OBJECTIVES
Upon completion of this chapter, you should be able to:
■ Describe how a tire is constructed.
■ Understand the various size designations of tires.
■ Tell the design differences between radial and bias tires.
■ Be able to select the best replacement tire for a vehicle.

KEY TERMS
alloy, aspect ratio, belt, bias-ply, drop center, footprint, GVW, GVWR, hub-centric, hydroplaning, load index, M+S, MS, M&S, M/S, negative wheel offset, placard, plus sizing, positive wheel offset, profile, radial-ply, SEMA, size equivalent, speed rating, stud-centric, traction, traction grade, UTQG

INTRODUCTION
A service technician will often advise customers about tires, discuss aspects of tire design, and help the customer to make the safest (and best) choice when purchasing new tires and/or wheels. Tires and wheels are an important automotive safety and service specialty area. In-depth information about them is presented in this chapter and Chapter 62.

TIRE CONSTRUCTION
Tires are constructed of several layers of rubber materials, cords, and two rings of wire, called beads (Figure 61.1). The casing or carcass is the internal structure of the tire. A ply is metal or fabric cord that is rubberized (covered with a layer of rubber). The plies provide strength to the tire to support the load of the vehicle.

The ends of the plies wrap around the steel bead before being bonded to the side of the tire. The beads are coils of wires at the side edges of the tire. They give the tire the strength to stay firmly attached to the wheel. Chafing strips are hard strips of rubber that...
protect the beads from damage that could result from chafing against the wheel rim.

A **belt** is a cord structure made up of plies. It is only in the area of a tire under the tread and does not extend under the sidewalls.

The **tread** is the section of the tire that contacts the road. A rubber sidewall covering protects the casing plies between the tire tread and the tire bead.

### Tubeless Tires

Due to safety considerations and ease of service, manufacturers in the 1950s began to put tubeless tires on all of their vehicles. Almost all passenger car tires sold since the early 1960s are tubeless tires. Some imported cars still had tube-type tires until the mid-1970s. Also, tube-type tires are used with wire wheels to prevent leakage from the spoke holes.

The inside of a tubeless tire has a bonded **inner liner** that seals air in the tire. The liner is thicker than the liner on a **tube-type tire**. Tubeless tires are actually safer than tube tires. When a tubeless tire is punctured, it will usually not go flat immediately. A nail tends to be held in the tire by the inner liner, allowing air to escape more slowly. A tube-type tire tends to go flat instantly when punctured because the walls of the inner tube tend to tear.

### Tire Tread

The tread is a band of rubber compound designed to have various traction and wear characteristics. A federal grading standard (discussed later in this chapter) molded into the tire sidewall describes its traction and treadwear characteristics. Grooves in the tread allow traction on wet surfaces, giving the water a place to go. They also allow the tire to flex without squirming against the road surface, which would cause wear.

Treads are designed for specific types of weather and conditions. Design selection is always a compromise. The best traction on a dry paved road would be with a racing **slick**, or a bald tire. However, that same tire would be dangerous in the rain. Water forms a wedge under a tire that can actually float the car. This is called **hydroplaning** or **aquaplaning**. A deep tread pattern will break through a water film and grip the road at low speeds. At high speed, however, the tire can hydroplane (**Figure 61.2**).

Tires with large grooves are designed for use in mud and snow. But the large tread pattern can result in noise on the highway. Treads are often spaced at random intervals to minimize noise.

**Sipes** are small grooves in the tire tread that look like knife cuts (**Figure 61.3**). They allow the tread to grip evenly as the tire flexes. Sipes also clear water off the road, wiping the contact area to provide a better grip. **Ribs** in the tread are designed to pump water from the road through the grooves to the back of the tire, where it is thrown out onto the road.

### Tread Pattern Designs

Tires have tread patterns for differing driving conditions. Some tire treads are unidirectional (**Figure 61.4**). The tread design diverts water to the outside of the tire and resists hydroplaning at higher speeds. It has less rolling resistance, which allows a vehicle to accelerate and stop faster. When unidirectional tires are rotated, they must remain on the same side of the vehicle.

Symmetric tires have treads of the same design on both sides (**Figure 61.5**). They can be installed on either side of the vehicle.

Asymmetric tread patterns improve wet performance but performance is unchanged in dry conditions. They combine water ejection and snow traction abilities with dry traction characteristics by varying the tread

![Figure 61.2 Hydroplaning.](image-url)
NOTE: Asymmetric tires must be mounted in one direction only, which makes them more expensive, and their position on the vehicle cannot be rotated except from front to rear (provided they are the same size).

TIRE TREAD MATERIAL

The tread material calls for compromise. Hard materials might wear longer but not provide sufficient traction. Materials for mud and snow tires must remain soft in cold weather. Soft materials must provide sufficient wear. Natural rubber is compounded in different proportions with synthetic rubber to achieve the desired characteristics. Synthetic rubbers are more resistant to heat and solvents, whereas natural rubbers are better in other areas.

SCIENCE NOTE

Pure rubber is a hydrocarbon derived from the latex of a tree grown in all of the subtropical areas of the world. It freezes at only 40°F and becomes sticky at 86°F. It swells when contacted by many liquids and is damaged by sunlight. For rubber to be useful, it must be vulcanized by heat to make it stable. Charles Goodyear patented the vulcanization process in 1842. Isoprene, the core substance of natural rubber, was synthesized in 1910 in Germany. Natural and/or synthetic rubbers have chemicals such as carbon black and antioxidants added to them to improve grip, abrasion resistance, flexibility, and oxidation resistance.

