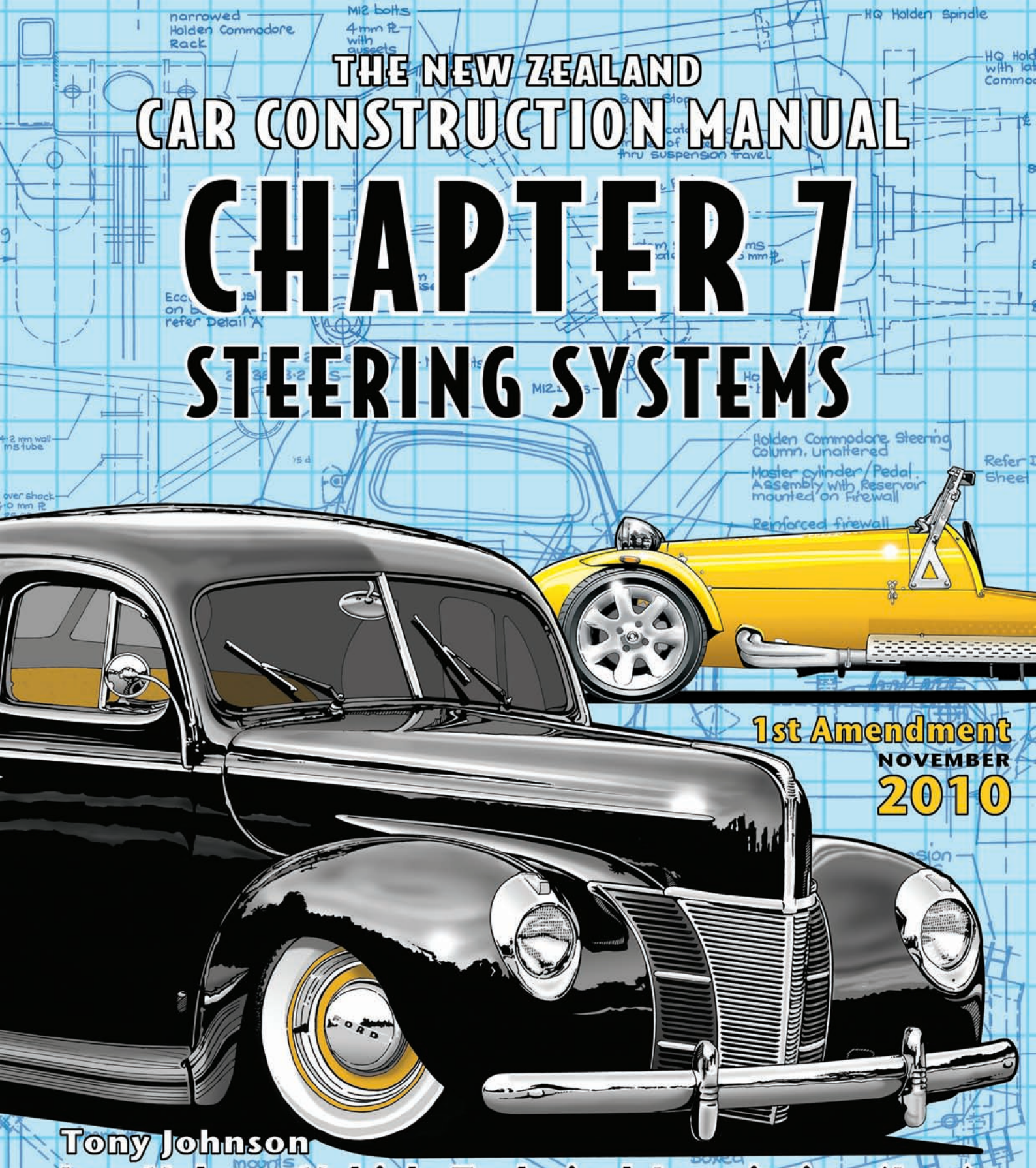
THE NEW ZEALAND

CAR CONSTRUCTION MANUAL

CHAPTER 7

STEERING SYSTEMS



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THE NEW ZEALAND
CAR
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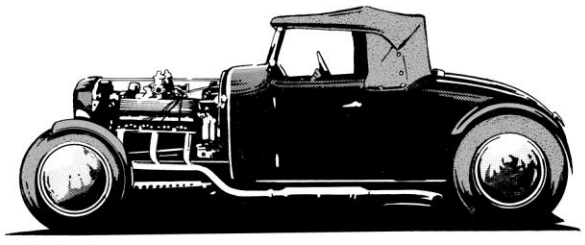

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Postal address:	P. O. Box 50-600, Porirua 5024, Wellington, New Zealand
Website:	www.lvvta.org.nz
E-mail address:	info@lvvta.org.nz

AUTHOR

The New Zealand Car Construction Manual was written by Tony Johnson of Auckland New Zealand, for the NZHRA, who originally commissioned the development of the Manual in 2002. Tony has continued to take responsibility for the on-going amendments to the Manual for NZHRA, and for LVVTA since LVVTA took ownership of the Manual in October 2010.

Tony is a self-employed illustrator, journalist, technical writer, and automotive consultant, and is a member of various car clubs and associations.

E-mail address:	autosportart@xtra.co.nz
	tony@lvvta.org.nz

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NZHRA, and its key personnel, have, and continue to since the inception of LVV certification, form the back-bone of the LVV certification system in New Zealand. LVVTA is very appreciative of NZHRA's on-going commitment and integrity.

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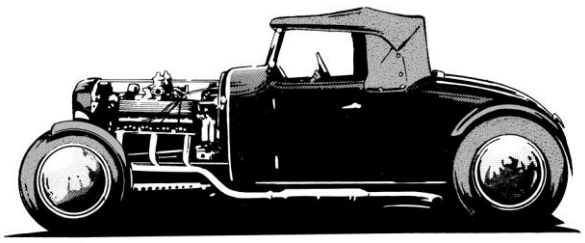

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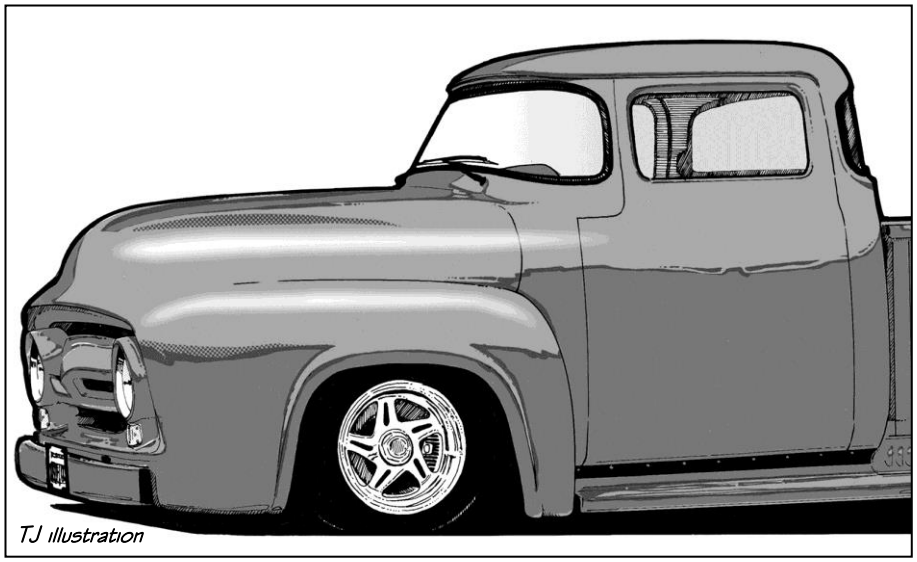
Chapter 7:

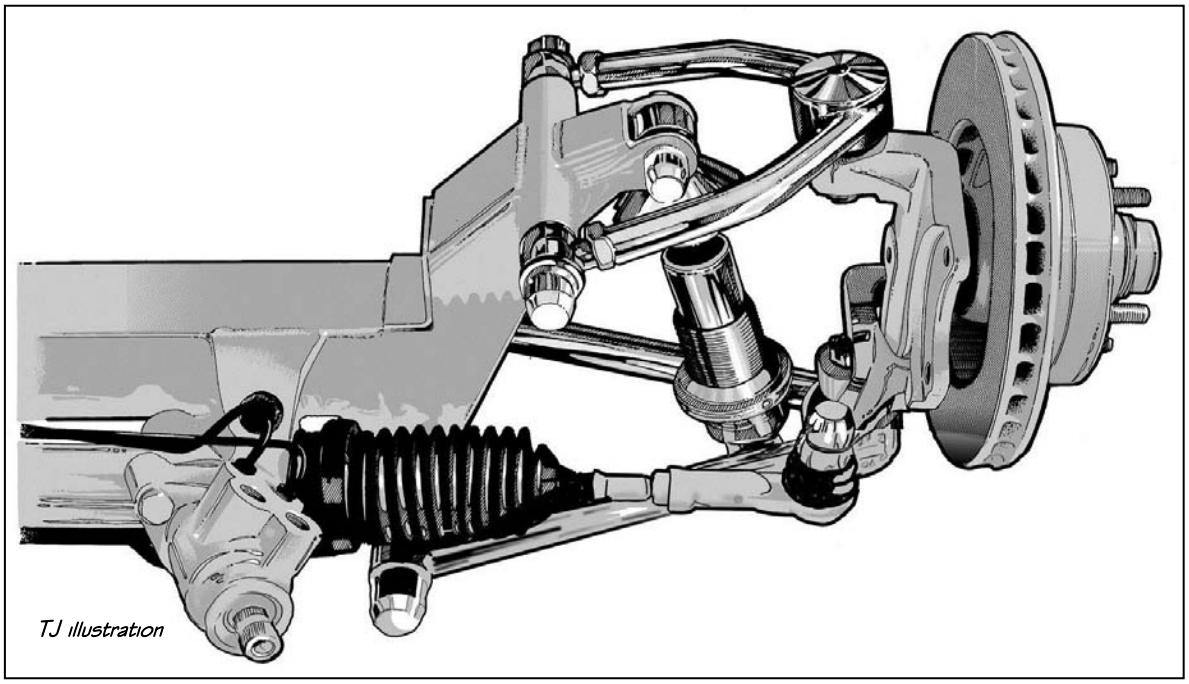
STEERING SYSTEMS



Chapter 7 Contents

Key: (for full key details, refer to 'Chapter 2 – About this Manual')

Normal type: Provisions of the NZ Car Construction Manual for all vehicles
Normal type in shaded box: Special provisions of the NZ Car Construction Manual for vehicles built or modified before specified dates
Italic type: *Extracts from any relevant LVVTA Low Volume Vehicle Standards*
Script type: Helpful hints, tips, explanations, clarifications, and interpretations
Shaded text & dotted vertical stroke in margin: Latest amendments since previous version



CHAPTER 7: STEERING SYSTEMS

Introduction:

Steering component selection, compatibility, geometry, and attachment is undoubtedly the single-most important aspect of any hobby car's design and construction. In this area, there can be no compromises. Aside from the obvious safety aspect, a well-designed steering system can make the difference between a vehicle that is, or isn't, a pleasure to drive and ride in, and compared to other parts of a hobby car, the steering system doesn't represent a big part of the overall cost. You'll never regret spending a bit of extra money or getting the right advice in this area.

