

Trailer connections. Both the tractor and trailer have a seven-terminal trailer receptacle that accepts the trailer electrical cable plug (*Figure 6-54*). Trailers used as a part of double and triple trailers have trailer receptacles at both the front and rear of the trailer to provide interconnection between trailers and dollies.

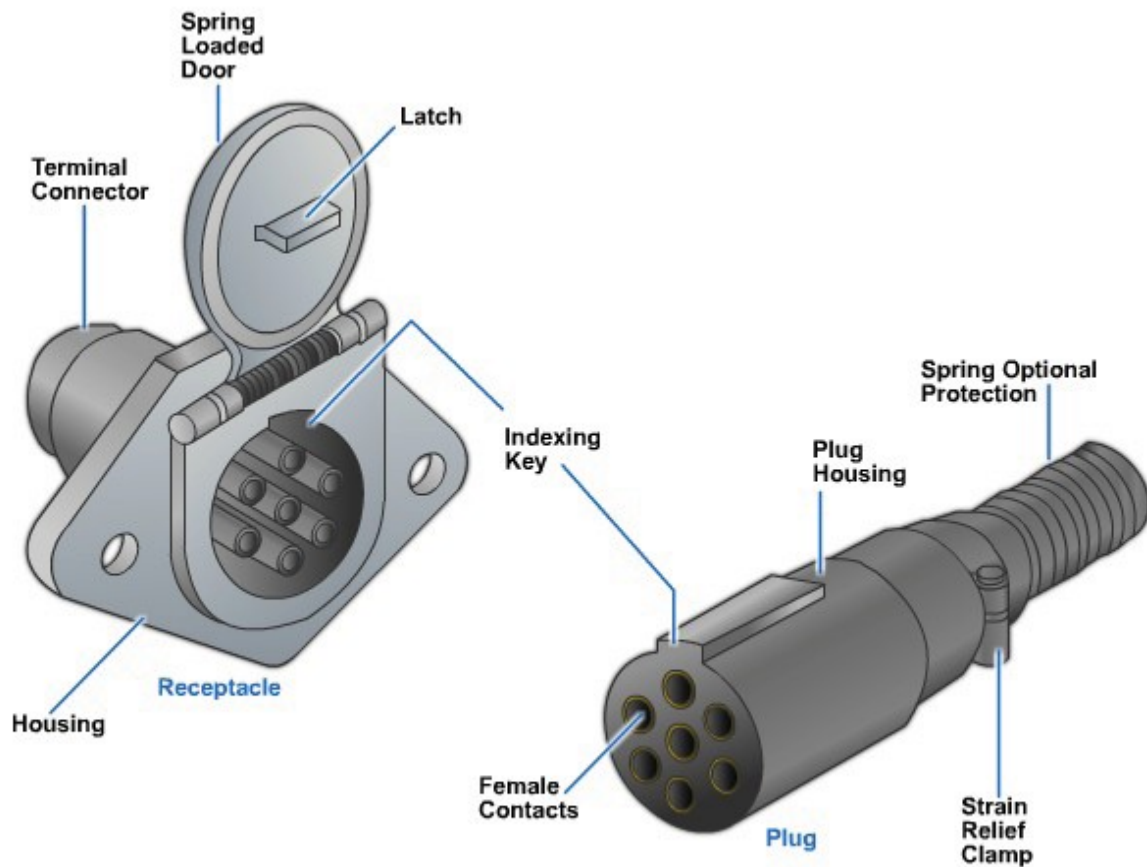


Figure 6-54 - Tractor-trailer connectors.

Because most tractors do not pull the same trailer all the time, the trailer receptacle and cable are standardized throughout North America. The trailer interconnection is defined by SAE recommended practice J560. Each of the seven circuits on all trucks and trailers should be wired in the prescribed manner to permit tractors and trailers throughout North America to be interchangeable.

The color of wiring insulation for each trailer circuit is also standardized, as shown in *Figure 6-55*. This wiring convention should be followed to aid in troubleshooting and identification.

SAE J560 STANDARDS		
Conductor Identification	Wire Color	Lamp and Signal Circuits
Wht	White	Ground return to towing vehicle
Blk	Black	Clearance, side marker & license plate
Yel	Yellow	Left-hand turn signal & hazard signal lamps
Red	Red	Stop lamps and antilock devices
Grn	Green	Right-hand turn signal & hazard signal lamps
Brn	Brown	Tail, clearance, side marker lamps, & identification lamps
Blu	Blue	Auxiliary

Figure 6-55 - Trailer standard wiring colors.

Note in the schematic layout *Figure 6-56* that the trailer running lights are broken down into two circuits: the black wire and the brown wire. The black wire should be connected to the front marker and clearance lamps, the identification lamp (three-bar light), the two lower rear-side marker lamps, and the center marker lamps (if applicable). The brown wire should be connected to the rear clearance lamps, the tail lamps, and the license plate lamp. These circuits should be kept isolated from each other because they may be protected by two different circuit protection devices in the tractor. Otherwise, a short circuit at one place in the trailer running lamp wiring would disable all trailer running lamps.

The illustration of the trailer plug and the trailer receptacle in *Figure 6-57* is something that you should become familiar with. It shows the views of the mating end of the tractor receptacle and of the trailer plug. A test light or a special trailer light test tool is used to test for voltage at the specific terminal to determine if the problem is with the truck or the trailer. Notice the larger-diameter terminal at the top; this is the trailer ground terminal. Because all trailer light current must pass through the ground circuit, it uses a larger-diameter terminal than the other terminals and uses a larger-diameter wire than the other wires in the seven-way cable.

The tractor normally provides the circuit protection for trailer wiring. However, some trailers may have circuit breakers for trailer lights as well, (*Figure-58*). The trailer power distribution module is usually mounted on the left frame rail aft of the cab or on a rear crossmember at the end of the frame rail, as shown in *Figure 6-59*. The trailer PDM contains fuses and relays to enable high current outputs via a wiring harness and relays to enable high current outputs via a wiring harness to the trailer connector.

The length of the trailer wiring must be considered when replacing trailer wiring. Even though the rear trailer lamps may have the same ratings as the truck lamps, the long distance to the lamps can result in a substantial voltage drop on the wiring. This reduces the voltage at the trailer lamps. Wire gauge is especially important for double

and triple trailers because the total circuit from the rear trailer light feed to the tractor can be more than 80 feet. *Figure 6-60* should be used to determine the wire gauge necessary for trailer wiring repair or replacement.

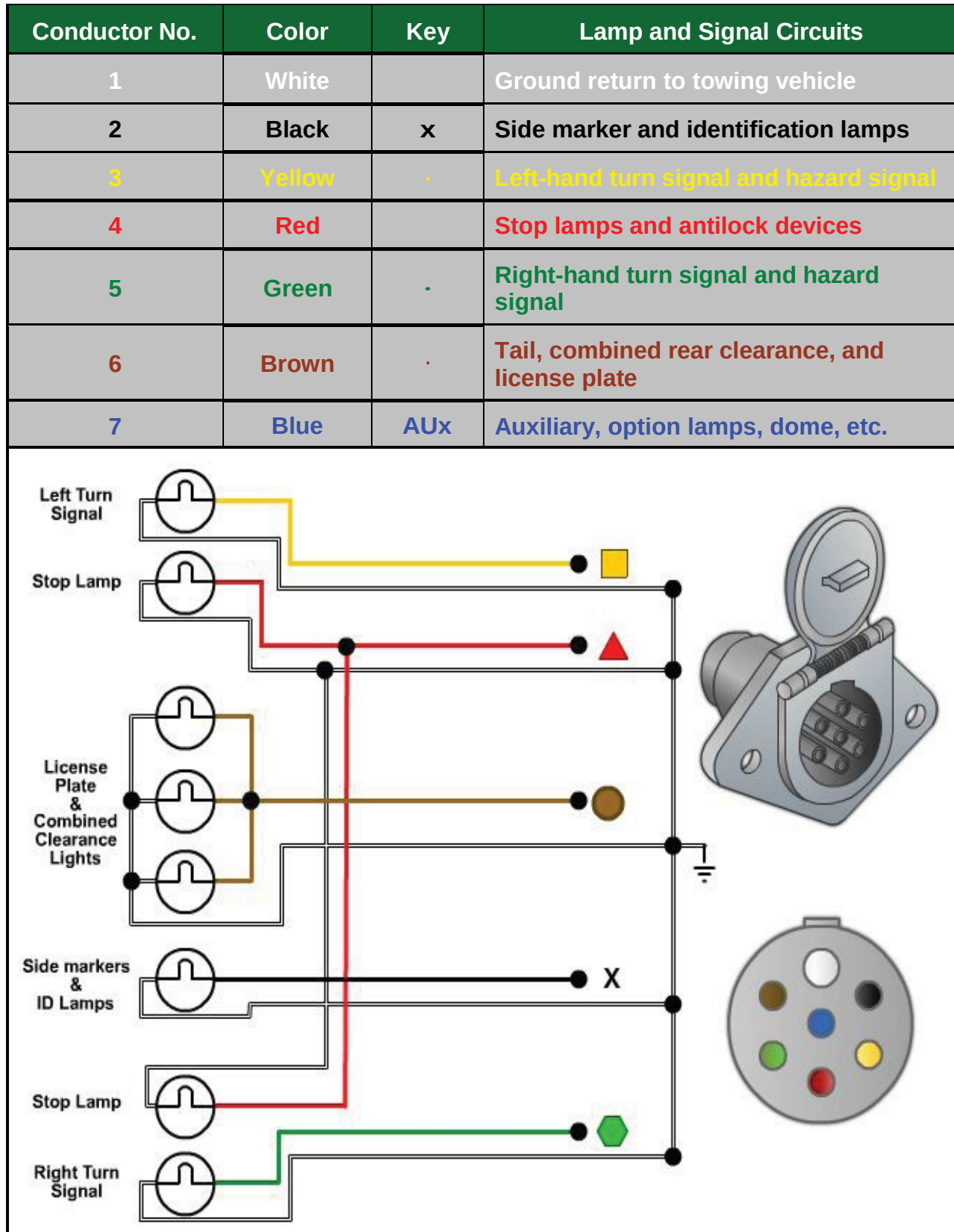


Figure 6-56 - Schematic layout of a trailer electrical system.

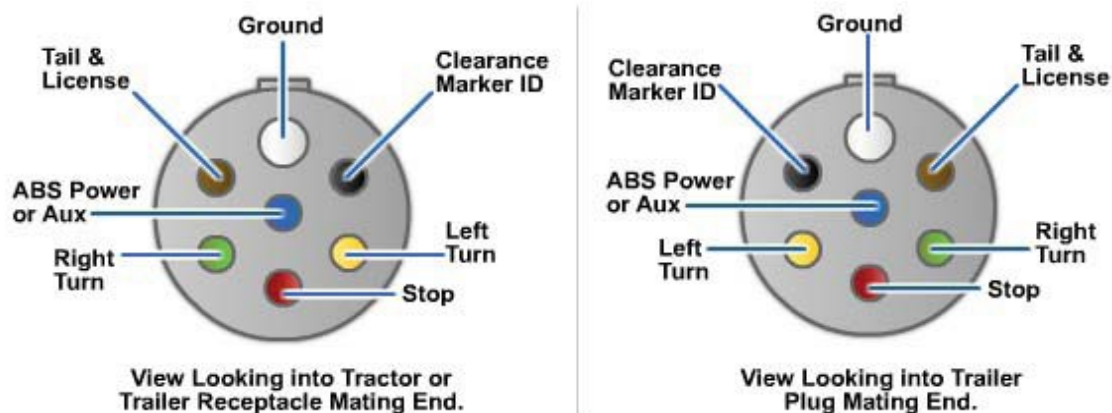


Figure 6-57 - Tractor and trailer mating ends.

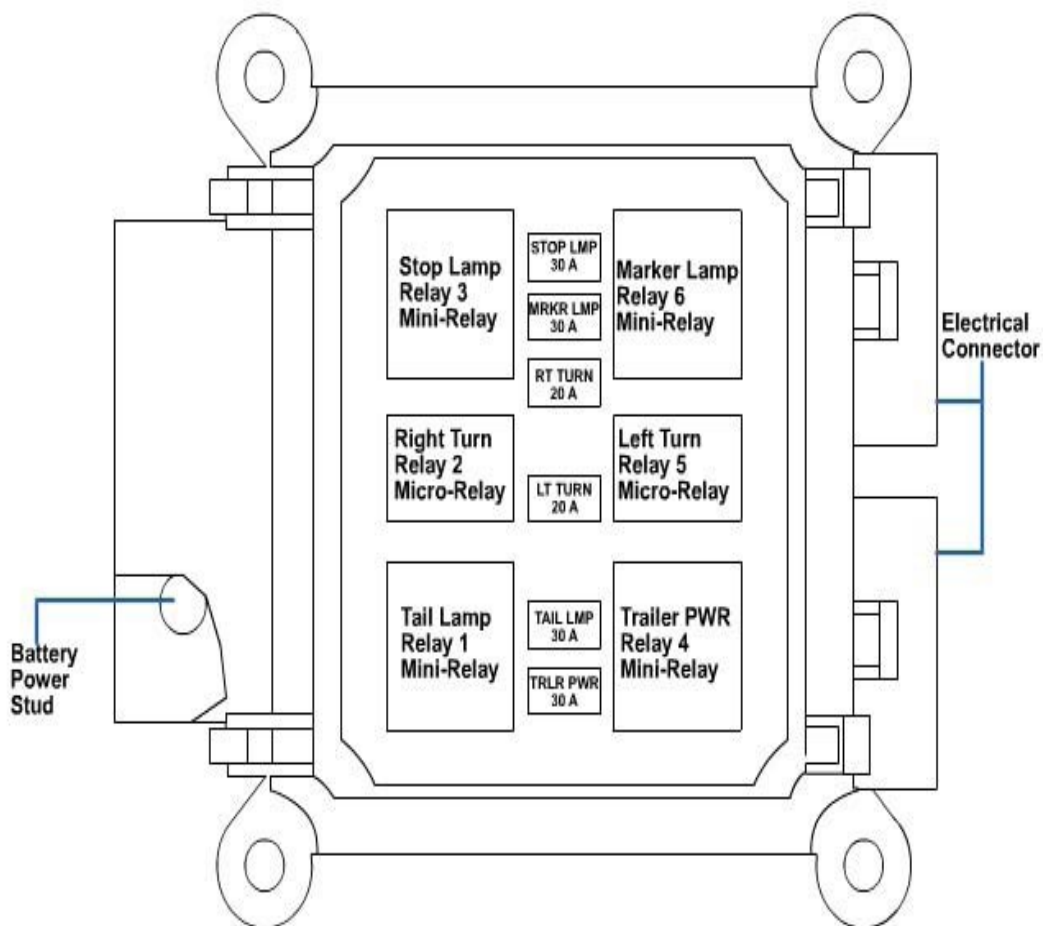


Figure 6-58 - Trailer power distribution module.

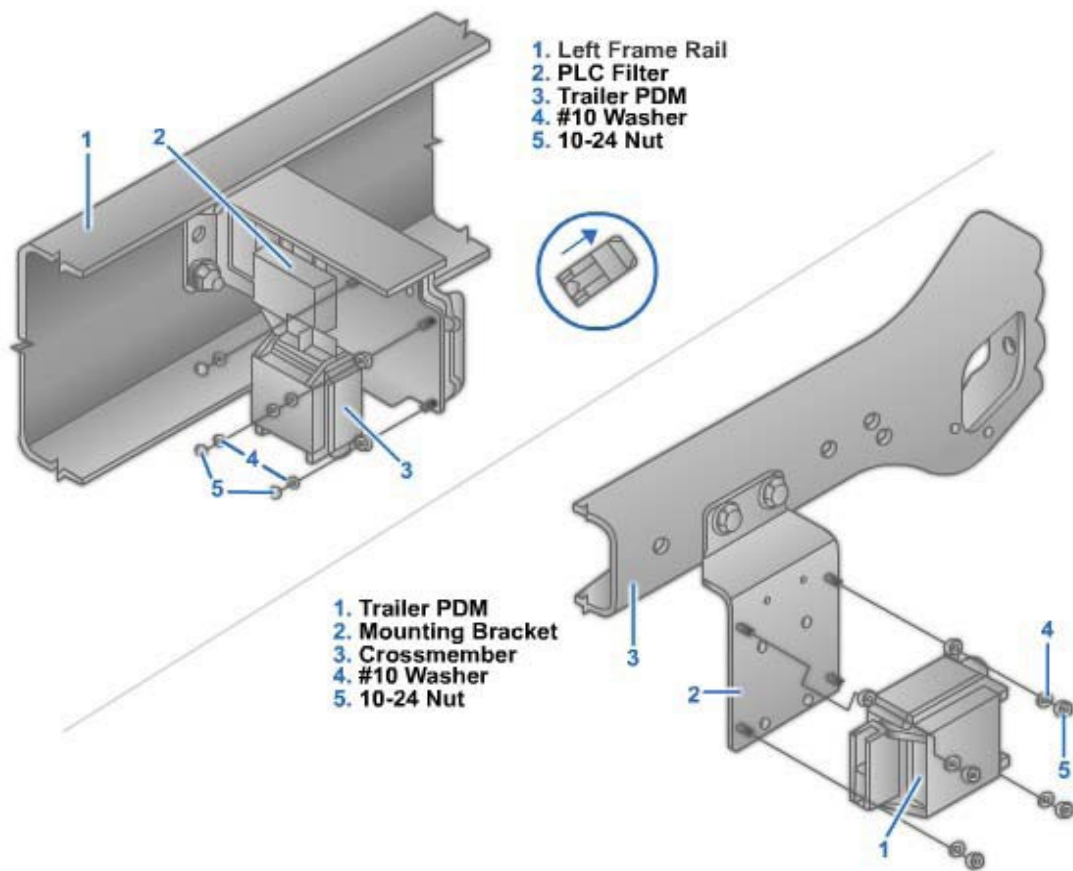


Figure6-59-TrailerPDMinstallation.

TOTAL LENGTH OF CABLE IN CURCUIT FROM BATTERY TO MOST DISTANT LAMP							
12-Volt System							
Amperes (approx)	Up to 30 Feet	40 Feet	50 Feet	60 Feet	80 Feet	100 Feet	120 Feet
	Gauge	Gauge	Gauge	Gauge	Gauge	Gauge	Gauge
1.0	14	14	14	14	14	14	14
2	14	14	14	14	14	14	14
3	14	14	14	14	14	14	12
4	14	14	14	14	14	12	12
5	14	14	14	14	12	12	12
6	14	14	14	14	12	12	10
7	14	14	12	12	12	10	10
8	14	12	12	12	10	10	10
10	14	12	12	12	10	10	8
11	14	12	12	10	10	8	8
12	14	12	12	10	10	8	8
15	12	12	10	10	8	8	8
18	12	10	10	8	8	8	8
20	12	10	10	8	8	8	6
25	12	10	8	8	8	6	6
30	12	10	8	8	8	6	6
35	12	10	8	8	6	6	6
Recommended minimum wire gauge for stop light and ground circuits.							
				STOP LIGHT (Red)		GROUND (White)	
Single trailer (up to 50' length)				-12 Gauge		10 Gauge	
Doubles trailer (2-28' lengths)				-12 Gauge		10 Gauge	
Doubles trailer (2-40' lengths)				-10 Gauge		8 gauge	
Triples trailer (3-28' lengths)				10 Gauge		8 gauge	

Figure 6-60 - Recommended wire gauges for trailer wiring.

Figure 6-61 is a quick reference for troubleshooting electrical systems. It is always recommended to refer to the service manual for detailed information for troubleshooting and repairs.

Electrical Troubleshooting	
Description of Fault	Possible cause
Stop lights on at all times	Battery Mega Fuse that supplies the trailer power distribution module (ODM) is open or missing.
Trailer connector center pin (pin 7) is not providing desired power condition	Incorrect Reference Parameter
Intermittent or no electrical trailer operation at all outputs	Loss connection. Check trailer PDM electrical connections and ground.
No operation on single output.	Trailer PDM components are inoperable. Check PDM fuse (blown) and relay (stuck) for that output.
Intermittent or no operation on single output	Terminal connection(s) damaged wire. Trace the suspect circuit.

Figure 6- 61 - Quick reference electrical troubleshooting.

11.5.1 Horns

The horn system uses a coil-operated diaphragm to produce sound waves and an audible sound. The horn system is simple; it consists of:

1. Fuse or circuit breaker - electrical safety device that protects horn circuit from shorts
2. Horn wiring harness - wires that connect fuse to harness and horns to horn button switch
3. Horns - diaphragm-operated devices that vibrate to produce sound waves
4. Horn switch - steering wheel- or steering column-mounted switch for completing horn circuit

Figure 6-62 shows a basic horn system. Power is present at the horns and in the harness whenever the ignition switch is turned on. The horns switch grounds the circuit to activate the horns.

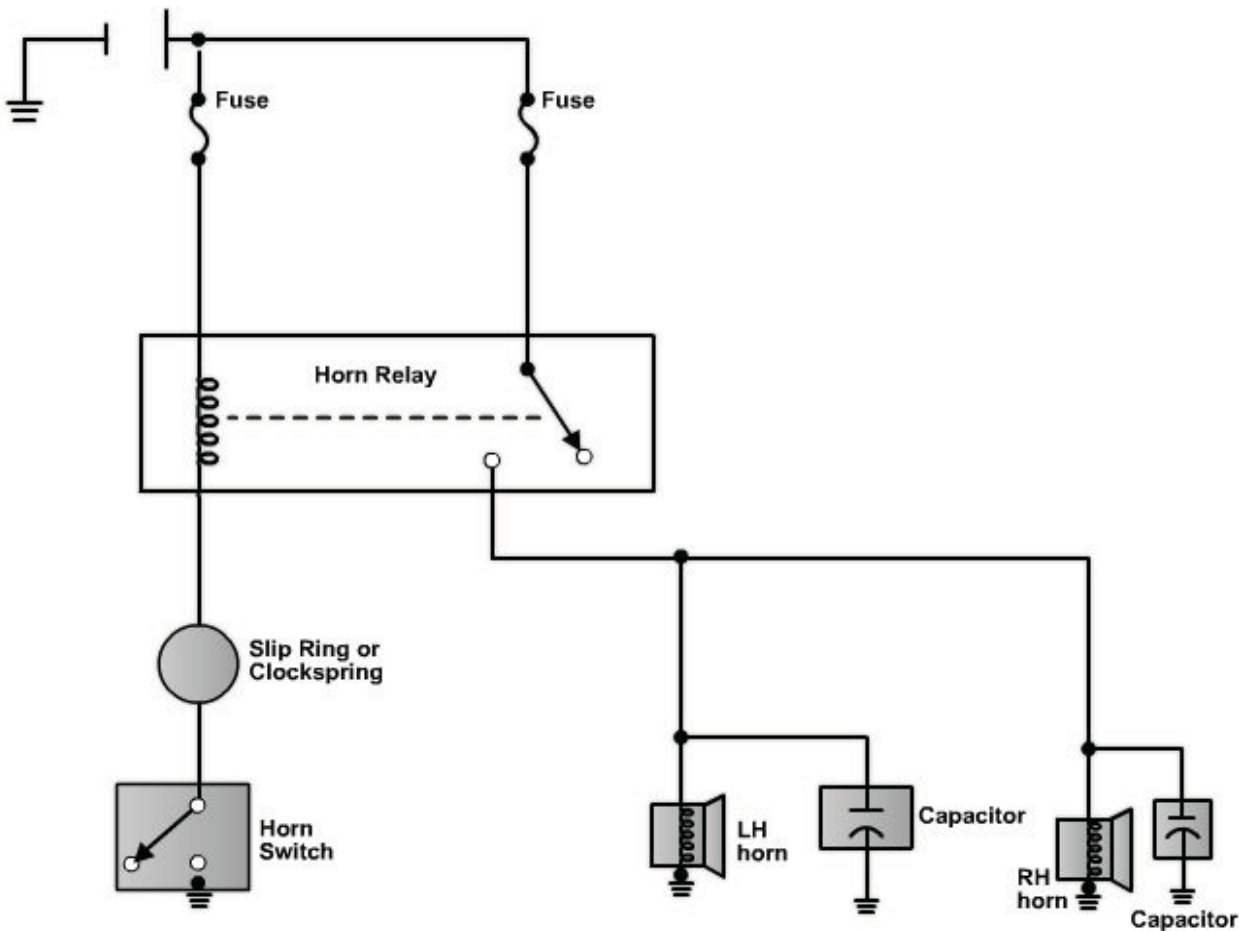


Figure 6-62 – Horn circuit.

When the driver presses the horn button, the wire leading from the horns is grounded. This causes current to flow through the fuse and horns. The resistance in the horn coils limits how much current flows into ground.

When the driver releases the horn button, a spring pushes the switch back open. This breaks or disconnects the ground circuit. No current can then flow through the horns and they stop sounding.

Horn nomenclature. A cutaway view of a typical horn is given in Figure 6-63. It is made up of the following components:

1. Horn coil - set of windings that produce magnetic field when energized by current flow

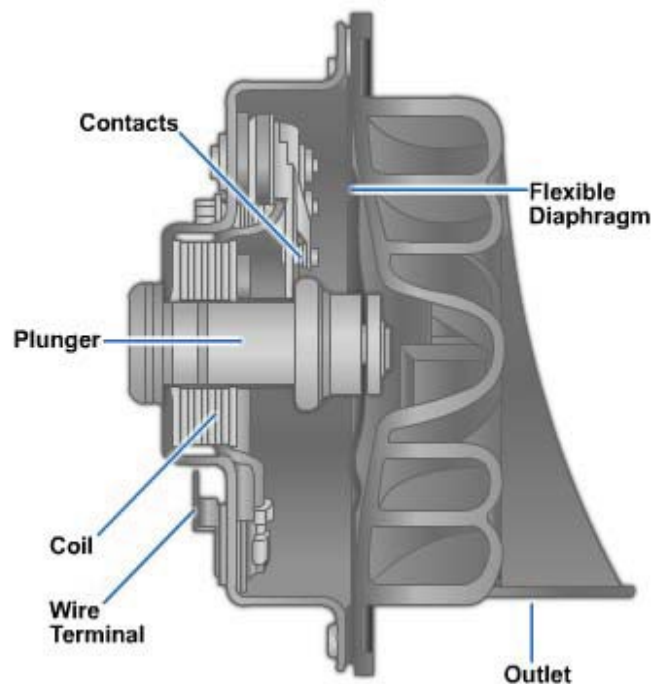


Figure 6-63 – Cutaway view of a horn.

2. Contacts - breaker points that open and close to control current flow through horn coil
3. Diaphragm - flexible membrane in horn that moves back and forth to produce air waves and sound
4. Plunger - metal core that is attached by magnetic field of coil windings
5. Wire terminal - connector for making electrical connection with wiring harness
6. Outlet - opening of horn housing for directing sound to front of vehicle

When the driver presses the horn button, current flow enters the wire terminal and horn coil. A magnetic field forms around the coil. The field attracts and pulls the plunger into the coil. Since the plunger is attached to the diaphragm, the diaphragm is flexed back toward the coil.

With enough movement, the edge of the plunger touches one of the contact point arms. This pushes the contacts open and interrupts the current flow through the coil. Without current, the magnetic field collapses, and the diaphragm snaps or flexes back into its normal position.

Once the diaphragm and plunger move back, the contacts reclose. This reenergizes the coil and the diaphragm is again pulled back toward the coil. The process is repeated rapidly and the diaphragm vibrates back and forth in the horn housing. The resulting vibration set up in the surrounding air can be heard as a "honking" sound.

A tone adjustment screw is normally provided for changing the sound of the horn. It can be turned to affect the action of the contact points and frequency of the diaphragm vibration.

Horn relay. A horn relay is sometimes used between the horn switch and the horns. It is used to reduce the amount of current flowing through the horn switch.

When the driver presses the horn switch, a small current flow enters the horn relay. This energizes the small coil in the relay to close the relay contacts. Then, a larger current flows through the closed relay points and to the horns.

Horn Service. When a horn will not sound, check the fuse and connections, and test the voltage at the horn terminal. If a horn blows continuously, the horn switch may be bad. A relay is another cause of horn problems. The contacts in the relay could be burned, or they may be stuck together.

A horn current adjusting screw is sometimes provided on the horn to set the amp draw through the horn. To adjust horn current, connect an ammeter between the feed wire and horn terminal. To prevent meter damage, be sure the ammeter can read more than 30 amps.

Get another person to sound the horn while you read the meter. If the current is not within specifications (typically 4-5 amps), turn the amps screw on the horn until the meter reads properly. Also, make sure you are getting adequate supply current/voltage and there is not a high resistance in the horn circuit. If you cannot get the horn to read within current specifications, replace it or isolate the circuit problem.

11.6.0 Small Accessory Motors

11.6.1 Windshield Wipers

A typical windshield wiper system is made up of a switch, wiper motor assembly, wiper linkage, wiper arms, and wiper blades. Either a fuse or circuit breaker protects the system.

The windshield wiper switch is a multiposition switch that sometimes contains a rheostat. Each switch position provides a different wiping speed. The rheostat operates the delay mode for slow wiping action. A relay is frequently used to complete the circuit between the battery and the wiper motor.

A wiper motor assembly consists of a permanent magnet motor and a transmission. The wiper motor transmission changes rotary motion into a back-and-forth wiping motion. The transmission is normally a set of plastic gears, an end housing, and a crank.

On the windshield wiper assembly the drive crank on the transmission connects to the wiper linkage.

The wiper linkage is a set of arms that transfers motion from the wiper motor transmission to the wiper arms. The rubber wiper blades fit on the wiper arms.

Windshield wiper service. Windshield wiper blades should be inspected periodically. If they are hardened, cut, or split, replace them.

With electrical problems in a wiper system, refer to the service manual and its wiring diagram of the circuit. First, check the fuses and electrical connections. If they are good, use a test light to check for power to the wiper motor.

If power is being fed to the wiper, the motor or transmission may be at fault. Before replacing the motor or transmission gears, make sure the motor is properly grounded. If power is not reaching the wiper motor, check the wiper switch and circuit connections for openings.

If the windshield washer does not work, check the fuse and connections. Use a test light to check for power going to the motor. If the test light does not glow, the wiper switch may be bad.

When working on a windshield wiper system, always follow the exact recommendations given by the manufacturer, as systems and procedures vary with each vehicle.

Normally, the wiper motor must be replaced as a unit. The transmission gears are usually the only serviceable part in the assembly.

11.6.2 Windshield Washer

A windshield washer consists of a solvent reservoir, pump, rubber hoses, connections, and washer nozzles. The solvent reservoir, located in the engine compartment, holds a supply of water and solvent. When the washer switch or button is activated, the wiper motor and washer pump turn on. Solvent is forced out of the reservoir and onto the windshield.

There are two common types of pumps used with windshield washer systems: a rotary pump and a bellows (diaphragm) pump. Most new vehicles use a rotary pump mounted in the solvent reservoir. A tiny electric motor spins an impeller, which forces the washer solution onto the windshield. A bellows pump is normally mounted on and powered by the wiper motor.

Windshield washer service. Many washer problems are caused by restrictions in the fluid lines or nozzles. To check for restrictions, remove the hose from the pump and operate the system. If the pump ejects a stream of fluid, then the fault is in the delivery system. The exact location of the restriction can be found by reconnecting the fluid line to the pump and disconnecting the line at another location. If the fluid still streams out, the problem is after that new disconnect. If the fluid does not flow out, the problem is before the hose was disconnected. Repeat this process until the problem is found.

If the pump does not spray out a steady stream of fluid, the problem is in the pump circuit. It should be tested in the same way as any other electrical circuit. Make sure it gets power from the switch when it should, then check the ground. If the power to the pump is good and there is a good ground, the problem is the pump. Pumps are not rebuilt or repaired; they must be replaced.

11.6.3 Power Windows

A power window uses a control switch, reversible electric motor, circuit breaker, fuse, and related wiring to operate the door windows.

A small electric power window motor is located inside each door to operate the window regulator (up-down mechanism for the glass). The motors have a gearbox, or transmission (usually worm and ring gear), that changes the rotating motion of the motor armature into a partial rotation of a larger gear. This action pushes the window open or closed.

A circuit breaker protects the window motor from overheating damage. The breaker can open if the switch is held in one position too long. The circuit breaker can be located inside the motor or elsewhere in the circuit. A simple power window circuit for a passenger-side power window is shown in *Figure 6-64*.

Some power windows will stop or reverse direction if an obstruction resists window closing. In some of these systems, a magnetic trigger wheel is mounted on the motor's armature shaft. As the trigger wheel turns, it creates a signal in a magnetic or Hall-effect sensor in the motor assembly. If the sensor outputs a slower-than-normal signal, the power windows ECM will cut voltage or reverse polarity of the voltage going to the window motor. This stops the window or lowers it to prevent damage to objects or injury to people who accidentally put their hands, head, or arms into the path of the window as it closes.

Power window service. When none of the power windows work, you first check the fuse or circuit breaker for the whole system. If only one of the windows is inoperative, use a test light to check for power to its switches.

If you hear a humming sound when a window switch is pressed, the motor gearbox may have stripped gear teeth. The plastic gears in the window motor gearbox can strip after prolonged service. The motor will spin, but movement will not be transferred to the window. If the motor or the switches are found to be bad, they should be replaced.

With hard-to-find problems, refer to the service manual wiring diagram for the power windows, which will show all the components that could affect power window operation and help with troubleshooting.

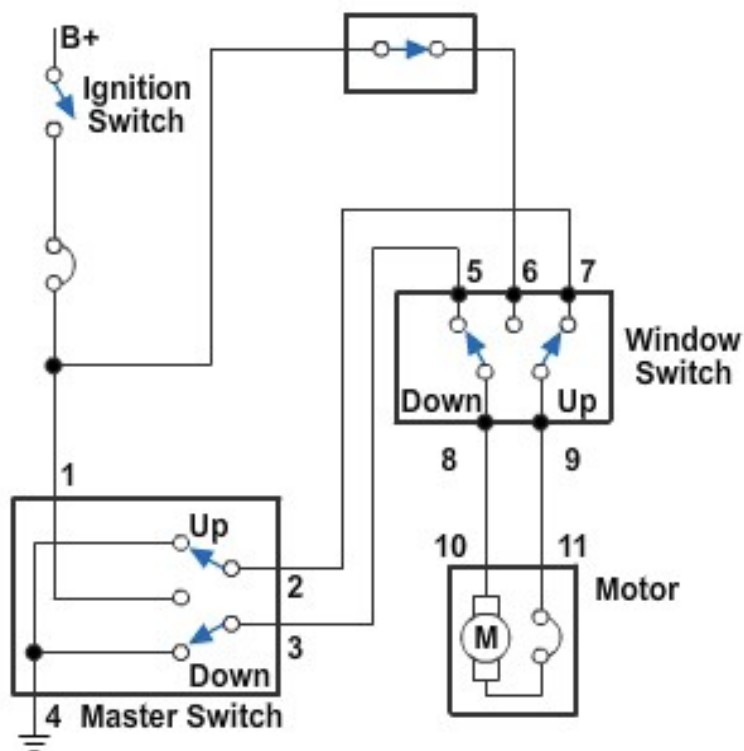


Figure 6-64- Schematic simple power window circuit for a passenger-side window.

Summary

This chapter has presented information and procedures in troubleshooting electrical systems. You covered the alternator and its components and function, along with rectifiers, voltage regulators, and troubleshooting procedures.

The succeeding topics encompassed troubleshooting the cranking system with emphasis on the various tests, the ignition system and its components and subsystems, lighting systems, and electrical accessories.

Electric and electronic devices can be found almost everywhere on an automobile, truck, power generation equipment, and construction equipment. These components have even replaced some mechanical devices. They are more efficient, compact, and lighter.

Troubleshooting equipment takes complex diagnostic procedures, much service literature, and specialized equipment. It is uncommon for the mechanic to get through even one day without referring to a service manual or technical literature.

Specialized tools, test equipment, and other diagnostic equipment, as well as service manuals and technical literature, are rapidly becoming a necessary requirement.

Review Questions (Select the Correct Response)

1. The voltage regulator maintains an alternator output of how many volts?
 - A. 10 to 12
 - B. 12 to 14
 - C. 13 to 15
 - D. 14 to 16
2. Diodes, heat sink, and electrical terminal make up what assembly?
 - A. rotor
 - B. rectifier
 - C. brush
 - D. stator
3. **(True or False)** The stator is a rotating set of windings mounted between the end frames.
 - A. True
 - B. False
4. There are commonly two types of bearings used in an alternator, one being ball type. What is the other type of bearings sometimes used?
 - A. roller thrust
 - B. roller
 - C. friction
 - D. needle
5. The text lists three types of alternator belts. Which of the following is not an alternator belt?
 - A. ribbed V-belt
 - B. conventional V-belt
 - C. ribbed belt
 - D. cogged V-belt
6. Which component of the alternator feeds the diode trio?
 - A. stator
 - B. rotor
 - C. rectifier
 - D. diode feeder

7. When a diode is connected to voltage source where the current passes through the diode, the diode is said to be what?
- A. Reverse biased
 - B. Biased
 - C. Forward biased
 - D. An insulator
8. There are four basic types of voltage regulators. Where might the electronic regulator be mounted?
- A. Inside the alternator
 - B. Away from alternator in engine compartment
 - C. On the rear of the alternator
 - D. On the front of the alternator
9. The electronic voltage regulator increases alternator output by doing what?
- A. Allowing more current into the rotor windings
 - B. Preventing more current into the rotor windings
 - C. Allowing less current into the rotor windings
 - D. Allowing more current into the stator windings
10. Field circuit modulation refers to how the _____ can cycle the rotor field current on and off to control charging system output.
- A. stator
 - B. diode trio
 - C. voltage regulator
 - D. rectifier bridge
11. **(True or False)** It is not necessary to disconnect the battery before moving any charging system components if the ignition is off.
- A. True
 - B. False
12. While testing a 12-volt system, the voltmeter reads 15 volts. What is the reason for this high output?
- A. Blown fuse
 - B. Shorted field wire
 - C. Grounded field
 - D. Current limiter relay of the regulator

13. Circuit resistance tests are used to locate wiring problems in a charging system by testing voltage between which components?
- A. Alternator output terminal and the negative battery post
 - B. Alternator output terminal and positive battery terminal or negative battery terminal and alternator housing.
 - C. Alternator housing and positive battery terminal
 - D. Alternator input terminal and negative battery terminal or positive battery terminal and alternator housing
14. When performing a regulator ground circuit resistance test, a voltmeter reading exceeding how many volts indicates a possible damaged ground strap or loose mountings?
- A. 0.01
 - B. 0.10
 - C. 1.00
 - D. 1.10
15. When using an ohmmeter to test diodes, what must you do?
- A. Connect the diodes with a piece of wire.
 - B. Remove the diodes from the alternator.
 - C. Disconnect the stator windings.
 - D. Unsolder the diodes and isolate them.
16. When testing a diode with an ohmmeter and it reads high resistance in one direction and low resistance in the other, what does this reading tell you?
- A. The diode is good.
 - B. The diode is shorted.
 - C. The diode is open.
 - D. Replace the diode.
17. A weak diode will produce what type of pattern on an analyzer screen?
- A. A high or low peak every sixth pulse
 - B. A flat signal each sixth pulse
 - C. A low ripple pattern
 - D. A steep peak every sixth pulse
18. On a vehicle equipped with a 24-volt series parallel starting system, what minimum voltmeter reading is considered normal for a cranking voltage test?
- A. 12 volts
 - B. 14 volts
 - C. 16 volts
 - D. 18 volts

19. While conducting a starter insulated circuit test, what maximum allowed voltage drop is the norm across the length of a cable?
- A. 0.01
 - B. 0.10
 - C. 1.00
 - D. 1.10
20. During a starter ground circuit resistance test, the measured voltage loss exceeds 0.2 volt or the loss given by the manufacturer's specifications. This loss can result from which of the following problems?
- A. Loose starter bolt
 - B. Poor battery ground terminal post connector
 - C. Damaged undersized ground system wire
 - D. Each of the above
21. What component of the ignition system boosts battery voltage to as much as 60,000 volts?
- A. Alternator coil
 - B. Ignition switch
 - C. Ignition coil
 - D. Battery booster
22. **(True or False)** An electronic ignition is more dependable than a contact point because there are no mechanical breakers to wear or burn.
- A. True
 - B. False
23. A solid-state chip or module that produces an electrical signal when triggered by a slotted wheel is called what?
- A. Hall-effect pickup
 - B. Trigger wheel
 - C. Permanent magnet
 - D. Pickup coil
24. In the distributorless ignition system, what component consists of two or more ignition coils?
- A. power distribution module
 - B. distributorless coil module
 - C. ignition module
 - D. electronic coil module

25. The following are all advantages of distributorless ignition system over ignition systems with a distributor except:
- A. No mechanical weights
 - B. No vacuum advance diaphragm
 - C. More moving parts to wear and malfunction
 - D. No rotor or distributor cap
26. What component is eliminated with a direct ignition system?
- A. coils
 - B. spark plugs
 - C. ignition wires
 - D. spark plug wires
27. In a computerized ignition system, heat will upset the operation of the electronic components in what unit?
- A. Power distribution module
 - B. Ignition control module
 - C. Electronic power module
 - D. Computer module
28. In the electronic ignition system, what test compares actual resistance or voltage output?
- A. Magnetic pickup coil
 - B. Ignition coil
 - C. Electronic ignition resistance
 - D. Magnetic voltage
29. When conducting a Hall-effect sensor with an oscilloscope, how should the waveform appear?
- A. Switch slowly, angled sides, top square reaching reference voltage, and bottom should reach zero
 - B. Switch rapidly, sloped sides, top rounded reaching reference voltage, and bottom should reach zero
 - C. Switch rapidly, vertical sides, top square reaching reference voltage, and bottom should reach zero
 - D. Switch intermittently, vertical sides, top arched reaching reference voltage, and bottom should reach zero
30. **(True or False)** In a direct ignition coil test, you will measure both primary and secondary winding resistance.
- A. True
 - B. False

31. The halogen lamp typically consists of a bulb filled with what type of vapor?
- A. halogen
 - B. oxygen
 - C. iodine
 - D. fluoride
32. How would you identify a type 1 sealed-beam headlight?
- A. Both low and high beam and three terminals
 - B. Both low and high beam and two electrical terminals
 - C. "H" molded on the lens
 - D. High beam only and two electrical terminals
33. If one bulb is not working and you determined it is not burned out, what should you check for before replacing the bulb?
- A. voltage at socket
 - B. ignition switch
 - C. headlight control module
 - D. amperage
34. Most fuses are designed to maintain what percent of overload current indefinitely?
- A. 105
 - B. 110
 - C. 115
 - D. None of the above
35. **(True or False)** Blade fuses come in three sizes, sometimes referred to by their trade names. They are Mini-fuse, auto-fuse, and Maxi-fuse.
- A. True
 - B. False
36. Trucks will have large, bolt-in type fuses that are commonly used to protect main battery power feed cable that supplies what?
- A. The trailer electrical system
 - B. The engine electrical system
 - C. The headlights and taillights
 - D. The cab electrical system
37. The special insulation material used in a fusible link has what characteristics?
- A. Melts off and is flammable
 - B. Does not melt off nor support flame
 - C. Does not melt off but is flammable
 - D. None of the above

38. A Type I circuit breaker has which characteristic?
- A. Resets automatically
 - B. Resets automatically after cause is relinquished
 - C. Manually resets
 - D. Resets automatically with operator intervention
39. The turn signal flasher unit operates by the heating and cooling of which temperature-sensitive component?
- A. Bimetallic strip
 - B. Metallic connector
 - C. Copper wire
 - D. Bimetallic filament
40. Which type of flasher typically contains a power metal-oxide-semiconductor field-effect transistor?
- A. Hybrid
 - B. Solid-state
 - C. Bimetallic
 - D. Electronic
41. The brake light switch is normally mounted on the brake pedal, but can also be mounted at what other location?
- A. Master cylinder
 - B. Brake line
 - C. Steering column
 - D. Both A and B
42. The color of wiring insulation is standardized. What color is the wire for the STOP lamps and antilock devices?
- A. Red
 - B. Green
 - C. Brown
 - D. Blue
43. The tractor normally provides the circuit protection for trailer wiring or can have a separate component mounted on the tractor. What is the additional component with fuses and relays for trailers called?
- A. Electrical relay system
 - B. Power delivery box
 - C. Power distribution module
 - D. Tractor/trailer power transmitter

44. **(True or False)** The horn system uses a coil-operated diaphragm to produce audible sound.
- A. True
 - B. False
45. The metal core that is attached by magnetic field of coil windings is what part of a horn?
- A. Outlet
 - B. Plunger
 - C. Contacts
 - D. Horn coil
46. What should the amp reading generally be when troubleshooting a horn?
- A. 2-3
 - B. 3-4
 - C. 4-5
 - D. 5-6
47. After making all the required checks on the windshield washer and determining that the pump is bad, what is the next step ?
- A. Rebuild the pump
 - B. Replace the pump
 - C. Repair the pump
 - D. Tap on the pump
48. When troubleshooting an inoperative power window, you can hear a humming noise where the motor is spinning, but there is no movement of the window. What may be the problem?
- A. Stripped plastic gears
 - B. Stripped window cam
 - C. Bent tracking system
 - D. Stripped plastic rotor

Additional Resources and References

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

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

Auto Engine Performance and Drivability, Chris Johanson, The Goodheart-Wilcox Company, Inc., 2004. (ISBN: 1-59070-257-3)

Automotive Technology, A Systems Approach, 4th Edition, Jack Erjavec, Thomas, Delmar Learning, 2005. ((SBN: 1-4018-4831-1)

Auto Electricity and Electronics, James Duffy, The Goodheart-Wilcox Company, Inc., 2004. (ISBN: 1-59070-272-7)

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Chapter 7

Clutches and Automatic Transmissions

Topics

1.0.0 Clutch Systems

2.0.0 Automatic Transmissions

To hear audio, click on the box.



Overview

This chapter provides information about the clutch and the automatic transmission to enable you to understand the operation of these units, to diagnose problems, and to prescribe corrective action. To obtain more detailed information on the operation and repair of specific units, refer to the specific manufacturer's maintenance and repair manual.

Objectives

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

1. Understand the principles of and how to troubleshoot clutch systems.
2. Understand the principles of and how to troubleshoot automatic transmissions.

Prerequisites

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

Air Conditioning Systems		C M A D V A N C E D
Air Compressor Overhaul		
Inspecting and Troubleshooting Brake Systems		
Hydraulic Systems		
Wheel and Track Alignment		
Troubleshooting Transmissions, Transfer Cases and Differentials		
Clutches and Automatic Transmissions		
Troubleshooting Electrical Systems		
Fuel System Overhaul		
Engine Troubleshooting and Overhaul		
The Shop Inspectors		
Alfa Company Shop Supervisor		
Public Works Shop Supervisor		

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 CLUTCH SYSTEMS

It is important to briefly review the purpose of the clutch and also the various types of clutches. The clutch permits the operator to couple and uncouple the engine and transmission. When the clutch is in the ***coupling*** (or normal running) position, power flows through it from the engine to the transmission. If the transmission is in gear, power flows through to the vehicle wheels, so the vehicle moves. Essentially, the clutch enables the operator to ***uncouple*** the engine temporarily, so the gears can be shifted from one forward gear position to another or into reverse or neutral. The flow of power must be interrupted before the gears are shifted; otherwise, gear shifting is extremely difficult if not impossible.

The clutch assembly (*Figure 7-1*) contains a friction disc, or driven plate, about a foot in diameter. It also contains a spring arrangement and a pressure plate for pressing the disc tightly against the face of the flywheel. The friction disc is splined to the clutch shaft. The splines consist of two sets of teeth: an internal set on the hub of the friction disc and a matching external set on the clutch shaft. They permit the friction disc to slide back and forth along the shaft but force the disc and the shaft to rotate together.

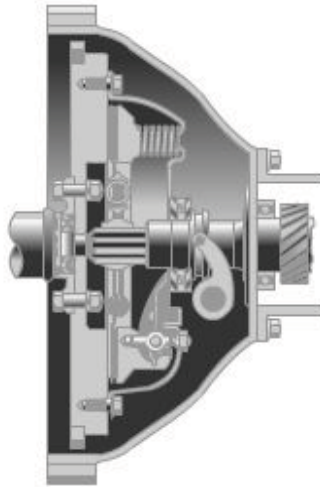


Figure 7-1 – Single disc clutch.

The flywheel, attached to the end of the engine crankshaft, rotates when the engine is running. When the clutch is engaged in the coupling position, the friction disc is held tightly against the flywheel by the pressure plate springs so that it rotates with the flywheel. This rotary motion is carried through the friction disc and clutch shaft to the transmission.

To disengage (or uncouple) the clutch, the clutch operator presses the clutch pedal down. This causes the clutch fork to pivot so the clutch release bearing is forced inward. As the release bearing is moved inward, it operates the pressure plate release levers (*Figure 7-2*). The release levers take up the spring pressure and lift the pressure plate away from the friction disc. The friction disc is no longer pressed against the flywheel face, and the engine can run independently of the power train. Releasing the clutch pedal permits the clutch fork to disengage the release bearing, so the springs will again cause the pressure plate to force the friction disc against the flywheel face to rotate together.

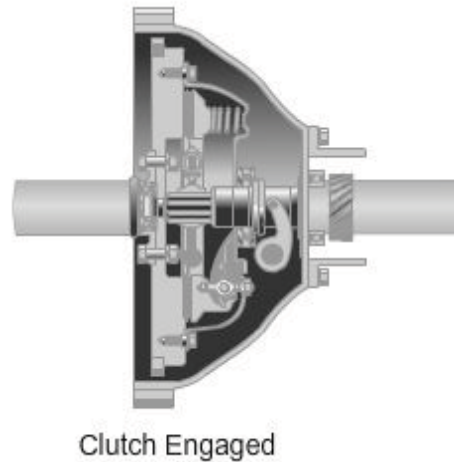


Figure 7-2- Clutch operation.

There are two types of clutch operating systems: mechanical and hydraulic. The mechanical system is the most common and uses a rod type of linkage (*Figure 7-3*); other mechanical systems use a flexible type of cable (*Figure 7-4*). These systems are normally found in automotive applications. The hydraulic operating system (*Figure 7-5*) moves the release lever by hydraulic pressure. Depressing the clutch pedal creates pressure in the clutch master cylinder, actuating the slave cylinder which, in turn, moves the release arm and disengages the clutch. Hydraulic types of clutch operating systems are normally found in heavy construction equipment where extreme pressure is required to operate the clutch.

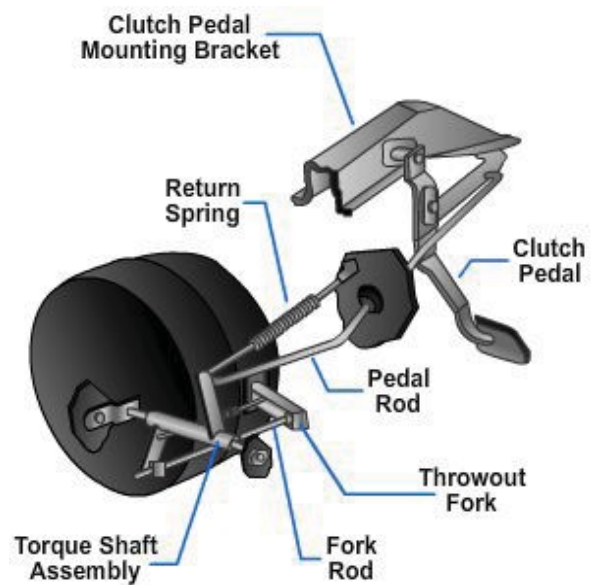


Figure 7-3- Clutch linkage.

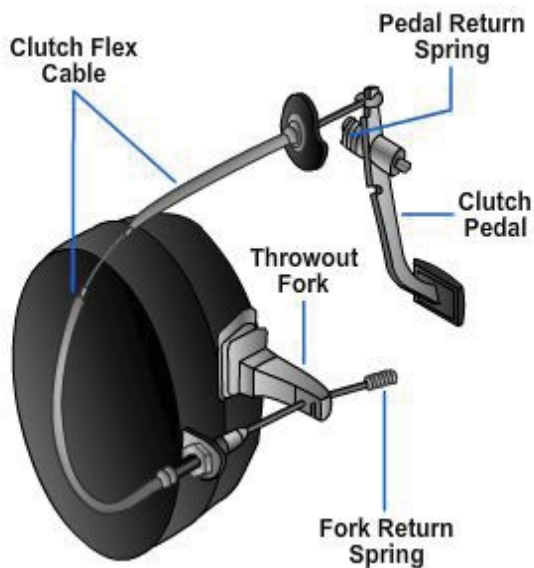


Figure 7-4 – Clutch cable.

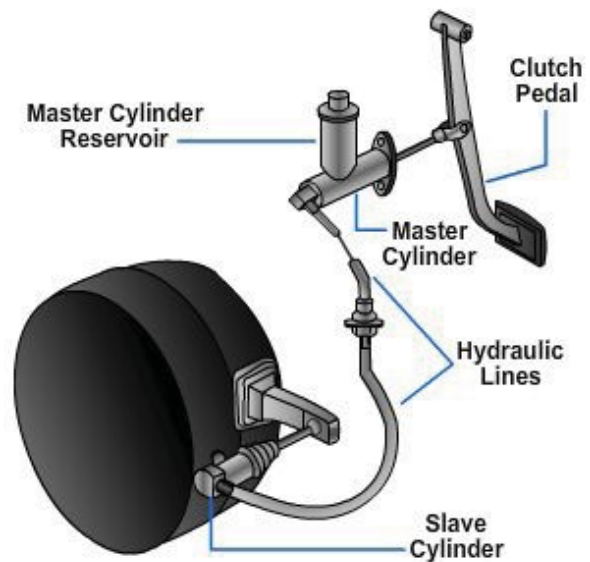


Figure 7-5- Hydraulic clutch.

Most automotive and construction equipment clutches work on the same principle and are similar in construction. The differences are mainly in pressure plate assemblies, linkages, and overall size.

Of the different types of clutch assemblies, the one that was shown in *Figure 7-1* is known as the plate clutch. The plate clutch is a simple clutch with two plates and one disc, clamped between the two plates. Another type (*Figure 7-6*) is the double-disc clutch. The driving members of the single-disc clutch consist of the flywheel and driving (pressure) plate. The driven member consists of a single disc splined to the clutch shaft and faced on both sides with friction material. When the clutch is fully engaged, the driven disc is firmly clamped between the flywheel and the driving plate by the pressure of the pressure plate springs, and a direct, nonslipping connection between the driving and driven members of the clutch is formed. In this position, the driven disc rotates the clutch shaft to which it is splined. The clutch shaft is connected to the driving wheels through the power train.

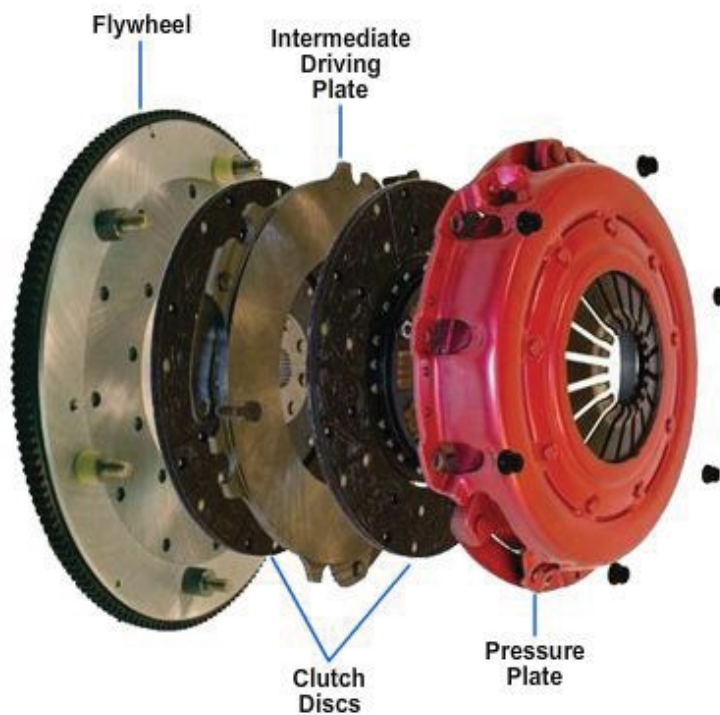


Figure 7-6-Double-disc clutch.

The double-disc clutch is substantially the same as the single-disc clutch described in the section above, except that an additional driven disc and intermediate driving plate are added.

1.1.0 Clutch Malfunctions

The information given in this section is general and may be applied to nearly every type of clutch you are likely to encounter. Refer to the manufacturer's repair manuals for problems not listed here.

The most common symptoms of clutch malfunctions are dragging, slipping, and noise. Improper adjustment is one condition that leads to clutch problems. You should always adjust the clutch according to the manufacturer's specifications. An improperly adjusted clutch can cause clutch slippage and hard shifting.

1.1.1 Dragging

This condition results when the clutch disc does not completely disengage from the flywheel or pressure plate when the clutch pedal is depressed. As a result, the clutch disc tends to continue turning with the engine and attempts to drive the transmission.

Dragging may be caused by any of the following conditions:

- Excessive free travel in the clutch linkage
- The clutch disc binding on the transmission input shaft

- A warped or damaged pressure plate
- Improper adjustment of the pressure plate release lever (Some pressure plates require this adjustment before the part is installed.)

To correct clutch dragging, adjust the free travel. Make this adjustment according to the manufacturer's specifications. If the problem is not corrected with this adjustment, you may need to remove the clutch for repairs or replacement.

1.1.2 lipping

Because of heat generation, slipping of the clutch (while it is engaged) can severely damage the clutch disc facings. The contact surfaces on the pressure plate and the flywheel may also be damaged. If a clutch is allowed to continue to slip, complete clutch failure may result. Clutch slipping is most obvious when you are just starting out from a dead stop or upon sudden acceleration in a low gear. Slipping will be very noticeable in a vehicle with a heavy load.

Causes of clutch slippage include incorrect clutch pedal free travel, binding in the clutch linkage, and "riding the clutch." If the free travel is insufficient, there is a tendency for the release bearing to contact the release levers, even though the operator's foot is off the clutch pedal. As a result, the clutch disc may not be clamped tightly between the flywheel and the pressure plate. Readjustment of the pedal free travel will solve this problem. If you do not adjust the free travel at once, the release bearing, as well as the clutch disc, will wear rapidly.

If a binding condition exists in the clutch linkage, the pedal will be reluctant to return when it is released. So again, you may encounter clutch slippage. To solve this problem, "free up" the linkage that is binding by simply lubricating or aligning the clutch linkage. If this fails to correct the problem, you may have to remove the clutch for further inspection and repair.

"Riding the clutch" is an operator problem whereby the operator steadily drives with a foot on the clutch pedal. As a result, the pedal may be partially depressed and cause clutch slippage. If this form of operator abuse is suspected, contact the transportation supervisor. The problem should be corrected through proper operator training.

1.1.3 1.1.3 Grabbing

Occasionally, you may encounter a clutch that grabs or chatters, no matter how evenly or gradually you try to engage it. If the linkage operates satisfactorily and the engine and clutch mountings are not loose, you may have to remove the clutch assembly from the vehicle to cure the trouble. The probable causes are loose, glazed, oily, or greasy disc facings; binding of the disc on the clutch shaft; broken or otherwise defective pressure plate springs; or a broken or otherwise defective pressure plate.

A careful inspection of all clutch parts should reveal any defective items. In any case, replace any damaged parts and rebuild the clutch as specified by the manufacturer. In most cases, it is best that you install the clutch as a unit, which includes replacing the clutch disc, pressure plate, release bearing, and pilot bearing, and resurfacing the flywheel. Replacing the complete assembly prevents the need for rework.

1.1.4 Noises

A noisy clutch may be caused by a number of conditions. Most of these conditions can be corrected only after you have removed the assembly from the vehicle. Start your inspection by noting whether or not the noise occurs when the clutch is engaged or

disengaged. Do this with the engine idling since the noise is likely to be most apparent at this time.

To begin with, when you have the clutch disengaged, you may discover that the noise coming from the clutch is due to lack of lubrication or to defects in the assembly. For instance, a dry or binding release bearing is likely to squeal when it is placed in operation. If it does, you will usually need to replace the bearing. On some vehicles, however, provisions are made for lubricating this bearing. If so, you can generally lubricate or replace the bearing without removing the clutch assembly. Still, you may need to remove the transmission and the lower cover from the flywheel housing to get to the bearing. It usually pays for you to go a little further and inspect the entire clutch assembly if you must remove the transmission for any reason.

Noise may also come from a worn or dry pilot bearing. Such a bearing tends to "whine" when it is out of grease. This noise usually occurs when the vehicle is stationary with the engine running, the transmission in gear, and the clutch disengaged. To remedy this, replace the bearing and make sure it is properly lubricated if it is not a prepacked bearing.

Other clutch noises may occur when you have the clutch disengaged. Any one of several conditions can be responsible for noisy operation. For example, the clutch disc may be loose on the transmission shaft (disc hub loose on shaft splines). If this is the case, depending on the amount of wear, you may have to replace the input shaft and the clutch disc. Another condition involving noise and necessitating disc replacement is loose or weak torsional springs surrounding the disc hub. You may also find that the antirattle springs on the pressure plate assembly are weak and require replacement. A hose or misaligned transmission will cause noisy clutch operation. You can easily correct this by loosening the transmission, shifting it into proper alignment, and retightening it.

1.1.5 Clutch Pedal Pulsation

Movement felt on the clutch pedal or operating lever when the clutch is being disengaged is called clutch pedal pulsation. These pulsations are noticeable when slight pressure is applied to the clutch pedal. This is an indication of trouble that could result in serious damage if not immediately corrected. Several conditions could cause these pulsations.

One condition that can cause this vibration is misalignment of the engine and transmission. If the engine and transmission are not in line, detach the transmission and remove the clutch assembly. Check the clutch housing alignment with the engine and crankshaft. At the same time, check the flywheel for wobble. A bent crankshaft flange or an improperly seated flywheel produces clutch pedal pulsations. After the flywheel is properly seated, check it using a dial indicator. If the crankshaft flange is bent, the crankshaft must be remachined or replaced.

Other causes of clutch pedal pulsations include uneven release lever adjustments, a warped pressure plate, or a warped clutch disc. If the clutch disc or pressure plate is warped, it should be replaced.

It would be impractical to list every possible clutch problem and its remedy for repair in this training manual. Consult the manufacturer's operation and repair manual before making adjustments to any clutch system.

Test your Knowledge (Select the Correct Response)

1. A hydraulic type of clutch release mechanism is normally found on heavy construction equipment for which of the following reasons?
 - A. Low-release pressure is required to operate the clutch.
 - B. A slow-release action is required to operate the clutch.
 - C. Extreme pressure is required to operate the clutch.
 - D. Extreme release action is required to operate the clutch.

2.1.1 AUTOMATIC TRANSMISSIONS

Automatic transmissions (*Figure 7-7*) are found in all types of automotive and construction equipment. The purpose of the automatic transmission is the same as standard transmissions—to match the load requirements of a vehicle to the power and speed of the engine. Changing the gear ratio automatically is controlled by throttle position, shift control lever position, and vehicle speed. It relieves the operator of the responsibility of selecting the best possible gear ratio for each condition and makes driving easier and safer.

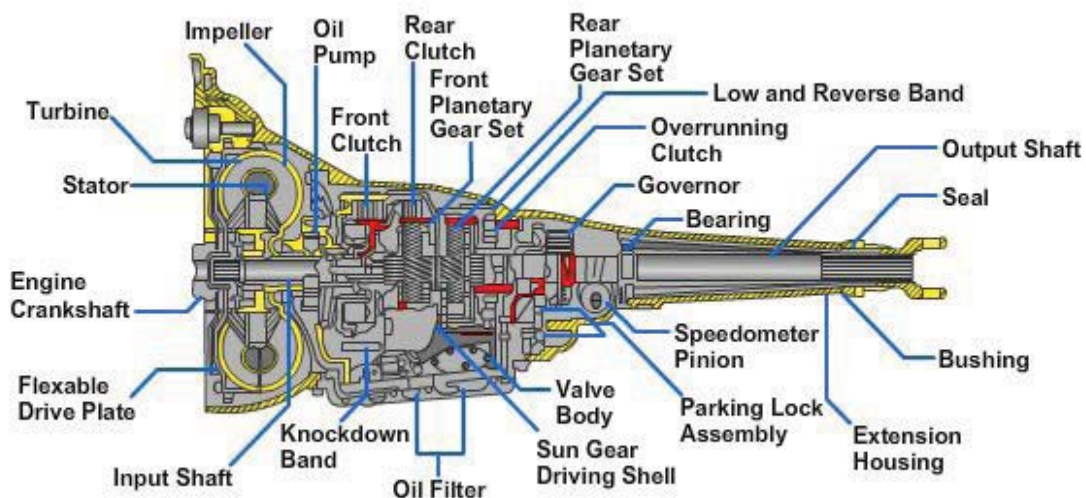


Figure 7-7 - Automatic transmission.

Many different models of automatic transmissions are manufactured today. Automotive applications usually have three speeds forward and one reverse. More recently the automotive industry has added a lockup clutch to the torque converter, and on some models, an overdrive gear. Automatic transmissions for material handling and construction equipment will normally have a lower gear ratio, be considerably larger, and may have over six speeds forward and more than one reverse gear.

Whatever the case and regardless of design or construction, all automatic transmissions have the following six basic systems that enable them to function:

1. A torque converter or fluid coupling
2. A hydraulic system
3. A planetary gearset (usually more than one)

4. One or more spool valves used to direct fluid flow
5. Multidisc clutch packs or lockup bands
6. A control valve or a combination of control valves

In automatic transmissions, these systems all serve the same purposes. For this reason, we will only discuss one type of automatic transmission in this TRAMAN. If you want information on a specific type, use the manufacturer's maintenance and repair manual for that unit.

2.1.0 4L60/4L80, 4L80E, Allison

The TH400 Hydramatic transmission was a stout and versatile transmission; however, it lacked any real fuel economy. With a three-speed gear set, it could not keep up with the demands of the rising fuel prices. Along came some new additions to the transmission world: the 4L60/4L80, 4L80E, and the Allison. These transmissions were based off the ever popular TH400, but had a kick overdrive.

The 4L80E (*Figure 7-8*) is a truck automatic transmission that was introduced by GM in the early 1990s. It basically uses many of the same internal components as the TH400 but has an overdrive fourth gear and uses electronics to control shift points and firmness.

Roughly 75 percent of the 4L80Es internal parts are interchangeable with a TH400, and the bellhousing bolt pattern and flexplate are the same as the 400, so it bolts up to big- or small-blocks just like normal.

