ASE 4 - Suspension and Steering

Module 4
Alignment Fundamentals

Acknowledgements

General Motors, the IAGMASEP Association Board of Directors, and Raytheon Professional Services, GM's training partner for GM's Service Technical College wish to thank all of the people who contributed to the GM ASEP/BSEP curriculum development project 2002-3. This project would not have been possible without the tireless efforts of many people. We acknowledge:

- The IAGMASEP Association members for agreeing to tackle this large project to create the curriculum for the GM ASEP/BSEP schools.
- The IAGMASEP Curriculum team for leading the members to a single vision and implementation.
- Direct contributors within Raytheon Professional Services for their support of translating a good idea into reality. Specifically, we thank:

  – Chris Mason and Vince Williams, for their leadership, guidance, and support.

  – Media and Graphics department under Mary McClain and in particular, Cheryl Squicciarini, Diana Pajewski, Lesley McCowey, Jeremy Pawelek, & Nancy DeSantis.

  – For his help on the Steering and Suspension curriculum volume, Subject Matter Expert, John Fisher, for his wealth of knowledge.

Finally, we wish to recognize the individual instructors and staffs of the GM ASEP/BSEP Colleges for their contribution for reformatting existing General Motors training material, adding critical technical content and the sharing of their expertise in the GM product. Separate committees worked on each of the eight curriculum areas. For the work on this volume, we thank the members of the Steering and Suspension committee:

– Jason Hill, Oklahoma State University - Okmulgee

– Marty Kamimoto, Fresno City College

– Tony Marchetti, Camden County College

– Doug Massey, Community College of Baltimore County - Catonsville

– Tom Pease, Florida Community College at Jacksonville

– Daniel Unruh, South Texas Community College

– Vincent Williams, Raytheon

Contents

Module 4a – Alignment Fundamentals

Road Testing the Vehicle

Check for Power Steering Pull

Check for steering wheel movement while starting the engine. Steering wheel movement indicates an imbalance in the power steering control valve. Also check for unequal power assist while steering left and right. A few steering gears are adjustable, most require replacement.

Check for Low Speed Pull

Check for a hard pull under 15 mph. Most low speed pulls are caused by component problems such as:

- Tire conicity or wear problems
- Brake drag
- Power steering imbalance

Check for High Speed Pull

Check for a pull over 20 mph. Many high speed pulls can be corrected by adjusting cross camber or cross caster.

Perform a hard stop. If the vehicle pulls only when braking, suspect the following:

- Brake lining contamination
- Restricted brake hose
- Defective master cylinder
- Worn suspension components, particularly control arm or strut rod bushings
- Excessive rear thrust angle

Check for Pull When Braking

To separate brake problems from suspension problems, drive the vehicle and just barely apply the brake. If the steering wheel turns in the direction of the pull, check the brake system. Suspension or thrust angle problems will usually be apparent only during hard braking.

Check for Excessive Torque Steer

Accelerate quickly and note any steering wheel movement or pull. If you notice excessive torque steer, check the following:

- Worn engine or transaxle mounts
- Worn suspension components, particularly control arm or strut rod bushings
- Tire conicity or wear problems
- Tire circumference differences

Check for Noise When Turning

Check for noise when making hard left and right turns.

A clicking noise while turning may indicate worn outer (fixed) CV joints.

A grinding sound while turning hard and over a bump (such as turning into a driveway) indicates steering stops may be worn or require lubrication.

Noise or vibration when turning may indicate worn or binding outer u-joints on 4-wheel drive vehicles.

Check for Noise During Jounce or Rebound

If you hear noise when driving over bumps or dips in the road check the following:

- Worn shock absorber mounting bushings
- Worn MacPherson strut mounts
- Worn or missing jounce or rebound stops
- Weak shocks or springs allowing the vehicle to bottom out

Check for Steering Wheel Movement During Jounce or Rebound

If you notice steering wheel movement when driving over bumps or dips in the road check the following:

- Worn rack mounting bushings
- Rack housing not level
- Tie rod assembly lengths not equal
- Tie rod assembly angles not equal (worn spring on one side)
- Centerlink not level

Check for Vibration While Braking

If the steering wheel shakes or you notice vibration only when braking check the following:

- Front brake rotors for excessive thickness variation
- Rear brake rotors for excessive thickness variation
- Rear brake drums for excessive diameter variation

Check the Steering Wheel's Position

Check the position of the steering wheel while traveling straight ahead on a level surface such as a parking lot.

If the steering wheel is not level, the front individual toe needs adjustment.

If the steering wheel is level on a level surface but NOT level when driving on a crowned road, you may have to compensate for the road crown when you adjust the front individual toe.

Road crown compensation procedure.

Note how far and in which direction the steering wheel is off center when traveling on a crowned road.

Position the steering wheel that amount in the OPPOSITE direction and adjust the front individual toe to specifications.

Suspension Systems

A suspension system is necessary to:

- Provide comfort
- Provide driver control
- Support weight
- Absorb and dampen shock
- Maintain tire contact with the road
- Provide wheel to wheel alignment.

