Chapter 16
Rear Axle Assembly
Construction and Operation

After studying this chapter, you will be able to:
- Explain the purpose of a rear axle assembly.
- Identify the major parts of a rear axle assembly.
- Describe the differential drive gears and related parts.
- Calculate rear axle ratio.
- Compare differential and rear axle assembly design variations.
- Describe the operation of a standard differential and of the various types of locking differentials.

Technical Terms

<table>
<thead>
<tr>
<th>Solid-axle rear suspension</th>
<th>Spider gears</th>
<th>Pinion pilot bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent rear suspension</td>
<td>Side gears</td>
<td>Side bearings</td>
</tr>
<tr>
<td>Differential drive gears</td>
<td>Locking differential</td>
<td>Integral carrier</td>
</tr>
<tr>
<td>Drive pinion gear</td>
<td>Limited-slip differential</td>
<td>Solid drive axle</td>
</tr>
<tr>
<td>Pinion bearing</td>
<td>Clutch-plate differential</td>
<td>Axle flange</td>
</tr>
<tr>
<td>Collapsible spacer</td>
<td>Cone differential</td>
<td>Axle bearing</td>
</tr>
<tr>
<td>Jam nut</td>
<td>Ratchet differential</td>
<td>Axle collar</td>
</tr>
<tr>
<td>Pinion shim</td>
<td>Torsen differential</td>
<td>Axle retainer plate</td>
</tr>
<tr>
<td>Ring gear</td>
<td>Hydraulic locking differential</td>
<td>Semi-floating axle</td>
</tr>
<tr>
<td>Wheel hop</td>
<td>Differential carrier</td>
<td>Axle shim</td>
</tr>
<tr>
<td>Standard differential</td>
<td>Axle tube</td>
<td>Full-floating axle</td>
</tr>
<tr>
<td>Differential case</td>
<td>Removable carrier</td>
<td>Independently suspended drive axle</td>
</tr>
</tbody>
</table>
Introduction

The rear axle assembly is used on rear-wheel drive vehicles. This assembly is the final leg of the drive train. It is often called the final drive or rear end. The rear axle assembly is often mistakenly called the differential. The differential is only part of the rear axle assembly.

The basic design of rear axle assemblies has been adopted by all manufacturers for many years. There are several variations, but all operate according to the same basic principles. The major difference between rear axle assemblies depends on whether the vehicle has solid-axle rear suspension or independent rear suspension. Solid-axle rear suspension incorporates rigid and nonflexing drive axles and axle tubes; both wheels move as one solid unit in response to bumps and potholes. Independent rear suspension incorporates jointed drive axles (no axle tubes) that allow for flexibility and independent axle movement.

This chapter is designed to identify and explain the construction and operation of various rear axle assemblies. The material in this chapter provides a basis for understanding how to properly troubleshoot and repair rear axle assemblies.

Construction and Operation Overview

The rear axle assembly includes the differential assembly, the rear drive axles, and the rear axle housing. Rear axle assemblies are subjected to heavy loads from the engine and road. They are ruggedly constructed and seldom fail. The most common rear end failures are axle bearing failures. A typical rear axle assembly is shown in Figure 16-1.

In a rear axle assembly, engine power enters the drive pinion gear from the drive shaft assembly and differential pinion yoke/flange. The drive pinion gear, which is in mesh with the ring gear, causes the ring gear to turn. The interaction of the ring and drive pinion gears turns the power flow at a 90° angle. The difference in the number of teeth on the ring and pinion gears causes a reduction gear ratio. This reduces turning speed, while increasing torque. Power from the ring gear flows through the differential case, spider gears, and side gears to the drive axles. The drive axles transfer power from the differential assembly to the rear wheels.

The bearings and rear axle housing are key components of the rear axle assembly. They are designed to support and align the differential assembly and the drive axles. Notice that the bearings and axle housing are large, heavy-duty parts. This is to ensure they will stand up under hard usage.

Seals and gaskets are also very important to the operation of the rear axle assembly. Seals are used at the differential pinion yoke/flange and at the outer drive axles. Gaskets are used at housing interfaces, such as between the differential cover and the housing, to provide a tight seal from the outside.

Figure 16-2 is an exploded view of a common type of rear axle assembly. Notice the relationship of the internal parts to the housing and to each other. Note that the rear wheel, or axle, bearing is shown in this cutaway. Most rear axle assemblies contain the same parts as shown in this cutaway. Note that some drive axles differ from this basic design. (Ford)

Figure 16-1. Most rear axle assemblies contain the same parts as shown in this cutaway. Note that some drive axles differ from this basic design. (Ford)

Figure 16-2. Exploded view of a rear axle assembly shown in Figure 16-1. (Ford)
Differential Assembly

The differential assembly in a rear-wheel drive vehicle has three functions. The first, and most obvious, is to redirect the power flow to drive the rear wheels. The power flow must make a 90° turn between the drive shaft and the rear wheels. This is accomplished in the differential assembly by the drive pinion and ring gears.

The second function of the differential assembly is to multiply engine power, reducing speed at the output in the process. If there were no gear reduction (1:1 gear ratio), the vehicle would accelerate very slowly. In some cases, the engine would be unable to move the vehicle. At the very least, gas mileage would be harmed, since the engine would not reach its most efficient rpm range. For this reason, the ring and drive pinion assembly, by design, provides a reduced speed at its output. The reduction is between 2:1 and about 5:1, depending on the engine size, vehicle weight, and intended use of the vehicle.

