Chapter 14

Automotive Chassis and Body

Topics

1.0.0 Frames

2.0.0 Suspension Systems

3.0.0 Steering System

4.0.0 Steering System Maintenance

5.0.0 Tires, Wheels, and Wheel Bearings

6.0.0 Wheel Alignment

7.0.0 Body Repair

To hear audio, click on the box.

Overview

The automotive chassis provides the strength necessary to support a vehicle's components and the payload placed upon it. The suspension system contains the springs, shock absorbers, and other components that allow the vehicle to pass over uneven terrain without an excessive amount of shock reaching the passengers or cargo. The steering mechanism is an integral portion of the chassis, as it provides the operator with a means of controlling the direction of travel. The tires grip the road surface to provide good traction that enables the vehicle to accelerate, brake, and make turns without skidding. Working in conjunction with the suspension, the tires absorb most of the shocks caused by road irregularities. The body of the vehicle encloses the mechanical components and passenger compartment. It is made of relatively light sheet metal or composite plastics. The components which make up the chassis are held together in proper relation to each other by the frame. In this chapter we will discuss the operational characteristics and components of the automotive chassis and body.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Understand the function, construction, and types of frames used on wheeled vehicles.
2. Identify automotive suspension components, their functions, and maintenance requirements.
3. Identify the major components of a steering system.
4. Understand the operating principles of steering systems.
5. Understand the differences between the linkage and rack and pinion type steering.
6. Understand the operation of power steering.

7. Understand service and repair procedures for manual and rack and pinion type steering mechanisms.
8. Identify the procedures for servicing power steering belts, hoses, and fluid.
9. Identify the characteristics and basic construction of a tire.
10. Understand tire and wheel sizes.
11. Understand tire ratings and the different types of wheels.
12. Identify the parts of driving and nondriving hubs and wheel-bearing assemblies.
13. Understand how to diagnose common tire, wheel, and wheel-bearing problems.
14. Understand tire inflation and rotation procedures.
15. Understand static and dynamic wheel balance.
16. Understand the different methods for balancing tires and wheels.
17. Understand wheel-bearing service.
18. Understand the procedures for maintaining tires, wheels, and wheel bearings.
19. Understand the purpose of each wheel alignment setting.
20. Identify the different types of equipment used during wheel alignment service.
21. Understand the procedures for repairing and refinishing automotive bodies.
22. Understand the Naval Construction Force (NCF) policy on corrosion control.

Prerequisites

None

This course map shows all of the chapters in Construction Mechanic Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Automotive Chassis and Body	↑	C
Brakes		M
Construction Equipment Power Trains		
Drive Lines, Differentials, Drive Axles, and Power Train Accessories		
Automotive Clutches, Transmissions, and Transaxles		
Hydraulic and Pneumatic Systems		
Automotive Electrical Circuits and Wiring		B A
Basic Automotive Electricity		S
Cooling and Lubrication Systems		I
Diesel Fuel Systems		C
Gasoline Fuel Systems		
Construction of an Internal Combustion Engine		
Principles of an Internal Combustion Engine		
Technical Administration		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with italicized instructions telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 FRAMES

The separate ***frame*** and body type of vehicle construction is the most common technique used when producing most full-sized and cargo vehicles. In this type of construction, the frame and the vehicle body are made separately, and each is a complete unit by itself. The frame is designed to support the weight of the body and absorb all of the loads imposed by the terrain, suspension system, engine, drive train, and steering system. The body merely contains and, in some cases, protects the cargo. The body generally is bolted to the frame at a few points to allow for flexure of the frame and to distribute the loads to the intended load-carrying members. The components of this type of frame are the side members, the cross members, and the gusset plates (*Figure 14-1*).

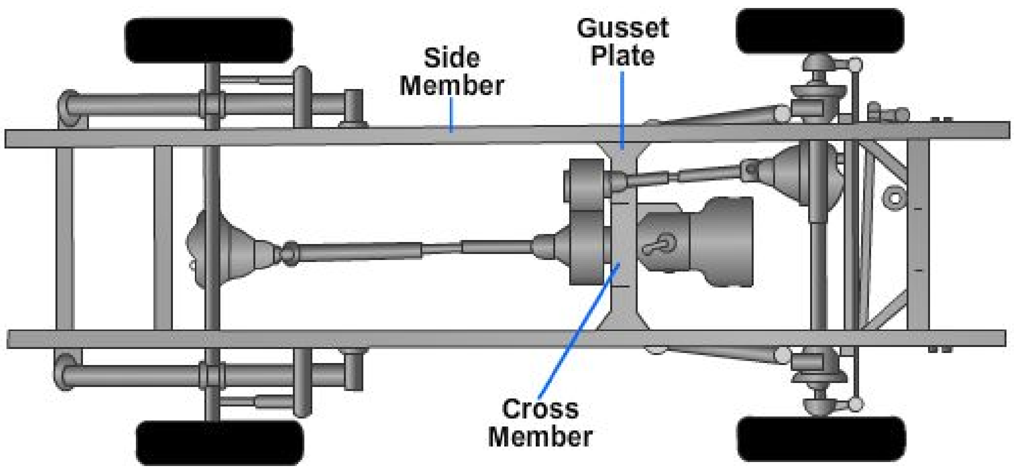

Figure 14-1 — Typical frame design.

The side members, or rails, are the heaviest part of the frame. The side members are shaped to accommodate the body and support the weight. They are narrow toward the front of the vehicle to permit a shorter turning radius for the wheels, and then widen under the main part of the body where the body is secured to the frame. Trucks and trailers commonly have frames with straight side members to accommodate several designs of bodies and to give the vehicle added strength to withstand heavier loads.

The cross members are fixed to the side members to prevent weaving and twisting of the frame. The number, size, and arrangement of the cross members depend on the type of vehicle for which the frame was designed. Usually, a front cross member supports the radiator and the front of the engine. The rear cross members furnish support for the fuel tanks and rear trunk on passenger cars and the tow bar connections for trucks. Additional cross members are added to the frame to support the rear of the engine or power train components.

The gusset plates are angular pieces of metal used for additional reinforcement on heavy-duty truck frames.

With this type of frame construction, the body structure only needs to be strong and rigid enough to contain the weight of the cargo and resist any dynamic loads associated with cargo handling and cargo movement during vehicle operation and to absorb shocks and vibrations transferred from the frame. In some cases, particularly under severe operating conditions, the body structure may be subjected to some torsional loads that are not absorbed completely by the frame. This basically applies to heavy truck and not passenger vehicles. In a typical passenger vehicle, the frame supplies approximately 37 percent of the torsional rigidity and approximately 34 percent of the bending rigidity; the balance is supplied by the body structure. The most important advantages of the separate body and frame construction are as follows:

- Ease of mounting and dismounting the body structure.
- Versatility--various body types can be adapted to a standard truck chassis.
- Strong, rugged designs—these are easily achieved, though vehicle weight is increased.
- Isolation of noise generated by drive train components from the passenger compartment through the use of rubber mounts between the frame and the body.
- Simplistic design that yields a relatively inexpensive and easy manufacturing process.

Frame members serve as supports to which springs, independent suspensions, radiators, or transmissions may be attached. Additional brackets, outriggers, and engine supports are added for the mounting of running boards, longitudinal springs, bumpers, engines, towing blocks, shock absorbers, gas tanks, and spare tires.

1.1.0 Integrated Frame and Body (Monocoque)

The integrated frame and body type of construction, also referred to as unitized construction, combines the frame and body into a single, one-piece structure (*Figure 14-2*). This is done by welding the components together, by forming or casting the entire structure as one piece, or by combining these techniques. Simply by welding a body to a conventional frame, however, does not constitute an integral frame and body construction. In a truly integrated structure, the entire frame-body unit is treated as a load-carrying member that reacts to all loads experienced by the vehicle-road loads as well as cargo loads.

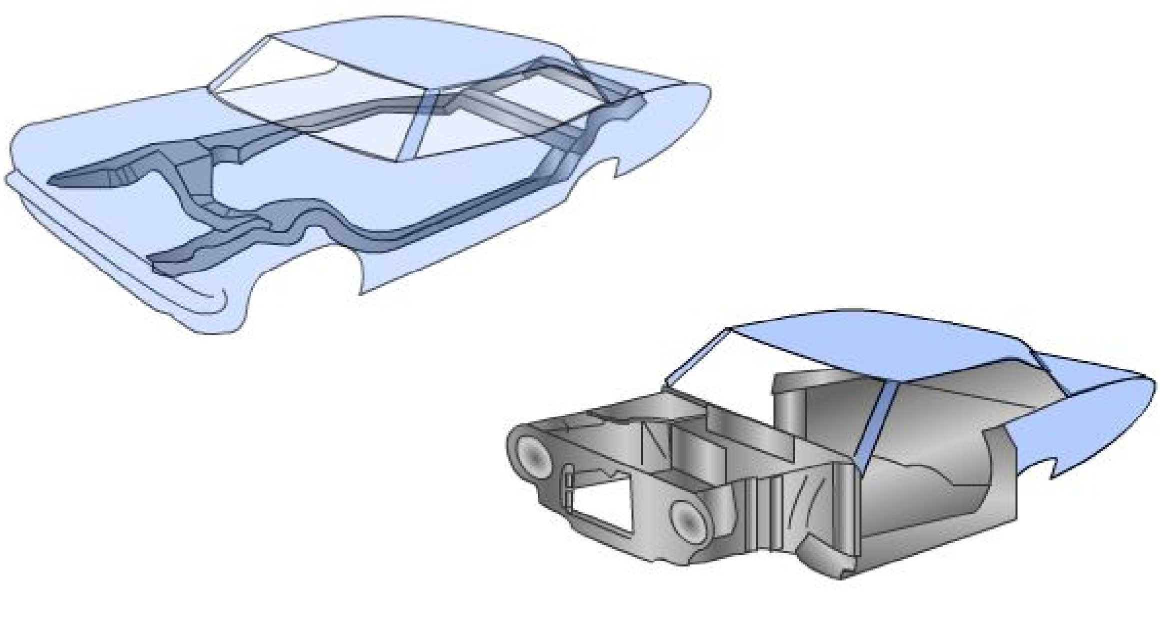

Figure 14-2 — Integrated frame and body.

Integrated-type bodies for wheeled vehicles are ***fabricated*** by welding preformed metal panels together. The panels are preformed in various load-bearing shapes that are located and oriented so as to result in a uniformly stressed structure. Some portions of the integrated structure resemble frame-like components, while others resemble body-like panels. This is not surprising, because the structure must perform the functions of both of these elements.

An integrated frame and body type construction allows an increase in the amount of noise transmitted into the passenger compartment of the vehicle. However, this disadvantage is negated by the following advantages:

- Substantial weight reduction, which is possible when using a well designed unitized body.
- Lower cargo floor and vehicle height.
- Protection from mud and water required for drive line components on amphibious vehicles.
- Reduction in the amount of vibration present in the vehicle structure.

1.2.0 Truck Frame (Ladder)

The truck frame allows for different types of truck beds or enclosures to be attached to the frame (*Figure 14-3*). For larger trucks, the frames are simple, rugged, and constructed from channel iron. The side rails are parallel to each other at standardized widths to permit the mounting of stock transmissions, transfer cases, rear axles, and other similar components. Trucks that are to be used as prime movers have an additional reinforcement of the side rails and rear cross members to compensate for the added towing stresses.

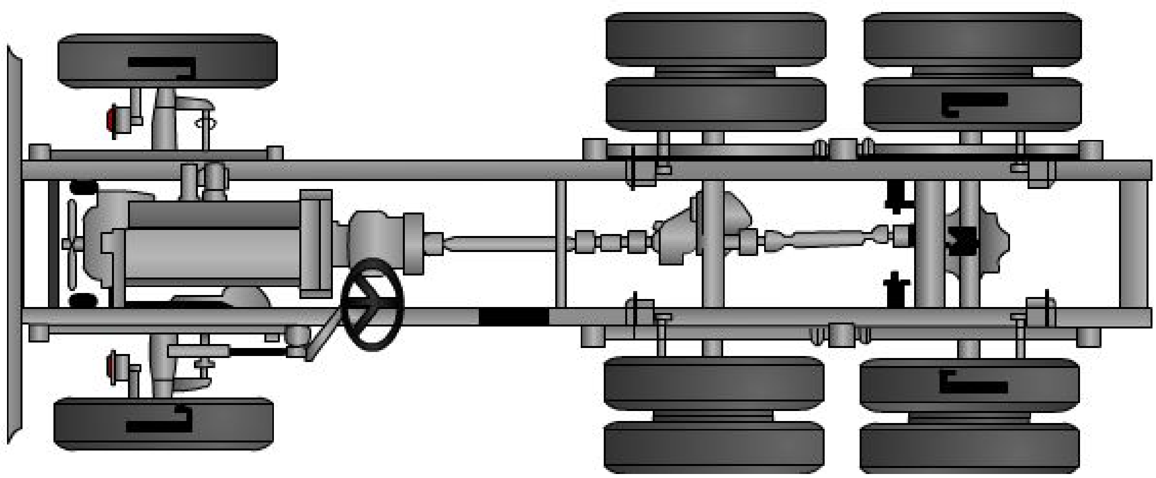

Figure 14-3 — Truck frame (ladder).

1.3.0 Frame Maintenance

Frames require little, if any, maintenance. However, if the frame is bent enough to cause misalignment of the vehicle or cause faulty steering, the vehicle should be removed from service. Drilling the frame and ***fish plating*** can temporarily repair small cracks in the frame side rails. Care should be exercised when performing this task, as the frame can be weakened. The frame of the vehicle should not be welded by gas or arc welding unless specified by the manufacturer. The heat removes temper from the metal, and, if cooled too quickly, causes the metal to crystallize. Minor bends can be removed by the use of hydraulic jacks, bars, and clamps.

Test your Knowledge (Select the Correct Response)

1. What is the function of the cross members in a frame assembly?

   A. Reduce vibration.
   B. Add extra strength at the joints.
   C. Prevent weaving and twisting of the frame.
   D. Support the payload of the vehicle.

2.0.0 SUSPENSION SYSTEM

The suspension system works with the tires, frame or unitized body, wheels, wheel bearings, brake system, and steering system. All the components of these systems work together to provide a safe and comfortable means of transportation. The suspension system functions are as follows:

- Support the weight of the frame, body, engine, transmission, drive train, passengers, and cargo.
- Provide a smooth, comfortable ride by allowing the wheels and tires to move up and down with minimum movement of the vehicle.
- Work with the steering system to help keep the wheels in correct alignment.
- Keep the tires in firm contact with the road, even after striking bumps or holes in the road.
- Allow rapid cornering without extreme body roll (vehicle leans to one side).
- Allow the front wheels to turn from side to side for steering.
- Prevent excessive body squat (body tilts down in rear) when accelerating or carrying heavy loads.
- Prevent excessive body dive (body tilts down in the front) when braking.

2.1.0 Independent Suspension

The independent suspension allows one wheel to move up and down with a minimum effect on the other wheels (*Figure 14-4*). Since each wheel is attached to its own suspension unit, movement of one wheel does NOT cause direct movement of the wheel on the opposite side of the vehicle. With the independent front suspension, the use of ball joints provides pivot points for each wheel. In operation, the swiveling action of the ball joints allows the wheel and spindle assemblies to be turned left and right and to move up and down with changes in road surfaces. This type of suspension is most widely used on modern vehicles.

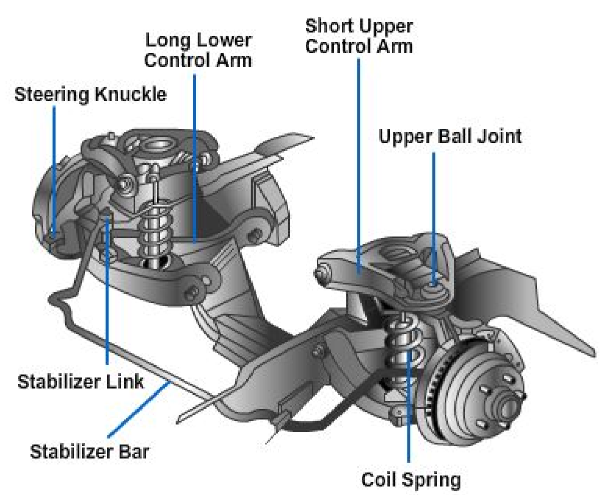

Figure 14-4 — Independent suspension.

2.2.0 Suspension System Components

The basic components of a suspension system are as follows:

- Control arm (a movable lever that fastens the steering knuckle to the vehicle frame or body).
- Control arm bushing (a sleeve which allows the control arm to move up and down on the frame).
- Strut rod (prevents the control arm from swinging to the front or rear of the vehicle).
- Ball joints (a swivel joint that allows the control arm and steering knuckle to move up and down, as well as side to side).
- Shock absorber or strut (keeps the suspension from continuing to bounce after spring compression and extension).
- Stabilizer bar (limits body roll of the vehicle during cornering).
- Spring (supports the weight of the vehicle; permits the control arm and wheel to move up and down).

2.2.1 Control Arms and Bushings

The control arm, as shown in *Figure 14-4*, holds the steering knuckle, bearing support, or axle housing in position as the wheel moves up and down. The outer end of the control arm has a ball joint, and the inner end has bushings. Vehicles having control arms on the rear suspension may have bushings on both ends. The control arm bushings act as bearings, which allow the control arm to move up and down on a shaft bolted to the frame or suspension unit. These bushings may be either pressed or screwed into the openings of the control arm.

2.2.2 Strut Rods

The strut rod fastens to the outer end of the lower control arm to the frame (*Figure 14-5*). This prevents the control arm from swinging toward the rear or front of the vehicle. The front of the strut rod has rubber bushings that soften the action of the strut rod.

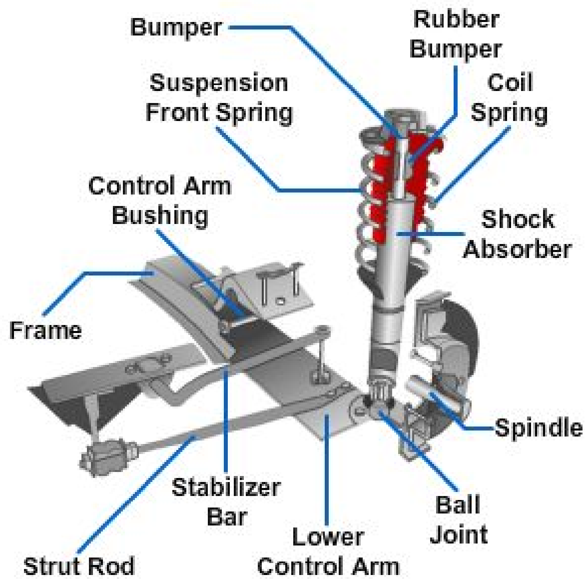

Figure 14-5 — Strut rods.

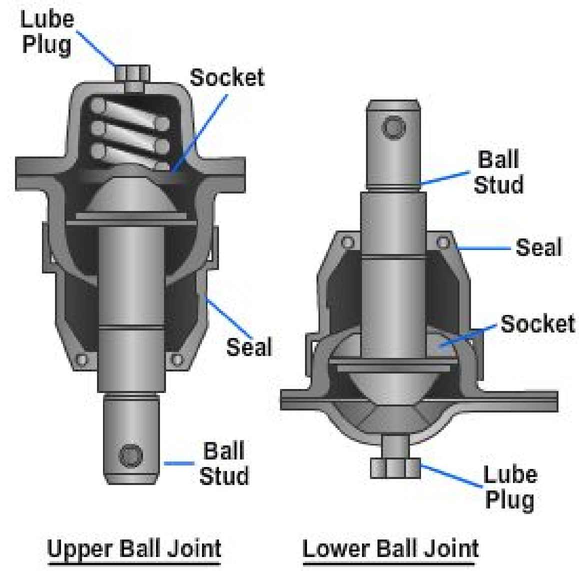

Figure 14-6 — Ball joints.

These bushings allow a controlled amount of lower control arm movement while allowing full suspension travel.

2.2.3 Ball Joints

The ball joints are connections that allow limited rotation in every direction and support the weight of the vehicle (*Figure 14-6*). They are used at the outer ends of the control arms where the arms attach to the steering knuckle. In operation, the swiveling action of the ball joints allows the wheel and steering knuckle to be turned left or right and to move up and down with changes in road surface. Since the ball joint must be filled with grease, a grease fitting and grease seal are normally placed on the joint. The end of the stud on the ball joint is threaded for a large nut. When the nut is tightened, it force fits the tapered stud in the steering knuckle or bearing support.

2.2.4 Shock Absorbers and Struts

Shock absorbers are necessary because springs do not "settle down" fast enough. After a spring has been compressed and released, it continues to shorten and lengthen for a period of time. Such spring action on a vehicle would produce a very bumpy and uncomfortable ride. It would also be dangerous because a bouncing wheel makes the vehicle difficult to control; therefore, a dampening device is needed to control the spring oscillations. This device is the shock absorber.

The most common type of shock absorber used on modern vehicles is the double-acting, direct-action type because it allows the use of more flexible springs (*Figure 14-7*). The direct-action shock absorber consists of an inner cylinder filled with special hydraulic oil divided into an upper and lower chamber by a double-acting piston. In operation, the shock absorbers lengthen and shorten as the wheels meet irregularities in the road. As they do this, the piston inside the shock absorber moves within the cylinder filled with oil; therefore, the fluid is put under high pressure and forced to flow through small openings. The fluid can only pass through the openings slowly. This action slows piston motion and restrains spring action.

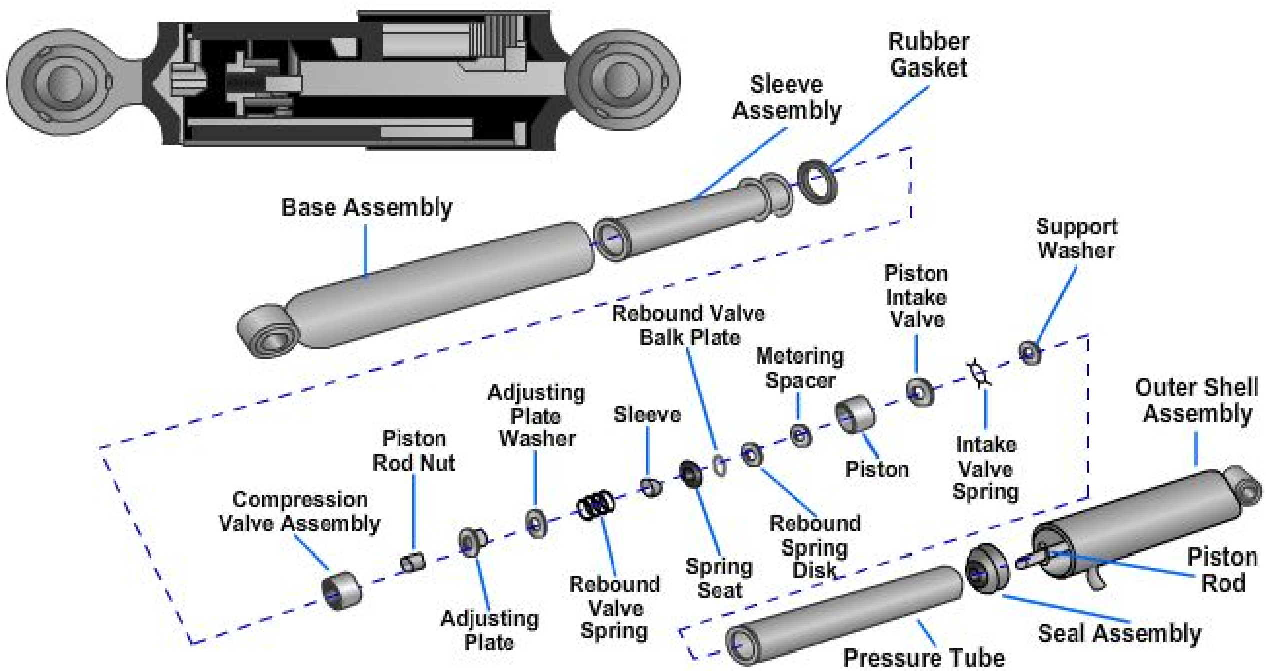

Figure 14-7 — Double-acting, direct-action shock absorber.

During compression and rebound, the piston is moving. The fluid in the shock absorber is being forced through small openings, which restrains spring movement. There are small valves in the shock absorber that open when internal pressure becomes excessive. When the valves are open, a slightly faster spring movement occurs; however, restraint is still imposed on the spring. An outer metal cover protects the shock absorber from damage by stones that may be kicked up by the wheels. One end of the shock absorber connects to a suspension component, usually a control arm. The other end fastens to the frame. In this way, the shock absorber piston rod is pulled in and out and resists these movements.

