2C

GENERAL ENGINE OVERHAUL PROCEDURES

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Reference to other Chapters

Camshaft - removal and installation - See Chapter 2A or 2B
SERVICE ENGINE SOON light - See Chapter 6

1 General information - engine overhaul

Included in this portion of Chapter 2 are the general overhaul procedures for the cylinder head(s) and internal engine components.

The information ranges from advice concerning preparation for an overhaul and the purchase of replacement parts to detailed, step-by-step procedures covering removal and installation of internal engine components and the inspection of parts.

The following Sections have been written based on the assumption that the engine has been removed from the vehicle. For information concerning in-vehicle engine repair, as well as removal and installation of the external components necessary for the overhaul, see Sections 5 and 7, and Chapters 2A and 2B.

The Specifications included in this Part are only those necessary for the inspection and overhaul procedures which follow. Refer to Parts A or B for additional Specifications.

It's not always easy to determine when, or if, an engine should be completely overhauled, as a number of factors must be considered.

High mileage is not necessarily an indication that an overhaul is needed, while low mileage doesn't preclude the need for an overhaul. Frequency of servicing is probably the most important consideration. An engine that's had regular and frequent oil and filter changes, as well as other required maintenance, will most likely give many thousands of miles of reliable service. Conversely, a neglected engine may require an overhaul very early in its life.

Excessive oil consumption is an indication that piston rings, valve seals and/or valve guides are in need of attention. Make sure that oil leaks aren't responsible before deciding that the rings and/or guides are bad. Perform a cylinder compression check to determine the extent of the work required (see Section 3).

Check the oil pressure with a gauge installed in place of the oil pressure sending unit (see Section 2) and compare it to the Specifications. If it's extremely low, the bearings and/or oil pump are probably worn out. Also check the vacuum readings under various conditions (see Section 4).

Loss of power, rough running, knocking or metallic engine noises, excessive valve train noise and high fuel consumption rates may also point to the need for an overhaul, especially if they're all present at the same time. If a complete tune-up doesn't remedy the situation, major mechanical work is the only solution.

An engine overhaul involves restoring the internal parts to the specifications of a new engine. During an overhaul, the piston rings are replaced and the cylinder walls are reconditioned (rebored and/or honed). If a rebore is done by an automotive machine shop, new oversize pistons will also be installed. The main bearings, connecting rod bearings and camshaft bearings are generally replaced with new ones and, if necessary, the crankshaft may be reground to restore the journals. Generally, the valves are serviced as well, since they're usually in less-than-perfect condition at this point.

While the engine is being overhauled, other components, such as the distributor, starter and alternator, can be rebuilt as well. The end result should be a like new engine that will give many thousands of trouble free miles.

➡Note: Critical cooling system components such as the hoses, drivebelts, thermostat and water pump MUST be replaced with new parts when an engine is overhauled.

There are engine rebuilders who will not guarantee their work if the radiator hasn't been professionally cleaned at the time of a rebuilt-engine installation. The radiator should be checked carefully to ensure that it isn't clogged or leaking (see Chapter 3). Also, we don't recommend overhauling the oil pump - always install a new one when an engine is rebuilt.

Before beginning the engine overhaul, read through the entire procedure to familiarize yourself with the scope and requirements of the job. Overhauling an engine isn't difficult if you have the right equipment and follow the instructions carefully, but it is time-consuming. Plan on the vehicle being tied up for a minimum of two weeks, especially if parts must be taken to an automotive machine shop for repair or reconditioning. Check on availability of parts and make sure that any necessary special tools and equipment are obtained in advance.

Most work can be done with typical hand tools, although a number of precision measuring tools are required for inspecting parts to determine if they must be replaced. Often an automotive machine shop will handle the inspection of parts and offer advice concerning reconditioning and replacement.

➡Note: Always wait until the engine has been completely disassembled and all components, especially the engine block, have been inspected before deciding what service and repair operations must be performed by an automotive machine shop.

Since the block's condition will be the major factor to consider when determining whether to overhaul the original engine or buy a rebuilt one, never purchase parts or have machine work done on other components until the block has been thoroughly inspected. As a general rule, time is the primary cost of an overhaul, so it doesn't pay to install worn or substandard parts.

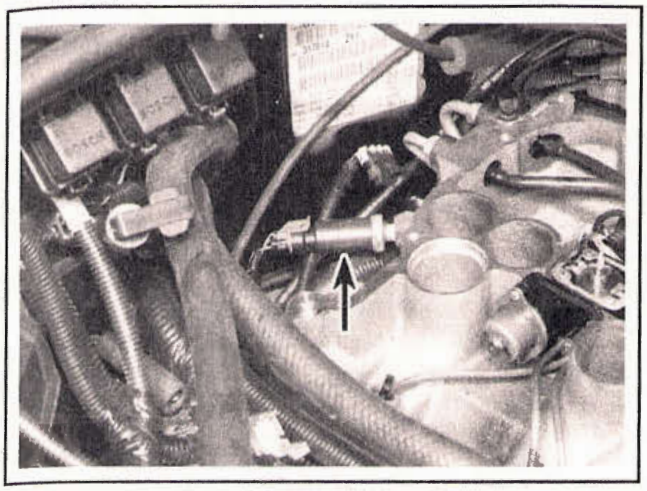
As a final note, to ensure maximum life and minimum trouble from a rebuilt engine, everything must be assembled with care in a spotlessly-clean environment.

2 Oil pressure check

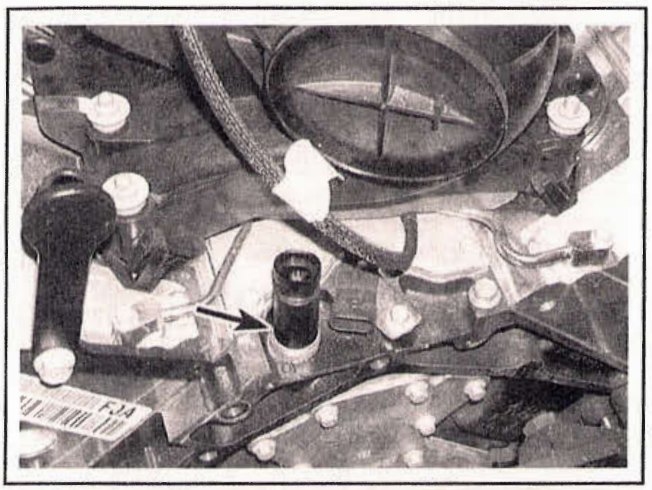
♦ Refer to illustrations 2.2a, 2.2b and 2.5

1 Low engine oil pressure can be a sign of an engine in need of rebuilding. A "low oil pressure" indicator (often called an "idiot light") is not a test of the oiling system. Such indicators only come on when the oil pressure is dangerously low. Even an original pressure gauge in the instrument panel is only a relative indication, although it's much better for driver information than a warning light. An accurate test can only be performed with a mechanical (not electrical) oil pressure gauge. When used in conjunction with an accurate tachometer, the engine's oil pressure performance can be compared to the manufacturer's Specifications for that year and model.

2 Locate the oil pressure indicator sending unit behind the rear of the intake manifold (see illustrations).



2.2a Oil pressure sending unit location - V6 engine

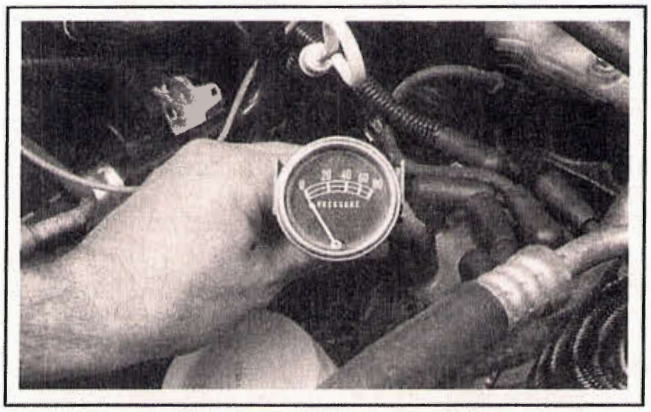


2.2b Oil pressure sending unit location - V8 engines

3 Remove the oil pressure sending unit and install a fitting which will allow you to directly connect your hand-held, mechanical oil pressure gauge. Use Teflon tape or sealant on the threads of the adapter and the fitting on the end of your gauge's hose.

4 Connect an accurate tachometer to the engine, according to the tachometer manufacturer's instructions.

5 Check the oil pressure with the engine running (full operating temperature) at the specified engine speed, and compare it to this Chapter's Specifications (see illustration). If it's extremely low, the bearings and/or oil pump are probably worn out.



2.5 Check the oil pressure with the engine running (full operating temperature) at the specified engine speed and compare it to this Chapter's Specifications

3 Compression check

Refer to illustration 3.6

1 A compression check will tell you what mechanical condition the upper end (pistons, rings, valves, head gaskets) of your engine is in. Specifically, it can tell you if the compression is down due to leakage caused by worn piston rings, defective valves and seats or a blown head gasket.

Note: The engine must be at normal operating temperature and the battery must be fully charged for this check.

2 Begin by cleaning the area around the spark plugs before you remove them (compressed air should be used, if available). The idea is to prevent dirt from getting into the cylinders as the compression check is being done.

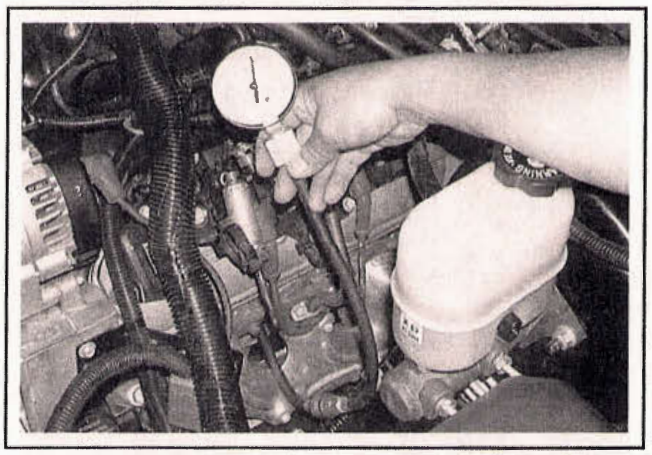
3 Remove all of the spark plugs from the engine (see Chapter 1).

4 Block the throttle wide open.

5 Disable the ignition system by disconnecting the primary electrical connectors at the ignition coil packs (V8 engines) or by disconnecting the primary (low voltage) electrical connectors from the distributor (V6 engines). The fuel pump circuit should also be disabled by removing the fuel pump relay (it's located in the underhood fuse/relay box - see Chapter 12).

6 Install the compression gauge in the number one spark plug hole (see illustration).

7 Crank the engine over at least seven compression strokes and



3.6 A compression gauge with a threaded fitting for the spark plug hole is preferred over the type that requires hand pressure to maintain the seal

watch the gauge. The compression should build up quickly in a healthy engine. Low compression on the first stroke, followed by gradually increasing pressure on successive strokes, indicates worn piston rings. A low compression reading on the first stroke, which doesn't build up during successive strokes, indicates leaking valves or a blown head gasket (a cracked head could also be the cause). Deposits on the undersides of the valve heads can also cause low compression. Record the highest gauge reading obtained.

8 Repeat the procedure for the remaining cylinders and compare the results to this Chapter's Specifications.

9 Add some engine oil (about three squirts from a plunger-type oil can) to each cylinder, through the spark plug hole, and repeat the test.

10 If the compression increases after the oil is added, the piston rings are definitely worn. If the compression doesn't increase significantly, the leakage is occurring at the valves or head gasket. Leakage past the valves may be caused by burned valve seats and/or faces or warped, cracked or bent valves.

11 If two adjacent cylinders have equally-low compression, there's a strong possibility that the head gasket between them is blown. The appearance of coolant in the combustion chambers or the crankcase would verify this condition.

12 If one cylinder is slightly lower than the others, and the engine has a rough idle, a worn lobe on the camshaft could be the cause.

13 If the compression is unusually high, the combustion chambers are probably coated with carbon deposits. If that's the case, the cylinder head(s) should be removed and decarbonized.

14 If compression is way down or varies greatly between cylinders, it would be a good idea to have a leak-down test performed by an automotive repair shop. This test will pinpoint exactly where the leakage is occurring and how severe it is.

4 Vacuum gauge diagnostic checks

♦ Refer to illustrations 4.4 and 4.6

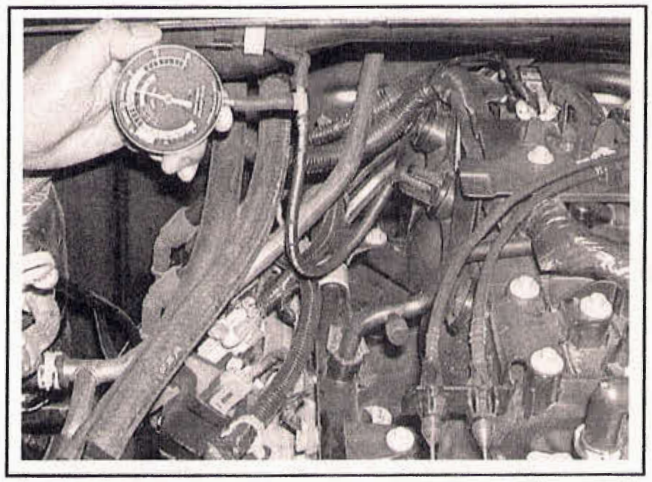
1 A vacuum gauge provides valuable information about the condition of internal engine components. You can check for worn rings or cylinder walls, leaking head or intake manifold gaskets, restricted exhaust, stuck or burned valves, weak valve springs, improper ignition or valve timing and ignition problems.

2 Unfortunately, vacuum gauge readings are easy to misinterpret, so they should be used in conjunction with other tests to confirm the diagnosis.

3 Both the absolute readings and the rate of needle movement are important for accurate interpretation. Most gauges measure vacuum in inches of mercury (in-Hg). The following references to vacuum assume the diagnosis is being performed at sea level. As elevation increases (or atmospheric pressure decreases), the reading will decrease. For every 1,000 foot increase in elevation above approximately 2000 feet, the gauge readings will decrease about one inch of mercury.

4 Connect the vacuum gauge directly to intake manifold vacuum, not to ported (throttle body) vacuum (see illustration). Be sure no hoses are left disconnected during the test or false readings will result.

5 Before you begin the test, allow the engine to warm up completely. Block the wheels and set the parking brake. With the transmission in Park or Neutral, start the engine and allow it to run at normal idle speed.



4.4 An inexpensive vacuum gauge can tell you a lot about an engine's condition

⁂ WARNING:

Always keep your hands, loose clothing and tools clear of the fan and do not stand in front of the vehicle or in line with the fan when the engine is running.

6 Read the vacuum gauge; an average, healthy engine should normally produce about 17 to 22 inches of vacuum with a fairly steady needle (see illustration). Refer to the following vacuum gauge readings and what they indicate about the engine's condition:

a) A low steady reading usually indicates a leaking gasket between the intake manifold and throttle body, a leaky vacuum hose, late ignition timing or incorrect camshaft timing. Check ignition timing with a timing light and eliminate all other possible causes, utilizing the tests provided in this Chapter before you remove the timing chain cover to check the timing marks.

b) If the reading is three to eight inches below normal and it fluctuates at that low reading, suspect an intake manifold gasket leak at an intake port or a faulty fuel injector.

c) If the needle has regular drops of about two-to-four inches at a steady rate, the valves are probably leaking. Perform a compression check or leak-down test to confirm this.

d) An irregular drop or down-flick of the needle can be caused by a sticking valve or an ignition misfire. Perform a compression check or leak-down test and read the spark plugs.

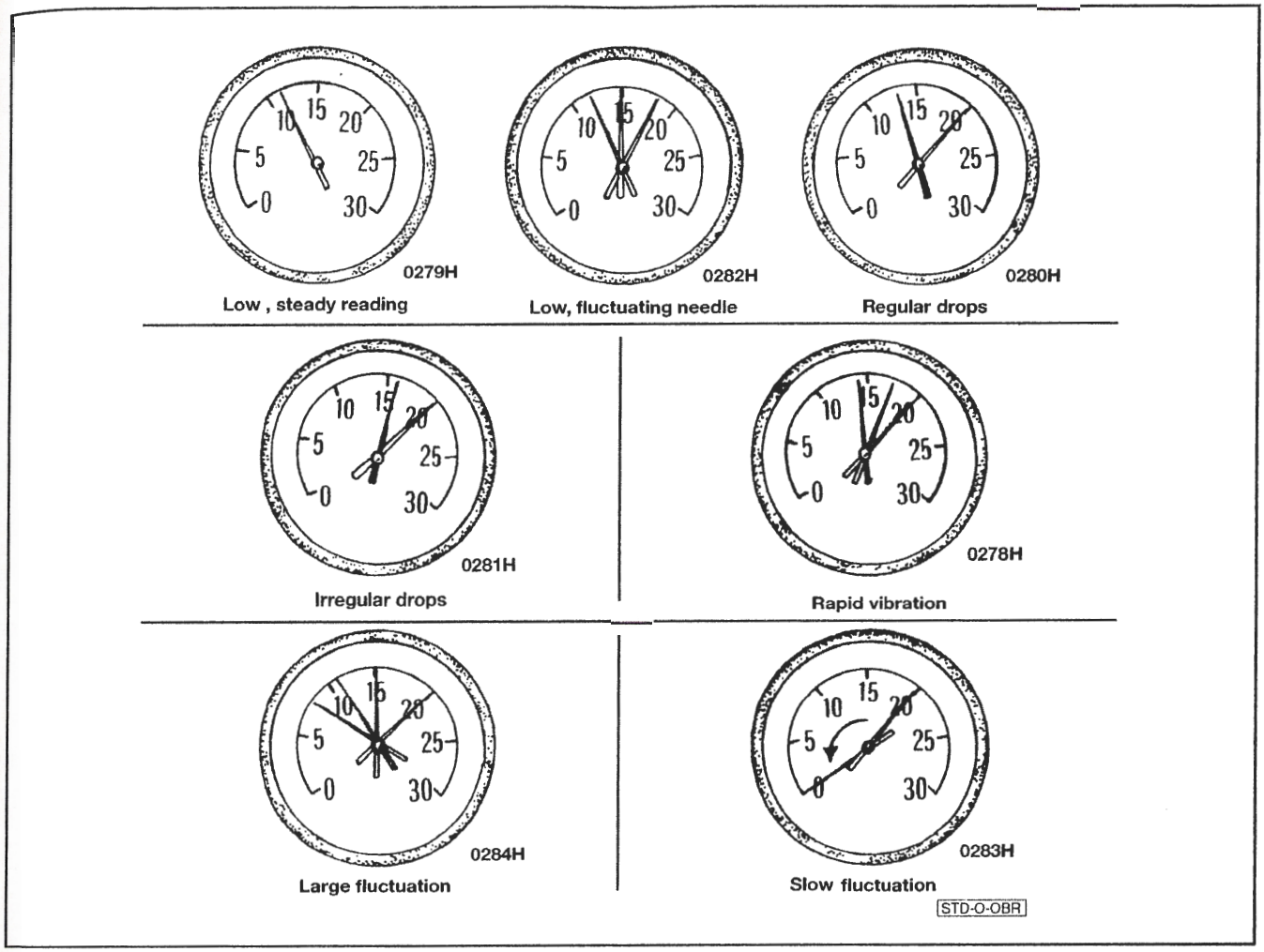
e) A rapid vibration of about four inches Hg vibration at idle combined with exhaust smoke indicates worn valve guides. Perform a leak-down test to confirm this. If the rapid vibration occurs with an increase in engine speed, check for a leaking intake manifold gasket or head gasket, weak valve springs, burned valves or ignition misfire.

f) A slight fluctuation, say one inch up and down, may mean ignition problems. Check all the usual tune-up items and, if necessary, run the engine on an ignition analyzer.

g) If there is a large fluctuation, perform a compression or leak-down test to look for a weak or dead cylinder or a blown head gasket.

h) If the needle moves slowly through a wide range, check for a clogged PCV system, incorrect idle fuel mixture, carburetor/throttle body or intake manifold gasket leaks.

i) Check for a slow return after revving the engine by quickly snapping the throttle open until the engine reaches about 2,500 rpm



4.6 Typical vacuum gauge readings

and let it shut. Normally the reading should drop to near zero, rise above normal idle reading (about 5 in.-Hg over) and then return to the previous idle reading. If the vacuum returns slowly and doesn't peak when the throttle is snapped shut, the rings may be worn. If there is a long delay, look for a restricted exhaust system (often the muffler or catalytic converter). An easy way to check this is to temporarily disconnect the exhaust ahead of the suspected part and re-test.

5 Engine rebuilding alternatives

The do-it-yourselfer is faced with a number of options when performing an engine overhaul. The decision to replace the engine block, piston/connecting rod assemblies and crankshaft depends on a number of factors, with the number one consideration being the condition of the block. Other considerations are cost, access to machine shop facilities, parts availability, time required to complete the project and the extent of prior mechanical experience on the part of the do-it-yourselfer.

Some of the rebuilding alternatives include:

Individual parts - If the inspection procedures reveal that the engine block and most engine components are in reusable condition, purchasing individual parts may be the most economical alternative. The block, crankshaft and piston/connecting rod assemblies should all be inspected carefully. Even if the block shows little wear, the cylinder bores should be surface-honed.

Crankshaft kit - This rebuild package consists of a reground crankshaft and a matched set of pistons and connecting rods. The pistons will already be installed on the connecting rods. Piston rings and the necessary bearings will be included in the kit. These kits are commonly available for standard cylinder bores, as well as for engine blocks which have been bored to a regular oversize.

Short block - A short block consists of an engine block with renewed crankshaft and piston/connecting rod assemblies already installed. All new bearings are incorporated and all clearances will be correct. The existing cylinder head(s), camshaft, valve train components and external parts can be bolted to the short block with little or no machine shop work necessary.

Long block - A long block consists of a short block plus an oil pump, oil pan, cylinder heads, valve covers, camshaft and valve train

components, timing sprockets, timing chain and timing cover. All components are installed with new bearings, seals and gaskets incorporated throughout. The installation of manifolds and external parts is all that is necessary.

Used engine assembly - While overhaul provides the best assurance of a like-new engine, used engines available from wrecking yards and importers are often a very simple and economical solution. Many used engines come with warranties, but always give any engine a thorough diagnostic check-out before purchase. Check compression, vacuum and also for signs of oil leakage. If possible, have the seller run the engine, ether in the vehicle or on a test stand so you can be sure it runs smoothly with no knocking or other noises.

