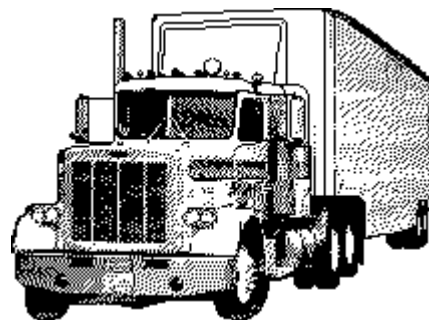
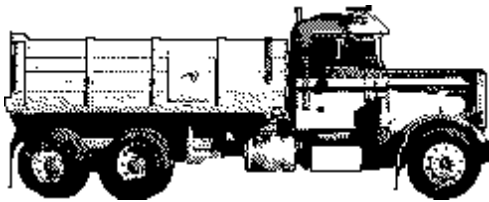


Section C

TAILSHAFTS



HEAVY VEHICLE MODIFICATIONS**1. SCOPE**

This Section relates to the fitting of tailshafts.

It outlines the minimum design and installation requirements for the fitment of modified tailshafts on heavy vehicles. It covers modifications to single, two-piece and three-piece tailshafts.

2. GENERAL INFORMATION

Alterations to tailshafts are usually necessary when modifications are performed on the wheelbase and/or chassis, engine and/or gearbox, or the axle configuration.

The tailshaft assembly's principal function is to transfer torque from the gearbox to the drive axle(s). The tailshaft must be capable of transmitting the maximum driveline torque and rotating at the maximum driveline speed without causing any undue vibration or reduction in the working life of any components.

Driveline torsional vibration is a major consideration as the torsional vibration characteristics of the driveline could be affected by shaft modification and could result in unacceptable vibration, tooth loading etc. This can apply especially when the wheelbase is reduced.

If possible, the vehicle should be modified to a standard specification offered by the manufacturer to enable the use of a standard driveline layout. However, if it is not possible to use a standard manufacturer's specification, then either the vehicle manufacturer's recommendations for tailshaft alterations or this section of this National Code of Practice should be followed.

The safety implications of tailshaft modifications must be understood. The rotating tailshafts of a heavy vehicle contain a high level of energy, and their accidental failure may cause considerable damage and possible injury. Failure may result from incorrect selection, design or construction, therefore any modification must be made with great care.

The major safety requirement is the prevention of shaft 'whirling'. In practice, no rotating shaft is in perfect balance or alignment and, depending on the 'out of balance' and the flexibility of the end supports, some vibration will be present. As the rotation speed approaches the 'critical' speed of the shaft, the imbalance will result in increasing lateral deflection or 'whirling' and possible self destruction. To prevent this, the shaft length and stiffness must be chosen to give a 'critical' speed, which is at a safe margin above maximum operating speed.

3. ADR's AFFECTED

Nil.

4. AFFECTING MODIFICATIONS

Modifications that would affect tailshafts include:

- Changes in wheelbase.
- Changes in type or configuration of power plant, transmission and/or transfer cases and drive axles.
- Changes involving maximum shaft speeds or torque.

HEAVY VEHICLE MODIFICATIONS**5. GENERAL REQUIREMENTS**

For the tailshaft to be capable of transmitting the maximum driveline torque, the size of the tailshaft components including universal joints, flanges, centre bearings, tubing diameter and wall thickness, and tailshaft length must be within the tailshaft manufacturer's specifications.

For the tailshaft to be capable of operating at the maximum driveline speed without causing any undue vibration or reduction in working life of any components, the driveline must have a layout such that the working angles of the universal joints and the lengths of the tailshafts are within the tailshaft manufacturer's specifications.

A high standard of workmanship must be attained in installing a shaft to prevent vibration or mechanical failure with resultant damage to other components. Because of the special equipment and expertise required to accurately align and dynamically balance the shaft assembly, this work, including work on inter-axle shafts, will usually be required to be carried out by specialist workshops.

It is recommended that a tailshaft safety loop be fitted to restrain the front end of each tailshaft on category NB1, MD3, MD4 and ME vehicles, in case of shaft failure.

Vehicles that had loops fitted as original equipment must retain safety loops and have safety loops on additional shafts.

Note: The fitting of tail shaft loops is mandatory for ADR 58/.. complying vehicles.

