DRIVELINE BASICS

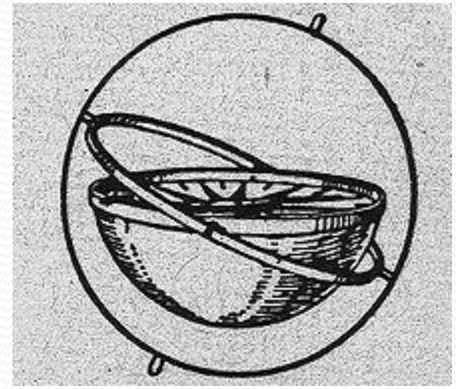
PRESENTED BY

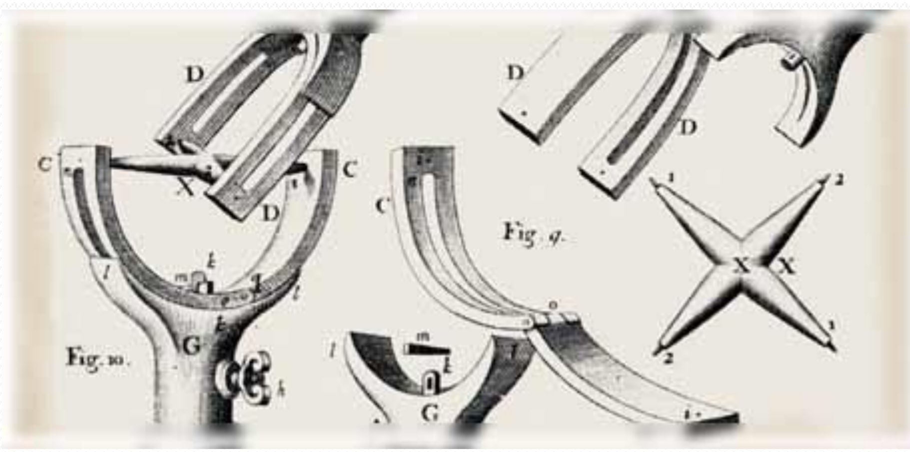
MACHINE SERVICE, INC.

UNIVERSAL DRIVESHAFTS

History of the Universal Joint

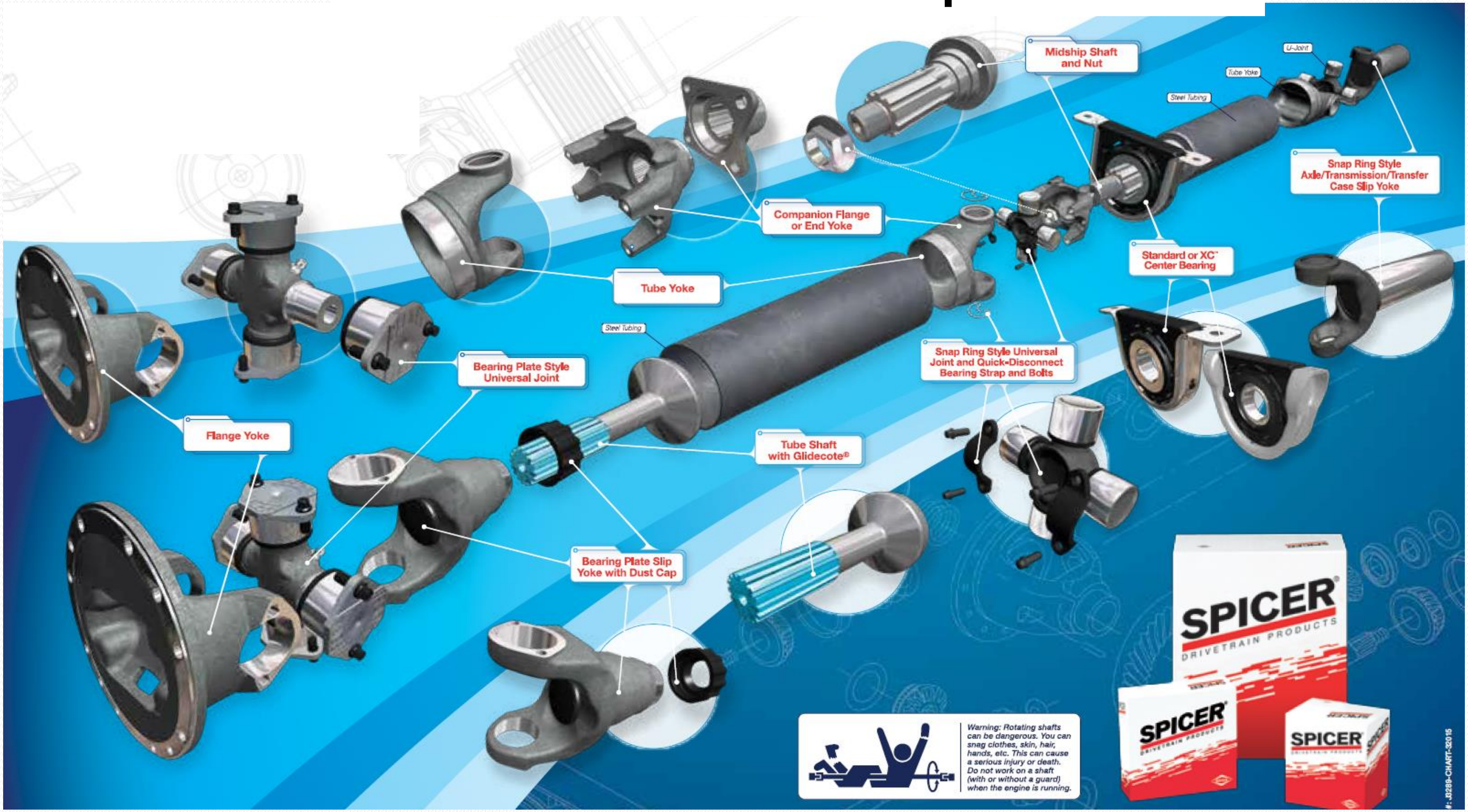
The first known application of the universal joint occurred in China more than 2,000 years ago. The Chinese had invented what we call “gimbals,” a series of interlocking rings within a device that allowed a candle placed in the center to remain upright regardless of the device’s position. Today, gimbals are used to keep ships’ compasses level and as components in gyroscopes.





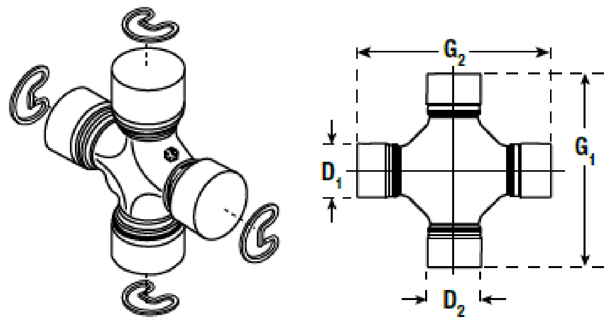
In 1545, Italian mathematician Girolamo Cardano theorized that the principle of gimbals could be used to transmit rotary motion through an angle. This theory was developed over many years into today's Cardan joint. (also known as Hookes joint)