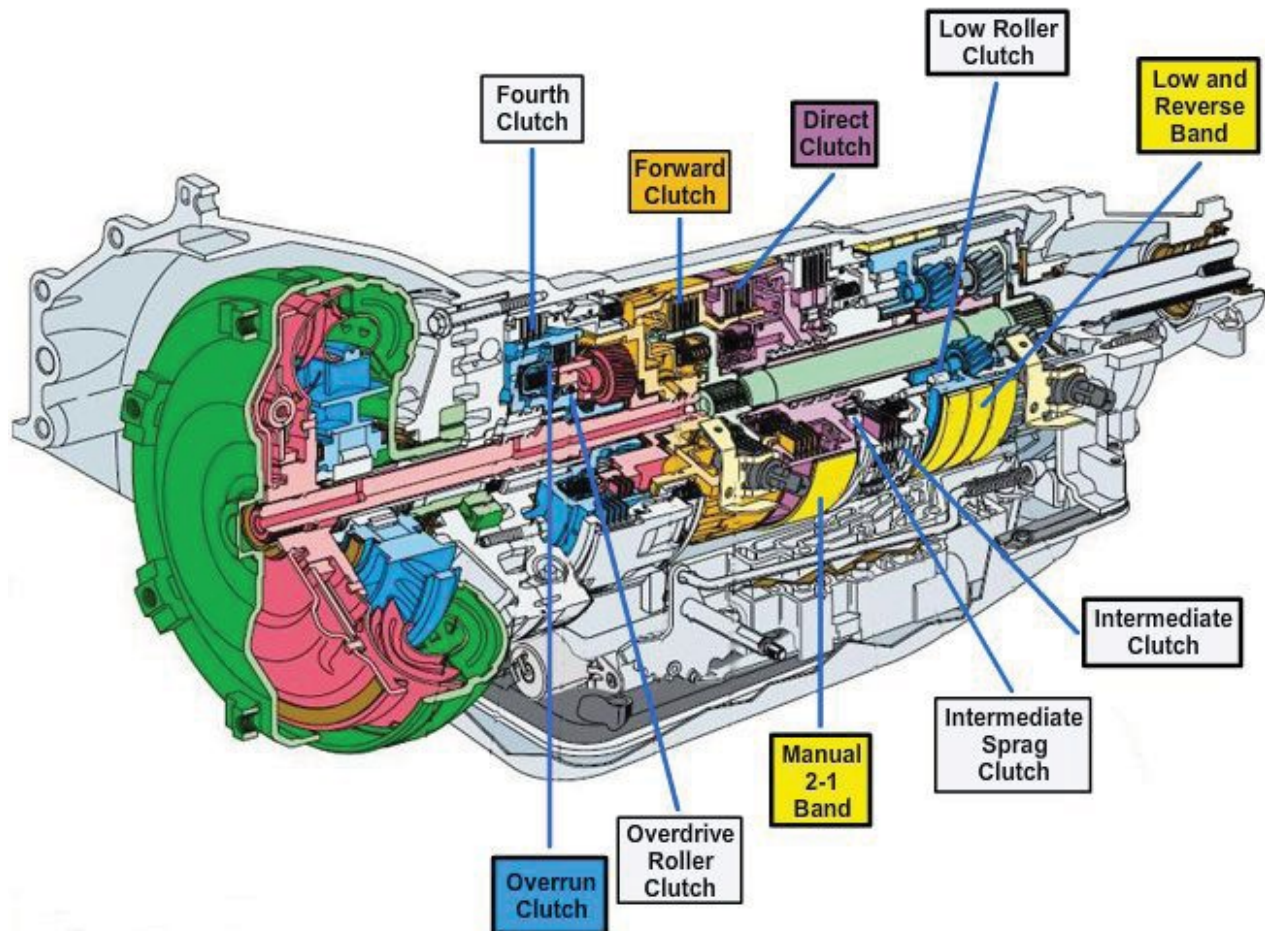


Figure 7-8 - 4L80E automatic transmission.

2.2.0 Planetary Gears

Planetary gears are used in the automatic transmission as a basic means of multiplying the torque from the engine. The name is derived from the physical arrangement of the gears. They are always in mesh and thus cannot "clash" like other gears that go in and out of mesh. The gears are designed so that several teeth are in mesh or in contact at one time. This distributes the forces over several teeth at one time for greater strength. Because the shafts generally used with planetary gear trains can be arranged on the same centerline, a compact system can be obtained.

A planetary gear train consists of a center or sun gear, an internal or ring gear, and a planetary carrier assembly, which includes and supports the smaller planet gears or pinions (*Figure 7-9*). A planetary gearset can be used to increase speed, increase torque, reverse the direction of rotation, or function as a coupling for direct drive. Increasing the torque is known as operating in reduction because there is always a decrease in the speed of the output member proportional to the increase in the output of torque. This means that with a constant input speed, the output torque increases as the output speed decreases.

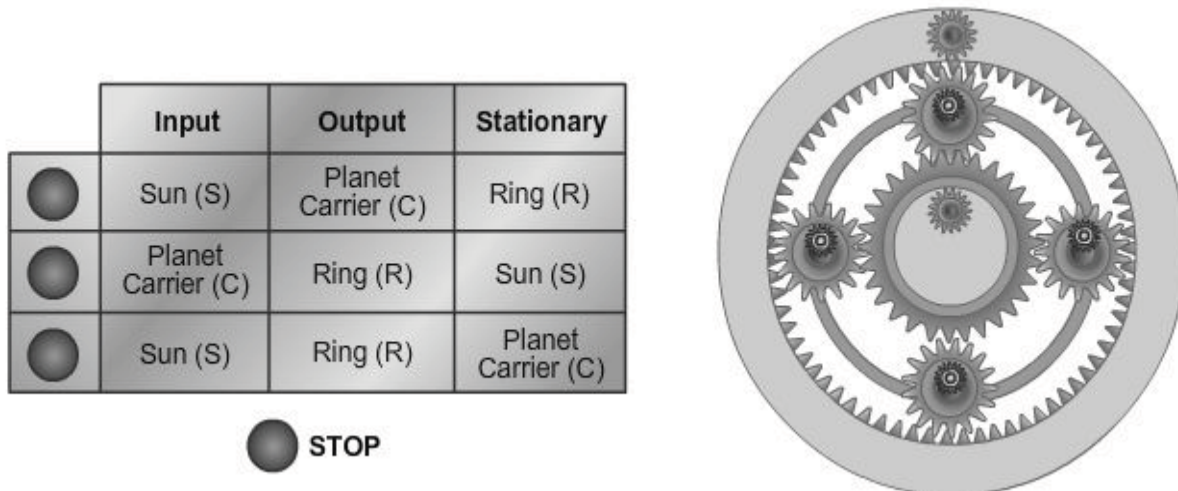


Figure 7-9 - Planetary gearset operation.

Reduction can be obtained in several ways. In a simple reduction, the sun gear is held stationary, and the power is applied to the internal gear in a clockwise direction. The planetary pinions rotate in a clockwise direction and "walk" around the stationary sun gear, thus rotating the carrier assembly clockwise in reduction (*Figure 7-9, View A*).

Direct drive results when any two members of the planetary gear train rotate in the same direction at the same speed, as shown in *Figure 7-9, View B*. In this condition, the pinions do not rotate on their pins but act as wedges to lock the entire unit together as one rotating assembly.

To obtain reverse, restrain the carrier from turning freely and power is applied to either the sun or the internal gear. This causes the planet pinions to act as idlers, thus driving the output member in the opposite direction (*Figure 7-9, View C*). In both cases, the output member is turning in the opposite direction of the input member.

2.3.0 Coupling (Torque Converter Operation)

The automatic transmission is coupled to the engine through a torque converter. The torque converter is used with the automatic transmission because it does not have to be manually disengaged by the operator each time the vehicle is stopped. The cushioning effect of the fluid coupling within the torque converter allows for shifting without interruption of engine torque application.

The torque converter serves two primary functions. First, it acts as a fluid coupling to connect engine power smoothly through oil to the transmission gear train. Second, it multiplies the torque from the engine when additional performance is desired.

The torque converter, as shown in *Figure 7-10*, consists of the pump (driving member), the turbine (driven or output member), and the stator (reaction member). The converter cover is welded (some maybe bolted) to the pump to seal all three members in an oil-filled housing. The converter cover is bolted to the engine flex-plate, which is bolted directly to the engine crankshaft. The converter pump is, therefore, mechanically connected to the engine and turns at engine speed whenever the engine is operating.

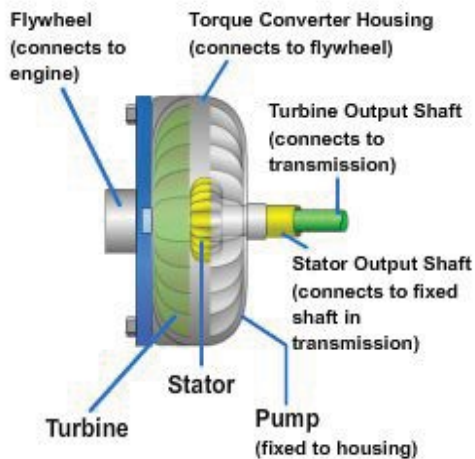


Figure 7-10 - Torque converter.

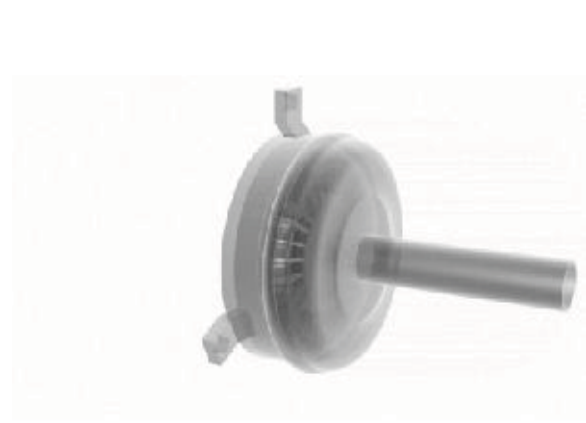


Figure 7-11 - Torque converter operation.

When the engine is running and the converter pump is spinning (*Figure 7-11*), it acts as a centrifugal pump, picking up oil at the center and discharging this oil at its rim between the blades. The shape of the converter pump shells and blades causes this oil to leave the pump, spinning in a clockwise direction toward the blades of the turbine. As the oil strikes the turbine blades, it imparts a force to the turbine, causing it to turn. When the engine is idling and the converter is not spinning fast, the force of the oil is not great enough to turn the turbine with any efficiency. This allows the vehicle to stand in gear with the engine idling. As the throttle is opened and the pump speed is increased, the force of the oil increases and the engine power is more efficiently transmitted to the turbine member and the gear train. After the oil has imparted its force to the turbine, the oil follows the contour of the turbine shell and blades so that it leaves the center section of the turbine spinning counterclockwise.

Because the turbine member has absorbed the force required to reverse the direction of the clockwise spinning of oil, it now has greater force than is being delivered by the

engine. The process of multiplying engine torque through the converter has begun. If the counterclockwise spinning oil was allowed to continue to the section of the pump member, the oil would strike the blades of the pump in a direction that would hinder its rotation and cancel any gains obtained in torque. To prevent this, a stator assembly is added.

The stator is located between the pump and the turbine and is mounted on a one-way or roller clutch, which allows it to rotate clockwise but not counterclockwise. The purpose of the stator is to redirect the oil returning from the turbine and change its direction of rotation back to that of the pump member. The energy of the oil is then used to assist the engine in turning the pump. This increases the force of the oil, driving the turbine, and as a result, multiplying the torque. The force of the oil flowing from the turbine to the blades of the stator tends to rotate the stator counterclockwise, but the one way roller clutch prevents this from happening.

With the engine operating at full throttle, the transmission in gear and the vehicle standing still, the torque converter is capable of multiplying engine torque by approximately 2:1. As turbine and vehicle speed increase, the direction of the oil leaving the turbine changes. The oil flows against the rear side of the stator vanes in a clockwise direction. Since the stator is now impeding the smooth flow of oil, its roller clutch automatically releases, and the stator revolves freely on its shaft. Once the stator becomes inactive, there is no further multiplication of engine torque within the converter. At this point, the converter is merely acting as a fluid coupling as both the converter pump and the turbine are turning at the same speed or at a 1:1 ratio.

2.4.1 Hydraulic System Operation

The hydraulic system has five basic functions:

1. The planetary holding devices are all actuated by hydraulic pressure from hydraulic slave systems.
2. It keeps the torque converter charged with fluid at all times.
3. The shifting pattern is controlled by the hydraulic system by switching hydraulic line pressure to programmed shifting devices according to vehicle speed and load.
4. It circulates the oil through a remote oil cooler to remove excess heat that is generated in the transmission and torque converter.
5. The hydraulic system provides a constant supply of lubricating oil to all critical wearing surfaces of the transmission.

A hydraulic system requires a source of clean hydraulic fluid and a pump to pressurize the fluid. The oil is drawn through the strainer from the transmission sump. The pump drive gear is geared or keyed to the driven member of the torque converter; therefore, whenever the engine is in operation, the pump is functioning. As the pump drive gear rotates, it rotates the pump-driven gear, causing the oil to be lifted from the sump into the oil pump. As the pump gears turn, oil is carried past the crescent section of the pump. Beyond the crescent, the gear teeth begin to come together again, forcing the oil out of the pump and into the hydraulic system under pressure. At this point, the oil is delivered to the pressure control system.

2.4.1 Park, Engine Running

When the shift lever is in park and the engine is running, the pump is turning and therefore supplying pressure to the main pressure regulator. The main regulator consists of the regulator valve and a boost valve. There is a pressure regulator spring installed between the two valves.

Line pressure also passes through the manual valve and the low overrun valve and applies the low and reverse clutch. The low and reverse clutch has no effect when the transmission is in park.

Line pressure is also sent to the actuator fell limit (AFL) valve. The AFL valve limits the amount of pressure in the pressure control, and shift solenoids feed circuits because the excess pressure can damage the solenoids.

AFL oil pressure is also delivered to the shift valves and solenoids. The Electronic Control Module (ECM) energizes both solenoids in park. AFL oil from the accumulator limit valve cannot exit through the solenoids and pushes the shift valves to the left. Since the solenoids are not supplied with drive oil, they cannot apply any holding members.

The main pressure regulator also directs some oil to the torque converter clutch valve. The torque converter clutch valve is in the released position at this time. The oil flows through the release and apply sides of the converter clutch plate, and the converter is unlocked.

2.4.2 Engine Running

In neutral with the engine running, the flow of oil is much like it is when the transmission is in park. AFL oil is sent to the pressure control solenoid and continues to regulate line pressure but has no effect on the shift valves.

In neutral, the manual valve is positioned to cut off the oil flow to the low reverse clutch piston, and no holding members are applied in neutral.

2.4.3 Drive, First Gear

When the transmission is placed in drive with the vehicle not moving, line oil is sent to the forward clutch piston and engages the forward clutch. This oil is called D4 oil. Under normal conditions, the number 12 check ball seals the oil passage, forcing the D4 oil to travel through the smaller orifice next to it. This will engage a smoother, more gentle shift.

If the engine is at a high RPM when shifted into drive, the pressure control solenoid will raise line pressure. This will cause the D4 oil to be higher than normal, opening the forward abuse valve. When this valve is open, D4 oil is sent directly to the forward clutch piston, bypassing the orifice and check ball assembly. The forward abuse valve prevents clutch plate damage by quickly applying the clutch.

D4 oil is also directed to the accumulator valve, which fills and pressurizes the 1-2 and 3-4 accumulators. This oil is also delivered to one of the pressure switches in the pressure switch assembly. This normally open switch closes when it is pressurized to tell the ECM that the transmission is in drive.

2.4.4 Drive, Second Gear

When the ECM decides the transmission is to be shifted into second gear, it de-energizes the 1-2 shift solenoid. Since this solenoid is normally open, oil exits through

the solenoid when it is de-energized. Spring pressure pushes the 1-2 shift valve to the right and allows D4 oil to pass through the valve and applies the 2-4 band servo. This oil pressure, called 2nd oil, applies the band and shifts the transmission into second gear. The number 8 check ball is used to restrict 2nd oil pressure to the servo and cushions the shift. Pressure is also now available at the 3-2 downshift valve.

2.4.5 Drive, Third Gear

The 2-3 shift solenoid is a normally open solenoid, and oil exits through the valve when it is de-energized. AFL oil pushes the 2-3 shift valve and 2-3 shuttle valve to the right. 2nd oil can now pass through the 2-3 shift valve. This oil is now called 3-4 SIG oil after it passes through the 2-3 shift valve. In addition to applying and releasing holding members, 3-4 SIG oil goes to the 3-2 downshift valve, 3-2 control valve, and 3-4 shift valve for later use.

To apply the clutch, the 3-4 SIG oil passes through a check ball and orifice number 4. The number 4 check ball and orifice restricts oil flow to the clutch piston to cushion the shift. This oil is now named 3-4 CL (CL is for clutch) oil after it passes through the number 4 check ball orifice. 3-4 CL oil is also sent to the 3-2 downshift valve and the 3-2 control valve for use during 3-2 downshifts.

With the 3-4 clutch applied by 3-4 CL oil and band released by 3rd ACC oil, the transmission is now in third gear.

2.4.6 ve, Fourth Gear

When enough speed is attained and other sensor inputs are correct, the ECM decides that the transmission should be shifted into fourth gear. The ECM energizes the 1-2 shift solenoid, sealing the exhaust passage in the solenoid. The 2-3 shift solenoid remains de-energized.

With the 1-2 shift solenoid back on, AFL oil pressure can build up on the right side of the 1-2 shift valve through the orifice above the valve. Once through the orifice, the oil is renamed SIG A oil.

The extra oil supplied by the 2-3 shuttle valve assists the spring and keeps the 1-2 shift valve from moving. The AFL oil, renamed the SIG A oil, builds up to its full value and moves the 3-4 shift valve.

With the 3-4 oil shift valve in the upshifted position, 3-4 SIG oil, renamed 4th SIG oil in this circuit only, pushes the 3-4 relay and 4-3 sequence valves to the right. This allows 2nd oil to charge the 3-4 circuit that sends oil to the outer side of the servo. The outer side of the servo is an apply area that helps the 2nd clutch oil overcome release oil and spring pressure and reapply the band. Some 3-4 SIG oil is diverted to the 3-4 accumulator to improve shift feel. This is renamed 3-4 ACC oil.

2.5.0 Automatic Transmission Service

Automatic transmission service can be easily divided into the following three parts: preventive maintenance, troubleshooting, and major overhaul. Before you perform any maintenance or repairs on an automatic transmission, consult the maintenance manual for instructions and proper specifications.

2.5.1 Preventive Maintenance

Normal preventive maintenance includes:

- Checking the transmission fluid daily
- Adjusting the shifting and kickdown linkages
- Adjusting lockup bands
- Changing the transmission fluid and filter at recommended service intervals (Example: 15,000 miles or yearly for heavy or severe service)

2.5.1.1 Checking the Fluid

The operator is responsible for first echelon (operator's) maintenance. The operator should be trained not only to know to look for the proper fluid level, but also to know how to look for discoloration of the fluid and debris on the dipstick.

Fluid levels in automatic transmissions are most commonly checked at operating temperature. This is important to know, since the level of the fluid may vary as much as three quarters of an inch between hot and cold.

The fluid should be either reddish or clear. The color varies due to the type of fluid. (For example, construction equipment using OE-10 will be clear). A burnt smell or brown coloration of the fluid is a sign of overheated oil from extra heavy use or slipping bands or clutch packs. The vehicle should be sent to the shop for further inspection.



Not all transmission fluids are the same. Before you add fluid, check the manufacturer's recommendations first. The use of the wrong fluid will lead to early internal parts failure and costly overhaul.

Overfilling the transmission can result in the fluid foaming and the fluid being driven out through the vent tube. The air that is trapped in the fluid is drawn into the hydraulic system by the pump and distributed to all parts of the transmission. This situation will cause air to be in the transmission in place of fluid and in turn cause slow application and burning of clutch plates and facings. Slippage occurs, heat results, and failure of the transmission follows.

Another possible, but remote, problem is water, indicated by the fluid having a "milky" appearance. A damaged fluid cooling tube in the radiator (automotive) or a damaged oil cooler (construction) could be the problem. The remedy is simple. Pressure-test the suspected components and perform any required repairs. After repairs have been performed, flush and refill the transmission with clean, fresh fluid.

2.5.1.2 Linkage and Band Adjustment

The types of linkages found on an automatic transmission are gearshift selection and throttle kickdown. The system can be a cable or a series of rods and levers. These systems do not normally present a problem, and preventive maintenance usually involves only a visual inspection and lubrication of the pivot points of linkages or the cable. When adjusting these linkages, you should strictly adhere to the manufacturer's specifications.

If an automatic transmission is being used in severe service, the manufacturer may suggest periodic band adjustment, as shown in *Figure 7-12*. Always adjust lockup

bands to the manufacturer's specifications. Adjust the bands by loosening the locknut and tightening down the adjusting screw to a specified value. Back off the band adjusting screw with a specified number of turns and tighten down the locking nut.

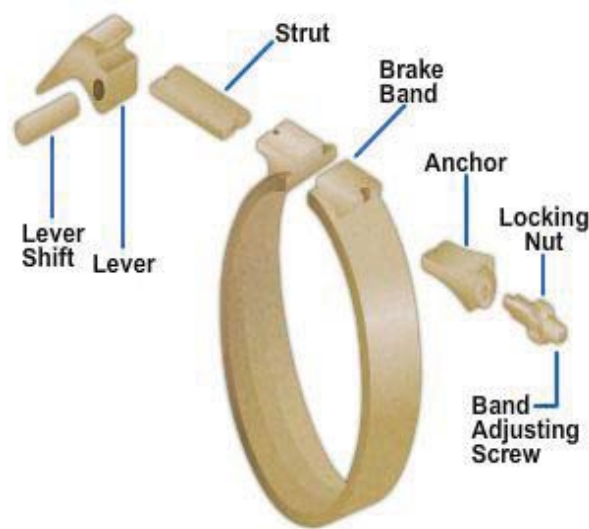


Figure 7-12 - Band adjustment.

NOTE

Not all bands are adjustable. Always check the manufacturer's service manual before any servicing of the transmission.

2.5.1.3 Fluid Replacement

Perform fluid replacement according to the manufacturer's recommendations. These recommendations vary considerably for different makes and models. Before you change automatic transmission fluid, always read the service manual first.

Service intervals depend on the type of use the vehicle receives. In the NCF, because of the operating environment, more than a few of the vehicles are subjected to severe service. Severe service includes the following: hot and dusty conditions, constant stop-and-go driving (taxi service), trailer towing, constant heavy hauling, and around-the-clock operations (contingency). Any CESE operating in these conditions should have its automatic transmission fluid and filter changed on a regular schedule, based on the manufacturer's specifications for severe service. Ensure the vehicle is on level ground or a lift, and let the oil drain into a proper catchment device.

The draining of the transmission can be accomplished in one of the following three ways:

1. Removing the drain plug
2. Loosening the dipstick tube
3. Removing the oil pan



Oil drained from automatic transmissions contains heavy metals and is considered hazardous waste and should be disposed of according to local instructions.

Once the oil is drained, remove the pan completely for cleaning by paying close attention to any debris in the bottom of the pan. The presence of a high amount of metal particles may indicate serious internal problems. Clean the pan, and set it aside.

All automatic transmissions have a filter or screen attached to the valve body. The screen is cleanable, whereas the filter is a disposable type and should always be replaced when removed. Screens and filters are retained in different ways: with retaining screws, with metal retaining clamps, or with O-rings made of neoprene. Clean the screen with solvent and use low-pressure air to blow-dry it. Do not use rags to wipe the screen dry, as they tend to leave lint behind that will be ingested into the hydraulic system of the transmission. If the screen is damaged or is abnormally hard to clean, replace it.

Draining the oil from the pan of the transmission does not remove all of the oil-draining the oil from the torque converter completes the process. To do this, remove the torque converter cover and remove the drain plug, if so equipped. For a torque converter without a drain plug, special draining instructions may be found in the manufacturer's service manual. Before performing this operation, clear it with your shop supervisor.

2.5.1.4 Refilling the Transmission

Reinstall the transmission oil pan, the oil plug, and the fill tube. Fill the transmission with the fluid prescribed by the manufacturer to the proper level. With the brakes applied, start the engine and let it idle for a couple of minutes. Move the gear selector through all gear ranges several times, allowing the fluid to flow through the entire hydraulic system to release any trapped air. Return the selector lever to park or neutral and recheck the fluid level. Bring the fluid to the proper level. Run the vehicle until operating temperature is reached, checking for leaks. Also, recheck the fluid and adjust the level as necessary.



Overfilling an automatic transmission will cause foaming of the fluid. This condition prevents the internal working parts from being properly lubricated, causing slow actuation of the clutches and bands. Eventually, burning of the clutches and bands results. Do **NOT** overfill an automatic transmission.

2.5.2 ng

Good troubleshooting practices save a lot of time and money for the Navy. If you know what you are doing when you troubleshoot an automatic transmission, you should be able to pinpoint the problem before you remove it from the vehicle. In some cases, you may be able to make the repairs without removing the transmission.

Before troubleshooting the transmission, make sure the engine is in good running condition. An engine that is not operating properly will not allow the transmission to function normally.

NOTE

A malfunction may have more than one probable cause. Complete all the tests and inspections for each cause to find the correct cause.

Keep in mind that it is impossible to list each and every malfunction and its possible corrective action in this training manual. Below is a seven-step process that will enable you to quickly isolate some problems.

2.5.2.1 Determine the Exact Nature of the Complaint

The first step when troubleshooting a transmission problem is to verify the problem. Begin by asking the operator to describe what the vehicle is doing. Remember that the operator may not be a mechanic so they might misinterpret the symptoms.

Now it is time to check the fluid level and road test the equipment. Once you have determined what the problem is, proceed to the next step.

2.5.2.2 Check for Obvious Causes

Check the simple things first. You have already checked for appropriate fluid levels. Also check to see if the transmission is overheating, or if the fluid is burnt.

If there is a shifting problem, check to see if the linkage is bent, broken, or out of adjustment. Check for loose electrical connectors. Check to see if the vacuum modulator has become disconnected.

If you are checking an electronically controlled transmission, see if you can get a trouble code from the ECM.

2.5.2.3 Determine Which Component is the Most Probable Cause

Using your knowledge of transmissions, determine if the problem is due to the mechanical system, the hydraulic system, or the electrical system.

2.5.2.4 Perform Pinpoint Tests

This step takes the most time. You need to check each system and look at the major parts involved. Start with the easiest tests first, then move on from there. Once you have discovered the problem, you can go on to the next step.

2.5.2.5 Check for Related Problems

At this point, you want to review what the problem was and determine if this is a stand alone problem or if it has evolved because of something else that is wrong.

If your testing causes you to come back to the same problem as above, you have more than likely discovered the problem.

2.5.2.6 Correct the Defect

In this step, you will need to make the necessary repairs to the transmission.

2.5.2.7 Recheck System Operation

In this step, you will need to recheck the transmission. Give it another road test. Be sure to fully evaluate the transmission and be sure to pay attention to what you fixed to make sure that the problem no longer exists.

2.5.3 verhaul

Because of the complexity of automatic transmissions, the need for special tools, and personnel skills, in overhauling these major components is usually done at a Construction Equipment Department located at a Construction Battalion Center. Overhaul of automatic transmissions is not a job for an inexperienced person. If the job must be performed in the field, it is recommended that only a highly capable mechanic be assigned to this type of work.

NOTE

Before proceeding with automatic transmission disassembly or reassembly, get the applicable repair instructions and have them on hand. **Read this information carefully and completely!** Incorrect disassembly procedures can lead to severe parts damage, causing unnecessary equipment downtime.

Have a workplace away from the main CM shop. A dust-free air-conditioned room is the best, but this is not always available. Obtain the cleanest work space possible! Have on hand any special tools needed for the job, such as snap ring pliers, torque wrenches, or special pullers. It is also a good idea to have an air compressor available for test purposes and for blowdrying individual parts. The steps listed below are common procedures listed for a generic automatic transmission and may not follow the type you are working on.

⚠ CAUTION ⚠

Compressed air used for cleaning purposes should not exceed 30 psi. Wear goggles and other appropriate protective equipment when you use compressed air.

1. Clean the outside of the transmission and drain out as much fluid as possible.
2. Remove the torque converter and set it aside for separate cleaning and testing.
3. Check the input (*Figure 7-13*) and output (*Figure 7-14*) shaft endplay. This should be checked before disassembly and after reassembly. Record the endplay readings for later reference.

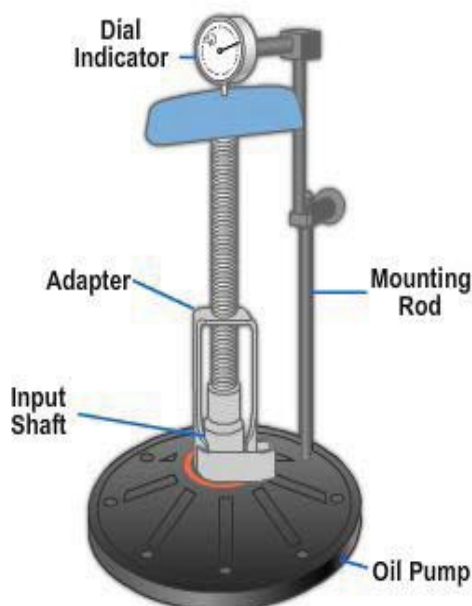


Figure 7-13 – Checking input shaft endplay.

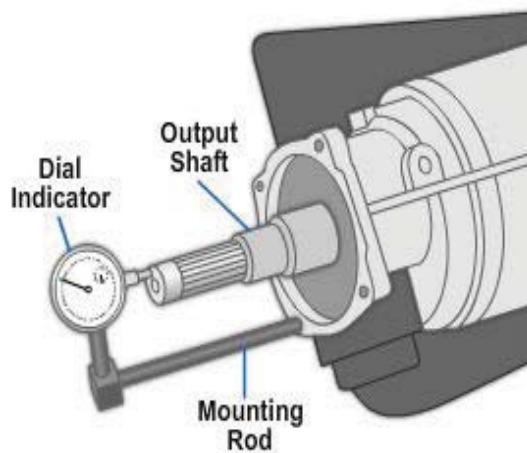


Figure 7-14 – Checking output shaft endplay.

4. Place the transmission on the workbench (*Figure 7-15*) and remove the oil pan and oil filter.

NOTE

The type of debris found in the bottom of the oil pan is indicative of the type of internal damage you may find in the transmission.

5. Remove the bolts holding the valve body to the transmission. As you lift off the valve body, note the position of all valve body parts, springs, oil feed tubes, linkage attachments, and check balls.
6. Remove the vacuum modulator, push rod, and throttle valve from the case at this time.
7. Remove the bolts holding the extension housing to the case. Extension housings are sometimes called tailshaft housings. The extension housing should pull off over the output shaft after the bolts are removed.
8. Remove the governor. This step only applies to governors mounted on the output shaft.
9. Remove the front oil pump oil seal (*Figure 7-16*). It is generally easier to remove the seal before the oil pump is removed (*Figure 7-17*) because the extra weight of the transmission assembly allows you to use the slide hammer more efficiently. You should always replace the seal when the pump is serviced.

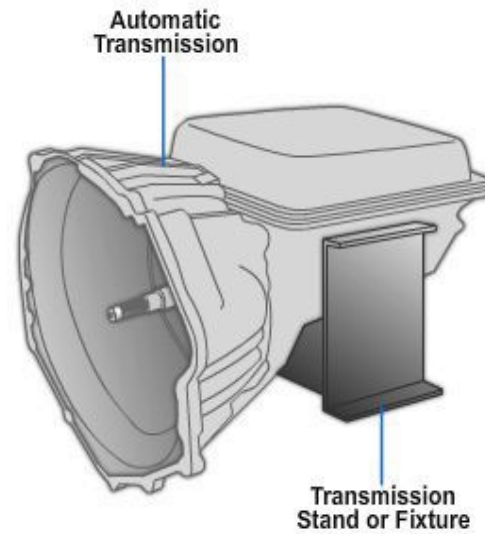


Figure 7-15 – Transmission in a cradle.

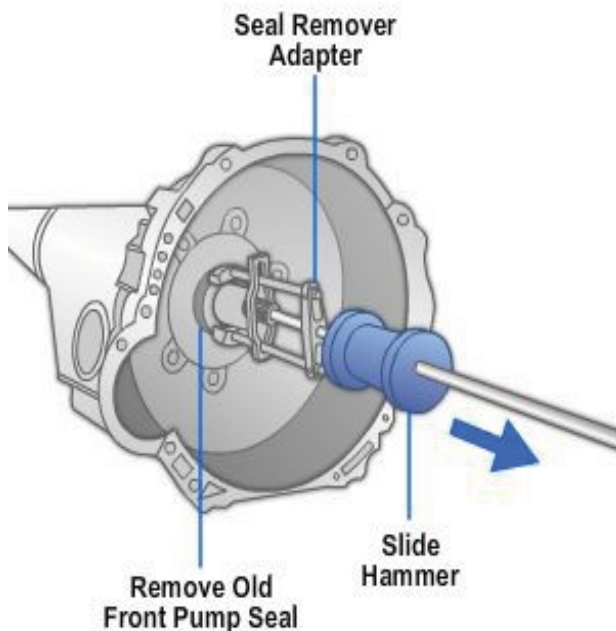


Figure 7-16 – Removing oil pump seal.

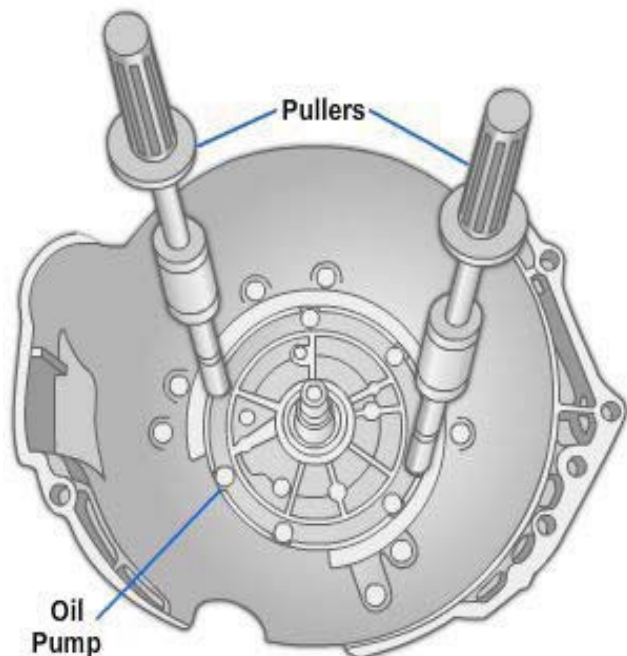


Figure 7-17 – Removing oil pump.

10. Remove the oil pump. Some manufacturers recommend removing the input shaft before removing the oil pump. However, some transmissions are constructed so that the input shaft is pressed into the front clutch drum.

Now that the external parts have been removed you can start removing the internal components, such as the input shaft, bands, clutch packs, planetary gearsets, and output shaft.

11. Loosen the front band adjuster, slide the band out of the way, remove the forward clutch packs, front planetary gearset, and input shell as an assembly.

NOTE

Be sure to save all thrust washers, as they come out with these parts.

12. Remove the rear gearsets through the front of the case. The output shaft will usually come out through the rear of the case.

NOTE

Some clutch packs are held in place by a snap ring, located on the sun gear inside the input shell. This snap ring must be removed before the clutch pack and other internal parts can be removed.

13. Some transmissions have a center support (Figure 7-18). It may be retained by one or two case bolts located either inside or outside the case. These must be removed before you can remove the center support and the rear clutches and gearsets.

14. Remove any servos, accumulators, clutch apply pistons, and governors.

NOTE

Many servos and accumulators are under strong spring pressure. Always consult the service manual before removing any retaining bolts or rings.

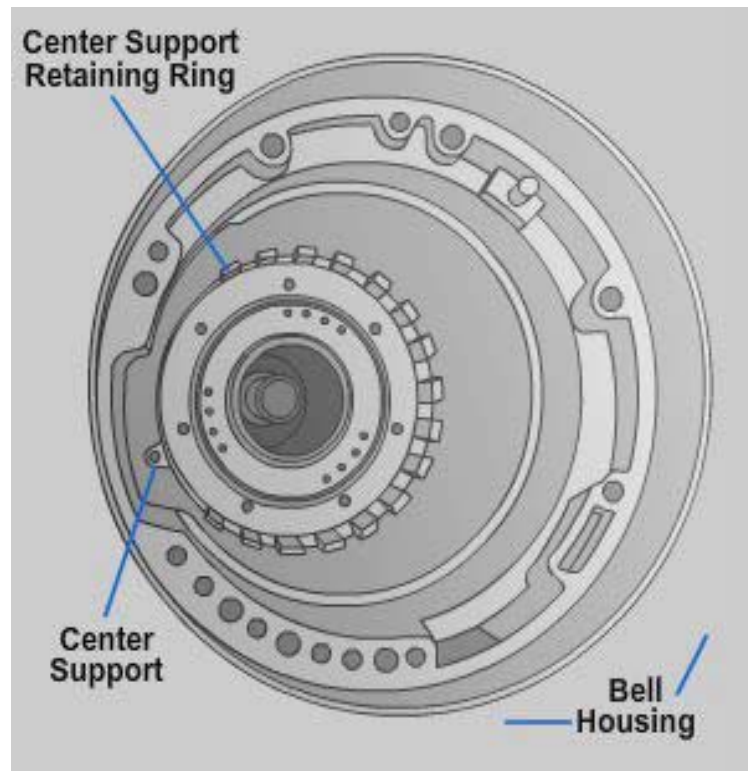


Figure 7-18 - Transmission center support.

With the major components removed, the transmission case is ready to be thoroughly cleaned out and inspected for wear or damage.

All assemblies that have been removed from the transmission should be disassembled, inspected, and rebuilt to the manufacturer's specifications. Always replace seals and gaskets before reassembly. Look for any worn thrust washers and replace them as required.

Check the condition and proper operation of all vacuum or electronic devices connected to the unit. The automotive type of torque converter is usually a welded unit and can

only be flushed out, usually with solvent, and pressure tested. If this type of torque converter proves to be the problem, replace it. Because of size and expense, construction equipment torque converters are made to be disassembled and repaired.

Remember, the instructions for disassembly given here are for description only; they do not apply to any one type of transmission. The information is only to give you an idea of the complexities involved in automatic transmission overhaul, not to make you an expert in this field. Be sure to check the transmission serial numbers to ensure you are getting the correct overhaul parts.

Aside from size and weight, construction equipment automatic transmissions are the same in many respects as automotive automatic transmissions and only specific instructions for that particular unit will be different. For these "specific" instructions, go to your technical library and check out the correct repair manual.

Test your Knowledge (Select the Correct Response)

2. The automatic transmission of a vehicle matches power and speed to what factor?
 - A. RPM
 - B. Maximum torque
 - C. Load requirements
 - D. Minimum torque required

Summary

In this chapter, you learned how to troubleshoot problems with the clutch systems and how the automatic transmission works. In addition you learned preventive maintenance on the automatic transmission, how to troubleshoot it, and basic guidelines on how to overhaul it. The power flow to the drive wheels is something a construction mechanic needs to understand to enable you to properly troubleshoot and diagnose equipment. When you have mastered the knowledge of these systems, you will become a better CM.

Review Questions (Select the Correct Response)

1. The pressure plate of a clutch assembly is held tightly against the flywheel by what means?
 - A. Spring pressure
 - B. Hydraulic pressure
 - C. Inertia
 - D. Lever links
2. A flexible cable clutch release mechanism is most commonly used with what type of equipment?
 - A. Construction
 - B. Automotive
 - C. Allied
 - D. MHE
3. Which of the following symptoms is common to clutch malfunction?
 - A. Dragging
 - B. Slipping
 - C. Noise
 - D. Each of the above
4. Clutch slippage is most noticeable during which of the following conditions?
 - A. When the vehicle is cold
 - B. When the vehicle is hot
 - C. When the vehicle is heavily loaded
 - D. When the vehicle is traveling at high speeds
5. When you notice insufficient clutch pedal free travel, you should check which of the following items?
 - A. The linkage for proper adjustment
 - B. The release bearing for wear or dryness
 - C. The friction disc facing for normal surface condition
 - D. The pilot bearing for unusual wear
6. Which of the following practices is recommended to correct a stiff clutch pedal?
 - A. Oiling the disc facings
 - B. Riding the clutch
 - C. Lubricating the clutch linkage
 - D. Adjusting free travel of the pedal

7. When the clutch is being uncoupled, a series of slight movements (pulsations) can be felt on the clutch pedal. The trouble indicated may be caused by which of the following conditions?
- A. A warped pressure plate or warped clutch disc
 - B. The flywheel not being seated on the crankshaft flange
 - C. Misalignment of the engine and transmission
 - D. Each of the above
8. In automatic transmissions, gears are designed so that several teeth are in contact with one another at one time. This design is used for which of the following reasons?
- A. To provide greater strength
 - B. To provide greater gear reduction
 - C. To reduce gear clash
 - D. To increase torque
9. When torque is increased during the operation of a planetary transmission, what will happen to the output speed?
- A. It will remain the same.
 - B. It will increase.
 - C. It will decrease.
10. Your holding the sun gear stationary and applying power to the internal gear in a clockwise direction will produce what result in gearing?
- A. Overdrive
 - B. Reverse
 - C. Direct drive
 - D. Reduction
11. What results when two members of a planetary gearset rotate together?
- A. Reverse
 - B. Low gearing
 - C. High gearing
 - D. Direct drive
12. What means or device within the torque converter allows for shifting without interruption of engine torque application?
- A. The turbine
 - B. The fluid coupling
 - C. The stator
 - D. The impeller

13. In an automotive application, the converter cover is normally attached to the engine by what means?
- A. Bolted to a slotted drive
 - B. Bolted to a flex-plate
 - C. Bolted to a flywheel ring
 - D. Bolted to a clutch plate
14. **(True or False)** When the engine is running, the converter pump is operational.
- A. True
 - B. False
15. In addition to giving off a burnt smell, overheated transmission fluid will turn what color?
- A. Brown
 - B. Black
 - C. Red
 - D. Milky
16. Air trapped in the hydraulic system of an automatic transmission will cause which of the following problems?
- A. Hardshifting
 - B. High-line pressure
 - C. Slow application of the clutch packs
 - D. Low-torque output
17. Water mixed with automatic transmission fluid will turn the fluid what color?
- A. Brown
 - B. Milky
 - C. Pink
 - D. Clear
18. **(True or False)** Rags are an acceptable item to dry a screen in an automatic transmission.
- A. True
 - B. False
19. Which of the following methods should you use to remove air trapped in a transmission hydraulic system?
- A. Road test the vehicle and recheck the fluid upon return
 - B. Moving the gear selector through all positions several times with the engine running and the brakes applied
 - C. Letting the unit sit for 10 minutes while the fluid settles
 - D. Keep adding fluid until all air bubbles are removed

20. What would most likely cause the fluid in an automatic transmission to foam?
- A. Underfilling
 - B. Wrong fluid
 - C. Overfilling
 - D. Freezing temperatures
21. During overhaul, the incorrect disassembly of an automatic transmission may cause what result?
- A. Minor parts damage only
 - B. Severe parts damage only
 - C. Unnecessary equipment down time only
 - D. Severe parts damage and unnecessary equipment down time
22. During an automatic transmission overhaul, an air compressor is used for which of the following purposes?
- A. To conduct tests
 - B. To blow-dry parts
 - C. Both A and B
 - D. To disassemble clutch packs
23. When you disassemble an automatic transmission, you must remove what component before removing the valve body?
- A. The control valve spacer
 - B. The vacuum modulator
 - C. The rear servo
 - D. The oil pan

Trade Terms Introduced in this Chapter

Coupling

To join the engine with the transmission

Uncouple

To separate the engine and transmission

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.

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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Chapter 8

Troubleshooting Transmissions, Transfer Cases, and Differentials

Topics

- 1.0.0 The Standard Transmission
- 2.0.0 Troubleshooting Transfer Cases
- 3.0.0 Troubleshooting the Power Takeoff
- 4.0.0 Troubleshooting the Propeller Shaft Assembly
- 5.0.0 Troubleshooting the Differentials

To hear audio, click on the box. 

Overview

This chapter covers the troubleshooting and overhaul of the systems and assemblies of the drivetrain, to include the transmission, transfer case, power takeoff, propeller shaft assembly, and differential. The information is intended as a general guide since there are a number of different models for all the assemblies presented, but it will provide you enough background information for troubleshooting and overhaul for each assembly.

The first topic is troubleshooting the standard or manual transmission. Although standard transmissions are not as common as they once were, even in military vehicles, the construction mechanic still must be accomplished in the troubleshooting and overhaul of the standard transmission.

The next topic covers the transfer case, which is found on a great number of military type vehicles. It can be said it is as common as the transmission since there are so many 4x4 or 6x6 vehicles. Troubleshooting the power takeoff is another topic. The power takeoff is what allows a dump truck to dump, a fuel truck to dispense fuel, a transit mixer to mix cement, and a wrecker to lift its load.

The topic of troubleshooting propeller shafts is an extensive one, covering driveline geometry, inspection, lubrication, U-joint replacement and lubrication analysis, yoke inspection, U-joint reassembly, driveshaft installation, chassis vibration diagnosis and PTO driveshafts.

The last topic covered is troubleshooting differentials, which provides a wide range of exposure to the components of the differential. The drivetrain is the last bastion for a mechanic to be a mechanic, with its gears, yokes, bushings, universal joints, splines, etc.

Objectives

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

1. Understand how to troubleshoot and overhaul the standard transmission.
2. Understand how to troubleshoot transfer cases.
3. Understand how to troubleshoot the power takeoff.
4. Understand how to troubleshoot the propeller shaft assembly.
5. Understand how to troubleshoot differentials.

Prerequisites

None

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

Air Conditioning Systems		C
Air Compressor Overhaul		M
Inspecting and Troubleshooting Brake Systems		
Hydraulic Systems		A
Wheel and Track Alignment		D
Troubleshooting Transmissions, Transfer Cases, and Differentials		V
Clutches and Automatic Transmissions		A
Troubleshooting Electrical Systems		N
Fuel System Overhaul		C
Engine Troubleshooting and Overhaul		E
The Shop Inspectors		D
Alfa Company Shop Supervisor		
Public Works Shop Supervisor		

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 an italicized instruction 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 THE STANDARD TRANSMISSION

1.1.1 Troubleshooting Transmissions

To isolate the root cause of any transmission problem, you have to follow a troubleshooting procedure. Begin by discussing the problem and its symptoms with the driver/operator. Check any information you can get from the driver/operator with the vehicle history jacket.

Visually inspect the transmission. Look for obvious problems such as broken transmission mounts, fittings, or brackets, and signs of leakage. Check the air system for leaks. Road test the vehicle whenever possible. Mechanics usually get second- or third-hand reports of trouble experienced with the unit, and these reports do not always accurately describe the actual conditions. Sometimes symptoms may point toward a transmission problem but the true problem is actually elsewhere in the drivetrain, such as the axle, propeller shaft, U-joint, engine, or clutch. This can be especially true of complaints of noise and vibration. Road testing the unit yourself reduces the importance of secondhand reports on performance from the drivers. Riding with the driver can also be informative, but if the mechanic drives, the road test can be more effective.

Troubleshooting should always begin with information gathering. Next, you will have to analyze the information and attempt to identify a root cause. Nothing is more helpful than experience with troubleshooting and knowledge.

Noisy Operation

This complaint is common and can be caused by so many different things that you should begin with a road test. Noise has a way of reverberating through the drivetrain, so let us begin with some non-transmission noise.

- Engine fan out of balance or blades bent
- Defective vibration damper
- Crankshaft out of balance
- Flywheel out of balance
- Flywheel mounting bolts
- Engine rough at idle, producing rattle in gear train
- Clutch assembly out of balance
- Engine mounts loose and broken
- Power takeoff engaged
- U-joints out of phase or at excessive working angle
- Hanger bearings in driveline dry or out of alignment
- Wheels out of balance
- Tire treads humming or vibrating at certain speeds
- Flywheel housing not concentric

It is your responsibility as a mechanic to determine the cause, so it is really important that you do not jump to conclusions based on the driver's/ operator's complaint. First determine the source of the noise. Next, if you are sure it is coming from the

transmission, attempt to define the nature of the noise. Be aware of the exact conditions that produce the noise.

Growling. Low frequency noises such as growling, humming, or a grinding sound are usually caused by worn, chipped, rough, or cracked gears. Once the symptoms are first noted, as gears continue to wear, a growling/grinding noise becomes more noticeable, usually in gear positions that throw the most load on the worn or damaged gears. Growling can also be caused by improper timing of the transmission during reassembly, or improper timing due to a gear turning on the counter shaft.

Thumping or knocking. A thumping or knocking noise can begin as growling. As bearings wear and retainers start to break up, a thumping or knocking noise can be produced. This noise is heard at a low shaft speeds in any gear position. Irregularities on gear teeth such as cracks, bumps, and swells can also cause thumping or knocking. Bumps or swells can be identified as highly polished spots on the face of the gear tooth, and these are often caused by rough handling during assembly (*Figure 8-1*). In most housings, the noise produced will be more prominent when the gear is loaded, making it easier to identify the problem gear. At high speeds a knocking or thumping noise can turn into a howl.

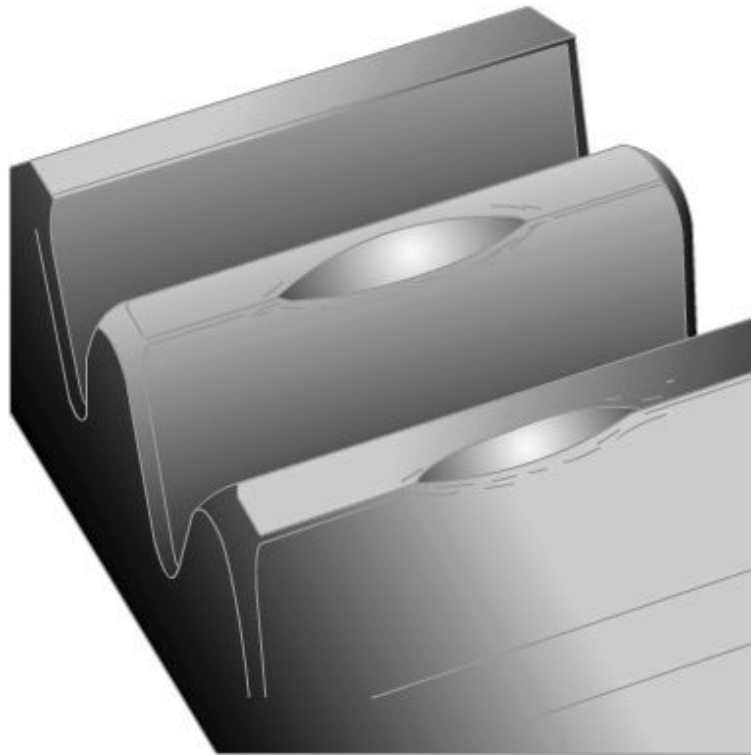


Figure 8-1 – Bumps or swells on the gear teeth caused by improper handling.

Rattles. Metallic rattles within the transmission result from a variety of conditions. Engine torsional vibrations are transmitted to the transmission through the clutch. In heavy-duty equipment featuring clutch discs without vibration dampers, rattles may result that are most noticeable in neutral. In general, engine speeds should be 600 rpm or above to eliminate rattle and vibrations noticeable during idle. A cylinder misfire could cause an irregular or lower idle speed, producing a rattle in the transmission. Another cause of rattles is excessive backlash in the PTO unit mounting.

Vibration. Drivetrain vibrations can be very difficult to source. Never forget that they can be produced by any component in the drivetrain, so your troubleshooting must involve everything from the engine to the drive wheel assemblies. Most driveline vibrations are produced only at a specific road speed or in a specific gear; these clues can help to determine whether the cause is in the transmission or elsewhere.

If you have isolated the cause of the vibration to the transmission, first note the speeds at which it is most prominent. Use what you know of the transmission to make your diagnosis. Remember that the input shaft rotates at engine speed when the clutch is engaged, and the output shaft rotates at driveshaft speed. Make a note of the gear the vibration occurs at, and note whether it occurs only in high range or only in low. Make

sure that you have some evidence that the cause is in the transmission before removing it from the chassis.

Whining. Gear whine is usually caused by insufficient backlash between mating gears, such as improper shimming of a PTO. A high-pitched whine or squeal can also be caused by mismatched gear sets. Such gear sets are identified by an uneven wear pattern on the face of the gear teeth. Pinched bearings with insufficient axial or radial clearance can also produce a whine.

Noise in neutral. Possible causes of noise while the transmission is in neutral include:

- Misalignment of transmission
- Worn or seized flywheel pilot bearing
- Worn or scored countershaft bearings
- Worn or rough reverse idler gear
- Sprung or worn countershaft
- Excessive backlash in gears
- Worn mainshaft pilot bearing
- Scuffed gear tooth contact surface
- Insufficient lubrication
- Use of incorrect grade of lubricant

Noise in gear. Possible causes of noise while the transmission is in gear include:

- Worn or damaged mainshaft rear bearing
- Rough, chipped, or tapered sliding gear teeth
- Noisy speedometer gears
- Excessive end play of mainshaft gears
- Most of the conditions that can cause noise in neutral

Difficult to shift. Difficult to shift is a condition that occurs when the shift lever is difficult to move from gear to gear. In some instances, only one gear is hard to select; in others, all shifting may be difficult.

The usual causes of hard shifting are bent or worn shift linkage and linkage in need of lubrication. Hard shifting may also be caused by binding of the shift rails or forks. Occasionally, hard shifting may be caused by a misaligned transmission case or a problem in the clutch.

Hard shifting can be diagnosed easily. If the gearshift lever is hard to move even when the engine is stopped, the shift linkage is probably the source of the problem. If the gearshift lever moves easily when the engine is stopped but shifting becomes hard with the engine running, the problem is probably in the vehicle clutch, or else the case is misaligned.

In transmissions having an external shift linkage, hard shifting may be corrected by adjusting or lubricating shift linkages. In contrast, if internal parts of a shift linkage are bent or sticking, the transmission must be removed and disassembled to make repairs. Bad synchronizers, which can be responsible for hard shifting, or clutch problems will require transmission removal. Misalignment problems may require transmission

removal; however, if the case is misaligned because of dirt or other foreign material, it may be possible to clean and realign it without removal.

Jumps out of gear. When a transmission jumps out of gear, the shift lever "pops," or moves into neutral during operation.

First, check the transmission linkage and shift lever arms. If the shift assembly is badly worn, it should be rebuilt or replaced.

A worn clutch pilot bearing may also cause the transmission to jump out of gear. Severe vibration, caused by the wobbling transmission input shaft, can wiggle and move the shift forks and synchronizers.

Other problems inside the transmission can cause it to jump out of gear. They include worn synchronizer inserts and springs, worn shift fork assemblies or shift rails, and wear and excessive play in the countershaft and output shaft assemblies.

Locked in gear. When the shifter is locked in one gear, check the transmission shifter assembly and linkage. Look for bent shift rods, worn linkage, bushings, and shifter arms. Also check linkage adjustment. With a shift rail mechanism, worn or damaged rails, detents, or forks could be the cause.

A transmission can also become locked in gear when drive gear teeth are broken. The teeth can jam together and be locked by bits of metal from chipped teeth.

Diagnosis chart. Refer to the quick reference diagnosis chart (*Figure 8-2*).

Manual Transmission Quick Reference Diagnosis Chart		
Condition	Possible cause	Correction
Leaks lubricant	- Cover loose - Cover gasket loose or defective - Front bearing retainer loose, broken, or gasket defective - Front bearing retainer seal defective - Output shaft seal worn - Countershaft lose in case - Lubricant level too high - Shaft expansion plugs loose in case - No sealer on bolt threads - Damaged shifter shaft seal - Vent plugged - Wrong lubricant - Cracked case or extension housing - Drain or filler plug loose	- Tighten cover - Tighten cover and/or replace gasket - Tighten retainer, replace gasket or retainer - Replace seal - Replace seal - Replace case - Drain to level of filler plug - Replace plugs. Use sealer - Seal threads - Replace seal - Open vent - Drain and refill with recommended lubricant - Replace case or housing - Tighten plug
Shifts hard	- Excessive clutch pedal free travel - Worn or defective clutch - Failure to fully depress clutch pedal when shifting - Shift cover loose - Shift fork, shafts lever, or detents worn loose - Improper shift linkage adjustment - Linkage needs lubricant - Linkage binding, bent, or loose - Wrong transmission lubricant - Insufficient lubricant - Excess amount of lubricant - Transmission misaligned - Front bearing retainer loose or cracked - Synchronizer worn, damaged, or improperly assembled	- Adjust free travel - Replace worn parts - Instruct driver - Tighten cover - Tighten or replace - Adjust linkage - Lubricate - Free, straighten, or tighten as needed - Drain and fill with recommended lubricant - Add lubricant to filler plug level - Drain to level of filler plug - Correct alignment - Tighten or replace retainer - Replace or reassemble synchronizer
Slips or jumps out of gear	- Transmission loose or misaligned - Clutch housing loose or misaligned - Shift linkage improperly adjusted - Shift rail detents worn or detent springs weak - Synchronizer clutch sleeve teeth worn - Loose shifter cover - Shift fork, shaft, or levers worn - Worn teeth on main drive gear or other gears - Worn countershaft gear assembly bearings and/or thrust washers - Worn reverse idler gear assembly bushing or bearings - Worn output shaft pilot bearing - Front bearing retainer loose - Other parts striking shift linkage - Worn input or output shaft bearings - Worn input shaft bushing in flywheel - Bent output shaft	- Tighten and/or align - Tighten and/or align - Adjust linkage - Replace detents and/or springs - Replace synchronizer - Tighten cover - Replace worn part - Replace input shaft or gears - Replace countershaft gear bearings and washings - Replace gear, bearings, and shaft - Replace rollers, replace shafts if necessary - Tighten retainer - Make adjustments to provide clearance - Replace bearings - Replacing bushing or bearing - Replace shaft
Gear clash during downshifting	- Synchronizer worn, damaged, improperly assembled - Shifting too fast (ramming into lower gear) - Shifting to a lower gear when road speed is excessive - Clutch not releasing properly - Excessive output shaft endplay	- synchronizer - Force into gear with a smooth, slower shift - Slow down to appropriate speed before shifting - Adjust or repair as needed - Adjust endplay
Gear clash shifting from Neutral to Reverse	- Insufficient clutch pedal free travel - Worn lubricant - Engine rpm too high - Driver not waiting long enough after depressing clutch - Sticking clutch pilot bearing	- Adjust free travel - Drain and fill with correct lubricant - Set to correct idle rpm - Instruct driver - Replace pilot bearing

Figure 8-2 - Transmission quick reference diagnosis chart.

Transmission noisy in Neutral	1. Worn or damaged front bearing 2. Worn or damaged gears 3. Lack of lubrication 4. Countershaft gear assembly bearings worn or damaged 5. Output shaft pilot bearing worn or damaged 6. Countershaft gear antilash plate worn or damaged 7. Lubricant contaminated with broken bits of gears, bearings, or other parts	1. Replace bearing 2. Replace gears 3. Fill to filler plug 4. Replace bearings, countershaft gear, and countershaft 5. Replace all rollers 6. Replace plate or countergear as required 7. Disassemble, clean and repair transmission
Transmission noisy in direct drive	1. Defective front (input shaft) bearing 2. Defective output shaft bearing 3. Defective synchronizer assembly 4. Defective speedometer gears	1. Replace bearing 2. Replace bearing 3. Replace damaged parts 4. Replace damaged parts
Transmission noisy in reduction gears	1. Defective countershaft bearings 2. Defective synchronizer assembly 3. Counter gear or bushings worn, loose	1. Replace bearings 2. Replace damaged parts 3. Replace damaged parts
Transmission noisy in overdrive gears	1. Defective countershaft bearings 2. Defective synchronizer assembly 3. Counter gear or bushings worn, loose	1. Replace bearings 2. Replace damaged parts 3. Replace damaged parts
Transmission noisy in reverse	1. Defective reverse idler gear 2. Defective countershaft bearings 3. Defective reverse synchronizer 4. Counter gear or bushings worn, loose	1. Replace gear 2. Replace bearings 3. Replace damaged parts 4. Replace damaged parts
Transmission noisy in all gears	1. Insufficient lubrication 2. Worn or damaged bearings 3. Worn or damaged gears 4. Wrong lubricant 5. Excessive synchronizer wear 6. Defective speedometer gears 7. Transmission misaligned 8. Excessive input or output shaft and/or countershaft gear endplay 9. Contaminated lubricant	1. Fill to filler plug 2. Replace bearings 3. Replace gears 4. Drain and fill with recommended lubricant 5. Replace synchronizer 6. Replace gears 7. Correct alignment 8. Adjust endplay 9. Disassemble, clean, and repair transmission

Figure 8-2 - Transmission quick reference diagnosis chart (cont).

1.1.1 Inspecting the Transmission

A good preventive maintenance program can help avoid failures, minimize vehicle down time, and reduce the cost of repairs. Often the transmission failure can be traced directly or indirectly to poor maintenance.

Daily Inspections. Many of the practices listed here are part of the driver/operator pre-trip inspection:

- **Air tanks.** Drain air tanks to remove water or oil. To be sure of removing all liquid contaminants from an air tank, the drain cock must be fully opened and all air discharged. Most of the liquid will drain from the tank after the air has been bled.
- **Oil leaks.** Visually check for oil leaks around bearing covers, PTO covers, and other machined surfaces. Check for oil leakage on the ground before starting the truck each morning.
- **Shifting performance.** Report any shifting performance problems such as hard shift or jumping out of gear.

A Inspection. The following should be checked at each A or lube inspection.

- **Fluid level.** Remove filler plug(s) and check lubricant level. Top off if necessary and tighten plugs securely.
- **Fasteners and gaskets.** Use a wrench to check the torque on bolts and plugs, paying special attention to those on PTO covers/flanges and the rear bearing cover assembly. Look for oil leakage at all gasket mating surfaces.

- **Output yoke seal.** Check for leaks around the seal, especially if the transmission has recently been serviced or rebuilt.

B Inspection. Figure 8-3 identifies key areas of a transmission that should be routinely checked during B inspection.

- **Air control system.** (1) Check for leaks, worn hoses and air lines, loose connections, and loose fasteners.
- **Bell/clutch housing mounting flange.** (2) Check fastener torque.
- **Clutch shaft yoke bushings.** (4) If the clutch shaft bushings are equipped with zerk fittings, grease them lightly. Pry upward on the shaft to check for wear. If excessive movement is found, remove the clutch release mechanism and check for worn bushings.
- **COE remote shift linkage.** Check the linkage U-joints for wear and binding. Lubricate the U-joints. Check any bushings in the linkage for wear.
- **Air filter.** Check and clean or replace the air filter element.
- **Transmission output yoke.** (10) Uncouple the U-joint and check the flange nut for proper torque. Tighten if necessary.
- **Output shaft assembly.** (11) Pry upward on the output shaft to check radial play in the mainshaft rear bearing. Check the splines on the output shaft (12) for wear from movement and chucking action of the U-joint yokes.

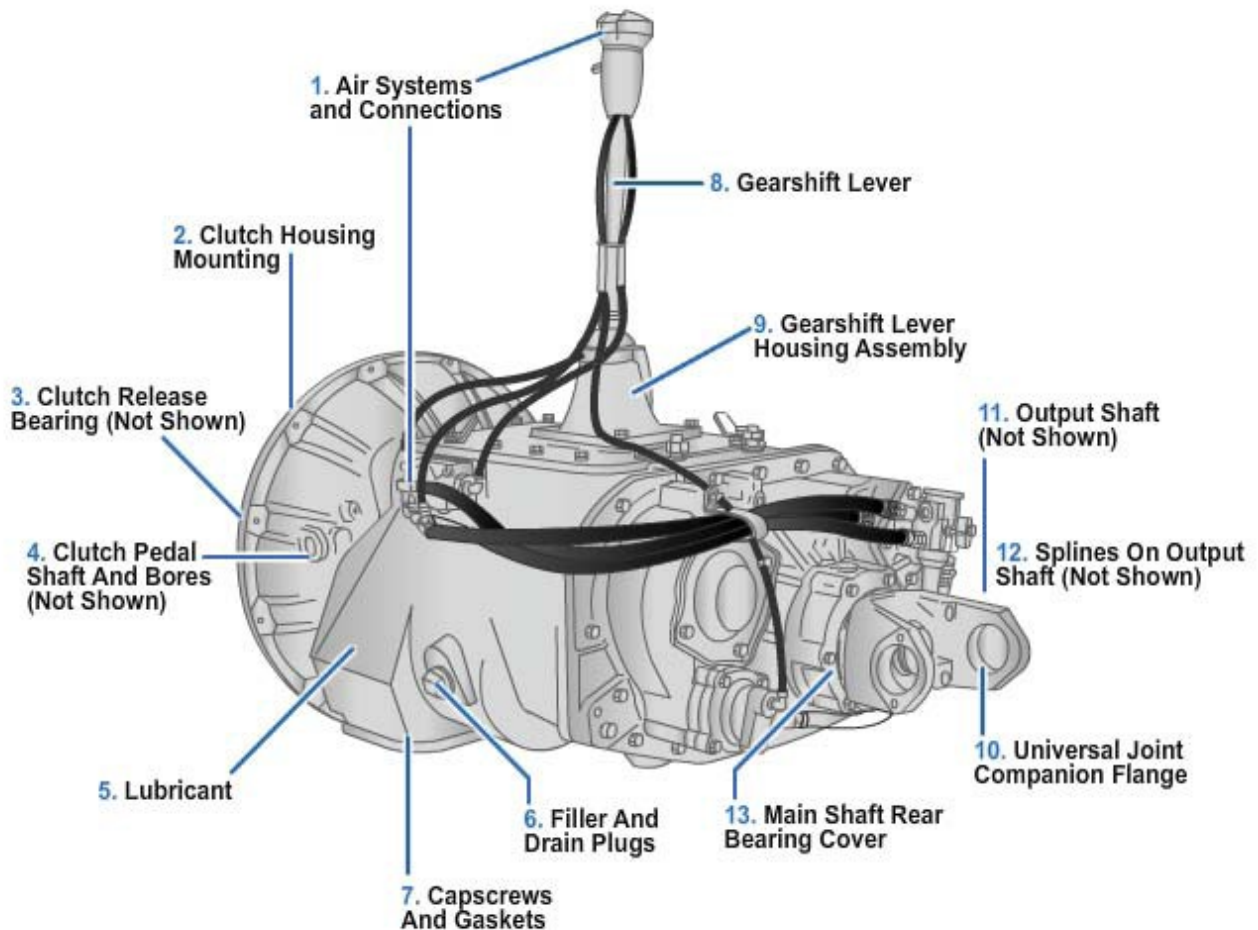


Figure 8-3 - Inspection points on standard transmission.

C Inspection.

