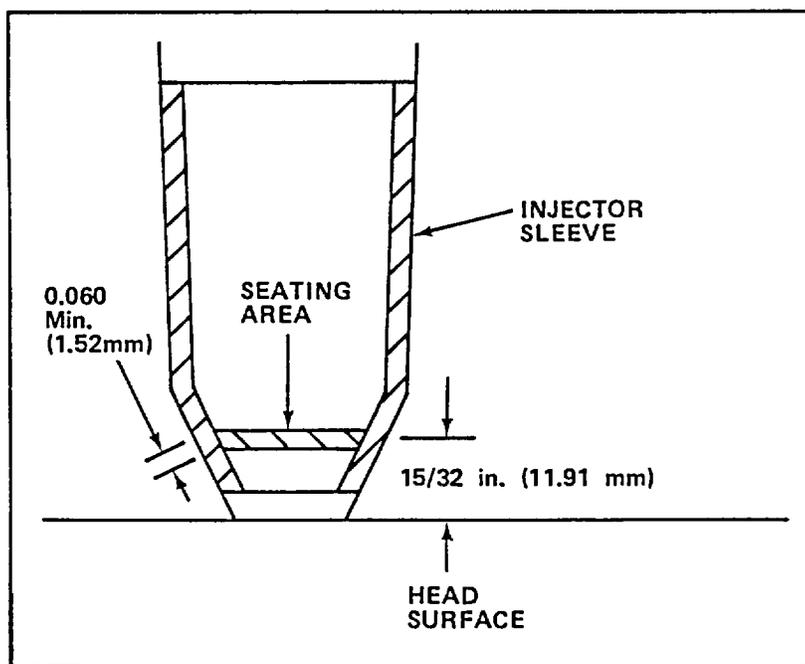
- (f) Place ST-884 seat cutter in drill press with ST-884-6 pilot.
- (g) Direct a solid stream of cutting oil to cutter to prevent chatter.

- (h) Cut injector seat to required depth.
- (i) Remove cutter and pilot.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC).**

- (j) Thoroughly clean bore with compressed air.
- (k) Lightly coat injector cup with Prussian bluing.
- (l) Install injector and torque securing capscrews to specifications in table 3-3.
- (m) Remove injector and check seat pattern.



TA295361

- (n) Bluing band must be 0.060 in. (1.524 mm) minimum width and located approximately 15/32 in. (11.91 mm) from bottom of head surface.
- (o) Reinstall fuel injector and recheck tip protrusion.
- (p) Retest head using air pressure method.

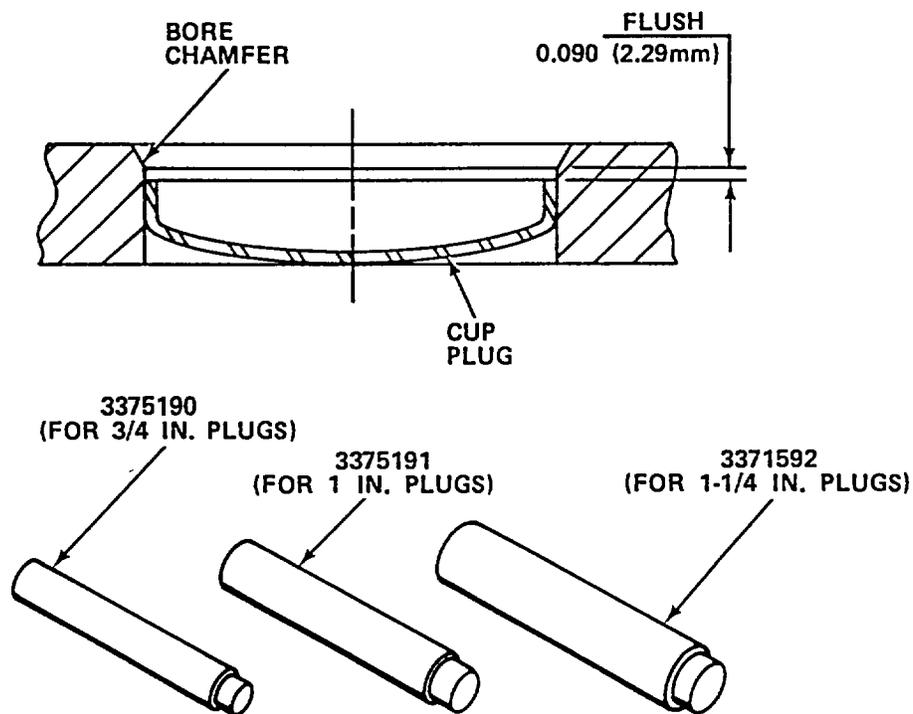
**3-32. ASSEMBLE CYLINDER HEAD**

a. Install pipe plugs, fittings, and cup plugs.

- (1) Coat threads of pipe plugs with thread sealant.
- (2) Install in same positions as removed.
- (3) Torque plugs according to size table below:

Plug Size In. (mm)	Minimum Ft Lbs (N•m)	Maximum Ft Lbs (N•m)
1/16 (1.58)	3 (4)	6 (8)
1/8 (3.17)	5 (7)	10 (14)
3/8 (9.52)	35 (47)	45 (61)
1/2 (12.70)	60 (81)	70 (95)
3/4 (19.05)	65 (88)	75 (102)
1 (25.40)	135 (182)	145 (197)

- (4) Coat threads of fuel inlet and outlet fittings with thread sealant.
- (5) Install fittings in read end of no. 3 cylinder head.
- (6) Coat outside diameter of cup plugs (if removed) and inside diameter of water passage port with 3375068 plug sealing compound.



TA295362

- (7) Install plug flush to 0.090 in. (2.29 mm) below bore chamfer with driver.

**b. Install valves.**

- (1) Dip valve stems in clean engine oil.
- (2) Insert valve into guide.

**CAUTION**

**PROTECT HEAD SEALING SURFACE AGAINST MARRING OF FINISH. HEAD GASKET LEAKAGE MAY OCCUR.**

- (3) Place head on bench face down.

**NOTE**

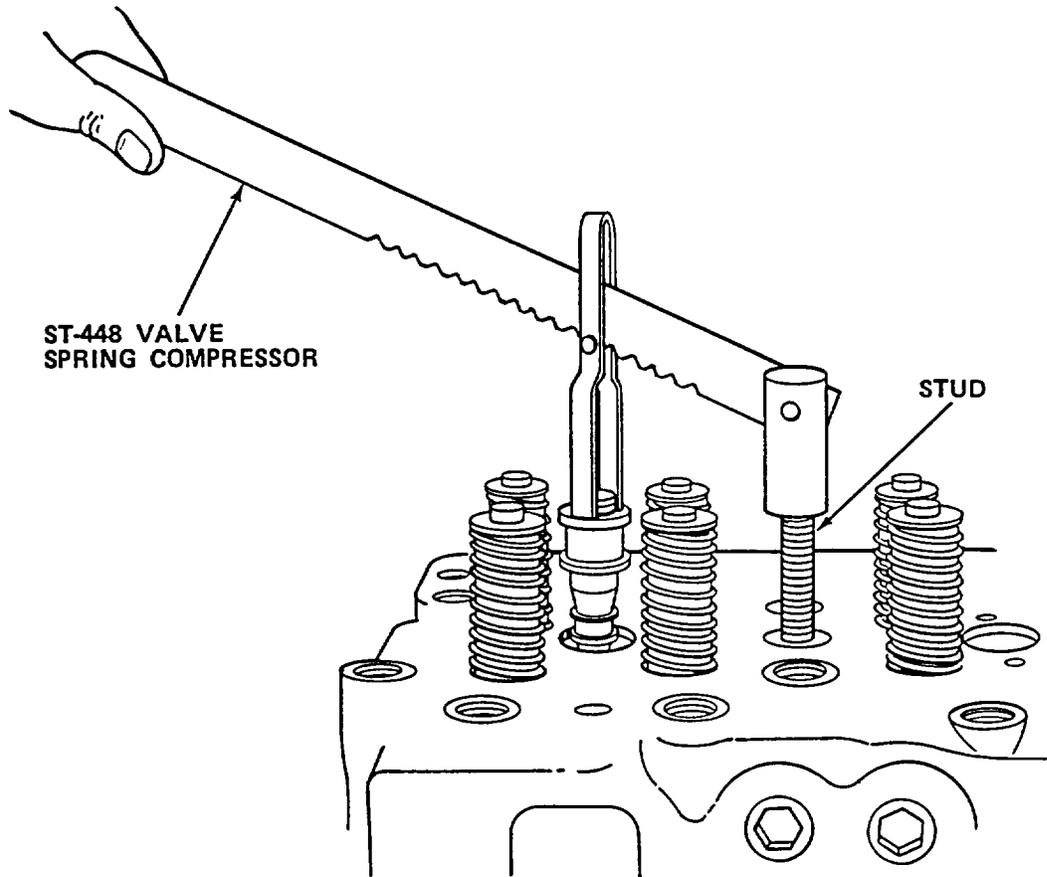
**If oversize valve guides were installed, it may be necessary to ream valve spring retainers to 0.768 0.773 in. (19.51 19.63 mm) to accommodate oversize guides.**

- (4) Place lower valve spring seat over valve guide.

**NOTE**

**Spacers should be used under valve spring when seat insert and valve have been reground more than a total of 0.030 in. (0.76 mm). A minimum of two spacers may be used.**

- (5) Place spacer(s) (if used) on lower spring seat.
- (6) Place spring and upper spring seat in position.



TA295363

- (7) Screw ST-448 valve spring compressor stud into rocker lever housing mounting capscrew hole in head.
- (8) Compress valve spring and install new half collets.
- (9) Release tension on spring.
- (10) Check collets to ensure they are properly seated.
- (11) Remove spring compressor.

c. Valve seating test.

**WARNING**

- P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.
- COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC).

