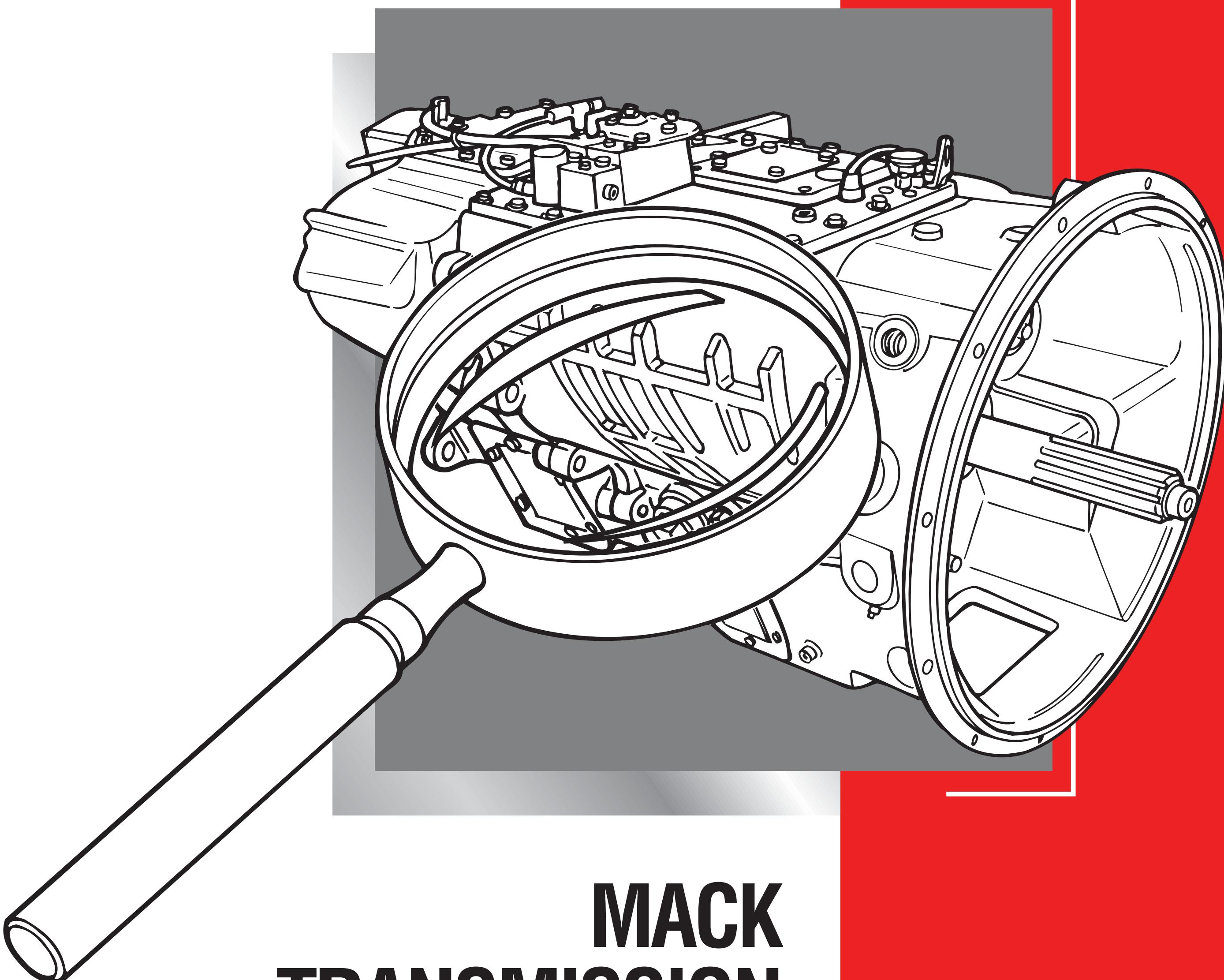
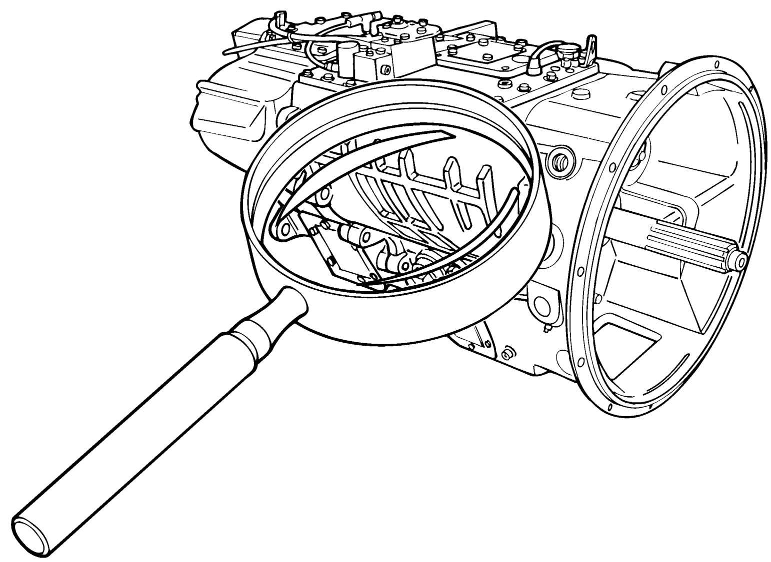


MACK TRANSMISSION

FAILURE ANALYSIS

OCTOBER 2007
(REVISED)
FAILURE ANALYSIS
21-203

MACK TRANSMISSION FAILURE ANALYSIS



OCTOBER 2007
(REVISED — SUPERSEDES ISSUE DATED AUGUST 1997)

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21-203

ATTENTION

The information in this manual is not all inclusive and cannot take into account all unique situations. Note that some illustrations are typical and may not reflect the exact arrangement of every component installed on a specific chassis.

The information, specifications, and illustrations in this publication are based on information that was current at the time of publication.

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300 INTRODUCTION

SAFETY INFORMATION

Advisory Labels

Cautionary *signal words* (Danger-Warning-Caution) may appear in various locations throughout this manual. Information accented by one of these signal words must be observed to minimize the risk of personal injury to service personnel, or the possibility of improper service methods which may damage the vehicle or cause it to be unsafe. Additional Notes and Service Hints are used to emphasize areas of procedural importance and provide suggestions for ease of repair. The following definitions indicate the use of these advisory labels as they appear throughout the manual:

DANGER

Danger *indicates an unsafe practice that could result in death or serious personal injury. Serious personal injury is considered to be permanent injury from which full recovery is NOT expected, resulting in a change in life style.*

WARNING

***Warning* indicates an unsafe practice that could result in personal injury. Personal injury means that the injury is of a temporary nature and that full recovery is expected.**

CAUTION

***Caution** indicates an unsafe practice that could result in damage to the product.*

NOTE

Note indicates a procedure, practice, or condition that must be followed in order for the vehicle or component to function in the manner intended.

SERVICE HINT

A helpful suggestion that will make it quicker and/or easier to perform a procedure, while possibly reducing service cost.

Service Procedures and Tool Usage

Anyone using a service procedure or tool not recommended in this manual must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects. Individuals deviating in any manner from the instructions provided assume all risks of consequential personal injury or damage to equipment involved.

Also note that particular service procedures may require the use of a special tool(s) designed for a specific purpose. These special tools must be used in the manner described, whenever specified in the instructions.

⚠ DANGER

1. ***Before starting a vehicle, always be seated in the driver's seat, place the transmission in neutral, apply the parking brakes, and push in the clutch pedal. Failure to follow these instructions could produce unexpected vehicle movement, which can result in serious personal injury or death.***
2. ***Before working on a vehicle, place the transmission in neutral, set the parking brakes, and block the wheels. Failure to follow these instructions could produce unexpected vehicle movement, which can result in serious personal injury or death.***

⚠ DANGER

Engine-driven components such as Power Take-Off (PTO) units, fans and fan belts, driveshafts and other related rotating assemblies, can be very dangerous. Do not work on or service engine-driven components unless the engine is shut down. Always keep body parts and loose clothing out of range of these powerful components to prevent serious personal injury. Be aware of PTO engagement or nonengagement status. Always disengage the PTO when not in use.

⚠ DANGER

Do not work under a vehicle that is supported only by a hydraulic jack. The hydraulic jack could fail suddenly and unexpectedly, resulting in severe personal injury or death. Always use jackstands of adequate capacity to support the weight of the vehicle.

⚠ CAUTION

Before towing the vehicle, place the transmission in neutral and lift the rear wheels off the ground, or disconnect the driveline to avoid damage to the transmission during towing.

REMEMBER,
SAFETY . . . IS NO ACCIDENT!

Mack Trucks, Inc. cannot anticipate every possible occurrence that may involve a potential hazard. Accidents can be avoided by recognizing potentially hazardous situations and taking necessary precautions. Performing service procedures correctly is critical to technician safety and safe, reliable vehicle operation.

The following list of general shop safety practices can help technicians avoid potentially hazardous situations and reduce the risk of personal injury. DO NOT perform any services, maintenance procedures or lubrications until this manual has been read and understood.

- Perform all service work on a flat, level surface. Block wheels to prevent vehicle from rolling.
- DO NOT wear loose-fitting or torn clothing. Remove any jewelry before servicing vehicle.
- ALWAYS wear safety glasses and protective shoes. Avoid injury by being aware of sharp corners and jagged edges.
- Use hoists or jacks to lift or move heavy objects.
- NEVER run engine indoors unless exhaust fumes are adequately vented to the outside.
- Be aware of hot surfaces. Allow engine to cool sufficiently before performing any service or tests in the vicinity of the engine.
- Keep work area clean and orderly. Clean up any spilled oil, grease, fuel, hydraulic fluid, etc.
- Only use tools that are in good condition, and always use accurately calibrated torque wrenches to tighten all fasteners to specified torques. In instances where procedures require the use of special tools which are designed for a specific purpose, use only in the manner described in the instructions.
- Do not store natural gas powered vehicles indoors for an extended period of time (overnight) without first removing the fuel.
- Never smoke around a natural gas powered vehicle.

EXPLANATION OF NUMERICAL CODE

The organization of MACK service manuals has been upgraded to standardize manual content according to a reference system based on component identification. The new reference system will help to link the information contained in this publication with related information included in other MACK service/warranty publications, such as associated service bulletins, warranty manuals, and MACK Service Labor Time Standards.

The system is based on a numerical code, the first **digit** of which identifies the general component grouping as listed here:

GROUP **0**00 — GENERAL DATA

GROUP **1**00 — CHASSIS

GROUP **2**00 — ENGINE

GROUP **3**00 — CLUTCH, TRANSMISSION, TRANSFER CASE AND PTO

GROUP **4**00 — STEERING, AXLES, WHEELS AND TIRES, DRIVELINE

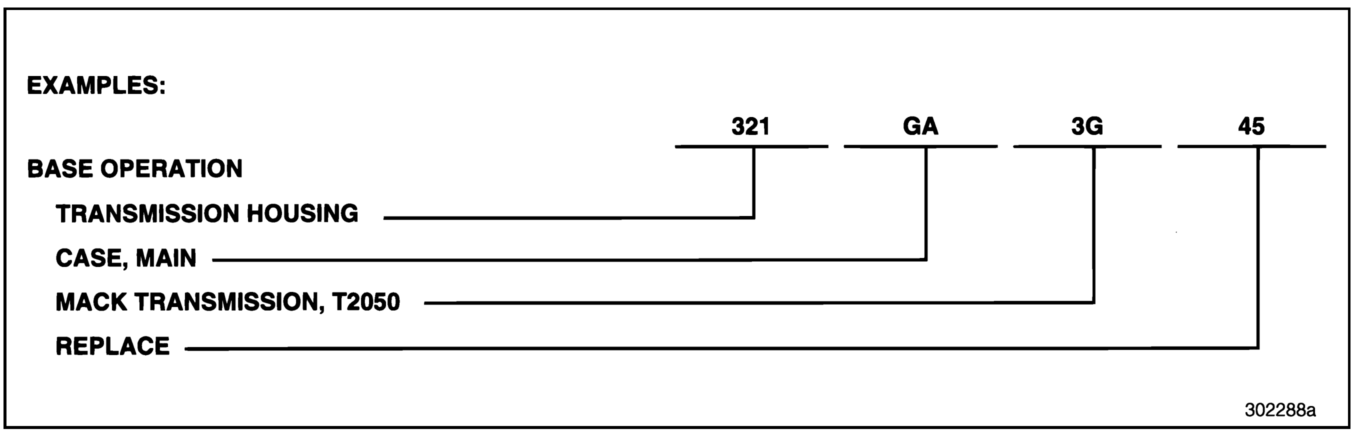
GROUP **5**00 — BRAKES, AUXILIARY SYSTEMS

GROUP **6**00 — CAB, TRUCK BODY

GROUP **7**00 — ELECTRICAL

The second two digits of the three-digit code are used to identify the **system, assembly** or **subassembly**, as appropriate, within each of the groupings. The codes applicable to this publication are shown at the top of the page, as necessary, to guide you to specific component information.

Additionally, a two-character alpha code (i.e., [GA] CASE, MAIN) may be referenced. This alpha code, in combination with the three-digit Group number, identifies the specific assembly, subassembly or part, and directly relates to the first five positions of the operation code listed in MACK Service Labor Time Standards.



GLOSSARY OF TERMS

The entries in this glossary can be found as *italicized* words in the text of this book. Use the words in italics to reference these glossary items as needed.

Abrasion

The process of polishing, grinding or wearing away of material from a surface by friction, usually by hard particles or a hard, rough mating surface.

Addendum

The portion of a gear tooth between the pitch line and the tip of the tooth. (See “Workings of a Spur Gear” on page 25.)

Adhesion/Adhesive Wear

Metal transfer or smearing caused by localized welding, fracture and/or burnishing. See Scuffing. (See “Seizing” on page 34.)

Backlash (Gears)

The clearance, or “play,” between two teeth in mesh.

Beach Marks

Contour lines on a somewhat smooth fracture surface that indicate fatigue. These features are created as a part successfully resists, for a time, the advance of a fatigue crack. (See “Broken Mainshaft Due to Torsional Fatigue” on page 54.)

Bending Fatigue

Characterized by beach marks on the fractured area. It is fracture under repeated or fluctuating stress which has a maximum value less than the tensile strength of the material. Fatigue fractures are progressive, beginning as tiny cracks that grow under the action of the fluctuating stress. Fatigue results from load and time.

Brinelling, False

Depressions produced when rolling element bearings are subjected to vibration or low-radial-angle oscillation (or to both) while not rotating. The bearing surfaces are either polished or show a characteristic red-brown stain. (See “Brinelling” on page 35.)

Brinelling, True

Indentations produced by plastic flow when rolling elements are forced against bearing raceway surfaces by stationary overload or especially, by impact during mounting. Original surface features such as machining marks, are usually visible at bottoms of indentations. (See “Brinelling” on page 35.)

Burning

Permanent damage to metal or alloy by heat, causing either incipient melting or oxidation. (See “Burned Fork Ring” on page 65.)

Carburizing

The addition of carbon to the surface of steel parts, by heat treatment, to provide high hardness for improved wear resistance and durability. A form of case-hardening often applied to highly loaded gears.

Case Crushing

Crushing of the outer surface (case) of a gear that has been case-hardened by heat treatment.

Cavitation Erosion/Damage

Pitting of a metal surface exposed to a moving liquid caused by the collapse of entrained vapor bubbles. Corrosion is often a factor.

Cold Flow

Metal movement under high pressure at room temperature. See Plastic Deformation.

Contamination

Foreign material that can damage a part. (See “Contamination” on page 34.)

Contingent Damage

Damage to a component that is caused by the malfunction of another component.

Corrosion

Chemical or environmental attack, includes rust. (See “Rust and Corrosion” on page 46.)

Cyclic Compression Load

Repeated contact loads, like on gear teeth. Cyclic compression can cause pitting and spalling. (See “Gear Tooth Surface Fatigue Progression” on page 32.)

Dedendum

The portion of the gear tooth between the pitch line and the root of the tooth. (See “Workings of a Spur Gear” on page 25.)

Dirt Scratches

See Scoring.

Electric Pitting

Small pits or depressions on the surfaces in contact caused by an electrical current. (See “Indentations” on page 45.)

Erosion

Destruction of metals or other materials by the abrasive action of moving fluids, usually accelerated by the presence of solid particles or matter in suspension. When corrosion occurs simultaneously, the term erosion-corrosion is often used.

Fatigue

Fracture under repeated or fluctuating stresses having a maximum value less than the tensile strength of the material. Fatigue fractures are progressive, beginning as minute cracks that grow under the action of the fluctuating stress. Fatigue results from load, temperature and time. (See “Broken Mainshaft Due to Torsional Fatigue” on page 54.)

Fatigue Strength

The maximum cycle stress that can be sustained for a specified number of cycles without fracture.

Ferrous Metal

Metal which contains, or is derived from, iron (includes steel).

Final Fast Fracture Zone

The part of a breakthrough of a cross section that has a rough, sometimes crystalline appearance. It can be the entire area in a shock fracture or a small part of the cross section area in a fatigue fracture. (See “Broken Teeth” on page 56.)

Flaking

Another name for spalling. Material breaks off the surface in the form of flakes or chips. Flaking results from high-contact loads and many loading cycles and can occur on gear tooth surfaces.

Flaking can also describe when a plating, like chromium, breaks off. It usually does not apply to edge chipping. (See “Tapered Roller Bearing Flaking or Spalling” on page 42.)

Fretting (Fretting Corrosion)

Surface damage that results when there is relative micromotion between solid surfaces in contact under pressure. Can produce red powder or a surface that looks like adhesive wear, but without evident sliding direction and it can lead to cracks. Occurs even with oil or grease present. (See “Fretting and Fretting Corrosion” on page 47.)

Frosting

Superficial material displacement on gear teeth that presents a nondestructive milky appearance. (See “Gear Tooth Surface Fatigue Progression” on page 32.)

Galling

Surface damage on mating, moving metal parts due to friction. A severe form of adhesive wear. See Scuffing.

Gouging

Severe grooving of a surface caused by sliding or impact of large, hard particles.

Impact Loading

Rotating gears clashing at engagement. See Shock Loading. (See “Shock Loading (T107 Series Transmission)” on page 81.)

Lubrication

Use of grease, oil, etc., to prevent metal-to-metal contact and reduce friction and heat between parts.

- **Inadequate Lubrication** — The lubricant fails to prevent metal-to-metal contact and damage under normal operating conditions. This may be caused by inadequate lubricant supply or pressure, by contamination or breakdown of the lubricant, or by the use of incorrect lubricant. Overloading and overheating can also cause metal-to-metal contact or breakdown of the lubricant.

Oil Contamination

Pollution of lubricating oil by a foreign substance. (See “Contaminated Lubricant” on page 29.)

Overheating

Heating a metal or an oil to such a high temperature that its properties are impaired. (See “HEAT AND LUBRICATION” on page 29.)

Overloading

A force or torque that is greater than the design force or torque specification of a particular component. (See “OVERLOAD” on page 28.)

- **Shock Load (Instantaneous Overload)** — A sudden load that immediately causes part damage. The part may break immediately or it may be cracked, distorted in a way that leads to fatigue fracture or premature wear.
- **Sustained Overload** — Long-term overloading. This will eventually cause premature wear or fatigue damage, including premature spalling.

Pitch Line

Location of a gear tooth midway up the tooth. There is usually rolling contact, but no sliding at the pitch line. (See “Workings of a Spur Gear” on page 25.)

Pitting

Tiny, pinhole-sized cavities in a surface that result from cyclic contact pressure. This may eventually lead to spalling. Pits can also be produced by corrosion. (See “Pitting” on page 33.)

Plastic Deformation (Plastic Flow/Cold Flow)

Permanent deformation of a surface; metal flows on the surface (over the tips and ends of the gear teeth, for example). This condition can quickly become destructive.

Ratchet Marks

Steps that indicate multiple fatigue initiations on different planes. These steps disappear as the fatigue fronts merge.

Root Diameter

Innermost part of a stress concentration, such as the bottom of a groove or tooth root. (See “SPUR GEARS” on page 24.)

Scoring

Grooved damage that occurs when metal or dirt particles cut and embed in the mating surface. See Abrasion. (See “Debris Damage” on page 59.)

Scuffing

Adhesive wear, usually resulting in metal transfer and heating. See Galling. (See “Inadequate Lube/Lack of Lube” on page 58.)

Seizure

The sudden stopping of motion between two parts because of excessive friction and heat between parts. Heat causes the parts to expand, reducing clearance between the two parts to zero. (See “Seizing” on page 34.)

Shock Load

A rapidly applied load or force that is severe enough to exceed the strength of the component and cause it to crack or fail instantly. (See “SHOCK LOAD” on page 28 and “Broken Teeth” on page 56.)

Sludge

A combination of oil, water and dirt blended together by moving parts.

Smearing

See Adhesive Wear, Galling, Scuffing, and Plastic Deformation.

Spalling

Material breaks off the surface in the form of flakes or chips. Results from high-contact loads and many loading cycles. (See “Surface Fatigue/Spalling” on page 57.)

Stress Risers/Raisers

Notches, grooves or gouges that cause local increases in stress. Some stress raisers are part of the component design, and others result from damage or modification.

Torque/Torsion

A twisting force. (See “Mechanical Loads” on page 31.)

Torsional Fatigue

Damage, possibly including cracks, resulting from repeated torsional loads. (See “Broken Mainshaft Due to Torsional Fatigue” on page 54.)

Torsional Vibration

Fluctuations in the rotating speed or torsional load. (See “Advanced Stage of Flank Wear” on page 64 and “Worn Disc Splines” on page 70.)

MANUAL OBJECTIVE

The objective of this manual is to assist the skilled technician in properly diagnosing the root cause(s) of transmission failures. This, in turn, allows better identification of all the contributing causes of failure. The technician will be able to not only repair the transmission successfully, but also to pinpoint any conditions that may need correction to prevent a repeat failure.

FAILURE ANALYSIS

Failure analysis is the process of determining the **original cause** of component failure to prevent it from happening again.

<u>When a failed component is replaced without determining the cause, the failure continues to occur.</u> For example, if a transmission main case top cover is opened, revealing a countershaft gear with a broken tooth, do not assume that the broken tooth is the cause of the transmission failure. Other parts of the transmission must be examined.

Many clues can be discovered by carefully examining the failed component. By knowing what to look for, you can tell how a piece of equipment was running and what problems may have existed. It may be necessary to examine the overall condition of the vehicle and its components. In some instances, the service records must be checked.

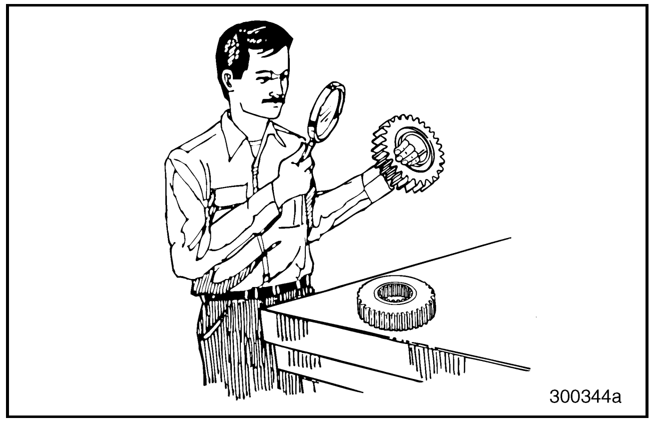


Figure 1 — Inspect Other Components

No one benefits when a failed component goes on the junk pile with the cause unknown.

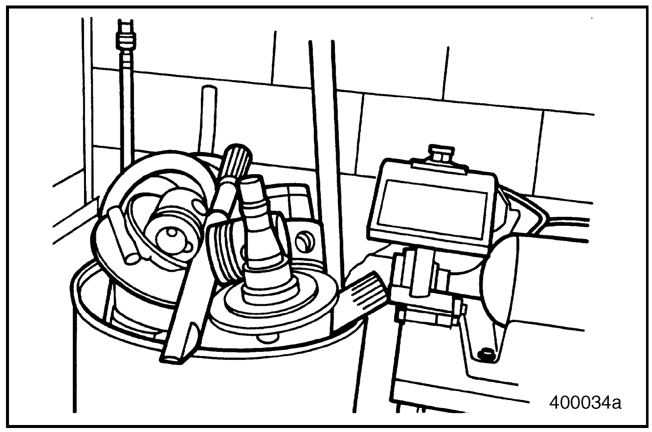


Figure 2 — Unexamined Failed Components Provide No Benefit

Nothing is more disturbing to a customer than a repeat failure. If a transmission fails in exactly the same way twice, the customer will likely become upset.

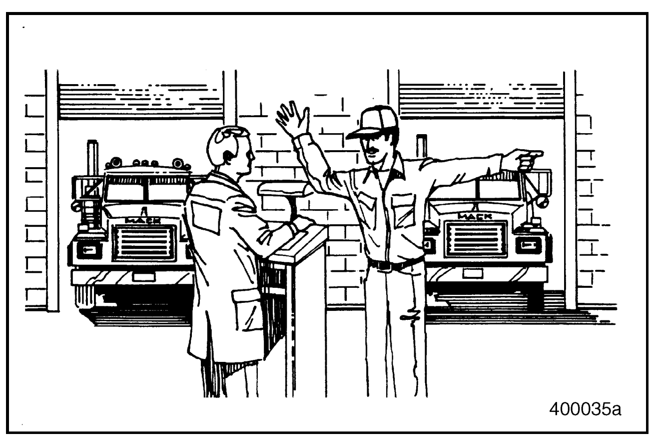


Figure 3 — Avoid Repeat Failures

Systematically analyzing a failure assures quality service by avoiding unnecessary downtime and further customer expense caused by a repeat of the same failure.

In some cases, the part itself is at fault; for example, gears may have been improperly cut. In the case of a rebuilt transmission, incorrect gears may have been installed.

The more successful shops prevent repeat equipment failures by developing good failure analysis practices. Knowing how to diagnose the cause of a failure is becoming one of the main prerequisites of a good heavy-equipment technician. In addition to replacing failed parts, the technician must determine and correct the cause of the failure.

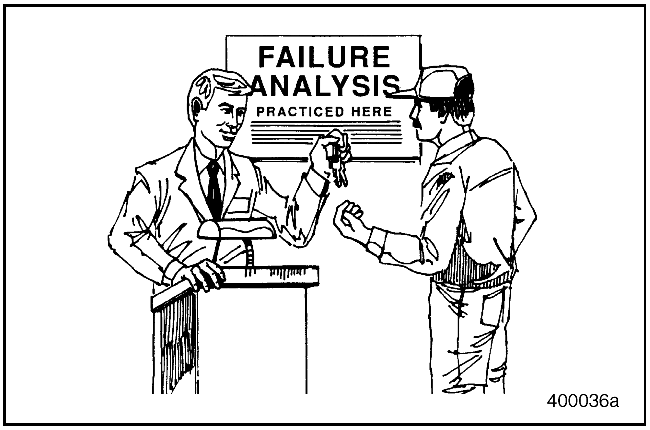


Figure 4 — Failure Analysis

Sometimes a failure is obvious; but this is generally the exception, rather than the rule. Good failure analysis techniques require that the technician follow a definite procedure, or systematic approach.

Mack Trucks, Inc. has established recommended maintenance and specification practices and procedures to ensure the transmission in a vehicle will perform to given optimum service. Evaluating transmission failure should start with a knowledge of the vehicle application or usage, vehicle specification and maintenance.

Reasons for Transmission Failures

The reasons for transmission failures usually fall into five categories:

- Vehicle misapplication or usage
- Improper vehicle operation
- Improper (or lack of) maintenance
- Defects in material or workmanship
- Lack of an oil cooler when required

If vehicle operations exceed design limitations, premature failures and reduced life can be expected. To avoid failures due to misapplication or specification, it is important for owners to understand the GCW/GVW ratings of their vehicles and the terrain over which the vehicles will be operated. For straight trucks, Gross Vehicle Weight (GVW) is the weight of the vehicle plus its payload. For the tractor-trailer combinations, GCW is the Gross Combined Weight of the tractor, trailer and payload.

Each straight truck or tractor-trailer combination must be operated within Mack Trucks, Inc. approved maximum loading-weight rated capacity. Exceeding the maximum rated capacity will reduce the life of the transmission. GCW/GVW must never be greater than the GCW/GVW specified when the vehicle was ordered from Mack Trucks, Inc.

Road grades and surfaces also affect transmission performance. It takes more effort to move a vehicle up a hill than on level ground. The amount of effort required to move a vehicle up a grade is directly proportional to the steepness of the grade.

When ordering a vehicle, the order should include an estimate of the highest grade over which the vehicle will be operated. For example, when ordering vehicles, do not specify the maximum operating grade will be 3% when it is known the vehicle will operate over terrain that exceeds grades of 3%. Operating a Mack truck on grades higher than specified may reduce transmission life.

The type of road surface on which the vehicle will operate also determines what transmission should be ordered for a vehicle operation. Harder road surfaces require lower rolling resistance than softer and rougher surfaces.

All Mack truck transmissions are designed to give years of trouble-free service, provided they are properly specified for usage, are operated according to Mack guidelines, and are maintained according to the maintenance and lubrication requirements as outlined in TS494. When vehicles are ordered or placed into service, it is the responsibility of the customer and the delivering Mack Sales Facility to ensure the vehicle is properly specified to match the job requirements. Care in supplying the customer with the proper transmission(s) for his operation is one of the most important steps toward ensuring that the transmission(s) will provide satisfactory performance and life.

If this manual is to be used to make warranty determinations, warranty is defined as a defect in material and/or workmanship and is governed by well-defined boundaries.

NOTES

300 SYSTEMATIC APPROACH

SYSTEMATIC APPROACH

The following steps are recommended as an effective approach to good failure diagnostics:

1. Document the problem.
2. Perform a preliminary investigation.
3. Prepare the parts for examination.
4. Find the exact cause of the failure.
5. Correct the cause of the problem.

Document the Problem

Talk to the operator of the truck. Look at the service records. Find out when the truck was last serviced. In what type of service is the unit being used? Has the particular failure occurred before? How was the truck working prior to the failure?

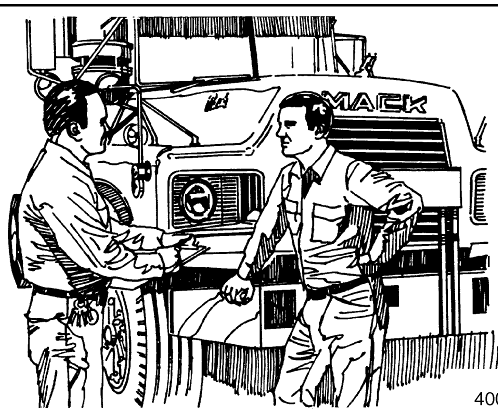

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Figure 5 — Document the Problem

Be a good listener. Sometimes, insignificant or unrelated symptoms can point to the cause of the failure. Was the vehicle at normal operating temperature? Were the gauges showing normal ranges of operation? Was there any unusual noise or vibration?

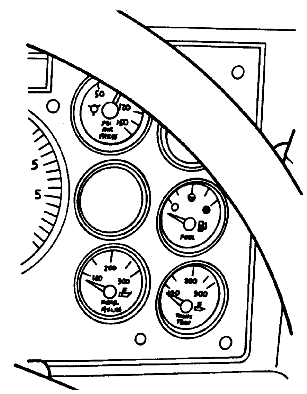
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Figure 6 — Record Gauge Readings

After listening, review the previous repair and maintenance records. If there is more than one driver, talk to all of them and compare their observations for consistency with the service and maintenance records. Verify the chassis serial number from the vehicle identification plate, as well as the mileage and hours on the vehicle.

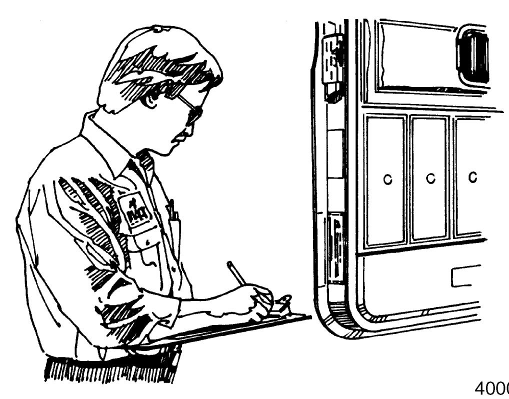
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Figure 7 — Verify Chassis Serial Number

Preliminary Investigation

A brief visual, external inspection may reveal leaks, cracks or other damage that can point to the cause of the failure.

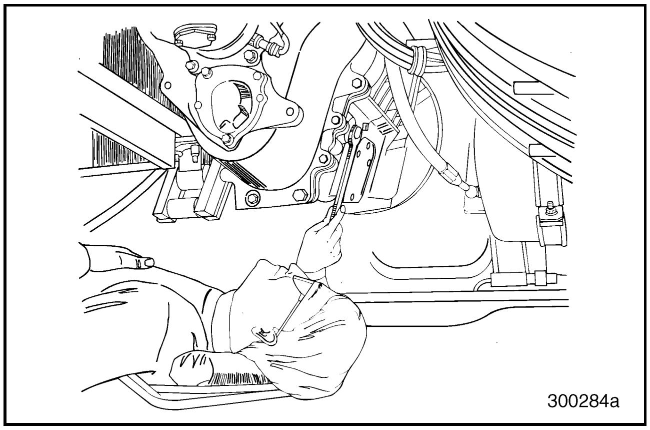


Figure 8 — Visual External Inspection

Make note of any obvious leaks around plugs and seals. A missing fill or drain plug would be an obvious cause for concern. Harder to see, but sometimes visible, are actual cracks in the transmission housing.

Does the general mechanical condition of the vehicle indicate proper maintenance or are there signs of neglect? If the transmission is equipped with an air control system, is it working properly? Check any electronic device control interfaces with the transmission to ensure they are working properly.

During the preliminary investigation, write down anything out of the ordinary for later reference. Something of little significance now may take on more importance when the subassemblies are torn down.

Finally, depending on the problem, it may be necessary to drain a small quantity of transmission oil into a clean container for later analysis. This would be especially important where the wrong lubricant type is suspected.

Prepare the Parts

After the preliminary investigation, locate the failure and prepare the parts for examination. In transmission failure analysis, it may be necessary to disassemble the unit.

SERVICE HINT

Disassembly of the failed unit is an important part of the analysis process. Take care to watch for clues of possible failure causes during disassembly. Do not clean the parts immediately, since cleaning may destroy some of the evidence.

When breaking down the transmission, follow the recommended procedure to minimize any further damage to the unit. Ask a few more questions when examining the interior of the transmission. Does the lubricant meet the manufacturer's specifications regarding quality, quantity and viscosity? As soon as you have located the failed part, take time to analyze the data.

Determine the Cause of the Failure

The challenge to determine the exact cause of the failure begins here. Again, there is no benefit to replacing a failed part without determining the cause of failure. Determine the specific type of failure. The following sections show different types of failures and explore the possible causes. Use this as a guide in determining types of failures and in correcting problems.

For example, after examining a failed part, it is found that the failure is caused by a lack of lubrication. Determine if there was an external leak. If this is the cause, just replacing the failed part is not going to correct the situation.

NOTE

Always review the previous repair records if a failure is assembly related.

Correct the Cause of the Problem

Once the cause of the problem has been determined, refer to the appropriate service manual to perform the repairs.

NOTES

300 TRANSMISSION TYPES

EXPLODED VIEWS

Use the following illustrations as a guide. They show exploded views of typical Mack truck transmission assemblies. Some parts may appear slightly different as improvements to components are introduced in successive models. Remember to use the illustrations as a general guide only.

