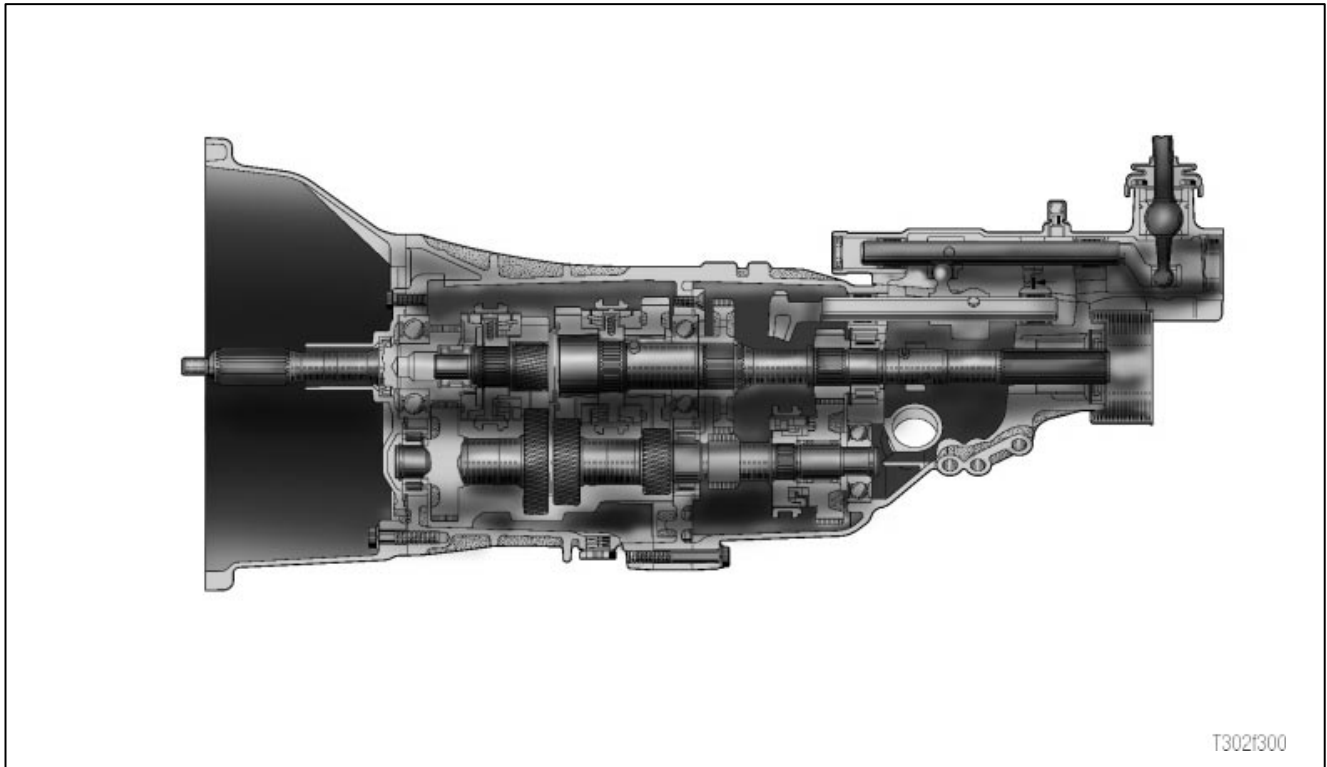


## Section 3

# Manual Transmissions

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- Learning Objectives:**
1. Identify and describe manual transmission design features and operation.
  2. Describe transmission powerflow.
  3. Describe manual transmission construction.
  4. Identify and describe the operation of the following transmission components:
    - a. Synchronizers
    - b. Shift mechanisms
    - c. Key inertia lock mechanism
  5. Identify and describe gear shift control.
  6. Describe transmission lubrication.

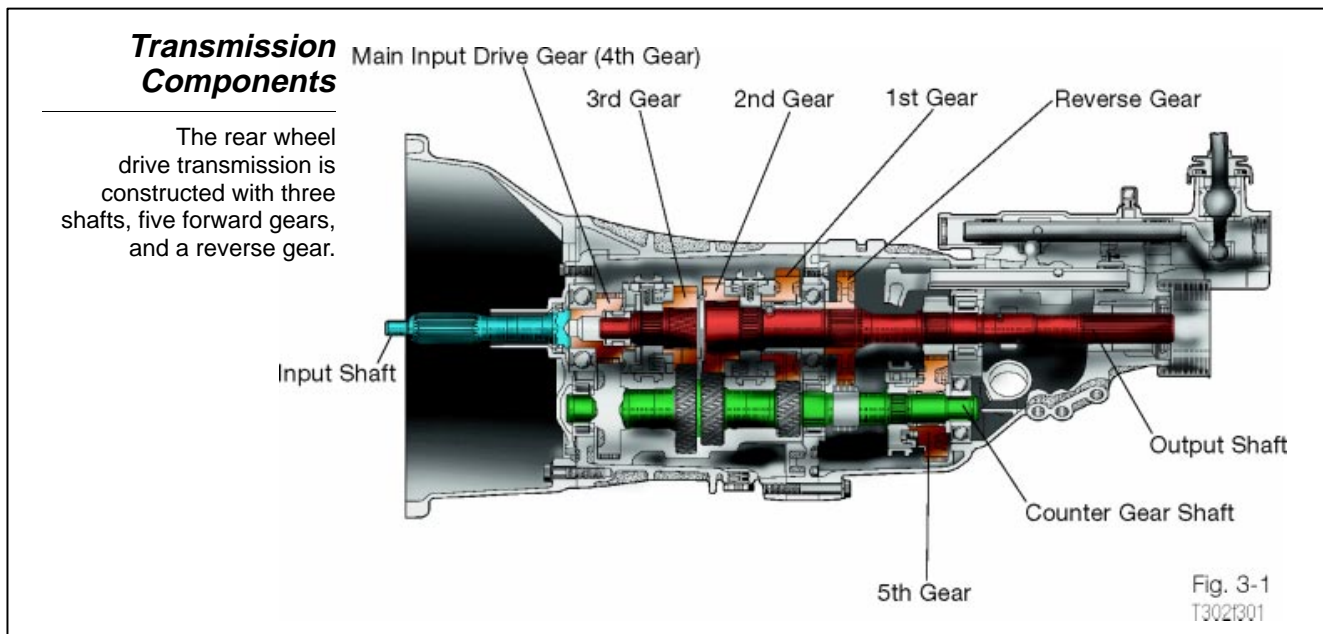
# Manual Transmissions

**Introduction** The manual transmission transfers power from the engine to the propeller shaft. It converts and multiplies rotational speed, allowing engine RPM to remain in its limited optimal power range while providing a wide range of RPM to the propeller shaft; which, in turn, controls vehicle speed.

Multiple gear sets within the transmission provide gear ratios to best utilize the engine's torque. A gear ratio of about 4:1 in first gear provides high torque to begin moving the vehicle. In contrast, a higher gear ratio of about 1:1 reduces engine speed at higher vehicle speeds when less torque is required to maintain momentum.

Understanding manual transmission design features increases your knowledge of transmission operation, and provides for easier and more accurate problem diagnosis.

**Components** The rear wheel drive transmission is constructed with three shafts, five forward gears, and a reverse gear.



**Input Shaft** The **input shaft**—also known as a main drive gear or clutch shaft—is driven by the clutch disc and drives the counter gear shaft. The input shaft is supported by the pilot bearing at the end of the crankshaft and a bearing at the front of the transmission case.

**Counter Gear Shaft** The **counter gear shaft**—also known as a cluster gear—drives the gears (1st, 2nd, 3rd, and 5th) on the output shaft. This shaft is supported by bearings in the intermediate plate, at the front of the transmission case, and in the extension housing.

**Output Shaft** The **output shaft**—also known as the mainshaft—drives the propeller shaft. It is splined at the rear to allow a sliding connection to the propeller shaft. The output shaft gears rotate on the shaft and are locked to the shaft by synchronizers. The synchronizers are splined to the output shaft. The output shaft is supported by a pocket bearing at the rear of the input shaft, a bearing at the intermediate plate and a bearing at the extension housing of the transmission.

### **Transmission Construction**

A rear wheel drive transmission has three sections: the clutch housing, the transmission case, and the extension housing.

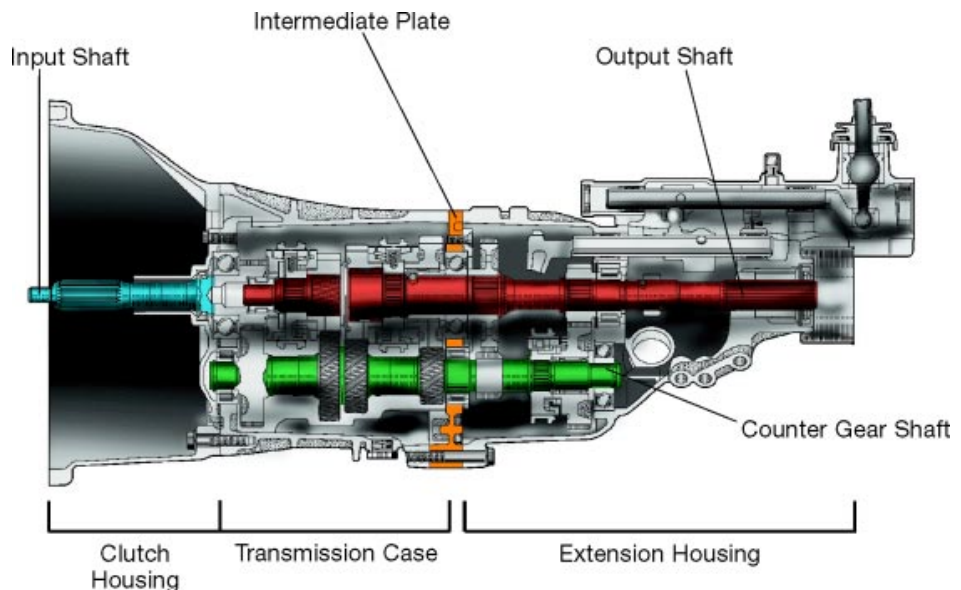


Fig. 3-2  
T302T302

**Gears** Gears transfer engine power from the input shaft, through the counter gear shaft, to the output shaft. There are five forward gears and one reverse gear. Only one gear is engaged at a time.

**Forward Gears** All forward motion gears are helical gears because of their smooth and quiet operating characteristics. Helical gears create end thrust under load, and therefore have a thrust surface on the side of the gear. Gear side clearance is limited to reduce noise and potential damage, which could result from gear motion.

**Reverse Gears** Reverse requires an additional gear in the gear train. A reverse idler gear is used to change the direction of the output shaft for reverse.

The reverse gear is a straight cut spur gear and does not have a synchronizer. Spur gears are suitable for this application because they shift into mesh more easily than helical gears, and they don't generate end thrust under load.

Straight cut gears may create a whine or light growl during operation.

### ***Reverse Idler Gear***

An idler gear is used to change the direction of the output shaft for reverse.

