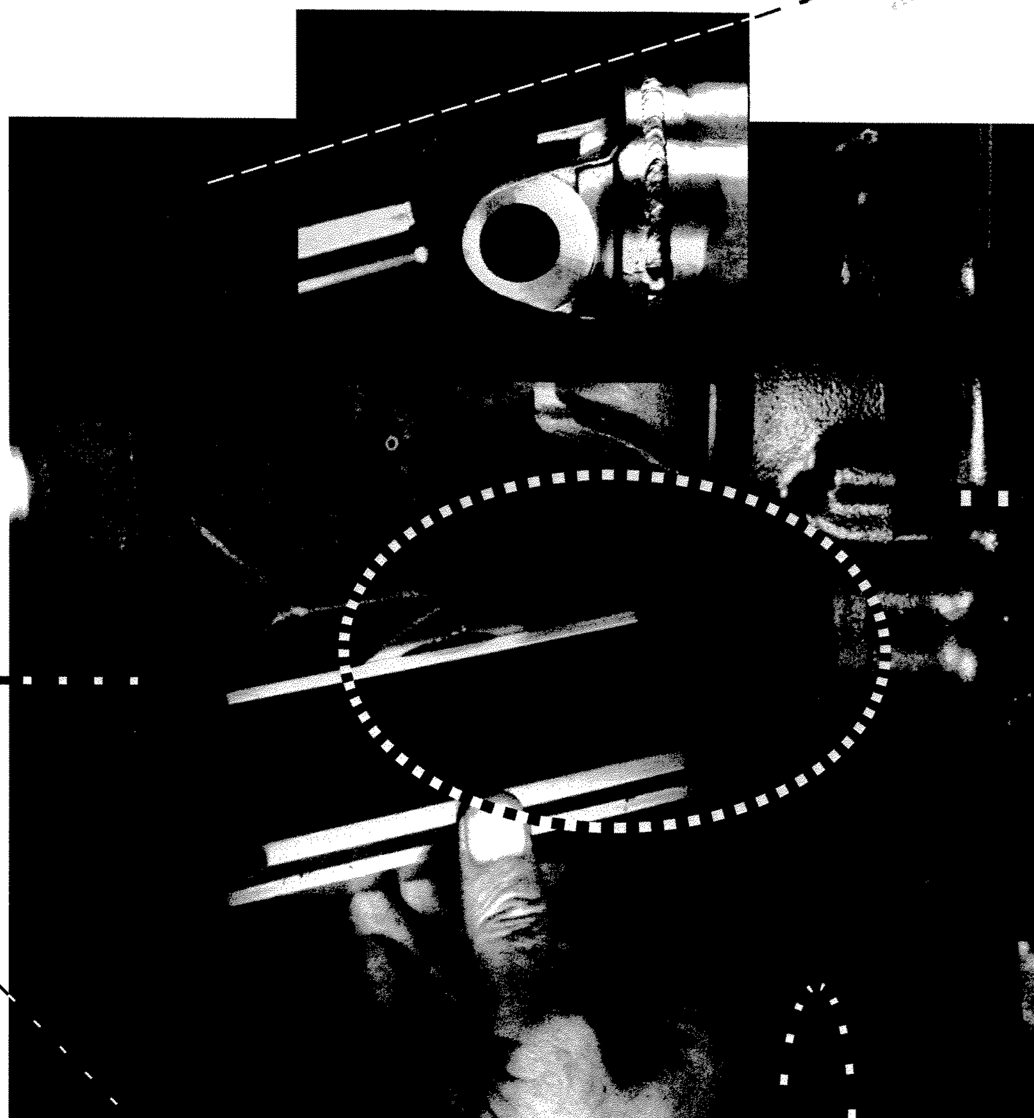
SPICER® DRIVESHAFT INSTALLATION

TECHNIQUES



SPICER®

DANA

DRIVESHAFT INSTALLATION TECHNIQUES THAT SOLVE VIBRATION PROBLEMS AND MAKE ACCESSORY MOUNTING AND VEHICLE CHASSIS MODIFICATIONS EASIER

Driveshaft Installation Techniques

This brochure is intended for:

- ❑ Installers who install Spicer driveshafts into an application where the transmission and axle are not in direct line with each other, causing the driveshaft U-joints to operate at an angle.
- ❑ Anyone experiencing vibration problems with their application or their vehicle that driveshaft assembly balancing will not correct.
- ❑ Truck Equipment Distributors who:
  - ❑ Re-work a chassis to change the wheel base.
  - ❑ Install a midship mounted power take-off or fire pump.
  - ❑ Mount any other PTO-driven device such as a blower, hydraulic pump or hydraulic motor.

