C H A P T E R 8

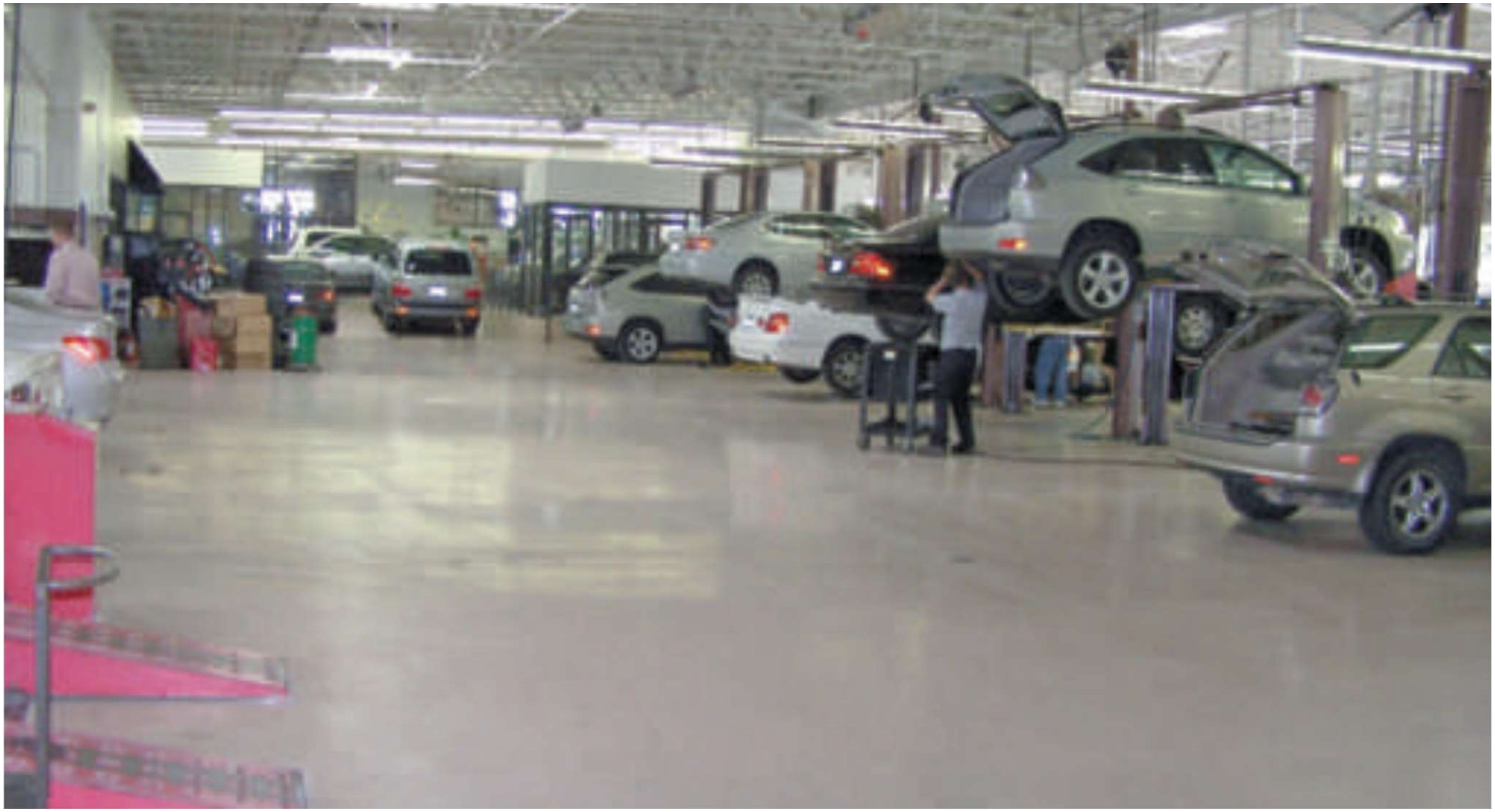
PREVENTIVE MAINTENANCE AND BASIC SERVICES

Preventive maintenance services are those services performed not to correct problems but rather to prevent them.

REPAIR ORDERS

A repair order (RO) is written for every vehicle brought into the shop.

ROs may also be called service or work orders.



Service facilities run smoothly when there is good communication between the customer and the technician.

most ROs contain the following information:

■ Complete customer information
■ Complete vehicle identification
■ Service history of the vehicle
■ The customer’s concern
■ Preliminary diagnosis of the problem
■ Estimate of the amount of time and costs required for the service
■ Time the services should be completed
■ Name of the technician assigned to perform the services
■ Actual services performed with their cost
■ Parts replaced during the services and their cost
■ Recommendations for future services

An RO is signed by the customer, who in doing so authorizes the services and accepts the terms noted on the RO.

- **Parts Replacement**
- Very often when a service is performed, parts are replaced. This appears on the RO as “R&R,” which stands for “remove and replace.”
- Many shops offer the part to the customer as proof that the part was removed and a new one installed.

- **Sublet repairs** are sent to shops that specialize in certain repairs, such as radiator repairs. The cost of the subletting is added to the costs of the services performed by the service facility.

- **When Estimating the Cost of a Repair or Service:**

■ Make sure you have the correct contact information for the customer and the correct information about the vehicle.

■ Always use the correct labor and parts guide or database for that specific vehicle.

■ Locate the exact service for that specific vehicle in the guide or database.

■ Using the guidelines, choose the proper time allocation listed for the service.

■ Multiply the allocated time by the shop's hourly labor rate.

■ If any sublet repairs are anticipated, list this service as a sublet repair and add the cost to the labor costs.

■ Using the information given, identify the parts that will be replaced for that service.

■ Locate the cost of the parts that will be replaced.

■ Repeat the process for all other services required or requested by the customer.

■ Add all of the labor costs together; this sum is the labor estimate for those services.

■ Add the cost of all the parts together; this sum is the estimate for the parts required for the services.

■ Add the total labor and parts costs together.

- **VEHICLE IDENTIFICATION**

Before any service is done to a vehicle, it is important to know exactly what type of vehicle you are working on. The best way to do this is to refer to the **vehicle's identification number (VIN)** . The VIN is on a plate behind the lower corner of the driver's side of the windshield.

Each character of a VIN has a particular purpose. The first character identifies the country where the vehicle was manufactured; for example:

- 1 or 4 – U.S.A.
- 2 – Canada
- 3 – Mexico
- J – Japan
- K – Korea
- S – England
- W – Germany

The second character identifies the manufacturer; for example:

- A – Audi
- B – BMW
- C – Chrysler
- D – Mercedes-Benz
- F – Ford
- G – General Motors
- H – Honda
- N – Nissan
- T – Toyota

The third character identifies the vehicle type or manufacturing division (passenger car, truck, bus, and so on).

The fourth through eighth characters identify the features of the vehicle, such as the body style, vehicle model, and engine type.

The ninth character is used to identify the accuracy of the VIN and is a check digit. The tenth character identifies the model year; for example:

- 8 – 2008
- 9 – 2009
- A – 2010
- B – 2011
- C – 2012
- D – 2013
- E – 2014
- F – 2015
- G – 2016

- The eleventh character identifies the plant where the vehicle was assembled.
- The twelfth to seventeenth characters identify the production sequence of the vehicle as it rolled off the manufacturer’s assembly line.

PREVENTIVE MAINTENANCE

Preventive maintenance (PM) involves performing certain services to a vehicle on a regularly scheduled basis before there is any sign of trouble.

Regular inspection and routine maintenance can prevent major breakdowns and expensive repairs. It also keeps cars and trucks running efficiently and safely.

Maintenance Schedules and Reminders

A typical PM schedule recommends particular service at mileage or time intervals. Driving habits and conditions should also be used to determine the frequency of PM service intervals.

For example, vehicles that frequently are driven for short distances in city traffic often require more frequent oil changes due to the more rapid accumulation of condensation and unburned fuel in the oil.

- **Safety Inspections**

The intent of these inspections is to improve road safety

INSPECT WINDSHIELD AND OTHER GLASS FOR:

Cloudiness, distortion, or other obstruction to vision.

Cracked, scratched, or broken glass.

Window tinting.

Operation of front door glass.

INSPECT WINDSHIELD WIPER/WASHER FOR:

Operating condition.

Condition of blade.

INSPECT WINDSHIELD DEFROSTER FOR:

Operating condition.

INSPECT MIRRORS FOR:

Rigidity of mounting.

Condition of reflecting surface.

View of road to rear.

INSPECT HORN FOR:

Electrical connections, mounting, and horn button.

Emits a sound audible for a minimum of 200 feet.

INSPECT DRIVER'S SEAT FOR:

Anchorage.

Location.

Condition.

INSPECT SEAT BELTS FOR:

Condition.

