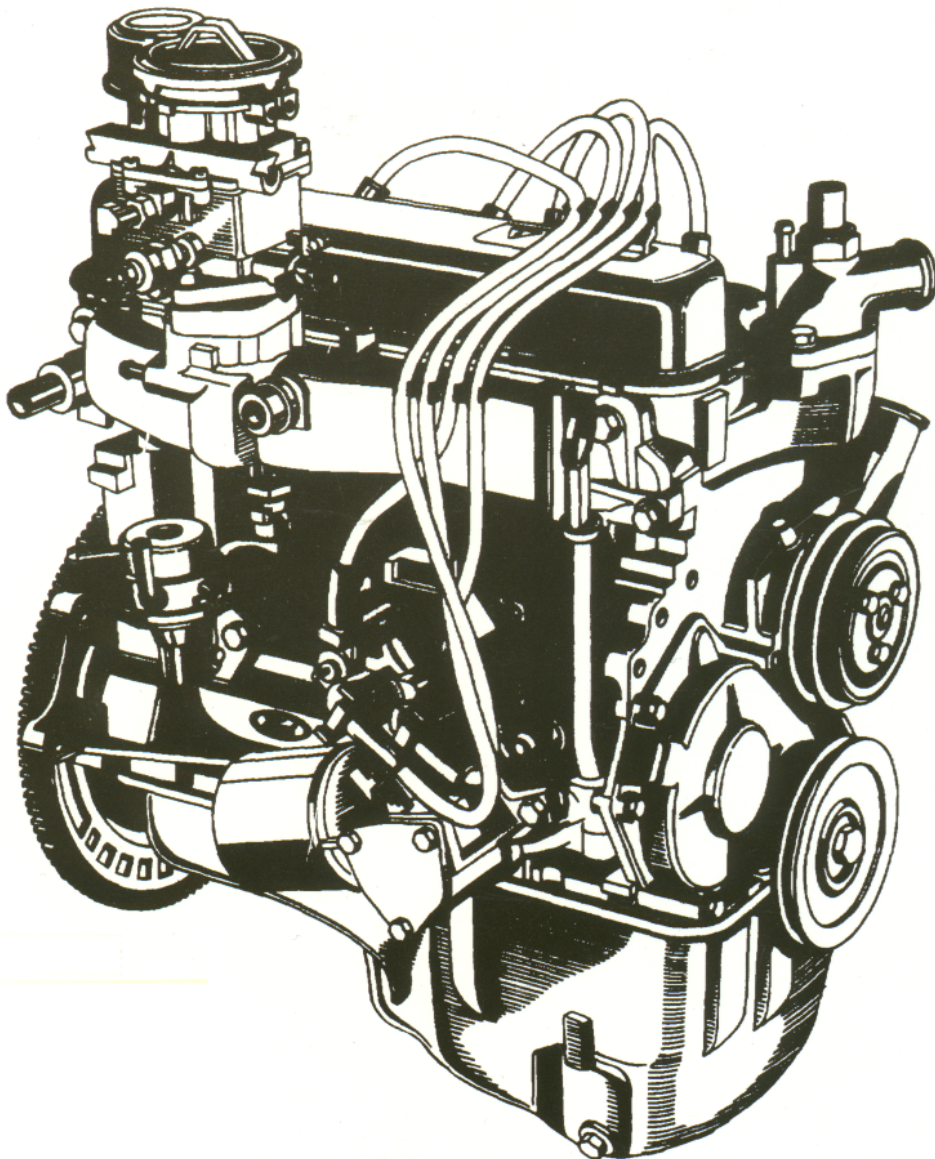




VSG-411/413 ENGINE SERVICE MANUAL

The Source for Power...
Worldwide™

For Engines Produced 1993 and Later



IMPORTANT SAFETY NOTICE

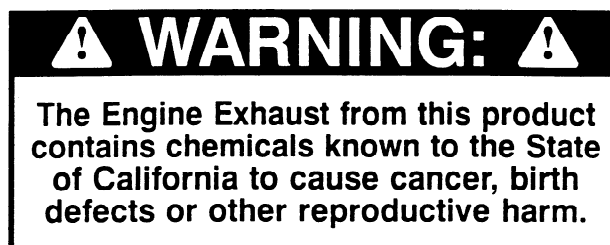
Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles as well as the personal safety of the individual doing the work. This Shop Manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This Manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in this Manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

NOTES, CAUTIONS, AND WARNINGS

As you read through the procedures, you will come across NOTES, CAUTIONS, and WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific operation. Place wood blocks (4" x 4" or larger) to the front and rear surfaces of the tires to provide further restraint from inadvertent vehicle movement.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind the head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.



Introduction

In general, this manual covers the servicing of the engine and associated standard equipment. In many cases, engines are supplied with accessories and equipment that are unique to the application. If service information is ever required on such unique accessories or equipment it is suggested that Power Products Division/GRI be contacted. The proper information will either be forwarded or the Service Technician will be advised where it can be obtained.

The information in this manual is grouped in sections according to the type of work being performed. The various sections are indicated in the index. In addition, each section is subdivided to include topics such as diagnosis and testing, cleaning and inspection, overhaul, removal and installation procedures, disassembly and assembly procedures, and service specifications.



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POWER PRODUCTS DIVISION/GRI
28333 TELEGRAPH ROAD - #300
SOUTHFIELD, MICHIGAN 48034

The descriptions and specifications contained in this manual were in effect at the time the book was released for printing. Power Products Division/GRI reserves the right to discontinue models at any time, or change specifications or design, without notice and without incurring obligation.

NOTE: *The recommendations and suggestions contained in this*

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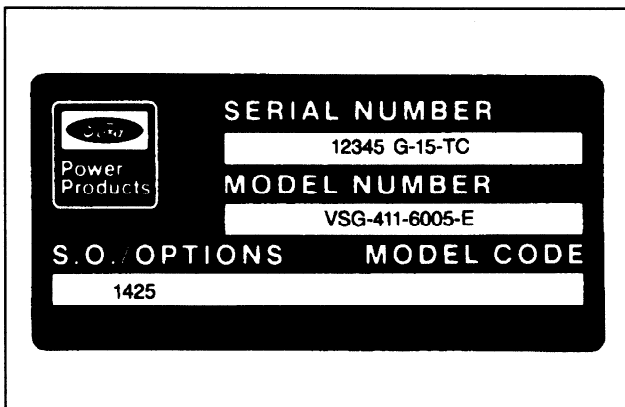
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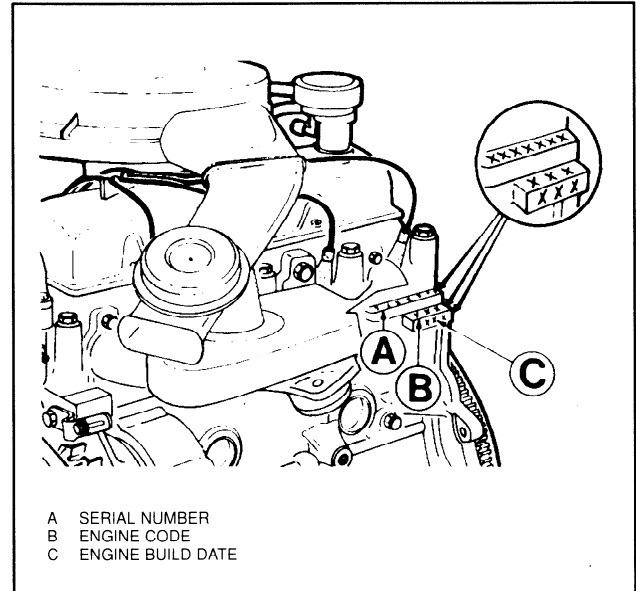
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IDENTIFICATION

An Identification Decal is affixed to the left side of the rocker cover of each engine. The decal contains the engine serial number which identifies this unit from all others. Next is the engine displacement which determines the engine specifications, then the model number and S.O. or special options which determine the parts or components required on this unit. Use all numbers when seeking information or ordering replacement parts for this engine.



Identification of the cylinder block and therefore of the basic engine type can be made by reference to the stampings on the left rear top edge of the cylinder block.



The engine code will begin with a "G" This will indicate that it is a 1.1 liter engine.

The engine build date follows the corporate system. Example: "4K26". The first number indicates the year. The letter indicates the month in alphabetical sequence, A January, B February, etc. omitting I. The last two numbers are the day of the month.

DESCRIPTION

The engine is a water-cooled, 4 cylinder, 4 stroke, in-line gasoline engine. The cylinder head in which the combustion chambers are located is of a cross-flow type, the fresh fuel/air mixture is drawn in on one side and burnt gases are passed into the exhaust system on the opposite side.

The valves are suspended in the cylinder head and are operated by means of tappets, pushrods and rocker arms.

The valves are disposed in an alternating pattern in the cylinder head starting with an exhaust valve by the thermostat housing.

The three-bearing camshaft is located on the right side of the cylinder block and driven by roller chain from the crankshaft.

The common driving gear shared by the distributor and oil pump is located behind the second cam on the camshaft, the eccentric cam driving the fuel pump is located between the sixth and seventh cams.

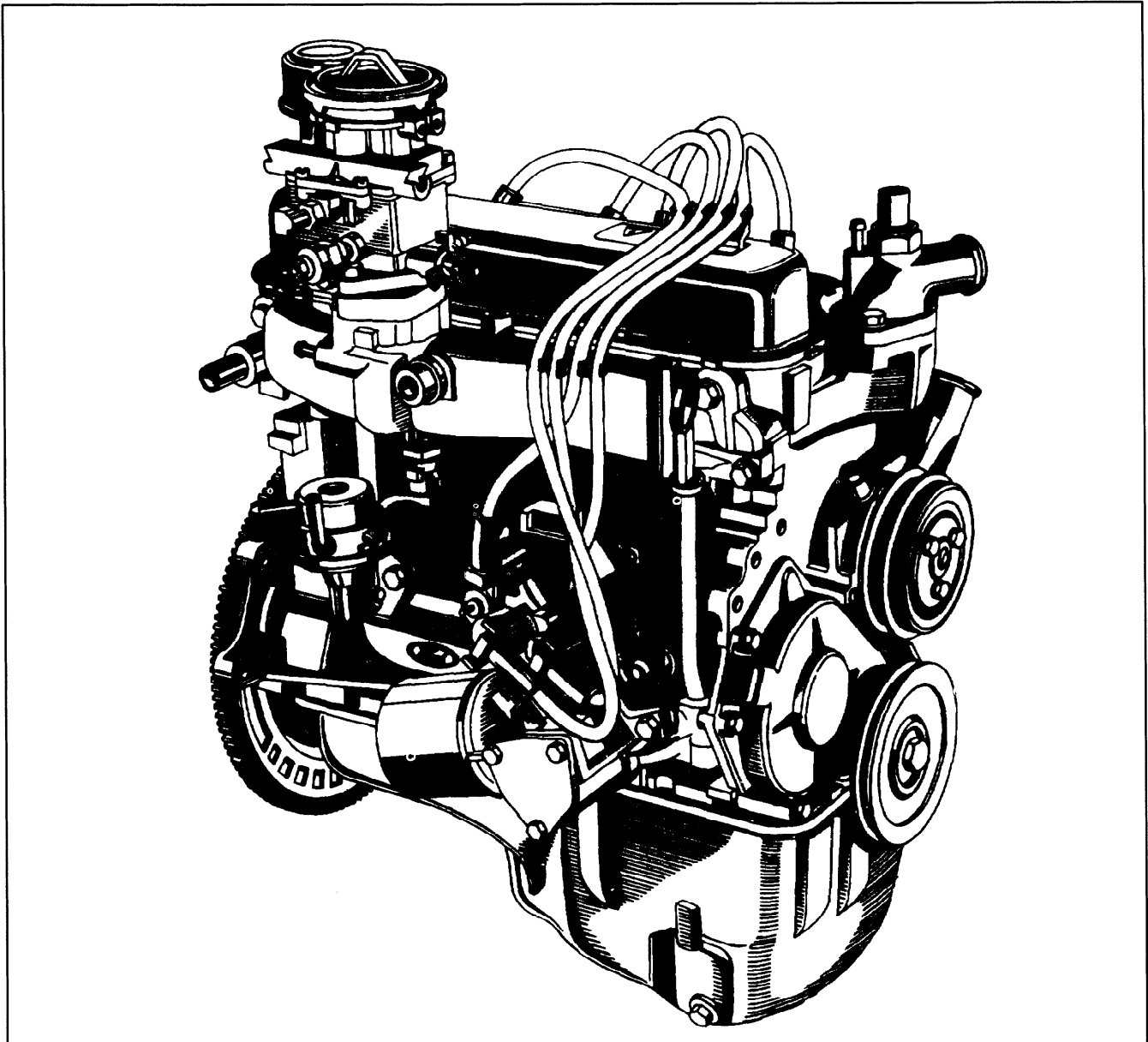
The oil pump is bolted onto the outside of the cylinder block below the distributor. The full-flow oil filter is angled downwards and mounted directly on the oil pump.

The crankshaft is mounted in five bearings. The crankshaft end play is determined by thrust half rings at the center main bearing.

The front crankshaft journal is sealed by means of an oil seal installed in the timing cover.

The rear crankshaft journal is sealed by means of an oil seal pressed into an oil seal carrier.

The timing cover has cast ignition timing degree marks or a TDC reference pointer. A notch on the crankshaft belt pulley is used in conjunction with either the degree or TDC reference points when installing the distributor and checking timing. They are visible on the front, left side of the engine.



