Engine Performance

ENGINE PERFORMANCE

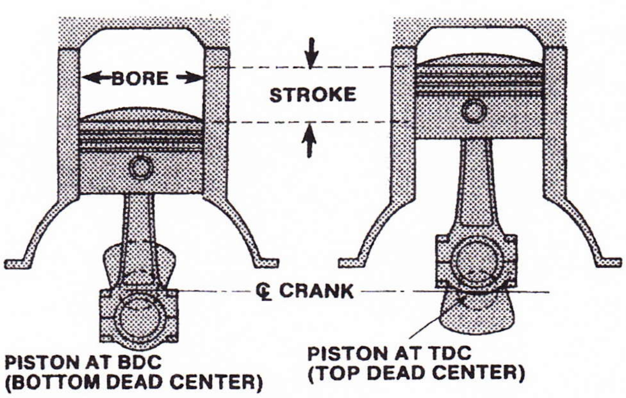
ENGINE MEASUREMENT AND PERFORMANCE

Some of the engine measurements and performance characteristics a technician should be familiar with follow.

BORE AND STROKE The **bore** of a cylinder is simply its diameter measured in inches (in.) or millimeters (mm). The stroke is the length of the piston travel between TDC and BDC. Between them, bore and stroke determine the displacement of the cylinders (Figure 6–16). When the bore of the engine is larger than its stroke, it is said to be oversquare. When the stroke is larger than the bore, the engine is said to be undersquare. Generally, an oversquare engine will provide for high engine speeds, such as for automobile use. An undersquare or long-stroke engine will deliver good low-speed power, such as an engine for a truck or tractor.

The **crank throw** is the distance from the crankshaft's main bearing centerline to the crankshaft throw centerline. The stroke of any engine is twice the crank throw (Figure 6–17).

DISPLACEMENT **Displacement** is the volume of a cylinder between the TDC and BDC positions of the piston. It is usually measured in cubic inches, cubic centimeters, or liters (Figure 6–18). The total displacement of an engine (including all cylinders) is a rough indicator of its power output. Displacement can be increased by opening the bore to a larger diameter or by increasing the length of the stroke. Total displacement is the sum of displacements for all cylinders in an engine. Cubic inch displacement (CID) may be calculated as follows.



$\frac{\text{BORE}}{\text{STROKE}}$ = BORE STROKE RATIO

FIGURE 6–16 The bore and stroke of a cylinder.

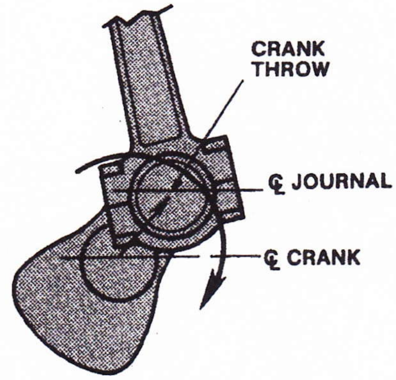


FIGURE 6–17 The stroke of an engine is equal to twice the crank throw.

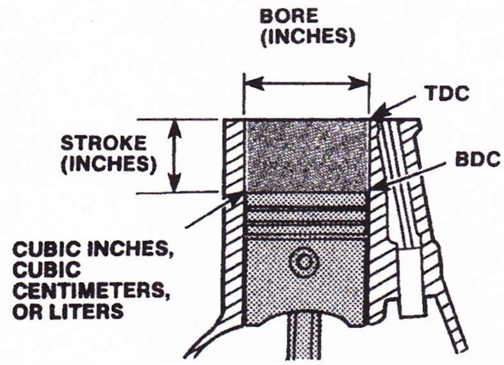


FIGURE 6–18 Displacement is the volume the cylinder holds between TDC and BDC.

$$CID = \pi \times R^2 \times L \times N$$

in which $\pi = 3.1416$
R = bore radius or bore diameter/2
L = length of stroke
N = number of cylinders

Example: Calculate the cubic inch displacement (CID) of a six-cylinder engine with a 3.7-in. bore and 3.4-in. stroke.

$$CID = 3.1416 \times 1.85^2 \times 3.4 \times 6$$
$$CID = 219.66$$

Most of today's engines are described by their metric displacement. Cubic centimeters and liters are determined by using metric measurements in the displacement formula.

Example: Calculate the metric displacement of a four-cylinder engine with a 78.9-mm stroke and a 100-mm bore.

$$\text{Displacement} = 3.1415 \times 100^2 \times 78.9 \times 4$$
$$\text{Displacement} = 2479 \text{ cubic centimeters (cc)} = 2.5 \text{ liters (L)}$$

Larger, heavier vehicles are provided with large displacement engines. Large displacement engines produce more torque than smaller displacement engines. They also consume more fuel. Smaller, lighter vehicles can be adequately powered by lower displacement engines that use less fuel.

COMPRESSION RATIO The **compression ratio** of an engine expresses how much the air/fuel mixture will be compressed during the compression stroke. The compression ratio is defined as the ratio of the volume in the cylinder above the piston when the piston is at BDC to the volume in the cylinder above the piston when the piston is at TDC (Figure 6–19). The formula for calculating the compression ratio is as follows.

$$\frac{\text{volume above the piston at BDC}}{\text{volume above the piston at TDC}}$$

or

$$\frac{\text{total cylinder volume}}{\text{total combustion chamber volume}}$$

In many engines, the top of the piston is even or level with the top of the cylinder block at TDC. The combustion chamber is in the cavity in the cylinder head above the piston. This is modified slightly by the shape of the top of the piston. The volume of the combustion chamber must be added to each volume in the formula in order to get an accurate calculation of compression ratio.

Example: Calculate the compression ratio if the total piston displacement is 45 cubic inches and the combustion chamber volume is 5.5 cubic inches.

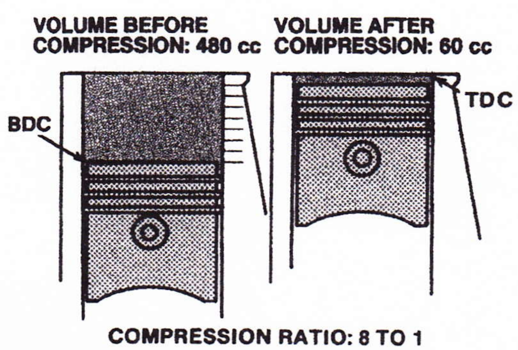


FIGURE 6–19 Compression ratio measures the amount the air and fuel have been compressed.

$$\frac{45 + 5.5}{5.5} = \text{compression ratio}$$
$$9.1{:}1 = \text{compression ratio}$$

(Be sure to add the combustion chamber volume to the piston displacement to get the total cylinder volume.)

The higher the compression ratio, the more power an engine theoretically can produce. Also, as the compression ratio increases, the heat produced by the compression stroke also increases. Gasoline with a low octane rating burns fast and may explode rather than burn when introduced to a high compression ratio. This can cause preignition. The higher a gasoline's octane rating, the less likely it is to explode.