INSPECT HEADLIGHTS FOR:

Approved type, aim, and output.

Condition of wiring and switch.

Operation of beam indicator.

INSPECT OTHER LIGHTS FOR:

Operation of all lamps, lens color, and condition of lens.

Aim of fog and driving lamps.

INSPECT SIGNAL DEVICE FOR:

Correct operation of indicators (visual or audible).

Illumination of all lamps, lens color, and condition of lens.

INSPECT FRONT DOORS FOR:

Handle or opening device permits the opening of the door from the outside and inside of the vehicle.

Latching system that holds door in its proper closed position.

INSPECT HOOD FOR:

Operating condition of hood latch.

INSPECT FLUIDS FOR:

Levels that are below the proper level.

INSPECT BELTS AND HOSES FOR:

Belt tension, wear, or absence.

Hose damage.

INSPECT POLLUTION CONTROL SYSTEM FOR:

Presence of emissions system—evidence that no essential parts have been removed, rendered inoperative, or disconnected.

INSPECT BATTERY FOR:

Proper anchorage.

Loose or damaged connections.

INSPECT FUEL SYSTEM FOR:

Any part that is not securely fastened.

Liquid fuel leakage.

Fuel tank filler cap for presence.

INSPECT EXHAUST SYSTEM FOR:

Damaged exhaust—manifold, gaskets, pipes, mufflers, connections, etc.

Leakage of gases at any point from motor to point discharged from system.

INSPECT STEERING AND SUSPENSION FOR:

Play in steering wheel.

Wear in bushings, kingpins, ball joints, wheel bearings, and tie-rod ends.

Looseness of gear box on frame, condition of drag link, and steering arm.

Wheel alignment and axle alignment.

Broken spring leaves and worn shackles.

Shock absorbers.

Broken frame.

Broken or missing engine mounts.

Lift blocks.

INSPECT FLOOR PAN FOR:

Holes that allow exhaust gases to enter occupant compartment.

Conditions that create a hazard to the occupants.

INSPECT BRAKES FOR:

Worn, damaged, or missing parts.

Worn, contaminated, or defective linings or drums.

Leaks in system and proper fluid level.

Worn, contaminated, or defective disc pads or discs.

Excessive pedal play.

INSPECT PARKING BRAKE FOR:

Proper adjustment.

INSPECT TIRES, WHEELS, AND RIMS FOR:

Proper inflation.

Loose or missing lug nuts.

Condition of tires, including tread depth.

Mixing radials and bias ply tires.

Wheels that are cracked or damaged so as to cause unsafe operation.

- **Engine Oil**

Engine oil is a clean or refined form of **crude oil** . Crude oil, when taken out of the ground, is dirty and does not work well as a lubricant for engines. Crude oil must be refined to meet industry standards. Engine oil is specially formulated to:

■ Flow easily through the engine

■ Provide lubrication without foaming

■ Reduce friction and wear

■ Prevent the formation of rust and corrosion

■ Cool the engine parts it flows over

■ Keep internal engine parts clean

TABLE 8–1 ENGINE OIL SERVICE RATINGS

Rating	Comments
SA	Straight mineral oil (no additives), not suitable for use in any engine
SB	Non-detergent oil with additives to control wear and oil oxidation
SC	Obsolete since 1964
SM	Started in 2005
SN	Started in 2011

Petroleum Institute (API) classifies engine oil as standard or S-class for passenger cars and light trucks and as commercial or C-class for heavy-duty commercial applications.

In addition to the API rating, oil **viscosity** is important in selecting engine oil. The ability of oil to resist flowing is its viscosity. The thicker the oil, the higher its viscosity rating.

Using the incorrect weight oil can cause excessive oil consumption, increased fuel consumption, VVT system faults, and other concerns.

The Society of Automotive Engineers (SAE) has established an oil viscosity classification system that is accepted throughout the industry.

This system is a numeric rating in which the higher viscosity, or heavier weight, oils receive the higher numbers.

For example, oil classified as SAE 50 weight oil is heavier and flows slower than SAE 10 weight oil.

Modern engine oils are **multiviscosity oils** . These oils carry a combined classification such as 5 W - 30 . This rating says the oil has the viscosity of both a 5 - and a 30 -weight oil.

The “W” after the 5 notes that the oil’s viscosity was tested at 0 ° F (– 18 ° C). This is commonly referred to as the “winter grade.” Therefore, the 5 W means the oil has a viscosity of 5 when cold. The 30 rating is the hot rating.

To formulate multiviscosity oils, polymers are blended into the oil. Polymers expand when heated. With the polymers, the oil maintains its viscosity to the point where it is equal to 30 - weight oil.

Synthetic Oils

Synthetic oils are made through a chemical, not natural, process. The introduction of synthetic oils dates back to World War II.

Synthetic oils have many advantages over mineral oils, including better fuel economy and engine efficiency by reducing friction;

they have low viscosity in low temperatures and a higher viscosity in warm temperatures, and they tend to have a longer useful life.

Synthetic oils cost more than mineral oils, which is the biggest drawback for using them.

Maintenance

Perhaps the PM service that is best known to the public is changing the engine’s oil and filter. Because oil is the lifeblood of an engine, it is critical that the oil and filter are changed on a regular basis.

In between oil and filter changes, the level of the oil should be periodically checked. When doing this, makesure the vehicle is parked on level ground.

Oil change video

Cooling System

Whenever you change an engine’s oil, you should also do a visual inspection of the different systems under the hood, including the cooling system.

Inspect all cooling system hoses for signs of leakage and/or damage. Replace all hoses that are swollen, cracked, or show signs of leakage.

The radiator should also be checked for signs of leaks; if any are evident the radiator should be repaired or replaced. Also, check the front of the radiator for any

buildup of dirt and bugs The level and condition of the engine’s coolant should also be checked.

Figure 8-13 A buildup of dirt and bugs can restrict airflow through the radiator.

Figure 8-14 The level of coolant in the cooling system should be checked at the coolant recovery tank.

C A U T I O N !

Never remove the radiator cap when the coolant is hot. Because the system is pressurized, the coolant can be hotter than boiling water and will cause severe burns.

Coolant Engine **coolant** is a mixture of water and antifreeze. Water alone has a boiling point of 100 ° C and a freezing point of 0 ° C at sea level.

A mixture of 70 percent antifreeze and 30 percent water will raise the boiling point of the mixture to 136 ° C under 15 psi of pressure and lower the freezing point to − 64 ° C .

Normally, the recommended mixture is a 50 / 50 solution of water and antifreeze.

Drive Belts

- **V-belts** and **V-ribbed belts (serpentine belts)** are used to drive water pumps, power-steering pumps, air-conditioning compressors, generators, and emission control pumps.
- Picture of **V-belts** and **V-ribbed belts (serpentine belts)**
- Heat has adverse effects on drive belts and this can cause the belts to harden and crack.
- Excessive heat normally comes from slippage. Slippage can be caused by improper belt tension or oily conditions. When there is slippage, the support bearing of the component driven by the belt can be damaged.

- **V-Belt Inspection** Even the best V-belts last only an average
- of 4 years.
- If a pulley is damaged, it should be replaced. Rust, dirt, and oil should be cleaned off the pulley before installing a new belt.
- Misalignment of the pulleys reduces the belt’s service life and brings about rapid pulley wear, which causes thrown belts and noise.
- pulleys should be in alignment within 1 /1 6 inch (1.59mm) per foot
- of the distance across the face of the pulleys.

Video for belt alignment

Air Filters

If an air filter is doing its job, it will get dirty. Most air filters are made of pleated paper to increase the filtering area.

As a filter gets dirty, the amount of air that can flow through it is reduced.

This is not a problem until less air than what the engine needs can get through the filter.

Without the proper amount of air, the engine will not be able to produce the power it should; nor will it be as fuel efficient as it should be.

Included in the PM plan for all vehicles is the replacement of the air filter.