DESCRIPTION (Continued)

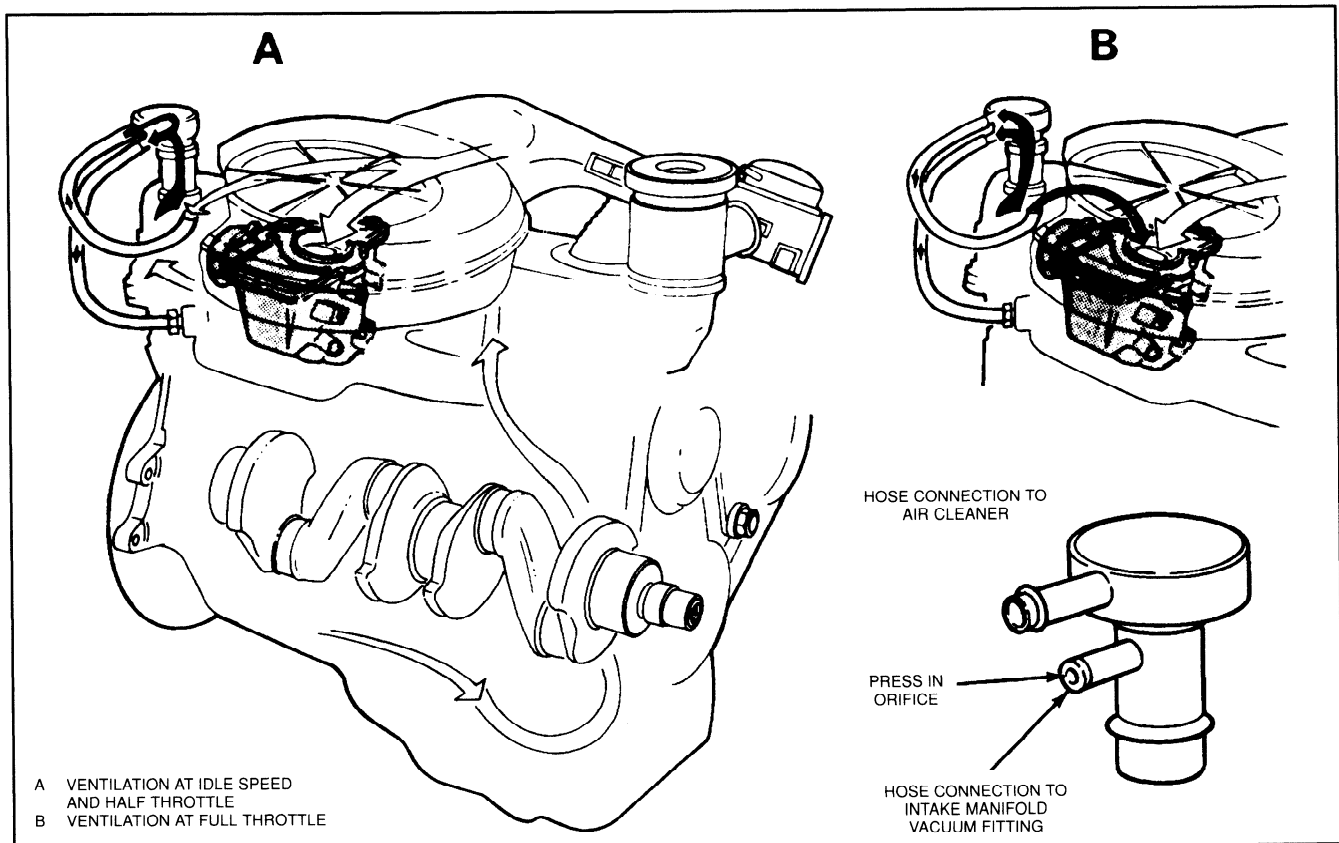
The spark plugs have a tapered seat without a sealing ring.

Engine Ventilation:

The ventilation system consists of an oil filler cap with two connecting hoses, one of which passes to the inlet manifold and the other to the air cleaner.

The result is a closed ventilation system in which the fumes from the crankcase pass back via the inlet manifold into the cylinders for combustion.

Gas flow is regulated by a calibrated orifice in the oil filler cap.



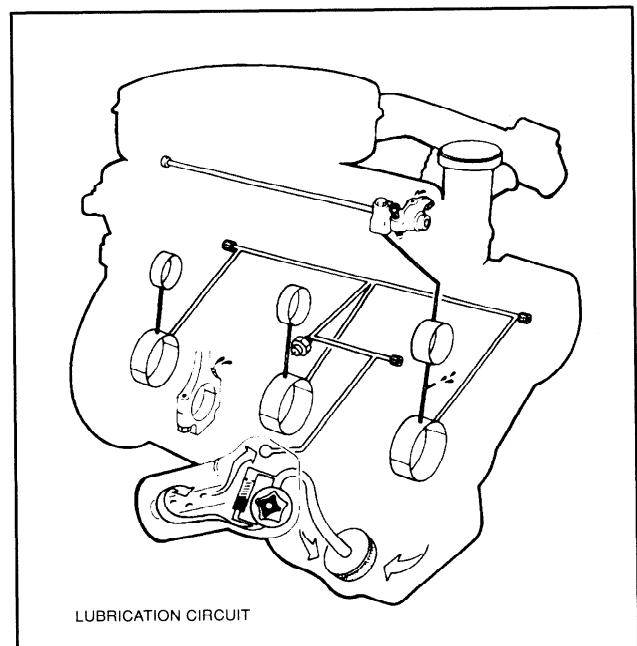
Lubrication Circuit:

An eccentric twin-rotor oil pump draws oil via a strainer from the sump and forces it into the full-flow oil filter.

Oil pressure is regulated by a relief valve inside the pump. The filtered oil passes through the center of the filter element, then along a short passage (right hand side of the engine) to the oil pressure switch and through a transverse bore to the main oil gallery (left hand side of the engine).

The crankshaft main bearings are fed directly from the main oil gallery and the camshaft bearings are linked, in turn for their lubrication with the front, center and rear main bearings. Each of the rod journals are supplied with oil by the nearest main bearing through oblique passages.

An oil hole in the connecting rod ensures splash lubrication of the piston pins and the trailing side of the cylinders. Timing chain and sprockets are also lubricated via a splash hole. The camshaft front bearing journal has a machined groove through which oil is intermittently forced to the rocker shaft (via passages in cylinder block and cylinder head).

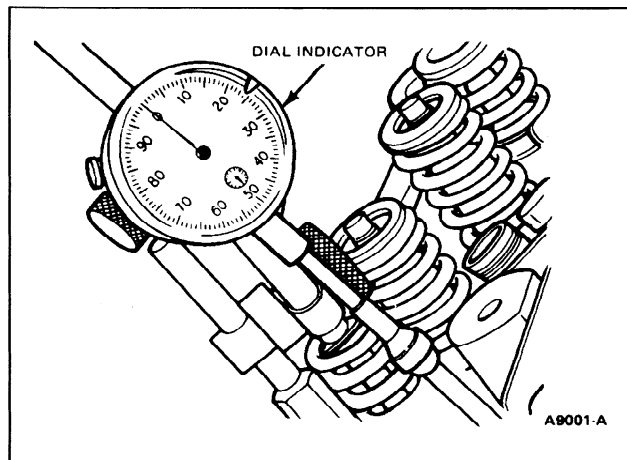


DIAGNOSIS AND TESTING

Camshaft Lobe Lift

Check the lift of each lobe in consecutive order and make a note of the readings.

1. Remove the air cleaner and the valve rocker arm cover.
2. Remove the valve rocker arm shaft assembly as detailed in the pertinent section.
3. Make sure the push rod is in the valve lifter socket. Install a dial indicator in such a manner as to have the ball socket adapter of the indicator on the end of the push rod and in the same plane as the push rod movement.



4. Connect an auxiliary starter switch in the starting circuit. Crank the engine with the ignition switch OFF. Bump the crankshaft over until the tappet or lifter is on the base circle of the camshaft lobe. At this point, the push rod will be in its lowest position.
5. Zero the dial indicator. Continue to rotate the crankshaft slowly until the push rod is in the fully raised position (highest indicator reading).
6. Compare the total lift recorded on the indicator with specifications.
7. To check the accuracy of the original indicator reading, continue to rotate the crankshaft until the indicator reads zero. **If the lift on any lobe is below specified wear limits, the camshaft and the valve lifters operating on the worn lobe(s) must be replaced.**
8. Remove the dial indicator and auxiliary starter switch.
9. Install the rocker arm shaft assembly as detailed under Removal and Installation.
10. Install the valve rocker arm cover and the air cleaner.

Compression Test

Compression Gauge Check

1. Be sure the crankcase is at the proper level and the battery is properly charged. Operate the engine for a minimum of 30 minutes at 1200 rpm or until the engine is at normal operating temperature. Turn the ignition switch off; then remove all the spark plugs.
2. Set the carburetor throttle plates and choke plate in the wide open position.
3. Install a compression gauge in No. 1 cylinder.
4. Install an auxiliary starter switch in the starting circuit. Using the auxiliary starter switch, crank the engine (with the ignition switch off) at least five compression strokes and record the highest reading.

Note the approximate number of compression strokes required to obtain the highest reading.

5. Repeat the test on each cylinder as was required to obtain the highest reading on the No. 1 cylinder.

Test Conclusion

The indicated compression pressures are considered normal if the lowest reading cylinder is within 75% of the highest. Refer to the following example.

Seventy-five percent of 140, the highest cylinder reading, is 105. Therefore, cylinder No. 7 being less than 75% of cylinder No. 3 indicates an improperly seated valve or worn or broken piston rings.

If one or more cylinders read low, squirt approximately 15 ml (one tablespoon) of engine oil on top of the pistons in the low reading cylinders. Repeat compression pressure check on these cylinders.

1. If compression improves considerably, the piston rings are at fault.
2. If compression does not improve, valves are sticking or seating poorly.
3. If two adjacent cylinders indicate low compression pressures and squirting oil on the pistons does not increase the compression, the cause may be a cylinder head gasket leak between the cylinders. Engine oil and/or coolant in the cylinders could result from this problem.

It is recommended the following quick reference chart be used when checking cylinder compression pressures. The chart has been calculated so that the lowest reading number is 75% of the highest reading.

Example

After checking the compression pressures in all cylinders, it was found that the highest reading obtained was 196 psi. The lowest pressure reading was 155 psi. The engine is within specifications and the compression is considered satisfactory.

DIAGNOSIS AND TESTING (Continued)

Maximum		Minimum		Maximum		Minimum		Maximum		Minimum	
kPa	PSI	kPa	PSI	kPa	PSI	kPa	PSI	kPa	PSI	kPa	PSI
924	134	696	101	1200	174	903	131	1476	214	1103	160
938	136	703	102	1214	176	910	132	1489	216	1117	162
952	138	717	104	1227	178	917	133	1503	218	1124	163
965	140	724	105	1241	180	931	135	1517	220	1138	165
979	142	738	107	1255	182	938	136	1531	222	1145	166
993	144	745	108	1269	184	952	138	1544	224	1158	168
1007	146	758	110	1282	186	965	140	1558	226	1165	169
1020	148	765	111	1296	188	972	141	1572	228	1179	171
1034	150	779	113	1310	190	979	142	1586	230	1186	172
1048	152	786	114	1324	192	993	144	1600	232	1200	174
1062	154	793	115	1338	194	1000	145	1613	234	1207	175
1076	156	807	117	1351	196	1014	147	1627	236	1220	177
1089	158	814	118	1365	198	1020	148	1641	238	1227	178
1103	160	827	120	1379	200	1034	150	1655	240	1241	180
1117	162	834	121	1393	202	1041	151	1669	242	1248	181
1131	164	848	123	1407	204	1055	153	1682	244	1262	183
1145	166	855	124	1420	206	1062	154	1696	246	1269	184
1158	168	869	126	1434	208	1076	156	1710	248	1282	186
1172	170	876	127	1448	210	1083	157	1724	250	1289	187
1186	172	889	129	1462	212	1089	158				

CA1005-A

Crankshaft End Play

1. Force the crankshaft toward the rear of the engine.
2. Install a dial indicator so that the contact point rests against the crankshaft flange and the indicator axis is parallel to the crankshaft axis.
3. Zero the dial indicator. Push the crankshaft forward and note the reading on the dial.
4. If the end play exceeds the wear limit, replace the thrust washers. If the end play is less than the minimum limit, inspect the thrust bearing faces for scratches, burrs, nicks, or dirt.

Flywheel Face Runout

Install a dial indicator so that the indicator point bears against the flywheel face. Turn the flywheel, making sure that it is full forward or rearward so that the crankshaft end play will not be indicated as flywheel runout.

If the clutch face runout exceeds specifications, remove the flywheel and check for burrs between the flywheel and the face of the crankshaft mounting flange. If no burrs exist, check the runout of the crankshaft mounting flange. Replace the flywheel, or machine the crankshaft-flywheel mounting face sufficiently to true up the surface if the mounting flange runout exceeds specifications. Replace it or reinstall it on the flywheel.

Camshaft End Play

Push the camshaft toward the rear of the engine. Install a dial indicator so that the indicator point is on the camshaft sprocket attaching screw or gear hub. Zero the dial indicator. Position a large screwdriver between the camshaft sprocket and the cylinder head. Pull the camshaft forward and release it. Compare the dial indicator reading with specifications. If the end play is excessive, replace the thrust plate retaining the camshaft. Remove the dial indicator.

OVERHAUL

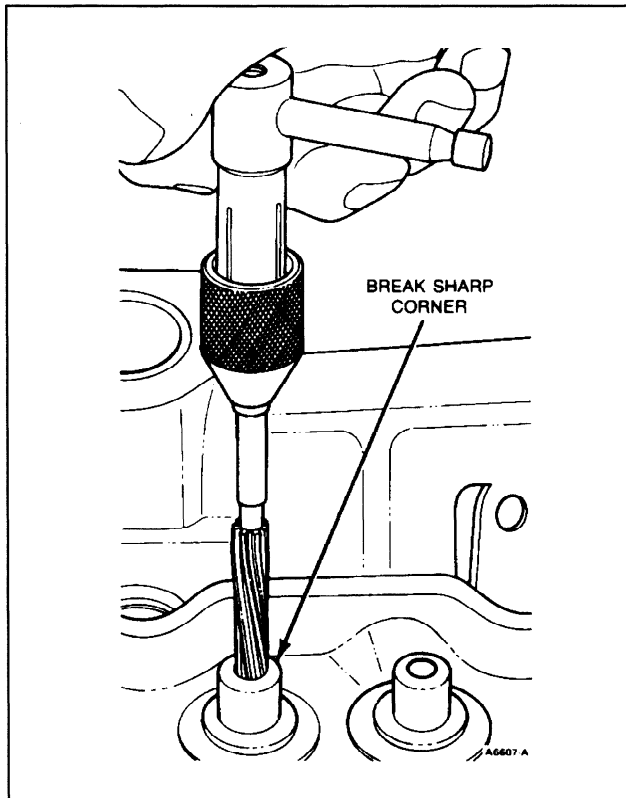
Cylinder Head

Replace the head if it is cracked. **Do not plane or grind more than 0.25 mm (0.010 inch) from the cylinder head gasket surface.** Remove all burrs or scratches with an oil stone.

Reaming Valve Guides

If it becomes necessary to ream the valve guide, to an oversize valve always use the reamer in sequence.

Always reface the valve seat after the valve guide has been reamed, and use a suitable scraper to break the sharp corner (ID) at the top of the valve guide.



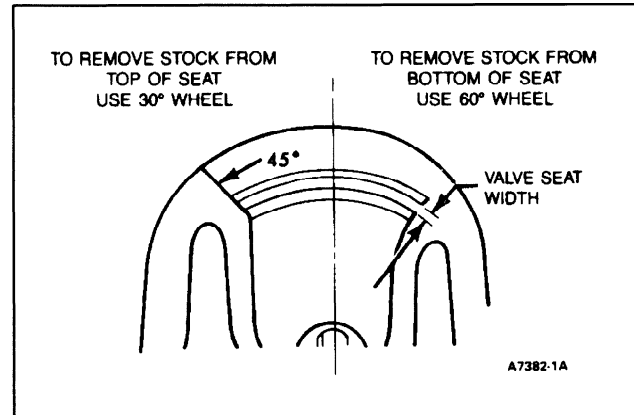
Refacing Valve Seats

Refacing of the valve seat should be closely coordinated with the refacing of the valve face so that the finished seat and valve face will be concentric and the specified interference fit will be maintained. This is important so that the valve and seat will have a compression-tight fit. Be sure that the refaced grinding wheels are properly dressed.

