

Differentials and Drive Axles

Upon completion and review of this chapter, you should be able to:

- ❑ Describe the purpose of a differential.
- ❑ Identify the major components of a differential and explain their purpose.
- ❑ Describe the various gears in a differential assembly and state their purpose.
- ❑ Describe the various methods used to mount and support the drive pinion shaft and gear.
- ❑ Explain the need for drive pinion bearing preload.
- ❑ Describe the difference between hunting, nonhunting, and partial nonhunting gearsets.
- ❑ Explain the purpose of the major bearings within a differential assembly.
- ❑ Describe the operation of a limited-slip differential.
- ❑ Describe the construction and operation of a rear axle assembly.
- ❑ Identify and explain the operation of the two major designs of rear axle housings.
- ❑ Explain the operation of a FWD differential and its drive axles.
- ❑ Describe the different types of drive axles and the bearings used to support each of them.

Introduction

The drive axle assembly of a RWD vehicle is mounted at the rear of the car. Most of these assemblies use a single housing to mount the differential gears and axles (Figure 7-1). The entire housing is part of the suspension and helps to locate the rear wheels.

Another type of rear drive axle is used with **IRS**. With IRS the differential is bolted to the chassis and does not move with the suspension. The axles are connected to the differential and drive wheel CV or U-joints. Because the axles move with the suspension and the differential is bolted to the chassis, a common housing for these parts is impossible.

On most RWD cars, the **final drive** is located in the rear axle housing. On most FWD cars, the final drive is located within the transaxle. Some current FWD cars mount the engine and transaxle longitudinally. These configurations use a differential that is similar to other FWD models. Some FWD cars have a longitudinally mounted engine fitted to a special transmission with a separate differential mounted to it.

A differential is needed between any two drive wheels, whether in a RWD, FWD, or 4WD vehicle. The two drive wheels must turn at different speeds when the vehicle is in a turn.



AUTHOR'S NOTE: I began to learn about cars many years ago by tinkering on them and hanging out with guys who also tinkered. Some of what I learned was good, and some was not. One of the errors I learned back then has stayed with me; calling a final drive gearset the “diff.” I know better now but it still stays in my mind. The reason for this is simply, back then, most rear axle work involved pulling the carrier from a removable carrier housing and changing the ring and pinion. We called the thing we pulled out the differential. Hopefully I used the term *differential* correctly throughout this chapter. If I did not, I apologize.

RWD final drives normally use a hypoid ring and pinion gearset that turns the powerflow 90 degrees from the drive shaft to the drive axles. A hypoid gearset allows the drive shaft to be posi-



Shop Manual
Chapter 7, page 250

IRS stands for independent rear suspension.

Final drive is the final set of reduction gears the engine's power passes through on its way to the drive wheels.

Normally, rear axles on RWD vehicles are called live axles because they transmit power.

tioned low in the vehicle because the final drive pinion gear centerline is below the ring gear centerline (Figure 7-2).

On FWD cars with transversely mounted engines, the powerflow axis is naturally parallel to that of the drive axles. Because of this, a simple set of helical gears in the transaxle serve as the final drive gears.

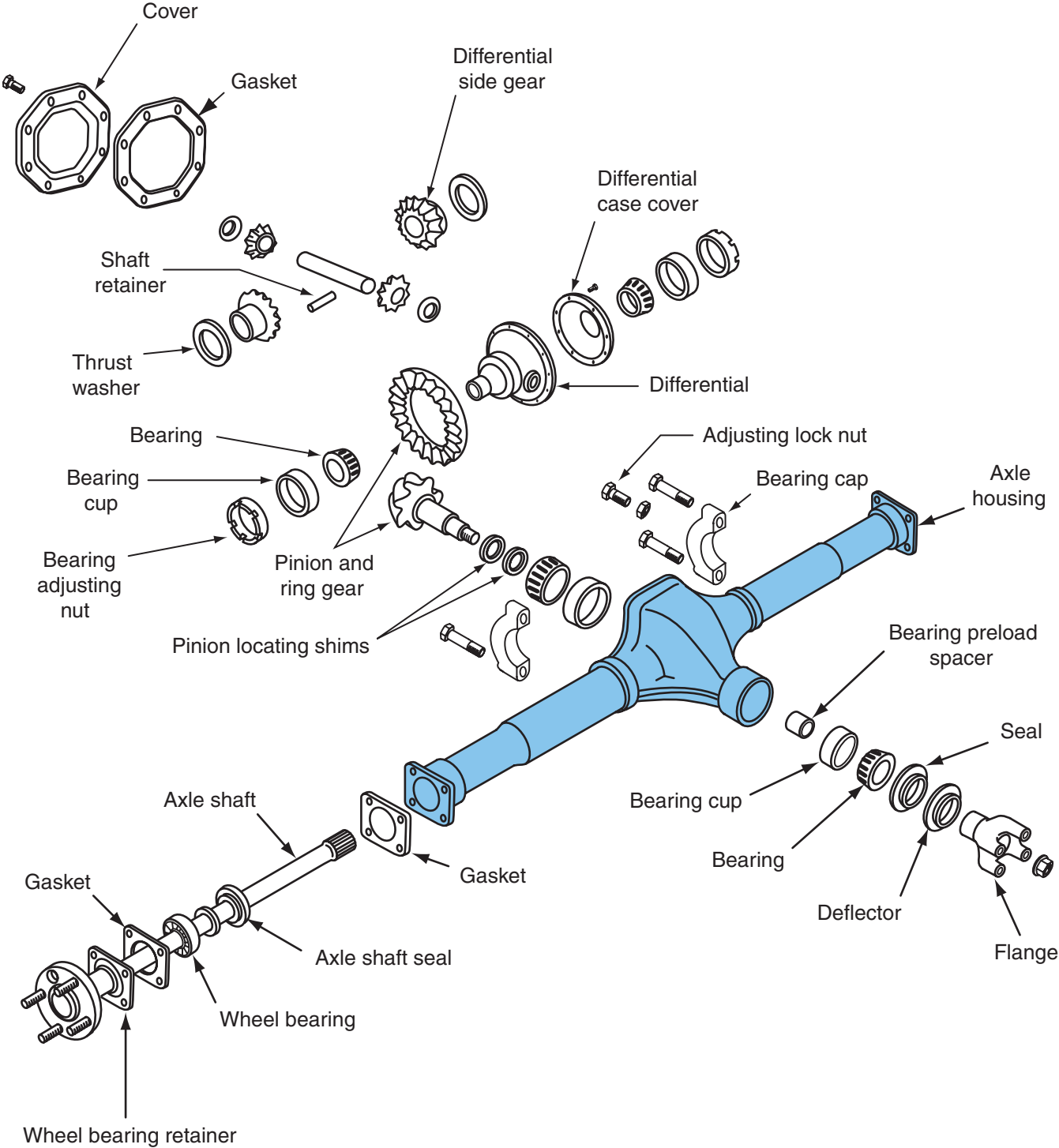


Figure 7-1. Typical RWD axle assembly.

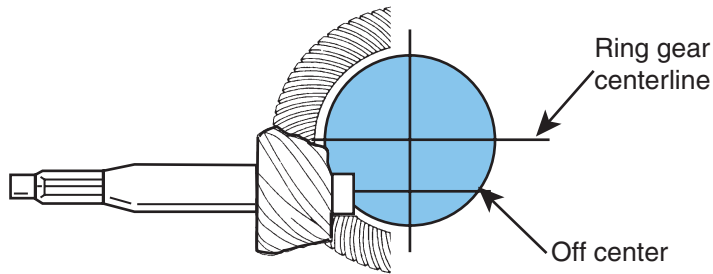


Figure 7-2 A hypoid gearset.

The differential is a geared mechanism located between the two driving axles. It rotates the driving axles at different speeds when the vehicle is turning a corner. It also allows both axles to turn at the same speed when the vehicle is moving straight. The drive axle assembly directs drive-line torque to the vehicle's drive wheels. The gear ratio of the differential's ring and pinion gear is used to increase torque, which improves driveability. The differential serves to establish a state of balance between the forces or torques between the drive wheels and allows the drive wheels to turn at different speeds when the vehicle changes direction.

Function and Components

The differential allows for different speeds at the drive wheels when a vehicle goes around a corner or any time there is a change of direction. When a car turns a corner, the outside wheels must travel farther and faster than the inside wheels (Figure 7-3). If compensation is not made for this

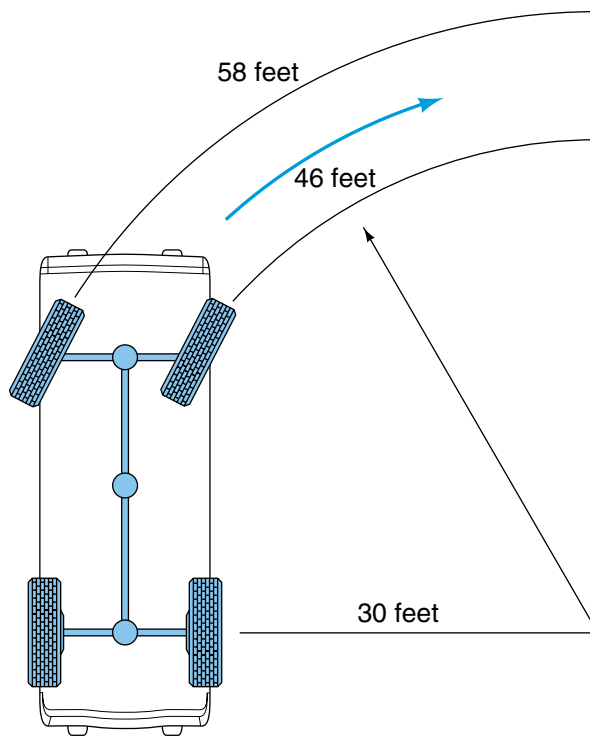


Figure 7-3 Travel of wheels when a vehicle is turning a corner.

Not too long ago, a differential was something that was in the rear axle assembly. Now, with the popularity of FWD vehicles, the differential is part of the transaxle and is most often called the final drive.

When engines are placed longitudinally in the car, they are said to have "north/south" placement.

Helical gears are gears on which the teeth are at an angle to the gear's axis of rotation.

When engines are mounted transversely in the car, they are said to have "east/west" or sideways placement.

difference in speed and travel, the wheels would skid and slide, causing poor handling and excessive tire wear. Compensation for the variations in wheel speeds is made by the differential assembly. While allowing for these different speeds, the differential also must continue to transmit torque.

The differential of a RWD vehicle is normally housed with the drive axles in a large casting called the rear axle assembly. Power from the engine enters into the center of the rear axle assembly and is transmitted to the drive axles. The drive axles are supported by bearings and are attached to the wheels of the car. The power entering the rear axle assembly has its direction changed by the differential. This change of direction is accomplished through the hypoid gears used in the differential.

A BIT OF HISTORY

Early automobiles were driven by means of belts and ropes around pulleys mounted on the driving wheels and engine shaft or transmission shaft. As there was always some slippage of the belts, one wheel could rotate faster than the other when turning a corner. When belts proved unsatisfactory, automobile builders borrowed an idea from the bicycle and applied sprockets and chains. This was a positive driving arrangement, which made it necessary to provide differential gearing to permit one wheel to turn faster than the other.



Power from the drive shaft is transmitted to the rear axle assembly through the pinion flange. This flange is the connecting yoke to the rear universal joint. Power then enters the final drive on the **pinion gear** (Figure 7-4). The pinion teeth engage the ring gear, which is mounted upright at a 90-degree angle to the pinion. Therefore, as the drive shaft turns, so do the pinion and ring gears.

The **ring gear** is fastened to the differential case with several hardened bolts or rivets. The differential case is made of cast iron and is supported by two tapered-roller bearings in the rear axle housing. Holes machined through the center of the differential housing support the differential pinion shaft. The pinion shaft is retained in the housing case by clips or a specially designed bolt. Two beveled differential pinion gears and thrust washers are mounted on the differential pinion shaft. In mesh with the differential pinion gears are two axle side gears splined internally to mesh with the external splines on the left and right axle shafts (Figure 7-5). Thrust washers are placed between the differential pinions, axle side gears, and differential case to prevent wear on the inner surfaces of the differential case.

In a **ring** and **pinion gearset**, the pinion is the smaller drive gear and the ring gear is the larger driven gear.

The term *differential* means relating to or exhibiting a difference or differences.

Other names commonly used to refer to the differential of RWD vehicles are rear axle, drive axle, third member, center section, or "pumpkin."

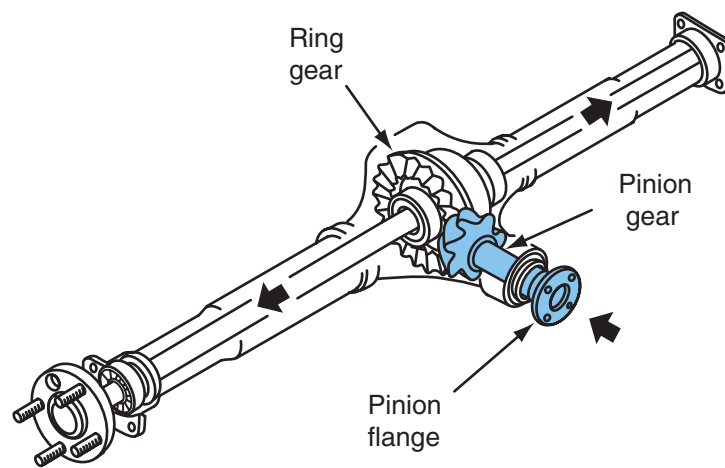


Figure 7-4 Main components of a RWD drive axle.

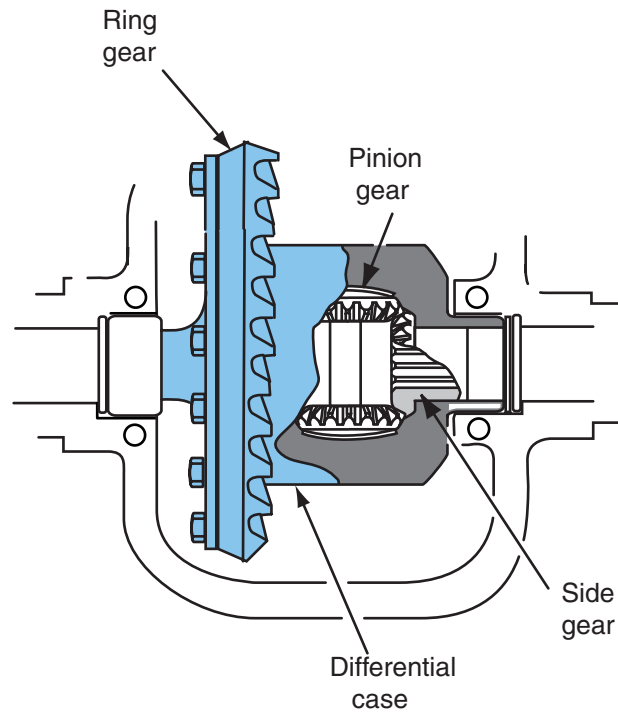


Figure 7-5 Components of a typical differential.

Differential Operation

The two drive wheels are mounted on axles that have a differential side gear fitted on their inner ends (Figure 7-6). To turn the power flow 90 degrees, as is required for RWD vehicles, the side gears are bevel gears.



Shop Manual
Chapter 7, page 251

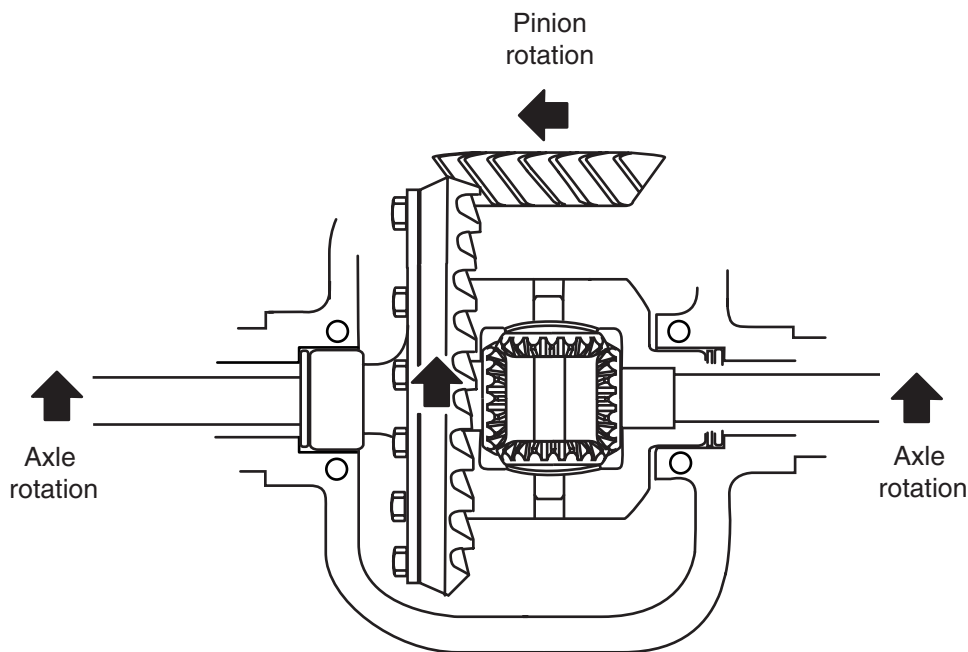


Figure 7-6 Power flow through a RWD differential.

