CHAPTER 20

ENGINE CONDITION DIAGNOSIS

OBJECTIVES

After studying Chapter 20, the reader will be able to:

1. Prepare for ASE Engine Performance (A8) certification test content area "A" (General Engine Diagnosis).
2. List the visual checks to determine engine condition.
3. Discuss engine noise and its relation to engine condition.
4. Describe how to perform a dry and a wet compression test.
5. Explain how to perform a cylinder leakage test.
6. Discuss how to measure the amount of timing chain slack.
7. Describe how an oil sample analysis can be used to determine engine condition.

KEY TERMS

Backpressure (p. 350)
Compression Test (p. 342)
Cranking Vacuum Test (p. 347)
Cylinder Leakage Test (p. 345)
Dynamic Compression Test (p. 345)
Idle Vacuum Test (p. 347)
Inches of Mercury (in. Hg) (p. 347)
Paper Test (p. 343)
Power Balance Test (p. 346)
Restricted Exhaust (p. 349)
Running Compression Test (p. 345)
Vacuum Test (p. 347)
Wet Compression Test (p. 344)

If there is an engine operation problem, then the cause could be any one of many items, including the engine itself. The condition of the engine should be tested anytime the operation of the engine is not satisfactory.

TYPICAL ENGINE-RELATED COMPLAINTS

Many driveability problems are *not* caused by engine mechanical problems. A thorough inspection and testing of the ignition and fuel systems should be performed before testing for mechanical engine problems.

Typical engine mechanical-related complaints include the following:

- Excessive oil consumption
- Engine misfiring
- Loss of power
- Smoke from the engine or exhaust
- Engine noise

ENGINE SMOKE DIAGNOSIS

The color of engine exhaust smoke can indicate what engine problem might exist.

Typical Exhaust Smoke Color	Possible Causes
Blue	Blue exhaust indicates that the engine is burning oil. Oil is getting into the combustion chamber either past the piston rings or past the valve stem seals. Blue smoke only after start-up is usually due to defective valve stem seals. See Figure 20-1.
Black	Black exhaust smoke is due to excessive fuel being burned in the combustion chamber. Typical causes include a defective or misadjusted throttle body, leaking fuel injector, or excessive fuel-pump pressure.
White (steam)	White smoke or steam from the exhaust is normal during cold weather and represents condensed steam. Every engine creates about 1 gallon of water for each gallon of gasoline burned. If the steam from the exhaust is excessive, then water (coolant) is getting into the combustion chamber. Typical causes include a defective cylinder head gasket, a cracked cylinder head, or in severe cases a cracked block. See Figure 20-2.

NOTE: White smoke can also be created when automatic transmission fluid (ATF) is burned. A common source of ATF getting into the engine is through a defective vacuum modulator valve on the automatic transmission.

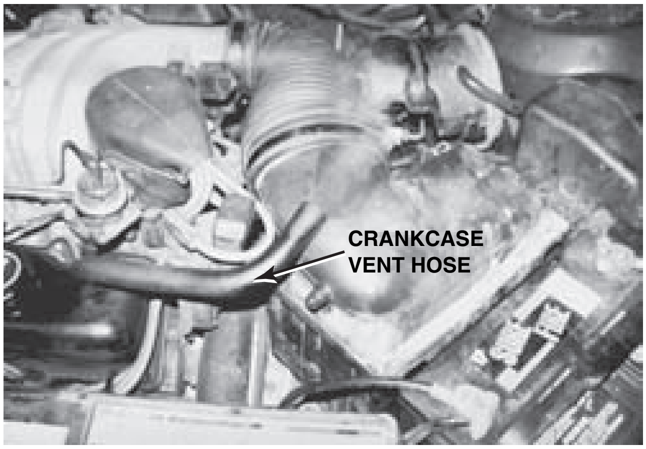


FIGURE 20-1 Blowby gases coming out of the crankcase vent hose. Excessive amounts of combustion gases flow past the piston rings and into the crankcase.

FIGURE 20-2 White steam is usually an indication of a blown (defective) cylinder head gasket that allows engine coolant to flow into the combustion chamber where it is turned to steam.

THE DRIVER IS YOUR BEST RESOURCE

The driver of the vehicle knows a lot about the vehicle and how it is driven. *Before* diagnosis is started, always ask the following questions:

- When did the problem first occur?
- Under what conditions does it occur?
    1. Cold or hot?
    2. Acceleration, cruise, or deceleration?
    3. How far was it driven?

After the nature and scope of the problem are determined, the complaint should be verified before further diagnostic tests are performed.

VISUAL CHECKS

The first and most important "test" that can be performed is a careful visual inspection.

Oil Level and Condition

The first area for visual inspection is oil level and condition.

1. Oil level—oil should be to the proper level
2. Oil condition
   a. Using a match or lighter, try to light the oil on the dipstick; if the oil flames up, gasoline is present in the engine oil.
   b. Drip some of the engine oil from the dipstick onto the hot exhaust manifold. If the oil bubbles or boils, there is coolant (water) in the oil.
   c. Check for grittiness by rubbing the oil between your fingers.

Coolant Level and Condition

Most mechanical engine problems are caused by overheating. The proper operation of the cooling system is critical to the life of any engine.

NOTE: Check the coolant level in the radiator only if the radiator is cool. If the radiator is hot and the radiator cap is removed, the drop in pressure above the coolant will cause the coolant to boil immediately and can cause severe burns when the coolant explosively expands upward and outward from the radiator opening.

1. The coolant level in the coolant recovery container should be within the limits indicated on the overflow bottle. If this level is too low or the coolant recovery container is empty, then check the level of coolant in the radiator (only when cool) and also check the operation of the pressure cap.
2. The coolant should be checked with a hydrometer for boiling and freezing temperature. This test indicates if the concentration of the antifreeze is sufficient for proper protection.
3. Pressure test the cooling system and look for leakage. Coolant leakage can often be seen around hoses or cooling system components because it will often cause:
   a. A grayish white stain
   b. A rusty color stain
   c. Dye stains from antifreeze (greenish or yellowish depending on the type of coolant)
4. Check for cool areas of the radiator indicating clogged sections.
5. Check operation and condition of the fan clutch, fan, and coolant pump drive belt.

TECH TIP

WHAT'S LEAKING?

The color of the leaks observed under a vehicle can help the technician determine and correct the cause. Some leaks, such as condensate (water) from the air-conditioning system, are normal, whereas a brake fluid leak is very dangerous. The following are colors of common leaks:

Sooty black	Engine oil
Yellow, green, blue, or orange	Antifreeze (coolant)
Red	Automatic transmission fluid
Murky brown	Brake or power steering fluid or very neglected antifreeze (coolant)
Clear	Air-conditioning condensate (water) (normal)

Oil Leaks

Oil leaks can lead to severe engine damage if the resulting low oil level is not corrected. Besides causing an oily mess where the vehicle is parked, the oil leak can cause blue smoke to occur under the hood as leaking oil drips on the exhaust system. *Finding* the location of the oil leak can often be difficult. See Figures 20-3 and 20-4. To help find the source of oil leaks follow these steps:

Step 1 Clean the engine or area around the suspected oil leak. Use a high-powered hot-water spray to wash the engine. While the engine is running, spray the entire engine and the engine compartment. Avoid letting the water come into direct contact with the air inlet and ignition distributor or ignition coil(s).