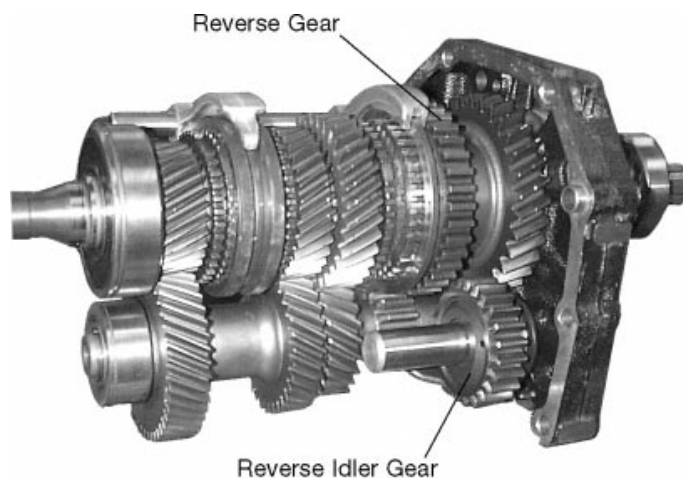


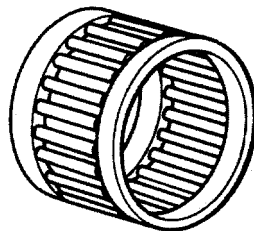
Fig. 3-3  
T302F303

**Bearings** Bearings and bushings are used to support shafts in the transmission. Depending upon design, transmissions use a wide variety of bearings, including:

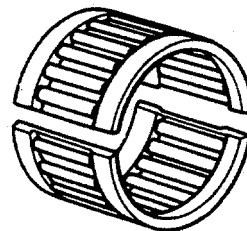
- **Needle bearings** – can support large side loads but are unable to control end thrust loads. Individual needles are housed in a single enclosure or a split bearing holder. They are used in most forward speed gears.
- **Ball bearings** – can support moderate to high side and thrust loads and are commonly used for the input shaft and output shaft.
- **Roller bearings** – can support large side loads but are unable to control end thrust loads. Individual rollers are housed in a single enclosure.
- **Plain bushings** – can support large side loads and allow free in-and-out movement. Bushings are used on the reverse gear and to support the propeller shaft slip yoke in the extension housing.

### ***Transmission Bearings***

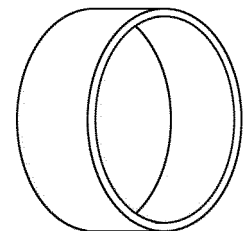
Depending upon design, transmissions use a wide variety of bearings.



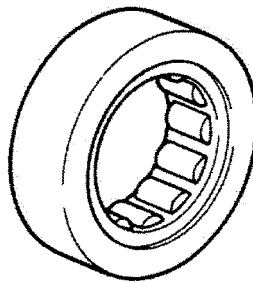
One-Piece  
Needle Bearing



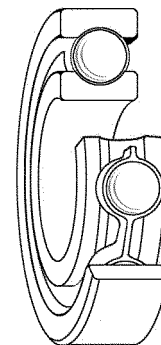
Split Needle Bearing



Plain Bushing



Roller Bearing



Ball Bearing

Fig. 3-4  
T302f304

## Synchronizer Assemblies

Synchronizer assemblies are used to make all forward shifts and to assist reverse gear engagement. The role of the synchronizer is to allow smooth gear engagement. It acts as a clutch, bringing the gears and shaft to the same speed before engagement occurs. Synchronizer components help make the speeds equal while synchronizing the shift.

Gears on the output shaft are in mesh (contact) with gears on the counter gear shaft at all times. Consequently, when the counter shaft turns, the gears on the output shaft rotate. When shifting gears, the synchronizer ring supplies the friction force, which causes the speed of the gear that is being engaged to match the speed of the hub sleeve. This allows the gear shift to occur without the gear and hub sleeve splines clashing or grinding.

### Synchronizer Assemblies

Synchronizers are used to make all forward shifts and to assist with reverse.

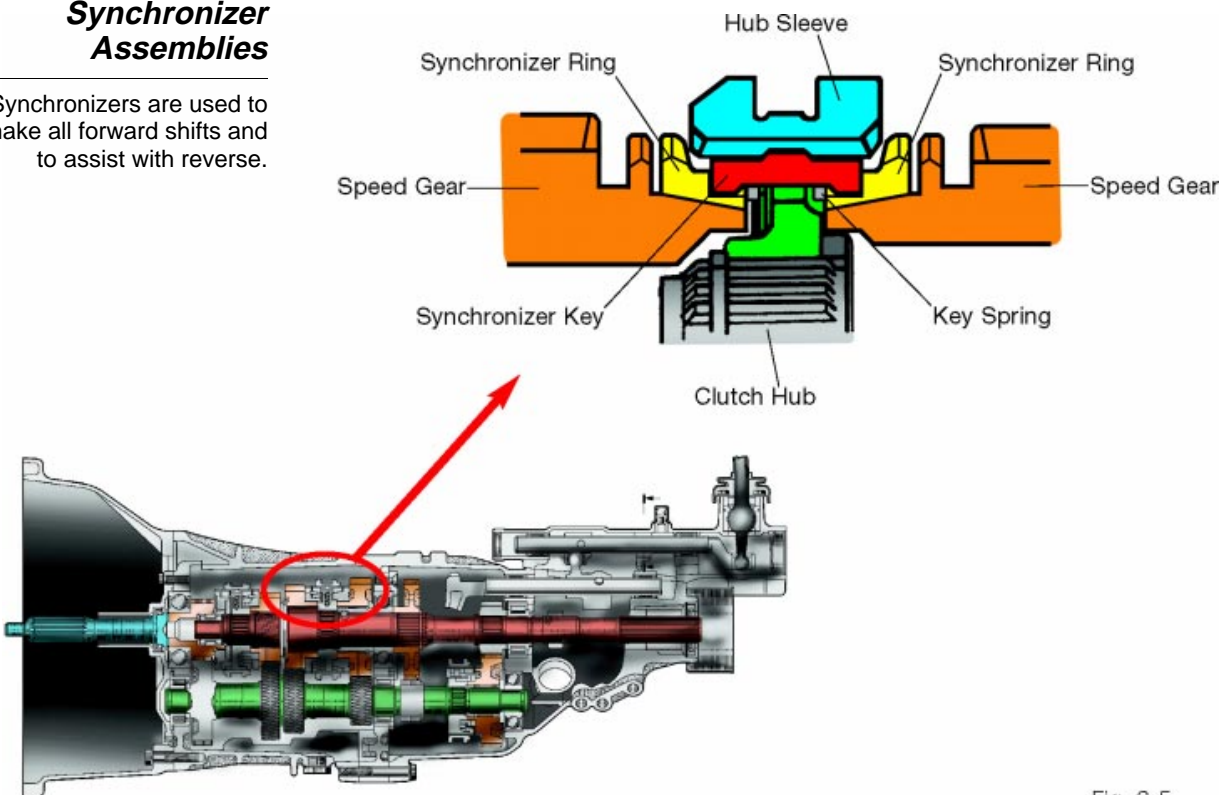


Fig. 3-5  
T302f305

### Synchronizer Components

The synchronizer mechanism is constructed of the following components:

- The **speed gear** is mounted on the output shaft. A needle roller bearing is installed between the speed gear and the output shaft, allowing the gear to rotate freely on the shaft.
- The **synchronizer ring** – also called a **blocker ring** – is made of brass and is installed on the conical portion of the gear. Narrow grooves are cut in the inside area of the synchronizer ring to provide the necessary clutch action of the gear. Three equally spaced slots are cut on the outside surface for the synchronizer keys to fit into.
- Two **key springs** are installed, one on each side of the clutch hub to hold the synchronizer keys in place against the hub sleeve.
- The **clutch hub** is fit to the output shaft on splines and is secured by a snap ring.
- Three **synchronizer keys** are installed in the three equally spaced slots in the clutch hub and are aligned with the slots in the synchronizer ring.
- The **hub sleeve** has internal splines that slip over the clutch hub splines, engaging the spline teeth of the speed gear. An internal groove cut in the center of the hub sleeve splines centers the hub sleeve. The hub sleeve is indexed by the three spring loaded synchronizer keys.

### Synchronizer Components

The Synchronizer is made up of the speed gear, synchronizer ring, synchronizer keys, key springs, clutch hub, and hub sleeve.

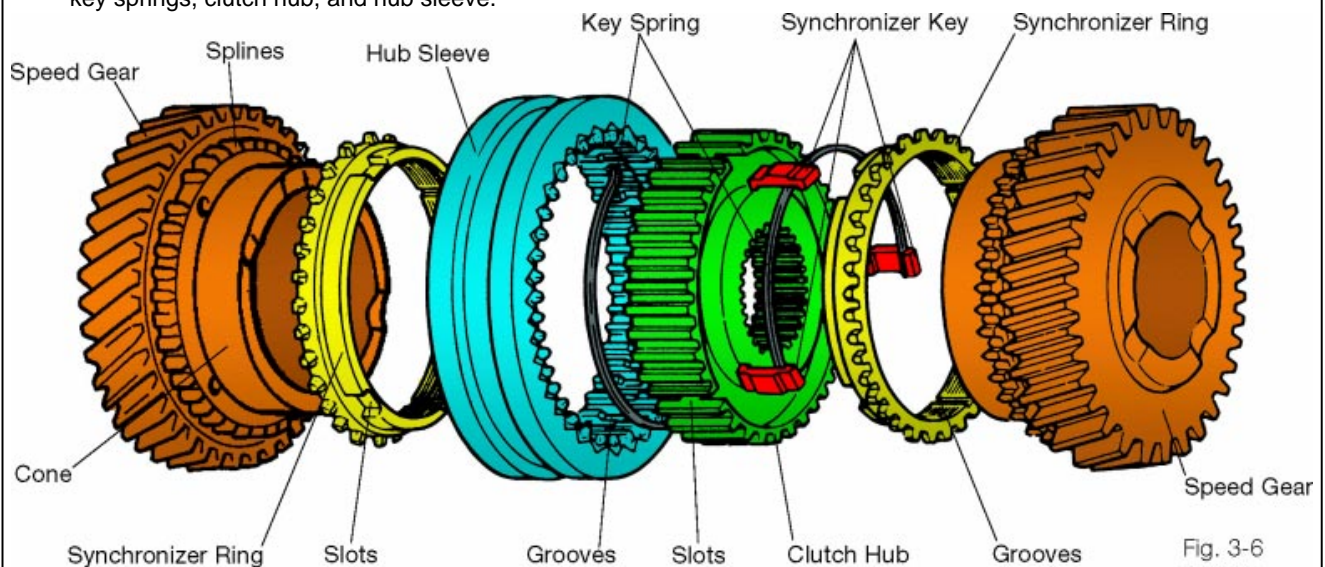


Fig. 3-6  
T3021306



**Synchronizer Operation** When the transmission is in neutral, the hub sleeve groove fits onto the synchronizer key detent. This allows the gears to free wheel on the output shaft. As the clutch pedal is depressed and the shift lever is moved into a gear, three stages are involved for the gearshift to occur.

**1st Stage - Initial Synchronization** As the shift lever moves, the shift fork moves the hub sleeve to the right causing the spring-loaded keys to push the synchronizer ring against the cone clutch surface of the gear.

Engagement of the synchronizer ring to the cone clutch on the faster spinning gear cause the synchronizer ring to rotate, about one-half the width of a spline.

Rotation of the ring causes the sleeve to be out of alignment with the splines preventing further movement, while pressure applied to the cone clutch by the sleeve creates a braking action to slow the gear.

### ***Synchronized Gear Shift - 1st Stage***

When the transmission is in neutral, the synchronizer key detents hold the hub sleeve in the neutral position.