The strut assembly, also called a MacPherson strut, is similar to a conventional shock absorber. However, it is longer and has provisions (brackets and connections) for mounting and holding the steering knuckle (front of vehicle) or bearing support (rear of vehicle) and spring. The strut assembly consists of a shock absorber, coil spring (in most cases), and an upper damper unit. The strut assembly replaces the upper control arm. Only the lower control arm and strut are required to support the front-wheel assembly. The basic components of a typical strut assembly are as follows (*Figure 14-8*):

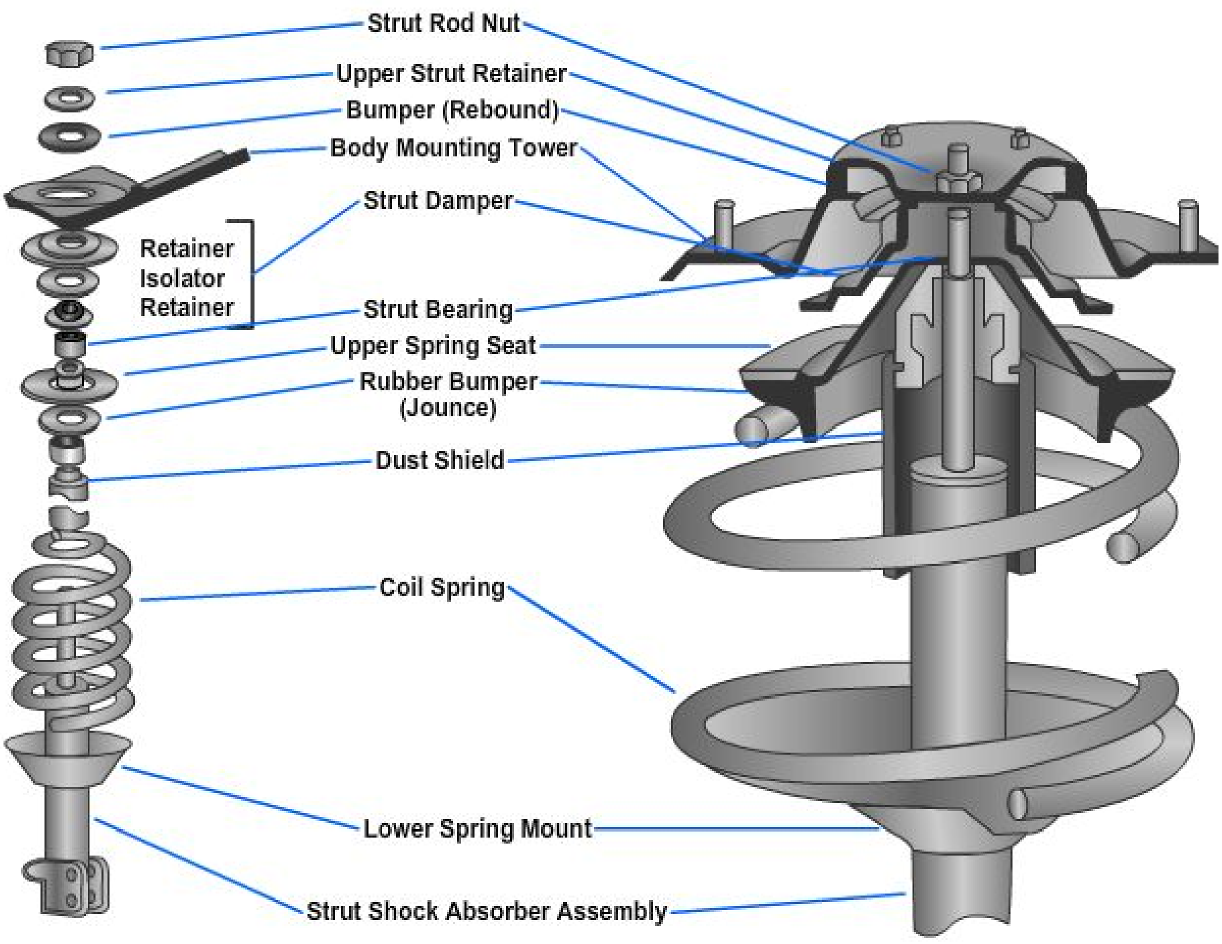

Figure 14-8 — Exploded view of a strut assembly.

- Strut shock absorber--a piston operated, oil-filled cylinder that prevents coil spring oscillations.
- Dust shield--a metal shroud or rubber boot that keeps road dirt off the shock absorber.

- Lower spring seat--a lower mount formed around the body of the shock absorber for the coil spring.
- Coil spring--supports the weight of the vehicle and allows for suspension action.
- Upper strut seat--holds the upper end of the coil spring and contacts the strut bearing.
- Strut bearing--a ball bearing that allows the shock absorber and coil spring assembly to rotate for steering action.
- Rubber bumpers--jounce and rebound bumpers which prevent metal-to-metal contact during extreme suspension compression and extension.
- Rubber isolators--parts of the strut damper which prevent noise from being transmitted into the body structure of the vehicle.
- Upper strut retainer--mounting that secures the upper end of the strut assembly to the frame or unitized body.

In a MacPherson strut type suspension, only one control arm and a strut are used to support each wheel assembly. A conventional lower control arm attaches to the frame and to the lower ball joint. The ball joint holds the control arm to the steering knuckle or bearing support. The top of the steering knuckle or bearing support is bolted to the strut. The top of the strut is bolted to the frame or reinforced body structure. This type of suspension is the most common type used on late model passenger vehicles. The advantages are a reduced number of parts in the suspension system, lower unsprung weight, and a smoother ride. On some vehicles you may find a modified strut suspension that has the coil springs mounted on the top of the control arm, not around the strut.

2.2.5 Stabilizer Bar

The stabilizer bar, as shown in *Figure 14-4*, also called the sway bar, is used to keep the body of the vehicle from leaning excessively in sharp turns. Made of spring steel, the stabilizer bar fastens to both lower control arms and to the frame. Rubber bushings fit between the stabilizer bar, the control arms, and the frame.

When the vehicle rounds a corner, centrifugal force tends to keep the vehicle moving in a straight line. Therefore, the vehicle “leans out” on the turn. This lean out is also called a body roll. With lean out, or body roll, additional weight is thrown on the outer spring. This puts additional compression on the outer spring, and the control arm pivots upward. As the control arm pivots upward, it carries its end of the stabilizer bar up with it. At the inner wheel on the turn, there is less weight on the spring. Weight has shifted to the outer spring because of centrifugal force. Therefore, the inner spring tends to expand. The expansion of the inner spring tends to pivot the lower control arm downward. As this happens, the lower control arm carries its end of the stabilizer bar downward.

The outer end of the stabilizer bar is carried upward by the outer control arm. The inner end is carried downward. This combined action twists the stabilizer bar, and its resistance to this twisting action limits body lean in corners.

2.2.6 Torque Arms

On vehicles with a high-performance suspension, you may encounter torque arms (*Figure 14-9*). These arms work with the axle to reduce axle wind up. Axle wind up occurs when the vehicle is accelerating; the torque is transferred through the axle housing and can actually spin the axle housing under the vehicle.

A torque arm provides additional resistance to help prevent axle wind up. It is attached to the axle housing and runs forward under the vehicle parallel to the drive shaft between the rear axle and transmission, cushioned through a bracket to allow some flex.

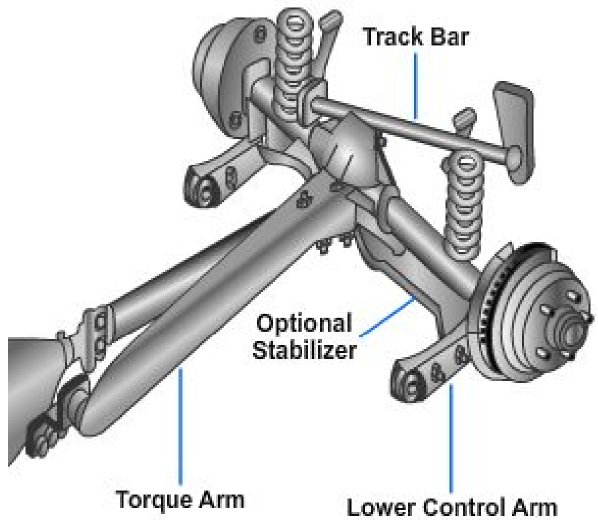

Figure 14-9 — Torque arm.

2.3.0 Suspension System Springs

The vehicle body or frame supports the weight of the engine, the power train, and the passengers. The body and frame are supported by the springs on each wheel. The weight of the frame, body, and attached components applies an initial compression to the springs. The springs compress further as the wheels of the vehicle hit bumps or expand, such as when the wheels drop into a hole in the road. The springs cannot do the complete job of absorbing road shocks. The tires absorb some of the irregularities in the road. The springs in the seats of the vehicle also help absorb shock. However, the passengers feel little shock from road bumps and holes.

The ideal spring for an automotive suspension should absorb road shock rapidly and then return to its normal position slowly; however, this action is difficult to attain. An extremely flexible, or soft, spring allows too much movement. A stiff, or hard, spring gives too rough a ride. To attain the action to produce satisfactory riding qualities, use a fairly soft spring with a shock absorber.

2.3.1 Spring Terminology

There are four basic types of automotive springs: coil, leaf, torsion bar, and air bag. Before discussing these types of springs, you must understand three basic terms: spring rate, sprung weight, and unsprung weight.

Spring rate refers to the stiffness or tension of a spring. The rate of a spring is the weight required to deflect it 1 inch. The rate of most automotive springs is almost constant through their operating range, or deflection, in the vehicle. Hooke’s law, as applied to coil springs, states that a spring will compress in direct proportion to the weight applied. Therefore, if 600 pounds will compress a spring 3 inches, then 1,200 pounds will compress the spring twice as far, or 6 inches.

Sprung weight refers to the weight of the parts that are supported by the springs and suspension system. Sprung weight should be kept high in proportion to unsprung weight.

Unsprung weight refers to the weight of the components that are NOT supported by the springs. The tires, wheels, wheel bearings, steering knuckles, and axle housing are considered unsprung weight. Unsprung weight should be kept low to improve ride smoothness. Movement of high unsprung weight (heavy wheel and suspension components) will tend to transfer movement into the passenger compartment.

2.3.2 Leaf Spring

The leaf spring acts as a flexible beam on self-propelled vehicles and transmits the driving and breaking forces to the frame from the axle assembly. Leaf springs are semi-elliptical in shape and are made of high quality alloy steel. There are two types of leaf springs: the single leaf and the multileaf. The single leaf spring, or monoleaf, is a single layer spring that is thick in the center and tapers down at each end. Single leaf springs are used in lighter suspension systems that do not carry great loads. A multileaf spring is made up of a single leaf with additional leaves. The additional leaves make the spring stiffer, allowing it to carry greater loads.

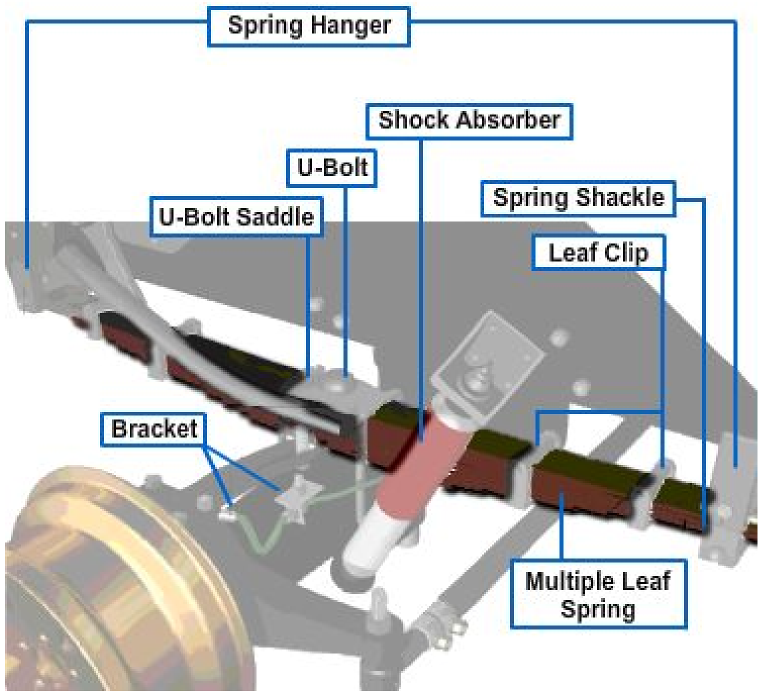

Figure 14-10 — Multileaf spring.

The most common type is the multileaf spring that consists of a single leaf with a number of additional leaves attached to it using spring clips (*Figure 14-10*). Spring clips, also known as rebound clips, surround the leaves at intervals along the spring to keep the leaves from separating on the rebound after the spring has been depressed. The clips allow the springs to slide, but prevent them from separating and causing the entire rebound stress to act on the master leaf. The multileaf spring uses an insulator (frictional material) between the leaves to reduce wear and eliminate any squeaks that might develop. To keep the leaves equally spaced lengthwise, use a center bolt for the multileaf spring. The center bolt rigidly holds the leaves together in the middle of the spring, preventing the leaves from moving off center. Each end of the largest leaf is rolled into an eye, which serves as a means of attaching the spring to the vehicle. Leaf springs are attached to the vehicle using a spring hanger that is rigidly mounted to the frame in the front, and the spring shackle in the rear, which allows the spring to expand and contract without binding as it moves through its arc. Bushings and pins provide the bearing or support points for the vehicle. Spring bushings may be made of bronze or rubber and are pressed into the spring eye. The pins that pass through the bushings may be plain or threaded. Threaded bushings and pins offer a greater bearing surface and are equipped with lubrication fittings. Leaf springs are used on the front and rear of heavy-duty trucks and the rear of passenger vehicles and light trucks. Trucks that carry a wide variety of loads use an auxiliary or overload spring. This auxiliary spring may be mounted on top of the rear springs and clamped together with long U-bolts, or it may be located under the axle separate from the main spring (*Figure 14-11*). In either case, the end of the spring has its own support brackets. When the truck is under a load, the auxiliary spring assumes part of the load when its ends contact the bearing plates or special brackets attached to the frame side rails.

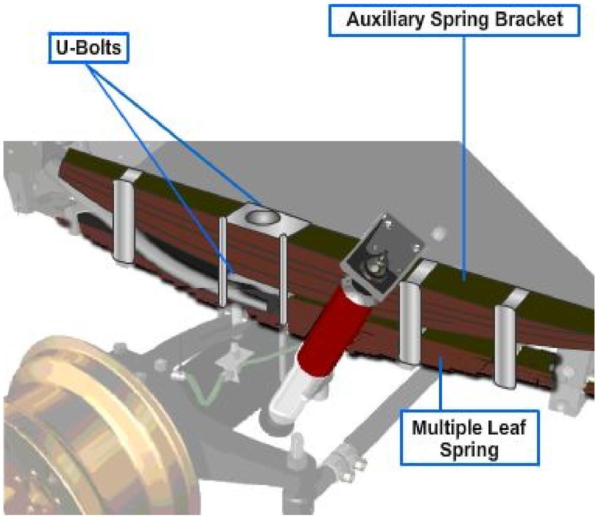

Figure 14-11 — Auxiliary spring suspension.

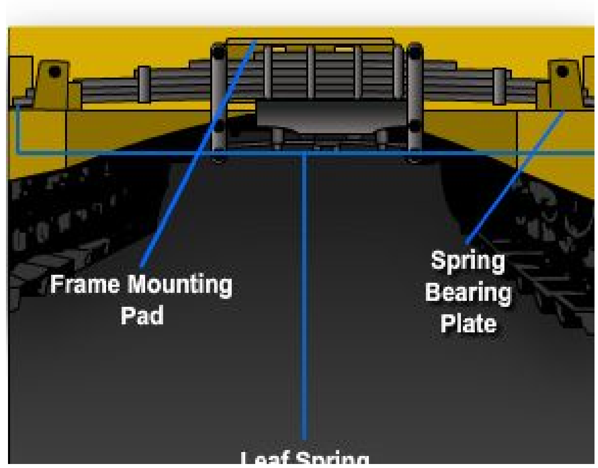

Figure 14-12 — Bogie suspension.

A large portion of six-wheel drive vehicles utilize a bogie suspension which uses leaf springs (*Figure 14-12*). This suspension is a unit consisting of two axles joined by torque rods. A trunnion axle acts as a pivot for the drive axles and is supported by bearings that are part of the spring seat. The ends of each spring rest in the guide brackets bolted to the axle housings. Mounting the springs on a central pivot enables them to distribute half of the rear load onto each axle. As a result, this type of suspension allows the vehicle to carry a much heavier load than a single axle without losing its ability to move over unimproved terrain.

When one wheel of a bogie suspension is moved up or down because of an irregularity in the road, the spring pivots on the trunnion shaft and both ends of the spring deflect to absorb the road shock. This causes the load to be placed on the center of the spring resulting in equal distribution of the load to both axles. The torque rods ensure proper spacing and alignment of the axles and transmit the driving and braking forces to the frame.

2.3.3 Torsion Bar

The torsion bar consists of a steel rod made of spring steel and treated with heat or pressure to make it elastic so it will retain its original shape after being twisted. Torsion bars, like coil springs, are frictionless and require the use of shock absorbers. The torsion bar is serrated on each end and attached to the torsion bar anchor at one end and the suspension system at the other end (*Figure 14-13*). Torsion bars are marked to indicate proper installation by an

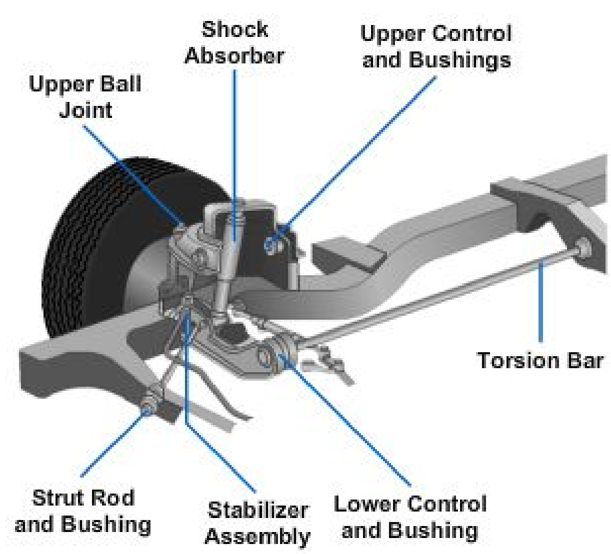

Figure 14-13 — Torsion bar.

arrow stamped into the metal. It is essential that they be installed properly because they are designed to take the stress in one direction only. The up-and-down movement of the suspension system twists the steel bar. The torque resistance will return the suspension to its normal position in the same manner as a spring arrangement.

2.3.4 Coil Spring

The coil spring is made of round spring steel wound into a coil (*Figure 14-14*). Because of their simplicity, they are less costly to manufacture and also have the widest application. This spring is more flexible than the leaf spring, allowing a smoother reaction when passing over irregularities in the road. Coil springs are frictionless and require the use of a shock absorber to dampen vibrations. Their cylindrical shape requires less space to operate in. Pads are sometimes used between the spring and the chassis to eliminate transferring vibrations to the body. Because of its design, the coil spring cannot be used for torque reaction or absorbing side thrust. Therefore, control arms and stabilizers are required to maintain the proper geometry between the body and suspension system. This is the most common type of spring found on modern suspension systems.

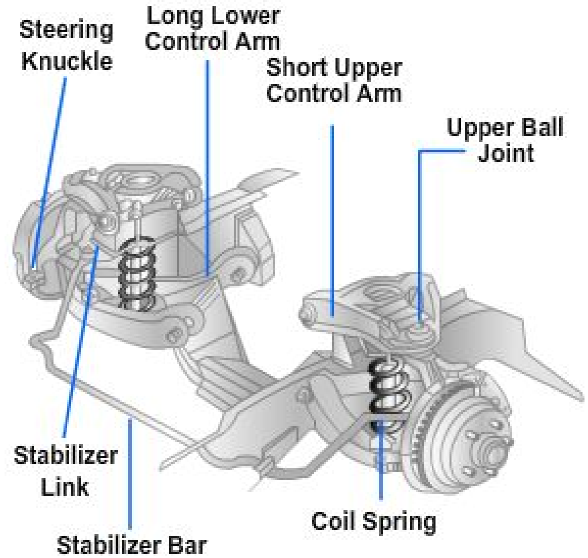

Figure 14-14 — Coil spring.

Coil spring mountings are quite simple in construction. The hanger and spring seat are shaped to fit the coil ends and hold the spring in place. Cups that fit snugly on each coil end are often used for mounting. The upper cup can be formed within the frame, in the control arms, or as part of a support bracket rigidly fixed to the cross member or frame rail. The lower cup is fastened to a control arm hinged to a cross member or frame rail. Rubber bumpers are included on the lower spring support to prevent metal-to-metal contact between the frame and control arm as the limits of compression are reached.

2.3.5 Air Bags

The air bag is a rubber air chamber that is replacing either of the aforementioned springs, usually in your higher end luxury vehicles (*Figure 14-15*). The unit is closed at the bottom by a piston fitted into a control arm or strut shock absorber. The top usually provides a means for inflating and monitoring the pressure within the bag. This bag replaces the metal spring that is usually installed to provide suspension in most vehicles.

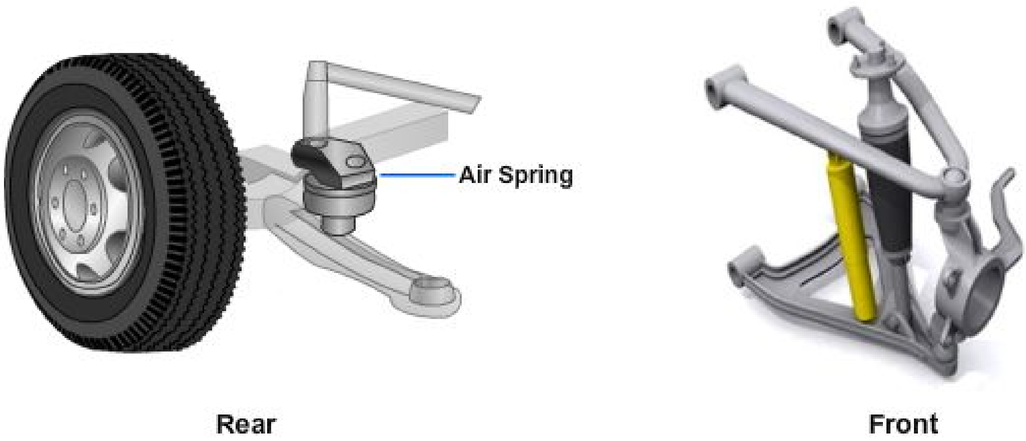

Figure 14-15 — Air bag suspension.

An onboard air compressor will charge the air bag to a set pressure. Usually air bags are installed to provide a level ride for the vehicle. Sensors are in place to check if the vehicle needs more or less air in each bag.

2.4.0 Suspension System Service

A suspension system undergoes tremendous abuse during normal vehicle operation. Bumps and potholes in the road surface cause constant movement, fatigue, and wear of the shock absorbers, or struts, ball joints, bushings, springs, and other components. Suspension system problems usually show up as abnormal noises (pops, squeaks, and clunks), tire wear, steering wheel pull, or front end shimmy (side-to-side vibration). Suspension system wear can upset the operation of the steering system and change wheel alignment angles. Proper service and maintenance of these components greatly increase reliability and vehicle life.

2.4.1 Suspension Bushing Service

Rubber bushings are commonly used in the inner ends of front control arms and rear control arms. These bushings are prone to wear and should be inspected periodically.

Worn control arm bushings can let the control arms move sideways. This action causes tire wear and steering problems. To check for control arm bushing wear, try to move the control arm against normal movement. For example, pry the control arm back and forth while watching the bushings. If the control arm moves in relation to its shaft, the bushings are worn and must be replaced.

Generally, to replace the bushings in a front suspension requires the removal of the control arm. This usually requires the separation of the ball joints and compression of the coil spring. The stabilizer bar and strut rod are also unbolted from the control arm. The bolts passing through the bushings are then removed, which allows for the control arm to be removed from the vehicle. With the control arm placed in a vise, either press or screw out the old bushings and install new ones.

With new bushings installed, replace the control arm in reverse order. Torque all bolts to the manufacturer’s specifications. Install the ball joint’s cotter pin. Check the manufacturer’s service manual for information concerning preloading control arm bushings.

NOTE

Always refer to the manufacturer’s service manual for exact directions and specifications. This will assure a safe, quality ride.

2.4.2 Ball Joint Service

Worn ball joints cause the steering knuckle and wheel assembly to be loose on the control arm. A worn ball joint may make a clunking or popping sound when turning or driving over a bump. Ball joint wear is usually the result of improper lubrication or prolonged use. The load-carrying ball joints support the weight of the vehicle while swiveling into various angles. If the joints are improperly lubricated (dry), the swiveling action will cause them to wear out quickly.

Grease fittings are provided for ball joint lubrication. If the ball joint has a lube plug, it must be removed and replaced with a grease fitting. Using a hand-powered grease gun, inject only enough grease to fill the boot of the ball joint. Do not overfill the boot, because too much grease will rupture it. A ruptured boot will allow dirt to enter the joint, which causes the joint to wear out quicker.

Ball joints can be checked for wear while the wheel is supported, as shown in *Figures 14-16* and *14-17*. Axial play or tolerance, also called vertical movement, is checked by moving the wheel straight up and down. The actual amount of play in a ball joint is measured with a dial indicator.

