CHAPTER 21

ENGINE DISASSEMBLY, CLEANING, AND CRACK DETECTION

OBJECTIVES

After studying Chapter 21, the reader will be able to:

1. Prepare for ASE Engine Repair (A1) certification test content area "A" (General Engine Diagnosis).
2. Describe how to remove an engine from a vehicle.
3. Discuss how to remove cylinder heads without causing warpage.
4. List the steps necessary to remove a piston from a cylinder.
5. Explain how to remove a valve from a cylinder head.
6. List the types of engine cleaning methods.
7. List the various methods that can be used to check engine parts for cracks.
8. Describe crack-repair procedures.

KEY TERMS

Acid Materials (p. 363)
Agitation (p. 365)
Aqueous-Based Solutions (p. 363)
Caustic Materials (p. 363)
Fogging Oil (p. 365)
Fusible Link (p. 365)
Harmonic Balancer (p. 360)
Hydroseal (p. 365)
Keepers (p. 361)
pH (p. 363)
Putty Knife (p. 363)
Pyrolytic (p. 364)
Soluble (p. 363)
Stop Drilling (p. 367)
Ultrasonic Cleaning (p. 365)
Valve Locks (p. 361)
Vibration Damper (p. 360)
Zyglo (p. 367)

The decision to repair an engine should be based on all the information about the engine that is available to the service technician. In some cases, the engine might not be worth repairing. It is the responsibility of the technician to discuss the advantages and disadvantages of the different repair options with the customer.

ENGINE REMOVAL

The engine exterior and the engine compartment should be cleaned before work is begun. A clean engine is easier to work on and the cleaning not only helps to keep dirt out of the engine but also minimizes accidental damage from slipping tools. The battery ground cable is disconnected to avoid the chance of electrical shorts. An even better procedure is to remove the battery from the vehicle.

NOTE: **Most technicians lightly scribe around the hood hinges prior to removal to make aligning the hood easier during reinstallation.**

Working on the top of the engine is made easier if the hood is removed. With fender covers in place, the hood is loosened from the hinges. With a person on each side of the hood to support it, the hood is lifted off as the bolts that hold the hood are removed. The hood is usually stored on fender covers placed on the top of the vehicle, where it is least likely to be damaged.

The coolant is drained from the radiator and the engine block to minimize the chance of coolant getting into the cylinders when the head is removed. The exhaust manifold is disconnected.

NOTE: **On some engines, it is easier to remove the exhaust pipe from the manifold. On others, it is easier to separate the exhaust manifold from the head and leave the manifold attached to the exhaust pipe.**

On *V*-type engines, the intake manifold must be removed before the heads can be taken off. In most cases, a number of wires, accessories, hoses, and tubing must be removed before the manifold head can be removed. If the technician is not familiar with the engine, it is a good practice to put tape on each of the items removed, marked with the proper location of each item so that all items can be easily replaced during engine assembly.

All coolant hoses are removed, and the transmission oil cooler lines are disconnected from the radiator. The radiator mounting bolts are removed, and the radiator is lifted from the engine compartment. This gets the radiator out of the way so that it will not be damaged while you are working on the engine. This is a good time to have the radiator cleaned, while it is out of the chassis.

TECH TIP

A PICTURE IS WORTH A THOUSAND WORDS

Take pictures of the engine being serviced with a digital, or video camera. These pictures will be worth their weight in gold when it comes time to reassemble or reinstall the engine. It is very difficult for anyone to remember the *exact* location of every bracket, wire, and hose. Referring back to the photos of the engine before work was started will help you restore the vehicle to like-new condition.

The air-conditioning compressor can usually be separated from the engine, leaving all air-conditioning hoses securely connected to the compressor and lines. The compressor can be fastened to the side of the engine compartment, where it will not interfere with engine removal. If it is necessary to disconnect the air-conditioning lines, use a refrigerant recovery system to prevent loss of refrigerant to the atmosphere. All open air-conditioning lines should be securely plugged immediately after they are disconnected to keep dirt and moisture out of the system. They should remain plugged until immediately prior to reassembly.

There are two ways to remove the engine:

- The engine can be lifted out of the chassis with the transmission/transaxle attached.
- The transmission/transaxle can be disconnected from the engine and left in the chassis.

Under the vehicle, the drive shaft (propeller shaft) or half shafts are removed and the exhaust pipes disconnected. In some installations, it may be necessary to loosen the steering linkage idler arm to give clearance. The transmission controls, speedometer cable wiring, and clutch linkages are disconnected and tagged.

A sling, either a chain or lift cable, is attached to the engine.

NOTE: **For the best results, use the factory-installed lifting hooks that are attached to the engine. These hooks were used in the assembly plant to install the engine and are usually in the best location to remove the engine.**

A hoist is attached to the sling and snugged to take most of the weight. This leaves the engine resting on the mounts. (Most engines use three mounts, one on each side and one at the back

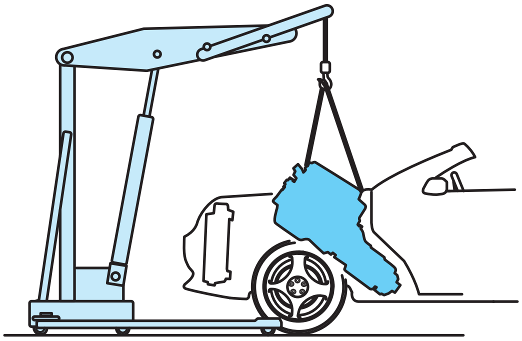


FIGURE 21-1 An engine must be tipped as it is pulled from the chassis.

FIGURE 21-2 When removing just the engine from a front-wheel-drive vehicle, the transaxle must be supported. Shown here is a typical fixture that can be used to hold the engine if the transaxle is removed or to hold the transaxle if the engine is removed.

of the transmission or at the front of the engine.) The rear crossmember is removed, and on rear-wheel-drive vehicles, the transmission is lowered. The hoist is tightened to lift the engine. The engine will have to nose up as it is removed, and the front of the engine must come almost straight up as the transmission slides from under the floor pan, as illustrated in Figure 21-1. The engine and transmission are hoisted free of the automobile, swung clear, and lowered onto an open floor area.

NOTE: **The engine is lowered and removed from underneath on many front-drive vehicles. See Figures 21-2 and 21-3.**

ENGINE DISASSEMBLY

The following disassembly procedure applies primarily to pushrod engines. The procedure will have to be modified somewhat when working on overhead cam engines. Engines should be cold before disassembly to minimize the chance of warpage.

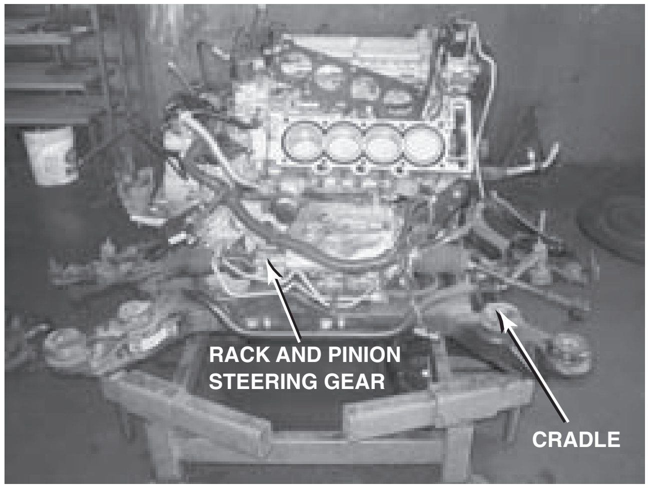


FIGURE 21-3 The entire cradle, which included the engine, transaxle, and steering gear, was removed and placed onto a stand. The rear cylinder head has been removed to check for the root cause of a coolant leak.