The third function of the differential assembly is to allow the vehicle to make turns. If the assembly did not make allowances for the difference in speeds of the rear wheels during turns, one tire would lose traction with the ground as the vehicle turned corners. The differential assembly allows the vehicle to make smooth turns.

The differential assembly consists of numerous parts, including the differential drive gears (ring and drive pinion gears), pinion bearings, differential case, spider and side gears, and side bearings. See Figure 16-3. These parts and their function are described in detail in the following section.

Differential Drive Gears

The differential drive gears also called the ring and pinion gearset, consist of the ring and drive pinion gears, Figure 16-4. These hypoid gears redirect power flow by 90° and multiply engine power. The number of teeth in the ring gear compared to the number of teeth in the drive pinion gear sets the rear axle ratio. For instance, if the ring gear has 40 teeth and the pinion gear has 10 teeth, the ratio is 40:10, or 4:1. The ring gear always has more teeth than the drive pinion gear. Rear axle ratios can always be determined by dividing the number of teeth on the ring gear by the number of teeth on the drive pinion gear.

Drive pinion gear

The drive pinion gear is a hardened-steel gear with an integral shaft, Figure 16-5. It is machined to mesh with and rotate the ring gear. The end of the shaft opposite the gear has external splines that fit the internal splines of the differential pinion yoke/flange. The gear is supported by two tapered roller bearings, called pinion bearings.

By design, the axial centerline of the drive pinion gear lies below that of the ring gear. With this design, the pinion gear is placed lower in the rear axle housing. This is done to lower the drive shaft and, therefore, the drive shaft hump in the vehicle passenger compartment. The spiral design of the gear teeth allows the gears to mesh with a sliding motion, creating a smooth power transfer. As a result of the sliding action, the gears must have a good supply of the proper lubricant. Gears of this type are called hypoid gears.
These terms will be used differentially. Also called a spider gears, this is usually a one-piece unit. The ring gear is bolted to the differential case and meshes with the drive pinion gear. When installed, the ring gear is bolted to the differential case and meshes with the drive pinion gear. A—The ring gear has convex and concave sides. The convex side is the drive side. It contacts the drive pinion gear when the vehicle is accelerating.

The purpose of the differential case assembly is to allow the vehicle to make turns without slippage or wheel hop. It does this with an arrangement of gears that allows the rear wheels to turn at different speeds. Two basic types of differential case assemblies used to accomplish this task are the standard differential and the locking differential.

Standard differential

The standard differential, also called a single-pull differential, is composed of meshing spider and side gears enclosed in a differential case. See Figure 16-10.

The standard differential case is usually a one-piece unit. The ring gear is bolted to the case. The case is usually made of cast iron. Occasionally, it is made of aluminum. Side bearings are usually pressed onto the case.

The spider gears are made of hardened steel and are held in place by a steel shaft called the pinion shaft. The pinion shaft passes through the differential case and the center of the spider gears. It is attached to the case with a bolt. Spider gears are also called pinion gears.

Spider gears mesh with side gears, which are also made of hardened steel. When the ring gear and differential case turn, the spider and side gears also turn. Power flows through the case, into the spider gears, and on to the side gears. The side gears are splined to the drive axles.

Figure 16-10. The basic components of a differential case assembly. The ring gear is bolted to the case, and the spider gears and side gears are mounted inside. On most differential assemblies, side bearings are pressed onto the case. All differentials contain the same general parts.

They transfer power to the drive axles and rear wheels. Side gears are also called axle end gears.

Some heavy-duty differentials contain four spider gears and two pinion shafts. In this design, there is a center hole in one of the shafts. The other shaft passes through it. The side gears are splined to the drive axle. On some differentials, the side gears contain C-locks, which hold the axles in place. See Figure 16-11.

The spider and side gears are bevel gears. Power transfer through the bevel gears causes them to be forced away from each other. This causes high thrust forces on the backs of the gears, where they contact the differential case. Hardened-steel washers are usually installed between the back of the gears and the case. These washers provide a sliding surface and reduce wear. See Figure 16-12.

Figure 16-13 shows the operating states of the differential while driving straight ahead and while driving around a corner. In Figure 16-13A, the vehicle is moving straight ahead and both wheels are traveling at the same speed. The spider and side gears rotate with the case but do not move in relation to it. The entire case assembly rotates as a unit.

When the vehicle makes a turn, the axles and the side gears begin turning at different speeds. The outer wheel—wheel on the outside of the turn—rotates faster than the inner wheel, and the left side gear turns faster than the right side gear. See Figure 16-13B. As a result of the differential speed change, the spider gears begin to rotate. The left side gear, which is moving faster than the right side gear, drives the spider gears, causing them to rotate, or walk, on the left side gear.

Note that the differential case speed on turns is the average of the side gear speeds. This is because one side gear is rotating faster than the case and the other side gear is rotating slower than the case. In Figure 16-14, when the vehicle makes a turn, the action of the differential allows the outer wheel to turn at 110% of case speed, while the inner wheel turns at 90% of differential case speed. These percentages will vary with the radius of the turn.

Locked differential

The standard differential works well in most situations. However, on very slippery surfaces, such as icy or muddy roads, lack of traction can cause the rear wheels to slip. This is because the standard differential will drive the wheel with the least traction.

If one drive wheel is on dry pavement and the other is on ice or mud, the ring gear and differential case will drive the spider gears. However, the spider gears will not drive both side gears. When the spider gears are driven by the differential case, they will walk around the side gear related to the wheel on dry pavement. As a result, the spider gears drive the slipping wheel, and the vehicle will not move. The standard differential sends almost all engine power to the slipping wheel.

