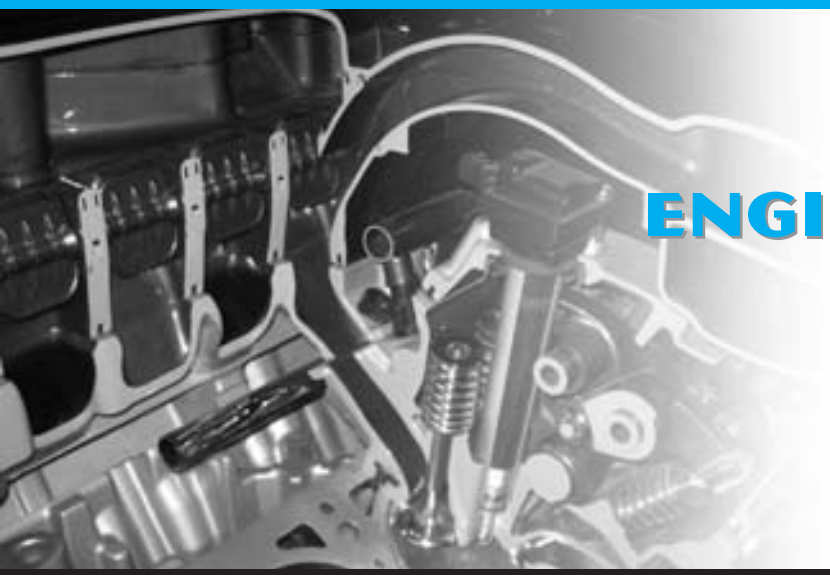
CHAPTER 31



ENGINE INSTALLATION AND IN-VEHICLE SERVICE

OBJECTIVES

After studying Chapter 31, the reader will be able to:

1. Prepare for Engine Repair (A1) ASE certification test content area "E" (Fuel, Electrical, Ignition, and Exhaust System Inspection and Service).
2. List the steps necessary to install and start-up a rebuilt engine.
3. Discuss the importance of torquing all bolts or fasteners that connect accessories to the engine block.
4. Describe what precautions must be taken to prevent damage to the engine when it is first started.
5. Explain how to break-in a newly rebuilt engine.
6. Describe how to replace a timing belt on an overhead camshaft engine.

KEY TERMS

Lugging (p. 604)

Normal Operating Temperature (p. 603)

When installing an engine, the engine installation will have to be thoroughly checked to make sure that it is in proper condition to give the customer dependable operation for a long time.

All operating accessories have to be reinstalled on the engine. They have to be adjusted so that the engine will operate correctly.

PREINSTALLATION CHECKLIST

Before installing or starting a new or rebuilt engine in a vehicle, be sure all of the following items have been checked.

1. Battery fully charged.
2. Prelube the engine and check for proper oil pressure. See Figure 31-1.
3. Check that all of the vacuum lines are correctly installed and routed.
4. Know the ignition timing specification and procedure.
5. Check that fresh fuel is in the fuel tank.
6. Be sure that the radiator has been tested, is free from leaks, and flows correctly.
7. Check that all accessory drive belts are routed and tensioned correctly.

CAUTION: Be sure to have a fire extinguisher near when the engine is first started.

FIGURE 31-1 Prelubricating the engine is a very important step that should be performed before starting the engine. Notice that oil is flowing through the pushrods, over the rocker arms, and onto the valve springs.

MANUAL TRANSMISSION INSTALLATION

If the engine was removed with the transmission attached, the transmission should be reinstalled on the engine before other accessories are added. The flywheel is installed on the back of the crankshaft. Often, the attaching bolt holes are unevenly spaced so that the flywheel will fit in only one way to maintain engine balance. The pilot bearing or bushing in the rear of the crankshaft is usually replaced with a new one to minimize the possibility of premature failure of this part.

The clutch is installed next. Usually, a new clutch is used; at the least, a new clutch friction disk is installed. The clutch friction disk must be held in position using an alignment tool (sometimes called a dummy shaft) that is secured in the pilot bearing. This holds the disk in position while the pressure plate is being installed. Finally, the engine bell housing is put on the engine, if it was not installed before. The alignment of this type of bell housing is then checked. See Figure 31-2.

CAUTION: Perfectly round cylinders can be distorted whenever another part of the engine is bolted and torqued to the engine block. For example, it has been determined that after the cylinders are machined, the rear cylinder bore can be distorted to be as much as 0.006 inch (0.15 millimeter) out-of-round after the bell housing is bolted onto the block! To help prevent this distortion, always apply the specified torque to all fasteners going into the engine block and tighten in the recommended sequence.

The clutch release yoke should be checked for free movement. Usually, the clutch release bearing is replaced to ensure that the new bearing is securely attached to the clutch release yoke. The transmission can then be installed.

