

INTRODUCTION

Most automotive engines use the four-stroke cycle of events. The process begins by the starter motor rotating the engine until combustion takes place. The four-stroke cycle is repeated for each cylinder of the engine. A piston that moves up and down, or reciprocates, in a cylinder. The piston is attached to a crankshaft with a connecting rod. This arrangement allows the piston to reciprocate (move up and down) in the cylinder as the crankshaft rotates. Fig 1.

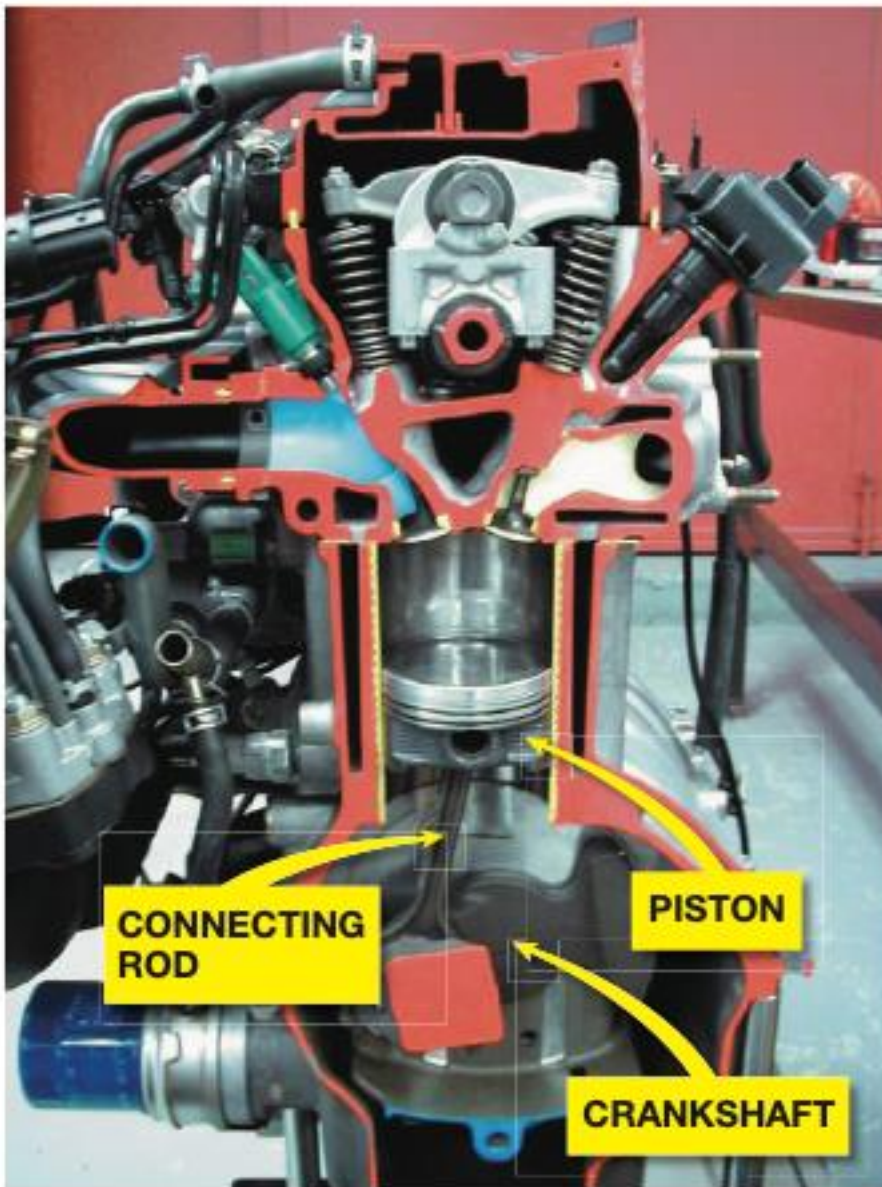


Figure 1. The internal parts of an engine.

Engine cycles are identified by the number of piston strokes required to complete the cycle. A piston stroke is a one-way piston movement either from top to bottom or bottom to top of the cylinder. During one stroke, the crankshaft rotates 180 degrees (1/2 revolution). A cycle is a complete series of events that continually repeats. Most automobile engines use a four-stroke cycle. Fig 2.