As the compression ratio increases, the octane rating of the gasoline also should be increased to prevent abnormal combustion.

ENGINE EFFICIENCY Engine **efficiency** is a measure of the relationship between the amount of energy put into the engine and the amount of available energy from the engine. Engine efficiency is expressed in a percentage. The formula for determining efficiency is:

$$\text{efficiency} = \frac{\text{output energy}}{\text{input energy}} \times 100$$

There are other aspects of the engine that are expressed in efficiencies. These include mechanical efficiency, volumetric efficiency, and thermal efficiency. They are expressed as a ratio of input (actual) to output (maximum or theoretical). Efficiencies are expressed as percentages. They are always less than 100 percent. The difference between the efficiency and 100 percent is the percentage lost during the process. For example, if there were 100 units of energy put into the engine and 28 units came back, the efficiency would be equal to 28 percent. This would mean that 72 percent of the energy received was wasted or lost.

TORQUE AND HORSEPOWER **Torque** is a turning or twisting force. The engine's crankshaft rotates with a torque that is transmitted through the drivetrain to turn the drive wheels of the vehicle. **Horsepower** is the rate at which torque is produced.

Engines produce power by turning a crankshaft in a circular motion. To convert terms of force applied in a straight line to a force applied in a circular motion, the formula is:

$$\text{torque} = \text{force} \times \text{radius}$$

Example: A 10-pound force applied to a wrench 1 foot long will produce 10 pound-feet (lb-ft) of torque.

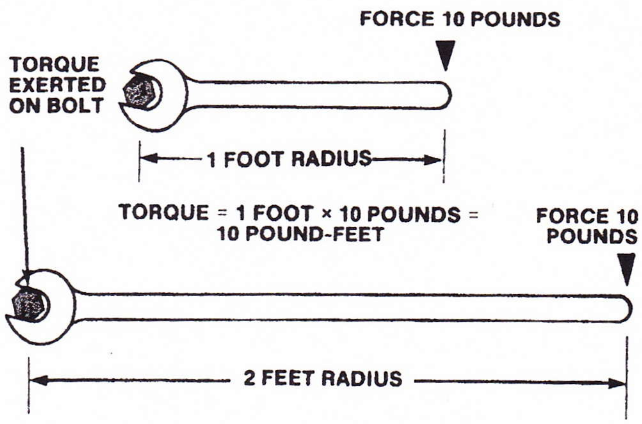


FIGURE 6–20 Force applied to a wrench produces torque.

Imagine that the 1-foot-long wrench is connected to a shaft. If 1 pound of force is applied to the end of the wrench, 1 pound-foot of torque is produced. Ten pounds of force applied to a wrench 2 feet long will produce 20 pound-feet of torque (Figure 6–20).

The technically correct torque measurement is stated in pound-feet (lb-ft). However, it is rather common to state torque in terms of foot-pounds (ft-lb). In the metric or SI system, torque is stated in Newton-meters (N-m) or kilogram-meters (kg-m).

If the torque output of an engine at a given speed (rpm) is known, horsepower (HP) can be calculated by the following formula.

$$HP = (\text{torque} \times \text{rpm}) \div 5{,}252$$

An engine produces different amounts of torque based on the rotational speed of the crankshaft and other factors. A mathematical representation, or graph, of the relationship between the horsepower and torque of an engine is shown in Figure 6–21.

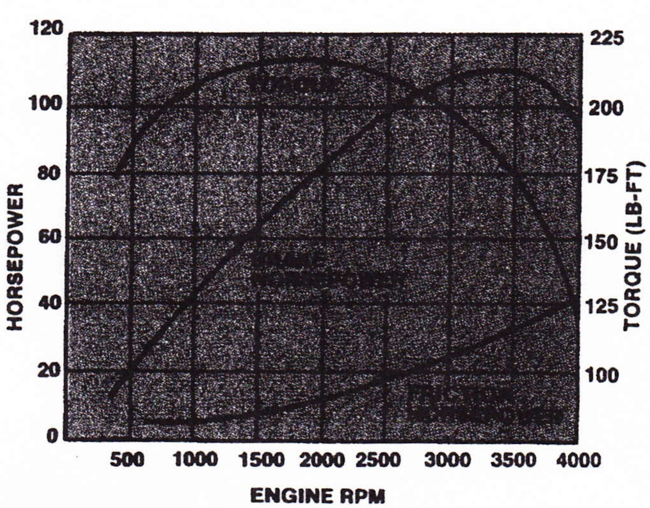


FIGURE 6–21 The relationship between horsepower and torque.

GENERAL SPECIFICATIONS	
DISPLACEMENT	1.9L
NUMBER OF CYLINDERS	1-4
BORE AND STROKE	
1.9L	82 x 88 (3.23 x 3.46)
FIRING ORDER	1-3-4-2
OIL PRESSURE (HOT 2000 RPM)	240-450 kPa (35-65 PSI)
DRIVE BELT TENSION	178-311 (40-70 Lb-Ft)
CYLINDER HEAD AND VALVE TRAIN① ②	
COMBUSTION CHAMBER VOLUME (cc)	EFI-HO 55 ± 1.6
VALVE GUIDE BORE DIAMETER	EFI 39.9 ± 0.8
Intake	13.481-13.519mm (0.531-0.5324 in.)
Exhaust	13.481-13.519mm (0.531-0.532 in.)
VALVE GUIDE I.D.	
Intake and Exhaust	8.063-8.094 N-m (.3174-.3187 in.)
VALVE SEATS	
Width — Intake & Exhaust	1.75-2.32mm (0.069-0.091 in.)
Angle	45°
Runout (T.I.R.)	0.076mm (0.003 in.) MAX.
Bore Diameter (Insert Counterbore Diameter)	
Intake	(EFI-HO) 43.763mm (1.723 in.) MIN. 43.788mm (1.724 in.) MAX. (EFI) 39.940 mm (1.572 in.) MIN. 39.965 mm (1.573 in.) MAX.
Exhaust	(EFI-HO) 38.263mm (1.506 in.) MIN. 38.288mm (1.507 in.) MAX. (EFI) 34.940 mm (1.375 in.) MIN. 39.965 mm (1.573 in.) MAX.
GASKETS SURFACE FLATNESS	0.04mm (0.0016 in.)/26mm (1 in.) 0.08mm (0.003 in.)/156mm (6 in.) 0.15mm (0.006 in.) Total
HEAD FACE SURFACE FINISH	0.7/2.5 0.8 (28/100 .030)
VALVE STEM TO GUIDE CLEARANCE	
Intake	0.020-0.069mm (0.0008-0.0027 in.)
Exhaust	0.046-0.095mm (0.0018-0.0037 in.)
VALVE HEAD DIAMETER	
Intake	42.1-41.9mm (1.66-1.65 in.)
Exhaust	37.1-36.9mm (1.50-1.42 in.)
VALVE FACE RUNOUT	
LIMIT	Intake & Exhaust 05mm (0.002 in.)
VALVE FACE ANGLE	45.6°
VALVE STEM DIAMETER (Std.)	
Intake	8.043-8.025mm (0.3167-0.3159 in.)