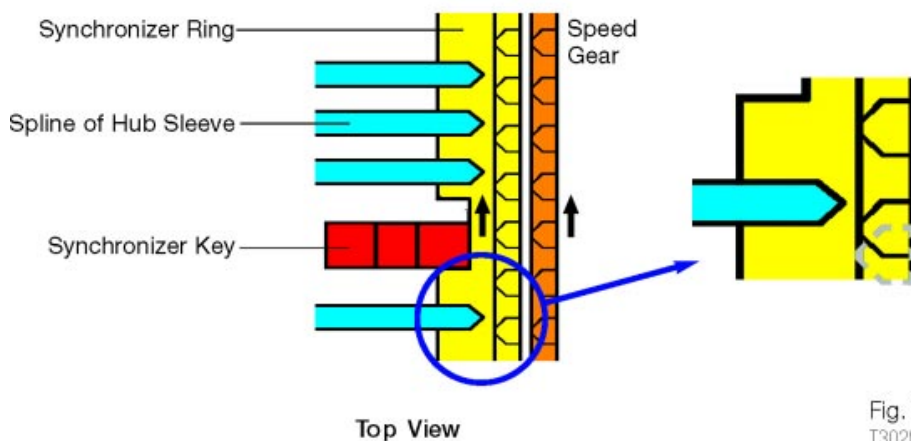
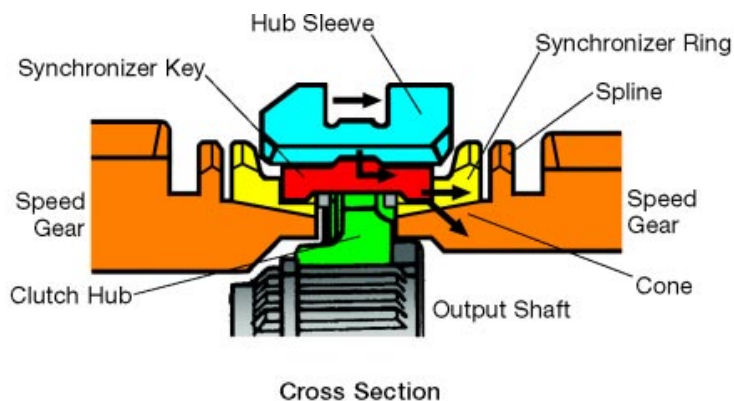


Fig. 3-7  
T302f307



**2nd Stage - Synchronization** When the shift lever is moved further, the force (which is applied to the hub sleeve) overcomes the force of the synchronizer key springs. The hub sleeve moves over the detents of the keys. This movement also causes more pressure to be exerted on the synchronizer ring and gear.

The grooves on the inside surface of the ring help to cut through the oil film on the conical surface of the gear. This ensures that the ring will provide the needed clutching action for engagement.

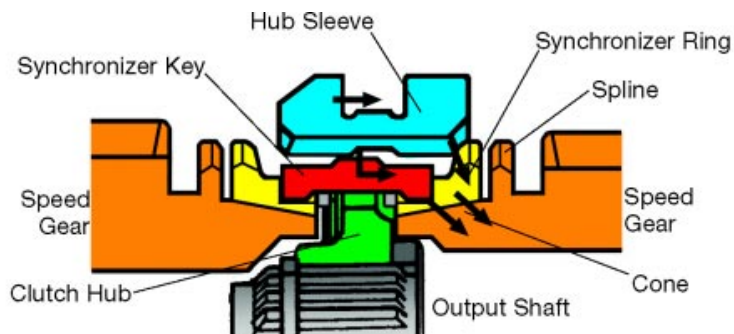
The taper of the sleeve spline pushes against the taper of the ring teeth, causing added pressure to the gear cone.

As the gear slows to the same speed as the hub and sleeve, it will rotate slightly backward to allow alignment of the splines.

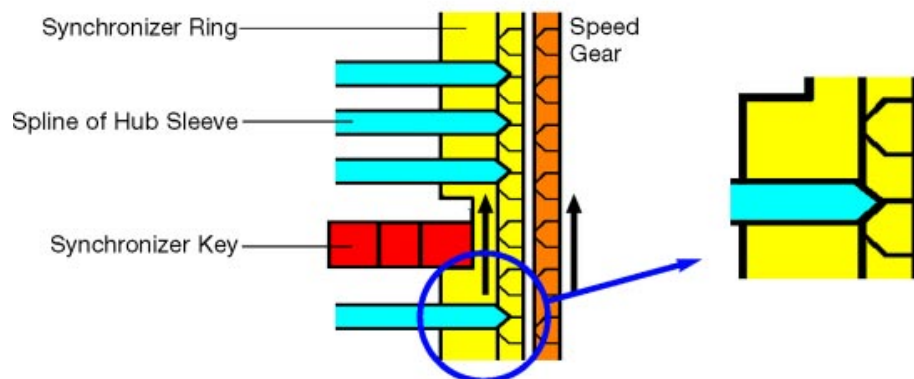
The synchronizer ring and gear splines line up at this time and the splines of the hub sleeve are ready to engage.

### ***Synchronized Gear Shift - 2nd Stage***

The taper of the sleeve spline pushes against the taper of the ring teeth to exert more pressure on the gear cone.



Cross Section



Top View

Fig. 3-8  
T302f308

**3rd Stage - Synchronized Meshing** When the speeds of the hub sleeve and the gear become equal, the synchronizer ring is not in contact with the key. The ring and gear are free to move and the splines of the hub sleeve can engage smoothly.

The sleeve continues to move over the splines of the speed gear, locking the key to the gear, completing gear engagement.

### ***Synchronized Gear Shift - 3rd Stage***

When the speed of the hub sleeve and the gear become equal the hub sleeve engages the splines of the gear.

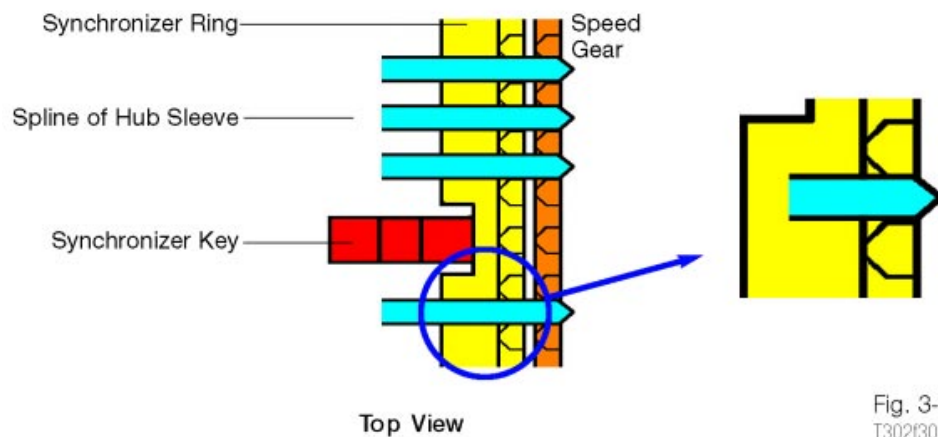
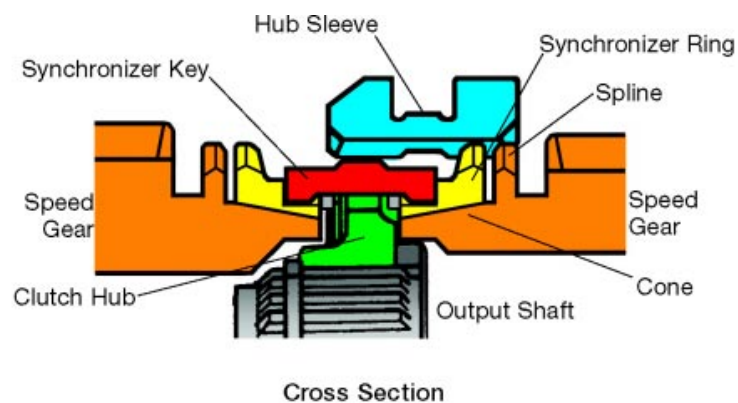


Fig. 3-9  
T302f309

### Synchronizer Hub Sleeve & Splines

Synchronizer hub sleeves have a slight back cut at the ends of the splines. This cut matches a similar cut on the spline gear teeth of the speed gears. This locks the gears in engagement and prevents the sleeve from jumping out of mesh.

#### **Synchronizer Hub Sleeve and Splines**

Hub sleeve splines are back cut to lock the gears in engagement, preventing the sleeve from jumping out of mesh.

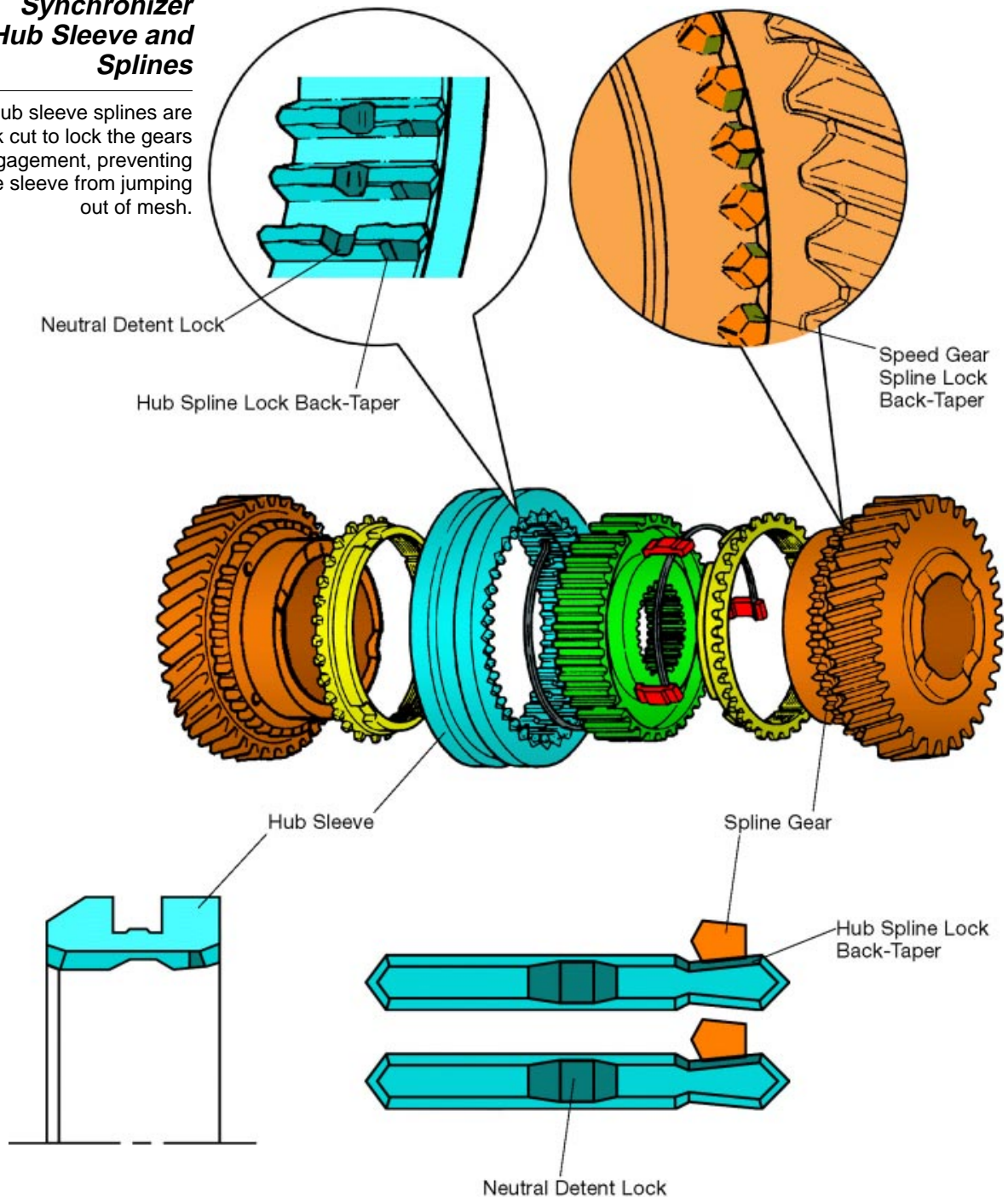
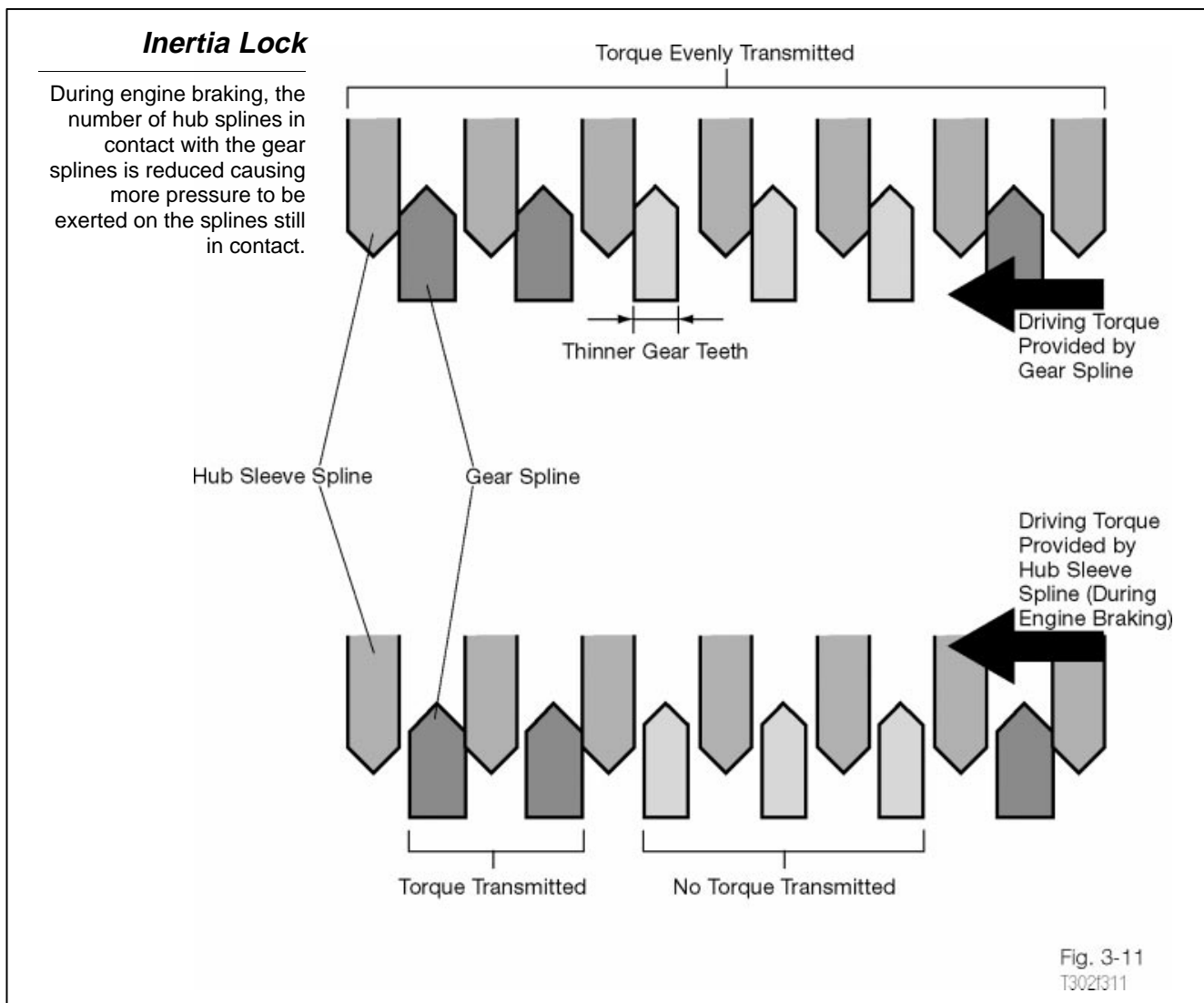


