Total Vehicle Alignment and Axle Correction.

Heavy vehicle alignment services provide specialist services to the transport industry which enable vehicles to operate profitably and safely in the many various environments in which transport services are required.

The primary objective of heavy vehicle alignment services is to minimise tyre and fuel costs.

Secondary objectives are to improve vehicle safety and reliability by optimising steering and handling characteristics of the vehicles and ensuring that mechanical components are not damaged by being subjected to improper stresses caused by misalignment of components.

A further, indirect, benefit is to improve operational safety by reducing driver stress and fatigue by making the vehicle easier to control.

These alignment services may be provided by:

- The vehicle manufacturer.
- Authorised or independent service dealers
- Tyre services
- Suspension specialist services.
- Alignment specialist services.

In the simplest terms, heavy vehicle wheel alignment is concerned with only two things.

1. Tracking Angles.

Ensuring that each wheel's plane of rotation is aligned to their direction of travel.

2. Camber Angles.

Ensuring that each wheel stands squarely on the road surface on which it travels. More specifically this means ensuring that each tyre footprint is uniformly and symmetrically loaded and stressed so that the tyre wears evenly throughout it's service life.

At all times, the need for these services is shown by the tyre and fuel usage and the handling characteristics of the vehicle.

Over the last twenty years, vehicle and tyre design have altered radically and alignment services have had to change to match today's products. Two most significant changes have occurred during this time. The first has been grasping the concept that **all** wheels and tyres on a vehicle contribute to the steering effect of the vehicle. **All** of the tyres also contribute to the rolling resistance that wastes horsepower and thus fuel. Understanding this has replaced the idea that alignment was "Front end service", with the concept of "Total Vehicle Alignment".

The second change has been the great reduction of tolerance to miss-alignment by modern steel-belted radial tyres. The standards of accuracy required by heavy vehicle aligners today are not only four times greater than twenty years ago, they are almost two times greater than that required for modem passenger vehicles.

The quest for these standards of accuracy have met with some interesting challenges.

The laser measuring equipment popularly used today is capable of the required accuracy and although the modern equipment is easier to use, it is in concept similar to the original versions introduced nearly thirty years ago.

The main challenge with measuring accuracy remains that of training technicians to use the equipment correctly and to adjust vehicles to the necessary standard to achieve the correct results. Most towns still have a great old blacksmith who has been aligning trucks, and horse drawn wagons probably, for forty years and "don't need no new-fangled ideas about how to do it now".

Another challenge is that many of our new heavy vehicles have been derived from components that have remained unchanged for even longer than forty years. A modern truck with a five hundred horse-power motor may use a suspension that was designed before world war two. Although some of our local heavy vehicle manufacturers are now leading the world with understanding and reengineering these areas, others see it as too hard, and most have only reluctantly become involved after fleet owners have complained about the high cost of modifications or the high costs of fuel and tyres if they ignore the issue.

This brings us to the largest, and possibly most urgent, challenge and the one which I specifically wish to address today, and that is the fact that many components which affect alignment, can not be mechanically adjusted and so have to be modified to achieve ideal results.

Particularly in relation to axles, changing the shape of the axle to achieve ideal wheel alignment could be interpreted as an unauthorised modification, and so could be technically illegal. Most government regulations relating to motor vehicle components, especially steering components, prescribe against any process not authorised by the manufacturer or which changes the vehicle from the manufactures specification. Unfortunately the main reason for steer-axle correction is to correct errors in the manufactures specification.

These incorrect specifications are not even related to the fact that most of our vehicles are derived from European, American or Japanese markets where vehicles are driven on the other side of the road. Rather, they are a continuation of a design philosophy handed down from the days of horse drawn vehicles when a degree of positive camber was used to stop the wheels from falling off. This design philosophy certainly has nothing to do with temperature differentials or asymmetric deformation within the foot print area of modern tyres.

In the case of drive and trailer axles, many vehicle manufacturers did not even have a specification for toe-in / toe-out and camber of their axles, and axle squareness and axle parallelity have only been loosely defined in relation to the position of the physical axle, rather than the steering effect of the tyres which is the true factor we must control.

We are working on these regulatory challenges in Australia also. At this time our alignment services perform around one hundred axle corrections each working day. Most of these corrections could technically be termed illegal as they modify the axle away from the original manufacturers specifications. This is not always the case, of course, as several of the large manufacturers use alignment services to modify imported axles to conform to their correct local specification.

I have no intention of addressing the legal aspects of this problem here today as I am not qualified to discuss New Zealand laws and regulations, however I do want to clarify the mechanical processes used and the advantages and disadvantages of each process. I intend to cover both cold correction which is used mainly on steer axles, and hot correction which is used mainly on hollow, non-heatmodified drive and trailer axles. Although "bending" steer-axles is often the only issue debated in this regard, both processes are necessary to ensure correct vehicle alignment.

Reasons for Axle Corrections.

i) To ensure optimum, or at least acceptable, tyre wear.
ii) To allow the correct fitment of Diff. Centres, output shafts and half-shafts.

Causes of Error - Axles

i) Manufacturing Error.

Both the axle manufacturer and the vehicle builder can be guilty of delivering product that is not capable of achieving acceptable results from modern tyres.

Particularly when truck or trailer or bus manufacturers buy "bare" axles and weld on suspension or brake booster brackets.

ii) Application Damage.