6. TAILSHAFT SELECTION**6.1 General**

The variables that must be determined in the design of a tailshaft are:

- length(s) of shaft(s).
- size (diameter and wall thickness) of tubing.
- type of universal joints or flanges.
- position of centre bearing(s), if applicable.
- operational angles of the universal joints.

6.2 Design Data

The Information required to design the tailshaft layout is:

- the position of the centre of the yoke or flange for the gearbox output.
- the position of the centre of the yoke or flange for the rear axle input with the axle in the chassis unladen condition and with the axle in the chassis fully laden condition.
- the position of the centre bearing(s), (if applicable).
- the angle of inclination of the gearbox (to the horizontal).

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- the angle of inclination of the rear axle (to the horizontal).
- the maximum tailshaft speed.
- the maximum driveline torque.

6.3 Length of Shafts

All rotating shafts deflect during rotation. The magnitude of this deflection is dependent on the shaft speed and the stiffness of the shaft.

The stiffness of the shaft is dependent on the length of the shaft, the tube diameter and the tube wall thickness. The rotating speed, which corresponds with the natural frequency of the shaft in bending and produces a resonance that can result in the bending and sometime destruction of the shaft, is called the 'critical' speed. All installations must be designed to have the first critical speed of all shafts comfortably above the maximum operating speed.

The safe operating speed for shafts in straight normal drives is not greater than 85 per cent of the 'critical' speed. As a guide to safe working speeds and lengths for various tube sizes, refer to the nomogram in Figure 1. For universal joint angles up to 4 degrees, the safe operating speed is not greater than 65 per cent of the first 'critical' speed. For larger universal joint angles, the safe operating speed should be taken as 50 per cent of the first 'critical' speed.

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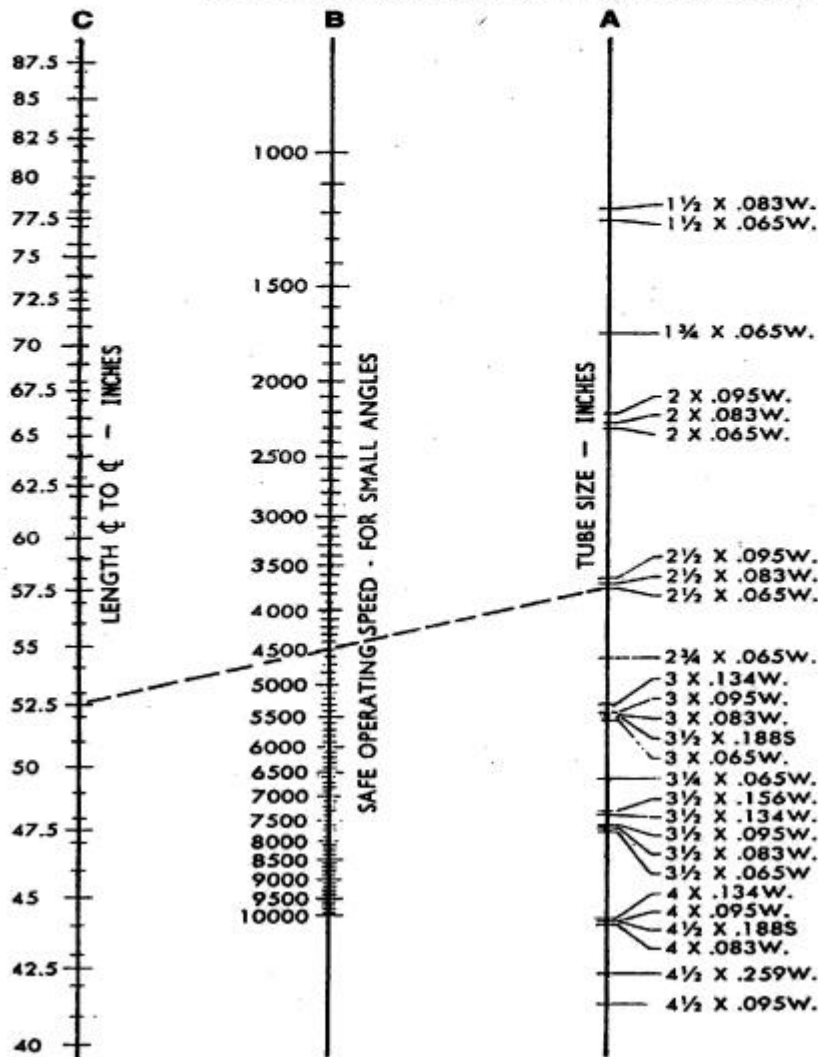
Figure 1

Nomogram for Determining Safe Operating Speed of Tailshaft by Tubing Size and Length

Length 'C' for two joint assembly - C/L to C/L of joints
for joint and shaft - C/L of joint to C/L of centre bearing.