NOTE: If the engine starts to run rough or stalls when the engine gets wet, then the secondary ignition wires (spark plug wires) or distributor cap may be defective or have weak insulation. Be certain to wipe all wires and the distributor cap dry with a soft, dry cloth if the engine stalls.

An alternative method is to spray a degreaser on the engine, then start and run the engine until warm. Engine heat helps the degreaser penetrate the grease and dirt. Use a water hose to rinse off the engine and engine compartment.

Step 2 If the oil leak is not visible or oil seems to be coming from "everywhere," use a white talcum powder. The leaking oil will show as a dark area on the white powder. See the Tech Tip, "The Foot Powder Spray Trick."

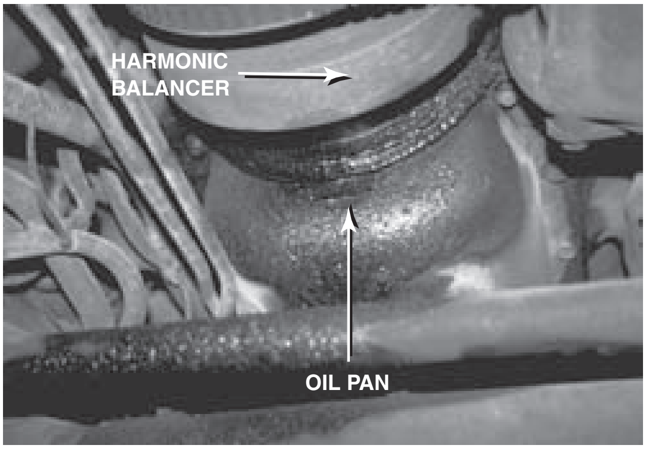


FIGURE 20-3 What looks like an oil pan gasket leak can be a rocker cover gasket leak. Always look up and look for the highest place you see oil leaking; that should be repaired first.

FIGURE 20-4 The transmission and flex plate (flywheel) were removed to check the exact location of this oil leak. The rear main seal and/or the oil pan gasket could be the cause of this leak.

Step 3 Fluorescent dye can be added to the engine oil. Add about 1/2 oz (15 cc) of dye per 5 quarts of engine oil. Start the engine and allow it to run about 10 minutes to thoroughly mix the dye throughout the engine. A black light can then be shown around every suspected oil leak location. The black light will easily show all oil leak locations because the dye will show as a bright yellow/green area. See Figure 20-5.

FIGURE 20-5 Using a black light to spot leaks after adding dye to the oil.

TECH TIP

THE FOOT POWDER SPRAY TRICK

The source of an oil or other fluid leak is often difficult to determine. A quick and easy method that works is the following. First, clean the entire area. This can best be done by using a commercially available degreaser to spray the entire area. Let it soak to loosen all accumulated oil and greasy dirt. Clean off the degreaser with a water hose. Let the area dry. Start the engine, and using spray foot powder or other aerosol powder product, spray the entire area. The leak will turn the white powder dark. The exact location of any leak can be quickly located.

NOTE: Most oil leaks appear at the bottom of the engine due to gravity. Look for the highest, most forward location for the source of the leak.

NOTE: Fluorescent dye works best with clean oil.

ENGINE NOISE DIAGNOSIS

An engine knocking noise is often difficult to diagnose. Several items that can cause a deep engine knock include:

- **Valves clicking.** This can happen because of lack of oil to the lifters. This noise is most noticeable at idle when the oil pressure is the lowest.

- **Torque converter.** The attaching bolts or nuts may be loose on the flex plate. This noise is most noticeable at idle or when there is no load on the engine.
- **Cracked flex plate.** The noise of a cracked flex plate is often mistaken for a rod- or main-bearing noise.
- **Loose or defective drive belts or tensioners.** If an accessory drive belt is loose or defective, the flopping noise often sounds similar to a bearing knock. See Figure 20-6.
- **Piston pin knock.** This knocking noise is usually not affected by load on the cylinder. If the clearance is too great, a double knock noise is heard when the engine idles. If all cylinders are grounded out one at a time and the noise does not change, a defective piston pin could be the cause.
- **Piston slap.** A piston slap is usually caused by an undersized or improperly shaped piston or oversized cylinder bore. A piston slap is most noticeable when the engine is cold and tends to decrease or stop making noise as the piston expands during engine operation.
- **Timing chain noise.** An excessively loose timing chain can cause a severe knocking noise when the chain hits the timing chain cover. This noise can often sound like a rod-bearing knock.
- **Rod-bearing noise.** The noise from a defective rod bearing is usually load sensitive and changes in intensity as the load on the engine increases and decreases. A rod-bearing failure can often be detected by grounding out the spark plugs one cylinder at a time. If the knocking noise decreases or is eliminated when a particular cylinder is grounded (disabled), then the grounded cylinder is the one from which the noise is originating.
- **Main-bearing knock.** A main-bearing knock often cannot be isolated to a particular cylinder. The sound can vary in intensity and may disappear at times depending on engine load.

FIGURE 20-6 An accessory belt tensioner. Most tensioners have a mark that indicates normal operating location. If the belt has stretched, this indicator mark will be outside of the normal range. Anything wrong with the belt or tensioner can cause noise.

Typical Noises	Possible Causes
Clicking noise—like the clicking of a ballpoint pen	1. Loose spark plug 2. Loose accessory mount (for air-conditioning compressor, alternator, power steering pump, etc.) 3. Loose rocker arm 4. Worn rocker arm pedestal 5. Fuel pump (broken mechanical fuel pump return spring) 6. Worn camshaft 7. Exhaust leak. (See Figure 20-7.)
Clacking noise—like tapping on metal	1. Worn piston pin 2. Broken piston 3. Excessive valve clearance 4. Timing chain hitting cover
Knock—like knocking on a door	1. Rod bearing(s) 2. Main bearing(s) 3. Thrust bearing(s) 4. Loose torque converter 5. Cracked flex plate (drive plate)
Rattle—like a baby rattle	1. Manifold heat control valve 2. Broken harmonic balancer 3. Loose accessory mounts 4. Loose accessory drive belt or tensioner
Clatter—like rolling marbles	1. Rod bearings 2. Piston pin 3. Loose timing chain
Whine—like an electric motor running	1. Alternator bearing 2. Drive belt 3. Power steering 4. Belt noise (accessory or timing)
Clunk—like a door closing	1. Engine mount 2. Drive axle shaft U-joint or constant velocity (CV) joint

TECH TIP

ENGINE NOISE AND COST

A light ticking noise often heard at one-half engine speed and associated with valve train noise is a less serious problem than many deep-sounding knocking noises. Generally, the deeper the sound of the engine noise, the more the owner will have to pay for repairs. A light "tick tick tick," though often not cheap, is usually far less expensive than a deep "knock knock knock" from the engine.