Common Causes of Vibrations

The three most common causes of driveshaft vibration are: Driveshaft Imbalance, Critical Speed and U-Joint Operating Angles.

Driveshaft Imbalance

Eliminate the potential for balance problems before you undertake any other measures.

A driveshaft on a vehicle usually rotates at a higher rate of speed than the tires; often three to four times the speed of the tires. For that reason, like tires, driveshafts should be balanced.

Anytime you build or rework a driveshaft, make sure it is dynamically balanced, at 3000 RPM, to the following specifications:

Series	Specification
1310, 1330	.375 ounce/inch total at each end of shaft
1350, 1410	.500 ounce/inch total at each end of shaft
1480 - 1880	1.00 ounce/inch for each ten pounds of driveshaft weight divided proportionally at each end of shaft.

Critical Speed . . . And Half Critical Speed

Every driveshaft has a critical speed and a half-critical speed. Critical speed is the point at which a rotating driveshaft begins to bow off its normal rotating centerline. Half-critical is just what you expect it to be; one half of critical speed.

Driveshafts begin to vibrate as they approach critical speed. If they are operated at or near critical speed for an extended period, they often fail. This can damage the vehicle and possibly injure persons nearby.

Driveshafts that are operated at a cruising speed or have a constant running speed that occurs at, or near, half-critical speed may experience a continuous vibration that cannot be fixed by balancing or any of the other common vibration remedies.

As a driveshaft fabricator or installer, you are responsible for checking the critical speed of any driveshaft you fabricate or specify into an application. Make sure it will not operate at or near critical speed and does not have a cruising or constant operating RPM that is near half-critical speed.

Checking for a Possible Critical Speed Problem

Here's what you must do to make sure you won't have a critical speed problem.

- ❑ Determine the critical speed of the driveshaft you want to use in your application. Insert the tube diameter and center-to-center installed length of the shaft you want to use into a Spicer critical speed calculator (No. J310-13). The calculator will tell you the critical speed of the shaft you have chosen.
- ❑ Determine the NORMAL and MAXIMUM POSSIBLE operating speed of the driveshaft. REMEMBER:
  - ❑ On vehicles with a standard transmission that have a 1:1 direct drive high gear and no overdrive, MAXIMUM POSSIBLE driveshaft RPM is the same as the maximum possible ENGINE RPM.

- On vehicles that have an overdrive transmission, MAXIMUM POSSIBLE driveshaft RPM is higher than maximum possible ENGINE RPM.

To calculate the MAXIMUM POSSIBLE driveshaft RPM in vehicles having an overdrive transmission, divide the maximum possible ENGINE RPM by the overdrive ratio. (See examples below.)

EXAMPLE 1:
Max. engine RPM: 2100
Overdrive ratio: .79
2100/.79 = 2658 MAXIMUM POSSIBLE driveshaft RPM

EXAMPLE 2:
Max. engine RPM: 6000
Overdrive ratio: .66
6000/.66 = 9091 MAXIMUM POSSIBLE driveshaft RPM

Compare the MAXIMUM POSSIBLE driveshaft RPM with the actual critical speed determined from the Critical Speed Calculator. If the MAXIMUM POSSIBLE driveshaft RPM meets or exceeds the critical speed determined from the calculator, you must do whatever is required to lower the critical speed of the driveshaft you have chosen for the application.

Sample Specification:

To specify a driveshaft for the application described in example 1 above, compare the critical speed for the driveshaft selected with the MAXIMUM POSSIBLE driveshaft RPM calculated (2658 RPM). Make sure the critical speed of the driveshaft is greater than 2658 RPM and the cruising or constant operating RPM of the driveshaft is not at or near 1329 RPM (1/2 of 2658 RPM).