Procedure:

1. Locate tailshaft tube size on line A.
2. Locate tailshaft length on line C.
3. Connect points on lines A & C with straight line.
4. Read safe operating speed on line B at intersection point



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The safe operating speeds shown on the nomogram are based on a critical speed less approximately 15 per cent, (i.e. assuming zero universal joint angles) and the lengths shown are from centre line to centre line of the universal joints. When a centre bearing is used, the shaft length used for critical speed determination may be taken as the distance between the centre line of the centre bearing and the centre line of the universal joint.

The maximum operating speed of the tailshaft is the highest shaft speed that the vehicle is likely to generate in service. This must be assumed to be higher than road speed at maximum engine speed in top gear (with transmission over-drive(s), if applicable) to take into account downhill coasting. The following maximum speeds are recommended for shaft design calculations:

- Light duty trucks - 160 km/h (100 mph);
- Heavy vehicles - 135 km/h (85 mph); or
- 20 per cent above governed road speed, whichever is the lesser.

The shaft speed for the appropriate road speed is calculated using the rolling circumference of the tyres and the vehicle final drive ratio. The shaft speed from engine speed considerations is calculated by multiplying the maximum engine speed by the highest gear ratio of the gearbox. The maximum engine speed should be presumed to be 120 per cent of the governed engine speed, in the case of diesel engines, and 120 per cent of the maximum recommended engine speed, in the case of petrol engines. This is to take into account the case of downhill running or downhill coasting.

Normally, the size of tubing, universal joints and flanges and/or yokes for the modified tailshaft would be the same as those components in the original tailshaft. If, however, modifications to the vehicle result in a large change in transmitted torque (e.g. fitting of a larger engine), then the tailshaft manufacturer's guidelines for the selection of components should be followed.

Example:

Find the maximum safe length of a tailshaft with tube size 3.5" (89 mm) outside diameter and 0.065" (1.65 mm) wall thickness, transmitting torque from an engine with a governed speed of 2400 rpm and a gearbox with a maximum gear ratio of 0.85:1 (over-drive).

- Maximum tailshaft speed = $2400 \times 120\% \times \frac{1}{0.85} = 3388 \text{ rpm}$.
- From the nomogram, the maximum safe length would be 72" (1830mm).
- Whilst the nomogram may indicate that shaft lengths up to 2 m or 80" are acceptable, practical considerations in the construction of the shafts limit the maximum length of shafts to 1.5 m or 60". Lengths in excess of 60" may be acceptable, in special circumstances.

HEAVY VEHICLE MODIFICATIONS**6.4 Operating Angles of Universal Joints**

Should a suitable manufacturer's standard driveline layout not be available, it will be necessary to determine the operation angles of any proposed driveline layout to ensure the driveline and associated components have a good working life. Knowing the positions of the yoke or flange of the gearbox output and the drive axle input, and the inclination angles of the gearbox and drive axles, the operating angles of the universal joints may be derived.

In the case of a single tailshaft driveline, the operating angles at the universal joints may only be adjusted by changing the inclination angle of the engine/gearbox or drive axle. In the case of a multi-piece driveline, the operating angles at the universal joints may be adjusted by changing the inclination angles of the tailshafts. This is achieved by changing the height of the centre bearing(s).

The operating angle of the universal joint is calculated by subtracting the inclination angle of the gearbox from the inclination angle of the tailshaft, or the inclination angle of one tailshaft to the inclination angle of the adjacent tailshaft, or the inclination angle of the tailshaft to the inclination angle of the drive axle.

6.5 Calculation of Operating Angles

The positions of the gearbox output yoke and drive axle input yoke should be defined by horizontal (longitudinal) and vertical coordinates from a convenient datum - usually the horizontal position is defined as a distance from the front axle, and the vertical position is defined as a distance from either the upper or lower side of the chassis rail (as opposed to the distance from the ground).