When two beveled gears are meshed, the driving and driven shafts can rotate at a 90-degree angle.

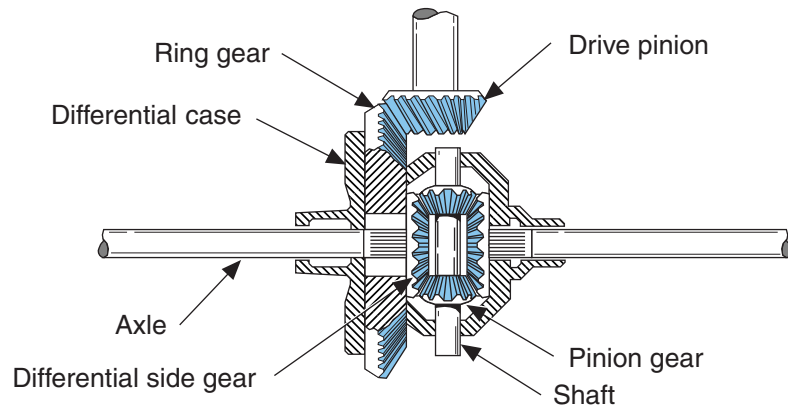


Figure 7-7 Basic differential.

The **differential case** is the metal unit that encases the differential side gears and pinion gears and to which the ring gear is attached.

The two side gears are placed on the side of the differential case, which is why they are called **side gears**.

The gear ratio in a differential is known as the axle ratio.

The **differential case** is mounted on bearings so that it is able to rotate independently of the drive axles. A pinion shaft, with small pinion gears, is fitted inside the differential case. The pinion gears mesh with the **side gears**. The ring gear is bolted to the flange of the differential case and the two rotate as a single unit. The drive pinion meshes with the ring gear and is rotated by the drive shaft (Figure 7-7).

Engine torque is delivered by the drive shaft to the drive pinion gear, which is in mesh with the ring gear and causes it to turn. Power flows from the pinion gear to the ring gear. The ring gear is bolted to the differential case, which drives the side gears, pinions, and axles as an assembly. The differential case extends from the side of the ring gear and normally houses the pinion gears and the side gears. The side gears are mounted so they can slip over splines on the ends of the axle shafts.

There is a gear reduction between the drive pinion gear and the ring gear, causing the ring gear to turn about one-third to one-fourth the speed of the drive pinion. The pinion gears are located between and meshed with the side gears (Figure 7-8), thereby forming a square inside the differential case. Differentials have two or four pinion gears that are in mesh with the side gears (Figure 7-9). The differential pinion gears are free to rotate on their own centers and can travel in a circle as the differential case and pinion shaft rotate. The side gears are meshed with the pinion gears and are also able to rotate on their own centers.

The small pinion gears are mounted on a pinion shaft that passes through the gears and the case. The pinion gears are in mesh with the axle side gears, which are splined to the axle shafts.

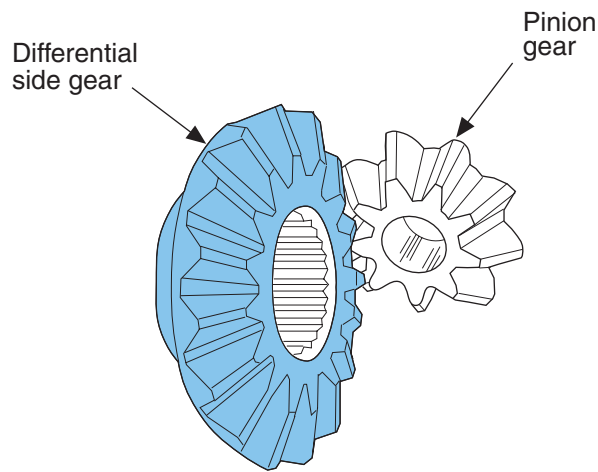


Figure 7-8 Pinion gears in mesh with the side gears.

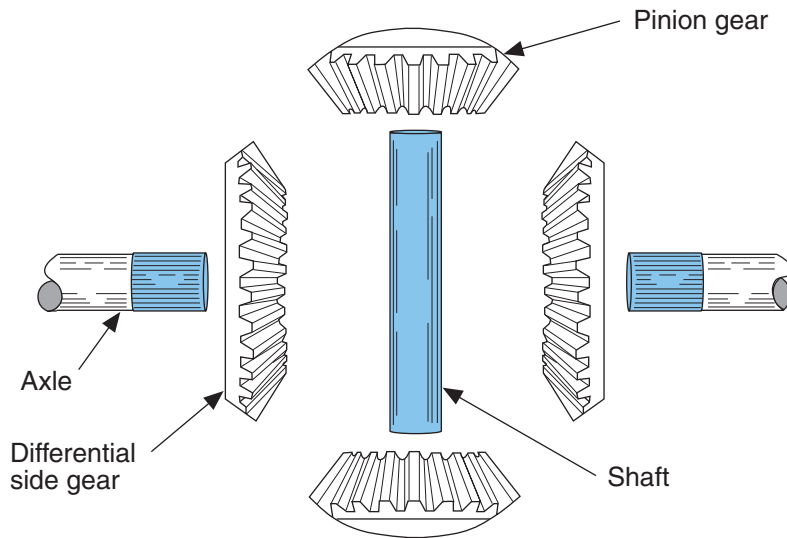


Figure 7-9 Position of side and pinion gears.

In operation, the rotating differential case causes the pinion shaft and pinion gears to rotate end over end with the case (Figure 7-10). Because the pinion gears are in mesh with the side gears, the side gears and axle shafts are also forced to rotate.

When a car is moving straight ahead, both drive wheels are able to rotate at the same speed. Engine power comes in on the pinion gear and rotates the ring gear. The differential case is rotated with the ring gear. The pinion shaft and pinion gears are carried around by the ring gear and all of the gears rotate as a single unit. Each side gear rotates at the same speed and in the same plane as does the case and they transfer their motion to the axles. The axles are thus rotated, and the car moves. Each wheel rotates at the same speed because each axle receives the same rotation (Figure 7-11).

As the vehicle goes around a corner, the inside wheel travels a shorter distance than the outside wheel. The inside wheel must therefore rotate more slowly than the outside wheel. In this situation, the differential pinion gears will “walk” forward on the slower turning or inside side gear (Figure 7-12). As the pinion gears walk around the slower side gear, they drive the other side gear at a greater speed. An equal percentage of speed is removed from one axle and given to the other (Figure 7-13), however the torque applied to each wheel is equal.

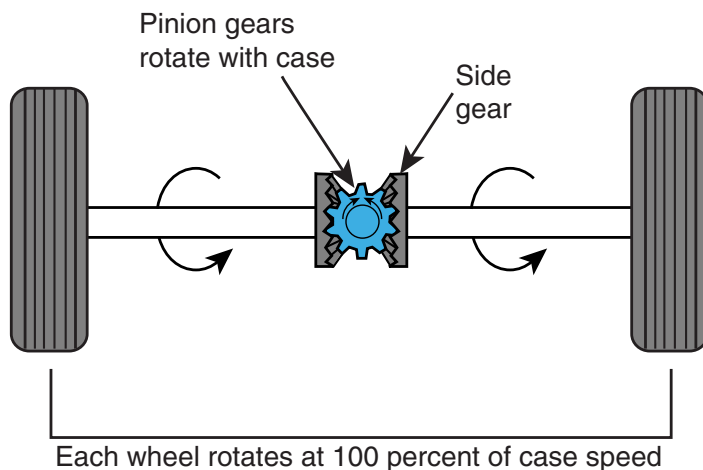


Figure 7-10 Position of pinion gears in the case causes the side gears to rotate.

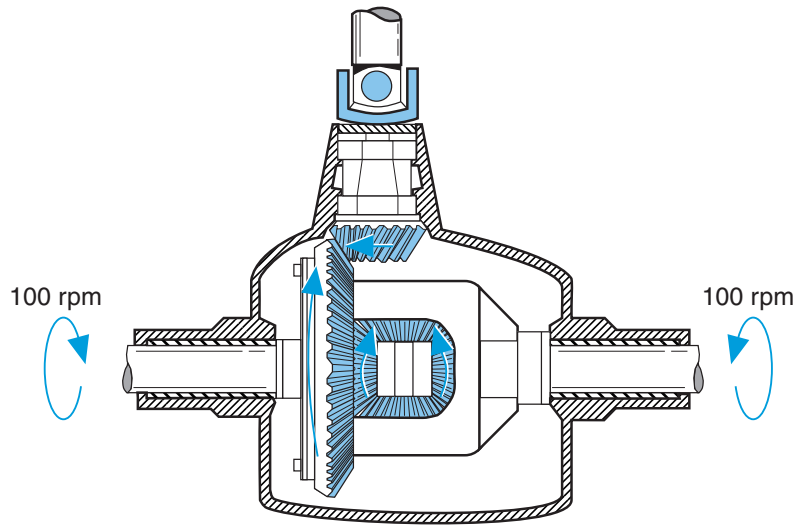


Figure 7-11 Differential action when the vehicle is moving straight ahead.

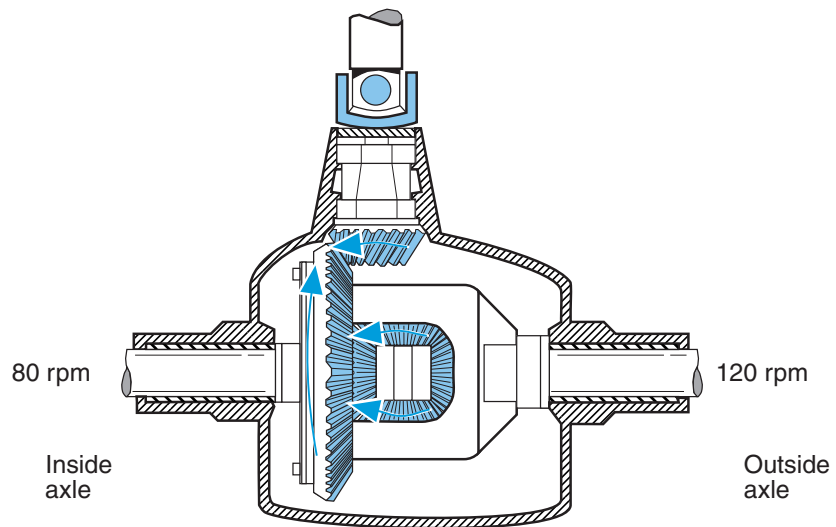


Figure 7-12 Differential action while the vehicle is turning a corner.

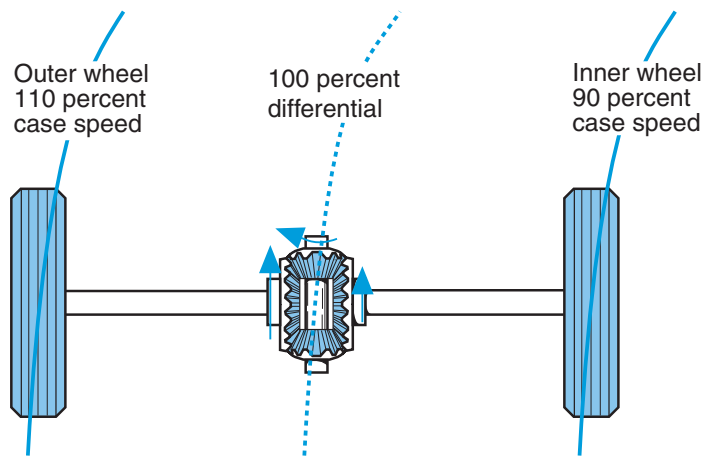


Figure 7-13 Speed differentiation when turning.

Only the outside wheel rotates freely when a car is making a very sharp turn; therefore, only one side gear rotates freely. Because one side gear is stationary, the pinion gears now turn on their own centers as they walk around the stationary side gear. As they walk around that side gear, they drive the other side gear at twice their own speed. The moving wheel is now turning at twice the speed of the differential case, but the torque applied to it is only half of the torque applied to the differential case. This increase in wheel speed occurs because of these two actions: the differential pinion gears are rotating end over end with the pinion shaft and the action of the differential pinion gears rotating around the differential pinion shaft.

When one of the driving wheels has little or no traction, the torque required to turn the wheel without traction is very low. The wheel with good traction in effect is holding the axle gear on that side stationary. This causes the pinions to walk around the stationary side gear and drive the other wheel at twice the normal speed but without any vehicle movement. With one wheel stationary, the other wheel turns at twice the speed shown on the speedometer. Excessive spinning of one wheel can cause severe damage to the differential. The small pinion gears can actually become welded to the pinion shaft or differential case.

Axle Housings

Live rear axles use a one-piece housing with two tubes extending from each side. These tubes enclose the axles and provide attachments for the axle bearings. The housing also shields the parts from dirt and retains the differential lubricant.

In IRS (Figure 7-14) or FWD systems, the housing is in three parts. The center part houses the final drive and differential gears. The outer parts support the axles by providing attachments for the axle bearings. These parts also serve as suspension components and attachment points for the steering gear and/or brakes. In FWD applications, the differential and final drive are either enclosed in the same housing as the transmission or in a separate housing bolted directly to the transmission housing.

Based on their construction, rear axle housings can be divided into two groups, integral carrier or removable carrier. An **integral carrier** housing attaches directly to the rear suspension. A service cover, in the center of the housing, fits over the rear of the differential and rear axle assembly (Figure 7-15). When service is required, the cover must be removed. The components of the differential unit are then removed from the rear of the housing.

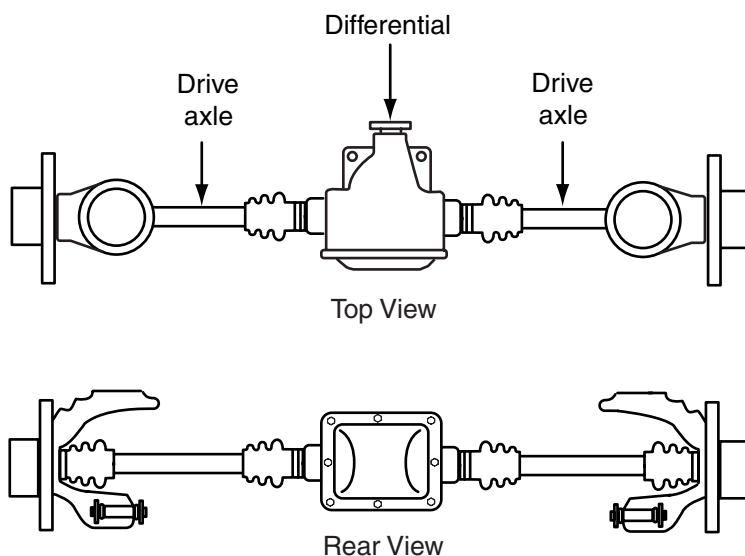


Figure 7-14 Drive axle assembly on a RWD vehicle with IRS.



Shop Manual
Chapter 7, page 255

An **integral carrier** housing attaches directly to the rear suspension. A service cover, in the center of the housing, fits over the rear of the differential and rear axle assembly. When service is required, the cover must be removed. Integral carriers are commonly referred to as unitized or Salisbury-type differentials.

The rear axle housing is sometimes called a banjo because of the bulge in the center of the housing. The bulge contains the final drive gears and differential gears.

In the rear, the outer sections of the housing may be called the uprights and in the front they are usually called the steering knuckle.

The differential assembly of a **removable carrier** assembly can be removed from the front of the axle housing as a unit. The differential is serviced on a bench and then installed into the axle housing. Removable carriers are often referred to as the third member, dropout carrier, or pumpkin.

In appearance the two designs of rear axle housing look similar except that the opening for the differential unit on a removable type is at the front and the rear of the housing is solid.