TYPICAL MULTI-SPEED REVERSE TRANSMISSION

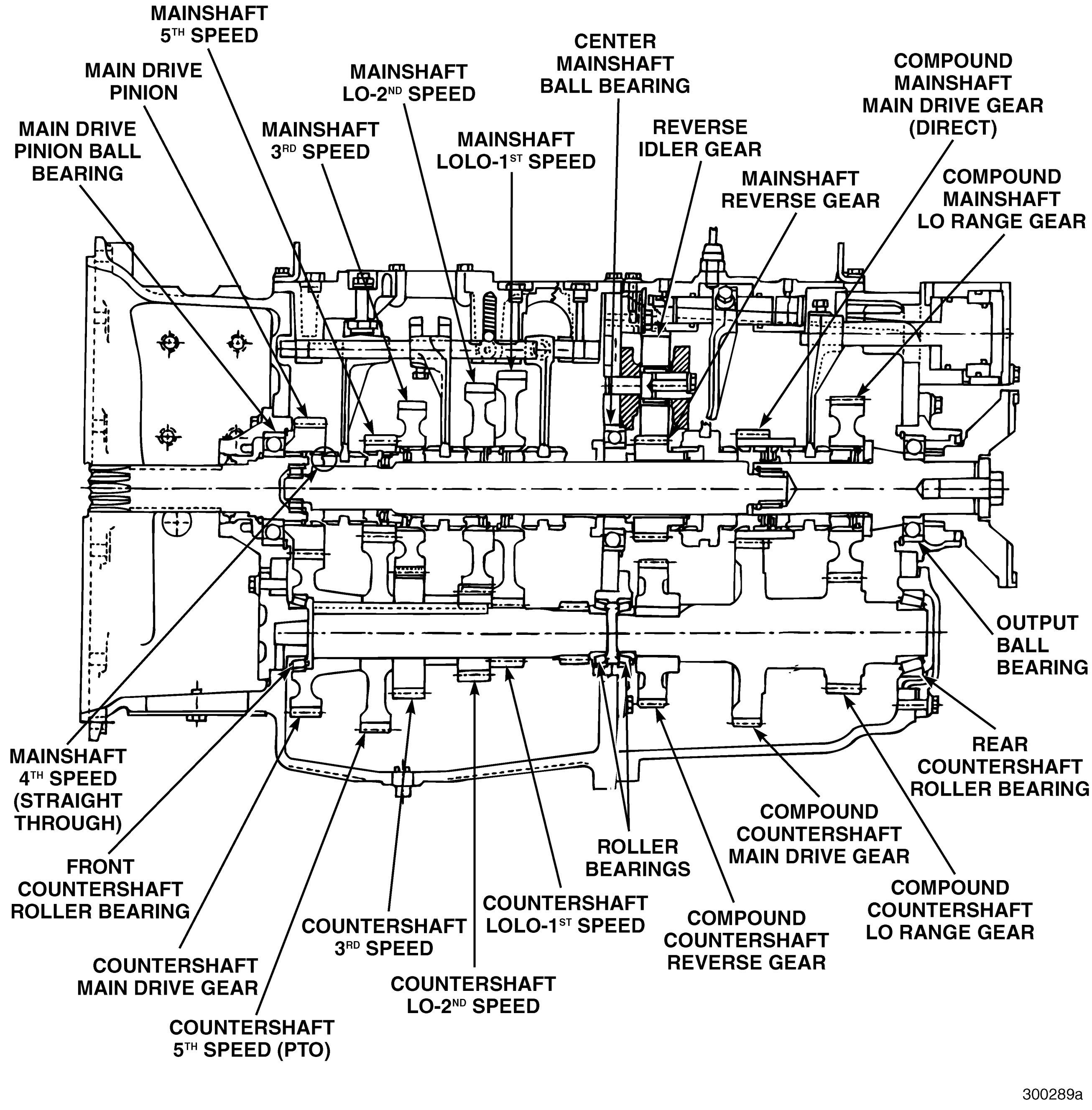
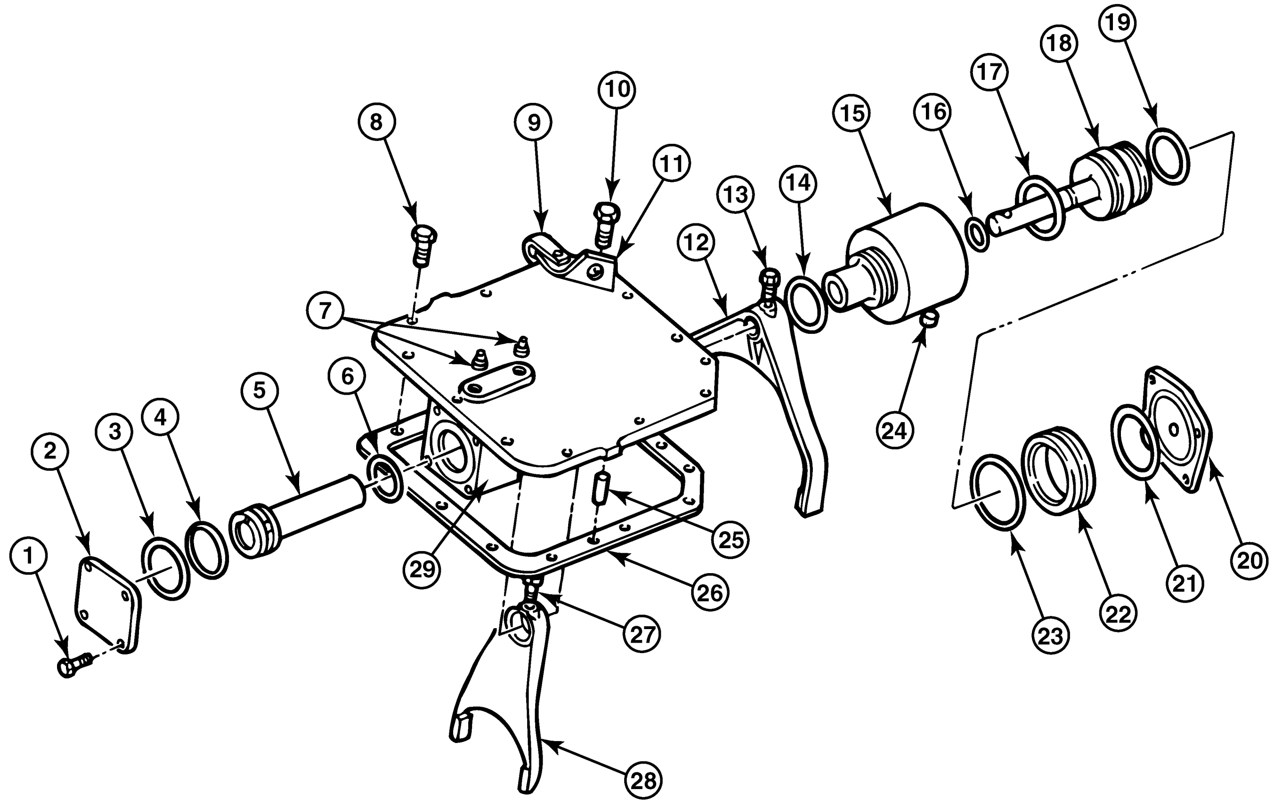


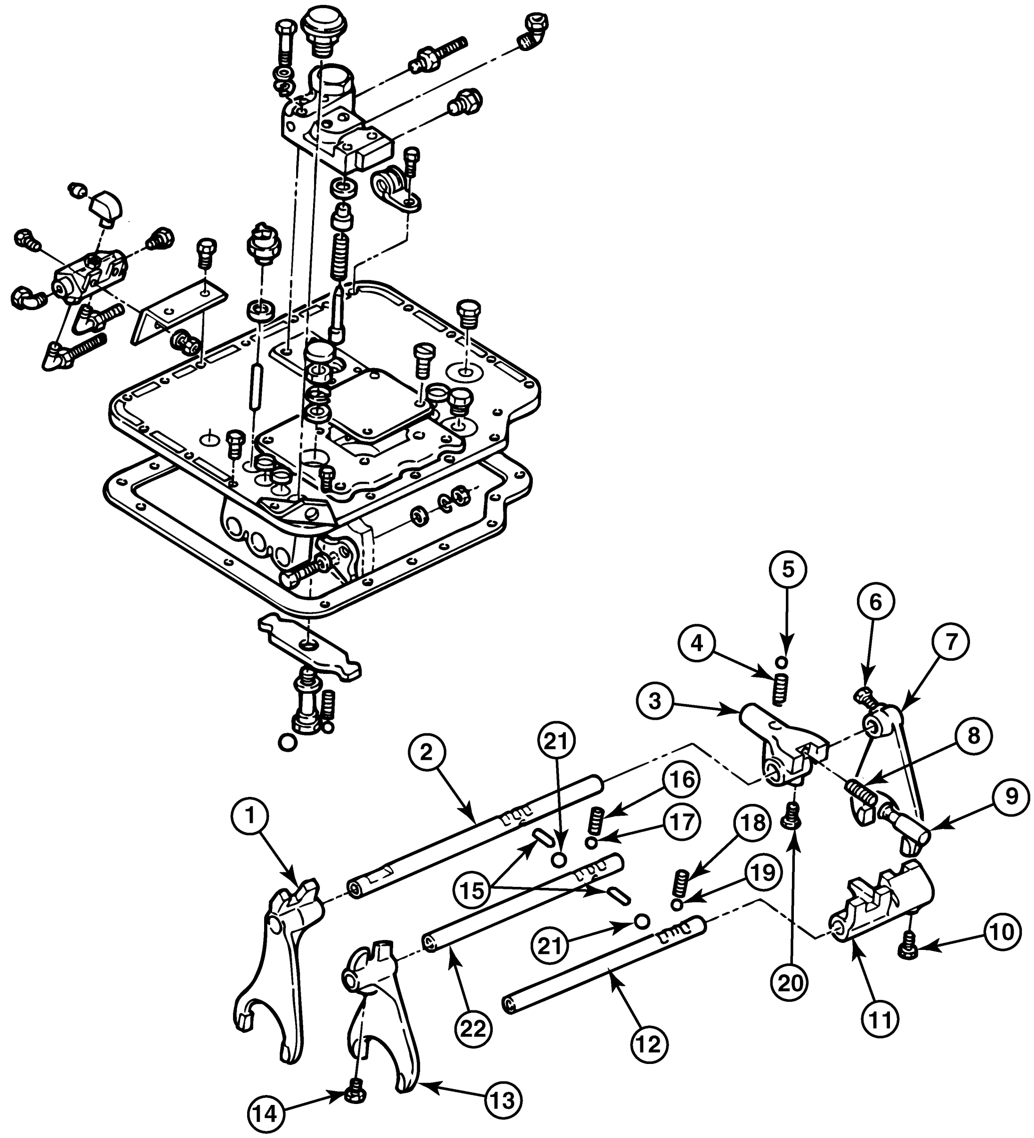
Figure 9 — Typical Transmission Configuration



1. SELF-LOCK HEX-HEAD SCREW
2. COMPOUND SPLITTER COVER
3. O-RING
4. O-RING
5. SPLITTER SHIFT PISTON
6. O-RING
7. LIFT TAB PLUG
8. HEX BOLT
9. CLAMP
10. HEX BOLT
11. TRANS LIFTING BRACKET
12. RANGE SHIFT FORK
13. LOCKING HEX-HEAD SETSCREW
14. O-RING
15. RANGE SHIFT HOUSING
16. O-RING
17. O-RING
18. RANGE SHIFT RAIL
19. O-RING
20. PISTON HOUSING COVER
21. O-RING
22. RANGE SHIFT PISTON
23. O-RING
24. SHIFT HOUSING BREATHER
25. COMPOUND SHIFT COVER DOWEL
26. GASKET
27. LOCKING HEX-HEAD SCREW
28. SPLITTER FORK
29. REAR CASE (COMPOUND) TOP COVER

300269a

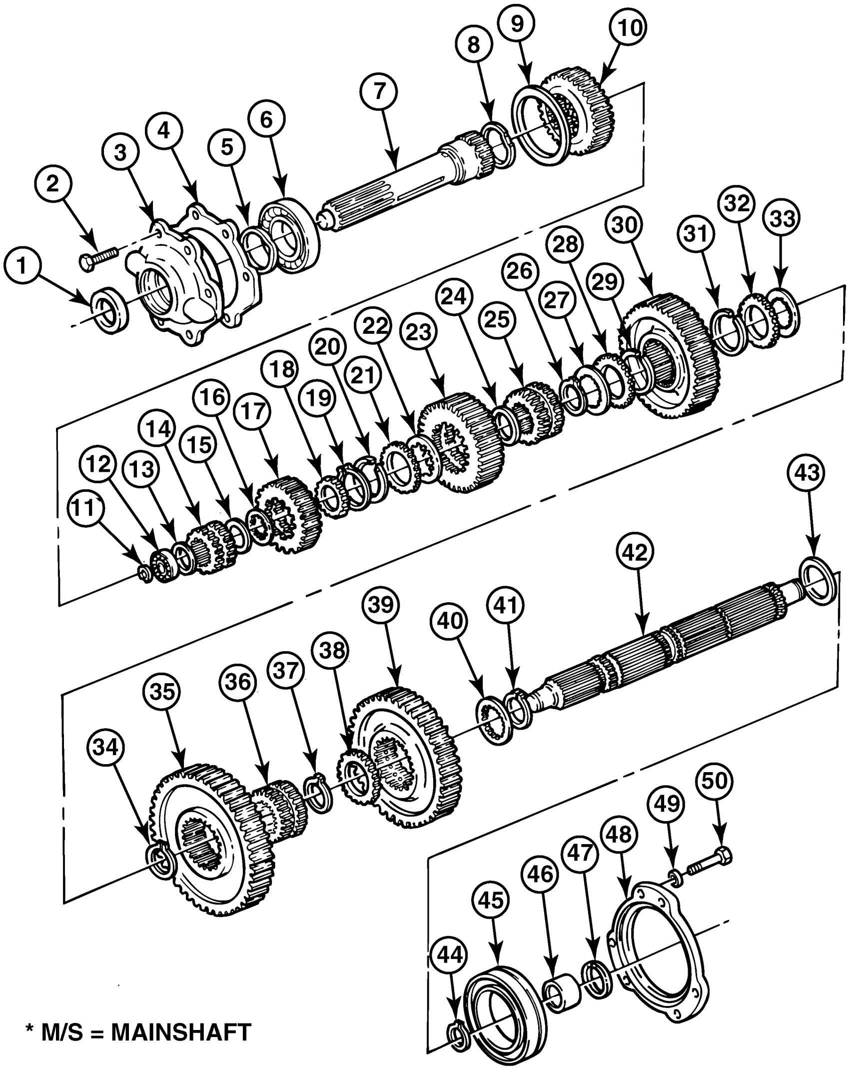
Figure 10 — Rear Case Top Cover Group



1. 3RD, 4TH, 7TH, 8TH SPEED SHIFT FORK
2. LO AND REVERSE SHIFT RAIL
3. LO AND REVERSE SPEED SHIFTER
4. LO AND REVERSE SHIFTER BALL SPRING
5. STEEL BALL
6. LOCKING HEX-HEAD SETSCREW
7. LO AND REVERSE SHIFT FORK
8. 1ST AND REVERSE SHIFT PLUNGER SPRING
9. LO AND REVERSE SHIFT PLUNGER
10. LOCKING HEX-HEAD SETSCREW
11. 3RD, 4TH, 7TH, 8TH SPEED SHIFTER
12. 3RD, 4TH, 7TH, 8TH SPEED SHIFT RAIL
13. 1ST, 2ND, 5TH, 6TH SPEED SHIFT FORK
14. LOCKING HEX-HEAD SETSCREW
15. SHIFT RAIL INTERLOCK PIN
16. 1ST, 2ND, 5TH, 6TH SPEED RAIL BALL SPRING
17. STEEL BALL
18. 3RD, 4TH, 7TH, 8TH SPEED RAIL BALL SPRING
19. STEEL BALL
20. LOCKING HEX-HEAD SETSCREW
21. STEEL BALL
22. 1ST, 2ND, 5TH, 6TH SPEED SHIFT RAIL

300270a

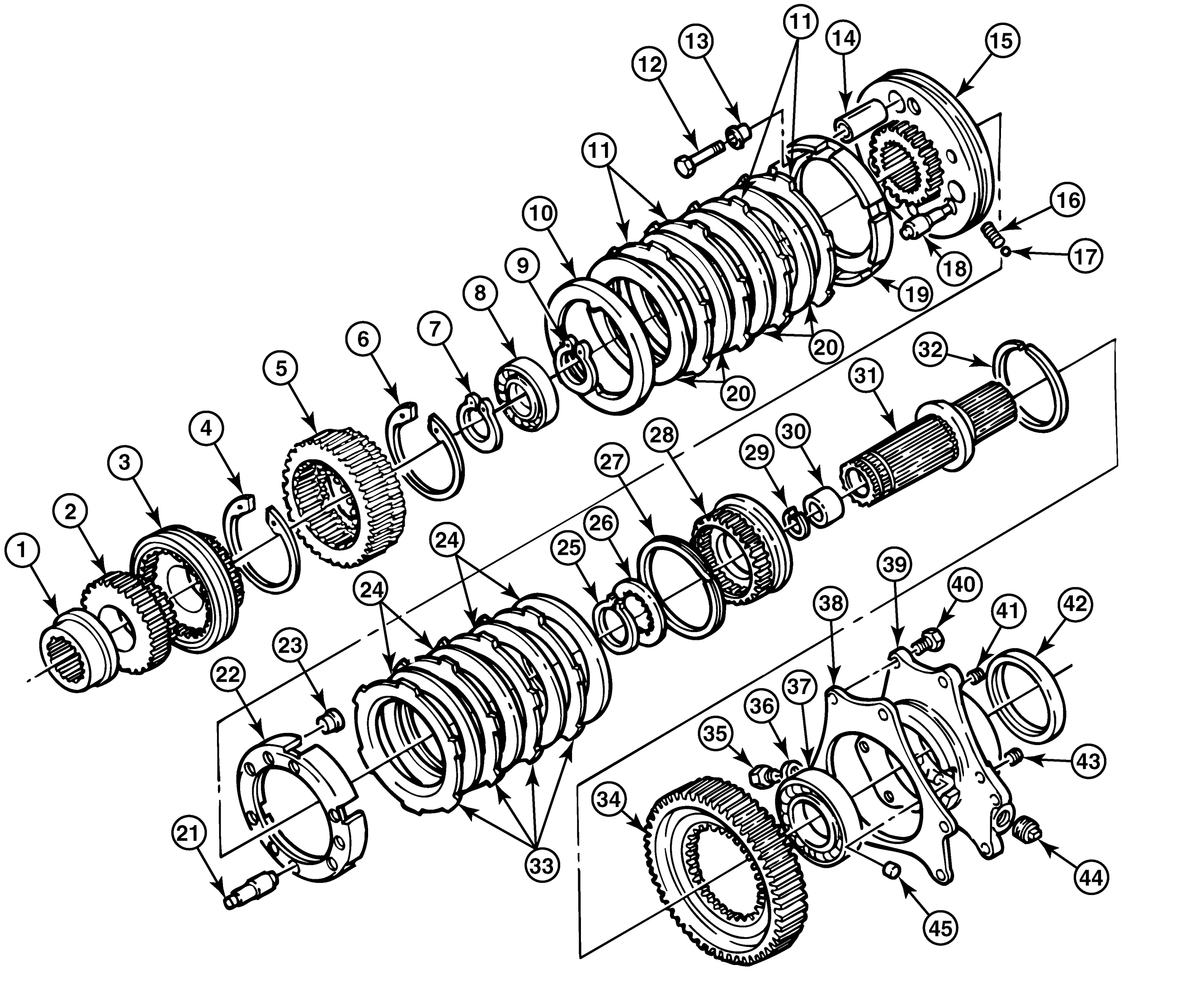
Figure 11 — Main Case Shift Cover Group



1. OIL SEAL
2. CAPSCREW
3. MAIN DRIVE PINION BEARING COVER
4. MAIN DRIVE PINION BEARING COVER GASKET
5. RETAINING RING
6. BALL BEARING
7. MAIN DRIVE PINION
8. RETAINING RING
9. RETAINING RING
10. MAIN DRIVE PINION GEAR
11. RETAINING RING
12. BALL BEARING
13. RETAINING RING
14. 4TH AND 5TH SPEED SLIDING CLUTCH
15. RETAINING RING
16. 5TH SPEED M/S GEAR THRUST WASHER
17. 5TH SPEED M/S GEAR
18. 5TH SPEED M/S GEAR SUPPORT WASHER
19. RETAINING RING
20. RETAINING RING
21. 2ND SPEED M/S GEAR SUPPORT WASHER
22. 2ND SPEED M/S GEAR THRUST WASHER
23. 2ND AND 6TH SPEED M/S GEAR
24. SNAP RING
25. 2ND AND 3RD SPEED SLIDING CLUTCH
26. SNAP RING
27. 1ST SPEED M/S GEAR THRUST WASHER
28. 1ST SPEED M/S GEAR SUPPORT WASHER
29. RETAINING RING
30. 1ST AND 5TH SPEED M/S GEAR
31. RETAINING RING
32. M/S LO GEAR SUPPORT WASHER
33. M/S LO GEAR THRUST WASHER
34. SNAP RING
35. M/S LO GEAR
36. LO AND REVERSE SLIDING CLUTCH
37. SNAP RING
38. M/S REVERSE GEAR SUPPORT WASHER
39. M/S REVERSE GEAR
40. M/S REVERSE GEAR THRUST WASHER
41. SNAP RING
42. MAINSHAFT
43. M/S REVERSE GEAR SPACER
44. RETAINING RING
45. BALL BEARING
46. BEARING
47. RETAINING RING
48. M/S REAR BEARING RETAINER
49. WASHER
50. BOLT

300272a

Figure 12 — Main Drive Pinion/Mainshaft Group

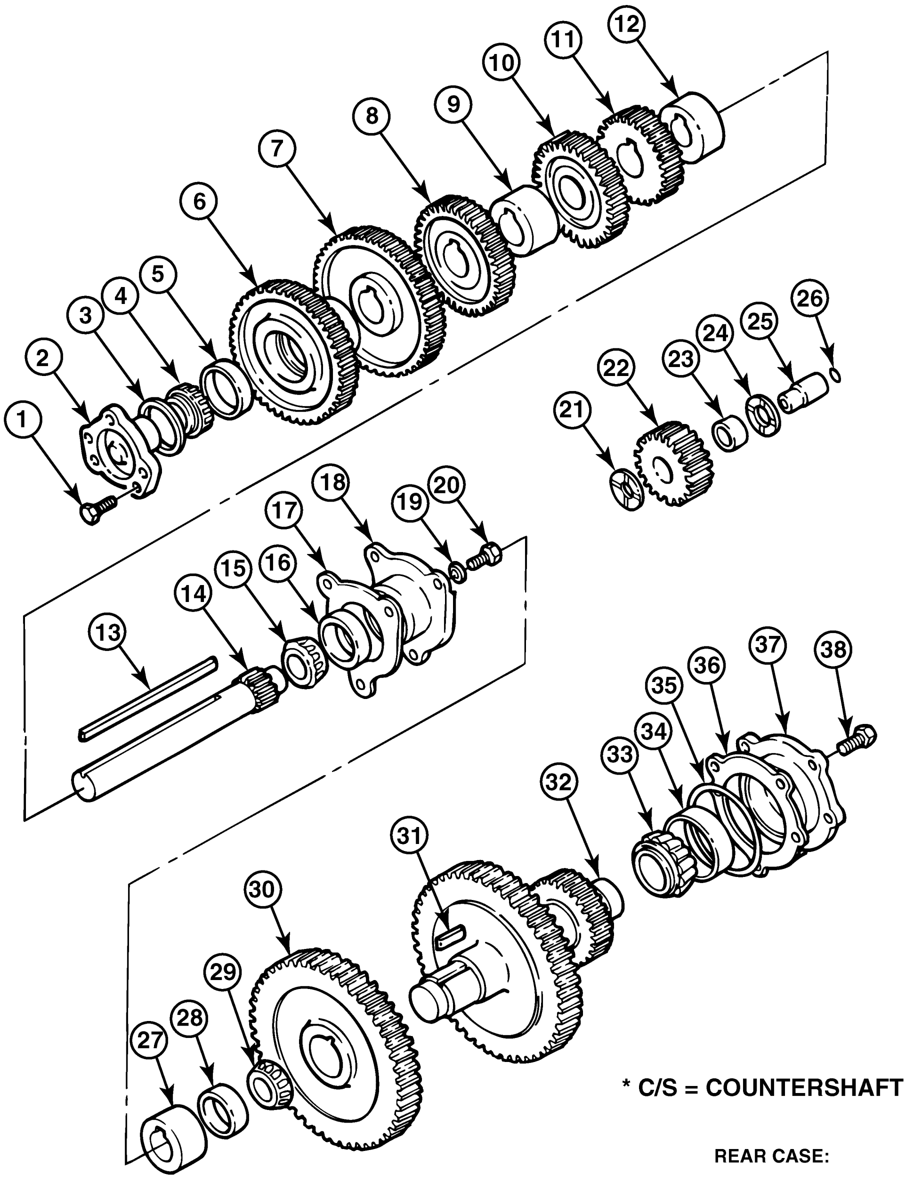


1. REAR CASE (COMPOUND) M/S SLEEVE
2. REAR CASE (COMPOUND) MAIN DRIVE GEAR
3. REAR CASE (COMPOUND) SPLITTER CLUTCH
4. RETAINING RING
5. REAR CASE (COMPOUND) MAIN DRIVE GEAR
6. RETAINING RING
7. SNAP RING
8. BALL BEARING
9. SNAP RING
10. SYNCHRO CLUTCH BACKING PLATE
11. SYNCHRO REACTION DISC
12. HEX BOLT
13. SYNCHRO CLUTCH SUPPORT PIN CLAMP
14. SYNCHRO CLUTCH SUPPORT PIN
15. SYNCHRO HI-LO SLIDING CLUTCH
16. HI-LO CLUTCH PLUNGER SPRING
17. STEEL BALL
18. LO CLUTCH SHIFT PIN
19. SYNCHRO CLUTCH HOUSING
20. SYNCHRO FRICTION DISC
21. HI CLUTCH SHIFT PIN
22. SYNCHRO CLUTCH HOUSING
23. SYNCHRO CLUTCH SUPPORT PIN CLAMP
24. SYNCHRO FRICTION DISC
25. SNAP RING
26. REAR CASE (COMPOUND) M/S LO-RANGE GEAR THRUST WASHER
27. RETAINING RING
28. REAR CASE (COMPOUND) M/S HUB
29. RETAINING RING
30. BEARING
31. REAR CASE (COMPOUND) MAINSHAFT
32. RETAINING RING
33. SYNCHRO REACTION DISC
34. REAR CASE (COMPOUND) M/S LO-RANGE GEAR
35. HEX-HEAD PLUG
36. WASHER
37. BALL BEARING
38. REAR CASE (COMPOUND) M/S REAR BEARING COVER GASKET
39. REAR CASE (COMPOUND) M/S REAR BEARING COVER ASSEMBLY
40. HEX BOLT
41. PLUG
42. OIL SEAL
43. PLUG
44. MECHANICAL OPENING PLUG
45. SPEEDOMETER GEAR SHAFT BUSHING

M/S = MAINSHAFT

300271a

Figure 13 — Rear Case Mainshaft Group



MAIN CASE:

1. HEX BOLT
2. C/S FRONT BEARING RETAINER
3. O-RING
4. TAPERED ROLLER BEARING
5. BEARING CUP
6. C/S MAIN DRIVE GEAR
7. 5TH SPEED C/S GEAR
8. 3RD SPEED C/S GEAR
9. 2ND AND 3RD SPEED C/S GEAR SPACER
10. 2ND SPEED C/S GEAR
11. LO SPEED C/S GEAR
12. REVERSE C/S GEAR SPACER
13. COUNTERSHAFT KEY
14. COUNTERSHAFT

MAIN CASE:

15. TAPERED ROLLER BEARING
16. BEARING CUP
17. C/S REAR BEARING RETAINER SHIM
18. C/S REAR BEARING RETAINER
19. WASHER
20. BOLT
21. REVERSE IDLER FRONT THRUST WASHER
22. REVERSE C/S GEAR
23. BEARING
24. REVERSE IDLER REAR THRUST WASHER
25. REVERSE IDLER SHAFT
26. PLUG

REAR CASE:

27. REAR CASE (COMPOUND) C/S SPACER
28. BEARING CUP
29. TAPERED ROLLER BEARING
30. REAR CASE (COMPOUND) C/S UNDER DRIVE GEAR
31. KEY
32. REAR CASE (COMPOUND) COUNTERSHAFT
33. TAPERED ROLLER BEARING
34. BEARING CUP
35. O-RING
36. REAR CASE (COMPOUND) C/S REAR BEARING SHIM
37. REAR CASE (COMPOUND) C/S REAR BEARING RETAINER
38. HEX BOLT

300273a

Figure 14 — Countershaft Group (Main Case and Rear Case)

SPUR GEARS

Spur gears have straight-cut teeth and are the simplest type of gear used in truck component applications. The gears contact each other over the entire width of the tooth at the same instant.

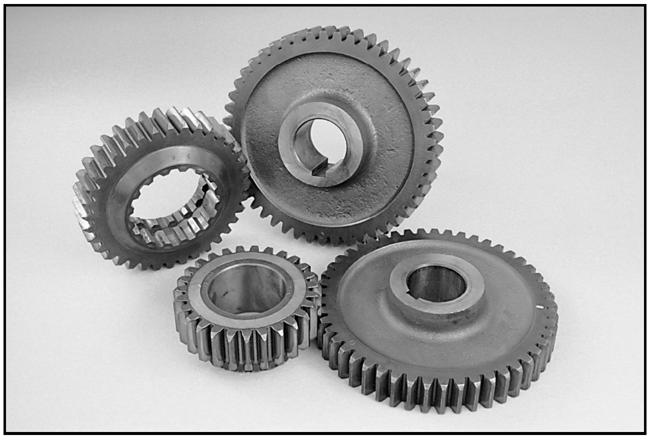


Figure 15 — Typical Spur Gears

Transmission applications use spur gears for all forward speed gears as well as the reverse idler gears.

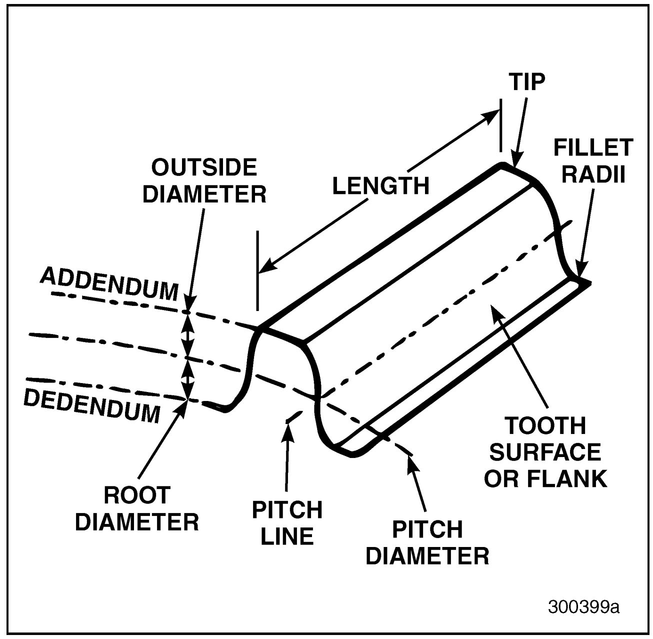


Figure 16 — Spur Gear Teeth

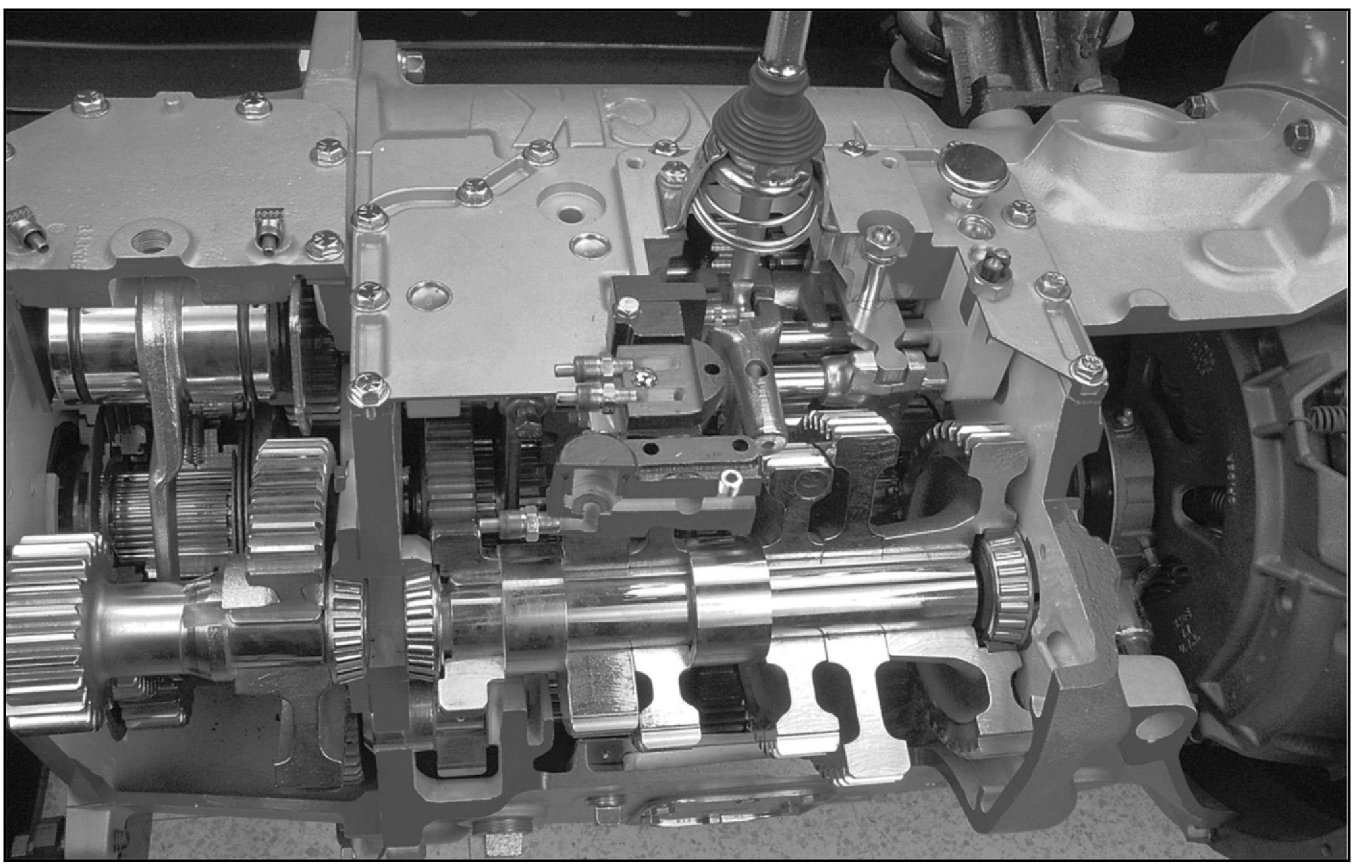


Figure 17 — Spur Gear Application

Workings of a Spur Gear

For a better understanding of how spur gears operate, the following description defines how two gears pass (or mesh) through three stages of contact while in operation.

1. As the gears begin to mesh, the initial contact occurs in the *dedendum* (lower) portion of one tooth (on the driving gear) and in the *addendum* (upper) portion of the mating tooth (on the driven gear). At this point of torque transfer, tooth loading is relatively light since most of it is carried by the teeth in full mesh and a portion by the teeth going out of mesh. Contact between the two teeth moves in a sliding action as they proceed through mesh. The sliding velocity decreases until it is zero when the contact points reach the intersection of their common pitch lines.
2. At full mesh when the two teeth meet at their common or “operating”*pitch line*, there is only a rolling motion, no sliding. However, at this stage, tooth loading is at its greatest.
3. Coming out of mesh, the two mating teeth also move in a sliding action, basically opposite of the initial contact stage.

