Chapter 11

Drive Lines, Differentials, Drive Axles, and Power Train Accessories

Topics

To hear audio, click on the box.

Overview

An important function of the power train is to transmit the power of the engine to the wheels. In a simple situation, a set of gears or a chain could perform this task, but automotive vehicles usually are not designed for such simple operating conditions. In this chapter you will learn the fundamentals of operation and upkeep of the drive lines, differentials, drive axles, and power takeoffs.

Objectives

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

1. Identify the components and explain the functions and the maintenance procedures for a drive line assembly, differentials, drive axles, a transfer case, and a power takeoff unit.
2. Identify the parts and the functions of different types of drive lines.
3. Understand the different types of universal and constant velocity joints.
4. Identify differential design variations.
5. Describe the principles of the limited slip differential.
6. Understand basic service and repair of a differential.
7. Understand the adjustment of the ring and pinion gears.
8. Identify the parts of the rear drive axle and front drive axle.
9. Understand the function of the rear axle.
10. Compare the different types of axles.
11. Understand the procedures for removing and replacing axle bearings and seals.
12. Understand the operation of a transfer case.
13. Understand basic service operations on a transfer case.
14. Understand the operation of a power takeoff unit.

Prerequisites

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

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

Features of this Manual

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

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

incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

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

1.0.0 DRIVE LINE ASSEMBLY

The drive line assembly has several important functions. It must perform the following:

- Send turning power from the transmission to the rear axle assembly.
- Flex and allow up-and-down movement of the rear axle assembly.
- Provide a sliding action to adjust for changes in drive line length.
- Provide a smooth power transfer.

The assembly provides a path through which power is transmitted from the transmission to the drive axle assemblies or auxiliary equipment. Vehicles having a long wheelbase are equipped with a drive shaft that extends from the transmission or transfer case to a center support bearing and a drive shaft that extends from the center support bearing to the rear axle.

The drive line assembly (*Figure 11-1*) consists of the following:

- Slip yoke—connects the transmission output shaft to the front universal joint.
- Front universal joint—the swivel connection that fastens the slip yoke to the drive shaft.
- Drive shaft—a hollow metal tube that transfers turning power from the front universal joint to the rear universal joint.
- Rear universal joint—a flex joint that connects the drive shaft to the differential yoke.
- Rear yoke—holds the rear universal joint and transfers torque to the gears in the rear axle assembly.

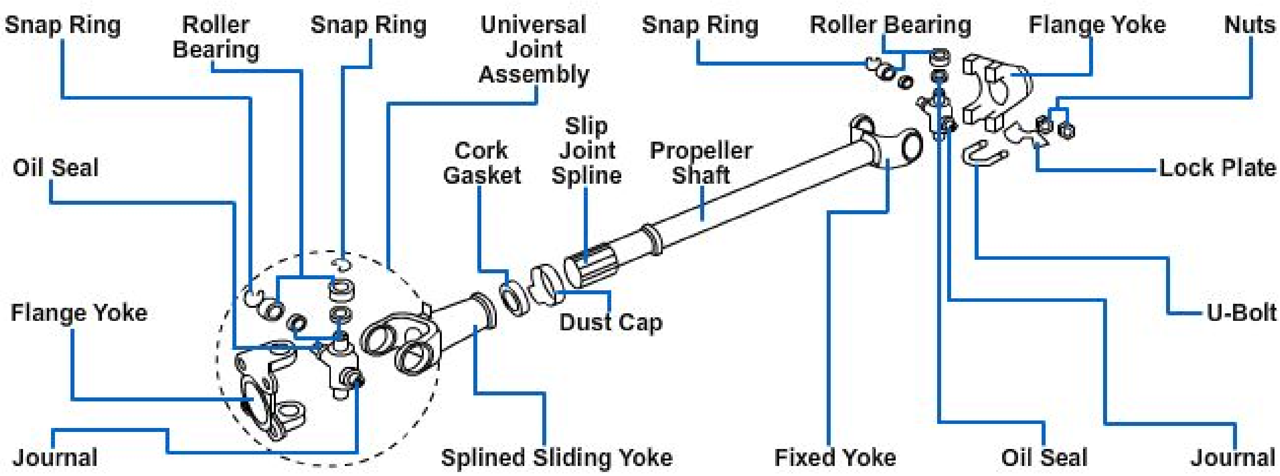


Figure 11-1 — Drive line assembly.

1.1.0 Slip Yoke (Joint)

The type of transmission (manual or automatic) determines how the slip joint is connected to the drive shaft. On a manual transmission, the slip yoke is splined to the drive shaft with the yoke for the universal joint directly behind the transmission or transfer case, whereas with the automatic transmission, the slip yoke is splined to the output shaft. Either way they serve the same purpose—to provide the necessary telescopic action for the drive shaft. As the axle housing moves forward and backward, the slip joint gives freedom of movement in a ***horizontal*** direction and yet is capable of transmitting rotary motion.

The slip yoke used with an automatic transmission has the outer diameter machined smooth. This smooth surface provides a bearing surface for the bushing and rear oil seal in the transmission. The transmission rear oil seal rides on the slip yoke and prevents fluid leakage out of the rear of the transmission. The seal also keeps dirt out of the transmission and off the slip yoke.

1.2.0 Drive Shafts

The drive shaft, also called a propeller shaft, is commonly a hollow steel tube with yoke(s) welded on the end. The tubular design makes the drive shaft strong and light. Most vehicles use a single, one-piece drive shaft. However, many trucks have a two-piece drive shaft. This cuts the length of each shaft to avoid drive line vibration.

Since a drive shaft spins at full engine speed in high gear, it must be straight and perfectly ***balanced***. If **NOT** balanced, the shaft can vibrate violently. To prevent this vibration, drive shaft balancing weights are welded to the shaft at the factory. Small metal weights are attached to the light side to counteract the heavy side for smooth operation.

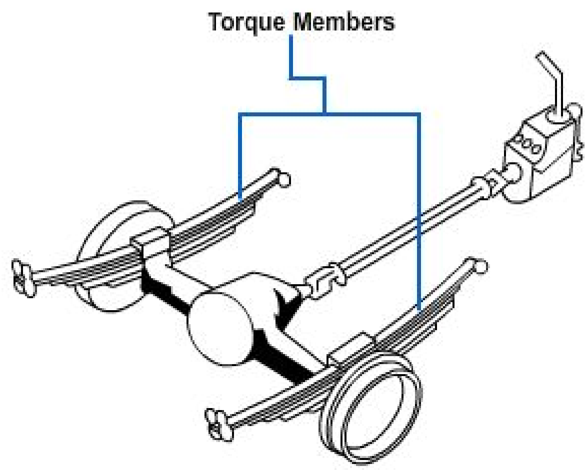


Figure 11-2 — Hotchkiss drive assembly.

The drive shaft can be either open or enclosed, depending on the type of drive used. The Hotchkiss drive has an open drive shaft that operates a rear axle assembly mounted on springs (*Figure 11-2*). The Hotchkiss drive requires that the springs be rigid enough to withstand the twisting action (torque) of the rear axle and the driving and braking forces that the springs transmit to the frame. This type of drive is common to the equipment you will encounter in the Navy.

Another type of drive is a torque tube. Torque tubes differ from the Hotchkiss design in that a solid drive shaft is enclosed in a hollow torque tube and rotates within a support bearing to prevent whipping. One universal joint is used at the front of the drive shaft, and the rear of the drive shaft is attached to the axle drive pinion through a flexible coupler.

1.3.0 Universal Joints

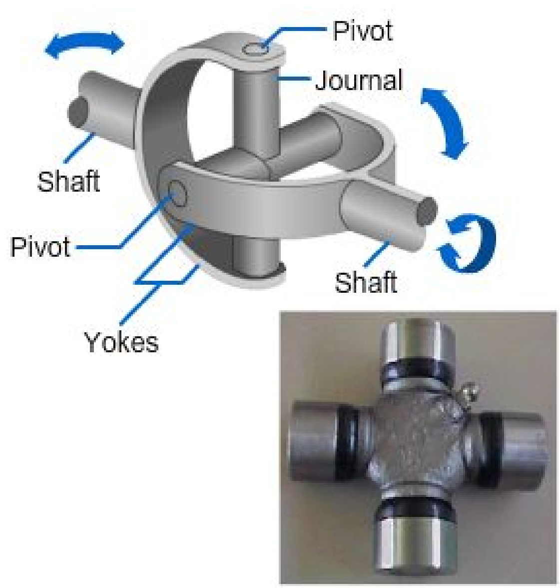


Figure 11-3 — Universal joint.

A universal joint, also called a U-joint, is a flexible coupling between two shafts that permits one shaft to drive another at an angle to it (*Figure 11-3*). The universal joint is flexible in a sense that it will permit power to be transmitted while the angle of the other shaft is continually varied. A simple universal joint is composed of three fundamental units consisting of a journal (cross) and two yokes. The two yokes are set at right angles to each other and their open ends are connected by the journal. This construction permits each yoke to pivot on the axis of the journal and also permits the transmission of rotary motion from one yoke to the other. As a result, the universal joint can transmit power from the engine through the shaft to the rear axle, even though the engine is mounted in the frame at a higher level than the rear axle, which is constantly moving up and down in relation to the engine.

A peculiarity of the conventional universal joint is that it causes a driven shaft to rotate at a variable speed in respect to the driving shaft. There is a cyclic variation in the form of an acceleration and deceleration of speed. Two universal joints are placed in a drive shaft to eliminate the speed fluctuations of the shaft while the shaft is at an angle to the power source. The universal joints are placed at a 90-degree angle to each other, and one counteracts the action of the other while in motion.

Three common types of automotive drive shaft universal joints are used on rear-wheel drive vehicles: cross and roller, ball and trunnion, and double-cardan (constant velocity) universal joints.

1.3.1 Cross and Roller Universal Joint

The cross and roller design is the most common type of drive shaft U-joint. It consists of four bearing caps, four needle roller bearings, a cross or journal, grease seals, and snap rings (*Figure 11-4*).

The bearing caps are held stationary in the drive shaft yokes. Roller bearings fit between the caps and the cross to reduce friction. The cross is free to rotate inside the caps and yokes. Snap rings usually fit into grooves cut in the caps or the yoke bores to secure the bearing caps and bearings. There are several other methods of securing the bearing caps in the yokes. These are bearing covers, U-bolts, and bearing caps.

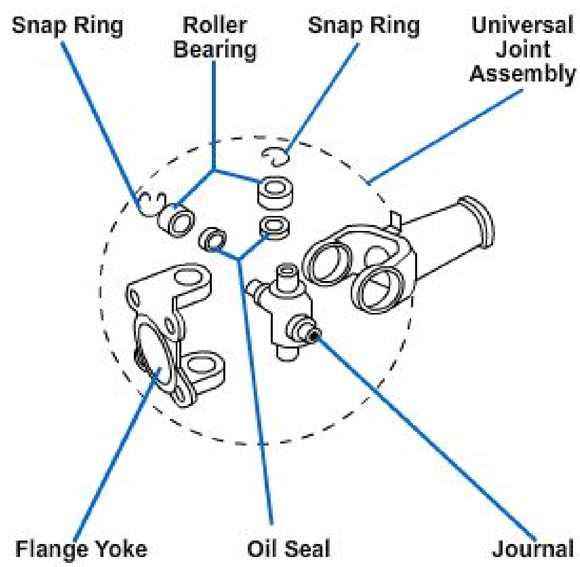


Figure 11-4 — Cross and roller universal joint.

1.3.2 Ball and Trunnion Universal Joint

The ball and trunnion universal joint is a T-shaped shaft that is enclosed in the body of the joint (*Figure 11-5*). The trunnion ends are each equipped with a ball, mounted in needle bearings, and move freely in grooves in the outer body of the joint, in effect, creating a slip joint. Compensating springs at each end of the drive shaft hold it in a centered position.

Variations in length are permitted by the longitudinal movement of the balls in the body grooves. Angular displacement is allowed by outward movement of the balls on the trunnion pins. This type of universal joint is recognized easily by the flexible dust boot that covers it.

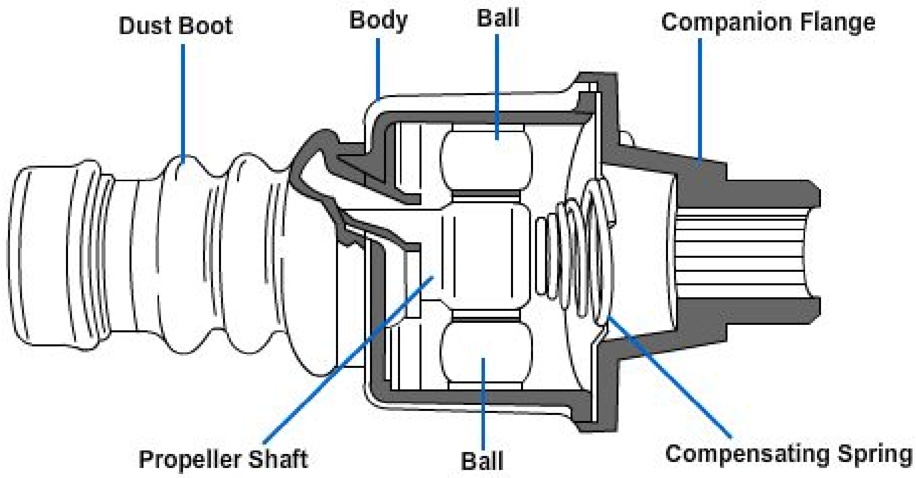


Figure 11-5 — Ball and trunnion universal joint.

1.3.3 Double-Cardan Universal Joint

The double-cardan universal joint uses two cross and roller joints in tandem to form a single joint (*Figure 11-6*). The joints are linked through a centering yoke that works in conjunction with a specially designed spring-loaded centering ball. The components are contained within the centering coupling yoke.