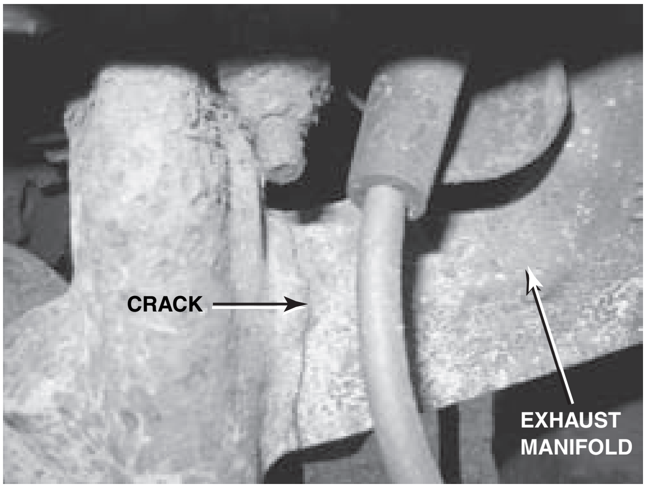


FIGURE 20-7 A cracked exhaust manifold on a Ford V-8.

Regardless of the type of loud knocking noise, after the external causes of the knocking noise have been eliminated, the engine should be disassembled and carefully inspected to determine the exact cause.

OIL PRESSURE TESTING

Proper oil pressure is very important for the operation of any engine. *Low oil pressure can cause engine wear, and engine wear can cause low oil pressure.*

If main thrust or rod bearings are worn, oil pressure is reduced because of leakage of the oil around the bearings. Oil pressure testing is usually performed with the following steps:

Step 1 Operate the engine until normal operating temperature is achieved.

Step 2 With the engine off, remove the oil pressure sending unit or sender, usually located near the oil filter. Thread an oil pressure gauge into the threaded hole. See Figure 20-8.

NOTE: An oil pressure gauge can be made from another gauge, such as an old air-conditioning gauge and a flexible brake hose. The threads are often the same as those used for the oil pressure sending unit.

Step 3 Start the engine and observe the gauge. Record the oil pressure at idle and at 2500 RPM. Most vehicle manufacturers recommend a minimum oil pressure of 10 PSI per 1000 RPM. Therefore, at 2500 RPM, the oil pressure should be at least 25 PSI. Always compare your test results with the manufacturer's recommended oil pressure. Besides engine bearing wear, other possible causes for low oil pressure include:

- Low oil level
- Diluted oil
- Stuck oil pressure relief valve

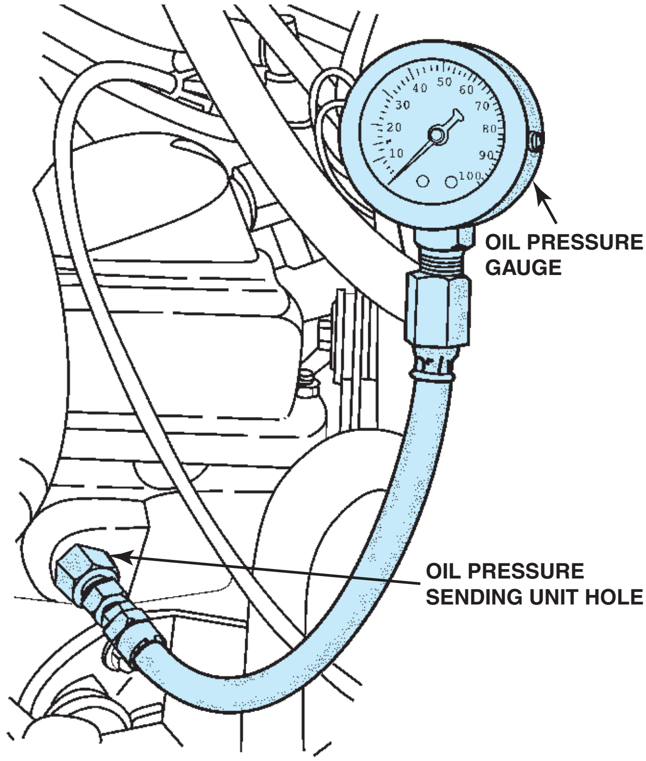


FIGURE 20-8 To measure engine oil pressure, remove the oil pressure sending (sender) unit usually located near the oil filter. Screw the pressure gauge into the oil pressure sending unit hole.

OIL PRESSURE WARNING LAMP

The red oil pressure warning lamp in the dash usually lights when the oil pressure is less than 4 to 7 PSI, depending on vehicle and engine. The oil light should not be on during driving. If the oil warning lamp is on, stop the engine immediately. Always confirm oil pressure with a reliable mechanical gauge before performing engine repairs. The sending unit or circuit may be defective.

COMPRESSION TEST

An engine **compression test** is one of the fundamental engine diagnostic tests that can be performed. For smooth engine operation, all cylinders must have equal compression. An engine can lose compression by leakage of air through one or more of only three routes:

- Intake or exhaust valve
- Piston rings (or piston, if there is a hole)
- Cylinder head gasket

TECH TIP

USE THE KISS TEST METHOD

Engine testing is done to find the cause of an engine problem. All the simple things should be tested first. Just remember KISS—"keep it simple, stupid." A loose alternator belt or loose bolts on a torque converter can sound just like a lifter or rod bearing. A loose spark plug can make the engine perform as if it had a burned valve. Some simple items that can cause serious problems include the following:

Oil Burning

- Low oil level
- Clogged PCV valve or system, causing blowby and oil to be blown into the air cleaner
- Clogged drainback passages in the cylinder head
- Dirty oil that has not been changed for a long time (Change the oil and drive for about 1,000 miles (1,600 kilometers) and change the oil and filter again.)

Noises

- Carbon on top of the piston(s) can sound like a bad rod bearing (often called a carbon knock)
- Loose torque-to-flex plate bolts (or nuts), causing a loud knocking noise

NOTE: Often this problem will cause noise only at idle; the noise tends to disappear during driving or when the engine is under load.

- A loose and/or defective drive belt, which may cause a rod- or main-bearing knocking noise (A loose or broken mount for the generator [alternator], power steering pump, or air-conditioning compressor can also cause a knocking noise.)

For best results, the engine should be warmed to normal operating temperature before testing. An accurate compression test should be performed as follows:

Step 1 Remove all spark plugs. This allows the engine to be cranked to an even speed. Be sure to label all spark plug wires.

CAUTION: Disable the ignition system by disconnecting the primary leads from the ignition coil or module or by grounding the coil wire after removing it from the center of the distributor cap. Also disable the fuel-injection system to prevent the squirting of fuel into the cylinder.

TECH TIP

THE PAPER TEST

A soundly running engine should produce even and steady exhaust at the tailpipe. You can test this with the **paper test.** Hold a piece of paper or a ″3 × 5″ card (even a dollar bill works) within 1 inch (2.5 centimeters) of the tailpipe with the engine running at idle. See Figure 20-9.

The paper should blow out evenly without "puffing." If the paper is drawn *toward* the tailpipe at times, the exhaust valves in one or more cylinders could be burned. Other reasons why the paper might be sucked toward the tailpipe include the following:

1. The engine could be misfiring because of a lean condition that could occur normally when the engine is cold.
2. Pulsing of the paper toward the tailpipe could also be caused by a hole in the exhaust system. If exhaust escapes through a hole in the exhaust system, air could be drawn in during the intervals between the exhaust puffs from the tailpipe to the hole in the exhaust, causing the paper to be drawn toward the tailpipe.
3. Ignition fault causing misfire.

