ASE 3 - Manual Drivetrain and Axles

Module 6
Rear Axles
Acknowledgements

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## Contents

### Module 6 – Rear Axles

Acknowledgements .................................................................................................................. 2

1. Introduction to Rear Axles .................................................................................................. 7
   **Overview** ......................................................................................................................... 7
   **Objectives** ....................................................................................................................... 7
   - Rear Wheel Driveline Features .......................................................................................... 8
   - Rear Axle Assembly Features ............................................................................................. 9
   - Rear Axle Identification ....................................................................................................... 11
   - Rear Axle Applications ....................................................................................................... 14
   - Major Components of a Rear Axle ................................................................................... 15
   - Types of Ring and Pinion Gearsets ................................................................................... 17
   - Differential Gearset ......................................................................................................... 18
   - Rear Axle Bearing Assemblies ............................................................................................ 20
   - Axle Shaft Assemblies ....................................................................................................... 21
   - Lubrication ......................................................................................................................... 23
   - Routine Maintenance ......................................................................................................... 24

2. Rear Axle Theory and Operation ......................................................................................... 27
   **Objectives** ....................................................................................................................... 27
   - Powertrain Operation ......................................................................................................... 28
   - Rear Axle Operation and Components ............................................................................... 33
   - Gear Types ......................................................................................................................... 38
   - Gear Malfunctions ............................................................................................................ 59
   - Differential Operation ........................................................................................................ 63

3. Rear Axle Diagnosis ........................................................................................................... 67
   **Objectives** ....................................................................................................................... 67
   - Rear Axle Assembly Diagnosis .......................................................................................... 68
   - Types of Rear Axle Seals ................................................................................................... 73
   - Noise Diagnosis ................................................................................................................ 75
   - Road Testing ....................................................................................................................... 77
   - Noise Classification Chart ................................................................................................. 83
1. Introduction to Rear Axles

Overview

This course and book are designed to provide information on the design and operation of automotive rear axles. This book is divided into the following seven sections:

• Section 1: Introduction to Rear Axles
• Section 2: Rear Axle Theory and Operation
• Section 3: Rear Axle Diagnosis
• Section 4: Rear Axle Service
• Section 5: Limited Slip Differentials
• Section 6: Propeller Shafts
• Section 7: Reference

Sections 1 through 6 start with an Objectives page. This page contains the learning objectives that can be met by understanding the information covered in that section of the book, performing shop exercises and participating in classroom discussions.

Section 7: Reference, contains additional information that may not be covered in the course. The first part of this section contains support information for other sections of this book. The last several pages contain illustrations of disassembled rear axles.

Objectives

Upon completion of Section 1 of the course, you will be able to:

• Explain the basic function of the rear axle.
• Identify the different types of rear axles.
• Identify the major internal components of the rear axle.
• Explain the need for lubrication in the rear axle.
• Identify the resources that provide rear axle diagnostic and service information.
• Identify conditions that cause the rear axle to need service.
Rear Wheel Driveline Features

The rear axle is part of the powertrain of a rear-wheel-drive vehicle. The term “powertrain” is used to describe the parts of a vehicle which make the drive wheels move. Rear-wheel-drive vehicles have three separate powertrain members:

• The engine, or first member
• The transmission, or second member
• The rear axle assembly, or third member

The powertrain can also be divided into two groups of parts:

• The power plant, consisting of the engine and transmission
• The driveline, consisting of the propeller shaft and rear axle assemblies

The primary function of the rear axle is to transfer engine torque (rotating force) from the propeller shaft to the rear wheels. The amount of torque (or rotating force) is measured in pounds per foot or Newtons per meter at a given speed, measured in revolutions per minute.

Since the rotation of the vehicle wheels is perpendicular to the rotation of the propeller shaft, the rear axle is designed to provide a 90-degree change in rotation (refer to Figure 3-1). The rear axle is also designed to split the engine torque between the two wheels. These functions are accomplished by the rear axle gearsets.

Rear axles are also designed to provide torque multiplication to assist the engine in moving the vehicle from a stop and to allow the wheels to rotate at different speeds during turning maneuvers, to prevent tire scrubbing.

Figure 3-1, 90 Degree Change in Rotation
Rear Axle Assembly Features

The rear axle assembly is typically part of several vehicle systems (refer to Figure 3-2):

• The powertrain
• The rear suspension
• The rear brakes

As part of the powertrain, the rear axle must be strong enough to transmit torque from the propeller shaft to the rear wheels as efficiently and quietly as possible.

As part of the rear suspension, the rear axle assembly must support part of the vehicle’s weight and hold the rear wheels in proper alignment with the road surface.

The rear braking system is supported by the rear axle assembly. Backing plates are bolted to the axle tube flanges, and braking torque is absorbed by the rear axle assembly and the vehicle body through the rear suspension components. Hydraulic lines and parking brake cables can also use the rear axle assembly for support.

Some rear axles (like the Corvette) do not support brake components.

Figure 3-2, Rear Axle with Rear Suspension and Brake Components
Figure 3-3, Rear Axle Cover Identification
Rear Axle Identification

General Motors has used several different rear axles based on the vehicle application. The rear axles used by GM are produced by American Axle & Manufacturing (AAM, formerly GM Saginaw Division – Final Drive), Borg Warner and Dana. Some of the rear axles contain components produced by Eaton. Rear axles are typically designated by the outer diameter of the ring gear. For example, an AAM (Saginaw) 8.50" rear axle contains an 8 1/2" outer diameter ring gear. Rear axles produced by other manufacturers may only be designated by a model number, i.e., Dana Model 44.

The type of rear axle used in a vehicle is based on the type of load that the rear axle is required to handle.

This load includes:

• The type of vehicle (size, weight and function).
• The torque output of the engine and the RPM for the highest torque.
• The type of transmission (torque multiplication in the lowest gear)
• The type of vehicle service (subjected loads and road surfaces)

Since this criteria is not the same for each vehicle, there are many different sizes of rear axles. Each rear axle has its strengths and weakness. Typically larger rear axles (i.e., AAM 10.50") are used with vehicles that are required to handle higher loads. These axles have components that are physically larger than the smaller axles and are designed to handle high loads. However, the physical size of these axles prevent their use in smaller vehicle applications. This is why there is a need for the smaller rear axles (i.e., AAM 7.65").

Rear axles can be initially identified by the shape of the rear axle cover (refer to Figure 1-3). The physical characteristics of the rear cover can be used to identify the manufacturer and possibly the diameter of the ring gear.

All rear axles are given a specific part number and code to provide the specifications of the rear axle (i.e., gear ratio, manufacturer and build date). This information can be stamped on the axle tubes or on a tag bolted to the rear axle (refer to Figure 3-4).
Manufacturer
C - Buffalo
K - Canada
G - AAM

Axle Code Location

Dana Rear Axle I.D.

Date
Model Number
Bill Of Material

Figure 3-4, Stamp Codes
The part number for a rear axle has an identification code (such as HZP, Figure 3-5). This code identifies the design specifications for that rear axle assembly. For example, a rear axle assembly with code HZP has the detailed engineering design specifications shown in Figure 3-5.

These specifications are necessary to build a complete axle assembly, P/N 26004487. This assembly is only one of the many rear axle units available for passenger cars and light duty trucks.

A technician usually needs to know the following information about a rear axle assembly in order to repair it:

- Vehicle manufacturer and model
- Rear axle assembly manufacturer
- Ring gear diameter size and gearset ratio
- Differential type
- Other powertrain identification features:
  - Engine size and type
  - Transmission type
  - Wheel/tire size and type

Upon occasion, a technician may need to know details about suspension system and brake system features in order to correctly identify the axle assembly.

- Customer and model: GM Truck and Bus, S-Truck
- Ring gear size: 7.50-inch diameter
- Ratio: 3.73 to 1
- Differential type: limited slip (Eaton locking type)
- Axle rating: 34,000 lb./in. torque, 2600 lbs weight load
- Axle flange wheel bolt circle: 4.75 inches
- Overall installation dimensions:
  - Axle mounting flanges: 1375 mm
  - Brake mounting flanges: 1238.3 mm
  - Centerlines of springs: 972 mm
- Carrier design: #14030340 from chart #14030390
- Axle tube design: #26004570 from chart #14047255
  - Material: SAE 1020 steel
  - Outer diameter: 60.73 mm
  - Wall thickness: 4.47 mm
- Brake assemblies: #18013080 (L.H.) and #18013081 (R.H.)
- Brake size: 241.0 mm x 51.0 mm
- Parking brake cables: #1557895 (L.H.) and #15547896 (R.H.)
- Pinion flange: #7827670, joint size 844

*Figure 3-5, Rear Axle Build Specifications*
## Rear Axle Applications

Figure 3-6 shows the rear axles currently used by General Motors and the vehicle applications.

### Rear Axles Currently Used By GM (1987-1998 M.Y.)

<table>
<thead>
<tr>
<th>Rear Axle Assembly</th>
<th>Chevrolet</th>
<th>Pontiac</th>
<th>Oldsmobile</th>
<th>Buick</th>
<th>Cadillac</th>
<th>Light Duty Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.50 (6 1/2 in.)</td>
<td>T</td>
<td>T</td>
<td></td>
<td></td>
<td></td>
<td>S/T, M, L</td>
</tr>
<tr>
<td>7.50 (7 1/2 in.)</td>
<td>B, G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>S/T, M, L</td>
</tr>
<tr>
<td>7.625 (7 5/8 in.)</td>
<td>B, F, G</td>
<td>F</td>
<td>B, G</td>
<td>B, G</td>
<td>D</td>
<td>R/V/G-10 and 20</td>
</tr>
<tr>
<td>8.50 (8 1/2 in.)</td>
<td>B</td>
<td>B</td>
<td>B, G</td>
<td>B, G</td>
<td>D</td>
<td>C/K/G-10 and 20</td>
</tr>
<tr>
<td>8.625 (8 5/8 in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C/K/G-20 and 30</td>
</tr>
<tr>
<td>9.50 (9 1/2 in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C/K/G-30</td>
</tr>
<tr>
<td>10.50 (10 1/2 in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Manufacturer: Borg-Warner of Australia, Limited
Plant: Fairfield, New South Wales, Australia

<table>
<thead>
<tr>
<th>Rear Axle Assembly</th>
<th>Pontiac</th>
<th>Chevrolet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 78 (7 3/4 in.)</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

### Spicer Division, Dana Corporation

<table>
<thead>
<tr>
<th>Rear Axle Assembly</th>
<th>Chevrolet</th>
<th>Light Duty Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 ICA (7 7/8 in.)</td>
<td>Y (A.T.)</td>
<td></td>
</tr>
<tr>
<td>44 ICA (8 1/2 in.)</td>
<td>Y (M.T.)</td>
<td></td>
</tr>
<tr>
<td>60 HD (9 3/4 in.)</td>
<td>G-30,125-in wheelbase</td>
<td></td>
</tr>
<tr>
<td>70 OU (10 1/2 in.)</td>
<td>G-30 146-in. wheelbase</td>
<td></td>
</tr>
<tr>
<td>70 HD (10 1/2 in.)</td>
<td>R/V/C/K/P-30</td>
<td></td>
</tr>
</tbody>
</table>

Note: ICA means Independent Carrier Assembly

### Getrag Gear of America

<table>
<thead>
<tr>
<th>Rear Axle Assembly</th>
<th>Chevrolet</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.625 in. (7 5/8 in.)</td>
<td>Y (1997 and Later)</td>
</tr>
</tbody>
</table>

### Opel

<table>
<thead>
<tr>
<th>Rear Axle Assembly</th>
<th>Cadillac</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.410 in.</td>
<td>V</td>
</tr>
</tbody>
</table>

GM Model Designations

- B (car): Caprice, Safari, Custom Cruiser, LeSabre/Electra Estate
- D (car): Fleetwood Brougham
- F (car): Camaro, Firebird
- Y (car): Corvette
- G (car): Monte Carlo, Grand Prix, Cutlass Supreme, Regal
- G (van): Full size van in 1/2-ton (10), 3/4-ton (20) and 1-ton (30) versions
- M, L (van): Mini-van, 1/2-ton version
- S (truck): Two-wheel-drive mini pick-up and utility in 1/2-ton (10), 3/4-ton (20) and 1-ton (30) versions
- T (car): Chevette, T-1000
- T (truck): Four-wheel-drive mini pick-up and utility in 1/2-ton (10), 3/4-ton (20) and 1-ton (30) versions
- R, C (truck): Two-wheel-drive full size pick-up and utility in 1/2-ton (10), 3/4-ton (20) and 1-ton (30) versions
- V, K (truck): Four-wheel-drive full size pick-up and utility in 1/2-ton (10), 3/4-ton (20) and 1-ton (30) versions
- V (car): Catara
- P (truck): Forward-control step-van in 3/4-ton (20) and 1-ton (30) versions
Major Components of a Rear Axle

There are three major parts to a rear axle:

- The ring and pinion gearset
- The differential gearset
- The carrier housing

Both the ring and pinion gearset and the differential gearset are contained within the carrier housing.

Ring and Pinion Gearset

The ring and pinion gearset has two components, the ring gear and the pinion gear (refer to Figure 3-7). The pinion gear is connected to the propeller shaft, by the companion flange. The pinion gear is supported in the carrier housing by two bearings. The ring gear is connected to the differential case (part of the differential gearset). The ring and pinion gearset provide the 90-degree change in rotation required for torque transfer from the propeller shaft to the wheels.

![Figure 3-7, Ring and Pinion Gearset](image)
Torque Multiplication

The ring and pinion gearset provide torque multiplication (designated by the gear ratio) to assist the engine in moving the vehicle from a stop. Torque multiplication is a process where the input torque is increased by using a gearset. It results in an output torque that is higher than the input torque. Torque multiplication in the rear axle has a direct relationship to the size and number of teeth on both the pinion gear and the ring gear.

Since the pinion gear is smaller and has fewer teeth than the ring gear, the pinion gear will complete multiple revolutions for each ring gear revolution (refer to Figure 3-8). The number of pinion gear revolutions to one ring gear revolution is called the gear ratio. With a gear ratio of 3.73 to 1 (3.73:1), the pinion gear completes 3.73 (or approximately 3 3/4) revolutions to one ring gear revolution. The gear ratio has a direct relationship to torque multiplication. (Refer to the Reference Section for a detailed explanation of torque multiplication.)

Although torque multiplication is necessary for moving the vehicle from a stop, it has one negative side effect. Torque multiplication results in the output speed being slower than the input speed. A higher gear ratio (higher torque multiplication) will result in a slower maximum vehicle speed than a lower gear ratio in the same vehicle.

The diameter of the wheels and tires also have an effect on acceleration and maximum vehicle speed. Increasing the wheel and tire diameter (with the same gear ratio) will result in a slower acceleration and higher maximum vehicle speed. This is due to the principle of leverage; refer to the Reference Section.

If the Driveshaft RPM is 800 revolutions per minute:
The Pinion Gear will complete 800 revolutions in 1 minute.
The Ring Gear will complete 214.5 revolution in 1 minute.

Figure 3-8, Gear Ratio
Types of Ring and Pinion Gearsets

There are three types of ring and pinion gearsets:

- Bevel
- Spiral Bevel
- Hypoid

The bevel type of ring and pinion gearset is not currently used. The spiral bevel type ring and pinion gearset is still used on medium and heavy duty truck applications. The hypoid type of ring and pinion gearset is used on light duty trucks and cars. Each type has benefits and weakness. Figure 3-9 show the three different types and their differences.

**Bevel Gearset:**
- Straight-cut Teeth
- Pinion Gear on Center with Ring Gear
- Very Noisy

**Spiral Bevel Gearset:**
- Teeth Cut on an Angle
- Pinion Gear on Center with Ring Gear
- Quieter than a Bevel Gearset
- Resistant to Scoring
- Allows for a Large Differential Case

**Spiral Bevel Gearset:**
- Teeth Cut on an Angle
- Pinion Gear Offset from the Center of the Ring Gear
- Quieter than both the Bevel and Spiral Bevel Gearsets
- Sensitive to Scoring
- Differential Case must be Smaller
- Requires special lubricant

Figure 3-9, Different Ring and Pinion Gearsets
**Differential Gearset**

The differential gearset is used to connect the ring gear to the axle shafts. There are two different types of differential gearsets, the open differential and the limited slip differential (which includes the locking differential). Both types provide the torque split between the two rear wheels and allow the axles to rotate at different speeds during turning maneuvers.

The differential gearset has the following major components (refer to Figure 3-10):

- Differential case
- Side gears (2)
- Differential pinion gears (typically two)
- Pinion shaft

The differential case is supported in the carrier housing by two bearings and bearing caps.

The differential case contains the differential gearset, which includes two side gears and two differential pinion gears. The differential pinion gears are opposite of each other in the differential case and are held in position by the pinion shaft, which is bolted to the differential case. The differential pinion gears are meshed with the side gears and have internal splines for connection to the axle shafts.

*Figure 3-10, Differential Components*
The ring gear is bolted to the differential case and, as the ring gear rotates, the differential case also rotates. Since the pinion shaft is connected to the differential case, it will also rotate with the ring gear (refer to Figure 3-11).

During straight ahead vehicle movement, the differential pinion gears and side gears will rotate with the differential case. Since the axle shafts are splined to the side gears, the axles will also rotate with the differential case.

The operation of the differential gearset is different during vehicle turns or when one wheel loses traction. These modes of operation will be discussed in Section 2 of this book.

The limited slip differentials are designed to compensate for some of the limitations of the open type differential.

*Figure 3-11, Basic Differential Operation*
Rear Axle Bearing Assemblies

Rear axle bearing assemblies are designed to support rotating components while allowing them to rotate independently of the support component (the rear axle carrier housing). Rear axle bearing assemblies have the following components (refer to Figure 3-12):

- Inner bearing race
- Outer bearing race
- Bearings
- Bearing cage

Rear axle bearings can be either ball bearings, straight roller bearings or tapered roller bearings. Rear axles typically use tapered roller bearings to support the pinion gear and the differential case. Ball bearing or tapered roller bearings are used to support the axle shafts.

Figure 3-12, Bearing Components
Axle Shaft Assemblies

The axle shafts are used to connect the rear axle gearsets to the wheels of the vehicle. One end of the axle shaft has splines for meshing with the differential side gears. There are two types of axle shaft assemblies:

- Semi-Floating
- Full Floating

Semi-Floating Axle Shafts

The semi-floating axle shafts support the vehicle weight and are typically used in light duty trucks and cars. The semi-floating axle shafts have flanges for mounting the brake drums/discs and wheels. Wheel bearings are used to support the axle shaft in the axle tubes.

Currently there are two methods used to retain semi-floating axle shafts in the carrier housing (refer to Figure 3-13):

- “C” locks
- Seal retainer plates

The “C” lock method is the most widely used in GM vehicles. The axle shafts used with this method have recesses at the inner end of the shaft for the “C” locks. The “C” locks keep the axle shafts splined to the differential side gears. In this method, the wheel bearings are pressed into the axle tubes.

The second method uses wheel bearings that are pressed onto the axle shafts. A seal retainer plate is positioned between the bearing and the axle flange. The seal retainer bolts to the axle tube and positions the outer race of the wheel bearing inside the axle tube. The press fit of the bearing on the axle shaft prevents the axle shafts from coming out of the axle tubes.

*Figure 3-13, Semi-Floating Rear Axles with “C” Locks and Seal Retainer Plates*
Full Floating Axle Shafts

The full floating axle shafts do not support the vehicle weight and are typically used in medium and heavy duty truck applications. Full floating axle shafts are also used in some 3/4- and 1-ton light duty trucks (based on Gross Vehicle Weight, GVW). Like semi-floating axle shafts, the full floating shafts are splined to the differential side gears. The other end of the axle shaft is bolted to the wheel hub (refer to Figure 3-14).

The vehicle weight is supported by bearings between the wheel hubs and the axle tubes. Bearings are not used to support full floating axle shafts.

Figure 3-14, Full Floating Rear Axle
Lubrication

The rear axle assembly is similar to other automotive mechanical systems in its need for lubrication. The rotating components inside the rear axle create friction, which causes heat and wear. Lubrication is used to reduce the friction between moving parts. The lubrication is also used to remove the heat from the moving components by absorbing the heat and transferring it to the rear axle carrier housing.

The carrier design uses cast-in oil channels which work with the formed carrier to provide oil circulation (refer to Figure 3-15). The ring gear moves oil forward through passages to lubricate the drive pinion bearings. Oil is also pushed into the differential bearings by the rotating differential case. The rear wheel bearings receive oil by way of the axle tubes.

The fill plug may be located in the carrier casting or in the cover. The vent can be fitted to either the carrier or on an axle tube.

*Figure 3-15, Rear Axle Lubrication (Dana Models 60 and 70)*
Routine Maintenance

Rear axles require routine maintenance. The maintenance schedule is dependent on the type of rear axle and its use. Limited slip-type differentials require more frequent maintenance than open-type differentials. The following is a list of the scheduled maintenance for rear axles:

- Each time the oil is changed, check fluid level and add, if necessary.
- Inspect pinion flange seal, axle shaft seals, and carrier cover gasket areas for signs of fluid leaks.
- In dusty areas or trailer towing applications, drain fluid at every oil change interval (7,500 miles) and refill. This applies to all rear axle applications.
- Rear axles with disc-type limited slip differential units or Eaton locking differential units require a fluid change at the first oil change interval (7,500 miles) for normal service.
- Cone-type limited-slip differentials do not require an initial fluid change at 7,500 miles for normal service.
- Light-duty trucks over 8,000 GVWR with open differentials require a fluid change every fourth oil change (30,000 miles). Light duty trucks over 8,500 GVWR with Eaton locking differentials require an initial fluid change at 7,500 miles, followed by changes at 15,000-mile intervals.

Rear Axle Fluid Capacities

- AAM Axles
  - 7.50" 3.5 pints (1.7 liters)
  - 7.625" 3.5 pints (1.7 liters)
  - 8.50" 4.3 pints (2.0 liters)
  - 8.625" 4.3 pints (2.0 liters)*
  - 9.50" 5.5 pints (3.1 liters)
  - 10.50" 5.4 pints (3.1 liters)
- Borg-Warner Axles
  - Model 78, 7.75" 3.6 pints (1.8 liters)
• Dana (Spicer) Axles
  – Model 36 I.C.A., 7.875” 4.8 pints (2.3 liters)
  – Model 44, I.C.A., 8.50” 4.8 pints (2.3 liters)
  – Model 60 HD, 9.75” 6.0 pints (2.8 liters)
  – Model 70 OU and HD, 10.50” 7.2 pints (3.4 liters)

Rear axles with certain limited slip differentials (disc-type) require a friction-modifier additive. This additive is used to prevent “chattering.”

*Use only synthetic lubricant; do not exceed the specified capacity. Exceeding the capacity could cause a fluid leak at the vent.

Axle Service Conditions

Except for regular maintenance, there are three main reasons why rear axle service is necessary:

• Incorrect operation
• Noise or vibration
• Oil leaks

Incorrect Operation

Incorrect operation is when the rear axle is unable to transmit engine power to the rear wheels. This is typically caused by damage to one or more of the internal components:

• Ring and pinion gearset
• Differential gearset
• Axle shafts

Service for incorrect operation typically requires replacement of rear axle components.
Noise or Vibration
If the rear axle produces a noise or vibration that is excessive, rear axle service is required to eliminate the malfunction causing the concern. Prior to repairing a noise (or vibration) concern, the noise must be determined as unacceptable. Rear axles normally produce some amount of noise. If the noise level matches that of other vehicles of the same type, the rear axle is considered commercially quiet and should not be repaired.

Oil Leaks
Oil leaks are the third condition requiring rear axle service. Most oil leaks are the result of failed oil seals.
However, carrier housing porosity and incorrectly installed axle tubes can be the source of rear axle leaks.
Prior to repairing a leak, the source of the leak must be correctly identified. There are many other components in a vehicle that can leak fluids.
2. Rear Axle Theory and Operation

Objectives

Upon completion of Section 2 of the course, you will be able to:

• Identify different types of gears and gear applications.
• Explain how the ring and pinion gearset operates.
• Explain how the differential operates.
• Describe different types of axle configurations.
• Identify the different types, characteristics and applications of rear axle fluids.
Powertrain Operation

For a vehicle to move, the power from the engine must be transmitted to the driving wheels. In a rear-wheel drive vehicle, power from the engine is transmitted through the transmission and propeller shaft to the rear axle. The rear axle provides the torque to the vehicle wheels (refer to Figure 3-16).

All of these components are combined to form the powertrain of a rear-wheel drive vehicle. The rear axle is only one part of the powertrain equation. The speed and acceleration provided by the powertrain is dependent on all of the components of the powertrain:

- Engine (torque and speed)
- Transmission gear ratios
- Rear axle ratio
- Wheel and tire specifications (diameter, contact surface and composition)

Figure 3-16,
The torque produced by the engine at low RPMs is typically insufficient to move the vehicle from a stop. To assist the engine, both the transmission and the rear axle are designed to provide torque multiplication. During torque multiplication, gearsets are used to multiply (or compound) the torque provided by the engine and transmission. This results in an output torque that is higher than the input torque. By using torque multiplication, sufficient torque is applied to the wheels to accelerate the vehicle from a stop. To increase the rate of acceleration (for a specific engine RPM), the amount of torque multiplication must be increased (refer to Figure 3-17). This is achieved by increasing the gear ratio in either the rear axle or the transmission.

The rate of acceleration is also very dependent on the tires. The friction between the tires and the road surface determines the maximum amount of torque that can be applied to the wheels before the tires will break traction. If the total gear ratio (a combination of the transmission gear ratio and the rear axle ratio) is increased to the point where the output torque exceeds what can be transmitted to the road by the tires, the tires will lose traction and spin, negating the benefit of the higher gear ratio.

The side effect of torque multiplication is that the output speed is lower than the input speed. However, this reduction in output speed is necessary when accelerating from a stop. It allows the engine to maintain at least the minimum operating speed (to prevent engine stalling) and allows the vehicle speed to gradually increase without breaking traction. Again, the rate of acceleration is determined by the amount of torque produced by the engine and the amount of torque multiplication produced by the transmission and rear axle. Most final gear ratios (transmission ratio multiplied by rear axle ratio) in first gear are between 9.00:1 and 13.00:1.

As the vehicle speed increases, the need for torque multiplication decreases and the need for output speed increases. Since the rear axle has a fixed gear ratio, the transmission must have additional gear ratios for the maximum vehicle speed to be increased (refer to Figure 3-17). Newer transmissions have at least four gear ratios, with one of the gear ratios being overdrive. Overdrive provides an output speed that is higher than the input speed and a reduction in output torque.

![Figure 3-17,](image)
Figure 3-18 shows the effect of gear ratio on the maximum vehicle speed in each transmission gear. The example uses a 4L60-E transmission, a rear axle with a 3.73:1 gear ratio and P235/75R15 tires (with rolling circumference of 7.5 ft.). The final ratio for each transmission speed is determined by multiplying the transmission gear ratio by the axle ratio. To determine the vehicle speed for a specific engine RPM and transmission gear, the engine speed is divided by the final ratio to determine the wheel RPM. The wheel RPM is then multiplied by the rolling circumference to determine the distance traveled in each minute (feet per minute). To determine miles per hour, the number must be multiplied by 60 (minutes in an hour) and divided by 5280 (feet in a mile).

Notice that as the transmission gear ratio becomes smaller, the vehicle speed produced by the engine speed (RPM) increases.