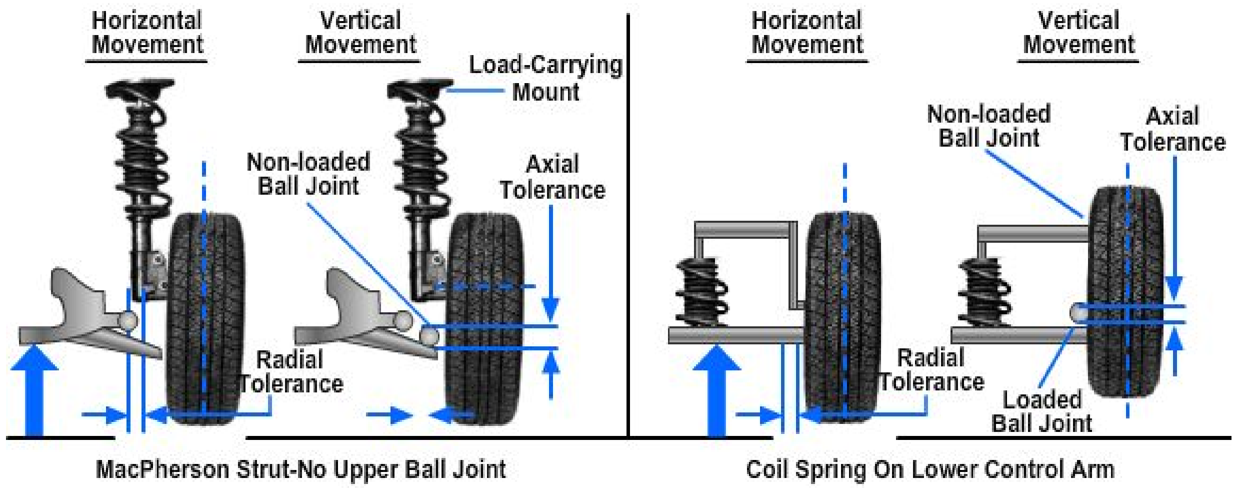

Figure 14-16 — Checking ball joints in front suspension with coil spring.

Figure 14-18 shows the dial indicator clamped to the lower control arm. The dial indicator tip rests against the leg of the steering knuckle. With a pry bar, try to raise and lower the steering knuckle. If you use too much force, the ball joint may give you a false reading. You want to measure the movement of the wheel and ball joint as the joint is moved up to the load position. Note the movement as indicated on the dial indicator.

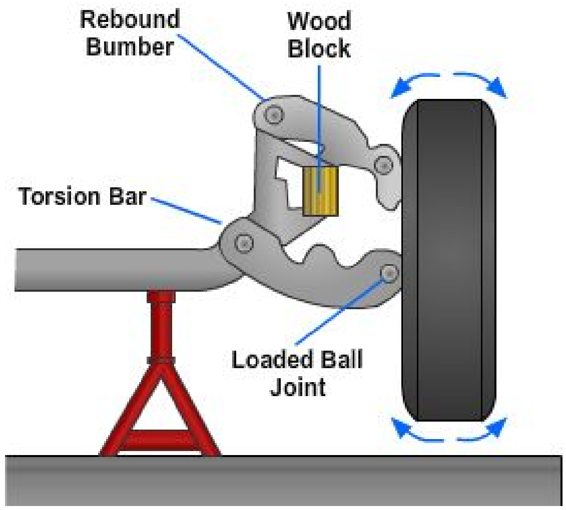

Figure 14-17 — Checking ball joints in front suspension with a torsion bar.

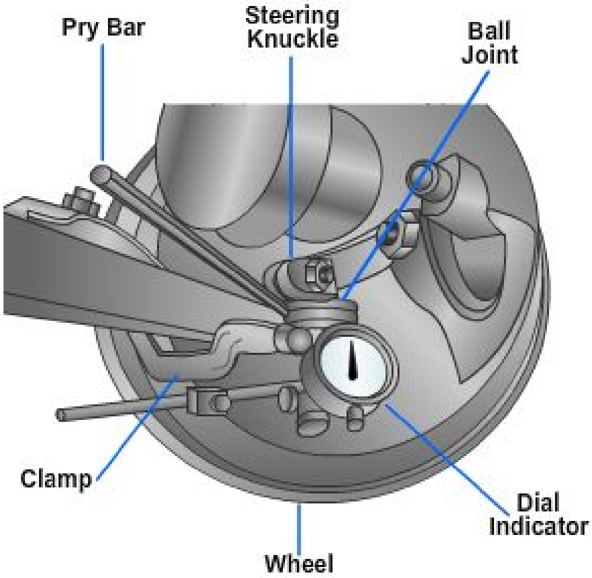

Figure 14-18 — A dial indicator mounted to measure the amount of end play in a ball joint.

Rocking the wheel in and out at the top and bottom checks radial play or tolerance. This action also is known as horizontal movement. Grasp the tire at the top and bottom, and try to wobble it. However, now we are assuming that the wheel bearings have been checked and either adjusted or properly tightened. Therefore, we are now checking the horizontal movement of the ball joints. Some manufacturers do not accept horizontal movement as an indicator of ball joint wear.

The actual specifications for allowable wear limits of the ball joints are listed in the manufacturer's service manual. Refer to the specifications for the vehicle you are checking. Any ball joint should be replaced if there is excessive play.

Ball joint replacement can usually be done without removing the control arm. Generally, place the vehicle on jack stands. Remove the shock absorber and install a spring compressor on the coil spring. Unbolt the steering knuckle and separate the steering knuckle and ball joint. The ball joint may be pressed, riveted, bolted, or screwed into the control arm. If the ball joint is riveted to the control arm, replace the rivets with bolts.

NOTE

For exact ball joint removal and installation procedures, consult the manufacturer's service manual.

2.4.3 Strut Service

The most common trouble with a strut type suspension is worn shock absorbers. Just like conventional shock absorbers, the pistons and cylinders inside the struts can begin to leak. This reduces the dampening action and the vehicle rides poorly. When a strut shock absorber leaks, it must be replaced, and ALWAYS as a pair.

Basically, strut removal involves unbolting the steering knuckle (front suspension) or bearing support (rear suspension), any brake lines, and the upper strut assembly-to-body fasteners. Remove the strut assembly (coil spring and shock) as a single unit.

CAUTION

Do **NOT** remove the nut on the end of the shock rod or the unit can fly apart.

A strut spring compressor is required to remove the coil spring from the strut. After the coil spring is compressed, remove the upper damper assembly. With the upper damper assembly removed, release the tension on the coil spring and lift the spring off the strut. Inspect all parts closely for damage.

WARNING

When compressing any suspension system spring, be extremely careful to position the spring compressor properly. If the spring were to pop out of the compressor, serious injuries or death could result.

With the coil spring and upper damper unit removed, you can now remove the shock cartridge. A new shock cartridge can be installed in the strut outer housing to restore the strut to perfect condition. Some manufacturers recommend that the strut shock absorber be rebuilt once the strut shock absorber is repaired or replaced. The strut can be reassembled and installed in reverse order of disassembly.

NOTE

For exact procedures for the removal, repairs, and installation of a strut assembly, refer to the manufacturer's service manual.

2.4.4 Spring Service

Springs require very little periodic service. Leaf spring service usually involves bushing replacement. Torsion bars require adjustment, and coil springs require no periodic service.

Spring service requirements can be found in the service manual of the vehicle you are working on.

Spring fatigue (weakening) can occur after prolonged service. The fatigue lowers the height of the vehicle, allowing the body to settle toward the axles. This settling or sagging changes the position of the control arms, resulting in misalignment of the wheels. This condition also affects the ride and appearance of the vehicle.

To check spring condition or torsion bar adjustment, measure curb height (distance from a point on the vehicle to the ground). Place the vehicle on a level surface. Then measure from a service manual specified point on the frame, body, or suspension down to the shop floor. Compare the measurement to the specifications in the service manual. If the curb height is too low (measurement too small), replace the fatigued springs or adjust the torsion bar.

NOTE

For instructions on the removal and installation of springs, refer to the manufacturer's service manual.

The vehicle should also be at curb weight when checking spring condition and curb height. Curb weight is generally the total weight of the vehicle with a full tank of fuel and no passengers or cargo. Also, make sure nothing is in the passenger compartment that could possibly increase curb weight. Curb weight is given in pounds or kilograms.

Test your Knowledge (Select the Correct Response)

2. In a vehicle equipped with MacPherson struts, what components are required to support the front-wheel assembly?

   A. Strut assembly and lower control arm
   B. Steering knuckle and upper damper unit
   C. Strut assembly and upper damper unit
   D. Steering knuckle and lower control arm

3.0.0 STEERING SYSTEM

The steering system allows the operator to guide the vehicle along the road and turn left or right as desired. The system includes the steering wheel, which the operator controls, the steering mechanism, which changes the rotary motion of the steering wheel into straight-line motion, and the steering linkage. At first most systems were manual then power steering became popular. It is now installed in most vehicles manufactured today. The steering system must perform several important functions:

- Provide precise control of front-wheel direction.
- Maintain the correct amount of effort needed to turn the front wheels.
- Transmit road feel (slight steering wheel pull caused by road surface) to the operator's hands.
- Absorb most of the shock going to the steering wheel as the tires hit bumps and holes in the road.
- Allow for suspension action.

3.1.0 Steering Linkage

Steering linkage is a series of arms, rods, and ball sockets that connect the steering mechanism to the steering knuckles. The steering linkage used with most manual and power steering mechanisms typically includes a pitman arm, center link, idler arm, and two tie-rod assemblies. This configuration of linkage is known as parallelogram steering linkage and is used on many passenger vehicles (*Figure 14-19*).

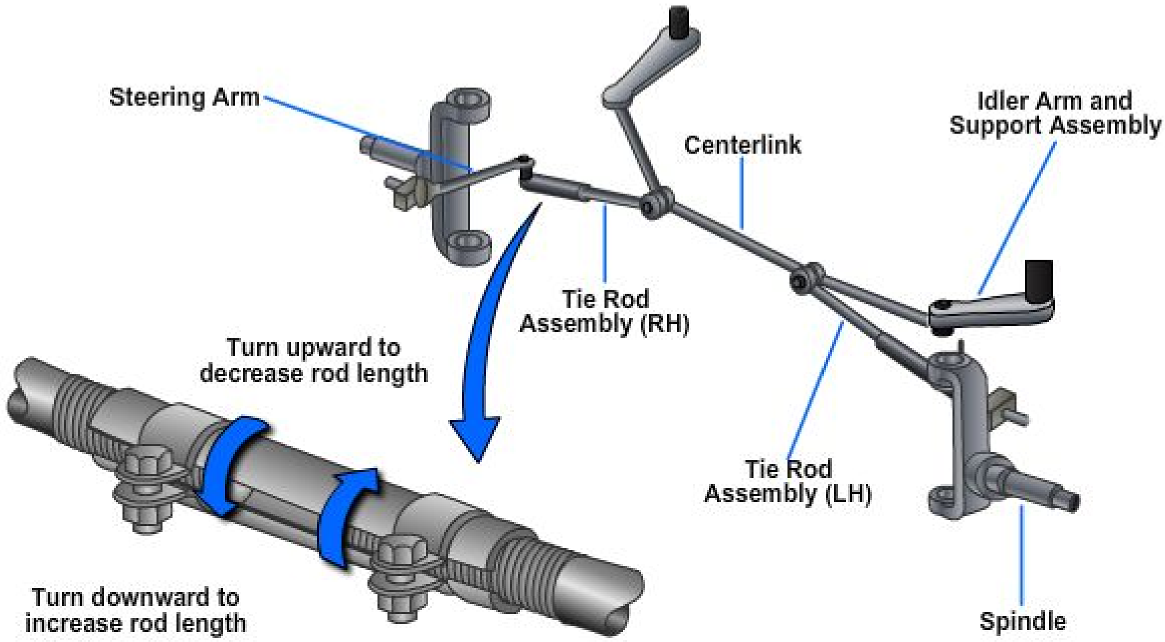

Figure 14-19 — Steering linkage.

3.1.1 Pitman Arm

The pitman arm transfers steering mechanism motion to the steering linkage (*Figure 14-19*). The pitman arm is splined to the steering mechanism's output shaft (pitman arm shaft). A large nut and lock washer secure the pitman arm to the output shaft. The outer end of the pitman arm normally uses a ball-and-socket joint to connect to the center link.

3.1.2 Center Link

The parallelogram steering linkage uses a center link, otherwise known as an intermediate rod, track rod, or relay rod, which is simply a steel bar that connects the steering arms (pitman arm, tie-rod ends, and idler arm) together (*Figure 14-19*). The turning action of the steering mechanism is transmitted to the center link through the pitman arm.

3.1.3 Idler Arm

The center link is hinged on the opposite end of the pitman arm by means of an idler arm (*Figure 14-19*). The idler arm supports the free end of the center link and allows it to move left and right with ease. The idler arm bolts to the frame or subframe.

3.1.4 Ball Sockets

Ball sockets are like small ball joints; they provide for motion in all directions between two connected components (*Figure 14-19*). Ball sockets are needed so the steering linkage is NOT damaged or bent when the wheels turn or move up and down over rough roads. Ball sockets are filled with grease to reduce friction and wear. Some have a grease fitting that allows chassis grease to be inserted with a grease gun. Others are sealed by the manufacturer and cannot be serviced.

3.1.5 Tie-Rod Assemblies

Two tie-rod assemblies are used to fasten the center link to the steering knuckles (*Figure 14-19*). Ball sockets are used on both ends of the tie-rod assembly. An adjustment sleeve connects the inner and outer tie rods. These sleeves are tubular in design and threaded over the inner and outer tie rods. The adjusting sleeves provide a location for toe adjustment. Clamps and clamp bolts are used to secure the sleeve. Some manufacturers require the clamps be placed in a certain position in relation to the tie rod top or front surface to prevent interference with other components.

3.1.6 Draglink

The steering system most commonly used on four-wheel drive vehicles has a draglink (*Figure 14-20*). The draglink connects the pitman arm to the spindle at a point near the spindle; the tie rod will connect the two steer wheels together. The objective is to keep the tie rod as close to parallel with the axle as possible.

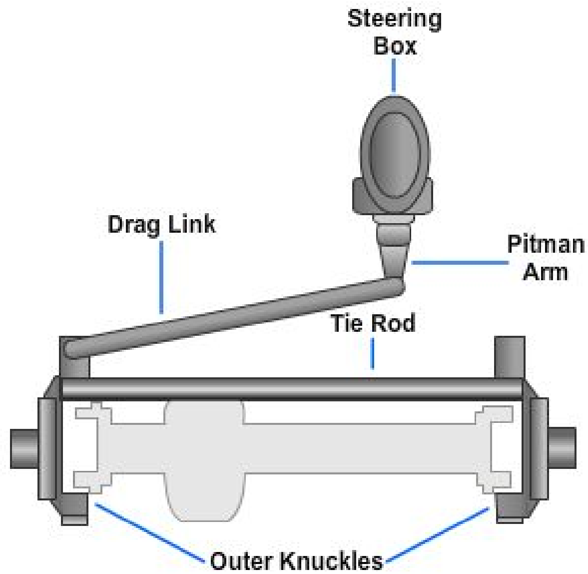

Figure 14-20 — Draglink assembly.

3.2.0 Steering Ratio

One purpose of the steering mechanism is to provide mechanical advantage. In a machine or mechanical device, it is the ratio of the output force to the input force applied to it. This means that a relatively small applied force can produce a much greater force at the other end of the device.

In the steering system, the operator applies a relatively small force to the steering wheel. This action results in a much larger steering force at the front wheels. For example, in one steering system, applying 10 pounds to the steering wheel can produce up to 270 pounds at the wheels. This increase in steering force is produced by the steering ratio.

The steering ratio is a number of degrees that the steering wheel must be turned to pivot the front wheels 1 degree. The higher the steering ratio (30:1, for example), the easier it is to steer the vehicle, all other things being equal. However, the higher the steering ratio, the more the steering wheel has to be turned to achieve steering. With a 30:1 steering ratio, the steering wheel must turn 30 degrees to pivot the front wheels 1 degree.

Actual steering ratio varies greatly, depending on the type of vehicle and type of operation. High steering ratios are often called slow steering because the steering wheel has to be turned many degrees to produce a small steering effect. Low steering ratios, called fast or quick steering, require much less steering wheel movement to produce the desired steering effect.

Steering ratio is determined by two factors: steering-linkage ratio and the gear ratio in the steering mechanism. The relative length of the pitman arm and the steering arm determines the steering linkage ratio. The steering arm is bolted to the steering spindle at one end and connected to the steering linkage at the other.

When the effective lengths of the pitman arm and the steering arm are equal, the linkage has a ratio of 1:1. If the pitman arm is shorter or longer than the steering arm, the ratio is less than or more than 1:1. For example, the pitman arm is about twice as long as the steering arm. This means that for every degree the pitman arm swings, the wheels will pivot about 2 degrees. Therefore, the steering linkage ratio is about 1:2.

Most of the steering ratio is developed in the steering mechanism. The ratio is due to the angle or pitch of the teeth on the worm gear to the angle or pitch on the sector gear. Steering ratio is also determined somewhat by the effective length and shape of the teeth on the sector gear.

In a rack-and-pinion steering system, the steering ratio is determined largely by the diameter of the pinion gear. The smaller the pinion, the higher the steering ratio. However, there is a limit to how small the pinion can be made.

3.3.0 Manual Steering Systems

Manual steering is considered to be entirely adequate for smaller vehicles. It is tight, fast, and accurate in maintaining steering control. However, larger and heavier engines, greater front overhang on larger vehicles, and a trend toward wide tread tires have increased the steering effort required. Steering mechanisms with higher gear ratios were tried, but dependable power steering systems were found to be the answer. There are several different types of manual steering systems; the worm and sector, worm and roller, cam and lever, worm and nut, and the rack and pinion.

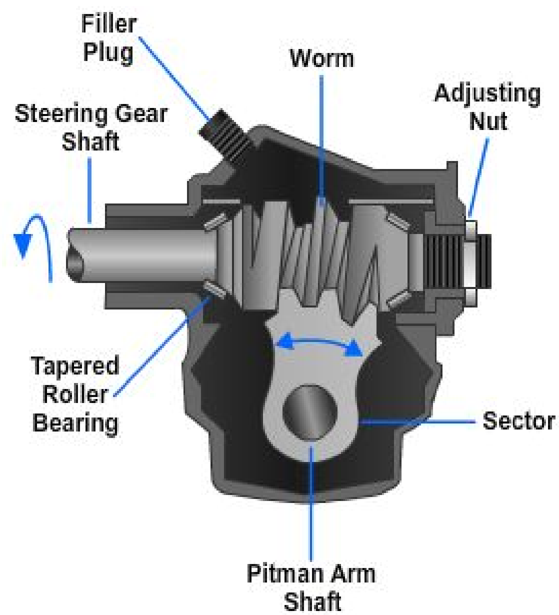

Figure 14-21 — Worm and sector steering gear.

3.3.1 Worm and Sector

In the worm and sector steering gear, the pitman arm shaft carries the sector gear that meshes with the worm gear on the steering gear shaft (*Figure 14-21*),. Only a sector of gear is used because it turns through an arc of approximately 70 degrees. The steering wheel turns the worm on the lower end of the steering gear shaft, which rotates the sector and the pitman arm through the use of the shaft. The worm is assembled between tapered roller bearings that take up the thrust and load. An adjusting nut or plug is provided for adjusting the end play of the worm gear.

3.3.2 Worm and Roller

The worm and roller steering gear is quite similar to the worm and sector, except a roller is supported by ball or roller bearings within the sector mounted on the pitman arm shaft (*Figure 14-22*). These bearings assist in reducing sliding friction between the worm and sector. As the steering wheel turns the worm, the roller turns with it, forcing the sector and pitman arm shaft to rotate.

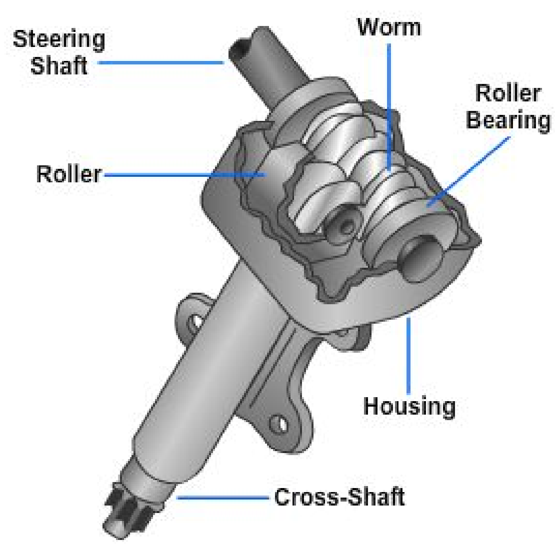

Figure 14-22 — Worm and roller steering gear.

The hourglass shape of the worm, which tapers from both ends to the center, affords better contact between the worm and roller in all positions. This design provides a variable steering ratio to permit faster and more efficient steering.

"Variable steering ratio" means that the ratio is larger at one position than another. Therefore the wheels are turned faster at certain positions than at others. At the center or straight-ahead position, the steering gear ratio is high, giving more steering control. However, as the wheels are turned, the ratio decreases so that the steering action is much more rapid. This design is very helpful for parking and maneuvering the vehicle.

3.3.3 Cam and Lever

The cam and lever steering gear, in which the worm is known as a cam and the sector as the lever, is shown in *Figure 14-23*. The lever carries two studs that are mounted in bearings and engage the cam. As the steering wheel is turned, the studs move up and down on the cam. This action causes the lever and pitman arm shaft to rotate. The lever moves more rapidly as it nears either end of the cam. This action is caused by the increased angle of the lever in relation to the cam. Like the worm and roller, this design allows for variable steering ratio.

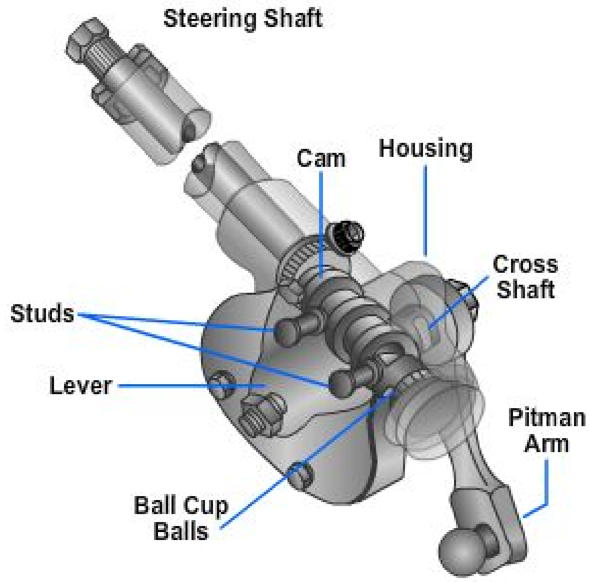

Figure 14-23 — Cam and lever steering gear.

3.3.4 Worm and Nut

The worm and nut steering gear is made in several different combinations. A nut is meshed with and screws up and down on the worm gear. The nut may operate the pitman arm directly through a lever or through a sector on the pitman arm shaft.

The recirculating ball is the most common type of worm and nut steering gear (*Figure 14-24*). In this steering gear, the nut, which is in the form of a sleeve block, is mounted on a continuous row of balls on the worm gear to reduce friction. Grooves are cut into the ball nut to match the shape of the worm gear. The ball nut is fitted with tubular ball guides to return the balls diagonally across the nut to recirculate them as the nut moves up and down on the worm gear. With this design, the nut is moved on the worm gear by rolling instead of sliding contact. Turning the worm gear moves the nut and forces the sector and pitman arm shaft to turn.

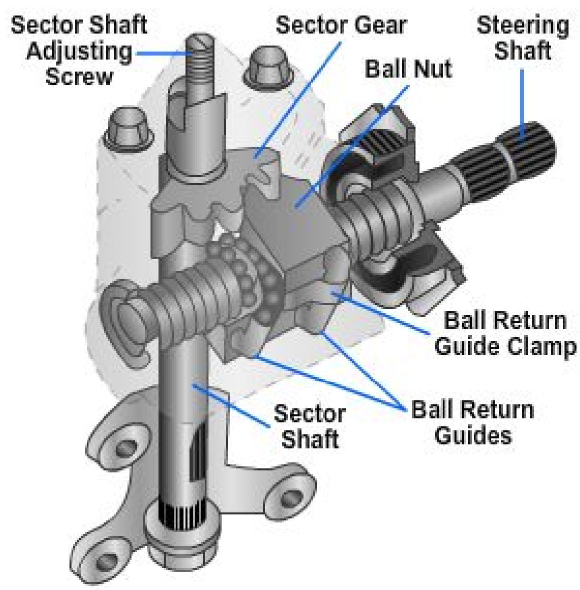

Figure 14-24 — Worm and nut steering gear.

3.3.5 Rack and Pinion

The rack-and-pinion steering gear has become increasingly popular on smaller passenger vehicles. It is simpler, more direct acting, and may be straight mechanical or power-assisted.

The manual rack-and-pinion steering gear basically consists of a steering gear shaft, pinion gear, rack, thrust spring, bearings, seals, and gear housing. In the rack-and-pinion steering system the end of the steering gear shaft contains a pinion gear which meshes with a long rack (*Figure 14-25*). The rack is connected to the steering arms by tie rods, which are adjustable for maintaining proper toe angle. The thrust spring preloads the rack-and-pinion gear teeth to prevent excessive gear backlash. Thrust spring tension may be adjusted by using shims or an adjusting screw.