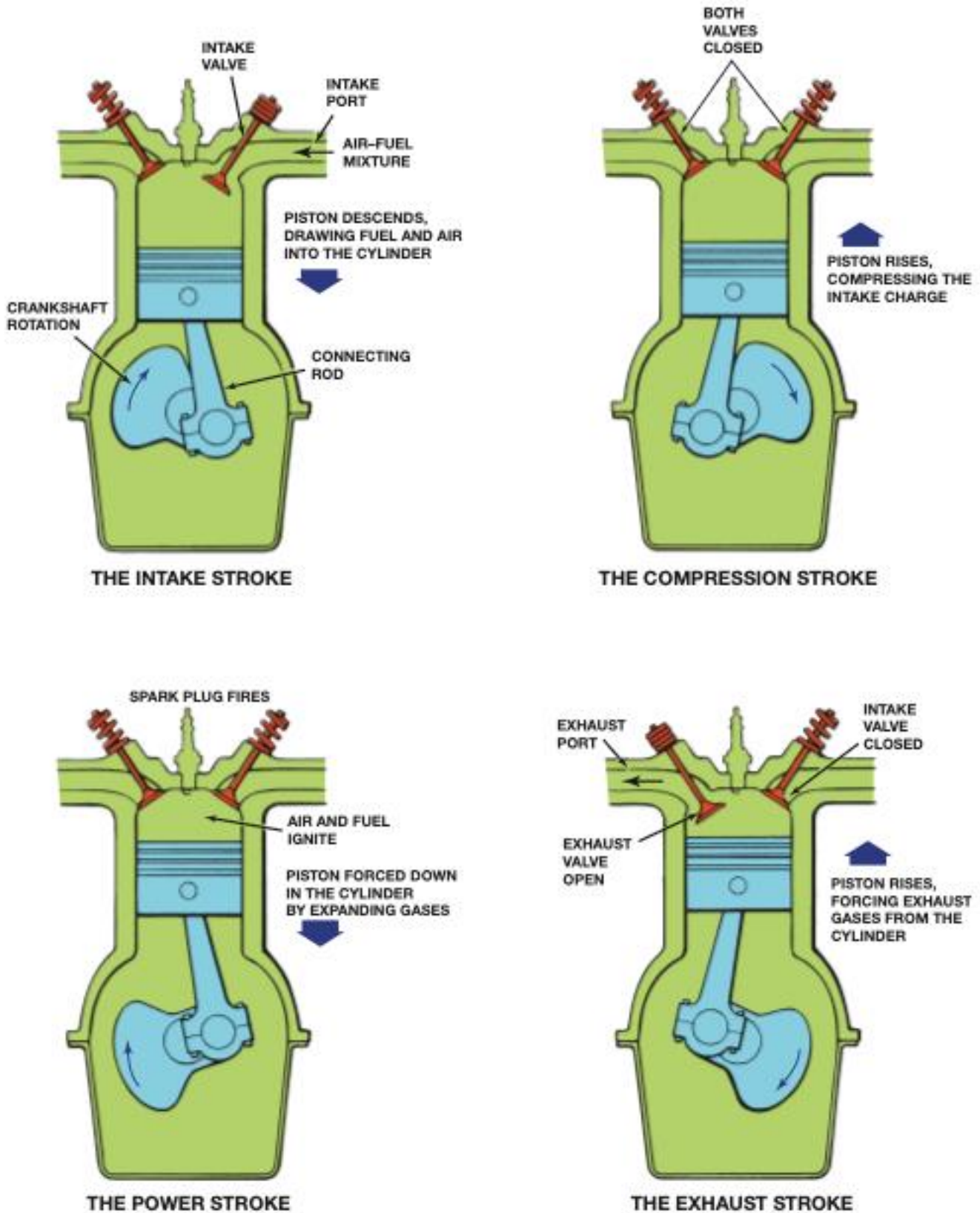


Figure 2. The downward movement of the piston draws the air-fuel mixture into the cylinder through the intake valve on the intake stroke. On the compression stroke, the mixture is compressed by the upward movement of the piston with both valves closed. Ignition occurs at the beginning of the power stroke, and

combustion drives the piston downward to produce power. On the exhaust stroke, the upward-moving piston forces the burned gases out the open exhaust valve.