Overloading, may cause axles to fail, almost always by stretching the bottom section of the axle, usually under the suspension bracket, which causes Negative camber error on one or both wheels.

iii) Accident Damage

Accident damage to axles is usually seen as bending, often adjacent to the suspension brackets, which can cause both camber error and tracking errors. Accident damage can also require repair to machined surfaces to enable refitting diff centres or through-shafts.

iii) Twisting Damage

Twist is theoretically possible from accident damage, but is unusual in practice, as impacts usually contact the wheel which is mounted to the axle by bearings which do not transmit twisting forces to the axle.

With steer axles it is possible for twisting to occur in an accident, but it is more common to occur either intentionally or accidentally, when the axle is being adjusted for camber by cold bending.

Correction of hollow, non heat-modified, drive and trailer axles.

The most commonly needed axle correction is probably toe-in/toe-out tracking error and camber error in trailer axles. This process also applies to drive axles however it is a much less common problem..

The only way to alter the toe-in/toe-out or camber of a rigid axle is to change the shape of the axle.

Two processes are in common use and each may be correctly used where applicable.

1. Cold Correction

This process applies force from a hydraulic cylinder or cylinders and suitable devises to attach the axle to a rigid structure or beam which has greater bending strength than the axle. Sufficient force is applied until the material of the axle yields and is permanently deformed to the correct shape. In the case of adjusting toe-in/toe-out the axle can be supported over a length more than four times its section width and there is little difficulty achieving good corrections, even in the case of accident damaged axles which require large adjustments.

In the case of camber error however, cold corrections are most suited to an equal increase or decrease or camber on each side of the axle. It may be difficult or even impossible to increase camber one side and decrease camber on the other side. This is especially true if the correction must take place in a very short section of the axle and in this case correction by controlled heat deformation may be the only way possible to achieve the desired result.

This process is preferred when:

(i) The equipment is available

(ii) The best available operator prefers this process

(iii) The process is acceptable to the vehicle owner, vehicle manufacturer, or axle manufacturer, but hot correction is not.

This process is **not** preferred when:

(i) The correction must be achieved in a section of the axle that cannot be supported over a length greater than four times its section width. Compression and sheer stresses (crushing) may produce unacceptable damage to the axle.

(ii) In the case of large accident damage where considerable material elongation has occurred which should be corrected by shrinking.

(iii) The process is specifically not preferred by the owner or manufacturer of the vehicle or manufacturer of the axle. Manufacturers who recommend or allow the alternate process include Volvo, Scania and BPW.

Equipment Required (Cold Correction)

Standard use requires at least 50 tomes of hydraulic force in the easiest applications. i.e. in trailer axles which are supported over a length greater than the distance between the suspension mounts.

If a correction is required within a shorter length, it may be necessary to use two fifty tonne cylinders or one seventy five tonne cylinder. Forces greater than one hundred tonnes should not be used unless the axle is protected from local crushing damage.

In all cases yokes, chains and cylinders must not damage brake or suspension fittings or leave marks, that could cause fatigue cracking, on the surface of the axle. Mild steel packing plates should be used where necessary to redistribute high point loading and to protect the surface of the axle.

2. Hot Correction

This process is preferred when:

(i) The equipment is available

(ii) The best available operator prefers this process

(iii) The process is acceptable to the vehicle owner, vehicle manufacturer, or axle manufacturer, but cold correction is not.

(iv) The axle to be corrected is a hollow, non-heat-modified, steel axle.

This process is **not** preferred when:

(i) The axle to be corrected is heat-modified steel. Unless specific time, temperature and finishing processes can be achieved. We are not aware of any drive or trailer axles of this type used in the Australian market.

(ii) The process is specifically not preferred by the owner or manufacturer of the vehicle or manufacturer of the axle.

Equipment Required

Standard use requires a 10 tonne hydraulic cylinder with suitable 10 tonne rated, rigid extensions to provide a pre-load to the axle. If larger cylinders are used an accurate gauge must be incorporated to ensure rims or brake drums are not damaged during correction.

A suitable heating device which is able to heat a strip of the axle 25mm wide to 700°C in a reasonable time period.

Usually an oxy-acetylene torch of at least 60 Mj / hour capacity will be required (This means a #20 cutting tip minimum up to a #40 heating tip maximum). Personal choice will dictate exact jet size or multi-jet arrangements. Induction heat may be preferred for speed and less heat loss to adjacent areas if this equipment is available.

Insulation or protection material to keep heat from any part which may be damaged during the heating process.

Oxy propane may not considered suitable unless it is of high capacity to make up for the lower flame temperature.

Correction camber errors in heat-modified or micro alloyed steer-axles.

In order to achieve exact requirements for camber on steer axles, it is necessary to change the physical shape of the axle. In these cases cold bending is the only acceptable process currently available.

Equipment Required

With solid I-Beams, manufactured from heat-modified or micro alloyed steel, as are typically used for steer axles, the use of heat is not perceived to be legally or politically acceptable and is not to be considered at this time.

Any correction of shape in these axles must be achieved by cold bending the material past its yield point. Sufficient force is applied until the material of the axle yields and is permanently deformed to the correct shape. We should note that in this process we actually change the King Pin Inclination (KPI) of the axle. However the reason for this change is to achieve the correct angle between the stub axle and the average road surface on which the wheel will be driven. We therefore measure and define the corrected result as a camber, not KPI, adjustment.