There are two major categories of design:

1. Non-independent
2. Independent

Non-independent Suspension

The **solid I-beam axle** is an example of a non-independent suspension.

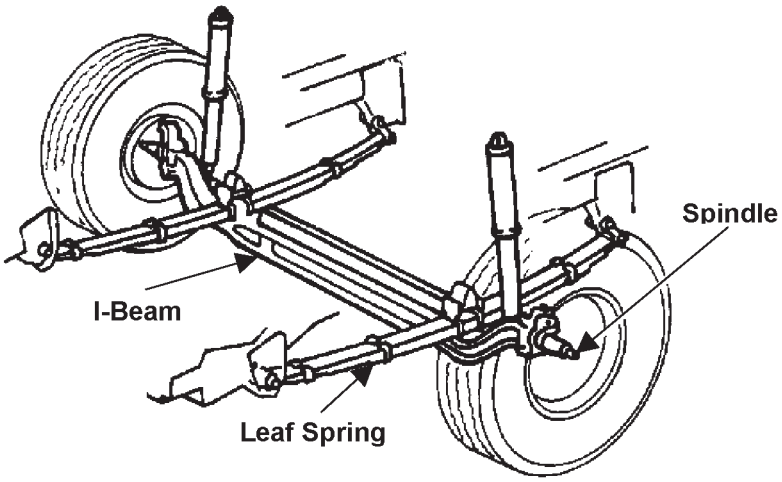


Figure 4-1, Solid I-Beam

Solid I-Beam

The axle is an I-beam construction and usually made of steel or aluminum.

Leaf springs provide support and attachment. The wheels are located outboard on the spindles which are attached to kingpins.

This system is still used on trucks, busses, and off-road equipment because of its great load carrying capacity.

Independent Suspensions

Independent suspensions improve ride and handling by providing an isolated mounting for each wheel.

The "short-long arm" (SLA) suspension is one of the most widely used independent designs.

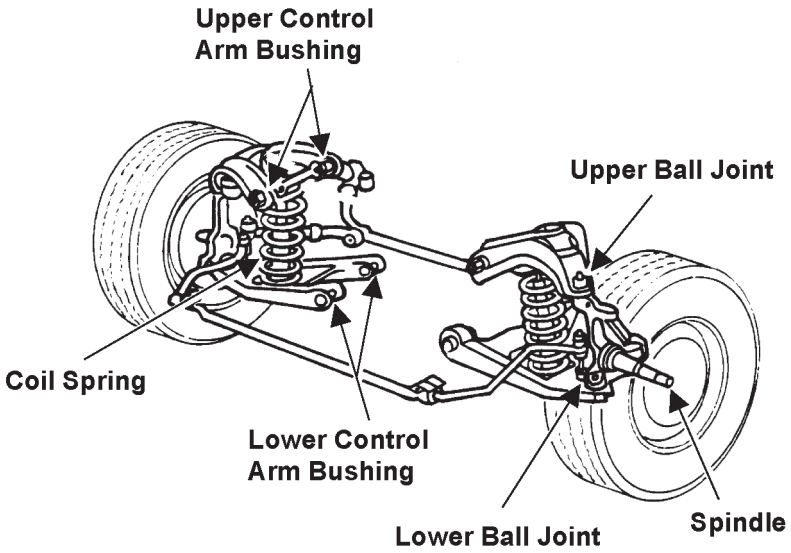


Figure 4-2, Short-long Arm

Short-long Arm

A short-long arm/strut hybrid suspension known as "wishbone" is common on many of today's cars and light trucks.

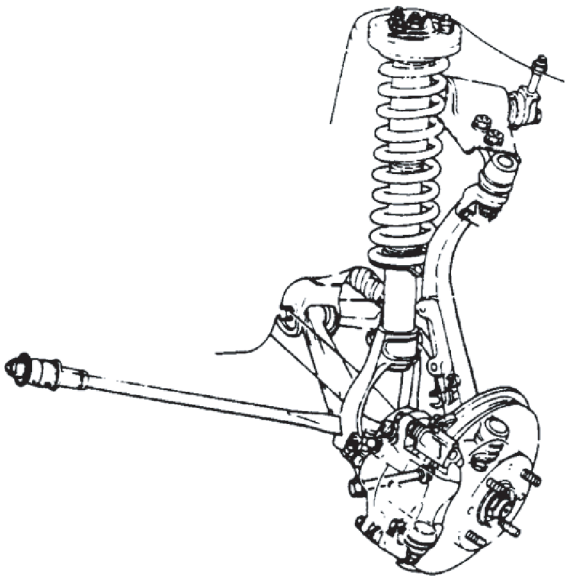


Figure 4-3, Wishbone Strut

Late model Audi's and the VW Passat use an advanced four-link front suspension.

