OBJECTIVES

After studying Chapter 29, the reader will be able to:

1. Prepare for ASE Suspension and Steering (A4) certification test content area “A” (Steering System Diagnosis and Service).
2. Identify steering linkage components.
3. Describe how the movement of the steering wheel causes the front wheels to turn.
4. Describe how to perform a dry park test to determine the condition of steering system components.
5. Perform an under-the-vehicle inspection of the steering system components.
6. List the service procedures for under-the-vehicle steering system service.
7. Explain how to replace steering linkage parts.
KEY TERMS

- Articulation test
- Ball socket assembly
- Center link
- Center take-off rack
- Cross-steer linkage
- Dry park test
- Front steer
- Grease fitting
- Opposite-phase steering
- Parallelogram linkage
- Pitman arm
- RBS
- Rear steer
- Same-phase steering
- Steering dampener
- Steering stops
- SWPS
- Tie rods
- Zerk fitting
The steering linkage relays steering forces from the steering gear to the front wheels.

Most conventional steering linkages use the parallelogram-type design.

A parallelogram is a geometric box shape where opposite sides are parallel and equal distance.

A parallelogram-type linkage uses four tie rods, two inner and two outer (left and right), a center link (between the tie rods), and an idler arm on the passenger side and a pitman arm attached to the steering gear output shaft (pitman shaft).
FIGURE 29–1 Steering movement is transferred from the pitman arm that is splined to the sector shaft (pitman shaft), through the center link and tie rods, to the steering knuckle at each front wheel. The idler arm supports the passenger side of the center link and keeps the steering linkage level with the road. This type of linkage is called a parallelogram-type design.
Why Is a Grease Fitting Sometimes Called a Zerk Fitting?

FREQUENTLY ASKED QUESTION

- In 1922 the zerk fitting was developed by Oscar U. Zerk, an employee of the Alemite Corporation, a manufacturer of pressure lubrication equipment. A zerk or grease fitting is also known as an Alemite fitting.
STEERING LINKAGE

- As the steering wheel is rotated, the pitman arm is moved.
- The pitman arm attaches to a center link.
- At either end of the center link are inboard (inner) tie rods, adjusting sleeves, and outboard (outer) tie rods connected to the steering arm, which moves the front wheels.
- The passenger side of all these parts is supported and held horizontal by an idler arm that is bolted to the frame.
The most common type of steering is the parallelogram. The cross-steer and Haltenberger linkage designs are used on some trucks and vans.

**FIGURE 29–2**
FIGURE 29–3 Typical steering dampener used on a Hummer H2.
STEERING LINKAGE
TIE ROD ENDS

• Tie rod ends connect the steering linkage to the steering knuckles and to other steering linkage components.

• Conventional tie rod ends use a hardened steel ball stud assembled into a hardened steel and thermoplastic bearing.

• An internal preload spring limits the ball stud endplay and helps compensate for ball-and-socket wear.
FIGURE 29–4 (a) A dual bearing design with a preload spring. The use of two bearing surfaces allows for one surface for rotation (for steering) and another surface for pivoting (to allow for suspension up-and-down movement). (b) The nylon wedge bearing type allows for extended lube intervals. Wear is automatically compensated for by the tapered design and spring-loaded bearing.
FIGURE 29–5 (a) A rubber-bonded socket is constructed of a rubber casing surrounding the ball stud, which is then inserted into the socket of the tie rod end. The hole in the socket allows air to escape as the ball stud is installed and there is not a place for a grease fitting. (b) The socket is crimped over the ball so that part of the socket lip retains the stud.
RACK-AND-PINION INNER TIE ROD ENDS

- Inner tie rod end assemblies used on rack-and-pinion steering units require special consideration and often special tools.
- The inner tie rod end is also called a ball socket assembly.
- The inner tie rod assemblies are attached to the end of the steering rack by one of several methods.
FIGURE 29–6 Rack-and-pinion steering systems use a ball-and-socket-type inner tie rod end.
• STAKED
• RIVETED OR PINNED
• CENTER TAKE-OFF RACKS
A variety of methods are used to secure the inner tie rod end socket assembly to the end of the rack.
FIGURE 29–8 Exploded view of a center-take-off-style rack-and-pinion steering gear assembly.
FRONT STEER VERSUS REAR STEER