Give careful thought to which alternative is best for you and discuss the situation with local automotive machine shops, auto parts dealers or parts store countermen before ordering or purchasing replacement parts.

6 Engine removal - methods and precautions

If you've decided that an engine must be removed for overhaul or major repair work, several preliminary steps should be taken.

Locating a suitable place to work is extremely important. Adequate work space, along with storage space for the vehicle, will be needed. If a shop or garage isn't available, at the very least a flat, level, clean work surface made of concrete or asphalt is required.

Cleaning the engine compartment and engine before beginning the removal procedure will help keep your tools and your hands clean.

An engine hoist or A-frame will also be necessary. Make sure the equipment is rated in excess of the combined weight of the engine and accessories. Safety is of primary importance, considering the potential hazards involved in lifting the engine out of the vehicle.

If the engine is being removed by a novice, a helper should be available. Advice and aid from someone more experienced would also be helpful. There are many instances when one person cannot simultaneously perform all of the operations required when lifting the engine out of the vehicle.

Plan the operation ahead of time. Arrange for or obtain all of the tools and equipment you'll need prior to beginning the job. Some of the equipment necessary to perform engine removal and installation safely and with relative ease are (in addition to an engine hoist) a heavy-duty floor jack, complete sets of wrenches and sockets as described in the front of this manual, wooden blocks and plenty of rags and cleaning solvent for mopping up spilled oil, coolant and gasoline. If the hoist must be rented, make sure that you arrange for it in advance and perform all of the operations possible without it beforehand. This will save you money and time.

Plan for the vehicle to be out of use for quite a while. A machine shop will be required to perform some of the work which the do-it-yourselfer can't accomplish without special equipment. These shops often have a busy schedule, so it would be a good idea to consult them before removing the engine in order to accurately estimate the amount of time required to rebuild or repair components that may need work.

Always be extremely careful when removing and installing the engine. Serious injury can result from careless actions. Plan ahead, take your time and a job of this nature, although major, can be accomplished successfully.

7 Engine - removal and installation

WARNING 1:

The air conditioning system is under high pressure. Do not loosen any hose fittings or remove any components until after the system has been discharged. Air conditioning refrigerant should be properly discharged into an EPA-approved recov-ery/recycling unit at a dealer service department or an automotive air conditioning repair facility. Always wear eye protection when disconnecting air conditioning system fittings.

WARNING 2:

Gasoline is extremely flammable, so take extra precautions when you work on any part of the fuel system. Don't smoke or allow open flames or bare light bulbs near the work area, and don't work in a garage where a natural gas-type appliance (such as a water heater or a clothes dryer) is present. Since gasoline is carcinogenic, wear latex gloves when there's a possibility of being exposed to fuel, and, if you spill any fuel on your skin, rinse it off immediately with soap and water. Mop up any spills immediately and do not store fuel-soaked rags where they could ignite. The fuel system is under constant pressure, so, if any fuel lines are to be disconnected, the fuel pressure in the system must be relieved first (see Chapter 4 for more information). When you perform any kind of work on the fuel system, wear safety glasses and have a Class B type fire extinguisher on hand.

WARNING 3:

The models covered by this manual are equipped with airbags. Always disable the airbag system before working in the vicinity of any airbag system components to avoid the possibility of accidental deployment of the airbag(s), which could cause personal injury (see Chapter 12).

REMOVAL

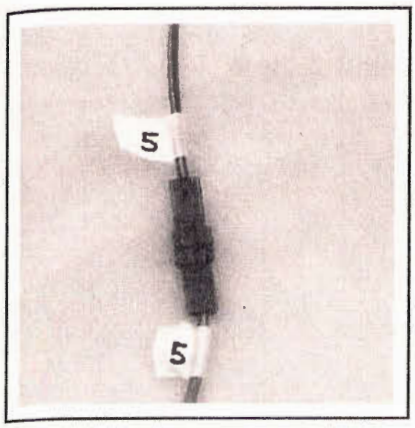
▶ Refer to illustrations 7.5a, 7.5b, 7.5c, 7.12, 7.15, 7.22 and 7.27

1 If the vehicle is equipped with air conditioning, have the system discharged and the refrigerant recovered by an air conditioning specialist.

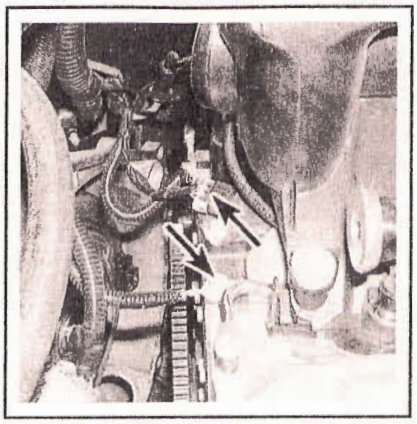
2 Refer to Chapter 4 and relieve the fuel system pressure, then disconnect the cable from the negative terminal of the battery.

CAUTION:

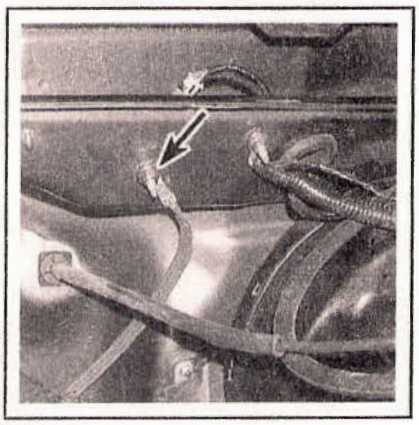
On models equipped with the Theftlock audio system, be sure the lockout feature is turned off before performing any procedure which requires disconnecting the battery (see the front of this manual).



7.5a Label both ends of each wire before unplugging the connector



7.5b Don't forget to disconnect the electrical connections (arrows) at the rear of the block . . .



7.5c . . . and the ground straps (arrow) at the firewall

3 Cover the fenders and cowl and remove the hood (see Chapter 11). Special pads are available to protect the fenders, but an old bedspread or blanket will also work.

➡Note: As an alternative to removing the hood, the side bolt in each hood hinge can be removed and installed in the lower hole of the hinge, which will secure the hood in an upright position. Have an assistant help hold the hood during this procedure.

4 Remove the air cleaner assembly (see Chapter 4). Drain the cooling system (see Chapter 1).

5 Label the vacuum lines, emissions system hoses, wiring connectors, ground strap and fuel lines, to ensure correct reinstallation, then detach them (see illustrations). If there's any possibility of confusion, make a sketch of the engine compartment and clearly label the lines, hoses and wires. Detach the wiring harness brackets from the intake manifold and set the engine wiring harness aside.

6 Label and detach all coolant hoses from the engine.

7 Remove the drivebelt(s) (see Chapter 1). On V6 engines, remove the distributor cap and spark plug wires to avoid contact with the firewall as the engine is lifted from the vehicle.

8 Remove the cooling fan, shroud and radiator (see Chapter 3).

9 Remove the intake manifold cover if equipped. Disconnect the throttle linkage and the cruise control cable, (if equipped) from the throttle body (see Chapter 4).

10 Disconnect the fuel lines running from the engine to the chassis (see Chapter 4). Plug or cap all open fittings/lines. Remove the secondary air injection pipe, if equipped, from the intake manifold and the exhaust manifolds (see Chapter 6).

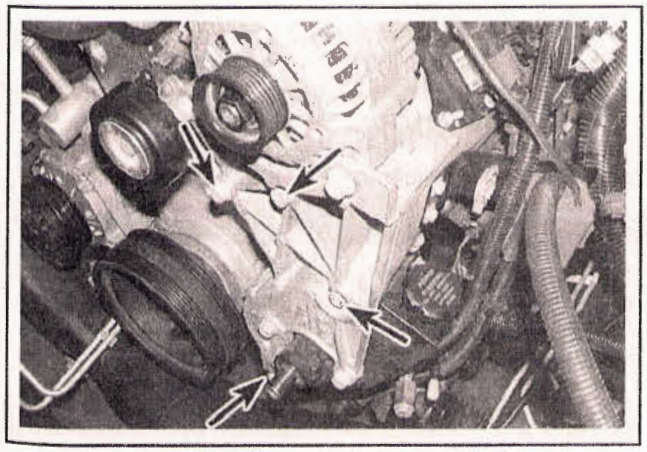
11 On air-conditioned vehicles, disconnect the refrigerant lines from the compressor (see the Warning at the beginning of this Section). Plug all the hoses to avoid contamination of the A/C system and set the hoses aside. On V8 engines, unbolt the compressor from the compressor mounting bracket on the side of the block and remove it from the engine compartment (see Chapter 3).

12 On power steering equipped vehicles, disconnect the power steering pump lines and unbolt the rear of the power steering pump from the engine. Detach the power steering pump/air conditioning compressor bracket (V6 engines) or the power steering pump/alternator bracket (V8 engines) from the front of the engine (see illustration). Make sure the pump is kept in an upright position after being removed from the engine compartment. On V6 engines, this Step will remove the power steering pump, the power steering pump bracket and the air conditioning compressor. On V8 engines, this Step will remove the power steering pump, the power steering pump bracket and the alternator.

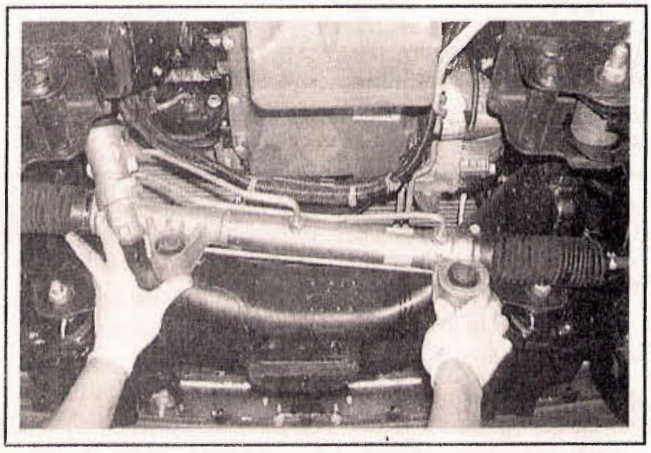
13 Raise the front of the vehicle and support it securely on jackstands. Working under the vehicle, drain the engine oil (see Chapter 1).

14 Unbolt the exhaust system from the exhaust manifolds.

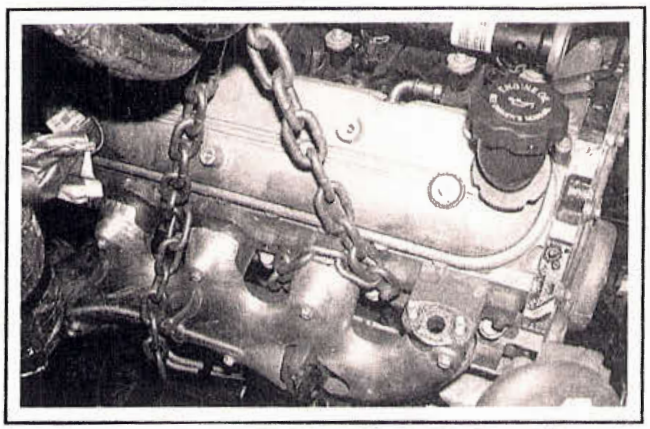
15 On models with rack-and-pinion steering, remove the bolts securing the steering gear to the frame and lower the steering gear,



7.12 Alternator/power steering pump mounting bracket bolts (arrows) (V8 engine shown, V6 engine similar except that the A/C compressor is mounted where the alternator is on V8 engines)



7.15 Lowering the steering gear on 2WD 1500 pick-up models will allow clearance for the oil pan as the engine is moved forward to clear the cowl



7.22 On V8 engines, it will be necessary to attach the sling or chain to the cylinder heads

allowing it to hang by the tie-rods (see illustration). This Step will allow clearance for the oil pan as the engine is moved forward to clear the cowl.

16 Remove the oil pan skid plates if equipped. Remove the lower control arm crossmember from below the oil pan (see illustration 14.4 in Chapter 2B).

17 Remove the starter motor (see Chapter 5).

18 Remove the transmission inspection cover and the bellhousing covers from the bellhousing (see illustrations 8.8a and 8.8b in Chapter 7B). If you're working on a vehicle with an automatic transmission, refer to Chapter 7B and remove the torque converter-to-driveplate fasteners.

19 Remove the wiring harness bracket from the front of the oil pan and the bracket on the passenger side of the oil pan securing the transmission oil cooler lines (if equipped) and the starter motor wiring. Disconnect the electrical connector from the oil level sensor and the crankshaft position sensor. Also disconnect the engine block heater if equipped.

20 If the vehicle is equipped with an engine oil cooler, remove the engine oil cooler lines and adapter from the driver's side of the oil pan.

21 Support the transmission with a jack. Position a block of wood between the jack and transmission to prevent damage to the transmission. Special transmission jacks with safety chains are available - use one if possible.

22 Attach an engine sling or a length of chain to the lifting brackets on the engine.

CAUTION:

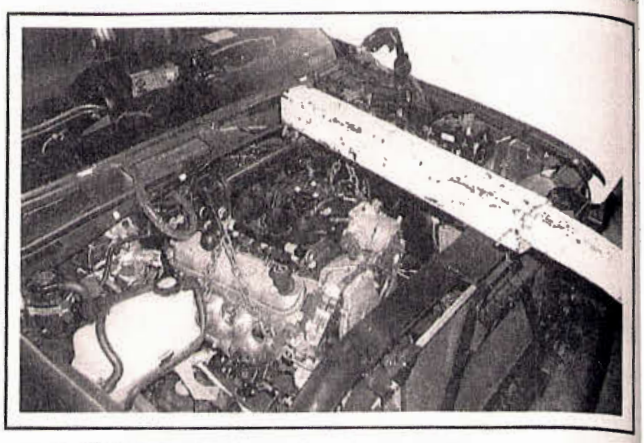
DO NOT lift the engine by the intake manifold. Lift the engine by the block or the cylinder head only.

➡Note: V8 engines are not equipped with lifting brackets. On these engines it will be necessary to attach a sling to the exhaust manifold bolts or directly to the cylinder heads (see illustration).

23 Roll the hoist into position and connect the sling to it. Take up the slack in the sling or chain, but don't lift the engine.

WARNING:

DO NOT place any part of your body under the engine when it's supported only by a hoist or other lifting device.



7.27 Pull the engine forward as far as possible to clear the transmission and the cowl, then lift the engine high enough to clear the body

24 Remove the transmission-to-engine block bolts.

25 Remove the engine mount-to-frame bolts (see Chapter 2A or 2B for engine mount removal procedures).

26 Recheck to be sure nothing is still connecting the engine to the transmission or vehicle. Disconnect anything still remaining.

27 Raise the engine slightly. Carefully work it forward to separate it from the transmission. If you're working on a vehicle with an automatic transmission, be sure the torque converter stays in the transmission (clamp a pair of vise-grips to the housing to keep the converter from sliding out). If you're working on a vehicle with a manual transmission, the input shaft must be completely disengaged from the clutch. Slowly raise the engine out of the engine compartment (see illustration). Check carefully to make sure nothing is hanging up.

28 Remove the flywheel/driveplate and mount the engine on an engine stand.

INSTALLATION

29 Install the flywheel/driveplate on the engine (see Chapter 2A or 2B). Check the engine and transmission mounts. If they're worn or damaged, replace them.

30 If you're working on a vehicle with a manual transmission, install the clutch and pressure plate onto the flywheel (see Chapter 7A). Now is a good time to install a new clutch.

31 Carefully lower the engine into the engine compartment - make sure the engine mounts line up.

32 If you're working on a vehicle with an automatic transmission, guide the torque converter into the crankshaft following the procedure outlined in Chapter 7B.

33 If you're working on a vehicle with a manual transmission, apply a dab of high-temperature grease to the input shaft and guide it into the crankshaft pilot bearing until the bellhousing is flush with the engine block.

➡Note: It may be necessary to place the transmission into first gear, then turn the output shaft on the transmission until the teeth on the input shaft align with the teeth on the clutch disc.

34 Install the transmission-to-engine bolts and tighten them securely.

CAUTION:

DO NOT use the bolts to force the transmission and engine together!

35 Reinstall the remaining components in the reverse order of removal.

CAUTION:

On 2001 and later models, the throttle linkage should be replaced with a new one when the engine is reinstalled.

36 Add coolant, oil, power steering and transmission fluid as needed.

37 Run the engine and check for leaks and proper operation of all accessories, then install the hood and test drive the vehicle.

38 Have the air conditioning system recharged and leak tested.

8 Engine overhaul - disassembly sequence

1 It's much easier to disassemble and work on the engine if it's mounted on a portable engine stand. A stand can often be rented quite cheaply from an equipment rental yard. Before the engine is mounted on a stand, the flywheel/driveplate should be removed from the engine.

2 If a stand isn't available, it's possible to disassemble the engine with it blocked up on the floor. Be extra careful not to tip or drop the engine when working without a stand.

3 If you're going to obtain a rebuilt engine, all external components must come off first to be transferred to the replacement engine, just as they will if you're doing a complete engine overhaul yourself. These include:

Alternator and brackets
Emissions control components
Distributor, spark plug wires and spark plugs (V6 engines)
Ignition coils, spark plug wires and spark plugs (V8 engines)
Thermostat and housing cover
Water pump
Fuel injection components
Intake/exhaust manifold(s)
Oil filter
Engine mounts
Clutch and flywheel/driveplate

Note: When removing the external components from the engine, pay close attention to details that may be helpful or important during installation. Note the installed position of gaskets, seals, spacers, pins, brackets, washers, bolts and other small items.

4 If you're obtaining a short block, which consists of the engine block, crankshaft, pistons and connecting rods all assembled, then the cylinder head(s), oil pan and oil pump will have to be removed as well. See *Engine rebuilding alternatives* for additional information regarding the different possibilities to be considered.

5 If you're planning a complete overhaul, the engine must be disassembled and the internal components removed in the following order:

Valve cover(s)
Intake and exhaust manifolds
Rocker arms and pushrods
Cylinder head(s)
Valve lifters
Oil pan
Oil pump (V6 engines)
Timing chain cover
Oil pump (V8 engines)
Timing chain and sprockets
Camshaft
Balance shaft (V6 engines)
Piston/connecting rod assemblies
Rear main oil seal retainer
Crankshaft and main bearings

6 Before beginning the disassembly and overhaul procedures, make sure the following items are available. Also, refer to Section 23 for a list of tools and materials needed for engine reassembly.

Common hand tools
Small cardboard boxes or plastic bags for storing parts
Gasket scraper
Ridge reamer
Crankshaft balancer puller
Micrometers
Telescoping gauges
Dial-indicator set
Valve spring compressor
Cylinder surfacing hone
Piston ring groove-cleaning tool
Electric drill motor
Tap and die set
Wire brushes
Oil gallery brushes
Cleaning solvent

9 Cylinder head - disassembly

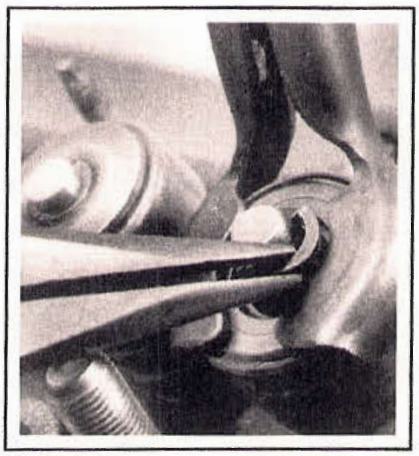
Refer to illustrations 9.2, 9.3 and 9.4

Note: New and rebuilt cylinder heads are commonly available for most engines at dealerships and auto parts stores. Due to the fact that some specialized tools are necessary for the disassembly and inspection procedures, and some parts may not be readily available, it may be more practical and economical for the home mechanic to purchase replacement head(s) rather than taking the time to disassemble, inspect and recondition the original(s).

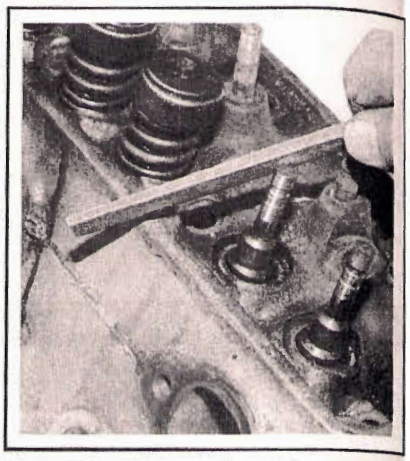
1 Cylinder head disassembly involves removal of the intake and exhaust valves and related components. If they're still in place, remove the rocker arm bolts, pivots and rocker arms from the cylinder head. Label the parts or store them separately so they can be reinstalled in their original locations.

2 Before the valves are removed, arrange to label and store them,

9.2 A small plastic bag, with an appropriate label, can be used to store the valve train components so they can be kept together and reinstalled in the correct guide



9.3 Use a valve spring compressor to compress the spring, then remove the keepers with a magnet or needle-nose pliers



9.4 If the valve won't pull through the guide, deburr the edge of the stem and the area around the top of the keeper groove with a file

along with their related components, so they can be kept separate and reinstalled in the same valve guides they were removed from (see illustration).

3 Compress the springs on the first valve with a spring compressor and remove the keepers (see illustration). Carefully release the valve spring compressor and remove the retainer, the spring and the spring seat (if used).

4 Pull the valve out of the head, then remove the oil seal from the guide. If the valve binds in the guide (won't pull through), push it back into the head and deburr the area around the keeper groove with a fine file or whetstone (see illustration).

5 Repeat the procedure for the remaining valves. Remember to keep all the parts for each valve together so they can be reinstalled in the same locations.

6 Once the valves and related components have been removed and stored in an organized manner, the head should be thoroughly cleaned and inspected. If a complete engine overhaul is being done, finish the engine disassembly procedures before beginning the cylinder head cleaning and inspection process.

10 Cylinder head - cleaning and inspection

CLEANING

Refer to illustrations 10.12, 10.14, 10.15, 10.16, 10.17 and 10.18

1 Thorough cleaning of the cylinder head(s) and related valve train components, followed by a detailed inspection, will enable you to decide how much valve service work must be done during the engine overhaul.

Note: If the engine was severely overheated, the cylinder head is probably warped (see Step 12).

