Chapter Three

Engine and Engine Rebuilding

Engine Electrical

DISTRIBUTOR

Removal

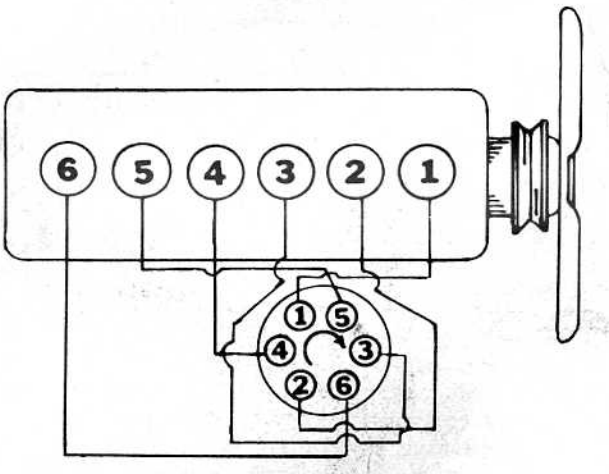
1. Remove the cables from the spark plugs, after marking the wiring order.
2. Remove the primary wire and the vacuum line from the distributor. Remove the distributor cap.
3. Match-mark the distributor housing and the engine block; mark the rotor position in the distributor as well. This will aid in correct positioning of the distributor during installation.
4. Remove the clamp from the distributor. Remove the distributor from the block.

NOTE: *It is easier to install the distributor if the engine timing is not disturbed while it is removed. If the timing has been lost, see "Installation—Timing Lost," below.*

Installation—Timing Not Disturbed

1. Insert the distributor in the block and align the matchmarks made during removal.
2. Engage the distributor drive with the oil pump driveshaft.
3. Install the distributor clamp, cap, primary wire, and vacuum line.

Firing Order



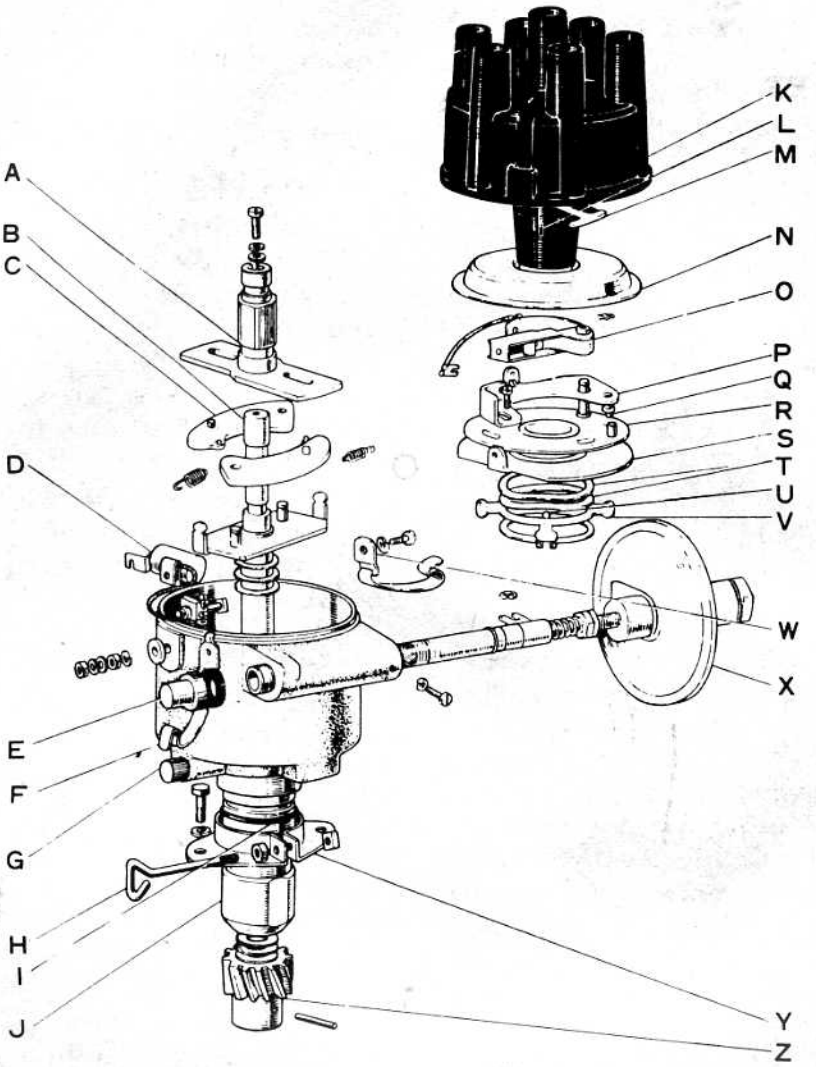
Firing order and wiring sequence for the F Series engine

4. Install the wires on the spark plugs. Remember to check the marks made during removal to be sure that the right wire goes to the right plug.
5. Start the engine. Check and adjust the timing, as outlined in Chapter 2.

Installation—Timing Lost

If the engine has been cranked, dismantled, or the timing otherwise lost, proceed as follows:

1. Determine top dead center (TDC) of the number one (no. 1) cylinder's compression stroke by removing the spark plug from the no. 1 cylinder and



Exploded view of the distributor

A. Distributor cam
B. Distributor shaft
C. Governor weight
D. Condenser
E. Adjuster cap
F. Spring clip
G. Oil cap
H. Holder screw
I. O-ring
J. Distributor housing
K. Distributor cap
L. Carbon piece
M. Distributor rotor
N. Dustproof cover
O. Breaker arm
P. Contact point plate
Q. Eccentric bolt
R. Breaker plate
S. Stationary plate
T. Washer
U. Ball
V. Breaker plate set spring
W. Spring clip
X. Vacuum advancer
Y. Distributor clamp
Z. Distributor drive gear

placing a finger or a compression gauge over the spark plug hole.

Crank the engine until compresssion pressure starts to build up. Continue cranking the engine until the timing marks indicate TDC.

2. Next, align the timing marks to the specifications given in the "Ignition Timing" column of the tune-up chart at the beginning of Chapter 2.

3. Temporarily install the rotor in the distributor without the dust cover. Turn the distributor shaft so that the rotor is pointing toward the No. 1 terminal in the distributor cap. The points should just be about to open.

4. Use a small screwdriver to align the slot on the distributor drive (oil pump driveshaft) with the key on the bottom of the distributor shaft.

5. Lightly oil the distributor spiral gear and the oil pump driveshaft end.

6. Install the distributor in the block by rotating it slightly (no more than one gear tooth in either direction) until the driven gear meshes with the drive.

7. Rotate the distributor, once it is installed, so that the points are just about

to open. Temporarily tighten the pinch bolt.

8. Remove the rotor and install the dust cover. Replace the rotor and the distributor cap.

9. Install the primary wire and the vacuum line.

10. Install the no. 1 cylinder spark plug. Connect the cables to the spark plugs in the proper order by using the marks made during removal.

11. Start the engine and adjust the breaker point dwell and ignition timing.

ALTERNATOR

Alternator Precautions

To prevent damage to the alternator and regulator, the following precautionary measures must be taken when working with the electrical system.

1. Never reverse the battery connections. Always check the battery polarity visually. This is to be done before any connections are made to be sure that all of the connections correspond to the negative ground polarity of the Land Cruiser.

2. Booster batteries for starting must be connected properly. Make sure that the positive cable of the booster battery is connected to the positive terminal of the battery which is getting the boost.

3. Disconnect the battery cables before charging. The charger has a tendency to force current through the alternator diodes in the opposite direction for which they were designed. This burns out the diodes.

4. Never use a fast battery charger as a booster for starting the vehicle.

5. Never operate the alternator with the battery cables disconnected, the leads disconnected from the regulator, or with any open circuit in the charging system.

6. Never ground the alternator output terminal or the regulator terminals while operating the alternator.

7. Always disconnect the battery ground cable when replacing electrical components.

8. Never subject the alternator to excessive heat or dampness if the engine is being steam cleaned.

9. Never use arc welding equipment on the vehicle with the alternator and battery connected.

10. Never attempt to polarize an alternator.

Removal and Installation

1. Disconnect the battery-to-starter cable from the battery.

2. Disconnect the electrical leads from the rear of the alternator.

3. Remove the air cleaner assembly.

4. Remove the fan belt adjusting bar bolt, and then remove the drive belt.

5. Remove the alternator retaining bolt, and remove the alternator from the bracket, lifting upward.

6. Install the alternator in the reverse order of removal.

Belt Tension Adjustment

Inspection and adjustment to the alternator drive belt should be performed every 3,000 miles or if the alternator has been removed.

1. Inspect the drive belt to see that it is not cracked or worn. Be sure that its surfaces are free of grease or oil.

2. Push down on the belt halfway between the fan and the alternator pulleys, with a force of about 22 lbs. The belt should deflect ⅜–½ in.

3. If the belt tension requires adjustment, loosen the adjusting link bolt and move the alternator until the proper belt tension is obtained.

CAUTION: *Do not overtighten the belt; damage to the alternator bearings could result.*

4. Tighten the adjusting link bolt.

REGULATOR

Removal and Installation

1. Disconnect the battery-to-starter cable from the battery.

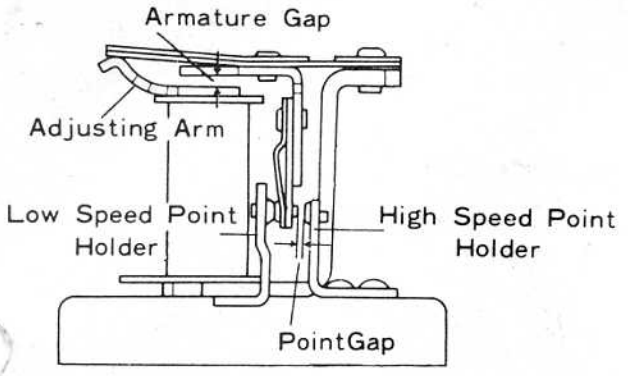
2. Disconnect the electrical leads from the regulator, taking note of their positions for reinstallation.

3. Remove the regulator retaining screws and remove the regulator.

4. Install the regulator in the reverse order of removal.

Adjustment

1. Remove the regulator from the vehicle and remove the cover.



Regulator adjustments

2. Dress dirty or slightly pitted point contacts with fine sandpaper. Wash and rinse the points with a suitable solvent.

3. Inspect the point contacts and replace the regulator assembly if the points are excessively burned or pitted.

4. Check the point gap with a feeler gauge. The gap should be 0.010–0.018 in.

5. Adjust the point gap to specifications by bending the high-speed point holder.

6. Install the regulator on the vehicle, leaving the cover off.

7. Connect a voltmeter to the IG terminal on the regulator.

8. Start the engine and rev it until maximum voltage is reached on the voltmeter. The maximum voltage should be 13.6–14.6 volts.

9. To adjust the voltage, bend the regulator adjusting arm.

10. Remove the voltmeter and install the cover.

STARTER

Removal and Installation

1. Disconnect the battery ground cable.

2. Disconnect the starter cable and the wire from the starter solenoid terminal.

3. Remove the two retaining bolts and remove the starter from the vehicle.

4. Install the starter in the reverse order of removal.

Starter Solenoid and Brush Replacement

1. Remove the starter from the vehicle and remove the field coil lead from the solenoid terminal.

2. Unscrew the solenoid retaining screws. Remove the solenoid by tilting it upward and withdrawing it.

3. Unscrew the end frame bearing cover screws and remove the cover.

4. Unscrew and withdraw the thrubolts. Remove the commutator endframe.

5. Remove the brushes from their holder if they are to be replaced.

6. Check the brush length against the specification in the "Battery and Starter Specifications" chart. Replace the brushes with new ones if required.

7. Dress the new brushes with emery cloth so that they will make proper contact.

8. Use a spring scale to check the brush spring tension against the specification in the chart. Replace the springs if they do not meet specification.

9. Assembly is the reverse order of disassembly. Remember to pack the end bearing cover with multipurpose grease before installing it.

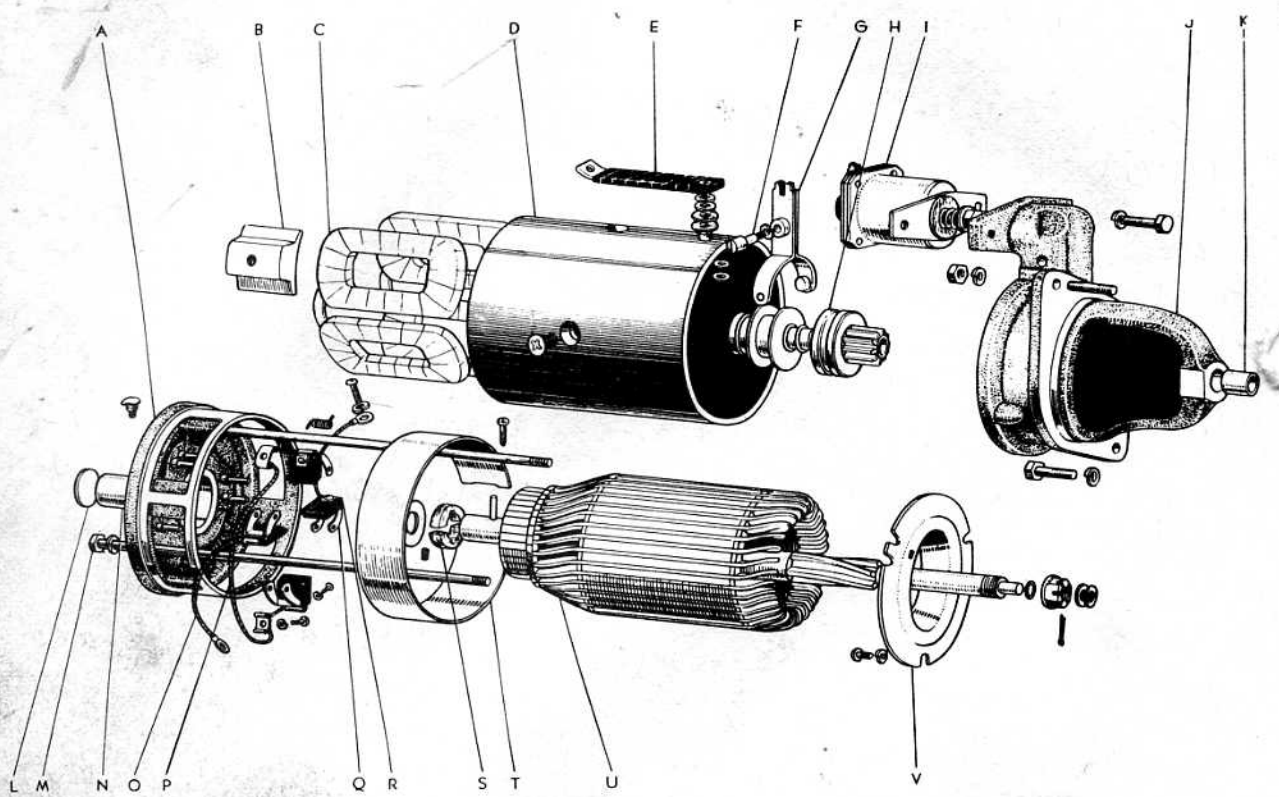
BATTERY

Removal and Installation

1. Remove the battery ground cable at the negative (−) battery terminal, *first*.

Alternator and Regulator Specifications

Alternator			*Regulator*						
				Field Relay			*Regulator*		
Engine	*Manufacturer*	*Output (amps)*	*Manufacturer*	*Contact Spring Deflection (in.)*	*Point Gap (in.)*	*Volts to Close (in.)*	*Air Gap (in.)*	*Point Gap (in.)*	*Volts*
F Series	Nippondenso	38	Nippondenso	—	—	4.5–5.8	—	0.012–0.018	13.6–14.8



An exploded view of the starter used on the F Series engine from 1966 to 1968

A. Commutator end frame
B. Pole core
C. Field coil
D. Yoke
E. Switch connecting lead
F. Drive lever set pin
G. Pinion drive lever
H. Starter clutch
I. Magnet switch
J. Starter drive housing
K. Drive housing bushing
L. Bearing cover
M. Through-bolt
N. Commutator end frame bushing
O. Lead wire
P. Brush connecting lead
Q. Brush holder
R. Brush
S. Brake shoe
T. Starter cover
U. Armature
V. Center bearing

2. Next, remove the "hot" cable at the starter.

3. Loosen the hold-down clamps and remove the battery.

CAUTION: *Use care in handling the battery; it is filled with a highly corrosive acid.*

Installation is the *exact* reverse of removal.