Changing the Critical Speed of a Driveshaft

A driveshaft's critical speed can be altered by changing its tube diameter or by changing the installed center-to-center length of the driveshaft. Changing the installed length of a driveshaft will require the use of multiple driveshafts with center bearings.

Important: The critical speed of an assembly can be affected by driveshaft imbalance, improper u-joint operating angles or improperly phased driveshafts. (A propery phased driveshaft has the in-board yokes of the shaft in line with each other.) Each of the above items will tend to LOWER the true critical speed from the values shown on the calculator.

Since critical speed can ultimately cause driveshaft failure, it is extremely important to be very precise in all applications.

U-Joint Operating Angles

Every U-Joint That Operates at an Angle Creates a Vibration.

U-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.

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

RULE NO. 1: U-JOINT OPERATING ANGLES AT EACH END OF A SHAFT SHOULD ALWAYS BE AT LEAST 1 DEGREE.

RULE NO. 2: U-JOINT OPERATING ANGLES ON EACH END OF A DRIVESHAFT SHOULD ALWAYS BE EQUAL WITHIN ONE DEGREE OF EACH OTHER. (ONE HALF DEGREE FOR MOTOR HOMES)

RULE NO. 3: U-JOINT OPERATING ANGLES SHOULD NOT BE LARGER THAN 3 DEGREES. IF THEY ARE, MAKE SURE THAT THEY DO NOT EXCEED THE MAXIMUM RECOMMENDED ANGLES.

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

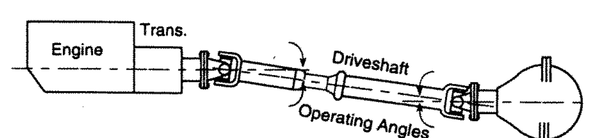


Fig. 1

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

Reducing and canceling vibration

A key point to remember about u-joint operating angles: To reduce the amount of vibration, the angles on each end of a driveshaft should always be SMALL.

To cancel an angle vibration, the u-joint operating angles need to be EQUAL within one degree at each end of a shaft. On motor home applications and auxiliary transmission installation the tolerance is 1/2 degree. (See Fig. 2)

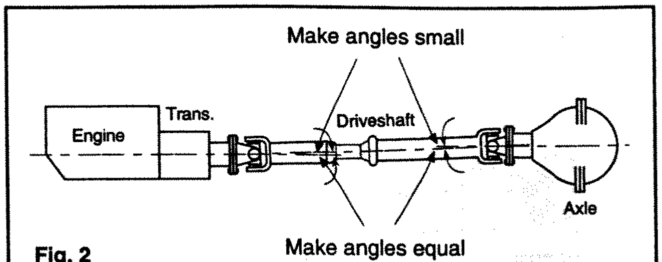


Fig. 2

SINGLE PLANE AND COMPOUND U-JOINT OPERATING ANGLES

There are two types of u-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 u-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)