In addition, this chapter sets out requirements to minimise crushing or penetrating injuries to the driver from the steering wheel and upper column in the event of a frontal impact. Note that where a production vehicle is fitted with its original unmodified steering system, the requirements in this chapter do not apply.

Steering wheel requirements:

7.1 All steering wheels

7.1.1

A steering wheel fitted to a low volume vehicle must:

(a) incorporate a continuous 360-degree steering wheel rim; and

(b) be predominantly circular in shape; and

7.1.1(b)

'Predominantly circular' allows the use of aftermarket racing-style steering wheels that have a flat bottom section.

(c) attach to a steering hub or boss that is compatible with the upper section of the steering column; and

(d) incorporate, in order to secure the steering wheel against the steering wheel hub or boss, a fastener that either:

(i) is supplied by the steering wheel manufacturer specifically for that purpose; or

(ii) is of a vibration-proof type.

7.1.2

A steering wheel that is fitted to a low volume vehicle must be of a diameter that is:

(a) not less than 245 mm (10”); and

(b) large enough in diameter to enable the vehicle to be safely steered, taking into consideration:

(i) the weight of the vehicle; and

(ii) the number of turns required to turn the vehicle from lock to lock.

7.1.3

A steering wheel that is fitted to a low volume vehicle must have no surfaces, fittings, or projections that may cause additional injury to the driver in the event of contact during an impact.

7.2 Airbag-equipped steering wheels

7.2.1

A steering wheel that incorporates a supplementary restraint system airbag that is fitted to a modified production low volume vehicle, may not be replaced by any steering wheel other than a direct factory replacement, unless either:

(a) the vehicle:

(i) is 14 years old or older; and

(ii) meets the requirements of LVVTA Low Volume Vehicle Standard 155-30 (Frontal Impact);

or

(b) the vehicle is issued with a valid LVV Authority Card, which specifies ‘Frontal impact protection system’.

7.3 After-market & non-original production steering wheels

7.3.1

A steering wheel fitted to a low volume vehicle must, other than one specified in 7.4, be either:

(a) sourced from a mass-produced vehicle; or

(b) manufactured by an after-market steering wheel manufacturer.

7.3.1(b)

Some older aftermarket steering wheels are attached to the steering hub with rivets. These wheels should not be used, as there have been several known cases where the rivets have failed.

7.3.2

A steering wheel that is manufactured by an after-market steering wheel manufacturer must either:

(a) be manufactured predominantly from aluminium; or

(b) in the case of a steering wheel manufactured from a material with more impact resistance than aluminium, be designed so as to absorb impact energy by deforming away from the upper torso in the event of contact during an impact.

7.3.2(b)

This precludes 'chain-link' steering wheels, or other wheels constructed from large non-deformable sections of material like mild steel.

7.4 Individually-constructed steering wheels

7.4.1

A steering wheel that is individually-constructed, and fitted to a low volume vehicle, must be individually approved in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc).

7.4.1

'Individually constructed' means built as a one-off by someone who is not professionally engaged in the steering wheel manufacturing industry.

7.5 Quick-release steering wheels

7.5.1

A steering wheel fitted to a low volume vehicle that is able to be removed and re-attached without the use of tools to assist entry and exit to and from the vehicle, must:

(a) self-lock into position, with no separate devices or non-integral parts of the system required to lock the wheel into its locked position; and

(b) not be able to be removed without a deliberate and firm action applied in order to achieve the removal.

7.5.1

Quick-release wheels are not recommended for road use, and should only be used where the design of the vehicle makes a quick-release steering wheel necessary for easing entry and exit.

7.6 Steering wheel hubs

7.6.1

A steering wheel hub or boss fitted to a low volume vehicle must attach to an upper section of steering column that incorporates sufficient spline depth to provide for the fitment of the hub and a vibration-proof fastener.

Steering column requirements:

7.7 Steering column positioning

7.7.1

A steering column fitted to a low volume vehicle must be located so as to enable the rim face of the steering wheel to be positioned at an angle of not less than 30 degrees from the horizontal plane. (see Diagram 7.1)

7.7.1

Vertical columns must not be fitted to newly constructed vehicles, or where a new steering system is fitted to an existing vehicle, as a vertical or near-vertical column does not enable optimum steering control.

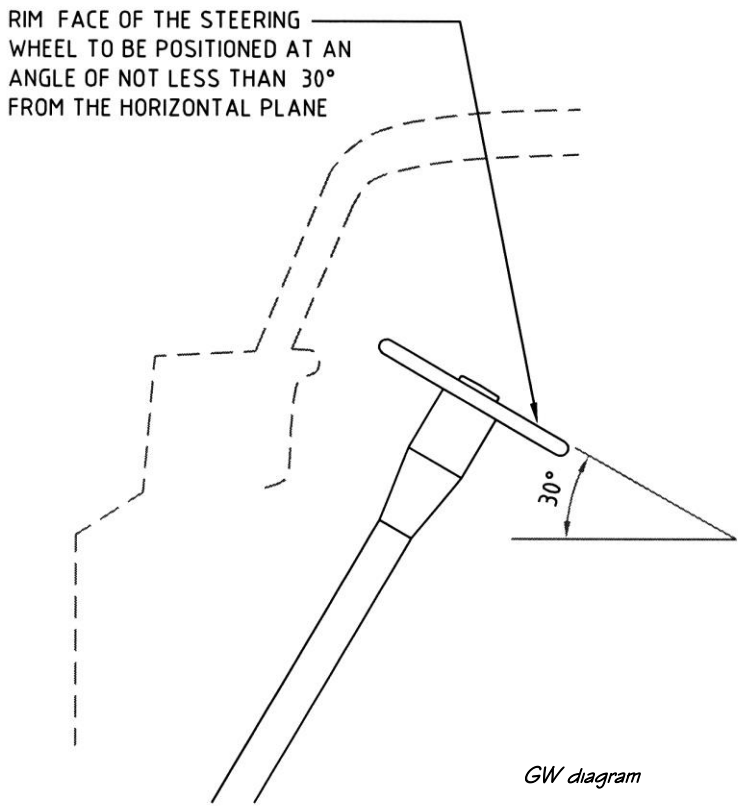


Diagram 7.1 Steering column positioning

A low volume vehicle that was built, or was fitted with a vertical steering column prior to 1992, is not required to comply with 7.7.1, and may remain in use, provided that:

(a) the rack and pinion assembly is positioned so that its angle, when viewed from both above and side-on, is within 10 degrees of parallel to the drag-link, with the wheels facing directly forward; and

(b) the vehicle can be easily steered, with no more than two and a half turns of the steering wheel required to turn the system from lock to lock.

7.7.1 (b)

1.5 turns lock to lock is considered ideal for a light-weight vehicle with a vertical steering column.

7.7.2

A steering column fitted to a low volume vehicle must not be positioned between the brake pedal and the accelerator pedal.

A low volume vehicle that was built, or was fitted with a new or changed steering system before 1992, which incorporates a steering column between the brake and accelerator pedals, is not required to comply with 7.7.2

7.8 Steering column modification & attachment

7.8.1

A steering column fitted to a low volume vehicle must be adequately supported at both the upper and lower ends of the column, to ensure that the column remains secure throughout all normal vehicle operation.

7.8.2

No safety-critical part of a steering column may be welded, unless the welded section is the vehicle manufacturer's unmodified original equipment.

7.8.2

A steering column fitted to a low volume vehicle must not have any part, other than an outer housing which is not relied upon for the directional control of the vehicle, welded, unless the welded section is the vehicle manufacturer's unmodified original equipment.

Steering universal joint, coupling, & intermediate shaft requirements:

7.9 Steering universal joints

7.9.1

A change of direction between a steering column, and a rack and pinion or box, in a low volume vehicle, must only be effected by steering universal joints, which:

7.9.1

Unless a vehicle manufacturer's original equipment operating in the same application for which it was originally designed, a universal that attaches by way of a hexagon, square, keyway, or cotter pin, is to be considered an industrial or agricultural unit, and not automotive, and therefore must not be used in any hobby car application.

(a) are purpose-designed universal joints for automotive applications, manufactured by a recognised automotive universal manufacturer; and

(b) except in the case of a universal joint that is a production vehicle manufacturer's original equipment:

(i) are accompanied by written specifications and application information, provided by the manufacturer of the universal joint; and

(ii) incorporate an attachment cross-pin that operates on needle rollers or bearings.

7.9.1 (b)(ii)

Some vehicles such as XJ6 Jaguar have an OE hard steel bush and pin assembly, which is acceptable, as they incorporate a sintered bronze bush, unlike some steel-on-steel aftermarket or industrial units.

7.9.2

A universal joint incorporated within a steering system in a low volume vehicle must not exceed:

(a) the amount of angularity specified by the universal joint manufacturer; or

(b) if the universal joint manufacturer's specifications are not available, 30 degrees.

7.9.3

Where more than one steering universal joint is incorporated within a steering system in a low volume vehicle, the universal joints must be correctly phased for the application, which will be somewhere between the two positions shown in Diagram 7.2, depending on angularity between the two universals. (see Diagram 7.2)

7.9.3

'Correct for the application' will vary depending on the amount of angularity of the intermediate shaft between the first and second universal. If the angularity between the two is similar, the phasing shown in the top diagram will be close to correct. Some minor phasing adjustment maybe required after installation. For this reason alone, a splined universal on at least one end is essential.

Often, when this is wrong, 'notchiness' is experienced at certain points of the steering lock.