The number of valves per cylinder and the number and location of camshafts are major factors in engine operation. A typical older-model engine uses one intake valve and one exhaust valve per cylinder. Many newer engines use two intake and two exhaust valves per cylinder. The valves are opened by a camshaft. Some engines use one camshaft for the intake valves and a separate camshaft for the exhaust valves. When the camshaft is located in the block, the valves are operated by lifters, pushrods, and rocker arms.

When one overhead camshaft is used, the design is called a single overhead camshaft (SOHC) design. When two overhead camshafts are used, the design is called a double overhead camshaft (DOHC) design. Fig 3.

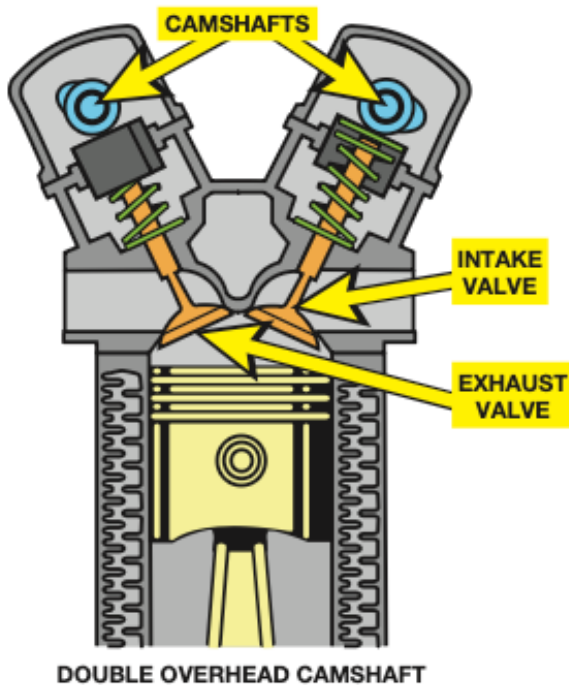
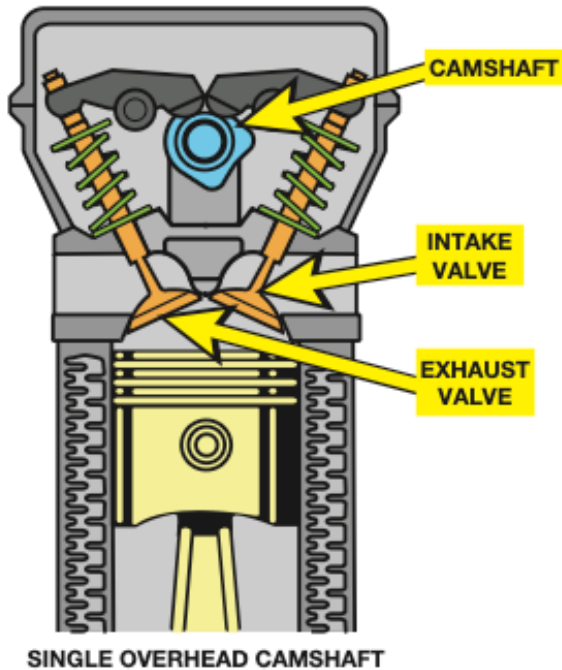


Figure 3. Single and double overhead camshafts.

ASE TEST TOPICS

1. Verify customer concern and/or road test vehicle.

The diagnostic process is a strategy that eliminates known good components or systems in order to find the root cause of automotive problems. All vehicle manufacturers recommend a step-by-step diagnostic procedure. Fig 4.

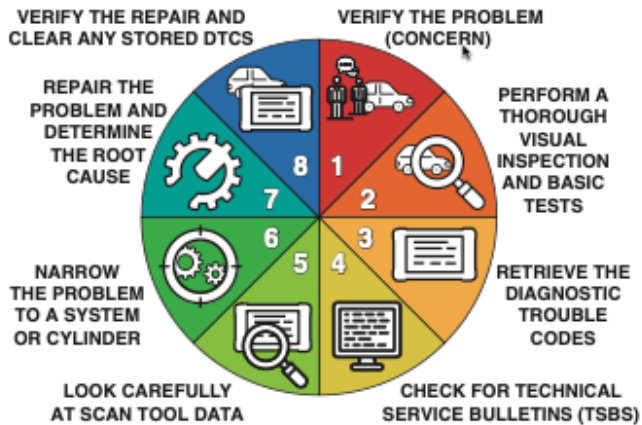


Figure 4. Diagnostic process.