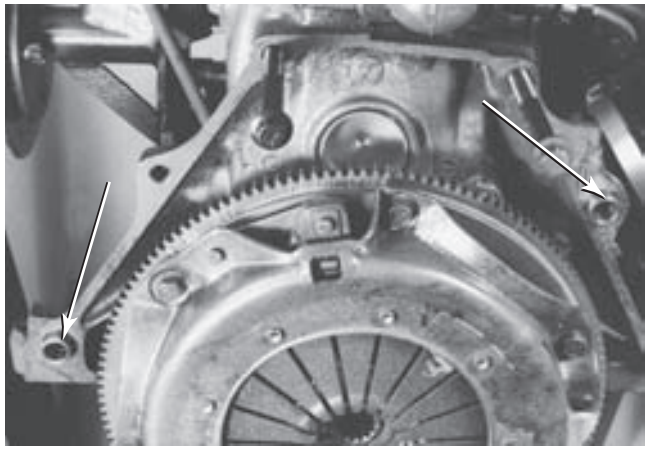


FIGURE 31-2 Bell housing alignment dowel pins are used to ensure proper alignment between the engine block and the transmission.

TECH TIP

THE HEADLESS BOLT TRICK

Sometimes parts do not seem to line up correctly. Try this tip the next time. Cut the head off of extra-long bolts that are of the same diameter and thread as those being used to retain the part, such as a transmission. See Figure 31-3. Use a hacksaw to cut a slot in this end of the guide bolts for a screwdriver slot. Install the guide bolts; then install the transmission. Use a straight-blade screwdriver to remove the guide bolts after securing the transmission with the retaining bolts.

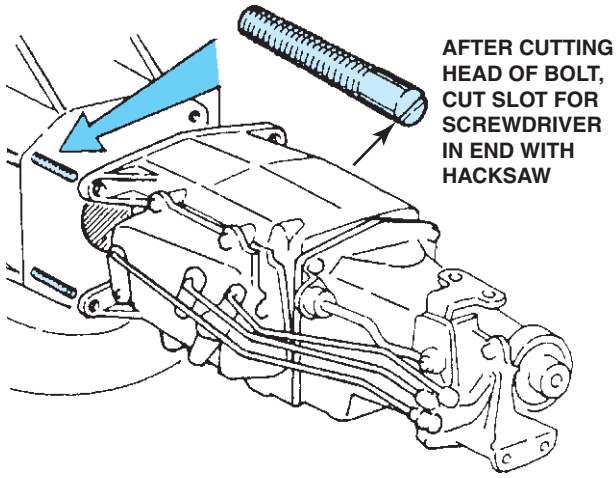


FIGURE 31-3 Headless long bolts can be used to help install a transmission to the engine.

The transmission clutch shaft must be guided straight into the clutch disk and pilot bearing. See the Tech Tip, "The Headless Bolt Trick." The transmission clutch shaft is rotated, as required, to engage in the splines of the clutch disk. The assembly bolts are secured when the transmission fully mates with the bell housing.

CAUTION: Always adjust the clutch free play *before* starting the engine to help prevent thrust bearing damage.

AUTOMATIC TRANSMISSION INSTALLATION

On engines equipped with automatic transmission, the drive plate is attached to the back of the crankshaft. Its assembly bolts are tightened to the specified torque. The bell housing is part of the transmission case on most automatic transmissions. Usually, the torque converter will be installed on the transmission before the transmission is put on the engine. See Figure 31-4. The torque converter should be rotated as it is pushed onto the transmission shafts until the splines of all shafts are engaged in the torque converter. The torque converter is held against the transmission as the transmission is fitted on the back of the engine. The transmission mounting bolts are attached finger tight. The torque converter should be rotated to make sure that there is no binding. The bell housing is secured to the block; then the torque converter is fastened to the drive plate. The engine should be rotated. Any binding should be corrected before any further assembly is done.

FIGURE 31-4 Typical automatic transmission torque converter.

STARTER

It is generally easier to install the starter before the engine is put in the chassis. The starter should be checked to make sure that the starter drive pinion does not bind on the ring gear. Shims can be installed between the starter mounting pad and the starter to adjust the pinion-to-ring gear clearance on the

GM-type mounting. The starter mounting bolts are then tightened to the specified torque.

ACCESSORIES

All belt-driven engine accessories are mounted on the front of the engine. Some engines drive all these accessories with one belt. Other engines use as many as four belts. Service information or decals under the hood should be checked to determine the specific belt routing for the accessories used on the engine being built up. On some engines it is more convenient to install the front accessories before the engine is installed; on other engines, it is easier to put the engine in the chassis before installing the front accessories.

Install new spark plugs and spark plug wires. Service information should be checked for the proper routing of the plug wires.

ENGINE INSTALLATION

A sling, either a chain or lift cable, is attached to the manifold or head bolts on the top of the engine. A hoist is attached to the sling and snugged up to take the weight and to make sure that the engine is supported and balanced properly.

NOTE: Many engines for front-wheel-drive vehicles are installed from underneath the vehicle. Often the entire drivetrain package is placed back in the vehicle while it is attached to the cradle. Always check the recommended procedure for the vehicle being serviced.

The engine must be tipped as it was during removal to let the transmission go into the engine compartment first. The transmission is worked under the floor pan on rear-wheel-drive vehicles as the engine is lowered into the engine compartment. The front engine mounts are aligned; then the rear cross-member and rear engine mount are installed. The engine mount bolts are installed, and the nuts are torqued. Then the hoist is removed. Controls are connected to the transmission under the vehicle. This is also a good time to connect the electrical cables and wires to the starter. The exhaust system is then attached to the exhaust manifolds. If any of the steering linkage was previously disconnected, it can be reattached while work is being done under the vehicle. After the engine is in place, the front engine accessories can all be installed, if they were not installed before the engine was put in the chassis. The air-conditioning compressor is reattached to the engine, with care being taken to avoid damaging the air-conditioning hoses and lines.