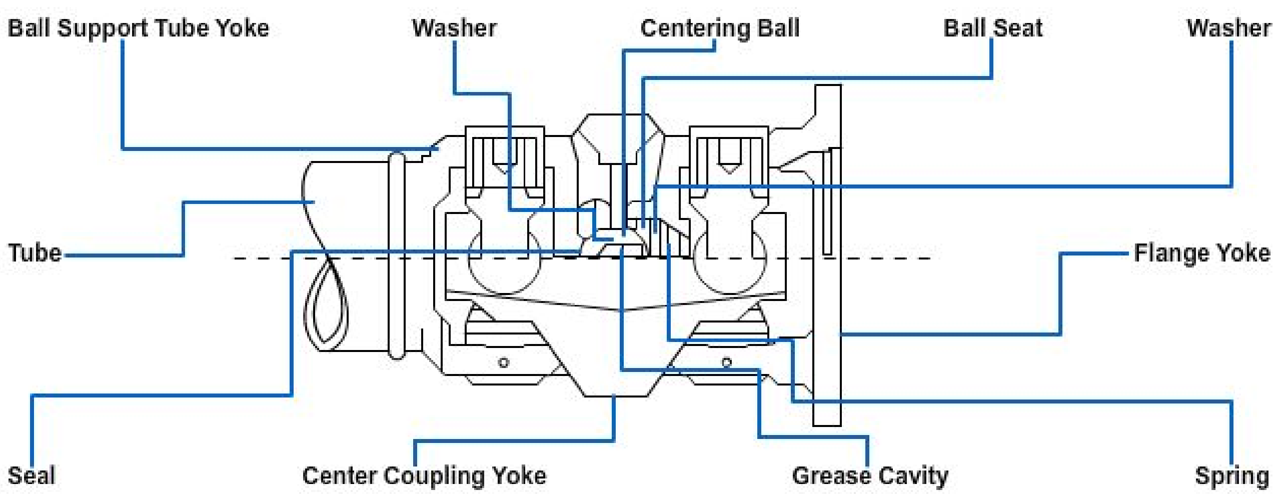


Figure 11-6 — Double-cardan universal joint.

As the shafts rotate, the action of the centering ball and yoke maintains an equally divided drive angle between the connected shafts, resulting in a constant drive velocity.

1.4.0 Constant Velocity (CV) Joints

The speed fluctuations caused by the conventional universal joints do not cause much difficulty in the rear-wheel drive shaft where they have to drive through small angles only. In front-wheel drives, the wheels are cramped up to 30 degrees in steering. For this reason velocity fluctuations present a serious problem. Conventional universal joints would cause hard steering, slippage, and tire wear each time the vehicle turns a corner. Constant velocity joints eliminate the pulsations because they are designed to be used exclusively to connect the front axle shaft to the driving wheels.

Basic operation of a CV joint is as follows:

- The outboard CV joint is a fixed joint that transfers rotating power from the axle shaft to the hub assembly.

- The inboard CV joint is a sliding joint that functions as a slip joint in a drive shaft for rear wheel drive vehicles.

The constant velocity joints you will normally encounter are the Rzeppa, Bendix-Weiss, and tripod types *(Figure 11-7).*

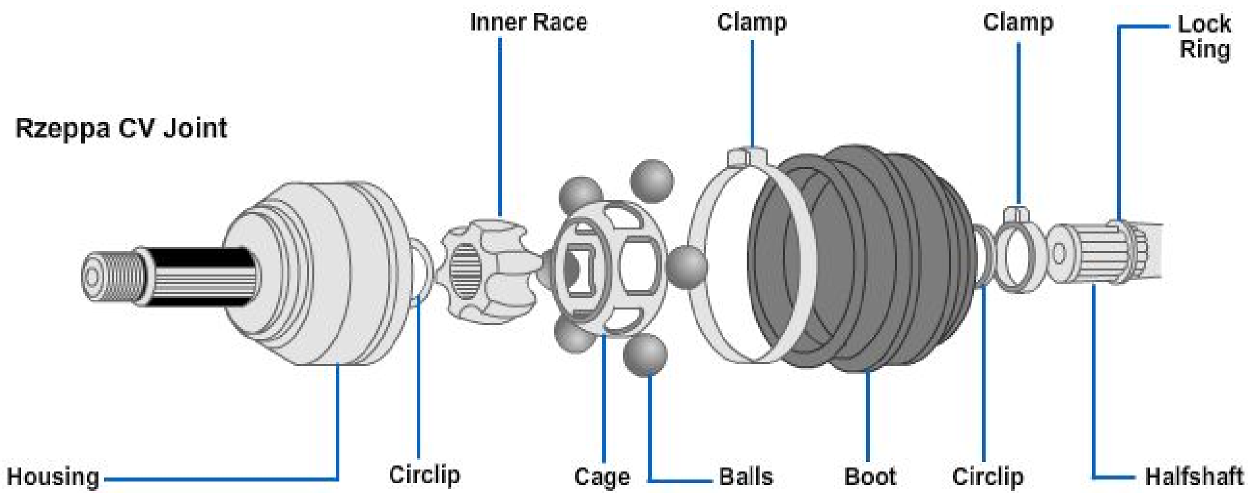


Figure 11-7 — Rzeppa CV Joint.

1.4.1 Rzeppa CV Joint

The Rzeppa constant velocity (CV) joint is a ball bearing type in which the balls furnish the only points of driving contact between the two halves of the coupling. A Rzeppa CV joint consists of a star-shaped inner race, several ball bearings, bearing cage, outer race or housing, and a rubber boot.

The inner race (driving member) is splined to the inner axle shaft. The outer race (driven member) is a spherical housing that is an integral part of the outer shaft; the balls and ball cage are fitted between the two races. The close spherical fit between the three main members supports the inner shaft whenever it is required to slide in the inner race, relieving the balls of any duty other than the transmission of power.

The movement of the balls is controlled by the ball cage. The ball cage positions the balls in a plane at right angles to the two shafts when the shafts are in the same line. A pilot pin located in the outer shaft moves the pilot and the ball cage by simple leverage in such a manner that the angular movement of the cage and balls is one half of the angular movement of the driven shaft. For example, when the driven shaft is moved 20 degrees, the cage and balls move 10 degrees. As a result, the balls of the Rzeppa joint are positioned, from the top view, to bisect the angle formed.

1.4.2 Tripod Joint

A tripod or ball and housing CV joint consists of a spider, usually three balls, needle bearings, outer yoke, and boot. The inner spider is splined to the axle shaft with the needle bearings and three balls fitting around the spider. The yoke then slides over the balls. Slots in the yoke allow the balls to slide in and out and also swivel.

During operation, the axle shaft turns the spider and ball assembly. The balls transfer power to the outer housing. Since the outer housing is connected to the axle stub shaft or hub, power is sent through the joint to propel the vehicle.

1.5.0 Center Support Bearings

When two or more drive shafts are connected in tandem, their alignment is maintained by a rubber bushed center support bearing (*Figure 11-8*). The center support bearing bolts to the frame or underbody of the vehicle. It supports the center of the drive shaft where the two shafts come together.

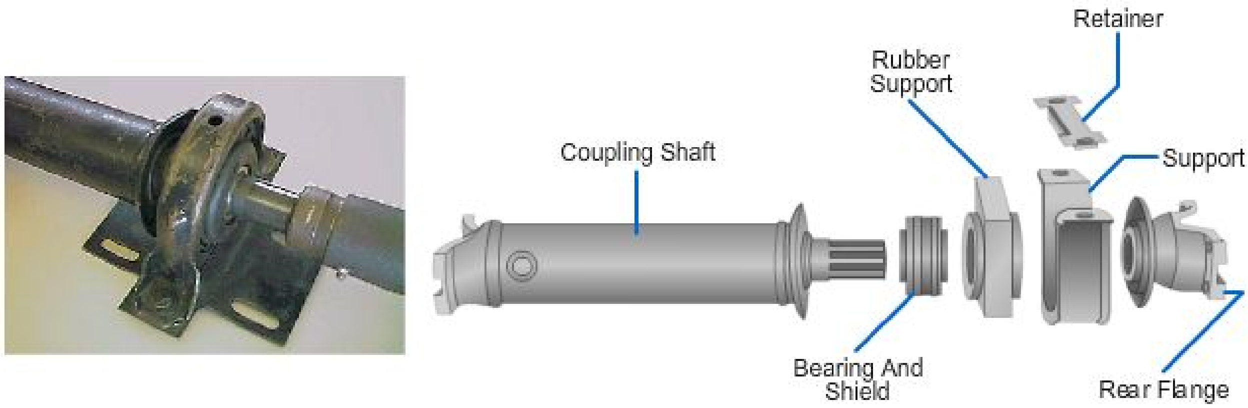


Figure 11-8 — Center support bearing.

A sealed ball bearing allows the drive shaft to spin freely. The outside of the ball bearing is held by a thick, rubber, doughnut-shaped mount. The rubber mount prevents vibration and noise from transferring into the operator’s compartment.

A bearing similar to the center support bearing is often used with long drive lines containing a single drive shaft. This bearing is called a pillow block bearing. It is commonly used in drive lines that power auxiliary equipment. Its purpose is to provide support for the drive shaft and maintain alignment. When used at or near the center of the shaft, it reduces the whipping tendency of the shaft at high speed or when under heavy loads. The construction of pillow blocks varies. The simplest form is used on solid power takeoff drive shafts, which is no more than a steel sleeve with a bronze bushing.

1.6.0 Drive Line Maintenance

A drive line is subjected to very high loads and rotating speeds. When a vehicle is cruising down the road, the drive shaft and universal joints or constant velocity joints may be spinning at full engine rpm. They are also sending engine power to either the front or rear axle assemblies. This makes drive line maintenance very important.

The drive shafts must be perfectly straight and the joints must be unworn to function properly. If any component allows the drive shafts to wobble, severe vibration, abnormal noises, or even major damage can result.

1.6.1 Drive Shaft Noises

When operating a vehicle to verify a complaint, keep in mind that other components could be at fault. A worn wheel bearing, squeaking spring, defective tire, transmission, or differential troubles could be at fault. You must use your knowledge of each system to detect which component is causing the trouble.

Drive shaft noises are usually caused by worn U-joints, slip joint wear, or a faulty center support bearing. Drive shaft noises and possible causes are as follows:

- Grinding and squeaking from the drive shaft is frequently caused by worn universal joints. The joints become dry, causing the rollers to wear. The unlubricated, damaged rollers then produce a grinding or squeaking sound as they operate on the scored cap and cross surfaces.
- A clunking sound, when going from acceleration to deceleration or deceleration to acceleration, may be caused by slip yoke problems. The splines may be worn. The yoke transmission extension housing bushing may also be worn. This will let the yoke move up and down with changes in drive line torque. An excessively worn U-joint or differential problem can also cause a similar noise.
- A whining sound from the drive shaft is sometimes caused by a dry, worn center support bearing. Since this bearing makes complete revolutions, it will make a different sound than a bad universal joint. A high pitched, more constant whine will usually come from a faulty center support bearing.

Any other abnormal sound should be traced using your knowledge of mechanics, a stethoscope, and the vehicle's service manual troubleshooting chart.

1.6.2 Drive Shaft Inspection

To inspect the drive shaft for wear or damage, raise the vehicle and place it on jack stands. Look for undercoating or mud on the drive shaft. Check for missing balance weights, cracked welds, and other drive shaft problems.

To check for working U-joints, wiggle and rotate each U-joint back and forth. Watch the universal joint carefully. Try to detect any play between the cross and the yoke. If the cross moves inside the yoke, the U-joint is worn and needs to be replaced.

Also, wiggle the slip yoke up and down. If it moves in the transmission bushing excessively, either the yoke or the bushing is worn. Inspect the rear yoke bolts for tightness. Make sure the rear motor mount is **NOT** broken. Look at any condition that can upset the operation of the drive shaft.

If after a thorough check of the drive shaft you fail to determine the problem, notify the shop supervisor. The drive shaft may require detailed measuring (drive shaft run out and drive shaft angle) or may need to have its balance checked.

1.6.3 Universal Joint Service

The universal joints on many automotive vehicles are factory lubricated. However, construction equipment has universal joints that have lubrication fittings that should be lubricated at regular intervals.

Service to universal joints that are factory lubricated is limited to replacement when signs of excessive wear are present. The universal joints provided with lubrication fittings are lubricated only with a hand operated low-pressure grease gun. Use of a high-pressure grease gun will damage the seals, resulting in early failure of the universal joint.

Another area to be concerned with when servicing the universal joints is the slip yoke (joint). Slip yokes may be lubricated from the transmission or through a lubrication fitting.

NOTE

Always consult the manufacturer's service manual for lubrication intervals and proper lubricants to be used.

A worn universal joint is the most common drive line problem, causing squeaking, grinding, clunking, or clicking sounds. The grease inside the joint can dry out. The roller bearings will wear small indentations in the cross. When the bearings try to roll over these dents, a loud metal-on-metal grinding or chirp sound can result.

Quite often, a worn U-joint is discovered when the transmission is placed in reverse. When the vehicle is backed up, the roller bearing is forced over the wear indentation against normal rotation. When this occurs, the rollers will catch on the sharp edges in the worn joint, causing even a louder sound.

The universal joint may require removal and disassembly to enable you to check the condition of the join physically. Steps for the removal and disassembly of a U-joint are as follows:

1. Raise the vehicle and place it on jack stands.
2. Scribe the alignment marks on the differential yoke and universal joint so drive shaft balance is ensured upon reassembly.
3. Unbolt the rear joint from the differential. If used, also unbolt the center support bearing. Pry the shaft forward and lower the shaft slightly.

⚠ CAUTION ⚠

Do **NOT** allow the full weight of the drive shaft to hang from the slip yoke. Support the drive shaft to prevent damage to the extension housing, rear bushing, and front U-joint.

4. Wrap the tape around the caps to prevent them from falling off and spilling the roller bearings.
5. Slide the drive shaft out of the transmission. If the transmission lubricant begins to leak, install a plastic plug into the extension housing.
6. Before disassembling the universal joint, especially constant velocity joints, scribe mark each component. The marks will show you how to reassemble the joint.
7. Clamp the drive shaft yoke in a vise. Do **NOT** clamp the weaker center section of the drive shaft or it will bend. If used, remove the snap rings, using a screwdriver, snap-ring pliers, or needle nose pliers.

⚠ CAUTION ⚠

Wear safety glasses to protect your eyes in case the snap rings fly out of the universal joint during removal.