2. Research system operation using technical service information to determine service procedures and specifications.

Before a minute is spent on diagnosis, it is important to know if a problem actually exists. If the problem cannot be verified, it cannot be solved or tested to verify that the repair was complete. The driver of the vehicle knows much about the vehicle and how it is driven. Because drivers differ, it is sometimes the best policy to take the customer on the test-drive to verify the concern.

Service information is needed to correctly service or repair vehicles because it contains all of the specifications, as well as the specified procedures to follow when servicing or repairing a vehicle. The most comprehensive and accurate service information is the service information from the vehicle manufacturer. ALLDATA and Mitchell 1ProDemand are examples of commonly used aftermarket subscription services that include service information for many vehicles.

3. Determine if no-crank, crank/no-start, or hard start condition is an engine mechanical problem or is caused by another vehicle subsystem.

The cranking circuit includes those mechanical and electrical components required to crank the engine for starting. The cranking circuits include the following:

1. Starter motor. The starter is normally a 0.5–2.6 horsepower (0.4–2.0 kW) electric motor that can develop nearly 8 horsepower (6 kW) for a very short time when first cranking a cold engine.
2. Battery. The battery must be of the correct capacity and be at least 75% (12.4 volts) charged to provide the necessary current and voltage for correct operation of the starter.
3. Starter solenoid or relay. A small current switch (ignition switch) operates a solenoid or relay that controls the high starter current.
4. Ignition Switch/Button. The ignition switch and safety control switches control the starter motor operation. The ignition switch will not operate the starter unless the automatic transmission is in neutral

or park. This is to prevent an accident that might result from the vehicle moving forward or backward when the engine is started. Fig 5.

5. Cranking Motor (Starter) The engine is cranked by an electric motor that is controlled by a key operated ignition switch or the PCM on vehicles equipped with electronic starting. Fig 6.

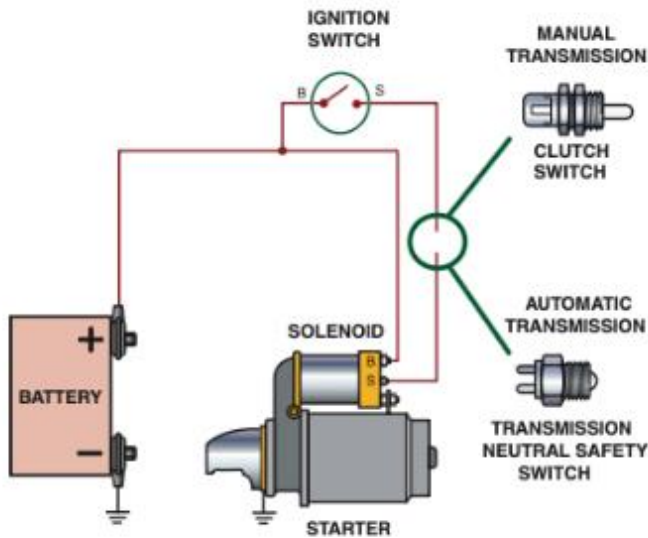


FIGURE 13-3

Figure 5. System and safety switches.

