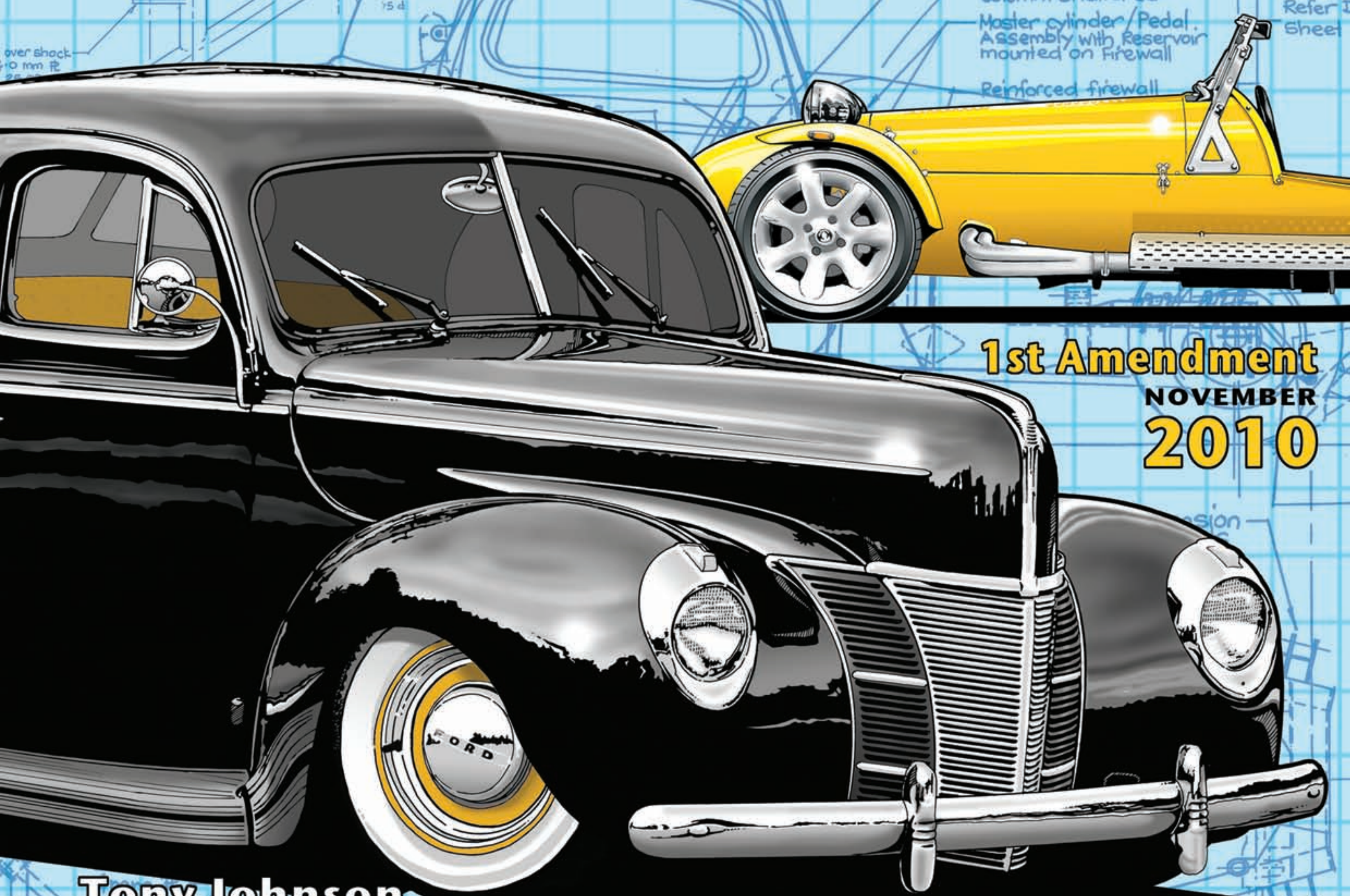
THE NEW ZEALAND

CAR CONSTRUCTION MANUAL

CHAPTER 6

SUSPENSION SYSTEMS



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CAR
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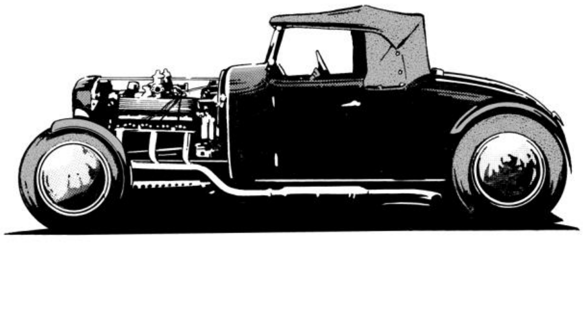

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NZHRA, and its key personnel, have, and continue to since the inception of LVV certification, form the back-bone of the LVV certification system in New Zealand. LVVTA is very appreciative of NZHRA's on-going commitment and integrity.

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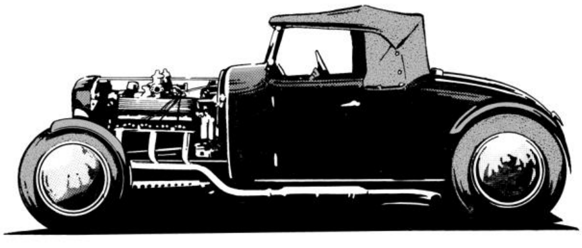

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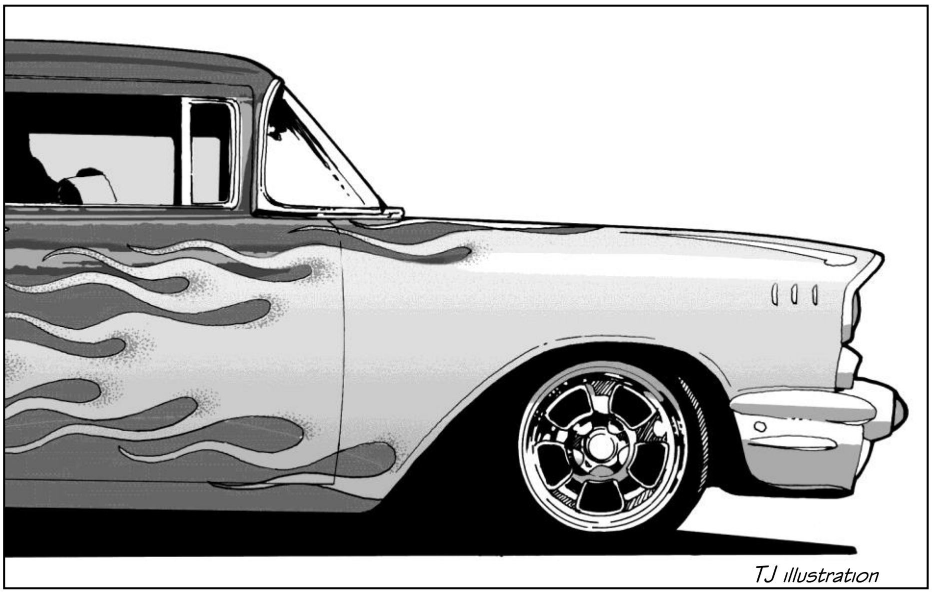
Chapter 6:

SUSPENSION SYSTEMS



Chapter 6 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
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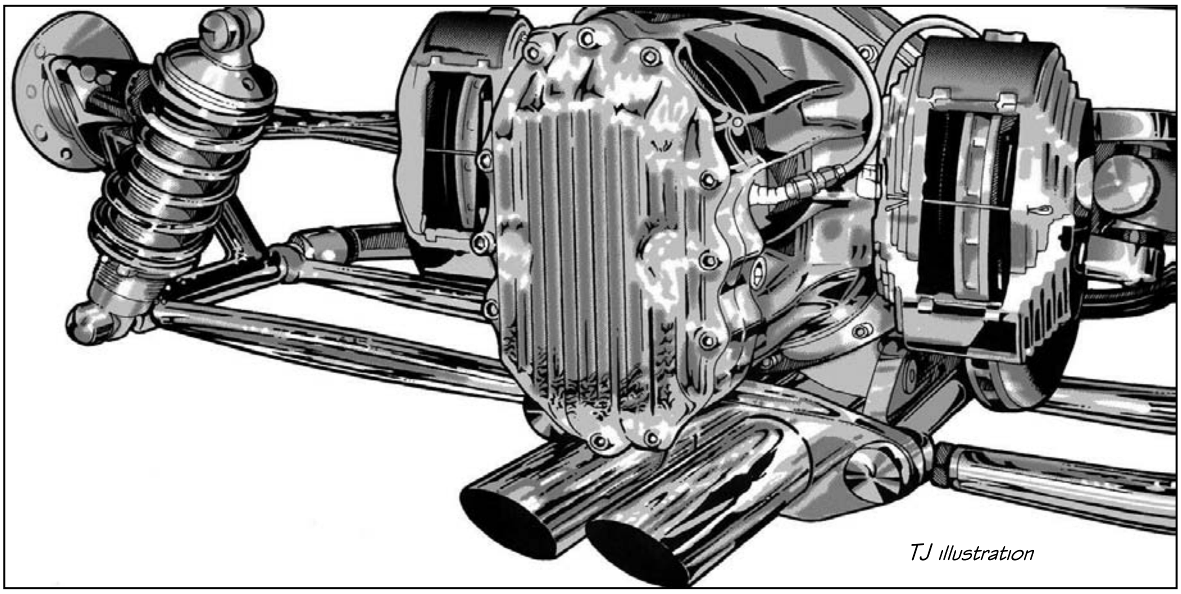


CHAPTER 6: SUSPENSION SYSTEMS

Introduction:

In any motor vehicle, the suspension plays a dual role; it isolates the body and chassis from harsh shock loads transmitted from the road surfaces, and maintains the contact patch of each tyre to the road surface. Correct suspension design, construction, and geometry is critical in a hobby vehicle, from the point of view of safety, and also to achieve a vehicle that is ultimately a pleasure to drive. After correcting bad suspension geometry or design as a result of the LVV certification process over the last two decades, literally hundreds, if not thousands of vehicles have been transformed in the way they drive and ride, and as a result the owners' fun-factor has increased hugely.

This section covers the many typical suspension system types commonly used, and provides tried and true good engineering formulas that history and experience have taught us will work reliably and safely. Note that where a production vehicle is fitted with its original unmodified suspension system, the requirements in this chapter do not apply.

Production independent front suspension modification & installation requirements

6.1 Production independent front suspension suitability

6.1.1

A production vehicle independent front suspension unit fitted to a low volume vehicle must be sourced from a donor vehicle of a similar or greater front axle weight to that of the vehicle being modified or constructed.

6.1

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

6.2 Production independent front suspension design

6.2.1

Custom control arms fitted to a production vehicle independent front suspension assembly in a low volume vehicle must be individually approved in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc), through the build approval process in 'Chapter 4 - Build Approval Process' to confirm that the control arms incorporate design principles, material specifications, and construction methods that are suitable for their application, prior to commencement of construction.

6.3 Production independent front suspension modifications

6.3.1

A custom control arm fitted to a production vehicle independent front suspension assembly in a low volume vehicle, must:

(a) meet the material requirements specified in Table 6.1; and

(b) be constructed in such a way that any threaded section provided for adjustability is incorporated directly into the control arm material; and

(c) in the case of welded joints, have the material sections joined in such a way as to provide the greatest weld area practicable; and

(d) in the case of an arm which supports the corner-weight of the vehicle, incorporate at the outer end, either:

(i) a purpose-designed automotive ball-joint from a production vehicle of a similar or greater corner weight; or

(ii) a custom bush assembly that is purpose-designed for supporting at least the corner-weight of the vehicle to which the suspension is fitted.

6.3.2

Welding within the modification process of an original independent front suspension cross-member within a low volume vehicle must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 and 18.8 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.3.2, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.2.1

'Custom' means manufactured by someone other than a reputable aftermarket manufacturer or high-volume motor vehicle manufacturer.

See 'Chapter 4 - Build Approval Process'.

Also look for more information on custom suspensions within LVVTA (Inc)'s Information Sheets, available on www.lvvta.org.nz.

6.3.1(a) & (b)

For example, use, say, schedule 80 15mm (19/32") nominal bore tube drilled & tapped directly for a 16 mm (5/8") rod end – this keeps the material spec beefy (which it needs to be) and avoids the need to weld threaded 'spuds' into the arms to accept the rod-end.

6.3.1

A 'custom bush assembly' includes spherical bushes.

6.3.3

Welding within the modification process of a production vehicle independent front suspension component in a low volume vehicle, other than the main cross-member, must be carried out:

(a) only on components manufactured from a low to medium tensile strength mild steel; and

(b) in accordance with the welding requirements for critical components specified in 18.9 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.3.3(b), provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.3.4

Welding within the manufacturing process of a custom component which replaces an original component within a production vehicle independent front suspension in a low volume vehicle, must be carried out:

(a) only on components manufactured from readily weldable steels, such as low to medium tensile strength mild steel, weldable stainless steel, or chrome-moly; and

(b) in accordance with the welding requirements for critical components specified in 18.9 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.3.4(b), provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.3.5

A suspension component within a production vehicle independent front suspension in a low volume vehicle that is manufactured using a casting or forging process, must not, in any circumstances, be either:

(a) heated; or

(b) bent; or

(c) welded.

6.3.6

A custom suspension joint, such as an adjustable rod end, may be fitted to a production independent front suspension in a low volume vehicle to replace an original suspension joint, in order to achieve an increased range of adjustability and improved suspension geometry, provided that the joint:

6.3.4(a)

A typical weldable stainless steel is a 304L or 316L grade. The 'L' denotes low carbon, which means it can be successfully welded.

6.3.5

No heating, bending, or welding of a casting or a forging is a basic low volume vehicle system principle that should never be broken, except in special circumstances that are specified and controlled within this manual.

6.3.6

Custom suspension joints include rubber or urethane-bushed aftermarket rod ends, and spherical bearing rod ends.

See sections 6.41 to 6.46 for the technical requirements for custom suspension joints.

(a) meets the applicable requirements specified for the suspension joints in 6.42 or 6.43; and

(b) is only loaded in compression or tension through its longitudinal axis.

6.4 Production independent front suspension installations

6.4.1

An installation of a production vehicle independent front suspension cross-member in a low volume vehicle that involves welding must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 and 18.8 of ‘Chapter 18 - Attachment Systems’.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.4.1, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.4.2

An installation of a production vehicle independent front suspension beam in a low volume vehicle that is attached by bolting onto the chassis, must incorporate no less number and size fasteners than that used in the suspension beam’s original location.

6.4.3

A production vehicle independent front suspension fitted with brake reaction rods that are installed in a low volume vehicle, must incorporate sufficiently reinforced or gusseted attachment points to ensure that the brake reaction rods are supported no less rigidly than in their original location.

6.4.4

A production vehicle independent front suspension fitted with torsion bar springing that is installed in a low volume vehicle, must be attached in such a way that enables the loads transmitted by the torsion bars to be supported by a sufficiently reinforced part of the chassis.

6.4.5

A production vehicle independent front suspension must be installed in a low volume vehicle in such a way as to enable the correct caster angle, as specified in 7.34 in ‘Chapter 7 - Steering Systems’, to be achieved during final alignment.

6.3.6 (b)

This means that a rod end can’t be used as a bottom ball joint, because rod ends are not designed for constant side-load, and they wear faster than a proper automotive load-carrying ball-joint will.

6.4.3

Brake reaction rods are also known as strut rods or lower arm rods, and can be subjected to very high loads.

6.4.5

This needs to be carefully set-up taking into account tyre sizes and final front to rear vehicle rake before installation, especially if the beam is being welded into the chassis.

See notes on caster in the ‘Useful Information’ section at the end of this chapter.

Custom independent front suspension requirements

6.5 Custom independent front suspension design

6.5.1

A custom-built independent front suspension assembly 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), through the build approval process specified in 'Chapter 4 - Build Approval Process', to confirm that the suspension assembly incorporates design principles, material specifications, and construction methods that are suitable for their application, prior to commencement of construction.

A custom-built independent front suspension assembly built before 1992 is not required to comply with 6.5.1.