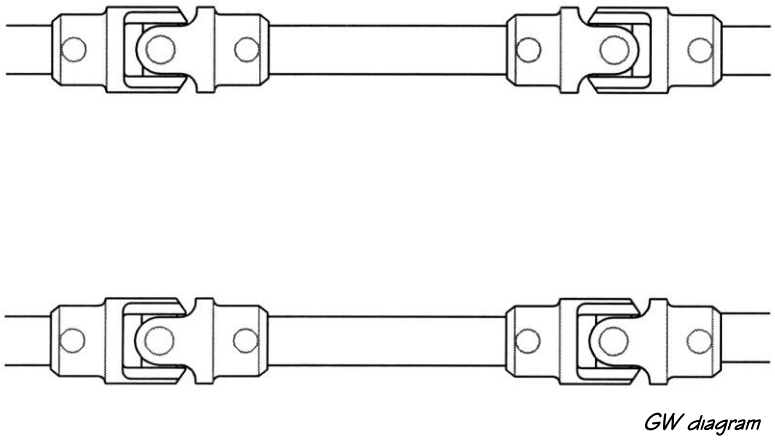


Diagram 7.2 Universal joint phasing

7.9.4

A steering universal joint incorporated within a steering system in a low volume vehicle must either be:

(a) positioned with adequate clearance from the exhaust system; or

(b) provided with a shield to protect the universal from excessive heat from the exhaust system.

7.9.4

An acceptable distance from the exhaust system for a steel universal is generally considered to be 25 mm (1").

7.10 Flexible steering couplings

7.10.1

In the case of a vehicle that has a flexible mounting system that allows the body to move independently from the chassis, some form of flexible steering coupling must be incorporated within the steering system, to prevent the system from being loaded during body movement on the chassis.

7.10.1

This applies mostly to off-road vehicles that use large flexible block-type mounts to isolate vibration and shock, rather than the strips of rubber typically used in old passenger vehicles.

7.10.2

A flexible steering coupling fitted within a steering system in a low volume vehicle must;

(a) be in good condition; and

(b) contain no more attachment holes than required for the application in which it is being used; and

(c) incorporate minimal end-load against the coupling; and

(d) have either:

(i) no misalignment; or

(ii) a maximum of 5 degrees of misalignment if the coupling is used in a situation that duplicates its original set up in the production vehicle from which the coupling was sourced.

7.10.2

A flexible steering coupling is otherwise known as a 'fabric damper' or a 'rag coupling'.

A flexible steering coupling includes modern replacement urethane items.

7.10.3

A flexible steering coupling fitted within a steering system in a low volume vehicle must either:

(a) be positioned with adequate clearance from the exhaust system; or

(b) be provided with a shield to protect the flexible coupling from excessive heat from the exhaust system.

7.10.3

An acceptable distance from the exhaust system for a flexible coupling is generally considered to be 50 mm (2"), and the distance for modern urethane materials should be more. A heat-shield is the preferred option.

7.11 Steering intermediate shafts

7.11.1

A custom-manufactured steering intermediate shaft incorporated within a steering system in a low volume vehicle, must be manufactured from a high quality, easily-machinable material that is readily available.

7.11.1

SAE 4130 is an ideal material for this application.

7.11.2

A steering intermediate shaft in a low volume vehicle, positioned between the steering rack or box, and the steering column, must, except as specified in 7.11.4, attach to the output shaft or ends of the steering rack and pinion or box, and column, with either:

(a) a correctly machined spline that is compatible with the steering universal to which it attaches; or

(b) a non-circular clamping system, that is a close tolerance fit to the universal to which it attaches; or

(c) another suitable form of retention that replicates a recognised system used in modern vehicle construction by a mass-production vehicle manufacturer.

7.11.2(b)

This can be a common 'double-d' or triangular system typically found in production vehicles.

7.11.2(c)

Examples of this include a drilled and bolted system such as that used on Chevrolet pick ups, or the sliding cross-pin system used in HQ Holdens.

7.11.3

An intermediate shaft positioned between the steering rack or box and the steering column in a low volume vehicle, must incorporate, in order to ensure against the splined or clamped sections becoming loose and separating, a secondary means to keep the splined or clamped sections firmly locked together, which can be either:

(a) a clamp; or

(b) a roll-pin; or

(c) a grub-screw.

7.11.3

Some OEM steering attachment systems have only one means of attachment. An example of this is the Holden Torana and other GM systems, where the sole attachment method is a tapered cotter-pin positioned against a machined flat surface. Where such a system from a mass-produced vehicle is used, exactly as employed in its OEM application, 7.11.3 does not apply.

7.11.4

A steering intermediate shaft must not be welded, unless in the case of either:

(a) a vehicle manufacturer's unmodified original equipment operating in the same application for which it was originally designed; or

(b) a custom-manufactured or modified item, in which:

(i) the welding is carried out in accordance with the welding requirements specified in 7.41.2; and

7.11.4

A steering intermediate shaft - and for that matter any other steering component – should not be welded unless there is no other option available, and every potential risk is removed from the welding process.

(ii) individual approval in writing is obtained from the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc).

A low volume vehicle that was built, or was fitted with a welded steering intermediate shaft before January 2007, may continue to use that shaft provided that the shaft meets the requirements of 18.9 of 'Chapter 18 – Attachment Systems'.

7.11.5

Each pair of steering universal joints incorporated within a steering system in a low volume vehicle must be supported by either:

7.11.5(c)

Teflon for example, will swell and extrude, and therefore cannot be used in this application.

(a) a suitable self-aligning bearing; or

(b) a suitable self-aligning sleeve; or

(c) a bush manufactured from a material that will maintain its shape under load.

Steering system collapsibility requirements:

7.12 Steering system collapsibility design

7.12.1

A low volume vehicle must incorporate a steering system that, at the front, will collapse in order to minimise rearward displacement of the upper end of the steering column, as a result of a frontal impact, and which:

(a) incorporates a securely and rigidly mounted upper column attachment and supporting structure; and

(b) ensures that the failure mode of the steering column will, in the event of a frontal impact, be by its lower collapsible system.

7.13 Methods of achieving steering system collapsibility

7.13.1

The collapsibility of a steering system in a low volume vehicle may be provided by incorporation of either:

(a) the steering box or rack and pinion mounted behind the front suspension beam; or

(b) a collapsible steering column from a mass-produced vehicle, provided that:

(i) the attachment of the steering column and associated components duplicates the installation in the vehicle to which it was originally fitted; and

(ii) the structure to which the steering column and associated components are attached has at least the same structural integrity as the corresponding areas of the vehicle to which they were originally fitted; and

(iii) the angle of any couplings between the lower end of the upper steering column and the connecting lower steering shaft does not exceed the donor vehicle or component manufacturer's specifications;

or

(c) collapsibility into the lower steering column or steering intermediate shaft, by a sliding section; or

(d) a longitudinal steering drag-link that connects the steering box to the driver's side steering arm; or

(e) collapsibility into the steering system by ensuring that an angle of not less than 10 degrees is intentionally designed into the system, between the lower end of the steering column, and the steering box or rack and pinion. (see Diagram 7.3)

7.13.1(c)

An example of this method of collapsibility is the flat sliding shaft system used in the Holden Commodore.

7.13.1(d)

This means a typical side-steered beam axle 'push-pull' drag-link system.

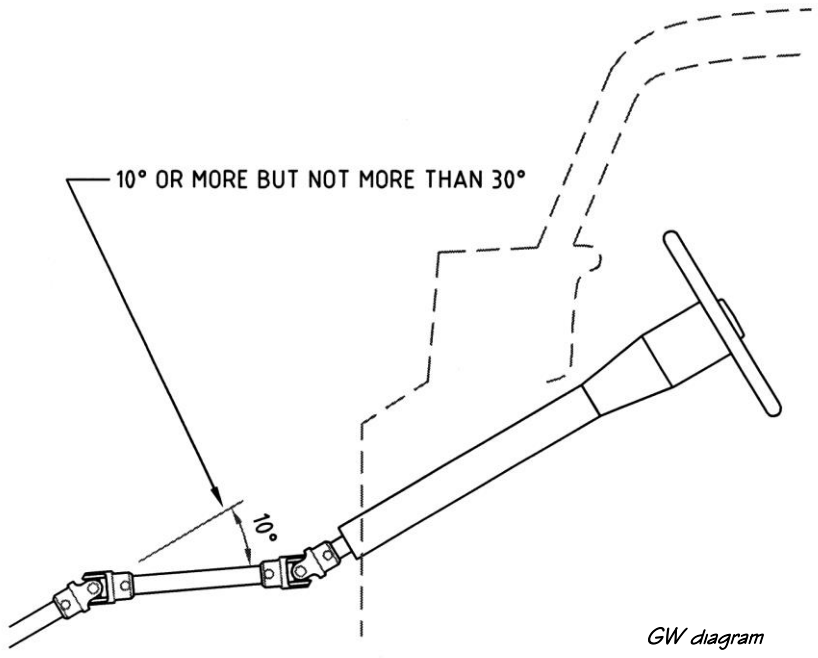


Diagram 7.3 Steering system collapsibility

7.13.2

Any steering column support, or support for a pair of steering universals within a steering system in a low volume vehicle, must be positioned and attached in such a way so as not to compromise the performance of any part of the steering system's collapsibility features.

Steering rack & pinion assembly requirements:

7.14 Steering rack and pinion suitability

7.14.1

A steering rack and pinion assembly fitted to a low volume vehicle must be:

(a) of a type designed specifically for automotive applications; and

(b) of an appropriate size and strength for the vehicle to which it is fitted, taking into consideration front axle weight.

7.14

A power rack and pinion assembly may be used in a non-power application. This often occurs in race car construction, so as to take advantage of better ratio availability.

7.15 Steering rack and pinion ratios

7.15.1

The ratio of a rack and pinion steering system in a low volume vehicle must be a compatible match, and have an appropriate feel for the type of vehicle to which it is fitted, taking into consideration:

(a) the weight of the vehicle; and

(b) the amount of travel within the suspension system.

7.15.1

A very high-ratio steering system which results in one-and-a-half turns lock to lock, for example, would not be suited to a heavy vehicle, particularly one with a lot of suspension travel.

7.15.2

A steering rack and pinion fitted to a low volume vehicle must be of a ratio that is compatible with the length of the steering arms, in order to provide a steering system that:

(a) does not require excessive force to turn; and

(b) is not so over-sensitive as to cause difficulty in maintaining directional control of the vehicle.

7.16 Steering rack and pinion assembly attachment

7.16.1

A steering rack and pinion assembly fitted to a low volume vehicle must be mounted to the vehicle structure:

(a) using the same type of mounting method, and with no less strength and rigidity than that provided by the manufacturer of the vehicle to which the rack and pinion assembly was originally fitted; and

(b) with the attachment points as far apart as practicable to reduce leverage on the rack and pinion assembly housing during turning loads; and

(c) in such a way that the rack and pinion assembly cannot move transversely within its mounting position.

7.16.1(c)

The mounting system of a rack and pinion must feature some form of machined shoulder to 'register' the clamping system, so as to properly locate the rack and prevent against sideways movement.

This does not preclude the use of cushioning mounts, providing that the mounts are properly locked.

