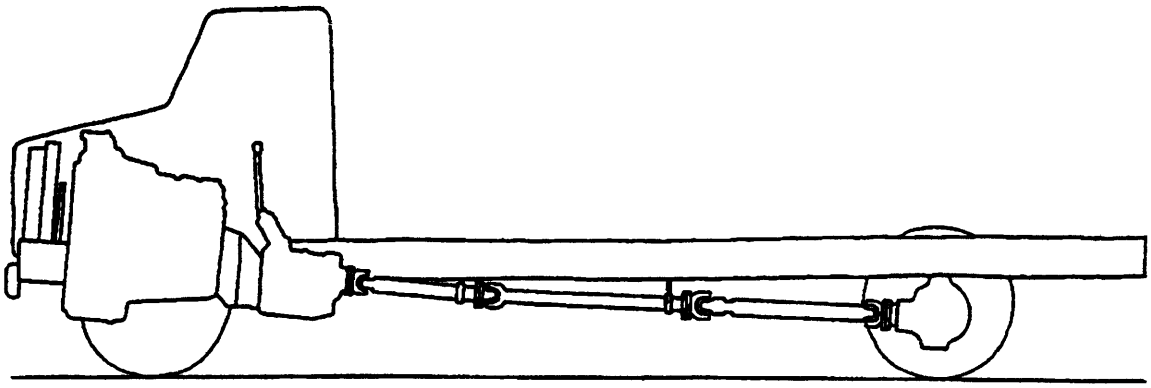
Drive Shaft Phase Angles



T4006302

There are vehicles which have various sections of the drive shaft phased at specific angles. Factory set phase angles are vitally important to the quality of the ride, the reduction of drive line vibration and major component life.

⚠ CAUTION

Under no circumstances should the phasing of any component of the drive shaft system be changed or tampered with in any way. Doing so could cause severe vibration, decreased U-joint life and/or damage to axles or transmissions.

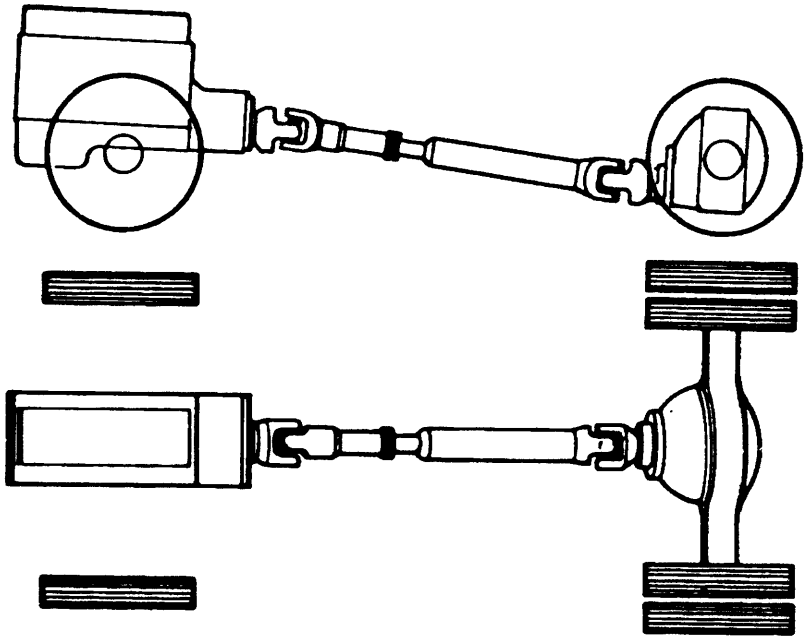
VOLVO
Volvo Trucks North America, Inc.
Greensboro, NC USA

TSI

This TSI Service Bulletin replaces TSI Service Manual 451–600, "Drive Shafts and Universal Joints" (6.94), publication number PV776–451–600SM.

Date	Group	No.	Supp.	Page
3.2001	451	011		1(30)

Drive Shafts and Universal Joints



W4000036

This information covers design information, specifications, and service of drive shafts and universal joints used on Volvo vehicles.

