Modified Vehicle Engineering

BULLETIN

Body Builder Advisory Service:
1-800-635-5560

QVM
QUALIFIED VEHICLE MODIFIER PROGRAM

QVM Bulletin No. Q-14 **Revised: August 31, 1994**

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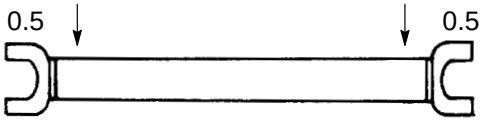
GUIDELINES FOR MODIFYING LIGHT TRUCK DRIVELINES:

Improper driveline modifications have been found to influence service claims for transmission damage, premature wear-out of universal joints and increased noise and vibration. When modifying a driveline, use the following to help ensure proper driveline integrity. Although these guidelines cover most immediate concerns, they are not comprehensive. The reader is encouraged to further consult the references listed on page 8.

Refer to page 5 for common “things gone wrong” found on vehicles with modified drivelines to quickly identify problem areas in the process.

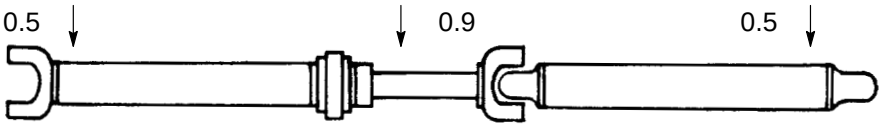
GUIDELINE — DRIVELINE BALANCE

A. INDIVIDUAL DRIVESHAFTS: Maximum imbalance of 0.5 ounce-inch at both ends.



B. MULTIPLE DRIVESHAFT SYSTEMS SHOULD BE SYSTEM-BALANCED

1. TWO-PIECE DRIVESHAFT SYSTEMS: Maximum imbalance of 0.5 ounce-inch at both ends of the system, and 0.9 ounce-inch at the center of the system where the shafts are joined.



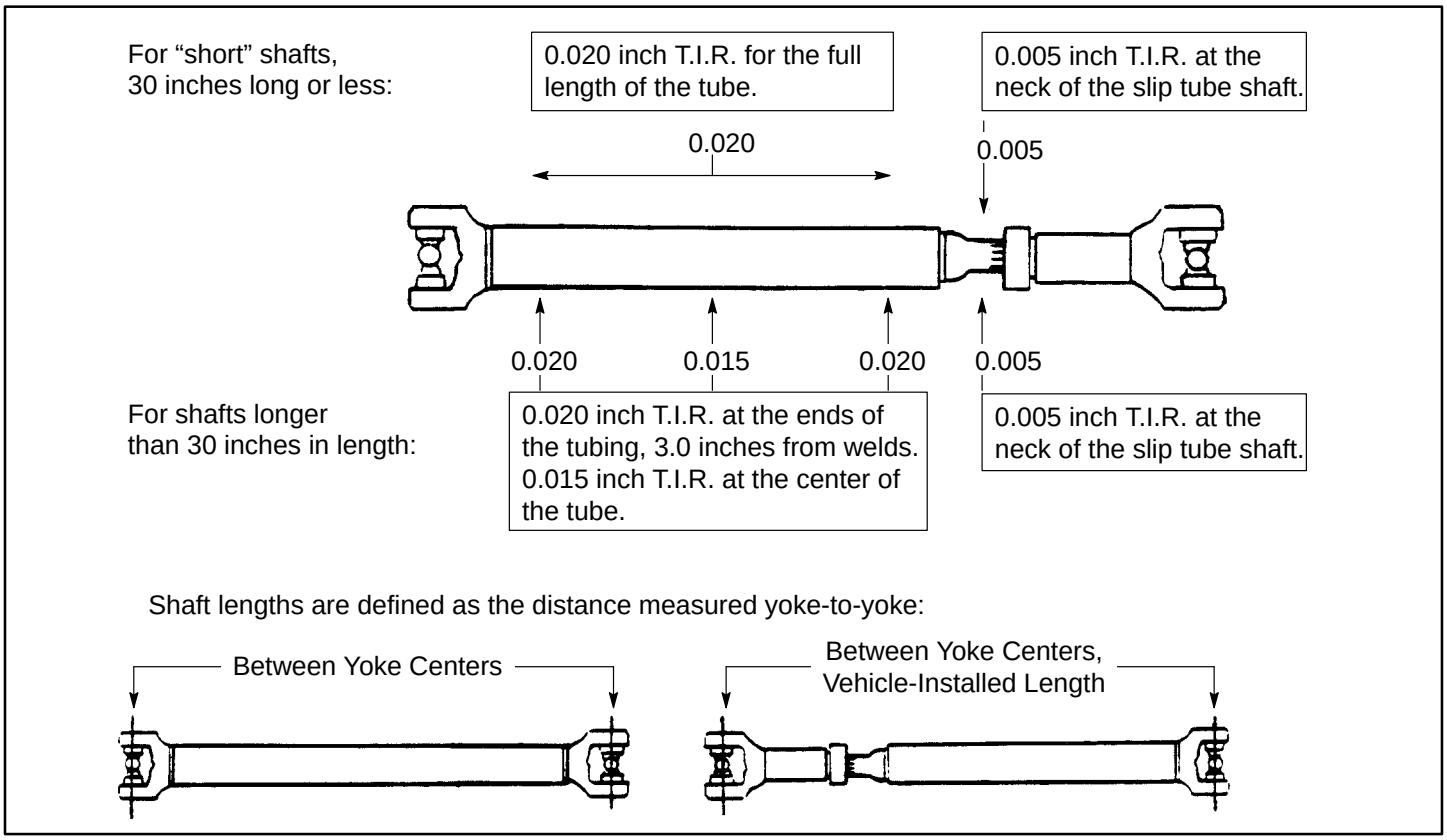
2. THREE-PIECE DRIVESHAFT SYSTEMS: System-balance two of the shafts as in “B”, then assemble the third after it has been balanced individually as in “A”.