6.5.2

A custom-built independent front suspension assembly fitted to a low volume vehicle must incorporate control arms manufactured from a material specification not less than that specified in Table 6.1.

A custom-built independent front suspension assembly built before 1992 is not required to comply with 6.5.2, provided that after thorough inspection, no bending, fatigue cracking, or fracturing is evident on the arms. Specific investigation for fatigue cracking must be carried out, with removal of paint if necessary to assist the inspection process.

6.5.1

'Custom' means manufactured by someone other than a reputable aftermarket manufacturer or high-volume motor vehicle manufacturer.

See 'Chapter 4 - Build Approval Process'.

Also look for more information on custom suspensions within LVVTA (Inc)'s Information Sheets, available on www.lvvta.org.nz.

6.5.2

Table 6.1 assumes that the upper arm is unloaded and the lower arm is loaded. Where this does not occur (eg rocker arm, or spring is mounted to top arm) the TAC should be consulted.

The lower arm must never be reduced below that specified in the table, irrespective of whether or not the lower arm is loaded.

See additional A-arm material notes next page.

VEHICLE TYPE	WEIGHT	A-ARM MATERIAL	
		Upper arms	Lower arms
▪ Lotus 7 replica ▪ Light-weight space-frame sports special	500 kg (1100 lb) ↓	22 mm (7/8") OD x 1.6 mm (1/16") wall thickness, ERW or seamless tube	25 mm (1") OD x 2.0 mm (5/64") wall thickness, ERW or seamless tube
▪ Heavy-weight space-frame sports special ▪ Medium-weight ladder-chassis sports car (MGTF replica) ▪ Light-weight hot rod (T-bucket, fenderless roadster) ▪ Small unit-construction sedan (Civic, Mazda 323)		15 mm (19/32") NB schedule 40 (22 mm [7/8"] OD x 3.3 mm [9/64"])	20 mm (51/64") NB schedule 40 (25 mm [1"] OD x 3.2 mm [1/8"])
▪ Heavy-weight ladder-chassis sports car (Cobra) ▪ Medium-weight hot rod (coupe, pick-up) ▪ Large unit-construction sedan (Camaro, Commodore)		15 mm (19/32") NB schedule 80 (22 mm [7/8"] OD x 4.0 mm [5/32"])	20 mm (51/64") NB schedule 80 (25 mm [1"] OD x 4.0 mm [5/32"])

▪ Heavy-weight hot rod (30s & 40s sedan)	2200 kg (4840 lb)	20 mm (51/64") NB schedule 80 (25 mm [1"] OD x 4.0 mm [4/32"])	20 mm (51/64") NB schedule 80 (25 mm [1"] OD x 4.0 mm [5/32"])
▪ Full size body/chassis car (50s & 60s sedan)		20 mm (51/64") NB schedule 80 (25 mm [1"] OD x 4.0 mm [4/32"])	25 mm (1") NB schedule 80 (33 mm [1 5/16"] OD x 5.0 mm [3/16"])

Table 6.1 Custom IFS A-arm material guide table

6.6 Custom independent front suspension construction

6.6.1

A custom-built independent front suspension assembly fitted to a low volume vehicle, must:

(a) be constructed in such a way that any threaded section that is provided for adjustability is incorporated directly into the control arm material; and

(b) in the case of welded joints, have the material sections joined in such a way as to provide the greatest weld area practicable; and

(c) incorporate at the outer end, except in the case where the suspension arm is not a loaded arm, either:

(i) a purpose-designed automotive ball-joint from a production vehicle of a similar corner weight; or

(ii) a custom bush assembly that is purpose-designed for carrying the corner weight of the vehicle to which the suspension is fitted.

6.6.2

Welding within the construction process of a front suspension cross-member within a custom independent front suspension in a low volume vehicle, must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 and 18.8 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.6.2, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.6.3

Welding within the construction process of a custom component within a custom independent front suspension assembly in a low volume vehicle, must be carried out:

6.5.2 (cont'd)

Note that oval-section thin-wall tubing may be used in the construction of IFS A-arms, however in such circumstances the TAC should be consulted.

The ideal approach for material selection for custom built control arms is to use, say, schedule 80 15mm (19/32") nominal bore tube drilled & tapped directly for a 16 mm (5/8") rod end – this keeps the material spec beefy (which it needs to be) and avoids the need to weld threaded 'spuds' into the arms to accept the rod-end.

See 'Custom IFS A-arm material specifications' under the Useful Information section at the back of this chapter for some exceptions to these arm size rules.

6.6.1(c)(i)

See 'loaded suspension joints' in the 'Useful Information' section.

(a) only on components manufactured from readily weldable steels, such as a low to medium tensile strength mild steel, weldable stainless steel, or chrome-moly; and

(b) in accordance with the welding requirements for critical components specified in 18.9 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.6.3(b), provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.6.3(a)

A typical weldable stainless steel is a 304 L or 316 L grade. The 'L' denotes low carbon, which means it can be successfully welded.

6.6.4

A suspension component within a custom independent front suspension in a low volume vehicle that is manufactured using a casting or forging process, must not, in any circumstances, be:

(a) heated; or

(b) bent; or

(c) welded.

6.6.4

No heating, bending, or welding of a casting or a forging is a basic engineering principle that should never be broken, except for in special circumstances that are specified and controlled within this manual.

6.6.5

A custom suspension joint, such as a custom bushed rod end, may be fitted within a custom independent front suspension in a low volume vehicle, provided that the joint:

(a) meets the applicable requirements specified for suspension joints in 6.42 or 6.43; and

(b) is only loaded in compression or tension through its longitudinal axis.

6.6.5

Custom suspension joints include rubber or urethane-bushed aftermarket rod ends, and spherical bearing rod ends.

'I-beam' refers to the beam axles used prevalently by high volume vehicle manufacturers (particularly Ford) from the turn of the century to the late 1940s, and beyond for commercial vehicles.

Beam axle front suspension requirements

6.7 I-beam axle front suspension systems

6.7.1

An I-beam axle in a low volume vehicle must be sourced from either:

(a) a production vehicle of a comparable or greater weight than the vehicle being modified or constructed; or

(b) a reputable aftermarket company that has a long history in manufacturing quality suspension components.

6.7.1

After-market I-beam axles such as those made by Magnum, Superbell, and Chassis Engineering are all considered to be good quality components.

6.7.2

An I-beam axle in a low volume vehicle that incorporates coil springs to support the vehicle weight must not have the springs mounted on attachment points that were originally designed and manufactured for mounting just shock absorbers.

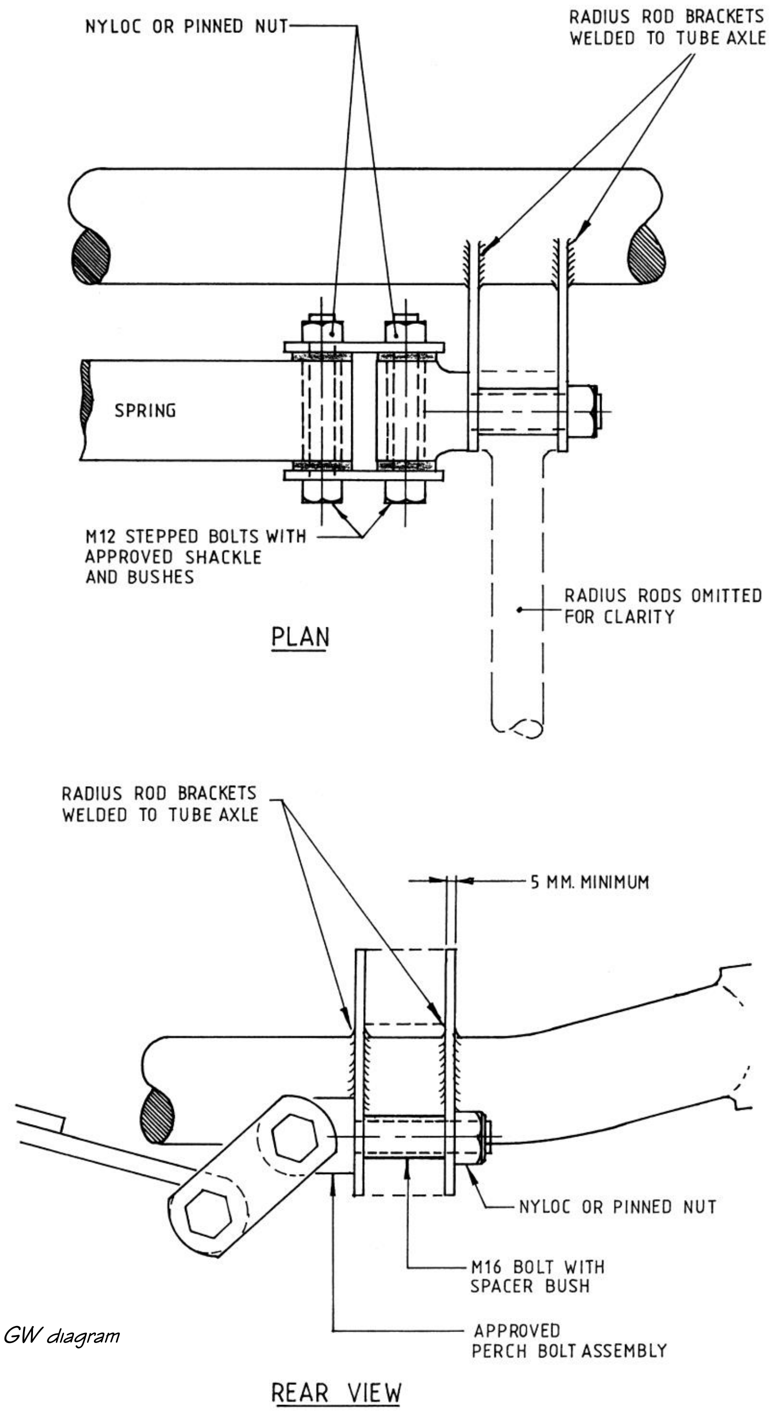


Diagram 6.1 Approved spring shackle assembly design

6.7.2

This means 'Pete & Jake' style shock mounts can't be used to support the vehicle weight through mounting coil-over shocks onto them – these are designed for shock absorbers on their own, and rely on a leaf spring to take the vehicle weight.

6.7.3

An I-beam axle in a low volume vehicle that is attached to a leaf spring must incorporate a spring shackle assembly that:

(a) follows the approved design principles shown in Diagram 6.1; and

(b) in order to prevent binding of the spring shackle assembly when fully tightened, incorporates either:

(i) the correct stepped-shoulder bolt; or

(ii) a steel inner sleeve.

6.7.3

See Diagram 6.1 for approved spring shackle assembly design.

6.8 I-beam axle front suspension modifications

6.8.1

An I-beam axle that is manufactured using a forging process, and has been drilled across the web section of the beam, may be fitted to a low volume vehicle that has a tare of not more than 1500 kgs (3300 lbs), provided that:

(a) the holes are drilled centrally within the web section of the beam; and

(b) the hole size does not exceed 20 mm (51/64”); and

(c) not less than 5 mm (3/16”) of beam material remains above and below the holes within the vertical web section of the beam; and

(d) not less than 20 mm (51/64”) of beam material remains between the holes; and

(e) the outboard holes are positioned no closer to the perch-bolt housing than 80 mm (3 5/32”); and

(f) the vehicle’s front tyre size is kept close to the minimum allowable size.

A low volume vehicle may be built or modified using a drilled cast axle before 2007, but no drilled axles manufactured using a casting process may be fitted to a low volume vehicle after that date.

6.8.1

‘Tare’ is the unladen weight of the vehicle.

The TAC believes that, at the time of print, other than OE I-beam axles, only Chassis Engineering (USA) are forged, whereas other aftermarket units are manufactured using a casting process.

Note that aftermarket I-beam axles manufactured by reputable companies like Magnum, Superbell, and Chassis Engineering can have holes larger than those specified here, provided that the axles are in unmodified as-manufactured condition.

6.8.2

A pre-1950s era production vehicle I-beam axle that is manufactured using a forging process, and has been heated and bent to ‘drop’ the axle, may be fitted to a low volume vehicle that has a tare weight of not more than 1500 kg (3300 lb), provided that:

6.8.2

‘Dropping’ an I-beam axle means the ‘dropping’ or ‘stretching’ process applied to an I-beam axle to lower the vehicle’s ride height.

(a) the I-beam has not been electroplated prior to the heating and bending process; and

(b) the I-beam is a low-tensile strength forged steel; and

(c) the correct temperature has been applied during the heating process so as not to alter the steel's molecular structure or strength; and

(d) the correct equipment has been used to apply the change in shape; and

(e) the process is carried out only by a specialist within the field specifically nominated by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc); and

(f) a consistent and flowing shape has been maintained in the affected area; and

(g) the area of the I-beam axle where the heating and bending has occurred is non-destructively tested, using either the ultra-sonic, x-ray, or magnetic particle method, by a person specified by the specialist who carries out the dropping process.

6.8.3

An I-beam axle in a low volume vehicle that is manufactured using a casting or forging process must not be welded in any circumstances, except for that specified in 6.8.4.

6.8.4

An I-beam axle in a low volume vehicle that is manufactured using a forging process, may be converted into a swing axle suspension system, incorporating a pivot eye welded to each section of the axle beam, provided that:

(a) the I-beam has not been electroplated prior to the welding process; and

(b) the I-beam is a low-tensile strength forged steel; and

(c) a mild steel pivot eye is welded over the maximum available weld area to each beam section; and

(d) the welding is confined to within the third of each axle section closest to the vehicle longitudinal centre-line; and

(e) no binding or twisting occurs within either axle section whilst they travel throughout their arcs when connected to the radius rods; and

6.8.2(c)

This requires a thorough visual inspection with the material in its raw and cleaned state, to ensure that 'over-cooking' has not occurred.

6.8.2(f)

This refers particularly to 'necking' (thinning out) of the beam section that occurs if the stretching process is applied without the correct amount of heat being applied.

6.8.2(g)

The NDT methods specified here will identify any surface cracking or fracturing as a result of the heating and bending process.

6.8.4

A swing-axle suspension system is a modification that was popular amongst predominantly smaller pre-1960s sports vehicles modified for use in hill climbs and other motor-sport activities.

(f) the welded pivot eye incorporates a flexible bushing material and pivots freely; and

(g) the welded pivot eye is positioned and attached to the vehicle structure in such a way so as not to be supporting the weight of the vehicle; and

(h) the welding is carried out in accordance with the welding requirements for critical components specified in 18.9 'Chapter 18 - Attachment systems'.

6.8.4(g)

This means the spring and shock absorber must be positioned as far toward the outside of the vehicle as possible, in order to reduce the amount of vehicle weight being supported by the pivot eyes.

6.9 Tubular beam axle front suspension systems

6.9.1

A tubular beam axle in a low volume vehicle that is attached to a leaf spring must incorporate a spring shackle assembly that:

(a) follows the approved design principles shown in Diagram 6.1; and

(b) in order to prevent binding of the spring shackle assembly when fully tightened, incorporates either:

(i) the correct stepped-shoulder bolt; or

(ii) a steel inner sleeve.

6.9.1

See Diagram 6.1 for approved spring shackle assembly design.

6.10 Tubular beam axle front suspension construction and modification

6.10.1

Welding within the modification or construction process of a tubular beam axle front suspension system in a low volume vehicle, must be carried out:

(a) only on components manufactured from readily weldable steels, such as a low to medium tensile strength mild steel, weldable stainless steel, or chrome-moly; and

(b) in accordance with the welding requirements for critical components specified in 18.9 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.10.1(b), provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.10.1(a)

A typical weldable stainless steel is a 304 L or 316 L grade.

The 'L' denotes low carbon, which means it can be successfully welded.

6.10.2

A suspension component within a tubular beam axle front suspension system in a low volume vehicle that is manufactured using a casting or forging process must not, in any circumstances, be:

(a) heated; or

(b) bent; or

(c) welded.

6.10.2

No heating, bending, or welding of a casting or a forging is a basic engineering principle that should never be broken, except in special circumstances that are specified and controlled within this manual.

This is detailed further under 'Welding of castings and forgings' in the 'Useful Information' section, at the end of this chapter.