10 Series driveshaft components

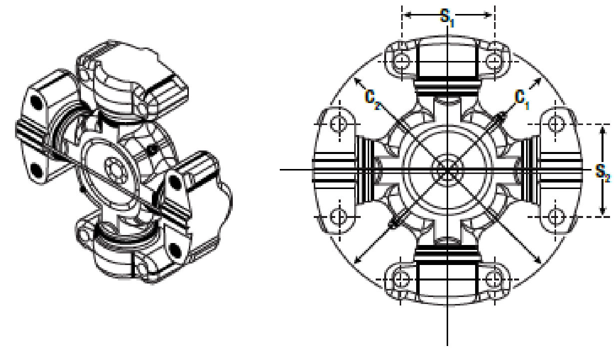


Universal Joint Styles

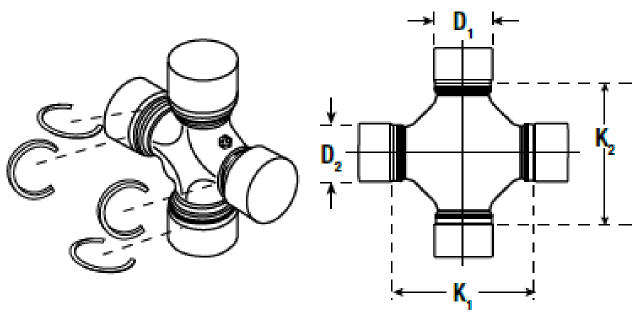
Outside Snap Rings



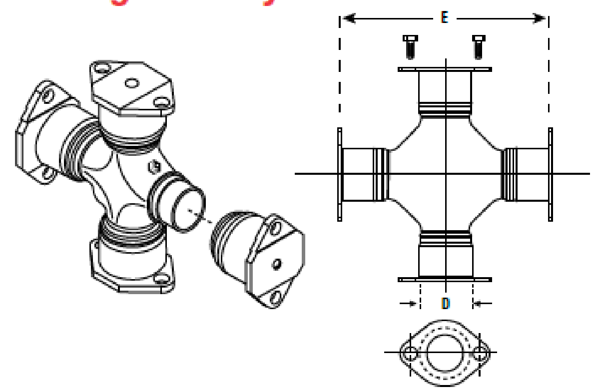
Wing™ Series



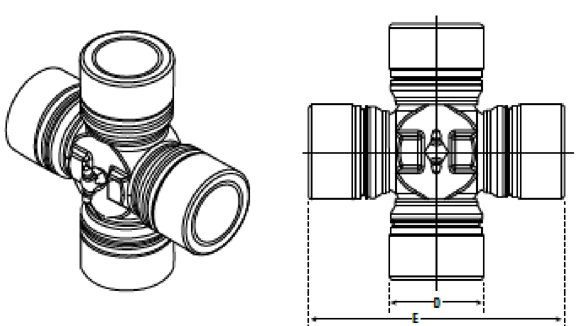
Inside Snap Rings



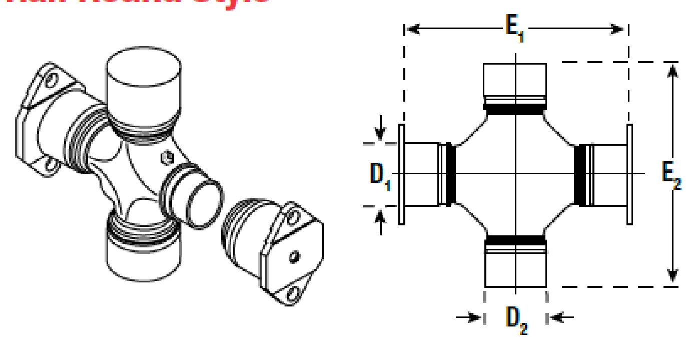
Bearing Plate Style



Spicer Life Series® (SPL® 140, 170, 250, and 350)



Half Round Style



FULL ROUND UNIVERSAL JOINT

HALF ROUND UNIVERSAL JOINT

WING STYLE UNIVERSAL JOINT

LWD - Low Wing Drilled
LWT - Low Wing Threaded

HWD - High Wing Drilled
HWT - High Wing Threaded

DWT - Delta Wing Threaded

Rotary Principles of a Single Cardan Joint

Kinematics of Hooke's joints

1. The joints

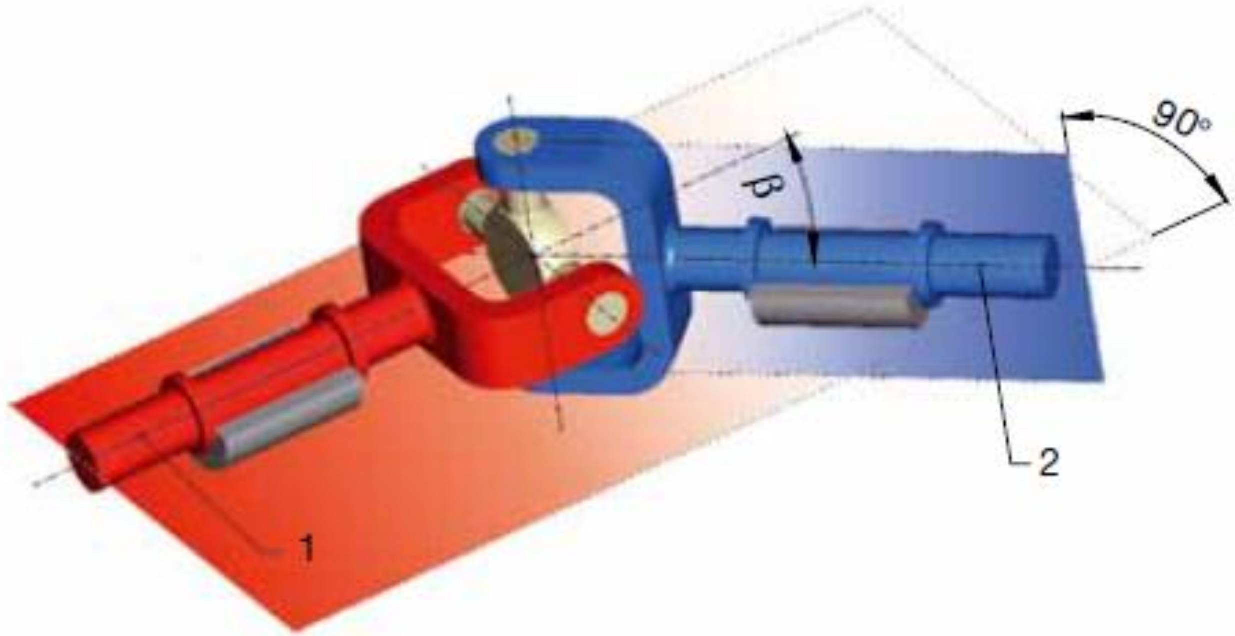
In the theory of mechanics, the cardan joint (or Hooke's joint) is defined as a spatial or spherical drive unit with a non-uniform gear ratio or transmission. The transmission behavior of this joint is described by the following equation:

$$\alpha_2 = \arctan\left(\frac{1}{\cos\beta} \cdot \tan\alpha_1\right)$$

β = Deflection angle of joint [∢°]

α_1 = angle of rotation drive side

α_2 = angle of rotation driven side



A single cardan joint creates non-constant rotational speed

Cardan error
(Angular lag of a single universal joint)

2.1 Rotation angle of a single joint
as a function of deflection angle ß

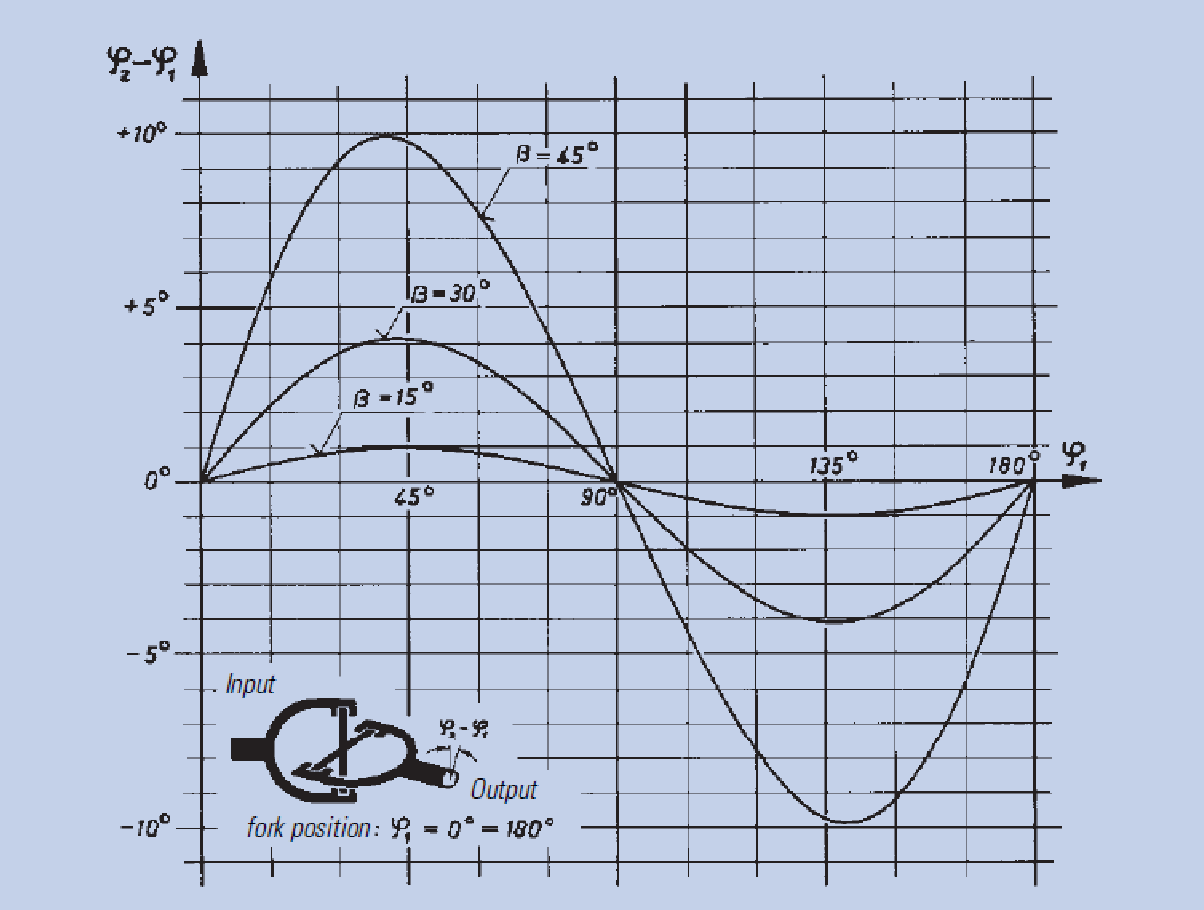
φ_1 = Input – rotation angle
φ_2 = Output – rotation angle