2 Scrape all traces of old gasket material and sealing compound off the head gasket, intake manifold and exhaust manifold sealing surfaces. Be very careful not to gouge the cylinder head. Special gasket removal solvents that soften gaskets and make removal much easier are available at auto parts stores.

3 Remove all built up scale from the coolant passages.

4 Run a stiff wire brush through the various holes to remove deposits that may have formed in them.

5 Run an appropriate size tap into each of the threaded holes to remove corrosion and thread sealant that may be present. If compressed air is available, use it to clear the holes of debris produced by this operation.

WARNING:

Wear eye protection when using compressed air!

6 Clean the rocker arm pivot bolt threads (V8 engines) or studs (V6 engines) with a wire brush.

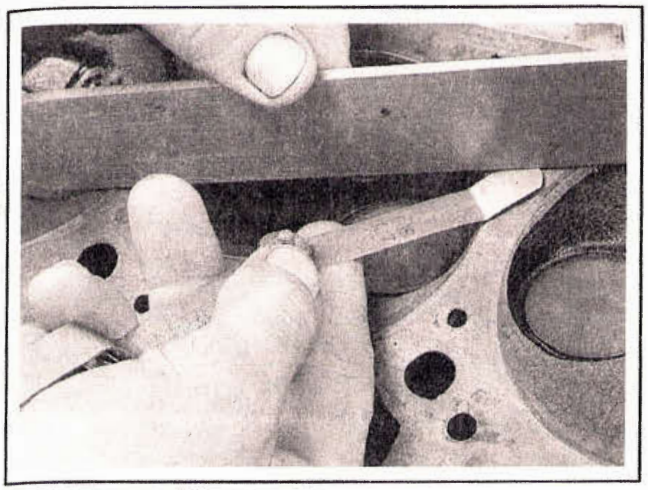
7 Clean the cylinder head with solvent and dry it thoroughly. Compressed air will speed the drying process and ensure that all holes and recessed areas are clean.

Note: Decarbonizing chemicals are available and may prove very useful when cleaning cylinder heads and valve train components. They are very caustic and should be used with caution. Be sure to follow the instructions on the container.

8 Clean the rocker arms, pivot balls or fulcrums, nuts or bolts and pushrods with solvent and dry them thoroughly (don't mix them up during the cleaning process). Compressed air will speed the drying process and can be used to clean out the oil passages.

9 Clean all the valve springs, spring seats, keepers and retainers (or rotators) with solvent and dry them thoroughly. Do the components from one valve at a time to avoid mixing up the parts.

10 Scrape off any heavy deposits that may have formed on the valves, then use a motorized wire brush to remove deposits from the valve heads and stems. Again, make sure the valves don't get mixed up.



10.12 Check the cylinder head surface for warpage by trying to slip a feeler gauge under the straightedge - see the Specifications for the maximum warpage and use a feeler gauge of that size

INSPECTION

➡Note: Be sure to perform all of the following inspection procedures before concluding that machine shop work is required. Make a list of the items that need attention.

Cylinder head

11 Inspect the head very carefully for cracks, evidence of coolant leakage and other damage. If cracks are found, check with an automotive machine shop concerning repair. If repair isn't possible, a new cylinder head must be obtained.

12 Using a straightedge and feeler gauge, check the head gasket mating surface for warpage (see illustration). If the warpage exceeds the specified limit, it can be resurfaced at an automotive machine shop.

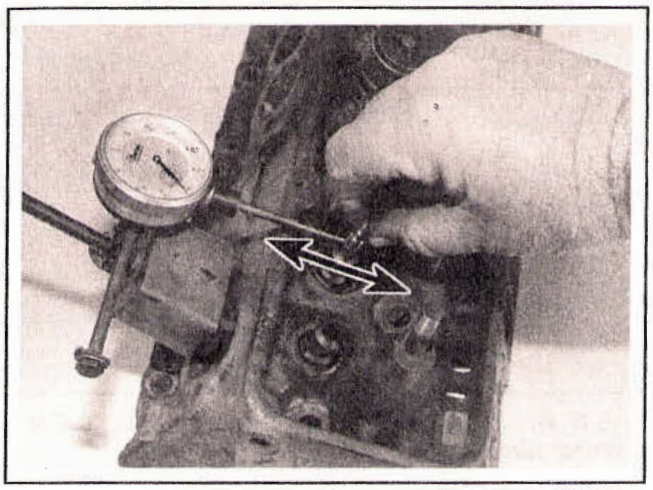
➡Note: If the cylinder heads are resurfaced, the intake manifold flanges may also require machining.

13 Examine the valve seats in each of the combustion chambers. If they're pitted, cracked or burned, the head will require valve service that's beyond the scope of the home mechanic.

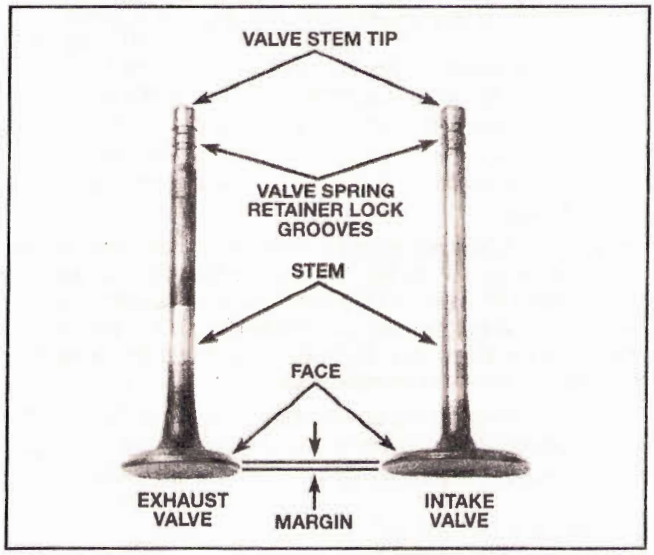
14 Check the valve stem-to-guide clearance by measuring the lateral movement of the valve stem with a dial indicator attached securely to the head (see illustration). The valve must be in the guide and approximately 1/16-inch off the seat. The total valve stem movement indicated by the gauge needle must be divided by two to obtain the actual clearance. After this is done, if there's still some doubt regarding the condition of the valve guides, they should be checked by an automotive machine shop (the cost should be minimal). if the clearance is excessive, the machine shop will have to install new valve guides in the head(s).

Valves

15 Carefully inspect each valve for uneven wear, deformation, cracks, pits and burned areas (see illustration). Check the valve stem for scuffing and galling and the neck for cracks. Rotate the valve and check for any obvious indication that it's bent. Look for pits and excessive wear on the end of the stem. The presence of any of these conditions indicates the need for valve service by an automotive machine shop.

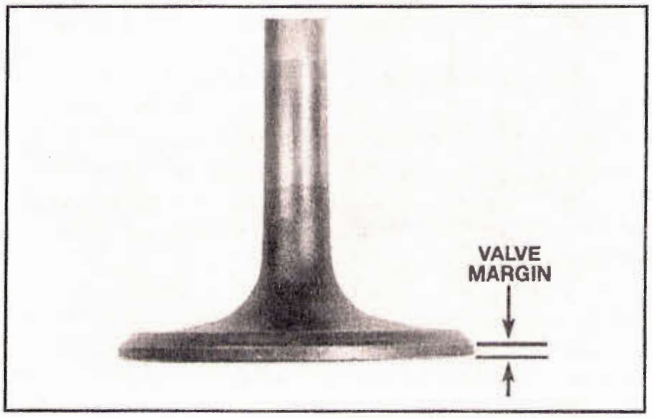


10.14 A dial indicator can be used to determine the valve stem-to-guide clearance - move the stem as indicated by the arrows

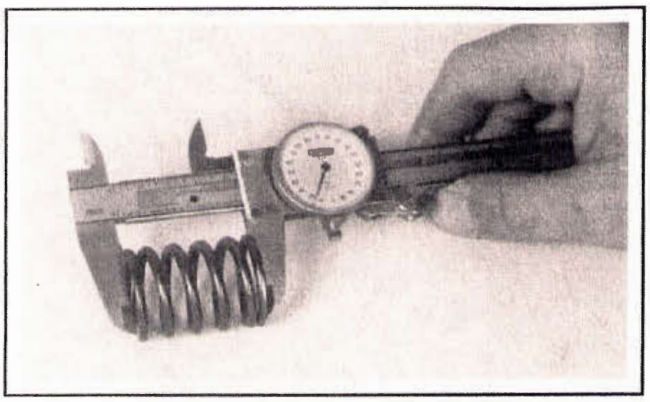


10.15 Check for valve wear at the points shown here

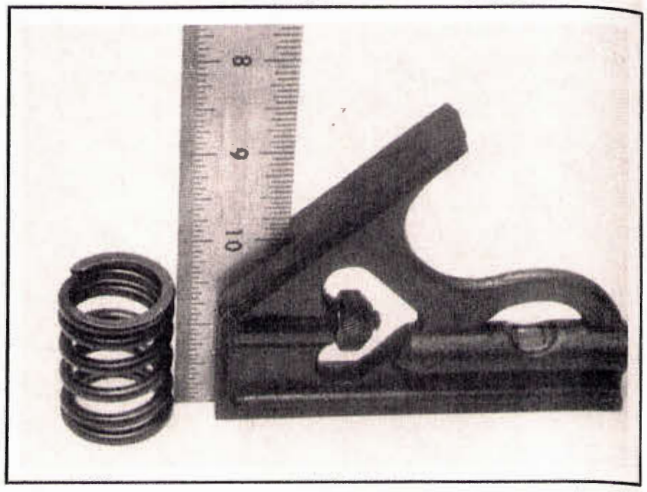
16 Measure the margin width on each valve (see illustration). Any valve with a margin narrower than that listed in this Chapter's Specifications will have to be replaced with a new one.



10.16 Valve margin width must be as specified - if no margin exists, the valve cannot be reused



10.17 Measure the length of each valve spring with a dial or vernier caliper



10.18 Check each spring for squareness

Valve components

17 Check each valve spring for wear (on the ends) and pits. Measure the free length and compare it to this Chapter's Specifications (see illustration). Any springs that are shorter than specified have sagged and should not be reused. The tension of all springs should be checked with a special fixture before deciding that they're suitable for use in a rebuilt engine (take the springs to an automotive machine shop for this check).

18 Stand each spring on a flat surface and check it for squareness (see illustration). If any of the springs are distorted or sagged, replace all of them with new parts. Springs that aren't square can cause accelerated guide wear.

➡Note: V8 engines are equipped with conical type valve springs which are smaller at the top. On these models it will be necessary to place the square along both sides of the spring (180 degrees apart) and note the measurements between the top of the spring and the square. if the spring is square the measurement will be the same on both sides.

19 Check the spring retainers (or rotators) and keepers for obvious wear and cracks. Any questionable parts should be replaced with new ones, as extensive damage will occur if they fail during engine operation.

Rocker arm components

20 Check the rocker arm faces (the areas that contact the pushrod ends and valve stems) for pits, wear, galling, score marks and rough spots. Check the rocker arm pivot contact areas and pivots as well. Look for cracks in each rocker arm and nut or bolt. On V8 engines check the pivot bearings for binding and roughness.

21 Inspect the pushrod ends for scuffing and excessive wear. Roll each pushrod on a flat surface, like a piece of plate glass, to determine if it's bent.

22 Check the rocker arm bolt holes or stud threads in the cylinder heads for damaged threads and secure installation.

23 Any damaged or excessively worn parts must be replaced with new ones.

24 If the inspection process indicates that the valve components are in generally poor condition and worn beyond the limits specified, which is usually the case in an engine that's being overhauled, reassemble the valves in the cylinder head and refer to Section 11 for valve servicing recommendations.

11 Valves - servicing

1 Because of the complex nature of the job and the special tools and equipment needed, servicing of the valves, the valve seats and the valve guides, commonly known as a valve job, should be done by a professional.

2 The home mechanic can remove and disassemble the head(s), do the initial cleaning and inspection, then reassemble and deliver it (or them) to an automotive machine shop for the actual service work. Doing the inspection will enable you to see what condition the head and valvetrain components are in and will ensure that you know what work and new parts are required when dealing with an automotive machine shop.

3 The automotive machine shop, will remove the valves and springs, recondition or replace the valves and valve seats, recondition the valve guides, check and replace the valve springs, spring retainers or rotators and keepers (as necessary), replace the valve seals with new ones, reassemble the valve components and make sure the installed spring height is correct. The cylinder head gasket surface will also be resurfaced if it's warped. On V6 and V8 engines, both heads must be surfaced the same amount, and if more than .020-inch is taken off, the bottom and sides of the intake manifold must also be machined so that all passage and holes still line up properly. Note that some cylinder heads have a minimum resurfacing height (similar to a brake rotor or drum). If they're resurfaced past the minimum height they'll have to be replaced. Measure the height of the heads and check them against Specifications at the end of this Chapter to be sure. This information will tell you the maximum amount of material that can be machined off the deck surface of the cylinder head. Be sure to give this information to your machine shop, don't assume they already know.

4 After the valve job has been performed by a professional, the head will be in like-new condition. When the head is returned, be sure to clean it again before installation on the engine to remove any metal particles and abrasive grit that may still be present from the valve service or head resurfacing operations. Use compressed air, if available, to blow out all the oil holes, bolt holes and coolant passages.

12 Cylinder head - reassembly

Refer to illustrations 12.6, 12.7 and 12.9

1 Regardless of whether or not the head was sent to an automotive repair shop for valve servicing, make sure it's clean before beginning reassembly.

2 If the head was sent out for valve servicing, the valves and related components will already be in place. Begin the reassembly procedure with Step 8.

3 Beginning at one end of the head, lubricate and install the first valve. Apply moly-base grease or clean engine oil to the valve stem.

4 Install the spring seat and shims, if originally installed, before the valve seals.

5 install a new valve stem seal over the valve stem and press it down over the valve guide to the specified depth using hand pressure (see illustrations 6.13b in Chapter 2A and 6.15b in Chapter 2B). Don't force the valve seal against the top of the guide.

CAUTION:

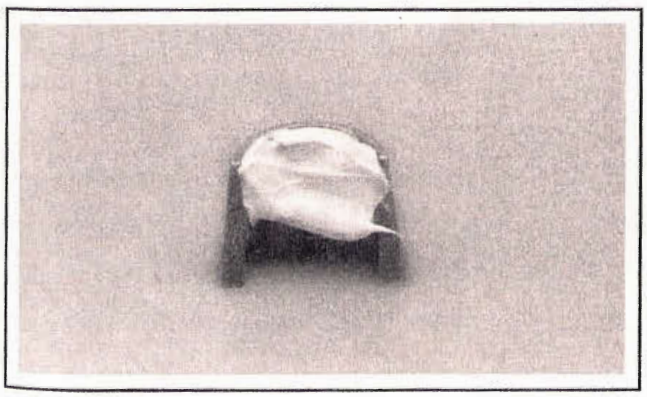
Intake and exhaust valves on these models require different seals. Do not install an exhaust valve seal on an intake valve, as high oil consumption will result. Exhaust valve seals are typically brown in color and intake valve seals are typically black in color.

Do not hammer on the seals or they could be driven down too far and subsequently leak. Don't twist or cock the seals during installation or they won't seal properly on the valve stems. Many seal sets come with a plastic installer that slides over the top of the valve stem to keep the valve seal from catching in the valve keeper groove.

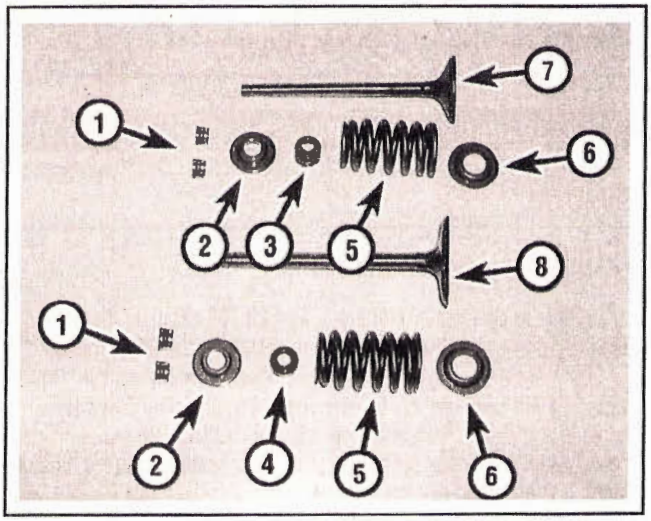
6 The valve components (see illustration) may be installed in the following order:

Valves
Valve spring seat (aluminum cylinder heads)
Valve stem seals
Valve spring shims (if any)
Valve springs
Retainers or rotators
Keepers

7 Compress the springs with a valve spring compressor and carefully install the keepers in the groove, then slowly release the compressor and make sure the keepers seat properly. Apply a small dab of grease to each keeper to hold it in place if necessary (see illustration). Tap the valve stem tips with a plastic hammer to seat the keepers, if necessary.



12.7 Apply a small dab of grease to each keeper as shown here before installation - it will hold them in place on the valve stem as the spring is released

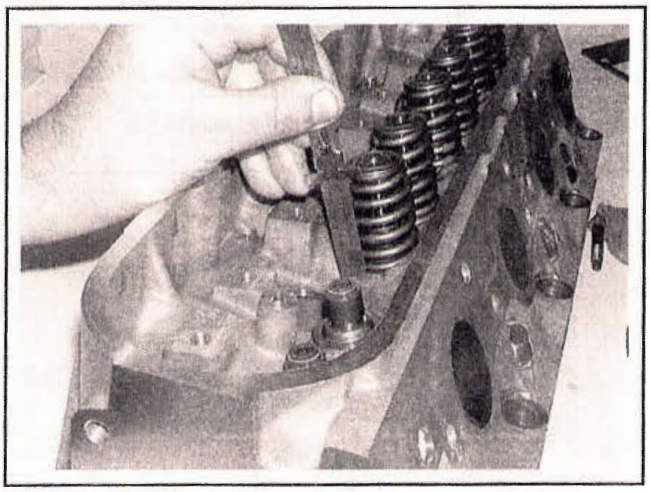


12.6 Valves and related components (V8 engine shown, V6 similar)

1 *Valve keeper*
2 *Retainer*
3 *Exhaust valve seal*
4 *Intake valve seal*
5 *Valve spring*
6 *Valve spring seat (aluminum heads)*
7 *Exhaust valve*
8 *Intake valve*

8 Repeat the procedure for the remaining valves. Be sure to return the components to their original locations - don't mix them up!

9 Check the installed valve spring height with a ruler graduated in 1/32-inch increments or a dial caliper (see illustration). If the head was sent out for service work, the installed height should be correct (but don't automatically assume it is). The measurement is taken from the top of each spring seat or top shim to the bottom of the retainer. If the height is greater than specified in this Chapter, shims can be added under the springs to correct it.



12.9 Be sure to check the valve spring installed height (the distance from the top of the seat/shims to the top of the shield or the bottom of the retainer)

CAUTION:

Do not, under any circumstances, shim the springs to the point where the installed height is less than specified.

10 Apply moly-base grease to the rocker arm faces and the pivots then install the rocker arms and pivots on the cylinder heads. Tighter the bolts or nuts finger-tight.

13 Camshaft, lifters and bearings - removal and inspection

REMOVAL

Refer to illustrations 13.1a and 13.1b

1 Refer to Chapter 2A (V6 engine) or 2B (V8 engines) for the camshaft and lifter removal procedure. Disregard the Steps that do not apply, since the engine is already removed from the vehicle. On V8 engines it will be necessary to remove the engine valley cover. Remove the bolts and detach the cover from the engine block. Be sure to install a new gasket and knock sensor oil seals upon installation (see illustrations). It is assumed that the cylinder heads and the coolant vapor vent tube is already removed at this point.

INSPECTION

Camshaft lobe lift check

Refer to illustrations 13.3, 13.9a and 13.9b

2 The first and easiest method to check camshaft lobe lift is through the use of a dial indicator with the camshaft installed in the engine block and the rocker arms and spark plugs removed.

Note: The following method can also be used if the cylinde heads and or pushrods have been removed by simply mounti the dial indicator on the deck surface of the engine block and placing the plunger against the top surface of the lifter on the cylinder you're checking.

3 Beginning with the number one cylinder, mount a dial indicator on the engine and position the plunger against the top surface of the pushrod or lifter. Position the number one cylinder at TDC on th compression stroke (see Section 3, in Chapter 2A or 2B). The plung should be directly above and in line with the pushrod (see illustratio

4 Zero the dial indicator, then very slowly turn the crankshaft in normal direction of rotation (clockwise) until the indicator needle stc and begins to move in the opposite direction. The point at which it stops indicates maximum cam lobe lift.

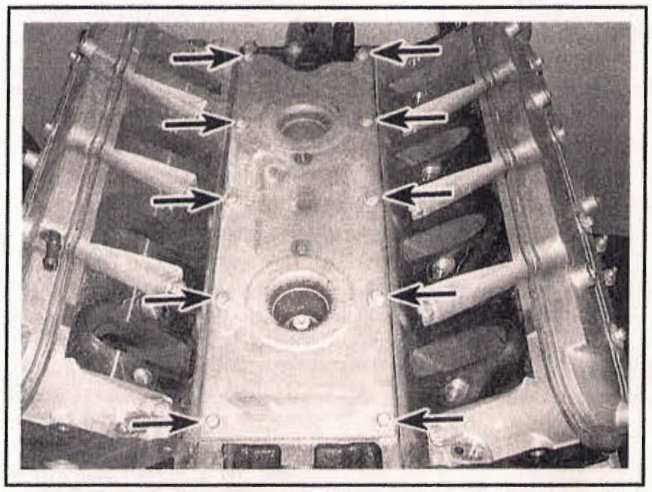
5 Record this figure for future reference, then reposition the pist at TDC on the compression stroke again.

6 Move the dial indicator to the other number one cylinder push rod or lifter and repeat the check. Be sure to record the results for ea valve.

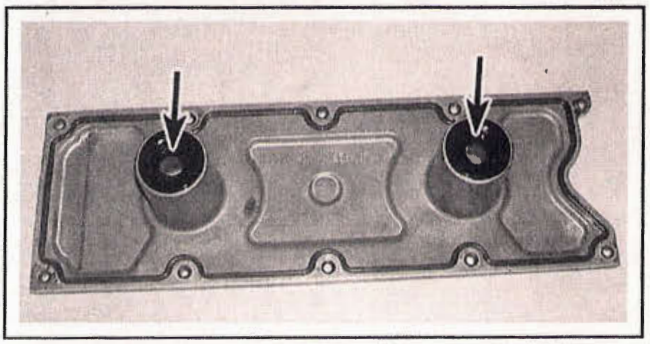
7 Repeat the check for the remaining valves. Since each piston must be at TDC on the compression stroke for this procedure, work from cylinder-to-cylinder following the firing order sequence.