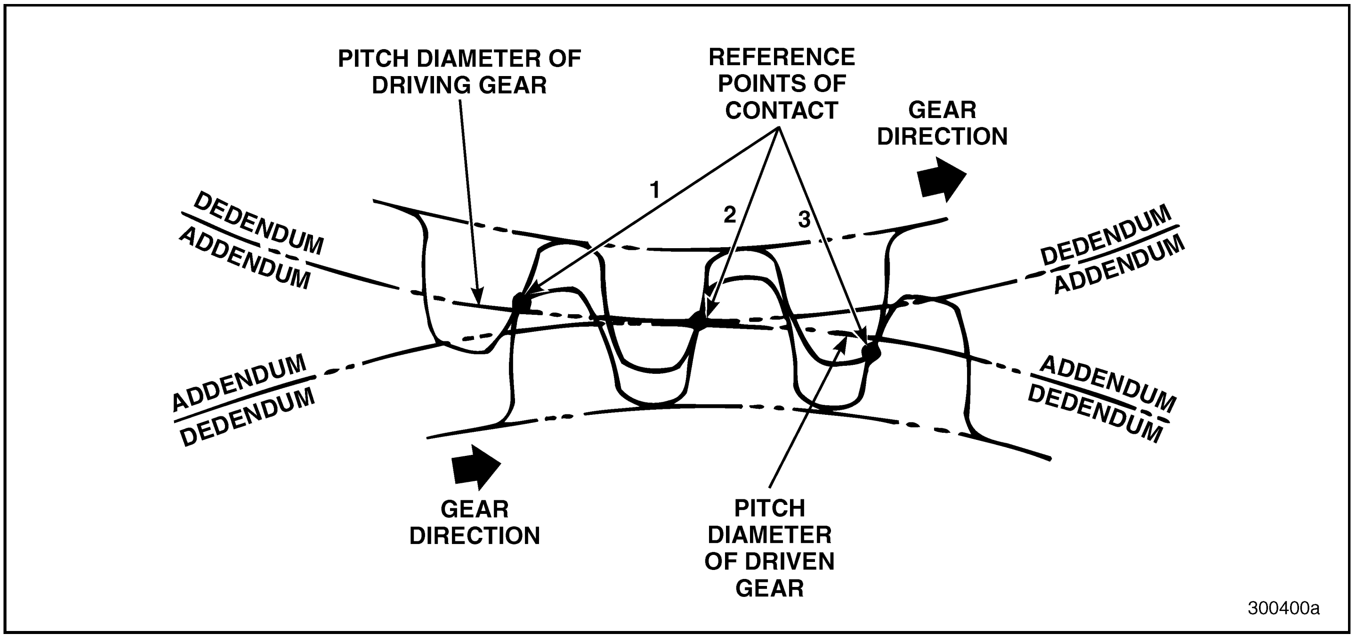


Figure 18 — Spur Gear Points of Contact

300 GENERAL TYPES OF FAILURE

OVERLOAD

Overload refers to a force that is **much higher than the intended force**, which causes severe, premature damage. It does **not** necessarily mean that abuse has occurred; rather, overload of one part **may** be caused by the malfunction of another part or system.

Overloading may be short-term or it may be sustained. Short-term overloading may be so sudden that it can be called *shock loading*. A shock load may be large enough to break the part instantly. An example of this would be a shaft or a gear which breaks in two without any sign of fatigue “beach marks” on the crack surface.

A shock load (or short-term load) may also be just large enough to distort or crack the part, so the part may continue to work but then break later. An example of this would be a tooth which breaks off with a rough fracture near the surface, and smoother “beach marks” radiating inward from the point of fracture.

Sustained overloading will eventually cause severe wear, premature pitting or spalling, or bending or torsional fatigue fracture. Generally, in a transmission, *sustained overloading* is more likely than shock loading.

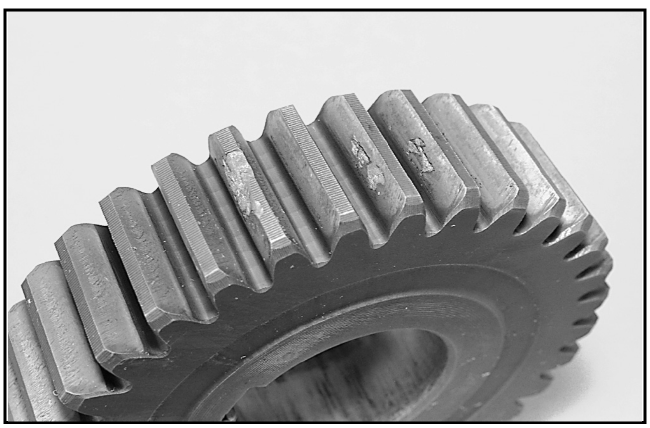


Figure 19 — Sustained Overload

SHOCK LOAD

Shock load is a rapidly applied load or force which may be severe enough to exceed the strength of the component and cause immediate damage.

If the failed part separates into two or more pieces, the operator will usually notice immediately. If, however, the part is only cracked, the operator may not be aware of the damage until some time later.

The crack then becomes a point of origin for fatigue, which can progress until the part fails. Thus, failure can occur later while the vehicle is being operated under normal conditions.

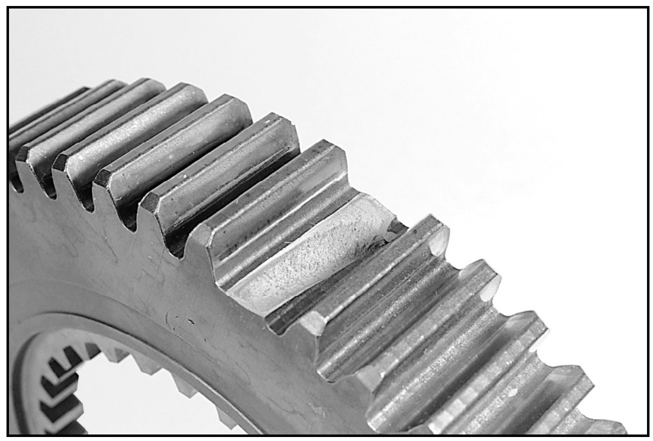


Figure 20 — Shock Load Failure

LUBRICATION PROBLEMS

Contaminated Lubricant

Any lubricant which contains moisture, dirt or wear particles is a contaminated lubricant. Contaminated lubricant (oil contamination) is a common cause of geared unit failure.

There are a number of ways that the lubricant in a geared unit can become contaminated.

- Moisture and dirt can enter the unit through a faulty oil seal or a breather.
- If the unit is not thoroughly cleaned around the drain or level plugs, dirt and moisture can enter the unit when checking or refilling lubricant level.
- Wear particles can build up through normal wear while the unit is in service.

Lubrication Failure

Lubrication failure can be caused by:

- Low oil level
- Improper oil quality
- Contaminated oil
- Oil leaks
- Clogged passages
- Lack of an Extreme Pressure (EP) additive

Failures resulting from improper lubricants or from EP additive depletion show up on the gear teeth as unusual wear patterns. As the condition worsens, wear particles from the gear teeth contaminate the lubricant and may cause secondary damage to the unit.

NOTE

Do not mix brands or types of lubricant. The chemical additives may be incompatible and, as a result, may cause sludge, acid formation or hardening of the lubricant.

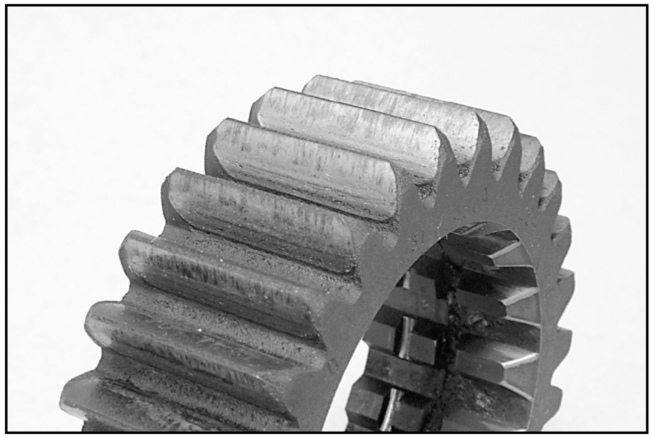


Figure 21 — Inadequate Lubrication

Improper Lubricant Maintenance

USING THE WRONG OIL

Improper lubricant or lubricant with depleted additives can cause failure. The wrong lubricant does not provide adequate film protection.

To meet the demands of the higher operating temperatures generated in today's transmissions, a thermally stable gear oil is the factory fill for all Mack geared components. This thermally stable oil is **mandatory** for use in all components for which Mack gear oil is specified.

It is also important to note that noncurrent specification oils should not be used as a makeup oil to units using newer oils. Benefits of the latest specification oil will not be realized if mixed with standard gear oils.

HEAT AND LUBRICATION

A continuous transmission operating temperature of 121°C (250°F) for mineral-based oil (140°C [300°F] for synthetic-based oil) should be considered as maximum for reasonable drain intervals. If temperatures continuously exceed this level *(overheating)*, adjust the service schedule accordingly or correct the condition causing the high temperatures.

NOTE

Always refer to the latest TS494 or maintenance manual for current lubricant specifications, drain intervals and operating temperature information.

A rise in temperature of 11°C (20°F) over 121°C (250°F) for mineral-based oil (149°C [300°F] for synthetic-based oil) doubles the oxidation rate, thus shortening the effective life of the oil. Short periods over 149°C (300°F) do not necessarily indicate a transmission problem, but do affect transmission oil life.

Certain conditions can cause a temperature increase, creating the need for a transmission oil cooler. These include:

- Any vehicle application that has high transmission shaft speed at low ground speed or runs above a continuous temperature of 121°C (250°F) for mineral-based oil (149°C [300°F] synthetic-based oil).
- Geographical locations in which the vehicle is to be operated, such as mountains, or in high ambient temperatures.
- Transmissions running a PTO in stationary application.
- Vehicle configurations that restrict air movement around the transmission (for example, aero body configurations, low front bumpers, deck plates, skirting or an exhaust pipe near the transmission).
- Refer to Service Manual Oil Cooler, 10-101, for T200 transmission oil cooler usage requirements for engine horsepower or GCW/GVW.

PROPER LUBRICATION LEVEL

Lubrication fill levels for transmissions are critical. Always fill to the proper lubricant level. Overfilling the transmission with lubricant causes it to churn, foam and overheat. This prematurely breaks down the lubricant. Too little lubricant allows heat buildup and prevents adequate coating and protection of components. The lubricant should be level with the transmission oil fill plug.

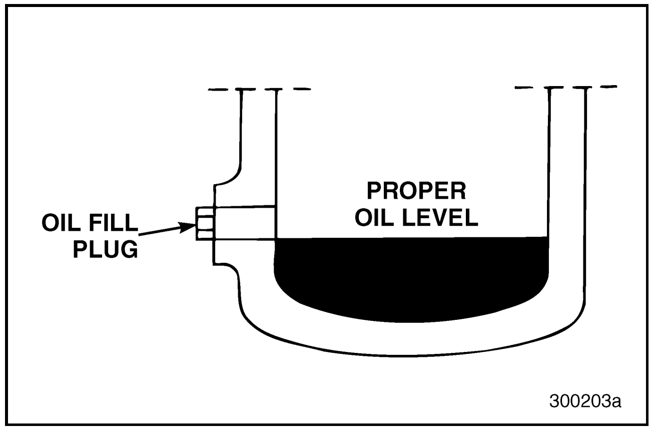


Figure 22 — Transmission Oil Level

Lubrication-Related Failure Modes

LOW LUBRICANT LEVEL

This failure is usually the result of leakage or checking the lubrication level improperly. A transmission operated low on lube may eventually cause the transmission gears or bearings to fail.

FATIGUE

When a part cracks or breaks, it is often a result of fatigue. A fatigue crack can occur when a part is subjected to high, cyclic loads, which are not high enough to break the part immediately, but are high enough to eventually create a crack, and then make the crack grow into the part.

If the crack is broken open, and its surface is not damaged, it will usually show “beach marks” or “contour lines” on a basically smooth area. Each line shows where the crack stopped after one of the cyclic loads made it grow slightly deeper into the part. Eventually, the part may break completely into two pieces, in a “fast fracture.” The fast fracture area will have a noticeably rougher texture and shape than the fatigue crack.

The higher the cyclic loads are, the faster the fatigue crack will grow into the part. If the cyclic loads are low enough, the part will not crack, or an existing crack will not grow.

If a fastened joint carries cyclic loads, for example in a connecting rod, it is important to have full torque on the fastener, because this greatly reduces the cyclic loads on the fastener itself. Undertorquing a fastener can cause a fatigue crack.

A fatigue crack can grow from a pre-existing crack. Cuts, nicks, or improper repair welds can also cause fatigue cracks. A fatigue crack may be difficult to see because the part is not broken or deformed yet. Careful visual inspection may reveal the crack. Other methods such as dye penetrant and magnetic particle inspection are more sensitive in discovering cracks.

Mechanical Loads

There are several different types of mechanical loads:

- Shear
- Tension
- Bending
- Compression
- Torsion

These loads can be constant or they can be cyclic. Often, a part is subjected to two or more types of load at the same time.

Shear is a load in a sliding direction. Gear teeth and shifter forks experience shear loads at their sliding surfaces. These loads are much higher if the lubrication is inadequate. Gear-mounting screws and shaft keys also carry shear loads at the joint line, because their job is to prevent sliding. If they are loose, the shear load on them will be even higher.

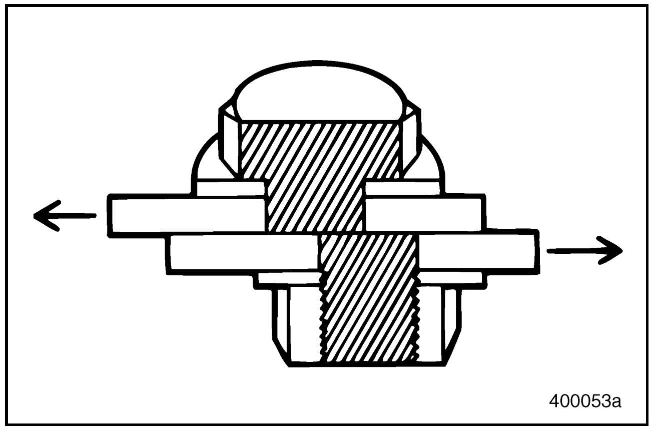


Figure 23 — Shear

Tension is a stretching or pulling load. Torquing a fastener creates tension in the fastener’s shank.

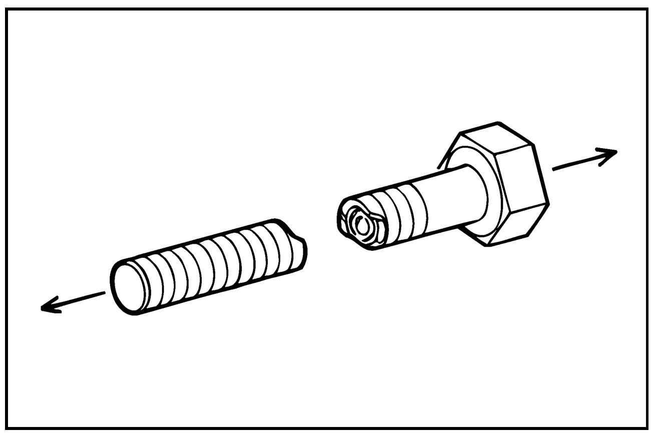


Figure 24 — Tension

Bending — Shifter forks and the roots of gear teeth carry bending loads. Bending loads can be created unintentionally or aggravated by out-of-straightness conditions or installation errors.

Compression is a pressing or crushing force. Gaskets are held under compression. Roller bearings and races, and the faces of the gear teeth, carry compression loads as they roll or slide against each other. Surface fatigue (pitting and spalling) is caused by high cyclic compression force, often acting together with sliding force (friction).

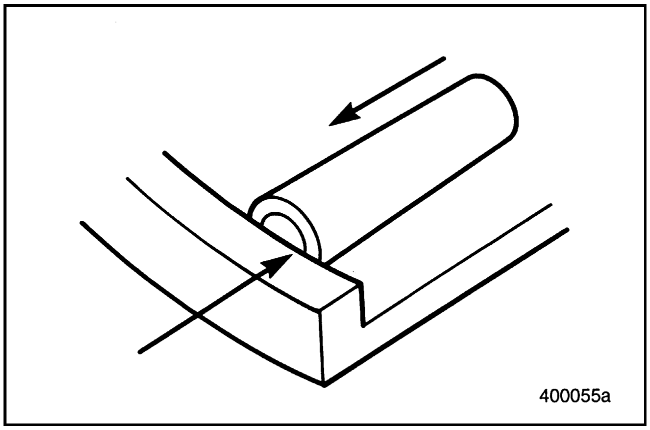


Figure 25 — Compression

Torsion is a twisting force, like screw assembly torque. When a shaft breaks in torsional overload, the fracture may be helical (as shown in Figure 26 and Figure 67) or transverse (as shown in Figure 61). Cyclic torsional loads can cause torsional fatigue cracks, which may also be transverse, but more often start as lengthwise or helical cracks with beach marks.

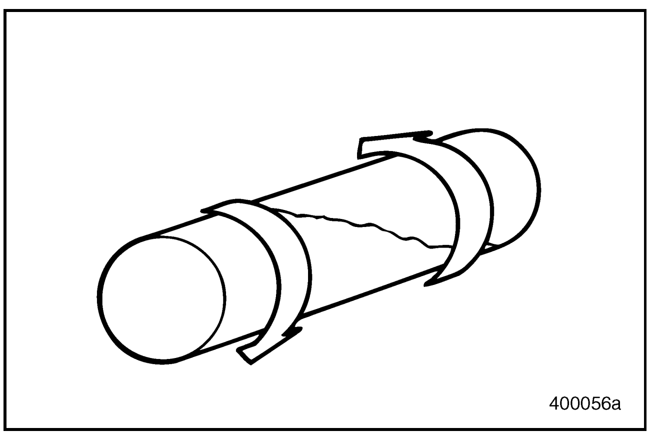


Figure 26 — Torsion

Gear Tooth Surface Fatigue Progression

Cyclic compression, often with sliding, can gradually damage a tooth face in stages, as follows:

1. **Frosting** — A milky or *frosty* appearance from superficial material displacement. This is a normal wear condition, and in fact it often "polishes out" to a shiny appearance long before pitting develops.
2. **Pitting** — Formation of small cavities on the surface of a gear tooth. Pits may start as pinpoint-sized cavities and slowly grow to the size of a pinhead. Pits may form at a point of localized high-pressure contact, and then stabilize as parts wear in. It is not necessary to replace a gear with small pits because it will not cause noise and will provide substantial additional service.
3. **Spalling or Flaking** — One or more larger chips or flakes break from the surface. A spall will grow as its edges break down under continued loads. The gear may become noisy, and tooth bending fatigue cracks may grow from the spalls. Gears found in this condition should be replaced.

BEARING FAILURE MODES

Antifriction bearings used in Mack transmissions include tapered roller, ball bearings and cylindrical roller bearings. The normal and most common mode of antifriction bearing failure is spalling or flaking.

Spalling or Flaking

Irregular flakes or chips break off the surface as a result of cyclic compression. This may be caused by very high loads, misalignment, lubricant breakdown or, on a ball bearing, too much assembly press-fit which removes the clearances between the ball and races. In a tapered roller bearing, excessive loading is indicated by heavy wear on the ends of the rollers from the unintended compression, as shown in Figure 25.

Spalling that develops on one side of a ball bearing raceway (as shown in Figure 27) indicates excessive thrust loading.

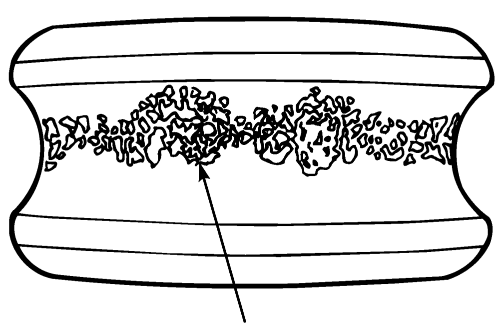


Figure 27 — Off-Center Flaking or Spalling

When the area of spalling cuts across a race, an angular loading should be suspected. This may be due to a bent shaft, bearings that are cocked in their mounts or misalignment of bearing seats. Figure 28 illustrates these three possible conditions. It will be necessary to rebuild a transmission with care to realign bearings and end premature failures that result from these conditions.

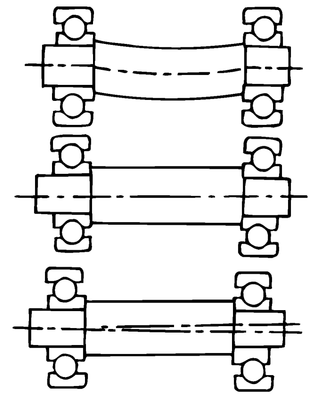


Figure 28 — Angular Loading Caused by Misalignment

Pitting

Pits are small cavities in the surface of the bearing, usually the rollers or the race. Initially, pits may be as small as the size of a pinhead or even smaller. Pitting may progress to spalling. *Pitting* is caused by improper bearing adjustment, contaminated lubricant, foreign material in the bearing, an improperly cleaned housing or electrical current through the bearing (as shown in Figure 50).

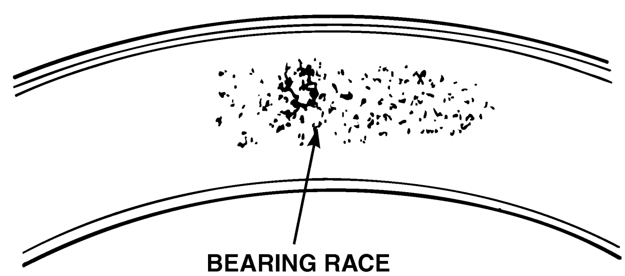


Figure 29 — Pitted Bearing Race

Seizing

When rolling elements fail to roll, the resulting friction generates excessive heat very rapidly. This heating reduces the surface hardness of the races and balls (or rollers), and quickly renders the bearing unfit for use. Discoloration, scoring or *adhesive wear* (metal transfer) may occur. *Seizing* is one of the most common forms of damage encountered when bearings are first put into service. It may be caused by insufficient lubrication, misalignment or excessive load.

The example in Figure 30 shows roller material that has seized on the cone thrust face.

Figure 30 — Tapered Roller Bearing Inner Race

Seizing is generally caused by one of three factors:

- Improper clearances between bearing parts
- Improper lubrication
- Excessive load

Any of these conditions can cause seizing, with resulting overheating and bearing damage.

Contamination

When bearings fail as a result of *contamination*, it is due to either contaminants entering the transmission case or that the bearings have been improperly handled during service or storage. Bearings affected by contamination are identified by scoring, scratching or pitting of the raceways and balls or rollers, or a buildup of rust or **corrosion** on the bearing parts. In addition, the presence of very fine particles in the oil, such as abrasive dust, or the use of overly active EP (extreme pressure) oils, will act as a lapping compound and produce a very highly polished surface on the raceways and balls or rollers.

This lapping process will significantly shorten the life of the bearing.

Impurities will always enter the transmission during its normal breathing process. This will not seriously affect the bearings if the transmission oil is changed as recommended.

Retainer Failures

Retainer damage appears in as many forms as there are types and materials of retainers. They are made of steel, bronze or various plastics and may be mere spacing bands or cages which enclose all but the load-carrying surfaces of the rolling elements.

The most common cause of bearing retainer failure is misassembly (i.e., applying a load directly to the retainer and not the bearing race during installation).

Force should only be applied to the bearing inner race when installing bearings onto a shaft. When pressing a bearing into a housing, apply force only to the bearing outer race. Never apply force directly through the balls or rollers, as this will damage the bearing and cause premature bearing failure. The resulting damage may not be evident at the time of installation, but will eventually cause failure. This condition is known as “brinelling,” which is defined in the Glossary as well as later in this section under Brinelling.

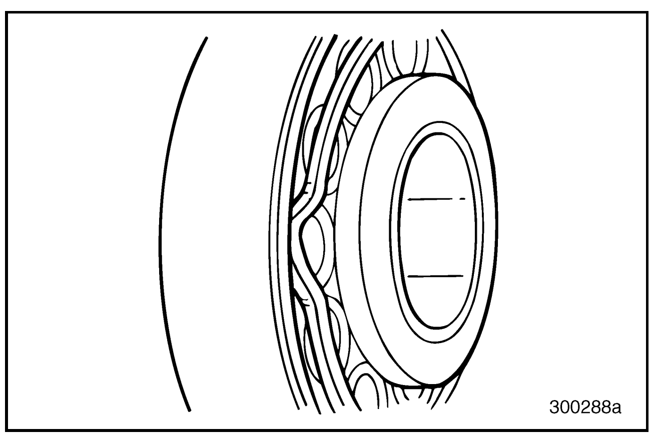


Figure 31 — Retainer Damage

Retainers may also be damaged by foreign matter such as dirt that has penetrated the bearing, or metal particles produced by flaking or cracking. When retainers fail, the cause can be identified by examining the races or looking for contact marks on the retainers.

Rust

Rusting results mostly from improper care of bearings, either in storage, during maintenance or when a transmission is out of service for an extended period of time. Relatively few bearings are made from corrosion-resistant materials and no sealing method can provide absolute protection from moisture. Therefore, always store bearings in a dry place, in the manufacturer's original sealed package until needed for installation. When removed during maintenance, they must not be left unprotected from atmospheric condensation. Rust will also form on gears when the transmission is out of service for an extended period of time.

Moist or perspiring fingers will start rust on unlubricated bearings that will continue even after greasing. Such rusting is usually unimportant except when it appears on raceways or rolling elements, where it forms microscopic pitting that later may cause flaking.

The example in Figure 32 shows a bearing inner race that is rusting due to water that has worked its way into the lubricant.

Figure 32 — Tapered Roller Bearing Rust on Raceway

Corrosion can be found on the outer surfaces of a bearing. This form of rust is unimportant unless it becomes severe. However, it results from poor maintenance practices which should be corrected to protect the load-carrying surfaces of the bearing.

Brinelling

True Brinelling — When a bearing is dropped during assembly or is subjected to an impact, the rolling elements may be driven against the races hard enough to cause dents at points of contact. This condition is known as *true brinelling*. A related form of brinelling results if driving force is applied through the balls or rollers instead of only to the races. A chattering or skipping movement may produce similar dents or only a graying of the visible polished surfaces. Brinelling causes noisy operation and vibration.

False Brinelling — Depressions produced when rolling element bearings are subjected to vibration or low-radial-angle oscillation (or to both) while not rotating is *false brinelling*. The bearing surfaces are either polished or show a characteristic red-brown stain.

General Bearing Guidelines

- If a bearing cone or cup needs replacement, install a complete **new** assembly including cup and mating cone.
- Do not remove a new bearing from its packing until it is time to install it.
- Never clean protective grease from new bearings.
- Do not handle bearings with dirty hands. Rags must be clean and free of lint.
- Never spin bearing unit using compressed air as this may destroy the bearings and cause personal injury.

OIL SEAL FAILURE MODES

Seals generally have two functions, to retain lube and to exclude dust and dirt. To function properly, seals must be clean, void of defects and properly installed.

Seals usually consist of three parts:

- Outer shell
- Seal
- Spring

The seal lip which contacts the rotating yoke is the most important factor governing seal performance. To do an effective job, it must be correctly positioned under pressure against the yoke surface.

Three major factors affect seal performance:

- Condition of the cover mounting bore
- Condition of the yoke contact surface
- Condition of the seal

Seal Lips

The following examples include some possible seal lip failures or problems that can occur with lube leakage problems.

1. A new seal lip has a sharp edge as shown in Figure 33, item No. 1. Normal wear will dull this edge. Check the seal lip; if sharp edge is worn to a flat surface, replace the seal.
2. Check the seal contact area (Figure 33, item No. 2). If this area seems too wide (over 1/32 inch), the seal may be excessively worn or the material may have lost its consistency. Check the yoke for rough or scored condition. Replace the seal and repair or replace the yoke.
3. Check the seal for bonding separating from the outer shell (Figure 33, item No. 3). This could change the flexibility of the seal lip and cause leaks. Replace the seal if separation occurs.
4. Check the seal spring as shown in Figure 33, item No. 4. If the spring has lost its tension or is missing, replace the seal.

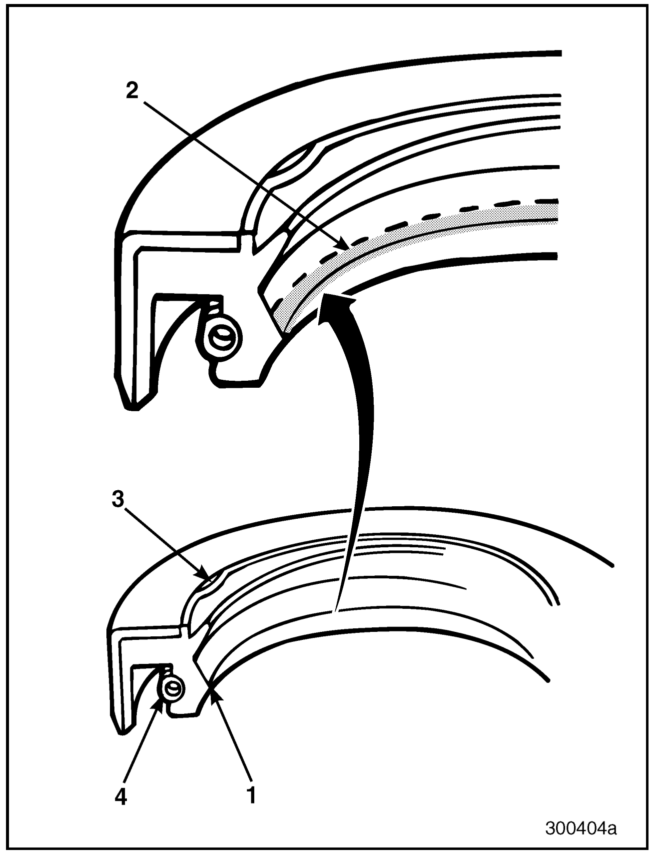


Figure 33 — Seal Lips

GENERAL SEAL LIP CHECKS

- Check the seal lip for cuts, nicks or other defects. Do this carefully, as the smallest defect on the lip can cause a leak.
- Check the seal for a hardened, brittle or cracked condition. This is usually caused by excessive temperatures. A nonflexible seal that has no other defects will still leak.
- Check for accumulation of sludge and other contamination on the inside of the seal lip and casing. The seal should be as clean as possible and void of foreign contaminants.
- Check the fit of the seal lip against the yoke. If a loose fit exists, the seal lip may have lost its material consistency. Seal replacement could be required.

Seal Shells

Light and dark areas on the seal outer shell could indicate the seal outer shell is distorted or the mounting bore is out-of-round. Leakage could occur between the seal shell and the mounting bore. Replace or repair all faulty parts.

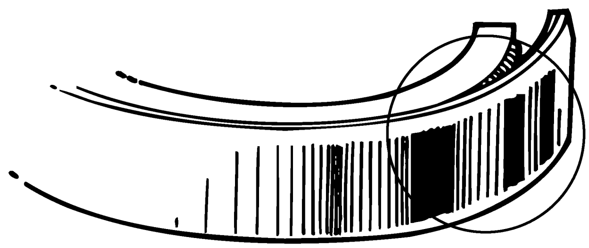


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Figure 34 — Seal Shell Distortion

Deep scratches will cause leakage between the cover and the seal outer case. This condition could have been caused by a burr or other defect in the seal mounting bore that was not detected during installation.

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Figure 35 — Deep Scratches

A bent or damaged outer shell may cause leakage. Damage probably occurred during installation.

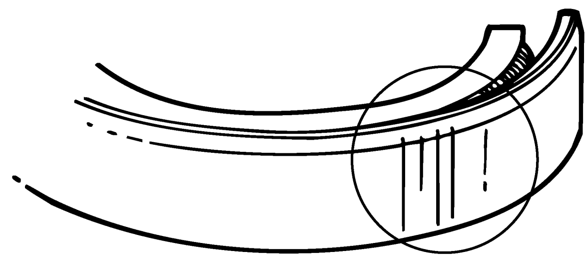

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Figure 36 — Bent or Damaged Shell

Improper Seal Installation

Many seal failures are caused by improper installation. The following list highlights common installation problems that cause seal failures:

- Nicks, burrs or dirt on the shaft
- Nicks, burrs or dirt on the seal bore
- Driving seal too far into its bore
- Cocking seal in its bore
- Not lubricating new seals
- Improper polishing with abrasive

To avoid seal failure due to incorrect installation, begin by inspecting the shaft surfaces. Some shafts have rough surfaces that can scratch the lip of the seal during installation. A scratch in the lip, even a very small one, can cause a seal to leak. Be sure to check the machined surface of the shaft that comes in contact with the lip of the seal during service. Do not perform any maintenance action that would cause a seal leak.

VIBRATION

Vibration problems are often difficult to trace and isolate. While its effects often cause transmission problems, the vibration itself usually originates somewhere else.

Intermittent vibration can be isolated under specific conditions of engine idle or rpm, gear selection, load and speed. Constant vibration should also vary with engine rpm, load and speed to provide clues to its source.

Some possible causes of (and solutions for) vibration include:

- Loose output shaft nut which is sometimes indicated by shiny areas on the output shaft (caused by yoke movement)
  - — Tighten nut to specifications.
  - — Check output shaft for wear.
- Rough idling engine
  - — Use dampened disc clutch.
  - — Correct the idle problem.
- Loose or broken engine mounts
  - — Replace.

Driveline Vibration

Sometimes vibration originates in the driveline. Potential causes include improper universal joint working angles, out-of-phase shafts and shafts that are not balanced. If the driveline is the source of vibration, these conditions must be corrected.

Driveshaft vibrations are divided into two main categories:

- Transverse vibration
- Torsional vibration

TRANSVERSE VIBRATION

Transverse vibration is the result of imbalance as the driveshaft rotates. When a part having an out-of-balance (heavy) side is rotated, unbalanced centrifugal force is created and increases at the square of the speed. The faster the shaft turns, the greater the force acting on the shaft.

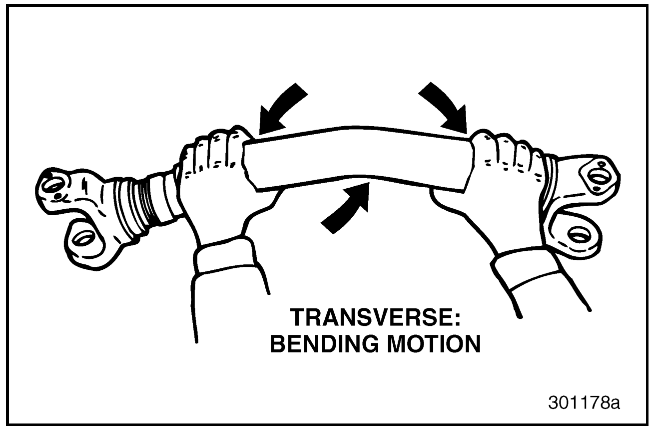


Figure 37 — Transverse Vibration

The force produced by this out-of-balance condition tends to bend the supporting members. Since the supporting members have a natural frequency of vibration similar to a swinging pendulum, a violent vibration may occur at certain periods when the speed of rotation and the natural frequency of the supports coincide.

Transverse vibration caused by driveshaft imbalance is usually characterized by noise and mechanical shaking that can be felt by the driver. **The force from the imbalance increases as a result of speed, not torque load.** Driveshaft speed is determined by vehicle speed, and the vibration is demonstrated best by road-testing the vehicle. Bring the vehicle up to usual operating speed, disengage the engine, and check for vibration while coasting with the engine noise eliminated.

After the road test, remove the rear axle shafts so the driveshaft can be observed dynamically while the truck is in the shop. The driveshaft will have a blurred appearance when operated at the critical vibration speed.