C. Balancing of the driveshaft, or system, should be done at 3,000 rpm.

D. Balance weights should be placed within 3.0 inches from the ends of the driveshaft tube, and no closer than 1.0 inch from a weld.

In general, limit the amount of balance weight to approximately 3 ounces or less at each end of the shaft. If excessive weight is required for balance, it is likely that the shaft is distorted beyond the runout specifications and it should not be used. Compare the shaft runout against the specifications listed below to determine if any given shaft is worth balancing.

GUIDELINE — RUNOUT LIMITS FOR AN UNBALANCED DRIVESHAFT (T.I.R. — Total Indicator Reading)



GUIDELINE — COUPLING SHAFT & DRIVESHAFT DIAMETERS, AND SIZING OTHER COMPONENTS

If the shaft length is:	Then the minimum shaft diameter should be:
0 to 51 inches long	> 3.0 inch
Up to 55 inches long	> 3.5 inch
Up to 59 inches long	> 4.0 inch

TO MEET MINIMUM SHAFT QUALITY REQUIREMENTS, THE SHAFT SHOULD BE MADE FROM COLD-ROLLED STEEL, 0.083-INCH MINIMUM THICKNESS; WELD SEAM TO FORM TUBE.

Refer to the Dana/Spicer "Driveline Selector Guide" for instruction on the proper sizing of driveshafts, joints, and other components.

GUIDELINE — DRIVELINE ANGLES

After vehicle build is complete, the driveline angles must meet the following “rules”, both at unloaded, and fully-loaded, vehicle attitudes.

RULE #l: The NET OPERATING ANGLE, at any individual joint, must be at least 1/2 degree, and not exceed 3 degrees.

The NET OPERATING ANGLE (Θ) at any one joint is the combination of the joint angles in both the side view and the plan (top) view.

This NET OPERATING ANGLE (Θ) equals:

$$\sqrt{[\text{plan view angle}]^2 + [\text{side view angle}]^2}$$

By example, using Figure 1:

The NET OPERATING ANGLE at JOINT A = (Θa) = $\sqrt{[0]^2 + [\text{angle-a}]^2}$ ≥ 0.5° ≤ 3.0°

The NET OPERATING ANGLE at JOINT-B = (Θb) = $\sqrt{[\text{angle-x}]^2 + [\text{angle-b}]^2}$ ≥ 0.5° ≤ 3.0°

The NET OPERATING ANGLE at JOINT-C = (Θc) = $\sqrt{[\text{angle-x}]^2 + [\text{angle-c}]^2}$ ≥ 0.5° ≤ 3.0°

Symbol (≥) means: greater-than or equal-to.
Symbol (≤) means: less-than or equal-to.