Specifications

Drive Shaft

Universal Joint Journal Cross Dimensions

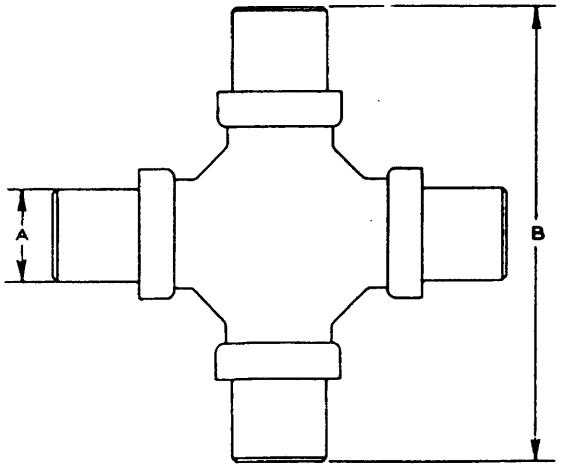


Fig. 1: Universal Joint Journal Cross Dimensions

Series	A		B	
	mm	in	mm	in
1600	32.54	1 9/32	127.00	5
1610	32.15	1 17/64	127.00	5
1650	26.59	1 3/64	131.76	5 3/16
1700	33.34	1 5/16	136.92	5 25/64
1710	32.94	1 19/64	146.84	5 25/32
1760	32.94	1 19/64	159.54	6 9/32
1800	42.86	1 11/16	159.54	6 9/32

Series	A		B	
	mm	in	mm	in
1800HD	42.47	1 43/64	155.97	6 9/64
1810	32.94	1 19/64	184.15	7 1/4
1820	34.93	1 3/8	192.88	7 19/32
1850	34.93	1 3/8	192.88	7 19/32
1900	49.61	1 61/64	211.93	8 11/32

Note: Measure the diameter "A" and the span, or length "B" of the journal cross to determine universal joint size or series.

Half-Round End Yoke

Series	Thread Size	Bolt Torque	
		Nm	ft-lb
1610	(3/8) 0.375–24	68–81	50–60
1710	(1/2) 0.500–20	156–176	115–130
1760	(1/2) 0.500–20	156–176	115–130
1810	(1/2) 0.500–20	156–176	115–130

Full Round End Yoke

Series	Thread Size	Capscrew Torque	
		Nm	ft-lb
1610	(5/16) 0.312–24	19–35	14–26
1710	(3/8) 0.375–24	38–65	28–48
1760	(3/8) 0.375–24	38–65	28–48
1810	(3/8) 0.375–24	38–65	28–48

Maximum Drive Shaft Operating Angle

Normal Angles	
Drive Shaft rpm	Maximum Operating Angles
5000	3°–15′
4500	3°–40′
4000	4°–15′
3500	5°–0′
3000	5°–50′
2500	7°–0′
2000	8°–40′
1500	1°–30′

Drive Shaft, Maintenance Intervals

Service	miles (km)	Time/Month
City	5 000/8 000 (8 000/13 000)	3
On Highway	10 000/15 000 (16 000/24 000)	1
On/Off Highway	5 000/8 000 (8 000/13 000)	3
Extended Line Haul (1610–1880)	50 000 (80 000)	1
Severe Use Off Highway 4 x 4	2 000/3 000 (3 000/5 000)	1