8. Use two sockets—one larger than the bearing cap and one smaller than the bearing cap. Place the smaller socket on the bearing cap of the universal joint (*Figure 11-9*). The larger socket is to be placed over the outside diameter of the bearing cap on the opposite side of the joint.
9. With both sockets and the universal inside the vise, slowly tighten the

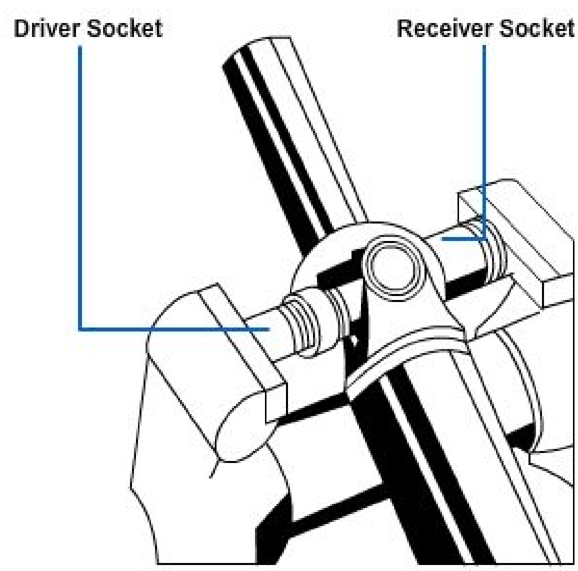


Figure 11-9 — Universal joint disassembly.

vise to force the bearing caps out of the yoke. Use the same procedure on the remaining bearing caps, as required.

Normally, a universal joint is replaced anytime it is disassembled. However, if the joint is relatively new, you can inspect, lubricate, and reassemble it.

During the inspection, clean the roller bearings and other parts in solvent. Then check the cross and rollers for signs of wear. If you find the slightest sign of roughness or wear on any part, replace the U-joint.

Once you have cleaned, inspected, and found the U-joint to be in a serviceable condition, you must reassemble it. Steps for reassembling a U-joint are as follows:

1. Pack the roller bearings in high-temperature grease. A good method of keeping the bearing in place is to fill the bearing cap with grease.
2. Position the cross inside the yoke. Align your marks. Then fit the bearing caps into each end of the yoke.
3. Center the cross partially into each cap to keep the roller bearing from falling.
4. Place the assembly in a vise. Tighten the vise so that the bearing caps are forced into the yoke.

⚠ CAUTION ⚠

If the bearing cap fails to press into place with normal pressure, disassemble the joint and check the roller bearings. It is easy for a roller bearing to fall and block cap installation. If you try to force the cap with excess pressure, the universal and drive shaft could be damaged.

5. Press the caps fully into position by placing a small socket on one bearing cap. Tighten the vise until the cap is pushed in far enough to install the snap ring. With one snap ring in place, use the socket to force the other cap into position. Install its snap ring.
6. Repeat this procedure on the other universal joint, if needed.

After assembly, check the action of the U-joint. Swing it back and forth into various positions. The joint should move freely, without binding. Double check that all snap rings have been installed properly. Once the U-joint has been checked and is working properly, reinstall the drive shaft back into the vehicle as follows:

1. Wipe off the outside slip yoke and place a small amount of grease on the internal splines. Align the marks and slide the yoke into the rear of the transmission.
2. Push the slip yoke all the way into the extension housing and position the rear U-joint at the differential.
3. Pull back on the drive shaft and center the rear universal properly. Check your rear alignment marks.
4. Install the U-bolts, bearing caps, or yoke bolts to secure the rear universal joint.
5. With the rear universal joint secured, lower the vehicle to the ground.
6. Test drive the vehicle for proper operation. Check for unusual noises, vibration, and other abnormalities.

1.6.4 Constant Velocity Joint Service

Constant velocity joint service requires disassembly of the joint. Refer to the service manual for the vehicle when servicing a CV joint. The manual will give special detailed directions that are required depending on the type of joint.

Once the CV joint is disassembled, obtain a CV joint repair kit (usually includes new joint components, grease, boot, and bootstraps). When the joint is being assembled, refer back to the service manual for detailed directions.

⚠ CAUTION ⚠

Always use the recommended type of grease on a CV joint. The wrong type of grease will cause boot deterioration and joint failure. CV joint kits provide the correct type and amount of grease required.

After reassembling the CV joint, fit the boot over the joint. Make sure the boot ends fit into their grooves. Install the bootstraps. Do not over tighten the straps, as they may cut the boot or break.

1.6.5 Center Support Bearing Service

The center support bearing is normally prelubricated and sealed at the factory. However, some support bearings have lubrication fittings and require lubrication at regular intervals. Even though lubrication extends the useful life of the bearing, they eventually wear out. The first indication of support bearing failure is excessive chassis vibration at low speed. This is caused by the bearing turning with the drive shaft in the rubber support.

When a faulty bearing is suspected, it should be inspected for wear and damage. If the rubber support shows any evidence of hardening, cracking, or tearing, it should be replaced.

Should you encounter a faulty support bearing, replacement procedures are usually limited to separating the drive shafts, unbolting the bearing support from the frame or cross member, and sliding the bearing and support assembly from the shaft.

If only the bearing is available from the parts room, disassemble the unit by gently prying the bearing out of the rubber support. Next, remove the dust shield from the bearing. Clean all parts that are to be reused. When the bearing is being replaced, some manufacturers recommend that waterproof grease be placed on both sides of the bearing, not for a lubricant but to exclude water and dust from the bearing. Install the dust shield and press the new bearing into the support.

Before securing the bearing support to the frame or cross member, check the service manual to determine if shims are required for alignment purposes. When reassembling support bearings, you should exercise care to ensure that proper alignment of the drive line is maintained. This will prevent abnormal wear of the universal joints.

Test your Knowledge (Select the Correct Response)

1. Which is NOT a function of a drive line assembly?

   A. Provide a smooth power transfer.
   B. Allow up-and-down movement of the rear axle.
   C. Send power from the transmission to the rear axle.
   D. Maintain proper alignment of the rear axle and transmission.

2.0.0 DIFFERENTIALS

Another important unit in the power train is the differential, which is driven by the final drive. The differential is located between the axles and permits one axle to turn at a different speed from that of the other. The variations in axle speed are necessary when a vehicle rounds a corner or travels over uneven ground. At the same time, the differential transmits engine torque to the drive axles. The drive axles are on a rotational axis that is 90 degrees different than the rotational axis of the drive shaft.

2.1.0 Differential Construction

A differential assembly uses drive shaft rotation to transfer power to the axle shafts. The term differential can be remembered by thinking of the words different and axle. The differential must be capable of providing torque to both axles, even when they are turning at different speeds. The differential assembly is constructed from the following: the differential carrier, the differential case, the pinion gear, the ring gear, and the spider gears (*Figure 11-10*).

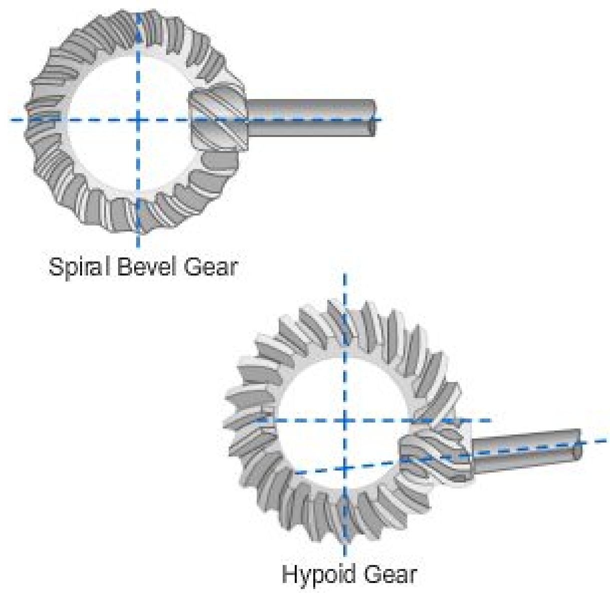


Figure 11-10 — Differential.

2.1.1 Differential Carrier

The differential carrier provides a mounting place for the pinion gear, the differential case, and other differential components. There are two types of differential carriers: the removable type and the integral (unitized) type.

Removable type—a carrier that bolts to the front of the axle housing. Stud bolts are installed in the housing to provide proper carrier alignment. A gasket is installed between the carrier and the housing to prevent leakage.

Integral type—a carrier that is constructed as part of the axle housing. A stamped metal or cast aluminum cover bolts to the rear of the carrier for inspection of the gears.

2.1.2 Differential Case

The differential case holds the ring gear, the spider gears, and the inner ends of the axles. It mounts and rotates in the carrier. Case bearings fit between the outer ends of the differential case and the carrier.

2.1.3 Pinion Gear

The pinion gear turns the ring gear when the drive shaft is rotating. The outer end of the pinion gear is splined to the rear U-joint companion flange or yoke. The inner end of the pinion gear meshes with the teeth on the ring gear.

The pinion gear is mounted on tapered roller bearings that allow the pinion gear to move freely on the carrier. Either a crushable sleeve or shims are used to preload the pinion gear bearings. Some differentials use a pinion pilot bearing that supports the extreme inner end of the pinion gear. The pinion pilot bearing assists the tapered roller bearings in supporting the pinion gear during periods of heavy loads.

2.1.4 Ring Gear

The pinion gear drives the ring gear. It is bolted securely to the differential case and has more teeth than the pinion gear. The ring gear transfers rotating power through an angle change or 90 degrees.

The ring and pinion gears are a matched set. They are ***lapped*** at the factory. Then one tooth on each gear is marked to show the correct teeth engagement. Lapping produces quieter operation and assures longer gear life.

2.1.5 Spider Gears

The spider gears are a set of small bevel gears that include two axle gears (differential side gears) and two pinion gears (differential idler gears). The spider gears mount inside the differential case. A pinion shaft passes through the two pinion gears and case. The two side gears are splined to the inner ends of the axles.

2.2.0 Final Drive

A final drive is that part of a power transmission system between the drive shaft and the differential. Its function is to change the direction of the power transmitted by the drive shaft through 90 degrees to the driving axles. At the same time, it provides a fixed reduction between the speed of the drive shaft and the axle driving the wheels.

The reduction or gear ratio of the final drive is determined by dividing the number of teeth on the ring gear by the number of teeth on the pinion gear. In passenger vehicles, this speed reduction varies from about 3:1 to 5:1. In trucks it varies from about 5:1 to 11:1. To calculate rear axle ratio, count the number of teeth on each gear. Then divide the number of pinion teeth into the number of ring gear teeth. For example, if the pinion gear has 10 teeth and the ring gear has 30 (30 divided by 10), the rear axle ratio would be 3:1. Manufacturers install *a* rear axle ratio that provides a compromise between performance and economy. The average passenger car ratio is 3.50:1.

The higher axle ratio, 4.11:1 for instance, would increase acceleration and pulling power but would decrease fuel economy. The engine would have to run at a higher rpm to maintain an equal cruising speed.

The lower axle ratio, 3:1, would reduce acceleration and pulling power but would increase fuel mileage. The engine would run at a lower rpm while maintaining the same speed.

The major components of the final drive include the pinion gear, connected to the drive shaft, and a bevel gear or ring gear that is bolted or riveted to the differential carrier. To maintain accurate and proper alignment and tooth contact, the ring gear and differential assembly are mounted in bearings. The bevel drive pinion is supported by two tapered roller bearings mounted in the differential carrier. This pinion shaft is straddle mounted, meaning that a bearing is located on each side of the pinion shaft teeth. Oil seals prevent the loss

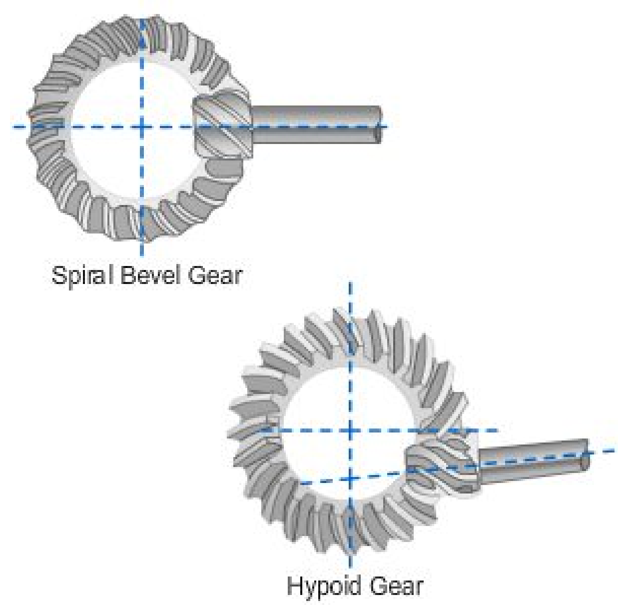


Figure 11-11 — Types of final drives.

of lubricant from the housing where the pinion shaft and axle shafts protrude. As a mechanic, you will encounter the final drive gears in the spiral bevel and hypoid design, as shown in *Figure 11-11*.

2.2.1 Spiral Bevel Gear

Spiral bevel gears have curved gear teeth with the pinion and ring gear on the same center line. This type of final drive is used extensively in trucks and occasionally in older automobiles. This design allows for constant contact between the ring gear and pinion. It also necessitates the use of heavy grade lubricants.

2.2.2 Hypoid Gear

The hypoid gear final drive is an improvement or variation of the spiral bevel design and is commonly used in light and medium trucks and all domestic rear wheel drive automobiles. Hypoid gears have replaced spiral bevel gears because they lower the hump in the floor of the vehicle and improve gear-meshing action. As you can see in *Figure 11-11*, the pinion meshes with the ring gear below the center line and is at a slight angle (less than 90 degrees). This angle and the use of heavier (larger) teeth permit an increased amount of power to be transmitted while the size of the ring gear and housing remain constant.

The tooth design is similar to the spiral bevel but includes some of the characteristics of the worm gear. This permits the reduced drive angle. The hypoid gear teeth have a more pronounced curve and steeper angle, resulting in larger tooth areas and more teeth to be in contact at the same time. With more than one gear tooth in contact, a hypoid design increases gear life and reduces gear noise. The wiping action of the teeth causes heavy tooth pressure that requires the use of heavy grade lubricants.

2.2.3 Double-Reduction Final Drive

In the final drives shown in *Figure 11-11*, there is a single fixed gear reduction. This is the only gear reduction in most automobiles and light- and some medium-duty trucks between the drive shaft and the wheels.

Double-reduction final drives are used for heavy-duty trucks (*Figure 11-12*). With this arrangement it is not necessary to have a large ring gear to get the necessary gear reduction. The first gear reduction is obtained through a pinion and ring gear as the single fixed gear reduction final drive. Notice that the secondary pinion is mounted on the primary ring gear shaft. The second gear reduction is the result of the secondary pinion which is rigidly attached to the primary ring gear, driving a large helical gear attached to the differential case. Double-reduction final drives may be found on military design vehicles such as the 5-ton truck. Many commercially designed vehicles of this size use a single- or double-reduction final drive with provisions for two speeds to be incorporated.