7.16.2

A steering rack and pinion assembly fitted to a low volume vehicle must be attached using:

(a) all of the fastening points incorporated within the steering rack and pinion assembly housing by the vehicle manufacturer; and

(b) fasteners of equal or greater size and strength as originally used by the vehicle manufacturer.

7.16.3

A steering rack and pinion assembly fitted to a low volume vehicle must be positioned equidistantly, enabling the steering rack ends to be the same length to the steering arm pivots on each side.

7.16.4

A steering rack and pinion assembly fitted to a low volume vehicle must be mounted, wherever practicable, in a double-shear method of attachment.

7.16.4

The recommendation for double-shear mounting is especially important when the rack is mounted to a light-gauge cross-member.

7.17 Steering rack and pinion assembly modification

7.17.1

The housing of a rack and pinion assembly fitted to a low volume vehicle may be shortened provided that:

(a) the housing is joined so as to maintain correct alignment of the rack and pinion housing bushes; and

7.17

No part of a steering rack and pinion assembly, other than the housing, may incorporate welds, unless the welded section is the vehicle manufacturer's unmodified original equipment.

(b) any welding involved in the shortening process is in accordance with the welding requirements specified in 7.41.2.

7.17.2

The internal components within a manual rack and pinion steering assembly fitted to a low volume vehicle may be shortened, provided that the shortening process occurs only to either:

(a) the parts of the rack shaft to the outside of the teeth, in which case the cut end must replicate the original end before it was shortened; or

(b) the rack ends, which must be correctly re-threaded.

7.17.3

The only internal components within a power rack and pinion steering assembly fitted to a low volume vehicle that may be shortened are the rack ends, which must be correctly re-threaded.

7.17.4

The internal components within a rack and pinion steering assembly fitted to a low volume vehicle must not incorporate any welding.

7.18 Steering rack and pinion assemblies with beam axles

7.18.1

A rack and pinion steering system must not be fitted directly onto a tubular beam or I-beam front axle in a low volume vehicle.

7.18.2

A rack and pinion steering system must not be positioned transversely on a low volume vehicle fitted with a tubular beam or I-beam front axle.

7.18.2

This is because the independent arcs of the tie-rods, during suspension travel of the tubular or I-beam axle, will create a toe-in/toe-out bump-steer situation.

7.18.3

A low volume vehicle fitted with a tubular beam or I-beam front axle may incorporate a rack and pinion steering system positioned longitudinally, operating on the driver's side steering arm in the push-pull style, provided that:

(a) the rack and pinion assembly is from a production vehicle with a substantially heavier front axle weight than the vehicle to which it is fitted; and

(b) the angle of the rack end is minimised in order to prevent the rack and pinion assembly from being subjected to loadings which it was not designed for.

Steering box assembly requirements:

7.19 Steering box suitability

7.19.1

A steering box fitted to a low volume vehicle must be:

(a) of a type designed specifically for automotive applications; and

(b) of an appropriate size and strength for the vehicle to which it is fitted, taking into consideration front axle weight.

7.20 Steering box ratios

7.20.1

The ratio of a steering box in a low volume vehicle must be a compatible match, and have an appropriate feel for the type of vehicle to which it is fitted, taking into consideration:

(a) the weight of the vehicle; and

(b) the amount of travel within the suspension system.

7.20.1

A very high-ratio steering system which results in one-and-a-half turns lock to lock, for example, would not be suited to a heavy vehicle, particularly one with a lot of suspension travel.

7.20.2

A steering box fitted to a low volume vehicle must be of a ratio that is compatible with the length of the steering arms, in order to provide a steering system that:

(a) does not require excessive force to turn; and

(b) is not so over-sensitive as to cause difficulty in maintaining directional control of the vehicle.

7.21 Steering box attachment

7.21.1

A steering box fitted to a low volume vehicle must be attached using:

(a) all of the fastening points incorporated within the steering box housing by the vehicle manufacturer; and

(b) fasteners of equal or greater size and strength as originally used by the vehicle manufacturer.

7.22 Right-angle drive boxes

7.22.1

A right-angle drive box must not be used within the construction or modification of a low volume vehicle, unless its application, configuration, and attachment duplicates the way in which the right-angle drive box was used in its original mass-production vehicle application.

7.22.1

A right-angle drive box is also known as a 'bevel-box', or a 'V-drive box'. These are commonly used to effect a change in direction from the column to the rack in late-model forward-control vans and trucks.

7.22.2

A gearbox that is designed to reverse the rotation of a steering system may be used within a low volume vehicle, if the gearbox and its application has been individually approved in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc).

Steering box drop-arm & steering arm requirements:

7.23 Production steering box drop-arms

7.23.1

A steering box drop-arm sourced from a production vehicle, incorporated within a steering system in a low volume vehicle must:

(a) be from a vehicle designed for steering loads and axle weight of no less than that which would be applied by the vehicle being constructed or modified; and

(b) not be modified in any manner, including:

(i) heating; or

(ii) bending; or

(iii) welding.

7.23.1

'Production' means manufactured by a high-volume motor vehicle manufacturer.

A steering box drop-arm is also known as a 'Pitman arm'.

7.24 Custom steering box drop-arms

7.24.1

A custom-manufactured one-piece mild-steel steering box drop-arm incorporated within a steering system in a low volume vehicle may be bent to suit the needs of the application, provided that the bending process is carried out by a suitably skilled and experienced person.

7.24.2

A steering box drop-arm sourced from other than a production vehicle, except for one specified in 7.24.4, incorporated within a steering system in a low volume vehicle must be a one-piece item, without any welding involved in its manufacture, that is either:

(a) an aftermarket unit designed for automotive applications, manufactured by a recognised and reputable aftermarket steering component manufacturer; or

(b) a custom-manufactured one-piece mild-steel item.

7.24.2(b)

Such a drop-arm would typically be flame-cut or laser-cut from a sheet or bar-stock.

7.24.3

A custom-manufactured one-piece mild-steel steering box drop-arm incorporated within a steering system in a low volume vehicle must be of dimensions of not less than: (see Diagram 7.4)

(a) 20 mm (51/64″) in nominal thickness throughout the entire length of the arm; and

(b) 45 mm (1 45/64″) in total width across the steering box end of the arm; and

(c) 30 mm (1 3/16″) in total width across the drag-link end of the arm; and

(d) 8 mm (5/16″) from the outside edge of the arm to the outer edge of either opening within the arm.

A drop-arm that was fitted to a low volume vehicle before 1992 may be 16 mm (5/8″) in thickness throughout the entire length of the arm.

7.24.4

A custom-manufactured one-piece mild-steel steering box drop-arm must, in order to attach to the steering box, be bored out and either: (see Diagram 7.4)

(a) have a tapered spline machined into the drop-arm by a slotting head; or

(b) incorporate a splined section machined out of a drop-arm manufactured by a production vehicle manufacturer, that is:

(i) heat-shrunk into place; and

(ii) welded in accordance with the requirements specified in 7.41.2.

7.24.4

A slotting head is a reciprocating attachment for a milling machine that enables a tapered spline to be cut. This is approximately twice the cost of the process described in 7.24.4(b). However, the machined tapered-spline is a vastly superior process, and is by far the recommended option.

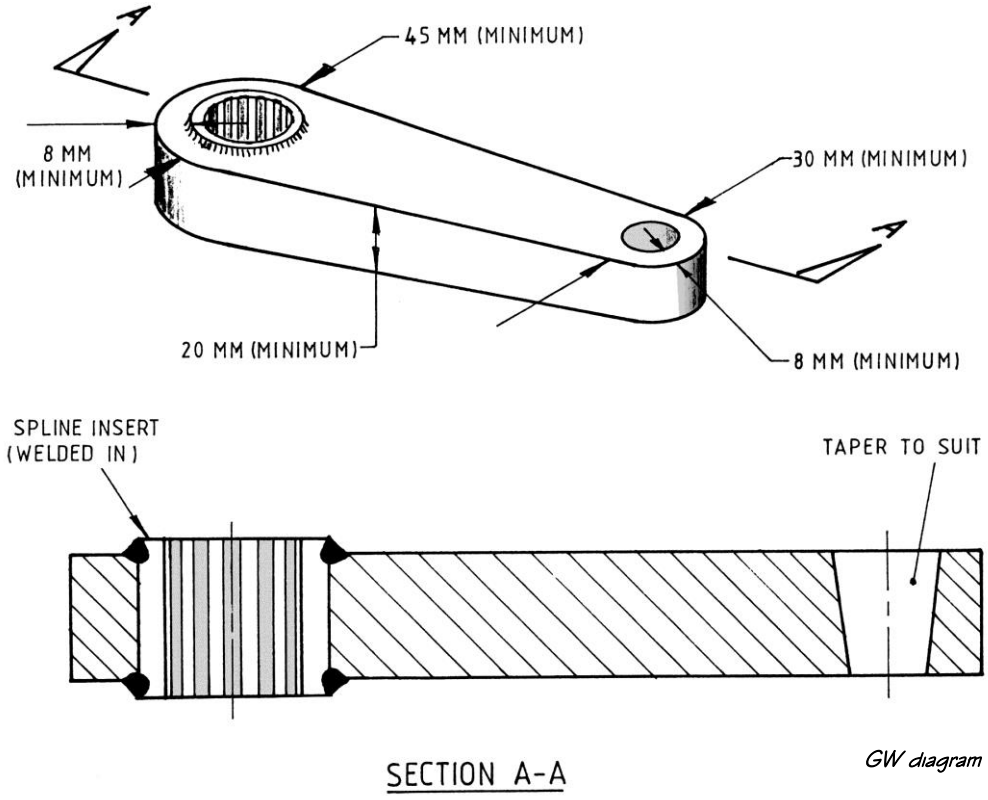


Diagram 7.4 Custom-manufactured steering box drop-arm specification

7.25 Production steering arms

7.25.1

A steering arm sourced from a production vehicle, incorporated within a steering system in a low volume vehicle, must:

(a) be from a vehicle designed for steering loads and axle weight of no less than that which would be applied by the vehicle being constructed or modified; and

(b) not be modified in any manner, including:

(i) heating; or

(ii) bending; or

(iii) welding.

7.26 Custom steering arms

7.26.1

A steering arm sourced from other than a high volume vehicle, incorporated within a steering system in a low volume vehicle must be either:

(a) an aftermarket item designed for automotive applications, manufactured by a recognised and reputable aftermarket steering component manufacturer; or

(b) a custom-manufactured mild-steel unit, that meets the requirements specified in 7.26.2.

7.26.1 (a)

Be wary of anything other than mainstream brands – the Technical Advisory Committee has seen some big-name branded components from overseas that are not suitable for road use due to their poor design.