Fig. 3-10  
T3021310

**Inertia Lock** Splines of different thickness have been used where the gears fit into the hub sleeve to increase the meshing pressure (surface pressure) of the hub and gears, and to prevent the sleeve from jumping out of engagement.

As a result, when driving torque is transmitted from a gear to the hub sleeve, all of the splines of the gear mesh with the hub sleeve, but during engine braking (driving torque transmitted from the hub sleeve to the gears), the number of gear splines meshing with the hub sleeve decreases. This causes the meshing pressure of the hub sleeve and the gear to increase, thus preventing the sleeve from jumping out of engagement.



**Multi-Cone Synchronizer** Some transmissions use two or three cone synchronizer units. Multiple cone synchronizers have more surface area available to provide low shift effort for the lower gear ranges.

**Two-Cone Synchronizer** The two cone synchronizer is so named from the two cone shaped surfaces which make up the assembly. The middle ring provides two cone surfaces and almost twice the surface area to slow the gear to the speed of the output shaft.

In a two-cone synchronizer, the inner and outer rings are indexed together and turn with the transmission output shaft. The middle ring is indexed to the gear and they turn together driven by the input shaft.

During shifting, the hub sleeve pushes the synchronizer keys against the outer ring. The inside surface of the outer ring mates with the outside surface of the middle ring creating one friction surface. The inside surface of the middle ring mates with the outside surface of the inner ring providing the second friction surface.

### ***Two-Cone Synchronizer***

In a two-cone synchronizer, the inner and outer rings turn with the transmission output shaft. The middle ring and gear turn together driven by the input shaft.

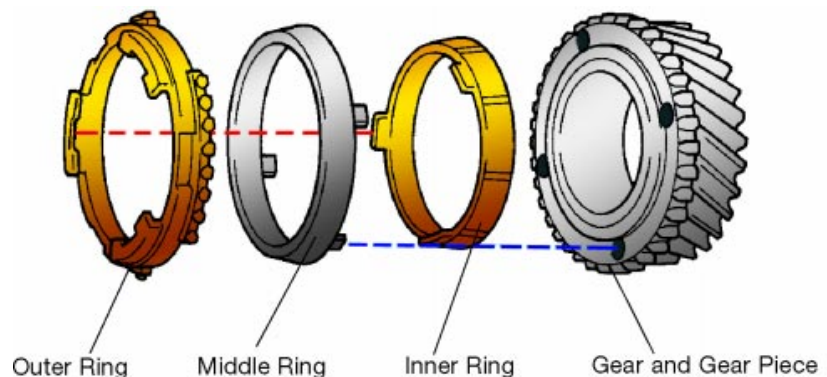


Fig. 3-12  
T3021312

**Three-Cone Synchronizer** The three cone synchronizer is so named from the three cone shaped surfaces which make up the assembly. In addition to the middle ring providing two cone surfaces, the speed gear has a third cone surface providing three surface areas to slow the gear to the speed of the output shaft.

In a three-cone synchronizer, the inner and outer rings turn with the transmission output shaft. The middle ring is indexed to the gear and they turn together driven by the input shaft.

During shifting, the hub sleeve pushes the synchronizer keys against the outer ring. The inside surface of the outer ring mates with the outside surface of the middle ring creating one friction surface. The inside surface of the middle ring mates with the outside surface of the inner ring providing the second friction surface. The inside surface of the inner ring mates with the cone surface of the speed gear providing the third friction surface.

### Three-Cone Synchronizer

In a three-cone synchronizer, the inner and outer rings turn with the transmission output shaft. The middle ring is indexed to the gear and they turn together driven by the input shaft.

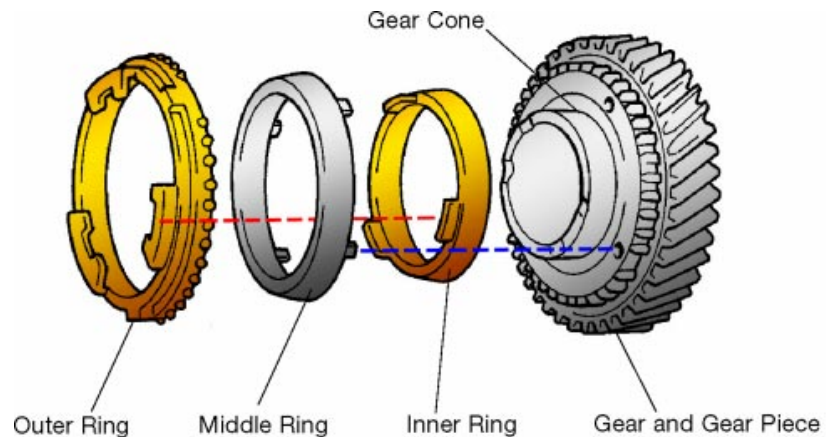


Fig. 3-13  
T302F313

### Transmission Powerflow

Understanding the powerflow through a transmission helps the technician in diagnosing complaints and determining the proper repairs to be done. The following illustrations show the typical powerflow through a five-speed transmission.

For example, in first gear, power flows from the input shaft and main drive gear to the counter shaft. First gear, on the counter shaft, drives first gear on the output shaft. The first gear is locked to the synchronizer clutch hub transmitting power to the output shaft.

On the following three pages, in figures 3-14 through figure 3-19, the powerflow for 1st, 2nd, 3rd, 4th, 5th, and Reverse are highlighted and traced through a transmission.