As the steering wheel is rotated, the pinion gear on the end of the steering shaft rotates. The pinion gear moves the rack from one side to the other. This action pushes or pulls on the tie rods, forcing the steering knuckles or wheel spindles to pivot on their ball joints. This turns the wheels to one side or the other so the vehicle can be steered.

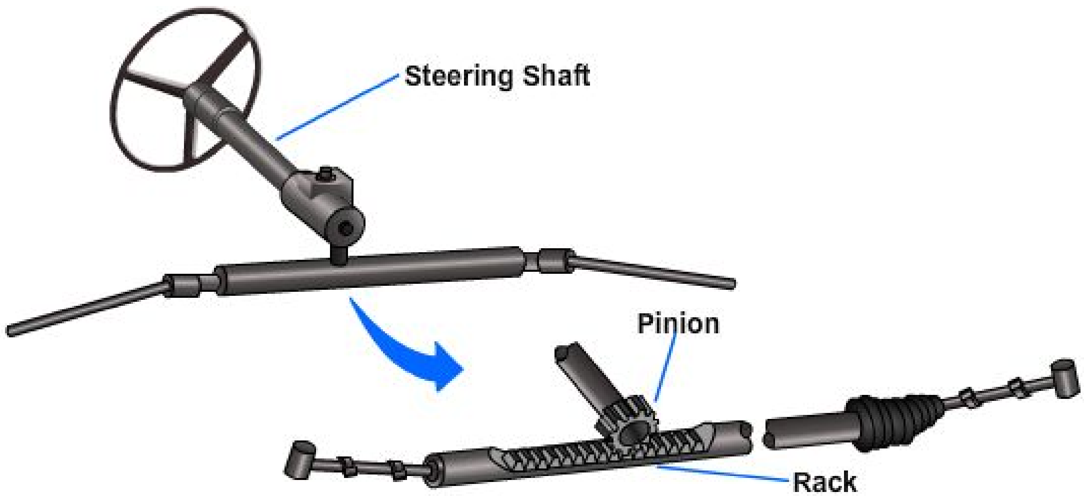

Figure 14-25 — Rack and pinion steering gear.

3.4.0 Power Steering Systems

Power steering systems normally use an engine-driven pump and hydraulic system to assist steering action. Pressure from the oil pump is used to operate a piston and cylinder assembly. When the control valve routes oil pressure into one end of the piston, the piston slides in its cylinders. Piston movement can then be used to help move the steering system components and front wheels of the vehicles. The components that are common to all power steering systems are the power steering pump, the control valve, and power steering hoses.

The power steering pump is engine-driven and supplies hydraulic fluid under pressure to the other components in the system (*Figure 14-26*). There are four basic types of power steering pumps: vane, roller, slipper, and gear types. A belt running from the engine crankshaft pulley normally powers the pump. During pump operation, the drive belt turns the pump shaft and pumping elements. Oil is pulled into one side of the pump by vacuum. The oil is then

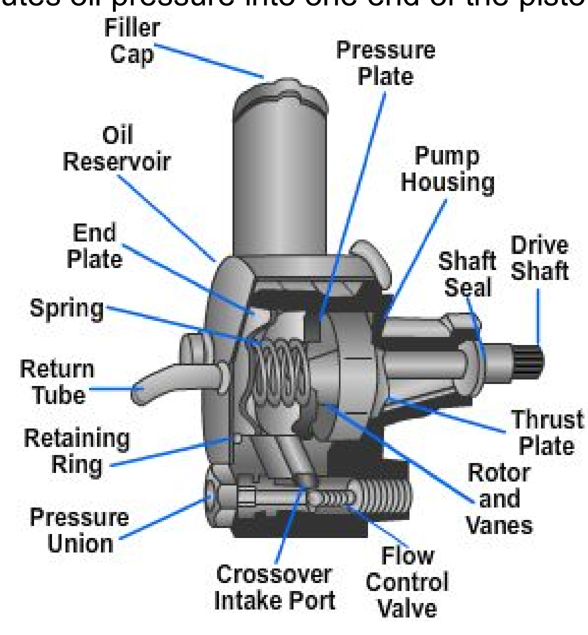

Figure 14-26 — Power steering pump.

trapped and squeezed into a smaller area inside the pump. This action pressurizes the oil at the output as it flows to the rest of the system. A pressure relief/flow valve is built into the pump to control maximum oil pressure. This action prevents system damage by limiting pressure developed throughout the different engine speeds.

The control valve, a rotary or spool type valve which is actuated by steering wheel movements, is designed to direct the hydraulic fluid under pressure to the proper location in the steering system (*Figure 14-27*). The control valve may be mounted either in the steering mechanism or on the steering linkage, depending on which system configuration is used.

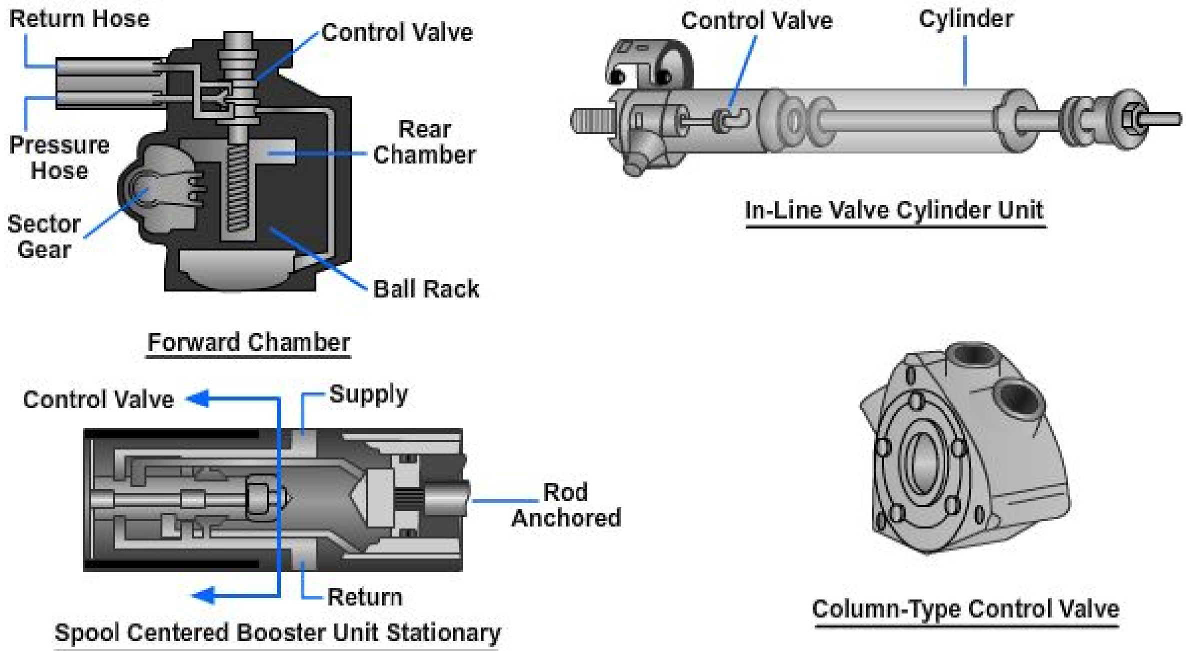

Figure 14-27 — Control valve.

Power steering hoses are high-pressure, hydraulic rubber hoses that connect the power steering pump and the integral gearbox or power cylinder. One line serves as a supply line, the other acts as a return line to the reservoir of the power steering pump. There are three major types of power steering systems used on modern passenger vehicles: integral piston or linkage type (*Figure 14-28, View A*), external cylinder or linkage type (*Figure 14-28, View B*), and rack and pinion (*Figure 14-28, View C*). The rack and pinion can further be divided into integral and external power piston systems. The integral rack and pinion steering system is the most common.

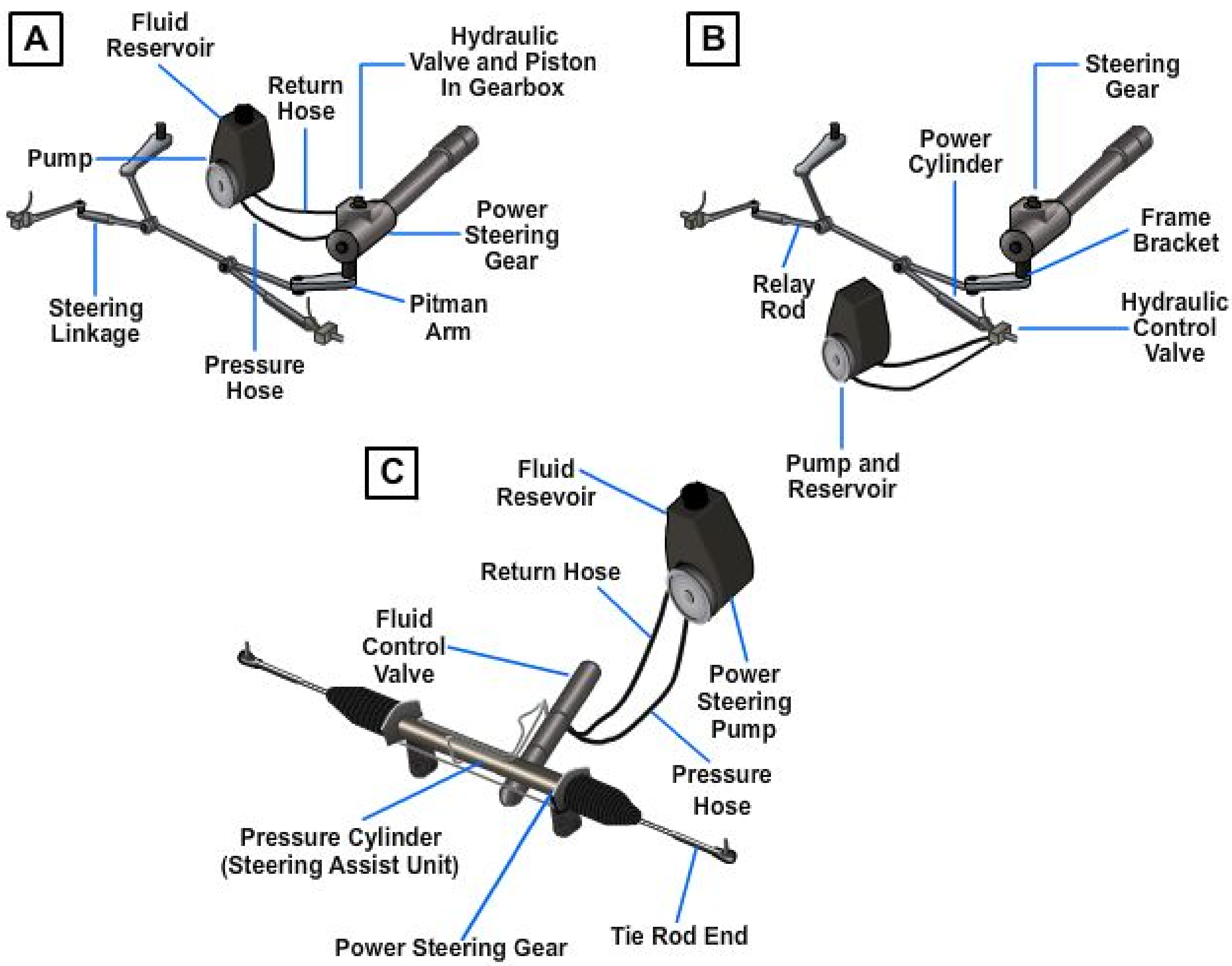

Figure 14-28 — Three major power steering systems.

3.4.1 Integral Piston (Linkage Type)

The integral piston (linkage type) power steering system has the hydraulic piston mounted inside the steering gearbox. This is the most common type of power steering system. Basically, this system consists of a power steering pump, hydraulic lines, and a special integral power-assist gearbox.

The integral piston power steering gearbox contains a conventional worm and sector gear arrangement, a hydraulic piston, and a control valve. The control valve may be either a spool valve or a rotary valve depending upon the manufacturer.

The operation of an integral power steering system is as follows:

- With the steering wheel held straight ahead or in neutral position, the control valve balances hydraulic pressure on both sides of the power piston. Oil returns to the pump reservoir from the control valve.
- For a right turn, the control valve routes oil to the left side of the power piston. The piston is pushed to the right in the cylinder to aid pitman shaft rotation.
- For a left turn, the control valve routes oil to the right side of the power piston. The piston is pushed to the left in the cylinder to aid pitman shaft rotation.
- In both left and right turns, piston movement forces oil on the nonpressurized side of the piston back through the control valve and to the pump.

3.4.2 External Cylinder (Linkage Type)

The external cylinder power steering system has the power cylinder mounted to the frame and the center link. In this system the control valve may be located in the gearbox or on the steering linkage. Operation of this system is similar to the one previously described.

3.4.3 Power Rack and Pinion

Power rack-and-pinion steering uses hydraulic pump pressure to assist the operator in moving the rack and front wheels. A basic power rack-and-pinion assembly consists of a power cylinder, power piston, hydraulic lines, and a control valve.

- Power cylinder (hydraulic cylinder formed around the rack). The power cylinder is precisely machined to accept the power piston. Provisions are made for the hydraulic lines. The power cylinder bolts to the vehicle frame, just like the rack of a manual unit.
- Power piston (a double-acting hydraulic piston formed on the rack). The power piston is formed by attaching a hydraulic piston to the center of the rack. A rubber seal fits around the piston to prevent fluid from leaking from one side of the power cylinder to the other.
- Hydraulic lines (steel tubing that connects the control valve and power cylinder).
- Control valve (a hydraulic valve which regulates hydraulic pressure entering each end of the power piston). There are two types of control valves: rotary and spool. Using a torsion bar connected to the pinion gear operates the rotary valve, whereas the spool valve is operated by the thrust action of the pinion shaft.
- Other components of the power rack and pinion are similar to those that are found on manual rack-and-pinion steering system.

Power rack-and-pinion operation is fairly simple. When the steering wheel is turned, the weight of the vehicle causes the front tire to resist turning. This resistance twists a torsion bar (rotary valve) or thrusts the pinion shaft (spool valve) slightly. This action moves the control valve and aligns the specific oil passages. Pump pressure is then allowed to flow through the control valve, the hydraulic line, and into the power cylinder. Hydraulic pressure then acts on the power piston and the piston action assists in pushing the rack and front wheels for turning.

Test your Knowledge (Select the Correct Response)

3. The oil flow with a power steering system is directed by the _______.

   A. hydraulic pump
   B. power cylinder
   C. control valve
   D. hydraulic gear housing

4.0.0 STEERING SYSTEM MAINTENANCE

Maintenance of the steering system consists of regular inspection, lubrication, and adjusting components to compensate for wear. When inspecting the steering system, you will need someone to assist you by turning the steering wheel back and forth through the free play while you check the steering linkage and connections. You will also be able to determine if the steering mechanism is securely fastened to the frame. A slight amount of free play may seem insignificant, but if allowed to remain, the free play will quickly increase, resulting in poor steering control.

After prolonged use, steering components can fail. It is important that the steering system be kept in good working condition for obvious safety reasons. It is your job to find and correct any system malfunctions quickly and properly.

4.1.0 Steering Linkage Service

Any area containing a ball-and-socket joint is subjected to extreme movements and dirt. The combination of these two will cause the ball-and-socket joint to wear. When your inspection finds worn steering linkage components, they must be replaced with new components. Two areas of concern are the idler arm and the tie-rod ends.

4.1.1 Idler Arm Service

A worn idler arm causes play in the steering wheel. The front wheels, mostly the right wheel, can turn without causing movement of the steering wheel. This is a very common wear point in the steering linkage and should be checked carefully.

To check an idler arm for wear, grab the outer end of the arm (end opposite the frame) and force it up and down by hand. Note the amount of movement at the end of the arm and compare it to the manufacturer's specifications. Typically, an idler arm should NOT move up and down more than 1/4 inch.

The replacement of a worn idler arm is as follows:

1. Separate the outer end of the arm from the center link. A ball joint fork or puller can be used to force the idler arm's joint from the center link.
2. With the outer end removed from the center link, unbolt and remove the idler arm from the frame.
3. Install the new idler arm in reverse order of removal. Make sure that all fasteners are torqued to manufacturer's specifications. Install a new cotter pin and bend it properly.

4.1.2 Tie-Rod End Service

A worn tie-rod end will also cause steering play. When movement is detected between the ball stud and the socket, replacement is necessary.

The replacement of a worn tie-rod end is as follows:

1. Separate the tie rod from the steering knuckle or center link. As with the idler arm, a ball joint fork or puller can be used.
2. With the tie rod removed from the steering knuckle or center link, measure tie-rod length. This will allow you to set the new tie rod at about the same length as the old one.

NOTE

The alignment of the front wheel is altered when the length of the tie rod is changed.

3. Loosen and unscrew the tie-rod adjustment sleeve from the tie-rod end. Turn the new tie-rod end into the adjustment sleeve until it is the exact length of the old tie rod.

4. Install the tie-rod ball stud into the center link or steering knuckle. Tighten the fasteners to manufacturer's specifications. Install new cotter pins and bend correctly. Tighten the adjustment sleeve and check steering action.

4.2.0 Manual Steering System Service

Steering system service normally involves the adjusting or replacement of worn parts. Service is required when the worm shaft rotates back and forth without normal pitman arm shaft movement. This would indicate that there is play inside the gearbox. If excess clearance is NOT corrected after the adjustments, the steering gearbox must be replaced or rebuilt.

Manual gearbox adjustment--Since there are numerous steering gearbox configurations, we will discuss the most common type, recirculating ball and nut. There are two basic adjustments: worm bearing preload and over center clearance.

Worm bearing preload--Assures that the worm shaft is held snugly inside the gearbox housing. If the worm shaft bearings are too loose, the worm shaft can move sideways and up and down during operation.

Over center clearance--Controls the amount of play between the pitman arm shaft gear (sector) and the teeth on the ball nut. It is the most critical adjustment affecting steering wheel play.

NOTE

Set the worm bearing preload first and then the over center clearance.

Basic procedures for adjusting worm-bearing preload are as follows:

1. Disconnect the pitman arm from the pitman arm shaft.
2. Loosen the pitman arm shaft over center adjusting locknut and screw out the adjusting screw a couple of turns. Then turn the steering wheel from side to side slowly.
3. Using a torque wrench or spring scale, measure the amount of force required to turn the steering wheel to the center position. Note the reading on the torque wrench or the spring scale and compare it to the manufacturer’s specifications.
4. If readings are out of specifications, loosen the worm-bearing locknut. Then tighten the worm bearing adjustment nut to increase the preload. Loosen it to decrease preload and turning effort. With the preload set to specifications, tighten the locknut. Make sure the steering wheel turns freely from stop to stop.

NOTE

If the steering wheel binds or feels rough, then the gearbox has damaged components and should be rebuilt or replaced.

Basic procedures for adjusting the over center clearance are as follows:

1. Find the center position of the steering wheel. This is done by turning the steering wheel from full right to full left while counting the number of turns. Divide the number of turns by two to find the middle. This allows you to turn the steering wheel from full stop to the center.

NOTE

Most gearboxes are designed to have more gear tooth backlash (clearance) when turned to the right or left. A slight preload is produced in the center position to avoid steering wheel play during straight-ahead driving.

2. With the steering wheel centered, loosen the over center adjusting screw locknut. Turn the over center adjusting screw in until it bottoms lightly. This will remove the backlash.
3. Using the instructions in the service manual, measure the amount of force required to turn the steering wheel. Loosen or tighten the adjustment screw to meet the manufacturer’s specifications. Tighten the locknut and recheck the gearbox action.

When adjustment fails to correct the problems, the steering gearbox needs to be overhauled or replaced. Overhauling a gearbox is done by disassembling, cleaning, inspecting, and replacing worn components and seals. After reassembling the gearbox, fill the housing with the correct type of lubricant. Most manual steering systems use SAE 90 gear oil. Make sure that you do NOT overfill the gearbox. Refer to the manufacturer's service manual for the particular gearbox you are working on since procedures, specifications, and type of lubricants vary.

4.2.1 Rack and Pinion Service

Rack and pinion steering systems have few parts that fail. When problems do develop, they are frequently in the tie-rod ends. When NOT properly lubricated, the rack and pinion will also wear, causing problems.

Depending upon the manufacturer, some rack-and-pinion steering systems need periodic lubrication. Others only need lubrication when the unit is being reassembled after being repaired.

Most rack-and-pinion systems have a rack guide adjustment screw. This screw is adjusted when there is excessive play in the steering. Basic procedures for adjusting rack-and-pinion steering system are as follows:

1. Loosen the locknut on the adjusting screw. Then turn the rack guide screw until it bottoms slightly. Back off the rack guide screw the recommended amount (approximately 45 degrees or until the prescribed turning effort is achieved).
2. Tighten the locknut. Check for tight or loose steering and measure steering effort. Compare with the manufacturer's specifications. If not within specifications, an overhaul of the system will be required.
3. For instructions on the removal/installation and overhaul of the rack-and-pinion system, refer to the manufacturer’s service manual for the equipment you are repairing.

4.3.0 Power Steering System Maintenance

Many of the components of a power steering system are the same as those used on a manual steering system. However, a pump, hoses, a power piston, and a control valve are added. These components can also fail, requiring repair or replacement. Power steering system service typically consists of the following:

- Checking power steering fluid level.
- Checking belts and hoses.

- Checking the system for leaks.
- Pressure testing the system.
- Bleeding the system.

4.3.1 Checking Power Steering Fluid

To check the level of the power steering fluid, you should NOT let the engine run. With the parking brake set, place the transmission in either PARK or NEUTRAL. Basic procedures for checking the level of the power steering fluid are as follows:

1. Unscrew and remove the cap to the power steering reservoir. The cap will normally have a dipstick attached.
2. Wipe off the dipstick and reinstall the cap. Remove the cap and inspect the level of the fluid on the dipstick. Most dipsticks will have HOT and COLD markings. Make sure you read the correct marking on the dipstick.

NOTE

The fluid level will rise on the dipstick as the steering system warms.

3. If required, add only enough fluid to reach the correct mark on the dipstick. Automatic transmission fluid is commonly used in a power steering system. Some power steering systems, however, do NOT use automatic transmission fluid and require a special power steering fluid. Always refer to the manufacturer’s service for the correct type of fluid for your system.

CAUTION

Do NOT overfill the system. Overfilling will cause fluid to spray out the top of the reservoir and onto the engine and other components.

4.3.2 Servicing Power Steering Hoses and Belt

Always inspect the condition of the hoses and the belt very carefully. The hoses are exposed to tremendous pressures; if a hose ruptures, a sudden and dangerous loss of power assist occurs. Make sure that the hose is NOT rubbing on moving or hot components. This can cause hose failure.

CAUTION

Power steering pump pressure can exceed 1,000 psi. This is enough pressure to cause serious eye injury. Wear eye protection when working on a power steering system.

If it is necessary to replace a power steering hose, use a flare nut or tubing wrench. This action will prevent you from stripping the nut. When starting a new hose fitting, use your hand. This action will prevent cross threading. Always tighten the hose fitting properly.

A loose power steering belt can slip, causing belt squeal and erratic or high steering effort. A worn or cracked belt may break during operation, which would cause a loss of power assist.

When it is necessary to tighten a power steering belt, do NOT pry on the side of the power steering pump. The thin housing on the pump can easily be dented and ruined. Pry ONLY on the reinforced flanged or a recommended point.

Basic procedures for installing a power steering belt are as follows:

1. Loosen the bolts that hold the power steering pump to its brackets.

2. Push inward on the pump to release tension on the belt. With the tension removed, slide the belt from the pulley.
3. Obtain a new belt and install it in reverse order. Remember: when adjusting belt tension to specifications, pry only on the reinforced flange or a recommended pry point.

4.3.3 Power Steering Leaks

A common problem with power steering systems is fluid leakage. With pressure over 1,000 psi, leaks can develop easily around fittings, in hoses, at the gearbox seals, or at the rack-and-pinion assembly. To check for leaks, wipe the fluid-soaked area(s) with a clean rag. Then have another person start and idle the engine. While watching for leaks, have the steering wheel turned to the right and left. This action will pressurize all components of the system that might be leaking. After locating the leaking component, remove and repair or replace it.

4.3.4 Power Steering Pressure Test

A power steering pressure test checks the operation of the power steering pump, the pressure relief valve, the control valve, the hoses, and the power piston. Basic procedures for performing a power steering pressure test are as follows:

1. Using a steering system pressure tester, connect the pressure gauge and shutoff valve to the power steering pump outlet and hose. Torque the hose fitting properly.
2. With the system full of fluid, start and idle the engine (with the shutoff valve open) while turning the steering wheel back and forth. This will bring the fluid up to temperature.
3. Close the shutoff valve to check system pressure. Note and compare the pressure reading with manufacturer’s specifications.

CAUTION

Do NOT close the shutoff valve for more than 5 seconds. If the shutoff value is closed longer, damage will occur to the power steering pump from overheating.

4. To check the action of the power piston, control valves, and hoses, measure the system pressure while turning the steering wheel right and left (stop to stop) with the shutoff valve open. Note and compare the readings to the manufacturer’s specifications. If the system is not within specifications, use the manufacturer’s service manual to determine the source of the problem.