6.11 King-pin attachment & modifications for front suspensions

6.11.1

A king-pin within a tubular or I-beam axle fitted to a low volume vehicle must:

(a) be of a size that is a neat fit within the king-pin housing section of the axle; and

(b) features a positive means of preventing the king-pin from:

  (i) rotating within the housing; or

  (ii) moving vertically within the housing.

6.11.2

A tubular or I-beam axle must be designed and manufactured in such a way that a cotter-pin can be positioned to positively locate the king-pin in its correct location.

A low volume vehicle that was built or modified before 2007 may use a grub-screw to locate the king-pin in its correct location instead of the cotter pin required by 6.11.2, provided that the grub-screw:

(a) is lock-nutted to prevent unintended loosening of the grub-screw; and

(b) locates against a flat surface machined into the king-pin of sufficient depth to enable secure engagement against; and

(c) is supplemented by a secondary method of securing the king-pin within the king-pin housing.

Shaded box (c)

A frost-plug at the bottom of the king-pin housing is not considered an acceptable secondary method.

6.11.3

A cotter pin, a grub-screw, or other securing device, must not be used as a means of securing a worn king-pin, or king-pin of an incorrect size, from moving within the king-pin housing.

Front suspension stub axle and hub assembly requirements

6.12 Stub axle suitability in front suspensions

6.12

The term 'stub axle' means the complete stub axle or 'upright' assembly. The 'spindle' is the machined section that the hub bearings run on, otherwise known as the 'pin' or 'axle'. Sometimes the spindle is not part of the stub axle forging, but is a separate pressed-in item, such as those found on early Jaguars.

6.12.1

A hub assembly in a low volume vehicle must:

(a) be securely attached to the stub axle using a vibration-proof fastening method; and

(b) incorporate a dust cap or other suitable sealing device to protect the axle bearings from foreign matter.

6.12.1(b)

An LVV Certifier should remove the dust cap to verify that this has taken place.

6.12.2

A production vehicle stub axle assembly fitted to a low volume vehicle must be sourced from a donor vehicle of a similar or greater front axle weight to that of the vehicle being modified or constructed.

6.12.3

A production low volume vehicle that retains its original hub assembly, and is fitted with an engine that is substantially heavier than that which the vehicle's original hub assembly was designed to support, must have either:

(a) an increased number of wheel studs fitted; or

(b) the original wheel studs replaced by studs of a larger diameter.

6.12.4

A stub axle fitted to a low volume vehicle must be supported at mounting points that are vertically loaded, by load-bearing ball-joints, and not other rod end-type suspension joints that are not designed for load-carrying operation.

6.12.4

Typical spherical bearing rod ends are not designed to support vehicle weight – they are designed for compression and tension loadings. This does not apply to typical non-load bearing situations such as the top pivot/camber adjustment plate on a McPherson strut assembly.

6.13 Stub axle modifications in front suspensions

6.13.1

A production vehicle stub axle assembly fitted to a low volume vehicle must not incorporate any:

(a) welding to any cast or forged suspension upright or stub axle, or steering arm; or

(b) reduction of the spindle diameter by machining or any other means; or

(c) alteration to the original radii contained on the spindle.

A stub axle fitted to a low volume vehicle built or modified before 1992 is not required to comply with (b) or (c) of 6.13.1, provided that the original radii has been replicated during the machining process.

6.14 Custom stub axle design and construction in front suspensions

6.14.1

A custom spindle fitted to a low volume vehicle that is either integral with the stub axle assembly, or separate to the stub axle assembly, must not be manufactured using a casting process.

6.14.2

A custom spindle fitted to a low volume vehicle, that is separate to the stub axle assembly, must:

(a) be manufactured from a high quality low alloy steel; and

(b) incorporate correct machining procedures including maintaining the correct radii at diameter changes; and

(c) be comparable in all critical dimensions to a spindle from a production vehicle of a similar weight as that of the vehicle to which the custom spindle is fitted.

6.14.3

A custom-built stub axle assembly may be fitted to a low volume vehicle provided that it has been individually approved in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc), through the build approval process specified in 'Chapter 4 - Build Approval Process', prior to the commencement of construction.

6.13.1(b)

The only stub axle spindle machining that may be carried out is to extend an existing bearing surface for bearing adaptation, or to shorten the outer end of a spindle.

Where a brake adaptation has taken place, or where an LVV Certifier suspects a brake adaptation has taken place, the hub assembly will need to be removed to enable a thorough visual inspection of radii.

LVV Certifiers must look very carefully to ensure that disallowed modifications have not occurred to cast or forged stub axles, and where in doubt, they may need to make a visual comparison with a known original unit.

6.14.2

'Custom' means manufactured by someone other than a reputable aftermarket manufacturer or high-volume motor vehicle manufacturer.

6.14.2(a)

A medium grade chrome-moly material such as 4140 is considered a suitable material for spindle manufacture.

6.14.3

See more information on next page.

Longitudinal (front suspension) location link requirements

6.15 All radius rods in front suspensions

6.15.1

A radius rod used to locate an I-beam or tubular axle in a low volume vehicle must be either:

(a) sourced from a production vehicle of a comparable or greater weight than the vehicle being modified or constructed; or

(b) of a design and material specification that will withstand the suspension and braking reaction loads that the rods are subjected to.

6.15.2

In the case of a radius rod used to locate an I-beam or tubular axle in a low volume vehicle, the rods must be as long as practical, so as to minimise caster angle changes throughout the suspension's range of travel.

6.15.3

A radius rod used to locate an I-beam or tubular axle in a low volume vehicle must be attached at both the axle end and the chassis end with fasteners that:

(a) are of a diameter of not less than 12 mm (1/2"); and

(b) meet the requirements specified for fasteners in 'Chapter 18 - Attachment Systems'.

6.16 Split production radius rods in front suspensions

6.16.1

Production radius rods may be split away from their original single mounting point triangulated configuration and attached to new mounting points on each side of the chassis of a low volume vehicle, provided that:

(a) the vehicle to which the axle and radius rods are fitted has minimal suspension travel; and

(b) the axle to which the radius rods attach is an I-beam axle manufactured using either:

6.14.3

This process is necessary even for units manufactured by lesser known aftermarket manufacturers, as whilst the more reputable aftermarket stub axle manufacturers (such as Bell-tech, Lorider) sell good products, there are other aftermarket units that are poorly designed and unacceptable.

6.15.1

A 'longitudinal' link is a link that locates an axle in the fore-aft direction, such as a radius rod, or 4-bar system.

6.15.2

Approximately 600 mm (23 5/8") or longer is considered a suitable length for a radius rod in most applications.

6.16.1

Original radius rods may be attached to a tube axle if they meet at the center of the vehicle as per original, or even if slightly shortened to overcome clearance problems, provided the rods follow the same angle as original.

(i) a forging process; or

(ii) a casting process provided that the material used in the casting process is a steel or ductile iron.

A low volume vehicle built or modified before 2007, is not required to comply with 6.16.1, provided that no apparent cracking, twisting, or other damage has occurred to the axle, radius rods, or their mounting points.

6.16.2

Production radius rods split away from their original single mounting point triangulated configuration must not be attached to new mounting points on each side of the chassis of a low volume vehicle if locating either a:

(a) tubular axle; or

(b) custom I-beam axle that is manufactured using a casting process, and where the material used in the casting process is not steel or ductile iron.

A low volume vehicle built or modified before 2007 is not required to comply with 6.16.2, provided that no apparent cracking, twisting, or other damage has occurred to the axle, radius rods, or their mounting points.

6.16.3

Split production radius rods used to locate an I-beam axle in a low volume vehicle must be attached at the chassis with either:

(a) custom bushed rod ends that meet the requirements specified in 6.42.1; or

(b) custom spherical bearing rod ends that meet the requirements specified in 6.43.1; or

(c) tie-rod ends that meet the requirements specified in 6.44.1.

6.16.4

Split production radius rods used to locate an I-beam axle in a low volume vehicle must be attached at the axle with either:

(a) custom bushed rod ends that meet the requirements specified in 6.42.1; or

(b) custom clevis rod ends that meet the requirements specified in 6.45.

6.16.1(b)

A commonly-used I-beam axle manufactured using a casting process is the 'Superbell'. This axle uses a highly-malleable steel, which results in properties similar to that of a forged axle. As such, these may be used.

6.16.2

Old Ford I-beam axles will twist to some degree, however a certain amount of caster change will occur as a result of the twisting effect on the axle that takes place during suspension travel. This is why this system should not be used on vehicles with a lot of suspension travel.

The TAC believes that, at the time of print, other than OE I-beam axles, only Chassis Engineering (USA) are forged, whereas other aftermarket units are manufactured using a casting process. Cast axles must never be used in a suspension system that can apply any twisting loads to the axle unless the material used in the casting process is either steel or ductile iron. A forged I-beam axle is always preferred by the TAC over a cast axle, irrespective of material type.

6.16.5

The forward end of a production vehicle radius rod used to locate an axle in a low volume vehicle may be modified by re-welding or heating and bending, providing that:

(a) the process is being applied in order to enable correct caster and spring alignment during the process of splitting the radius rods from their original single mounting point to new mounting points on each side of the chassis;

(b) and either:

(i) in the case of welding, the welding is carried out in accordance with the welding requirements for critical components specified in 18.9 of 'Chapter 18 - Attachment Systems'; or

(ii) in the case of heating and bending, the heating and bending is carried out by a specialist within the field specifically nominated by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc).

Welding carried out on a vehicle built before 1992 is not required to comply with 6.16.5(b), provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.17 Production radius rod modification in front suspensions

6.17.1

A production vehicle radius rod that is manufactured using a forging process, and has been drilled through its neutral axis, may be fitted to the front axle of a low volume vehicle that has a tare of not more than 1500 kg (3300 lb), provided that:

(a) the holes are drilled centrally within the radius rod; and

(b) the hole size does not exceed half of the radius rod depth throughout the length of the rod; and

(c) the holes are 'tubed' with a mild steel material of not less than 3 mm (1/8") in wall thickness; and

(d) the welding of the tubing into the radius rods is carried out in accordance with requirements specified in 18.7 of 'Chapter 18 - Attachment Systems'; and

(e) not less than 30 mm (13/16") of radius rod material remains between the holes; and

(f) the outboard holes are positioned no closer to the perch-bolt housing than 80 mm (3 5/32").

6.17.1

Radius rods referred to here are primarily those used by high volume vehicle manufacturers (particularly Ford) from shortly after the turn of the century to the late 1940s.

'Tare' is the unladen weight of the vehicle.

Drilled through the 'neutral axis' means drilled through the sides (on a horizontal plane), rather than from top to bottom.

6.18 Hairpin radius rods in front suspensions

6.18.1

Hairpin radius rods may be attached to mounting points on each side of the chassis of a low volume vehicle, provided that:

(a) the vehicle to which the axle and hairpin radius rods are fitted has minimal suspension travel; and

(b) the hairpin radius rods are as long as can practicably be achieved so as to minimise caster change during suspension travel; and

(c) the axle to which the hairpin radius rods attach is an I-beam axle manufactured using either:

(i) a forging process; or

(ii) a casting process provided that the material used in the casting process is a steel or ductile iron.

A low volume vehicle built or modified before 1992 is not required to comply with 6.18.1, provided that no apparent cracking, twisting, or other damage has occurred to the axle, radius rods, or their mounting points.

6.18.1

Old Ford I-beam axles will twist to some degree, however a certain amount of caster change will occur as a result of the twisting effect on the axle that takes place during suspension travel. This is why this system should not be used on vehicles with a lot of suspension travel.

The subject of caster, and its effects, is covered in detail in the 'Useful Information' section at the end of 'Chapter 7 – Steering Systems'

6.18.2

Hairpin radius rods fitted to a low volume vehicle must not be attached to mounting points on each side of the chassis if locating either a:

(a) tubular axle; or

(b) custom I-beam axle that is manufactured using a casting process, and where the material used in the casting process is not steel or ductile iron.

A low volume vehicle built or modified before 1992 is not required to comply with 6.18.2, provided that no apparent cracking, twisting, or other damage has occurred to the axle, radius rods, or their mounting points.

6.18.3

Hairpin radius rods used to locate an I-beam axle in a low volume vehicle must be attached at the chassis with either:

(a) custom bushed rod ends that meet the requirements specified in 6.42.1; or

(b) custom spherical bearing rod ends that meet the requirements specified in 6.43.1; or

(c) tie-rod ends that meet the requirements specified in 6.44.1.

6.18.4

Hairpin radius rods used to locate an I-beam axle in a low volume vehicle must be attached at the axle with either:

(a) custom bushed rod ends that meet the requirements specified in 6.42.1; or

(b) custom clevis joints that meet the requirements specified in 6.45.1.

6.19 Parallel four-link radius rods in front suspensions

6.19.1

A parallel four-link radius rod system used to locate an I-beam or tubular axle in a low volume vehicle must:

(a) be equal in length; and

(b) maintain the same distance between the front and rear of each pair of four-link radius rods; and

(c) be of a design and material specification, and maintain sufficient distance between each upper and lower pair of four-link radius rods, so as to be able to withstand the suspension and braking reaction loads that the rods are subjected to; and

(d) in the case of a parallel four-link radius rod manufactured from aluminium, be supported by documented evidence to substantiate that the material that the aluminium rods are made from, provides equal or greater strength than a typical mild steel rod.

6.19.1(b)

A typical minimum material specification for a medium weight vehicle is schedule 80 12 mm (½") nominal bore seamless tubing (equivalent to 22 mm [7/8"] 8-gauge).

6.19.1(c)

The minimum practical distance between top and bottom arms for a medium-weight vehicle in order to resist brake reaction loads is 120 mm (4 ¾").

6.19.2

A parallel four-link radius rod used to locate an I-beam or tubular axle in a low volume vehicle must be attached to bat-wing brackets and perch-bolt assemblies by either:

(a) a double-shear attachment method that incorporates:

  (i) the approved design principles shown in Diagram 6.2; and

  (ii) custom bushed or spherical bearing rod ends that meet the requirements specified in 6.42.1 or 6.43.1;

6.19.2

Double-shear is always a preferred method over single-shear.

or

(b) a single-shear attachment method that incorporates:

(i) mild steel plate of a thickness not less than 8 mm (5/16"); and

(ii) a custom spherical bearing rod end that meets the requirements specified in 6.43.1

6.19.3

A parallel four-link radius rod used to locate an I-beam or tubular axle in a low volume vehicle must be attached at the chassis with either:

(a) custom bushed rod ends that meet the requirements specified in 6.42.1; or

(b) custom spherical bearing rod ends that meet the requirements specified in 6.43.1.

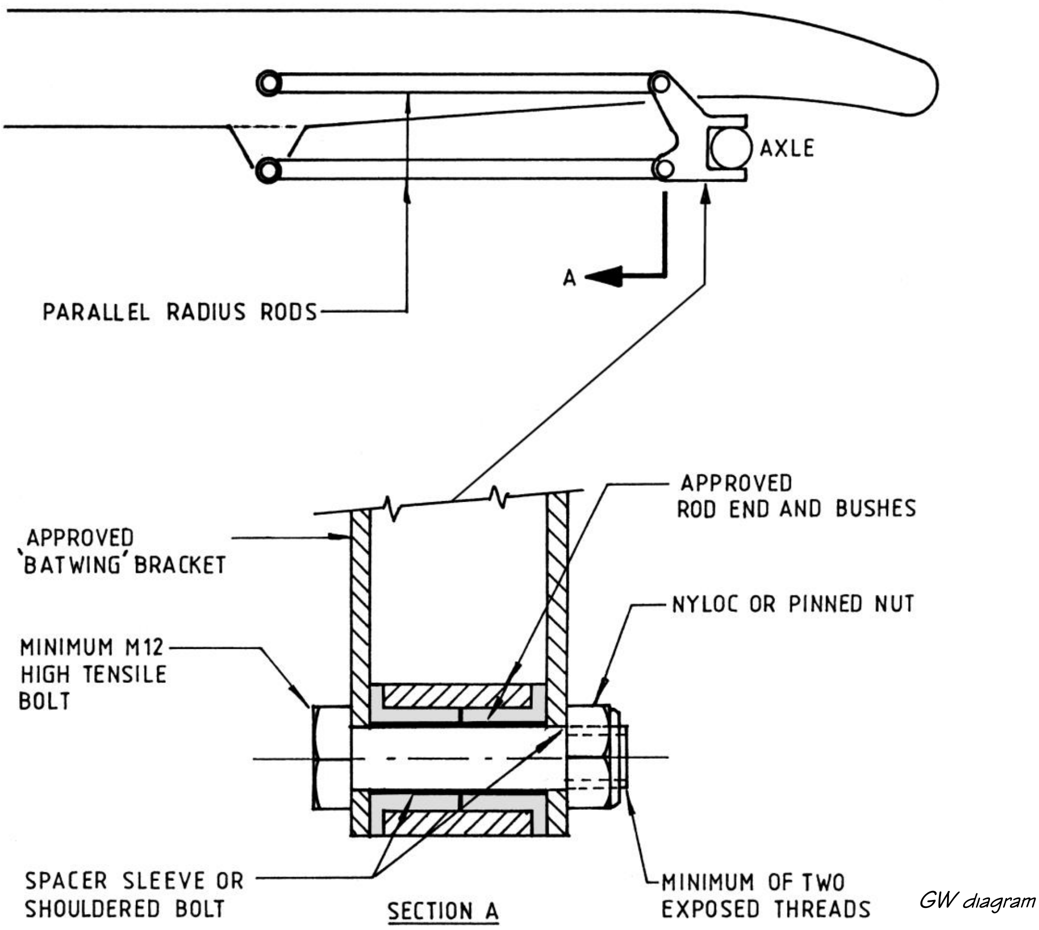


Diagram 6.2 Approved bat-wing bracket assembly design

Production solid and independent rear axle assembly requirements

6.20 Production solid axle housing suitability

6.20.1

A production vehicle solid axle housing assembly fitted to a low volume vehicle must be sourced from a donor vehicle of a similar or greater rear axle weight to that of the vehicle being modified or constructed.