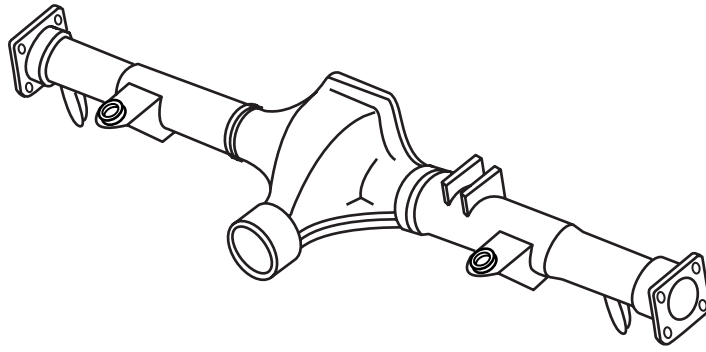


Figure 7-15 Typical integral carrier axle housing.

In an integral-type axle housing, the differential carrier and the pinion bearing retainer are supported by the axle housing in the same casting. The pinion gear and shaft is supported by two opposing tapered-roller bearings located in the front of the housing. The differential carrier assembly is also supported by two opposing tapered-roller bearings, one at each side (Figure 7-16).

The differential assembly of a **removable carrier** assembly can be removed from the front of the axle housing as a unit. The differential is serviced on a bench and then installed into the axle housing. The differential assembly is mounted on two opposing tapered-roller bearings retained in the housing by removable caps. The pinion gear, pinion shaft, and the pinion bearings are typically assembled in a pinion retainer, which is bolted to the carrier housing (Figure 7-17).

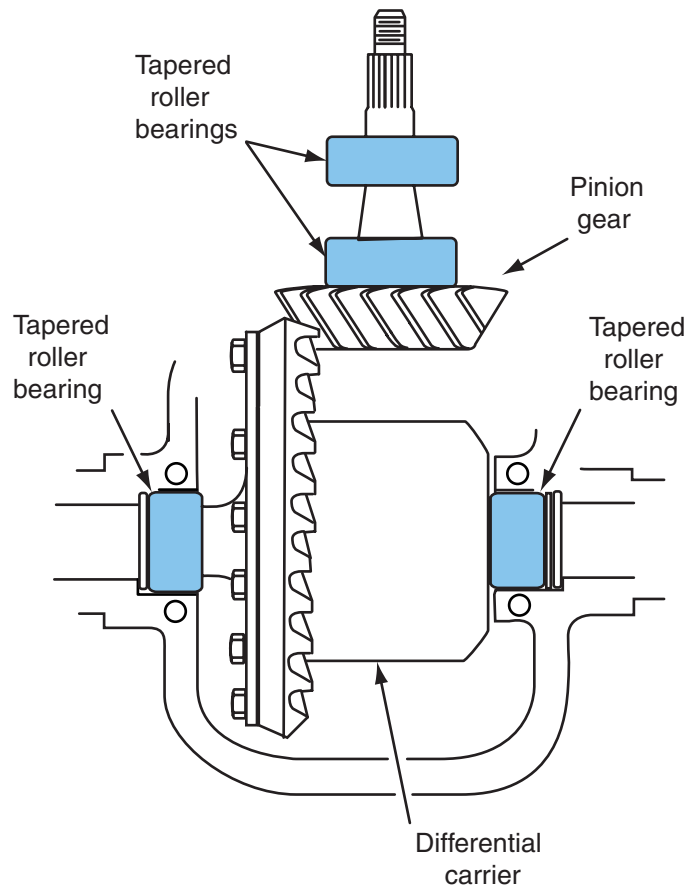


Figure 7-16 Location of bearings in a typical integral housing.

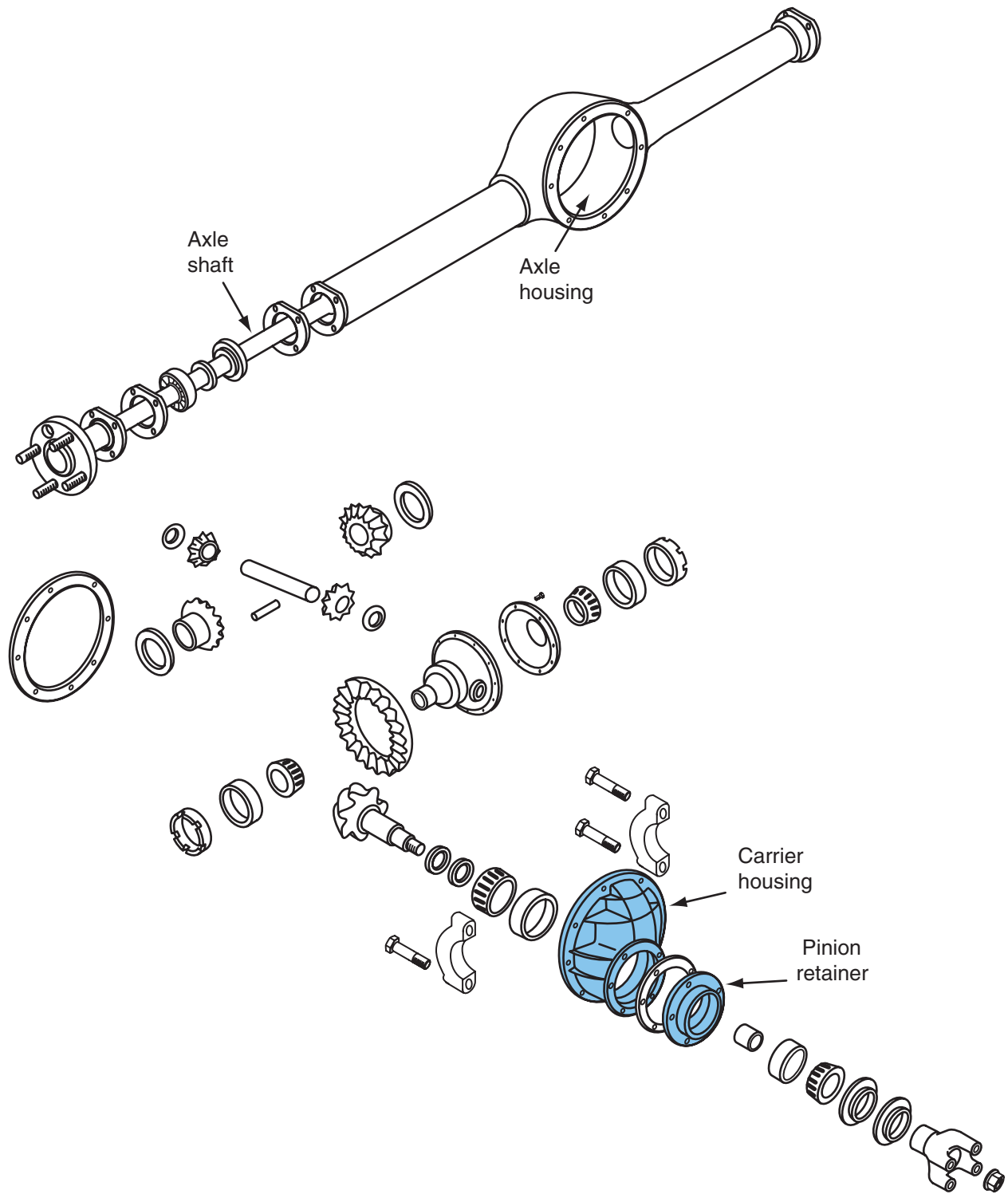


Figure 7-17 Typical removable carrier axle housing.

A typical housing has a cast-iron center section with axle shaft tubes pressed and welded into either side. The rear axle housing encloses the complete rear-wheel driving axle assembly. In addition to housing the parts, the axle housing also serves as a place to mount the vehicle's rear suspension and braking system. With IRS, the differential housing is mounted to the vehicle's chassis and does not move with the suspension.



The drive side of the teeth is the side that has engine power working on it, whereas the coast side is the side of the teeth that has contact during deceleration.

When there is no torque applied either in drive or in coast, the condition is known as float.

The climbing action of the drive pinion is sometimes called wind-up.

The gear ratio of the pinion and ring gear is often referred to as the final drive ratio.

Differential Gears

Two types of gears are currently being used as RWD differential gears: spiral bevel and hypoid (Figure 7-18). Spiral bevel gears are commonly used in heavy duty applications. In a spiral bevel gearset, the centerline of the drive pinion gear intersects the centerline of the ring gear. These designs are noisier than hypoid gears.

Hypoid gearsets are commonly used in RWD passenger car and light truck applications. The pinion gear in a hypoid gearset is mounted well below the centerline of the ring gear. Hypoid gears are quiet running.

This design allows for lower vehicle height and more passenger room inside the vehicle. By lowering the drive pinion gear on the ring gear, the entire drive shaft can be lowered. Lowering the drive shaft allows for a lower drive shaft tunnel, which in turn allows for increased passenger room and a lower ride height.

The teeth of a hypoid gear are curved to follow the form of a spiral, causing a wiping action while meshing. As the gears rotate, the teeth slide against each other. Because of this sliding action, the ring and pinion gears can be machined to allow for near perfect mating, which results in smoother action and a quiet-running gearset. Because this sliding action produces extremely high pressures between the gear teeth, only a hypoid-type lubricant should be used with hypoid gearsets.

The spiral-shaped teeth result in different tooth contacts as the pinion and ring gear rotate. The drive side of the teeth is curved in a convex shape, and the coast side of the teeth is concave (Figure 7-19). The inner end of the teeth on the ring gear is known as the toe and the outer end of the teeth is the heel (Figure 7-20).

While engine torque is being applied to the drive pinion gear, the pinion teeth exert pressure on the drive side of the ring gear teeth. During coast or engine braking, the concave side of the ring gear teeth exerts pressure on the drive pinion gear.

Upon heavy acceleration, the drive pinion attempts to climb up the ring gear and raises the front of the differential. The suspension's leaf springs or the torque arm on coil spring suspensions absorb much of the torque to limit the movement of the axle housing (Figure 7-21).

Gear Ratios

Gear ratios express the number of turns the drive gear makes compared to one turn of the driven gear it mates with. The ring gear is driven by the pinion gear, therefore causing torque multiplication. The ring gear is always larger than the pinion. This combination causes the ring gear to turn more slowly but with greater torque.

Many different final drive ratios are used. A final drive ratio of 2.8:1 is commonly used, especially on cars equipped with automatic transmissions. A 2.8:1 final drive ratio means the drive pinion must turn 2.8 times to rotate the ring gear one time. On cars equipped with manual transmissions, more torque multiplication is often needed, therefore a 3.5:1 final drive ratio is often used. To allow a car to accelerate more quickly or to move heavy loads, a final drive ratio of 4:1 can be used. Also, small engine cars with overdrive fourth and fifth gears often use a 4:1 final drive ratio, which allows them to accelerate reasonably well in spite of the engine's low power output.

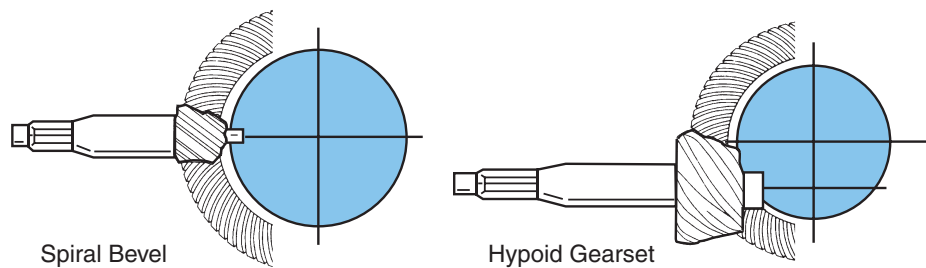


Figure 7-18 Comparison of a spiral bevel and hypoid gearset.

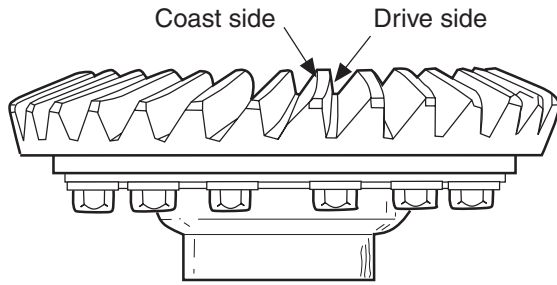


Figure 7-19 The drive and coast side of a ring gear.

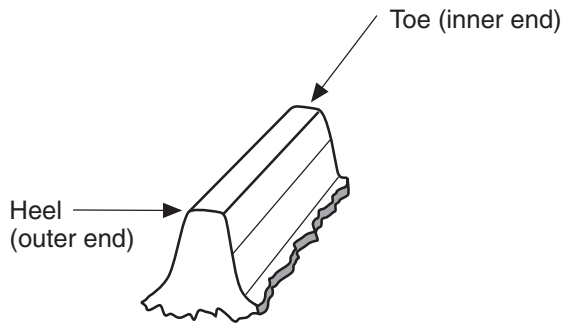


Figure 7-20 The toe and heel of a ring gear's tooth.

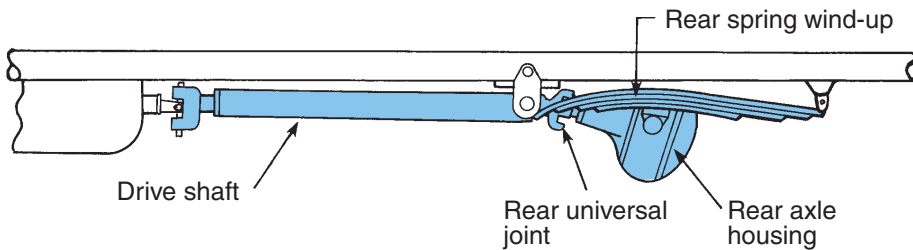


Figure 7-21 Great amounts of torque and good traction can cause the rear axle assembly to "wind up".

The overdrive in fourth and fifth gear effectively reduces the final drive ratio when the car is moving in those gears. Trucks also use a final drive ratio of 4:1 or 5:1 to provide more torque to enable them to pull or move heavy loads.

It is important to remember that the actual final drive or overall gear ratio is equal to the ratio of the ring and pinion gear multiplied by the ratio of the speed gear the car is operating in. For example, if a car has a final drive ratio of 3:1, the total final drive ratio for each transmission speed is as follows:

	Transmission Ratio	×	Final Drive Ratio	=	Total Final Drive Ratio
First gear	3:1		3:1		9:1
Second gear	2.5:1		3:1		7.5:1
Third gear	1.5:1		3:1		4.5:1
Fourth gear	1:1		3:1		3:1
Fifth gear	0.75:1		3:1		2.25:1

The frontal area of a vehicle has much to do with the air resistance on the vehicle's body while it is moving at speed.

Vehicles equipped with numerically low gear ratios are said to have high gears, whereas vehicles with numerically high gear ratios are said to have low gears.


Notice that, in this example, the only time the total final drive ratio is the same as the ratio of the ring and pinion gear is when the transmission is in fourth gear, which has a speed ratio of 1:1.

Many factors are considered when a manufacturer selects a final drive ratio for a vehicle. Some of these factors are vehicle weight, engine rpm range, designed vehicle speed, frontal area of the body, fuel economy requirements, engine power output, and transmission type and gear ratios. Cars with final drive ratios around 2.5:1 will take longer to accelerate but will typically give a higher top speed. At the other end of the scale, a 4.11:1 ratio will give faster acceleration with a lower top speed. Since the 1970s there has been an emphasis on fuel economy, and most cars have been equipped with high gears to allow for lower engine speeds at normal driving speeds.

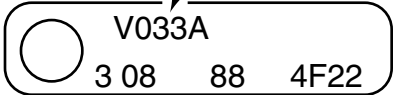
Determining Final Drive Ratio

To replace a ring and pinion gearset with one of the correct ratio, the ratio of the original set must be known. There are several ways to determine the final drive ratio of a ring and pinion gearset. If a shop manual is available, you can decipher the code found on the assembly or on a tag attached to it (Figure 7-22). Normally a table is given that lists the various codes and the ratios each represents.

Most axles are shipped with an identification tag bolted to them. These tags contain all of the information needed to identify the axle for diagnosis and service. The tags are located under the housing-to-carrier stud nut or are attached by a cover-to-carrier bolt. Manufacturers also often stamp identification numbers into the axle housing. These codes are normally located on the front side of an axle tube (Figure 7-23). Always refer to your shop manual to locate and decipher the codes.

 **SERVICE TIP:** If the stamped numbers cannot be found or if the axle tag is not there, refer to the axle code letter or number on the vehicle identification number (VIN) plate (Figure 7-22). This will identify the ratio and type of axle with which the car was originally equipped.