To overcome this problem, locking differentials are used. Locking differentials overcome traction problems by sending some power to both wheels, allowing the vehicle to make normal turns. There are several different types of locking differentials, including limited-slip, ratchet, and Torser® differentials.

The most common types of limited-slip differential are the clutch-plate differential and the cone differential. The clutch-plate differential uses several friction discs that look like small manual clutch discs. The cone differential uses a cone-shaped clutch that engages a matching cone-shaped receptacle. Limited-slip differentials have various brand names, including Positive Trac®, Sure-Grip, Anti-Spin, Traction-Lock, and TXT. Many technicians refer to limited-slip differentials as Positrack differentials, although this is actually a General Motors brand name dating back to the 1950s.

Due to their complexity and higher cost, limited-slip differentials are used only on high performance versions of rear-wheel drive automobiles. Limited-slip differentials are commonly found on modern trucks and SUVs. Many SUVs, and some trucks have limited-slip differentials on the front and rear axles. Some companies make aftermarket limited-slip differentials to replace original equipment designs or to convert standard differentials to limited-slip units.

An example of a common clutch-plate differential is shown in Figure 16-15. The most obvious difference between this limited-slip differential and a standard differential is the clutch packs placed between the side gears and the differential case.

The clutch friction discs are made of steel covered with a friction material. The clutch plates are made of steel. The discs and plates are alternately splined to the side gears and driven (meaning tabs fit into grooves) to the differential case, Figure 16-16. Grooves in the discs or plates are for better gripping power.

Figure 16-17 shows the moving parts of a clutch-plate differential. The spider gears, side gears, and other parts are very similar to those used in a standard differential. The
1. Drive coupling
2. Thrust washer
3. Lock nut
4. Oil seal
5. Drive pinion bearing
6. Front pinion bearing
7. Preload spacer
8. Rear pinion bearing
9. Pinion depth shim
10. Differential carrier
11. Ring gear
12. Differential case
13. Ring gear bolt
14. Pinion shaft
15. Lock screw
16. Pinion gear
17. Thrust washer
18. Side gear
19. Side bearing
20. Shim/spacer
21. Drive axle
22. Drive axle C-lock
23. Bearing cup bolt
24. Bearing cup
25. Differential cover gasket
26. Inspection cover

**Figure 16-11.** A section view of a typical differential contained in rear axle assembly. The differential case is installed in the rear axle housing. The ring gear, which is attached to the differential case, meshes with the drive pinion gear. The relative positions of the parts are similar on all differentials. Note the C-locks on the differential side gears. They retain the drive axles in the housing. (General Motors)

**Figure 16-12.** This is an exploded view of the differential gears. Note the relationship of the side and spider gears to each other. Also note the thrust washers that separate the gears from the case and the C-lock that holds the axle shaft in place. The pinion shaft is held in place by a pin that passes through both the shaft and differential case. (DaimlerChrysler)

**Figure 16-13.** Differential action is shown here. Note the use of four spider gears, rather than the regular two. A—Straight ahead: Differential case gears turn as a unit. Both the drive axles and differential case are turning at the same speed. B—Right turn: The left axle is moving faster than the right axle. The left side gear drives the pinion gears. The pinion gears turn and walk around the right side gear. Note that the differential works the same way for a left turn, except the action of the left and right sides is reversed. (Deere & Co.)

**Figure 16-14.** The speed of the differential case on turns is the average of the side gear speeds. (DaimlerChrysler)

differential case of the limited-slip differential is often made in two parts to allow for clutch pack removal, as shown in Figure 16-18.

The discs and plates are applied by the preload springs and by the mechanical pressure of the spider gears on the side gears. Since the spider and side gears are bevel gears, their teeth try to come out of engagement when the differential is transmitting engine torque. This creates a
When the vehicle is moving straight ahead, the differential—which is a standard differential—functions normally. Since there is a normal tendency for the side gears to rotate at different speeds, the clutch packs are applied, but they are not needed. The side gear is under load because its related wheel has traction. The pressure on this side gear causes the related clutch pack to be pressed tightly together. The side gear is locked to the case by the clutch pack, and power is delivered to the wheel with traction.

Since there is a normal tendency for the side gears to move away from the spider gears under load, the other side gear moves outward and away from the spider gears. The side gear is under load because its related wheel has traction. The pressure on this side gear causes the related clutch pack to be pressed tightly together. The side gear is locked to the case by the clutch pack, and power is delivered to the wheel with traction.

The clutch pack is designed to slip when some preset torque value is reached. When the vehicle is making a turn, a high torque, caused by the outer wheel rotating faster than the case, causes the clutch pack to slip. This allows the differential to operate in the same manner as a standard differential when making turns. The discs and plates slide against each other—discs turning with side gears, plates turning with case—allowing different rotating speeds between case and side gears and, therefore, between rear wheels.

Figure 16-16. Exploded view shows the clutch pack of a limited-slip differential. Each clutch pack has the same number of clutch discs and plates. Note the internal teeth on the friction discs and the external tabs on the steel plates. Grooves in the discs and plates reduce the chance of slippage. (DaimlerChrysler)

Figure 16-17. This shows the relative positions of the clutch packs, spider gears, and side gears of the limited-slip differential. Notice the similarity to the standard differential. (DaimlerChrysler)

Figure 16-18. The differential case of a limited-slip differential is often made in two parts. Note the parting line on the case of this limited-slip differential. (DaimlerChrysler)

Figure 16-19. Study the action of the limited-slip differential. A—Traction on both wheels. The differential parts are locked together and rotate as a unit. The clutch packs are not operating.