COOLING SYSTEM

The radiator is installed and secured in place, followed by the cooling fan and shroud. The fan and new drive belts are then installed and adjusted. New radiator hoses, including new heater hoses, should be installed. Coolant, a 50/50 mixture of antifreeze and water, is put in the cooling system after making sure that the radiator petcock is closed and the block drain plugs are in place. See Chapter 13 for proper procedures to follow to bleed trapped air from the cooling system. See Figure 31-5 for additional precautions.

FUEL AND EMISSION CONTROLS

The carburetor (if the vehicle is so equipped) should be installed with a new gasket. The fuel and vacuum hoses should be inspected carefully and replaced as required. The fuel-injection system (if the vehicle is so equipped) should be carefully inspected for damage while it is off the engine and then reinstalled, being certain to follow recommended procedures and torque settings. The fuel and air filters should be replaced. If the vacuum hoses and/or electrical wiring were not marked, refer to the engine emission decal and service manual for the proper location and routing.

NOTE: The oxygen sensor should be replaced, especially if the engine had a blown head gasket or other problem that could have caused coolant to get on the sensor.

FIGURE 31-5 Most engine rebuilders install a temperature-sensitive device on the engine. These sensors are used by the rebuilders for warranty purposes to record any occurrence of engine overheating. This small disk is glued to the engine block and will pop out if the engine overheats.

ELECTRICAL SYSTEM

Connect all wiring to the starter and generator (alternator) as required. Connect the instrument and computer sensor wires to the sensors on the engine. Double-check the condition and routing of all wiring, being certain that wires have not been pinched or broken, before installing a fully charged battery. Attach the positive cable first and then the ground cable. Check to make sure that the starter will crank the engine. Install and time the distributor; then connect the ignition cables to the spark plugs, again being sure that they are routed according to the manufacturer's recommendations.

ENGINE START

The engine installation should be given one last inspection to ensure that everything has been put together correctly before the engine is started. If the engine overhaul and installation are done properly, the engine should crank and start on its own fully charged battery without the use of a fast charger or jumper battery. As soon as the engine starts and shows oil pressure, it should be brought up to a fast idle speed and *kept there* to ensure that the engine gets proper lubrication. The fast-running oil pump develops full pressure, and the fast-turning crankshaft throws plenty of oil on the cam and cylinder walls.

NOTE: In camshaft-in-block engines, the only lubrication sent to the contact point between the camshaft lobes and the lifters (tappets) is from the splash off the crankshaft and connecting rods. At idle, engine oil does not splash enough for proper break-in lubrication of the camshaft.

FREQUENTLY ASKED QUESTION

WHAT IS BREAK-IN ENGINE OIL?

Many years ago, vehicle manufacturers used straight weight nondetergent engine oil as break-in oil. Today, the engine oil recommended for break-in (running in) is the same type of oil that is recommended for use in the engine. No special break-in oil is recommended or used by the factory in new vehicles. SAE 5W-30 or SAE 10W-30 engine oil is usually the specified viscosity recommended by most vehicle manufacturers.

After the engine has started, the following items should be checked:

1. Is the valve train quiet? Some engines will require several minutes to quiet down.
2. Record the engine vacuum. It should be 17 to 21 in. Hg at sea level.
3. Check for any gasoline, coolant, or oil leaks. Stop the engine and repair the leaks as soon as possible.
4. Check the charging system for proper operation. The charging voltage should be 13.5 to 15.0 volts.

As soon as you can tell that no serious leaks exist, and the engine is running reasonably well, the vehicle should be driven to a road having minimum traffic. Here, the vehicle should be accelerated, full throttle, from 30 to 50 miles per hour (48 to 80 kilometers per hour). Then the throttle is fully closed while the vehicle is allowed to return to 30 miles per hour (48 kilometers per hour). This sequence is repeated 10 to 12 times. The acceleration sequence puts a high load on the piston rings to properly seat them against the cylinder walls. The piston rings are the only part of the modern engine that needs to be broken in. Good ring seating is indicated by a dry coating inside the tailpipe at the completion of the ring seating drive.

The vehicle is returned to the service area, where the basic ignition timing is set and the idle speed is properly adjusted, if possible. The engine is again checked for visible fluid leaks. If the engine is dry, it is ready to be turned over to the customer.

The customer should be instructed to drive the vehicle in a normal fashion, neither babying it at slow speeds nor beating it at high speeds for the first 100 miles (160 kilometers). The oil and filter should be changed at 500 miles (800 kilometers) to remove any dirt that may have been trapped in the engine during assembly and to remove the material that has worn from the surfaces during the break-in period.

A well-designed engine that has been correctly reconditioned and assembled using the techniques described should give reliable service for many miles.

NORMAL OPERATING TEMPERATURE

Normal operating temperature is the temperature at which the upper radiator hose is hot and pressurized. Another standard method used to determine when normal operating temperature is reached is to observe the operation of the electric cooling fan, when the vehicle is so equipped. Many manufacturers define **normal operating temperature** as being reached when the cooling fan has cycled on and off at least once after the engine has been started. Some vehicle manufacturers specify that the cooling fan should cycle twice. This method also helps assure the technician that the engine is not being overheated.