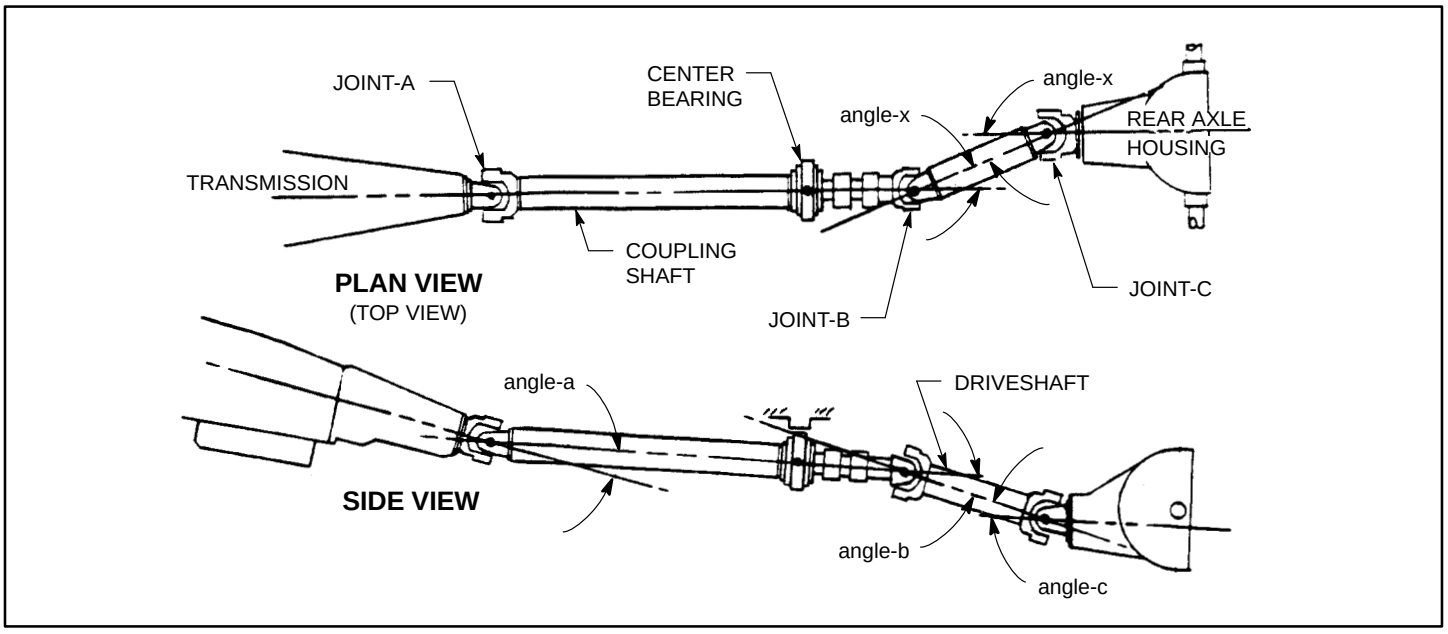


FIGURE 1

GUIDELINE — DRIVELINE ANGLES (continued)

RULE #2: The combination of NET OPERATING ANGLES, throughout the whole driveline, must "cancel." It is preferred that the NET OPERATING ANGLES at either end of a shaft be within 1 degree of each other. But, at a minimum, the following formulas must be satisfied for sufficient "cancellation" to occur:

For a 1-shaft driveline: (2-joint) $\sqrt{\Theta a^2 - \Theta b^2} \leq 3.0$

For a 2-shaft driveline: (3-joint) (as exemplified in Figure 1) $\sqrt{\Theta a^2 - \Theta b^2 + \Theta c^2} \leq 3.0$

For a 3-shaft driveline: (4-joint) $\sqrt{\Theta a^2 - \Theta b^2 + \Theta c^2 - \Theta d^2} \leq 3.0$

RULE #3: The center bearing mounting bracket, surrounding the rubber insulator, must be 90 ± 3 degree to the center bearing. In other words, no more than 3 degrees of misalignment can be absorbed by the rubber surrounding the center bearing. See Figure 2.

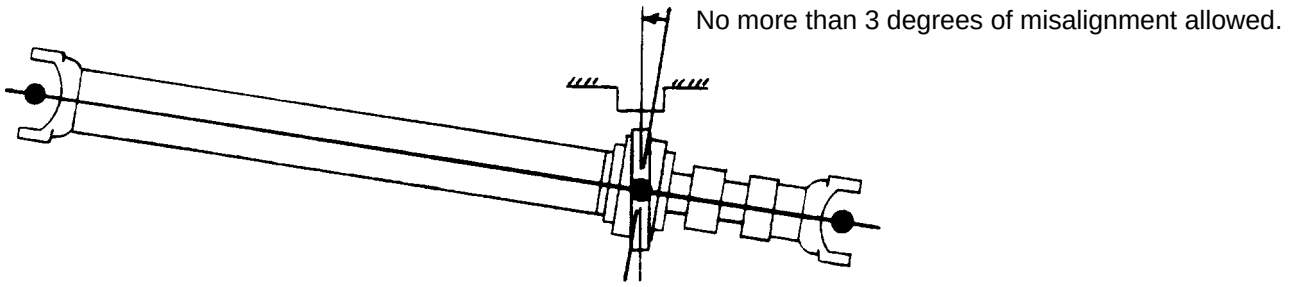
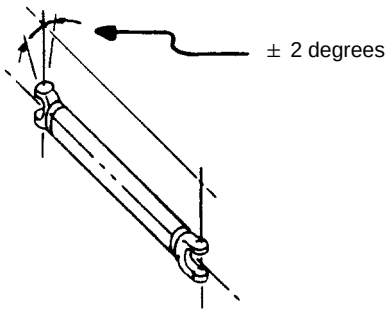