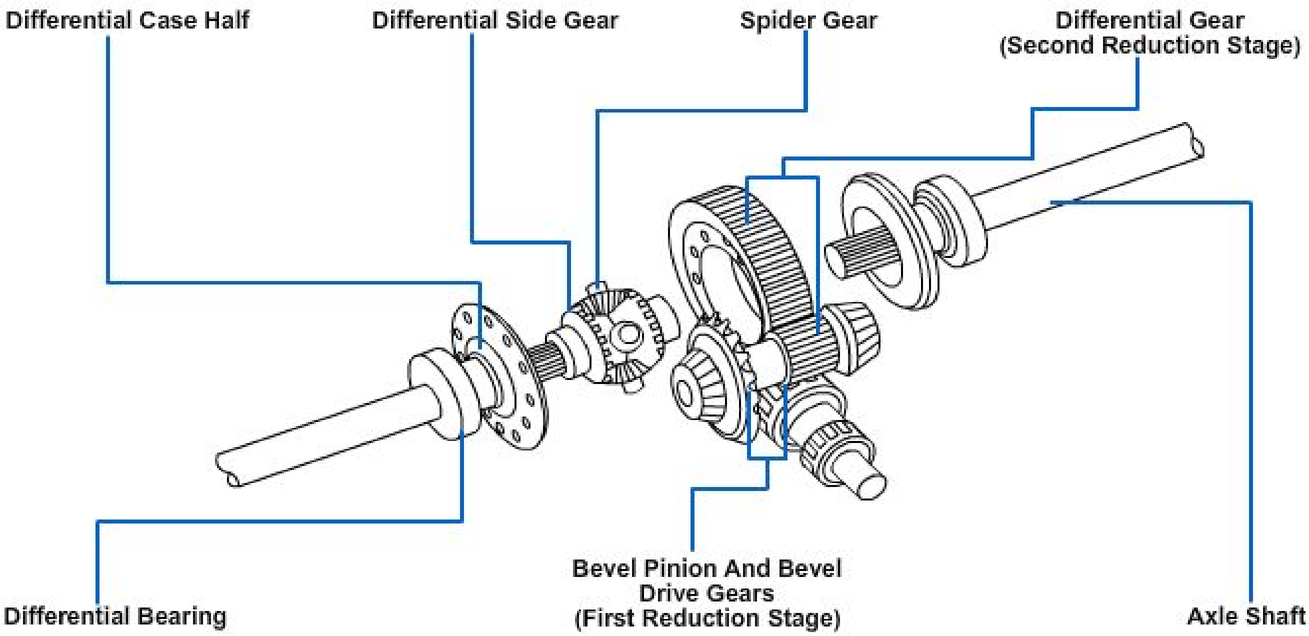


Figure 11-12 — Double-reduction final drive.

2.2.4 Two-Speed Final Drive

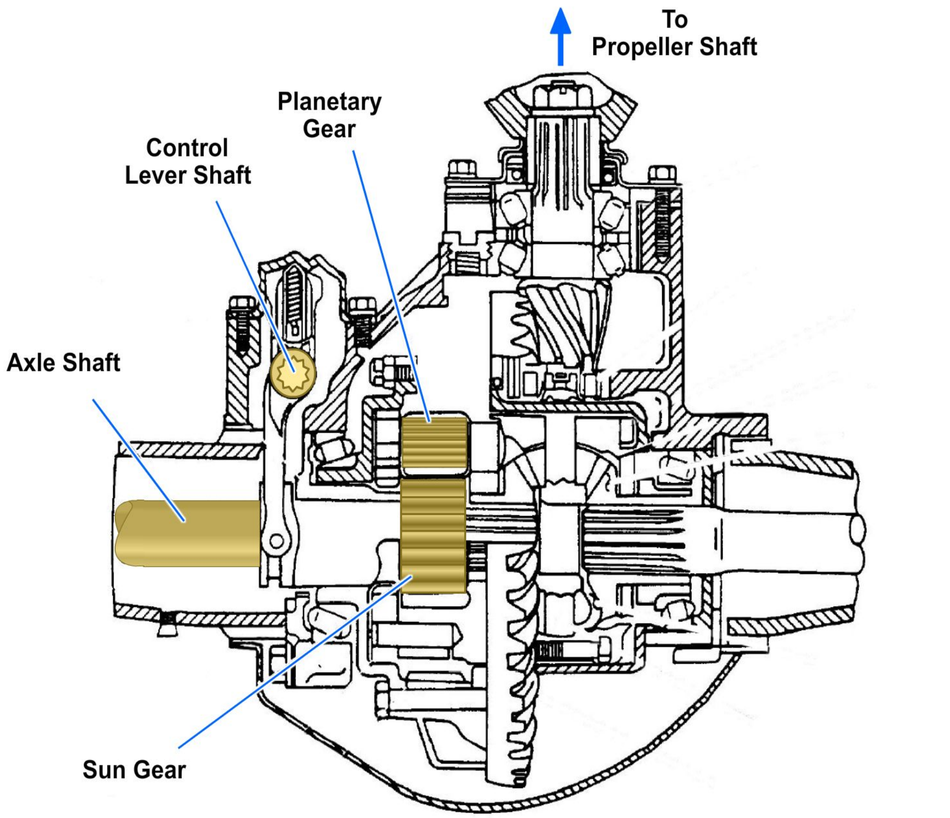
The two-speed or dual-ratio final drive is used to supplement the gearing of the other drive train components and is used in vehicles with a single drive axle (*Figure 11-13*). The operator can select the range or speed of this axle with a button on the shifting lever of the transmission or by a lever through linkage.

The two-speed final drive doubles the number of gear ratios available for driving the vehicle under various load and road conditions. For example, for a vehicle with a two-speed unit and a five-speed transmission, ten different forward speeds are available. This unit provides a gear ratio high enough to permit pulling a heavy load up steep grades and a low ratio to permit the vehicle to run at high speeds with a light load or no load.

The conventional spiral bevel pinion and ring gear drives the two-speed unit, but a planetary gear train is placed between the differential drive ring gear and the differential case. The internal gear of the planetary gear train is bolted rigidly to the bevel drive gear. A ring on which the planetary gears are pivoted is bolted to the differential case. A member consisting of the sun gear and a dog clutch slides on one of the axle shafts and is controlled through a button or lever accessible to the operator.

When in high range, the sun gear meshes with the internal teeth on the ring carrying the planetary gears and disengages the dog clutch from the left bearing adjusting ring, which is rigidly held in the differential carrier. In this position, the planetary gear train is locked together. There is no relative motion between the differential case and the gears in the planetary drive train. The differential case is driven directly by the differential ring gear, the same as in the conventional single fixed gear final drive.

When shifted into low range, the sun gear is slid out of mesh with the ring carrying the planetary gears. The dog clutch makes a rigid connection with the left bearing adjusting ring. Because the sun gear is integral with the dog clutch, it is also locked to the bearing adjusting rings and remains stationary. The internal gear rotates the planetary gears around the stationary sun gear, and the differential case is driven by the ring on which the planetary gears are pivoted. This action produces the gear reduction, or low speed, of the axle.



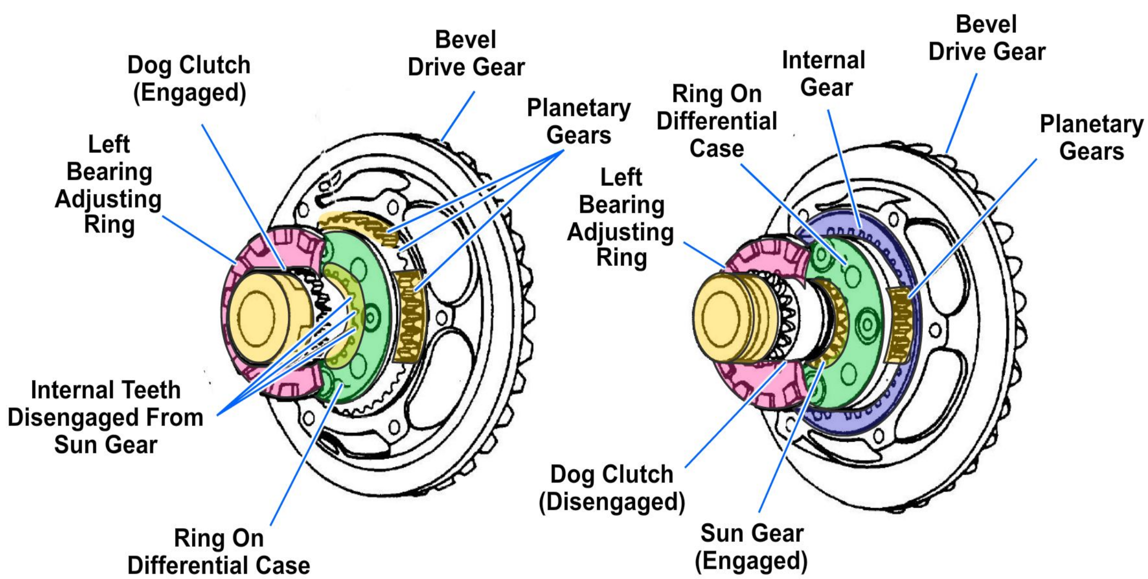


Figure 11-13 — Two-speed final drive.

2.3.0 Differential Action

The rear wheels of a vehicle do not always turn at the same speed. When the vehicle is turning or when tire diameters differ slightly, the rear wheels must rotate at different speeds.

If there were a solid connection between each axle and the differential case, the tires would tend to slide, squeal, and wear whenever the operator turned the steering wheel of the vehicle. A differential is designed to prevent this problem.

2.3.1 Driving Straight Ahead

When a vehicle is driving straight ahead, the ring gear, differential case, differential pinion gears, and differential side gears turn as a unit. The two differential pinion gears do **NOT** rotate on the pinion shaft, because they exert equal force on the side gears. As a result, the side gears turn at the same speed as the ring gear, causing both rear wheels to turn at the same speed.

2.3.2 Turning Corners

When the vehicle begins to round a curve, the differential pinion gears rotate on the pinion shaft. This occurs because the pinion gears must walk around the slower turning differential side gear. Therefore, the pinion gears carry additional rotary motion to the faster turning outer wheel on the turn.

Differential speed is considered to be 100 percent. The rotating action of the pinion gears carries 90 percent of this speed to the slowing mover inner wheel and sends 110 percent of the speed to the faster rotating outer wheel. This action allows the vehicle to make the turn without sliding or squealing the wheels.

2.4.0 Limited Slip Differentials

The conventional differential delivers the same amount of torque to each rear wheel when both wheels have equal traction. When one wheel has less traction than the other, for example, when one wheel slips on ice, the other wheel cannot deliver torque. All turning effort goes to the slipping wheel. To provide good, even traction even though one wheel is slipping, a limited slip differential is used in many vehicles. It is very similar to the standard unit but has some means of preventing wheel spin and loss of traction. The standard differential delivers maximum torque to the wheel with minimum traction. The limited slip differential delivers maximum torque to the wheel with maximum traction. Other names for a limited slip differential are posi-traction, sure-grip, equal-lock, and no-spin.

2.4.1 Clutch Pack Limited Slip Differential

The clutch pack limited slip differential uses a set of friction discs and steel plates to lock the axles together whenever one drive wheel experiences uncontrolled slippage (*Figure 11-14*). The friction discs are sandwiched between the steel plates inside the differential case. The friction disc is splined and turns with the differential side gears. The steel plates turn with the differential case.

Springs (bellville springs, coil springs, or leaf springs) force the friction disc and steel plates together. As a result, both rear axles try to turn with the differential case. Spring force and thrust action of the spider gears

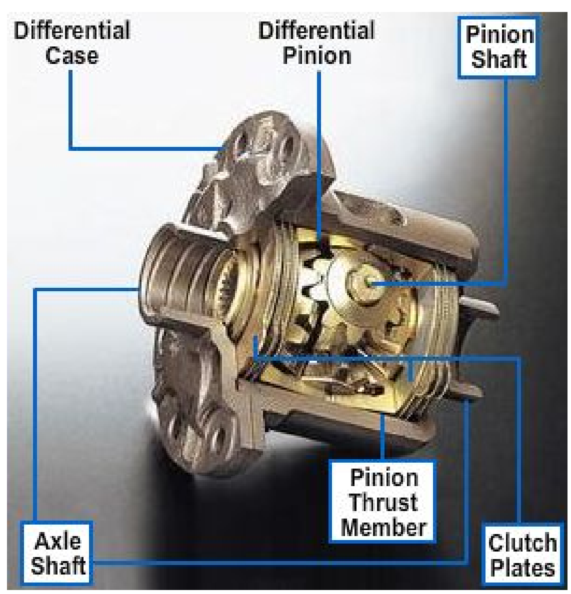


Figure 11-14 — Clutch pack limited slip differential.

applies the clutch pack. Under high torque conditions, the rotation of the differential pinion gear will push out on the axle side gears. The axle side gears then push on the clutch discs. This action helps lock the disc and keeps both wheels turning.

However, when driving normally, the vehicle can turn a corner without both wheels rotating at the same speed. As the vehicle turns a corner, the inner drive wheel must slow down. The unequal speed between the side gears causes the side gear pinions to walk around the side gears. This walking will cause the outer axle shaft to rotate faster than the differential case, allowing the pinion shaft on the side to slide down a V-shaped ramp. This action releases the outer clutches, causing the clutch pack to slip when the vehicle is turning.

2.4.2 Cone Clutch Limited Slip Differential

A cone clutch limited slip differential uses the friction produced by cone-shaped axle gears to provide improved traction (*Figure 11-15*). These cones fit behind and are splined to the axle shafts. With the axles splined to the cones, the axles tend to rotate with the differential case. Coil springs are situated between the side gears to wedge the clutches into the differential case.