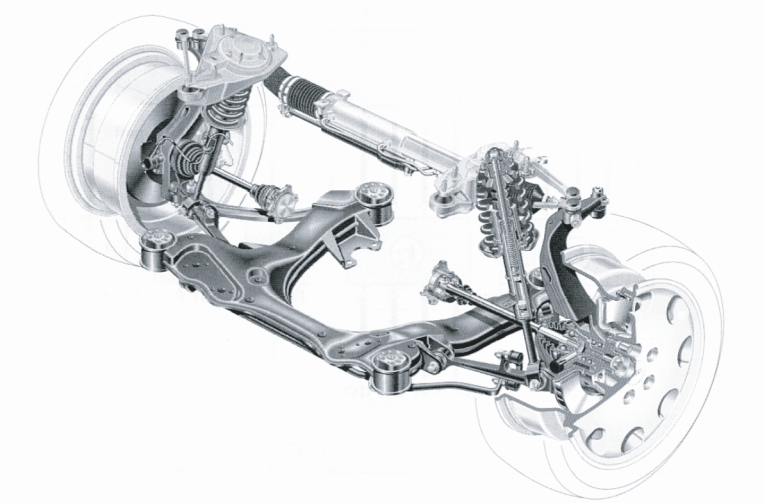


Figure 4-4, Front Four-link Suspension and Subframe

These vehicles have a factory adjustment for "Bump Steer."

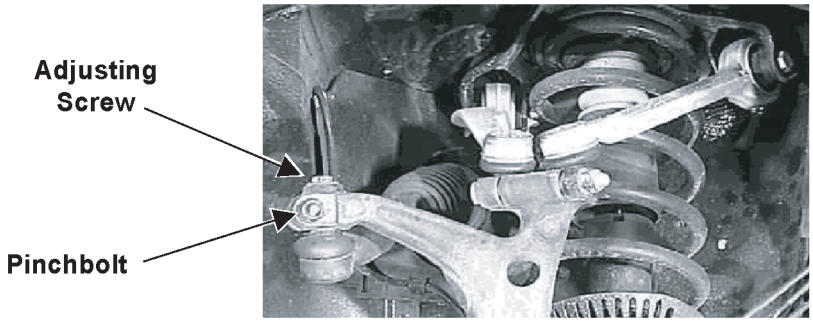


Figure 4-5, Bump Steer

MacPherson strut suspension is common on down-sized vehicles because it is:

- Lighter
- Less costly to manufacture
- Consumes less space

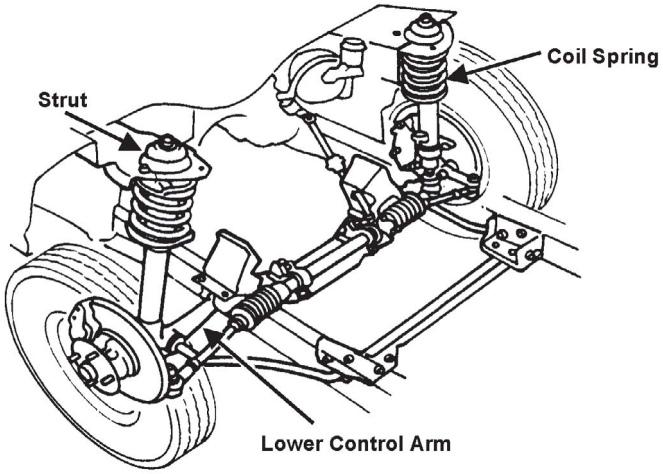


Figure 4-6, MacPherson Strut

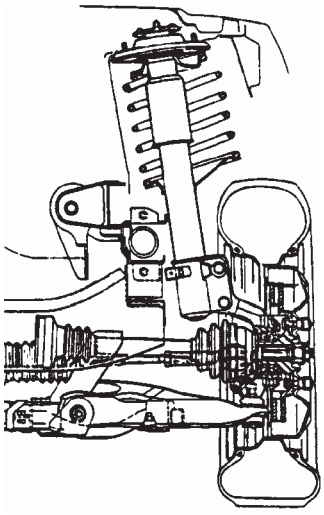


Figure 4-7, Iso Strut

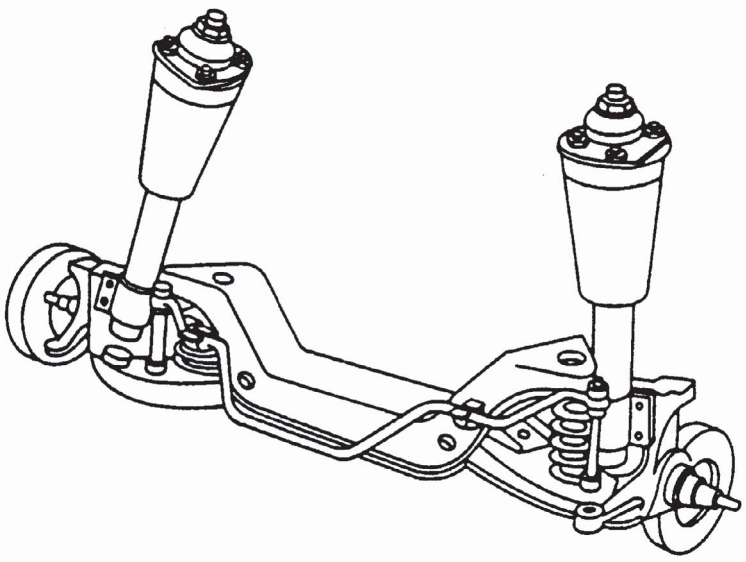


Figure 4-8, Modified Strut

Twin I-beam

The Twin-I-beam suspension is a unique independent design found on Ford and some Mazda light trucks and vans.