This process may be achieved with the axle in or out of the vehicle.

(i) In vehicle correction

The most common equipment in use throughout the world today is the Bear Axle correction press or the equivalent copies..

This equipment allows the correction to be done in the vehicle by means of a strong beam beneath a set of ramps which support the vehicle. The axle can be tied to the beam by means of specially designed yokes, pins and clamps. Force is applied upward in the appropriate places by either one or more hydraulic cylinders. Typically these would be one, two or three 50 tonne cylinders or one or two 100 tonne cylinders. Special adaptors are used to protect the axle and to ensure that the correction occurs at the best possible position.

In New Zealand, an alternative Bee-line in-vehicle system has been extensively used although this is not popular in many places in the world, and is almost unused in Australia, because of it's tendency to produce unsightly bends, inboard of the spring mountings.

An alternative system, which has been recently introduced to New Zealand, allows the correction to be done in the vehicle and uses a leverage beam with a mechanical advantage of at least 4 to 1 which is attached to the axle by means of specially designed yokes, pins and clamps. Force is applied by a single 50 tonne cylinder. Again special adaptors are used to protect the axle and ensure that the correction occurs at the best possible position.

This system will probably become the most popular new equipment in Australia and New Zealand for in-vehicle correction.

(ii) Out of Vehicle Correction

If the axle is removed from the vehicle, correction may achieved with a conventional 150 tonne vertical press and suitable adaptors to protect the axle and ensure that the correction occurs at the best possible position.

Alternatively if the axle is out of the vehicle it is possible to use a more complex movable bed, or movable press head, press with adaptors especially designed to fix the axle to the bed, such as the Bee-Line out-of-vehicle axle press, or any equivalent copy.

Each of these two processes has its particular advantages and disadvantages.

In-vehicle correction is quicker and cheaper and measurement of the achieved result is easier with the axle in the vehicle.

Out of vehicle correction allows a larger correction in the most suitable area, minimises the angles through which the axle is deformed and may produce lower stresses in the material.

However both must be considered acceptable as long as certain criteria are fulfilled.

(i) The correction is economically justifiable.

(ii) The procedure is approved by the axle manufacturer or the vehicle manufacturer or the vehicle owner.

(iii) The axle is not subjected to local damage which could affect is suitability for service,

(iv) Other components which may be damaged by the process are removed or protected (e.g. steering arms, king pins etc.).

(v) The resulting shape of the axle will not adversely effect the vehicle in any way. For example, spring seats that are no longer straight or parallel could cause undue wear on U-bolts, springs and shackles. The vehicle leaning to one side due to one spring seat being lower than the other must be minimised or corrected for.

Adjustment of Castor Variation Errors.

In order to achieve exact requirement for variation in castor from side to side in steer axles, it may necessary to change the physical shape of the axle. In these cases only one process is in common use.

Change the axle shape, by cold twisting , to alter the castor angles of a rigid i-beam steering axle from side to side.

It is some times considered desirable to ensure that the castor angle is slightly lower on the wheel on the high side of the road, (i.e. the right hand side in Australia and New Zealand). In any case it is definitely not desirable to have the opposite variation and so it may be necessary to be able to correct the axle in this area to optimise vehicle performance. We do not believe that this process directly affects tyre wear.

To some degree it is possible to twist the axle against the springs, or alternatively to ensure that the axle is not twisted incorrectly against the springs, by fitting castor wedges with different values from side to side. This process is in common use and must be considered acceptable as long as certain criteria are fulfilled.

(i) The correction is economically justifiable.

(ii) The procedure is approved by the axle manufacturer or the vehicle manufacturer or the vehicle owner.

(iii) The amount of variation of wedge (not resulting caster variation) from side to side does not exceed 2°, or such an amount as could cause deformation or damage to the springs.

NOTE: There is no possibility of damaging the axle by this process but excessive variation of wedge value can cause, and has caused, major damage to springs.

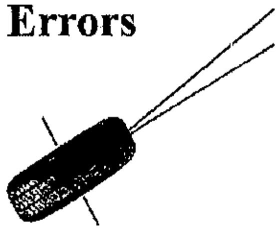
When the desired result cannot be achieved as above, and if the equipment required is economically available, or if the process is preferred, it is possible to cold twist the axle to achieve either zero or other optimum Caster variation from side to side. The same equipment as is used to adjust camber is used for this process with special adaptors to twist, rather than bend, the axle. Sufficient force is applied until the material of the axle yields and is permanently deformed and the correct shape. After this correction it may again be necessary to fit wedges of differing values from side to side to ensure that the axle is **not** twisted incorrectly against the springs.

Peter Laidely
Director:
Josam Truck Technics Australia Pty. Ltd.

JOSAM TYRE MANAGEMENT

Causes of Premature Tyre Wear

Tracking Errors



Toe-in / Toe-out Errors

Out of Square Error

Out of Parallel Error

Turn Angle Error (Ackerman Error)

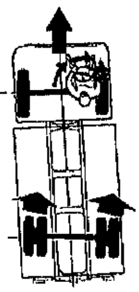
JOSAM TRACKING ANGLES

The relative effects of:

Axles Out of Square

Rear Axle is 10mm/M Out of Square to the Right.
If the Primary wheelbase is 6.0 Metres:
The Turn Centre will be 600 Metres to the Left.