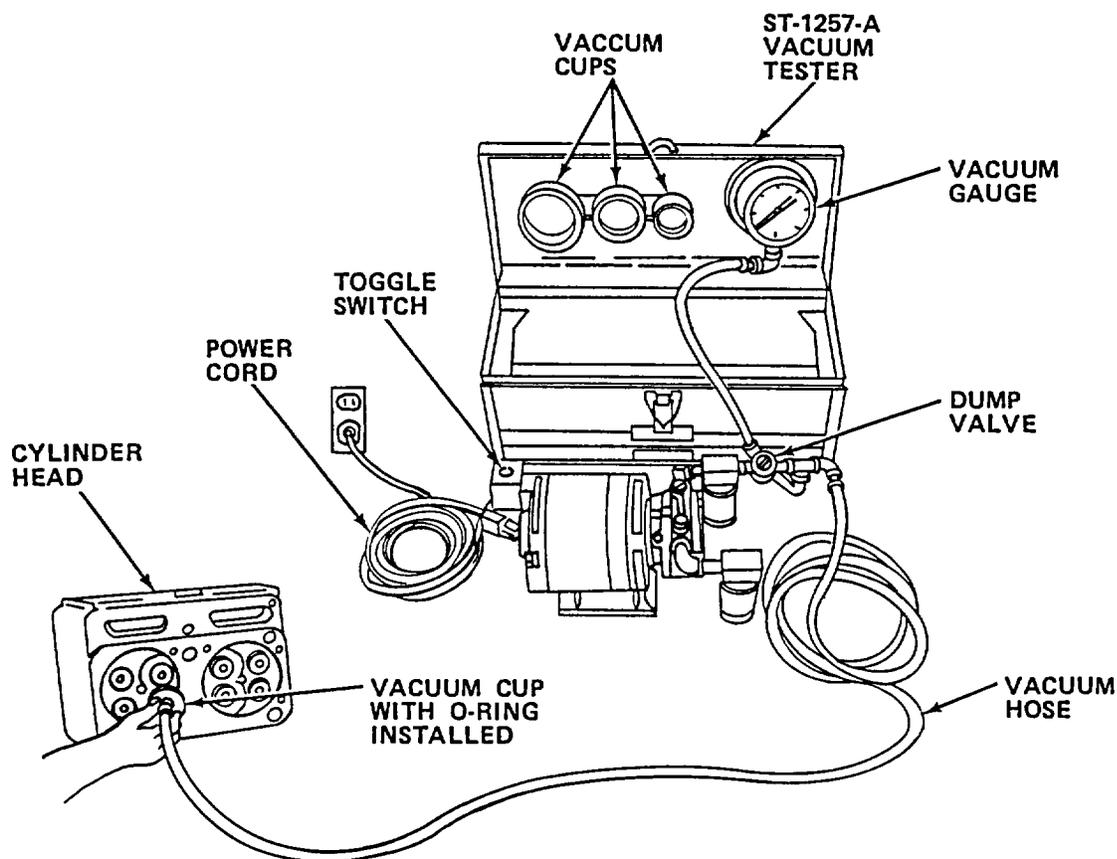
**CAUTION**

DO NOT VACUUM TEST HEADS WITH INJECTORS INSTALLED. INJECTORS COULD CAUSE MISALIGNMENT OF VALVES IN SEATS AND RESULT IN LEAKAGE DURING TESTING.

**NOTE**

ST-1257-A valve vacuum tester is used to determine if valves are properly seated in head.

- (1) Clean valves and seats with solvent and dry with compressed air.



TA295364

- (2) Secure ST-1257-6 vacuum cup to vacuum pump suction hose.
- (3) Grease ST-1257-3 O-ring and insert into vacuum cup.
- (4) Insert power plug in 110 vac wall outlet.
- (5) Place vacuum cap over valve head. O-ring on cup should seat on flat surface of head.
- (6) Turn pump valve to open position.
- (7) Place toggle switch on. This provides power to motor driven vacuum pump.
- (8) Operate pump until vacuum gage indicates 25 in. (635 mm) vacuum.
- (9) Close dump valve and place toggle switch off.
- (10) Time drop off of vacuum as follows:
  - (a) Begin timing when gage hand reaches 18 in. (457.2 mm).
  - (b) Stop timing when hand reaches 8 in. (203.2 mm).
  - (c) If elapsed time is less than 10 seconds, valve seat is unsatisfactory.
- (11) Tap stem end of valve with softfaced mallet and retest.
- (12) If valve seat is still unsatisfactory:
  - (a) Check for leaking connection in tester by placing vacuum cup against clean window pane or any other flat surface. If vacuum drop occurs, check tester for loose connections.
  - (b) Check valve and seat face contact area to ensure it is free of dirt particles.

**NOTE**

**It is possible to have leak around valve seat insert and mistake that leak for valve seating area leakage.**

- (13) Apply grease around outside edge of insert to make a grease seal.
- (14) Retest valve.
- (15) Inspect grease seal for a break indicating air leakage is between wall of counterbore and outside edge of seat insert.
  - (a) Stake insert and retest.
  - (b) If unsatisfactory leak still exists around insert, remove insert and install next oversize.

- (16) If leakage is determined to be at valve-to-seat sealing area, regrind seat insert and reface valve.
- (17) Detach power plug from wall outlet.
- (18) Wipe entire head clean.

## **Section XII. ROCKER LEVER HOUSING ASSEMBLY REPAIR**

### **3-33. DISASSEMBLE ROCKER LEVER HOUSING ASSEMBLY AND LEVERS.**

- a. Clean rocker lever housing assembly.

#### **WARNING**

- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
- **P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (1) Clean housing in solvent. Dry with compressed-air.

#### **CAUTION**

**TAKE CARE NOT TO GOUGE OR GROOVE SEALING SURFACES. CAN RESULT IN OIL LEAKAGE.**

#### **NOTE**

**Housings are made of steel or aluminum.**

- (2) Carefully scrape gasket material from sealing surfaces. Wipe with cloth dampened with solvent.

#### **WARNING**

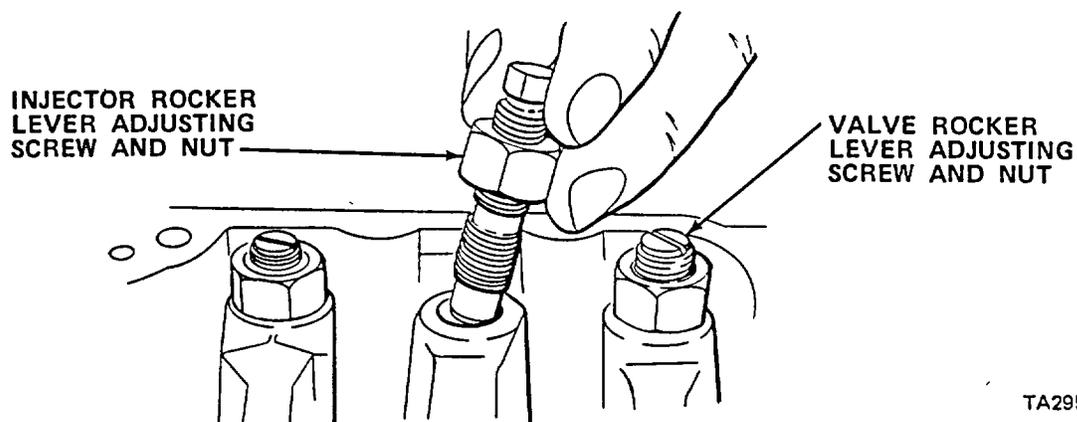
**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- (3) Dry with compressed air.

b. Disassemble housing.

**NOTE**

Injector rocker lever adjusting screws have hex heads. All others have slotted heads.

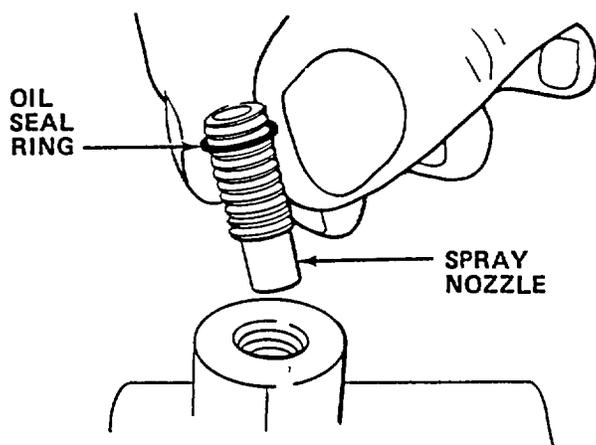


TA295365

(1) Remove adjusting screw nuts and screws from levers.

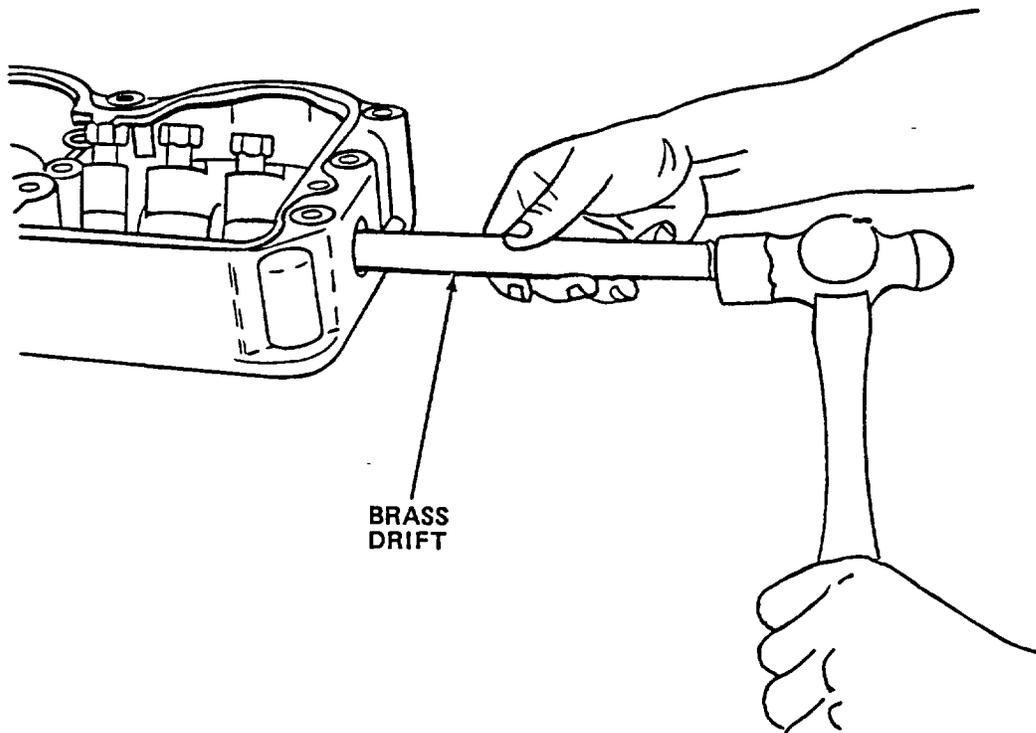
**NOTE**

Threaded oil spray nozzle has a drilled orifice which directs oil to engine brake housing. This oil operates brake system. Spray nozzle also secures rocker lever shaft in position.



TA295366

(2) Remove oil seal ring and spray nozzle from housing. Discard seal ring.

