TOYOTA star ServiceNews
TOYOTA'S SUPPORT TO AFTERMARKET REPAIR

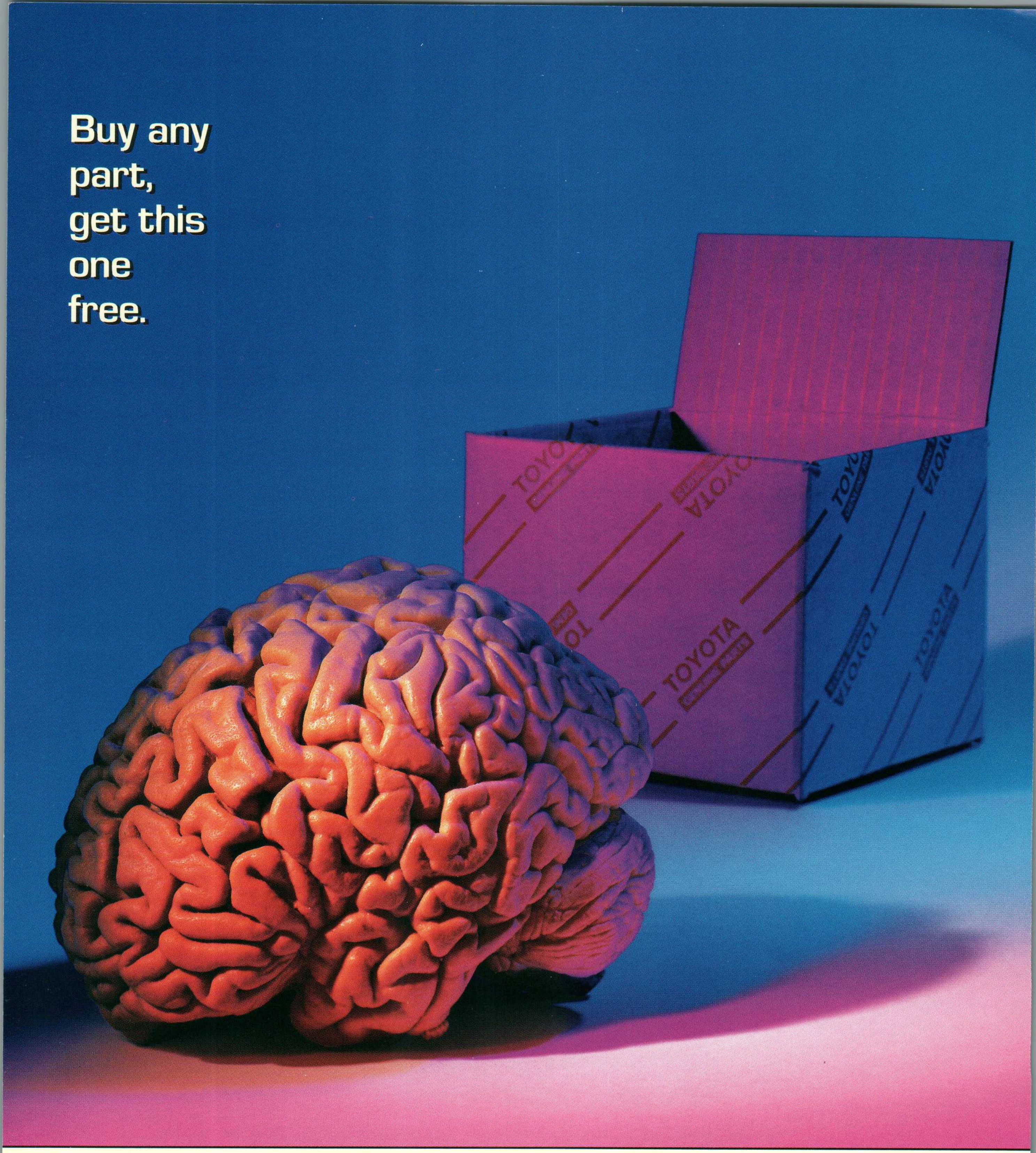
Steering and Suspension

Chassis Diagnosis and Alignment

Vehicle Dynamics and Alignment Angles
Vehicle Handling and Chassis Diagnosis
Tech Tips, Parts News

TOYOTA

March/April 1997 Issue 63



TOYOTA star SUPPORT TO AFTERMARKET REPAIR

Who says "parts is parts"? Not your Toyota STAR Dealers. They supply a complete inventory of competitively priced Toyota Genuine Parts that fit right from the get-go. And deliver just about as conveniently and quickly as your local pizza place. But what really sets them apart is their expert technical advice. These guys have Toyota parts on the brain. All of which makes doing business with them pretty much of a no-brainer for you. For the Toyota STAR Dealer nearest you call 1-800-537-6033.

TOYOTA
I love what you do for me

TOYOTA star

ServiceNews

Steering and Suspension

Chassis Diagnosis and Alignment

contents

What is a STAR dealer?

STAR (Support to Aftermarket Repair) is a special Toyota support program offered by a select group of Toyota dealers, recognized by Toyota as having made an extraordinary commitment to serving the special needs of independent repair and body shops. From extra parts inventory and special local or WATS telephone lines to specially trained counter people backed by outstanding delivery services, Toyota STAR dealers are a unique group of parts wholesale specialists who offer support, services and benefits not usually found at the typical dealership.

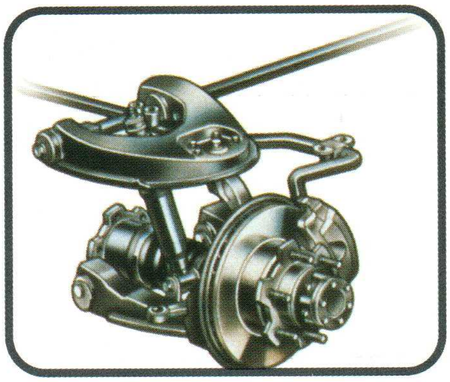
Toyota STAR Service News is available through Toyota's wholesale parts specialists, Toyota STAR dealers, and is also available by subscription. Articles and technical data in this periodical are based in whole or in part on prior communications to Toyota dealers.

feature articles

departments

Chassis Diagnosis and Alignment

Introduction



Vehicle Dynamics and Alignment Angles

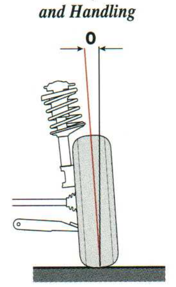
Wheel alignment geometry describes the positioning of the wheels, tires, and suspension components in relation to each other and to the vehicle as a whole. Proper relationships between these elements are necessary for safe, responsive handling and maximum tire life.

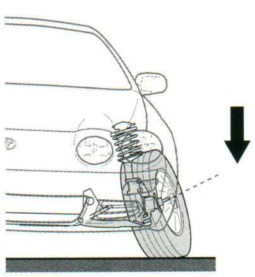
Incorrect wheel alignment geometry can be the cause or a contributing factor to nearly every type of handling complaint. The inspection of wheel alignment geometry reveals not only adjustment errors, but also allows you to further verify the condition of suspension components and the relationship of the suspension and steering components to the body of the vehicle.

Alignment geometry is **not** the most likely cause of every type of handling complaint. However, considering its far-reaching influences on handling and its impact on tire wear, alignment geometry and the individual elements that comprise a vehicle's wheel alignment geometry deserve particular attention.

In this issue of Toyota STAR Service News, we'll explore the primary geometric elements that comprise a vehicle's wheel alignment geometry.

Vehicle Dynamics and Handling





Handling Diagnosis

Vehicle Handling and Chassis Diagnosis

Customer expectations regarding vehicle handling can vary widely based on the intended use of an automobile. When these expectations are not met, the vehicle will be brought in for service. Diagnosis of handling complaints is similar to the diagnosis of any other vehicle problem. You must thoroughly understand the proper function and operation of the systems, subsystems, and individual components involved, as well as follow a consistent troubleshooting procedure.

Tech Tips Steering and Suspension

This assortment of vehicle-specific tech tips will bring you up to date on factory modifications to vehicle service procedures and parts requirements.

Parts News Expanded Reman Rack Program

A thorough and accurate diagnosis of the power steering system will help you confirm the root cause of a customer's complaint for lack of or inadequate steering assist. Should these steps convince you of the need for steering rack replacement, Toyota has recently announced the third phase of a new reman parts program—offering 12 more Toyota reman power rack and pinion applications (for Toyota's most popular models).

Vehicle Dynamics and Alignment Angles

Vehicle Dynamics, Handling, and Alignment

Vehicle dynamics involves all of the forces cancelled, created, or compensated for by an automobile. These forces include acceleration, braking, aerodynamic, cornering, and road forces. They involve every vehicle system from the powertrain to the suspension; even the body.

Handling is a contributing element to a vehicle's dynamic operation. It also describes a vehicle's ride quality, maneuverability, and relative responsiveness to a driver's input.

The following section details the effect of alignment geometry on a vehicle's directional control, ride quality, and tire wear.

Basic Front Wheel Geometry

The basic front wheel alignment angles include:

- **Camber**
- **Caster**
- **Toe**

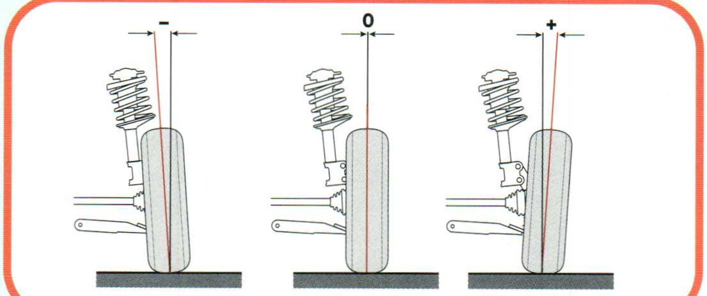
The following details the function of each of these elements, the effect of each element on directional control and their influence on tire wear.

Camber compares the centerline of the tire to vertical. The top of a tire with positive camber is tilted away from the vehicle. A tire with negative camber is tilted inward, toward the center of the car.

Camber

Camber describes the inward or outward tilt of the top of the tire compared to a vertical reference. The camber angle is the angle formed by vertical and the tire's centerline. This value is measured in degrees.

Positive camber describes the top of the tire tilting away from the vehicle and negative camber describes the opposite; the top of the tire tilts inward toward the center of the vehicle. Zero camber is that point where vertical and the tire centerline are the same plane.



Camber

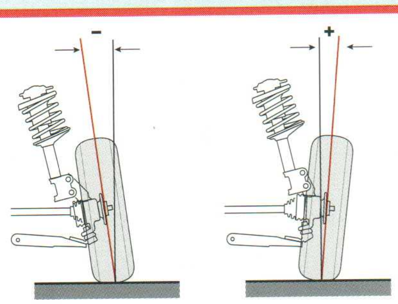
A camber angle of zero would appear to be the best position for maximum tire life. The load is equally applied across the tread and therefore wear should be consistent at all points across the tread surface. However camber is measured with the vehicle at rest and vehicle loading and suspension reactions to road irregularities result in a camber value that changes as the vehicle is in motion. A tire's static camber value is specified to achieve a balance between tire wear and handling performance when the vehicle is **moving.**

Benefits of Positive Camber - Both positive and negative camber have distinct advantages and those advantages are selected by the car's design engineers to help define the handling characteristics of a specific vehicle. A slightly positive camber value provides the following benefits:

- **Reduced road shock**
- **Enhanced directional stability**
- **Minimized tread wear**

The advantages of positive camber stem primarily from placing the vehicle load closer to the inner edge of the spindle. This positioning places the greatest load on the larger, inner wheel bearing and reduces the effect of leverage when road shocks are transmitted to the spindle.

As the camber value moves negative, the leverage applied to the spindle increases. The impact of increased leverage is analogous to using a longer wrench to multiply torque. The greater the leverage, the more road shocks are magnified.



Spindle Leverage

Consider the force applied to the spindle when the wheel hits a bump in the road. The force is transmitted to the spindle following the tire's centerline. With the wheel cambered positive, the spindle is angled downward locating the transmission path (vertical line) closer to the inner portion of the spindle, reducing leverage.

When the wheel is cambered negative, the transmission path meets the spindle, further outward. The farther out on the spindle the tire centerline crosses, the longer the lever and the greater magnification of force because of leverage.

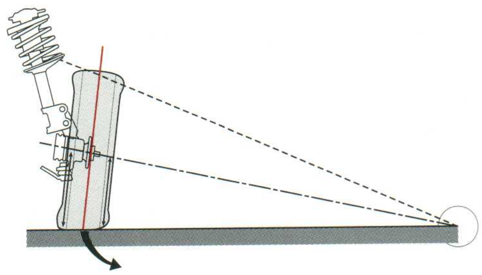
Tire wear can be minimized with a static positive camber setting as this provides nearly zero camber when the vehicle is loaded. Remember strut type suspensions camber negative on jounce. A slightly positive static camber value compensates for this suspension induced camber change.