Drive Shafts

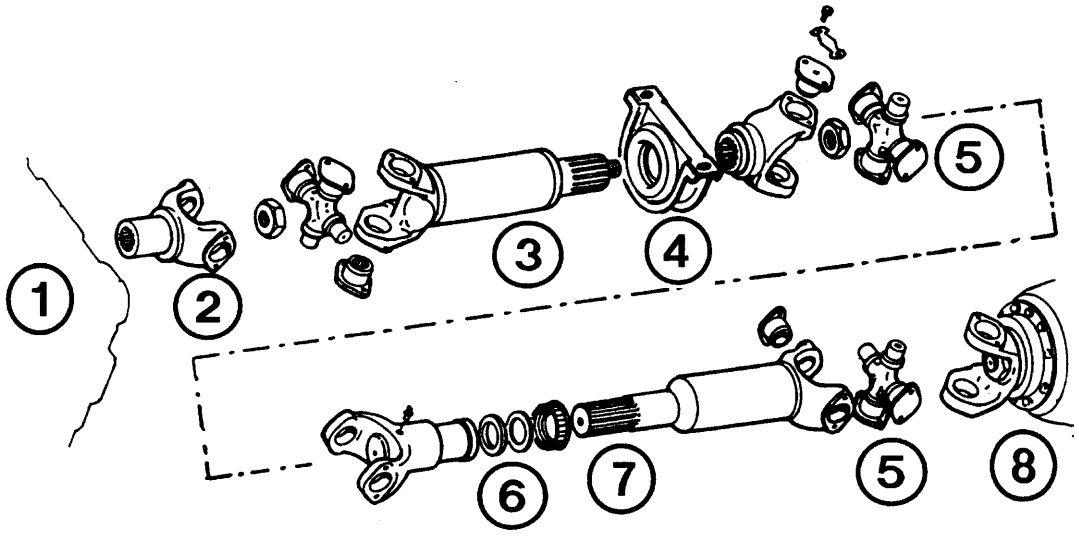


Fig. 2: Typical Drive Shaft and Universal Joint Assembly

1	Transmission	**4**	Center bearing	**6**	Seal	**8**	Differential
2	Yoke	**5**	Universal Joint	**7**	Slipshaft spline		
3	Drive shaft tubing						

The drive shaft is a steel tube that transmits power from the transmission output shaft to the differential. To accommodate various model, wheelbase and transmission combinations, drive shafts differ in length, diameter and the type of splined yoke. Each shaft is installed in the same manner. A universal joint and splined yoke are located at the transmission rear extension. The slip yoke permits fore and aft movement of the drive shaft as the differential assembly moves up and down. The spline is lubricated internally through a grease fitting. An oil seal prevents leakage and protects the slip yoke from dust, dirt and other harmful materials.

Since the drive shaft is a balanced unit, it should be kept completely free of undercoating and other foreign material which would upset shaft balance.

One-, two- and three-piece drive shafts are used, depending on the total length.

On models that use a two-piece or three-piece shaft, the shaft is supported near its splined end in a rubber-cushioned ball bearing (commonly referred to as the center bearing) which is mounted in a bracket attached to a frame crossmember. The center bearing is permanently lubricated and sealed.

Drive Shaft Center Bearing

If replacing the center bearing, it is not necessary to pack it with grease. However, chassis lubricant should be packed within the dust shields to form a dam to help prevent water and dirt from reaching the bearing. The dust shields are staked into position.

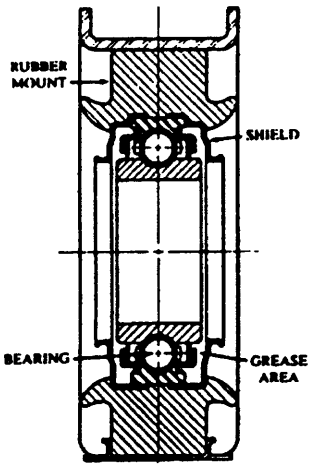


Fig. 3: Cutaway View of Center Bearing

Drive Shaft Function

The basic function of the drive shaft is to transmit power from one point to another in a smooth, continuous action. In trucks and construction equipment, the drive shaft is designed to send torque through an angle from the transmission to the axle (or auxiliary transmission).

The drive shaft must operate through constantly changing relative angles between the transmission and axle. It must also be capable of changing length while transmitting torque. The axle of a vehicle is not attached directly to the frame, but rides suspended by springs in an irregular, floating motion. This means the drive shaft must be able to change length and operating angles when going over bumps or depressions. This is accomplished through universal joints, which permit the drive shaft to operate at different angles, and slip joints, which permit lengthening or shortening of the drive shaft to take place.

Construction of a Drive Shaft

To transmit required torque loads, the drive shaft must be durable and strong. Forged steel and high-strength, cast, end yoke for heavy-duty vehicles are used to provide the necessary rigidity required to maintain bearing alignment under torque loads.

Anti-friction bearings are used to withstand oscillating loads while the drive shaft is rotating at high speeds. The needle roller bearings on the cross trunnions carry large loads and are used because of their high capacity in a limited space.

The bearing assembly inside-diameter crowning and tapered thrust pads distribute load more evenly on needle roller bearings and cross trunnion ends to significantly reduce end galling. Bearing assemblies are individually sealed to retain lubricants and keep foreign material out. If lubricants become contaminated with water or abrasive material, needle roller bearing life is seriously affected.