TECH TIP

USE THE PROPER DISASSEMBLY PROCEDURE

When an engine is operated, it builds up internal stresses. Even cast-iron parts such as cylinder heads can warp if the proper disassembly procedure is not followed. To disassemble any engine without causing harm, just remember these two important points:

- Disassemble parts from an engine only after it has been allowed to sit for several hours. All engines should be disassembled when the engine is at room temperature.
- Always loosen retaining bolts/nuts in the reverse order of assembly. Most vehicle manufacturers recommend tightening bolts from the center of the component such as a cylinder head toward the outside (ends). Therefore, to disassemble the engine, the outside (outer) bolts should be loosened first, followed by bolts closer to the center.

Taking these steps will help reduce the possibility of warpage occurring when the parts are removed.

Remove the manifold hold-down cap screws and nuts, and lift off the manifold.

With the manifold off of the V-type engine, loosen the rocker arms, and remove the pushrods. The usual practice is

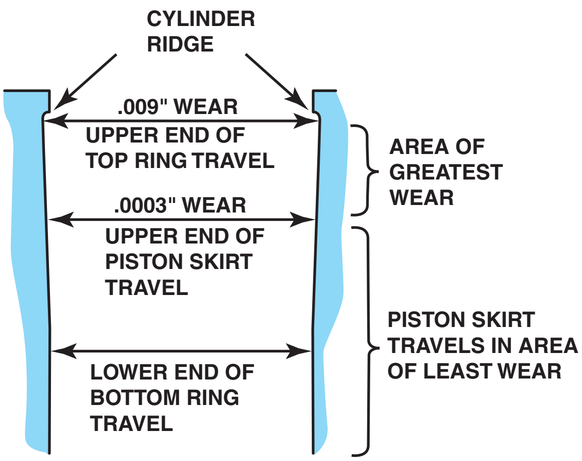


FIGURE 21-4 Most of the cylinder wear is on the top inch just below the cylinder ridge. This wear is due to the heat and combustion pressures that occur when the piston is near the top of the cylinder.

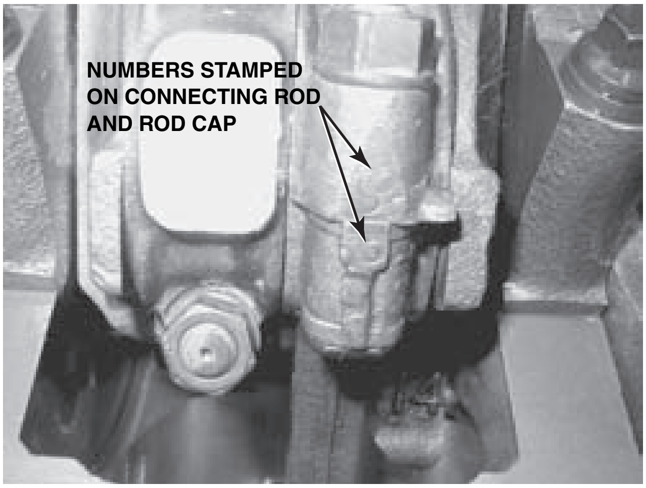


FIGURE 21-5 These connecting rods were numbered from the factory.

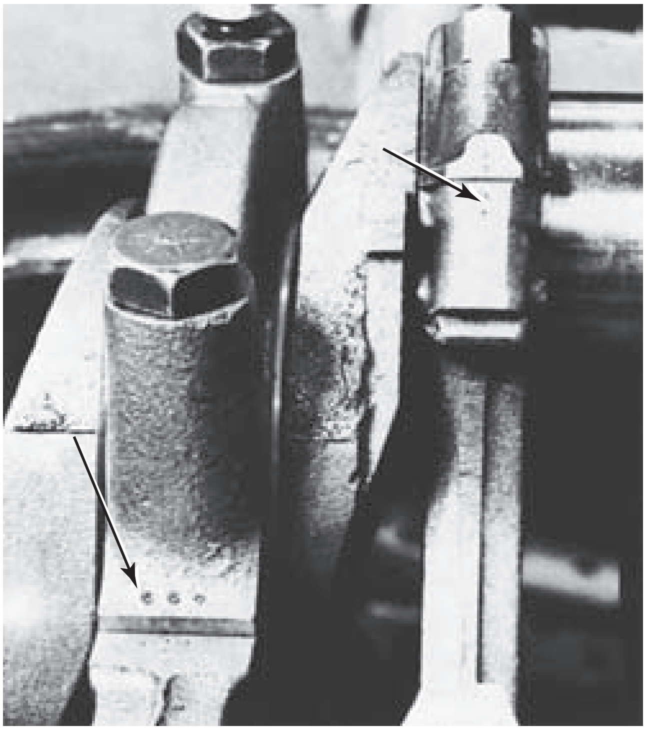


FIGURE 21-6 If the rods and mains are not marked, it is wise to use a punch to make identifying marks *before* disassembly of the engine.

to leave the lifters in place when doing only a valve job. Remove the head cap screws and lift the head from the block deck.

CHECKING CYLINDER BORE

At this point, the cylinder taper and out-of-round of the cylinder bore should be checked just below the ridge and just above the piston when it is at the bottom of the stroke, as shown on the cutaway cylinder in Figure 21-4. These measurements will indicate how much cylinder-wall work is required. If the cylinders are worn beyond the specified limits, they will have to be rebored to return them to a satisfactory condition.

REMOVING THE OIL PAN

To remove the oil pan, turn the engine upside down. This will be the first opportunity to see the working parts in the bottom end of the engine. Deposits are again a good indication of the condition of the engine and the care it has had. Heavy sludge indicates infrequent oil changes; hard carbon indicates overheating. The oil pump pickup screen should be checked to see how much plugging exists. The connecting rods and caps and main bearing caps should be checked to make sure that they are *numbered*; if not, they should be numbered with number stamps or a punch so that they can be reassembled in exactly the same position. See Figures 21-5 and 21-6.

REMOVING THE CYLINDER RIDGE

The ridge above the top ring must be removed before the piston and connecting rod assembly is removed. Cylinder wear leaves an upper ridge and removing it is necessary to avoid catching a ring on the ridge and breaking the piston. Failure to remove the ridge is likely to cause the second piston land to break when the engine is run after reassembly with new rings, as pictured in Figure 21-7. The ridge is removed with a cutting tool that is fed into the metal ridge. One type of ridge reamer is shown in Figure 21-8. A guide on the tool prevents accidental cutting below the ridge. The reaming job should be done carefully with frequent checks of the work so that no more material than necessary is removed.

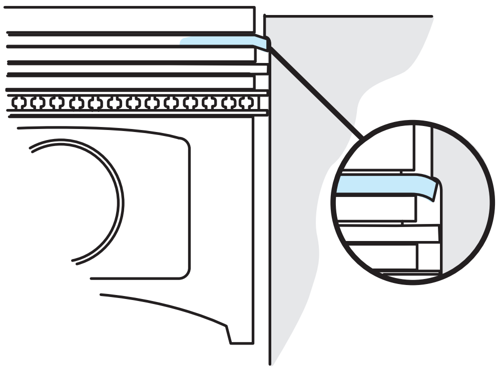


FIGURE 21-7 If the ridge at the top of a cylinder is not removed, the top piston ring could break the second piston ring land when the piston is pushed out of the cylinder during disassembly, or the second piston ring land could break when the engine is first run after reassembly with new rings.

FIGURE 21-8 Ridge being removed with one type of ridge reamer before the piston assemblies are removed from the engine.

REMOVING THE PISTONS

Rotate the engine until the piston that is to be removed is at top dead center (TDC). Remove connecting rod nuts from the rod so that the rod cap with its bearing half can be taken out. Fit the rod bolts with protectors to keep the bolt threads from damaging the crankshaft journals, and remove the piston and rod assemblies.

REMOVING THE HARMONIC BALANCER

The next step in disassembly is to remove the coolant pump and the crankshaft **vibration damper** (also called a **harmonic balancer**). First, the bolt and washer that hold the damper are removed. The damper itself should be removed only with a threaded puller similar to the one in Figure 21-9. If a hook-type puller is used around the edge of the damper, it may pull the damper ring from the hub. If this happens, the damper assembly will have to be replaced with a new assembly.

