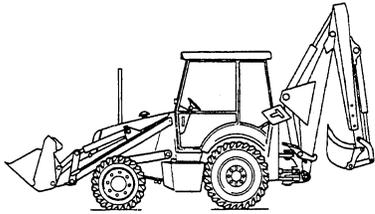


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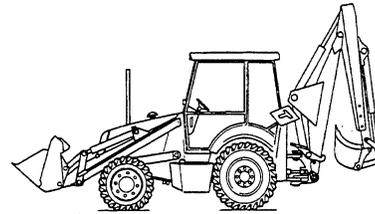
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**E SERIES  
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**555E, 575E, 655E, 675E**

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# **555E, 575E, 655E, 675E LOADER BACKHOE REPAIR MANUAL CONTENTS**

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**SECTION 2 -- FUEL SYSTEMS**

**SECTION 3 – ELECTRICAL**

**SECTION 4 -- TRANSMISSIONS**

**SECTION 5 -- REAR AXLE AND BRAKES**

**SECTION 6 -- STEERING AND FRONT AXLE**

**SECTION 7 -- CAB**

**SECTION 8 -- HYDRAULIC SYSTEM**

**SECTION 9 -- ACCESSORIES**

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# SECTION 1

## ENGINE

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# ENGINE

## DESCRIPTION AND OPERATION

Industrial engines are 4-cylinder and available in naturally aspirated and turbocharged forms.

All engines feature cross flow cylinder heads, with the inlet and exhaust manifolds on opposite sides of the cylinder head. The fuel and air combustion process takes place in the specially designed bowl in the crown of the pistons.

### Cylinder Head Assembly

The cylinder head incorporates valves and springs, with the valve rocker arm shaft assembly bolted to the cylinder block through the cylinder head. Cylinder head retaining bolts are evenly spaced with a six point pattern around each cylinder, this ensures an even clamping load across the cylinder head area.

The intake and exhaust manifolds are bolted to the head, the intake manifold is mounted on the right-hand side of the engine, with the diesel injectors mounted outside the rocker cover. The exhaust manifold is mounted on the left-hand side of the engine. Water outlet connections and thermostat are attached to the front of the cylinder block directly behind the radiator.

Valve guides are integral in the cylinder head, and valves with oversize stems are available in service. Special replaceable cast alloy valve seats are pressed into each valve port during manufacture, with oversize valve seats also available in service.

The exhaust valves are fitted with positive valve rotators with all valves using umbrella type oil seals. Valve lash is maintained by adjustment of the self locking adjusting screw, mounted in each of the rocker arms.

### Camshaft Assembly

The camshaft runs in three replaceable bearings. The camshaft drive gear is in mesh with and driven by the camshaft idler gear and crankshaft timing gear.

Camshaft end thrust is controlled by a thrust plate bolted to the block, and located between the camshaft gear and the front camshaft journal.

A helical gear is mounted on the rear of the camshaft, and drives the engine oil lubrication pump mounted forward of the flywheel.

### Crankshaft Assembly

The crankshaft is supported in the cylinder block by five main bearings. The crankshaft is manufactured from nodular cast iron with machined finished crank webs. End thrust is controlled by a thrust bearing incorporated in the center main bearing of the crankshaft.

Front and rear crankshaft oil sealing is effected by one-piece seals that are designed for long and durable service life.

### Connecting Rods

Connecting rods, wedge shaped at the small end, have been designed to reduce the reciprocating weight at the piston end. The connecting rods are of a heavy beam construction and are assembled as a matched set to each engine, attached to the crankshaft, by means of insert-type bearings.

They are retained in position by the connecting rod big end cap and secured by two bolts per rod. The small end of the connecting rod is fitted with a replaceable bronze bushing, through which the free floating piston pin is fitted. The steel pin is held in place within the piston by two snap rings.

### Pistons

Pistons are constructed of an aluminum silicon alloy with an iron insert for the top ring. The combustion chamber is recessed into the piston crowns. Each piston has two compression rings and one oil control ring, to reduce friction and increase positive sealing. All rings are located above the piston pin.

### Manifolds

The cross flow design aluminum intake and cast iron exhaust manifolds are on opposite sides of the cylinder head. This is designed to maintain balanced heat distribution within the cylinder head. The configuration of the manifolds also ensures minimum heat transfer to the intake manifold.

The intake manifold is connected through tubing to the air cleaner and in the rear end of the manifold a tapped hole is provided for installation of a thermostart or an ether cold starting aid.

**NOTE: On tractors where cold start equipment is not installed ensure the plug in the intake manifold is kept tight at all times. Considerable damage to the cylinder bores may be incurred by entry of dust or other foreign material if the plug is left loose or missing. Also, dirt and grit may be drawn through the air cleaner connections if they are not properly secured.**

### Cylinder Block Assembly

The cylinder block is an alloy cast iron with deep cylinder skirts, and water jackets for cooling the cylinders. The cylinder bores are machined integral with the cylinder block during the manufacturing process.

Cylinders are in line and vertical and numbered from 1 to 4 from the front to the rear of the engine. They can be bored oversize for installation of sleeves, which are available in service.

The oil pan which is attached to the bottom of the cylinder block is the reservoir for the engine oil lubrication system. An aluminum engine front cover and front plate is attached to the front of the engine and covers all of the timing gear assembly.

## Timing Gears

The crankshaft timing gear is heated and press fitted onto the front of the crankshaft, to a high degree of accuracy during manufacturing. This enables precise timing being maintained during the life of the engine. The crankshaft gear drives the camshaft idler gear which is attached to the front of the cylinder block. The idler gear then drives the camshaft and the injection pump via meshing helical gears. The camshaft gear is bolted to the front of the camshaft, and is keyed to maintain position of the gear on the camshaft.

## Lubrication System

Lubrication of the engine, Figure 1-1, is maintained by a rotor type oil pump mounted in the rear of the engine block, behind the flywheel. The oil pump is driven from the rear of the camshaft and draws oil from the engine oil pan through a tube and screen assembly.

A spring loaded relief valve is integral with the oil filter body mounted on the left-hand side of the engine block, and prevents overpressurization of the system.

A modine engine oil cooler is situated above the spin-on type oil filter mounted to its support housing, on the left-hand side of the engine. Oil flows from the filter to main oil gallery, which runs the length of the block and intersects the camshaft follower chamber.

The main gallery also supplies oil to the crankshaft main bearings, connecting rods, big ends and small ends. The underside of the pistons and pins are lubricated by oil pressure jets mounted adjacent to each main journal housing.

The camshaft drive gear bushing is pressure lubricated through a drilled passage from the front main bearing. The gear has small oil passages machined on both sides allowing excess oil to escape.

Timing gears are lubricated by splashed oil from the cam follower chamber, and the pressure lubricated camshaft drive gear bushing.

An intermittent flow of oil is directed to the valve rocker arm shaft assembly via a drilled passage in the cylinder block. This is located vertically above No. 1 camshaft bearing, and aligns to a hole in the cylinder head. The rotation of the camshaft allows a controlled intermediate flow of lubrication.

The turbocharger, where fitted, is supplied with oil from the oil filter support housing, mounted on the left-hand side of the engine.

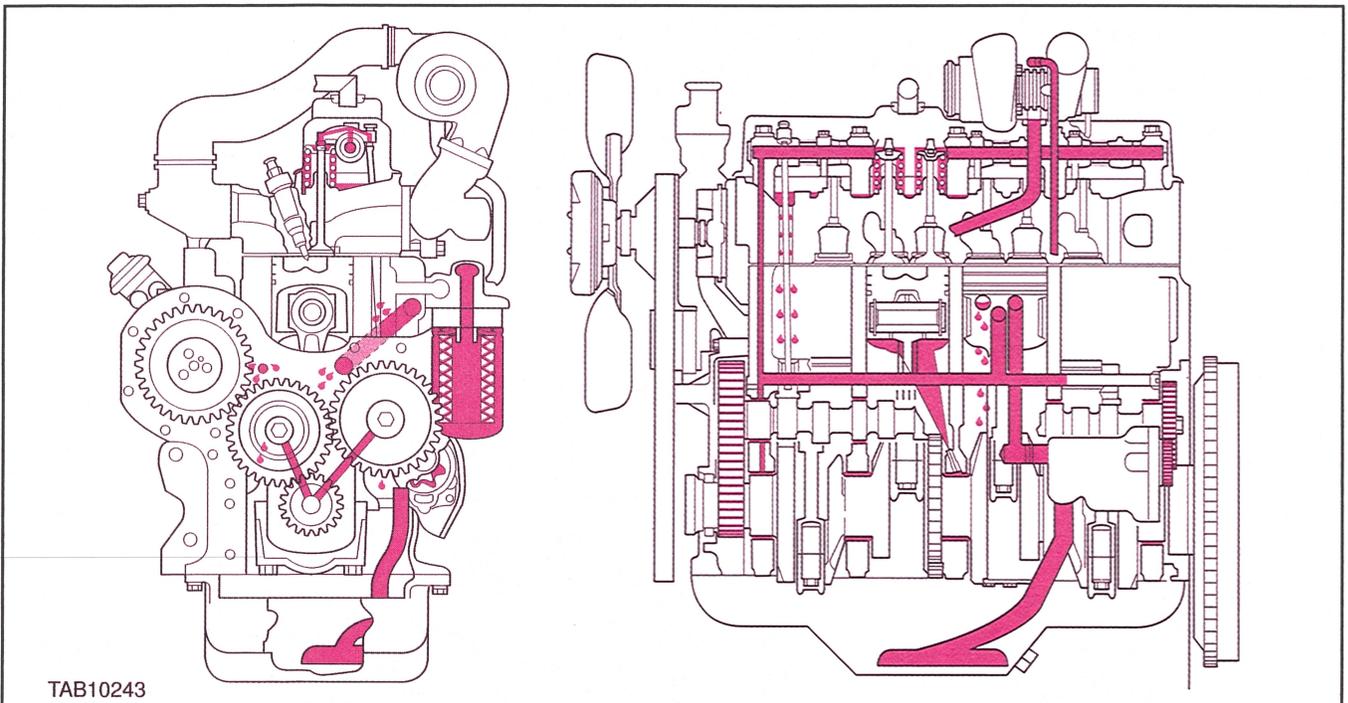


Figure 1-1

## Cooling System

**NOTE: Do not operate an engine without a thermostat. It is recommended that a solution of 50% clean water and 50% recommended antifreeze, with 5% corrosion inhibitor, see Specifications, is used. When the recommended antifreeze is not used, a 5% solution of the recommended corrosion inhibitor must be added to the cooling system.**

The function of the water pump mounted at the front of the engine is to maintain a continuous flow of water around the cooling system. This is essential to ensure correct engine temperature and performance during vehicle operation.

The pump is driven by a V-belt from the crankshaft pulley, when the engine is running.

The cooling system for the new generation engines is of the recirculating by-pass type with full length water jackets for each cylinder. The coolant is drawn from the bottom tank of the radiator by the water pump, which passes the coolant to the cylinder block. This coolant then cools the cylinder walls.

Passages in the cylinder head gasket allow coolant to flow from the cylinder block into the cylinder head. Cored passages also conduct the coolant to the fuel injector nozzle locations, before reentering the water pump below the thermostat.

The thermostat is located in the top of the water pump body, and controls the flow of the water as required by temperature changes.

**NOTE: A faulty thermostat may cause the engine to operate at too hot, or cold, an operating temperature. If not replaced this could result in a damaged engine, or impaired engine performance.**

When the thermostat is closed, Figure 1-2, a recirculating by-pass is provided to allow the coolant to recirculate from the head to the block to effect a faster warm-up.

Once the engine has reached its normal operating temperature, the thermostat will open, Figure 1-3, and allow water to be drawn through the radiator by the pump action. Cooled water then returns to the engine system.

Cooling occurs as the coolant passes down through the radiator cores, which are exposed to the air as it is drawn through the radiator by the fan.

The cooling system incorporates a drain plug on the right-hand side of the cylinder block, 1, Figure 1-4.