Abrasive material is a major problem for vehicles operating in extremely moist and dirty environments. To combat this problem, synthetic rubber seals were developed and resulted in increased life, ability to withstand high temperatures and a less critical relubrication cycle for drive shafts.

Special high-strength tubing is used to provide maximum torque carrying capacity at minimum practical weight. Drive shafts have been developed to meet the vehicular industry needs.

The sliding splines between slip joint and permanent joint must support the drive shaft and be capable of sliding under full torque loads. To aid in this axial or slip movement, Glidecote was developed to reduce sliding friction, reducing thrust under high torque. This non-metallic coating also prevents spline galling and extends spline life.

Balancing a Drive Shaft

(All types)

Rebuilding the drive-shaft assembly usually includes replacing worn cross and bearing assemblies with a new kit. These kits replace the part of a drive shaft most subject to wear in operation. The potential off-center condition present in the cross and bearing assemblies make it desirable to balance every assembly after installing new cross and bearing kits. When the tubing is bent or twisted or the tube fittings are distorted, it will be necessary to replace the drive shaft assembly.

Drive Shaft Angles and Phasing

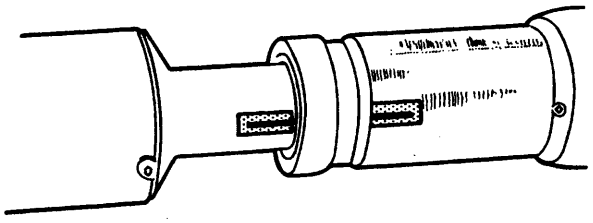
(All types)

Proper drive shaft angles and correct phasing of the yokes are very important in maintaining long life and quiet running drive shafts.

When in phase, the slip yoke lugs (ears) and tube yoke lugs (ears) are in line. Normally, this is the ideal condition and gives the smoothest running drive shaft. There should be an alignment arrow stamped on the slip yoke and on the tube shaft to ensure proper phasing when assembling these components. If there are no alignment marks, they should be added before disassembly of the drive shaft to ensure proper reassembly.

Be careful not to change or remark a drive shaft assembly manufactured out-of-phase for special applications. Locate the arrows marked for the out-of-phase drive shaft and do not change them. Do not replace an out-of-phase drive shaft with a drive shaft that is in phase.

Phasing is relatively simple on a two-joint set. Be sure that the slip yoke lugs and the tube yoke lugs are in line.



W4000020

Fig. 4: Drive-Shaft Arrows Lined Up "In Phase"

Drive shaft angles are a little more complicated. The U-joint operating angle is the angle formed by two yokes connected by a cross and bearing kit. There are two kinds of U-joint angles.

The simple one-plane angle found in most installations confines all driveline slopes to one plane, usually the vertical plane.

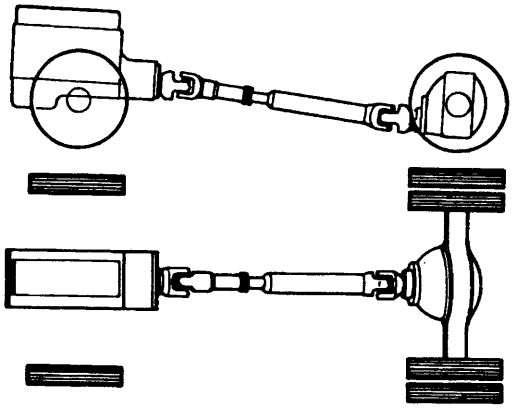
The other type of drive shaft angle is the compound angle in two planes. This is found in drive-shaft designs where offset exists in both the vertical and horizontal planes.

High angles combined with high rpm reduce U-joint life. Too large and unequal U-joint angles can cause vibration and contribute to U-joint, transmission and differential problems. Improper U-joint angles must be corrected.

Ideally, the operating angles on each end of the drive shaft should be equal to or within 1° of each other, have a 3° maximum operating angle and have at least 1/2 of 1° continuous operating angle.