Each end of the shaft must be balanced individually, as each support responds to imbalance in the portion of the shaft that it supports. An out-of-balance condition manifests itself only when the shaft is rotating; therefore, it is necessary to dynamically balance the driveshafts at high speed.

Factors that affect driveshaft balance include missing or mislocated balance weights, bent or dented tubing, accumulation of foreign material and/or phasing problems.

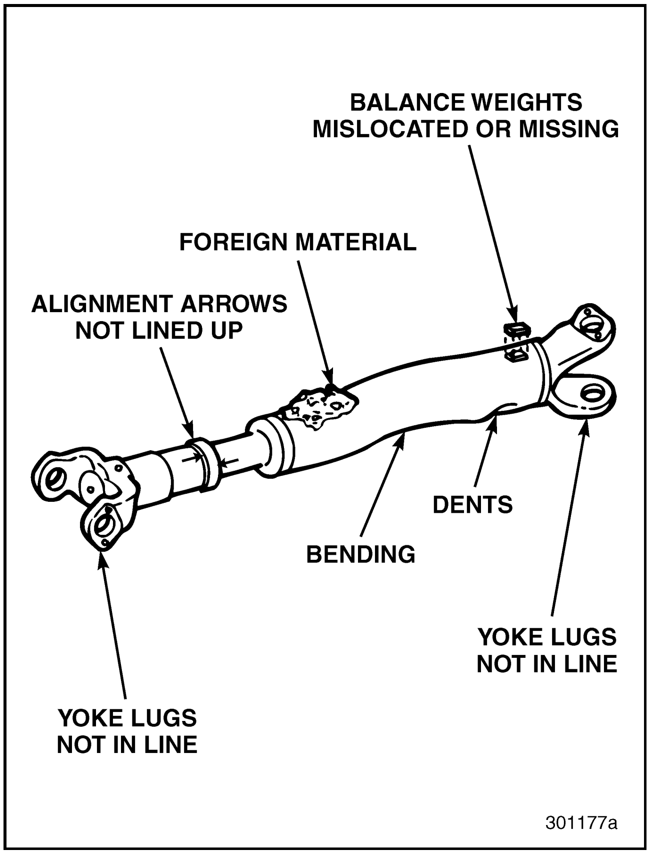


Figure 38 — Factors Affecting Propeller Shaft Balance (Typical)

TORSIONAL VIBRATION

The energy that produces torsional vibration can come from engine power impulses or from improper universal joint angles. Torsional vibration is difficult to identify when road-testing, but certain characteristics do exist. Torsional vibration normally causes a noticeable sound disturbance and can occasionally cause mechanical shaking. In addition, it sometimes causes a transmission gear rattle.

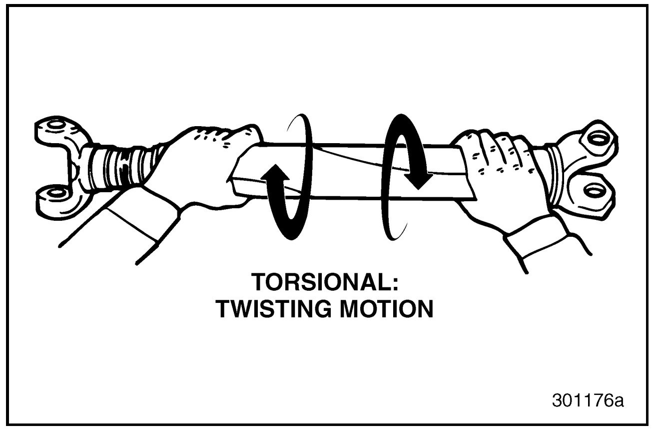


Figure 39 — Torsional Vibration

Torsional vibration can occur more than once anywhere in the operating range, and tends to be most severe at lower speeds. **Changes in torque load usually affect the vibration.**

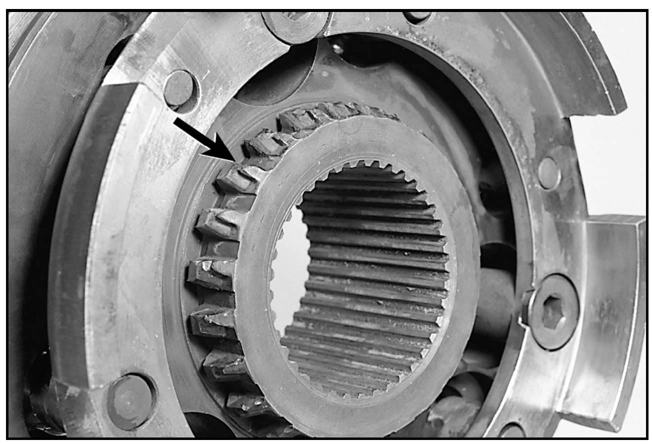


Figure 40 — Torsional Driveline Vibration Could Cause Worn Clutching Teeth

The nonuniform velocity obtained when a universal joint operates at an angle also produces torsional vibration. In a driveline, it is desirable to arrange the individual joint angles so that the net result of the angles minimizes nonuniform movement.

Even with optimum joint angles, torsional vibration will be produced if the joints are out of phase. This condition can exist if the yoke lugs are incorrectly aligned. Such misalignment could occur because the splined connection between the driveshaft halves is incorrectly aligned. It should be verified that misalignment does not exist.

It is practically impossible to maintain the desired joint angles throughout the operating range. Therefore, it is necessary to determine some acceptable maximum limit of torsional excitation.

The amount of torsional movement that can occur without causing excessive disturbance depends on operating speed and characteristics of the supporting structures and other units in the driveline/drivetrain system.

With certain powertrain combinations, it is necessary to add mass to the driveshaft to control torsional vibrations. Without the added mass, other problems can occur such as gear rattle, spline wear and audible vibration within the cab of the truck. To add mass, a damper is placed either at the transmission or at the carrier.

Usually the damper is most effective at the carrier. However, because of the pinion location, this placement is not always possible. When the damper cannot be placed at the carrier, it should be placed at the transmission. Also, driveshaft angles can contribute to the need for a damper. Therefore, on certain four-wheel chassis, a damper is standard.

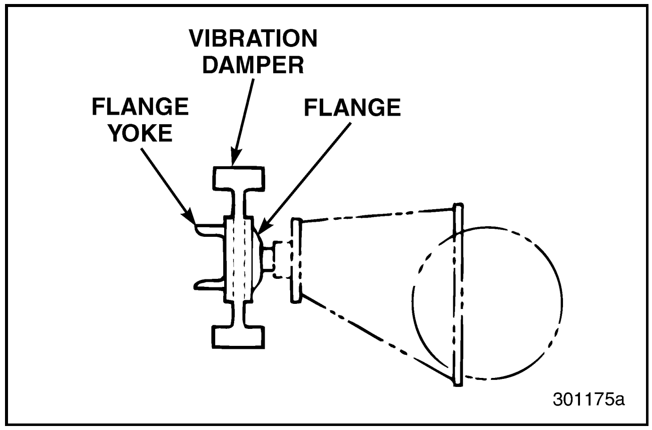


Figure 41 — Vibration Damper

Other vibrational problems in the driveshaft assembly can result from worn or damaged universal joints. Proper maintenance of these joints, in accordance with recommended lubrication intervals, is essential to prevent premature wear and/or failure.

300 SPECIFIC FAILURE ANALYSIS

BEARINGS AND THRUST WASHERS

Tapered Roller Bearing Flaking or Spalling

This tapered roller bearing is *flaking* on the inner race. The outer race and rollers are discolored light brown. The cause of this failure is excessive preload.

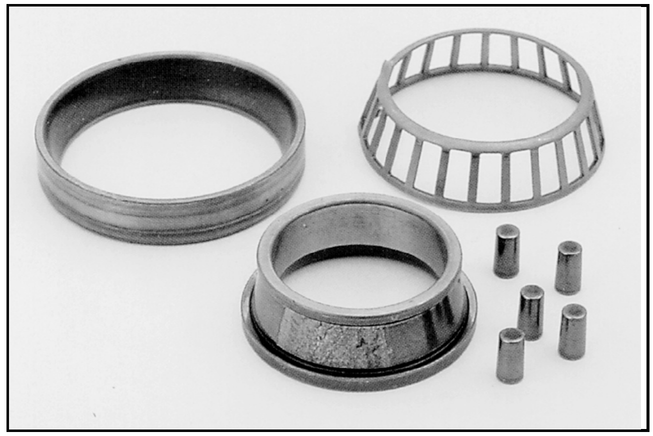


Figure 42 — Tapered Roller Bearing Flaking/Spalling

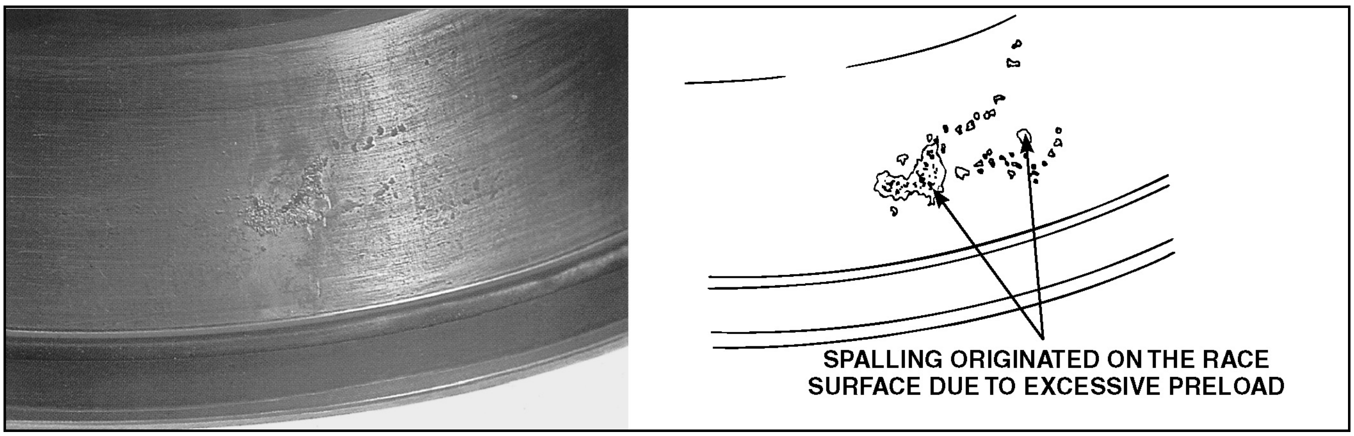


Figure 43 — Outer Race

BEARINGS AND THRUST WASHERS

Ball Bearing Flaking or Spalling

The race on this ball bearing is flaking. The surfaces of all the bearing components are very rough after flaking. The probable cause of this failure is rolling fatigue. Flaking may be caused by overload, excessive load due to improper installation, poor shaft or housing accuracy, entry of foreign objects or rust.

Figure 44 — Ball Bearing Flaking/Spalling

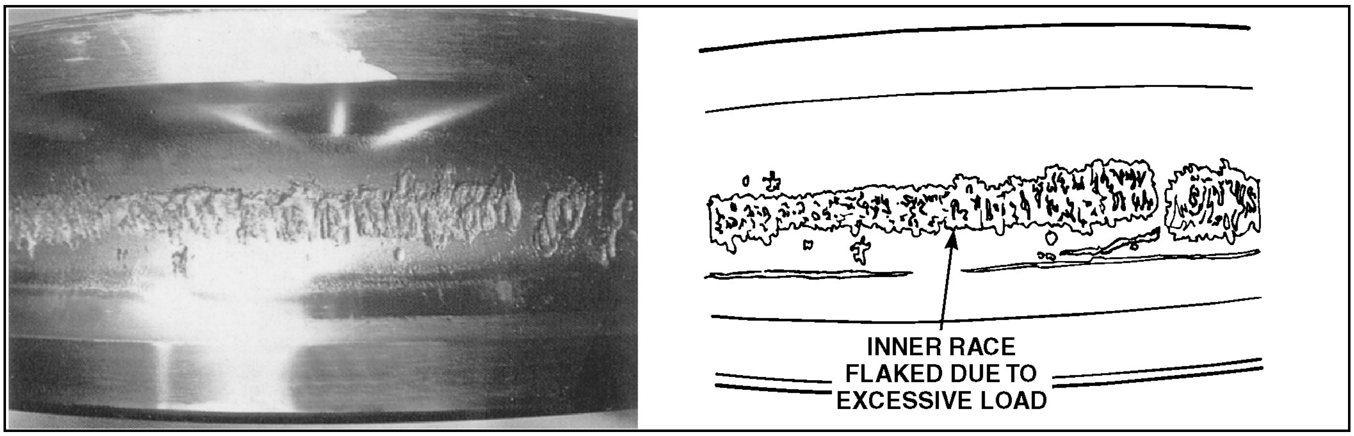


Figure 45 — Ball Bearing Inner Race

BEARINGS AND THRUST WASHERS

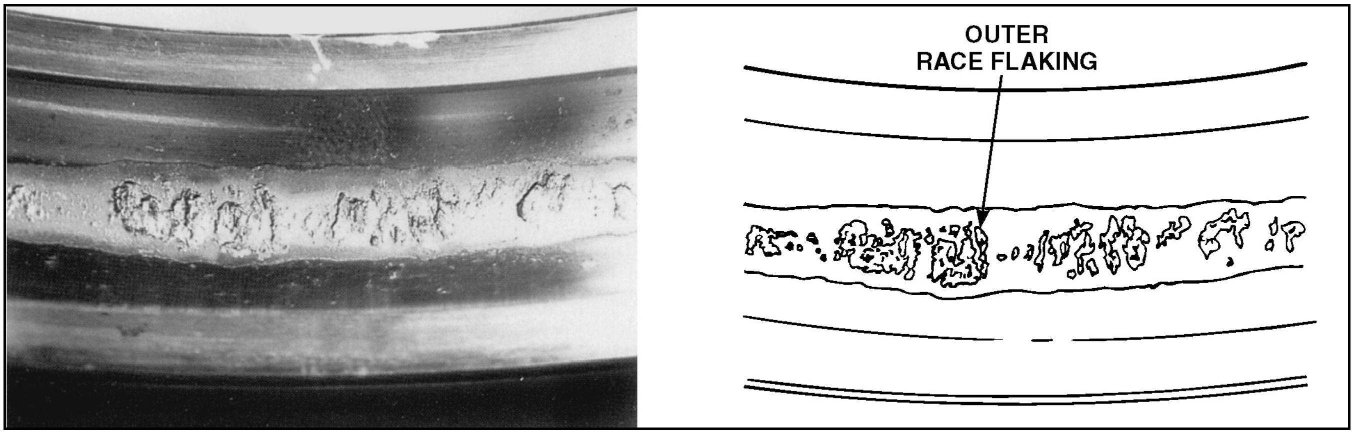


Figure 46 — Ball Bearing Outer Race

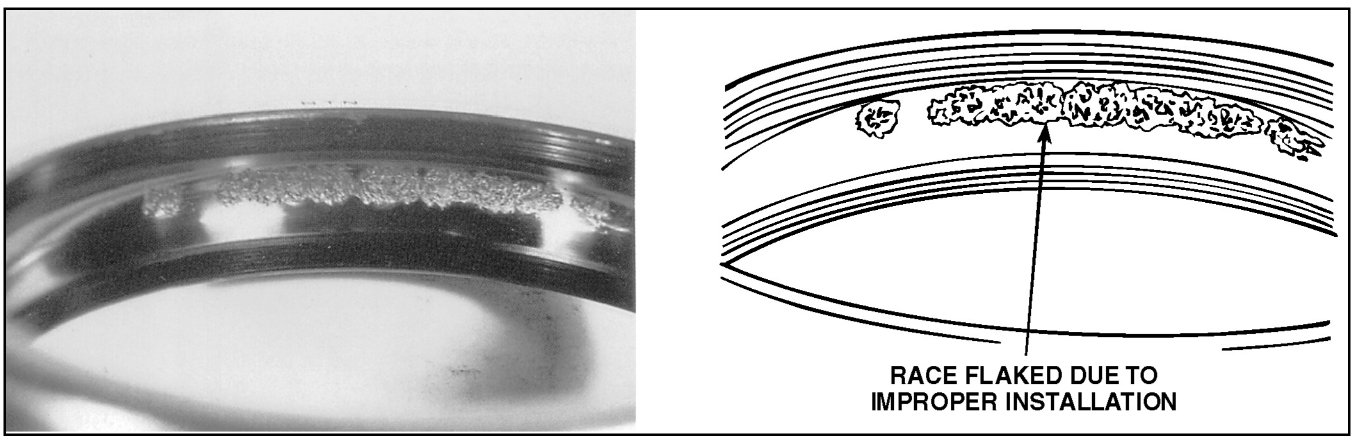


Figure 47 — Flaking on One Side of the Race Surface

BEARINGS AND THRUST WASHERS

Indentations

Indentations in the race surface are caused by trapped solid foreign objects, flaking race surface material trapped in the bearing, or impacts. Indentations can also be attributed to careless handling.

Figure 48 — Bearing Indentations

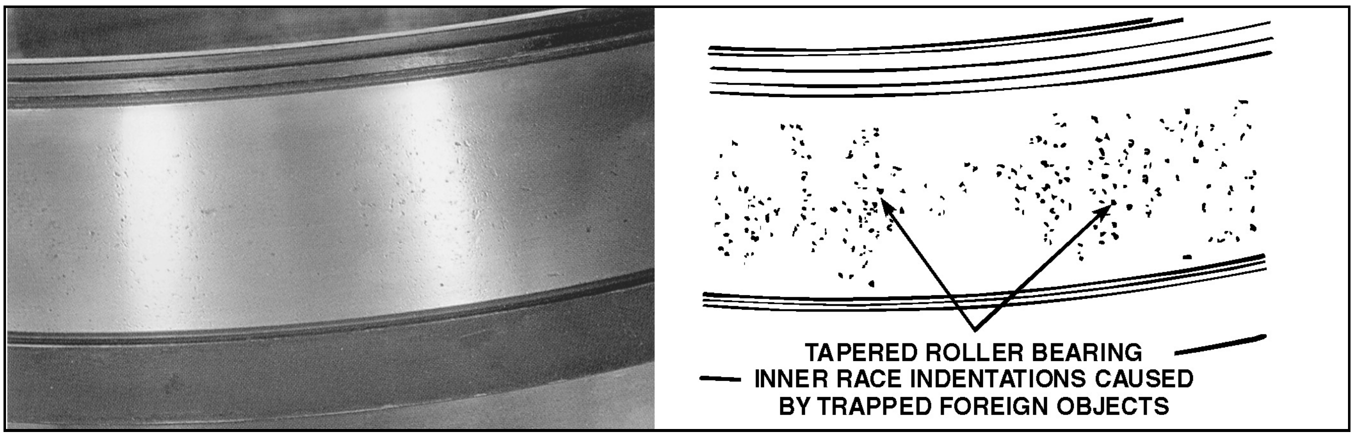


Figure 49 — Inner Race Surface Indentations

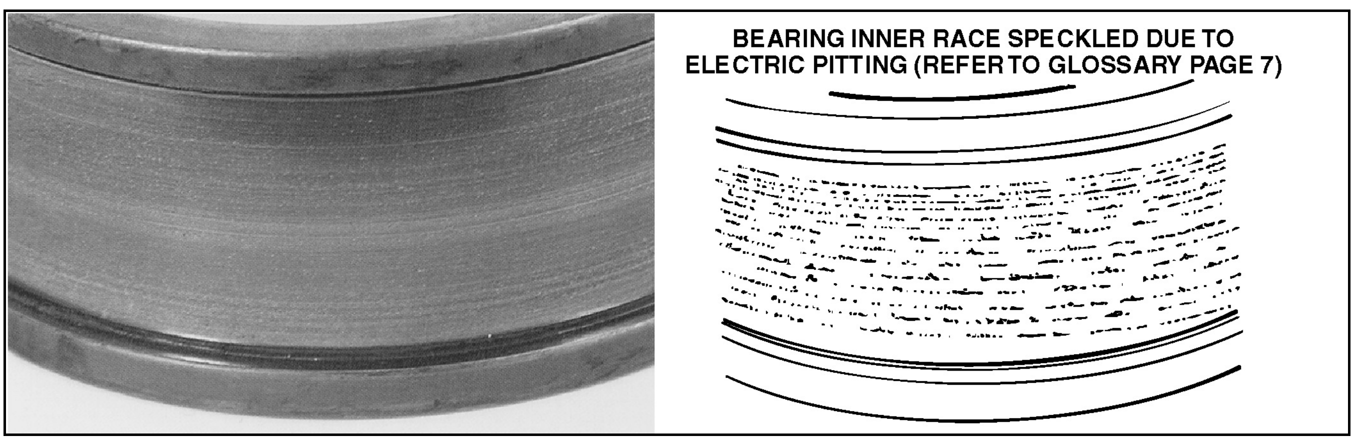


Figure 50 — Speckled Race Surface

BEARINGS AND THRUST WASHERS

Rust and Corrosion

This is an example of rusting or *corrosion* of the bearing race and rolling element surfaces. Sometimes the rust marks are of equal spacing to the bearing roller elements. This results when water or corrosive material (such as acid) comes into contact with the bearing surface. The water can enter the bearings when moisture in the air condenses. Poor packaging or storing conditions, as well as handling with bare hands, can also cause rust.

Figure 51 — Rust and Corrosion

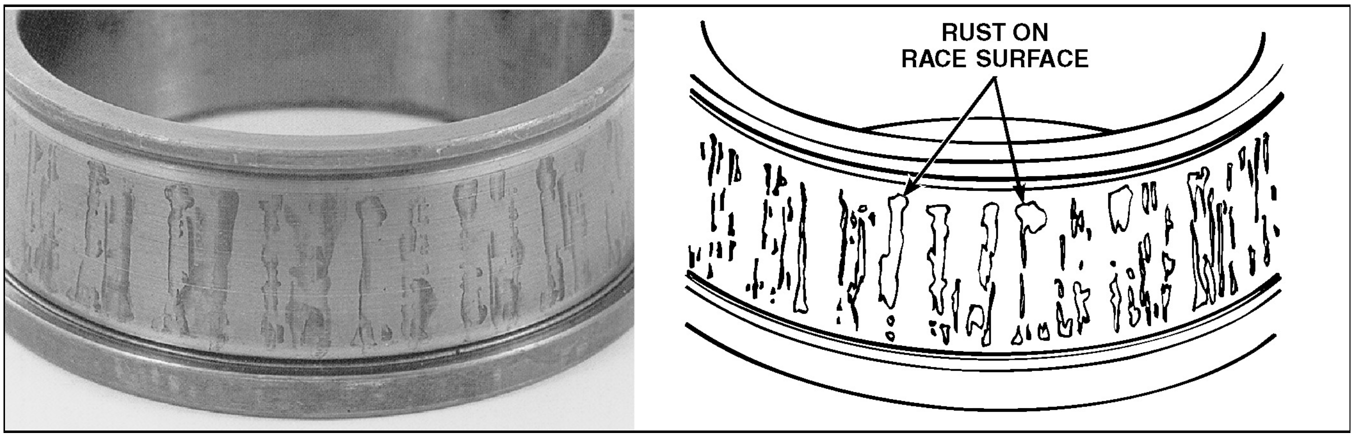


Figure 52 — Water in the Lubricant Caused Rust on the Tapered Roller Inner Race

BEARINGS AND THRUST WASHERS

Fretting and Fretting Corrosion

Fretting produces surface damage often resulting in red rust-colored particles. This fretting can be caused by any of the following:

- Vibration
- Shaft deflection (small-scaled sliding motion under pressure)
- Installation error
- Loose fit

Figure 53 — Fretting and Fretting Corrosion

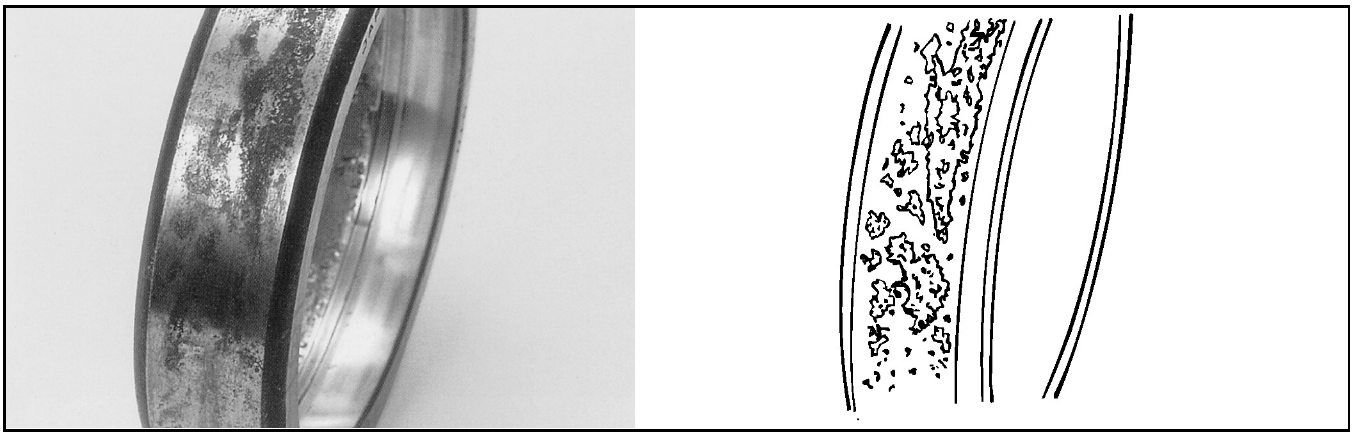


Figure 54 — Fretting Rust on Outer Race Outside Diameter

BEARINGS AND THRUST WASHERS

Thrust Washer Wear

Excessive thrust washer wear can be caused by improper running clearances. This condition can also be caused by inadequate lubrication.

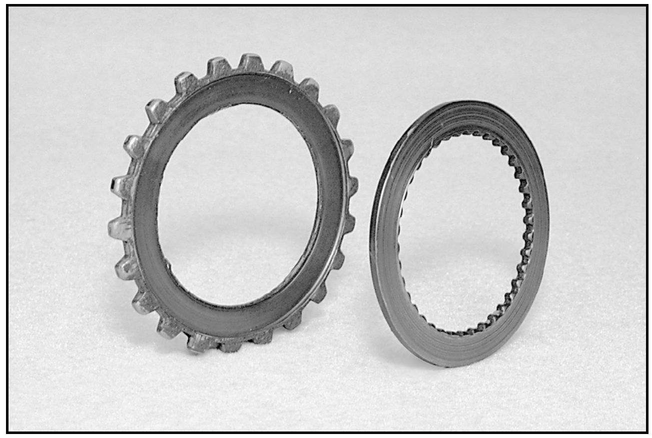


Figure 55 — Thrust Washer Wear

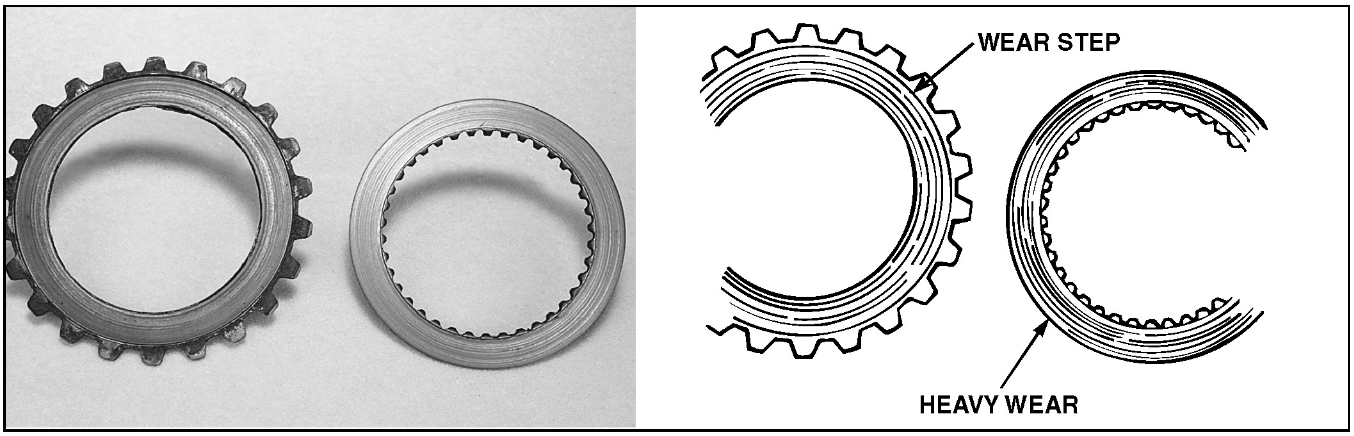


Figure 56 — Thrust Washer Wear

BEARINGS AND THRUST WASHERS

Bearing Debris Damage

Small pieces of metal may get into a bearing race and cause the rollers to skid along a mating surface. The debris also makes small indentations in the race. There is no discoloration to the bearing since the lubrication system keeps the bearing from getting hot and discoloring.

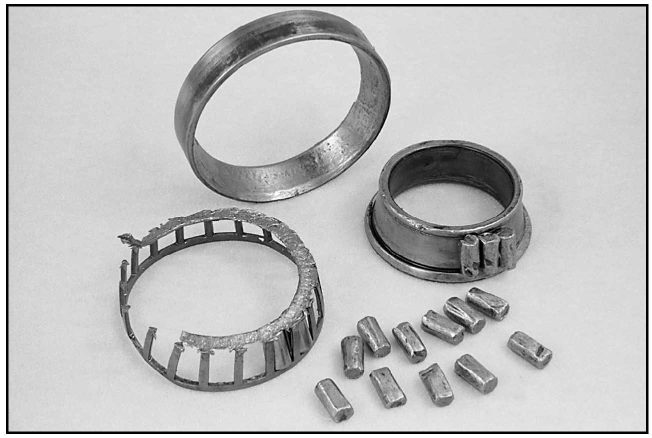


Figure 57 — Debris-Damaged Bearing

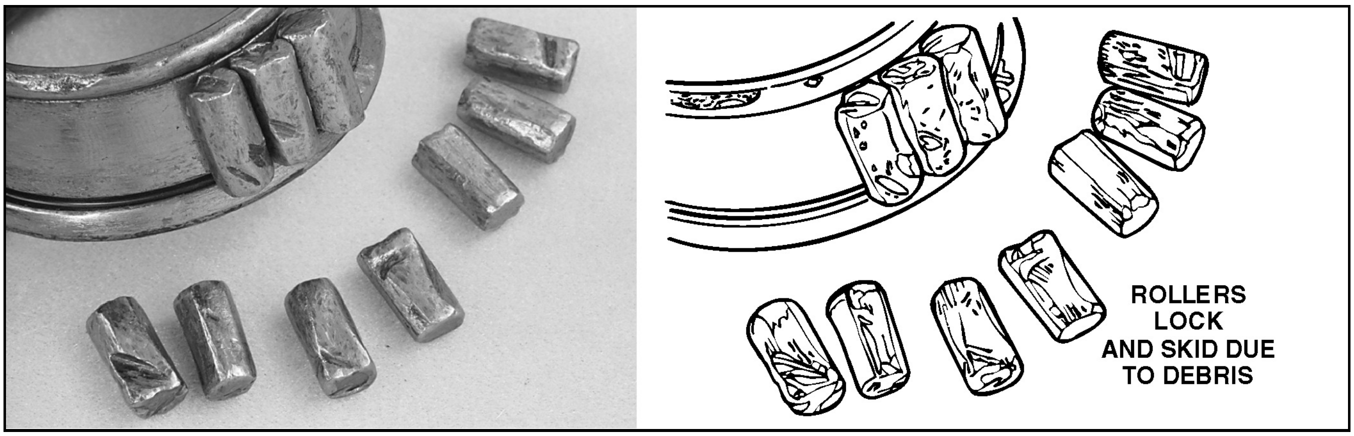


Figure 58 — Roller Bearings and Inner Race

BEARINGS AND THRUST WASHERS

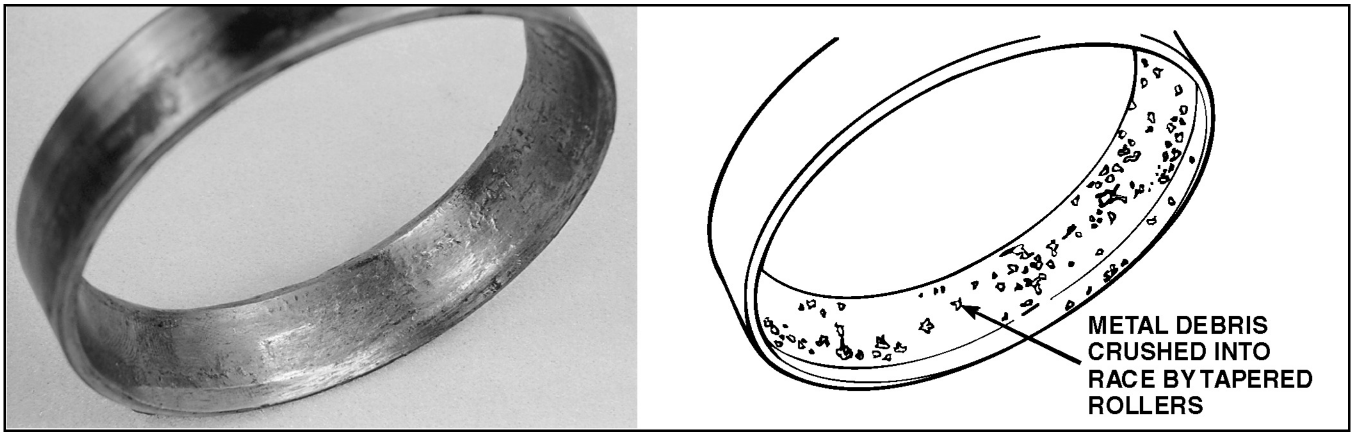


Figure 59 — Bearing Outer Race

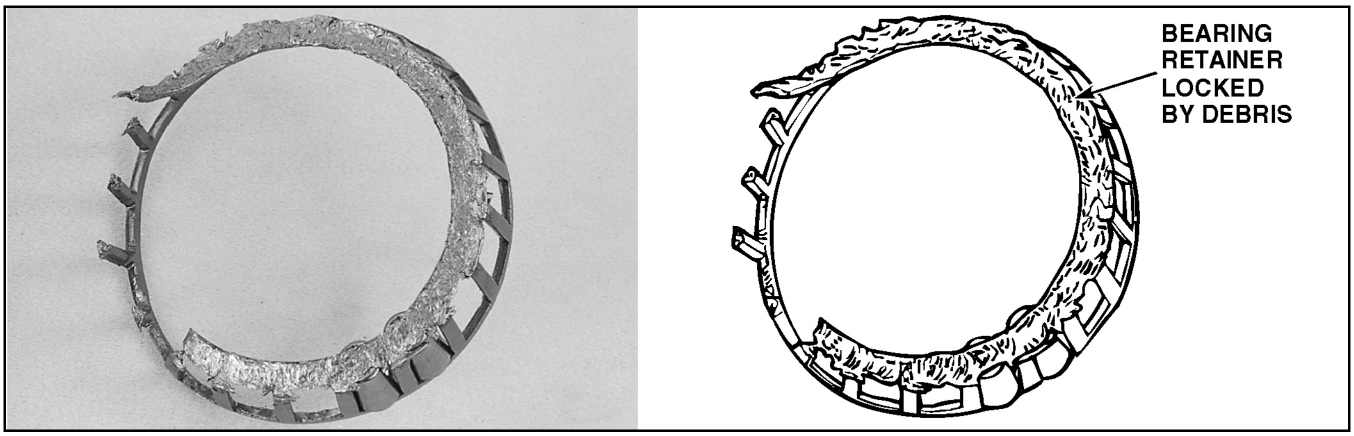


Figure 60 — Bearing Retainer (Cage)

MAINSHAFT/COUNTERSHAFT

Broken (Shock Load)

Occasionally, the transmission can lock into two gears at once. When this happens, the mainshaft instantaneously snaps into two pieces. It creates a smooth break 90 degrees to the center line of the shaft.