Plant code



MFD. By :		Date: 09/92		GVWR: 5345 - 2425 KG	
Front GAWR: 2713 LB.		Rear GAWR: 2682 LB			
1231 KG		1215 KG			
Vehicle conforms to all applicable federal motor vehicle safety and bumper standards on the date of manufacture shown above.					
Veh. Ident No. 1FABP43H9GH052068					
Type: Passenger					
3H					
Exterior paint colors					
Body	VR	MLDG	INT TRIM	A/C	R S
53H	HD	G6D	DD	A	2 B
					AX TR
					G xxxxB

← Axle ID code

Axle code	Ratio
8(M*)	2:73:1
G	2:26:1
Y(Z*)	3:08;1
F(R*)	3:45:1
B	2:47:1

* Traction-Lok

Figure 7-22 Deciphering differential codes from information given on the differential tag or from the VIN.

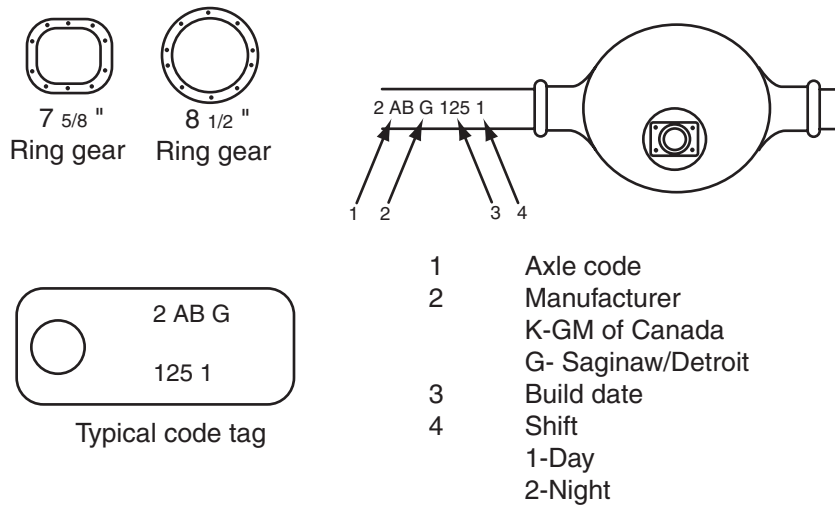


Figure 7-23 Different locations for the differential codes on an axle assembly.

Another way to determine the final drive ratio is to compare the number of revolutions of the drive wheels with those of the drive shaft. While turning both wheels simultaneously, note how many times the drive shaft turns to complete one revolution of the drive wheels. This count represents the ratio of the gears.

The gear ratio can also be determined when the differential is disassembled. Count the number of teeth on both the drive pinion and the ring gear. Divide the ring gear teeth number by the pinion drive number to calculate the final drive ratio.

Hunting and Nonhunting Gears

Ring and pinion gearsets are usually classified as hunting, nonhunting, or partial nonhunting gears. Each type of gearset has its own requirements for a satisfactory gear tooth contact pattern. These classifications are based on the number of teeth on the pinion and ring gears.

A **nonhunting gearset** is one in which any one pinion tooth comes into contact with only some of the ring gear teeth. One revolution of the ring gear is required to achieve all possible gear tooth contact combinations. As an example, if the ratio of the ring gear teeth to the pinion gear teeth is 39 to 13 (or 3.00:1), the pinion gear turns three times before the ring gear completes one turn. One full rotation of the pinion gear will cause its 13 teeth to mesh with one third of the ring gear's teeth. On the next revolution of the pinion gear, its teeth will mesh with the second third of the ring gear's teeth and the third revolution will mesh with the last third of the ring gear. Each tooth of the pinion gear will return to the same three teeth on the ring gear each time the pinion rotates.

A **partial nonhunting gearset** is one in which any one pinion tooth comes into contact with only some of the ring gear teeth, but more than one revolution of the ring gear is required to achieve all possible gear tooth contact combinations. If the ratio of the ring gear teeth to the pinion gear teeth is 35 to 10 (or 3.5:1), any given tooth of the pinion will meet seven different teeth (seven complete revolutions of the pinion gear) of the ring gear before it returns to the space where it started.

When **hunting gearsets** are rotating, any pinion gear tooth will contact all the ring gear teeth. If the ring gear has 37 teeth and the pinion gear has 9, the gearset has a ratio of 37 to 9 (or 3.89:1). Any given tooth in the pinion gear meets all of the teeth in the ring gear before it meets the first tooth again.

A **nonhunting gearset** is one in which any one pinion tooth comes into contact with only some of the ring gear teeth. One revolution of the ring gear is required to achieve all possible gear tooth contact combinations.

A **partial nonhunting gearset** is one in which any one pinion tooth comes into contact with only some of the ring gear teeth, but more than one revolution of the ring gear is required to achieve all possible gear tooth contact combinations.



Shop Manual
Chapter 7, page 280

The alignment of nonhunting and partial nonhunting gears is often referred to as timing the gears.

When **hunting gearsets** are rotating, any pinion gear tooth will contact all the ring gear teeth.

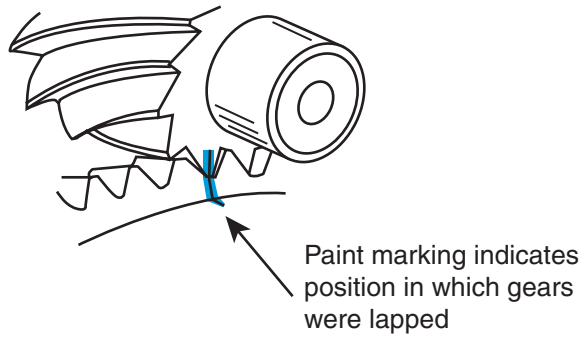


Figure 7-24 Index marks of a ring and pinion gearset.

During assembly the nonhunting and partial nonhunting gears must be assembled with the index marks properly aligned (Figure 7-24). When these gearsets were manufactured, they were probably **lapped** to ensure proper meshing and because specified teeth on the pinion will always meet specific teeth on the ring gear, a noisy gear will result if they are not properly aligned. Hunting gears do not need to be aligned because any tooth on the pinion may mesh with any tooth on the ring gear.

Lapping is the process of using a grinding paste to produce a fine finish on the teeth of the two gears that will be in full contact with each other.

Differential Bearings

At least four bearings are found in all differentials. Two fit over the drive pinion shaft to support it and the other two support the differential case and are usually mounted just outboard of the side gears (Figure 7-25). The drive pinion and case bearings are typically tapered-roller bearings.

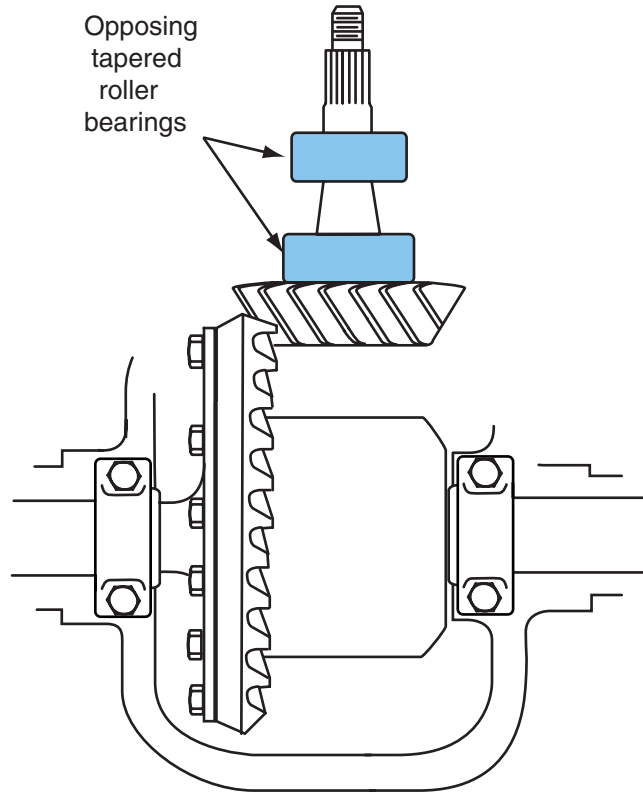


Figure 7-25 Position of bearings in a typical differential assembly.

Different forces are generated in the differential due to the action of the pinion gear. As the pinion gear turns, it tries to climb up the ring gear and pull the ring gear down. Also, as the pinion gear rotates, it tends to move away from the ring gear and pushes the ring gear equally as hard in the opposite direction. Because of these forces, the differential must be securely mounted in the carrier housing. The bearings on each end of the differential case support the case and absorb the thrust of the forces (Figure 7-26). The pinion gear and shaft are mounted on bearings to allow the shaft to rotate freely without allowing it to move in response to the torque applied to it. All of these bearings are installed with a preload to prevent the pinion gear and ring gear from moving out of position.

Pinion Mountings

As torque is applied to a pinion gear, the pinion gear rotates and drives the ring gear. As it rotates, three separate forces are produced by its rotation and the torque applied to it. The pinion gear tries to screw itself out of the ring gear and move forward. It also tries to climb up on the teeth of the ring gear and it is forced to the side and away from the ring gear. These forces make it necessary to securely mount the pinion gear.

The **drive pinion flange** is splined to the rear axle's drive pinion gear. The drive pinion gear is placed horizontally in the axle housing and is positioned by one of two types of mounting, straddle or overhung. The straddle-mounted pinion gear is used in some removable carrier-type axle housings. The **straddle-mounted pinion** has two opposing tapered-roller bearings positioned close together with a short spacer between their inner races and ahead of the pinion gear. A third bearing, usually a straight roller bearing, is used to support the rear of the pinion gear (Figure 7-27).

The **overhung-mounted pinion** also uses two opposing tapered-roller bearings but does not use a third bearing. The two roller bearings must be farther apart than the opposing bearings

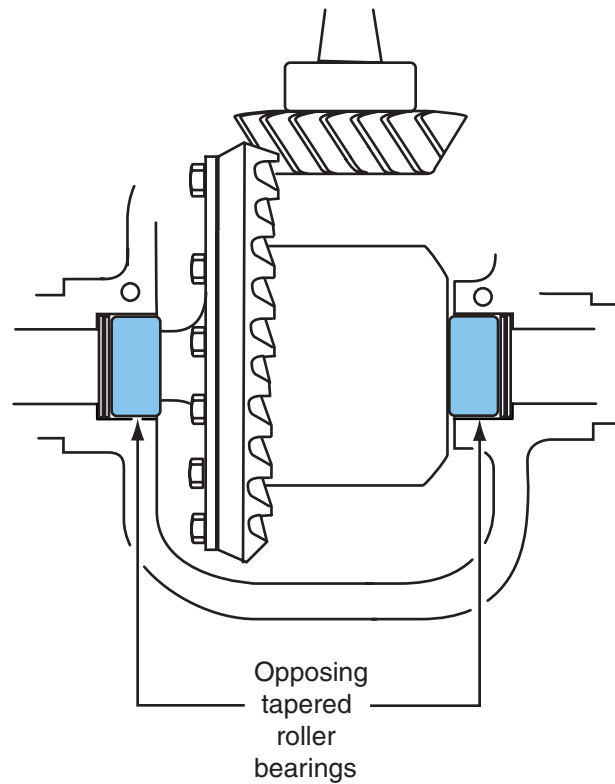


Figure 7-26 Position of differential case side bearings.

The rear Universal joint on the drive shaft attaches to the drive pinion flange or the companion flange.



Shop Manual
Chapter 7, page 280

The **drive pinion flange** is a rim used to connect the rear of the drive shaft to the rear axle drive pinion.

The **straddle-mounted pinion** has two opposing tapered-roller bearings positioned close together with a short spacer between their inner races and ahead of the pinion gear. A third bearing, usually a straight roller bearing, is used to support the rear of the pinion gear.

The **overhung-mounted pinion** also uses two opposing tapered-roller bearings but does not use a third bearing. This type of pinion gear mounting can be found on either the removable carrier or integral-type driving axle.

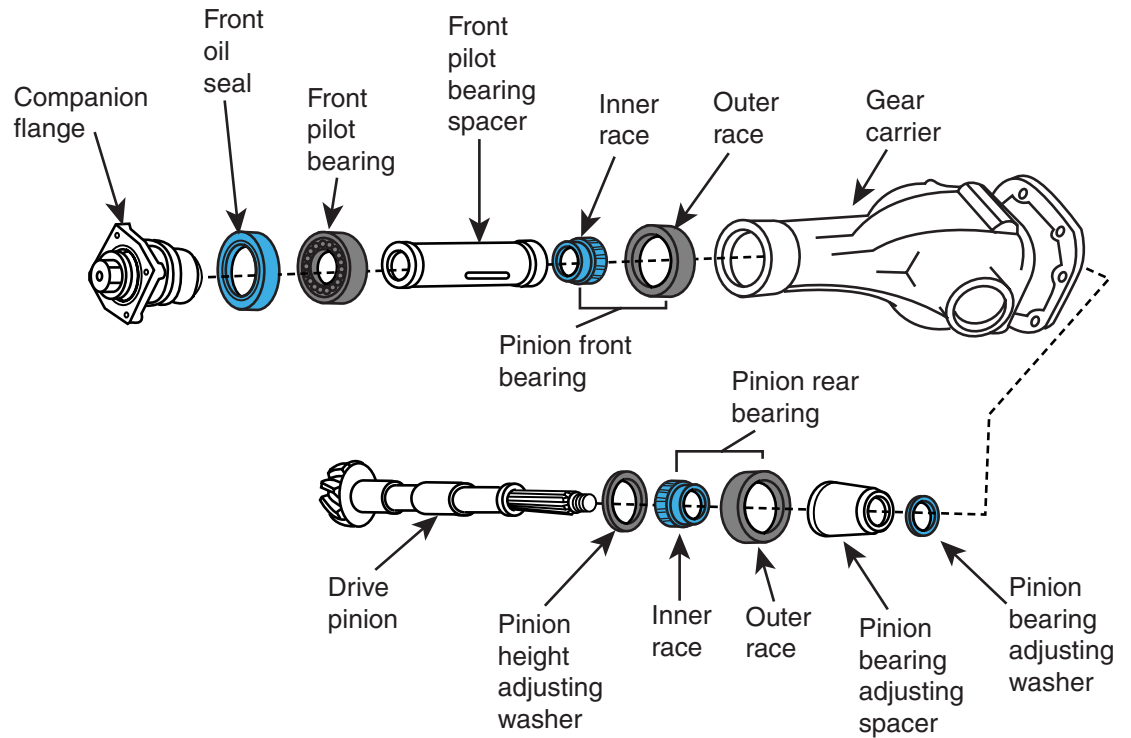


Figure 7-27 Typical straddle-mounted pinion gear.

of a straddle-mounted pinion because a third bearing is not used to support the pinion gear (Figure 7-28). This type of pinion gear mounting can be found on either the removable carrier or integral-type driving axle.

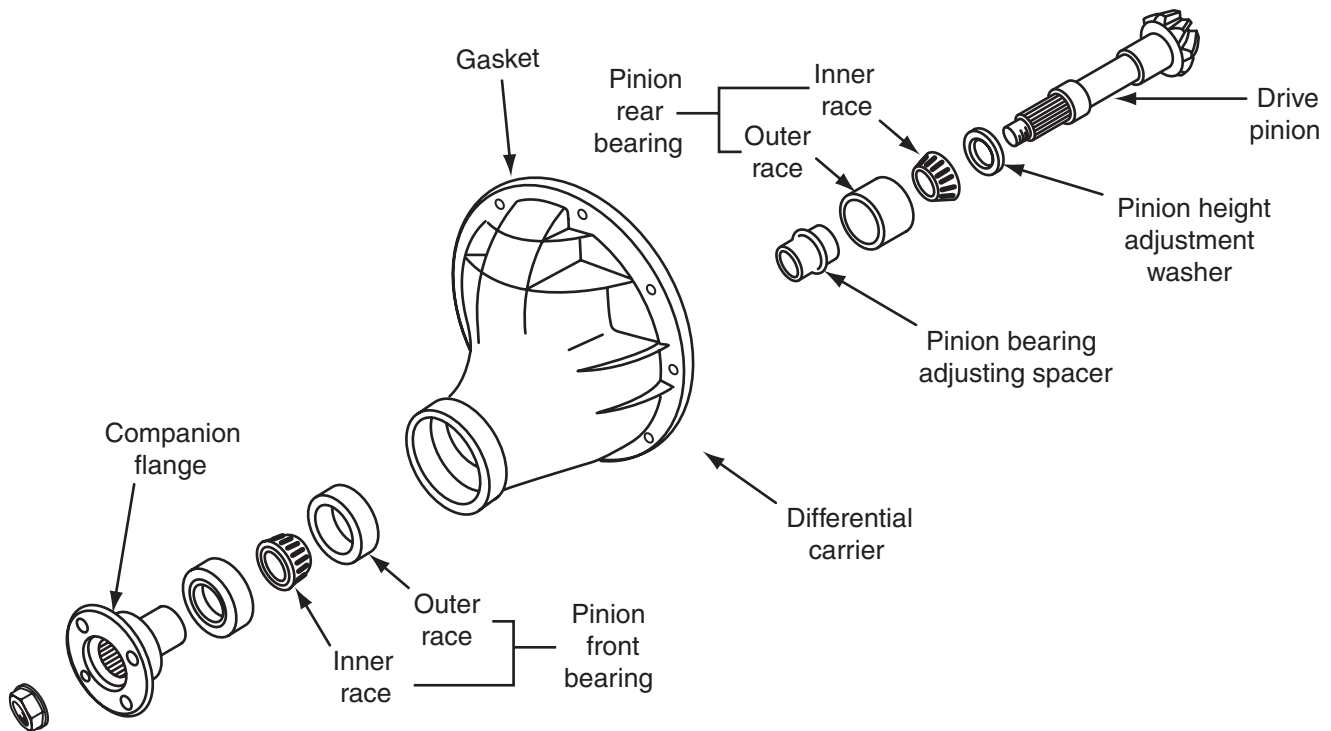


Figure 7-28 Typical overhung-mounted pinion gear.