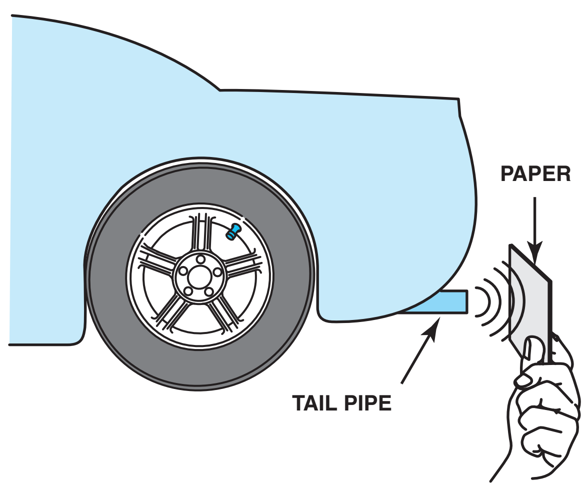


FIGURE 20-9 The paper test involves holding a piece of paper near the tailpipe of an idling engine. A good engine should produce even, outward puffs of exhaust. If the paper is sucked in toward the tailpipe, a burned valve is a possibility.

FIGURE 20-10 A two-piece compression gauge set. The threaded hose is screwed into the spark plug hole after removing the spark plug. The gauge part is then snapped onto the end of the hose.

Step 2 Block open the throttle. This permits the maximum amount of air to be drawn into the engine. This step also ensures consistent compression test results.

Step 3 Thread a compression gauge into one spark plug hole and crank the engine. See Figure 20-10.

Continue cranking the engine through *four* compression strokes. Each compression stroke makes a puffing sound.

NOTE: Note the reading on the compression gauge after the first puff. This reading should be at least one-half the final reading. For example, if the final, highest reading is 150 PSI, then the reading after the first puff should be higher than 75 PSI. A low first-puff reading indicates possible weak piston rings. Release the pressure on the gauge and repeat for the other cylinders.

Step 4 Record the highest readings and compare the results. Most vehicle manufacturers specify the minimum compression reading and the maximum allowable variation among cylinders. Most manufacturers specify a maximum difference of 20% between the highest reading and the lowest reading. For example:

If the high reading is	150 PSI
Subtract 20%	−30 PSI
Lowest allowable compression is	120 PSI

NOTE: To make the math quick and easy, think of 10% of 150, which is 15 (move the decimal point to the left one place). Now double it: $15 \times 2 = 30$. This represents 20%.

NOTE: During cranking, the oil pump cannot maintain normal oil pressure. Extended engine cranking, such as that which occurs during a compression test, can cause hydraulic lifters to collapse. When the engine starts, loud valve clicking noises may be heard. This should be considered normal after performing a compression test, and the noise should stop after the vehicle has been driven a short distance.

TECH TIP

THE HOSE TRICK

Installing spark plugs can be made easier by using a rubber hose on the end of the spark plug. The hose can be a vacuum hose, fuel line, or even an old spark plug wire end. See Figure 20-11.

The hose makes it easy to start the threads of the spark plug into the cylinder head. After starting the threads, continue to thread the spark plug for several turns. Using the hose eliminates the chance of cross-threading the plug. This is especially important when installing spark plugs in aluminum cylinder heads.

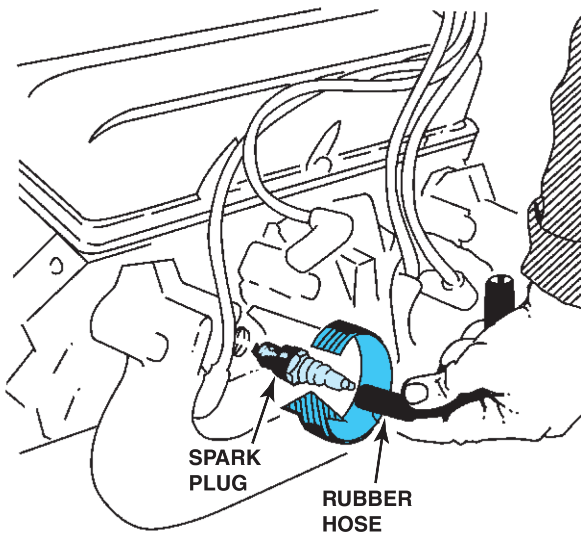


FIGURE 20-11 Use a vacuum or fuel line hose over the spark plug to install it without danger of cross-threading the cylinder head.

WET COMPRESSION TEST

If the compression test reading indicates low compression on one or more cylinders, add three squirts of oil to the cylinder and retest. This is called a **wet compression test,** when oil is used to help seal around the piston rings.

CAUTION: Do not use more oil than three squirts from a hand-operated oil squirt can. Too much oil can cause a hydrostatic lock, which can damage or break pistons or connecting rods or even crack a cylinder head.

Perform the compression test again and observe the results. If the first-puff readings greatly improve and the readings are

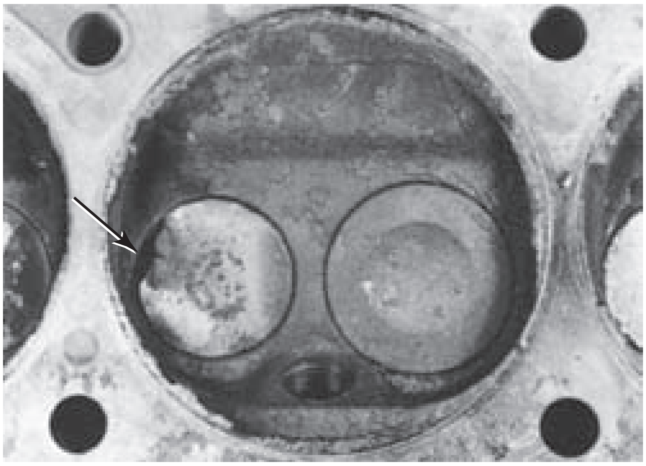


FIGURE 20-12 Badly burned exhaust valve. A compression test could have detected a problem, and a cylinder leakage test (leak-down test) could have been used to determine the exact problem.

much higher than without the oil, the cause of the low compression is worn or defective piston rings. If the compression readings increase only slightly (or not at all), then the cause of the low compression is usually defective valves. See Figure 20-12.

NOTE: During both the dry and wet compression tests, be sure that the battery and starting system are capable of cranking the engine at normal cranking speed.

RUNNING (DYNAMIC) COMPRESSION TEST

A compression test is commonly used to help determine engine condition and is usually performed with the engine cranking.

What is the RPM of a cranking engine? An engine idles at about 600 to 900 RPM, and the starter motor obviously cannot crank the engine as fast as the engine idles. Most manufacturers' specifications require the engine to crank at 80 to 250 cranking RPM. Therefore, a check of the engine's compression at cranking speed determines the condition of an engine that does not run at such low speeds.

But what should be the compression of a running engine? Some would think that the compression would be substantially higher, because the valve overlap of the cam is more effective at higher engine speeds, which would tend to increase the compression.

A **running compression test,** also called a **dynamic compression test,** is a compression test done with the engine running rather than during engine cranking as is done in a regular compression test.