FIGURE 6–22 Service manuals contain engine specifications. *Courtesy of Ford Motor Company*

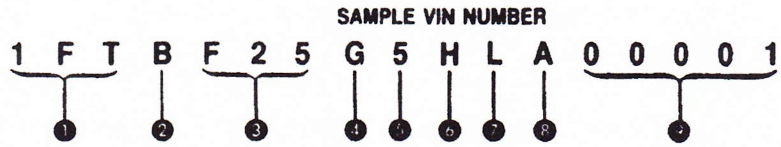
This graph shows that torque begins to decrease when the engine's speed reaches about 1,700 rpm. Brake horsepower increases steadily until about 3,500 rpm. Then it drops. The third line on the graph indicates the horsepower needed to overcome the friction or resistance created by the internal parts of the engine rubbing against each other.

Complete engine specifications can usually be found in service manuals as shown in Figure 6–22.

ENGINE IDENTIFICATION

To find the correct specifications for an engine, a technician must know how to use the vehicle identification number (**VIN**). The VIN is a code of seventeen numbers and letters stamped on a metal tab that is riveted to the instrument panel close to the windshield (Figure 6–23). From this number much information about the vehicle can be found.

FIGURE 6–23 The VIN is visible through the driver's side of the windshield.



① POSITION 1, 2, AND 3—MANUFACTURER, MAKE, AND TYPE (WORLD MANUFACTURER IDENTIFIER)
② POSITION 4—BRAKE SYSTEM
③ POSITION 5, 6, AND 7—MODEL OR LINE, SERIES, CHASSIS, CAB OR BODY TYPE
④ POSITION 8—ENGINE TYPE
⑤ POSITION 9—CHECK DIGIT
⑥ POSITION 10—MODEL YEAR
⑦ POSITION 11—ASSEMBLY PLANT
⑧ POSITION 12—CONSTANT A UNTIL SEQUENCE NUMBER 99,999 IS REACHED, THEN CHANGES TO A CONSTANT B AND SO ON.
⑨ POSITION 13 THROUGH 17—SEQUENCE NUMBER—BEGINS AT 00001

FIGURE 6–24 The VIN provides a great deal of information.

USING SERVICE MANUALS

Normally, information used to identify the size of an engine is given in service manuals at the beginning of the section covering that particular manufacturer. ■

The adoption of the seventeen-number-and-letter code became mandatory beginning with 1981 vehicles. The standard VIN of the United States National Highway Transportation and Safety Administration Department of Transportation is being used by all manufacturers of vehicles, both domestic and foreign.

By referring to the VIN, much information about the vehicle can be determined (Figure 6–24). An engine serial number is also stamped on many blocks (Figure 6–25). Its location is different for the different manufacturers. The service manual will tell you where to look for it. The engine code is generally found beside the serial number. A typical engine code might be DZ or MO. These letters indicate the horsepower rating of the engine, whether it was built for an automatic or manual transmission, and other important details. The engine code will help you determine the correct specifications for that particular engine.

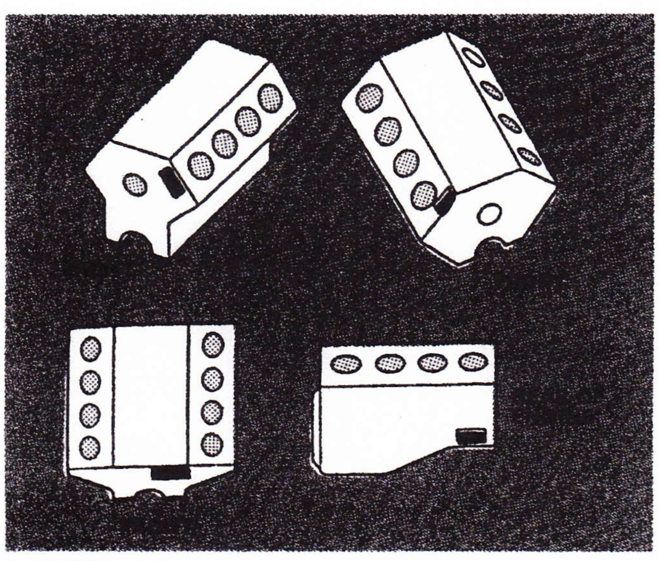


FIGURE 6–25 Common engine serial number locations.

Casting numbers are often mistaken for serial numbers and engine codes. Manufacturers use a casting number to identify major engine parts on the assembly line. They seldom can be used to identify the type of engine.

ENGINE DIAGNOSTICS

In the previous chapter, different types of test equipment were discussed. Many of these tested the mechanical condition of an engine, such as the wet and dry compression, cylinder leakage, and engine vacuum. In addition to these, two other common tests can be performed to evaluate the condition of an engine and to identify any problem areas. The cylinder power balance test checks the efficiency of individual cylinders. The results of this test are often used in conjunction with the results of compression and cylinder leakage tests.

Unlike other engine tests, an oil pressure test does not test a cylinder's ability to seal. It is used to determine wear on the engine's parts. Excessive clearances, often the result of wear, between a shaft and its bearings will have an affect on oil pressure. The oil pressure test is performed with an oil pressure gauge and measures the pressure of the oil while it is circulating through the engine. The pressure of the oil depends upon the efficiency of the oil pump and the clearances through which it travels.

USING SERVICE MANUALS

Whenever you test oil pressure, be sure to refer to the service manual to find out the required conditions for the test and the desired pressure readings. ■

OIL PRESSURE TESTING

Loss of performance, excessive engine noise, and poor starting can be caused by abnormal oil pressures. An insufficient amount of pressure may also cause premature wear on rotating parts. An oil pressure tester is a gauge with a high-pressure hose attached to it. The scale of the gauge typically reads from 0 to 100 psi. The hose is connected to the engine block in a place where oil pressure can be measured (usually where the oil pressure indicator light sensor is screwed into the block).

To conduct the test, simply follow the guidelines given in the service manual and observe the gauge. The pressure is read when the engine is at normal operating temperatures and at a fast idle speed. Low oil pressures can be caused by a worn oil pump, excessive wear on the crankshaft or camshaft and their bearings, a plugged oil pickup screen, or a weak or broken oil pressure relief valve. High oil pressure is normally caused by restrictions in the oil passages or a faulty pressure regulator.