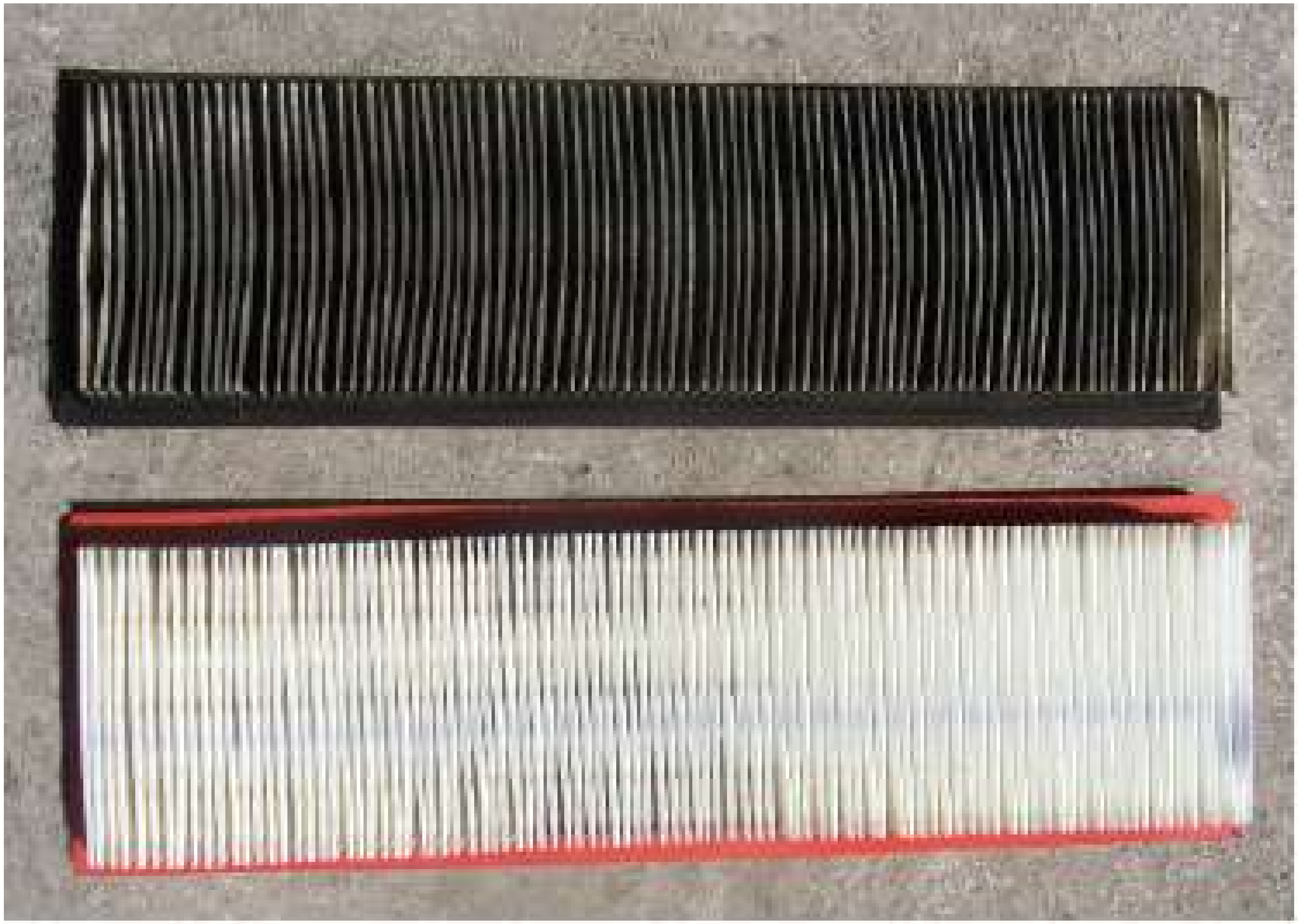


Figure 8-26 A dirty and a clean air filter.

Battery The battery is the main source of electrical energy for the vehicle. It is very important that it is inspected and checked on a regular basis.

PROCEDURE

1. Visually inspect the battery cover and case for dirt and grease.

2. Check the electrolyte level (if possible).

3. Inspect the battery for cracks, loose terminal posts, and other signs of damage.

4. Check for missing cell plug covers and caps.

5. Inspect all cables for broken or corroded wires, frayed insulation, or loose or damaged connectors.

6. Check the battery terminals, cable connectors, metal parts, holddowns, and trays for corrosion damage or buildup—a bad connection can cause reduced current flow.

7. Check the heat shield for proper installation on vehicles so equipped.

Figure 8-27 A really dirty battery.

Battery clean video

Transmission Fluid

The oil used in automatic transmissions is called automatic transmission fluid (ATF).

This special fluid is dyed red so that it is not easily confused with engine oil.

Before checking the fluid, make sure the engine is warm and the vehicle is level.

Then set the parking brake and allow the engine to idle. Sometimes it is recommended that the ATF level be checked when the transmission is placed into Park

SHOP TALK

Many late-model vehicles do not have a transmission dipstick and require special procedures to check the fluid. Refer to the vehicle's service information t

o find out how to check the fluid.

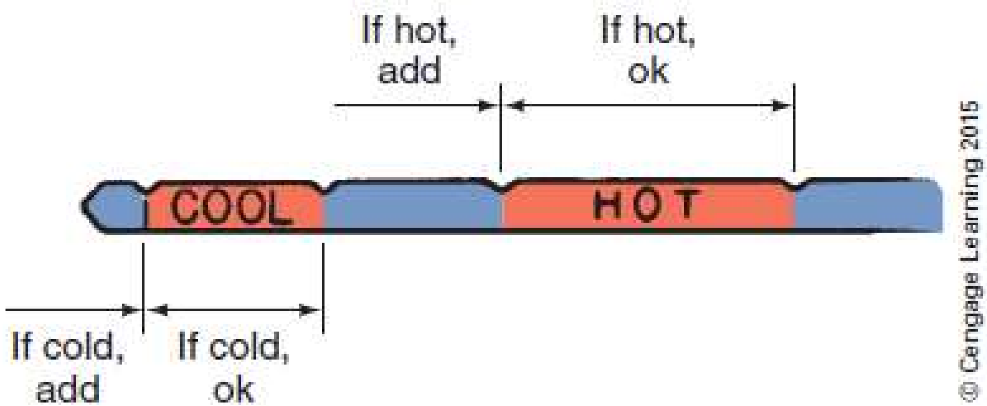


Figure 8-29 Automatic transmission fluid should be checked regularly. Normally the level is checked when the engine is warm. The normal cold level is well below the normal hot level.

Chapter 9

AUTOMOTIVE ENGINE DESIGNS AND DIAGNOSIS

OBJECTIVES

■ Describe the various ways in which engines can be classified.

■ Explain what takes place during each stroke of the four-stroke cycle.

■ Outline the advantages and disadvantages of the inline andV-type engine designs.

■ Define important engine measurements and performance characteristics, including bore and stroke, displacement, compression ratio, engine efficiency, torque, and horsepower.

■ Outline the basics of diesel, stratified, and Miller-cycle engine operation.

■ Explain how to evaluate the condition of an engine.

■ List and describe abnormal engine noises.

Three Cs: Concern, Cause, Correction

ALL TECH AUTOMOTIVE				REPAIR ORDER
Year: 2008	**Make:** Kia	**Model:** Rio	**Mileage:** 64,285	**RO:** 5512
Concern:	Customer complains the engine has a rough idle and does not have as much power as it used to. Also, stated engine is difficult to start when cold but seems to run better at highway speeds.			

Given this customer concern, use what you learn in this chapter to determine possible causes for this concern, methods of diagnosing the concern, and what steps will be necessary to correct the concern.

INTRODUCTION TO ENGINES

The engine provides the power to drive the vehicle’s wheels.

All automobile engines, both gasoline and diesel, are classified as internal-combustion engines because the combustion or burning that creates energy takes place inside the engine.

The biggest part of the engine is the cylinder block.

The cylinder block is a large casting of metal drilled with holes to allow for the passage of lubricants and coolant through the block and provide spaces for parts to move.

The main bores in the block are the cylinders, which are fitted with pistons. The block houses or holds the major engine parts.

Figure 9-1 Today's engines are complex, efficient machines.

Figure 9-2 A cylinder block for an eight-cylinder engine.

The cylinder head fits on top of the cylinder block to close off and seal the top of the cylinders (**Figure 9–3)** .

The cylinder head contains all or most of the combustion chamber.

The combustion chamber is the area where the air-fuel mixture is compressed and burned.

The cylinder head also contains ports through which the air-fuel mixture enters and burned gases exit the cylinders and bores for the spark plugs.