4.3.5 Bleeding a Power Steering System

Anytime you replace or repair a hydraulic component (pump, hoses, and power piston), you should bleed the system. Bleeding the system assures that all of the air is out of the hoses, the pump, and the gearbox. Air can cause the power steering system to make a buzzing sound. The sound will occur as the steering wheel is turned right or left.

To bleed out any air, start the engine and turn the steering wheel fully from side to side. Keep checking the fluid and add as needed. This will force the air into the reservoir and out of the system.

4.4.0 Troubleshooting Steering Systems

The most common problems of a steering system are as follows:

- Steering wheel play
- Hard steering
- Abnormal noises when turning the steering wheel

These problems normally point to component wear, lack of lubrication, or an incorrect adjustment. You must inspect and test the steering system to locate the source of the trouble.

4.4.1 Steering Wheel Play

The most common of all problems in a steering system is excessive steering wheel play. Steering wheel play is normally caused by worn ball sockets, worn idler arm, or too much clearance in the steering gearbox. Typically, you should not be able to turn the steering wheel more than 1 1/2 inches without causing the front wheels to move. If the steering wheel rotates excessively, a serious steering problem exists.

An effective way to check for play in the steering linkage or rack-and-pinion mechanism is by the dry-park test. With the full weight of the vehicle on the front wheels, have someone move the steering wheel from side to side while you examine the steering system for looseness. Start your inspection at the steering column shaft and work your way to the tie-rod ends. Ensure that the movement of one component causes an equal amount of movement of the adjoining component.

Watch for ball studs that wiggle in their sockets. With a rack-and-pinion steering system, squeeze the rubber boots and feel the inner tie rod to detect wear. If the tie rod moves sideways in relation to the rack, the socket is worn and should be replaced.

Another way of inspecting the steering system involves moving the steering components and front wheel by hand. With the steering wheel locked, raise the vehicle and place it on jack stands. Then force the front wheels right and left while checking for component looseness.

4.4.2 Hard Steering

If hard steering occurs, it is probably due to excessively tight adjustments in the steering gearbox or linkages. Hard steering can also be caused by low or uneven tire pressure, abnormal friction in the steering gearbox, in the linkage, or at the ball joints, or improper wheel or frame alignment.

The failure of power steering in a vehicle causes the steering system to revert to straight mechanical operation, requiring much greater steering force to be applied by the operator. When this happens, the power steering gearbox and pump should be checked as outlined in the manufacturer's service manual.

To check the steering system for excessive friction, raise the front of the vehicle, and turn the steering wheel and check the steering system components to locate the source of excessive friction. Disconnect the pitman arm. If this action eliminates the frictional drag, then the friction is either in the linkage or at the steering knuckles. If the friction is NOT eliminated when the pitman arm is disconnected, then the steering gearbox is probably faulty.

If hard steering is not due to excessive friction in the steering system, the most probable causes are incorrect front end alignment, a misaligned frame, or sagging springs.

Excessive tire caster causes hard steering. Wheel alignment will be described later in this chapter.

4.4.3 Steering System Noises

When problems exist, steering systems can produce abnormal noises (rattles, squeaks, and squeals). Noises can be signs of worn components, unlubricated bearings or ball joints, loose components, slipping belts, low power steering fluid, or other troubles.

Rattles in the steering linkage may develop if linkage components become loose. Squeaks during turns can develop due to lack of lubrication in the joints or bearings of the steering linkage. This condition can also produce hard steering.

Some of the connections between the steering linkage components are connected by ball sockets that can be lubricated. Some ball sockets are permanently lubricated on original assembly. If permanently lubricated ball sockets develop squeaks or excessive friction, they must be replaced.

Belt squeal is a loud screeching sound produced by belt slippage. A slipping power steering belt will usually show up when turning. Turning the steering wheel to the full right or left will increase system pressure and belt squeal. Belt squeal may be eliminated by either adjusting or replacing the belt.

Test your Knowledge (Select the Correct Response)

4. When you perform a pressure test on a power steering system, the shut-off valve should NOT be closed for more than how many seconds?

   A. 20
   B. 15
   C. 10
   D. 5

5.0.0 TIRES, WHEELS, and WHEEL BEARINGS

This section introduces the various tire designs used on modern vehicles. It explains how tire and wheels are constructed to give safe and dependable service. This section also covers hub and wheel-bearing construction for both rear-wheel and front-wheel drives.

5.1.0 Tire Construction

Most modern passenger vehicles and light trucks use tubeless tires that do NOT have a separate inner tube. The tire and wheel form an airtight unit. Many commercial and construction vehicles use inner tubes, which are soft, thin, leak-proof rubber liners that fit inside the tire and wheel assemblies. However, in the last few years tubeless tires have been introduced to commercial and construction vehicles, reducing the need for tube type tires. Tires perform the following two basic functions:

- They must act as a soft cushion between the road and the metal wheel.
- They must provide adequate traction with the road surface.

Tires must transmit driving, braking, and cornering forces to the road in all types of weather. At the same time, they should resist puncture and wear. Although there are several tire designs, the six major parts of a tire are as follows:

- Tire beads (two steel rings encased in rubber that holds the tire sidewalls against the wheel rim).
- Body plies (rubberized fabric and cords wrapped around beads. forming the carcass or body of the tire).
- Tread (outer surface of the tire that contacts the road surface).
- Sidewall (outer surface of the tire extending from bead to tread; it contains tire information).
- Belts (used to stiffen the tread and strengthen the plies; they lie between the tread and the inner plies).
- Liner (a thin layer of rubber bonded to the inside of the plies: it provides a leak-proof membrane for tubeless tires).

There are many construction and design variations in tires. A different number of plies may be used and run at different angles. Also, many different materials may be used. The three types of tires found on late model vehicles are bias-ply, belted bias, and radial.

5.1.1 Bias-Ply Tire

A bias-ply tire is one of the oldest designs, and it does NOT use belts. The position of the cords in a bias-ply tire allows the body of the tire to flex easily. This design improves the cushioning action, which provides a smooth ride on rough roads. A bias-ply tire has the plies running at an angle from bead to bead (*Figure 14-29*). The cord angle is also reversed from ply to ply, forming a crisscross pattern. The tread is bonded directly to the top ply. A major disadvantage of a bias-ply tire is that the weakness of the plies and tread reduce traction at high speeds and increase rolling resistance.

5.1.2 Belted Bias Tire

A belted bias tire provides a smooth ride and good traction, and offers some reduction in rolling resistance over a bias-ply tire. The belted bias tire is a bias-ply tire with stabilizer belts added to increase tread stiffness. The belts and plies run at different angles. The belts do NOT run around to the sidewalls but lie only under the tread area. Two stabilizer belts and two or more plies are used to increase tire performance.

5.1.3 Radial Ply Tire

The radial ply tire has a very flexible sidewall, but a stiff tread (*Figure 14-30*). This design provides for a very stable footprint (shape and amount of tread touching the road surface) which improves safety, cornering, braking, and wear. The radial ply tire has plies running straight across from bead to bead with stabilizer belts directly beneath the tread. The belts can be made of steel, flexten, fiberglass, or other materials.

A major disadvantage of the radial ply tire is that it produces a harder ride at low speeds. The stiff tread does NOT give or flex as much on rough road surfaces.

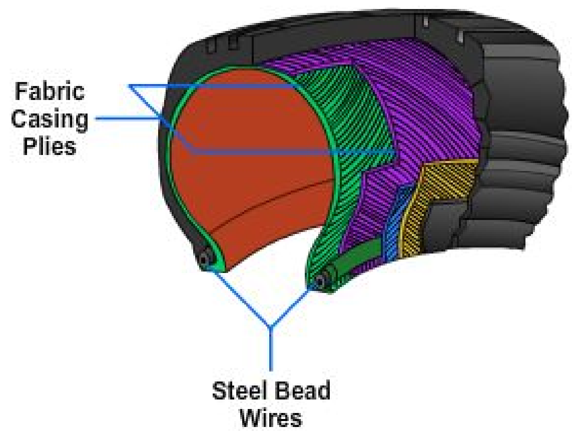

Figure 14-29 — Bias ply tire.

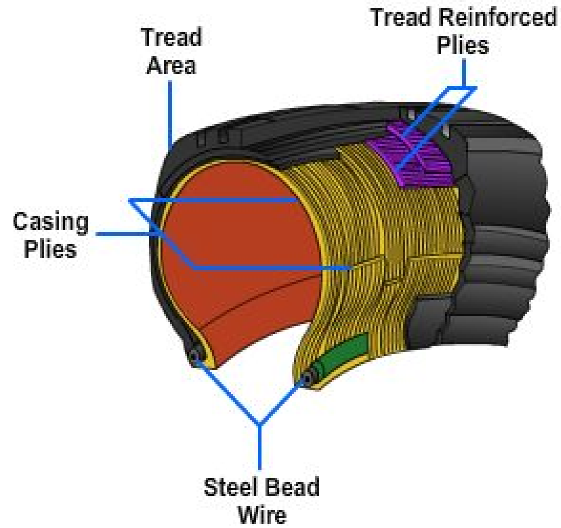

Figure 14-30 — Radial tire.

5.2.0 Tire Markings

There is important information on the sidewall of a tire. Typically, you will find Uniform Tire Quality Grading (UTQG) ratings for treadwear, traction, and temperature. You will also find the tire size, load index and speed rating, and inflation pressure. It is important that you understand these tire markings.

5.2.1 Tire Size

Tire size on the sidewall of a tire is given in a letter-number sequence. There are two common size designations (*Table 14-1*)—alphanumeric (conventional measuring system) and P-metric (metric measuring system). The alphanumeric tire size rating system, as shown in *Table 14-1*, uses letters and numbers to denote tire size in inches and load-carrying capacity in pounds. The letter G indicates the load and size relationship. The higher the letter, the larger the size and load-carrying capability of the tire. The letter R designates the radial design of the tire. The first number "78" is the aspect ratio, also known as height-to-width ratio. The last number "15" is the rim diameter in inches. The P-metric tire size identification system, as shown in *Table 14-1*, uses metric values and international standards. The letter P indicates a passenger vehicle (T means temporary and C means commercial). The first number "155" indicates the section width in millimeters measured from sidewall to sidewall. The second number "80" is the aspect ratio, also known as height-to-width ratio. The letter R indicates radial (B means bias belted, D means bias-ply construction).

Table 14-1 — Tire Size Designation Numbering System.

Alpha-Numeric Tire Size (GR 78-15)				
G	R	78	15	
Load/Size Relationship	Radial Design	Height-to-Width Ratio	Rim or Wheel Diameter in Inches	
P-Metric Tire Size (P 155/80 R13)				
P	155	80	R	13
Type Tire (P=Passenger) (T=Temporary) (C=Commercial) (LT= Light Truck)	Section Width in Millimeters (155, 185, 195)	Height-to-Width Ratio in Percentage (70, 75, 80)	Tire Construction (R=Radial) (B=Bias Belted) (D=Diag. Bias)	Rim or Wheel Diameter in Inches

NOTE

Truck tires are sometimes marked with the designation LT for "light truck" before the size.

The aspect ratio or height-to-width ratio in the tire size is the most difficult value to understand. Aspect ratio is the comparison of the height of a tire (bead to tread) to the width of a tire (sidewall to sidewall). It is height divided by width. An 80-series tire, for example, has a section height that is 80 percent of the section width.

As the aspect ratio becomes smaller, the tire becomes squatted (wider and shorter). A 60-series tire would be "short" and "fat," whereas an 80-series tire would be "narrower" and "taller."

5.2.2 Load Index and Speed Rating

The term load index, or load range, is used to identify a given size tire with its load and inflation limits when used in a specific type of service. The load index of a tire and proper inflation pressure determines how much of a load the tire can carry safely.

A letter identifies the load index for most light trucks, these letters being B, C, D, or E. A tire with a B load rate is restricted to a load specified at 32 psi. Where a greater load-carrying ability is required, load rate C, D, or even E tires are used.

Table 14-2 — Load Index Chart for a Passenger Vehicle.

Load Index and Load in LBS.							
Load Index	Load (lbs)	Load Index	Load (lbs)	Load Index	Load (lbs)	Load Index	Load (lbs)
76	882	86	1,168	96	1,565	106	2,094
77	908	87	1,201	97	1,609	107	2,149
78	937	88	1,235	98	1,653	108	2,205
79	963	89	1,279	99	1,709	109	2,271
80	992	90	1,323	100	1,764	110	2,337
81	1,019	91	1,356	101	1,819	111	2,403
82	1,047	92	1,389	102	1,874	112	2,469
83	1,074	93	1,433	103	1,929	113	2,535
84	1,102	94	1,477	104	1,934	114	2,601
85	1,135	95	1,521	105	2,039	115	2,679

Passenger vehicle tires come with a service description added to the end of the tire size. These service descriptions contain a number, which is the load index, and a letter, which indicates the speed rating. The load index represents the maximum load each tire is designed to support (*Table 14-2*). Because the maximum tire load capacity is branded on the sidewall of the tire, the load rate is used as a quick reference. Speed ratings signify the safe top speed of a tire under perfect conditions (*Table 14-3*).

Table 14-3 — Speed Rating Chart for a Passenger Vehicle.

Speed Rating Symbol		
Rating Symbol	Speed (KM/H)	Speed (MPH)
L	120	75
M	130	81
N	140	87
P	150	93
Q	160	99
R	170	106
S	180	112
T	190	118
U	200	124
H	210	130
V	240	149
W	270	168
Y	300	186
Z	Open ended	Open ended

5.2.3 Maximum Inflation Pressure

The maximum inflation pressure, printed on the sidewall of a tire, is the highest air pressure that should be induced into the tire. The tire pressure is a “cold” pressure and should be checked in the morning before operating the vehicle.

In most parts of the world, fall and early winter months are the most critical times to check inflation pressures because the days are getting colder. And since air is a gas, it contracts when cooled. For every 10°F change in ambient temperature, the inflation pressure of a tire will change by 1 psi. It will go down with lower temperatures and up with higher temperatures. The typical difference between summer and winter temperatures is about 50°F, which results in a loss of 5 psi and will sacrifice handling, traction, durability, and safety.

5.2.4 Tire Grades

The Department of Transportation requires each manufacturer to grade its tires under the UTQG labeling system and establishes ratings for treadwear, traction, and temperature resistance (*Figure 14-31*). These tests are conducted independently by each manufacturer following government guidelines to assign values that represent a comparison between the tested tire and a control tire. While traction and temperature resistance ratings are specific performance levels, the treadwear ratings are assigned by the manufacturers following field-testing

Figure 14-31 — Uniform tire quality grade system ratings on the sidewall of the tire.

and are most accurate when comparing tires of the same brand.

- Treadwear receives a comparative rating based on wear rate of the tire in field-testing following a government-specified course. Treadwear is given as a number: 100, 120, or 130, for instance. The higher the number, the more resistant the tire is to wear. For example, a tire grade of 150 wears 1.5 times longer than a tire graded 100. Actual performance of the tire will vary significantly depending on conditions, driving habits, care, road characteristics, and climate.
- Straight-a-head wet braking traction has been represented by a grade of A, B, or C with A being the highest. In 1997 a new top rating of "AA" was introduced to indicate even greater wet braking traction. Traction grades do NOT indicate wet cornering ability.
- Temperature resistance is indicated by grades A, B. or C. This represents the resistance of the tire to heat generated by running at high speed. Grade C is the minimum level of performance for all passenger vehicle tires as set under Federal Motor Vehicle Safety Standards. This grade is established for a tire that is properly inflated and not overloaded.

NOTE

Uniform Tire Quality Grade ratings are NOT required on winter, light truck, and commercial tires.

5.3.0 Tubes

Tubes (inner tubes) are circular rubber containers that fit inside the tire and hold the air that supports the vehicle. Though it is strong enough to hold only a few pounds of air when not confined, the tube bears extremely high pressures when enclosed in a tire and wheel assembly. Because the tube is made of comparatively soft rubber to fulfill its function, it is easily chafed, pinched, punctured, or otherwise damaged. Tubes generally are made of a synthetic rubber that has air-retention properties superior to natural rubber. There are two types of synthetic rubber tubes: butyl and GR-S. A butyl type tube is identified by a blue stripe, and GR-S has a red stripe. Other than the standard tube, there are three special types of tubes: radial tire, puncture sealing, and safety.

- Radial-tire tube. The construction of an inner tube for use in a radial tire differs from the tube used in a bias tire. A radial tire flexes in such a manner that it concentrates the flex action in one area and at the edge of the belts in the shoulder of the tire. This concentration of stress will damage a standard tube, causing it to fail. To overcome this problem, the radial tube is made of a special rubber compound that is designed to overcome this concentrated stress; therefore, standard tubes must NEVER be used in radial tires.
- Puncture-sealing tube. This type of tube has a coating of plastic material in the inner surface. When the tube is punctured, this plastic material is forced into the puncture by the internal air pressure. The plastic material then hardens, sealing the puncture.
- Safety tube. The safety tube is really two tubes in one, one smaller than the other, and joined at the rim edge. When the tube is filled with air, the air flows first into the inside tube. From there the air passes through an equalizing passage into the space between the two tubes. Therefore, both tubes are filled with air. If a puncture occurs, air is lost from between the tubes. However, the inside tube, which has not been damaged, retains its air pressure. It is sufficiently

strong enough to support the weight of the vehicle until the vehicle can be slowed and stopped. Usually, the inside tube is reinforced with nylon fabric. The nylon fabric takes the suddenly imposed weight of the vehicle, without giving way, when a blowout occurs.

5.3.1 Tube Repair

If a tube tire has been punctured but has no other damage, it can be repaired with a patch. Remove the tube from the tire to find the leak. Inflate the tube and then submerge it in water. Bubbles will appear where there is a leak. Mark the spot. Then deflate and dry the tube.

There are two methods to patch a tube leak: the cold-patch method and the hot-patch method. With the cold-patch method (also known as chemical vulcanizing), first make sure the area is clean, dry, and free of grease and oil. Scuff the area around the leak. Then cover the area with vulcanizing cement. Let the cement dry until tacky. Press the patch into place. Roll it from the center out with a "stitching tool" or the edge of the patch kit can.

With the hot-patch method, prepare the tube in the same way as for the cold patch. Put the hot patch into place and clamp it. Then, with a match, light the fuel on the back of the patch. As the fuel burns, the heat vulcanizes the patch to the tube. After the patch has cooled, inflate the tube and recheck for leaks by submerging the tube in water. Another kind of hot patch uses a vulcanizing hot plate. The hot plate supplies the heat required to bond the patch to the tube.

5.4.0 Wheels

Wheels must have enough strength to carry the weight of the vehicle and withstand a wide range of speed and road conditions. Automobiles and light trucks are equipped with a single piece wheel. Larger vehicles have a lock ring (side ring) that allows for the easy removal of the tire from the wheel and, when in place, it provides a seat for one side of the inflated tire.

A standard wheel consists of the RIM (outer lip that contacts the bead) and the SPIDER (center section that bolts to the vehicle hub). Normally the spider is welded to the rim. Common wheel designs are as follows:

- Drop center
- Semidrop center
- Safety
- Split

5.4.1 Drop Center Wheel

The drop center wheel is made in one piece and is commonly used on passenger vehicles because it allows for easier installation and removal of the tire (*Figure 14-32*). Bead seats are tapered to match a corresponding taper on the beads of the tire.

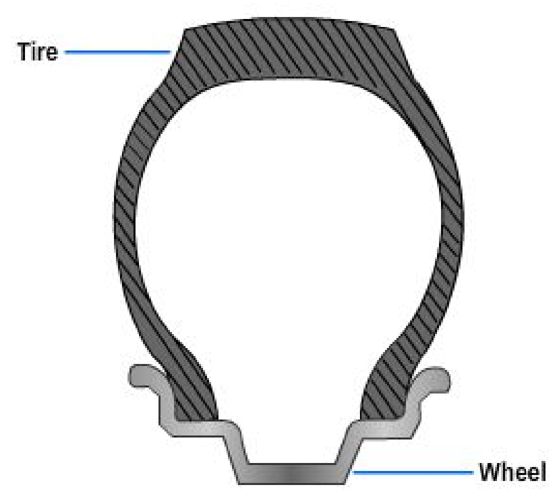

Figure 14-32 — Drop center wheel.

5.4.2 Semidrop Center Wheel

The semidrop center wheel has a shallow well, tapered-head seat to fit the taper of the beads of the tire (*Figure 14-33*). It also has a demountable flange or side ring which fits into a gutter on the outside of the rim, holding the tire in place.

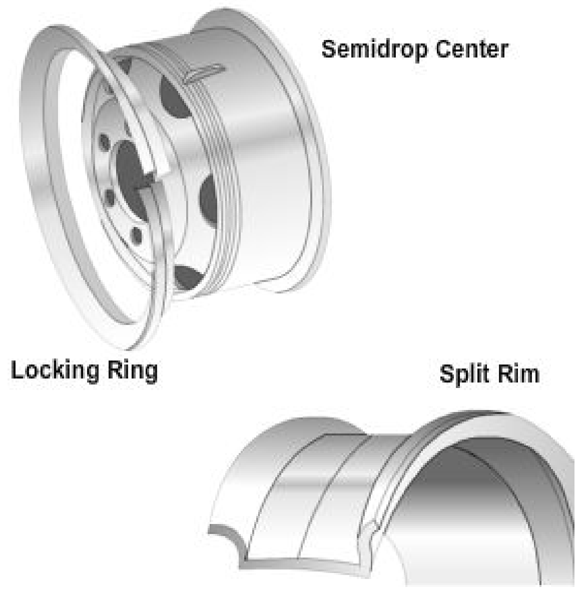

Figure 14-33 — Semidrop center and a split wheel.

5.4.3 Safety Wheel

A safety wheel is similar to the drop center wheel (*Figure 14-34*). The major difference is that the safety wheel has a slight hump at the edge of the bead ledge that holds the bead in place when the tire goes flat.

5.4.4 Split Wheel (2 Piece Wheel)

A split wheel (rim) has a removable bead seat on one side of the rim (*Figure 14-33*). The seat is split to allow for its removal so tires can be easily changed. Some bead seats also require the use of a lock ring to retain the seat. These wheels are used on large commercial and military vehicles.

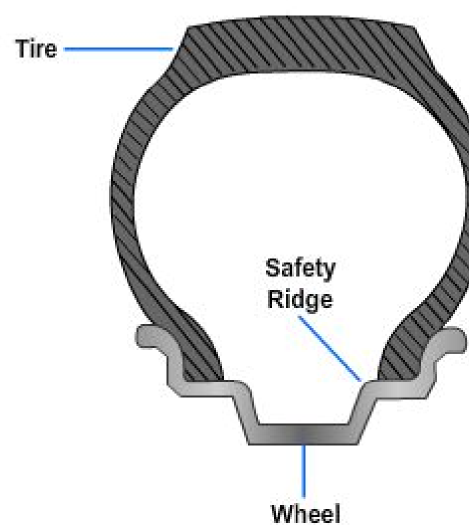

Figure 14-34 — Safety wheel.

5.5.0 Lug Nuts, Studs, and Bolts

Lug nuts hold the wheel and tire assembly on the vehicle. They fasten onto special studs. The inner face of the lug nut is tapered to help center the wheel on the hub. Lug studs are special studs that accept the lug nuts. The studs are pressed through the back of the hub or axle flange. A few vehicles use lug bolts instead of nuts. The bolts screw into threaded holes in the hub or axle flange.

Normally, the lug nuts and studs have right-hand threads (turn clockwise to tighten). When left-hand threads are used, the nut or stud will be marker with an "L." Metric threads will be identified with the letter M or the word Metric.

5.6.0 Wheel Bearing and Hub Assembly

Wheel bearings allow the wheel and tire assembly to turn freely around the spindle, in the steering knuckle, or in the bearing support. Wheel bearings are lubricated with heavy, high-temperature grease. This allows the bearing to operate with very little friction and wear.

The two basic wheel-bearing configurations are tapered roller or ball bearing types. The basic parts of a wheel bearing are as follows:

- Outer race (cup or cone pressed into the hub, steering knuckle, or bearing support).
- Balls or rollers (anti-friction elements that fit between the inner and outer races).
- Inner race (cup or cone that rests on the spindle or drive axle shaft).

There are two types of wheel bearing and hub assemblies: nondriving and driving. For example, the front wheels on a rear-wheel drive vehicle are nondriving.

5.6.1 Nondriving Wheel Assembly

The components of a nondriving wheel bearing and hub assembly (*Figure 14-35*) include the following:

- Spindle (a stationary shaft extending outward from the steering knuckle or suspension system to which the following components are attached).