8 The second method for measuring camshaft lobe lift is obtaine through the use of a micrometer with the camshaft removed from the engine block.

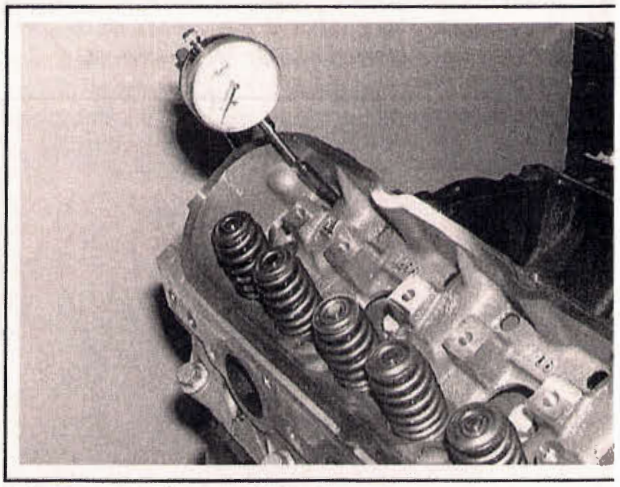
9 Using this method, measure the camshaft lobe height and the base circle (see illustrations). The difference between the two measu ments is the lobe lift (lobe height - base circle = lobe lift). Record th figure for future reference and repeat the check on the remaining can shaft lobes.



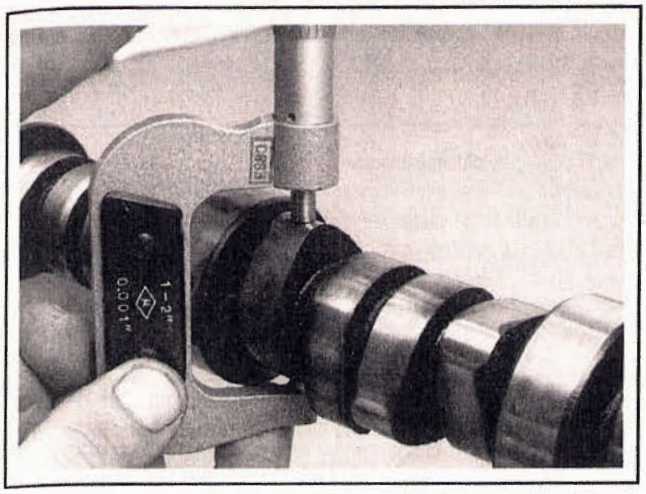
13.1a Valley cover mounting bolts - V8 engine



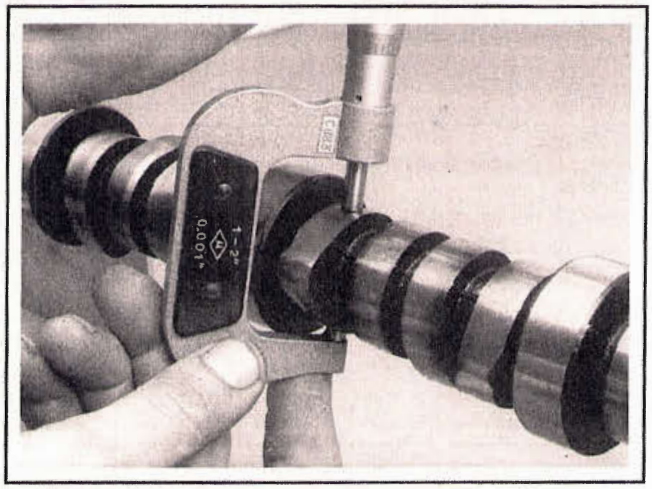
13.1b Be sure to replace the valley cover gasket and the knock sensor oil seals (arrows) upon installation



13.3 Checking camshaft lobe lift with the camshaft installed in the engine - always make sure the dial indicator plunger i directly in-line with the pushrod or lifter



13.9a If the camshaft is removed from the engine, lobe lift can be obtained by measuring camshaft lobe height . . .



13.9b . . . and by measuring the camshaft base circle - the difference between the two measurements equals lobe lift

10 After the lobe lift check is complete, compare the results to the Specifications listed in Chapter 2A (V6 engine) or 2B (V8 engines). If the lobe lift is 0.002 inch less than specified, cam lobe wear has occurred and a new camshaft should be installed.

Bearing journals, lobes and bearings

◗ Refer to illustration 13.12

11 After the camshaft has been removed from the engine, cleaned with solvent and dried, inspect the bearing journals for uneven wear, pitting and evidence of seizure. If the journals are damaged, the bearing inserts in the block are probably damaged as well. Both the camshaft and bearings will have to be replaced.

➡Note: Camshaft bearing replacement requires special tools and expertise that place it beyond the scope of the average home mechanic. The tools for bearing removal and installation are available at stores that carry automotive tools, possibly even found at a tool rental business. It is advisable though, if the bearings are bad and the procedure is beyond your ability, take the engine block to an automotive machine shop to ensure that the job is done correctly.

12 Measure the bearing journals with a micrometer to determine if they are excessively worn or out-of-round (see illustration).

13 Check the camshaft lobes for heat discoloration, score marks, chipped areas, pitting and uneven wear. If the lobes are in good condition and if the lobe lift measurements recorded earlier are as specified, the camshaft can be reused.

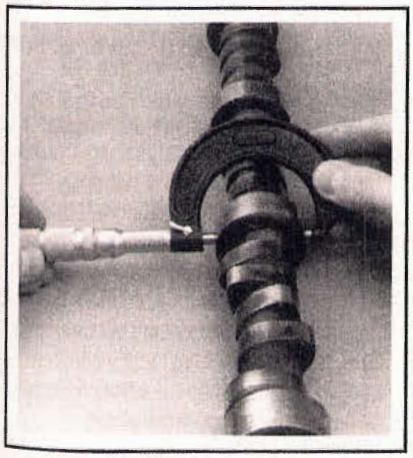
LIFTERS

◗ Refer to illustrations 13.14 and 13.15

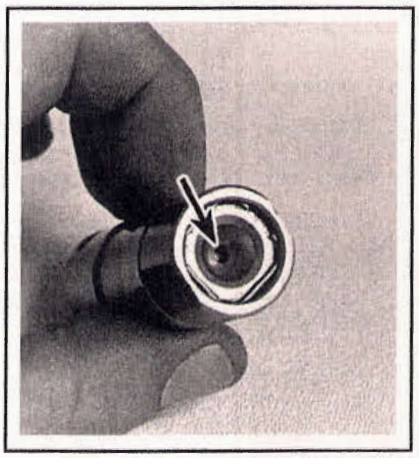
14 Clean the lifters with solvent and dry them thoroughly without mixing them up. Check each lifter wall and pushrod seat and for score marks and uneven wear (see illustration). If the lifter walls are damaged or worn (which is not very likely), inspect the lifter bores in the engine block as well. If the pushrod seats are worn, check the pushrod ends.

15 Check the rollers carefully for wear and damage and make sure they turn freely without excessive play (see illustration).

16 Used roller lifters can not be reinstalled with a new camshaft, but the original camshaft can be used if new lifters are installed. Always use new lifters when installing a new camshaft.



13.12 Check the diameter of each camshaft bearing journal to pinpoint excessive wear and out-of-round conditions



13.14 Check the pushrod seat (arrow) in the top of each lifter for wear

13.15 The roller on hydraulic roller lifters must turn freely - check for wear and excessive play as well

14 Balance shaft and bearings (V6 engines) - removal and inspection

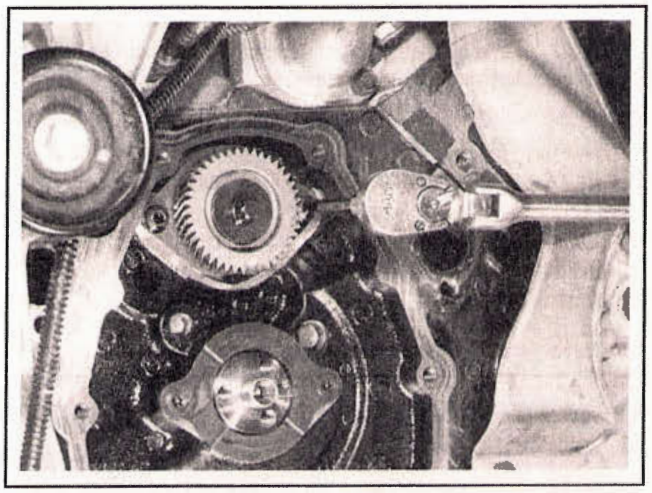
REMOVAL

Refer to illustrations 14.1 and 14.2

Note: If the balance shaft is to be removed, the balance shaft gear bolt should be removed before the timing chain is removed, so that the shaft is held while the bolt is loosened.

1 Remove the two bolts and the balance shaft retainer at the front of the block (see illustration).

2 The balance shaft front bearing fits tightly into the block; use a slide-hammer threaded into the front of the balance shaft to knock it out (see illustration).



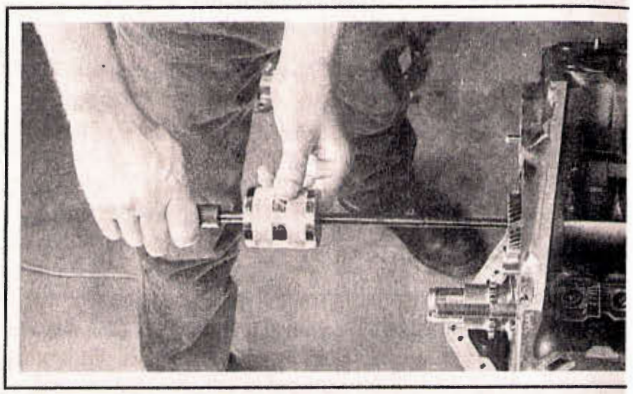
14.1 Remove the two Torx bolts and the balance shaft retainer on V6 engines

INSPECTION

3 Inspect the balance shaft and measure the rear bearing journal diameter in the same manner as the camshaft. If the journal diameter doesn't fall within the values listed in this Chapter's Specifications, replace the balance shaft, bearing and bushing as a set. The balance shaft rides in a bearing at the front of the block and a bushing at the rea

4 The rear bushing is similar to a camshaft bearing, pressed into the rear of the block. It must be installed by a machine shop with the proper tools, to the proper depth and with the oil hole aligned.

5 Inspect the balance shaft drive gear (the one behind the camshaf gear), and the balance shaft driven gear (bolted to the front of the balance shaft) for signs of wear, pitting, broken teeth or rough operation. As with the balance shaft and its bearings, the two balance shaft gears are serviced only as a set.

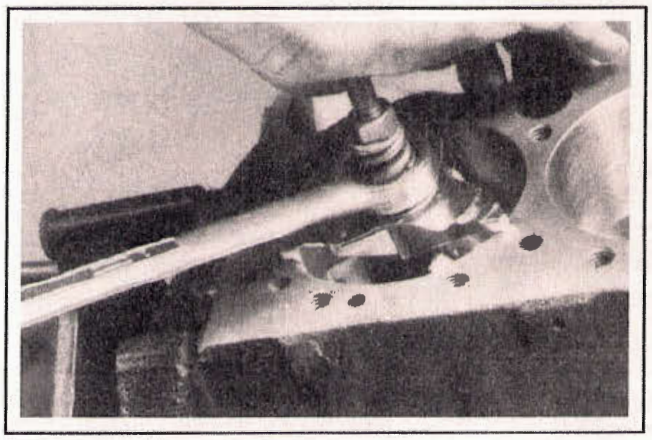


14.2 A small slide-hammer must be threaded into the front of the balance shaft to pull the balance shaft and front bearing out of the block

15 Pistons/connecting rods - removal

Refer to illustrations 15.1, 15.3, 15.4 and 15.6

Note: Prior to removing the piston/connecting rod assemblies, remove the cylinder head(s), the oil pan, the oil pump and the crankshaft windage tray if equipped by referring to the appropriate Sections in Chapter 2A or 2B.



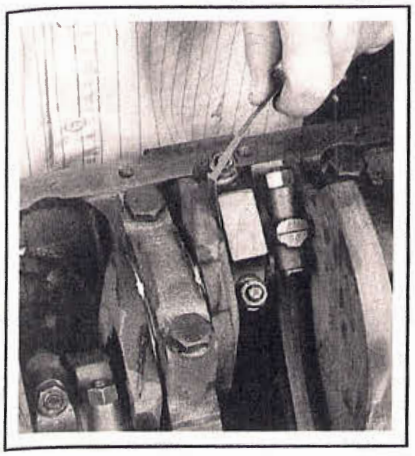
15.1 A ridge reamer is required to remove the ridge from the top of each cylinder - do this before removing the pistons!

1 Use your fingernail to feel if a ridge has formed at the upper lim of ring travel (about 1/4-inch down from the top of each cylinder). If carbon deposits or cylinder wear have produced ridges, they must be completely removed with a special tool (see illustration). Follow the manufacturer's instructions provided with the tool. Failure to remove the ridges before attempting to remove the piston/connecting rod assemblies may result in piston breakage.

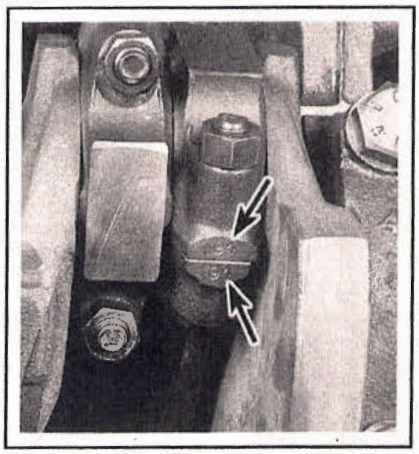
2 After the cylinder ridges have been removed, turn the engine upside-down so the crankshaft is facing up.

3 Before the connecting rods are removed, check the endplay with feeler gauges. Slide them between the first connecting rod and the crankshaft throw until the play is removed (see illustration). The endplay is equal to the thickness of the feeler gauge(s). If the endplay exceeds the service limit, new connecting rods will be required. If new rods (or a new crankshaft) are installed, the endplay may fall under the specified minimum (if it does, the rods will have to be machined to restore it - consult an automotive machine shop for advice if necessary). Repeat the procedure for the remaining connecting rods.

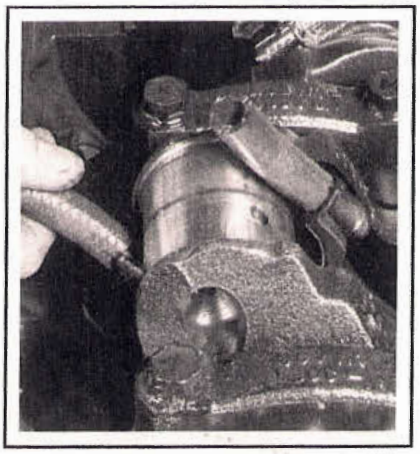
4 Check the connecting rods and caps for identification marks (se illustration). If they aren't plainly marked, use a small center punch to make the appropriate number of indentations on each rod and cap (1, 2, 3, etc., depending on the engine type and cylinder they're associate with).



15.3 Check the connecting rod side clearance (endplay) with a feeler gauge as shown here between the rod and the crankshaft journal



15.4 The connecting rods should be marked with the corresponding cylinder number at the parting line of each rod and cap



15.6 To prevent damage to the crankshaft journals and cylinder walls, slip sections of rubber hose over the rod bolts before removing the piston/rod assemblies

5 Loosen each of the connecting rod cap nuts 1/2-turn at a time until they can be removed by hand. Remove the number one connecting rod cap and bearing insert. Don't drop the bearing insert out of the cap.

6 Slip a short length of plastic or rubber hose over each connecting rod cap bolt to protect the crankshaft journal and cylinder wall as the piston is removed (see illustration).

➡Note: On V8 engines the rod bolts are removed with the caps, so it may be helpful to make a set of connecting rod guides. Find several bolts that fit the rods at your local hardware store, or purchase a couple of new rod bolts. Cut the heads of the bolts off with a hacksaw or similar tool and slip a short length of hose over the end of each bolt to make a pair connecting rod guides. Screw the guides into the connecting rods during removal and installation of the piston/connecting rod from the engine block.

7 Remove the bearing insert and push the connecting rod/piston assembly out through the top of the engine. Use a wooden hammer handle to push on the upper bearing surface in the connecting rod (DO NOT tap on the connecting rod bolt). If resistance is felt, double-check to make sure that all of the ridge was removed from the cylinder.

8 Repeat the procedure for the remaining cylinders.

9 After removal, reassemble the connecting rod caps and bearing inserts in their respective connecting rods and install the cap nuts finger tight. Leaving the old bearing inserts in place until reassembly will help prevent the connecting rod bearing surfaces from being accidentally nicked or gouged.

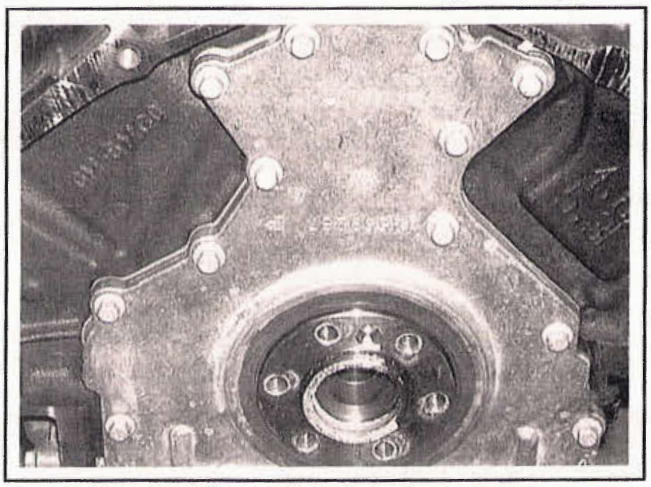
10 Don't separate the pistons from the connecting rods (see Sec-tion 20 for additional information).

16 Crankshaft - removal

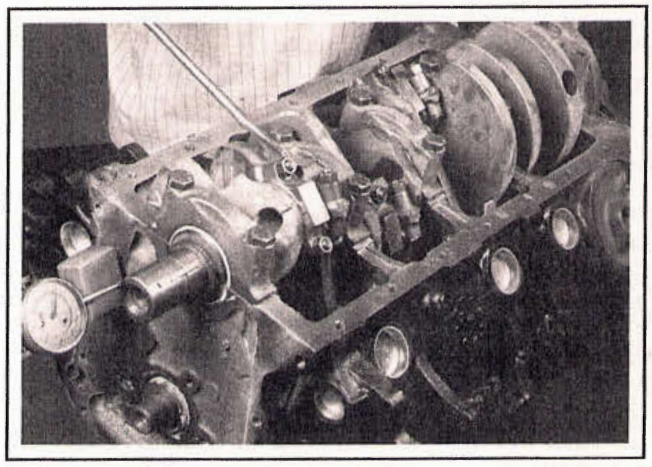
♦ Refer to illustrations 16.1a, 16.1b, 16.3, 16.4a and 16.4b

➡Note: The crankshaft can be removed only after the engine has been removed from the vehicle. It's assumed that the flywheel or driveplate, vibration damper, timing chain, oil pan, oil pump, windage tray and piston/connecting rod assemblies have already been removed.

1 Before the crankshaft can be withdrawn from the engine, the rear main oil seal retainer must be removed (see illustration) and the crankshaft endplay must be checked. Mount a dial indicator with the stem in line with the crankshaft and touching one of the crank throws or the nose of the crank (see illustration).



16.1a Rear main oil seal retainer mounting bolts - V8 engine shown



16.1b Checking the crankshaft endplay with a dial indicator

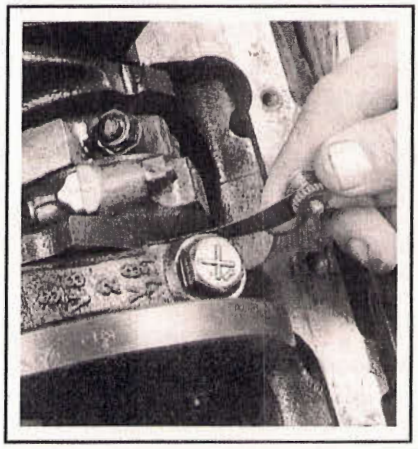
2 Push the crankshaft all the way to the rear and zero the dial indicator. Next, pry the crankshaft to the front as far as possible and check the reading on the dial indicator. The distance that it moves is the endplay. If it's greater than specified, check the crankshaft thrust surfaces for wear. If no wear is evident, new main bearings should correct the endplay.

3 If a dial indicator isn't available, feeler gauges can be used. Gently pry or push the crankshaft all the way to the front of the engine. Slip feeler gauges between the crankshaft and the front face of the thrust main bearing to determine the clearance (see illustration).

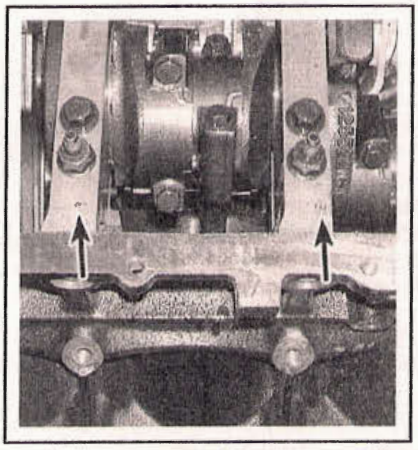
4 Check the main bearing caps to see if they're marked to indicate their locations. They should be numbered consecutively from the front of the engine to the rear (see illustration). If they aren't, mark them with number-stamping dies or a center punch (see illustration). Main bearing caps often have a cast-in arrow, which points to the front of the engine. If not, mark a paint arrow before removing the main caps. Loosen the main bearing cap bolts 1/4-turn at a time each, until they can be removed by hand. Note if any stud bolts are used and make sure they're returned to their original locations when the crankshaft is reinstalled.

5 Gently tap the caps with a soft-face hammer, then separate them from the engine block. If necessary, use the bolts as levers to remove the caps. Try not to drop the bearing inserts if they come out with the caps.