Hysteresis is a term used by chemical engineers to describe a rubber’s energy absorption characteristics. A high hysteresis compound results in quiet running, a comfortable ride, and better wet and dry grip. A low hysteresis compound has good lateral stability, low rolling resistance, and minimized tread wear.
**TIRE CORD**

Because rubber is elastic and not very strong, it must be reinforced with material such as fabric, fiber, or steel cords. Without these materials, a tire would blow up like a balloon. Until World War II, the most common cord material was cotton. Today cord material in the tire casing is made of rayon, nylon, or polyester. Cord material for belts can be steel, rayon, nylon, fiberglass, or aramid (Kevlar®), which was developed specifically for the tire industry.

**TIRE PLY DESIGN**

Most of today’s tires are radial-ply tires, although some trucks and recreational vehicles (RVs) still use bias-ply tires. Figure 61.7 shows the difference between radial and bias tire construction. A bias tire is made in a full-circle mold that has two halves, like a bagel cut in half. The parting line for a tire made in this type of mold will run down the center of the tire’s tread. A segmented mold is usually used for constructing radial tires. A radial tire that has been made in a segmented mold will have several radial parting lines running from bead to bead across its tire tread.

Bias-ply, diagonal, or cross-ply tires have casing plies that cross each other at angles of 35–45 degrees. They ride softer than radials, but their tread tends to squirm when rolling. This results in tire wear.

Belts beneath the tread give the tire stability. Bias tires with belts under the tread last longer than unbelted bias tires because the belts keep the tread from squirming (Figure 61.8).

**Radial-Ply Tires**

Radial tires have casing plies that run across the tire from bead seat to bead seat in the “radial” direction of the wheel. The outside circumference of the tire is held together by reinforcing belt rings of slightly angled cord material (Figure 61.9).

The tire is a part of the suspension system as it supports the load of the car, isolating the passengers from road shock as its sidewall deflects. Sidewall deflection allows more of the tread to be in contact with the road surface. The larger area of contact, called the tire's footprint, allows the load on the tire to be spread across a wider area of the tire. A larger footprint also causes the tire to grip better so it can transmit forces of the engine and brakes to the road surface.

A radial tire flexes on its sidewall and is more resistant to wear because its tread surface remains flat on the ground (Figure 61.10). Because of the bulging sidewall, a properly inflated radial can appear to be low on air.

Radial tires provide a better grip to the road surface. They also have longer tread life and have lower rolling resistance for improved fuel economy. Fuel economy standards have been mandated by the United States Congress for many years. Each manufacturer must meet a corporate average fuel economy (CAFE) standard or pay a “gas-guzzler” penalty to the government. Because radial tires help the vehicle to achieve better fuel economy, they have been included on all new cars as original equipment for many years.
TIRE SIDEWALL MARKINGS

The U.S. Department of Transportation (DOT) requires certain information to be listed on the tire (Figure 61.11). A typical passenger car tire includes the following on the tire sidewall:

- The tire size
- The maximum permissible cold air pressure
- The load rating—an indication of the load limit for each of the vehicle's tires under cold inflation
- The name of the material that the cords of the tire are made of
- The number of plies in the tread and sidewall areas
- If the tire is a radial tire
- Whether the tire is tube-type or tubeless
- The DOT manufacturing code
- M+S—indicating that the tire meets the RMA definition for a mud and snow tire
- The Uniform Tire Quality Grade Standard (UTQG)—DOT grading for traction, treadwear, and temperature

Tire Size

A tire information sticker called a placard (see Figure 13.31) has been required on cars sold in the United States since 1968. It is located on the door post, the edge of the door, the gas filler door, or inside the door on the glove box. The placard indicates the correct original equipment tire size, the cold inflation pressure, and the gross axle weight (for commercial vehicles). If there is no placard, check the owner’s manual for the information.

A tire's size is listed on the sidewall, using one of several ratings (Figure 61.12).

- P-Metric (P205-75 R15).
- European Metric (185/70 R14).
- 4WD Tires Numeric (6.70-15) (36 × 10.5 × 15).

VINTAGE TIRES

Customers with older vehicles that have bias tires often wish to upgrade to radial tires. Cars built prior to 1972 usually do not have suspension systems designed for radial tires. Installing radials on these cars can result in a somewhat harsher ride at slow speeds. Installing radials on wheels that were designed only for bias tires can result in a dangerous wheel failure because radials exert more pressure against the sides of the rim. Cars produced after 1975 have numbers on the rims that designate their use with radial tires. If the number includes an R, the rim is designed to be used with radials.

The difference in handling characteristics between radials and diagonal bias tires makes it best not to mix them on the same vehicle. Sometimes, a customer’s car will have two belted-bias tires that are in good condition. The customer might want to begin to make the switch to radials without buying all four new tires. The Rubber Manufacturers Association (RMA) recommends that the two new radial tires be installed on the rear.

See Chapter 62 for more information on radial tire service.
Alphanumeric (FR78-15).
Light trucks (LT 235/75R-15) (Figure 61.13).
European Metric (205/40 R17). Note that European tires do not list a “P” or “LT” at the front of the rating (Figure 61.14).

The alphanumeric rating was commonly used until the early 1970s, but metric cross-section measurement is universal today.

Figure 61.15 shows how the tire size designation is interpreted for the P-metric radial tire, the most common tire in use today. The first letter describes the type of tire:
- P means passenger car.
- LT means light trucks, or C means commercial.
- T—temporary spare.