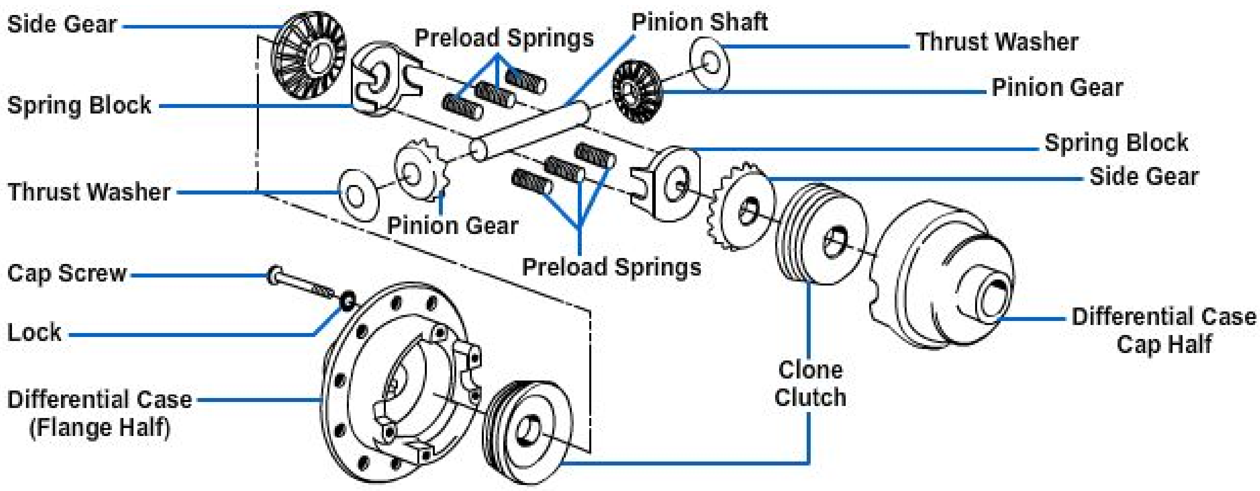


Figure 11-15 — Cone clutch limited slip differential.

Under rapid acceleration or when one wheel loses traction, the differential pinion gears, as they drive the cones, push outward on the cone gears. This action increases friction between the cones and case, driving the wheels with even greater torque.

When a vehicle goes around a corner, the inner drive wheel must slow down. The unequal speed between the side gears will cause the side gear pinions to walk around the side gears. This walking action causes the outer axle shaft to rotate faster than the differential case. Because the cones have spiral grooves cut into their clutch surfaces, the inner cone will draw itself into the case and lock tight and the outer cone clutch will back itself out of the case. This action allows the outer drive axle to free wheel. The end result is the majority of the engine torque is sent to the inner drive wheel.

2.5.0 Differential Service and Maintenance

Differentials in a properly operated vehicle seldom cause any maintenance problems. With the maintenance of the proper lubrication level and occasional changing of a seal or gasket, the assembly will normally last as long as the vehicle.

The first hint of existing trouble is generally an unusual noise in the axle housing. To diagnose the trouble properly, you must determine the source of the noise and under what operating conditions the noise is most pronounced. Defective universal joints, rough wheel bearings, or tire noises may be improperly diagnosed by an inexperienced mechanic as differential trouble.

Some clue may be gained as to the cause of trouble by noting whether the noise is a growl, hum, or knock; whether it is heard when the vehicle is operating on a straight road, or on turns only; and whether the noise is most noticeable when the engine is driving the vehicle or when it is coasting with the vehicle driving the engine.

A humming noise in the differential generally means the ring gear or pinion needs an adjustment. An improperly adjusted ring gear or pinion prevents normal tooth contact between the gears and therefore produces rapid tooth wear. If the trouble is not corrected immediately, the humming noise will gradually take on a growling sound, and the ring and pinion will probably have to be replaced.

It is very easy to mistake tire noise for differential noise. Tire noise will vary according to the type of pavement the vehicle is being operated on, while differential noise will not. To confirm a doubt as to whether the noise is caused by tire or differential, drive the vehicle over various pavement surfaces. If the noise is present in the differential only when the vehicle is rounding a comer, the trouble is likely to be in the differential case. If the backlash (clearance) between the ring and pinion is too great, a clunking sound is produced by the gears. For example, when an automatic transmission is shifted into drive, the abrupt rotation of the drive shaft can bring the gears together with a loud thump.

The ring and pinion gears can become worn, scored, out of adjustment, or damaged. The problems can result from prolonged service, fatigue, and lack of lubricant. You need to inspect the differential to determine whether adjustment or part replacement is required.

A differential identification (ID) number is provided to show the exact type of differential for ordering parts and looking up specifications. The number may be on a tag under one of the carrier or inspection cover bolts; it also may be stamped on the housing or carrier. Use the ID number to find the axle type, axle ratio, make of the unit, and other information located in the service manual.

2.5.1 Differential Lubricant Service

Many vehicle manufacturers recommend that the differential fluid be checked and replaced at specific intervals. To check the fluid level in a differential, remove the filler plug, which is located either in the front or rear of the assembly. The lubricant should be even with the fill hole when hot and slightly below the hole when cold.

When the manufacturer recommends that the differential fluid be replaced, remove the drain plug located on the bottom of the differential housing. Some differentials require the removal of the inspection cover to drain the lubricant. With all the fluid drained, replace the drain plug or inspection cover and refill with the proper lubricant.

NOTE

Always install the correct type of differential lubricant. Limited slip differentials often require a special type of lubricant for the friction clutches.

2.5.2 Differential Gear Tooth Pattern

The ring and pinion tooth contact pattern is used to double check ring and pinion adjustment.

To check the accuracy of your adjustments, coat the ring gear teeth with a thin coat of red lead, white grease, hydrated ferric oxide (yellow oxide or iron), or Prussian blue. Turn the ring gear one way and then the other to rub the teeth together, producing a contact pattern on the teeth. Carefully note the contact pattern that shows up on the teeth where the substance used has been wiped off.

A good contact pattern is one located in the center of the gear teeth. *Figure 11-16* shows several ring and pinion gear contact patterns. Study each and note the suggested correction for the faulty contact. Note the names of the areas on the ring gear. These include the following:

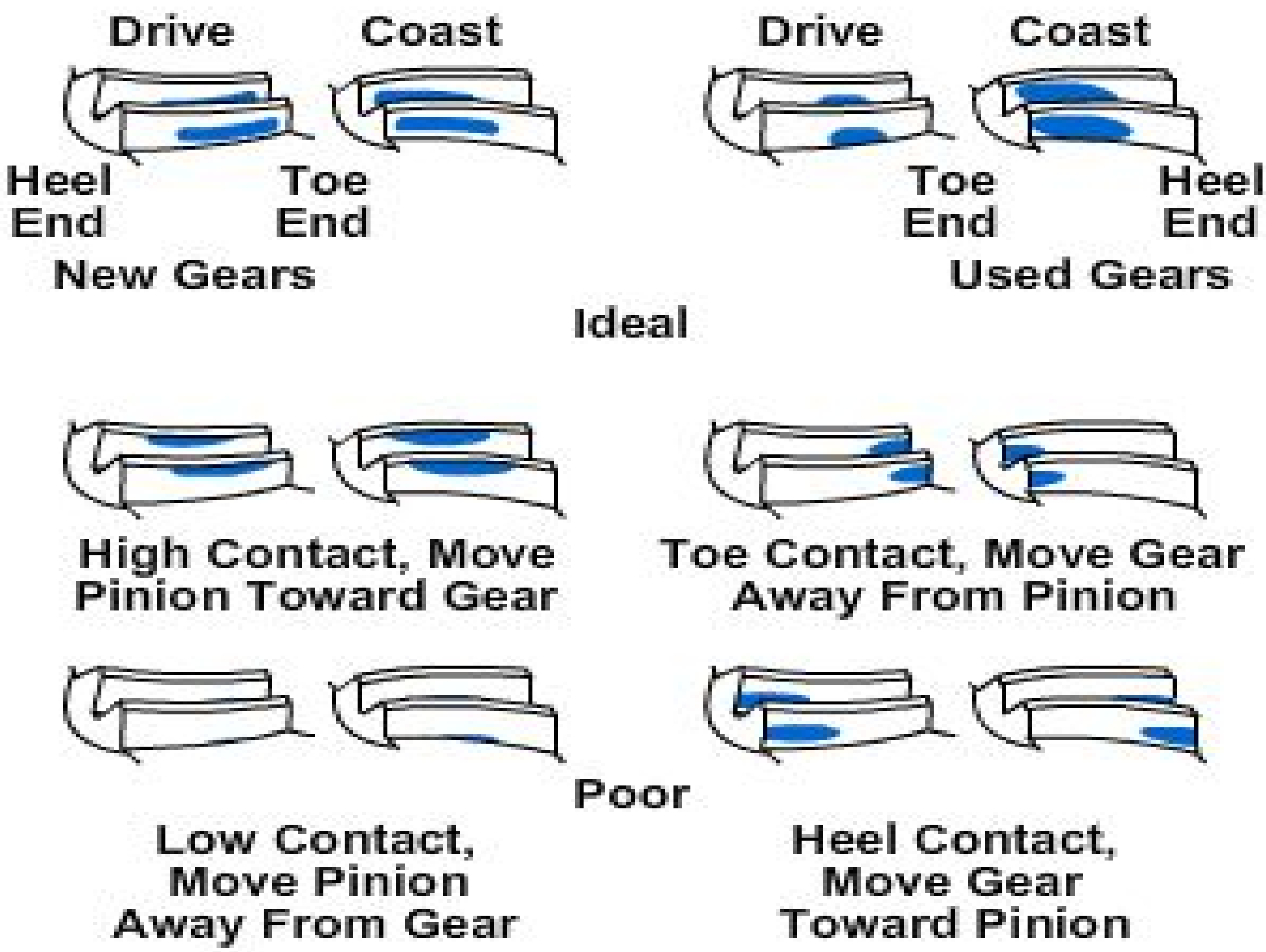


Figure 11-16 — Differential gear tooth patterns.

- Toe-narrow part of the gear tooth
- Heel-wide part of the gear tooth
- Drive side-convex side of the gear tooth
- Coast side-concave side of the gear tooth

When used gears are adjusted properly, the contact pattern will vary from that of new gears. The important thing to keep in mind with used gears is that the pattern should be closer to the toe than the heel of the tooth, as shown in *Figure 11-16*. Notice that the ideal tooth pattern on new teeth is uniform on both sides, whereas the used gear indicates considerably more contact on the coasting side.

Once you have obtained the proper adjustment on the ring and pinion, bolt the carrier housing in place. Make sure you use a new gasket. Tighten the bolts according to the manufacturer's specifications to prevent them from working loose. Reinstall the axle shafts and new gaskets. Reconnect the drive shaft and fill the axle housing with the proper lubricant.

Test your Knowledge (Select the Correct Response)

2. What component of a differential is splined to the inner ends of the axles?

   A. Integral gears
   B. Idler gears
   C. Pinion gears
   D. Side gears

3.0.0 DRIVE AXLES

Axles are classified as either live or dead. The live axle is used to transmit power. The dead axle serves only as a support for part of the vehicle while providing a mounting for the wheel assembly. Many commercial trucks and truck-tractors have dead axles on the front, whereas practically all passenger vehicles use independent front-wheel suspensions and have no front axles.

The shaft in a live axle assembly may or may not actually support part of the weight of a vehicle, but it does drive the wheels connected to it. A live axle is involved with steering when it is a front drive axle. Some live rear axles are also designed to steer. The rear axle of conventional passenger vehicles is a live axle, while in a four-wheel drive vehicle both front and rear axles are live. In some six-wheel vehicles, all three axles are live axles.

3.1.0 Front Drive Axle

A front drive axle is very similar to a rear drive axle (*Figure 11-17*); however, provisions must be made for steering the front wheels. Power is transmitted from the transfer case to the front axle by a drive shaft. The differential housing may be set off center in the axle housing to permit the drive shaft to pass beside the engine oil pan and maintain sufficient road clearance without excessive height at the front end of the vehicle.

Since the front wheels must turn on the spindle arm pivots, they must be driven by the axle shaft through universal joints, which are located on the outer ends of the axles. The

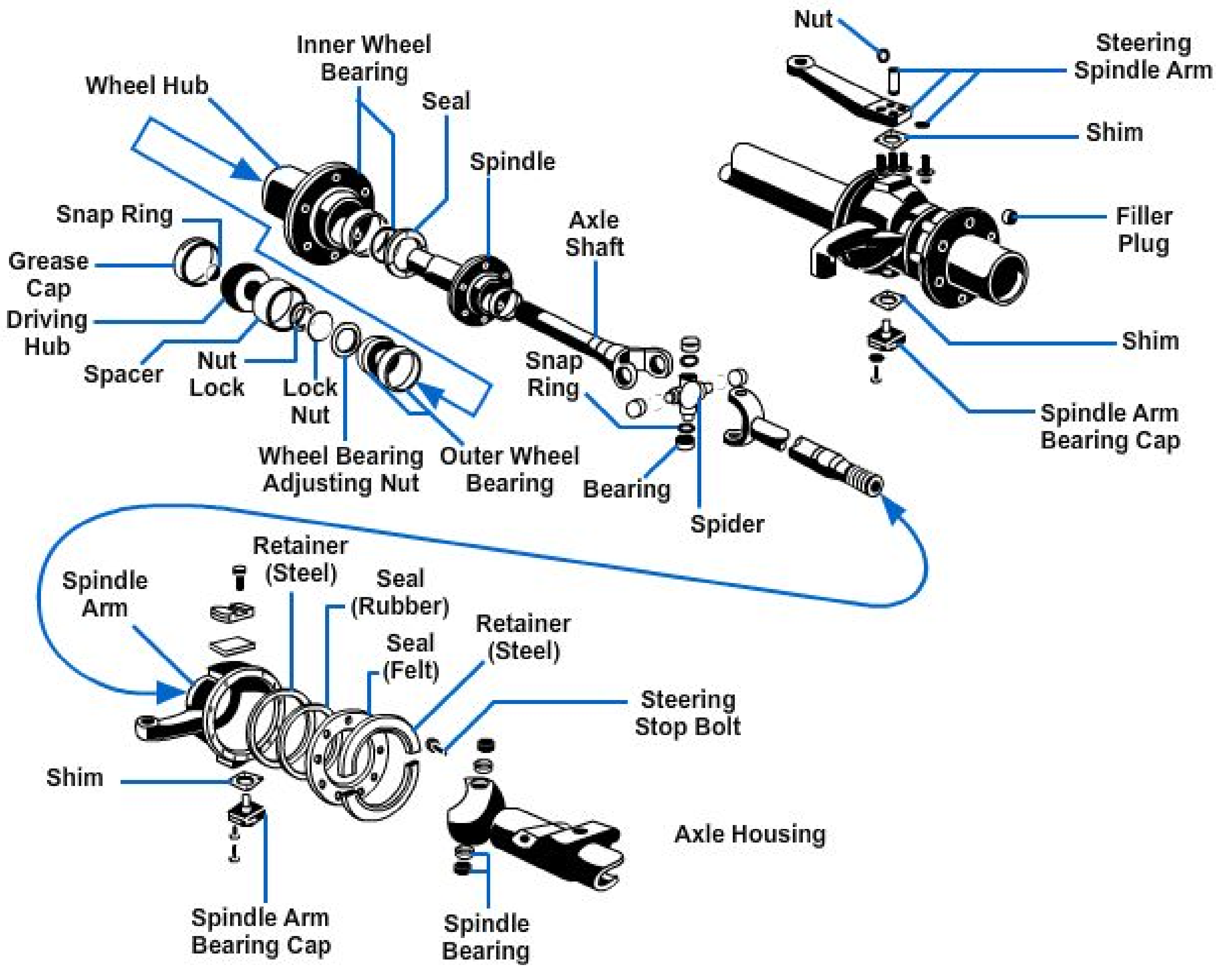


Figure 11-17 — Front drive axle.

universal joints allow the front wheels and hubs to swivel while still transferring driving power to the hubs and wheels.