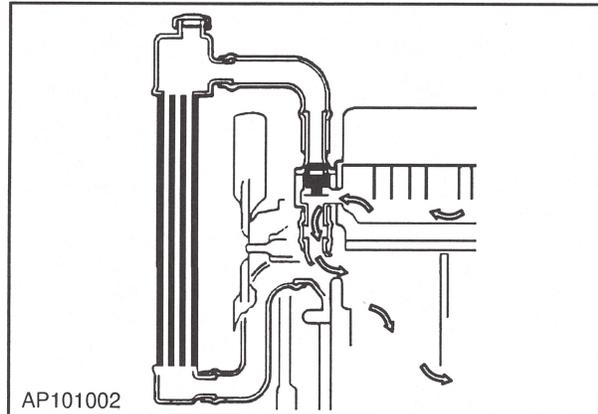


Figure 1-2

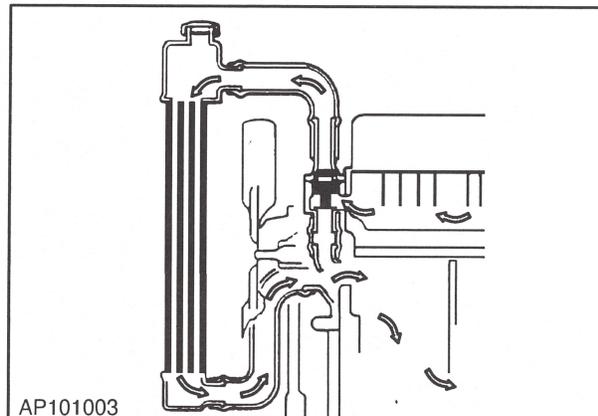


Figure 1-3

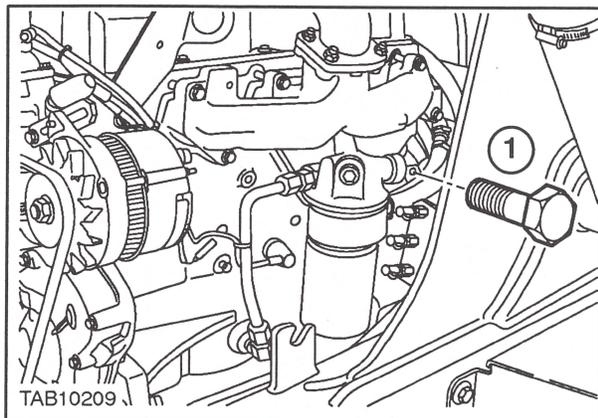
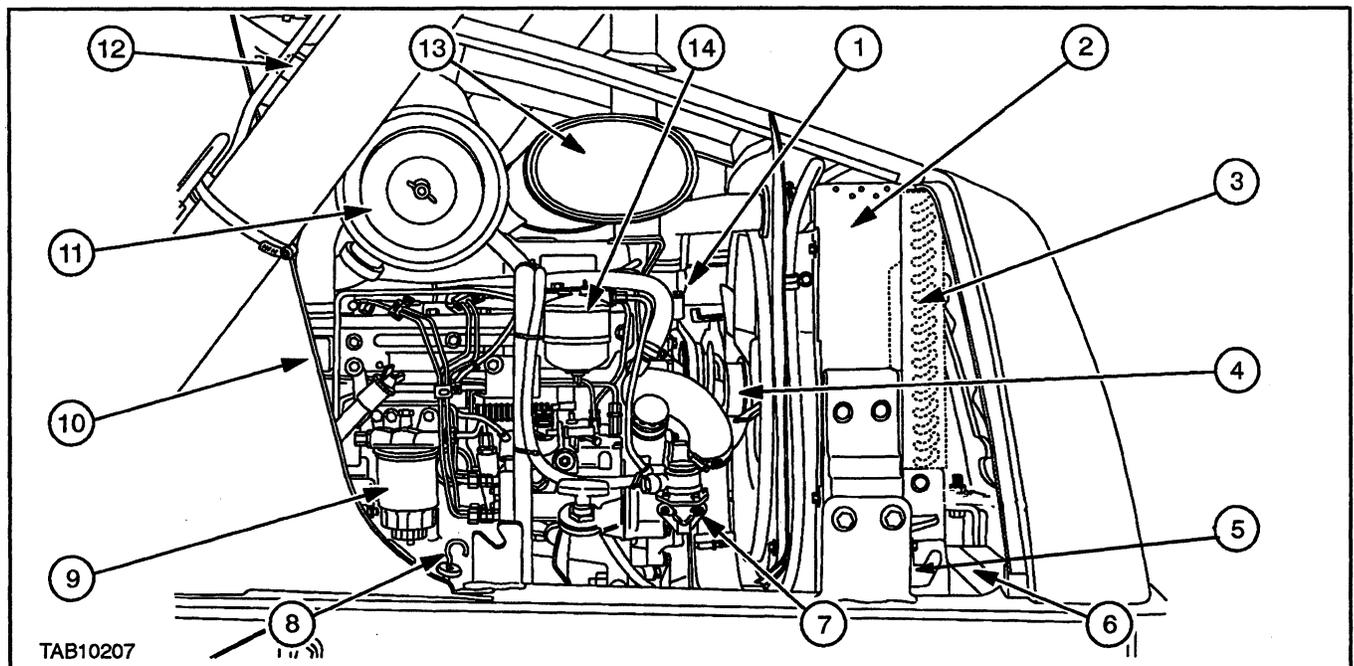


Figure 1-4

**NON-EMISSIONIZED ENGINE OVERHAUL****Diesel Engine Disassembly**

Right-Hand View of Engine

Figure 1-5

- |   |                              |                               |
|---|------------------------------|-------------------------------|
| 1. Thermostat                               | 5. Transmission Oil Cooler   | 10. Cold Start                |
| 2. Coolant Radiator                         | 6. Battery                   | 11. Air Cleaner               |
| 3. Air Conditioning Condenser (When Fitted) | 7. Fuel Lift Pump            | 12. Coolant Recovery Tank     |
| 4. Water Pump                               | 8. Engine Oil Level Dipstick | 13. Muffler                   |
|   | 9. Fuel Filter               | 14. Fuel Sedimentor/Separator |



**WARNING: ALLOW THE ENGINE TO COOL TO AMBIENT TEMPERATURE BEFORE CLEANING. CLEANING A HOT ENGINE IN COOL WATER COULD RESULT IN DAMAGE TO THE FUEL PUMP AND OTHER COMPONENTS.**

In the following procedures and illustrations the engine generally is shown removed from the tractor.

The engine overhaul procedure initially describes the assembly process for rebuilding an engine using all new components. Following this section are defined headings which describe detailed repair specifications and procedures, where components are suitable for reuse. Refer to the Specifications Section to ensure components are serviceable.

Where overhaul of components is required without engine being removed from the tractor refer to the following headings, and the relevant paragraphs, in the main overhaul procedure.

#### **Operations or repairs that can be performed with the engine still in the tractor.**

- Cylinder head and associated components

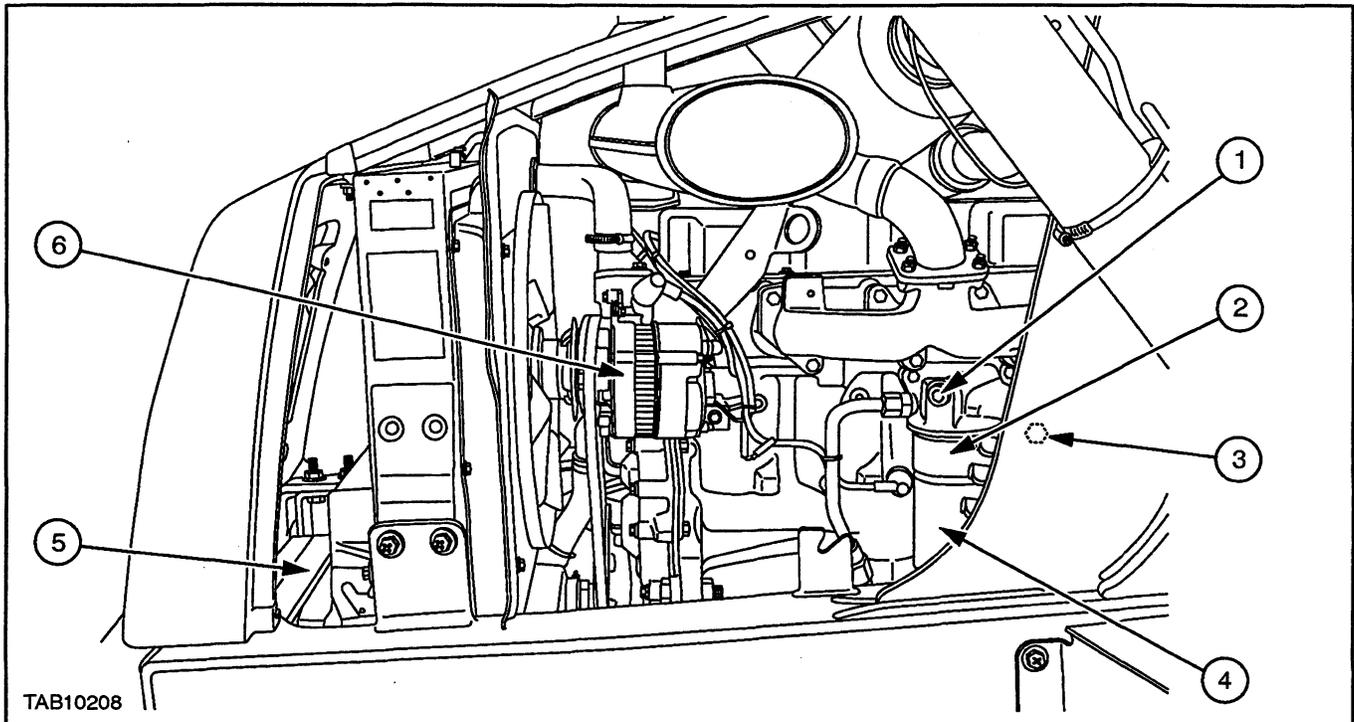
- Fuel injection pump and related parts
- Water pump, thermostat and associated components
- Oil pump relief valve
- Oil pan and gasket
- Turbocharger
- Front timing cover/timing gear removal
- Oil pan removal for access to crankshaft, bearing shells, piston removal and oil pump suction tubing
- Front pulley and damper assembly

#### **Operations or repairs that can be performed only with the engine removed from the vehicle and separated from the transmission housing, with oil pan removed.**

- Crankshaft rear oil seal and carrier removal (with oil pan removed)
- Oil pump and drive gear removal

**NOTE: All gaskets, seals and O rings must be replaced with new upon reassembly. Where new sealant is to be applied refer to "Engine Specifications".**

## Diesel Engine Disassembly



TAB10208

Left-Hand View of Engine

Figure 1-6

- |  |               |
|--|---------------|
| 1. Oil Filter Head Assembly<br>(Incorporating the Pressure Relief Valve) | 4. Oil Filter |
| 2. Engine Oil (Modine) Cooler  | 5. Battery    |
| 3. Engine Block Coolant Drain Plug                                       | 6. Alternator |

### Removal of Engine / Transmission from the Vehicle



**WARNING: BEFORE PERFORMING ANY SERVICE OR MAINTENANCE ON THE MACHINE ENSURE THE WHEELS ARE CHOCKED / BLOCKED TO PREVENT THE MACHINE FROM MOVING.**

1. Lock loader in raised position and crowd bucket fully forward.
2. Drop backhoe to the ground, switch off engine and release any pressure in the system.
3. Isolate battery.
4. Remove all engine panels.
5. Remove front cast cowling.
6. Drain engine coolant and remove hoses.
7. Pull main hydraulic cooler over radiator tabs.
8. Remove all fixing bolts and move radiator forward.
9. Disconnect transmission cooler pipes.
10. Remove radiator, taking care not to damage the fan or hydraulic oil cooler.
11. Remove air cleaner assembly.
12. Disconnect all electrical connections.
13. Disconnect cable and hydraulic pipe clamp.

14. Disconnect the heater and air conditioning hoses.

*IMPORTANT: If air conditioning is fitted, disconnect at the air conditioning quick release couplings only. If it is necessary to disassemble the air conditioning at any other point, it will be necessary to discharge the system using a suitable reclaim/recharging station.*

15. Disconnect the fuel tank feed and return pipes.  
16. Disconnect the throttle cable at the injection pump.

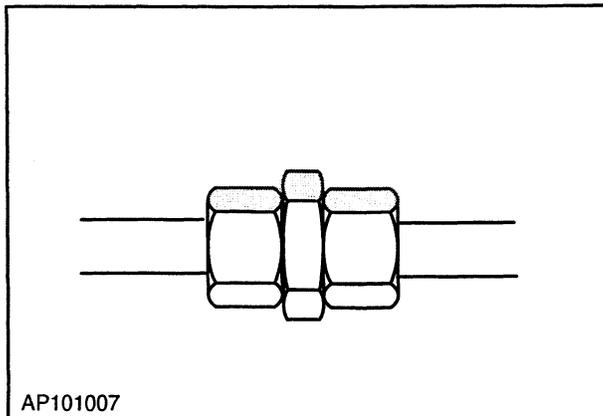


Figure 1-7

17. Remove the cab mat.  
18. Remove the cab floor access panel.  
19. Disconnect the electrical connections.  
- Forward Reverse solenoids (on top of the transmission)  
- Transmission lever at base of lever  
- FWD solenoid

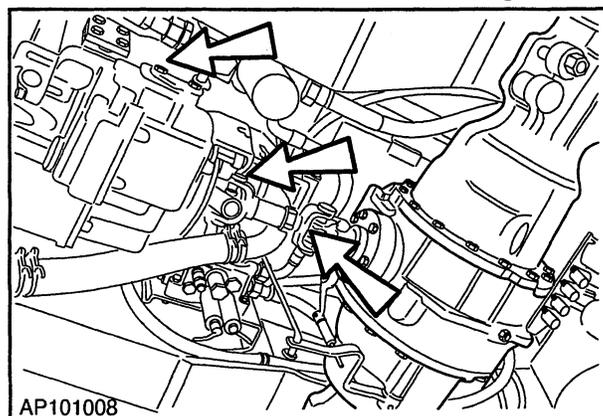


Figure 1-8

20. Disconnect the transmission to boomlock valve pipe.  
21. Disconnect boomlock return pipe and plug the hole (oil will leak out of transmission).  
22. Remove front drive shaft (where fitted) and remove rear drive shaft, Figure 1-8.

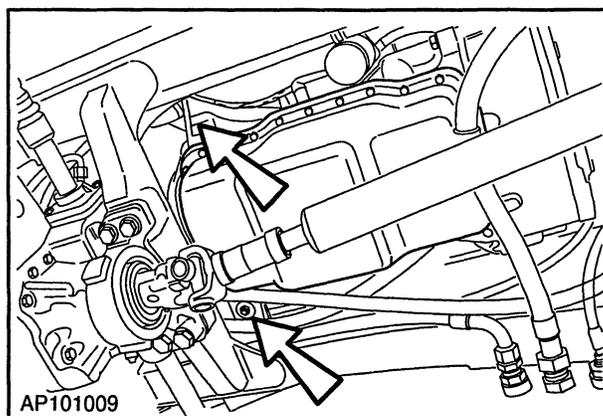


Figure 1-9

23. Disconnect the hand brake cable.  
24. Disconnect the gear lever.  
25. Pull back hydraulic pumps (leaving all pipes attached). Check that the oil pump drive shaft does not slide out with the pump.  
26. Check return from steering motor is on the outside of transmission oil level tube.

27. With the engine supported and using a hoist capable of supporting a total weight of 800 kg (1760 lb) loosen and remove the engine and transmission mounting bolts, Figure 1-9.