### 1st Gear

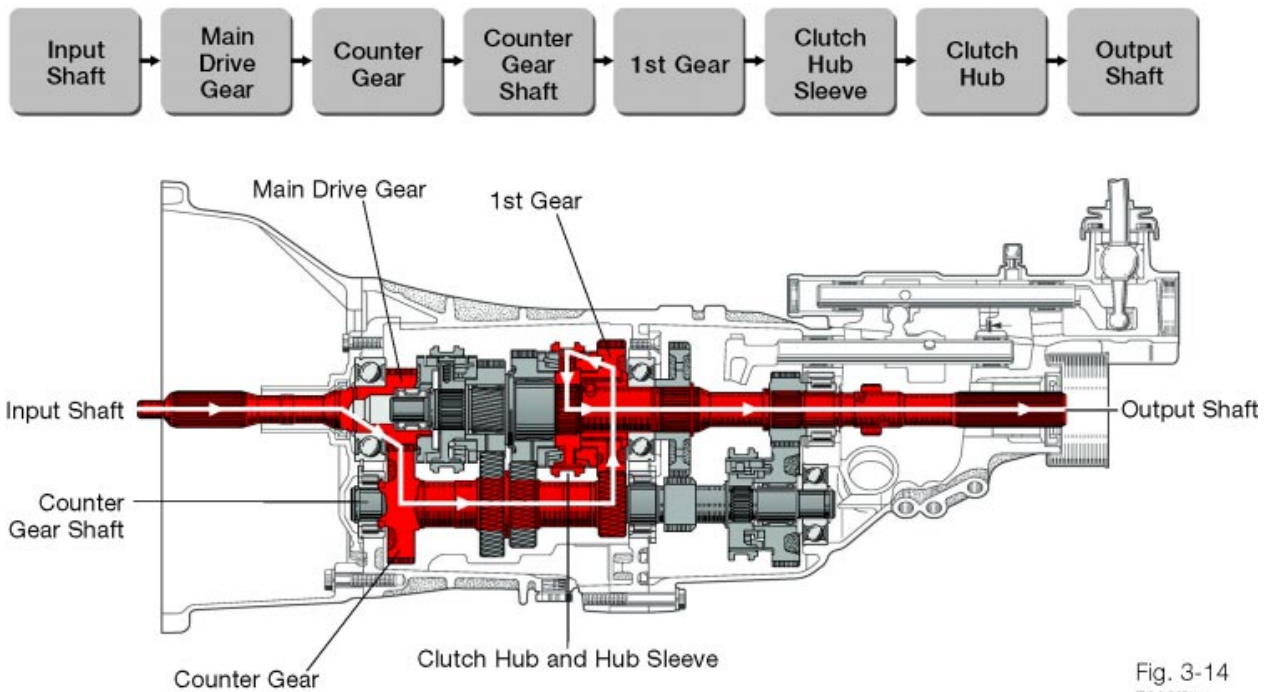


Fig. 3-14  
T302f314

### 2nd Gear

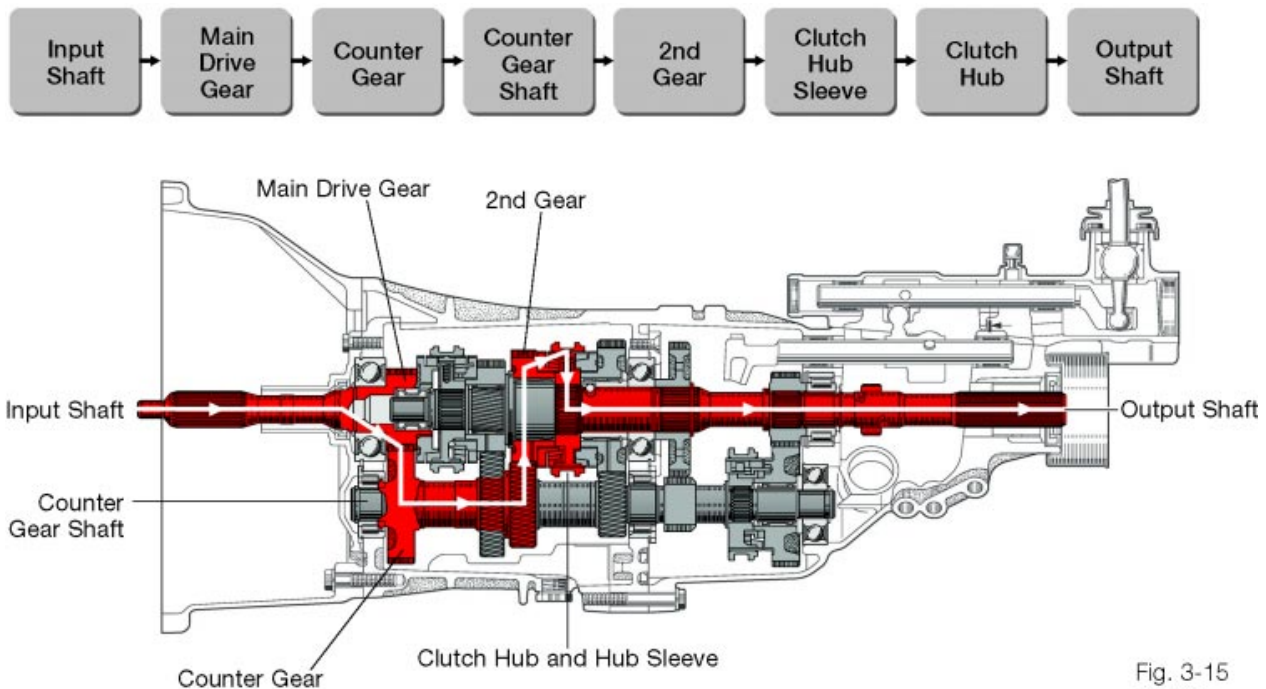


Fig. 3-15  
T302f315



### 3rd Gear

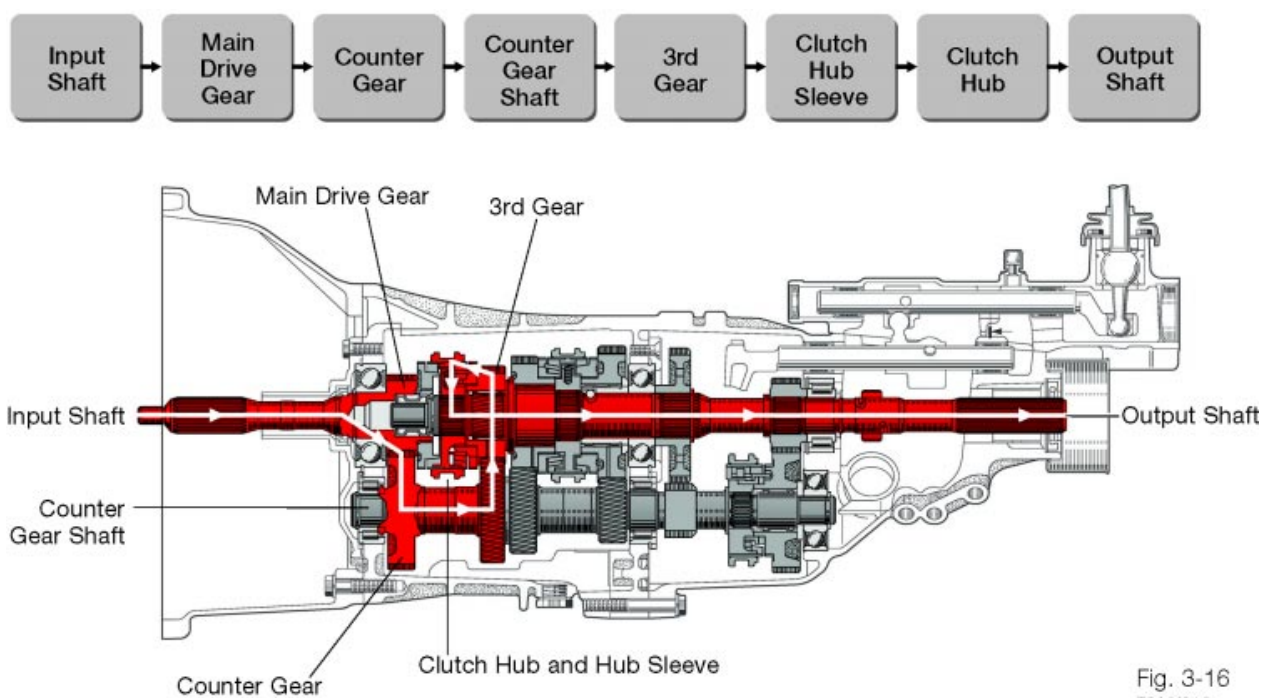


Fig. 3-16  
T302F316

### 4th Gear

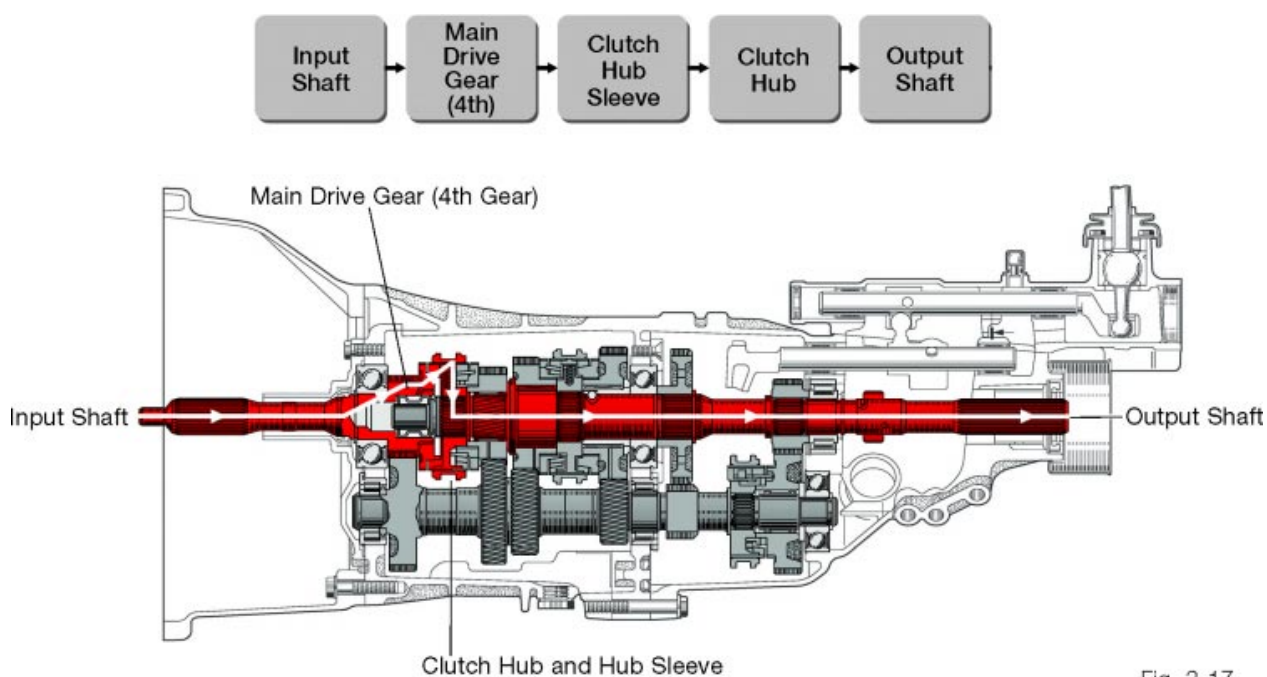


Fig. 3-17  
T302F317

### 5th Gear

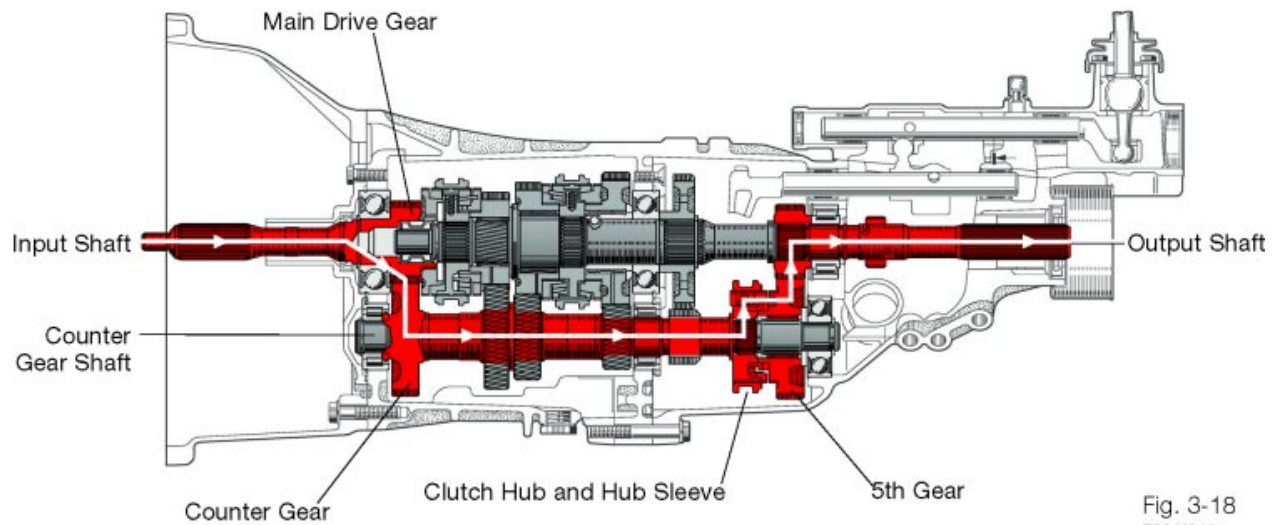


Fig. 3-18  
T302f318

### Reverse Gear

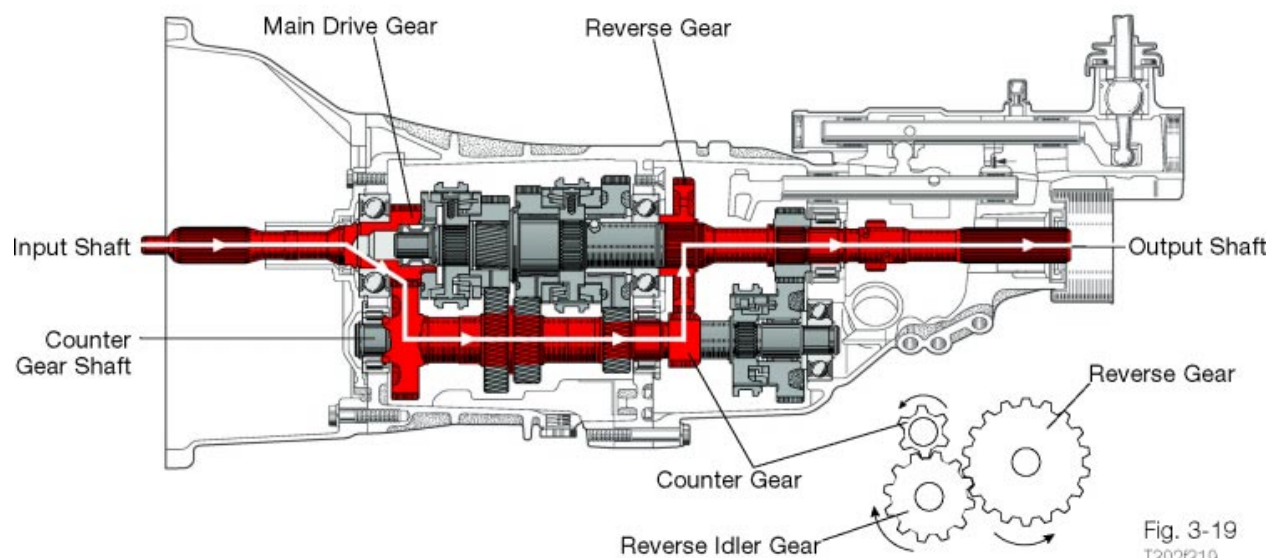


Fig. 3-19  
T302f319

## Gear Shift Mechanism

The gear shift lever and internal linkage allow the transmission to be shifted through the gears.