7.26.1 (b)

These can always be successfully made as one-piece items without an over-tight radius, even in a tight-fit situation such as where a steering arm bolts to a stub axle attached to a dropped tube axle.

7.26.2

A custom-manufactured steering arm incorporated within a steering system in a low volume vehicle must:

(a) in the case of a one-piece item without any welding involved in its manufacture (see Diagram 7.5):

(i) be manufactured from a single piece of mild steel bar material, not less than 16 mm (5/8") in thickness; and

(ii) incorporate a correctly machined radius at any points where the section thickness changes; and

(iii) incorporate an internal thread for the attachment of the steering arm to the stub axle;

or

(b) in the case of an item that incorporates welding within its manufacture:

(i) be manufactured from a single piece of mild steel solid rod material, not less than 18 mm (3/4") in diameter; and

(ii) incorporate a fully-welded boss for the tie-rod end that is carried out in accordance with the requirements for welding specified in 7.41.2; and

(iii) incorporate an internal thread for the attachment of the steering arm to the stub axle.

7.26.2(a)

In the case of extreme situations where vehicle weight is substantially high and power steering is fitted, 16 mm (5/8") mild steel bar should be increased to 18 mm (3/4") mild steel bar.

7.26.2(a)

See Diagram 7.5.

7.26.2(b)

In the case of extreme situations where vehicle weight is substantially high and power steering is fitted, 18 mm (3/4") mild steel solid rod should be increased to 20 mm (51/64") mild steel solid rod.

A custom steering-arm that was fitted to a low volume vehicle before 1992 is not required to meet the requirements in 7.26.2(b), provided that 18.9.2 of 'Chapter 18 - Attachment Systems' is complied with.

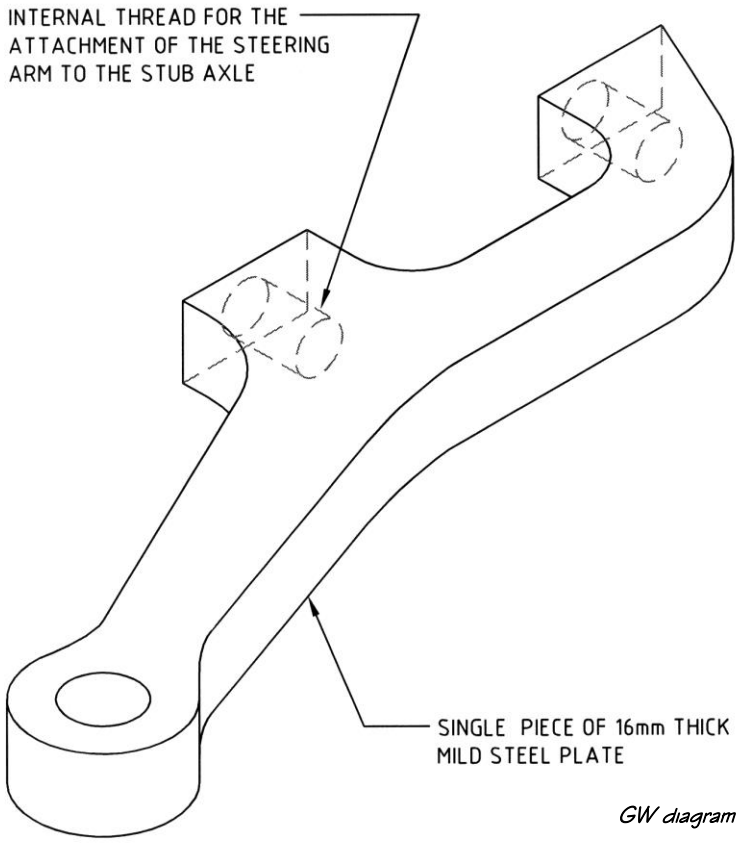


Diagram 7.5 Custom-manufactured steering arm design

Steering drag-link, tie-rod, & drag-link & tie-rod end requirements:

7.27 Steering drag-links and tie-rods

7.27.1

A custom steering drag-link or tie-rod incorporated within a steering system in a low volume vehicle must:

(a) be manufactured from a single piece of material; and

(b) attach to the drag-link or tie-rod ends by the use of threading and jamb-nut securing; and

(c) be manufactured from a material specification in accordance with Table 7.1. (see Table 7.1)

7.27.1

Where there is no alternative but to incorporate a bend within a drag-link or tie-rod, the bend must be kept to a minimum, and the material specification must be increased.

DRAG-LINK OR TIE-ROD LENGTH	MINIMUM MATERIAL SIZE
▪ Drag link or tie-rod of less than 1300 mm (51 3/16") in length	22 mm (7/8") OD x 5 mm (13/64") wall thickness mild steel tubing
▪ Drag link or tie-rod of more than 1300 mm (51 3/16") in length	25 mm (1") OD x 5 mm (13/64") wall thickness mild steel tubing

Table 7.1 Steering drag-link and tie-rod material size guide table

7.27.2

A steering drag-link or tie-rod incorporated within a steering system in a low volume vehicle must be manufactured from a material with sufficient wall thickness that drilling and tapping will provide the correct thread for the appropriate rod end to screw directly into.

7.27.2

For example, 12 mm (½") nominal bore schedule 80 tubing has an outside diameter of 22 mm (7/8"), which can be tapped to accept a 16 mm (5/8") rod end.

7.27.3

A steering drag-link or tie-rod incorporated within a steering system in a low volume vehicle must not be welded, except in the case of a stitch-welded reinforcement strip for an MC-class vehicle, provided that:

7.27.3

'MC-class' is a 4WD off-road type vehicle.

(a) the drag-link or tie-rod is manufactured from mild steel; and

(b) the welding is carried out in accordance with the requirements specified in 18.7.1 of 'Chapter 18 - Attachment Systems'.

7.28 Steering drag-link and tie-rod ends

7.28.1

A steering drag-link or tie-rod incorporated within a steering system in a low volume vehicle must use drag-link or tie-rod ends that are either:

(a) unmodified ball-joint ends from a production vehicle with a front axle weight comparable to the vehicle to which the drag-link or tie-rod ends are fitted; or

(b) custom spherical bearing rod ends that meet the requirements specified in 7.28.2.

7.28.2

A custom spherical bearing rod end incorporated within a steering system in a low volume vehicle must:

(a) be of premium quality, having a radial load-rating appropriate to the rod end size of not less than that specified in Table 7.2; and

(b) be designed for axial loading; and

(c) be positioned in such a way that binding of the end can not occur throughout the full range of suspension travel; and

(d) incorporate engagement of the male thread section of the rod ends into the drag-link or tie-rod tube of not less than one and a half times the diameter of the thread section to ensure the rod ends are securely held in position; and

(e) be injected with a high quality flexible lining material such as Kevlar; and

(f) incorporate retaining washers to prevent bearing pull-out if the ends become worn; and

(g) incorporate a shank length and a bolt size that is in accordance with Table 6.2 of 'Chapter 6 - Suspension Systems'; and

(h) incorporate fasteners to clamp the rod ends to the steering arms that:

(i) are a close tolerance fit both in the rod end bearing and in the steering arm; and

(ii) are loaded by the steering arms on the shank section of the fasteners only; and

(iii) meet all other requirements specified for fasteners in a critical location in 18.4 to 18.6 in 'Chapter 18 - Attachment Systems'.

7.28.2(c)

High-misalignment bearings should be used for large angular movement situations rather than packing washers.

7.28.2(d)

A 'witness hole' should be drilled into the tube to enable inspection of thread engagement.

7.28.2(e)

Teflon can swell and extrude, therefore should not be used in this application.

7.28.2(h)(i)

Any taper previously machined into a steering arm must, where a spherical rod end is attached, be removed.

ROD END SIZE	LOAD-RATING
▪ 10 mm (3/8")	1770 kg (3900 lb) radial load
▪ 11 mm (7/16")	1900 kg (4200 lb) radial load
▪ 12 mm (1/2")	3020 kg (6650 lb) radial load
▪ 16 mm (5/8")	3340 kg (7350 lb) radial load
▪ 19 mm (3/4")	5230 kg (11,500 lb) radial load

Table 7.2 Custom spherical bearing rod end (radial) load-rating table

Steering system geometry requirements:

7.29 Steering system geometry inspection

7.29.1

A low volume vehicle that has been fitted with a new or changed steering system must undergo an assessment to ensure that both front and rear axles are:

(a) parallel to each other; and

(b) square to the longitudinal centre-line of the vehicle.

7.29.2

A low volume vehicle that has been fitted with a new or changed steering system, or has had a steering rack fitted or relocated, must undergo a full steering geometry swing-check throughout the full range of the vehicle's suspension travel, with springs removed, and results recorded, by an appropriately authorised low volume vehicle certifier, to ensure that:

(a) bump-steer is either not present, or is at an acceptably minimal level; and

(b) no ball-joint or steering joint binding is present; and

(c) no rubbing or wearing of any suspension or steering componentry is evident.

7.30 Rack & pinion steering and IFS geometry

7.30.1

In the case of a low volume vehicle that is fitted with an independent front suspension, and a rack and pinion steering system: (see Diagram 7.6)

(a) the length of the rack and pinion assembly must be as close as practicable to the distance between the suspension a-arm inner pivots; and

(b) the steering tie-rods, and the lower suspension a-arms, must be as parallel as practicable to each other, throughout the full range of suspension travel.

7.29.1

This can be assessed through a wheel alignment report, or by thorough visual inspection or use of a string-line check by a Low Volume Vehicle Certifier.

7.29.2

The inspection should be in accordance with the procedures specified for suspension and steering bump-steer swing-check, available in an Information Sheet from LVV Certifiers, or the LVVTA (Inc).

7.30.1

As a very rough starting-point guideline, the rack and pinion length should be within 10% of the distance between the suspension pivot points.

It is very important to carry out the bump-steer swing-check while the system is mocked-up before final installation, to ensure the correct rack positioning.

This requirement also applies to a production vehicle that has undergone a rack and pinion change.

7.30.1

See 'Useful Information' section at the back of this chapter for more information about bump-steer.