- **Check lubricant change interval.** This means checking the type of lubricant used in the transmission. Remember that many synthetic lubes are performance rated for oil change intervals upward to 500,000 miles, so it is wasteful to change them more frequently. If an oil change is required, drain and refill the transmission with the specified oil. Transmission oil analysis can be used to establish more precise oil change intervals that are better suited to the actual operating condition of the vehicle.
- **Gearshift lever. (8)** Check for bending and free play in the lower housing. A lever that is excessively loose indicates wear.
- **Shift tower assembly. (9)** Remove the air lines at the slave valve and remove the shift tower from the transmission. Check the tension spring and washer for wear and loss tension. Check the gearshift lever spade pin/shaft finger for wear. Also take a look at all critical contact points.

1.1.2 Cause of Leaking Lubricants

Oil leakage in standard transmissions is not common, but when leaks occur the rear transmission seal is a common offender (*Figure 8-4*). A leaking rear main seal can lead to complete transmission failure, so it must be repaired. It can be difficult to source oil leaks on transmissions, however, so be sure to identify the leak path before disassembling any components. You can use a checklist such as the following to help you identify the source of oil leaks, but it is most important before beginning to pressure wash the transmission, removing all evidence of oil leaks. Take care not to directly aim the pressure hose into the rear main seal.

Rather, use a wiper to clean up this area. Next, run the vehicle. It

can really help to run a vehicle on a chassis dynamometer when attempting to locate hard-to-find leaks, because leaking oil is not smeared all over the transmission housing by the air flow.

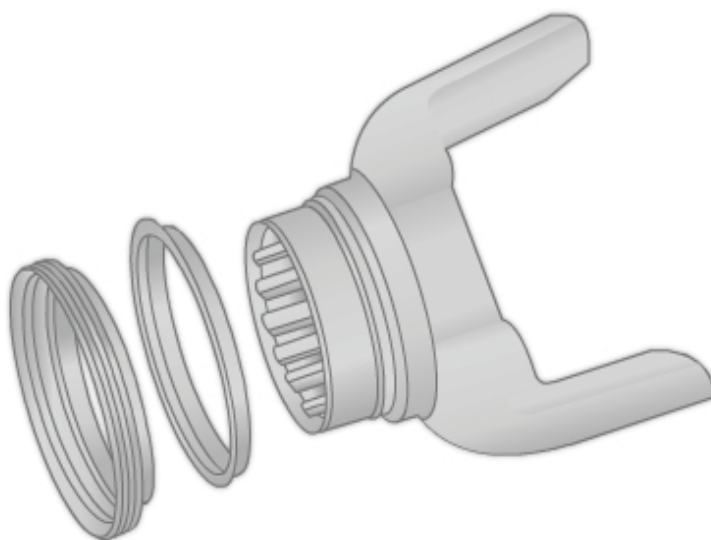


Figure 8-4 - Transmission yoke seal.

Transmission oil checklist:

1. Inspect the speedometer connections. Both mechanical and inductive speedometers connect to the tailshaft assembly. Check the speedometer sleeve torque and ensure the O-ring or gasket has not failed. Hydraulic thread sealant applied to the threads can sometimes cure this type of leak.
2. Inspect the rear bearing cover assembly bolts for tightness. These fasteners should be torqued to specification. Thread sealant is required to seal the fastener

threads on the rear bearing cover assembly. Leakage will result if this sealant fails.

3. Check the rear bearing cover gasket and nylon collar. Verify that the collar and gasket are installed at the chamfered hole that is aligned near the mechanical speedometer opening. The fastener must be torqued to specification with thread sealant applied to the fastener thread. Use the same procedure to check an electronic tailshaft speed sensor.
4. Check the output yoke retaining nut for tightness. The retaining nut should be torqued to specification (typically 450 to 600 ft.-lb.). You will need a yoke holder to hold the yoke stationary. A torque wrench capable of handling 600 ft.-lb. or a lower-rated torque wrench used with a 4 x 4 torque multiplier is required to accurately torque the nut.



Overtorquing a transmission output yoke retaining nut can cause output shaft bearing failure. Using a 1-inch air gun to tighten yoke retaining nuts should be avoided, although it is okay to remove the nut using this tool.

5. Check the PTO manifolds and gaskets, making sure the fasteners are torqued to specification.



Many fasteners used to couple flanges and manifolds to the transmission are bored completely through the housing. These fasteners must have thread sealant applied to the threads. If oil leakage is observed at the PTO covers, replace the PTO cover gaskets and thoroughly clean the fasteners and their mating threads before reinstalling.

6. Check the cover plates and manifolds bolted to the transmission housing for cracks or breaks, including the front bearing cover plate, front housing, shift bar housing, rear bearing cover, and the clutch housing. All of these components can be a source of oil leaks.
7. Check the front bearing cover plate. Oil return grooves that have been damaged by contact with the input shaft can cause oil leakage. If the grooves are damaged, you must replace the front bearing cover. If the front bearing cover has an oil seal installed, inspect the oil seal. Damaged or worn seals must be replaced to prevent oil leakage; in the case of the front bearing cover seal, the transmission will have to be pulled.
8. An oil leak in the front bearing cover, in the auxiliary housing, or in some housings (such as the air breather in the shift bar housing) can be caused by a damaged O-ring in the range air shift cylinder. The damaged O-ring bleeds air into the transmission, pressurizing it and resulting in oil leakage.
9. If the transmission is equipped with an oil cooler and an oil filter, inspect the connectors, hoses, and a filter element to make sure they are tight and leak-free.
10. Inspect the oil drain plug and oil fill plug for leakage. The oil drain plug and oil fill plug should be torqued to specification.

Always check for a plugged transmission breather when identifying the cause of a transmission oil leak. When transmission oil is raised from cold to operating

temperatures, it expands to occupy a greater volume. If the breather is plugged, this can cause seal failure.

1.1.3 Leaking Seals

With the power plant in the vehicle, you can inspect all seals except the input shaft retainer seal. If this seal is leaking, oil will drip out through the plughole in the bottom of the pan under the flywheel housing when the plug is removed.

If oil does drip out at the flywheel housing drain plug, examine the oil closely. It may be engine oil leaking from the engine crankshaft rear oil seal. The engine oil is much thinner (has less viscosity) than the transmission oil, so you should be able to tell which seal is leaking.

An oil leak, either from the engine or transmission input shaft seals, is serious, because the oil can ruin the clutch. An oil-soaked clutch disk will almost always slip or grab.

1.2.0 Testing Transmission for Malfunctions

In addition to the leakage problems, there are other problems that can develop in the standard transmissions used in almost all trucks. We can classify these as mechanical problems.

The best way to locate mechanical problems in the transmission is to road test the vehicle. Before road testing, however, check for missing or loose bolts and be sure the oil is at the proper level in the transmission case. Check the parking brake mechanism for proper mounting and correct adjustment. Check all moisture seals or boots. Check the action of the gearshift levers.

The transmission is often blamed for problems that are elsewhere. For example, with the engine running and the vehicle standing still, disengage the clutch and move the gearshift lever into first or reverse. You should be able to shift into either of these gear positions without any gear clashing or without the vehicle moving. If the gears clash or the vehicle attempts to move with the clutch disengaged, the trouble is in the clutch and not the transmission.

Check the clutch pedal free travel and adjust it if necessary. The clutch must be correctly adjusted before the transmission can operate properly. The clutch must fully disengage every time the clutch pedal is pushed all the way down, and it must fully engage every time the pedal is released.

With the transmission in neutral, the engine running, and the clutch engaged, all of the constant-mesh gears in the transmission will be turning. There should be very little gear or bearing noise.

If the transmission is quiet in neutral with the clutch engaged, disengage the clutch. If a noise is now heard, the trouble is with the clutch and not the transmission. Usually, the clutch release bearing or the clutch shaft pilot bearing is at fault if a noise is heard only when the clutch is disengaged.

Sometimes, noises in other parts of the power train, such as U-joints, propeller shafts, and differential, sound as if they are in the transmission. The misalignment of power train components usually produces a noise that may sound as if it is coming from the transmission. So be sure to check all mounting bolts on the engine, transmission, and differentials before road testing the vehicle. Also, check the propeller shafts and U-joints for evidence of wear or looseness.

Loose, bent, or shifted suspension system components will cause misalignment of the power train components that can produce a noise that may sound like a defective transmission.

Noises that may originate in the transmission are difficult to describe. A noise that may sound like a howl to you may sound like a squeal to someone else. Other terms often used to describe gear or bearing noises may include such words as "hum," "knock," "grind," "whine," and "thump."

If a tooth is broken off of one of the gears, a distinct thumping noise will be heard once during a complete revolution of the gear. The thump will be more pronounced if torque is being delivered through that gear.

Gears with worn, rough teeth will usually produce a grinding noise, especially when torque is being transmitted through them. Bearing noise is usually described as a howl, whine, or squeal. Actually, the type of noise made by a defective bearing will vary, depending on the type of defect and the load the bearing is supporting. In any event, loud noises coming from inside the transmission mean trouble.

Some whining or grinding noise can be expected, especially when the vehicle is being driven in first or reverse gear. The first-and-reverse sliding gear together with its mating countershaft gear and reverse idler gear are spur gears. Spur gears are always noisy, but they are frequently used because they are cheaper and do not produce thrust.

In the second-, third-, and fourth-speed ranges, the transmission should be much quieter than in first or reverse.

If, after a road test, you think the transmission is too noisy, be sure and report it to the maintenance supervisor. Be sure to describe the conditions under which the noise occurs.

Another common mechanical problem with transmissions of this type is slipping or jumping out of gear. Actually, the transmission is much less likely to slip or jump out of first or reverse than out of second-, third-, or fourth-speed gear. Second-, third-, and fourth-speed gears are all helical gears which, you recall, produce thrust.

The most likely causes of the transmission slipping out of gear are worn detent balls or springs in the shifter shaft cover. These spring-loaded balls hold the shifter shaft in position. If the spring does not have enough tension or if the balls are worn, the transmission will almost certainly slip or jump out of gear. Synchronizer damage will also cause the transmission to jump out of gear.

Slipping out of any gear is most likely to occur when the driver suddenly takes his or her foot off the accelerator pedal, especially when descending a steep hill. The thrust produced by the helical gears will tend to move all rotating gears and shafts to the rear of the transmission, as long as the torque provided by the engine is being delivered to the rear wheels by the transmission. However, when the driver takes his or her foot off of the accelerator pedal, the situation is changes. The rear wheels now try to drive the engine through the transmission. This reverses the direction of the torque being delivered through the transmission gears, and the thrust is now toward the front of the transmission. If this thrust is not controlled by the thrust washers and bearing retainers, it is likely to force the shifter shaft to move in spite of the spring-loaded ball that holds it. When this happens, the transmission slips out of gear.

Occasionally, a transmission slips out of gear because the driver does not fully engage the gear when moving the lever. However, when a transmission slips out of gear fairly often, it should be replaced.

1.3.0 Overhaul of Transmission

1.3.1 Transmission Identification

When repairing a manual transmission, you must be able to identify the exact type of transmission that you will be working on. Usually, there will be an ID tag or stamped set of numbers on the transmission (*Figure 8-5*). Many tend to look alike from the outside, but the tag will identify the characteristics of your transmission. **DO NOT REMOVE OR DESTROY THE TRANSMISSION IDENTIFICATION TAG!**

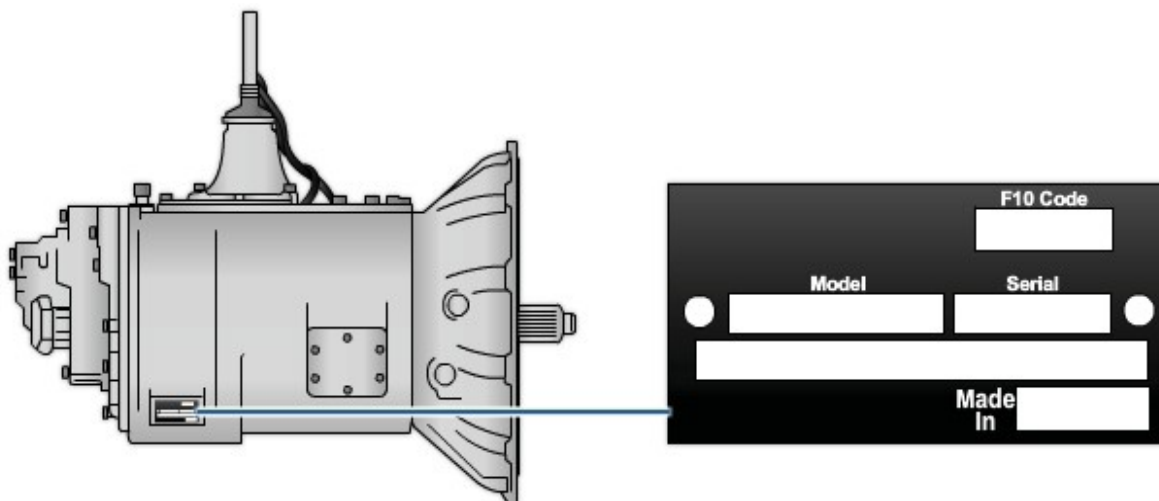


Figure 8-5 - Sample transmission identification tag and location.

1.3.2 Removal

When removing a transmission, use a transmission jack. A transmission jack has a special saddle and chains or straps for securing the transmission to keep from falling during removal and installation (*Figure 8-6*). If you do not have a transmission jack, you can use a floor jack. When using a floor jack, place a piece of wood between the jack pad and the transmission case as illustrated in *Figure 8-7, View A*, or a transmission adapter for the floor jack as shown in *Figure 8-7, View B*. Move the transmission to the workbench with the jack lowered.

Use the following procedure to remove a manual transmission:

1. Secure the vehicle on a hoist or set of jack stands.
A hoist is better because it allows you to stand while working.
2. Remove the transmission drain plug and drain the oil into a catch pan.

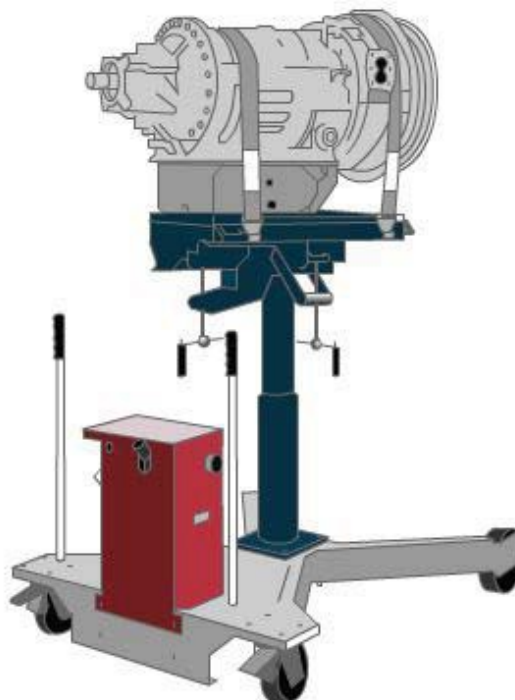


Figure 8-6 - Transmission jack.

3. Remove the drive shaft.
4. Install a plastic cup over the end of the transmission shaft. This will keep oil from dripping out.
5. Disconnect the transmission linkage at the transmission.
6. Unbolt and pull the speedometer cable out of the extension housing.
7. Remove all electrical wires going to switches on the transmission.
8. Often, a cross member (transmission support bolted to frames) must be removed. Support the transmission with a jack and use another jack under the rear of the engine. Operate the jack on the engine to take the weight off the transmission. Be careful not to crush the oil pan. Never let the engine hang suspended by only the front motor mounts.

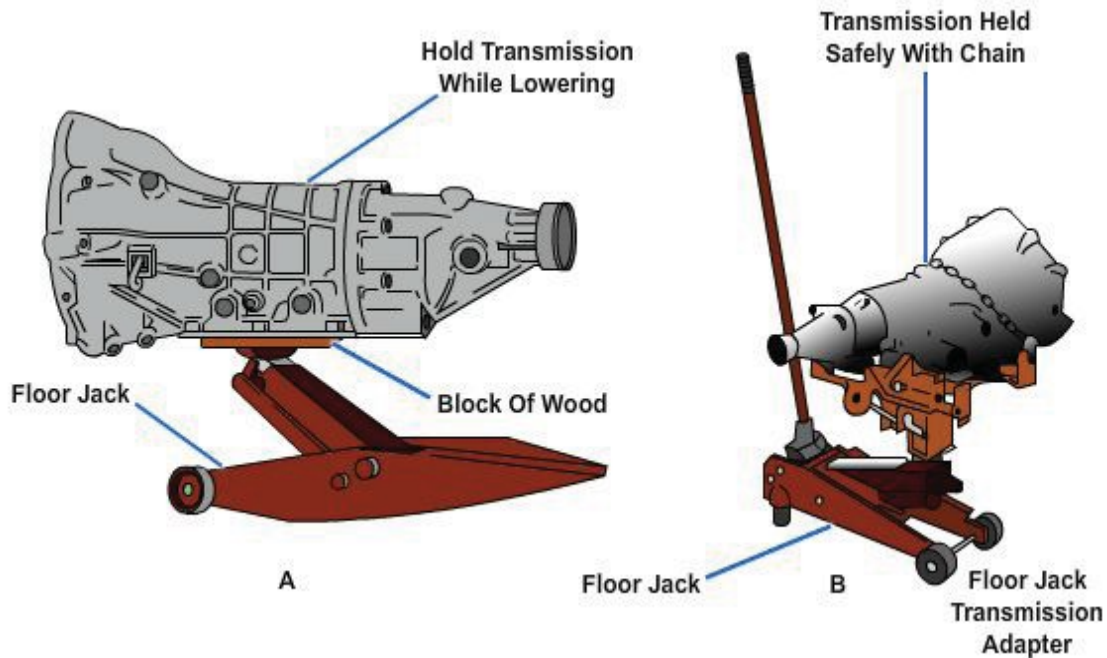


Figure 8-7 - Floor jacks converted as transmission jacks.

9. Depending upon what is recommended in the service manual, remove either the transmission-to-clutch cover bolts or the bolts going into the engine from the clutch cover.
10. Slide the transmission straight back, holding it in alignment with the engine (*Figure 8-8*). You may have to wiggle the transmission slightly to free it from the engine.
11. Clean the outside of the transmission and take it to a workbench.

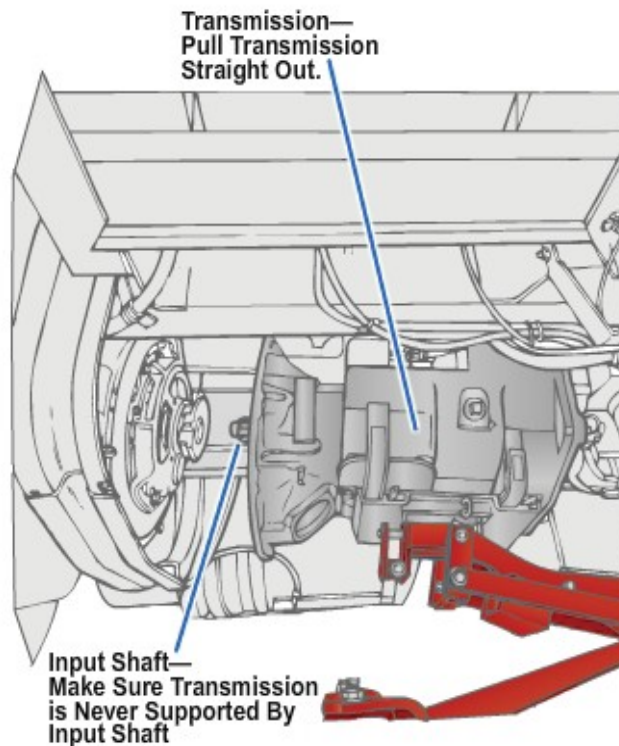


Figure 8-8 - Removing the transmission.

1.3.3 Disassembly

Teardown procedures will vary from one transmission to another. Always consult the service manual for detailed procedures.

Basically, remove the shift fork assembly and cover. With a shift rail type, remove the shift lever assembly (*Figure 8-9*).

If the transmission has an inspection cover, observe transmission action with the cover removed. Shift the transmission into each gear by moving the small levers on the shift forks. At the same time, rotate the input shaft while inspecting the condition of the gears and synchronizers.

Unbolt the rear extension housing. Tap the extension housing off with a brass hammer.

Going to the front of the transmission, remove the front bearing cover and any snap rings. Carefully pry the input shaft and gear forward far enough to free the main output shaft.

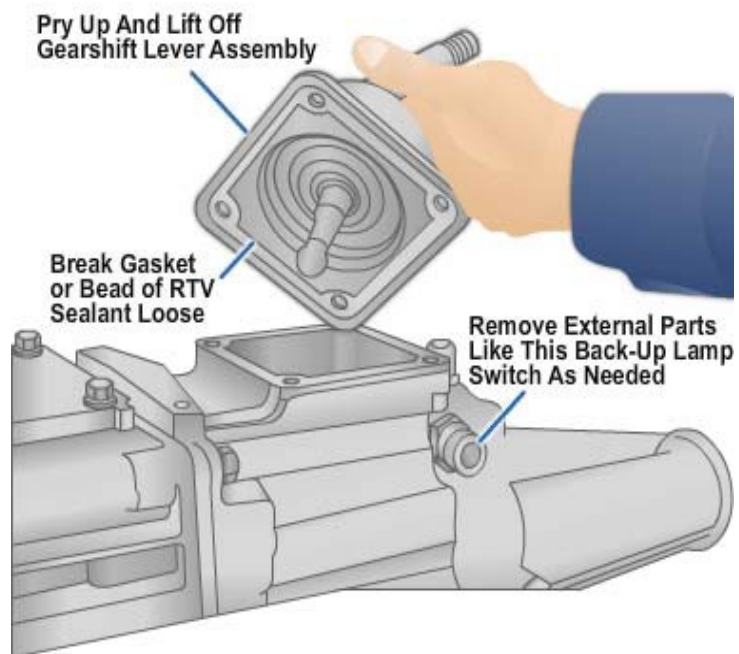


Figure 8-9 – Removing the shift fork assembly.

Next, use a dummy shaft or arbor shaft (shaft tool designed for driving) to drive out the counter shaft and reverse idler shaft.

Now you can remove the input shaft and the output shaft assemblies. Slide the output shaft and gears out of the back or top of the transmission as a unit. Be careful not to nick the gears on the case (*Figure 8-10*).

1.3.4 Cleaning and Inspecting Disassembly

With all of the parts removed from the case for metal shavings, inspect them closely. First, check inside the case for metal shavings. If brass-colored particles are found, one or more of the synchronizers or thrust washers are damaged. These are normally the only parts in the transmission made of this material.

If iron chips are found, the output drive gears are probably damaged. After checking the case, clean the inside with solvent. Then blow it dry with compressed air while wearing eye protection. Also clean the transmission mission bearings.

Next, inspect all of the output gears. Look for wear patterns or chips on the gear teeth. The gears are usually case-hardened. If wear is more than a few thousandths of an inch, the hard outer layer will be worn through, and the gear must be replaced.

Transmission shaft runout is the amount of wobble produced when a bent or worn shaft is rotated. If gear tooth wear is uneven, check the shaft bearings and shafts. They may be worn or bent. A dial indicator can be used to check the transmission shafts for straightness. Refer to specifications for the amount of allowable runout.

Inspect the synchronizer assemblies, especially if the transmission had gear shift problems (*Figure 8-11*). Check the teeth, splines, and grooves on the synchronizers. Replace parts as needed. *View A* shows all the components of the assembly. *View B* shows basic synchronizer components. *View C* shows checking shift forks and synchronizers for wear. *View D* illustrates inspect ridges inside the blocking ring.

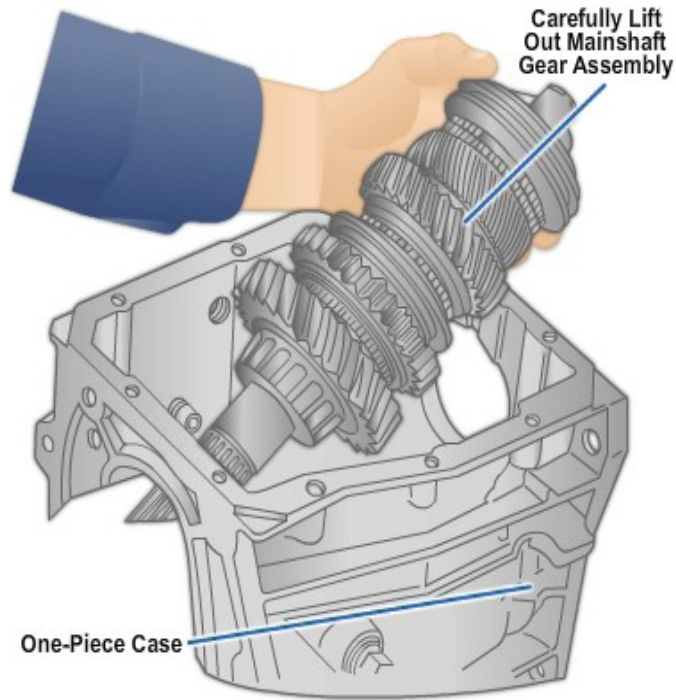


Figure 8-10 - Removing the mainshaft

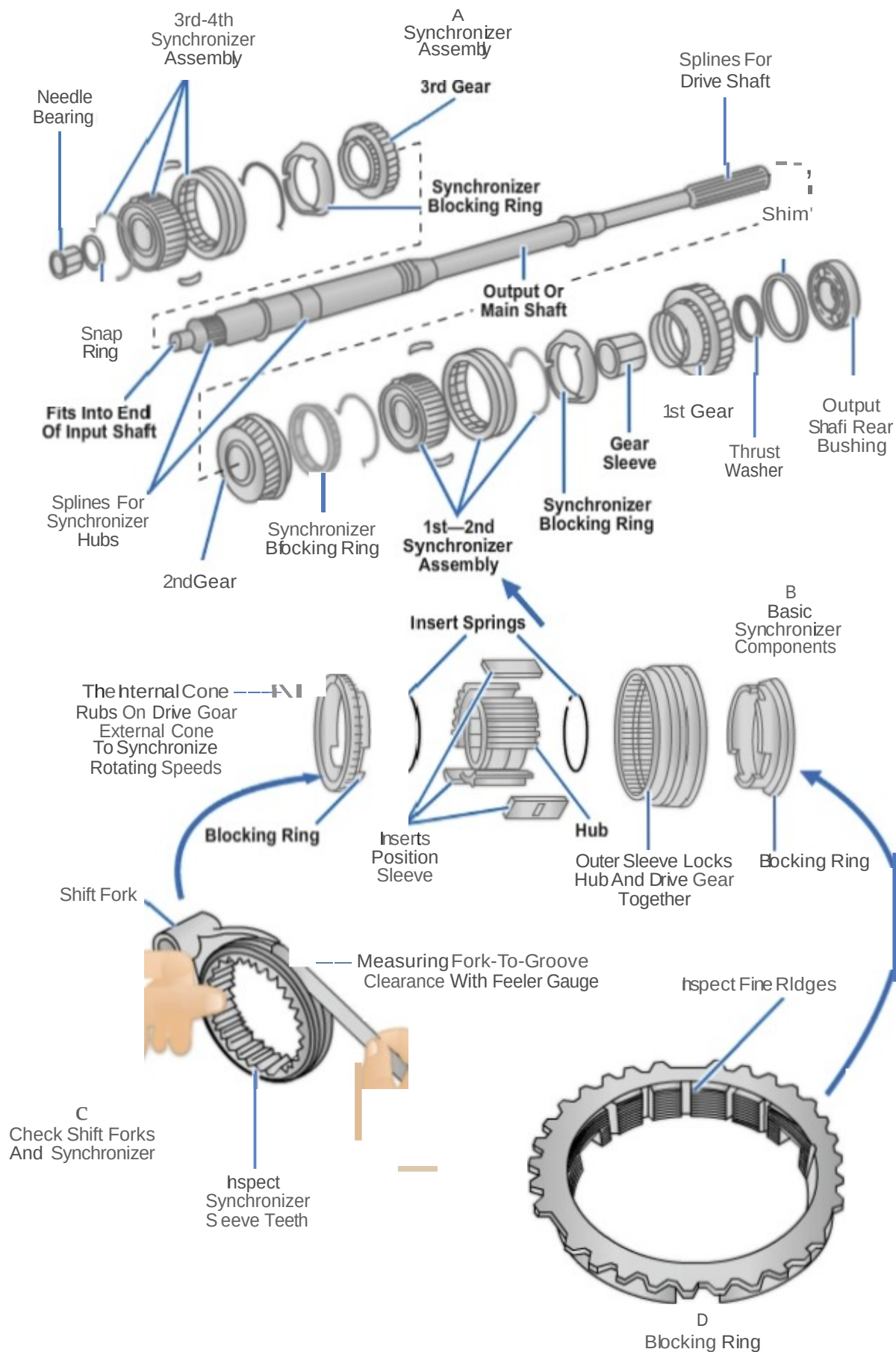


Figure 8-11 -Inspecting synchronizer assembly.

1.3.5 Replace Worn or Damaged Parts

Any worn or damaged part in the transmission must be replaced. This is why your inspection is very important. If any trouble is not corrected, the transmission rebuild may fail. You would have to complete the job a second time.

It is generally recommended to always replace all gaskets and seals in the transmission. Even though a seal or gasket might not leak before teardown, it could start to leak after assembly. *Figure 8-12* shows a typical way of replacing a rear seal. The rear seal can be removed and installed with the transmission still in the vehicle. *View A* shows the seal being removed and *View B* shows driving in a new seal. Coat the outside of the new seal with non-hardening sealer before installing.

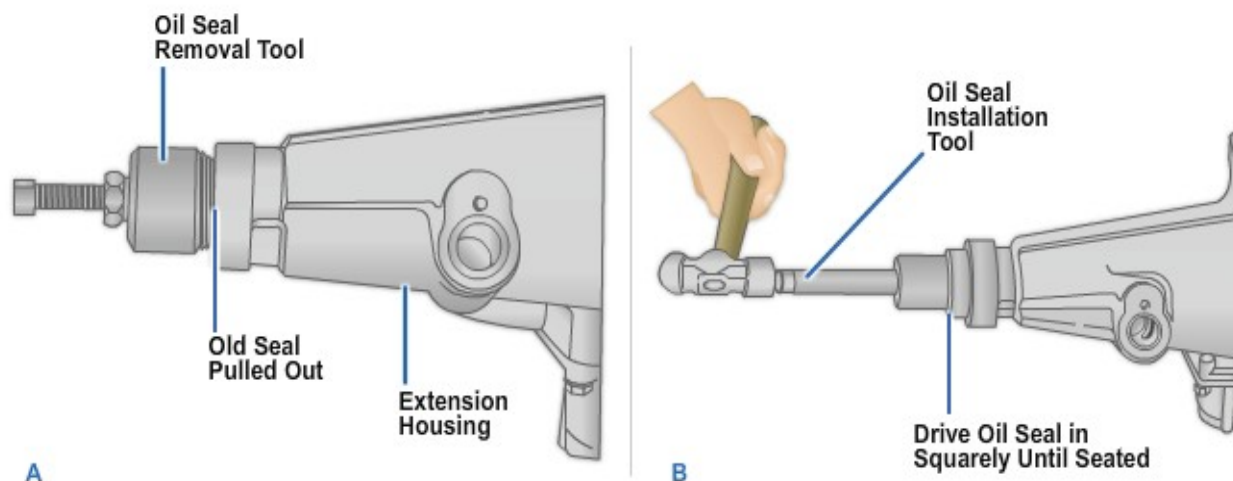


Figure 8-12 – Replacing the oil seal.

When replacing a gear on the output shaft, you should also replace the matching gearset on the countershaft. If a new gear is meshed with an old worn gear, gear noise can result.

Frequently, you will need to replace input shaft bearings. These bearings are prone to wear because they support a great amount of load. You can turn by hand to feel signs of wear or unevenness. A special puller may be needed to remove some bearings (*Figure 8-13*).

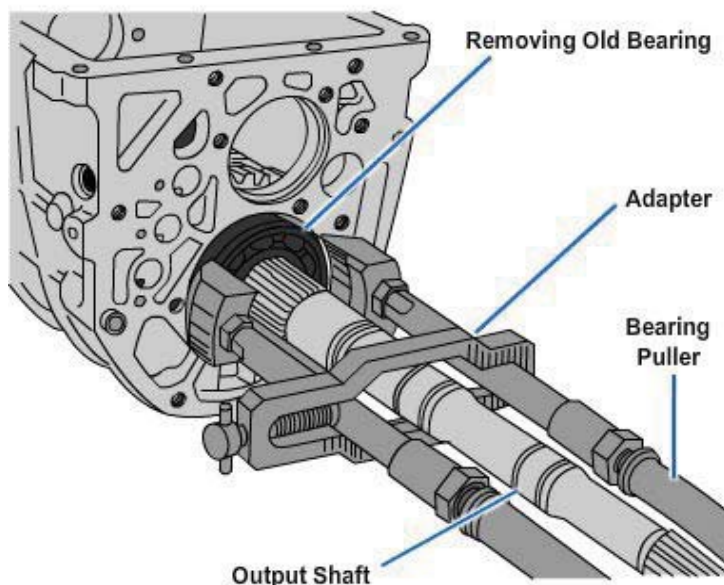


Figure 8-13 - Removing bearings with puller.

1.3.6 Reassembly

After obtaining new parts to replace the old worn ones, you are ready for reassembly. Typically, the transmission is assembled in reverse order of disassembly. Again, refer to the service manual for detailed procedures for reassembly.

The service manual will usually have exploded views of the transmission (*Figure 8-14*) and assemblies (*Figure 8-15*). They

will show how each part is located in relation to the others. Step-by-step instructions will accompany the illustrations.

To hold the needle bearings in countershaft gears, coat the bearings with heavy grease. Then fit each bearing into position. The grease will hold the bearings as you slide the countershaft into the gear (*Figure 8-16*).

Also, following the manufacturer's instructions, measure the end play or clearance of the gears and synchronizers (*Figure 8-17*).

Assemble the shift fork mechanism and with the synchronizers and shift forks in neutral, fit the shift fork assembly on or in the case. Check the action of the shift forks.

Make sure the transmission shifts properly before installing it. This will definitely save you from having to remove the transmission later when problems are discovered.

While the transmission is removed from the vehicle, it would be recommended to disassemble and inspect the clutch.

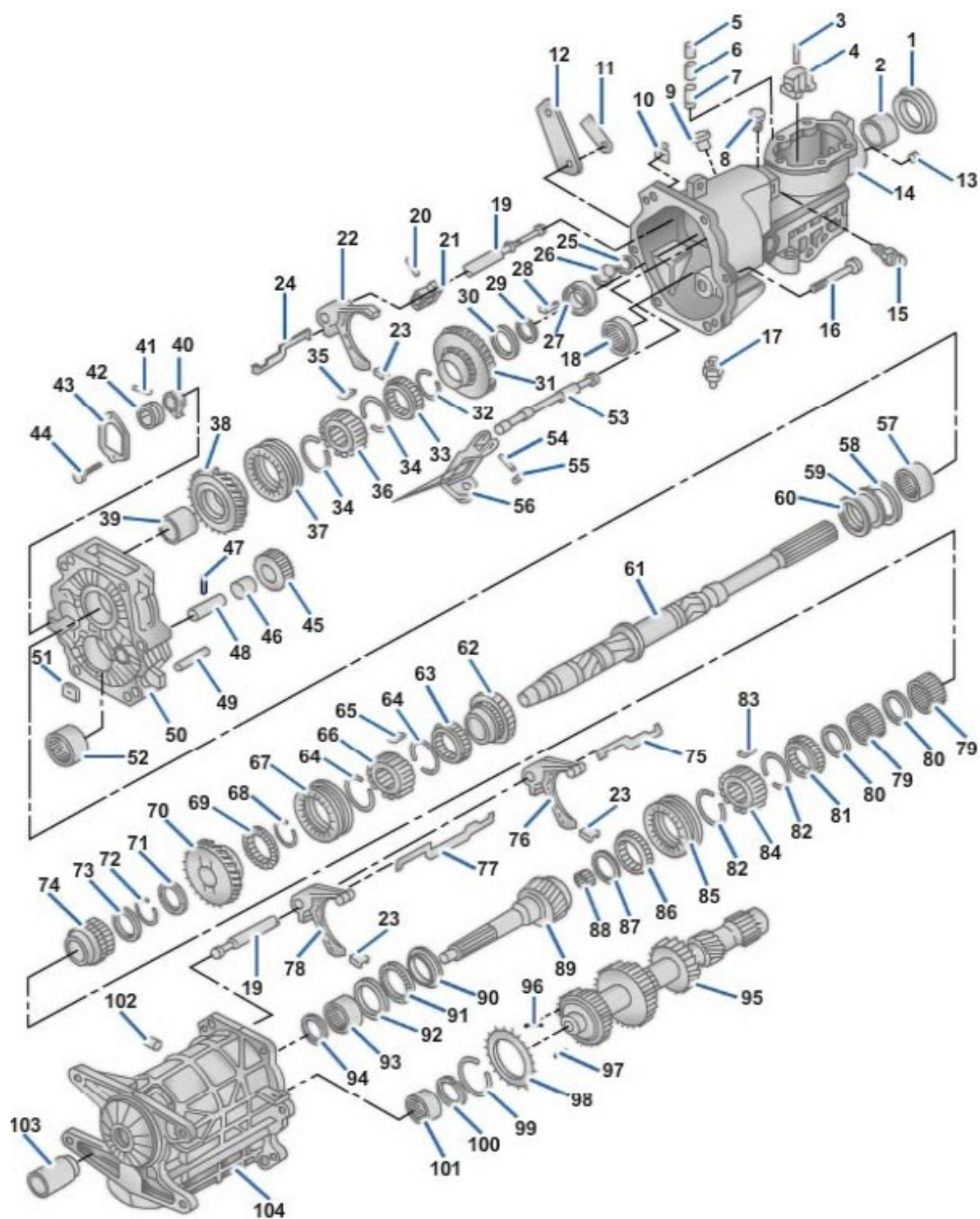


Figure 8 14 Exploded view of a 5-speed transmission.

1.3.7 Installation

Before transmission installation, place a small amount of grease in the pilot bearing and on the inner surface of the throw-out bearing. Do not place lubricant on the end of the clutch shaft, input shaft splines, or pressure plate release levers. Grease in these locations can spray onto the clutch friction disk, causing clutch slippage and failure.

Shift the transmission into high gear. This will help position the input shaft into the clutch disk during transmission installation.

Place the transmission on the transmission jack. Position it behind the engine. Double check that the throw-out bearing is in place on the clutch fork. Carefully align the transmission with the engine.

The input and output shaft must line up perfectly with the centerline of the engine crankshaft. If the transmission is tilted, even slightly, it will not fit into place.

With the transmission in high gear to hamper input shaft rotation, slowly push the transmission into the clutch housing. You may need to raise or lower the transmission slightly to keep it in alignment. When the transmission is almost in place, wiggle the extension housing in a circular pattern while pushing toward the engine. This should help start the input in the crankshaft pilot bearing. If the clutch and pilot bearing are installed correctly, the transmission should slide fully into place by hand.



Do not use the transmission bolts to draw the transmission into the clutch housing. The transmission input shaft could be smashed into the crankshaft pilot bearing. Serious component damage may result.

Index No.	Description	Index No.	Description	Index No.	Description
1.	Oil seal	37.	Clutch sleeve	71.	Thrust washer
2.	Bushing	38.	Reverse gear & bushing assembly	72.	Snap ring
3.	Pin	39.	Bushing	73.	Spacer
4.	Shifter head	40.	Selector arm	74.	5 th Speed gear
5.	Threaded plug	41.	Spring pin	75.	2 nd & 3 rd Shift link
6.	Poppet spring	42.	Interlock pawl	76.	2 nd & 3 rd Shift fork
7.	Mesh lock plunger	43.	Retaining plate	77.	4 th & 5 th Shift link
8.	Breather	44.	%-20 x % Hex head self tapping screw	78.	4 th & 5 th Shift fork
9.	Selector lever pilot	45.	Reverse idler gear & bushing	79.	Needle rollers
10.	Wiring harness clip	46.	Bushing	80.	Spacer
11.	Name plate	47.	Spring pin	81.	Synchronizer blocking ring
12.	Back-up light bracket	48.	Reverse idler shaft	82.	Synchronizer spring
13.	Cup plug	49.	Dowel pin	83.	Shift plate
14.	Extension housing	50.	Center support	84.	Clutch hub
15.	Switch	51.	Magnet	85.	Clutch sleeve
16.	3/8-16 x 3-1/4 Hex head bolt	52.	Needle bearing	86.	Synchronizer blocking ring
17.	Switch	53.	Shift rail	87.	Needle thrust bearing
18.	Needle bearing	54.	Pin	88.	Needle rollers
19.	Shift rail	55.	Retaining clip	89.	Input drive gear
20.	Spring pin	56.	Selector lever	90.	Needle thrust plate
21.	Rail selector	57.	Needle bearing	91.	Needle thrust bearing
22.	First & reverse shift link	58.	Thrust washer	92.	Thrust washer
23.	Shift fork pad	59.	Needle thrust bearing	93.	Needle bearing
24.	First & reverse shift link	60.	Needle thrust race	94.	Oil seal
25.	Gasket	61.	Output shaft	95.	Cluster gear
26.	9/16-18 Plug	62.	3 rd Speed gear	96.	Spring
27.	Speedometer gear	63.	Blocking ring	97.	Spring pin
28.	Speedometer gear retainer	64.	Synchronizer spring	98.	Gear damper
29.	Snap ring	65.	Synchronizer shift plate	99.	Snap ring
30.	Thrust washer	66.	Clutch hub	100.	Thrust washer
31.	1 st Speed gear	67.	Clutch sleeve	101.	Needle bearing
32.	Snap ring	68.	Snap ring	102.	1-2 Inch pipe plug
33.	Blocking ring	69.	Synchronizer blocking ring	103.	Transmission case sleeve
34.	Synchronizer spring	70.	2 nd Speed gear	104.	Transmission case
35.	Shift plate				
36.	Clutch hub				

Figure 8-14 - Exploded view of a 5-speed transmission (cont.).

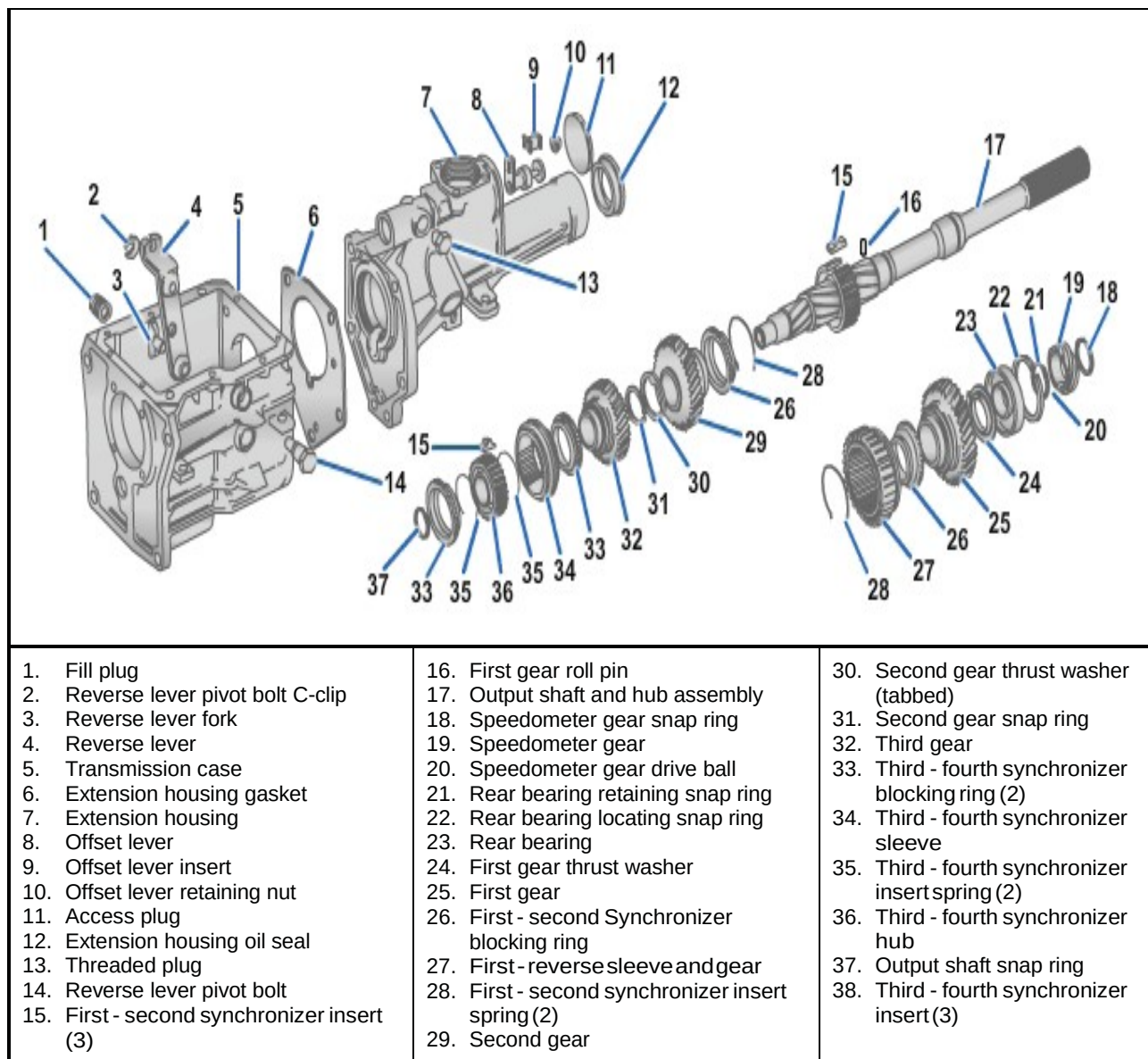


Figure 8-15 - Exploded view of a mainshaft assembly.

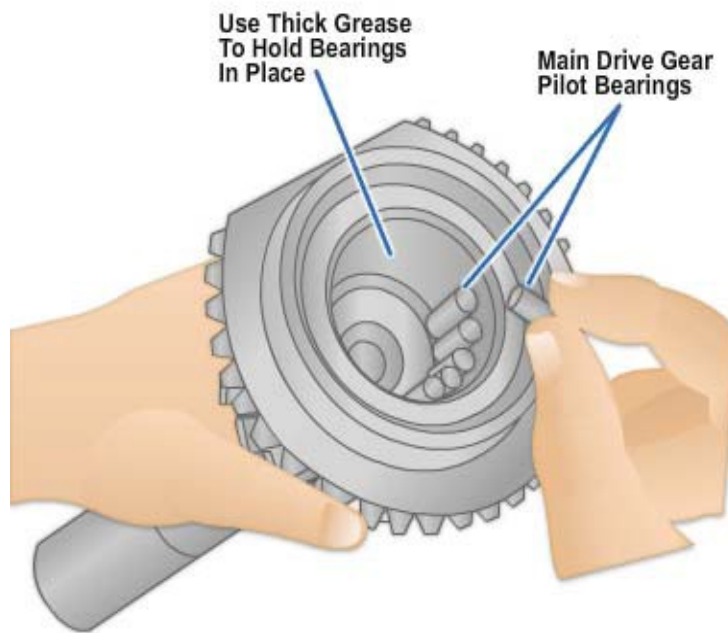


Figure 8-16 - Installing needle bearings.

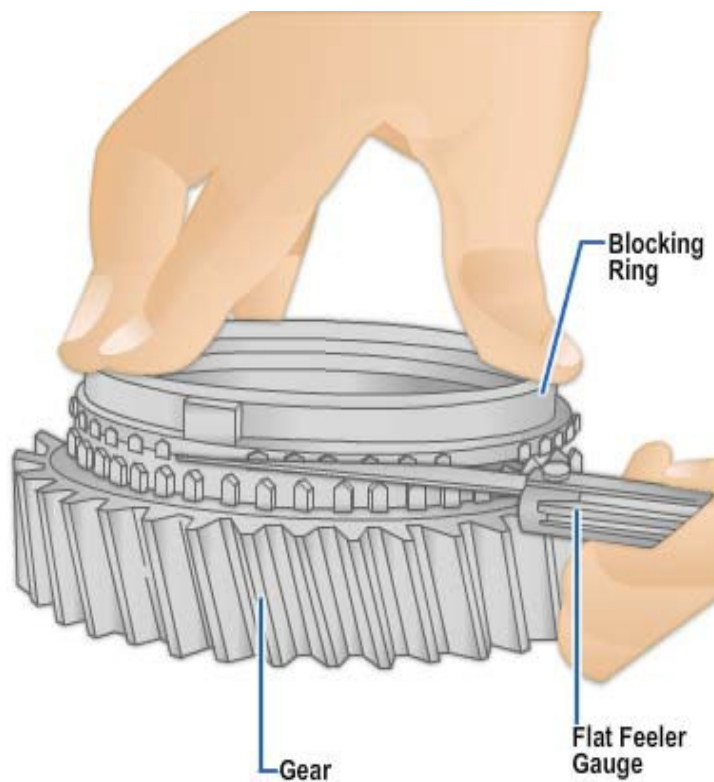


Figure 8-17 – Using a feeler flat gauge to measure clearance between mating parts.

With the transmission bolted to the clutch cover, install the rear cross member and motor mount.

Reinstall the clutch linkage and transmission linkage.

Reconnect electrical connectors. Install parking brake hardware and exhaust pipes (if removed). Install the speedometer cable assembly.

Install the driveshaft assembly, making sure to line up the marks you made during removal.

Fill the transmission to the proper level using specified lubricant. Install the fill plug and tighten.

To adjust many types of transmission linkage, place the gearshift lever and transmission levers in neutral. Then insert an alignment pin (special diameter tool or rod) through the linkage arms. The pin must fit through the holes in the shifter levers (Figure 8-18).

If the pin will not fit through the hole, lengthen or shorten the linkage rods. Adjust the rods so that the alignment pin fits easily through the hole in the shifter assembly and into the corresponding hole in the housing.

This basic procedure will vary with different types of gear shift mechanisms. When in doubt, refer to the service manual for specific instructions for your particular condition.

After all the drivetrain parts are reinstalled, lower the vehicle and reconnect any disconnected hardware under the hood, including the battery negative cable. Install the boot to the floor inside the vehicle and screw the gear shift knob back if removed.

After everything has been reconnected, operate the clutch pedal a few times to see that the clutch engages and disengages properly. Also, move the gearshift lever to check operation of the shift linkage.

Carefully road test the vehicle, making sure the transmission and clutch operate properly. If any problems are detected, correct them before releasing the vehicle. Make any other adjustments as needed and recheck the oil level.

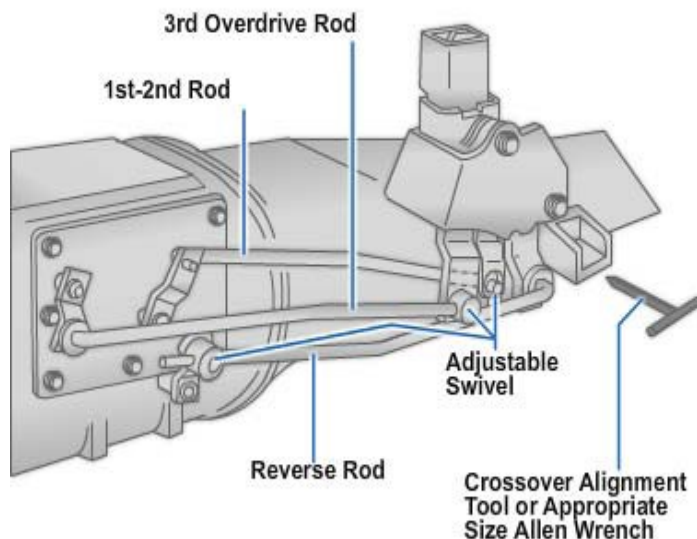


Figure 8-18 - Adjust external linkage.

2.0.0 TROUBLESHOOTING TRANSFER CASES

The transfer case is the mechanical unit that splits power between the front and rear wheels (axles) (*Figure 8-19*). It is attached to the rear of the transmission or transaxle and receives power from the transmission or transaxle output shaft. Power leaves the transfer case through two output shafts. In addition to various drive gears, transfer cases may contain drive chains, a differential assembly, or a viscous coupling. The term all-wheel drive (AWD) in heavy-duty trucks usually refers to a chassis with a front drive axle in addition to rear tandem drive axles. *Figure 8-20* shows the location of the transfer case on a typical truck chassis.

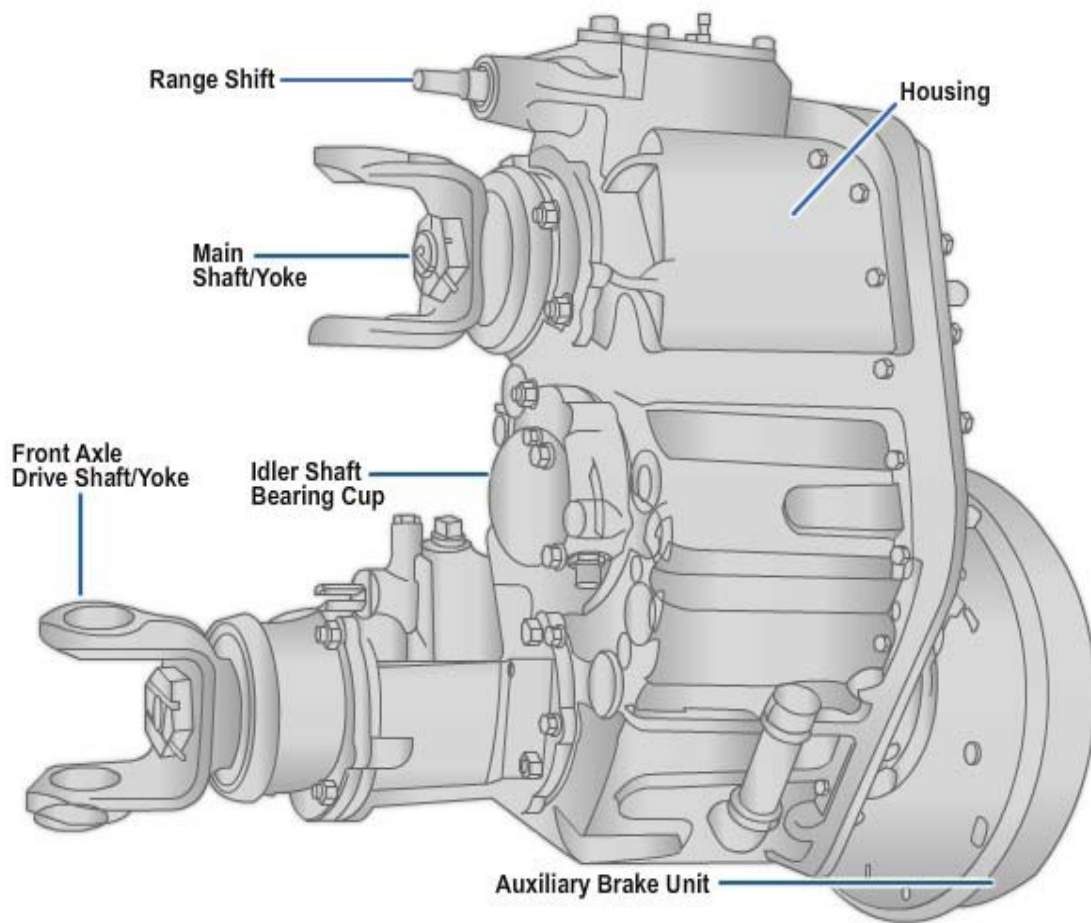
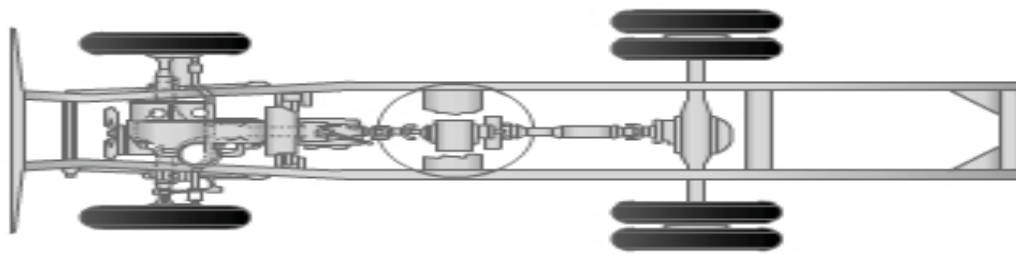


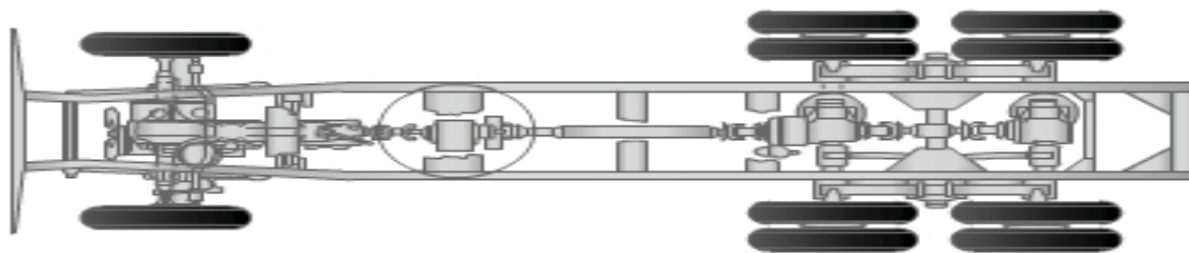
Figure 8-19 - Three-shaft design transfer case.

Transfer cases can transfer drive torque directly using a 1:1 gear ratio, or can be used to provide low gear reduction ratios of 2:1 additional to those in the transmission. The drop box design of a transfer case housing permits its front driveshaft output to clear the underside of the main transmission

Most transfer cases are available with power takeoff (PTO) capability and front axle declutch. The front axle declutch is used to option-drive to the front axle when negotiating steep grades or slippery or rough terrain. Both the PTO and front axle drive declutch are driver engaged by dedicated shift levers.



Typical 4 x 4 Hookup



Typical 6 x 6 Hookup

Figure 8-20 - All-wheel drive vehicles

2.1.0 Transfer Case Problems and Troubleshooting

Although it is relatively small, the transfer case can develop problems that affect the entire drive train. Accurately determining the source of the problem is the first step in repairing a transfer case. *Figure 8-21* illustrates some of the components that can develop problems in a typical transfer case.



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2.1.1 eakage

Lubricant leakage in a transfer case is a loss of lubricating fluid from the housing, gaskets, or seals. Leaks may be noticed as oil drips on the pavement. Always begin troubleshooting an oil leak by making sure the leak is from the transfer case. Engine oil, transmission fluid, or power steering fluid can be mistaken for transfer case lubricant. As a vehicle is driven, oil leaking from the front components is sometimes blown onto the rear components. This makes it difficult to determine the origin of the leak.

One way to verify a transfer case leak is to check the oil level in the case. In most transfer cases, the oil level is correct if the oil just wets the bottom of the fill plug threads (*Figure 8-22*). If the oil level is low, there is generally a leak somewhere in the transfer case. If the oil level is too high, overfilling may be the cause of the leak. Overfilling may cause oil to be forced out of a seal or out through the case vents.

When looking for transfer case leak, remember that oil will drip downward and is often blown to the rear of the vehicle. Look for the leaks from loose or broken bearing retainers or from retainer gaskets. Check the seals in the area where the drive shaft yokes enter the transfer case. Leaks may also originate from loose case housing bolts and defective housing gaskets. Check for leaks from the drain and fill plugs, and from bolts at the bottom of the transfer case. Some bolts must be installed with a thread sealant to prevent leaks.

2.1.2 Engagement

When a transfer case fails to engage properly, no power will be transmitted to one or both sets of wheels. However, a transfer case rarely fails to drive at least one set of wheels. If the vehicle will not move in any transfer case mode, the problem is usually caused by a defective transmission or by a binding axle. If the transfer case fails in only one gear, the problem may be caused by defective internal parts or linkage.

Transfer case failure causing a no-drive condition in all gears is usually caused by stripped gears or splines, a broken chain, a broken shaft, or a viscous coupling that has lost its fluid. Generally, a transfer case must be removed from the vehicle to repair these defects.

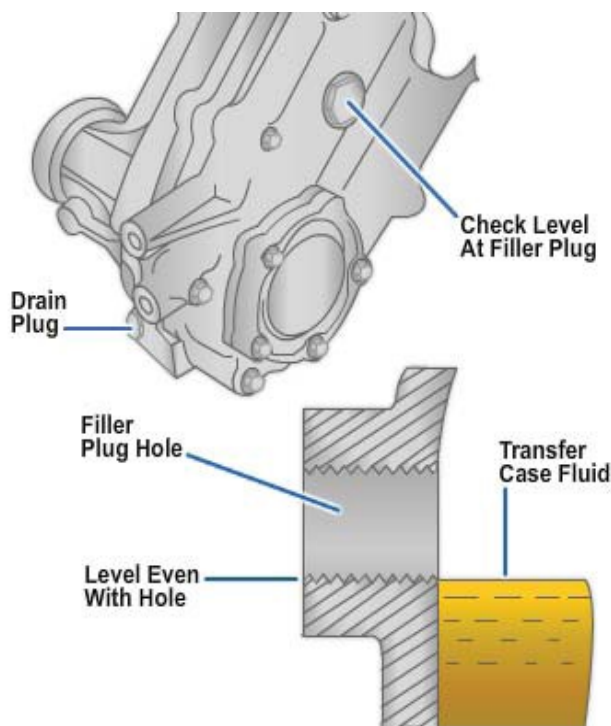


Figure 8-22 – Checking oil level.

2.1.3 Abnormal Noises

Abnormal noises in the transfer case include whines and rumbles that occur during operation. Other abnormal noises include grinding, knocking, popping, or snapping sounds. Since the transfer case is mounted directly behind the transmission, it is easy to mistake transmission or drive noise for transfer case noise. Always make sure the noise is actually coming from the transfer case and not from some other part of the vehicle.

Transfer case noises usually vary from driving conditions. If the transfer case is the part-time type, road test the vehicle to determine the mode in which the problem occurs. If the transfer case is the full-time type, the vehicle should be placed on a lift to listen to for abnormal noises, such as grinding, knocking, or excessive whining. Remember that normal drive train noises will seem louder when you are under the vehicle.

Typical causes of whining or rumbling noises in the transfer case include a low lubricant level, worn or damaged input gear, worn or damaged driven gear, worn bearings, worn planetary gears (where used), and damaged input or output shaft bearings. If the speedometer gears are installed on the transfer case, check them for damage. A worn drive chain can cause popping or snapping noises as the vehicle is accelerated. Sometimes, the transfer case will be noisy because the front and rear axle ratios do not match due to modifications. This can cause friction in the transfer case planetary gears or coupling. To repair damaged or worn transfer case parts, the unit must be removed and overhauled.

2.1.4 Gear Disengagement

When the transfer case jumps out of gear, the shift mechanism will move into Neutral at undesirable times. The first step in troubleshooting this type of problem is to determine the gear in which the problem occurs. If the problem occurs in only one gear, the teeth on that particular gear may be chipped or worn. Further, a blocking ring of a sliding clutch of the affected gear may be worn.

2.1.5 Hard Shifting

In some cases, it may become difficult to change transfer case gears. Hard shifting may be caused by a shift linkage that is bent or worn. In some cases, the linkage simply needs lubrication. *Figure 8-23* shows shift linkage adjustment. If the linkage is okay, the problem may be caused by bent or damaged shift forks inside the transfer case.

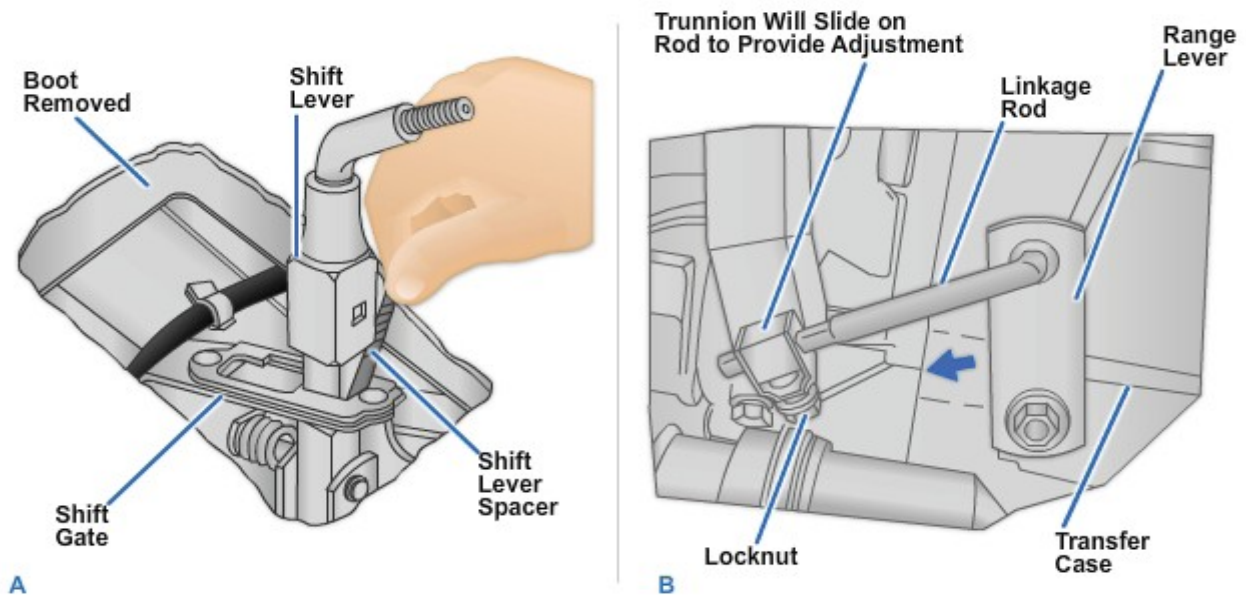


Figure 8-23 - Transfer case shift linkage adjustment.

2.1.6 for Case Shudder

Transfer case shudder is a jerking motion that typically occurs during acceleration. Possible shudder causes are low fluid level, loose transfer case fasteners, worn gears or bearings, or defective internal clutches. A shudder may also occur at low speeds on vehicles with a defective viscous coupling or clutch pack.

When diagnosing this problem, make sure the shudder is not caused by the engine, clutch, transmission, limited-slip differential, or universal joints. Check the fluid level, and make sure all fasteners are tight. Pay particular attention to the fasteners holding the transfer case to the rear of the transmission. If fluid level is at the normal mark, and the fasteners are tight, it will probably be necessary to remove and disassemble the transfer case to locate the problem. If the vehicle has a viscous coupling, check for silicone in the transfer case lubricant. Because silicone does not mix with oil, it will appear as globules in the lubricant. This will indicate the silicone has leaked from the viscous coupling and the coupling requires attention. If the viscous coupling has failed, check the different front and rear axle ratios, which may have caused it to fail. Refer to *Figure 8-24* for quick reference to troubleshooting.