This case of *contingent damage* could be caused by a broken shift fork, snap ring out of position, thrust washer damage or other such condition.

The example in Figure 61 and Figure 62 **resembles** a torsional fatigue fracture, but is not. A torsional fatigue fracture would have beach marks progressing inward from the outside diameter and then show a definite change to final fast fracture.

Figure 61 — Broken Mainshaft

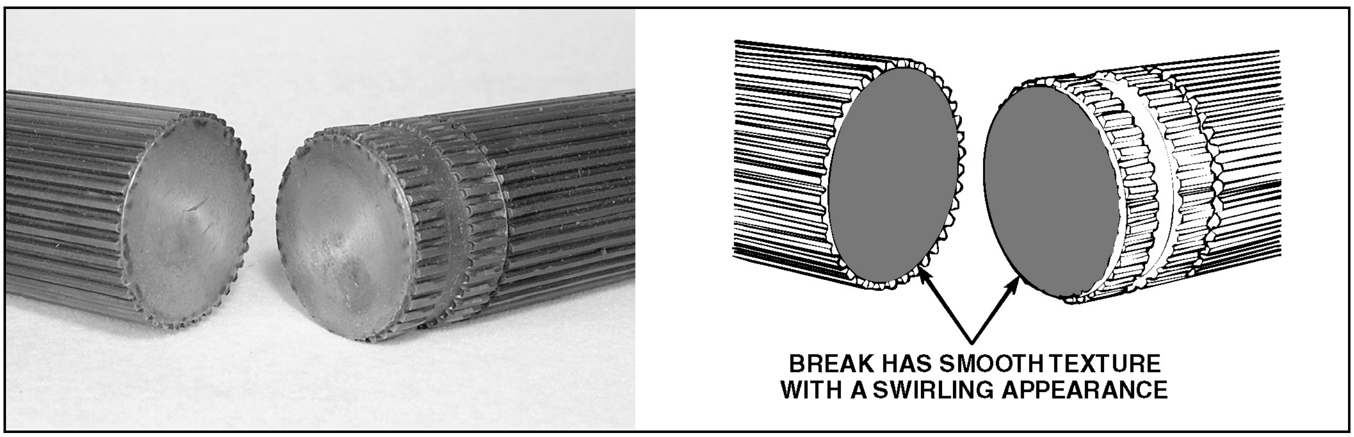


Figure 62 — Broken Mainshaft

MAINSHAFT/COUNTERSHAFT

Twisted Mainshaft

These splines are no longer in alignment, so the sliding clutch cannot slide freely on the shaft. This twist may have been caused by shock load or, at some point in its lifetime, the transmission may have gone into two gears at once.

If the transmission momentarily went into two gears at once, this would be contingent damage resulting from a broken shift fork, snap ring out of position or thrust washer damage.

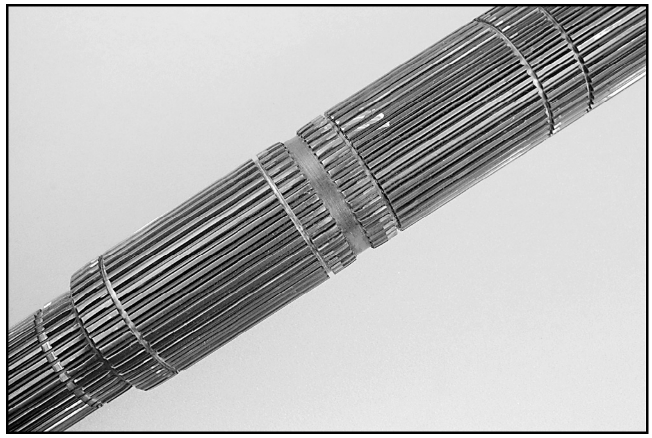


Figure 63 — Twisted Mainshaft

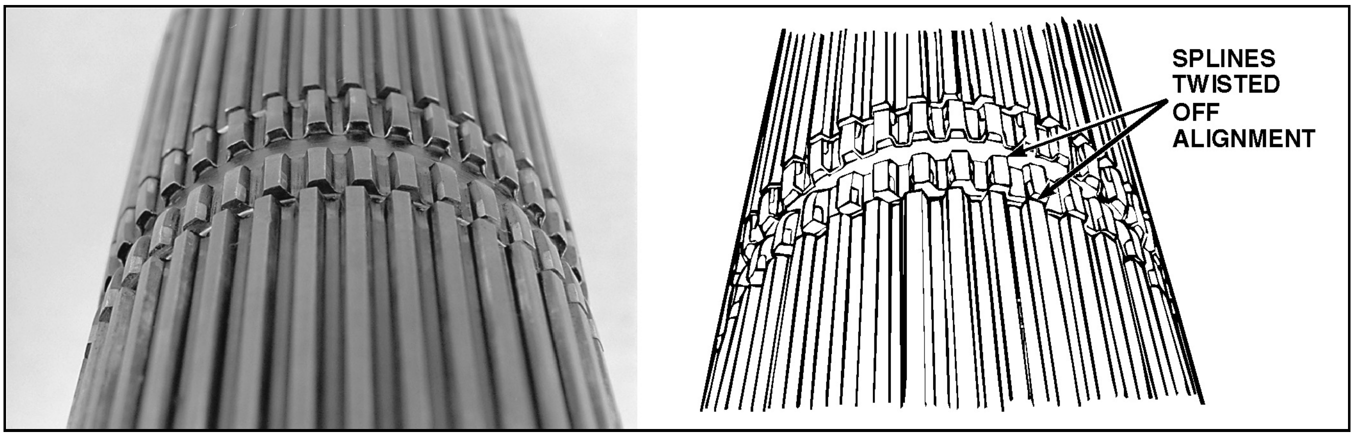


Figure 64 — Mainshaft Splines

MAINSHAFT/COUNTERSHAFT

NOTE

The splines across the relief area are machined independently of each other and may or may not be aligned. The splines across the snap ring grooves are machined together and must align (see Figure 65 and Figure 66).

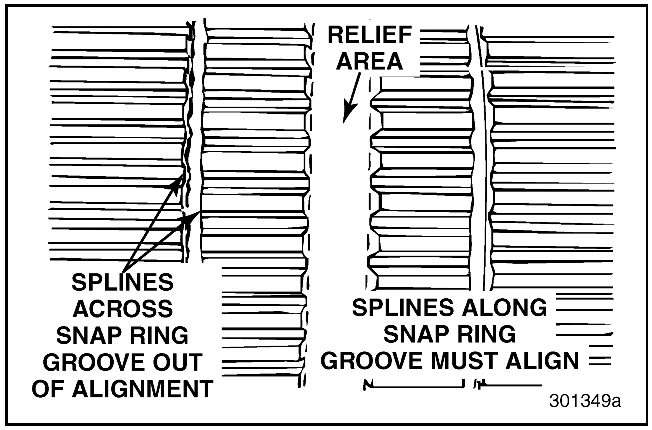


Figure 65 — Spline Alignment

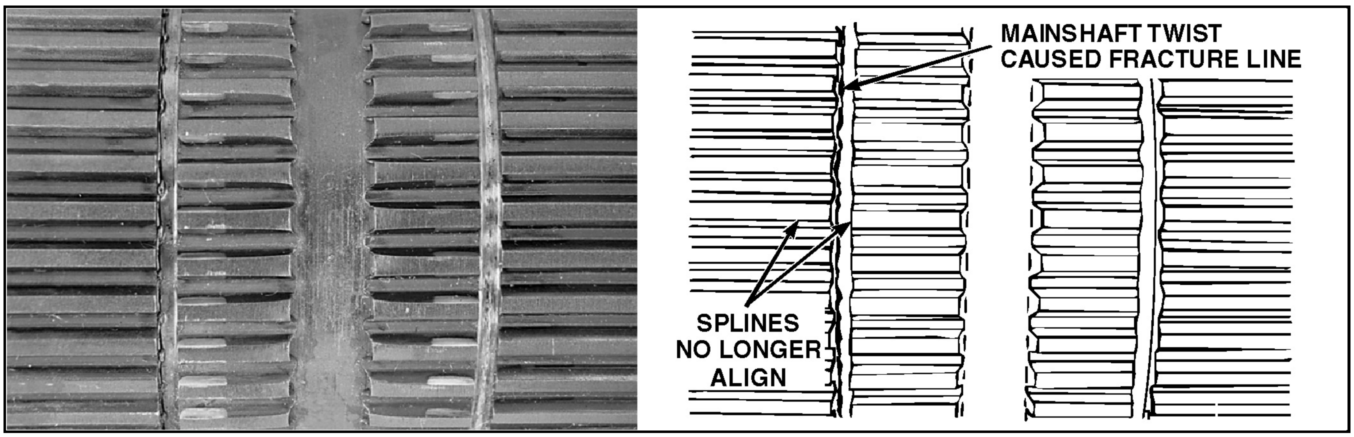


Figure 66 — Mainshaft Splines

MAINSHAFT/COUNTERSHAFT

Broken Mainshaft Due to Torsional Fatigue

This input pinion shaft was probably cracked sometime during its life and continued use caused the crack to work through the shaft until it finally failed. The initial crack may have resulted from a shock load.

This is a torsional failure. *Torsional fatigue* can produce longitudinal cracks, especially (but not always) at spline roots.

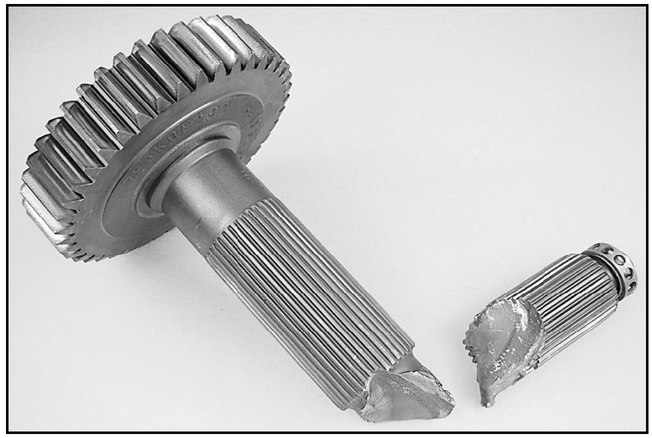


Figure 67 — Broken Mainshaft Due to Fatigue

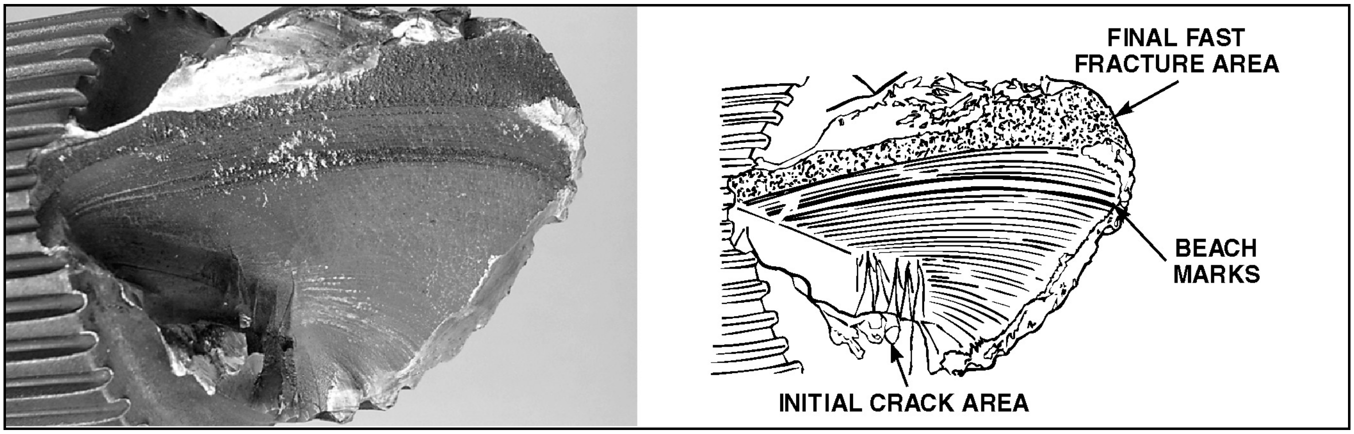


Figure 68 — Input Pinion

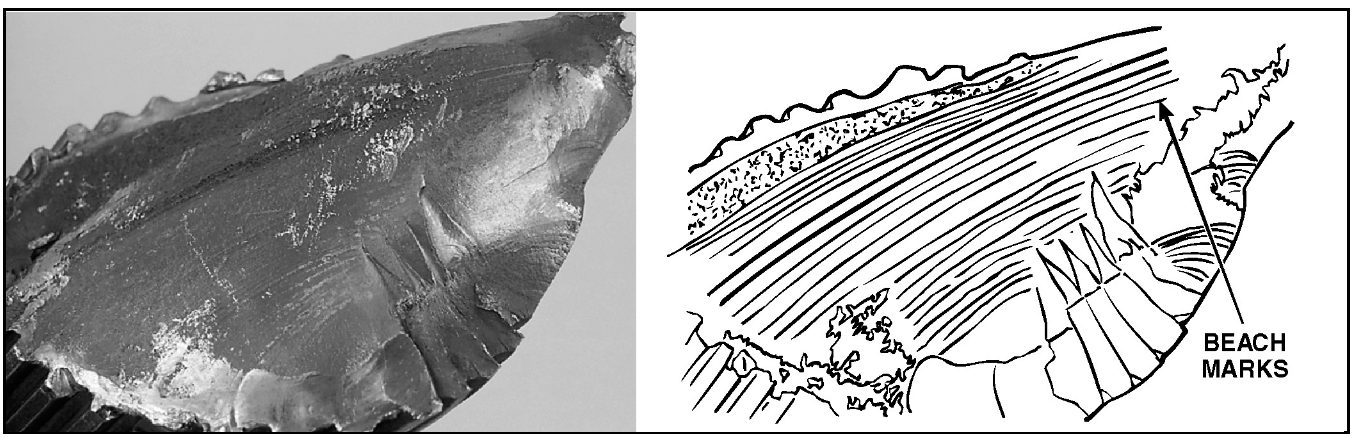


Figure 69 — Input Pinion

MAINSHAFT/COUNTERSHAFT

Worn Splines

If you look closely you can see a wear step in the splines, possibly caused by torsional vibration from the engine or from the driveline. This will cause difficulty in shifting as the clutch slides over the wear step.

This shaft must be replaced, and other components should be checked to find the source of the problem.

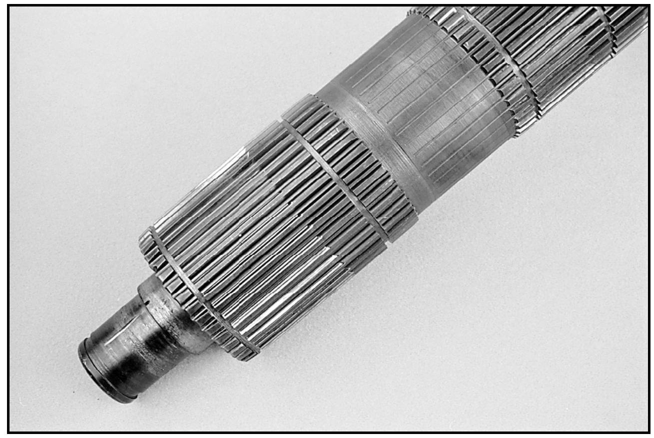


Figure 70 — Worn Splines

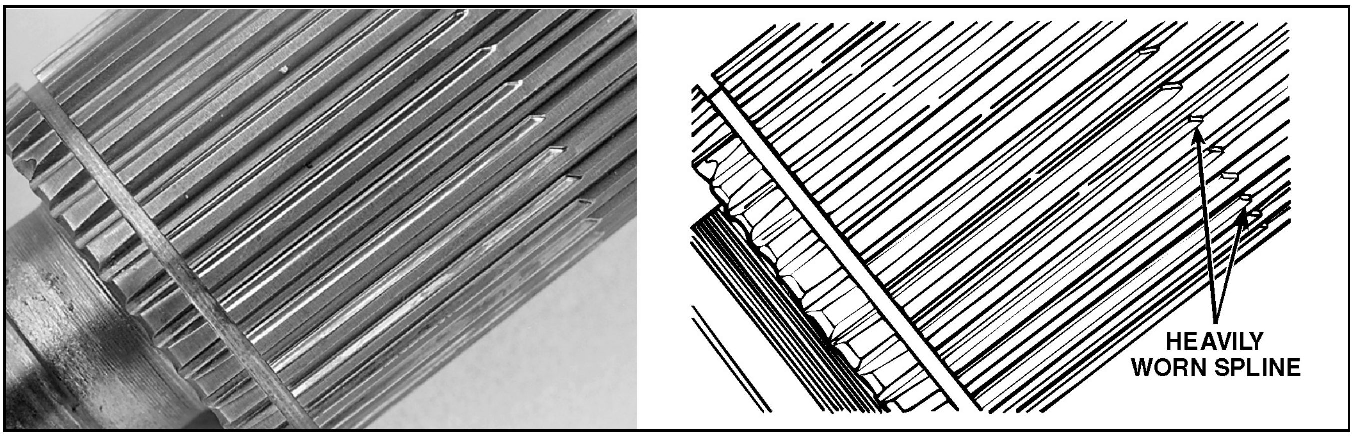


Figure 71 — Mainshaft Splines

TRANSMISSION GEARS

Broken Teeth

Teeth may break from bending fatigue or overload. Fatigue fractures usually have a smooth curved area with “beach marks” (see Figure 68 and Figure 69) followed by a rough fast fracture area. Overload fractures (including *shock load*) usually have only a rough fast fracture surface. A partial crack caused by overload or spalling on the tooth face may also cause a bending fatigue crack.

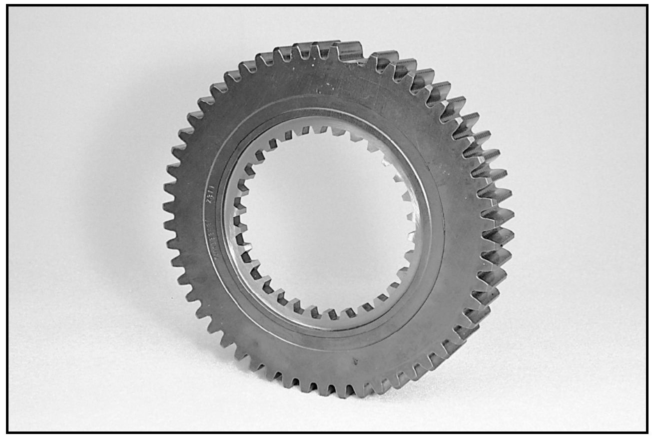


Figure 72 — Broken Tooth

Always replace the damaged gear and the mating gears, even if they do not look damaged. Also check the rest of the transmission for damage from the broken gear tooth traveling through the unit. In the case of overload, make sure that other components were not also damaged by the high load. Careful visual inspection may reveal the damage, but other methods such as dye penetrant and magnetic particle inspection are more sensitive.

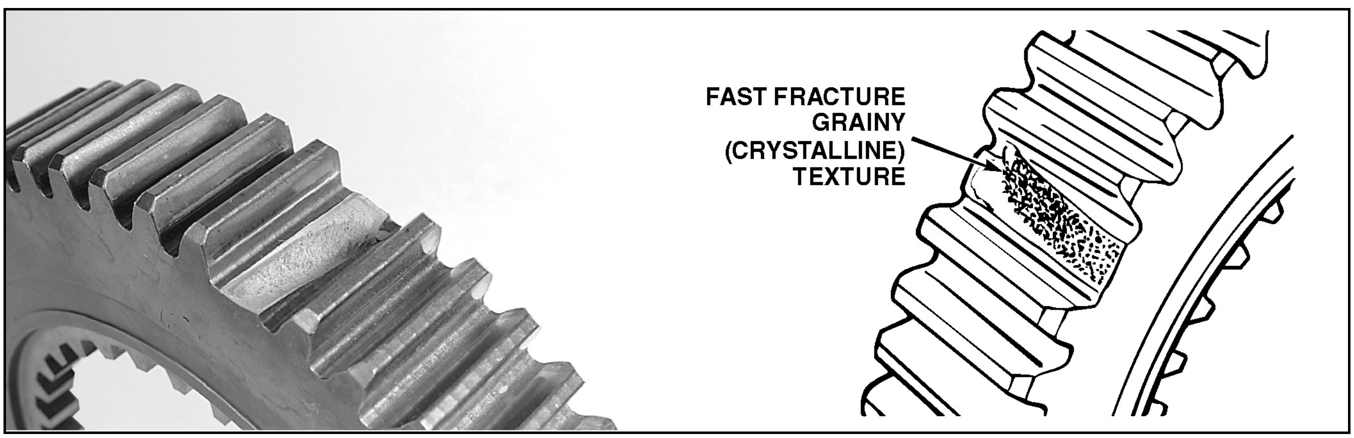


Figure 73 — Broken Gear Tooth Fast Fracture

TRANSMISSION GEARS

Surface Fatigue/Spalling

Overload has caused wear, pitting and *spalling* across the transmission gear tooth flanks in the following figure.

Figure 74 — Surface Fatigue/Spalling

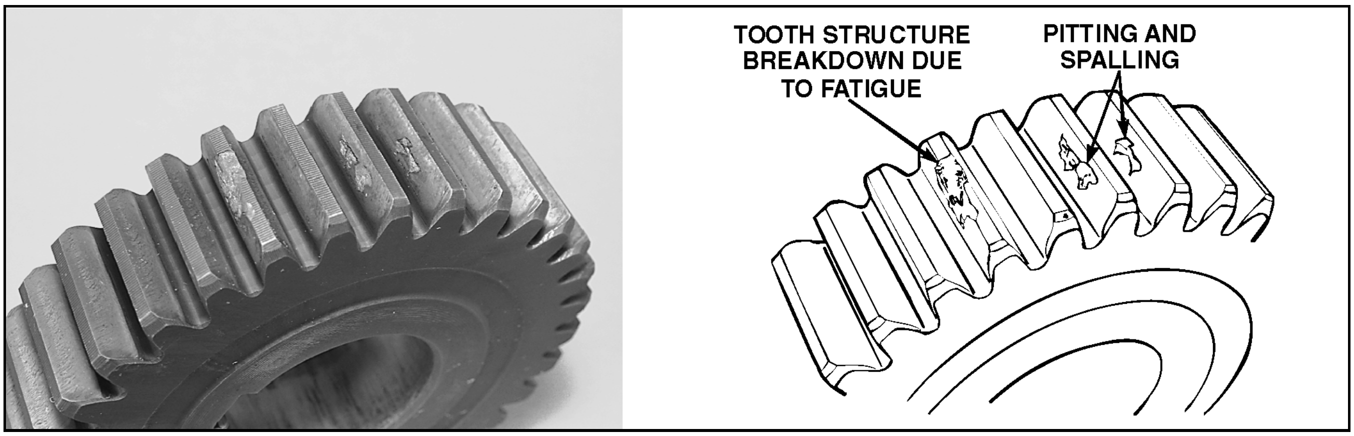


Figure 75 — Countershaft Gear

TRANSMISSION GEARS

Inadequate Lube/Lack of Lube

Inadequate lubrication causes vertical scuffing of the gear teeth and discoloration of the gears.

This *scuffing* can result from lack of lubrication or using poor quality lubricant.

This condition usually affects smaller diameter mainshaft gears.

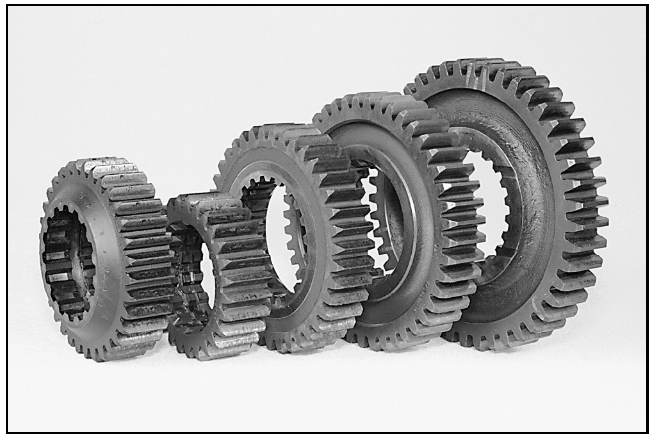


Figure 76 — Inadequate Lube/Lack of Lubrication

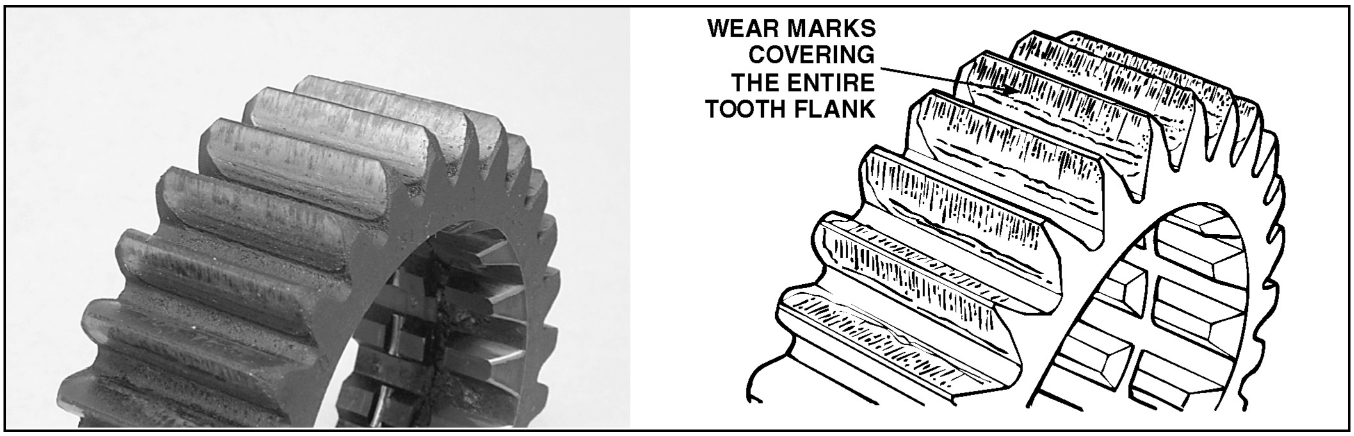


Figure 77 — Gear Tooth Wear Marks

TRANSMISSION GEARS

Debris Damage

This gear shows heavy *scoring* on the teeth, similar to what would result from inadequate lubrication. The difference is that inadequate lube also causes discoloration from heat buildup and there is no discoloration in this example.

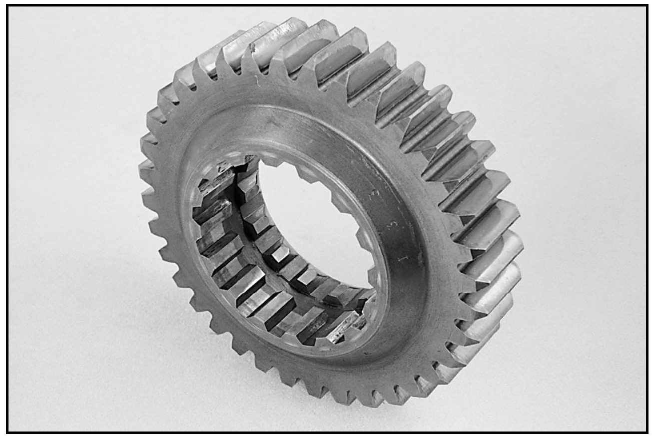


Figure 78 — Debris Damage

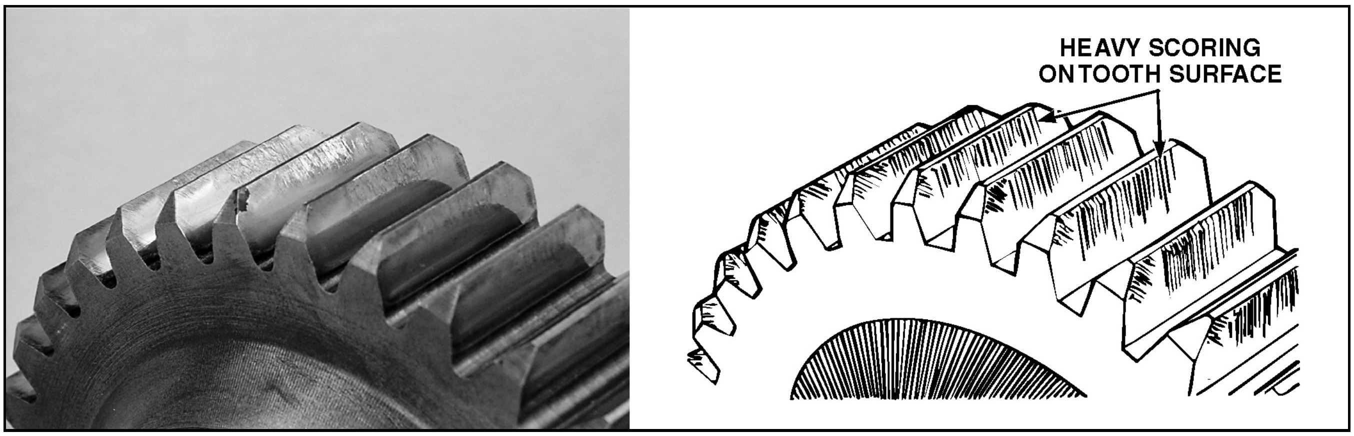


Figure 79 — Damaged Tooth Flank

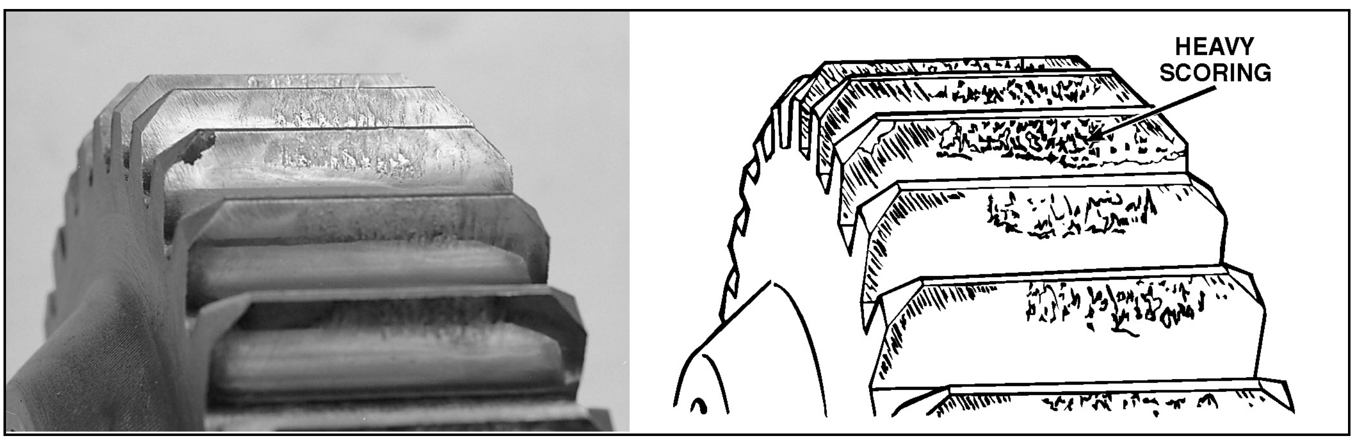


Figure 80 — Damaged Tooth Flank

SLIDING CLUTCHES

Wear (Rounding)

If this type of failure occurs on a low-mileage vehicle, the operator is using an improper or incomplete shift technique.

If the mileage is high (for example, over 160 934 km [100,000 miles]), the wear is normal.

Figure 81 — Clutch Wear

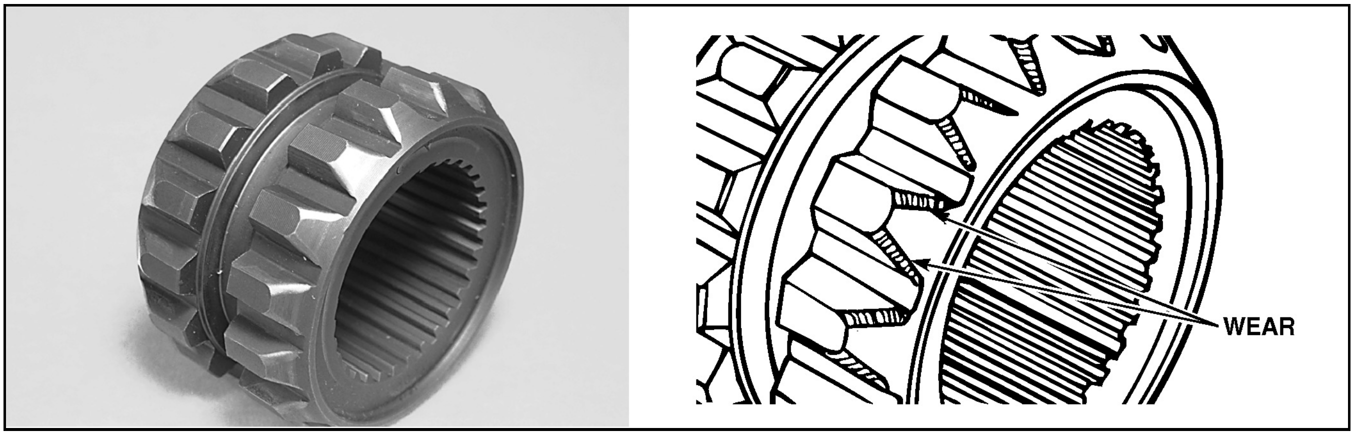


Figure 82 — Sliding Clutch

SLIDING CLUTCHES

Broken Teeth

Broken teeth on the sliding clutch may be caused by a fatigue failure. This can result from continuous operation at high load conditions. Look for uniformity of contact pattern on clutch teeth. Nonuniformity of the contact pattern may indicate another source of failure. These sources could include improper tooth indexing or out-of-roundness.

This type of failure could also result from torsional vibration.

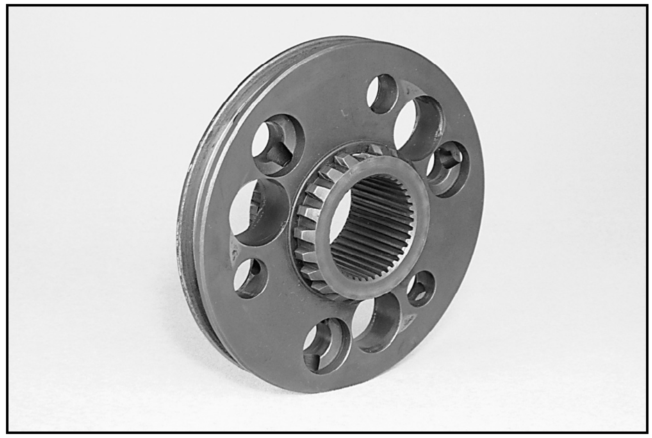


Figure 83 — Broken Tooth

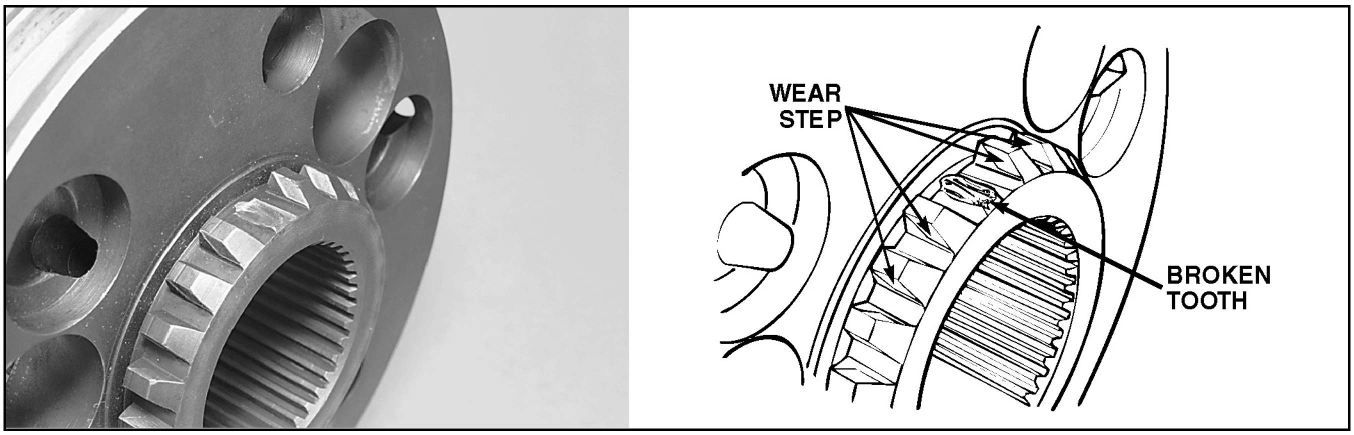


Figure 84 — Synchronizer Hi-Lo Sliding Clutch

SLIDING CLUTCHES

Chipped Teeth

Chipping of the sliding clutch teeth and mating parts is caused by an improper shifting technique, an incomplete shift or a malfunctioning synchronizer.