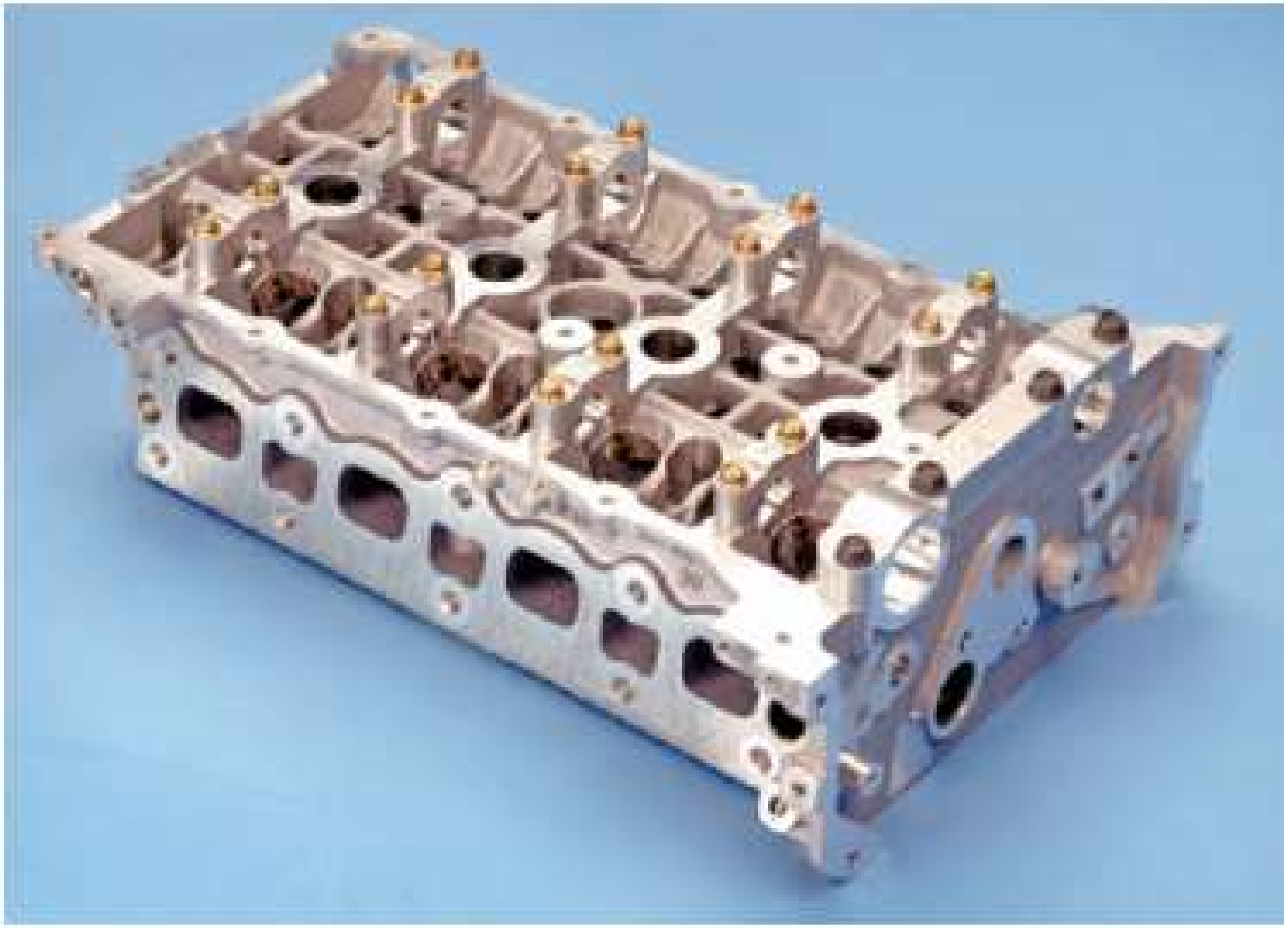


Figure 9-3 A cylinder head for a late-model inline four-cylinder engine.

The valve train opens and closes the intake and exhaust ports. Movable valves open and close the ports.

A camshaft controls the movement of the valves. Springs are used to help close the valves.

The up-and-down motion of the pistons must be converted to a rotary motion before it can drive the wheels of a vehicle.

To do this, the pistons are connected to a crankshaft by connecting rods **(Figure 9–4)** . The upper end of the connecting rod moves with the piston. The lower end is attached to the crankshaft and moves in a circle. The end

of the crankshaft is connected to the flywheel or flexplate. Through the flywheel, the power from the engine is indirectly sent to the drive wheels.

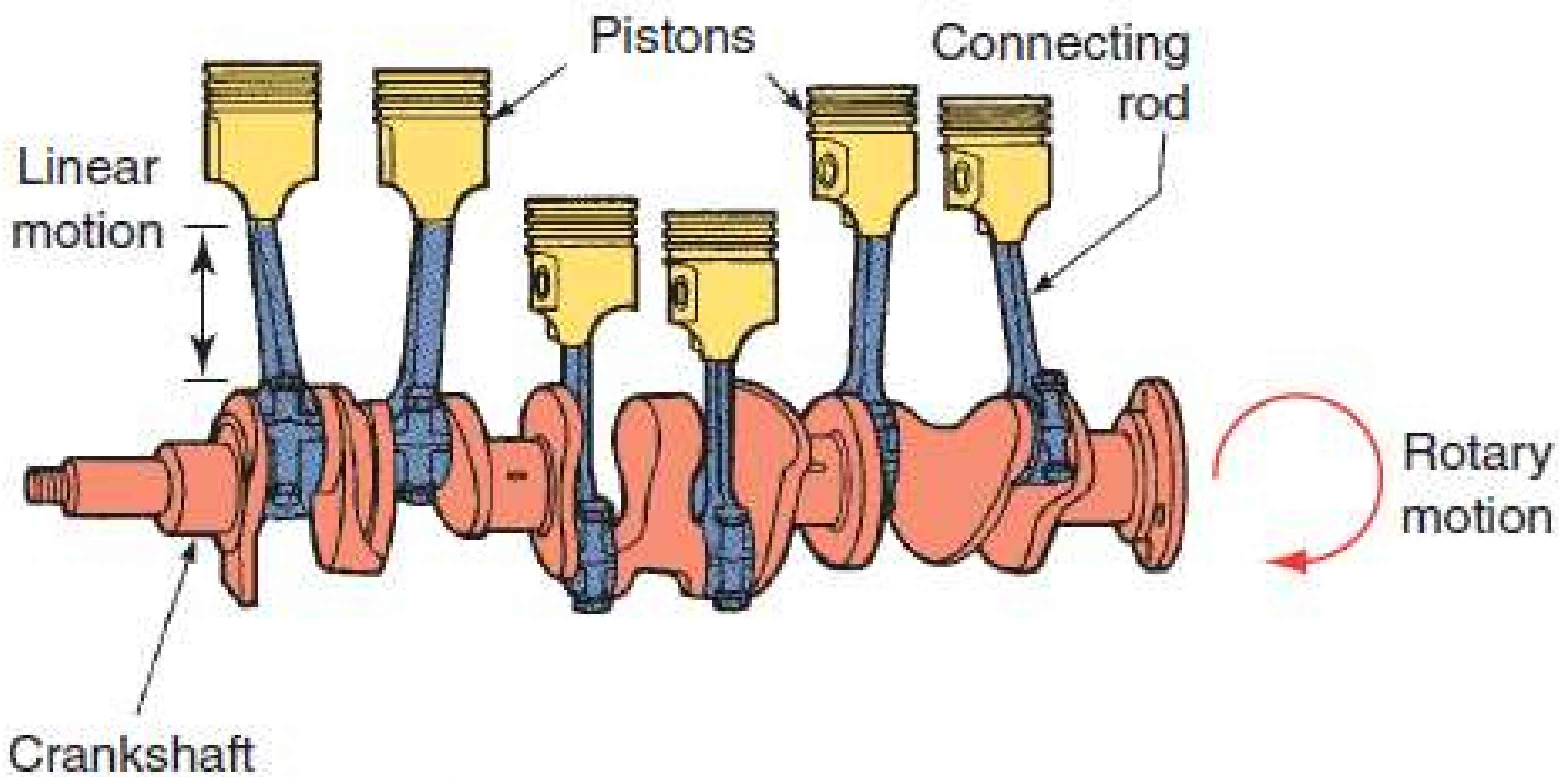


Figure 9-4 The linear (reciprocating) motion of the pistons is converted to rotary motion by the crankshaft.

Engine Construction

Modern engines are designed to meet the performance and fuel efficiency demands of the public.

Most are made of lightweight, noniron materials (for example, aluminum, magnesium, fiber-reinforced plastics); and with fewer and smaller fasteners to hold things together.

Fewer fasteners are made possible due to joint designs that optimize loading patterns. Each engine type has its own distinct personality, based on construction materials, casting configurations, and design.

ENGINE CLASSIFICATIONS

Today's automotive engines can be classified in several ways depending on the following design features:

■ *Operational cycles.* Most technicians will come in contact with only four-stroke cycle engines. A few older cars have used, and some in the future may use, a two stroke engine.

■ *Number of cylinders.* Current engine designs include 3 - , 4 - , 5 - , 6 - , 8 - , 10 - , 12 - , and 16 - cylinder engines.

■ *Cylinder arrangement.* The cylinders of an engine can be arranged inline with each other, in a "V" with an equal number of cylinders on each side, or arranged directly across from each other, these engines are called horizontally opposed (**Figure 9–5**).

■ *Valve train type.* Valve trains can be either the overhead camshaft (OHC) or the camshaft in-block overhead valve (OHV) design. Some engines have separate camshafts for the intake and exhaust valves.