<table>
<thead>
<tr>
<th>TRANS. GEAR</th>
<th>GEAR RATIO</th>
<th>FINAL RATIO</th>
<th>VEHICLE SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>3.059:1</td>
<td>11.41:1*</td>
<td>5.97 mph @ 800 rpm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.059 x 3.73)</td>
<td>37.34 mph @ 5000 rpm</td>
</tr>
<tr>
<td>2nd</td>
<td>1.625:1</td>
<td>6.0612:1</td>
<td>36.55 mph @ 2600 rpm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.625 x 3.73)</td>
<td>70 mph @ 5000 rpm</td>
</tr>
<tr>
<td>3rd</td>
<td>1.00:1</td>
<td>3.73:1</td>
<td>68 mph @ 3000 rpm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.00 x 3.73)</td>
<td>114 mph @ 5000 rpm</td>
</tr>
<tr>
<td>4th</td>
<td>0.696:1</td>
<td>2.59608:1</td>
<td>111 mph @ 3400 rpm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.696 x 3.73)</td>
<td>164 mph @ 5000 rpm</td>
</tr>
</tbody>
</table>

*POWERTRAIN: 4L60-E Transmission*  
**NOTE:** Most vehicles have a final ratio in first gear from 9:1 to 13:1.
Figure 3-19, Table A, shows the effect of a higher rear axle ratio (4.11:1) on the vehicle speed. The example uses the same transmission and tires that were used on the previous example. Notice that the maximum vehicle speed is lower as compared to the 3.73:1 gear ratio (previous example). However, the 4.11:1 gear ratio in this example will provide quicker acceleration than the 3.73.1 gear ratio.

This increase in ratio does have a negative effect on the fuel economy (MPG). This is because the engine speed (RPM) must be higher to maintain the vehicle speed (refer to Figure 3-19, Table B). Notice that the 4.11:1 gear ratio requires the engine to operate at a higher RPM than the 3.73:1 gear ratio. Since fuel consumption is based on engine RPM, the vehicle with the 4.11:1 gear ratio will consume more fuel and have lower fuel economy.

### TABLE A

<table>
<thead>
<tr>
<th>TRANS. GEAR</th>
<th>VEHICLE SPEED AT 5000 RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.73 REAR AXLE RATIO</td>
</tr>
<tr>
<td>1st</td>
<td>37 MPH</td>
</tr>
<tr>
<td>2nd</td>
<td>70 MPH</td>
</tr>
<tr>
<td>3rd</td>
<td>114 MPH</td>
</tr>
<tr>
<td>4th</td>
<td>164 MPH</td>
</tr>
</tbody>
</table>

Based on a 4L60-E Transmission and P235/75R15 Tires (Rolling Circumference of 7.5 ft.)

### TABLE B

<table>
<thead>
<tr>
<th>TRANS. GEAR</th>
<th>ENGINE SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.73 REAR AXLE RATIO</td>
</tr>
<tr>
<td>55 MPH</td>
<td>1675 RPM</td>
</tr>
<tr>
<td>65 MPH</td>
<td>1980 RPM</td>
</tr>
</tbody>
</table>

Based on a 4L60-E Transmission and P235/75R15 Tires (Rolling Circumference of 7.5 ft.)

*Figure 3-19, The Effect of a Higher Rear Axle Ratio on Vehicle and Engine Speed*
The diameter of the wheels and tires also have a large effect on the amount of torque that is transmitted to the road surface. Larger diameter wheels and tires require more torque to turn one revolution than smaller diameter wheels and tires. This is a result of reduced leverage that the ring gear has on the larger diameter tire. Figure 3-20 compares the amount of leverage that the ring gear has on a large tire as opposed to a small tire.

To compensate for the reduced leverage provided by large diameter tires, engineers will often use a larger diameter ring gear or increase the gear ratio. Increasing the diameter of the ring gear provides better leverage on larger tires. This approach is typically used on trucks, since they are often equipped with large diameter tires and can accommodate the larger rear axle. The larger rear axle is also capable of handling the heavier loads of trucks.

Increasing the gear ratio increases the amount of torque applied to the wheels. This will also increase the rate of acceleration with large diameter tires.

Figure 3-20, The Effect of Increasing the Tire Diameter
Rear Axle Operation and Components

In addition to providing engine torque to the rear wheels and torque multiplication, the rear axle must also provide a 90-degree change in rotation and split the torque between the two wheels. The rotation change is a result of the 90-degree difference in the axis of rotation of the propeller shaft and the wheels. The ring and pinion gearset are designed to provide this change in direction.

The differential gearset is used to split the torque between the two wheels. The construction of the differential allows an even split of the torque between the wheels and also allows the wheels to rotate at different speeds.

This is necessary to prevent tire scrubbing during turning maneuvers.

Rear Axles typically have the following components (refer to Figure 3-21):

- Axle Carrier Housing
- Axle Shafts
- Ring and Pinion Gearset
  - Pinion Gear
  - Pinion Bearings
  - Pinion Shims
  - Companion Flange
  - Collapsible Spacer (some applications)
  - Ring Gear
- Differential Gearset
  - Differential Case
  - Differential Pinion Gears
  - Pinion Shaft
  - Side Gears
  - Side Bearings
  - Side Bearing Shims
  - Threaded Adjuster (some applications)

![Figure 3-21, Rear Axle Components](image-url)
Axle Carrier Housing Assembly

Although all rear axles perform the same basic functions, the designs of rear axles vary. There are three basic rear axle carrier housing assembly designs that are used by GM. They include:

- Salisbury
- Banjo
- Independent Carrier Assembly (ICA)

The Salisbury type is the most commonly used rear axle carrier housing assembly. The carrier housing contains the rear axle components and has axle tubes welded to it. The Salisbury carrier housing has these features (refer to Figure 3-22):

- Machined bores for the drive pinion bearings
- Machined bores for the differential case side bearings, with bolted caps
- Machined bores for the axle tubes
- Provision for mounting the fill plug, vent, and inspection cover
- Provision for mounting brake and suspension parts

![Figure 3-22, Salisbury Type Carrier Housing](image-url)
The "Banjo" carrier housing construction shown in Figure 3-23 has a removable carrier that supports the drive pinion and ring gear/differential case assemblies. The “Banjo” axle housing has integral axle tubes. This type of rear axle design is only used on specific GM applications (i.e., Geo Tracker).

Both the Salisbury and “Banjo” designs have axle tubes and are an integral part of the rear suspension and brake system.

Figure 3-23, Banjo Type Carrier Housing
The axle tube assemblies are made from seamless steel tubes which have brackets welded to them to connect various parts to the axle:

- Rear suspension springs
- Suspension bumpers and shock absorbers
- Brake lines and backing plates
- Suspension control arms

The axle tubes are machined to support the rear wheel bearings. There are two basic axle tube designs used to support the axle shafts and wheels:

- Semi-floating axle shaft type
- Full-floating axle shaft type

With the semi-floating design, the axle tube transmits the force of the vehicle’s weight through a bearing, the axle shaft, and finally to the wheel (see Figure 3-24). The axle shafts must transmit rotating force to the wheels, and also bear vehicle weight.

A full-floating axle design (as shown in Figure 3-25) uses the axle tube to transmit the vehicle’s weight directly to the wheel through a hub supported by bearings. The axle shafts have only one job: to transmit torque to the hubs and wheels.

All passenger cars use semi-floating axle designs. Most light-duty trucks also have semi-floating axles. The heavier light-duty series of trucks use full-floating axle design, as do all medium- and heavy-duty trucks. The presence of shaft-to-hub bolts at the wheels can be used to identify a full-floating axle design.
Independent Carrier Assembly

The Independent Carrier Assembly (ICA) is used with rear-wheel-drive vehicles that have independent suspensions (such as Corvette). This type of carrier does not have axle tubes or axle shafts (refer to Figure 3-26). Yoke shafts are splined to the side gears of the differential and torque is transmitted to the wheels through axle half shafts connected to the yoke shafts. The carrier is connected to a carrier cover.

The carrier cover has the following functions:

- Transmit vehicle weight to the transverse rear leaf spring
- Support and locate the rear wheel suspension knuckles by connecting them to the frame using spindle support rods and tie rods

The carrier itself is independent of the suspension and braking systems, a design that has advantages for vehicle handling. The major advantage is that it reduces the amount of unsprung mass. On the other rear axle designs, the springs must compensate for the unsprung mass of the wheels and tires as well as the rear axle assembly. ICAs, or Independent Carrier Assemblies, reduce the amount of unsprung mass by eliminating the mass of the rear axle. This allows the suspension to react quicker to vehicle maneuvering and changes in road surface.

![Diagram of Independent Carrier Assembly](image-url)
Gear Types

There are many different types of gears used in automotive applications. Each has specific benefits and applications. The following are the gear types used in automotive applications (refer to Figure 3-27):

- Straight Bevel
- Spiral Bevel
- Hypoid
- Spur
- Helical
- Worm

Rear axles use only a few of these different types of gears. Some of the gear types have not been used in rear axles for many years.

Figure 3-27, Gear Types
Straight Bevel Gears

Straight bevel gears are used when power is to be transmitted at an angle (refer to Figure 3-28). Differential side gears are bevel gears. Ring and pinion gearsets typically do not use the straight bevel design.

Figure 3-28, Straight Bevel Gear

Spiral Bevel Gears

Ring and pinion gearsets of the spiral bevel design are typically used in medium and heavy-duty truck applications. Like straight bevel gears, spiral bevel gears are used when power is transmitted at an angle (refer to Figure 3-29). Unlike straight bevel gears, spiral bevel gears have curved teeth.

Spiral bevel ring and pinion gearsets have the pinion gear aligned with the center line of the ring gear.

Figure 3-29, Spiral Bevel Gear
Hypoid Gears

Hypoid gears resemble spiral bevel gears. The difference between the two is that the hypoid-designed pinion gear is offset above or below the centerline of the ring gear (refer to Figure 3-30).

Hypoid gears offer the following advantages over spiral bevel designs:

- Hypoid gears provide a better meshing action
- The offset design of the hypoid gear allows for a lower driveline tunnel in the floor of the vehicle
- Quieter operation

Worm Gears

Worm gears resemble a screw and are actually a type of hypoid gear (refer to Figure 3-31). Worm gears are used in slow speed situations like speedometer drives and steering systems. Worm gears are not used in rear axles.
Spur Gears
Spur gears are cut straight and are sometimes referred to as “straight cut” gears (refer to Figure 3-32). The teeth are parallel to the axis of rotation. Spur gears are somewhat noisy and are not used in the rear axle. Spur gears are used in some manual transmissions for reverse, but typically not as part of the main drive gearset because of noise.

Helical Gears
Helical gears have their teeth cut at an angle to the centerline of gear rotation (see Figure 3-33). Helical gears are stronger and quieter than spur gears. Helical type gears are commonly used in the main drive set of manual transmissions. They are not used in rear axles.
Ring-and-Pinion Gearset

The ring-and-pinion gearset is the primary gearset in the rear axle. The gearset is designed to transmit the power from the engine to the rear wheels. The ring-and-pinion gearset has two gears, the ring gear and the pinion gear (refer to Figure 3-34). The pinion gear is connected to the propeller shaft by the companion flange. The ring gear is connected to the rear wheels by the differential gearset and axle shafts.

The ring and pinion gears are a matched set. The ring gear is matched to the drive pinion gear in manufacturing when the two gears are operated on a computer controlled machine. The machine applies lapping compound on the meshing teeth. The compound is applied according to computer-made measurements to obtain a precise mating of the two gears for quiet operation. This process ensures that the gearset will be as quiet as it can be, if all the adjustments are made correctly.

The ring and pinion gears transmit power through a 90° change in direction typically using the hypoid design. Heavy-duty trucks use the spiral bevel design in some applications, but all of the passenger cars and light-duty trucks have hypoid gearsets.

The ring-and-pinion gearset also multiplies the torque from the propeller shaft to the axle shafts. Fewer teeth on the pinion require it to rotate at a faster speed than the ring gear, but also cause it to increase the rotating force to the ring gear. The gearset torque-handling ability is related to physical size. The outer diameter of the ring gear is used to identify this size.
Rear Axle Gear Design Considerations

When axle designers are planning the features of a ring-and-pinion gearset, they must consider the following factors:

- The type of vehicle (size, weight, function)
- The engine(s) to be used (gasoline vs. diesel, torque output at a given RPM)
- The transmission(s) to be used (automatic vs. manual, torque multiplication in the lowest speed range)
- The type of vehicle service (subjected loads, road surfaces)

Once these loads on the gearset are determined, three groups of specifications are blended to result in what the ring gear and drive pinion have as features:

- Type of gear combination (bevel, spiral bevel, or hypoid)
- Size of gears in the set (dimensions of both ring and pinion gears)
- Gear tooth specifications (details of construction)

In choosing what type of gear combination to use for the ring and pinion gears, axle designers usually do not consider the straight bevel gearset. Rather, they choose between spiral bevel and hypoid designs. Spiral bevel gears have the drive pinion on center with the ring gear. Compared to straight bevel gears, spiral bevel gears have larger tooth cross-section size, and more tooth contact area. Torque load is shared by two or more teeth in contact at the same time and there is no lengthwise sliding of teeth. Spiral bevel gear teeth have low surface pressure between tooth surfaces, as compared to straight bevel gears.

Hypoid gears have the drive pinion offset with respect to the centerline of the ring gear. This permits a larger, stronger drive pinion with more tooth contact. Hypoid gears are smoother and quieter than spiral bevel gears. The gear tooth surface pressure is also lower on hypoid ring-and-pinion gears. Hypoid gearsets, however, have a considerable amount of lengthwise tooth sliding, which makes them sensitive to scoring conditions at high speeds if the correct lubricant is not used.

Notice:

Use of the wrong lubricant with hypoid gearsets will result in excessive gearset wear.
Gear Tooth Nomenclature

Before introducing specifics associated with ring and pinion gear operation, technicians should understand the terms (nomenclature) related to the gear teeth. Understanding these terms is important, especially when interpreting contact patterns on the ring gear. There are seven terms used to describe gear tooth characteristics, and they include those referred to in Figure 3-35:

- **Drive side**: convex side of the gear tooth (the side that curves out)
- **Coast side**: concave side of the gear tooth (the side that curves in)
- **Toe**: narrow part of the gear tooth (on the inside diameter of the ring gear)
- **Heel**: wide part of the gear tooth (on the outside diameter of the ring gear)
- **Pitch line**: imaginary line along the center of the gear tooth
- **Face**: area on the gear tooth above the pitch line
- **Flank**: area on the gear tooth below the pitch line

Figure 3-35, Gear Tooth Nomenclature
Ring and Pinion Gear Ratios

The rear axle gear ratio refers to the gearing relationship between the ring and pinion gears. It is the ratio of pinion gear teeth to ring gear teeth. If the pinion gear has 11 teeth and the ring gear has 41 teeth, the ratio is 3.73 to 1 (41 divided by 11 equals 3.73). The ring gear has 3.73 teeth for each pinion gear tooth. This results in the pinion gear completing 3.73 revolutions for each revolution of the ring gear.

When engineers design rear axle gearsets, they typically make certain that the number ring gear teeth are not evenly divisible by the number of pinion gear teeth. If the ring gear teeth are evenly divisible by the pinion gear teeth, each tooth of the pinion gear will contact the same ring gear teeth during each revolution. This can result in excessive gearset wear since the same teeth continually mesh with each other and create a wear pattern. The following is an example of a gearset with evenly divisible teeth: a pinion gear with 8 teeth and a ring gear with 32 teeth result in a ratio of 4.00:1, 32 is evenly divisible by 8.

To prevent this excessive wear pattern, engineers typically design gearsets with at least one gear with a prime number of teeth. A prime number is any number that is only evenly divisible by 1 or itself (i.e., 1, 3, 5, 7 and 11). If the pinion gear has 7 teeth (a prime number) and the ring gear has 32 teeth, the resulting gear ratio will be 4.57:1 (32 divided by 7 equals 4.57). With this type of gearset, each tooth of the pinion gear contacts different ring gear teeth during each revolution of the ring gear. Since the gearset must make several revolutions before the same teeth will contact each other, a wear pattern between teeth is prevented.

There are two terms that are sometimes used when describing gearset ratio:

- Hunting
- Non-Hunting

A hunting gearset has at least one gear with a prime number of teeth. It is called a hunting gearset because the pinion teeth are continually hunting for the same ring gear teeth during each ring gear revolution. The gearset must complete multiple revolutions before the same teeth contact each other.

A non-hunting gearset has a ring gear with the number of teeth evenly divisible by the pinion gear teeth (refer to Figure 3-36). It is called a non-hunting gearset because the pinion teeth are continually contacting the same ring gear teeth during each ring gear revolution. Non-hunting gearsets have ratios with whole numbers (i.e., 3.00:1 and 4.00:1).
There is also a type of gearset that is called a partial non-hunting gearset. This type of gearset has ratios of 3.50:1, 4.50:1 and so on. The pinion gear teeth of a partial non-hunting gearset contact the same teeth of the ring gear on every other ring gear revolution.

**Figure 3-36, Hunting Versus Non-Hunting Gearsets**

- **HUNTING:** RING GEAR TEETH ARE NOT EVENLY DIVISIBLE BY THE PINION TEETH.
  - 3.73:1
  - 4.11:1
- **NON-HUNTING:** RING GEAR TEETH ARE EVENLY DIVISIBLE BY THE PINION TEETH.
  - 3.00:1
  - 4.00:1
Ring and Pinion Gear Positioning

In order for the ring and pinion gearset to operate correctly and quietly, the pinion and ring gears must be correctly positioned in the carrier housing. When correctly positioned, the teeth of the gears mesh to create the correct gear tooth contact pattern. Typically shims are used to position both the ring and pinion gears (refer to Figure 3-37). The location of the shims is dependent on the type of rear axle.

The shims are used to compensate for variations in the carrier housing bearing seats (or cups). The depth of the bearing seats (the surface of the carrier housing where the outer race of the bearing is seated) can vary from carrier to carrier. The shims correctly position the gearset and negate the effect of carrier housing variations.

In addition to correctly positioning the ring and pinion gears, the support bearings for these gears must also be preloaded. Preloading the bearings makes certain that the bearings are correctly seated in the races. This helps prevent component shifting under a load. Preloading also reduces component wear.

![Figure 3-37, Ring and Pinion Positioning]
Pinion Depth and Pinion Bearing Preload

The drive pinion is supported in the carrier by two opposed tapered roller bearings (refer to Figure 3-38). On most of the rear axle assemblies, a collapsible spacer (crush sleeve) is used to assist in setting bearing preload. When the pinion flange nut is tightened, the collapsible spacer located between the two bearings is crushed. The collapsible spacer maintains tension (tightening torque) on the pinion assembly. This tension retains the original pinion preload established by the high torque applied to the pinion nut.

The pinion bearings are correctly preloaded when approximately 15 to 25 lb.-in. of torque is required to rotate the pinion (Dana rear axles require 40 lb.-in.). Without preload, the tooth contact between the ring and pinion gears will change under load. See the Diagnosis and Service Sections of this book for further detail.

The drive pinion gear teeth are positioned to mesh with the ring gear teeth in an exact, specified way. On most of the rear axle assemblies, a selective thickness shim is placed between the head of the pinion and the rear (inner) pinion bearing cone (Figure 3-38). This determines how “deep” the pinion head is located in the carrier.

Changing the thickness of the pinion depth shim moves the pinion closer to or farther from the ring gear. A gauging procedure is required for determining the thickness of the depth shim and is described in the Service Section of this book.

The above information is related to most AAM rear axles. Other rear axles use different methods to adjust the pinion depth and the pinion bearing preload.
Dana Pinion Adjustment

The rear axle assemblies produced by Dana Corporation for use in Corvette and some light-duty trucks have a different method for adjusting pinion depth and pinion bearing preload.

Shim packs (refer to Figure 3-39) are used for both pinion location (depth) and pinion bearing preload adjustment. The shim pack for pinion location is between the rear (inner) pinion bearing cup and the carrier. The bearing preload shim pack is placed between a shoulder of the pinion shank and the front (outer) pinion bearing cone.

The pinion depth shim pack thickness is determined by a gauging process. Rotating torque is used to determine the correct preload shim pack thickness.

Groups of shims varying in thickness are used to make up the total shim pack thickness, so a pack may contain one or more shims of the same thickness.

Figure 3-39, Dana Pinion Depth and Pinion Bearing Preload
AAM 10.50-Inch Pinion Adjustment

Another variation in pinion depth adjustment is found in the AAM 10.50-inch rear axle assembly. A drive pinion bearing retainer supports the pinion and is positioned closer to, or further from, the carrier by a selective thickness shim (refer to Figure 3-40. This sets the depth of the pinion gear.

A collapsible spacer is used to assist in setting the pinion bearing preload.

![Diagram of AAM 10.50-Inch Pinion Depth and Pinion Bearing Preload](image)

Figure 3-40, AAM 10.50" Pinion Depth and Pinion Bearing Preload
Borg-Warner Model 78 Pinion Adjustment

The Borg-Warner Model 78 (refer to Figure 3-41) rear axle assembly, like the Dana design, uses a pinion depth shim located between the rear (inner) pinion bearing cup and the carrier. Like the AAM design, it uses a collapsible spacer to assist in setting the pinion bearing preload.

Figure 3-41, Borg-Warner Model 78 Pinion Depth and Pinion Bearing Preload
Nominal Pinion Gears

Most pinion gears used in current vehicles are nominal gears. This means that the gear is within the manufacturing tolerances for pinion depth. The nominal pinion depth is the distance (depth) between the pinion gear end and the ring gear center line that provides the best contact pattern for most pinion gears. Nominal gears typically do not have a pinion depth markings. However, some nominal gears will have a “0” pinion depth marking.

Some gears, due to the manufacturing process, do not provide the best tooth contact pattern at the nominal depth. These gears are not nominal gears and are marked with a positive (+) or negative (-) number. The number indicates the difference (in thousandths of an inch) between the nominal depth and the correct depth for that pinion gear (refer to Figure 3-42).

The gauging procedure used to determine pinion depth assumes that the pinion gear is a nominal gear. As long as a nominal gear is used, the gauging procedure will determine the correct shim thickness. If the pinion gear is not a nominal gear, the indicated shim thickness (determined by the gauging procedure) must be adjusted to compensate for the pinion gear. The markings on these gears are used to adjust the shim measurement.

If the pinion gear has a positive (+) number (on Dana and Borg-Warner), this indicates that ideal pinion depth for that gear is greater than the nominal depth. To adjust for a positive number, the indicated shim thickness must be reduced by that number. For example, if the marking is +3, the indicated shim thickness must be reduced by 0.003.

If the pinion gear has a negative (-) number (on Dana and Borg-Warner), this indicates that the ideal pinion depth for that gear is less than the nominal depth. To adjust for a negative number, the indicated shim thickness must be increased by that number. For example, if the marking is -3, the indicated shim thickness must be increased by 0.003.

The markings on Rockwell and AAM gears are opposite of Dana and Borg-Warner. A positive number indicates that additional shim thickness is need. A negative number indicates that less shim thickness is need.
Ring Gear Positioning and Side Bearing Preload

The ring gear is bolted to the differential case with bolts which may have thread-locking compound on them or may have left-handed threads. The inner bore of the ring gear has an interference fit with the differential case.

The flange of the differential case is carefully machined to prevent warping the ring gear as the two parts are assembled together. This is why it is important to follow the correct bolt tightening procedure when installing the ring gear on the case.

The differential case supports the ring gear by using two opposed tapered roller bearings which are preloaded by shims. Without preload, the tooth contact between the ring and pinion gears will change under a load. The differential case would be able to shift position in the carrier housing under this condition.

The differential case side bearing shims do three things (Figure 3-43):

• They take up the clearance between the side bearing cups and the shoulders of the carrier side bearing bores.
• They allow for side bearing preload
• They control the position of the ring gear teeth relative to the drive pinion gear teeth.

Figure 3-43, Side Bearing Shims
Three things must be done to correctly position and preload the ring gear/differential case assembly of most rear axles.

- Shims must be installed to take up all clearance between the differential side bearing cups
- Additional shims must be installed to provide sufficient side bearing preload
- The shims must be positioned to provide the correct ring-to-pinion gear backlash

Section 4 of this book contains procedures for determining shim thickness and position.

The thickness of the shims on both the left and right side bearings determines the side-to-side position of the ring gear. The position of the ring gear affects the ring to pinion gear backlash. Backlash is the amount of clearance between the faces of the ring and pinion gear teeth (refer to Figure 3-44).

Friction and heat is produced as the gears operate. Heat causes the gears to expand. A certain amount of backlash is required to allow for this expansion. Too little backlash could cause the gears to jam. Too much backlash can cause noise concerns.

Improper backlash is corrected by making changes in the thickness of both the left and right side bearing shims without disturbing the total thickness of the two shims combined (Figure 2-30). If the total shim thickness is disturbed, the differential case will either move sideways (too much clearance) or the bearings will be damaged from too much preload.

Figure 3-44, Backlash Adjustment
Side bearing preload is necessary to properly set the side bearings in their races. Preloading the side bearings involves changing shim thickness small amounts – usually 0.003 to 0.004 in. per side. As with the other adjustments, check the vehicle specifications information for each axle. Without preload, the ring gear/differential case may move sideways, especially under high torque situations.

As with the two pinion adjustments (depth and preload), the backlash and side bearing preload adjustment procedures for the various rear axle assemblies are the same in principle.

Most AAM-produced rear axles use a cast iron shim to control both backlash and side bearing preload. This shim is installed when the carrier is spread open slightly. When performing service on AAM axles, use one service spacer and one or more selective thickness shims (refer to Figure 3-45) to replace cast iron shim. The cast iron shims should not be reused.

Notice:

Do not re-use cast iron shims. Cast iron shims can break when driven in place. This can result in carrier damage.
Other variations in control of ring gear/differential case backlash and side bearing preload include:

- **AAM 9.50-Inch**: A combination of one-piece (cast iron) shims on both left and right sides (for backlash) and a right-side threaded adjuster (for preload) (refer to Figure 3-45).

- **AAM 10.50-Inch**: Threaded adjusters for both the left and right side bearings (refer to Figure 3-46) and one-piece steel shims for both production and service.

When threaded adjusters are used, a tool, which operates like a spanner wrench, is used to make changes to the position of the adjusters.

**Important:**

The cast iron shim used in the AAM 9.50-inch rear axle can be re-used.
The Dana-produced rear axle assemblies use the shim pack concept for positioning and preloading the ring gear/differential case assembly.

The shim packs are located inboard of the side bearing cones (refer to Figure 3-47). Just as with the pinion depth and bearing preload shim packs, various combinations of shim thickness add to the total thickness of an entire pack. Just as with other rear axles, the shim pack thicknesses are adjusted to:

- Take up side bearing-to-carrier clearance
- Provide ring-to-pinion gear backlash
- Add preload for the side bearings

On Dana rear axles, the ring gear/differential case assembly is removed and installed after the carrier is spread (refer to Figure 3-48). Spreading the carrier requires a special tool.
One Dana axle assembly, the 70 HD (Figure 3-49), uses spacers mounted outboard of the side bearing races to take up the majority of side bearing-to-carrier clearance. Inboard shim packs are used to complete the clearance adjustment, set backlash, and add side bearing preload.

Figure 3-49, Dana Model 70 HD Shim Packs and Spacers
Gear Malfunctions

Pitch Line Runout

The pitch line is the point near the center of the gear tooth where the pitch (or angle changes). When the ring and pinion gears are installed, the pitch line of each gear should be on the same plane (assuming the ring gear and the differential case are not out-of-round).

For example, if a pointer was positioned in the rear axle so that it pointed to the pitch line of a gear tooth, the pitch line of every tooth should line up with the pointer as the gear is rotated. If it did not, this would indicate Pitch Line Run Out (PRLO). PLRO is a condition where the pitch line on the gear teeth varies around the gear (refer to Figure 3-50), normal gears do not have variation in pitch line. PLRO is typically the result of an incorrectly manufactured gear. PLRO can cause noise and vibration. PLRO may not be identified by a gear tooth contact pattern test.