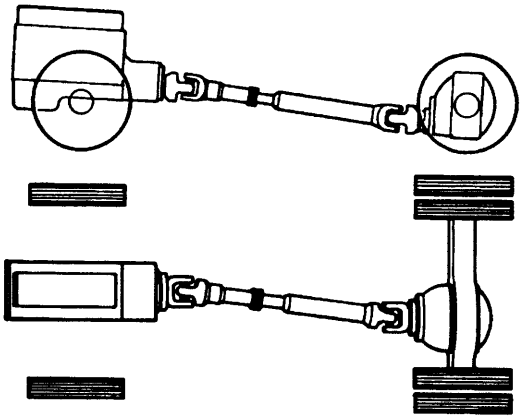
The main factor in determining maximum allowable operating angles is rpm. As a guide to maximum normal operating angles, refer to "Maximum Drive Shaft Operating Angle" page 3.

Tube diameter and normal operating rpm determine maximum allowable tube length. If "critical length" is reached, use a three-joint drive shaft with center support. Refer to the Spicer "Drive Shaft Speed Calculator", Form M3-11.



W4000036

Fig. 5: One-Plane Angle Drive Shaft



W4000037

Fig. 6: Two-Plane Angle Drive Shaft

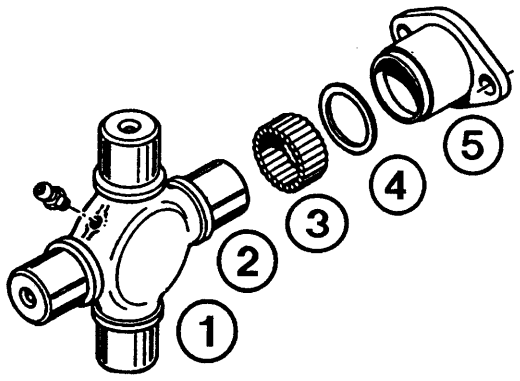
Universal Joints

The simple universal joint is basically two Y-shaped yokes connected by a crossmember called a "spider." The spider is shaped like an "X", and has arms that extend from it called trunnions. The spider allows two yoke/shafts to operate at an angle to each other.

This type of universal joint is designed to make disassembly and reassembly a comparatively simple matter. No hand fitting or special tools are required. The journals and needle bearing assemblies are the parts most subject to wear. When it becomes necessary to replace bearings, remove the drive shaft from the vehicle.

The procedure used to remove a drive shaft depends on the type and design of the universal joints. A shaft with flange-type yokes is disconnected by removing the attaching bolts and nuts from the flanges and separating the flange yokes from the companion flanges. A shaft connected to an end yoke is disconnected by partially disassembling the universal joint. Universal joints with strap or cap-and-bolt type end yokes are disconnected by removing the strap and bolts or caps and bolts.

After disassembling a universal joint, check the fit of each bearing on its respective journal. If looseness is evident, the journal cross and all four bearing assemblies and journal cross are in serviceable condition. Clean bearings and reassemble universal joint with bearings and journals in their original positions.



W4000011

Fig. 7: Exploded View of Universal Joint

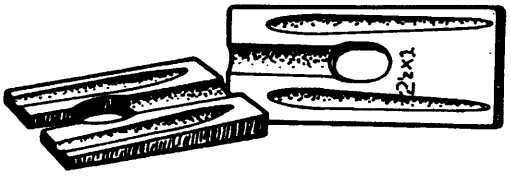
1 Trunnion
2 Seal
3 Bearing
4 Washer
5 Bearing cap

Correcting Universal Joint Operating Angles

The recommended method for correcting severe universal joint operating angles depends on the vehicle's suspension or drive-shaft design.

Typical chart to record drive shaft/yoke angles

On vehicles with leaf-spring suspensions, axle shims (thin wedges) can be installed between the spring and axle housing. This will tilt the axle housing to raise the pinion up and correct the universal joint operating angles. Shims are available in a range of sizes to change the pinion angle of the rear axle.



W4000042

Fig. 8: Typical Axle Housing Shims

Vehicles with tandem suspensions use torque or radius rods to control the pinion angles. Various methods are used: shims between the torque rod and axle; adjustable torque rods; and eccentric bushings in the radius rod leaf eye. The control of these angles can also depend on the suspension or vehicle manufacturer as to what method is used. If a fixed torque rod is used, the angle is controlled by the use of various size rods.

Generally, adding or removing a 6 mm (1/4 in.) shim from a torque rod changes the pinion angle 3/4°. A 3/4° change in the pinion angle changes the universal joint operating angle about 1/4°.

Note: Both sides of the axle must be changed to balance the pinion and universal joint angles. Also, remember that changing the pinion angle may affect the rear axle(s) lube level(s).