Benefits of Negative Camber - The primary advantage to negative camber is simply cornering performance. As a vehicle enters a turn, centrifugal force and body roll tend to force the outside wheel to camber positively. This camber change, known as **camber thrust**, results in less tread in contact with the road surface. With a negative static camber value, when the vehicle enters a turn the outside wheel camber moves less positive. The camber change actually increases the tread contact with the road surface rather than causing a decrease. The compromise made for improved cornering performance is increased road shock, reduced stability and greater loading of the outer wheel bearing.

Directional Control - Camber is often described as the single most influential alignment angle in terms of both directional control and tire wear. Excessive camber, either positive or negative, can cause both pulling complaints and rapid treadwear at the tire's edge.

A cambered tire has two different rolling diameters like a cone. A cone will always try to roll around its center.

The cone effect explains how excessive camber causes a vehicle to pull and how it rapidly accelerates tread wear. A tilted or cambered tire has two different rolling diameters similar to a cone. As a cone is rolled, it tries to rotate in a circle around its center. A cambered tire does the same, rolling around the cone formed by the intersection of the road surface and a line extended from the top of the tire. The force of the tire trying to rotate in a circle is the force that causes the car to pull.


Cone Effect

Camber spread or cross camber is the difference in camber values between the left and right side of the vehicle. This difference is normally specified as a maximum of 30' (0.5º) or 45' (0.75º) depending upon model.

For diagnosis of pulling complaints, remember camber values may be within specification and still cause a complaint from excessive camber spread. The diagnostic rule is **camber pulls positive, the car will pull in the direction of the wheel with the most positive camber value.**

Road Crown - Road crown refers to the 1-2 percent right-hand slope built into most United States roadways for water drainage. A side effect of crowned roads is many cars that travel straight on a level road will experience a significant pull to the right when operated on crowned roads. In years past, compensation for this pull was done with up to 30' more positive camber on the left wheel than the right wheel. Adding slightly more positive camber to the left wheel counteracted the effect of road crown.

Today's Toyota vehicles are designed to travel on crowned roads and **usually compensation with alignment geometry is not necessary**. In extreme cases, where a customer drives on heavily crowned rural roads, compensation for road crown may be necessary. Up to 30' more positive camber at the left wheel should correct the complaint. Cross camber is the preferred method of road crown compensation.

Most roads are sloped 1-2 degrees to allow for water drainage. Alignment compensation for road crown is generally not necessary on Toyota vehicles as the tire's ply steer creates a leftward lateral force.

NOTE: Interstate and other multi-lane highways may also be crowned, however they are crowned to drain water toward the center divider or the left as well as toward the shoulder or the right. A customer may notice a pull to the left when in the far left lanes of traffic and notice a right pull or no pull when traveling in the right lanes of traffic of the very same roadway. This environmental effect cannot be corrected with camber spread or any other wheel alignment modification and the situation should be completely explained to the customer.

Tire Wear - A cambered tire and wheel assembly is not allowed to roll in a circle but is forced to roll straight ahead. The side of the tire with the smaller rolling diameter is forced to rotate faster than the side with the larger diameter. This faster rotation results in the tread surface being scrubbed off as the tire rotates.

The wear area is greatest near the edge of the tire and progressively minimizes nearer the center of the tread. Camber wear can be identified by significant wear at one edge of the tread surface often accompanied by a sharp edge where the tread meets the sidewall. Excessive **positive camber** will wear the **outside edge of the tread** and excessive **negative camber** will wear the **inside edge of the tread** surface.

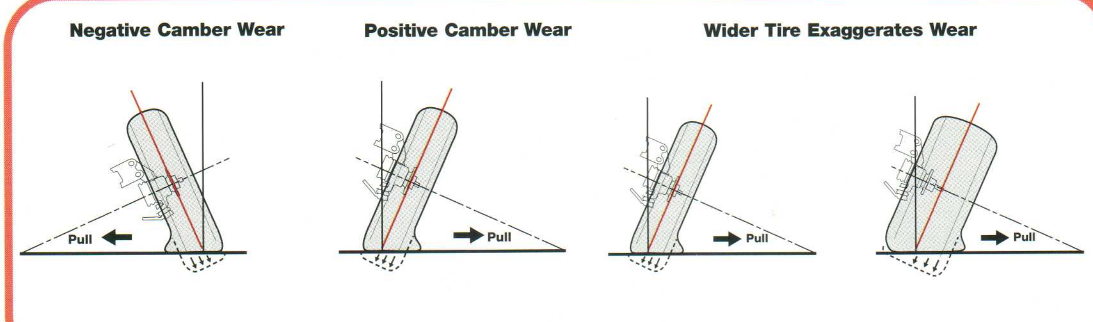
Generally static camber values are specified in the camber "no wear" zone; between +3/4º and -l/4º.
It is important to note that the wider the tire, the greater the tire wear caused by small amounts of camber error.

Measuring Camber - Camber can be measured simply with a protractor or a level comparing the tilt of the tire to a vertical reference. The camber measurement is taken with the vehicle on a level surface at the proper ride height. Whether using a manual bubble type gauge or an electronic alignment system, the measurement is still the same; how much is the tire tilted and in which direction?

Remember camber is the direct result of spindle attitude. Anything that alters the attitude or level of the spindle alters the camber value. As the spindle moves upward, camber moves negative and as the spindle moves downward, camber moves positive.

Other alignment angles, particularly caster, may also influence camber. Therefore it is important to keep the wheels straight ahead and correct extreme toe errors when measuring camber to prevent inaccurate readings. Ride height, worn control arm bushings, strut position, spindle condition, all affect camber; anything that moves the spindle, changes the camber of the tire/wheel assembly.

A cambered tire is forced to roll straight ahead with virtually two different rolling diameters.



Camber Caused Treadwear

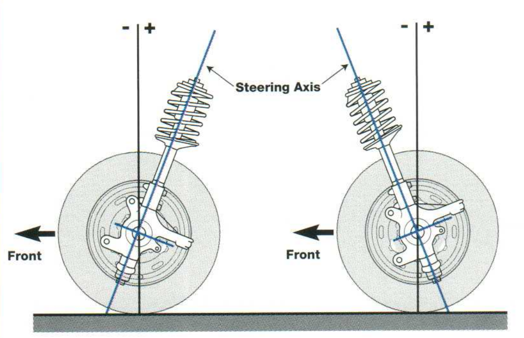
This results in the tread on the shorter side of the tire being scrubbed off. Excessive positive camber will wear the outside edge of the tread and excessive negative camber will wear the inside edge. Also note that a wide tire will tolerate less camber error than a comparably narrow one.

Caster

Caster describes the forward or rearward tilt of the steering axis compared to a vertical reference. The angle formed by the intersection of the steering axis and vertical is defined as **caster**.

The steering axis is an imaginary line that the spindle pivots around. On a double wishbone suspension, the steering axis is a line extended through the upper and lower ball joints, the pivot points for the spindle. The upper strut bearing and the lower ball joint define the steering axis on a MacPherson strut suspended vehicle.

When viewed from the side, if the steering axis tilts toward the front of the vehicle, the caster angle is said to be negative. If the steering axis tilts toward the rear of the vehicle, caster is positive.



Caster

The caster angle is positive when the steering axis is tilted rearward, toward the rear of the vehicle and negative when the steering axis is tilted forward, toward the front of the vehicle.

Caster is designed into the front suspension geometry of a vehicle for two reasons:

- **Directional control**
- **Steering returnability**

Caster accomplishes these two functions through the principles of caster trail or lead and spindle arc.

A vehicle's weight or load is projected downward through the steering axis to the point where the steering axis meets the roadway. By tilting the steering axis rearward (positive caster) the point of load, or the weight of the vehicle, actually extends ahead of the tire's contact patch. The distance between the tire's contact patch and the point of maximum load is known as **caster trail** or lead. Caster trail causes the front tires to follow the weight of the vehicle.

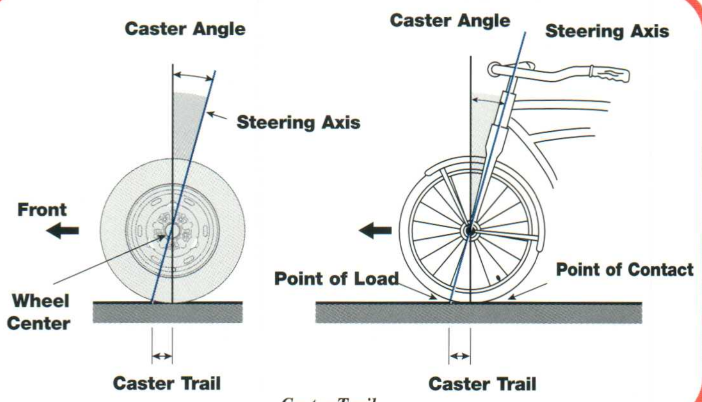
Consider a bicycle as an example. Bicycles typically use a significant amount of positive caster. The caster trail is large as the point of load projects significantly ahead of the tire's contact patch. Recall how easy it is to ride a bike without using your hands. The front tire follows your weight because of the caster trail. Now turn the handle bars backwards and try to ride without using your hands. The caster angle is now negative and the point of load follows the tire's contact patch providing no stability and very poor directional control. In other words, the weight or load is pushing the wheel forward instead of the load pulling the wheel.

Two significant drawbacks to a large caster trail are:

- **Increased steering effort.**
- **Increased road shock.**

As the caster trail increases, the point of load is positioned farther ahead of the tire's contact patch requiring more effort to move the weight of the vehicle.

Vehicles that do not have power assist steering use very small amounts of positive caster or even negative caster. Placing the steering axis behind the tire's contact patch makes a car much easier to steer as the point of load follows the tire's pivot point. The drawback to this ease of steering is a sacrifice in straight line stability and reduction in steering returnability.



Caster Trail

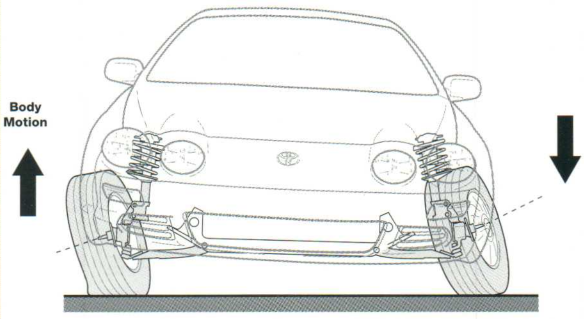
Caster trail provides straight line stability. Positive caster projects the point of load ahead of the tire's contact patch. The weight of the vehicle pulls the tire along behind it.

Increased caster trail also results in a harsher ride. With the point of load ahead of the tire's contact patch, obstructions in the road surface transmit more directly to the passenger compartment. The steering axis is in a more direct line with the road irregularities and the force is transmitted nearly straight to the passenger compartment without the absorbing action of the tire and suspension.

Spindle arc describes the tendency of the spindle to move horizontally as the wheels are turned. With the steering axis tilted, the spindle moves up and down as the wheels pivot. On vehicles with positive caster, the spindle attempts to move downward on the inside wheel of a turn and upward on the outside wheel.

When the wheels are turned to the right for example, the right spindle tries to move down. Because the road surface will not allow the spindle to move downward, the entire steering knuckle and suspension are forced upward, raising the vehicle slightly. At the same time the left spindle moves upward.

The weight of the vehicle forces both the right and left spindles to seek a balanced, level position following the turn. This force provides both steering returnability and directional stability. The amount of steering return ability is proportional to the amount of positive caster and the resulting spindle arc.



Spindle Arc and Camber Roll

Positive caster results in a camber change as the front wheels are turned. The horizontal movement of the spindle also lifts the body of the vehicle which provides steering returnability.

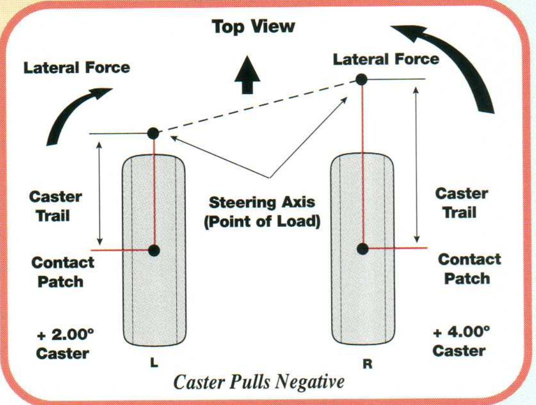
The greater the caster value, the faster the spindle returns to its normal position following a turn. Excessive positive caster may actually result in the spindle returning over-center. The spindle swings past its level position and then snaps back in the opposite direction. A shimmy condition results as the wheels are oscillating back and forth trying to find their center point of travel. Vehicles designed with high positive caster may use a steering damper to slow the return of the spindle following a turn to prevent this shimmy effect.

Anytime the level of the spindle changes, camber changes. As the wheels turn, the inner spindle moving downward changes the camber of this wheel positive, while the outer wheel spindle moves upward changing camber at this wheel negative. The front wheels camber into the turn thereby improving tread contact with the road surface. This effect is known as **camber roll**.