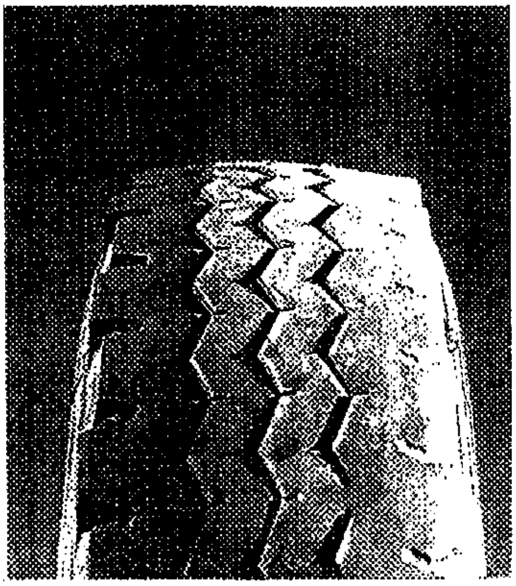
Turn Centre
600 Metres of to the Left.



and Axles Out of Parallel

Rear Axles are 10mm/M Out of Parallel, Close on the Left.
If the Secondary wheelbase is 1.2 Metres:
The Turn centre will be 120 Metres to the Left.

Turn Centre



FEATHERED WEAR

SLIDE NO. 1

FEATHERED WEAR

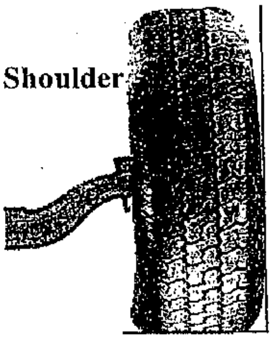
SLIDE NO. 2

JOSAM TYRE MANAGEMENT

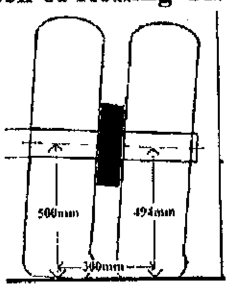
Causes of Premature Tyre Wear

Camber Errors

Smooth Wear on One Shoulder
(No Feathers)

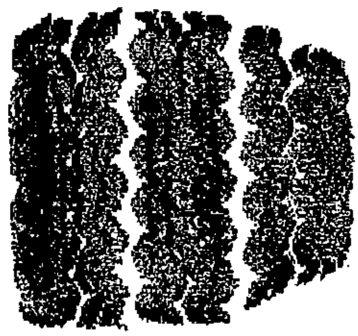


Miss-match of Rolling Circumpherences on Duals



JOSAM TYRE MANAGEMENT

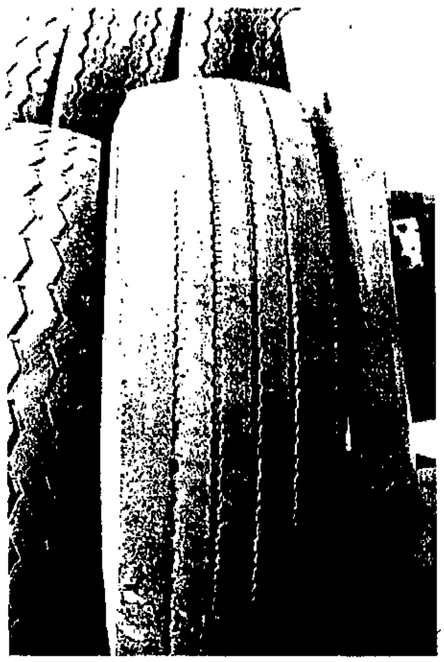
Footprint (3)



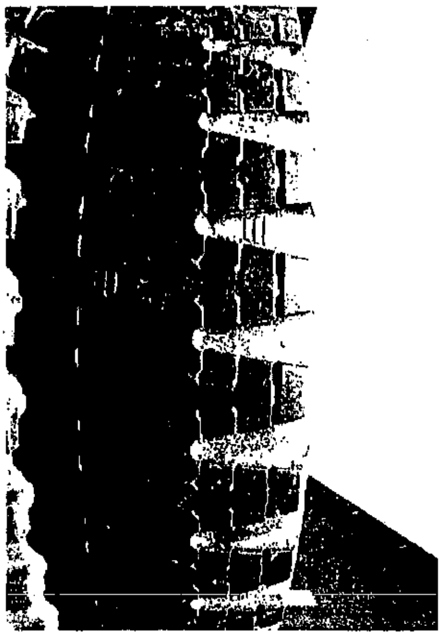
Pressure and tempreture differential from side to side of the footprint of a tyre subjected to a camber error.

Courtesy of Goodyear America.