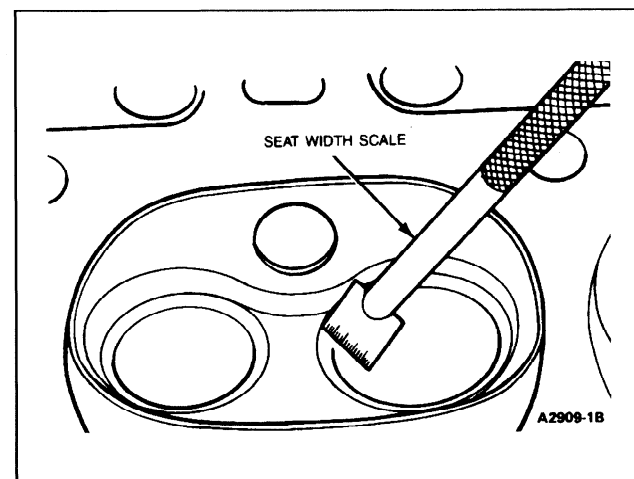
Grind the valve seats to a true 45 degree angle. Remove only enough stock to clean up pits and grooves or to correct the valve seat runout. After the seat has been refaced, use a seat width scale or a machinist scale to measure the seat width. Narrow the seat, if necessary, to bring it within specifications.

If the valve seat width exceeds the maximum limit, remove enough stock from the top edge and/or bottom edge of the seat to reduce the width to specifications.

On the valve seats of all engines, use a 60 degree angle grinding wheel to remove stock from the bottom of the seats (raise the seats) and use a 30 degree angle wheel to remove stock from the top of the seats (lower the seats).



The finished valve seat should contact the approximate center of the valve face. It is good practice to determine where the valve seat contacts the face. To do this, coat the seat with Prussian blue and set the valve in place. Rotate the valve with light pressure. If the blue is transferred to the center of the valve face, the contact is satisfactory. If the blue is transferred to the top edge of the valve face, lower the valve seat. If the blue is transferred to the bottom edge of the valve face, raise the valve seat.



Valves

Minor pits, grooves, etc., may be removed. Discard valves that are severely damaged, if the face runout cannot be corrected by refinishing or stem clearance exceeds specifications. Discard **any excessively worn or damaged valve train parts.**

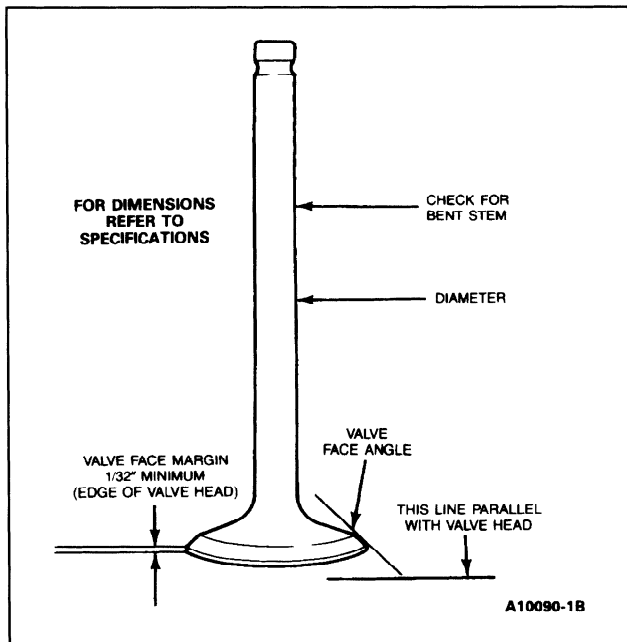
Refacing Valves

The valve refacing operation should be closely coordinated with the valve seat refacing operations so that the finished angles of the valve face and of the valve seat will be to specifications and provide a compression-tight fit. Be sure that the refaced grinding wheels are properly dressed.

OVERHAUL (Continued)

Under no circumstances should the faces of aluminized intake valves be ground or the valves lapped in as this will remove the diffused aluminum coating and reduce the valves' wear and heat resistant properties. If the valve faces are worn or pitted it will be necessary to install new valves and to resurface the valve seats or, alternatively, lap the seats using dummy valves. The exhaust valves may be lapped in or the faces ground if required.

If the valve face runout is excessive and/or to remove pits and grooves, reface the valves to a true 44 degree angle. Remove only enough stock to correct the runout or to clean up the pits and grooves. If the edge of the valve head is less than 0.8 mm (1/32 inch) thick after grinding, replace the valve as the valve will run too hot in the engine. **The interference fit of the valve and seat should not be lapped out. Remove all grooves or score marks from the end of the valve stem, and chamfer it as necessary. Do not remove more than 0.25 mm (0.010 inch) from the end of the valve stem.**



If the valve and/or valve seat has been refaced, it will be necessary to check the clearance between the rocker arm pad and the valve stem with the valve train assembly installed in the engine.

Select Fitting Valves

If the valve stem to valve guide clearance exceeds the wear limit, ream the valve guide for the **next** oversize valve stem. Valves with oversize stem diameter are available for service.

Always reface the valve seat after the guide has been reamed. Refer to Reaming Valve Guides.

Camshaft Repair

Remove light scuffs, scores or nicks from the camshaft machined surfaces with a smooth oil stone.

Crankshaft

Dress minor scores with an oil stone. If the journals are severely marred or exceed the wear limit, they should be refinished to size for the next undersize bearing.

Refinishing Journals

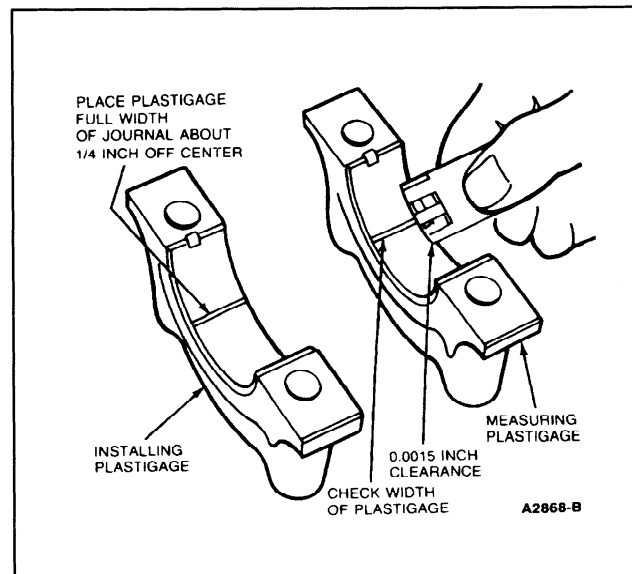
Refinish the journals to give the proper clearance with the next undersize bearing. If the journal will not clean up to maximum undersize bearing available, replace the crankshaft.

Always reproduce the same journal shoulder radius that existed originally. Too small a radius will result in fatigue failure of the crankshaft. Too large a radius will result in bearing failure due to radius ride of the bearing.

After refinishing the journals, chamfer the oil holes; then polish the journal with a No. 320 grit polishing cloth and engine oil. Crocus cloth may also be used as a polishing agent.

Fitting Main or Connecting Rod Bearings With Plastigage

1. Clean crankshaft journals. Inspect journals and thrust faces (thrust bearing) for nicks, burrs or bearing pickup that would cause premature bearing wear. **When replacing standard bearings with new bearings, it is good practice to fit the bearing to minimum specified clearance.** If the desired clearance cannot be obtained with a standard bearing, try a 0.05 mm (0.002 inch) undersize in combination with a standard bearing to obtain the proper clearance.
2. If fitting a main bearing in the chassis, **position a jack under the counterweight adjoining bearing which is being checked. Support crankshaft with jack so its weight will not compress Plastigage and provide an erroneous reading.**
3. Place a piece of Plastigage on bearing surface across full width of bearing cap and about 6.4 mm (1/4 inch) off center.



OVERHAUL (Continued)

4. Install cap and torque bolts to specifications. Do not turn crankshaft while Plastigage is in place.
5. Remove cap. Using Plastigage scale, check width of Plastigage at widest point to get minimum clearance. Check at narrowest point to get maximum clearance. Difference between readings is taper of journals.
6. If clearance exceeds specified limits on the connecting rod bearings, try a 0.05 mm (0.002 inch) undersize bearing in combination with the standard bearings. Bearing clearance must be within specified limits. If 0.05 mm (0.002 inch) undersize main bearings are used on more than one journal, be sure they are all installed in cylinder block side of bearing. If standard and 0.05 mm (0.002 inch) undersize bearings do not bring clearance within desired limits, refinish crankshaft journal, then install undersize bearings.
7. After bearing has been fitted, remove Plastigage, apply light coat of engine oil to journal and bearings. Install bearing cap. Torque cap bolts to specifications.
8. Repeat procedure for remaining bearings that require replacement.

Pistons, Pins and Rings

Fitting Pistons

Pistons are available for service in standard sizes and the oversizes shown in the parts list.

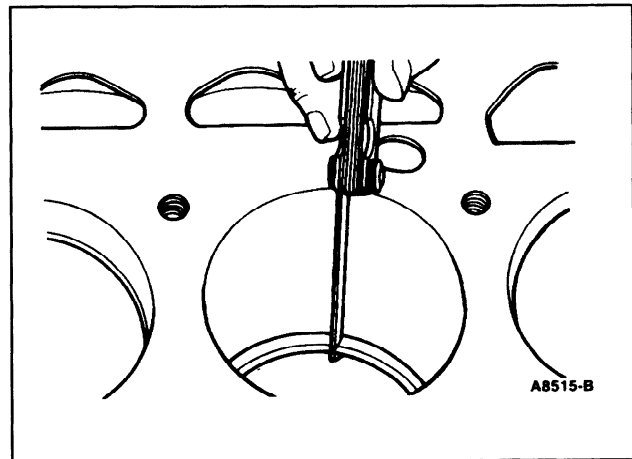
Measure the piston diameter to ensure that the specified clearance is obtained. It may be necessary periodically to use another piston that is either slightly larger or smaller to achieve the specified clearance. **If none can be fitted, refinish the cylinder to provide the proper clearance for the piston. When a piston has been fitted, mark it for assembly in the cylinder to which it was fitted. If the taper, out-of-round and piston to cylinder bore clearance conditions of the cylinder bore are within specified limits, new piston rings will give satisfactory service. If new rings are to be installed in a used cylinder that has not been refinished, remove the cylinder wall glaze (Refer to Cylinder Block, Refinishing Cylinder Walls). Be sure to clean the cylinder bore thoroughly.**

1. Calculate the size piston to be used by taking a cylinder bore check. Follow the procedures outlined under Cleaning and Inspection.
2. Select the proper size piston to provide the desired clearance (refer to the specifications). The piston should be measured 57.2 mm (2-1/4 inches) below the dome and at 90° to the piston pin bore.
3. Make sure the piston and cylinder block are at room temperature 21 degrees C (70 degrees F). **After any refinishing operation allow the cylinder bore to cool, and make sure the piston and bore are clean and dry before the piston fit is checked.**

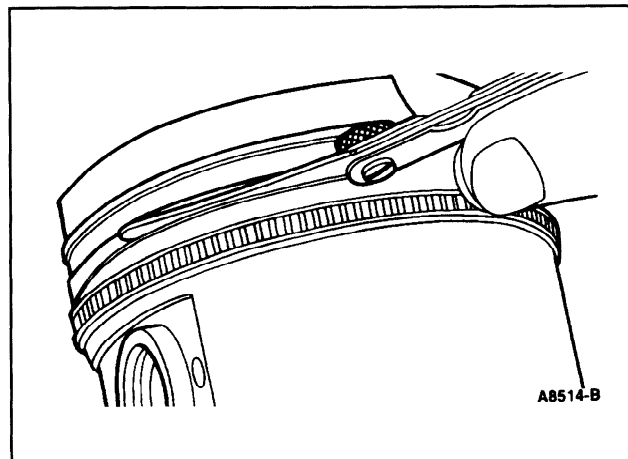
Fitting Piston Rings

Three piston rings are fitted, two compression and one oil control ring.

1. Select the proper ring set for the size cylinder bore.
2. Position the ring in the cylinder bore in which it is going to be used.
3. Push the ring down into the bore area where normal ring wear is not encountered.
4. Use the head of a piston to position the ring in the bore so that the ring is square with the cylinder wall. **Use caution to avoid damage to the ring or cylinder bore.**
5. Measure the gap between the ends of the ring with a feeler gauge. If the ring gap is less or greater than the specified limits, try another ring set.



6. Check the ring side clearance of the compression rings with a feeler gauge inserted between the ring and its lower land. The gauge should slide freely around the entire ring circumference without binding. Any wear that occurs will form a step at the inner portion of the lower land. **If the lower lands have high steps, the piston should be replaced.**



OVERHAUL (Continued)

Fitting Piston Pins

The piston pins are selected to give the correct fit in the piston pin bore and bushing in the connecting rod. Pistons are only supplied in service complete with the piston pin, to ensure the correct fit. The piston pins should not be interchanged.

Valve Rocker Arm and/or Shaft Assembly

Dress up minor surface defects on the rocker arm shaft and in the rocker arm bore with a hone.

If the pad at the valve end of the rocker arm has a grooved radius, replace the rocker arm. **Do not attempt to true this surface by grinding.**

Push Rods

Following the procedures under Push Rod Inspection, check the push rods for straightness.

If the runout exceeds the maximum limit at any point, discard the rod. **Do not attempt to straighten push rods.**

Cylinder Block

Refinishing Cylinder Walls

Honing is recommended for refinishing cylinder walls **only** when the walls have minor scuffs or scratches, or for fitting pistons to the specified clearance. The grade of hone to be used is determined by the amount of metal to be removed. Follow the instructions of the hone manufacturer. If coarse stones are used to start the honing operation, leave enough material so that all hone marks can be removed with the finishing hone which is used to obtain the proper piston clearance. Cylinder walls that are severely marred and/or worn beyond the specified limits should be refinished. **Before any cylinder is refinished, all main bearing caps must be in place and tightened to the proper torque so that the crankshaft bearing bores will not become distorted from there finishing operation.** Refinish only the cylinder or cylinders that require it. All pistons are the same weight, both standard and oversize; therefore, various sizes of pistons can be used without upsetting engine balance. Refinish the cylinder with the most wear first to determine the maximum oversize. If the cylinder will not clean up when refinished for the maximum oversize piston recommended, replace the block. Refinish the cylinder to within approximately 0.04 mm (0.0015 inch) of the required oversize diameter. This will allow enough stock for the final step of honing so that the correct surface finish and pattern are obtained. For the proper use of the refinishing equipment follow the instructions of the manufacturer. Only experienced personnel should be allowed to perform this work. Use a motor-driven, spring pressure-type hone at a speed of 300-500 rpm. Hones of grit sizes 180-220 will normally provide the desired bore surface finish of 15/32 RMS. When honing the cylinder bores use a lubricant mixture of equal parts of kerosene and SAE No. 20 motor oil. Operate the hone in such a way to produce a cross-hatch finish on the cylinder bore. The

cross-hatch pattern should be at an angle of approximately 30 degrees to the cylinder bore. After the final operation in either of the two refinishing methods described and prior to checking the piston fit, thoroughly clean and oil the cylinder walls. Mark the pistons to correspond to the cylinders in which they are to be installed. When the refinishing of all cylinders that require it has been completed and all pistons are fitted, thoroughly clean the entire block and oil the cylinder walls.