Actually, the compression pressure of a running engine is much *lower* than cranking compression pressure. This results from the volumetric efficiency. The engine is revolving faster, and therefore, there is less *time* for air to enter the combustion chamber. With less air to compress, the compression pressure is lower. Typically, the higher the engine RPM, the lower the running compression. For most engines, the value ranges are as follows:

- Compression during cranking: 125 to 160 PSI
- Compression at idle: 60 to 90 PSI
- Compression at 2000 RPM: 30 to 60 PSI

As with cranking compression, the running compression of all cylinders should be equal. Therefore, a problem is not likely to be detected by single compression values, but by *variations* in running compression values among the cylinders. Broken valve springs, worn valve guides, bent pushrods, and worn cam lobes are some items that would be indicated by a low running compression test reading on one or more cylinders.

Performing a Running Compression Test

To perform a running compression test, remove just one spark plug at a time. With one spark plug removed from the engine, use a jumper wire to *ground* the spark plug wire to a good engine ground. This prevents possible ignition coil damage. Start the engine, push the pressure release on the gauge, and read the compression. Increase the engine speed to about 2000 RPM and push the pressure release on the gauge again. Read the gauge. Stop the engine, reattach the spark plug wire, and repeat the test for each of the remaining cylinders. Just like the cranking compression test, the running compression test can inform a technician of the *relative* compression of all the cylinders.

CYLINDER LEAKAGE TEST

One of the best tests that can be used to determine engine condition is the **cylinder leakage test.** This test involves injecting air under pressure into the cylinders one at a time. The amount and location of any escaping air helps the technician determine the condition of the engine. The air is injected into the cylinder through a cylinder leakage gauge into the spark plug hole. See Figure 20-13. To perform the cylinder leakage test, take the following steps:

Step 1 For best results, the engine should be at normal operating temperature (upper radiator hose hot and pressurized).

Step 2 The cylinder being tested must be at top dead center (TDC) of the compression stroke. See Figure 20-14.

FIGURE 20-13 A typical handheld cylinder leakage tester.

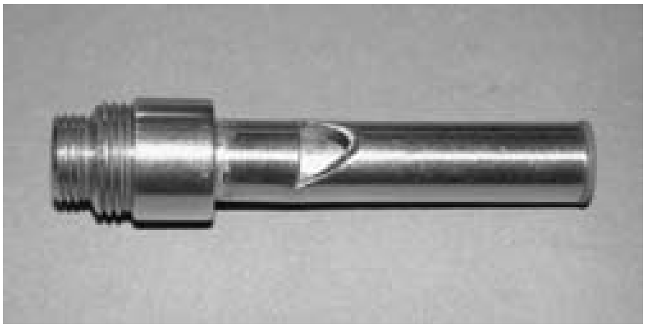


FIGURE 20-14 A whistle stop used to find top dead center. Remove the spark plug and install the whistle stop, then rotate the engine by hand. When the whistle stops making a sound, the piston is at the top.

NOTE: The greatest amount of wear occurs at the top of the cylinder because of the heat generated near the top of the cylinders. The piston ring flex also adds to the wear at the top of the cylinder.

Step 3 Calibrate the cylinder leakage unit as per manufacturer's instructions.

Step 4 Inject air into the cylinders one at a time, rotating the engine as necessitated by firing order to test each cylinder at TDC on the compression stroke.

Step 5 Evaluate the results:

Less than 10% leakage: good
Less than 20% leakage: acceptable
Less than 30% leakage: poor
More than 30% leakage: definite problem

NOTE: If leakage seems unacceptably high, repeat the test, being certain that it is being performed correctly and that the cylinder being tested is at TDC on the compression stroke.

6. Check the source of air leakage.
   a. If air is heard escaping from the oil filler cap, the *piston rings* are worn or broken.
   b. If air is observed bubbling out of the radiator, there is a possible blown *head gasket* or cracked *cylinder head*.
   c. If air is heard coming from the throttle body or air inlet on fuel injection-equipped engines, there is a defective *intake valve(s)*.
   d. If air is heard coming from the tailpipe, there is a defective *exhaust valve(s)*.

CYLINDER POWER BALANCE TEST

Most large engine analyzers and scan tools have a cylinder power balance feature. The purpose of a cylinder **power balance test** is to determine if all cylinders are contributing power equally. It determines this by shorting out one cylinder at a time. If the engine speed (RPM) does not drop as much for one cylinder as for other cylinders of the same engine, then the shorted cylinder must be weaker than the other cylinders. For example:

Cylinder #3 is the weak cylinder.

Cylinder Number	RPM Drop When Ignition Is Shorted
1	75
2	70
3	15
4	65
5	75
6	70

NOTE: Most automotive test equipment uses automatic means for testing cylinder balance. Be certain to correctly identify the offending cylinder. Cylinder #3 as identified by the equipment may be the third cylinder in the firing order instead of the actual cylinder #3.

POWER BALANCE TEST PROCEDURE

When point-type ignition was used on all vehicles, the common method for determining which, if any, cylinder was weak was to remove a spark plug wire from one spark plug at a time while watching a tachometer and a vacuum gauge. This method is not recommended on any vehicle with any type of electronic ignition. If any of the spark plug wires are removed from a spark plug with the engine running, the ignition coil tries to supply increasing levels of voltage attempting to jump the increasing gap as the plug wires are removed. This high voltage could easily track the ignition coil, damage the ignition module, or both.

The acceptable method of canceling cylinders, which will work on all types of ignition systems, including distributorless, is to *ground* the secondary current for each cylinder. See Figure 20-15. The cylinder with the least RPM drop is the cylinder not producing its share of power.

VACUUM TESTS

Vacuum is pressure below atmospheric pressure and is measured in **inches** (or millimeters) **of mercury (Hg).** An engine in good mechanical condition will run with high manifold vacuum. Manifold vacuum is developed by the pistons as they move down on the intake stroke to draw the charge from the throttle body and intake manifold. Air to refill the manifold comes past the throttle plate into the manifold. Vacuum will increase anytime the engine turns faster or has better cylinder sealing while the throttle plate remains in a fixed position. Manifold vacuum will decrease when the engine turns more slowly or when the cylinders no longer do an efficient job of pumping. **Vacuum tests** include testing the engine for **cranking vacuum, idle vacuum,** and vacuum at 2500 RPM.

Cranking Vacuum Test

Measuring the amount of manifold vacuum during cranking is a quick and easy test to determine if the piston rings and valves are properly sealing. (For accurate results, the engine should be warm and the throttle closed.) To perform the cranking vacuum test, take the following steps:

Step 1 Disable the ignition or fuel injection.

Step 2 Connect the vacuum gauge to a manifold vacuum source.

Step 3 Crank the engine while observing the vacuum gauge.

Cranking vacuum should be higher than 2.5 inches of mercury. (Normal cranking vacuum is 3 to 6 inches Hg.) If it is lower than 2.5 inches Hg, then the following could be the cause:

- Too slow a cranking speed
- Worn piston rings
- Leaking valves
- Excessive amounts of air bypassing the throttle plate (This could give a false low vacuum reading. Common sources include a throttle plate partially open or a high-performance camshaft with excessive overlap.)

Idle Vacuum Test

An engine in proper condition should idle with a steady vacuum between 17 and 21 inches Hg. See Figure 20-16.

NOTE: Engine vacuum readings vary with altitude. A reduction of 1 inch Hg per 1,000 feet (300 meters) of altitude should be subtracted from the expected values if testing a vehicle above 1,000 feet (300 meters).