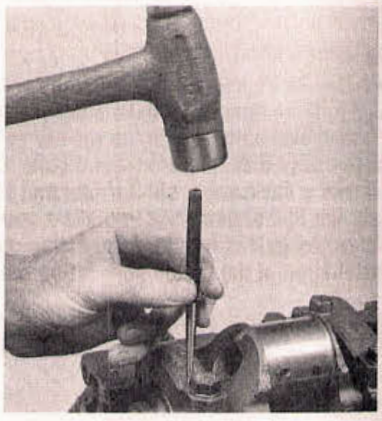
6 Carefully lift the crankshaft out of the engine. It may be a good idea to have an assistant available, since the crankshaft is quite heavy. With the upper bearing inserts in place in the engine block and the lower bearing inserts in place in the main bearing caps, return the caps to their respective locations on the engine block and tighten the bolts finger tight.



16.3 Checking crankshaft endplay with a feeler gauge



16.4a Main bearing caps are typically marked to indicate their locations (arrows) - they should be numbered consecutively from the front of the engine to the rear



16.4b If the main cap numbers aren't marked or they're not visible, mark the caps with a number stamp or a center punch

17 Engine block - cleaning

♦ Refer to illustrations 17.1a, 17.1b, 17.4, 17.8 and 17.10

1 Most engine core plugs are corroded firmly in place on an engine that has been in service for years. Use a small punch at the edge of the plug and carefully drive that edge in with a hammer (see illustration). Drive one edge in only far enough for the opposite side to protrude far enough to grab it with pliers and pull out (see illustration).

CAUTION:

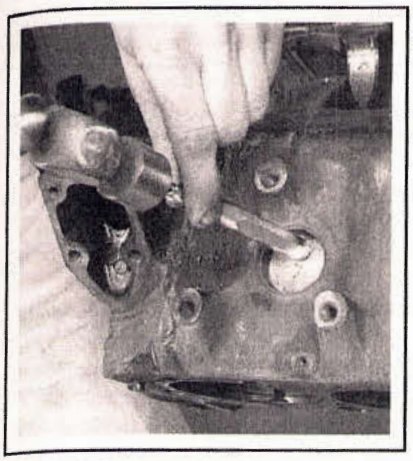
The core plugs (also known as freeze or soft plugs) may be difficult or impossible to retrieve if they're driven completely into the block coolant passages.

2 Using a gasket scraper, remove all traces of gasket material from the engine block. Be very careful not to nick or gouge the gasket sealing surfaces.

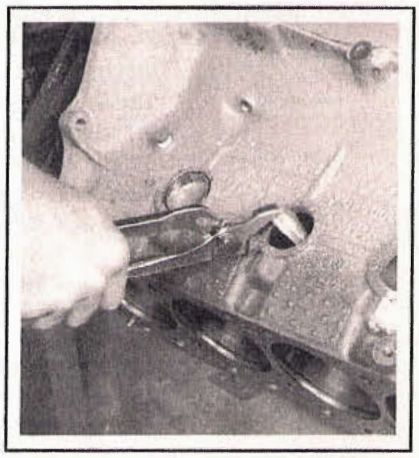
3 Remove the main bearing caps and separate the bearing inserts from the caps and the engine block. Tag the bearings, indicating which cylinder they were removed from and whether they were in the cap or the block, then set them aside.

4 Remove all of the threaded oil gallery plugs from the block (see illustration). The plugs are usually very tight - they may have to be drilled out and the holes retapped. Use new plugs when the engine is reassembled.

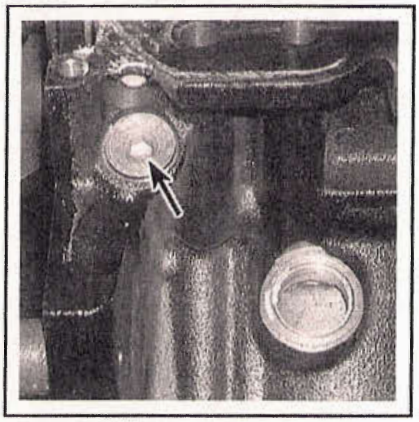
5 The engine should be taken to an automotive machine shop to be steam cleaned or hot tanked, although with patience it can be



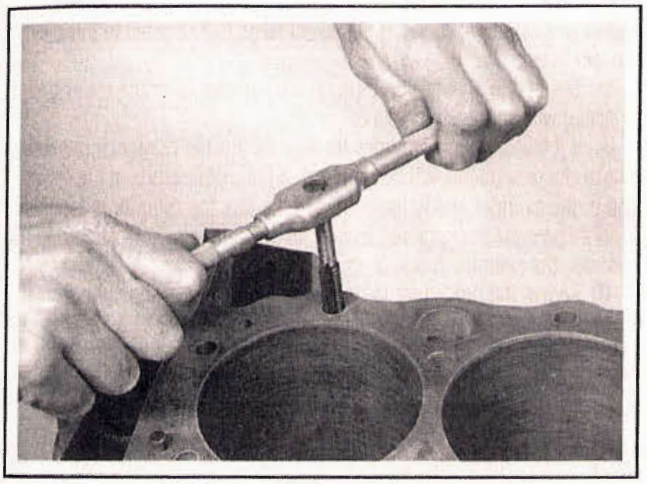
17.1a The core plugs should be removed carefully by tapping in one side . . .



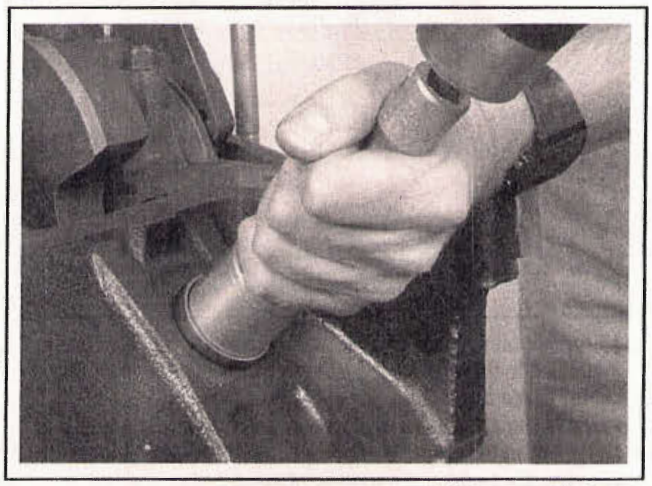
17.1b . . . then pulling out the opposite side with locking pliers



17.4 Removal of all the oil gallery plugs (arrow) will allow a more thorough cleaning of debris from the internal oil passages of the engine block



17.8 All bolts in the block, particularly the main bearing cap and head bolt holes, should be cleaned with the proper-sized tap



17.10 A large socket on an extension can be used to drive the new core plugs into the block - go slowly and stop when the plug is evenly flush with the block

cleaned at home.

6 After the block is returned, clean all oil holes and oil galleries one more time. Brushes specifically designed for this purpose are available at most auto parts stores. Flush the passages with warm water until the water runs clear, dry the block thoroughly and wipe all machined surfaces with a light, rust-preventive oil. If you have access to compressed air, use it to speed the drying process and to blow out all the oil holes and galleries.

WARNING:

Wear eye protection when using compressed air!

7 If the block isn't extremely dirty or sludged up, you can do an adequate cleaning job with hot soapy water and a stiff brush. Take plenty of time and do a thorough job. Regardless of the cleaning method used, be sure to clean all oil holes and galleries very thoroughly, dry the block completely and coat all machined surfaces with light oil.

8 The threaded holes in the block must be clean to ensure accurate torque readings during reassembly. Run the proper size tap into each of the holes to remove rust, corrosion, thread sealant or sludge and restore damaged threads (see illustration). If possible, use compressed air to clear the holes of debris produced by this operation.

WARNING:

Wear eye protection when using compressed air!

Now is a good time to clean the threads on the head bolts and the main bearing cap bolts as well.

9 Reinstall the main bearing caps and tighten the bolts finger tight.

10 After coating the sealing surfaces of the new core plugs with core plug sealant, install them in the engine block (see illustration). Make sure they're driven in straight and seated properly or leakage could result. Special tools are available for this purpose, but a large socket, with an outside diameter that will just slip into the core plug, a 1/2-inch drive extension and a hammer will work just as well.

11 Apply non-hardening sealant (such as Permatex no. 2 or Teflon pipe sealant) to the new oil gallery plugs and thread them into the holes in the block. Make sure they're tightened securely.

12 If the engine isn't going to be reassembled right away, cover it with a large plastic trash bag to keep it clean.

18 Engine block - inspection

Refer to illustrations 18.4a, 18.4b and 18.4c

1 Before the block is inspected, it should be cleaned as described in Section 17.

2 Visually check the block for cracks, rust and corrosion. Look for stripped threads in the threaded holes. It's also a good idea to have the block checked for hidden cracks by an automotive machine shop that has the special equipment to do this type of work. If defects are found, have the block repaired, if possible, or replaced.

3 Check the cylinder bores for scuffing and scoring.

4 Measure the diameter of each cylinder at the top (just under the ridge area), center and bottom of the cylinder bore, parallel to the crankshaft axis (see illustrations).

5 Next, measure each cylinder's diameter at the same three locations across the crankshaft axis. Compare the results to this Chapter's Specifications.

6 If the required precision measuring tools aren't available, the piston-to-cylinder clearances can be obtained, though not quite as accurately, using feeler-gauge stock. Feeler gauge stock comes in 12-inch lengths and various thicknesses and is generally available at auto parts stores.

7 To check the clearance, select a feeler gauge and slip it into the cylinder along with the matching piston. The piston must be positioned exactly as it normally would be. The feeler gauge must be between the piston and cylinder on one of the thrust faces (90-degrees to the piston-pin bore).

8 The piston should slip through the cylinder (with the feeler gauge in place) with moderate pressure.

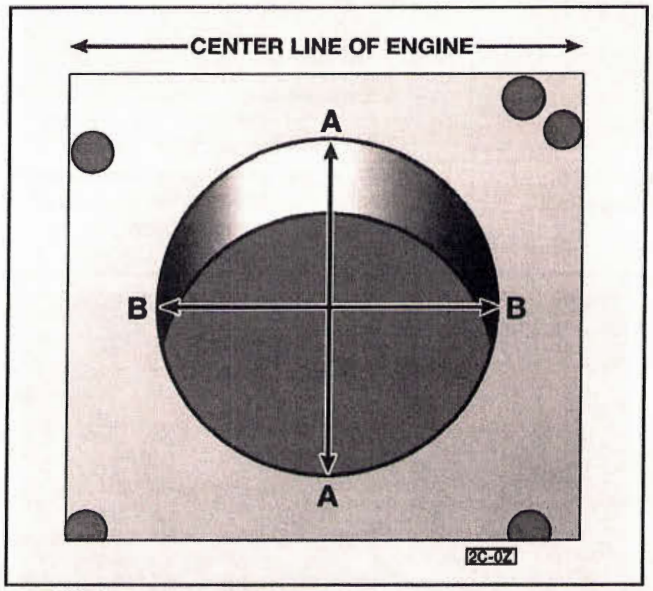
9 If it falls through or slides through easily, the clearance is excessive and a new piston will be required. If the piston binds at the lower end of the cylinder and is loose toward the top, the cylinder is tapered. If tight spots are encountered as the piston/feeler gauge is rotated in the cylinder, the cylinder is out-of-round.

10 Repeat the procedure for the remaining pistons and cylinders.

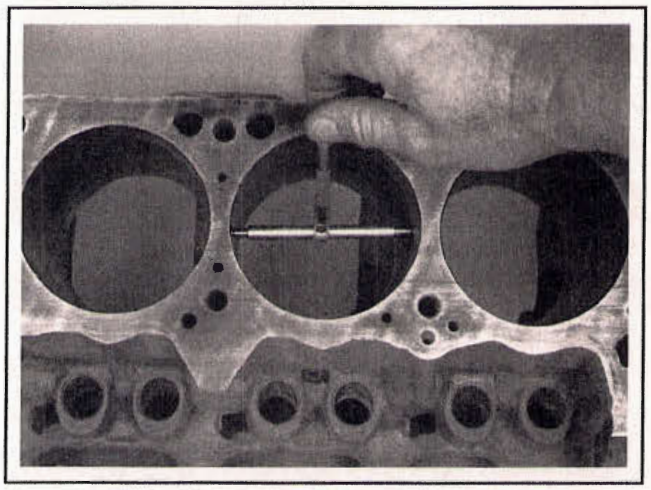
11 If the cylinder walls are badly scuffed or scored, or if they're out-of-round or tapered beyond the limits given in the specifications, have the engine block rebored and honed at an automotive machine shop. If a rebore is done, oversize pistons and rings will be required.

12 If the cylinders are in reasonably-good condition and not worn to the outside of the limits, and if the piston-to-cylinder clearances can be maintained properly, then they don't have to be rebored. Honing is all that's necessary (see Section 19).

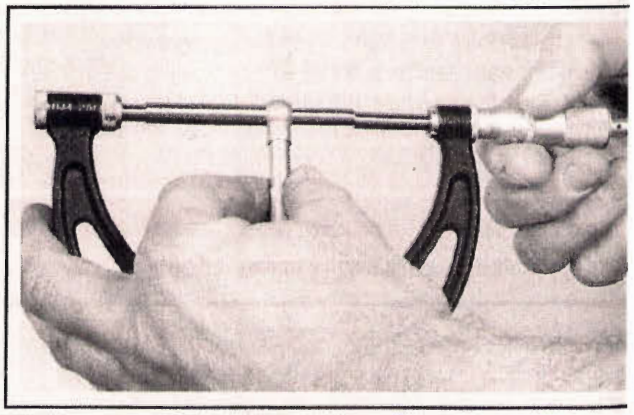
13 Using a precision straightedge and feeler gauge, check the block deck (the surface that mates with the cylinder head) for distortion and compare the results to this Chapter's Specifications.



18.4a Measure the diameter of each cylinder at point A and at point B in three places, just under the wear ridge, at the center of the bore and at the bottom of the bore - out-of-round is the difference in diameter between point A and B at any place in the cylinder - taper is the difference in diameter between the top and the bottom of the cylinder



18.4b The ability to "feel" when the telescoping gauge is at the correct point will be developed over time, so work slowly and repeat the check until you're satisfied the bore measurement is accurate



18.4c The gauge is then measured with a micrometer to determine the bore size

19 Cylinder honing

Refer to illustrations 19.3a and 19.3b

1 Prior to engine reassembly, the cylinder bores must be honed so the new piston rings will seat correctly and provide the best possible combustion-chamber seal.

Note: If you don't have the tools or don't want to tackle the honing operation, most automotive machine shops will do it for a reasonable fee.

2 Before honing the cylinders, install the main bearing caps and tighten the bolts to the torque listed in this Chapter's Specifications.

3 Two types of cylinder hones are commonly available - the flex hone or "bottle brush" type and the more traditional surfacing hone with spring-loaded stones. Both will do the job, but for the less experienced mechanic the "bottle brush" hone will probably be easier to use. You'll also need some kerosene or honing oil, rags and an electric drill motor. Proceed as follows:

a) *Mount the hone in the drill motor, compress the stones (if applicable) and slip it into the first cylinder (see illustration). Be sure to wear safety goggles or a face shield!*

b) *Lubricate the cylinder with plenty of honing oil or kerosene, turn on the drill and move the hone up-and-down in the cylinder at a pace that will produce a fine crosshatch pattern on the cylinder walls. Ideally, the crosshatch lines should intersect at approximately a 60-degree angle (see illustration). Be sure to use plenty of lubricant and don't take off any more material than is absolutely necessary to produce the desired finish*

Note: Piston ring manufacturers may specify a smaller crosshatch angle than the traditional 60-degrees - read and follow any instructions included with the new rings.

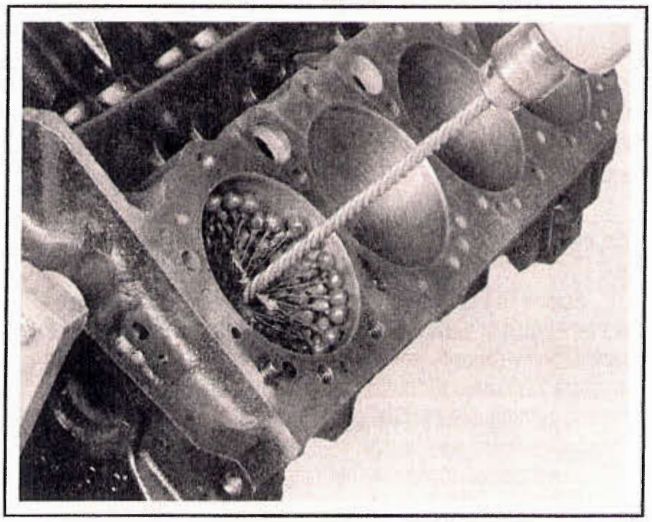
c) *Don't withdraw the hone from the cylinder while it's running. Instead, shut off the drill and continue moving the hone up-and-down in the cylinder until it comes to a complete stop, then compress the stones and withdraw the hone. If you're using a "bottle brush" type hone, stop the drill motor, then turn the chuck in the normal direction of rotation while withdrawing the hone from the cylinder.*

d) *Wipe the oil out of the cylinder and repeat the procedure for the remaining cylinders.*

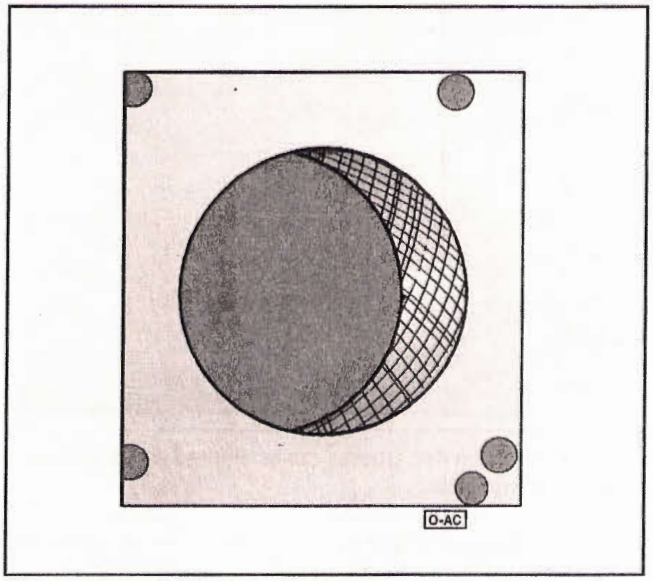
4 After the honing job is complete, chamfer the top edges of the cylinder bores with a small file so the rings won't catch when the pistons are installed. Be very careful not to nick the cylinder walls with the end of the file.

5 The entire engine block must be washed again very thoroughly with warm, soapy water to remove all traces of the abrasive grit produced during the honing operation.

Note: The bores can be considered clean when a lint-free white cloth - dampened with clean engine oil - used to wipe them out doesn't pick up any more honing residue, which will show up as gray areas on the cloth. Be sure to run a brush through all oil holes and galleries and flush them with running water.



19.3a A "bottle brush" hone is the easiest type of hone to use



19.3b The cylinder hone should leave a smooth, crosshatch pattern with the lines intersecting at approximately a 60-degree angle

6 After rinsing, dry the block and apply a coat of light rust preventive oil to all machined surfaces. Wrap the block in a plastic trash bag to keep it clean and set it aside until reassembly.

20 Pistons/connecting rods - inspection

Refer to illustrations 20.4a, 20.4b, 20.10 and 20.11

1 Before the inspection process can be carried out, the piston/connecting rod assemblies must be cleaned and the original piston rings removed from the pistons.

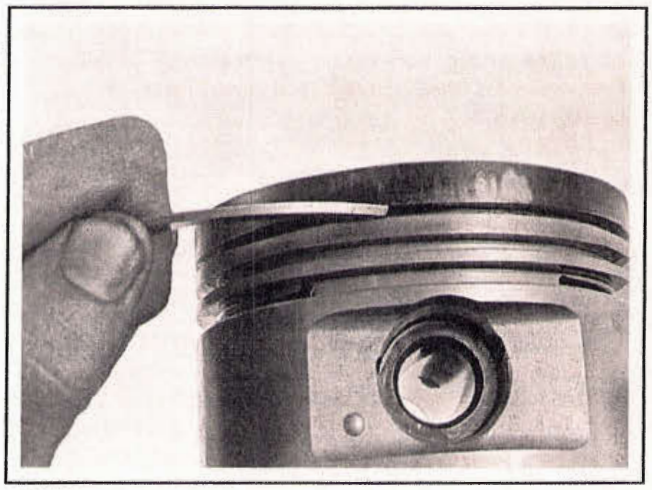
Note: Always use new piston rings when the engine is reassembled.

2 Using a piston ring installation tool, carefully remove the rings from the pistons. Be careful not to nick or gouge the pistons in the process.

3 Scrape all traces of carbon from the top of the piston. A hand-held wire brush or a piece of fine emery cloth can be used once the majority of the deposits have been scraped away. Do not, under any circumstances, use a wire brush mounted in a drill motor to remove deposits from the pistons. The piston material is soft and may be eroded away by the wire brush.

4 Use a piston-ring groove cleaning tool to remove carbon deposits from the ring grooves. If a tool isn't available, a piece broken off the old ring will do the job. Be very careful to remove only the carbon deposits - don't remove any metal and do not nick or scratch the sides of the ring grooves (see illustrations).

20.4a The piston ring grooves can be cleaned with a special tool, as shown here . . .



20.4b . . . or a section of a broken ring

5 Once the deposits have been removed, clean the piston/rod assemblies with solvent and dry them with compressed air (if available). Make sure the oil return holes in the back sides of the ring grooves are clear.

6 If the pistons and cylinder walls aren't damaged or worn excessively, and if the engine block is not rebored, new pistons won't be necessary. Normal piston wear appears as even vertical wear on the piston thrust surfaces and slight looseness of the top ring in its groove. New piston rings, however, should always be used when an engine is rebuilt.

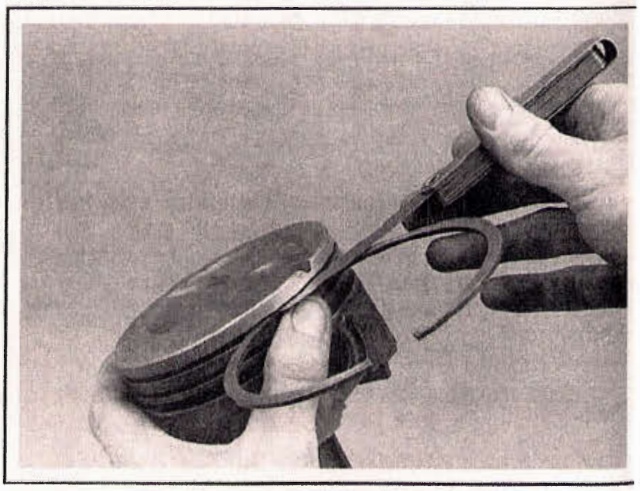
7 Carefully inspect each piston for cracks around the skirt, at the pin bosses and at the ring lands.