- **Front steer**, also called *forward steer*, is the term used to describe a vehicle that has the steering gear in front of the front wheel centerline.
  - Having the steering gear located in this position improves handling and directional stability, especially when the vehicle is heavily loaded.
- Front-steer vehicles usually produce an understeer effect that makes the vehicle feel very stable while cornering.
  - If the steering gear linkage is located behind the wheels, it is called **rear steer** and the cornering forces are imposed on the steering in the direction of the turn.
  - This is an oversteer effect.
  - It tends to make the steering easier and makes the vehicle feel less stable.
FIGURE 29–9 In a rear-steer vehicle, the steering linkage is behind the centerline of the front wheels, whereas the linkage is in front on a front-steer vehicle.
FOUR-WHEEL STEERING SYSTEMS

• Some vehicles were equipped with a system that steers all four wheels.
• Two terms are commonly used when discussing four-wheel steering:
  • Same-phase steering
  • Opposite-phase steering
FOUR-WHEEL STEERING SYSTEMS

FIGURE 29–10 Opposite-phase four-wheel steer is usually used only at low vehicle speed to help in parking maneuvers. Sample-phase steering helps at higher speeds and may not be noticeable by the average driver.
FOUR-WHEEL STEERING SYSTEMS

- QUADRASTEER
  - Quadrasteer™ is a four-wheel steering system that dramatically enhances low-speed maneuverability, high-speed stability, and towing capability.

- REAR WHEEL STEERING CONTROL MODULE
- REAR WHEEL STEERING MODE SWITCH
  - REAR WHEEL STEERING MOTOR ASSEMBLY
  - STEERING WHEEL POSITION SENSOR
  - REAR WHEEL POSITION SENSOR
  - STEERABLE REAR AXLE
FIGURE 29–11 Being equipped with four-wheel steer allows a truck to make shorter turns than would otherwise be possible.
FIGURE 29–12 The Quadrasteer system includes many components that all work together.
FIGURE 29–13 Rear steer select switch schematic.
FIGURE 29–14 The dash-mounted select switch showing the three positions for the four-wheel steer system.
FIGURE 29–15 The output of the handwheel sensor digital signal.
FIGURE 29–16 Handwheel analog signal.
FIGURE 29–17 Handwheel position sensor analog signal to control module.
FIGURE 29–18 Handwheel position sensor digital signal to control module.
FIGURE 29–19 A Quadrasteer system showing all of the components. The motor used to power the rear steering rack can draw close to 60 amperes during a hard turn and can be monitored using a Tech 2.
What Is “Goofy Mode”??

FREQUENTLY ASKED QUESTION

- Trucks that are equipped with the Quadrasteer system have a three-position switch on the dash:
  - 1. 2WS
  - 2. 4WS
  - 3. Tow
What Is “Goofy Mode”? 

The Quadrasteer module then determines the right amount of rear steer and in which direction based on vehicle speed and steering wheel angle. If trailer towing mode is selected and the truck is not towing a trailer, the computer will adjust the steering as if there is a trailer and will slightly delay the rear steering action when changing lanes and other maneuvers. As a result, when the steering wheel is turned the front wheels will of course turn in direct proportion to the input from the steering wheel; however, the rear wheels will be delayed in their action to allow the trailer to track properly. If, however, a trailer is not being towed, this delay feels “goofy” and could result in customer concerns about the proper operation of the Quadrasteer system. Be sure that the control switch is placed in the off or normal modes unless a trailer is in fact being towed.
Keeping all joints equipped with a grease fitting properly greased is necessary for long life and ease of steering.

FIGURE 29–20 Greasing a tie rod end. Some joints do not have a hole for excessive grease to escape, and excessive grease can destroy the seal.
STEERING LINKAGE LUBRICATION

- During a chassis lubrication, do not forget to put grease on the steering stop, if so equipped.
- **Steering stops** are the projections or built-up areas on the control arms of the front suspension designed to limit the steering movement at full lock.

**FIGURE 29–21** Part of steering linkage lubrication is applying grease to the steering stops. If these stops are not lubricated, a grinding sound may be heard when the vehicle hits a bump when the wheels are turned all the way one direction or the other. This often occurs when driving into or out of a driveway that has a curb.
DRY PARK TEST

- Since many steering (and suspension) components do not have exact specifications for replacement purposes, it is extremely important that the beginning service technician work closely with an experienced veteran technician.

- While most technicians can determine when a steering component such as a tie rod end is definitely in need of replacement, marginally worn parts are often hard to spot and can lead to handling problems.

- One of the most effective, yet easy to perform, steering component inspection methods is called the dry park test.
FIGURE 29–22 Checking for freeplay in the steering.
Why Do Only a Few Vehicles Use Grease Fittings?