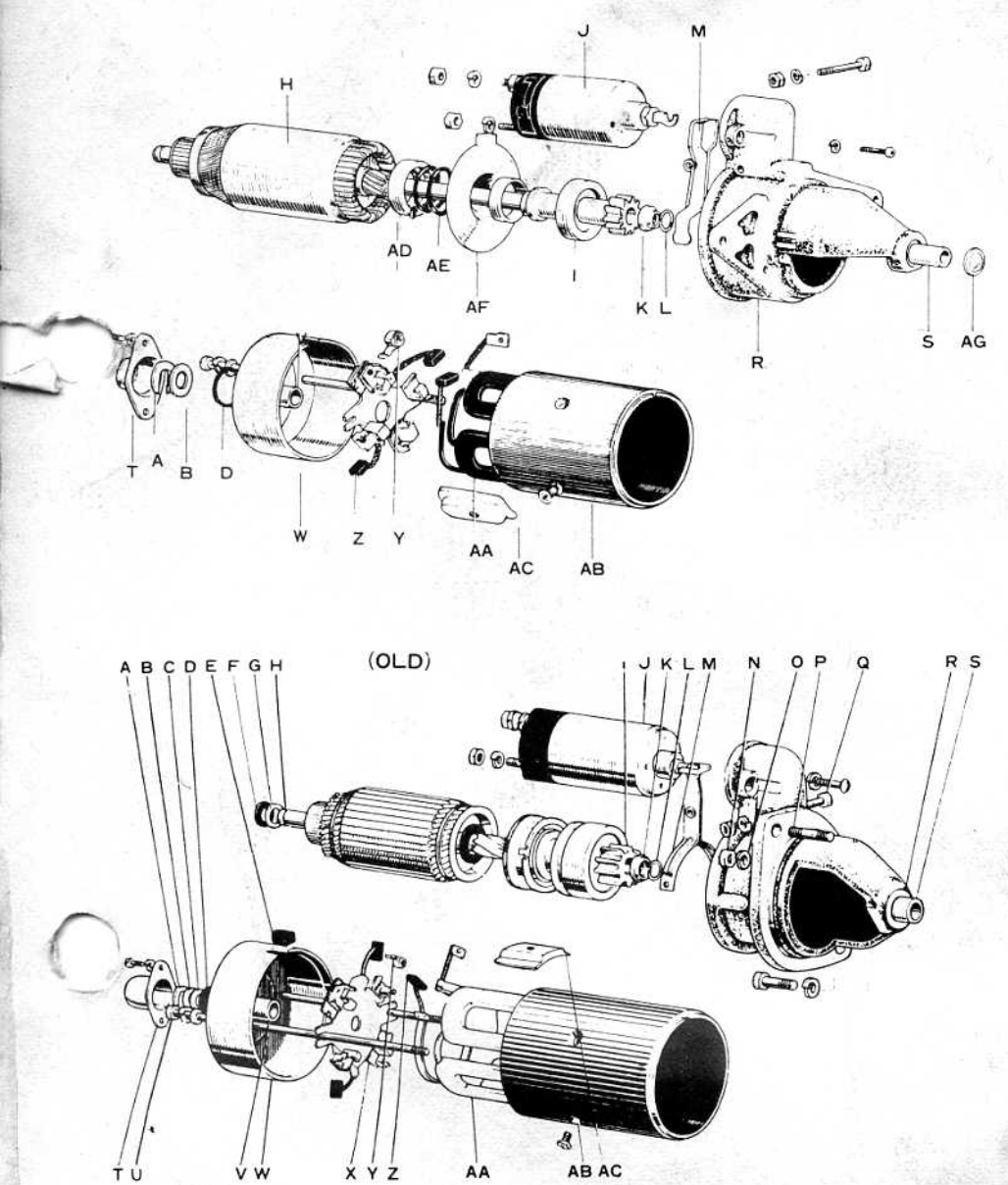
Engine Mechanical

DESIGN

The F Series engine is a 4 cycle, inline 6 cylinder, overhead valve type engine with force feed lubrication and is water-cooled.

Battery and Starter Specifications

	Battery			Starter							
				Lock Test			No-Load Test				
Engine	Ampere Hour Capacity	Volts	Terminal Grounded	Amps	Volts	Torque (ft lbs)	Amps	Volts	RPM	Minimum Brush Tension (oz)	Brush Minimum Length (in.)
F Series	50	12	Neg	430	7.3	11	45	11	3500	21	0.51



A. Lockplate
B. Washer
C. Washer
D. Rubber ring
E. Rubber bushing
F. Bakelite washer
G. Washer
H. Starter armature
I. Starter clutch
J. Magnetic switch
K. Pinion stop nut
L. Snap-ring
M. Pinion drive lever
N. Nut
O. Lockwasher
P. Stud bolt
Q. Drive lever set pin
R. Starter drive housing
S. Bushing
T. Bearing cover
U. Through-bolt
V. Bushing
W. Commutator end frame
X. Brush holder
Y. Brush spring
Z. Starter brush
AA. Field coil
AB. Starter yoke
AC. Pole core
AD. Spring holder
AE. Starter brake spring
AF. Center bearing
AG. Expansion plug

Exploded views of the starter used on the F Series engine from 1969 to 1971 (bottom) and after 1972 (top)

The cylinder head is cast iron with wedge-shaped combustion chambers.

The cylinder block and crankcase is cast iron with integral cooling passages.

The counterbalanced crankshaft is supported by 4 main bearings which are of steel backed aluminum alloy linings and replaceable type. The crankshaft end-play thrust is taken by the third main bearing.

The pistons are made of special light alloy and have 2 compression rings and 2 oil control rings on each piston.

The connecting rods are of "I" beam shaped forged steel. The rods are connected to the piston pin by a clamp bolt.

The distributor is mounted on the right-side of the engine and is gear-driven by the camshaft. The distributor driveshaft extends past the camshaft and drives the oil pump.

Engine Removal and Installation

1. Scribe marks on the hood and hinges to aid in alignment during installation. Remove the hinge bolts from the hood and then remove the hood.

2. Drain the cooling system and engine oil.

3. Remove the radiator grille mounting bolts and remove the grille.

NOTE: *On station wagon models, remove the parking light assembly and wiring first.*

4. Remove the hood latch support rod. Detach the hood latch assembly from

Valve Specifications

Engine Type	Seat Angle (deg)	Face Angle (deg)	Spring Test Pressure (lbs @ in.) Inner	Spring Test Pressure (lbs @ in.) Outer	Spring Installed Height (in.) Inner	Spring Installed Height (in.) Outer	Stem to Guide Clearance (in.) Intake	Stem to Guide Clearance (in.) Exhaust	Stem Diameter (in.) Intake	Stem Diameter (in.) Exhaust
F (1966–68)	45	45	③	④	①	②	0.0010–0.0022	0.0014–0.0027	0.3142	0.3137
F (1969–71)	45	45	——	132–171 @ 1.3	——	1.324	0.0010–0.0026	0.0014–0.0028	0.3141	0.3137
F (1972–74)	45	45	——	71.5–59.4 @ 1.7	——	1.693	0.0010–0.0026	0.0014–0.0028	0.3141	0.3137

① Intake 1.590 in.; Exhaust 1.598 in.
② Intake 1.709 in.; Exhaust 1.717 in.
③ Exhaust inner—7.5 lbs @ 1.598 in.; Intake inner—7.9 lbs @ 1.590 in.
④ Exhaust outer—44 lbs @ 1.717 in.; Intake outer—45 lbs @ 1.709 in.
—— Not applicable

Crankshaft and Connecting Rod Specifications

All measurements are given in inches

Engine Type	Crankshaft: Main Brg Journal Dia	Crankshaft: Main Brg Oil Clearance	Crankshaft: Shaft End-Play	Crankshaft: Thrust on No.	Connecting Rod: Journal Diameter	Connecting Rod: Oil Clearance	Connecting Rod: Side Clearance
F (1966–68)	2.6366–2.6378①	0.0008–0.0024	0.0012–0.0051	3	2.1252–2.1260	0.0008–0.0024	0.0040–0.0090
F (1969–71)	2.6366–2.6378①	0.0012–0.0018	0.0024–0.0065	3	2.1252–2.1260	0.0008–0.0024	0.0040–0.0090
F (1972–74)	2.6366–2.6378①	0.0014–0.0018	0.0024–0.0065	3	2.1252–2.1260	0.0008–0.0024	0.0040–0.0090

① Front bearing given. Second bearing—2.6957–2.6969; third bearing—2.7547–2.7559; rear bearing—2.8138–2.8150 in.

Torque Specifications

(All readings in ft lbs)

Engine Type	Cylinder Head Bolts	Rod Bearing Bolts	Main Bearing Bolts	Crankshaft Pulley Bolt	Flywheel to Crankshaft Bolts	Manifold	
						Intake	Exhaust
F (1966–68)	95①	50	101②	NA	50	37④	
F (1969–71)	83–98	35–55	90–108③	NA	43–51	14–22④	
F (1972–74)	83–98	35–55	90–108③	NA	43–51	14–22④	

① Tighten in 4 steps; 35, 55, 75 ft lbs; then to final torque given above
② Rear bearing—87 ft lbs
③ Rear bearing—76–94 ft lbs
④ Intake and exhaust manifolds combined
NA Not available

Piston and Ring Specifications

(All measurements in inches)

Engine Type	Piston Clearance 68° F	Ring Gap			Ring Side Clearance		
		Top Compression	Bottom Compression	Oil Control	Top Compression	Bottom Compression	Oil Control
F (1966–71)	0.0012–0.0020	0.006–0.018	0.006–0.016	①	0.0016–0.0031	0.0016–0.0031	②
F (1972–74)	0.0012–0.0020	0.008–0.016	0.006–0.014	0.006–0.014	0.0012–0.0028	0.0008–0.0024	0.0008–0.0026

① Oil control gap:
Top—0.006–0.018 in.
Bottom—0.006–0.016 in.
② Oil control clearance:
Top—0.0016–0.0031 in.
Bottom—0.0016–0.0033 in.

General Engine Specifications

Year	Engine Type	Engine Displacement (cc/cu in.)	Carburetor Type	Horsepower @ rpm ▲	Torque @ rpm (ft lbs)▲	Bore x Stroke (in.)	Compression Ratio
1966–68	F	3878/236.7	2-bbl	145 @ 4000	230 @ 2200	3.54 x 4.00	7.7 : 1
1969–71	F	3878/236.7	2-bbl	155 @ 4000	230 @ 2000	3.54 x 4.00	7.8 : 1
1972–74	F	3878/236.7	2-bbl	135 @ 4000	213 @ 2000	3.54 x 4.00	7.8 : 1

▲ Horsepower and torque ratings are given in SAE net figures in 1972–74

the radiator upper bracket. Remove the bracket.

5. Disconnect the heater hose from the radiator.

6. Detach the upper radiator hose at the water outlet housing and the lower hose at water pump.

7. Remove the six bolts which secure the radiator and lift the radiator out of the vehicle.

8. Disconnect the heater hoses from the water valve and heater box. Disconnect the temperature control cable from the water valve.

9. Detach both of the battery cables and remove the batttery.

10. Unfasten the wires from the starter solenoid terminal.

11. Detach the fuel lines from the pump and remove the fuel filter assembly.

12. Disconnect the primary wire from the ignition coil.

13. Detach both of the intermediate rods from the shifter shafts (column-shift models only).

14. Remove the air cleaner assembly complete with hoses, from its bracket.

15. Remove the emission control system cables and hoses as necessary.

16. Disconnect the alternator multi-connector.

17. Disconnect the hand throttle, accelerator, and choke linkages from the carburetor.

18. On Land Cruiser models with vacuum assisted 4wd engagement, remove the control unit vacuum hose from its manifold fitting.

19. Disconnect the oil pressure and water temperature gauge sender's wiring.

20. Disconnect the downpipe from the exhaust manifold.

21. Detach the parking brake cable from the intermediate lever.

22. Disconnect the front driveshaft from the flange on the transfer case output shaft.

23. Remove both the left and right engine stone shields. Remove the transmission skid-plate.

24. Remove the cotter pin and disconnect both the high and low-range shifter rods from their respective inner levers.

25. Remove the high/low range shifter link lever and the high/low shift rod.

26. Disconnect the clutch release fork spring. Remove the clutch release cylinder from its mounting bracket at the rear of the engine.

27. Remove the clamp screws and withdraw the vacuum lines from the transfer case control unit vacuum chamber (only on models with vacuum-assisted 4wd engagement).

28. Remove the 4wd indicator switch assembly.

29. Disconnect the speedometer cable from the transmission.

30. Disconnect the rear driveshaft from the transmission.

31. Detach the gearshift rod and gear selector rod from the shift outer lever and the gear selector outer lever, respectively.

32. Remove the nuts which secure the rear engine mounts to the frame.

33. Perform Step 32 to the front engine mounts.

34. Install lifting hooks on the engine lift-points. Connect a suitable (large) hoist to the hooks.

35. Lift the engine slightly and toward the front, so the engine/transmission assembly clears the front of the vehicle. Engine installation is performed in the reverse order of its removal. Refill

the engine with coolant and lubricant. Check and adjust all linkages. Install the hood and align it.

CYLINDER HEAD

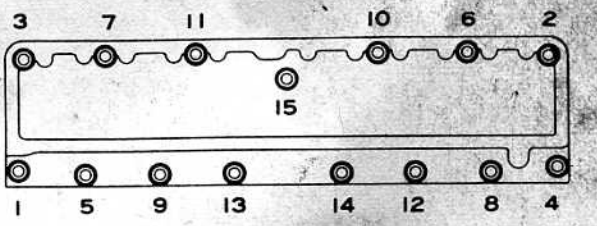
Removal and Installation

1. Disconnect the battery and drain the cooling system.
2. Remove the air cleaner assembly from its bracket, complete with its attendant hoses.
3. Detach the accelerator cable from its support on the cylinder head cover and also from the carburetor throttle arm.
4. Remove the choke cable and the fuel lines from the carburetor.
5. Remove the water hose bracket from the cylinder head cover.
6. Loosen the water hose clamps and remove the hoses from the water pump and the water valve. Remove the heater temperature control cable from the water valve.
7. Disconnect the PCV line from the cylinder head cover.
8. Disconnect the vacuum lines, which run from the vacuum switching valve, at the various components of the emission control system.
9. Drain the engine oil. Unfasten the oil lines from the oil filter and remove the filter assembly from the manifold.
10. Detach the vacuum valve solenoid wire from the coil.
11. Disconnect any remaining lines from the carburetor and remove the carburetor from the manifold.
12. Unfasten the alternator adjusting link and then remove the drivebelt and the alternator.
13. Disconnect the distributor vacuum line from the distributor. Remove the wire from its supports on the head.
14. Disconnect the carburetor fuel line from the fuel pump. Remove the line.
15. Disconnect the spark plug and coil cables, after marking their respective locations.
16. Unfasten the primary wire from the distributor. Remove the distributor clamp bolts and withdraw the distributor.
17. Remove the oil gauge sender.
18. Remove the coil from its bracket on the cylinder head.
19. Unfasten the fuel pump securing bolts and remove the pump.
20. Remove the oil filler tube clamping bolt from the valve lifter (side) cover. Drive the oil filler tube out of the cylinder block.
21. Remove the combination intake exhaust manifold from the clyinder block.
22. Take off the cylinder head cover and its gasket.
23. Unfasten the oil delivery union, spring, and sleeve from the valve rocker shafts.
24. Unfasten the securing nuts and bolts from the valve rocker shaft supports. Withdraw the rocker assembly.
25. Withdraw the pushrods from their bores. Be sure to keep them in the same order in which they were removed.
26. Remove the valve lifter (side) cover and gasket.
27. Withdraw the valve lifters from the block.

NOTE: *The valve lifters should be kept, with their respective pushrods, in the sequence in which they were removed.*

28. Unfasten the oil delivery union from the oil feed pipe.
29. Loosen the cylinder head bolts in two or three stages and in the order illustrated.