HOW TO WARM UP A COLD ENGINE

The greatest amount of engine wear occurs during start-up. The oil in a cold engine is thick, and it requires several seconds to reach all the moving parts of an engine. After the engine starts, the engine should *not* be raced, but rather allowed to idle at the normal fast idle speed as provided for by the choke fast idle cam (on carburetor-equipped engines) or by the computer-controlled speed on fuel-injected engines. After the engine starts, allow the engine to idle until the oil pressure peaks. This will take from 15 seconds to about 1 full minute, depending on the outside temperature. *Do not allow the engine to idle for longer than 5 minutes.* Because an engine warms up faster under load, drive the vehicle in a normal manner until the engine is fully warm. Avoid full-throttle acceleration until the engine is completely up to normal operating temperature. This method of engine warm-up also warms the rest of the power train, including transmission and final drive component lubricants.

BREAK-IN PRECAUTIONS

Any engine overhaul represents many hours of work and a large financial investment. Precautions should be taken to protect the investment, including the following:

1. Never add cold water to the cooling system while the engine is running.
2. Never lug any engine. **Lugging** means increasing the throttle opening without increasing engine speed (RPM). Applying loads to an engine for *short periods* of time creates higher piston ring pressure against the cylinder walls and helps in the breaking-in process by helping to seat the rings.
3. Change the oil and filter at 500 miles (800 kilometers) or after 20 hours of operation.
4. Remember that the proper air–fuel ratio is important to the proper operation and long life of any engine. Any air leak (vacuum leak) could cause engine damaging detonation.
5. Be certain to use spark plugs for the proper heat range.

OIL CHANGE Step-by-Step

STEP 1

Begin the oil change process by safely hoisting the vehicle.

STEP 2

Locate and remove the oil drain plug. On this 5.0 L, V-8 Ford Mustang, two oil drain plugs are used. This is the front drain plug.

STEP 3

Loosen and remove the rear oil drain plug.

STEP 4

Allow the oil to drain into a suitable container. For best results, the oil drain should be close to the oil pan to help prevent the possibility of the oil splashing onto the floor or onto the service technician.

STEP 5

Carefully inspect the oil drain plug and gasket. Replace the gasket as needed or specified by the vehicle manufacturer (for example, Honda specifies that the aluminum seal on the drain plug be replaced at every oil change).

STEP 6

After all of the oil has been allowed to drain from the oil pan, reinstall the plug in the rear portion of the oil pan.

(continued)

OIL CHANGE continued

STEP 7

Also replace the oil drain plug in the front portion of the oil pan.

STEP 8

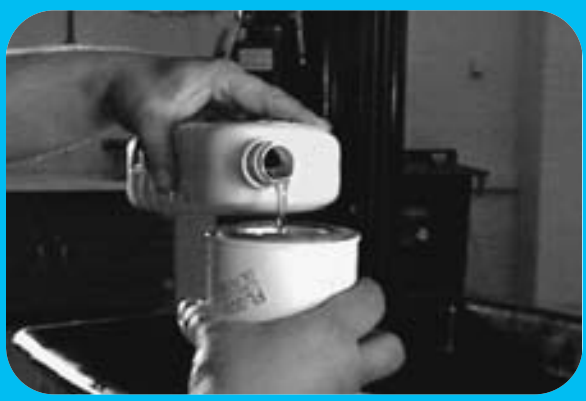
Using an oil filter wrench, remove the oil filter. Remember, "righty, tighty and lefty, loosy." Also be sure the oil drain pan is placed under the oil filter.

STEP 9

Check the area where the oil filter gasket seats to be sure that no part of the gasket remains that could cause an oil leak if not fully removed.

STEP 10

Also check the old oil filter to make sure the gasket has been removed with the oil filter. Also compare the replacement filter with the oil filter to double-check that the correct filter will be installed.



STEP 11

The wise service technician adds oil to the oil filter whenever possible. This provides faster filling of the filter during start-up and a reduced amount of the time that the engine does not have oil pressure.

STEP 12

Apply a thin layer of clean engine oil to the gasket of the new filter. This oil film will allow the rubber gasket to slide and compress as the oil filter is being rotated on the oil filter thread.

OIL CHANGE continued

STEP 13

Install the new oil filter and tighten the recommended amount—usually 3/4 of a turn after the gasket contacts the engine.

STEP 14

Use a funnel to help avoid spills and add the specified amount of oil to the engine at the oil-filling opening. Oil capacity for passenger vehicles can vary from 3 quarts (liters) to over 7 quarts (liters).

STEP 15

Inspect and clean the oil-fill cap and reinstall it before starting the engine.

STEP 16

Start the engine and allow it to idle while watching the oil pressure gauge and/or oil pressure warning lamp.

STEP 17

The oil pressure gauge should register and the oil pressure warning lamp should go out within 15 seconds of starting the engine. If not, stop the engine and determine the cause before starting the engine again.

STEP 18

Look underneath the vehicle to check for any oil leaks at the oil drain plug(s) or oil filter. Pull out the oil-level dipstick and wipe it clean with a shop cloth.