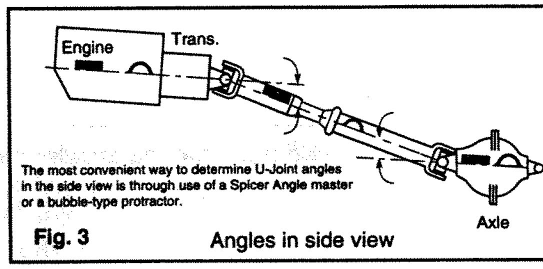
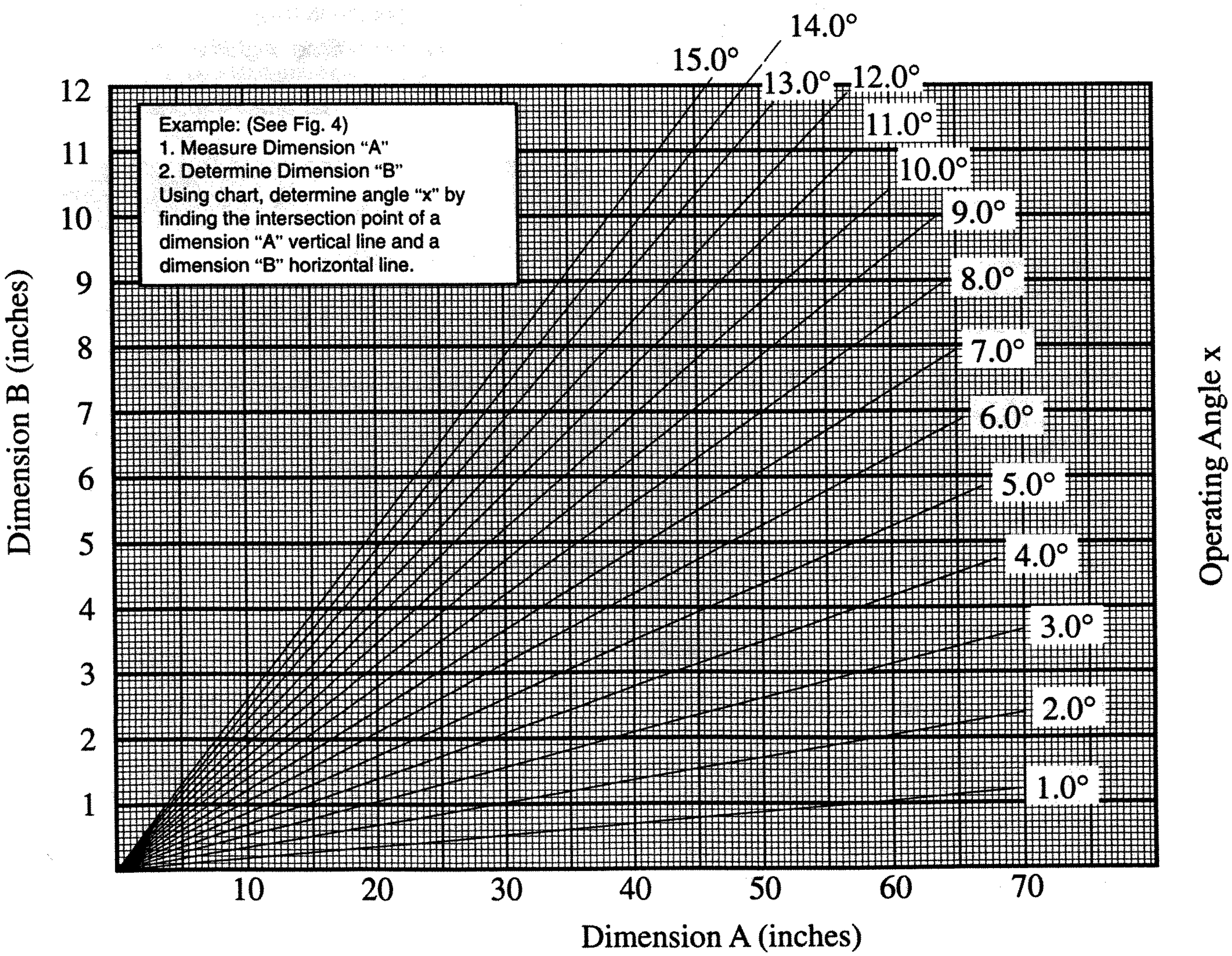


Fig. 3 Angles in side view

ANGLE CHART

For Driveshafts Having An Angle In The Top View



These angles should be SMALL and equal within one degree.

Determining the u-joint operating angles on a shaft that is straight when viewed from the side and offset when viewed from the top requires the use of a special chart (See chart at bottom of previous page). In this type of application, the centerlines of the connected components **must be parallel** when viewed from the top as shown. These angles also should be SMALL and equal within one degree. (See Fig. 4)

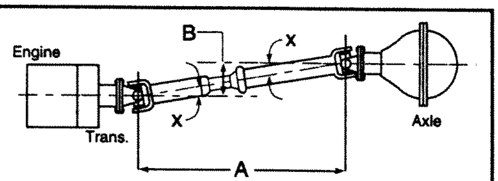


Fig. 4 Angles in top view

Look at the angle chart and note that the smaller the offset, the smaller the resultant angle.

So, to reduce the possibility of vibration, keep any offset between connected points to a minimum.