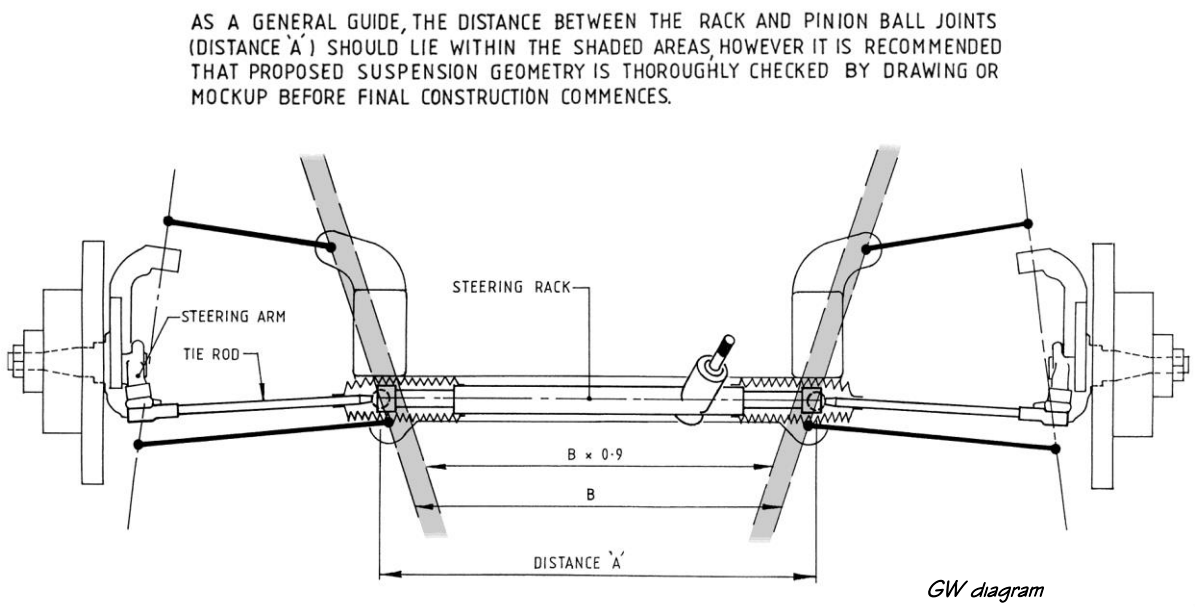


Diagram 7.6 Rack & Pinion steering geometry with independent front suspension

7.31 Steering box drop-arm geometry

7.31.1

A steering box drop arm fitted to a low volume vehicle must operate in an arc that:

(a) does not exceed a total of 90 degrees, consisting of an equidistant amount of 45 degrees on either side of the straight-ahead position; and

(b) does not allow the steering system to:

(i) go over-centre at either extreme of lock; or

(ii) bind throughout the steering travel.

7.32 Steering box drop-arm and drag-link geometry

7.32.1

In the case of a low volume vehicle that is fitted with a steering box attached near the firewall, with a longitudinal drag-link operating the right side steering arm, the drag-link must: (see Diagram 7.7)

7.32.1

A drag-link that is not parallel to, or the same length as the four-bars or radius rods, will create a bump-steer situation.

See the 'Useful Information' section at the back of this chapter for more information about bump-steer.

(a) be positioned at 90 degrees to the steering box drop-arm when the front wheels are aimed directly forward; and

(b) be positioned as parallel as possible to the suspension four-bars or radius rods; and

(c) be as close as practicable to the same length as the suspension four-bars or radius rods.

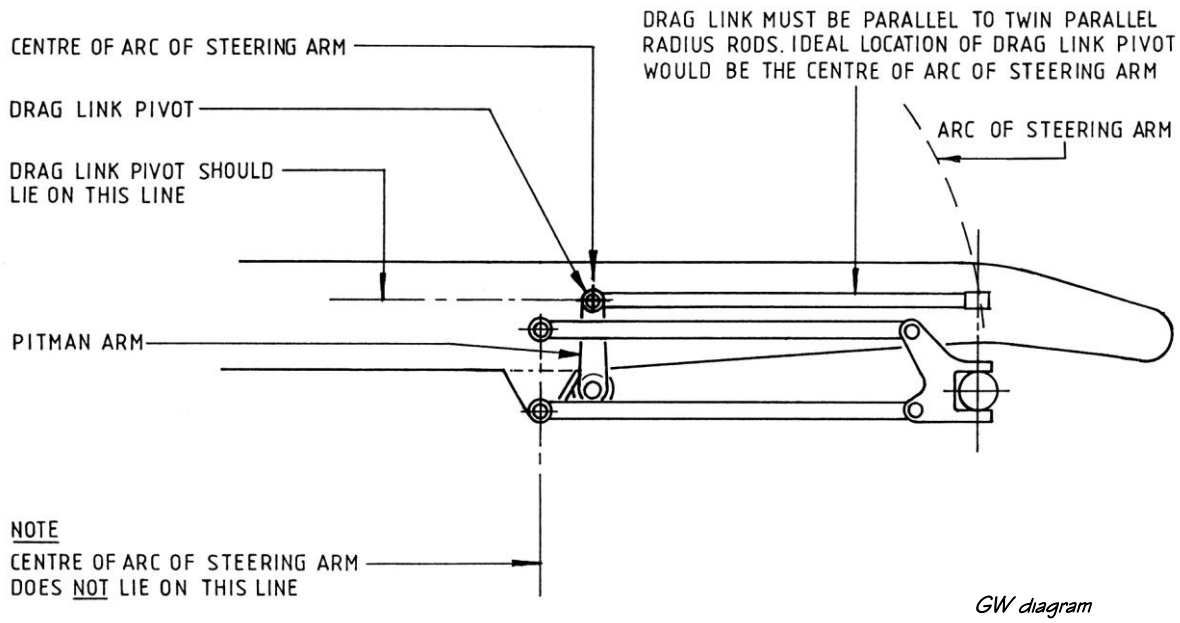


Diagram 7.7 Steering box drop-arm & drag-link geometry

7.32.2

In the case of a low volume vehicle that is fitted with a steering box attached toward the front of the chassis, with a transverse drag-link operating the left side steering arm, the drag-link must:

(a) be parallel to the axle; and

(b) be positioned at 90 degrees to the steering box drop-arm when the front wheels are aimed directly forward.

7.32.2

This system is known as a 'cross-steer' system.

7.33.1

This is important, as continued steering input after the travel has reached its end will result in loading of the chassis section or cross-member to which the rack and pinion or box is attached.

7.33 Steering travel and lock-stops

7.33.1

A rack and pinion or box steering system in a low volume vehicle must be designed in such a way that:

(a) the rack and pinion or box lock-stops prevent the continuation of steering, before the rack and pinion or box has reached the limit of its travel; and

(b) steering lock-stops are incorporated to cease steering travel to prevent the wheel and tyre assemblies coming into contact with the chassis, body, or other suspension or steering components.

7.33.1 (a)

In-built steering stops within a rack and pinion assembly, achieve this requirement.

7.34 Caster angle geometry

7.34.1

The amount of positive caster required to be incorporated within the steering of a low volume vehicle is:

(a) in the case of an independent front suspension, with engine weight positioning similar to that of a typical high-volume sedan-type vehicle, 1-3 degrees; or

(b) in the case of an independent front suspension, with engine weight positioning significantly set back compared with a typical high-volume sedan-type vehicle, 3-6 degrees; or

(c) in the case of a beam or tubular axle front suspension, with engine weight positioning similar to that of a typical high-volume sedan-type vehicle, 4-8 degrees; or

(d) in the case of a beam or tubular axle front suspension, with engine weight positioning significantly set back compared to a typical high-volume sedan-type vehicle, 6 or more degrees.

7.34.1

Achieving the correct amount of caster is a very important part of getting a good steering set-up, and has been one of the most common problems with hobby cars over the years, with builders typically not getting enough caster into the front end.

These figures are approximate and can be varied at the discretion of the LVV Certifier in certain circumstances. If in doubt when setting up, always go for more caster than less.

See more information on caster in the 'Useful Information' section at the end of this chapter.

7.35 Steering system scrub-radius geometry

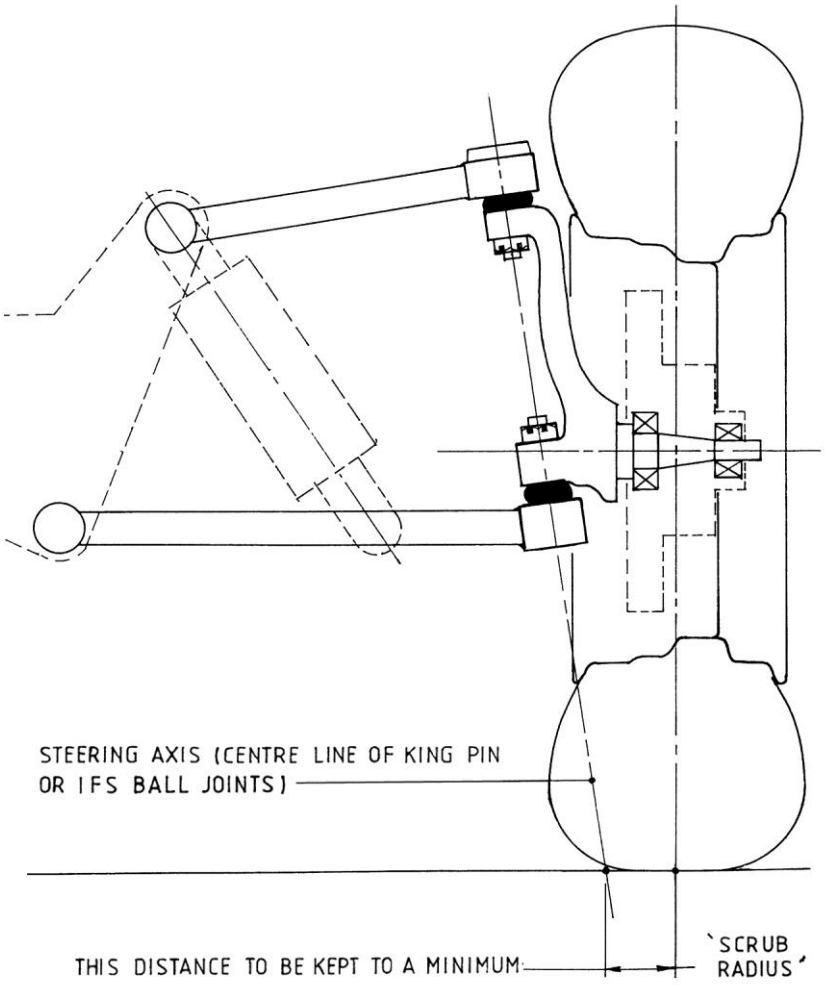
7.35.1

The centre-line of a front wheel-rim on a low volume vehicle must be positioned as closely as practicable to the centre-line of the king-pins, or in the case of a vehicle with an independent front suspension, the intersecting line of the upper and lower ball-joints. (see Diagram 7.8)

7.35.1

Keeping wheel off-sets to a minimum at the front helps toward achieving good scrub-radius.

Excess scrub-radius can have a negative effect on braking performance, and increase road-shock back to the driver through the steering wheel.