(continued)

OIL CHANGE continued

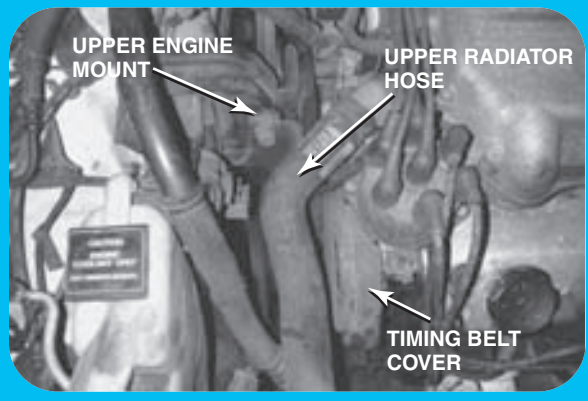
STEP 19 Reinstall the oil-level dipstick to check the oil level.

STEP 20 Remove the dipstick a second time and read the oil level. The oil level should be at the full mark as shown. If overfilled, hoist the vehicle and drain some oil out. An engine that has been overfilled with oil can be damaged because the oil can be aerated (filled with air like a milkshake) reducing the lubricating properties of the engine oil. Be sure to thoroughly wash your hands with soap and water after touching used engine oil or wear protective rubber gloves.

WATER PUMP AND TIMING BELT REPLACEMENT Step-by-Step

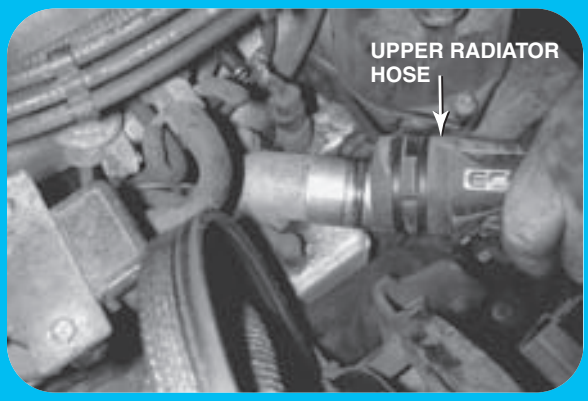
STEP 1

A view of the 3.0 L, V-6 Dodge minivan that needs a new water pump because it is leaking from the weep hole.



STEP 2

Because the entire front of the engine has to be disassembled, including the removal of the upper engine mount on the passenger side, the timing belt will also be replaced.



STEP 3

After draining the cooling system, the upper radiator hose and the accessory drive belt are removed.

STEP 4

The vehicle is hoisted and the right front wheel/tire assembly is removed to gain access to the front of the engine.

STEP 5

The splash shield has to be removed to gain access to the front accessory drive pulley.

STEP 6

The retaining bolts holding the accessory drive belt pulley to the harmonic balancer are removed.

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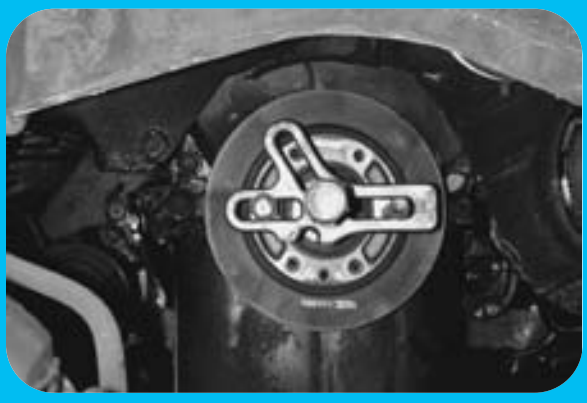
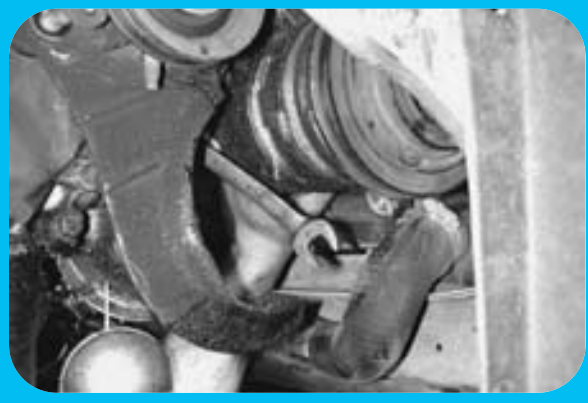
WATER PUMP AND TIMING BELT REPLACEMENT continued



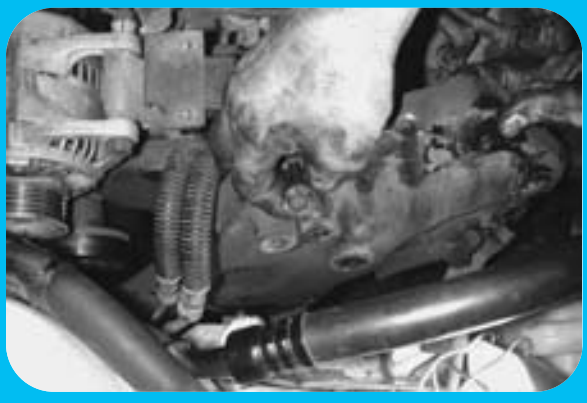
STEP 7 A puller is used to remove the harmonic balancer.