There are two things that you can do to always make sure single plane angles are SMALL and EQUAL: Make sure that the transmission and axle is mounted so that their centerlines are parallel when viewed from both the side and the top. Make sure the offset between them is small in both views.

Compound Angles

Compound u-joint operating angles occur when the transmission and axle are not in line when viewed from BOTH the top and side. Their centerlines, however, are parallel in both views. (See Fig. 5)

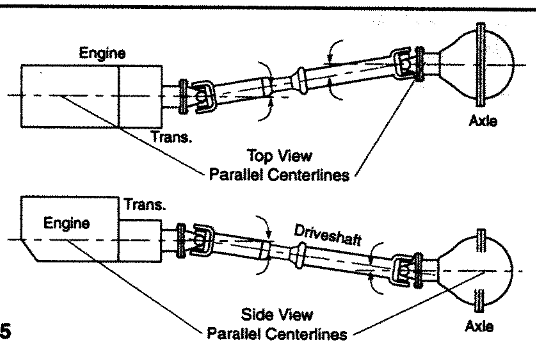


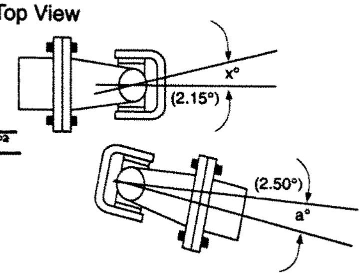
Fig. 5

True U-joint Operating Angle

The true u-joint operating angle, which must be calculated for each end of the shaft with compound angles, is a combination of the u-joint operating angle in the top view, as determined from the chart, and the measured u-joint operating angle in the side view.

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

Fig. 6



Compound Angle (C°) = $\sqrt{x^{o2} + a^{o2}}$

x = 2.15° (A calculated angle)

a = 2.5° (The measured angle)

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

$a = \sqrt{10.873}$

a = 3.3° (True operating angle)

Do the same for the other end of the shaft. Compare the resultant calculated u-joint operating angle for each end. They should be EQUAL within one degree. If they're not, the driveshaft will vibrate.

Eliminating Compound Angle Induced Vibrations

Compound u-joint operating angles are one of the most common causes of driveline vibration. To avoid these problems, remember these important points:

- ❑ When setting up an application that requires compound u-joint operating angles, always keep the centerlines of the transmission and axle parallel in both views.
- ❑ Always keep the offset between their horizontal and vertical centerlines small.

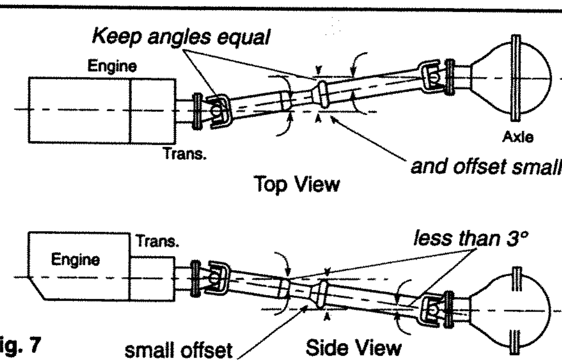


Fig. 7

NOTE: Centerlines of transmission and axle must be parallel in both top and side views to use this method of determining true U-joint operating angle. Please contact the Drivetrain Service Division Spicer Universal Joint product manager at 419-866-3900 if you have an application where the components cannot be installed with their centerlines parallel.

Angle Size

The magnitude of a vibration created by a u-joint operating angle is proportional to the size of the u-joint operating angle. Spicer engineers recommend true u-joint operating angles of 3 degrees or less.

Obtain the true u-joint operating angle, as explained above, and if it is greater than 3 degrees, compare it to this chart.

Driveshaft RPM	Maximum Operating Angle
5000	3.2°
4500	3.7°
4000	4.2°
3500	5.0°
Driveshaft RPM	**Maximum Operating Angle**
3000	5.8°
2500	7.0°
2000	8.7°
1500	11.5°

The angles shown on the chart are the MAXIMUM u-joint operating angles recommended by Spicer engineers and are directly related to the speed of the driveshaft. Any u-joint operating angle greater than 3 degrees will lower u-joint life and may cause a vibration. Remember to check maximum safe driveshaft RPM by using the Spicer critical speed calculator.