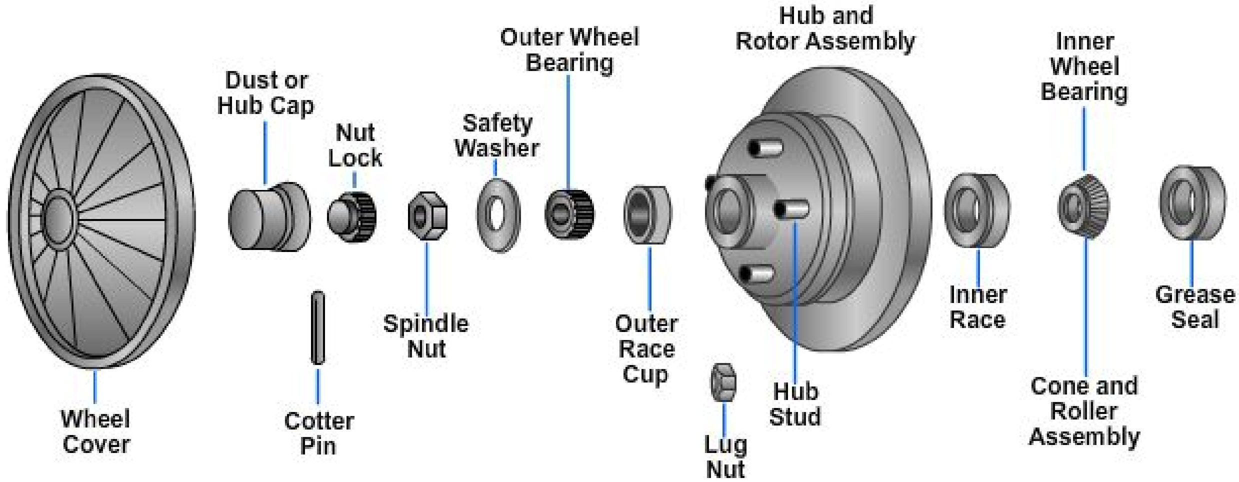

Figure 14-35 — View of a nondriving wheel bearing and hub assembly.

- Wheel bearings (normally tapered roller bearings mounted on the spindle and in the wheel hub).
- Hub (outer housing that holds the brake disc, or drum, wheel, grease, and wheel bearing).
- Grease wheel (a seal that prevents loss of lubricant from the inner end of the spindle and hub).
- Safety washer (a flat washer that keeps the outer wheel bearing from rubbing on and possibly turning the adjusting nut).
- Spindle adjusting nut (a nut threaded on the end of the spindle for adjusting the wheel bearing).
- Nut lock (a thin, slotted nut that fits over the main spindle nut).
- Dust cap (a metal cap that fits over the outer end of the hub to keep grease in and dirt out of the bearings).

Since a nondriving wheel bearing and hub assembly does NOT transfer driving power, the spindle is stationary. The spindle simply extends outward and provides a mounting surface for the wheel bearings, hub, and wheel. With the vehicle moving, the wheel and hub spin on the wheel bearings and spindle. The hub simply freewheels.

5.6.2 Driving Wheel Assembly

The components of a driving wheel bearing and hub assembly (*Figure 14-36*) includes the following:

- Outer drive axle (a stub axle shaft that extends through the wheel bearings and is splined to the hub).
- Wheel bearings (either ball or roller type bearings that allow the drive axle to turn in the steering knuckle or bearing support).
- Steering knuckle or bearing support (a suspension or steering component that holds the wheel bearings, axle stub, and hub).
- Drive hub (a mounting place for the wheel which transfers driving power from the stub axle to the wheel).

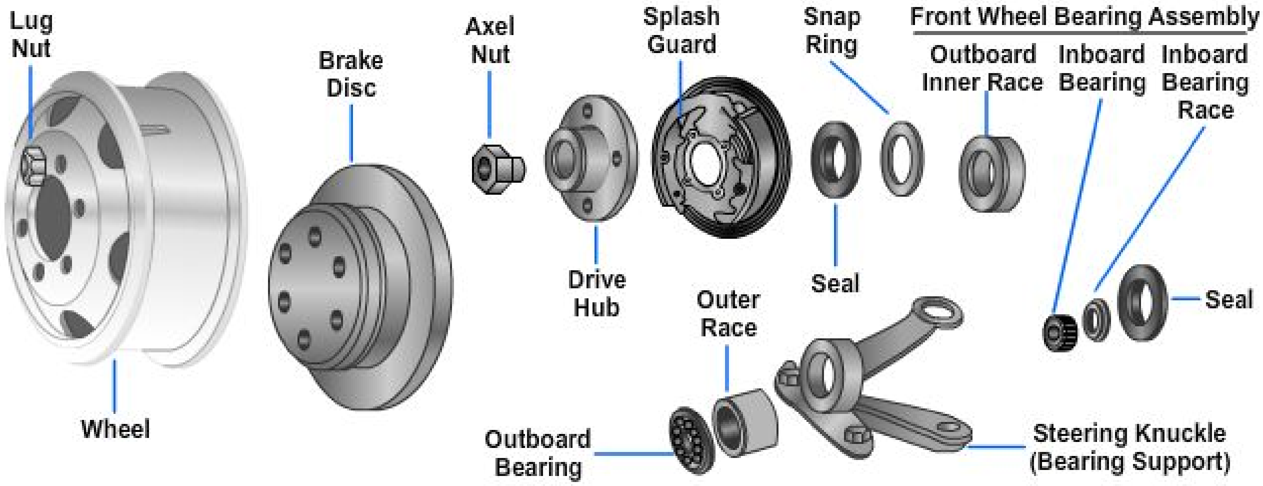

Figure 14-36 — View of a driving wheel bearing and hub assembly.

- Axle washer (a special washer that fits between the hub and locknut).
- Hub or axle locknut (a special nut that screws onto the end of the drive axle stub shaft to secure the hub and other parts of the assembly).
- Grease seal (prevents lubricant loss between the inside of the axle and the steering knuckle and bearing support).

The driving wheel bearing and hub assembly has bearings mounted in a stationary steering knuckle or bearing support. The drive axle fits through the center of the bearings. The hub is splined to the axle shaft. Instead of a stationary spindle, the axle shaft spins inside the stationary support. With the hub splined to the axle shaft, power is transferred to the wheels.

5.6.3 Wheel-Bearing Service

Wheel bearings are normally filled with grease. If this grease dries out, the bearing will fail. Some wheel bearings can be disassembled and packed (filled) with grease, while others are sealed units that require replacement when worn. When performing tire-related service, check the wheel bearings for play and wear.

NOTE

For procedures on checking, removing, and replacing wheel bearings, refer to the manufacturer’s service manual.

5.7.0 Tire Repair

Leaks from a tubeless tire are located by filling the tire with air and then placing the tire in a drum full of water. Bubbles will show the location of any leaks. If a drum of water is not available, coat the tire with soapy water. Soap bubbles will show the location of the leak.

It has been common practice to attempt the repair of some punctures without dismounting the tire through the use of a rubber plug. However, this practice is no longer recommended, because of serious safety concerns.

WARNING

Using a plug to attempt tire repair without dismounting is effective only 80 percent of the time. The remaining 20 percent of such repairs will result in tire failure, which may take the form of a dangerous sudden deflation (blowout).

The safe and correct procedure for tire repair is to always remove the tire from the wheel and make the repairs from the inside of the tire. After the tire has been dismounted, it should be thoroughly inspected. During this inspection, check the inside surface carefully, to locate the puncture and determine the nature and extent of the damage.

The Rubber Manufacturers of America lists two requirements for correctly repairing a puncture: the repair MUST fill the injury to the tire and the repair MUST soundly patch the inner liner. Various products are available for repairing the puncture to the tire, including plugs and liquid sealants.

Before replacing a tubeless tire, examine the rim carefully for dents, roughness, and rust; any defects may impair or break the air seal. Straighten out any dent with a hammer, and use steel wool or a wire brush to clean out any rust or grit in the bead seat area. After cleaning, paint any bare metal spots where the tire bead seats so that the tire is easier to remove later. If the rim is badly damaged, replace it with a new one.

The procedure for repairing a tubeless tire (*Figure 14-37*) is as follows:

1. Inspect the inside of the tire and remove nails or other damaging items. Then scrape the damaged area with a sharp-edged tool and buff. Be careful not to damage the liner or expose any cords.

WARNING

Serious injury can result using your bare hand to feel for obstructions; use a rag to feel inside the tire.

2. Lubricate the hole by pushing bonding compound into it from both sides of the tire. Also, pour bonding compound on the insertion tool and push it through the hole with a twisting motion until it can be inserted and withdrawn easily.
3. Place a plug slightly larger than the hole in the tire in the eye of the insertion tool hole. Wet the plug with bonding compound. Always pour it directly from the can so the compound in the can does not become contaminated.
4. While stretching and holding the plug with your hand, insert the plug into the hole from the inside of the tire. Stretch and hold the plug until it is forced into the hole and one end extends through it.
5. After the plug extends through the tire, remove the insertion tool and cut off the plug approximately 1/16 inch above the surface.

6. When using a cold patch, carefully remove the backing from the patch and center the base of the patch on the damaged area. Stitch the patch down firmly with the stitching tool, working from the center out.
7. When using a vulcanizing hot patch, cover the area with a light coat of glue and allow it to dry. This glue normally comes with the hot patch kit. Remove the backing from the patch and center it on the damaged area. Clamp it finger tight, apply heat, and allow it to cure and then cool.

NOTE

Each patch or plug kit should contain specific instructions.

A few basic safety rules for repairing a tubeless tire are as follows:

- Do NOT attempt to repair a puncture by plugging the tire from the outside.

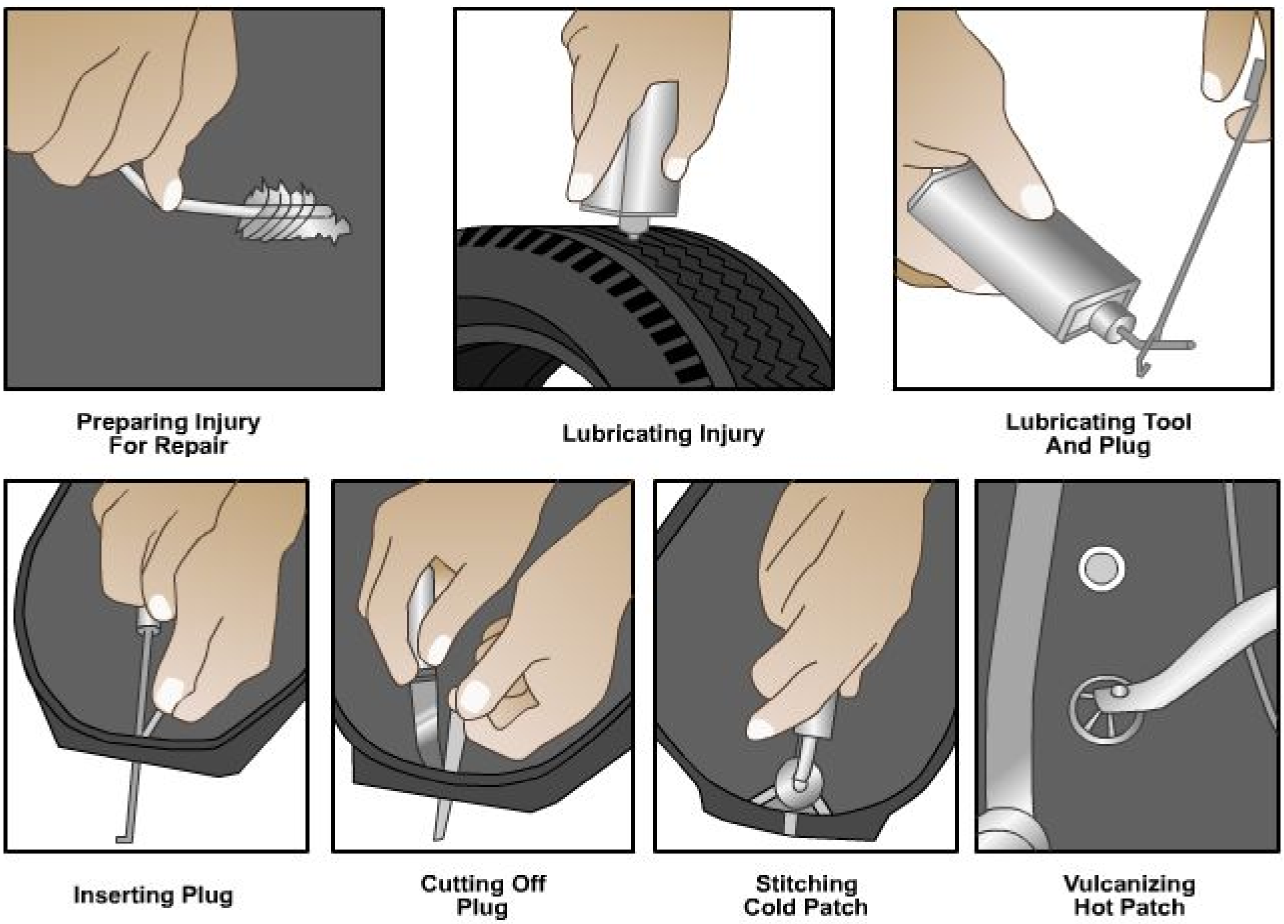

Figure 14-37 — Repairing a tire puncture.

ALWAYS dismount the tire and patch the inner liner.

- Do NOT attempt to repair sidewalls or tires with punctures larger than a 1/2 inch.
- Reduce the air pressure to at least 15-psi when removing an object from the tire.
- Broken strands in a steel belted tire can indicate more serious damage than initially suspected. Replace the tire.
- Follow the procedures given in the tire repair kit.

5.8.0 Preventive Maintenance

Preventive maintenance of tires and wheels involves periodic inspections, checking inflation pressure, wheel balancing, and rotation. Wheel bearings are periodically lubricated and checked for wear.

5.8.1 Rotating Tires

Rotating the tires will preserve balanced handling and traction of the tires and even out tire wear. Manufacturers recommend that tires be rotated every 6 months or 6,000 miles (whichever comes first), even if they do not show signs of wear. Tire rotation when done at the recommended times helps even out tire wear by allowing each tire to serve in as many of the wheel positions of the vehicle as possible.

NOTE

Remember that tire rotation CANNOT correct problems due to worn mechanical parts or incorrect inflation pressures.

While every vehicle is equipped with four tires, usually tires on the front need to accomplish very different tasks than the rear tires. Each wheel position can cause different wear rates and different types of tire wear. It is to your advantage that all four tires wear together because wear reduces tread depth of a tire, and uniform wear allows tires to respond to the operator's input more quickly, maintains the handling, and helps increase the cornering traction of a tire. *Figure 14-38* shows common tire rotation diagrams. A description of each is as follows:

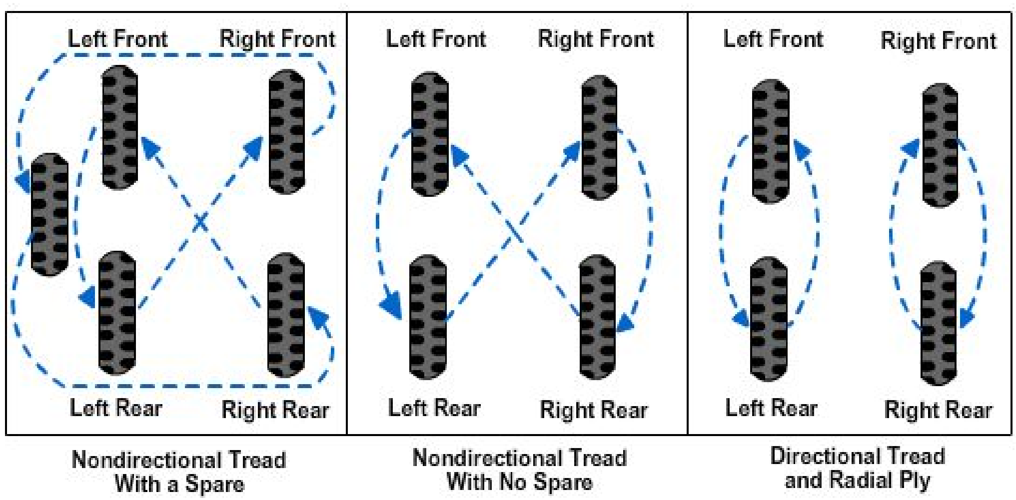

Figure 14-38 — Tire rotations.

- On vehicles that have nondirectional tread patterns, rotate the tires in a forward cross pattern; you can include the spare tire as well.
- If the vehicle has directional tires, rotate these tires from front to back only and vice versa.
- If the vehicle has nondirectional tires that are a different size from front to rear, rotate these tires from side to side only.

When your tires wear out together, you can get a new set of tires without being forced to change tires in pairs. You will also be able to maintain the original handling balance of the vehicle.

5.8.2 Wheel Balancing

Improper wheel balance is the most common cause of tire vibration. Often a tire will appear to be round and true when rotated slowly. However, when one side is heavier than the other, centrifugal force tries to throw the heavy area outward during operation. To obtain maximum tire wear and a comfortable ride, you should balance the wheels. The two types of tire imbalance are as follows:

- Dynamic imbalance (*Figure 14-39*) lies on either or both sides of the center line of the tire, which causes the tire to vibrate up and down (wheel hop) and from side to side (wheel shimmy). To be in dynamic balance, the top-to-bottom weight and the side-to-side weight must all be equal.

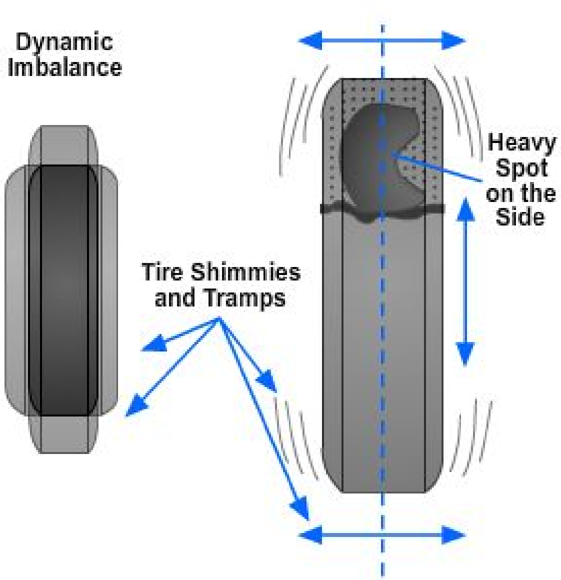

Figure 14-39 — Dynamic imbalance.

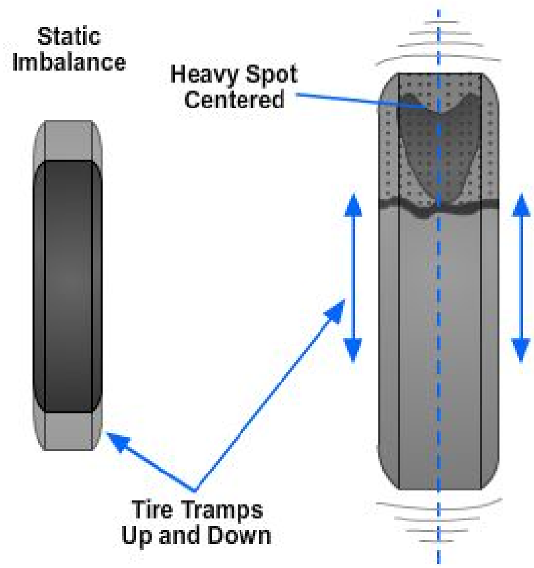

Figure 14-40 — Static imbalance.

- Static imbalance (*Figure 14-40*), also called wheel tramp or hop, lies in the plane of wheel rotation, which causes the tire to vibrate up and down. For a wheel and tire assembly to be in static balance, the weight must be evenly distributed around the axis of rotation.

To static balance a wheel and tire assembly, add wheel weights opposite the heavy area of the wheel. If a large amount of weight is needed, add half to the outside and the other half to the inside of the wheel. This will keep the dynamic balance of the tire. However, when dynamically balancing a wheel and tire assembly, you must add the weights exactly where needed (*Figure 14-41*).

A wheel-balancing machine is used to determine which part of a wheel

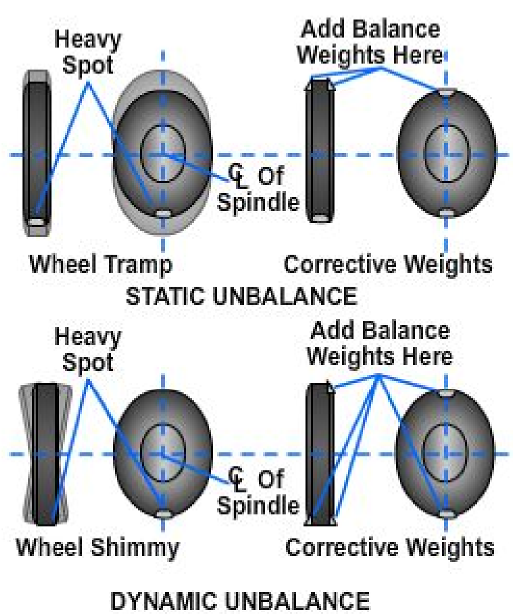

Figure 14-41 — Where to add weights to a wheel.

assembly is heavy. The three types of balancing machines are as follows:

- Bubble balancer is the most common type of balancer used by the NCF (*Figure 14-42*). This type of balancer will ONLY statically balance a wheel assembly. The wheel assembly must be removed from the vehicle and placed on the balancer. An indicating bubble on the machine is used to locate the heavy area of the assembly. Wheel weights are added to the assembly until the bubble CENTERS on the crosshairs of the machine.
- Off-the-vehicle balancer (spin balancer) can statically and dynamically balance a wheel assembly. The wheel assembly is removed from the vehicle and mounted on the balancer. The assembly is then spun at a high rate of speed. The machine detects any vibration of the assembly and indicates where the wheel weights are to be added. After adding the weights to the assembly, spin the assembly to again check for vibration.

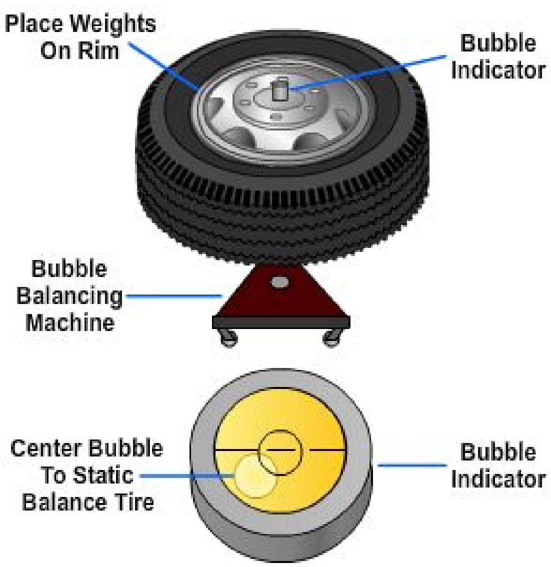

Figure 14-42 — Bubble balancer.

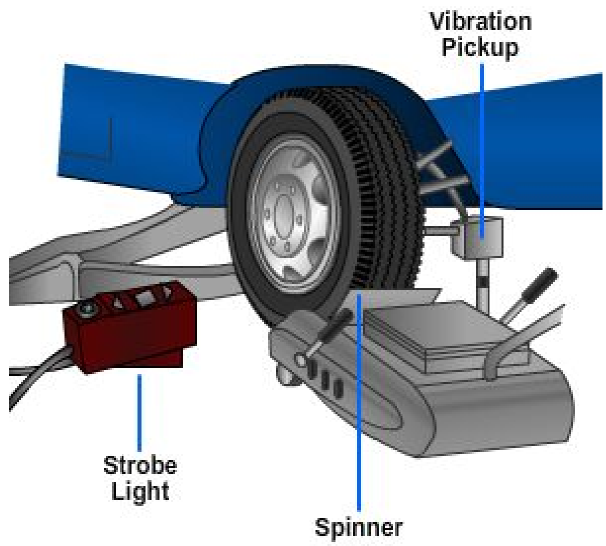

Figure 14-43 — On the vehicle balancer.

- On-the-vehicle balancer (spin balancer) is also used to balance a tire statically and dynamically (*Figure 14-43*). An electric motor is used to spin the wheel assembly, and either an electronic pick-up unit or hand-operated device is used to determine the location for the wheel weights. An on-the-vehicle type balancer is desirable because it can balance not only the wheel assembly, but also the wheel cover, brake disc or drum, and lug nuts. Everything is rotated as a unit.

5.9.0 Troubleshooting

Tire problems usually show up as vibrations, abnormal wear patterns, abnormal noises, steering wheel pull, and other similar symptoms. In some cases, you may need to operate the vehicle to verify the problem. Make sure that symptoms are NOT being caused by steering, suspension, or front-wheel alignment problems.

When inspecting tires, you should look closely at the outer sidewall, tread area, and inner sidewall for bulges, splits, cracks, chunking, cupping, and other abnormal wear or damage. If problems are found before repairing or replacing the tire, determine what caused the failure.

5.9.1 Tire Impact Damage

Tire impact damage or road damage includes tears, punctures, cuts, and other physical injuries. Depending upon the severity of the damage, the tire must either be repaired or replaced.

5.9.2 Tire Wear Patterns

Tire wear patterns can be studied to determine the cause of abnormal tread wear. By inspecting the tread wear, you can determine what parts should be serviced, repaired, or replaced. Common tread wear patterns are as follows (*Figure 14-44*):

- Feathering is caused by erratic scrubbing against the surface of the road when the tire is in need of toe-in or toe-out alignment correction (*Figure 14-44, View A*).
- Overinflation causes fast center line wear in bias and bias belted tires (*Figure 14-44, View B*). In this case, the center of the tread has more contact with the road and wears faster than the outer area of the tread.
- Underinflation causes the outer tread areas (shoulders) of the tire to have more contact with the road; therefore, they wear faster than the center area of the tread (*Figure 14-44, View C*).
- One-side wear is caused by excessive camber, which means that the tire is leaning too much to the inside or outside (*Figure 14-44, View D*). This places all the work on one side of the tire, resulting in excessive wear.
- Cupping is caused by several problems, such as imbalanced wheels, faulty shock absorbers, faulty ball joints, or a combination of these troubles (*Figure 14-44, View E*).