If a single joint is deflected by angle ß and rotated in this condition, rotation angle φ_2 of the output shaft differs from rotation angle φ_1 of the input shaft. The relationship between the two rotation angles is as follows:

$$\tan \varphi_2 = \frac{\tan\varphi_1}{\cos ß}$$

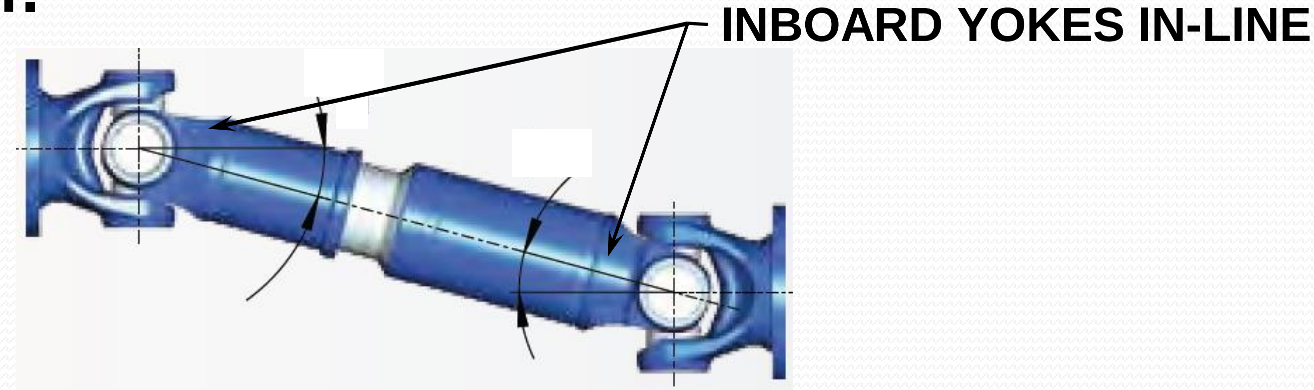
As can be seen from the adjacent diagram, maximum lead occurs at about 45 °, maximum lag at about 135°.

Fork position $\varphi_1 = 0°$ is then obtained, when the input fork is located in the deflection-plane of the joint.



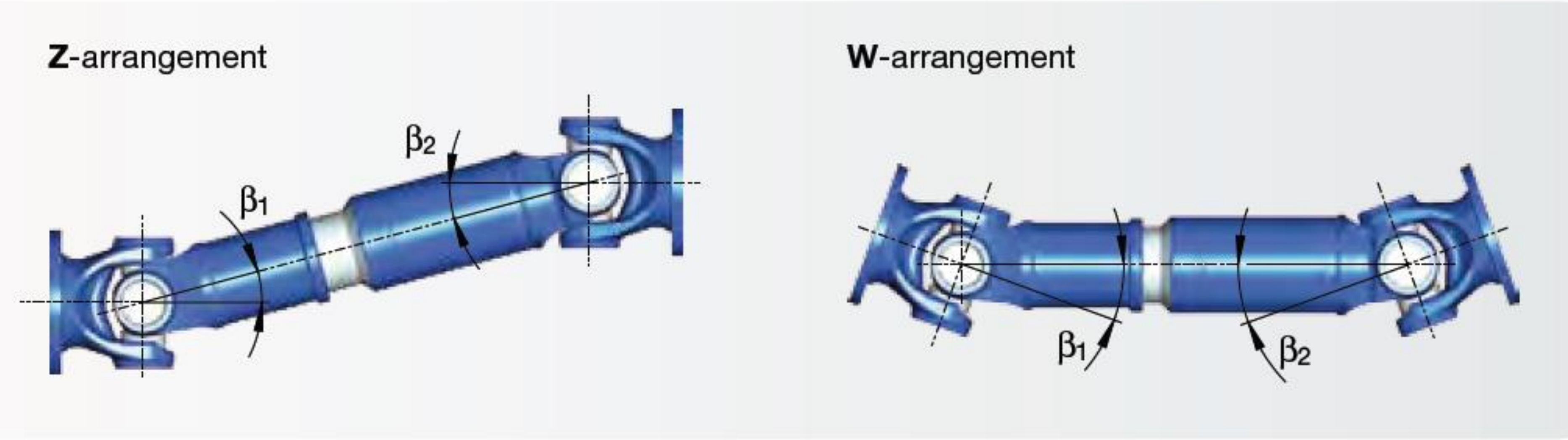
Driveshaft yoke phasing

Normally, the inner yokes of the driveshaft are inline with each other and operate at the same angle in order to cancel the effect of cardan error.



However, there are <u>special</u> situations where the inner yokes are turned with respect to each other in order to cancel cardan error.

Common Driveshaft layouts



Driving and driven shaft centerlines are parallel to each other

Driving and driven shaft centerlines intersect

In both cases β_1 & β_2 must be equal to achieve constant velocity

Note: Do not run a W arrangement in plan and a Z arrangement in elevation or vice versa at the same time on one shaft.

Universal Joint Operating Angles

Every Universal Joint that Operates at an Angle Creates a Vibration

Universal joint operating angles are probably the most common causes of driveline vibration in vehicles that have been reworked, or in vehicles that have had auxiliary equipment installed.

Universal joint operating angles are a primary source of problems contributing to:

- Vibrations
- Reduced universal joint life
- Problems with other drivetrain components that may include:
  - Transmission gear failures
  - Synchronizer failures
  - Differential problems
  - Premature seal failures in axles, transmissions, pumps, or blowers
  - Premature failure of gears, seals, and shafts in Power Take-Offs

Rules of thumb for driveshaft angles

When you rework a chassis or install a new driveshaft in a vehicle, make sure that you follow the basic rules that apply to universal joint operating angles:

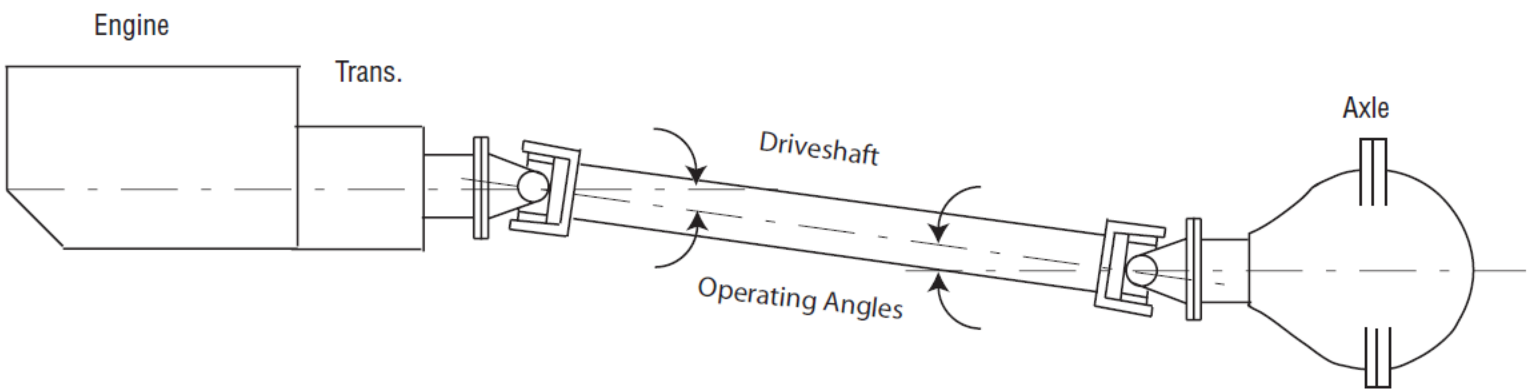
RULE 1: UNIVERSAL JOINT OPERATING ANGLES AT EACH END OF A DRIVESHAFT SHOULD ALWAYS BE AT LEAST 1 DEGREE.