These are based on the OHC design and are called **double overhead camshaft (DOHC)** engines. V-type DOHC engines have four camshafts—two on each side.

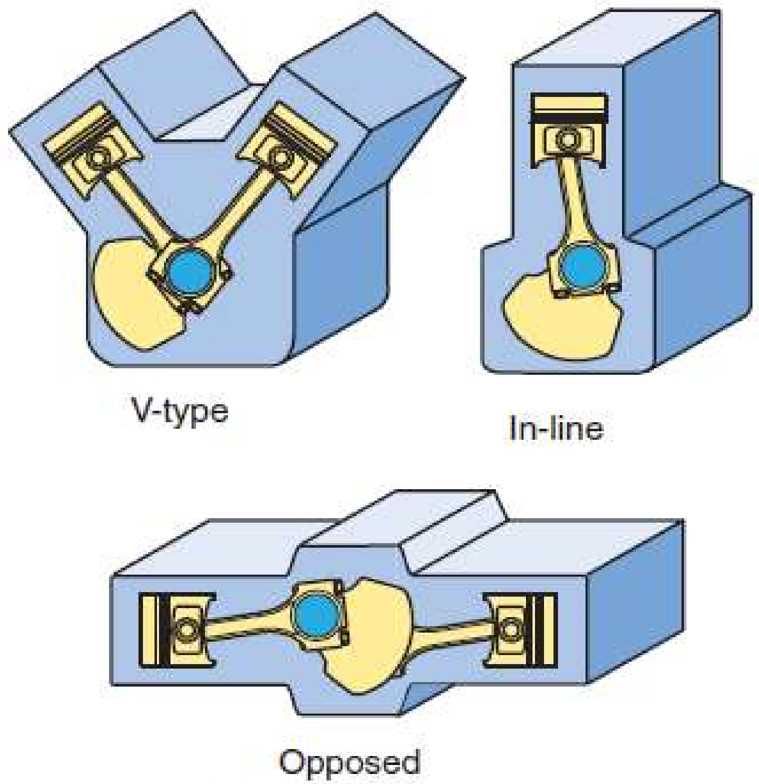


Figure 9-5 The basic configurations of V-type.

Ignition type. There are two types of ignition systems: spark and compression. Gasoline engines use a spark ignition system. In a spark ignition system, the air-fuel mixture is ignited by an electrical spark.

Diesel engines, or compression ignition engines, have no spark plugs.

A diesel engine relies on the heat generated as air is compressed in the cylinder to ignite the fuel.

■ *Cooling systems.* There are both air-cooled and liquid cooled engines in use. All current engines have liquid cooling systems.

■ *Fuel type.* The fuels currently used in automobiles include gasoline, natural gas, methanol, diesel, ethanol, and propane. The most commonly used is gasoline although most gasoline is blended with ethanol.

Four-Stroke Gasoline Engine

The engine provides the rotating power to drive the wheels through the transmission and driving axles.

They require an engine that is made to withstand the high temperatures

and pressures created by the burning of thousands of fuel droplets.

The **combustion chamber** is the space between the top of the piston and the cylinder head. It is an enclosed area in which the fuel and air mixture is burned. If all of the fuel in the chamber is burned, complete combustion has taken place.

In order to have complete combustion, the right amount of fuel must be mixed with the right amount of air.

This mixture must be compressed in a sealed container, then shocked by the right amount of heat (spark) at the right time. When these conditions exist, all the fuel that enters a cylinder is burned and converted to power to move the vehicle. Automotive engines have more than one cylinder.

Each cylinder should receive the same amount of air, fuel, and heat, if the engine is to run efficiently.

Although the combustion must occur in a sealed cylinder, the cylinder must also have a way to allow heat, fuel, and air into it.

There must also be a way to allow the burnt air-fuel mixture out so a fresh mixture can enter and the engine can continue to run.

To meet these requirements, engines are fitted with valves.

There are at least two valves at the top of each cylinder. The air-fuel mixture enters the combustion chamber through an intake valve and leaves (after having been burned) through an exhaust valve **(Figure 9–6)** . Need better pictures of the valves from the net

A valve is said to be seated or closed when it rests in its opening or seat. When the valve is pushed off its seat, it opens.

Figure 9-6 A cutaway of an engine showing the intake passages (blue) and valve and exhaust passage (red) and valve.

A rotating camshaft, driven and timed to the crankshaft, opens and closes the intake and exhaust valves.

Cams are raised sections of a shaft that have high spots called **lobes** . Cam lobes are oval shaped.

The placement of the lobe on the shaft determines when the valve will open. The height and shape of the lobe determines how far the valve will open and how long it will remain open in relation to piston movement **(Figure 9–7)**.

As the camshaft rotates, the lobes rotate and push the valve open by pushing it away from its seat. Once the cam lobe rotates out of the way, the valve, forced by a spring, closes. The camshaft can be located either in the cylinder block or in the cylinder head. The camshaft is driven by the crankshaft through gears, or sprockets, and a cogged belt, or timing chain.

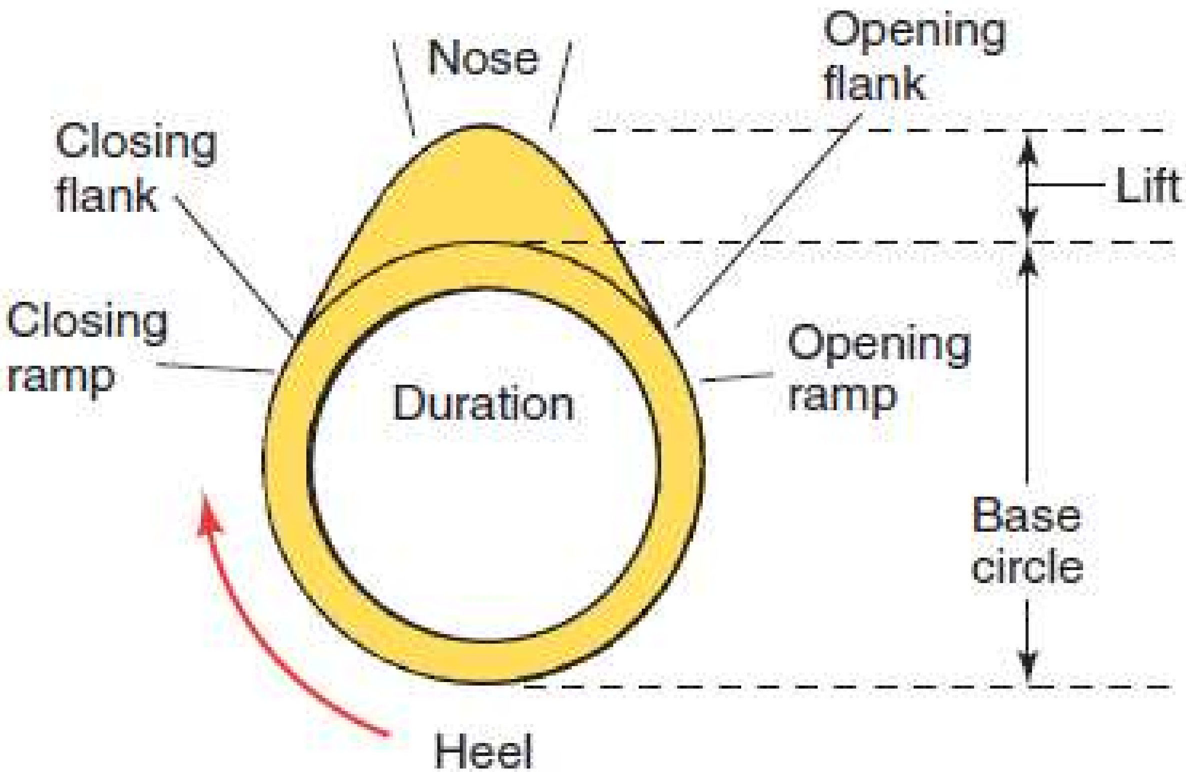


Figure 9-7 The height and width of a cam lobe determine when and for how long a valve will be open.

When the action of the valves and the spark plug is properly timed to the movement of the piston, the combustion cycle takes place in four movements or strokes of the piston:

the intake stroke,

the compression stroke,

The power stroke,

and the exhaust stroke.

The camshaft turns at half the crankshaft speed and rotates one complete turn during each complete four-stroke cycle.

Four-Stroke Cycle

A stroke is the full travel of the piston either up or down in a cylinder's bore.

It takes two full revolutions of the crankshaft to complete the four-stroke cycle.

One complete rotation of the crankshaft is equal to 360 degrees; therefore, it takes 720 degrees to complete the four-stroke cycle. During one piston stroke, the crankshaft rotates 180 degrees.

The piston moves down by the pressure produced during combustion, but this moves the piston only enough to complete one stroke.

In order to keep the engine running, the piston must travel through the other three strokes.