CAUTION: *Do not remove the cylinder head bolts one at a time.*



Cylinder head bolt removal sequence

30. Lift off the cylinder head and the gasket.

CAUTION: *Do not attempt to slide the cylinder head off; it is located with dowels.*

Installation of the cylinder head is performed in the following order:

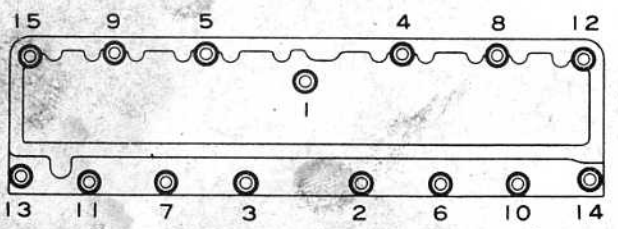
1. Clean the gasket mounting surfaces of both the cylinder head and block.

2. Place a *new* head gasket over the dowels on the block.

3. Lower the cylinder head on to the block with the air cleaner mounting bracket attached.

CAUTION: *Do not attempt to slide the cylinder head across the block—because of the locating dowels.*

4. Tighten the bolts, in stages, and in the sequence illustrated, to the torque given in the "Torque Specifications" chart.



Cylinder head bolt tightening sequence

5. Install the oil feed pipe.

6. Place each valve lifter in the original position from which it came.

CAUTION: *Do not interchange valve lifters.*

7. Perform Step 6 for the pushrods, being careful to mate each pushrod with its original lifter.

8. Install the valve rocker assembly, oil delivery union, spring, and connecting sleeve in the head. Tighten the rocker assembly support nuts and bolts to the following torque specifications, in several stages:

10 mm nuts and bolts—25–30 ft lbs
8 mm bolts—14–22 ft lbs

9. Adjust the valves as outlined in Chapter 2, to the following *cold* specifications (each piston TDC of its compression stroke):

Intake—0.0079 in.
Exhaust—0.0138 in.

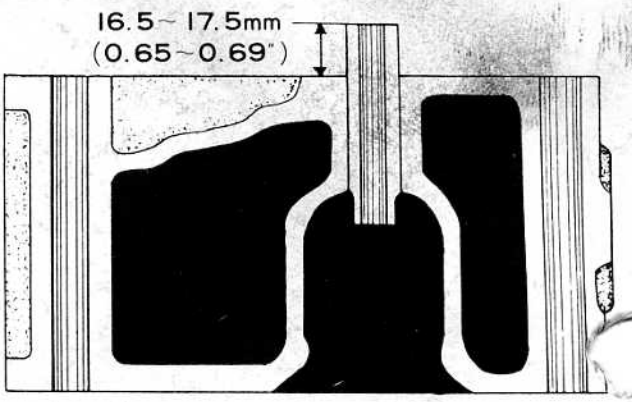
NOTE: *Adjust the valve clearance again after the engine is assembled and warmed up.*

10. The rest of cylinder head installation is performed in the reverse order of the removal procedure.

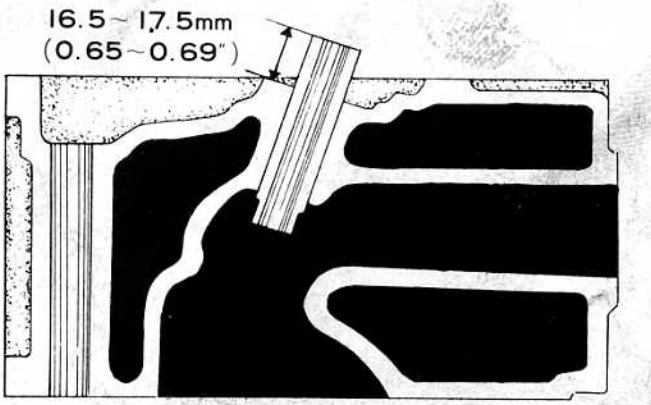
Valve Guide Replacement

1. Drive the valve guide out of the cylinder head through the top of the cylinder head with a suitable driver.

2. Install the new valve guide from the top of the cylinder head with a suitable driver. The valve guide should be installed so that it protrudes 0.65–0.69 in. above the top of the cylinder head.



Intake valve guide installation



Exhaust valve guide installation

3. Measure the valve stem-to-valve guide clearance and ream the inside of the valve guides with a valve guide reamer to obtain the proper clearance as necessary.

ROCKER SHAFTS

Removal and Installation

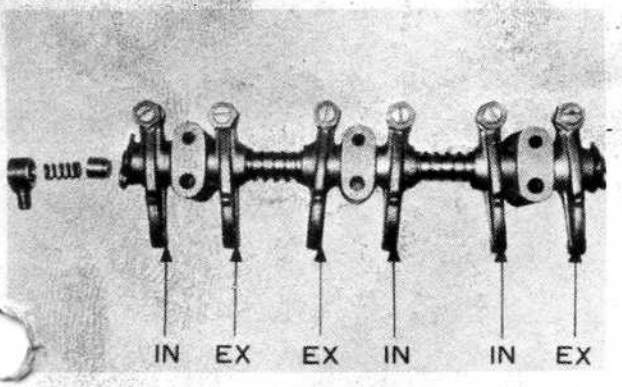
1. Remove the air cleaner assembly together with all of the attending hoses.

2. Remove the cylinder head cover retaining screws and remove the cover and gasket.

3. Disconnect the rocker shaft oil delivery union, spring and the oil connection sleeve from the rocker shafts.

4. Remove the rocker shaft support retaining nuts and bolts, and remove the shaft assemblies.

5. Install the rocker shafts in the reverse order of removal. If the rocker shaft assemblies are disassembled for cleaning and inspection, assemble all of the components in the exact positions from which they were removed. Clean all of the gas-



Identification and assembly of the rocker shaft

ket material from the cylinder head and the rocker cover and install a new gasket.

INTAKE AND EXHAUST MANIFOLD

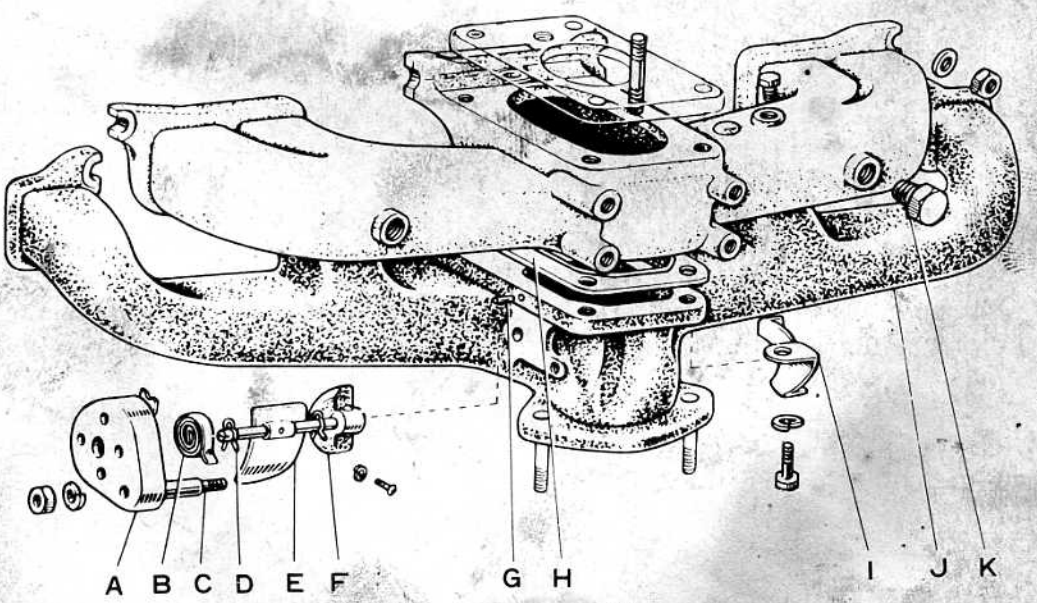
Removal and Installation

1. Remove the air cleaner assembly complete with hoses.
2. Disconnect the hand throttle, accelerator and choke linkages from the carburetor, as well as the fuel and vacuum lines.
3. Remove or move aside any of the emission control system components which are in the way.
4. Disconnect the oil filter lines and remove the oil filter assembly from the intake manifold. Disconnect the solenoid valve wire from the ignition coil terminal.
5. Unscrew the retaining bolts and remove the carburetor from the manifold.
6. Loosen the manifold retaining nuts, working from the inside out, in two stages.
7. Remove the intake/exhaust manifold assembly from the cylinder head as a unit.
8. Install in the reverse order of removal. Always use new gaskets. Tighten the bolts, working from the inside out to the specifications given in the "Torque Specifications" chart. Tighten the attaching nuts in two stages.

TIMING GEAR COVER

Removal and Installation

1. Drain the cooling system and the crankcase.
2. Disconnect the battery.
3. Remove the air cleaner assembly, complete with hoses.
4. Remove the hood latch as well as its brace and support.
5. Remove the headlight bezels and the grille assembly.
6. Loosen the upper and lower radia-



Intake and exhaust manifold assembly

A. Heat control bimetal case
B. Heat control valve coil
C. Case bolt
D. Retainer spring
E. Heat control valve
F. Heat control shaft
G. Dowel pin
H. Manifold gasket
I. Counter weight stopper
J. Exhaust manifold
K. Taper screw plug

tor hose clamps and remove both of the hoses from the engine.

7. Remove the radiator retaining bolts and remove the radiator.

8. Remove the alternator and drive belt.

9. Remove the air pump and drive belt.

10. Remove the fan and water pump.

11. Remove the gravel shield from under the engine.

12. Remove the front driveshaft.

13. Remove the front oil pan bolts, to gain access to the bottom of the timing chain cover. It may be necessary to insert a knife blade between the pan and the gasket in order to break the pan loose. *Use care not to damage the gasket.*

14. Remove the crankshaft pulley with a gear puller.

15. Remove the gear cover retaining screws and remove the cover from the engine.

16. Clean all of the gasket mating surfaces and install the timing gear cover in the reverse order of removal.

Timing Chain Cover Oil Seal Replacement

1. Remove the timing chain cover, as detailed above.

2. Inspect the oil seal for signs of wear, leakage, or damage.

3. If worn, pry the old seal out, using a large flat-bladed screwdriver. Remove it toward the *front* of the cover.

NOTE: *Once the oil seal has been removed, it must be replaced with a new one.*

4. Use a socket, pipe, or block of wood and a hammer to drift the oil seal into place. Work from the *front* of the cover.

CAUTION: *Be extremely careful not to damage the seal or else it will leak.*

5. Install the timing chain cover as outlined above.

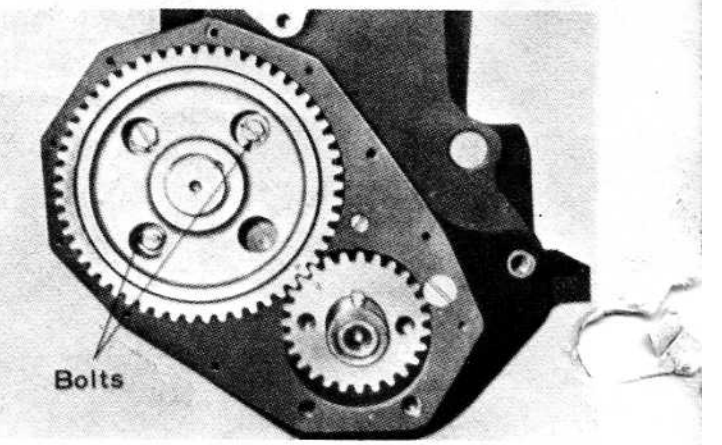
TIMING GEARS AND CAMSHAFT

Removal and Installation

1. Remove the cylinder head, valve lifter and timing gear cover.

2. Slip the oil slinger off the crankshaft.

3. Remove the camshaft thrust plate retaining bolts by working through the holes provided in the camshaft timing gear.



Remove the camshaft thrust plate bolts through the access holes

4. Withdraw the camshaft through the front of the cylinder block. Support the camshaft while removing it, so as not to damage its bearings or lobes.

NOTE: *The timing gear is a press-fit and cannot be removed without removing the camshaft.*

5. Inspect the crankshaft timing gear. Replace it if it has worn or damaged teeth.

6. To remove it, remove the slidin key from the crankshaft. Withdraw the timing gear with a gear puller.

Installation is performed in the following order:

1. Use a large piece of pipe to press the timing gear onto the crankshaft. Lightly and evenly tap the end of the pipe until the gear is in its original position.

2. Apply a coat of engine oil to the camshaft journals and bearings.

3. Insert the camshaft into the block.

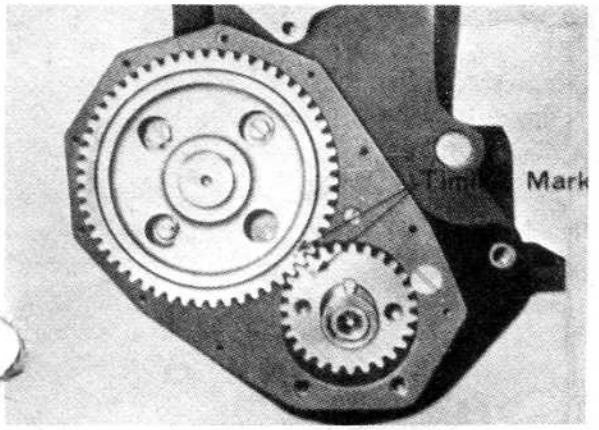
CAUTION: *Use care not to damage the camshaft lobes, bearings, or journals.*

4. Align the mating marks on each of the gears.

5. Slip the camshaft into positio Tighten the camshaft thrust plate bo to 14.5 ft lbs.

6. Check the gear backlash with a feeler gauge, inserted between the crankshaft and the camshaft timing gears. The backlash should be no more than 0.002–0.005 in.; if it exceeds this, replace one or both of the gears, as required.

7. Check the gear run-out with a dial



Alignment of the timing marks on the crankshaft and camshaft gears

indicator. Run-out, for both gears, should not exceed 0.008 in.; if it does, replace the gear.

8. Install the oil nozzle, if it was removed, by screwing it in place with a screwdriver and punching it in two places, to secure it.

NOTE: *Be sure that the oil hole in the nozzle is pointed toward the timing gear before securing it.*

9. Install the oil slinger on the crankshaft.

10. Install the timing gear cover, valve lifters and cylinder head.

PISTONS AND CONNECTING RODS

Removal and Installation

1. Remove the cylinder head as outlined in the appropriate section above.
2. Remove the oil pan and pump; see "Engine Lubrication," below.
3. Ream the ridges from the top of the cylinder bores, as detailed in "Engine Rebuilding," at the end of this chapter.
4. Unbolt the connecting rod caps. Mark the caps with the number of the cylinder from which they were removed.
5. Remove the connecting rod and piston through the top of the cylinder bore.

CAUTION: *Use care not to scratch the journals or the cylinder walls.*

6. Mark the pistons and connecting rods with the numbers of the cylinders from which they were removed.

Installation is performed in the following order:

1. Apply a light coating of engine oil to the pistons, rings, and wrist pins.
2. Examine the piston to see that it has been assembled with its parts positioned correctly. (See illustrations.) Be sure that the ring gaps are not pointed toward the thrust face of the piston and that they do not overlap.
3. Install the pistons, using a ring compressor, into the cylinder bore. Be sure that the "Front" mark on the piston faces the front of the engine and the oil hole on the connecting rod faces the camshaft.

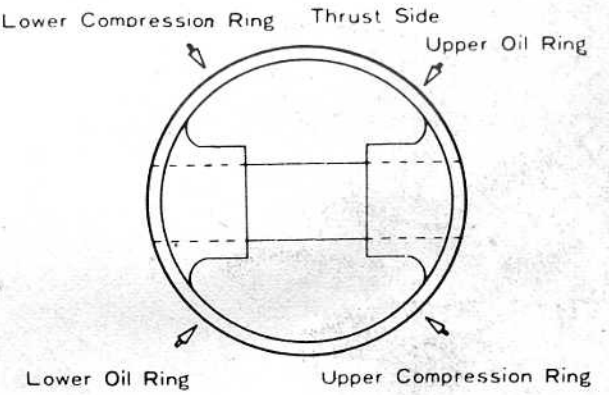
CAUTION: *It is important that the pistons, rods, bearings, etc., be returned to the same cylinder bore from which they were removed.*

4. Install the connecting rod bearing caps and tighten them to the torque figures given in the torque specifications chart.