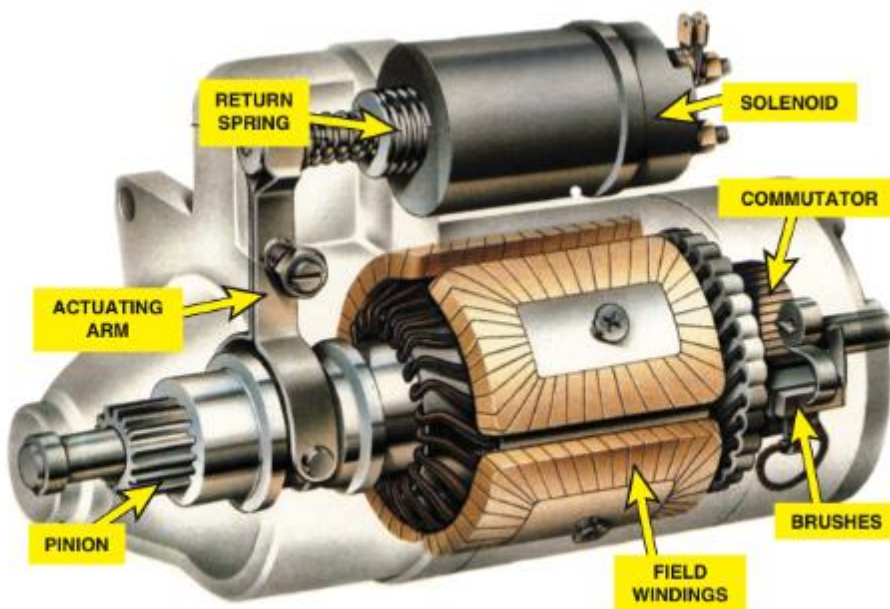


FIGURE 13-18

Figure 6. Starter and internal components.

The proper operation of the starting system depends on a good battery, good cables and connections, and a good starter motor. Because a starting problem can be caused by a defective component

anywhere in the starting circuit , it is important to check for the proper operation of each part of the circuit to diagnose and repair the problem quickly.

- Visually inspect the battery and battery connections. The starter is the highest amperage draw device used in a vehicle and any faults , such as corrosion on battery terminals, can cause cranking system problems.
- Test battery condition. Perform a battery load or conductance test on the battery to be sure that the battery is capable of supplying the necessary current for the starter.
- Check the control circuit . An open or high resistance anywhere in the control circuit can cause the starter motor to not engage. Items to check include:
 - “S” terminal of the starter solenoid
 - Neutral safety or clutch switch
 - Starter enable relay (if equipped)
 - Antitheft system fault (If the engine does not crank or start and the theft indicator light is on or flashing, there is likely a fault in the theft deterrent system.
- Check voltage drop of the starter circuit . Any high resistance in either the power side or ground side of the starter circuit causes the starter to rotate slowly or not at all. Fig 7.