The inertia of a flywheel attached to the end of the crankshaft keeps the crankshaft rotating and allows the piston to complete the rest of the four-stroke cycle.

A heavy flywheel is only found on engines equipped with a manual transmission.

Engines fitted to automatic transmissions have a flexplate and a torque converter. The weight and motion of the fluid inside the torque converter serve as a flywheel.

Intake Stroke

The first stroke of the cycle is the intake stroke. As the piston moves away from **top dead center (TDC)** , the intake valve opens **(Figure 9–8A)**.

The downward movement of the piston increases the volume of the cylinder above it, reducing the pressure in the cylinder.

This reduced pressure, commonly referred to as engine vacuum, causes the atmospheric pressure to push air through the open intake valve.

Some engines are equipped with a super- or turbocharger that pushes more air past the valve.

Air continues to enter the cylinder until the intake valve is closed. In most engines, the intake valve closes after the piston has reached **bottom dead center (BDC)** .

This delayed closing of the valve increases the volumetric efficiency of the cylinder by packing as much air into it as possible.

Compression Stroke

The compression stroke begins as the piston starts to move from BDC. With the intake valve closed, the air in the cylinder is trapped **(Figure 9–8B)** .

The upward movement of the piston compresses the air, thus heating it up. The amount of pressure and heat formed by the compression stroke depends on the amount of air in the cylinder and the compression ratio of the engine.

The volume of the cylinder with the piston at BDC compared to the volume of the cylinder with the piston at TDC determines the compression ratio of the engine. In most modern engines, fuel is injected into the cylinder sometime

during the compression stroke.

Power Stroke

The power stroke begins as the compressed fuel mixture is ignited **(Figure 9–8C)** .

With both valves closed, an electrical spark across the electrodes of a spark plug ignites the air-fuel mixture.

The burning mixture rapidly expands, creating a very high pressure against the top of the piston.

This drives the piston down toward BDC.

The downward movement of the piston is transmitted through the connecting rod to the crankshaft.

Exhaust Stroke

The exhaust valve opens just before the piston reaches BDC on the power stroke **(Figure 9–8D)** .

Pressure within the cylinder causes the exhaust gas to rush past the open valve and into the exhaust system.

Movement of the piston from BDC pushes most of the remaining exhaust gas from the cylinder.

As the piston nears TDC, the exhaust valve begins to close as the intake valve

starts to open.

The exhaust stroke completes the four stroke cycle.

The opening of the intake valve begins the cycle again. This cycle occurs in each cylinder and is repeated over and over, as long as the engine is running.

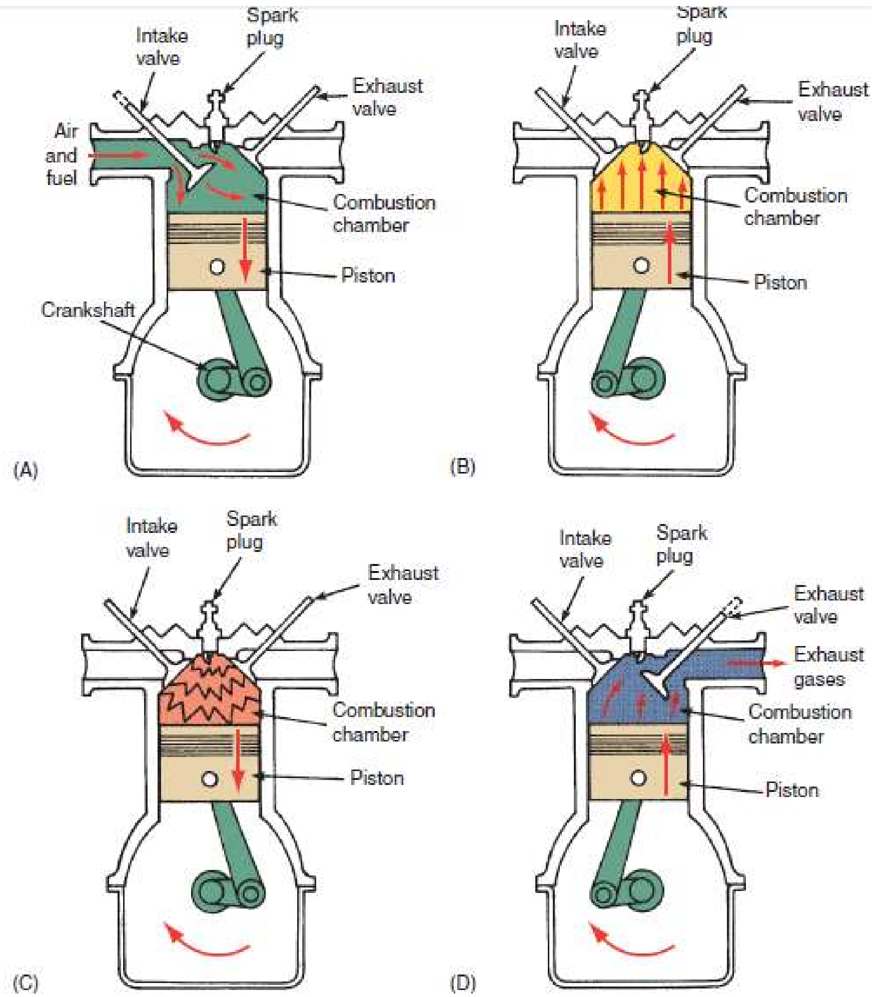


Figure 9-8 (A) Intake stroke, (B) compression stroke, (C) power stroke, and (D) exhaust stroke.

Firing Order

An engine’s firing order states the sequence in which an engine’s pistons are on their power stroke and therefore the

order in which the cylinders’ spark plugs fire.

The firing order also indicates the position of the other pistons in an engine when a cylinder is firing. For example, consider a

four- cylinder engine with a firing order of 1 - 3 - 4 - 2 .

The sequence begins with piston #1 on the compression stroke. During that time, piston #3 is moving down on its intake

stroke, #4 is moving up on its exhaust stroke, and #2 is moving down on its power stroke.

These events are identified by what needs to happen in order for #3 to be ready to fire next, and so on.

Not all engines have the same firing order, as it is determined by the design and manufacturer of the engine.

The firing order of a particular engine can be found on the engine or on its emissions label and in service information.

Combustion

Although many different things can affect the combustion in the engine's cylinders, the ignition system has the

responsibility for beginning and maintaining combustion.

Obviously when combustion does not occur in any of the cylinders, the engine will not run. If combustion occurs in all but one or two cylinders, the engine may start and run but will run poorly. Poor combustion is not always caused by the ignition system, it can also be caused by problems in the engine, air-fuel system, or exhaust system.

When normal combustion occurs, the burning process moves from the gap of the spark plug across the compressed air-fuel mixture.

The movement of this flame front should be rapid and steady and should end when all of the air-fuel mixture has been burned **(Figure 9–11)** .

During normal combustion, the rapidly expanding gases push down on the piston with a powerful but constant force.

When all of the air and fuel in the cylinder are involved in the combustion process, complete combustion has occurred.

When something prevents this, the engine will misfire or experience incomplete combustion. Misfires cause a variety of driveability problems, such as a lack of power, poor gas mileage, excessive exhaust emissions, and a rough running engine.

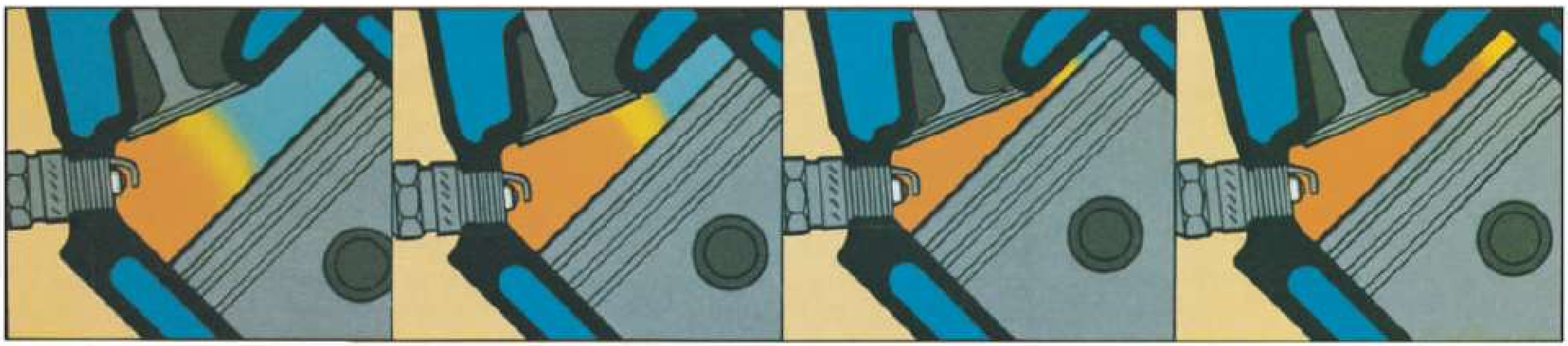


Figure 9-11 Normal combustion.