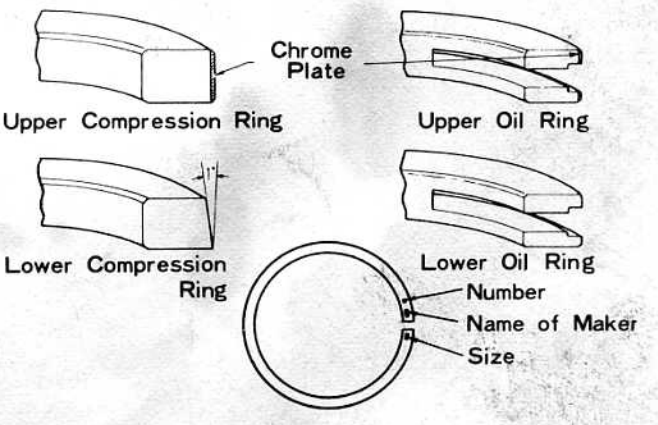
CAUTION: *Be sure that the mating marks on the connecting rods and rod bearing caps are aligned.*

5. The rest of the removal procedure is performed in the reverse order of installation.

Piston Ring Positioning

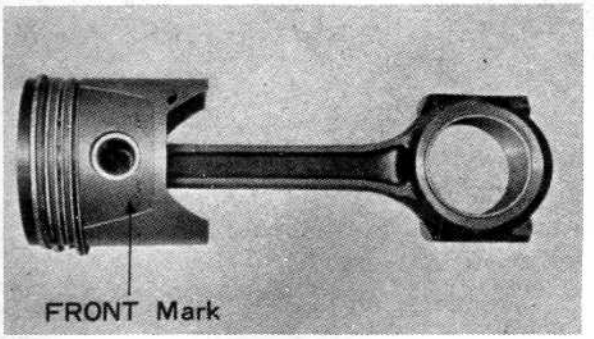


Piston ring gap placement on the piston

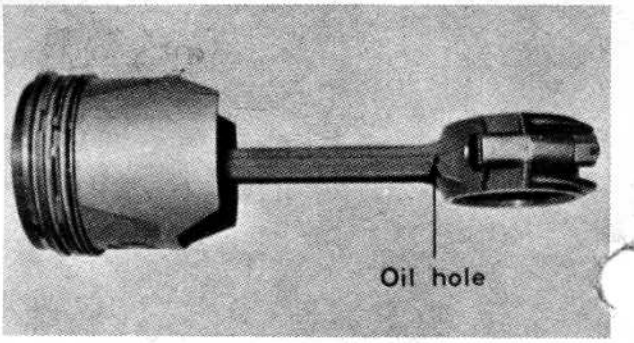


Piston ring identification

Piston and Connecting Rod Positioning



Install the piston so that the "Front" mark faces toward the front of the engine



Install the connecting rod so that the oil hole faces the camshaft

Engine Lubrication

OIL PAN

Removal and Installation

1. Remove the engine skid plates.
2. Remove the flywheel side cover and skid plate.
3. Remove the front driveshaft.
4. Drain the engine lubricant.
5. Remove the bolts which secure the oil pan; withdraw the pan and its gasket.
6. Install in the reverse order of removal. Always use a new pan gasket.

REAR MAIN OIL SEAL

Replacement

1. Remove the transmission.
2. Remove the clutch cover assembly and flywheel.
3. Remove the oil seal retaining plate, complete with the oil seal.
4. Use a screwdriver to pry the old seal from the retaining plate. Be careful not to damage the plate.
5. Install the new seal, carefully, by using a block of wood to drift it into place.

CAUTION: *Do not damage the seal; a leak will result.*

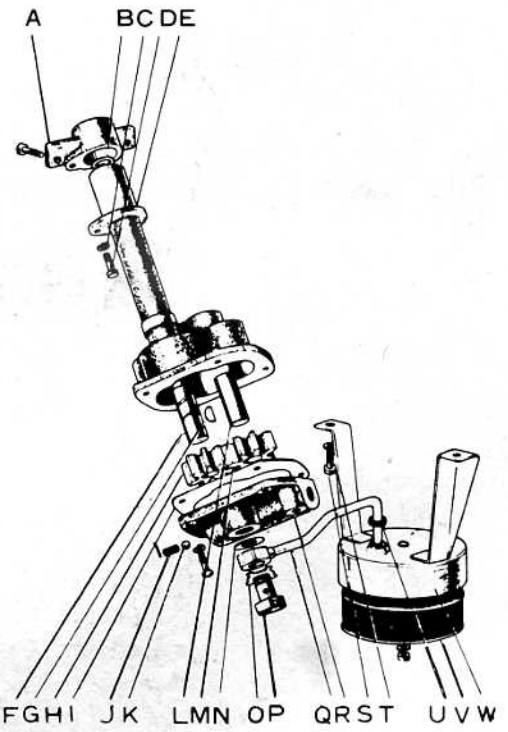
6. Lubricate the lips of the seal with multipurpose grease.

Installation is performed in the reverse order from removal.

OIL PUMP

Removal and Installation

1. Remove the oil pan.
2. Remove the oil strainer and remove the retaining nuts on the oil pump pipe.
3. Remove the lock wire and the oil pump retaining bolt. Remove the oil pump and pipe from the cylinder block.
4. Install in the reverse order of removal, using a new oil pan gasket.



Exploded view of the oil pump assembly

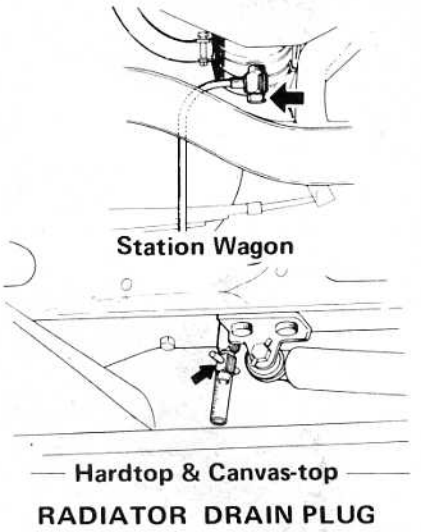
A. Oil pump supporter
B. Body thrust ring
C. Lockwasher
D. Bolt
E. Oil pump body
F. Oil pump shaft
G. Oil pump shaft key
H. Oil pump drive gear
I. Oil pump cover gasket
J. Valve spring
K. Valve ball
L. Oil pump driven shaft
M. Oil pump driven gear
N. Gasket
O. Union bolt washer
P. Suction pipe union bolt
Q. Oil pump inlet pipe
R. Oil pump cover
S. Bolt
T. Lockwasher
U. Rubber washer
V. Oil strainer
W. Oil strainer shell

Engine Cooling

RADIATOR

Removal and Installation

1. Drain the cooling system.
2. Loosen the hose clamps and remove the upper and lower hoses from the radiator.
3. Remove the bolts retaining the radiator to the radiator support.
4. Remove the radiator upward, taking care not to damage the fins with the fan.
5. Install in the reverse order of removal.



Cooling system drain points

WATER PUMP

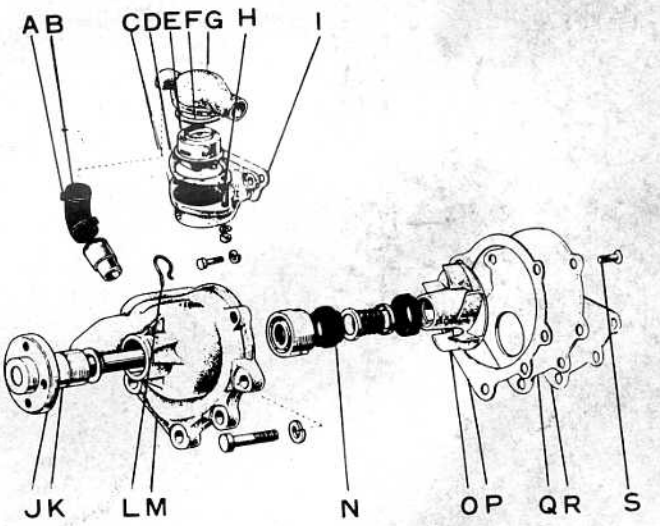
Removal and Installation

1. Drain the cooling system and remove the alternator adjusting bar.
2. Remove the fan, fan pulley, and the fan belt.
3. Loosen the hose clamps and disconnect the radiator lower hose and the by-pass hose from the water pump.
4. Remove the water pump retaining bolts and remove the pump assembly and gasket.
5. Install in the reverse order of removal.

THERMOSTAT

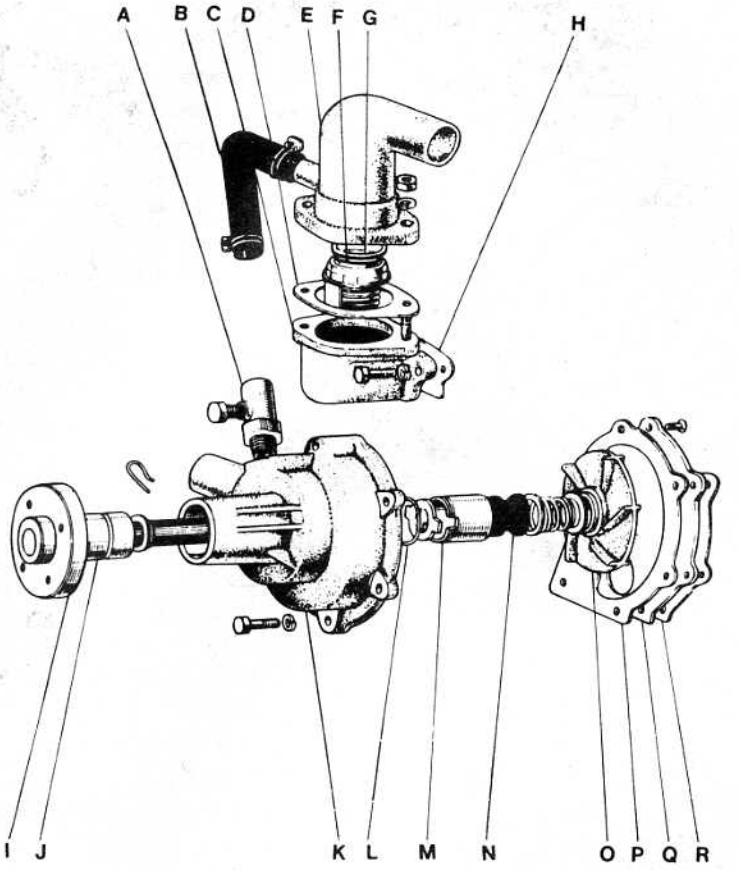
Removal and Installation

1. Drain the cooling system.
2. Loosen the clamp and remove the upper radiator hose from the water outlet elbow.
3. Unbolt and remove the water outlet (thermostat housing).
4. Remove the thermostat.
5. Install in the reverse order of removal, using a new gasket. The thermostat is installed with the spring pointing toward the inside of the engine.



Exploded view of the water pump assembly used on 1969 and later models

A. Hose clamp
B. By-pass hose
C. Water outlet
D. Gasket
E. Thermostat
F. Gasket
G. Water outlet housing
H. Stud bolt
I. Gasket
J. Pulley seat
K. Water pump bearing
L. Bearing retaining wire
M. Water pump body
N. Shaft seal
O. Water pump rotor
P. Gasket
Q. Seat plate
R. Gasket
S. Screw



Exploded view of the water pump assembly used on 1966–68 models

A. Union
B. Radiator hose
C. Water outlet
D. Gasket
E. Water outlet housing
F. Bellows
G. Gasket
H. Gasket
I. Water pump pulley seat
J. Water pump bearing
K. Water pump
L. Snap-ring
M. Guide pipe
N. Shaft seal
O. Rotor
P. Gasket
Q. Seat plate
R. Gasket

Engine Rebuilding

This section describes, in detail, the procedures involved in rebuilding a typical engine. The procedures specifically refer to an inline engine, however, they are basically identical to those used in rebuilding engines of nearly all design and configurations. Procedures for servicing atypical engines (i.e., horizontally opposed) are described in the appropriate section, although in most cases, cylinder head reconditioning procedures described in this chapter will apply.

The section is divided into two sections. The first, Cylinder Head Reconditioning, assumes that the cylinder head is removed from the engine, all manifolds are removed, and the cylinder head is on a workbench. The camshaft should be removed from overhead cam cylinder heads. The second section, Cylinder Block Reconditioning, covers the block, pistons, connecting rods and crankshaft. It is assumed that the engine is mounted on a work stand, and the cylinder head and all accessories are removed.

Procedures are identified as follows:

Unmarked—Basic procedures that must be performed in order to successfully complete the rebuilding process.

Starred (*)—Procedures that should be performed to ensure maximum performance and engine life.

Double starred (**)—Procedures that may be performed to increase engine performance and reliability. These procedures are usually reserved for extremely heavy-duty or competition usage.

In many cases, a choice of methods is also provided. Methods are identified in the same manner as procedures. The choice of method for a procedure is at the discretion of the user.

The tools required for the basic rebuilding procedure should, with minor exceptions, be those

TORQUE (ft. lbs.)*

U.S.

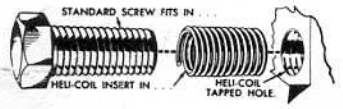
Bolt Diameter (inches)	*Bolt Grade (SAE)* 1 and 2	5	6	8	*Wrench Size (inches)* Bolt	Nut
1/4	5	7	10	10.5	3/8	7/16
5/16	9	14	19	22	1/2	9/16
3/8	15	25	34	37	9/16	5/8
7/16	24	40	55	60	5/8	3/4
1/2	37	60	85	92	3/4	13/16
9/16	53	88	120	132	7/8	7/8
5/8	74	120	167	180	15/16	1
3/4	120	200	280	296	1-1/8	1-1/8
7/8	190	302	440	473	1-5/16	1-5/16
1	282	466	660	714	1-1/2	1-1/2

Metric

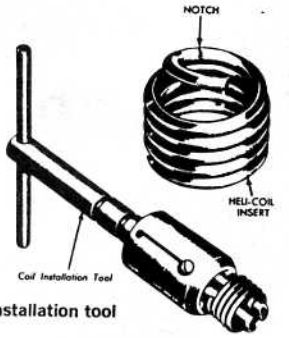
Bolt Diameter (mm)	*Bolt Grade* 5D	8G	10K	12K	*Wrench Size (mm) Bolt and Nut*
6	5	6	8	10	10
8	10	16	22	27	14
10	19	31	40	49	17
12	34	54	70	86	19
14	55	89	117	137	22
16	83	132	175	208	24
18	111	182	236	283	27
22	182	284	394	464	32
24	261	419	570	689	36

*—Torque values are for lightly oiled bolts. CAUTION: Bolts threaded into aluminum require much less torque.

General Torque Specifications



Heli-Coil installation
(© Chrysler Corp.)



Heli-Coil and installation tool

Heli-Coil Insert			Drill	Tap	Insert. Tool	Extracting Tool
Thread Size	Part No.	Insert Length (In.)	Size	Part No.	Part No.	Part No.
1/2 -20	1185-4	3/8	17/64(.266)	4 CPB	528-4N	1227-6
5/16-18	1185-5	15/32	Q(.332)	5 CPB	528-5N	1227-6
3/8 -16	1185-6	9/16	X(.397)	6 CPB	528-6N	1227-6
7/16-14	1185-7	21/32	29/64(.453)	7 CPB	528-7N	1227-16
1/2 -13	1185-8	3/4	33/64(.516)	8 CPB	528-8N	1227-16

Heli-Coil Specifications

included in a mechanic's tool kit. An accurate torque wrench, and a dial indicator (reading in thousandths) mounted on a universal base should be available. Bolts and nuts with no torque specification should be tightened according to size (see chart). Special tools, where required, all are readily available from the major tool suppliers (i.e., Craftsman, Snap-On, K-D). The services of a competent automotive machine shop must also be readily available.

When assembling the engine, any parts that will be in frictional contact must be pre-lubricated, to provide protection on initial start-up. Vortex Pre-Lube, STP, or any product specifically formulated for this purpose may be used. NOTE: *Do not use engine oil.* Where semi-permanent (locked but removable) installation of bolts or nuts is desired, threads should be cleaned and coated with Loctite. Studs may be permanently installed using Loctite Stud and Bearing Mount.