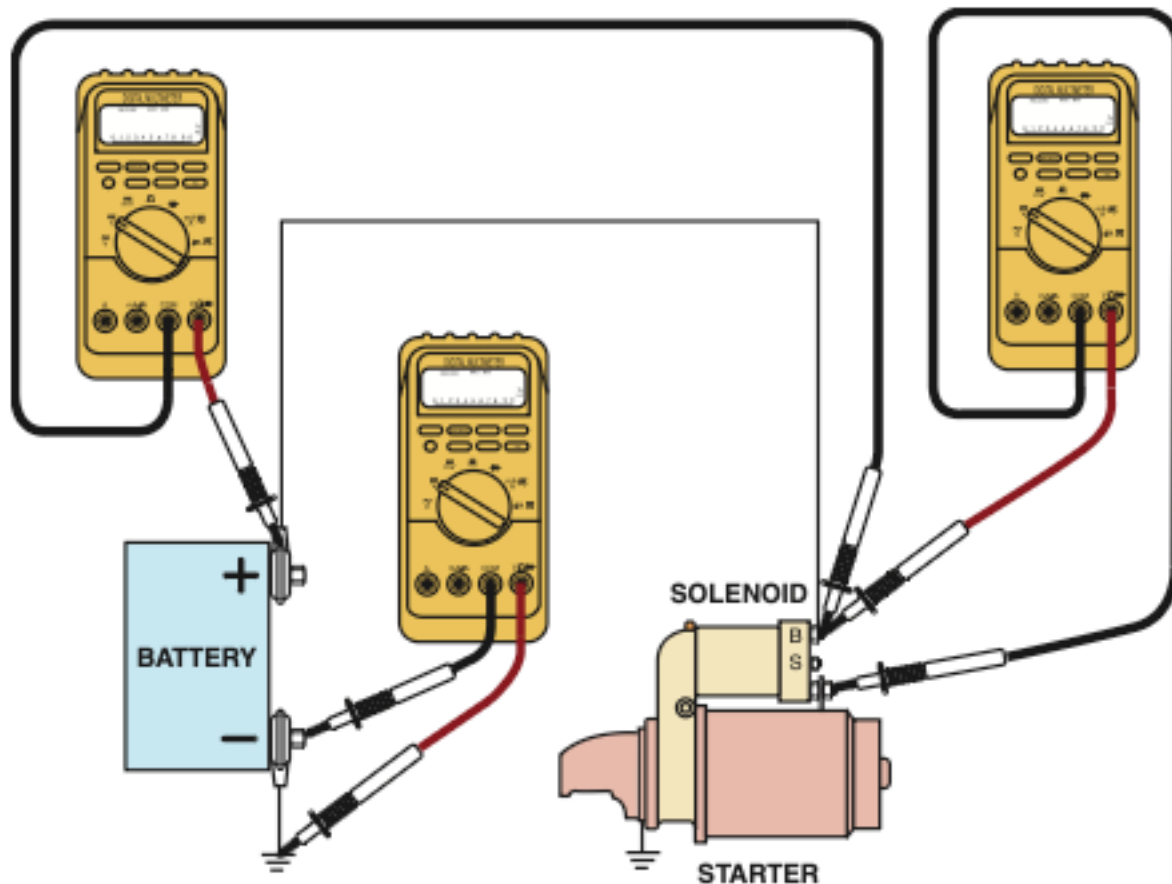


Figure 7. Voltmeter connections for voltage drop tests.

A1-A General Engine Diagnosis

A starter should be tested to see if the reason for slow or no cranking is due to a fault with the starter motor or another problem. A voltage drop test is used to find out if the battery cables and connections are okay. A starter amperage draw test determines if the starter motor is the cause of a no or slow cranking concern. Normal amperage draw:

- 4 cylinder engines 150 to 185 amperes (normally less than 100 amperes) at room temperature
- 6 cylinder engines 160 to 200 amperes (normally less than 100 amperes) at room temperature
- 8 cylinder engines 185 to 250 to amperes (normally less than 125 amperes) at room temperature

Excessive current draw may indicate one or more of the following:

1. Binding of starter armature as a result of worn bushings
2. Oil too thick (viscosity too high) for weather conditions
3. Shorted or grounded starter windings or cables
4. Tight or seized engine
5. Shorted starter motor (usually caused by fault with the field coils or armature)

Lower amperage draw and slow or no cranking may indicate one or more of the following:

- Dirty or corroded battery connections
- High internal resistance in the battery cable(s)
- High internal starter motor resistance
- Poor ground connection between the starter motor and the engine block

4. Inspect engine assembly for fuel, oil, coolant and other leaks.

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.

<u>Color</u>	<u>What's Leaking</u>
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)

5. Isolate engine noises and vibrations.

Several items that can cause an engine noise include the following:

- Valves clicking. 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.
- 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.

6. Diagnose the cause of excessive oil consumption and/or coolant consumption, diagnose the cause of unusual engine exhaust color and odor.

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

1. Oil level—oil should be to the proper level

2. Oil condition

- If the oil is very thin or has a gas smell, gasoline is present in the engine oil.
- If the oil is cloudy or milky, there is coolant (water) in the oil.
- Check for grittiness by rubbing the oil between your fingers.

Coolant level should be checked.

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, check the level of coolant in the radiator (only when cool) and also check the operation of the pressure cap.

2. 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 rust-colored stain

c. Dye stains from antifreeze (greenish or yellowish depending on the type of coolant)

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

- 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.
- Black exhaust smoke is due to excessive fuel being burned in the combustion chamber. Typical causes include a leaking fuel injector or excessive fuel-pump pressure.
- White smoke or steam from the exhaust is normal during cold weather and represents condensed steam. 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. Fig 8.



Figure 8. Excessive white exhaust indicates water or coolant in the combustion chamber.

7. Perform engine manifold vacuum or pressure tests; interpret test results.

For a cranking vacuum test, crank the engine while observing the vacuum gauge. Cranking vacuum should be higher than 2.5 inch Hg. (Normal cranking vacuum is 3 to 6 inch Hg.) If it is lower than 2.5 inch Hg, the following could be the cause:

- Too slow a cranking speed
- Worn piston rings
- Leaking valves
- Excessive amounts of air bypassing the throttle plate

An engine in proper condition should idle with a steady vacuum between 17 and 21 inch Hg. Fig 9.