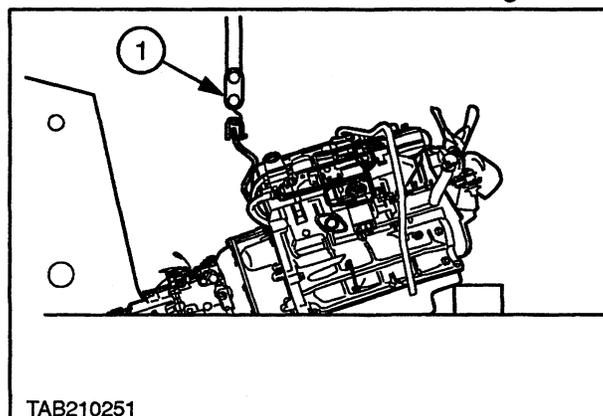


Figure 1-10

28. Using lifting tool NH01250, 1, Figure 1-10 very carefully raise the hoist and guide the engine/transmission assembly from the vehicle.

## Separating Engine From Transmission with Assembly Removed From the Vehicle

1. Place the engine/transmission assembly on a suitable splitting stand.

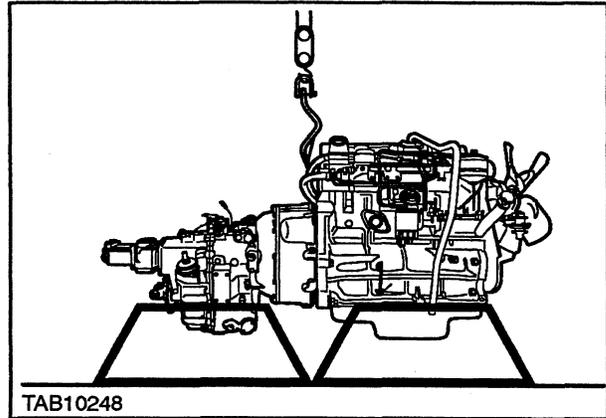


Figure 1-11

2. Remove the starter motor assembly.
3. Remove the torque converter attaching bolts accessed through the starter motor aperture, 1.
4. Remove the engine timing tab, 2.

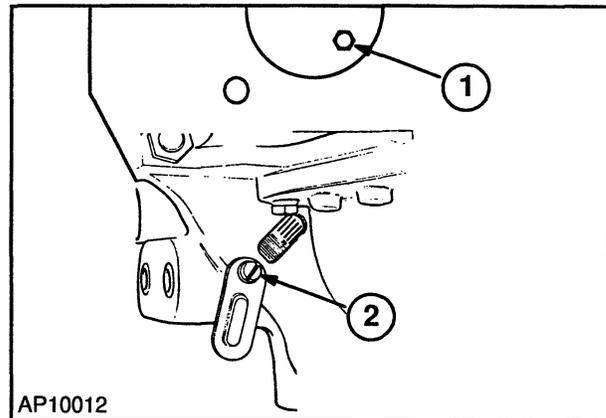


Figure 1-12

5. Remove the bell housing bolts.
6. Gently slide the transmission with the torque converter from the engine.

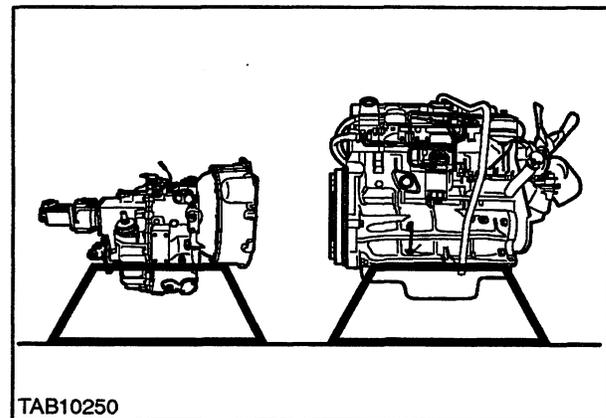


Figure 1-13

## Engine Installation

Installation of the engine is the reversal of the removal procedure, noting the following points:

- Ensure all attaching hardware is tightened to the correct torque value as detailed in the specifications.
- Ensure after installation that all fluid levels are correct prior to start-up. Start and run the engine until correct operating temperature is achieved to purge air from cooling system. Stop engine, check for leaks, correct as required and recheck fluid levels.

## Engine Disassembly

### Cylinder Head, Valves and Related Parts

#### Cylinder Head Removal

**NOTE:** The cylinder head can be removed with the engine installed in the vehicle.

Remove or disconnect the following components to allow removal of the cylinder head:

- Remove the engine hood.
- Drain the engine coolant into a clean receptacle.
- Disconnect/remove the air cleaner, air cleaner tubes and muffler assembly.
- Disconnect low pressure fuel lines to the filters, injector leak-off tube, thermostart/ether feed tube and injector to injection pump high pressure tubes (cap all exposed openings).
- Disconnect and remove the rocker cover ventilation tube.

**NOTE:** Removal of the radiator will greatly assist water pump removal.

- Remove the fan belt and the water pump.
- Clean around the injectors and remove the injector/washer assembly.

**NOTE:** Ensure injectors and washers have been removed prior to placing the cylinder head onto a bench as they protrude below the head face.

- Remove the turbocharger assembly, if fitted, ensuring all openings are capped to prevent dirt ingress.
- Remove the rocker cover and gasket.

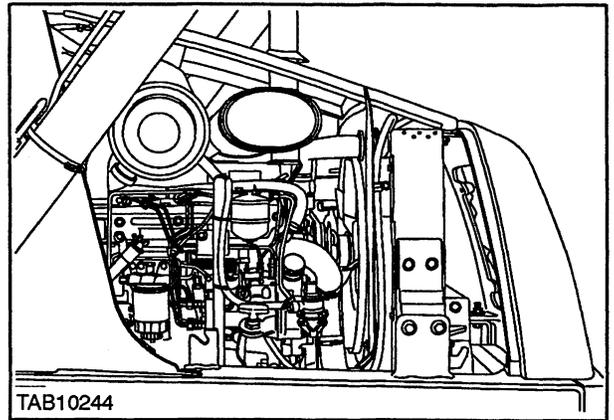


Figure 1-14

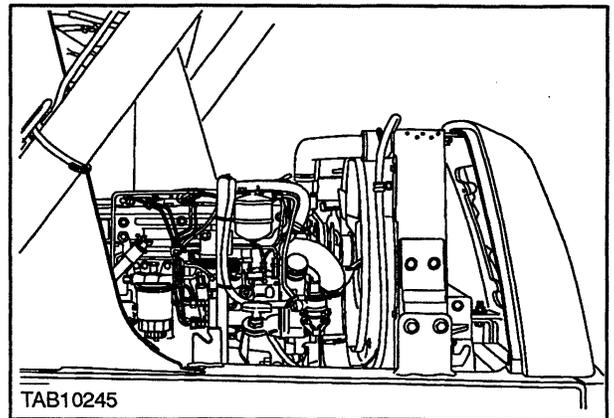


Figure 1-15

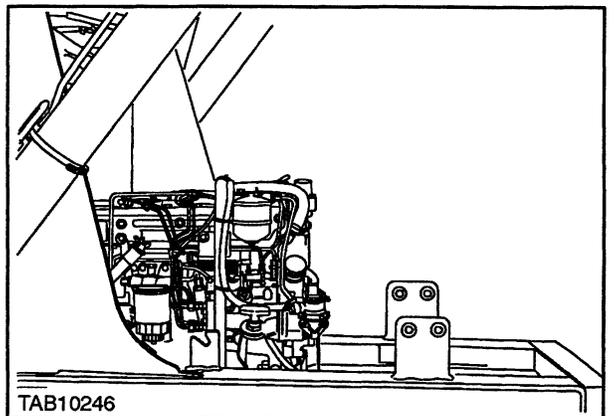


Figure 1-16

- Remove the cylinder head bolts, 1, which pass through the rocker shaft supports and remove the rocker shaft assembly as an assembly. Remove the push rods, 2, check for straightness and place in a numbered rack for reassembly.

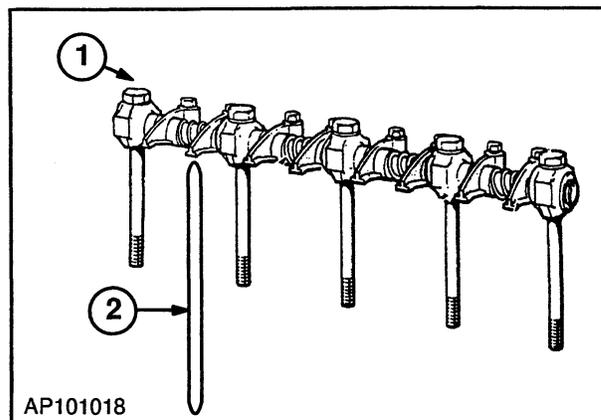
**NOTE: Leave bolts, 1, in the rocker shaft supports during removal as they retain the support on the shaft.**

- Remove remaining cylinder head bolts working inward from the end of the cylinder head, alternately to the center of the cylinder head.
- Carefully lift the cylinder head assembly away from the engine block.

### Cylinder Head Disassembly

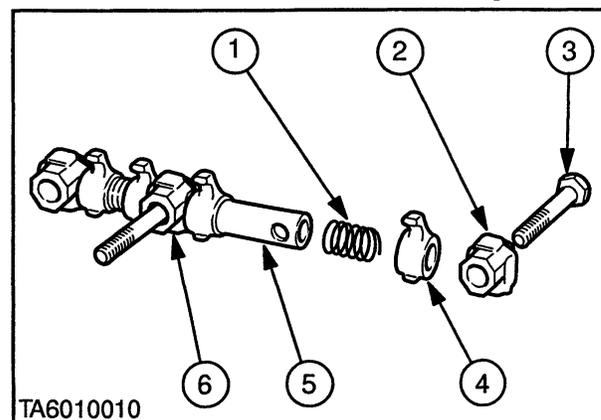
#### Rocker Shaft Disassembly

- Remove the cylinder head bolts, 3, and withdraw the supports, 2, springs, 1, rockers, 4, shaft, 5, and spacers, 6.



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Figure 1-17

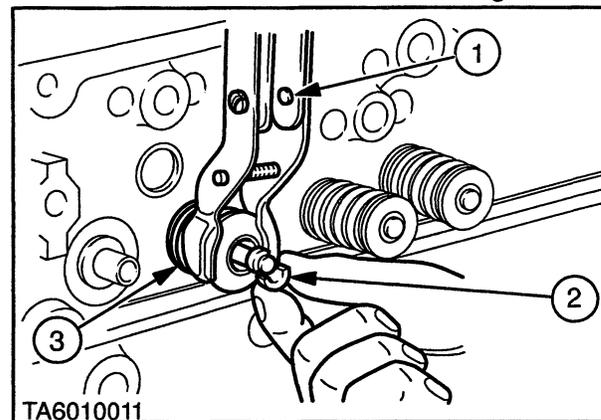


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Figure 1-18

#### Valve and Spring Assembly Removal

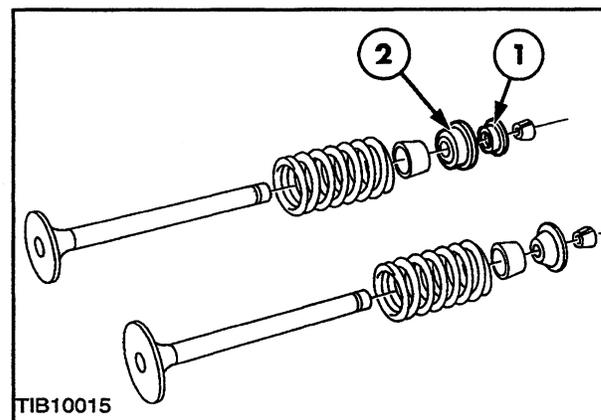
- Using a valve spring compressor, 1, remove the retainer locks, 2, springs, seals and rotators and place in a numbered rack.



TA6010011

Figure 1-19

**NOTE: The exhaust valves are fitted with inner, 1, and outer, 2, rotators.**



TIB10015

Figure 1-20

## Inspection and Repair, Cylinder Head

**IMPORTANT:** Before cleaning the cylinder head inspect for signs of discoloration, leaking or cracks. Once cleaned, concerns may not be apparent.

1. Clean the cylinder head, and remove carbon deposits from around the valve heads.
2. Cylinder head core plugs, if discolored (rusty) or leaking, will require changing. Before fitting new plugs remove all old sealer from the cylinder head. Apply sealant (Loctite® 641/640/609) to the new plug mating faces, and drive the new plugs into location.

Core plugs required in the cylinder head:

4 off, in the top of the cylinder head  
 1 off, in the rear of the cylinder head  
 3 off, mounted in the intake face

3. Scrape all gasket surfaces clean and wash cylinder head in a suitable solvent, also cleaning valve guide bores.
4. Inspect cylinder head for nicks and burrs on mating face. Remove, using a suitable abrasive and ensure faces are clean after repair.
5. Using a straight edge, 1, and feeler gauge, 2, check that flatness of the cylinder head in all directions does not exceed 0.03 mm (0.001") in any 25.4 mm (1"), or 0.127 mm (0.005"), overall limit.

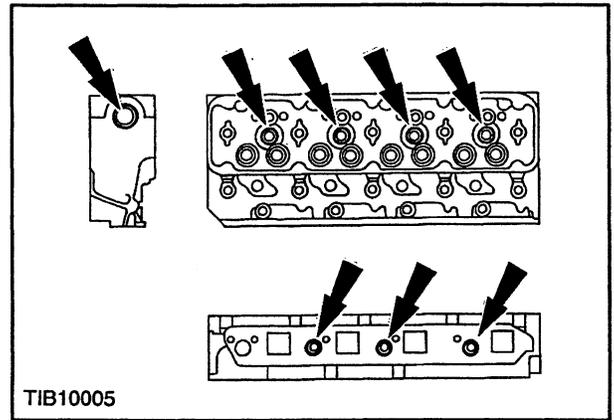


Figure 1-21

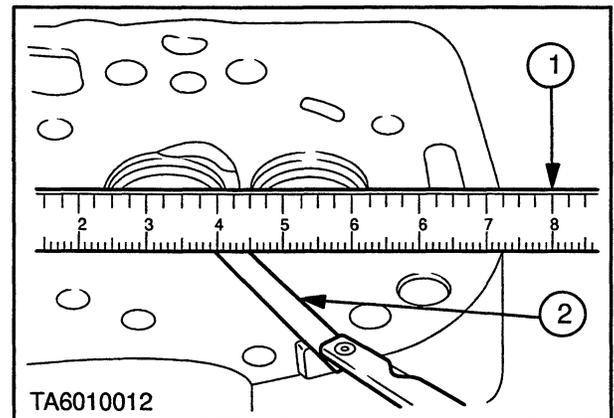


Figure 1-22

6. If the cylinder head has been resurfaced, determine all head bolt faces will seat by placing the cylinder head, less gasket, on the cylinder block and installing bolts hand tight.
7. Ensure rocker shaft supports are fitted with long bolts, 1. Using a feeler gauge, check the clearance between the underside of bolt heads and cylinder head or rocker shaft support.
8. If a 0.25 mm (0.010") feeler gauge can be inserted under the bolt head the bolt has bottomed. Therefore the cylinder block thread must be increased using a 9/16-13 UNC-2A thread tap. Identify the bolt heads and ensure they are reinstalled in the bolt holes they were checked in.