The tire's cross-section width (215 mm) is listed next. With each size increase (from 215 to 225, for instance), the width of the tire increases by 10 millimeters.

There is usually a letter in the size designation. Some of the possible letters are:
- R (radial)
- B (belted bias construction)—sometimes left blank
- D (diagonal bias construction)

A tire’s height is called its profile. A low-profile tire is shorter than a normal tire. The number that comes after the cross-sectional width of the tire is the aspect ratio, which is a measurement of the height-to-width ratio (Figure 61.16). In Figure 61.15, aspect ratio is expressed as the number 65. A 60 would have a lower profile. When there is no designation for the aspect ratio, the tire is an 80 series (P215 R15).

The last part of the sequence (R15) tells that the tire is a radial tire to be mounted on a 15" diameter rim. This is sometimes followed by an optional load/speed index.

Temporary Spare Tire
Most new cars are equipped with a compact temporary spare tire. It is considerably smaller than a regular tire and is to be used only temporarily. Many have a limited speed of 31 mph (50 km/h) and a distance of 31 miles (50 kilometers). The speed and distance warning will be printed on the sidewall of the tire.

Speed Rating
Sometimes a speed rating (Figure 61.17) is listed as part of the size designation. This rating was originally developed in Europe, where higher freeway speeds are legal. Tires made for use in the United States have speed ratings based on tests that meet SAE J1561 standards.

Newer tires have the speed rating and load index listed separately after the size designation.
Chapter 61

The new designation is a two- or three-digit load index followed by the speed symbol. The load index, developed by the International Standards Organization (ISO), provides an industry standard for a tire's maximum load at the designated speed rating. A tire's load-carrying ability is related to the strength of its sidewall plies. A tire with a higher load capacity will also have a higher inflation pressure.

The speed rating also serves as an indicator of better handling characteristics that result from improvements to the tire. At high speeds, non–speed-rated tires distort in the sidewall and tread areas (Figure 61.19). Speed-rated tires require extra reinforcement in the sidewall, including sidewall bead stiffeners and nylon cap plies or belt edge strips (Figure 61.20). Bead stiffeners are made of extra-hard rubber that prevents the sidewall from bulging. Tires with these additions provide a quicker steering response time. You can feel the difference at as little as 35 mph.

Low-profile tires often have one or more sections of sidewall that extend beyond the flange of an expensive aluminum wheel to protect it from damage when it rubs against a curb (Figure 61.21a). Figure 61.21b shows damage that occurred when a wheel rubbed against a curb with a tire without a protective sidewall extension.

Nylon cap plies are extra plies on the sides of the normal tire plies. Additional centrifugal force results from higher speed, but nylon shrinks when heated, pulling back on the sidewall and flattening the tire footprint. This helps to keep the rear end from breaking loose. Tires used for extreme high speeds have a sidewall reinforced with a band of steel.

Figure 61.12 Different ways of measuring tire size.

Figure 61.13 A tire size label for a light truck tire.

Europeen tire size

Figure 61.14 A European tire size label. Notice that there is no P in the size designation.
Speed symbols for passenger cars range from the L rating (74.5 mph/120 km/h), to ZR (over 149 mph/240 km/h). The letters that denote changes in speed ratings change in 20-kilometer per hour (km/h) increments. H-rated tires were the first speed-rated tires, so that is why this letter is out of order.

These are some of the most common ratings:
- Q—99 mph (160 km/h)—winter tires
- R—106 mph (170 km/h)—heavy-duty light truck tires
- S—112 mph (180 km/h)—family cars and vans
- T—118 mph (190 km/h)—family cars and vans
- H—130 mph (210 km/h)—high-performance passenger cars
- V—149 mph (240 km/h)—high-performance sports cars

**NOTE:** Good winter tires tend to only have a Q-rating because they generate a great deal more heat than conventional tires.

Light truck tires run hotter and do not dissipate heat as well as passenger car tires. Some of the newer truck tires carry an R or S speed rating.
## Vintage Tires

Under the original speed rating system, V-rated tires (130 mph/210 km/h) were the highest achievable speed rating. This category was originally defined as “unlimited.” As tire manufacturing abilities improved and safety considerations increased, the V-rating became a “limited” rating. The Z-rating was added as the top speed rating, for speeds in excess of 149 mph, with the exact speed rating determined by the manufacturer and varying with size.

### Very High-Speed Ratings

Because some new vehicles are capable of very high speeds, new tire speed ratings have been developed. W-rated tires are rated at 168 mph (270 km/h), and a

---

### SPEED SYMBOLS/RATINGS

<table>
<thead>
<tr>
<th>SPEED SYMBOL</th>
<th>MAXIMUM SPEED</th>
<th>APPLIES TO PASSENGER CAR TIRES</th>
<th>APPLIES TO LIGHT TRUCK TIRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZR</td>
<td>Above 149 mph (240 km/h)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Y</td>
<td>186 mph (300 km/h)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>W</td>
<td>168 mph (270 km/h)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>V</td>
<td>(with service description)</td>
<td>149 mph/(240 km/h)</td>
<td>Yes</td>
</tr>
<tr>
<td>H</td>
<td>130 mph (210 km/h)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>U</td>
<td>124 mph (200 km/h)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>T</td>
<td>118 mph (190 km/h)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>S</td>
<td>112 mph (180 km/h)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R</td>
<td>106 mph (170 km/h)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Q</td>
<td>99 mph (160 km/h)</td>
<td>(Winter tires only)</td>
<td>Yes</td>
</tr>
<tr>
<td>P</td>
<td>93 mph (150 km/h)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>87 mph (140 km/h)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>M</td>
<td>81 mph (130 km/h)</td>
<td>Temporary spare tires</td>
<td>No</td>
</tr>
</tbody>
</table>

---

**Figure 61.17** Tire speed ratings.

**Figure 61.18** This tire has a Y speed rating and a 92 load rating. It is rated for 186 mph and can carry a load of 1,521 pounds. The ZR is required in the size designation on “Y”-rated tires.