Engine Configurations

Depending on the vehicle, either an inline, V-type, slant, or opposed cylinder design can be used. The most popular designs are inline and V-type engines.

Inline Engine

In an inline engine design **(Figure 9–12)** ,

the cylinders are placed in a single row. There is one crankshaft and one cylinder head for all of the cylinders. The block is cast so that all cylinders are located in an upright position.

Inline engine designs have certain advantages and disadvantages.

They are easy to manufacture and service. However, because the cylinders are positioned vertically, the front of the vehicle must be higher. This affects the aerodynamic design of the car.

Figure 9-12 The cylinder block for an inline cylinder engine.

V-Type Engine

A V-type engine design has two rows of cylinders located 60 to 90 degrees away from each other. A V-type engine uses one crankshaft, which is connected to the pistons on both sides of the V.

This type of engine has two cylinder heads, one over each row of cylinders.

One advantage of using a V-configuration is that the engine is not as high or long as one with an inline configuration.

If eight cylinders are needed for power, a V- configuration makes the engine much shorter, lighter, and more compact.

Many years ago, some vehicles had an inline eight-cylinder engine. The engine was very long and

its long crankshaft also caused increased torsional vibrations in the engine.

A variation of the V-type engine is the W-type engine. These engines are basically two V-type engines joined together at the crankshaft. This design makes the engine more compact. They are commonly found in late-model Volkswagens, Bentleys, and the Bugatti Veyron.

ENGINE MEASUREMENT AND PERFORMANCE

Many of the important engine measurements and performance characteristics were discussed in Chapter 3 . What follows are some of the important facts of each.

Bore and Stroke

The bore of a cylinder is simply its diameter measured in inches (in.) or millimeters (mm). The stroke is the distance the piston travels between TDC and BDC. The bore and stroke determine the displacement of the cylinders. When the bore and stroke are of equal size, the engine is called a *square engine* . Engines that have a larger bore than stroke are called oversquare and engines with a larger stroke than bore are referred to as being undersquare.

Oversquare engines can be fit with larger valves in the combustion chamber and longer connecting rods, which means these engines are capable of running at higher engine speeds. But due to the size of the bore, these engines tend to be physically larger than undersquare engines.

Undersquare engines have short connecting rods that allow for more power at low engine speeds. A square engine is a compromise between the two designs.

The **c rank throw** is the distance from the crankshaft’s main bearing centerline to the connecting rod journal centerline. An engine’s stroke is twice the crank throw (**Figure 9–16)** .

Displacement A cylinder’s displacement is the volume of the cylinder

when the piston is at BDC. The trend in recent years has been toward smaller displacement engines fitted with turbo- or superchargers. Many manufacturers have

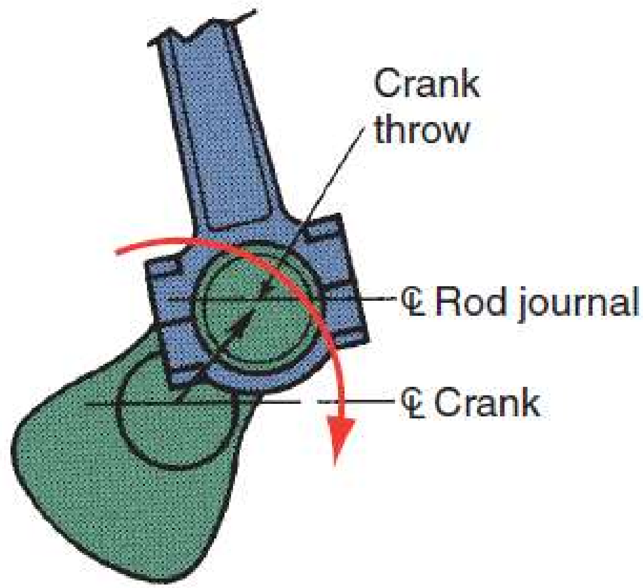


Figure 9-16 The stroke of an engine is equal to twice the crank throw.

Displacement

A cylinder's displacement is the volume of the cylinder when the piston is at BDC. The trend in recent years has been toward smaller displacement engines fitted with turbo- or superchargers.

Many manufacturers have moved from 8 -cylinder to 6 -cylinder or 6 -cylinder to 4 -cylinder engines to improve fuel economy. Using a turbo- or supercharger maintains high levels of performance while the smaller engine improves economy. As an example, Ford recently announced it will be offering its 1.0 liter turbocharged 3 -cylinder EcoBoost engine in the United States.

An engine's displacement is the sum of the displacements of each of the engine's cylinders **(Figure 9–17)** . Typically, an engine with a larger displacement produces more torque than a smaller displacement engine; however, many other factors influence an engine's power output. Engine displacement can be changed by changing the size of the bore and/or stroke of an engine.

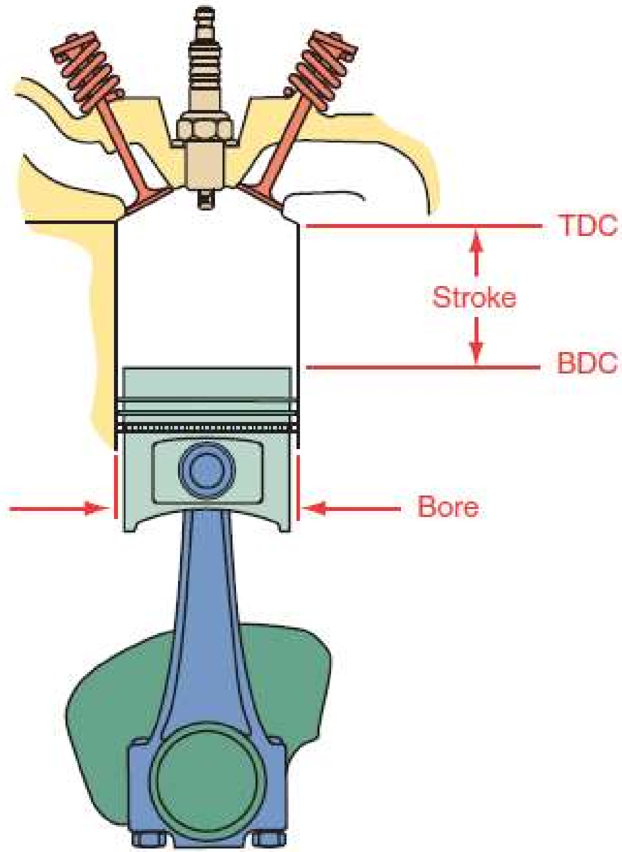


Figure 9-17 Displacement is the volume the cylinder holds between TDC and BDC.

Compression Ratio

The compression ratio is a statement of how much the air fuel mixture will be compressed during the compression stroke. It is important to keep in mind that this ratio can change through wear and carbon and dirt buildup in the cylinders. For example, if a great amount of carbon collects on the top of the piston and around the combustion chamber, the volume of the cylinder changes. This buildup of carbon will cause the compression ratio to increase because the volume at TDC is smaller.

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, which 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 should also be increased to prevent abnormal combustion.

Engine Efficiency

One of the dominating trends in automotive design is increasing an engine's efficiency. **Efficiency** is simply a measure of the relationship between the amount of energy put into an engine and the amount of energy available from the engine. Other factors, or efficiencies, affect the overall efficiency of an engine.

Volumetric Efficiency Volumetric efficiency describes the engine's ability to fill its cylinders with air and fuel. If the engine's cylinders can be filled during its intake stroke, the engine has a volumetric efficiency of 100 percent. Typically, engines have a volumetric efficiency of 80 percent to 100 percent if they are not equipped with a turbo- or supercharger. Basically, an engine becomes more efficient as its volumetric efficiency is increased. Turbochargers and superchargers force more air into the cylinders and therefore increase the volumetric efficiency of the engine. In fact, anything that is done to an engine to increase the intake air volume will increase its volumetric efficiency.

Thermal Efficiency

Thermal efficiency is a measure of how much of the heat formed during combustion is available as power from the engine. Normally only one-fourth of the heat is used to power the vehicle. The rest is lost to the surrounding air and engine parts and to the engine's coolant **(Figure 9–18)** . Obviously, when less heat is lost, the engine is more efficient.

Mechanical Efficiency

Mechanical efficiency is a measure of how much power is available once it leaves the engine compared to the amount of power that was exerted on the pistons during the power stroke. Power losses occur because of the friction generated by the moving parts. Minimizing friction increases mechanical efficiency.