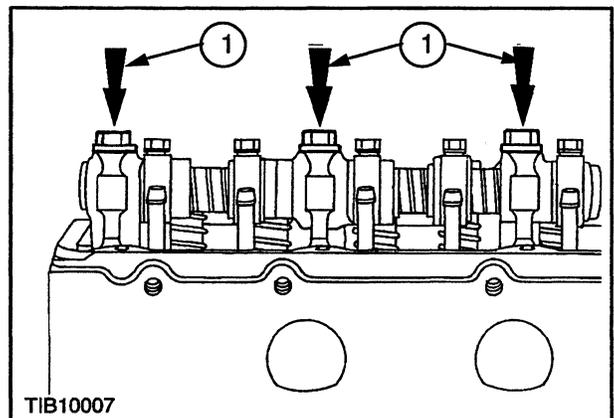


Figure 1-23

## Valve Inserts

Insert Oversize	Counterbore in Cylinder Head	
	Exhaust Valve Insert	Intake Valve Insert
0.25 mm (0.010")	44.17-44.20 mm (1.739-1.740")	50.01-50.04 mm (1.969-1.970")
0.58 mm (0.020")	44.42-44.45 mm (1.749-1.750")	50.27-50.29 mm (1.979-1.980")
0.76 mm (0.030")	44.68-44.70 mm (1.759-1.760")	50.52-50.55 mm (1.989-1.990")

**NOTE: Refacing the valve seat should always be coordinated with refacing of the valve to ensure a compression tight fit.**

1. Examine the valve seat inserts and reface if pitted. Replace if loose or damaged.
2. To install a new valve insert, the cylinder head must be counterbored, as described in the above chart. The new insert must be chilled in dry ice prior to installation.

### Valve Seat Specifications

Valve seat angle, 1,

Intake = 30.0-30.30°

Exhaust = 45.0-45.30°

Valve seat width, 2,

Intake = 1.9-2.4 mm (0.078-0.098")

Exhaust = 1.8-2.3 mm (0.072-0.092")

Valve head face to cylinder head face depth, 3,

Intake = 0.86-1.32 mm (0.034-0.052")

Exhaust = 1.2-1.6 mm (0.047-0.065")

**NOTE: Valve inserts of 0.25 mm (0.010") and 0.5 mm (0.020") oversize on diameter are sometimes installed during manufacture. Cylinder heads with oversize inserts are stamped SO10OS, SO20OS, on the exhaust manifold side in line with the valve seat concerned.**

3. Check the width of the valve seat inserts and, as required, reface by grinding to correct dimensions.
4. Measure the concentricity of valve seats, using a dial indicator and measure concentricity of seat to the valve guide bore. Total Indicator Reading should not exceed 0.002" (0.051 mm).

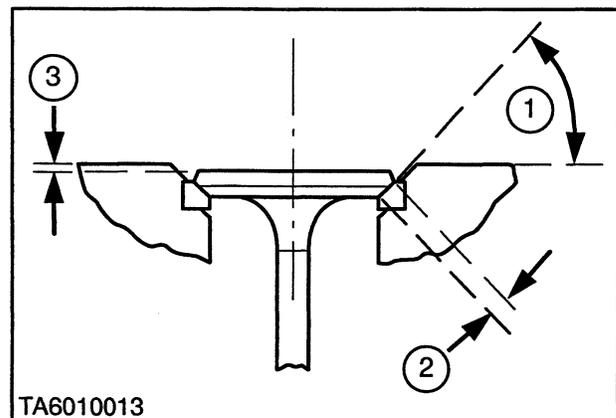


Figure 1-24

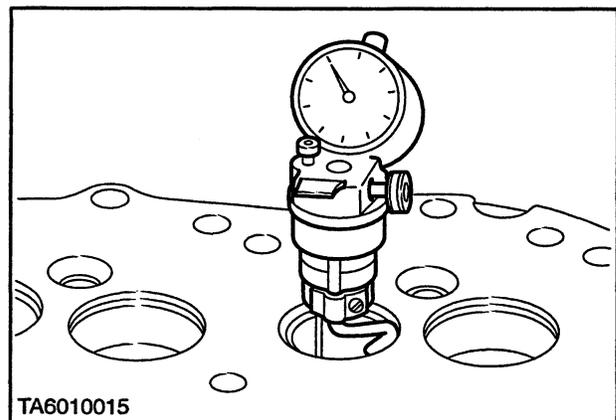


Figure 1-25

5. Use a seat cutter to correct any seat eccentricity, or clean up of pits and grooves. Ensure after any rework that seat width is within specified limits.
6. Rotate a new or refaced valve in the seat using engineering blue. Ensure all the blue is transferred to the valve head protrusion. If any blue remains below or around the seat raise or lower the seat accordingly, in the following manner:

Lower the valve seats by removing material from the top of seat, 1, by using a 30° grinding wheel for exhaust valves and a 15° grinding wheel for intake valves.

Raise the valve seats by removing material from the bottom of seat, 2, by using a 60° grinding wheel for exhaust valves and a 45° grinding wheel for intake valves.

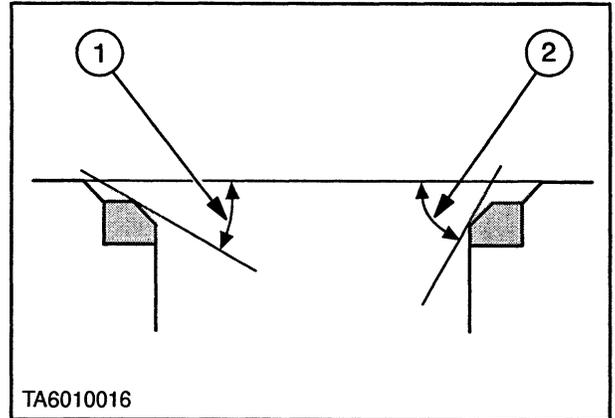


Figure 1-26

### Valve Guides

1. Using a telescopic gauge, 1, and micrometer, 2, measure the valve guide bore clearance and ensure it does not exceed 0.023-0.069 mm (0.0009-0.0027"), on the intake valve stem, 0.048-0.094 mm (0.0019-0.0037"), on the exhaust valve stem.

**NOTE:** Production cylinder heads may have one or more oversize valve guide bores and valves installed, 0.38 mm (0.015"). Such cylinder heads have 15 or VO15OS stamped on the cylinder head exhaust manifold side adjacent to the valve concerned.

2. Using a suitable reamer, ream out the valve stem guide, with three reamer and pilot combinations as follows:
3. When going from a standard valve stem to an oversize, always use reamers in sequence.

0.076 mm (0.003") oversize reamer, and standard diameter pilot.

0.38 mm (0.015") oversize reamer, and 0.076 mm (0.003") oversize pilot.

0.76 mm (0.030") oversize reamer, and 0.38 mm (0.015") oversize pilot.

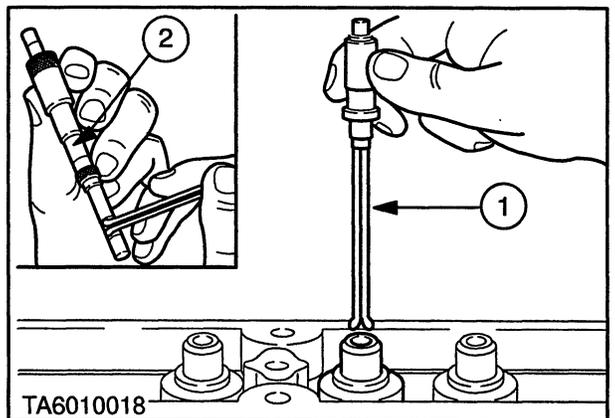


Figure 1-27

## Valve Springs

1. Checked on a flat surface, squareness should not exceed 1.52 mm (0.060") between the square and spring at the top edge.

Length of valve springs should be checked on both free length and loaded length.

Free length = 60.7 mm (2.39")

Installed length = 47.2-49.6 mm (1.86-1.95")

Loaded length = 48.26 mm. (1.9") using a weight of 28-31 kg (61-69 lb)

Loaded length = 35.69 mm (1.4") using a weight of 61-69 kg (135-153 lb)

Ensure the valve spring retainers locks are in good condition, and replace if worn or damaged.

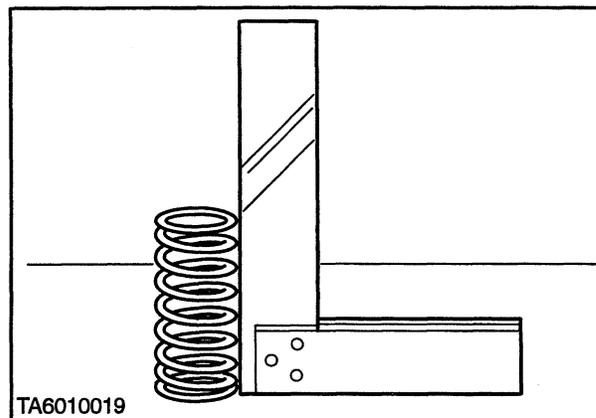


Figure 1-28

## Rocker Shaft Inspection and Reassembly

1. Inspect rocker arm adjusting screws, 1, and push rod ends of the rocker arm, including the ball end of the screws, 2, for nicks, damage, or excess wear.
2. Also inspect the inside diameter of the rocker arm for damage or wear. If any of these characteristics are not to specification replace with new parts.
3. Check the ends of the push rods for damage or wear. If not to specification or push rods were found not to be straight during dismantling install new rods.

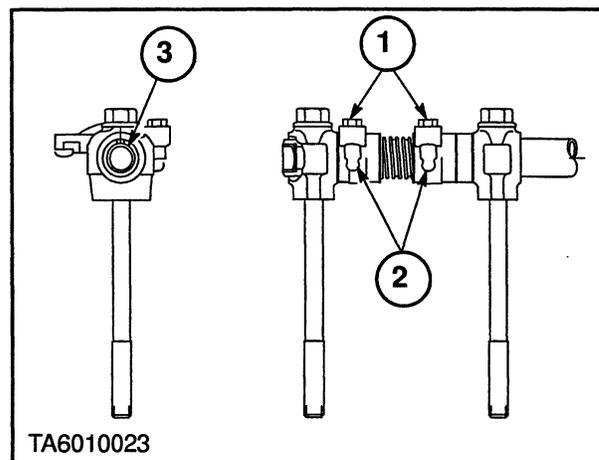


Figure 1-29

**NOTE: Do not attempt to straighten bent push rods, replace with new.**

4. Check the rocker shaft assembly for signs of wear or damage on internal and external diameters respectively. If not to specification replace with new. If reused, before reassembly clean thoroughly in solvent making sure all oil passages are clear.
5. Position the shaft identification groove, 3, Figure 1-29, forward and upward. This ensures oil grooves and holes face downward.
6. Assemble rocker shaft support with long head bolts, ensuring springs and spacers are reassembled and torque to 217 N·m (160 ft. lbs.).

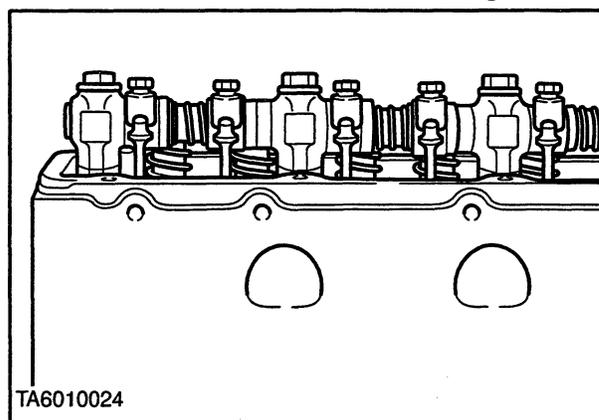


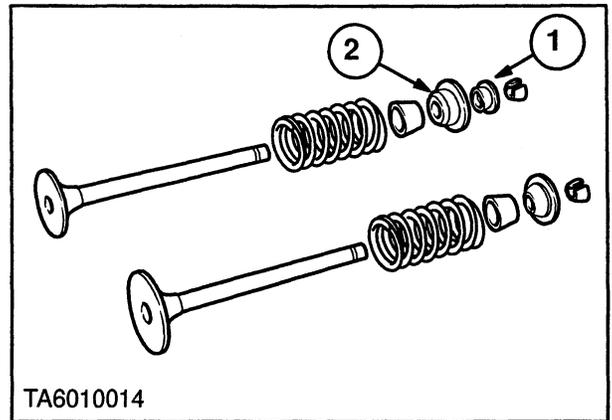
Figure 1-30

## Cylinder Head Reassembly

1. Insert the valves into the guide bores from which they were removed and lap with a suitable paste. Ensure all traces of paste are removed after lapping.
2. Lubricate all components with clean engine oil on reassembly. Use a spring compressor to reassemble the valves, valve springs, rotators and collets, with new umbrella seals.