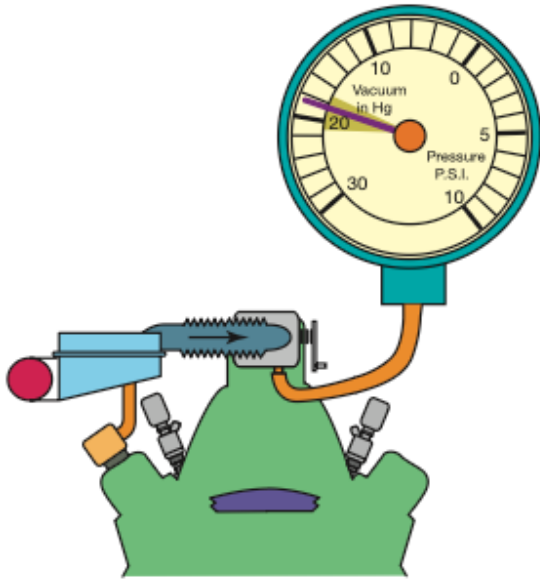


Figure 9. Normal vacuum at idle.

8. Perform cylinder power balance tests; interpret test results.

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, the shorted cylinder must be weaker than the other cylinders.

One way to check to see if all cylinders are mechanically able to contribute to the operation of the engine is to perform a cylinder contribution test using a scan tool. A cylinder contribution test, also called a power balance test, is an automated test that a scan tool performs by turning a fuel injector off to one cylinder at the time and monitoring the drop, or increase in engine speed. This change in engine speed should be the same for all cylinders if all cylinders are working correctly.

9. Perform cylinder cranking, relative, and running compression tests; interpret test results.

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

For a cranking compression test, thread a compression gauge into one spark plug hole at a time and crank the engine. Continue cranking the engine through four compression strokes. Record the highest readings and compare the results. Most manufacturers specify a maximum difference of 20% between the highest reading and the lowest reading.

A relative compression test uses a digital storage oscilloscope (DSO) and a current clamp to measure the change in current that occurs when an engine is cranking to determine the relative compression. This relative compression test uses the starter motor current to determine the compression values of all cylinders.

A relative compression test uses an amp clamp around the starter motor power cable and a Pico scope. The result is a waveform that displays the current needed for each cylinder under compression. This test indicates all cylinders are requiring the same current to rotate the starter motor which indicates that all cylinders have the same relative compression. Fig 10.

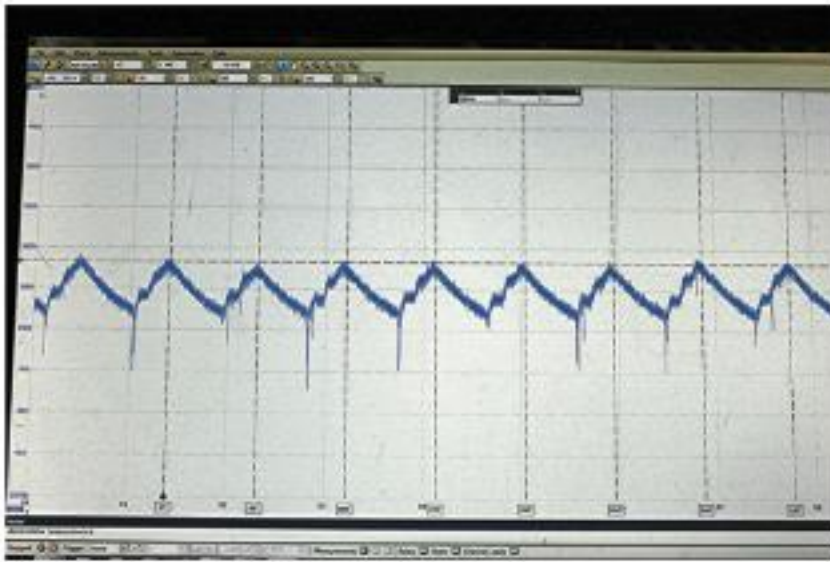


Figure 10. Relative compression test using a DSO.

10. Perform cylinder leakage/leak-down tests; interpret test results.

The cylinder leakage 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.

Air is injected 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.