CYLINDER POWER BALANCE TESTING

The **cylinder power balance** test is used to see if all the engine's cylinders are producing the same amount of power. Ideally, all cylinders produce the same amount. This minimizes the amount of power that is lost by keeping the engine running and allows the engine to run smoothly. To check the balance of the cylinders, the cylinders are shorted out one at a time and the change in engine speed is recorded. Ideally, the changes in engine rpm should be about equal as each cylinder is shorted out. Unequal cylinder power can mean a problem in the cylinders themselves, as well as the rings, valves, intake manifold, head gasket, fuel system, or ignition system.

The power balance test is performed quickly and easily using an engine analyzer, because the spark plugs can be controlled with push buttons. Changes are measured in rpm drop. Keep in mind that the push-button numbers refer to the cylinder firing order, not the cylinder number designation. For example, when testing an engine with a firing order of 1-3-4-2, pushing the first button shorts out the number of 1 cylinder, pushing the second button shorts out the number 3 cylinder, and so on.

SHOP TALK

A cylinder power balance test can be conducted with just a tachometer. To do this, simply remove a spark plug wire and ground it. Do this to each spark plug, one at a time, and observe the change in engine rpm. If the engine is equipped with electronic ignition, do not ground the spark plug wire directly to ground. Insert a test spark into the end of the wire and ground the test plug before running the engine. ■

Test Precautions

On some computer-controlled or fuel-injected engines, certain components must be disconnected before attempting the power balance test. Because of the wide variations from manufacturer to manufacturer, consult the vehicle's service manual for specific instructions.

If the engine being tested has an exhaust gas recirculation (EGR) system, added precautions must be taken. If the system is valve controlled, disconnect the vacuum or electrical connection to the EGR valve. This will prevent the valve from cycling due to vacuum changes when the cylinders are shorted out. For engines with a floor jet EGR system, the power balance test cannot be performed accurately because of the possibility of the unburned fuel mixture being sent back into the cylinders. The compression test is the recommended alternative in such cases.

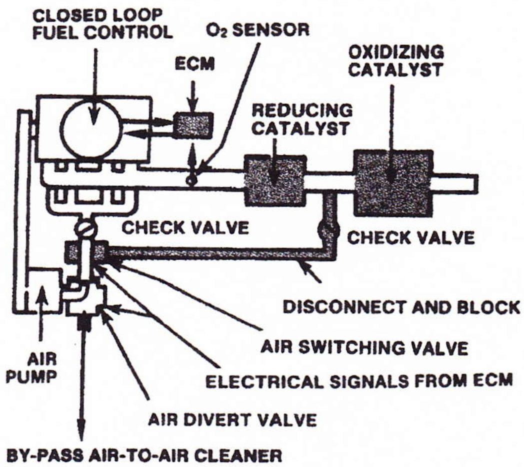
Care must be taken when performing the power balance test on vehicles with catalytic converters. To prevent unburned fuel from building up in the converter, short each spark plug for less than 15 seconds, then allow the engine to run for another 30 seconds before shorting another one.

Performing the Test

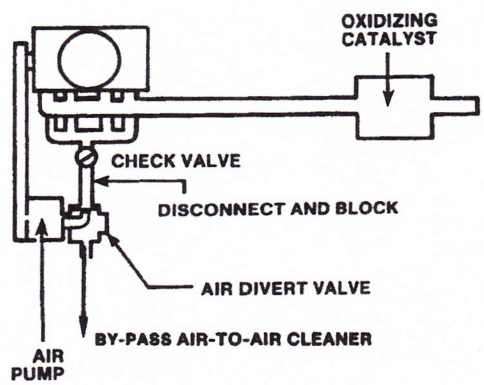
The standard power balance test is fairly simple. If the engine has an air/fuel mixture feedback control or O_2 sensor (Figure 6–26A), disconnect the plug, either the air pump hose going to the catalytic converter or the downstream hose between the air switching valve and the check valve. On some Ford models, the air switching valve can routinely have up to 10 percent leakage, in which case both hoses must be disconnected and plugged. If the engine does not have an air/fuel mixture feedback control or O_2 sensor (Figure 6–26B), disconnect and block the air pump on the valve side.

Override the controls of the electric cooling fan by jumper wiring the controls so the fan runs constantly. If the fan cannot be bypassed, disconnect it. Be careful that the engine does not overheat during the test.

Connect the engine analyzer's leads, referring to the equipment's instruction manual for specific instructions.



A



B

FIGURE 6–26 The procedure for conducting a cylinder power balance test differs, depending on whether the engine (A) has an air/fuel mixture feedback control or (B) does not have an air/fuel mixture feedback control.

Turn on the engine and let it reach its normal operating temperature before beginning the test. Engine speed should be stabilized at approximately 1,000 rpm. When a cylinder is shorted, note any drop in rpm or manifold vacuum.

As each cylinder is shorted out, a noticeable drop in engine speed should occur. Little or no decrease in rpm indicates a weak cylinder. If all the readings are fairly close to each other, the engine is in sound mechanical condition. If a reading in one or more cylinders differs greatly from the rest, there is a problem. Further testing should be done to determine the exact cause of the problem.

EVALUATING THE ENGINE'S CONDITION

Once the compression, cylinder leakage, vacuum, and power balance tests are performed, a technician is ready to evaluate the engine's condition. For example, an engine with good relative compression but high cylinder leakage past the rings is typical of a high-mileage worn engine. This engine would have these symptoms: excessive blowby, lack of power, poor performance, and reduced fuel economy.

If these same compression and leakage test results are found on an engine with comparatively low mileage, the problem is probably stuck piston rings that are not expanding properly. If this is the case, try treating the engine with a combustion chamber cleaner, oil treatment, or engine flush. If this fails to correct the problem, an engine overhaul is required.

A cylinder that has poor compression but minimal leakage indicates a valve train problem. Under these circumstances, a valve might not be opening at the right time, might not be opening enough, or might not be opening at all. This condition can be confirmed on engines with a pushrod-type valve train by pulling the rocker covers and watching the valves operate while the engine is cycled. If one or more valves fail to move, either the lifters are collapsed or the cam lobes are worn. If all of the cylinders have low compression with minimal leakage, the most likely cause is incorrect valve timing.

If compression and leakage are both good, but the power balance test reveals weak cylinders, the cause of the problem is outside the combustion chamber. Assuming there are no ignition or fuel problems, check for broken, bent, or worn valve train components, collapsed lifters, leaking intake manifold, or excessively leaking valve guides. If the latter is suspected, squirt some oil on the guides. If they are leaking, blue smoke will be seen in the exhaust.

NOISE DIAGNOSIS

More often than not, malfunction in the engine will reveal itself first as an unusual noise. This can happen before the problem affects the driveability of the vehicle. Problems such as loose pistons, badly worn rings or ring lands, loose piston pins, worn main bearings and connecting rod bearings, loose vibration damper or flywheel, and worn or loose valve train components all produce telltale sounds. Unless the technician has experience in listening to and interpreting engine noises, it can be very hard to distinguish one from the other.