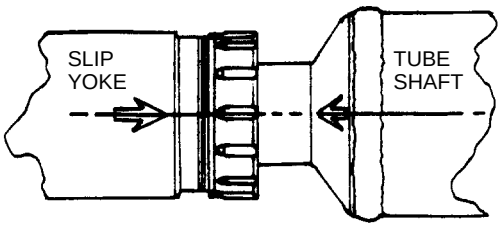
FIGURE 2

GUIDELINE — DRIVELINE COMPONENT PHASING

A. Ensure that u-joints are in-line to within ± 2 degrees.

B. Ensure matching alignment arrows between slip yoke and tube shaft.





Observe alignment arrows stamped on parts. If there are no alignment marks then add them before disassembly to ensure proper phasing alignment of shaft and yoke.

COMMON "THINGS GONE WRONG" ON MODIFIED DRIVESHAFTS:

- "Balanced" shafts on modified vehicles having over four times the maximum imbalance allowed by this guideline.
- Muffler pipe used to make driveshafts (poor quality pipe stock displaying non-uniform metal thickness, out of round cross section, and poor corrosion resistance).
- Too many weights used for balance.
- Lengthened driveshafts that are not increased in diameter when necessary.
- Universal joints that are not upgraded when necessary.
- Excessive pinion angles on modified rear suspensions.
- Excessive universal joint operating angles.
- Universal joints that are not in phase or installed crooked to the shaft.
- Alignment arrows not matched on slip yokes.
- Improper electrical grounding of eddy current brake retarders.

Poor driveline modifications have been made for years. These modifications often set up powerful vibrations in the driveline that pound and bend the critical components attached to the shafts (universal joints, transmissions, and axles). Frequent universal joint replacements, cracked transmission housings, and needless (and useless) front-wheel alignments and balances are often attributable to poor driveline modifications. The C6 automatic transmission appeared to be relatively indifferent to driveshaft concerns. However, the E40D transmission has internal components that are more sensitive. Therefore, adherence to the guidelines in this bulletin is necessary to maintain the reliability of modern drivelines.

MULTIPLE PIECE DRIVESHAFTS AND SYSTEM BALANCE:

System balancing means assembling the entire driveline, with universal joints, and placing this complete assembly in the balancer. This procedure is required with two-piece driveshafts. However, it may be impractical with driveshafts of three or more sections. In these cases, it is permissible to limit the system balance to two segments at a time.

BALANCE SPEED:

Most small shops making driveshafts for body builders only have balancers that spin up to 500 rpm. Ford driveshafts are balanced at 3000 rpm, mainly to find damaging vibration resonances measurable only at these higher speeds. Vehicle drivelines can see rotational speeds of over 5000 rpm in normal use. An imbalance beyond specification at this speed can be destructive to the drivetrain. It is, therefore, recommended that the vehicle modifier pursue actions that ensure balance accuracy to 3000 rpm. The following suggests ways in which the vehicle modifier can meet this recommendation.

a. Dana Corporation is a possible source for driveshafts and associated components that meet Ford specifications. Their address and telephone numbers are listed in the "REFERENCES" section of this bulletin.

b. The following must be followed and is particularly critical if only a 500 rpm shaft balance is available:
   - Use a straight shaft with uniform metal thickness.
   - Use only high tolerance universal joints, as supplied by the original equipment vehicle manufacturer. (Joints from automobile parts stores are not likely to meet the required tolerances.)

EDDY CURRENT BRAKE RETARDERS:

The duty cycles of brake retarders add more work to the drivetrain (through more severe torque reversals) and require more emphases on maintenance and the quality of new and replacement parts. The retarder supplier and the vehicle modifier have the shared responsibility for ensuring that the components meet or exceed OEM quality levels. They must ensure that the driveline components (such as the universal joints) are adequately sized so that the completed driveline affected by the retarder maintains OEM reliability. Use of the "Spicer Drivetrain Selector Guide" is recommended for help in determining the proper sizing of driveline parts.