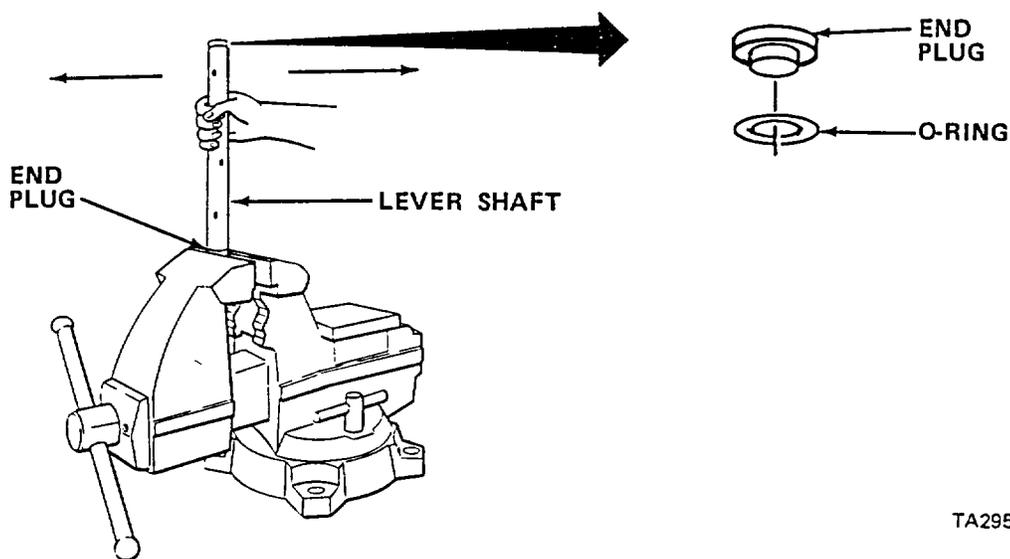


TA295367

**NOTE**

**Tag rocker levers for position as they are removed to ensure correct reassembly.**

- (3) With brass drift and hammer, drive lever shaft out of housing.
- (4) Lift rocker levers from housing.



TA295368

- (5) Clamp rocker lever shaft end plug in vise.
- (6) Move shaft back and forth until it separates from plug.
- (7) Discard plug and its O-ring.

**WARNING**

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- (8) Clamp opposite end plug in vise and remove and discard plug and O-ring.

**WARNING**

- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
- **P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

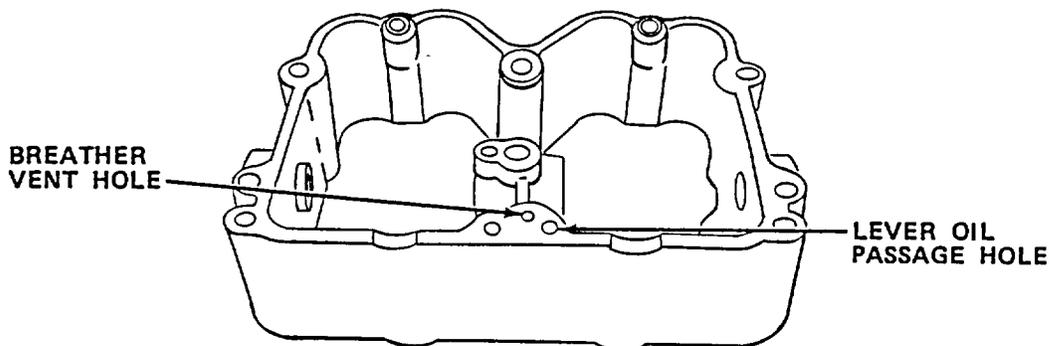
**CAUTION**

**ENSURE THAT ALL OIL HOLES ARE OPEN. CLOGGED HOLES WILL LEAD TO LEVER FAILURE.**

- (9) Flush shaft bore with solvent and dry with compressed air.

**3-34. INSPECT ROCKER LEVER HOUSING ASSEMBLY**

- a. Inspect housing and shaft.
- (1) Inspect all capscrew holes for damaged threads.
  - (2) Inspect housing for cracks, breaks, chips, uneven gasket surfaces, distortions, and broken out areas. Discard housing if cracked, distorted or broken.
  - (3) Inspect entrance of shaft bores for sharp edges, nicks, or burrs. Bores should have slight radius. Mark housing for repair if defects found.

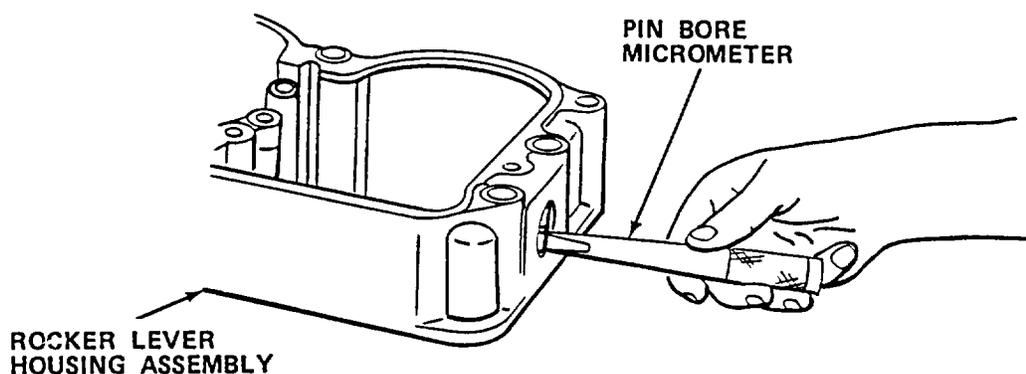


TA295369

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

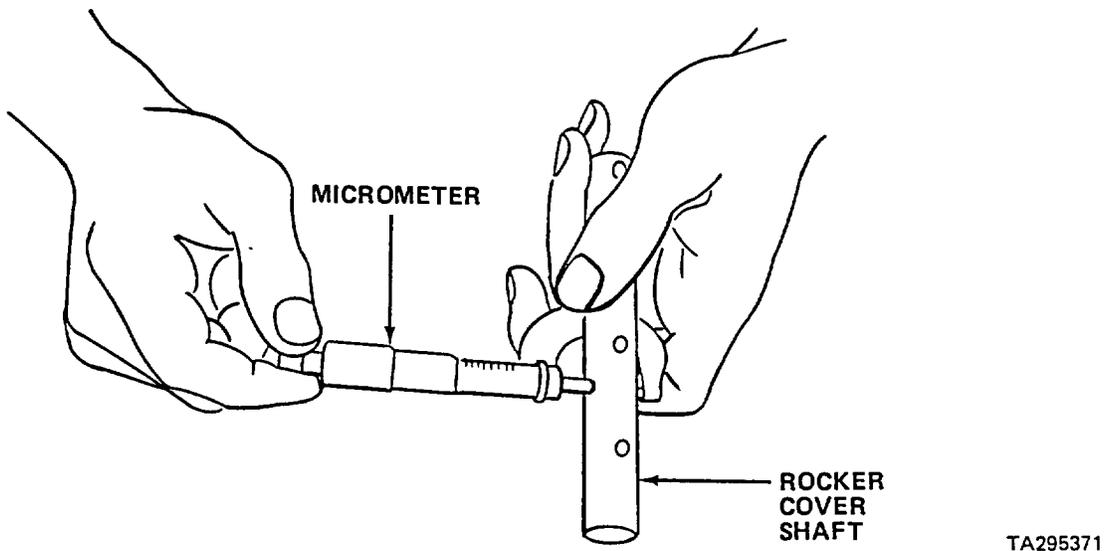
- (4) Check breather vent hole and lever oil passage hole to ensure they are free of dirt or deposits. Blow compressed air through holes to clear out any foreign matter.



TA295370

- (5) Measure inside diameter of rocker lever shaft bores in housing. Discard housing if diameter not within 1.1238 1.1246 in. (28.5445 28.5648 mm).

- (6) Check rocker lever shaft for wear or scoring and ridges.
- (7) If shaft has shoulders, and is scored or ridged due to rocker lever action, discard shaft.



- (8) Measure diameter of rocker cover shaft at several points along its length.
- (9) Discard shaft if diameter exceeds 1.122 in. (28.498 mm).

b. Inspect rocker levers.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (1) Clean levers in solvent. Dry thoroughly.

**WARNING**

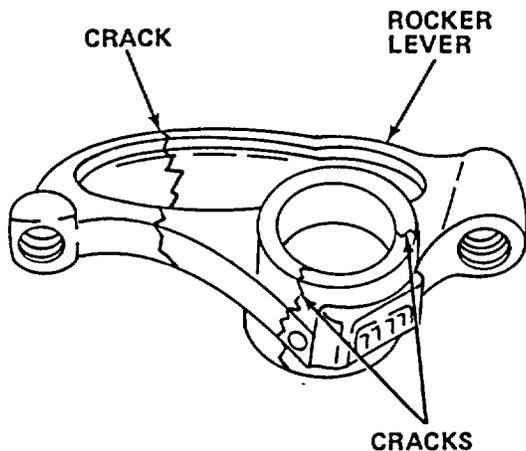
**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- (2) Blow out oil passages in levers with compressed air.

**NOTE**

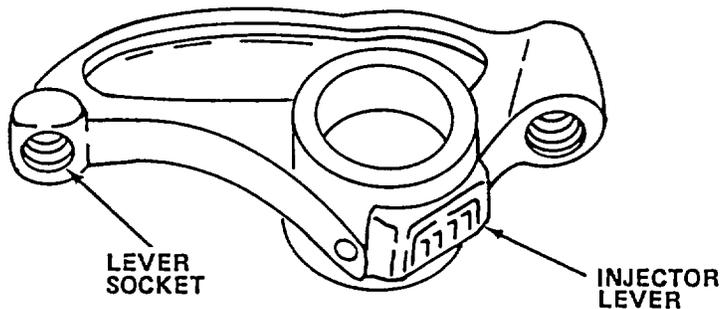
**Use magnetic particle inspection method to check for lever cracks.**

- (3) Apply coil magnetization with amperage at 300 - 500 with residual Magnaglo.



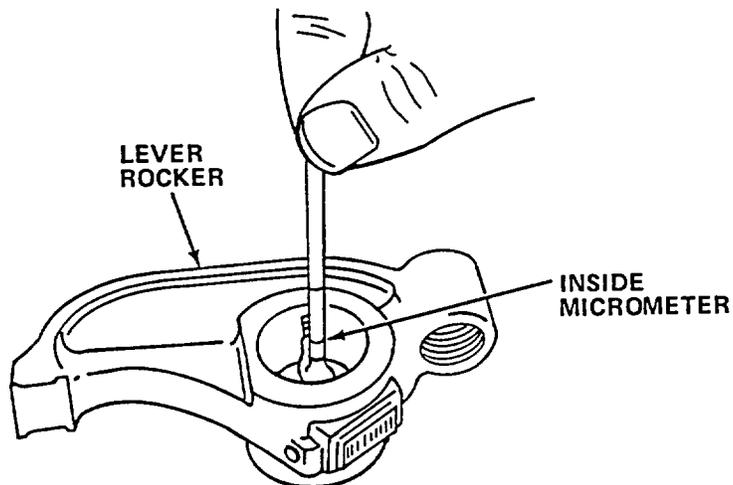
TA295372

- (4) Check levers for cracks. Illustration shows most likely areas for cracks to be found.