REMOVING THE TIMING CHAIN AND CAMSHAFT

With the damper assembly off, the timing cover can be removed, exposing the timing gear or timing chain. Examine these parts for excessive wear and looseness. A worn timing chain on a high-mileage engine is shown in Figure 21-10. Bolted cam sprockets can be removed to free the timing chain. If camshaft thrust plate retaining screws are used, it will be necessary to remove them.

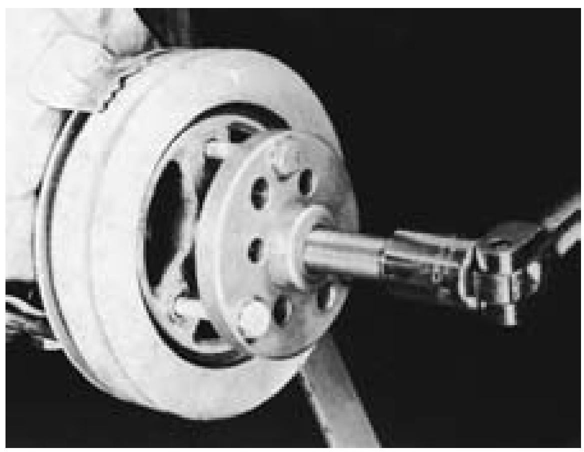


FIGURE 21-9 Puller being used to pull the vibration damper from the crankshaft.

FIGURE 21-10 Worn timing chain on a high-mileage engine. Notice that the timing chain could "jump a tooth" at the bottom of the smaller crankshaft gear where the chain is in contact with fewer teeth. Notice also that the technician placed all of the bolts back in the block after removal of the part. This procedure helps protect against lost or damaged bolts and nuts.

The camshaft can be removed at this time, or it can be removed after the crankshaft is out. It must be carefully eased from the engine to avoid damaging the cam bearings or cam lobes. This is done most easily with the front of the engine pointing up. Bearing surfaces are soft and scratch easily, and the cam lobes are hard and chip easily.

REMOVING THE MAIN BEARING AND CRANKSHAFT

The main bearing caps should be checked for position markings before they are removed. They have been machined in place and will not fit perfectly in any other location. See Figure 21-11. After marking, they can be removed to free the crankshaft. When the crankshaft is removed, the main bearing caps and bearings are reinstalled on the block to reduce the chance of damage to the caps.

REMOVE AND DISASSEMBLE THE CYLINDER HEAD

Remove the cylinder head retaining bolts by loosening them from the outside toward the center to help prevent the possibility of warpage of the head. Remove the cylinder head(s) and check the head gasket for signs of failure. See Figure 21-12.

After the heads are removed and placed on the bench, the valves are removed. A C-type valve spring compressor, similar to the one in Figure 21-13, is used to free the **valve locks** or **keepers.** The valve spring compressor is air powered in production shops where valve jobs are done on a

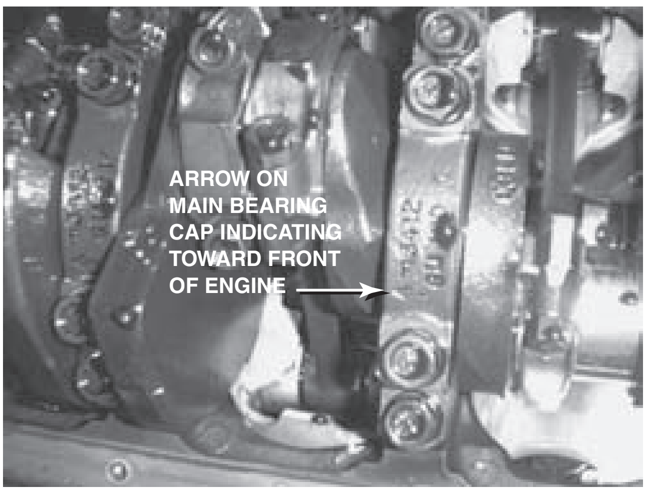


FIGURE 21-11 Most engines such as this Chevrolet V-8 with 4-bolt main bearing caps have arrows marked on the bearing caps which should point to the front of the engine.

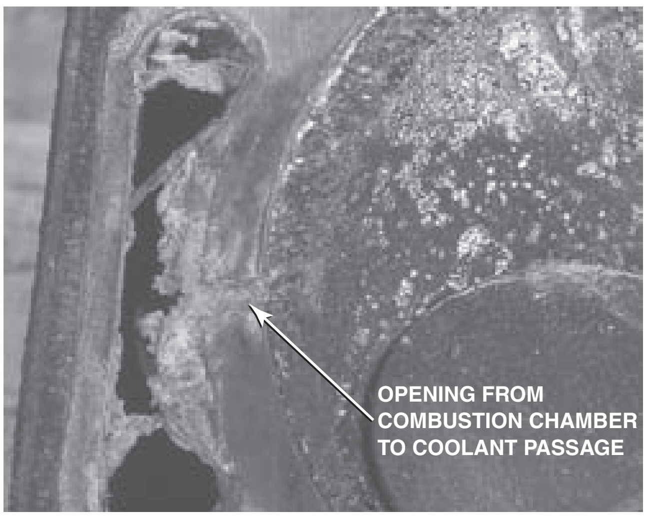


FIGURE 21-12 This defective cylinder head gasket was discovered as soon as the head was removed. This cylinder head will require machining or replacement.

FIGURE 21-13 A valve spring compressor being used to remove the valve keepers (locks).

FIGURE 21-14 After removing this intake valve, it became obvious why this engine had been running so poorly.

regular basis. Mechanical valve spring compressors are used where valve work is done only occasionally. After the valve lock is removed, the compressor is released to free the valve retainer and spring. The spring assemblies are lifted from the head together with any spacers used under them. The parts should be removed in order to aid in diagnosing the exact cause of any malfunction that shows up. The valve tip edge and lock area should be lightly filed to remove any burrs *before* sliding the valve from the head. Burrs will scratch the valve guide.

When all valves have been removed following this procedure for each one, the valve springs, retainers, locks, guides, and seats should be given another visual examination. See Figure 21-14.

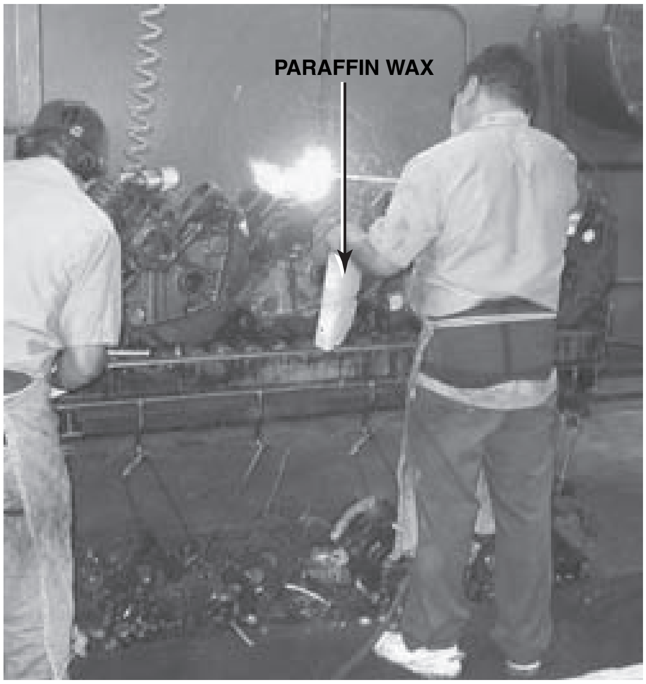


FIGURE 21-15 A torch is used to heat gallery plugs. Paraffin wax is then applied and allowed to flow around the threads. This procedure results in easier removal of the plugs and other threaded fasteners that cannot otherwise be loosened.

TECH TIP

THE WAX TRICK

Before the engine block can be thoroughly cleaned, all oil gallery plugs must be removed. A popular trick of the trade for plug removal involves heating the plug (not the surrounding metal) with an oxyacetylene torch. The heat tends to expand the plug and make it tighter in the block. Do not overheat.