Repairing Sand Holes or Porous Engine Castings

Porosity or sand hole(s) which will cause oil seepage or leakage can occur with modern casting processes. A complete inspection of engine and transmission should be made. If the leak is attributed to the porous condition of the cylinder block or sand hole(s), repairs can be made with metallic plastic (part No. C6AZ-19554-A). **Do not repair cracks with this material.** Repairs with this metallic plastic must be confined to those cast iron engine component surfaces where the inner wall surface is not exposed to engine coolant pressure or oil pressure. For example:

1. Cylinder block surfaces extending along the length of the block, upward from the oil pan rail to the cylinder water jacket but not including machined areas.
2. Lower rear face of the cylinder block.
3. Intake manifold casting.
4. Cylinder head, along the rocker arm cover gasket surface.

The following procedure should be used to repair porous areas or sand holes in cast iron.

1. Clean the surface to be repaired by grinding or rotary filing to a clean bright metal surface. Chamfer or undercut the hole or porosity to a greater depth than the rest of the cleaned surface. Solid metal must surround the hole. Openings larger than 6.4 mm (1/4 inch) should not be repaired using metallic plastic. Openings in excess of 6.4 mm (1/4 inch) can be drilled, tapped and plugged using common tools. Clean the repair area thoroughly. Metallic plastic will not stick to a dirty or oily surface.
2. Mix the metallic plastic base and hardener as directed on the container. Stir thoroughly until uniform.
3. Apply the repair mixture with a suitable clean tool, (putty knife, wood spoon, etc.) forcing the epoxy into the hole or porosity.
4. Allow the repair mixture to harden. This can be accomplished by two methods, heat cure with a 121 degrees C (250 degrees F) lamp placed 254 mm (10 inches) from the repaired surface, or air dry for 10-12 hours at temperatures above 10 degrees C (50 degrees F).
5. Sand or grind the repaired area to blend with the general contour of the surrounding surface.
6. Paint the surface to match the rest of the block.

CLEANING AND INSPECTION

The cleaning and inspection procedures are for a complete engine overhaul; therefore, for partial engine overhaul or parts replacement, follow the pertinent cleaning or inspection procedure.

Intake Manifold

Cleaning

Remove all gasket material from the machined surfaces of the manifold. Clean the manifold in a suitable solvent and dry it with compressed air.

Inspection

Inspect the manifold for cracks, damaged gasket surfaces, or other defects that would make it unfit for further service. Replace all studs that are stripped or otherwise damaged.

Remove all filings and foreign matter that may have entered the manifold as a result of repairs.

Exhaust Manifolds

Cleaning

Remove all gasket material from the manifolds.

Inspection

Inspect the cylinder head joining flanges of the exhaust manifold for evidence of exhaust gas leaks.

Inspect the manifolds for cracks, damaged gasket surfaces, or other defects that would make them unfit for further service.

Valve Rocker Arm and/or Shaft Assembly

Cleaning

Clean all the parts thoroughly. Make sure all oil passages are open.

Make sure the oil passage in the rocker arm is open.

Inspection

On rocker arm shaft assemblies, check the clearance between each rocker arm and the shaft by checking the ID of the rocker arm bore and the OD of the shaft. If the clearance between any rocker arm and the shaft exceeds the wear limit, replace the shaft and/or the rocker arm. Inspect the shaft and the rocker arm bore for nicks, scratches, scores or scuffs.

Inspect the pad at the valve end of the rocker arm for indications of scuffing or abnormal wear. If the pad is grooved, replace the rocker arm. **Do not attempt to true this surface by grinding.**

Check the adjusting nut(s) torque. If not within specifications, replace the nut(s). Check the rocker arm pad and fulcrum seat for excessive wear, cracks, nicks or burrs.

Push Rods

Cleaning

Clean the push rods in a suitable solvent. Blow dry the push rod with compressed air.

Inspection

Check the ends of the push rods for nicks, grooves, roughness or excessive wear.

The push rods can be visually checked for straightness while they are installed in the engine by rotating them with the valve closed. They also can be checked with a dial indicator.

If the push rod is visibly bent, it should be replaced.

Cylinder Heads

Cleaning

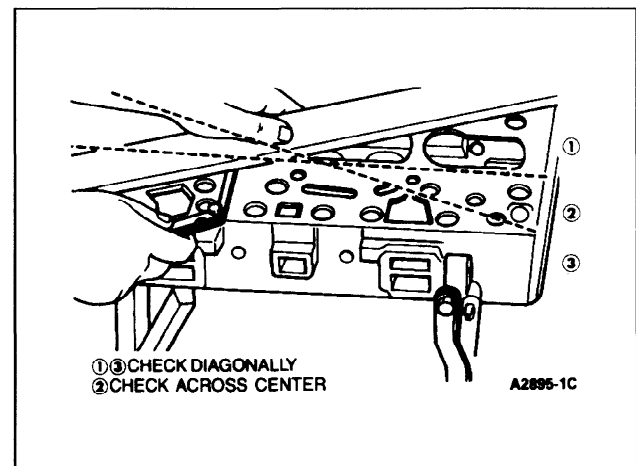
With the valves installed to protect the valve seats, remove deposits from the combustion chambers and valve heads with a scraper and a wire brush. Be careful not to damage the cylinder head gasket surface. After the valves are removed, clean the valve guide bores with a valve guide cleaning tool. Use cleaning solvent to remove dirt, grease and other deposits. Clean all bolt holes. Remove all deposits from the valves with a fine wire brush or buffing wheel.

Inspection

Check the cylinder head for cracks and inspect the gasket surface for burrs and nicks. Replace the head if it is cracked.

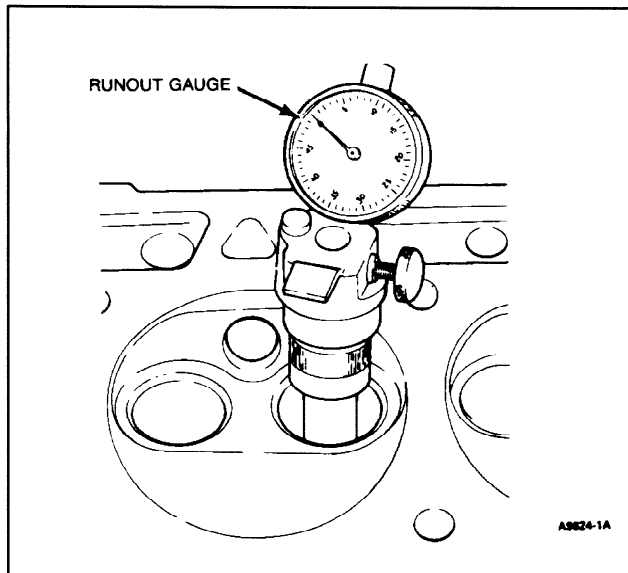
The following inspection procedures are for a cylinder head that is to be completely overhauled. For individual repair operations, use only the pertinent inspection procedure.

When a cylinder head is removed because of gasket leaks, check the flatness of the cylinder head gasket surface for conformance to specifications. If necessary to refinish the cylinder head gasket surface, **do not plane or grind off more than 0.25 mm (0.010 inch).**



CLEANING AND INSPECTION (Continued)

Check the valve seat runout with an accurate gauge. Follow the instructions of the gauge manufacturer. If the runout exceeds the wear limit, reface the valve and valve seat. Measure the valve seat width. Reface any valve seat whose width is **not within specifications**.



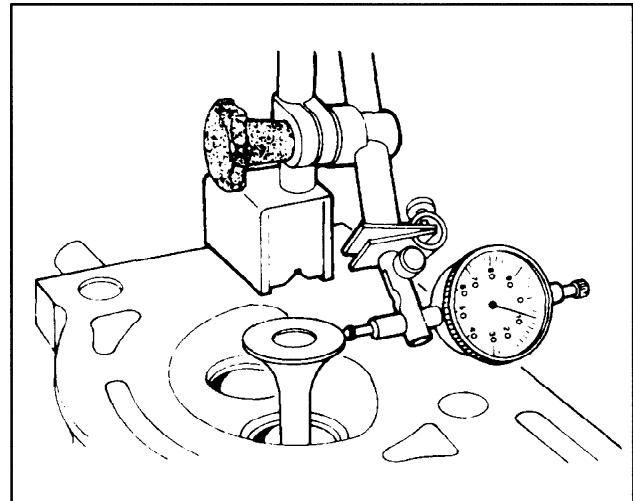
Inspect the valve face and the edge of the valve head for pits, grooves, scores or other damage. Inspect the stem for a bent condition and the end of the valve head for pits, grooves, scores or other wear. Inspect the stem for a bent condition and the end of the stem for grooves or scores. Check the valve head for signs of burning, erosion, warpage and cracking. Minor pits, grooves, etc., may be removed. Discard valves that are severely damaged.

Inspect the valve spring, valve spring retainers, locks and sleeves for wear or damage. Discard any visually damaged parts.

Check the valve stem to valve guide clearance of each valve in its respective valve guide with the tool shown below, or its equivalent. Use a flat end indicator point.

With the cylinder head gasket face up, slide a new standard intake or exhaust valve into the valve guide to be checked until the tip of the valve stem is flush with the top of the valve guide.

Mount a dial test indicator on the cylinder head by the valve to be checked.

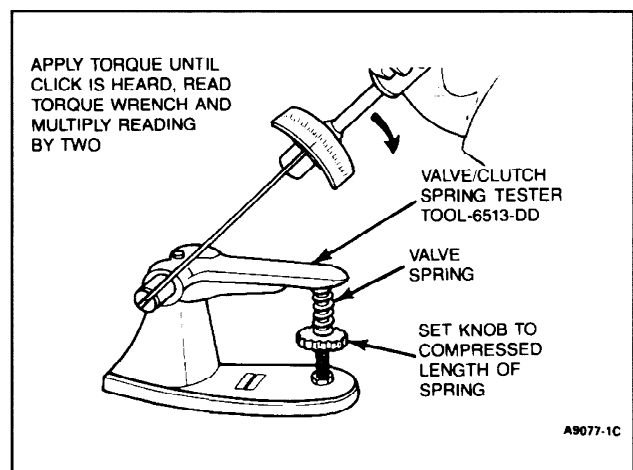


Position the plunger of the dial test indicator on the edge of the valve head and measure the valve head movement by applying lateral pressure to the valve. If the valve head movement is greater than the values given below, the valve guide in question must be reamed using the appropriate reamer, and a new oversize valve installed.

Maximum permissible valve head movement values for the above test procedure:

Intake valve	0.50 mm (0.020 in.)
Exhaust valve	0.60 mm (0.024 in.)

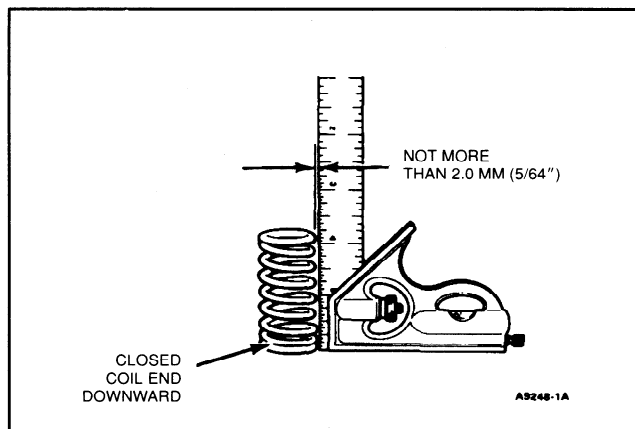
Check the springs for proper pressure at the specified spring lengths. (Tool 6513-DD.) **Manually rotating the valve spring assemblies while installed in the engine, must not be used to determine good and/or bad valve springs.** Weak valve springs cause poor engine performance. Replace any spring not within specifications.



CLEANING AND INSPECTION (Continued)

Check each spring for squareness, using a steel square and a flat surface. Stand the spring and square on end on the flat surface. Slide the spring up to the square. Revolve the spring slowly and observe the space between the top coil of the spring and the square. The out-of-square limits are 2 mm (5/64 inch).

Follow the same procedure to check new valve springs before installation. **Make certain the proper spring (color coded) is installed.**



Tappets

Cleaning

Thoroughly clean the tappets in cleaning solvent and wipe them with a clean lint-free cloth.

Inspection

Check the tappets for wear or scores. Check the bottom end of tappet to make sure that it has a slight convex. Replace tappets that are scored, worn, or if the bottom is not smooth. If the bottom surface is worn flat, it may be used with the original camshaft only.

Timing Chain and Sprockets

Cleaning

Clean all parts in solvent and dry them with compressed air. Lubricate the timing chain with engine oil before installing it on the sprockets.

Inspection

Inspect the chain for broken links. Inspect the sprockets for cracks and worn or damaged teeth. Replace all the components of the timing chain and sprocket assembly, if any one item needs replacement.

Camshaft

Cleaning

Clean the camshaft in solvent and wipe it dry.

Inspection

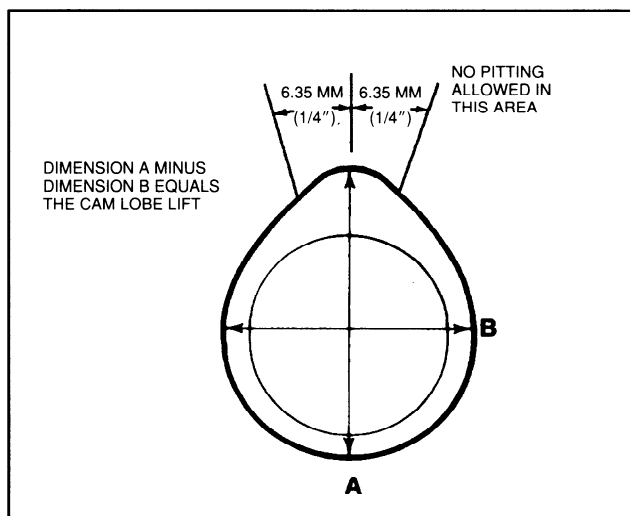
Inspect the camshaft lobes for scoring and signs of abnormal wear. Lobe pitting except in the general area

of the lobe toe is not detrimental to the operation of the camshaft; therefore, the camshaft should not be replaced unless the lobe lift loss has exceeded specifications or pitting has occurred in the lobe lift area.