A difference in caster results in a condition where a larger lateral force is created by the side with more positive caster. The side of the car with the larger caster trail (more positive caster) pushes the car towards the side with the shorter caster trail.

Directional Control - Caster's influence on directional control is quite significant, providing both the steering returnability and directional stability previously outlined. A difference in caster between the left and right sides of the vehicle will induce a pulling condition. This difference in caster is described as **caster spread** or **cross caster**.

A vehicle will pull or drift toward the side of the vehicle with the least amount of positive caster. The diagnostic rule regarding caster spread is **caster pulls negative**.



Caster Pulls Negative

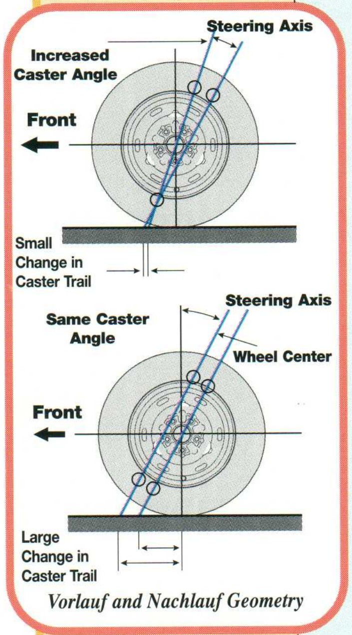
Caster spread creates a pulling condition toward the more negative side of the vehicle because of an imbalance in the lateral forces applied to the steering linkage. The weight of the vehicle on the steering knuckle, which pivots around the steering axis, creates this lateral force. Without steering linkage both wheels would tend to collapse inward (spindles moving upward) due to the angle of the steering axis.

As the caster angle increases toward positive, a greater lateral force is applied to the wheel assembly and linkage. A difference in caster values between the left and right sides of the vehicle allows the side with more positive caster to actually push the car toward the side with the least amount of caster.

Caster spread or cross caster is specified as 30' or 45' maximum to minimize the lateral force difference between the left and right sides of the vehicle. Caster spread should not be used to compensate for road crown. Smaller amounts of camber spread can perform the same function and are less likely to cause directional control problems under braking.

The actual amount of directional influence as a result of caster is largely dependent upon vehicle design. Rear wheel drive cars typically use larger caster values than do front wheel drive vehicles. Front wheel drive cars pull the front wheels down the road as opposed to being pushed, as is the case with rear wheel drive designs. This pulling effect provides some inherent directional stability allowing for a smaller caster value. Some caster is necessary on front drive designs however, to provide stability under braking and coast conditions. Front wheel drive vehicles, as a function of their design, are less sensitive to caster spread than their rear drive counterparts. This characteristic is notable for one reason. Caster spread will likely have to be quite large to cause a steady speed pull complaint on front wheel drive models.

Vorlauf geometry provides significant increases in caster without significant increases in the caster trail.



Vorlauf and Nachlauf Geometry

Nachlauf geometry provides increased caster trail without an increase in caster angle.

Tire Wear - Caster is often referred to as a **non-tire wearing** angle. However, caster does cause the front wheels to camber when turning and the higher the caster value, the greater this camber roll. Therefore on vehicles with high caster values, **treadwear at both the inside and outside edges of the tread** may occur because of camber roll.

Vehicles that exhibit this type of wear operate primarily under urban driving conditions that involve many tight radius turns. These conditions cause the wheels to operate excessively cambered and result in premature tire wear. The only method to prolong tire life is frequent rotation and highway driving as opposed to urban driving.

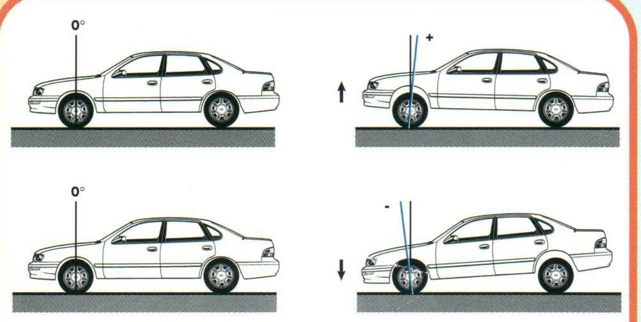
Vorlauf and Nachlauf Geometry - In recent years, some Toyota vehicles have been designed to take advantage of the virtues of high positive caster without dramatic increases in steering effort and road shock. The front suspensions of the Previa, Cressida and Celica (1990-1993) utilize Vorlauf geometry. ➤

By offsetting the steering axis rearward of the wheel centerline the caster angle can be increased without greatly increasing the caster trail. On conventional front suspension designs, the steering axis intersects the wheel centerline, consequently any increase in caster provides a proportional increase in caster trail.

Nachlauf geometry offsets the steering axis ahead of the front wheel centerline. This arrangement increases the caster trail without a corresponding increase in caster angle. This provides improved directional control without a large amount of camber roll.

A change in ride height at the front or rear of the vehicle has a significant influence on caster. As the rear of the vehicle is raised, caster moves negative and as the rear of the vehicle is lowered, caster moves positive.

Measuring Caster - The steering axis is very difficult to contact for a direct measurement of its angle. As a result, caster is typically calculated by measuring the amount of camber change through a 40º turn of the wheels and multiplying this result by a constant value. Electronic measurement systems perform this function and will refer you to the direction and degree of the turn, as well as any other necessary details specific to your machine. If the vehicle you are measuring has excessive toe error, the toe value should be adjusted close to specification before measuring and adjusting caster.



Ride Height and Influence on Caster

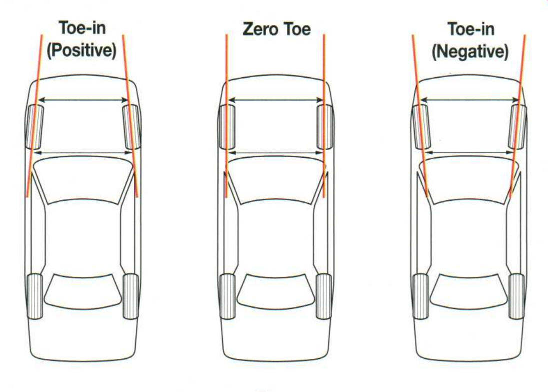
A caster value deviating from specification may have several causes. Caster error at both front wheels can often be traced to the relationship between caster and the attitude or level of the vehicle. A change in the height of either the front or the rear of the vehicle will alter caster at a rate of approximately one degree of caster for each one degree change in vehicle attitude. By raising the rear of the vehicle caster is moved negative and by lowering the rear of the vehicle (sagging springs or an overloaded condition) caster is moved positive. Large individual caster errors suggest possible bent or worn suspension components or even structural damage.

Toe

Toe is the difference in distance between the front of the tires and the rear of the tires. When measured as an angle, toe describes the angle formed by the vehicle's centerline and a line extended through the center of the tires.

Toe is the difference in distance between measurements taken at the front and the rear of the tires.

Toe-in results when the front of the tires are closer together than the rear of the tires, this condition is also described as positive toe. Toe-out results when the rear of the tires are closer together than the front of the tires, also known as negative toe. If both the front and rear of the tires are the same distance apart, they are said to have zero toe.



Toe

Toe can also be described as total toe or individual toe. Individual toe refers to a single wheel compared to the vehicle's centerline and total toe describes the sum of individual toe values.

The primary purpose of a static toe angle is to keep the front wheels operating at nearly zero toe when the vehicle is in motion. Toe provides compensation for the various forces acting on the steering linkage while the vehicle is moving. Differences in suspension and powertrain design determine the static toe specification. Most vehicles operate with a slight amount of toe-in, however some front wheel drive designs may be specified for zero toe or even toe-out.

Directional Control and Tire Wear

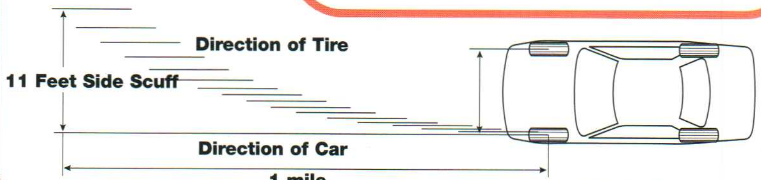
Directional Control and Tire Wear - The most noticeable effect of an improper toe value is premature tire wear. Toe is the most critical alignment angle with regard to premature tire wear. An incorrect toe value can remove up to 50 percent of the tire's tread in as little as 2000 miles. When the tire is excessively toed-in or toed-out it does not roll straight as the vehicle moves forward down the road. The vehicle forces the tire to roll forward, which in effect drags the tire sideways. This side scrub or scuffing action removes tread at a rapid rate. The resulting tread-wear appears as shoulder wear, appearing similar to camber caused wear on radial tires and as feathered or saw tooth type of wear on bias-ply tire designs.

Excessive toe-in or toe-out removes tread from the shoulder of the tire. If the toe value is incorrect, the tire is scuffed or dragged sideways down the road.

Excess Toe-in - Outside Shoulder Worn

Beyond rapid tire wear, improper toe may also influence the vehicle's directional control. Excessive **toe-in** causes a condition where each wheel individually attempts to align itself straight forward. As each wheel aligns itself straight, the opposite wheel assumes all of the toe value. As the wheels alternate between straight and toe-in positions, the steering linkage and steering wheel oscillate back and forth, creating a **shimmy**.

With excessive **toe-out**, each wheel will roll in opposite directions and neither can find a straight position. When the two front wheels are pointing in separate directions, the **vehicle wanders**. The result is a car that seems to require constant steering input to keep traveling straight forward.



Tire Wear Caused By Toe Error

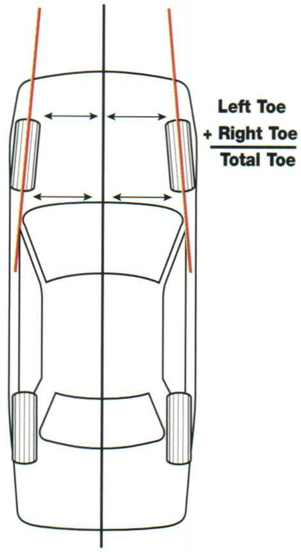
Measuring Toe

Measuring Toe - Whether measured in linear units or as an angle, both individual and total toe must be inspected. Individual and total toe are both measured with the wheels steered straight ahead and the vehicle at its correct ride height. Correct ride height is very important as when the suspension moves through jounce and rebound toe values change. This toe change, described as bump steer, results from the different travel paths of the steering linkage and the suspension.

Individual toe is a comparison of the wheel's position to the geometric centerline of the vehicle. The sum of the individual toe values equals total toe.

Individual toe values help determine the position of the steering wheel. If individual toe is equal and the rear wheels are in proper alignment, the steering wheel will be centered when the vehicle is traveling straight down the road. Toyota Repair Manuals specify total toe and require tie rod length to be equal from side to side. This procedure applies one-half the total toe value to each individual wheel equalizing individual toe.

Any changes in wheel/tire position such as caster or camber adjustments change the toe value. Consequently, front wheel toe is measured and **adjusted last**, after all other alignment adjustments have been made. Other factors that can cause incorrect toe stem from changes in the length of the steering linkage by damage or adjustment error or a change in overall tire/wheel diameter.



Individual and Total Toe

Camber at the rear wheels is defined the same as front wheel camber. Positive camber describes the tire tilted outward at the top and negative camber describes the tire tilted inward at the top.

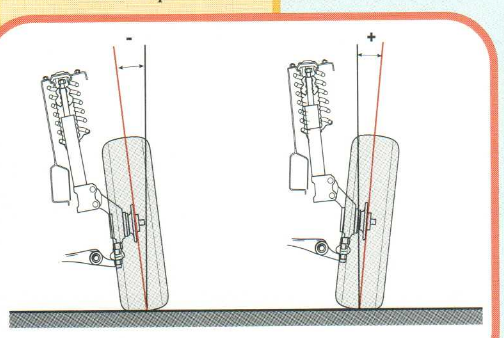
Rear Wheel Geometry

Wheel alignment geometry at the rear of the vehicle consists of three basic elements:

- **Camber**
- **Toe**
- **Thrust angle/Thrust line**

Rear wheel Camber

Camber of the rear wheels is defined the same as front wheel camber; the angle formed by the tire centerline and vertical. The descriptions for positive, negative and zero camber are consistent with the front of the vehicle.



Rear Camber

Rear wheel camber is generally specified as negative on vehicles with independent rear suspension (IRS). A small amount of negative camber at the rear improves cornering performance by applying maximum tread to the road surface. As a vehicle enters a turn the outside wheels (front and rear) camber positive as result of centrifugal force. This camber change reduces the amount tread in contact with the road surface. A static negative camber value maximizes tread contact in a turn by preventing the wheel camber from moving excessively positive.

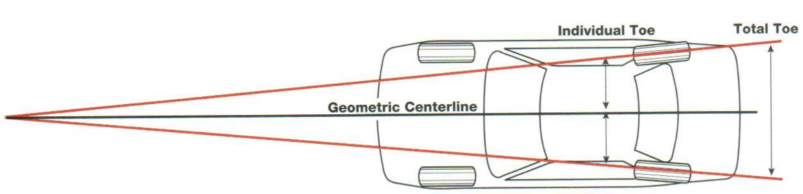
Solid rear axle designs operate with zero camber. Any significant camber with this style of suspension may indicate bent components.