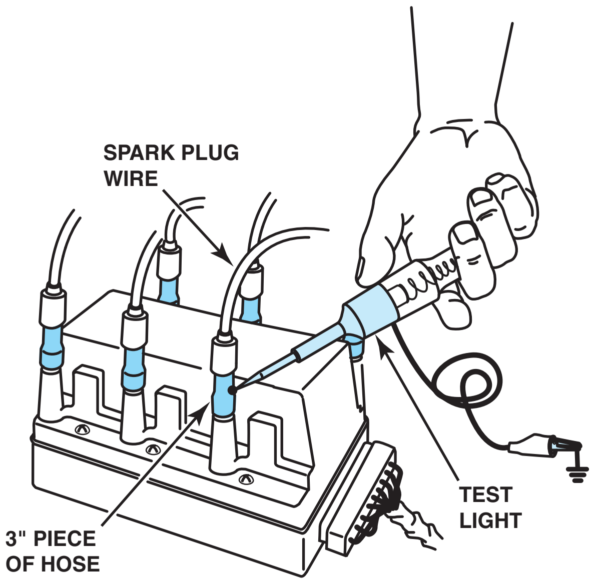


FIGURE 20-15 Using a vacuum hose and a test light to ground one cylinder at a time on a distributorless ignition system. This works on all types of ignition systems and provides a method for grounding out one cylinder at a time without fear of damaging any component.

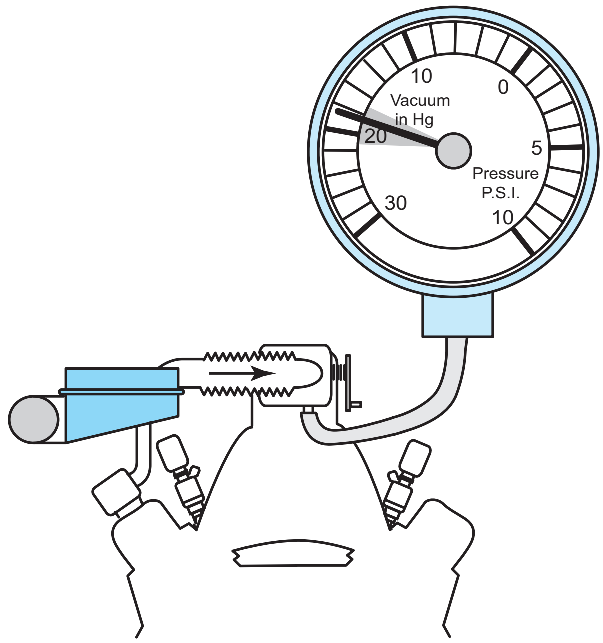


FIGURE 20-16 An engine in good mechanical condition should produce 17 to 21 in. Hg of vacuum at idle at sea level.

Low and Steady Vacuum

If the vacuum is lower than normal, yet the gauge reading is steady, the most common causes include:

- Retarded ignition timing
- Retarded cam timing (check timing chain for excessive slack or timing belt for proper installation)

See Figure 20-17.

Fluctuating Vacuum

If the needle drops, then returns to a normal reading, then drops again, and again returns, this indicates a sticking valve. A common cause of sticking valves is lack of lubrication of the valve stems. See Figures 20-18 through 20-26. If the vacuum gauge fluctuates above and below a center point, burned valves or weak valve springs may be indicated. If the fluctuation is slow and steady, unequal fuel mixture could be the cause.

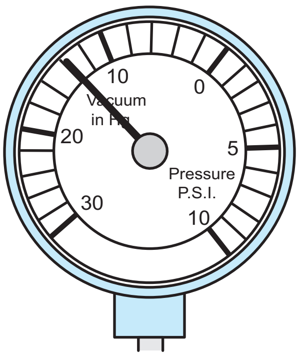


FIGURE 20-17 A steady but low reading could indicate retarded valve or ignition timing.

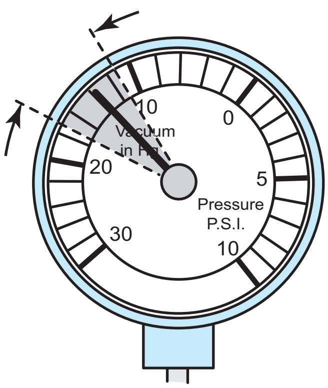


FIGURE 20-18 A gauge reading with the needle fluctuating 3 to 9 in. Hg below normal often indicates a vacuum leak in the intake system.

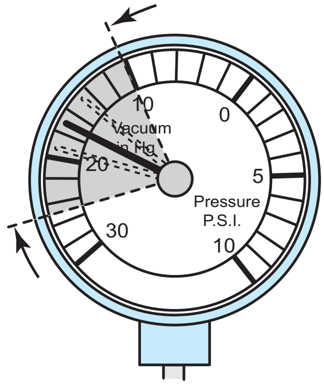


FIGURE 20-19 A leaking head gasket can cause the needle to vibrate as it moves through a range from below to above normal.

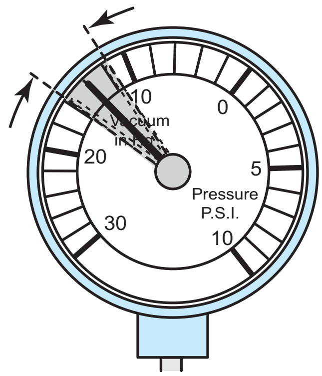


FIGURE 20-20 An oscillating needle 1 or 2 in. Hg below normal could indicate an incorrect air–fuel mixture (either too rich or too lean).

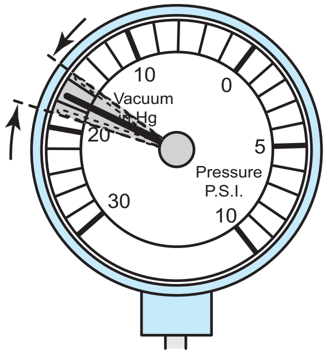


FIGURE 20-21 A rapidly vibrating needle at idle that becomes steady as engine speed is increased indicates worn valve guides.

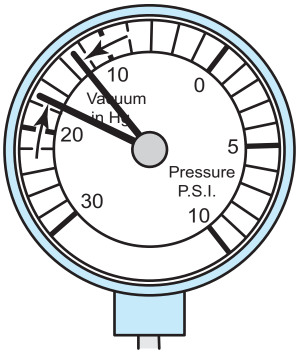


FIGURE 20-22 If the needle drops 1 or 2 in. Hg from the normal reading, one of the engine valves is burned or not seating properly.

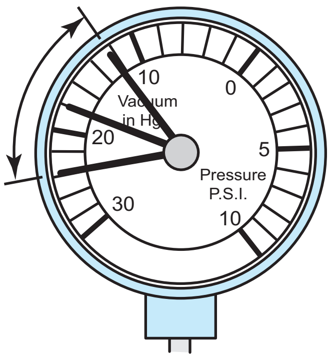


FIGURE 20-23 Weak valve springs will produce a normal reading at idle, but as engine speed increases, the needle will fluctuate rapidly between 12 and 24 in. Hg.