6.21 Production and custom solid axle housing modification

6.21.1

Welding within the modification process of a production or custom solid axle housing in a low volume vehicle must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.21.1, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.22 Production independent rear suspension suitability

6.22.1

A production vehicle independent rear suspension assembly fitted to a low volume vehicle must be sourced from a donor vehicle of a similar or greater rear axle weight to that of the vehicle being modified or constructed.

6.23 Production independent rear suspension modifications

6.23.1

Welding within the modification process of a production independent rear suspension assembly in a low volume vehicle must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.23.1, provided that after thorough inspection, no fatigue cracking or fracturing is evident.

6.24 Production rear axle modifications

6.24.1

A rear axle in a low volume vehicle may be re-drilled to accept a different wheel's pitch circle diameter, provided that any welding of original holes that is required due to an overlap of the new pitch circle diameter and the original holes, meets the welding requirements for non-critical components specified in 18.7 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.24.1, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.24.2

The modification of a rear axle in a low volume vehicle, such as shortening, must be carried out by a person who is suitably experienced, and has a successful track record in, the field of shortening axles.

6.24.2

The process of shortening axles is also referred to as 'narrowing' axles.

Custom independent rear suspension requirements

6.25 Custom independent rear suspension design

6.25.1

A custom-built independent rear suspension assembly 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), through the build approval process specified in 'Chapter 4 - Build Approval Process', to confirm that the suspension assembly incorporates design principles, material specifications, and construction methods suitable for the application, prior to commencement of construction.

6.25

'Custom' means manufactured by someone other than a reputable aftermarket manufacturer or high-volume motor vehicle manufacturer.

6.25.1

See 'Chapter 4 - Build Approval Process'.

6.26 Custom independent rear suspension construction

6.26.1

A custom-built independent rear suspension assembly fitted to a low volume vehicle, must:

(a) be constructed in such a way that any threaded section provided for adjustability is incorporated directly into the control arm material; and

(b) in the case of welded joints, have the material sections joined in such a way as to provide the greatest weld area practicable; and

6.26.1(a) & (b)

For example, use, say, schedule 80 15mm (19/32") nominal bore tube drilled & tapped directly for a 16 mm (5/8") rod end – this keeps the material spec beefy (which it needs to be), and avoids the need to weld in threaded 'spuds' to the arms to accept the rod-ends.

(c) incorporate at the outer end, either:

(i) a purpose-designed automotive ball-joint from a production vehicle of a similar corner weight; or

(ii) a custom bush assembly that is purpose-designed for carrying the corner weight of the vehicle to which the suspension is fitted.

6.26.2

Welding within the construction process of a rear suspension cross-member within a custom independent rear suspension assembly in a low volume vehicle, must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 and 18.8 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.26.2, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.26.3

Welding within the construction process of a custom component within a custom independent rear suspension assembly in a low volume vehicle, must be carried out:

(a) only on components manufactured from readily weldable steels, such as a low to medium tensile strength mild steel, weldable stainless steel, or chrome-moly; and

(b) in accordance with the welding requirements for critical components specified in 18.9 of 'Chapter 18 - Attachment Systems'.

6.26.3(a)

A typical weldable stainless steel is a 304 L or 316 L grade. The 'L' denotes low carbon, which means it can be successfully welded.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.26.3, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.26.4

A suspension component within a custom independent rear suspension assembly in a low volume vehicle that is manufactured using a casting or forging process, must not be:

(a) heated; or

(b) bent; or

(c) welded.

6.26.4

No heating, bending, or welding of a casting or a forging is a basic engineering principle that should never be broken, except in special circumstances that are specified and controlled within this manual.

6.26.5

A custom suspension joint, such as a bushed rod end, may be fitted within a custom independent rear suspension assembly in a low volume vehicle, provided that the joint:

(a) meets the applicable requirements specified for suspension joints in 6.42.1 or 6.43.1; and

(b) is only loaded in compression or tension through its longitudinal axis.

6.26.5

Custom suspension joints include rubber or urethane-bushed aftermarket rod ends and spherical bearing rod ends.

6.26.5(b)

This means that a rod end can't be used as a bottom ball joint, because rod ends are not designed for constant side-load, and they wear faster than a proper automotive load-carrying ball-joint will.

Rear suspension hub carrier requirements

6.27 Hub carrier modifications in rear suspensions

6.27.1

A modified hub carrier assembly 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), through the build approval process specified in 'Chapter 4 - Build Approval Process', prior to commencement of modification.

6.27.1

See 'Chapter 4 - Build Approval Process'.

6.28 Custom hub carrier design and construction in rear suspensions

6.28.1

A custom-built hub carrier assembly 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), through the build approval process specified in 'Chapter 4 - Build Approval Process', prior to the commencement of construction.

6.28

'Custom' means manufactured by someone other than a reputable aftermarket manufacturer or high-volume motor vehicle manufacturer.

6.28.1

See 'Chapter 4 - Build Approval Process'.

Longitudinal (rear suspension) location link requirements

A 'longitudinal' link is a link that locates an axle in the fore-aft direction, such as a radius rod, or four-bar system.

6.29 All radius rods in rear suspensions

6.29.1

A radius rod used to longitudinally locate an axle housing in a low volume vehicle must be either:

(a) sourced from a production vehicle of a comparable or greater weight than the vehicle being modified or constructed; or

(b) of a satisfactory design and material specification, and maintain sufficient distance between each upper and lower pair of four-link radius rods so as to be able to resist the brake reaction loadings and torque loadings applied by the axle housing.

6.29.2

In the case of a radius rod used to locate an axle housing in a low volume vehicle, the rods must be as long as practical, so as to minimise pinion angle changes throughout the suspension's range of travel.

6.29.3

Welding within the process of radius rod attachment and axle housing modification within a low volume vehicle must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.29.3, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.29.4

A radius rod used to locate an axle housing in a low volume vehicle must be attached at both the axle housing end and the chassis end with fasteners that:

(a) are of a size that match the custom spherical bearing rod-end size guide Table 6.4; and

(b) meet the requirements specified for fasteners in 'Chapter 18 - Attachment Systems'.

6.30 Production radius rod modification in rear suspensions

6.30.1

A production vehicle radius rod that is manufactured using a forging process, and has been drilled through its neutral axis, may be fitted to a low volume vehicle that has a tare of not more than 1500 kgs (3300 lbs), provided that:

(a) the holes are drilled centrally within the radius rod; and

(b) the hole size does not exceed half of the radius rod depth throughout the length of the rod; and

6.30.1

Radius rods referred to here are primarily those used by high volume vehicle manufacturers (particularly Ford) from shortly after the turn of the century to the late 1940s, and beyond for commercial vehicles.

It is strongly recommended that when drilling a rear radius rod, the rod be reinforced down its length (so as to effectively turn it into a ladder bar) to prevent bending under severe loading.

'Tare' is the unladen weight of the vehicle.

Drilled through the 'neutral axis' means drilled through the sides (on a horizontal plane), rather than from top to bottom.

(c) the holes are 'tubed' with a mild steel material of not less than 3 mm (1/8") in wall thickness; and

(d) the welding of the tubing into the radius rods is carried out in accordance with requirements specified in 18.7 and 18.8 of Chapter 18 - Attachment Systems'; and

(e) not less than 30 mm (1 3/16") of radius rod material remains between the holes.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.30.1(d), provided that after thorough inspection, no fatigue cracking or fracturing is evident.

6.31 Split production radius rods in rear suspensions

6.31.1

Production radius rods may be split away from their original single central mounting point and attached to new mounting points on each side of the chassis of a low volume vehicle, provided that:

(a) flexible bushes or tie-rod ends that allow a substantial amount of movement are fitted at the chassis mounts; and

(b) the vehicle to which the split production radius rods are fitted has minimal suspension travel.

6.31.1

A split production radius rod fitted to an axle housing without compliance at the chassis end will bind, and possibly break. Chassis end bushes where a split radius rod attaches, must be substantially thicker than in normal bush situations and need to be along the lines of those found on Jaguar IRS radius rods.

6.32 Hairpin radius rods in rear suspensions

6.32.2

A low volume vehicle may be fitted with hairpin radius rods to locate an axle housing, provided that:

(a) the hairpin radius rods are attached at the axle housing with custom spherical bearing rod ends or custom clevis joints that meet the requirements specified in 6.43.1 or 6.45.1; and

(b) the hairpin radius rods are attached at the chassis with custom bushed rod ends or tie-rod ends that meet the requirements specified in 6.42.1 or 6.44.1; and

(c) the vehicle to which the hairpin radius rods are fitted has minimal suspension travel.

6.32.2

A hairpin radius rod fitted to an axle housing without compliance at the chassis end will bind, and possibly break.

Chassis end bushes where a hairpin radius rod attaches must be substantially thicker than in normal bush situations and need to be along the lines of those found on Jaguar IRS radius rods.

6.33 Ladder bar radius rods in rear suspensions

6.33.1

A low volume vehicle may be fitted with ladder bar radius rods to locate an axle housing provided that:

(a) the ladder bar radius rods are attached at the axle housing with custom spherical bearing rod ends or custom clevis joints that meet the requirements specified in 6.43.1 or 6.45.1; and

(b) the ladder bar radius rods are attached at the chassis with custom bushed rod ends or tie-rod ends that meet the requirements specified in 6.42.1 or 6.44.1.

(c) the vehicle to which the ladder bar radius rods are fitted has minimal suspension travel.

6.33.2

In the case of a ladder bar radius rod system operating in conjunction with longitudinal semi-elliptic leaf springs, the:

(a) pivot points of the ladder bar radius rods must be parallel with the front spring hangers to allow full suspension movement; and

(b) ladder bar radius rod ends must incorporate:

(i) flexible bushes at the chassis end of the ladder bar radius rod; and

(ii) custom bushed rod ends at the diff housing end of the ladder bar radius rod.

6.34 Parallel four-link radius rods in rear suspensions

6.34.1

Four-link radius rods used to locate an axle housing in a low volume vehicle must incorporate geometry that ensures against excessive pinion rotation as the axle housing travels through its arc during suspension travel.

6.34.2

Four-link radius rods used to locate an axle housing in a low volume vehicle must be manufactured from a material specification in accordance with Table 6.2.

6.33.1

A ladder bar radius rod fitted to an axle housing without compliance at the chassis end will bind, and possibly break. Chassis end bushes where a ladder bar attaches to the chassis must be substantially thicker than required in normal bush situations, and needs to be along the lines of those found on Jaguar IRS radius rods.

6.33.2

This is to prevent the ladder bar restricting the leaf spring movement, and binding the diff housing.

6.34.1

A good 4-bar set-up will have about 150 mm (6") between the top and bottom bars at the diff end, and about 125 mm (5") between the top and bottom bars at the chassis end.

6.34.2

Table 6.2 assumes the rod is of a 'normal' range of length, between 350 mm (14") and 700 mm (28 ½"). Longer rods should be up-sized.

VEHICLE TYPE	LOW POWER OUTPUT	HIGH POWER OUTPUT
▪ Lotus 7 replica ▪ Light-weight space-frame sports or vintage special	22 mm (7/8”) OD x 1.6 mm (1/16”) wall thickness, ERW or seamless tube	22 mm (7/8”) OD x 2.0 mm (5/64”) wall thickness, ERW or seamless tube
▪ Heavy-weight space-frame sports special ▪ Medium-weight ladder-chassis sports car (MGTF replica) ▪ Light-weight hot rod (T-bucket, f-glass roadster) ▪ Small unit-construction sedan (Civic, Mazda 323)	22 mm (7/8”) NB schedule 80 x 4.2 mm (11/64”)	22 mm (7/8”) NB schedule 80 x 4.2 mm (11/64”)
▪ Heavy-weight ladder-chassis sports car (Cobra) ▪ Medium-weight hot rod (steel coupe, pick-up) ▪ Large unit-construction sedan (Camaro, Falcon, Commodore, Skyline)	22 mm (7/8”) NB schedule 80 x 4.2 mm (11/64”)	25 mm (1”) NB schedule 80 x 4.2 mm (11/64”)
▪ Heavy-weight hot rod (30s & 40s sedan) ▪ Full size body/chassis car (50s & 60s USA sedan)	25 mm (1”) NB schedule 80 x 4.2 mm (11/64”)	25 mm (1”) NB schedule 80 x 4.2 mm (11/64”)

Table 6.2 Parallel four-link radius rod material guide table

6.35 Triangulated four-link radius rods in rear suspensions

6.35.1

The angle at which a non-parallel radius rod used to locate a rear axle housing in a low volume vehicle is positioned, must be sufficient to locate the rear axle housing transversely.

Transverse (front and rear) location link requirements

6.36 All transverse links in front suspensions

6.36.1

Where radius rods are used to locate a front axle in a low volume vehicle, some method of transverse location must be provided, except in the case of:

(a) a triangulated four-bar system; or

(b) a radius rod system with a transverse leaf spring.

Table 6.2

The dimensions specified in Table 6.2 are based on the use of mild steel tubing. Aluminium tubing should be avoided for road use, unless top quality material is used, and the diameter is substantially increased in order to provide strength equal to or better than the mild steel equivalent.

6.35.1

Production vehicles using triangulated four link systems should be studied to provide a guide on the amount of angularity that is necessary to provide transverse support.

6.36

See more information on next page.

6.37 All transverse links in rear suspensions

6.37.1

Where radius rods are used to locate a rear axle housing in a low volume vehicle, some method of transverse location must be provided, except in the case of:

(a) a triangulated four-bar system; or

(b) a radius rod system with a transverse leaf spring.

6.37.2

A transverse link used to laterally locate an axle housing in a low volume vehicle must be either:

(a) sourced from a production vehicle of a comparable or greater weight than the vehicle being modified or constructed; or

(b) of a design and material specification that will withstand the suspension and braking reaction loads that the rods are subjected to.

6.37.3

Welding within the process of transverse link attachment and axle housing modification within a low volume vehicle must be carried out in accordance with the welding requirements for non-critical components specified in 18.7 of 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.37.3, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.37.4

A transverse link used to locate an axle housing in a low volume vehicle must be attached at both the axle housing end and the chassis end with fasteners that:

(a) are of a size specified in the custom spherical bearing rod end size guide Table 6.4; and

(b) meet the requirements specified for fasteners in 'Chapter 18 - Attachment Systems'.

6.38 Panhard rods in front and rear suspensions

6.38.1

A panhard bar fitted to a low volume vehicle must:

6.36

'Transverse link' means something that runs sideways across the vehicle, to secure the axle laterally in the chassis, like a panhard bar, or watts linkage.