**Figure 61.19** This tire does not have a speed rating. Under high speed it distorts in the tread and sidewall areas.
Y-rated tire is rated at 186 mph (300 km/h). These tires will still carry a Z in their tire number designation, with the W or the Y listed after the load rating, such as 245/30/ZR22 92Y. When the load and Y speed rating are enclosed in parentheses, the tire has been tested in excess of 186 mph (300 km/h), 275/35/ZR19 (99Y), for instance.

**LOAD RATING**

A tire’s load rating tells how much weight it can safely support at a specified air pressure. It is very important not to use a tire that has too low a load rating for the weight of the vehicle.

P-metric radial tires found on today’s passenger cars are all of a uniform standard-load rating or an extra-load rating. The amount of load one of these tires can support is determined by the area of the tire and the amount of air pressure within. Standard-load tires reach their maximum load-carrying capacity when inflated to 35 psi. Extra-load tires achieve maximum load at 41 psi. An extra-load tire is labeled with “XL,” as in P270R15XL.

Although a P-metric standard-load tire has a normal maximum inflation pressure of 35 psi, its tire sidewall might be branded with a maximum pressure of 44 psi. Although the tire can be safely inflated to this pressure, its maximum load-carrying capacity is not increased.

The correct tire pressure is the manufacturer’s specification listed on the placard or in the owner’s manual, not the maximum pressure listed on the tire sidewall. Tire pressure is part of the suspension design for the vehicle. If you inflate tires to the maximum pressure listed on the sidewall, this is most likely not what the manufacturer has specified. Inflating tires to a higher pressure than manufacturer’s specifications leaves a business owner open to liability in the event that an accident investigator discovers tire pressures higher than specified.

**NOTE:** Tire companies recommend that heavy RVs be weighed separately at each wheel. This is to determine the load rating and the air pressure that should be used to safely support the load at each corner of the vehicle.

Racing tires are also selected based on the tire load rating. As long as the tire load rating × 2 is more than the gross axle weight rating (GAWR), the tires will not be overloaded when racing.

A tire load chart is found in the Appendix K.1 at the back of the book.

**Gross Vehicle Weight**

The gross vehicle weight rating (GVW or GVWR) includes the weight of the vehicle, the weight of all...
of the passengers for which it has seats (estimated at 150 lb each), and the maximum amount of luggage load. The GVW can be found on a plate or sticker on the door post (Figure 61.22). It is sometimes listed on the vehicle registration document as well.

Curb weight is the weight of the vehicle without passengers or luggage but includes a full tank of fuel and all fluids.

Vehicles, especially pickup trucks, are often overloaded. It is important that tires, brakes, and axles be of sufficient size or capacity to support the load and that a vehicle not be loaded beyond its weight rating.

When towing, be certain that the weight of the trailer is within the maximum capacity of the vehicle. The best way to prevent overloading is to weigh each axle of the vehicle on platform scales. The RMA (http://www.rma.org/) provides free information on vehicle weighing procedures.

**DOT Tire Codes**

The DOT symbol (Figure 61.23) signifies that the tire meets DOT safety standards. Before the year 2000, there were ten characters (a combination of numbers and letters) in the DOT code. Today there are up to 12, but usually 11. All of the characters except for the fifth, sixth, and seventh are regulated by the DOT.

Figure 61.24 shows a typical DOT code and the meaning of its numbers and letters.

- The first two characters list the plant and manufacturer where the tire was made. There is a separate code for the same manufacturer in different countries so that the country of origin can be determined.
- The second set of characters in the code tells the tire size and type.
- The third set is a group consisting of three characters that are not regulated and can be used by manufacturers as they choose.
- The final four digits tell the week and year the tire was made. The first two digits are the week and the last two are the year. Prior to the year 2000, the date of manufacture was listed as three digits, but since then four digits have been used so it is possible to tell the decade when the tire was manufactured.

**ALL-SEASON TIRES**

When a tire has specially designed pockets and slots in at least one tread edge, it can be labeled on the tire sidewall with a mud and snow designation. This can be any combination of the letters M and S (M+S, MS, M&S, M/S) and means that the tire meets definitions set by the RMA (Figure 61.25). M&S tires do not guarantee winter driving performance or safety, however. A snow, or winter, tire is specially designed for winter performance.

**SNOW TIRES**

In 1999, the U.S. RMA and the Rubber Association of Canada decided on a performance-based standard for snow tires that would allow consumers to identify tires designed to enhance traction in harsh winter conditions. Snow tires are designed specifically for use in winter. Winter tires must meet traction tests on packed snow specified by the American Society for Testing and Materials (ASTM). Tires that meet this standard are labeled with a “snowflake on the mountain”
symbol on the tire sidewall next to the M&S symbol (see Figure 61.25).

With summer tires the rubber becomes harder in the winter. Winter tires, however, are made with a tire rubber compound that remains soft in the winter. If winter tires are used during the summer, they will be excessively soft and will experience rapid tire wear and generate a good deal of heat. As mentioned earlier in the chapter, they have the low Q-speed rating.