CUSTOMER CARE

When attempting to diagnose the cause of abnormal engine noise, it may be necessary to temper the enthusiasm of a customer who thinks they have pinpointed the exact cause of the noise using nothing more than their own two ears. While the owner's description may be helpful (and should always be asked for), it must be stressed that one person's "rattle" can be another person's "thump." You are the professional. The final diagnosis is up to you. If customers have been proven correct in their diagnosis, make it a point to tell them so. Everyone feels better about dealing with an automotive technician who listens to them. ■

When correctly interpreted, engine noise can be a very valuable diagnostic aid. For one thing, a costly and time-consuming engine teardown might be avoided. Always make a noise analysis before doing any repair work. This way, there is a much greater likelihood that only the necessary repair procedures will be done. Careful noise diagnosis also reduces the chances of ruining the engine by continuing to use the vehicle despite the problem.

WARNING!

Be very careful when listening for noises around moving belts and pulleys at the front of the engine. Keep the end of the hose or stethoscope probe away from the moving parts. Physical injury can result if the hose or stethoscope is pulled inward or flung outward by moving parts. ■

Using a Stethoscope

Some engine sounds can be easily heard without using a listening device, but others are impossible to hear unless amplified. A stethoscope or rubber hose (as mentioned earlier) is very helpful in locating engine noise by amplifying the sound waves. It can also distinguish between normal and abnormal noise. The procedure for using a stethoscope is simple. Use the metal prod to trace the sound until it reaches its maximum intensity. Once the precise location has been discovered, the sound can be better evaluated. A sounding stick, which is nothing more than a long, hollow tube, works on the same principle, though a stethoscope gives much clearer results.

The best results, however, are obtained with an electronic listening device. With this tool you can tune into the noise. Doing this allows you to eliminate all other noises that might distract or mislead you.

Common Noises

Following are examples of abnormal engine noises, including a description of the sound, its likely cause, and ways of eliminating it. An important point to keep in mind is that insufficient lubrication is the most common cause of engine noise. For this reason, always check the oil level first before moving on to other areas of the vehicle. Some noises are more pronounced on a cold engine because clearances are greater when parts are not expanded by heat. Remember that aluminum and iron expand at different rates as temperatures rise. For example, a knock that disappears as the engine warms up is probably piston slap or knock. An aluminum piston expands more than the iron block, allowing the piston to fit more closely as engine temperature rises.

RING NOISE This sound can be heard during acceleration as a high-pitched rattling or clicking in the upper part of the cylinder. It can be caused by worn rings or cylinders, broken piston ring lands, or insufficient ring tension against the cylinder walls. Ring noise is corrected by replacing the rings, pistons, or sleeves or reboring the cylinders.

PISTON SLAP This is commonly heard when the engine is cold. It often gets louder when the vehicle accelerates. When a piston slaps against the cylinder wall, the result is a hollow, bell-like sound. Piston slap is caused by worn pistons or cylinders, collapsed piston skirts, misaligned connecting rods, excessive piston-to-cylinder wall clearance, or lack of lubrication, resulting in worn bearings. Correction requires either replacing the pistons, reboring the cylinder, replacing or realigning the rods, or replacing the bearings. Shorting out the spark plug of the affected cylinder might quiet the noise.

PISTON PIN KNOCK Piston pin knock is a sharp, metallic rap that can sound more like a rattle if all the pins are loose. It originates in the upper portion of the engine and is most noticeable when the engine is idling and the engine is hot. Piston pin knock sounds like a double knock at idle speeds. It is caused by a worn piston pin, piston pin boss, piston pin bushing, or lack of lubrication, resulting in worn bearings. To correct it, either install oversized pins, replace the boss or bushings, or replace the piston.

RIDGE NOISE This noise is less common but very distinct. As a piston ring strikes the ridge at the top of the cylinder, the result is a high-pitched rapping or clicking noise that becomes louder during deceleration (Figure 6–27).

There can be more than one reason for the ridge interfering with the ring's travel. For one thing, if new rings are installed without removing the old ridge, the new rings will contact the ridge and make a noise. Also, if the piston pin is very loose or the

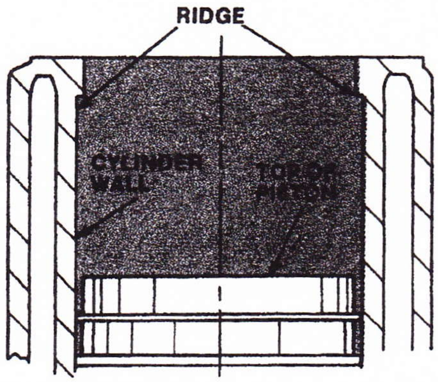


FIGURE 6–27 When the piston strikes the ridge at the top of the cylinder, a high-pitched rapping or clicking sound is made.

connecting rod has a loose or burned-out bearing, the piston will go high enough in the cylinder for the top ring to contact the ridge. Thus, in order to eliminate ridge noise, remove the old ring ridge and replace the piston pin or piston.

ROD-BEARING NOISE The result of worn or loose connecting rod bearings, this noise is heard at idle as well as at speeds over 35 mph. Depending on how badly the bearings are worn, the noise can range from a light tap to a heavy knock or pound. Shorting out the spark plug of the affected cylinder can lessen the noise, unless the bearing is extremely worn. In this case, shorting out the plug will have no effect. Rod-bearing noise is caused by a worn bearing or crankpin, a misaligned rod, or lack of lubrication, resulting in worn bearings. To correct it, service or replace the crankshaft, realign or replace the connecting rods, and replace the bearings.

MAIN OR THRUST BEARING NOISE A loose crankshaft main bearing produces a dull, steady knock, while a loose crankshaft thrust bearing produces a heavy thump at irregular intervals. The thrust bearing noise might only be audible on very hard acceleration. Both of these bearing noises are usually caused by worn bearings or crankshaft journals. To correct the problem, replace the bearings or crankshaft.

TAPPET NOISE Tappet noise is characterized by a light, regular clicking sound that is more noticeable when the engine is idling. It is the result of excessive clearance in the valve train. The clearance problem area is located by inserting a feeler gauge between each lifter and valve, or between each rocker arm and valve tip, until the noise subsides. Tappet noise can be caused by improper valve adjustment, worn or damaged parts, dirty hydraulic lifters, or lack of lubrication. To correct the noise, adjust the valves, replace any worn or damaged parts, or clean or replace the lifters.

ABNORMAL COMBUSTION NOISES Preignition and detonation noises are caused by abnormal engine combustion. For instance, **detonation** knock or **ping** is a noise most noticeable during acceleration with the engine under load and running at normal temperature. Excessive detonation can be very harmful to the engine. It is often caused by advanced ignition timing or substantial carbon buildup in the combustion chambers that increases combustion pressure. Carbon deposits that get so hot they glow will also preignite the air/fuel mixture, causing detonation. Another possible cause is fuel with octane that is too low. Detonation knock can usually be cured by removing carbon deposits from the combustion chambers with a rotary wire brush as well as recommending the use of a higher octane gasoline. A malfunctioning EGR valve can also cause detonation and even rod knock.