TA295373

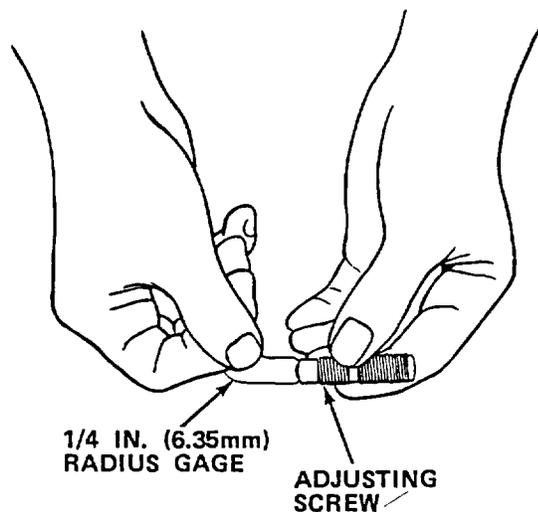
- (5) Check injector rocker lever sockets for scuffing and galling. Discard if defects found.
- (6) Coat a 0.500 in. (12.700 mm) ball or new injector link with Prussian bluing.
- (7) Insert ball or link into lever socket and then remove ball or link.
- (8) Check blue pattern in socket.
- (9) Mark socket for replacement if pattern does not cover at least 80 percent of socket seat area.
- (10) Check rocker lever bushings for scratches, pitting, or scoring.
- (11) Mark bushing for replacement if defects found.



TA295374

- (12) Measure inside diameter of bushing at several points across bushing.
- (13) Mark bushing for replacement if worn out-of-round or diameter exceeds 1.1286 in. (28.6664 mm).
- (14) Check each intake and exhaust lever-to-crosshead contact surface.
- (15) Replace lever if surface worn or damaged.

c. Inspect rocker lever adjusting screws.



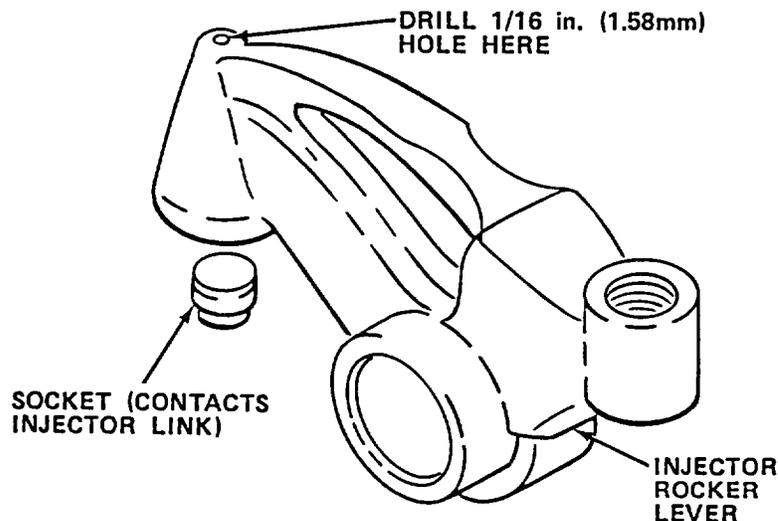
TA295375

- (1) Check adjusting screw ball end with 1/4 in. (6.35 mm) radius gage.
- (2) Discard screw if flat on bottom and ball not true sphere.
- (3) Discard screw if end galled.
- (4) Check thread condition on all screws and in levers. Check closely for thread distortions at assembly position of locknut. Screws must run freely through levers.

**3-35. REPAIR ROCKER LEVER HOUSING ASSEMBLY**

## a. Repair injector rocker lever.

- (1) Replace injector rocker lever socket.



TA295376

- (a) Drill 1/16 in. (1.58 mm) hole in lever above socket.
- (b) Insert pin punch through drilled hole and drive out socket.
- (c) Press new socket into lever. Ensure socket is fully seated.

- (2) Press plug into drilled hole and stake in position.

## b. Repair rocker lever housing.

**NOTE**

**Repair limited to removal of sharp edges, nicks, and burrs at shaft entrance bores.**

- (1) Place small strip of 240 grit aluminum oxide sanding cloth on steel rod split to accept paper.
- (2) Clean bores with sanding cloth and rod secured to hand drill.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- (3) Blow out bores with compressed air.

- c. Replace rocker lever bushings.

#### NOTE

**Bushings must be replaced if scratched, pitted, scored or worn beyond specification in table 3-3.**

**ST-691 block and mandrel set is used to remove and install lever bushings. One end is used for removal and other end (shouldered) for installation.**

**Block is cut out to allow lever to lay flat.**

- (1) Place rocker lever on block.
- (2) With non-shouldered end of mandrel alined with bushing, press bushing out of lever.

#### WARNING

- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
  - **P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**
- (3) Wipe bore with solvent and blow dry with compressed air.

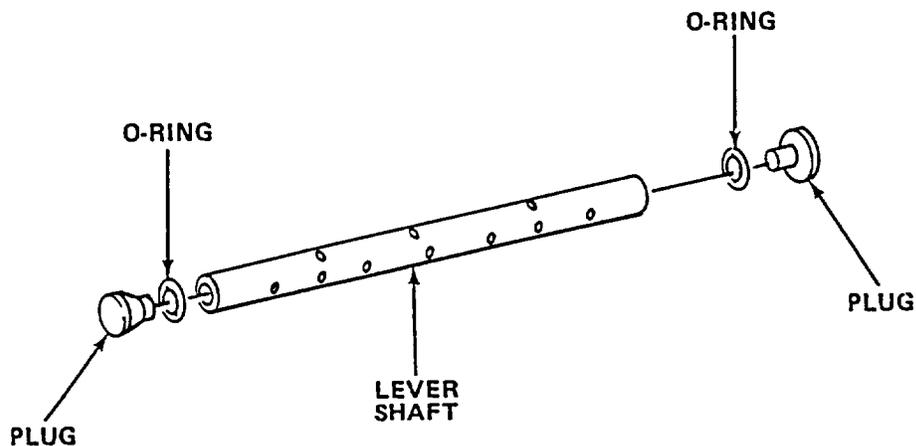
#### NOTE

**On injector and exhaust valve levers, install bushing so oil holes to crosshead nose or injector link and adjusting screw are open for oil flow. On intake valve levers with oil holes to crossover nose, install bushing so nose hole is closed and bushing slot hole is in line with adjusting screw oil hole.**

- (4) Place new bushing on shouldered end of mandrel.
- (5) Aline bushing oil holes and/or slot with holes in lever bore.
- (6) Press bushing into bore until mandrel shoulder contacts lever.
- (7) Remove mandrel.
- (8) Wipe assembly clean.

**3-36. ASSEMBLE ROCKER LEVER HOUSING ASSEMBLY**

- a. Assemble rocker lever shaft.



TA295377

- (1) Lubricate new O-ring with engine oil and place on new shaft plug.

**NOTE**

**Both plugs can be pressed into shaft at same time.**

- (2) Press plugs into shaft.

- b. Assemble rocker levers.

- (1) Screw adjusting screws into levers.

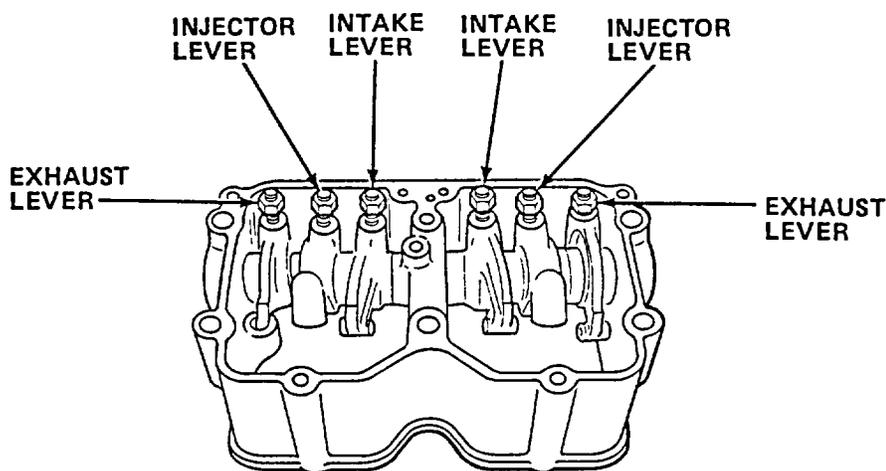
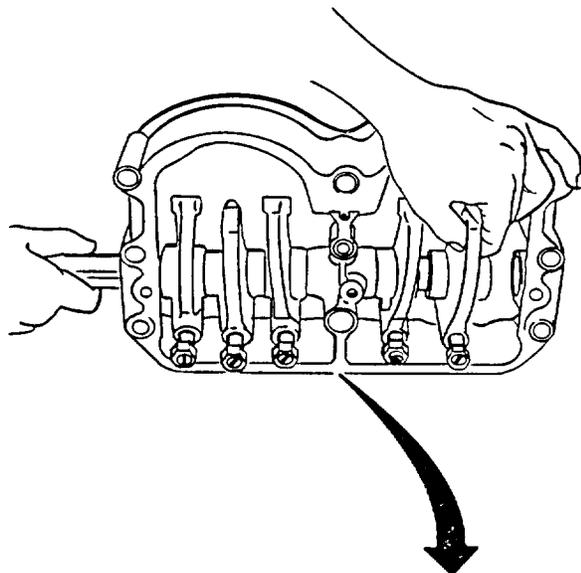
- (2) Install nuts onto adjusting screws.

- c. Assemble rocker lever housing assembly.

- (1) Lubricate shaft with engine oil.

- (2) Aline locking hole in shaft with locking hole in housing.

- (3) Coat rocker lever bushings with engine oil.



TA295378

- (4) Start shaft into housing, sliding levers on shaft as it is pushed through housing. Ensure that correct part numbered levers are in correct position as shown and remove tags.
- (5) Install and secure oil spray nozzle securing lever shaft to housing.
- (6) Install new oil seal ring on spray nozzle.
- (7) Check levers for freedom of movement on shaft.
- (8) Wipe assembly clean.

## Section XIII. PUSH TUBES REPAIR

## 3-37. INSPECT PUSH TUBES

- a. Inspect push tubes.

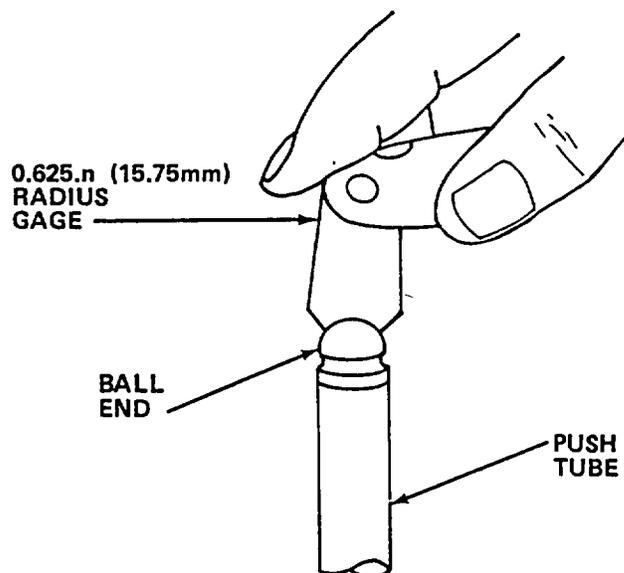
**WARNING**

- COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).
- P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.