The lift of the camshaft lobes can be checked with the camshaft installed in the engine or on centers. Refer to Camshaft Lobe Lift.

To measure the camshaft lobe lift proceed as follows:

1. Measure distance between the major (A-A) and minor (B-B) diameters of each cam lobe with a Vernier caliper and record the readings. The difference in the readings on each cam diameter is the lobe lift.



2. If the readings do not meet specification, replace the camshaft.

Camshaft Bores

Inspection

Check camshaft bores for size, taper, roundness, runout, and finish. If any of these dimensions exceeds the limits given in Specifications, install new camshaft bearings.

Crankshaft

Cleaning

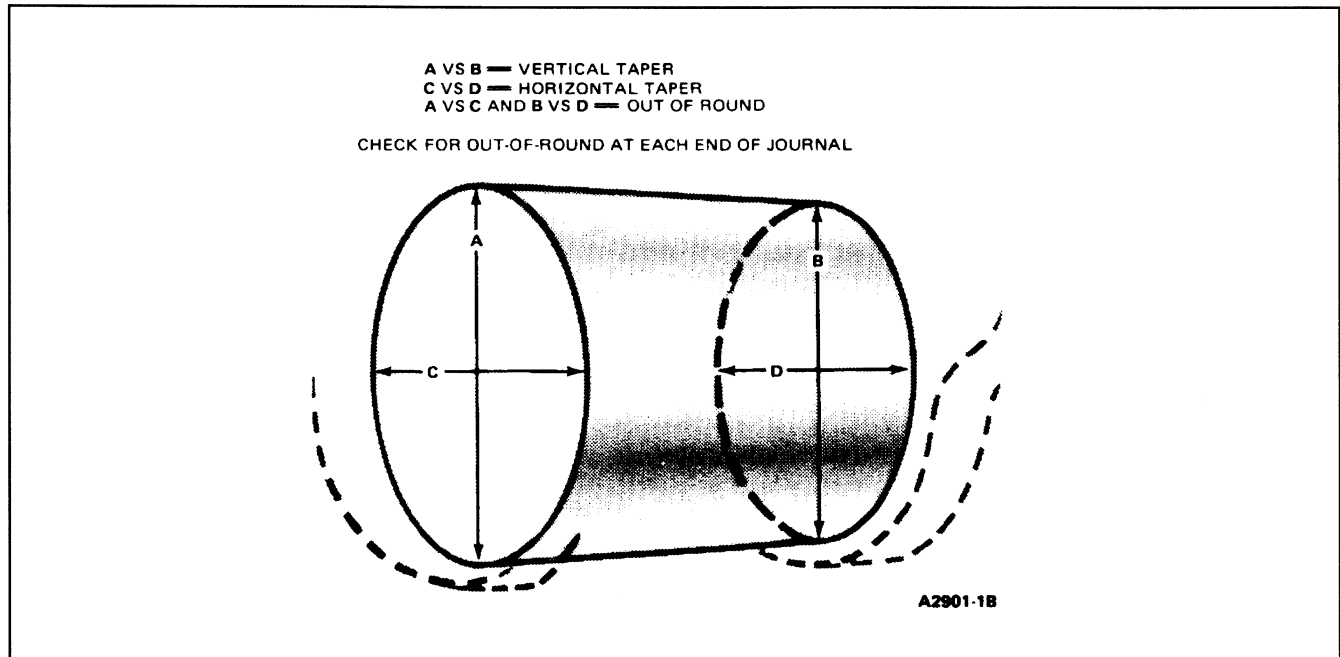
Handle the crankshaft with care to avoid possible fractures or damage to the finished surfaces. Clean the crankshaft with solvent, then blow out all oil passages with compressed air.

Inspection

Inspect the main and connecting rod journals for cracks, scratches, grooves or scores. Inspect the crankshaft oil seal surface for nicks, sharp edges or burrs that might damage the oil seal during installation or cause premature seal wear.

Measure the diameter of each journal in at least four places to determine an out-of-round, taper or undersize condition.

CLEANING AND INSPECTION (Continued)



Flywheel

Inspection

Inspect the flywheel for cracks, heat check, or other damage that would make it unfit for further service. Machine the friction surface of the flywheel if it is scored or worn. If it is necessary to remove more than 1.14 mm (0.045 inch) of stock from the original thickness, replace the flywheel.

Inspect the ring gear for worn, chipped, or cracked teeth. If the teeth are damaged, replace the ring gear.

With the flywheel installed on the crankshaft, check the flywheel face runout, following the procedure under Diagnosis and Testing.

Connecting Rods

Cleaning

Removing the bearing from the rod and cap. Identify the bearing if they are to be used again. Clean the connecting rod in solvent, including the rod bore and the back of the inserts. **Do not use a caustic cleaning solution.** Blow out all passages with compressed air.

Inspection

The connecting rods and related parts should be carefully inspected and checked for conformance to specifications. Various forms of engine wear caused by these parts can be readily identified.

A shiny surface on either pin boss side of the piston usually indicates that a connecting rod is bent.

Abnormal connecting rod bearing wear can be caused by either a bent connecting rod, worn or damaged crankpin, or a tapered connecting rod bore.

Twisted connecting rods will not create an identifiable wear pattern, but badly twisted rods will disturb the action of the entire piston, rings and connecting rod assembly and may be the cause of excessive oil consumption.

Inspect the connecting rods for signs of fractures and the bearing bores for out-of-round and taper. If the bore exceeds the recommended limits and/or if the connecting rod is fractured, it should be replaced. Check the ID of the connecting rod piston pin bore. If the pin bore in the connecting rod is larger than specifications, install a 0.05 mm (0.002 inch) oversize piston pin. First, prefit the oversize piston pin to the piston pin bore by reaming or honing the piston. Then, assemble the piston, piston pin and connecting rod following the procedures for assembly. **It is not necessary to ream or hone the pin bore in the connecting rod. Replace damaged connecting rod nuts and bolts. Check the connecting rods for bend or twist on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. If the bend and/or twist exceeds specifications, the connecting rod must be straightened or replaced.**

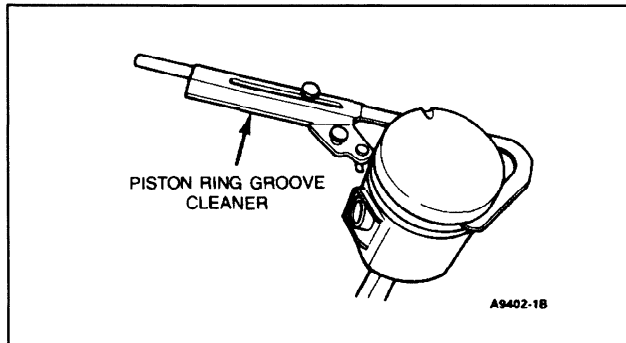
CLEANING AND INSPECTION (Continued)

Pistons, Pins and Rings

Cleaning

Remove deposits from the piston surfaces. Clean gum or varnish from the piston skirt, piston pins and rings with solvent. **Do not use a caustic cleaning solution or a wire brush to clean pistons.**

Clean the ring grooves with a ring groove cleaner. Make sure the oil ring slots (or holes) are clean.



Inspection

Carefully inspect the pistons for fractures at the ring lands, skirts and pin bosses, and for scuffed, rough or scored skirts. If the lower inner portion of the ring grooves has a high step, replace the piston. The step will interfere with ring operation and cause excessive ring side clearance.

Spongy, eroded areas near the edge of the top of the piston are usually caused by detonation or pre-ignition. A shiny surface on the thrust surface of the piston, offset from the centerline between the piston pin holes, can be caused by a bent connecting rod. Replace pistons that show signs of excessive wear, wavy ring lands or fractures or damage from detonation or pre-ignition.

Check the piston to cylinder bore clearance by measuring the piston and bore diameters. Refer to the specifications for the proper clearance. Refer to Cylinder Block Inspection for the bore measurement procedure. **Measure the OD of the piston with micrometers approximately 57.2 mm (2-1/4 inches) below the dome and at 90 degrees to the piston pin bore.** Check the ring side clearance.

Replace piston pins showing signs of fracture, etching or wear. Check the piston pin fit in the piston and rod. Refer to Piston and Connecting Rod Assembly.

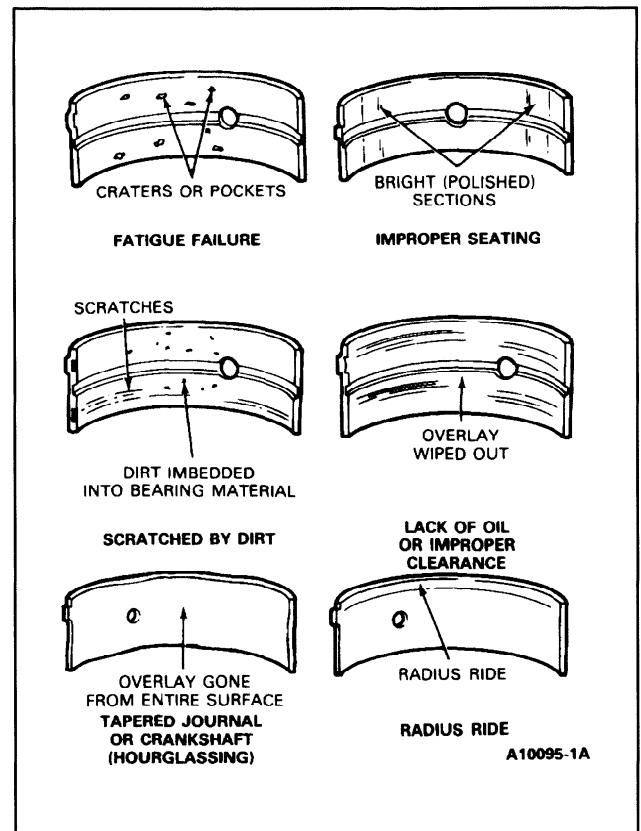
Check the OD of the piston pin and the ID of the pin bore in the piston. Replace any piston pin or piston that is not within specifications.

Replace all rings that are scored, broken, chipped or cracked. Check the end gap and side clearance. **Rings should not be transferred from one piston to another regardless of mileage or hours.**

Main and Connecting Rod Bearings

Cleaning

Clean the bearing inserts and caps thoroughly in solvent, and dry them with compressed air. **Do not scrape gum or varnish deposits from the bearing shells.**



Inspection

Inspect each bearing carefully. Bearings that have a scored, chipped, or worn surface should be replaced. The copper lead bearing base may be visible through the bearing overlay. This does not mean that the bearing is worn. It is not necessary to replace the bearing if the bearing clearance is within recommended limits. Check the clearance of bearings that appear to be satisfactory with Plastigage as detailed under Overhaul — Main and Connecting Rod Bearings.

Cylinder Block

Cleaning

After any cylinder bore repair operation, such as honing or deglazing, clean the bore(s) with soap or detergent and water. Then, thoroughly rinse the bore(s) with clean water to remove the soap or detergent, and wipe the bore(s) dry with a clean, lint-free cloth. Finally wipe the bore(s) with a clean cloth dipped in engine oil. If these procedures are not followed, rusting of the cylinder bore(s) may occur.

CLEANING AND INSPECTION (Continued)

If the engine is disassembled, thoroughly clean the block with solvent. Remove old gasket material from all machined surfaces. Remove all pipe plugs that seal oil passages; then clean out all the passages, bolt holes, etc., with compressed air. Make sure the threads in the cylinder head bolt holes are clean. Dirt in the threads may cause binding and result in a false torque reading. Use a tap to true up threads and to remove any deposits. Thoroughly clean the grooves in the crankshaft bearing and bearing retainers.

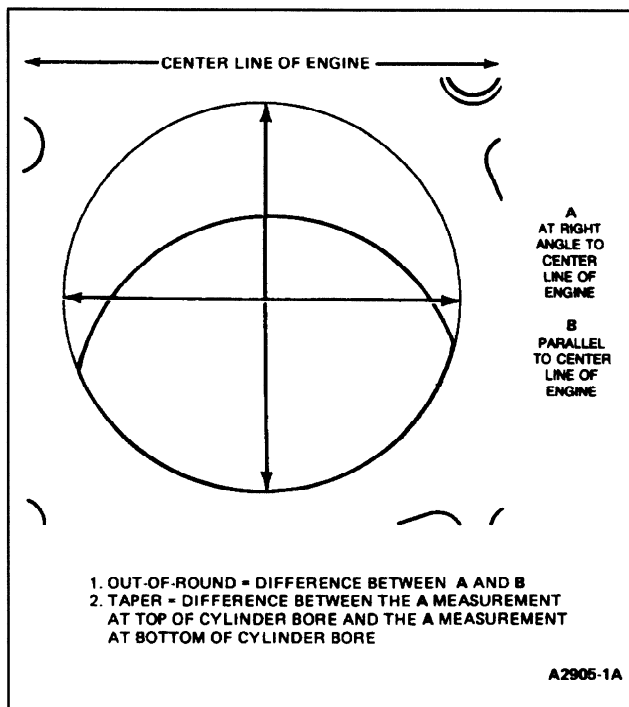
Inspection

After the block has been thoroughly cleaned, check it for cracks. Minute cracks not visible to the naked eye may be detected by coating the suspected area with a mixture of 25% kerosene and 75% light engine oil. Wipe the part dry and immediately apply a coating of zinc oxide dissolved in wood alcohol. If cracks are present, the coating will become discolored at the defective area. Replace the block if it is cracked.

Check all machined gasket surfaces for burrs, nicks, scratches and scores. Remove minor imperfections with an oil stone.

Replace all expansion-type plugs that show evidence of leakage.

Inspect the cylinder walls for scoring, roughness, or other signs of wear. Check the cylinder bore for out-of-round and taper. Measure the bore with an accurate bore gauge following the instructions of the manufacturer. Measure the diameter of each cylinder bore at the top, middle and bottom with the gauge placed at right angles and parallel to the centerline of the engine. **Use only the measurements obtained at 90 degrees to the engine centerline when calculating the piston to cylinder bore clearance.**



Refinish cylinders that are deeply scored and/or when out-of-round and/or taper exceed the wear limits. If the cylinder walls have minor surface imperfections, but the out-of-round and taper are within limits, it may be possible to remove the imperfections by honing the cylinder walls and installing new service piston rings providing the piston clearance is within specified limits.

Oil Pan

Cleaning

Scrape any dirt or metal particles from the inside of the pan. Scrape all old gasket material from the gasket surface. Wash the pan in a solvent and dry it thoroughly. Be sure all foreign particles are removed from below the baffle plate.

Inspection

Check the pan for cracks, holes, damaged drain plug threads, and a loose baffle or a damaged gasket surface.

Inspect for damage (uneven surface) at the bolt holes caused by over-torquing the bolts. Straighten surfaces as required. Repair any damage, or replace the pan if repairs cannot be made satisfactorily.

Oil Pump

Cleaning

Wash all parts in a solvent and dry them thoroughly with compressed air. Use a brush to clean the inside of the pump housing and the pressure relief valve chamber. Be sure all dirt and metal particles are removed.