6.36.1

6.36.1 does not include the situation where a cross-steer system is used. In such cases, a panhard bar must always be used.

'Cross-steer' is an 'east-west' steering system which directly links the steering box drop arm to the left side steering arm.

6.36.1(b)

A transverse leaf spring, although not ideal, can provide transverse location.

(a) be as straight as can practicably be designed and fitted; and

(b) be as long as can practicably be designed and fitted; and

(c) have each of its ends positioned as closely as practicable to the horizontal plane, or be parallel to, the axle or axle housing.

6.38.2

A panhard bar fitted to a low volume vehicle must attach to the chassis and axle housing with either:

(a) custom bushed rod ends that meet the requirements specified in 6.42.1; or

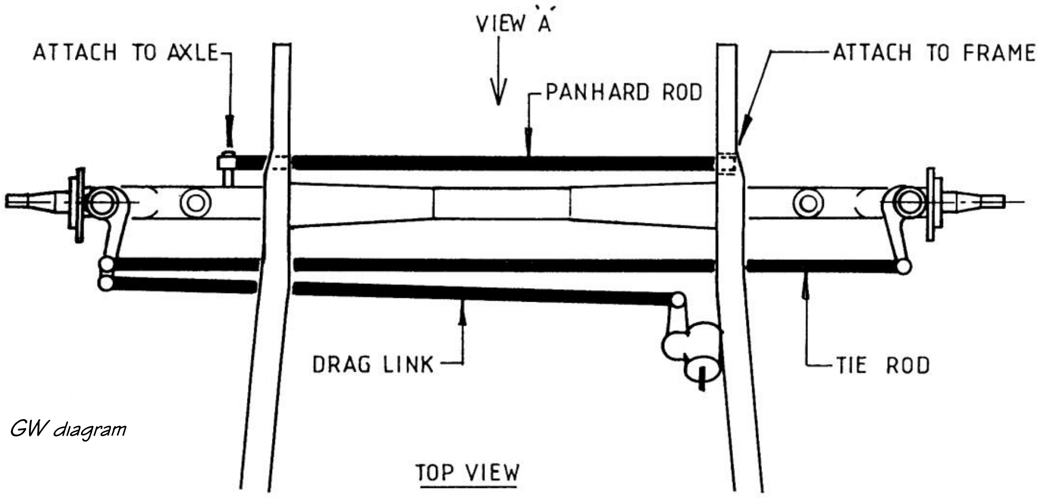
(b) custom spherical bearing rod ends that meet the requirements specified in 6.43.1.

6.38.1(b)

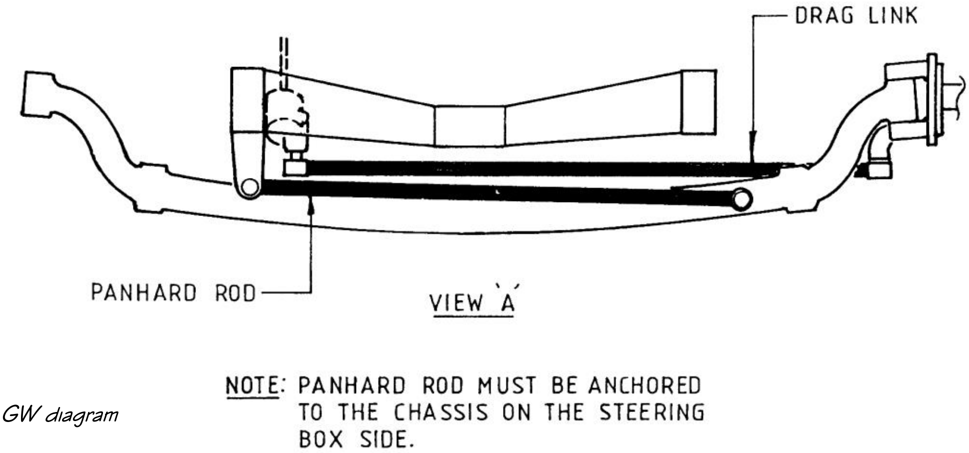
Achieving the maximum possible length for the panhard bar is extremely important for optimum handling.

6.38.1(c)

This includes the pick-up points at each end of the panhard bar.



GW diagram



GW diagram

Diagram 6.3 Panhard bar attachment

6.38.3

A panhard bar mounted to the front of a low volume vehicle, must be attached at the chassis on the same side of the vehicle as that upon which the steering box is positioned. (see Diagram 6.3)

6.38.4

In the case of a panhard bar fitted to both the front and rear of a low volume vehicle, the panhard bar must be attached to the chassis on the same side at both the front and the rear ends of the vehicle.

6.39 Watts linkage rods in front and rear suspensions

6.39.1

Each bar within a watts linkage rod fitted to a low volume vehicle, must, at normal ride height:

(a) be positioned as closely as practicable to:

(i) the horizontal plane, or parallel to the axle or axle housing; and

(ii) parallel to each other;

and

(b) be as long as can practicably be designed and fitted.

6.39.1(a)

This includes the pick-up points at each end of the watts linkage rod.

6.39.1(b)

Achieving the maximum possible length for the watts linkage is extremely important for optimum handling.

6.39.2

A watts linkage rod fitted to a low volume vehicle must attach to the chassis and axle housing with either:

(a) custom bushed rod ends that meet the requirements specified in 6.42.1; or

(b) custom spherical bearing rod ends that meet the requirements specified in 6.43.1

6.40 Diagonal track locator rods in rear suspensions

6.40.1

A diagonal track locator, which is positioned between the rear of one lower four-link radius rod and the front of the other lower four-link radius rod, if fitted to a low volume vehicle, must incorporate fasteners and bracketry within the attachment system that are substantially stronger than the equivalent systems typically employed in a drag racing application.

6.40.1

This is a common set-up on drag racing vehicles. However, the joints typically used to attach a diagonal track locator in a drag car are not designed to withstand the cornering loads of a road-going vehicle.

Suspension joint (front and rear) requirements

6.41 Production ball-joints

6.41.1

A vertically loaded suspension joint fitted to a low volume vehicle must be a purpose-designed load-bearing automotive ball-joint designed to support the corner weight of the vehicle in which it is positioned.

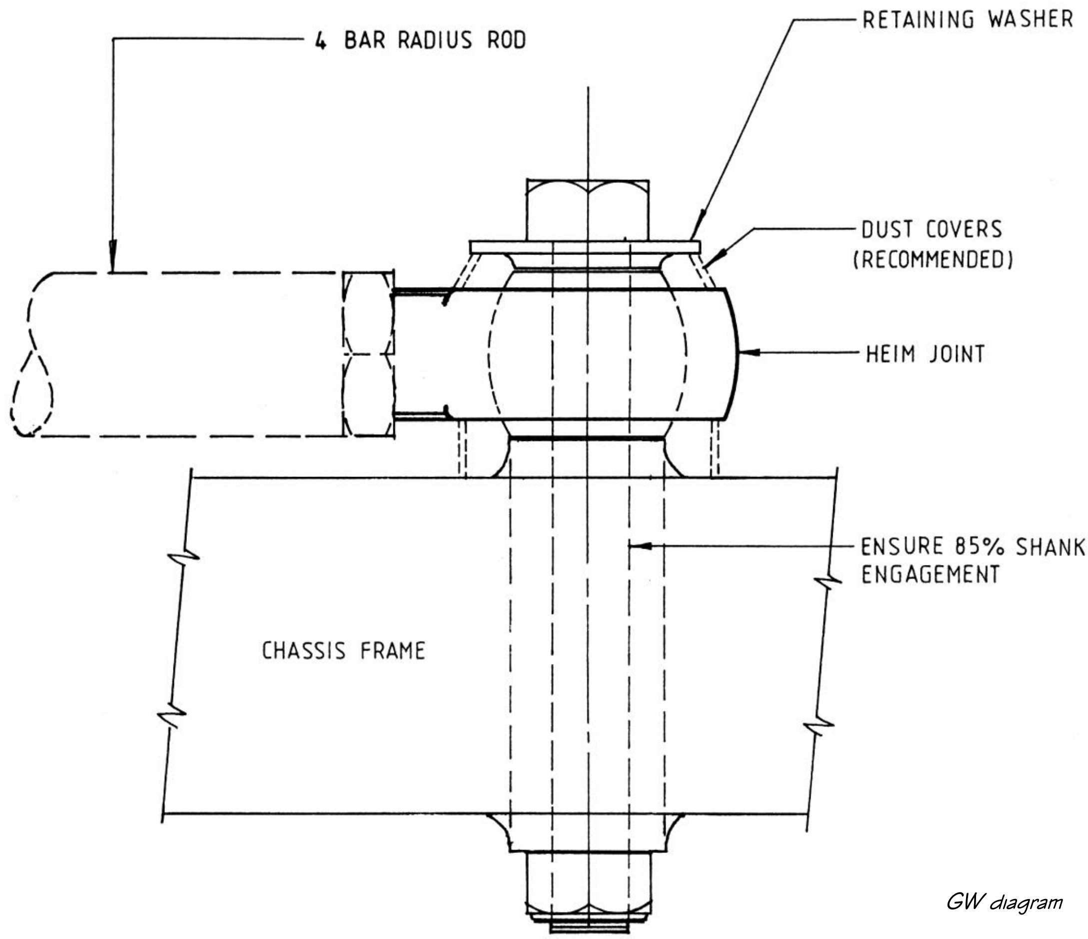


Diagram 6.4 Custom spherical bearing rod end retaining washers

6.42 Custom bushed rod ends

6.42.1

A custom adjustable, or non-adjustable bushed rod end used in a low volume vehicle must incorporate:

(a) purpose designed rubber or urethane bushing; and

(b) a steel inner sleeve; and

(c) in the case of a single-shear attachment of the rod end, a purpose designed pull-out prevention retaining washer. (see Diagram 6.4)

6.42.1(c)

Double-shear is always a preferred attachment method.

6.43 Custom spherical bearing rod ends

6.43.1

A custom spherical bearing rod end fitted to 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 6.3; and

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

(c) incorporate sufficient thread engagement to ensure the rod end is securely held in position; and

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

(e) incorporate a retaining washer to prevent pull-out if the end becomes worn; (see Diagram 6.4) and

(f) incorporate a shank size and a bolt size in accordance with Table 6.4.

6.43.1

Spherical bearing rod ends are commonly known as 'rose' joints or 'heim' joints.

6.43.1(c)

See details on ensuring sufficient thread engagement in 'inspection holes' in the 'Useful Information' section.

6.43.1(d)

This specifically precludes the use of brass-lined rod ends.

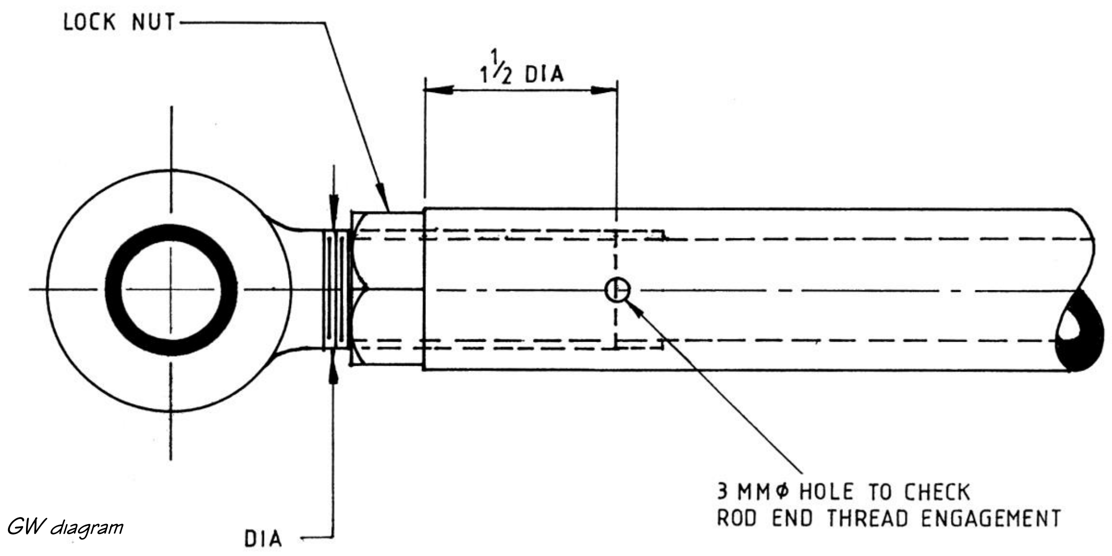


Diagram 6.5 Custom spherical bearing rod end inspection hole

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

VEHICLE TYPE	VEHICLE WEIGHT RANGE	SHANK SIZE	BOLT SIZE
▪ Lotus 7 replica ▪ Light-weight space-frame sports or vintage special	500 – 800 kg (1100 – 1760 lb)	11 mm (7/16”)	11 mm (7/16”)
▪ Heavy-weight space-frame sports special ▪ Medium-weight ladder-chassis sports car (MGTF replica) ▪ Light-weight hot rod (T-bucket, f-glass roadster) ▪ Small unit-construction sedan (Civic, Mazda 323)	800 – 1150 kg (1760 – 2530 lb)	12 mm (1/2")	12 mm (1/2")
▪ Heavy-weight ladder-chassis sports car (Cobra) ▪ Medium-weight hot rod (steel coupe, pick-up) ▪ Large unit-construction sedan (Camaro, Falcon, Commodore, Skyline)	1150 – 1500 kg (2530 – 3300 lb)	16 mm (5/8”)	12 mm (1/2")
▪ Heavy-weight hot rod (30s & 40s sedan) ▪ Full size body/chassis car (50s & 60s USA sedan) ▪ Full-size four-wheel drive vehicles	1500 – 2200 kg (3300 – 4800 lb)	16 mm (5/8”)	16 mm (5/8”)

Table 6.4 Custom spherical bearing rod end size-guide table

6.44 Tie-rod ends

6.44.1

A tie-rod end may be used in a low volume vehicle for the attachment of split radius rods or hairpin radius rods to the chassis at the front or the rear of the vehicle, provided that:

(a) a male thread size of not less than 17 mm (11/16”) is used; and

(b) there is sufficient thread-depth of the tie-rod end into the radius rod; and

(c) an attachment boss at the chassis has:

(i) a correctly machined taper to accept the tie-rod end; and

(ii) sufficient depth so as to accommodate all of the taper in the tie-rod end; and

6.45 Custom clevis joints

6.45.1

A custom clevis joint used in a low volume vehicle must be:

(a) purpose-designed for automotive use; and

(b) of a size appropriate for the application.

6.46 Suspension joint bushings

6.46.1

A bushing incorporated within a suspension joint in a low volume vehicle must be manufactured from a material that is durable, has shock-loading resistance characteristics, and that will retain its shape and position within the joint, throughout all normal vehicle use.

6.46.1

Typical materials regarded as good are urethanes, and rubbers that are supplied specifically for automotive bushing purposes.

Suspension geometry requirements

6.47 General geometry requirements

6.47.1

A low volume vehicle that has undergone significant changes to the suspension system must feature no abnormal suspension geometry, and be aligned so as to provide satisfactory handling characteristics, and ensure against excessively shortened tyre life.

6.47.2

Moving components and systems fitted to a low volume vehicle which are affected by suspension travel, must not be detrimentally affected at extremes of suspension travel by exceeding the operating limits specified by the equipment manufacturer, including:

(a) *binding or excessive angularity of ball-joints, swivel-joints or constant velocity-joints; or*

(b) *binding or excessive angularity of steering arms or tie-rod ends; or*

(c) *binding or shortening the normal working life of drive-shaft universals.*

6.47.3

A front suspension system fitted to a low volume vehicle must incorporate provision for the correct adjustment and alignment of camber, toe-in, and toe-out.

6.48 Caster angle geometry

6.48.1

Positive caster is required to be incorporated within the front suspension of a low volume vehicle, as specified in 7.34 of ‘Chapter 7 - Steering Systems’.

6.48.1

The subject of caster, and its effects, is covered in detail in the ‘Useful Information’ section at the end of ‘Chapter 7 – Steering Systems’

6.49 Production independent rear suspension geometry

6.49.1

A production vehicle independent rear suspension assembly fitted to a low volume vehicle must:

(a) be attached to the chassis using components and attachment methods that duplicate or improve the suspension geometry of the donor vehicle; and

(b) not bind throughout all normal operating suspension travel; and

(c) in the case of a Jaguar independent rear suspension system from the 1960s to 1980s era, follow the installation and geometry principles outlined in the applicable Low Volume Vehicle Technical Association (Inc) Information Sheet.