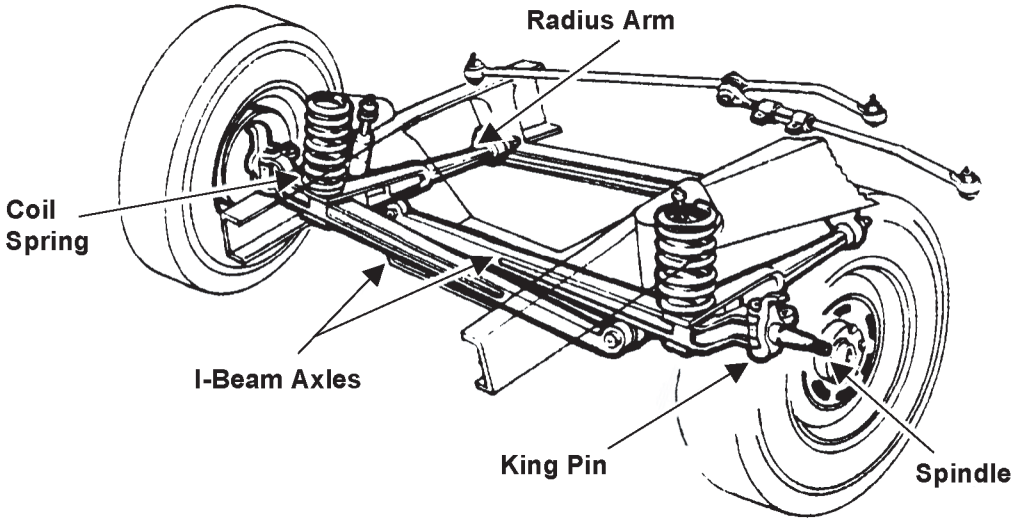


Figure 4-9, Twin I-beam

The Twin-I-beam suspension is popular because it provides both the necessary load capacity and ride quality.

Alignment adjustments require special bending equipment or after-market kits.

Rear Non-independent Suspensions

Rear suspensions affect the overall ride quality, handling and tracking of the vehicle.

A widely used non-independent rear suspension is very similar to the design of the front solid-I-beam axle.

The I-beam is replaced with a drive axle housing, which is suspended and attached with leaf springs.

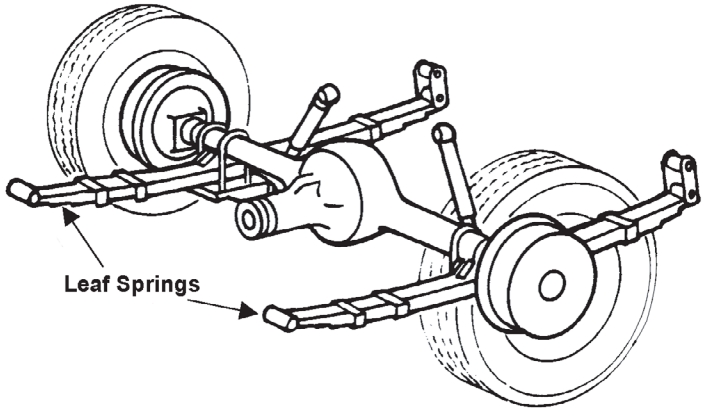


Figure 4-10, Non-independent Rear Leaf Springs

The non-independent rear coil spring suspension is a variation of the same design. The leaf springs are replaced with coil springs and control arms.

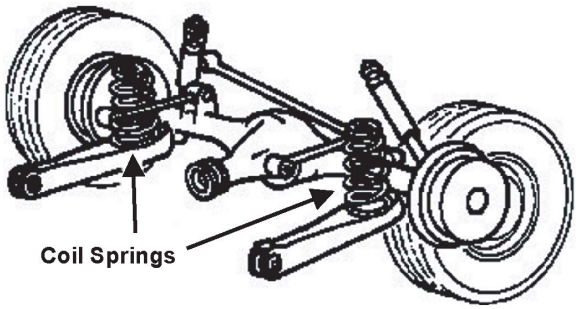


Figure 4-11, Non-independent Rear Coil Spring

The "beam axle" is commonly used on front-wheel-drive cars and mini-vans.