Some pinion shafts are mounted in a bearing retainer that is removable from the carrier housing. This type of pinion assembly utilizes a pilot bearing to support the rear end of the pinion and is equipped with two opposing tapered-roller bearings.

Drive Pinion Bearing Preload

A spacer is placed between the opposing tapered bearings to control the distance between them (Figure 7-29). This spacer also controls the amount of preload or loading pressure applied to the bearings. Preload prevents the pinion gear from moving back and forth in the bearing retainer.

Often a collapsible spacer is used between the two large tapered bearings to provide for proper pinion bearing preload. Some differentials use a solid noncollapsible spacer with selective thickness shims to adjust pinion bearing preload.



SERVICE TIP: Collapsible spacers should never be reused. After they have been compressed once, they are not capable of maintaining preload when they are compressed again. The spacers should always be replaced when servicing the differential.

When the pinion shaft nut is tightened to specifications, pressure is exerted by the pinion drive flange against the inner race of the front pinion bearing. This applies pressure against the spacer and the rear bearing, which cannot move because it is located against the drive pinion gear. This load on the two pinion bearings assures that there will be no pinion shaft end play. Any pinion shaft end play will result in rapid failure and noise.

Differential Case

The differential case is supported in the carrier by two tapered-roller side bearings. This assembly can be adjusted from side to side to provide the proper backlash between the ring gear and pinion and the required side bearing preload. This adjustment is achieved by threaded bearing adjusters (Figure 7-30) on some units and the placement of selective shims and spacers (Figure 7-31) on others.

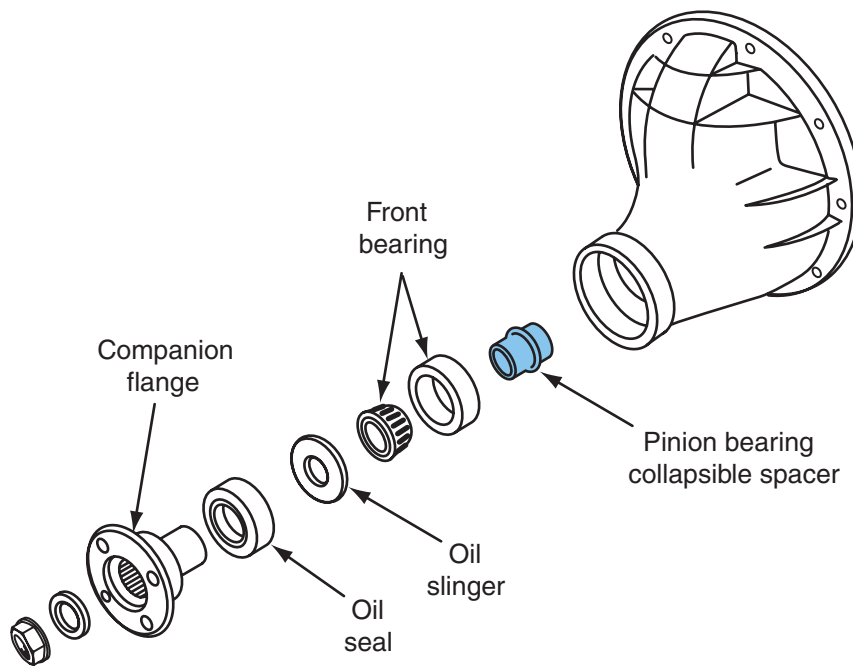


Figure 7-29 Location of pinion bearing spacer.



Shop Manual
Chapter 7, page 283

Preload is a fixed amount of pressure constantly applied to a component. Preload on bearing eliminates looseness. Preload on limited-slip differential clutches also provides torque transfer to the driven wheel with the least traction.

End play is the amount of axial or end-to-end movement in a shaft due to clearance in the bearings.



Shop Manual
Chapter 7, page 274

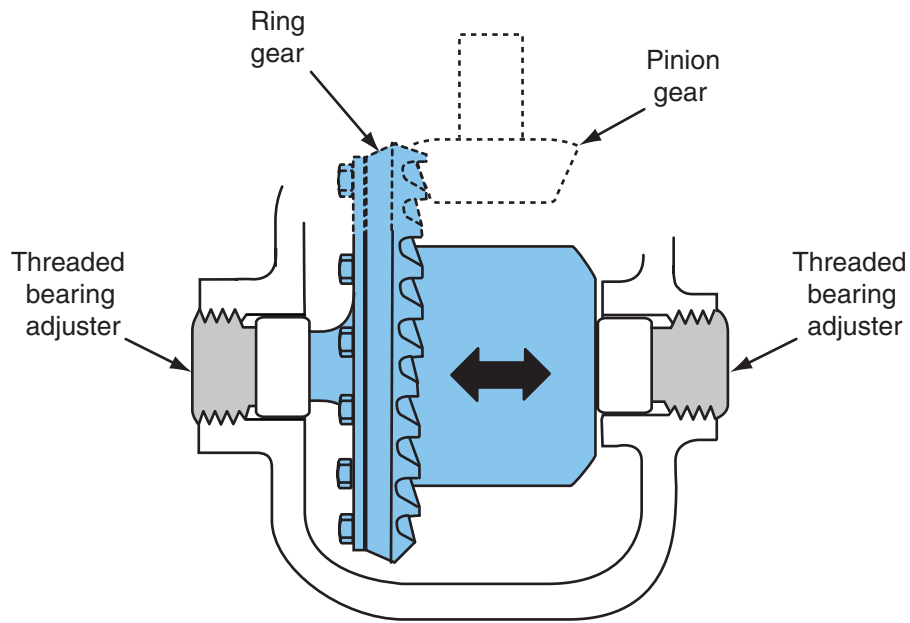


Figure 7-30 Location of bearing adjusting nuts.

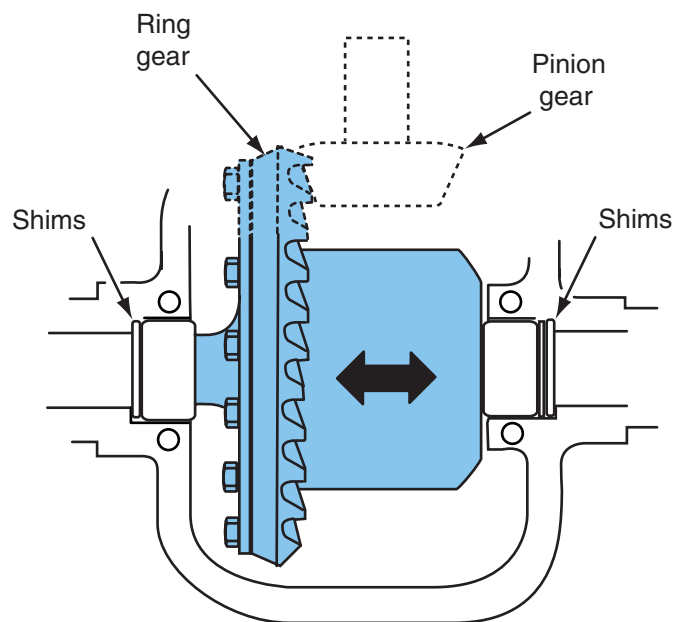


Figure 7-31 Location of bearing selective shims.



Shop Manual
Chapter 7, page 295

Transaxle Final Drive Gears and Differential

Transaxle final drive gears provide the means for transmitting transmission output torque to the differential section of the transaxle.

The differential section of the transaxle has the same components as the differential gears in a RWD axle and basically operate in the same way. The power flow in transversely mounted powertrains is in line with the wheels and therefore the differential unit does not need to turn the power 90 degrees.

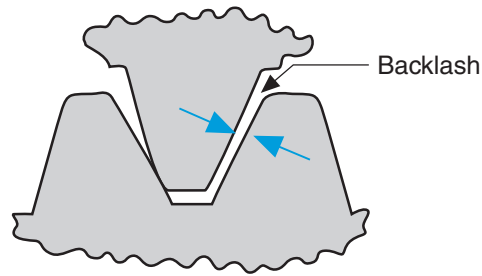


Figure 7-32 Gear backlash.

The drive pinion and ring gears and the differential assembly are normally located within the transaxle housing of FWD vehicles. There are three common configurations used as the final drives on FWD vehicles: helical, planetary, and hypoid. The helical and planetary final drive arrangements are usually found in transversely mounted power trains. Hypoid final drive gear assemblies are used with longitudinal powertrain arrangements.

The drive pinion gear is connected to the transmission's output shaft and the ring gear is attached to the differential case. Like the ring and pinion gearsets in a RWD axle, the drive pinion and ring gear of a FWD assembly provide for a multiplication of torque.

The teeth of the ring gear usually mesh directly with the transmission's output shaft (Figure 7-33). However on some transaxles, an intermediate shaft is used to connect the transmission's output to the ring gear.

On some models, the differential and final drive gears operate in the same lubricant as the transmission section of the transaxle. On other designs, the differential section is separately enclosed and is lubricated by a different lubricant than the transmission section. These designs require positive sealing between the differential unit and the transmission to keep the different lubricants from mixing. All transaxles use seals between the differential and the drive axles to prevent dirt from entering the transaxle and to prevent lubricant from leaking past the attachment point of the drive axles.

Helical Final Drive Assembly

Helical (Figure 7-34) final drive assemblies use helical gearsets that require the centerline of the pinion gear to be at the centerline of the ring gear. The pinion gear is cast as part of the main shaft

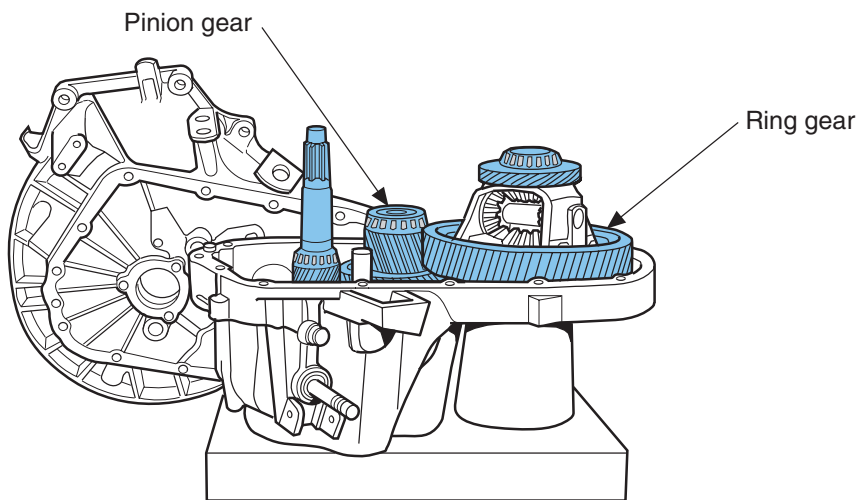


Figure 7-33 Typical ring and pinion gearset in a transaxle.

Backlash is the clearance or play between two gears in mesh. It is the amount one of the gears can be moved without moving the other (Figure 7-32).

Another name for collapsible spacer is crush sleeve.

The ring gear in a transaxle is sometimes referred to as the differential drive gear.

Helical gears are gears with teeth that are cut at an angle to the gear's axis of rotation.

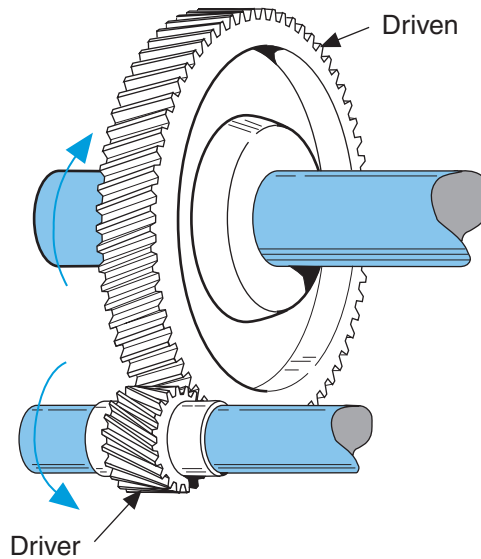


Figure 7-34 Helical gearset.

and is supported by tapered-roller bearings. The pinion gear is meshed with the ring gear to provide the required torque multiplication. Because the ring is mounted on the differential case, the case rotates in response to the pinion gear.

Planetary Final Drive Assembly

The ring gear of a planetary final drive assembly has lugs around its outside diameter. These lugs fit into grooves machined inside the transaxle housing. These lugs and grooves hold the ring gear stationary. The transmission's output shaft is splined to the planetary gearset's sun gear. The planetary pinions are in mesh with both the sun gear and ring gear and form a simple planetary gearset (Figure 7-35). The planetary carrier is constructed so that it also serves as the differential case.

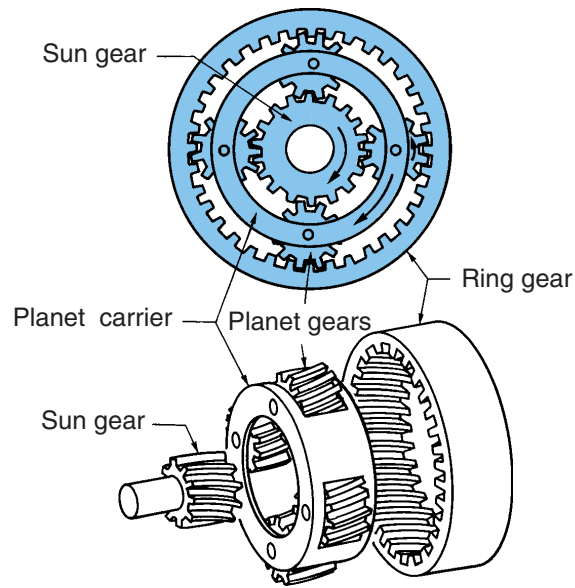


Figure 7-35 Planetary final drive gearset.

In operation, the transmission's output drives the sun gear, which, in turn, drives the planetary pinions. The planetary pinions walk around the inside of the stationary ring gear. The rotating planetary pinions drive the planetary carrier and differential housing. This combination provides maximum torque multiplication from a simple planetary gearset.

Hypoid Final Drive Assembly

Hypoid gears have the advantage of being quiet and strong because of their thick tooth design. And due to their strength, hypoid-type gears can be used with large engines that are longitudinally mounted in vehicles. This type of final drive unit is identical to those used in RWD vehicles.

Limited-Slip Differentials

An open differential is built with a combination of interlocking gears that eliminates tire scrubbing, as the outer tire has further distance to travel during cornering. Although this differential is the easiest on the car's tires and suspension, it has one major disadvantage—a lack of traction. Power, is for the most part, transferred to the wheel with the least resistance or traction.