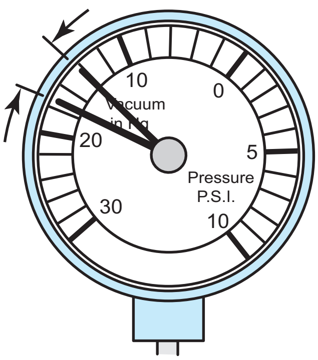


FIGURE 20-24 A steady needle reading that drops 2 or 3 in. Hg when the engine speed is increased slightly above idle indicates that the ignition timing is retarded.

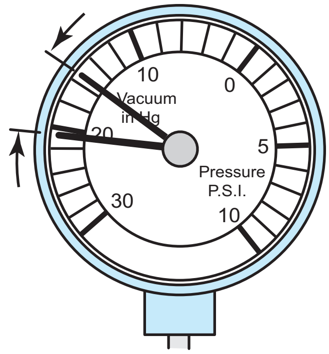


FIGURE 20-25 A steady needle reading that rises 2 or 3 in. Hg when the engine speed is increased slightly above idle indicates that the ignition timing is advanced.

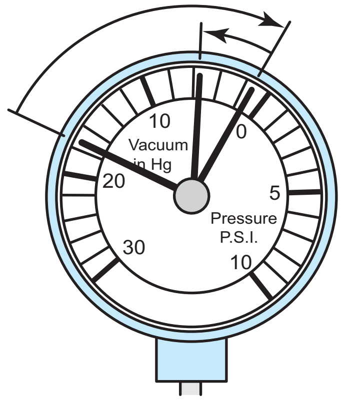


FIGURE 20-26 A needle that drops to near zero when the engine is accelerated rapidly and then rises slightly to a reading below normal indicates an exhaust restriction.

NOTE: A common trick that some technicians use is to squirt some automatic transmission fluid (ATF) down the throttle body or into the air inlet of a warm engine. Often the idle quality improves and normal vacuum gauge readings are restored. The use of ATF does create excessive exhaust smoke for a short time, but it should not harm oxygen sensors or catalytic converters.

EXHAUST RESTRICTION TEST

If the exhaust system is restricted, the engine will be low on power, yet smooth. Common causes of **restricted exhaust** include the following:

- **Clogged catalytic converter.** Always check the ignition and fuel-injection systems for faults that could cause excessive amounts of unburned fuel to be exhausted. Excessive unburned fuel can overheat the catalytic converter and cause the beads or structure of the converter to fuse together, creating the restriction. A defective fuel delivery system could also cause excessive unburned fuel to be dumped into the converter.

- **Clogged or restricted muffler.** This can cause low power. Often a defective catalytic converter will shed particles that can clog a muffler. Broken internal baffles can also restrict exhaust flow.
- **Damaged or defective piping.** This can reduce the power of any engine. Some exhaust pipe is constructed with double walls, and the inside pipe can collapse and form a restriction that is not visible on the outside of the exhaust pipe.

TESTING BACKPRESSURE WITH A VACUUM GAUGE

A vacuum gauge can be used to measure manifold vacuum at a high idle (2000 to 2500 RPM). If the exhaust system is restricted, pressure increases in the exhaust system. This pressure is called **backpressure.** Manifold vacuum will drop gradually if the engine is kept at a constant speed if the exhaust is restricted.

The reason the vacuum will drop is that all exhaust leaving the engine at the higher engine speed cannot get through the restriction. After a short time (within 1 minute), the exhaust tends to "pile up" above the restriction and eventually remains in the cylinder of the engine at the end of the exhaust stroke. Therefore, at the beginning of the intake stroke, when the piston traveling downward should be lowering the pressure (raising the vacuum) in the intake manifold, the extra exhaust in the cylinder *lowers* the normal vacuum. If the exhaust restriction is severe enough, the vehicle can become undriveable because cylinder filling cannot occur except at idle.

TESTING BACKPRESSURE WITH A PRESSURE GAUGE

Exhaust system backpressure can be measured directly by installing a pressure gauge into an exhaust opening. This can be accomplished in one of the following ways:

- **With an oxygen sensor.** Use a backpressure gauge and adapter or remove the inside of an old, discarded oxygen sensor and thread in an adapter to convert to a vacuum or pressure gauge.

NOTE: An adapter can be easily made by inserting a metal tube or pipe. A short section of brake line works great. The pipe can be brazed to the oxygen sensor housing or it can be glued in with epoxy. An 18-millimeter compression gauge adapter can also be adapted to fit into the oxygen sensor opening. See Figure 20-27.

FIGURE 20-27 A technician-made adapter used to test exhaust system backpressure. The upstream oxygen sensor is removed and the adaptor is threaded into the opening in the exhaust and then a pressure gauge to connected to the hose fitting so that backpressure can be measured.

- **With the exhaust gas recirculation (EGR) valve.** Remove the EGR valve and fabricate a plate to connect to a pressure gauge.
- **With the air-injection reaction (AIR) check valve.** Remove the check valve from the exhaust tubes leading down to the exhaust manifold. Use a rubber cone with a tube inside to seal against the exhaust tube. Connect the tube to a pressure gauge.

At idle, the maximum backpressure should be less than 1.5 PSI (10 kPa), and it should be less than 2.5 PSI (15 kPa) at 2500 RPM.

DIAGNOSING HEAD GASKET FAILURE

Several items can be used to help diagnose a head gasket failure:

- **Exhaust gas analyzer.** With the radiator cap removed, place the probe from the exhaust analyzer above the radiator filler neck. If the HC reading increases, the exhaust (unburned hydrocarbons) is getting into the coolant from the combustion chamber.
- **Chemical test.** A chemical tester using blue liquid is also available. The liquid turns yellow if combustion gases are present in the coolant. See Figure 20-28.
- **Bubbles in the coolant.** Remove the coolant pump belt to prevent pump operation. Remove the radiator cap and start the engine. If bubbles appear in the coolant before it begins to boil, a defective head gasket or cracked cylinder head is indicated.
- **Excessive exhaust steam.** If excessive water or steam is observed coming from the tailpipe, this means that coolant is getting into the combustion chamber from a defective head gasket or a cracked head. If there is leakage

FIGURE 20-28 A tester that uses a blue liquid to check for exhaust gases in the exhaust, which would indicate a head gasket leak problem.

between cylinders, the engine usually misfires and a power balancer test and/or compression test can be used to confirm the problem.

If any of the preceding indicators of head gasket failure occur, remove the cylinder head(s) and check all of the following:

1. Head gasket
2. Sealing surfaces—for warpage
3. Castings—for cracks

NOTE: A leaking thermal vacuum valve can cause symptoms similar to those of a defective head gasket. Most thermal vacuum valves thread into a coolant passage, and they often leak only after they get hot.

DASH WARNING LIGHTS

Most vehicles are equipped with several dash warning lights often called "telltale" or "idiot" lights. These lights are often the only warning a driver receives that there may be engine problems. A summary of typical dash warning lights and their meanings follows.

Oil (Engine) Light

The red oil light indicates that the engine oil pressure is too low (usually lights when oil pressure is 4 to 7 PSI [20 to 50 kPa]). Normal oil pressure should be 10 to 60 PSI (70 to 400 kPa) or 10 PSI per 1000 engine RPM.