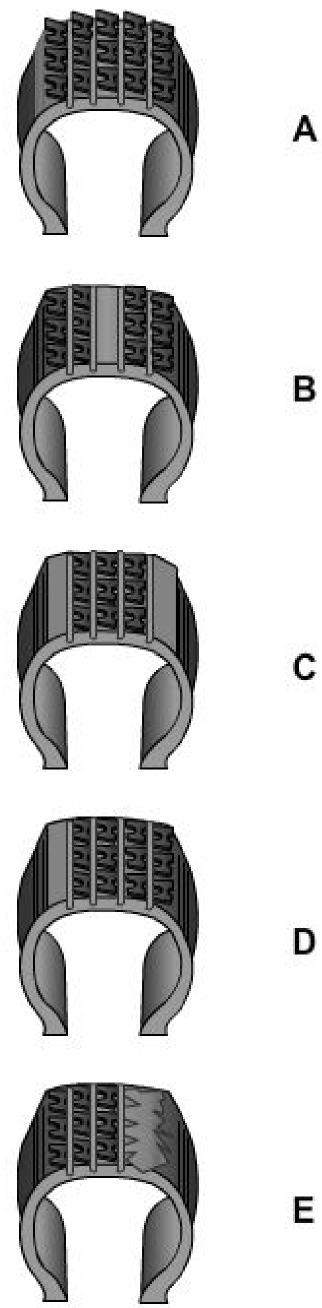

Figure 14-44 — Tire wear patterns.

5.9.3 Tire Inflation Problems

The correct tire inflation pressure is important to the service life of the tire. Proper inflation is required to ensure that the tread of the tire fully contacts the road surface. This condition allows for even wear across the tread, therefore resulting in increased tire life and improved handling and safety. Tire over inflation causes the center area of the tread to wear quickly. The high pressure causes the body of the tire to stretch outward, pushing the center of the tread against the road surface. This action lifts the outer edges of the tread off the road. An overinflated tire produces a rough or hard ride. It is also more prone to impact damage.

Tire under inflation is a very common and destructive problem. This condition wears the outer edges of the tread (shoulders) because low pressure allows the sidewalls of the tire to flex, which builds up heat during operation. The center of the tread flexes upward and does not touch the surface of the road. Under inflation will cause rapid tread wear, loss of fuel economy, and possibly ply separation (plies tear away from each other).

Uneven tire inflation pressure can cause steering wheel pull. For example, when a vehicle that has the left front tire underinflated and the right front tire properly inflated, the vehicle has a tendency to pull to the left. The low air pressure in the left tire has more rolling resistance. This action tends to pull the steering wheel away from the normally inflated tire.

5.9.4 Tire Vibration Problems

When one of the front tires is vibrating, it can be felt in the steering wheel. When one of the rear tires is vibrating, the vibration can be felt in the center and rear of the vehicle. Tire vibration can be attributed to several problems, such as out-of-balance condition, ply separation, tire run out, a bent wheel, or tie cupping.

5.9.5 Tire and Wheel-Bearing Noise

Tire noise usually shows up as a whine due to abnormal tread wear or a thumping sound caused by ply separation. Tire replacement is required to correct these problems.

Wheel-bearing noise is produced by dry, worn wheel bearings. The bearing will make a steady humming type sound. This is due to the rollers or balls being damaged from lack of lubrication and being no longer smooth. To check for a worn wheel bearing, raise and secure the vehicle, and rotate the tire by hand. Feel and listen carefully for bearing roughness. Also, wiggle the tire back and forth to check for bearing looseness. It may be necessary to disassemble the wheel bearing to verify the problem.

Test your Knowledge (Select the Correct Response)

5. What type of tire has the plies running at an angle from bead to bead?

   A. Bias ply
   B. Radial
   C. Belted bias
   D. Belted radial

6.0.0 WHEEL ALIGNMENT

The term alignment means being positioned in a straight line. Relating to vehicles, alignment means to position the tires so they roll freely and evenly over the road surface. The main purpose of wheel alignment is to make the tires roll without scuffing, slipping, or dragging under all operating conditions. Correct wheel alignment is essential to vehicle safety, handling, extension of tire life, and maximum fuel economy.

The different types of wheel alignments are front end alignment, thrust angle alignment, and four-wheel alignment.

- In a front end alignment, the front only is checked. This is fine in some cases, but are the front tires properly positioned in front of the rear tires?
- With the thrust angle alignment, the wheels are squared to each other. This action will eliminate “dog tracking” that you may have seen on a vehicle that appears to be going down the road with the rear end a foot over from the front.

- The best way to align a vehicle is a four-wheel alignment. This alignment not only does what the thrust angle alignment does but also includes adjusting the settings on the rear of the vehicle as well as the front.

Not all vehicles are fully adjustable, so before any alignment always consult the manufacture's service manual. Regular wheel alignments will save you as much in tire wear as they cost and should be considered routine, preventive maintenance.

6.1.0 Steering Geometry

Steering geometry is the term manufacturers use to describe steering and wheel alignment. The six fundamental angles or specifications that are required for a proper wheel alignment are caster, camber, toe, steering axis inclinination, toe-out on turns, tracking, and scrub radius.

6.1.1 Caster

Caster is the steering angle that uses the weight and momentum of the vehicle's chassis to lead the front wheels in a straight path (*Figure 14-45*). Caster is the backward or forward tilt of the steering axis that tends to stabilize steering in a straight direction by placing the weight of the vehicle either ahead or behind the area of tire-to-road contact.

Caster controls where the tire touches the road in relation to an imaginary center line drawn through the spindle support. It is NOT a tire wear angle. The basic purposes for caster are as follows:

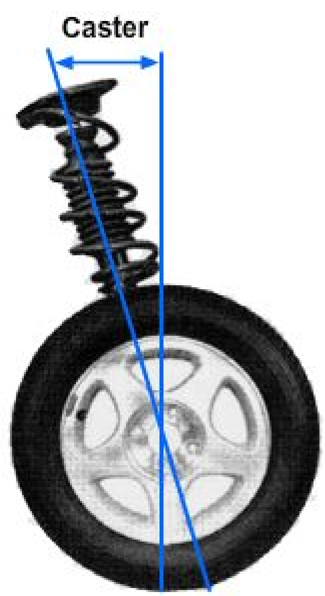

Figure 14-45 — Caster angle.

- To aid directional control of the vehicle.
- To cause the wheels to return to the straight ahead position.
- To offset road crown pull (steering wheel pull caused by the slope of the road surface).

Caster is measured in DEGREES starting at the true vertical (plumb line). Manufacturers give specifications for caster as a specific number of degrees positive or negative. Typically, specifications list more positive caster for vehicles with power steering and more negative caster for vehicles with manual steering (to ease steering effort). Depending upon the vehicle manufacturer and type of suspension, caster may be adjusted by using wedges or shims, eccentric cams, or adjustable struts.

Negative caster tilts the top of the steering knuckle toward the front of the vehicle. With negative caster, the wheels will be easier to turn. However, the wheels tend to swivel and follow imperfections in the road surface.

Positive caster tilts the top of the steering knuckle towards the rear of the vehicle. Positive caster helps keep the wheels of the vehicle traveling in a straight line. When you turn the wheels, it lifts the vehicle. Since this takes extra turning effort, the wheels resist turning and try to return to the straight-ahead position.

6.1.2 Camber

Camber is the inward and outward tilt of the wheel and tire assembly when viewed from the front of the vehicle. It controls whether the tire tread touches the road surface evenly. Camber is a tire-wearing angle measured in degrees. The purposes for camber are as follows:

- To aid steering by placing vehicle weight on the inner end of the spindle.
- To prevent tire wear on the outer or inner tread.
- To load the larger inner wheel bearing.

Positive and negative camber is measured from the true vertical (plumb line) (*Figure 14-46*). If the wheel is aligned with the plumb line, camber is zero.

With positive camber, the tops of the wheels tilt outward when viewed from the front. With negative camber, the tops of the wheels tilt inward when viewed from the front.

Figure 14-46 — Camber angle.

Most vehicle manufacturers suggest a slight positive camber setting from a 1/4 to a 1/2 degree. Suspension wear and above normal curb weight caused by several passengers or heavy loads tend to increase negative camber. Positive camber counteracts this.

6.1.3 Toe

Toe is determined by the difference in distance between the front and rear of the left and right side wheels (*Figure 14-47*). Toe controls whether the wheels roll in the direction of travel. Of all the alignment factors, toe is the most critical. If the wheels do NOT have the correct toe setting, the tires will scuff or skid sideways. Toe is measured in fractions of an inch or millimeters.

Toe-in is produced when the front wheels are closer together in the front than at the rear when measured at the hub height. Toe-in causes the wheels to point inward at the front.

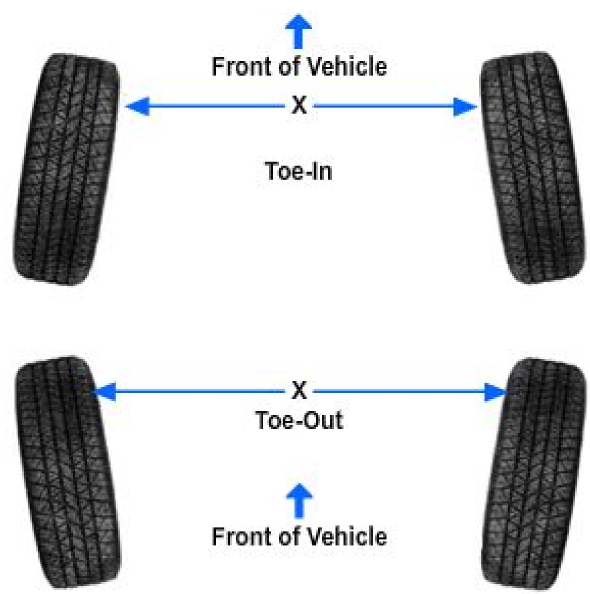

Figure 14-47 — Toe-in and out.

Toe-out results when the front of the wheels are farther apart than the rear. Toe-out causes the front of the wheels to point away from each other.

The type of drive (rear or front wheel) determines the toe settings. Rear-wheel drive vehicles are usually set to have toe-in at the front wheels. This design is due to the front wheels moving outward while driving, resulting in toe-out. If the wheels are adjusted for a slight toe-in (1/16 to 1/4 in.), the wheels and tires will roll straight ahead when driving.

Front-wheel drive vehicles require different adjustment for toe, due to the front wheels driving the vehicle and being pushed forward by engine torque. This makes the wheel toe-in or point inward while driving. To compensate for this, front-wheel drive vehicles have the front wheels adjusted for a slight toe-out (1/16 inch). This adjustment will give the front end a zero toe setting as the vehicle travels down the road.

6.1.4 Steering Axis Inclination

Steering axis inclination (SAI) is the angle away from the vertical formed by the inward tilt of the kingpin, ball joints, or MacPherson strut tube (*Figure 14-48*). Steering axis inclination is always an inward tilt regardless of whether the wheel tilts inward or outward.

Steering axis inclination is NOT a tire-wearing angle. As with caster, it aids directional stability by helping the steering wheel to return to the straight-ahead position. Steering axis inclination is NOT adjustable. It is designed into the suspension of the vehicle. If the angle is not correct, then the suspension system should be checked for damaged or worn parts. Replace the parts to correct the problem.

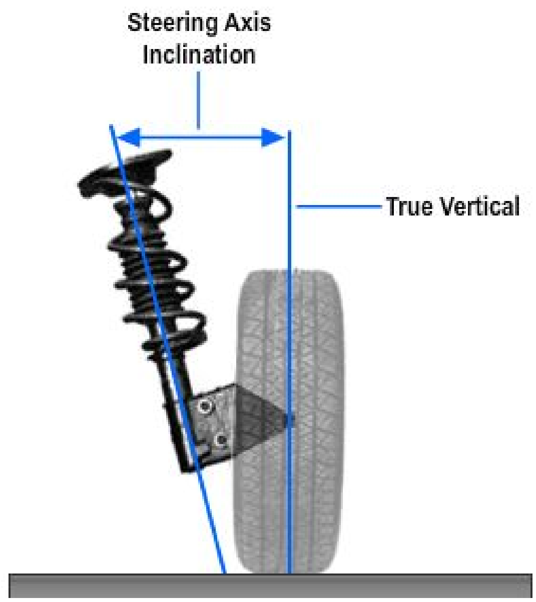

Figure 14-48 — Steering axis inclination.

6.1.5 Toe-Out On Turns

Toe-out on turns, also known as turning radius angle, is the amount the front wheels toe-out when turning corners. As the vehicle goes around a turn, the inside tire must travel in a smaller radius circle than the outside tire. To accomplish this, the steering arms are designed to angle several degrees inside of the parallel position. The exact amount depends on the tread and wheelbase of the vehicle and on the arrangement of the steering control linkage. Toe-out on turns is NOT an adjustable angle. If the angle is incorrect, it is an indication of damaged steering components.

Figure 14-49 shows toe-out on turns. Note how each front wheel turns a different number of degrees. This prevents tire scrubbing and squeal by keeping the tires rolling in the right direction on corners.

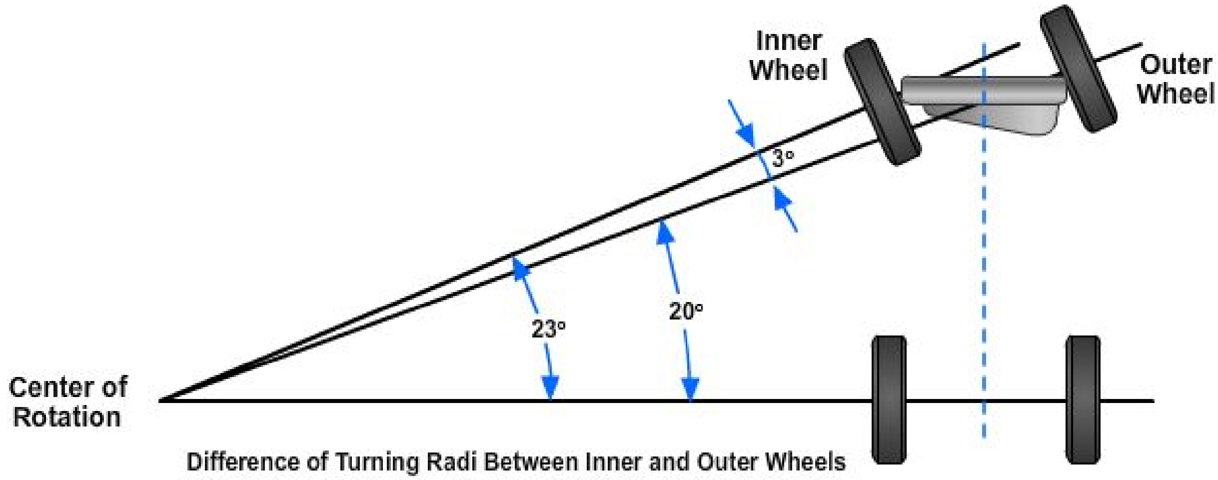

Figure 14-49 — Toe out on turns.

6.1.6 Tracking

Tracking is the ability of the vehicle to maintain a right angle between the center line of the vehicle and both front and rear axles or spindles (*Figure 14-50*). (The rear of the vehicle should follow the front wheels.) With improper tracking, the vehicle rear tires do NOT follow the tracks of the front tires. This causes the vehicle body or frame to actually shift partially sideways when moving down the road. Poor tracking will increase tire wear, lower fuel economy, and upset handling.

Improper tracking has many causes, such as shifted or broken leaf springs, bent or broken rear axle mounts, bent frame, bent steering linkage, or a misadjusted front end alignment.

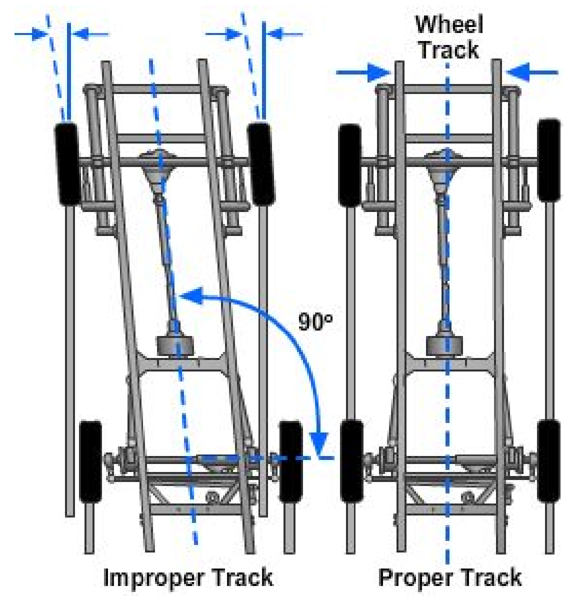

Figure 14-50 — Tracking.

6.1.7 Scrub Radius

The scrub radius, sometimes called steering offset, is the distance between the lines of steering axis and the center line of the wheel at the contact point on the road. These lines are determined by drawing by a line through the center of the upper and lower ball joints, or the center line of the strut all the way to the road. The second line is drawn through the center of the tire, up and down as the tire sits on the road. The point at which these two lines intersect is known as the scrub radius.

The scrub radius is not adjustable and cannot be measured. The scrub radius can be zero, positive, or negative. A zero scrub radius results when the two lines intersect at the road surface. A positive scrub radius means that the two lines intersect below the surface of the road, and a negative means that the lines intersect above the surface of the road.

Negative scrub radius will cause the tire to toe-in during acceleration, braking, and traveling over bumps in the road. Zero scrub radius is acceptable. Positive scrub radius is less desirable because it causes the wheel to toe-out during acceleration, braking, or going over bumps and causes instability of the vehicle.

A bent spindle or changing the tire size can affect the center line location of the wheel. The height of the tire can also change the scrub radius, which can negatively affect the steering control. When larger diameter tires are installed on a vehicle, the scrub radius becomes positive, and the wheels tend to toe-out, which causes the vehicle to wander, handle poorly, and wear out the tires faster.

6.2.0 Wheel Alignment Tools and Equipment

The most basic types of equipment for wheel alignment are the turning radius gauge, the caster-camber gauge, and the tram gauge. These are the least complicated of all alignment equipment and easily illustrate the fundamentals for wheel alignment.

In larger shore facilities these basic types of equipment are normally replaced with a large alignment rack. The alignment rack consists of ramps, turning radius gauges, and specialized equipment for measuring alignment angles.

6.2.1 Turning Radius Gauges

Turning radius gauges measure how many degrees the front wheels are turned right or left (*Figure 14-51*). They are used when measuring caster, camber, and toe-out on turns.

The portable type turning radius gauges are the most common in the Naval Construction Force. However, they are also mounted on alignment racks as integral units.

The front wheels of the vehicle are centered on the turning radius gauges. With the front wheels centered, the locking pins are pulled out, which allows the gauge and tire to turn together. The pointer on the gauge will indicate how many degrees the wheels have been turned.

Figure 14-51 — Portable turning radius gauge.

The procedures for checking toe-out on turns using turning radius gauges are as follows:

1. Center the front tires of the vehicle on the turning radius gauges and remove the locking pins.
2. Turn one of the front wheels until the gauge reads 20 degrees.
3. Read the number of degrees showing on the other gauge. Check toe-out on turns on both right and left sides. Note the readings.
4. If not within the manufacturer's specifications, check for bent or damaged components.

6.2.2 Caster-Camber Gauge

The caster-camber gauge is used with the turning radius gauge to measure caster and camber in degrees. The caster-camber gauge either fits on the hub magnetically or may be mounted on the wheel with an adapter (*Figure 14-52*). Caster and camber are adjusted together since one affects the other.

The procedures for using a caster-camber gauge for measuring caster are as follows:

1. With the vehicle centered on the turning radius gauges, turn one of the front wheels inward until the turning radius gauge reads 20 degrees.
2. Turn the adjustment knob on the caster-camber gauge until the bubble is centered on zero. Then turn the wheel out 20 degrees.
3. The degree marking next to the bubble will equal the caster of that front wheel. Compare the reading to the manufacturer's specifications and adjust as needed.
4. Repeat this operation on the opposite side of the vehicle.

Figure 14-52 — Caster-camber gauge attached to a wheel.

The procedures for using a caster-camber gauge for measuring camber are as follows:

1. With the vehicle on a perfectly level surface, turn the front wheels straight ahead until the turning radius gauges read zero.
2. Read the number of degrees next to the bubble on the camber scale of the caster-camber gauge. This will show camber for that wheel. If not within the manufacturer's specifications, adjust the camber.
3. Double check the caster readings, especially when an excessive amount of camber adjustment is required.

NOTE

If shims are used to adjust camber, add or remove the same number of shims from the front and rear of the control arm. This will keep the caster set correctly.

6.2.3 Tram Gauge

The tram gauge is a metal rod or shaft with two pointers used to compare the distance between the front and rear of the tires of the vehicle for toe adjustment (*Figure 14-53*). The pointers slide on the gauge so they can be set to the distance between the tires. The tram gauge will indicate toe-out or toe-in in inches or millimeters.

Figure 14-53 — Tram gauge.

The procedures for using a tram gauge for measuring toe are as follows:

1. Raise the front wheels of the vehicle and rub a chalk line all the way around the center rib on each tire.
2. With a scribing tool, rotate each tire and scribe a fine line on the chalk line. This will give you a very thin reference line for measuring the distance between the tires.
3. Lower the vehicle back on the turning radius gauges.
4. Position the tram gauge at the back of the tires. Move the pointers until they line up with the scribe marks on the tires.
5. Without bumping the tram gauge pointers, reposition the gauge to the front of the tires. The difference between the lines on the front and rear of the tires shows toe.

If the lines on the front of the tires are closer together than on the rear, the wheels are toed-in. If the lines are the same distance apart at the front and rear, toe is zero. Use the manufacturer's service manual for specifications and adjustment procedures.

Test your Knowledge (Select the Correct Response)

6. Correct wheel alignment is essential to vehicle safety, handling extended tire life and _______?

A. Achieving maximum fuel economy
B. Achieving maximum speed
C. Achieving maximum ride height
D. Achieving maximum turning radius

7.0.0 BODY REPAIR

The automotive body provides protection for the engine, power train components, operator, and any cargo or passengers. At the same time, it adds strength to the frame and provides adequate vision for the operator. Last but not least, the body design provides a pleasant outward appearance.

For military vehicles, appearance is secondary. The Naval Facility Engineering Command (NAVFAC), which controls all Navy vehicles, states that transportation equipment will be repainted when inadequate protection is afforded against rust and corrosion. It also states that spot painting should be used instead of complete painting unless necessary for protection of the entire vehicle.

Part of your job as a Construction Mechanic is to perform body maintenance of the vehicles assigned to your command. In order to perform this task, you must know the procedures used for straightening fenders and body panels. Preparation and painting of the vehicle are other important tasks associated with this responsibility.

7.1.0 Body Tools

Regardless of whether the vehicle is in need of extensive bodywork or has a dented fender, it is desirable to have a number of special tools. One of the most important tools required to repair heavily damaged areas is a portable hydraulic jack (porta-power) (*Figure 14-54*). The porta-power is provided with a number of adapters or accessories that will allow you to use it in many types of body repair work. When applied as shown in *Figure 14-55*, this tool will force the damaged area to return to near original shape and save many hours of labor.

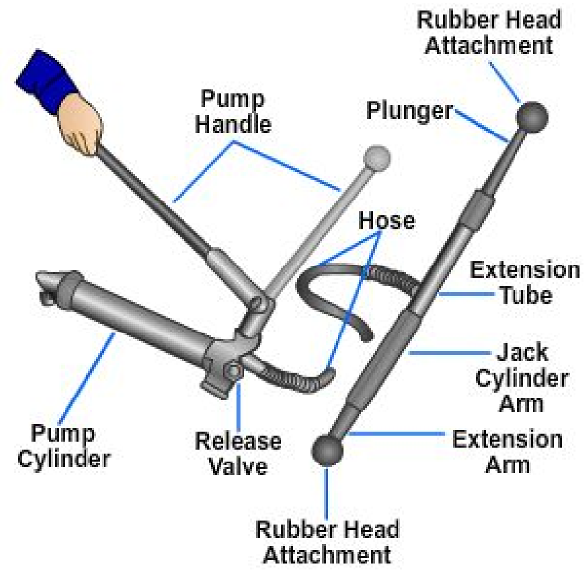

Figure 14-54 — Portable hydraulic jack.

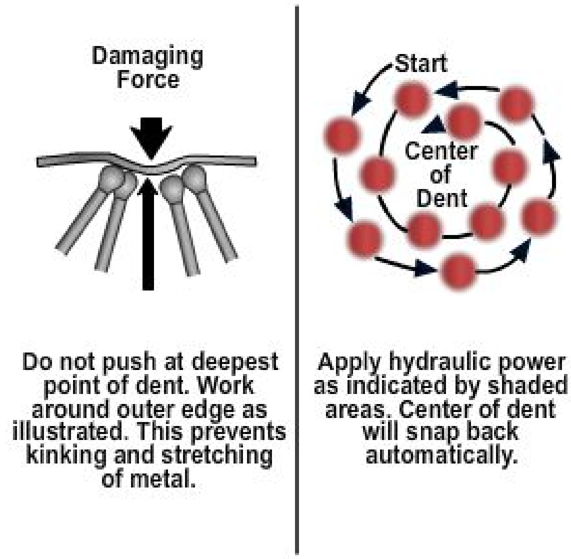

Figure 14-55 — Pushing a dent out using a portable hydraulic jack.