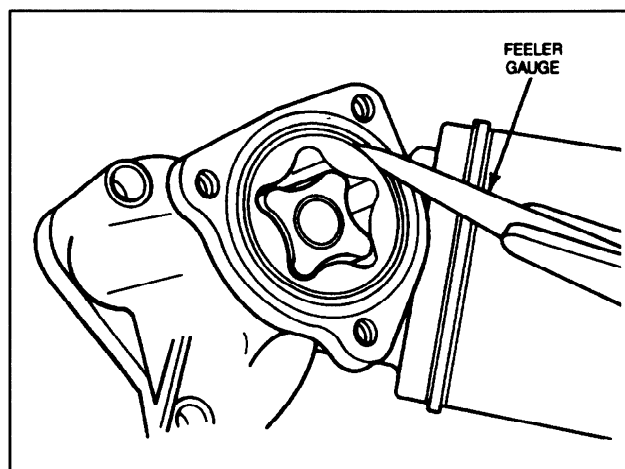
Inspection

Refer to the specifications for clearances and wear limits.

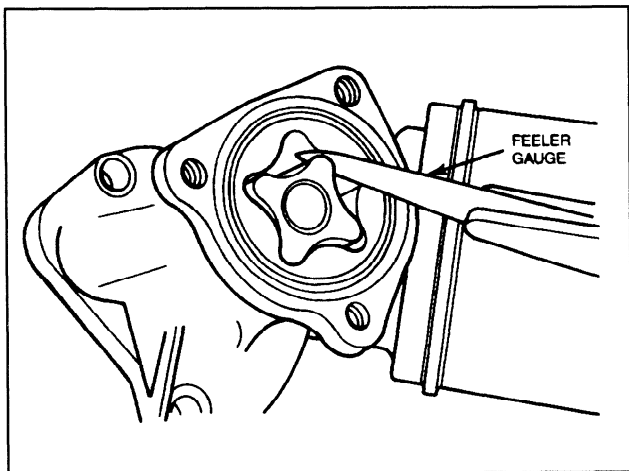
Check the inside of the pump housing and the outer race and rotor for damage or excessive wear.

Check the mating surface of the pump cover for wear. If the cover mating surface is worn, scored or grooved, replace the cover.

Measure the outer race to housing clearance. Then check the clearance between the outer race and the rotor lobes.

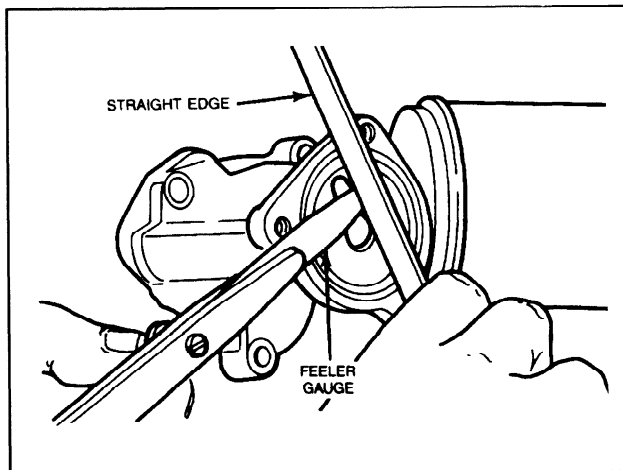


CLEANING AND INSPECTION (Continued)



With the rotor assembly installed in the housing, place a straight edge over the rotor assembly and the housing. Measure the clearance (rotor end play) between the straight edge and the rotor and outer race. **The outer race, shaft and rotor are replaceable only as an assembly.** Check the drive shaft to housing bearing clearance by

measuring the OD of the shaft and the ID of the housing bearing. Inspect the relief valve spring for a collapsed or worn condition. Check the relief valve spring tension. If the spring is worn or damaged, replace the spring. Check the relief valve piston for scores and free operation in the bore.

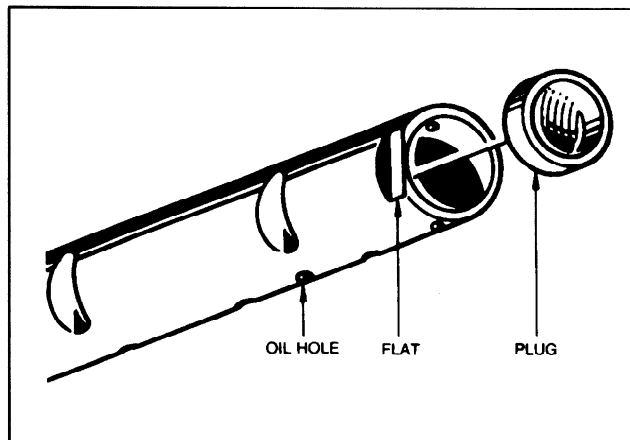


REMOVAL AND INSTALLATION

Valve Rocker Arm Cover, Rocker Arm and/or Shaft

Removal

1. Remove the air cleaner from the carburetor.
2. Disconnect the spark plug leads, remove them from the clip on the rocker cover and position aside.
3. Remove the rocker cover attaching screws, remove the rocker cover and discard the gasket.
4. Remove the rocker arm shaft attaching bolts evenly and lift off the rocker arm shaft assembly.
5. Remove the cotter pin from one end of the shaft and slip the flat washer, crimped washer and second flat washer off the shaft. The rocker arm shaft supports, rocker arms and springs can now be removed from the shaft.
6. Remove the plugs from the rocker shaft ends by drilling a hole in one plug. Insert a long rod through the drilled plug and knock the opposite plug out of the shaft. Remove the drilled plug in the same manner.
7. Clean the component parts of the shaft assembly in any suitable degreasing fluid.



Installation

1. Refit new plugs to the rocker shaft ends.
2. Assemble the rocker arm shaft. **The bolt hole in the rocker arm shaft support must be on the same side as the adjusting screw in the rocker arm. The oil holes must point downward and the flat on the shaft to the front of engine. The rocker arms are right and left handed, the rocker pads being inclined towards the support.** Install the cotter pins with the heads upwards and bend over the legs to secure.
3. Lubricate the valve stem tips, rocker arm pads and the push rod ends with Lubriplate or equivalent. Position the rocker shaft assembly on the cylinder head engaging the push rods with the adjusting screws. Install and tighten the bolts evenly to specifications.

4. Adjust the valve clearance to specifications.
5. Ensure that the mating surfaces on the cylinder head and rocker cover are free from all traces of the old gasket material.
6. Position the rocker cover and gasket on the cylinder head and secure with the attaching screws. Torque the screws to specifications.
7. Locate the spark plug leads in the rocker cover clip and reconnect them to their respective plugs.
8. Install the air cleaner.

Intake Manifold

Removal

1. Partially drain the cooling system.
2. Remove the air cleaner.
3. Disconnect the throttle rod from the carburetor throttle lever.
4. Disconnect the fuel line and the distributor vacuum line from the carburetor.
5. Disconnect the water outlet hose and the crankcase ventilation hose from the intake manifold.
6. Remove the attaching nut and bolts and remove the intake manifold.
7. Remove the gasket.
8. If a new manifold is to be installed, transfer all necessary components to the new manifold.

Installation

1. Apply a water resistant sealer to both sides of the gasket around the water port and position it on the cylinder head.
2. Install the intake manifold and tighten the nuts and bolts evenly to specifications.
3. Connect the water hose and the crankcase ventilation hose to the intake manifold.
4. Connect the distributor vacuum line and the fuel supply line to the carburetor.
5. Connect the throttle rod.
6. Install the air cleaner.
7. Refill the cooling system with the recommended coolant.

Exhaust Manifold

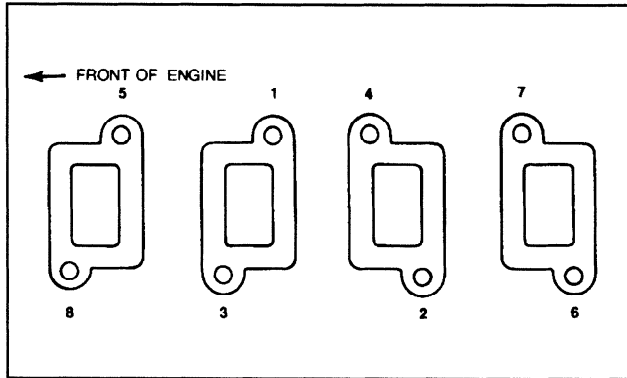
Removal

1. Remove the exhaust pipe retaining nuts and exhaust pipe.
2. Remove the eight exhaust manifold retaining nuts.
3. Remove the exhaust manifold.
4. Remove the four exhaust gaskets and discard them.

REMOVAL AND INSTALLATION (Continued)

Installation

1. Install four new exhaust manifold gaskets onto the studs.
2. Install the exhaust manifold and torque the nuts to specification in the sequence shown.
3. Install the exhaust pipe and torque the retaining nuts to specification.



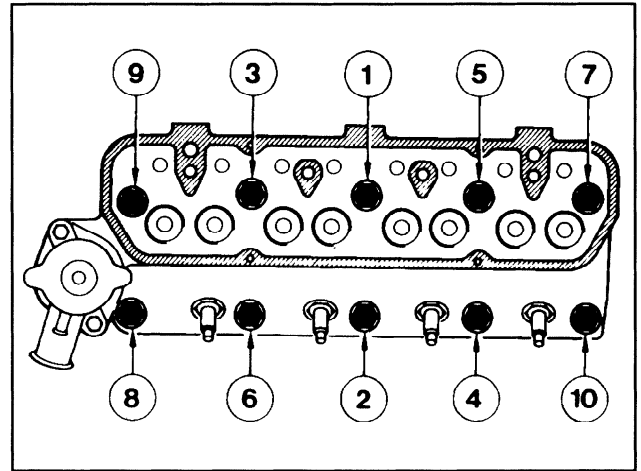
Cylinder Head

Removal

1. Remove the air cleaner.
2. Disconnect the fuel line at the fuel pump and carburetor.
3. Drain the coolant.
4. Disconnect the spark plug leads, remove them from the clip on the rocker cover and position out of the way.
5. Disconnect the water outlet and crankcase ventilation hoses at the intake manifold.
6. Disconnect the wire from the temperature gauge sending unit.
7. Detach the exhaust pipe.
8. Disconnect the throttle rod, choke cable and the distributor vacuum advance hose from the carburetor.
9. Disconnect the throttle linkage at the governor and position out of the way.
10. Remove the governor mounting bolts and remove governor.
11. Remove the thermostat housing, pull to one side and remove the thermostat.
12. Remove the rocker arm cover and gasket.
13. Remove the rocker arm shaft bolts evenly and lift off the rocker arm shaft assembly.
14. Lift out the push rods from their locations and keep them in their correct order.
15. Remove the cylinder head bolts and lift off the cylinder head and gasket. **Do not lay the cylinder head flat on its face as damage to the spark plugs or gasket surface can occur.**

Installation

1. Clean all gasket material from the mating surfaces and position the cylinder head gasket on the cylinder block using pilot studs.
2. Position the cylinder head, remove pilot studs and install the cylinder head bolts. Tighten the bolts down evenly in sequence and in four steps to specifications.



3. Lubricate both ends of the push rods with Lubriplate or equivalent and install them in their respective bores.
4. Install the rocker arm shaft assembly to the cylinder head, locating the push rods on the adjusting screws. Tighten the bolts evenly to specifications.
5. Adjust the valve clearances.
6. Install the rocker arm cover.
7. Connect the exhaust pipe.
8. Connect the distributor vacuum advance line, the throttle rod, and choke cable to the carburetor.
9. Connect the wire to the temperature gauge sender unit.
10. Connect the water outlet and crankcase ventilation hoses to the intake manifold.
11. Locate the thermostat in its bore in the cylinder head and install the gasket and thermostat housing.
12. Refill the cooling system.
13. Position governor and mounting bracket to cylinder head and install bolts.
14. Loosen governor adjusting bolts and position drive belt to governor. Adjust belt to specification and tighten bolts.
15. Connect the throttle linkage to the governor.
16. Install the alternator bracket mounting bolt to cylinder head.
17. Connect the ignition wires to the spark plugs in the correct firing order.
18. Install the air cleaner to the carburetor.
19. Adjust the carburetor idle speed and mixture settings.
20. Check governor operation, adjust as required.

REMOVAL AND INSTALLATION (Continued)

Valve Spring, Retainer and Stem Seal

Cylinder Head Removed

Removal

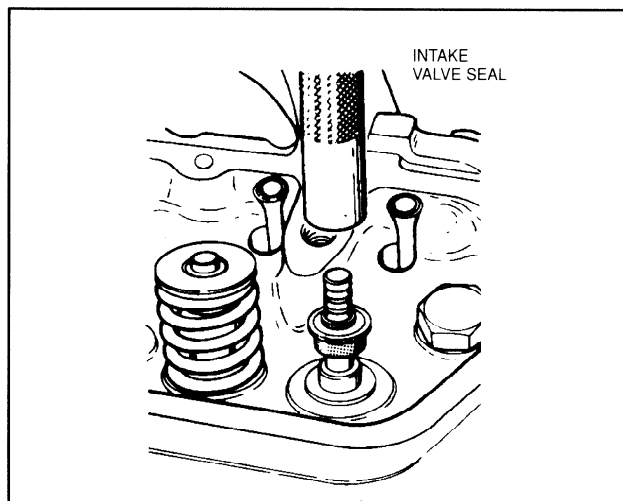
1. Remove the exhaust manifold and the spark plugs.
2. Compress the valve spring with a valve spring compressor. Remove the valve spring retainer locks, release the spring and remove the spring and retainer.
3. Remove the seal and withdraw the valve.

Installation

Lubricate all valves, valve stems and valve guides with heavy engine oil, SAE 50 weight.

1. Install each valve in the valve guide hole from which it was removed or to which a new valve is to be used.
2. Cover the valve grooves with plastic tape, slide the new seal onto the valve stem, remove the tape.

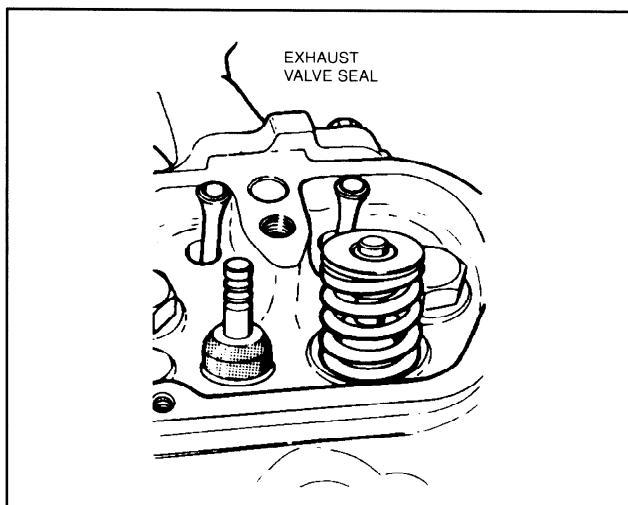
NOTE: The exhaust valves are fitted with umbrella type seals. The intake valves have the "positive" guide mounted seals which must be pressed on with a special service tool. "Positive" type seals may only be installed on intake valves not having the Ford oval on the stem.