![Figure 3-50, Pitch Line Runout](image-url)
**Backlash Variation**

When the backlash around the ring gear has excessive variation, this indicates an out-of-round condition or PLRO condition. If the ring gear is out-of-round, the teeth of the ring gear move closer or farther away from the pinion gear teeth as the ring gear rotates (refer to Figure 3-51). This condition can also be the result of a differential case that is out-of-round.

Backlash variation can be determined by measuring backlash at eight different locations and subtracting the highest measurement from the lowest measurement. If the variation exceeds 0.002", the backlash variation is excessive.

![OUT-OF-ROUND](image)

**Figure 3-51, Backlash Variation**
**Ring Gear Runout**

Ring gear runout is an out-of-round condition where the teeth of the ring gear move closer or farther away from the pinion gear teeth as the ring gear rotates. Variation in backlash can be caused by ring gear runout. Ring gear runout will also cause a gear tooth contact pattern that changes around the gear.

Ring gear run-out is detected using a dial indicator placed against the side of the ring gear (refer to Figure 3-52). As the ring gear rotates the difference between the lowest and highest reading should not exceed 0.002”.

It is important to note that an out-of-round condition identified by a ring gear runout check does NOT necessarily mean the ring gear is out-of-round. The concern could be caused by an out-of-round differential case.

If an out-of-round condition is indicated by a ring gear runout check, follow up with a runout check of the differential case.

*Figure 3-52, Ring Gear Runout*
Differential Unit Assembly

The following are the components of the differential unit (refer to Figure 3-53):

- The differential pinion shaft and lock screw
- The differential pinion gears and thrust washers
- The differential side gears and thrust washers
- The differential case (same part as discussed in the previous section)

Force is transferred from the ring gear to the differential case and then to the differential pinion shaft. The shaft may be a single, straight piece or two half-pieces. The shaft may also be called a “spider,” especially when more than two pinion gears are supported by it (refer to Figure 3-54).

The pinion shaft supports the differential pinion (spider) gears, and transmits power to them. These pinions are straight bevel gears which mesh with two bevel gears known as side gears.

The side gears are splined to the axle shafts and are supported in the counterbores of the differential case. The differential case may be one-piece, or may be an assembly of two matched halves.
Differential Operation

The transfer of power from the differential pinion gears to the side gears involves allowing the gears to rotate inside the differential case at times. Thrust washers (refer to Figure 3-54) are used to allow the pinion gears and side gears to move without wearing the internal surfaces of the differential case.

When the vehicle is moving in a straight-ahead path, power flows through the differential unit as follows:

- The differential case rotates as the ring gear is driven by the drive pinion.
- The differential pinion shaft and gears rotate along with the differential case.
- The wheels and axles rotate at the same speed, so the side gears receive force from the differential pinions equally (refer to Figure 3-55).

Figure 3-54, Thrust Washers

Figure 3-55, Straight-Ahead Drive
When the same vehicle is cornering, power flows as follows:

- The differential case rotates as the ring gear is driven by the drive pinion.
- The differential pinion shaft and gears rotate along with the differential case.
- The "outer" wheel (refer to Figure 3-56) rotates at a speed which is faster than the "inner" wheel's speed, causing the side gears to rotate at different speeds. The side gears cause the differential pinion gears to rotate on the differential pinion shaft.

When one wheel has little or no traction, the same powerflow occurs as with cornering, but with rotation of only one axle shaft and side gear (refer to Figure 3-57). This is the principle drawback of this type of differential, known as the "open" type unit.

In an open type differential, the torque applied to the wheels during a one wheel slip situation never exceeds the torque required to break traction at the slipping wheel, regardless of the available torque from the powertrain. In order for applied torque to increase there must be resistance. In this situation, the resistance is small since there is very little friction between the tire and the road surface.

Once the one wheel breaks traction, the torque available to both wheels is less than the break-away torque. This amount of torque is typically insufficient to move the vehicle.

More information about differential gearing is found in the Reference Section of this book.

Information on limited-slip and locking differential units is found in Section 5 of this book, as well.
Open Differential

An open type differential (see Figure 3-58) allows the axle shafts to rotate at different speeds from each other and from the ring gear/ differential case. As previously illustrated, this allows the vehicle to perform turning maneuvers without scrubbing the tires.

The disadvantage of an open differential is that if one wheel loses traction, the differential allows the wheel without traction to spin which reduces the amount of torque applied to both wheels. The reduced torque prevent vehicle movement.

Limited-Slip Differential

A limited-slip differential (see Figure 3-59) also allows turning maneuvers without tire scrubbing. However, it limits the amount of wheel slip during a loss of traction.

When one wheel loses traction, the mechanical action of the limited-slip differential forces the side gears to rotate at the same speed and direction as the differential case. This allows torque to be applied to both the slipping and non-slipping wheel. This action is achieved by friction (in clutch pack or cone-type differentials) or by a locking mechanism (in locking differentials).

Locking differentials are considered a type of limited-slip differential since they also limit the amount of wheel slip before forcing the side gears to rotate in the same direction and speed as the ring gear.
3. Rear Axle Diagnosis

Objectives

Upon completion of Section 3 of the course, you will be able to:

• Identify the potential sources of rear axle fluid leaks, and the required corrective actions.
• Identify the rear axle causes for an immovable vehicle.
• Differentiate between normal and abnormal rear axle related noises and vibrations.
• Identify the steps required to isolate rear axle concerns during a road test.
• Perform the ring-and-pinion gear backlash procedures.
• Interpret backlash results and determine corrective action.
• Perform a tooth contact pattern test.
• Interpret tooth contact pattern check results and determine corrective action.
• Measure and interpret total turning preload.
• Identify bearing wear patterns and determine corrective action.
Rear Axle Assembly Diagnosis

There are three categories of rear axle diagnosis:
1. Improper operation
2. Fluid leaks
3. Noise

Improper Operation Diagnosis

Diagnosing the cause of improper rear axle operation is a rather easy task. If power cannot be transmitted from the drive pinion flange to the rear wheels, an initial inspection can be made with the carrier cover removed.

Inspect the following parts for movement while rotating the drive pinion flange with the propeller shaft:
- The ring gear/differential case
- The differential pinion gears and side gears
- The axle shaft ends

Next, remove the axle shafts and the ring gear and differential case assembly (refer to Figure 3-60) and inspect the drive pinion gear teeth.

If necessary, a further inspection of the drive pinion and differential unit parts (refer to Figure 3-61) can be done at this point.
Fluid Leak Diagnosis

Fluid leaks can occur at these locations (refer to Figure 3-62):
- Axle tube-to-carrier joint (2)
- Fill plug
- Vent tube
- Carrier cover gasket-to-carrier
- Companion flange oil seal
- Axle shaft-to-tube oil seal (2)
- Axle housing porosity
- Drain plug

Figure 3-62, Seal Cocked on Shaft

The most often reported sources of fluid loss are at the oil seals. The following information is a guide to understanding how seal inspection will reveal the true cause of the leak.

Using improper tools or careless use of approved tools can distort the seal or leave it in a cocked position within the bore (see Figure 3-63). Lubricant can easily leak out around the case and at the sealing lip because uniform contact has not been made all around the shaft.

Figure 3-63, Rear Axle Sealing Areas
Seals can leak because of bore or shaft defects, use of the wrong size or type of seal or improper seal installation. Other leak sources are gaskets and around bolts (refer to Figure 3-64, View A).

The sealing lip surface of a seal may have hardened and lost flexibility. This condition can be caused by inadequate lubrication or by excessive operating temperatures (refer to Figure 3-64, View B).

A brittle or cracked lip (refer to Figure 3-64, View C) is a good indication that lubricant temperature has exceeded the operating limits of the seal material. Overheating could also be caused by too tight of a fit on the shaft. Conversely, cold cracks can occur if cold temperatures exceed the lower operating limits of the lip material.

If the seal is not lubricated properly before installation, or if the shaft is too rough at the point of lip contact, excessive wear around the entire circumference of the sealing lip may result (refer to Figure 3-64, View D).

Figure 3-64, Examples of Seal Failures (1 of 3)
Shaft-to-bore misalignment will cause rapid or uneven wear at one point of the sealing lip (see Figure 3-65, View A). A warped or mis-machined housing may cause this.

Careless storage or handling, improper installation, failure to properly clean and prepare the shaft, or failure to protect the seal lip when installing the seal over splines or keyways can nick or scratch the seal lip (see Figure 3-65, View B).

The seal lip can be “blown out” (see Figure 3-65, View C). The direction of lip contact on the shaft is reversed. The cause is excessive pressure due to plugged vents or an improper lubricant level. If too much lubricant is contained, heat leads to expansion and the pressure can “blow out” the seal.

If the housing bore is out-of-round or if the seal O.D. is too large for the bore, the case can be distorted during installation. Similar distortion may occur if improper installation tools were used to press-fit the seal into place (see Figure 3-65, View D).

Figure 3-65, Examples of Seal Failures (2 of 3)
Leakage around the outside diameter of the seal could mean that the bore is out-of-round, the seal could be cocked in the bore or the bore is scarred deeply enough to provide a leak path (refer to Figure 3-66, View A).

Seal bore leaks are often mistaken for seal lip leaks. To avoid possible repeat repairs, a sealant should be used in the seal bore. This preventative measure could stop a out-of-round or scarred bore from leaking.

What may appear to be a minor leak around the shaft may not actually be seal leakage. When too much pre-lubrication is used, the excess will melt, temporarily run out and correct itself. However, a seal lip leak due to wear or lip damage is the most common type of leak. In this case, it is necessary to remove the old seal and install a new one (refer to Figure 3-66, View B).

Figure 3-66, Examples of Seal Failures (3 of 3)
**Types of Rear Axle Seals**

There are three main oil seals in rear axles:

- Pinion Oil Seal
- Right Axle Oil Seal
- Left Axle Oil Seal

These oil seals are a lip-type seal. In this design, the seal has a rubber lip that rests against the rotating shaft. The rubber lip prevents oil from leaking past the seal. The rubber seal is supported by a metal case. The metal case is press-fit into the carrier housing or axle tube. The press-fit prevents oil from leaking around the metal case.

Some rear axles use newer designs of the lip-type seal (refer to Figure 3-67). These newer designs incorporate two or three rubber lips. The additional rubber lips provide better a seal than the single-lip design. The newer multi-lip seals are **NOT** interchangeable with the single-lip design. The seal bores (on the carrier and axle tubes) for the multi-lip seals are deeper.

*Figure 3-67, Single-Lip and Multi-Lip Seals*
<table>
<thead>
<tr>
<th></th>
<th>POOR</th>
<th>AVERAGE CUSTOMER</th>
<th>NOT ACCEPTABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>POOR</td>
<td>ALL CUSTOMERS</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>POOR</td>
<td>AVERAGE CUSTOMER</td>
<td>NOT ACCEPTABLE</td>
</tr>
<tr>
<td>3</td>
<td>POOR</td>
<td></td>
<td>NOT ACCEPTABLE</td>
</tr>
<tr>
<td>4</td>
<td>CUSTOMER COMPLAINT</td>
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<td>BORDERLINE</td>
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<tr>
<td>6</td>
<td>BARELY ACCEPTABLE</td>
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<td></td>
<td>TRACE</td>
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<tr>
<td>9</td>
<td>VERY GOOD</td>
<td></td>
<td>NOT NOTICEABLE</td>
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<tr>
<td>10</td>
<td>EXCELLENT</td>
<td>TRAINED OBSERVER</td>
<td>NONE</td>
</tr>
</tbody>
</table>

Figure 3-68, General Motors Universal Test Standard (GMUTS)
Noise Diagnosis

Many noises reported as coming from the rear axle assembly actually originate from other sources such as tires, road surfaces, wheel bearings, engine, transmission, muffler or body drumming. A thorough and careful check should be made to determine the source of the noise before disassembling the rear axle.

Noise that originates in other places cannot be corrected by adjustment or replacement of components in the differential. It is important to note that rear axles, like any other mechanical device, are not absolutely quiet and should be accepted as being “commercially quiet” unless some abnormal noise is present.

“Commercially quiet” means that the noise level matches that of other identical vehicles which are operating as designed. This means that there are different noise levels for the different models of passenger cars and light-duty trucks, all of which are “commercially quiet.” Identical rear axles in different vehicles will produce different noise levels.

The table shown in Figure 3-9 is the General Motors Universal Testing Standards (GMUTS) chart. It is a subjective way to determine if a noise is acceptable. The first column of the table is the ranking (#1-#10) of noises. A rear axle with a #1 ranking is considered unacceptable. A rear axle with a #10 ranking is considered excellent since it produces no noise.

The second column is the level of the noise (ranked from poor to excellent). Poor indicates that rear axle produces excessive noise. The third column indicates what type of observer could detect the noise. The fourth column indicates the amount of the noise (#1 through #3 produce enough noise to be considered unacceptable).

The following are examples of four different ranks:

• Rank #2: has a poor level of noise that is detectable by the average customer and is unacceptable. This rear axle requires repair.

• Rank #5: has an amount of noise that is considered borderline. Critical customers would consider this a moderate amount of noise. This rear axle may require adjustment or repair.

• Rank #8: is considered good since a critical customer could only detect a trace of noise from the rear axle. This axle does not require repair.

• Rank #10: is considered excellent since a trained observer would not be able to detect rear axle noise.
Figure 3-70, Noise Diagnostic Chart
Road Testing

To perform a systematic check for rear axle noise under standard conditions, perform the following road testing procedures (refer to Figure 3-71):

- Select a level smooth asphalt road to reduce tire noise and body drumming. Road test the vehicle to verify the condition. At this point, determine if the condition exists and is repeatable.

- Raise the vehicle and perform the following visual inspections:
  - Check rear axle lubricant to ensure the correct level.
  - Check for metal-to-metal contact between the rear springs and frame. Also inspect rear control arm bushings for abnormal contact with the axle housing or frame.

- Rear suspension rubber bushings and spring insulators dampen the rear axle noise when correctly installed. Metal-to-metal contact at suspension points may result in transmitting road noise and normal axle noise, which would not be objectionable if dampened by the bushings.
  - Check the front wheel bearings for rough operation and looseness.
  - Temporarily inflate all tires to approximately 50 pounds pressure for test purposes. This will change noise caused by the tires but will not affect rear axle noise.

- Road test the vehicle with a tachometer:
  - Use the same road surface that was used to perform the noise verification road test.
  - Drive the vehicle far enough to thoroughly warm-up the rear axle lubricant.
  - Listen for tire noise which is constant and more pronounced between 20 and 30 mph. If the noise has changed since inflating the tires to 50 psi, the tires could be the source of the noise.

  - Rear axle noise usually stops when coasting at speeds under 30 mph. However, tire noise continues with a lower tone as vehicle speed is reduced. Rear axle noise usually changes when comparing acceleration and coast, but tire noise remains about the same.

  - To distinguish between tire noise and rear axle noise, determine if the noise varies with vehicle speed or sudden acceleration and deceleration. Exhaust and axle noise show variations under these conditions while tire noise remains constant and is more pronounced at speeds of 20 to 30 mph.
- Further check for tire noise by driving the vehicle over smooth pavement and dirt roads (not gravel) with tires at normal pressure. If noise is caused by tires, it will noticeably change or disappear and reappear with changes in road surface.

- Lightly apply the brakes to diminish front wheel bearing noise. Loose or rough front wheel bearings will cause noise which may be confused with rear axle noises. However, front wheel bearing noise does not change when comparing drive and coast.

- Light application of brakes while holding vehicle speed constant will often cause wheel bearing noise to diminish, since this takes some weight off the bearing. Front wheel bearings may be easily checked for noise by lifting the wheels off the ground and spinning them. Also shaking the wheels will help determine if the bearings are loose.

- Change the transmission gear ranges while holding the vehicle speed constant. This will make engine and transmission noises more pronounced.

- Note the engine speed where the noise occurs. With the engine running, vehicle stopped and transmission in neutral, duplicate the engine speed where the noise occurred and listen for noise. This will determine if the noise is caused by the exhaust, muffler roar or other engine/transmission conditions.

The above procedures should help determine if the rear axle is the source of the noise. If the noise originates from the rear axle, the noise must be further isolated to the component(s) in the rear axle. This is necessary to perform the correct rear axle repairs.
Gear Noise

Gear noise or whine (one of several noises that can be produced by the rear axle) is audible from 20 to 55 mph under four driving conditions:

- **Drive**: Acceleration or heavy pull.
- **Road load**: Vehicle driving load or constant speed.
- **Float**: Using enough throttle to keep the vehicle from driving the engine, vehicle slows down gradually but the engine still pulls slightly.
- **Coast**: Deceleration, throttle closed and vehicle in gear.

Gear noise most frequently has periods where noise is more prominent, usually 30 to 40 mph and 50 to 53 mph. Gear whine is corrected by either ring-and-pinion gear replacement or adjustment, depending on the mileage on the gearset.

Bearing Noise

Worn bearings (side and pinion bearings) generally produce more of a rough growl or grating sound, rather than the whine typical of gear noise. Bearing noise frequently “wow-wows” at bearing rpm, indicating a worn pinion or case side bearing. This noise could be easily confused with rear wheel bearing noise. Bearing noise is corrected by replacing the bearing and any components that may have caused premature failure of the bearing.

Rear Wheel Bearing Noise

A rough rear wheel bearing produces a noise which continues with the car coasting at low speed and the transmission in neutral. Noise may diminish some by gentle braking. The noise may also change when performing side-to-side maneuvers with the vehicle.

With the rear wheels lifted off the ground, spin the rear wheels by hand while listening at the hubs for evidence of rough (noisy) wheel bearings. Rear wheel bearing noise is corrected by replacing the bearing and any components that may have caused premature failure of the bearing.

Knock at Low Speeds

Low speed knock can be caused by worn universal joints or a differential side-gear hub counterbore in a case that has worn oversize. Knock at low speeds is corrected by either replacing the universal joint or differential side-gear and/or case.
**Backlash Clunk**

Excessive clunk with acceleration and deceleration can be caused by:

- Worn differential pinion shaft
- Excessive clearance between axle shafts and side gear splines
- Excessive clearance between differential side-gear hub and counter bore in the case
- Worn pinion and side-gear teeth
- Worn thrust washers
- Excessive drive pinion and ring gear backlash.

Backlash clunk is corrected by replacing worn parts (selecting close fitting parts when possible) or by adjusting pinion and ring gear backlash, if it is excessive.
Rear Axle Noises and Causes

The following is a list of noises and some of the causes of these noises:

1. Noise or vibration is the same in Drive or Coast:
   - Road noise
   - Tire noise
   - Wheel bearing noise
   - Incorrect driveline angle (load sensitive vibration)

2. Noise changes on a different type of road:
   - Road noise
   - Tire noise

3. Noise tone lowers as car speed is lowered:
   - Tire noise
   - Bearings

4. Similar noise is produced with car standing and driving
   - Engine noise
   - Transmission noise
   - Exhaust moan

5. Vibration
   - Rough rear axle wheel bearing
   - Unbalanced or damaged propeller shaft
   - Tire unbalance
   - Worn universal joint in propeller shaft
   - Incorrect driveline angle
   - Mis-indexed propeller shaft at pinion flange
   - Pinion flange runout too great
6. A knock or click approximately every two revolutions of the rear wheel
   • A rear wheel bearing

7. Noise most pronounced on slow turns
   • Rear axle side-gear and differential pinion noise

8. A continuous low pitch whirring or scraping noise starting at relatively low speed
   • Pinion bearing noise

9. Drive noise, coast noise or float noise
   • Ring-and-pinion gear noise

10. Clunk on acceleration or deceleration
   • Worn rear axle pinion shaft in case or side-gear hub counterbore in case worn oversize
   • Insufficient lubrication on propeller shaft slip yoke
   • Worn U-joints on propeller shaft, front or rear

11. Groan in forward or reverse
   • Wrong or contaminated lubricant in rear axle
   • Worn bushings

12. Chatter on turns
   • Wrong or contaminated lube in rear axle
   • Clutch cone worn and/or spring(s) worn
   • Incorrect lubricant change intervals

13. Clunk or knock on rough road operation
   • Excessive end play of axle shafts to differential cross shaft
### Noise Classification Chart

The following chart in Figure 3-71 classifies various noises and their frequency range.

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>NOISE TYPE</th>
<th>FREQUENCY RANGE Hz</th>
<th>COMMON CAUSES</th>
<th>SYMPTOMS</th>
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</thead>
<tbody>
<tr>
<td>Ring &amp; Pinion Gear Mesh Noise</td>
<td>Whine</td>
<td>375 - 500</td>
<td>Incorrect Pattern Adjustment/Gear Face Finish</td>
<td>Torque Sensitive/Highway Speed</td>
</tr>
<tr>
<td>Ring &amp; Pinion Gear Mesh Harmonic Noise</td>
<td>Whistle</td>
<td>2000 - 2500</td>
<td>Defective Ring &amp; Pinion Gear Set</td>
<td>Torque Sensitive/Highway speed</td>
</tr>
<tr>
<td>Driveline Disturbance</td>
<td>Boom Vibration/Boom-Beat</td>
<td>38 - 45</td>
<td>Pinion Pitch-Line Run Out/Defective Ring &amp; Pinion Gear Set/Housing/Pinion Bearings</td>
<td>Vehicle Speed and Torque Sensitive</td>
</tr>
<tr>
<td>Front Diff Gear Noise in 2WD</td>
<td>Growl</td>
<td>100 - 200</td>
<td>Excessive Clearance/Backlash</td>
<td>Vehicle Speed Sensitive/30-50 MPH/Gone in 4WD</td>
</tr>
<tr>
<td>Axle Shaft Whine</td>
<td>Whine</td>
<td>300 - 600</td>
<td>Axle Shaft Surface Finish</td>
<td>Vehicle Speed Related/Not Torque Sensitive/5 MPH and UP</td>
</tr>
<tr>
<td>Pinion Bearing Noise</td>
<td>Howl/Growl</td>
<td>Wide Band</td>
<td>Bearing Defect/Worn</td>
<td>Torque Sensitive Accel=Rear BRG Decel=Front BRG</td>
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<tr>
<td>Side Bearing Noise</td>
<td>Howl/Growl</td>
<td>Wide Band</td>
<td>Bearing Defect/Worn</td>
<td>Not Torque Sensitive Not Side Load Sensitive</td>
</tr>
<tr>
<td>Axle Bearing Noise</td>
<td>Howl/Growl</td>
<td>Wide Band</td>
<td>Bearing Defect/Worn</td>
<td>Not Torque Sensitive/May be Side Load Sensitive</td>
</tr>
<tr>
<td>Tire Noise</td>
<td>Howl/Growl</td>
<td>Wide Band</td>
<td>Tire Wear, Tread Design</td>
<td>Vehicle Speed/Changes With Road Surface/5 MPH and UP</td>
</tr>
</tbody>
</table>

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Rear Axle Diagnostic Procedures

After a noise is isolated to the rear axle, certain procedures must be performed to isolate the root cause of the noise. The following procedures must be performed during diagnosis and disassembly of a rear axle. Even if the noise is isolated to a pinion or case side bearing, these procedures could help determine what caused the bearing failure.

The diagnostic procedures include checking (refer to Figure 3-71):

- Ring-to-pinion gear backlash
- Ring-to-pinion gear tooth contact
- Total turning pre-load

These procedures are also part of the reassembly procedures to ensure correct operation of the rear axle. However, during reassembly, they are not performed in the order presented. Refer to the Service Section of this book for reassembly procedures.

Figure 3-71, Diagnostic Procedures
Checking Ring-to-Pinion

Backlash is the amount of space between the sides of the ring-and-pinion gear teeth (refer to Figure 3-72). Checking the ring-to-pinion gear backlash is one of the first diagnostic procedures that must be performed. Incorrect backlash or a variation in backlash can affect the other diagnostic procedures (including the gear tooth contact pattern).

Gear Backlash

To check the backlash, use a dial indicator with a small contact button. Screw a bolt approximately three inches long into an inspection cover bolt hole near the ring gear. Mount the dial indicator onto the bolt so that it’s in line with the ring gear (refer to Figure 3-73).

Position the contact button against the heel of one of the teeth on the ring gear. Preload the indicator approximately 0.025 inch, then set it to zero. Make sure the indicator stem is as close to being in line with the gear rotation as possible and at a right angle to the gear tooth.

Also, make sure the gear teeth do not contact and move the body of the dial indicator. If necessary, use the J-7057 extension for the dial indicator to prevent this from occurring.

Hold onto the pinion flange holding tool to be sure the pinion gear does not move. Then, rock the ring gear back and forth so the teeth on the ring gear touch the teeth on the drive pinion (refer to Figure 3-73). Record the indicator reading. The specification for ring-to-pinion gear backlash is usually 0.005 to 0.009 inch. Check the Vehicle Service Manual for the correct specification.

Lift the indicator stem off the gear tooth, then rotate the differential assembly 1/8 of a turn. Place the indicator stem against the heel of another gear tooth and preload it again. Zero the indicator and check the backlash. Backlash should be checked in eight (8) different locations on the ring gear. This is used to determine if there is variation in the backlash. A variation of 0.002 inch or more in the backlash indicates an out-of-round condition or pitch line runout.
If the backlash readings vary more than 0.002 inch, check for unevenly torqued ring gear bolts or burrs between the ring gear mounting flange and the ring gear. If these are found to be in good condition, the following could be causing the variation:

- Ring gear warped (ring gear runout)
- Differential case warped (differential runout)
- Rear axle carrier housing warped
- Damaged side bearings
- Ring-and-pinion gear pitch line runout

Ring gear runout can be checked by installing the dial indicator on the carrier (refer to Figure 3-74) as in the backlash check.

Preload the indicator (approximately 0.025 inch) against the machined flat surface of the ring gear that mates with the flange of the differential case. Rotate the ring gear and differential case assembly while watching the dial indicator. The total indicator reading of runout should not exceed 0.003 inch in one revolution of the ring gear and differential case assembly.

Differential case runout is measured in a similar manner. The ring gear must be removed from the differential case to perform differential case runout measurements. The runout measurements must be performed in two locations (refer to Figure 3-75): the ring gear flange and the machined case surface. Measuring the ring gear flange measures the lateral runout. Measuring the machined case surface measures the radial runout. Neither measurement should exceed 0.003 inch.

If either of the measurements indicates runout, the differential case could be out-of-round, the side bearings could be damaged or the carrier housing could be warped.
If the backlash is incorrect or has excessive variation, this could be the root cause of the noise. Adjust the backlash to specifications and continue diagnosis to determine if there are other malfunctions within the rear axle.

**Important:**
The gear tooth contact pattern could be misleading if the backlash is not corrected. However, do not attempt to repair backlash variation malfunctions at this time, since it requires component replacement.

**Important:**
If the gearset has been used for 100 miles, adjustments may not repair the noise concern. Also, if the gearset is to be reused, make certain that the measurements performed during diagnosis are recorded so that the gearset can be reassembled with the same specifications.

The backlash can be corrected by increasing the thickness of one side-bearing shim and decreasing the thickness of the other shim by the same amount. For example, if the thickness of the right bearing shim is increased by 0.002 inch, the thickness of the left-hand bearing shim must be decreased by 0.002 inch. Adjusting the backlash in this manner prevents accidentally changing the bearing preload.

- If the backlash is too great, the ring gear is too far away from the drive pinion (refer to Figure 3-76). To bring it closer to the drive position, use a thinner shim on the right side and a thicker one on the left.
- If the backlash is too small, the ring gear is too close to the drive pinion. To move it away from the drive pinion, decrease the thickness of the left shim and increase the thickness of the right shim.