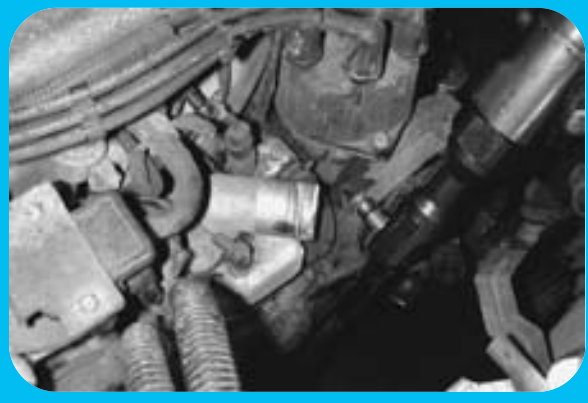
STEP 8 While under the vehicle, the air-conditioning compressor bracket is removed.

STEP 9 Before removing the upper engine mount, the engine is being supported by a floor jack. Notice that a block of wood is placed between the oil pan and the jack.

STEP 10 With the engine supported from underneath, the upper engine mount is removed.



STEP 11 The accessory support plate is removed.



STEP 12 The timing belt cover(s) can now be removed.

WATER PUMP AND TIMING BELT REPLACEMENT continued

STEP 13

A view of the front of the engine with the timing belt covers removed.

STEP 14

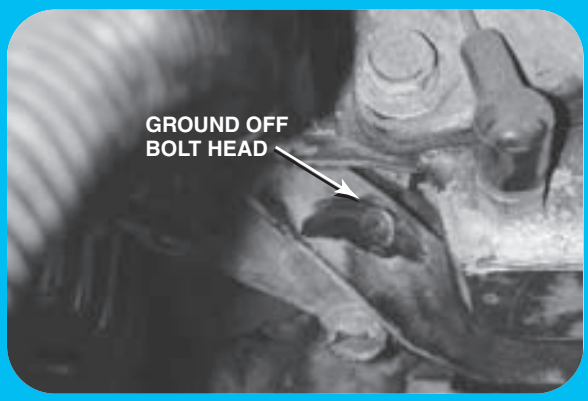
Before removing the timing belt, the wise service technician marks the location of the belt and pulley as a precaution to be sure that the new replacement belt will be placed back into proper time.

STEP 15

The spring tensioner is moved and the belt removed.

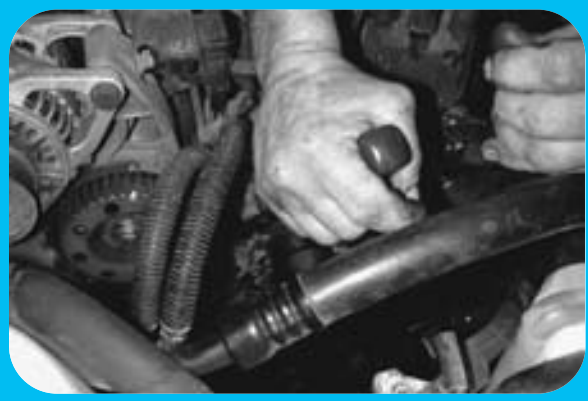
STEP 16

To save time, this service technician is cutting off the head of one bolt that holds a support bracket. This bolt cannot be removed without removing the entire intake manifold.



STEP 17

With the bolt head removed, the bracket is lifted up slightly, allowing room to remove the water pump. The bracket is still retained by another bolt.



STEP 18

After the water pump retaining bolts have been removed, a screwdriver or pry bar is needed to remove the water pump.

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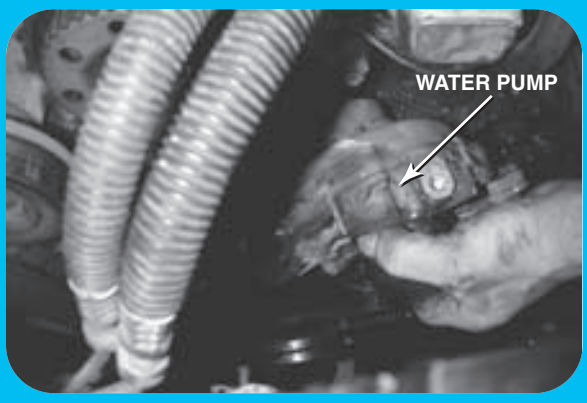
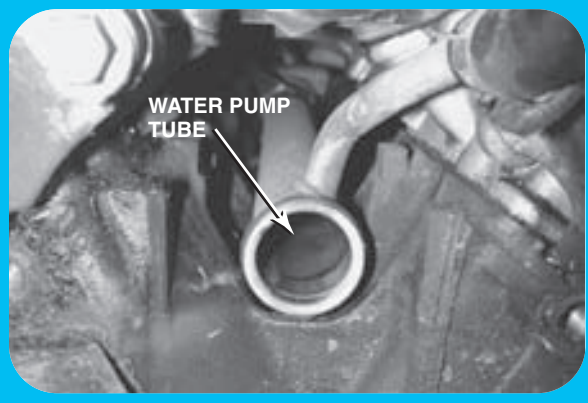
WATER PUMP AND TIMING BELT REPLACEMENT continued

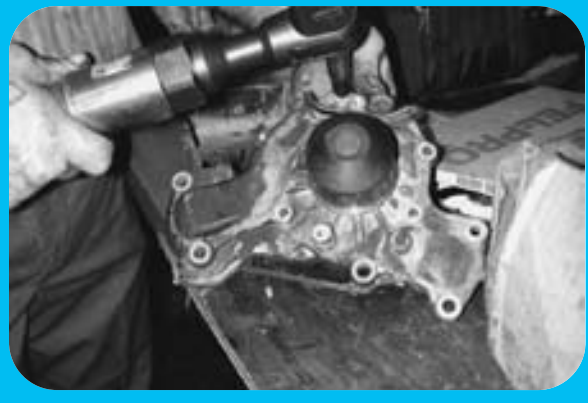


STEP 19 Removing the water pump from the front of the engine.