Drive axles often have the input yoke transversely offset from the centre of the axle. To simplify calculations, this offset can generally be ignored, except in extreme cases, which use a very short shaft.

The horizontal position(s) of the centre bearing(s) is dependent on the placement of components suitable for the mounting of the centre bearing (cross members, etc.) and associated attachment brackets, and the length(s) of the shaft(s). To determine the position of the yoke immediately to the rear of the centre bearing, the distance from the centre bearing to the centre of the front yoke must be known.

The operational angles should be a maximum of 6 degrees for heavy vehicles and 8 degrees for light vehicles. However, vibrational problems may arise even at these angles, so to minimise this possibility and maximise the working life of the universal joints, operational angles greater than 4 degrees for heavy applications and greater than 6 degrees for light applications should be avoided.

Whilst these recommended angles of operation should not be exceeded, joints should not be allowed to operate at very low angles for extended periods, or brinelling of the journals and cups by the needle rollers may occur. To prevent the load between the needles and journals and cups being applied in the one region all the time, a minimum operating angle of 0.5 degrees should be used to ensure that the needles roll slightly.

Hence, the operating angles for universal joints should fall between 0.5 degrees and 4 degrees for heavy applications, and 0.5 degrees and 6 degrees for light applications.

A longer service life of the universal joints of the rearmost tailshaft can generally be expected if the change in operating angles of the joints can be minimised. This may be achieved by using a shaft as long as practicable, which reduces the actual change in angle of the shaft for any given axle movement.

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Depending of the type of suspension used, the angle of inclination of the drive axle may change during excursion of the axle from the unladen position to the laden position. Any change in angle should be considered when calculating the operating angle of the universal joint at the input to the rear axle.

The drive axle manufacturer's recommendations for installation angles of the axles must be followed to ensure the correct operating angles of the universal joints of the inter-axle tailshaft. In this case, installation of the inter-axle tailshaft will not be of concern to the vehicle modifier.

Note: The working angle of the forward universal joint of the interaxle shaft should be as near as possible to that of the rear universal joint.

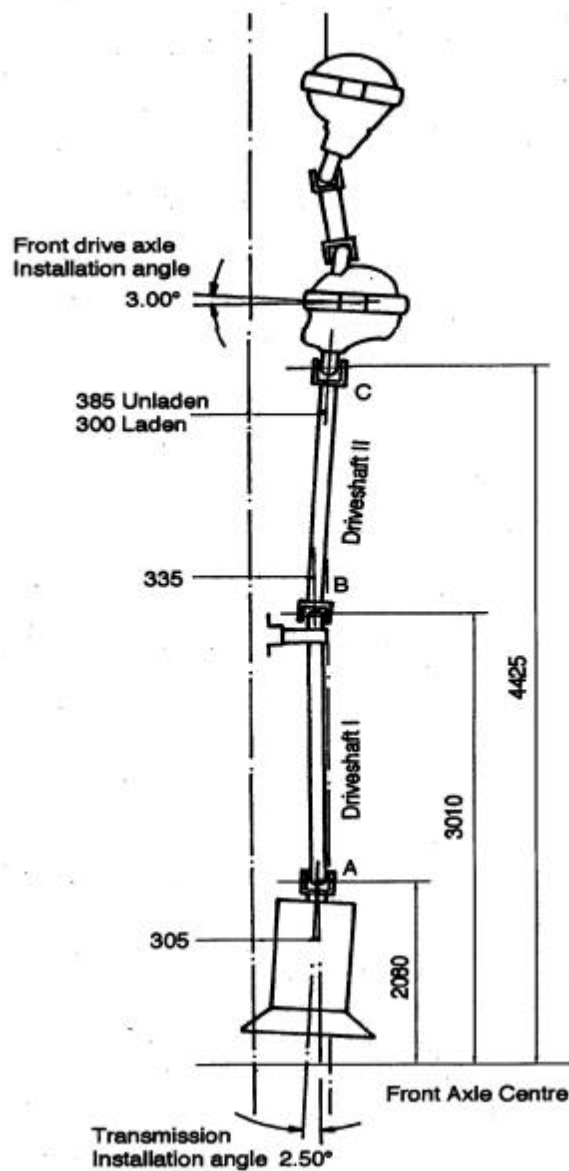


Figure 2

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Example:

Determine the working angles of the yokes in the two-shaft tailshaft shown in Figure 2. Working angles of the inter-axle tailshaft yokes will be ignored.