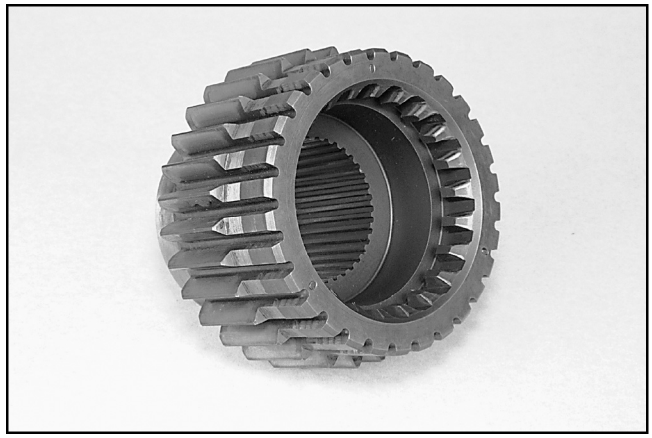


Figure 85 — Chipped Teeth

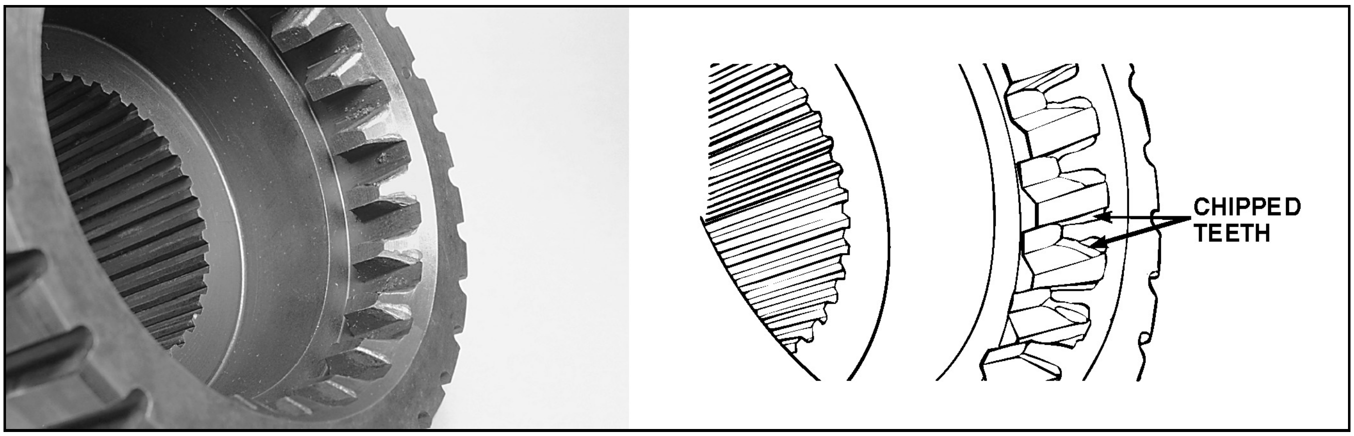


Figure 86 — Compound Mainshaft Hub

SLIDING CLUTCHES

Early Stage of Flank Wear

Sliding clutch flank wear is a progressive failure. If caught early, it is early flank wear; if allowed to continue, it is advanced flank wear. Flank wear results from torsional/driveline vibration. It can occur when the driveline is out-of-phase or the powertrain and/or axle angles are incorrect.

Changing the parts will not solve this failure. The source of the problem must first be identified and corrected or the same failure will ultimately occur again.

Flank wear occurs on the sides of the teeth. Mating clutch teeth show the same wear. It is important to remember that all mating parts show the same wear and that all worn parts (the clutches and the gears) must be changed as a set.

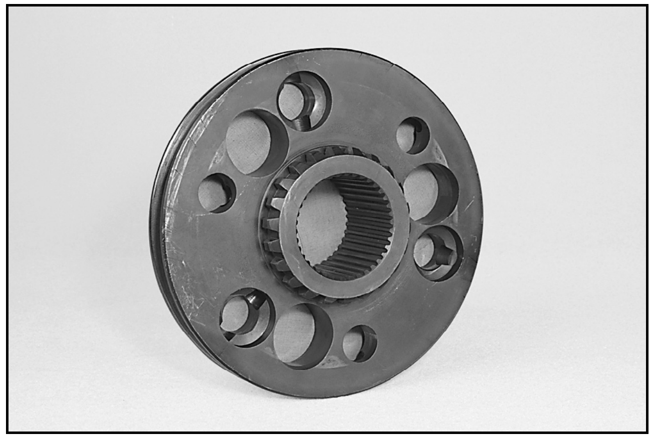
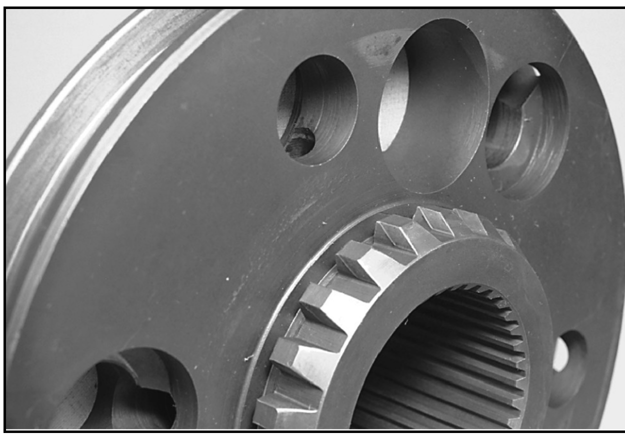


Figure 87 — Early Flank Wear



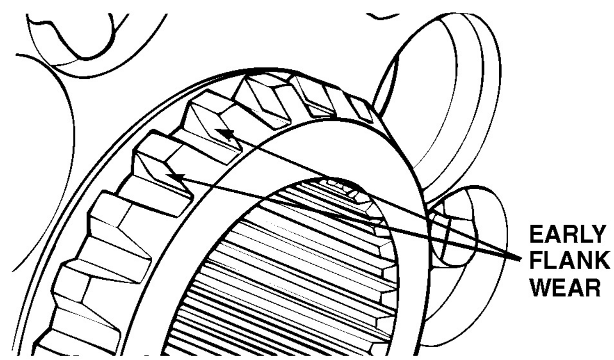


Figure 88 — Synchronizer Hi-Lo Sliding Clutch

SLIDING CLUTCHES

Advanced Stage of Flank Wear

Figure 89 shows an example of sliding clutch flank wear that has progressed to the advanced stage. *Torsional/driveline vibration* has caused the clutch to progressively deteriorate to the point that the clutch teeth no longer stay engaged and burn the shift fork as it tries to maintain engagement.

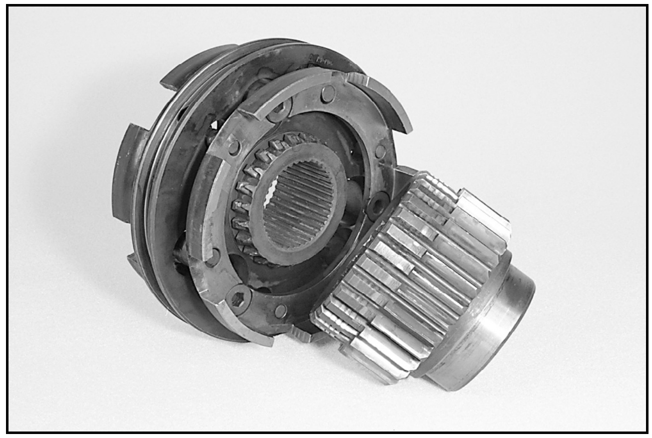


Figure 89 — Advanced Flank Wear

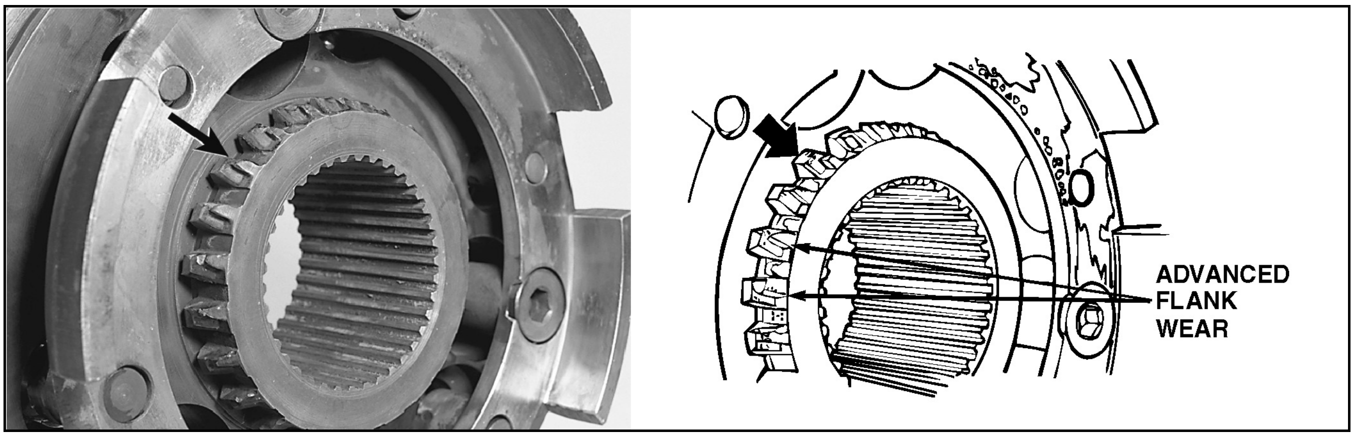


Figure 90 — Synchronizer Hi-Lo Sliding Clutch

Figure 91 shows advanced flank wear to the point of destruction. Clutch teeth are completely removed and power can no longer be transferred through this transmission.

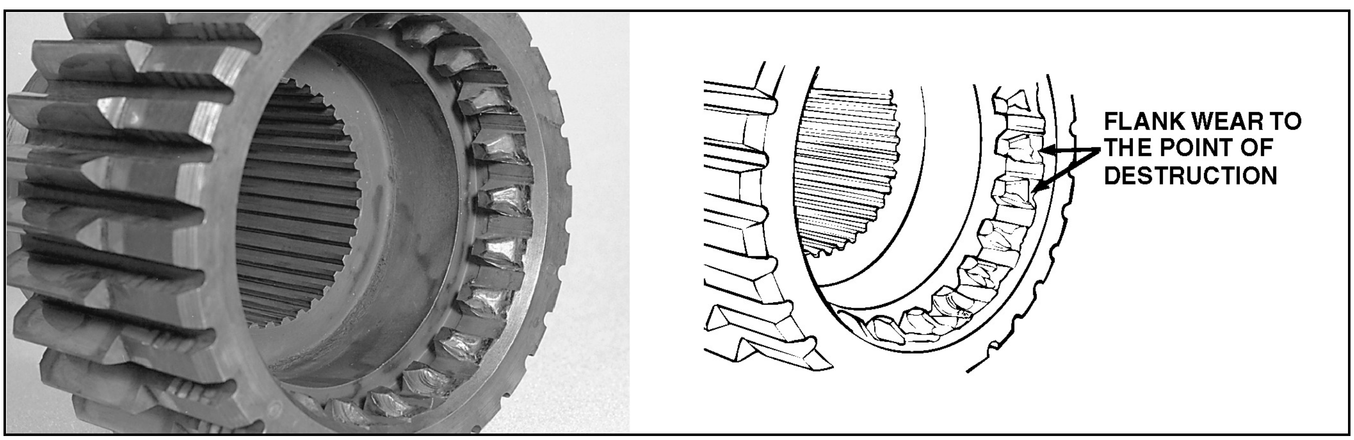


Figure 91 — Compound Mainshaft Hub (Pinion Gear)

SLIDING CLUTCHES

Burned Fork Ring

This failure is caused by metal-to-metal contact of the shift fork and the range clutch ring as the shift fork attempts to hold the clutch engaged. A malfunctioning or worn range clutch tries to disengage while the fork holds its position. The resulting friction causes wear on the fork and *burning* of the range clutch.

The cause is improper or less-than-full engagement of the clutch teeth. The synchronizer disc(s) may have also overheated and failed.

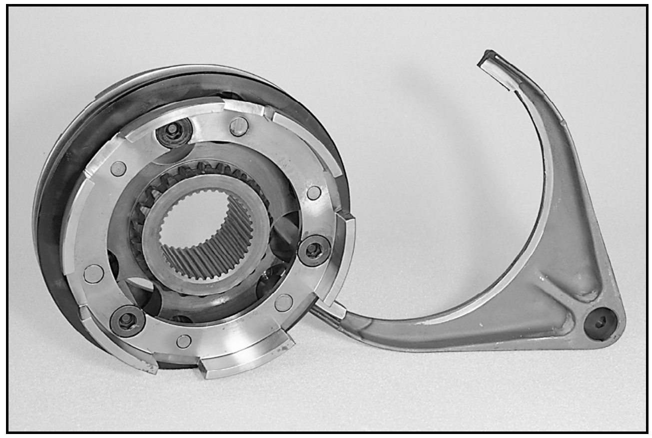


Figure 92 — Burned Fork Ring

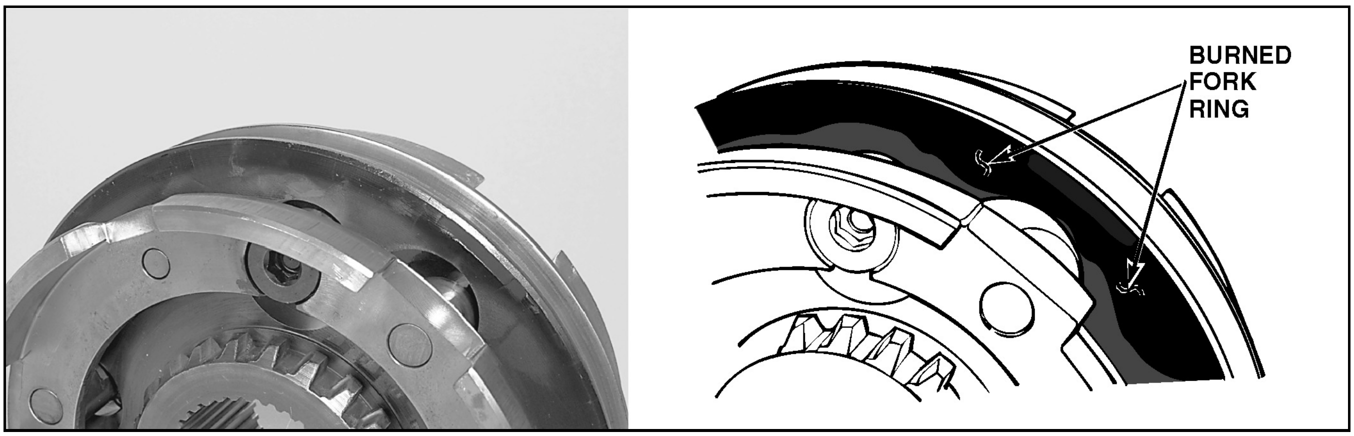


Figure 93 — Synchronizer Hi-Lo Sliding Clutch

SLIDING CLUTCHES

High Range Hub Gear Synchronizer Teeth

T309, T310 AND T318 TRANSMISSIONS

When the high range hub gear synchronizer teeth show excessive chipping and wear on the coast side of the synchronizer teeth, the most likely cause is the driver shifting the range clutch while in reverse. This is an unsynchronized shift that wears down the case hardness on the face of the teeth until the synchronizer teeth start to lose engagement on the normal forward drive side of the teeth.

The damage to the T310 high range hub gear synchronizer teeth appears to be worse than other T300 transmissions and occurs in less mileage due to the range ratio. The range ratio for the T310 is much greater which results in a higher delta speed when making this unsynchronized range shift while in reverse gear. This causes a higher wear rate on the teeth.

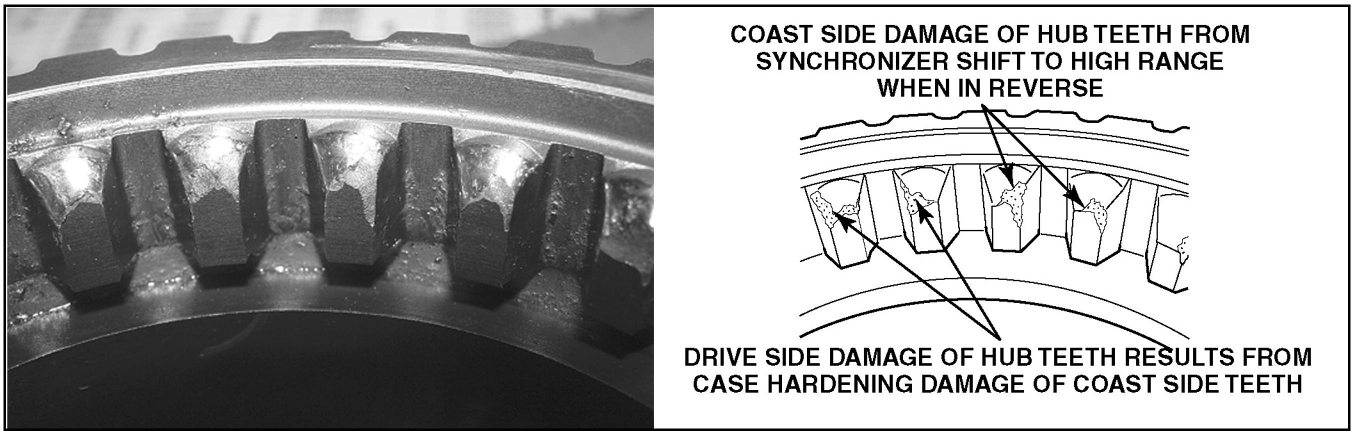


Figure 94 — Typical Warranty Returned T310 High Range Hub Gear Synchronizer Teeth Failure

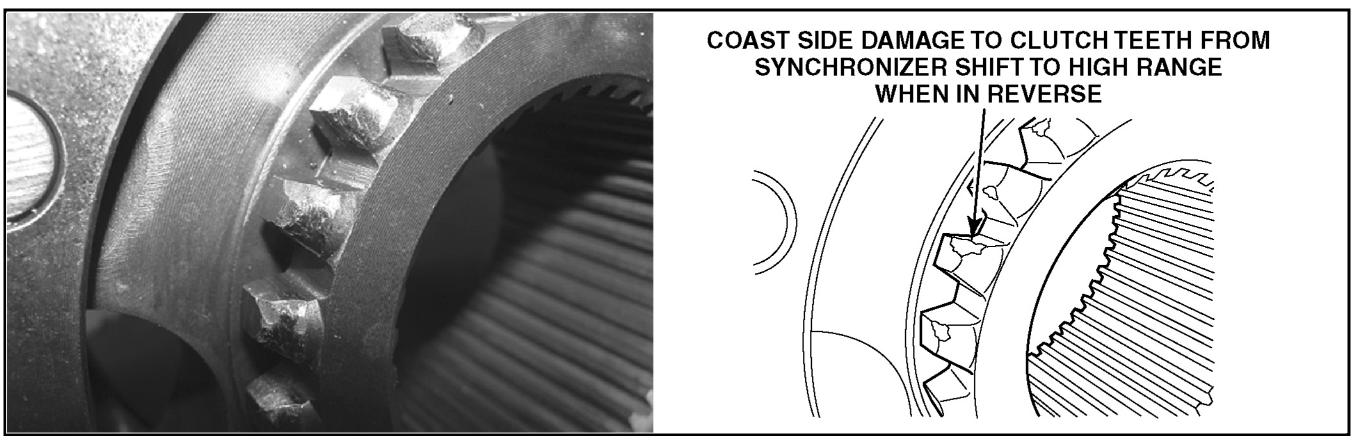


Figure 95 — Typical T310 High Range Synchronizer Clutch Teeth Failure

SLIDING CLUTCHES

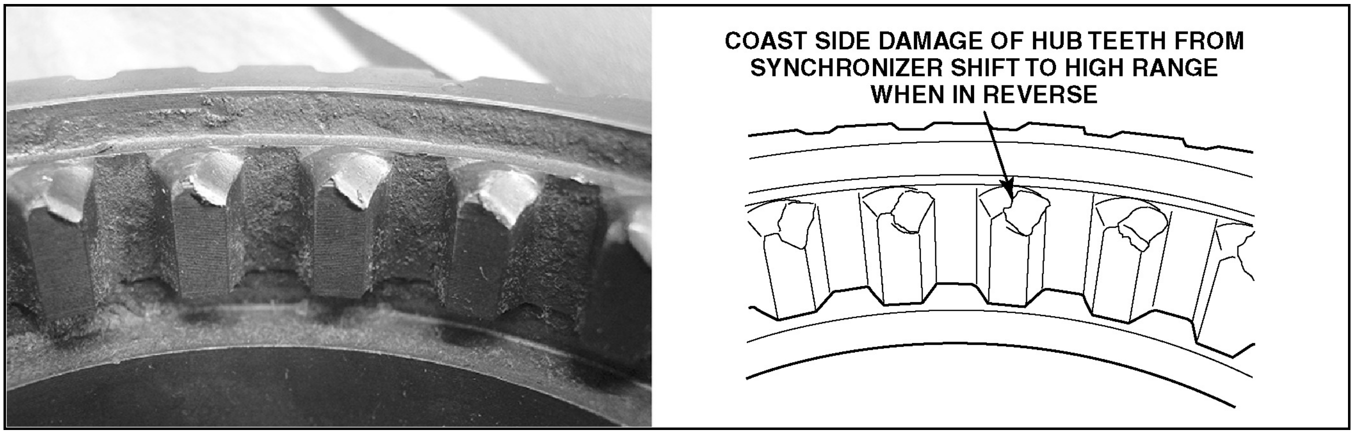


Figure 96 — Typical Warranty Returned T309 High Range Hub Gear Synchronizer Teeth Failure

Figure 97 — T310 Transmission Shifting Instructions

The transmission shifting instructions located in the cab have a caution that states “to avoid transmission damage, do not change range while moving in reverse.”

SLIDING CLUTCHES

Low Range Hub Gear Synchronizer Teeth

T310M TRANSMISSION

Low range synchronizer teeth chipping and wear in T310M transmissions on the reverse side of the teeth can result in the range jumping out of gear with the transmission in reverse.

The shift knob for the T310M transmission has a mechanical interlock that does not allow a range change when reverse is selected. However, an unsynchronized shift can occur as follows: if the driver has the transmission main box in a forward gear and is in high range, stops the vehicle, leaves the main box in gear, selects low range (range does not change), selects reverse, and while moving in reverse, shifts the main box gear, it allows the range to shift into LOW in reverse. An unsynchronized shift will occur which results in chipping and wear of the teeth.

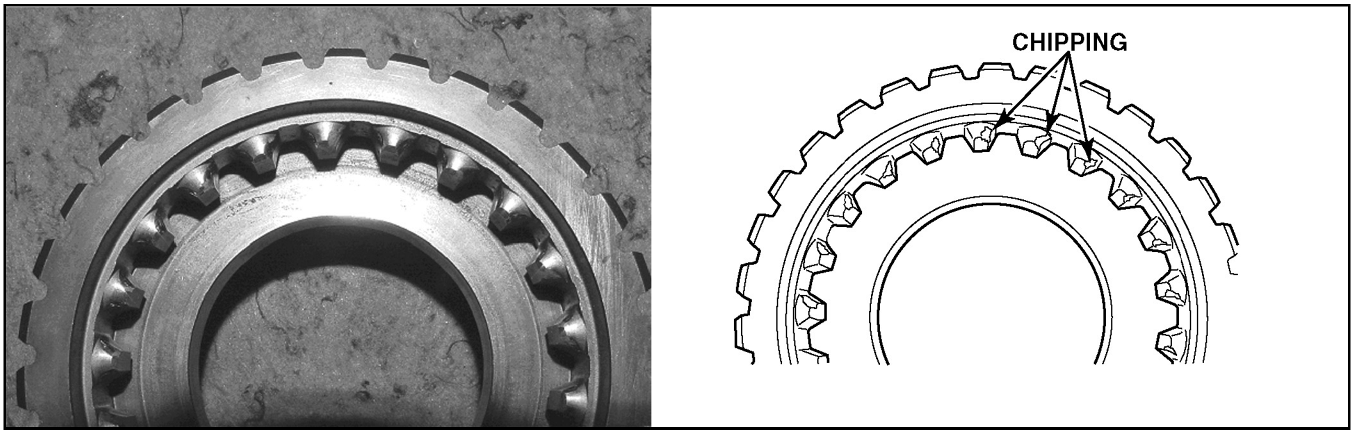


Figure 98 — Typical Warranty Returned T310M Low Range Hub Gear Synchronizer Teeth Failure

T310M AND T318 WITH COMPOUND NEUTRALIZING

- If the dash-mounted compound neutral control valve is in the ON position, with the range in HIGH, the main box in a forward gear position and the clutch pedal released, the chassis will not move because the range is neutralized. When the dash control valve is moved to the OFF position (un-neutralized), the synchronizer does not unblock into high so the engine drives through the high range discs and the chassis creeps forward. This is an undesirable condition and will lead to high range disc failure.
- If the dash-mounted compound neutral control valve is in the ON position, with the range in LOW, the main box in a forward gear position and the clutch pedal released, the chassis will not move because the range is neutralized. When the dash control valve is moved to the OFF position (un-neutralized), the synchronizer does unblock and the chassis jumps forward.
- If the dash-mounted compound neutral control valve is in the ON position, with the range in LOW, the main box in the reverse gear position and the clutch pedal released, the chassis will not move because the range is neutralized. When the dash control valve is moved to the OFF position (un-neutralized), the synchronizer does not unblock into LOW so the engine drives through the low range discs and the chassis creeps rearward. This is an undesirable condition and will lead to low range disc failure.

RANGE CLUTCH SYNCHRONIZER

Burned Discs

A burned synchronizer disc can be caused by any of the following:

- Lubricant contaminants
- Improper shifting techniques
- Incomplete shift
- Improper range shift valve interlock pin adjustment
- Improper lubricant

This particular failure could have been eliminated by using the recommended lubricant.

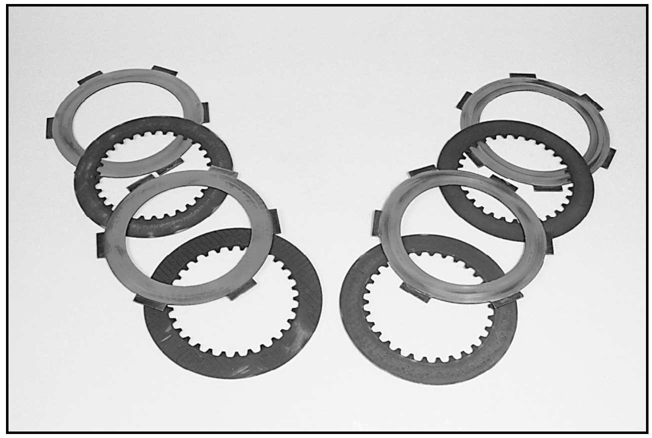


Figure 99 — Burned Discs

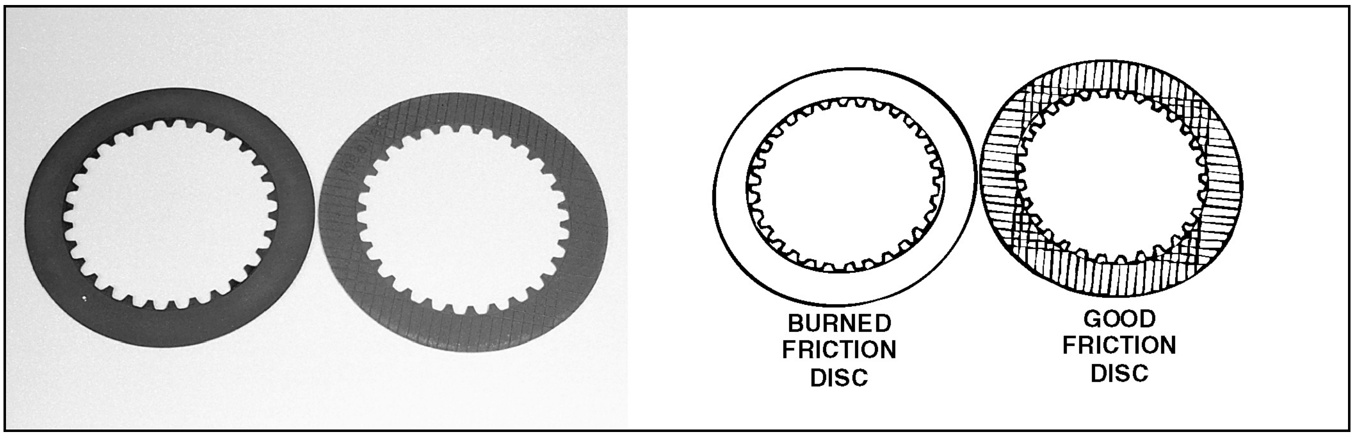


Figure 100 — Friction Discs

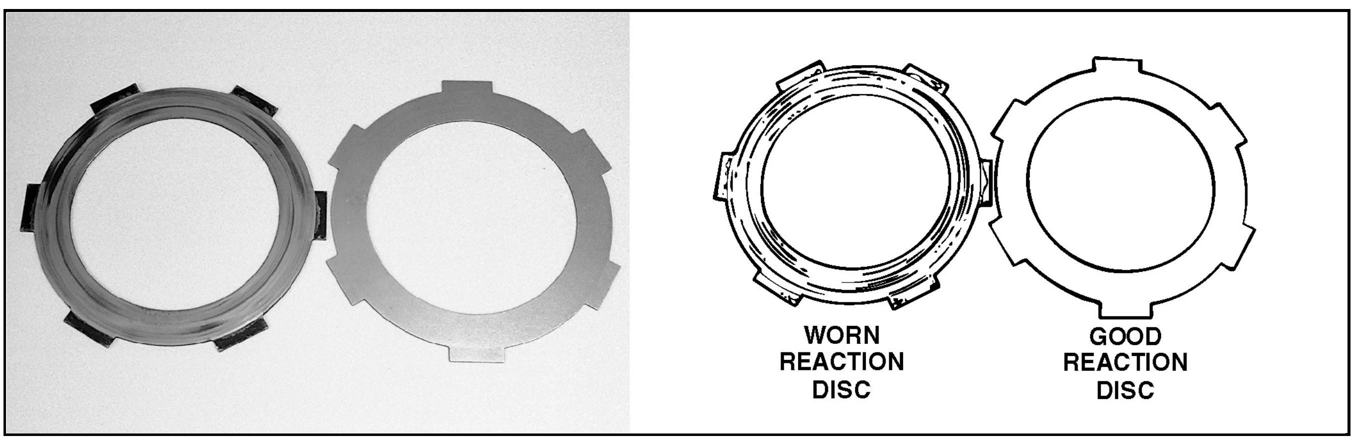


Figure 101 — Reaction Discs

RANGE CLUTCH SYNCHRONIZER

Worn Disc Splines

High torsional vibration loads may be applied to the friction disc splines. These loads work away at the splines until the entire disc is worn to the point it rotates freely and provides no benefit.

This failure is another example of damage resulting from *torsional vibration*.

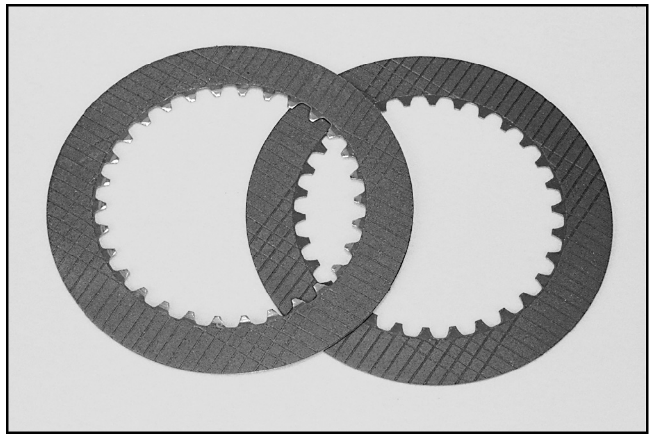


Figure 102 — Worn Disc Splines

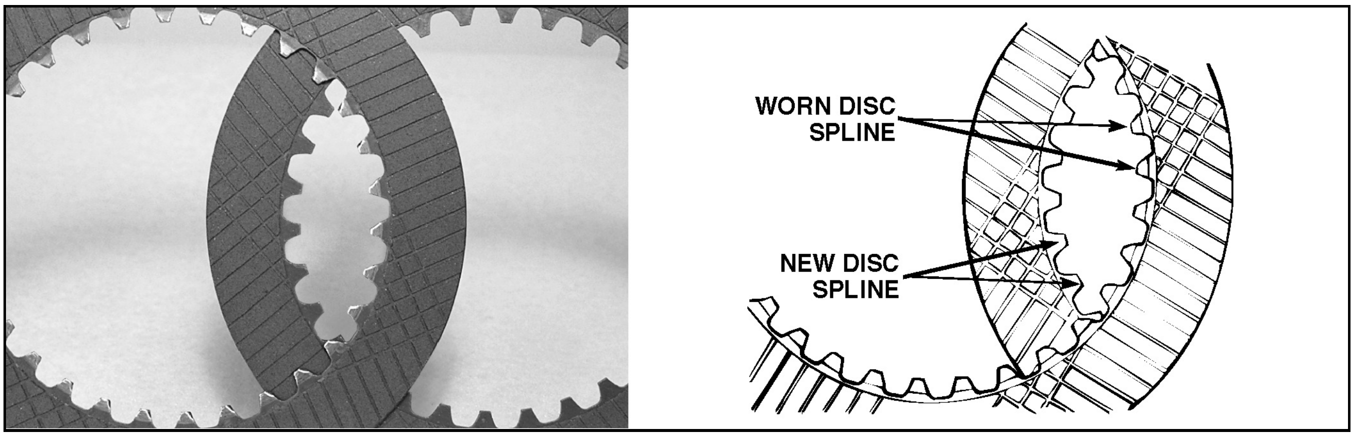


Figure 103 — Friction Discs

SHIFT RAIL

Range Shift Piston Rail

The break of the range shift piston rail occurring through the setscrew staking hole is caused by overtorquing the setscrew. The clean, smooth break indicates a sudden (fast) fracture and not a long-term condition.

The shift rail in the front box can also break from this same failure mode, but is less likely to occur.