Aluminum has become increasingly popular for use in engines, due to its low weight and excellent heat transfer characteristics. The following precautions must be observed when handling aluminum engine parts:

—Never hot-tank aluminum parts.

—Remove all aluminum parts (identification tags, etc.) from engine parts before hot-tanking (otherwise they will be removed during the process).

—Always coat threads lightly with engine oil or anti-seize compounds before installation, to prevent seizure.

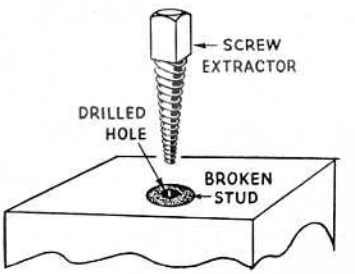
—Never over-torque bolts or spark plugs in aluminum threads. Should stripping occur, threads can be restored according to the following procedure, using Heli-Coil thread inserts:

Tap drill the hole with the stripped threads to the specified size (see chart). Using the specified tap (NOTE: *Heli-Coil tap sizes refer to the size thread being replaced, rather than the actual tap size*), tap the hole for the Heli-Coil. Place the insert on the proper installation tool (see chart). Apply pressure on the insert while winding it clockwise into the hole, until the top of the insert is one turn below the surface. Remove the installation tool, and break the installation tang from the bottom of the insert by moving it up and down. If the Heli-Coil must be removed, tap the removal tool firmly into the hole, so that it engages the top thread, and turn the tool counter-clockwise to extract the insert.

Snapped bolts or studs may be removed, using a stud extractor (unthreaded) or Vise-Grip pliers (threaded). Penetrating oil (e.g. Liquid Wrench) will often aid in breaking frozen threads. In cases where the stud or bolt is flush with, or below the surface, proceed as follows:

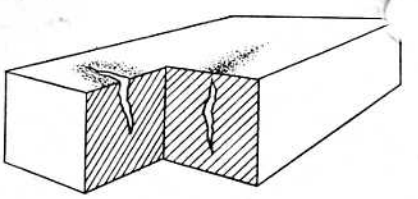
Drill a hole in the broken stud or bolt, approximately ½ its diameter. Select a screw extractor (e.g., Easy-Out) of the proper size, and tap it into the stud or bolt. Turn the extractor counterclockwise to remove the stud or bolt.

Magnaflux and Zyglo are inspection techniques used to locate material flaws, such as stress cracks. Magnafluxing coats the part with fine magnetic particles, and subjects the part to a magnetic field. Cracks cause breaks



Screw extractor

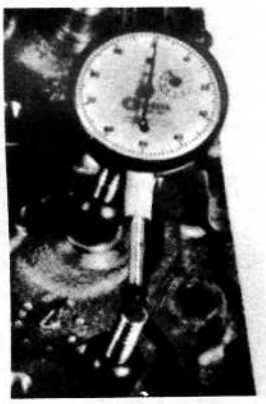
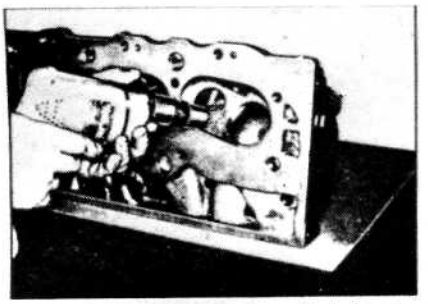
in the magnetic field, which are outlined by the particles. Since Magnaflux is a magnetic process, it is applicable only to ferrous materials. The Zyglo process coats the material with a fluorescent dye penetrant, and then subjects it to blacklight inspection, under which cracks glow bright-

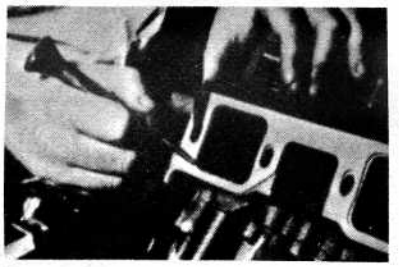
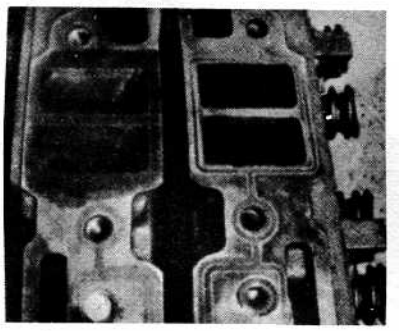


Magnaflux indication of cracks

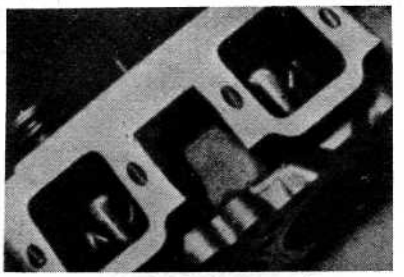
ly. Parts made of any material may be tested using Zyglo. While Magnaflux and Zyglo are excellent for general inspection, and locating hidden defects, specific checks of suspected cracks may be made at lower cost and more readily using spot check dye. The dye is sprayed onto the suspected area, wiped off, and the area is then sprayed with a developer. Cracks then will show up brightly. Spot check dyes will only indicate surface cracks; therefore, structural cracks below the surface may escape detection. When questionable, the part should be tested using Magnaflux or Zyglo.

CYLINDER HEAD RECONDITIONING

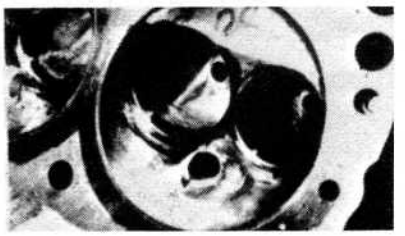
Procedure	*Method*
Identify the valves:  Valve identification (© SAAB)	Invert the cylinder head, and number the valve faces front to rear, using a permanent felt-tip marker.
Remove the rocker arms:	Remove the rocker arms with shaft(s) or balls and nuts. Wire the sets of rockers, balls and nuts together, and identify according to the corresponding valve.
Remove the valves and springs:	Using an appropriate valve spring compressor (depending on the configuration of the cylinder head), compress the valve springs. Lift out the keepers with needlenose pliers, release the compressor, and remove the valve, spring, and spring retainer.
Check the valve stem-to-guide clearance:  Checking the valve stem-to-guide clearance (© American Motors Corp.)	Clean the valve stem with lacquer thinner or a similar solvent to remove all gum and varnish. Clean the valve guides using solvent and an expanding wire-type valve guide cleaner. Mount a dial indicator so that the stem is at 90° to the valve stem, as close to the valve guide as possible. Move the valve off its seat, and measure the valve guide-to-stem clearance by moving the stem back and forth to actuate the dial indicator. Measure the valve stems using a micrometer, and compare to specifications, to determine whether stem or guide wear is responsible for excessive clearance.
De-carbon the cylinder head and valves:  Removing carbon from the cylinder head (© Chevrolet Div. G.M. Corp.)	Chip carbon away from the valve heads, combustion chambers, and ports, using a chisel made of hardwood. Remove the remaining deposits with a stiff wire brush. NOTE: *Ensure that the deposits are actually removed, rather than burnished.*

Procedure	*Method*
Hot-tank the cylinder head:	Have the cylinder head hot-tanked to remove grease, corrosion, and scale from the water passages. NOTE: *In the case of overhead cam cylinder heads, consult the operator to determine whether the camshaft bearings will be damaged by the caustic solution.*
Degrease the remaining cylinder head parts:	Using solvent (i.e., Gunk), clean the rockers, rocker shaft(s) (where applicable), rocker balls and nuts, springs, spring retainers, and keepers. Do not remove the protective coating from the springs.
Check the cylinder head for warpage:  **Checking the cylinder head for warpage** (© Ford Motor Co.)	Place a straight-edge across the gasket surface of the cylinder head. Using feeler gauges, determine the clearance at the center of the straight-edge. Measure across both diagonals, along the longitudinal centerline, and across the cylinder head at several points. If warpage exceeds .003″ in a 6″ span, or .006″ over the total length, the cylinder head must be resurfaced. NOTE: *If warpage exceeds the manufacturers maximum tolerance for material removal, the cylinder head must be replaced.* When milling the cylinder heads of V-type engines, the intake manifold mounting position is altered, and must be corrected by milling the manifold flange a proportionate amount.
** Porting and gasket matching:  **Marking the cylinder head for gasket matching** (© Petersen Publishing Co.)  **Port configuration before and after gasket matching** (© Petersen Publishing Co.)	** Coat the manifold flanges of the cylinder head with Prussian blue dye. Glue intake and exhaust gaskets to the cylinder head in their installed position using rubber cement and scribe the outline of the ports on the manifold flanges. Remove the gaskets. Using a small cutter in a hand-held power tool (i.e., Dremel Moto-Tool), gradually taper the walls of the port out to the scribed outline of the gasket. Further enlargement of the ports should include the removal of sharp edges and radiusing of sharp corners. Do not alter the valve guides. NOTE: *The most efficient port configuration is determined only by extensive testing. Therefore, it is best to consult someone experienced with the head in question to determine the optimum alterations.*

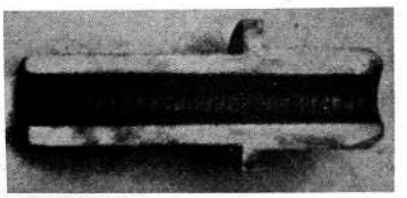
Procedure	*Method*
** Polish the ports:	** Using a grinding stone with the above mentioned tool, polish the walls of the intake and exhaust ports, and combustion chamber. Use progressively finer stones until all surface imperfections are removed. NOTE: *Through testing, it has been determined that a smooth surface is more effective than a mirror polished surface in intake ports, and vice-versa in exhaust ports.*
* Knurling the valve guides:	* Valve guides which are not excessively worn or distorted may, in some cases, be knurled rather than replaced. Knurling is a process in which metal is displaced and raised, thereby reducing clearance. Knurling also provides excellent oil control. The possibility of knurling rather than replacing valve guides should be discussed with a machinist.
Replacing the valve guides: NOTE: *Valve guides should only be replaced if damaged or if an oversize valve stem is not available.*	Depending on the type of cylinder head, valve guides may be pressed, hammered, or shrunk in. In cases where the guides are shrunk into the head, replacement should be left to an equipped machine shop. In other cases, the guides are replaced as follows: Press or tap the valve guides out of the head using a stepped drift (see illustration). Determine the height above the boss that the guide must extend, and obtain a stack of washers, their I.D. similar to the guide's O.D., of that height. Place the stack of washers on the guide, and insert the guide into the boss. NOTE: *Valve guides are often tapered or beveled for installation.* Using the stepped installation tool (see illustration), press or tap the guides into position. Ream the guides according to the size of the valve stem.



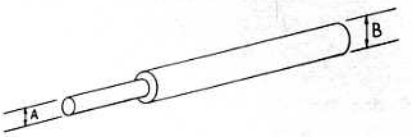
Relieved and polished ports
(© Petersen Publishing Co.)



Polished combustion chamber
(© Petersen Publishing Co.)

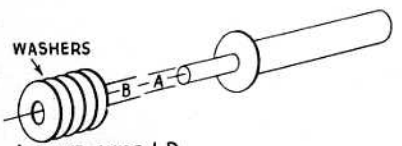


Cut-away view of a knurled valve guide
(© Petersen Publishing Co.)



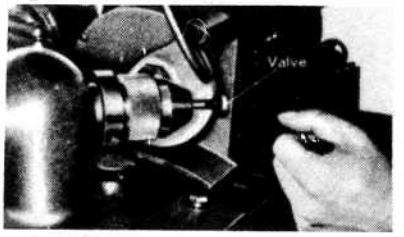
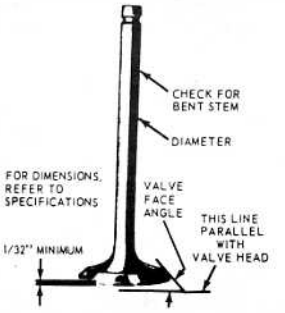
A-VALVE GUIDE I.D.
B-SLIGHTLY SMALLER THAN VALVE GUIDE O.D.

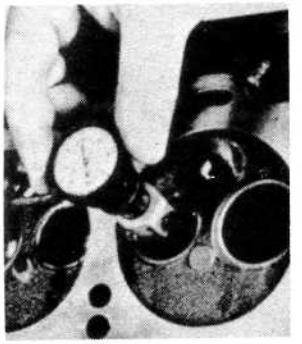
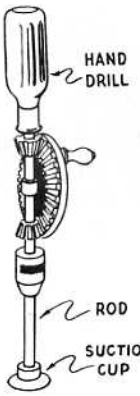
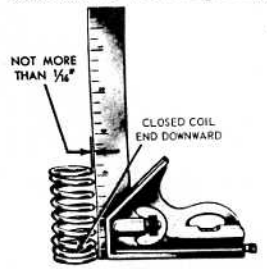
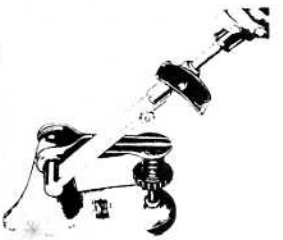
Valve guide removal tool

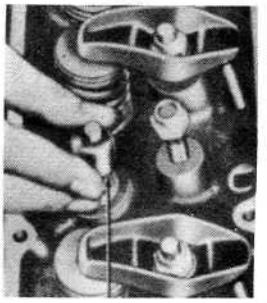
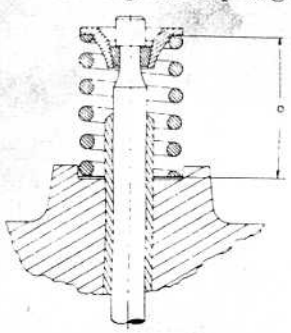
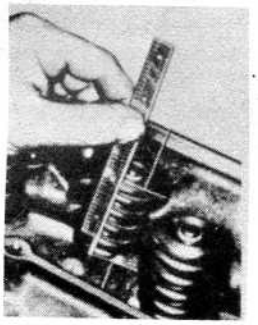


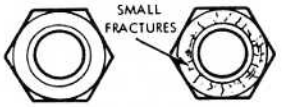
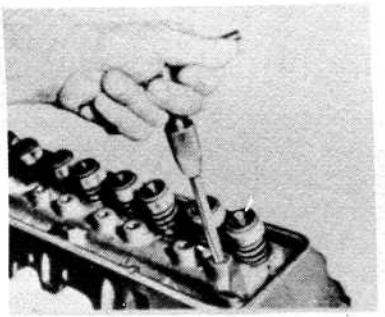
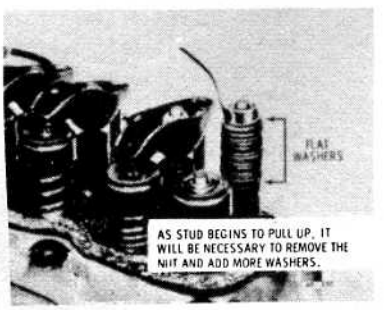
A-VALVE GUIDE I.D.
B-LARGER THAN THE VALVE GUIDE O.D.