**NOTE: Exhaust valves are fitted with inner, 1, and outer, 2, rotators.**

3. Coat all components with clean engine oil prior to assembly, and insert each push rod into its original position, ensuring each ball end is seated in its cam follower.



TA6010014

Figure 1-31

## Cylinder Head Installation

Installation of the cylinder head assembly and components is the reverse of the removal procedure, observing the following:

1. Install new cylinder head, intake and exhaust manifold gaskets.

**NOTE: Ensure exhaust manifold gasket is fitted correctly to suit profile of exhaust ports.**

2. Tighten the cylinder head bolts in sequence from the center of the head, progressively in three stages.

Stage 1, 156 N·m (115 ft. lbs.)

Stage 2, 190 N·m (140 ft. lbs.)

Stage 3, 217 N·m (160 ft. lbs.)

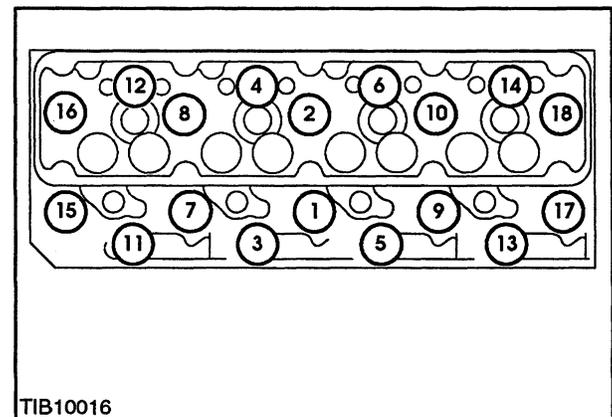
**NOTE: Bolts are to be lubricated prior to assembly, and should be tightened to torque specification, with the engine cold.**

3. Adjust valve lash setting with each piston in turn at top dead center, and rockers free to move, by adjusting the rocker bolt.

Intake valve lash,  
0.36-0.46 mm (0.014-0.018")

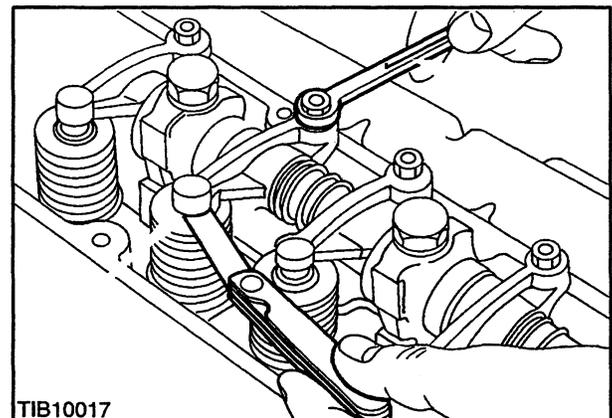
Exhaust valve lash,  
0.43-0.53 mm (0.017-0.021")

**NOTE: Valve lash is to be set only when the engine is cold.**



TIB10016

Figure 1-32



TIB10017

Figure 1-33

4. Install the injectors, 1, with new seat washers, 3, and cork seals, 2, and torque to 23 N·m (17 ft. lbs.).
5. Install the injector lines, and leak off pipes with new washers, and torque the leak off banjo bolts to 10 N·m (8 ft. lbs.).

**NOTE:** Hold the leak off plastic tubing when tightening to prevent the pipes pivoting, during torque up.

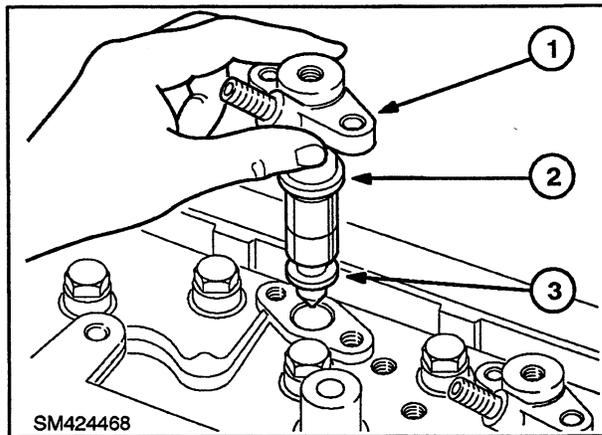


Figure 1-34

6. Exhaust manifold bolts are to be installed and tightened to a torque of 38 N·m (28 ft. lbs.).
7. Install intake manifold bolts and tighten to a torque of 38 N·m (28 ft. lbs.).

### Engine Front Cover and Timing Gear Removal

**NOTE:** Timing cover and gears can only be serviced after removing the radiator.

1. Remove the fan belt and withdraw the bolt and washer from the crankshaft pulley.
2. Using puller FNH05939, and shaft protector FNH09212, remove pulley, spacer and O ring from the shaft.
3. Withdraw the bolts retaining the front cover plate, and remove the front plate.
4. Before removing the timing gears, use a dial indicator or feeler gauge to measure the backlash between each set of gears.

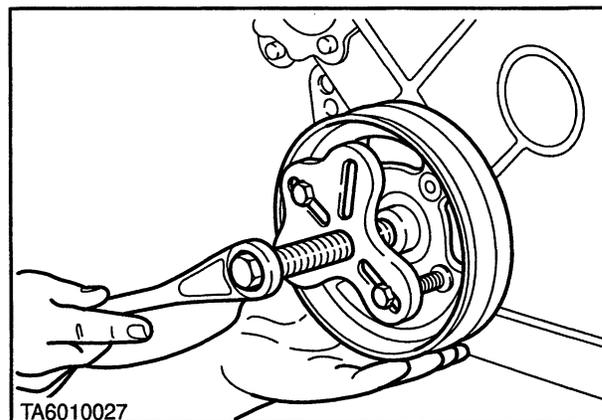


Figure 1-35

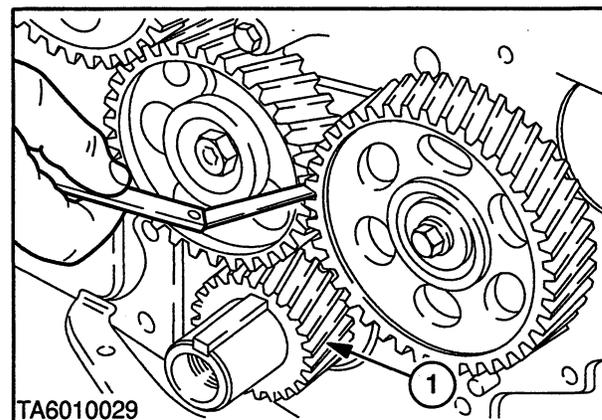


Figure 1-36

- Rotate the gears and check the backlash, using a feeler gauge or dial indicator at four equal points on the gears. Replace the affected gears if the backlash exceeds the following:

Backlash to camshaft gear, 1,  
0.15-0.20 mm (0.006-0.008")

Backlash to crankshaft gear, 2,  
0.15-0.20 mm (0.006-0.008")

Backlash to fuel injection pump gear, 3,  
0.10-0.15 mm (0.004-0.006")

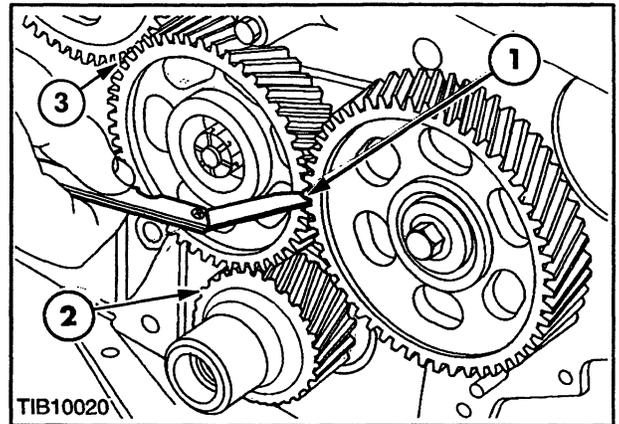


Figure 1-37

### Camshaft Drive Gear

- Pry the camshaft gear using a lever, 1, away from thrust plate. Using a dial indicator or feeler gauge, 2, check the clearance. If outside of 0.076-0.35 mm (0.002-0.007") limit, fit a new camshaft thrust plate.
- Remove the camshaft idler gear retaining bolt, gear and adapter from the block then remove the camshaft gear bolt and disassemble.
- Remove retaining nut and washer from the fuel pump and remove the gear from the shaft using a puller.
- If required, the timing gear rear cover, 3, may now be removed. Remove the six retaining bolts and carefully pry the cover from the engine block.

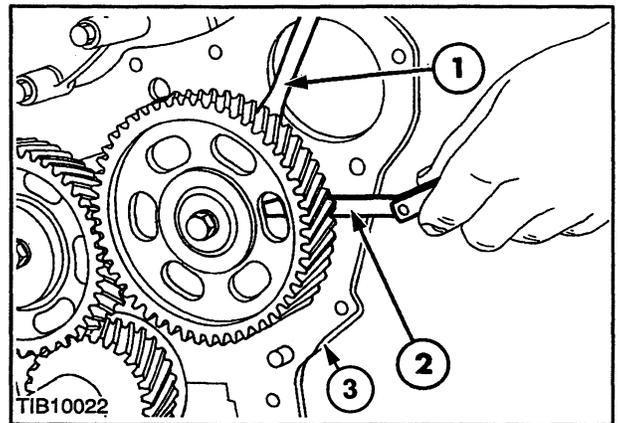


Figure 1-38

### Inspection and Repair Of Gears

- Wash the gears using a suitable solvent and examine gear teeth for wear, burrs or scratches. Minor marks can be removed using a fine abrasive, thoroughly clean before reassembly.
- Ensure the camshaft idler gear adapter is free from obstruction and bushing is not damaged. Camshaft key and keyway should be checked for damage and repaired as required.

## Installation

1. Position piston No.1 at top dead center, install the spacer, key and camshaft gear, and tighten bolt, 4, to 69 N·m (51 ft. lbs.).
2. Install the camshaft idler gear to the block, aligning the timing marks to the crankshaft, 2, and camshaft gears, 1, and torque to 250 N·m (184 ft. lbs.).
3. With piston No. 1 at top dead center, assemble the pretimed fuel injection pump with a new O ring, aligning the mark on the pump flange to the 0 degree timing mark on the front cover. Torque pump retaining bolts to 22 N·m (18 ft. lbs.). Install the pump gear over the pump shaft. Align timing marks to the idler gear, 3, in Figure 1-39 and torque to pump shaft 79 N·m (58 ft. lbs.). Holding the idler gear, check the backlash between the pump and idler gear with a feeler gauge or dial indicator.

**NOTE: Fuel injection pump dynamic internal timing is set at 10° before top dead center.**

4. The front oil seal should be replaced every time the front plate is removed. Drive out the old seal using a punch, taking care not to damage the front plate.
5. Coat a new seal in a suitable lubricant, and drive the seal, 1, into the rear of the front plate using tool No. 630-16, step plate from set FNH09211, 2. Alternatively use tool No. FNH07536 and drive the seal into position from the front.

6. Ensure the front cover mating face and cylinder block face are thoroughly clean before reassembly. Apply a 2 mm (0.078") wide bead of sealer (Loctite® 5900/598 Ultra Black) along the center of each mating face. Position a new gasket on the front cover.
7. Install the front cover ensuring alignment with dowel pins and tighten the bolts in order of sequence:

5/16"-18 UNC bolts, tighten to 8-24 N·m (13-18 ft. lbs.).

3/8"-16 UNC bolts, tighten to 34-41 N·m (25-30 ft. lbs.).

8. Apply a 2 mm (0.078") wide bead of sealer (Loctite® 5900/598 Ultra Black) to clean oil pan face, install a new gasket and torque oil pan bolts to 38 N·m (28 ft. lbs.).