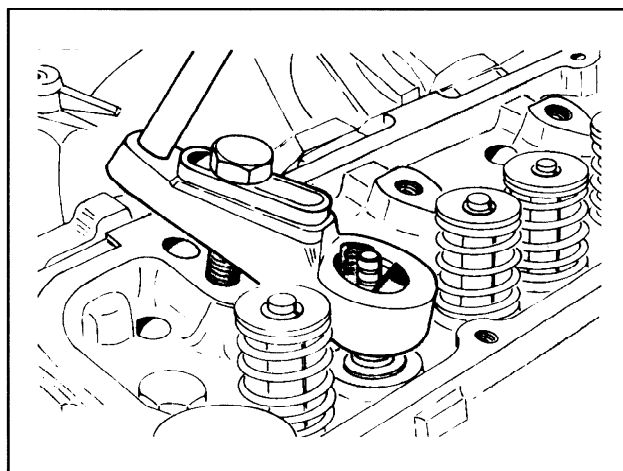
Cylinder Head Installed

Removal

1. Remove the air cleaner.
2. Disconnect the spark plug leads, remove them from the clip on the rocker cover and position out of the way.
3. Remove the rocker arm cover and gasket.
4. Remove the rocker arm shaft bolts evenly and lift off the rocker arm shaft assembly.
5. Lift the push rods from their locations and keep them in their correct order.
6. Remove the spark plugs.
7. Suitably support the appropriate valve with air pressure.
8. Compress the valve spring, using special service tool. Remove the valve spring retainer locks. Release the spring compressor, remove the valve spring retainer and the valve stem oil seal.



3. Install valve spring and damper assembly over the valve, then install spring retainer. Compress spring and install retainer key locks.
4. Measure the assembled height of the valve spring from the underside of the spring to the underside of the spring retainer. If the assembled height is not within specification, valve spring load loss may be excessive. Shim spring to specification.



REMOVAL AND INSTALLATION (Continued)

Installation

- Cover the valve grooves with plastic tape, slide the new seal onto the valve stem, remove the tape.
NOTE: The exhaust valves are fitted with umbrella type seals. The intake valves have the "positive" guide mounted seals which must be pressed on with a special service tool.
- Position the valve spring and retainer over the valve stem.
- Compress the valve spring using the special service tool. Position the valve spring retainer locks in the valve stem grooves and slowly release the spring to engage the locks in the retainer. Remove the air hose and adapter.
- Lubricate both ends of the push rods with Lubriplate or equivalent and install them in their respective bores. Install the rocker arm shaft assembly to the cylinder head, locating the push rods on the adjusting screws. Tighten the bolts evenly to specifications.
- Adjust valve clearances to specification.
- Install the rocker cover with a new gasket and torque the attaching screws to specification.
- Install the spark plugs.
- Locate the spark plug leads in the rocker cover clip and reconnect them to their respective plugs.
- Install the air cleaner assembly.

Water Pump

Removal

- Drain the cooling system.
- Loosen the governor adjusting bolts and remove drive belt.
- Loosen the alternator adjusting and mounting bolts. Pivot the alternator towards the engine and remove the drive belt.
- Remove the fan and pulley attaching bolts. Remove the fan and pulley.
- Loosen the clamps and remove the lower hose from the water pump.
- Remove bolts securing water pump to cylinder block and remove the pump and gasket.

Installation

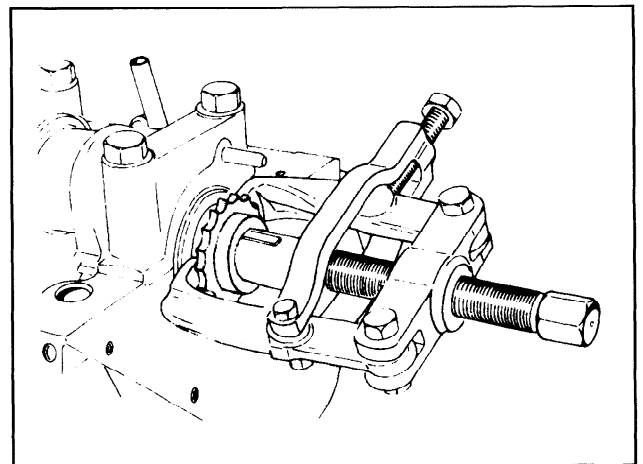
- Make sure that the mating faces of cylinder block and pump are clean.
- Position the pump and gasket on the cylinder block and secure with the attaching bolts.
- Position lower hose on water pump and tighten the clamp.
- Position the pulley and fan and secure with bolts. Torque the bolts to specification.

- Position drive belt over crankshaft, fan and alternator pulley and adjust the belt tension to specifications using Tool No. T63L-8620-A. Tighten the alternator mounting and adjusting bolt to specifications.
- Position the governor drive belt to governor and fan pulley. Adjust the belt to specification. Tighten adjusting bolts.
- Refill radiator and install cap. Start the engine and check for leaks.

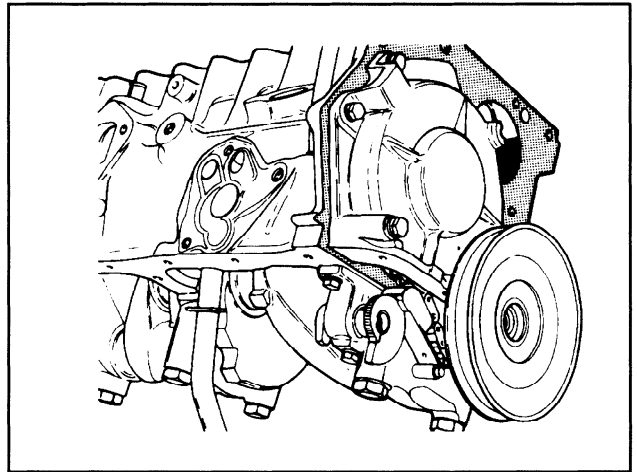
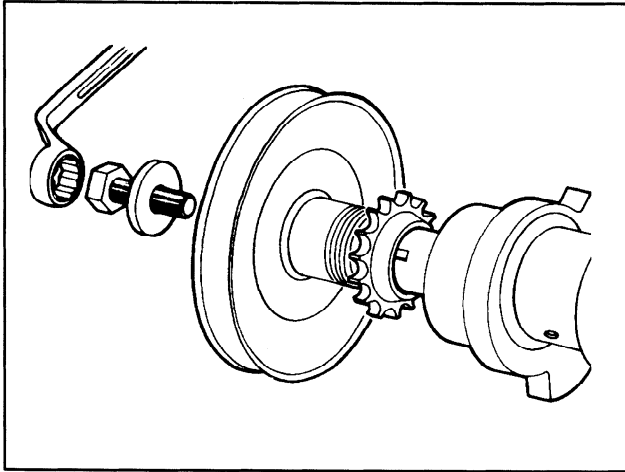
Cylinder Front Cover and Timing Chain, or Crankshaft Sprockets

Removal

- Drain the engine coolant by opening the drain cock on the radiator and removing the drain plug in the cylinder block.
- Disconnect the radiator hoses at the engine.
- Remove the radiator.
- Remove the governor and fan belts and then remove the fan and the water pump pulley.
- Remove the water pump.
- Remove the crankshaft pulley.
- Remove the oil pan to cylinder front cover and front cover to block attaching bolts. Use a thin knife to cut the oil pan gasket flush with cylinder block face prior to separating the cover from the cylinder block. Remove the front cover.
- Remove the crankshaft oil slinger. Remove the camshaft sprocket retainer and bolts.
- Remove the timing chain tensioner arm. Remove the camshaft sprocket, and disconnect the timing chain.
- If crankshaft sprocket is to be removed, use a standard two-jaw puller.

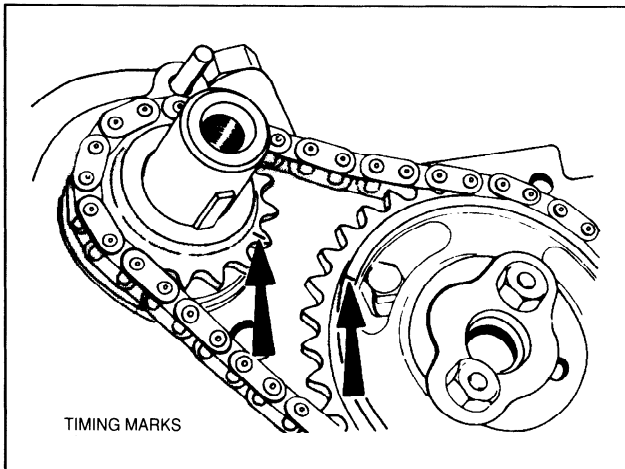


REMOVAL AND INSTALLATION (Continued)



Installation

1. If crankshaft sprocket was removed, install using the pulley, bolt and washer. The timing mark on the sprocket must face the end of the crankshaft.
2. Position the timing chain over the camshaft and crankshaft sprockets so that the timing marks are aligned when the sprocket is installed. **The number 4 cylinder is on top dead center when using the gear marks as reference.** Tighten the bolts to specification, then bend up the locking tabs.



3. Locate the tensioner arm on the pivot pin while holding the tensioner cam in the released position.
4. Install the oil slinger on the crankshaft.
5. Position the gasket, portions of oil pan gasket, if necessary, and the end seal on the front cover with an oil resistant sealer at the ends. Install the front cover and align the seal by installing the crankshaft pulley. Tighten the attaching bolts evenly to specification.

6. Install and torque crankshaft pulley retaining bolt.
7. Install the water pump and torque the attaching bolts to specification.
8. Install the water pump pulley and fan. Install the governor and fan belts and adjust the tension of the belts to specifications using Tool T63L-8620-A.
9. Install the radiator.
10. Install the radiator upper and lower hoses and tighten the clamps.
11. Refill the radiator.
12. Start engine and check for oil and water leaks.

Adjusting Valve Clearances

1. **Only** turn the crankshaft belt pulley **clockwise** while adjusting the valve clearances and start by aligning the mark on the belt pulley with the "O" mark on the front cover.
2. If belt pulley is now turned to and fro slightly, valves of cylinder No. 1 or 4 will be rocking, i.e., the two rockers and push rods move in opposite directions.
3. When valves in cylinder No. 4 are rocking, No. 1 cylinder valve clearances should be adjusted.
4. Then rotate belt pulley a further half turn. In this position valves of cylinder No. 3 will rock and valve clearances of cylinder No. 2 can be adjusted and so on according to firing order. (See Technical Data for settings.)

Cylinder No. 4 rocking — adjust cylinder No. 1
 Cylinder No. 3 rocking — adjust cylinder No. 2
 Cylinder No. 1 rocking — adjust cylinder No. 4
 Cylinder No. 2 rocking — adjust cylinder No. 3

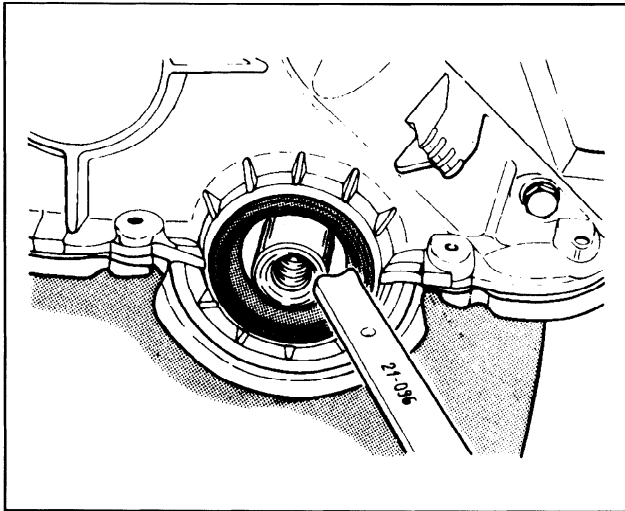
REMOVAL AND INSTALLATION (Continued)

Crankshaft Front Oil Seal

Removal

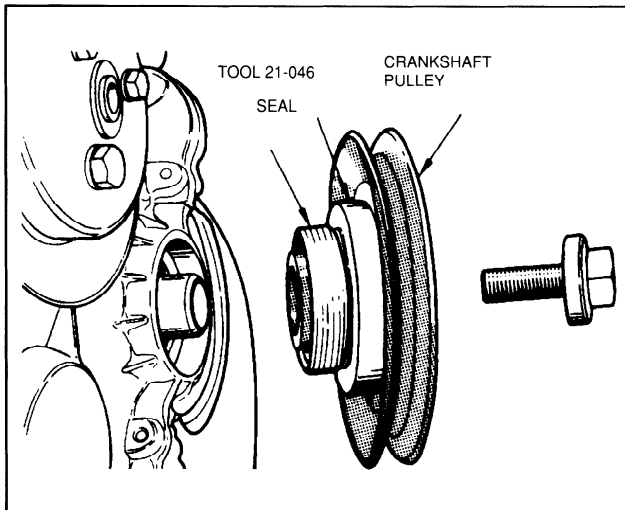
1. Loosen alternator and adjusting bracket bolts and remove fan belt.
2. Remove crankshaft pulley bolt and remove pulley by hand.
3. Remove oil seal from front cover using special service tool (21-096).

NOTE: Use short end of tool on this seal.



Installation

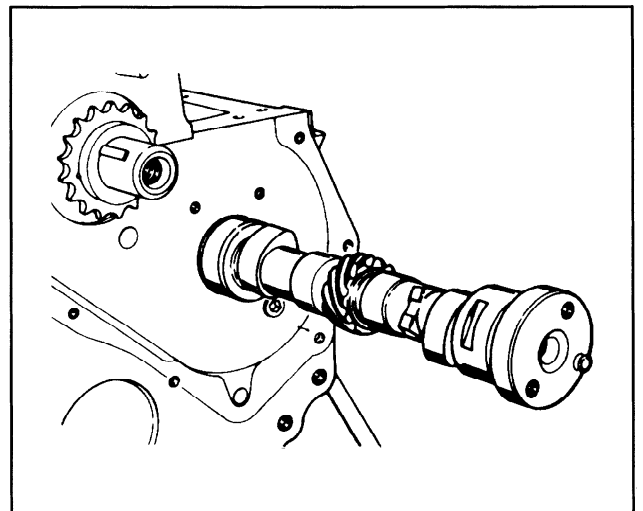
1. Lubricate the sealing lip of the new seal with engine oil and push new seal into front cover using tool 21-046, crankshaft pulley, bolt and washer.
2. Remove special service tool and reinstall crankshaft pulley. Torque bolt to specification.
3. Install fan belt and adjust the tension of the belts to specification using Tool T63L-8620-A. Tighten alternator and adjusting bracket bolts.