When this light comes on, the driver should shut off the engine immediately and check the oil level and condition for possible dilution with gasoline caused by a fuel system fault. If the oil level is okay, then there is a possible serious engine problem or a possible defective oil pressure sending (sender) unit. The automotive technician should always check the oil pressure using a reliable mechanical oil pressure gauge if low oil pressure is suspected.

NOTE: Some automobile manufacturers combine the dash warning lights for oil pressure and coolant temperature into one light, usually labeled "engine." Therefore, when the engine light comes on, the technician should check for possible coolant temperature and/or oil pressure problems.

Coolant Temperature Light

Most vehicles are equipped with a coolant temperature gauge or dash warning light. The warning light may be labeled "coolant," "hot," or "temperature." If the coolant temperature warning light comes on during driving, this usually indicates that the coolant temperature is above a safe level, or above about 250°F (120°C). Normal coolant temperature should be about 200° to 220°F (90° to 105°C).

If the coolant temperature light comes on during driving, the following steps should be followed to prevent possible engine damage:

1. Turn off the air conditioning and turn on the heater. The heater will help get rid of some of the heat in the cooling system.
2. Raise the engine speed in neutral or park to increase the circulation of coolant through the radiator.
3. If possible, turn the engine off and allow it to cool (this may take over an hour).
4. Do not continue driving with the coolant temperature light on (or the gauge reading in the red warning section or above 260°F) or serious engine damage may result.

NOTE: If the engine does not feel or smell hot, it is possible that the problem is a faulty coolant temperature sensor or gauge.

TECH TIP

MISFIRE DIAGNOSIS

If a misfire goes away with propane added to the air inlet, suspect a lean injector.

COMPRESSION TEST Step-by-Step

STEP 1 The tools needed to perform a compression test include a compression gauge, an air nozzle, and the socket ratchets and extensions that may be necessary to remove the spark plugs from the engine.

STEP 2 To prevent ignition and fuel-injection operation while the engine is being cranked, remove both the fuel-injection fuse and the ignition fuse.

STEP 3 Block open the throttle (and choke, if the engine is equipped with a carburetor). Here a screwdriver is being used to wedge the throttle linkage open.

STEP 4 Before removing the spark plugs, use an air nozzle to blow away any dirt that may be around the spark plug.

STEP 5 Remove all of the spark plugs. Be sure to mark the spark plug wires so that they can be reinstalled onto the correct spark plugs after the compression test.

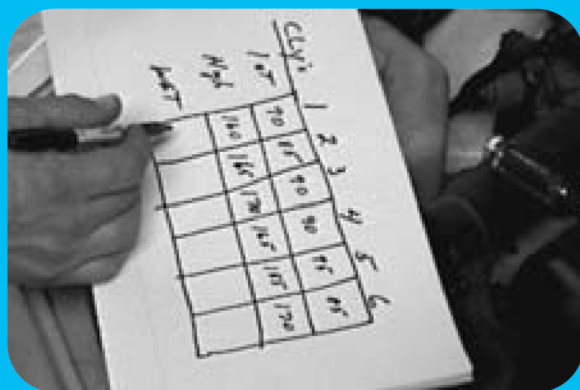
STEP 6 Select the proper adapter for the compression gauge. The threads on the adapter should match those on the spark plug.

COMPRESSION TEST continued

STEP 7 If necessary, connect a battery charger to the battery before starting the compression test. It is important that consistent cranking speed be available for each cylinder being tested.

STEP 8 If the first puff reading is low and the reading gradually increases with each puff, weak or worn piston rings may be indicated.

STEP 9 After the engine has been cranked for four "puffs," stop cranking the engine and observe the compression gauge.



STEP 10 Record the first puff and this final reading for each cylinder. The final readings should all be within 20% of each other.

STEP 11 If a cylinder(s) is lower than most of the others, use an oil can and squirt two squirts of engine oil into the cylinder and repeat the compression test. This is called performing a wet compression test.

STEP 12 If the gauge reading is now much higher than the first test results, then the cause of the low compression is due to worn or defective piston rings. The oil in the cylinder temporarily seals the rings which causes the higher reading.

SUMMARY

1. The first step in diagnosing engine condition is to perform a thorough visual inspection, including a check of oil and coolant levels and condition.
2. Oil leaks can be found by using a white powder or a fluorescent dye and a black light.
3. Many engine-related problems make a characteristic noise.
4. A compression test can be used to test the condition of valves and piston rings.
5. A cylinder leakage test fills the cylinder with compressed air, and the gauge indicates the percentage of leakage.
6. A cylinder balance test indicates whether all cylinders are working okay.
7. Testing engine vacuum is another procedure that can help the service technician determine engine condition.

REVIEW QUESTIONS

1. Describe the visual checks that should be performed on an engine if a mechanical malfunction is suspected.
2. List three simple items that could cause engine noises.
3. Describe how to perform a compression test and how to determine what is wrong with an engine based on a compression test result.
4. Describe the cylinder leakage test.
5. Describe how a vacuum gauge would indicate if the valves were sticking in their guides.
6. Describe the test procedure for determining if the exhaust system is restricted (clogged) using a vacuum gauge.

CHAPTER QUIZ

1. Technician A says that the paper test could detect a burned valve. Technician B says that a grayish white stain on the engine could be a coolant leak. 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. Two technicians are discussing oil leaks. Technician A says that an oil leak can be found using a fluorescent dye in the oil with a black light to check for leaks. Technician B says that a white spray powder can be used to locate oil leaks. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
3. Which of the following is the *least likely* to cause an engine noise?
   - **a.** Carbon on the pistons
   - **b.** Cracked exhaust manifold
   - **c.** Loose accessory drive belt
   - **d.** Vacuum leak
4. Normal vacuum at idle (sea level) should be:
   - **a.** 21 in. Hg. or higher
   - **b.** 10–12 in. Hg.
   - **c.** 14–16 in. Hg.
   - **d.** 17–21 in. Hg.

5. A smoothly operating engine depends on _________.

a. High compression on most cylinders

b. Equal compression between cylinders

c. Cylinder compression levels above 100 PSI (700 kPa) and within 70 PSI (500 kPa) of each other

d. Compression levels below 100 PSI (700 kPa) on most cylinders

6. A good reading for a cylinder leakage test would be _________.

a. Within 20% between cylinders

b. All cylinders below 20% leakage

c. All cylinders above 20% leakage

d. All cylinders above 70% leakage and within 7% of each other

7. Technician A says that during a power balance test, the cylinder that causes the biggest RPM drop is the weak cylinder. Technician B says that if one spark plug wire is grounded out and the engine speed does not drop, a weak or dead cylinder is indicated. Which technician is correct?

a. Technician A only

b. Technician B only

c. Both Technicians A and B

d. Neither Technician A nor B

8. *Cranking* vacuum should be _________.

a. 2.5 inches Hg or higher

b. Over 25 inches Hg

c. 17 to 21 inches Hg

d. 6 to 16 inches Hg

9. An engine that has retarded valve timing due to a stretched timing chain or a timing belt incorrectly installed will show _________ on a vacuum gauge.

a. Lower than normal and varying

b. Higher than normal

c. Fluctuating

d. Lower than normal and steady

10. The low oil pressure warning light usually comes on _________.

a. Whenever an oil change is required

b. Whenever oil pressure drops dangerously low (4 to 7 PSI)

c. Whenever the oil filter bypass valve opens

d. Whenever the oil filter antidrainback valve opens