RULE 2: UNIVERSAL JOINT OPERATING ANGLES ON EACH END OF A DRIVESHAFT SHOULD ALWAYS BE EQUAL WITHIN 1 DEGREE OF EACH OTHER (ONE HALF DEGREE FOR MOTOR HOMES AND SHAFTS IN FRONT OF TRANSFER CASE OR AUXILIARY DEVICE).

RULE 3: FOR VIRTUAL VIBRATION FREE PERFORMANCE, UNIVERSAL JOINT OPERATING ANGLES SHOULD NOT BE LARGER THAN 3 DEGREES. IF THEY ARE, MAKE SURE THEY DO NOT EXCEED THE MAXIMUM RECOMMENDED ANGLES.

A universal joint operating angle is the angle that occurs at each end of a driveshaft when the output shaft of the transmission and driveshaft and the input shaft of the axle and driveshaft are not in line. (See Fig 1)

The connecting driveshaft operates with an angle at each universal joint. It is that angle that creates a vibration.



Single Plane and Compound Universal Joint Operating Angles

There are two types of universal joint operating angles: Single Plane and Compound.

Single Plane

Single Plane angles occur when the transmission and axle components are in line when viewed from either the top or side, but not both.

Determining the universal joint operating angle in an application where the components are in line when viewed from the top, but not in line when viewed from the side, is as simple as measuring the slope of the components in the side view, and adding or subtracting those slopes to determine the angle. (See Fig. 3)

These angles should be **small** and **equal** within 1 degree.

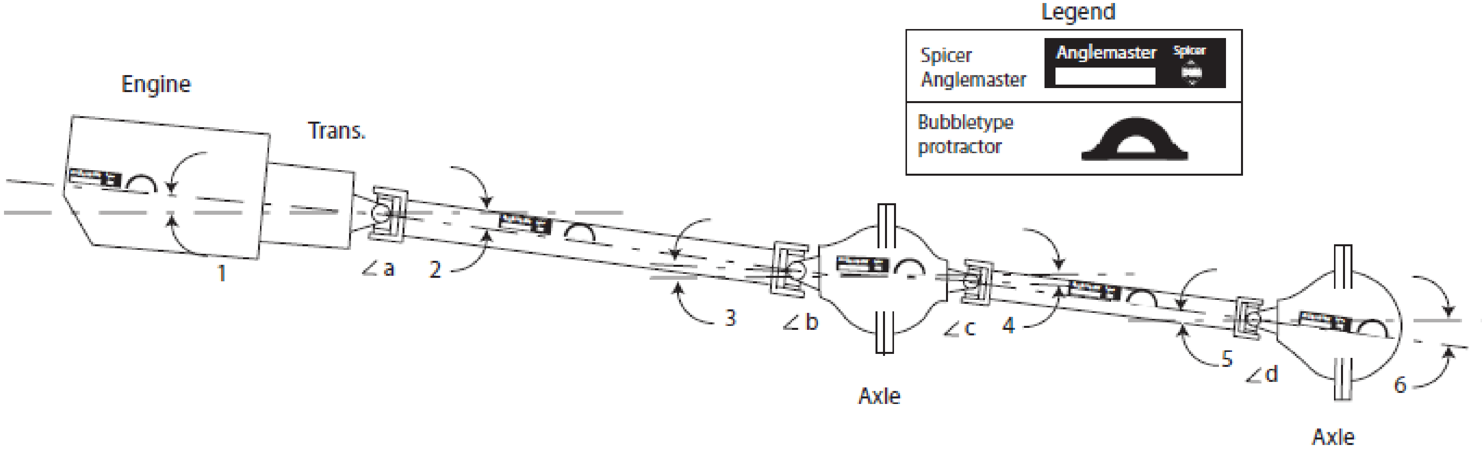


Figure 3

Determining Angles in one plane

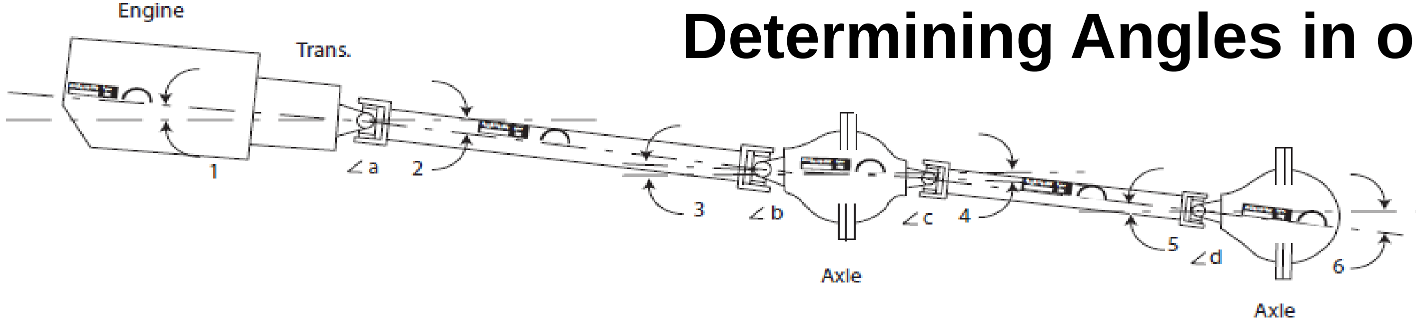


Figure 3

The most convenient way to determine universal joint angles in the side view is through the use of a Spicer Anglemaster™ or a bubble type protractor.

Using an Anglemaster or a bubble protractor, record inclination angles of drivetrain components. Set Anglemaster or protractor on machined surfaces of engine, transmission, axle, or on machined lugs of transmission and axle yoke(s).

Note: Universal joint angles can change significantly in a loaded situation. Therefore, check vehicle loaded and unloaded to achieve the accepted angle cancellation.

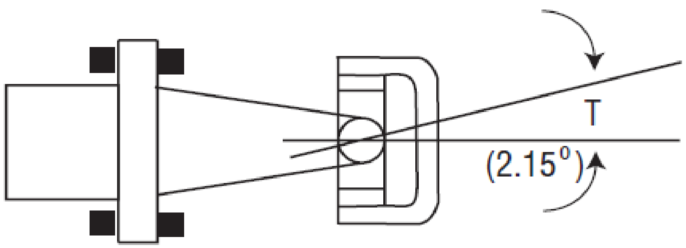
<u>Example:</u>

Engine-Transmission Output	4°30' Down (1)
Main Driveshaft	7°00' Down (2)
Input 1st Rear Axle	4°00' Up (Input Shaft Nose Up) (3)
Output 1st Rear Axle	4°00' Down (4)
Inter-axle Shaft	7°00' Down (5)
Input 2nd Rear Axle	4°15' Up (Pinion Shaft Nose Up) (6)
Note: If inclination of driveshaft is opposite connecting component, add angles to obtain the universal joint operating angle.	
Angle a = (2) - (1) = 7°00' - 4°30' = 2°30' (2.50°)	
Angle b = (2) - (3) = 7°00' - 4°00' = 3°00' (3.00°)	
Angle c = (5) - (4) = 7°00' - 4°00' = 3°00' (3.00°)	
Angle d = (5) - (6) = 7°00' - 4°15' = 2°45' (2.75°)	

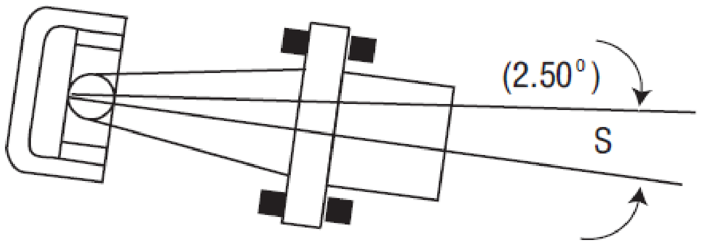
True Universal Joint Operating Angle

The True Universal Joint Operating Angle, which must be calculated for each end of the shaft with compound angles, is a combination of the universal joint operating angle in the top view, as determined from the chart, and the measured universal joint operating angle in the side view.

To determine the true universal joint operating angle for one end of a shaft, (compound angle C° in the formula shown in Fig. 6) insert the universal joint operating angle measurement obtained in the side view and the universal joint operating angle obtained from the chart into the formula.