8 Look for scoring and scuffing on the thrust faces of the skirt, holes in the piston crown and burned areas at the edge of the crown. If the skirt is scored or scuffed, the engine may have been suffering from overheating and/or abnormal combustion, which caused excessively high operating temperatures. Such pistons should be replaced. The cooling and lubrication systems should be checked thoroughly. A hole in the piston crown is an indication that abnormal combustion (preignition) was occurring. Burned areas at the edge of the piston crown are usually evidence of spark knock (detonation). If any of the above problems exist, the causes must be corrected or the damage will occur again. The causes may include intake air leaks, incorrect fuel/air mixture and incorrect ignition timing.

9 Corrosion of the piston, in the form of small pits, indicates that coolant is leaking into the combustion chamber and/or the crankcase. Again, the cause must be corrected or the problem may persist in the rebuilt engine.

10 Measure the piston ring side clearance by laying a new piston ring in each ring groove and slipping a feeler gauge in beside it (see illustration). Check the clearance at three or four locations around each groove. Be sure to use the correct ring for each groove - they are different. If the side clearance is greater than specified, new pistons will have to be used.

11 Check the piston-to-bore clearance by measuring the bore (see Section 18) and the piston diameter. Make sure the pistons and bores are correctly matched. Measure the piston across the skirt, at a 90-degree angle to piston pin and at the specified height (see illustration).



20.10 Check the ring side clearance with a feeler gauge at several points around the groove

Subtract the piston diameter from the bore diameter to obtain the clearance. If it's greater than specified, the block will have to be rebored and new pistons and rings installed.

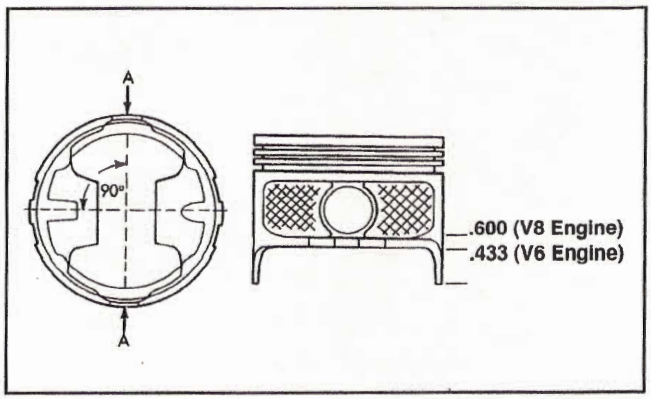
12 Check the piston-to-rod clearance by twisting the piston and rod in opposite directions. Any noticeable play indicates excessive wear, which must be corrected. The piston/connecting rod assemblies should be taken to an automotive machine shop to have the pistons and rods resized and new pins installed.

13 If the pistons must be removed from the connecting rods for any reason, they should be taken to an automotive machine shop. While they are there, have the connecting rods checked for bend and twist, since automotive machine shops have special equipment for this purpose.

➡Note: Unless new pistons and/or connecting rods must be installed, do not disassemble the pistons and connecting rods.

14 Check the connecting rods for cracks and other damage. Temporarily remove the rod caps, lift out the old bearing inserts, wipe the rod and cap bearing surfaces clean and inspect them for nicks, gouges and scratches. After checking the rods, replace the old bearings, slip the caps into place and tighten the nuts finger tight.

➡Note: If the engine is being rebuilt because of a connecting rod knock, be sure to install new or reconditioned connecting rods.



20.11 Measure the piston diameter at a 90-degree angle (A) to the piston pin and at the specified height from the bottom of the skirt

21 Crankshaft - inspection

♦ Refer to illustrations 21.3, 21.4, 21.6 and 21.8

1 Check the main and connecting rod bearing journals for uneven wear, scoring, pits and cracks.

2 Rub a penny across each journal several times. If a journal picks up copper from the penny, it's too rough and must be reground.

3 Remove all burrs from the crankshaft oil holes with a stone, file or scraper (see illustration).

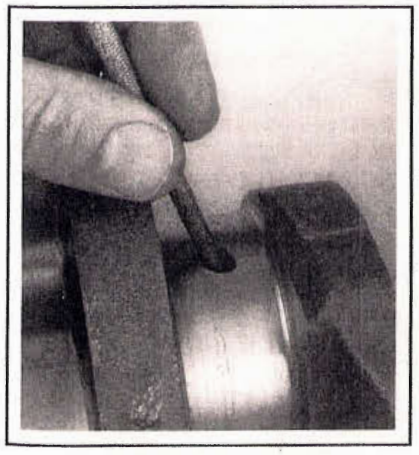
4 Clean the crankshaft with solvent and dry it with compressed air (if available). Be sure to clean the oil holes with a stiff brush and flush them with solvent (see illustration).

5 Check the rest of the crankshaft for cracks and other damage. It should be magnafluxed to reveal hidden cracks - an automotive machine shop will handle the procedure. Also on V8 engines, check the crankshaft reluctor ring teeth for obvious damage and be sure to inspect the crankshaft rear oil gallery plug for proper installation and leakage.

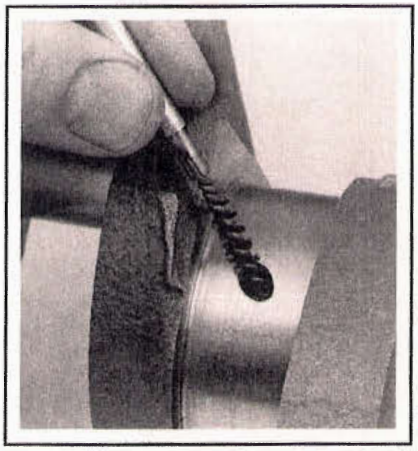
6 Using a micrometer, measure the diameter of the main and connecting rod journals and compare the results to the specifications (see illustration). By measuring the diameter at a number of points around each journal's circumference, you'll be able to determine whether or not the journal is out-of-round. Take the measurement at each end of the journal, near the crank throws, to determine if the journal is tapered.

7 If the crankshaft journals are damaged, tapered, out-of-round or worn beyond the limits given in the specifications, have the crankshaft reground by an automotive machine shop. Be sure to use the correct-size bearing inserts if the crankshaft is reconditioned.

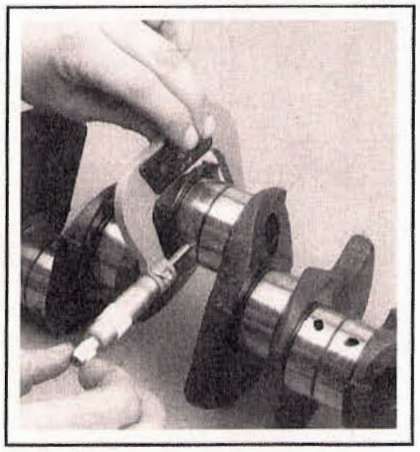
8 Check the oil seal journal at rear of the crankshaft for wear and



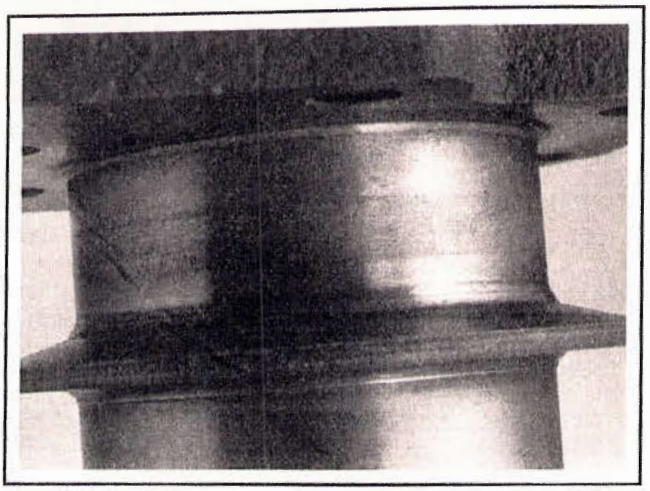
21.3 The oil holes should be chamfered so sharp edges don't gouge or scratch the new bearings



21.4 Use a wire or stiff plastic bristle brush to clean the oil passages in the crankshaft



21.6 Measure the diameter of each crankshaft journal at several points to detect taper and out-of-round conditions



21.8 If the rear seal has worn a groove in the crankshaft journal, or if the seal contact surfaces are nicked or scratched, the new seal will leak

damage (see illustration). If the seal has worn a groove in the journal, or if it's nicked or scratched, the new seal may leak when the engine is reassembled. In some cases, an automotive machine shop may be able to repair the journal by pressing on a thin sleeve. If repair isn't feasible, a new or different crankshaft should be installed.

9 Refer to Section 22 and examine the main and rod bearing inserts.

22 Main and connecting rod bearings - inspection

Refer to illustration 22.1

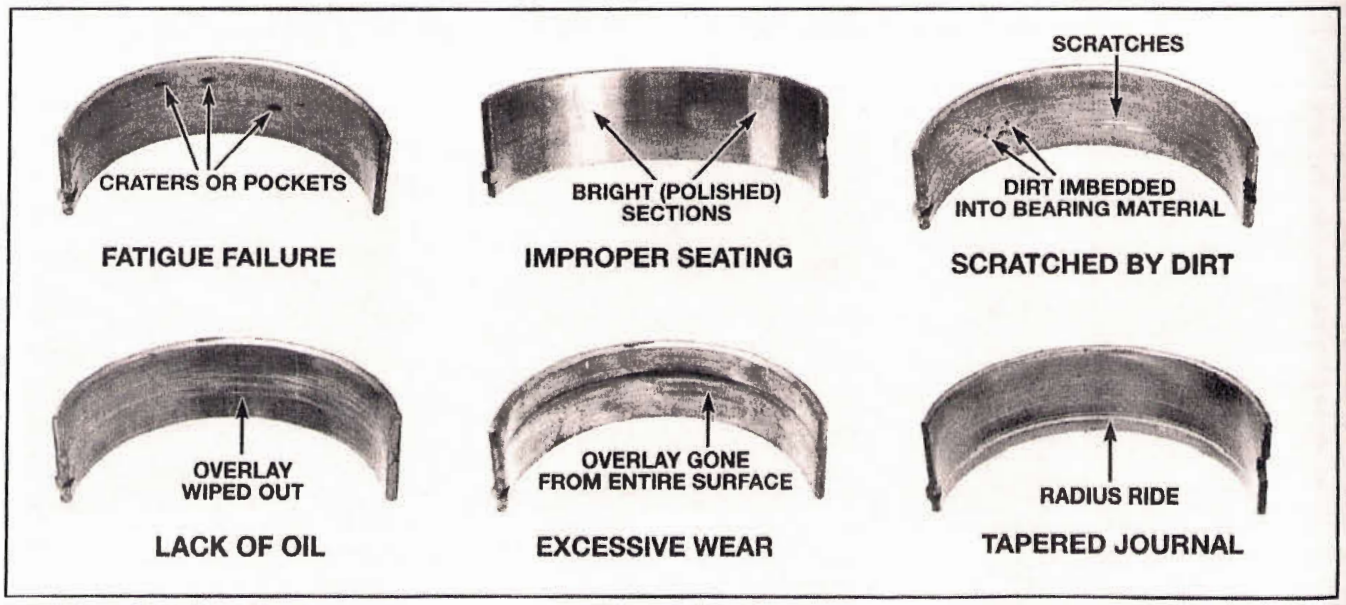
1 Even though the main and connecting rod bearings should be replaced with new ones during the engine overhaul, the old bearings should be retained for close examination, as they may reveal valuable information about the condition of the engine (see illustration).

2 Bearing failure occurs because of lack of lubrication, the presence of dirt or other foreign particles, overloading the engine and corrosion. Regardless of the cause of bearing failure, it must be corrected before the engine is reassembled to prevent it from happening again.

3 When examining the bearings, remove them from the engine block, the main bearing caps, the connecting rods and the rod caps and lay them out on a clean surface in the same general position as their location in the engine. This will enable you to match any bearing problems with the corresponding crankshaft journal.

4 Dirt and other foreign particles get into the engine in a variety of ways. It may be left in the engine during assembly, or it may pass through filters or the PCV system. It may get into the oil, and from there into the bearings. Metal chips from machining operations and normal engine wear are often present. Abrasives are sometimes left in engine components after reconditioning, especially when parts are not thoroughly cleaned using the proper cleaning methods. Whatever the source, these foreign objects often end up embedded in the soft bearing material and are easily recognized. Large particles will not embed in the bearing and will score or gouge the bearing and journal. The best prevention for this cause of bearing failure is to clean all parts thoroughly and keep everything spotlessly clean during engine assembly. Frequent and regular engine oil and filter changes are also recommended.

5 Lack of lubrication (or lubrication breakdown) has a number of



22.1 Typical bearing failures

interrelated causes. Excessive heat (which thins the oil), overloading (which squeezes the oil from the bearing face) and oil leakage or throw off (from excessive bearing clearances, worn oil pump or high engine speeds) all contribute to lubrication breakdown. Blocked oil passages, which usually are the result of misaligned oil holes in a bearing shell, will also oil starve a bearing and destroy it. When lack of lubrication is the cause of bearing failure, the bearing material is wiped or extruded from the steel backing of the bearing. Temperatures may increase to the point where the steel backing turns blue from overheating.

6 Driving habits can have a definite effect on bearing life. Low speed operation in too high a gear (lugging the engine) puts very high loads on bearings, which tends to squeeze out the oil film. These loads cause the bearings to flex, which produces fine cracks in the bearing face (fatigue failure). Eventually the bearing material will loosen in pieces and tear away from the steel backing. Short-trip driving leads to corrosion of bearings because insufficient engine heat is produced to drive off the condensed water and corrosive gases. These products collect in the engine oil, forming acid and sludge. As the oil is carried to the engine bearings, the acid attacks and corrodes the bearing material.

7 Incorrect bearing installation during engine assembly will lead to bearing failure as well. Tight-fitting bearings leave insufficient bearing oil clearance and will result in oil starvation. Dirt or foreign particles trapped behind a bearing insert result in high spots on the bearing which lead to failure.

23 Engine overhaul - reassembly sequence

1 Before beginning engine reassembly, make sure you have all the necessary new parts, gaskets and seals as well as the following items on hand:

Common hand tools
3/8-inch and 1/2-inch-drive torque wrenches
Piston ring installation tool
Piston ring compressor
Crankshaft balancer installation tool
Short lengths of rubber or plastic hose to fit over connecting rod bolts
Plastigage
Feeler gauges
A fine-tooth file
New engine oil
Engine assembly lube or moly-base grease
Gasket sealant
Thread locking compound

2 In order to save time and avoid problems, engine reassembly must be done in the following general order:

New camshaft bearings (must be done by automotive machine shop)
Piston rings
Crankshaft and main bearings
Piston/connecting rod assemblies
Camshaft and lifters
Balance shaft and gears (V6 engines)
Timing chain and sprockets
Windage tray (if equipped)
Oil pump and pick up tube
Front timing chain cover
Engine valley cover (V8 engines)
Cylinder head(s), pushrods and rocker arms
Rear main oil seal and retainer
Oil pan
Intake and exhaust manifolds
Rocker arm cover(s)
Flywheel/driveplate

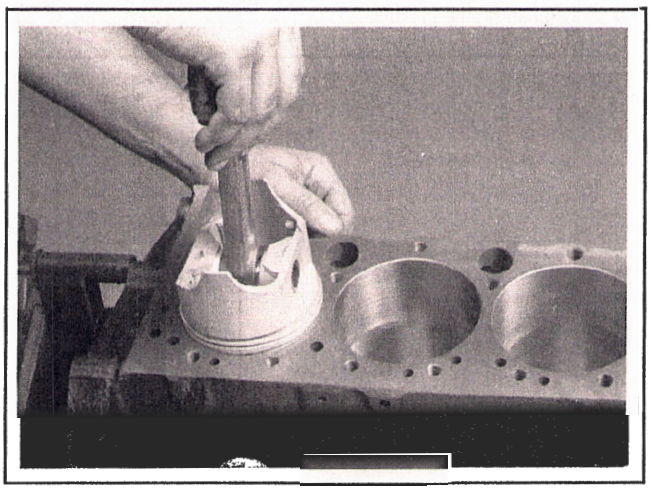
24 Piston rings - installation

Refer to illustrations 24.3, 24.4, 24.5, 24.9a, 24.9b and 24.12

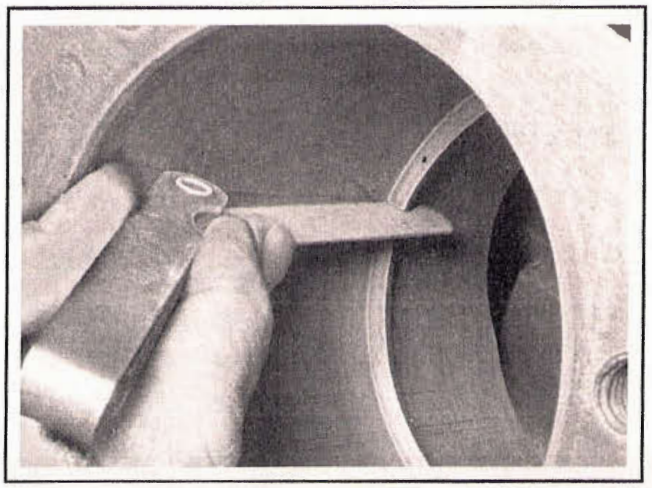
1 Before installing the new piston rings, the ring end gaps must be checked. It's assumed that the piston ring side clearance has been checked and verified correct (see Section 20).

2 Lay out the piston/connecting rod assemblies and the new ring sets so the ring sets will be matched with the same piston and cylinder during the end gap measurement and engine assembly.

3 Insert the top (number one) ring into the first cylinder and square it up with the cylinder walls by pushing it in with the top of the piston (see illustration). The ring should be near the bottom of the cylinder, at the lower limit of ring travel.



24.3 When checking piston ring end gap, the ring must be square in the cylinder bore - use a piston to push it down approximately two inches from the bottom of the bore



24.4 With the ring square in the cylinder, measure the end gap with feeler gauges

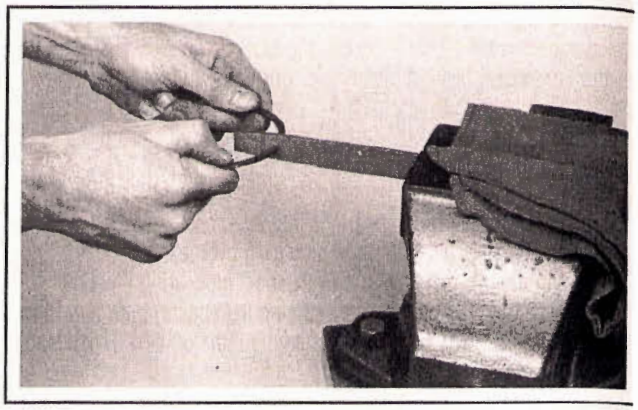
4 To measure the end gap, slip feeler gauges between the ends of the ring until a gauge equal to the gap width is found (see illustration). The feeler gauge should slide between the ring ends with a slight amount of drag. Compare the measurement to the Specifications. If the gap is larger or smaller than specified, double-check to make sure you have the correct rings before proceeding.

5 If the gap is too small, it must be enlarged or the ring ends may come in contact with each other during engine operation, which can cause serious damage to the engine. The end gap can be increased by filing the ring ends very carefully with a fine file. Mount the file in a vise equipped with soft jaws, slip the ring over the file with the ends contacting the file face and slowly move the ring to remove material from the ends. When performing this operation, file only from the outside in (see illustration). The ring ends must be filed squarely, and any tiny burrs on the end should be removed before final ring installation.

6 Excess end gap isn't critical unless it's greater than 0.040-inch. Again, double-check to make sure you have the correct rings for your engine.

7 Repeat the procedure for each ring that will be installed in the first cylinder and for each ring in the remaining cylinders. Remember to keep rings, pistons and cylinders matched up.

8 Once the ring end gaps have been checked/corrected, the rings can be installed on the pistons.



24.5 If the end gap is too small, clamp a fine file in a vise and file ring ends a little at a time and re-measure in the bore - file from the outside of the ring inward only

9 The oil control ring (lowest one on the piston) is usually installed first. It's normally composed of three separate components. Slip the spacer/expander into the groove (see illustration). If an anti-rotation tang is used, make sure it's inserted into the drilled hole in the ring groove. Next, install the lower side rail. Don't use a piston ring installation tool on the oil ring side rails, as they may be damaged. Instead, place one end of the side rail into the groove between the spacer/expander and the ring land, hold it firmly in place and slide a finger around the piston while pushing the rail into the groove (see illustration). Next, install the upper side rail in the same manner.

10 After the three oil ring components have been installed, check to make sure that both the upper and lower side rails can be turned smoothly in the ring groove and that the expander ends are butted together.

11 The number two (middle) ring is installed next. It's usually stamped with a mark which must face up, toward the top of the piston.

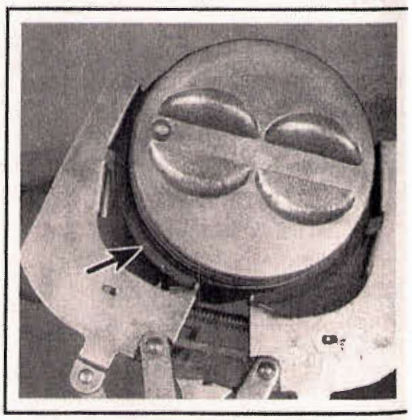
CAUTION:

Always follow the instructions printed on the ring package or box - different manufacturers may require different approaches. Do not mix up the top and middle rings, as they have different cross sections.

12 Use a piston ring installation tool and make sure the identifica-

24.9a Installing the spacer/expander in the oil control ring groove

24.9b Slip the oil ring side rails in by hand - do not use a ring expander



24.12 Install the compression rings using a ring-expander tool like this one - note that the mark (arrow) on the ring should face UP

tion mark is facing the top of the piston, then slip the ring into the middle groove on the piston (see illustration). Don't expand the ring any more than necessary to slide it over the piston.