The **shift lever** is mounted in the transmission extension housing and pivots on a **ball socket**. The **shift fork shaft** connects the shift lever to the shift forks. A detent ball and spring prevent the forks from moving on their own. The **shift forks** are used to lock and unlock the synchronizer hub sleeve and are mounted on the shafts either by bolts or roll pins. The shift forks ride in the grooves of the synchronizer hub sleeves.

Shift forks contact the spinning synchronizer sleeve and apply pressure to engage the gear. To reduce wear, the steel or aluminum forks can have contact surfaces of hardened steel, bronze, low-friction plastic, or a nylon pad attached to the fork.

After the sleeve has been positioned, there should be very little contact between the fork and sleeve. The fork is properly positioned by the detent. The back taper of the hub sleeve splines and spline gear, and gear inertia lock mechanism, keep it in mesh during different driving conditions.

Holding a gear into mesh with the fork results in rapid wear of the fork and hub sleeve groove. Wear at the shift lever ball socket, shift fork shaft bushings, and shift fork contact surfaces may cause the synchronizer sleeve to be improperly positioned, causing the sleeve to jump out of gear.

### Gear Shift Mechanism

The gear shift mechanism includes the shift lever, shift fork shafts, shift forks, and shift detents.

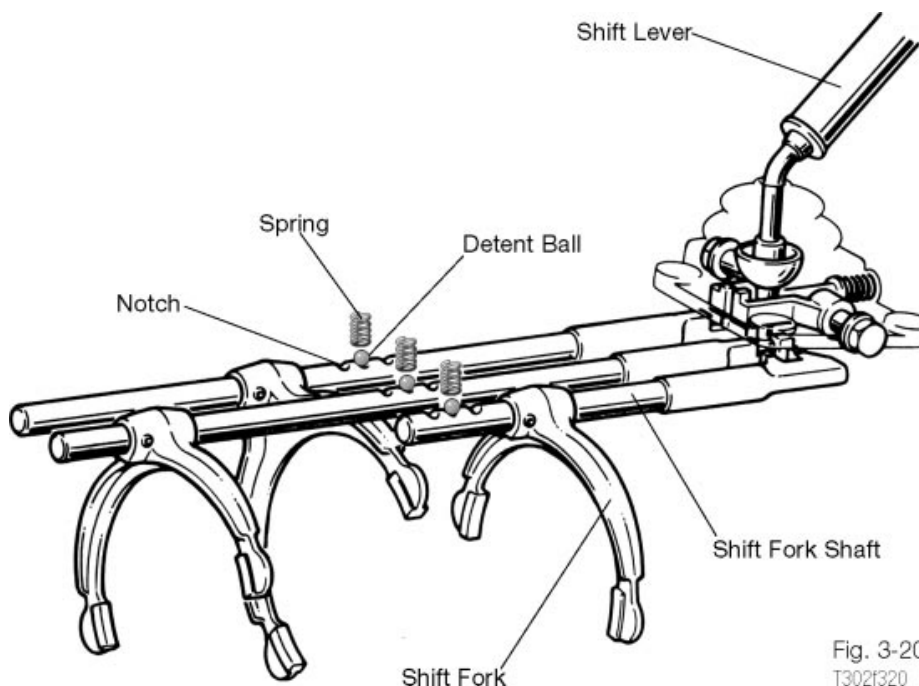


Fig. 3-20  
T3021320

Other mechanisms that make up gear shift control are the:

- Shift detent mechanism
- Shift interlock mechanism
- Mis-shift prevention
- Reverse mis-shift prevention
- Reverse pre-balk mechanism
- Shift detent mechanism
- Reverse one-way mechanism

#### Shift Detent Mechanism

**Detents** locate the internal shift forks in one of their three positions. The detent ball rides in one of three notches cut into the shift fork shaft. The center detent position is neutral. Moving the shift shaft to a detent on either side of center engages a speed gear. When the shaft is moved either forward or backward, the ball rides on the shaft and is forced into a notch by the spring. The spring holds the ball secure in the notch and will not let the shaft move unless the shift lever applies enough force to overcome the spring tension.

#### Shift Detent Mechanism

The detent ball rides in one of three notches cut into the shift fork shaft.

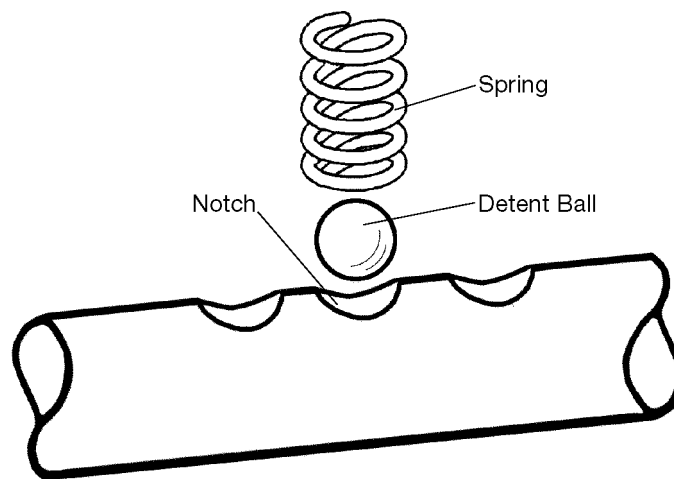


Fig. 3-21  
T302f321

#### Shift Interlock Mechanism

The shift interlock prevents engaging more than one gear at a time. A set of pins hold the other shift fork shafts in place when one of the shafts has been moved by the shift lever. This operation insures that the transmission will not be shifted into two gears at the same time.

### Shift Interlock Mechanism

A set of interlock pins hold the other shift fork shafts in place when the shift lever moves one of the shafts.

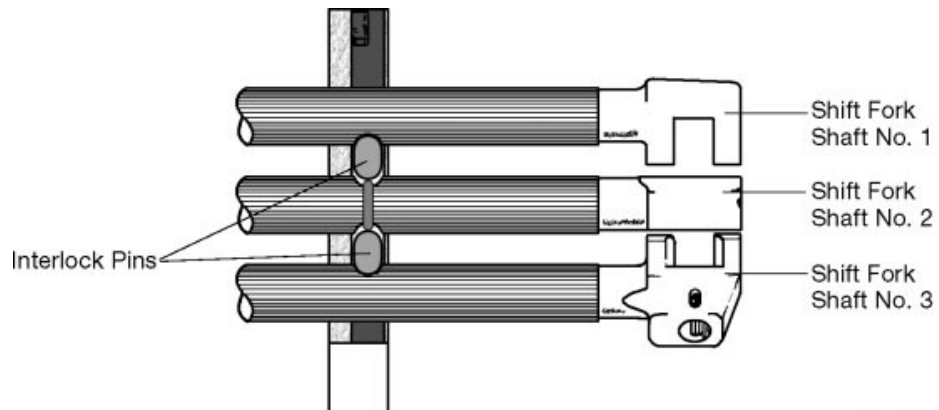


Fig. 3-22  
T302f322

**Shaft Locking** When **shift fork shaft No. 1** is moved to the left, the **two interlock pins** are pushed out by the shaft and into the slots on the other shafts. As a result, shafts two and three are locked in position.

When **shift fork shaft No. 2** is moved to the left, the **two interlock pins** are pushed out by the shaft and into the slots on the other shafts. As a result, shafts one and three are locked in position.

When **shift fork shaft No. 3** is moved to the left, the **two interlock pins** are pushed out by the shaft and into the slots on the other shafts. As a result, shafts one and two are locked in position.

### Shift Fork Shafts and Interlock Pins

When a shift fork shaft is moved to the left, the two interlock pins are pushed out, locking the other two shafts in position.

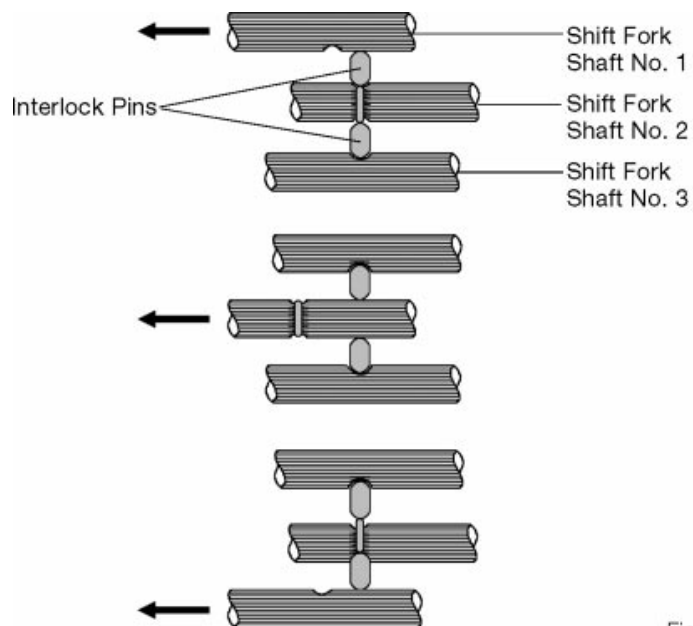


Fig. 3-23  
T302f323

**Mis-Shift Prevention** The mis-shift prevention mechanism is located in the transmission extension housing. The shift lever is spring loaded to provide the driver with a sense of the shift lever position during shifting,

**Mis-Shift Prevention Upshift** **Shift restrict pins** are installed on opposite sides of the extension housing adjacent to the shift lever. The pins contain **springs** of different tension and are color coded for that reason. The restrict pins ensure that the shift lever is always pushed toward the 3rd and 4th gear select position. When shifting from 2nd to 3rd gear, the pins will help the driver engage 3rd gear and not 1st.

### ***Mis-Shift Prevention Upshift***

Shift restrict pins have different tension and push the shift lever toward the third and fourth gear select position.