Angle in Top View (from Chart)



SideView

Compound Angle (C°) = $\sqrt{T^2 + S^2}$

$T = 2.15^\circ$ (A calculated angle)

$S = 2.5^\circ$ (The measured angle)

$C = \sqrt{2.15^2 + 2.5^2}$

$C = \sqrt{10.873}$

$C = 3.3^\circ$ (True operating angle)

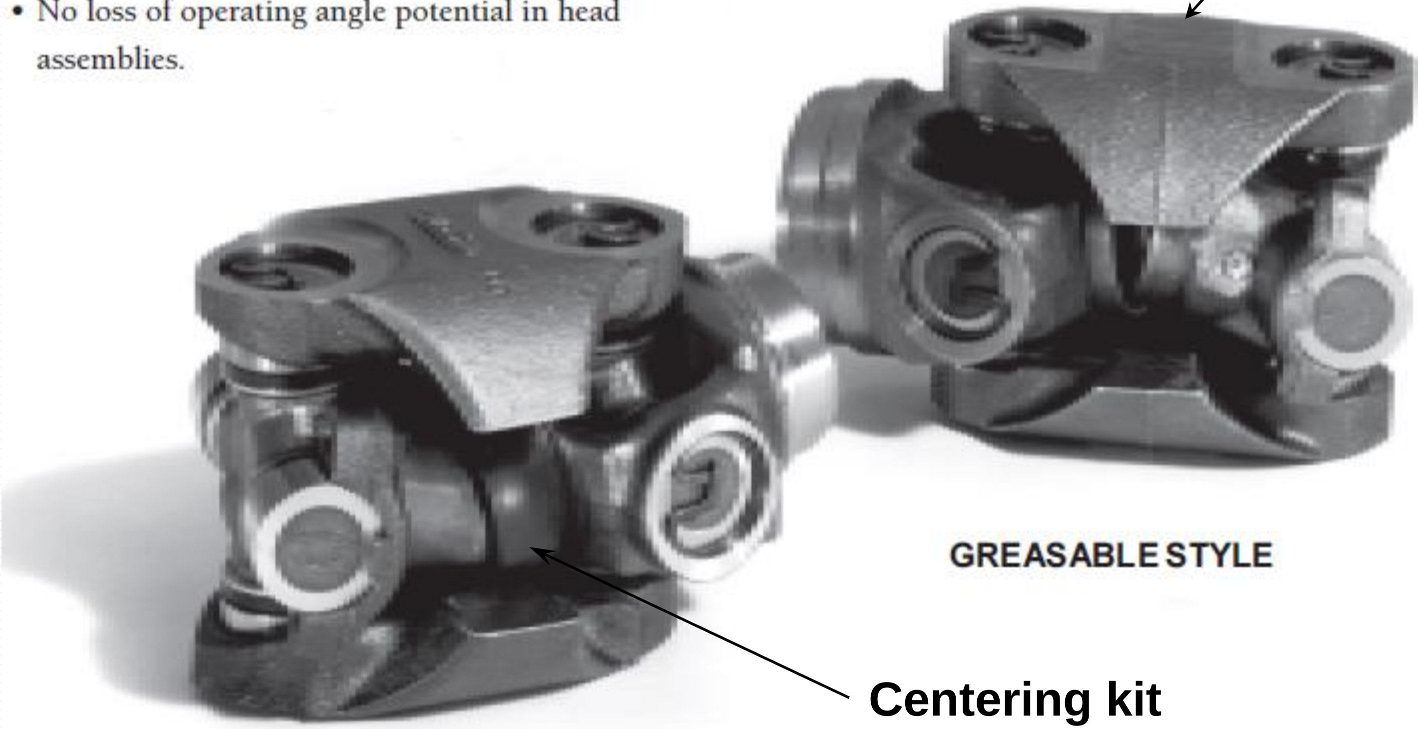
Double Cardan style CV joints

NON-GREASABLE STYLE

- Prelubed at factory.
- Maintenance free — no service interval.
- Centering kit sealing package improved for lube retention.
- Improved outer wiper seal keeps contaminents out.
- No loss of operating angle potential in head assemblies.

GREASABLE STYLE

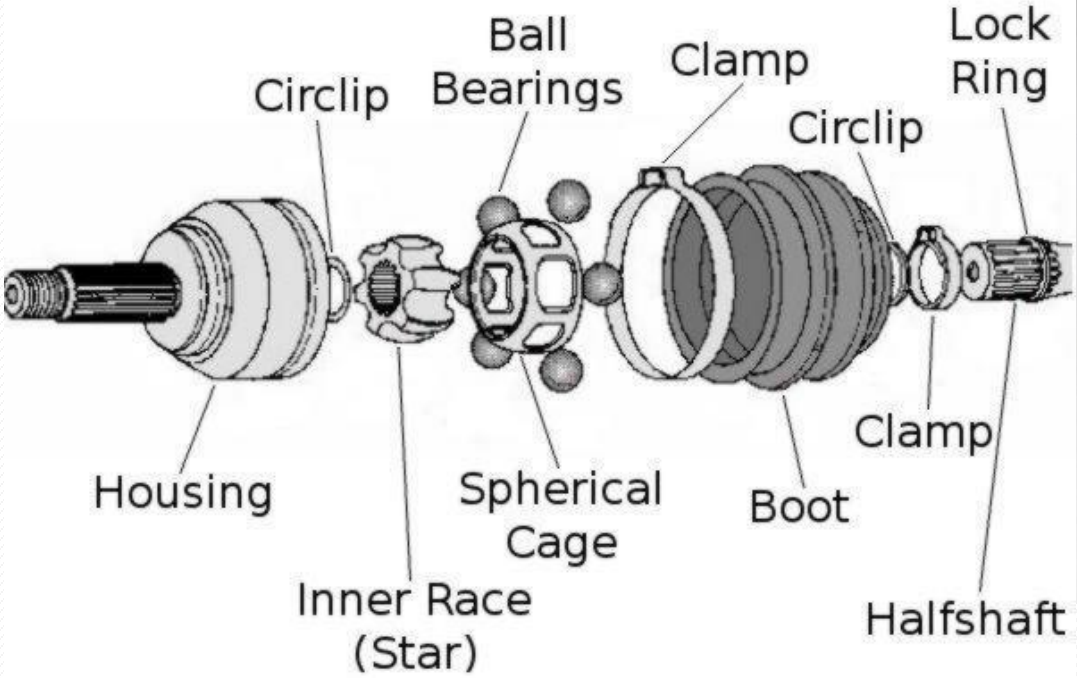
- Can be greased with special needle-nose type grease gun attachment.
- Sevice at normal driveshaft maintenance intervals of 2,000 to 3,000 miles, or one month, whichever comes first.



GREASABLE STYLE

NON-GREASABLE STYLE

Rzeppa style CV Joints



Driveshaft Inspection

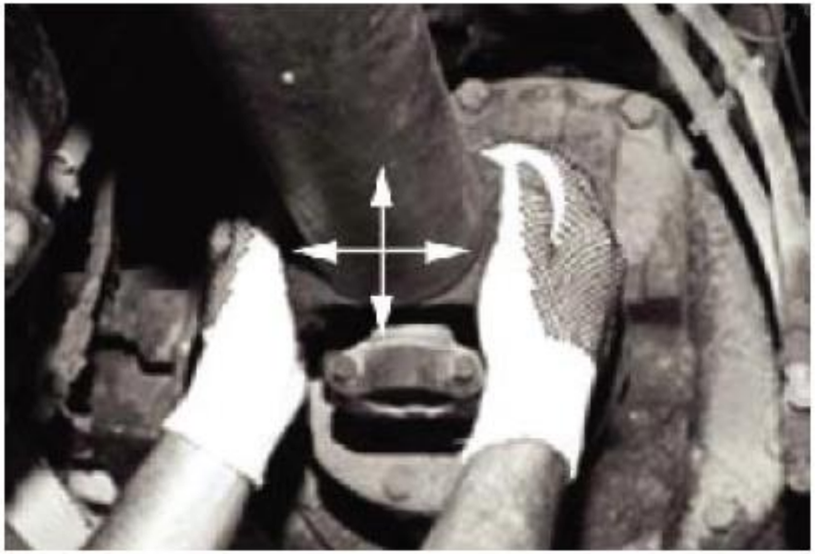
Safety First !

- Always follow all safety practices when servicing, removing and/or installing a driveshaft.
- Always use support straps to prevent the driveshaft from falling out of the vehicle during removal and installation.
- Always put the transmission in neutral before working on the driveshaft.
- Never heat components or use a sledgehammer or floor jack to remove the driveshaft from the vehicle.
- Do not reuse bearing plate bolts.