Sometimes abnormal combustion combines with other engine parts to cause noise. For example, rumble is a term that is used to describe the knock or noise resulting from another form of abnormal ignition. Rumble is a vibration of the crankshaft and connecting rods that is caused by multi-surface ignition. Rumble is a form or preignition in which several flame fronts occur simultaneously from overheated deposit particles. Multi-surface ignition causes a tremendous sudden pressure rise near top dead center. It has been reported that the rate of pressure rise during rumble is five times the rate of normal combustion.

A loose vibration damper causes a heavy rumble or thump in the front of the engine that is more apparent when the vehicle is accelerating from idle under load or is idling unevenly. A loose flywheel causes a heavy thump or light knock at the back of the engine, depending on the amount of play and the type of engine. Both of these problems are corrected either by tightening or replacing the damper or flywheel.

OTHER ENGINE DESIGNS

The gasoline-powered, internal combustion piston engine has been the primary automotive power plant for many years and probably will remain so for years to come. Present-day social requirements and new technological developments, however, have necessitated searches for ways to modify or replace this time-proven workhorse. This portion of the chapter takes a brief look at the most likely contenders, and how they work. The orbital two-stroke cycle engine was discussed earlier and is not explained in the following. This certainly does not mean that this engine design is not a viable one.

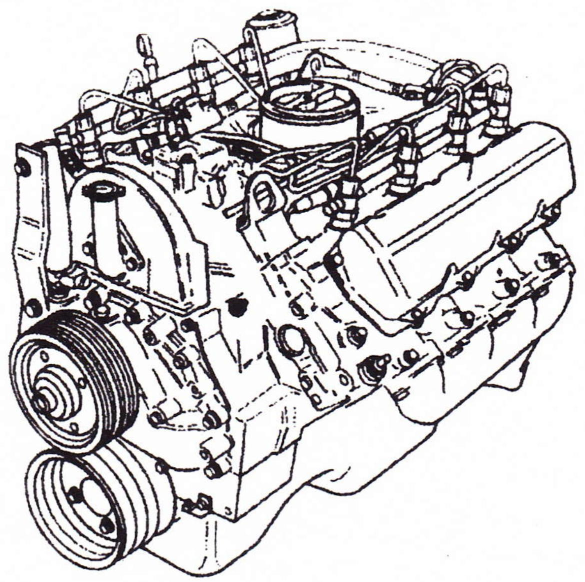


FIGURE 6–28 Typical four-stroke diesel engine. *Courtesy of Ford Motor Company*

Diesel Engine

Diesel engines represent tested, proven technology with a long history of success. Invented by Dr. Rudolph Diesel, a German engineer, and first marketed in 1897, the diesel engine is now the dominate power plant in heavy-duty trucks, construction equipment, farm equipment, buses, and marine applications.

During the late 1970s and early 1980s, many predicted small diesel engines would replace gasoline engines in passenger vehicles. However, stabilized gas prices and other factors dampened the enthusiasm for diesels in these markets. The use of diesel engines in cars and light trucks is now limited to a few manufacturers.

Diesel engines (Figure 6–28) and gasoline-powered engines share several similarities. They have a number of components in common, such as the crankshaft, pistons, valves, camshaft, and water and oil pumps. They both are available in four-stroke combustion cycle models. However, the diesel engine and four-stroke compression-ignition engine are easily recognized by the absence of a ignition system. Instead of relying on a spark for ignition, a diesel engine uses the heat produced by compressing air in the combustion chamber to ignite the fuel. The systems used in diesel-powered vehicles are essentially the same as those used in gasoline vehicles.

Figure 6–29 shows the four-strokes of a diesel engine. Fuel injection is used on all diesel engines. Injectors spray pressurized fuel into the cylinders just as the piston is completing its compression stroke. The heat of the compressed air ignites the fuel and begins the power stroke.

Glow plugs are used only to warm the combustion chamber when the engine is cold. Cold starting is impossible without these plugs because even the high-compression ratios cannot heat cold air enough to cause combustion.

Diesel combustion chambers are different from gasoline combustion chambers because diesel fuel burns differently. Three types of combustion chambers are used in diesel engines: open combustion chamber, precombustion chamber, and turbulence combustion chamber. The open combustion chamber has the combustion chamber located directly inside the piston. Diesel fuel is injected directly into the center of the chamber. The shape of the chamber and the quench area produces turbulence. The precombustion chamber is a smaller, second chamber connection to the main combustion chamber. On the power stroke, fuel is injected into the small chamber. Combustion is started there and then spreads to the main chamber. This design allows lower fuel injection pressures and simpler injection systems on diesel engines.

The turbulence combustion chamber is designated to create an increase in air velocity or turbulence in the combustion chamber. The fuel is injected into the turbulent air and burns more completely. The prechambers on a diesel engine head must be proper-

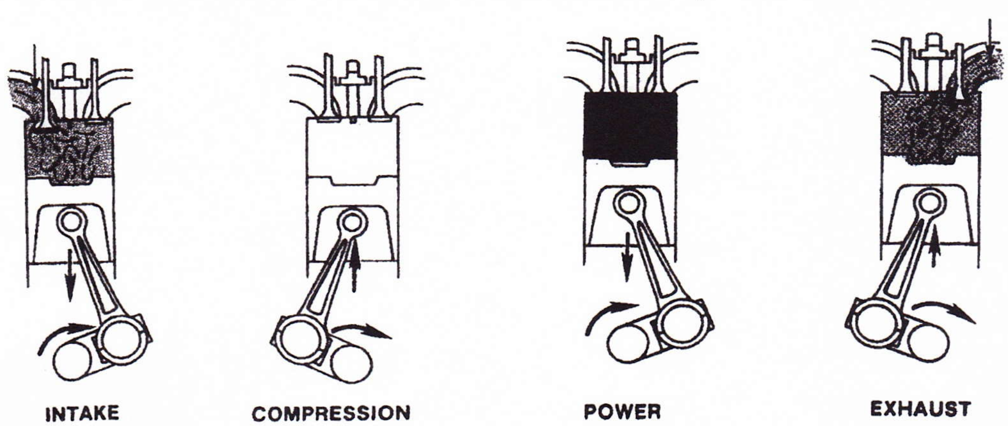


FIGURE 6–29 Four-stroke diesel engine cycle.

COMPRESSION AND VACUUM TESTERS

Internal combustion engines depend on compression of the air/fuel mixture to maximize the power produced by the engine. The upward movement of the piston on the compression stroke compresses the air/fuel mixture within the combustion chamber. The air/fuel mixture gets hotter as it is compressed. The hot mixture is easier to ignite, and when ignited it will generate much more power than the same mixture at a lower temperature.