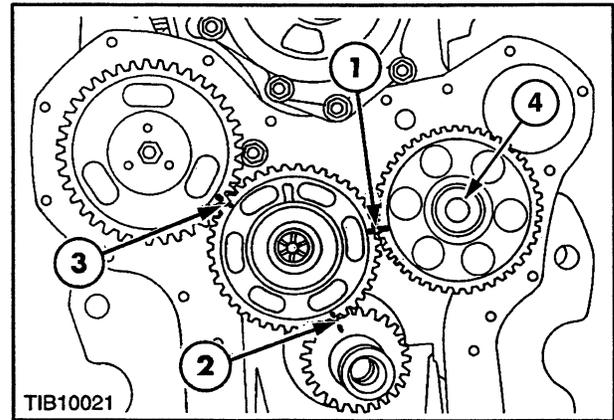


Figure 1-39

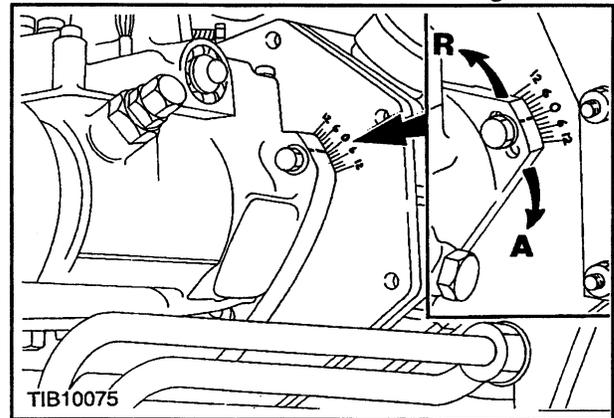


Figure 1-40

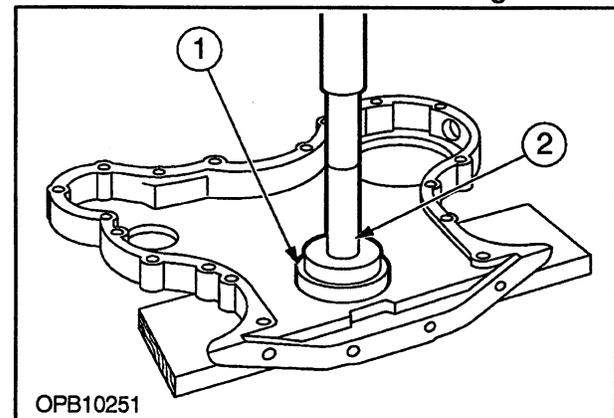


Figure 1-41

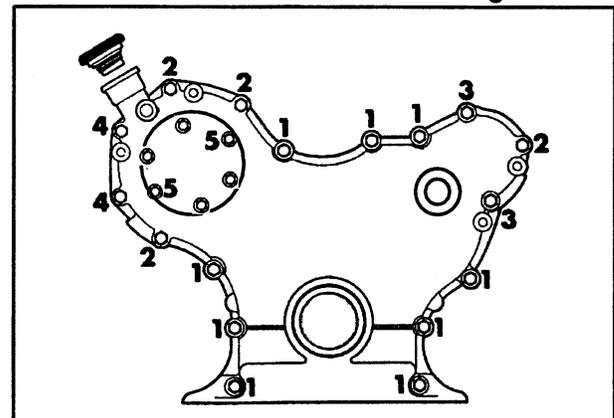


Figure 1-42

## Oil Pan Removal

1. Drain engine oil through oil pan plug, 1, and into a suitable clean receptacle and remove the oil level indicator.

**NOTE:** To facilitate the oil pan, 2, removal it may be necessary to first remove the driveshaft.

2. Remove oil pan bolts and lower pan to ground.

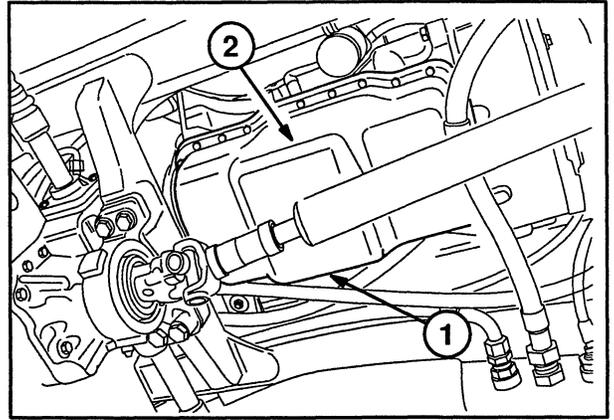


Figure 1-43

## Inspection and Repair

1. Clean gasket material from sump face, clean sump in a suitable solvent, inspect sump for cracks, damaged threads or damaged sump face.

## Installation

1. Installation is the reverse of removal but with the following requirements.
2. Ensure block face is clean and free of gasket material. Install a new gasket to the front cover, and oil pan. Ensure sealer (Loctite® 5900/598 Ultra Black) is applied to the front plate and rear oil seal return joints.
3. Position the oil pan and install a bolt at each corner finger tight to hold in position, install remaining bolts, and torque from the center of the pan to the end to 38 N·m (28 ft. lbs.).

## Connecting Rods, Bearings, Pistons, and Rings, Removal

**NOTE:** The connecting rods and pistons can be removed with the engine installed after removal of the cylinder head and oil pan sump.

1. With cylinder head removed clean off any ridge from the top of the cylinder bores with a ridge remover to enable removal of the pistons. This is essential if old pistons are to be reused as failure to do so could result in ring land damage.
2. With the piston at the bottom of the stroke remove the end cap bolts, cap and liner, 1. Using the handle end of a hammer push the piston assembly out through the top of the block and remove the bearing liner from the connecting rod.

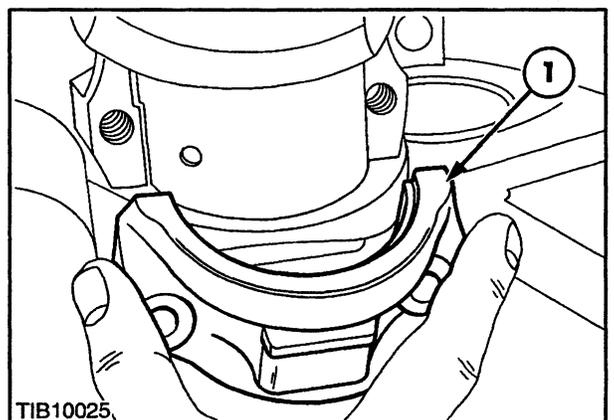


Figure 1-44

**NOTE: Bearing caps and liners must be kept with their respective connecting rods.**

3. Turn the crankshaft again and repeat the process for the remaining pistons.
4. Remove piston pin snap rings from each side of piston and remove pin. Using an expander, 1, remove the piston rings.
5. Ensure each piston and rod assembly remain matched together for reassembly into the cylinder block.

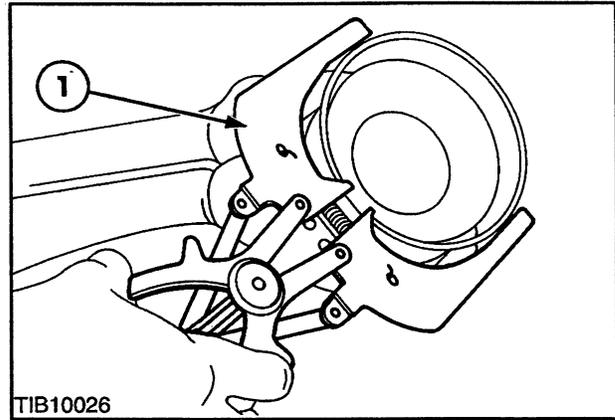


Figure 1-45

### Inspection and Repair

1. Clean the piston and connecting rod assembly in a suitable solvent and inspect for damage to ring lands, skirts or pin bosses.

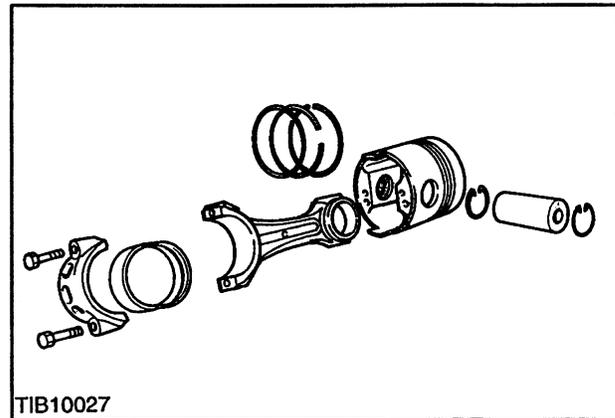


Figure 1-46

2. Check connecting rod components for damage and place in an alignment fixture to check for distortion. Ensure that any distortion is within specification as follows:

Maximum twist 'A', 0.30 mm (0.012")

Maximum bend 'B', 0.10 mm (0.004")

3. Check piston pin bushing for damage or wear in the following manner:

Measure the outside diameter of the piston pin, 1, and inside diameter of the connecting rod bushing, 2, to the following specifications.

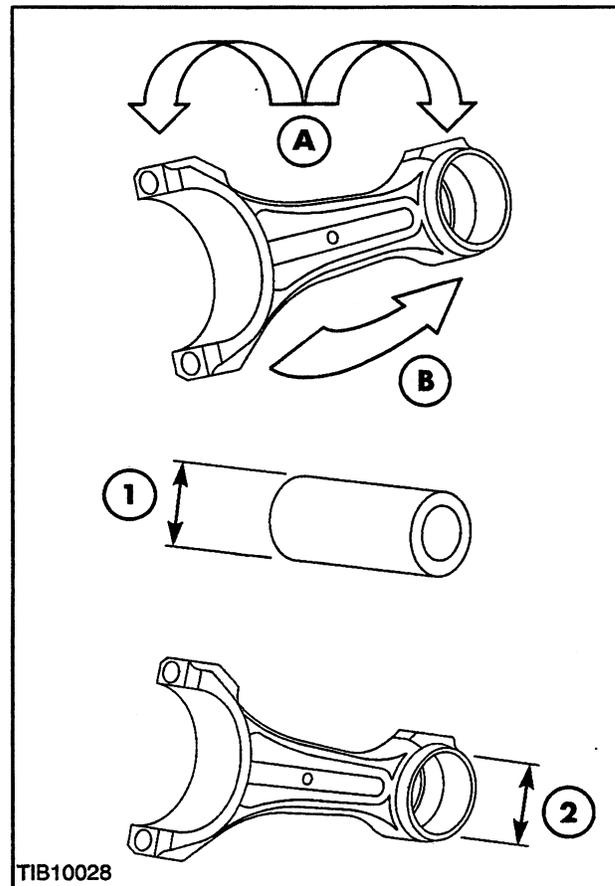


Figure 1-47

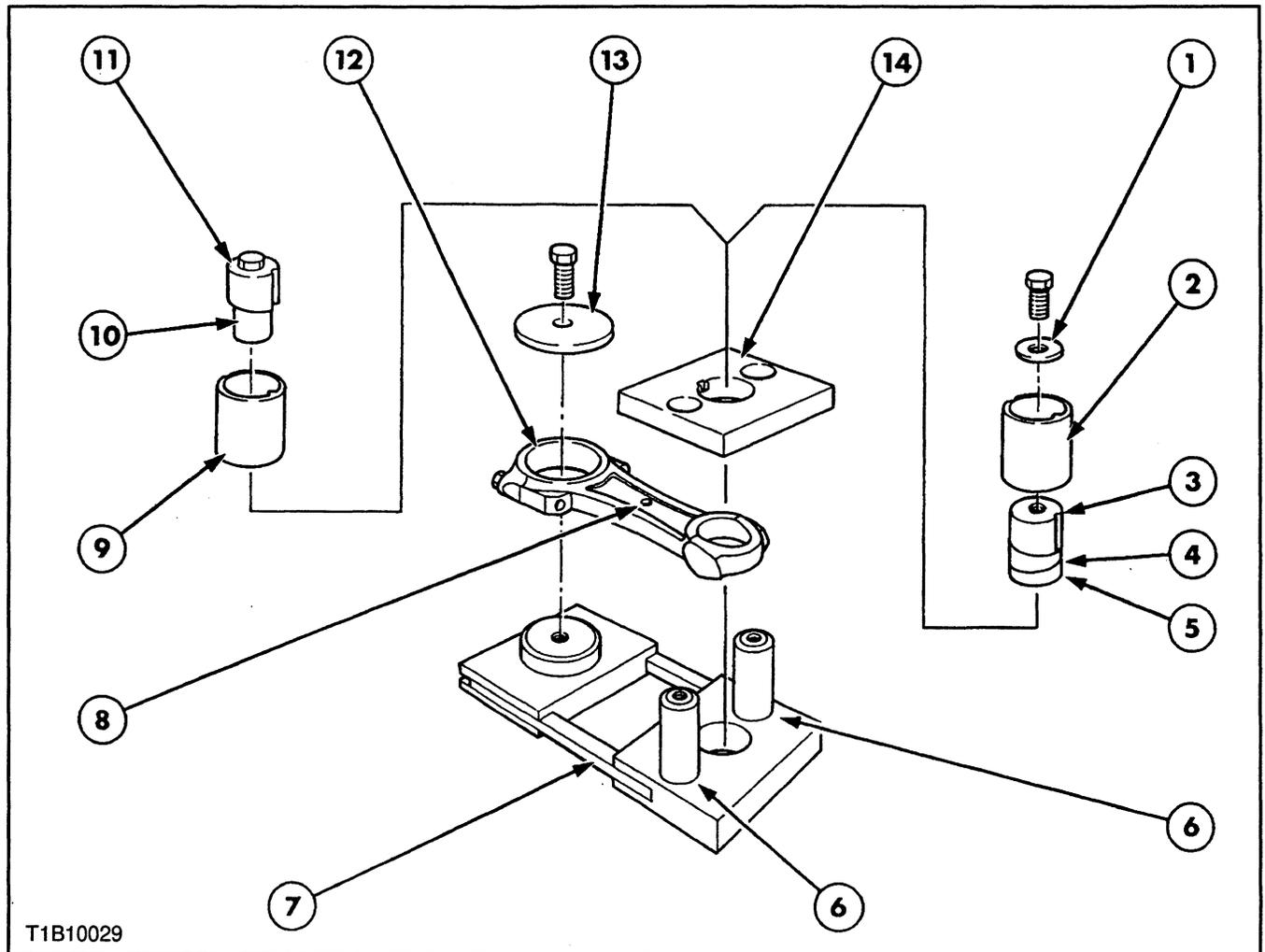
### Piston Pin Outside Diameter

Naturally aspirated,  
38.095-38.100 mm (1.4998-1.500")  
Turbocharged,  
41.270-41.275 mm (1.6248-1.625")

### Connecting Rod Bushing Internal Diameter

Naturally aspirated,  
38.113-38.120 mm (1.5005-1.5008")  
Turbocharged,  
41.288-41.295 mm (1.6255-1.6258")

## Connecting Rod Bushing



Connecting Rod Bushing Installation

Figure 1-48

## Removal

1. Washer
2. Collar
3. Installation Insert 1
4. Bushing
5. Installation Insert 2

6. Pins
7. Fixture
8. Connecting Rod Facing Up
9. Remover Insert 1
10. Remover Insert 2

## Installation

11. Remover Insert 3
12. Connecting Rod Location
13. Washer
14. Location Plate

4. If not to specification use tool No. FNH00053, and press out the old bushing using the removal fixture as shown. Press fit a new bushing through the fixture using the installation detail, and into the connecting rod. After installing a new bushing ensure all sharp edges and burrs are removed.

**IMPORTANT:** Ensure the split in the small end bushing is at right angles to center line of connecting rod.

Connecting rods should only be changed as matched sets.

5. Where special tooling is not available for the removal or installation of the connecting rod bushing, a standard bushing can be installed in the following manner.
6. Place the connecting rod securely in a bench press. Manufacture from suitable bar stock a press tool with the end face ground at an angle to suit the connecting rod bushing side face. Position the tool on the bushing and gently drive the bushing from its position. It is recommended a guide be manufactured to assist alignment of the bar stock during this operation.
7. A new bushing can then be installed in a similar manner by using a suitable piece of bar stock, with an end face machined flat to suit the standard parallel bushing. Use a guide as described and gently drive the new bushing into the connecting rod.