Directional Control and Tire Wear - Rear wheel camber, in most cases, has little influence on the directional control of a vehicle. Since the rear wheels do not pivot, the cone effect caused by excessive camber is unable to move the vehicle off course. This explanation holds true in all cases except slippery roadways. When there is a difference in traction between the rear wheels, the cone effect can cause the rear of the vehicle to wander providing an unsettled feeling to the driver.

Tire wear resulting from incorrect rear camber can be diagnosed similar to front camber error. Excessive positive camber results in tread wear near the outside edge of the tire, often with a sharp edge where the tread area meets the sidewall. Excessive negative camber wears the inside edge of the tread surface prematurely.

Total and individual toe at the rear wheels are defined the same as front wheel toe.

Rear Wheel Toe



Rear Toe

Total toe and individual toe are defined the same when applied to the rear wheels of the vehicle as the front.

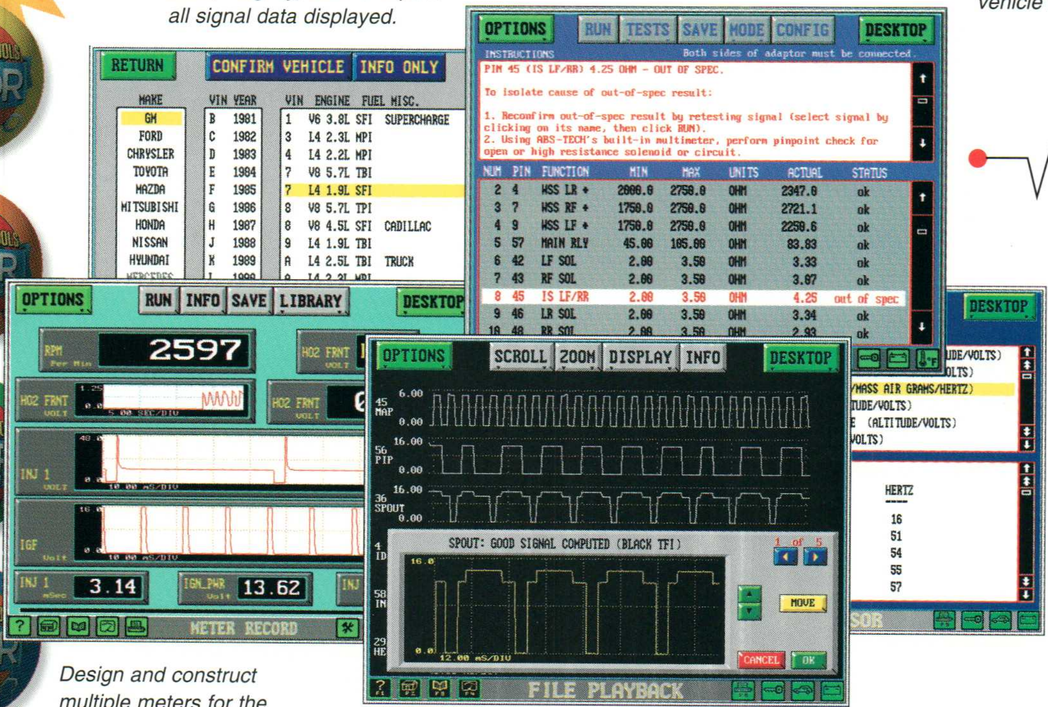
Toe-in or positive toe is applied to the rear wheels of independent rear suspension vehicles to improve both cornering performance and straight line stability. As tire profiles have decreased (shorter sidewalls, wider tread), suspension bushing compliance has increased to maintain acceptable ride quality. This compliance, when excessive, can produce some negative influences of vehicle handling.

Directional Control and Tire Wear - Incorrect rear toe can cause the same tire wear patterns as front toe error. Another irregular wear pattern caused by rear toe inaccuracy is **diagonal wear**. This pattern results from an excessive side load placed on the tire. The load increases to a maximum and the tire slips sideways across the pavement releasing the energy it has stored. Once the tire slips, the load builds and the tire slips again reducing the load removing tread in diagonal stripes. This type of wear often begins as heel and toe type wear. High side loads cause abnormal wear on individual tread blocks, which degenerates into wear across the entire tread surface. ➢

Intermittent, hard-to-find, no-code driveability problems. Even I/M240 problems. No problem!

Simply click on the name of each signal you want to view to have the fully self-configuring multi-trace lab scope display the live signal output of the up to seven signals you select. Then use the library of online reference waveforms. Record, play back, magnify, save and print all signal data displayed.

Diagnose the computerized electronic systems of all the major domestic and import vehicle manufacturers.



Comprehensive online help, as well as such vehicle-specific tech info as recommended testing procedures, scan tool references, ECU/ECM locations, and more.

Design and construct multiple meters for the diagnostic tasks you routinely perform on specific makes and models of vehicles.

Systematically sweep virtually every sensor, actuator and signal circuit typically in about 60 seconds. Pass or Fail result returned for every device and circuit measured, along with comprehensive diagnostic messages.

CALL TODAY TO ORDER YOUR FREE VIDEO ON SIMU-TECH!

SIMU-TECH. The only complete solution to diagnosing today's vehicle electronics!

Install and run the award-winning SIMU-TECH software program on any 486-based or more powerful PC to give you the complete solution to diagnosing even the most sophisticated engine, emissions and ABS control systems of every major domestic and import automaker. Or install SIMU-TECH on any PC-based piece of equipment in your shop. SIMU-TECH's revolutionary range of diagnostic functionality and simplicity of operation are some of the reasons the editors of MOTOR named a diagnostic product from EDGE a winner of its prestigious 'Top New Tool of the Year' award in the magazine's annual 'Best of the Best' competition the last five straight years! **Add to all that the reliability and assurance you get from John Bean's standing behind the products it sells.**

EDGE Diagnostic Systems®

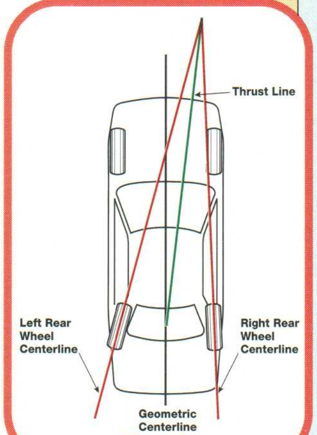
John BEAN Company

CALL 1-800-362-8326 FOR MORE INFORMATION TODAY!

The positioning of the rear wheels also determines the straight ahead position of the front wheels. While the front wheels provide the steering for the vehicle, it is **the rear wheels that determine the direction the vehicle will travel**. If the rear individual toe values are equal, the front and rear wheels will both be parallel to the vehicle's centerline while traveling straight ahead. If the rear toe values are not equal, the vehicle will not track properly. To further understand the implications of rear toe a discussion of thrust angle is necessary.

Toe-out at the rear is the source of most rear suspension caused handling complaints. Negative toe may cause the vehicle to wander at the rear when traveling straight ahead. When turning, excess rear wheel toe-out may also cause an oversteer condition. A static toe-in setting prevents this situation by providing understeer, which gives stable handling for the average driver.

The thrust line determines the direction of vehicle travel. It is determined by the rear individual toe values. When the average direction of the rear wheels is not in line with the geometric centerline, a thrust angle is formed.



Thrust Line

Thrust Angle

The thrust line is the average direction of the rear wheels. The thrust line actually divides or bisects the vehicle's rear total toe value. The intersection of the vehicle's geometric centerline and the thrust line form the thrust angle. Remember that the geometric centerline is simply a line extending through the midpoint of both the front and rear axles.

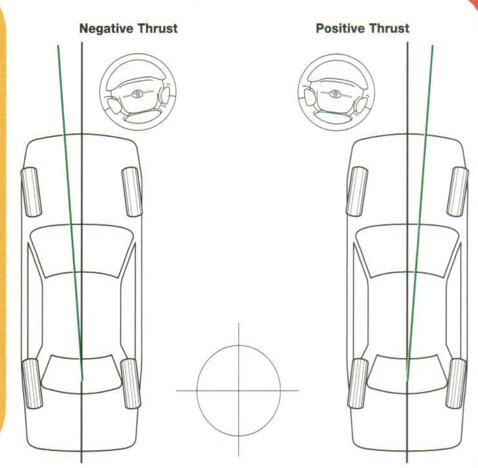
When the thrust line extends to the left of the geometric centerline, the thrust angle is negative. The rear wheels of the vehicle are pointed to the left. A positive thrust angle describes a thrust line extending to the right of the geometric centerline. The rear wheels of the vehicle are pointed to the right.

Directional Control - The positioning of the rear wheels determines the vehicle's direction of travel. This directional control effect is also described as tracking. The thrust line and the geometric centerline must be in the same position to prevent the vehicle from tracking sideways.

To compensate for improper tracking or thrust error, a driver must turn the steering wheel in the direction of the thrust line. When a thrust condition occurs, the steering wheel will be off center when the vehicle travels straight ahead. Outside, the vehicle appears to be traveling sideways or "dog-tracking."

To illustrate the effect of thrust angle, consider a 1º thrust angle (toward the right) on a vehicle with a wheelbase of 100". This thrust error results in a 1 3/4" error at the front wheels. To keep the vehicle traveling straight, the driver must turn the wheels to the right in the direction of the thrust.

Thrust angle is negative when the thrust line is to the left of the vehicle's geometric centerline. A positive thrust angle has the thrust line extending to the right of center. Since the rear wheels actually determine the direction of vehicle travel, the steering wheel will be off center in the direction of the thrust line when the car is traveling straight down the road.



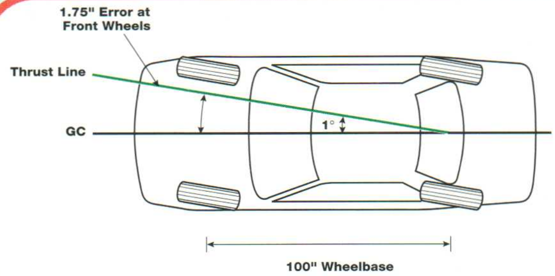
Negative and Positive Thrust

Also, consider the effect of caster and camber roll as the wheels are turned from center. Not only will the steering wheel be off center, but a pull or premature tire wear at the front wheels may occur because of the change in spindle position or camber roll.

Measuring Thrust - Thrust angle is determined by comparing rear individual toe values to the geometric centerline of the vehicle. Electronic alignment equipment identifies both the geometric centerline and the thrust line by comparing the positions of each individual wheel. The individual positions of each wheel form a rectangle, the center of which is the vehicle's geometric centerline. This centerline forms the reference point for determining front and rear toe, as well as the thrust line.

When inspecting, **maximum thrust angle is specified as 0.5º (30')** for all Toyota vehicles. An IRS vehicle's rear individual toe should be adjusted equally to provide a thrust angle less than 0.1º. Thrust angles exceeding 0.1º will likely cause a steering wheel off center (SWOC) condition.

Excessive thrust angle on solid rear axles is an indicator of component movement or damage. For example, an excessively toed in right wheel and an excessively toed-out left wheel will produce a negative thrust angle and indicates a shifted axle assembly or a mounting problem. A bent axle however, may show as toe error at one wheel alone. Both problems are easily identified using thrust angle for diagnosis.



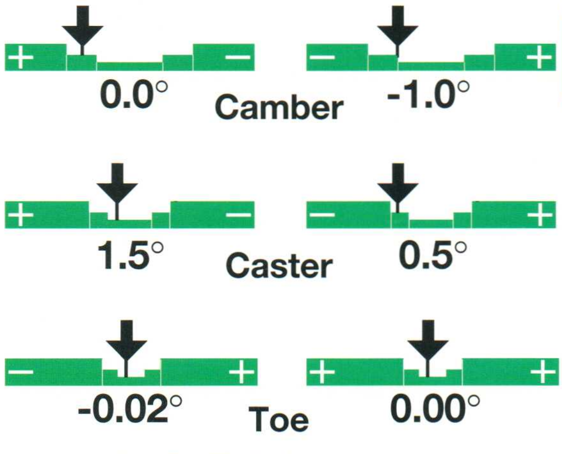
Example of Thrust Error

Small amounts of thrust error require significant correction at the front wheels. In this example, the steering wheel will be off center to the right correcting for the thrust angle.

Summary

Individually, each element of a vehicle's wheel alignment geometry influences its handling characteristics. Since each of these elements must work in concert to provide safe, responsive handling and acceptable tire wear it is important that they be considered together and not separately.

The directional control effects of each element may add to or cancel the effects of another. For example, a 1º negative camber spread will likely cause a pull to the left. Accompany this with a 1º positive caster spread at the right wheel and the vehicle may travel straight down the road. The point is, alignment geometry must be diagnosed as the interrelated system that it is, not as individual elements.