- (1) Clean push tubes in solvent and dry with compressed air.

**NOTE**

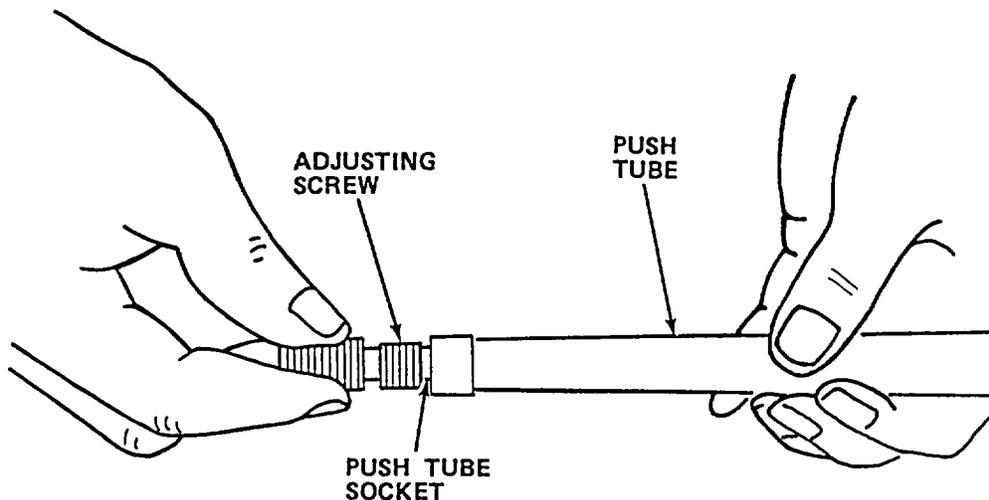
Injector push tubes are larger in diameter than valve push tubes. Intake and exhaust valve push tubes are identical.



TA295379

- (2) Check injector and valve push tube ball end for wear with 0.625 in. (15.875 mm) radius gage.
- (3) Replace tube if radius less than 0.619 in. (15.722 mm).

- (4) Check socket wear of push tube with ball end of new rocker lever adjusting screw or 1/2 in. (12.70 mm) check ball.



TA295380

- (a) Coat adjusting screw with Prussian bluing.
- (b) Insert screw into tube socket then remove screw.
- (c) Check blue pattern in socket.
- (d) Replace tube if pattern does not cover at least 80 percent of socket seat area.

**CAUTION**

**AN EXCESSIVELY WORN TUBE SOCKET OR BALL OR A BENT OR OUT-OF-ROUND TUBE WILL RESULT IN LOSS OF OIL PRESSURE AND MAY CREATE INCORRECT INJECTOR OR VALVE TIMING. NEW PUSH TUBES SHOULD BE USED ANYTIME NEW CAM FOLLOWER INSERTS ARE INSTALLED.**

**NOTE**

**Bent push tubes are usually a result of over-torqued adjusting screws.**

- (5) Check for bent push tubes.
  - (6) Discard tubes bent out-of-round more than 0.035 in. (0.89 mm) when located in centers of socket and ball.
  - (7) Shake tubes to see if oil has leaked into them.
  - (8) Replace tubes if internal leakage noted.
- b. Wipe tubes clean.

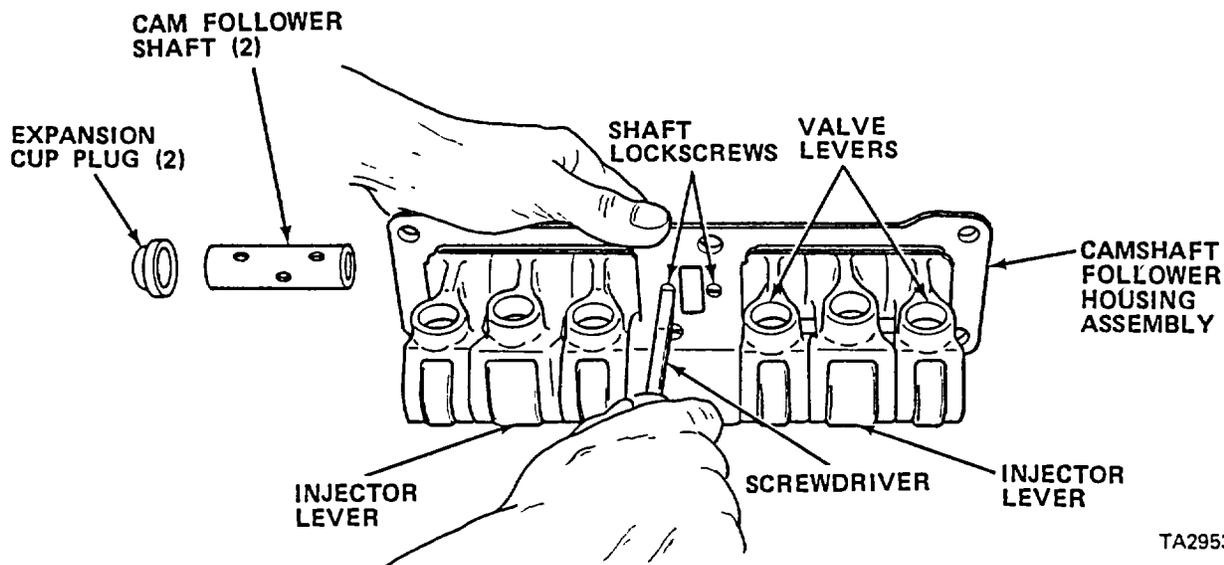
## Section XIV. CAM FOLLOWER HOUSING ASSEMBLY REPAIR

## 3-38. DISASSEMBLE CAM FOLLOWER HOUSING ASSEMBLY

**WARNING**

- COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).
- P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.

- a. Clean housing and cam follower assembly with solvent. Dry with compressed air.
- b. Disassemble cam follower housing assembly.



TA295381

**NOTE**

Each housing has two cam follower shafts.

- (1) Remove two lock screws securing shafts to housing.
- (2) With sharp pointed prick punch, punch hole in center of housing expansion cup plug.

- (3) Tap punch to side to force plug out of hole.
- (4) Use pliers (if necessary) to pull plug from hole. Discard plug.
- (5) With suitable mandrel, press both shafts out of opposite end of housing. This forces expansion cup plug out of housing bore. Discard plug.

**NOTE**

**Tag cam follower for position to ensure correct reassembly.**

- (6) Remove cam follower levers.

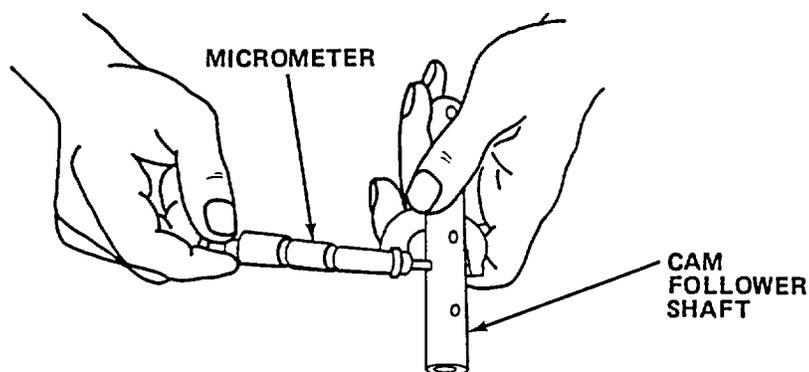
**3-39. INSPECT CAM FOLLOWER HOUSING ASSEMBLY**

- a. Inspect shafts.

**WARNING**

- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
- **MINERAL SPIRITS ARE POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (1) Dip shafts in mineral spirits and dry with compressed air.
- (2) Carefully check shafts around lockscrew end to ensure oil grooves are clean.
- (3) Check shafts for cracks, breaks, and galling. Discard if defects found.



TA295382

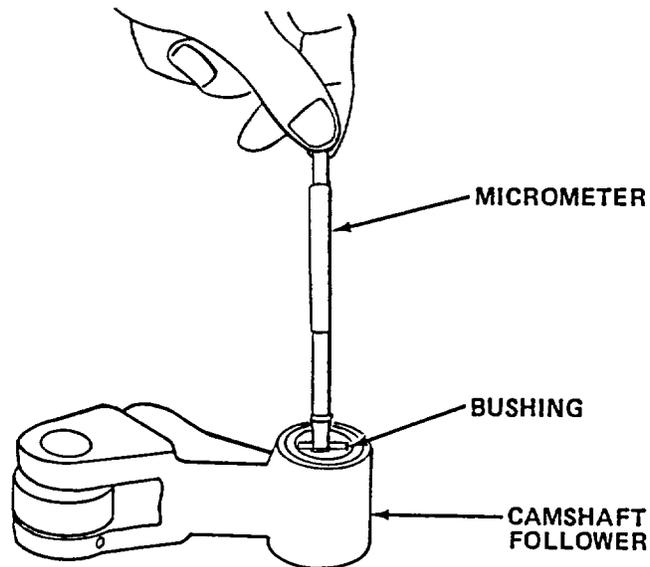
- (4) Measure diameter of shaft at various points along its length for wear and out-of-round.
- (5) Discard shaft if diameter less than 0.748 in. (18.999 mm).

b. Inspect housing.

- (1) Check housing for cracks or mating surfaces imperfections. Discard if defects found.
- (2) Check edges of expansion cup plug bores in housing for sharp edges or burrs.
- (3) If damage during removal of expansion cup plug is found, mark bore for repair.

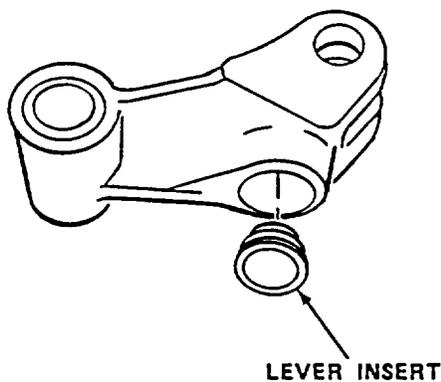
c. Inspect cam follower levers.

- (1) Check cam follower lever bushings for scratches, pitting, or scoring.
- (2) Mark bushing for replacement if defects found.