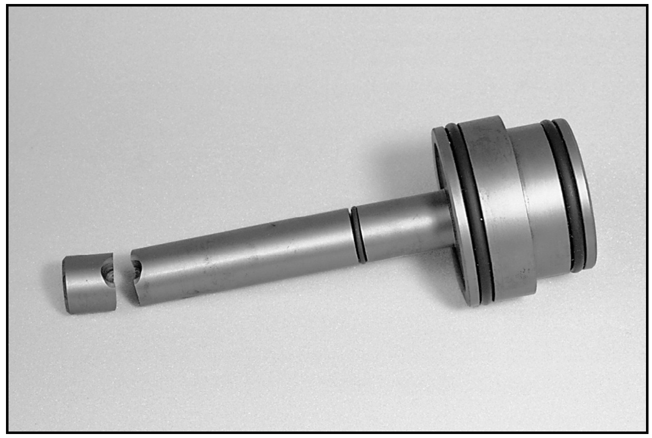


Figure 104 — Range Shift Piston

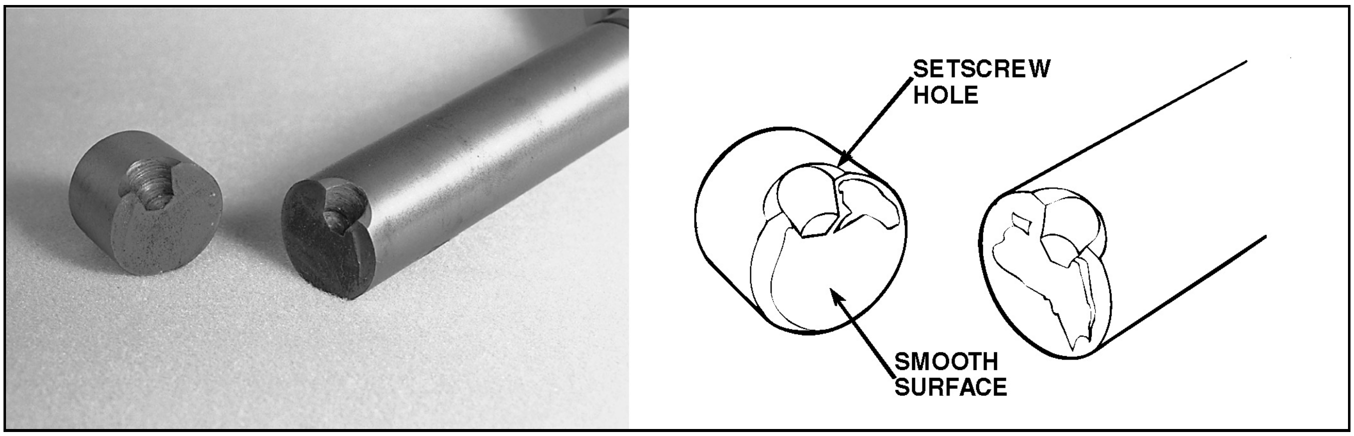


Figure 105 — Range Shift Piston Rail

SHIFT FORKS

Worn

If the range clutch tries to disengage, the fork holds its position. This causes metal-to-metal contact or friction. The friction causes wear on the fork and burning of the range clutch.

The cause is improper or less-than-full engagement of the teeth.

It is important to check the air shift piston and cover assembly during examination of this failure.

Shift fork wear can also result if the synchronizer disc(s) is damaged.

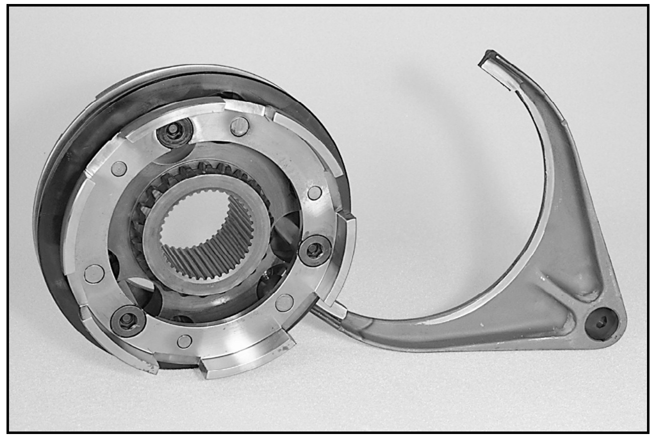


Figure 106 — Worn Shift Fork

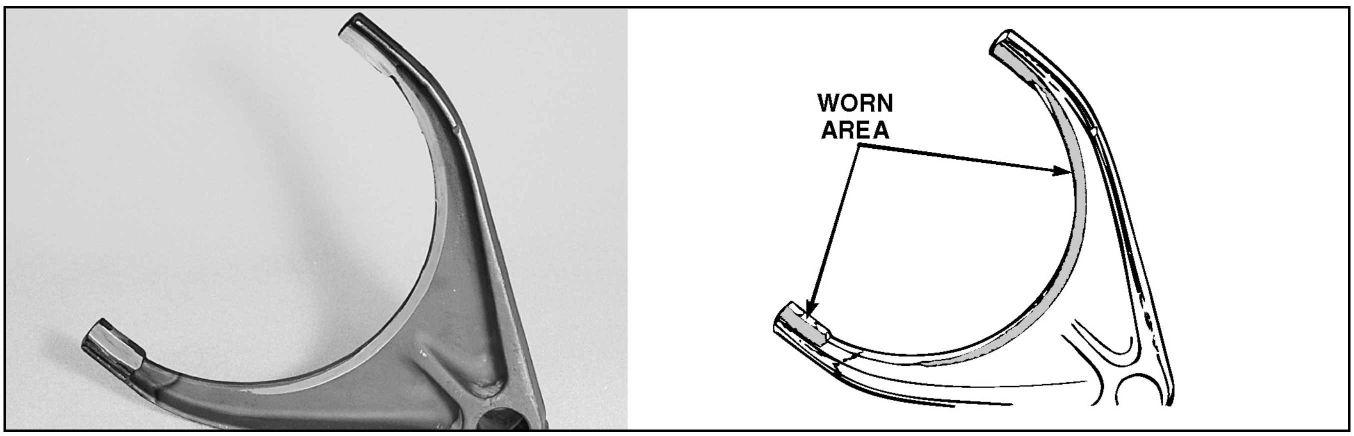


Figure 107 — Worn Shift Fork

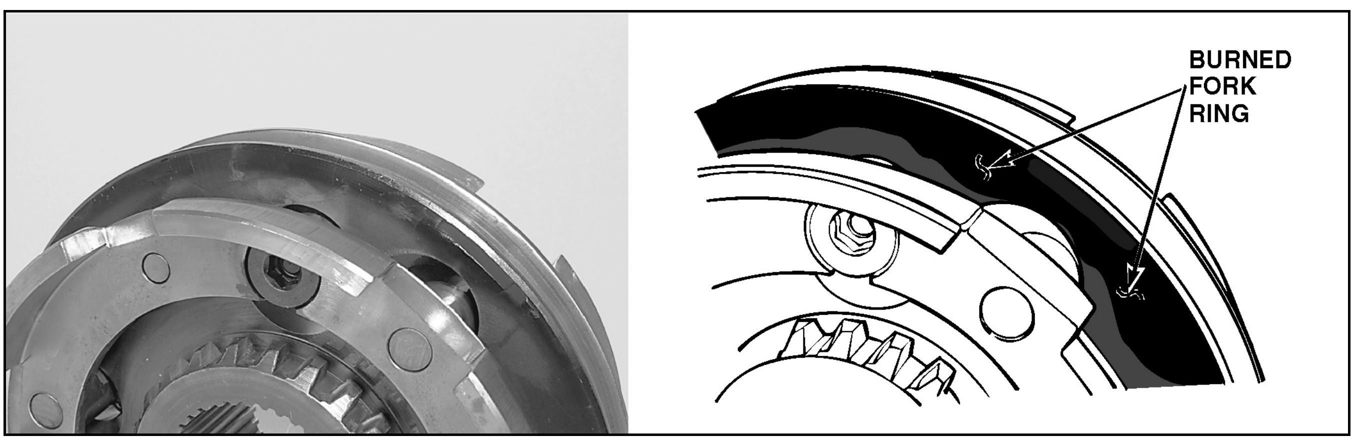


Figure 108 — Range Clutch Shift Ring

SHIFT FORKS

Splitter Fork and Hub Groove Wear

T313 AND T318 TRANSMISSIONS

It has been determined that excessive wear to the splitter hub groove and selector fork in T313/T318 MACK transmissions most likely has been caused by the driver of the vehicle making an improper split shift from gear to gear.

Failure to make the split shift properly will cause excessive wear on the splitter hub groove and the selector fork. If you see this condition, it is important to rule out driver error and bring into question the driver's ability to make proper split shifts. This type of failure is not considered a warrantable item.

NOTE

The splitter switch must not be actuated, either up or down, until IMMEDIATELY before the driveline torque is relieved (by depressing the clutch pedal and releasing it, or by backing off the throttle and reapplying it).

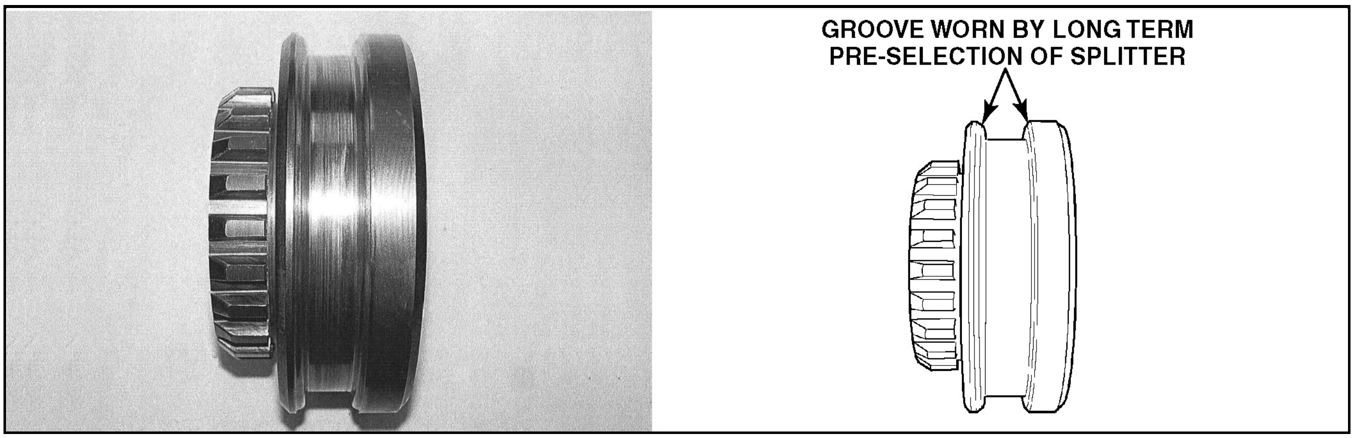


Figure 109 — Splitter Hub Groove Wear

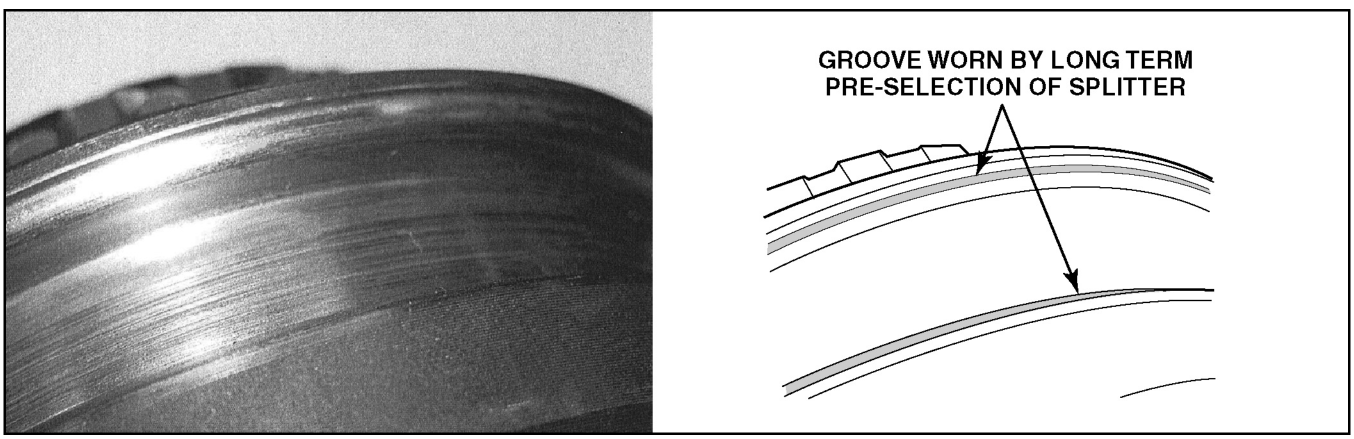


Figure 110 — Splitter Hub Groove Wear

SHIFT FORKS

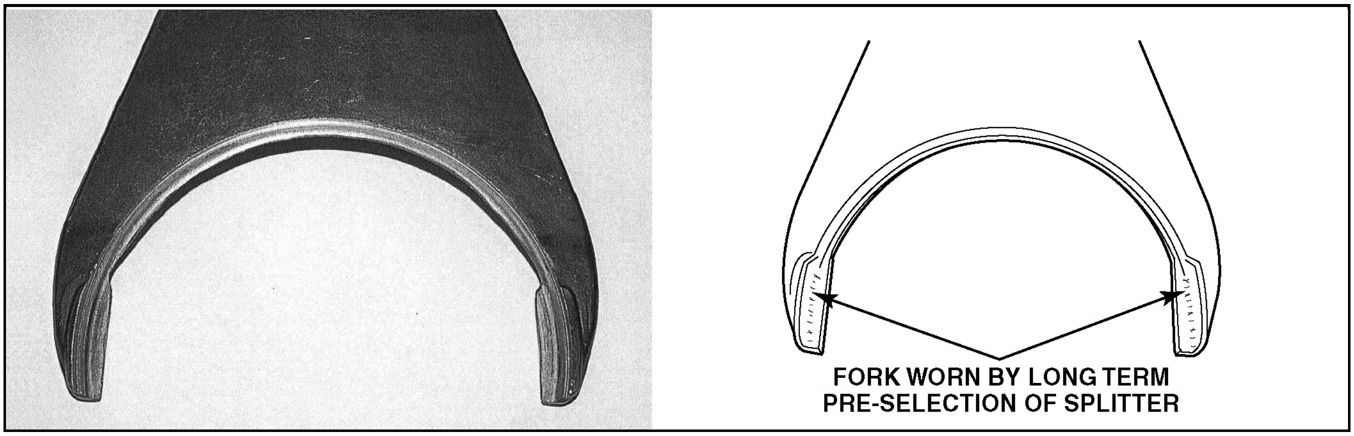


Figure 111 — Selector Fork Wear

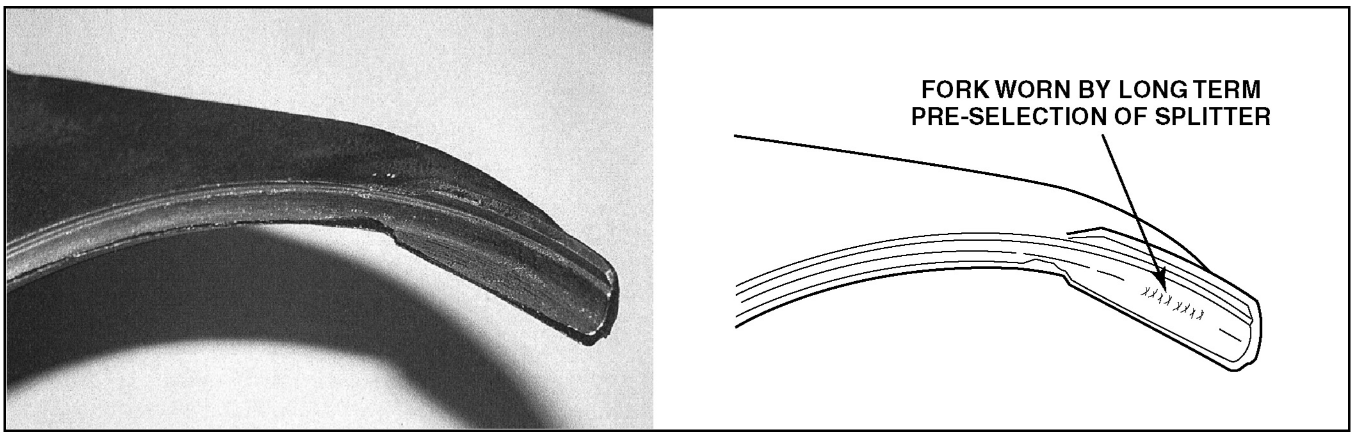


Figure 112 — Selector Fork Wear

PISTONS

Worn

The assembly consists of the air-shift pistons and cover. The piston and cover bore show heavy scoring.

This wear can result when the shift piston must continually reengage a range clutch which is attempting to move out of engagement. Wear can be aggravated by dirt or moisture contamination. If the range clutch teeth, fork ring or range shift fork are worn, these parts should be replaced and the air system should be checked for contamination.

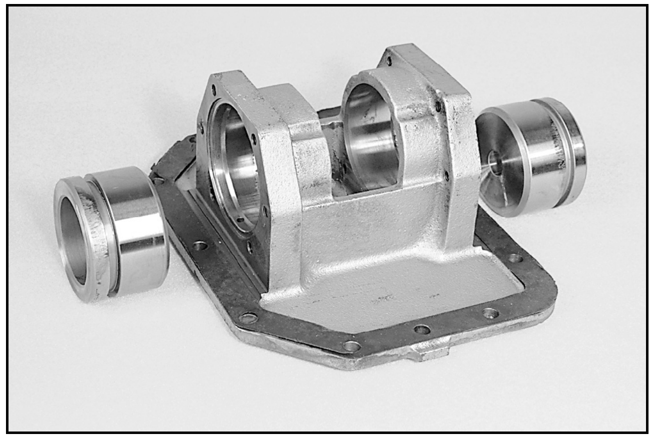


Figure 113 — Worn Piston

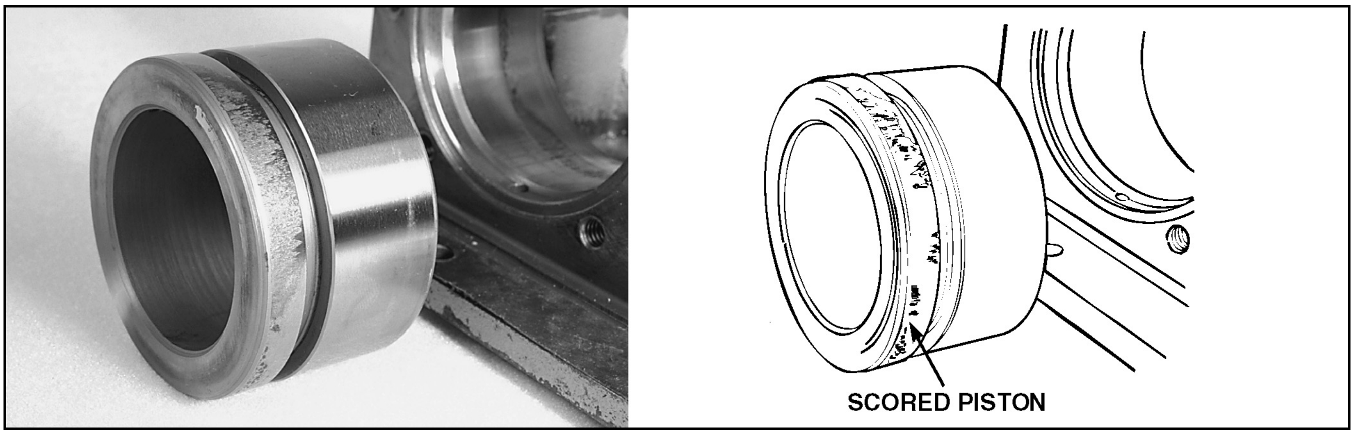


Figure 114 — Piston

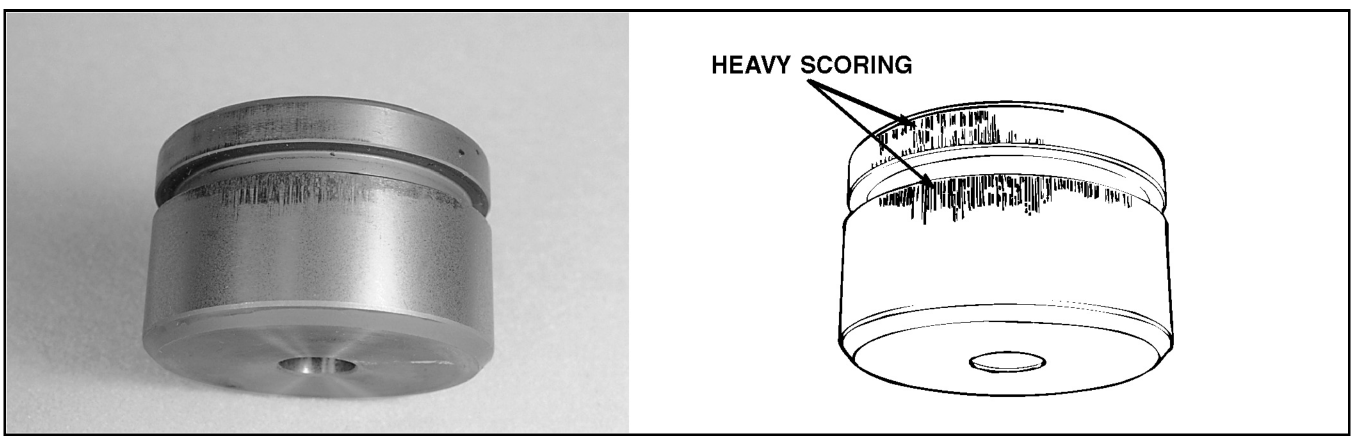


Figure 115 — Piston

PISTONS

Rust/Corrosion

Moisture in the air lines can also enter the air-shift cylinder causing the piston to rust. The rust then galls the mating surfaces and causes incomplete shifts or hang-ups. To prevent this, the air system must be maintained and kept free of moisture.

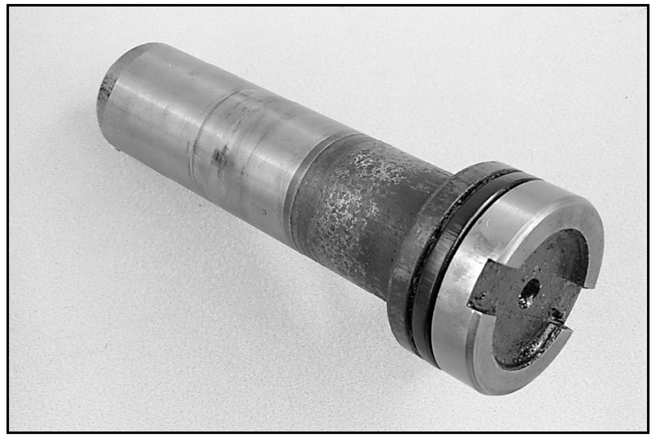


Figure 116 — Rusted Piston

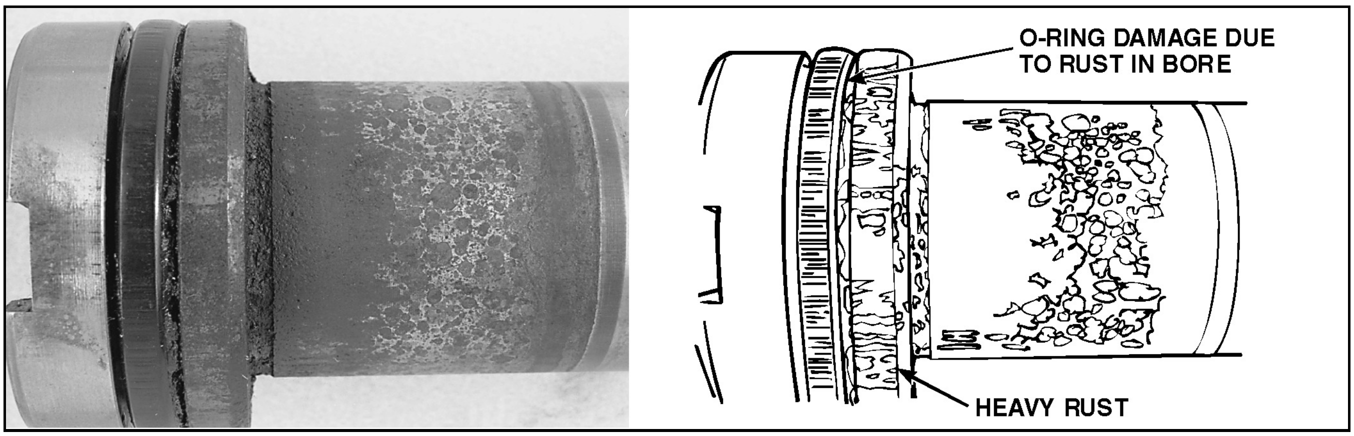


Figure 117 — Air-Shift Piston

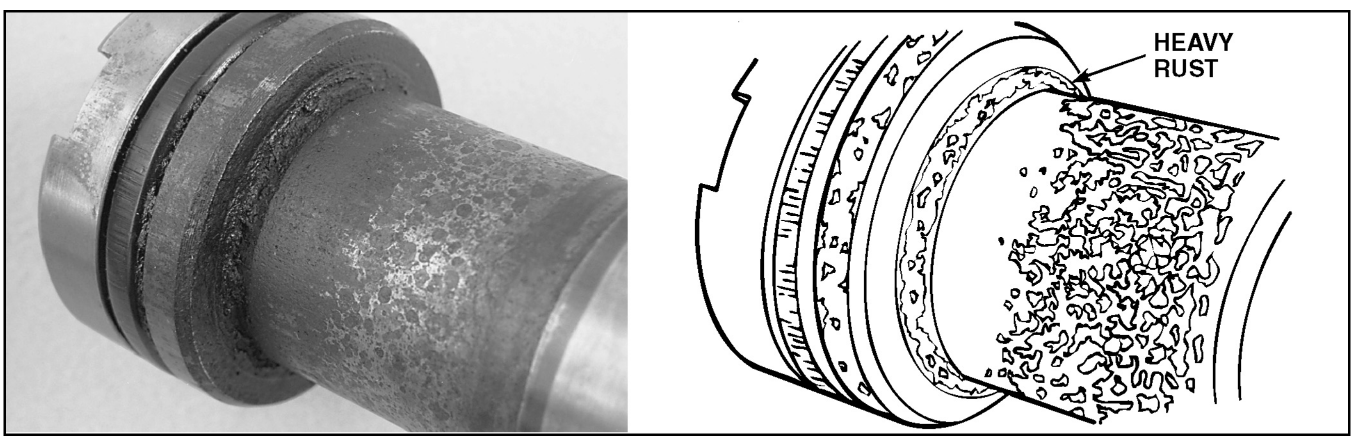


Figure 118 — Air-Shift Piston

TRANSMISSION CASE

Cracked Bell Housing

This transmission bell housing has cracks adjacent to the mounting holes on the side of the case. These cracks can result from shock. They can also occur when the mounting bolt holes break loose, in which case there would be damage in the threaded area. Another possible cause is frame laddering which can result from loose or broken crossmembers.

Figure 119 — Cracked Bell Housing (T107 Shown)

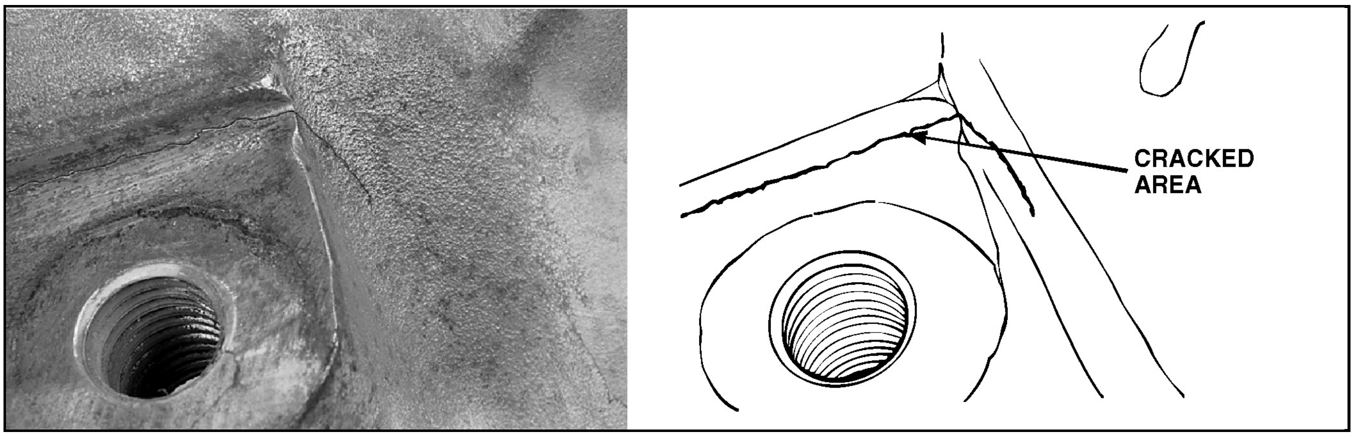


Figure 120 — Bell Housing

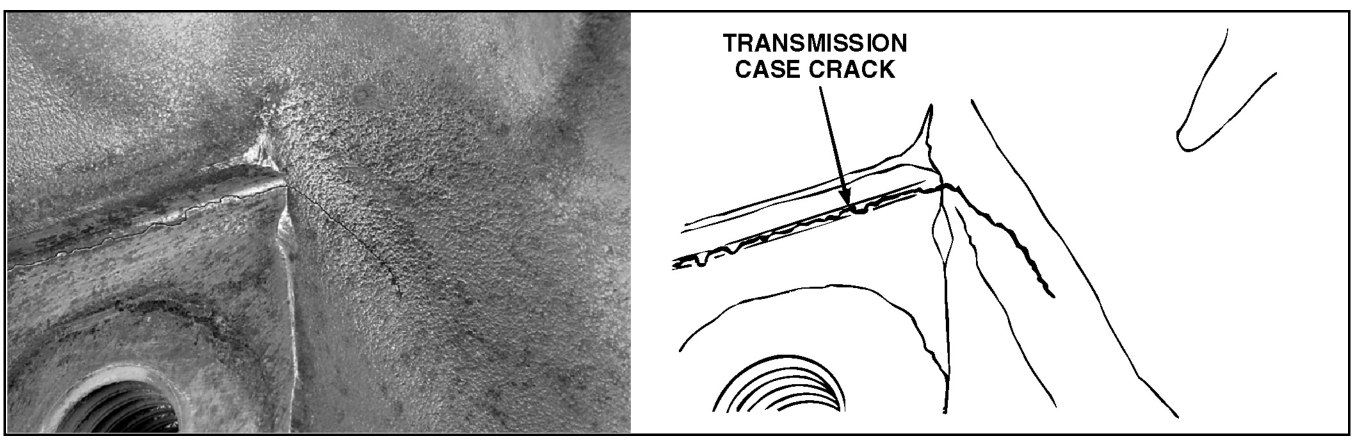


Figure 121 — A Closer Look at Bell Housing

RANGE CLUTCH HOUSING

Worn Shift Pin Holes

In the range clutch housing, the pin holes shown are worn to an egg (or oblong) shape.

This is caused by torsional vibration or synchronizers that have failed, in which case vibration will occur and contribute to the failure.

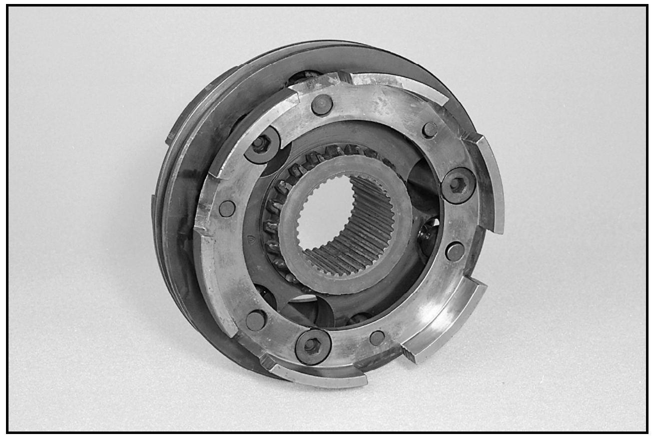


Figure 122 — Worn Shift Pin Holes

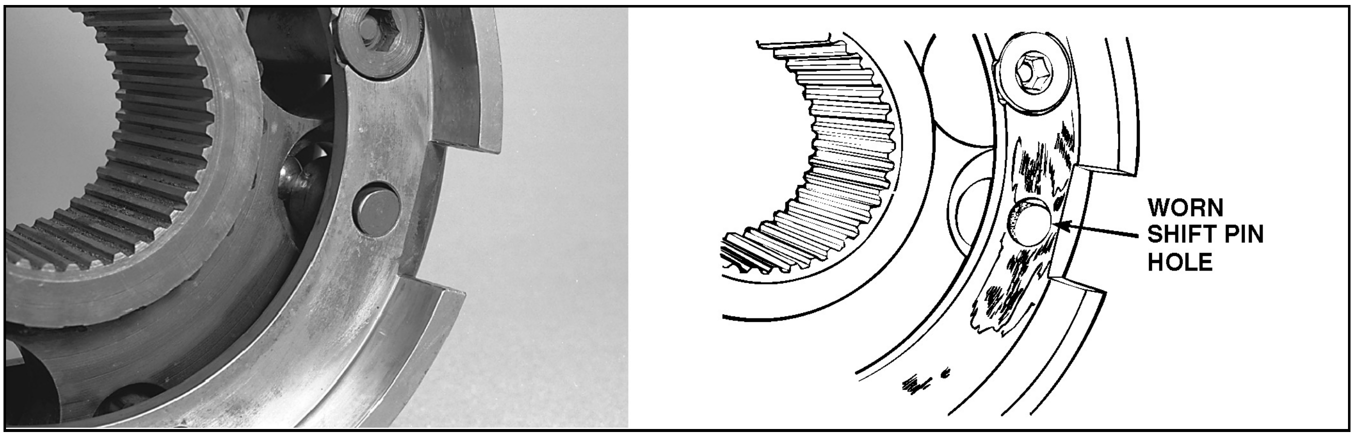


Figure 123 — Range Clutch Housing

OUTPUT SHAFT

Snap Ring Out of Groove

Operation thrust loads can at times, cause the snap ring to push out of the groove.

To eliminate this condition, a ball bearing support for the rear compound mainshaft has been released for service. Refer to Service Bulletin SB322011 for detailed rework instructions.