Tyre Wear

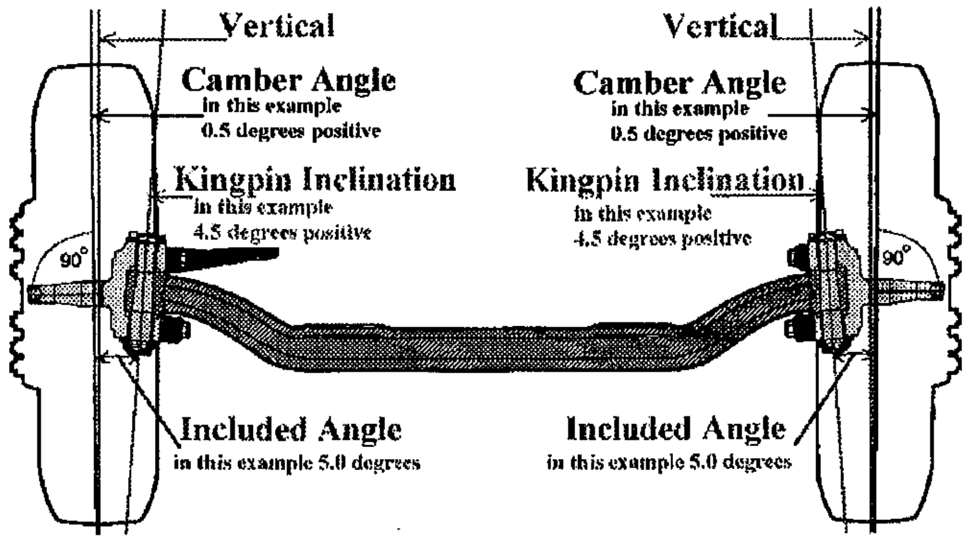


FULL SHOULDER WEAR



Typical camber error of military tyre.

Camber. K.P.I. and Included Angle (#1)

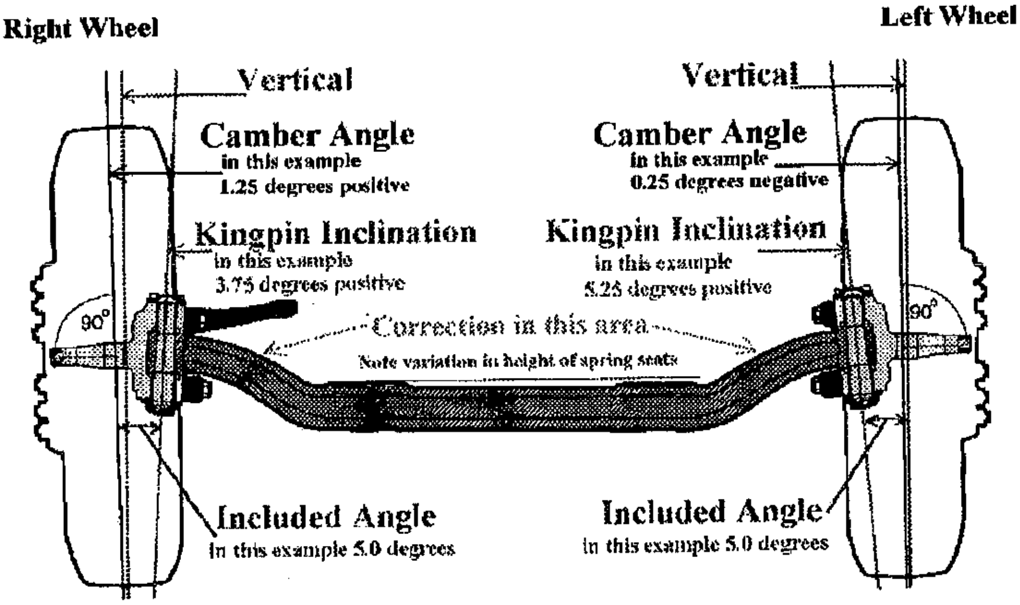


Camber and K.P.I. are both measured from Vertical, with the axle on a true horizontal floor.

Included Angle, which is the relationship between the kingpin axis and a line square to the bearing axis of the stub axle, is the sum of the Camber and K.P.I.

JOSAM Training Program
O.H.T. Name Geometry 07

Camber. K.P.I. and Included Angle (#2)



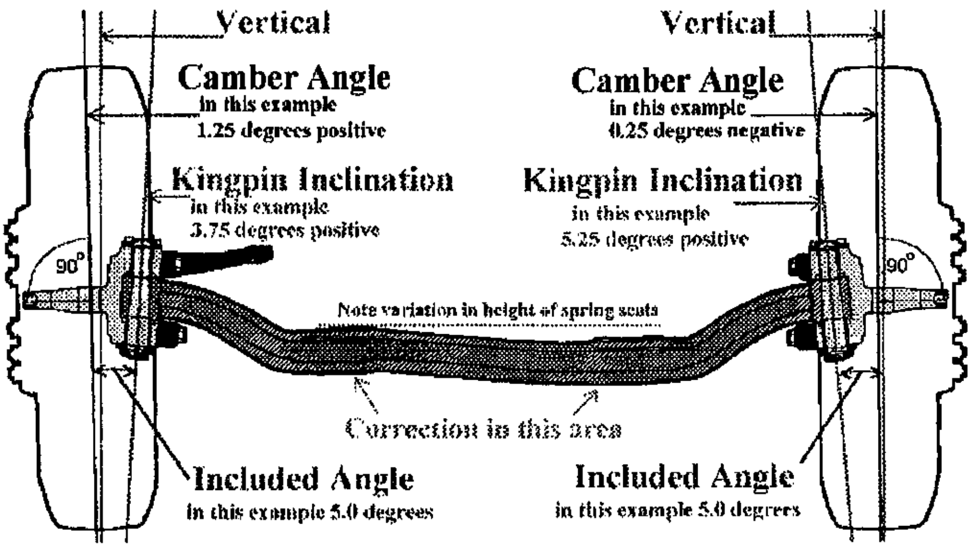
When the Axle is cold corrected to obtain ideal Camber angles for optimum tyre life, it is in fact the Kingpin Inclination that is changed.