As the plug is cooling, touch the plug with paraffin wax (beeswax or candle wax may be used). See Figure 21-15. The wax will be drawn down around the threads of the plug by capillary attraction as the plug cools and contracts. After being allowed to cool, the plug is easily removed.

MECHANICAL CLEANING

Heavy deposits that remain after chemical cleaning will have to be removed by mechanical cleaning. Mechanical cleaning involves scraping, brushing, and abrasive blasting. It should, therefore, be done very carefully on soft metals.

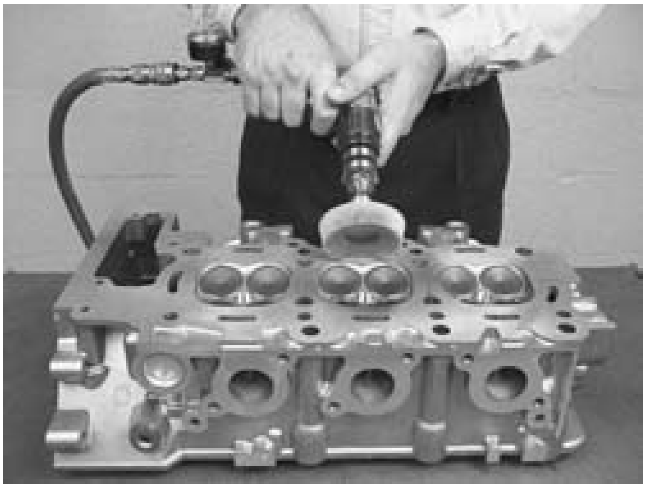


FIGURE 21-16 An air-powered grinder attached to a bristle pad being used to clean the gasket surface of a cylinder head. The color of the bristles indicates the grit number. The white is the finest and should be used on aluminum. Yellow is coarse and can be used on aluminum. Green is designed for cast-iron parts only. This type of cleaning pad should not be used on the engine block where the grit could get into the engine oil and cause harm when the engine is started and run after the repair.

The scraper most frequently used is a **putty knife** or a plastic card. The broad blade of the putty knife helps avoid scratching the surface as it is used to clean the parts. A rotary disc can be used on disassembled parts that will be thoroughly cleaned to remove the fine abrasive that is part of the plastic bristles. See Figure 21-16.

CAUTION: Do not use a steel wire brush on aluminum parts! Steel is harder than aluminum and will remove some of the aluminum from the surface during cleaning.

CHEMICAL CLEANERS

Cleaning chemicals applied to engine parts will mix with and dissolve deposits. The chemicals loosen the deposits so that they can be brushed or rinsed from the surface. A deposit is said to be **soluble** when it can be dissolved with a chemical or solvent.

Most chemical cleaners used for cleaning carbon-type deposits are strong soaps called **caustic materials.** A **pH** value, measured on a scale from 1 to 14, indicates the amount of chemical activity in the soap. The term *pH* is from the French *pouvoir hydrogine*, meaning "hydrogen power." Pure water is neutral; on the pH scale, water is pH 7. Caustic materials have pH numbers from 8 through 14. The higher the number, the stronger the caustic action will be. **Acid materials** have pH numbers from 1 through 6. The lower the number, the stronger the acid action will be. Caustic materials and acid materials neutralize each other. This is what happens when baking soda (a caustic) is used to clean the outside of the battery (an acid surface). The caustic baking soda neutralizes any sulfuric acid that has been spilled or splashed on the outside of the battery.

CAUTION: Whenever working with chemicals, you must use eye protection.

SOLVENT-BASED CLEANING

Chemical cleaning can involve a spray washer or a soak in a cold or hot tank. The cleaning solution is usually solvent based, with a medium pH rating of between 10 and 12. Most chemical solutions also contain silicates to protect the metal (aluminum) against corrosion.

Strong caustics do an excellent job on cast-iron items but are often too corrosive for aluminum parts. Aluminum cleaners include mineral spirit solvents as well as alkaline detergents.

CAUTION: When cleaning aluminum cylinder heads, blocks, or other engine components, make sure that the chemicals used are "aluminum safe." Many chemicals that are not aluminum safe may turn the aluminum metal black. Try to explain that to a customer!

WATER-BASED CHEMICAL CLEANING

Because of environmental concerns, most chemical cleaning is now performed using water-based solutions (called **aqueous-based**). Most aqueous-based chemicals are silicate based and are mixed with water. Aqueous-based solutions can be sprayed on or used in a tank for soaking parts. Aluminum heads and blocks usually require overnight soaking in a solution kept at about 190°F (90°C). For best results, the cleaning solution should be agitated.

SPRAY WASHING

A spray washer directs streams of liquid through numerous high-pressure nozzles to dislodge dirt and grime on an engine surface. The force of the liquid hitting the surface, combined with the chemical action of the cleaning solution, produces a clean surface. Spray washing is typically performed in an enclosed washer (like a dishwasher), where parts are rotated on a washer turntable. See Figure 21-17.

Spray washing is faster than soaking. A typical washer cycle is less than 30 minutes per load, compared to eight or

FIGURE 21-17 A pressure jet washer is similar to a large industrial-sized dishwasher. The part(s) is then rinsed with water to remove chemicals or debris that may remain on the part while it is still in the tank.

more hours for soaking. Most spray washers use an aqueous-based cleaning solution heated to 160° to 180°F (70° to 80°C) with foam suppressants. High-volume remanufacturers use industrial dishwashing machines to clean the disassembled engines' component parts.

STEAM CLEANING

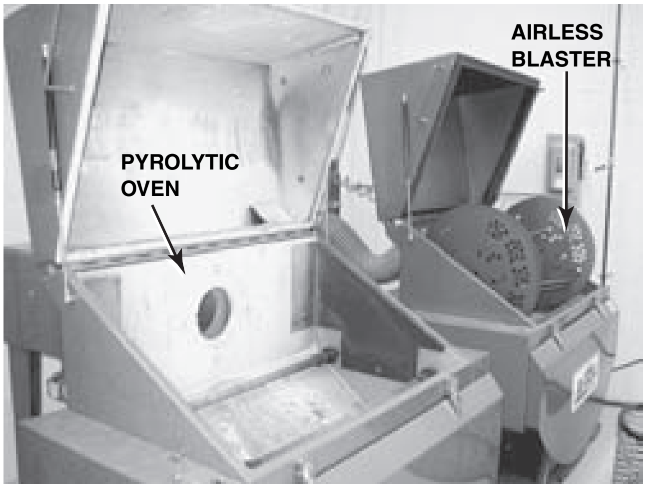
Steam cleaners are a special class of sprayers. Steam vapor is mixed with high-pressure water and sprayed on the parts. The heat of the steam and the propellant force of the high-pressure water combine to do the cleaning. Steam cleaning must be used with extreme care. Usually, a caustic cleaner is added to the steam and water to aid in the cleaning. This mixture is so active that it will damage and even remove paint, so painted surfaces must be protected from the spray. Engines are often steam cleaned before they are removed from the chassis.

THERMAL CLEANING

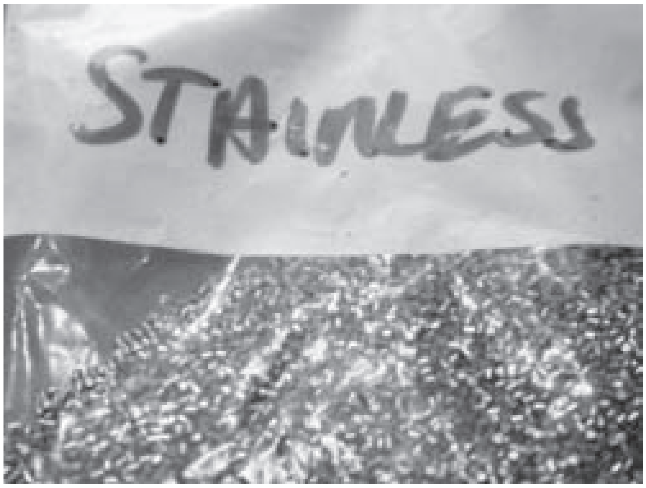
Thermal cleaning uses heat to vaporize and char dirt into a dry, powdery ash. Thermal cleaning is best suited for cleaning cast iron, where temperatures as high as 800°F (425°C) are used, whereas aluminum should not be heated to over 600°F (315°C).