6.49.1

The Jaguar IRS has caused a lot of problems over the years, through incorrect installations. The LVVTA (Inc)’s Information Sheet provides the necessary information to get the Jaguar IRS installation right. This is available from the LVVTA (Inc)’s website, down-loadable free of charge at www.lvvta.org.nz

Air-bag suspension system requirements

6.50 Air-bag system installation

6.50.1

An air-bag system fitted to a low volume vehicle must be:

(a) an appropriate selection for the vehicle type and weight; and

(b) designed and installed in accordance with the air-bag manufacturer's specifications.

6.50.2

An air-bag system fitted to a low volume vehicle must be designed and installed in such a way that either:

(a) the air-bag system is only able to be operated whilst the vehicle is stationary; or

(b) the air-bag system can be operated whilst the vehicle is in motion, provided that:

(i) the ride-height of any part of the vehicle is electronically prevented from being adjusted or changed when the vehicle is being driven over a speed of 20 kph (12 mph); and

(ii) the vehicle automatically reverts to its pre-determined correct ride-height when a speed sensor determines that the vehicle is traveling faster than 20 kph (12 mph).

6.50.2

This requirement is to prevent the vehicle from being driven at any stance that could cause the vehicle to be unsafe to drive, through excessive or insufficient ride-height, or incorrect steering or suspension geometry.

6.50.2 (cont'd)

A system used to meet the requirements specified in 6.50.2(b)(i) must be as resistant to post-certification tampering as possible. Park-brake activated systems are not permitted.

6.50.3

An air-bag system fitted to a low volume vehicle must be designed and installed in such a way that the air-bag system:

(a) can raise or lower the vehicle in the fore-aft, and side-to-side combination, but cannot raise an individual corner of the vehicle; and

(b) cannot enable the vehicle to 'bounce' or 'hop' on its suspension.

6.50.3

It is particularly necessary to prevent the vehicle from being twisted diagonally, which causes major stress and damage to the vehicle structure over time.

6.50.4

An air-bag incorporated within an air-bag system fitted to a low volume vehicle must be installed in such a way that, at normal ride-height:

(a) the top and bottom mounting plates to which the air-bag attaches are as close as practicable to parallel with each other; and

(b) the air-bag as much as practicable, maintains its intended shape.

6.50.4

This means that the bag does not 'banana' due to incorrect platform positioning.

6.50.5

An air-bag system fitted to a low volume vehicle must be designed and installed in such a way that under full suspension droop, the air-bag cannot:

(a) extend beyond the air-bag manufacturer's specifications; or

(b) dislodge or come out.

6.51 Vehicle ride-height with air-bag systems

6.51.1

An air-bag system fitted to a low volume vehicle must be designed and installed in such a way that, when the vehicle is being driven, the ride-height of the vehicle cannot be altered.

6.51.2

An air-bag system fitted to a low volume vehicle must be designed and installed in such a way that, when the vehicle is being driven, the ride-height of the system can only be positioned at a setting which ensures that:

(a) all normal steering and suspension requirements are maintained; and

(b) all suspension arms are in the neutral plane; and

(c) the vehicle's position in relation to the road surface is not offset either side to side, diagonally, or significantly offset front to rear; and

(d) the vehicle's ride-height is not so high that it could become unstable; and

(e) the vehicle's ride-height is not so low that the vehicle no longer meets the scrub-line requirements specified in 7.37 of 'Chapter 7 – Steering Systems'.

6.51.2(b)

Suspension arms include all axle locaters including radius rods, wishbone arms, panhard bars, and watts linkage bars.

6.51.2(c)

This means that the vehicle can have a normal 'rake', but maintains a 'flat' stance side to side and diagonally.

An LVV Certifier is responsible for assessing the minimum and maximum height ranges throughout which the vehicle can be safely operated, and having these recorded on the LVV certification plate.

6.52 Air-bag system dampers and bump-stops

6.52.1

Each corner of a low volume vehicle to which an air-bag system is fitted, must incorporate an effective damping system, either:

(a) as part of the air-bag system; or

(b) in the case of an air-bag system which does not incorporate integral dampers, in addition to the air-bag system.

6.52.2

An air-bag system fitted to a low volume vehicle must be designed and manufactured in such a way that:

(a) effective bump-stops similar to those expected in a spring and shock-absorber combination are incorporated within the system that are either:

(i) separate units mounted externally from the air-bag; or

(ii) incorporated internally within the air-bag;

and

(b) in the event of a failure of all or any part of the system, bump-stops will prevent the vehicle from being able to be driven at a ride-height below the specified minimum safe setting.

6.52.2(a)

An air-bag system is typically a lot harder on bump-stops than a conventional suspension system. Therefore, extra attention should be put into trying to use the best possible bump-stops, and the vehicle owner should be prepared to replace the bump-stops more regularly than on a conventional suspension system.

6.53 Air-bag system air supply

6.53.1

An air-bag incorporated within an air-bag system fitted to a low volume vehicle must be either:

(a) a bag supplied as part of a complete kit manufactured by a reputable company that manufactures purpose-designed automotive suspension systems; or

(b) made from a material that can be proven through documented evidence to be capable of withstanding the pressures and loads to which it will be subjected, during all aspects of the system's intended use.

6.53.2

An air-bag system fitted to a low volume vehicle must be installed in a such a way that, when the vehicle is being driven:

(a) each air-bag maintains its pressure; and

(b) no transfer of air between individual corners of the vehicle can occur.

6.53.2

In a 4-way mode, the system will prevent air transfer from side to side or front to back, which ensures against increased body roll from unequal and changing loads.

6.53.3

An air-bag system fitted to a low volume vehicle must incorporate:

(a) an air supply tank that is a purpose-designed pressure vessel that:

(i) is mounted securely to the vehicle structure in a safe position; and

(ii) complies with the appropriate pressure vessel requirements;

and

(b) air-valves, lines, fittings, and hoses that are:

(i) securely attached; and

(ii) protected from moving components; and

(iii) adequately shielded from heat; and

(iv) rated for operational use at a pressure of not less than that at which the system operates;

and

(c) an external auxiliary fill valve that will enable re-filling from an external compressor.

6.53.4

An air-bag system fitted to a low volume vehicle that incorporates a pressure bottle, must incorporate an independent relief valve or pressure switch to prevent the air supply tank from over-pressurising.

6.53.3(c)

This is to enable a vehicle to have its air system re-filled from a compressor at a petrol station in order to maintain normal suspension system height and operation in the event of a slow leak.

6.53.4

'Pressure bottle' generally means a dive bottle. This requirement is in case of a failure of the bottle's pressure regulator.

6.54 Chassis and suspension modifications (for air-bags)

6.54.1

Modifications to the chassis and suspension of a low volume vehicle fitted with air-bag suspension must:

(a) incorporate adequate reinforcing where metal removal has occurred on any suspension arms, so as to ensure the suspension arms have not been weakened as a result of the modification; and

(b) incorporate adequate remaining chassis strength where metal removal has occurred so as to ensure the chassis has not been weakened as a result of the modification; and

(c) have at least 5 mm (13/64") clearance between brake lines and moving parts when the hydraulic system is at maximum or minimum level; and

(d) have adequate drive-shaft clearance from the chassis when the airbag system is at maximum or minimum level; and

(e) have adequate clearance between the wheels and tyres and suspension or bodywork at any stage of suspension travel; and

(f) incorporate flexible brake hoses that are of such a length, and are so positioned and secured, that they cannot contact or become pinched by any part of the vehicle's structure or components, throughout the suspension system's full range of suspension travel; and

(g) not have any components mounted lower than that specified for steering system scrub-line geometry in 7.37 'Chapter 7 - Steering Systems'.

6.54.2

Shock absorbers fitted to a low volume vehicle with an air-bag suspension system, must, if repositioned or remounted, be:

(a) mounted using a mounting and attachment system that is capable of withstanding the loads that will be imposed on it through all normal driving operation and air-bag action; and

(b) positioned in such a way as to provide maximum damping effect; and

(c) mounted in such a way so as:

(i) to duplicate or improve the original mounting system design; and

(ii) not to bind or interfere with any other part of the vehicle.

6.54.3

A low volume vehicle fitted with an air-bag suspension system must incorporate a mudguard over each wheel and tyre.

Hydraulic suspension system requirements

6.55 Hydraulic suspension design principles

6.55.1

A hydraulically-actuated adjustable ride-height suspension system may be fitted to a low volume vehicle provided that:

(a) the vehicle incorporates a spring for each wheel, that is:

6.54.1(e)

It is accepted that in 'limp-home mode' with total air-bag failure, the steering lock may be limited due to rubbing.

6.54.3

'Mini-trucks' with airbags or hydraulics may use the deck tonneau cover or hard-bed as its mudguards for the rear wheels.

6.55.1

Put in simplest terms, a hydraulic suspension can only be LVV certified if:

- the vehicle has a spring with a suitable rate for normal road use; and
- a working shock absorber for each wheel; and
- the hydraulic system cannot be operated when the vehicle exceeds 20 kph (12 mph) and
- the system cannot 'bounce' or 'hop' the car.

(i) capable of providing sufficient suspension bump travel for the vehicle to be able to be driven safely; and

(ii) of a rate that enables the vehicle to absorb all road irregularities in a normal manner;

and

(b) the vehicle incorporates an operative and effective shock absorber for each wheel, that is capable of adequately damping springing operation; and

(c) adequate safeguards are incorporated to ensure that the vehicle retains its normal road handling, braking and steering performance when used on-road; and

(d) the design is such that safety components are not overstressed during extreme suspension travel when off-road.

6.55.2

A hydraulically-actuated adjustable ride-height suspension system may only be fitted to a low volume vehicle that incorporates coil suspension.

6.55.1(a)(i)

Minimum sufficient bump travel is, as a very general rule of thumb, considered to be 40 mm (1 9/16") for a medium weight vehicle.

6.55.2

This means hydraulics cannot be used in conjunction with leaf spring suspension systems.

6.56 Hydraulic suspension geometry

6.56.1

A hydraulically-actuated adjustable ride-height suspension system fitted to a low volume vehicle must not allow:

(a) maximum suspension component and ball-joint angles to be exceeded at any stage of suspension travel; and

(b) maximum drive-shaft universal joint operating angles to be exceeded at any stage of suspension travel.

6.56.2

A hydraulic actuator incorporated within an adjustable ride-height system fitted to a low volume vehicle must be installed in such a way that, at all ride-heights:

(a) the actuator and spring locator cup acts as squarely as can be achieved on the spring; and

(b) the spring is located so that it cannot fall out during ram operation; and

(c) the top and bottom mounting plates to which a ram/spring combination attaches are as close as practicable to parallel with each other; or

(d) a swivel mounting is used on the lower end where the actuator is mounted to the axle or suspension arm.

6.57 Vehicle ride-height with hydraulic suspension

6.57.1

A hydraulic suspension system fitted to a low volume vehicle must be designed and installed in such a way that either:

(a) the hydraulic suspension system is only able to be operated whilst the vehicle is stationary; or

(b) the hydraulic suspension system can be operated whilst the vehicle is in motion, provided that:

(i) the ride-height of any part of the vehicle is electronically prevented from being adjusted or changed when the vehicle is being driven over a speed of 20 kph (12 mph); and

(ii) the vehicle automatically reverts to its pre-determined correct ride-height when a speed sensor determines that the vehicle is traveling faster than 20 kph (12 mph).

6.57.2

A hydraulic suspension system fitted to a low volume vehicle must be designed and installed in such a way that, when the vehicle is being driven, the ride-height of the system can only be positioned at a setting which ensures that:

(a) all normal steering and suspension requirements are maintained; and

(b) all suspension arms are as close as practicable to the neutral plane; and

(c) the vehicle's position in relation to the road surface is not offset either side to side, diagonally, or significantly offset front to rear; and

(d) the vehicle's ride-height is not so high that it could become unstable; and

(e) the vehicle's ride-height is not so low that the vehicle no longer meets the scrub-line requirements specified in 7.37 of 'Chapter 7 - Steering Systems'.

6.56.2(c)

It is accepted that there will always be some offset loading as any suspension system moves throughout its arc. However, the spring and ram platforms must be set up squarely at normal ride-height, so that the ram or ram/spring combination does not 'banana' during suspension travel.

6.57.1

A LVV Certifier will need to assess the approved operating ride-height, and have this recorded on the LVV Certification Plate.

A system used to meet the requirements specified in 6.57.1(b)(i) must be as resistant to post-certification tampering as possible. Park-brake activated systems are not permitted.

6.57.2(b)

Suspension arms include all axle locaters including radius rods, wishbone arms, panhard bars, and watts linkage bars.

6.57.2(c)

This means that the vehicle can have a normal 'rake', but maintains a 'flat' stance side to side and diagonally.

6.58 Hydraulic system bump-stops

6.58.1

A low volume vehicle must be fitted with bump-stops that:

(a) are similar in design to those expected in a normal non-hydraulic suspension spring and shock-absorber combination, that are separate units mounted externally from the hydraulic rams; and

(b) will operate in such a way that upon a total hydraulic system failure, sufficient clearance between the vehicle's wheels and tyres, and the suspension, steering and body will exist, so that basic controllability of the vehicle will be maintained.

6.58.1(a)

A hydraulic system is typically a lot harder on bump-stops than a conventional suspension system. Therefore, extra attention should be put into trying to use the best possible bump-stops, and the vehicle owner should be prepared to replace the bump-stops more regularly than on a conventional suspension system.

6.58.1(b)

Upon a hydraulic system failure, at 'collapsed' height, a vehicle with hydraulic suspension must still maintain sufficient driveability to be able to be pulled onto a transporter, or operated in a 'limp home' mode.

6.59 Hydraulic system oil supply

6.59.1

A hydraulic ram incorporated within a hydraulic suspension system fitted to a low volume vehicle must be a ram that is either:

(a) supplied as part of a complete kit manufactured by a reputable company that manufactures purpose-designed automotive suspension systems; or

(b) can be proven through documented testing evidence to be capable of withstanding the pressures and loads to which it will be subjected, during all aspects of the system's intended use.

6.59.2

A hydraulic system fitted to a low volume vehicle must be installed in a such a way that, when the vehicle is being driven at over 20 kph (12 mph):

(a) each hydraulic ram maintains its pressure; and

(b) no transfer of oil between individual corners of the vehicle can occur.

6.59.2

In a 4-way mode, the system will prevent oil transfer from side to side or front to back, which ensures against increased body roll from unequal and changing loads.

6.59.3

A hydraulic system fitted to a low volume vehicle must incorporate:

(a) a separate pump for each axle; and

6.59.3

This is to overcome differences in front and rear axle weights.

(b) an oil supply reservoir that is a purpose-designed vessel that:

(i) is mounted securely in a safe position; and

(ii) holds at least 25% more fluid than the combined volume of all the hydraulic rams.

6.59.4

Valves, lines, fittings, and hoses that are incorporated within a hydraulic system fitted to a low volume vehicle must be:

(a) securely attached using purpose-designed clamping systems at maximum intervals of 300 mm (12"); and

(b) protected from the road surface, road debris, and jacks; and

(c) protected from moving components; and

(d) adequately shielded from heat; and

(e) purpose-designed components that are rated for operational use at a pressure of not less than that at which the system operates.

6.59.4(c)

Lines and hoses must not be mounted on the underside of chassis or sub-frame rails.

6.59.4(e)

Such equipment needs to be rated for a minimum of 3000 psi (20,670 kPa).

6.59.5

Fluid within a hydraulic suspension system that passes through the passenger compartment of a low volume vehicle must be contained within hard-line only.

6.60 Hydraulic system electrical power

6.60.1

Where a hydraulic suspension utilises banks of batteries for hydraulic pump operation, they must:

(a) operate at a maximum of 48 volts; and

(b) operate through relays that are capable of withstanding the electrical loads being applied; and

(c) be securely retained in a structure specifically designed for the weight and load of the batteries being used, and

(d) have some method of preventing acid spills from entering the passenger compartment of the vehicle; and

(e) are sealed and ventilated where charging and subsequent gas emission may occur while the vehicle is operating; and

6.60.1(a)

The LVV Certifier must measure the as-installed pump supply voltage, which is not to exceed 48 volts, or 4 12-volt batteries.