Cancelling Effect of Alignment Angles

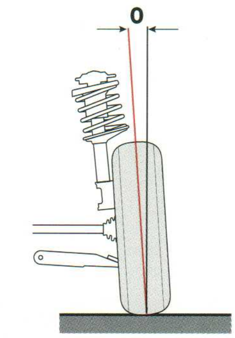
Wheel alignment geometry must be considered as an interrelated system. The effects of one element may cancel or enhance the effects of another.

Several other systems also can have significant influence on the handling of an automobile. Steering, braking and drivetrain systems should not be overlooked when you are trying to diagnose the root cause of handling complaints.

Basic

Alignment Angle

Summary



DESCRIPTION

Camber is defined as the inward or outward tilt of the tire compared to vertical.
The definitions are the same for both the front and rear wheels.

Positive camber describes the top of the tire tilted away from the vehicle.
Negative camber describes the top of the tire tilted inward toward the center of the vehicle.

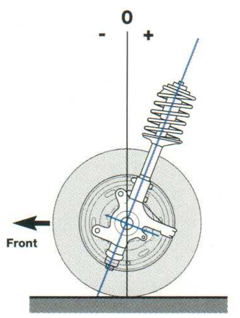
DIRECTIONAL CONTROL AND TIRE WEAR

Camber pulls toward the wheel with a more positive value.

Camber error at the rear wheels generally will not create a pulling condition.

Excess **positive camber** wears the tire at the **outside edge**.

Excess **negative camber** wears the tire at the **inside edge**.



DESCRIPTION

Caster is defined as the forward or rearward tilt of the top of the steering axis compared to vertical.

Positive caster describes the steering axis tilted rearward from vertical
Negative caster describes the steering axis tilted forward.

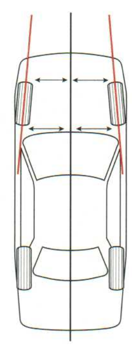
DIRECTIONAL CONTROL AND TIRE WEAR

Caster pulls toward the wheel with a more negative value.

Excess **positive caster** may create hard steering, increased road shock, or steering wheel shimmy following a turn.

Insufficient caster or **negative caster** may result in wander or poor steering wheel return.

Caster is normally referred to as a **non-tire wearing angle**. Camber roll as a result of caster may wear the inside and outside edges of tires on vehicles with very high caster values.



DESCRIPTION

Toe is defined as the difference in distance between two tires measured at the front and the rear. When displayed as an angle toe describes the angle formed by the tire centerlines (total toe) or one tire centerline and the vehicle's geometric centerline (individual toe). ***Individual toe*** *is the comparison of one tire's position to the vehicle's geometric centerline.* ***Total toe*** *is the sum of the individual toe values on an axle.*

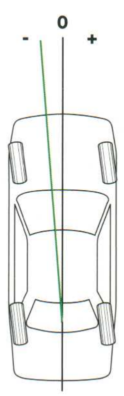
Toe-in or positive toe describes the tires closer together at the front than the rear.
Toe-out or negative toe describes the tires farther apart at the front than the rear.

DIRECTIONAL CONTROL AND TIRE WEAR

Toe error results primarily in premature tire wear. Excess **toe-in** will result in tread loss from the **outside shoulder** of the tire. **Toe-out** will result in tread loss from the tire's **inside shoulder**.

Toe error at the rear wheels may also result in **diagonal wear**.

Excess **front wheel toe-in** may result in a shimmy condition. Excessive **front toe-in** or **toe-out** may cause the vehicle to **wander**.



DESCRIPTION

Thrust angle is the angle formed by the thrust line and the vehicle's geometric centerline. The thrust line is established by the rear individual toe values.

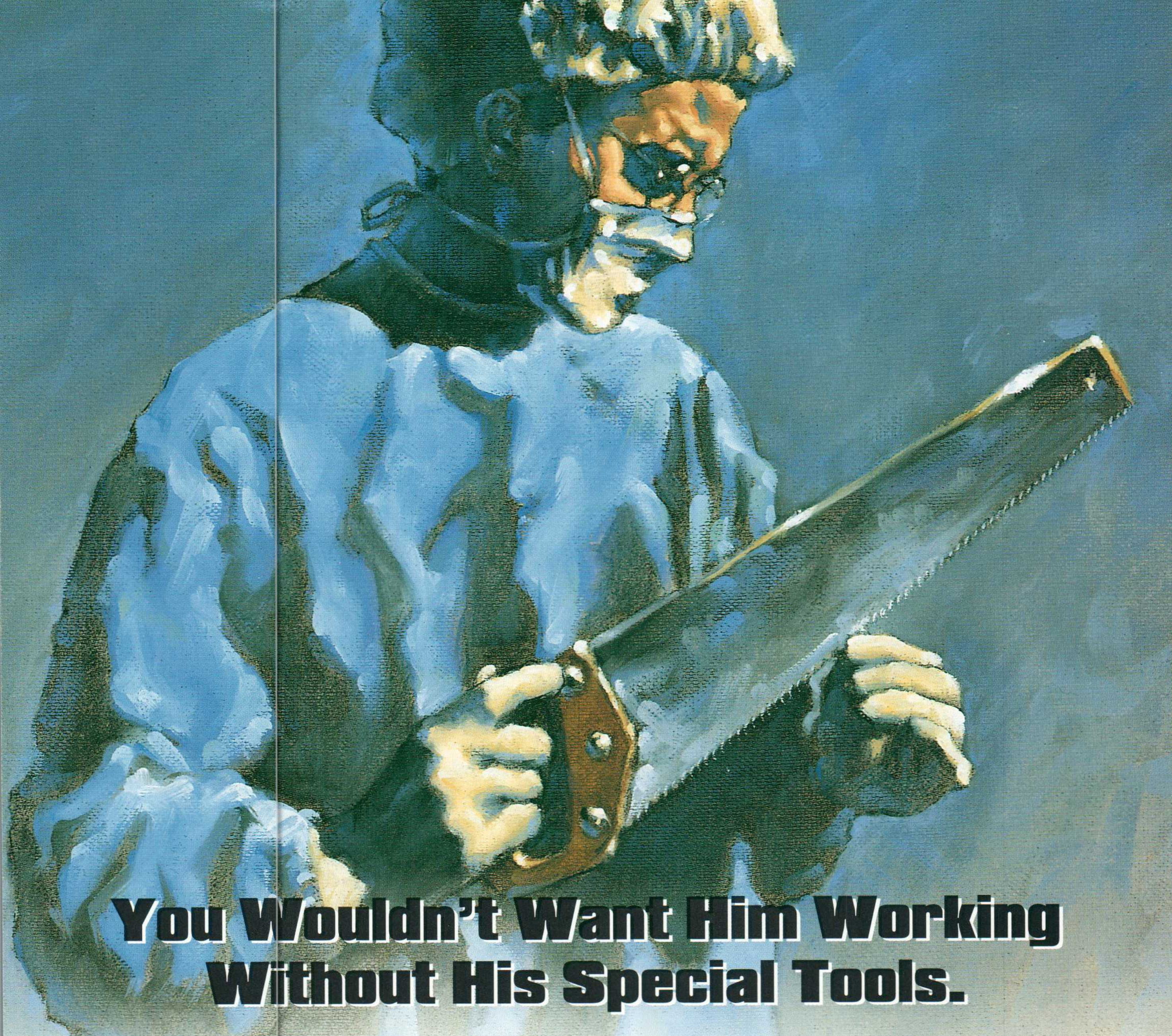
Positive thrust describes a thrust line extending to the right of the geometric centerline.
Negative thrust describes a thrust line extending to the left of the geometric centerline.

DIRECTIONAL CONTROL AND TIRE WEAR

The position of the rear wheels determines the vehicle's direction of travel or tracking.
Small amounts of thrust error will result in an off-center steering wheel; the vehicle "dogtracks".

Positive thrust angle causes the steering wheel to be **off-center to the right** when the vehicle is traveling straight ahead.

Negative thrust angle causes the steering wheel to be **off-center to the left** when the vehicle is traveling straight ahead.



You Wouldn't Want Him Working Without His Special Tools.

In every profession, the right tools for each job are chosen with care. In the transportation service industry, professionals reach for **OTC** tools every time.

And why not? Nearly 75 years ago, **OTC** was one of the first to design special tools for the transportation service industry. And today, there's no better substitute for a **OTC** tool. From their proven reliability and OE approval to their lifetime warranty*, the industry depends on **OTC** for products they can trust. And with **OTC's** same day shipment and extensive inventory, you can get the tool you need when you need it. When the job is critical, choose the tool with care. Choose **OTC**.

OTC®

OE Tool and Equipment Group
SPX Corporation
655 Eisenhower Drive
Owatonna, MN 55060-0995

Fax 800-578-7375
Phone 800-933-8335

*See full details in our catalog.

Vehicle Handling and Chassis Diagnosis

Handling Diagnosis

Customer expectations regarding vehicle handling can vary widely based on the intended use of an automobile. Consider the differences in intended use between an Avalon and a Supra, as well as the different expectations between the drivers of these two vehicles. One driver expects a quiet, smooth ride with long tire life and safe, predictable handling. While the other driver expects superior cornering ability, rapid acceleration, superior stopping ability and is willing to sacrifice some ride quality and tire life to get it.Although these are both extremes, there are several consistent themes that apply to all on-highway passenger vehicles regarding a customer s handling expectations. Customers expect vehicles that will:

Toyota customers have high expectations with regard to vehicle handling no matter which model they drive.

Customer Expectations

- **Travel straight with minimal driver input**
- **Stop safely**
- **Steer responsively**
- **Absorb road shocks**
- **Maintain passenger cabin stability (limit body roll etc..)**
- **Drive comfortably and quietly**
- **Minimize tire wear**

When these expectations are not met the vehicle will be brought in for service. Diagnosis of handling complaints is similar to the diagnosis of any other vehicle problem. You must thoroughly understand the proper function and operation of the systems, subsystems and individual components involved, as well as follow a consistent troubleshooting procedure.

Diagnostic Procedure Overview

The diagnosis of handling complaints follows a six step troubleshooting process. This process provides a proven, systematic method for resolving customer complaints.

We'll take you through the first four steps of the **trouble shooting process** in this issue of **Toyota Star Service News**.

1 Verify Complaint

Repeat the condition to see, feel and hear what the customer is concerned about.

2 Classify Complaint

Completely and accurately describe the complaint and any related conditions.

3 Chassis Inspection

Perform a general inspection of the chassis to eliminate possible causes of the complaint and direct your diagnostic effort.

4 Pinpoint Diagnosis

Inspect only those items that could be possible causes of the customer complaint.

5 Repair

Adjust or replace the components causing the concern.

6 Verify Resolution

Repeat the complaint conditions to confirm the cause of the complaint has been resolved.

Step 1 Verify Complaint

Verification of the customer complaint is the single most important step of any diagnosis. It is impossible to repair a complaint that cannot be verified or a normal characteristic of a specific vehicle. In the interest of customer satisfaction, simply attempting a wheel alignment for every type of handling complaint is not acceptable. Understanding the exact reason the customer brought their car in for service is vital to an accurate diagnosis and repair, and more importantly to fulfilling their expectations. Verification of the complaint involves three components:

1. Customer communication
2. Visual inspection
3. Test driving

Customer Communication

Why is the customer concerned or requesting service? Understanding why the customer feels service is necessary can provide valuable clues to the root cause of the complaint.

- **Abnormal tire wear**
- **New tires**
- **Changes or problems in the vehicle's handling**
- **Recent accident damage**
- **Major powertrain service**

All of these are reasons a customer may request an alignment or require handling diagnosis.

Three questions should be answered by the customer, if possible, before you begin service. These answers will help ensure a proper repair the FIRST time the vehicle is brought to the dealer for service.

1. What is the specific complaint or concern?
Details of what the customer sees, feels, and hears that they perceive as abnormal.

2. Under what conditions is the vehicle normally operated and under what conditions does the complaint occur?
Operation, load, road and weather characteristics both normally and when the complaint occurs.

3. What is the vehicle's recent service history?
Any and all service both mechanical and body /paint.

Brief Visual Inspection

The visual inspection is a precautionary measure and an initial diagnostic step to allow you to identify any safety concerns, obvious vehicle damage or other visible problems that may be affecting the handling of the vehicle.

A short, but concise walk-around inspection can reveal a great deal about both the mechanical and operating conditions of the vehicle. Specific items of attention include:

- **Tire wear, size, type, and inflation pressure on each axle pair**
- **Position of new tires**
- **Vehicle loading or signs of typical loading**
- **Accident damage or recently repaired accident damage including body panel fit and finish**

It is important to only note your findings and **not** attempt any repairs prior to the test drive, unless you find obvious safety concerns. The visual inspection is only a brief information gathering step. Any changes or repairs made at this point may influence the results of the test drive and prevent accurate duplication of the customer complaint.

Test Drive

The third and final step involved in verifying the customer complaint is the test drive. The test drive provides an opportunity for the customer to repeat the symptom and related conditions with you. Understandably, it is not always feasible to have the customer accompany you on the test drive. In that event take special care to closely follow the customer's described conditions for repeating the complaint.