As a rule, a 0.002 inch shim thickness change changes backlash by 0.001 inch. Check the Vehicle Service Manual for the specific shim change effect.
Checking Ring-To-Pinion Tooth Contact

Tooth Contact Pattern Test

The ring-to-pinion tooth contact pattern is the second diagnostic procedure that should be performed during disassembly. Perform the following procedures to determine the tooth contact pattern (refer to Figure 3-77):

1. Wipe oil out of the carrier and carefully clean each tooth of the ring gear.
2. Use gear marking compound #1052351 or equivalent and apply this mixture sparingly to all ring gear teeth, using a medium-stiff brush. When properly used, the area of pinion tooth contact will be visible when a hand load is applied.
3. Tighten the bearing cap bolts to specified torque.
4. Expand the brake shoes until a torque of 40 to 50 lb. ft. is required to turn the pinion.

A test made without loading the gears will not give a satisfactory pattern. Turn the pinion flange with a wrench so that the ring gear rotates one full revolution, then reverse the rotation so that the ring gear rotates one revolution in the opposite direction.

5. Observe and interpret the pattern on the ring gear teeth. The following pages will assist you in interpreting the contact pattern.
Effects of Increasing Load on Tooth Contact Pattern

When the "load" on the ring-and-pinion gearset is increased, such as when the car is accelerated forward from a standstill, the tooth contact will tend to spread out. Under very heavy load, it will extend from near the toe to near the heel on the drive side. The entire contact also tends to shift toward heel under increasingly heavier loads and will become somewhat broader with respect to tops and bottoms of teeth. The patterns obtained by the tooth contact pattern test approximate a light load and, for this reason, they will extend only about halfway as compared to a gearset under a heavier load (refer to Figure 3-78).

The important thing to note is that the contact pattern is centrally located up and down on the ring gear teeth. Insufficiently preloaded drive pinion and differential side bearings will adversely affect the tooth contact pattern.

Figure 3-78, Effects of a Load on the Contact Pattern
Adjustments Affecting Tooth Contact

Two adjustments can be made which will affect tooth contact pattern: backlash, and the position of the drive pinion in the carrier. The effects of bearing preloads are not readily apparent on (hand-loaded) tooth contact pattern tests; however, these adjustments should be within specifications before proceeding with backlash and drive pinion adjustments.

Backlash is adjusted by means of the side bearing adjusting shims which move the entire case and ring gear assembly closer to, or farther from, the drive pinion. (The adjusting shims are also used to set side bearing preload.) (Refer to Figure 3-79.)

If the thickness of the right shim is increased (along with decreasing the left shim thickness), backlash will increase.

The backlash will decrease if the left shim thickness is increased (along with a decrease in the right shim thickness).

The position of the drive pinion is adjusted by increasing or decreasing the shim thickness between the pinion head and inner race of the rear bearing (refer to Figure 3-80). The shim is used in the rear axle to compensate for manufacturing tolerances. Increasing shim thickness on most rear axles will move the pinion closer to the centerline of the ring gear. Decreasing shim thickness will move the pinion farther away from the centerline of the ring gear.
Correct Gear Tooth Contact Pattern

The pattern on the ring gear teeth should be near the center of the tooth along the pitch line as shown in Figure 3-81. The patterns on both the drive and coast sides should be aligned and consistent around the ring gear. If the pattern is inconsistent around the ring gear, this indicates either an out-of-round condition or a defective gearset (which includes pitch line runout).

Even when the pattern is incorrect (as shown on the following pages), the incorrect pattern should be consistent on every ring gear tooth.

Figure 3-81, Correct Gear Tooth Contact Pattern
Effects of Backlash on Tooth Contact Pattern

When the ring gear is too far away from the pinion gear (excessive backlash), the pattern will be near the heel of the ring gear (refer to Figure 3-82). The pattern will be consistent on both the drive and coast sides of the gear teeth. Moving the ring gear closer to the pinion gear will decrease the backlash and move the pattern closer to the middle of the gear teeth.

If the backlash is greater than approximately 0.007 inch, the pattern will move up on the face (above the pitch line) of the gear tooth. The pattern on the drive side (convex) will be near the heel. On the coast side (concave), the pattern will be near the toe.

![Figure 3-82, The Effects of Excessive Backlash on the Contact Pattern](image)

When the ring gear is too close to the pinion gear (insufficient backlash), the pattern will be near the toe of the ring gear teeth (refer to Figure 3-83). It will also be closer to the flank (below the pitch line) of the teeth. The pattern will be consistent on both the drive and coast sides of the gear teeth. Moving the ring gear away from the pinion gear will increase the backlash and move the pattern closer to the middle of the gear teeth.

![Figure 3-83, The Effects of Insufficient Backlash on the Contact Pattern](image)
Effects of Pinion Position on Tooth Contact Pattern

When the drive pinion is too far away from the centerline of the ring gear, the pattern on the drive side will be high on the teeth (on the face) and near the heel – high heel contact. On the coast side, the pattern will be high on the teeth and near the toe – high toe contact (refer to Figure 3-84). Moving the pinion closer to the centerline of the ring gear by increasing shim thickness will cause the high heel contact on the drive side to lower and move toward the toe; the high toe contact on the coast side will lower and move toward the heel.

When the pinion is too close to the centerline of the ring gear, the pattern will be a low (on the flank) toe contact on the drive side, and a low heel contact on the coast side (refer to Figure 3-85). Moving the pinion farther away from the ring gear by decreasing shim thickness will cause low toe contact on the drive side to raise and move toward the heel; the low heel contact on the coast side will raise and move toward the toe. Pinion depth is correct when the contact on the drive side is directly opposite the contact on the coast side.

Figure 3-84, The Effects of a Pinion Gear Too Far Away From the Ring Gear Centerline

Figure 3-85, The Effects of a Pinion Gear Too Close to the Ring Gear Centerline
Patterns Requiring Gearset Replacement

The patterns shown in Figure 3-86, indicate gearsets that were incorrectly manufactured. If a gear set has one of these patterns and the backlash and pinion depth are correct, the ring-and-pinion gearset requires replacement.

Unusual Contact Patterns Requiring Gearset Replacement

Causes: Improper Gear Cutting and Improper Gear Lapping

Figure 3-86, Patterns That Require Ring-and-Pinion Gearset Replacement
Total Turning Preload

The final diagnostic procedure that must be performed before disassembling the rear axle is the total turning preload check. The total turning preload is a combination of the pinion bearing preload and the side bearing preload. This check helps to determine if the preload was sufficient to correctly seat the bearings and prevent excessive movement under a load. If the preload is insufficient, it could cause premature bearing failure and rear axle noise due to the movement of the gearset under a load. The specification is 18-35 lb.-in. for AAM axles.

During normal operation, the pinion gear will try to move away from the ring gear during acceleration (refer to Figure 3-87). This is due to the characteristics of the ring-and-pinion gearset. During deceleration, the ring gear will pull the pinion gear closer.

Total turning preload is measured with the wheels and brake drums (or rotors) removed. A torque wrench is used to measure the amount of torque required to rotate the pinion gear (not the break-away torque, which is the amount of torque to initially move the pinion).

During disassembly, the pinion (only) preload is measured. This is different from the total turning preload.

However, it is related to the total turning preload, since the total turning preload is a combination of the pinion and side bearing preloads.

At this point, rear axle service can be started.

Figure 3-87, Pinion Gear Movement During Driving and Coast
Rear Axle Bearing Inspection/Diagnosis

The bearings inside the rear axle can also cause noise. Figure 3-88 shows the location of the bearings inside the rear axle:

- Axle shaft-to-axle tube bearing (rear wheel bearings)
- Differential case-to-carrier housing bearing (side bearings)
- Drive pinion front (outer) and rear (inner) bearing

Bearing failure can be the result of age, overheating or abusive driving. Bearing failure can also be the result of incorrect installation (including insufficient preload) and rear axle component malfunctions.

The bearing location drawing (Figure 3-88) can be used to pinpoint a particular noisy bearing while the vehicle is raised on a hoist. A stethoscope can be used to compare the sounds of suspect bearings at these locations. Also, the axle housing can be checked for higher temperature at the location of the faulty bearing.

Checking the amount of effort required to rotate the parts of the rear axle assembly (with a total turning preload measurement) can help diagnose bearing problems. Since both the drive pinion and differential side bearings are assembled with preload, checking the effort required to rotate the drive pinion flange during disassembly may help find the source of a bearing noise.

Figure 3-88, Bearing Locations
Rear Wheel Bearing Inspection/Diagnosis

**WEAR (MINOR)**
Light pattern on races and rollers caused by fine abrasives.
Clean all parts and housings. Check seals and replace bearings if rough or noisy. Replace shaft if damaged.

**WEAR (MAJOR)**
Heavy pattern on races and rollers caused by fine abrasives.
Clean all parts and housings. Check seals and replace bearings if rough or noisy. Replace shaft if damaged.

**BRINELLING**
Surface indentations in raceway caused by rollers either under impact loading or vibration while the bearing is not rotating. Replace bearing if rough or noisy. Replace shaft if damaged.

**INDENTATIONS**
Surface depressions on race and rollers caused by hard particles of foreign material.
Clean all parts and housings. Check seals and replace bearings if rough or noisy. Replace shaft if damaged.

**SINGLE EDGE PITTING**
Flaking of surface metal resulting from fatigue, usually at one edge of race and rollers. Replace bearing - clean all related parts. Replace shaft if damaged.

**DOUBLE EDGE PITTING**
Flaking of surface metal resulting from fatigue, usually at both edges of race and rollers. Replace bearing - clean all related parts. Replace shaft if damaged.

**MISALIGNMENT**
Replace bearing and make sure races are properly seated. Replace shaft if bearing operating surface is damaged.

**FRETTAGE**
Corrosion set up by small relative movement of parts with no lubrication. Replace bearing. Clean related parts. Check seals for proper fit and lubrication. Replace shaft if damaged.

**SMEARS**
Smearing of metal due to slippage. Smearing can be caused by poor fits, lack of lubrication, overheating, overloads or handling damage. Replace bearings. Clean related parts and check for proper fit and lubrication.

*Figure 3-88, Rear Wheel Bearing Inspection/Diagnosis*
Tapered Roller Bearing Nomenclature

Figure 3-89, Tapered Roller Bearing Construction
Tapered Roller Bearing Inspection/Diagnosis

**ABRASIVE ROLLER WEAR**
Pattern on races and rollers caused by fine abrasives.
Clean all parts and housings, check seals and bearings and replace if leaking, rough or noisy.

**ABRASIVE STEP WEAR**
Pattern on roller ends caused by fine abrasives.
Clean all parts and housings, check seals and bearings and replace if leaking, rough or noisy.

**GALLING**
Metal smears on roller ends due to overheat, lubricant failure or overload.
Replace bearing, check seals and check for proper lubrication.

**ETCHING**
Bearing surfaces appear gray or grayish black in color with related etching away of material, usually at roller spacing.
Replace bearing, check seals and check for proper lubrication.

*Figure 3-90, Tapered Roller Bearing Inspection/Diagnosis (1 of 5)*
Wear around outside diameter of cage and roller pockets caused by abrasive material and insufficient lubrication.
Clean related parts and housings.
Check seals and replace bearings.

Surface depressions on race and rollers caused by hard particles of foreign material.
Clean all parts and housing.
Check seals and replace bearings if rough or noisy.

Figure 3-91, Tapered Roller Bearing Inspection/Diagnosis (2 of 5)
Figure 3-92, Tapered Roller Bearing Inspection/Diagnosis (3 of 5)

**MISALIGNMENT**
Outer race misalignment due to foreign object. Clean related parts and replace bearing. Make sure races are properly sealed.

**CRACKED INNER RACE**
Race cracked due to improper fit, cocking, or poor bearing seats. Replace bearing and correct bearing seats.

**FATIGUE SPALLING**
Flaking of surface metal resulting from fatigue. Replace bearing, clean all related parts.

**BRINELLING**
Surface indentations in raceway caused by rollers either under impact loading or vibration while the bearing is not rotating. Replace bearing if rough or noisy.
Discoloration can range from light brown to black caused by incorrect lubricant or moisture. Re-use bearings if stains can be removed by light polishing or if no evidence of overheating is observed. Check seals and related parts for damage.

Smearing of metal due to slippage. Slippage can be caused by poor fits, lubrication, overheating, overloads or handling damage. Replace bearings, clean related parts, check for proper fit and lubrication.

Corrosion set up by small relative movement of parts with no lubrication. Replace bearing. Clean related parts. Check seals and check for proper lubrication.

Heat discoloration can range from faint yellow to dark blue resulting from overload or incorrect lubricant. Excessive heat can cause softening of races or rollers. To check for loss of temper on races or rollers, a simple file test may be made. A file drawn over a tempered part will grab and cut metal; whereas, a file drawn over a hard part will glide readily with no metal cutting. Replace bearings if overheating damage is indicated. Check seals and other parts.

Figure 3-92, Tapered Roller Bearing Inspection/Diagnosis (4 of 5)
Pattern is inconsistent around outer race due to misalignment or insufficient preload.

Pattern is inconsistent in two areas 180° apart. The housing is most likely damaged or incorrectly machined.

Figure 3-92, Tapered Roller Bearing Inspection/Diagnosis (5 of 5)
4. Rear Axle Service

Objectives

Upon completion of Section 4 of the course, you will be able to:

• Identify and describe on-vehicle service procedures.
• Differentiate between a balanced and an unbalanced companion flange.
• Disassemble the rear axle assembly and re-assemble it to factory specifications.
• Isolate and repair faults in a rear axle.
• Measure and adjust pinion depth.
• Correctly position the ring gear and differential case assembly in the carrier housing.
• Perform a side bearing pre-load adjustment and backlash check.
• Describe the "break-in period" for a new ring-and-pinion gearset.
On-Vehicle Service Procedures (AAM 7.50-Inch, 7.625-Inch, 8.50-Inch and 8.625-Inch)

Carrier Cover Gasket Replacement

Removal

- With a container in place, remove the cover bolts and pry the cover loose to drain the lubricant.
- Make sure that both of the gasket sealing surfaces are clean.

Installation

- Torque the cover bolts in a crosswise pattern to ensure a uniform draw on the gasket. Tighten the bolts to 27 N•m (20 lb.-ft.) torque.
- Fill the axle with the proper lubricant to the specified level.

Figure 3-93, J-35640 Pinion Shaft Removal Tool
Axle Shaft Replacement

Removal

1. Raise the vehicle and remove the wheel and brake drum.
2. Clean all dirt from the area of the carrier cover.
3. Drain the lubricant from the carrier by removing its cover.
4. If the pinion shaft lock screw breaks, use tool J-35640 to push the pinion shaft out of the differential case (refer to Figure 3-94) Remove the differential pinion shaft lock screw (refer to Figure 3-95) and the differential pinion shaft. The axle shaft end play may be checked at this time, if necessary. Refer to “Axle Shaft End-Play Checking Procedure” in Section 7 of this book.

![Figure 3-94, Removing Pinion Shaft Lock Screw]

Important:

If the pinion shaft lock screw breaks, the differential case must be replaced.

5. Push the flanged end of the axle shaft toward the center of the differential and remove the “C” lock from the bottom end of the shaft (refer to Figure 3-96).
6. Remove the axle shaft from the housing, being careful not to damage the oil seal. (refer to Figure 3-97).
Installation

1. Slide the axle shaft into place taking care that the splines on the end of the shaft do not damage the oil seal and that they engage with the splines of the rear axle side gear.

2. Install an axle shaft “C” lock on the button end of the axle shaft and push the shaft outward so that the shaft lock seats in the counterbore of the rear axle side gear.

3. Position the differential pinion shaft through the case and pinions, aligning the hole in the shaft with the lock screw hole. Install the lock screw and tighten it to 27 N•m (20 lb.-ft.) torque.

4. Using a new gasket, install the carrier cover and tighten the bolts to 27 N•m (20 lb.-ft.) torque.

5. Fill the axle with lubricant to the specified level.

6. Install the brake drum and wheel.

7. Lower the vehicle and test drive the vehicle for proper operation of the axle.
Removal

- Remove the oil seal from the axle housing with a pry bar behind the seal's steel case, being careful not to damage the housing.
- Insert tool J-22813-01 into the bearing bore and position it behind the bearing so that the tangs on the tool engage the bearing outer race. Remove the bearing, using a slide hammer as shown in Figure 3-97.

Installation

- Lubricate the new bearing with gear lubricant and install the bearing so that tool J-23765 or J-23690 bottoms against the shoulder in the housing, using tool J-8092 (refer to Figure 3-98).
- Lubricate the seal lips with gear lubricant. Position the seal on tool J-23771 or J-21128 and position the seal into the housing bore. Tap the seal into place so that it is flush with the axle tube (refer to Figure 3-98).
Axle Shaft Flange Bolt Replacement

When replacing hub bolts (full floating axle shafts or axle flange bolts, use the following recommended actions:

- Stripped bolt(s) – Replace the bolt(s) involved.
- One loose bolt – Replace all bolts in the hub or axle flange.
- One broken bolt – Replace all bolts in the hub or axle flange.
- Wheel hole elongated – Replace the wheel.

Removal

- Hoist car; remove the wheel and drum.
- Install the wheel nut on the bolt and using tool J-5504, press the bolt from the hub (refer to Figure 3-99).

Important:

It may be necessary to press the bolt without a nut if a stripped bolt is being replaced.
- Remove the nut from the bolt.

Installation

- Install the bolt, four washers and nut (refer to Figure 3-100).
- Tighten the nut until the bolt is completely seated against the hub. Tighten to the wheel-torque specification for the vehicle.
- Remove the nut and washers.
- Install the drum and wheel. Lower the hoist.

Figure 3-99, Removing Axle Shaft Flange Bolt

Figure 3-100, Installing Axle Shaft Flange Bolt
Pinion Oil Seal Replacement

Removal
1. Mark the drive shaft and pinion flange so they can be reassembled in the same position.
2. Disconnect the drive shaft from the rear axle pinion flange and support the shaft. If the joint bearings are not retained by a retainer strap, use a piece of tape to hold the bearings on their journals.
3. Mark the position of the pinion flange, pinion shaft and nut so that the proper pinion bearing preload can be maintained.
4. Remove the pinion flange nut and washer using tool J-8614, a socket and driver.
5. With a suitable container in place to hold any fluid that may drain from the pinion seal, remove the pinion flange (refer to Figure 3-102).

Figure 3-101, Marking for Re-Assembly

Figure 3-102, Removing Pinion Flange

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6. Remove the oil seal by driving it out of the carrier with a blunt chisel. Do not damage the carrier (refer to Figure 3-103).

7. Examine the seal surface of the pinion flange for tool marks, nicks, or damage such as a groove worn by the seal. If damaged, replace the flange as outlined under Pinion Flange Replacement.

8. Examine the carrier bore and remove any burrs that might cause leaks around the O.D. (Outside Diameter) of the seal.

Installation

- Install a new seal as shown in Figure 3-104.
- Apply rear axle lubricant to the O.D. of the pinion flange and sealing lip of a new seal.
- Install the pinion flange and tighten its nut to the same position as marked in Step 3 of Removal. While holding the pinion flange as during pinion nut removal, tighten the nut 1.59 mm (1 1/16 in.) beyond the alignment marks.

Important:
The pinion seal can be replaced one time before the crush sleeve must be replaced.
Pinion Flange Replacement

Removal
1. Raise the vehicle and remove both rear wheels and drums.
2. Mark the drive shaft and pinion flange, then disconnect the rear joint and support the drive shaft out of the way. If joint bearings are not retained by a retainer strap, use a piece of tape to hold the bearings on their journals.
3. Check preload with an pound-inch torque wrench and record the measurement. This will give the combined pinion bearing, carrier bearing, axle bearing and seal preload (Figure 3-104).

Notice:
Recording the preload must be performed when replacing the pinion companion flange. If it is not recorded, the correct preload cannot be set after pinion flange replacement.
4. Remove the pinion flange nut and washer.
5. With a suitable container in place to hold any fluid that may drain from the rear axle, remove the pinion flange.

Figure 3-104, Checking Pinion Preload
**Installation**

1. Apply rear axle lubricant to the O.D. of the new pinion flange, then install the pinion flange, washer and pinion flange nut finger tight.

2. While holding the pinion flange with tool J-8614 as shown in Figure 3-101, tighten the nut a little at a time and turn the drive pinion several revolutions after each tightening to set the rollers. Check the preload of the bearings each time with an pound-inch torque wrench until preload is 0.30-0.60 N\(\text{m}\) (3-5 lb.-in.) more than the reading obtained in Step 3 of Removal.

3. Connect the drive shaft to the rear axle pinion flange. Tighten the strap bolts to 12 to 17 lb.-ft. of torque.

4. Install the drums and wheels.

5. Check and add the correct lubricant as necessary.
Rear Axle Assembly Removal

It is not necessary to remove the rear axle assembly for any normal repairs. However, if the carrier housing is damaged, the rear axle assembly may be removed and installed using the following procedures:

Removal

1. Hoist the vehicle and support it at the frame. The hoist must remain under the rear axle housing.
2. Disconnect the shock absorbers from the axle.
3. Mark the drive shaft and pinion flange, then disconnect the drive shaft and support it out of the way.
4. Remove the brake line junction block bolt at the axle housing, then disconnect the brake lines at the junction block. On some models, disconnect the brake lines at the wheel cylinders.
5. Disconnect the upper control arms from the axle housing on vehicles with coil-spring suspensions. On vehicles with leaf-spring suspensions, disconnect the springs from the axle housing tubes.
6. Lower the rear axle assembly on the hoist and remove the springs, if they are of the coil type.
7. Remove the rear wheels and drums.
8. Remove the rear axle cover bolts and remove the cover.
9. Remove the axle shaft. Refer to “Axle Shaft Removal.”
10. Disconnect the brake lines from the axle housing clips.
11. Remove the brake backing plates.
12. Disconnect the lower control arms from the axle housing.
13. Remove the rear axle housing by lowering the vehicle.
Installation
1. Install the rear axle housing.
2. Install the brake backing plate.
3. Position the brake lines under the axle housing clips. On some models, connect the brake lines to the wheel cylinders.
4. Install the axle shaft. Refer to “Axle Shaft Installation.”
5. Install the rear axle cover and the cover bolts.
6. Install the brake drums and wheels.
7. Raise the axle assembly on a hoist and install the springs. Then connect the upper and lower control arms; refer to the torque specification in the Rear Suspension Section of the Vehicle Service Manual.
8. Connect the brake lines to the junction block and install the junction block bolt to the axle housing.
9. Connect the drive shaft. Tighten the strap bolts to the torque specification in the Drive Shaft Section of the Vehicle Service Manual.
10. Connect the shock absorbers to the axle housing; refer to the Suspension Section of the Vehicle Service Manual.
11. Fill the rear axle to the proper level with the specified lubricant.
13. Remove the jack stands and lower the vehicle.
Rear Axle Disassembly Procedures

The procedure described in the following pages apply primarily to the AAM rear axles (7.50", 7.625", 8.50" and 8.625"). However, there is information related to other rear axles within this section.

Disassembly of Rear Axle Assembly

Before attempting any service procedures, the technician must know what type rear axle is to be serviced. Refer to an application chart to identify codes, ring gear size, and ratios. Remember that some ring gear bolts have L.H. threads.

Most rear axle service repairs can be made by supporting the vehicle by the frame with the axle housing supported and lowered to its lowest travel. On some series, it may be necessary to disconnect shock absorbers to obtain additional clearance. When doing this, do not allow the rear brake hose to become kinked or stretched.

Lubricant may be drained by backing out all cover bolts and breaking the cover loose at the bottom.

If the rear axle housing is removed for any reason, rear axle service can be performed on the bench.

Holding fixture J-3289-01 may be used to support the axle assembly on the end of a work bench, using the J-3289-20 fixture base. Adapter set J-8622 will also be needed for this mounting of the rear axle (see Figure 3-105).

Notice:

When a new ring gear and pinion are installed, the owner should be advised NOT to accelerate rapidly or exceed 50 mph for the first 50 miles of driving. The customer also should NOT tow for the first 500 miles. Damage to the new ring-and-pinion gearset may result.
Differential Case Removal and Disassembly

Removal (With Axle Shafts Removed)

- Before removing the differential case from the housing, ring gear-to-drive pinion backlash should be checked in 8 locations (refer to Figure 3-106). There should not be more than 0.002 inch difference in the measurements. If there is, this indicates gear or bearing wear or an error in backlash or preload setting.

- A tooth contact pattern check and a total turning preload check should be performed at this time to aid in diagnosis. These checks are discussed in Section 3 – Rear Axle Diagnosis.

- Remove the differential bearing cap bolts. Bearing caps must be marked “R” and “L” to make sure they will be reassembled in their original location.

- Remove the differential case as shown in Figure 3-107. Exercise caution in prying on the carrier so that the gasket sealing surface is not damaged. Place the right and left bearing outer races and shims in sets with marked bearing caps so that they can be reinstalled in their original positions.

Disassembly

- If the differential side bearings are to be replaced, they can be removed as shown in Figure 3-108.

- Remove the differential pinions, side gears and thrust washers from the case. Mark the side gears and the case so that they can be installed in their original location.

- If the ring gear is to be replaced and it is tight on the case after removing the bolts (L.H. threads), drive it off, using a brass drift and hammer.

Notice:

Do not pry between the ring gear and case. Damage to the case and/or the ring gear may result.
Drive Pinion, Bearings and Races Removal

Checking Preload/Looseness

- Check the drive pinion bearing preload (new bearings 15-25 lb.-in., old bearings 10-15 lb.-in.). If there is no preload reading, check for looseness of the pinion assembly by shaking. Looseness could be caused by defective bearings or worn pinion flange. If the rear axle was operated for an extended period with very loose bearings, the ring gear and drive pinion will also require replacement.

Removal

- Remove the pinion flange nut and washer.
- Remove the pinion flange.
- Install the drive pinion remover J-22536 and drive out the pinion. Apply heavy hand pressure on the pinion remover toward the rear of axle housing to keep the front bearing seated to avoid damage to the outer race (see Figures 3-109 and 3-110).
Bearing Replacement

The rear pinion bearing must be removed when it becomes necessary to adjust the pinion depth.

Disassembly

- With the drive pinion removed from the carrier, press the bearing from the pinion gear as shown in Figure 3-111.

- Drive the pinion oil seal from the carrier and remove the front pinion bearing. If this bearing is to be replaced, remove the outer race from the carrier (Figure 3-112, view A).

- If the rear pinion bearing is to be replaced, remove the outer race from carrier using a punch in the slots provided for this purpose (Figure 2-112, view B).

Figure 3-111, Removing Rear Pinion Bearing

Figure 3-112, Removing Pinion Bearing Races
Cleaning and Inspection

1. Clean all rear axle bearings thoroughly in clean solvent. Examine bearings visually and by feel. All bearings should feel smooth when oiled and rotated while applying as much hand pressure as possible. Minute scratches and pits that appear on the rollers and races at low mileage are due to the initial preload, and bearings having these marks should not be rejected.

2. Examine the sealing surface of the pinion flange for nicks, burrs, or rough tool marks which would cause damage to the seal and result in an oil leak. Replace if damaged.

3. Examine the carrier bore and remove any burrs that might cause leaks around the O.D. of the pinion seal.

4. Examine the ring gear and drive pinion teeth for excessive wear and scoring. If any of these conditions exist, replacement of the gearset will be required.

5. Inspect the pinion gear shaft for unusual wear; also check the pinion and side gears and thrust washers.

6. Check the press fit of the side bearing inner race on the rear axle case hub by prying against the shoulder at the puller recess in the case. Side bearings must be a tight press fit on the hub.