Transfer Case Diagnosis Part-Time Drive		
Condition	Possible causes	Correction
Jumps out of gear in two-wheel drive.	- Shift lever detent spring weak or broken. - Sliding clutch spline engaging surface worn or tapered.	- Replace spring. - Replace worn parts.
Noise. Note: Transfer cases using a gear drive produce considerable gear whine, which is normal.	- Worn bearings, splines, chipped gears, or worn shafts. - Low lubrication level. - Loose or broken mounts.	- Rebuild unit. - Fill to proper level. - Tighten or replace mounts.
Jumps out of gear in four-wheel drive.	- Shift lever interference with floor pan. - Excessive transfer case movement. - Sliding clutch engaging surface tapered or worn. - Bent shift fork. - Shift rod detent spring weak or broken. - Shift lever torsion spring (where used) not holding. - Worn bearings, gear teeth, or shafts.	- Provide proper clearance. - Check and replace transfer case mounts. - Replace worn parts. - Replace shift fork. - Replace detent spring. - Replace torsion spring. - Overhaul unit.

Transfer Case Diagnosis Full-Time Drive		
Condition	Possible causes	Correction
Noisy operation.	- Low lubrication level. - Operating in "lockout" on hard, dry surface roads. - Improper lubricant. "Slip-stick" condition. Makes a grunting, pulsating, rasping sound. - Excessive wear on gears, chains, or differential unit. - Loose or deteriorated mounts.	- Fill to correct level. - Shift out of "Lockout." Advise driver. - Drain and fill with recommended lubricant. - Normal if vehicle has been driven for a week or two. Should stop after some usage. If it persists, drain fluid and refill. Use special additive, if required. Make certain tire sizes are the same and pressures are equal. - Rebuild as needed. - Tighten or replace.
Jumps out of low range and/or is hard to shift into or out of low range.	- Shift linkage improperly adjusted, bent, or broken. - Shift rails dry or scored. - Improper driver operation. - Reduction unit parts worn or damaged.	- Adjust correctly. Straighten or replace. - Clean, polish. Or lubricate or replace as needed. - Follow shift procedure recommended by manufacturer. - Repair as needed.
Lockout will not engage.	- Lockout parts damaged. - Defective vacuum control. Loose or damaged vacuum lines. - Defective shift linkage.	- Repair as needed. - Replace control. Replace or connect vacuum hoses. - Repair or replace.
Will not engage in two-wheel drive.	- No vacuum. Loose or broken hoses. - Defective shift motor (axle). - Defective shift motor (transfer case).	- Replace hoses. Secure all loose connections. - Replace shift motor. - Replace shift motor.
Will not engage in four-wheel drive.	- No vacuum. Loose or broken hoses. - Defective axle shift motor. - Binding or broken transfer case shift linkage. - Defective axle shift linkage. - Damaged transfer case.	- Replace hoses. Secure all loose connections. - Replace shift motor. - Repair or replace shift linkage. - Repair or replace shift linkage. - Repair or replace transfer case.
Vehicle wanders when driving straight ahead.	- Improperly matched tire size. - Uneven tire pressure.	- Use a matched set of tires. - Adjust air pressure to recommended levels.

Figure 8-24 - Transfer case quick reference troubleshooting guide.

2.2.0 Transfer Case Overhaul

Many of the problems encountered in all-wheel drive systems result from improper transfer case operation. Worn or damaged transfer cases must often be removed from the vehicle for service.

2.2.1 Transfer Case Removal

Transfer case removal is similar to manual transmission removal. Nevertheless, recommended removal procedures vary among manufacturers, and for that reason only the basics of transfer case removal will be discussed. Refer to the manufacturer's service manual for your particular transfer case for detailed procedures for overhaul, such as details regarding whether or not the transmission and transfer case should be removed as a unit. The general procedure for removing a transfer case is as follows:

1. Disconnect the negative battery cable. This will prevent accidental operation of the starter when you are working on the vehicle.
2. Raise the vehicle with an approved hoist or hydraulic jack. If using a hydraulic jack, be sure to install good quality jack stands before getting under the vehicle. If the vehicle has an off-road skid plate or splash shield, remove it. Drain the oil from the transfer case. Sometimes the transmission and transfer case share the same oil. In these systems, it may necessary to drain the oil at the transmission.
3. Place a transmission jack or stand under the transmission. This helps support the transmission and transfer case during removal.
4. Remove any ground straps and electrical connectors from the transfer case and remove the speedometer cable assembly. Disconnect the transfer case shift linkage and, if necessary, the transmission linkage. Vehicles with full-time four-wheel drive or electronic transfer cases usually do not have linkage on the transfer case.
5. Mark the drive shafts or yokes so they can be correctly reattached to the transfer case. Then, remove the drive shafts from the transfer case. It may not be necessary to remove the drive shaft assemblies from the vehicle. If possible, leave them attached at the differentials and secure them to the underside of the chassis with wire.
6. If necessary, raise the transmission slightly and remove the rear engine mount and cross member.
7. Remove any brackets or fasteners holding the transfer case to the vehicle frame.
8. Place a transmission jack (or floor jack) under the transfer case. Then, remove the bolts or nuts holding the transfer case to the transmission.



WARNING

If the transfer case is not properly supported, it will drop when the bolts holding it to the transmission are removed, causing injury or damage.

9. Slide the transfer case away from the transmission and lower the case. Note that the transmission output shaft extends into the transfer case. During removal, the transfer case must be removed away from the transmission until it clears the output shaft. As you lower the transfer case, make sure it does not catch on

adjacent parts. Also, make sure all straps, wires, and other attachments have been disconnected.

2.2.2 Transfer Case Disassembly

After removing the transfer case, drain any remaining oil. Clean the outside of the housing and mount the unit securely on a clean workbench. Make sure the transfer case will not fall off the bench during the disassembly procedure.

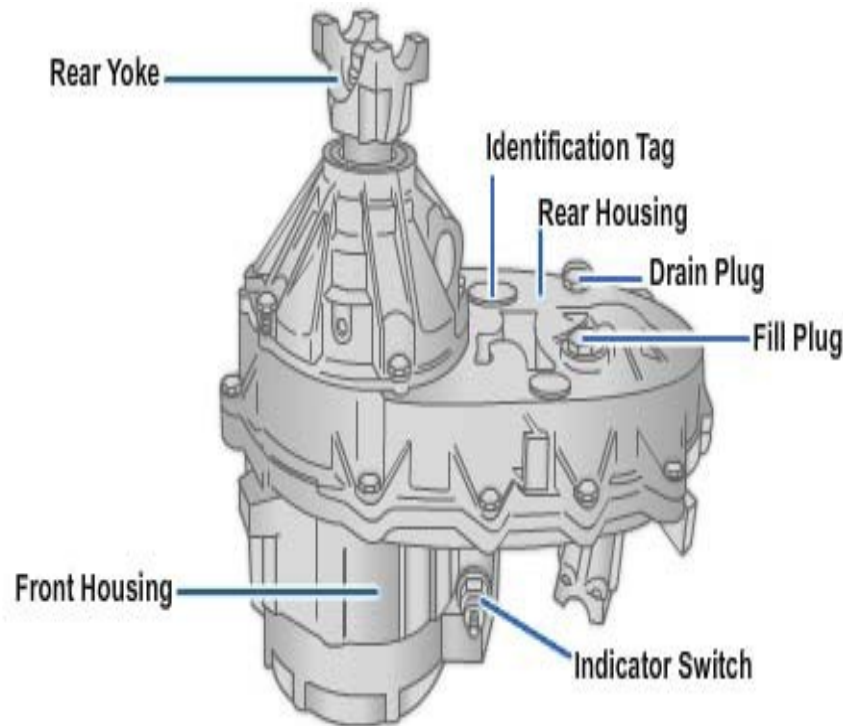


Figure 8-25 - Transfer case with a two-piece or split-type housing.

If not removed previously, remove the drive shaft yokes. Most drive shaft yokes are secured to the output shafts with large nuts. The nuts can be removed with the proper wrench. The yoke should be held securely with a special tool or a large pipe wrench as the nut is loosened. Mark the front and back yokes to ease reassembly.

Remove the speedometer gear and housing from the transfer case. Also, remove electrical switches and other external transfer case parts as necessary.

If the transfer case housing is the common two-piece type as the one shown in *Figure 8-25*, remove the bolts holding the front and rear halves together. Notice the identification tag on the transfer case. The same as previously discussed with the transmission, this should be used to order parts and to determine which service specifications you should use. The halves can then be split apart. If the gasket sticks, pry the halves apart with pry bars (*Figure 8-26*). If the housing is a one-piece type, the front and rear retainers that hold the input shaft bearings should be removed to gain access to the internal parts (*Figure 8-27*). As you see in *View A*, most bearing retainers can be unbolted from the case and then lightly pried up, always being careful not to damage any machined parts. *View B* shows the basic procedure for removing the bearing retainer and shaft on the one-piece case. Always use a soft-face hammer to avoid damaging the shaft or gears.

After accessing the internal parts, remove any snap rings that hold the transfer case gears to the shaft or secure the shafts to the housing. Then remove the internal parts as

necessary. All shafts, sliding gears, and planetary gears, if used, should be removed at this time. Refer to the service manual for detailed disassembly procedures for your particular transfer case.

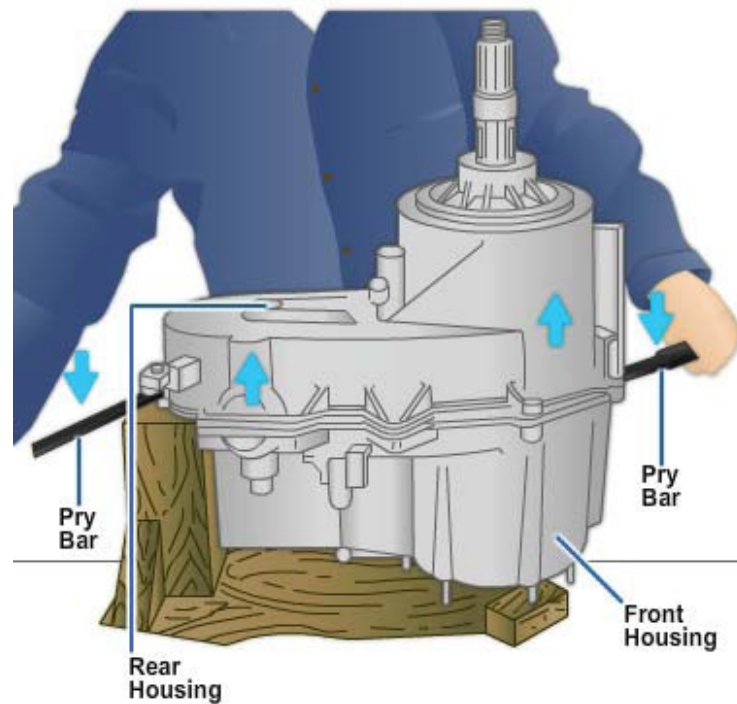


Figure 8-26 – Prying apart a transfer case housing.

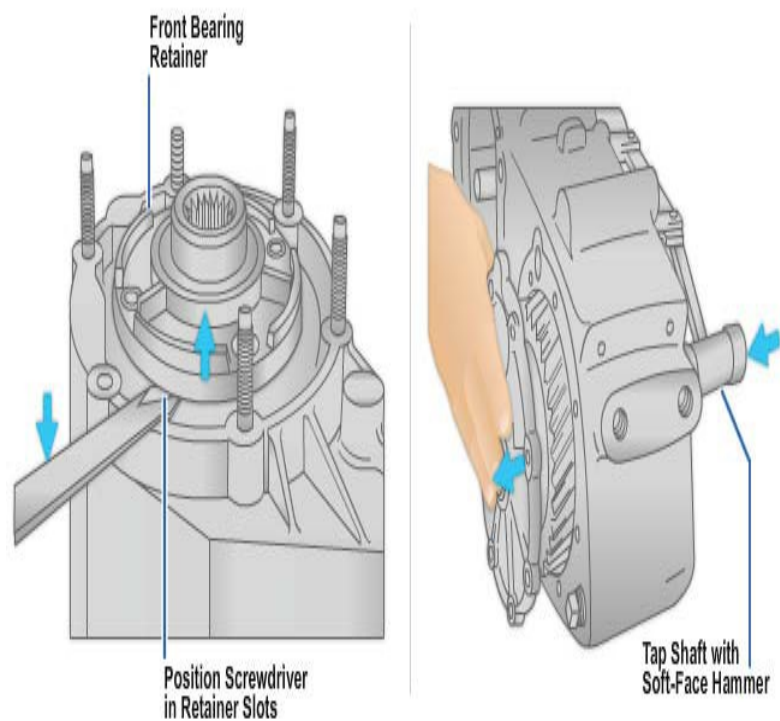


Figure 8-27 - Disassembly of a one-piece transfer case.

Figure 8-28 shows a mechanic removing a mainshaft, complete with gears, shift fork, and rail. Removal procedures for other parts are similar. Some transfer cases do not have an input shaft. Instead, the transmission output shaft is splined to the inside of the transfer case input gear. Remove the differential unit, viscous coupling, or clutch drum as applicable.

If the transfer case is equipped with a drive chain, lift the front output shaft, sprocket, and chain out of the case. In many transfer cases, the chain and sprockets are removed as an assembly. In some designs, however, it is necessary to slide the chain off the mainshaft drive sprocket during the removal process. After removing the chain and sprockets, carefully remove any thrust washers that were located under the sprocket.

While disassembling the transfer case, note the relationship of all parts so that they can be reinstalled properly. If necessary, mark the parts with a punch or a scribe to ensure proper assembly.

2.2.3 Transfer Case Inspection

Before inspecting the transfer case parts, scrape all gasket material from the transfer case housing, being careful not to damage the surfaces. Check the bottom of the housing for needle bearings or other small parts. Clean the inside of the housing and all internal parts. Make sure all sludge and metal particles are removed.

After cleaning, thoroughly inspect the transfer case housing, bearing retainers, and extension housings for cracks or other damage. Additionally, check all bushings and seals for wear.

All internal transfer case parts should be inspected for wear and damage. Examine all shaft bearings, needle bearings, shift

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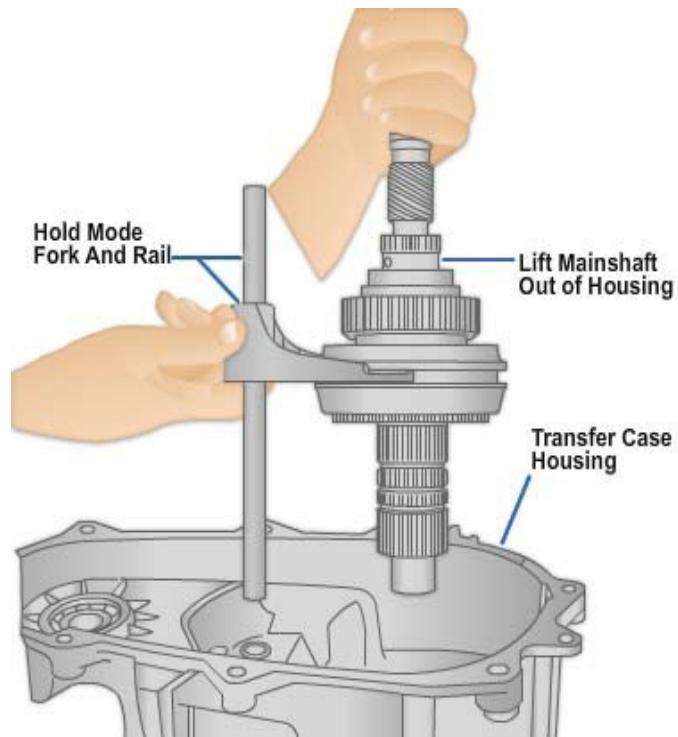


Figure 8-28 - Removal of mainshaft, complete with gears, shift fork, and rail.

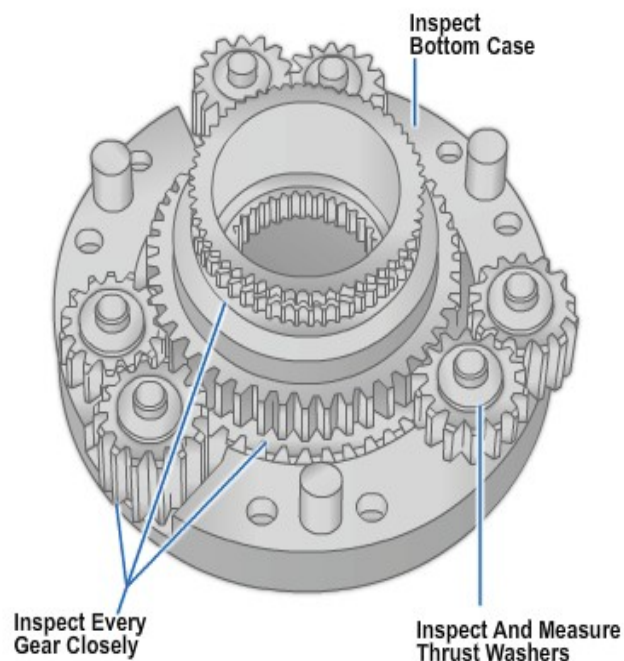


Figure 8-29 - Check planetary gear assembly.

forks, sliding clutch sleeves, and washers. Replace worn components as needed.

Figure 8-29 illustrated the checks that should be made to a transfer case planetary gear assembly. Examine the gears for worn, cracked, or chipped teeth. Damaged gears should be replaced. Check for wear between gear bushings and the shafts. Look for wear or damage to the splines on the shafts and to the planetary housings. Splines can strip off so cleanly that splined surfaces appear to be machined smooth. This makes it very important to compare these parts to specifications.

If used, check the transfer case blocking rings of the sliding clutch assembly for wear on the outer teeth. Also, inspect the areas where the inner cone ridges contact the gear cone. Replace blocking rings showing signs of wear or damage.

It may be necessary to disassemble the mainshaft to inspect the shaft-mounted components. In the service manual there may be a sectional view similar to the one shown in *Figure 8-30* which is helpful in guiding you through the proper steps in disassembling and reassembling the mainshaft without damage or incorrect assembly.

Check the sliding clutch sleeves where the shift forks ride. If the shift forks are equipped with separate pads at the riding surfaces as illustrated in *Figure 8-31*, the pad should be replaced whenever the transfer case is disassembled. Replace the entire shift fork if it is bent or worn. Seals used in areas where the shift forks or levers pass through the case should be replaced.

If the transfer case uses a differential assembly or a viscous coupling, it should be checked for wear and damage. Always follow the inspection procedures outlined in the factory service manual.

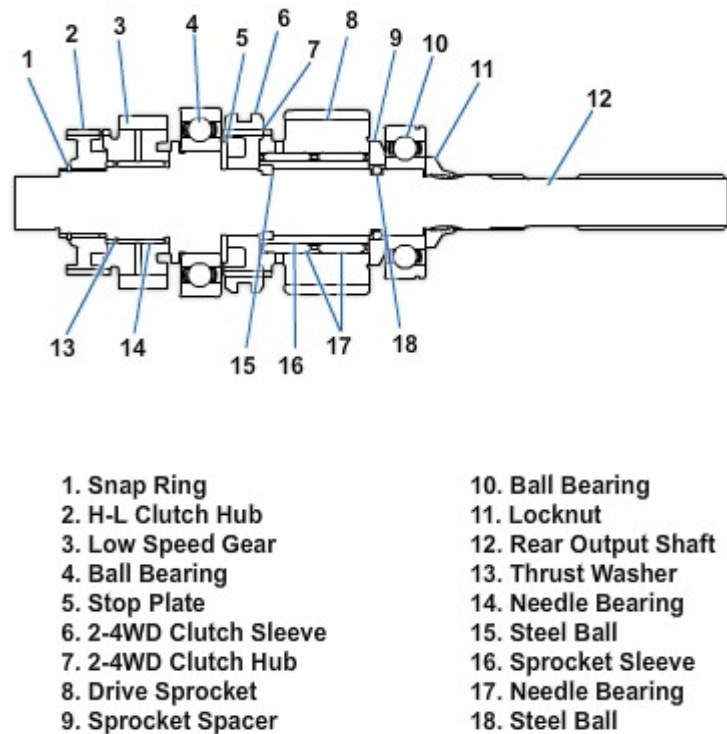


Figure 8-30 – Assembly details of a transfer case mainshaft.

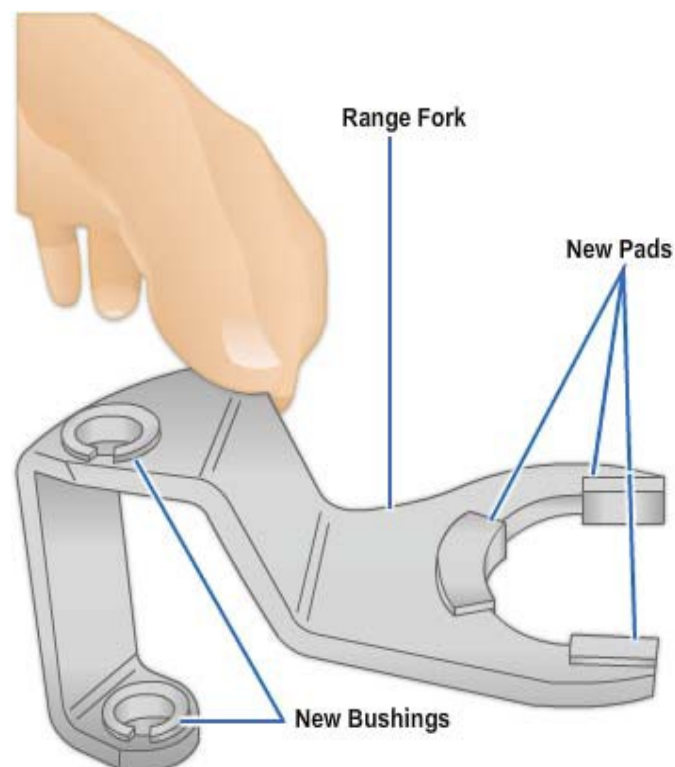


Figure 8-31 – Checking shift fork for wear.

If the transfer case has a clutch pack, carefully check the condition of the clutch plates. Replace any clutch plates that are worn or burned. Clutch pack clearance is vital to proper operation and must be carefully checked. Adjust clearance by adding or subtracting shims or replacing the existing shims with shims of the proper thickness.

2.2.4 Reassembly

The transfer case should be reassembled in the reverse order of disassembly. Before beginning, replace worn bushings and seals (*Figure 8-32*).

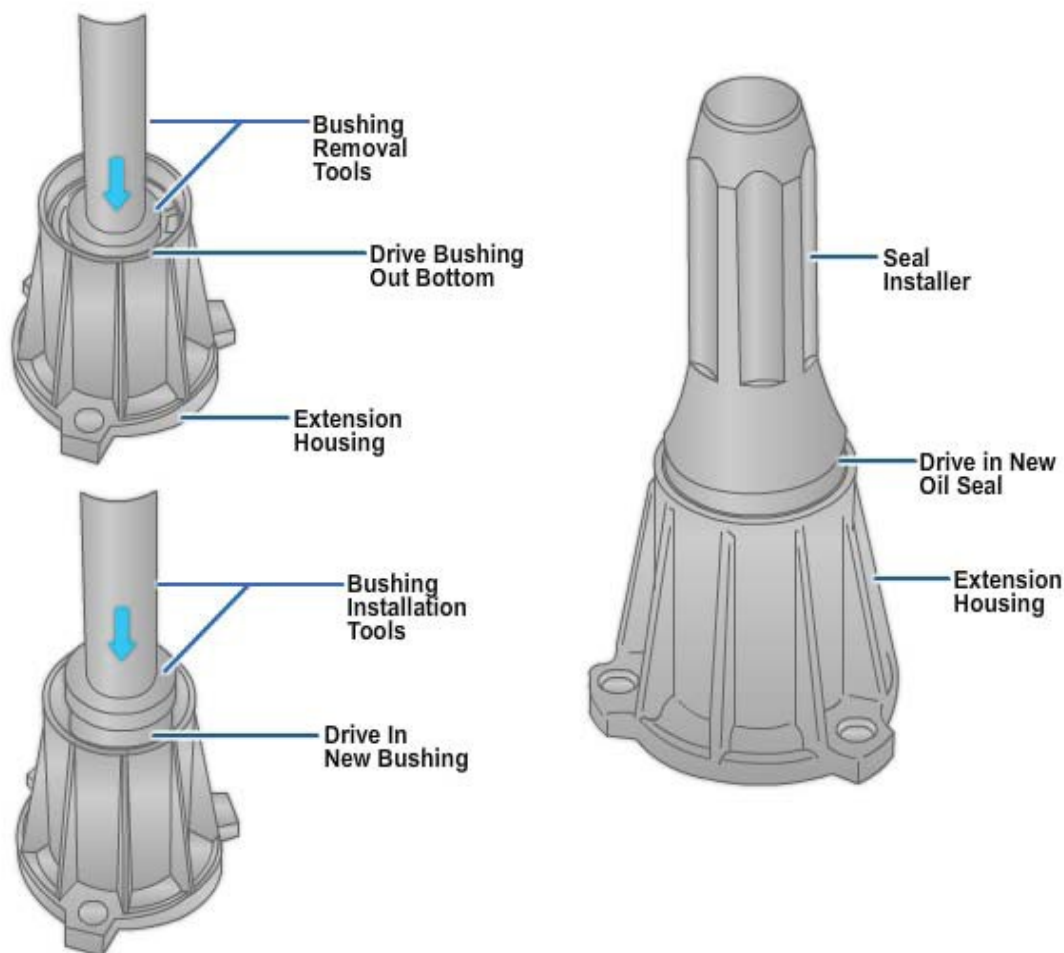
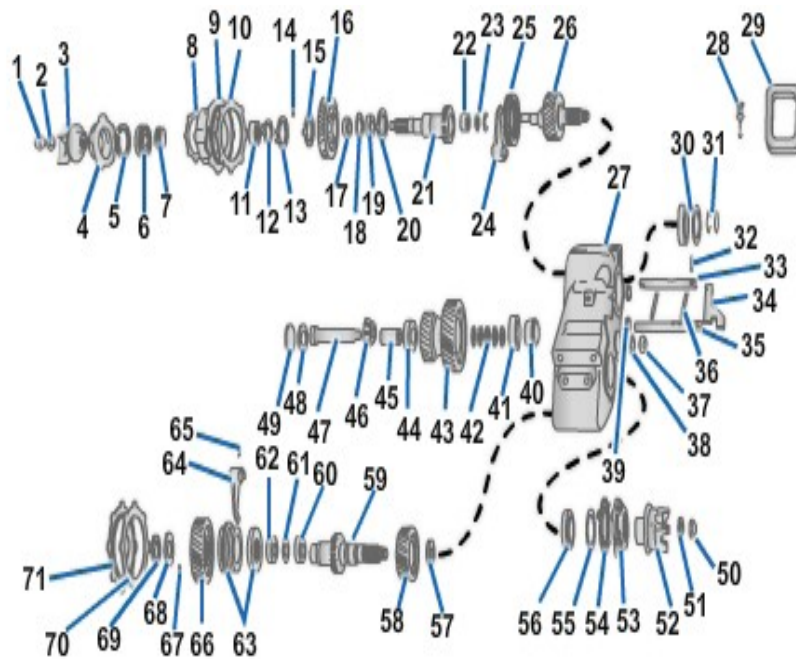


Figure 8-32 - Replacing worn bushings and seals.

Begin reinstalling the parts in the transfer case. The service manual will provide an exploded view such as the one shown in *Figure 8-33* and, along with sequential numbering, is very helpful in determining where parts are placed. Take your time and do it right the first time, especially installing the internal parts. If not, you will just have to disassemble and reassemble correctly. Reassembly procedures may vary with the transfer cases you will overhaul. The following procedures will serve as a general guide to reassembly.



- | | | |
|---------------------------------------|--|--------------------------------|
| 1. Rear output shaft locknut | 25. Sliding clutch | 48. Cover gasket |
| 2. washer | 26. Input shaft | 49. Rear cover |
| 3. Yoke | 27. Transfer case | 50. Front output shaft locknut |
| 4. Bearing retainer and seal assembly | 28. Poppet spring & ball, light switch spring & ball | 51. Washer |
| 5. Snap ring | 29. P.T.O. gasket and cover | 52. Yoke |
| 6. Bearing | 30. Input shaft bearing and snap ring | 53. Bearing retainer and seat |
| 7. Speedometer gear | 31. Snap ring and rubber ring | 54. Gasket |
| 8. Gasket | 32. Shift link clevis pin | 55. Snap ring |
| 9. Bearing | 33. Range shift rail | 56. Front bearing |
| 10. Gasket | 34. Shift rail connector link | 57. Thrust washer |
| 11. Bearing | 35. Front wheel drive shift rail | 58. Front wheel high gear |
| 12. Snap ring | 36. Interlock pins | 59. Front output shaft |
| 13. Thrust washer | 37. Rear idler lockout | 60. Needle bearing |
| 14. Thrust washer lock pin | 38. Washer | 61. Spacer |
| 15. Thrush washer (tanged) | 39. Shift rail seals | 62. Needle bearing |
| 16. Low speed gear | 40. Idler shaft bearing | 63. Synchronizer |
| 17. Needle bearing | 41. Bearing cup | 64. Shift fork |
| 18. Spacer | 42. Shims | 65. Roll pin |
| 19. Needle bearing | 43. Idler gear | 66. Front output low gear |
| 20. Tanged washer | 44. Bearing cup | 67. Thrust washer lock pin |
| 21. Rear output shaft | 45. Spacer | 68. Thrust washer |
| 22. Needle bearings | 46. Idler shaft bearing | 69. Snap ring |
| 23. Washer and retainer | 47. Idler shaft | 70. Rear cover gasket |
| 24. Shift fork | | 71. Rear cover and bearing |

Figure 8-33 - Exploded view of a typical one-piece transfer case.

Assemble the mainshaft gears and hubs onto the mainshaft. Use new parts as needed. Install all internal parts in the transfer case housing. When referring to *Figure 8-34*, notice that the shift forks are usually installed at the same time as the gears they operate. Make sure the shafts are properly seated in the bottom of the housing to avoid binding.

Install the drive chain, making sure the sprockets and shafts are properly aligned with the chain as *Figure 8-35* illustrates. After installing the chain, make sure all thrust washers are installed as shown in *Figure 8-36*. Next, install the snap rings that hold the chain and shafts in place.

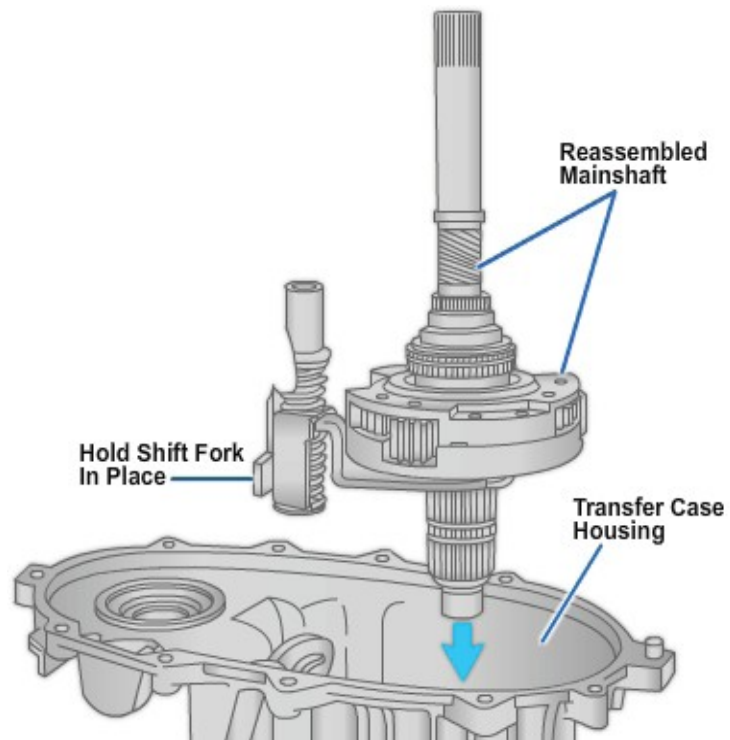


Figure 8-34 - Reassembly of internal components.

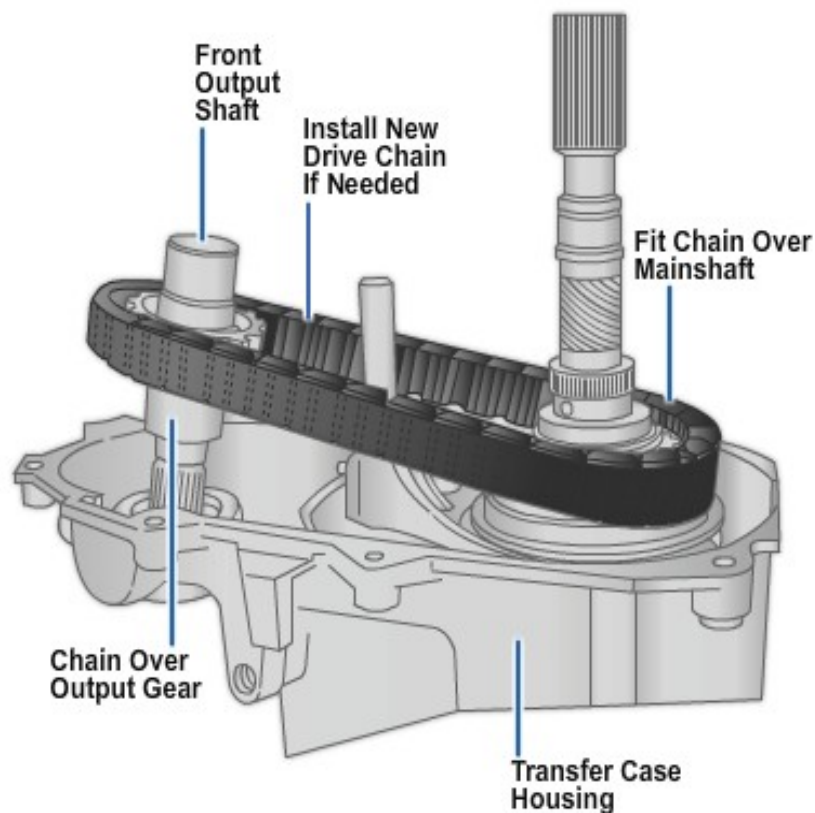


Figure 8-35 - Reinstalling drive chain and sprockets.

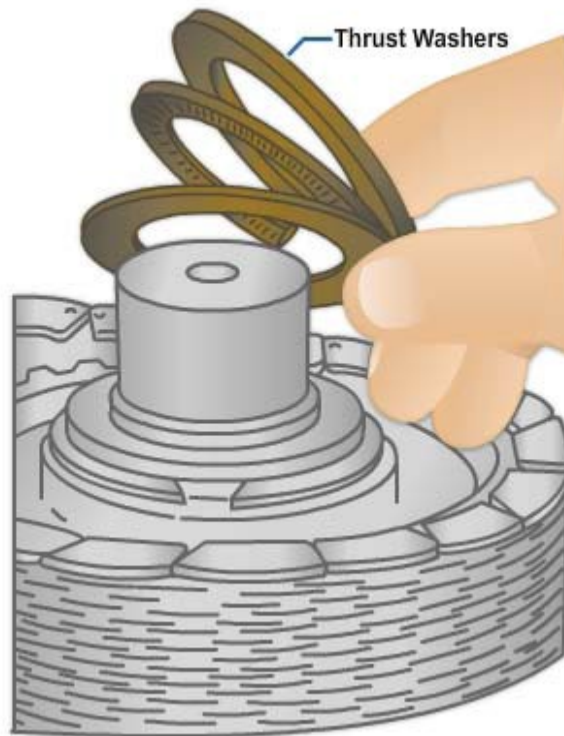


Figure 8-36 - Installing thrust washers.

On two-piece housings, place a new gasket, an appropriate sealer, or both on the mating surface of the front housing. Make one last check of all internal parts and install the rear housing on the front housing (*Figure 8-37*). Install and tighten the housing bolts. Then, make sure both shafts turn. If either shaft is binding, the transfer case must be disassembled to determine the cause.

On one-piece housings, install the bearing retainers using new gaskets. After installing the retainers, make sure the shafts turn. Do not install the transfer case if the shafts are binding; correct the problem first. Adjust the bearing preload according to the manufacturer's service manual.

Manufacturers provide specifications for shaft endplay. If specifications are provided, the endplay should be measured. If endplay is incorrect, the rear half of the housing or the bearing retainer must be removed, and thicker or thinner thrust washers must be installed.

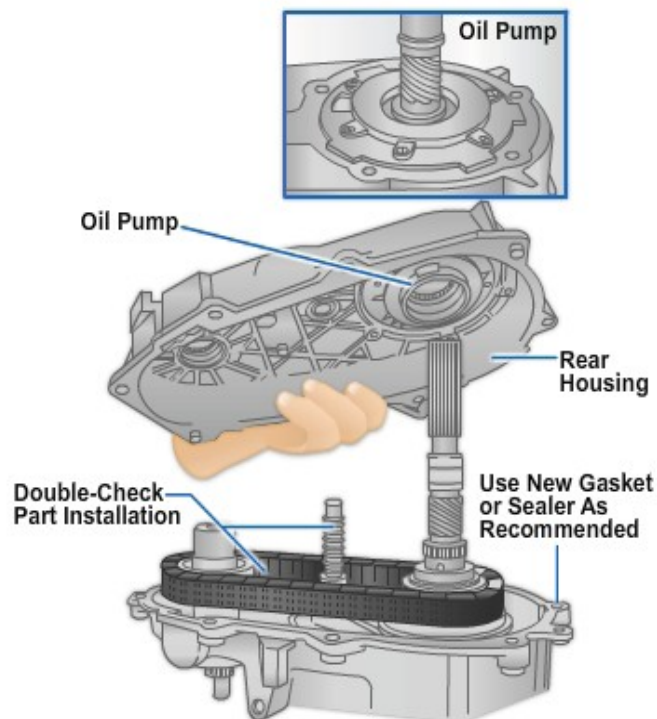


Figure 8-37 - Recheck all components before installing rear housing.

If hypoid drive and driven gears are used in the transfer case, they may require adjustment. The adjustment procedure is similar to that used for a ring or pinion (*Figure 8-38*). Be sure to refer to the service manual for detailed procedures.

Finally, install the external housing components, such as the speedometer drive gear, front and rear drive shaft yokes, electrical components, and drain and fill plugs.

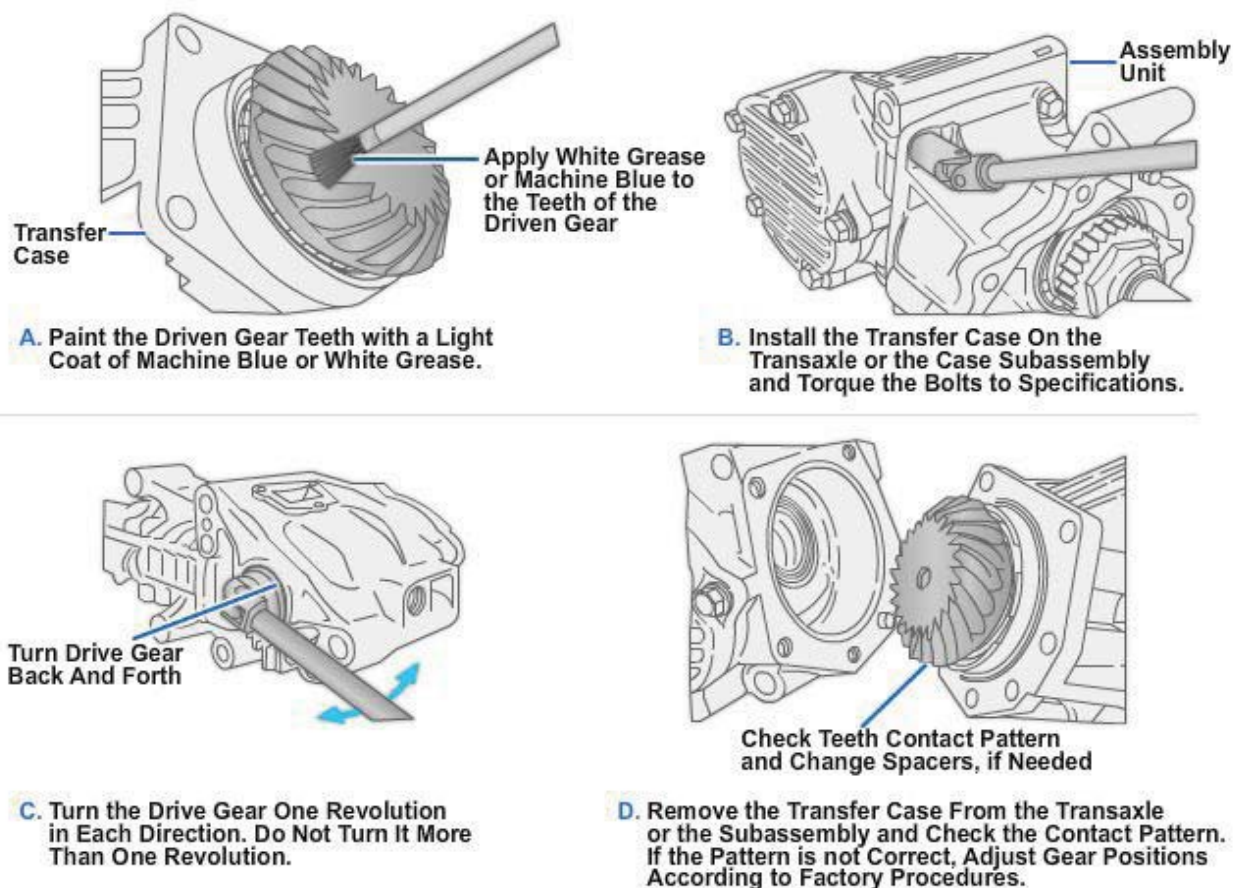


Figure 8-38 - Checking the adjustments of the hypoid gear on the transfer.

2.2.5 Installation

The transfer case is installed in the reverse order of removal. Because the transfer case is heavy and unbalanced, exercise caution when lifting it or working around it.

1. Use a transmission jack or a jackstand to raise the transfer case to the level of the transmission. Slide the case into alignment with the transmission. Work carefully to prevent damaging the splines of the transmission or the transfer case. The transmission case may have alignment lugs to make installation easier.
2. Install and tighten the bolts that secure the transfer case to the transmission. Make sure the drive shaft yokes will still turn after the transfer case is tightened.
3. If necessary, install the crossmember and rear engine mount, then remove the transmission jack.
4. Reconnect both drive shafts to the transfer case output yokes.

5. Install the transfer case shift linkage, the speedometer cable assembly, and any electrical connectors or ground straps. Install the transmission shift linkage, if removed.
6. Fill the transfer case with the proper type and amount of lubricant. Some manufacturers recommend gear oil, while others specify automatic transmission fluid. If the transmission and transfer case use the same oil, check the oil level at the transmission.
7. If necessary, install the skid plate. Then, lower the vehicle.
8. Reconnect the negative battery cable and start the engine. Road test the vehicle to make sure the linkage adjustments are correct and the transfer case operates properly. Recheck the oil level after the road test and inspect for leaks.

3.1.1 TROUBLESHOOTING the POWER TAKEOFF

A variety of accessories on heavy-duty trucks and construction equipment require an auxiliary drive. Auxiliary drive can be sourced directly from the engine or by means of the transmission or transfer case. Auxiliary drive systems are power takeoffs or PTOs. When a PTO is coupled to the transmission or transfer case, it is an assembly such as the two shown in *Figure 8-39*. Vehicles and equipment that have a PTO are wreckers, fuel tank trucks, dump trucks, cement transit mixers, fire trucks, water well drilling rigs, auger trucks, aerial bucket trucks, lube trucks, and cranes.

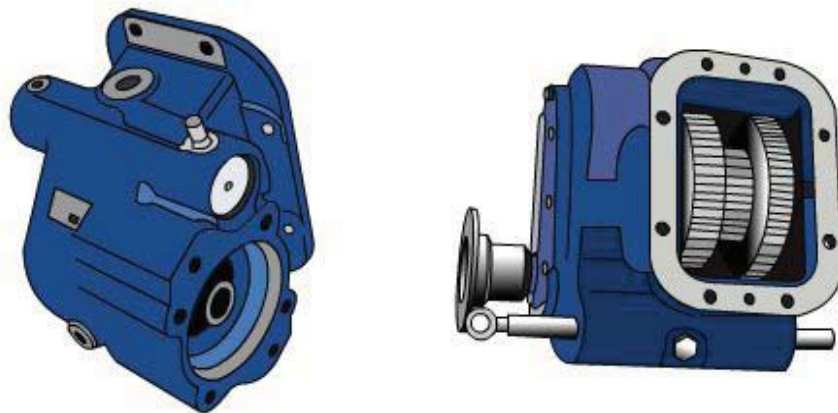


Figure 8-39 - Power takeoffs are used to operate auxiliary equipment.

The PTO is simply a means of using the chassis engine to power accessories, eliminating the need for an additional auxiliary engine. There are six basic types of PTOs classified by their installation or drive source:

1. Side mount-is bolted to the side of the main transmission and is the most common type found on trucks.
2. Split shaft-transmits torque from the chassis driveshaft, is located behind the transmission and requires special mounting to the chassis frame.
3. Top mount-is usually found mounted to the top of an auxiliary transmission.
4. Countershaft-is mounted behind the transmission and when used replaces the bearing cap located at the rear of one countershaft on a twin-countershaft transmission.

5. Forward crankshaft driven-is driven by gearing at the front of the engine crankshaft, and is used in applications that require auxiliary power while the truck is in motion, such as a cement truck.
6. Rear crankshaft or flywheel driven-is sandwiched between the bell housing and the transmission and permits continuous operation while the engine is running.

The objective of a PTO is to provide driving torque to auxiliary equipment such as pumps, compressors, and winches. The driven equipment can be mounted either directly to the PTO or indirectly using a small drive shaft. The PTO input gear is placed in constant mesh with a gear in the truck transmission. The PTO may couple into a transmission by a means of a dedicated PTO gear on the transmission countershaft. Any rotation of the PTO countershaft gear drives the PTO input gear. The on/off capability required by a PTO is provided within the PTO assembly.

Gears in most PTO units can either be spur or helical. Establishing the correct mesh between the PTO drive gear and its partner in the transmission is critical: too little or too much backlash can produce problems. Backlash is defined as the space between meshing surfaces of the gears in gearbox devices. Space is needed for expansion caused by heat and viscosity changes in lubricants. Refer to the PTO service manual for the correct backlash adjustment procedure which is to be performed on every PTO installation. Use of a dial indicator is recommended. The recommended backlash between the transmission and PTO is from .006 to .012 inches.

Too many gaskets will create too much backlash and cause the PTO to rattle when running at no load. To correct - remove one or more gaskets and recheck backlash. Too few gaskets will cause PTO to whine and may cause difficult shifting of the PTO and transmission. To correct - add one or more gaskets and recheck backlash. PTOs will not always make noises when improperly spaced. Correct backlash must also be established when gear adapters are used. Transmissions using automatic transmission fluid may have higher noise levels caused by the thinner consistency of the lubricant and the large PTO drive gear in the transmission.

Gear ratio is also critical in PTO operation. Gear ratio must be set to the torque capacity and operating speed required of the driven equipment.

As previously mentioned, some PTOs function when the vehicle is running and they can operate at a fixed ratio of engine speed, while others vary depending on which gear the transmission is in. Other PTOs are designed to work only when the transmission has been shifted to the neutral position. All transmission-mounted PTOs are clutch-dependent in that they transmit torque only when the vehicle clutch is engaged. Flywheel and forward crank-shaft-driven PTOs operate independently of vehicle clutch engagement, so they are used in applications where continuous auxiliary power is required as previously mentioned; a cement transit mixer is an example.

Several types of shift mechanisms are used to connect the power takeoff with operator controls. Cable, lever, electric-over air, and electric are options used on trucks. The newest version is electronic-over electric PTOs.

Most PTOs feature simple designs and rugged construction. Care should be taken to properly mount a PTO. Setting backlash to specification is critical; this operation is performed by setting the gasket thickness at the PTO mounting flange. Contaminated transmission oil can damage a PTO, so regular maintenance is important.

3.1.0 PTO Maintenance

The power takeoff, being an integral part of the transmission, should be serviced at the same intervals as the transmission. Transmission fluid changes should follow the interval recommended by the vehicle manufacturer for severe service. Transmission oil level is important. Checking for PTO leaks and checking the transmission oil level should be done on a regular basis.

The PTO is also part of a system. The PTO system may include the activation control parts, a driveshaft, or hydraulic pump. This PTO requires periodic checks and service. Typically the interval for maintenance checks of the PTO system depends on the application of the system. Every time the chassis is lubricated or a mechanic is under the vehicle, the PTO system should be checked and serviced. For severe duty PTO system applications, it is recommended that the system be checked for service every 100 hours of use. Service should include checking and lubricating direct mount pump shaft connections. PTO gears can be checked for wear by removing the inspection or shifter cover. If pitting, galling, cracking, or deformation of the gears has occurred, then the PTO needs to be rebuilt or replaced.

After installing a new PTO or overhauling, recheck the PTO within the first week of use. Check for leaks and loose mounting hardware such as studs, cap screws, and nuts. Recheck the cable or lever connections for proper adjustment and tighten any loose connections. At regular maintenance intervals, check adjustments, lubricate moving parts, and tighten and repair the connections, mounting hardware, and cable or lever linkages.

Pumps that are mounted directly to the PTO output require the application of an antiseize or a high temperature, high pressure grease. The purpose of this grease is to help make the PTO easier to service and to reduce the effects of fretting corrosion on the mating PTO and pump shafts. PTO applications under severe duty cycles and/or high torque requirements may require servicing this shaft connection, periodically re-greasing the vibrations inherent in these vehicles. Fretting corrosion cannot be stopped by applying grease; the grease is only a deterrent.

If the system utilizes a driveline between the PTO and another device and if you have noise in your system that was not there before, the angularity or phasing of your driveline may be the cause. Check driveline angularity and reduce total angularity per the recommendation in *Figure 8-40*, and be sure the PTO shaft is parallel within 1.5° to the pump shaft (or driven unit). Drivelines must be in phase, that is, the yoke ears on the PTO and pump shafts must be in alignment; *Figure 8-41* provides a quick reference for troubleshooting a power takeoff.

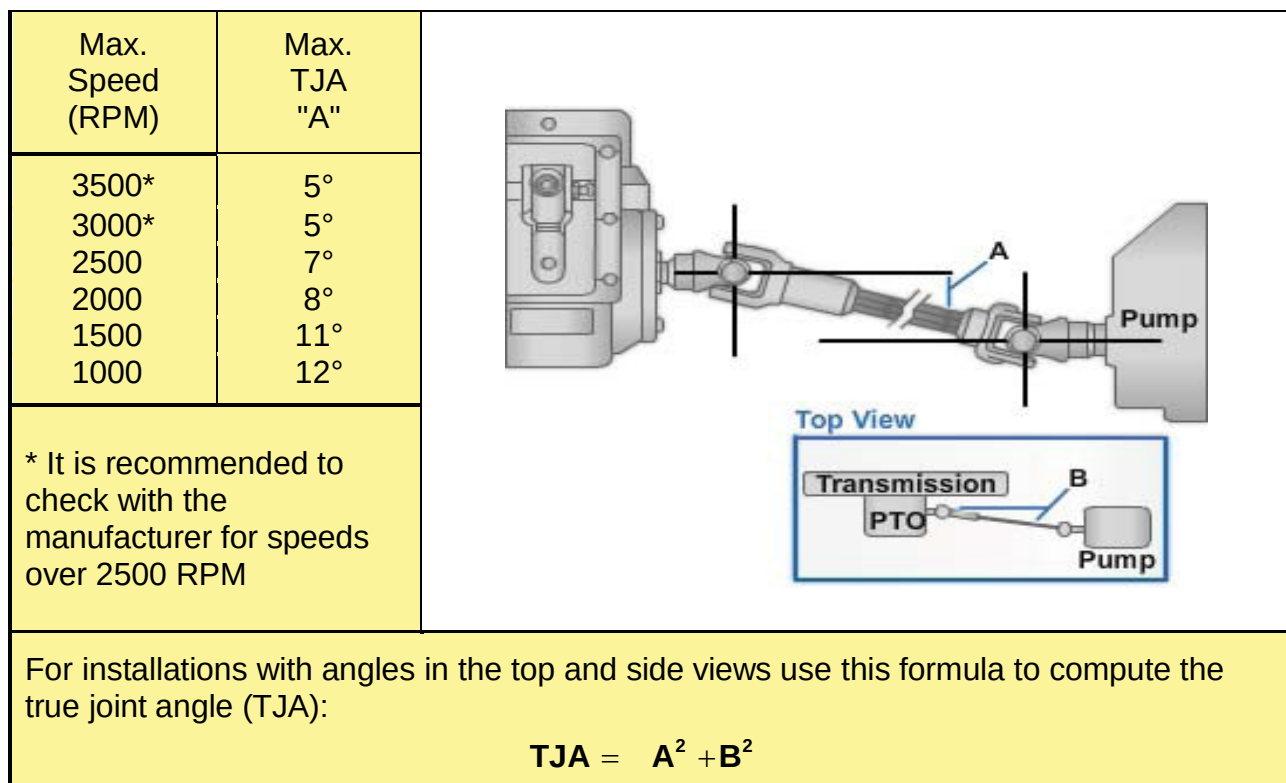


Figure8-40-PTO driveline angularity.

Troubleshooting the Power Takeoff		
Condition	Possible Causes	Correction
Noisy power takeoff.	1. Stripped gears. 2. Worn bearings. 3. Worn shaft splines	1. Replace defective gears. 2. Replace defective bearings. 3. Replace shafts.
Slipping out of gear.	1. Gears partially engaged. 2. Weakened poppet springs.	1. Correctly adjust shift linkage. 2. Replace springs.

Figure 8-41 - Power takeoff quick reference diagnosis.

4.1.1 TROUBLESHOOTING the PROPELLER SHAFT ASSEMBLY

Propeller shafts or driveshafts have a simple function: to transmit drive torque from one driveline component to another. This should be accomplished in a smooth, vibration-free manner. In a heavy-duty truck, that means transmitting engine torque from the output shaft of the transmission to a rear axle or to an auxiliary transmission. Driveshafts also are used to connect forward and rear axles *Figure 8-42* shows the driveshaft arrangement used in a tandem drive tractor equipped with an auxiliary transmission.

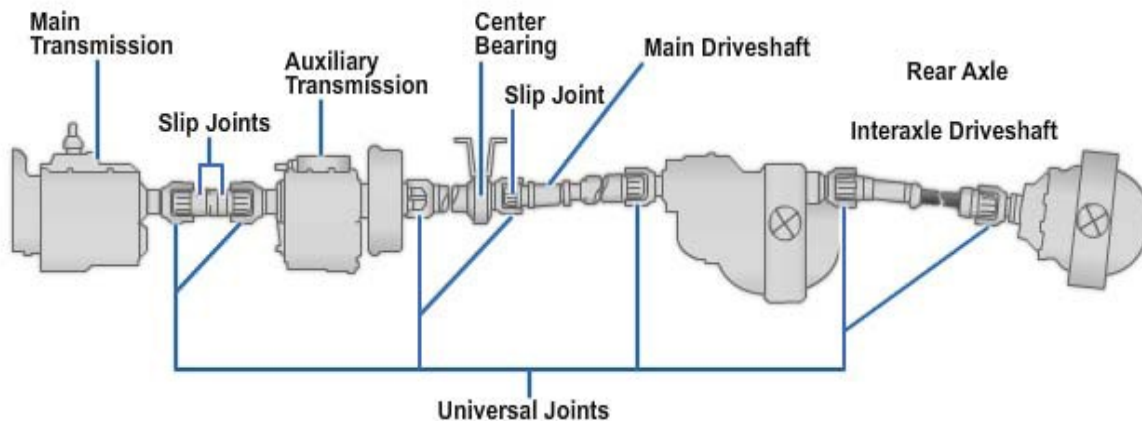


Figure 8-42 - Driveshafts transmit torque between driveline components.

In most cases, a driveshaft is required to transfer torque at an angle to the centerlines of the driveline components it connects to. Because the rear drive axle is part of the suspension and not connected to the rigid frame rails of the vehicle, the driveshaft must be capable of consistently changing angles as the rear suspension reacts to road or terrain profile and load effect. In addition to being able to sustain constantly changing angles, a driveshaft must be able to change in length when transmitting torque. When the rear axle reacts to terrain or road surface changes, torque reactions, and braking forces, it pivots both forward or backward, requiring a corresponding change in the length of the driveshaft.

A driveshaft assembly is made up of the following:

1. Universal joints (U-joints)
2. Yokes
3. Slip splines
4. Propeller shafts

The propeller shafts have a tubular construction designed to sustain high torque loads and be light in weight. *Figure 8-43* shows the components of a typical heavy-duty truck driveshaft.

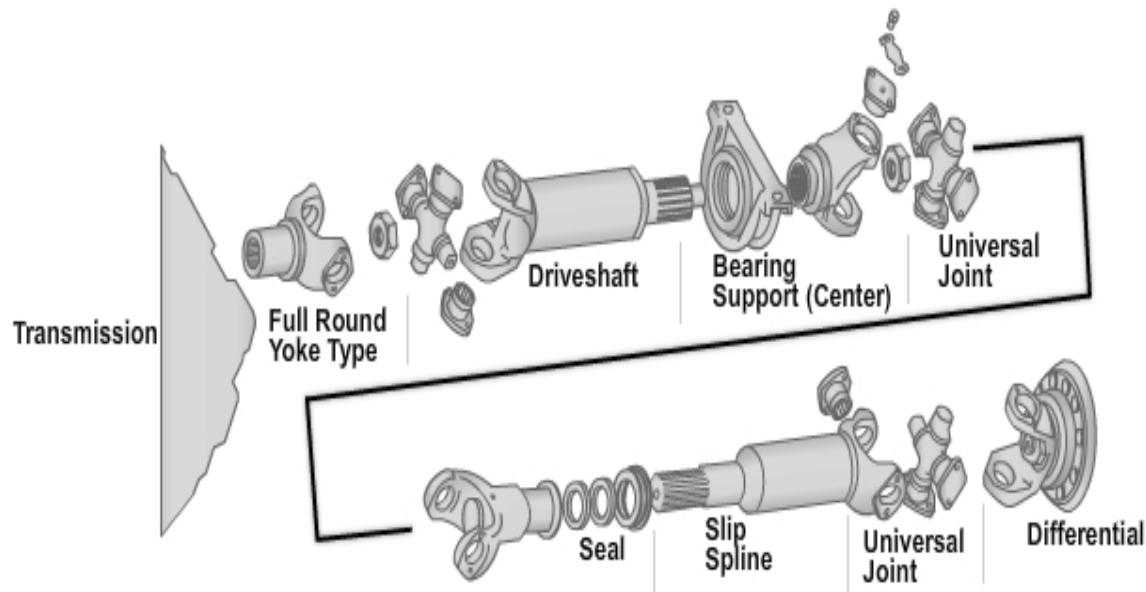


Figure 8-43 - Exploded view of a heavy-duty truck driveshaft.

4.1.0 Driveline Geometry

Two types of driveline configurations are used to transmit drive torque to the drive wheels: the parallel-joint driveline and the non-parallel or broken-back driveline. In the parallel-joint type, all the companion flanges or yokes in the driveline are on a parallel plane to each other with working angles of the joints of a given shaft being equal and opposite (*Figure 8-44*). For instance, if the transmission output shaft centerline angles down 5 degrees from a true horizontal plane, the centerline at the front of the auxiliary main shaft or rear axle pinion shaft must angle 5 degrees up.

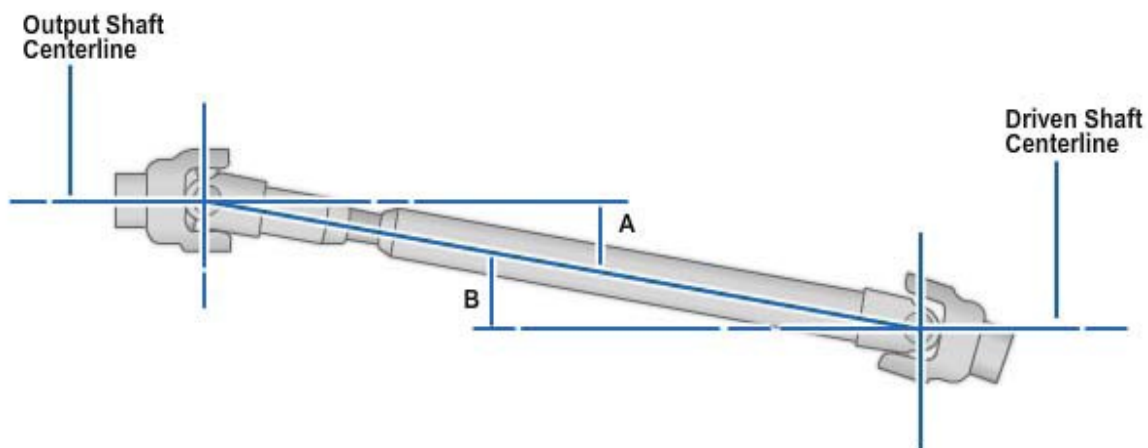


Figure 8-44 - Parallel joint driveline arrangement.

With the no-parallel or broken-back installation, the working angles of the U-joints of the driveshaft are equal, but the companion flanges and/or yokes are not parallel (*Figure 8-45*). For example, the transmission yoke is angled 3 degrees down from horizontal plane, while the rear axle pinion flange is angled up at 12 degrees. Providing that the U-joint angles of this propeller shaft remain equal, the shaft will run vibration free.

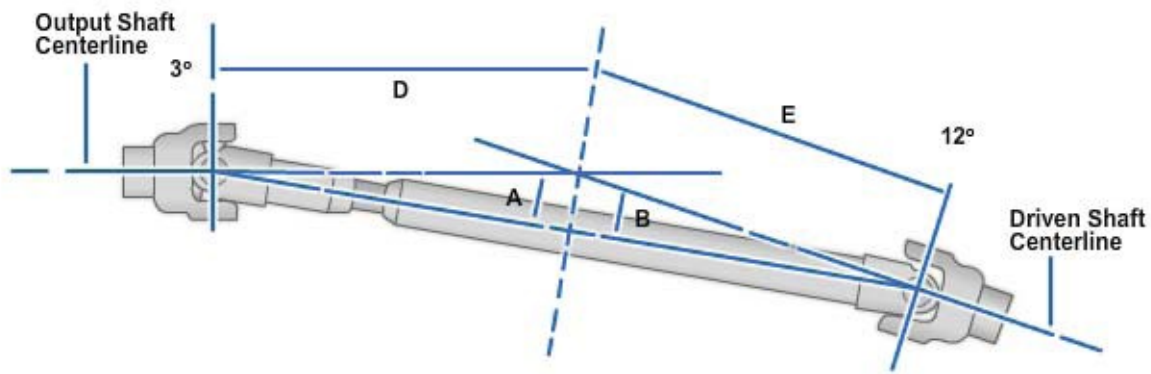


Figure 8-45 - "Broken back"-type driveshaft, angles A and B are equal.

4.1.1 joint Working Angles

Proper U-joint working angles are required for vibration-free and long-lasting driveline operation. Most drivelines are angled on a vertical plane as shown in *Figure 8-46, View A*, but on some trucks, the drivelines are also horizontally offset (angled) as shown in *Figure 8-46, View B*. When a driveshaft is angled on both the vertical and horizontal planes, a compound angle exists.

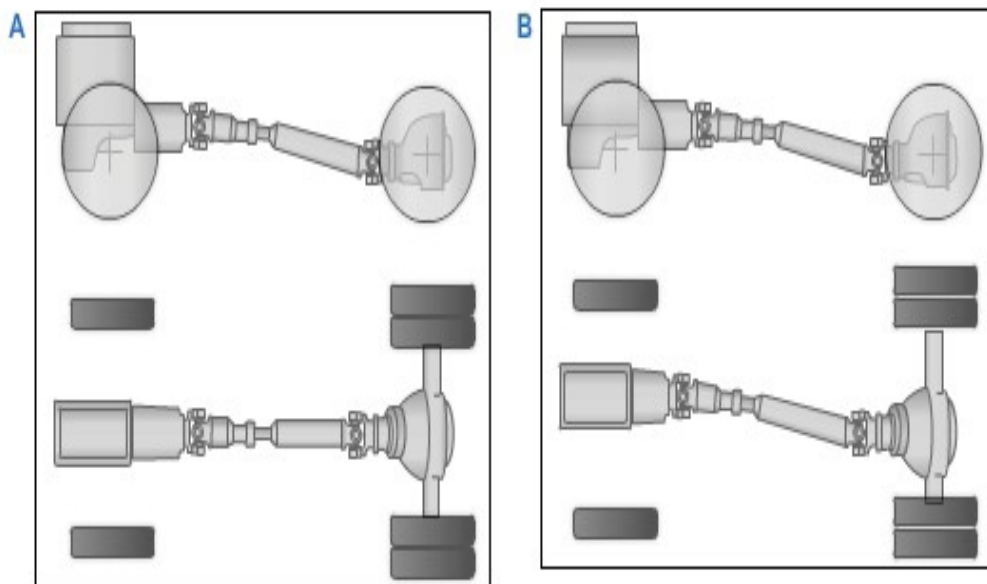


Figure 8-46 - One-plane-angle and two-plane angle driveshafts.

All U-joints have a maximum working angle at which they can smoothly transmit torque. This working angle depends in part on the U-joint size and design. Exceeding the maximum recommended working angles of U-joints can destroy a U-joint rapidly and also damage interconnected driveline components.

High working angles combined with high rpms tend to result in a reduced U-joint life. Unequal U-joint working angles can cause vibrations and contribute to U-joint transmission, and differential problems. Ideally, the operating angles on each end of a driveshaft should be equal or within 1 degree of each other and have a 3-degree-

maximum operating angle. Driveshaft rpm is the primary factor in determining the maximum allowable operating angles in a give application.

Figure 8-47 correlates expected driveshaft rpms with maximum working angles. You can see that the faster a driveshaft turns, the lower the allowable working angle drops. Angles are calculated at the U-joints as the driveshaft angles downward from the transmission to connect to the input yoke on the rear axle differential carrier yoke. For example, a 2,100 rpm engine running through a fast overdrive transmission and a fairly slow axle ratio might turn

Driveshaft rpm	Maximum Normal Operating Angles
5000	3°15'
4500	3°40'
4000	4°15'
3500	5°00'
3000	5°50'
2500	7°00'
2000	8°40'
1500	11°30'

Figure 8-47 - Maximum U-joint angles.

a driveshaft faster than 3,000 rpm. This would limit the maximum permissible angle to 5 degrees, measured as the truck sits on level pavement.