Many years ago, all vehicles were equipped with grease fittings, while today very few vehicles are so equipped. The reasons for this, as given by engineers, include the following:

- It has been determined that the use of the wrong type of grease can cause more harm than good.
- If a grease fitting is used to allow grease to enter the suspension or steering joint, then water can also get inside the joint.
- Grease fittings are often ignored or the greasing of the joint is not performed by the service technician.
- Low-friction joints do not require routine service like the older metal-to-metal joints required.
It is important to check each and every joint and component of the steering system, including the following:

- The intermediate shaft and flexible coupling.
- All steering linkage joints, including the inner tie rod end ball socket.
- Steering gear mounting and rack-and-pinion mounting bushings.
**FIGURE 29–23** All joints should be felt during a dry park test. Even inner tie rod ends (ball socket assemblies) can be felt through the rubber bellows on many rack-and-pinion steering units.
Jounce/Rebound Test

TECH TIP

- All steering linkage should be level and “work” at the same angle as the suspension arms, as shown in A simple test to check these items is performed as follows:
  - Park on a hard, level surface with the wheels straight ahead and the steering wheel in the unlocked position.
  - Bounce (jounce) the vehicle up and down at the front bumper while watching the steering wheel. The steering wheel should not move during this test. If the steering wheel moves while the vehicle is being bounced, look for a possible bent steering linkage, suspension arm, or steering rack.
FIGURE 29–24 The steering and suspension arms must remain parallel to prevent the up-and-down motion of the suspension from causing the front wheels to turn inward or outward.
FIGURE 29–25 The center link should be parallel to the ground.
COMMON WEAR ITEMS

- On a vehicle equipped with a conventional steering gear and parallelogram linkage, typical items that wear first, second, and so on include the following:

<table>
<thead>
<tr>
<th>Steering Component</th>
<th>Estimated Mileage to Wear Out*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Idler arm</td>
<td>40,000–60,000 miles</td>
</tr>
<tr>
<td></td>
<td>(60,000–100,000 km)</td>
</tr>
<tr>
<td>2. Outer tie rod ends</td>
<td>60,000–100,000 miles</td>
</tr>
<tr>
<td>(replaced in pairs only)</td>
<td>(100,000–160,000 km)</td>
</tr>
<tr>
<td>3. Inner tie rod ends</td>
<td>80,000–120,000 miles</td>
</tr>
<tr>
<td></td>
<td>(130,000–190,000 km)</td>
</tr>
<tr>
<td>4. Center link</td>
<td>90,000–130,000 miles</td>
</tr>
<tr>
<td></td>
<td>(140,000–180,000 km)</td>
</tr>
<tr>
<td>5. Pitman arm</td>
<td>100,000–150,000 miles</td>
</tr>
<tr>
<td></td>
<td>(160,000–240,000 km)</td>
</tr>
</tbody>
</table>

*Mileage varies greatly due to different road conditions and levels of vehicle maintenance. This chart should be used as a guide only.
FIGURE 29–26 Typical parallelogram steering linkage. The center link can also be named the relay rod, drag link, or connecting link.
Some center links are equipped with ball-and-socket joints, which can wear. Other center links are manufactured with holes for ball joint studs only. Generally, the center links that do not use joints are unlikely to need replacement unless a joint becomes loose and wears the tapered stud hole. Knowing which style of center link is used will help determine the most likely location to check for excessive steering linkage play.
Wear and Non-wear Center Links

**FIGURE 29–27** Some center links have ball joints while others have tapered socket holes to accept ball joints on the pitman arm, idler arm, and inner tie rod ends.
UNDER-VEHICLE INSPECTION

• After checking the steering system components as part of a dry park test, hoist the vehicle and perform a thorough part-by-part inspection:
  • Inspect each part for damage due to an accident or bent parts due to the vehicle’s hitting an object in the roadway.
  • Idler arm inspection is performed by using hand force of 25 lb (110 N-m) up and down on the arm. If the total movement exceeds 1/4 in. (6 mm), the idler arm should be replaced.
  • All other steering linkage should be tested by hand for any vertical or side-to-side looseness.
  • All steering components should be tested with the wheels in the straight-ahead position.
FIGURE 29–28 To check an idler arm, most vehicle manufacturers specify that 25 pounds of force be applied by hand up and down to the idler arm. The idler arm should be replaced if the total movement (up and down) exceeds 1/4 in. (6 mm).
FIGURE 29–29 Steering system component(s) should be replaced if any noticeable looseness is detected when moved by hand.
FIGURE 29–30 All joints should be checked by hand for any lateral or vertical play.
Bump steer, or orbital steer, is used to describe what happens when the steering linkage is not level: The front tires turn inward or outward as the wheels and suspension move up and down. (Automotive chassis engineers call it roll steer.) The vehicle’s direction is changed without moving the steering wheel whenever the tires move up and down over bumps, dips in the pavement, or even over gentle rises!
Bump Steer