The major advantages of thermal cleaning include the following:

1. This process cleans the inside as well as the outside of the casting or part.
2. The waste generated is nonhazardous and is easy to dispose of. However, the heat in the oven usually discolors the metal, leaving it looking dull.



(a)



(b)

FIGURE 21-18 (a) A pyrolytic (high temperature) oven cleans by baking the engine parts. After the parts have been cleaned, they are then placed into an airless blaster. This unit uses a paddle to scoop stainless steel shot from a reservoir and forces it against the engine part. The parts must be free of grease and oil to function correctly. (b) Stainless steel shot used in an airless blaster.

A **pyrolytic** (high-temperature) oven cleans engine parts by decomposing dirt, grease, and gaskets with heat in a manner similar to that of a self-cleaning oven. This method of engine part cleaning is becoming the most popular because there is no hazardous waste associated with it. Labor costs are also reduced because the operator does not need to be present during the actual cleaning operation. See Figure 21-18.

COLD TANK CLEANING

The cold soak tank is used to remove grease and carbon. The disassembled parts are placed in the tank so that they are *completely* covered with the chemical cleaning solution. After a soaking period, the parts are removed and rinsed until the milky appearance of the emulsion is gone. The parts are then dried with compressed air. The clean, dry parts are then usually given a very light coating of clean oil to prevent rusting. Carburetor cleaner, purchased with a basket in a bucket, is one of the most common types of cold soak agents in the automotive shop. Usually, there will be a layer of water over the chemical to prevent evaporation of the chemical. This water layer is called a **hydroseal.**

Parts washers are often used in place of soaking tanks. This equipment can move parts back and forth through the cleaning solution or pumps the cleaning solution over the parts. This movement, called **agitation,** keeps fresh cleaning solution moving past the soil to help it loosen. The parts washer is usually equipped with a safety cover held open by a low-temperature **fusible link.** If a fire occurs, the fusible link will melt and the cover will drop closed to snuff the fire out.

HOT TANK CLEANING

The hot soak tank is used for cleaning heavy organic deposits and rust from iron and steel parts. The caustic cleaning solution used in the hot soak tank is heated to near 200°F (93°C) for rapid cleaning action. The solution must be inhibited when aluminum is to be cleaned. After the deposits have been loosened, the parts are removed from the tank and rinsed with hot water or steam cleaned, which dries them rapidly. They must then be given a light coating of oil to prevent rusting.

NOTE: Fogging oil from a spray can does an excellent job of coating metal parts to keep them from rusting.

VAPOR CLEANING

Vapor cleaning is popular in some automotive service shops. The parts to be cleaned are suspended in hot vapors above a perchloroethylene solution. The vapors of the solution loosen the soil from the metal so that it can be blown, wiped, or rinsed from the surface.

ULTRASONIC CLEANING

Ultrasonic cleaning is used to clean small parts that must be absolutely clean; for example, hydraulic lifters and diesel injectors. The disassembled parts are placed in a tank of cleaning solution which is then vibrated at ultrasonic speeds to loosen all the soil from the parts. The soil goes into the solution or falls to the bottom of the tank.

VIBRATORY CLEANING

The vibratory method of cleaning is best suited for small parts. Parts are loaded into a vibrating bin with small, odd-shaped ceramic or steel pieces, called media, with a cleaning solution of mineral spirits or water-based detergents that usually contain a lubricant additive to help the media pieces slide around more freely. The movement of the vibrating solution and the scrubbing action of the media do an excellent job of cleaning metal.

BLASTERS

Cleaning cast-iron or aluminum engine parts with solvents or heat usually requires another operation to achieve a uniform surface finish. Blasting the parts with steel, cast-iron, aluminum, or stainless-steel shot or glass beads is a simple way to achieve a matte or satin surface finish on the engine parts. To keep the shot or beads from sticking to the parts, they must be dry, without a trace of oil or grease, prior to blasting. This means that blasting is the second cleaning method, after the part has been precleaned in a tank, spray washer, or oven. Some blasting is done automatically in an airless shot-blasting machine. Another method is to hard-blast parts in a sealed cabinet. See Figure 21-19.

CAUTION: Glass beads often remain in internal passages of engine parts, where they can come loose and travel through the cylinders when the engine is started. Among other places, these small, but destructive, beads can easily be trapped under the oil baffles of rocker covers and in oil pans and piston-ring grooves. To help prevent the glass beads from sticking, make sure that the parts being cleaned are free of grease and dirt and completely *dry*.

FIGURE 21-19 Small engine parts can be blasted clean in a sealed cabinet.

VISUAL INSPECTION

After the parts have been thoroughly cleaned, they should be reexamined for defects. A magnifying glass is helpful in finding defects. Critical parts of a performance engine should be checked for cracks using specialized magnetic or penetration inspection equipment. Internal parts such as pistons, connecting rods, and crankshafts that have cracks should be replaced. Cracks in the block and heads, however, can often be repaired, and these repair procedures are described in a later section.

MAGNETIC CRACK INSPECTION

Checking for cracks using a magnetic field is commonly called Magnafluxing, a brand name. Cracks in engine blocks, cylinder heads, crankshafts, and other engine components are sometimes difficult to find during a normal visual inspection, which is why all remanufacturers and most engine builders use a crack detection procedure on all critical engine parts.

Magnetic flux testing is the method most often used on steel and iron components. A metal engine part (such as a cast-iron cylinder head) is connected to a large electromagnet. Magnetic lines of force are easily conducted through the iron part and concentrate on the edges of a crack. A fine iron powder is then applied to the part being tested, and the powder will be attracted to the strong magnetic concentration around the crack. See Figures 21-20 through 21-22.

DYE-PENETRANT TESTING

Dye-penetrant testing is usually used on pistons and other parts constructed of aluminum or other nonmagnetic material. A dark-red penetrating chemical is first sprayed on the component being tested. After cleaning, a white powder is sprayed over the test area. If a crack is present, the red dye will stain the white powder. Even though this method will also work on iron and steel (magnetic) parts, it is usually used only on nonmagnetic parts because magnetic methods do not work on these parts.

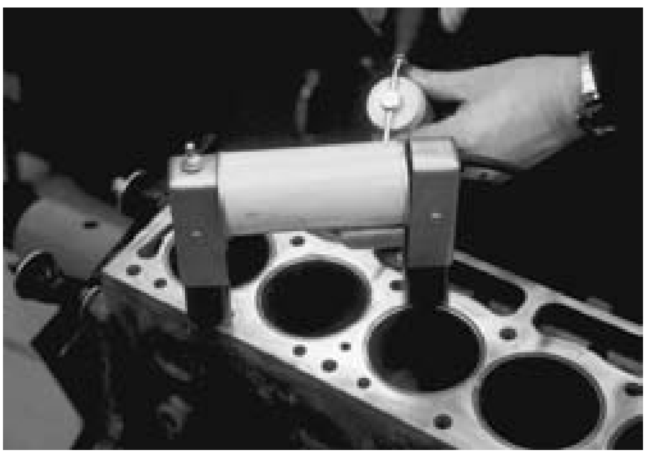


FIGURE 21-20 The top deck surface of a block being tested using magnetic crack inspection equipment.