With equal working angles, the rear U-joint will slow down by the same amount that the forward joint speeds up during a rotation, resulting in U-joint cancellation. The driving and driven shafts will turn at constant and identical speeds. If the working angles of two opposed U-joints vary more than 1 degree, the driveshaft will not rotate smoothly because it accelerates and decelerates during a cycle. The result is vibration and ultimate U-joint failure.

U-joint working angles become greater when the vehicle suspension flexes over uneven road surfaces. If this occurs at slow speeds, it should not be a major problem unless driveline angles are high to begin with. Driveline angles tend to present fewer problems these days than when tractors with a short wheelbase were mandated to keep vehicle overall length within legal limitations. Relaxation of those legal restrictions has led to the use of a longer wheelbase that allows driveshafts to be longer and eliminates aggressive U-joint working angles.

The longer the driveshaft, the greater the weight and therefore the greater the radial forces, especially as driveshaft rpm increases. At high speeds, balance becomes more critical. This is why manufacturers limit tube length. For example, at 3,000 rpm the length of any single driveshaft section, measured between the centerline of the U-joints at either end, should not usually exceed 70 inches.

4.1.2 Driveline Phasing

Heavy-duty U-joints have a unique characteristic. Because they are always operating at an angle, they do not transmit constant torque or turn at a uniform speed during their 360-degree rotation (*Figure 8-48*).

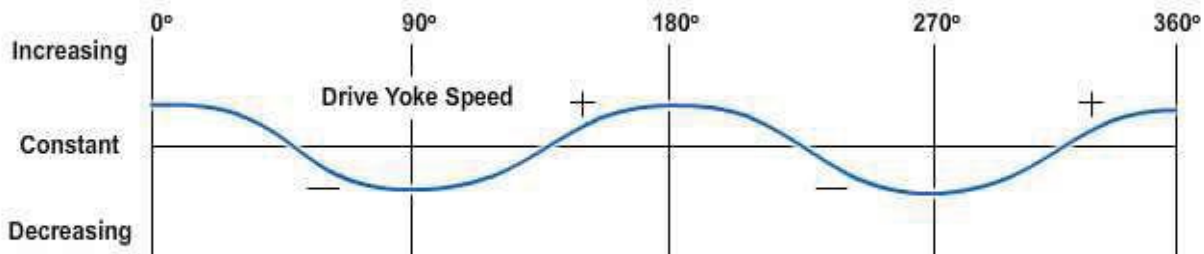


Figure 8-48 - A driveshaft will increase and decrease speed once each revolution.

With the drive yoke turning at a constant rpm, a driveshaft increases and decreases speed once each revolution. To counterbalance this fluctuation above and below mean (average) driveshaft speed, the U-joints must be positioned in-phase with each other as demonstrated in *Figure 8-49*. An out-of-phase condition produces an effect similar to what occurs when two children are turning a rope, and the rope is snapped on one side; by contrast, if the rope is snapped at both ends at the same time, the resulting waves through the rope cancel each other, and neither child feels the reaction of the wave the snap causes.

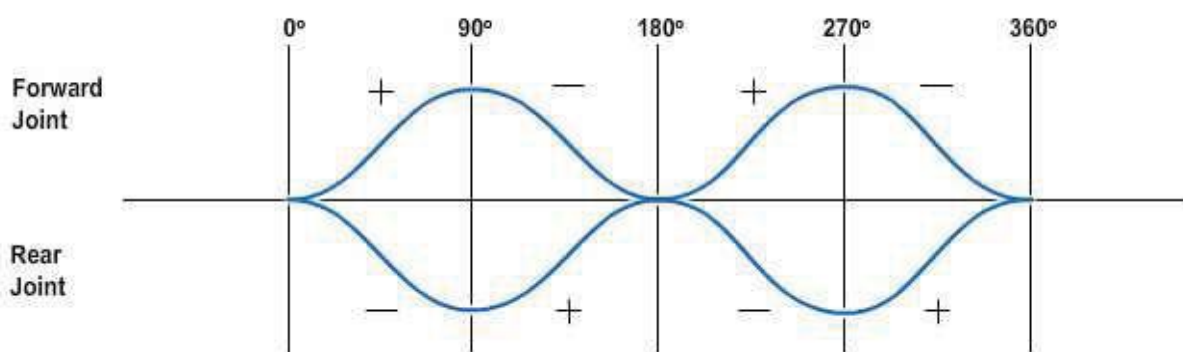


Figure 8-49 - Two universal joints in-phase will cancel out the speed fluctuations in the driveshaft.

When in phase, the slip yoke lugs (ears) and welded yoke at the opposite end should be perfectly in line as illustrated in *Figure 8-50*. If a driveshaft is assembled one spline out, the driveshaft is out of phase and the result can be a significant vibration. There should be opposing alignment arrows stamped on the slip yoke and on the tube shaft so you

can assemble a driveshaft in phase. If a driveshaft is not marked with timing arrows, do it yourself. Make a light score mark using a steel scribe.

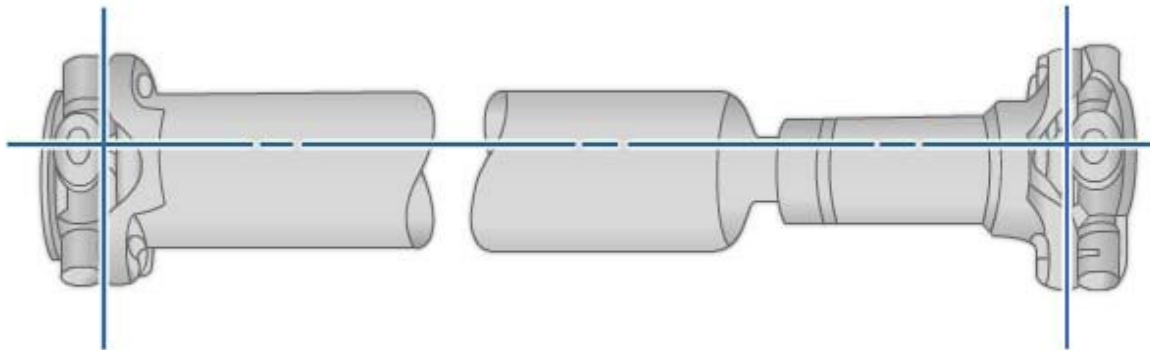


Figure 8-50 – Driveshaft in phase.

4.2.1 Driveshaft Inspection

Driveshafts should be routinely inspected and lubricated. Driveline vibrations, U-joint failures, and hanger bearing problems are caused by such things as loose end yokes, excessive radial play (side-to-side), slip spline play, bent driveshaft tubing, and missing lube plugs in slip joint assemblies.

You can limit driveshaft performance problems by performing some simple inspection procedures each time the driveshaft is lubed.

1. Check the yokes on both the transmission and drive axle(s) for looseness. If loose, disconnect the driveshaft and re-torque the end yoke retaining nut to the OEM specification. If this does not correct the problem, yoke replacement may be required. If you do not have to replace the yoke, check the OEM recommendation regarding replacement frequency of the end yoke retaining nut.
2. If end yokes are tight, check for excessive radial looseness of the transmission output shaft and drive axle input and output shafts in their respective bearings. Consult transmission and OEM specifications for acceptable radial looseness limits and method of checking. If the radial play exceeds the specifications, the bearing should be replaced.
3. Check for looseness across the U-joint bearing caps and trunnions. This looseness should not exceed the OEM specification (typically as little as 0.006 inch).
4. Check the slip splines for radial movement. Radial looseness between the slip yoke and the driveshaft stub should not exceed the OEM specification (typically as little as 0.007 inch).
5. Inspect the driveshaft for damage, bent tubing, or missing balance weights. Ensure there is no buildup of foreign material on the driveshaft, such as asphalt or concrete. Anything adhering to the driveshaft has the potential to unbalance it.
6. Check the hanger bearing visually, making sure it is mounted securely. Check for damaged seals, rubber insulator failure, or lubricant leaking from the bearing.

Replace the hanger bearing if there is evidence of damage. Do not attempt to repair or lubricate it.

4.3.0 Lubrication

One of the most common causes of U-joint and slip joint problems is the lack of proper lubrication. If U-joints are properly lubricated at recommended service intervals, they will meet or exceed their projected operating life span. Regular lubing ensures that the bearings have adequate grease and, additionally, that the trunnion races are flushed, which removes contaminants from the critical surface contact areas.

Clean grease fittings thoroughly to remove accumulated grease and abrasives before use. Any contaminants and abrasives can be forced through the grease fitting into the bearing during lubing.

A hole in each trunnion leads to the center of the cross (*Figure 8-51*). A grease fitting often connects to the center of the cross. Grease injected through the fitting flows through the holes in the trunnions to each needle bearing. Some universal joints are sealed at the factory and cannot be greased unless they are disassembled.

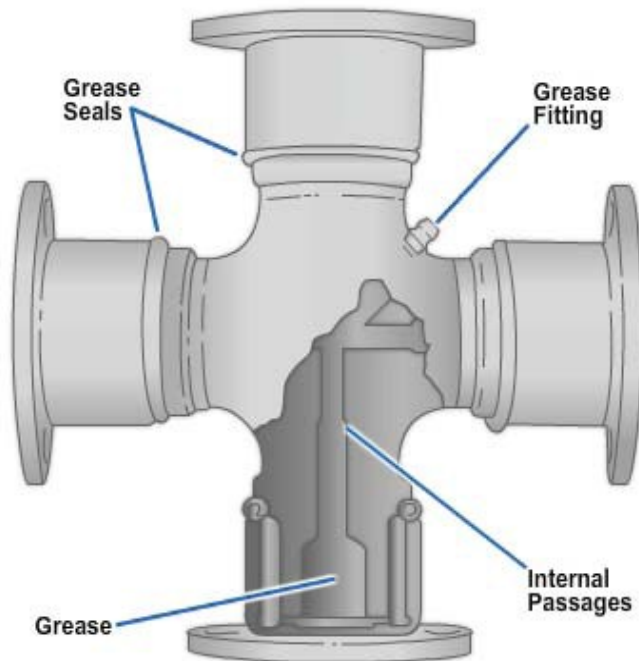


Figure 8-51 - Internal passageways in this cross-and-roller universal joint act as a grease reservoir.

4.3.1 4.3.1 U-Joint Lubricants

Heavy duty driveshafts typically use lithium soap-based extreme pressure (EP) grease, National Lubricating Grease Institute classification grades 1 and 2 specifications. Grades 3 and 4 are not recommended; because of their greater thickness they are less effective in the cold. Most lubed-for-life bearings use synthetic greases. When replacing a U-joint, note that the grease in the U-joint is only there to protect it during shipping and storage. Lubing the U-joint after installation is a service requirement and should never be put off. Lubrication schedules can vary greatly depending on operating conditions. Off-road equipment generally requires that the severe duty cycle recommendations on lube charts be followed. Off-road classifications are generally considered to apply to equipment that operates on unpaved roadways for 10% or more of the time.

4.3.2 Lubricating a U-Joint

1. Apply chassis grease through either one of two zerk fittings on the U-joint cross. Fit the grease nozzle over the zerk nipple. Pump grease slowly into the fitting until each of the four trunnion seals pops. Allow a small quantity of the old grease to be forced out of the bearings. This flushes contaminants out of the bearings and helps ensure that all four have taken grease. The U-joint is properly greased when evidence of purged grease is seen at all four bearing trunnion seals.



WARNING

If grease is seen to exit only from three of the four trunnion seals, the bearing is not properly lubed and will almost certainly fail. You must take appropriate corrective action when U-joints fail to take grease. If a driveshaft separates because of a U-joint failure, it can take out air tanks and fuel tanks, and can generally cause damage that greatly exceeds the cost of replacing a single U-joint.

2. If grease does not exit from a U-joint trunnion seal, try forcing the driveshaft from side to side when applying gun pressure. This allows greater clearance on the thrust end of the bearing assembly that is not purging. If the U-joint has two grease fittings, try greasing from the opposite fitting. If this does not work, proceed to the next step
3. Back off the bearing cap bolts on the trunnion that is not taking grease and pop the cap out about 1/4 inch. Apply grease. This usually will cure the problem, but if it does not, you should remove the U-joint to investigate the cause.
4. After working the U-joint that fails to take grease, make sure you torque the bearing cap bolts to the OEM specification.



CAUTION

Half-round end yoke self-locking retaining bolts should not be reused more than five times. If in doubt as to how many times the bearing bolts have been removed, replace with new bolts.

4.3.3 Slip Splines

The chassis lubricant used for U-joints is satisfactory for use on slip splines. An EP grease meeting NLGI grade 1 or 2 specifications is required. Slip splines should be lubed on the same service schedule as U-joint intervals.

1. Apply grease to the zerk fitting until lubricant appears at the relief hole at the slip yoke end of the slip spline assembly.
2. Seal the pressure relief hole with a finger and continue to apply grease until it starts to exit at the slip yoke seal. Sometimes it is easier to purge the slip yoke by removing the dust cap and reinstalling it after grease appears.



CAUTION

In cold temperatures, you should drive the vehicle immediately after lubricating the driveshafts. This activates the slip spline assembly and removes excessive lubricant. Excess lubricant in slip splines can freeze in cold weather to a wax consistency and force the breather plug out. This would expose the slip joint to contaminants and eventually result in wear and seizure.

4.3.4 Lubricating Hanger Bearings

Hanger bearings are usually lubed for life by the manufacturer and are not serviceable. However, when replacing a support bearing assembly, fill the entire cavity around the bearing with chassis grease to shield the bearing from water, salt, and other contaminants. You should put enough grease to fill the cavity to the edge of the slinger around the bearing.

When replacing a hanger bearing, make sure you look for and do not lose track of the shim pack that is usually located between the bearing mount and cross member. The shims set the driveshaft angles, and omitting them will result in a driveshaft vibration.

4.4.0 U-Joint Replacement

Replacing U-Joints is a routine shop task and usually requires no special tools. However, an arbor press or U-joint puller can make the procedure easier and reduce the risk of damaging the yoke. In most truck applications, you do not have to raise the vehicle to perform a U-joint replacement. You should begin by removing the grease fittings because these are easily sheared during the removal process.



When removing a driveshaft with half-round or flange type yokes, support the weight of the driveshaft with a sling before separating the U-joints.

Before removing a driveshaft, mark the slip yoke assembly and tube shaft with a paint stick to ensure the correct phasing alignment on reassembly. If the shaft assembly is to be cleaned before reassembly, use a steel scribe to indent alignment marks (*Figure 8-52*).

4.4.1 ving U-Joints

The key here is to use the least amount of force possible.

Although U-joints are relatively inexpensive and commonly replaced, the driveshaft, yokes, and slip spline assembly are expensive and designed to last the life of the vehicle.

4.4.1.1 Bearing Plate U-joints

The removal procedure is as follows:

1. If the U-joint is connected to full round yokes with bearing cups, use a hammer and a chisel to bend back the lock tabs away from the bolt.
2. Then remove the four bolts on the two end caps on the yoke you are separating.
3. There are several ways to remove the bearing assemblies from the end yoke bores. A hydraulic jack can be used to apply a pressure under the driveshaft, raising the bearing cup up out of the yoke bore. If you use this separation method, you use the weight of the truck, so you can expect it to give suddenly. Gently tap on the outside of the yoke with a light hammer if the bearing cup does not loosen when initial pressure is applied. After the bearing cup has been exposed above the bore, it can usually

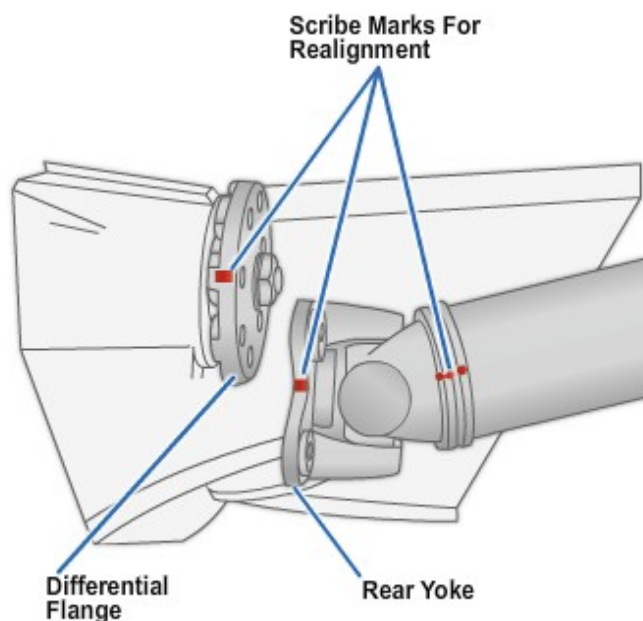


Figure 8-52 – Scribe mark the driveshaft, rear yoke, and universal joints before disassembly.

be pulled out by hand. Rotate the driveshaft 180 degrees and repeat the procedure to remove the bearing from the opposite side of the yoke. After separating the U-joint cups, ensure the bearing cups stay matched to the trunnion from which they were removed. Do not reinstall the bearing caps on any trunnion other than on their original.

4. A safer method of removing the bearing cup assembly is with the use of a two-jaw puller designed for separating U-joints. Bolt the puller to the bearing assembly and apply torque to separate each bearing cap (*Figure 8-53*).
5. Free the trunnion from its yoke by tilting the U-joint cross until the trunnions clear the yoke bore.
6. Force the driveshaft inboard on the slip joint and then lower it to the ground.

4.4.1.2 Removing Other Types of U-joints

The main problem when replacing U-joints is the potential to damage the driveshaft and slip yoke assembly. It is important to exert only enough force to separate the U-joint. Remember that using heat to free a seized bearing cap almost always destroys the U-joint, so this is not acceptable when you are removing the driveshaft for reasons other than replacing the U-joint. Many shops use a 50-lb. slide hammer to separate U-joints. This can result in damaging the driveshaft tube when the U-joint cups seize in the yoke bores.

Snapping U-joint. If the U-joints are secured in the yoke by snaprings, remove the snaprings and raise the driveshaft using either the jack or puller methods described earlier to separate the cups.

Half-round yoke assemblies. If the driveshaft has half-round end yokes, remove the strap retaining bolts or the U-bolts. Then collapse the driveshaft by moving it inboard to separate the bearing cups from the yoke. An advantage of this design is the ease it lends to removing driveshafts.

Flange type yokes. If the driveshaft has flange type yokes, loosen and remove the fasteners securing the flange yoke to the transmission or drive axle carrier flange. Hold the shaft firmly when tapping the flanges free. When separated, compress the driveshaft by forcing it inboard and lower the assembly to the floor.

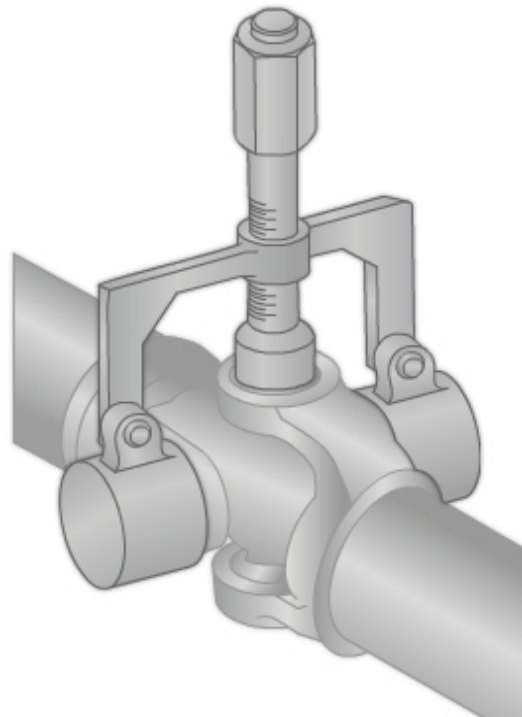


Figure 8-53 - Universal joint puller.

⚠ CAUTION ⚠

Never use a sledge hammer directly on a yoke to separate a U-joint. The result will almost certainly be a damaged driveshaft.

4.4.2 General U-Joint Removal Precautions

Do not distort the driveshaft tube by applying excessive clamping force. Using an appropriate puller such as the one shown in *Figure 8-54* is the best way to remove plate-type bearing caps. If a puller is not available or if the U-joint is not equipped with bearing plates, you can use an arbor press or hammer and soft round drift to remove the bearings.

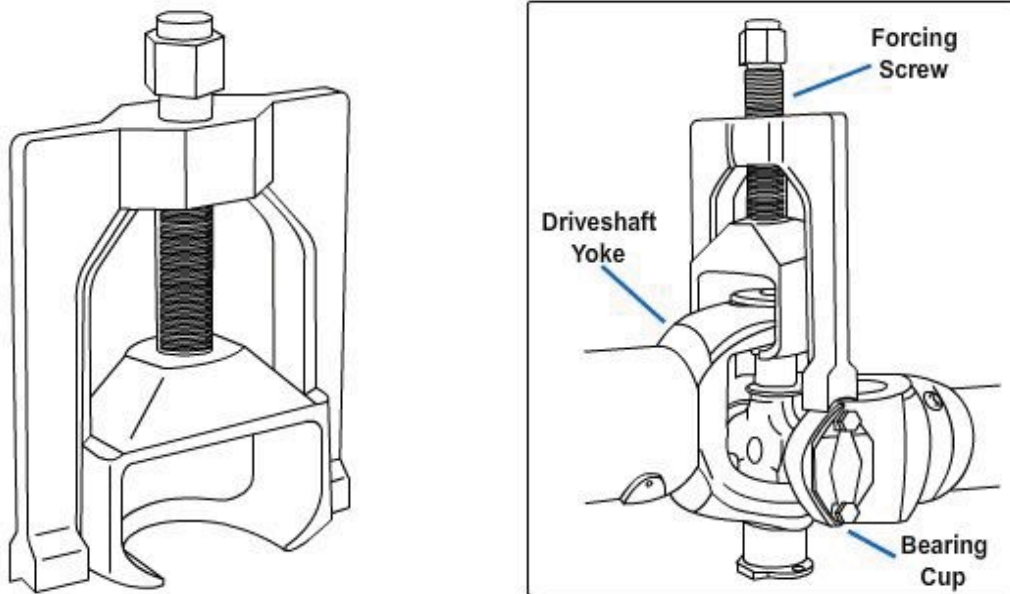


Figure 8-54 - Plate-type bearings can be removed with a puller.

Another way to remove U-joints is to support the cross on vise jaws, and then tap the yoke to drive the bearing cup forward. This is the least preferred method because of its potential to damage either the yoke or the slip spline assembly. Use a minimum amount of aggression. When the bearing cup can be pulled out by hand, reverse the yoke and U-joint and repeat the procedure to remove the opposite bearing cap.

4.5.1 U-Joint Lubricating Analysis

Inspect the U-joints and bearing cups for signs of wear and damage.

- Cracks are stress lines caused by metal fatigue. Severe and numerous cracks will weaken the metal until it breaks.
- Galling occurs when metal is cropped off or displaced because of friction between surfaces. Galling is commonly found on trunnion ends.
- Spalling (surface fatigue) occurs when chips, scales, or flakes of metal break off due to fatigue rather than wear. Spalling is usually found on splines and U-joint trunnion races.

- Pitting (small pits or craters in metal surfaces) is caused by corrosion and can lead to surface wear and eventually failure.
- Brinelling is a type of surface. Brinelling is often caused by improper installation of the U-joints. Do not confuse the polishing of a surface (false-brinelling), where no structural damage occurs, with actual brinelling. False-brinelling is a manufacturing characteristic that surface-polishes bearing races without actually creating any damage. Technicians should learn to recognize false-brinelling to avoid replacing bearings that are functionally sound.

4.6.0 Yoke Inspection

After removing the U-joint cross and bearing cups, inspect the yoke bores for damage or burns. Some bore irregularities can be removed with a rat tail or half-round file, followed by finishing with emery cloth.

Check the yoke bores for wear, using a go-no-go wear gauge. Use an alignment bar (a bar with approximately the same diameter as the yoke bore) to inspect for misalignment of the yoke lugs. Slide the bar through both yoke bores simultaneously. If the alignment bar will not pass through both yoke bores simultaneously, the yoke has been distorted either by disassembly malpractice or excessive torque and should be replaced. Next, clean and inspect the mating yoke with an alignment bar gauge. Do not risk reusing a defective yoke.

4.7.1 U-Joint Reassembly

Use the following procedure to assemble a driveshaft installing new U-joints.

1. Place the slip yoke end of the driveshaft assembly in a bench vise so that you can see the phase mark made on disassembly. Locate the phase mark on the main section of the driveshaft and assemble mating the slip joint. Double check the phasing. An out-of-phase driveshaft will cause an immediate driveline vibration.
2. Remove the new U-joint from its packing and separate the bearing caps from the cross trunnions. Visually inspect the cross, ensuring that the one-way check valve in each trunnion lube hole is present. Then position the cross into the driveshaft yoke aligning the lube zerk fitting as close as possible to the slip spline lube fitting. The zerk fitting should be directed toward the inboard side.
3. Paste some antiseize compound to the outside diameter of four bearing assemblies. This facilitates installation and removal next time around. Angle the cross and insert into the yoke. Fit the first bearing cup by inserting a trunnion into the needle bearings, and then push the bearing cup into the yoke bore. When the trunnion is inserted into the first bearing cup assembly, it is aligned. Insert the opposing bearing cup into the yoke bore and press home. You can now insert the lock tabs and fasteners, but do not torque yet.



If the bearing cap binds in the yoke bore, gently tap with a ball peen hammer in the center of the bearing cap. Do not tap the outer edges of the bearing cap because this could damage either the bearing cup or the yoke.

4. Move the cross back and forth to check the cross for binding. It should pivot freely with zero drag. You can now torque the fasteners, but do not bend up the lock tabs in case you have to loosen the bearing caps for lubing.
5. Now repeat the foregoing process to install the U-joint at the opposite end of the driveshaft. Again, position the cross in the yoke so that the lube zerk fitting aligns with the lube fitting at its opposite end.
6. For flange yoke applications, you can install the flange yoke, bearing assemblies, and fasteners at this time.

4.8.1 Driveshaft Installation

You now have the U-joint at each end of the driveshaft assembly. Make a final inspection of the driveshaft, checking the following:

1. No damage or dents are on the driveshaft tubing.
2. There is spline movement with minimal drag.
3. Both crosses turn in their bearing cups without bind. A slight drag is acceptable (but no binding), but no looseness should be detectable.
4. Yoke flanges are free from burrs, paint, and contamination, any of which could prevent the bearing caps from seating properly.



Once in use, bearing caps and their trunnions should remain matched. Also, never take assembly short cuts by installing only the new bearing caps on a used trunnion, as this will usually result in a rapid failure. Regard a U-joint cross, its four bearing assemblies, and mounting hardware as a unit, and replace as such.

4.8.1 II Round End Yoke

1. First put the transmission in neutral and jack one drive axle wheel off the ground. This will allow you to rotate both the transmission output yoke and the differential carrier yoke. Turn each yoke so that the yoke bores are horizontal.
2. Swivel the U-joint cross on the driveshaft so that it is angled. This will allow you to insert the trunnions into the yoke on the transmission and when both trunnions are located in the yoke bores, you can rest the weight of the driveshaft. Remember that a slip joint is always positioned so that it is closest the source of power flow, which means on the transmission side. If the driveshaft is heavy, use a sling to aid in handling and raising the driveshaft.



It makes sense to remove the grease fittings when installing a driveshaft; if they are knocked against the yoke, they intend to shear. You can easily reinstall them after the driveshaft has been installed.

3. Apply a thin coating of antiseize compound to the outside of the two bearing cups. Then raise the driveshaft slightly and move it to one side of the yoke so that a trunnion protrudes through it. In this position, you can place a bearing cup over the protruding trunnion, align it, and press it home by hand into the yoke bore.

4. Next slide the U-joint over to the opposite side so that the trunnion exits the bearing cup you have already installed by about half its length. Now align the second bearing cup over the trunnion first, then in the yoke bore, and press home until it is flush.
5. If a bearing cap assembly binds in the yoke bore during installation, you can tap it lightly with a hammer in the center of the cap plate. Never strike the bearing cup on the outer edges of the cap plate.
6. After both bearing cups have been seated in the yoke, put the lock plate tab in place and insert the bolts into the yoke threads, turning them in first by hand, then with a wrench. Torque to specification. Check that the bearing cup plates are flush with the yoke. Then back the fasteners off slightly.
7. Install the zerk fitting(s) if you removed them and lubricate the U-joint assembly until the grease appears to exit at all four trunnion seals.
8. Torque the bearing cap bolts to specification. Next, bend the lock plate tabs up against the flat of the capscrew hex heads to lock them in place.
9. Repeat the process at the opposite end of the driveshaft. Do not forget to lube the slip joint when you have finished.

4.8.2 End Yoke

For driveshafts using half-round end yokes, first support the driveshaft more or less in position using slings. Then install the bearing cups onto the cross trunnions. Install the bearing cups into the end yoke shoulders and place the retaining straps over the bearing assemblies. Thread the self-locking capscrews into the threaded holes and torque the bolts to specification. Lubricate the cross and bearing assemblies.

4.8.3 Flange Yoke

Using slings to support the driveshaft, align the (permanent end) flange pilots of the driveshaft, flange yoke, and drive axle companion flange with each other. Align the bolt holes and then install bolts, lockwashers, and nuts to temporarily secure the driveshaft to the axle. Compress the slip joint assembly to position the opposite end of the driveshaft to the transmission companion flange. Align bolt holes and install bolts, lockwashers, and nuts. Torque the fasteners to OEM specifications.

4.9.0 Chassis Vibration Diagnosis

Driveline vibrations are the source of many trouble cards, and some of them can be very difficult to isolate. Vibration is not as apparent on the off-road equipment as it is on the over-the-road vehicles. Operators are not likely to complain about vibration on off-road equipment. When investigating the source of a driveline vibration, you always should be aware that the cause can originate in an area other than in the driveline. It is probably not good practice to rely solely on a driver's report of a driveline vibration, so make it part of your normal routine to road test the vehicle.

The first challenge is for you to determine the source of the complaint. The cause of a vibration can be in the steering or suspension systems, in the engine or transmission systems, in the wheels or tires. Road test the vehicle loaded and unloaded, if possible, while recording engine rpm and road speed. Note any irregularities and at what engine or road speeds they occur. If the problem is noticeable only when pulling a trailer, try coupling to a different trailer to see if the problem persists.

4.9.1 Driveline Balancing

An unbalanced driveline causes transverse vibrations or bending movements in a driveshaft. This type of vibration is directly related to driveshaft rpm and usually is most noticeable at a specific driveshaft speed. The cause is imbalance in the driveshaft and, without using specialized equipment, it can be difficult to pinpoint.

Attempting to balance a driveshaft without spinning it up is so much of a hit-and-miss process that it is unrealistic to attempt it. We will outline here a simple method of dynamically balancing a driveshaft assembly using a balance sensor and strobe light.

4.9.1.1 Dynamic balancing

You need a balance sensor and strobe light, preferably from a kit designed to dynamically balance driveshafts. You will need to raise the truck off the ground and place it on stands ensuring the following:

1. Frame is level.
2. Transmission and differential carrier housing(s) angles are the same when raised as when on the ground.
3. Chassis is secure enough on the stands that the engine safely drives the drivetrain to normal road speeds.

Fit the balance sensor to the chassis to be tested. The test procedure is similar to that used when balancing tire and wheel assemblies. Using the strobe light and white machinist's crayon, mark the driveshaft and spin it up. If it is out of balance on this initial test, begin by removing any counterweights tacked onto the driveshaft with a cold chisel. Remove any weld by lightly grinding with an angle grinder.

Run the vehicle at those equivalent road speeds noted on the road test when the vibration was most noticeable. Use hose clamps to clamp counter weights (steel washers or blockweights) into position with the clamp worm screw located over the weight washer (*Figure 8-55*). When the imbalance has been neutralized, tack weld the weight or weights into position. The weight of the weld tacks should be approximately equivalent to that of the hose clamp worm, so make a practice of always locating the worm over the balance weight.

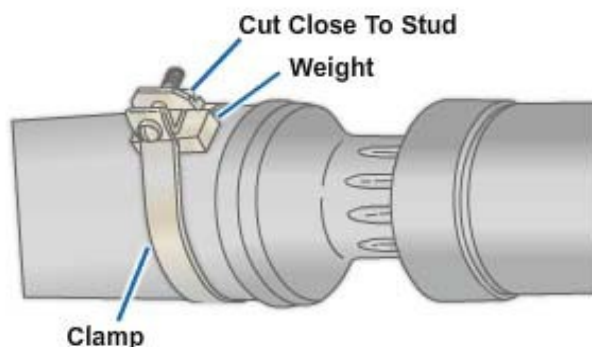


Figure 8-55 – Balancing a propeller shaft.



Use small tack welds to attach weights. Larger welds can create another imbalance or, worse, distort driveshaft tubing.

4.9.1.2 Check Operating Angles

To determine whether vibrations are caused by improper driveline angles, run through the following routine:

1. Inflate all tires to the pressure at which they are normally operated. Park the vehicle on a surface that is level both from the front to rear axles. Shift the transmission into neutral and block the front tires. Jack up a rear drive wheel.
2. Rotate the wheel by hand until the output yoke on the transmission is vertical and lower the wheel you raised back to the floor. This simplifies measurement later. Check driveshaft angles in the same loaded or unloaded condition as when the vibration was noted. It is good practice to try to check driveline angles with the chassis loaded and unloaded.
3. To measure driveline angles, you can use a magnetic base protractor or an inclinometer, but the inclinometer is definitely preferred as it measures relative angles. Good quality electronic inclinometers are not expensive and will quickly pay for themselves in time saved setting up drivelines. To use the magnetic base protractor or an electronic driveline inclinometer, place it on the component to be measured (*Figure 8-56*). Some inclinometers have adapters for attaching to universal joints and end yokes. A display window will show the angle and the direction it slopes. Track the measured angles working from the front of the drivetrain to the rear. A component slopes downward if it is lower at the rear than at the front. A component slopes upward when it is higher at the rear than it is in front.
4. Check and record the angle on the main transmission. This reading can be taken on the end yoke lug, with the U-joint cap removed, or on a flat surface of the main transmission parallel to the output yoke lug plane. Record your readings on a sketch of the driveline.

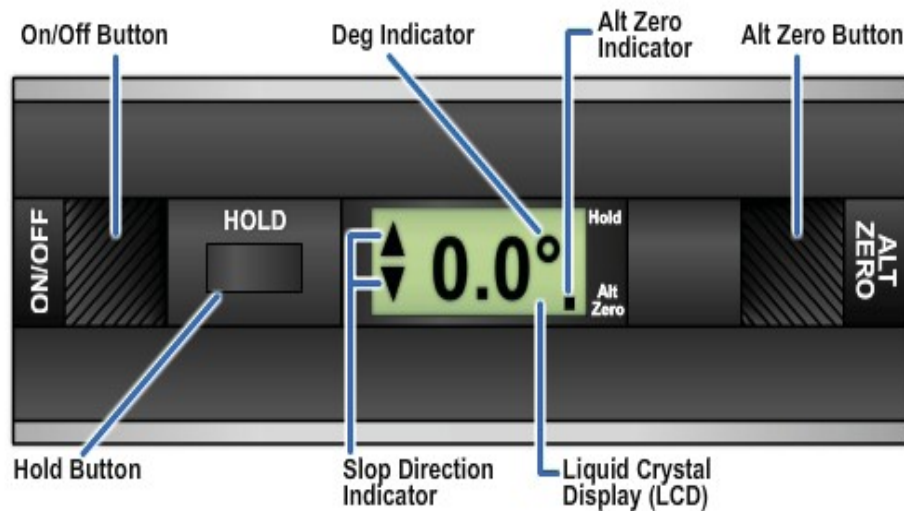


Figure 8-56 - Digital inclinometer.

5. Now check the driveshaft angle between the transmission and drive axle carrier. On short tube length driveshafts, measure the angle of the driveshaft on either tube or slip yoke lug with the bearing cap removed. On long tube length driveshafts, measure the angle on the tube at least 3 inches away from the yoke circumferential weld and at least 1 inch away from any balance weights, (*Figure 8-57*). Make sure you remove any rust, scale, or flaking from the driveshaft tube so that you can obtain an accurate measurement.

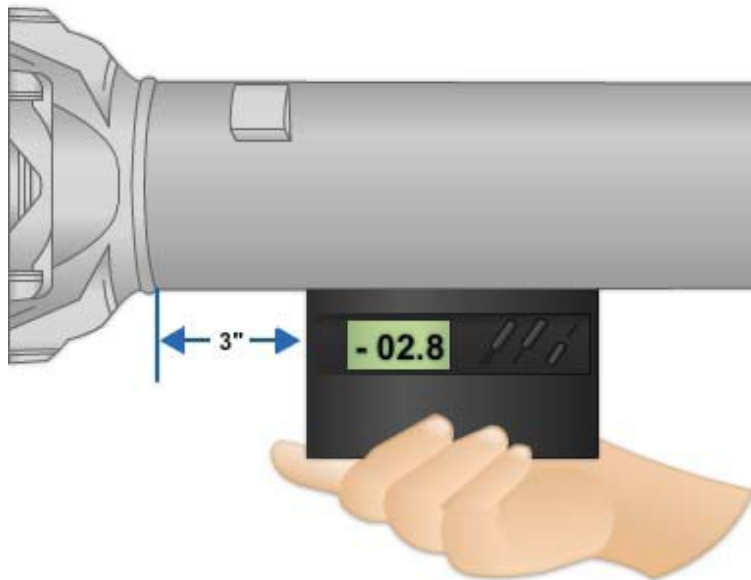


Figure 8-57 - Checking the driveshaft angle.

6. Check the forward drive axle carrier input yoke angle by removing a bearing cap and measuring the angle of the yoke lug, or alternatively, locate a flat surface on the axle housing parallel. Some differential carrier housings have a machined surface designed precisely for this purpose.
7. In tandem drive arrangements, measure the output yoke angle of the forward drive axle, the angle of the tandem driveshaft that connects the forward rear drive axle carriers, and the input yoke angle of the rear drive axle carrier. When you have measured all of the angles, record the data onto a drawing similar to that shown in *Figure 8-58*. Up to this point, you have not recorded any U-joint operating angles in the drawing, just the inclination of the components.

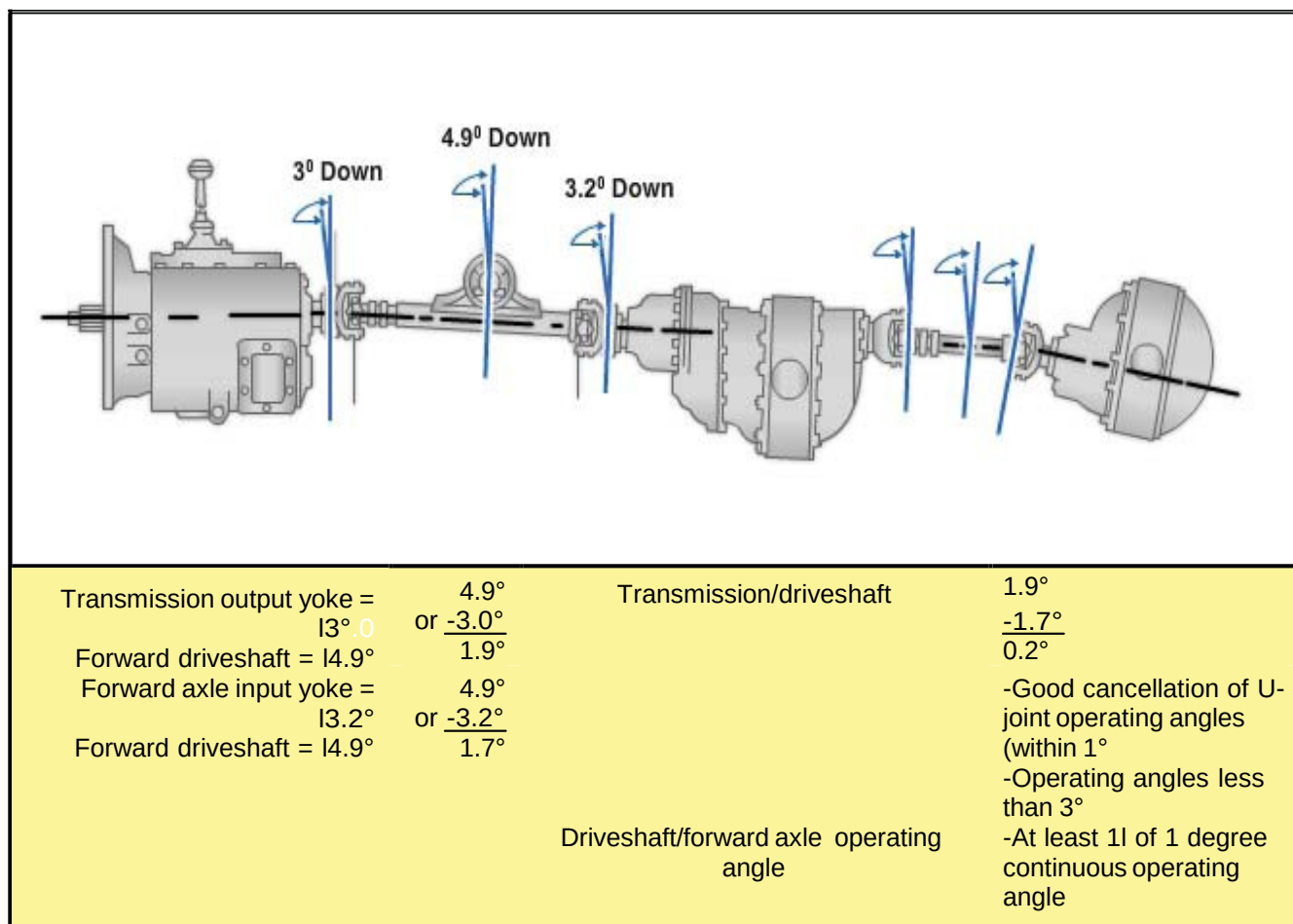


Figure 8-58 - Method for calculating the driveshaft operating angles between the transmission and axle differential carriers.

- To determine U-joint operating angles, simply find the difference in inclination of the components. When the inclination occurs in the same direction on two connected components, subtract the smaller number from the larger to find the U-joint operating angle. When the inclination occurs in the opposite direction on two connected components, add the measurements to find the U-joint operating angle. Now compare the U-joint operating angles on the drawing to the guidelines provided previously in *Figure 8-58*.

4.9.1.3 Correcting U-joint Operating Angles

The recommended method for correcting severe U-joint operating angles depends on the type of vehicle suspension and driveshaft design. On vehicles with a leaf spring suspension, thin wedges called axle shims can be installed under the leaf springs on the axle saddle to tilt the axle and thereby adjust U-joint operating angles. Wedges are available in a range of sizes to alter pinion angles.

On some vehicles with tandem drive axles, shimming of longitudinal torque rods can be used to adjust the drive carrier operating angle. Longitudinal torque rod shims fractionally rotate the drive axle pinion that alters the U-joint operating angle. A longer or

shorter torque rod might be available from the manufacturer if shimming is not practical. Some torque rods are adjustable.

As a rule, the addition or removal of a $\frac{1}{16}$ -inch shim from the rear torque arm will alter the axle angle approximately $\frac{1}{2}$ degree. A $\frac{1}{2}$ degree change in the pinion angle will typically change a U-joint operating angle by about $\frac{1}{2}$ degree.

Factors that can cause the U-joint operating angle to change are the following:

1. Suspension changes caused by worn bushings in the spring hangers, worn bushings in the torque rods, or incorrect airbag height
2. Driveshaft adjustments
3. Stretching or shortening the chassis
4. Addition of an auxiliary transmission or transfer case into the driveline
5. Worn engine or transmission mounts

4.9.1.4 1.4 Checking Driveshaft Runout

Any runout in a driveshaft can result in driveline vibrations. Driveshaft runout can be checked by using a dial indicator. *Figure 8-59* shows the locations used to measure driveshaft runout and the tolerance limits for total indicated runout (TIR). Note that these are fine measurements, so before measuring, clean the surfaces from where you are going to take the dial indicator readings.

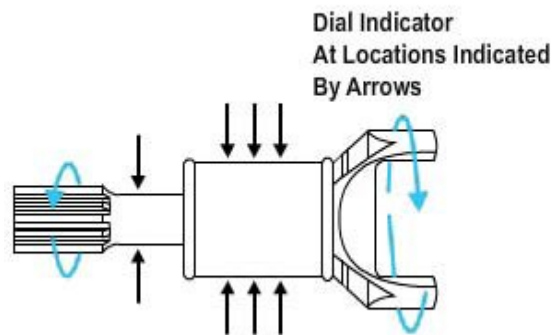


Figure 8-59 – Checking driveshaft runout.

4.9.2 and Alignment

Not only must the driveshaft be straight but the yokes attached to the transmission, auxiliary transmission, and drive axles must also be true and straight and in alignment with the shafts to which they are attached.

4.9.2.1 2.1 Checking Yoke Runout

Mount a dial indicator to the transmission or axle housing as shown in *Figure 8-60* and *Figure 8-61*. If the yoke is the half round type, place the tip of the indicator measuring plunger onto the machined surface of the yoke shoulder. If the yoke is the full round type, pop a bearing cup out just enough to insert the indicator plunger onto the cup as shown in *Figure 8-61*. Take the measurement, and then rotate the yoke 180 degrees and measure again. If runout exceeds 0.005 inch, the yoke should be replaced. Note that the reason for a yoke damaged in this manner is usually mechanic abuse caused by aggressive separation of a Y-joint.

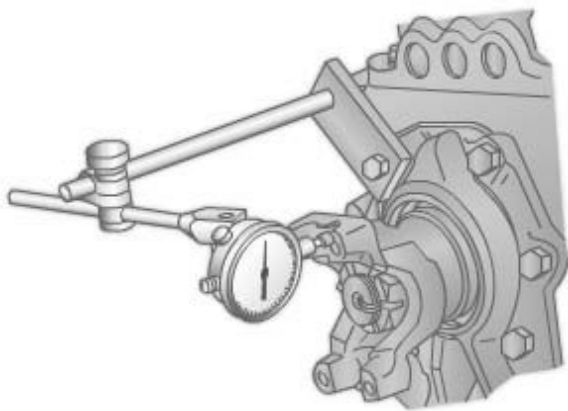


Figure 8-60 – When checking half-round end yoke for runout, place the indicator plunger on smooth surface of shoulder.

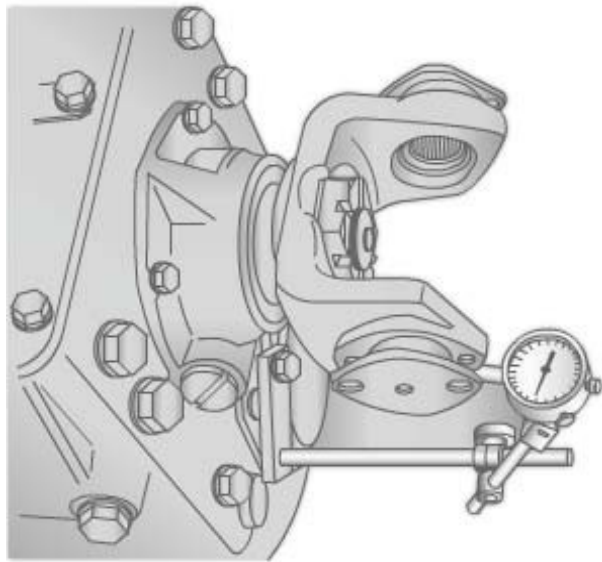


Figure 8-61 – When checking a full-round end yoke for runout, be sure to leave enough surface for the indicator plunger.

4.9.2.2 Checking yoke vertical alignment

The machined shoulder of a half-round yoke or yoke bores in a full-round yoke should be exactly 90 degrees to the centerline of the shaft to which the yoke is attached. If the shaft is horizontal (0 degrees), the yoke should be vertical (90 degrees); if the shaft angles away from a true horizontal plane, the yoke should be at an angle equal to 90 degrees minus the inclination of the shaft.

Before checking vertical alignment, make sure the vehicle is on a level surface. The engine and transmission mounts should be secure. Also check the yoke for looseness and tighten to specification if required.

When measuring the alignment of a yoke attached to the main transmission, first disconnect the driveshaft from the end yoke. Next, put the transmission in neutral and rotate the transmission output shaft until the yoke lugs are positioned vertically one above the other. Then, if the yoke is a half-round type, place a protractor with a magnetic base in a vertical position across the mechanical surfaces of the yoke (*Figure 8-62*). The protractor dial should read 90 degrees minus the inclination of the engine/transmission plane.

If the yoke is the full-round type, place the protractor base on the outside surface of the machined shoulder as shown in *Figure 8-63*. The protractor should read the angle of the engine/transmission inclination. If the output yoke is more than 1 degree out of vertical alignment, it is either loose or it is distorted and should be replaced.

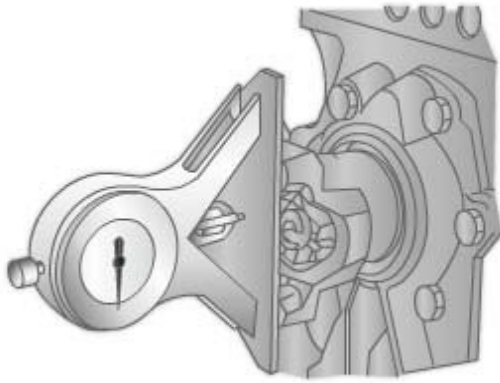


Figure 8-62 - Checking vertical alignment of a half-round yoke.

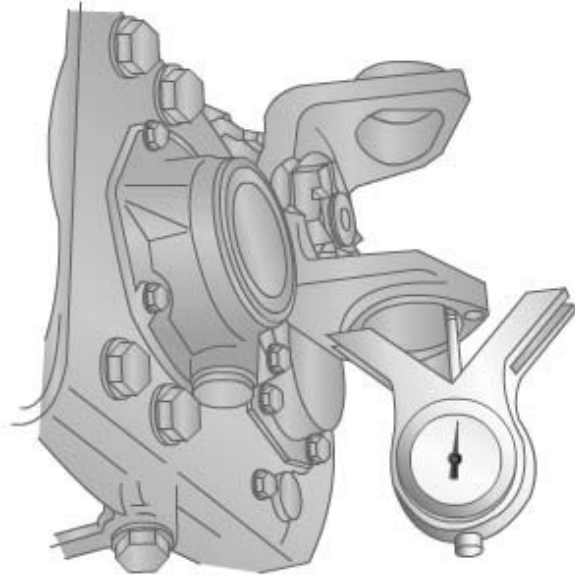


Figure 8-63 - Checking vertical alignment of a full-round end yoke.

When checking the input yoke attached to the pinion shaft of a drive axle, jack up one wheel and rotate the wheel until the lugs of the yoke are aligned vertically. Then measure the vertical alignment of the yoke, using the foregoing procedure just described for checking the transmission output yoke. Refer to *Figure 8-64*, which outlines a driveshaft troubleshooting guide.

4.10.0 PTO Driveshafts

In some applications, an auxiliary power unit, such as a pump, can be directly mounted to the power takeoff (PTO) assembly (*Figure 8-65, View A*). However, it is more common to locate PTO driven units remotely and drive them using a driveshaft (*Figure 8-65, View B*).

Driveshaft Troubleshooting Guide		
Symptom	Probable Cause	Remedy
Vibration - low gear shudder - at certain speeds under full drive or full coast - under light loaded conditions	- Secondary couple load reaction at shaft support bearing - Improper phasing - Incompatible drive shaft - Driveshaft weight not compatible with engine transmission mounting or driveshaft too long for speed - Loose outside diameter fit on slip spline - Excessively loose U-joint for speed - Driveshaft out of balance; not straight - Unequal U-joint angles - U-joint angle too large for continuous running - Worn u-joint - Inadequate torque on bearing plate capscrews - Tensional or inertial excitation	- Reduce U-joint continuous running angle. Check with transmission or axle manufacturer-replace shaft bearing. - Check driveshaft for correct yoke phasing. - Use larger diameter tube. - Install two piece driveshaft with shaft support bearing. - Replace spline or yoke. - Replace U-joint. - Straighten and balance shaft. - Shim drive train components to equalize U-joint angles. - Reduce U-joint continuous running angle. - Replace U-joint - Inspect U-joint flex effort for looseness; torque to specification. - Straighten and balance shaft. Check driveshaft for correct yoke phasing.
Premature wear - low mileage U-joint wear - repeat U-joint wear - end galling of cross trunnion and bearing assembly - needle rollers brinnelled into bearing cup and cross trunnion - broken cross and bearing assemblies	- End yoke cross hole misalignment - Excessive angularity - Improper lubrication - Excessive U-bolts torque on retaining nuts - Excessive continuous running load - Continuous operation at high angle high speed - Contamination and abrasion; worn or damaged seals - Excessive torque load (shock loading) for U-joint and driveshaft size	- Use alignment bar to check for end yoke cross hole misalignment; replace end yoke if misaligned. - Check U-joint operating angles with an electronic driveline inclinometer, reduce excessive U-joint operating angles. - Lubricate according to specifications. - Replace U-joint kit. - Replace U-joint continuous running angle. - Replace with a higher capacity U-joint and driveshaft. - Check U-joint flex effort; replace joint or yoke is necessary; clean and relubricate U-joint. - Realign to proper running angle minimum 1 degree; torque bearing retention method to specification.
Slip spline wear - seizure - galling	Improper lubrication	Lubricate slip sp[pline according to specifications.

Figure 8-64 - Driveshaft Troubleshooting Guide

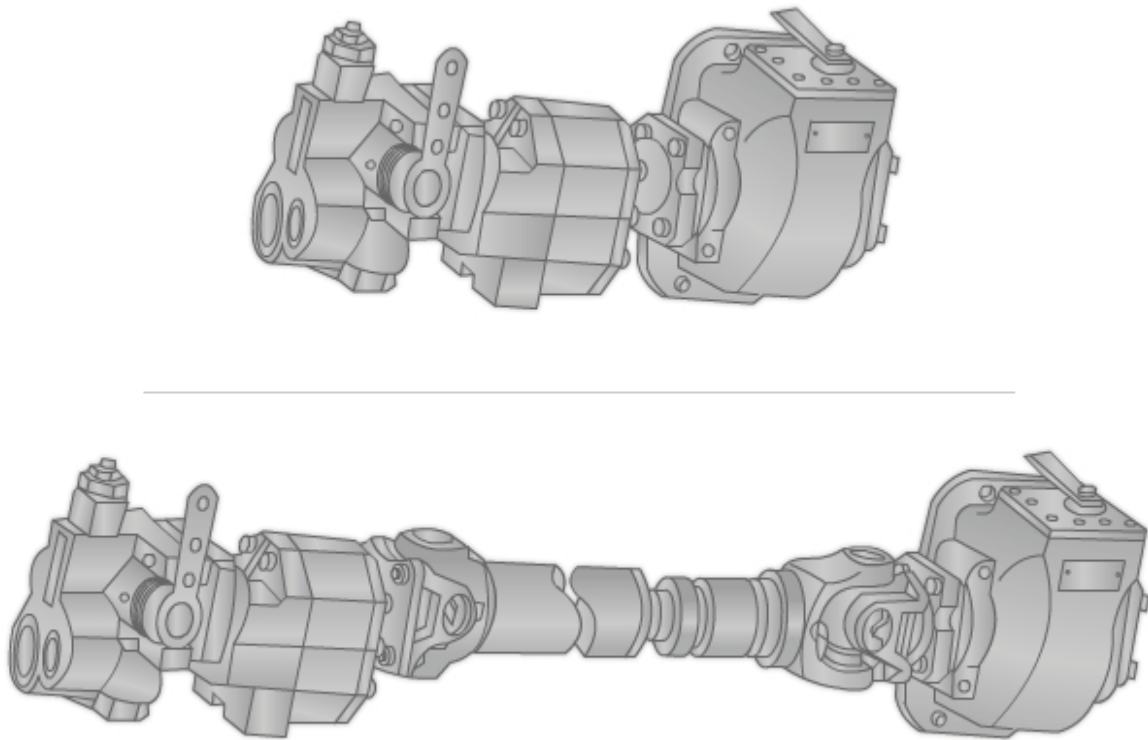


Figure 8-65 - Power takeoff mounted without and with driveshaft.

5.1.1 TROUBLESHOOTING the DIFFERENTIALS

Differential Service

When symptoms point to differential troubles, remove the differential carrier or rear inspection cover. Inspect the ring gear, pinion drive gear, bearings, and spider gears.

A differential 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 fasteners. It may also be stamped on the axle housing or carrier. Use the ID number to find the axle type, axle ratio, make of unit, and other information.

Differential Removal

To remove a differential carrier from the banjo housing, use the following procedure:

1. Use a hydraulic jack to raise the vehicle axle housing so that the wheels just clear the floor.
2. Place axle stands under each side of the axle housing to hold the vehicle in the raised position. Try to make sure the axle housing is horizontally close to level.
3. Remove the drain plug from the bottom of the axle housing and drain the lubricant from the assembly. Dispose of the lube properly.

4. Disconnect the driveline U-joint from the piston yoke or flange on the carrier.
5. Back off the capscrews or stud nuts from the flanges of both axle shafts at each wheel. Do not completely remove the fasteners.
6. Next, loosen the tapered spring dowels from the axle shaft flanges. Use a brass drift and large hammer to loosen the dowels (*Figure 8-66*). Remember that when they loosen, they will pop at once and can fly off like bullets if the axle retaining nuts have been removed.

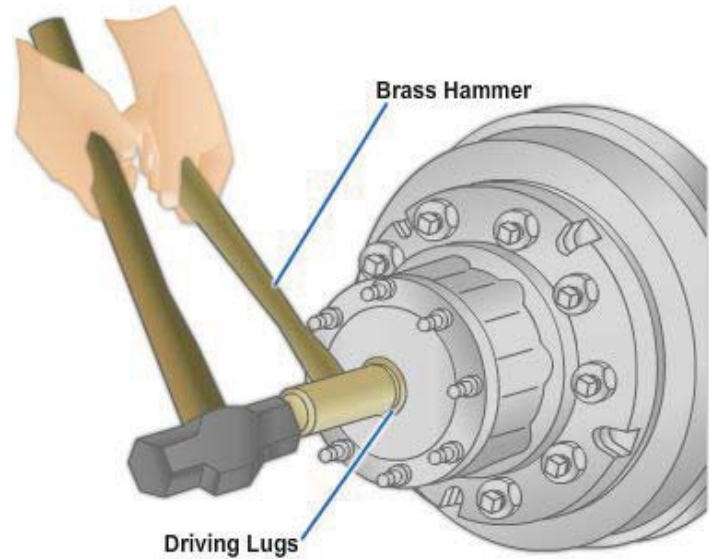


Figure 8-66 - Loosen the tapered dowels with a brass drift and large hammer.

7. When the shaft has popped free, you can remove the nuts, washers, and tapered spring dowels. Pull both axle shafts from the axle housing.
8. On dual range drive axles, disconnect the shift unit air lines. Remove the shift nut, catching any oil that escapes from the reservoir.

9. Place a differential jack, a transmission jack with a differential cradle, or a hydraulic jack under the differential carrier to support the assembly (*Figure 8-67*). The differential carrier should be properly fixed to the jack supporting it.

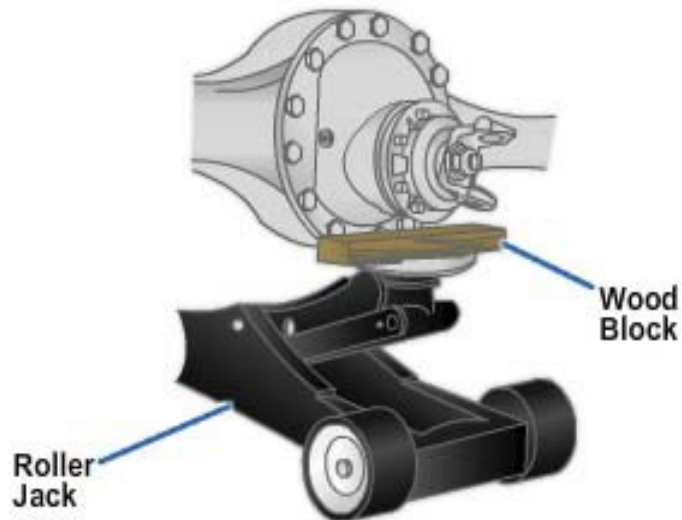


Figure 8-67 - Support the differential carrier with a hydraulic jack.

10. Remove all but the top two carrier flange-to-housing capscrews or stud nuts and washers.
11. Back off the top two carrier-to-housing fasteners, leaving them attached to the assembly. The fasteners will hold the carrier in the housing.

12. Loosen the differential carrier from the axle housing. Use some thrust force applied to the nose of the differential carrier to achieve this.
13. Carefully remove the carrier assembly from the banjo housing by wriggling the jack from side to side while pulling away. If you have to use a pry bar, make sure that you do not damage the flange faces or gearing.



Most of the weight of a differential carrier assembly is on the inboard side of its mounting flange. Ensure that the assembly is properly fastened to the jacking device and that you do not damage the flange faces or gearing.

14. Remove and discard the carrier flange-to-banjo housing gasket.
15. Move the differential carrier from under the vehicle, raise it by its yokes, and mount in a repair stand. You can use a cherry picker or chain hoist for this procedure.

Differential Carrier Disassembly

Before disassembling the carrier, visually inspect the hypoid gearset for damage. If no damage is apparent, you should be able to reuse the gearset. Measure the backlash of the gearset and record the dimension. On reassembly, the crown and pinion backlash should be adjusted to the same dimension. The best overhaul results are obtained when used gearing is adjusted to run in established wear patterns. Omit this procedure if the gearset is to be replaced. To remove the differential and ring gear from the carrier, use the following procedures:

1. Loosen the jam nut on the thrust screw (if applicable; some carriers do not have a thrust screw).
2. Remove the thrust screw and jam nut from the differential carrier (*Figure 8-68*).
3. Rotate the differential carrier assembly in the repair stand until the ring gear is at the top of the assembly.
4. Mark one carrier leg and bearing cap for the purpose of correctly matching the parts when the carrier is reassembled. A center punch and hammer can be used to mark these components (*Figure 8-69*). Avoid using paint because it may contaminate when placed back in service.

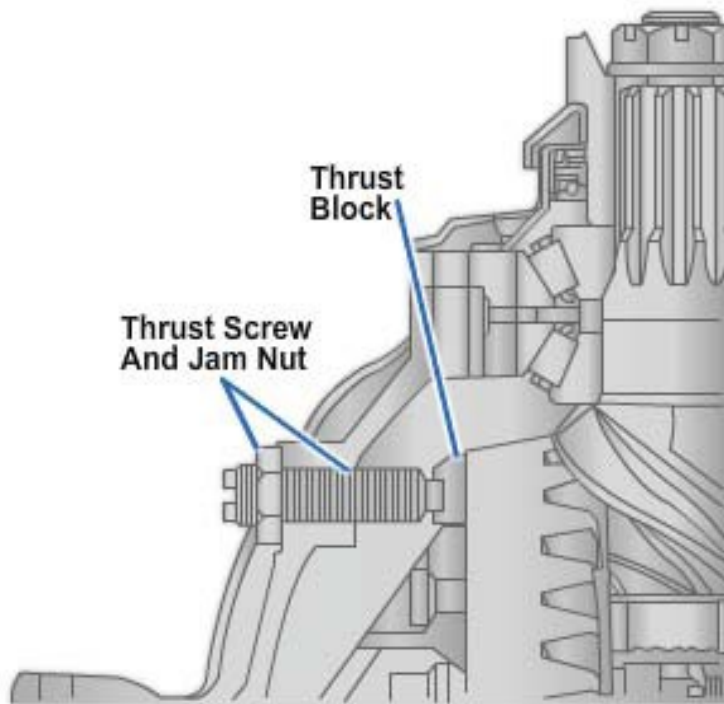


Figure 8-68 – Thrust screw, jam nut, and thrust block.

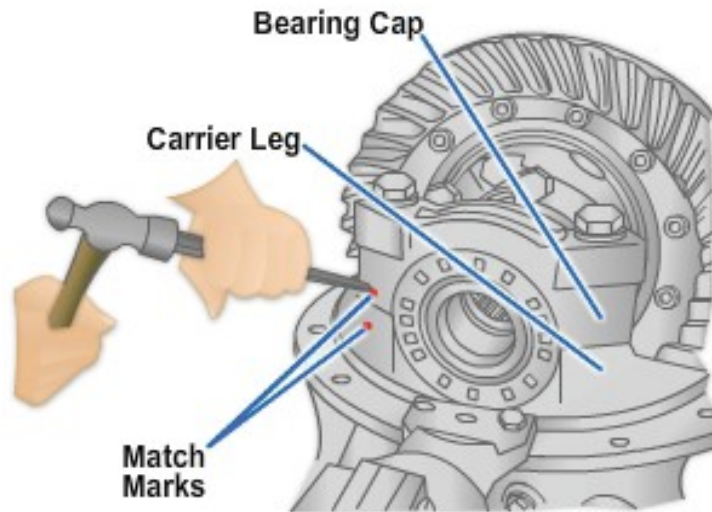


Figure 8-69 - Mark the carrier components for reassembly.

5. Remove the cotter keys, pins, or lock plates that hold the two bearing adjusting rings in position. Use a small drift and hammer to remove the pins. Each lock plate is held in position by two capscrews (Figure 8-70).

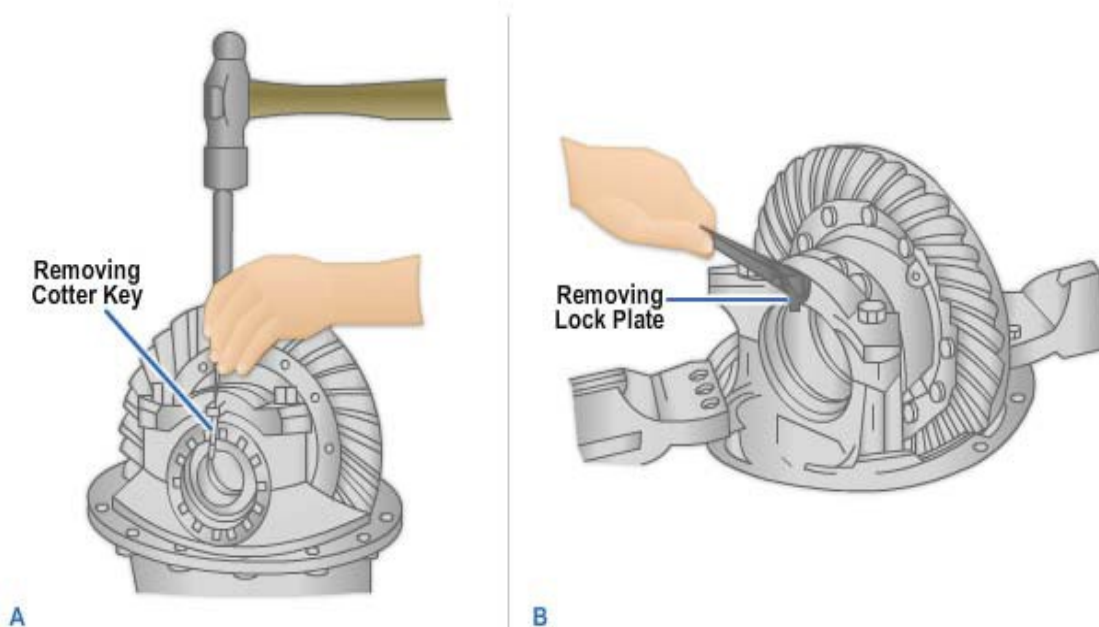


Figure 8-70 - Removing the cotter key and lock plate.