B—One wheel is slipping. Pressure on the side gear of the wheel with traction causes the discs and plates of the related clutch pack to grab, sending most of the engine power to that wheel.

Figure 16-20 shows a cone differential, which is another version of the limited-slip differential. In place of clutch packs, friction-lined cones are used. The operation is similar to that of the clutch-plate differential. Preload spring and side gear pressures force the cone into a dished depression in the differential case. Friction tries to lock the cone and, therefore, the side gear to the case, sending
Worm wheels

Exploded view of the cone differential shows the relationship of parts. Grooves in the cones help to solidly engage

Study the construction of the cone differential.

power to the wheel with the most traction. Figure 16-21 is an exploded view of the cone differential.

Note that both clutch-plate and cone differentials require special limited-slip gear oil. Using ordinary gear oil in limited-slip differentials will cause the discs and plates or locked and slip in the differential.

The ratchet differential, nicknamed a Detroit locker, uses a series of cams and ramps to direct power to the wheel with the most traction. Figure 16-22 shows an example of the ratchet differential. An example of the ratchet differential is shown in Figure 16-22.

For straight-ahead driving, both sets of teeth are engaged, and the differential case and wheels turn at the same speed. During turns or when one wheel loses traction, the speed difference between the wheels causes the internal cam and ramp to disengage the teeth on the side of the faster moving wheel. During turns, the loss of power to the outer wheel is not noticeable. This design is durable and does not require special gear oil, but it is often rough and noisy in operation. It is usually used in off-road and racing vehicles.

The Torsen differential is a locking differential using complex worm gearsets. The gearsets include worms (drive gears) and worm wheels (driven gears). The Torsen differential has been available since the 1980s. A high-performance replacement unit for standard differentials. It is now being offered as original equipment on some European cars. The basic mechanism principle of this differential is that while the worm can drive the worm wheel, the worm wheel cannot drive the worm.

As shown in Figure 16-23, the Torsen differential has two central worms. For purposes of clarity, these will be referred to as axle gears. One axle gear is attached to each axle shaft. Worm wheels ride on and are driven by the axle shafts. The worm gears are held in place by the differential case. Spur gears meshed on the ends of the worm wheels mesh and form the only connection between the worm gears, and the worm wheels, held by the case, turn with it. The worm wheels cannot turn the axle gears, so they lock themselves to the gears. In this way, power is transmitted; the axle gears and axles are locked to the case, and they rotate with it.

During straight-ahead operation, the differential assembly operates like a standard differential: all internal gears turn as a unit. When the vehicle is making a turn, or when one drive wheel is slipping, the relative speed of the drive wheels and, therefore, of the axles, changes. This speed change is transmitted from the faster axle to the slower one by the action of the meshing spur gears. The axle gear on the faster axle can drive the respective worm wheels. This driving force is transferred from the slower axle gear to the faster worm wheel by the interaction of the gears. The worm wheel on the slower side can drive the slower axle gear, but it cannot drive the worm gear on the faster axle. Engine power is transmitted from the faster worm wheel to the slower axle gear, but it does allow it to turn with more force.

Hydraulic Locking Differentials

Some late-model SUVs have locking differentials that are operated by hydraulic pressure. It may be called a Hydra-Lock, Van-Lock, or Georotor system. A hydraulic locking differential consists of a pump with internal and external gears, a ring-shaped pressure diaphragm, and a clutch pack that resembles the clutch pack used in a conventional locking differential. Figure 16-24A. The gear oil that operates the hydraulic system comes from the rear axle assembly sump. Special oil is not needed. The same oil is used for rear axle lubrication, and the hydraulic system does not have to be sealed from the rear axle components.

The pump resembles a rotor-type engine oil pump, with a six-point external gear that turns inside of an internal gear with seven cavities. The spaces between the pump internal and external gears are filled with gear oil at all times. When the gears move in relation to each other, the fluid is carried around to the output side of the pump, where the spaces begin to close. Closing the

Figure 16-20. Study the construction of the cone differential. The operation of this limited-slip differential is similar to that of the clutch-plate differential. Pressure on the side gear of the axle shaft. Worm wheels mesh and form the only connection between the worm gears, and the worm wheels, held by the case, turn with it. The worm wheels cannot turn the axle gears, so they lock themselves to the gears. In this way, power is transmitted; the axle gears and axles are locked to the case, and they rotate with it.

Figure 16-21. Exploded view of the cone differential shows the relationship of parts. Grooves in the cones help to solidly engage the case. (DaimlerChrysler)

Figure 16-22. This ratchet differential uses matching sets of teeth on each side of the differential case. Teeth are engaged and disengaged to transfer power. A—Differential operates in straight-ahead operation. Teeth are engaged on both sides of the case, and power is transferred equally to each wheel. B—When the vehicle makes a left turn, the greater speed of the right wheel causes the internal cam on the right side of the case to take the right-side teeth out of engagement. All power goes through the left axle and wheel. C—When the vehicle makes a right turn, the greater speed of the left wheel causes the left-side cam to take the left-side teeth out of engagement. All power goes through the right axle and wheel. (Ford)

Figure 16-23. The Torsen differential uses a unique arrangement of gears to transfer power. This differential has been available as a high-performance aftermarket replacement for about 25 years. It is now being offered as original equipment on some European vehicles. The operation of this differential is complex. (Torsen)