If the combustion chamber leaks, some of the air/fuel mixture will escape when it is compressed, resulting in a loss of power and a waste of fuel. The leaks can be caused by burned valves, a blown head gasket, worn rings, slipped timing belt or chain, worn valve seats, a cracked head, and more.

An engine with poor compression (lower compression pressure due to leaks in the cylinder) will not run correctly and cannot be tuned to factory specifications. To see if a driveability problem is caused by poor compression, a compression test is performed.

A **compression gauge** is used to check cylinder compression. The dial face on the typical compression gauge indicates pressure in both pounds per square inch (**psi**) and metric kilopascals (**kPa**). The range is usually 0 to 300 psi and 0 to 2,100 kPa.

There are two basic types of compression gauges: the push-in gauge (Figure 5–28) and a screw-in gauge.

The push-in type has a short stem that is either straight or bent at a 45-degree angle. The stem ends in a tapered rubber tip that fits any size spark plug hole. The rubber tip is placed in the spark plug hole, after the spark plugs have been removed, and held there while the engine is cranked through several compression cycles. Although simple to use, the push-in gauge may give inaccurate readings if it is not held tightly in the hole.

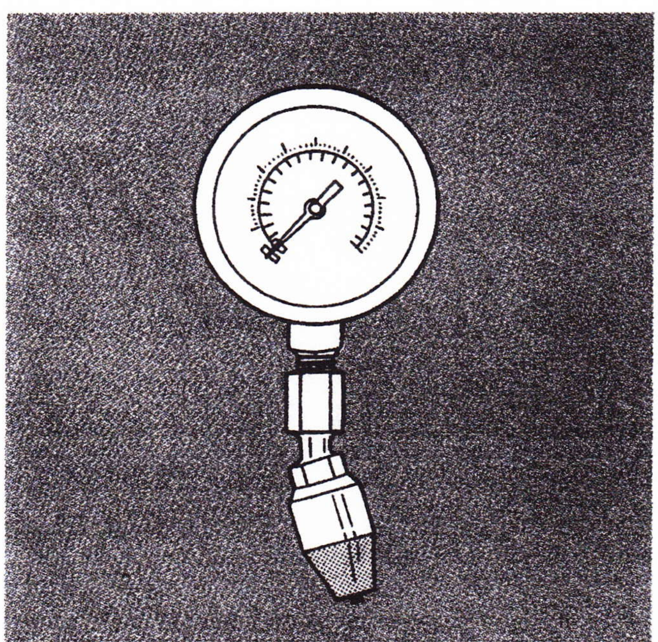


FIGURE 5–28 Push-in compression gauge.

The screw-in gauge has a long, flexible hose that ends in a threaded adapter. This type compression tester is often used because its flexible hose can reach into areas that are difficult to reach with a push-in type tester. The threaded adapters are changeable and come in several thread sizes to fit 10-mm, 12-mm, 14-mm, and 18-mm diameter holes. The adapters screw into the spark plug holes in place of the spark plugs.

Most compression gauges have a vent valve that holds the highest pressure reading on its meter. Opening the valve releases the pressure when the test is complete. The steps for conducting a cylinder compression test are shown in Photo Sequence 3.

Cylinder Leakage Tester

If a compression test shows that any of the cylinders are leaking, a **cylinder leakage** test can be performed to measure the percentage of compression lost and help locate the source of leakage.

A cylinder leakage tester (Figure 5–29) applies compressed air to a cylinder through the spark plug hole. Before the air is applied to the cylinder, the piston of that cylinder must be at TDC on its compression stroke. A threaded adapter on the end of the air pressure hose screws into the spark plug hole. The source of the compressed air is normally the shop's compressed air system. A pressure regulator in the tester controls the pressure applied to the cylinder. An analog gauge registers the percentage of air pressure lost from the cylinder when the compressed air is applied. The scale on the dial face reads 0 to 100 percent.

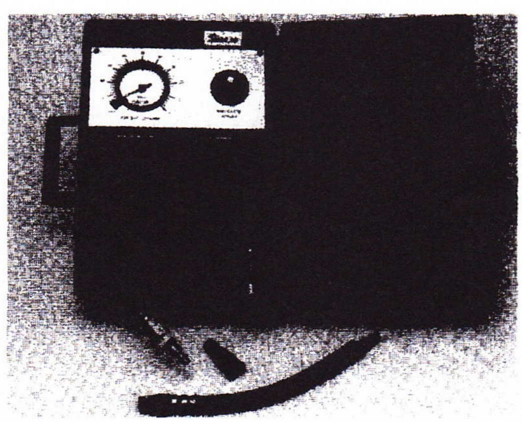


FIGURE 5–29 Typical cylinder leakage tester. *Courtesy of Snap-on Tools Corporation*

A zero reading means there is no leakage from the cylinder. Readings of 100 percent would indicate that the cylinder will not hold any pressure. The location of the compression leak can be found by listening and feeling around various parts of the engine. If air is felt or heard leaving the throttle plate assembly, a leaking intake valve is indicated. If a bad exhaust valve is responsible for the leakage, air can be felt leaving the exhaust system during the test. Air leaving the radiator would indicate a faulty head gasket or a cracked block or head. If the piston rings are bad, air will be heard leaving the valve cover's breather cap or the oil dipstick tube.

Most vehicles, even new cars, experience some leakage around the rings. Up to 20 percent is considered acceptable during the leakage test. When the engine is actually running, the rings will seal much better and the actual percent of leakage will be lower. However, there should be no leakage around the valves or the head gasket.

Vacuum Gauge

Measuring intake manifold vacuum is another way to diagnose the condition of an engine. Manifold vacuum is tested with a vacuum gauge (Figure 5–30). Vacuum is formed on a piston's intake stroke. As the piston moves down, it lowers the pressure of the air in the cylinder—if the cylinder is sealed. This lower cylinder pressure is called engine vacuum. Vacuum is best defined as any pressure lower than atmospheric pressure. Atmospheric pressure is the pressure of the air around us. If there is leak, atmospheric pressure will force air into the cylinder and the resultant pressure will not be as low. The reason atmospheric pressure will enter is simply that whenever there is a low and high pressure, the high pressure will always move toward the low pressure.

FIGURE 5–30 Vacuum gauge kit. *Courtesy of MAC Tools, Inc.*

The vacuum gauge measures the difference in pressure between intake manifold vacuum and atmospheric pressure. If the manifold pressure is lower than atmospheric pressure, a vacuum exists. Vacuum is measured in inches of mercury (in./Hg) and in kilopascals (kPa) or millimeters of mercury (mm/Hg).

To measure vacuum, a flexible hose on the vacuum gauge is connected to a source of manifold vacuum, either on the manifold or a point below the throttle plates. Sometimes this requires removing a plug from the manifold and installing a special fitting.