If unusual universal-joint operating angle problems are experienced, or for troubleshooting three or more universal joints or multiple drive-shaft arrangements, consult your authorized Volvo Trucks dealer.

Troubleshooting

Drive Shaft Troubleshooting

Fault	Reason	Remedy
Vibration		
Low-gear shudder	U-joint angle too large for continuous running	Reduce U-joint continuous running angle
	Worn U-joint	Replace U-joint
	Incompatible drive shaft	Install two-piece drive shaft with center support bearing
	Drive shaft weight not compatible with engine/transmission mounting	Use larger diameter tube
	Drive shaft too long for speed	Shim drive train components to equalize U-joint angles
	Unequal U-joint angles	Shim drivetrain components to equalize U-joint angles
	Excessively loose U-joint for speed	Inspect U-joint flex effort for looseness, torque to specification, straighten and balance shaft
	Drive shaft out of balance; not straight torsional and/or inertial excitation; secondary couple load reaction at center support bearing Improper phasing	Consult component manufacturer; replace shaft bearing
	Inadequate torque on bearing plate capscrews	Check drive shaft for correct yoke phasing. Torque bearing capscrews to specifications
Premature Wear		
Low-mileage U-joint wear	End yoke cross hole misalignment	Use Spicer alignment bar to check for end-yoke cross-hole misalignment
Repeated U-joint wear	Excessive angularity	Check U-joint operating angles with a Spicer Anglemaster™ Electronic Drive Shaft Inclinometer; reduce excessive operating angles
	Contamination and abrasion	Lubricate to Spicer specifications. Replace U-joint kit
End galling of cross trunnion and bearing assembly	Excessive U-bolts torque on retaining nuts	Torque bearing retention method to specifications
	Contamination and abrasion	Replace U-joint kit
	Improper lubrication	Lubricate to Spicer specifications

Fault	Reason	Remedy
Needle rollers brinelled into bearing cup and cross trunnion	Excessive continuous running load	Reduce U-joint continuous running U-joint operating angles
	Excessive torque load (shock loading) angle Continuous operation at high angle and or high speed	Replace with higher capacity U-joint assemblies
Broken cross and bearing	Worn or damaged seals	Realign to proper running angle, minimum 1/2°

Causes of Universal Joint Operating Angle Changes

- Suspension changes, worn bushings in the spring hangers, worn bushings in the torque rods, incorrect air spring height.
- Revisions in the components of the drive shaft.
- Stretching or shortening of the chassis.
- Adding an auxiliary transmission or transfer case in the main drive shaft.
- Worn engine mounts.

Vibration-Related Problems

Drive shaft assemblies can be the source of first order vibrations (one excitation per revolution) and second order vibration (two excitations per revolution).

First order vibration

First order vibration results from an imbalance in the drive shaft assembly caused by improper balancing procedures, loss of the drive shaft balancing weights, excessive runout, poor spline fit or undercoating on the drive shaft.

Drive shaft vibration problems due to an imbalance or first order excitation are vehicle-speed sensitive since drive shaft speed is directly related to vehicle speed by the rear axle ratio.

In the case of conditions as a "sloppy" spline fit, imbalance may be engine-torque sensitive in that the torque causes the spline to center itself differently than if no torque were present.

Second order vibration

Second order vibration occurs when the drive shaft transmits torque through an angle at each end. The excitation level is related to both the amount of angle the U-joints operate through and the amount of torque transmitted. A second order drive shaft excitation is sensitive to vehicle speed, torque and jounce. Drive shaft angles must be set in the optimum position to accommodate various loads and rear-axle windup during acceleration.

To determine if the drive shaft is the source of a vibration, drive the vehicle and note the speed range at which the vibration occurs and the vibration frequency (using a Reed tachometer). Determine the drive shaft speed by placing the transmission in direct drive and reading the drive shaft rpm with an engine tachometer. If it is determined that the vibration is related to first order excitation of the drive shaft, balance the drive shaft.

Lubrication Related Problems

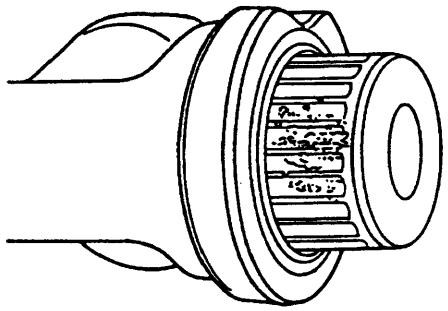
The most common reasons for U-joint wear are lack of lubrication, inadequate lube quality, inadequate initial lubrication or failure to lubricate properly and often enough.