TA295383

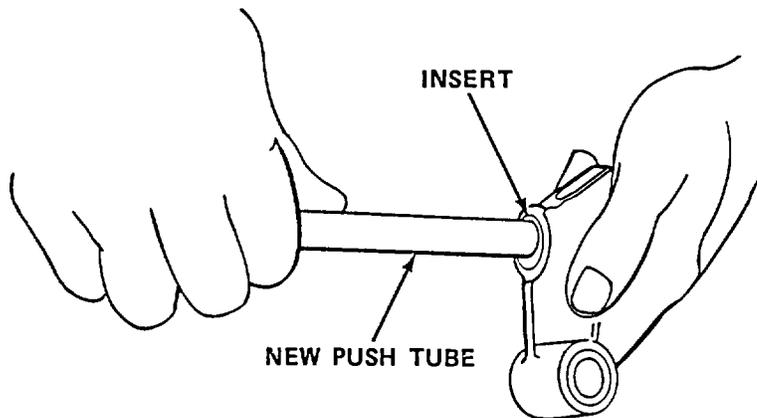
- (3) Measure inside diameter of bushing.
- (4) Mark bushing for replacement if inside diameter exceeds 0.752 in. (19.100 mm).



TA295384

- (5) Check follower lever insert for scoring.

- (6) Mark insert for replacement if scored.
- (7) Apply Prussian bluing to 0.625 in. (15.88 mm) check ball or new push tube ball.



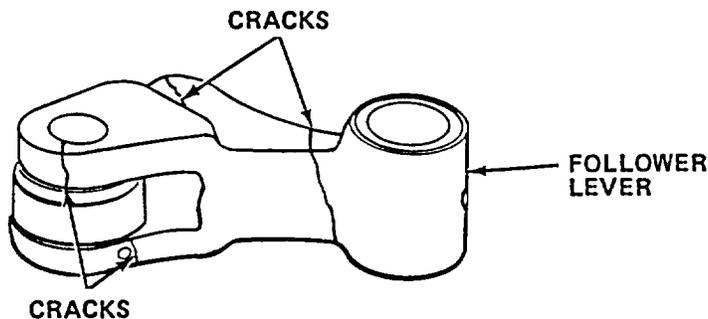
TA295385

- (8) Insert check ball or push tube into follower lever insert.
- (9) Remove ball or tube.
- (10) Check bluing area in insert. Area must blue-in a minimum of 80 percent.
- (11) Mark insert for replacement if blue-in specification not met.

**NOTE**

**Use magnetic particle method to inspect follower lever for cracks.**

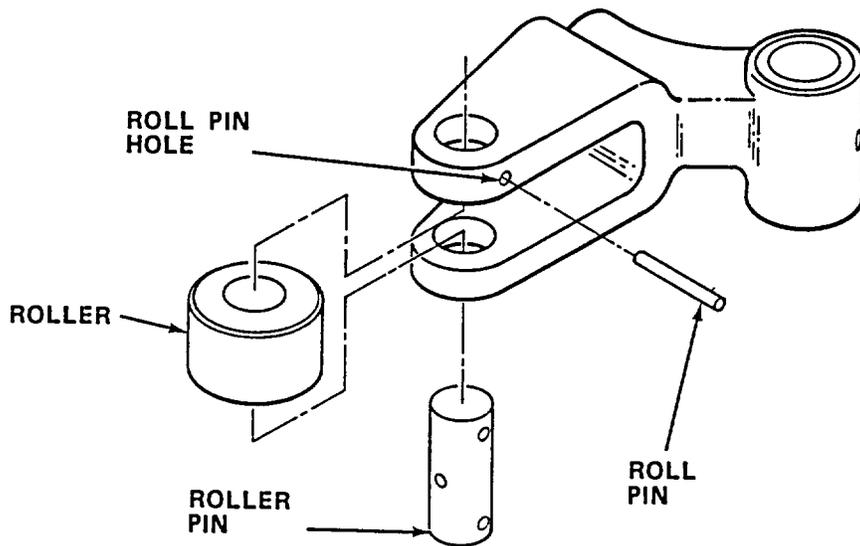
- (12) Apply coil magnetization with amperage at 300 to 500 with residual Magnaglo.



TA295386

- (13) Check follower lever for cracks. Illustration shows most likely area where cracks could occur.
- (14) Discard lever if any cracks are found on lever.

- d. Inspect cam follower lever rollers and pins.



TA295387

- (1) Drive out roll pin retaining cam roller pin to follower lever. Discard pin.
- (2) Remove roller pin and roller.

**WARNING**

- COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).
- MINERAL SPIRITS ARE POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.

- (3) Clean roller and roller pin with mineral spirits and dry with compressed air.
- (4) Direct air through small oil passages in lever to clear of foreign matter.

**CAUTION**

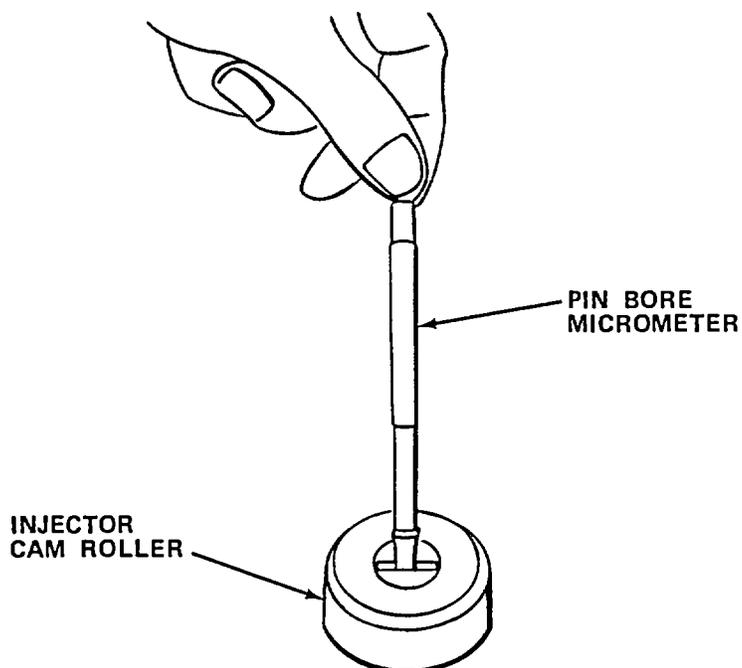
**IF ROLLERS SCORED OR GALLED, MAKE CAREFUL INSPECTION OF CAMSHAFT LOBES FOR DAMAGE.**

- (5) Inspect cam rollers for scoring and galling. Discard if defects found.

**NOTE**

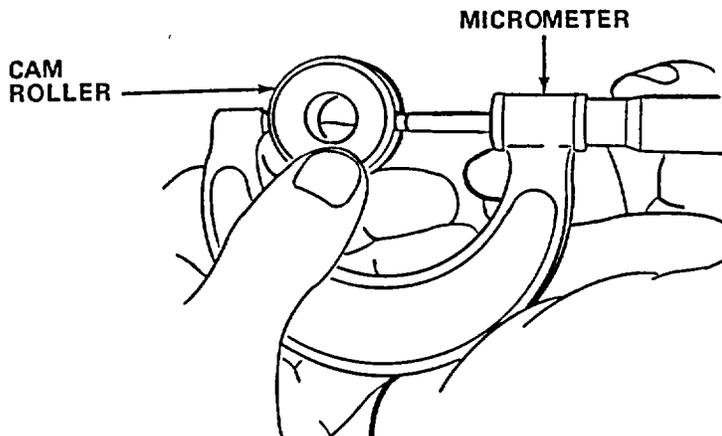
**Injector cam rollers have larger inside diameters than valve cam rollers.**

- (6) Set small bore telescoping gage to 0.7052 in. (17.9120 mm).



TA295388

- (7) Attempt to insert gage into bore of injector cam roller.
- (8) If gage enters bore, discard injector cam roller.
- (9) Use inside diameter micrometer to check roller bore for out-of-round. Discard if out-of-round.
- (10) Set telescoping gage to 0.5032 in. (12.7812 mm).
- (11) Attempt to insert gage into bore of valve cam roller.
- (12) If gage enters bore, discard valve cam roller.
- (13) Use inside diameter micrometer to check roller bore for out-of-round. Discard if out-of-round.

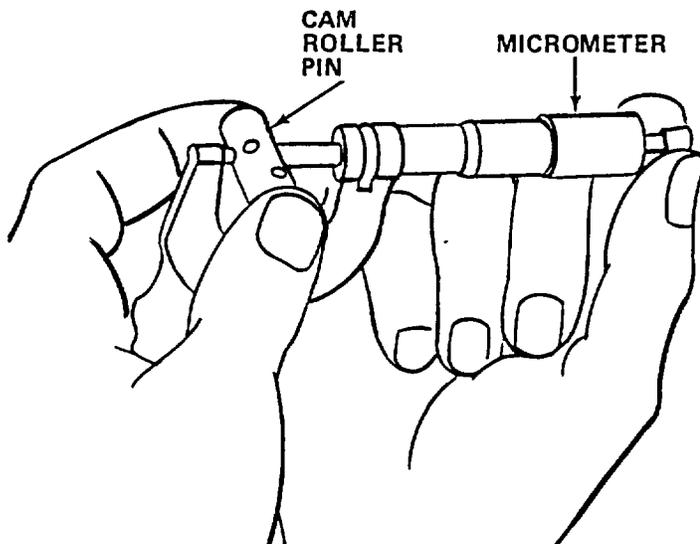


TA295389

**NOTE**

**Injector cam and valve cam rollers have same size outside diameters.**

- (14) Measure outside diameter of roller.
- (15) Discard roller if diameter less than 1.2485 in. (31.711 mm).
- (16) Measure concentricity of roller. Outside diameter must be concentric to inside diameter within 0.002 in. (0.05 mm).
- (17) Discard if not within specifications.

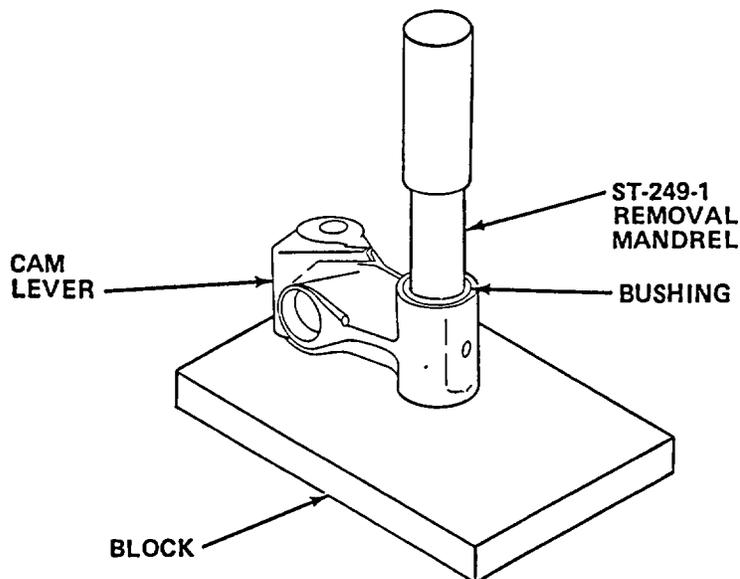


TA295390

- (18) Measure outside diameter of injector cam roller pin.
- (19) Discard pin if diameter less than 0.697 in. (17.70 mm).
- (20) Measure outside diameter of valve cam roller pin.
- (21) Discard pin if diameter less than 0.497 in. (12.62 mm).