GW diagram

Diagram 7.8 Scrub-radius geometry

7.36 Ackermann angle geometry

7.36.1

A low volume vehicle that incorporates a custom-built suspension system must incorporate within its steering system, some ackermann angle geometry (see Diagram 7.9).

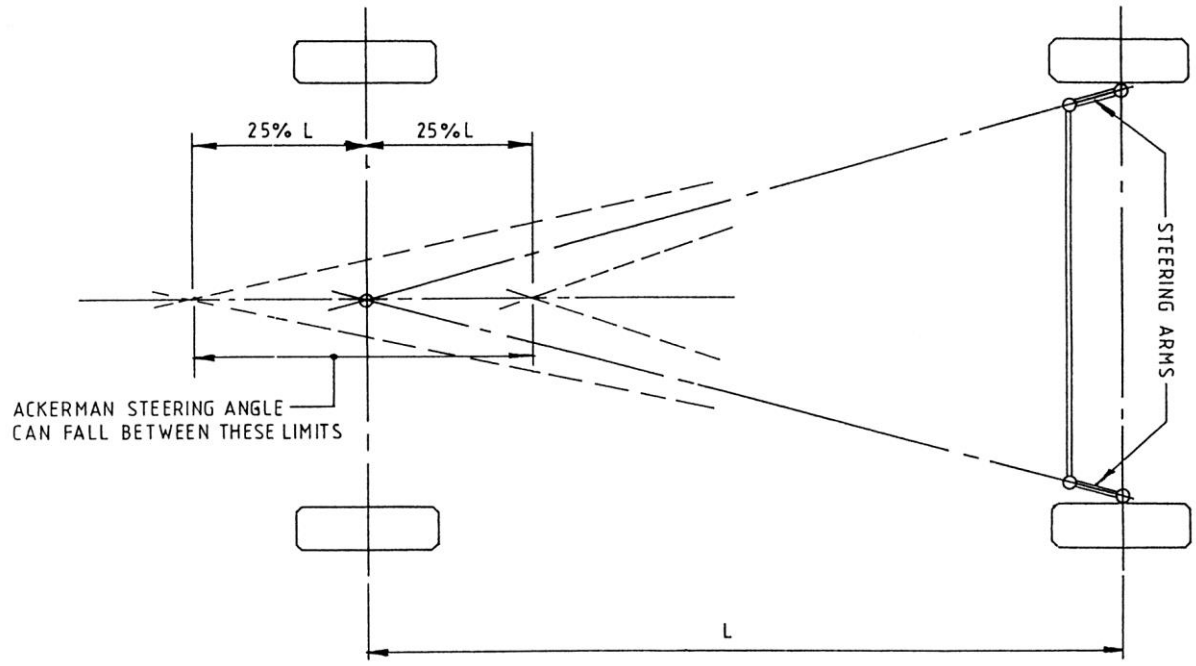
7.36.2

A low volume vehicle that incorporates an OEM suspension assembly must not, if the suspension assembly incorporates anti-ackermann angle geometry, incorporate any more anti-ackermann geometry than that built into the OEM donor vehicle (see Diagram 7.9).

7.36.2

Some OEM IFS units such as HQ Holden actually have a small amount of anti-ackermann built in.

See the 'Useful Information' section at the end of this chapter for more information on ackermann angle geometry.



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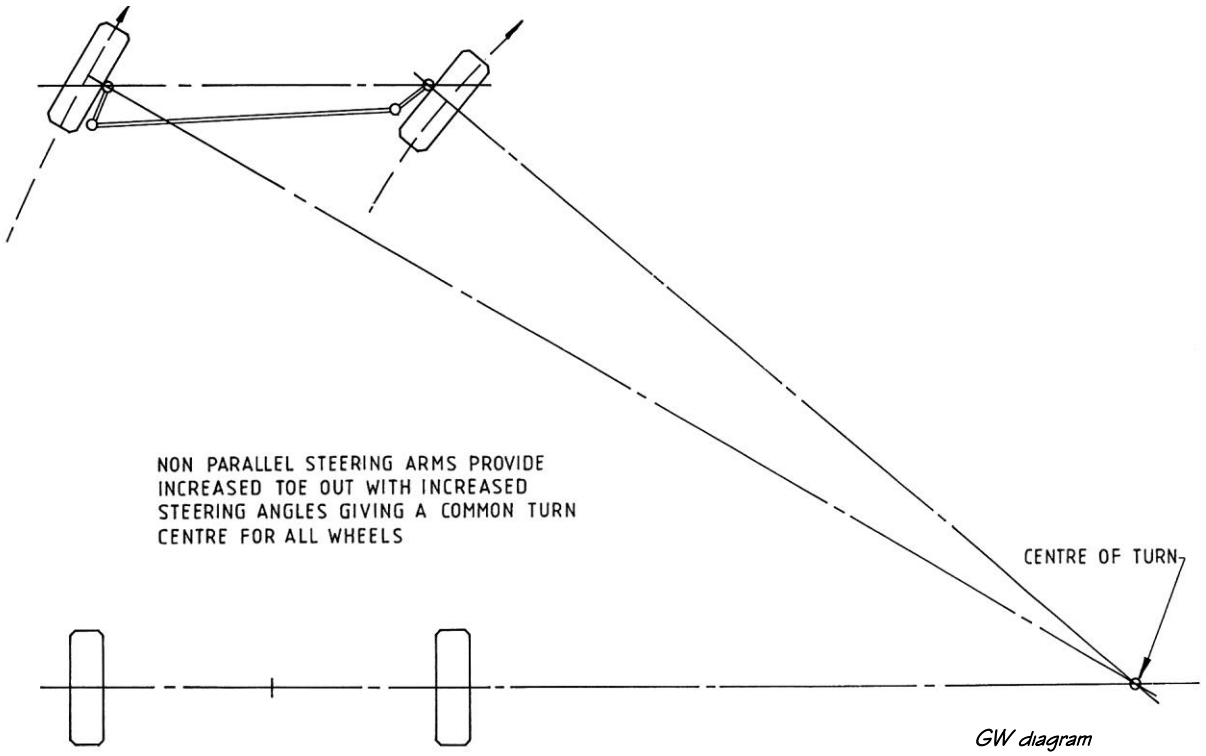


GW diagram

Diagram 7.9 Ackermann geometry

7.37 Steering system scrub-line geometry

7.37.1

A steering system within a low volume vehicle must be attached in such a way that no part of the steering system is positioned below an area defined by: (see Diagram 7.10)

(a) a line from the bottom of the right side front wheel-rim to the road contact patch of the left side front tyre; and

(b) a line from the bottom of the left side front wheel-rim to the road contact patch of the right side front tyre.

7.37.1

This needs to be checked with the full vehicle weight on the suspension.

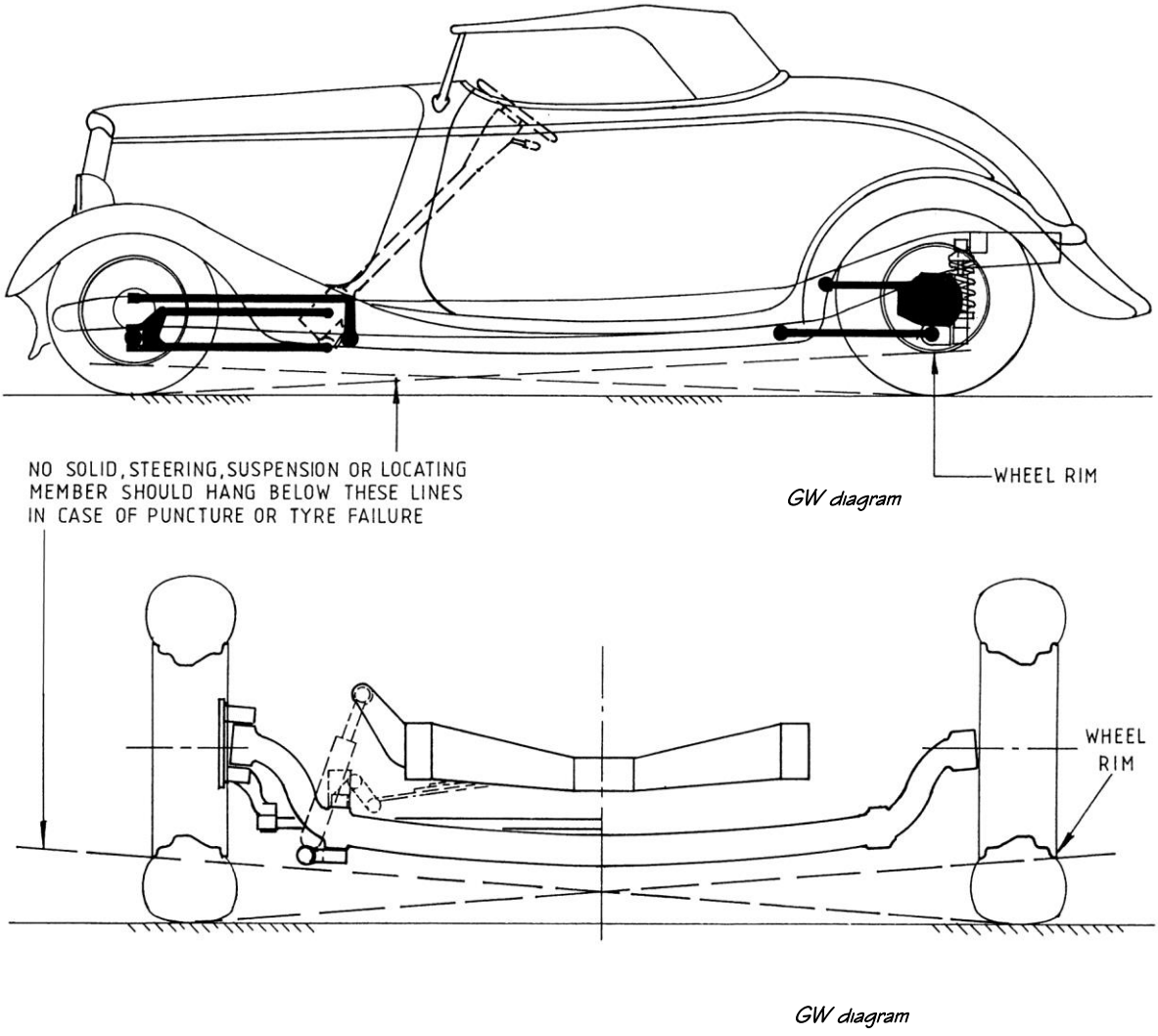


Diagram 7.10 Scrub-line geometry

7.38 Geometry adjustment

7.38.1

A steering system fitted to a low volume vehicle must incorporate provision for the correct adjustment of toe-in and toe-out.