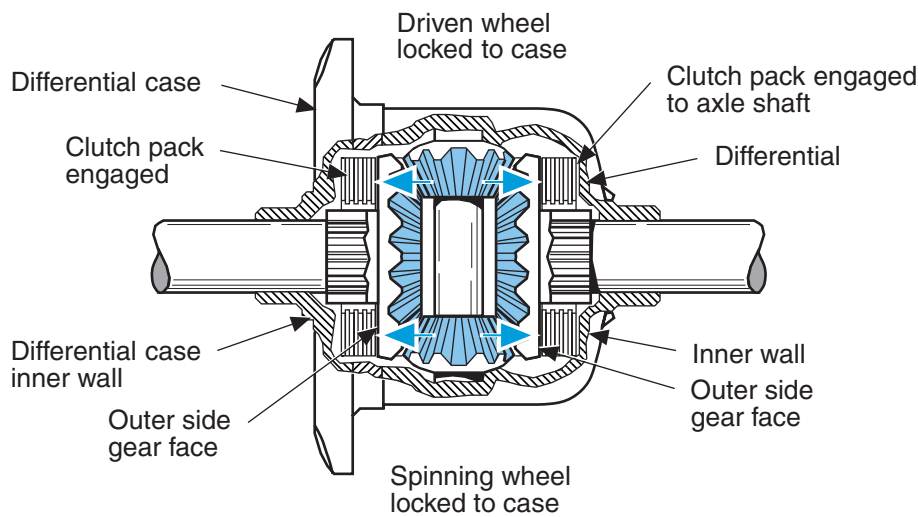
When a car is stuck in mud or snow, one drive wheel spins while the other remains stationary. In this example, the differential is transferring all of the torque and rotary motion to the drive wheel with the least resistance. Resistance, in this case, means traction. Applying torque to the wheel without traction does little good while trying to move the car.

A limited-slip differential assembly provides more driving force to the wheel with traction when one wheel begins to spin. With the addition of clutches to the differential case (Figure 7-36), differential action can be restricted so that if one drive wheel has no traction, the other wheel that has some traction will at least receive some torque. This is the theory behind the limited-slip differential.

Limited-slip differentials are used on high-performance and sports cars for increased traction while cornering and on off-road vehicles in which the drive wheels are constantly losing traction. Power flows in the same way as in an open differential. Most limited-slip differentials transfer at least 20 percent of the available torque to the wheel with traction. Limited-slip differentials merely limit the ease of differential action between the side gears through the use of these clutches.

An open differential is a standard-type differential, often called by racers the peg leg type.

Many names are used for limited-slip differentials, including Posi-Traction, Traction-Lok, and Posi-units.



Energized clutches cause locked differential

Figure 7-36 Action of clutches in a limited-slip differential.

Limited-slip differential cases are similar to open differential cases except for a large internal recess around the area of each side gear. This recess accepts either a clutch pack, a cone clutch, or a viscous clutch assembly, depending on design.



Shop Manual

Chapter 7, page 299

A clutch pack

consists of a complete set of alternating clutch plates and discs.

Common names for factory limited-slip differentials are Trac-Lok for Chrysler and Ford, Limited-Slip and Posi-Traction for GM, and Power-Lok and Sure-Grip for Chrysler.

Clutch Pack

The most common limited-slip differentials use two sets of multiple disc clutches to control differential action. Each **clutch pack** consists of a combination of steel plates and friction plates. The plates are stacked on the side gear hub and are housed in the differential case. A preload spring applies an initial force to the clutch packs (Figure 7-37).

The friction plates are splined to each side gear's hub. The ears of the steel plates are fitted into the case so that the clutch packs are always engaged. The discs rotate with the side gear and the plates with the differential case.

The clutch assembly consists of a multiple plate clutch, a center block, preload springs, and a preload plate (Figure 7-38). The clutch assembly is always engaged due to pressure constantly being applied to it by the preload springs. Under normal driving conditions, the clutch brake slips as the torque generated by differential action easily overcomes the capacity of the clutch assembly. This allows for normal differential action when the vehicle is turning. During adverse road conditions, where one or both wheels may be on a low friction surface such as snow, ice, or mud, the friction between the clutch plates will transfer a portion of usable torque to the wheel with the most traction.

The clutch packs are mounted behind each of the axle's side gears and springs between the side gears force the gears against the clutches. Although the springs allow enough slippage to permit driving around a curve, during slippery conditions they keep the side gears against the clutches with enough pressure to make those gears spin at the same speed. If one wheel begins

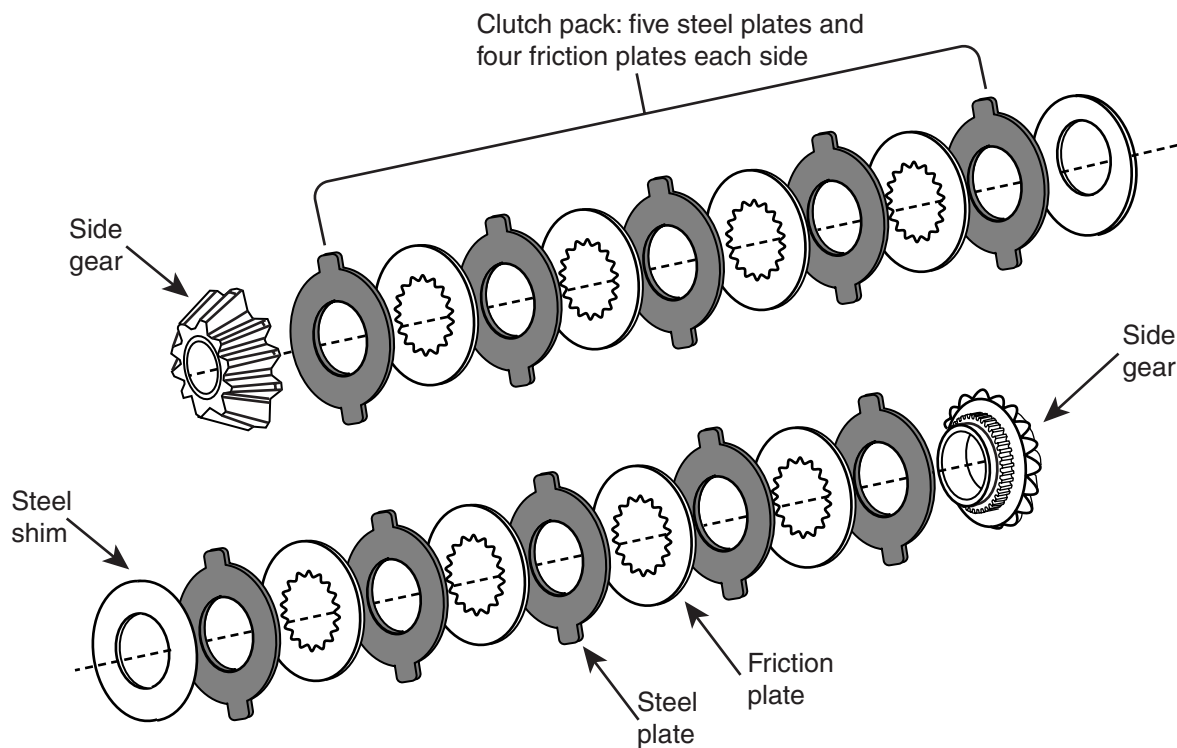


Figure 7-37 The clutch assembly in a typical limited-slip differential assembly

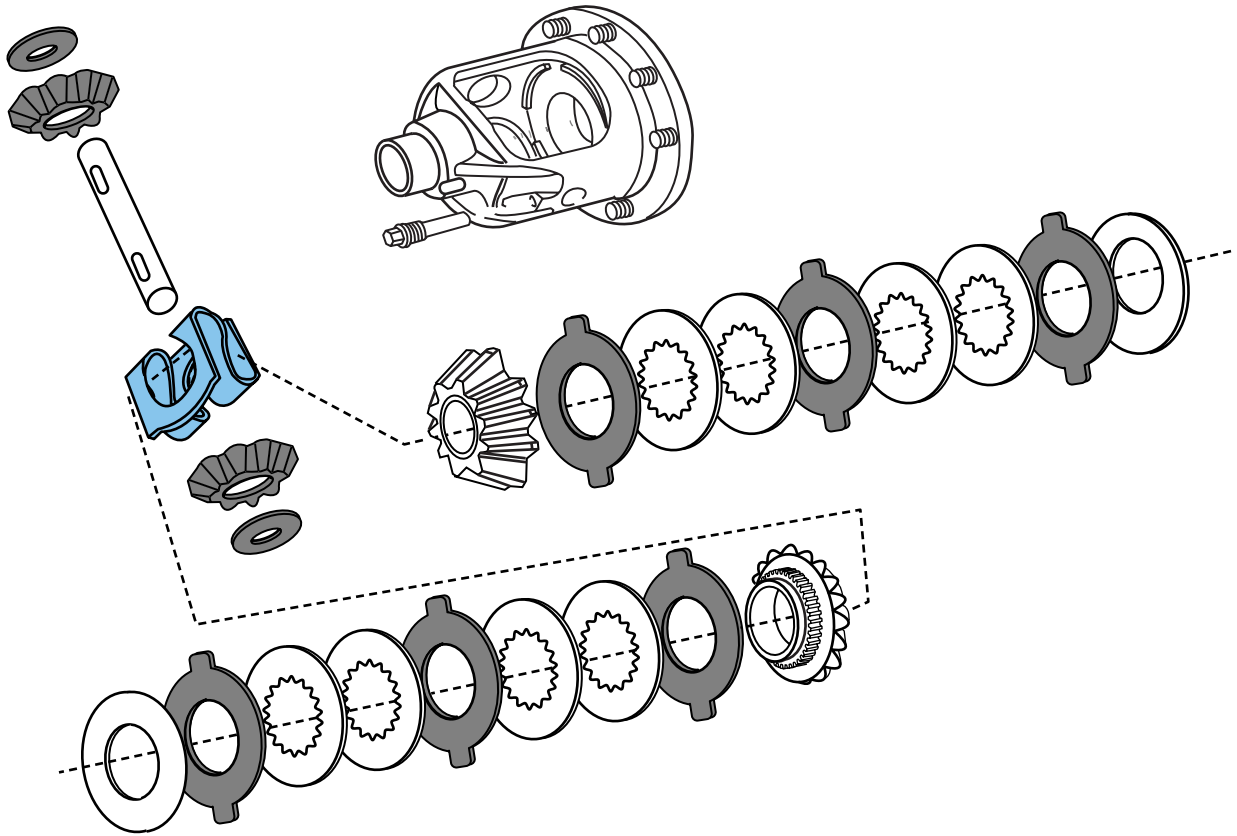


Figure 7-38 Typical limited-slip differential assembly.

to slip, the friction of the clutches ensures that the slipping wheel does not receive all of the engine's torque.

Limited-slip differentials are applied by torque differences between the side gears. High torque on one side gear causes the differential's pinion gears to push against the opposite side gear. The clutch is applied by this pressure, allowing power to move to that axle. Preload springs (or a single spring) assist in applying the clutch. This provides enough pressure on the clutch to drive both axles when the drive wheels have an unequal amount of traction. However, the pressure of the springs is low enough to allow clutch slippage when the vehicle is turning a corner.

A few aftermarket companies make replacement differentials that use clutch plates much like those in a factory limited-slip differential. These aftermarket differentials offer greater holding power by using higher spring pressures and better gripping clutches. One aftermarket unit that is being offered as an option by automobile manufacturers is the Torsen or Torque Sensitive differential manufactured by Currie Enterprises. These differentials use worm gears to limit differential action.

There are a few variations of limited-slip differentials used by various manufacturers. Some of torque sensing, such as a Torsen unit. Others are speed-sensitive, such as the Gerodisc differential (Figure 7-39). The Gerodisc uses a clutch pack that is activated or energized hydraulically. A hydraulic gerotor-type pump is driven by one of the drive axles. When a wheel slips, the pump's speed and output pressure increases. The pressurized fluid then works on the clutch pack to transmit torque to the wheel with the most traction. The amount of slippage determines the amount of pressure applied to the clutch pack. As the clutch pack is compressed more tightly, more torque is moved to the nonslipping wheel.

Torsen style differentials may be found as standard equipment on some models from Audi, BMW, and Mercedes.

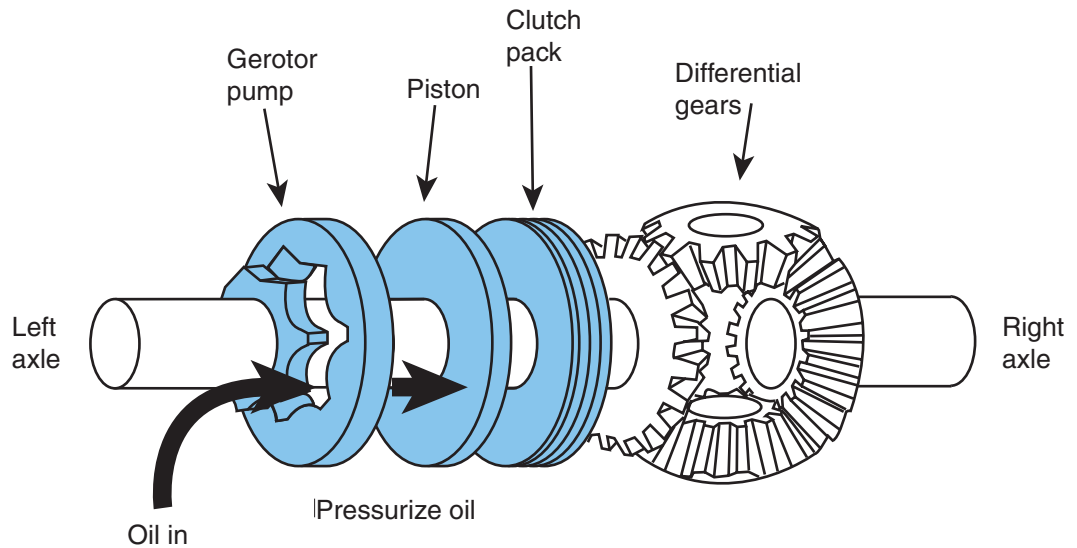


Figure 7-39 A Gerodisc differential setup.



Shop Manual

Chapter 7, page 299

A **cone clutch** is simply a cone covered with frictional material that fits inside an internal cone in the differential case.

Sure-Grip (limited-slip) differentials are often called **ramp-type differentials**. BMW also uses a differential similar in design to the Sure-Grip.

Cone Clutches

Some vehicles are equipped with a limited-slip differential that uses cone clutches (Figure 7-40) preloaded by five springs. A **cone clutch** is simply a cone covered with frictional material that fits inside an internal cone in the differential case (Figure 7-41). When the two cones are pressed together, friction allows them to rotate as one. The cones' frictional surfaces have spiral grooves cut in them. These grooves allow lubricant to flow through the cones. When the vehicle is moving straight, spring pressure and the separating force created by the pinion gears pushes each clutch cone against the internal cone in the differential case. During cornering, normal differential action overcomes the pressure of the springs, releasing the clutches, and allows the inner axle to slip.

Some cone-clutched limited-slip differentials, such as Chrysler's Sure-Grip, have beveled ends on the differential's pinion shafts and matching "ramps" cut in the shaft openings of the differential case. When torque is applied to the **ramp-type differential**, the ramps tend to force the side gears apart and apply pressure to the clutch assembly on the axle with the best traction. The cone clutches simultaneously grip the side gears and the inside of the differential case.

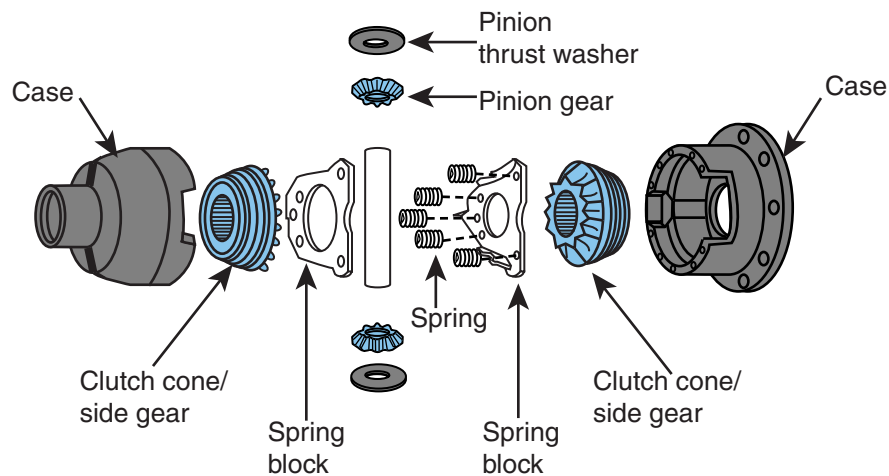


Figure 7-40 Typical cone-clutched, limited-slip differential.