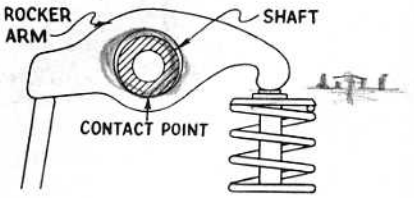
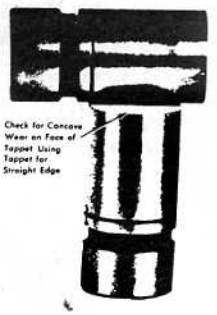
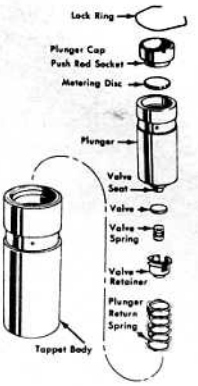
Valve guide installation tool (with washers used during installation)

Procedure	*Method*
Replacing valve seat inserts:	Replacement of valve seat inserts which are worn beyond resurfacing or broken, if feasible, must be done by a machine shop.
Resurfacing (grinding) the valve face:  Grinding a valve (© Subaru)  Critical valve dimensions (© Ford Motor Co.)	Using a valve grinder, resurface the valves according to specifications. CAUTION: *Valve face angle is not always identical to valve seat angle.* A minimum margin of 1/32" should remain after grinding the valve. The valve stem tip should also be squared and resurfaced, by placing the stem in the V-block of the grinder, and turning it while pressing lightly against the grinding wheel.
Resurfacing the valve seats using reamers:  Reaming the valve seat (© S.p.A. Fiat)  Valve seat width and centering (© Ford Motor Co.)	Select a reamer of the correct seat angle, slightly larger than the diameter of the valve seat, and assemble it with a pilot of the correct size. Install the pilot into the valve guide, and using steady pressure, turn the reamer clockwise. CAUTION: *Do not turn the reamer counter-clockwise.* Remove only as much material as necessary to clean the seat. Check the concentricity of the seat (see below). If the dye method is not used, coat the valve face with Prussian blue dye, install and rotate it on the valve seat. Using the dye marked area as a centering guide, center and narrow the valve seat to specifications with correction cutters. NOTE: *When no specifications are available, minimum seat width for exhaust valves should be 5/64", intake valves 1/16".* After making correction cuts, check the position of the valve seat on the valve face using Prussian blue dye.
* Resurfacing the valve seats using a grinder:  Grinding a valve seat (© Subaru)	Select a pilot of the correct size, and a coarse stone of the correct seat angle. Lubricate the pilot if necessary, and install the tool in the valve guide. Move the stone on and off the seat at approximately two cycles per second, until all flaws are removed from the seat. Install a fine stone, and finish the seat. Center and narrow the seat using correction stones, as described above.

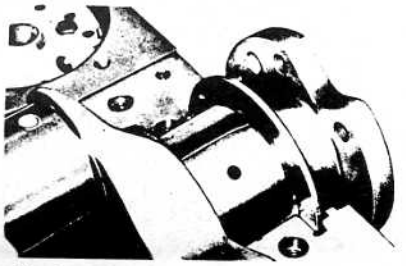
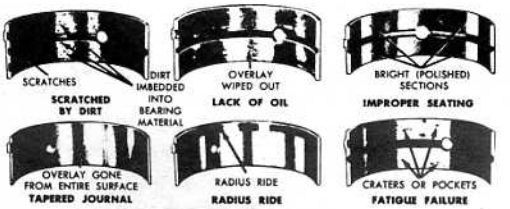
Procedure	*Method*
Checking the valve seat concentricity:  Checking the valve seat concentricity using a dial gauge (© American Motors Corp.)	Coat the valve face with Prussian blue dye, install the valve, and rotate it on the valve seat. If the entire seat becomes coated, and the valve is known to be concentric, the seat is concentric.
	* Install the dial gauge pilot into the guide, and rest the arm on the valve seat. Zero the gauge, and rotate the arm around the seat. Run-out should not exceed .002".
* Lapping the valves: NOTE: *Valve lapping is done to ensure efficient sealing of resurfaced valves and seats. Valve lapping alone is not recommended for use as a resurfacing procedure.*  Hand lapping the valves  Home made mechanical valve lapping tool	* Invert the cylinder head, lightly lubricate the valve stems, and install the valves in the head as numbered. Coat valve seats with fine grinding compound, and attach the lapping tool suction cup to a valve head (NOTE: *Moisten the suction cup*). Rotate the tool between the palms, changing position and lifting the tool often to prevent grooving. Lap the valve until a smooth, polished seat is evident. Remove the valve and tool, and rinse away all traces of grinding compound.
	** Fasten a suction cup to a piece of drill rod, and mount the rod in a hand drill. Proceed as above, using the hand drill as a lapping tool. CAUTION: *Due to the higher speeds involved when using the hand drill, care must be exercised to avoid grooving the seat.* Lift the tool and change direction of rotation often.
Check the valve springs:  Checking the valve spring free length and squareness (© Ford Motor Co.)  Checking the valve spring tension (© Chrysler Corp.)	Place the spring on a flat surface next to a square. Measure the height of the spring, and rotate it against the edge of the square to measure distortion. If spring height varies (by comparison) by more than 1/16" or if distortion exceeds 1/16", replace the spring.
	** In addition to evaluating the spring as above, test the spring pressure at the installed and compressed (installed height minus valve lift) height using a valve spring tester. Springs used on small displacement engines (up to 3 liters) should be ± 1 lb. of all other springs in either position. A tolerance of ± 5 lbs. is permissible on larger engines.

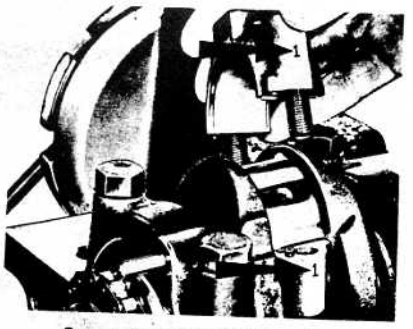
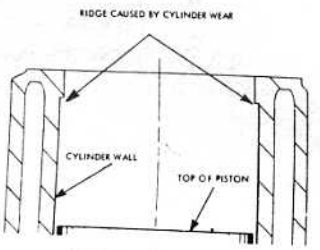
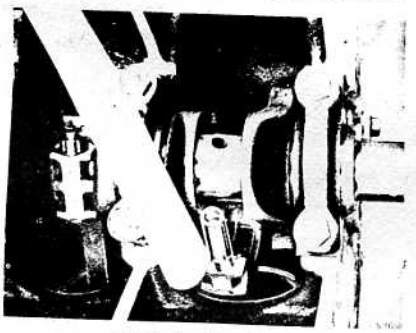
Procedure	*Method*
* Install valve stem seals:  Valve stem seal installation (© Ford Motor Co.) SEAL	* Due to the pressure differential that exists at the ends of the intake valve guides (atmospheric pressure above, manifold vacuum below), oil is drawn through the valve guides into the intake port. This has been alleviated somewhat since the addition of positive crankcase ventilation, which lowers the pressure above the guides. Several types of valve stem seals are available to reduce blow-by. Certain seals simply slip over the stem and guide boss, while others require that the boss be machined. Recently, Teflon guide seals have become popular. Consult a parts supplier or machinist concerning availability and suggested usages. NOTE: *When installing seals, ensure that a small amount of oil is able to pass the seal to lubricate the valve guides; otherwise, excessive wear may result.*
Install the valves:	Lubricate the valve stems, and install the valves in the cylinder head as numbered. Lubricate and position the seals (if used, see above) and the valve springs. Install the spring retainers, compress the springs, and insert the keys using needlenose pliers or a tool designed for this purpose. NOTE: *Retain the keys with wheel bearing grease during installation.*
Checking valve spring installed height:  Valve spring installed height dimension (© Porsche)  Measuring valve spring installed height (© Petersen Publishing Co.)	Measure the distance between the spring pad and the lower edge of the spring retainer, and compare to specifications. If the installed height is incorrect, add shim washers between the spring pad and the spring. CAUTION: *Use only washers designed for this purpose.*
** CC'ing the combustion chambers:	** Invert the cylinder head and place a bead of sealer around a combustion chamber. Install an apparatus designed for this purpose (burette mounted on a clear plate; see illustration) over the combustion chamber, and fill with the specified fluid to an even mark on the burette. Record the burette reading, and fill the combustion chamber with fluid. (NOTE: *A hole drilled in the plate will permit air to escape*). Subtract the burette reading, with the combustion chamber filled, from the previous reading, to determine combustion chamber volume in cc's. Duplicate this procedure in all combustion

Procedure	*Method*
 **CC'ing the combustion chamber** (© Petersen Publishing Co.)	chambers on the cylinder head, and compare the readings. The volume of all combustion chambers should be made equal to that of the largest. Combustion chamber volume may be increased in two ways. When only a small change is required (usually), a small cutter or coarse stone may be used to remove material from the combustion chamber. NOTE: *Check volume frequently.* Remove material over a wide area, so as not to change the configuration of the combustion chamber. When a larger change is required, the valve seat may be sunk (lowered into the head). NOTE: *When altering valve seat, remember to compensate for the change in spring installed height.*
Inspect the rocker arms, balls, studs, and nuts (where applicable):  **Stress cracks in rocker nuts** (© Ford Motor Co.)	Visually inspect the rocker arms, balls, studs, and nuts for cracks, galling, burning, scoring, or wear. If all parts are intact, liberally lubricate the rocker arms and balls, and install them on the cylinder head. If wear is noted on a rocker arm at the point of valve contact, grind it smooth and square, removing as little material as possible. Replace the rocker arm if excessively worn. If a rocker stud shows signs of wear, it must be replaced (see below). If a rocker nut shows stress cracks, replace it. If an exhaust ball is galled or burned, substitute the intake ball from the same cylinder (if it is intact), and install a new intake ball. NOTE: *Avoid using new rocker balls on exhaust valves.*
Replacing rocker studs:  **Reaming the stud bore for oversize rocker studs** (© Buick Div. G.M. Corp.)  **Extracting a pressed in rocker stud** (© Buick Div. G.M. Corp.)	In order to remove a threaded stud, lock two nuts on the stud, and unscrew the stud using the lower nut. Coat the lower threads of the new stud with Loctite, and install. Two alternative methods are available for replacing pressed in studs. Remove the damaged stud using a stack of washers and a nut (see illustration). In the first, the boss is reamed .005-.006″ oversize, and an oversize stud pressed in. Control the stud extension over the boss using washers, in the same manner as valve guides. Before installing the stud, coat it with white lead and grease. To retain the stud more positively, drill a hole through the stud and boss, and install a roll pin. In the second method, the boss is tapped, and a threaded stud installed. Retain the stud using Loctite Stud and Bearing Mount.

Procedure	*Method*
Inspect the rocker shaft(s) and rocker arms (where applicable):  Disassembled rocker shaft parts arranged for inspection (© American Motors Corp.)  Rocker arm to rocker shaft contact	Remove rocker arms, springs and washers from rocker shaft. NOTE: *Lay out parts in the order they are removed.* Inspect rocker arms for pitting or wear on the valve contact point, or excessive bushing wear. Bushings need only be replaced if wear is excessive, because the rocker arm normally contacts the shaft at one point only. Grind the valve contact point of rocker arm smooth if necessary, removing as little material as possible. If excessive material must be removed to smooth and square the arm, it should be replaced. Clean out all oil holes and passages in rocker shaft. If shaft is grooved or worn, replace it. Lubricate and assemble the rocker shaft.
Inspect the camshaft bushings and the camshaft (overhead cam engines):	See next section.
Inspect the pushrods:	Remove the pushrods, and, if hollow, clean out the oil passages using fine wire. Roll each pushrod over a piece of clean glass. If a distinct clicking sound is heard as the pushrod rolls, the rod is bent, and must be replaced.
	* The length of all pushrods must be equal. Measure the length of the pushrods, compare to specifications, and replace as necessary.
Inspect the valve lifters:  Checking the lifter face (© American Motors Corp.)	Remove lifters from their bores, and remove gum and varnish, using solvent. Clean walls of lifter bores. Check lifters for concave wear as illustrated. If face is worn concave, replace lifter, and carefully inspect the camshaft. Lightly lubricate lifter and insert it into its bore. If play is excessive, an oversize lifter must be installed (where possible). Consult a machinist concerning feasibility. If play is satisfactory, remove, lubricate, and reinstall the lifter.
* Testing hydraulic lifter leak down:  Exploded view of a typical hydraulic lifter (© American Motors Corp.)	Submerge lifter in a container of kerosene. Chuck a used pushrod or its equivalent into a drill press. Position container of kerosene so pushrod acts on the lifter plunger. Pump lifter with the drill press, until resistance increases. Pump several more times to bleed any air out of lifter. Apply very firm, constant pressure to the lifter, and observe rate at which fluid bleeds out of lifter. If the fluid bleeds very quickly (less than 15 seconds), lifter is defective. If the time exceeds 60 seconds, lifter is sticking. In either case, recondition or replace lifter. If lifter is operating properly (leak down time 15-60 seconds), lubricate and install it.

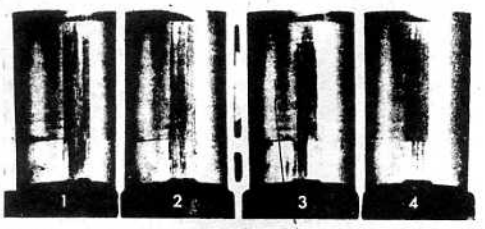
CYLINDER BLOCK RECONDITIONING

Procedure	*Method*
Checking the main bearing clearance:  **Plastigage installed on main bearing journal** (© Chevrolet Div. G.M. Corp.)  **Measuring Plastigage to determine main bearing clearance** (© Chevrolet Div. G.M. Corp.)	Invert engine, and remove cap from the bearing to be checked. Using a clean, dry rag, thoroughly clean all oil from crankshaft journal and bearing insert. NOTE: *Plastigage is soluble in oil; therefore, oil on the journal or bearing could result in erroneous readings.* Place a piece of Plastigage along the full length of journal, reinstall cap, and torque to specifications. Remove bearing cap, and determine bearing clearance by comparing width of Plastigage to the scale on Plastigage envelope. Journal taper is determined by comparing width of the Plastigage strip near its ends. Rotate crankshaft 90° and retest, to determine journal eccentricity. NOTE: *Do not rotate crankshaft with Plastigage installed.* If bearing insert and journal appear intact, and are within tolerances, no further main bearing service is required. If bearing or journal appear defective, cause of failure should be determined before replacement.
 **Causes of bearing failure** (© Ford Motor Co.)	* Remove crankshaft from block (see below). Measure the main bearing journals at each end twice (90° apart) using a micrometer, to determine diameter, journal taper and eccentricity. If journals are within tolerances, reinstall bearing caps at their specified torque. Using a telescope gauge and micrometer, measure bearing I.D. parallel to piston axis and at 30° on each side of piston axis. Subtract journal O.D. from bearing I.D. to determine oil clearance. If crankshaft journals appear defective, or do not meet tolerances, there is no need to measure bearings; for the crankshaft will require grinding and/or undersize bearings will be required. If bearing appears defective, cause for failure should be determined prior to replacement.
Checking the connecting rod bearing clearance:  **Plastigage installed on connecting rod bearing journal** (© Chevrolet Div. G.M. Corp.)	Connecting rod bearing clearance is checked in the same manner as main bearing clearance, using Plastigage. Before removing the crankshaft, connecting rod side clearance also should be measured and recorded.
	* Checking connecting rod bearing clearance, using a micrometer, is identical to checking main bearing clearance. If no other service

Procedure	*Method*
 Measuring Plastigage to determine connecting rod bearing clearance (© Chevrolet Div. G.M. Corp.)	is required, the piston and rod assemblies need not be removed.
Removing the crankshaft:  Connecting rod matching marks (© Ford Motor Co.)	Using a punch, mark the corresponding main bearing caps and saddles according to position (i.e., one punch on the front main cap and saddle, two on the second, three on the third, etc.). Using number stamps, identify the corresponding connecting rods and caps, according to cylinder (if no numbers are present). Remove the main and connecting rod caps, and place sleeves of plastic tubing over the connecting rod bolts, to protect the journals as the crankshaft is removed. Lift the crankshaft out of the block.
Remove the ridge from the top of the cylinder:  Cylinder bore ridge (© Pontiac Div. G.M. Corp.)	In order to facilitate removal of the piston and connecting rod, the ridge at the top of the cylinder (unworn area; see illustration) must be removed. Place the piston at the bottom of the bore, and cover it with a rag. Cut the ridge away using a ridge reamer, exercising extreme care to avoid cutting too deeply. Remove the rag, and remove cuttings that remain on the piston. CAUTION: *If the ridge is not removed, and new rings are installed, damage to rings will result.*
Removing the piston and connecting rod:  Removing the piston (© SAAB)	Invert the engine, and push the pistons and connecting rods out of the cylinders. If necessary, tap the connecting rod boss with a wooden hammer handle, to force the piston out. CAUTION: *Do not attempt to force the piston past the cylinder ridge* (see above).