In Australia it is normal to Increase the RHS Camber to 1.0 to 1.25 degrees positive, and to Decrease the LHS Camber to 0.0 to 0.25 degrees negative.

Because it is not possible to alter the angle at the extreme end of the Axle, some change in height of the Spring Seats is inevitable.

JOSAM Training Program
O.H.T. Name. Geometry.08

Camber. K.P.I. and Included Angle (#3)



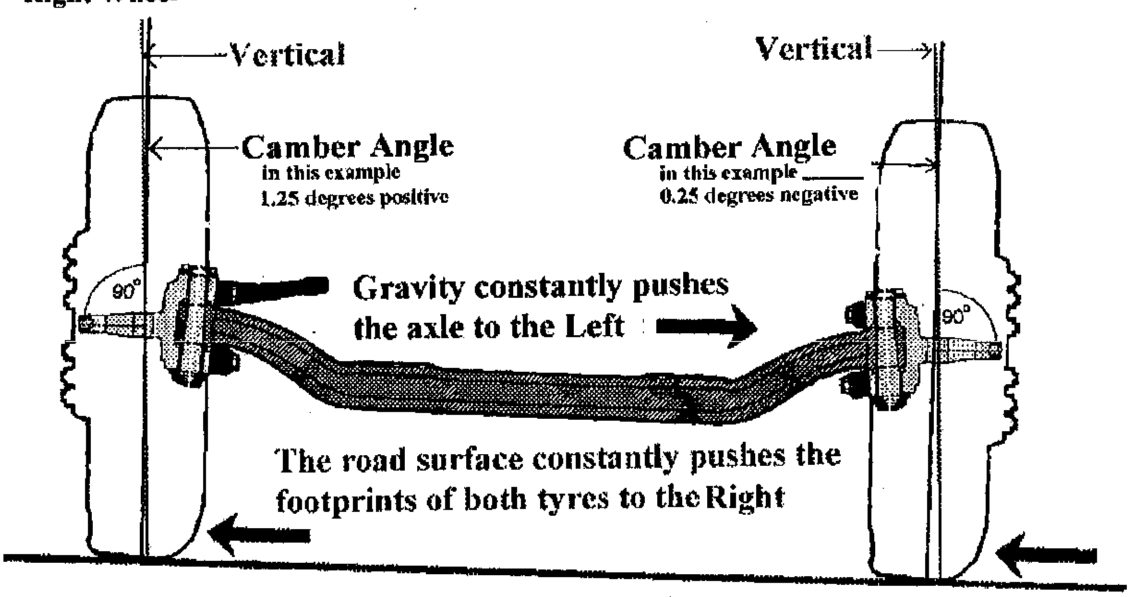
If the cold correction occurs closer to the centre of the Axle, not only will the change in height of the spring seats be greater, but also the angle through which each side must be deformed, will be greater.

This process can also curve the spring seats, which makes U-bolt clamping more difficult, and change the angle between the spring seats, which can cause abnormal wear on spring hangers and swing-shackles.

For these reasons, we recommend that all cold corrections should take place as far outward as possible, and definitely outside the spring seats.

JOSAM Training Program
O.H.T. Name. Geometry 09

Camber and the " Average Road Surface "