Do not add an electric ground strap between the vehicle frame and the transmission housing or support crossmember. Excessively high current has been found to run through the E40D transmission during cranking and braking when the retarder is not grounded directly to the frame. This high current results in internal transmission damage. Follow the grounding instructions in the QVM Ambulance Guide or the Motor Home and Transit Bus Guide.

MAXIMUM UNIVERSAL JOINT OPERATING ANGLE:

Universal joint operating angles can be quite high, sometimes as high as 12 degrees. But to get a vehicle to operate successfully above 3 degrees often requires larger universal joints, double cardan or constant velocity joints, or restrictions on operating speed. A reduction in universal joint life becomes noticeable when they are operated at more than 3 degrees if precautions are not taken.

An input shaft, rotating at a constant speed, connected with a single cardan joint to a driven shaft will introduce no angular acceleration that could cause a vibration if the shafts are in-balance and “in-line” (zero angle between them). When there is an angle between them and the input shaft is turning at a constant speed, the driven shaft is forced to continuously accelerate and decelerate, twice per revolution, creating a vibration. If the speed changes are small, the vibration is not objectionable. The guidelines in this bulletin limit driveline angular acceleration to a maximum of 400 radians per second. This is the requirement for all Ford light trucks. (SAE specifies 500.) Some modified drivelines have been measured at over 11,000 radians per second causing driveline failures at very low mileage.

FRAME SIDE RAILS FOR REFERENCE ANGLES:

The long straight frame rails on an F-Super Duty stripped chassis are suitable for use as an angle reference. Specific instructions published for this vehicle which ask the modifier to use the frame rail as a reference should be obeyed. However, this bulletin and the referent Dana literature do not require the use of a frame reference angle. All driveline angles are measured relative to each other.

Driveline angle measurements should be made with the vehicle supported by the tires and resting on a level surface. Avoid hoisting a vehicle by the frame, since this will distort the chassis enough to make any measurements inaccurate.

MATCH MOUNTING DRIVESHAFTS TO THE REAR AXLE:

The runout is measured on OEM rear axle input shafts and the maximum measurement is marked with a yellow dot on the yoke or pilot bearing flange. The OEM driveshafts also are marked with a yellow dot on the “light” side. When the parts are assembled, the marks are aligned to aid the overall system balance. Vehicle modifiers should look for these dots and maintain this match when the drivetrain is reassembled after modification. Remanufactured or modified driveshafts should also have their “light” sides matched to the yellow dot on the axle.

DRIVELINE VIBRATION DAMPERS:

Driveline vibration dampers are sometimes added to driveshafts or axles to eliminate noise and vibration harshness (NVH). If the chassis has these devices when it is received, they should be retained on the modified chassis.

USE OF DOUBLE CARDAN UNIVERSAL JOINTS FOR GREATER DRIVE ANGLES:

In general, these joints can allow increased drive angles up to as much as 8 degrees. However, the use of this type of universal joint at the rear of a coupling shaft will prevent cancellation from occurring at the forward end of the shaft. Therefore, the single cardan joint must still be maintained at less than 3 degrees (less than 2 degrees is preferred).

GENERAL COMMENTS:

It is good practice, for any chassis that will have a driveline modification, to measure and record the driveline angles in each of the following conditions for later comparison.

a. The chassis as first received from Ford (note that the drive angles may not conform exactly to this bulletin in this incomplete condition).
b. The completed vehicle, unloaded.
c. The completed vehicle loaded to GVWR with maximum front GAWR.
d. The completed vehicle loaded to GVWR with maximum rear GAWR.

Do not over torque the universal joint fasteners. In some designs, the end caps can be distorted, causing premature failure. The Ford Light Truck Shop Manual lists the correct torque ranges to use for the various universal joint designs.

REFERENCES

Spicer Universal Joints and Driveshafts — Service Manual

Servicing the Driveshaft
Balance, Runout, and Operating Angles
How to Measure Angles
Order Form for the “Spicer Drivetrain Selector Guide”

Spicer Driveline Components — Troubleshooting Guideline

Causes and Solutions to Field Problems
Measuring and Calculating Operating Angles
Measuring and Calculating Universal Joint Angle Cancellation

Dana/Spicer Driveline Support Hot Line: 800-666-8688

A general “clearing house” for your driveline questions. Telephone personnel will further direct you to the appropriate activity, based on your question.

Dana Driveline Service Address:

Dana Corporation
Driveline Service Division
Post Office Box 320
Toledo, Ohio 43619
Telephone: 419-866-3900

If you have any questions concerning any issue, please call the **Ford Body Builders’ Advisory Service** on 800-635-5560.

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