Figure 16-24A. A hydraulic locking differential. A—Pump assembly. B—Driven clutches and center drive member engaged and locked rotate at same speed. C—Driven clutches are engaged and locked rotate at same speed.
Manual Drive Trains and Axles

Two methods of suspending the rear axle assembly of a vehicle with a solid-axle rear suspension are shown. Both axle tubes, and A—A hydraulic locking differential, consisting of a rear axle assemblies will almost always have fill rear locking differential. (Toyota)

These parts align the rear axle assembly to which enclose the drive axles and brake line pump with internal and external gears, a ring-shaped pressure diaphragm, and a clutch pack. B—The arrangement of the internal and external pump gears to move in relation to each other. They do not, however, produce enough pressure to apply the clutches. Therefore, the differential does not attempt to lock up during normal turns.

Some locking differentials are operated by an electric motor attached to the axle assembly. Note the additional parts installed on a standard rear axle; Figure 16-25. The shift fork shaft and shift fork are operated by the motor and move a hub sleeve. The hub sleeve has splines that can engage matching splines on the differential carrier and side gear. During normal non-locking operation, the shift fork shaft and shift fork are positioned to keep the hub sleeve disengaged. The hub sleeve has no effect on differential operation.

To lock the differential, the motor moves the shift fork shaft and shift fork to engage the hub sleeve splines with the splines on the differential carrier and side gear. The splines lock the hub sleeve, differential carrier, and side gear into a single unit. Locking the carrier and side gear together prevents the other differential gears from turning. The differential assembly turns as a unit, delivering equal power to each drive wheel.

spaces produces pressure that can be used to operate the other components of the differential assembly. Figure 16-24B shows the operation of a rotor-type pump. Check valves ensure that pressure is always produced, no matter what the direction of pump rotation.

The internal gear is attached to one of the side axles. The external gear is attached to the other side axle. When both wheels have equal traction, both side axles turn at the same speed. Therefore, the internal and external pump gears do not move in relation to each other, and no pressure is developed. When the vehicle loses traction to one wheel, one of the side axles begins turning at a faster rate than the other. The difference in axle speeds causes the internal and external pump gears to move in relation to each other, producing hydraulic pressure. This pressure is delivered to the ring diaphragm, which expands against the clutch pack. With the clutch pack applied, the side axles lock together and turn as a unit. When the wheels begin turning at the same speed, the internal and external gears do not move in relation to each other, and no pressure is produced. With no pump pressure produced, the ring diaphragm depressurizes and releases the clutches. If one wheel again begins to slip, the pump starts operating again, and the system reappears the clutches.

When the vehicle makes a turn, the pump gears move slightly in relation to each other. They do not, however, produce enough pressure to apply the clutches. Therefore, the differential does not attempt to lock up during normal turns.

The rear axle housing associated with solid-axle rear suspension consists of a central housing, or differential carrier, and axle tubes, which enclose the drive axles and extend to the rear wheels. (Vehicles with independent rear suspension will not have axle tubes.) Rear axle housings will have a vent to relieve pressure buildup. They will also have oil drain and fill plugs. See Figure 16-26.

Most rear axle housings are made of steel. Steel axle tubes are pressed and welded into the housing or are cast integral with the housing. The axle tubes usually have an integral flange at the outer end. The flange provides a mounting surface for the brake backing plate and an axle retainer plate.

Since the rear axle housing is a solid structure, it moves up and down with the wheels as they move over bumps and holes. To control this movement, the rear axle housing is attached to the vehicle body through an arrangement of springs, shock absorbers, and control arms, Figure 16-27. These parts align the rear axle assembly to the vehicle while isolating most of the axle movement.
Removable Carrier

The removable carrier has a separate housing for the differential assembly, Figure 16-28. It can be unbolted and removed from the rest of the rear axle housing after the drive axles are removed. All of the internal differential parts, then, will be removed with it. Differential assemblies housed in this kind of carrier are, in general, easier to service, since repairs can be done on the bench instead of on the vehicle. The carrier mounting flange is where the carrier attaches to the rest of the rear axle housing. Usually, threaded studs are installed in the housing. The studs pass through holes in the mounting flange when the carrier is installed. The carrier is then tightened in place by installing and tightening nuts over the threaded studs. This attaching method makes it easier to align and reinstall the carrier. A gasket is always used between the carrier and axle housing.

The differential pinion bearings are installed in the carrier in the pinion bearing bores. When tapered roller bearings are used, the bearing cups are tightly pressed into the bores. Some removable carriers have an extra support bearing at the end of the pinion gear. This bearing is called a pinion pilot bearing. Figure 16-29 shows the attaching points for the differential side bearings, also called case bearings. The side bearings are held in place by bolted, U-shaped caps. Most differential side bearing mounts have a provision for adjusting the side bearing preload. This adjustment is usually made with a threaded end cap, or adjusting nut. The end cap is tightened against the bearing cup until the proper preload is attained. Drain and fill plugs may be mounted on the differential carrier or on the rear axle housing, depending on the particular manufacturer. The bolts on the front of the carrier strengthen it without adding a great deal of weight to the assembly.

Integral Carrier

The integral carrier, as the name implies, is an integral part of the rear axle housing. See Figure 16-30. This type of rear axle housing has a sheet metal or cast metal inspection cover. The inspection cover can be removed to service the rear end components. Service operations must be performed under the vehicle, since the carrier cannot be separated from the rest of the rear axle housing.