13 Install the number one (top) ring in the same manner. Making sure that the dot or mark (if equipped) is facing up. Be careful not to confuse the number one and number two rings. Always check the instructions with the ring set your are using.

14 Repeat the procedure for the remaining pistons and rings.

25 Crankshaft - installation and main bearing oil clearance check

1 Crankshaft installation is the first major step in engine reassembly. It's assumed at this point that the engine block and crankshaft have been cleaned, inspected and repaired or reconditioned.

2 Position the engine with the bottom facing up.

3 Remove the main bearing cap bolts and lift out the caps. Lay the caps out in the proper order to ensure correct installation.

4 If they're still in place, remove the old bearing inserts from the block and the main bearing caps. Wipe the main bearing surfaces of the block and caps with a clean, lint free cloth. They must be kept spotlessly clean!

MAIN BEARING OIL CLEARANCE CHECK

Refer to illustrations 25.9, 25.11 and 25.13

5 Clean the back sides of the new main bearing inserts and lay the bearing half with the oil groove in each main bearing saddle in the block. Lay the other bearing half from each bearing set in the corresponding main bearing cap. Make sure the tab on each bearing insert fits into the recess in the block or cap. Also, the oil holes in the block must line up with the oil holes in the bearing insert.

CAUTION:

Do not hammer the bearings into place and don't nick or gouge the bearing faces. No lubrication should be used at this time.

6 Clean the faces of the bearings in the block and the crankshaft main bearing journals with a clean, lint-free cloth. Check or clean the oil holes in the crankshaft, as any dirt here can go only one way - straight through the new bearings.

7 Once you're certain the crankshaft is clean, carefully lay it in position in the main bearings.

8 Before the crankshaft can be permanently installed, the main bearing oil clearance must be checked.

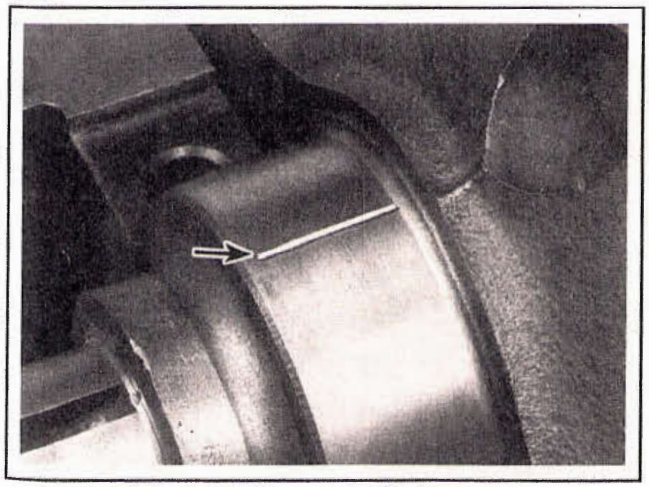
9 Trim several pieces of the appropriate-size Plastigage (they must be slightly shorter than the width of the main bearings) and place one piece on each crankshaft main bearing journal, parallel with the journal axis (see illustration).

10 Clean the faces of the bearings in the caps and install the caps in their respective positions (don't mix them up) with the arrows pointing toward the front of the engine. Don't disturb the Plastigage. Apply a light coat of oil to the bolt threads and the under sides of the bolt heads, then install them.

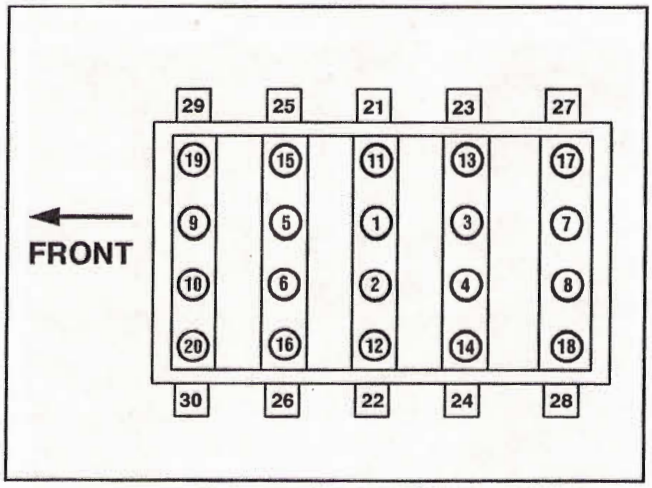
11 On V6 engines, tighten the main bearing cap bolts, starting in the center and working towards the ends, in two steps, to the torque listed in this Chapter's Specifications. Don't rotate the crankshaft at any time during this operation!

Note: On V8 engines, the main bearing tightening procedure requires five steps. First tighten the inner bolts (bolts 1 through 10) in two steps to the torque and angle of rotation listed in this Chapter's Specifications, then tighten the outer bolts (bolts 11 through 20) in two steps to the torque and angle of rotation listed in this Chapter's Specifications (see illustration). The fifth step is tightening the side bolts, but DO NOT use the new side bolts during the oil clearance check as this will damage the O-ring on the new side bolts.

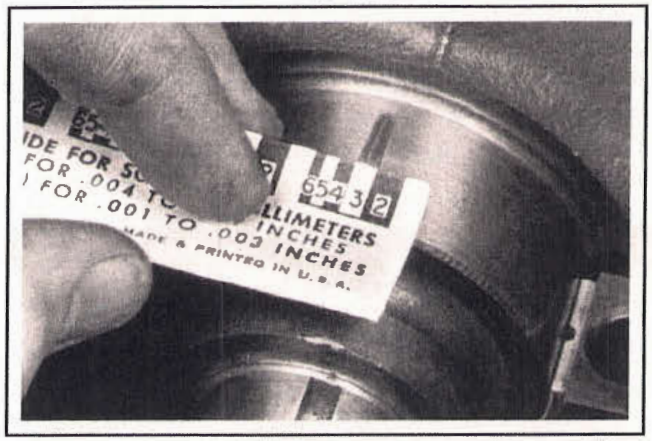
12 Remove the bolts and carefully lift off the main bearing caps. Keep them in order. Don't disturb the Plastigage or rotate the crankshaft. If any of the main bearing caps are difficult to remove, tap them gently from side-to-side with a soft-face hammer to loosen them.



25.9 Lay the Plastigage strips (arrow) on the main bearing journals, parallel to the crankshaft centerline



25.11 Main bearing cap TIGHTENING sequence - V8 engines



25.13 Compare the width of the crushed Plastigage to the scale on the envelope, taking the measurement at the widest point of the Plastigage

13 Compare the width of the crushed Plastigage on each journal to the scale printed on the Plastigage envelope to obtain the main bearing oil clearance (see illustration). Check the Specifications to make sure it's correct.

➡Note: Make sure you are using the correct scale, both metric and standard ones are included in the package.

14 If the clearance is not as specified, the bearing inserts may be the wrong size (which means different ones will be required). Before deciding that different inserts are needed, make sure that no dirt or oil was between the bearing inserts and the caps or block when the clearance was measured. If the Plastigage is noticeably wider at one end than the other, the journal may be tapered.

15 Carefully scrape all traces of the Plastigage material off the mai bearing journals and/or the bearing faces. Don't nick or scratch the bearing faces (a plastic credit card edge does the job).

FINAL CRANKSHAFT INSTALLATION

16 Carefully lift the crankshaft out of the engine. Clean the bearing faces in the block, then apply a thin, uniform layer of engine assembl lube to each of the bearing surfaces.

17 Make sure the crankshaft journals are clean, then lay the crankshaft back in place in the block. Clean the faces of the bearings in the caps, then apply lubricant to them. Install all the caps in their respecti positions.

18 Apply a light coat of oil to the bolt threads and the under sides the bolt heads, then install them finger tight.

19 Pry the crankshaft slightly back and forth in the block to seat th thrust bearings. Tighten all main bearing cap bolts as described in Ste 11 to specifications. On V8 engines, install new main bearing cap sid bolts and tighten the bolts to the torque listed in this Chapter's Specifi cations. Be sure to tighten both side bolts on a main bearing cap befo proceeding to the next cap and always install new side bolts or oil lea may develop.

20 Check the crankshaft endplay with a feeler gauge or a dial indic tor as described in Section 16. The endplay should be correct if the crankshaft thrust faces aren't worn or damaged and new bearings have been installed.

21 On manual transmission models, install a new pilot bearing in the end of the crankshaft (see Chapter 8).

22 Rotate the crankshaft a number of times by hand to check for ar obvious binding.

26 Balance shaft (V6 engines) - installation

♦ Refer to illustrations 26.2 and 26.6

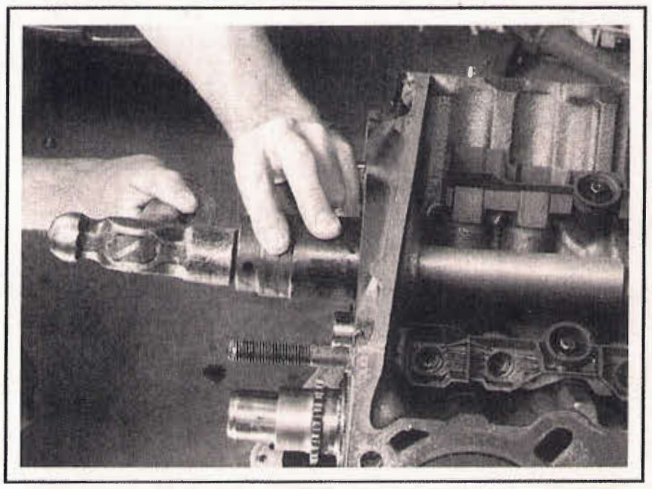
➡Note: The balance shaft is installed after the camshaft. Refer to the camshaft installation procedures in Part B of this Chapter.

1 Lubricate the balance shaft bearing journals with clean engine oil or engine assembly lube.

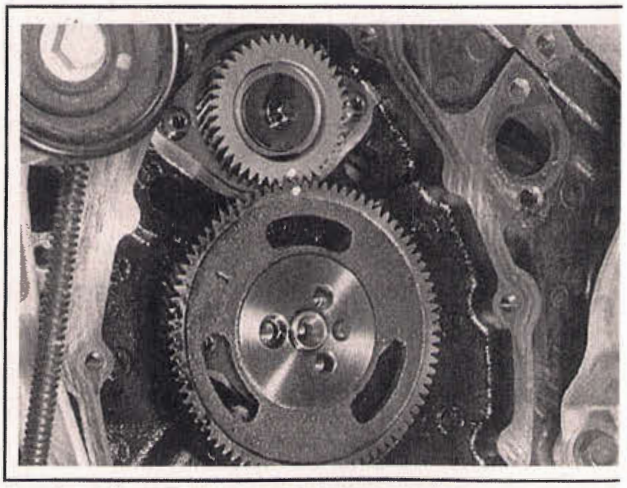
2 Slide the balance shaft into the engine. Support the balance shaft near the block and be careful not to scrape or nick the rear bearing. Using a bearing driver or large socket, gently drive the shaft into the block until the front bearing is seated (see illustration).

3 Install the balance shaft retainer and two bolts and tighten therr to the torque listed in this Chapter's Specifications (see illustration 14.1).

4 Install the balance shaft driven gear and tighten the bolt to the torque listed in Chapter Specifications.



26.2 Drive the balance shaft and front bearing into the block until the bearing retainer can be bolted in place



26.6 Position the balance shaft drive and driven gears with the timing marks aligned as shown

5 Rotate the camshaft so that, with the balance shaft drive gear temporarily installed, the timing mark is straight up at the 12 o'clock position. Remove the drive gear.

6 Rotate the balance shaft until the timing mark on the driven gear is facing straight down at the 6 o'clock position. Reinstall the balance shaft drive gear to the camshaft and make sure both balance shaft gears are aligned (see illustration).

7 Install the timing chain, sprockets and cover (see Part A of this Chapter).

27 Rear main oil seal and housing - installation

Refer to illustrations 27.7 and 27.9

1 All engines covered by this manual are equipped with a one-piece rear main seal and a seal housing that bolts to the rear of the engine block. Although the rear main seal housings on V6 and V8 engines differ in appearance, seal installation is essentially the same with the exception of installing the seal housing onto the engine block. V6 engines use alignment dowels on the rear of the block to automatically center the seal housing over the end of the crankshaft. V8 engines are not equipped with alignment dowels on the rear of the block and therefore must be aligned manually prior to tightening of the rear seal housing.

2 The crankshaft must be installed first and the main bearing caps bolted in place, then the new seal should be installed in the housing and the housing bolted to the block .

3 Before installing the crankshaft, check the seal contact surface very carefully for scratches and nicks that could damage the new seal lip and cause oil leaks. If the crankshaft is damaged, the only alternative is a new or different crankshaft.

4 The old seal can be removed from the housing by inserting a large screwdriver into the three notches provided and prying it out (see Chapter 2A or 2B).

5 Be sure to note how far it's recessed into the housing bore before removing it; the new seal will have to be recessed an equal amount. Be very careful not to scratch or otherwise damage the bore in the housing or oil leaks could develop.

6 Make sure the housing is clean, then apply a thin coat of engine oil to the outer edge of the new seal. The seal must be pressed squarely into the housing bore, so hammering it into place is not recommended. If you don't have access to a press, sandwich the housing and seal between two smooth pieces of wood and press the seal into place with the jaws of a large vise. The pieces of wood must be thick enough to distribute the force evenly around the entire circumference of the seal. Work slowly and make sure the seal enters the bore squarely.

7 On V6 engines, make sure the dowel pins are in place before installing the housing. Lubricate the seal lips with small amount of clean engine oil and slide the rear seal/housing over the rear of the crankshaft (see illustration). Be sure to use a new gasket between the rear seal housing to the engine block - no sealant is required.

V6 ENGINE

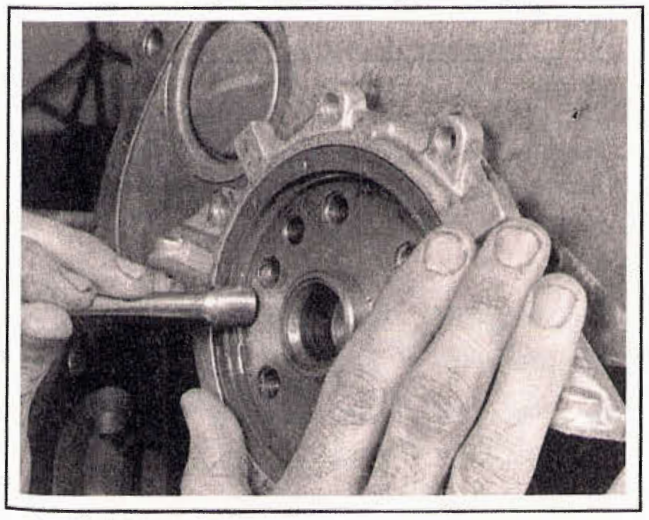
8 Tighten the bolts a little at a time until the seal housing is fully seated against the engine block, then tighten them to the torque listed in this Chapter's Specifications.

V8 ENGINES

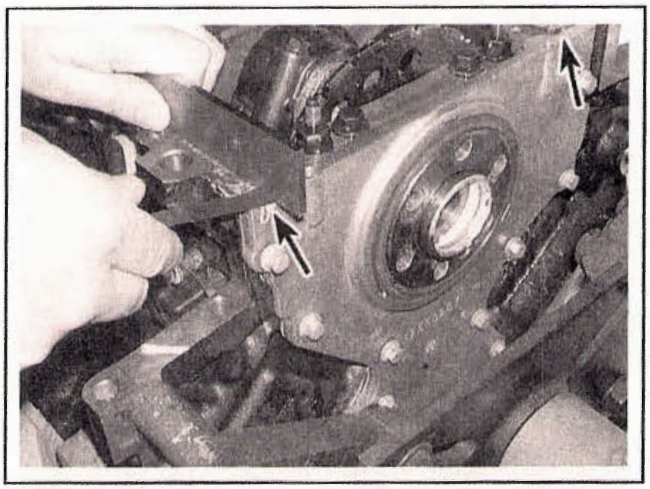
9 Install the rear seal housing retaining bolts on the engine loosely and align the rear housing as follows:

a) Place a straightedge on the engine block oil pan rail. Measure the distance on each side of the block from the oil pan rail to the rear housing with a feeler gauge (see illustration). This Step measures the difference between the sealing surface of the oil pan and the sealing surface of the rear seal housing in relationship to each other.

b) Tilt the rear seal housing as necessary to achieve an even measurement on each side. This Step properly aligns the rear seal housing to oil pan sealing surfaces. Typically 0.000 to 0.020 inch is an acceptable tolerance.



27.7 On these engines it will be necessary to install the new seal in the housing first, then install a new gasket and the seal housing on the block - be sure to lubricate the seal lip and carefully work the seal over the crankshaft with blunt tool



27.9 With the rear seal housing in place and the bolts installed LOOSELY, measure the distance between the oil pan rail and the seal housing on each side (arrows) - then adjust the housing so the measurements are even on both sides before tightening the cover bolts

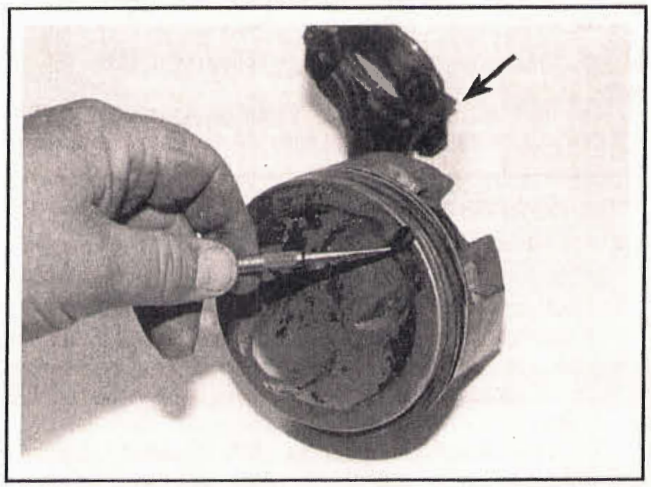
➡Note: Ideally the rear seal housing should be flush with the oil pan rail, but because of the differences in seal thickness, this may not always be obtainable. That is why there is a tolerance of 0.000 to 0.020 inch. Always let the rear seal center itself around the crankshaft and tilt the cover from side-to-side to even up the measurement at both oil pan rails. Never push downward on the rear seal housing in an attempt to make the oil pan sealing surface flush, as this will distort the rear oil seal and eventually lead to an oil leak!

c) With the rear seal housing properly aligned, tighten the housing bolts to the torque listed in this Chapter's Specifications.

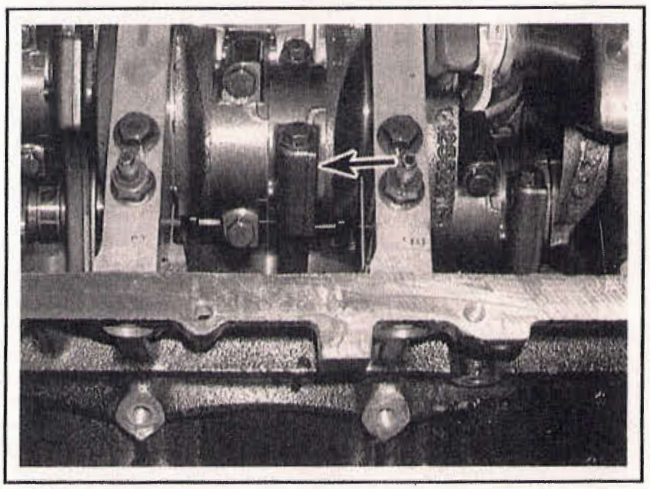
28 Pistons/connecting rods - installation and rod bearing oil clearance check

▶ Refer to illustrations 28.1a, 28.1b, 28.3, 28.5, 28.9, 28.11, 28.13 and 28.17

1 Before installing the piston/connecting rod assemblies, the cylinder walls must be perfectly clean, the top edge of each cylinder must be chamfered, and the crankshaft must be in place. If new pistons or connecting rods were installed, check the orientation of the connecting rod to the piston for correct installation by the machine shop. On V6 engines, the left bank connecting rod flanges must face the front of the engine and the right bank connecting rod flanges must face the rear of the engine, with the mark on the top of the pistons facing the front of the engine (see illustration). You should have three pistons with the connecting rod flanges and the mark on the pistons aligned on the same side (these are the left bank pistons) and three pistons with the connecting rod flanges opposite the mark on the pistons (these are the right bank pistons). On V8 engines, the flat side of the connecting rods and the marks on the top of each piston must all face the front of the engine (see illustration). So, the pistons and connecting rod assemblies can be installed in either the right or left bank if new rods were installed.



28.1a On V6 engines, the flanges on the rod (arrow) must be positioned correctly with the notch on the piston to have proper oiling of the cylinder walls - left bank piston shown, right bank pistons are opposite



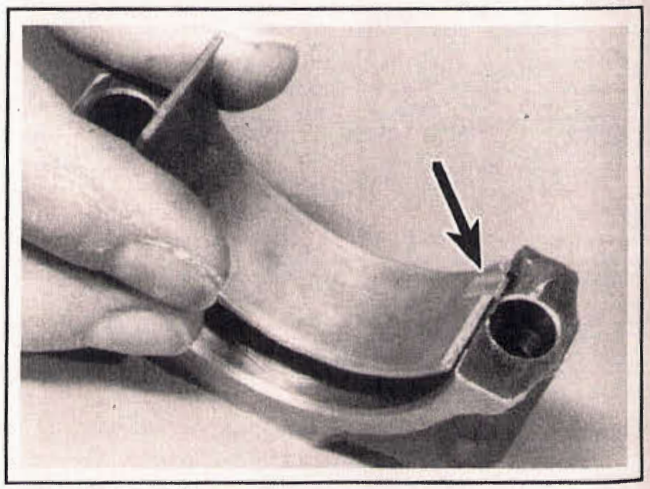
28.1b On V8 engines, the flat side of the rods (arrow) and the notch in the top of the piston must face the front of the engine

2 Remove the cap from the end of the number one connecting rod (refer to the marks made during removal). Remove the original bearing inserts and wipe the bearing surfaces of the connecting rod and cap with a clean, lint-free cloth. They must be kept spotlessly clean.