**3-40. REPAIR CAM FOLLOWER HOUSING ASSEMBLY**

- a. Replace lever bushing.



TA295391

**NOTE**

**ST-249 mandrel and block set is used to remove and install lever bushing.**

- (1) Place lever on block.
- (2) Insert ST-249-1 mandrel in bushing.
- (3) Press bushing out of lever. Discard bushing.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

- (4) Used compressed air to clean out oil passage in lever bushing bore.
- (5) Wipe bore clean.

**CAUTION**

**OIL HOLES MUST ALINE TO PREVENT RAPID BUSHING WEAR AND FAILURE.**

- (6) Aline oil hole in new bushing with hole in follower lever.

- (7) Slide ST-249-2 sleeve and bushing onto mandrel.
- (8) Press bushing into lever with ST-249-2 mandrel and block while observing bushing oil hole through sleeve.
- (9) Remove mandrel and sleeve and check alinement of oil holes.
- (10) Chamfer each end of bushing with approximate 60 degree angle cutter secured in slow speed drill.
- (11) Fill oil hole in bushing with soft soap to prevent chips from entering oil passage during boring operation.
- (12) Check bored' bushing with ST-195 Go, No-Go gage.
- (13) Bore bushing to 0.750 - 0.7511 in. (19.053 - 19.078 mm).
- (14) Recheck bore bushing with ST-195 Go, No-Go gage.

**WARNING**

**COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**

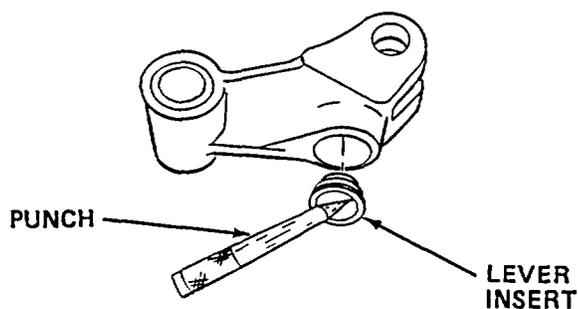
- (15) Blow soap from oil hole with compressed air.

**WARNING**

**P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (16) Clean lever in solvent and dry with compressed air.

- b. Replace follower lever insert.



TA295392

- (1) Carefully pry out follower lever insert with sharp pointed punch. Discard insert.

**WARNING**

- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
- **P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

(2) Clean insert bore with solvent and dry with compressed air.

**CAUTION**

**USE NEW PUSH TUBE ANYTIME INSERT IS REPLACED. THIS PRACTICE ENSURES PROPER VALVE AND INJECTOR PERFORMANCE.**

(3) Carefully press new insert into follower lever.

(4) Check insert to ensure it is fully seated.

c. Repair cam follower housing.

**NOTE**

**Repair limited to removal of sharp edges, nicks, and burrs at shaft entry points.**

(1) Place small strip of 240 grit aluminum oxide sanding cloth on steel rod, split to accept paper.

(2) Clean bore with sanding cloth and rod secured to hand drill.

**WARNING**

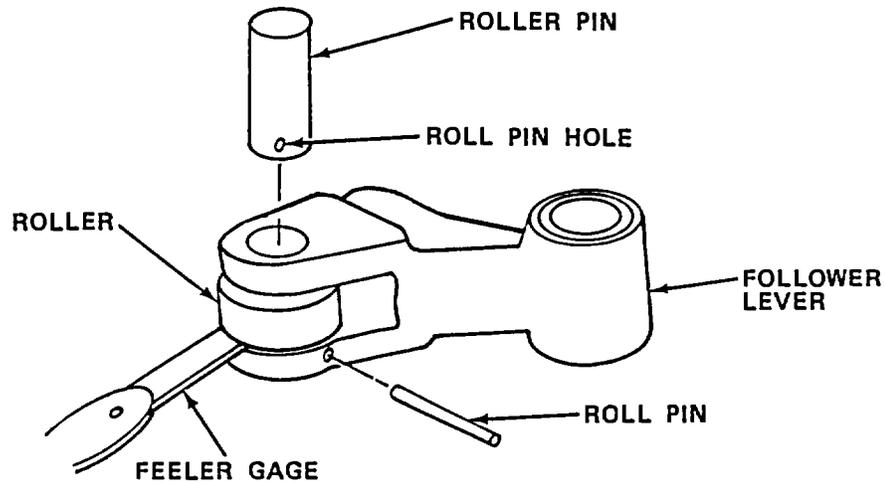
- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
- **P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

(3) Dip housing in solvent and dry with compressed air.

**3-41. ASSEMBLE CAM FOLLOWER HOUSING ASSEMBLY**

## a. Assemble cam follower lever.

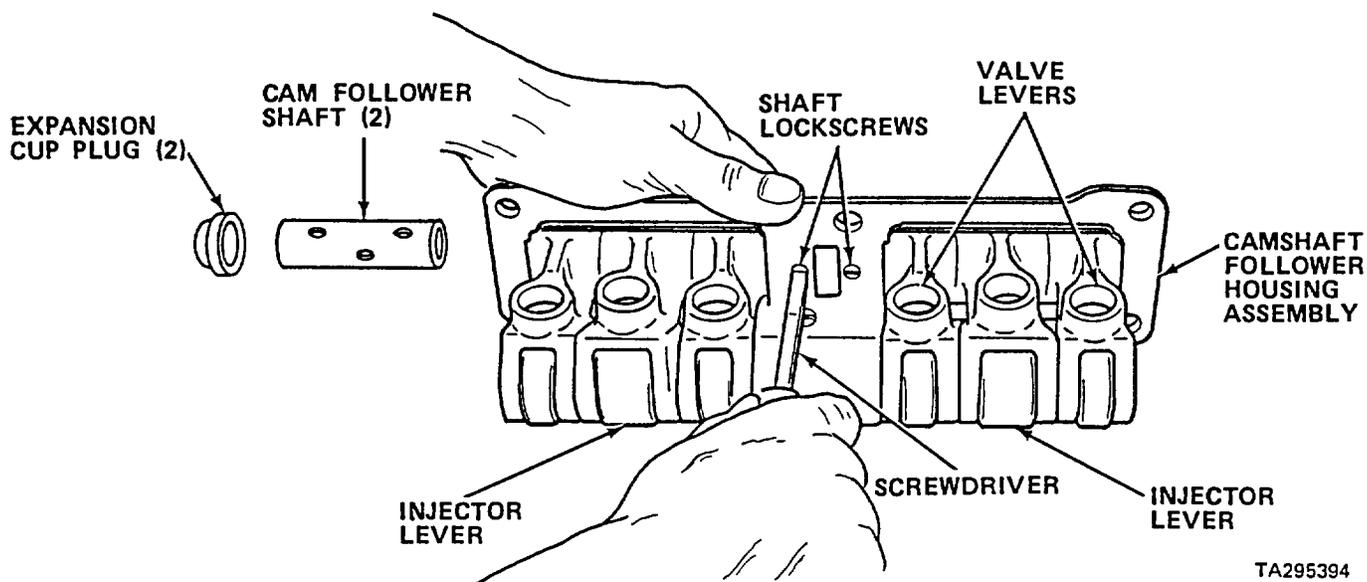
- (1) Place follower roller in position.
- (2) Aline roll pin hole in roller pin with hole in lever.



TA295393

- (3) Place 0.006 in. (0.15 mm) feeler gage between roller and lever.
- (4) Press roller pin into lever until roll pin holes are alined.
- (5) Remove feeler gage.
- (6) Install new roll pin.

- b. Assemble cam follower housing assembly.



TA295394

- (1) Position housing so that dowel pin alignment holes are at top of housing.
- (2) Apply coat of engine oil to lever bushing and place follower levers in position with push tube sockets facing upward. Ensure that injector lever is in center position in each assembly.
- (3) Apply coat of engine oil to shafts and slide them into housing.

#### NOTE

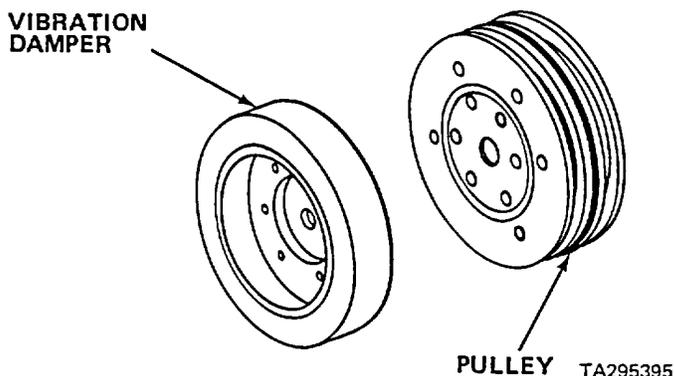
**Substitute lockbolt is installed to temporarily secure shaft to housing. This prevents lock screw breakage when expansion cup plugs are pressed into housing bore.**

- (4) Install substitute lockbolt into housing to temporarily secure shafts.
- (5) Apply light coat of retaining compound to housing expansion cup plug bore.
- (6) With ST-1053 plug driving mandrel (end marked 175831), press new plugs into housing.
- (7) Check that plug is flush to 0.010 in. (0.254 mm) below edge of hole.
- (8) Remove substitute bolt and install shaft lock screws.
- (9) Wipe assembly clean.

Section XV. VIBRATION DAMPER REPAIR

3-42. INSPECT VIBRATION DAMPER AND PULLEY

- a. Separate damper from pulley.
- b. Clean damper and pulley.



**WARNING**

- WEAR PROTECTIVE CLOTHING AND GOGGLES WHILE STEAM CLEANING TO PREVENT PERSONAL INJURY.
- P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.
- COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSI (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC).

(1) Steam clean both components and dry thoroughly with compressed air.

(2) Remove stubborn dirt, tar, and grease with solvent.

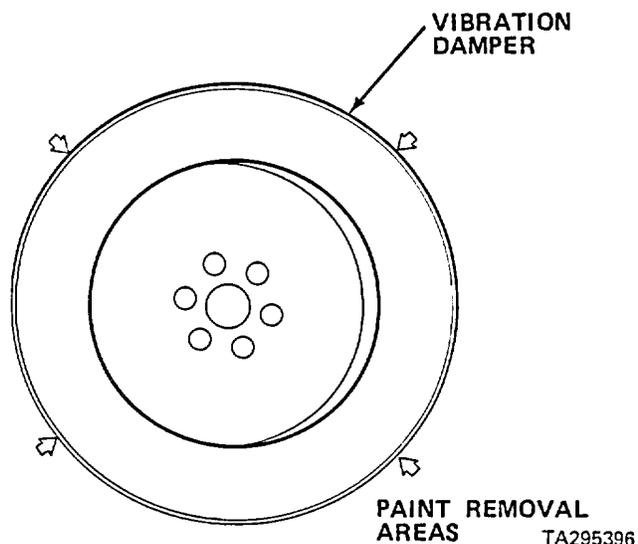
- c. Inspect damper.