7. Diagnosis of a rear axle failure, such as chipped bearings, loose (lapped-in) bearings, chipped gears, and so on, is a warning that some foreign material is present; therefore, the axle housing must be cleaned.

Drive Pinion Bearing Race Installation

Assembly

- If a new rear pinion bearing is to be installed, install new outer race as shown in Figure 3-113.

- If a new front pinion bearing is to be installed, install new outer race as shown in Figure 3-114.
Balanced and Non-Balanced Pinion Gears

Some rear axles require balance weights to prevent vibrations. These weights are installed during axle manufacturing. The weights are located on the pinion companion flange. There are two locations for balancing weights (shown in Figures 3-115 and 3-116).

If the ring and pinion gearset is system balanced and requires replacement, the companion flange must be replaced. If it is not replaced, vibrations could occur with the new gearset.

Important:

Companion flanges with a runout compensation weight do **NOT** need to be replaced if the ring and pinion gearset is replaced.
Setting Pinion Depth

Pinion depth is set with the Pinion Setting Gauge J-21777-01. The pinion setting gauge provides, in effect, a “nominal” or “zero” pinion as a gauging reference. Instructions are included in the gauge set.

1. Make certain that all gauge parts are clean.
2. Lubricate the front and rear pinion bearings liberally with rear axle lubricant.
3. While holding the pinion bearings in position, install the depth setting gauge assembly as shown in Figures 3-117 and 3-118.
4. Hold the stud stationary with a wrench positioned over the flats on the ends of the stud and tighten the nut to 2.2 N•m (20 lb.-in.) torque. Rotate the gauge plate assembly several complete revolutions to seat the bearings (also tap on the carrier housing near the bearings with a hammer to help seat the bearings). Then, tighten the nut until a torque between 1.6 and 2.2 N•m (15 and 25 lb.-in.) is obtained to keep the gauge plate in rotation.
5. Rotate the gauge plate until the gauging area is parallel with the bearing saddles (Figures 3-119 and 3-120).
6. Make certain that the differential side bearing support bores are clean and free of burrs.
7. Install the correct disc on the gauge arbor.

8. Position the gauge arbor assembly in the carrier housing so that the dial indicator rod is centered on the gauging area of the gauge block and the discs seated fully in the side bearing bores.

Install the side bearing caps and Lighten the bolts to 75 N•m (55 lb.-ft.) torque.

9. Set the dial indicator to zero. Use dial indicator J-8001 or an equivalent indicator that reads from 0 to 0.100 in. Then, position the indicator on the mounting post of the gauge arbor, with the contact button touching the indicator pad. Push the dial indicator downward until the needle rotates approximately 3/4 turn clockwise.

Tighten the dial indicator in this position and recheck. Ensure that the dial indicator contact pad is not bottomed when the rod is on the gauge block. The pad should still be touching the contact button when the rod is rotated from the gauge block. DO NOT EXCEED THE DIAL INDICATOR’S RANGE OF TRAVEL.

10. Rotate the gauge arbor slowly back and forth until the dial indicator rotates the farthest clockwise. At this point, set the dial indicator to zero. Repeat the locking action on the gauge arbor to verify the zero setting.

11. After the zero setting is obtained, rotate the gauge arbor until the plunger does not touch the gauge block.
12. Record the dial reading at the pointer position. Example: If the pointer moved to a dial reading of 0.033 inch (as shown in Figure 3-120), this indicates a shim thickness of 0.033 inch. The dial indicator reading should be within the range of 0.020 to 0.050 inch. For a more detailed explanation, see Figures 3-121 and 3-122.

All AAM axle assemblies use “nominal” pinions. This means that the technician does not need to look at markings on the pinion which indicate the need to add or subtract from the gauged thickness dimension.

In some previous years, some pinions were marked as described in Step 13.

13. (Type “O” or “K”) Select the correct drive pinion shim to be used during pinion reassembly on the following basis:

- If a drive pinion with no marking is being used, the correct shim will have a thickness EQUAL to the indicator gauge reading found in Step 12.
Figure 3-121, Pinion Depth Gauge Tools and Checking Pinion Depth
ON THE GAUGE BLOCK

- The plunger is squarely in contact with the gauge block.
- The dial indicator needle points to zero off the gauge block.

OFF THE GAUGE BLOCK

- The plunger is no longer in contact with gauge block assembly as the technician rotates the gauge arbor.
- As the gauge arbor is rotated, the plunger extends, allowing the dial indicator stem to extend.
- The dial indicator changes its reading. The needle now points to the number which is the thickness of the pinion shim Needed.

*Figure 3-122, Pinion Depth Gauge Tools – Side View*
On drive pinions that are marked “+” (plus) (Figure 3-123), the shim thickness indicated by the dial indicator on the pinion setting gauge must be INCREASED by the amount on the drive pinion.

If the drive pinion is marked “-” (minus), the shim thickness indicated by the dial indicator on the pinion setting gauge must be DECREASED by the amount on the drive pinion. Shims are available in 0.001 to 0.037 inch. Each shim has the thickness etched on its flat surface for identification. Do not trust the markings. Measure the shim thickness with a micrometer to be sure. “C,” “G” or “P” drive pinions will not have any markings; they are nominal gears.

14. Loosen stud J-21777-43 (see Figures 3-118 and 3-119) and remove the gauge plate, washer and both bearings from the carrier.

15. Position the correct shim on the drive pinion and install the drive pinion rear bearings as shown in Figure 3-124.

**Important:**

The “+” and “-” designations on Dana (Spicer) and Borg-Warner pinion gears are different than AAM pinion gears. On these pinions a “+” indicates that the shim thickness must be reduced by the amount on the pinion. A “-” indicates that the shim thickness must be increased by the amount on the pinion.
Alternate Methods for Setting

Pinion Depth

Some rear axles have different methods for setting the pinion depth. These rear axles include:

- Dana
- Borg-Warner
- AAM 10.50 inch

The different methods are discussed in Section 2.

Adjusting Pinion Depth Based on Pinion Numbers

If the pinion has a "+" or "-" number, the shim thickness determined by the gauging process must be adjusted to compensate for the pinion. If an old pinion with a "+" or "-" is being replaced with a pinion with a "+" or "-", the gauging process will still determine the correct shim thickness after being adjusted by the number on the new pinion. If the new pinion does not have a designation or has a "0", the gauging process will indicate the correct shim thickness.

The charts in Figure 3-125 can be used as a second check of the correct shim thickness for the new pinion. The charts compare the old pinion to the new pinion. The number where the two cross indicates the necessary adjustment to the old shim thickness to determine the new shim thickness.

Example: If the rear axle is manufactured by Dana and the old pinion is -2 and the new pinion is +3 (see Figure 3-125), the old shim thickness must be decreased by 0.005 inch. If the old shim thickness was 0.033", the new shim thickness is 0.028 inch (0.033" - 0.005" = 0.028").
<table>
<thead>
<tr>
<th>Old Pinion Marking</th>
<th>Dana (Spicer) and Borg Warner New Pinion Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-4</td>
</tr>
<tr>
<td>+4</td>
<td>+0.008</td>
</tr>
<tr>
<td>+3</td>
<td>+0.007</td>
</tr>
<tr>
<td>+2</td>
<td>+0.006</td>
</tr>
<tr>
<td>+1</td>
<td>+0.005</td>
</tr>
<tr>
<td>0</td>
<td>+0.004</td>
</tr>
<tr>
<td>-1</td>
<td>+0.003</td>
</tr>
<tr>
<td>-2</td>
<td>+0.002</td>
</tr>
<tr>
<td>-3</td>
<td>+0.001</td>
</tr>
<tr>
<td>-4</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Old Pinion Marking</th>
<th>AAM and Rockwell New Pinion Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-4</td>
</tr>
<tr>
<td>+4</td>
<td>-0.008</td>
</tr>
<tr>
<td>+3</td>
<td>-0.007</td>
</tr>
<tr>
<td>+2</td>
<td>-0.006</td>
</tr>
<tr>
<td>+1</td>
<td>-0.005</td>
</tr>
<tr>
<td>0</td>
<td>-0.004</td>
</tr>
<tr>
<td>-1</td>
<td>-0.003</td>
</tr>
<tr>
<td>-2</td>
<td>-0.002</td>
</tr>
<tr>
<td>-3</td>
<td>-0.001</td>
</tr>
<tr>
<td>-4</td>
<td>0</td>
</tr>
</tbody>
</table>

*Figure 3-125, Adjusting Pinion Depth Based on Pinion Numbers*
**Drive Pinion, Bearings and Races Installation**

1. Install a NEW collapsible spacer on the pinion and position the assembly in the carrier. Lubricate the pinion bearings with rear axle lubricant before installing the pinion (Figure 3-126).

2. Hold forward on the pinion in the carrier.

3. Install the front bearing on the pinion and drive the bearing onto the pinion shaft until it is nearly seated in the race, using tool J-6133-01 and a hammer.

4. Position the pinion oil seal in the carrier and install the seal.

5. Coat the lips of the pinion oil seal and the seal surface of the pinion flange with axle lubricant. Install the pinion flange on the pinion by tapping it with a soft hammer until a few pinion threads project through the flange (Figure 3-127).

6. Install the pinion washer and nut. Hold the pinion flange. While intermittently rotating the pinion bearings, tighten the pinion flange nut until the end play begins to be taken up. As soon as no further end play is detectable and as soon as the holder will no longer pivot freely as the pinion is rotated, the preload specifications are being approached. No further tightening should be attempted until the reload has been checked.

**Notice:**

*Do NOT use an impact wrench to tighten the pinion nut. It could cause excessive preload and crush the collapsible spacer too much. It could also cause bearing damage.*
7. Check the preload by using a pound-inch torque wrench (refer to Figure 3-128). After the preload has been checked, final tightening should be done very carefully. For example, if when checking, preload was found to be 0.6 N•m (5 lb.-in.), any additional tightening of the pinion nut can add many additional pounds-inch of torque. Therefore, the pinion nut should be further tightened only a little at a time, and the preload should be checked after each slight amount of tightening. Exceeding the preload specifications will compress the collapsible spacer too far and require the installation of a new collapsible spacer.

While observing the preceding recommendation, carefully set the preload at the specified value for new bearings or for used bearings.

8. Rotate the pinion several times to insure that the bearings have been seated. Tapping on the carrier housing near the bearings will also help to seat them. Check the preload again. If the preload has been reduced by rotating the pinion, reset the preload to specification.

Notice:
Slowly apply torque to the pinion nut. If the nut is over-tightened and the collapsible sleeve is crushed excessively, it must be replaced.
Differential Case Assembly

Assembly (With Axle Shafts Removed)

Before assembling the differential case, lubricate all of the parts with rear axle lubricant.

1. Place the side-gear thrust washers over the side-gear hubs and install the side gears in the case. If some parts are reused, install them in their original sides.

2. Position one pinion (without washer) between the side gears and rotate the gears until the pinion is directly opposite from the loading opening in the case. Place the other pinion between the side gears so that the pinion shaft holes are in line; then rotate the gears to make sure the holes in the pinions will line up with the holes in the case.

3. If the holes line up, rotate the pinions back toward the loading opening just enough to permit sliding in the pinion thrust washers.

4. After making certain that the mating surfaces of the case and ring gear are clean and free of burrs, thread two bolts into opposite sides of the ring gear; then install the ring gear on the case (Figure 3-129). Install NEW ring rear attaching bolts just snug. NEVER REUSE OLD BOLTS. Tighten the bolts alternately in progressive stages to 120 N•m (90 lb.-ft.) torque.

5. If the case side bearings were removed, install the bearings as shown in Figure 3-130.

Important:
The differential pinion to side gear clearance can be checked for excessive clearance. Refer to Section 5 of this book. The specification is 0.003 inch to 0.009 inch.
Side Bearing Preload and Backlash Adjustment

There are three methods in this section that can be used to set the side bearing preload and backlash. All three methods accomplish the same objective.

The first two methods are slightly more efficient than the third method. Method #3 requires removal of the ring gear from the differential case or removal of the pinion gear.

Regardless of the method used, NEVER reuse production shims. Production shims are cast iron and vary in thickness from 0.210 to 0.272 inch in 0.002-inch increments (Figure 3-131). They should be replaced by service shims and spacers.

Do not attempt to reinstall the production shims as they may break when tapped into place. If service shims were previously installed, they can be reused.

Standard service spacers are 0.170-inch thick and steel service shims are available in thicknesses from 0.040 to 0.082 inch in 0.002-inch increments (Figure 3-132).

Important:

When performing backlash measurements always measure the backlash in 8 locations on the ring gear. If the variation in the measurements is greater than 0.002 inch, there is excessive backlash variation. Refer to Section 2 of this book for information on excessive backlash variation.

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ASE 3 - Manual Drivetrain and Transaxle
Module 6 - Rear Axles

6-134

SHIM

SPACER

Figure 3-131, Side Bearing Production Shim

Figure 3-132, Side Bearing Service Spacer and Service Shim
Method #1 – The Wedge

Gauge Method

Before installation of the case assembly, make sure that the side bearing surfaces in the carrier are clean and free of burrs. If the same bearings are reused, they must have the original outer races in place.

The following are the procedures for Method #1:

1. Install the differential case and insert shims with approximately 0.021 inch thickness on the left side of the case (ring gear side).

2. Insert the wedge gauge on the right side of the case (refer to Figure 3-133).

3. Tighten the wedge gauge on the right side of the case.

4. Tighten the wedge gauge until there is moderate drag when removing the gauge. (Over-tightening can spread the housing and result in incorrect shim selection.)

5. Remove all of the shims and the wedge gauge and measure the thickness of each. (Measure the wedge gauge in three locations and average the measurements. Measure the shims individually.)

6. Record your measurements.

7. Add the total shim thickness to the wedge gauge thickness.

8. The result is the total shim thickness without preload (refer to Figure 3-134).

9. Insert on the right side (the side opposite the ring gear) one bent 0.040 inch shim against the bearing and one 0.040 inch shim against the axle housing.

10. Install the wedge gauge on the left side and tighten the gauge until there is 0.001 to 0.002 inch backlash between the ring and pinion gears (refer to Figure 3-135).
11. Remove the wedge gauge and measure the thickness of the gauge in three locations and, again, take the average. This is the left side shim thickness.

12. Subtract this measurement from the total shim thickness (determined in Step 8). The result is the thickness of the right side to take up the clearance (refer to Figure 3-136).

To provide preload and an additional 0.004 inch backlash, 0.008 inch must be added to the right side shim thickness. Example:

<table>
<thead>
<tr>
<th>Description</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Shim Thickness</td>
<td>0.480&quot;</td>
</tr>
<tr>
<td>Left Side Wedge Gauge</td>
<td>-0.230&quot;</td>
</tr>
<tr>
<td>For Preload</td>
<td>+0.008&quot;</td>
</tr>
<tr>
<td>Total Right Side Shim</td>
<td>0.258&quot;</td>
</tr>
</tbody>
</table>

13. Install the service spacers against the axle housing on each side of the differential case and use service shims to complete the total shim thickness for each side.

14. Measure the backlash.

15. If the backlash is not between 0.005 inch and 0.009 inch, some shim thickness must be removed from one side and transferred to the other side (maintaining total shim thickness). Moving 0.002 inch of shim thickness will change the backlash by 0.001 inch.
16. Install the side bearing caps and tighten them to 75 N\(\cdot\)m (55 lb.-ft.).
17. Calculate the side bearing preload (see page 3-136 in this section) to
determine if the side bearing preload is within specifications.
18. Perform a tooth contact pattern test.
19. Install the axles.
20. Install a new cover gasket and the cover.
21. Fill the rear axle with the specified lubricant to the correct level.

![Wedge Gauge Thickness Diagram]

**TOTAL SHIM THICKNESS (WITHOUT PRELOAD)**

**RIGHT SIDE SHIM THICKNESS (WITHOUT PRELOAD)**

+0.008 INCH (FOR PRELOAD)

TO ADJUST BACKLASH:

**MORE BACKLASH** – SUBTRACT 0.002" FROM THE LEFT SIDE FOR EACh 0.001 INCREASE IN BACKLASH AND ADD THIS TO THE RIGHT SIDE

**LESS BACKLASH** – SUBTRACT 0.002" FROM THE RIGHT SIDE FOR EACH 0.001 REDUCTION IN BACKLASH AND ADD THIS TO THE LEFT SIDE
Method #2 – The Shim Method

1. Install the differential case into the carrier housing.

2. Install a 0.040 inch bent shim on the right side (opposite the ring gear). The bent shim will keep pressure on the differential case and force it to the left (refer to Figure 3-137).

3. Install a 0.170 inch service spacer on the left side (ring gear side).

4. Install progressively larger service shims between the service spacer and the bearing race on the left side. Install the shims until there is no longer backlash between the ring and pinion gears. Increase the shim size in 0.002 inch increments. This step will remove any end play that may exist between the left side bearing and the housing.

5. Remove the bent shim from the right side (refer to Figure 3-138).

6. Install a service spacer on the right side.

7. Install progressively larger shims (in 0.002 inch increments) on the right side until there is a very slight amount of backlash. This step will remove end play between the right side bearing and the housing without creating backlash. At this point, there should not be any backlash or side bearing preload.

8. Remove and measure the service shims that were installed on the right and left sides. Keep the right and left side shims separate.
9. Select a shim that is 0.006 inch smaller than the shim that was installed on the left side. This will be the shim used for the left side (refer to Figure 3-139).

10. Select a shim that is 0.014 inch larger than the shim that was installed on the right side. This will be the shim used for the right side.

11. Steps 9 and 10 will set the backlash and preload. The total shim change is 0.008 inch (0.014" - 0.006" = 0.008"). This was performed to set the correct side bearing preload (0.004 inch per side). Reducing the left side by 0.006 inch and increasing the right side by 0.014 inch sets the backlash.

12. Measure the backlash.

13. If the backlash is not between 0.005 inch and 0.009 inch, some shim thickness must be removed from one side and transferred to the other side (maintaining total shim thickness).

   Moving 0.002 inch of shim thickness will change the backlash by 0.001 inch.

14. Install the side bearing caps and tighten them to 75 N•m (55 lb. ft.) torque.

15. Calculate the side bearing preload to determine if the side bearing preload is within specifications.

16. Perform a tooth contact pattern test.

17. Install the axles.

18. Install a new cover gasket and the cover.

19. Fill the rear axle with specified lubricant to the correct level.

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**Figure 3-139, Changing Shim Thickness to Set Backlash**

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**Method #3 – Feeler Gauge Method**

**Side Bearing Preload Adjustment**

This side bearing preload adjustment should be made before installing the pinion. If the pinion is installed, remove the ring gear.

<table>
<thead>
<tr>
<th>4.32 MM (0.170 IN.) SERVICE SPACER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL THICKNESS OF BOTH PRODUCTION SHIMS REMOVED</strong></td>
</tr>
<tr>
<td>10.57 MM (0.420 IN.)</td>
</tr>
<tr>
<td>10.92 MM (0.430 IN.)</td>
</tr>
<tr>
<td>11.18 MM (0.440 IN.)</td>
</tr>
<tr>
<td>11.43 MM (0.450 IN.)</td>
</tr>
<tr>
<td>11.68 MM (0.460 IN.)</td>
</tr>
<tr>
<td>11.94 MM (0.470 IN.)</td>
</tr>
<tr>
<td>12.19 MM (0.480 IN.)</td>
</tr>
<tr>
<td>12.45 MM (0.490 IN.)</td>
</tr>
<tr>
<td>12.70 MM (0.500 IN.)</td>
</tr>
<tr>
<td>12.95 MM (0.510 IN.)</td>
</tr>
<tr>
<td>13.21 MM (0.520 IN.)</td>
</tr>
<tr>
<td>13.46 MM (0.530 IN.)</td>
</tr>
</tbody>
</table>

Case side bearing preload is adjusted by changing the thickness of both the right and left shims by an equal amount. By changing the thickness of both shims equally, the original backlash will be maintained.

1. Determine the approximate thickness of the shims needed by measuring each production shim or each service spacer and shim pack.

2. In addition to the service spacer, a service shim will be needed. To determine a starting point in selecting service shim thickness, use the shim thickness chart in Figure 3-140.

3. Place the case with bearing outer races in position into the carrier. Slip the service spacer between each bearing race and the carrier housing with the chamfered edge against the housing (refer to Figures 3-141 and 3-142).
• Install the left bearing cap loosely so that the case may be moved while checking adjustments. Another bearing cap bolt can be added in the lower right bearing cap hole. This will prevent the case from dropping while making the shim adjustments.

• Select one or two shims totaling the amount shown in the right-hand column of the shim thickness chart (Figure 3-140) and position it or them between the right bearing race and the service spacer. Be sure the left bearing race and spacer are against the left side of the housing (see Figure 3-142).

Figure 3-142, Installing the Service Spacers

Figure 3-143, Installing the Bearing Shims
4. Insert progressively larger feeler gauge sizes (0.010 in., 0.012 in., 0.014 in., etc.) between the right shim and the service spacer until there is noticeably increased drag. Push the feeler gauge downward until the end of the gauge makes contact with the carrier bore so as to obtain a correct reading. The point just before additional drag begins is the correct feeler gauge thickness. Rotate the case while using the feeler gauge to insure an even reading. The original light drag is caused by the weight of the case against the carrier while the additional drag is caused by the side bearing preload. By starting with a thin feeler gauge, a sense of “feel” is obtained so that the beginning of preload can be recognized to obtain zero clearance. It will be necessary to work the case in and out and to the left in order to insert the feeler gauge (Figure 3-143).

5. Remove the left bearing cap and the shim from the carrier (Figure 3-144). The total shim pack needed (with no preload on the side bearings) is the feeler gauge reading found in Step 4 plus the thickness of the shims installed in Step 3.

6. Select two shims of approximately equal size whose combined thickness is equal to the value obtained in Step 5.

For example, if the feeler gauge thickness was 0.030 inch and the shim thickness was 0.110 inch, add these figures together.

| FEELER GAUGE | 0.030 in. |
| SHIM THICKNESS | +0.110 in. |
| TOTAL | =0.140 in. |
The total of these figures is 0.140 inch. To determine the thickness of the shims needed to take up the side bearing free play, divide 0.140 inch by 2:

\[ \frac{0.140 \text{ in.}}{2} = 0.070 \text{ in.} \]

These shims will be installed between each side bearing race and service spacer when the case is installed in the carrier. The object of Step 7 is to obtain the equivalent of a “slip fit” of the case in the carrier. For convenience in setting the backlash, the preload will not be added until the final step.

7. If the pinion is in position, install the ring gear, then proceed to Rear Axle Backlash Adjustment.
**Differential Backlash Adjustment**

1. Install the differential case into the carrier, using the proper shims as determined by the side bearing preload adjustment.

2. Rotate the differential case several times to seat the bearings, then mount the dial indicator. Use a small button on the indicator stem so that contact can be made near heel end of tooth. Set the dial indicator so that its stem is in line as nearly as possible and perpendicular to the tooth angle to obtain an accurate backlash reading (refer to Figure 3-146).

3. Check backlash at eight points around the ring gear. Lash must not vary over 0.002 inch around the ring gear. The pinion must be held stationary when checking backlash. If the variation is over 0.002 inch, check for burrs, uneven bolting conditions or a distorted case flange and make corrections as necessary.

4. Backlash at the point of minimum lash should be between 0.005 and 0.008 inch for all new gears (specifications may vary).

5. If backlash is not within specifications, correct it by increasing the thickness of one shim and decreasing the thickness of other shim by the same amount. This will maintain the correct differential side bearing preload. For each 0.001-inch change in backlash desired, transfer 0.002-inch in shim thickness. To decrease backlash 0.001 inch, decrease the thickness of the right shim 0.002 inch. To increase backlash 0.002 inch, increase thickness of the right shim 0.004 inch and decrease the thickness of the left shim 0.004 inch (refer to Figure 3-147).
6. When backlash is correctly adjusted, remove both bearing caps and both shim packs. Keep the shim packs in their respective position, right or left side. Select a shim 0.004 inch thicker than the one removed from left side, then insert the left side shim pack between the spacer and the left bearing race (Figure 3-148). Loosely install the bearing cap.

7. Select a shim 0.004 inch thicker than the one removed from the right side and insert it between the spacer and the right bearing race. It will be necessary to drive the right shim into position (refer to Figure 3-149).

8. Install the side bearing caps and tighten them to 75 N•m (55 lb.-ft.) torque.

9. Recheck the backlash and correct it if necessary.

10. Calculate the side bearing preload to determine if the side bearing preload is within specifications.

11. Perform a tooth contact pattern test.

12. Install the axles.

13. Install a new cover gasket and the cover.

14. Fill the rear axle with the specified lubricant to the correct level.
Backlash and Preload Variations

The procedures listed on the previous pages are for most AAM rear axles. GM uses rear axles that have different methods to set the backlash and preload. These include:

- AAM 9.50-Inch
- AAM 10.50-Inch
- Dana

These variations are located of this book.

Calculating Side Bearing Preload

The side bearing preload can be calculated (see Figure 3-150) to determine if it is sufficient after performing the procedures for one of the three methods discussed earlier in this section. If the side bearing preload is insufficient, an equal amount of shims must be added to or subtracted from each side to maintain the backlash and increase the side bearing preload.

Measure the total preload by rotating the pinion and ring gear with a torque wrench. Rotate the pinion gear 12 times to seat the bearings. The axles should not be installed at this time.

Subtract the Pinion Preload (PP) from the Total Preload (TP) and then multiply this number by the Axle Ratio (AR) to determine the Side Bearing Preload (SBP):

\[ (TP - PP) \times AR = SBP \]

The side bearing preload should be between 15 and 35 lb.-in.
5. Limited Slip Differentials

Objectives

Upon completion of Section 5 of the course, you will be able to:

• Describe limited slip theory and operation.
• Describe the operation of a locking-type limited-slip differential.
• Disassemble and re-assemble a locking-type differential assembly to factory specifications.
Limited-Slip Differentials

As described earlier in Section 2 of this book, the open-type differential unit allows the axle shafts to rotate at different speeds from each other and from the ring gear and differential case assembly. This “differentiation” allows the vehicle to turn a corner without forcing the wheels to slip and the tires to scrub the pavement (refer to Figure 3-151).

Also mentioned was the one major drawback of the open differential unit, it allows one wheel to slip without transferring sufficient rotating force to the other wheel which has traction (refer to Figure 3-152).

The ideal differential unit is one which will allow the side gears, axle shafts, and wheels to:

- Rotate at different speeds from each other and from the differential case, while the vehicle is cornering on dry pavement.
- Rotate at the same speed as the differential case when one wheel loses traction, while the vehicle is moving on slippery surfaces.

A limited-slip differential unit is a design which aims at doing both jobs required for an ideal unit. There are three major types of limited-slip differentials (refer to Figure 3-153):

- Disc-Type Clutch
- Cone-Type Clutch
- Locking Type
The locking type is different from the other two types since uses a locking mechanism to physically lock the side gears to the differential case to prevent slip. The disc- and cone-type limited-slip differentials do not lock the side gears to the differential case. These two types of limited-slip differentials use friction to force the side gears to move with the differential case.