Tailshaft Installation Angles:

- Angle of tailshaft I = $\tan^{-1} \frac{335 - 305}{3010 - 2080} = 1.85^\circ$
(to chassis rail)
- Angle of tailshaft II in unladen condition = $\tan^{-1} \frac{385 - 335}{4425 - 3010} = 2.02^\circ$
(to chassis rail)
- Angle of tailshaft II in laden condition = $\tan^{-1} \frac{300 - 335}{4425 - 3010} = -1.42^\circ$
(to chassis rail)

Operating angles at universal joints:

- Operating angle at A = $2.50^\circ - 1.85^\circ = 0.65^\circ$
- Operating angle at B in the unladen condition
= $1.85^\circ - 2.02^\circ = -0.17^\circ$
- Operating angle at B in the laden condition
= $1.85^\circ - (-1.42^\circ) = 3.27^\circ$
- Operating angle at C in the unladen condition
= $2.02^\circ - 3.00^\circ = -0.98^\circ$
- Operating angle at C in the laden condition
= $-1.42^\circ - 3.00^\circ = -4.42^\circ$
- It should be noted in the above example that the operating angle at point B, 0.17 degrees, is less than the recommended minimum of 0.5 degrees.
- This may be rectified by adjusting the height of the centre bearing. However, when the height of the centre bearing is changed, the operating angles at points A, B and C will all change, and must be recalculated and checked.

6.6 Non-Uniformity - Nomogram Approach

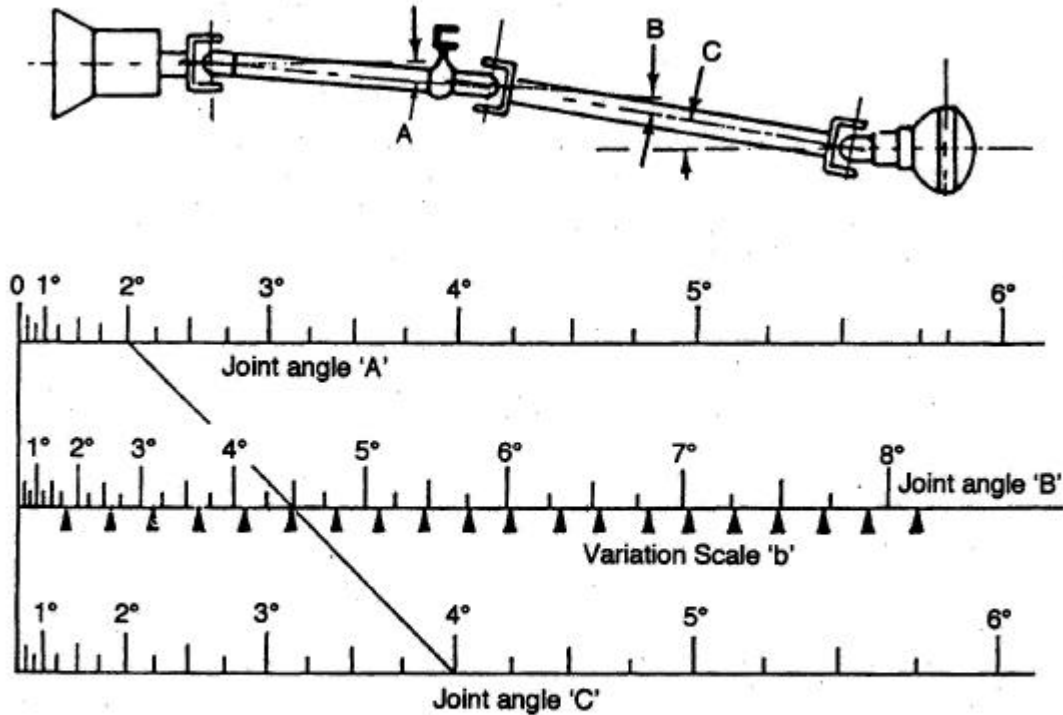
For satisfactory operation with a three joint, (two shaft) system, special angular relations between the joints must be maintained. Two approaches to evaluating the suitability of a layout are offered. The first is shown in the nomogram in Figure 3.