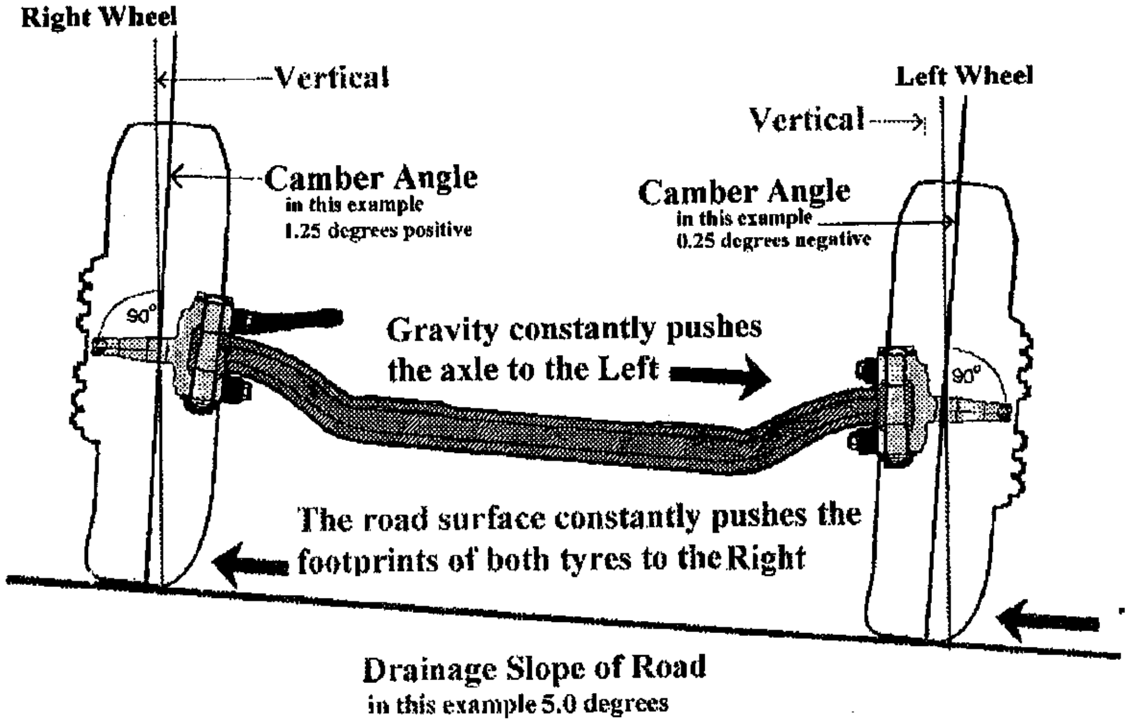


Because almost all road surfaces are designed to drain the water outwards from the centre, and in Australia we drive on the Left side of the road, steer axles are constantly subjected to gravitational pull to the Left.

This causes the footprints of both tyres to be constantly deformed to the Right.

JOSAM Training Program
O.H.T. Name Geometry 21

Camber and the " Average Road Surface " (#2)



This example shows a high (but realistic) Road Drainage Slope of 5.0 degrees. In this case, not only are the tyres further deformed by the lateral force, but the weight of the axle is vertically transfered to the outer left shoulder and inner right shoulder of the tyres.

Note that these diagrams are drawn to scale and the slope that is shown here is common on Australian roads in high rainfall areas.

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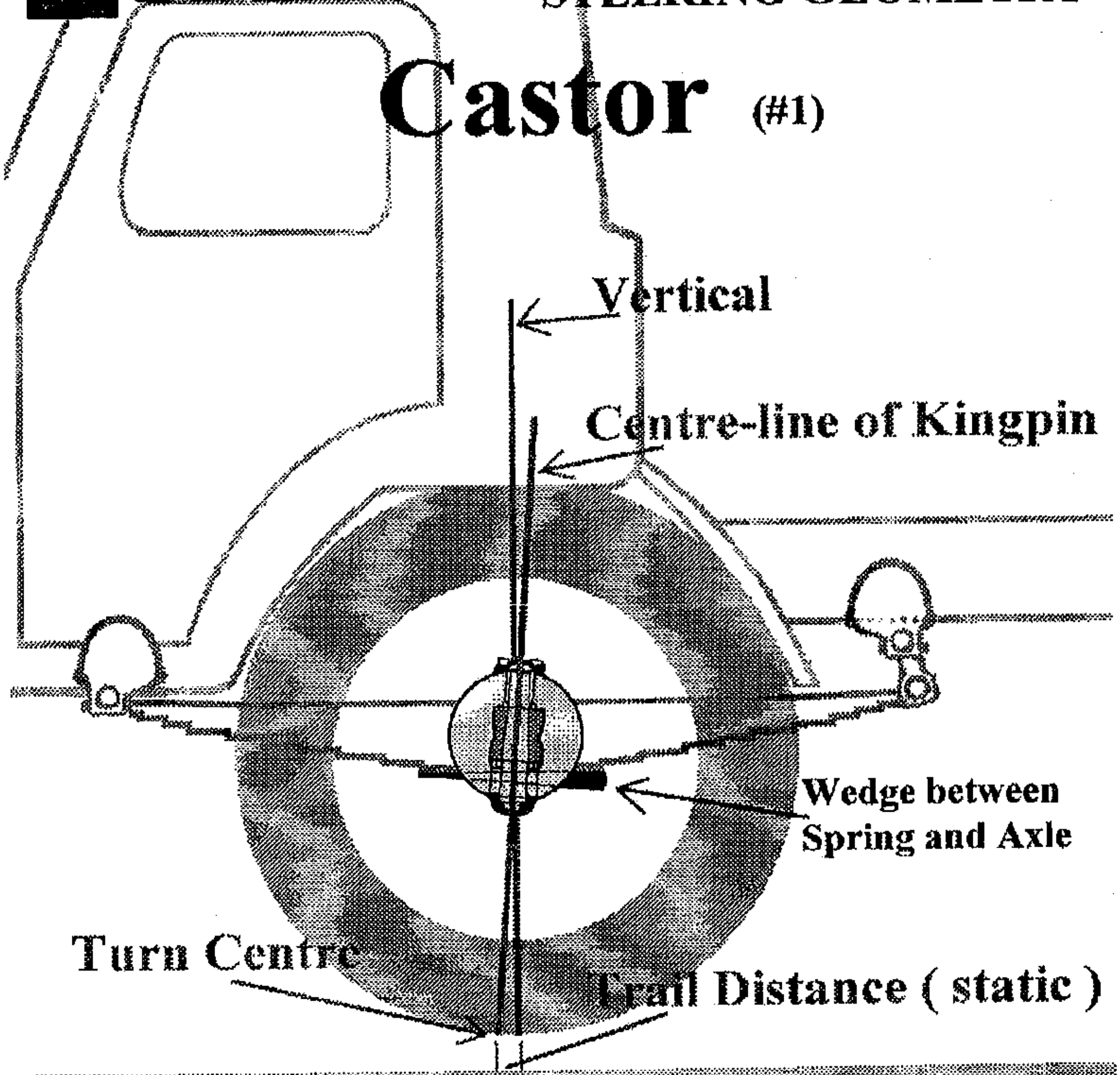
O.H.T. Name. Geometry 21a