Figure 16-31 shows a typical integral carrier. Notice that almost all the rear end components are installed inside the rear axle housing. Most of these can be removed through the opening that is kept closed off by the inspection cover. The cover is sealed with a gasket of some sort. The pinion front and rear bearing cups are pressed into the carrier portion of the rear axle housing. Integral carriers do not normally have a pinion pilot bearing.

Differential side bearings are installed in the integral carrier in the same manner as on a removable carrier. The side bearing preload adjustment is sometimes made with shims. These shims are placed between the bearing cup and the rear axle housing. In other instances, the preload adjustment is made with a threaded end cap, as on the removable carrier.

Rear Axle Housing: Independent Rear Suspension

On vehicles having independent rear suspensions, a modified rear axle housing is used. Figure 16-32 shows such a housing. Notice that the housing has no axle tubes. The drive axles assemble drive shaft assemblies to some degree, complete with conventional or constant-velocity universal joints. This design allows each wheel to react independently to the road surface, improving ride quality and handling.

The housing has oil seals to prevent oil loss where the axles enter the housing. The internal construction of the housing is identical to the previously discussed carriers. To reduce vibration and strengthen the drive train, a torque tube is sometimes used to attach the front of the housing to one of the vehicle’s crossmembers. (Torque tubes were explained in Chapter 12.)

Rear Drive Axles

The rear drive axles transfer power from the differential assembly to the rear wheels. There are two major kinds of drive axle design. One is the solid drive axle, shown in Figure 16-33; the other is the independently suspended drive axle, shown in Figure 16-34.

Solid Drive Axle

A solid drive axle, or live axle, is a hardened-steel shaft. See Figure 16-35. Each rear axle assembly in solid-axle rear suspension systems has two. External splines on the inboard (inner) end of each axle mate with internal splines on the differential side gear to which it is connected. An axle flange at the outboard (outer) end of each axle acts as a wheel hub. It provides the mounting surface for the brake drum or rotor and the wheel. The brake assembly and wheel are installed directly on the flange wheel studs.

Each shaft is supported on the outboard end by an axle bearing, also called a wheel bearing. The axle...
bearing can be installed on the shaft or in the axle tube.

Axle bearings that are installed on the shaft are usually packed with grease. An axle seal is pressed into the housing behind, or on the inboard side of, the bearing. The lip of the seal seats against a machined area of the shaft. This seal keeps rear end lubricant from reaching the bearing. An outer seal prevents water and dirt from leaking through the outer ends of the rear axle housing and entering the bearing.

Axle bearings that are installed in the housing are lubricated by rear end lubricant (gear oil). When the vehicle makes a turn, lubricant is thrown outward from the carrier, reaching the axle bearing. An axle seal is installed in front of, or on the outboard side of, the bearing to keep lubricant from leaking out from the outer ends of the rear axle housing. The shaft is held in place by a clip as explained in the next section.

An axle bearing installed on the shaft is held in place by an axle collar. The axle collar is tightly pressed on the shaft. In addition, some will have a spacer to keep the bearing at the proper distance from the end of the axle. The axle retainer plate holds the axle and axle bearing to the axle tube.

**Semi-floating axles**

Solid drive axles can be semi-floating or full-floating. Most automobiles and light trucks have semi-floating axles. In the semi-floating axle, the weight of the vehicle

**Figure 16-31.** This is an exploded view of an integral carrier rear axle assembly. Notice that most of the moving parts fit inside the rear axle housing. The inspection cover often contains a fill plug. (DaimlerChrysler)

**Figure 16-32.** The rear axle housing used on vehicles with independent rear suspension has no axle tubes. The carrier has oil seals where the drive axles enter. A torque tube is often used at the front of the housing to increase rigidity and reduce vibration. (DaimlerChrysler)

**Figure 16-33.** The axle shaft used on a solid drive axle, or a live axle, is a single piece of steel that is supported on both ends. The outer support is provided by an axle bearing, and an inner support is provided by the differential side bearings. Note that the differential has been rotated 90° for the purpose of illustration. (Fiat)
shows three versions of differential drive axle and related components are shown. The semi-floating axle is the most common shaft used on vehicles having independent rear suspensions somewhat resemble drive shafts. A flexible joint, such as a CV joint, is used on each end of each shaft.

Figure 16-36A shows a semi-floating axle using a ball bearing. This is a pregreased bearing, there is an axle seal behind the bearing. The axle collar is pressed onto the axle shaft. The bearing and axle are held in the housing by an axle retainer plate, mounted on the outer end of the rear axle housing. The retainer plate and bearing control endplay during turns.

Figure 16-36B shows a roller bearing version of the semi-floating axle. This bearing is lubricated by rear end lubricant. The axle seal is installed in front of the bearing. When this kind of bearing is used, the axle is held in the housing by a clip on the inboard end of the shaft, at the differential assembly. This kind of axle is sometimes called a C-lock axle, because of the shape of the locking clip. Endplay on turns is controlled by the fit of the axle shaft between the C-lock and the other parts of the differential assembly.

Figure 16-36C shows a semi-floating axle using a tapered roller bearing. This type of axle is usually found on older vehicles. When this type of bearing is used, there is usually some provision for adjusting the bearing preload to control endplay. This is generally done by using axle shims or by turning an adjusting nut. Tapered roller bearings may be packed with grease or lubricated from the rear axle passes through the axle bearing to the drive axle and on to the wheel and tire. Figure 16-36 shows three versions of the semi-floating axle.