Additional requirements for all steering systems:

7.39 Steering quickeners and reverse-rotation boxes

7.39.1

A custom-manufactured or aftermarket steering 'quickener' fitted to a low volume vehicle, must be individually approved in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc).

7.39.2

A custom-manufactured or aftermarket steering reverse-rotation box fitted to a low volume vehicle, must be individually approved in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc).

7.40 Attachment of steering system components

7.40.1

All fasteners incorporated in steering system attachment, modification, or adaptation within a low volume vehicle, must meet all requirements specified from 18.2 to 18.6 inclusive in 'Chapter 18 - Attachment Systems'.

7.41 Welding of steering system components

7.41.1

A component within a steering system in a low volume vehicle must not be welded, except where specifically stated for steering intermediate shafts, steering rack and pinion housings, and custom steering box drop arms.

7.41.2

A component within a steering system in a low volume vehicle specified in 7.41.1 may only be welded if:

7.41.1

Note that welding is, as a rule, not permitted within any 'critical' steering components. Any welding referred to here is restricted to situations where no other option is available.

(a) in the case of a vehicle manufacturer's original equipment, the component is operating in the same application for which it was originally designed; or

(b) a steering component has been modified or custom-manufactured, due to no other practical option being available, in which case:

(i) the component must meet all requirements specified in 18.9 'critical function welding requirements' in 'Chapter 18 - Attachment Systems'; and

(ii) the modification or custom-manufacturing process must be carried out by a person who is professionally engaged in motor vehicle construction, has substantial experience in steering component manufacture, and who is specifically nominated in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc).

7.41.2

See the 'Useful Information' section at the end of this chapter for information on welding castings and forgings.

General requirements:

7.42 General safety requirements

7.42.1

A steering system and its associated components fitted to a low volume vehicle must be suitably matched and appropriate for their application.

7.42.2

Modifications, adaptations, and attachments of any steering system and associated components in a low volume vehicle must incorporate sound automotive engineering principles and procedures.

7.42.3

All steering components incorporated within a steering system in a low volume vehicle must be appropriately suited to:

(a) the performance potential of the vehicle; and

(b) the weight of the vehicle over the steering axle.

7.42.4

A sprocket and chain system must not be used within a steering system in a low volume vehicle.

7.42.5

A low volume vehicle with the steering wheel and column assembly positioned to the left side of the longitudinal centre-line of the vehicle must not be certified to the Low Volume Vehicle Code if:

(a) it has been constructed in New Zealand; or

(b) converted to left-hand drive in New Zealand; or

(c) it has been constructed outside of New Zealand less than 20 years from the date of entry certification in New Zealand.

7.42.5

It has been illegal to build cars in left-hand drive form, or convert cars to left-hand drive, in NZ for many decades.

7.42.5(c)

This means that a LHD scratch-built replica vehicle cannot be LVV certified unless it was built in its country of origin over 20 years from the date of entry certification (first registration) in NZ.

Exclusions:

7.43 Motor-sport exclusions

7.43.1

A low volume vehicle for which a valid LVV Authority Card, that specifies 'Frontal Impact Protection System' has been issued, is not required to comply with 7.2, 7.12, or 7.13.

Useful information:

Scrub radius

The distance between the centre-line of the wheel, and the centre-line of the king-pins, or the IFS ball-joints, should be minimised (whilst still retaining adequate clearance between moving parts). Minimal scrub radius will:

- enhance steering feed-back under braking; and
- minimise road-shock through the steering wheel; and
- increase tyre life.

Ackermann geometry

Ackermann ensures correct wheel geometry and tyre contact during turning, for the most economic tyre wear, and maximum road adhesion, and to avoid excess tyre scuffing. Ackermann achieves this by enabling the inside front wheel to prescribe a tighter radius than the outside wheel during turns. Ackermann used to be considered important, but nowadays, some vehicle manufacturers incorporate very little ackermann geometry. Some race cars actually build in anti-ackermann, although there are good reasons why this shouldn't be applied to road-going vehicles.

A vehicle with a changed front end will have satisfactory ackermann if the donor vehicle is of a similar wheelbase to the vehicle being constructed.

Bump-steer

There are different kinds of bump-steer, all of which have detrimental effects on a vehicle's handling characteristics. The worst type of bump-steer, and one that must be avoided at all costs, is toe-out bump-steer, which can result in sudden changes in steering direction. An information sheet is available from LVV Certifiers or the Low Volume Vehicle Technical Association (Inc), that provides information and procedures for assessing, and ensuring against, bump-steer and other geometry issues. This Information Sheet can be obtained from LVVTA's website www.lvvta.org.nz.

Despite all the theory on causes and cures in this chapter for bump-steer, there's nothing better than carrying out a proper bump-steer swing-check. Have this done at early mock up stage by an experienced scratch-built LVV certifier

Caster angle geometry

Caster must be the most over-looked area in the basic suspension set-up of a hobby vehicle, with even professional hobby car builders sometimes not paying enough attention to this area when they are setting up the front end. Many of the hobby cars that have driven like rubbish over the years have done so simply because of a lack of positive caster.

Caster is the imaginary vertical line between the upper and lower ball-joints – and positive caster being the top ball-joint positioned rearward of the bottom ball-joint. Good-driving cars need plenty of positive caster. The reason you could ride your pushbike for a block with no hands on the handlebars when you were a kid, was because of the way the forks are designed – effectively with positive caster. On the other hand, the reason a shopping trolley is uncontrollable is because they are designed with negative caster, to enable easy manoeuverability.

It is caster that provides self-centering, and the tendency to want to 'track' straight and true, and it is this which provides the 'feel' that a nice-driving car gives. The only negative pay-back is that the more caster you build in, the heavier the steering becomes – so fit power steering - don't compromise your car's driveability by keeping manual steering and reducing the amount of caster to keep the steering light!

As a general rule of thumb, the range is between 1 and 8 degrees positive (check the requirements in the suspension geometry section for the varying figures for different front end types), and should increase as the amount of engine set-back increases. A rear-engined dragster can run anything up to 30 degrees – hard as hell to steer, but the car drives itself down the track! It's these same dramatic positive caster settings that cause the violent front-wheel wobble that you sometimes see when dragsters or altereds slow or back-up after the burn-out.

Care must be taken when setting up the front and rear ride height, to ensure that the correct amount of steering caster is incorporated into the steering system. The vehicle's finished stance must be established and mocked-up into position before the IFS beam is attached.

This process requires the wheel and tyre selection to be made at an early stage. If the beam is bolted into the chassis, you've got an opportunity to fix it later if you make a change that upsets the caster, but if the beam is welded into the frame, and it turns out to be wrong, you've got big troubles!

Steering system interference

If interference is encountered during engine positioning between the engine and part of the steering system, there is no reason why the engine can't be positioned across slightly to the left of centre (say, 20 mm [5 1/64"] or so), rather than compromising the steering system.

Rack and pinion steering systems

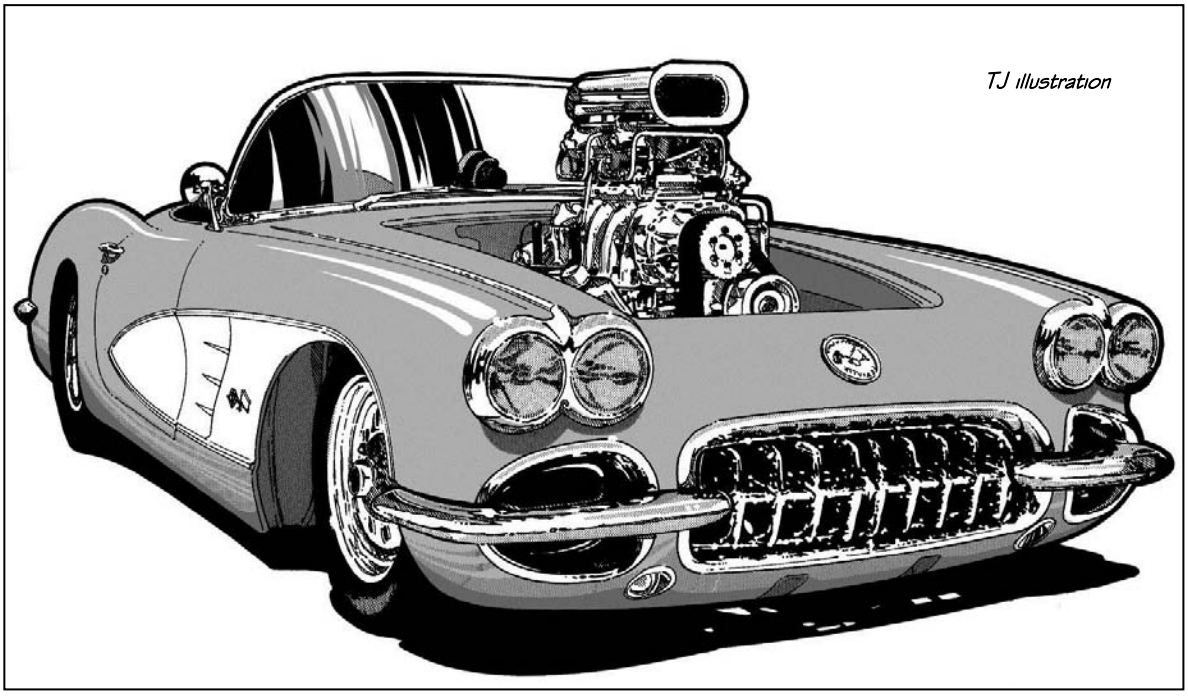
A rack and pinion steering system generally provides less steering effort than conventional steering boxes due to their virtually friction-free design. Therefore, less turns from lock to lock can be achieved by using a rack and pinion from the same, or even less, steering effort.

Welding of castings and forgings

A basic but very important engineering principle threaded throughout the whole LVV certification process in New Zealand is that a forging or casting in a critical situation like suspension, steering, or brakes, must not be heated and bent, or welded, except in highly controlled circumstances. A forging or casting that is heated during a welding process must be re-heat treated afterwards, and this can not be done correctly unless the exact molecular structure of the material of the forging or casting has been properly established beforehand by a metallurgist – which in turn enables the appropriate heat-treatment method to be established. This process is costly, and not practicable in one-off situations. There is a very real risk of changes occurring within the molecular structure of a steel forging or casting when a welding process is applied, particularly if too much heat is applied during the heating or welding process, and the problems that this can create are often irreversible.

If anyone has a legitimate need to do this, it may be allowed, but only after having received written approval from the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc) on a case-by-case basis.

The old practice of heating and bending, or welding, forgings or castings is for the history books; better components and machining processes are available now, to the extent that these practices can be left behind in the 'good old days' forever!



TJ illustration