Universal Joint Inspection

- U-joint inspections should be performed every time a vehicle comes in for scheduled maintenance.
- Visually inspect for damaged bearing retainers or stamped straps, loose bearing retainer or strap bolts, loose companion flange bolts and nuts, loose or missing spring tabs or spring tab bolts, damaged tangs on end fittings, damaged or missing snap rings and rotating bearing cups.
- If any of these situations are evident, replacement of the component is necessary.
- Check all input and output end fittings for looseness. Take hold of the end fitting with both hands. Try to move it vertically and horizontally to feel any looseness.

- There should be less than .006” movement in the U-joint relative to the end yoke. If looseness in greater than .006” the U-joint should be replaced.
- Check for the presence of all grease zerks fittings. Damaged zerks should be replaced. Loose zerks should be tightened.



Slip Member Assembly Inspection

1. Check all slip yoke assemblies to be sure the slip yoke plug is not loose, missing, or damaged. If any of these situations are evident, replacement of the yoke assembly is necessary.

2. Visually inspect for the presence of the grease zerk (nipple) fitting, if applicable, on the slip yoke. Grease zerk (nipple) fittings should not be missing, loose, or fractured.

3. If a grease zerk (nipple) fitting is loose, tighten it to required specifications. See the Universal Joint Grease Zerk (Nipple) Fitting and Plug Torque table

4. If a grease zerk (nipple) fitting is missing or damaged, the slip member assembly must be replaced.

Slip Member Assembly Inspection continued

5. Check the slip yoke seals and dust caps. Make sure the seal is properly attached to the slip yoke and is not loose or damaged. If any of these situations are evident, replacement of the slip member and/or seal may be necessary.
6. For an inboard and outboard slip yoke assembly design, check to be sure the slip yoke welch plug is not loose, missing, or damaged.
7. If there is excessive looseness between the mating components, with the presence of vibration, all slip assembly components should be replaced.

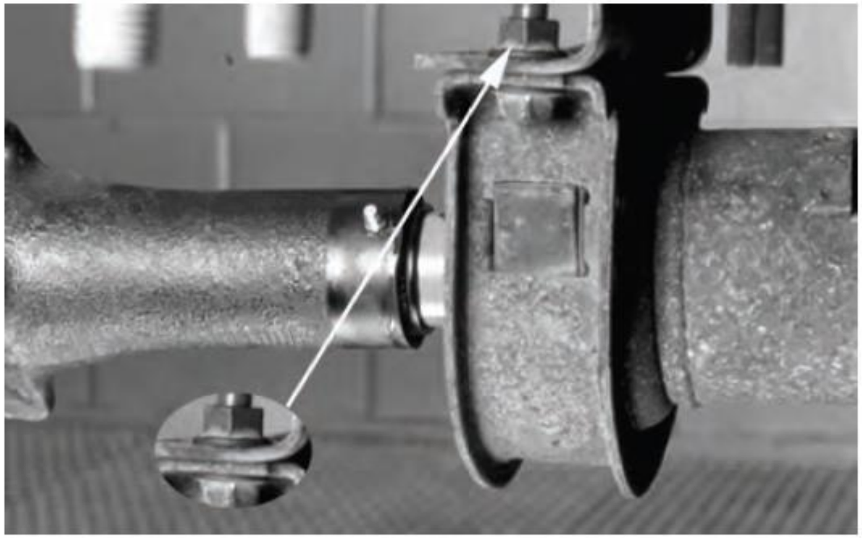
Tubing Inspection

1. Check the driveshaft for bent or dented tubing. If either of these situations is evident, replacement of the complete driveshaft assembly or tube is necessary.
2. Make certain there is no buildup of foreign material on driveshaft.

   If found, buildup should be removed carefully to avoid damaging the driveshaft.

   a. When removing dirt or mud, rinse with water.
   b. When removing tar or undercoating, use mineral spirits or any appropriate solvent.

Carrier bearing Inspection



Inspect the center bearing bracket bolts for looseness. If looseness is evident, re-tighten the center bearing bracket bolts. Consult the vehicle manufacturer's documentation for proper bolt torque. Check the alignment of the bracket before tightening the bolt. Bracket should not be skewed more than 3° in relation to the centerline of the driveshaft.

Visually inspect the center bearing rubber cushion for damage. Make sure the slingers are not rubbing against the rubber cushion. Verify that the rubber cushion is properly seated in the metal bracket.

Recommended lube intervals

SPICER DRIVESHAFT LUBRICATION INTERVALS*				
SERIES	**CITY**	**ON-HWY.**	**LINEHAUL**	**ON/OFF-HWY.**
10-Series (1480 thru 1810 & SPL-90) Slip member also requires lubrication.	5,000/8,000 MI (8,000/12,800 Km) or 3 Months (whichever comes first)	10,000/15,000 MI (16,000/24,000 Km) or 3 Months (whichever comes first)	10,000/15,000 MI (16,000/24,000 Km) or 30 Days (whichever comes first)	5,000/8,000 MI (8,000/12,000 Km) or 3 Months (whichever comes first)
Standard U-joints Medium-Duty - Spicer Life Series® (SPL-55, 70 & 100) Booted & permanently lubricated slip member.	25,000 MI 40,000 Km or 6 Months (whichever comes first)	25,000 MI 40,000 Km or 6 Months (whichever comes first)	25,000 MI 40,000 Km or 6 Months (whichever comes first)	25,000 MI 40,000 Km or 6 Months (whichever comes first)
Spicer Life XS Medium-Duty - Spicer Life Series® (SPL-55, 70 & 100) Booted & permanently lubricated slip member.	No Maintenance Required	No Maintenance Required	No Maintenance Required	No Maintenance Required

* Spicer Driveshaft Division recommends relubrication with Chevron Ulta-Duty EP-2 or a compatible grease meeting N.L.G.I. Grade 2 specifications with an operating range of +325°F/+163°C to -10°F/ -23°C.

City is defined as all applications that require a minimum of 90% of operation time within the city limits.

On-Highway is defined as all applications requiring less than 10% of operating time on gravel, dirt or unpaved roads.

Linehaul is defined as 100% of operation time on smooth concrete or asphalt.

On/Off-Highway is defined as all applications operating primarily on paved roads, but requiring more than 10% of operating time on gravel, dirt or unpaved roads.

Grease Zerks

- Replace damaged zerks.
- Zerk torque 15 ft. lb. (20 Nm)
- Clean zerk nipples before greasing.

Recommended Lubricant

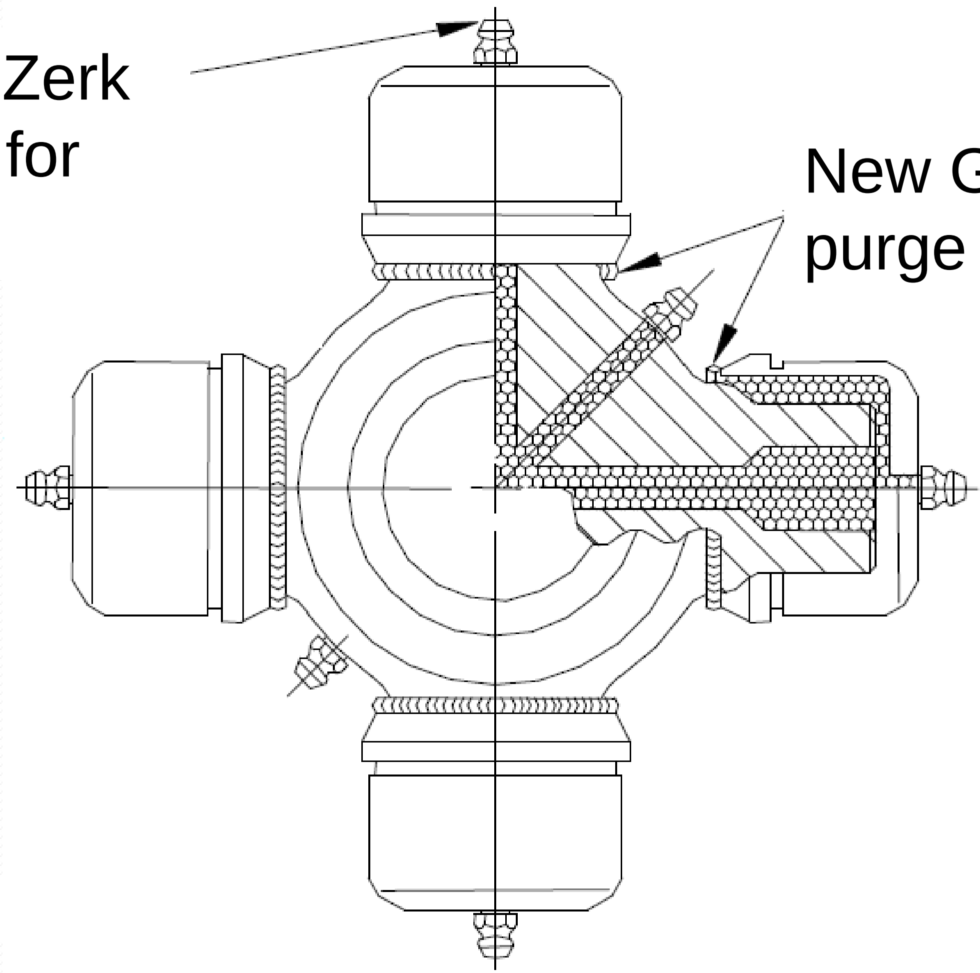
- Use a quality EP (extreme pressure) grease
- Meeting N.L.G.I.; EP., **Grade 2** specifications
- Grease must have operating range of +325°F to -10°F
- Must be compatible with Lithium soap types