**CAUTION**

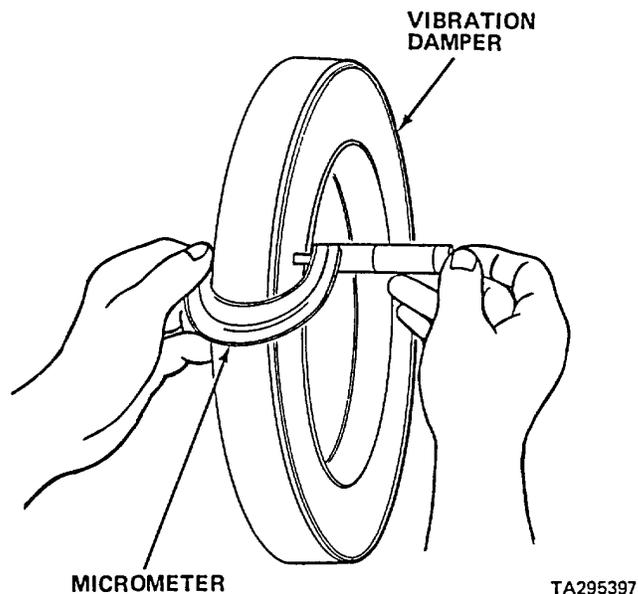
DO NOT USE COARSE EMERY CLOTH OR SCRAPER TO REMOVE PAINT. EXCESS MATERIAL REMOVAL MAY RESULT IN FALSE MEASUREMENTS.

**NOTE**

Damper is not repairable. If inspection shows defects, replace damper.



- (1) Remove paint with fine (240 grit) emery cloth from front and rear surfaces of damper at four equally spaced areas. Avoid areas with stamped lettering.
- (2) Measure and record thickness of damper at each of the equally spaced areas approximately 0.125 in. (3.175 mm) from outside edge of front cover plate.
- (3) Replace damper if variations of four dimensions exceed 0.010 in. (0.254 mm).
- (4) Spray damper with Spotcheck Developer, Type SKD-NF.
- (5) Place damper in oven heated to 200°F (93°C) for 15 minutes.



**WARNING**

**USE GLOVES TO PROTECT HANDS FROM BURNS. HANDLE DAMPER WITH CARE.**

- (6) Remove damper from oven.
  - (7) Inspect for oil smudges or fluid leakage.
  - (8) Replace damper if smudges or leakage is detected.
- d. Inspect pulley.

**NOTE**

**Pulley is not repairable. If inspection shows defects, replace pulley.**

- (1) Check pulley grooves for chips or cracks.
- (2) Check grooves for wear with new belt. Belt must not bottom in groove.
- (3) Discard pulley if defective.

**Section XVI. FLEX DISK AND RING GEAR ASSEMBLY REPAIR**

**3-43. INSPECT FLEX DISK AND RING GEAR ASSEMBLY**

**CAUTION**

**FLEX DISK AND RING GEAR ASSEMBLY MUST BE INSPECTED FOR CRACKS EVERY TIME IT IS REMOVED FROM ENGINE. A CRACKED DISK OR RING GEAR CAN DISINTEGRATE AND CAUSE SERIOUS ENGINE DAMAGE.**

**NOTE**

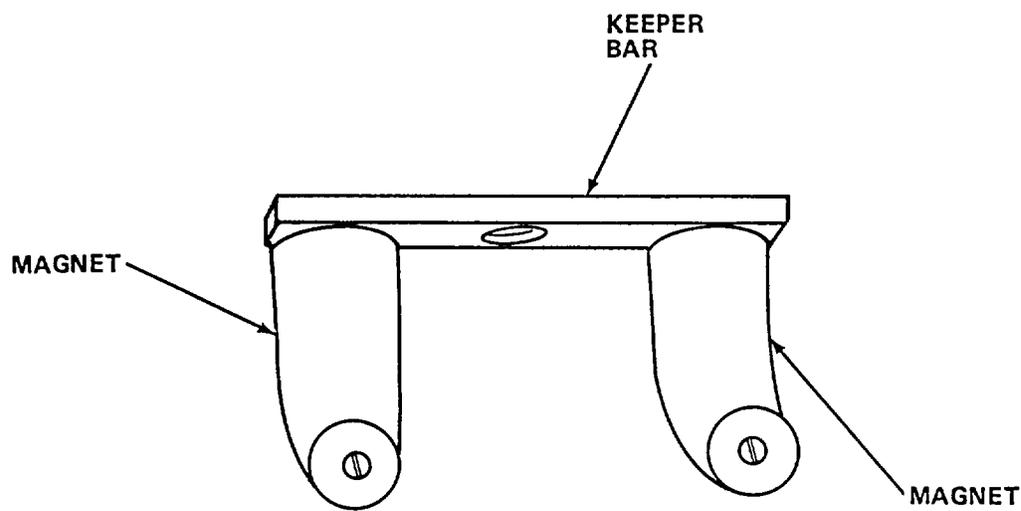
**No repair is authorized on flex disk and ring gear assembly**

- a. Inspect flex disk for cracks with ST-1166 magnetic crack detector.

**WARNING**

- **COMPRESSED AIR USED FOR CLEANING PURPOSES WILL NOT EXCEED 30 PSE (207 KPA). USE ONLY WITH EFFECTIVE CHIP GUARDING AND PERSONAL PROTECTIVE EQUIPMENT (GOGGLES, SHIELD, GLOVES, ETC.).**
- **P-D-680 SOLVENT IS POTENTIALLY DANGEROUS. AVOID PROLONGED OR REPEATED CONTACT WITH SKIN. KEEP AWAY FROM FLAME OR EXCESSIVE HEAT.**

- (1) Clean flywheel with solvent and dry with compressed air.



TA295398

- (2) Remove keeper bar from magnetic poles.
- (3) Place magnet on areas being inspected.

#### NOTE

**When dispensing powder, hold thumb partially over spray bulb head to keep cap from blowing off.**

- (4) Spray moderate amount of powder on area to be checked. Powder will remain in cracks and will show as a white line.
  - (5) If cracks discovered in bolt circle front or rear flanges, flex disk and ring gear assembly must be replaced.
  - (6) Wipe assembly clean.
- b. Inspect ring gear.
- (1) Inspect ring gear for broken, cracked, or worn teeth.
  - (2) If ring gear defective, replace flex disk and ring gear assembly. Ring gear and flex disk cannot be separated.

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TEAR ALONG PERFORATED LINE

## THE METRIC SYSTEM AND EQUIVALENTS

### LINEAR MEASURE

1 Centimeter = 10 Millimeters = 0.01 Meters = 0.3937 Inches  
 1 Meter = 100 Centimeters = 1000 Millimeters = 39.37 Inches  
 1 Kilometer = 1000 Meters = 0.621 Miles

### WEIGHTS

1 Gram = 0.001 Kilograms = 1000 Milligrams = 0.035 Ounces  
 1 Kilogram = 1000 Grams = 2.2 Lb  
 1 Metric Ton = 1000 Kilograms = 1 Megagram = 1.1 Short Tons

### LIQUID MEASURE

1 Milliliter = 0.001 Liters = 0.0338 Fluid Ounces  
 1 Liter = 1000 Milliliters = 33.82 Fluid Ounces

### SQUARE MEASURE

1 Sq Centimeter = 100 Sq. Millimeters = 0.155 Sq Inches  
 1 Sq. Meter = 10,000 Sq Centimeters = 10.76 Sq Feet  
 1 Sq Kilometer = 1,000,000 Sq Meters = 0.386 Sq Miles

### CUBIC MEASURE

1 Cu Centimeter = 1000 Cu Millimeters = 0.06 Cu Inches  
 1 Cu Meter = 1,000,000 Cu Centimeters = 35.31 Cu. Feet

### TEMPERATURE

$5/9 (^{\circ}\text{F} - 32) = ^{\circ}\text{C}$   
 212° Fahrenheit is equivalent to 100° Celsius  
 90° Fahrenheit is equivalent to 32° Celsius  
 32° Fahrenheit is equivalent to 0° Celsius  
 $9/5 ^{\circ}\text{C} + 32 = ^{\circ}\text{F}$

## APPROXIMATE CONVERSION FACTORS

<u>TO CHANGE</u>	<u>TO</u>	<u>MULTIPLY BY</u>
Inches .....	Centimeters .....	2.540
Feet.....	Meters .....	0.305
Yards .....	Meters .....	0.914
Miles .....	Kilometers .....	1.609
Square Inches .....	Square Centimeters .....	6.451
Square Feet .....	Square Meters .....	0.093
Square Yards .....	Square Meters .....	0.836
Square Miles .....	Square Kilometers .....	2.590
Acres .....	Square Hectometers .....	0.405
Cubic Feet.....	Cubic Meters .....	0.028
Cubic Yards .....	Cubic Meters .....	0.765
Fluid Ounces .....	Milliliters .....	29.573
Pints .....	Liters .....	0.473
Quarts .....	Liters .....	0.946
Quarts.....	Liters .....	0.946
Gallons .....	Liters .....	3.785
Ounces .....	Grams .....	28.349
Pounds .....	Kilograms .....	0.45
Short Tons.....	Metric Tons .....	0.0907
Pound-Feet.....	Newton-Meters .....	1.356
Pounds per Square Inch .....	Kilopascals .....	6.895
Miles per Gallon .....	Kilometers per Liter .....	0.425
Miles per Hour .....	Kilometers per Hour.....	1.609

<u>TO CHANGE</u>	<u>TO</u>	<u>MULTIPLY BY</u>
Centimeters .....	Inches .....	0.394
Meters .....	Feet .....	3.280
Meters .....	Yards .....	1.094
Meters .....	Yards .....	1.094
Kilometers .....	Miles .....	0.621
Square Centimeters .....	Square Inches .....	0.155
Square Meters .....	Square Feet .....	10.764
Square Meters .....	Square Yards .....	1.195
Square Kilometers .....	Square Miles .....	0.386
Square Hectometers .....	Acres .....	2.471
Cubic Meters .....	Cubic Feet.....	35.315
Cubic Meters .....	Cubic Yards .....	1.308
Milliliters .....	Fluid Ounces .....	0.034
Liters .....	Pints .....	2.113
Liters .....	Quarts .....	1.057
Liters .....	Gallons .....	0.264
Grams .....	Ounces .....	0.035
Kilograms.....	Pounds .....	2.205
Metric Tons.....	Short Tons .....	1.102
Newton-Meters .....	Pound-Feet.....	0.738
Kilopascals .....	Pounds per Square Inch .....	0.145
Kilometers per Liter.....	Miles per Gallon .....	2.354
Kilometers per Hour.....	Miles per Hour .....	0.621