**Figure 3-153, Limited-Slip Differentials**

**Figure 3-154, Eaton Disc-Type Clutch Differential Unit (Used in AAM/Saginaw Rear Axles)**
Disc-Type Clutch Design

The composition of a disc-type clutch limited-slip differential unit is as follows (refer to Figure 3-154):

- The differential case is machined to accommodate the side-gear clutch packs.
- The side gears are machined with spline teeth which mesh with splined friction discs.
- Friction discs, with ears to fit into the differential case pockets, are placed alternately between the splined discs.
- Selective shims are used to provide proper backlash between the side gears and the differential pinion gears.
- Springs and plates are used to provide initial clutch pack preload pressure (refer to Figure 3-155).
- The differential pinion shaft and lock screw are no different than those of an open-type differential.
- The differential pinion gears have tooth profiles which cause more sideways push on the side gears. Known as side-gear separating force, this helps to compress the clutch packs as torque is applied to the side gears.

The term “limited slip” comes from the operation of this type of differential unit during cornering on dry pavement.

There is always preload pressure on the clutch discs, which are made of special hardened steel with textured friction surfaces. This preload pressure lightly compresses the clutch packs, and can be overcome while the vehicle is cornering on dry pavement (refer to Figure 3-156). In this situation, a limited amount of slipping occurs.
The clutch pack discs, since they are hardened steel, can rub against each other during cornering. This is why GL-5 lubricant contains an “anti-chatter” additive (5-percent), which allows a small amount of designed-in clutch pack slippage.

When one wheel is on a slippery surface and the other wheel has traction, the spring is joined by the force of the pinion gears trying to separate the side gears. These forces act together to compress the clutch packs (refer to Figure 3-157). The resulting action of the clutch packs being clamped is that both side gears are held to the differential case.

This is just like an open differential unit in a straight-ahead driving situation (refer to Figure 3-158).

There are several things to note:

• If both wheels do not have traction, a limited-slip differential offers no added benefit to move the vehicle.

• If the drive pinion-to-ring gear torque is too high, the forces compressing the clutch packs will be overcome. In this situation, the clutch packs slip. A driver properly operates a limited-slip differential unit by slowly increasing vehicle speed.
Cone-Type Clutch Design

A cone-type clutch limited-slip differential unit operates similar to the disc-type unit. Preload spring force and side gear separating force push cones (instead of discs) attached to the side gears into mating machined surfaces on the differential case (refer to Figure 3-159). This provides enough friction to force the side gears to rotate at the same speed as the differential case and ring gear.

No special additive is required for this type of unit. GL-5 gear lubricant contains five-percent “anti-chatter” additive, and this is sufficient for cone-type clutches. Adding more “anti-chatter” additive to this unit’s lubricant will reduce any holding action the cone clutches provide.

![Figure 3-159, Cone Type Clutch Differential Unit (Borg Warner, Used in AAM/Saginaw)](image-url)
Additional Limited-Slip Applications

Dana Disc-Type Clutch

Two applications of limited-slip differential units not previously discussed are the Dana disc-type unit (refer to Figure 3-160) and the Auburn cone-type unit (refer to Figure 3-162). Both units operate on the same principles which make the other units work – preload spring pressure and side-gear separating pressure together compress plates or push cones.

![Figure 3-160, Dana Disc-Type Clutch (Models 36 and 44 I.C.A.)](image)

As Figure 3-160 shows, a dished spacer provides the preload spring tension for the Dana clutch pack. Special tools and procedures (refer to Figure 3-161) are required to remove the differential pinions and side gear clutch packs.

These units are found only on the Chevrolet Corvette (certain model years). Light-duty trucks which use Dana-produced rear axle assemblies use only the open-type differential unit.

![Figure 3-161, Removing Dana Clutches](image)
**Auburn Cone-Type Clutch**

The Auburn Gear-produced limited-slip differential unit is found in some passenger cars with AAM/Saginaw-rear axle assemblies. This type of differential (Figure 3-162) is a non-serviceable unit. Note the use of an end cover, as compared with an equally-split two-piece differential case.

![Figure 3-162, Auburn Cone-Type Unit (AAM/Saginaw Rear Axles)](image1)

**Figure 3-163, Eaton Disc-Type Clutch Locking Differential Unit**

![Figure 3-163, Eaton Disc-Type Clutch Locking Differential Unit](image2)
Eaton Locking Differential

Disc-Type Clutch

The Eaton locking differential takes the operation of a disc-type limited-slip differential unit one step closer toward being an ideal differential.

Nicknamed the Eaton "locker," this unit has the following features (refer to Figure 3-163):

Like the disc-type clutch limited-slip unit, it has:

- Side gears with splines which fit splined clutch discs
- Eared discs which are held in a specially-machined differential case
- Differential pinion gears which have tooth profiles designed to push the side gears with separating force
- Selective thickness shims which determine side gear-to-pinion gear backlash

In addition to the disc-type unit, the Eaton locking differential has the following features (refer to Figure 3-164).

- A left-side gear which has a cam surface with ramps and detent notches to mate with a cam plate with a similar cam surface and detent "humps"
- A wave spring to hold the cam plate in contact with the cam side gear
- A thrust block between the two side gears which allows slight movement of the left cam side gear to push and compress the right-side gear clutch pack
- A governor and latching bracket mechanism (refer to Figure 3-165) to allow the unit to operate in either a limited-slip or locking function.
Limited-Slip Function

Under normal conditions, when the differential is not locked, a small amount of limited-slip action occurs. The gear separating force developed in the right-hand (left-hand side on 10-1/2") clutch pack is primarily responsible for this.

Figure 3-166 shows the operation of the unit in a right-hand turn. Since the left wheel travels farther than the right wheel, it must rotate faster than the ring gear and differential case assembly. This results in the left axle and left-side gear rotating faster than the differential case. (The faster rotation is shown as large arrows on the illustration.) The faster rotation of the left-side gear causes the pinion gears to rotate on the pinion shaft. This causes the right-side gear to rotate slower than the differential case.

Although the side gear spreading force produced by the pinion gears compresses the clutch packs (primarily the right side), the friction between the tires and the road surface is sufficient to overcome the friction of the clutch packs. This prevents the side gears from being held to the differential case.

Figure 3-166, Limited-Slip Function
**Locking Function**

Locking action occurs through the use of some special parts (refer to Figure 3-167):

- A governor mechanism with two flyweights
- A latching bracket
- The cam plate and cam side gear (left)

When the wheel-to-wheel speed difference is 100 rpm or more, the flyweights of the governor will fling out and one of them will contact an edge of the latching bracket (Figure 3-167, inset box). This happens because the left cam side gear and cam plate are rotating at a speed different than that of the ring gear and differential case assembly (either slower or faster). The cam plate has teeth on its outer diameter surface in mesh with teeth on the shaft of the governor.

As the side gear rotates at a speed different than that of the differential case, the shaft of the governor rotates with enough speed to force the flyweights outward against spring tension. One of the flyweights catches its edge on the closest edge of the latching bracket, which is stationary in the differential case. This latching process triggers a chain of events.

*Figure 3-167, Locking Mechanism and Governor in the Latched Position*
When the governor latches, it stops rotating. A small friction clutch inside the governor allows rotation (with resistance) of the governor shaft while one flyweight is held to the differential case through the latching bracket. The purpose of the governor’s latching action is to slow the rotation of the cam plate as compared to the cam side gear. This will cause the cam plate to move out of its detent position, as shown in Figure 3-168.

*Figure 3-168, Cam Plate Moving Out of the Detent Position*
The cam plate normally is held in its detent position by a small wave spring and detent humps resting in matching notches of the cam side gear (refer to Figure 3-169, inset box). At this point, the ramps of the cam plate ride up the ramps of the cam side gear, and the cam plate compresses the left clutch pack (refer to Figure 3-169) with a self-energizing action.

As the left clutch pack is compressed, it pushes the cam plate and cam side gear slightly toward the right side of the differential case. This movement of the cam side gear pushes the thrust block, which compresses the right-hand side gear clutch pack.

At this point, the force of the self-energizing clutches and the side gear separating force combine to hold the side gears to the differential case in this locking stage.

The entire locking process occurs in less than one second. The process works with either the left or right wheel spinning, due to the design of the governor and cam mechanism. A torque reversal of any kind will unlatch the governor, causing the cam plate to ride back down to its detent position. Cornering or deceleration during a transmission shift will cause a torque reversal of this type. The differential unit returns to its limited-slip function.

Figure 3-169, Disc Compression – Locking Function
The self-energizing process would not occur if it were not for the action of one of the left clutch discs. This energizing disc (refer to Figure 3-170) provides the holding force for the ramping action to occur. It is the only disc which is splined to the cam plate itself. The other splined discs fit on the cam side gear.

If the rotating speed of the ring gear and differential case assembly is high enough, the latching bracket will pivot (due to the centrifugal force). This will move the contact edge far enough away from the governor flyweights so that no locking is permitted (Figure 3-171). During vehicle driving, this happens at approximately 20 mph and continues at faster speeds.
Eaton Locking Differential

Torque-Limiting Disc

The Eaton locking differential design was modified in mid-1986 to include a load-limiting feature to reduce the chance of breaking an axle shaft under abusive driving conditions. The number of tangs on the energizing disc in the left-hand clutch pack was reduced (refer to Figure 3-171), allowing these tangs to shear in the event of a high-torque engagement of the differential locking mechanism.

At the time of failure of the load-limiting disc, there will be a loud bang in the rear axle and the differential will operate as a standard differential with some limited-slip action of the clutch packs at low torques.

The service procedure, when the disc tangs shear, involves replacing the left-hand clutch plates and the wave spring. It is also necessary to examine the axle shafts for twisting because at high torques it is possible to not only shear the load-limiting disc, but to also twist the axle shafts.
Limited-Slip Differential Unit Diagnosis

Improper operation is generally indicated by clutch slippage or grabbing. Sometimes this produces a chatter or whirring sound. However, these sounds are not always indicative of failure, as they could be produced from a lack of proper lubrication. For example, under certain conditions where one wheel is on a very slippery surface and the other is on dry pavement, wheel spin can occur if over-acceleration is attempted. Continued spinning may cause audible noise, such as a whirring sound, due to the clutches or cones lacking sufficient lubricant. This does not necessarily indicate failure of the unit.

During regular operation (such as straight-ahead driving when both wheels rotate at equal speeds), there is an approximately equal driving force delivered to each wheel. When cornering, the inside wheel delivers extra driving force causing slippage in both clutch packs. Consequently, the operational life of the limited-slip unit is dependent upon equal rotation of both wheels during straight-ahead operation. If wheel rotation for both rear wheels is not equal during straight-ahead operation, the limited-slip unit will constantly be functioning as if the vehicle were cornering. This will impose constant slippage on the clutch packs and will eventually lead to abnormal wear on the clutch pack or cone. Therefore, it is important that there be no excessive differences in the rear wheel tire sizes, air pressures, or tire wear patterns. One indication of this condition is “swerving on acceleration.” If swerving on acceleration is encountered, check the rear wheels for different tire size, air pressure, or excessively different wear patterns and tread depths before proceeding into an overhaul operation.

Operating Characteristics

Limited-slip rear axles have several definite operating characteristics. An understanding of these characteristics is a necessary aid to diagnosis.

The clutch energizing force comes from the side thrust of the pinion gears. Consequently, a free spinning wheel may not have enough resistance to driving torque to apply the clutch packs or cones. If this occurs, apply the parking brake a few notches, which will provide enough resistance to energize the clutch pack or cones.

Energizing the clutch packs is independent of acceleration; therefore, a very slow application of the throttle on starting is recommended to provide maximum traction by preventing “break away” of either rear wheel.
Checking Limited-Slip Operation

- Place the transmission in the Park position with the parking brake released.
- Raise both wheels off of the floor.
- Remove the hub cap or wheel disc and apply a torque wrench as shown in Figure 3-173.
- Measure the torque required to turn one wheel. If the torque reading is less than specified, the unit should be disassembled and repaired as required.

![Figure 3-173, Measuring Limited-Slip Rotating Torque]
Checking Eaton Locking Differential Unit Operation

1. Place the vehicle on a frame-contact hoist, allowing free rotation of the rear wheels.

2. Raise the hoist until the wheels clear the floor. Holding one wheel stationary, slowly rotate the other wheel approximately 1/2 revolution per second in both the forward and reverse directions. The wheel should rotate freely. If both wheels attempt to turn together, the differential is locking and is defective.

3. Raise the hoist to its maximum height with one person in the vehicle.

4. Start the engine, making sure that the carburetor is set at a correct slow idle speed.

5. With an automatic transmission, apply the brakes, then place the transmission in Drive. With a manual transmission, depress the clutch and place the transmission in First Gear.

6. Have an assistant lock one rear wheel by pulling one parking brake cable from under the vehicle.

7. With the engine running at low idle, slowly release the brakes or slowly engage the clutch, as required.

8. The locked rear wheel will remain stationary and the free wheel will begin turning. It is important that the brakes or clutch be released slowly enough to start the free wheel turning and allow the free wheel to gradually increase in speed. As the speed of the free wheel is increased, the differential will lock, causing the rotating wheel to stop or both wheels to turn at the same speed. The engine may stall if equipped with a manual transmission. It may be necessary to accelerate the engine until approximately 10 mph is indicated on the vehicle speedometer to cause differential lock. If the indicated speed can be increased beyond 20 mph (32 km/h) without causing differential lock, the unit is not functioning properly. Rapid release of the brakes or clutch, or rapid acceleration of the engine will invalidate the test.

9. Lock the opposite rear wheel and repeat the procedure. The diagnosis chart (see Figure 3-174) provides guidelines for diagnosis and repair of various differential complaints.
<table>
<thead>
<tr>
<th>COMPLAINT</th>
<th>POSSIBLE CAUSE</th>
<th>CORRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does not lock.</td>
<td>1. Little or no spring preload on the latching bracket.</td>
<td>1. Replace governor assembly and latching bracket.</td>
</tr>
<tr>
<td></td>
<td>2. Flyweights on governor assembly stuck closed.</td>
<td>2. Replace governor assembly and latching bracket.</td>
</tr>
<tr>
<td></td>
<td>3. Broken drive teeth on governor and/or cam gear assembly.</td>
<td>3. Replace cam plate, governor assembly and latching bracket.</td>
</tr>
<tr>
<td></td>
<td>4. Broken clutch plates.</td>
<td>4. Replace clutch plates and wave spring.</td>
</tr>
<tr>
<td></td>
<td>2. Broken or weak governor flyweight spring.</td>
<td>2. Replace governor assembly and latching bracket.</td>
</tr>
<tr>
<td></td>
<td>3. Flyweight in governor assembly stuck open.</td>
<td>3. Replace governor assembly and latching bracket.</td>
</tr>
<tr>
<td></td>
<td>4. Broken cam plate and/or governor drive teeth.</td>
<td>4. Replace cam plate, governor assembly and latching bracket.</td>
</tr>
<tr>
<td></td>
<td>2. Clutch plates deteriorated.</td>
<td>2. Replace clutch plates.</td>
</tr>
<tr>
<td>Noisy.</td>
<td>NOTE: In addition to normal axle noise, the locking differential exhibits some clutch noise upon engagement and disengagement.</td>
<td>1. Replace clutch plates.</td>
</tr>
<tr>
<td></td>
<td>2. Broken clutch plates.</td>
<td>2. Replace thrust block.* Check closely for other damage. Replace entire unit if case is damaged.</td>
</tr>
<tr>
<td></td>
<td>3. Broken differential gears.</td>
<td>3. Replace gears.** Check closely for other damage. Replace entire unit if case is damaged.</td>
</tr>
</tbody>
</table>

*Figure 3-174, Eaton Locking Differential Diagnosis*
Rear Axle Flushing Procedure (Disc-Type Limited-Slip Units)

In some cases, after extended expressway driving during high ambient temperatures, a “slip/stick” condition may occur in the clutch plates with locking or limited-slip axles during tight turns. The condition may be described as “chatter.” A rubbing or moaning noise may accompany this “chatter.”

1. Remove the rear axle cover and gasket, drain the lubricant and clean out the housing. (The lubricant must be at operating temperature.)

2. Install the cover with a new gasket and tighten the cover bolts in a crosswise pattern to the specified torque.

3. Add rear axle lubricant additive to the rear axle and then fill the axle with the proper lubricant to the specified level.

4. Raise both rear wheels off of the floor and, with the vehicle properly supported, start the engine and place the transmission selector in “Drive.” Run the engine for four minutes at a speed not to exceed 30 mph (48 km/h) on the vehicle speedometer.

5. Drive the vehicle in a figure-eight manner, making at least ten (10) complete loops to thoroughly work the axle lubricant into the clutch pack.

If it is not possible to perform Step 5, the owner should be advised that it will require a minimum of 25 miles of normal driving to thoroughly work the new lubricant into the clutch pack.

If “chatter” re-occurs at a later mileage, add rear axle lubricant additive only.
Eaton Locking Differential Service

Important: These are general service procedures for the Eaton Locking Differentials (excluding the 10.50-inch unit). Refer to the Service Manual for more detailed procedures.

Disassembly of the Cam Unit Assembly

1. Remove the E-clips that hold the latching bracket in place on the bracket shaft. Then move the bracket down the shaft.

2. Remove the governor and its latching bracket bushings using tool J 26252 (refer to Figure 3-175).

Note: There is a bulletin for modifying this tool for use on newer differentials. After removing the bushings, remove the governor and latching bracket from the differential case.

3. Remove the pinion shaft lock screw and then remove the pinion shaft.

4. Remove the pinion gears and thrust washers by rotating one of the side gears. Next, remove the thrust block.

5. Remove the right- and left-hand side gears and the clutch packs from the differential case. Also, remove the two thrust washers.

Important:

On 9.50-Inch Eaton Locking Differentials, the overall length of the right-hand side-gear assembly must be measured prior to pressing off the
thrust sleeve. This measurement is from the front of the gear to the back of the side thrust sleeve, including the side gear thrust washer.

6. Disassemble the cam unit assembly by either removing the retaining ring from the right side gear using snap ring pliers (refer to Figure 3-176) or by pressing off the thrust sleeve.

7. Remove the clutch plates, wave washer and cam plate from the assembly.

---

**Figure 3-176, Cam Side-Gear Assembly**
9.50-Inch Eaton Locking Differentials

1. Install the cam plate on the side cam gear.
2. Install the wave washer.
3. Install the clutch plates. Alternate the plates as shown in Figure 3-177.
4. Press the thrust sleeve on the side gear flush with the side gear disc splines.
5. Install the guide clips on the clutch plates. Use a small amount of grease on the clips to hold them in place on the clutch plates.
   • If the side cam gear or side thrust sleeve has been replaced, measure and record the overall length of the gear assembly from the front of the gear to the back of the side thrust sleeve, including the side gear thrust washer.
   • Compare this measurement with the measurement obtained during disassembly.
   • If the new measurement is more than 0.003 inch (0.0762 mm) higher or lower than the original measurement, select a thrust washer that will return the measurement closer to the original measurement.

![Diagram of 9.50-Inch Cam Unit Assembly](image-url)

*Figure 3-177, 9.50-Inch Cam Unit Assembly*
Adjustment of the Differential

If it is necessary to replace the cam gear, right side gear or thrust block, the entire differential must be adjusted. The differential is adjusted by using selective thickness thrust washers behind each side gear and a selective thickness thrust block. There are three adjustments:

- Left side gear backlash
- Right side gear backlash
- Thrust block clearance

Side Gear Backlash

This procedure can be used with both the Eaton Locking and open-type differentials to determine if there is excessive clearance between the side gears and differential pinion gears.

1. Install one of the side gears in the differential case.
   - On locking differentials, the clutch plates and selective thickness shims must be installed on the side gears.

2. Install the pinion gears and the pinion shaft in the differential case.
   - On the locking differential, this may require pressing down on the side gear. If the side gear cannot be pressed down enough, replace the selective thrust washer with a thinner washer.

3. Rotate the pinion gear closest to the lock screw, so that one of the teeth is pointing downward.

4. Insert a large tapered screwdriver firmly between the side gear and the pinion shaft. (Refer to Figure 3-178).

5. Mount the dial indicator to the ring gear flange and place the stem of the indicator on one of the teeth on the pinion gear closest to the lock screw.

6. Pull the pinion gear firmly into its seat and rotate the gear back and forth while reading the dial indicator. Record the measurement.

7. Repeat Steps 3 through 6 for the other pinion gear.

8. Remove the differential gears.

Figure 3-178, Checking Backlash
9. Perform Steps 1 through 7 for the other side gear.

- The specification for open-type differentials is 0.003 inch to 0.009 inch for both side gears. If any of the measurement are outside of the specifications, the differential gearset must be replaced.
- The specification for the left side gear on locking differentials (excluding the 10.50-inch unit) is 0.010 inch to 0.018 inch. If the backlash is outside of the specifications, a different thickness thrust washer must be used.
- The specification for the right side gear on locking differentials (excluding the 10.50-inch unit) is 0.002 inch to 0.010 inch. If the backlash is outside of the specifications, a different thickness thrust washer must be used.

**Thrust Block Clearance Adjustment**

1. Install the left thrust washer in the differential case.
2. Install the cam unit in the differential case. This includes the cam side gear, cam plate and the clutch pack.
3. Install the right side gear thrust washer in the differential case.
4. Install the right side clutch pack in the differential case.
5. Install the right side gear in the differential case.
6. Install the pinion shaft and lock screw. Insert a large tapered screwdriver firmly between each side gear and the pinion shaft.
7. Install a 1-2 inch telescoping gauge between the side gear faces (not the gear teeth).
8. Measure the side gear spread (refer to Figure 3-179).
9. Remove the telescoping gauge and measure the gauge with a micrometer. Record the measurement.
10. Measure the original thrust block at the outer corner with a micrometer and record the measurement.

- If the thrust block is not 0.00 inch to 0.006 inch less than the side gear spread, the clearance must be adjusted by either:
  - Selecting a new thrust block to obtain the correct clearance.
  - Re-shimming the right and/or left clutch plates. The backlash must be rechecked and adjusted to specifications.
Assembly of the Differential

1. Install the left side thrust washer and cam unit. Refer to Figure 3-180.
2. Install the right side thrust washer and clutch pack with the guide clips.
3. Install the right side gear.
4. Install the thrust block, pinion thrust washers and pinion gears:
   • Place the pinion gears into the differential 180 degrees apart.
   • Rotate the gears and thrust block into position.
   • The open side of the thrust block must face the small window opening.
5. Install the pinion shaft and a new lock screw (finger tight). The lock screw will be tightened to specification once the axle shafts are installed.
6. Install the governor assembly and latching bracket.
   • The straight end of the latching bracket spring must be over and outside the governor assembly shaft.
7. On the 9.50-inch unit, install the stop pin, pressing it flush with the case.
8. Install the governor bushing:
   • Use the bushing with a straight hole, not a tapered hole.
   • Press the bushing in far enough to give 0.004 inch to 0.020 inch shaft end play.
9. Install the latching bracket bushing:
   • Press the bushing in far enough to eliminate all end play. Some bushings for the 9.50-inch unit have a tapered hole. Do not use a straight bushing, use only a tapered bushing.
Figure 3-180, Eaton Locking Differential Unit Assembly
6. Propeller Shafts

Objectives

Upon completion of Section 6 of the course, you will be able to:

• Identify and describe the different propeller shaft configurations.
• Identify and describe the disassembly and assembly procedures associated with single and double-Cardan universal joints.
• Perform service on a double-Cardan universal joint.
Propeller Shaft Assembly

The propeller shaft assembly transmits rotating force from the transmission or transfer case to the rear axle assembly. It has to be strong enough to handle the highest torque transferred to the rear axle, yet flexible enough to allow movement of the powertrain components – especially the rear axle.

To do its job, the propeller shaft is comprised of (refer to Figure 3-181):

- One or more propeller shaft assemblies (refer to Figure 3-182)
- A slip yoke, connecting the transmission to the propeller shaft and also one propeller shaft to another (in multi-shaft applications)
- A pinion companion flange yolk, which was discussed earlier in this book as part of the drive pinion assembly
- Two or more universal joint assemblies, connecting the component yokes to the yokes of the propeller shaft assembly

To accommodate various model, wheelbase and transmission combinations, propeller shaft assemblies differ in these features:

- Total assembled length
- One- or two-piece propeller shafts, which vary in:
  - Diameter and length of tubing
  - Tubing material (steel or aluminum)
- Slip yoke and pinion flange yoke construction
- Joint type (single- or double-Cardan)

With all of the varieties of construction, there are some basic features and principles of operation common to all propeller shaft assemblies.
Figure 3-182, One- and Two-Piece Propeller Shafts
Propeller Shaft

The propeller shaft assembly consists of:

- Tubing of a certain length and diameter (refer to Figure 3-183)
- Universal joint yokes welded to the tubing ends

The tubing material may be steel, with forged steel yokes welded to it in "phased" position. Aluminum tubing and yokes are also used.

*Figure 3-183, Propeller Shaft Tubing Types*
To dampen propeller shaft noises, cardboard may be used to line the propeller shaft walls (Figure 3-184).

In propeller shaft design for passenger cars and light-duty trucks, it is necessary to limit the length and diameter of the tubing. This is why drive shaft assemblies have more than one propeller shaft. The most common multi-piece assembly is used on light-duty trucks (Figure 3-185).

In the two-piece propeller shaft setup, a center bearing support holds the front shaft, and it does not move fore and aft. The support consists of a:

- Single-row radial ball bearing, permanently lubricated and sealed
- Metal bracket mounted to the vehicle frame so that the front shaft slip yoke “bottoms” into the transmission output shaft splines
- A rubber isolator cushion, which fits into the bracket and has a bore to fit the ball bearing

The rear shaft operates like a one-piece drive shaft, with a slip yoke at its connection to the front shaft which allows for a change in length.
The slip yokes used at both the transmission and between the front and rear shafts, operate with the “involute” spline construction (Figure 3-186). The slip yoke at the transmission output shaft uses what is known as a major diameter fit. Both the outside diameter of the transmission output shaft and the inside diameter of the slip yoke are carefully machined. As Figure 3-186 shows, this type of fit has some backlash between spline teeth built into its design.

As Figure 3-185 shows, a bushing is used to support not only the drive shaft, by way of the slip yoke, but also to support the transmission output shaft, as well.

On two-piece drive shaft assemblies, the center slip yoke uses a mating of spline teeth known as side fit. This is usually a very snug fit, with no visible backlash present, as with the transmission slip yoke.

Figure 3-186, Slip Yoke Sealing Design at Transmission Output Shaft

Figure 3-187, Spline Symbols and Terms
The center slip yoke can be designed with either internal or external splines. Center slip yokes with external splines on the yoke were used on older applications. Center slip yokes with internal splines are used on most newer applications (refer to Figure 3-188). The rear of the front propeller shaft on these applications has external splines on it, and the center slip yoke (rear propeller shaft) has internal splines.

The pinion companion flange yokes have construction features related to the type of universal joint being used.

The two yokes shown in Figure 3-189 are used for the single-Cardan universal joint.

If a double-Cardan universal joint is used, a circular flange yoke is used with a centering hub section.
Propeller Shaft Universal Joints

To allow the propeller shaft assembly to be flexible, joints are needed. The most common joint is the Cardan-design universal joint, often called a “U-Joint” (see Figure 3-190).

A simple universal joint is made from two Y-shaped yokes connected by a crossmember that may be called a “cross” or “spider” (Figure 3-190). The four arms that extend from the body of the cross are known as “trunnions.”

The cross allows the two yokes (and the shafts which are connected to them) to operated at an angle to each other. When torque is transmitted at an angle through this type of joint, the driving yoke rotates at a constant speed while the driven yoke speeds up and slows down twice per revolution. This changing of velocity (acceleration) of the driven yoke increases as the angle between the two yoke shafts increases.

This is the major reason why single universal joints are not used for angles greater than three degrees. At four degrees the change in velocity is 1/2 percent. At ten degrees, it is three percent.

If a universal joint was set at a 30-degree angle and the driving yoke was turning at 1000 rpm, the velocity of the driven yoke would change from 856 rpm to 1155 rpm at 1/4 revolution.