If the rear end will be subjected to heavy loads, such as the rear end of a large truck might be, a full-floating axle is used. Figure 16-37 shows an example of a full-floating axle. With this design, the axle drives the wheel but does not carry any of the vehicle weight. The weight passes through the bearings on the wheel hub. The wheel hub absorbs the stresses. This design reduces the stresses on the shaft, prolonging its life. Full-floating axles are not used on light duty vehicles because of their extra cost and complexity.

Independently Suspended Drive Axle

Independently suspended drive axles, used on vehicles with independent rear suspension, resemble miniature drive shaft assemblies. The axle consists of a central shaft with flexible joints and stub axles on each end. The flexible joints—either cross and roller U-joints or flexible joints on the stub axles—allow the vehicle to change shape as the suspension moves up and down. This action is required so that the wheels remain in the proper position on the road when the vehicle is turning. Axle tubes are used on light duty vehicles because of their extra cost and complexity.

Figures 16-36C, notice the use of the tapered axle. This is one of two methods used to secure a wheel hub to its axle. The tapered end wedges into a tapered hole in the wheel hub, and the key keeps the axle from rotating in the hub. The other method, mentioned earlier, has a hub axle flange, in this case, solidly mounted to the axle. The design of the semi-floating axle causes weight loads to be placed on the axle. These loads will shift as the axle rotates, placing flexing stresses on the shaft. On automobiles and light trucks, the loading is not serious and the axles will usually last the life of the vehicle.

Figure 16-37. The full-floating axle is used on trucks and other vehicles that carry heavy loads. Bearings on the hub transmit the vehicle weight from the rear axle housing to the wheel hub and the wheel without the loading axle. The only job of the axle is to propel the vehicle. (Deere & Co.)
Rzeppa-type CV joints—allow each wheel to move independently of the vehicle body and of each other.

A typical independently suspended drive axle arrangement is shown in Figure 16-38. Although they look different, these axles transfer power in much the same manner as solid drive axles.

**Figure 16-39** is an example of how an independently suspended drive axle and wheel hub are assembled. The hub is firmly attached to the suspension control arm. The inner portion of the hub rotates inside of a bearing and acts as a mounting flange for the wheel and brake assembly. The stub axle is splined to the hub and drives it. The universal joint allows free movement of the suspension control arm. Some splined axles can slide to compensate for changes in axle length when the rear suspension moves up and down.

**Summary**

All rear axle assemblies have the same basic design and operate by the same principles. Rear end variations depend on whether the vehicle has a solid axle or independent rear suspension, a removable or integral carrier, semi-floating or full-floating axles, and a standard or limited-slip differential.

The major parts of the rear axle assembly are the differential assembly, rear axle housing, drive axles, bearings, and seals. Engine power enters the drive pinion gear through the differential pinion yoke and drive shaft assembly. The drive pinion gear turns the ring gear. The interaction of the ring and pinion assembly turns the power at a 90° angle and reduces its speed. The ring gear is bolted to the differential case. Power flows from the ring gear into the differential case, which transfers the power to the spider gears. The spider gears transfer the power to side gears, which then transfer the power to the drive axles and rear wheels.

The differential assembly has three purposes. It redirects the drive shaft rotation in a 90° angle, reduces rotating speed to increase power, and allows the vehicle to make turns without wheel hop or axle breakup.

The relative positions of the ring and drive pinion gears must be set exactly, or the gears will be noisy and wear out prematurely. The position of the ring and drive pinion gears in the case and in relation to each other must be carefully adjusted.

The differential case assembly allows the vehicle to make turns without wheel hop. It has an arrangement of gears that allows the rear wheels to turn at different speeds. There are two kinds of differential case assemblies, standard and locking.

The standard differential is composed of meshing spider and side gears, enclosed in a differential case. The ring gear is bolted to the case. Power flow is through the case, into the spider gears, and on to the side gears. The side gears are splined to the drive axles. They transfer power to the drive axles and rear wheels.

When driving on slippery surfaces, the rear wheels of a vehicle with a standard differential will often slip. This is because the differential will always drive the wheel with the least traction. To overcome this problem, various kinds of locking differentials are used. They increase traction by sending power to the wheel with the most traction.

The most common locking differential is the limited-slip differential. One type uses clutch packs placed between the side gears and the differential case. Friction disc are splined to the side gears; steel plates are dogged to the case. The clutch packs are pressed together by the pressure of the side gears. When the vehicle is moving straight ahead, the limited-slip differential operates like a standard differential. The rear axle turns at the same speed, and the clutch packs are not used. When a wheel starts slipping, the difference in pressure on the side gears causes the clutch packs to apply. The difference in traction between the inner and outer wheels is not a factor during normal turns, and the friction discs and steel plates slip over each other.

Another version of the limited-slip differential uses cones instead of clutch packs. Operation is similar to the clutch-plate differential.

The ratchet differential has a series of internal cams and ramps that direct power to the wheel with the most traction. Its operation depends on relative wheel speeds, rather than wheel traction. The ratchet differential transfers power through a set of teeth, which can be engaged and disengaged.

The Torsen differential uses an arrangement of worms (drive gears) and worm wheels (Driven gears) to transfer power. On turns or when one wheel is slipping, the axle gear and worm wheel arrangement transfers power from the faster wheel to the slower wheel.

The rear axle housing encloses and supports the other parts of the rear axle assembly and forms a reservoir for the rear end lubricant. The rear brake assemblies are usually attached to the rear axle housing. The rear axle housing is attached to the vehicle body by the suspension system.