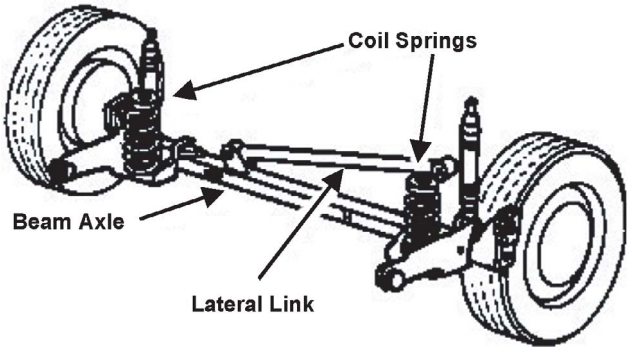


Figure 4-12, Rear Beam Axle

Rear Independent Suspension

Rear independent suspensions have become more widely used because of improved ride quality and performance.

A "trailing arm" is a typical design.

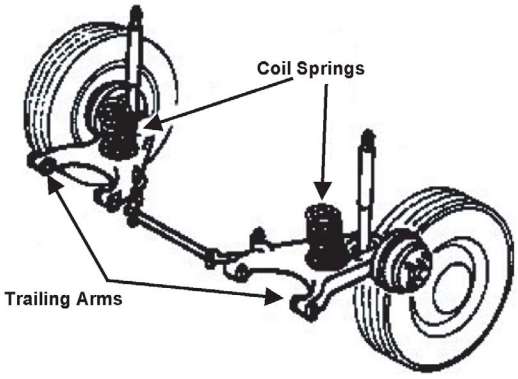


Figure 4-13, Trailing Arm

Note: Install rear slip plates or pull the pins from integral slip plates in order to get accurate alignment measurements and adjustments!

Torsion Bars

The longitudinal design is found on older Chrysler rear-wheel drive cars, General Motors "E" cars, and many domestic and import 4 wheel drive pickup trucks and sport utility vehicles.

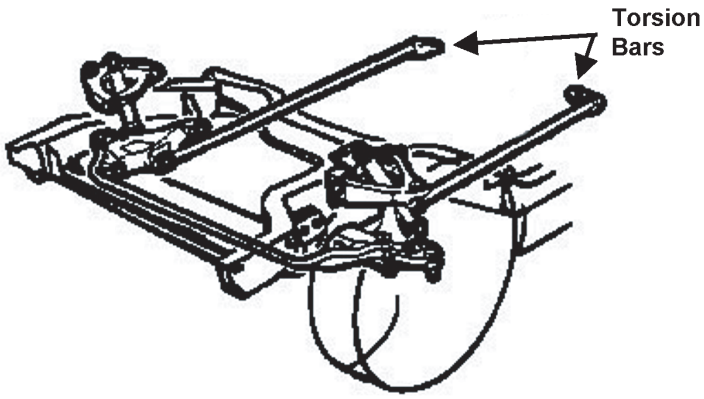


Figure 4-14, Longitudinal Torsion Bars

Check the specification book or shop manual for the location to measure ride height. This location varies from vehicle to vehicle.

The **transverse** design is found on mid 1970's and 1980's Chrysler rear-wheel drive cars.

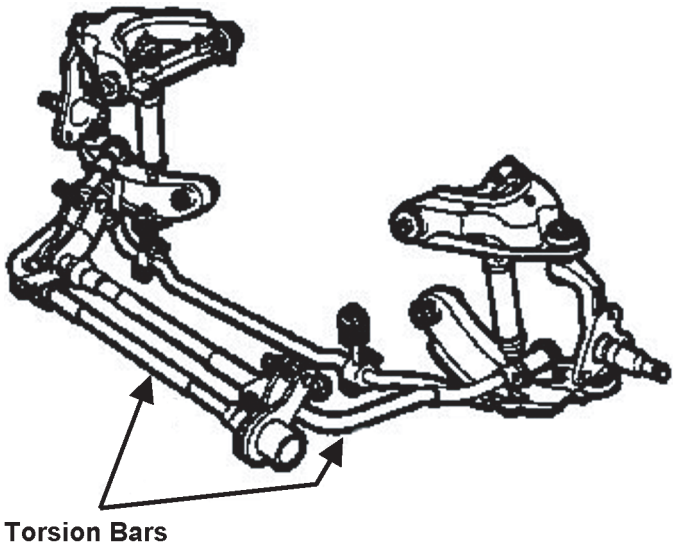


Figure 4-15, Transverse Torsion Bars

Note: Ride height affects camber, caster, and toe measurements. Set torsion bar height before aligning the vehicle.

Steering Systems

Many 4x4 light trucks and sport utility vehicles may use a relay rod steering system.

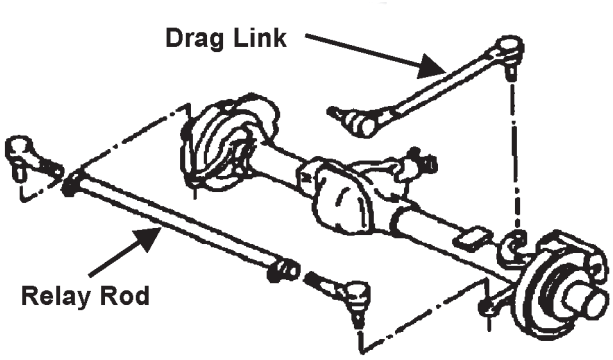


Figure 4-16, Relay Rod Steering System

Adjust the relay rod to set front total toe. Adjust the drag link to center the steering wheel. Remove and reposition the steering wheel when vehicles have a non-adjustable drag link.