6. Remove the capscrews and washers that hold the two bearing caps on the carrier. Each cap is held in position by a pair of capscrews and washers. When

reusing the crown and pinion gearset, remove the left-hand bearing cap, adjust, and lock washer as a unit. This will help return the gearset to its original adjustment during reassembly.

7. Remove the bearing caps and bearing adjusting rings from the carrier (Figure 8-71).
8. Safely lift the differential and crown/ring gear assembly from the carrier and place it on a workbench.
9. Remove the thrust block (if provided) from inside the carrier. (The thrust block will fall into the carrier when the thrust screw is removed.)

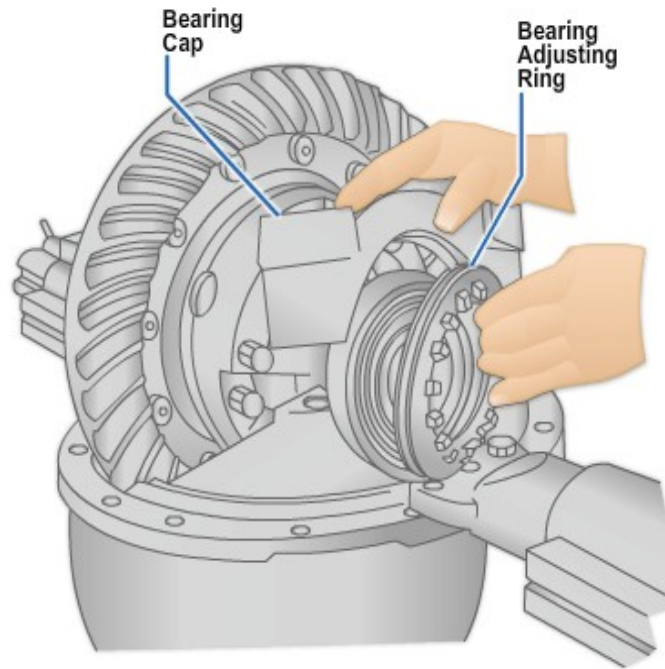


Figure 8-71 – Removal of the bearing cap and adjusting ring.

Differential and Crown Gear Assembly

To disassemble the differential and crown/ring gear assembly, you should use the following procedure:

1. If the matching marks on the case halves of differential assembly are not visible, mark each case half with a center punch and hammer. The purpose of these marks is to match the plain half and flange half correctly when reassembling the carrier.

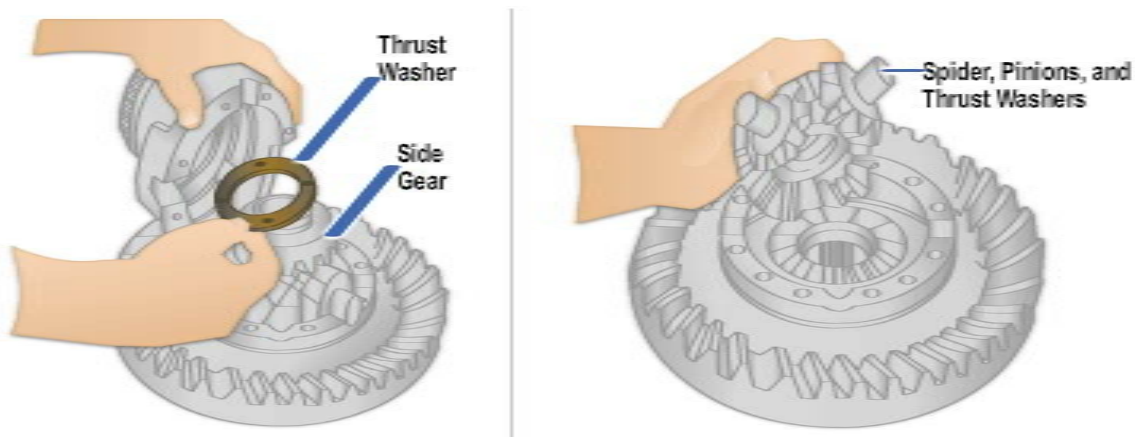


Figure 8-72 - Disassemble the differential and crown gear.

2. Remove all hardware that holds the case halves together.

3. Separate the case halves. Use a brass, plastic, or leather mallet to loosen the parts.
4. Remove the differential spider (cross), four pinion gears, two side gears, and six thrust washers from inside the case halves (*Figure 8-72*).
5. If the pinion and crown gearset is to be replaced, remove the hardware that holds the gear to the flange case half as follows:

- Carefully center punch each rivet head in the center on the crown gear side of the assembly.
- Drill each rivet head on the ring gear side of the assembly to a depth equal to the thickness of one rivet head. Use a drill bit that is 1/32-inch smaller than the body diameter of the rivets (*Figure 8-73*).
- Drive the rivets through the holes in the ring gear and flange case half. Press from the drilled rivet head.

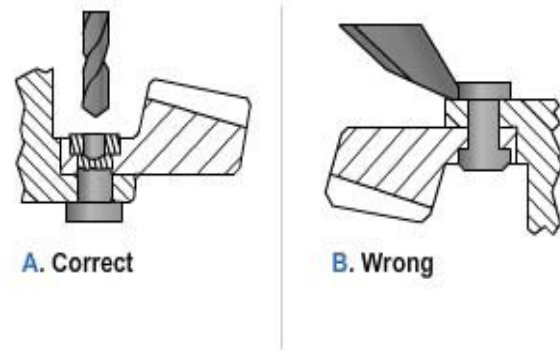


Figure 8-73 – Removing rivets on a ring gear.



Do not remove the rivet heads or rivets with a chisel and hammer because this can damage the flange case half or enlarge the rivet holes, resulting in loose rivets.

6. Separate the case half and ring gear using a press. Support the assembly under the ring gear with metal or wooden blocks and press the case half through the gear (*Figure 8-74*).
7. If the differential bearings need to be replaced, remove the bearing cones from the case halves. Use a bearing puller or press to remove them.

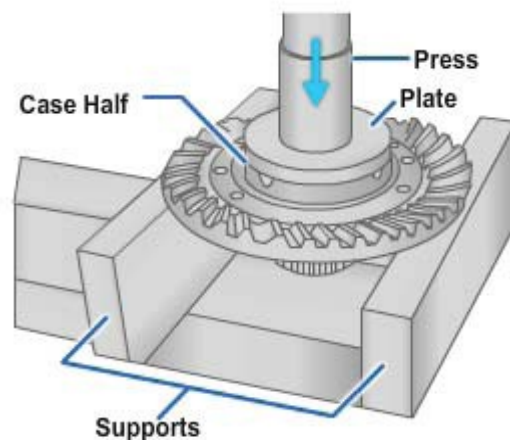


Figure 8-74 – Pressing the flange case half out of the crown gear.

Removing Drive Pinion and Bearing Cage

1. Fasten a yoke bar or flange bar to the input yoke to prevent it from turning while you remove the nut (*Figure 8-75*).
2. Remove the retaining nut from the drive pinion. Then remove the yoke or flange bar.

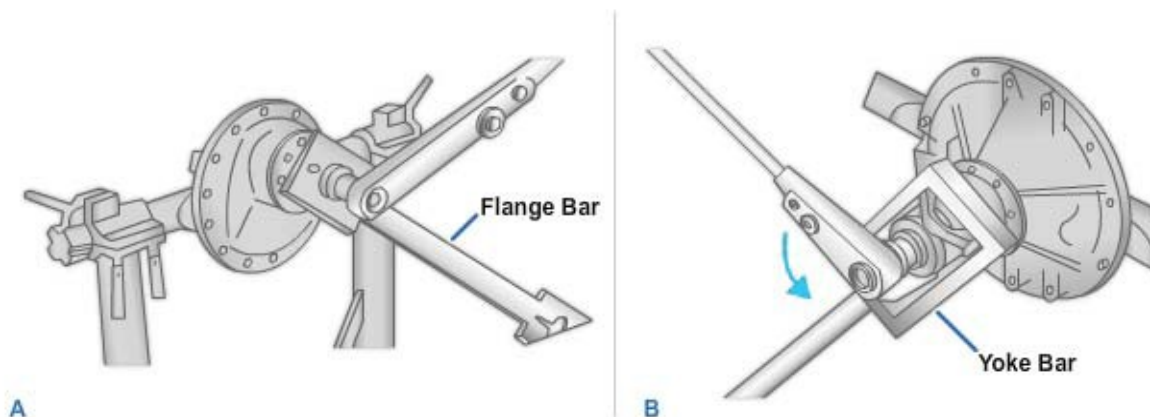


Figure 8-75 – Removing the A input flange or B yoke.

3. Remove the yoke or flange from the drive pinion. If the yoke or flange is tight on the pinion, use a puller to remove it.
4. Remove the fasteners that retain the bearing cage in the center in the carrier (*Figure 8-76*).
5. Remove the cover and seal assembly and the gasket from the bearing cage. If the cover is tight on the bearing cage, use a brass drift and hammer for removal.
6. If the pinion seal is damaged, remove the seal driver. If a press is not available, use a screwdriver or small pry bar for removal. Discard the pinion seal.

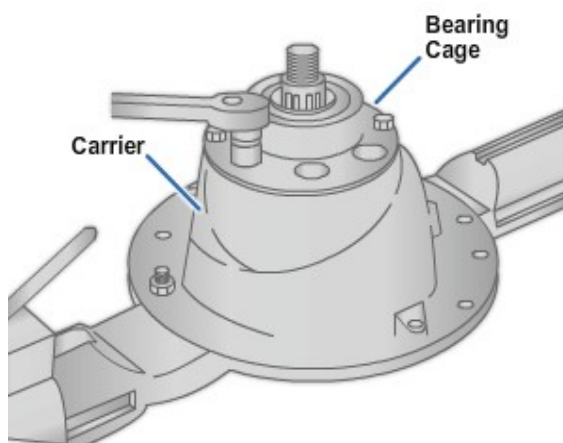


Figure 8-76 – Bearing cap removal.

7. Remove the drive pinion and bearing cage, plus the shims from the carrier (*Figure 8-77*).
8. If the shims are in good condition, keep them and use them for reassembly of the carrier.
9. If the shims are to be discarded because of damage, measure the shim pack total thickness with a micrometer. Record the dimension. You will need it to calculate the depth of the drive pinion in the carrier when the gearset is installed.

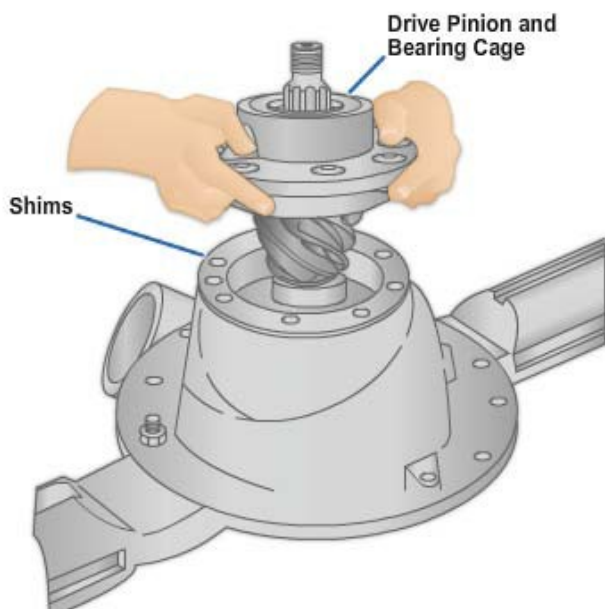


Figure 8-77 - Removing the drive pinion and bearing cage.

Drive Pinion and Bearing Cage Disassembly

1. Place the drive pinion and bearing cage in a press. The shaft end should be positioned toward the top of the assembly.
2. Support the bearing cage under the flange area with metal or wooden blocks.
3. Press the drive pinion through the bearing cage (*Figure 8-78*). Do not allow the pinion to fall to the floor from the press when the bearing is free.
4. If the pinion oil seal is mounted directly in the outer bore of the bearing cage, remove the seal at this time. Be careful that the mounting surfaces of the bearing cage are not damaged.

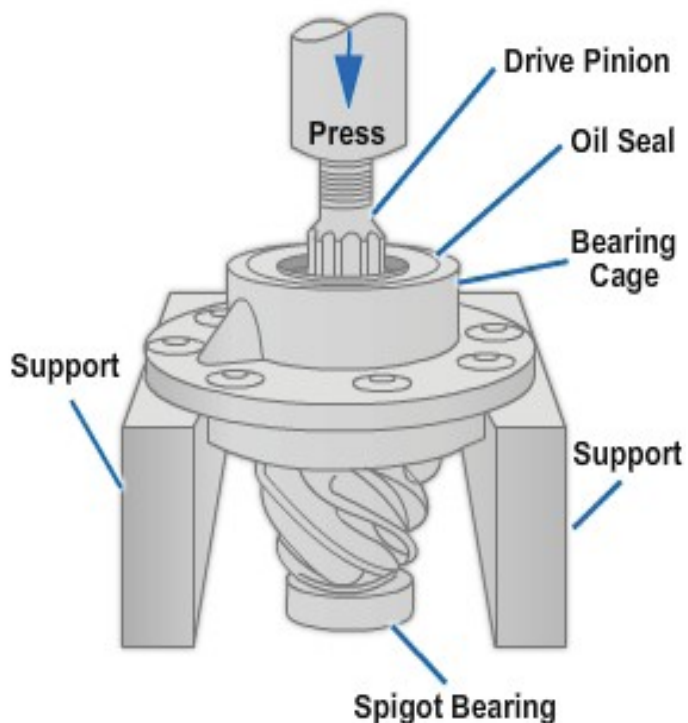


Figure 8-78 – Pressing the drive pinion from the bearing cage.

5. If the seal is a one-piece design (without mounting flange), discard the seal. If the seal is a triple-lid design (with flange), inspect the seal for damage. If the surfaces of the seal and yoke or flange are smooth and not worn or damaged, it is possible to reuse the seal again during reassembly of the unit. However, replacement is recommended to prevent the cost associated with premature seal failure in the rebuilt unit.
6. If the pinion bearings need to be replaced, remove the inner and outer bearing cups from the inside of the cage. Use a press and sleeve, bearing puller, or a small drift and hammer.
7. If the pinion bearings need to be replaced, remove the inner bearing cone from the drive pinion with a press or bearing puller. The puller must fit under the inner race of the cone to remove it correctly without damage.
8. If the spigot bearing needs to be replaced, put the drive pinion in a vise. Install a soft metal cover over each vise jaw to protect the drive pinion.
9. Remove the snapping from the end of the drive pinion (*Figure 8-79*).
10. Remove the spigot bearing from the drive pinion with a bearing puller.

Differential Carrier Reassembly

The reassembly procedure is essentially a reversal of the disassembly procedure. The procedure outlined is general. Always refer to the service manual for the proper and detailed procedures for the unit being overhauled.

Drive Pinion and Bearing Cage Reassembly

To reassemble the drive pinion and bearing cage, use the following procedure:

1. Place the bearing cage in a press. Support the bearing cage between metal or wooden blocks.
2. Press the bearing cup into the bore of the bearing cage until the cup is flat against the bottom of the bore. Use a sleeve of the correct size to install the bearing cup.
3. Put the drive pinion in a press with the gear head (teeth) toward the bottom.
4. Press the inner bearing cone onto the shaft of the drive pinion until the cone is flat against the gear head. Use a sleeve against the bearing inner race if necessary.
5. To install one-piece spigot bearing assemblies, put the drive pinion in a press, gear head teeth toward the top. Press the spigot bearing onto the end of the drive pinion until the bearing is flat against the gear head. Install the snap ring to secure the bearing. Be sure the snap ring is securely seated.
6. Apply axle lubricant on the bearing cups in the cage and bearing cones.
7. Install the drive pinion into the bearing cage.
8. Install the bearing spacer(s) onto the pinion shaft against the inner bearing cone (*Figure 8-80*).

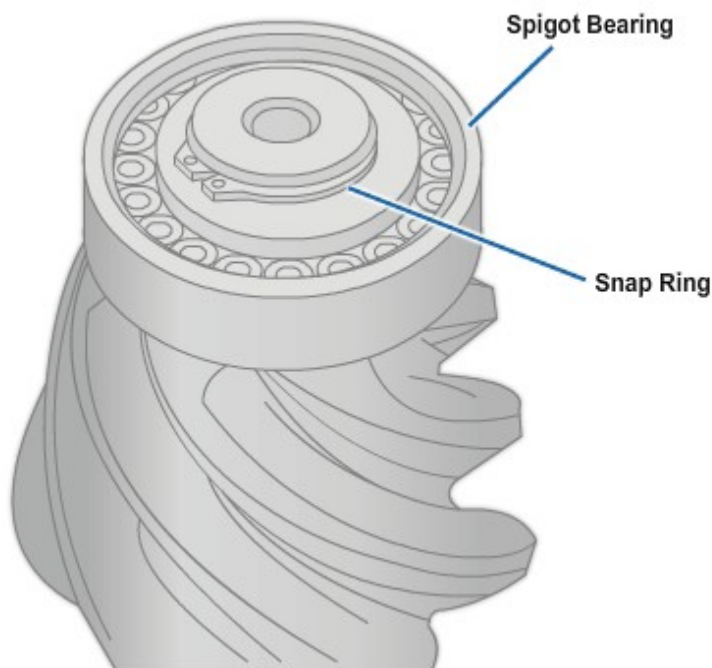


Figure 8-79 – A snap ring secures the spigot bearing to the pinion shaft.

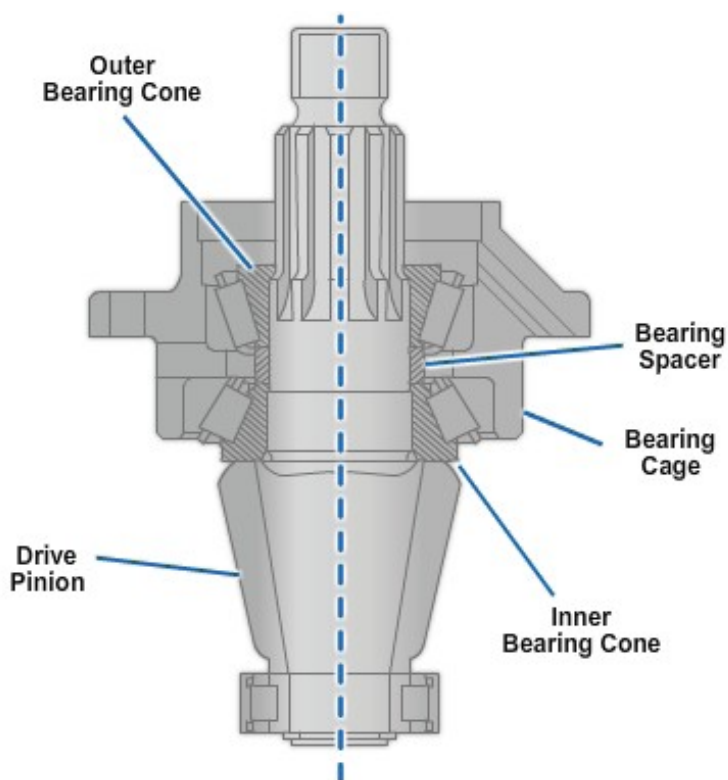


Figure 8-80 - Drive pinion assembly.

9. Install the outer bearing cone onto the pinion shaft against the spacer(s).
10. At this time, adjust the pinion bearing preload.
11. Once the preload has been set and adjusted, adjust the thickness of the shim pack in the pinion cage.

Install the Drive Pinion and Bearing Cage

When the drive pinion and bearing cage are assembled and adjusted, install them into the carrier as follows:

1. If a new drive pinion and crown gearset is to be installed, or if the depth of the drive pinion has to be adjusted, calculate the thickness of the shim pack.
2. Install the correct shim pack between the bearing cage and carrier.
3. Align the oil slots in the shims with the oil slots in the bearing cage and carrier. The use of guide studs will help align the shims (*Figure 8-81*).
4. Install the drive pinion and bearing cage into the carrier. If necessary, use a rubber, plastic, or leather mallet to tap the assembly into position.
5. If used, install the cover and seal assembly and gasket over the bearing cage (*Figure 8-82*).
6. Align the oil slots in the cover and gasket with the oil slots in the bearing cage.
7. Install the bearing cage to the carrier and tighten all hardware to correct torque value.
8. Install the input yoke or flange onto the drive pinion. The yoke or flange must be against the outer bearing

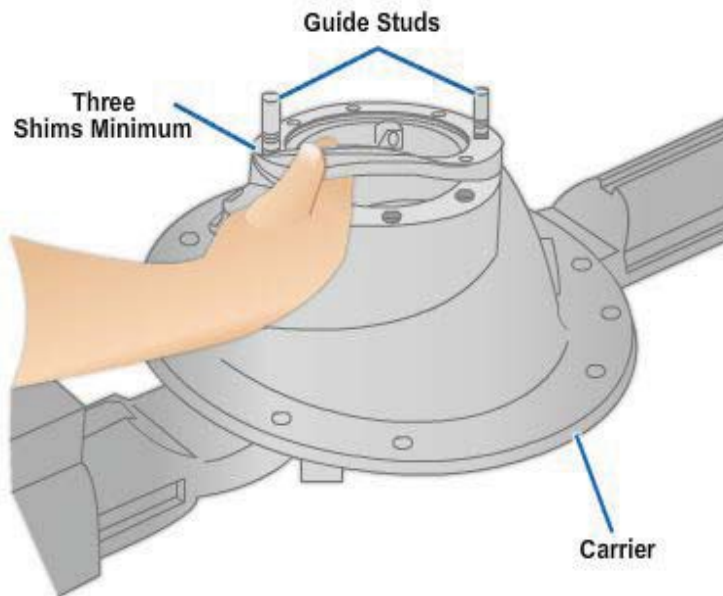


Figure 8-81 - Shim pack installation.

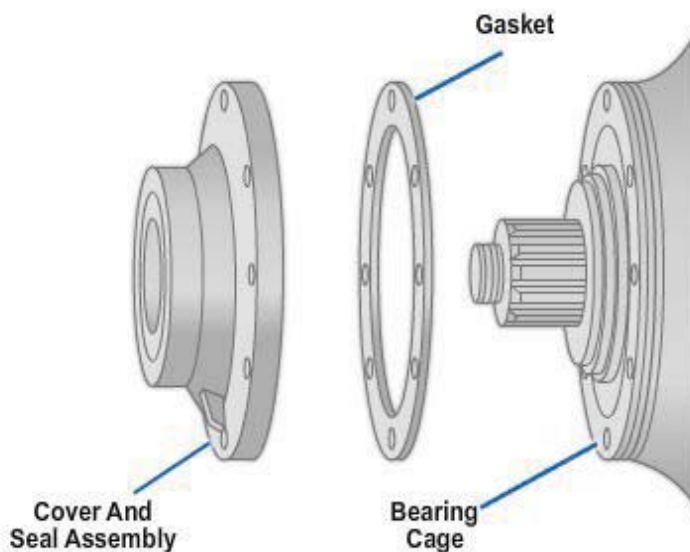


Figure 8-82 – Cover and seal assembly, gasket and bearing cage.

for proper installation.

9. Tighten the pinion nut to the correct torque value. Use the yoke or flange bar during the torquing operation.

Crown Gear and Differential Assembly

1. Expand the ring gear by heating it in a tank of water to a temperature of 160-180°F for 10-15 minutes. Never use a torch for this operation as you could damage the hardening.

NOTE

During assembly, do not attempt to press a cold crown gear into the flange case half. A cold crown gear will damage the case half because of the interference fit. The scraping that results produces metal particles that lodge between the components, resulting in gear runout that exceeds specifications.

2. Safely lift the crown gear onto the flange case half immediately after the gear has been heated. If the crown gear does not fit easily onto the case half, reheat it and try again.

3. Align the fastener holes of the crown gear and the flange case half. Rotate the crown gear as needed.

4. Install the fasteners that clamp the crown gear to the flange case half. Install the bolts from the gear side of the assembly. Bolt heads must be against the crown (Figure 8-83).

5. Tighten the bolts to the correct torque value. If rivets are used to hold the crown gear to the flange case half, install the correct size rivets in pairs opposite each other from the case half side of the assembly. The rivet heads must be against the flange case half (Figure 8-84, View A). Press the rivets into position from the crown/ring gear side of the assembly using a riveting pressure for at least 1 minute and check for gaps between the back surface of the ring gear and the case flange using a 0.003-inch thickness gauge (Figure 8-84, View B).

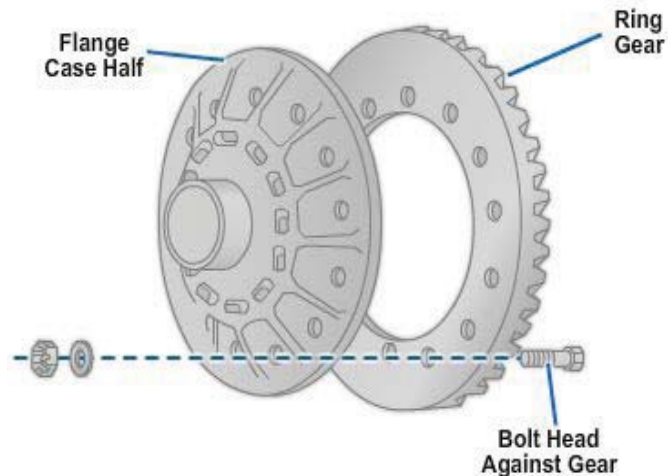


Figure 8-83 - Crown ring gear installation to flange case half.

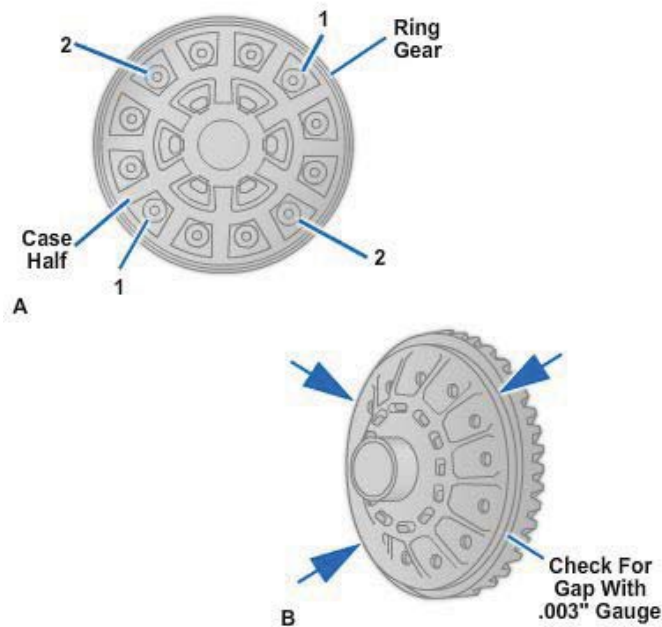


Figure 8-84 - Installing rivets to crown gear.

6. Install the bearing cones on both halves (*Figure 8-85*). Use a press and sleeve if necessary to install the cones.
7. Apply axle lubricant on the inside surfaces of both case halves, spider, thrust washers, side gears, and differential pinions.
8. Place the flange case half on the bench with the crown gear teeth facing upward.
9. Install one thrust washer and side gear into the flange case half (*Figure 8-86*).
10. Install the spider, differential pinions, and thrust washers into the flange case half (*Figure 8-87*).
11. Install the second side gear and thrust washer over the spider and differential pinions.
12. Put the plain half of the differential case over the flange half and gears. Rotate the plain half as needed to align the match marks.
13. Install hardware into the case halves. The distance between fasteners must be equal. Tighten the fasteners to the correct torque value in a pattern opposite each other.
14. Check the differential rolling resistance of the differential gears.

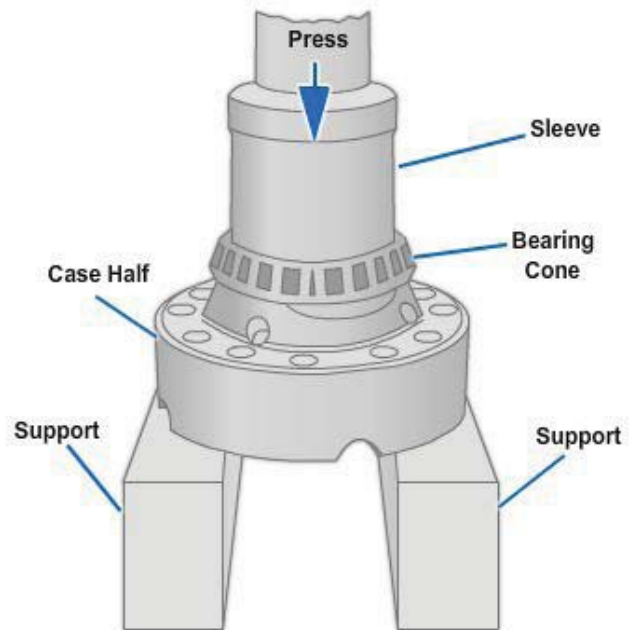


Figure 8-85 - Bearing cone installation in case half.

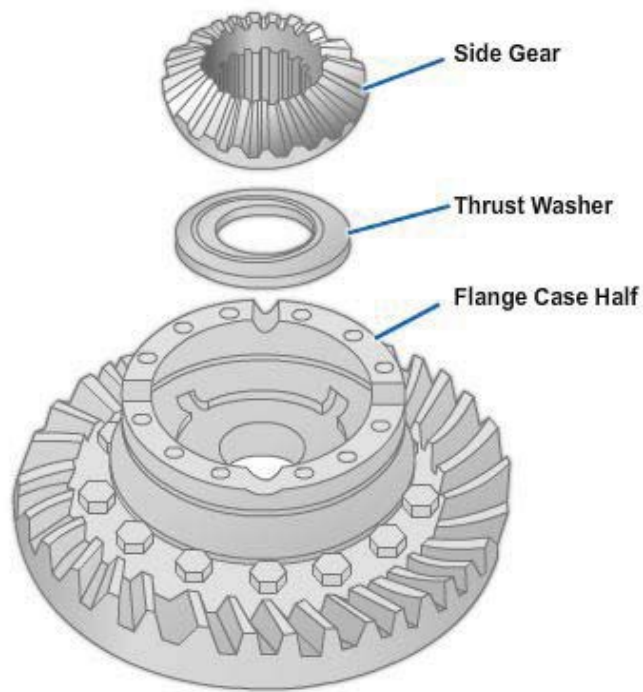


Figure 8-86 – Side gear installation.

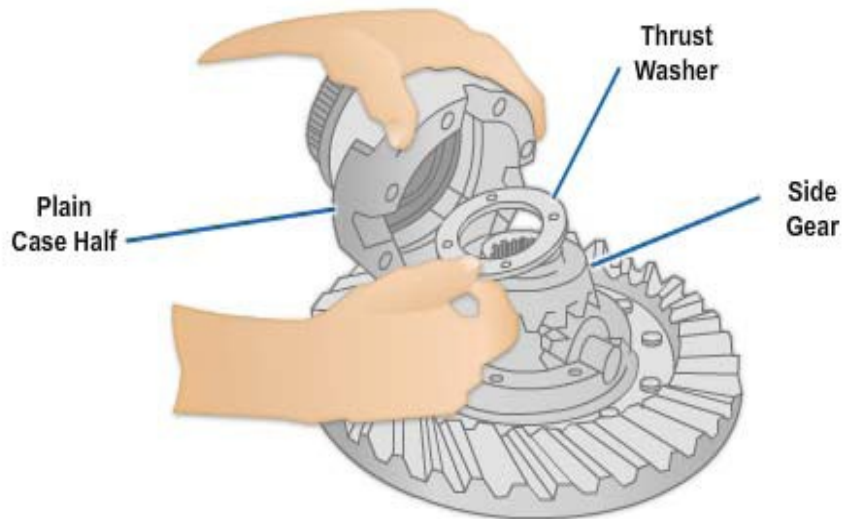


Figure 8-87 - Spider, differential pinion, and side gear installation.

Installing the Crown Gear Assembly into the Carrier

To install the assembled crown gear and differential assembly into the carrier, use the following procedure:

1. Clean and dry the bearing cups and bore of the carrier legs and bearing caps.
2. Apply axle lubricant on the inner diameter of the bearing cups and onto both bearing cones that are assembled on the case halves.
3. Apply a suitable adhesive in the bearing bores of the carrier legs and bearing caps.

4. Install the bearing cups over the bearing cones that are assembled on the case halves.
5. Safely lift the differential and ring gear assembly and install it into the carrier.
6. Install both of the bearing adjusting rings into position between the carrier legs (*Figure 8-88*). Turn each adjusting ring hand-tight against the bearing cup.
7. Install the bearing caps over the bearings and adjusting rings in the correct location as marked before removal (*Figure 8-89*).
8. Tap each bearing cap into position with a light leather, plastic, or rubber mallet. The caps must fit easily against the bearings, adjusting rings, and carrier.
9. Install the hardware that holds the bearing caps to the carrier. Tighten all hardware by hand first and then torque to the correct values.
10. Do not install the cotter keys or lock plates that hold the bearing adjusting rings in position.

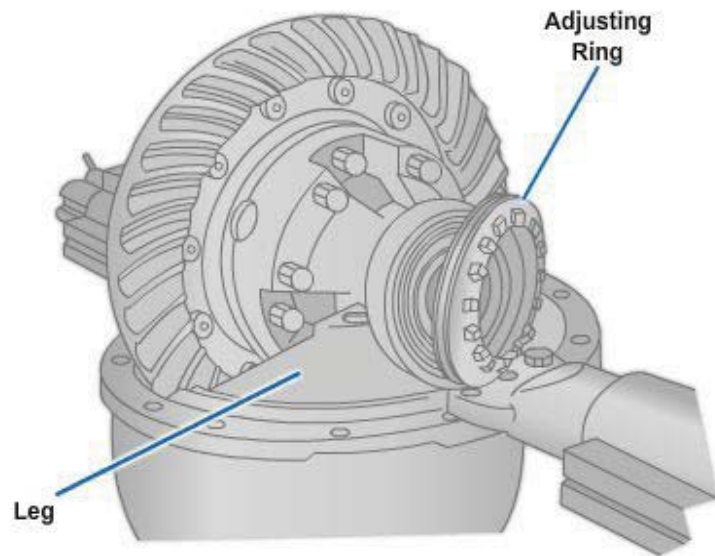


Figure 8-88 - Installation of adjusting rings.

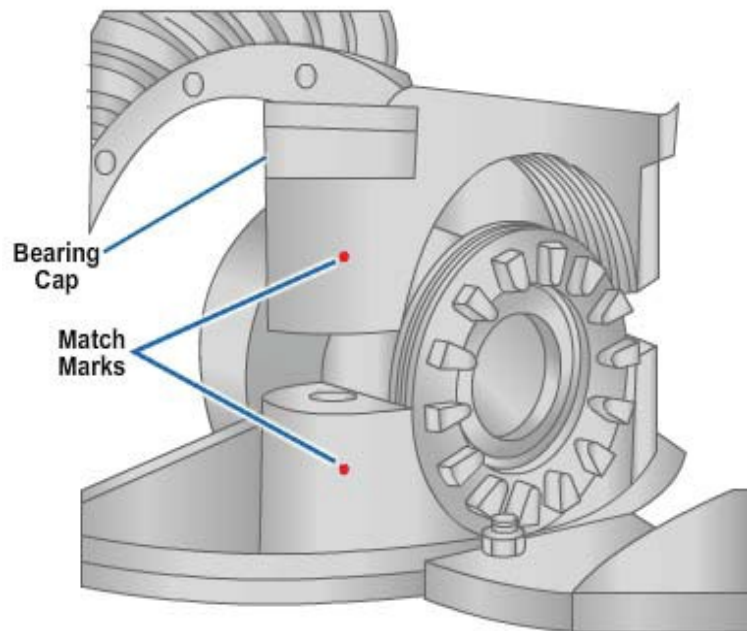


Figure 8-89 - Installation of bearing caps using match marks.

Continue the overall procedure by performing the following checks or adjustment:

1. Adjust preload of differential bearing.
2. Check runout of ring gear.
3. Adjust backlash of ring gear.
4. Check and adjust tooth contact pattern.

5. Adjust the thrust screw.

Installing the Differential Carrier into the Banjo Housing

Now that the differential carrier has been assembled, you can install it into the axle banjo housing using the following procedure:

1. Clean the inside of the axle housing and the carrier mounting flange. Use cleaning solvent and clean shop cloths to remove dirt and foreign matter. Blow dry the cleaned areas with air. Be sure to wear appropriate eye protection when using compressed air.
2. Inspect the axle housing for damage. Repair or replace if necessary.
3. Check for loose studs in the mounting surface of the housing where the carrier fasteners connect. Remove and clean the studs that are loose.
4. Apply liquid adhesive such as Loctite™ to the threaded holes and install the studs into the axle housing. Tighten the studs to the correct torque value.
5. Apply silicone or a gasket (depending on OEM recommendation) to the mounting flange of the banjo housing, as shown in *Figure 8-90*.
6. Install hardware in the four corner locations around the carrier and axle housing. Hand-tighten the fasteners.
7. Carefully push the carrier into position. Tighten the four fasteners two or three turns each in a pattern opposite each other.

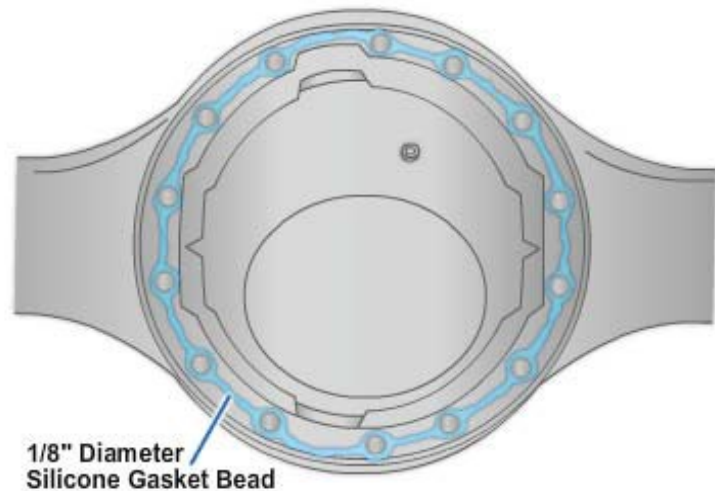


Figure 8-90 - Application of silicone gasket material to the mounting surface of the axle housing.

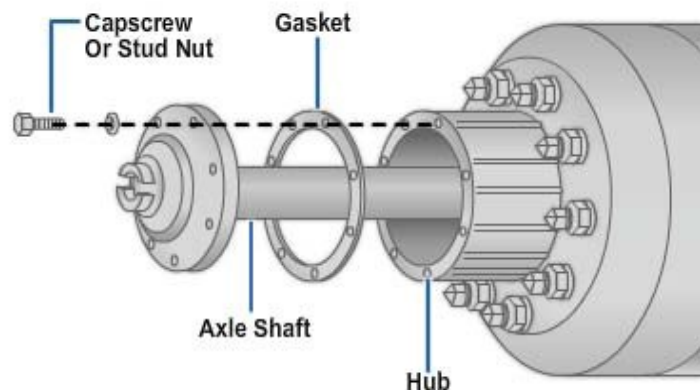


Figure 8-91 - Installing the gaskets and axle shafts into the axle housing and carrier.

8. Repeat Step 7 until the four fasteners are tightened to the correct torque value.
9. Install the other fasteners that hold the carrier in the axle housing. Tighten the fasteners to the correct torque value.
10. Connect the driveline universal joint to the pinion yoke or flange on the carrier.
11. Install the gaskets and axle shafts into the axle housing and carrier (*Figure 8-91*). The gasket and flange of the axle shafts must fit flat against the wheel hub.
12. Install the hardware that fastens the axle shafts to the wheel hubs. Tighten to the correct torque value.
13. If the wheel hubs have studs, install the tapered dowels at each stud and into the flange of the axle shaft. Use a punch or drift and hammer if needed. Install the hardware on the studs and tighten to the correct torque value.

End Play Adjustment

Input shaft end play requirements will vary with operating conditions, mileage, and rebuild procedures. To measure and adjust end play, do the following:

1. Measure end play with a dial indicator positioned at the yoke end of the input shaft.
2. Move the input shaft axially and measure the end play. A new power divider or a used unit rebuilt with all new components should read an endplay of 0.003-0.007 inch. A rebuilt unit with reused components will typically read from 0.013-0.017 inch.
3. If the end play reading is not correct, remove the input shaft nut, flat washer, and yoke. Remove the bearing cover capscrews and lock washers. Then remove the cover and shim pack.
4. To increase end play, add shims to the shim pack. To decrease end play, remove shims from the shim pack.
5. To reassemble the input shaft, install the adjusted shim pack and bearing cover. Install capscrews and lock washers, and torque to correct value.
6. Install the yoke, flat washer, and nut. Tighten the nut snugly. Tap the end of the input shaft lightly to seat the bearings.
7. Measure the input shaft end play again with a dial indicator. If the endplay is still incorrect, repeat Steps 3-7.
8. With the endplay correct, seal the shim pack to prevent lube leakage. Then torque the input shaft nut and cover capscrews to the correct value.

Crown/Ring Gear Runout Check

To check the runout of the crown/ring gear, do the following:

1. Attach a dial indicator on the mounting flange of the differential carrier (*Figure 8-92*).
2. Adjust the dial indicator so that the plunger or pointer is against the back surface of the crown gear.
3. Adjust the dial of the indicator to zero.
4. Rotate the differential and crown gear when reading the dial indicator. The runout of the crown gear must not exceed 0.008 inch.

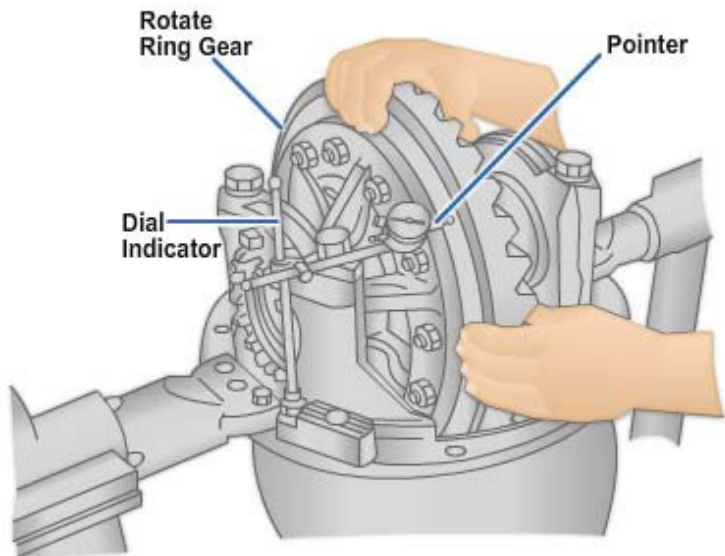


Figure 8-92 - Checking crown gear runout.

5. If runout of the crown gear exceeds the specification, remove the differential and crown gear assembly from the carrier. Check the differential components, including the carrier, for the problem causing the runout of the gear to exceed specification. Repair or replace the defective parts.
6. After the components are repaired or replaced, install the differential and crown gear into the carrier.
7. Repeat the preload adjustment of the differential bearings. Then repeat this runout procedure.

Check/Adjust Crown Gear Backlash

If the used crown and pinion gearset is installed, adjust the backlash to the setting that was measured before the carrier was disassembled. If a new gearset is to be installed, adjust backlash to the correct specification for the new gearset.

To check and adjust ring gear backlash, do the following:

1. Attach a dial indicator onto the mounting flange of the carrier.
2. Adjust the dial indicator so that the plunger is against the tooth surface at a right angle.
3. Adjust the dial indicator to zero, making sure the plunger is loaded through at least one revolution.
4. Hold the drive pinion in position.

5. When reading the dial indicator, rotate the crown gear a small amount in both directions against the teeth of the drive pinion (*Figure 8-93*). If the backlash reading is not within specification (typically ranging from 0.010 to 0.020 inch), adjust backlash as outlined in Steps 6 and 7.
6. Loosen one bearing adjusting ring one notch, and then tighten the opposite ring the same amount. Backlash is increased by moving the crown gear away from the drive pinion (*Figure 8-94*). Backlash is decreased by moving the crown gear toward the drive pinion (*Figure 8-95*).
7. Repeat steps 1 thru 5 until the backlash is within specifications.

Pinion and Crown Tooth Contact Adjustment

Correct tooth contact between the pinion and crown gear cannot be overemphasized because improper tooth contact results in noisy operation and premature failure. The tooth contact pattern consists of the lengthwise bearing (along the tooth of the ring gear) and the profile bearing (up and down the tooth). *Figure 8-96* shows crown gear tooth nomenclature.

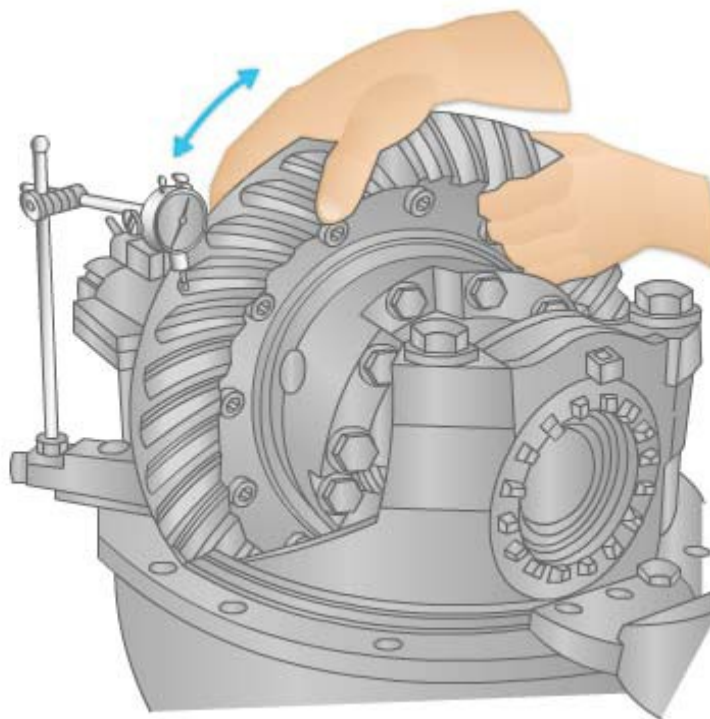


Figure 8-93 - Check crown gear backlash.

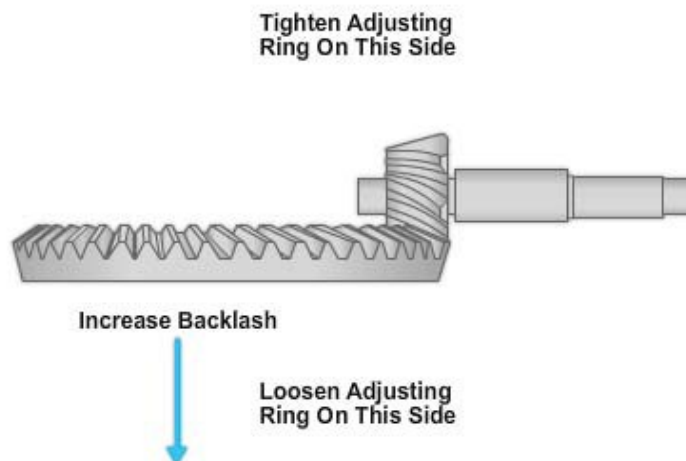


Figure 8-94 - Adjustments to increase backlash.

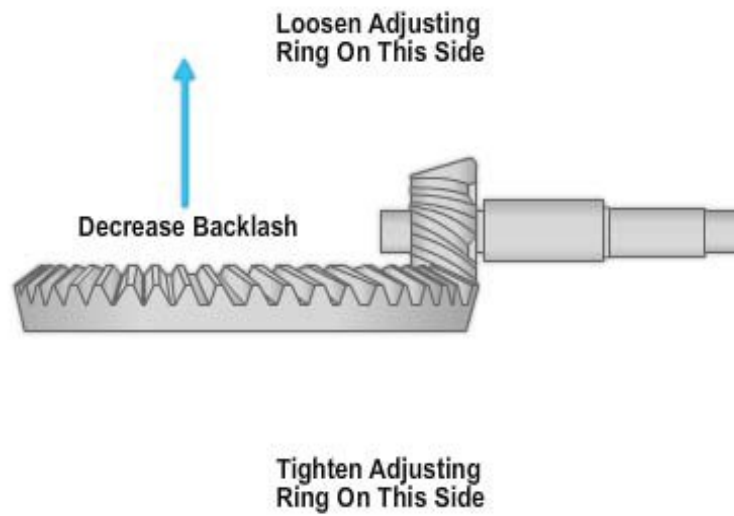


Figure8-95- Adjustments to decrease backlash.

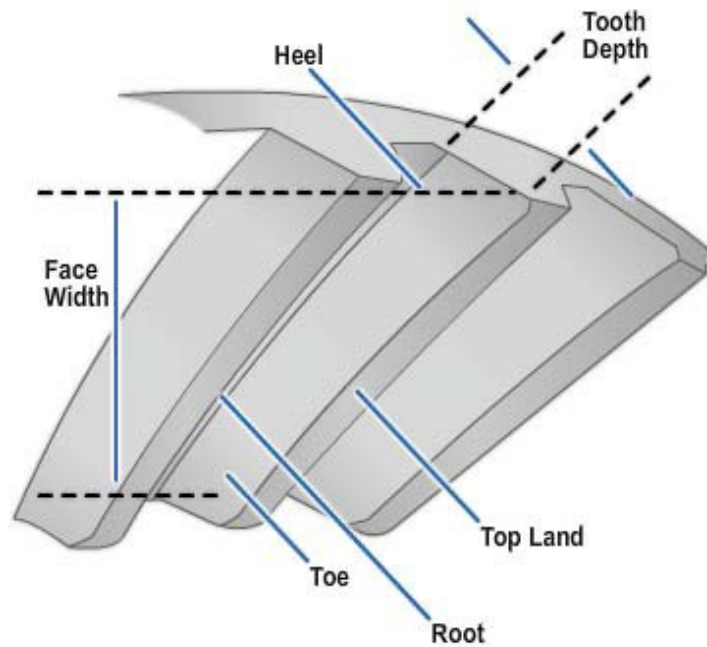


Figure8-96 – Crown gear tooth nomenclature.

Checking tooth contact pattern on a new gearset. Paint or coat 12 crown gear teeth with a marking compound such as white grease and roll the gear to obtain a tooth contact pattern (*Figure 8-97*). Machine blue, also called Prussian blue, can be used. Machine blue is a deep blue dye mixed in a grease-like substance. Use a small stiff bristle brush to apply a light even coat. A correct pattern should be well centered on the crown gear teeth with lengthwise contact clear of the toe (*Figure 8-98*). The length of the pattern in an unloaded condition will be approximately one-third to two-thirds of the crown gear tooth in most models and ratios.

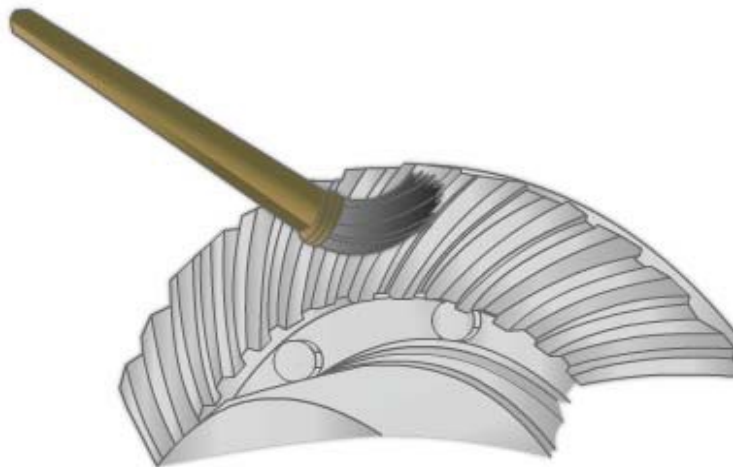


Figure 8-97 - Application of a compound to check tooth contact.

Checking tooth contact pattern on a used gearset. Used gearing will not usually display the square, even contact pattern found in new gearsets. The gear will normally have a pocket at the toe-end of the gear tooth that tails into a contact line along the root of the tooth (*Figure 8-99*). The more use a gear has had, the more the line becomes the dominant characteristic of the pattern.

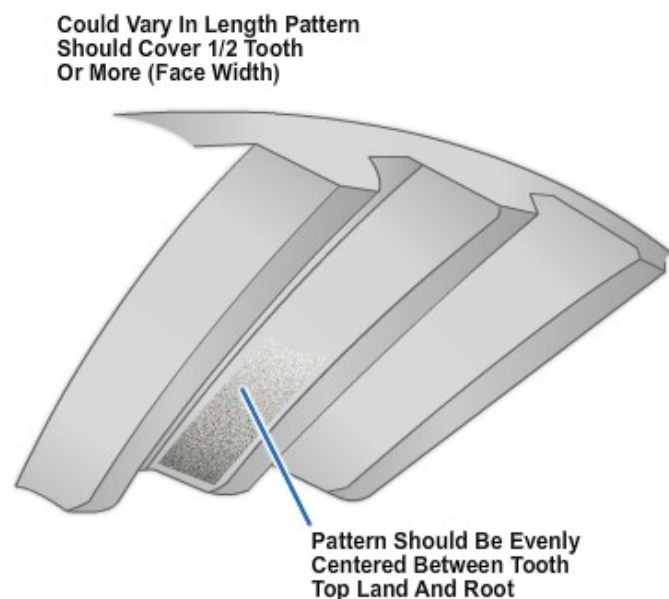


Figure 8-98 - Correct tooth contact pattern for new gearing.

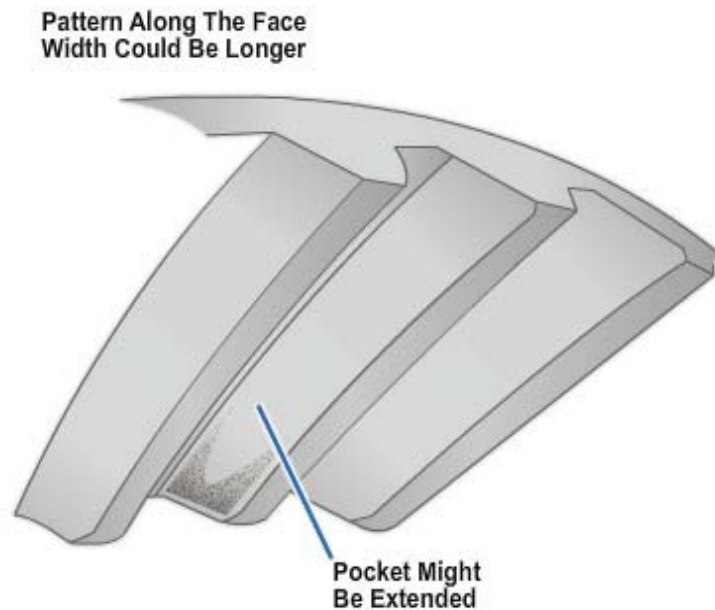


Figure 8-99 - Correct tooth contact pattern for used gearing.

Adjust tooth contact pattern.

When disassembling, make a drawing of the gear tooth contact pattern so that when reassembling it is possible to replicate approximately the same pattern. A correct pattern should be clear of the toe and should center evenly along the face width between the top land and the root. Otherwise, the length and shape of the pattern can be highly variable and are usually considered acceptable tooth contact pattern for new gearing-providing the pattern does not run off the tooth at any time. If necessary, adjust the contact pattern by moving the crown gear and drive pinion. Crown gear position controls the backlash setting. The adjustment also moves the contact pattern along the face width of the gear tooth (*Figure 8-100*). Pinion position is determined by the size of the pinion bearing cage shim pack. It controls contact on the tooth depth of the gear tooth (*Figure 8-101*).

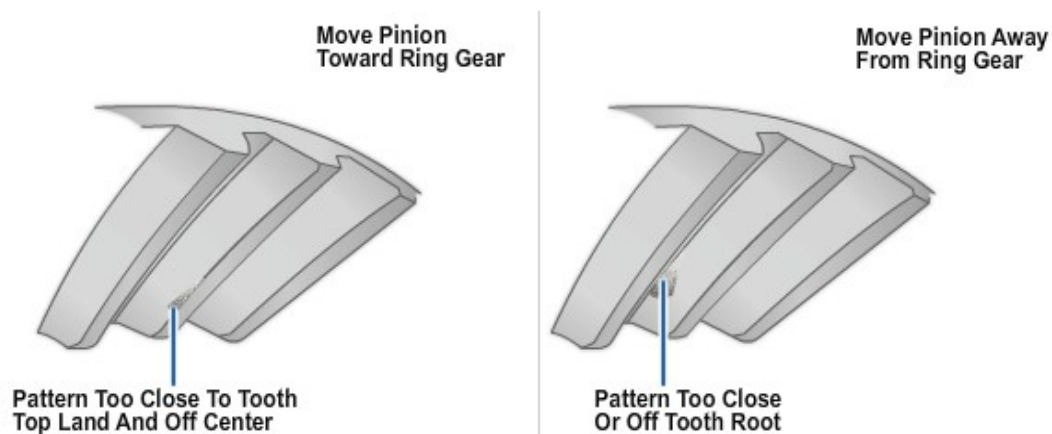


Figure 8-100 - Two incorrect patterns during adjust pinion position.

These adjustments are interrelated. As a result, they must be considered together even though the pattern is altered by two distinct operations. When making adjustments, first adjust the pinion and then the backlash. Continue this sequence until the pattern is satisfactory.



Figure 8-101 - Two incorrect patterns when adjusting backlash.

5.1.0 Axles, Wheels, and Tracks

5.1.1 5.1.1 Semi-floating Axles

In the semi-floating axle shaft, drive torque from the differential carrier is delivered by each axle half-shaft directly to the drive wheels. A single bearing assembly, located at the outer end of the axle, is used to support the axle half-shaft. The part of the axle extending beyond the bearing assembly is either splined or tapered to a wheel hub and brake drum assembly. The main disadvantage of this type of axle is that the outer end of each axle shaft is required to support the weight of the vehicle, and the weight is placed on the axle over the wheels and tires. These loads will shift as the axle rotates, placing flexing stresses on the shaft. If an axle half-shaft were to break, the wheel would fall off.

Figure 8-102 shows a semi-floating axle using a ball bearing. This is a pre-greased bearing. There is an axle seal behind the bearing. The axle collar is pressed onto the axle shaft. The bearing and axle are held in the housing by an axle retainer plate mounted on the outer end of the rear axle housing. The retainer

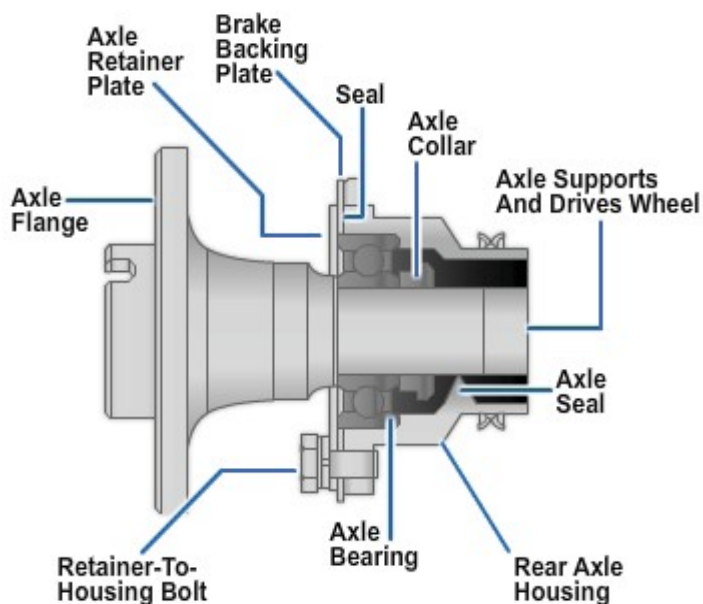


Figure 8-102 - Ball bearing semi-floating axle.

plate and bearing control endplay during turns.

Figure 8-103 shows a roller bearing version of the semi-floating axle. This bearing is lubricated by rear end lubricant. The axle seal is installed in front of the bearing. When this kind of bearing is used, the axle is held in the housing by a clip on the inboard end of the shaft at the differential assembly. This kind of axle is sometimes called a C-lock axle because of the shape of the locking clip. Endplay on turns is controlled by the fit of the axle shaft between the C-lock and the other parts of the differential assembly.

Figure 8-104 shows a semi-floating axle using a tapered roller bearing. This type of axle is usually found on older vehicles. When this type of bearing is used, there is usually some provision for adjusting the bearing preload to control endplay. This is generally done by using axle shims or by turning an adjustment nut. Tapered roller bearings may be packed with grease or lubricated from the rear axle housing, depending on the particular manufacturer's design.

In *Figure 8-104*, notice the use of the tapered axle. This is one of two methods used to secure a wheel hub to its axle. The tapered end wedges into a tapered hole in the wheel hub, and the key keeps the axle from rotating in the hub. The other method has the wheel hub (axle and flange, in this case) solidly mounted to the axle.

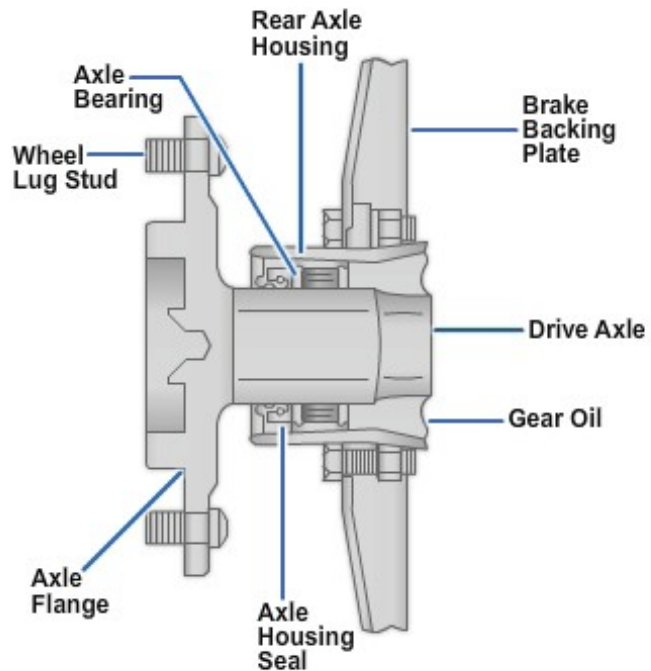


Figure 8-103 - Roller bearing semi-floating axle.

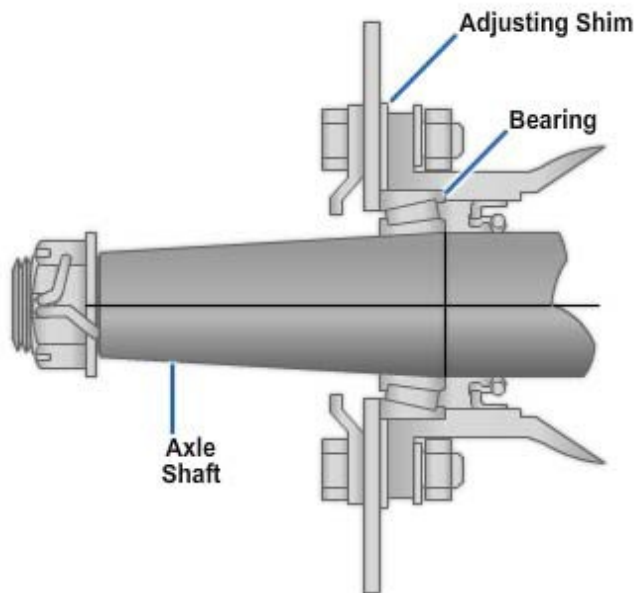


Figure 8-104 - Tapered roller bearing semi-floating axle.

5.1.2 Three-Quarter Floating Axles

The axle shafts in a three-quarter floating axle may be removed with the wheels that are keyed to the tapered outer ends of the shaft (*Figure 8-105*). The inner ends of the shafts are carried as in a semi-floating axle. The axle housing, instead of the shafts, carries the weight of the vehicle because the wheels are supported by bearings on the outer ends of the housing. However, axle shafts must take the stresses caused by the turning or skidding of the wheels. Three-quarter floating axles are used in some trucks but in very few passenger cars.

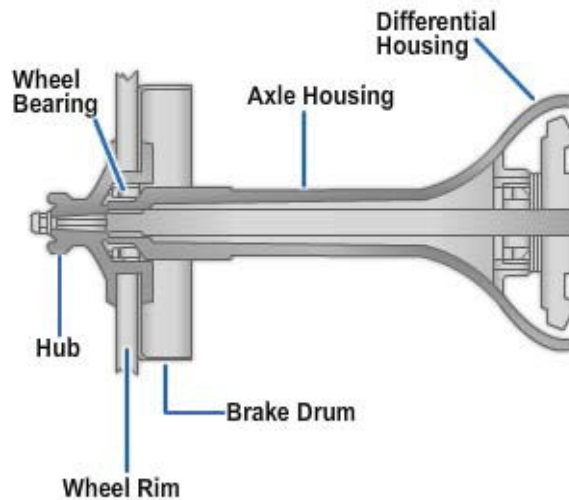


Figure 8-105 - Three-quarter floating axle.

5.1.3 Axles

A full-floating axle is used on large, slow moving off-road equipment with a drive wheel on each end of the axle housing. *Figure 8-106* shows two large tapered roller bearings that are mounted to the wheel hub and carry the full weight of the equipment and load. On larger equipment, the bearings are mounted on spindle bolts to the axle housing. The axle itself only transmits torque of the engine through it and does not carry any weight; hence the term "floating" is used to describe its function. On smaller equipment, the axle is connected to the drive wheels through a bolted flange that can be removed to gain access to the axle without removing the wheels.

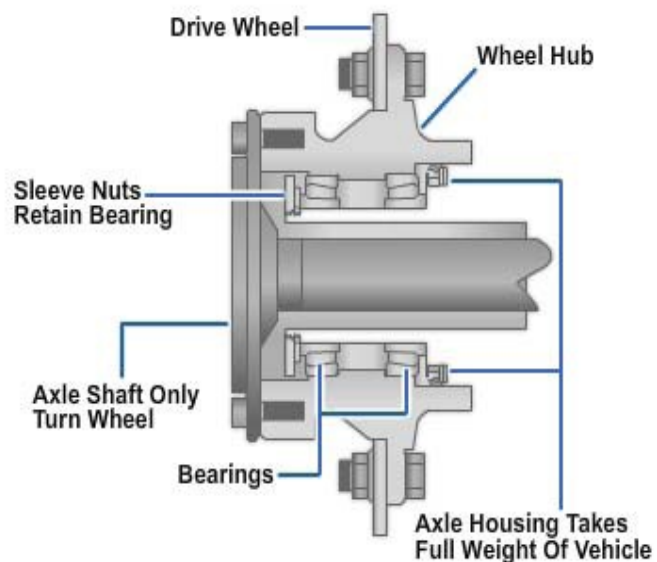


Figure 8-106 - Typical heavy-duty full-floating axle.

situation. Caution should be used when removing the axles to allow the wheels to free-wheel. The equipment should be secured either with wheel chocks or a tow hook to another piece of towing equipment to prevent accidental movement.