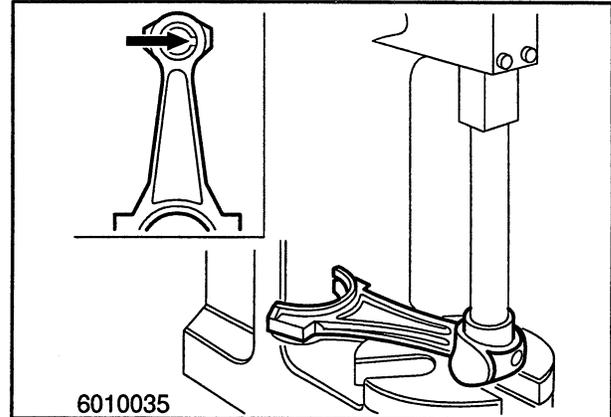


Figure 1-49

**NOTE: The seam of the new bushing must be placed at 90° to the center line of the connecting rod.**

8. After installation grind the side faces of the new bushing to match the side faces of the connecting rod. Ensure all sharp edges are removed, and loose chippings are cleaned from the connecting rod before reassembly into the engine.
9. With a new bushing installed, drill a hole through the top of the connecting rod using a 4.6 mm (0.187") bit. Drill through the existing oil hole.
10. Use an expanding reamer to obtain correct bushing to piston pin clearance. Refer to the Specification Section. Remove burrs and metal chips before installing.

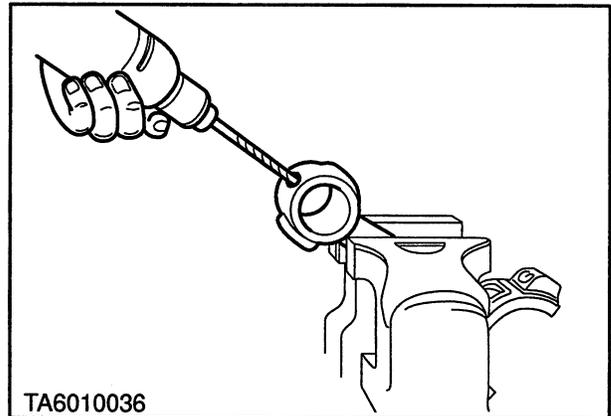


Figure 1-50

## Cylinder Block Overhaul

1. Cylinder block plugs and senders must be replaced if leaking or rusty. Clean the old sealant off the block, and fit new plugs with sealer.

**NOTE:** New part mating faces and threads should be coated in sealant. Refer to Specifications. Assemble in the following manner:

### Front and left-hand side of the engine block

Plug, 1, apply sealant (Loctite® 641/640/609) and drive into block.

Plug, 2, apply sealant (Loctite® 565 PST) and torque to 8-14 N·m (6-10 ft. lbs.).

Fitting, 3, apply sealant (Loctite® 565 PST) and torque to 24-34 N·m (18-25 ft. lbs.).

Plug, 4, apply sealant (Loctite® 565 PST) and torque to 68-95 N·m (50-70 ft. lbs.).

Fitting, 5, apply sealant (Loctite® 565 PST) and torque to 24-34 N·m (18-25 ft. lbs.).

Plug, 6, apply sealant (Loctite® 565 PST) and torque to 27-47 N·m (20-35 ft. lbs.).

### Rear and right-hand side of the engine block

Plug, 1, apply sealant (Loctite® 641/640/609) and drive into block.

Oil jets, 2, replace with new if damaged, apply engine oil only on reassembly. **Do not use sealant.**

Fitting, 3, apply sealant (Loctite® 565 PST) and torque to 8-14 N·m (6-10 ft. lbs.).

Plug, 4, apply sealant (Loctite® 565 PST) and torque to 54-81 N·m (40-60 ft. lbs.).

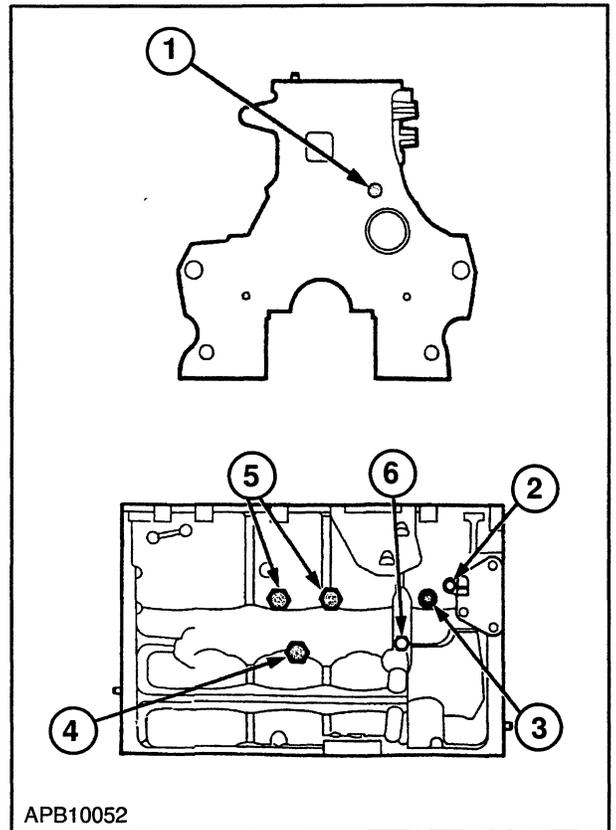


Figure 1-51

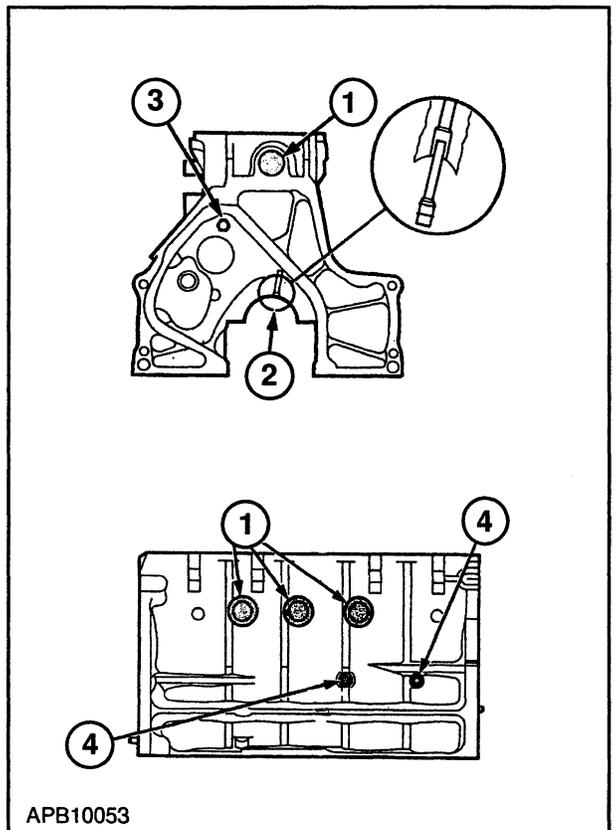


Figure 1-52

## Cylinder Bore

1. Check the cylinder bore for scuffing or rings around the ring travel area. Irregularities can be felt by running a finger over the surface. To check ovality, wear or taper, use a telescopic gauge.

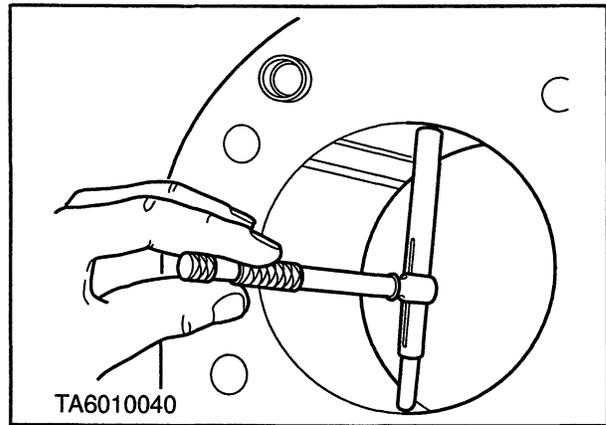


Figure 1-53

Measure lengthwise. Compare measurements A to B and C to D. Variances between the readings will indicate taper.

Measure crosswise. Compare measurements A to C and B to D. Variances will indicate ovality.

**NOTE: 'Repair limit' refers to the tolerance allowed after a repair has been performed. The 'Wear limit' is the tolerance prior to repair.**

Taper of cylinder bore,  
Repair limit - 0.025 mm (0.001")  
Wear limit - 0.127 mm (0.005")

Cylinder bore out-of-round,  
Repair limit - 0.03 mm (0.0015")  
Wear limit - 0.127 mm (0.005")

Cylinder bore diameter,  
111.778-111.841 mm (4.4007-4.4032")

2. Where only minor imperfections exist and bores are to specification, hone the bores prior to installing new piston rings, provided piston to bore clearance is less than 0.250 mm (0.011")
3. Sleeving of the cylinder bores becomes expedient when:
  - Cylinder bore is beyond specification limits.
  - Replacing sleeves already installed in service.

## Sleeving - Boring and Honing

1. Measure the outside diameter of the sleeve in several places and average the dimension. Counterbore the cylinder block (see step 2) using the average dimension to obtain a press fit between bore and sleeve. Interference of sleeve to the cylinder bore is to be 0.025-0.076 mm (0.001-0.003").

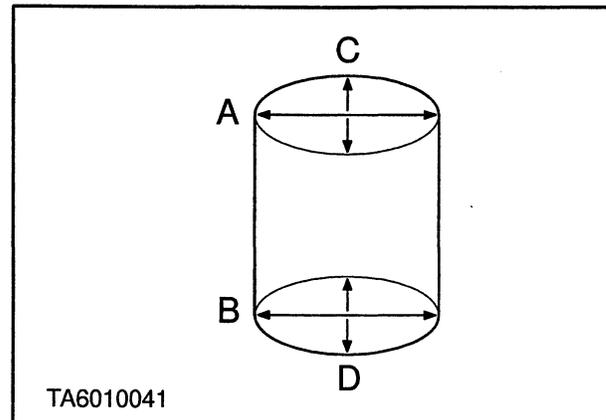


Figure 1-54

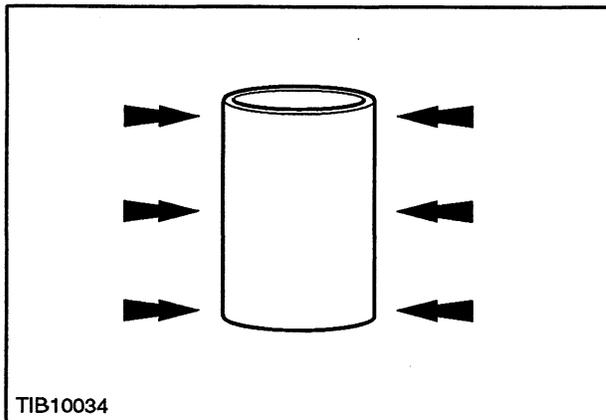


Figure 1-55

2. Counterbore, 1, to a depth of 204.7 mm (8.06"), from the block face. Surface finish of the bore is not to exceed 80 microns. Leave a step at the bottom of the bore a minimum of 9.60-10.16 mm (0.380-0.400"), allowing for run out of chamfers.
3. Bore the block through to the diameter of 113.13-113.18 mm (4.454-4.456").
4. Clean the cylinder bores and thoroughly dry.
5. Grease the sleeve with multi-purpose lithium grease and press the sleeve home to the lip in the bore. The top of the sleeve should protrude through the top of the block, 0.127-1.0 mm (0.005-0.040").
6. Bore the sleeve to 111.7-111.76 mm (4.3985-4.400").
7. Skim the block face and top of sleeves to achieve the specified flatness of 0.08 mm (0.003") in any 152 mm (6"), 0.03 mm (0.001") in any 25.4 mm (1"). A chamfer in the internal diameter at the top of the sleeve to  $45^\circ \times 0.5$  mm (0.020") should be maintained to prevent piston damage on reassembly.
8. Break the sharp edge at the bottom of the sleeve prior to honing.
- 9.hone the cylinder bore to:
  - Grade A, 111.77-111.798 mm (4.4007-4.4015")
  - Grade B, 111.798-111.81 mm (4.4015-4.4023")

**NOTE: Surface finish to be an average of 20 to 30 microns, cross hatched at 35-55°.**

Maximum taper,  
0.025 mm (0.001") through to bottom of the bore

Maximum ovality,  
0.038 mm (0.0015") through to bottom of the bore

## Reassembly

**NOTE: Pistons that are replaced must be of the same type that were removed and have the same identification letters and numbers, as embossed on the underside of the old piston.**

1. Upon reassembly with the piston at top dead center, ensure the piston to block height is correct using a dial indicator.

Naturally aspirated,  
0.28-0.58 mm (0.011-0.023")

Turbocharged,  
0-0.3 mm (0.000-0.012")

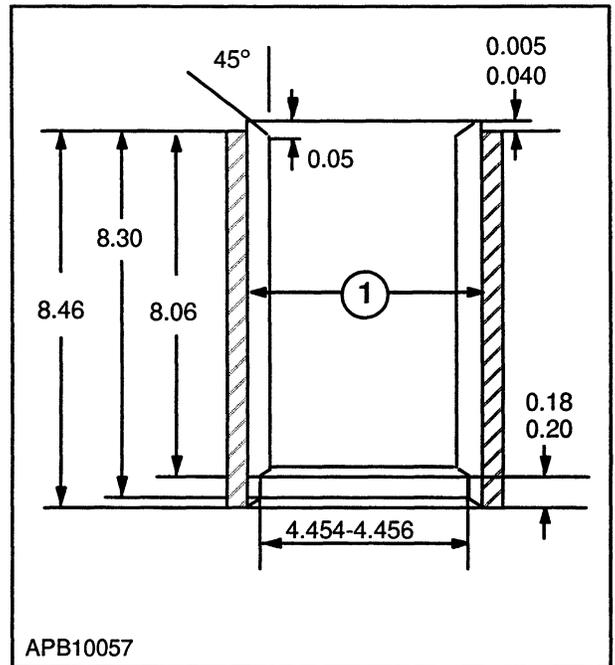


Figure 1-56

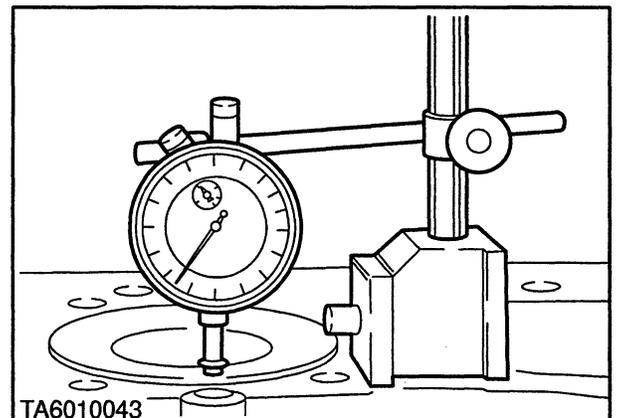


Figure 1-57

2. Check the piston-to-bore clearance, in the following manner:

Measure the cylinder bore diameter at point A, 82.6 mm (3.25") from the top of the block.