Lubrication Procedure

1. Use a recommended lubricant to purge **all** 4 seals of each universal joint.This flushes abrasive contaminates from each bearing assembly and assures proper filling of **all** four bearings.
2. Make sure fresh grease is evident at **all** U-joint bearing seals.

Lubrication Procedure

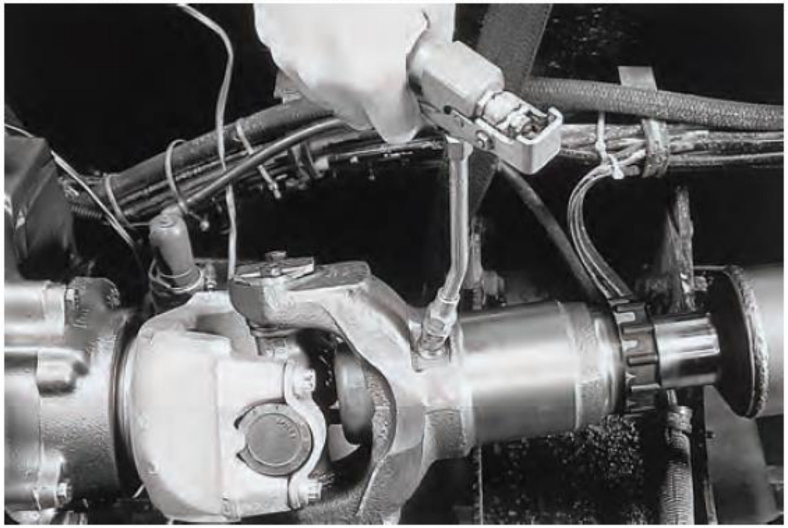
Optional Zerk
Location for
4X lube



New Grease must
purge from all 4 seals

Lubrication for Slip Members

The grease used for universal joints is satisfactory for slip members. Glidecote® and steel splines both use a high quality E.P. grease meeting N.L.G.I. Grade 2 specifications.



Grease splines at the intervals recommended in the Lubrication Intervals

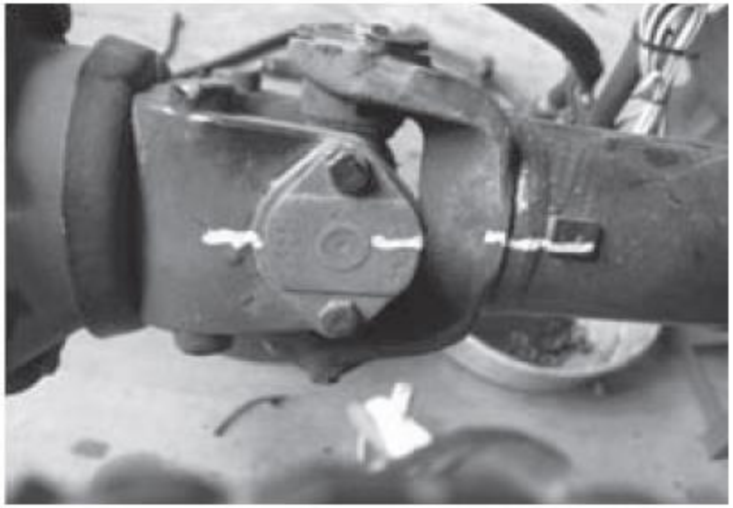
1. Apply grease gun pressure to the grease zerk (nipple) fitting until grease appears at the pressure relief hole in the plug.

2. Now cover the pressure relief hole with your finger and continue to apply pressure until grease appears at the slip yoke seal.

If you have to take the driveshaft out…..

Mark Driveshaft (Phasing Marks)

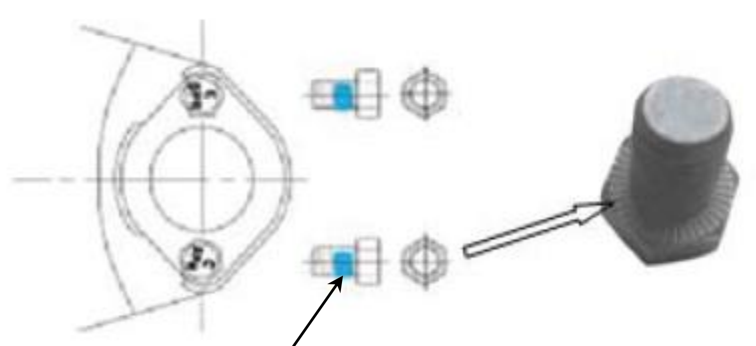
- Mark all mating driveshaft components with a paint marker to assure proper phasing during reassembly.
- Reassembly of a driveshaft that is out of phase can cause vibration and failure to driveshaft components.



Full round and half round bolts

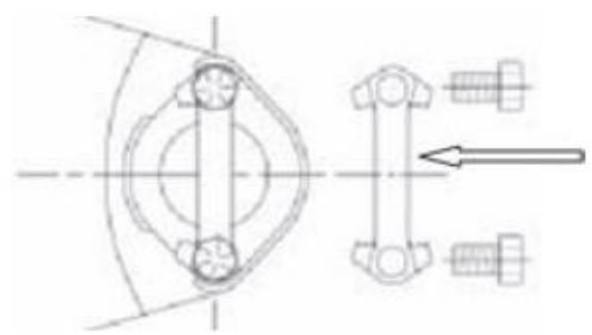
Standard hardware

Serrated Bolt Kit (Full Round)

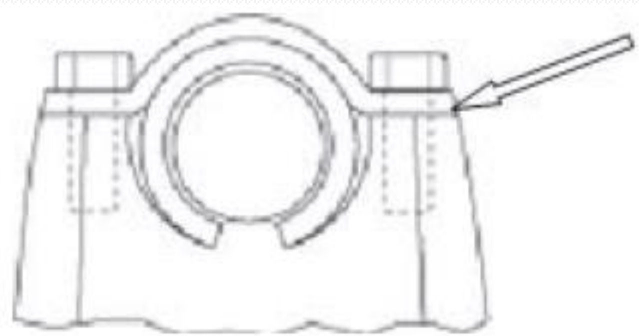


Optional hardware

Strap Bolt Kit (Full Round)



Quick Disconnect Bolt Kit (Half Round)



Bolt Torque (Half Rounds)

Series	Size	Bolt Torque
1610	.375-24	45-60 ft lb (61-81 Nm)
1710	.500-20	115-135 ft lb (156-183 Nm)
1760	.500-20	115-135 ft lb (156-183 Nm)
1810	.500-20	115-135 ft lb (156-183 Nm)

Always use new hardware !!

Dynamic balancing recommendation

Dynamic balancing of the driveshaft assembly is recommended any time a universal joint is changed and operates over 300 RPM.

The driveshaft should be dynamically balanced in two planes at the maximum operating speed to a ISO 1940/1 G16 specification.

If the driveshaft is a 2 pc or 3 piece assembly, all sections should be balanced together.