Snow tires have deeper tread grooves designed to provide a better grip when driving on snow-covered roads (Figure 61.26). Snow tire tread is $\frac{13}{32}$–$\frac{15}{32}$" deep, compared to new passenger car tread depth of $\frac{10}{32}$".

Snow tires have deeper tread grooves designed to provide a better grip when driving on snow-covered roads (Figure 61.26). Snow tire tread is $\frac{13}{32}$–$\frac{15}{32}$" deep, compared to new passenger car tread depth of $\frac{10}{32}$".

Most manufacturers recommend that snow tires be installed on all four wheels to prevent handling problems. Wide tires do not cut through snow as easily as narrow tires. Snow tires can be fitted in the original equipment (OE) size, but when the vehicle has wide tires, a tire dealer will often recommend narrower tires of the same load capacity. Changing tire sizes is covered later in this chapter.

Some states allow tires with the snow/mountain symbol to be used in place of studded tires or snow chains. Winter tires can provide better handling in snow than is afforded by four-wheel drive without winter tires.

**Snow Chains**

Snow chains are used in some mountain areas during severe winter weather when roads have become covered with ice and snow. Tire chains can be of either the cable or chain type. Cable chains (Figure 61.27) are not as effective as conventional chains, but they work well in low-clearance applications and are not as apt to cause damage due to incorrect installation. Figure 61.28 shows the different conventional types of tire chain. Heavy-duty conventional chains have reinforced lugs for a better bite into ice and snow.

Most manufacturers recommend against the use of traditional chains. In fact, some new vehicle sales procedures include having the buyer sign a paper saying that only cable chains can be used. When a vehicle has sufficient clearance between the tires, fenders, and suspension components, traditional tire chains provide a viable means of achieving traction on snow-covered roads.
Run-Flat Tires

Some new cars do not carry a spare but use one of several methods that allow them to be run with little or no air pressure. Because an underinflated tire will develop heat that will damage the tire, a run-flat tire must be used with a low-pressure detection system.

A typical run-flat tire has a stiffer sidewall and a tighter tire bead (Figure 61.29). The stiff reinforced sidewalls are four to six times as thick as a normal tire's sidewalls (Figure 61.30). When a conventional tire is driven without air, its beads tend to slip out of the safety bead areas and into the drop center of the rim. The vehicle can lose control and cause a serious accident. Run-flat tires have a special bead design to prevent this from happening. A run-flat tire can partly support the vehicle even when the tire is completely empty of air and can be driven up to 70 miles without air before suffering damage. When driving over expansion joints on the freeway, a driver should expect the reinforced sidewalls to contribute to a rougher ride.

Many modern vehicles have high-torque engines and high-performance brakes. Both can cause the tire to slip on the rim. When this happens, the wheel weights move to a different place in relation to the tire, resulting in imbalance and vibration. High-performance and run-flat tires with tighter fitting beads prevent the tire from slipping on the rim. Some luxury performance cars and sport utility vehicles (SUVs) have "bead lock" rims designed to hold the tire tightly to the rim.

Other run-flat designs use bead retention systems with special tires and rims. One method uses an insert in the drop center of the wheel (Figure 61.31). The insert maintains the original shape of the tire by preventing the beads from moving into that area during an air loss.

Figure 61.28 Conventional and heavy-duty chains.

Figure 61.29 A typical run-flat tire has a stiffer sidewall and a tighter tire bead.

Figure 61.30 The stiff reinforced sidewalls of a run-flat tire are four to six times as thick as a normal tire's sidewalls.

Figure 61.31 A cutaway of a run-flat tire with an insert to support the tire in case of air loss.
**TIRE PRESSURE MONITORING SYSTEM**

The Tread Act, legislated by the United States Congress in 2000, requires new vehicle manufacturers to install a tire low-pressure warning system on all cars. The tire pressure monitoring system (TPMS) was phased in until all vehicles had it by the year 2008. Low tire pressure can be monitored using a direct or an indirect method.

**Indirect TPMS**

An indirect tire pressure monitor system uses the anti-lock brake system to compare the speed of all of the vehicle’s wheels, allowing a 10 psi difference in pressure. But if all four tires are low, it does not detect a problem. Consumers might have a false sense of security if they believe their tires are correctly inflated because no instrument panel light is illuminated.

**Direct TPMS**

Direct tire pressure monitoring, which uses individual wheel sensors and a computer, is more costly but also more effective. Tire pressure sensors transmit a radio frequency (RF) to a receiver (Figure 61.32). In some pressure monitor systems, when the pressure in a tire drops below a predetermined point, 25 psi for instance, a yellow warning light on the instrument panel illuminates (Figure 61.33). Other systems monitor tire pressure continuously.

Early sensors (prior to 1997) were strapped in the drop center of the rim, opposite the valve stem (Figure 61.34). These are called banded sensors and are still found on some vehicles. Other sensors, called integral sensors, are part of the valve stem (Figure 61.35). Each wheel’s sensor sends a different signal to the monitor so it can determine which wheel has a pressure problem. Some systems have a tire pressure monitor mounted in the spare tire as well.

A typical sensor is powered by a lithium battery with a 10-year service life. To save the battery, it operates only at speeds over 20 mph (32 km/h) and sends a signal once an hour when parked.

The tire pressure monitor measures the pressure and temperature in the tire and transmits this information to the tire pressure monitor computer. The monitor also transmits its unique identification data. The TPMS ID is recognized by the computer, which compares it with the specified tire pressure. Pressure
below 24 psi (168 kPa) or above 39 psi (272 kPa) illuminates a warning light on the instrument panel.