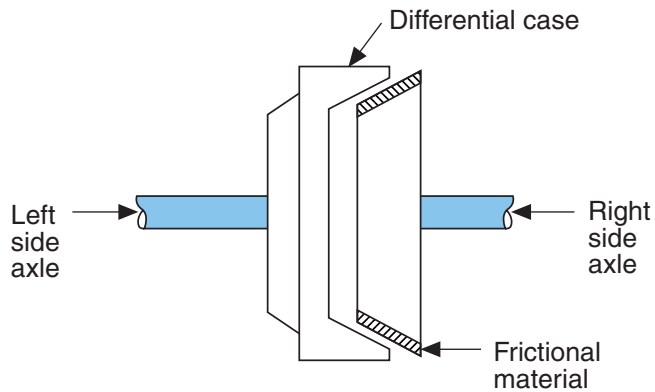


Figure 7-41 Basic construction of a cone-type clutch.

One aftermarket cone-clutched differential that is being offered as an option by automobile manufacturers is the Auburn (Figure 7-42). This differential uses interlocking cones to provide holding power when it can be used. These units are made with low spring pressures for street use or with higher spring pressures for higher breakaway torque, for racing only applications.

Viscous Clutch

Some late-model vehicles use a viscous clutch in their limited-slip differentials (Figure 7-43). A viscous limited-slip differential has a **viscous coupling** with alternately positioned steel and frictional plates connected to the two drive axles. The application of the plates relies on the resistance generated by a high-viscosity silicone fluid. When there is no rotational difference between the left- and right-side axles, power is distributed evenly to both axles. When one wheel has less traction than the other, there is a difference in rotational speeds between the axles. This speed differential causes the silicone fluid to shear, generating viscous torque. This torque effectively reduces the difference in speed and reduces the spinning of the wheel with the least traction.

Viscous couplings are often found in four-wheel-drive systems but are also found in the differentials of some performance cars. In 2001, BMW released what it calls a Variable M Differential Lock. This unit is based on a viscous coupling. It uses silicone fluid pressurized by any relative motion between the two rear wheels to clamp a multidisc clutch. When clamped, the clutch

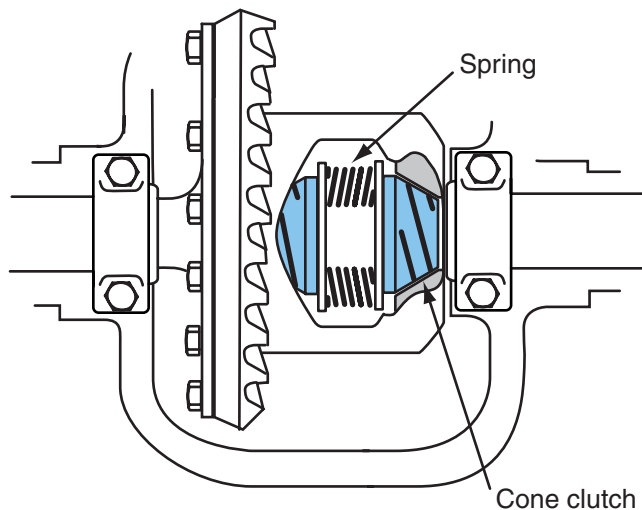


Figure 7-42 An Auburn cone-clutched limited-slip differential.

Late-model, high-performance cars from GM may be equipped at the factory with an Auburn limited-slip differential.

When speed differential increases, the viscous torque also increases.

Locked differentials are often called "lockers."



Shop Manual
Chapter 7, page 299

A viscous limited-slip differential has a **viscous coupling** with alternatively positioned steel and frictional plates connected to the two drive axles. The application of the plates relies on the resistance generated by a high-viscosity silicone fluid.

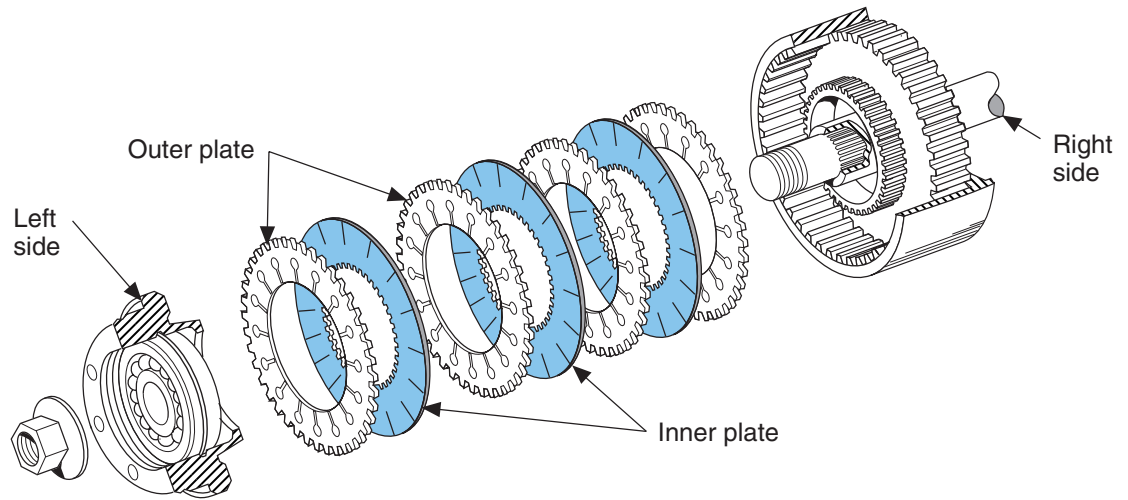


Figure 7-43 Typical viscous clutch assembly.

directs torque to the wheel with the most traction. The unit has no limit to the ratio of torque it can send to one side or the other.

Locked Differentials

A **locked differential** is a type of differential with the side and pinion gears locked together.

Another type of special traction differential is the **locked differential**. This provides very limited differential action, if any. It is designed to provide both drive axles with nearly the same amount of power regardless of traction. Needless to say, this differential is designed only for off-road use and for racing applications.

Some trucks, off-the-road equipment, and cars use differentials that can be locked and unlocked by pressing a button. The button activates an air pump, which applies pressure on the clutches and locks them to the side gears. This type of system gives the advantages of both an open and locked differential.

A commonly found, or at least much talked about, locked differential is the Detroit Locker. This unit is a ratcheting type of locking differential. It is very strong and will almost always provide equal torque application to each axle. It does not allow for much differential action; therefore, cornering is hampered. However, good drivers know when to lift off the throttle right before turning. This action allows time for the locker to unlock and provide some differential action during the turn. Detroit Lockers are primarily used in vehicles built for oval racing, such as NASCAR.

To eliminate all differential action, cars built for drag racing use a spool. A spool is basically a ring gear mounted to an empty differential case. Both the right and the left axles are splined to the case, providing for a solid connection between them. With a spool, even the slightest of turns causes the tires to scrub.

Operation

When a vehicle is moving straight ahead, the axle shafts are linked to the differential case through the clutch and each wheel gets equal torque. While the vehicle is making a turn, depending on the direction the vehicle is turning, one clutch assembly slips a sufficient amount to allow a speed differential between the two axles. This is necessary because the wheels must move through two different arcs during a turn and must therefore spin at slightly different speeds. When one wheel has less traction than the other, a larger portion of the torque goes to the wheel with the most traction.

Normally, each axle gets an equal amount of torque through the differential. However when one wheel slips, some of that wheel's torque is lost through the pinion gears spinning on the pin-

ion shaft. The clutch on the other wheel remains applied and some of the torque from the slipping side is applied to the wheel with traction. The amount of torque applied to the wheel with traction is determined by the frictional capabilities of its clutch assembly. Power is delivered to that wheel only until the torque overcomes the frictional characteristics of the clutch assembly, at which time it begins to slip. The friction between the clutch plates and discs will transfer a portion of the engine's torque to the wheel with the most traction. This action limits the maximum amount of torque that can be applied to the wheel with traction.

Gerodisc Differentials

Gerodisc differentials are speed-sensitive, slip-limiting differential units. These units contain a clutch pack and a hydraulic pump. The pump is a gerotor-type whose pressure output depends upon rotational speed. This is the speed-sensitive part of the differential. The left axle shaft drives the pump. The output from the pump is fed to the clutch pack and the amount of pressure determines how tightly the clutches will be squeezed together. When the clutch pack is fully engaged, the two drive axles are locked together. This type of differential unit smoothly and progressively sends power to the drive axle that has the best traction.

Operation. When one axle spins faster than the other, the rotational speed of the hydraulic pump increases. This increase in speed increases the pressure from the pump. The pressure is applied to the clutch pack, which begins to lock the two axles together. The amount of tire slip determines the amount of pressure delivered by the pump. The pressure works on the clutch pack to lock the axles. When there is no slip, the pump is not delivering pressure and the differential functions as an open unit. When slippage is high, the axles are locked together. When there is some slippage, the axles are partially locked.

Drive Axle Shafts and Bearings

Located within the hollow horizontal tubes of the axle housing are the axle shafts (Figure 7-44). The purpose of an axle shaft is to transmit the driving force from the differential side gears to the drive wheels. Axle shafts are heavy steel bars splined at the inner end to mesh with the axle side gear in the differential. The driving wheel is bolted to the wheel flange at the outer end of the axle shaft. The drive wheels rotate to move the vehicle forward or reverse.

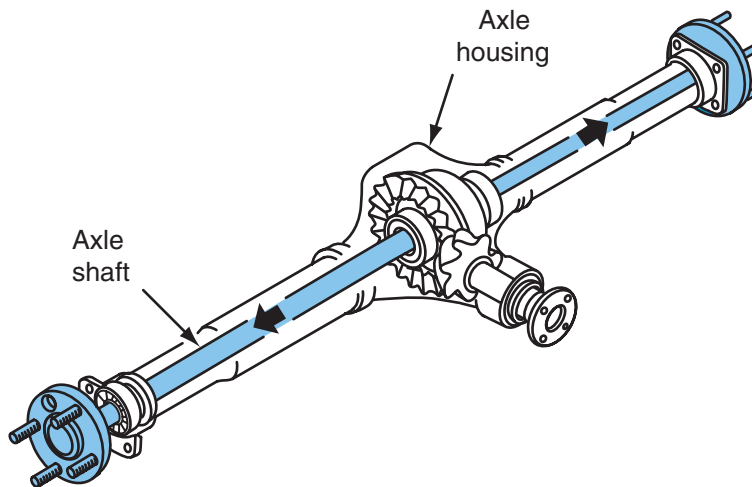


Figure 7-44 Position of drive axles within a RWD axle housing.



Shop Manual
Chapter 7, page 301

Dead axles are found on trailers and are the type of axle found in the rear of FWD vehicles.

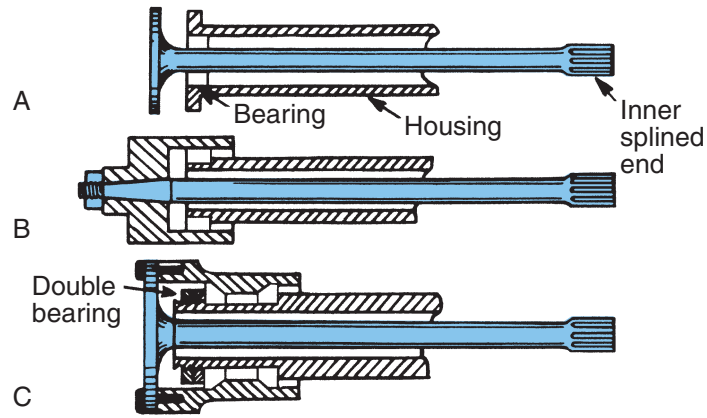


Figure 7-45 The types of rear axle shafts: (A) semi-floating; (B) three-quarter floating; and (C) full-floating.

The **live axle** transmits power from the differential to the wheels.

The bearing of a **full-floating axle** is located on the outside of the housing. This places all of the vehicle's weight on the axle housing with no weight on the axle.

Three-quarter and **semi-floating axles** are supported by bearings located in the housing and thereby carry some of the weight of the vehicle. Most passenger cars are equipped with three-quarter or semi-floating axles. Full-floating axles are commonly found on heavy-duty trucks.

The drive axles in a transaxle usually have two CV joints to allow independent front-wheel movement and steering of the drive wheels. These CV joints also allow for lengthening and shortening of the drive axles as the wheels move up and down.

The purpose of the axle shaft is to transfer driving torque from the differential assembly to the vehicle's driving wheels. There are two types of axles: the dead axle that supports a load and the **live axle** that supports and drives the vehicle.

There are basically three designs by which axles are supported in a live axle: full-floating, three-quarter floating, and semifloating. These refer to where the axle bearing is placed in relation to the axle and the housing. The bearing of a **full-floating axle** is located on the outside of the housing (Figure 7-45). This places all of the vehicle's weight on the axle housing with no weight on the axle.

Three-quarter and **semi-floating axles** are supported by bearings located in the housing and thereby carry some of the weight of the vehicle (Figure 7-46). Most passenger cars are equipped with three-quarter or semi-floating axles. Full-floating axles are commonly found on heavy-duty trucks.

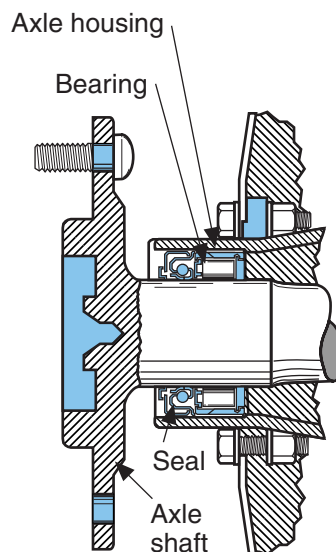


Figure 7-46 Locating the axle bearings in the axle housing places some of the vehicle's weight on the bearing.

The axle shaft bearing supports the vehicle's weight and reduces rotational friction. With semifloating axles, radial and thrust loads are always present on the axle shaft bearing when the vehicle is moving. Radial bearing loads act at 90 degrees to the axle's center of axis. Radial loading is always present whether or not the vehicle is moving. Thrust loading acts on the axle bearing parallel with the center of axis. It is present on the driving wheels, axle shafts, and axle bearings when the vehicle turns corners or curves.

Three designs of axle shaft bearings are used on semifloating axles: ball-type, straight-roller, and tapered-roller bearings. The load on a bearing that is of primary concern is the axle's end thrust. When a vehicle moves around a corner, centrifugal force acts on the vehicle's body, causing it to lean to the outside of the curve. As the body leans outward, a thrust load is placed on the axle shaft and axle bearing. Each type of axle shaft handles axle shaft end thrust differently.

The end-to-end movement of the axle is controlled by a C-type retainer on the inner end of the axle shaft or by a bearing retainer and retainer plate at the outer end of the axle shaft.

Ball-Type Axle Bearings

An axle with ball-type axle bearings has the axle shaft and bearing held in place inside the axle housing by a stamped metal bearing retainer plate (Figure 7-47). The plate is bolted to the axle housing and is held in place on the axle shaft by a retaining ring, which is pressed onto the axle shaft.

The operation of the ball-type bearing is designed to absorb radial load as well as the axle shaft end thrust. Because both bearing loads are taken at the bearing, there is no axle shaft end thrust absorption or adjustment designed into the rear axle housing.

To seal in the lubricant, an oil seal collar and oil seal is used. The oil seal collar is a machined sleeve or finished portion of the axle on which the lips of the seal ride. The oil seal retains the gear lubricant inside the axle housing. The axle seal prevents the lubricant from leaking into the brakes.

Straight-Roller Axle Bearings

The straight-roller bearing uses the axle shafts as its inner race (Figure 7-48). The outer bearing race and straight rollers are pressed into the axle tubes of the rear axle housing. The inner end of the axle shaft at the differential has a groove machined around its outside diameter where the **C-type retainer** fits.

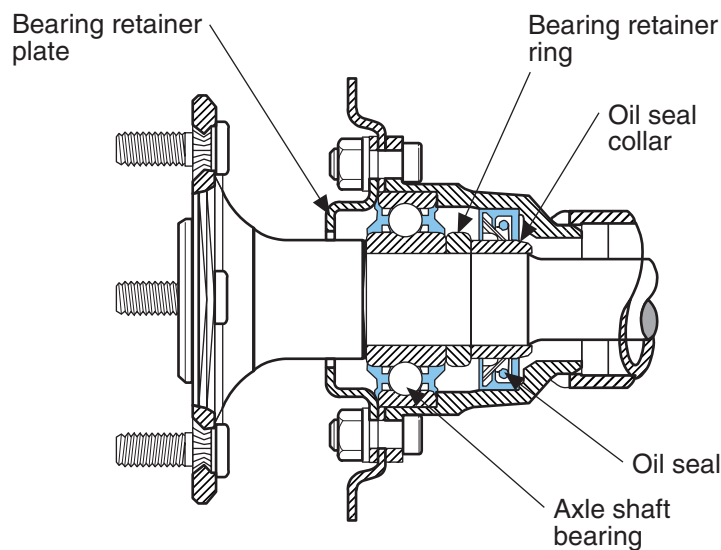


Figure 7-47 An axle shaft with a ball-type bearing.