Multiple Shaft Installations

Multiple Shaft Set Up Recommendations

In general, multiple shaft installations follow the same guidelines, except that there are different recommendations for setting up the driveline:

- ❑ For a 2-shaft application, set up the first coupling shaft (sometimes called a jackshaft) so that the u-joint operating angle that occurs at the transmission end is 1 to 1 1/2 degrees. (See Fig. 8)

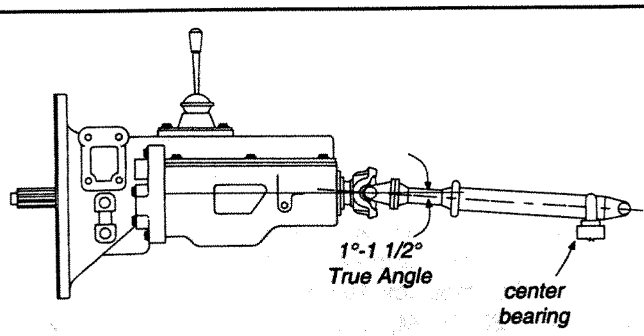


Fig. 8

- ❑ Try to avoid building a compound u-joint operating angle into the first coupling shaft by installing it in line with the transmission.
- ❑ If it ends up being compound, make sure that the true u-joint operating angle, determined by using the information mentioned earlier, is 1 to 1 1/2 degrees.

Install or tilt the axle so that it is mounted on the same angle as the first coupling shaft (the centerlines of the axle and the first coupling shaft will be parallel). **NOTE:** BY FOLLOWING THIS PROCEDURE, THE U-JOINT OPERATING ANGLE AT EACH END OF THE LAST SHAFT WILL AUTOMATICALLY BE EQUAL. (See Fig. 9)

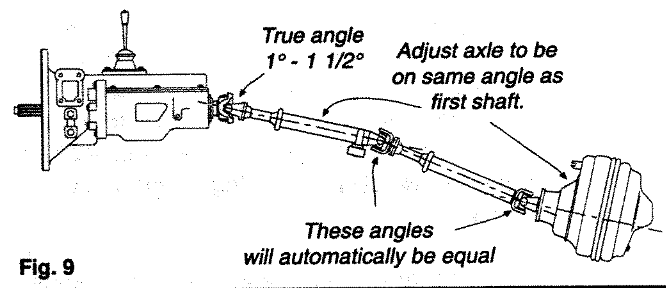


Fig. 9

If there is an offset in the installation of the axle, make sure it does not create too large of a compound u-joint operating angle. Whenever possible, mount the axle directly in line with the first coupling shaft (when viewed from the top).

Check the actual u-joint operating angle at the rear of the first coupling shaft. If it is less than one degree, rotate the end yoke or slip yoke so that the ears of the yoke are 90 degrees to the ears of the tube yoke on the transmission end of the coupling shaft. (See Fig. 10)

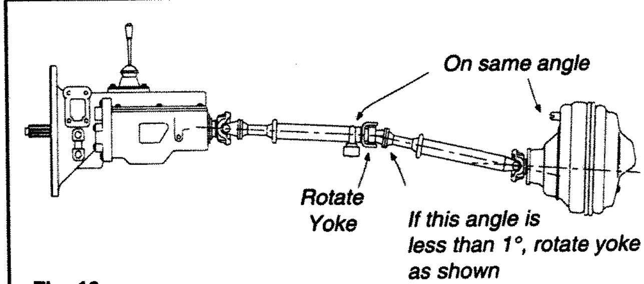


Fig. 10

On applications having more than two shafts, mount the first coupling shaft as outlined in the preceding example, and each additional coupling shaft at a 1 to 1 1/2 degree u-joint operating angle to the previous coupling shaft.

Install or tilt the axle to the same angle as the last fixed coupling shaft so that the centerline of the axle and the last fixed coupling shaft are parallel.