There are service procedures that must be followed following tire service on a vehicle with tire pressure monitors. For instance, when tires are rotated, the computer needs to relearn the location of each tire. More information on TPMS service can be found in Chapter 62.

### UNIFORM TIRE QUALITY GRADING

North American manufacturers use the Uniform Tire Quality Grade (UTQG) system, which rates treadwear, traction, and temperature dissipation ability. It is printed on the sidewall of the tire. The rating of the tire shown in Figure 61.36 is 420AA.

#### Tread Wear

Tire manufacturers follow government specified procedures to test their tires. The amount of tread wear will vary depending on many things, including wheel alignment, road surface texture, tire rotation maintenance, vehicle speed and braking practices, the weight of the vehicle, and the size of the tire. The government prescribes a test procedure and course: A convoy of less than four test vehicles drives the same 400-mile test course on public roads in Texas. The test sequence lasts 7,200 miles; tread depth is measured every 800 miles. Tire wear results are compared with those done on a control group of tires.

**NOTE:** Tread wear ratings are simply an overall indicator of performance, and ratings are not identical between manufacturers.

Tread wear ratings range from under 100 to over 150, increasing in increments of 20. The number 100 represents a standard tire. A 200 would be expected to last twice as long on the government test course, and a 150 would last about 1½ times as long. The actual life of a tire can vary due to road conditions, climate, air pressure, alignment, driving habits, vehicle loading, and other factors.

#### TRACTION GRADE

**Traction**

A tire’s ability to grip the road is called traction. Many things can affect traction, including the road surface and contaminants such as water, ice, or debris. It is also affected by the tire’s tread, the tread material, inflation pressure, width of the tread, cord ply design, and wheel alignment.

The first letter is the traction grade, which indicates stopping ability on wet asphalt pavement and concrete. The wet traction rating ranges from a high of AA to a low of C. Prior to 1997, A was the highest rating for wet braking traction. This rating is done on specified government test surfaces and covers braking only in a straight ahead direction, not cornering.

#### Temperature Grade

The second UTQG letter is the temperature grade. It indicates a properly inflated tire’s resistance to generating heat and its ability to dissipate heat at highway speeds. Temperature ratings are determined using specified government tests on a test wheel in a laboratory. Grade C is the minimum standard required by law. Standards B and A exceed this standard. Continuous high-speed driving can damage the tire. Combining high-speed driving with excessive temperatures can lead to sudden tire failure.

#### CHANGING TIRE SIZE

Selecting a replacement tire that is the exact same size as shown on the placard is not always possible. Customers...
sometimes want to change the size of their tires from the OE size. If tire size is changed, be sure to substitute a tire that has an equal or greater load-carrying capacity. Tire manufacturers make charts available that give the maximum load that various sizes of tires will provide at listed cold pressures. Be sure to use the pressure specification listed on the tire placard or in the owner’s manual. The maximum pressure specification listed on the tire sidewall is not likely to be the correct pressure.

**Tire Size Equivalents**

Changing the size of tires can usually be accomplished without sacrificing safety or design considerations provided the correct size equivalent is used. At first, this can be confusing. Tires with different bead-to-bead diameters (13", 14", 15", etc.) can all have the same outside diameter. For instance, the following five tire sizes all have the same diameter and load capacity:
- 175/70SR13
- 205/60R13 H
- 185/60R14 H
- 205/55VR14
- 195/50VR15

When changing tire sizes, the following five things need to be considered in the replacement tire:
- The intended use of the tire
- The width of the wheel rim
- The overall diameter of the replacement tire assembly
- The speed rating, which must be equal to or greater than that of the original tire
- The overall load-carrying capacity, which must be equal to or greater than the load index number listed on the original tire

Usually, as the diameter of the tire increases, the load capacity of the tire increases also.

**SAFETY NOTE**

Changing from a P185/65R14 (85 load index/1,124-pound maximum carrying capacity) to a P185/60R14 (82 load index/1,047-pound capacity) will result in almost 7% less load capacity.

Tire manufacturers publish information that includes tire dimensions, revolutions per mile, diameter, acceptable wheel rim sizes for each tire size, and the cross section of the tire. If you are unsure about a possible change in tire size, technical assistance is available through all of the major tire manufacturers.

**Plus Sizing**

Since the early 1970s, tires with lower profiles have become increasingly popular. When a tire with a lower profile is installed, a wider tire and a wheel with a larger diameter is used to make up the difference in overall tire assembly height. This method, called “plus sizing,” produces the same overall diameter as the OE tire (Figure 61.37). The new combination has less sidewall flexibility but has the same load capacity. It also has a larger footprint.

Lower profile tires grip better and they are more responsive. A high-profile tire provides better loose snow or mud traction because it does a better job of cutting through these materials. Narrow wheels and tires with the proper load capacity can be a better choice for drivers who find their snow traction to be inadequate.

---

Figure 61.37 Plus sizing maintains the same diameter tire assembly by using a larger wheel and lower tire profile.
When changing tire size, tire load capacity and diameter can be maintained by using the following formula: When changing to a 5% lower profile (reducing the aspect ratio by 5), choose a tire with a 10 mm wider cross section. For instance, change from 215/75 R15 to 225/70 R15.

Tire manufacturers recommend against changing from a lower-profile to a higher-profile tire, which results in reduced vehicle performance. When making a change in the size of tires on a vehicle, the recommendation is to replace tires in sets of four.

Wheel rim width must also be considered when changing tire size. A wider wheel provides more support to the tire sidewall. A narrower wheel allows the sidewall to flex more easily, providing a softer ride.