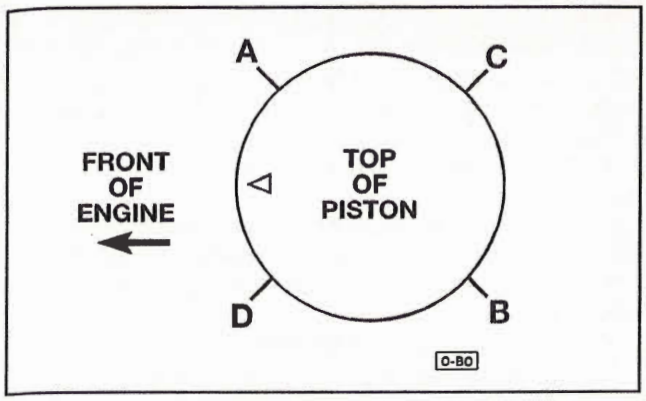
CONNECTING ROD BEARING OIL CLEARANCE CHECK

3 Clean the back side of the new upper bearing insert, then lay it in place in the connecting rod. Make sure the tab on the bearing fits into the recess in the rod (see illustration). Don't hammer the bearing insert into place and be very careful not to nick or gouge the bearing face. Don't lubricate the bearing at this time.

4 Clean the back side of the other bearing insert and install it in the rod cap. Again, make sure the tab on the bearing fits into the recess in the cap, and don't apply any lubricant. It's critically important that the mating surfaces of the bearing and connecting rod are perfectly clean and oil free when they're assembled.



28.3 Make sure the bearing tang fits securely into the notch on the rod cap



28.5 Position the piston ring gaps as shown here before installing the piston/connecting rod assembly into the engine

A Top compression ring gap
B Second compression ring and oil ring spacer gap
C Upper oil ring rail gap
D Lower oil ring rail gap

5 Position the piston ring gaps at intervals around the piston (see illustration).

6 Slip a section-of plastic or rubber hose over each connecting rod cap bolt. On V8 engines install the connecting rod guides that were fabricated previously.

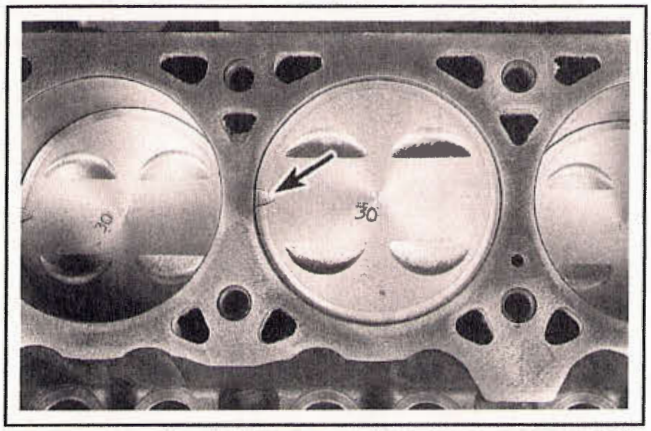
7 Lubricate the piston and rings with clean engine oil and attach a piston ring compressor to the piston. Leave the skirt protruding about 1/4-inch to guide the piston into the cylinder. The rings must be compressed until they're flush with the piston.

8 Rotate the crankshaft until the number one connecting rod journal is at BDC (bottom dead center) and apply a coat of engine oil to the cylinder walls.

9 With the arrow or notch on top of the piston (see illustration) facing the front of the engine, gently insert the piston/connecting rod assembly into the number one cylinder bore and rest the bottom edge of the ring compressor on the engine block.

10 Tap the top edge of the ring compressor to make sure it's contacting the block around its entire circumference.

11 Gently tap on the top of the piston with the end of a wooden or plastic hammer handle (see illustration) while guiding the end of the connecting rod into place on the crankshaft journal. The piston rings may try to pop out of the ring compressor just before entering the cylinder bore, so keep some downward pressure on the ring compressor. Work slowly, and if any resistance is felt as the piston enters the cylinder, stop immediately. Find out what's hanging up and fix it before proceeding. Do not, for any reason, force the piston into the cylinder - you might break a ring and/or the piston.



28.9 The notch (arrow) on the pistons must face forward

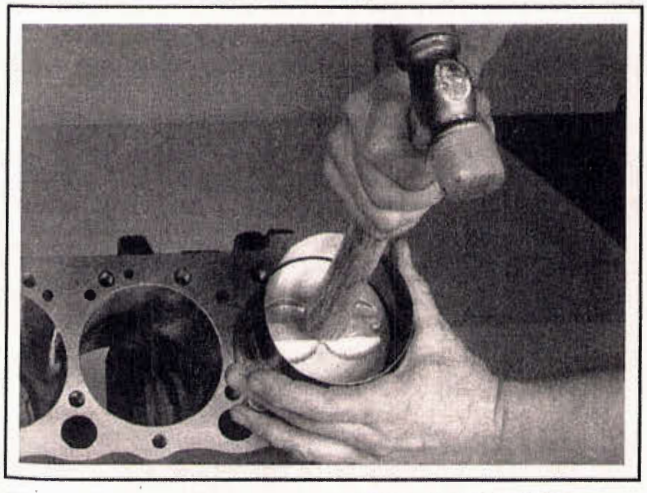
12 Once the piston/connecting rod assembly is installed, the connecting rod bearing oil clearance must be checked before the rod cap is permanently bolted in place.

13 Cut a piece of the appropriate size Plastigage slightly shorter than the width of the connecting rod bearing and lay it in place on the number one connecting rod journal, parallel with the journal axis (see illustration).

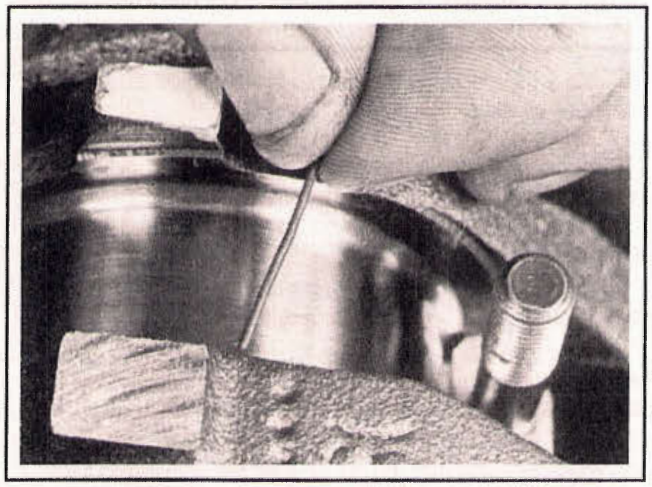
14 Clean the connecting rod cap bearing face, remove the protective hoses from the connecting rod bolts and install the rod cap. Make sure the mating mark on the cap is on the same side as the mark on the connecting rod.

15 Install the nuts or bolts and tighten them in two steps, to the torque and angle of rotation listed in this Chapter's Specifications.

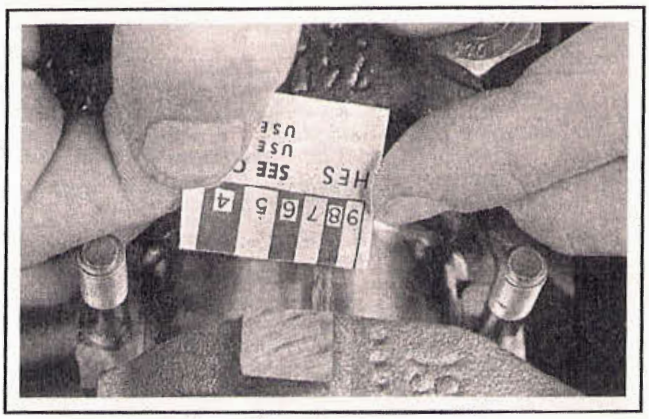
➡Note: Use a thin-wall socket to avoid erroneous torque readings that can result if the socket is wedged between the rod cap and nut. If the socket tends to wedge itself between the nut and the cap, lift up on it slightly until it no longer contacts the cap. Do not rotate the crankshaft at any time during this operation.



28.11 Drive the piston in gently with the end of a wooden hammer handle - go evenly and stop if you feel an obstruction



28.13 Lay the Plastigage strips on each rod bearing journal, parallel to the crankshaft centerline



28.17 Measure the width of the crushed Plastigage to determine the rod bearing oil clearance and compare it to the Specifications

16 Remove the nuts or bolts and detach the rod cap, being very careful not to disturb the Plastigage.

17 Compare the width of the crushed Plastigage to the scale printed on the Plastigage envelope to obtain the oil clearance (see illustration). Compare it to the Specifications to make sure the clearance is correct.

18 If the clearance is not as specified, the bearing inserts may be the wrong size (which means different ones will be required). Before deciding that different inserts are needed, make sure that no dirt or oil was between the bearing inserts and the connecting rod or cap when the clearance was measured. Also, recheck the journal diameter. If the Plastigage was wider at one end than the other, the journal may be tapered, in which case the crankshaft needs to be machined.

FINAL CONNECTING ROD INSTALLATION

19 Carefully scrape all traces of the Plastigage material off the rod journal and/or bearing face. Be very careful not to scratch the bearing - use your fingernail or the edge of a credit card.

20 Make sure the bearing faces are perfectly clean, then apply a uniform layer of clean moly-base grease or engine assembly lube to both of them. You'll have to push the piston into the cylinder to expose the face of the bearing insert in the connecting rod - be sure to slip the protective hoses over the rod bolts first.

21 Slide the connecting rod back into place on the journal, remove the protective hoses from the rod cap bolts or the connecting rod guides, install the rod cap and tighten the nuts or bolts in two steps, to the torque and angle of rotation listed in this Chapter's Specifications.

22 Repeat the entire procedure for the remaining pistons/connecting rods.

23 The important points to remember are:

a) Keep the back sides of the bearing inserts and the insides of the connecting rods and caps perfectly clean when assembling them.
b) Make sure you have the correct piston/rod assembly for each cylinder.
c) The notch or mark on the piston must face the front of the engine.
d) Stagger the ring end gaps (see illustration 28.5).
e) Lubricate the cylinder walls with clean oil.
f) Lubricate the bearing faces when installing the rod caps after the oil clearance has been checked.

24 After all the piston/connecting rod assemblies have been properly installed, rotate the crankshaft a number of times by hand to check for any obvious binding.

25 As a final step, the connecting rod side clearance must be checked. Refer to Section-15 for this procedure.

26 Compare the measured side clearance to the Specifications to make sure it's correct. If it was correct before disassembly and the original crankshaft and rods were reinstalled, it should still be right. If new rods or a new crankshaft were installed, the side clearance may be inadequate. If so, the rods will have to be removed and taken to an automotive machine shop for resizing.

27 The remainder of the engine assembly work is in attaching the cylinder heads, valvetrain, front cover, water pump, flywheel, intake and exhaust manifolds and accessories, all of which are covered in Chapter-2A or 2B.

29 Initial start-up and break-in after overhaul

WARNING:

Have a fire extinguisher handy when starting the engine for the first time.

1 Once the engine has been installed in the vehicle, double-check the engine oil and coolant levels.

2 With the spark plugs out of the engine and the ignition and fuel systems disabled (see Section 3), crank the engine until oil pressure registers on the gauge or the light goes out.

3 Install the spark plugs, connect the plug wires and restore the ignition and fuel system functions.

4 Start the engine. It may take a few moments for the fuel system to build up pressure, but the engine should start without a great deal of effort.

➡Note: If backfiring occurs through the throttle body, recheck the valve timing and, on V6 engines, the distributor installation.

5 After the engine starts, it should be allowed to warm up to normal operating temperature. Do not allow the engine to exceed a fast idle until the hydraulic lifters pump up and become quiet again (usually about five minutes).

6 While the engine is warming up, make a thorough check for fuel, oil and coolant leaks. If a new camshaft and lifters have been installed during the overhaul, the engine should run at a fast idle for 15 minutes after the lifters pump up and become quiet (keep an eye on the temperature gauge and don't allow the engine to overheat) to "break in" the cam and lifters.

7 Shut the engine off and recheck the engine oil and coolant levels.

8 Drive the vehicle to an area with minimum traffic, accelerate from 30 to 50 mph, then allow the vehicle to slow to 30 mph with the throttle closed. Repeat the procedure 10 or 12 times. This will load the piston rings and cause them to seat properly against the cylinder walls. Check again for oil and coolant leaks.

9 Drive the vehicle gently for the first 500 miles (no sustained high speeds) and keep a constant check on the oil level. It is not unusual for an engine to use oil during the break-in period.

10 At approximately 500 to 600 miles, change the oil and filter.

11 For the next few hundred miles, drive the vehicle normally. Do not pamper it or abuse it.

12 After 2000 miles, change the oil and filter again and consider the engine broken in.

Specifications

V6 and V8 engines

General

Displacement	
4.3L V6	262 cubic inches
4.8L V8	293 cubic inches
5.3L V8	325 cubic inches
6.0L V8	364 cubic inches
Cylinder compression pressure	
Minimum	100 psi
Maximum variation between cylinders	25 percent from highest reading
Oil pressure (minimum)	
1000 rpm	6 psi
2000 rpm	18 psi
4000 rpm	24 psi

Engine block

Bore diameter	
4.3L V6	4.007 to 4.0017 inches
4.8L V8	3.779 to 3.780 inches
5.3L V8	3.779 to 3.780 inches
6.0L V8	4.0007 to 4.0014 inches
Taper (maximum)	0.001 inch
Out-of-round (maximum)	0.002 inch
Deck (head gasket surface) warpage limit	0.003 inch per 6 inches
Lifter bore diameter	
V6 engine	not available
V8 engines	0.843 to 0.844 inch

Cylinder head and valves

Head warpage limit	0.003 inch per 6 inches
Valve margin (minimum)	
V6 engine	0.031 inch
V8 engines	0.050 inch
Valve face angle (intake and exhaust)	45-degrees
Valve seat angle (intake and exhaust)	46-degrees
Valve seat width	
V6 engine	
Intake	0.035 to 0.060 inch
Exhaust	0.065 to 0.098 inch
V8 engines	
Intake	0.040 to 0.060 inch
Exhaust	0.070 to 0.080 inch
Valve stem-to-guide clearance service limit	
V6 engine	0.0037 inch
V8 engine	
Intake	0.0037 inch
Exhaust	
1999 and 2000	0.0041 inch
2001 and later	0.0037 inch
Valve spring free length	
V6 engine	2.02 inches
V8 engines	2.08 inches

Cylinder head and valves (continued)	
Valve spring installed height	
V6 engine	1.670 to 1.700 inches
V6 engines	1.8 inches
Camshaft	
Journal diameters	
V6 engine	1.8677 to 1.8696 inches
V8 engines	2.164 to 2.166 inches
Journal taper and out-of-round (maximum, all engines)	0.001 inch
Lobe lift	
V6 engines	
1999 through 2004 models	
Intake	0.274 to 0.278 inch
Exhaust	0.283 to 0.287 inch
2005 and later models	
Intake	0.270 inch
Exhaust	0.279 inch
V8 engines	
1999 and 2000	
Intake	0.268 inch
Exhaust	0.274 inch
2001	
Intake	0.274 inch
Exhaust	0.281 inch
2002 and later models	
4.8L and 5.3L engines	
Intake	0.268 inch
Exhaust	0.274 inch
6.0L engines	
Intake	0.274 inch
Exhaust	0.281 inch
Runout	
V6 engines	
1999 through 2004 models	0.0026 inch
2005 and later models	0.0039 inch
V8 engines	0.0020 inch
Endplay	
V6 engine	0.001 to 0.009 inch
V8 engines	0.001 to 0.012 inch
Crankshaft and connecting rods	
Rod journal diameter	
V6 engine	2.2487 to 2.2497 inches
V8 engines	2.0990 to 2.100 inches
Rod journal taper (maximum)	
V6 engine	0.001 inch
V8 engines	0.0008 inch
Rod journal out-of-round (maximum)	
V6 engine	0.001 inch
V8 engines	0.0004 inch
Rod bearing oil clearance	
Desired	
V6 engine	0.0015 to 0.0031 inch
V8 engines	0.0009 to 0.0025 inch

Allowable	
V6 engine	0.0010 to 0.0031 inch
V8 engines	0.0009 to 0.003 inch
Connecting rod side clearance (endplay)	
V6 engine	0.006 to 0.017 inch
V8 engines	0.00043 to 0.020 inch
Main bearing journal diameter	
V6 engine	
Journal number 1	2.4488 to 2.4495 inches
Journal numbers 2 and 3	2.4485 to 2.4494 inches
Journal number 4	2.4480 to 2.4489 inches
V8 engines	2.558 to 2.559 inches
Main bearing journal taper (maximum)	
V6 engine	0.0003 inch
V8 engines	0.0008 inch
Main bearing journal out-of-round (maximum)	
V6 engine	0.0010 inch
V8 engines	0.0003 inch
Main bearing oil clearance	
V6 engine	
Journal 1	0.0008 to 0.0020 inch
Journals 2, 3 and 4	0.0011 to 0.0023 inch
V8 engines	0.0008 to 0.0021 inch
Crankshaft endplay	
V6 engine	0.002 to 0.008 inch
V8 engines	0.0015 to 0.0078 inch

Pistons and rings

Piston-to-bore clearance	
V6 engine	
Production	
1999 to 2005	0.0007 to 0.0024 inch
2006 and later	0.0005 to 0.0009 inch
Service limit	
1999 to 2005	0.0029 inch
2006 and later	0.0010 inch
V8 engines	
2006 and later	
4.8L and 5.3L engines	-0.0014 to +0.0006 inch
6.0L engines	-0.0009 to +0.0012 inch
Service limit	
1999 through 2001	0.0028 inch
2002	
4.8L, 5.3L, 6.0L LQ4 engines	0.0032 inch
6.0L LQ9 engine	0.0031 inch
2003 through 2005	0.0028 inch
2006 through 2007	
4.8L, 5.3L, 6.0L LQ4 engines	0.0028 inch
6.0L LQ9 engine	0.0031 inch
Piston ring end gap	
V6 engines	
Top compression ring	
Production	0.010 to 0.016 inch
Service limit	
1999 through 2001	0.019 inch
2002 and later	0.020 inch

V6 engines (continued)	
Second compression ring	
Production	
1999 through 2001	0.018 to 0.026 inch
2002 and later	0.015 to 0.023 inch
Service limit	0.031 inch
Oil ring	
Production	0.010 to 0.029 inch
Service limit	0.035 inch
V8 engines	
Top compression ring	
Production	
1999 through 2002	
4.8L and 5.3L engines	0.010 to 0.016 inch
6.0L engines	0.012 to 0.020 inch
2003 and later	
4.8L and 5.3L engines	0.009 to 0.017 inch
6.0L engines	0.012 to 0.020 inch
Service limit	
4.8L and 5.3L engines	0.020 inch
6.0L engines	0.023 inch
Second compression ring	
Production	
1999 and 2000	0.017 to 0.025 inch
2001	0.007 to 0.027 inch
2002 and later	
4.8L and 5.3L engines	0.017 to 0.027 inch
6.0L engines	0.020 to 0.030 inch
Service limit	
1999 through 2002	
4.8L and 5.3L engines	0.028 inch
6.0L engines	0.033 inch
2003 and later	
4.8L and 5.3L engines	0.030 inch
6.0L engines	0.033 inch
Oil ring	
Production	
4.8L and 5.3L engines	0.007 to 0.029 inch
6.0L engines	0.012 to 0.034 inch
Service limit	
4.8L and 5.3L engines	0.032 inch
6.0L engines	0.037 inch
Piston ring-to-groove clearance	
V6 engines	
Top compression ring	
Production	0.0012 to 0.0027 inch
Maximum	0.0033 inch
Second compression ring	
Production	
1999 through 2002	0.0015 to 0.0031 inch
2003 and later	0.0030 to 0.0110 inch
Maximum	0.0033 inch
Oil ring	
Production	
1999 through 2002	0.0018 to 0.0037 inch
2003 and later	0.0018 to 0.0077 inch

Maximum	
1999 through 2002	0.0039 inch
2003 and later	0.0079 inch
V8 engines	
Top compression ring	
Production	
1999 through 2001	0.0016 to 0.0031 inch
2002 and later	
4.8L and 5.3L engines	0.0016 to 0.0034 inch
6.0L engines	0.0014 to 0.0031 inch
Maximum	
1999 through 2001	0.0033 inch
2002 and later	
4.8L and 5.3L engines	0.0034 inch
6.0L engines	0.0031 inch
Second compression ring	
Production	
2003 and later 6.0L engines	0.0013 to 0.0030 inch
All other engines	0.0016 to 0.0031 inch
Maximum	
1999 through 2002 except	
6.0L engines	0.0033 inch
6.0L and all 2003 and later engines	0.0031 inch
Oil ring	
Production	
1999 through 2001	0.0004 to 0.0080 inch
2002 and later	0.0005 to 0.0078 inch
Maximum	
1999 through 2001	0.0080 inch
2002 and later	0.0078 inch

Balance shaft (V6 engine only)

Rear bearing journal diameter	1.4994 to 1.5000 inches
Rear bearing journal oil clearance	1.0020 to 1.0035 inch

Torque specifications* Ft-lbs (unless otherwise indicated)

Main bearing cap bolts	
V6 engine	
Step one	15
Step two	Turn an additional 73 degrees
V8 engines (in sequence - (see illustration 25.11)	
1999 through 2002	
Inner bolts (1 through 10)	
Step 1	15
Step 2	Tighten an additional 80-degrees
Outer stud nuts (11 through 20)	
Step 1	15
Step 2	Tighten an additional 50-degrees
Side bolts (21 through 30)	18
2003 and later	
Inner bolts (1 through 10)	
Step 1	15
Step 2	Tighten an additional 80-degrees

Torque specifications*	Ft-lbs (unless otherwise indicated)
2003 and later (continued)	
Outer stud nuts (11 through 20)	
Step 1	15
Step 2	Tighten an additional 51-degrees
Side bolts (21 through 30)	18
Connecting rod cap bolts or nuts	
V6 engine	
1999 through 2005 and 2006 with forged connecting rods	
Step 1	20
Step 2	Tighten an additional 70-degrees
2006 with powdered metal connecting rods and later	
Step 1	15
Step 2	Tighten an additional 100-degrees
V8 engines (first design)	
Step one	15
Step two	Turn an additional 60 degrees
V8 engines (second design)	
Step one	15
Step two	Turn an additional 75 degrees
Crankshaft rear oil seal housing bolts	
V6 engine	106 in-lbs
V8 engines	18
Engine valley cover bolts	18
Windage tray nuts (V8 engines)	18

*** Note: Refer to Part B for additional torque specifications.**