In the remaining 1/4 revolution, the velocity would change from 1155 rpm to 856 rpm.

On a one-piece drive shaft assembly, this problem can be eliminated by arranging two simple universal joints so that the two driving yokes are rotated 90 degrees from each other. However, the angle between the drive yoke and the driven yoke must be nearly the same on both joints for this to work (refer to Figure 3-191).
This allows the alternate acceleration and deceleration of one joint to be offset by the alternate deceleration and acceleration of the second joint. When the two joints do not run at approximately the same angle, operation can be rough and an objectionable vibration can be produced.

Universal joints are designed to consider the effects of various loadings and rear axle wind-up during acceleration. Within design-angle variations, the universal joints will operate safely and efficiently. However, when design angles are exceeded, the operational life of the joints may decrease.

The bearings used in universal joints are the needle roller type. The needle rollers are held in place on the trunnions by round bearing cups. The bearing cups are held in the yoke by either snap rings (internal or external) or by plastic injections (refer to Figure 3-192).

The plastic injection joints are usually lubricated for life and cannot be lubricated while on the vehicle. The joints using snap rings can be disassembled, lubricated, and reinstalled, if necessary.
Constant Velocity Joint – Double-Cardan Joint

As described previously, the simple universal joint will operate efficiently through small angles only. Also, two simple universal joints phased properly and operating through the same angle will transmit constant velocity. When a large angle is encountered in a driveline, a simple universal joint will introduce two vibrations in each revolution. It is in this situation that a constant-velocity joint is used (refer to Figure 3-193).

Essentially, the constant-velocity joint is two simple universal joints closely coupled by a coupling yoke, phased properly for constant velocity.

A centering ball socket between the joints maintains the relative position of the two units. This centering device causes each of the two units to operate through one-half of the complete angle between the drive shaft and differential carrier (refer to Figure 3-194).

The ball/socket on this constant-velocity joint requires periodic lubrication. A lubrication fitting is provided for this purpose.

Figure 3-193, Simplified Illustration of a Constant Velocity Joint

Figure 3-194, Rear Double-Cardan Universal Joint
Applications for the double-Cardan universal joint can be seen in Figure 3-195. The “Type 1-2” shaft assembly is used for a front drive axle connection to the transfer case on some light-duty trucks. “Type 1-2” means that there is one single universal joint and one double-Cardan universal joint. “Type 2-2” means that there are two double-Cardan universal joints.

**Figure 3-195, Type 1-2 and Type 2-2 Propeller Shaft Assemblies**
The “Type 2-2” shaft assembly was used on full-size passenger cars until recently, and the “Type 2-2-2” assembly (refer to Figure 3-196) has been found on full-size passenger cars built as “commercial chassis” vehicles.

![Figure 3-196, Type 2-2-2 Propeller Shaft Assembly](image)

**Figure 3-196, Type 2-2-2 Propeller Shaft Assembly**
Diagnosis of Drive Shaft Assemblies

Objectionable vibration, roughness, rumble or boom can be caused by the input from a number of systems.

The following diagnostic charts (refer to Figures 3-197 and 3-198) provide a systematic approach to finding the vehicle problem.

To determine whether the propeller shaft is causing the problem, drive the vehicle through the speed range and note at which speed the problem is most pronounced. Shift the transmission into a lower gear range and drive the vehicle at the same vehicle speed as when the problem was most pronounced. If the problem is still present at the same vehicle speed, the propeller shaft may be at fault. Refer to the propeller shaft diagnostic charts.

Propeller Shaft Runout Measurement

If a noise or vibration is present at high speed, it might be caused by a bent shaft; or if a shaft has been damaged through rough handling or a collision, it may be checked for straightness as follows:

1. Raise the vehicle on a twin-post hoist so that the rear is supported on the rear axle housing with the wheels free to rotate.

2. Mount a dial indicator on a moveable support that is high enough to permit contact of the indicator button with the propeller shaft or mount the dial indicator to a magnetic base and attach it to a suitable smooth place on the underbody of the vehicle. Readings should be taken at the points indicated in Figure 3-197.

3. With the transmission in neutral, check for runout by turning a rear wheel to rotate the propeller shaft.

Important:

Care must be taken not to include indicator variation caused by ridges, flat spots or other variations in the tube.

4. If runout exceeds specifications, reindex the propeller shaft 180 degrees at the rear axle companion flange and recheck runout.

5. If runout is still over specifications, check the rear axle companion flange for runout.

![Figure 3-197, Propeller Shaft Runout Measurement](image)
<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>CAUSE</th>
<th>CORRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak at front slip yoke. (An occasional drop of lubricant leaking from</td>
<td>1. Rough outside surface on slip yoke.</td>
<td>1. Replace seal if cut by burns on yoke. Minor burns can be smothed by</td>
</tr>
<tr>
<td>splined yoke is normal and requires no attention.)</td>
<td>2. Defective transmission rear oil seal.</td>
<td>careful use of crocus cloth or horning with a fine stone. Replace yoke if</td>
</tr>
<tr>
<td></td>
<td></td>
<td>outside surface is rough or badly burred.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Replace transmission rear oil seal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Bring transmission oil up to proper level after correction.</td>
</tr>
<tr>
<td>Knock in drive line; clunking noise when car is operated under float</td>
<td>1. Worn or damaged universal joints.</td>
<td>1. Replace.</td>
</tr>
<tr>
<td>condition at 10 mph in high gear or “Neutral.”</td>
<td>2. Side gear hub counterbore in differential worn</td>
<td>2. Replace differential case and/or side gears as required.</td>
</tr>
<tr>
<td></td>
<td>oversize.</td>
<td></td>
</tr>
<tr>
<td>Ping, snap, or click in drive line.</td>
<td>1. Loose upper or lower control arm bushing bolts.</td>
<td>1. Tightened bolts to specific torque.</td>
</tr>
<tr>
<td></td>
<td>2. Worn or damaged universal joints.</td>
<td>2. Replace.</td>
</tr>
<tr>
<td>Scraping noise.</td>
<td>1. Slinger rubbing on rear axle carrier.</td>
<td>1. Straighten slinger to remove interference.</td>
</tr>
</tbody>
</table>

Figure 3-198, Propeller Shaft Diagnosis – Chart #1
Figure 3-199, Propeller Shaft Diagnosis – Chart #2
Propeller Shaft Service

Propeller Shaft Replacement

The rear universal joint-to-propshaft bolt on some models requires a #10 “Six-Lobed Socket” (J-33051) for proper removal and installation.

Notice:

Do not pound on original propeller shaft yoke ears as nylon-injected joints may fracture.

Removal

• Raise the vehicle on a hoist. Mark the relationship of the shaft to the pinion flange and disconnect the rear universal joint by removing the retainers. If the bearing cups are loose, tape them together to prevent dropping and possible loss of the bearing rollers.

• For models with two-piece shafts, remove the bolts retaining the center bearing support to the hanger and disconnect the grease seal and cap.

• Slide the drive shaft forward, disengaging the trunnion from the axle flange.

• Withdraw the drive shaft slip yoke from the transmission by moving the shaft rearward, passing it under the axle housing. Do not allow the drive shaft to drop or allow the universal joints to bend to an extreme angle, as this might fracture the injected joint internally. Support the drive shaft during removal.

Installation

Inspect for the following conditions before reinstalling the drive shaft:

• Inspect the outer diameter of the splined yoke for damage to ensure that it is not burred, as this will damage the transmission seal.

• Inspect the splines of the slip yoke for damage or wear.

The drive shaft must be supported carefully during handling to avoid jamming or damaging any of the parts. Do not drive the shaft in place with a hammer. Check for burrs on the transmission output shaft spline, for twisted slip yoke splines, or possibly for the wrong U-joint yoke. Make sure the splines agree in number and fit. To prevent trunnion seal damage, do not place any tool between the yoke and U-joint.
One-Piece Drive Shaft

- Slide the drive shaft into the transmission.
- Position the rear universal joint to the rear axle pinion flange, making sure that the bearings are properly seated in the pinion flange yoke.
- When making the rear shaft connection, be sure to align the mark on the pinion flange with the mark on the drive shaft rear yoke.
- Install the rear joint fasteners and tighten them evenly to the torque specified.

Two-Piece Drive Shaft

1. Install the front half into the transmission and bolt the center bearing support to the crossmember.
2. The front drive shaft yoke must be bottomed out in the transmission (fully forward) before installation onto the support.
3. Tighten the center support bearing to the crossmember attachment. Maintain the alignment shown in Figure 3-200.
4. Rotate the front propshaft, to locate the “bridged” teeth on its output spline, and then position them at the bottom-most (i.e., 6 o’clock) position. Then, find the missing tooth in the slip yoke, and position the yoke to slide over the bridged teeth on the front shaft.
5. Position the rear U-joint to the rear axle pinion flange, making sure that the bearings are properly seated in the pinion flange yoke. When making the rear shaft connection, be sure to align the mark on the pinion flange with the mark on the propshaft.
6. Install the rear joint retainers and fasteners and tighten them evenly to the specified torque.
7. Attach the seal and grease cap to the center slip yoke. Tighten the seal and cap firmly.
After assembly to the hanger, the front face of the bearing support assembly must be perpendicular to the centerline of the prop shaft as shown.

**PROP SHAFT SPLINE SETTING WITH 2-PIECE DRIVE SHAFT.**

The 2-Piece drive shaft must be assembled as follows to prevent excessive driveline excitation:

1. The transmission yoke must first be placed in a vertical position.
2. The front yoke of the rear prop shaft is set to a horizontal position as shown.

*Figure 3-200, Alignment for Phasing*
Universal Joint Replacement

Important:
Mark the slip joint and propeller shaft to ensure correct reassembly.

Nylon-Injected Ring Type Disassembly

Notice:
Never clamp the propeller shaft tubing in a vise, as the tube may be dented. Always clamp on one of the yokes and support the shaft horizontally. Avoid damaging the slip yoke sealing surface. Nicks may damage the bushing or cut the transmission extension housing seal.

- Support the propeller shaft in a horizontal position in line with the base plate of a press, as shown in Figure 3-201. Place the universal joint so that the lower ear of the shaft yoke is supported on a 1-1/8-inch socket. Place tool J-9522-3 on the open horizontal bearing cap and press the lower bearing cap out of the yoke ear. This will shear the nylon-injected retaining ring on the lower bearing cap.

![Figure 3-201, Pressing Out Universal Joint Bearing Cap](image)

- If the bearing cap is not completely removed, lift tool J-9522-3 and insert spacer J-9522-5 between the seal and bearing cap being removed, as shown in Figure 3-202. Complete the removal of the bearing cap by pressing it out of the yoke.

- Rotate the propeller shaft, shear the opposite nylon-injected retaining ring and press the bearing cap out of the yoke.

- Disengage the cross from the yoke and remove it.

- If the front universal joint is being replaced, remove the pair of bearing caps from the slip yoke in the same manner.

![Figure 3-202, Spacer Tool Installation](image)
Assembly

Important:

Production universal joints of this type cannot be reassembled. There are no snap ring bearing retainer grooves in production nylon-injected, ring-retained bearing caps.

When reassembling a propeller shaft, always install a complete universal joint service kit. This kit includes one (1) pregreased cross assembly, four (4) service bearing cap assemblies with seals, needle rollers, washers, grease, and four (4) snap rings. Make sure that the seals are in place on the service bearing caps to hold the needle rollers in place during handling. Nylon-injected types are replaced by external snap ring types, unless specified otherwise in the Service Parts Manual.

1. Remove all of the remains of the nylon-injected bearing cap retainers from the grooves in the yokes. The sheared nylon may prevent the bearing caps from being pressed into place, and thus prevent the bearing retainers from being properly seated.

2. Install one (1) bearing cap part way into one side of the yoke, and turn this yoke ear to the bottom.

3. Insert the cross into the yoke so that the trunnion seats freely into the bearing cap.

4. Install the opposite bearing cap part way. Make sure that both of the trunnions are started straight and true into both of the bearing caps.

5. Press against the opposite bearing caps, working the cross all of the time to check for free movement of the trunnions in the bearing caps. If there seems to be a hang-up, stop pressing and recheck the needle bearings. One or more of them has probably been tipped under the end of the trunnion.

Figure 3-203, Partially Inserted Bearing Cap

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6. As soon as one bearing-cap, snap-ring retainer groove clears the inside of the yoke (external snap ring type) or one bearing cap clears the internal snap-ring retaining groove in the yoke (internal snap ring type), stop pressing and install the snap ring into place.

7. Continue to press until the opposite snap ring can be installed in place. If difficulty is encountered, strike the yoke firmly with a hammer to aid in seating the snap rings. This springs the yoke ears slightly.

8. Assemble the other half of the universal joint in the same manner.

Figure 3-204, Installing Retaining Rings – External and Internal
External and Internal Snap Ring Types

Disassembly

See Figures 3-205 and 3-206:

These universal joints are of the extended-life design and do not require periodic inspection or lubrication. However, when these joints are disassembled, repack the bearings and lubricant reservoir at the end of the trunnions with chassis lubricant. Use care not to loosen or damage the dust seals. If the dust seals are loose or damaged, the entire universal joint must be replaced.

• Remove the snap rings. If snap ring does not readily snap out of the grooves, tap the end of the bearing cap lightly to relieve the pressure against the snap ring.

• Support the propeller shaft in a horizontal position in line with the base plate of a press. Place the universal joint so the lower ear of the propeller shaft yoke is supported on a 1-1/8-inch socket. Place tool J-9522-3 on the open horizontal bearing cap and press the lower bearing cap out of the yoke ear.

• If the bearing cap is not completely removed, lift tool J-9522-3 and insert spacer J-9522-5 between the seal and bearing cap being removed, as shown. Complete the removal of the bearing cap by pressing it out of the yoke.

• Rotate the propeller shaft and press the bearing cap out of the yoke.

• Disengage the cross from the yoke and remove it.

![Figure 3-205, Seating Universal Joint Snap Rings](image)

![Figure 3-206, Special Tools](image)
Assembly

See Figures 3-207 and 3-208:

1. Install one (1) bearing cap part way into one side of the yokes and turn this yoke ear to the bottom.

2. Insert the cross into the yoke so that the trunnion seats freely into the bearing cap.

3. Install the opposite bearing cap part way, making sure that both trunnions are started straight and true into the bearing caps.

4. Press against the opposite bearing caps, working the cross all of the time to check for free movement of the trunnions in the bearing caps. If there seems to be a hang-up, stop pressing and recheck the needle bearings. One or more of them has probably been tipped under the end of the trunnion.

5. As soon as one bearing cap snap ring retainer groove clears the inside of the yoke (external snap ring type) or one bearing cap clears the internal snap ring retaining groove in the yoke (internal snap ring type), stop pressing and install the snap ring into place.

6. Continue to press until the opposite snap ring can be installed into place. If difficulty is encountered, strike the yoke firmly with a hammer to aid in seating the snap rings. This springs the yoke ears slightly.

7. Assemble the other half of the universal joint in the same manner.

8. Torque specifications are 16-27 N•m (12-20 lb.-ft.) for the rear universal joint strap bolts.
Constant Velocity (Double-Cardan) Universal Joint Service

Inspection

An inspection kit, including two bearing caps and two snap rings, is available to allow the removal of the two trunnion caps shown at location 1 in Figure 3-208. Mark the flange yoke and coupling yoke for reassembly in the same position, as shown in Figure 3-309.

To service the trunnion caps, use the appropriate procedures given in the beginning of this section.

When both bearing caps are free, disengage the flange yoke and trunnion from the centering ball. Note that the ball socket is part of the flange yoke assembly, while the centering ball is pressed onto a stud and is part of the ball stud yoke. Pry the seal from the ball socket and remove washers, spring and the three ball seats.

- Clean and inspect the ball-seat insert bushing for wear. If the bushing is worn, replace the flange yoke and cross assembly.
- Clean and inspect the seal and ball seats along with the spring and washers. If any parts show indication of excessive wear or are broken, replace the entire set with a service kit.
- Whenever the seal is removed to inspect the ball seat parts, it should be discarded and replaced with a new seal.
- Remove all plastic from the groove of the coupling yoke.
- Inspect the centering ball surface. If it shows signs of wear beyond smooth polish, replace it.

Figure 3-208, Bearing Cap Removal Sequence

Figure 3-209, Reassembling Coupling Yoke
Centering Ball Replacement

1. Place the fingers of inner part of tool J-23996 under the ball, as shown in Figure 3-210.

![Figure 3-210, Installing Tool J-23996 Over Ball](image)

2. Place the outer cylinder of tool J-23996 over the outside of the ball as shown in Figure 3-211.

![Figure 3-211, Installing Outr Cylinder of Tool J-23996 Over Ball](image)

3. Thread the nut on tool J-23996 and draw the ball off of the stud, using a wrench, as shown in Figure 3-212.

![Figure 3-212, Removing Centering Ball](image)

4. Place the replacement ball on the stud.
5. Using tool J-23996, drive the ball onto the stud as shown in Figure 3-213, until the ball can be seen to seat firmly against the shoulder at the base of the stud. This is important as the center of the double-Cardan joint is determined by the ball seating tightly in the proper location.

6. Using the grease provided in the ball seat it, lubricate all of the parts and insert them into the clean ball seat cavity in the following order:
   - spring
   - washer (smallest O.D.)
   - three ball seats (with largest opening outward to receive ball)
   - washer (largest O.D.)
   - seal

7. Lubricate the seal lip and press the seal flush with tool J-23694, as shown in Figure 3-214. Sealing lip should tip inward.

8. Fill the cavity with the grease provided in the kit.

9. Install the flange yoke to the centering ball, as shown in Figure 3-215, making sure that the alignment marks are correctly positioned. Install the trunnion and the bearing caps as previously outlined.
The constant velocity (C.V.) joint, located at the transfer case end of the front propshaft, must be lubricated periodically with special lubricant #1050679, or with an equivalent. If the fitting cannot be seen from beneath the vehicle, Figure 3-216 shows how the fitting may be lubricated from above the C.V. joint with a special adapter J-25512-2 on the end of a flex hose.

The various special tools available for servicing the constant velocity (C.V) universal joints are shown in Figure 3-217.

![Figure 3-216, Lubrication Fitting]

![Figure 3-217, Constant Velocity Universal Joint Special Tools]
Center Support Bearing Replacement

See Figure 3-218:

- Remove the strap retaining rubber cushion from the bearing support.
- Pull the support bracket from the rubber cushion and pull the cushion from the bearing.
- Pull the bearing assembly from the shaft.
- Assemble the bearing support as follows:
  - Install the inner deflector on the propeller shaft, if removed, and prick the punch deflector at two opposite points to make sure that it is tight on shaft.
  - Fill the space between the inner dust shield and bearing with lithium soap grease.
  - Start the bearing and slinger assembly straight on the shaft journal. Support the propeller shaft and, using a suitable length of pipe over splined end of the shaft, press the bearing and inner slinger against the shoulder on the shaft.
  - Install the dust shield over the shaft, small diameter. Install the bearing retainer.
  - Install the rubber cushion onto the bearing.
  - Install the bracket onto the cushion.
  - Install the retaining strap.

Figure 3-218, Propeller Shaft, Universal Joint and Bearing Support
Important:
When reinstalling the propshafts, it is necessary to place the shafts into particular positions to insure proper orientation. This is called phasing. All models with 32 splines use an alignment key, as shown in Figure 3-219, to obtain proper phasing. The shafts can mate only in the correct position.

Some models with 16 splines must be phased.

- For models with one-piece propeller shafts, slide the shaft into the transmission and attach the rear U-joint to the axle.
- On models equipped with an automatic transmission and a one-piece shaft only, apply a small amount (approximately 18 grams) of lubricant P/N 9985038 inside the slip yoke before installing the propshaft.

Important:
On vehicles with two-piece propshafts, the front propshaft yoke must be bottomed out in the transmission fully forward before installation to the hanger.

- For some models with two-piece propeller shafts, proper phasing is accomplished with the alignment key, shown in Figure 3-219.
- For other models with two-piece shafts, install the front half into the transmission and bolt the support to the crossmember.
  - Slide the grease cap and gasket onto the rear splines.
  - Rotate the shaft so the front U-joint trunnion is in the correct position.
  - Take the rear propeller shaft and before installing it, align the U-joint trunnions. Attach the rear U-joint to the axle and then install the grease cap on the shaft. Tighten the grease cap.
  - Tighten the bearing support to the crossmember and the U-joint to the axle attachments.
Slip Spline Lubrication

Apply chassis lubricant at the fitting until grease begins to leave through the vent hole. If the slip spline is dry or corroded, it may be necessary to disconnect the propshaft from the vehicle, remove the slip yoke, and wire brush the affected areas. Wipe the areas clean before reinstallation. When installing the propshaft to the transfer case front output flange attaching bolts, tighten them to the specified torque.

Figure 3-219, Alignment Key
7. Reference

Basic Gearing*

Power Transmission

Gears can be used to vary speed and also to transmit power produced by the engine.

The action of a gear in transmitting power can be compared to the action of a lever (refer to Figure 3-221). When a lever is used to apply force, the lever moves or pivots on one spot. This pivot point is called a fulcrum.

A force on a lever at a given distance from the fulcrum results in an equal and opposite force (“reaction,” as shown in Figure 3-221) at the same distance from the fulcrum, on the other side. For example, if a one-pound weight were placed on a lever one foot from the fulcrum, it would be necessary to place one-pound weight one foot from the fulcrum on the opposite side of the fulcrum to balance the lever. This demonstrates that an equal and opposite force is produced on the opposite side of the lever, as shown in Figure 3-220.

If the fulcrum were changed into a shaft, and the lever was solidly fastened to the shaft, any force applied to the lever would tend to twist the shaft (Figure 3-222). For example, a downward force of one pound applied five feet from the pivot point or shaft results in a force of five pound-feet force on the shaft. Similarly, if the one-pound weight were one foot from the pivot or shaft, a one pound-foot force would be the result. Since this force tends to turn the shaft, the value of this force is stated at pound-feet of torque.

Many common examples of this lever-torque are seen in everyday work. Such things as torque wrenches are based on this principle. Figure 3-223 illustrates the relationship between a gear and a torque wrench. By allowing the distance from a tooth of the gear to the center of its pivot shaft to represent the lever arm of a torque wrench, any force applied to the lever will exert torque on the shaft. Conversely, Figure 3-224 illustrates that a torque of five pound-feet results in a five pound-feet force on the lever.
Torque may be transferred from one shaft to another by using two shaft and lever units with their lever tips touching. That is, by applying torque to one shaft, the force is transmitted through the levers to turn the other shaft. If the levers are of equal length, the torque of the driven shaft will be the same as the input torque. However, if the lever on the input unit is one foot long, the torque of the driven shaft is doubled (Figure 3-225).

This action is also known as torque multiplication.

If the shaft of the longer lever is the driving member, the output torque would be one half the input torque, but the ratio remains the same. Thus, ten lb.-ft. torque on the shaft of the two-foot lever results in a five lb.-ft. torque on the short lever’s shaft.

These examples show that torque can be transmitted, and that it can be multiplied or reduced depending on the lever length.

---

![Figure 3-224, Torque Applied to Shaft Results in Lever Force](image)

\[ \text{TORQUE} = 5 \text{ POUND-FEET} \]

\[ 5 \text{ POUND-FEET} = 5 \text{ FEET} = 1 \text{ POUND} \]

*Figure 3-224, Torque Applied to Shaft Results in Lever Force*

![Figure 3-225, Different Lever Length Results in Different Torques](image)

*Figure 3-225, Different Lever Length Results in Different Torques*
As these lever and shaft units rotate, neither shaft can turn very far before it becomes disengaged. Therefore, more levers are added to the shaft until there is a complete circle of levers. This circle of levers reacts in the same manner as a set of gears (see Figure 3-226).

**Axle Ratio**

The drive pinion gear is smaller than the ring gear. Having fewer gear teeth, it must rotate several turns in order to rotate the ring gear once. For example, if the drive pinion has 11 teeth and the ring gear has 41 teeth, the drive pinion must rotate 3.73 revolutions to rotate the ring gear once. This is known as axle ratio. Specifically, it is the ratio of the number of teeth on the ring gear divided by the number of teeth on the drive pinion. Consequently, the ring gear will rotate at a slower speed than the pinion gear which drives it. If a gear drives another gear that is larger in diameter, there will be a resultant speed reduction. Likewise, if a gear drives another gear that is smaller in diameter, there will be a resultant speed increase.

---

*Figure 3-226, Evolution From Lever and Shaft to Gears*
Gears

As previously stated, the rear axle transmits power through a 90° turn. To do this, bevel gears were previously used (refer to Figure 3-227). Straight bevel and spiral bevel gears were used for the ring and pinion gears; but the drive and driven gear centerlines must intersect, or meet, each other. This is satisfactory for differential side gears, but the desire to lower the drive shaft brought about another variation of the bevel gear – the hypoid gear (see Figure 3-228). Meshing hypoid gears do not require a meeting of their centerlines. The drive pinion gear may then be placed below the centerline of the ring gear and allow lowering the drive shaft.

Figure 3-227, Typical Application of Bevel Gears

Figure 3-228, Hypoid Gears
Differential Operation

A differential is an arrangement of gears that divides the torque between the axle shafts and allows them to rotate at different speeds. A basic differential consists of a set of four gears (refer to Figure 3-229). Two of these gears are called differential side gears, and the other two are called differential pinion gears. Some differentials have more than two pinion gears. Each side gear is splined to an axle shaft. Consequently, each axle shaft must turn when its side gear rotates.

The differential pinion gears are mounted on a differential pinion shaft, and the gears are free to rotate on this shaft. The pinion shaft is fitted into a bore in the differential case and is at right angles to the axle shafts.

Powerflow through the differential is as follows: The drive pinion rotates the ring gear. The ring gear, being bolted to the differential case, rotates the case. The differential pinion forces the pinion gears against the side gears. When both wheels have equal traction, the pinion gears do not rotate on the pinion shaft because the input force on the pinion gear is equally divided between the two side gears (see Figure 3-230).

Consequently, the pinion gears revolve with the pinion shaft (but do not rotate on the shaft itself). The side gears, being splined to the axle shafts and in mesh with the pinion gears, rotate the axle shafts.
If a vehicle was always driven in a straight line, the ring and pinion gears would be sufficient. The axle shaft could then be solidly attached to the ring gear, and both driving wheels would turn at equal speeds.

However, if it became necessary to turn a corner, the tires would scuff and slide because the outer wheel travels farther than the inner wheel (refer to the diagram in Figure 3-231). To prevent tire scuffing and sliding, the differential becomes effective and allows the axle shafts to rotate at different speeds.

As the inner wheel slows down, the side gear splined to the axle shaft also slows down. At this point, the pinion gears act as balancing levers by maintaining equal tooth loads to both side gears while allowing unequal speeds of rotation of the axle shafts, as shown in Figure 3-232. If the vehicle speed remains constant and the inner wheel slows to 90 percent of vehicle speed, the outer wheel speeds up to 110 percent. If the inner wheel slowed to 75 percent, the outer wheel would turn 125 percent. If one wheel stopped, the other wheel would turn 200 percent.
Design of Rear Axle Gears

When axle designers are planning the features of a ring-and-pinion gearset, they must consider the following factors:

- The type of vehicle (size, weight, function)
- The engine(s) to be used (gasoline vs. diesel, torque output)
- The transmission(s) to be used (automatic vs. manual, torque multiplication in the lowest speed range)
- The type of vehicle service (subjected loads, road surfaces)

Once these loads on the gearset are determined, three groups of specifications are blended to result in what the ring gear and drive pinion have as features:

- Type of gear combination (bevel, spiral bevel, or hypoid)
- Size of gears in the set (dimensions of both ring and pinion gears)
- Gear tooth specifications (details of construction)

In choosing what type of gear combination to use for the ring and pinion gears, axle designers usually do not consider the straight bevel gearset. Rather, they choose between spiral bevel and hypoid designs.