Measure the diameter of the piston at right angles to the piston pin at point B, 97.28 mm (3.83") from the top of the piston.

Subtract the piston diameter from the bore diameter. The resultant figure should be:

Naturally aspirated,  
0.140-0.165 mm (0.0055-0.0065")

Turbocharged,  
0.165-0.190 mm (0.0065-0.0075")

After an engine has run and begun the break-in process, maximum piston-to-bore clearance allowed is 0.250 mm (0.011").

If the clearance is greater, try a similar new piston. If the limit is still exceeded, measure remaining cylinder bores and pistons and establish the greatest clearance. Based on the highest figure, rebore to take the next oversize piston.

If the clearance is less, hone the bore to obtain the required clearance.

**IMPORTANT:** Prior to reassembly ensure the letter or grade mark on the piston is aligned to the pip on the connecting rod and installed facing to the front of the engine.

3. Lubricate all of the components with engine oil and assemble the connecting rod/piston.

4. Check the piston ring gap width, using a feeler gauge, in a vertical position at the top, middle, and bottom of the bore to:

Top compression ring,  
0.38-0.84 mm (0.015-0.033")  
2nd compression ring,  
0.66-1.12 mm (0.026-0.044")  
Oil control ring,  
0.38-0.84 mm (0.015-0.033")

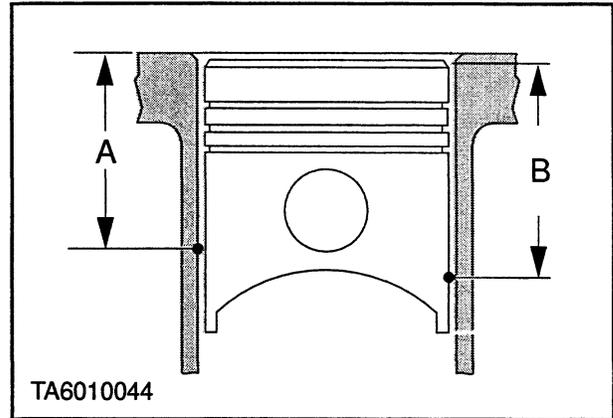


Figure 1-58

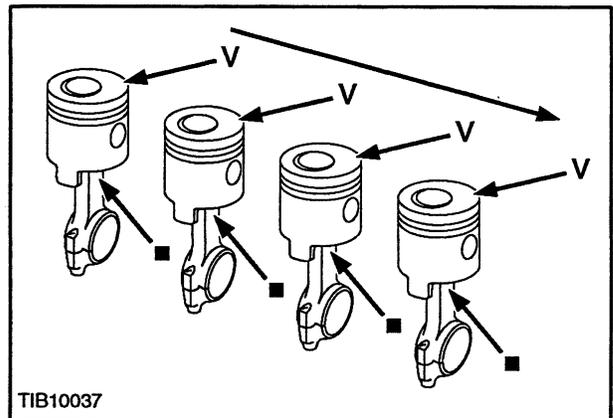


Figure 1-59

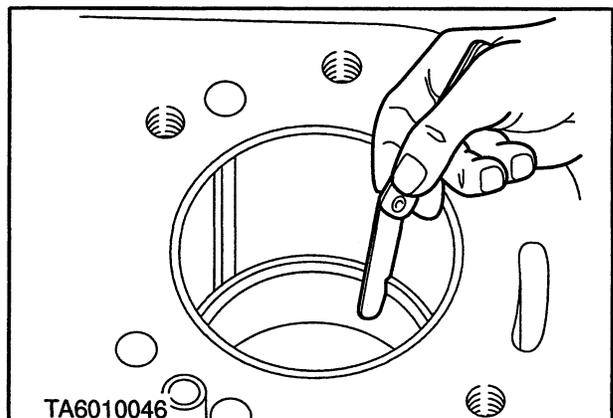


Figure 1-60

5. Using a new piston ring, check with a feeler gauge the gap between the ring and groove.

Top compression ring - naturally aspirated,  
0.112-0.155 mm (0.0044-0.0061")

Turbocharged engines use keystone top rings. Use  
ring groove wear gauge FNH00180 to check  
keystone ring lands for wear.

2nd compression ring,  
0.099-0.142 mm (0.0039-0.0056")

Oil control ring,  
0.061-0.104 mm (0.0024-0.0041")

6. Ensure the correct expander is used to remove or  
install rings.
7. Install new piston rings but note the following:

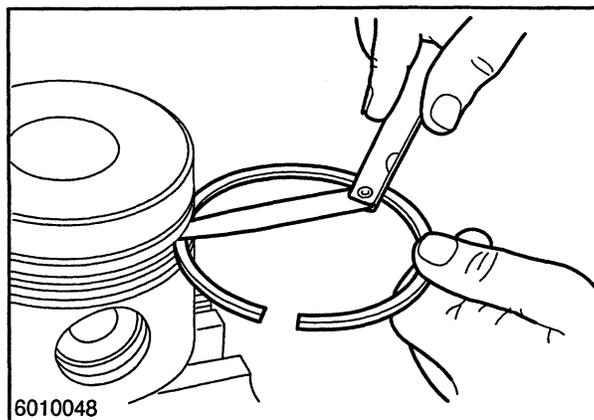
8. Install the top and second compression rings with  
the word top toward the top of the piston.

A = Turbocharged

B = Naturally aspirated

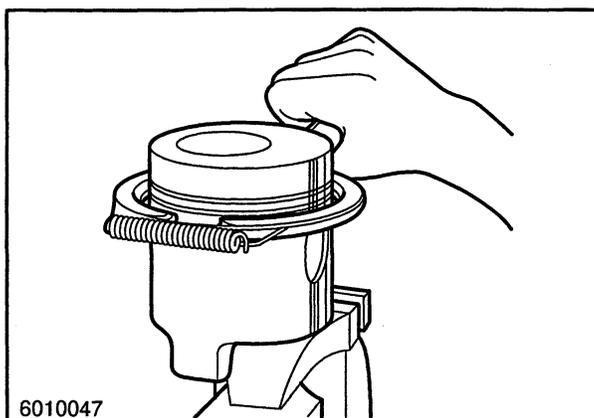
**NOTE:** Before installing new pistons and rings  
into a used cylinder bore remove the high  
polish from the cylinder walls by honing as  
previously described.

Ensure the ring gaps are staggered a minimum  
of 40° from each other on the diameter and with  
no gap on the thrust side of the piston.



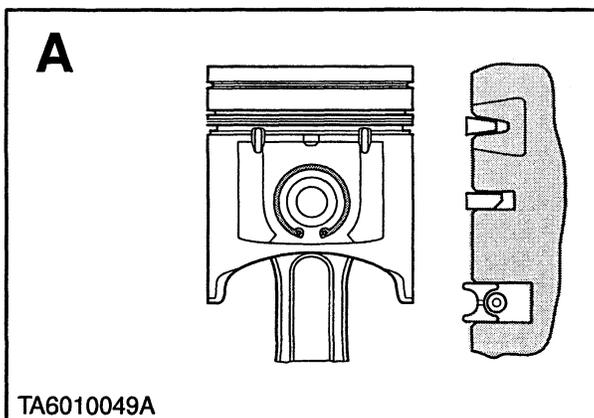
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Figure 1-61



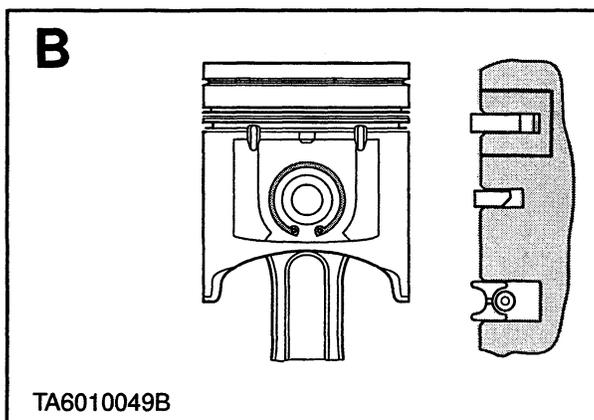
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Figure 1-62



TA6010049A

Figure 1-63



TA6010049B

Figure 1-64

**Piston Assembly Installation Into Block**

1. Select the correct bearing liners, as in the following crankshaft section, and install in the rod and cap. Carefully clean the back side of the liners and the rod and cap liner surfaces to remove any dirt which may prevent proper seating of the liner. Ensure the liner tang locates in the slots of the rod and cap.
2. Turn the crankshaft to position No. 1 crankpin at the bottom of the stroke. Lubricate all parts with new engine oil. Using a ring compressor and a soft drive, slide pistons into bores, ensuring grade letter on pistons is toward the front of the engine.
3. Ensure the connecting rod bearing liner seats on the crankpin with the bearing cap fitted to the connecting rod as a matched assembly. It is recommended that new bolts are fitted and lubricated with oil and tightened to a torque value of 149 N·m (110 ft. lbs.).
4. Using feeler gauges, 1, check the side clearance, 2, of each connecting rod to crankshaft to specification 0.13-0.33 mm (0.005-0.013").

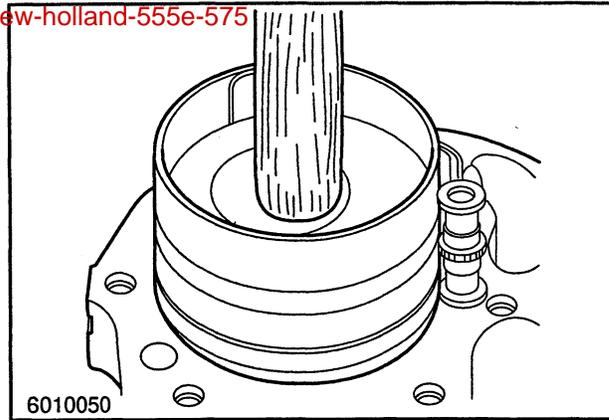


Figure 1-65

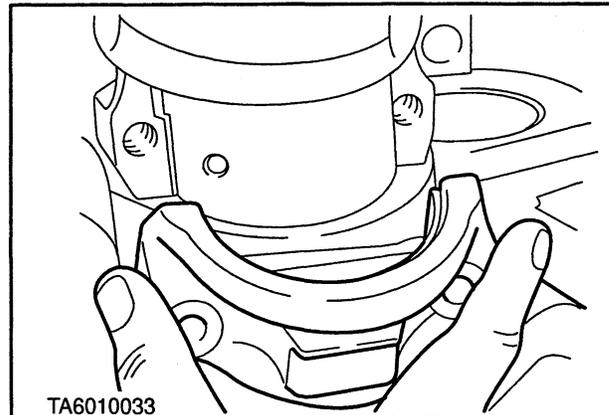


Figure 1-66

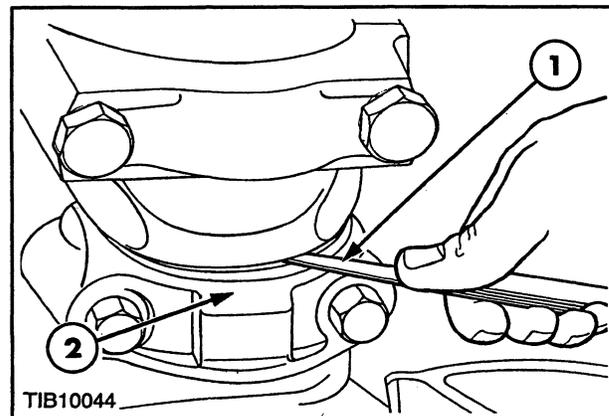


Figure 1-67

**Balancer / Vibration Damper****Removal**

1. Remove the oil pan to expose the balancer and, using a dial indicator gauge, 1, check backlash between crankshaft gear and balancer drive gear. Position the dial plunger to the face of one of the drive gear teeth, then rock the gear to measure backlash. Readings should be taken at 90° intervals around the drive gear, to 0.05-0.30 mm (0.002-0.012"). If the specification is exceeded, inspect the balancer shaft to bushing clearance. If within specification install new balancer gears.

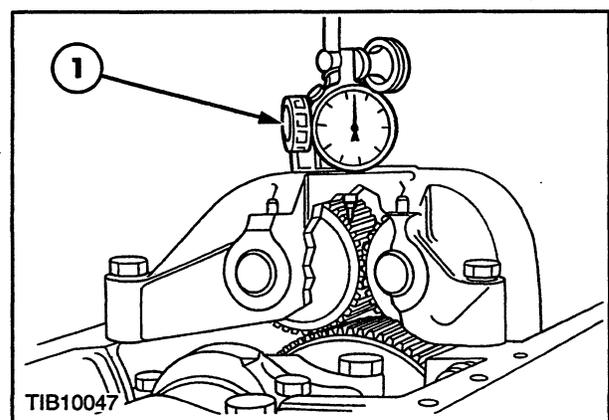


Figure 1-68