5.1.4 ving Wheels Full-Track

Wheels attached to live axles are the driving wheels. The number of driving wheels is sometimes used to identify equipment. You, as a mechanic, may identify a truck by the gasoline or diesel engine that provides the power. Then again, you may refer to it as a bogie drive.

Wheels attached to the outside of the driving wheels make up dual wheels. Dual wheels give additional traction to the driving wheels and distribute the weight of the vehicle over a greater area of road surface. They are considered as single wheels in describing vehicles; for example, a 4 x 2 could be a passenger car or a truck having four wheels with two of them driving. A 4 x 4 indicates a vehicle having four wheels with all four driving. In some cases, these vehicles will have dual wheels in the rear. You would describe such a vehicle as a 4 x 4 with dual wheels.

A 6 x 4 truck, although having dual wheels in the rear, is identified by six wheels, four of them driving. Actually, the truck has ten wheels, but the four wheels attached to the driving wheels could be removed without changing the identity of the truck. If the front wheels of this truck were driven by a live axle, it would be called a 6 x 6.

The tracks on track-laying vehicles are driven in much the same manner as wheels on wheeled vehicles. Sprockets instead of wheels are driven by live axles to move the tracks on the rollers. These vehicles are identified as full-track, half-track or vehicles that can be converted.

5.2.0 Service and Maintenance

The efficiency and life of mechanical equipment are as dependent on proper lubrication as they are on sound engineering design.

Proper lubrication depends on using the right type of lubricant at the proper intervals and maintaining the specified capacities. The recommended lubrication practices and specifications are general in nature and typical of manufacturer's procedures. It is always advisable to refer to the service manual for detailed procedures.

5.2.1 Drive Axle Lubrication

Mechanics who perform service on vehicles and off-road equipment must understand the importance of following the manufacturer's maintenance procedures. Many of the axle-related failures are caused by using a lubricant that is not meant for the application. This will result in a shorter component life than could be otherwise achieved. Many failures could be prevented by following sound maintenance practices concerning lubrication selection and use. Axle failures can and have produced many undesirable consequences. When lubrication levels are not properly maintained in axles, the life of the bearings and gears will be adversely affected, shortening their life or often leading to catastrophic failures. Regardless of how well the equipment is designed and operated if it is not properly maintained, premature axle component wear will occur and most definitely lead to early failure. Although some failures are caused by improper installation of components, mechanics need to make themselves aware of correct methods and ensure that the proper replacement parts and tools are used to assemble the components.

Lubrication-related damage may take place even if the correct lubricant is used. Often the intervals between servicing are inadequate for the application, resulting in component damage. Lubricants that are used in axle assemblies have three general functions:

- Provide an adequate lubrication film quickly and reduce friction between sliding and rolling surfaces.
- Remove excess heat from high friction areas and maintain correct operating temperatures.
- Remove dirt and wear particles from the bearings and other high friction areas.

If and when lubricating damage occurs to axle components, there are generally three basic problem areas that are responsible:

1. Contaminated lubrication
2. Low lubrication levels
3. Incorrect lubricant for the application or depleted additives

Lubricant practices that we will discuss are general examples, and you should always refer to the OEM manufacturer's service manuals for detailed procedures. Many manufactures allow the use of synthetic lubricants in axles; this extends service intervals significantly. The initial cost of synthetic lubricants is much higher upfront, but in the long run can be significantly less costly since drain intervals can often be increased by two or three times when compared to conventional crude-based lubricants. Synthetic lubricants have many qualities that conventional oils do not have, such as a much higher boiling point when compared to conventional oil, 600°F versus 350°F. Another important factor to consider when deciding on the use of synthetic oil is the amount of cold weather operation to which your equipment is exposed. Synthetic oil has much better fluidity than conventional oil in extremely cold weather; this could mean the difference between having lubrication instantly or operating for a few minutes before the oil can flow properly.

5.2.2 Proper Lubricant

Many differentials have been ruined by a phenomenon called "channeling," which occurs in cold weather; the thickened oil is parted by the rotating ring gear and is too thick to flow back. This results in inadequate lubrication until the oil heats up. Often, by then the gears and bearing have sustained damage from the lack of lubrication. A good solution to this type of problem is to use a high quality synthetic lube-one that meets API-GL-5 specifications. All lubricants used in axle assemblies must meet the American Petroleum Institute (API) and Society of Automotive Engineers (SAE) Gear Lubrication (GL) standards. Today, the use of GL-1, GL-2, GL-3, GL-4, and GL-6 is no longer approved for newer axle assemblies by many manufacturers and should be discontinued. The recommended lubricant to use in the drive axles now is API-GL-5, which is rated as an extreme pressure lubricant and is required for use in axle assemblies that use hypoid gears. Using the correct viscosity will be operating-temperature dependent, and should be adhered to. *Figure 8-107* shows the proper grade of lubricant for a given operating temperature.

Ambient Temperature Range	Correct Grade
-40°F to -15°F	75W
-15°F to 100°F	80W-90
-15°F and above	80W-140
10°F and above	85W-140

Figure 8-107 - Proper grade of lubricant.

Most OEMs approve the use of synthetic lubricants as long as they meet API-GL-5 classification standards. Due to the wide variety of operating extremes that vehicles and off-road equipment are subjected to, it is difficult to determine ideal drain intervals for all vehicles and equipment. Vehicles invariably use mileage, whereas off-road equipment service intervals are usually measure in hours of operation.

5.2.3 Contaminated Lubricant

It is not recommended to mix different brands of lubricants. Not all lubricants are compatible with each other. Every effort should be made to prevent the mixing of different lubricants in axle assemblies. Some additives used by certain manufactures are not compatible with other manufacturer's additives. Never mix different brands of gear lube. Some synthetic oils, when mixed with petroleum-based oil, will thicken. This can lead to foaming, which can result in early component failure. Water, dirt, and wear particles can cause extensive damage in a short period of time. Water can enter the axle assembly through a faulty shaft seal or through the carrier to a banjo housing joint. Wear particles are generally a result of normal wear and can be minimized by the use of magnetic drain plugs. The magnets collect metal particles that settle to the bottom of the axle housing during shutdown periods. Some manufacturers use an oil pump in the drive axle to distribute oil and a filter in the circuit to filter out dirt particles.

5.2.4 ts of Lubrication Failures

Whenever a lubricant does not perform up to the vehicle or equipment application standards, the life of the internal components will be shortened. Following is a list of causes and effects that may occur as a result of lubrication failures:

1. Lubrication that is contaminated with water can cause scoring, etching, or pitting on the running surfaces of the gears and bearings.
2. Underfilling the axle assembly may lead to metal-to-metal contact, which can lead to high friction that can cause overheating and result in oil breakdown. This will usually melt metal surfaces. The internal parts will often be blackened from the heat.
3. The use of an improper lubricant, which includes the practice of mixing different oils, may lead to surface etching or lubricant breakdown, leading to metal-to-metal contact.
4. Using a viscosity that is not suitable for the application temperatures may result in a lubrication film breakdown, leading to severe scoring and galling. The internal gears will often be blackened from the heat.

When filling the axle housing and planetary wheel ends, allow enough time for the oil to flow through the components and find its natural level. When filling is completed, allow a few minutes and then recheck the level again. The lubricant should be warm when drained; this ensures that contaminants are suspended in the oil and get flushed out.

5.2.5 ow Lubricant Levels

Lubrication levels for vehicles and off-road equipment should be checked according to the OEM service manual. Oil levels in drive axles must be checked properly; the oil level must be even with the bottom of the oil filler plug hole. Oil replacement can be adjusted according to your particular operations.

Remove the plug in the axle banjo housing; the oil should be even with the bottom of the oil level plug hole (*Figure 8-108*). Note that if the pinion angle is more than 7 degrees, a different oil level is used. To properly check the oil levels in a differential drive axle and the planetary wheel ends, the axle first should be run and then allowed to stand for approximately 5 minutes on level ground before checking the oil level. This allows time for the oil drain back down to the sump. Some axles have seals in the axles separating the oil in the wheel ends from the planetary drive. In this case, the oil level is checked independently in each wheel end and the differential banjo housing. When checking the oil level in a top mount or inverted pinion drive axle, a slightly different procedure must be followed. The oil hole on these units is located in the axle banjo housing. Note that some axles have another smaller hole located just below the oil level hole; this hole is for a temperature sensor and should not be used to fill or check the oil level.

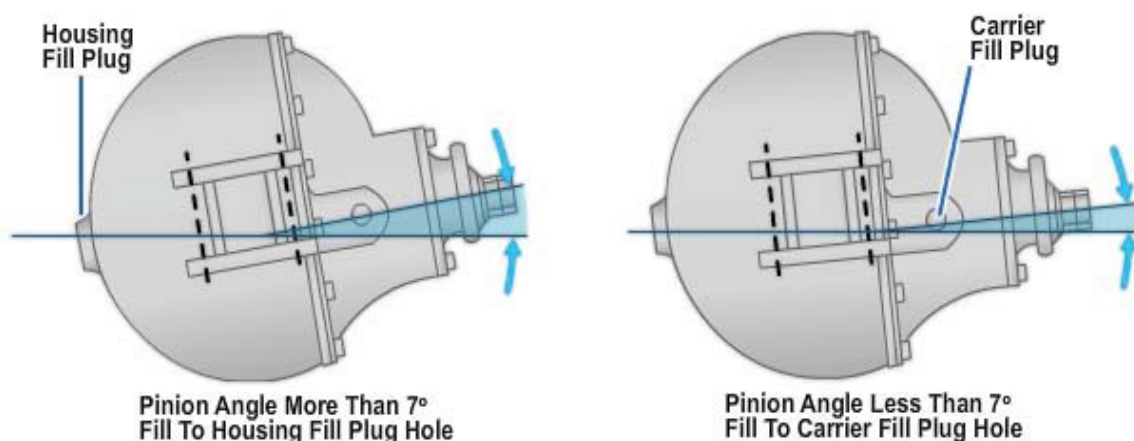


Figure 8-108 – Checking the oil level in an axle housing.

5.2.6 Intervals

Lubricants used in axle assemblies are necessary to provide lubrication to the internal components and, equally important, they distribute additives throughout the axle and wash away small wear particles that would otherwise cause accelerated wear to the gears and bearings. The oil also carries away excess heat from high friction areas. All these conditions, along with constant exposure to heat, lower the performance properties of the oil. Oil analysis should be used to determine optimum oil change intervals. Guidelines that are given in the manufacturer's service manual are based on average operating conditions. The average temperature of lubricants in axles is between 160°F and 220°F in summer months. Operating equipment with temperatures above 200°F causes the oil to oxidize at a higher rate, depleting the additives that give

the oil its increased load-carrying capacity. This reason alone makes more frequent oil change intervals desirable.

Refer to *Figure 8-109* for drive axle quick reference for troubleshooting the drive axle.

Drive Axle Troubleshooting		
Symptom	Probable Cause	Remedy
Noisy on turns only	Differential pinion gears tight on spider Side gears tight in differential case Differential or side gears defective Excessive backlash between side gears and pinion	Overhaul drive axle and make necessary adjustments.
Intermittent noise	Crown gear not running true Loose or broken differential bearings	Overhaul axle and replace defective crown gear or differential bearings.
Constant noise	Lubricant incorrect Lube level low Crown gear teeth chipped or worn; loose or worn bearings Crown gear and pinion not in adjustment for correct tooth contact Too much or too little pinion-to-gear backlash or overlap of wear pattern	Verify type and class of lubricant used. Check lube level and fill if needed. Overhaul axle and replace defective crown gear, pinion, or bearings. Adjust crown gear and pinion for correct tooth contact. Adjust gear backlash.
Rear wheels do not drive (driveline rotating)	Broken axle shaft Crown gear teeth stripped Differential pinion or side gear broken Differential spider broken	Replace broken axle. Overhaul axle and replace defective crown gear, pinion, or spider.

Figure 8-109 Drive axle quick reference troubleshooting guide.

Summary

This chapter presented extensive information on troubleshooting the drivechain assemblies of the transmission, transfer case, power takeoff, propeller shafts, and differentials.

Of the vast number of vehicles and construction equipment within the Seabee table of allowance, it is safe to say that almost every piece of CESE includes one of these assemblies. These assemblies give the vehicle or equipment its particular characteristic.

Even in the electronic age, working on these particular assemblies still requires the mechanic to possess the skills of disassembly and reassembly of components, inspecting components for wear and damage, and general hands-on mechanical know-how.

Lastly, and most importantly, you still will always be required to refer to the service manual for each vehicle or piece of equipment you are working on for the detailed specifications that will enable you to do the job correctly in order to turn out a finished product that operators can operate safely.

Review Questions (Select the Correct Response)

1. When bearings wear and retainers start to break up in the standard transmission, the noise this creates is generally referred to as what?
 - A. Growling
 - B. Rattle
 - C. thumping or knocking
 - D. Vibration
2. **(True or False)** Possible causes of noise while transmission is in gear include noisy speedometer gears.
 - A. True
 - B. False
3. Of the many places a transmission can leak oil, what is the one location that can cause a complete failure of the transmission should it leak?
 - A. Speedometer connection
 - B. Oil dip stick
 - C. Front main seal
 - D. Rear main seal
4. A damaged O-ring in the range air shift lever will bleed air into the transmission, pressurizing it and resulting in oil leakage in what component?
 - A. Output yoke retaining nut
 - B. Rear bearing cover
 - C. Speedometer connection
 - D. Front bearing cover in the auxiliary housing
5. Among the few causes, what is the most likely cause for the standard transmission to slip out of gear?
 - A. Worn detent balls or springs
 - B. Worn detent bearing or sprockets
 - C. Greasy shift linkage
 - D. Worn shifter shaft
6. Even though you have the repair manual for your vehicle, before ordering any parts for your transmission, what should you check to be sure it is the correct transmission?
 - A. Vehicle identification tag
 - B. Parts manual
 - C. Vehicle purchase order
 - D. Transmission identification tag

7. What safety feature does a transmission jack have to prevent the transmission from falling?
- A. Saddle
 - B. Chains
 - C. Straps
 - D. All the above
8. When removing the transmission, what should you do before removing any cross members?
- A. Place a jack under the transmission only
 - B. Place a jack under the engine only
 - C. Place a jack under the engine and transmission
 - D. Get someone to hold the engine
9. What tool might you use to drive out the counter shaft when disassembling the standard transmission?
- A. Five-pound hammer and spike
 - B. Arbor shaft
 - C. Puller
 - D. Counter shaft driver
10. What parts are generally recommended to be replaced during reassembly of the standard transmission even though they may show no indication of any problem before disassembly?
- A. Seals and gears
 - B. Sprockets and bearings
 - C. Bearings and seals
 - D. Seals and gaskets
11. One of the most tedious procedures is replacing needle bearings in countershaft gears. What can you do to make this procedure easier?
- A. Coat the bearings with heavy grease
 - B. Coat the bearings with light grease
 - C. Use a special needle bearing holder
 - D. Get someone else to do it
12. **(True or False)** When installing the standard transmission, one helpful action is to use the transmission bolts to draw the transmission into the clutch housing.
- A. True
 - B. False

13. What special tool or rod can you use to adjust the linkage on many types of standard transmissions ?
- A. Linkage tool
 - B. Alignment pin
 - C. Positioning tool
 - D. Connection rod
14. What mechanical unit splits power between the front and rear axles?
- A. Transaxle
 - B. Transmission
 - C. Power takeoff
 - D. Transfer case
15. What should be the next step if you detect an oil leak around the transfer case, and upon checking you find the oil level is satisfactory?
- A. Do nothing
 - B. Check other parts of the vehicle
 - C. Get someone else to check the transfer case
 - D. Remove the transfer case to ensure there are no leaks
16. As a mechanic you may encounter abnormal noises coming from the transfer case which unfortunately could be caused by one or more of its various components. What is the solution to this problem?
- A. Pull the inspection plate and make repairs
 - B. With the transfer case in place, repair only the damaged components
 - C. Remove the transfer case and overhaul it
 - D. Remove the transmission to get to the transfer case
17. What component has failed if, when checking the transfer case for shudder, you discover silicone in the oil?
- A. Silicone coupling
 - B. Oil coupling
 - C. Viscous bearing
 - D. Viscous coupling
18. What is the first step when removing the transfer case for repairs?
- A. Raise the vehicle high enough to stand underneath
 - B. Disconnect the negative battery cable
 - C. Remove the support brackets
 - D. Drain the oil

19. Which component(s) will you probably have to remove as an assembly if your transfer case has a drive chain?
- A. Front output shaft
 - B. Thrust washers
 - C. Rear thrust shaft
 - D. Sprockets
20. What component(s) can strip so cleanly as to appear machined smooth when you are inspecting the planetary gear assembly of the transfer case?
- A. Splines
 - B. Gear bushings
 - C. Shaft
 - D. Shift fork
21. What parts are usually installed at the same time as the gears they operate when you are assembling the transfer case?
- A. Gear forks
 - B. Shift forks
 - C. Shift rods
 - D. Drive chain
22. What should you install after removing the rear half of the housing or the bearing retainer after discovering the endplay of the transfer case to be incorrect?
- A. Thicker or thinner thrust washers
 - B. Thicker or thinner bushings
 - C. Thicker or thinner plunge washers
 - D. Additional grease
23. **(True or False)** You will find PTOs only on dump trucks.
- A. True
 - B. False
24. Of the six basic types of power takeoffs referred to in the chapter, which is the most common type found on trucks?
- A. Split shaft
 - B. Top mount
 - C. Countershaft
 - D. Side mount
25. What term refers to the space between meshing surfaces of the gears in the gearbox devices?
- A. Whiplash
 - B. Backlash
 - C. Gear clash
 - D. Gear conflict

26. What type of grease should be applied when pumps are mounted directly to the PTO output?
- A. Anti-seize
 - B. Axle
 - C. Silicone
 - D. Lithium
27. The basic driveshaft assembly is made up of U-joints, slip splines, propeller shafts, and_____.
- A. drive splines
 - B. yokes
 - C. differential
 - D. transmission extension
28. In what type of driveline configuration are the working angles of the U-joint's driveshaft equal, but the companion flanges and/or yokes are not parallel?
- A. Parallel-joint
 - B. Parallel-shaft
 - C. Broken-shaft
 - D. Broken-back
29. **(True or False)** The faster a driveshaft turns, the higher the allowable working angle rises.
- A. True
 - B. False
30. What two components of the driveshaft must be perfectly in line with each other to be in phase?
- A. Slip splines
 - B. Yokes
 - C. Zerk fittings
 - D. Driveshaft bolts
31. What is the typical minimum OEM specification, in inches, when you are inspecting the looseness across the U-joint bearing caps and trunnions?
- A. .0006
 - B. 0.006
 - C. 0.060
 - D. 0.600
32. Heavy-duty driveshafts typically use what type of grease?
- A. Silicone-based extreme pressure
 - B. Water-soluble
 - C. Bearing
 - D. Lithium soap-based extreme pressure

33. What service schedule could you use for servicing the slip splines?
- A. Same as the differential
 - B. Same as the transmission
 - C. Same as the U-joints
 - D. Same as the transfer case
34. When replacing the hanger bearings, make sure you look for and do not lose track of the_____.
- A. bolts
 - B. hanger locks
 - C. washers
 - D. shim pack
35. When removing the U-joint cups, ensure the bearing cups stay matched with the _____they came from.
- A. trunnion
 - B. yoke
 - C. transom
 - D. spline
36. Although acceptable, what is the least preferred method to remove a U-joint?
- A. Heat
 - B. Puller
 - C. Place in a vise and tap the yoke
 - D. Arbor press
37. **(True or False)** Regard a U-joint cross, its four bearing assemblies, and mounting hardware as a unit, and replace as such.
- A. True
 - B. False
38. With the full round end yoke, what is the next step after both bearing cups have been seated in the yoke, the lock plate tab is in place, and the bolts are in the yoke threads?
- A. Torque them down with a wrench
 - B. Turn them in first by hand
 - C. Add grease to the threads
 - D. Add the retainer clips
39. An unbalanced driveline causes transverse_____and bending_____in the driveshaft.
- A. movements, vibrations
 - B. action, movements
 - C. rotation, action
 - D. vibrations, movements

40. What tool is used to measure operating angle on the driveline?
- A. Builders level
 - B. Planimeter
 - C. Inclinator
 - D. Incline plane
41. What can be installed to correct the U-joint operating angle on a vehicle with leaf spring suspension?
- A. Axle shims
 - B. Axle risers
 - C. Leaf spring jacks
 - D. Torque rod shims
42. Driveshaft runout requires the taking of fine measurements, and generally the tool used is a/an_____.
- A. inside micrometer
 - B. driveshaft caliper
 - C. dial indicator
 - D. dial gauge
43. How many degrees should the machined shoulder of a half-round yoke or yoke bores in a full-round yoke be to the centerline of the shaft the yoke is attached to?
- A. 30
 - B. 60
 - C. 90
 - D. 180
44. **(True or False)** The PTO will always be driven by a driveshaft.
- A. True
 - B. False
45. As you go through the steps to remove the differential, as a safety precaution, you should not remove the axle retaining nuts until you have loosened which components?
- A. Capscrews
 - B. Flanges
 - C. Tapered spring dowels
 - D. Axle shafts

46. When removing the rivets on the crown gear, use a drill bit that is _____ inch smaller than the body diameter of the rivets.
- A. 1/32
 - B. 1/16
 - C. 1/8
 - D. 1/2
47. When removing the drive pinion and bearing cage, what tool(s) might you use if the yoke or flange is tight on the pinion?
- A. Two screw drivers
 - B. Pry bar
 - C. Hammer and chisel
 - D. Puller
48. When removing the pinion oil seal during disassembly of the drive pinion and bearing cage, what is the procedure if it is a one-piece design?
- A. Reuse
 - B. Discard
 - C. Do nothing
 - D. Inspect closely
49. Aligning the oil slots in the shims with the oil slots in the bearing cage and carrier is part of the installation of which component(s)?
- A. Crown gear and differential assembly
 - B. Crown gear only
 - C. Bearing cage only
 - D. Drive pinion and bearing cage
50. What can you do to the ring gear for easy installation?
- A. Expand by heating in a tank of water
 - B. Expand by heating with a torch
 - C. Contract by placing in a freezer
 - D. Contract using a CO₂ extinguisher
51. What is the proper procedure for the fasteners after installing the hardware into the case halves of the differential?
- A. Tighten in a clockwise pattern
 - B. Tighten every other counter clockwise
 - C. Tighten in an opposite pattern
 - D. Tighten in a staggered pattern

52. To install the bearing caps over the bearings and adjusting rings, tap each cap into position with which tool?
- A. Light leather mallet
 - B. Plastic mallet
 - C. Rubber mallet
 - D. All the above
53. What should the end play measurement typically be, in inches, when you are checking a rebuilt power divider with reused components?
- A. 0.003-0.007
 - B. 0.03- 0.07
 - C. 0.013-0.017
 - D. 0.13-0.17
54. The runout of the crown gear must not exceed_____inches.
- A. .0008
 - B. 0.008
 - C. 0.080
 - D. 0.800
55. **(True or False)** If the used crown and pinion gearset is installed, you can use the setting that was measured before disassembly.
- A. True
 - B. False
56. How should the correct pattern appear when you are checking the tooth contact pattern on a new gearset?
- A. Correct pattern will have a pocket
 - B. A pocket will be at the toe-end of the tooth
 - C. Pattern will be around the edge of the tooth
 - D. Pattern will be well centered on the crown teeth
57. There are a couple of variations of the semi-floating axle. Which type is sometimes referred to as the C-lock axle because of the shape of the locking clip?
- A. Tapered roller bearing
 - B. Roller bearing version
 - C. Encased semi-floating
 - D. Pinion version
58. The full-floating axle will typically be found on what type of vehicle/equipment?
- A. Sedans
 - B. Small pickups
 - C. Large, slow moving off-road
 - D. Track equipment

59. What will cool components that are subject to friction?
- A. Coolant
 - B. Lubrication
 - C. Proper air flow
 - D. Fans
60. How many degrees is typically the difference in boiling points of synthetic oil, which is higher, and conventional oil, which is lower?
- A. 250
 - B. 350
 - C. 600
 - D. 950
61. What is the recommended lubricant to use in drive axles?
- A. API-GL-1
 - B. API-GL-2
 - C. API-GL-4
 - D. API-GL-5
62. For approximately how many minutes should you wait before checking the oil level in the differential drive axle after operation?
- A. 3
 - B. 5
 - C. 10
 - D. 12

Additional Resources and References

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

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

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

Heavy Duty Truck Systems 4th Edition, Sean Bennett and Ian Andrew Norman, Delmar Cengage Learning, 2006, (ISBN 1-4018-7064-3)

Automotive Technology, A Systems Approach, 4th Edition, Jack Erjavec, Thomas, Delmar Learning, 2005. (ISBN: 1-4018-4831-1)

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Chapter 9

Wheel and Track Alignment

Topics

- 1.0.0 Steering Geometry
- 2.0.0 Adjusting Wheel Alignment
- 3.0.0 Aligning Procedures
- 4.0.0 Adjustable Suspension Angles
- 5.0.0 Nonadjustable Suspension Angles
- 6.0.0 Steering and Alignment Trouble
- 7.0.0 Track Alignment

To hear audio, click on the box. 

Overview

This chapter discusses vehicle wheel alignment and track alignment for construction equipment. For automotive vehicles and trucks, wheel alignment is a process of repositioning the suspension and steering parts and components for normal wear and effects of replacing parts. Track equipment is altogether different from wheeled vehicles, but the principle of track alignment is the same to ensure the track maintains proper alignment and adjustment to prevent wear and stress on the equipment.

The chapter starts with steering geometry and understanding that wheel alignment involves checking and adjusting a complex series of interrelated angles, covering camber angle, caster angle, kingpin inclination, toe-in, turning radius, and tracking.

The next topics include safety and tools for front-end alignment, and alignment procedures.

The subsequent topics break down the adjustable and nonadjustable angles and cover them in greater depth, discussing what to perform for each.

The following topics cover the various steering and alignment problems stemming from defective parts, bent frame, defective tires, road crown and road irregularities, vehicle load and acceleration, braking, and turning forces.

The final topic discusses track alignment along with track components and adjustment.

Objectives

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

1. Identify types of steering geometric angles.
2. Understand how to adjust front-end wheel alignment.

3. Understand how to adjust suspension angles.
4. Understand how to check nonadjustable angles.
5. Understand how to troubleshoot steering and alignment troubles.
6. Understand the principles of track alignment.

Prerequisites

None

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

Air Conditioning Systems		C
Air Compressor Overhaul		M
Inspecting and Troubleshooting Brake Systems		
Hydraulic Systems		A
Wheel and Track Alignment		D
Troubleshooting Transmissions, Transfer Cases and Differentials		V
Clutches and Automatic Transmissions		A
Troubleshooting Electrical Systems		N
Fuel System Overhaul		C
Engine Troubleshooting and Overhaul		E
The Shop Inspectors		D
Alfa Company Shop Supervisor		
Public Works Shop Supervisor		

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 an italicized instruction 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 STEERING GEOMETRY

1.1.0 Camber Angle

Camber is the inward or outward tilt of the top of the wheels when viewed from the front of the vehicle, as shown in *Figure 9-1*. If the centerline of the tire is exactly vertical, the tire has a camber setting of zero degrees. If the top of the tire tilts outward, it has positive camber, and if the top of the tire tilts inward, it has negative camber. Positive and negative camber is shown in *Figure 9-2*.

Camber settings of +% degrees for the curb side and +% degrees for the driver side wheels are typical. The amount of camber used depends on the kingpin inclination (KPI) setting. Kingpin inclination is the inclination of the steering axis to a vertical that is the equivalent of steering axis inclination (SAI) in automotive front ends.

Incorrect camber angle results in abnormal wear on the side of the tire tread. Excessive positive camber causes the tire to wear on its outside shoulder. Likewise, excessive negative camber causes the tire to wear on its inside shoulder. Unequal camber in the front wheels also can cause the steering to lead to the right or left. The vehicle will lead to the side that has the most positive camber.

Camber adjustments are not often made on heavy-duty truck axles. Some service facilities with specialized equipment adjust camber by cold bending axle beams, but, generally, axle manufacturers do not approve this practice. Bending an axle can damage the structural integrity of the beam, increase the risk of

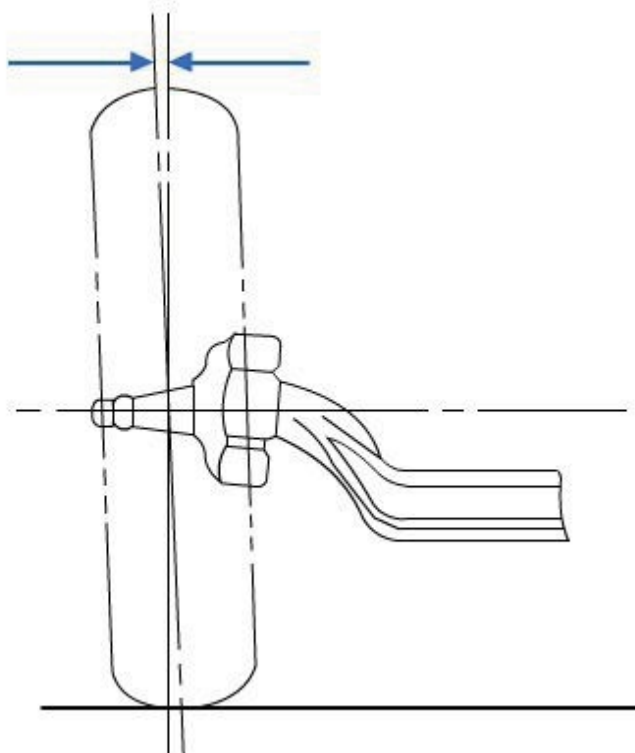


Figure 9-1 – Camber is the inward or outward tilt of the tire when viewed from the front of the vehicle.

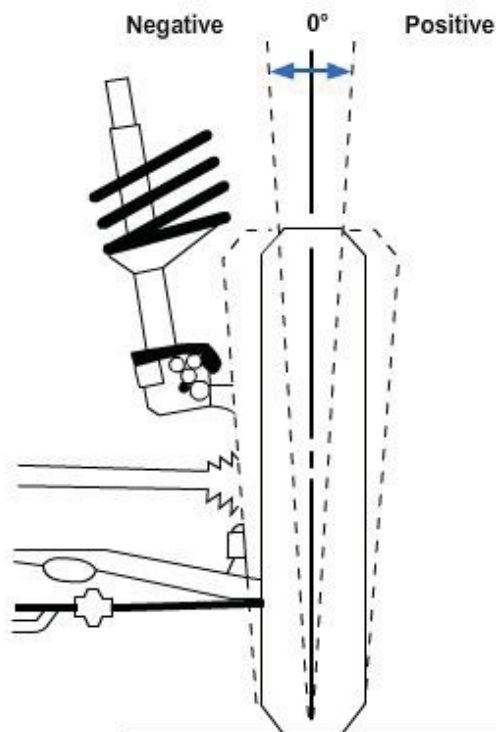


Figure 9-2 - Positive and negative camber.

metal fatigue, and lead to the axle breaking. Heating and bending the axle should never be attempted as it removes the heat-tempering camber.

1.2.0 Caster Angle

Look at a furniture caster and note that the caster can swivel around its attachment point. This attachment point can be thought of as the center about which the caster swivels. When the furniture is moved, the center moves before the caster wheel. If the center is behind the caster wheel, the wheel will swivel and follow behind the center. This occurs because the wheel has less resistance if it follows the center than if it attempts to stay ahead of it. Even when the wheel starts out directly ahead of the center, it will quickly move to one side or the other. This increases the friction on the wheel because it is trying to turn at an angle to the direction of movement. The wheel will continue to turn around the center until it reaches its point of least resistance, which is directly the center.

The principle that makes the caster work is applied to vehicles to make steering easier. The upper and lower ball joints or the lower ball joint and strut mounting form the steering axis, as shown in *Figure 9-3*. The steering axis is an imaginary line between the upper and lower ball joints or the lower ball joint and the strut mounting. The caster angle is usually referred to as caster. As with camber, caster is usually small. Common caster specifications range from one half degree to three degrees, with a maximum of about seven degrees. Caster can be positive or negative.

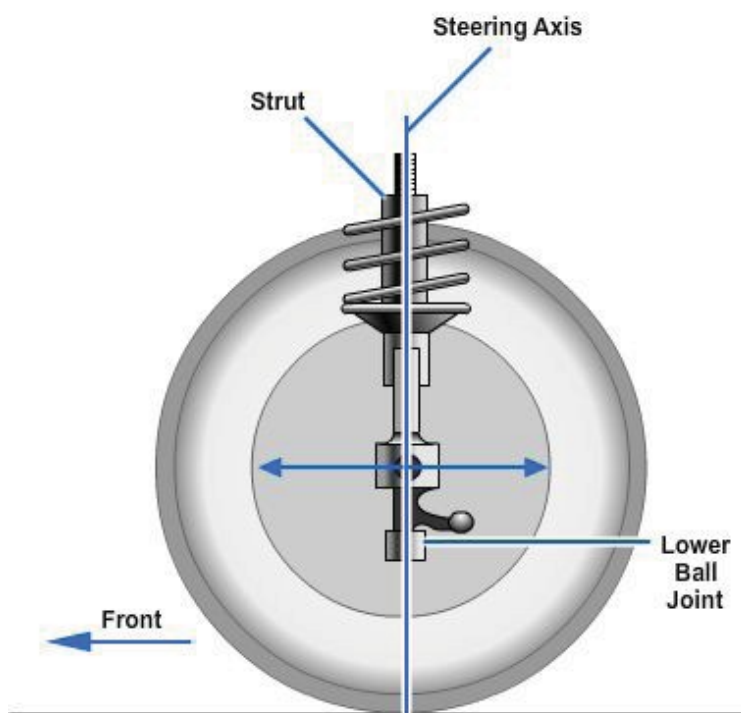


Figure 9-3- Steering axis.

Positive caster. If the imaginary line of the steering axis strikes the ground at the point at which the tire contacts the road, the tire and wheel will follow behind the steering axis (*Figure 9-4*). This keeps the wheel and tire assembly from wandering, since it wants to follow behind the centerline set up by the steering axis. This is positive caster. To get positive caster, the lower ball joint must be ahead of the top ball joint or the strut mounting. Like the furniture caster, the tire finds the path of least resistance by following behind the steering axis line. This tendency of the wheels to continue to move in a straight line is called tracking.

Positive caster causes the wheels to travel straight ahead and increases steering ability. Positive caster also assists in recovery. Recovery is the tendency of the wheels to turn back to the straight-ahead position after the driver completes a turn.

There are some disadvantages to positive caster. Positive caster makes it hard to turn the wheels from the straight-ahead position when entering a turn. On vehicles with power steering, this is not usually a problem. Positive caster also contributes to body roll. During a right turn, positive right wheel caster will cause the right steering knuckle to rise slightly, while the left side knuckle will drop slightly. This causes the vehicle to rise on the inside of the turn, reducing cornering ability. When the wheels are turned to the left, the left steering knuckle rises and the right knuckle drops.

Negative Caster. To ease turning, vehicles today have negative caster (*Figure 9-5*). Negative caster is obtained by placing the upper ball joint or the strut mounting ahead of the lower ball joint. With the steering axis behind the tire contact point, there is no caster force causing the wheels to track forward. Other alignment angles compensate for the lack of tracking to ensure steering stability is not compromised. Negative caster also helps compensate for body roll when the vehicle is turned. During turns, negative caster causes the outside steering knuckle to raise and the inner steering knuckle to lower. This compensates somewhat for body roll, making the vehicle more stable.

Caster has almost no effect on tire wear, but improper caster can cause wheel pull and other handling problems. Wheel pull is the tendency of the vehicle to drift to one side when the driver releases the steering wheel when the vehicle is moving. A large difference in caster between the

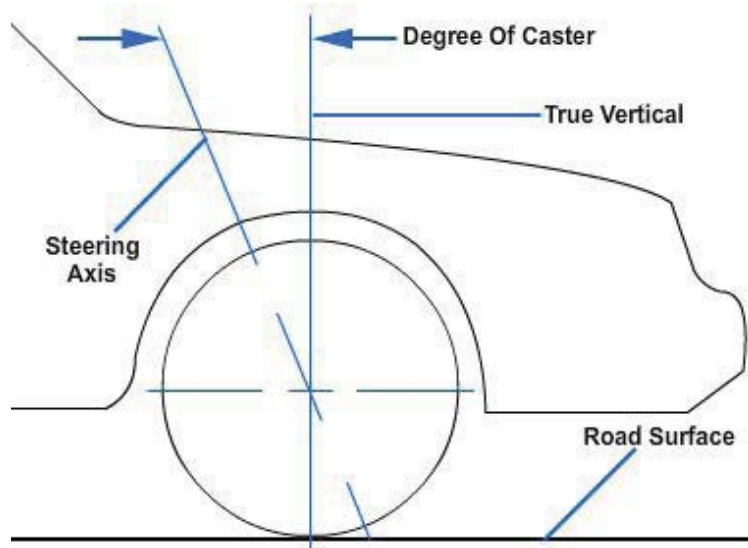


Figure9-4 – Positive caster.

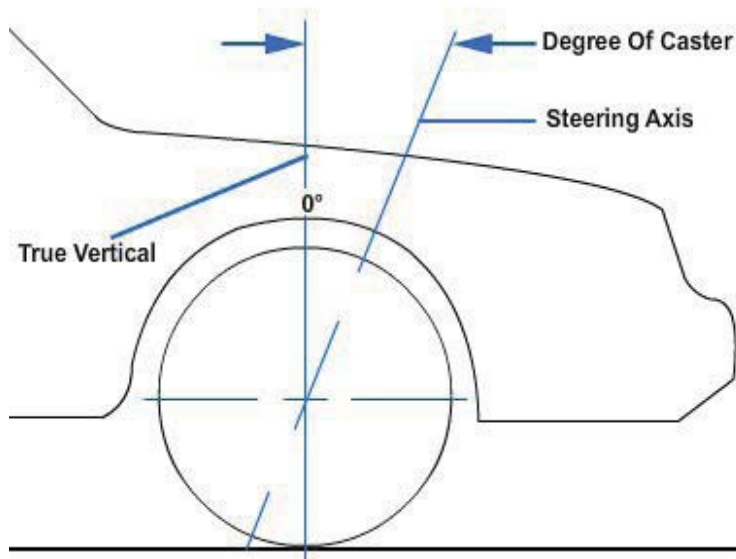


Figure9-5 – Negative caster.

two front wheels will cause pulling to the side with the least positive caster. If one wheel is more negative than the other (even if both are negative), the vehicle will pull toward that wheel. Excessive negative caster can also cause bump steer. Bump steer is a condition in which the vehicle tries to steer away from the driver when it travels over the road irregularities. Since caster primarily affects steering and front wheel tracking, it is not measured on the rear wheels.

1.3.0 Kingpin Inclination

Kingpin inclination (KPI) is the amount in degrees that the top of the kingpin inclines away from the vertical, viewed from the front of the truck. Kingpin inclination in conjunction with camber angles places the approximate center of the tire tread footprint in contact with the road. KPI reduces steering effort and improves the directional stability. KPI cannot be adjusted on trucks. Once set, KPI should not change unless the front axle has been bent. Corrections or changes to this angle are accomplished by replacement of broken, bent, or worn parts.

1.4.0 Toe-in

Toe is the tracking angle of the tires from a true straight-ahead track. If a line were drawn through the centerline of each tire and compared to the centerline of each tire and to the centerline of the vehicle (the true straight-ahead position), the amount of deviation between the two lines indicates the toe angle of the tire. When the centerline is exactly parallel with the vehicle centerline, the toe angle is zero. When the front end of the tire points inward toward the vehicle, the tire has toe-in. When the front of the tire points outward from the vehicle, the tire has toe-out. You can see toe-in and toe-out by looking at *Figure 9-6*, which you are observing from an overhead viewpoint.

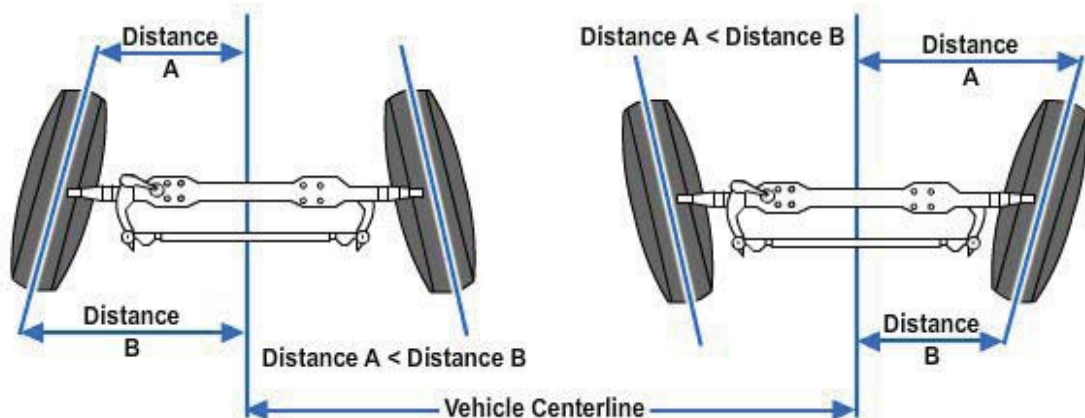


Figure 9-6 - Toe-in (left) and toe-out (right).

The ideal toe angle, when a vehicle is running loaded down a highway, is zero. We set toe angles statically. The objective of setting toe at a specified angle when aligning the front end is to have zero toe at highway speeds. Incorrect toe angles not only accelerate tire wear, but also can have an adverse effect on directional stability of the vehicle. In fact, incorrect toe angles have the potential to cause more front tire wear than any other incorrect alignment angle. Too much toe-in produces scuffing, or a feathered edge, along the inner edges of the tires. Excessive toe-out produces a similar wear pattern along the

outer edge of the tires. In extreme cases of toe-in or toe-out, feathered edges develop on the tread across the entire width of the tread face of both radial and bias-ply tires.

Because the objective is to have a zero toe angle under running conditions, most truck specifications require a zero or a slight toe-in setting. When a fully loaded vehicle is moving at highway speeds, there is a slight tendency of steering tires to toe-out. Any looseness in the steering linkage and tie-rod assembly also will contribute to the toe-out tendency. On newer vehicles, most radial steering tires are set with zero toe angle and bias-ply tires are set with a fractional toe-in.

1.4.1 Measuring Toe

Toe is specified in either degrees or fractions of inches, depending on the type of alignment instruments you are using. When a toe-in setting is required, settings of $1/16$ inch $\pm$ $1/32$ inch are usually specified. The toe specification usually depends on whether radial or bias-ply tires are used. Adjustment of toe angle or dimension requires lengthening or shortening the tie-rod dimension. This is achieved by loosening the tie-rod end clamp and then rotating the cross tube.

To determine the cause of excessive tire wear that you suspect to be related to toe angle, you should first check kingpin inclination, camber, and caster. Correct, if necessary, in this order. You should not make an adjustment to toe angle until the other factors of front-wheel align are known to be within specifications.

When measuring toe angle, the front suspension should be neutralized. To neutralize the suspension, roll the vehicle back and forth about half of a vehicle length. This relaxes the front suspension and steering linkages. Neutralizing the front suspension is important before making front-end adjustments, especially if the vehicle has been jacked up on either side to scribe the tires. This operation causes the front wheels to angle as each is returned to the floor. When possible, use a scissor jack that cradles both sides of the front axle when working on front ends.

If you begin by neutralizing the front end, both front wheels should at this point be in the exact straight-ahead position. Toe-in measurements should be taken across the hub centerline, front, and rear on each tire (*Figure 9-7*). Make sure that the wheels are on the ground and fully supporting the vehicle weight. Measure and record the measurements. The difference between the front and rear measurements is the toe specification.

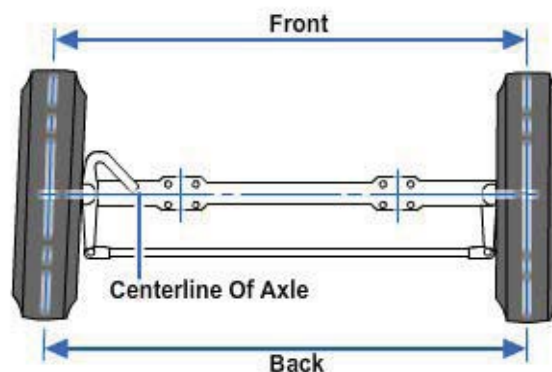


Figure 9-7 – Determining toe.

1.4.2 Adjusting Toe Angle

After measuring toe, you can use the following procedure to adjust toe angle:

1. Use the steering wheel to turn the steering gear to the exact mid-position (overcenter).
2. Loosen the clamping bolts on both tie-rod ends. Raise the weight off the axles.

3. Turn the tie-rod cross tube in the direction necessary to bring toe to the specified setting: turning the cross tube either lengthens or shortens it. After making the adjustment, lower the vehicle to the floor. Measure the toe setting again.
4. When the toe angle is set to specification, torque the tie-rod end clamp bolts to specification.



Recheck the toe setting after any change in caster or camber angle.

1.5.1 Turning Radius

Turning radius or angle is the degree of movement from a straight-ahead position of the front wheels to either an extreme right or left position. Two factors limit the turning angle: tire interference with the chassis and steering gear travel. To avoid tire interference or bottoming of the steering gear, adjustable stop screws are located on the steering knuckles (*Figure 9-8*). Turning radius or angle should be checked using the radius gauge described earlier. If turning angle does not meet specifications, it should be corrected.

To make an adjustment to the turning radius, use the following procedure:

1. Block the rear wheels and raise the truck off the ground. Position support stands under the front axle.
2. Turn the wheels to the extreme right turn until the steering gear bottoms or tire-to-chassis contact is made.
3. Back off the steering wheel 1/4 turn or until  to 1-inch clearance is obtained between the tire and chassis.
4. Check both front tires for clearance at full steering lock. When the specified clearance is set, back the wheel stop screw out until the screw contacts the axle stop (*Figure 9-8*), and tighten the jam nut.
5. Repeat the same procedure on the left extreme turn and set the left steering knuckle stop screw.

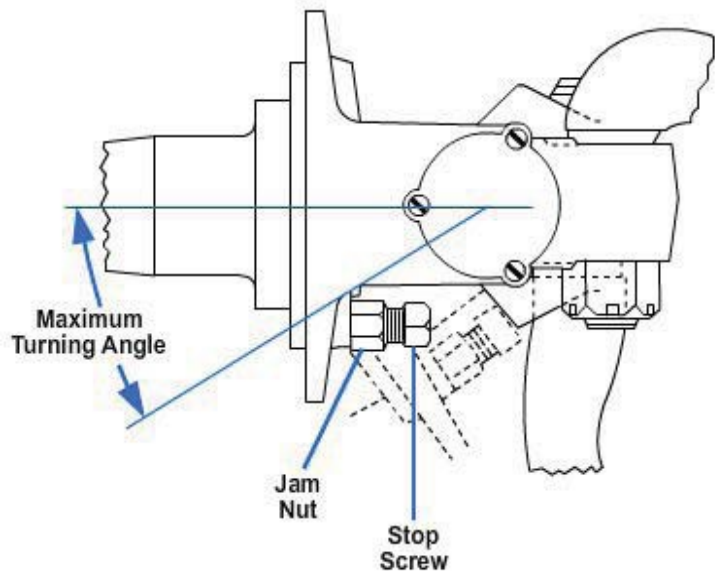


Figure 9-8 – Stop screw determines the maximum turning angle.

1.5.1 ving Front Axles

A stop screw is located on each end of the axle housing for the purpose of limiting the amount of the turning angle of the wheels. These screws are not adjusted in accordance with the frame and tire interference, as in conventional steer axles. The stop screws in front drive axles limit the operating angle of the universal joints in the drive axle shafts. You should reference the OEM service manual before making adjustments.

1.5.2 Ackerman Geometry

Ackerman geometry is the means used to steer a vehicle so that the tires track freely during a turn. During a turn, the inboard wheel on a steer axle has to track a tighter circle than the outer wheel. In other words, the outer tire has to travel just a little further because of the wider arc it has to follow. Ackerman geometry is also known as toe-out during turns. It allows the inner and outer wheel to turn at different angles so that both wheels can negotiate the turn without scrubbing, as shown in *Figure 9-9*.

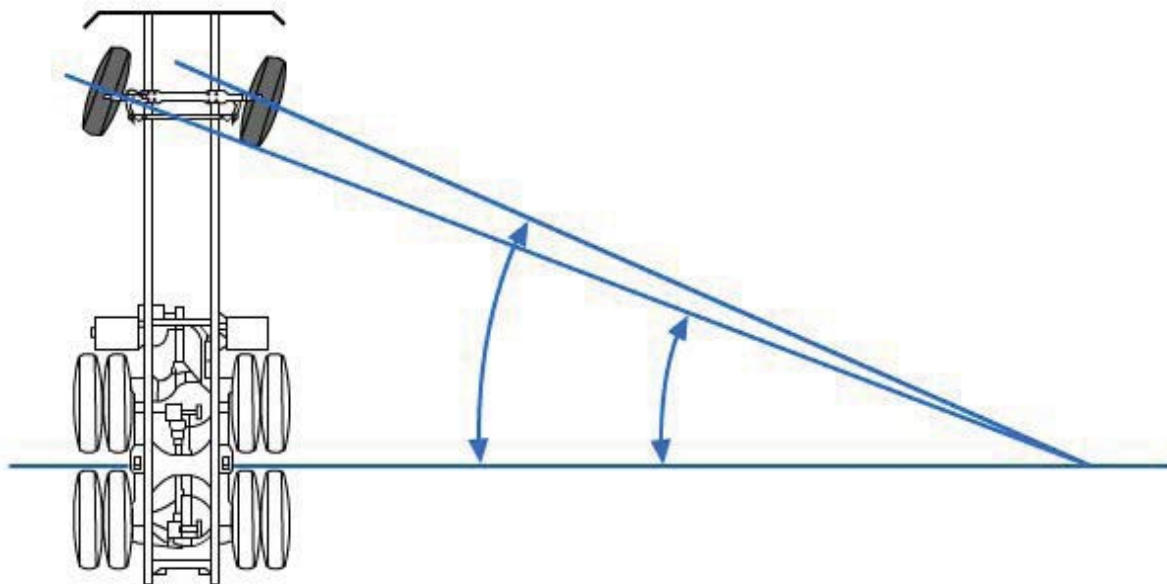


Figure 9-9 - Ackerman geometry.

To achieve the required Ackerman angle, the steering wheels intersect on the axis of the rear axle again (*Figure 9-9*). On single drive axles, the centerline of the drive axle is the rear axis. On tandem drive axles, the intersecting axle is centered between the two drive axles, as illustrated in *Figure 9-10*.

The Ackerman angle built into the steering geometry actually provides perfect rolling angles or both front wheels at only one turning angle. Anything other than this turning angle introduces an error, the size of which depends on the length and inclination of the tie-rod arms. As a result, the lengths of the cross tube and tie-rod arms have to be selected so as to minimize the error throughout the full range of steering angles possible on a particular front end. In trucks, the Ackerman steering error has to be smallest at low turning angles, where the most steering corrections are made and at the highest speeds.

Toe-out on turns is accomplished by having the ends of lower steering arms (those that connect to the tie-rods) closer together than the kingpins, as shown in Figure 9-11. Actual toe-out during a turn depends on the length and angle of the steering control arms and length of the cross tube. Even if the toe-in setting with the wheels in a straight-ahead position is correctly adjusted, a bent steering arm can cause the toe-out to be incorrect, causing tire scuffing.

Turning radius angle should be checked using radius plates. To check the turning radius angles, you can use the following:

1. Position the front wheels on the radius plates and in the straight-ahead position.
2. Remove the locking pins from each plate and adjust the scale on the edge of the plates so that the pointers indicate zero.
3. Turn the wheels to the right until the indicator gauge at the left wheel reads 20 degrees. Then read and record the angle of the right wheel.
4. The right wheel should then be turned to an angle of 20 degrees. The left wheel should read the same turn as the right wheel did in the previous step. If the angle is different, check the steering arms for damage and replace any that are bent. Do not attempt to straighten them.

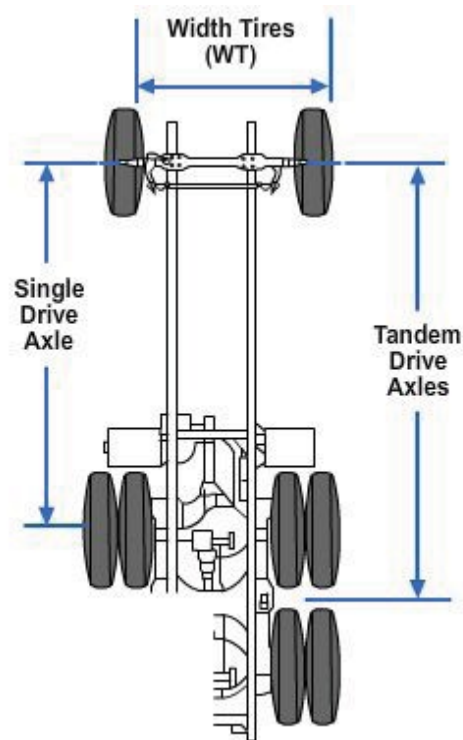


Figure 9-10 – Measuring wheel base for single and tandem drive axles.

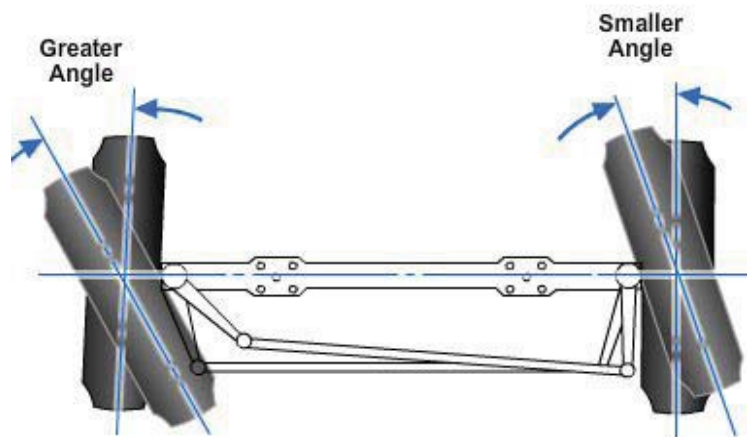


Figure 9-11 – In a toe-out condition on turns, the inside wheel turns at a greater distance than the outside wheel.

1.6.0 Tracking

When a vehicle is running on the highway, all of the axles should be tracking perpendicular to the vehicle centerline; that is, the rear wheels should track directly behind the front wheels when the vehicle is moving straight ahead. When this happens, the thrustline created by the rear wheels is parallel to the vehicle centerline, as shown in *Figure 9-12, View A*.

However, if the axles are not running perpendicular to the vehicle centerline, the rear wheels will not track directly behind the front wheels, and the thrustline of the rear wheel deviates from the centerline of the vehicle, as shown in *Figure 9-12, View B*. The steering controls fight the vehicle thrustline, resulting in an uncentered steering wheel and accelerated front tire wear, which causes the vehicle to oversteer when turning in one direction and understeer when turning in the other direction. Oversteering is an overresponse to steering input, which in vehicles yaw or lateral tracking off the intended turning radius. Understeer is an underresponse to steering input, most often causing steering tire slip at high speeds. Incorrect directional tracking can occur on single-axle vehicles, tandem-axle vehicles, and trailers. On a single-axle vehicle, the rear axle thrustline can be off if the entire axle is offset or if only one wheel has an improper toe angle. On a tandem axle, there are a number of different combinations that can cause incorrect tracking. *Figure 9-13* illustrates some of these combinations.

One method of checking a single axle for misalignment is to clamp a straightedge across the frame so that it is square with the frame rails on each side. Then measure from the straightedge to the center of the hub. The distance on each side should be within $\frac{1}{8}$ inch of each other. If not, the axle must be aligned.

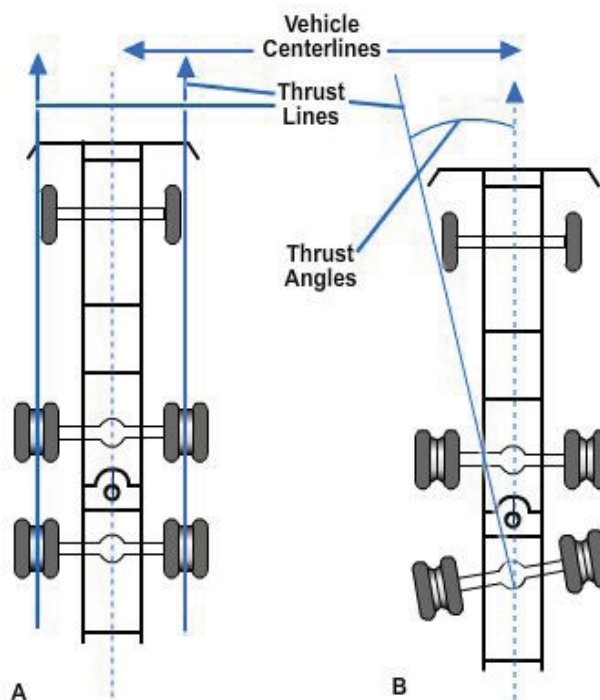


Figure 9-12 - Correct and incorrect thrustline.

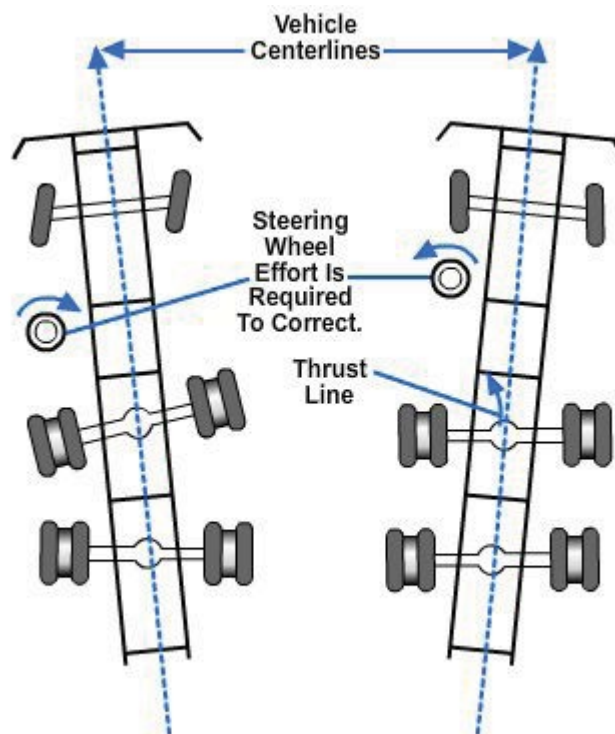


Figure 9-13 - Typical incorrect tracking of tandem-axle vehicles.

1.6.1 Trailer Tracking

It is also possible for the trailer axles to be out of alignment and cause a tracking problem. Depending on the severity of the trailer misalignment, it might be possible to see the effects of the misalignment as the trailer travels down the road. Usually, the trailer will travel at an angle to the tractor. Misalignment also makes it very hard to back up the trailer.

There are two basic ways that drive axles can be misaligned. In one case, if both axles are parallel but are not perpendicular to the vehicle centerline, then a resultant thrust angle is created. As shown in *Figure 9-14*, the drive axles try to push the vehicle away from the centerline.

If the drive axles are not parallel, then the situation is described as a scrub angle problem, as shown in *Figure 9-14*. In this case, the drive axles are trying to turn the vehicle. In either case, to bring the truck's travel back into a straight line, the driver has to provide an opposing steering input. This need for continual correction can induce driver muscular fatigue as well as increased tire wear and reduced fuel economy.

Essentially, trailer alignment involves adjusting all components in such a way that the trailer tracks straight and true, and is a matter of adjusting how trailer components line up according to three parameters-axle orientation, axle toe, and axle camber. While trailer wheels can be out of alignment relative to camber and/or toe, according to some industry experts, the most common problem is axle offset. Axle offset, or dog-tracking, is displacement of the rear of the trailer to one side of the tractor when the trailer is being towed. Axle offset is expressed in degrees based on variance with the geometric driving axis, or thrust angle. Thrust angle is the angle between the longitudinal center plane and the geometrical axis.

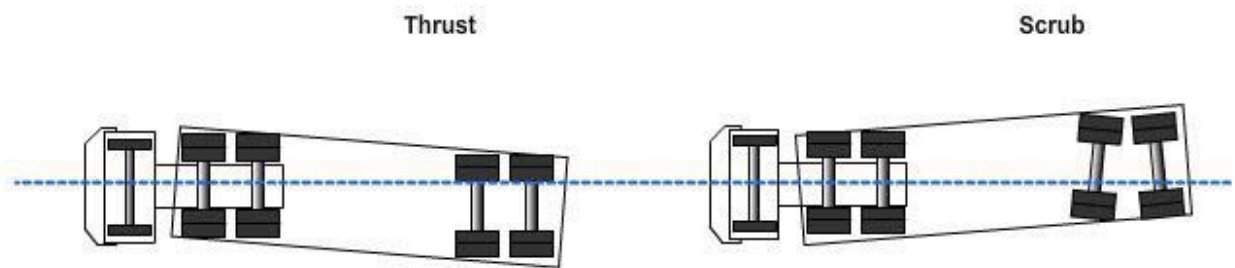


Figure 9-14 - Incorrect tracking of trailers.

2.0.0 ADJUSTING WHEEL ALIGNMENT

2.1.0 Safety Precautions

2.1.1 General Shop Safety

- Keep workbenches and work areas clean. A clean workbench reduces the chance of tool and parts falling from the bench onto the floor, where they could be lost or damaged. A falling tool or part can land on your foot, causing injury. A clean area reduces the possibility that critical parts will be lost.
- Clean up spills before they are tracked around the shop. People are often injured when they slip on floors coated with oil, antifreeze, or water. Gasoline spills can be extremely dangerous because even the smallest spark can ignite the vapors, causing an explosion or fire.
- Make sure your work area is well lighted. Poor lighting makes it hard to see what you are doing, leading to accidental contact with moving parts or hot surfaces. Overhead light should be bright and centrally located. Portable lights, or droplights, should be in proper operating condition. Droplight cages should be in place. Always use a rough-service light bulb in incandescent droplights. These bulbs are more rugged than normal light bulbs and will not shatter if they break. Do not use a high-wattage bulb in a droplight. Light bulbs get very hot and can melt the light socket or cause burns.
- Never overload electrical outlets or extension cords by operating several electrical devices from one outlet. Do not operate high-current electrical devices through extension cords.
- Inspect electrical cords and compressed air lines frequently to ensure that they are in good condition. Also check for improper air hose connections. Do not close vehicle doors on electrical cords or air hoses. Never run electrical cords in water or in the rain. Should you in an emergency need to use electrical tools under wet conditions, plug into a ground-fault circuit interrupter (GFCI).
- Make sure all shop equipment, such as grinders and drill presses, are equipped with the safety guards provided by the manufacturer. These guards should only be removed for service operations, such as changing grinding wheels. Never operate equipment without the proper guards.
- When servicing any piece of equipment, be sure it is turned off and unplugged. Closely monitor tool and equipment condition and make repairs when necessary. This includes replacing damaged leads on test equipment, checking and adding oil to hydraulic jacks, and regrounding tips on screwdrivers and chisels.
- Never leave open containers of any liquids.

2.1.2 Floor Jacks and Jack Stand Safety

The pad must be positioned under an area of the vehicle's frame or at one of the manufacturer's recommended lifting points. Your owner's manual will list safe jacking points in a few different areas, but is usually included in the spare tire section.

Never place the lifting pad under the floor pan or under steering and suspension components. These areas may look strong enough to hold a lot of weight but are not.

Not only can these parts be damaged by the weight of the vehicle, but they can also cause severe injury to you when they let loose.

Never use a hydraulic floor jack to move something heavier than it is designed for.

Always check the rating of the floor jack and also the jack stands to be used on the vehicle.

Then, verify that the vehicle weight is below this rating. The (GVW) gross vehicle weight is in your owner's manual and also on the driver's side front door jam on most automobiles.

Safety stands, also called jack stands, are supports of various heights that sit on the floor. Make sure the surface they sit on is strong, flat, and level.

Concrete is preferred, and blacktop areas could be unsafe due to softness. Use 1 -inch thick lumber under the jack stands on blacktop areas so they do not sink into the surface.

Safety stands are placed under a sturdy chassis member, such as the frame or axle housing, to support the vehicle's weight.

Once the safety stands are in position, the hydraulic pressure in the jack should be slowly released until the weight of the vehicle is on the stands.

Like floor jacks, safety stands also have a capacity rating. Always use a jack stand of the correct size and weight rating.

Never put yourself under a vehicle when only a hydraulic jack supports it. Rest the vehicle on the safety stands before moving around the vehicle.

The recommended reason for removing the hydraulic floor jack after it is safely supported on the stands is that this will eliminate a hazard, such as a jack handle sticking out into a walkway.

A hydraulic floor jack handle that is bumped or kicked can cause a tripping accident or the vehicle to fall.

2.1.3 Lift and Hoist Safety

Raising a heavy-duty truck on a lift requires special care. Adapters and hoist plates must be positioned correctly on twin-post and rail-type lifts to prevent damage to the underbody of the vehicle. There are specific lift points to use where the weight of the vehicle is evenly supported by adapters or hoist plates. The correct lift points can be found in the vehicle's service manual. Before operating any lift or alignment machine, carefully read the manufacturer's literature and understand all the operating and maintenance instructions.

Heavy subcomponents, such as engines and transmissions, should be removed using a chain hoist or jacks. To prevent serious injury, chain hoists or the jacks must be properly attached to the parts being lifted. Use equipment of sufficient strength rating for the object being lifted or lowered.

The following are some general rules for using jacks, lifts, frame machines, and hoists:

- Do not allow anyone to remain in a vehicle when it is being raised.
- Make certain you know how to operate the equipment and know its limitations.
- Never overload a lift, hoist, or jack.

- Chain hoists must be properly attached to the parts being lifted. Always use proper attaching devices of sufficient strength rating to attach the hoist to the object being lifted.
- Mechanical locks or stands must be engaged after lifting a vehicle or equipment on any kind of hoist.
- Do not use any lift, hoist, or jack that you believe to be defective or not operating properly. Tag it immediately and immediately take it out of service. Report it to the shop supervisor so it can either be repaired or disposed of.
- Make sure all persons and obstructions are clear before raising or lowering any heavy components or the vehicle.
- Avoid working, walking, or standing under suspended objects that are not mechanically supported.