Generally, a lubrication problem is one of two types; brinelling or end galling. The grooves made by the needle roller bearings on the trunnion of the cross are known as brinelling. Brinelling can also be caused by too much torque for the capacity of the U-joint used. End galling is a displacement of metal at the end of the trunnion and can also be related to angularity problems. Both of these problems can be caused by lack of lubrication.

Failures which are not a result of lubrication film breakdown are associated with the installation, angles and speeds, and manufacturing discrepancies.

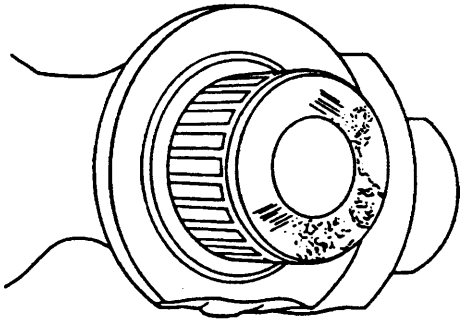
Drive shaft failures through torque, fatigue and bending are associated with overload, excessively high U-joint angles and drive shaft lengths excessive for operating speeds.

The troubleshooting chart in this manual (refer to "Drive Shaft Troubleshooting" page 10) is intended to help service people associate complaints with some of the probable causes and probable corrections. Through normal vehicle maintenance and recognition of discrepancies, this may enable them to make the corrections necessary to ward off a serious breakdown.



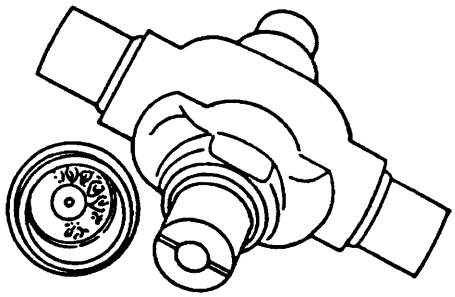
W4000050

Typical Lack of Lubrication



W4000052

Typical Trunnion Brinelling

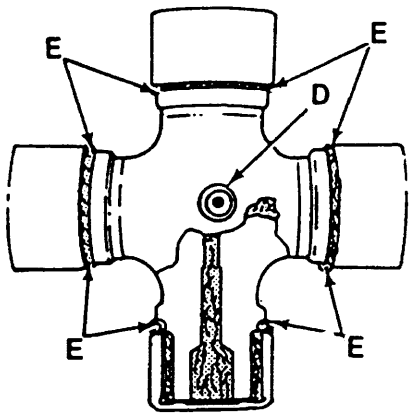


W4000053

Typical End Galling

4511-10-02-01
Drive Shaft, Lubrication

To avoid lubrication-related problems:



W4000051

Correct Purging of U-joint

- Lube all fittings, including those that are often overlooked, out of sight, dirt covered or difficult to reach.
- Note how some lube fittings appear different from regular chassis lube fittings and require a needle-nose attachment for the grease gun.
- Do not overlook slip-yoke lubrication.
- Use correct lube technique.
- Use recommended lubricant, such as NLGI Grade 2 with extreme pressure additives and high temperature resistance.
- Lubricate new U-joints when installing into the driveshaft yokes.
- Observe recommended lubrication cycle. Refer to "Drive Shaft, Maintenance Intervals" page 3. One of the most common causes of U-joint and slip yoke problems is lack of proper lubrication. Properly sized U-joints that are adequately lubricated at recommended intervals will normally meet or exceed vehicle operation requirements. Relubrication flushes the joints, removing abrasive contaminants from the bearings.

Lubrications for Universal Joints

For normal application, use a good-quality, lithium-base, extreme-pressure (E.P.) grease that meets NLGI Grade 2 specifications. Grades 3 and 4 are not recommended because of their greater thickness. For severe applications, use a good-quality, lithium-base (or equivalent) E.P. grease with an operating temperature range of 157–163°C (315–325°F). In addition, the grease should meet the NLGI Grade 2 specifications.

Consult your local lubricant source for greases that meet these specifications.