The cross and roller joint shown in *Figure 11-17* is similar to conventional U-joints used on the rear drive shaft, and in some cases they are interchangeable.

This type of U-joint is limited to use in light-duty vehicles. Other types of universal joints are used in the axles of heavy-duty vehicles. The types you will encounter in military designed vehicles are the Rzeppa and Bendix-Weiss constant velocity joints (*Figure 11-18*).

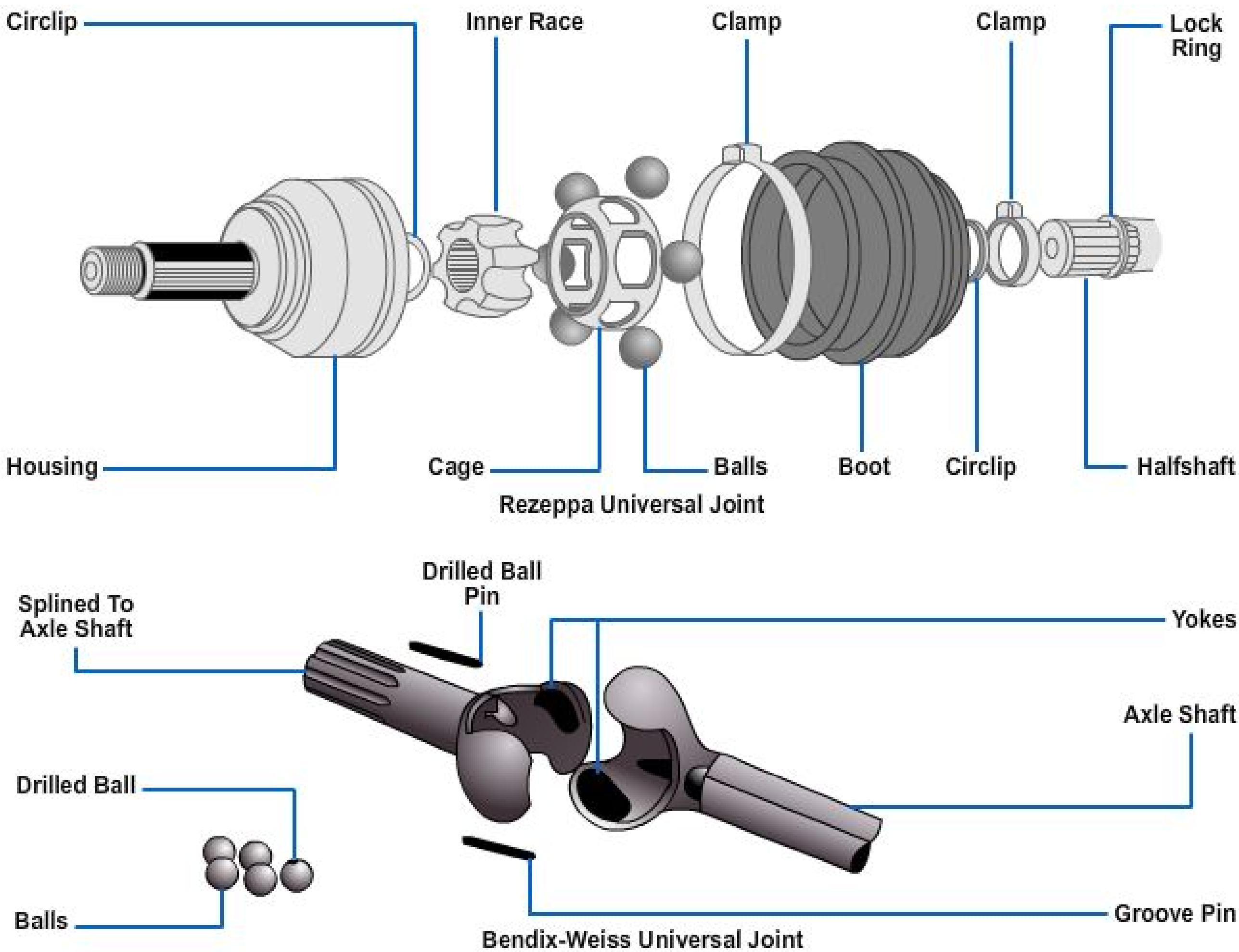


Figure 11-18 — Constant velocity universal joints.

The front drive axle of a four-wheel drive axle requires locking hubs. Locking hubs transfer power from the driving axles to the driving wheels on a four-wheel drive vehicle. There are three basic types of locking hubs:

Manual locking hub—requires the operator to turn a latch on the hub to lock the hub for four-wheel drive action.

Automatic locking hub—hub locks the front wheels to the axles when the operator shifts into four-wheel drive.

Full time hub—front hubs are always locked and drive the front wheels.

Manual and automatic locking hubs are the most common. Used with part-time, four-wheel drive, they enable the drive line to be in two-wheel drive for use on dry pavement. The front wheels can turn without turning the front axles. This allows for increased fuel economy and reduces drive line wear.

3.2.0 Rear Drive Axle

The rear drive axle connects the differential side gears to the drive wheels. The axle may or may not support the weight of the vehicle. Rear axles are normally induction hardened for increased strength. There are several types of rear axle designs: semi-floating, three-quarter floating, and full-floating. However, the semi- and full-floating types are the most common. Most automobiles use the semi-floating type, whereas four-wheel drive vehicles and trucks use full-floating axles.

3.3.0 Axle Housing

The axle housing may be of the one-piece or split (banjo) type construction. The former, known as the banjo type because of its appearance, is far more common (*Figure 11-19*). Notice that openings, both front and rear, are provided in the center housing. The front opening is closed by the differential carrier, while the rear is closed by a spherical cover plate.

Since the assembly must carry the weight of the vehicle, the axle housing in heavy trucks and tractors is a heavy cast unit. In light-duty trucks it may be a combination of cast and steel tube; in general, the center or differential and final drive case is a cast and machined unit, whereas the axle housings themselves may be welded or extruded steel tubing.

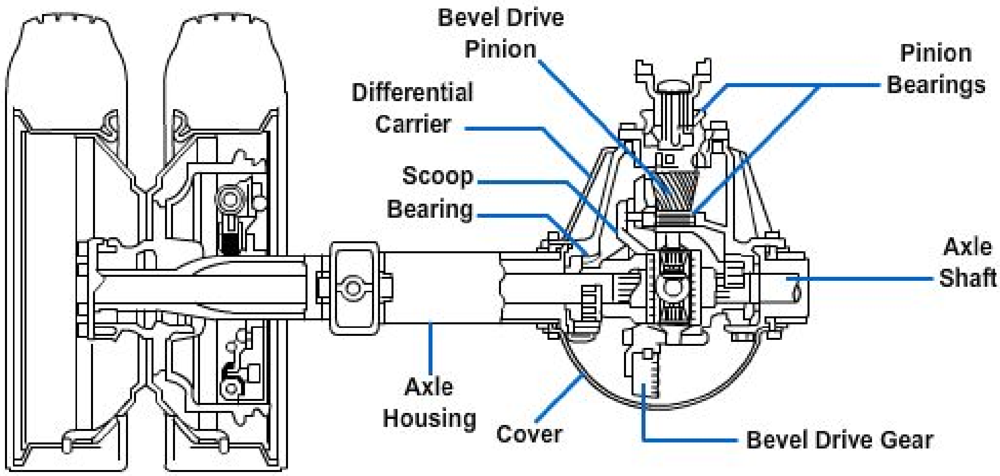


Figure 11-19 — Axle housing.

Items such as brake backing plates, mounting flanges, spring mounting plates, and accessory units may be riveted, welded, or cast into the axle housing. Inspection covers are often provided, through which the internal parts can be inspected, removed, and installed. Lubricant filler plugs are usually incorporated in the housing inspection cover.

To prevent pressure buildup when the axle becomes warm, a breather vent or valve is provided atop the housing. Without this valve, the resulting pressure could force the axle lubricant past the rear wheel oil seals and damage the brake linings. The valve is constructed so air may pass in or out of the axle housing; however, dirt and moisture are kept out.

3.4.0 Fixed or Solid Axle

A solid axle is a hardened-steel shaft that has splines on the inner end and an axle flange on the outer end that makes a mount for the brake and wheel assembly. Solid drive axles can either be semi-floating or full-floating.

3.4.1 Semi-Floating Axle

The semi-floating axle is used in passenger vehicles and light trucks. In vehicles equipped with this type of axle, the shaft as well as the housing supports the weight of the vehicle. The inner end of the axle is carried by the side gears in the differential housing. This relieves the axle shafts of the weight of the differential and the stresses caused by its operation that are taken by the axle housing. The inner ends of the axle transmit only turning effort, or torque, and are not acted upon by any other force.

The outer end is carried by a bearing located between the shaft and the housing. A tapered roller of ball-type bearing transfers the load from the shaft to the housing.

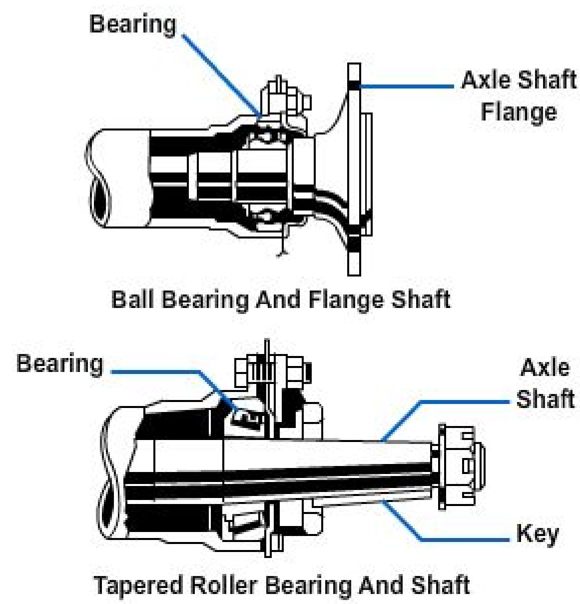


Figure 11-20 — Semi-floating axle installation.

The axle shafts take the stresses caused by turning, skidding, or wobbling of the wheels. The axle shafts are flanged or tapered on the ends (*Figure 11-20*). When the tapered axle is used, the brake drum and hub are pressed onto the shafts, using keys to prevent the assemblies from turning on the shafts. In some cases, the outer ends of the shafts may have serrations or splines to correspond with those on the drum and hub assembly. Should the axle break with this type of axle assembly, the wheel can separate from the vehicle.

3.4.2 Full-Floating Axle

The full-floating axle is used in many heavy-duty trucks (*Figure 11-21*). The drive wheel is carried on the outer end of the axle housing by a pair of tapered roller bearings. The bearings are located outside the axle housing. In this way, the axle housings take the full weight of the vehicle and absorb all stresses or end thrust caused by turning, skidding, and pulling. Only the axle shaft transmits torque from the differential.

The axle shaft is connected to the drive wheel through a bolted flange. This allows the axle shaft to be removed for servicing without removing the wheel.

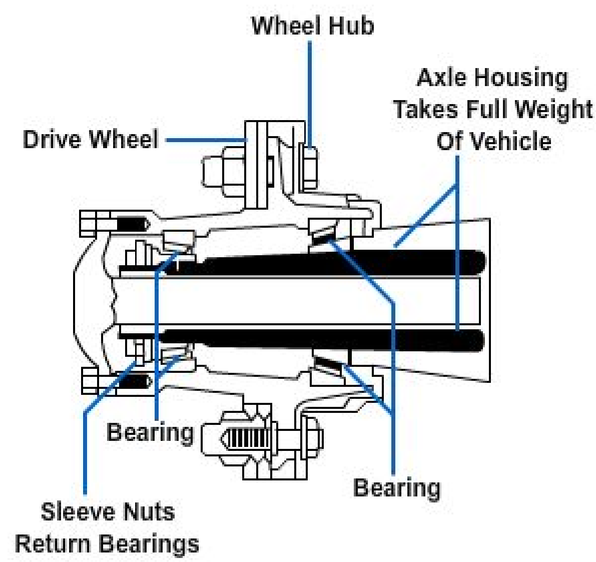


Figure 11-21 — Full-floating axle.

3.5.0 Front Wheel Drive Axles

Front-wheel drive axles, also called axle shafts or front drive shafts, transfer power from the transaxle differential to the hubs and wheel of a vehicle. Front wheel drive axles turn much slower than a drive shaft for a rear-wheel drive vehicle. They turn about one third slower. They are connected directly to the drive wheels and do **NOT** have to act through the reduction of the axle ring gear and pinion gears.

Front-wheel drive axles typically consist of the following:

- Inner stub shaft—the short shaft splined to the side gears in the differential and connected to the inner universal joint.
- Outer stub shaft—the short shaft connected to the outer universal joint and the front-wheel hub.
- Interconnecting shaft—the center shaft that fits between the two universal joints.

Universal joints that connect the drive axle are called CV joints. The outer CV joint is a fixed (nonsliding) ball and cage or Rzeppa-type joint that transfers rotating power from the axle shaft to the hub assembly. The inner CV joint is called a plunging (sliding) ball and housing or tripod-type joint that acts like a slip joint in a drive shaft for a rear-wheel drive vehicle.

The plunging action of the inner CV joint allows for a change in distance between the transaxle and the wheel hub. As the front wheels move up and down over bumps in the road, the length of the drive axle (inner joint) must change.