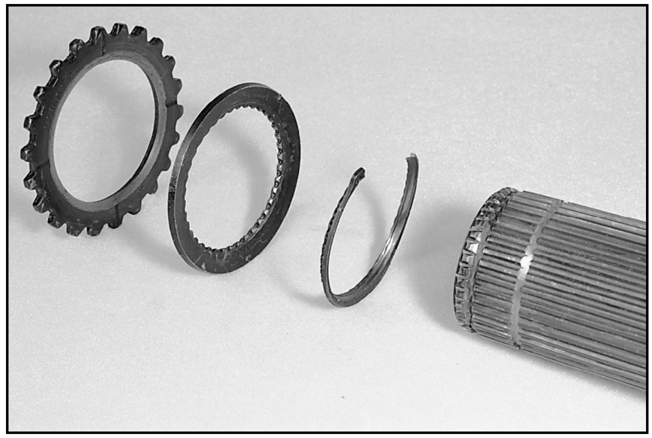


Figure 124 — Snap Ring Out of Groove

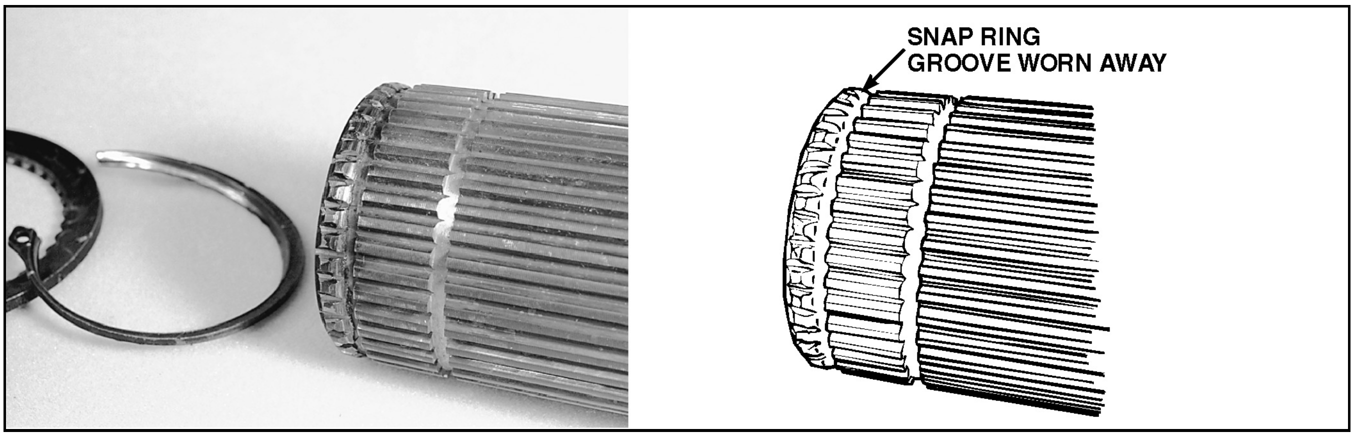


Figure 125 — Rear Compound Mainshaft

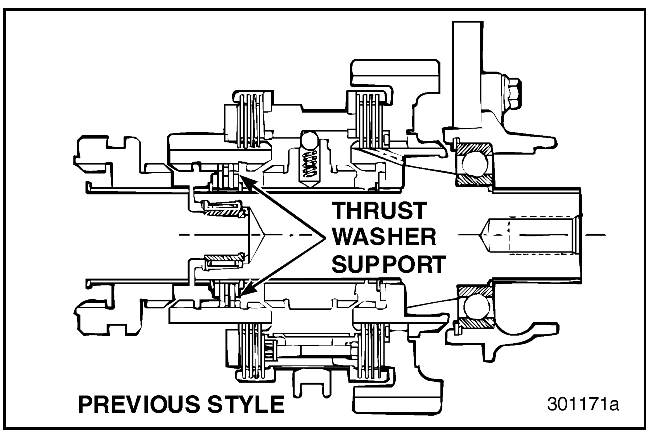


Figure 126 — Original Thrust Washer Configuration

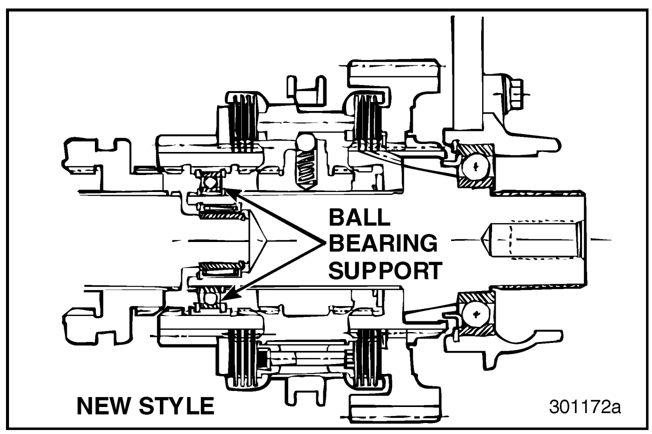


Figure 127 — Ball Bearing Configuration

REVERSE IDLER GEARS

Most reverse gear damage is caused by partial reverse gear engagement, impact loading (rotating gears clashing at engagement) or **shock loading** (gear overloading with full engagement).

Impact Loading (T107 Series Transmission)

Examination shows that the leading edge of the teeth are chipped and beaten. This can result from any of the following conditions:

- Inoperative clutch brake
  - — Adjust or repair the clutch brake and if necessary, install a current torque-limiting clutch brake.
- Improper use of the clutch brake
- Poor shifting technique
  - — Engage reverse gear only after a complete stop.
  - — Shifting into reverse requires more lever travel than a shift in the main box. For example, the reverse gear moves 33.33 mm (1.312 inches) as compared to a first-speed shift which requires only 14.28 mm (0.562 inch) of shift rail movement. Full engagement is required to avoid impact loading or side loading gears.
- Restricted shift lever travel (partial engagement)
  - — Remove restrictions to shift lever travel and adjust linkage if necessary.

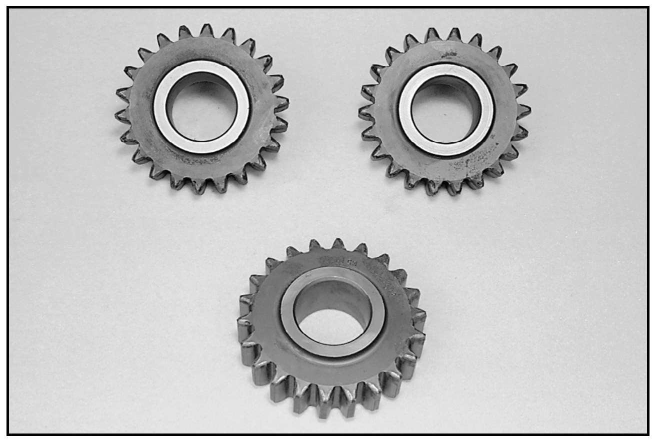


Figure 128 — Reverse Idler Impact Loading

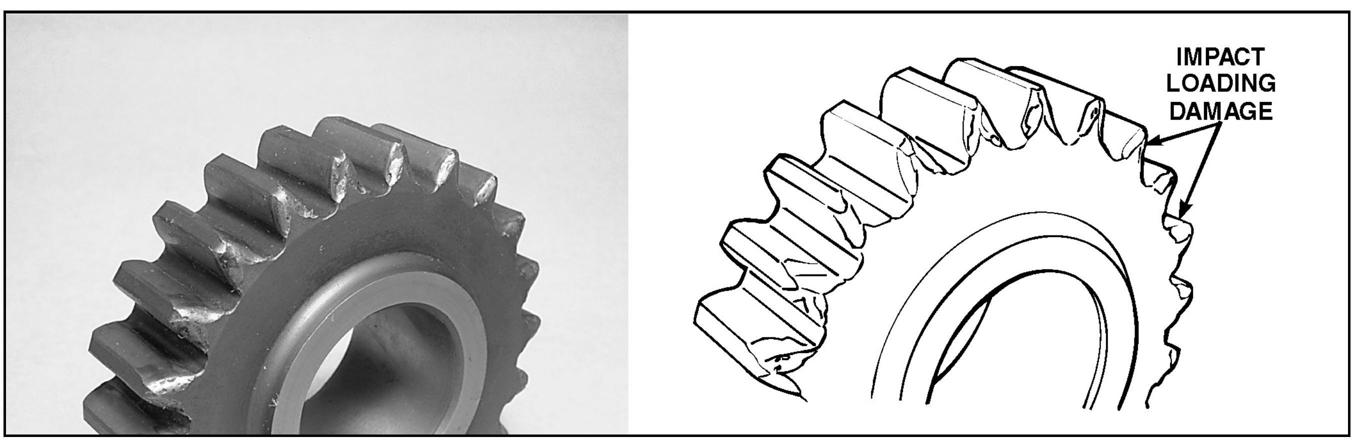


Figure 129 — Reverse Idler Gear

REVERSE IDLER GEARS

Shock Loading (T107 Series Transmission)

Shock loading the reverse idler gear involves overloading the gear set while it is in full engagement. This can be caused by any of the following conditions:

- Ramming a stationary object (such as a loading dock or other immovable object) while backing up.
- Harsh clutch pedal release (popping the clutch) under heavy loads.
- Inoperative torque limiter, if applicable. To adjust the torque limiter, refer to the Mack Torque Limiter System manual under Transmission 10.10.

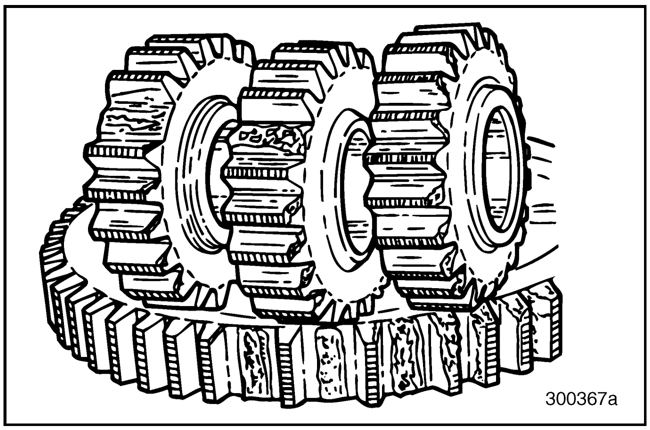


Figure 130 — Reverse Gear Shock Loading

300 OVERALL FAILURE ANALYSIS

CRITICAL INSPECTION AREAS DURING DISASSEMBLY

Transmission Overview

NOTE

This manual is a general failure analysis guide. Some procedures may differ depending on the series of transmission being serviced (for example, T200 versus T107 series).

A T200 series transmission was used in this example of critical inspection areas. Differences from the T107 are noted.

Visually inspect the entire exterior of the transmission for damage and lubrication oil leaks. Primary areas of inspection include the following:

- Main drive pinion and mainshaft rear seal areas
- Transmission case top covers and PTO covers and the area in proximity to the mounting for both the SAE six- and eight-bolt PTO as well as the rear-mounted PTO
- Front and rear countershaft bearing covers
- Transmission case damage (cracks, broken pieces or case porosity)
- Transmission top cover breather

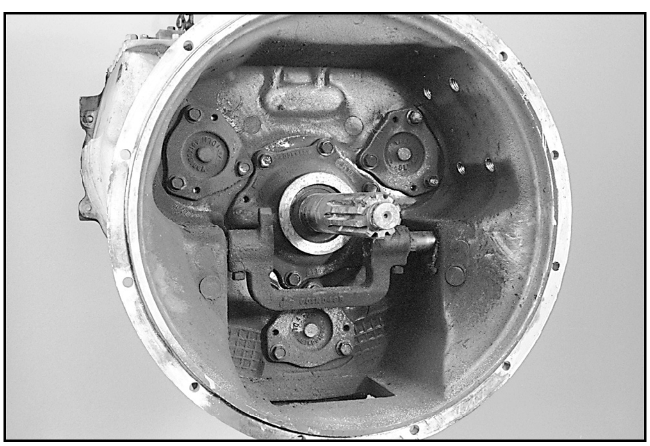


Figure 131 — Transmission Front Inspection

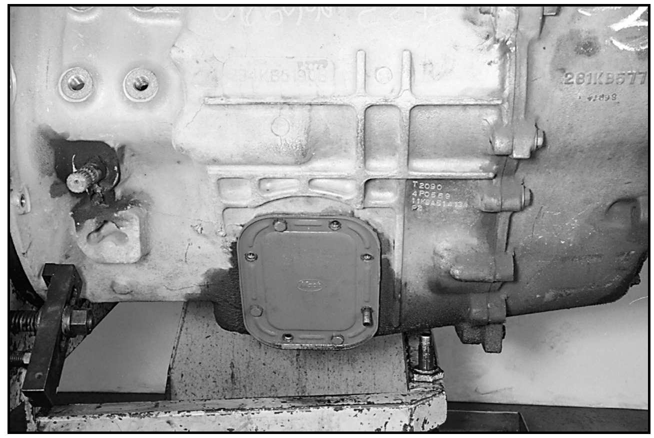


Figure 132 — Transmission Side Inspection

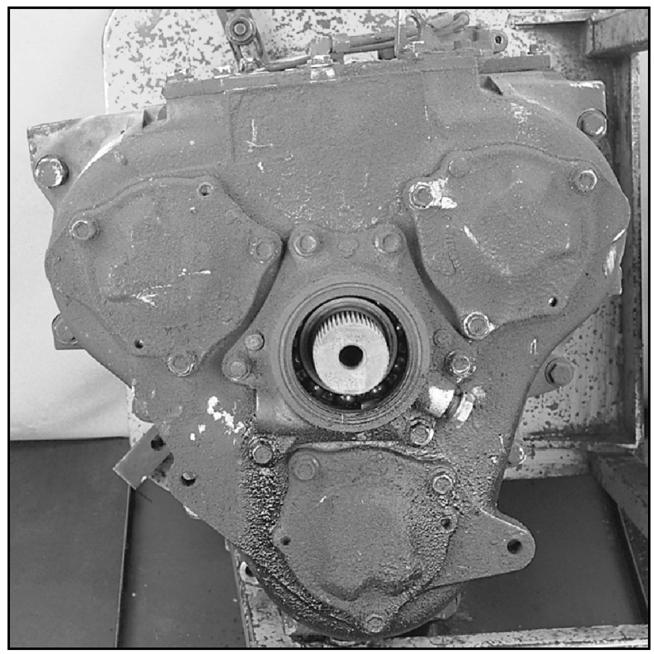


Figure 133 — Transmission Rear Inspection

Remove the magnetic oil drain plug at the bottom of the transmission and check for metallic particles. Any particles large enough to be felt between fingers would indicate a problem in the transmission. Very small particles of metal on the magnet are evidence of normal wear. If a lubrication-related problem is suspected, save a small sample of transmission oil for later analysis.

Figure 134 — Magnetic Oil Drain

Remove the magnetic filter plug from the side of the transmission and inspect for *ferrous metal* (iron and steel) particles. The same metal particle inspection criteria that was used for the lower drain also applies here. This transmission side filter and the lower drain plug are two good places to start determining the amount and severity of any transmission damage.

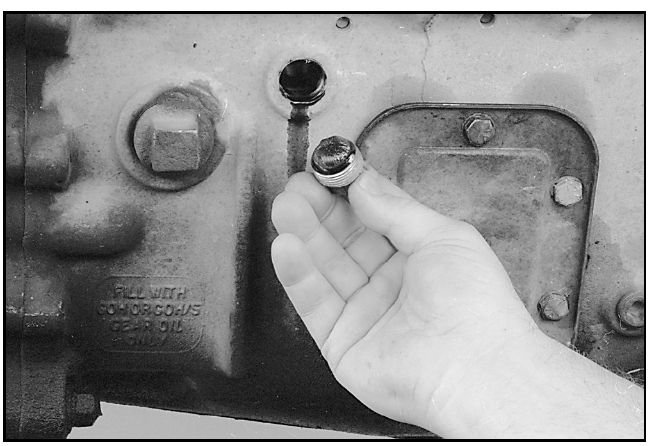


Figure 135 — Magnetic Filter Plug

Note the condition of the breather on the main case top cover. Check for dirt or *sludge* accumulations that could restrict air movement. A plugged breather allows pressure to build inside the transmission to the point that oil leaks and shaft seal damage could result.

Figure 136 — Top Cover Breather

Remove the main and compound case shift covers. Using a light source, visually inspect the interior of the main and rear cases. Inspect the transmission for the following:

- Condition of the lube oil film on interior parts and case for oxidation and coking, signs of poor or inadequate lubrication, heat damage on gears and shafts
- Main drive pinion gear, mainshaft gears and countershaft gears for scoring or signs of inadequate lube
- Damage to gears such as broken or chipped teeth or cracks to gear teeth or gear hub
- Broken or twisted mainshafts
- Visibly damaged bearings
- Foreign material (debris)
- Damage to shifter cover, rails, forks and rail bore wear

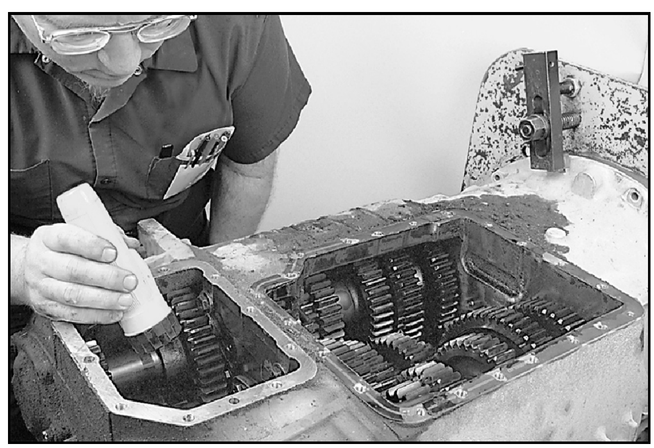


Figure 137 — Main or Rear Case Inspection

Use a pry bar to check shafts and gears of the main and compound cases for excessive movement that may indicate a thrust washer or snap ring is missing or a bearing problem exists. Check that all snap rings and thrust washers are installed in the correct positions. Verify that correct parts (such as forks, gears, etc.) are installed in the transmission.

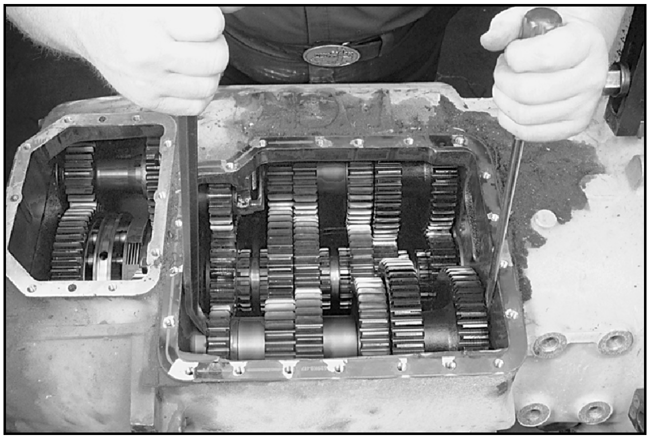


Figure 138 — Check Components

Inspect the shift forks on the main and compound cases for worn or bent arms. Inspect the fork-to-sliding clutch groove clearance. Forks or sliding clutches found to exceed specification limits (as specified in the appropriate transmission service manual) must be replaced.

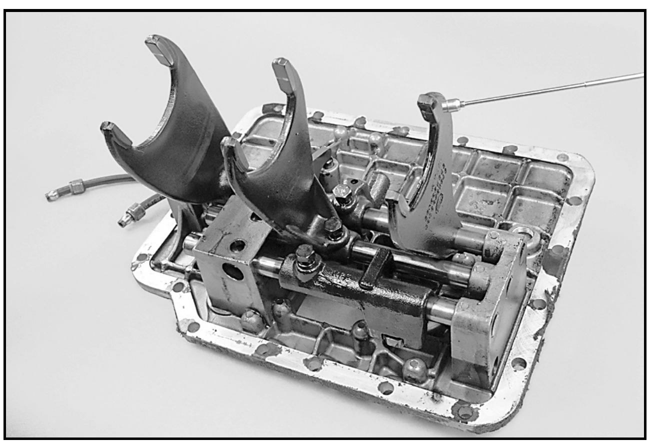


Figure 139 — Inspect Shift Forks

Using a pry bar or screwdriver, check for excessive shift rail-to-mating housing clearances and compare to specification. If excessive wear is found, disassemble to determine which part is worn. Check shaft wear by measuring shaft diameter at a point on the rail that is not subjected to wear. Compare the worn and unworn areas to determine the amount of shaft wear.

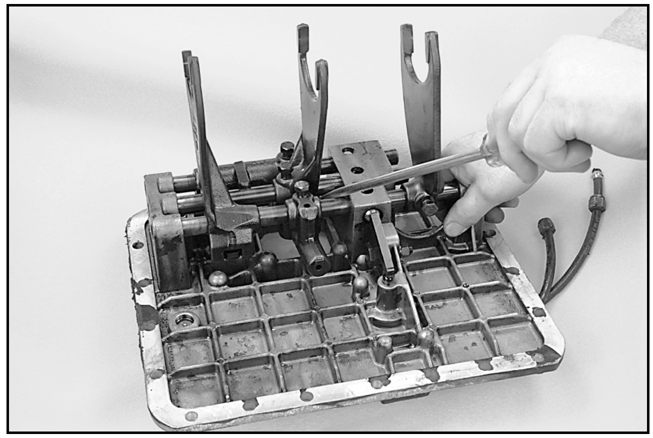


Figure 140 — Inspect Shift Rails

Inspect the shift rails for cracks in the poppet and setscrew holes.

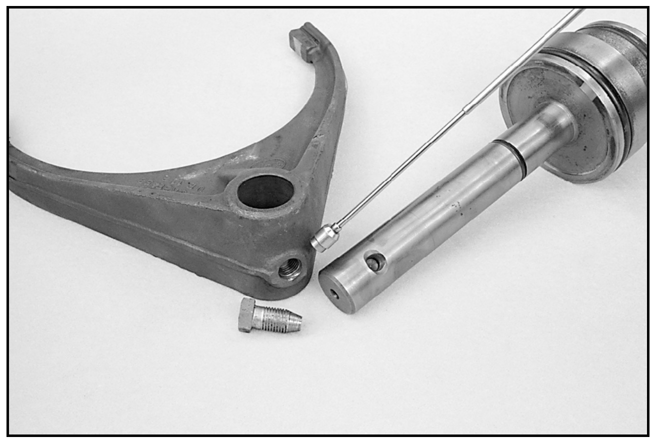


Figure 141 — Inspect Shift Rail Setscrew Holes

Remove the range shift cylinder, disassemble and inspect for contaminants. Inspect the condition of the cylinder bores and pistons for any scoring that may exist. Also inspect the breather vent in the side of the range shift cylinder for any restrictions.

Figure 142 — Range Shift Cylinder

Turn the transmission vertically on the transmission stand with the input shaft down and remove the mainshaft rear bearing cover. Inspect the condition of the mainshaft rear bearing and the output shaft spline for wear or damage. Check the condition of the oil seal.

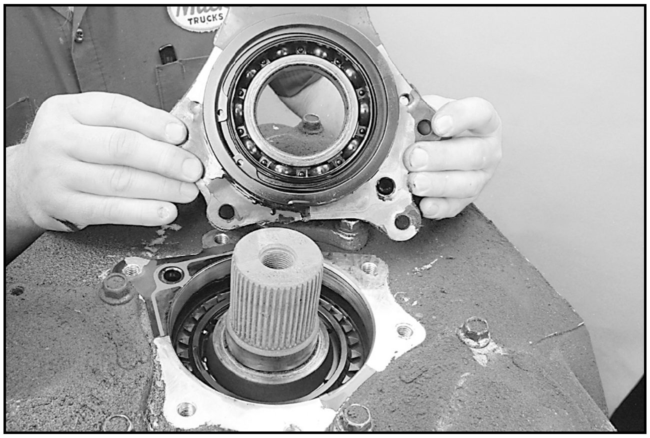


Figure 143 — Mainshaft Rear Bearing Area

NOTE

Some T107 models require removing the front compound (refer to the appropriate transmission service manual). Disassemble unit and place the gears on a clean work surface for inspection later.

Remove the three countershaft rear bearing covers. Inspect the countershaft bearing inner and outer races as well as the rollers or balls. Check the bearings for any signs of failure as outlined under "BEARING FAILURE MODES" on page 33 in the General Types of Failure section of this manual.

Look at the bearing covers for fretting on the mounting surfaces or for any signs of fastener looseness. Check for presence and condition of O-rings on the compound countershaft rear bearing covers.

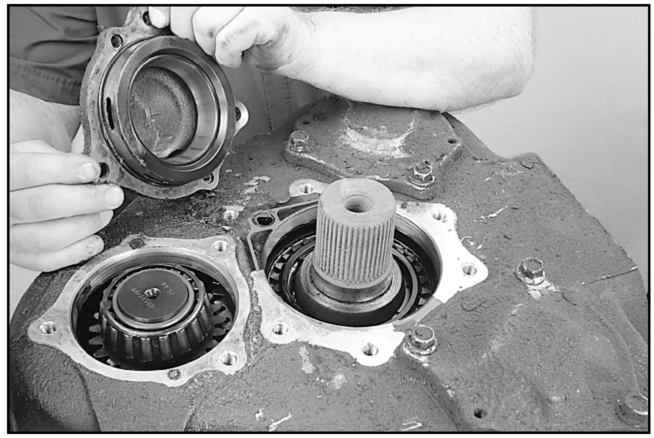


Figure 144 — Countershaft Rear Bearing Covers

Remove the rear case from the main case as outlined in the appropriate transmission service manual.

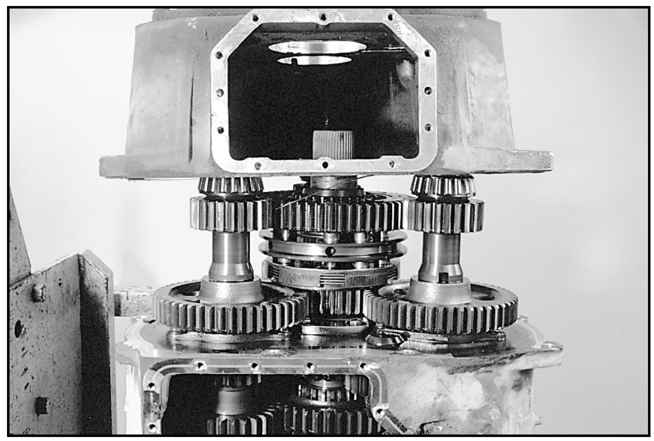


Figure 145 — Rear Case

NOTE

Disassemble the T107 rear compound using the appropriate transmission service manual and place the gears on a clean work surface for inspection.

Inspect the gears of the rear compound for any signs of abrasive wear, scratching (except for normal manufacturing tool marks), ridging, scoring, surface fatigue, pitting, spalling, corrosive wear, digging in or cracking. Gears suspected of cracking should also be inspected by Magnaflux or a similar system to verify the true condition of the gear.

NOTE

Also inspect the gears of the front compound on the T107 series.

Figure 146 — Inspect Rear Compound Gears

Remove the rear mainshaft and synchronizer from the rear of the transmission. Also remove the Hi-range synchronizer plates, and the main drive gear backing plate.

Inspect the synchronizer assembly and check for any damage to the synchronizer friction or reaction disc(s). Also check for the amount of wear on the synchronizer Hi-Lo sliding clutch teeth and its mating gear.

Figure 147 — Synchronizer Inspection

Remove the three rear compound countershafts as directed by the transmission service manual and check the three rear compound countershaft bearings and races.

NOTE

On the T107 series, remove the main case countershaft rear roller bearings. Inspect the roller bearing as outlined under "BEARING FAILURE MODES" on page 33 in the General Types of Failure section of this manual.

Remove and inspect the front countershaft rear bearing covers for fretting on the mounting surfaces and for any signs of fastener looseness. Check the front countershaft rear bearing cover bearing cups (both front and rear) for any signs of failure as outlined under "BEARING FAILURE MODES" on page 33 in the General Types of Failure section of this manual.

Also check the front countershaft rear bearing cones.

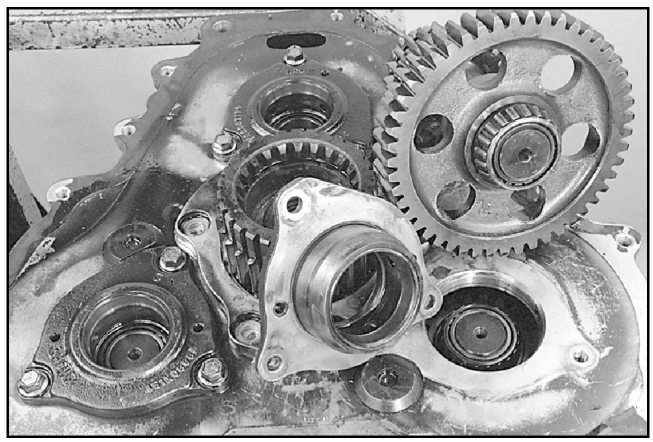


Figure 148 — Inspect Bearings

Remove the rear compound main drive gear retaining plate and main drive gear with attached ball bearing. Inspect the retaining plate for fretting on abutment faces and for any signs of fastener looseness. Check the main drive gear ball bearing for any signs of failure as outlined under "BEARING FAILURE MODES" on page 33 in the General Types of Failure section of this manual.

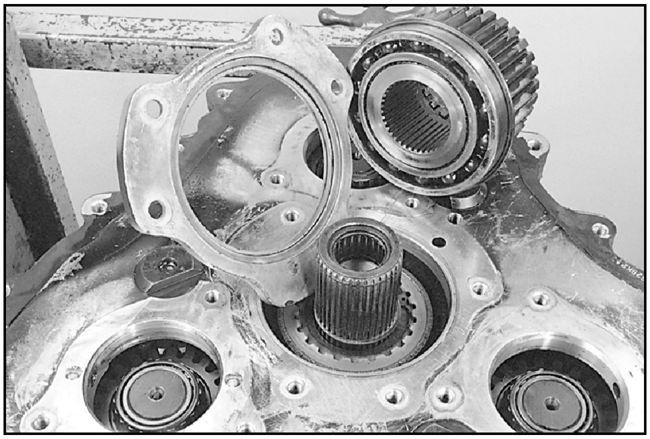


Figure 149 — Main Drive Gear

NOTE

On the T107 series, remove the Hi-range main drive gear and front mainshaft.

Remove the main drive pinion bearing cover and disassemble. Look at the condition of the internal ball bearing and the input splines for wear or damage. Also inspect the spigot bearing at the end of the pinion shaft. Check the condition of the oil seal. Look at the bearing cover for fretting on the mounting surfaces and for any signs of fastener looseness.

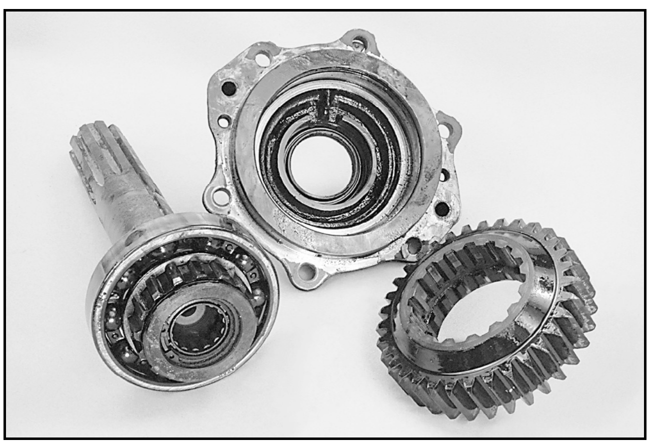


Figure 150 — Main Drive Pinion Cover

Remove the front countershaft front bearing covers and inspect the countershaft tapered roller or ball bearing inner and outer races as well as the balls or rollers. Check for any signs of failure as outlined under “BEARING FAILURE MODES” on page 33 in the General Types of Failure section of this manual.

Look at the bearing covers for fretting on the mounting surfaces and for any signs of fastener looseness. Check condition and presence of O-rings.

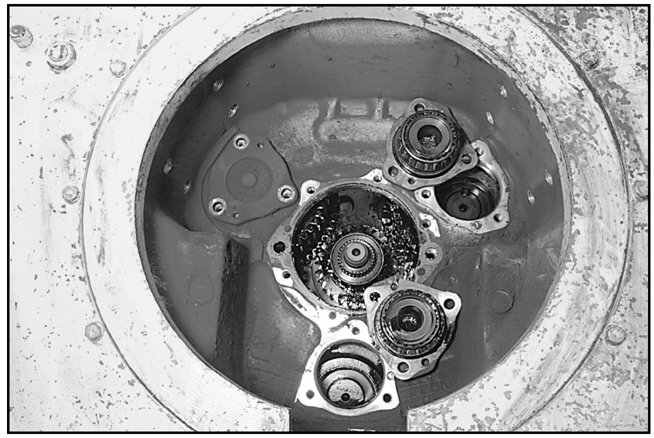


Figure 151 — Countershaft Front Bearing Covers

Following the appropriate transmission service manual procedure, remove the following from the transmission main case:

- Reverse idler gears (T200 series)
- Front upper right countershaft
- Mainshaft assemblies
- Upper left countershaft
- Lower center countershaft

Place the reverse idler gears, countershafts and mainshaft on a clean work surface for further inspection.

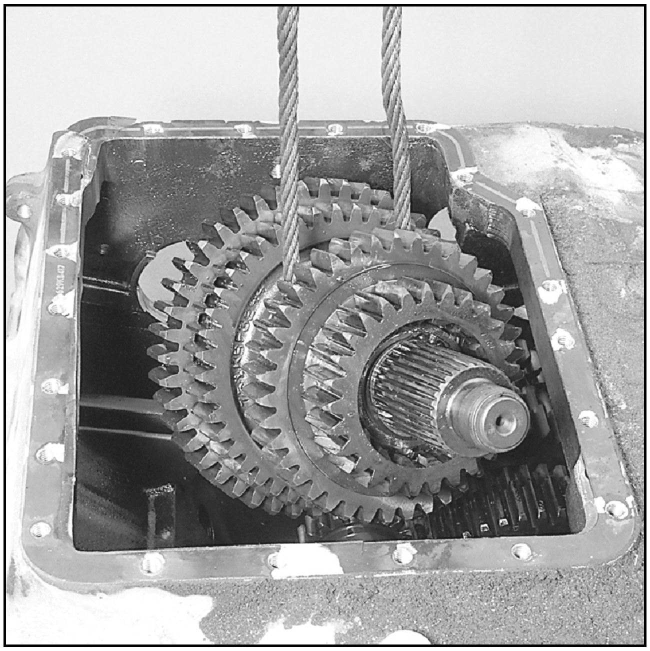


Figure 152 — Mainshaft Assembly

Inspect the gears of the main case for any signs of abrasive wear, scratching (except for normal manufacturing tool marks), ridging, scoring, surface fatigue, pitting, spalling, corrosive wear, digging in or cracking. Gears should also be inspected by Magnaflux or a similar system if a crack in a gear is suspected.

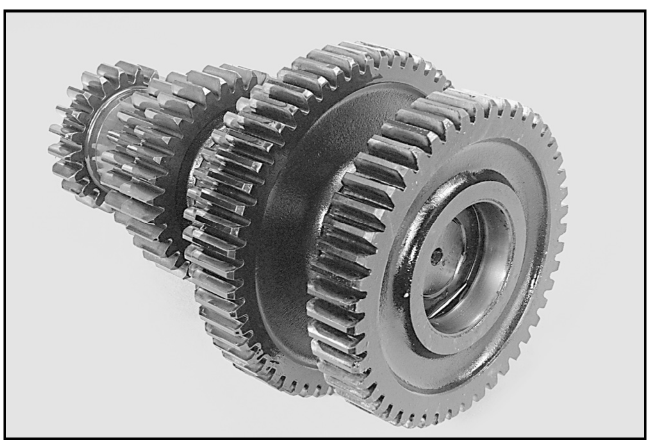


Figure 153 — Inspect Countershaft Gears

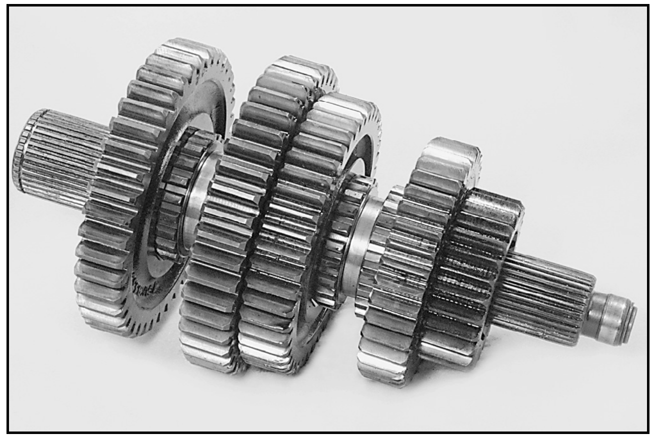


Figure 154 — Inspect Mainshaft Gears

Carefully inspect the transmission main and compound cases for cracks or signs of oil leakage or porosity. Replace any case found to be cracked. Clean up any slightly damaged threads. Repair stripped threads by using Heli-Coil or equivalent repair parts.

Figure 155 — Inspect Transmission Cases

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MACK TRANSMISSION

FAILURE ANALYSIS

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