“Undersizing” is when a smaller-sized tire is installed, often because they are less expensive. Never install undersized tires on a vehicle. They will wear faster and have less load-carrying ability. The vehicle will be lower, the speedometer will no longer be accurate, and the increase in engine rpm for a given speed will result in a decrease in fuel economy.

WHEELS

Wheels are made of many different materials, including steel, aluminum, or an alloy of aluminum. OE wheels on less-expensive passenger cars are made of steel. Wheels have two parts: the center or flange and the rim (Figure 61.38). The center flange of a steel wheel is stamped because this is the least expensive production method. A strip of steel is rolled and butt welded at the ends to form the rim, which is then spot welded to the center flange.

A drop center or rim well provides a means of removing and installing a tire from the wheel. The tire bead is reinforced with wire and it will not stretch. When a tire is installed on the wheel, one side of the bead is pushed into the drop center so that the other side of the bead can be pulled over the edge of the rim (see Chapter 62).

The raised sections on either side of the drop center are called bead seats. This is where a tubeless tire seals. Raised sections on the inside edges of the bead seats are called safety beads (Figure 61.39). These help

Overall Tire Diameter

DOT standards require the overall diameter of a replacement tire to be within +2% to 3% of what the tire was as OE. Changing the tire diameter can affect antilock brakes, the vehicle speed sensor signals to the computer, the speedometer reading, gear ratios, and four-wheel drive.

Many newer vehicles are equipped with antilock brake systems (ABS) (see Chapter 59). A small pickup coil at each wheel measures wheel rotation speed and generates a signal that is sent to the ABS computer. Tires of a different height than original can cause excessive tire chirping or erratic system operation during a panic stop. When the size difference is large enough, the ABS warning light can come on. A small amount of tire height difference between tires on different sides of the vehicle is enough to cause the computer to turn on the ABS warning light and set a trouble code. In this case, the brakes will continue to operate normally, but ABS function will be disabled.

NOTE: When the diameter of a tire is changed, front-end geometry is altered and the speedometer will need to be recalibrated. On many computer-controlled vehicles, the technician is able to access the computer using a scan tool to change the tire values.

When higher diameter tires are installed to provide increased load, this is called “over-sizing.” Higher diameter tires raise the vehicle’s center of gravity. This reduces a vehicle’s ability to hold the road and maneuver quickly in an emergency.
Sometimes a certain amount of offset is designed into a wheel to allow it to clear the fender well. The offset of the wheel is also important to proper brake cooling because it affects the distance between the brake caliper and the wheel. Improper offset will also cause wheel bearing wear.

Wheel clearance is not included in application handbooks. This is something that must be carefully checked on the vehicle. The use of wider tires and wheels, or wheels that are offset a different amount than stock, can result in interference between the tire and fender well or suspension components.

Wheel offset is described in various ways. The most common offset classification is as follows (Figure 61.41):

- **Negative wheel offset** increases the track width of the tires.
- **Positive offset** (the opposite of negative offset) is found often on front-wheel-drive cars.

When a wheel is replaced, the new wheel should be of the same offset to maintain the proper scrub radius.

CUSTOM WHEELS

Customers sometimes purchase custom wheels when they want to make a cosmetic change in the appearance of the vehicle or when different-sized tires are installed. Aftermarket wheel quality is rated by an affiliate of the Specialty Equipment Manufacturers Association (SEMA), the SEMA Foundation (SFI). Wheels carrying their certification are manufactured to SFI standards.

Aluminum wheels can be cast, forged, or rolled. They can be either a single-piece casting, or they can have lighter rolled rim halves bolted to a cast center section.

Race cars use alloy wheels. An **alloy** occurs when two or more metals are combined to make one metal. In the fifties, sixties, and seventies, aluminum wheels were commonly called “mags,” due to the magnesium part of the alloy. The alloy used for mags is a combination of magnesium and silicon. These wheels are strong and light but are not practical for passenger cars, because they are expensive and do not resist corrosion.

Custom wheels for street use can be single-piece castings of light alloy aluminum with a weather resistant coating. The more costly custom wheels fit a single application only. Less expensive wheels are made of weaker materials. They are stud-centric and are made to fit a variety of applications.

**Rim width** is the measurement from bead seat to bead seat (Figure 61.40). It is usually about 80% of the cross-sectional width of the tire. The centerline is at one-half of the rim width.

**Wheel offset** is the difference between the rim centerline and the mounting surface of the wheel. Sometimes a certain amount of offset is designed into a wheel to allow it to clear the fender well. The offset of the wheel is also important to proper brake cooling because it affects the distance between the brake caliper and the wheel. Improper offset will also cause wheel bearing wear.

Wheel clearance is **not** included in application handbooks. This is something that must be carefully checked on the vehicle. The use of wider tires and wheels, or wheels that are offset a different amount than stock, can result in interference between the tire and fender well or suspension components.

Wheel offset is described in various ways. The most common offset classification is as follows (Figure 61.41):

- **Negative wheel offset** increases the track width of the tires.
- **Positive offset** (the opposite of negative offset) is found often on front-wheel-drive cars.

When a wheel is replaced, the new wheel should be of the same offset to maintain the proper scrub radius.
CHAPTER 61

Scrub radius (see Chapter 67) affects vehicle handling and steering effort. Changing the height or centerline of a wheel from that designed by the manufacturer can result in a change in scrub radius from positive to negative, or vice versa. The result can seriously affect vehicle handling. This is just one reason why replacing stock tires and wheels with ones of a different size or offset is something that many shops avoid.