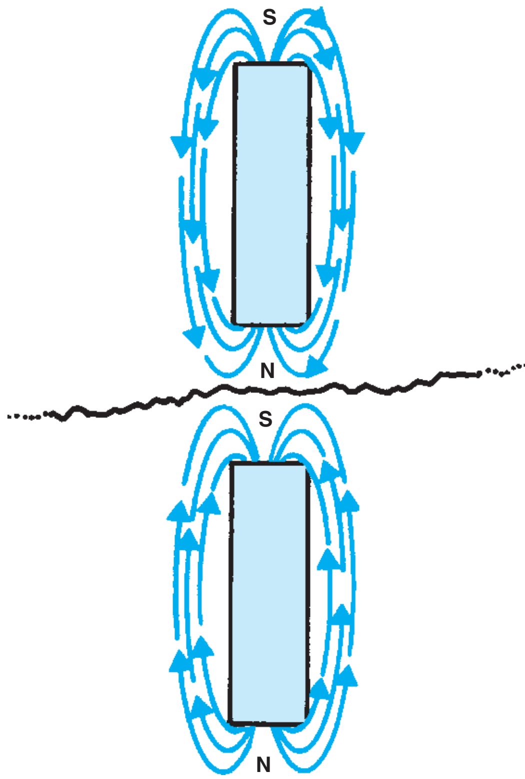


FIGURE 21-21 If the lines of force are interrupted by a break (crack) in the casting, two magnetic fields are created and the powder will lodge in the crack.

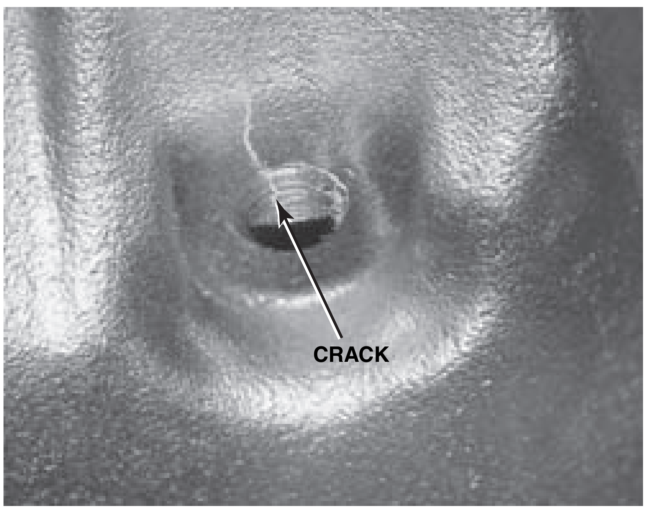


FIGURE 21-22 This crack in a vintage Ford 289, V-8 block was likely caused by the technician using excessive force trying to remove the plug from the block. The technician should have used heat and wax, not only to make the job easier, but also to prevent damaging the block.

FLUORESCENT-PENETRANT TESTING

To be seen, fluorescent penetrant requires a black light. It can be used on iron, steel, or aluminum parts. Cracks show up as bright lines when viewed with a black light. The method is commonly called **Zyglo,** a trademark of the Magnaflux Corporation.

PRESSURE TESTING

Cylinder heads and blocks are often pressure tested with air and checked for leaks. All coolant passages are blocked with rubber plugs or gaskets, and compressed air is applied to the water jacket(s). The head or block is then lowered into water, where air bubbles indicate a leak. For more accurate results, the water should be heated because the hot water expands the casting by about the same amount as an operating engine would. An alternative method involves running heated water with a dye through the cylinder or block. Any leaks revealed by the dyed water indicate a crack. See Figures 21-23 and 21-24.

CRACK REPAIR

Cracks in the engine block can cause coolant to flow into the oil or oil into the coolant. A cracked block can also cause coolant to leak externally from a crack that goes through to a coolant passage. Cracks in the head will allow coolant to leak into the engine, or they will allow combustion gases to leak into the coolant. Cracks across the valve seat cause hot spots on the valve, which will burn the valve face. A head with a crack will either have to be replaced or the crack will have to be repaired. Two common methods of crack repair are welding and plugging.

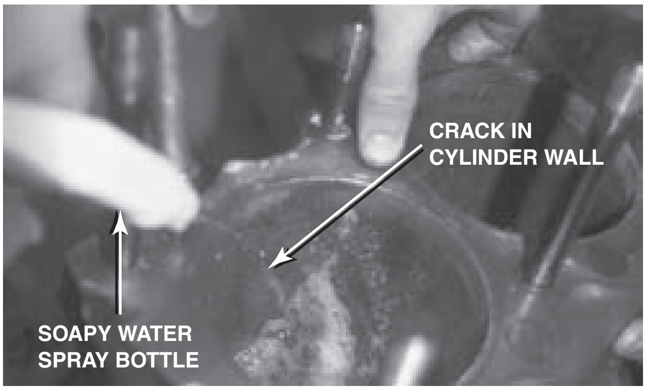


FIGURE 21-23 To make sure that the mark observed in the cylinder wall was a crack, compressed air was forced into the water jacket while soapy water was sprayed on the cylinder wall. Bubbles confirmed that the mark was indeed a crack.

NOTE: A hole can be drilled at each end of the crack to keep it from extending further, a step sometimes called **stop drilling.** Cracks that do not cross oil passages, bolt holes, or seal surfaces can sometimes be left alone if stopped.

CRACK-WELDING CAST IRON

It takes a great deal of skill to weld cast iron. The cast iron does not puddle or flow as steel does when it is heated. Heavy cast parts, such as the head and block, conduct heat away from the weld so fast that it is difficult to get the part hot enough to melt the iron for welding. When it does melt, a crack will often develop next to the edge of the weld bead. Welding can be done satisfactorily when the entire cast part is heated red hot.

A new technique involves flame welding using a special torch. See Figure 21-25.