3.6.0 Rear Axle Service

Rear axle service is needed when an axle bearing is noisy, when an axle is broken, bent, or damaged, or when an axle seal is leaking. The rear axles must be removed to allow removal and repair of the differential assembly.

3.6.1 Axle Bearing Service

Worn or damaged bearings in the carrier or on the axles produce a constant whirring or humming sound. When bad, these bearings make about the same sound whether accelerating, decelerating, or coasting. When diagnosing and repairing bearing failures, do the following:

- Check the general condition of all parts during disassembly, not just the most badly worn or damaged parts.
- Compare the failure to any added information in the service manual and your knowledge of the component’s operation.
- Determine the cause of the part failure. This helps in assuring that the problems do **NOT** reoccur.
- Perform all repairs following the manufacturer’s recommendations and specifications.

When an axle bearing is faulty, it must be removed from the axle or housing carefully and a new one installed. The type of axle configuration determines how the bearing is to be removed and replaced. Always refer to the manufacturer's service manual for instructions for the removal and installation of the bearing.

The procedures we will discuss are for a semi-floating axle with the bearing and collar pressed on. With the axle removed from the vehicle, proceed as follows:

NOTE

Procedures for axle removal may be found in the service manual for the applicable vehicle.

1. Carefully cut off the collar with a grinder and a sharp chisel.

2. With the collar off, place the axle in a hydraulic press. The driving tool should be positioned so that it contacts the inner bearing race. Use the press to push the axle through the bearing.
3. To install the new bearing, slide the bearing onto the axle. Make sure that the bearing is facing the right direction. Some bearings have a chamfered edge on the inner bearing race which must face the axle flange.
4. Applying force on the inner bearing race, press the bearing into place by pressing the axle back through the bearing. Then press the collar or retaining ring onto the axle.

CAUTION

Do NOT use a cutting torch to remove the collar and bearing. The heat will weaken and damage the axle.

WARNING

Wear eye and face protection when grinding or chiseling the collar from the axle. Small metal particles may fly into your eyes causing eye damage.

NEVER press on the outer race; bearing damage or explosion will result.

Wear face and eye protection when pressing a bearing on or off the axle shaft. The tremendous pressure used can cause the bearing to shatter and fly into your face with deadly force.

CAUTION

Do **NOT** attempt to press the bearing and collar on at the same time. Bearing and collar damage can result.

3.6.2 Axle Seal Service

Rear axle lubricant leaks can occur at numerous spots, such as at the pinion gear seal, carrier or inspection cover gaskets, and two axle seals. The leak will show up as a darkened, oily, dirty area below the pinion gear or carrier, or on the inside of the wheel and brake assembly.

Always make sure that a possible axle seal leak is not a brake fluid leak. Touch and smell the wet area to determine the type of leak.

Anytime the axle is removed for service, it is wise to install a new axle seal. This action ensures that the seal between the axle and axle seal is tight. The axle seal is normally force-fitted in the end of the axle housing.

To remove a housing-mounted seal, use a slide hammer puller equipped with a hooknose. Place the hook on the metal part of the seal. With an outward jerk on the puller slide, pop out the seal. If a slide hammer puller is not available, a large screwdriver will also work.

CAUTION

Be careful not to scratch the bearing bore in the axle housing.

Make sure that you have the correct new seal. Its outside and inside diameters must be the same as the old seal. A seal part number is stamped on the outside of the seal. This number and the seal manufacturer’s name will assist you when ordering a new seal.

Before installing the new seal, coat the outer diameter with a non-hardening sealer. Coat the inside of the seal with lubricant that is the same grade that is in the axle assembly. With the seal facing in the right direction (sealing lip toward the inside of the housing), drive the seal squarely into place using a seal-driving tool. Be careful not to bend the metal seal housing or a leak can result. Make sure the seal is fully seated.

Test your Knowledge (Select the Correct Response)

3. What type of drive axle allows the axle shaft to be removed without removing the wheel?

   A. Full-floating
   B. Semi-floating
   C. Three-quarter floating
   D. Half-floating

4.0.0 TRANSFER CASES

Transfer cases are used in off-road vehicles to divide engine torque between the front and rear driving axles. The transfer case also allows the front driving axle to be disengaged, which is necessary to prevent undue drive line component wear during highway use. Another purpose of the transfer case is to move the drive shaft for the

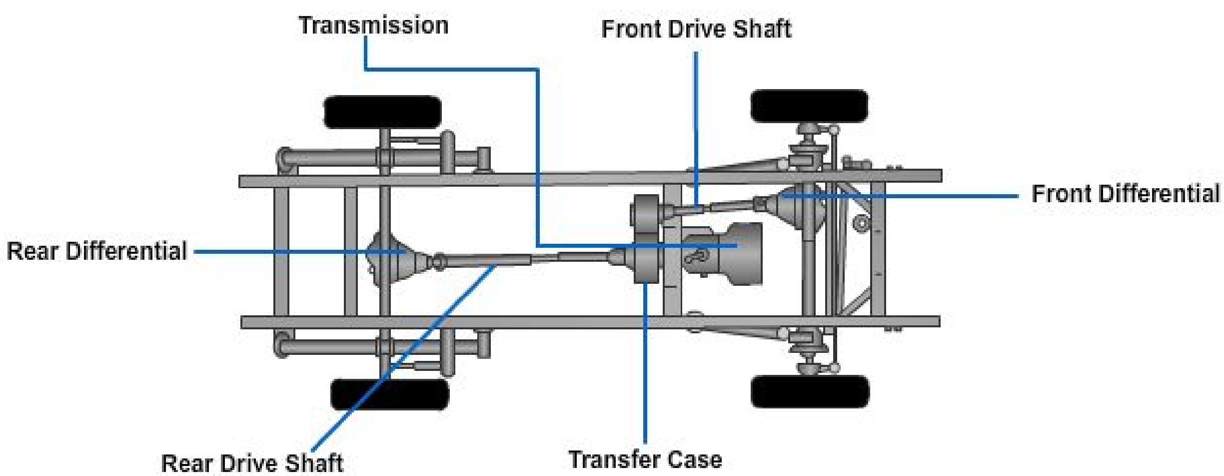


Figure 11-22 — Typical drive line arrangement with a transfer case.

front driving axle off to the side so that it can clear the engine. This arrangement is necessary to allow adequate ground clearance and to allow the body of the vehicle to remain at a practical height. *Figure 11-22* shows a typical drive line arrangement with a transfer case.

A conventional transfer case is constructed similar to a transmission in that it uses shift forks, splines, gears, shims, bearings, and other components found in manual and automatic transmissions. The transfer case has an outer case made of either cast iron or aluminum that is filled with a lubricant that cuts friction on all moving parts. Seals hold the lubricant in the case and prevent leakage from around the shafts and yokes. Shims are used to set up the proper clearances between the internal components and the case.

Conventional transfer cases in heavier vehicles have two-speed positions and a de-clutching device for disconnecting the front-driving wheels. Some light-duty vehicles use a chain to transmit torque to the front-driving axle.

4.1.0 Gear Type Transfer Case

Gear-driven transfer cases provide a high and low final drive gear range in the same manner as an auxiliary transmission (*Figure 11-23*). In most cases, the shifting is accomplished through a sliding dog clutch, and shifting must be done while the vehicle is not moving. Typical operation of a conventional two-speed transfer case is as follows:

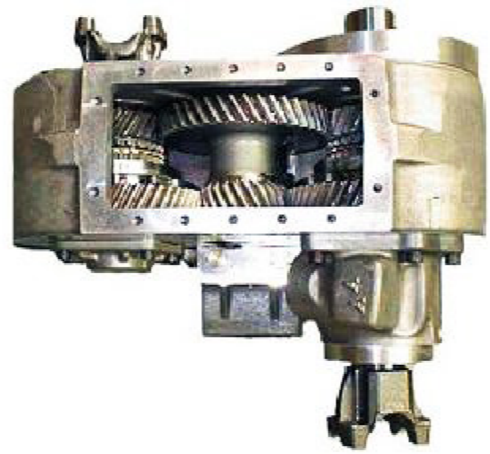


Figure 11-23 — Gear type transfer case.

High Range—When an operator is driving the front and rear axles in the high range (1:1 gear ratio), the external teeth of the sliding gear (splined to the transmission main shaft) are in mesh with the internal teeth on the constant mesh gear mounted on the transmission main shaft. Likewise, the external teeth of the front axle sliding gear are in mesh with the internal teeth of the constant mesh gear, or the sliding clutches are engaged. Disengagement of the drive to the front axle is accomplished by shifting the sliding gear on the front axle main shaft out of mesh with the constant mesh gear, permitting the latter to roll free on the shaft or sliding the clutches out of mesh.

Low Range—When an operator is using the low range in the transfer case, the sliding gear on the transmission main shaft is disengaged from the constant mesh gear and engaged with the idler gear on the idler shaft. This design reduces the speed by having the sliding gear mesh with the larger idler gear. The shifting linkage on some vehicles is arranged so shifting into low range is possible only when the drive to the front axle is engaged. This design prevents the operator from applying maximum torque to the rear drive only, which can cause damage.

4.2.0 Chain Type Transfer Case

Most new light-duty four-wheel drive systems today use a chain drive transfer case (*Figure 11-24*). Chain drives can be used in combination with many other transfer case components such as planetary gears, differential assemblies, and electronically controlled clutch packs. Chain drive systems can be controlled manually by the driver or by other systems such as pneumatic, hydraulic, electrical, or electronic devices.

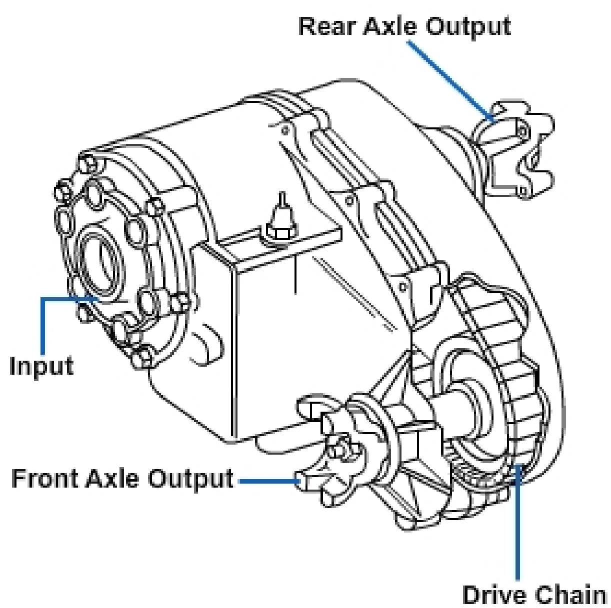


Figure 11-24 — Chain type transfer case.

Types of chain drive transfer cases vary greatly depending on the manufacturer. All chain drive transfer cases use a planetary unit for changing ratios.

When the vehicle is in two-wheel drive and high gear, power flows into the transfer case from the transmission output shaft and through the planetary gearset. The planetary gearset is in the high position and turns as a unit. This creates a one-to-one ratio. The output shaft rotates inside the upper drive chain sprocket but does not transfer power.

When shifted into four-wheel drive and high gear, power continues to flow from the transmission output shaft through the planetary gearset at the one-to-one ratio. At this point, the gear selector connects the output shaft to the upper drive chain sprocket. Engine power continues to flow through the output shaft to the rear axle. Power also flows through the upper drive train sprocket, through the drive chain, and into the lower sprocket. The lower sprocket is splined to the front output shaft so power will flow to the front axle.

When four-wheel low is selected, power flows through the planetary gearset that has been shifted into the low gear position, and the action of the gears reduces speed to a lower ratio. The lower ratio causes the input speed to be reduced while increasing the amount of torque.

4.3.0 Transfer Case Maintenance and Service

The fluid level in a transfer case should be checked at recommended intervals. To check the lubricant level, remove the transfer case fill plug, which is normally located on the side or rear of the case. The lubricant should be almost even with the fill hole. If required, add the recommended type and amount.

The first indication of trouble within a transfer case, as with other components of the power train, is usually noisy operation. If an operator reports trouble, make a visual inspection before removing the unit from the vehicle. Check for such things as oil level, oil leakage, and water in the oil.

Make sure the shift lever linkages are not bent or improperly lubricated. This will make it hard to shift or, in some cases, impossible to shift. Make sure other possible troubles, such as clutch slippage, damaged drive shaft, and damaged axles, have been eliminated.

Worn or broken gears, worn bearings, and excessive end play in the shafts can cause noisy operation. When transfer case service is required, follow the procedures outlined in the service manual. It will give directions for repairing the particular make and model.

Test your Knowledge (Select the Correct Response)

4. In a chain type transfer case, the lower sprocket is splined to what component?

   A. Front output shaft
   B. Rear output shaft
   C. Synchronizing gear
   D. Planetary gear set

5.0.0 POWER TAKEOFFS

A power takeoff (PTO) is an attachment for connecting the engine to power-driven auxiliary equipment. It is attached to the transmission, auxiliary transmission, or transfer case. A power takeoff installed at the left side of a transmission is shown in *Figure 11-25*. It is used to drive a winch at the front of a truck through a universal joint and drive shaft.

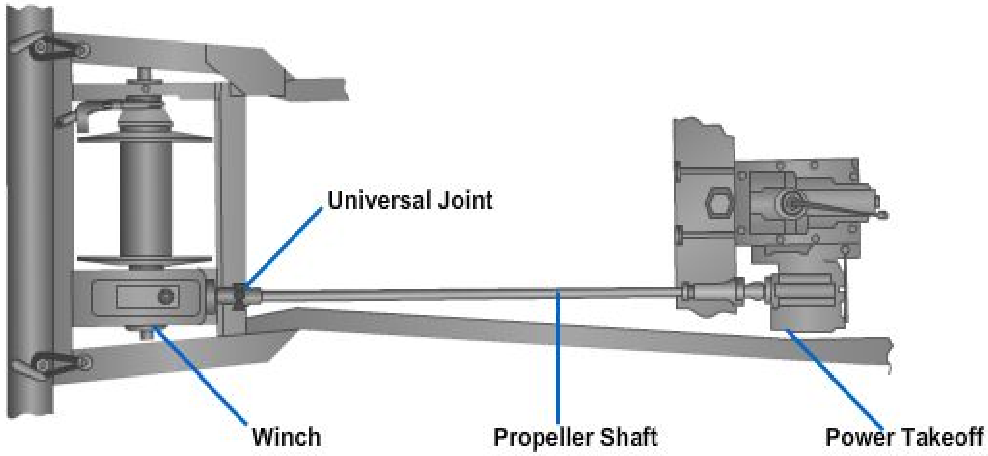


Figure 11-25— Power takeoff and winch installation.