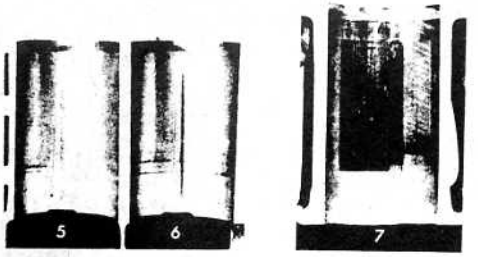
Procedure	*Method*
Service the crankshaft:	Ensure that all oil holes and passages in the crankshaft are open and free of sludge. If necessary, have the crankshaft ground to the largest possible undersize.
	** Have the crankshaft Magnafluxed, to locate stress cracks. Consult a machinist concerning additional service procedures, such as surface hardening (e.g., nitriding, Tuftriding) to improve wear characteristics, cross drilling and chamfering the oil holes to improve lubrication, and balancing.
Removing freeze plugs:	Drill a hole in the center of the freeze plugs, and pry them out using a screwdriver or drift.
Remove the oil gallery plugs:	Threaded plugs should be removed using an appropriate (usually square) wrench. To remove soft, pressed in plugs, drill a hole in the plug, and thread in a sheet metal screw. Pull the plug out by the screw using pliers.
Hot-tank the block:	Have the block hot-tanked to remove grease, corrosion, and scale from the water jackets. NOTE: *Consult the operator to determine whether the camshaft bearings will be damaged during the hot-tank process.*
Check the block for cracks:	Visually inspect the block for cracks or chips. The most common locations are as follows: Adjacent to freeze plugs. Between the cylinders and water jackets. Adjacent to the main bearing saddles. At the extreme bottom of the cylinders. Check only suspected cracks using spot check dye (see introduction). If a crack is located, consult a machinist concerning possible repairs.
	** Magnaflux the block to locate hidden cracks. If cracks are located, consult a machinist about feasibility of repair.
Install the oil gallery plugs and freeze plugs:	Coat freeze plugs with sealer and tap into position using a piece of pipe, slightly smaller than the plug, as a driver. To ensure retention, stake the edges of the plugs. Coat threaded oil gallery plugs with sealer and install. Drive replacement soft plugs into block using a large drift as a driver.
	* Rather than reinstalling lead plugs, drill and tap the holes, and install threaded plugs.

Procedure	*Method*
Check the bore diameter and surface:	Visually inspect the cylinder bores for roughness, scoring, or scuffing. If evident, the cylinder bore must be bored or honed oversize to eliminate imperfections, and the smallest possible oversize piston used. The new pistons should be given to the machinist with the block, so that the cylinders can be bored or honed exactly to the piston size (plus clearance). If no flaws are evident, measure the bore diameter using a telescope gauge and micrometer, or dial gauge, parallel and perpendicular to the engine centerline, at the top (below the ridge) and bottom of the bore. Subtract the bottom measurements from the top to determine taper, and the parallel to the centerline measurements from the perpendicular measurements to determine eccentricity. If the measurements are not within specifications, the cylinder must be bored or honed, and an oversize piston installed. If the measurements are within specifications the cylinder may be used as is, with only finish honing (see below). NOTE: *Prior to submitting the block for boring, perform the following operation(s).*



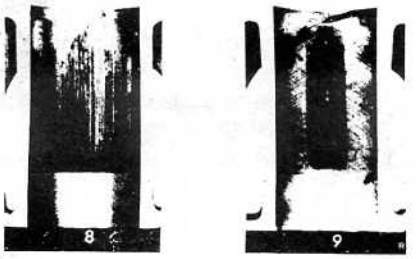
1, 2, 3 Piston skirt seizure resulted in this pattern. Engine must be rebored

4. Piston skirt and oil ring seizure caused this damage. Engine must be rebored



5, 6 Score marks caused by a split piston skirt. Damage is not serious enough to warrant reboring

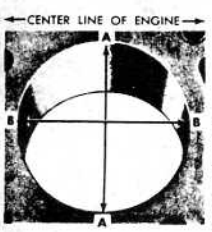
7. Ring seized longitudinally, causing a score mark 1 3/16" wide, on the land side of the piston groove. The honing pattern is destroyed and the cylinder must be rebored



8. Result of oil ring seizure. Engine must be rebored

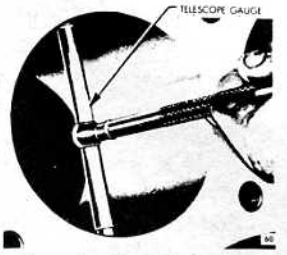
9. Oil ring seizure here was not serious enough to warrant reboring. The honing marks are still visible

Cylinder wall damage
(© Daimler-Benz A.G.)

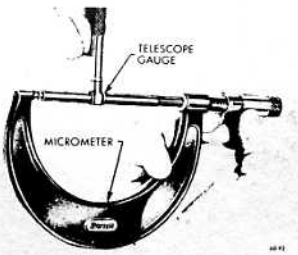


A AT RIGHT ANGLE TO CENTER LINE OF ENGINE
B PARALLEL TO CENTER LINE OF ENGINE

Cylinder bore measuring positions
(© Ford Motor Co.)

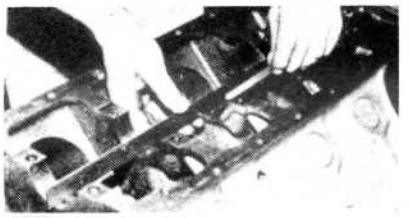
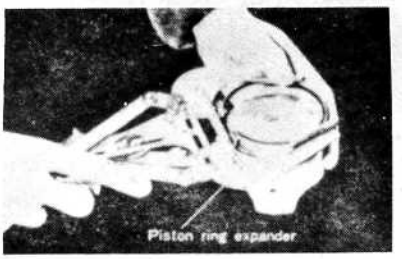


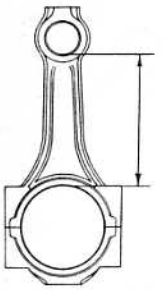
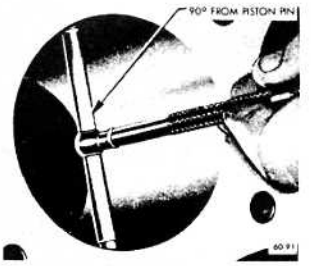
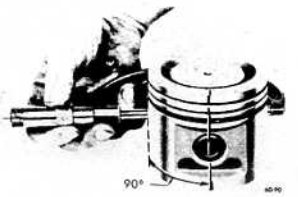
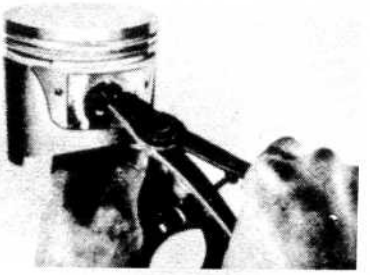
Measuring the cylinder bore with a telescope gauge
(© Buick Div. G.M. Corp.)

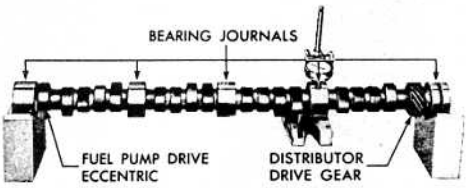
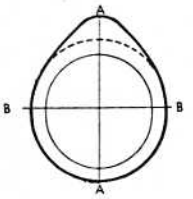
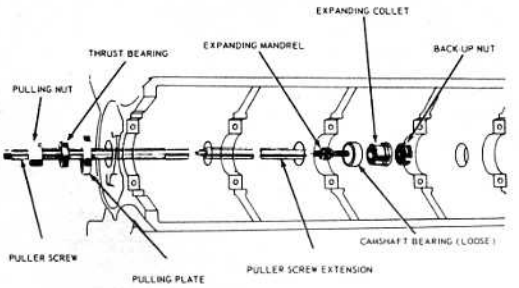
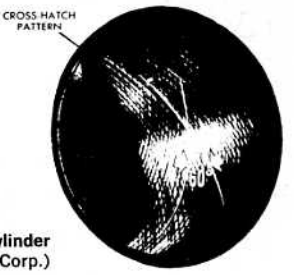


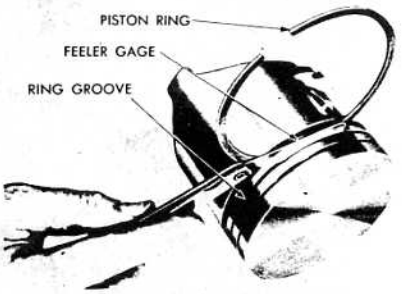
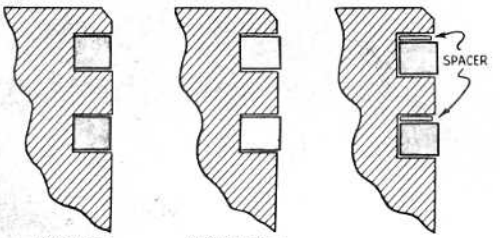
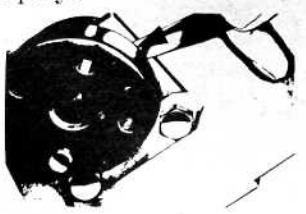
Determining the cylinder bore by measuring the telescope gauge with a micrometer
(© Buick Div. G.M. Corp.)

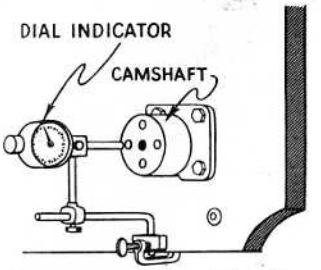
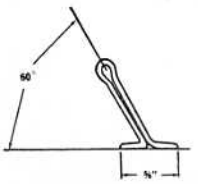
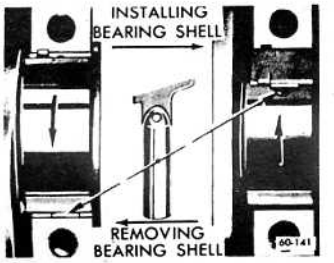
Measuring the cylinder bore with a dial gauge
(© Chevrolet Div. G.M. Corp.)

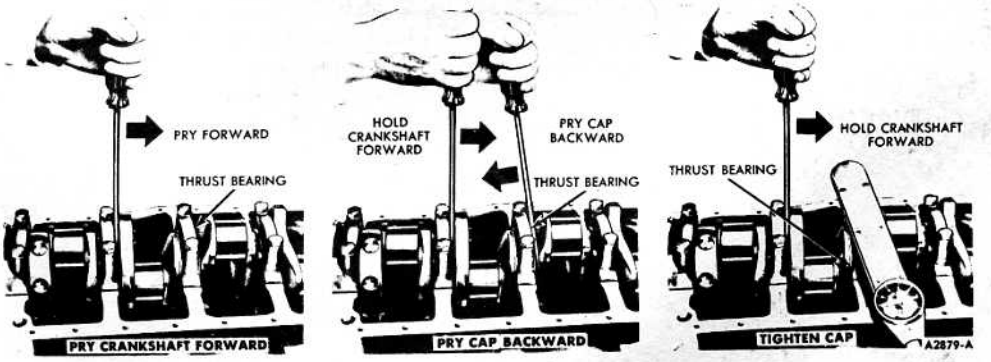
Procedure	*Method*
Check the block deck for warpage:	Using a straightedge and feeler gauges, check the block deck for warpage in the same manner that the cylinder head is checked (see Cylinder Head Reconditioning). If warpage exceeds specifications, have the deck resurfaced. NOTE: *In certain cases a specification for total material removal (Cylinder head and block deck) is provided. This specification must not be exceeded.*
* Check the deck height:	The deck height is the distance from the crankshaft centerline to the block deck. To measure, invert the engine, and install the crankshaft, retaining it with the center main cap. Measure the distance from the crankshaft journal to the block deck, parallel to the cylinder centerline. Measure the diameter of the end (front and rear) main journals, parallel to the centerline of the cylinders, divide the diameter in half, and subtract it from the previous measurement. The results of the front and rear measurements should be identical. If the difference exceeds .005", the deck height should be corrected. NOTE: *Block deck height and warpage should be corrected concurrently.*
Check the cylinder block bearing alignment:  **Checking main bearing saddle alignment** (© Petersen Publishing Co.)	Remove the upper bearing inserts. Place a straightedge in the bearing saddles along the centerline of the crankshaft. If clearance exists between the straightedge and the center saddle, the block must be align-bored.
Clean and inspect the pistons and connecting rods:  **Removing the piston rings** (© Subaru)	Using a ring expander, remove the rings from the piston. Remove the retaining rings (if so equipped) and remove piston pin. NOTE: *If the piston pin must be pressed out, determine the proper method and use the proper tools; otherwise the piston will distort.* Clean the ring grooves using an appropriate tool, exercising care to avoid cutting too deeply. Thoroughly clean all carbon and varnish from the piston with solvent. CAUTION: *Do not use a wire brush or caustic solvent on pistons.* Inspect the pistons for scuffing, scoring, cracks, pitting, or excessive ring groove wear. If wear is evident, the piston must be replaced. Check the connecting rod length by measuring the rod from the inside of the large end to the inside of the small end using calipers (see

Procedure	*Method*
 Cleaning the piston ring grooves (© Ford Motor Co.)  Connecting rod length checking dimension	illustration). All connecting rods should be equal length. Replace any rod that differs from the others in the engine.
	* Have the connecting rod alignment checked in an alignment fixture by a machinist. Replace any twisted or bent rods.
	* Magnaflux the connecting rods to locate stress cracks. If cracks are found, replace the connecting rod.
Fit the pistons to the cylinders:  Measuring the cylinder with a telescope gauge for piston fitting (© Buick Div. G.M. Corp.)  Measuring the piston for fitting (© Buick Div. G.M. Corp.)	Using a telescope gauge and micrometer, or a dial gauge, measure the cylinder bore diameter perpendicular to the piston pin, 2½" below the deck. Measure the piston perpendicular to its pin on the skirt. The difference between the two measurements is the piston clearance. If the clearance is within specifications or slightly below (after boring or honing), finish honing is all that is required. If the clearance is excessive, try to obtain a slightly larger piston to bring clearance within specifications. Where this is not possible, obtain the first oversize piston, and hone (or if necessary, bore) the cylinder to size.
Assemble the pistons and connecting rods:  Installing piston pin lock rings (© Nissan Motor Co., Ltd.)	Inspect piston pin, connecting rod small end bushing, and piston bore for galling, scoring, or excessive wear. If evident, replace defective part(s). Measure the I.D. of the piston boss and connecting rod small end, and the O.D. of the piston pin. If within specifications, assemble piston pin and rod. CAUTION: *If piston pin must be pressed in, determine the proper method and use the proper tools; otherwise the piston will distort.* Install the lock rings; ensure that they seat properly. If the parts are not within specifications, determine the service method for the type of engine. In some cases, piston and pin are serviced as an assembly when either is defective. Others specify reaming the piston and connecting rods for an oversize pin. If the connecting rod bushing is worn, it may in many cases be replaced. Reaming the piston and replacing the rod bushing are machine shop operations.

Procedure	*Method*
Clean and inspect the camshaft:  **Checking the camshaft for straightness** (© Chevrolet Motor Div. G.M. Corp.)  **Camshaft lobe measurement** (© Ford Motor Co.)	Degrease the camshaft, using solvent, and clean out all oil holes. Visually inspect cam lobes and bearing journals for excessive wear. If a lobe is questionable, check all lobes as indicated below. If a journal or lobe is worn, the camshaft must be reground or replaced. NOTE: *If a journal is worn, there is a good chance that the bushings are worn.* If lobes and journals appear intact, place the front and rear journals in V-blocks, and rest a dial indicator on the center journal. Rotate the camshaft to check straightness. If deviation exceeds .001", replace the camshaft. * Check the camshaft lobes with a micrometer, by measuring the lobes from the nose to base and again at 90° (see illustration). The lift is determined by subtracting the second measurement from the first. If all exhaust lobes and all intake lobes are not identical, the camshaft must be reground or replaced.
Replace the camshaft bearings:  **Camshaft removal and installation tool (typical)** (© Ford Motor Co.)	If excessive wear is indicated, or if the engine is being completely rebuilt, camshaft bearings should be replaced as follows: Drive the camshaft rear plug from the block. Assemble the removal puller with its shoulder on the bearing to be removed. Gradually tighten the puller nut until bearing is removed. Remove remaining bearings, leaving the front and rear for last. To remove front and rear bearings, reverse position of the tool, so as to pull the bearings in toward the center of the block. Leave the tool in this position, pilot the new front and rear bearings on the installer, and pull them into position. Return the tool to its original position and pull remaining bearings into position. NOTE: *Ensure that oil holes align when installing bearings.* Replace camshaft rear plug, and stake it into position to aid retention.
Finish hone the cylinders:  **Finish honed cylinder** (© Chrysler Corp.)	Chuck a flexible drive hone into a power drill, and insert it into the cylinder. Start the hone, and move it up and down in the cylinder at a rate which will produce approximately a 60° cross-hatch pattern (see illustration). NOTE: *Do not extend the hone below the cylinder bore.* After developing the pattern, remove the hone and recheck piston fit. Wash the cylinders with a detergent and water solution to remove abrasive dust, dry, and wipe several times with a rag soaked in engine oil.