Less than 10% leakage: good

Less than 20% leakage: acceptable

Less than 30% leakage: poor

More than 30% leakage: definite problem

11. Inspect and test positive crankcase ventilation (PCV) system components; interpret test results.

When an engine is running, the pressure of combustion forces the piston downward. This same pressure also forces gases and unburned fuel from the combustion chamber, past the piston rings, and into the

crankcase. Blowby is the term used to describe when combustion gases are forced past the piston rings and into the crankcase.

All systems use the following:

1. PCV valve, calibrated orifice, or orifice and separator
2. PCV inlet plus all connecting hoses

In normal operation, intake air flows freely and the PCV system functions properly. Engine design includes the air and vapor flow as a calibrated part of the air-fuel mixture. A flow problem in the PCV system results in drivability problems.

A blocked or plugged PCV system can cause:

- Rough or unstable idle
- Excessive oil consumption
- Oil in the air filter housing
- Oil leaks due to excessive crankcase pressure

The PCV system can be checked by testing for a weak vacuum at the oil dipstick tube using an inches-of-water manometer or gauge. Fig 11.



Figure 11. This gauge measures vacuum in units of inches of water to test the vacuum at the dipstick tube. Note that 28 inches of water equals 1 psi, or about 2 inches of mercury (inch Hg) of vacuum.

12. Diagnose engine mechanical, electrical, electronic, fuel, and ignition problems with an oscilloscope, digital multimeter (DMM), and/or scan tool.

Magnetic crankshaft position sensors use the changing strength of the magnetic field surrounding a coil of wire to signal the module and computer. This signal is used by the electronics in the module and computer to determine piston position and engine speed (RPM). Fig 12.

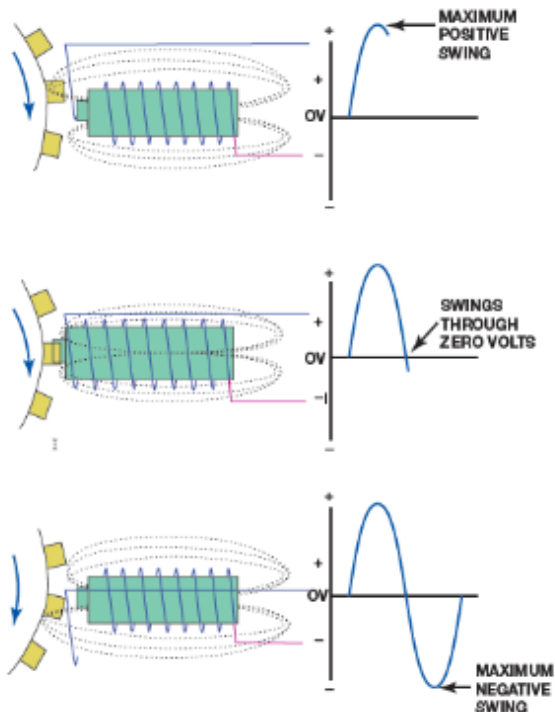


Figure 12. Crankshaft position sensor (CKP)

Some common tests for pickup coils and magnetic crankshaft position sensors include:

- Resistance. Usually between 150 and 1,500 ohms but check service information for the exact specifications. Fig 13.
- Coil shorted to ground. Check that the coil windings are insulated from ground by checking for continuity using an ohmmeter. With one ohmmeter lead attached to ground, touch the other lead of the ohmmeter to the pickup coil terminal. The ohmmeter should read OL (over limit) with the ohmmeter set on the high scale.-
- AC voltage output. The pickup coil also can be tested for proper voltage output. During cranking, most pickup coils should produce a minimum of 0.25 volt AC.

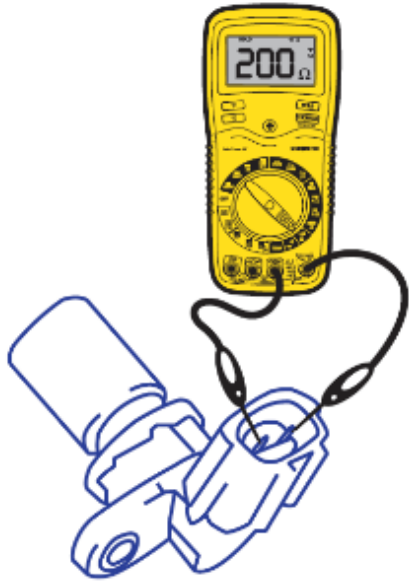


Figure 13. Checking CKP resistance.