Many Ford Twin I-Beam light trucks and sport utility vehicles may use a Haltenberger steering system.

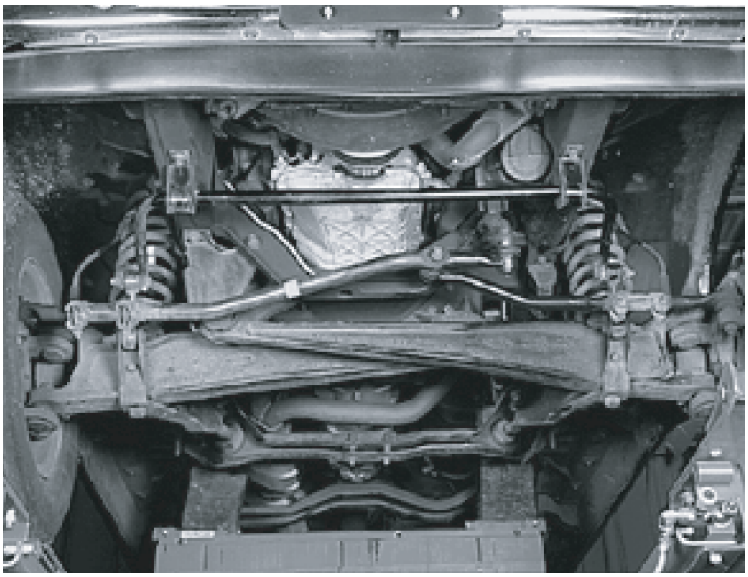


Figure 4-17, Haltenburger Steering System

To set front toe and center the steering wheel, first start the engine, level the steering wheel, then turn the engine off. Adjust each tie rod until individual toe is 1/2 the total toe specification. Remove and reposition the steering wheel when vehicles have only one adjustable tie rod assembly.

A "parallelogram" steering system is common on many cars and light trucks. Each tie rod assembly provides an "individual toe" adjustment.

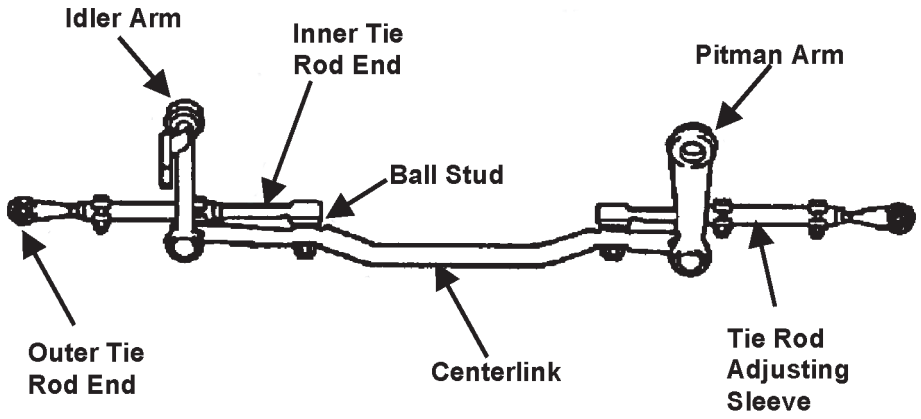


Figure 4-18, Parallelogram System

To set front toe and center the steering wheel, first start the engine, level the steering wheel, then turn the engine off. Adjust each tie rod until individual toe is 1/2 the total toe specification.

The "rack and pinion" steering system incorporates the steering gear and the steering linkage as one assembly.

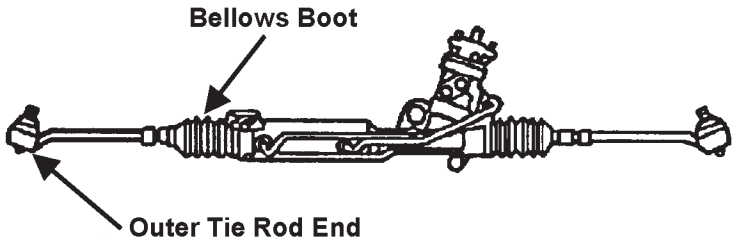


Figure 4-19, Rack and Pinion Steering System

Steering System Quick Checks

A visual steering quick check can reveal suspension and steering damage. Level the steering wheel and observe the position of the front tires.

If total toe is within specifications and both wheels are straight ahead the steering system is ok.

Steering Is OK

If both front wheels are turned left or right, check the engine cradle alignment. Verify the hole in the engine subframe lines up with the hole in the unibody.