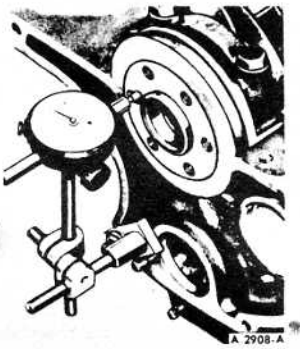
Procedure	*Method*
Check piston ring end-gap:  **Checking ring end-gap** (© Chevrolet Motor Div. G.M. Corp.)	Compress the piston rings to be used in a cylinder, one at a time, into that cylinder, and press them approximately 1" below the deck with an inverted piston. Using feeler gauges, measure the ring end-gap, and compare to specifications. Pull the ring out of the cylinder and file the ends with a fine file to obtain proper clearance. CAUTION: *If inadequate ring end-gap is utilized, ring breakage will result.*
Install the piston rings:  **Checking ring side clearance** (© Chrysler Corp.)  **Piston groove depth** **Correct ring spacer installation**	Inspect the ring grooves in the piston for excessive wear or taper. If necessary, recut the groove(s) for use with an overwidth ring or a standard ring and spacer. If the groove is worn uniformly, overwidth rings, or standard rings and spacers may be installed without recutting. Roll the outside of the ring around the groove to check for burrs or deposits. If any are found, remove with a fine file. Hold the ring in the groove, and measure side clearance. If necessary, correct as indicated above. NOTE: *Always install any additional spacers above the piston ring.* The ring groove must be deep enough to allow the ring to seat below the lands (see illustration). In many cases, a "go-no-go" depth gauge will be provided with the piston rings. Shallow grooves may be corrected by recutting, while deep grooves require some type of filler or expander behind the piston. Consult the piston ring supplier concerning the suggested method. Install the rings on the piston, lowest ring first, using a ring expander. NOTE: *Position the ring markings as specified by the manufacturer (see car section).*
Install the camshaft:	Liberally lubricate the camshaft lobes and journals, and slide the camshaft into the block. CAUTION: *Exercise extreme care to avoid damaging the bearings when inserting the camshaft.* Install and tighten the camshaft thrust plate retaining bolts.
Check camshaft end-play:  **Checking camshaft end-play with a feeler gauge** (© Ford Motor Co.)	Using feeler gauges, determine whether the clearance between the camshaft boss (or gear) and backing plate is within specifications. Install shims behind the thrust plate, or reposition the camshaft gear and retest end-play.

Procedure	*Method*
 Checking camshaft end-play with a dial indicator	* Mount a dial indicator stand so that the stem of the dial indicator rests on the nose of the camshaft, parallel to the camshaft axis. Push the camshaft as far in as possible and zero the gauge. Move the camshaft outward to determine the amount of camshaft end-play. If the end-play is not within tolerance, install shims behind the thrust plate, or reposition the camshaft gear and retest.
Install the rear main seal (where applicable):  Seating the rear main seal (© Buick Div. G.M. Corp.)	Position the block with the bearing saddles facing upward. Lay the rear main seal in its groove and press it lightly into its seat. Place a piece of pipe the same diameter as the crankshaft journal into the saddle, and firmly seat the seal. Hold the pipe in position, and trim the ends of the seal flush if required.
Install the crankshaft:  Home made bearing roll-out pin (© Pontiac Div. G.M. Corp.)  Removal and installation of upper bearing insert using a roll-out pin (© Buick Div. G.M. Corp.)	Thoroughly clean the main bearing saddles and caps. Place the upper halves of the bearing inserts on the saddles and press into position. NOTE: *Ensure that the oil holes align.* Press the corresponding bearing inserts into the main bearing caps. Lubricate the upper main bearings, and lay the crankshaft in position. Place a strip of Plastigage on each of the crankshaft journals, install the main caps, and torque to specifications. Remove the main caps, and compare the Plastigage to the scale on the Plastigage envelope. If clearances are within tolerances, remove the Plastigage, turn the crankshaft 90°, wipe off all oil and retest. If all clearances are correct, remove all Plastigage, thoroughly

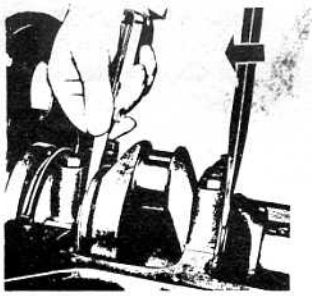


Aligning the thrust bearing
(© Ford Motor Co.)

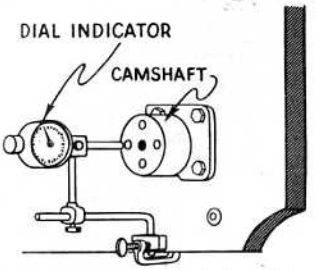
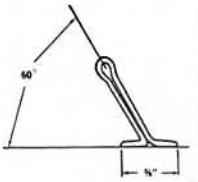
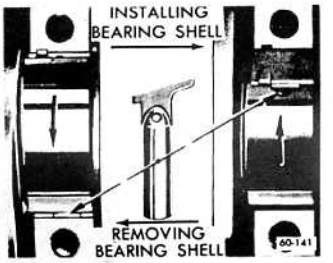
Procedure	*Method*
	lubricate the main caps and bearing journals, and install the main caps. If clearances are not within tolerance, the upper bearing inserts may be removed, without removing the crankshaft, using a bearing roll out pin (see illustration). Roll in a bearing that will provide proper clearance, and retest. Torque all main caps, excluding the thrust bearing cap, to specifications. Tighten the thrust bearing cap finger tight. To properly align the thrust bearing, pry the crankshaft the extent of its axial travel several times, the last movement held toward the front of the engine, and torque the thrust bearing cap to specifications. Determine the crankshaft end-play (see below), and bring within tolerance with thrust washers.
Measure crankshaft end-play:	Mount a dial indicator stand on the front of the block, with the dial indicator stem resting on the nose of the crankshaft, parallel to the crankshaft axis. Pry the crankshaft the extent of its travel rearward, and zero the indicator. Pry the crankshaft forward and record crankshaft end-play. NOTE: *Crankshaft end-play also may be measured at the thrust bearing, using feeler gauges* (see illustration).
Install the pistons:	Press the upper connecting rod bearing halves into the connecting rods, and the lower halves into the connecting rod caps. Position the piston ring gaps according to specifications (see car section), and lubricate the pistons. Install a ring compresser on a piston, and press two long (8") pieces of plastic tubing over the rod bolts. Using the plastic tubes as a guide, press the pistons into the bores and onto the crankshaft with a wooden hammer handle. After seating the rod on the crankshaft journal, remove the tubes and install the cap finger tight. Install the remaining pistons in the same man-

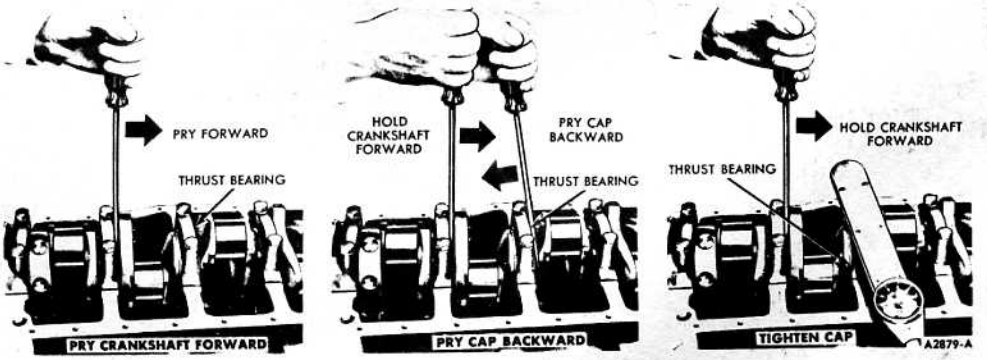


Checking crankshaft end-play with a dial indicator
(© Ford Motor Co.)



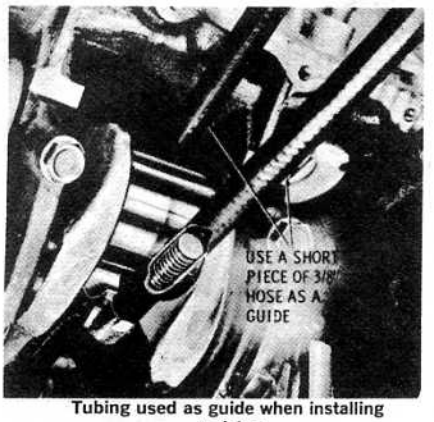
Checking crankshaft end-play with a feeler gauge
(© Chevrolet Div. (G.M. Corp.)

Procedure	*Method*
 Checking camshaft end-play with a dial indicator	* Mount a dial indicator stand so that the stem of the dial indicator rests on the nose of the camshaft, parallel to the camshaft axis. Push the camshaft as far in as possible and zero the gauge. Move the camshaft outward to determine the amount of camshaft end-play. If the end-play is not within tolerance, install shims behind the thrust plate, or reposition the camshaft gear and retest.
Install the rear main seal (where applicable):  Seating the rear main seal (© Buick Div. G.M. Corp.)	Position the block with the bearing saddles facing upward. Lay the rear main seal in its groove and press it lightly into its seat. Place a piece of pipe the same diameter as the crankshaft journal into the saddle, and firmly seat the seal. Hold the pipe in position, and trim the ends of the seal flush if required.
Install the crankshaft:  Home made bearing roll-out pin (© Pontiac Div. G.M. Corp.)  Removal and installation of upper bearing insert using a roll-out pin (© Buick Div. G.M. Corp.)	Thoroughly clean the main bearing saddles and caps. Place the upper halves of the bearing inserts on the saddles and press into position. NOTE: *Ensure that the oil holes align.* Press the corresponding bearing inserts into the main bearing caps. Lubricate the upper main bearings, and lay the crankshaft in position. Place a strip of Plastigage on each of the crankshaft journals, install the main caps, and torque to specifications. Remove the main caps, and compare the Plastigage to the scale on the Plastigage envelope. If clearances are within tolerances, remove the Plastigage, turn the crankshaft 90°, wipe off all oil and retest. If all clearances are correct, remove all Plastigage, thoroughly

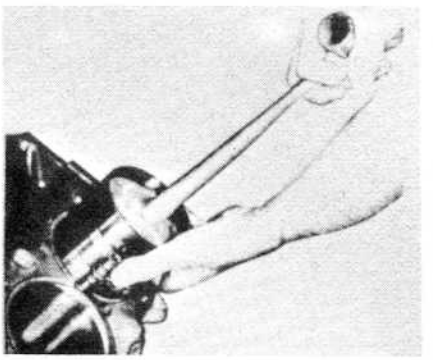


Aligning the thrust bearing
(© Ford Motor Co.)

Procedure	*Method*



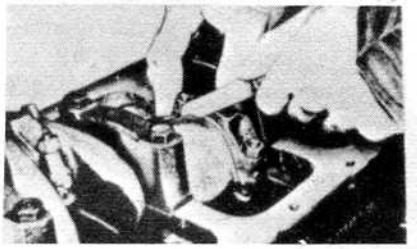
Tubing used as guide when installing a piston
(© Oldsmobile Div. G.M. Corp.)



Installing a piston
(© Chevrolet Div. G.M. Corp.)

ner. Invert the engine and check the bearing clearance at two points (90° apart) on each journal with Plastigage. NOTE: *Do not turn the crankshaft with Plastigage installed.* If clearance is within tolerances, remove *all* Plastigage, thoroughly lubricate the journals, and torque the rod caps to specifications. If clearance is not within specifications, install different thickness bearing inserts and recheck. CAUTION: *Never shim or file the connecting rods or caps.* Always install plastic tube sleeves over the rod bolts when the caps are not installed, to protect the crankshaft journals.

Check connecting rod side clearance:



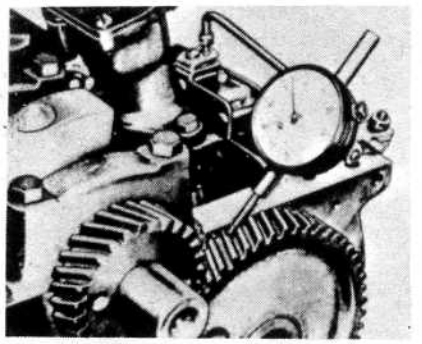
Checking connecting rod side clearance
(© Chevrolet Div. G.M. Corp.)

Determine the clearance between the sides of the connecting rods and the crankshaft, using feeler gauges. If clearance is below the minimum tolerance, the rod may be machined to provide adequate clearance. If clearance is excessive, substitute an unworn rod, and recheck. If clearance is still outside specifications, the crankshaft must be welded and reground, or replaced.

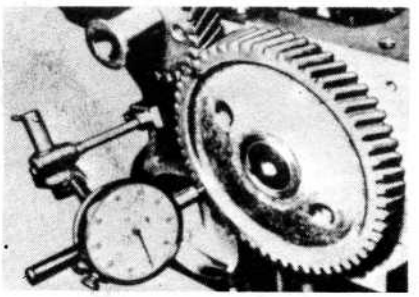
Inspect the timing chain:

Visually inspect the timing chain for broken or loose links, and replace the chain if any are found. If the chain will flex sideways, it must be replaced. Install the timing chain as specified. NOTE: *If the original timing chain is to be reused, install it in its original position.*

Procedure	*Method*
Check timing gear backlash and runout:	Mount a dial indicator with its stem resting on a tooth of the camshaft gear (as illustrated). Rotate the gear until all slack is removed, and zero the indicator. Rotate the gear in the opposite direction until slack is removed, and record gear backlash. Mount the indicator with its stem resting on the edge of the camshaft gear, parallel to the axis of the camshaft. Zero the indicator, and turn the camshaft gear one full turn, recording the runout. If either backlash or runout exceed specifications, replace the worn gear(s).



Checking camshaft gear backlash
(© Chevrolet Div. G.M. Corp.)



Checking camshaft gear runout
(© Chevrolet Div. G.M. Corp.)

Completing the Rebuilding Process

Following the above procedures, complete the rebuilding process as follows:

Fill the oil pump with oil, to prevent cavitating (sucking air) on initial engine start up. Install the oil pump and the pickup tube on the engine. Coat the oil pan gasket as necessary, and install the gasket and the oil pan. Mount the flywheel and the crankshaft vibrational damper or pulley on the crankshaft. NOTE: *Always use new bolts when installing the flywheel.* Inspect the clutch shaft pilot bushing in the crankshaft. If the bushing is excessively worn, remove it with an expanding puller and a slide hammer, and tap a new bushing into place.

Position the engine, cylinder head side up. Lubricate the lifters, and install them into their bores. Install the cylinder head, and torque it as specified in the car section. Insert the pushrods (where applicable), and install the rocker shaft(s) (if so equipped) or position the rocker arms on the pushrods. If solid lifters are utilized, adjust the valves to the "cold" specifications.

Mount the intake and exhaust manifolds, the carburetor(s), the distributor and spark plugs. Adjust the point gap and the static ignition timing. Mount all accessories and install the engine in the car. Fill the radiator with coolant, and the crankcase with high quality engine oil.

Break-in Procedure

Start the engine, and allow it to run at low speed for a few minutes, while checking for leaks. Stop the engine, check the oil level, and fill as necessary. Restart the engine, and fill the cooling system to capacity. Check the point dwell angle and adjust the ignition timing and the valves. Run the engine at low to medium speed (800-2500 rpm) for approximately ½ hour, and retorque the cylinder head bolts. Road test the car, and check again for leaks.

Follow the manufacturer's recommended engine break-in procedure and maintenance schedule for new engines.