2.1.4 Tension

To hold a 2,500- to 5,000- pound vehicle above the ground, the suspension must be very powerful. The weight of the vehicle puts the spring under a great deal of tension. This tension, known as spring tension, can injure you if it is not properly released. If you remove the bolts that secure parts under spring tension without properly releasing the spring tension, the parts could fly apart with great force. This force is great enough to break ribs or crush hands and feet. Always determine whether a part is under spring tension before removing its fasteners. If necessary, compress the spring to release the tension. If the fasteners seem to be under tension as the first few threads are loosened, stop immediately and determine why the part is still under spring tension. Never assume that the parts are not under tension.

2.2.1 Tools for Frontend Alignment

Alignment machines. Using an alignment machine is the most convenient and reliable way to align a vehicle. The alignment machine takes the place of all the individual alignment units. It has alignment units, usually called heads, that attach to the wheels of the vehicle. The heads are used in combination with a special rack, front and rear turning plates, and other components to check all alignment angles in one operation.

You may have once used an older alignment machine that used light beams to display readings on a screen mounted in front of the vehicle. Heads installed on the front wheels generated the light beams, which were directed on the screen. Markings on the screen allowed the mechanic to translate the position of the light beams into alignment angles.

Electronic align machines are now commonly used. These machines have four heads, one for each wheel. When all four heads are installed on the wheels, they transmit a laser beam or infrared light to each other. The system's computer receives readings from each of the heads and computes the front and rear wheel alignment. The alignment readings are displayed on a computer screen.

Alignment machines use flat panels that contain target dots. The panels attach to the vehicle's wheels. The alignment machine's computer calculates the position of the target dots and displays the vehicle alignment on the computer screen. This system is simpler to set up than older systems.

Alignment wrenches. Various specially designed wrenches are needed to perform alignments. Alignment wrenches are specially shaped wrenches. These wrenches are

often thinner than normal so they can fit in tight spots. Some alignment wrenches are self-contained; others are designed to be used with a ratchet.

Ball joint and tie-rod end removal tools. Many ball joint and tie-rod end removal tools are screw-type pullers with two or more arms that fit around the part. Tightening the central screw on the tool forces the tie-rod stud from the associated part. A variation of this tool expands between the stud and an adjacent component to remove the stud from the associated part.

A fork-shaped tool with two pointed tines is often used to remove a ball joint stud from a part. This tool is usually called a pickle fork. The fork section is inserted between the ball socket fitting and the linkage part. Hammering on the end of the tool forces the fork between the parts, breaking them loose.

Coil spring compressor. A coil spring compressor must often be used to compress coil springs during removal and installation. If the springs are not compressed before the fasteners are removed, the suspension parts will fly apart with great force. On most vehicles, an uncompressed coil spring cannot be reinstalled. Two types of coil spring compressors are required to service coil springs: the MacPherson strut spring compressor and the conventional spring compressor.

- **MacPherson strut compressor.** The MacPherson strut compressor is used to remove springs from the MacPherson strut assemblies. It mounts to the wall of the shop or workbench. To use this type of spring compressor, the strut assembly must be removed from the vehicle and placed in the compressor. The compressor is tightened to remove spring tension from the top mounting bolt. The strut assembly can be replaced and the tension removed.
- **Conventional spring compressor.** The conventional spring compressor is used on conventional or short-long arm suspension systems. It is installed before the spring is removed from the vehicle. Once the spring is compressed, fasteners holding the ball joints or other suspension parts can be removed. A new spring must generally be compressed before it is installed. After all parts are in place, the compressor is loosened and the spring expands into place.

Bushing installers. Bushing installers are used to install and remove bushings in control arm, strut rods, and stabilizer bars. Some installers are round drivers. Drivers are used with a hammer to drive bushings in control arms, strut rods, or stabilizer bars.

Another type of bushing installer resembles a large C-clamp with adapters. The bushing is placed in the installer and the screw is tightened to force the bushing into the part.

Hammers. Hammers are used to loosen parts and to drive bushings and seals into place. Typical hammers used are ball peen, soft face, or rubber mallet. It is important to use the proper hammer for the job. Select a hammer that is large enough for the job. Never use claw hammers or other woodworking hammers for automotive service.

Inner tie-rod tools. The inner tie rods of most rack-and-pinion gears are threaded directly into the rack. To remove the tie rods, an inner tie-rod tool is used. This tool is a tube with a slotted opening on one end and a $\frac{1}{2}$ -inch drive fitting on the other end. After removing the outer tie rod, bellows, and any locking pins at the rack, place the inner tie-rod tool over the inner tie rod. Turn the tool with a $\frac{1}{2}$ -inch wrench to remove the tie rod. Most inner tie-rod tools can also be used to install a new inner tie rod.

Lever-type adjusting tool. To move the control arms on various vehicles, a lever-type adjusting tool is needed. The tool is typically attached to the control arm and the frame.

With the control arm fasteners loosened, the tool's handle can be moved in either direction to move the control arm.

Mechanical alignment testers. Many shops have various alignment devices that operate mechanically. Using these devices requires more time and attention than using the alignment machines. However, if used carefully, mechanical devices do an excellent job of aligning front suspensions. These devices cannot be used to check rear suspensions.

- **Caster and camber gauges.** Simple caster and camber gauges use a bubble leveling device similar to that used in a carpenter's level. Camber can be checked after adjusting the position of the bubble, as called for in the instructions. Caster is checked by turning the wheels a certain amount in one direction and readjusting the bubble. The wheels are then turned the same amount in the other direction. The final position of the bubble indicates caster.
- **Toe gauges.** Toe gauges are used to measure vehicle toe. Toe is the difference in distance between the front and rear of the tires. A tape measure can be used to check toe, but it is more convenient to use a rigid toe gauge. Before toe can be measured, each tire must be raised and a line must be scribed completely around the tire. The line is used for reference when measuring the distance at the front and rear of the tires.
- **Turning plates.** To turn front wheels while checking caster, turning plates must be used. If the tires are turned without a turning plate, the measurements will be inaccurate due to the stresses built up in the suspension linkage. Excessive turning will also wear flat spots in the tires. A turning plate consists of a moveable upper plate that connects with a stationary bottom plate through ball bearings. This arrangement allows the wheels to turn easily.

Metal cutting tools. Suspension components or frame metal must be cut to allow for part removal and vehicle alignment. In other cases, suspension and steering parts are tightly installed and are almost impossible to remove with hand tools. In these cases, metal cutting tools must often be used. Typical cutting tools are the following:

- **Air chisel.** Many bushings and ball joints are pressed tightly into the control arm. The most convenient way-and sometimes the only way-they can be removed is by using an air chisel. The powerful hammering action of the air chisel quickly loosens parts. Many ball joints are held to the control arm by rivets, and an air chisel is sometimes used to remove them. On occasion, sticking alignment adjustment devices can be loosened with an air chisel and blunt bit.
- **Grinders.** To align some vehicles, part of the body metal must be cut away. The simplest way to remove metal is to use an air-powered hand grinder. The typical hand grinder, sometimes called a die grinder, uses an air, motor-driven, abrasive disc. This disc can quickly remove body metal to allow a suspension part to be moved. The grinder can also be used to remove stripped lug nuts and cut out frozen bushings.
- **Spot weld cutters.** For alignment purposes, the spot welds on some vehicles must be cut away. Although the welds can be chiseled or ground away, the most expedient method of spot weld removal is to use a spot weld cutter. The spot weld cutter is used with an electric or air-powered drill.
- **Rotary Cutter.** When a suspension part must be moved for alignment, the original mounting holes may be large enough to permit the necessary movement.

Rotary cutters can also be used for other jobs. Rotary cutters can be used with an air or electric drill.

Pitman arm puller. A pitman arm puller is used to remove the pitman arm from the gearbox of a conventional steering system. After removing the nut from the sector gear shaft, place the arms of the puller over the pitman arm. Then, tighten the central screw against the shaft to remove the pitman arm.

Pry bars. Pry bars are often used to free sticking or corroded parts. They are also used to move control arms during alignment procedures.

Punches and drifts. Punches and drifts are often needed to drive pins out of parts. Tapered punches are useful for aligning bolt holes in parts.

Tie-rod adjusters. On most conventional and some rack-and-pinion steering systems, the adjuster sleeves can be moved with a tie-rod tool. This tool has a hooked area that fits in the split in the sleeve. When the tool is turned, the hook tends to open the sleeve, allowing it to turn more easily. There are many variations of these tools. Some of them are self-contained units and others are used with a $\frac{1}{2}$ -inch drive ratchet.

Threaded adjusting tools. Threaded adjusting tools are used to move various parts of the suspension for alignment. These tools use a multiplying action of screw threads. The tool typically consists of two rods with a central, threaded nut. The tool is installed with the rods in matching holes. There is one hole in the suspension part and the other is in the frame. With the fasteners loose, turning the nut causes the rods to move the suspension part in relation to the frame. A variation of this tool is used to adjust caster and camber.

Torque Wrenches. Torque wrenches are sometimes needed to adjust the tightness of wheel bearings, lug nuts, power steering gears, and other components. There are three basic types of torque wrenches.

- The beam-type torque wrench displays torque readings using a pointer that is attached to the beam. When torque is applied to the fastener, the beam flexes, causing the pointer to move along the scale.
- The dial-type torque wrench gives torque readings on the face of the dial. This type of torque wrench is extremely accurate.
- To use a click-type torque wrench, you must set the desired amount of torque on the wrench's dial before tightening the fastener. The wrench will then produce a clicking sound when the desired torque is reached.

Torque wrenches are designed to measure torque in Newton-meters, inch-pounds, or foot-pounds.

3.0.0 ALIGNMENT PROCEDURES

Correct wheel alignment is vital to vehicle operation. Incorrect alignment can cause handling problems, steering difficulties, pulling, poor tracking, and rapid tire wear.

3.1.0 Pre-Alignment Checks

Talk to operator. If possible, talk to the vehicle's operator if available and find out why he or she thinks the vehicle needs an alignment. Ask about the specific problems and how the vehicle is reacting when operated. On occasion, the problem may be something that an alignment will not fix. Worn parts or unbalanced tires may cause what the operator perceives as a wheel alignment problem. This is particularly true of

vibration complaints. For future reference, explain to the operator that misalignment rarely causes vibration.

Road Test. If possible, road test the vehicle before beginning the alignment. Pick a quiet, level street for the road test. The road test can be brief, but it should be complete. Make a series of stops and turns. Drive several blocks in a straight line. Listen, look, and feel for road wander, unusual noises, pulling, hard steering effort, excessive road shocks, and other handling problems. The results of the road test will give you a basis for making other pre-alignment checks and for determining what alignment adjustments will be necessary.

To the shop. After the road test is complete and you have determined it is an alignment problem, drive the vehicle onto the alignment rack. Make sure that the front tires are centered on the turning plates.

Before beginning the alignment procedures, always check ride height, the tire and rims, and the vehicle's underbody.

Height. Check the riding height. If incorrect, adjust the height if the suspension uses torsion bars, or replace parts, as needed.

Before deciding that ride height is incorrect, check the backseat, trunk, or bed for excess weight. Remove excess weight before proceeding with the height check.

Worn parts. Once the vehicle is properly positioned on the rack, raise the front and rear wheels to check for worn parts. Do not skip this step. It is impossible to align a vehicle with worn or damaged parts.



If the vehicle is equipped with an electronic suspension system, open the trunk and turn the suspension switch off before raising the vehicle.

Raise the suspension so the ball joints are unloaded. On a suspension with the spring on the lower control arm, place the jack under the control arm. On suspensions with the spring on the upper control arm or around the MacPherson strut, place the jack on the frame. On solid axles, place the jack under the axle.

With the vehicle properly raised, perform a shake test. Grasp the wheel at the front and back and shake it. If the vehicle has an offset strut assembly, it may be necessary to grasp the wheel at about 45° counterclockwise from the top and bottom and then shake it. If the wheel moves excessively in any direction or makes knocking or clunking noises, look for worn or loose parts.

As a general rule, looseness when the wheel is shaken from the top and bottom indicates worn ball joints or very worn control arm or strut rod bushings. Worn tie rods or other steering system parts will cause looseness when the wheel is shaken from front and back. Loose or worn out wheel bearings usually cause looseness in all directions. If looseness is detected, have an assistant shake the wheel while you look for worn parts. Sometimes it is necessary to pry on parts using a pry bar. On some vehicles, the tie rods will be looser when the wheels are on the ground. Check your service manual for recommendations.

Once the shaker test is complete, visually inspect the suspension for wear, damaged seals, improper adjustment, or loose fasteners. Check the lower ball joints, upper ball joint (when used), control arm bushings, stabilizer bar bushings, and strut rod bushings. Check the steering gear, pitman arm and idler arm (when used), relay rod, and all tie-rod ends. Check the shock absorbers and struts for leaks. Check the operation of the power steering system and ensure that the power steering reservoir is full. If the vehicle has any kind of electronic suspension system, make sure the warning light is out and no other problems are evident. Check the drive shaft or CV axles, as applicable. Look for looseness, torn boots, or obvious dents or bends. Shake or twist all flexible joints to uncover any looseness.

Tires and wheels. Inspect the vehicle's tires and wheels for damage, as shown in *Figure 9-15*. Carefully note tire conditions that might indicate an alignment problem. *Figure 9-16* shows some common tire defects and their possible causes. If the tires were recently rotated, rear tire condition will be a sign of front-end problems, and front tire condition will indicate rear problems. Check the tire size and air pressure. You cannot align a vehicle when the tires are at different air pressures, are different sizes, or when one tire on an axle is worn and the other has ample tread. Add air or replace tires as needed. Spin the wheel to check for badly bent rims, dragging brakes, and loose wheel lugs.

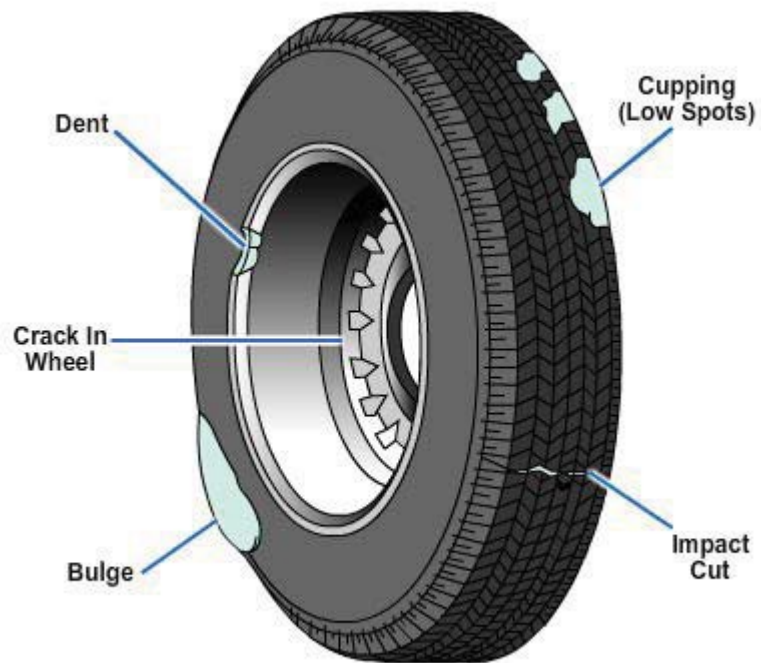
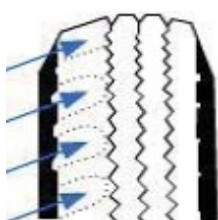
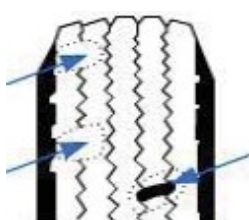


Figure 9-15 - Tire condition can indicate alignment problems.

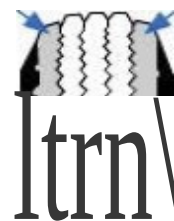
Underbody damage. Check all suspension and steering parts for bends, scrapes, and other signs of underbody damage. Carefully check the vehicle's frame at the front and rear for kinked areas or bends. Check for obvious severe setback on the front wheels, especially when collision damage is evident. The simplest way to check for setback is to measure the distance from the rear of each tire to the fender opening. If the setback varies by more than 1 inch between sides, a suspension part is bent. Make all necessary repairs before continuing with the alignment.



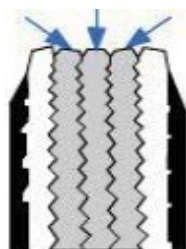
A



B



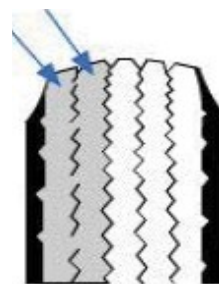
C



D



E



F

View	Symptom	Possible Cause
A	Scalloped Wear Balance	Out of Balance Lack of Rotation Worn Steering or Suspension Components Loose Wheel Bearings
B	Random Cupping	Out of Balance Excessive Runout Worn Steering or Suspension Components Loose Wheel Bearings
C	Shoulder Wear	Under Inflation Lack of Rotation Excessive Camber Roll Due to High Caster Setting High-Speed Corning
D	Central Tread Wear	Over Inflation (Bias Type Tires) Lack of Rotation
E	Feathered Edge Wear	Excessive Toe Angle (Bias Tire)
F	Uneven Wear (One Side of Tread)	Excessive Camber Angle Excessive Toe Angle (Radial Tire) Out of Spec. Turning Angle (Toe out on turns)

Figure 9-16-Tread wear.

3.2.0 Setting up Alignment Equipment

The following are procedures for setting up electronic or light alignment equipment.

Installing the Alignment Head. The alignment head consists of the electronic or light assembly and the head frame assembly. The electronic assembly is free to turn in relation to the head frame assembly, which is attached to the rim. A lock is used to tighten the electronic assembly to the wheel or frame when necessary. Most alignment heads are attached by clamping them on the inside of the rim. After the head is clamped to the rim, safety straps are attached to the rim to keep the head from falling on the floor and being damaged if the clamps slip. On some machines, alignment wires, called strings, must be installed between the front and rear heads.

Compensating the Alignment. All rims have some runout; therefore, there is no way to install the alignment head without slight misalignment between the rim and head. This runout must be removed to prevent inaccurate readings. The procedure to remove runout may vary from one equipment manufacturer to another. With most types of equipment, the procedure is to spin the wheel and rim  turn again and repeat the procedure.

Most computerized alignment machines use lights on the head or readouts on the screen to tell you when the head is properly compensated. Repeat the procedure for all wheels. When all four wheels are compensated, the screen will give a set of alignment readings. Since the wheels are off the ground, disregard the readings at this time.



Never allow the rim and head assembly to turn after it has been compensated. Any movement from the vertical (straight up and down) position will affect readings.

Lowering the Vehicle. Before lowering the vehicle, make sure the turning plates are centered under the wheels and remove the turntable locking pins. Apply the parking brake firmly and then lower the vehicle. When the vehicle is resting on the turning plates, bounce it at the front and rear bumpers. This will take any tension out of the suspension parts and allow the vehicle to settle to its normal resting position.

Centering the Steering Wheel. If the vehicle has power steering, start the engine and allow it to idle. Then turn the steering wheel from side to side several times to equalize play in the steering linkage. Then, center the steering wheel. Turn the engine off, if necessary. It is not necessary to install the wheel-holding tool. However, you will need this tool later during the alignment procedure.

Locking Brakes. Lock the brakes with a brake pedal depressor. This prevents excessive wheel movement while checking caster. At this time, you should firmly apply the parking brake. If the vehicle has an automatic transmission, shift it into park.

3.3.0 Measuring Alignment

After all preliminary steps have been completed, the alignment can be measured. This should be done in the order given in the following:

Checking Camber and Toe. If the alignment machine has a display screen, front and rear camber and toe will be shown on the screen. On most machines, this is an automatic process once the heads have been compensated. On older alignment machines using lighted heads, the front camber and toe will be shown by the position

and slant of the light lines on the display boards. If necessary, record the camber and toe readings.

Checking Caster. To check caster, be sure the brake pedal compressor is applied. Most alignment equipment manufacturers specify that the heads be locked into position (unable to pivot on the mounting frame) for the caster check. Turn the wheels to the left and right, according to the alignment machine manufacturer's instructions. This can be done by turning the wheels themselves or by turning the steering wheel. When using the steering wheel to turn the wheel, do not sit in or lean on the vehicle. This will change suspension height and affect the readings. On some systems, you must turn the steering wheel until the screen indicates that the readings have been obtained. On other systems, the turntables must be turned an exact amount, usually 20°. Record the caster reading if the alignment machine does not automatically do this.

Checking Steering Axis Inclination. Steering axis inclination (SAI) is usually checked as part of the caster checking process. SAI should be checked whenever there is evidence of collision damage or the vehicle has a handling or tire wear problem that cannot be accounted for by another cause. The brakes should be locked for the SAI check. Some equipment manufacturers specify that the heads be free to pivot on the head frame when both caster and SAI are checked in one position.

Checking Toe on Turns. Toe-out on turns is seldom incorrect, but it should be checked whenever you suspect steering arm damage or when the tires squeal excessively on turns. To check toe-out on turns, the brake pedal depressor should be in place. To make this check, turn one of the front wheels inward until the turntable indicator reads 20°. After this is done, move to the other side of the vehicle and read the indicator on that turntable. The reading should be slightly more than 20°. Record this reading; then turn the wheel inward to the 20° indicator on the turntable. Read the indicator on the other turntable. This reading should also be slightly more than 20°. Compare the readings with specifications. If the readings are incorrect, the steering arms should be replaced.

Adjusting Toe with Trammel Bars. When a vehicle needs only toe adjustment, a trammel bar can be used. To use a trammel bar, rise both wheels off the ground and scribe a mark completely around the tire. Hold a punch or other pointed tool against the outside of each tire tread as another mechanic spins the tire. Then place the vehicle on the ground and drive it back and forth a few times to settle the suspension. Use the trammel bar to measure the distance between the scribed lines at the front of the tire. Then measure the distance between the lines at the rear of the tires. The measurement can also be done with a steel tape if you have an assistant to hold one end of the tape. No matter what type of measurement device is used, the measuring point should be at the same height at the front and rear of the tire. The difference in the front and rear distances is the toe. If the measurement is greater at the rear, the vehicle is toed. If the measurement is greater at the front, the vehicle is toed out. The trammel bar method will give an acceptable toe measurement, but it cannot be used to center the steering wheel.

3.4.0 Caster and Camber-Trucks with Solid Axles

Many trucks use a solid or twin I-beam front axle, and there are no provisions for adjusting caster and camber. The only way to adjust caster and camber on these trucks is to replace the upper ball joint bushing with a special eccentric bushing, or sleeve.

Before installing one of these bushings, calculate the amount of caster and camber change needed. Then consult the correct chart to select the needed bushing. A typical bushing application chart is shown in *Figure 9-17*.

SLEEVE Number	Each	Total change of camber caster	
23001 (7979-1/8)	1	.13°	(1/8°)
23002 (7979-1/4)	1	.25°	(1/4°)
23003 (7979-3/8)	1	.38°	(3/8°)
23004 (7979-1/2)	1	.50°	(1/2°)
23005 (7979-5/8)	1	.63°	(5/8°)
23006 (7979-3/4)	1	.75°	(3/4°)
23007 (7979-7/8)	1	.88°	(7/8°)
23008 (7979-1)	1	1.00°	(1°)
23009 (7979-1-1/8)	1	1.13°	(1-1/8°)
23010 (7979-1-1/8)	1	1.25°	(1-1/4°)
23011 (7979-1-1/8)	1	1.38°	(1-3/8°)
23012 (7979-1-1/8)	1	1.50°	(1-1/2°)

Figure 9-17 - A sample chart listing camber and/or caster alignment sleeves.

To install the eccentric bushing, remove the alignment head and wheel. Then remove the upper ball joint nut from the ball joint. Pry up the old bushing to remove it. Install the eccentric bushing over the ball joint. Before reinstalling the nut, make sure the eccentric bushing is turned in the right direction. Then reinstall the ball joint nut and a new cotter pin. Reinstall the wheel and the alignment head, and recheck caster and camber.

On some trucks, the bushing can be turned after installation. If you are not sure about the exact placement of the bushing, install the nut loosely so it can be turned after the wheel and alignment head are reinstalled. Turn the new bushing as necessary, then tighten and install a new cotter pin.

4.0.0 ADJUSTABLE SUSPENSION ANGLES

4.1.1 Caster/Camber Adjustments

Recommended caster settings. Vehicle manufacturers specify varying caster settings, depending on the vehicle model, what type of load it is carrying, whether it is tandem or single drive axle, and whether it is manual or power steering. The objective is to provide just enough positive caster to ensure wheel stability and good wheel recovery. The following settings are some examples used for vehicles with a manual steering gear:

- Tandem drive axle: 1°-1½° degree positive
- Single drive: 1½°-2½° degrees positive
- No more than ½° degree difference between the left and right wheels
- Positive caster on the left wheel should not be greater than on the right

Caster specifications are based on vehicle design load (no load), which will usually result in a level frame. If the frame is not level when alignment checks are made, this must be factored in the caster measurement. With the vehicle on a smooth, level

surface, measure the frame angle with a protractor or inclinometer placed on the frame rail. Positive frame angle is defined as forward tilt (front end down) and negative angle as tilt to rear (front end high).

The frame tilt angle should be added or subtracted, as required, from the caster specification in the service manual, noting the following:

- Positive frame angle should be subtracted from the caster specification.
- Negative frame angle should be added to the caster specification.

For instance, if the specified caster setting is a positive 1 degree and you measure the vehicle frame angle to be positive 1 degree, the measured caster is $0 \pm \text{diamond}$ degree. This calculates to the desired 1 degree $\pm \text{diamond}$ degree caster angle when the chassis settles to level the frame under load.

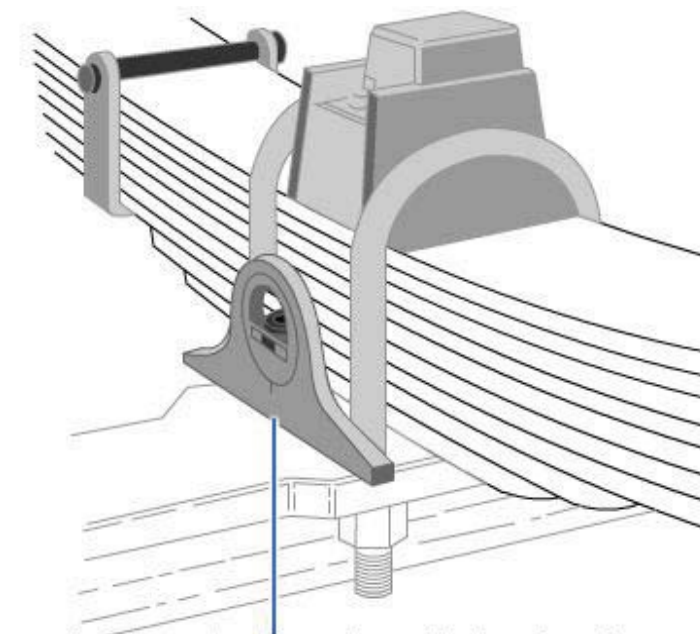
Caster should be measured with the vehicle on a level floor. If the vehicle is equipped with a manually controlled air-lift axle, adjust it so that the frame is as normal operating height. Replacement of worn suspension, frame, and axle components should be done before caster is measured.

Measuring caster. Caster can be measured in a number of ways. One way is to use a protractor. Another is to use a radius gauge. Modern computerized alignment equipment is the fastest, most accurate method measuring caster (and other equipment angles) and these are increasingly being used.

Protractor. A protractor measures the angle between its base and true horizontal, as determined by a bubble cylinder on one side of the dial.

To measure caster angle:

1. Place the protractor on the machined surface of the front axle pad, as shown in *Figure 9-18*. The axle pad must be free of dirt and debris. Make sure that the protractor contacts both U-bolts so that it is parallel with the vehicle frame.
2. Center the bubble in the cylinder by rotating the dial of the protractor. Lock the dial and remove the protractor to record the angle.
3. Make sure you determine whether the caster angle you measure is positive or negative. The original orientation of the protractor must be remembered when determining the direction of the caster



Place The Protractor On The Machined Surface Of The Front Axle Pad. The Axle Pad Must Be Free Of Dirt And Debris. Make Sure That The Protractor Contacts Both U-Bolts So That It Is Parallel With The Vehicle Frame.

Figure 9-18 – Placement of a protractor to measure caster.

angle. If the axle pad surface is level/parallel with the floor, the caster angle is zero. If it tilts toward the front of the vehicle, the caster is negative; toward the rear, it is positive.

4. Repeat the preceding procedure on the opposite side of the vehicle. If the caster difference on each side exceeds $\frac{1}{2}$ degree, the axle is probably twisted. Also, remember that the right side should not have less positive caster than the left. If the right side is less, it will tend to lead the vehicle to the right, particularly on crowned roads.

There are digital protractors or inclinometers (*Figure 9-19*) available that will do the same as the bubble protractor. The angle is displayed on a LCD screen and indicates whether negative or positive.



Figure 9-19 - Digital protractor.

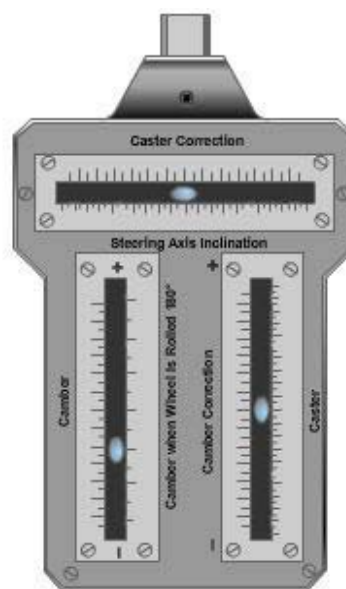


Figure 9-20 - Camber/caster gauge.

Camber/Caster Gauges. *Figure 9-20* shows a camber/caster gauge. The following steps must be performed before making both camber and caster measurements. Wheel runout should be checked using a tram bar or dial indicator to make an accurate camber/caster reading.

1. Drive the vehicle onto a level surface.
2. Raise the front end and position a radius gauge (*Figure 9-21*) with the lock pins installed under each front wheel. The degree scale should be pointing outward.
3. Turn the steering wheel so that the front wheels face straight ahead.
4. Lower the tires onto the radius gauges. Be sure that the tires contact the center of the turntables, as shown in *Figure 9-21*.
5. Remove the lock pins that hold the turntables in a fixed position.

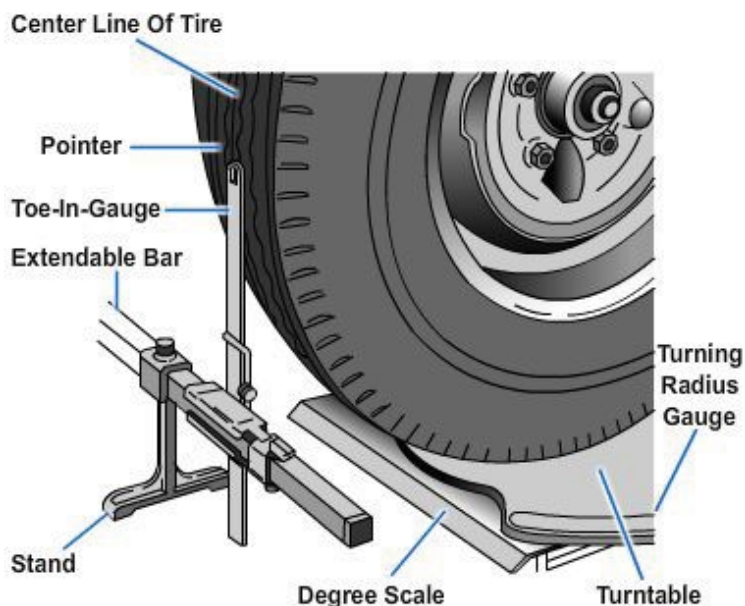
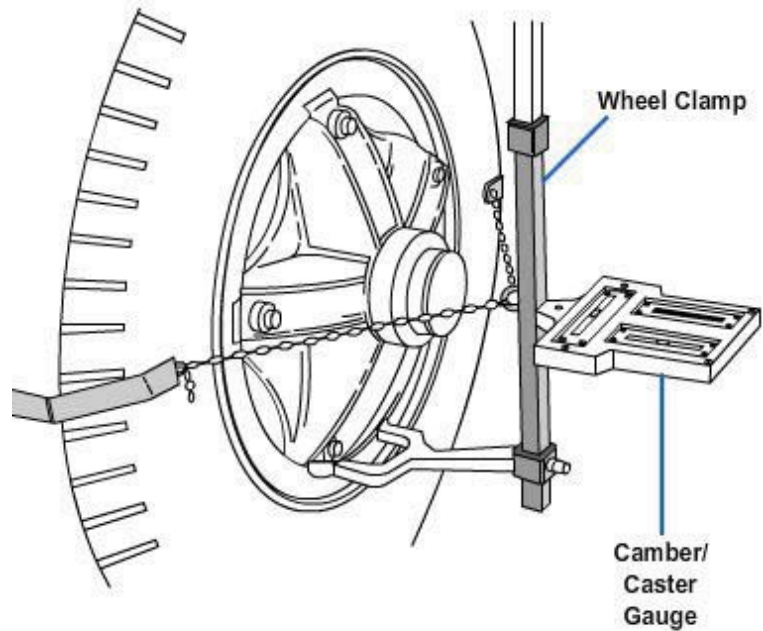


Figure 9-21 - Basic wheel alignment equipment.

6. Zero both radius scales.
7. Apply the brakes when using a full-floating turning gauge, but if a semi-floating type is used, leave them released.

8. Install the wheel clamp to the wheel rim, as shown in *Figure 9-22*, and the camber/caster gauge to the wheel clamp. On smaller wheels, the camber/caster gauge is usually fitted directly to the wheel hub instead of the wheel rim. Follow the equipment OEM's instructions.



9. To check and adjust wheel runout, first make sure that the wheel clamp fingers rest firmly against the rim and that the gauge rests firmly against its seat, as shown in *Figure 9-22*.

Figure 9-22 - The camber/caster gauge attached to the wheel clamp.

10. Raise the front wheel off the turning radius gauge.
11. Note the reading on the camber scale.
12. When turning the wheel, note the point of the greatest wheel runout and mark the tire in that location. Next, position this location in the forward or rearward direction. In this way, the true wheel centerline is brought into the vertical position, splitting the runout.
13. Lower the front end so that the tires sit again on the turning radius gauges.

Some camber/caster gauges have a runout compensation adjustment. Follow the OEM procedure when using this equipment.

Measure caster. To measure caster using radius gauges, use the following procedure:

1. Set both turning radius scales at zero.
2. Make a right-hand turn with the steering wheel so that the front wheel is turned to 20 degrees.
3. Turn the adjusting screw to center the left wheel caster gauge bubble.
4. Now turn the steering wheel to the left until the front wheel is at the 20-degree, left-hand turn position.
5. Rotate the gauge to level it.
6. Visually align the center of the bubble with the left- or right-hand caster graduation and read the degree of caster. The caster is positive if the bubble is toward the positive sign and negative if the bubble is toward the negative sign.
7. Repeat this procedure on the opposite side of the vehicle.

If the caster difference from side to side exceeds $\frac{1}{2}$ degree, the axle is probably twisted. Also, remember that the right side should not have less positive caster than the left. If the right side has less, it will tend to lead the vehicle to the right, particularly on crowned roads.

Caster shims. Caster angle is changed by using caster shims, which are angled metal wedges inserted between the spring seat and axle pad. Shims are typically manufactured in half-degree increments, from $\frac{1}{2}$ degree to about 4 degrees, and in a choice of 3-, $3\frac{1}{2}$ -, or 4-inch widths to accommodate typical spring pack widths.

When inserting caster shims under spring seats, you should observe the following:

- Use only one shim on each side. Do not stack them.
- The width of the shim should equal that of the spring.
- Do not use shims of more than 1 degree difference from side to side.

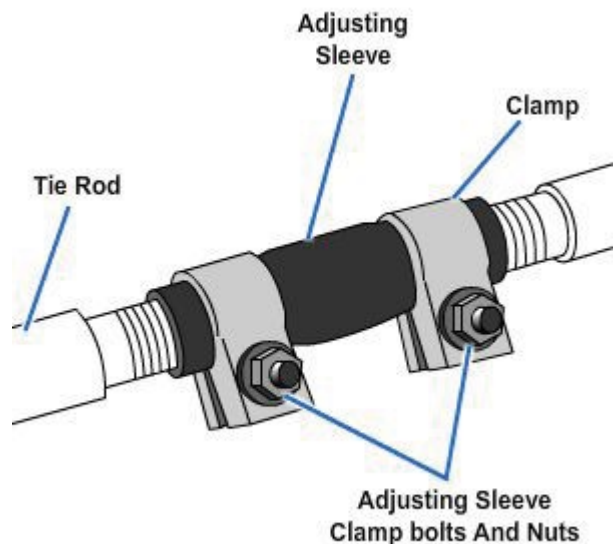
Changing caster. After determining the caster desired for each side of the axle, use the following procedure to install the caster shims:



When changing caster, be sure to block the wheels so that the vehicle will not roll. Also, use safety stands to support the springs when changing the caster shims.

1. Loosen all spring U-bolts on each side just enough to relieve clamping tension.
2. On one side, fully back off the U-bolt nuts without completely removing them from the U-bolt threads.
3. With a frame jack, raise the springs from the axle seat. Do not lift the wheel from the floor.
4. If the caster shim has been previously installed, remove it and make sure that the angle is factored in the calculation of desired caster angle. In the interest of safety, use a tool to remove the shim. Never insert your fingers between the axle and the springs.
5. Remove dirt and debris from the exposed axle pad.
6. Ensure that the spring center bolt cap protrudes sufficiently to pass through the caster shim and locate to the axle alignment recess.
7. Insert the shim, aligning the hole with the center bolt, and slowly lower the spring onto the axle, making sure the center bolt seats the axle alignment recess. The caster shim must be installed with the thick part of the wedge positioned to produce the correct caster reading.
8. Apply initial torque to the U-bolt nuts.
9. Repeat steps 2 through 8 on the other side of the axle.
10. Torque the U-bolt nuts to the OEM specifications in a crisscross pattern.
11. Measure the caster again. Changing shims does not always produce the exact caster change desired.
12. In most cases, caster angle should not change significantly when a load is added to the vehicle. If steering difficulties persist, caster should be rechecked with the vehicle loaded.

Measuring camber. The preparatory procedure that has to be performed before measuring camber is further detailed in the section on caster. Perform those steps first. Then stabilize the front end. Next, visually align the center of the bubble with the left- or right-hand camber graduation to read the camber from the camber scale. Camber is positive if the bubble gravitates toward the positive sign and negative if it gravitates toward the negative sign. It should be emphasized that the camber should be checked but seldom has to be adjusted in truck front ends.



4.2.0 Toe-in and Steering Wheel Adjustment

Figure 9-23 - Tie-rod adjusting sleeve.

Toe-in is the most important alignment setting for tire life. Incorrect toe can also cause poor handling. An extreme toe-in or toe-out condition is the only alignment problem that can cause vibration, although this rarely happens. The toe must be set correctly, or adjusting the other alignment settings is a waste of time.

To set the toe, turn the ignition switch to the ON position. If the vehicle has power steering, start the engine. Then turn the steering wheel and install the steering wheel holder. Turn the ignition switch to the locked position.

Carefully position the steering wheel before installing the steering wheel holder. If the steering wheel is not centered correctly, it will be crooked when the vehicle is driven.

Next, observe the toe readings on each side and decide what must be done to correct it. If centering the steering wheel causes the wheels to be severely toed to one side, the steering wheel may be improperly installed.

Never attempt to adjust the toe to compensate for an incorrectly installed steering wheel. If the tie-rod adjusters are moved excessively, they can cause the tie-rod ends to bind. The lock bolts used on sleeve-type adjusters may contact the body and cause the steering to jam. If the tie rods are turned too far out, there may not be enough threads left to allow the tie-rod locknuts or bolts to be properly tightened. The steering linkage may come apart when the vehicle is driven, causing an accident.

If the steering wheel is off by more than about $\frac{1}{4}$ of a turn (45°), check the steering linkage to ensure that there are no bent parts. Ensure that the toe was not previously misadjusted or that the steering component has not been improperly installed. If there are no serious problems, it can usually be assumed that the steering wheel was improperly installed in the past. In this situation, it is generally easier and safer to reposition the steering wheel than to change the alignment.

Loosen the tie-rod adjusting sleeve clamp bolts, as shown in *Figure 9-23*, or the tie-rod lockouts, as shown in *Figure 9-24*. If the vehicle has a metal bar preventing sleeve movement, loosen its clamp or bend it out of the way. This bar is used during vehicle assembly and does not have to be reinstalled.

Adjust toe by turning the sleeves or rods to obtain exactly half the needed toe on each wheel. If the toe is not divided exactly, the steering wheel will not be straight. Some

vehicles have an adjustment on only one side of the linkage. If there is only one sleeve, the steering wheel cannot be centered without removing the wheel.

Some vehicles have two sleeves, one for adjusting toe, and one for centering the steering wheel. When adjusting this type of vehicle, always set the toe first, and then the center wheel.

It is typical practice to center the steering wheel again once toe has been set. This is especially useful when the toe has been changed a great deal. If the toe is now different on each side, reset it as necessary. If the toe is still equal on both sides, tighten the sleeve bolts or locknuts as applicable.

It is advisable to torque the fasteners to manufacturer's specifications. Some vehicles with conventional steering have a specific location for the tie-rod adjusting sleeve clamp bolts. If the bolts are not placed in this position, they could contact other underbody parts. On any vehicle, make sure the bolts cannot contact any part of the underbody.

Centering the Steering Wheel after Alignment.

After the toe has been set, you may find that the steering wheel is slightly off center when the vehicle is driven in a straight line. To straighten the steering wheel without affecting toe, first drive the vehicle back onto the alignment rack. Make sure the turn plates are not locked and place the steering wheel in the centered position. Install the steering wheel lock.

Raise the vehicle to a comfortable working height and loosen the toe adjuster locknuts or lock bolts at the tie rods. Be sure not to move the adjusters themselves. Then sight down the front and rear of the outside sidewall of one front tire. Then sight down the outside of the other tire. One tire will appear to be toed in and the other will appear to be toed out. Turn each adjuster the same amount until both tires are straight ahead. For example, if the right adjuster is turned out $\frac{1}{2}$ turn, the left adjuster should be moved $\frac{1}{2}$ turn.

Tire position can be determined by sighting down the outside sidewall of each front tire. The front tires are straight when sighting down the front and rear sidewall allows you to see the outer sidewall of the rear tire. Once the tires appear to be pointed straight ahead, remove the steering wheel lock and turn the wheel from side to side several times. Then center the steering wheel and sight down the tire sidewalls again. Readjust the tire position if necessary. Once both tires are straight, retighten the adjuster locknuts. Lower the vehicle and road test to determine whether the steering wheel is straight. If the steering wheel is still not centered, repeat the centering procedure as needed.

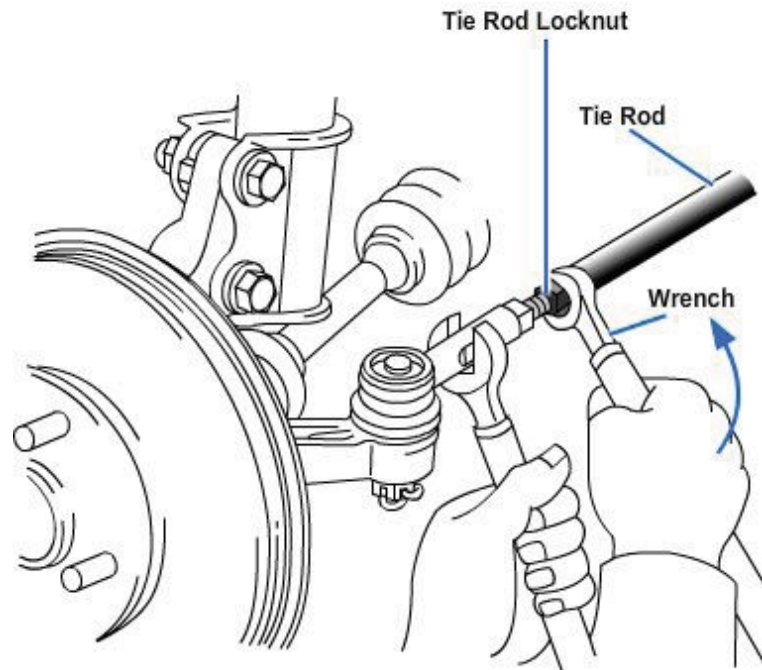


Figure 9-24 – Tie-rod locknut on a rack-and-pinion steering assembly.

5.0.0 NONADJUSTABLE SUSPENSION ANGLES

5.1.0 Turning Radius

When a vehicle turns a corner, the inner wheel must turn on a smaller circle than the outer wheel. The inner wheel is said to turn in a shorter radius. On the rear axle, the wheels are not connected by linkage, and the difference in turning radius does not affect vehicle operation. In the front, however, the linkage holds the wheels parallel and one tire has to break loose from the pavement every time the vehicle makes a turn. To prevent this, the front wheels must automatically toe out on turns to allow the inner wheel to turn in a shorter radius. The steering arms are designed to angle slightly toward the center of the vehicle. When the wheels are turned, the inside steering arm swivels at a greater angle. This causes the inner wheel to turn more sharply than the outer, increasing toe out. The bend in the steering arm does not affect toe when the vehicle is traveling straight ahead.

5.2.0 Steering Axis Inclination (SAI)

Like caster, steering axis inclination is a line formed by the relative positions of the top ball joint or strut mounting in relation to the bottom ball joint. While caster is formed by the back-and-forth positions of the upper and lower ball joints (for the lower ball joint and the strut mounting), steering axis inclination is formed by the in-and-out positions of these parts in relation to the centerline of the vehicle. SAI is always slanted inward at the top (*Figure 9-25*).

The imaginary lines formed by SAI, camber, and true vertical always contact the road very closely to each other. This causes road shocks to be absorbed by the steering knuckle instead of being transmitted to the steering linkage. The sideways angle of the SAI centerline also causes the force of the road shocks to enter the frame at a sideways angle, compensating somewhat for the upward shock of the wheel assembly. The SAI angle also keeps the vehicle weight on the inner wheel bearing, eliminating the need for excessive camber, which would wear the tire.

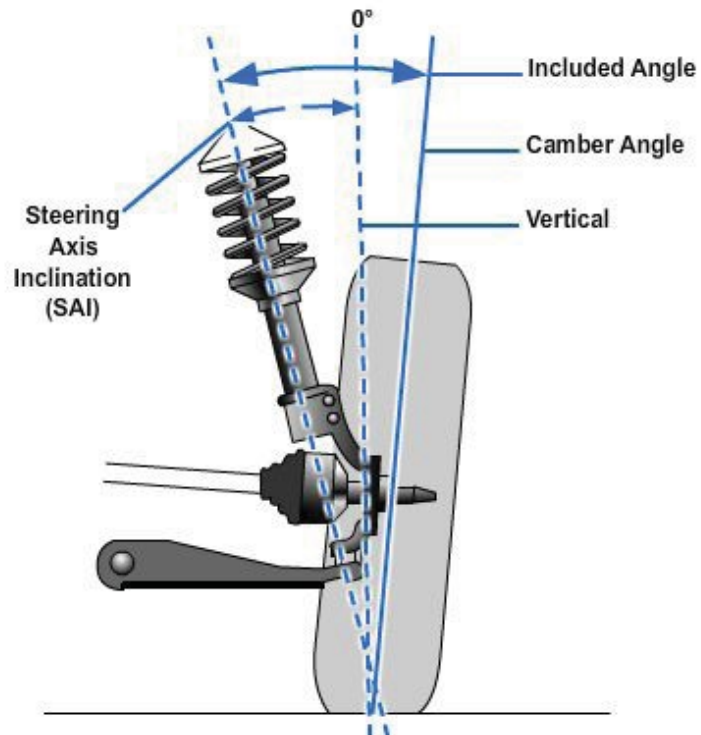


Figure 9-25 - Steering axis inclination shown on a front-wheel drive, independent suspension.

SAI uses the weight of the vehicle to improve tracking. Tracking improvements result from the fact that whenever the wheels are turned from the straight position, the vehicle caster setting raises the body on one side. When the turn is completed, the weight of the vehicle through the SAI centerline forces the spindles to swivel back to their original position. This returns the wheels to the straight-ahead position.

Included Angle. Included angle is the total of the SAI and the camber. A typical included angle is shown in *Figure 9-26*. The included angle is usually not needed, but may be used to calculate the points at which the SAI and camber centerline contact the road. SAI cannot be changed without replacing parts, but the included angle will change when the camber is changed.

Setback. When one wheel spindle is positioned behind the other spindle on a single axle, the condition is called setback. Slight setback will be found on all vehicles due to manufacturing tolerances. Severe setback, however, is mostly caused by collision damage. Setback usually affects the caster reading and may cause the vehicle to pull toward the side with the wheel that is farthest back.

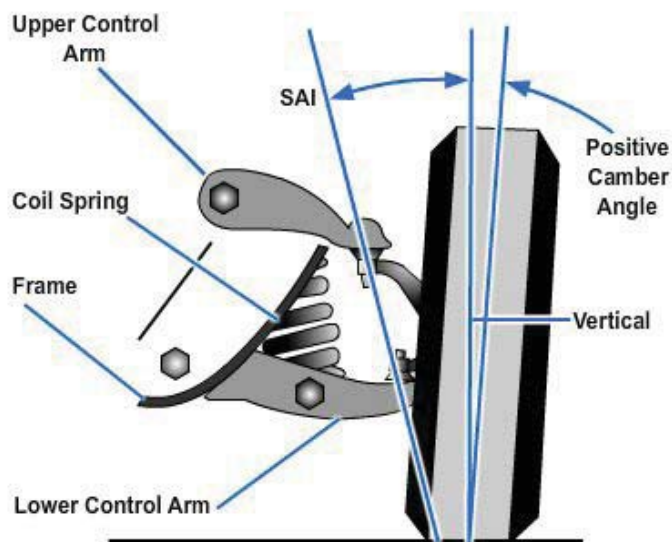


Figure 9-26 - Illustration depicting the included angle in relationship with steering axis inclination.

6.0.0 STEERING and ALIGNMENT TROUBLE

Many vehicle defects can affect the alignment of the suspension and steering. Some defects are directly related to the suspension and steering system, while others are less obvious. However, they can have an effect on the handling and tire life of the vehicle.

6.1.0 Defective Parts

Worn or otherwise damaged parts are the most common cause of alignment complaints, as well as of suspension and steering problems in general. Striking road debris, pot holes, or curbs can bend steering or suspension parts. Often, the driver is not aware that damage has occurred. Moving parts can wear out, again without the driver actually realizing it. The power steering can fail for many reasons. Electronic suspension and steering systems can develop defects. Remember that an alignment is useless unless all steering and suspension defects are corrected first.

Power steering systems can develop seal or valve problems that result in unequal pressures in the right and left power chambers. This will cause pulling that could be misdiagnosed as an alignment problem. Electronically controlled steering systems can fail and provide too much or too little power assist. This can cause hard steering at low speeds or road wander at cruising speeds. This could be mistaken for incorrect caster

or camber. Electronically controlled suspension can develop problems that cause one side (or one corner) of the vehicle to be below normal ride height. A height problem will affect camber. The mechanic who is not aware that there is a suspension defect may try to adjust camber when the real problem is in the electronic suspension.

6.1.1 Bent Frames

Even the smallest vehicles have frames and body structures that will keep their shape under normal operating conditions. However, a collision can bend the frame of the most rugged vehicle. Bent frames are relatively uncommon, but they should be checked for, especially when other body damage is evident, when wheel setback is excessive, or when the adjusting device is at its limit of travel without reaching the correct alignment.

A related problem occurs when the body mounting bushings are worn or damaged. These bushings are used where the frame or subframe contacts the body. Bolts can loosen or the bushing can be damaged. This may not affect the suspension directly, but it may cause incorrect ride height or noises. A common sign of damaged body mounting bushings is the inability to center the steering wheel.

6.1.2 Defective Tires

Tires are a common and often overlooked cause of problems. Other than obvious tread wear, the most common tire problem is tread separation. Tread separation is a common cause of pulling and vibration. Using tires that are too wide can cause hard steering. Using tires that are too wide for the rim can distort and stress the sidewalls, resulting in tire failure. Tires that are too narrow can result in noise and poor traction. Tires that are too small for the vehicle weight will also wear out quickly. Other factors, such as improper alignment, cause the tires to wear. The worn tires, in turn, can cause other handling problems or noises.

6.1.3 Road Crown

Road crown is the tendency of most roads to slope away from the center. Roads are designed in this manner to assist in water runoff. Since road crown causes the road to slope toward the right, the vehicle alignment can be set to cause the vehicle to drift slightly to the left. This compensates for the slope caused by the road crown and reduces the tendency of the vehicle to pull to the right.

Mechanics try to set the caster and camber to compensate for road crown. Camber should be slightly more positive on the left side than the right side; caster should be slightly more negative on the left than the right. This is called caster or camber split. Very little split is needed to compensate for road crown. In most cases, $\frac{1}{4}^{\circ}$ is sufficient. Too much compensation could cause the vehicle to pull left on roads with no road crown.

6.1.4 Road Irregularities

As the vehicle is driven, it inevitably travels over bumps, potholes, and other variations in the road surface. These variations cause the wheels to move up and down, changing camber. Depending on the suspension design, camber changes caused by suspension movement may also change caster a small amount.

General roughness of the road surface is caused by various paving materials, wear, and built-in, anti-skid grooves. Surface roughness varies greatly between roads and even along stretches of the same road. The rougher the road surface, the more noise and tire wear. There are no alignment adjustments to compensate for rough road surfaces.

6.1.5 Vehicle Load

Suspensions are designed so that normal loading will not change alignment excessively. However, vehicles are often overloaded, usually in the rear. Overloading causes the vehicle to be lower (called squat or sit down) in the rear, with corresponding rise in the front suspension. Raising the front suspension changes the camber, caster, and toe. If the rear suspension is an independent type, its alignment will change also. Vehicle handling will be greatly affected as long as the overload is present. If the vehicle is driven a long distance with an overload, tire wear will be greatly affected as long as the overload is present. If the vehicle is driven a long distance with an overload, tire wear will be severe.

6.1.6 Acceleration and Braking Forces

Acceleration and braking forces cause the suspension height to change. Acceleration causes the vehicle front end to rise, with a corresponding lowering of the rear. Braking causes the opposite effect. This raising and lowering of the vehicle causes changes to the suspension, altering the alignment. Vehicles are designed to compensate for acceleration and braking forces, but some alignment changes do occur.

6.1.7 6.1.7 Turning Forces

Turning forces occur whenever the vehicle turns in either direction. When the vehicle makes a turn, the tires are in contact with the road and try to turn the vehicle in the exact direction the wheels are aimed. The turning force created by the tires is called cornering force. Cornering force is opposed by inertia, which is the tendency of the vehicle to continue moving straight ahead. The actual path the wheels take is a combination of cornering force and inertia. The difference in the intended path and the actual path is called the slip angle. Slip angle is more pronounced at higher speeds. The higher the vehicle speed, the greater the slip angle, and large slip angles increase tire wear. There is no adjustment for slip angle, and the only way to reduce tire wear is to corner at reasonable speeds.

7.0.0 TRACK ALIGNMENT

The chain section of the track is made up of track links, pins, and bushings. A considerable number of these interconnect with each other to form the track. The complete track and undercarriage system is made up of more than just the chain section. There are actually a number of components that form the complete track system. The drive sprocket, front idler, track rollers, tension mechanism, roller guards, and the frame are all required to make up a track and undercarriage system.

The final drive on a crawler tractor drives a complete track and undercarriage system on each side of the equipment. Each link of the track is held together with a press-fit pin and bushing to keep each link section in proper alignment with each other link section during operation. This combination of parts is called a link assembly. Pressed together, each section acts like a hinge, which allows the chain flexibility when rotating on the undercarriage. The track links also provide a means for attaching the track shoes that are bolted to the links. The parts of each link assembly are induction hardened to provide good wear characteristics. Pins and bushings are machined to provide a smooth bearing between them, which also increases durability. A master link or master pin completes the track assembly.

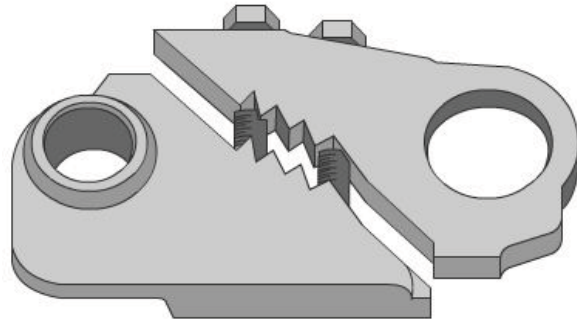


Figure 9-27 – Masterlink.

The master link, as shown in *Figure 9-27*, is slightly different from the rest of the links. The bushing used in the master link assembly is slightly shorter than the rest of the bushings, and the master pin, as shown in *Figure 9-28*, has a smaller diameter to facilitate easy installation and removal. Some manufacturer's master pins can be identified by a mark or drill hole on the end of the outside face of the pin; yet other manufacturers use a two-piece master link that bolts together. The master link uses the same pins and bushings as the rest of the track, making splitting the track easier because no special tools are required to disassemble the track. Before attempting any maintenance or repairs to a track and undercarriage system, always refer to the manufacturer's technical documentation or service manual.

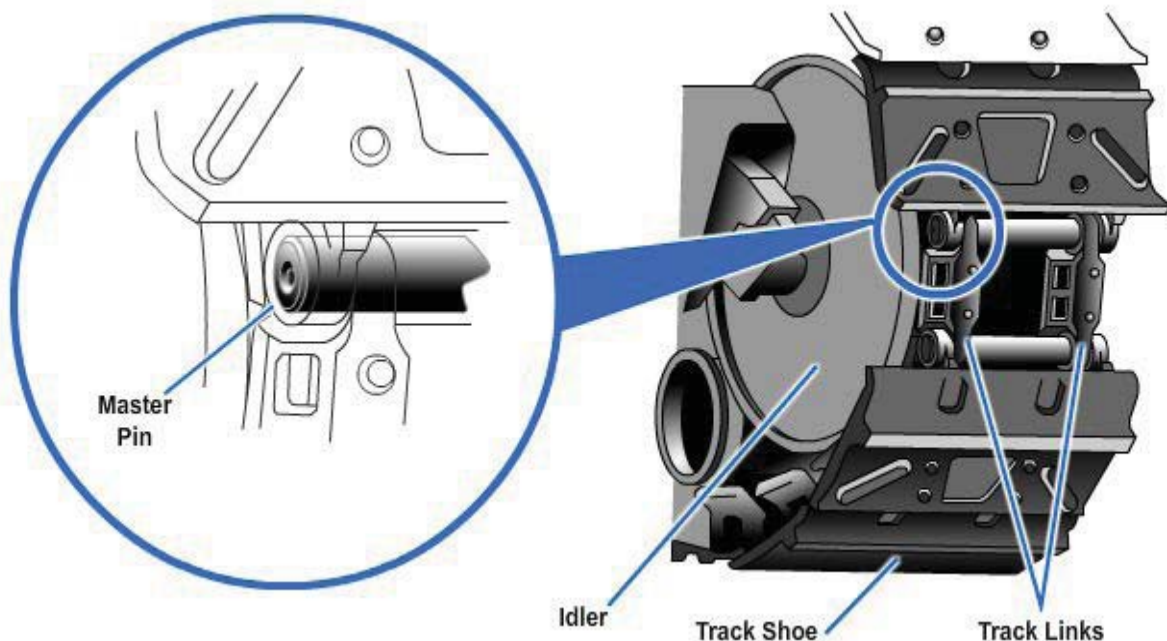


Figure 9-28 – Master pin.

Track systems also come in what is commonly called a sealed system, where the pin and bushing are lubricated on assembly and are sealed from dirt entering between them. This design eliminates internal wear.

Track shoes are bolted to the link assembly to provide a means of supporting the equipment and better traction and flotation during operation. They are generally constructed from a hardened metal plate and come in many different configurations. Refer to *Figure 9-29* for design features of a track shoe. The operating ground conditions will determine the type of shoes to be used. Operation on highly abrasive soil demands a high quality, hardened surface that will resist wear. The number of ridges (called grousers) on the track shoe designates the terrain on which the shoe will operate. The hardness of the surface material on the grousers determines whether they are standard or extreme-service track shoes.

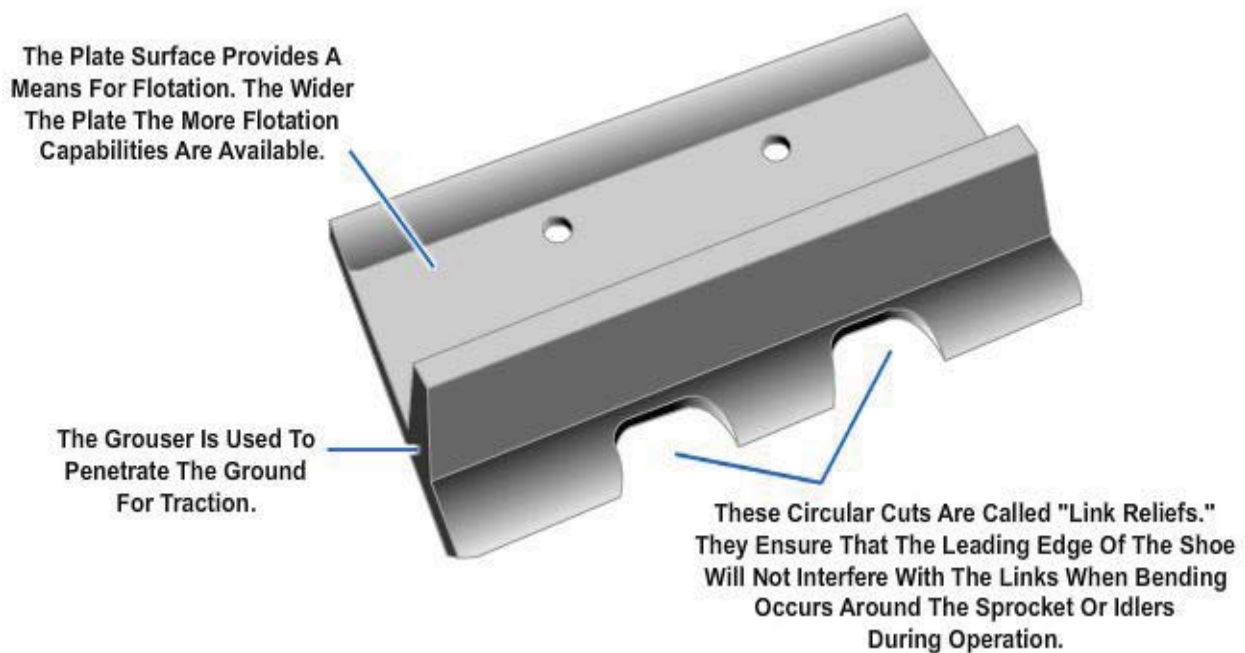


Figure 9-29 – Track shoe.

Track Links, Pins, and Bushings. Each track section is made up of two track links (*Figure 9-30*), a hardened pin, and bushing. These individual track sections are interconnected to the link assembly. The two track links used in a section have provisions for attaching a track shoe and also provide a rail for the track rollers to maintain accurate track alignment. Sealed tracks have a solid pin. Sealed and lubricated tracks have a hollow pin, which provides a path for lubricating the pin and bushing of the next track section (*Figure 9-31*). When installing a center-drilled pin, the cross drill hole must be installed toward the rail of the link, which keeps the pin in compression to resist the possibility of crushing. The pins and bushings are press-fit into the links. Be sure to follow the correct orientation; there are both right-hand and left-hand links. Clearance between the pins and bushings is minimal, providing only enough clearance for lubrication. In the case of a sealed track, the seal fits over the pin against the track link before installing another link.

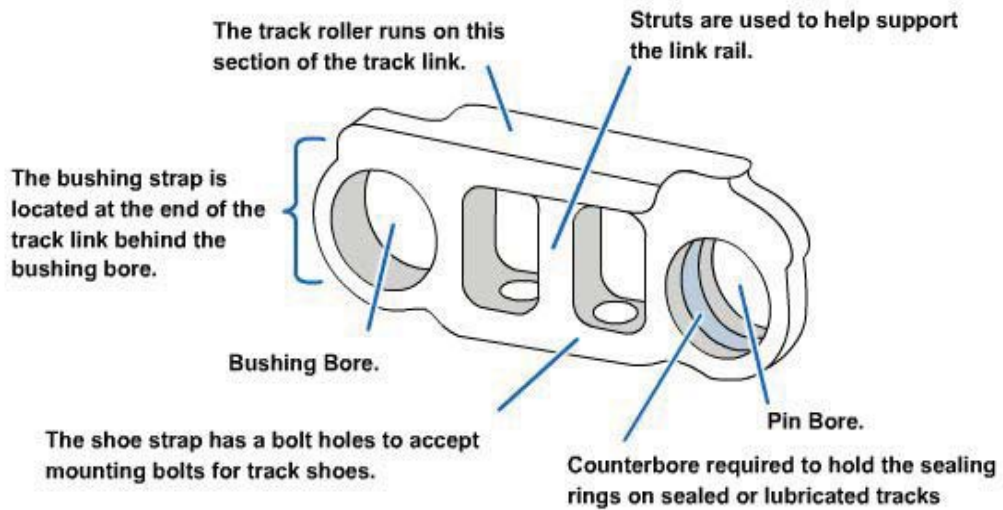


Figure9-30 – Tracklink.

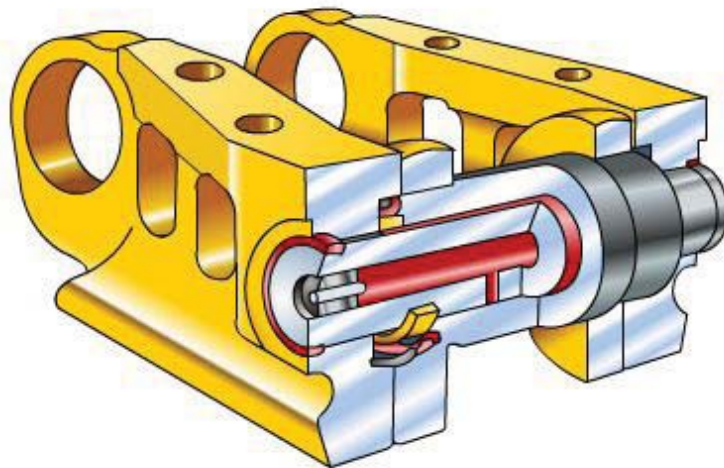


Figure9-31 - Lubricated track.