**LUG STUDS**

Wheels have different numbers of lug studs, between three and eight, depending on the load on the vehicle. Most passenger cars use four or five lug studs, whereas light trucks usually use six or eight. Heavier trucks and some RVs sometimes use fewer lug bolts or studs, but they are larger in diameter and are tightened to a much higher torque.

**Lug Bolt Patterns**

Different lug bolt patterns are used. A bolt pattern that is listed in a catalog as being 6–5½ is a six-bolt pattern spaced around a 5½-inch circle. Bolt patterns with an even number of bolt holes are easy to measure. Measure the distance from the center of one bolt to the center of the one across from it. Five-bolt patterns are more difficult to measure. Templates are available for determining the size of a bolt pattern.

**LUG NUTS**

Lug nut threads can be either metric or inch-standard. Always check stud threads when installing a new nut. The nut should screw all of the way onto the thread easily by finger-tightening.

Lug studs have a serrated shank so that they will remain tight in the hole in the hub during tightening. Lug nuts for cast wheels are long and thick and must fit into a large, deep hole (see Figure 62.19). These lug nuts must be used with a washer to avoid damaging the wheel. Most lug nuts are made with the washer permanently installed on them.

**TIRE VALVE STEMS**

Since 2008, valve stems usually contain a tire pressure monitor. These are not routinely replaced and are usually made of high-quality EPDM artificial rubber. Passenger car tire valve stems are designed to be used at pressures of less than 4.2 bar (62 psi). A spring-loaded valve core is screwed into the valve stem (Figure 61.42). Valve stems have a screw-on dust cap, some of which have a gasket that prevents air loss past the valve core.

---

**CAUTION**

Scrub radius (see Chapter 67) affects vehicle handling and steering effort. Changing the height or centerline of a wheel from that designed by the manufacturer can result in a change in scrub radius from positive to negative, or vice versa. The result can seriously affect vehicle handling. This is just one reason why replacing stock tires and wheels with ones of a different size or offset is something that many shops avoid.
NOTE: According to the Pirelli Armstrong Tire Corporation, an imperceptible leak of one bubble per minute can result in the loss of 0.1 bar (1.5 psi) per month.

Light trucks and custom wheels are usually equipped with threaded metal stems that have a rubber bushing and are fastened to the wheel with a nut (Figure 61.43). The common wheel hole size for metal stems is 11.5 mm.

**REVIEW QUESTIONS**

1. What is it called when water forms a wedge under the tire, causing it to lose traction?
2. Which tire allows better fuel economy, radial or bias?
3. What is the name for the area of tread contact with the road?
4. What is another name for a tire’s height?
5. What is the miles-per-hour limit for a tire with a speed rating of H?
6. What are the two letters that are found on snow or all-season tires?
7. When changing a tire sized 195/75 R15 to a 5% lower profile, the correct tire size would be ________.
8. What is the name of the lower area between the bead seats of a wheel rim?
9. When a wheel is offset to increase the track width of the front tires, this is called ________ offset.
10. A small leak of one bubble per minute can result in the loss of ________ psi per month.

**ASE-STYLE REVIEW QUESTIONS**

1. Technician A says that a tire with a tread wear rating of 200 would be expected to last twice as long under the same conditions as one with a 100 rating. Technician B says that when the diameter of a tire is changed, front-end geometry is altered. Who is right?
   a. Technician A  
   b. Technician B  
   c. Both A and B  
   d. Neither A nor B
2. Which of the following is/are true about custom wheels?
   a. Custom wheels are usually hub-centric.
   b. An alloy wheel is made of two or more metals combined to make one.
   c. Both A and B
   d. Neither A nor B

3. Technician A says that the DOT code identifies the manufacturer and country where the tire was made. Technician B says that the DOT code provides the week and year the tire was made. Who is right?
   a. Technician A
   b. Technician B
   c. Both A and B
   d. Neither A nor B

4. All of the following are true about winter tires except:
   a. A winter tire must have a snowflake on the mountain symbol.
   b. Winter tires are softer and wear more rapidly if used during the summer.
   c. Winter tires have a low speed rating.
   d. M&S tires guarantee winter driving performance or safety.

5. Which of the following is/are true about direct tire pressure monitoring?
   a. It uses individual wheel sensors.
   b. Integral sensors are a part of the valve stem.
   c. Pressure that is too low or too high will illuminate a warning light.
   d. All of the above

6. Two technicians are discussing plus sizing. Technician A says that when a lower profile tire is installed, a wider tire and a larger diameter wheel are used. Technician B says that the same overall diameter of the tire and wheel assembly is achieved. Who is right?
   a. Technician A
   b. Technician B
   c. Both A and B
   d. Neither A nor B

7. Tires of a different size than OE have been installed on a vehicle. This can cause:
   a. The ABS light to come on
   b. The speedometer to be off
   c. Both A and B
   d. Neither A nor B

8. Technician A says that a 70 is a lower profile tire than a 75. Technician B says that an H rating is for higher speeds than a Z rating. Who is right?
   a. Technician A
   b. Technician B
   c. Both A and B
   d. Neither A nor B

9. Which of the following is/are true about unidirectional tires?
   a. They allow faster vehicle acceleration.
   b. They allow faster stopping.
   c. Both A and B
   d. Neither A nor B

10. Technician A says that the P in a P-metric radial's size means performance. Technician B says that European tires do not display a P at the front of their tire rating. Who is right?
    a. Technician A
    b. Technician B
    c. Both A and B
    d. Neither A nor B