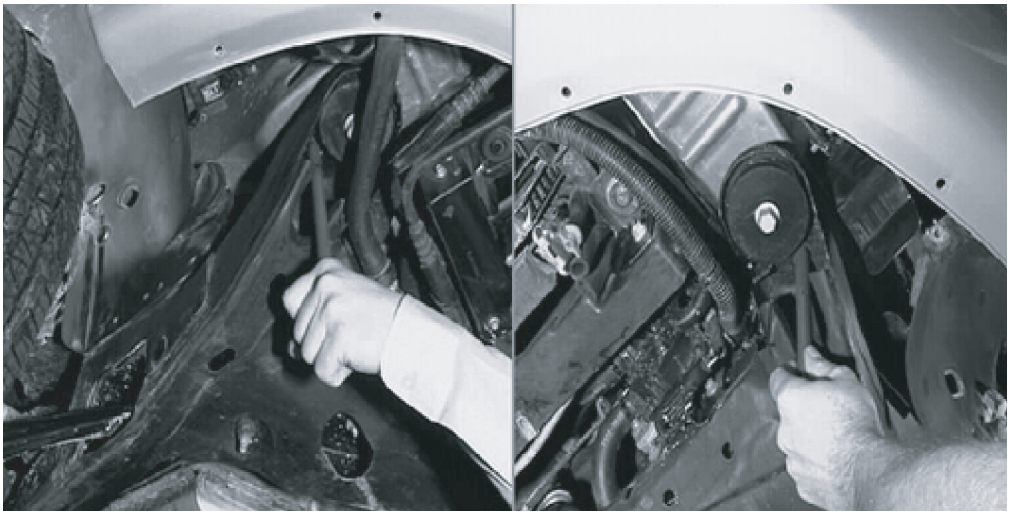


Figure 4-20, Check Engine Subframe to Unibody Alignment

Inspect the steering gear's sector shaft for twisted splines. The pitman arm should be facing straight ahead with the steering wheel centered.

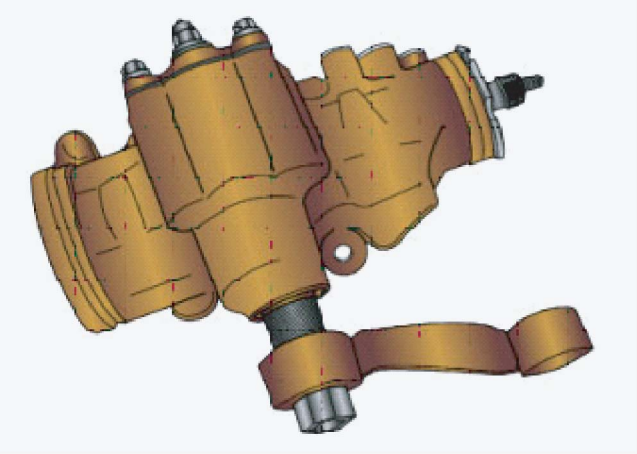


Figure 4-21, Check for Twisted Sector-Shaft Splines

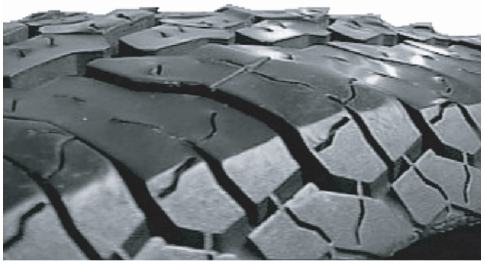
If one wheel is turned outward or inward at the front, inspect the steering arm and tie rod assembly on that side for damage.