Spiral bevel gears have the drive pinion on center with the ring gear (Figure 3-233). Compared to straight bevel gears, spiral bevel gears have larger tooth cross-section size, and more tooth contact area.
Torque load is shared by two or more teeth in contact at the same time and there is no lengthwise sliding of teeth. Spiral bevel gear teeth have low surface pressure between tooth surfaces, as compared to straight bevel gears.

Hypoid gears have the drive pinion offset with respect to the centerline of the ring gear (Figure 3-234). This permits a larger, stronger drive pinion with more tooth contact.

Hypoid gears are smoother and quieter than spiral bevel gears. The gear tooth surface pressure is also lower on hypoid ring-and-pinion gears. Hypoid gearsets, however, have a considerable amount of lengthwise tooth sliding, which makes them sensitive to scoring conditions at high speeds.
Figure 3-235 is a summary of what axle designers use to compare the two major types of gears which can be used in rear axle construction.

The physical size of ring and drive pinion gears is determined by how the gears have to handle rotating forces during vehicle operation. How much torque must be handled is determined by:

• How much torque is produced by the engine
• How the transmission (in its lowest gear ratio) multiplies the engine’s torque
• How much torque can be transferred to the drive wheels before they slip

The gear tooth specifications for the ring and pinion gears fall into these categories:

• Number of teeth
• Size of teeth
• Face-width of the teeth
• Amount of drive pinion offset
• Spiral angle of the teeth
• Amount of taper of the teeth
• Pressure angle between the teeth
• The “hand of spiral” of the teeth

As slight changes are made in any one of these categories, the total operation of the gearset can be greatly affected. The number of pinion teeth is usually an odd number, and the combined numbers of ring and pinion gear teeth do not have a common factor. This is done to give maximum smoothness and quietness after lapping.
<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>SPIRAL BEVEL (compared to straight bevel)</th>
<th>HYPOID (compared to spiral bevel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quietness</td>
<td>Quiet</td>
<td>Quieter</td>
</tr>
<tr>
<td>Strength</td>
<td>Lower</td>
<td>As much as 30% higher loads, depending on offset - also better strength balance.</td>
</tr>
<tr>
<td>Pitting Resistance</td>
<td>Lower</td>
<td>As much as as 175% higher loads, depending on offset.</td>
</tr>
<tr>
<td>Scoring Resistance</td>
<td>As much as 200% higher loads.</td>
<td>Lower</td>
</tr>
<tr>
<td>Sliding Velocity</td>
<td>Lower</td>
<td>As much as as 200% higher, depending on the offset.</td>
</tr>
<tr>
<td>Efficiency</td>
<td>As high as 99%, depending on load and ratio.</td>
<td>As high as as 96%, depending on load and ratio.</td>
</tr>
<tr>
<td>Lubricant</td>
<td>Mild EP</td>
<td>EP (extreme pressure)</td>
</tr>
<tr>
<td>Sensitivity to Misalignment</td>
<td>Varies with mounting rigidity and cutter diameter.</td>
<td>Varies with mounting rigidity and cutter diameter.</td>
</tr>
<tr>
<td>Manufacture</td>
<td>Smaller point width cutter. More difficult to lap.</td>
<td>Larger point width cutter. Easier to lap.</td>
</tr>
<tr>
<td>Position of Vehicle, Center of Gravity</td>
<td>Higher drive shaft.</td>
<td>Lower drive shaft.</td>
</tr>
<tr>
<td>Outside Diameter of Differential Case</td>
<td>Larger – due to greater available space.</td>
<td>Smaller – due to less available space as a result of drive pinion interference.</td>
</tr>
<tr>
<td>Bearing Reaction</td>
<td>Less thrust on pinion.</td>
<td>Greater thrust on pinion.</td>
</tr>
</tbody>
</table>

*Figure 3-235, Rear Axle Gear Type Comparison*
The face-width dimensions for both pinion and ring gears are expressed in percentages of “cone distance” (Figure 3-236). It is common for the face of the pinion to overlap the face of the ring gear at both ends (called “buttressing”). This permits thinning of the pinion teeth and thickening of the ring gear teeth for optimum strength and balance.

The amount of offset has advantages and disadvantages. An increase in offset allows an increase in the diameter of the pinion with a corresponding increase in the strength of the ring and pinion pair. However, lengthwise sliding between the gear teeth and the sensitivity to scoring increase as offset increases.

The “hand of spiral” can be seen in Figure 3-237. Both pinions shown in (A) and (B) are “below center” offset with pinions which are “left-hand” as far as how the gear teeth curve. This setup is what is preferred over “above center” offset right-hand pinions. If there is movement between the pinion and ring gear, a left-hand pinion will push away from the ring gear, rather than jamming teeth with it.
Another category of tooth specifications for hypoid gearsets is that of tooth taper.

Especially seen while looking at the ring gear, the tapers of the gearset teeth are in four areas (Figure 3-238):

- Depth-wise taper
- Thickness taper
- Space-width taper
- Point-width taper

**Differential Pinion and Side Gear Design**

When axle designers plan the features of the differential pinion and side gears, they use straight bevel gears (Figure 3-239). The pinions act as balance levers between two side gears, dividing torque equally, and coarse-pitch stubbed-tooth gears increase the differential gear strength under static torque loads.

The recommended numbers of teeth are:

- At least 9 for the differential pinion gears
- 14 to 25 for the differential side gears

Final tooth number selection is related to space requirements. The sum of the numbers of teeth in the two side gears must be evenly divisible by the number of pinions (2, 3, or 4) to have the pinions equally spaced around the differential case.

Tooth thicknesses are proportioned for equal stress on both the differential pinion and side gears.

A pressure angle of 22-1/2° is the most commonly used choice for the transmitting of force between the gears.

The face width of differential gears is measured differently than with ring-and-pinion gearsets. The width dimensions are limited to 1/3 the cone distance of the pinion gears.
Basics of Gear Lubricants

Gear Materials

The material that a gear is made from, and its design, have a direct bearing on the type of lubrication it requires. The more that is known about gear materials and designs, the more will be understood about gear lubricants (Figure 3-240).

Gears are commonly manufactured from steel, cast iron, bronze, and plastic. These different materials lend themselves to a variety of applications.

Steel is composed of iron, carbon and other elements. These other elements modify the properties of the steel so it is better suited to a particular purpose. Heat-treating a steel gear will give it maximum strength.

Cast iron, like steel, consists primarily of iron and carbon. However, the carbon in cast iron is structured differently than in steel. It is this structure that allows a cast iron gear to operate with minimal lubrication but also makes it brittle.

Bronze is also used in gear manufacturing and is basically composed of 90 percent copper and 10 percent tin. Since bronze has the capability of tolerating high sliding loads quite well, it is primarily used in worm gears, where the motion is almost pure sliding.

Plastics are also used for gears, especially where noise is a problem. Plastics reduce noise by smoothing out and absorbing inaccuracies in tooth profile and spacing. Lubrication of plastic gears depends on the type of plastic used. Some types use water as a lubricant, while others, like nylon, are self-lubricating.

Gear Types

There are several types of gear designs in use today, all of which fall into three basic categories. Spur, helical, bevel and spiral bevel gears make up Group 1; hypoid gears are in Group 2; and worm gears are in Group 3. The types of gears are discussed in Section 2 of this book.
Recommended Lubricants by Type

Each group of gears we’ve discussed has a different type of action between its teeth. Because of these different types of action, different types of gear oils are needed.

The gears in Group 1 – spur, helical and spiral bevel – use a rolling action between their teeth. Their meshed teeth also tend to rub against one another. Because of these two types of action, they require a lubricant with a small percentage of extreme pressure additives. The GL-1 oils are the right oils to use with these types of gears.

The gears in Group 2 – hypoid gears – have both a rolling and a sliding action between their meshed teeth. This enables hypoid gears to withstand higher unit pressures than the gears in Group 1. Hypoid gears require an oil with a larger percentage of extreme pressure additives than the gears in Group 1, such as a gear oil with a GL-5 rating (see Figure 3-241).

The gears in Group 3 – worm gears – use a motion which is practically all sliding. These gears also operate at a relatively slow speed. The sliding action, combined with slow speeds, requires a lubricant with a high fatty content to prevent failure. Gear oils with a GL-2 rating have a high fatty content and are recommended for worm gears.

Figure 3-241, Gear Lubricant

GM REAR AXLE LUBE
Part #1052271, 23 OZ.
#1052272, 15 GAL.
Specially formulated to GM engineering specifications for maximum lubricating qualities and extended gear life. Use for positraction and standard axles. See catalog for specific usage.
Manual Transmission and Rear Axle Oils

Classifications (API)

Manual transmission and rear axle oils are classified into five basic categories by the American Petroleum Institute (API). They are:

- GL-1
- GL-2
- GL-3
- GL-4
- GL-5

Since gear oils with the classification GL-3 and GL-4 are not used frequently in vehicle applications, we'll concentrate on the remaining three classifications.

Lubricants meeting the GL-1 standards are basically straight mineral oil. Oxidation and rust inhibitors, defoamers and pour depressants are sometimes used to improve the characteristics of the oil. GL-1 oils are used in some types of manual transmissions (Figure 3-242).

Lubricants that have achieved the GL-5 rating are mainly used to lubricate hypoid gears, like the kind that are used in rear axles. Oils with the GL-5 rating contain about 10-percent extreme pressure additives.

Lubricants that meet the GL-2 standard are basically used for worm gears and have a high fatty content. GL-2 oils used to contain a by-product of sperm whale oil, but now contain synthetic additives that make them more like animal fat. These additives also give the lubricant mild extreme pressure properties.

Other Characteristics

Testing is a necessary part of developing satisfactory gear oils. Oils that are recommended for use in manual transmissions and rear axles must pass tests for:

- Load-carrying capacity
- Viscosity
- Channeling
- Oxidation resistance
- Foaming
- Corrosion Resistance
- Seal compatibility
Load-carrying capacity is the capability of an oil to prevent metal-to-metal contact of gears under low speed, high torque conditions. An extreme pressure additive, such as zinc dithiophosphate (ZDP), is used to prevent this metal-to-metal contact (Figure 3-244).

Viscosity tests are another phase in the testing of gear oils. To pass this test, the viscosity of an oil must not increase more than 100 percent when it is exposed to a heat of 325° F for 50 hours.

Gear oils must resist channeling at low temperatures. Channeling is when a gear oil becomes so thick it can’t flow between the meshed surfaces of gear teeth. Thick oil tends to stay away from the gear contact surfaces and forms a path that looks like a channel. Channeling occurs more often as the outside temperature drops.

Oxidation resistance is also an important property that’s required of a gear oil. Long periods of time and high operating temperatures contribute to oil oxidation. Oxidation leads to the formation of sludges, varnishes and corrosive acids (Figure 3-245).

Foaming is caused by rotating gears whipping air into the oil. Foam remains for quite some time after the gears have stopped turning. Gear lubricants can minimize foaming, but not prevent it. The only time you need to be concerned about foaming is when the amount of foaming is so great that the gear oil escapes through seals or vents. In these rare cases, something else has caused the foaming, not the gear lubricant. The causes for excessive foaming are:

- Water contamination
- Low lubricant level
- High lubricant level
- Oxidized lubricant
- Air leakage

Figure 3-245, Sludge Formation
Corrosion resistance is another gear oil test. Basically the corrosion we’re talking about is in the form of rust and is caused by water and acids. Gear oils contain a small percentage of anti-rusting additives to prevent the formation of rust.

Seal compatibility is another quality that’s required of a gear oil. Gear oils must be compatible with the seals used in manual transmissions and rear axles (Figure 3-246). If the gear oil isn’t compatible with the seals, the seals can swell and deteriorate. This can lead to seal failure.

Probably the most important point of this section of gear oils is this: different transmissions and rear axles have different lubrication requirements. So, when adding or changing oil in a manual transmission or rear axle, be sure to check the manufacturer’s recommendations.
Limited-Slip Differential Lubricants

Limited-slip differentials require a different oil than conventional differentials. If the wrong oil is used, the clutch plates in the differential (if so equipped) will gum up and not release when turning a corner. This causes clutch chatter and accelerates tire wear.

If you’re having problems with clutch chatter, drain the axle while it’s warm. After the axle is drained, refill the axle with the proper differential oil and one four-ounce bottle of limited-slip differential lubricant additive, as shown in Figure 3-247. This will help stop clutch chatter in most instances.

When you need to add oil to a limited-slip differential, use an oil that’s approved for limited-slip differentials. Some oils are specially formulated to be used in either limited-slip or conventional differentials. Either way, be sure you use the right gear oil and follow the manufacturer’s recommendations.

Lubricant Specifications

Lubricant types are as follows:

A. 80W-90 GL-5 (GM Part No. 1052271)
B. 80W-90 modified GL-5 (GM Part No. 1050010)
C. Limited-slip differential additive (GM Part No. 1052358)

The recommended applications for these lubricants are shown in Figure 3-248.

<table>
<thead>
<tr>
<th>Rear Axle Assembly</th>
<th>Differential Type</th>
<th>Eaton Locking Disc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open</td>
<td>Disc L/S</td>
</tr>
<tr>
<td>AAM/Saginaw 6.50&quot;</td>
<td>A</td>
<td>A and C</td>
</tr>
<tr>
<td>7.50&quot; and 7.625&quot;</td>
<td>A</td>
<td>A and C</td>
</tr>
<tr>
<td>8.50&quot;</td>
<td>A</td>
<td>A and C</td>
</tr>
<tr>
<td>9.50&quot;</td>
<td>A</td>
<td>A and C</td>
</tr>
<tr>
<td>10.50</td>
<td>A</td>
<td>A and C</td>
</tr>
<tr>
<td>Borg-Warner (78) 7.75&quot;</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Dana (36) 7.875&quot;</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>(44) 8.50&quot;</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>(60) 9.75&quot;</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>(70) 10.50&quot;</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-248, Applicants for Lubricants
Axle and Manual Transmission Lubricant Designations*

The following designations are quoted from API Publication 1560, Lubricant Service Designations for Automotive Manual Transmissions and Axles, February 1976.

**API-GL-1**: Designates the type of service characteristic of automotive spiral-bevel and worm-gear axles and some manually operated transmissions operating under such mild conditions of low unit pressures and sliding velocities, that straight mineral oil can be used satisfactorily. Oxidation and rust inhibitors, defoamers, and pour depressants may be utilized to improve the characteristics of lubricants for this service. Frictional modifiers and extreme pressure agents shall not be utilized. Lubricants suitable for this type of service are, therefore, considered to be straight mineral gear oils. In anti-scoring protection, these lubricants are comparable to CRC RGO-100.

Due to speeds and loads involved, straight mineral oil is not a satisfactory lubricant for most 4-speed and some 3-speed passenger car manual transmissions.¹ For some truck and tractor manual transmissions, straight mineral oil is suitable.

**API-GL-2**: Designates the type of service characteristic of automotive type worm-gear axles operating under such conditions of load, temperature, and sliding velocities that lubricants satisfactory for API-GL-1 service will not suffice.

Products suited for this type of service contain antiwear or very mild extreme-pressure agents which provide protection for worm gears.

There are relatively very few differentials in use that are equipped with worm gears. The GL-2 designation is included in this list for those worm gears used in a service that has been found to require a lubricant other than straight mineral oil.

**API-GL-3**: Designates the type of service characteristic of manual transmissions and spiral-bevel axles operating under moderately severe conditions of speed and load. These service conditions require a lubricant having load carrying capacities greater than those which will satisfy API-GL-1 service, but below the requirements of lubricants satisfying API-GL-4 service.

Lubricants designed for this service typically contain additives which react with tooth surfaces at the temperatures resulting from a high speed or load. Due to the rate of reactivity or the relatively low concentration of the additives, products designated for GL-3 are not formulated to provide adequate protection for hypoid gears. The scoring resistance of such oils is comparable to that provided by CRC reference gear oils below RGO-104.
API-GL-4: This classification is still used commercially to describe lubricants, but the equipment required for the anti-scoring test procedures to verify lubricant performance is no longer available.

Designates the type of service characteristic of gears, particularly hypoid\(^2\) in passenger cars and other automotive type equipment operated under high-speed, low-torque, and low-speed, high-torque conditions.

Lubricants suitable for this service are those which provide anti-score protection equal to or better than defined by CRC Reference Gear Oil RGO-105 and have been subjected to the test procedures and provide the performance levels described in ASTM STP-512 dated April 1972.\(^3\)

API-GL-5: Designates the type of service characteristic of gears, particularly hypoid\(^2\) in passenger cars and other automotive equipment operated under high-speed, shock-load; high-speed, low-torque; and low-speed, high-torque conditions.

Lubricants suitable for this service are those which provide anti-score protection equal to or better than defined by CRC Reference Gear Oil RGO-110 and have been subjected to the test procedures and provide the performance levels described in ASTM STP-512 dated April 1972.\(^3\)

API-GL-6: This is an obsolete classification. The equipment required for the test procedures to verify lubricant performance is no longer available.

The type of service designated by API-GL-6 is characteristic of gears, specifically high offset hypoid\(^2\) gears (above 2 in offset and approaching 25 percent of ring gear diameter) in passenger cars and other automotive equipment operated under high-speed, high-performance conditions.

Lubricants suitable for this service are those which provide anti-score protection equal to or greater than Reference Gear Oil L-10004 and have been subjected to the test procedures and provide the performance levels described in ASTM-STP 512 dated April 1972.\(^3\)

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\(^1\) Automatic or semi-automatic transmissions, fluid couplings, torque converters, and tractor hydraulic systems usually require special lubricants. For the proper lubricant to be used, consult the manufacturer or lubricant supplier.

\(^2\) Limited-slip differentials generally have special lubricant requirements. The lubricant supplier should be consulted regarding the suitability of the lubricant for such differentials. Information helpful in evaluating lubricants for this type of service may be found in ASTM STP-512 dated April 1972.

\(^3\) The complete publication is titled “Laboratory Performance Gear Lubricants Intended for API-GL-4, GL-5 and GL-6 Services.”

\(^4\) Reference Gear Oil L-1000 is available for a fee from Southwest Research Institute, P.O. Drawer 28510, San Antonio, Texas 78284.
Axle Shaft End-Play Checking Procedure

**VEHICLE INVOLVED IN CAMPAIGN**

- **“C” TYPE AXLE**
  - **MILEAGE MORE THAN 20,000**
    - Use dial indicator to check end play of each axle (Steps 3, 4, 5, and 6)
  - **MILEAGE LESS THAN 20,000**
    - Check code on right front inboard axle tube (Steps 1 and 2)

**CHECK CODE ON RIGHT FRONT INBOARD AXLE TUBE (STEPS 1 AND 2)**

- **NOT “C” TYPE AXLE**

**CHART II**

**PINION SHAFT AND AXLE SHAFT REPLACEMENT**

<table>
<thead>
<tr>
<th>MILEAGE</th>
<th>AXLE SHAFT BUTTON THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 TO 20,000</td>
<td>Replacement (Steps 8 and 9)</td>
</tr>
<tr>
<td>20,000 TO 75,000</td>
<td>Replacement (Steps 8 and 9)</td>
</tr>
<tr>
<td>OVER 75,000</td>
<td>Replacement (Steps 8 and 9)</td>
</tr>
</tbody>
</table>

**CHART III**

**MAXIMUM ALLOWABLE END PLAY FOR EITHER AXLE SHAFT**

<table>
<thead>
<tr>
<th>MILEAGE</th>
<th>STANDARD AXLE</th>
<th>LIMITED SLIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO 45,000</td>
<td>.040</td>
<td>.065</td>
</tr>
<tr>
<td>OVER 45,000</td>
<td>.055</td>
<td>.085</td>
</tr>
</tbody>
</table>

**END PLAY LESS**

- Install completion identification label (Step 13)

**END PLAY MORE**

- Determine cause, contact zone

**INSTALL COMPLETION IDENTIFICATION LABEL (STEP 13)**

**REFER TO BULLETIN FOR COMPLETE INSTRUCTIONS**

*Figure 3-249, Axle Shaft Checking Procedure Flow Chart*
AAM 7.50-Inch/7.625-Inch Rear Axle Assembly Identification

Figure 3-250, AAM 6.50-Inch Rear Axle Assembly Views
AAM 8.50-Inch/8.625-Inch Rear Axle Assembly Identification

Figure 3-251, AAM 7.625-Inch Rear Axle Assembly Views
AAM 8.50-Inch/8.625-Inch Rear Axle Assembly Identification

Figure 3-252, AAM 8.625-Inch Rear Axle Assembly Views
Figure 3-253, AAM 7.50-Inch, 7.625-Inch, 8.50-Inch and 8.625-Inch Rear Axle Assemblies
### AAM 7.50-Inch, 7.625-inch, 8.50-Inch and 8.625-Inch Rear Axle Assemblies

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>REAR BRAKE DRUM (2)</td>
</tr>
<tr>
<td>2</td>
<td>REAR AXLE SHAFT (2)</td>
</tr>
<tr>
<td>3</td>
<td>ANCHOR PIN WASHER (2)</td>
</tr>
<tr>
<td>4</td>
<td>BACKING PLATE NUT (2)</td>
</tr>
<tr>
<td>5</td>
<td>PARKING BRAKE CABLE (2)</td>
</tr>
<tr>
<td>6</td>
<td>VENT</td>
</tr>
<tr>
<td>7</td>
<td>FRONT (OUTER) PINION BEARING</td>
</tr>
<tr>
<td>8</td>
<td>DRIVE PINION FLANGE SEAL</td>
</tr>
<tr>
<td>9</td>
<td>DRIVE PINION FLANGE NUT</td>
</tr>
<tr>
<td>10</td>
<td>DRIVE PINION FLANGE WASHER</td>
</tr>
<tr>
<td>11</td>
<td>DRIVE PINION FLANGE</td>
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<tr>
<td>12</td>
<td>REAR FILL PLUG</td>
</tr>
<tr>
<td>13</td>
<td>WHEEL BEARING (2)</td>
</tr>
<tr>
<td>14</td>
<td>REAR WHEEL BEARING SEAL (2)</td>
</tr>
<tr>
<td>15</td>
<td>BRAKE BACKING PLATE (2)</td>
</tr>
<tr>
<td>16</td>
<td>BRAKE BACKING PLATE SCREW (2)</td>
</tr>
<tr>
<td>17</td>
<td>AXLE HOUSING</td>
</tr>
<tr>
<td>18</td>
<td>PINION BEARING SPACER</td>
</tr>
<tr>
<td>19</td>
<td>AXLE SHAFT LOCK (2)</td>
</tr>
<tr>
<td>20</td>
<td>REAR (INNER) PINION BEARING</td>
</tr>
<tr>
<td>21</td>
<td>RING AND PINION GEARSET (MATCHED)</td>
</tr>
<tr>
<td>22</td>
<td>REAR PINION BEARING SHIM (SELECTIVE THICKNESS) (2)</td>
</tr>
<tr>
<td>23</td>
<td>DIFFERENTIAL PINION SHAFT</td>
</tr>
<tr>
<td>24</td>
<td>DIFFERENTIAL PINION SHAFT LOCK SCREW</td>
</tr>
<tr>
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<td>DIFFERENTIAL CASE</td>
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<tr>
<td>37</td>
<td>DIFFERENTIAL ASSEMBLY</td>
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PINION SHIM KITS FOR 7.50”, 7.625” AND 8.50”, AND DIFFERENTIAL SIDE BEARING SHIM KITS ARE AVAILABLE IN DIFFERENT SIZES AND THICKNESSES. CHECK PARTS CATALOG FOR DETAILS.
30  DIFFERENTIAL SIDE BEARING CAP BOLT (4)
31  CARRIER COVER BOLT (10)
32  CARRIER COVER
33  CARRIER COVER GASKET
34  DIFFERENTIAL GEAR KIT (2 PINIONS AND 2 SIDE GEARS)
35  DIFFERENTIAL SIDE GEAR THRUST WASHER (2)
36  DIFFERENTIAL CASE
37  DIFFERENTIAL ASSEMBLY

Pinion Shim Kits for 7.50”, 7.625” and *.50”, and differential side bearing shim kits are available in different sizes and thicknesses. Check parts catalog for details.
## AAM/Saginaw Shim Identification

![Diagram of AAM/Saginaw Shim](image)

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*Figure 3-254, AAM/Saginaw Shim Thickness and I.D./O.D. Notches*
AAM 9.50-Inch Rear Axle Assembly Identification

Figure 3-255, AAM 9.50-Inch Rear Axle Assembly Views
Figure 3-256, AAM 9.50-Inch Rear Axle Assembly
### AAM 9.50-Inch Rear Axle Assembly

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32 DIFFERENTIAL SIDE GEAR THRUST WASHER (2)
33 DIFFERENTIAL SIDE GEAR (2)
34 REAR BRAKE BACKING PLATE (2)
35 LOCK WASHER (8)
36 HEX BOLT (8)
37 AXLE SHAFT LOCK (2)

Pinion shim kits for 9.50" rear axle, and differential side bearing shims are available in different sizes and thicknesses. Check parts Catalog for details.
AAM 10.50-Inch Rear Axle Assembly Identification

Figure 3-257, AAM 10.50-Inch Rear Axle Assembly Views
Figure 3-258, AAM 10.50-Inch Rear Axle Assembly
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Borg-Warner Model 78 Rear Axle Assembly Identification

Figure 3-259, Borg-Warner Model 78 Rear Axle Views
Figure 3-260, Borg-Warner Model 78 Rear Axle View
Dana Model 36 I.C.A. Rear Axle Assembly Identification

Figure 3-261, Dana Model 36 I.C.A. Views
Dana Model 44 I.C.A. Rear Axle Assembly Identification

Figure 3-261, Dana Model 36 I.C.A. Views
Figure 3-262, Dana Model 36 and 44 I.C.A. Rear Axle Assemblies
## Dana Models 36 and 44 I.C.A. Rear Axle Assemblies

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### Rear Axle Identification

**Model 36**
- 7.875-in. (7 7/8-in.)
  - Automatic Transmission Only
  - RPO MXO (STD.)
  - GM Part Numbers: 14093143, 14087675
  - Gear Ratio: 2.59, 2.73
  - Teeth No. Ring: Pinion: 44:17, 41:15
  - Cover Bushing Color: BLUE
  - RPO MXO W/G92
  - GM Part Number: 14087678
  - Gear Ratio: 3.07
  - Teeth No. Ring: Pinion: 43:14
  - Cover Bushing Color: BLUE

**Model 44**
- 8.5-in. (8 1/2-in.)
  - 4-Speed Manual Transmission Only
  - RPO MM4 (STD.)
  - GM Part Number: 14087652
  - Gear Ratio: 3.07
  - Teeth No. Ring: Pinion: 43:14
  - Cover Bushing Color: BLUE
  - RPO MM4 W/Z51
  - GM Part Number: 14087652
  - Gear Ratio: 3.07
  - Teeth No. Ring: Pinion: 43:14
  - Cover Bushing Color: BLACK

---

Note: Identification is Electro-etched on the Underside of the Differential Carrier.

*Figure 3-263, Rear Axle Identification (Code Identification)*
Figure 3-264, Dana Model 70 HD Views
Figure 3-265, Dana Model 60 Rear Axle Assembly
### Dana Model 60 Rear Axle Assembly

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<td>INBOARD AXLE SHAFT SEAL (2)</td>
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Figure 3-266, Dana Model 70 Rear Axle Assembly
### Dana Model 70 Rear Axle Assembly

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