The simplest type of power takeoff is the single-speed, single-gear shown in *Figure 11-26*. This unit may be bolted to an opening provided in the side of a transmission, as shown in *Figure 11-27*.

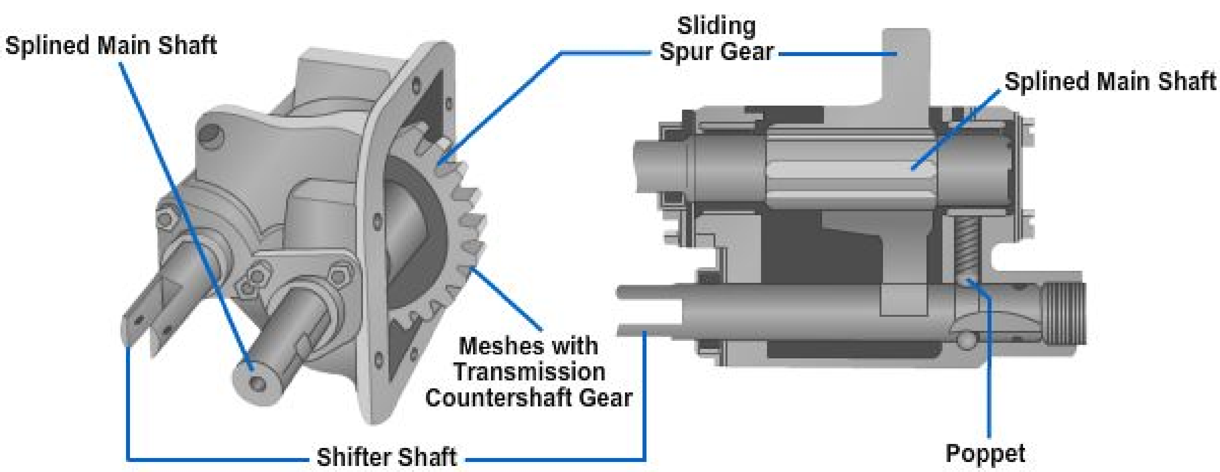


Figure 11-26— Single-speed, single-gear power takeoff.

Shims or spacers are often used to ensure proper contact is maintained between the teeth of the two meshing units. The sliding gear of the PTO can then mesh with, and be driven by, the countershaft gear of the transmission or the auxiliary transmission when engaged by the operator. The operator, by the use of a control lever, can move the gear in and out of mesh with the transmission gear. A spring-loaded ball (poppet) holds the shifter shaft in position.

On some vehicles you will find PTOs with gear arrangements that give you two speeds forward and one in reverse. Several forward speeds and a reverse gear are usually provided in a PTO unit used to operate a winch or hoist. Operation of this type of PTO is similar to that of the single-speed unit.

Faulty operation of a PTO is caused by damaged or broken linkage. To prevent this, exercise care when shifting. Trying to engage the unit with the transmission gears turning can damage the teeth, and rapid clutch engagement can break the housing. Rapid shifting may bend or damage the linkage. Forcing the control lever can bend or break the linkage.

Adjustment of the linkage to compensate for wear and lubrication is normally all the maintenance required for the PTO unit. The gears and bearings are lubricated from the transmission sump.

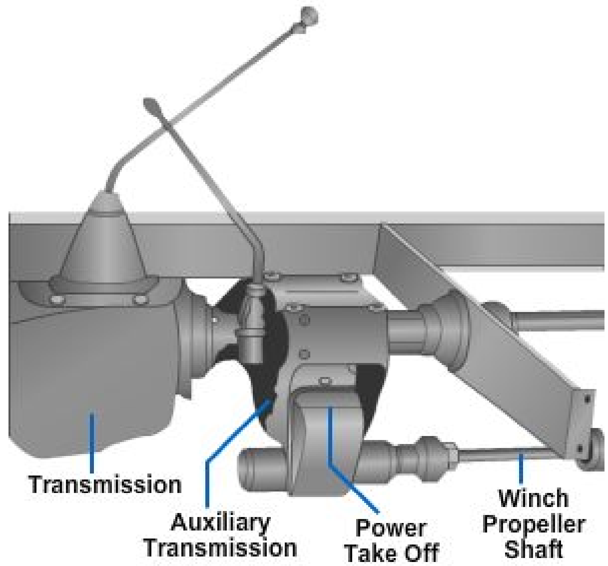


Figure 11-27 — Single-speed, single-gear power takeoff installation.

If the PTO is to be removed for repairs, disconnect the drive shaft and shift linkage and drain the transmission. Once the transmission is completely drained, remove the bolts that secure the unit to the transmission. Do **NOT** misplace or lose any shims or spacers that are between the two housings. Once the unit is removed from the vehicle, the inspection and repair procedures are the same as for a transmission. When reinstalling or replacing the PTO, carefully follow the manufacturer's procedures on the installation shims or spacers to prevent damage or unit failure.

Test your Knowledge (Select the Correct Response)

5. What component is used to connect the engine to a power-driven auxiliary device?

   A. Power lockout
   B. Power takeoff
   C. Power usage equipment enabler
   D. Power attachment device

Summary

In this chapter, you were introduced to the function of the power train. You learned how the power made by the engine is transmitted to the wheels through the transmission and transfer case. It is important to know how this power is distributed through the differentials and axles. You also learned how a vehicle can make a turn without the tires skidding around through the turn. In addition you learned about the problems associated with these systems, as well as how to troubleshoot them and make repairs. Mastering the knowledge of these systems will enable you to be a better construction mechanic.

Review Questions (Select the Correct Response)

1. What component of a drive shaft assembly provides free movement in a horizontal direction and is capable of transmitting torque?

   A. Slip yoke
   B. Rear yoke
   C. Front universal joint
   D. Rear universal joint

2. What type of drive shaft is enclosed and rotates within a support bearing to prevent whipping?

   A. Hotchkiss
   B. Companion
   C. Flange tube
   D. Torque tube

3. What type of universal joint is most often used?

   A. Double cardan
   B. Ball and trunnion
   C. Cross and roller
   D. Bendix-Weiss

4. When the driven shaft of a Rzeppa CV joint is moved 30 degrees, the cage and balls move what number of degrees?

   A. 30
   B. 20
   C. 15
   D. 10

5. Which is NOT a function of a pillow block bearing in an auxiliary power train?

   A. To support the drive shaft.
   B. To maintain drive shaft alignment.
   C. To prevent whipping under heavy loads.
   D. To prevent shimmy and poor control.

6. Which condition indicates that a center support bearing is faulty?

   A. Whining noise in the drive line
   B. Failure of the vehicle to start moving smoothly
   C. Frequent stalling when the clutch is engaged
   D. Vibration from the chassis at low speeds

7. When performing a drive shaft inspection, what action do you take to check the U-joints?

   A. Move them by prying with a pry bar.
   B. Completely disassemble the joints.
   C. Measure the play between the cross and roller.
   D. Wiggle and rotate each joint back and forth.

8. In what gear is a worn universal joint most often noticed?

   A. Fourth
   B. Third
   C. First
   D. Reverse

9. When you are removing the drive shaft from a vehicle, what component can be damaged if you allow the full weight of the drive shaft to hang from the slip yoke?

   A. Rear U-joint
   B. Front bushing
   C. Extension housing
   D. Support bearing

10. When reassembling a universal joint, you should use what type of lubricant to prevent the bearings from falling out of the bearing cap?

   A. High-temperature grease
   B. Wheel bearing grease
   C. Water pump lubricant
   D. Vaseline

11. When replacing the center support bearing, which condition should you ensure takes place?

   A. Bearing shield contains grease.
   B. Grease fitting is in place.
   C. Dust shield is placed in its grooves correctly.
   D. Drive shaft alignment is maintained.

12. Which is a function of the differential in an automotive vehicle?

   A. Connects the rear axles' shafts.
   B. Allows the axles to turn at different speeds when cornering.
   C. Permits the driving axles to be driven as a single unit.
   D. Transmits power indirectly to the drive axles.

13. What type of differential carrier is constructed as part of the axle housing?

A. Removable
B. Pinion
C. Integral
D. Axial

14. What component of a differential assembly holds the ring gear, the spider gears, and the inner ends of the axles?

A. Case
B. Carrier
C. Final drive
D. Windlass

15. The outer end of the pinion gear is joined to the rear U-joint companion flange by what components?

A. Bolts
B. Lock rings
C. Splines
D. Snap rings

16. What component of a differential drives the ring gear?

A. Side gear
B. Spider gear
C. Spiral bevel gear
D. Pinion gear

17. Which gear ratio of a final drive provides a substantial increase in acceleration but decreases fuel economy?

A. 4.11
B. 3.71
C. 3.50
D. 2.78

18. What type of final drive has the pinion gear meshing with the ring gear below the center line and at a slight angle?

A. Hypoid
B. Spiral bevel
C. Double reduction
D. Limited slip

19. In a two-speed final drive, what component is placed between the differential drive ring gear and the differential case?

    A. Clutch pack
    B. Cone clutch
    C. Planetary gear train
    D. Sliding pinion gear

20. In a clutch pack type limited-slip differential, clutch packs are applied by the _______.

    A. centrifugal force of the spider gears and spring pressure
    B. friction of the steel disc and spring pressure
    C. spring force and the thrust action of the spider gears
    D. side pinion gears walking inside the side gears

21. Under rapid acceleration, the differential pinion gears of a cone clutch limited-slip differential push outward on what components?

    A. Side gears
    B. Cone gears
    C. Flange casings
    D. Drive axles

22. What condition is generally accepted as the first hint of differential troubles?

    A. Loss of traction
    B. Vehicle vibration
    C. Loss of lubricant
    D. Unusual noises

23. Which differential trouble will produce a humming noise?

    A. Lack of lubrication
    B. Improperly adjusted ring and pinion gears
    C. Improperly adjusted pinion and side gears
    D. Excessive backlash

24. Which condition generates a clunking sound in the differential?

    A. Faulty differential gears
    B. Worn axle support bearings
    C. Excessive backlash between the ring-and-pinion gears
    D. Loose carrier bearings

25. The ideal tooth contact pattern on a used gear will have considerably more contact in which area of the gear?

    A. Toe
    B. Heel
    C. Drive side
    D. Coast side

26. Which condition permits the drive shaft of a front drive axle to pass beside the engine oil?

    A. Using a constant velocity joint.
    B. Using an intermediate drive shaft.
    C. Using a transfer case.
    D. Having an off-center differential housing.

27. In the front drive axle of a four-wheel drive vehicle, what component transfers power from the drive axles to the drive wheels?

    A. Locking hubs
    B. Interconnecting shaft
    C. Outer stub shaft
    D. Sliding hub

28. What type of axle housing is most often used?

    A. One-piece
    B. Two-piece
    C. Guitar
    D. Banjo

29. Why are automotive axle housings vented?

    A. To cool the lubricant.
    B. To prevent pressure buildup.
    C. To prevent overfilling.
    D. To adjust for loads.

30. Where are the vehicle weight-supporting bearings in a full-floating axle located?

    A. At the inner end of the axle housing
    B. On the outer end of the axle shaft
    C. On the outer end of the axle housing
    D. At the inner end of the axle shaft

31. In a front-wheel drive vehicle, what component of the front-wheel drive axle is splined to the side gears in the differential?

    A. Interconnecting shaft
    B. Outer stub shaft
    C. Inner stub shaft
    D. Rzeppa joint

32. What action allows for a change in distance between the transaxle and the wheel hub?

    A. Plunging action of the outer CV joint
    B. Plunging action of the inner CV joint
    C. Sliding action of the short shaft spline to the side gears
    D. Sliding action of the interconnecting shaft

33. Worn or damaged axle bearings produce what type of sound?

    A. Clunking
    B. Grinding
    C. Humming
    D. Growling

34. To help ensure axle bearing problems do NOT reoccur, you should take what action?

    A. Determine the cause of the part failure.
    B. Perform all repairs according to the manufacturer's manual.
    C. Follow the shop supervisor's instructions.
    D. Install a higher quality part.

35. When removing a pressed-on bearing collar from an axle, you should use which tool?

    A. Cutting torch
    B. Hand grinder
    C. Slide hammer
    D. Bearing puller

36. When removing an axle bearing using a hydraulic press, you should place the driving tool so it contacts what area of the bearing?

    A. Outer race
    B. Inner race
    C. Bearing collar
    D. Bearing sleeve

37. What is the proper tool for removing a housing-mounted axle seal?

A. Hand grinder
B. Pry bar
C. Cutting torch
D. Slide hammer

38. What component is used to divide engine torque between the front and rear driving axles?

A. Power takeoff
B. Auxiliary transmission
C. Transfer case
D. Power divider

39. Shifting is accomplished in a gear type transfer case by what component?

A. Sliding cone clutch
B. External shifting rail
C. Slide hammer
D. Sliding dog clutch

40. When an operator reports that the transfer case is hard to shift, which problem is NOT a possible cause?

A. Excessive end play
B. Clutch slippage
C. Bent linkage
D. Improper linkage lubrication

41. A power takeoff unit is driven by what shaft of the transmission?

A. Main shaft
B. Countershaft
C. Idler shaft
D. Accessory drive shaft

42. Faulty operation of a power takeoff unit is caused by which problem?

A. Damaged linkage
B. Improper spacing between the meshing gears
C. Excessive end play
D. Worn bearings

Trade Terms Introduced in this Chapter

Horizontal	At right angles to the vertical; parallel to level ground.
Balanced	Weight evenly distributed around center line of shaft.
Lapped	Meshed and spun together with an abrasive compound on the teeth.

Additional Resources and References

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

Medium/Heavy Duty Truck Engines, Fuel & Computerized Management Systems 2nd Edition, Sean Bennett, The Thomson/Delmar Learning Company, INC., 2004. (ISBN-13:978-1-4018-1499-1)

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

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

Automatic Transmissions and Transaxles, James Duffy, The Goodheart-Wilcox Company, Inc., 2005. (ISBN: 1-59070-426-6)

Manual Drive Trains and Axles, Chris Johanson, James Duffy, The Goodheart-Wilcox Company, Inc., 2004. (ISBN: 1-59070-320-0)

Power trains, Fundamentals of Service, Deere and Company, John Deere Inc., 2005. (ISBN: 0-86691-325-4)

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