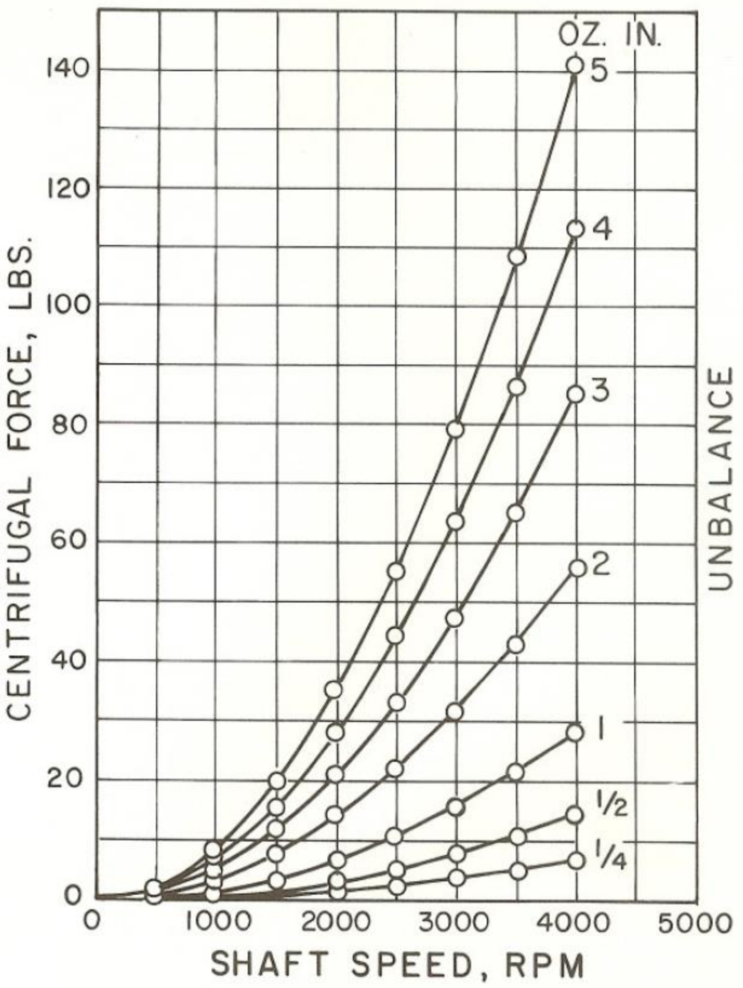
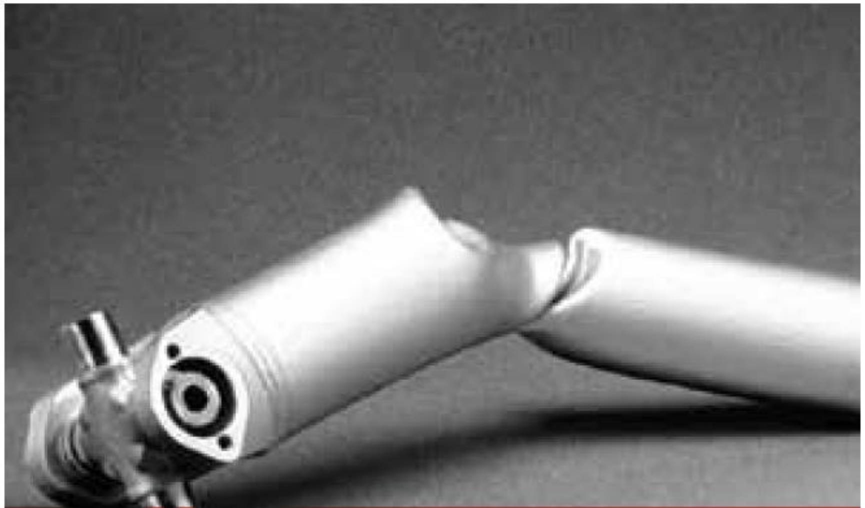


Fig. 5 — Centrifugal force characteristics versus shaft speed for various levels of unbalance

How to Identify Failure and Probable Cause

Tubing Failure

Tubing



Twisted Tubing

- Excessive torque
- Driving into immovable object under power
- Spinning tires that suddenly grab hold

Tubing

Failed Tubing

- Shock loads
- Improper welding procedures
- Excessive vibration
- Possible torsional vibration problem

How to Identify Failure and Probable Cause

Universal joint failure

Universal Joints

Burned U-Joint Cross

- Lack of lubrication (improper maintenance)
- Wrong lubrication type
- Improper application

Universal Joints

End Galling

- Excessive u-joint operating angles
- Improper assembly procedures
- Sprung or bent yoke
- Lack of lubrication (improper maintenance)

How to Identify Failure and Probable Cause

Universal joint failure

Universal Joints

- Excessive torque loads
- Shock loads
- Improper application

Universal Joints

- Water contamination
- Improper lube type
- Lubrication failure

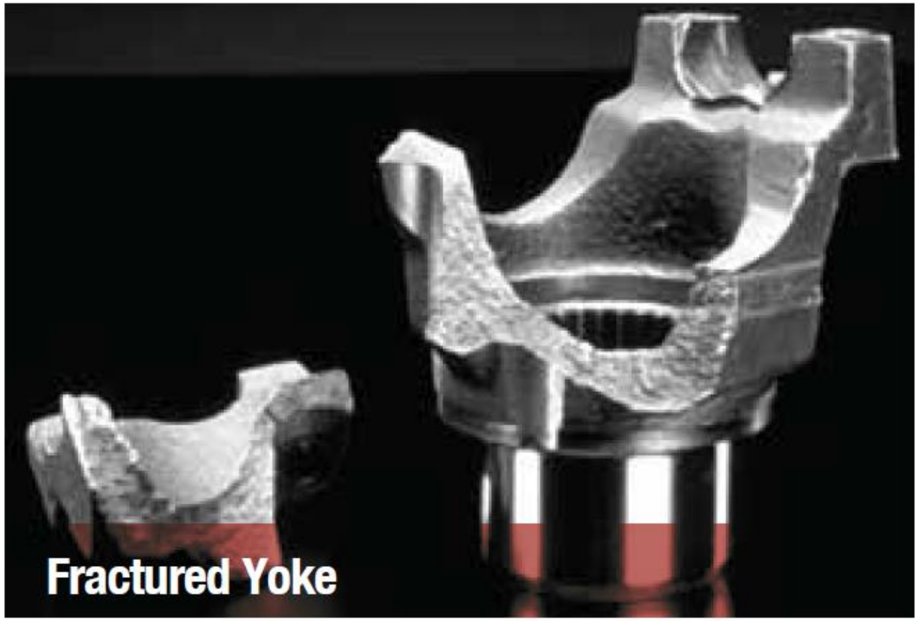
How to Identify Failure and Probable Cause

Universal joint and yoke failure

Universal Joints

- Excessive continuous torque loads
- Seized slip yoke splines
- Excessive driveline angles
- Sprung or bent yoke
- Overtightened U-bolts

Yoke



- Excessive torque loads
- Shock loads
- Improper application
- U-joint kit failure

How to Identify Failure and Probable Cause

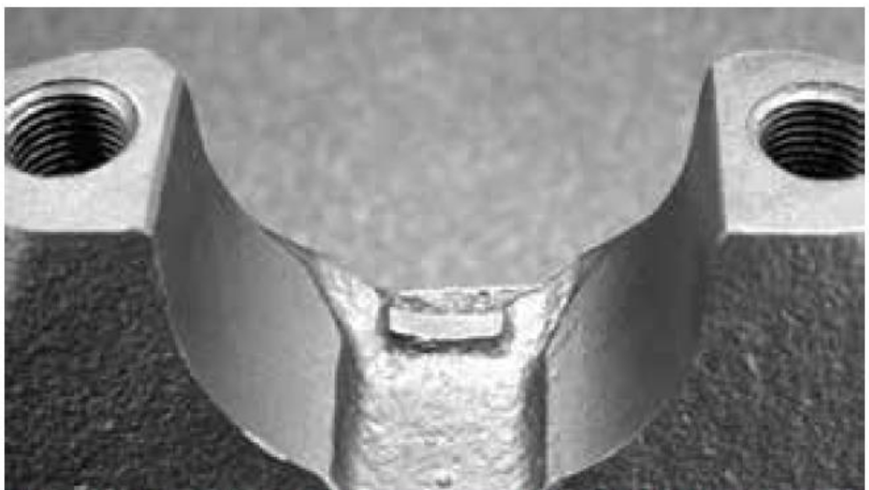
Yoke failure

Yoke

Bent Yoke

- Excessive torque
- Improper application
- Improper u-joint removal

Yoke



Broken Tang Half Round

- Improper bearing retainer bolt torque
- Improper installation
- Strap was reused instead of replaced

How to Identify Failure and Probable Cause

Tube shaft failure

Tube Shafts

Fractured Spline

- Excessive torque loads
- Shock loads
- Improper application

THANK YOU FOR YOUR TIME !

MACHINE SERVICE, INC.
UNIVERSAL DRIVESHAFTS