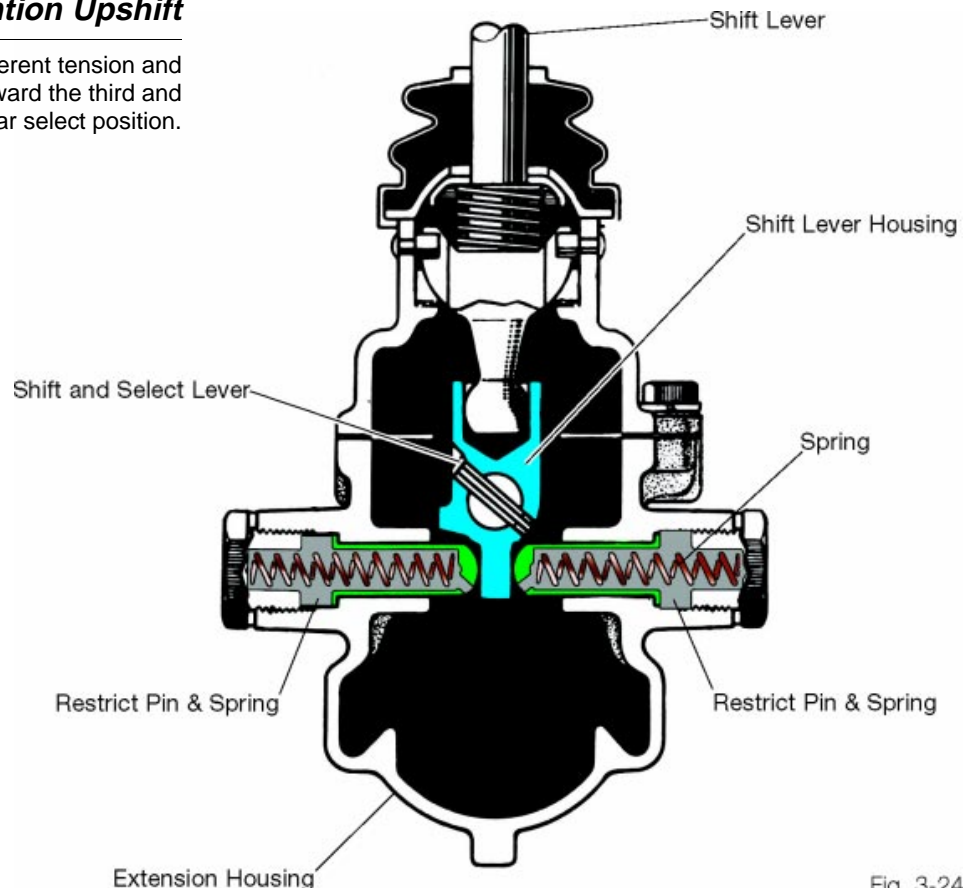


Fig. 3-24  
T302R324

**Reverse Mis-Shift Prevention** The reverse restrict pin is located in the extension housing and prevents the driver from down shifting from 5th gear into reverse by stopping the travel of the **shift and select lever**. When the transmission is shifted into 5th gear, the shift and select lever passes by the **reverse restrict pin**.

When shifting out of fifth gear the lever will contact the protrusion on the restrict pin, compress the spring on the shaft and force the pin against the stop. The shift and select lever is not allowed past the neutral position and into reverse gear.

**Shifting into Reverse** When shifting into reverse, the shift and select lever contacts the restrict pin protrusion, rotates the pin on the shaft and causes the spring to coil tighter. The lever can now move the required parts to engage reverse gear. The spring tension is relieved when the lever is moved to the neutral position and the restrict pin returns to original position.

### Reverse Mis-Shift Prevention

The reverse restrict pin prevents the driver from down shifting from 5th gear into reverse by stopping the travel of the shift and select lever.

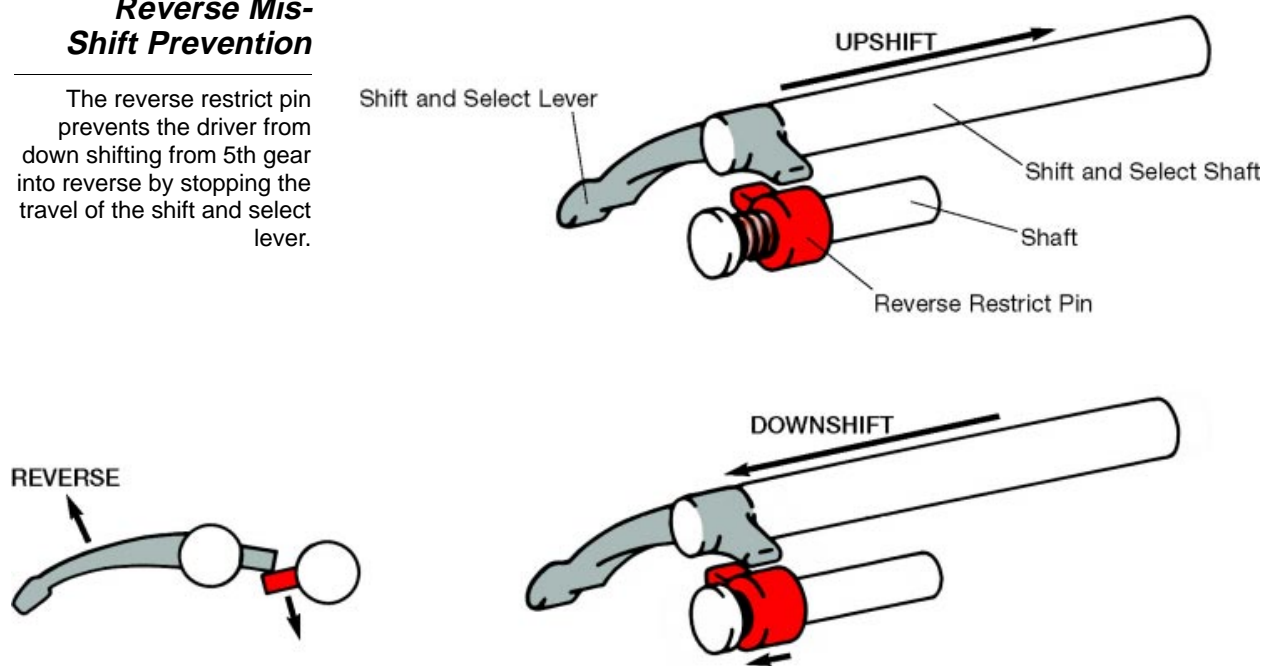


Fig. 3-25  
T302f325



### Reverse Pre-Balk Mechanism

The reverse pre-balk mechanism utilizes the fifth gear synchronizer assembly on the countershaft to reduce gear clash when shifting into reverse. By engaging the fifth synchronizer ring the input shaft, counter gear shaft and speed gears are slowed allowing the reverse idler gear and the reverse gears to engage with a minimum gear clash.

The synchronizer assembly components include the following:

- Reverse synchronizer ring
- 5th synchronizer hub sleeve (hub sleeve No. 3)
- 5th synchronizer ring
- Synchronizer cone ring
- Reverse synchronizer pull ring
- Gear spline piece No. 5

The **synchronizer cone ring** is indexed to the **gear spline piece** that is pressed to the counter gear shaft. It is the cone that the **5th synchronizer ring** contacts when shifting into 5th gear or reverse.

#### Reverse Pre-Balk Mechanism

The fifth gear synchronizer assembly on the countershaft is used to reduce gear clash when shifting into reverse.

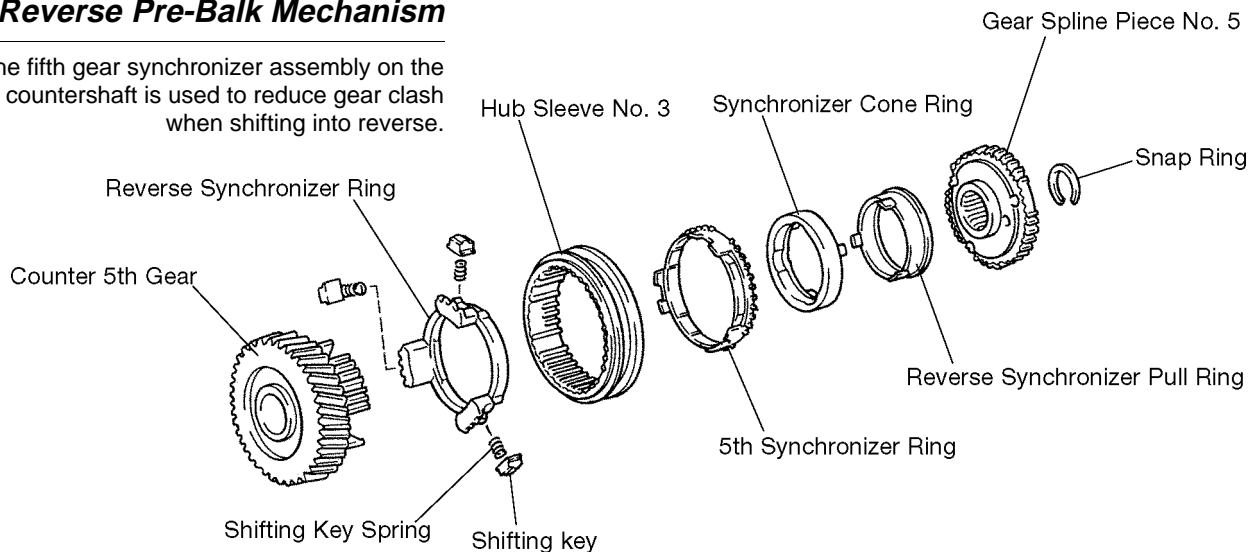
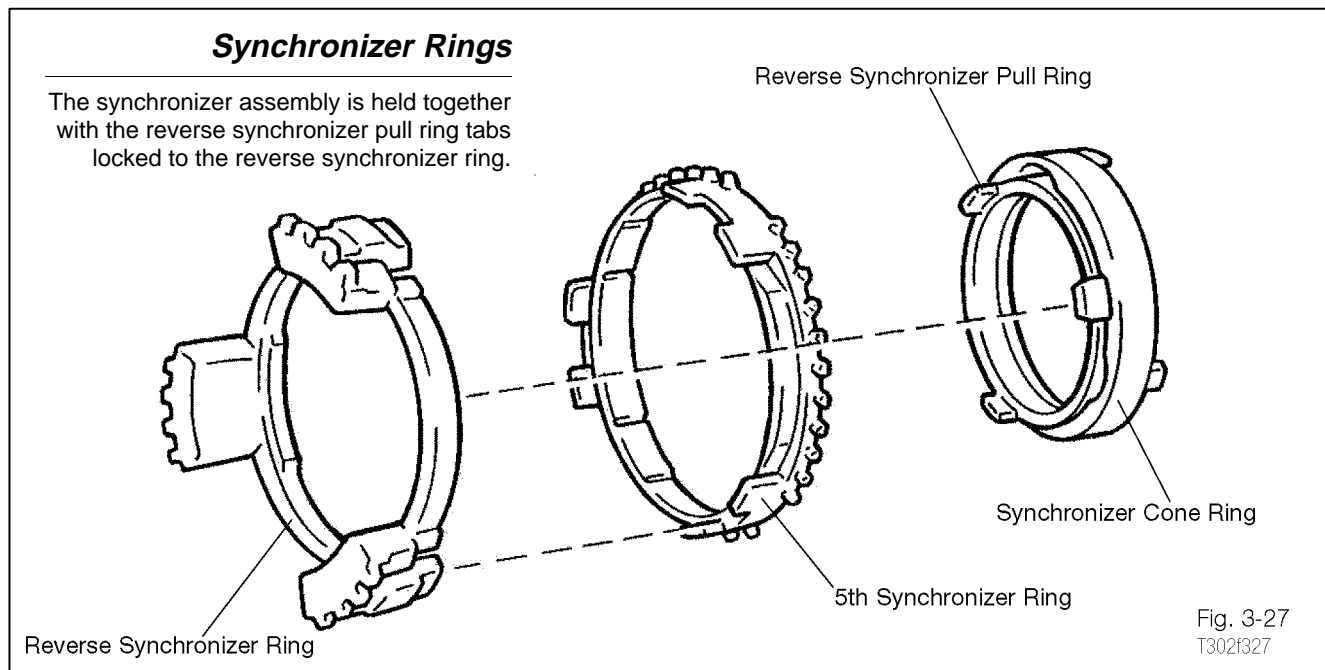


Fig. 3-26  
T302f326

The synchronizer assembly is held together with the **reverse synchronizer pull ring** tabs locked to the **reverse synchronizer ring**. The **synchronizer cone ring** and 5th synchronizer ring are located between these two parts and cause the braking action to slow the counter gear shaft and speed gears.