The test drive is critically important for two reasons. First, it provides an opportunity to see, feel, and hear the handling characteristics of the vehicle, which will ultimately allow for the confirmation of your repairs. Secondly, you may notice problems which may have onset so slowly the customer is unaware ➤

Following a consistent troubleshooting process is the key to successfully diagnosing handling complaints.

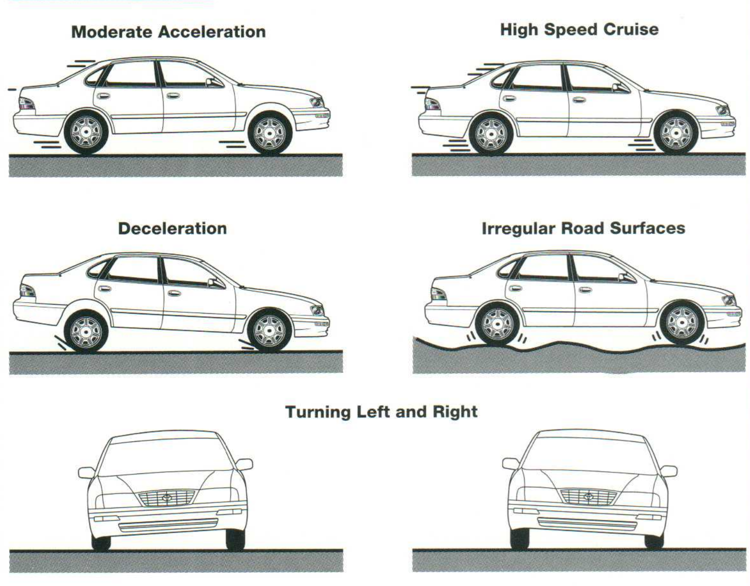
of them. Whether the customer is requesting an alignment for maintenance reasons or concerned about a handling problem, a test drive is always necessary to verify the condition of the vehicle both **before and after** the service or repair.

A thorough test drive should include all of the following conditions in addition to all of the complaint conditions described by the customer.

- **Acceleration from a stop** - Check for pulling, noise, excessive rear squat, vibration.
- **Constant speed cruising on a level road** - Check for steering wheel position, steering system play, pulling/drifting, wander, shimmy.
- **Deceleration and braking** - Check for pulling, brake dive, noises and vibration.
- **Turning both left and right** - Check for steering assist and response, returnability, body roll, tire squeal, noise.
- **Irregular surfaces** - Check for excessive suspension oscillation, suspension travel, road shock, bump steer, noise and vibration.

A good test route allows you to inspect the vehicle's operation under all of these conditions, is close to your service facility and is consistent. Thorough and consistent test driving allows you to accurately compare the performance of specific models and become familiar with their responses under similar conditions.

Perform a test drive before attempting any repairs. The test drive will provide a reference or baseline of the vehicle's condition before your repair for comparison afterward. Operate the vehicle through all of the conditions to identity any other symptoms or clues to the cause of the complaint.



Test Drive

Unverifiable Complaints

If the customer complaint cannot be verified during the test drive, further information should be gathered before any repairs are attempted. Perhaps the conditions required for duplicating the conditions were not fully understood or the concern is a natural characteristic of the vehicle.

Customer satisfaction may only require **consultation and education,** rather than diagnosis and repair. It is impossible to fix a concern that cannot be duplicated or worse yet is a normal condition of the vehicle. Keeping this in mind, remember the problem is important to the customer or they would not have brought the vehicle to you for service. Your job is to alleviate the customer's concern by repair or education.

Proper verification of the complaint cannot be stressed enough. If you do not confirm how the vehicle was operating before your repair, you have no valid basis for your post-repair expectations.

Step 2 Classify Complaint

Classification of the complaint begins with an accurate description of the symptom. Customer descriptions of a vehicle's symptoms may be unclear and can therefore be misleading to your diagnosis. After verifying the complaint personally, you should have the necessary information to accurately describe the symptom or symptoms and classify them accordingly. **Symptom classification is not a diagnosis,** rather it is a complete and accurate description of the handling complaint.

Accurate classification directs you to those areas that can be causing the complaint and eliminates testing and inspecting those that cannot. This process of elimination helps determine the pinpoint diagnosis methods you will select.

The list of symptoms and their definitions below describes the majority of handling complaints faced by suspension and alignment technicians. By evaluating the information gathered during the complaint verification and road test procedures, you should be able to classify the complaint as one or more of the following:

1. **Pulling -** A condition where steering effort is required to keep the vehicle traveling straight.

2. **Wander/directional stability -** A condition in which the vehicle requires continuous driver correction to maintain straight line traveling.

3. **Returnability -** The tendency of the front wheels to seek a straight ahead position following a turn. Returnability problems can be either poor returnability or excessive returnability.

4. **SWOC (steering wheel off center)** - A condition in which the steering wheel is off center to the left or to the right when the vehicle is traveling straight ahead.

5. **Hard steering** - A condition where excessive effort is required to turn the vehicle.

6. **Loose steering** - A condition where vehicle reaction to steering input is sluggish and unresponsive.

7. **Excessive road shock** - A condition where road forces are transmitted to the chassis and passenger compartment.

8. **Premature tire wear** - A condition where tread Tire is shorter than expected or wear is localized to one area of the tread surface.

9. **Shimmy** - A condition where the front wheels of the vehicle oscillate laterally, resulting in rotational movement at the steering wheel.

10. **Body shake** - Major vertical and/or lateral vibration of the body, seats and steering wheel.

11. **Cabin stability** - Conditions including body roll when turning, excessive squat on acceleration or dive on deceleration, and excessive bouncing when traveling over bumps.

If necessary, qualify your classification with the applicable conditions under which the complaint occurs. For example, the vehicle pulls to the right under braking or shimmy occurs at 55 m.p.h. in overdrive.

Following complaint verification and classification, the next step in the diagnosis of handling complaints is a chassis inspection. This step verifies the general condition of the suspension components, steering linkage and tires. The results of these inspections will determine your course of action for pinpoint diagnosis, as well as allow you to identify any additional items that may be in need of service.

Step 3 Chassis Inspection

Vehicle at Normal Ride Height

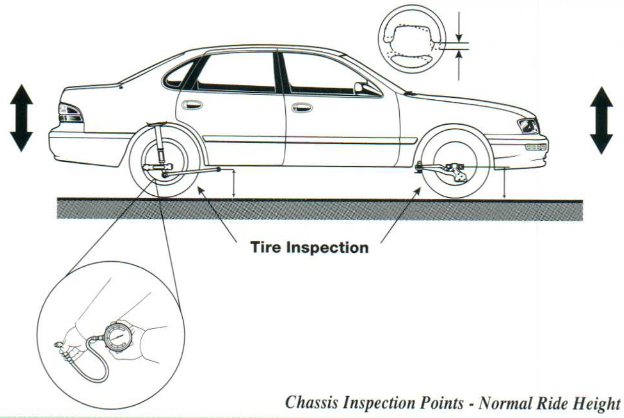
The chassis inspection consists of two stages; the vehicle at its normal operating posture and the vehicle raised.

With the wheels on the ground you are concerned with four inspections:

- **Tire Condition**
  Check for size, type and inflation pressure on each axle pair. Also check for excessive, abnormal or irregular treadwear.
- **Ride Height**
  Inspect ride height using the measuring points specified in the Repair Manual. Be certain the vehicle is not abnormally loaded and is resting on a level surface.
- **Steering System Free Play**
  Perform the dry park check, Max freeplay for most models is 30 mm.
- **Shock/Strut Jounce Test**
  Jounce the vehicle at each corner. Excessive oscillation (generally two or more) indicates worn shocks or struts.

After completing the checks with the vehicle in its normal posture raise the vehicle and support it properly. The preferred method is to support the vehicle with front suspension ball joints unloaded and the rear of the vehicle raised as well. This support method allows you to make all of your undercar inspections without changing the vehicle's position. Your inspections with the vehicle raised will focus on the condition of the components that can influence the vehicle's alignment geometry and handling.

Before raising the vehicle verify the tire condition and ride height, as well as the integrity of the steering system and the shock or struts.



Chassis Inspection Points - Normal Ride Height

Inspections with The Vehicle Raised

Undercar Visual - After raising the vehicle your first inspection should be a visual check. Look for obvious physical damage to any suspension or steering component, fluid leakage, the condition of all grease boots, and the condition of engine and transmission mounts.

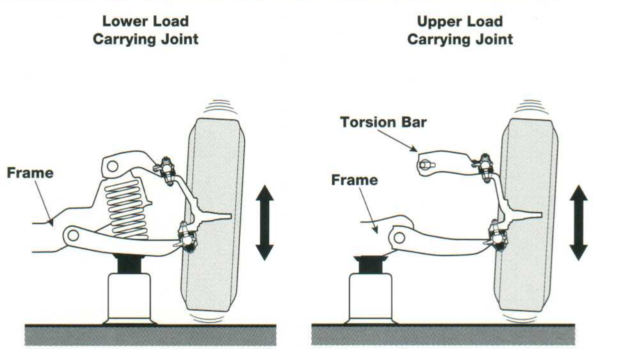
Ball Joints - Lift and support the vehicle correctly to unload the ball joints and inspect them for free play. Check for vertical play in the load carrying joint by trying to raise the tire with a pry bar. Any perceptible play in the joint will require you to closely inspect the joint following the specific procedures recommended in the Repair Manual. On strut suspensions this same inspection will identify any vertical play in the upper strut bearing (zero play is allowed) and the lower ball joint.

Rocking the tire from top to bottom (twelve and six o'clock positions) will often indicate any horizontal play in the non-load carrying joint or the upper strut bearing. Differentiating between wheel bearing play and play in the upper strut bearing or ball joints only ➢

requires application of the service brake. If the play is eliminated, the problem is likely the wheel bearing, if not, the ball joints or strut bearing may be the source of the play. Non-load carrying joints can also be checked by trying to move the control arm to which they are attached while watching for excessive movement at the joint. Again, any joints that appear questionable must be checked following the procedure outlined in the Repair Manual for the specific vehicle.

Ball joints should also be inspected for damaged grease boots as this leads to contamination of the joint and accelerated wear.

After unloading the suspension, check for any excess freeplay both laterally and vertically. Raise and support both the left and right sides of the suspension to prevent the stabilizer bar from preloading the joints. Any joints that appear questionable must be further inspected following the specific Repair Manual procedure.



Ball Joint / Strut Bearing Quick Checks

Springs/Shocks/Struts - Inspect visually for physical damage, mounting problems, missing spring insulators and any evidence of deformation or misalignment. Shock absorbers and strut assemblies should also be inspected for fluid leakage. Any significant oil leakage may require replacement of the shock or strut.

Steering Linkage - Facing the vehicle, grip both tires and move them laterally. Excessive play may indicate a loose joint in the steering linkage or possibly a loose wheel bearing. Pinpointing the source of the play involves careful examination of each joint in the steering linkage from the steering wheel to the steering arms.

Inspection of the individual joints involves physically moving each joint attempting to isolate the worn or loose component. Consider all of the following areas when attempting to isolate the source of excessive steering system play:

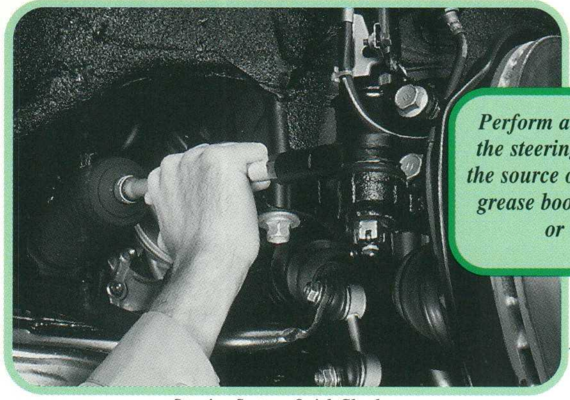
- **Worn tie rod ends - inner and outer**
- **Loose linkage mounting (idler arm)**
- **Loose steering shaft joints or flexible coupling**
- **Loose steering gear mounts**
- **Loose steering wheel**
- **Loose wheel bearings**
- **Steering gear lash**

Bushings and Links - Look closely at each bushing identifying any decay, damage or excessive play. Small hairline cracks are acceptable in rubber bushings as long as the bushing is not disintegrating. Using a pry bar inspect for play at the mounting points of the control arms, strut rods, stabilizer bars and lateral control rods, at both the front and rear of the vehicle, as equipped. Play at these locations may be caused by loose mounting or by worn bushings. Ball and socket joints used for anti-roll bar links should show little or no play.

Other Systems - Moving the wheels side to side, similar to the inspection for the upper strut bearing, will help identify any excessive wheel bearing play. Rotate each wheel several times after making this inspection to check the rotation condition of the wheel bearings as well as identify any brake problems. Also visually check the condition of engine and transmission mounts.

Document the results of your inspection on the repair order. If the chassis inspection reveals the cause of the customer complaint, further pinpoint diagnosis is not necessary. Move ahead with the repair or replacement of necessary components. Remember, wheel alignment correction is necessary if you replace any suspension or steering components that affects the position of the wheels.