This nomogram can only be used if all joint angles are approximately in the same plane.

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Using the nomogram, join angles A and C with a straight line and provided the joint angle B is within 3 marks on the variation scale 'b', then cancellation of the angular acceleration is within the accepted limits and should prove satisfactory.

Figure 3 Universal Joint Angles – Three Joint Drivelines



e.g. If Joint A is 2° and Joint C is 4°, Joint B should be 4.5°.
This can be 4.1° to 4.8° without any adverse effect on its operations

6.7 Non-Uniformity - Calculation Approach

This approach results in a qualitative measure of a driveline installation based on the operational angles of the universal joints. It is related to the accelerations of tailshaft components, which are inevitable when the operational angles of the universal joints are greater than zero. The formula for calculation of the non-uniformity is:

- Non-uniformity, $N = (\sin A \times \tan A) - (\sin B \times \tan B) + (\sin C \times \tan C) - (\sin D \times \tan D) + \dots$

where A, B, C, D, ... are the operational angles in degrees of the universal joints starting from the gearbox and working back to the rear axle input.

For simplicity, only the angles in the horizontal plane are considered.

From the previous example the working angles of the driveline in the laden condition are:

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Gearbox output: A = 0.65 degrees

Second Universal: B = 3.27 degrees

Rear axle input: C = 4.42 degrees

Therefore, Non-uniformity,

$$N = (\sin 0.65 \times \tan 0.65) - (\sin 3.27 \times \tan 3.27) + (\sin 4.42 \times \tan 4.42)$$

$$= 2.83 \times 10^{-3}$$

Non-uniformity should be calculated for both the unladen and laden conditions.

The non-uniformity of a driveline layout should lie between 0 and $+ 8.0 \times 10^{-3}$, and the lower the value, the longer the expected service life of the universal joints.

The non-uniformity is a guide to driveline layout and should be used as only a secondary check after following the guidelines given in the preceding parts of this Section.

6.8 Phasing of Yokes

The universal joints should be installed in phase throughout the driveline to prevent vibration, although in some complex driveline systems “out of phasing” may be required to eliminate vibration.

6.9 Length of Slip in Slip Joints

It must be ensured that the sliding joint of the slip-shaft never bottoms out or fully extends (known as binding) under any operational conditions. All possible suspension deflections and axle rotation under torque must be considered, and the length of the shaft and amount of slip selected accordingly. The minimum spline engagement with joint extended is 1.5 x spline diameter. The minimum spline end clearance with joint contracted is 1.0 x spline diameter.

6.10 General Design and Installation Guidelines

- Support bearings are required when the distance from the transmission to rear axles exceeds the maximum length at which a particular shaft can safely operate.
- As the wheelbase increases, it may be necessary to use more than one bearing.
- The support bearing locations should be chosen to minimise the variations in angular velocity over the complete driveline and in the individual shafts.
- When shaft diameters are increased, clearances from other chassis and body components must be checked through the whole range of suspension travel.
- Support bearing adaptor brackets, if used, must be designed to provide adequate strength of attachment to the cross members and bearing housing without prejudicing the strength of these parts. The flexible bushings of the support system must not be distorted by axial misalignment.

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- Removal/Installation of Universal Joints - Before disassembly, parts should be marked to ensure that they are re-installed in phase.

7. TESTING

The vehicle, or an example if a number of similar vehicles are to be built, must be road tested on smooth and undulating surfaces under a range of mass conditions and over the whole speed range to establish that no unacceptable vibrations are present.

8. RECORDING

In the Appendices of this document are:

- Appendix 1 - Tailshaft Modification Report Sheet. This form, completed in full, should be retained by the Certifying Officer.
- Appendix C1 which:
 - Summarises the scope of modification work that may be certified under Modification Code C1.
 - Includes a list of Sections of this National Code of Practice covering other areas of the vehicle which may have been affected by the modification and which should be analysed to determine whether they, too, require re-certification.
 - Includes a checklist appropriate to Modification Code C1 that should be completed.

It is suggested that records of analysis, work records, sketches and other vehicle data, together with copies of the Report Sheet and completed checklists be retained by the Certifying Officer for at least the period specified in Part A of this National Code of Practice.