When shifting into reverse the **5th synchronizer hub sleeve** is moved to the left and moves the reverse synchronizer ring and shifting keys. As with the key type synchronizer covered earlier, the reverse synchronizer ring rotates slightly causing the misalignment of the synchronizer spline teeth and the hub sleeve splines. As the taper on the front of the reverse synchronizer ring and hub sleeve splines make contact, greater force is applied to the reverse synchronizer ring and reverse synchronizer pull ring. The pull ring pulls the synchronizer cone ring into engagement with the 5th synchronizer ring, slowing the counter gear shaft and speed gears on the output shaft.



### Reverse One-Way Mechanism

The reverse one-way mechanism on the R and W series transmissions allows 5th gear and reverse to be selected using the same shift fork shaft. The reverse one-way mechanism prevents the movement of the reverse shift fork while shifting in or out of 5th gear. This is accomplished with the use of a snap ring and an interlock ball or pin. The interlock ball/pin is located in the reverse shift fork between shift fork shaft No. 3 and shift fork shaft No. 4. The snap ring is installed on shift fork shaft No. 3, between the intermediate plate and the reverse shift fork. Shift fork shaft No. 4 is a stationary shaft that is locked to the transmissions intermediate plate.

### Reverse One-Way Mechanism

The interlock pin is located in the reverse shift fork between the two shift fork shafts.

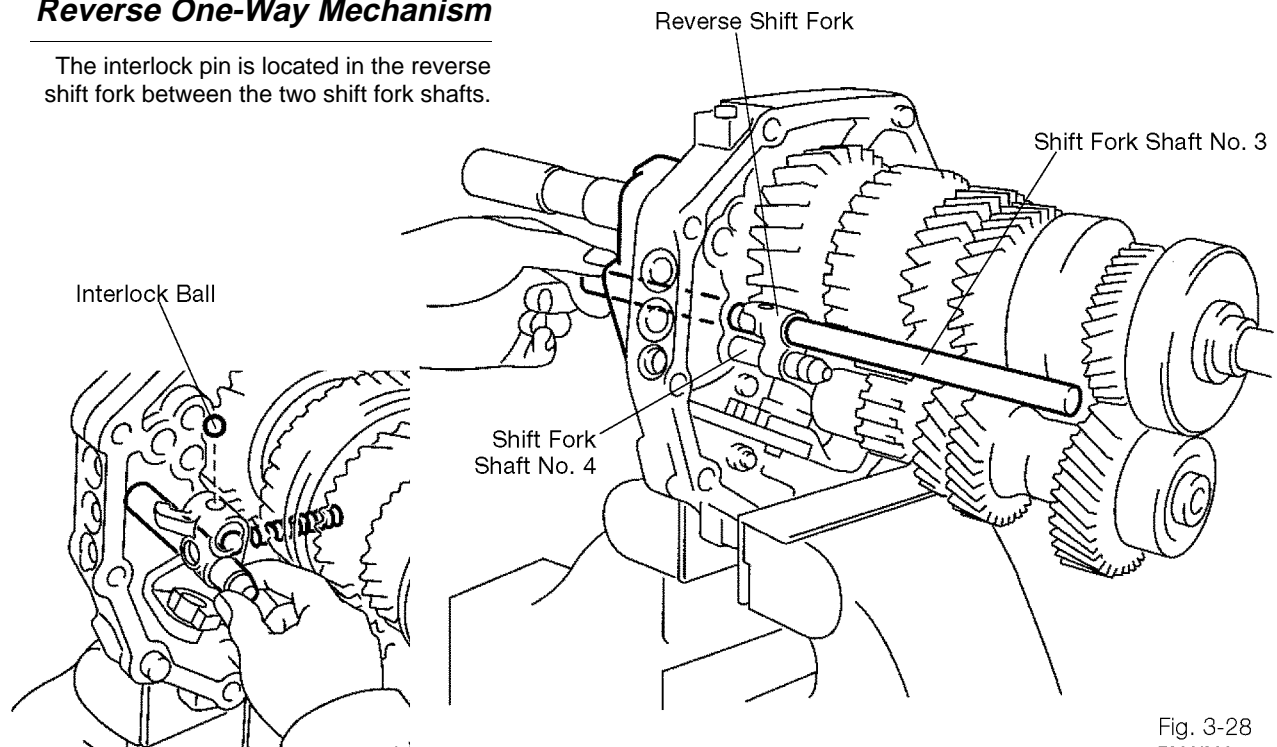


Fig. 3-28  
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**Operation** When 5th gear is selected, shift fork shaft No. 3 is moved to the right. The interlock ball is pushed into the notch in shift fork shaft No. 4, locking the reverse shift fork to the shaft.

The reverse shift fork can only move into reverse when shift fork shaft No. 3 is in the neutral position. When shifting into reverse, shift fork shaft No. 3 moves to the left causing the snap ring to move the reverse shift fork. As the shift fork moves over shift fork shaft No. 4, the interlock ball moves into the notch of shift fork shaft No. 3, locking the shift fork to shaft No. 3.

When shifting out of reverse, shift fork shaft No.3 moves to the right and the reverse shift fork also moves to the right. If the interlock ball were not installed during reassembly, the transmission would remain in reverse with no way to disengage reverse gear as it is held in position by its detent ball and spring. Selecting a forward gear and engaging the clutch will cause the engine to stall because two gears are engaged at the same time.

### Reverse One-Way Mechanism Operation

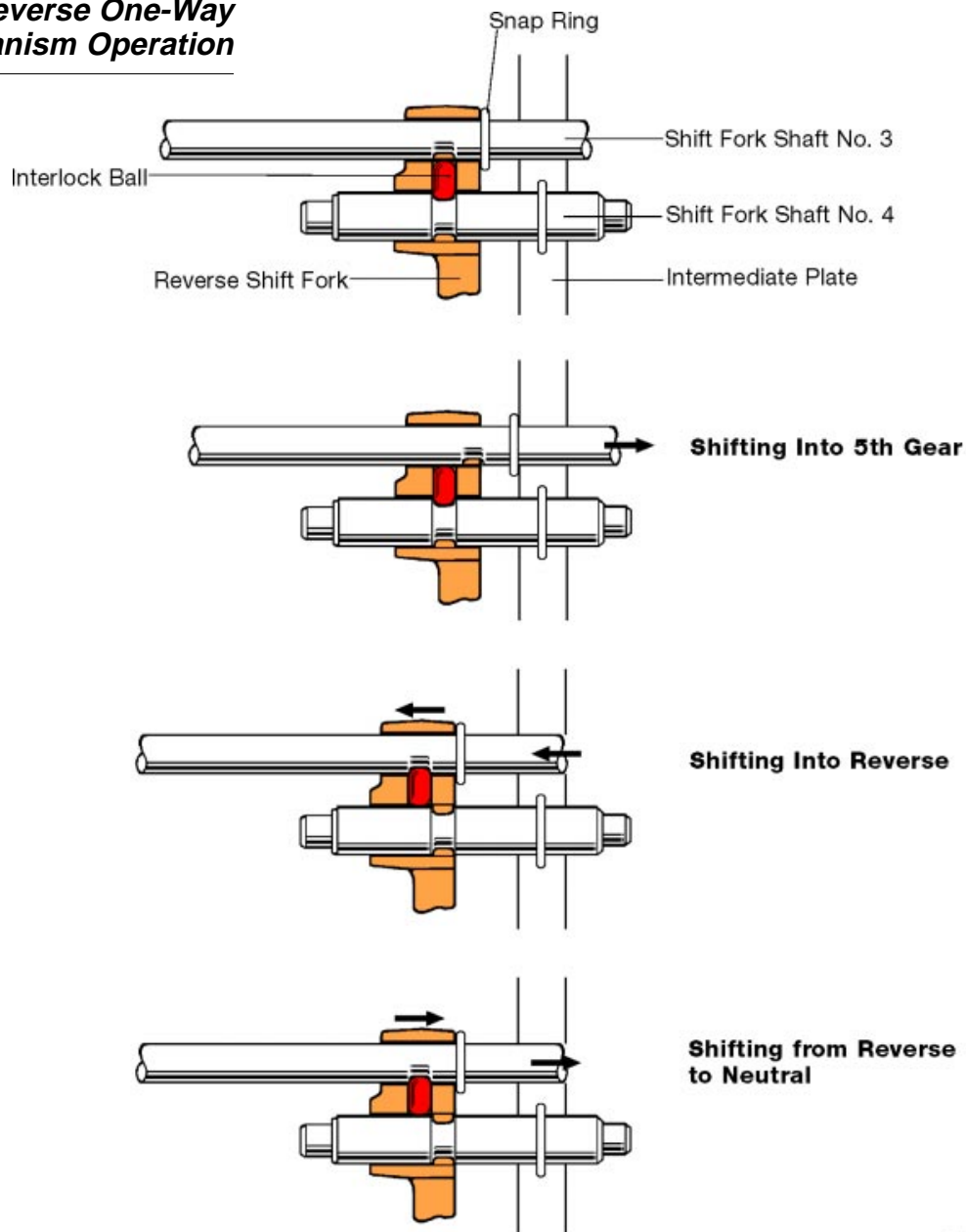


Fig. 3-29  
T302f329

**Transmission Lubrication**

To prevent overheating, the lower transmission gears run in a bath of lubricant. As they spin, their motion spreads the lubricant throughout the case.

Floating gears on the mainshaft or counter shaft of R series transmissions have oil passages drilled to get lubricant into critical areas. Some transmissions use scoops, troughs, or oiling funnels as lubrication paths. Each transmission includes a vent at the top, to relieve internal pressure (heat) during operation.

**Gear Lubrication** The transmission gears are lubricated to:

- Reduce friction
- Transfer heat away from gears and bearings
- Reduce corrosion and rust
- Remove dirt and wear particles from moving parts

The Society of Automotive Engineers (SAE) and the American Petroleum Institute (API) Service Classification provide rating systems for selection of proper lubricants for particular uses.

**Viscosity** is a measurement of fluid thickness and is determined by how fast a fluid runs through a precisely sized orifice at a particular temperature.

The following are API gear oil classifications:

- GL-1: Straight mineral oil; used in non-synchromesh transmissions; use additives; not suitable for modern automobile transmissions
- GL-2: A designation for worn gear drives used in mostly industrial applications
- GL-3: Contains mild EP additives; used in manual transmissions and transaxles with spiral bevel final drives
- GL-4: Used in manual transmissions and transaxles with hypoid final drives; contains half the additives found in GL-5
- GL-5: Contains enough EP additive to lubricate hypoid gears in drive axles

An additional classification, GLS (Gear Lubricant Special), is sometimes used to indicate a proprietary set of specifications determined by the vehicle or gearbox manufacturer.

Gear Lubrication Types Toyota manual transmissions use the following gear lubrication types:

- 75W-90 GL4/GL5
- 80W-90 GL4/GL5
- TOYOTA V160 (Supra 6-Speed V160MT)

Consult the vehicle repair manual for specific lubrication information.

**Case Sealants** Toyota transmission cases use **Formed-In-Place Gaskets (FIPG)**. FIPG gaskets are usually **Room-Temperature Vulcanizing (RTV)** or **anaerobic sealants**. RTV sealant is made from silicone and is one of the most widely used gasket compounds. It is extremely thick, and sets up to a rubber-like material very quickly when exposed to air.

Anaerobic sealant is similar in function to RTV. It can be used either to seal gaskets or to form gaskets by itself. Unlike RTV, anaerobic sealant cures only in the absence of air. This means that an anaerobic sealant cures only after the assembly of parts, sealing them together.



## Notes