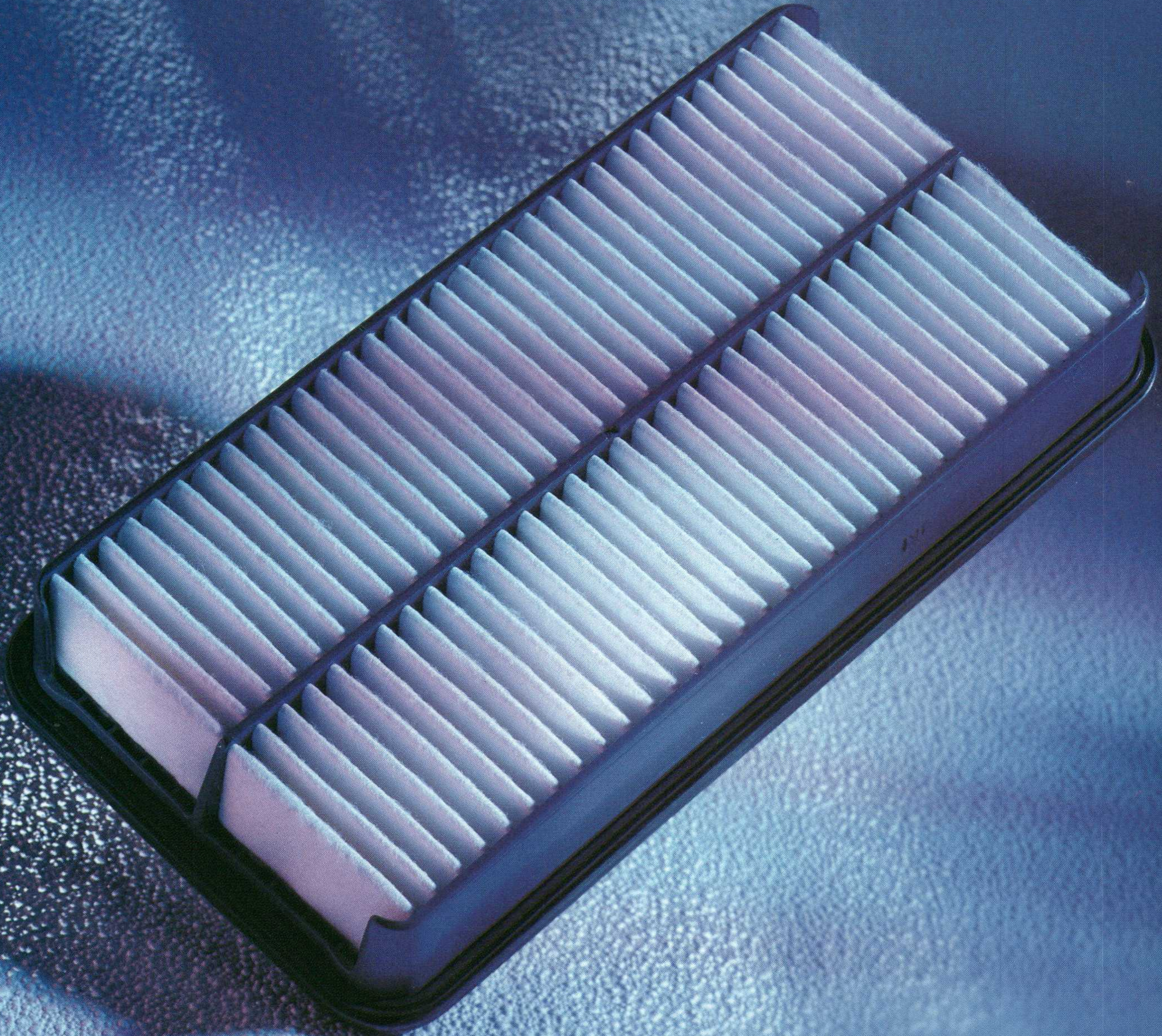
The first three steps of this diagnostic process determine your course of action for identifying and repairing the cause of the customer complaint. Following a consistent, systematic process for each diagnosis will enable you to repair more handling complaints, faster.



Perform a quick inspection of the steering linkage to identify the source of free play, damaged grease boots, physical damage or visible wear.

Steering System Quick Checks

10 out of 10 engines prefer clean air



Install Genuine Toyota Air Filters

- Engineered to OEM Specifications
- Superior Filtering Efficiency
- Reduced Engine Noise
- Tight Seal for Entire Filter Life
- Triple-layer (Course/Medium/Fine) Filter Element Traps More Contaminants

TOYOTA

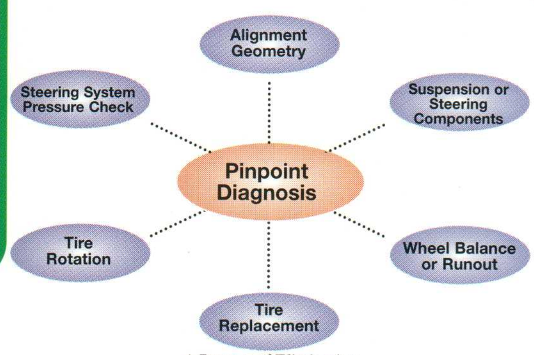
DENSO

Step 4 Pinpoint Diagnosis

The fourth step of the diagnostic process is pinpoint diagnosis. At this point in your diagnosis you must make several decisions about how to approach this customer concern. In other words, "What do I do to the car? Inspect, adjust, measure, replace?"

Remember diagnosis is simply **a process of elimination;** identifying what is not causing a concern and directing your energy toward those items that could be the cause. Pinpoint diagnosis really describes focusing your efforts to determine a strategy for finding the root cause of the handling complaint.

Pinpoint diagnosis really describes focusing your efforts. Based on the information you have gathered in from the diagnostic process determine your strategy for finding the root cause of the handling complaint.



A Process of Elimination

Selecting where to focus your diagnosis depends upon the likely causes of the complaint and which of those can be easily eliminated as possibilities.

For example, consider a customer complaint of a significant pull to the right on level roads under a steady cruise condition. After verifying the complaint, you find no other related symptoms or qualifying conditions and classify the complaint as Pulling.

Next, compare the results of a chassis inspection to the symptom matrix on the next page. Tire pressure, ride height, worn suspension and steering components, major physical damage and environmental influences can all be eliminated as causes by the test drive and chassis inspection. In this case, alignment geometry or tire concerns would then stand out as the most logical areas for further inspection.

Note that not every possible cause for a specific complaint is listed in the causes section of the matrix. Your understanding of how the tires, suspension, steering and other vehicle systems influence handling should allow you to narrow your search for a root cause.

Vehicle Handling Symptom Matrix

Pulling

DESCRIPTION

A condition where steering effort is required to keep the vehicle traveling straight.

POSSIBLE CAUSES

- Tire Pressure
- Tire size, construction. or wear mismatch
- Ride height
- Worn/bent steering components
- Worn/bent suspension components
- Tire conicity
- Camber spread
- Caster spread
- Dragging brakes
- Environmental effects
- Structural damage
- Power steering system

Wander/Directional Stability

DESCRIPTION

A condition where the vehicle requires continuous driver correction to maintain straight line traveling.

POSSIBLE CAUSES

- Worn tires
- Tire pressure
- Tire size or construction. mismatch
- Excessively negative caster, camber or toe
- Worn/bent steering components
- Worn/bent suspension components
- Excess steering gear lash
- Loose wheel bearings
- Structural damage

Returnability

DESCRIPTION

The tendency of the front wheels to seek a straight ahead position following a turn. Returnability problems can be either poor return or excessive return.

POSSIBLE CAUSES

- Caster error
- Worn/bent steering components
- Worn/bent suspension components
- Low tire pressure
- Steering gear or column binding
- Binding suspension components
- Steering damper
- Structural damage

SWOC (Steering Wheel Oft Center)

DESCRIPTION

A condition where the steering wheel is off center to the left or right when the vehicle is traveling straight ahead. No pulling condition is apparent.

POSSIBLE CAUSES

- Front individual toe error
- Thrust error
- Worn/bent steering components
- Worn/bent suspension components
- Structural damage

Hard steering

DESCRIPTION

A condition where excessive effort is required to turn the vehicle.

POSSIBLE CAUSES

- Low tire pressure
- Excess positive caster
- Binding ball joints or upper strut bearing
- Bent strut
- Bent steering linkage component(s)
- Steering gear lash too tight
- Lack of power assist

Loose Steering

DESCRIPTION

A condition where the vehicle's reaction to steering input is sluggish and unresponsive.

POSSIBLE CAUSES

- Worn steering system components
- Worn/bent suspension components
- Excessive steering gear lash
- Loose steering gear mounting
- Worn steering shaft joints
- Loose wheel bearings

Excessive Road shock

DESCRIPTION

A condition where road forces/shocks are transmitted to the body and passenger compartment.

POSSIBLE CAUSES

- Excessive positive caster
- Excessive negative camber
- Overinflated tires
- Worn shocks and/or springs
- Overloading
- Incorrect wheel offset (positive)
- Reduced tire aspect ratio (from OEM)

Premature Tire Wear

DESCRIPTION

A condition where tread life is shorter than expected or wear is localized to one area of the tread surface.

POSSIBLE CAUSES

- In correct tire pressure
- Overloading
- Alignment geometry error
- Worn/bent steering system components
- Worn/bent suspension system components
- Lack of tire rotation
- Wheel imbalance
- Driving style or driving habits

Shimmy

DESCRIPTION

A condition where the front wheels oscillate laterally resulting in rotational movement at the steering wheel.

POSSIBLE CAUSES

- Dynamic wheel imbalance
- Excess tire/wheel runout
- Radial force variation
- Excess positive caster
- Excess front toe-in
- Worn/bent steering components
- Worn/bent suspension components
- Wheel bearings
- Excess steering gear lash
- Steering damper
- Structural damage

Body Shake

DESCRIPTION

Major vertical and/or lateral vibration of the wheels, body, seats and steering wheel.

POSSIBLE CAUSES

- Static wheel imbalance
- Excess tire/wheel runout
- Radial force variation
- Axle or hub runout
- Worn/bent steering components
- Worn/bent suspension components
- Structural damage

Cabin Stability

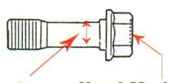
DESCRIPTION

Conditions including body roll, excessive squat on acceleration or dive on deceleration, or excessive bouncing when traveling over road irregularities.

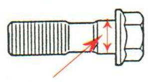
POSSIBLE CAUSES

- Worn shock or strut assemblies
- Broken or sagging springs
- Stabilizer bar or bar mounts
- Load placement or overloading
- Excess ride height

Camber Adjusting Bolt



Original Bolt



March/April 1997 Issue 63

New Camber Adjusting Bolts

To provide camber adjustment capability on Toyota Camry and Celica models, the steering knuckle set bolts can be replaced with new style camber adjusting bolts.

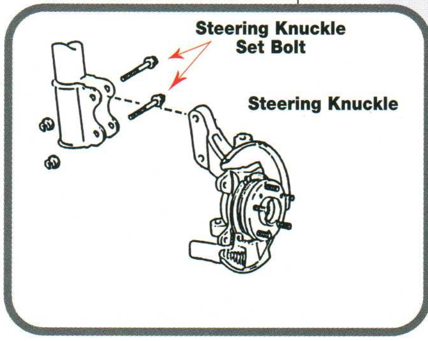
The replacement camber adjustment bolt has a smaller shank diameter than the original steering knuckle set bolt. This creates a gap between the bolt hole in the steering knuckle and the set bolt. Camber adjustment is performed by reducing the gap on either the positive or the negative side of the hole in the knuckle assembly. If the vehicle is within specs, but still pulls, the front camber settings may be changed by using the new style camber adjustment bolts.

Camber Adjusting Bolts Specs

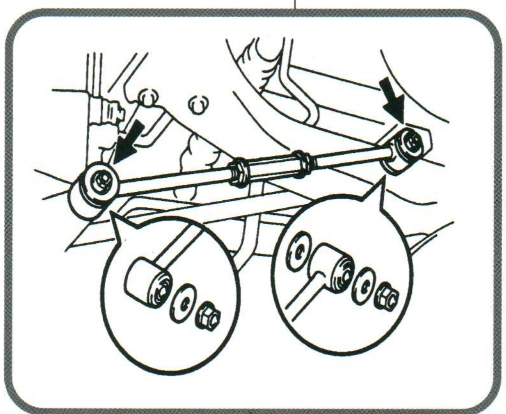
Diameter	Part Number	Adjustment Value	Head Mark
15.9 mm (0.626 in.)	90105-17003	+/- 15'	One Dot
15.0 mm (0.591 in.)	90105-17004	+/- 30'	Two Dots
14.0 mm	90105-17005	+/- 45'	Three Dots

Remarks

The different camber adjusting bolts can be distinguished by the number of projecting dots on the bolt head.