HEAVY VEHICLE MODIFICATIONS

Appendix 1

Tailshaft Modification Report Sheet				Report No.			
Vehicle Make & Model				Body Type			
General Description of Drive Line Modification							
Diagram of Drive Line Modification — (overlay new on old)							
Details		Before Modification			After Modification		
Shafts	Item No.	1	2	3	1	2	3
	Diameter						
	▲ Wall Thickness						
	Length						
	■ Max. R.P.M.						
	Safe Working Speed - Nomogram						
	Max. Torque Transmitted						
Universal Joints							
	Type						
	Rated Capacity						
	+ Installed Angle						
Support Bearing							
	Type						
	Rated Capacity						
Safety Loop		Y/N <input type="checkbox"/>	Y/N <input type="checkbox"/>	Y/N <input type="checkbox"/>	Y/N <input type="checkbox"/>	Y/N <input type="checkbox"/>	Y/N <input type="checkbox"/>
● Slip Joint(s)							
	Clearance (contracted)						
	Engagement (extended)						
● Min. Shaft Clearance to chassis etc.							
Road Test (vibration)							
▲ Only required if torque increase (transmission output) greater than 30%				+ Vehicle at half load condition			
■ At road speed: light truck 180km. Heavy truck 135kph or 20% above governed speed				● Static Tests			
Signed: _____		Date: _____		Res. No. _____			

HEAVY VEHICLE MODIFICATIONS**Appendix C1****Modification Code C1****TAILSHAFT ALTERATIONS**

Modifications that are covered under this Modification Code are:

1. Reduction in tailshaft length.
2. Increase in tailshaft length by fitting of longer tube (New full length seamless tubing must be used).
3. Redesign of tailshaft installations.
4. Upgrading of tailshaft and associated components.

Note: As manufacturing (changing the length and balancing of tailshafts) requires special skills and equipment, it is recommended that this work be performed by specialists in this field. This Modification Code is intended to be utilised for certifying the modified tailshaft installation and not for the approval of modified individual components.

Modifications that are **not** covered under this Modification Code are:

1. Increasing tailshaft length by extending the tailshaft tube i.e. cutting, sleeving and rejoining the tube.
2. Installation of a tailshaft assembly which has a torque capacity which is less than the maximum torque which is capable of being supplied by the vehicle's engine/gearbox combination.

NOTE: The modified vehicle/modifications must continue to comply with all applicable ADR's, Australian Standards or Regulations/Acts.

Outlined below are areas of the vehicle which may have been affected by the modifications and which may require recertification, testing and/or data to show compliance for the modified vehicle.

DETAIL**REQUIREMENTS**

Cross member Construction

National Code of Practice - Section H

Mounting and Aligning of Centre Bearing

National Code of Practice - Section C

Selection of Tailshaft Materials

Good Engineering Practice

Alignment of Universal Joints

National Code of Practice - Section C

Tailshaft Installation

Good Engineering Practice

HEAVY VEHICLE MODIFICATIONS

Checklist C1

TAILSHAFT MODIFICATION

If the tailshaft design, including the layout, is entirely as per the manufacturer’s specification for a vehicle identical to the modified vehicle, go to Question 1.6.

(Y=Yes N=No)
Delete if not applicable

1.0 General

- 1.1 Is the length of the tailshaft(s) within the allowable limit for the maximum tailshaft speed and maximum transmitted torque? Y N
1.2 Are the driveline components (i.e. tubing, universal joints and flanges) adequate for the transmitted torque? Y N
1.3 Are the universal joint operating angles within the recommended values under all operational conditions? Y N
1.4 Are the tailshaft yokes phased as per the driveline manufacturer’s recommendations or the National Code of Practice? Y N
1.5 Does the slip-shaft have an appropriate extended length and compressed length for all operational conditions? Y N
1.6 Is the quality of workmanship to a satisfactory standard? Y N

NOTE:If the answer to any relevant question is “NO”, the modification is not acceptable.

Vehicle Chassis No/VIN:.....

Vehicle Modifier:.....

Examined by:.....

Company (if applicable):.....

Certifying Officer No:..... Modification Certificate No:.....

Modification Plate No:.....

Signed:..... Date:.....