STEP 20 After the water pump is removed, the tube used to transfer coolant the length of the block is visible. The water pump slides over the seal on the end of the tube. This tube and seal are the reason why a pry bar was needed to remove the water pump.

STEP 21 The replaceable part of the water pump has to be removed from the housing. There is a hidden Phillips screw on the backside that has to be removed.



STEP 22 After removing the Phillips screw on the backside, turn the water pump over and remove the rest of the retaining bolts.

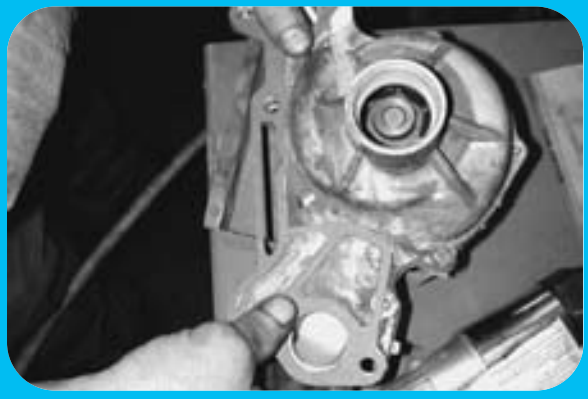
STEP 23 After all retaining bolts have been removed, separate the water pump from the housing.

STEP 24 A fiber disc on an air grinder is being used to remove the old gasket material.

WATER PUMP AND TIMING BELT REPLACEMENT continued

STEP 25 Gasket adhesive is being applied to the gasket surface of the replacement water pump.

STEP 26 Assembling the new water pump onto the original water pump housing.



STEP 27 Attaching new gaskets to the outlet flanges of the water pump.

STEP 28 Before installing the water pump, the block has to be cleaned of the old gaskets.

STEP 29 A view of the front of the engine with the replacement water pump installed.

STEP 30 After the water pump is installed, the new timing belt can be installed.

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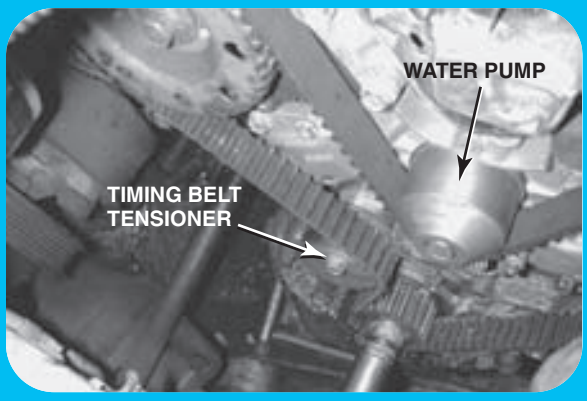
WATER PUMP AND TIMING BELT REPLACEMENT continued

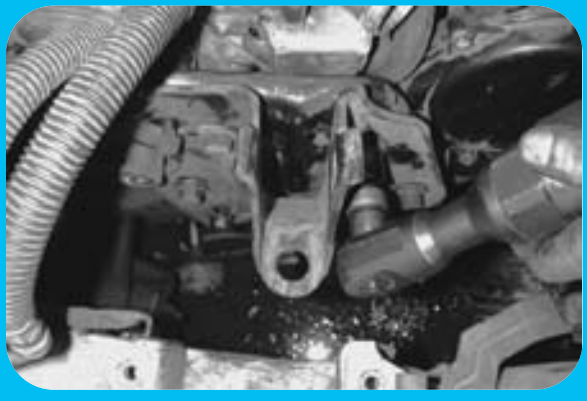


STEP 31

Notice that the timing belt drives the water pump. This is the reason why both the timing belt and the water pump are being replaced. The spring-loaded tensioner applies tension to the timing belt.

STEP 32

Before reinstalling everything, the cooling system is connected and partially filled and then pressure tested to check to make sure there are no leaks. This step is very important on this engine because of the design of the water pump fitting over the transfer tube.



STEP 33

After making sure that everything is okay with the installation of the water pump and there are no leaks, the timing belt cover and upper engine mount can be reinstalled.

STEP 34

After the engine mount has been replaced, the floor jack being used to support the engine is removed.