NOTE: THIS ASSURES THE U-JOINT OPERATING ANGLE AT EACH END OF THE LAST SHAFT WILL AUTOMATICALLY BE EQUAL. (See Fig. 11)

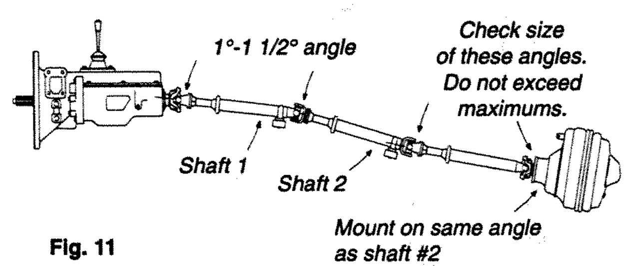


Fig. 11

Mounting A Midship-Mounted PTO, Pump, or Auxiliary Transmission

When installing a midship-mounted PTO, auxiliary transmission, or midship-mounted pump into the main driveline of a vehicle, install it at the same angle as the transmission. Keep the offset to a minimum to reduce u-joint operating angles. **NOTE: Do not make the u-joint operating angle less than 1 degree.**

Before bolting the device in place, check the u-joint operating angles that occur at each end of the driveshaft. They must be 1 to 1 1/2 degrees minimum to 3° maximum and they must be equal to within 1/2 degree for this type of application.

If the device ends up being installed in direct line with the transmission, with little or no u-joint operating angle on the joints, raise or lower it so there is enough offset to create the required 1 to 1 1/2 degree minimum u-joint operating angle on each end of the driveshaft. (See Fig. 12)

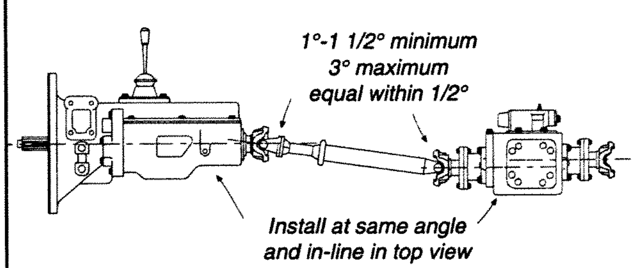


Fig. 12

If there is only one driveshaft between the device and the rear axle, rotate the rear axle (using shims in the appropriate place) so it is the same angle as the device. This makes the u-joint operating angle at each end of the driveshaft equal. (See Fig. 13). Check the size of the u-joint operating angles to determine if they meet recommendations.

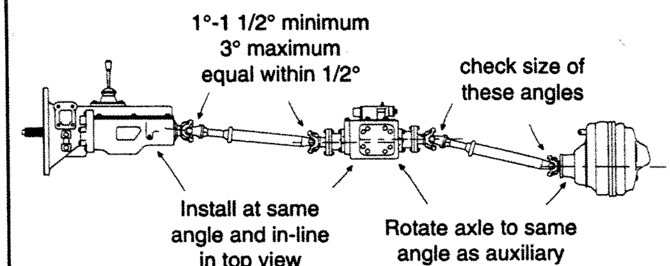


Fig. 13

If there is more than one driveshaft between the device and the rear axle, install the driveshafts as outlined earlier with a 1 to 1 1/2 degree u-joint operating angle on the input end of each shaft. Then rotate the axle so it is on the same angle as the last fixed shaft. The u-joint operating angle on each end of the last shaft will automatically be equal. (See Fig. 14)

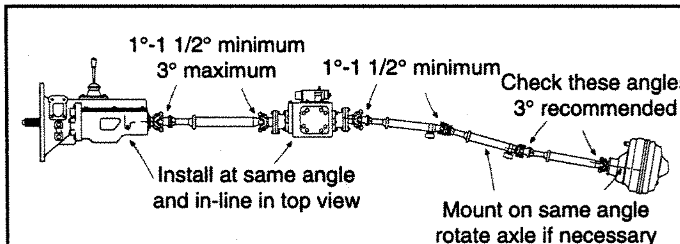


Fig. 14

Mounting A Remote-Driven Pump, Blower or Similar Device.

Remote mounted-pumps, blowers or similar devices are usually driven by a side, top or bottom mounted PTO and use an auxiliary driveshaft.

Many times these devices are mounted to the vehicle frame or cross member. The usual method of mounting, where the driven device is mounted parallel with the ground without regard to the mounted angle of the PTO, will produce a vibration that may cause failure of the PTO, pump, blower or other driven device.