REAL WORLD FIX

• This author experienced bump steer once and will never forget the horrible feeling of not having control of the vehicle. After replacing an idler arm and aligning the front wheels, everything was OK until about 40 mph (65 km/h); then the vehicle started darting from one lane of the freeway to another. Because there were no “bumps” as such, bump steer was not considered as a cause. Even when holding the steering wheel perfectly still and straight ahead, the vehicle would go left, then right. Did a tie rod break? It certainly felt exactly like that’s what happened. I slowed down to below 30 mph and returned to the shop.
Bump Steer

REAL WORLD FIX

- After several hours of checking everything, including the alignment, I discovered that the idler arm was not level with the pitman arm. This caused a pull on the steering linkage whenever the suspension moved up and down. As the suspension compressed, the steering linkage pulled inward on the tie rod on that side of the vehicle. As the wheel moved inward (toed in), it created a pull just as if the wheel were turned by the driver.
Bump Steer

REAL WORLD FIX

This is why all steering linkages must be parallel with the lower control. The reason for the bump steer was that the idler arm was bolted to the frame, which was slotted vertically. I didn’t pay any attention to the location of the original idler arm and simply bolted the replacement to the frame. After raising the idler arm back up where it belonged (about 1/2 in. [13 mm]), the steering problem was corrected.
Bump Steer

REAL WORLD FIX

- Other common causes of bump steer are worn or deteriorated rack mounting bushings, a non-centered steering linkage, or a bent steering linkage. If the steering components are not level, any bump or dip in the road will cause the vehicle to steer one direction or the other.

- Always check the steering system carefully whenever a customer complains about any “weird” handling problem.
**FIGURE 29–31** If a rack-and-pinion or any other steering linkage system is not level, the front tires will be moved inward and/or outward whenever the wheels of the vehicle move up or down.
The Killer Bs

TECH TIP

- The “three Bs” that can cause steering and suspension problems are bent, broken, or binding components. Always inspect each part under the vehicle for each of the killer Bs.
STEERING LINKAGE REPLACEMENT
PARALLELOGRAM TYPE

- When replacing any steering system component, it is best to replace all defective and marginally good components at the same time. Use the following guidelines.
- Parts that can be replaced \textit{individually} include the following:
  - Idler arm
  - Center link
  - Pitman arm
  - Intermediate shaft
  - Intermediate shaft U-joint
• Parts that should be replaced in *pairs only* include the following:
  • Outer tie rod ends
  • Inner tie rod ends
  • Idler arm (if there are two on the same vehicle, such as
    • GM’s Astro van)
STEERING LINKAGE REPLACEMENT
PARALLELOGRAM TYPE

- Replacing steering system components involves these steps:
  - Hoist the vehicle safely with the wheels in the straight-ahead position. Remove the front wheels, if necessary, to gain access to the components.
  - Loosen the retainer nut on tapered components, such as tie rod ends.
  - Replace the part using the hardware and fasteners supplied with the replacement part.
FIGURE 29–32 The preferred method for separating the tie rod end from the steering knuckle is to use a puller such as the one shown. A pickle-fork-type tool should only be used if the tie rod end is going to be replaced. A pickle-fork-type tool can damage or tear the rubber grease boot.
FIGURE 29–33 Two hammers being used to disconnect a tie rod end from the steering knuckle. One hammer is used as a backing for the second hammer. Notice that the attaching nut has been loosened, but not removed. This prevents the tie rod end from falling when the tapered connection is knocked loose.
A pitman arm puller is used to remove the pitman arm from the pitman shaft.

FIGURE 29–34
FIGURE 29–35 Pitman arm and pitman shaft indexing splines.
FIGURE 29–36 Align the hole in the tie rod end with the slot in the retaining nut. If the holes do not line up, always tighten the nut farther (never loosen) until the hole lines up.
FIGURE 29–37 Replacement tie rods should be of the same overall length as the originals. Measure from the edge of the tie rod sleeve to the center of the grease fitting. When the new tie rod is threaded to this dimension, the toe setting will be close to the original.
FIGURE 29–38 All tie rod ends should be installed so that the stud is in the center of its operating range, as shown.
FIGURE 29–39 (a) Tie rod adjusting sleeve. (b) Be sure to position the clamp correctly on the sleeve.
STEERING LINKAGE REPLACEMENT
SERVICE OF BALL SOCKET ASSEMBLIES

• Inner tie rod end assemblies used on rack-and-pinion steering units require special consideration and often special tools.