The LVV Certifier should be aware of the speed of the system, and satisfy himself that the system cannot operate at such a speed as to enable 'hopping' or 'bouncing'.

6.60.1(c)

On separate body/chassis vehicles, such structures should mount directly to the chassis.

(f) have a mechanical master isolation switch within reach of the driver that isolates the power supply to the hydraulic motors and motor controls; and

(g) be safely wired and protected from short circuits, and

(h) have electrical equipment such as pump motors and solenoids isolated from the fuel tank and system.

6.60.1(f)

A switch linked to a high current DC isolator relay is preferred, such as those used in electric fork-hoists.

6.61 Chassis and suspension system modifications (for hydraulic systems)

6.61.1

Modifications to the chassis and suspension of a low volume vehicle fitted with hydraulic suspension must:

(a) incorporate adequate reinforcing where metal removal has occurred on any suspension arms, so as to ensure the suspension arms have not been weakened as a result of the modification; and

(b) incorporate adequate remaining chassis strength where metal removal has occurred so as to ensure the chassis has not been weakened as a result of the modification; and

(c) have at least 5 mm (13/64") clearance between brake lines and moving parts when the hydraulic system is at maximum or minimum level; and

(d) have adequate drive-shaft clearance from the chassis when the hydraulic system is at maximum or minimum level; and

(e) have adequate clearance between the wheels and tyres and suspension or bodywork at any stage of suspension travel; and

6.61.1(e)

It is accepted that in 'limp-home mode' with total hydraulic failure, the steering lock may be limited due to rubbing.

(f) incorporate flexible brake hoses that are of such a length, and are so positioned and secured, that they can not contact or become pinched by any part of the vehicle's structure or components, throughout the suspension system's full range of suspension travel; and

(g) not have any components mounted lower than that specified for steering system scrub-line geometry in 7.37 'Chapter 7 - Steering Systems'.

6.61.2

Shock absorbers fitted to a low volume vehicle with a hydraulic suspension system, must, if repositioned or remounted, be:

(a) mounted using a mounting and attachment system that is capable of withstanding the loads that will be imposed on it through all normal driving operation and hydraulic action; and

(b) positioned in such a way as to provide maximum damping effect; and

(c) mounted in such a way so as:

(i) to duplicate or improve the original mounting system design; and

(ii) not to bind or interfere with any other part of the vehicle.

Additional requirements for all suspension systems

6.62 Coil-over shock absorber requirements

6.62.1

A coil-over shock absorber system incorporated within the rear suspension of a low volume vehicle, must be attached using either:

(a) the double-shear attachment method; or

(b) the single-shear attachment method that incorporates:

(i) a load-bearing surface that supports the coil-over shock absorber assembly which is incorporated integrally with the attachment bracket; and

(ii) an attachment bracket manufactured from a suitable material, of a thickness of not less than 5 mm 13/64”), and with adequate gusseting or reinforcement to prevent bending; and

(iii) a mounting stud that has a diameter of not less than that specified in Table 6.4; and

(iv) a spacer sleeve with a wall thickness of not less than 3 mm (1/8”) and a length of not less than one and a half times the diameter of the mounting stud. (see Diagram 6.6)

6.62.1(a)

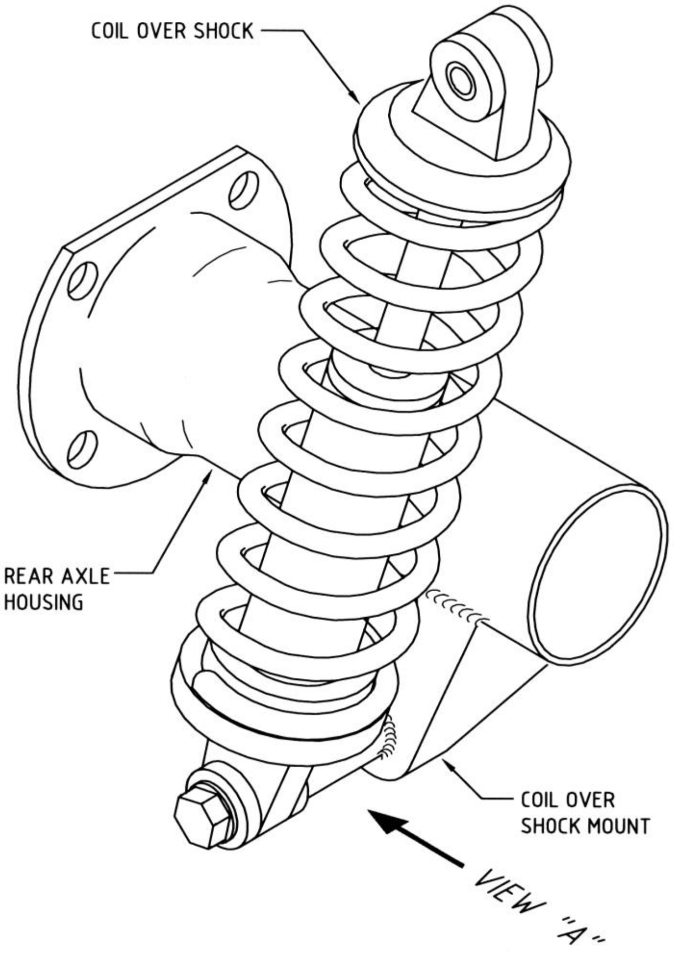
‘Double-shear’ means an attachment method that supports the component on both sides, rather than the cantilevered effect achieved by a single-shear attachment system.

6.62.1(b)(iv)

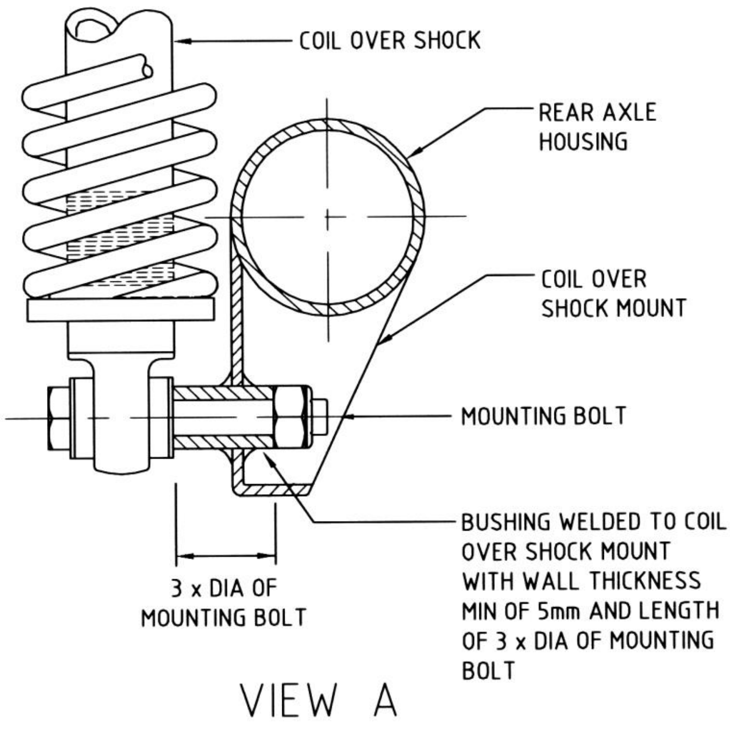
See Diagram 6.6 for single-shear mounting details.

6.62.2

A coil spring fitted to a low volume vehicle must be of a sufficient rate so as not to be able to fully compress upon full suspension travel.



GW diagram



GW diagram

Diagram 6.6 Single-shear coil-over shock absorber attachment

6.63 Heavy-duty and height-changing coil springs

6.63.1

A low volume vehicle fitted with coil springs must:

(a) *be fitted with shock absorbers which are able to satisfactorily control spring energy; and*

(b) *where a substantial increase in spring rate occurs, be reinforced as necessary in the areas of the body or chassis or sub-frame structure on which the increased loads being transmitted are likely to cause fracturing or failure.*

6.63.2

Coil springs fitted to a low volume vehicle that reduce the suspension travel and, as a result, the ride height of the vehicle, must be proportionately increased in stiffness rate so as to ensure against contact between the underside of the vehicle and the road surface during normal vehicle operation when fully laden.

6.63.3

Coil springs fitted to a low volume vehicle must be designed in such a way that the ends of the springs, whether of a plain, plain and ground, closed, or closed and ground configuration, are shaped to match the surfaces against which they seat, both top and bottom.

6.63.4

Progressive-rate coil springs fitted to a low volume vehicle must have the closely-wound section of the coil positioned either:

(a) *at the end nearest the body, chassis, or sub-frame structure; or*

(b) *in accordance with the spring or vehicle manufacturer's specifications.*

6.64 Coil spring containment

6.64.1

Coil springs fitted to a low volume vehicle must be firmly contained within their locating seats in such a way that the springs can not rotate, move vertically, or become dislodged when the suspension travel reaches its maximum rebound, limited by either:

6.64.1

A dislodged spring can have a substantial effect on a vehicle's handling, and a lost spring can multiply this effect further, as well as potentially puncturing a tyre sidewall.

An acceptable method of containing a coil is suitably strong hooked clips that attach to the suspension arm or strut by welding or bolting, that clamp around the spring. 'Keeper' springs are a common method of tensioning the spring in an adjustable platform suspension system.

(a) *a shock absorber of a compatible stroke length; or*

(b) *properly fastened retaining clamps; or*

(c) *properly fastened wire-rope straps of the type used in motor-sport applications, provided that the suspension mounting points are sufficiently strong to withstand the increased loadings imposed by the straps reaching the end of their travel, particularly in the case of MacPherson-strut suspension systems.*

6.65 Coil spring modifications

6.65.1

Coil springs fitted to a low volume vehicle must not be modified for the purpose of changing the vehicle's ride height unless either:

(a) *the spring is modified by a recognised spring manufacturer, and the configuration of the modified spring ends match the end configuration of the original spring; or*

(b) *the spring:*

(i) *fitted to the vehicle in its original configuration had plain unground ends; and*

(ii) *no heat is used during the modification process.*

6.65.2

Coil springs fitted to a low volume vehicle may be electro-plated provided that:

(a) the springs have not been previously electro-plated; and

(b) the springs are in good condition and require minimal time in the cleaning bath to prepare them; and

(c) the electroplating is carried out by a reputable electroplating company with experience in relieving hydrogen entrapment; and

(d) documented evidence is provided to substantiate that the springs have undergone an appropriate post-plating heat treatment process to avoid hydrogen embrittlement from the springs.

6.65.2

Reputable aftermarket electroplated springs (such as QA1 etc) may be used in their as-manufactured state.

6.65.2(d)

'Baking' at 200 degrees Celsius for 4 hours immediately after the plating process is the recommended procedure that is considered necessary to remove any hydrogen entrapment that is likely to occur (subsequently causing 'hydrogen embrittlement') as a result of the electroplating process.

6.66 Leaf spring modifications

6.66.1

A low volume vehicle must not be lowered by the fitting of a leaf spring mounted in the upside-down position.

6.66.2

The spring eyes of a leaf spring fitted to a low volume vehicle may be reversed, provided that the process is carried out by a recognised industry expert, professionally engaged in the manufacturing and modification of springs.

6.66.3

A dead-perch used to locate a front axle on a low volume vehicle must be positioned on the side of the vehicle opposite to the steering box.

6.66.4

A leaf spring fitted to a low volume vehicle may only be manufactured or modified by a recognised industry expert, professionally engaged in the manufacturing and modification of springs.

6.67 Leaf spring hanger systems

6.67.1

Spring shackles fitted to a low volume vehicle, if longer than 150 mm (6") between shackle pin centres, must be reinforced to prevent bending under cornering loadings.

6.68 Leaf spring height adjustment blocks

6.68.1

Spacer blocks which have been fitted to a leaf spring suspension system in a low volume vehicle, to raise or lower the ride height of the vehicle, must be of a depth no greater than:

(a) *50 mm (2") if not supported by lift-bars or anti-tramp rods; or*

(b) *if supported by correctly fitted and adjusted lift-bars or anti-tramp rods, 80 mm (3 5/32").*

6.68.2

A spacer block fitted to a leaf spring suspension system to raise or lower the ride-height of a low volume vehicle must be positively located at the top and the bottom of the block.

6.66.2

'Reversing' eyes is the process of changing the spring shackle mounting eye from one side of the spring surface to the other. This is a common method of lowering.

6.66.3

A dead-perch is a system by which one side of a transverse leaf spring is locked to prevent any lateral movement.

6.66.4

This does not include the removal or refitting of one or more leaves within a leaf spring.

6.69 Spring attachment points

6.69.1

The front or rear weight of a low volume vehicle must be supported through the vehicle's springing system, directly onto the front and rear axles, and not to the vehicle's longitudinal location links, unless the longitudinal location links and associated bushings are designed to withstand the vehicle's spring loads.

6.70 Shock absorbers

6.70.1

A low volume vehicle must have a method of effective road shock dampening for each wheel.

6.70.2

A shock-absorber fitted to a low volume vehicle must be compatible in stroke and rate to the spring with which it operates.

6.71 Suspension travel

6.71.1

A suspension system incorporated within a low volume vehicle may be modified to raise or lower the ride-height of a vehicle, provided that:

(a) any lever-actuated brake bias control, if fitted, is repositioned if necessary in order to maintain correct operation; and

(b) no binding of any suspension or steering joints can occur as a result of the changes in suspension geometry; and

(c) bump-steer geometry is not increased beyond that which would be expected at the original suspension height; and

(d) drive-shaft universal angularity does not exceed the maximum operating angles specified by the drive-shaft universal manufacturer; and

(e) sufficient drive-shaft yoke engagement remains throughout all extremes of suspension travel; and

(f) in the case of vehicles originally fitted with a front torque control rod positioned from the top of the diff housing forward to the chassis:

6.69.1

In all cases, the spring load should be applied as closely as possible over the axle (front and rear) centerline as possible, rather than applying spring load part way along the radius rods. Radius loads are usually designed to locate an axle, not to support or be subjected to spring loads.

A 'suicide front end' arrangement (where a transverse leaf spring is positioned behind the axle) is an exception to the above rule, and can work on OE radius rods, but not on hairpin radius rods.

(i) the torque rod is retained; and

(ii) the torque rod is lengthened or shortened as necessary in order to maintain correct suspension geometry throughout the full range of suspension travel.

6.71.2

Suspension travel available within a low volume vehicle must be such that:

(a) *no interference is likely to occur between the underside of the body and any drive-shafts or other drive-line components during full suspension movement; and*

(b) *full suspension compression is unlikely to be reached during normal vehicle operation on smooth road surfaces when fully laden.*

6.71.3

Tyres and wheel-rims fitted to a low volume vehicle must be positioned in such a way that they cannot contact any part of the vehicle to which they are fitted, other than the point of attachment, throughout the full range of steering and suspension movement during normal vehicle operation.

6.72 Bump-stops

6.72.1

A low volume vehicle must be fitted with purpose-designed bump-stops that:

(a) *are undamaged, and are not excessively worn; and*

(b) *are positioned to provide sufficient clearance from any suspension components so as to allow suspension travel suitable for the safe operation of the vehicle when fully laden; and*

(c) *limit the suspension travel before the ball-joints have reached the end of their effective travel; and*

(d) *function effectively to ensure that suspension or body components are cushioned from the transfer of excessive shock loading at the limit of suspension travel.*

6.72.1

This is to avoid shock load damage upon bottoming out under full suspension compression. A rubber donut type buffer stop is acceptable, and can be incorporated into coil-over shock absorbers that do not have one already fitted.

6.73 Suspension system component attachment

6.73.1

All fasteners incorporated in suspension 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'.

6.74 Welding of suspension components

6.74.1

All welding incorporated in suspension system attachment, modification, or adaptation within a low volume vehicle, not specifically covered elsewhere within this chapter, must meet all welding requirements specified in 'Chapter 18 - Attachment Systems'.

Welding carried out on a vehicle built before 1992 is not required to comply with 6.74.1, provided that after thorough visual inspection, no fatigue cracking or fracturing is evident.