Any remote driven device must be mounted parallel and in line, if possible, with the PTO.

To select the appropriate auxiliary driveshaft for these types of applications, you should consider proper torque, critical speed (which is different than the critical speed for tubular driveshafts) and angularity.

An auxiliary driveshaft must be capable of transmitting the maximum torque and RPM required by the driven equipment. For most low-torque applications operating at less than 1200 RPM, solid bar-stock constructed driveshafts are adequate. For applications requiring additional torque or RPMs, tubular shafts should be fabricated.

MAXIMUM OPERATING SPEED* BY TUBE SIZE, SOLID SHAFT SIZE, AND LENGTH

*(For speeds over 6000 RPM, contact Dana Corporation at 419-866-3900)

TUBING	MAXIMUM INSTALLED LENGTH IN INCHES FOR GIVEN R.P.M.										
Diameter & Wall Thickness W - Welded S - Seamless	Centerline to Centerline of Joints For a Two Joint Assembly or Centerline of Joint to Centerline of Center Bearing For a Joint & Shaft										
	RPM - Revolutions per Minute										
	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
1.750″ x .065″ W ...	82″	67″	58″	52″	—	—	—	—	—	—	—
1.250″ x .095″ S ...	64″	52″	45″	40″	37″	34″	32″	—	—	—	—
2.500″ x .083″ W ...	87″	70″	62″	55″	50″	45″	43″	41″	39″	37″	35″
3.000″ x .083″ W ...	—	—	85″	76″	70″	64″	60″	57″	54″	51″	49″
SOLID SHAFT DIAMETER											
.750″	42″	35″	30″	27″	25″	—	—	—	—	—	—
.812″	44″	36″	31″	28″	26″	—	—	—	—	—	—
.875″	46″	37″	32″	29″	27″	—	—	—	—	—	—
1.000″	49″	40″	35″	31″	28″	—	—	—	—	—	—
1.250″	55″	45″	39″	35″	32″	—	—	—	—	—	—

To prevent premature wear, auxiliary driveshaft breakage and possible injury to people or equipment, be aware of the critical speed of these types of driveshafts. Critical speed, explained earlier in this brochure, is different for these solid shaft and small tube driveshafts.

Refer to the chart above for maximum safe operating speed information on these types of shafts.

If the chart indicates that critical speed may be a problem, use multiple shafts. Be sure to use support bearings where necessary and set up the true u-joint operating angles as indicated earlier in this brochure.

As with all driveshafts, auxiliary driveshafts should be carefully installed to minimize vibrations caused by incorrect u-joint operating angles, should be capable of absorbing shock loads and should be capable of changing length as needed.

SPECIAL NOTES REGARDING AUXILIARY DRIVESHAFTS:

⚠ WARNING

Working on or near an auxiliary driveshaft when the engine is running is extremely dangerous and should be avoided. You can snag clothes, skin, hair, hands, etc. This can cause serious injury or death.

- Shut off engine before working on power take-off or driven equipment.
- Do not go under the vehicle when the engine is running.
- Do not engage or disengage driven equipment by hand from under the vehicle when the engine is running.
- Fasteners should be properly selected and torqued to the manufacturers specifications.

If a setscrew protrudes above the hub of an end yoke, you may want to replace it with a recessed (Allen-type) setscrew.

- If you decide that a recessed setscrew does not have enough holding power for your application and you must use a protruding setscrew, be sure no one can come in contact with the rotating driveshaft or the protruding setscrew.

Exposed rotating driveshafts must be guarded!

Lubricate auxiliary driveshafts according to manufacturers specifications.

Refer to the list below for other Spicer literature that may help you in the application, fabrication and installation of all types of driveshafts.

Form Number	Description
3264-*	Spicer Universal Joints and Driveshaft Service Manual
U330	Spicer Auxiliary Power Driveline components
J310-*	Spicer Driveshaft Speed Calculator
3119-*	Spicer Driveline Components Troubleshooting Guidelines

* Most current issue will be sent

To order Spicer driveshaft literature contact:

Drivetrain Service Division
Dana Corporation
P.O. Box 321
Toledo, OH 43697-0321