Thrust loads are loads placed on a part that is parallel to the center of the axis of rotation.

Radial loads are loads applied at 90 degrees to an axis of rotation.

Body lean is also called body roll.

A **C-type retainer** controls the end-to-end movement of the axle.



Shop Manual
Chapter 7, page 302

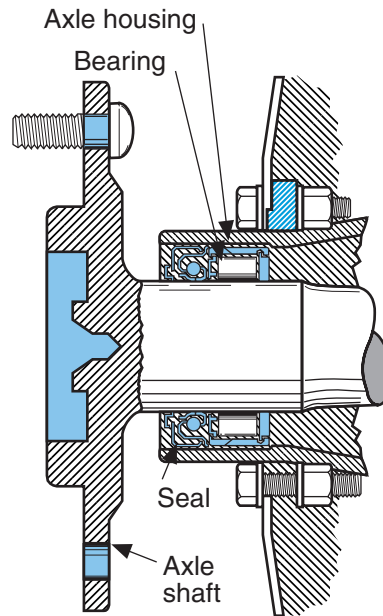


Figure 7-48 An axle shaft with a straight roller-type bearing.

The bearing is lubricated by hypoid lubricant from the differential area of the axle housing. The grease seal, located outside the axle shaft bearing, prevents the lubricant from leaking out of the housing.

When the vehicle takes a turn, the body and axle housing move outward and the axle shaft moves inward on the bearings. The inner end of the axle shaft contacts the differential pinion shaft. The axle shaft end thrust exerted against the differential pinion shaft tries to move the differential housing and differential side bearing assembly against the integral housing axle tube. The axle housing absorbs the axle shaft end thrust. There is no end thrust adjustment designed into the rear axle housing.



Shop Manual
Chapter 7, page 305

Tapered-Roller Axle Bearings

The tapered-roller bearing and axle shaft assembly are held inside the axle housing by a flange, which is bolted to the axle housing (Figure 7-49). The inside of the flange may be threaded to receive an adjuster or it is machined to accept adjustment shims.

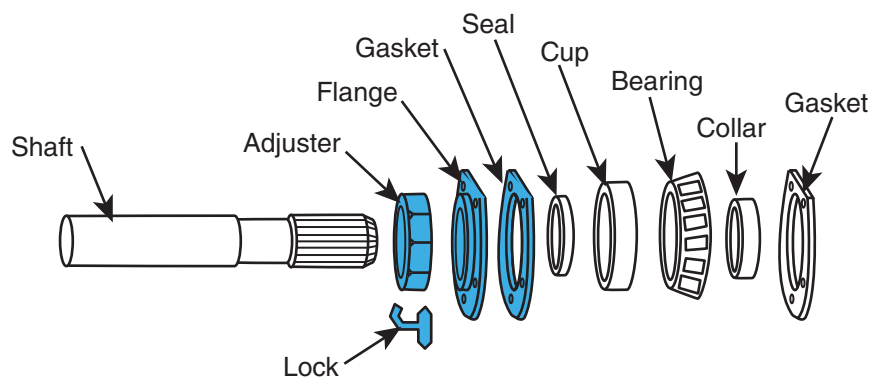


Figure 7-49 Tapered-roller bearing assembly.

The axle shaft is designed to float, based on the slight in and out movements of the axles. As the axle shaft moves inward, it contacts a thrust block that separates both axle shafts at the center of the differential. The inward moving axle shaft contacts the thrust block, which passes the thrust force to the opposite axle shaft. There the axle shaft end thrust becomes an outward moving force, which causes the opposite tapered-roller axle bearing to seat further in its bearing cup. Axle end thrust adjustments can be made by a threaded adjuster or thin metal shims placed between the brake assembly plate and the axle housing.

The tapered-roller bearing is lubricated prior to installation in the axle housing. A seal and two gaskets keep the hypoid lubricant and foreign matter out of the bearing operating area. A collar holds the rear axle bearing in place on the axle shaft.

A BIT OF HISTORY

The use of axle half-shafts and a transverse tube to position the rear wheels of a vehicle was patented in 1894 by De Dion-Bourton. This design of axle is known as the De Dion axle.



IRS Axle Shafts

The drive axles on most newer IRS systems use two U- or CV joints per axle to connect the axle to the differential and the wheels (Figure 7-50). They are also equipped with linkages and control arms to limit camber changes. The axles of an IRS system are much like those of a FWD system. The outer portion of the axle is supported by an upright or locating member that is also part of the suspension.

Swing axles are a form of IRS. In a swing axle car, the differential is also bolted to the chassis but the axles are U-jointed only to where they meet the differential and not at the wheel end. This makes the wheels move in an arc as they move up and down with the suspension. The swinging of the wheels in an arc causes large camber changes and raises and lowers the rear of

Swing axles are a form of IRS. In a swing axle car, the differential is also bolted to the chassis but the axles are U-jointed only to where they meet the differential and not at the wheel end.

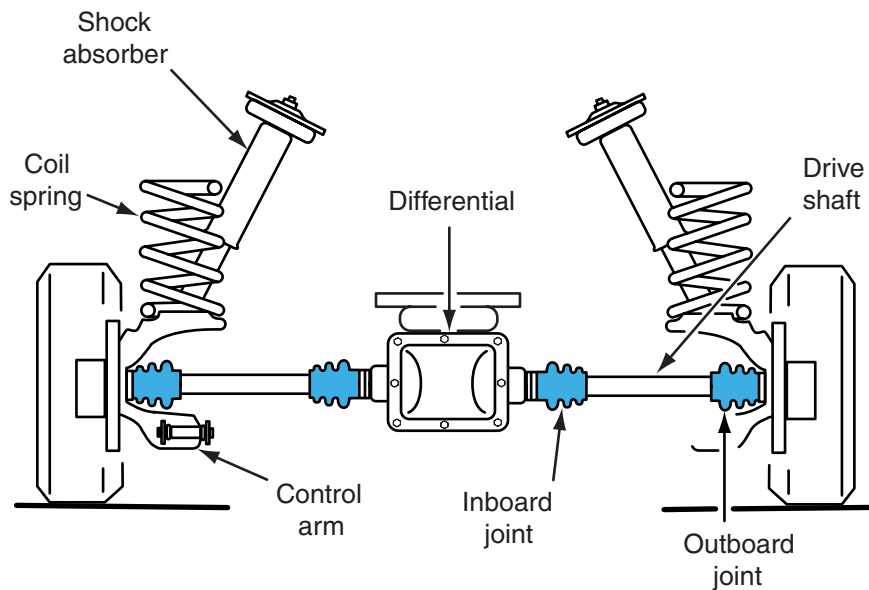


Figure 7-50 A typical IRS drive axle assembly.

Camber is a suspension alignment term used to define the amount that the centerline of a wheel is tilted inward or outward from the true vertical plane of the wheel. If the top of the wheel is tilted inward, the camber is negative. If the top of the wheel is tilted outward, the camber is positive.

Terms to Know

C-type retainer
Clutch pack
Cone clutch
Differential case
Drive pinion flange
Final drive
Full-floating axle
Hunting gearset
Integral carrier
IRS
Lapping
Live axle
Locked differential
Nonhunting gearset
Overhung-mounted pinion
Partial nonhunting gearset
Pinion gear
Ramp-type differential
Removable carrier
Ring gear
Semi-floating axle
Side gears
Straddle-mounted pinion

the car. These motions make the car difficult to drive in some situations, which is why swing axles are not found in many new cars. Swing axles were popular from the late 1940s through the 1960s because they were inexpensive to make and gave a softer ride than a solid live axle.

Maintenance

Hypoid gears require hypoid gear lubricant of the extreme pressure type. Gear lube viscosity is generally SAE 75 to 90. Limited-slip differentials require special limited-slip lubricant, which provides the required coefficient of friction for the clutch discs or cones, as well as proper lubrication.

Transaxles and some RWD differentials may require a lower viscosity oil, such as ATF. Also some transaxles may require separate lubricants for the transmission and differential. Always refer to manufacturers' recommendations for lubricants and frequency of change for every unit.

Summary

- ❑ The drive axle of a RWD vehicle is mounted at the rear of the car. It is a single housing for the differential gears and axles. It also is part of the suspension and helps to locate the rear wheels.
- ❑ The final drive is the final set of reduction gears the engine's power passes through on its way to the drive wheels.
- ❑ A differential is needed between any two drive wheels, whether in a RWD, FWD, or 4WD vehicle, because the two drive wheels must turn at different speeds when the vehicle is in a turn.
- ❑ RWD final drives use a hypoid ring and pinion gearset, which turns the power flow 90 degrees from the drive shaft to the drive axles. A hypoid gearset also allows the drive shaft to be positioned low in the vehicle.
- ❑ The differential rotates the driving axles at different speeds when the vehicle is turning and at the same speed when the vehicle is traveling in a straight line.
- ❑ The differential is normally housed with the drive axles in the rear axle assembly. Power from the engine enters into the rear axle and is transmitted to the drive axles, which are attached to the wheels of the car.
- ❑ The differential allows for different speeds between the two drive wheels.
- ❑ The pinion gear meshes with the ring gear, which is fastened to the differential case. The pinion shafts and gears are retained in the differential case and mesh with side gears splined to the drive axles.
- ❑ When both driving wheels are rotating at the same speed, the differential pinions do not rotate on the differential pinion shaft; the differential assembly rotates as one and the driving wheels, axles, and axle side gears rotate at the same speed.
- ❑ When the vehicle turns, the drive wheels rotate at different speeds because the differential case forces the pinion gears to walk around the slow turning axle side gear. This action causes the outside axle side gear to reach a higher speed than the inside wheel. The amount of differential action taking place depends on how sharp the corner or curve is. Differential action provides control on corners and prolongs drive tire life.
- ❑ Live rear axles use a one-piece housing with two tubes extending from each side. These tubes enclose the axles and provide attachments for the axle bearings. The housing shields all parts from dirt and retains the differential lubricant.

- ❑ Rear axle housings can be divided into two groups, integral carrier or removable carrier.
- ❑ An integral carrier housing has a service cover that fits over the rear of the differential and rear axle assembly.
- ❑ The differential assembly of a removable carrier assembly can be removed from the front of the axle housing as a unit and is serviced on a bench and then installed into the axle housing.
- ❑ The types of gears currently used as final drive gears are the helical, spiral bevel, and hypoid gears.
- ❑ Hypoid gearsets are commonly used in RWD passenger car and light trucks because they are quiet running and require a lower hump in the floor of the vehicle's body.
- ❑ With hypoid gears, the drive side of the teeth is curved in a convex shape, whereas the coast side of the teeth is concave. The inner end of the teeth on a hypoid ring gear is known as the toe and the outer end of the teeth as the heel.
- ❑ The gear ratio of the pinion and ring gear is often referred to as the final drive ratio.
- ❑ Gear ratios express the number of turns the drive gear makes compared to one turn of the driven gear it mates with.
- ❑ Ring and pinion gearsets are usually classified as hunting, nonhunting, or partial nonhunting gears.
- ❑ A nonhunting gearset is one in which any one pinion tooth comes into contact with only some of the ring gear teeth and is identified by a .00 gear ratio.
- ❑ A partial nonhunting gearset is one in which any one pinion tooth comes into contact with only some of the ring gear teeth, but more than one revolution of the ring gear is required to achieve all possible gear tooth contact combinations. These gears are identified by a .50 ratio.
- ❑ When hunting gearsets are rotating, any pinion gear tooth will contact all the ring gear teeth.
- ❑ During assembly the nonhunting and partial nonhunting gears must be assembled with the timing marks properly aligned. Hunting gears do not need to be aligned because any tooth on the pinion may mesh with any tooth on the ring gear.
- ❑ Lapping is the process of using a grinding paste to produce a fine finish on the teeth of the two gears that will be in constant contact with each other.
- ❑ At least four bearings are found in all differentials. Two fit over the drive pinion shaft to support it while the other two support the differential case.
- ❑ The drive pinion gear is placed horizontally in the axle housing and is positioned by one of two types of mounting, either straddle or overhung.
- ❑ The straddle-mounted pinion gear is used in most removable carrier-type axle housings and uses two opposing tapered-roller bearings positioned close together with a short spacer between their inner races and a third bearing to support the rear of the pinion gear.
- ❑ The overhung-mounted pinion uses two opposing tapered-roller bearings but not a third bearing.
- ❑ A spacer is placed between the opposing pinion shaft bearings to control the amount of preload applied to the bearings. Preload prevents the pinion gear from moving back and forth in the bearing retainer.
- ❑ Preload is a fixed amount of pressure constantly applied to a component to prevent it from loosening up.

Terms to Know
(continued)

Swing axles

Three-quarter axles

Viscous coupling

- ❑ The differential section of the transaxle has the same components as the differential gears in a RWD axle and basically operates in the same way, except that the power flow in transversely mounted powertrains does not need to turn 90 degrees.
- ❑ The final drive gears and differential assembly are normally located within the transaxle housing of FWD vehicles.
- ❑ There are three common configurations used as the final drives on FWD vehicles: helical, planetary, and hypoid. The helical and planetary final drive arrangements are usually found in transversely mounted powertrains. Hypoid final drive gear assemblies are normally used with longitudinal powertrain arrangements.
- ❑ A limited-slip unit provides more driving force to the wheel with traction when one wheel begins to spin by restricting the differential action.
- ❑ Most limited-slip differentials use either a clutch pack, a cone clutch, or a viscous clutch assembly.
- ❑ The purpose of the axle shaft is to transfer driving torque from the differential assembly to the vehicle's driving wheels.
- ❑ There are basically three ways drive axles are supported by bearings in a live axle: full-floating, three-quarter floating, and semifloating.
- ❑ There are three designs of axle shaft bearings used on semifloating axles: ball-type, straight-roller, and tapered-roller bearings.
- ❑ Hypoid gears require hypoid gear lubricant of the extreme pressure type. Gear lube viscosity is generally SAE 75 to 90.
- ❑ Limited-slip differentials require special limited-slip lubricant, which provides the required coefficient of friction for the clutch discs or cones as well as proper lubrication.
- ❑ Transaxles and some RWD differentials may require a lower viscosity oil, such as ATF. Some transaxles may also require separate lubricants for the transmission and differential.

Review Questions

Short Answer Essays

1. Define the term final drive.
2. Explain why a differential prolongs tire life.
3. List the reasons why hypoid gears are used in nearly all RWD final drives.
4. List the three major functions of a typical RWD differential.
5. Describe the main components of a differential and state their locations.
6. Explain the major differences between an integral carrier housing and a removable carrier housing.
7. Explain the differences between hunting, nonhunting, and partial nonhunting gears.
8. Describe the difference between a straddle-mounted pinion and an overhung pinion gear.
9. Explain the purpose and general operation of a limited-slip differential.
10. List the different ways drive axles are supported in an axle housing and explain the major characteristics of each one.

Fill-in-the-Blanks

1. The differential's _____ gear meshes with the _____ gear, which is fastened to the differential case, which houses the _____ shafts and gears, which are in mesh with the _____ gears, which are splined to the drive axles.
2. Rear axle housings can be divided into two groups: _____ carrier and _____ carrier.
3. The types of gears currently used as differential gears are the _____, _____, and _____.
4. The drive side of a hypoid's gear teeth is curved in a _____ shape, and the coast side of the teeth is _____. The inner end of the teeth on a hypoid ring gear is known as the _____ and the outer end of the teeth as the _____.
5. Gear ratios express the number of turns the _____ gear makes compared to one turn of the _____ gear it mates with.
6. Ring and pinion gearsets are usually classified as _____, _____, or _____ gears.
7. A straddle-mounted pinion gear is usually mounted on _____ bearings, whereas an overhung-mounted pinion is mounted on _____.
8. The three common configurations used as the final drives on FWD vehicles are: _____, _____, and _____.
9. Most limited-slip differentials use either a _____, a _____, or a _____ to limit the action of the differential.
10. There are three designs of axle shaft bearings used on semifloating axles: _____, _____, and _____.

Multiple Choice

1. *Technician A* says when a car is making a turn, the outside wheel must turn faster than the inside wheel. *Technician B* says a locked differential may cause the car to slide around a turn. Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B
2. While discussing the torque multiplication factor of the differential:

Technician A says all of the gears in a differential affect torque multiplication.
Technician B says there is a gear reduction as the power flows from the pinion to the ring gear. Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