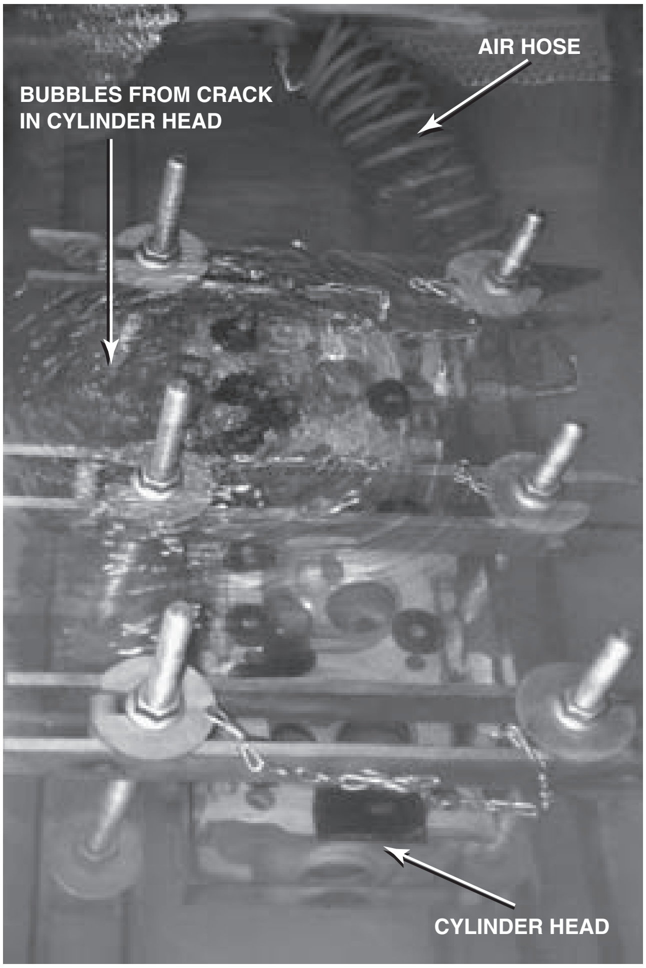
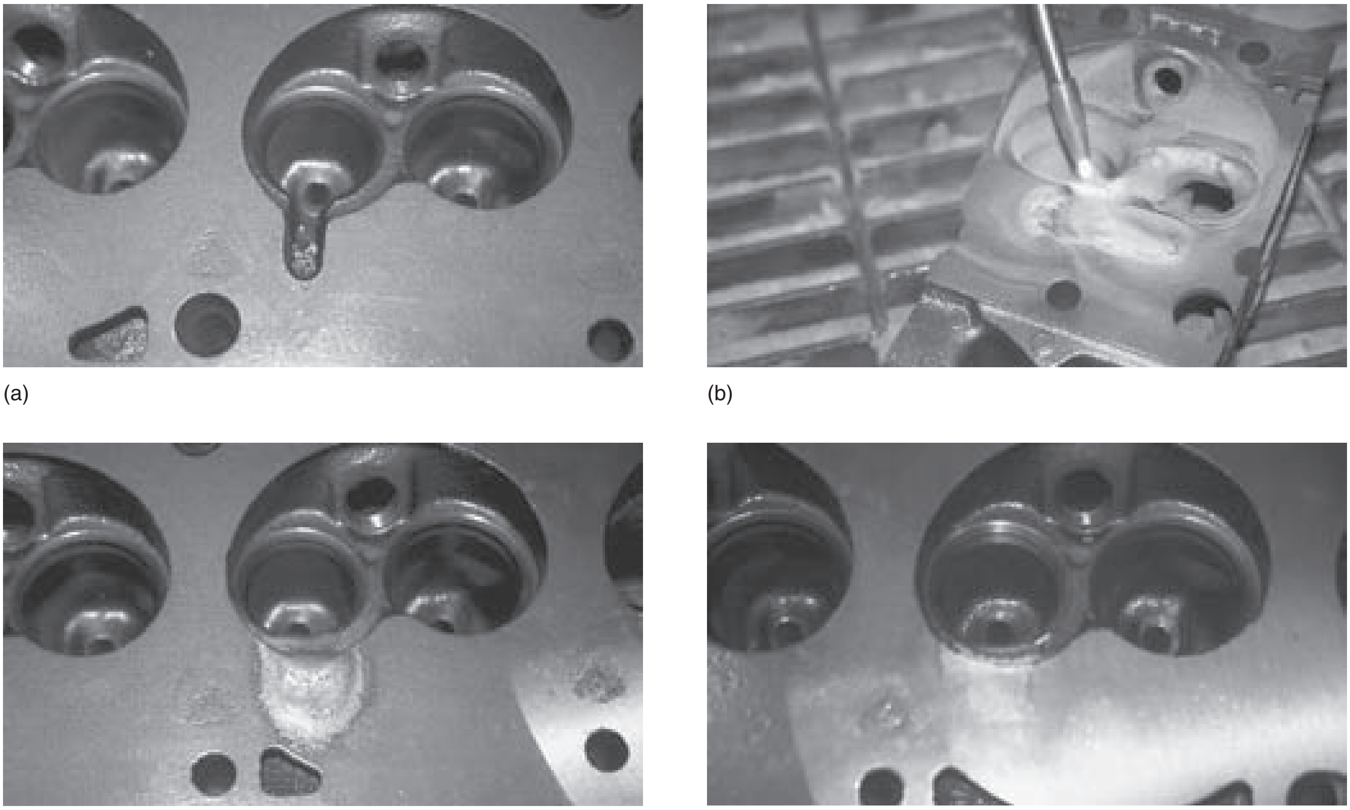


FIGURE 21-24 A cylinder head is under water and being pressure tested using compressed air. Note that the air bubbles indicate a crack.



(a) (b) (c) (d)

FIGURE 21-25 (a) Before welding, the crack is ground out using a carbide grinder. (b) Here the technician is practicing using the special cast-iron welding torch before welding the cracked cylinder head. (c) The finished welded crack before final machining. (d) The finished cylinder head after the crack has been repaired using welding.

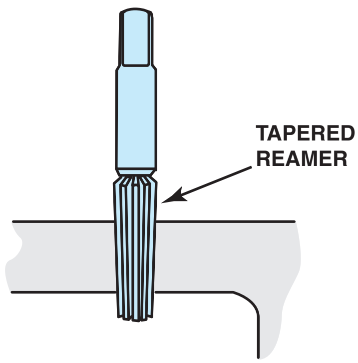


FIGURE 21-26 Reaming a hole for a tapered plug.

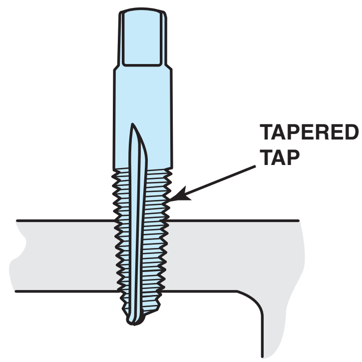


FIGURE 21-27 Tapping a tapered hole for a plug.

CRACK-WELDING ALUMINUM

Cracks in aluminum can be welded using a Heli-arc® or similar welder that is specially designed to weld aluminum. The crack should be cut or burned out before welding begins. The old valve-seat insert should be removed if the crack is in or near the combustion chamber.

CRACK PLUGGING

In the process of crack plugging, a crack is closed using interlocking tapered plugs. This procedure can be performed to repair cracks in both aluminum and cast-iron engine components. The ends of the crack are center punched and drilled with the proper size of tap drill for the plugs. The hole is reamed with a tapered reamer (Figure 21-26) and is then tapped to give full threads (Figure 21-27). The plug is coated with sealer; then

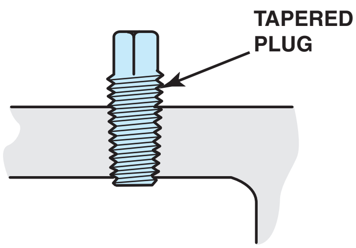


FIGURE 21-28 Screwing a tapered plug in the hole.

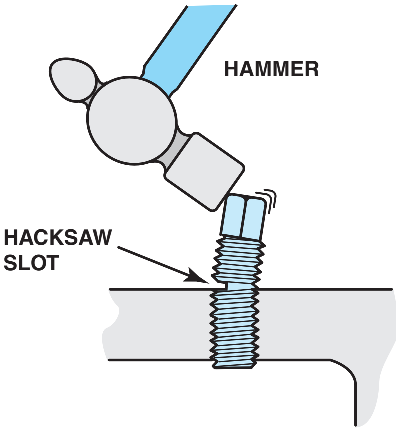


FIGURE 21-29 Cutting the plug with a hacksaw.

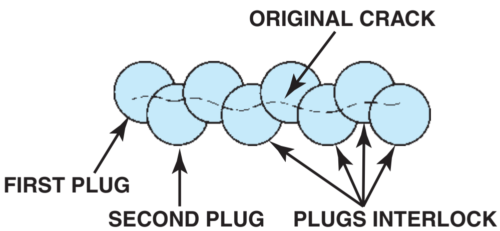
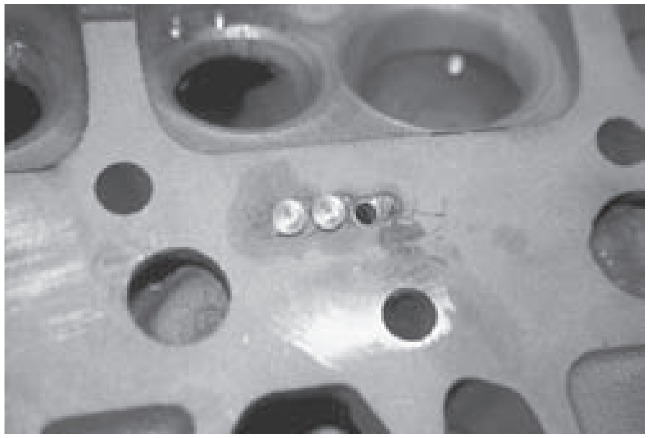
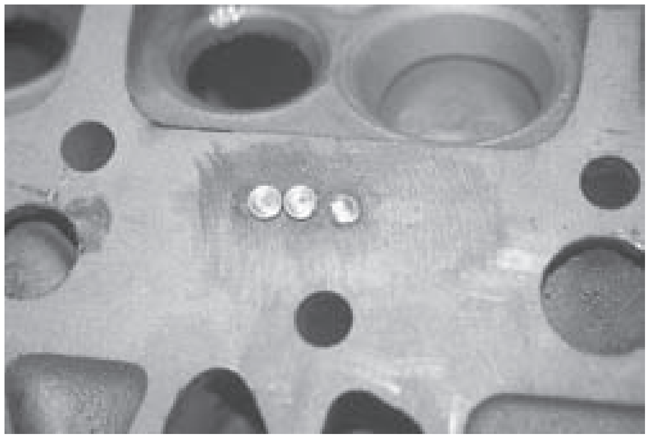


FIGURE 21-30 Interlocking plugs.