Spoons, dinging hammers, and dolly blocks are the common working tools found in the body shop (*Figure 14-56*). These tools are used to remove dents and smooth out and shape damaged areas.

NOTE

Make sure the surfaces of the spoons, hammers, and dollies are free from scratches and/or dents. Surface defects on these tools will cause similar defects in the sheet metal they are used on. To remove surface defect on these tools, use a file and fine grit sandpaper until you have a smooth surface.

Figure 14-56 — Hammers, spoons, and dolly blocks.

With these tools and experience you will be able to remove the dents and creases while restoring the body to a like-new condition. The ease and speed with which you can straighten the sheet metal is dependent on starting the repair work at the right point and correctly using the tools. If this is done, the amount of “dinging” (light tapping of the metal with a hammer) required to remove the dent is reduced considerably. As metal is dinged and formed, a certain amount of stretching occurs. This causes additional work when nearing completion of the repair. Always remember, when straightening a damaged panel, remove the damage in reverse order of how it occurred.

7.2.0 Removing Dents

Before attempting any body repairs, scrape off any undercoating or foreign matter located in the area to be repaired. Dirt or undercoating will cake on the dolly block. No amount of hammering will produce a smooth surface when this occurs. Next, to protect the hammer, make sure the outer side is clean. Without prior body repairing experience, a mechanic will usually start applying pressure at the spot where the panel was struck first and is depressed the most. The correct method is to apply pressure at the ridge farthest from the point of impact. To understand the procedure clearly, refer to the damaged panel in *Figure 14-57*.

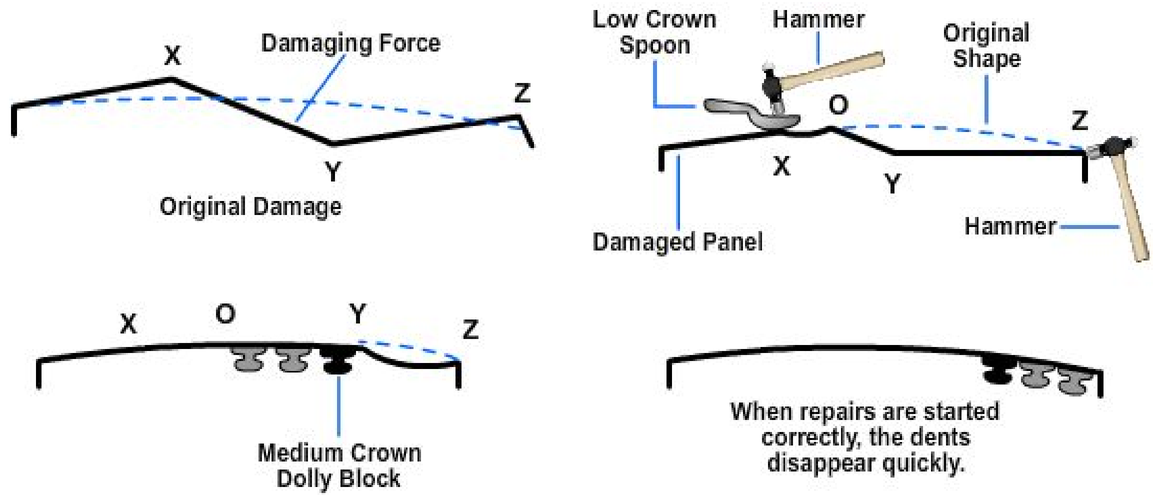

Figure 14-57 — Proper method for repairing a damaged body panel.

Assume that the original form of the panel is shown as the dotted line. Point Y is where it was struck, and X is a ridge that was formed last. With the use of a spoon and hammer or mallet, place the spoon on the ridge (X) and strike it with the hammer. Aim your hammer blows directly at the ridge (X). By following the ridge with the spoon and hammer, you will find that the ridge will gradually disappear while the major portion of the depression at point Y will spring back and very closely resemble the original contour of the panel.

Using a dolly block with the same general curvature as the panel, place it under the panel at point O and strike the dent as shown. In this way, the dolly block acts as a hammer and raises the dented portion to the original contour as the dolly block is gradually moved toward point Z. The most common mistake made by an inexperienced body repairman is trying to do all the work with one blow of the dolly. All that is necessary of the hammer or dolly is to press the metal back into position. A number of light blows with the hammer or dolly are better than a few heavy ones. Heavy blows result in the metal stretching excessively during the straightening process. This requires that the panel be shrunk later to remove bulges.

When working with the hammer, apply blows rapidly with a pulling action so the hammer tends to slide as it contacts the metal. Above all, do not try to rush the job by striking the metal too heavily. *Figures 14-58* and *14-59* show the procedures for removing dents when performing bodywork. Use of a flat-faced hammer should be confined to the flat or nearly flat surfaces and the outside of curved surfaces. Hammers with crowned faces are for use on concave surfaces only.

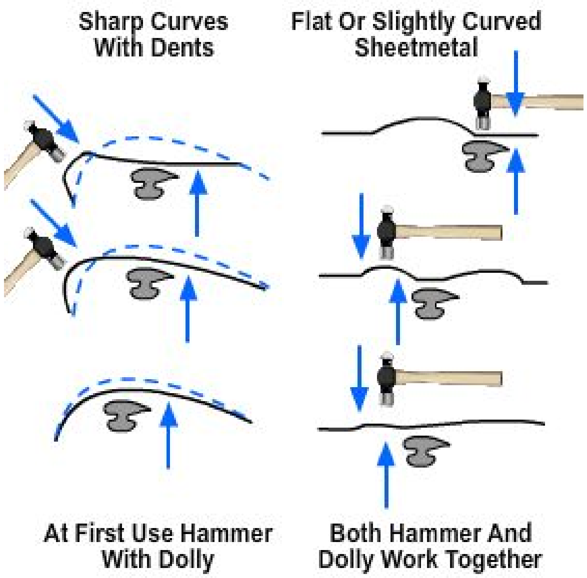

Figure 14-58 — Using a hammer and dolly to remove a dent.

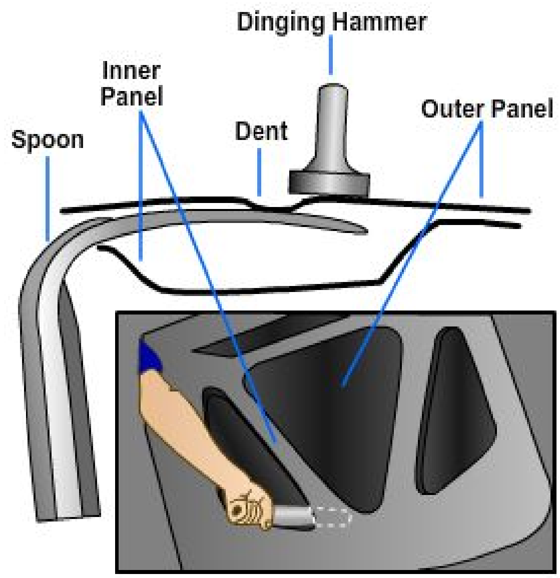

Figure 14-59 — Using a spoon and hammer to remove a dent.

7.3.0 Replacing Sheet Metal

Generally, a severely damaged panel will be replaced or repaired by cutting out the damaged area and replacing it with sheet metal. Should you have to repair a heavily damaged body panel, there are a few things you should consider before starting the job.

The first and most important consideration is to determine the direction of force that caused the damage. This will enable you to use the hydraulic jack and its attachments to push the panels back into a near original position. At the same time, the braces holding the sheet metal will move back to their original position and allow access to any bolts and fasteners that must be removed to disassemble the damaged body parts. Once you have reached this point, you must determine if the damaged panel is to be repaired or replaced.

If you decide to replace the damaged panel, make sure any braces that support the panel are ordered also. New braces will assist in aligning the new panels with the rest of the body. Should only a portion of the damaged panel be replaced, an oxygas cutting and welding outfit or a cut off wheel will be required to remove the damaged portion and weld the new sheet metal into position.

NOTE

Complete instructions on the use and care of oxygas cutting and welding outfit are contained in the current edition of the Steelworker training manuals. Consult these manuals for the proper method for adjusting and using the cutting and welding tips.

The procedures for replacing a portion of a damaged panel are as follows:

- Determine the amount of damaged area to be removed.
- Once the section of the damaged panel has been removed, straighten the remaining portion to the original contour.

- Place a piece of sheet metal over the area that is cut away. Mark the new sheet metal so that when you cut on the lines drawn, the piece will be slightly larger than the area being replaced.
- With the new piece of sheet metal held in place by clamps, weld the sheet metal into place. Work out to the sides then down the sides. Make a series of spot welds about one inch apart to reduce distortion. Then go back and connect the spot welds. Be sure to stagger the welds to further reduce distortion.
- With the new sheet metal welded into place, grind the weld down using a disc sander. Exercise care while sanding to prevent burning or cutting holes in the sheet metal.

7.4.0 Preparing the Surface for Painting

Before actual painting begins, it is essential that you prepare the surface for the paint by removing all traces of wax, grease, oil, and dirt. If the paint on the vehicle is of poor quality or deteriorated, remove it. In this final preparation of the body before applying paint, you have several methods to choose from. The method that is selected depends on the condition of the existing paint, the equipment available, and the quality of the desired finished product.

If the paint on the vehicle is in good condition (with good adherence and without surface defects), go over the surface with fine sand paper (usually a 400 grit sand paper is recommended).

To remove the paint to the metal, start with a coarse grit (usually 36 grit) and work your way up to a fine grit to remove any scratches in the metal.

If the paint is to be removed from only a portion of the panel, taper the sanded area down into the old paint to produce a featheredge. Follow up with a 150 grit paper in a block sander, and complete the featheredge by water sanding using wet or dry paper of 280 or 320 grit.

NOTE

Some manufacturers of abrasive paper advise different grits with variations of the above procedure. Follow the instructions of the manufacturer.

For removing paint from the entire vehicle, sandblasting is the preferred method. Among the advantages claimed for the sandblasting method are speed, low cost, and a surface that has good paint adherence.

After removing the old paint, clean the surface with a cleaning agent. If none is available, a lint-free cloth saturated with paint thinner can be used to wipe down the surface. This will help the new paint to adhere to the metal and will remove dust and other foreign matter.

Apply the primer coat as soon as possible after the paint is removed. This is particularly important when the surface has been sandblasted because the surface is practically in a raw state and quickly starts rusting.

7.5.0 Painting

Equipment shall be repainted when inadequate protection is afforded against rust and corrosion. Equipment will NOT be repainted merely to change the color or gloss characteristics if the finish is serviceable. Spot painting, in lieu of completely refinishing previously painted sections, should be done whenever practicable. Bare surfaces of body sections and sheet metal exposed by deterioration of paint or by accidents should be spot painted immediately to prevent deterioration of the metal.

WARNING

When using any paint product, particularly lead-base paint, all current health and safety regulations should be strictly enforced. Contact the activity health/safety department/office to obtain all applicable regulations and instructions pertaining to a safe painting environment.

All Navy equipment should be treated and painted in accordance with MIL-HDBK-1223. Equipment painting should meet all specifications and standards referenced within MIL-HDBK -1223. Colors and color numbers that are authorized for use when painting CESE are as follows:

- YELLOW 13538
- GREEN 14064
- SAND 33303
- BLACK 17038
- WHITE 17886
- GRAY 16187
- RED 11105

Before painting, apply a coat of primer to prevent peeling and flaking where bare metal is exposed. The primer serves as a bond between the paint and the metal of the vehicle. Each coat of primer that is applied should be allowed to dry and must be sanded lightly between coats. There may be occasions to use two coats of primer, but normally one coat is adequate.

Shake or stir paint and primer thoroughly, thin it with a thinning agent, and run it through a strainer or filter when using a spray gun. One of the "musts" of spray painting is that the paint should have the correct viscosity. This can be determined by following the instruction on the paint can. Too many painters determine the viscosity by the rate at which the paint runs from the stirring stick. This can lead to plenty of trouble, since only a slight change in viscosity can spoil an otherwise good job. This happens because the amount of thinner not only determines the thickness of the coat but also influences the evaporation rate between the time the material leaves the spray gun and the time it contacts the body panel.

NOTE

High viscosity paint produces paint sag and orange peel, while low viscosity paint produces improper flow out and waste of thinner. To avoid these problems, take care to measure the proportions of thinner and paint accurately in a graduated measuring cup.

The temperature at which the spraying is done is also an important factor in turning out a good job. This applies not only to the temperature of the shop but also to the temperature of the vehicle. Shop temperatures should be maintained at approximately 70°F. Whenever possible, bring the vehicle into the shop well in advance of painting so that it becomes the same temperature as the shop. Spraying paint on a surface that is too cold or too hot from being in the sun will upset the flowing time of the material and will cause orange peel and poor adherence to the surface.

Another important factor in doing a good job is the thickness of the paint film on the surface. Obviously, a thick film takes longer to dry than a thin one. As a result, the paint will sag, ripple, or orange peel. Ideally, you should produce a coat that will remain wet long enough for proper flow out, but no longer. The amount of material you spray on a surface with one stroke of a gun will depend on the width of the fan, the distance of the gun from the sprayed surface, the air pressure, and the amount of thinner used.

In addition, the speed of the spray stroke will also affect the thickness of the coat. The best procedure is to adjust the gun to obtain a wet film which will remain wet only long enough for good flow out. Get the final thickness by spraying an additional coat after the first one has dried.

Nearly all standard spray guns are designed to provide optimal coverage when held at a distance of 8 to 12 inches from the surface to be painted. When the gun is held too close, the air pressure tends to ripple the wet film, especially if the film is too thick. If the distance is too great, a large percentage of the thinner will be evaporated in the spraying operation. Orange peel or a dry film will result because the spray droplets will not have opportunity to flow together.

It is imperative to hold the spray gun at the specified distance from the work. In addition, do NOT tilt or hold the spray gun at an angle. Also, never swing the spray gun in an arc, but move it parallel to the work. The only time it is permissible to fan the gun is when you want the paint to thin out over the edges of a small spot.

Another ingredient that is sometimes added to the paint is "hardener." This substance causes the paint to set and dry much more rapidly than normal. Because a small amount of hardener is all that is required, the instruction on its use must be followed closely. Mixing paint and adding hardener are two critical parts of painting vehicles. Use of the wrong type of thinner, paint, or excessive hardener will cause the paint to fade, peel, or blister within a short period of time after completing the job.

Painting instructions for using chemical agent resistant coating (CARC) and the camouflage painting of CESE equipment are found in the NAVFAC P-404.

7.6.0 Epoxy Fillers

Epoxy fillers (body fillers) are simple to use in that the body portions do not have to be straightened as closely as when making repairs without it. By using the manufacturer’s instructions, you can apply body filler over rough places and form it with a body file or sanding until it conforms to the desired contour. The advantage of using body filler lies in the fact that a badly damaged vehicle can be returned to a like-new appearance quickly and with a limited amount of metal straightening. Additional, the use of thinner metals in the bodies of modern vehicles makes it difficult to reform panels into their original shape. Should you have an opportunity to use an epoxy filler, the recommended thickness of the filler should be kept to approximately 1/8 inch. If more is required, it should be applied in coats and allowed to dry before applying the next coat. Do not exceed an overall thickness of 1/4 inch.

7.7.0 Identification Markings

Once a vehicle has been repainted, you will be required to replace the vehicle identification markings. The placement of registration numbers and other equipment markings for identification purposes, as required by law, are described in the NAVFAC P-404.

Summary

In this chapter, you were introduced to the automotive chassis and its components. You learned about the springs, shock absorbers, and other components that allow the vehicle to pass over uneven terrain. You also learned about the steering mechanism and how it controls the direction of vehicle travel. We further discussed how to complete some body repair and the techniques used to restore body panels. You learned about how these systems operate and how to make adjustments and some repairs. This information will enable you to be a better Construction Mechanic when you have mastered the knowledge of these systems.

Review Questions (Select the Correct Response)

1. Which requirement is NOT satisfied by the components of the vehicle chassis?

    A. Support the vehicle and its payload.
    B. Provide for directional control.
    C. Allow smooth operation over rough terrain.
    D. Enclose the mechanical components and passenger compartment.

2. Why are the side members of many passenger vehicle frames closer together in the front than in the rear?

    A. To supply more rigid support for the engine.
    B. To allow the vehicle to make sharper turns.
    C. To supply a more rigid support for the front wheels.
    D. To reduce vibration from the engine.

3. What type of frame construction allows an increase in the amount of noise transmitted into the passenger compartment?

    A. Ladder
    B. Integrated
    C. Separated
    D. Jack

4. What component of the suspension system prevents the control arm from swinging to the front or rear of the vehicle?

    A. Control arm bushings
    B. Strut rod
    C. Stabilizer bar
    D. Strut

5. In a vehicle equipped with MacPherson struts, what component does the strut assembly replace?

    A. Upper control arm
    B. Lower control arm
    C. Upper damper unit
    D. Steering knuckle

6. What term refers to the stiffness or tension of a spring?

    A. Elastic tolerance
    B. Spring ratio
    C. Elastic deformation
    D. Spring rate

7. As a vehicle goes over a bump, its multileaf springs are held together by the _______.

   A. spring shackles
   B. rebound clips
   C. bumper blocks
   D. clip plates

8. What component in a bogie suspension system distributes the rear load evenly to the axles?

   A. Cross shaft
   B. Trunnion axle
   C. Springs
   D. Torque rods

9. What suspension component when worn will make a clunking or popping sound when the vehicle is turning or driving over a bump?

   A. Ball joint
   B. Strut rod
   C. Control arm
   D. Torsion bar

10. What tool is used to measure the axial play of a ball joint?

   A. Spring gauge
   B. Micrometer
   C. Dial indicator
   D. Outside caliper

11. What condition lowers the height of the vehicle, allowing the body to settle towards the axles?

   A. Faulty struts
   B. Spring fatigue
   C. Weak shock absorbers
   D. Worn control arm bushings

12. What two factors are used to determine steering ratio?

   A. Steering linkage ratio and steering mechanism gear ratio
   B. Turning ratio and steering linkage ratio
   C. Steering mechanism gear ratio and diameter of the pinion gear
   D. Diameter of the worm gear and diameter of the pinion gear

13. Which system is NOT a type of manual steering?

   A. Cam and lever
   B. Rack and pinion
   C. Sector and lever
   D. Worm and nut

14. What ratio does the design of the worm and roller steering gear provide?

A. High steering
B. Low steering
C. Medium steering
D. Variable steering

15. What is the most common type of worm and nut steering gear?

A. Rolling ball
B. Rotating ball
C. Recirculating ball
D. Reducing ball

16. In a manual rack-and-pinion steering gear, what component preloads the rack-and-pinion gear teeth to prevent excessive backlash?

A. Thrust plate
B. Thrust spring
C. Thrust washer
D. Thrust bearing

17. What are the three types of power steering systems?

A. Internal rotor, external spool, and rack-and-pinion
B. Internal spool, external slipper, and rack-and-pinion
C. Integral cylinder, external piston, and rack-and-pinion
D. Integral piston, external cylinder, and rack and pinion

18. What is the most common type of power steering system?

A. Integral piston
B. Integral cylinder
C. Internal spool
D. Internal rotor

19. When you check an idler arm for wear, as a general rule the idler arm should NOT move up and down more than _______ inch.

A. 1/8
B. 1/2
C. 1/3
D. 1/4

20. What are the two basic adjustments that may be made on a manual steering gearbox?

A. Over-center clearance and worm bearing preload
B. Sector bearing preload and pinion clearance
C. Pinion shaft preload and worm shaft clearance
D. Cam clearance and lever bearing preload

21. Which problem is NOT common to the steering system?

    A. Hard steering
    B. Steering wheel play
    C. Steering wheel vibration
    D. Abnormal sounds when turning

22. Which steering problem may be caused by improper frame alignment?

    A. Excessive steering wheel play
    B. Abnormal noises when turning
    C. Hard steering
    D. Steering wheel vibration

23. What are the two basic functions of a tire?

    A. To support the weight of the vehicle and provide adequate traction.
    B. To act as a cushion between the road and the wheel, and provide adequate traction on any road.
    C. To prevent road shock from being felt in the passenger compartment and provide adequate traction.
    D. To provide a means to control the vehicle and to provide traction.

24. What part of the tire has two steel rings encased in rubber that hold the sidewalls against the rim?

    A. Body plies
    B. Tire bead
    C. Belts
    D. Liner

25. What is a major disadvantage of a bias-ply tire?

    A. The strength of the plies decrease traction.
    B. It provides a rough ride on smooth roads.
    C. The body of the tire is too rigid.
    D. It increases rolling resistance.

26. A radial tire has plies running in which direction?

    A. Straight across from bead to bead with stabilizer belts directly beneath the tread
    B. From the sidewall at different angles than the stabilizer belts
    C. At an angle from bead to bead with the stabilizer belts between each ply
    D. Straight across from the sidewall with the stabilizer belts at a different angle

27. What information is presented in a letter-number sequence on the sidewall of a tire?

A. Tire size
B. Treadwear rating
C. Speed rating
D. Load index

28. A tire has a P-metric tire size-rating system. What does the letter "P" indicate?

A. Pneumatic
B. Ply rating
C. Passenger
D. Performance

29. What term refers to the comparison of the height of the tire to the width of the tire?

A. Section width
B. Aspect ratio
C. load index
D. Treadwear rating

30. What factors determine how much of a load a tire can safely carry?

A. Load range and speed index
B. Load index and aspect ratio
C. Load range and the grade of the tire
D. Load index and proper inflation pressure

31. For every 10 degrees Fahrenheit change in ambient temperature, the inflation pressure of a tire will change by _______ psi.

A. 1
B. 2
C. 3
D. 4

32. In 1997, what traction rating was introduced to indicate a greater wet braking traction?

A. A
B. A+
C. AA
D. AAA

33. What temperature resistance grade is the minimum level of performance for all passenger vehicle tires?

A. B
B. D
C. A
D. C

34. For easy identification, a butyl type synthetic rubber tube has a stripe on it that is what color?

A. Green
B. Blue
C. Red
D. White

35. A lug nut has the letter "M" stamped into it. What does the "M" indicate?

A. Military thread
B. Multipurpose thread
C. Metric thread
D. Machine thread

36. In a nondriving wheel bearing and hub assembly, what component extends outward from the steering knuckle?

A. Hub
B. Outer drive axle
C. Spindle
D. Bearing support

37. Using a plug to attempt a tire repair without dismounting the tire is effective only what percentage of the time?

A. 50
B. 60
C. 70
D. 80

38. You should NOT attempt to repair a tubeless tire that has a puncture larger than _______ inch.

A. 1/16
B. 1/8
C. 1/4
D. 1/2

39. What type of tire imbalance will cause the tire to vibrate up and down and from side to side?

A. Static
B. Radius
C. Dynamic
D. Spiral

40. If a large amount of weight is required to static balance a wheel and tire assembly, you should distribute the weight in what manner?

A. Add half to the outside and half to the inside.
B. Add a quarter to the outside and the rest to the inside.
C. Add a quarter to the inside and the rest to the outside.
D. Add exactly where needed.

41. What is the most common type of balancer used by the NCF?

A. Spin balancer
B. On-the-vehicle balancer
C. Bubble balancer
D. Computerized balancer

42. What type of tread wear pattern is caused by excessive camber?

A. Feathering
B. Cupping
C. One-side wear
D. Cornering wear

43. What type of alignment ensures that the wheels are "squared" to each other?

A. Front-end alignment
B. Frame alignment
C. Thrust angle alignment
D. Steering alignment

44. Negative caster tilts the top of the steering knuckle towards the _______ of the vehicle.

A. rear
B. front
C. right side
D. left side

45. What wheel alignment angle is determined by the difference in the distance between the front and the rear of the left and right wheels?

A. Steering axis inclination
B. Toe
C. Tracking
D. Toe-out on turns

46. When you are performing a wheel alignment on a front-wheel drive vehicle, what amount of toe-out is required, in inches?

A. 1/16
B. 1/8
C. 1/4
D. 1/2

47. Which of the following conditions will cause improper tracking?

A. Bent rear axle mount
B. Bent control arm
C. Broken shock mount
D. Loose sway bar

Trade Terms Introduced in this Chapter

frame	A rigid structure formed of relatively slender pieces, joined together to form a major support.
fabricated	To construct by combining or assembling diverse, typically standardized parts.
fish plating	Bolting or welding two pieces of metal over the frame to strengthen the two pieces of the frame.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Modern Automotive Technology 7th Edition, James Duffy, The Goodheart-Wilcox Company, Inc., 2009. (ISBN: 978-1-59070-956-6)

Automotive Chassis Systems 4th Edition, James D. Halderman, Pearson Prentice Hall, 2008. (ISBN-13: 978-0-13-238487-2)

Heavy Duty Truck Systems 4th Edition, Sean Bennet, Delmar Cengage Learning, 2006. (ISBN-13:978-1-4018-7064-5)

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