JOSAM

STEERING GEOMETRY

Castor (#1)

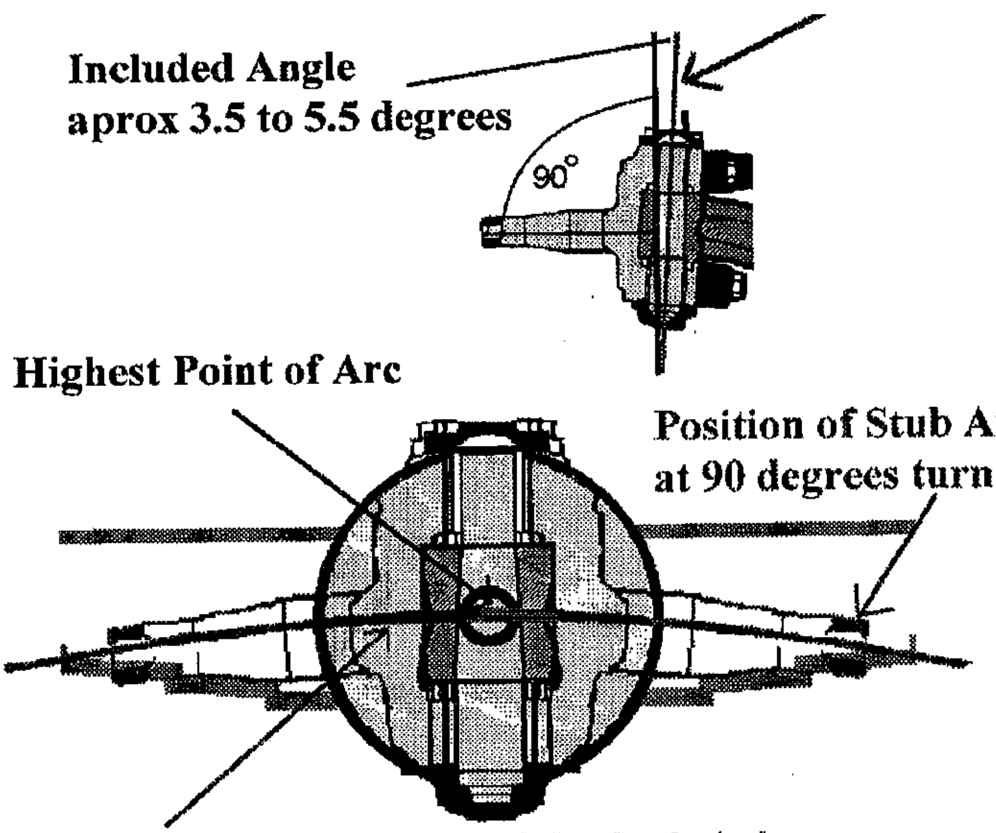


The angle which the King-pin of a steer axle is rotated, away from vertical, about the bearing axis. With zero Castor the King-pin is vertical.

With positive castor the bottom of the king pin is rotated forward in relation to the wheel's direction of travel.

JOSAM Training Program
O.H.T. Name. Geometry 12

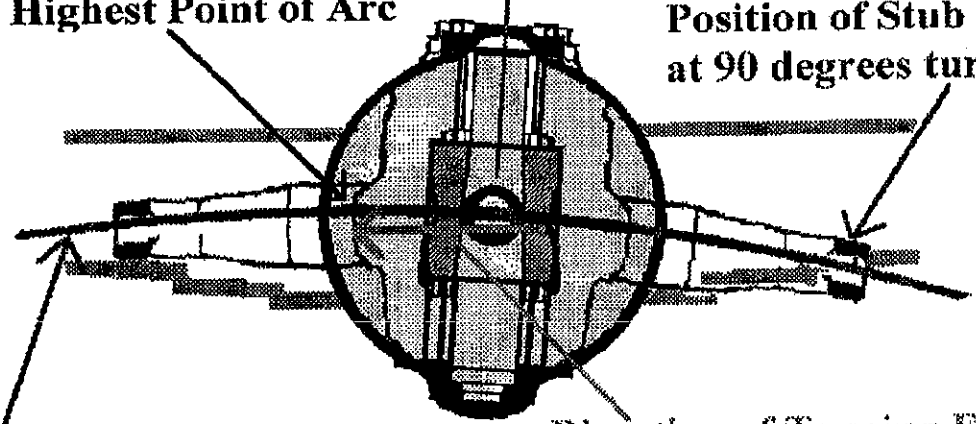
Self Centering Effect of Steer Axles (#1)



The Self Centering effect of Steer Axles is caused by the weight of the vehicle pushing down on the axle which causes the Stub Axle to turn to the highest point of the arc through which it travels.

JOSAM Training Program
O.H.T. Name Geometry 18

Self Centering Effect of Steer Axles (#2)



Arc travelled by the end of the Stub Axle.

When Castor is introduced, the effect tends to turn the stub axle inward in response to positive Castor. If the same Castor angle is used on both sides these forces balance each other.

If the Castor angle varies from side to side the forces will balance with the steering effect turned towards the Lowest Castor Angle.

Castor Variation causes the self-centering function of K.P.I. to turn the stub axles slightly away from the straight ahead position.

JOSAM Training Program
O.H.T. Name. Geometry 19