• The inner tie rod end, also called a ball socket assembly, should be replaced whenever there is any noticeable freeplay in the ball-and-socket joint.

• Another test of this joint is performed by disconnecting the outer tie rod end and measuring the effort required to move the tie rod in the socket.

• This is called the articulation test.
FIGURE 29–40 An articulation test uses a spring scale to measure the amount of force needed to move the tie rod in the ball socket assembly. Most manufacturers specify a minimum of 1 lb (4.4 N) of force and a maximum of 6 lb (26 N).
FIGURE 29–41 Removing a staked inner tie rod assembly requires two wrenches—one to hold the rack and the other to unscrew the joint from the end of the steering rack.
FIGURE 29–42 When the inner tie rod end is reassembled, both sides of the housing must be staked down onto the flat shoulder of the rack.
FIGURE 29–43 After replacing an inner tie rod end, the socket assembly should be secured with a rivet or set screw depending on the style of the replacement part.
SUMMARY

1. The dry park test is a very important test to detect worn or damaged steering parts. With the vehicle on the ground, have an assistant move the steering wheel back and forth while the technician feels for any looseness in each steering system part.

2. The steering system must be level side-to-side to prevent unwanted bump steer. Bump steer is when the vehicle’s direction is changed when traveling over bumps or dips in the road.

3. The idler arm usually is the first steering system component to wear out in a conventional parallelogram-type steering system. Following the idler arm in wear are the tie rods, center link, and then the pitman arm.
SUMMARY

4. Steering components should be checked for wear using hand force only.

5. All steering components should be installed and tightened with the front wheels in the straight-ahead position.

6. Always use a tie rod remover/puller or a taper breaker when separating tapered components, such as tie rods.
REVIEW QUESTIONS

1. Describe how to perform a dry park test.
2. List the steering parts that should be replaced in pairs.
3. What test procedure can be used to check that the steering linkage is straight and level?
4. What is the difference between a wear and nonwear center link?
1. A “dry park” test to determine the condition of the steering components and joints should be performed with the vehicle __________.
   a. On level ground on a drive-on lift
   b. On turn plates that allow the front wheels to move
   c. On a frame contact lift with the wheels off the ground
   d. Lifted off the ground about 2 in. (5 cm)
2. Two technicians are discussing bump steer. Technician A says that an unlevel steering linkage can be its cause. Technician B says that if the steering wheel moves when the vehicle is bounced up and down, the steering linkage may be bent. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B
3. A vehicle has an excessive amount of freeplay in the steering wheel and it is difficult to keep it traveling straight on a straight and level road. Which is the \textit{least likely} cause?

- a. Worn tie rod ends
- b. Excessive play in the ball socket assemblies
- c. Worn idler arms
- d. Loose pitman arm retaining nut
4. How are the inner tie rods attached to the rack on a center-take-off-type rack-and-pinion steering gear?
   a. Staked
   b. Bolted
   c. Riveted
   d. Pinned
5. What is the *most likely* cause of bump steer?
   a. Worn outer tie rod ends
   b. A worn center link
   c. Worn or oil-soaked rack bushings
   d. A lack of proper lubrication of all ball-and-socket joints
6. How much endplay is usually acceptable in tie rod ends?
   a. Zero
   b. 0.0010 to 0.030 in.
   c. 0.030 to 0.050 in.
   d. 0.050 to 0.100 in.
7. Technician A says that outer tie rod ends should be replaced in pairs, even if only one is worn. Technician B says that inner tie rod ends should be replaced in pairs, even if only one is worn. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B
8. Which tool is *not* recommended to be used to separate tapered steering components because it can do harm?
   a. Taper breaker
   b. Pickle fork
   c. Tie rod removal puller
   d. Two hammers
9. Technician A says that torque prevailing nuts can be reused unless damaged. Technician B says that a new cotter key should always be used. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
10. New tie rods are being installed. Technician A says to tighten the retaining nuts to specification and then loosen, if needed, to align the cotter pin hole. Technician B says to tighten farther to align the cotter key hole. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B