6.74.1

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

Exclusions

No exclusions apply to this chapter.

Useful information

After-market suspension components

Be careful not to fall into the trap of thinking 'because it's made in the USA or UK it'll be good'… This is not necessarily so. There have been several instances of 'big brand-name' components being looked at here in NZ and consigned to the junk-pile because of their sub-standard design and/or construction methods. In many cases, the typical clever Kiwi car builder can do a much better job than some of the big overseas brand names.

Any after-market component still has to meet the same basic good engineering principles and procedures as the ones you build yourself.

Unless the component has been individually approved in writing by the Technical Advisory Committee of the Low Volume Vehicle Technical Association (Inc), it still has to meet all the requirements of 'Chapter 6 - Suspension Systems'.

Shock absorber positioning

When planning your shock positioning, there are two main points to remember (this applies to both coil-over shocks and shock absorbers on their own).

Firstly, keep the mounting points as far apart (as close to the wheels) as reasonably possible. This is essential for general stability.

Secondly, keep the shocks near vertical, with ideally, 10-15 degrees of 'lean-in' at the top. This means that, when the vehicle is viewed from the front or the rear, the top end of the shock should be positioned inward toward the center of the vehicle by 10-15 degrees. By doing this, the shock approximately follows the arc prescribed by the suspension system. If there is too much inward angle, the piston rod travel will be reduced, which affects the preciseness of the shock's damping control.

Custom independent front suspension adjustment

Although not a requirement, by far the best method of providing caster and camber adjustment in custom independent front suspension top or bottom a-arms is through the use of eccentric bushings or shimming.

The simpler screw-in/out rod ends are not recommended as this system introduces the risk of stress on the threaded sections, pivot axis misalignment due to unequal adjustment of rod ends, and inadequate thread engagement into the suspension arms.

If the screw-in/out rod end system is used, the one-and-a-half diameter-depth inspection hole should be provided as shown in Diagram 6.5.

Custom independent front suspension A-arm material specifications

Table 6.1 on page 6-9 provides the minimum required material specifications for the manufacture of custom IFS A-arms, based on vast practical experience gained from established New Zealand car builders, together with other real-life knowledge accumulated from other parts of the world.

There are two situations where the specifications provided in Table 6.1 may be deviated from:

- In the case of a typical very lightweight Lotus 7 style sports car (assuming normal arm length and spring load mounting positions), the TAC will allow 19 x 1.5 mm (instead of the specified 22 x 1.6 mm) for the top arms, and 22 x 2.5 mm (instead of the specified 25 x 2.0 mm) for the lower arms.

  These specifications are allowed because of these sizes being successfully employed by overseas sports car manufacturers. Note however that (in theory at least) these specifications are considered borderline and allow very little margin for error, so the TAC would recommend staying with the specifications provided in Table 6.1.

- Table 6.1 assumes that the IFS is a standard design which applies the spring load to the lower suspension arm. Where an IFS shifts away from this 'standard' design and applies the spring load to the top arm instead of the bottom arm (such as where an inboard rocker arm system is used), the A-arm specifications for upper arms and lower arms should be applied conversely.

Note however, that the lower arm must never be reduced below that specified in the table, irrespective of whether or not the lower arm is loaded.

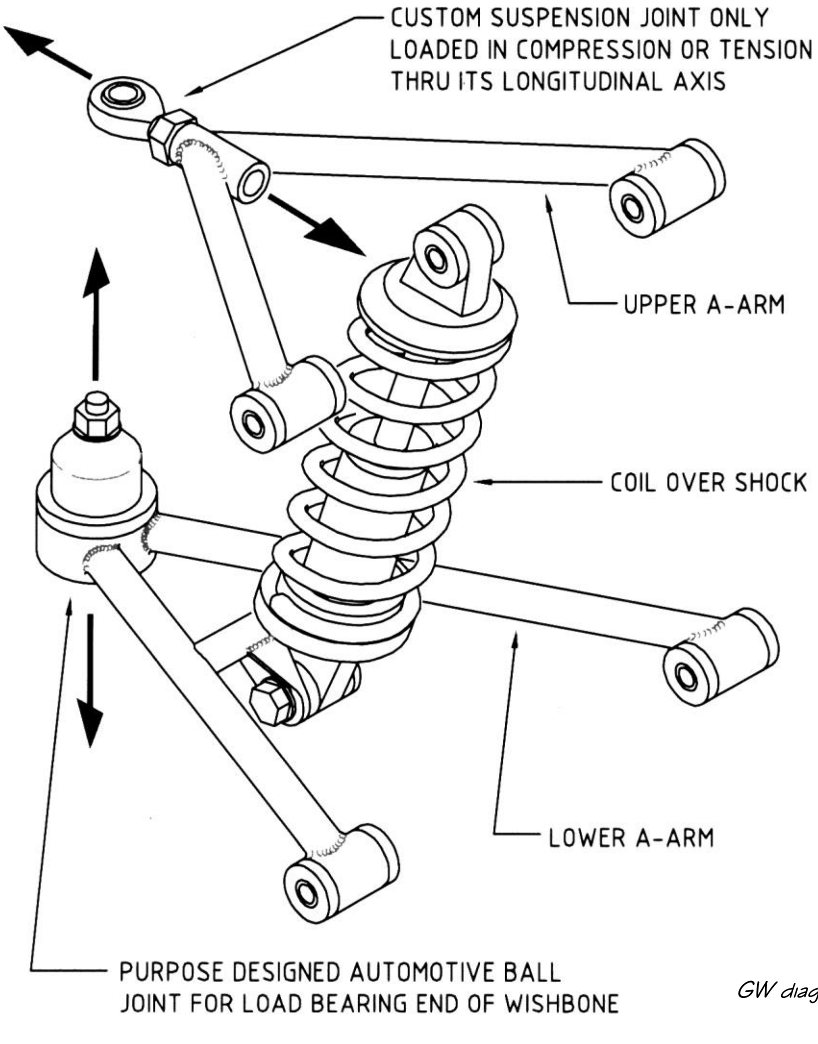
Inspection holes on radius rods

It is important that sufficient thread engagement of a rod end into a suspension radius rod must be visible (after wheel alignment has occurred). Although the LVV Certifier may accept the thread engagement on the basis of what is visible, and the fact that a quality end is used, an inspection hole of one-and-a-half diameter depth (of the radius rod material) in is still the ideal method of ensuring the rod end is properly engaged. (see Diagram 6.5)

Loaded suspension joints

In front suspension systems, it is important to ensure that the suspension joint that supports the vehicle weight – usually the lower outer joint – is in fact a proper automotive ball-joint designed for axial-loading. Typical spherical rod ends and tie-rod ends are not designed to support vehicle weight – they are designed for compression and tension loadings. Although the lower outer suspension joint is generally the axial-loaded joint, note that the upper joint becomes the loaded joint in the case of an inboard rocker-arm type suspension system. They also wear faster than a proper automotive load-carrying ball-joint will.

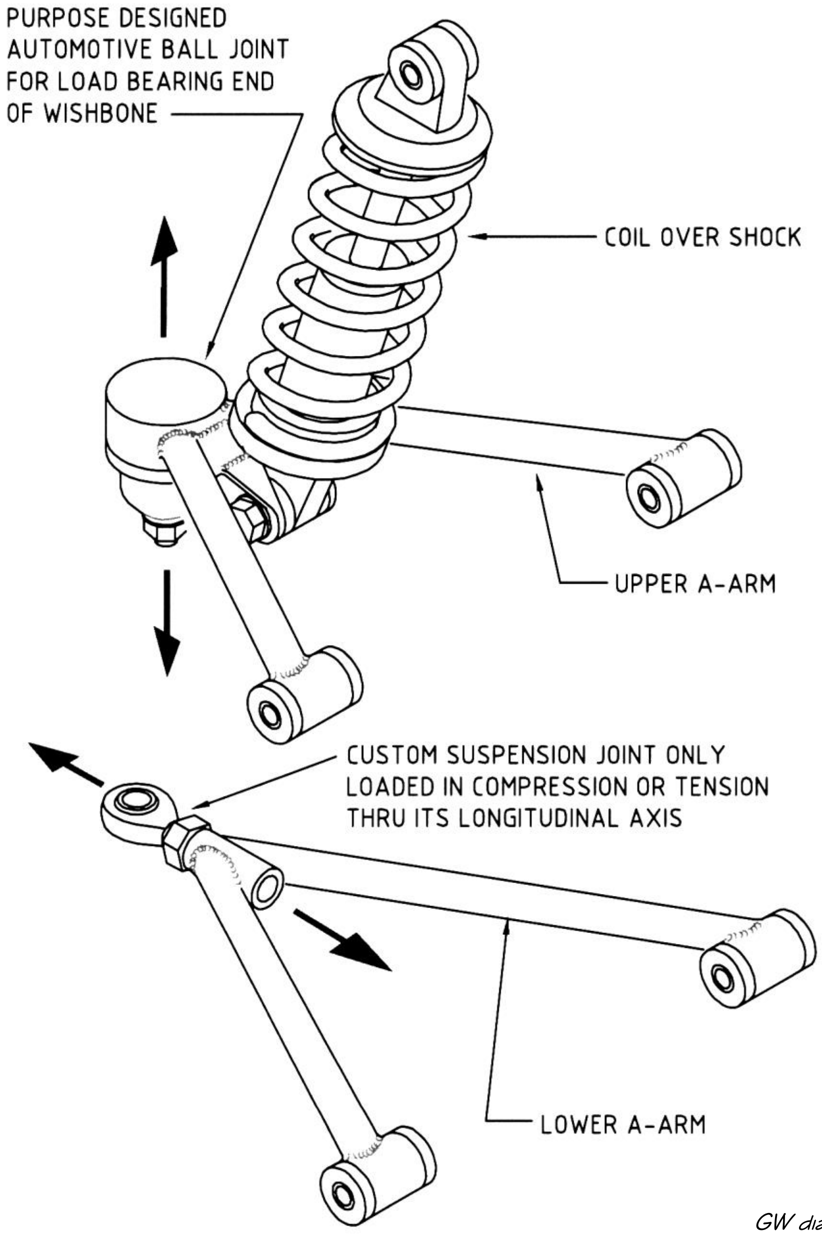
Although the (non-load bearing) joints in a front suspension should also be proper automotive ball-joints, in the case of very light sports cars, it is possible to get away with using premium quality spherical bearing rod ends, or tie-rod ends. The requirement for an upper ball-joint does not apply to typical non-load bearing situations such as the top pivot/camber adjustment plate on a McPherson strut assembly.



GW diagram

The illustration above shows a common type of independent front suspension configuration, which carries the load-path, or vehicle weight, at the outer end of the bottom wishbone. In this situation, the bottom wishbone must use a proper automotive ball-joint, and in the case of a very light-weight sports car, it would be acceptable to use a premium quality spherical rod end or tie-rod end.

Loaded suspension joints (continued)



GW diagram

The illustration above shows a less-common type of independent front suspension configuration, which carries the load-path, or vehicle weight, at the outer end of the upper wishbone. This system is often found in race cars (with the coil-over shock swung around and aimed downward) and is referred to as inboard rocker systems.

In this situation, the upper wishbone must use a proper automotive ball-joint, and again, in the case of a very light-weight sports car, it would be acceptable to use a premium quality spherical rod end or tie-rod end.

Jaguar independent rear suspension systems

One of the more common mistakes hot rodders and sports car builders made in the early days was to mess up the geometry when mounting an early Jaguar IRS into their hobby car.

If using a Jaguar IRS, and taking it out of its (hardly pretty) cage, care needs to be taken to ensure that the front mounting points of the radius rods are positioned in such a way that there is no binding as the IRS goes through its travel from full extension to full droop. Any minor misalignment can be dealt with by incorporating very large and soft rubber bushes, similar to that used by Jaguar in the IRS's original application.

More information will be available on this subject via an LVVTA (Inc) Information Sheet, which will be on the LVVTA website when completed. There are many theories surrounding the correct geometry in an early Jaguar IRS, and this will be fully explained, with some popular old mythology clarified within the Information Sheet.

Beam axles

Don't jack the front of a vehicle fitted with a production I-beam axle in the center of the beam. Old Ford I-beams are made from a very soft malleable iron, and can bend when jacked up in the center. (This same 'weakness' is what allows a split radius rod system or hairpin radius rod to work ok with a Ford I-beam)

Welding of castings and forgings

A basic but very important engineering principle, emphasised 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 cannot be done correctly unless the exact molecular structure of the forging or casting material 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 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!

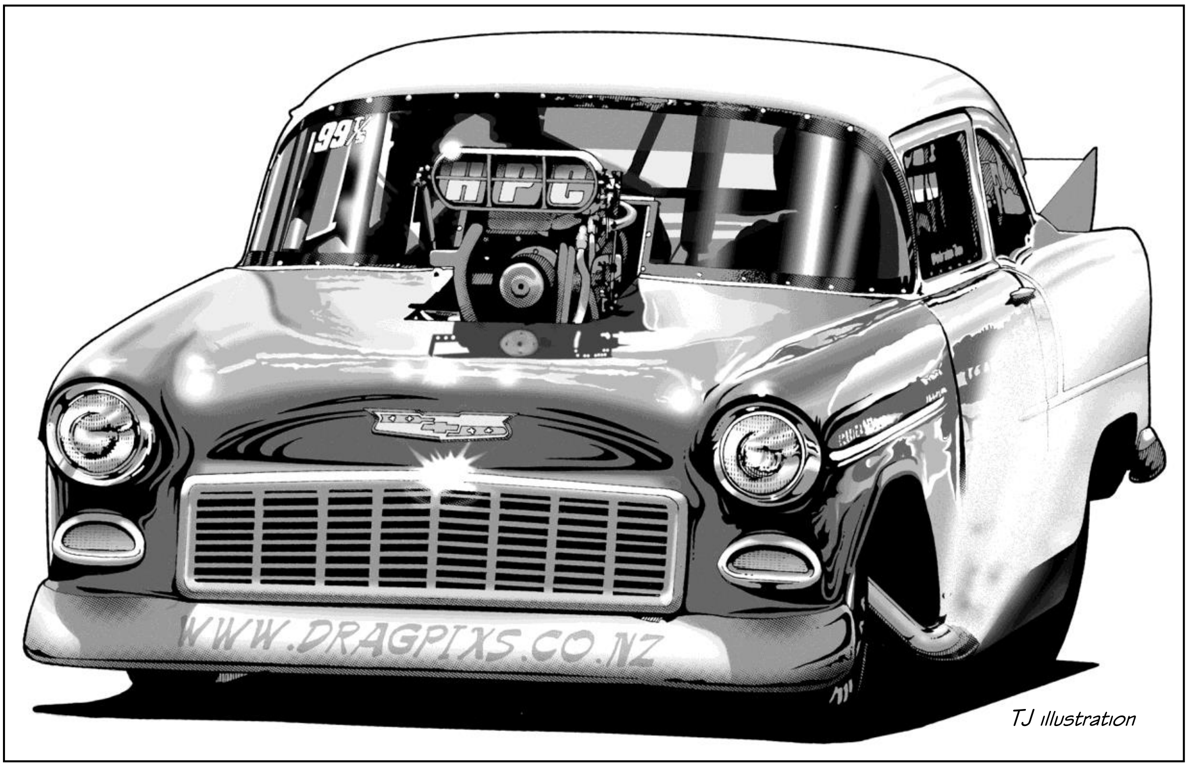
Old stub axles

Exercise caution when using old stub axles, particularly old Ford V8 items. These are often cracked and should be non-destructive tested (NDT'd – in this case crack-tested) before being used. The axles often have surface cracks or defects at the point where the steering arm joins the main body of the forging, which can often be polished out to prevent the minor surface defects continuing to become dangerous defects.

Good books on suspension

The following books provide some excellent advice on designing, fabricating, installing, and setting performance-orientated suspension systems, and are recommended by the Technical Advisory Committee:

- 'Engineer to Win' by Carrol Smith
- 'Tune to Win' by Carrol Smith
- 'Race Car Fabrication and Preparation' by Steve Smith Autosports
- 'Advanced Race Car Suspension Development' by Steve Smith Autosports
- 'Fundamentals of Motor Vehicle Technology' by V.A.W. Hillier and F Pittuck



TJ illustration