The test is made with the engine cranking or running. A good vacuum reading is typically at least 16 in./Hg. However, a reading of 15 to 20 in./Hg (50 to 65 kPa) is normally acceptable. Since the intake stroke of each cylinder occurs at a different time, the production of vacuum occurs in pulses. If the amount of vacuum produced by each cylinder is the same, the vacuum gauge will show a steady reading. If one or more cylinders are producing different amounts of vacuum, the gauge will show a fluctuating reading.

Low or fluctuating readings can indicate many different problems. For example, a low, steady reading might be caused by retarded ignition timing or incorrect valve timing. A sharp vacuum drop at regular intervals might be caused by a burned intake valve.

Other conditions that can be revealed by vacuum readings follow.

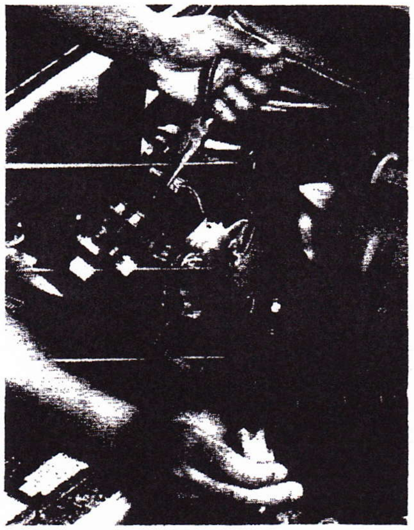
- Stuck or burned valves
- Improper valve or ignition timing
- Weak valve springs
- Leaking intake manifold or EGR valve
- Uneven compression
- Worn rings or cylinder walls
- Leaking head gaskets
- Incorrect carburetor adjustments
- Restricted exhaust system
- Ignition defects

Vacuum Pump

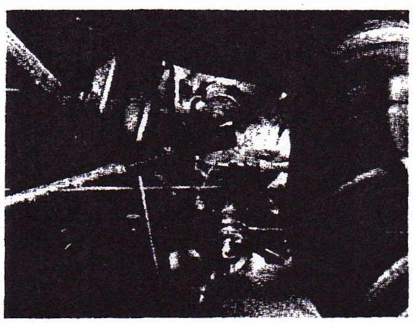
There are many vacuum-operated devices and vacuum switches of cars. These devices use engine vacuum to cause a mechanical action or to switch something on or off. The tool used to test vacuum-actuated components is the vacuum pump (Figure 5–31). There are two types of vacuum pumps: an electrically operated pump and a hand-held pump. The handheld pump is most often used for diagnostics. A hand-held vacuum pump consists of a hand pump, a vacuum gauge, and a length of rubber hose used to attach the pump to the component being tested. Tests with the vacuum pump can usually be performed without removing the component from the car.

PHOTO SEQUENCE 3

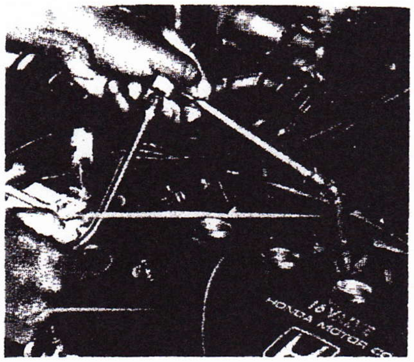
CONDUCTING A CYLINDER COMPRESSION TEST



P3–1 Before conducting a compression test, disable the ignition and the fuel injection system (if the engine is so equipped).

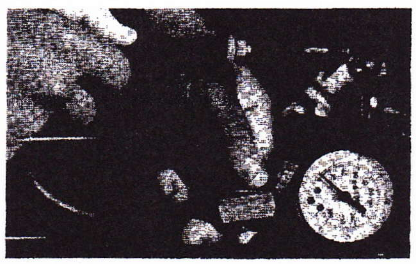


P3–2 Prop the throttle plate into a wide open position. This will allow an unrestricted amount of air to enter the cylinders during the test.

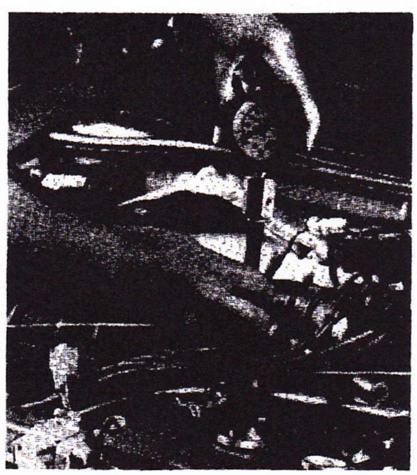


P3–3 Remove all of the engine's spark plugs.

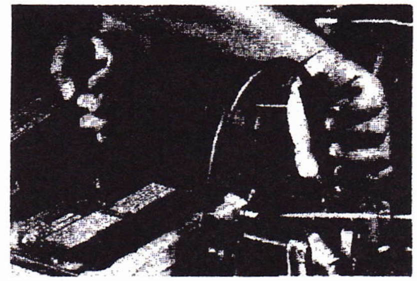
P3–4 Connect a remote starter button to the starter system.



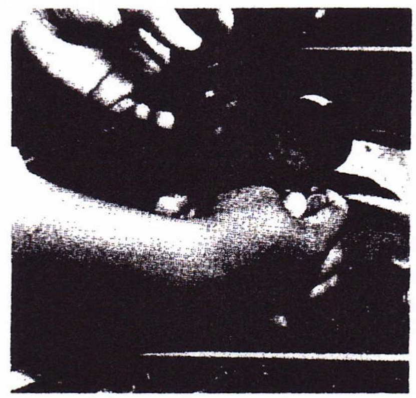
P3–5 Many types of compression gauges are available. The screw-in type tends to be the most accurate and easiest to use.



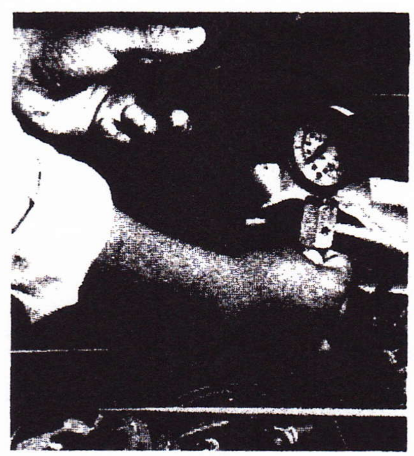
P3–6 Carefully install the gauge into the spark plug hole of the first cylinder.



P3–7 Connect a battery charger to the car. This will allow the engine to crank at consistent and normal speeds that are needed for accurate test results.



P3–8 Depress the remote starter button and observe the gauge's reading after the first engine revolution.



P3–9 Allow the engine to turn through four revolutions, and observe the reading after the fourth. The reading should increase with each revolution.