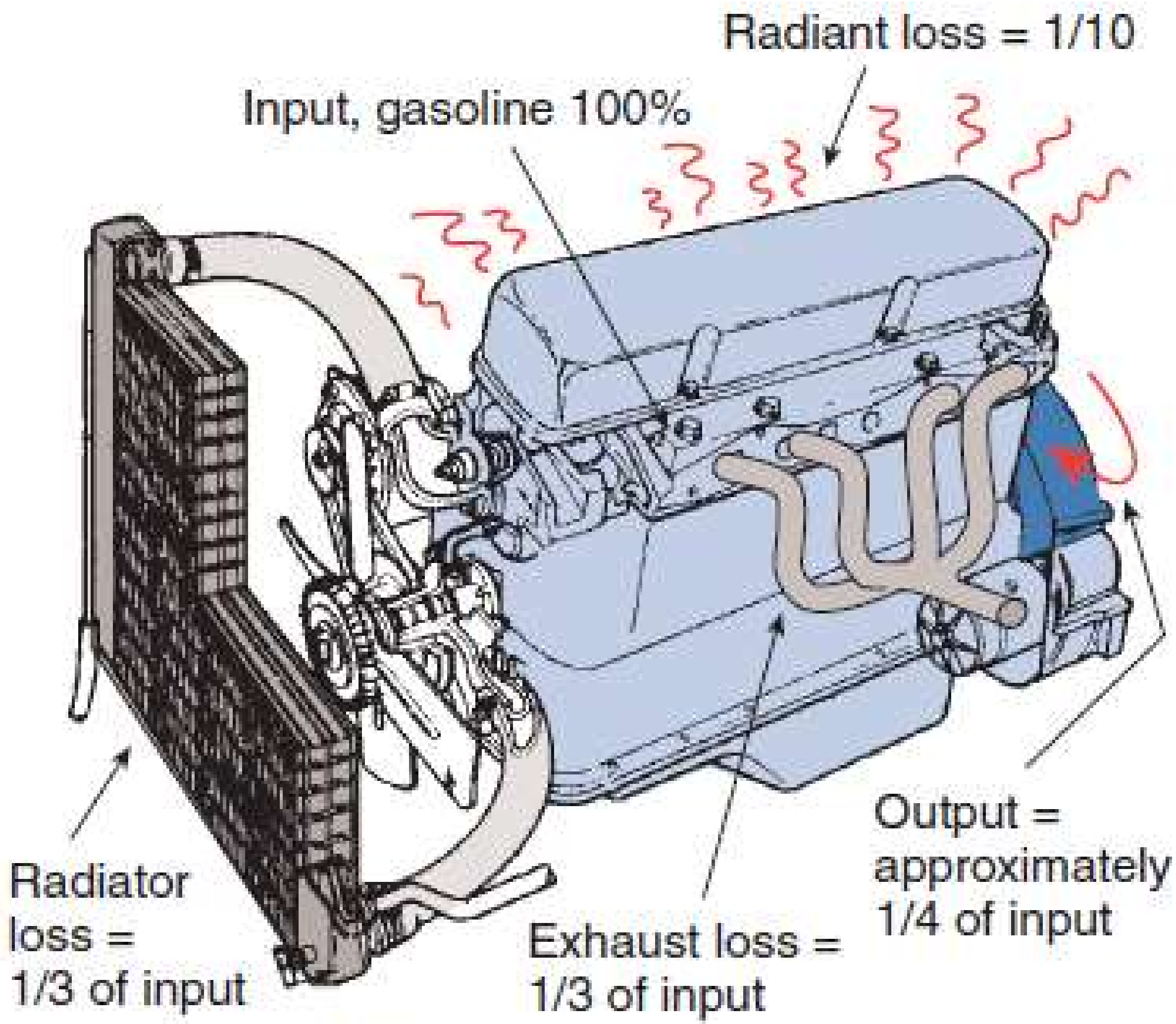


Figure 9-18 A gasoline engine is only about 25 percent thermal efficient.

DIESEL ENGINES

Diesel engines were invented by Dr. Rudolph Diesel, a German engineer, and first marketed in 1897. The diesel engine is now the dominant power plant in heavy-duty vehicles.

The operation of a **diesel engine** is comparable to a gasoline engine. They also have a number of components in common, such as the crankshaft, pistons, valves, camshaft, and water and oil pumps. They both are available as two- or four-stroke combustion cycle engines. However, diesel engines rely on compression ignition **(Figure 9–24)** .

A diesel engine uses the heat produced by compressing air in the combustion chamber to ignite the fuel. The compression ratio of diesel engines can be three times (as high as 25:1) that of a gasoline engine though newer engine technologies allow diesel engines to use lower compression ratios. As intake air is compressed, its temperature

rises to 1,300 ° F to 1,650 ° F (700 ° C to 900 ° C). Just before the air is fully compressed, a fuel injector sprays a small amount of diesel fuel into the cylinder. The high temperature of the compressed air instantly ignites the fuel. The combustion causes increased heat and the resulting high pressure moves the piston down on its power stroke.

Construction

A diesel engine must be made stronger to contain the extremely high compression and combustion pressures. A diesel engine produces less horsepower than a same-sized

gasoline engine. Therefore, to provide the required power, the displacement of the engine is increased. This results in a physically larger engine. Diesels have high-torque outputs

at very low engine speeds but do not run well at high engine speeds **(Figure 9–25)** . On many diesel engines, turbochargers and intercoolers are used to increase their power output. Fuel injection is used on all diesel engines. Older diesel engines had a distributor-type injection pump driven and

regulated by the engine. The pump supplied fuel to injectors that sprayed fuel into the engine's combustion chamber. Newer diesel engines are equipped with common rail system.

Hybrid cars

A hybrid vehicle has at least two different types of power or propulsion systems. Today's hybrid vehicles have an internal combustion engine and an electric motor (some vehicles have more than one electric motor). A hybrid's electric motor **(Figure 9–29)** is powered by batteries and/or ultracapacitors, which are recharged by a generator that is driven by the engine. They are also recharged through regenerative braking.

The engine may use gasoline, diesel, or an alternative fuel. Complex electronic controls monitor the operation of the vehicle. Based on the current operating conditions, electronics control the engine, electric motor, and generator.

Depending on the design of the hybrid vehicle, the engine may power the vehicle, assist the electric motor while it is propelling the vehicle, or drive a generator to charge the vehicle's batteries. The electric motor may propel the vehicle by itself, assist the engine while it is propelling the vehicle, or act as a generator to charge the batteries.

Many hybrids rely exclusively on the electric motor(s) during slow-speed operation, on the engine at higher speeds, and on both during certain driving conditions. The engines used in hybrids are specially designed for fuel economy and low emissions. The engines tend to be small displacement engines that use variable valve timing and the Atkinson cycle to provide low fuel consumption.

Often hybrids are categorized as series or parallel designs. In a series hybrid, the engine never directly powers the vehicle. Rather it drives a generator, and the generator either charges the batteries or directly powers the electric motor that drives the wheels **(Figure 9–30)**.

A parallel vehicle uses either the electric motor or the gas engine to propel the vehicle, or both **(Figure 9–31)** . Most current hybrids can be considered as having a series/parallel configuration because they have the features of both designs.

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Most current hybrids can be considered as having a series/parallel configuration because they have the features of both designs.

Although most current hybrids are focused on fuel economy, the same construction is used to create high performance vehicles.

The added power of the electric motor boosts the performance levels provided by the engine. Hybrid technology also enhances off-the-road performance.

By using individual motors at the front and rear drive axles, additional power can be applied to certain drive wheels when needed.

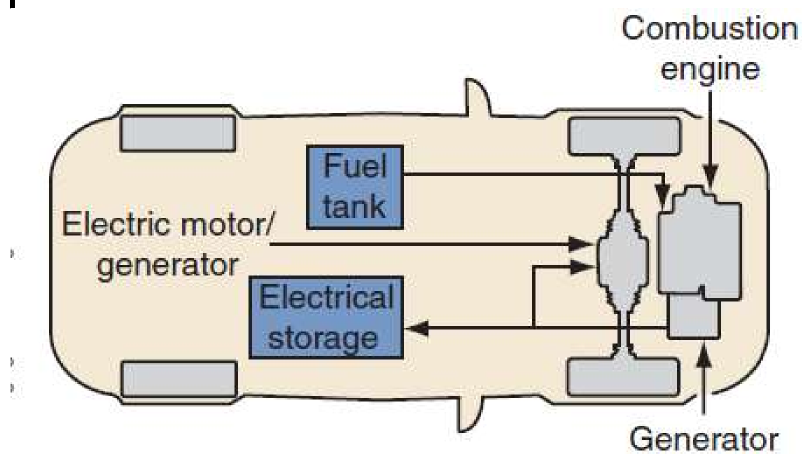

Figure 9-30 The configuration of a series hybrid vehicle.