Two kinds of rear axle housings are used on vehicles without independent rear suspensions. The removable carrier type has all of its moving parts, except the axles, in a carrier.
that can be unbolted from the rear axle housing. The integral carrier type is a one-piece unit. It is serviced by removing a sheet metal inspection cover, located at the rear of the housing. A modified rear axle housing is used on vehicles having independent rear suspension. The internal construction of the housing is identical to those used on live axles.

(A version of this housing is used on some front-wheel drive vehicles that have the engine mounted longitudinally.)

The rear drive axles transfer power from the side gears to the rear wheels. Drive axles can be solid or independently suspended. Solid axles are splined with, and supported by, the side gears at the inboard end. The outboard end is supported by axle bearings. The axle bearing can be installed on the shaft or in the housing. Bearings that are installed on the shaft are usually packed with grease. Bearings that are installed in the housing are lubricated by rear end lubricant. Seals are used to keep lubricant from leaking out of the rear axle housing.

Solid axles can be semi-floating or full-floating. In the semi-floating axle, the weight of the vehicle goes through the axle bearing to the shaft and out to the wheel. In the full-floating axle, the axle drives the wheel but does not carry any of the vehicle weight. Most passenger cars have semi-floating axles.

Independently suspended drive axles resemble drive shaft assemblies. They consist of a central shaft with flexible joints and stub axles on each end. The flexible joints can be conventional U-joints or CV joints. They allow each wheel to move independently of the vehicle body and of each other.

**Review Questions—Chapter 16**

Please do not write in this text. Place your answers on a separate sheet of paper.

1. Which of the following items does not belong with the others?
   (A) Rear axle assembly.
   (B) Final drive.
   (C) Differential.
   (D) Rear end.

2. What is independent rear suspension?

3. Which rear end components change the direction of power flow by 90°?

4. How can rear axle ratio be determined?

5. If the drive pinion gear has 10 teeth and the ring gear has 35 teeth, what is the rear axle ratio?

6. Describe the construction of a drive pinion gear.

7. Which of the following parts is used to set pinion bearing preload?
   (A) Jam nut.
   (B) Crush washer.
   (C) Lock washer.
   (D) Castle nut.

8. The convex side of ring gear teeth is the _____ side, and the concave side of ring gear teeth is the _____ side.

9. The standard differential is composed of meshing ____ and ____ gears enclosed in a differential case.

10. In terms of their construction, what is the major difference between a standard differential and a limited-slip differential?

11. The Torsen differential is a locking differential that uses a ____.
   (A) multiple-disc clutch
   (B) cone clutch
   (C) dog clutch
   (D) worm gearset

12. Explain the function of the rear axle housing.

13. Describe the two major kinds of carriers.

14. In the _____-floating axle, the weight of the vehicle passes through the axle bearing to the drive axle and on to the wheel and tire.

15. In an ____-floating axle, the wheel does not carry any of the vehicle weight.

**ASE-Type Questions—Chapter 16**

1. Technician A says that every rear axle assembly has a housing, a differential assembly, and rear drive axles. Technician B says that every rear axle housing has axle tubes. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

2. The most common rear axle assembly failures are ____.
   (A) axle bearing failures
   (B) pinion yokes failures
   (C) cracked spider gears
   (D) stripped ring and pinion gears

3. Each of the following is a primary function of the differential assembly except:
   (A) multiplying engine power.
   (B) allowing the vehicle to make turns.
   (C) supporting and aligning the drive axles.
   (D) redirecting power flow to the rear wheels.

4. Rear axle ratio can be found by dividing the number of teeth on the ring gear by the number of teeth on the ____.
   (A) side gear
   (B) spider gear
   (C) drive pinion gear
   (D) axle end gear

5. Each of the following is used to set the pinion bearing preload except:
   (A) a solid spacer.
   (B) a crush washer.
   (C) a collapsible spacer.
   (D) the rear pinion bearing.

6. The ring gear transfers power directly from the drive pinion gear to the ____.
   (A) axle flange
   (B) differential case
   (C) differential carrier
   (D) differential pinion yoke

7. A rear-wheel drive vehicle cannot be driven because one of its drive wheels is parked on ice. Technician A says that the ring gear and differential case will drive the spider gears. Technician B says that the differential spider gears will walk around the side gear related to the wheel on dry pavement. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.

8. Locking differentials overcome traction problems by sending power to ____.
   (A) the wheel with traction
   (B) both wheels
   (C) the slipping wheel
   (D) the wheel bearings

9. Each of the following is a locking differential except:
   (A) Torsen differentials.
   (B) ratchet differentials.
   (C) limited-slip differentials.
   (D) MacPherson differentials.

10. Each of the following functions is served by the rear axle housing except:
    (A) determining the depth of the drive pinion gear in the carrier.
    (B) forming a reservoir for rear end lubricant.
    (C) accommodating suspension system attachment.
    (D) supporting stationary parts of rear brake assemblies.

11. Each of the following types of drive axles is found on rear-wheel drive vehicles except:
    (A) full-floating axles.
    (B) Rzeppa axles.
    (C) semi-floating axles.
    (D) independently suspended axles.

12. Major differences among rear-wheel drive vehicles with solid-axle rear suspension include each of the following except:
    (A) conventional versus constant-velocity U-joints.
    (B) removable versus integral carrier.
    (C) semi-floating versus full-floating axles.
    (D) standard versus limited-slip differential.