Lower Suspension Arm Number 2 Installation



The 1993 Corolla Repair Manual procedure contains the following instructions for installing the Rear Suspension Number 2 Lower Arm (repair manual reference page SA-82):

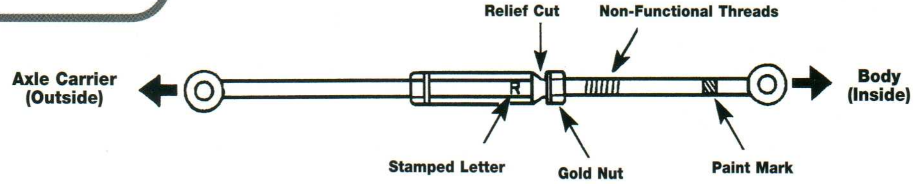
Install Number 2 Lower Suspension Arm

1. Install the Number 2 lower suspension arm with the three washers.

HINT: Face the paint mark to the inside.

2. Temporarily install the two lock nuts.

Because several suppliers are used for the Number 2 Lower Suspension Arm, the inside direction may be identified by any of the following marks shown below:



The identification mark should always face the centerline of the vehicle, regardless of which mark is used.

Shock Absorber Replacement Cartridge

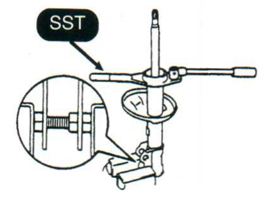
This bulletin explains the replacement procedure and model application for the cartridge type front shock absorber recently adopted for the Camry (1987-91) and Celica (1986-89).

Part Number Information:

Model	Part Number	Part Name
Camry - SV2#	48511-32030	Absorber, Shock Front (LH, RH)
Camry - VV2#	48511-32030	Absorber, Shock Front (LH, RH)
Celica - ST6#	48511-20150	Absorber, Shock Front (LH, RH) (Convertible, GTS)
Celica - ST6#	48511-20140	Absorber, Shock Front (LH,RH) (ST, GT)

Installation Procedure

1 Remove Lock Nut

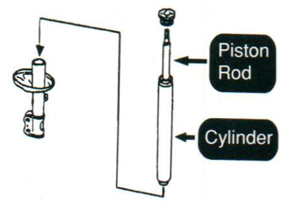


(a) Install a bolt and two nuts to the bracket at the lower portion of the shock absorber and secure it in a vice.

(b) Using SST, remove the lock nut. SST: 09721-00071 (available in SST Kit 09720-00012-02)

Notice: Loosen the lock nut slowly in order to sufficiently release the gas inside the shock absorber shell. If the gas is not released slowly, the fluid inside the shell will spray out when the lock nut is released.

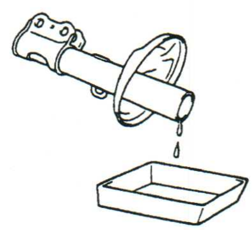
2 Remove Piston Rod With Cylinder From Shock Absorber Shell



Notice: Some fluid will remain in the piston rod and cylinder.

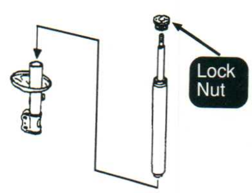
The base valve at the lower end of the cylinder sometimes remains inside the shock absorber shell. Ensure the base valve is removed.

3 Drain Fluid From Shock Absorber Shell



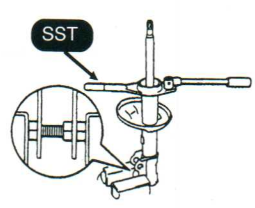
Drain the fluid into a suitable container.

4 Install Absorber Cartridge And New Lock Nut To Shock Absorber Shell

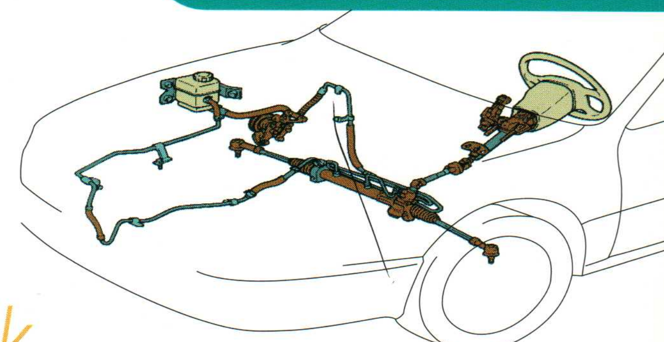


Notice: The lock nut removed in Step 1 is a different shape than the lock nut supplied as a set with the new shock absorber cartridge. Always use the new lock nut.

5 Tighten Lock Nut



Using SST, tighten the lock nut.
Torque: 100-145 Nm (1,000-1,500 kgf cm, 72-108 ft. lbf)
SST: 09721-00071



Toyota Reman Rack Program

TOYOTA GENUINE PARTS REMANUFACTURED

March/April 1997 Issue 63

Representing Toyota's high quality standards, assembled to Toyota's exacting specifications, and computer-tested to individual application requirements, technicians may use these reman racks with confidence. Even with prices slashed to less than half, reman products retain the same 12-month/unlimited mileage warranty as on new Toyota parts—an attractive customer satisfaction feature.

Expanded Reman Rack Program Offers *Quality, Reliability, and Value*

The third phase of a new reman parts program—offering 12 more Toyota reman power rack and pinion applications (for Toyota's most popular models) became available in January 1997.

In addition to the eight rack applications previously made available, the recent launch includes new applications for:

- ***1991 -96 Camry***
- ***1990 -93 Celica***
- ***1987 -90 Tercel***
- ***1986 -88 Supra***
- ***1985 -88 Cressida***
- ***1984 -88 Corolla***

An integral part of the reman program is a thorough and detailed inspection of your customer's complete steering system to determine if a rack replacement is necessary as well as to identify and repair any other potentially unsafe condition.

A Step-by-Step Diagnostic Process

As a technician, you perform the most critical step in the reman process—a thorough and accurate diagnosis of the power steering system. Confirming the root cause of customer's complaint for lack of or inadequate steering assist involves much more than replacing a steering gear. As with any complaint, a complete diagnostic process begins with verification of the customer's concern, followed by classification of the complaint, and a general inspection of the chassis. Should these steps lead you to the power steering system for further pinpoint inspection, several quick and easy diagnostic steps will allow you to determine the root cause of a steering assist complaint.

Proper inspection of the power steering system includes checks in the following areas:

- *quantity and quality of the hydraulic fluid*
- *the condition of the power steering pump drive belt*
- *power steering pump assembly*
- *steering gear assembly (rack and pinion unit)*

The power steering hydraulic fluid level should be checked with the vehicle at operating temperature. Rotate the steering wheel lock to lock several times to ensure the fluid is at least 80 degrees C (176 degrees F) and inspect the level on the dipstick inside the reservoir cap. Also note when the steering wheel is rotated from lock to lock, the fluid level should not drop more than 5 mm or foam excessively if the hydraulic system is free from excess air. While inspecting fluid level, place several drops of the fluid on a clean shop towel. The fluid should appear free of contaminants and not be burned.

Inspecting Power Steering Fluid

While you are under the hood checking fluid levels, all fluid hoses, lines, and connections should be inspected for leakage or physical damage that may result in fluid loss. Hoses should also be checked for any fraying and bulging as the wheels are turned that may indicate internal damage.

Since the hydraulic pump is belt-driven by the engine on all models, except MR2, any belt slippage will result in reduced steering assist. Belt tension should be checked with a belt tension gauge and compared to repair manual specifications. Remember that drive belts stretch slightly over their lifetime and for this reason tension specifications differ for new and used belts. Belt condition and alignment should be inspected as well.

To Replace or Not to Replace

If the cause of a steering assist complaint is not identified as fluid- or belt-related, the internal condition of the hydraulic pump and the steering gear must be checked. At this point you must identify whether the steering gear (rack) or the hydraulic pump is the root cause of the complaint. A power steering pressure test will verify the operation of each component separately and allow you to make an accurate diagnosis the first time.

Three quick checks can be performed using the Toyota Power Steering Pressure Gauge Set (SST# 00001-00009) to make the determination - is the steering gear or the hydraulic pump the root cause? The gauge set is connected between the power steering pump's high pressure outlet hose/line and the steering gear for the following three checks. Be sure to check for fluid leaks after installing the gauge set.

1 Maximum Pump Pressure

Begin with the engine idling at operating temperature and the valve on the gauge set OPEN. Next, CLOSE the valve for a maximum of 10 seconds and note the highest pressure reading on the gauge. Don't keep the valve closed in excess of 10 seconds or damage to the pump may result. This pressure reading is the pump's maximum output pressure. This value should be higher than the minimum value specified in the repair manual for the applicable model (approximately 800-900 psi). If the pressure reading is less than specification, the hydraulic pump is faulty.

2 Hydraulic Pump - Flow Control Valve

A second check confirms the power steering pump's internal flow control valve is functioning properly. Following the maximum pump pressure check, keep the gauge valve OPEN and record pressure values at engine speeds of 1000 and 3000 rpm. The pressure values should not differ greatly (approximately 70 psi, maximum) if the pump's internal flow control valve assembly is operating properly. If the pressure difference exceeds the allowable value provided in the repair manual, the hydraulic pump should be repaired or replaced.

3 Steering Gear Condition

The third and final check verifies the condition of the steering gear. With the engine idling, rotate the steering wheel to the lock position, both left and right, and record the maximum pressure displayed on the gauge at each position. Again, be sure not to hold the wheel at the full lock position longer than 10 seconds. These values should be about the same as the reading obtained in the maximum pump pressure test. If the displayed pressure value is lower than specified at either position, the steering gear is leaking internally and requires replacement.

The Choice for Convenience, Quality, and Customer Satisfaction

If the problem is in the steering rack gear, you have a choice of a new Toyota rack, aftermarket rack, or Toyota reman rack. By far the better value, a Toyota reman rack ensures like-new Toyota quality—at less than half the cost of a new Toyota rack—and provides your customers with the genuine article at prices highly competitive to aftermarket racks of questionable quality. Plus they come with the same warranty as new Toyota parts.

So instead of gambling with customer satisfaction by using aftermarket products (or attempting what would be an extremely complicated repair), you're ensuring customer satisfaction by replacing the faulty rack with a Genuine Toyota reman part that's tested, ready to go, and backed by the Toyota warranty. It all adds up to a confident repair and peace of mind for you—and your customers—as well as additional opportunities for service and parts sales.

A Complete Repair

Of course, any time a failed steering rack or hydraulic pump is replaced, the old fluid needs to be flushed and replaced with fresh fluid, and all air bled from the system. Replacement of a rack also requires wheel alignment service to ensure safe handling and acceptable tire life. Be sure to test-drive the vehicle to verify the repair has resolved the customer complaint. In addition, don't overlook other excellent sales and service opportunities such as bushings, outer tie rod ends, hoses, C.V. joints, rear suspension, tires, brakes, and exhaust system.

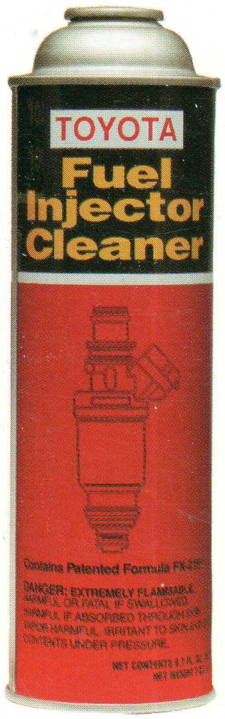
Enhancing an already proven customer satisfaction/retention resource, these additional reman rack applications provide even greater opportunity for quality service and attractively priced parts that will keep customers coming back again and again. STOP

Looking ahead

What's coming in ***the next issue of ServiceNews***

Air Conditioning and Automatic Temperature Control are the featured subject areas in the next issue of Toyota STAR Service News. The recent introduction of R-134a as the government-mandated refrigerant for all new Toyota air conditioning systems has brought significant changes to the service and repair of Toyota air conditioning and climate control systems. Whether you're servicing a newer system that was originally designed to operate with R-134a, retrofitting an older system from R-12 to R-134a, or performing routine service on an older R-12 system, there's plenty to know. We'll familiarize you with the theory of operation, troubleshooting techniques, and repair procedures necessary to effectively service Toyota air conditioning systems.

Genuine Toyota
Pressurized Fuel Injector Cleaner



- Dissolves harmful deposits
- Helps restore engine power
- Increases fuel economy
- Lowers emissions
- Enhances smooth idle and acceleration

Super Fast Satisfaction

Toyota Pressurized Fuel Injector Cleaner (PFIC) is TMC tested and approved to ***dissolve*** harmful deposits that form on injectors. This one-can system is hooked up to the vehicle's fuel rail using the PFIC Apparatus with the appropriate PFIC adapter, and the injectors are **cleaned** while the engine is running off the contents of the can. Most of the cleaning is completed within the first four minutes, and the entire process takes approximately **20 minutes** from beginning to end.

Toyota PFIC and the PFIC tools are available at your local Toyota dealership.
Call to order today.

TOYOTA

CustomerServicesDivision