Initial Lubrication and Relube Cycle

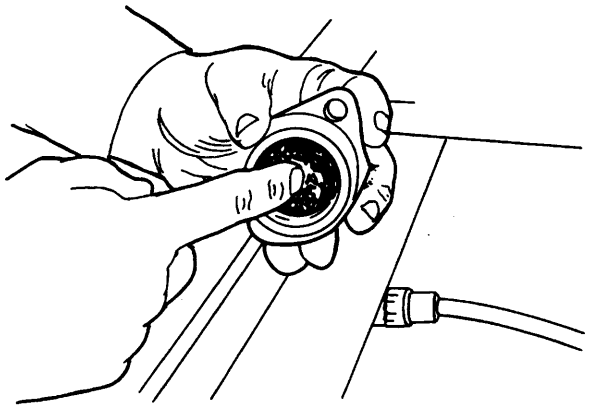
Replacement universal joint kits contain only enough grease to protect needle roller bearings during storage. It is, therefore, necessary to completely lubricate each replacement kit before assembly into the yokes. Each cross lube reservoir should be fully packed with a recommended grease and each bearing assembly should also be wiped with the same grease. Fill all cavities between the needle rollers and apply a liberal grease coating on the bottom of each bearing assembly.

Too much grease can cause hydraulic "lockup", making installation difficult. Relube the kits after installing into the yokes and before placing into service. Do this through the lube fitting, using the same grease.

Relubrication cycles vary, depending on vehicle service requirements and operating conditions. Relube splines at the intervals recommended in "Drive Shaft, Maintenance Intervals" page 3.

Note: On-highway is defined as all applications that operate less than 10% of the time on gravel, dirt or unimproved roads. If higher than 10% operating time, follow off-highway recommendations.

For extended linehaul tractors, use "10" series (1610, 1710, 1760 and 1810) U-joints and Glidecote slip splines.



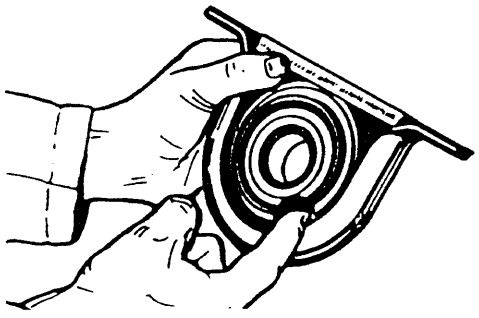
W4000054

Pre-lubing Bearing Cap

Drive Shaft Support Bearing Assemblies

Bearing manufacturers do the initial lubrication and all Spicer shaft support (center) bearings are lubed for life. When replacing a shaft support bearing assembly, be sure to fill the entire cavity around the bearing with waterproof grease to shield the bearing from water and contaminants. Put enough grease in to fill the cavity to the extreme edge of the slinger surrounding the bearing. Lubricants must be waterproof. Consult your grease supplier for recommendations.

Note: Often a special lubricant is required by vehicle specification or customer request. Lubrication recommendations in this information are suggested by Spicer U-Joint engineers. Any alternate lubricants, or lubrication procedures, are the responsibility of the user.



W4000059

Pre-lubing Center Bearing

4513-06-03-01 Universal Joint, Checking

DANGER

Before working on a vehicle, set the parking brakes, place the transmission in neutral, and block the wheels. Failure to do so can result in unexpected vehicle movement and can cause serious personal injury or death.

DANGER

Do not go under the vehicle while the engine is running. Do not engage or disengage driven equipment by hand from under the vehicle when the engine is running. Do not work on a shaft (with or without a guard) when the engine is running. Rotating shafts can snag clothes, skin, hair, and hands, etc. Failure to follow these instructions can result in serious personal injury or death.

The drive shaft and universal joints generally require little maintenance. Periodic inspection is recommended, however, for proper drive shaft balance and universal joint lubrication. If the area around the caps appears to be excessively dry, it may indicate a need for bearing relubrication or universal joint replacement. A failing universal joint often squeaks on start-up or "clunks" with direction change.

To keep a vehicle operating smoothly and economically, carefully inspect the drive shaft at regular intervals. Vibrations and problems with the U-joint and shaft support (center) bearing are caused by such things as loose end yokes, excessive radial (side-to-side or up-and-down)