STEP 35

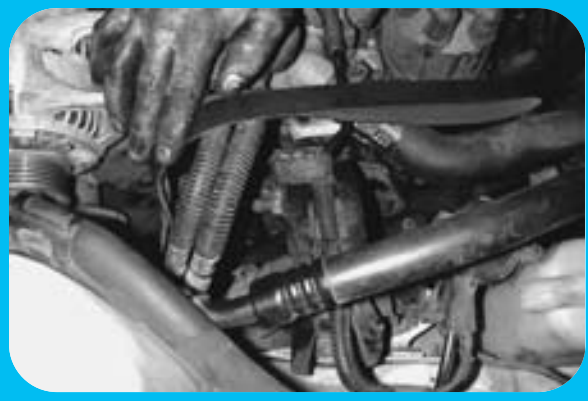
All the other brackets and hoses can now be reinstalled.

STEP 36

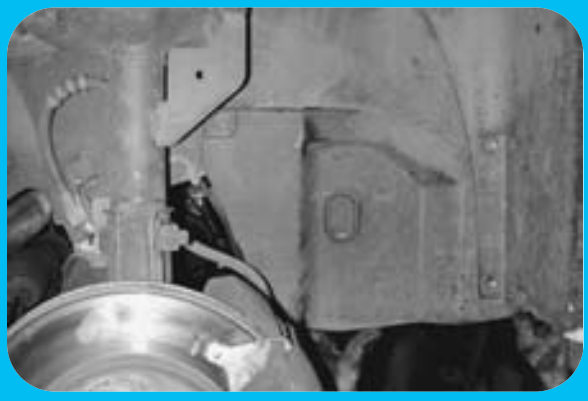
The vehicle is hoisted and the harmonic balancer and air-conditioning bracket is reinstalled.

WATER PUMP AND TIMING BELT REPLACEMENT continued

STEP 37 The accessory drive pulley is then installed on the harmonic balancer and the bolts torqued to factory specifications.



STEP 38 After the drive pulley has been installed, the accessory drive belt is installed.



STEP 39 After double-checking that everything is properly reinstalled and torqued, the splash shield can be installed.

STEP 40 Install the wheel/tire assembly and wheel cover.

STEP 41 The vehicle is now lowered and the cooling system filled with new coolant.

STEP 42 The repair is completed four hours after starting. The vehicle should be test driven and all connections double-checked before returning the vehicle to the customer.

SUMMARY

1. Carefully install all accessories.
2. When installing the transmission and other components on the engine block, be sure to use a torque wrench and tighten all fasteners to factory specifications.
3. Always adjust the clutch free play before starting the engine.
4. Temperature recording sensors should be installed on cylinder heads. This lets the rebuild technician know if the engine has been overheated.
5. A new oxygen sensor(s) should be installed to ensure that the engine operation is within acceptable limits. If the oxygen sensor is defective, the engine may operate too lean. A lean-operating engine runs hotter than normal.
6. Change the engine oil after 500 miles (800 kilometers) or sooner, and use SAE 5W-30 or SAE 10W-30 engine oil.

REVIEW QUESTIONS

1. How are the clutch and bell housing installed?
2. What should be done to help prevent rear cylinder distortion when the bell housing is being installed on the engine?
3. Describe the engine break-in procedure.

CHAPTER QUIZ

1. What can an engine rebuilder install that monitors if the engine has been overheated?
   - **a.** A thermal disc
   - **b.** A coolant leak detector
   - **c.** An oil level gauge
   - **d.** Either b or c
2. If the bell housing is not properly torqued to the engine block, _____.
   - **a.** The bell housing will distort
   - **b.** The engine block will crack
   - **c.** The rear cylinder can be distorted (become out-of-round)
   - **d.** The crankshaft will crack
3. Break-in engine oil is _____.
   - **a.** Of the same viscosity and grade as that specified for normal engine operation
   - **b.** SAE 40
   - **c.** SAE 30
   - **d.** SAE 20W-50
4. Normal operating temperature is reached when _____.
   - **a.** The radiator cap releases coolant into the overflow
   - **b.** The upper radiator hose is hot and pressurized
   - **c.** The electric cooling fan has cycled at least once (if the vehicle is so equipped)
   - **d.** Both b and c occur
5. Lugging an engine means _____.
   - **a.** Wide-open throttle in low gear above 25 miles per hour
   - **b.** That engine speed does not increase when the throttle is opened wider
   - **c.** Starting a cold engine and allowing it to idle for longer than 5 minutes
   - **d.** Both b and c
6. Which computer sensor should be replaced if the engine had been found to have a defective head gasket or cracked head?
   - **a.** Throttle position sensor
   - **b.** Oxygen sensor
   - **c.** Manifold absolute pressure sensor
   - **d.** Engine coolant temperature sensor
7. How should the vehicle be driven to best break in a newly overhauled engine?
   - **a.** At steady and low speeds
   - **b.** At varying speeds and loads
   - **c.** At high speeds and heavy loads
   - **d.** A idle speed and little or no load

8. Normal operating temperature is achieved when _____?

a. When heat comes from the heater

b. When the cooling fan cycle

c. When the engine exhaust gets hot

d. When the lower radiator hose gets hot

9. Pre-lubricating the engine should be done by using the starter motor to rotate the engine until oil pressure is displayed on a gauge.

a. True

b. False

10. Why must an engine equipped with flat-bottom lifters be broken in at a fast idle?

a. The camshaft in a cam-in-block engine is only lubricated by splash oil

b. The flat-bottom lifters have to wear slightly concave in order to rotate

c. Both a and b are correct

d. Neither a nor b are correct