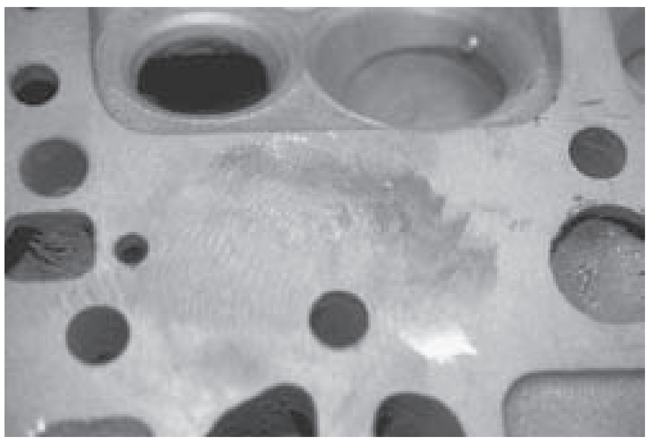
it is tightened into the hole (Figure 21-28), sawed about one-fourth of the way through, and broken off. The saw slot controls the breaking point (Figure 21-29). If the plug should break below the surface, it will have to be drilled out and a new plug installed. The plug should go to the full depth or thickness of the cast metal. After the first plug is installed on each end, a new hole is drilled with the tap drill so that it cuts into the edge of the first plug. This new hole is reamed and tapped, and a plug is inserted as before. The plug should fit about one-fourth of the way into the first plug to lock it into place (Figure 21-30). Interlocking plugs are placed along the entire crack, alternating slightly from side to side. The exposed ends of the plugs are peened over with a hammer to help secure them in place. The surface of the plugs is then ground or filed down nearly to the gasket surface. In the combustion chamber and at the ports,



(a)



(b)



(c)

FIGURE 21-31 (a) A hole is drilled and tapped for the plugs. (b) The plugs are installed. (c) After final machining, the cylinder head can be returned to useful service.

the plugs are ground down to the original surface using a hand grinder. The gasket surface of the head must be resurfaced after the crack has been repaired. See Figure 21-31 for an example of a cylinder head repair using plugs.

ENGINE REMOVAL Step-by-Step

STEP 1 Before beginning work on removing the engine, mark and remove the hood and place it in a safe location.

STEP 2 For safety, remove the negative battery cable to avoid any possible electrical problems from occurring.

STEP 3 Drain the coolant and dispose of properly.

STEP 4 Disconnect all cooling system and heater hoses and remove the radiator.

STEP 5 Remove the accessory drive belt(s) and set the generator (alternator), power steering pump, and air-conditioning compressor aside.

STEP 6 Remove the air intake system including the air filter housing as needed.

ENGINE REMOVAL continued

STEP 7 Remove the electrical connector from all sensors and label.

STEP 8 Disconnect the engine wiring harness connector at the bulkhead.

STEP 9 Safely hoist the vehicle and disconnect the exhaust system from the exhaust manifolds.

STEP 10 Mark and then remove the fasteners connecting the flex plate to the torque converter.

STEP 11 Lower the vehicle and remove the engine mount bolts and transaxle bell housing fasteners.

STEP 12 Secure the lifting chain to the engine hooks and carefully remove the engine from the vehicle.

SUMMARY

1. The factory-installed lifting hooks should be used when hoisting an engine.
2. Engine component parts should only be removed when the engine is cold. Also, the torque table should always be followed backward, starting with the highest-number head bolt and working toward the lowest-number. This procedure helps prevent warpage.
3. The ridge at the top of the cylinder should be removed before removing the piston(s) from the cylinder.
4. The connecting rod and main bearing caps should be marked before removing to ensure that they can be reinstalled in the exact same location when the engine is reassembled.
5. The tip of the valve stem should be filed before removing valves from the cylinder head to help prevent damage to the valve guide.
6. Mechanical cleaning with scrapers or wire brushes is used to remove deposits.
7. Steel wire brushes should never be used to clean aluminum parts.
8. Most chemical cleaners are strong soaps called caustic materials.
9. Always use aluminum-safe chemicals when cleaning aluminum parts or components.
10. Thermal cleaning is done in a pyrolytic oven in temperatures as high as 800°F (425°C) to turn grease and dirt into harmless ash deposits.
11. Blasters use metal shot or glass beads to clean parts. All of the metal shot or glass beads must be cleaned from the part so as not to cause engine problems.
12. All parts should be checked for cracks using magnetic, dye-penetrant, fluorescent-penetrant, or pressure testing methods.
13. Cracks can be repaired by welding or by plugging.

REVIEW QUESTIONS

1. When should the factory-installed lifting hooks be used?
2. State two reasons for the removal of the ridge at the top of the cylinder.
3. Explain why the burrs must be removed from valves before removing the valves from the cylinder head.
4. Describe five methods that could be used to clean engines or engine parts.
5. Explain magnetic crack inspection, dye-penetrant testing, and fluorescent-penetrant testing methods and where each can be used.

CHAPTER QUIZ

1. Technician A says that the intake and exhaust manifolds have to be removed before removing the engine from the vehicle. Technician B says that it is often easier to remove the engine from underneath rather than remove the engine from the top of the vehicle. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
2. Lifting hooks are often installed at the factory because _____.
   - **a.** They make removing the engine easier for the technician
   - **b.** They are used to install the engine at the factory
   - **c.** They are part of the engine and should not be removed
   - **d.** They make servicing the top of the engine easier for the technician

3. The ridge at the top of the cylinder _____.
   a. Is caused by wear at the top of the cylinder by the rings
   b. Represents a failure of the top piston ring to correctly seal against the cylinder wall
   c. Should not be removed before removing pistons except when reboring the cylinders
   d. Means that a crankshaft with an incorrect stroke was installed in the engine
4. Before the timing chain can be inspected and removed, the following component(s) must be removed:
   a. Rocker cover (valve cover)
   b. Vibration damper
   c. Cylinder head(s)
   d. Intake manifold (V-type engines only)
5. Before the valves are removed from the cylinder head, what operations need to be completed?
   a. Remove valve locks (keepers)
   b. Remove cylinder head(s) from the engine
   c. Remove burrs from the stem of the valve(s)
   d. All of the above
6. Cleaning chemicals are usually either a caustic material or an acid material. Which of the following statements is true?
   a. Both caustics and acids have a pH of 7 if rated according to distilled water.
   b. An acid is lower than 7 and a caustic is higher than 7 on the pH scale.
   c. An acid is higher than 7 and a caustic is lower than 7 on the pH scale.
   d. Pure water is a 1 and a strong acid is a 14 on the pH scale.
7. Many cleaning methods involve chemicals that are hazardous to use and expensive to dispose of after use. The least hazardous method is generally considered to be the _____.
   a. Pyrolytic oven
   b. Hot vapor tank
   c. Hot soak tank
   d. Cold soak tank
8. Magnetic crack inspection _____.
   a. Uses a red dye to detect cracks in aluminum
   b. Uses a black light to detect cracks in iron parts
   c. Uses a fine iron powder to detect cracks in iron parts
   d. Uses a magnet to remove cracks from iron parts
9. Technician A says that engine parts should be cleaned before a thorough test can be done to detect cracks. Technician B says that pressure testing can be used to find cracks in blocks or cylinder heads. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
10. Plugging can be used to repair cracks _____.
   a. In cast-iron cylinder heads
   b. In aluminum cylinder heads
   c. In both cast-iron and aluminum cylinder heads
   d. Only in cast-iron blocks