Camshaft and/or Valve Lifters

Removal

1. Remove the engine assembly and mount the engine on a stand. Drain the crankcase.
2. Disconnect the fuel line at the fuel pump.
3. Loosen the generator and governor adjustment bolts and remove the belts.
4. Remove the fan and water pump pulley.
5. Remove the oil and fuel pumps from the cylinder block.
6. Disconnect the spark plug wires from the plugs.
7. Remove the rocker arm cover attaching screws and rocker cover. Clean all gasket material from rocker arm cover and cylinder head.
8. Remove the rocker arm shaft support bolts evenly and lift off the rocker arm shaft.
9. Lift the push rods from their locations in the cylinder block, taking care to keep them in their correct order.
10. Invert the engine on the stand and remove the oil pan and gaskets.
11. Remove the crankshaft pulley, the front cover and oil slinger.
12. Remove the timing chain tensioner assembly.
13. Remove the camshaft sprocket and timing chain.
14. With the engine inverted, remove the camshaft thrust plate and remove the camshaft.
15. If necessary, remove the tappets from their locations in the cylinder block and keep them in the correct order.

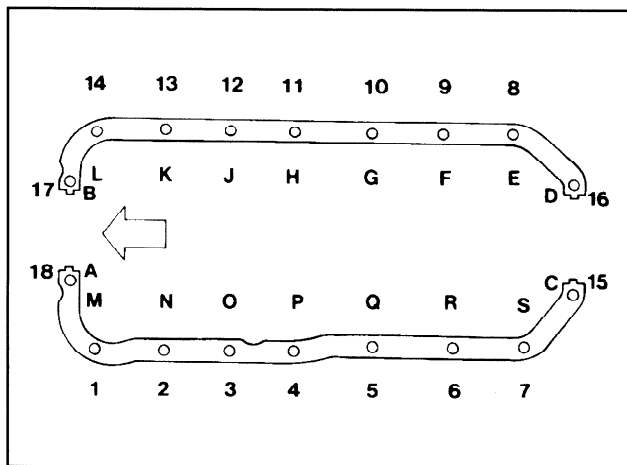


Installation

1. Install a new front cover oil seal, using Tool 21-046.
2. Install the tappets, if removed.
3. Install the camshaft and fit the thrust plate in the camshaft groove. Tighten the attaching bolts to specification and bend up the locking tabs.

REMOVAL AND INSTALLATION (Continued)

4. Check the camshaft end play.
5. Locate the timing chain on the camshaft sprocket and install the camshaft sprocket with the timing mark aligned with the one on the crankshaft sprocket. Tighten the attaching bolts to specification and bend up the locking tabs.
6. Locate the tensioner arm on the pivot pin and install the timing chain tensioner.
7. Install the oil slinger on the crankshaft.
8. Position the gasket on the front cover with an oil resistant sealer at the ends, align the front cover with the crankshaft pulley and tighten the bolts evenly to specification.
9. Position a new gasket on the block flange using an oil resistant sealer compound at each end. Position the end seals chamfered ends into the groove, again using an oil resistant sealer at the ends and install the oil pan. Tighten the oil pan bolts to the correct torque, **FOLLOWING FIRST THE ALPHABETICAL, THEN THE NUMERICAL SEQUENCES SHOWN.**



10. Install the dipstick.
11. Install the crankshaft pulley aligning the pulley slot with the crankshaft key. Tighten the pulley attaching bolt to specification.
12. Right the engine on stand.
13. Position a new gasket on the oil pump mounting flange and install the oil pump and filter assembly. Tighten the attaching bolts to specification.
14. Position a new gasket to the fuel pump flange and insert the rocker arm through the slot in the block wall so that the arm lies on the camshaft eccentric. Secure the fuel pump to the cylinder block with two washers and bolts, tightening the bolts evenly to specifications.

15. Lubricate push rod ends, valve stem tips and rocker pads with Lubriplate or equivalent. Install the push rods in their respective bores and install the rocker arm shaft assembly, making sure that the cupped ends of the push rods engage the adjusting screws. Tighten the rocker arm shaft attaching bolts evenly to specification.
16. Adjust the valve clearances to specification.
17. Install the rocker arm cover and a new gasket and secure with attaching screws and torque to specifications.
18. Connect the vacuum advance line to the carburetor.
19. Connect wires to spark plugs.
20. Install the water pump pulley and fan. Position the generator and governor drive belts on the pulley and adjust the belt tension to specifications. Connect the fuel line from the carburetor to the fuel pump.
21. Remove engine from stand.
22. Install the engine assembly in the unit.
23. Start the engine and check for oil and water leaks.
24. Install the air cleaner assembly.
25. Start engine, adjust the ignition timing, if necessary.
26. Adjust the carburetor idle speed and fuel-air mixture to specifications. Check governor operation.

Camshaft Bearings

The service bearings for the camshaft are pre-sized and require no machining after installation. When one bearing requires replacement it is advisable to replace all three, as camshaft alignment may be affected if only one bearing is changed.

The camshaft front and rear bearing are both approximately 19 mm (3/4 inch) wide, the front one having an additional oil hole for the rocker arm shaft oil feed, and the center bearing approximately 16 mm (5/8 inch) wide. Install the bearings using a replacer in addition to the adapters previously used. Make sure that the oil holes in the bearings and cylinder block are correctly aligned before installation and that the splits in the bearings are upwards and outwards at 45 degrees to the vertical.

Removal

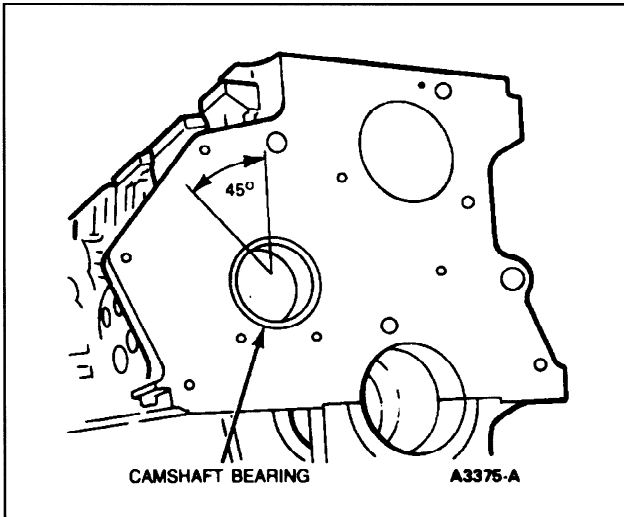
Remove camshaft following the appropriate procedures in this section.

1. Remove the flywheel.
2. Remove the crankshaft rear oil seal carrier.
3. Remove the camshaft bearings.
4. Check all the oil passages to make sure that they are clear. Apply an oil resistant sealer to the oil gallery plugs prior to installation.

REMOVAL AND INSTALLATION (Continued)

Installation

1. Install new camshaft bearings. Make sure that the oil holes in the bearings and cylinder block are aligned. The splits in the bearings should be upwards and outwards at 45 degrees to the vertical.



2. Install a new crankshaft rear oil seal using Tool 21-059A.
3. Position a new gasket to the rear oil seal carrier using an oil resistant sealer at the ends. Install the carrier on the cylinder block and tighten the bolts evenly to specification.
4. Locate the flywheel squarely on the crankshaft flange. Tighten the attaching bolts to specification.
5. Install the camshaft and related parts following the appropriate procedures in this section.

Oil Pump

The oil pump and filter assembly is bolted to the right side of the cylinder block and can be removed with the engine in place.

Removal

1. Place a drain pan under the oil pump.
2. Remove the oil filter from the oil pump.
3. Remove the three bolts attaching the oil pump and remove the assembly.

Installation

1. Ensure the mating surfaces are clean of old gasket material, then install the oil pump assembly on the cylinder block, using a new gasket together with an oil resistant sealer and secure with the three bolts. Tighten the bolts to specifications.
2. Install the oil filter to the oil pump assembly.
3. Check the oil level and add oil if necessary.
4. Start the engine and check for oil leaks.

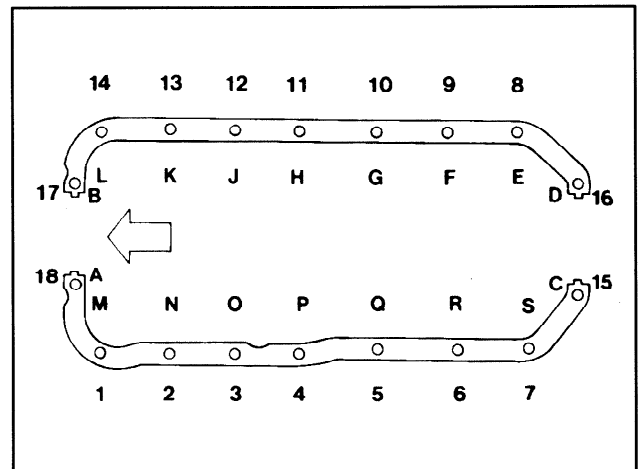
Oil Pan

Removal

1. Drain the crankcase.
2. Remove the oil level dipstick.
3. Remove the three bolts and remove the starter motor.
4. Remove the oil pan attaching bolts and remove the pan and gasket.

Installation

1. Clean the oil pump inlet tube and screen assembly.
2. Clean the gasket surfaces of the block and oil pan. Be sure to clean the seal retainer grooves in the cylinder front cover and the rear seal retainer. The oil pan has a two-piece gasket. Coat the block surface and the oil pan gasket surface with oil-resistant sealer. Position the oil pan gaskets on the cylinder block.
3. Position the end seals with the chamfered ends into the grooves, again using an oil resistant sealer. Position the oil pan and tighten the bolts evenly to specifications following first the alphabetical, then the numerical sequences shown.



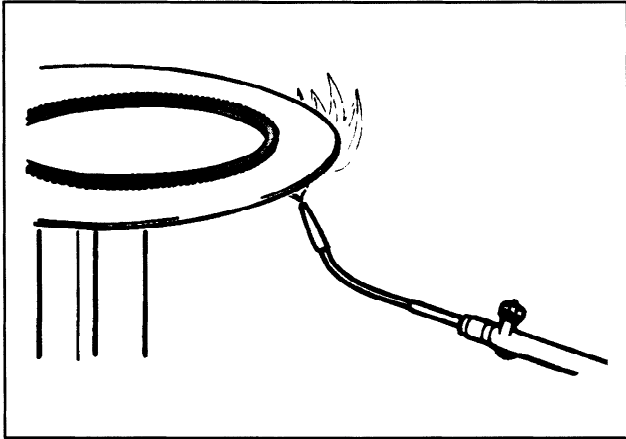
4. Clean and install the starter motor, securing it with the three bolts.
5. Refill the oil pan with the correct grade of engine oil and install the dipstick.
6. Start the engine and check for oil leaks.

Flywheel Ring Gear

The flywheel ring gear is located in a retention groove and can be removed by cutting between two adjacent teeth with a hacksaw and splitting the gear with a chisel. In no circumstances should pressure be applied in an attempt to remove the ring gear for repositioning on the flywheel.

REMOVAL AND INSTALLATION (Continued)

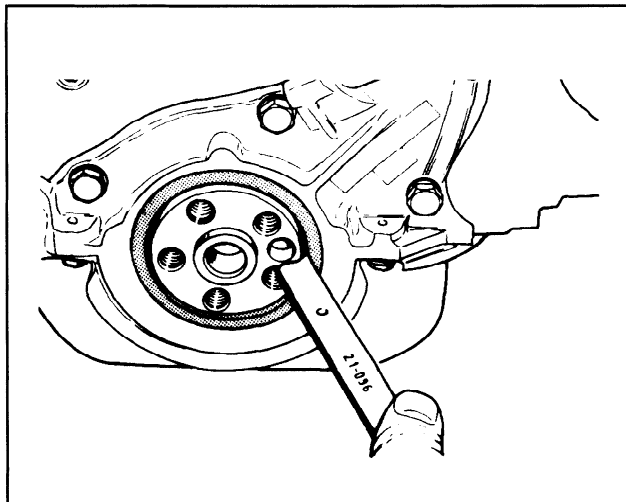
When installing the ring gear it must be heated evenly to a temperature of 260 to 280°C (500-535°F). Do not exceed 290°C (554°F) as the ring gear wear resistant properties will be destroyed. If the ring gear is to be heated by direct flame, place the ring gear on a metal plate approximately 2 to 3 mm (.079–.118 in.) thick and heat plate from below in the area of the ring gear until it reaches the required temperature. The correct temperature can be detected by using a special type of temperature sensitive crayon. Fit the ring gear with the chamfers on the leading faces of the gear teeth relative to the direction of rotation. Allow the ring gear to cool naturally in air. **Do not quench.**



Crankshaft Rear Oil Seal

Removal

1. Remove the P.T.O. or transmission clutch & pressure plate.
2. Remove the flywheel.
3. Remove the rear oil seal using tool 21-096.



Installation

1. Lubricate the sealing lip of the new seal with engine oil and push new seal into seal carrier using tool 21-059A.
2. Locate the flywheel squarely on the crankshaft flange. Tighten the bolts evenly to specification.
3. Install the P.T.O. or transmission, clutch and pressure plate.

Pistons and Connecting Rods

Removal

1. Drain the cooling system and the crankcase.
2. Refer to Cylinder Head Removal in this Section and remove the cylinder head and related parts.
3. Remove the oil pan following the procedure under Oil Pan Removal in this Section.
4. Turn the crankshaft until the piston to be removed is at the bottom of the stroke and place a cloth on the piston dome to collect the cuttings. Remove any ridge and/or deposits from the upper end of the cylinder bore with a ridge cutter. Follow the instructions furnished by the tool manufacturer. **Never cut into the ring travel area in excess of 0.8 mm (1/32 inch) when removing ridges.**
5. Make sure all the connecting rod caps are marked so that they can be installed in their original positions. Remove the connecting rod cap.
6. Push the connecting rod and piston assembly out the top of the cylinder with the handle end of a hammer. Avoid damage to the crankshaft journal or the cylinder wall when removing the piston and rod.

Installation

1. Refer to Cylinder Block — Refinishing in this Section.
2. Oil the piston rings, pistons and cylinder walls with light engine oil.
3. **Be sure to install the pistons in the same cylinders from which they were removed or to which they were fitted.** The connecting rods and bearing caps are numbered from 1 to 4 beginning at the front of the engine. The number on the connecting rod and bearing cap must be on the same side of rod when installing in the cylinder bore. If a connecting rod is ever transferred from one cylinder block to another or from one cylinder to another, new bearings should be fitted and the connecting rod should be re-numbered to correspond with the new cylinder number.
4. Make sure the ring gaps are properly spaced around the circumference of the piston. Oil the rings, then install a piston ring compressor on the piston. Make sure that the arrow in the dome of piston is toward the front, then push the piston into its bore with the handle end of a hammer until it is slightly below the top of the cylinder. Be sure to guide the connecting rods to avoid damaging the crankshaft journals.