Figure 4-22, Check for Tie Rod or Steering Arm Damage

Tire Wear Diagnosis

Normal

Slight front to back feathering



Improper Rotation

Deep Front to back feathering on nondrive tires

Excessive Camber or Toe

Wear on the shoulder

Excessive Front Toe

Shoulder wear and side to side feathering

Weak Shocks or Wheel Imbalance

Spotty Cupping

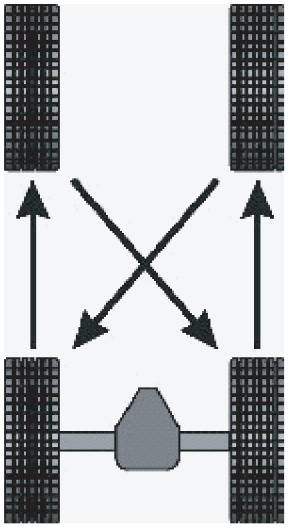
Unequal Rear Toe

Diagonal Cupping

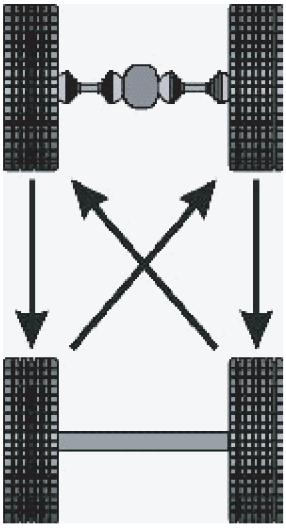
Figure 4-23, Tire Wear Diagnosis

Tire Rotation Procedures

Modified X Rotation

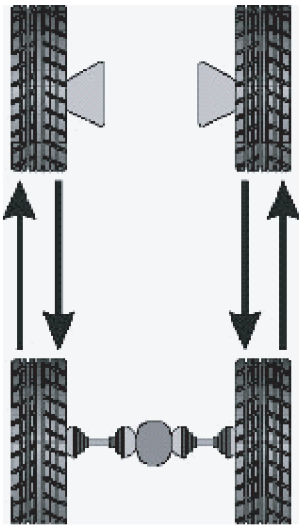


Rear-Wheel Drive

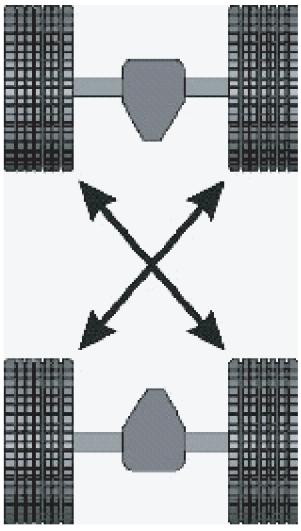


Front-Wheel Drive

Exceptions



Directional Tires



Sport Utility Vehicle

Figure 4-24, Tire Rotation Procedures

Vehicle Inspection Procedure

Rack on Floor

1. Secure vehicle on rack.
2. Leave transmission in park or 1st gear
3. Level and lock steering wheel
4. Bounce test. Check for:
   - Excessive bounce
   - Noise

Under Hood Inspection

1. Engine strut check
   - Rock car fore and aft.
2. Power steering
   - Belt
   - Pump
   - Hoses
   - Fluid condition
3. Upper control arm bushings
4. Upper shock mounting bushings
5. Verify vehicle year from the VIN.

Raise Rack Waist High

1. Preliminary tie rod inspection
2. Ride height check with tape measure; bottom of rim to top of wheel opening.

Raise rack eye level, tires on turnplates

Steering

1. Power steering gear
   - Leaks
   - Mounting
2. Shake the tire test. Check:
   - Outer tie rod ends
   - Inner tie rod ends
   - Pitman arm to centerlink connection
3. Idler arm check
   - Grab centerlink and move up and down

Suspension

1. Wear indicator balljoints
2. Control arm bushings
3. Shocks
4. Bushings
5. Springs
6. Jounce and rebound bumpers

Driveline

1. CV joints and half shafts
2. Engine and transaxle mounts
3. Oil and transmission leaks
4. U-joints and pinion seal

Chassis

1. Lower control arm mounting
2. Crossmember location to frame

Jack Up Vehicle to Unload Balljoints

1. Check load carrying balljoints for up and down movement.
2. Check follower balljoints for in and out movement.
3. Struts and shocks for leakage

Lower Rack Onto Leveling Legs

1. Upper balljoints
   - Load carrying for up and down movement
   - Follower for in and out movement
2. Strut mounts
   - In and out movement
   - Up and down movement
3. Tires
   - Pressure
   - Size
   - Tread designs
   - Wear patterns

Camber

Camber is the angle formed by the inward or outward tilt of the wheel referenced to a vertical line originating from the center base of the tire.

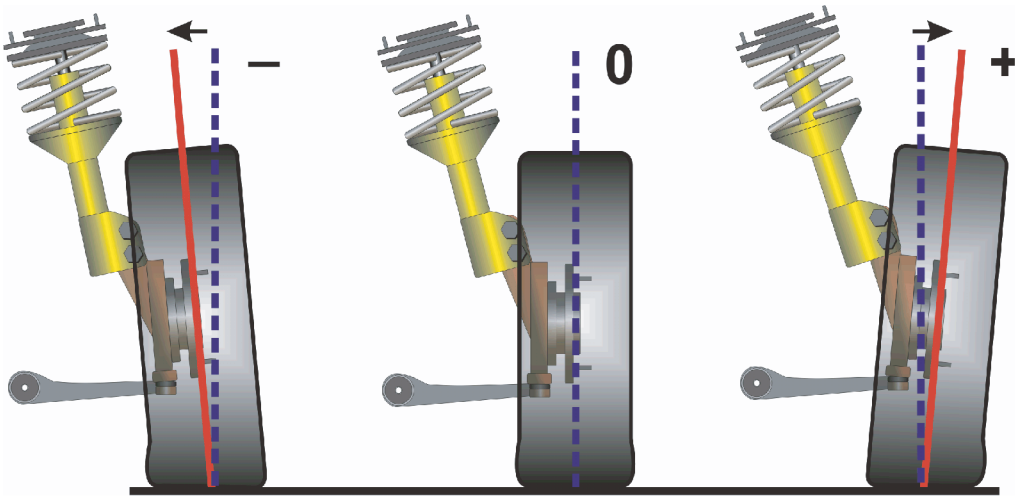


Figure 4-25, Camber is Measured and Displayed in Degrees

Camber specifications are given for each wheel separately.

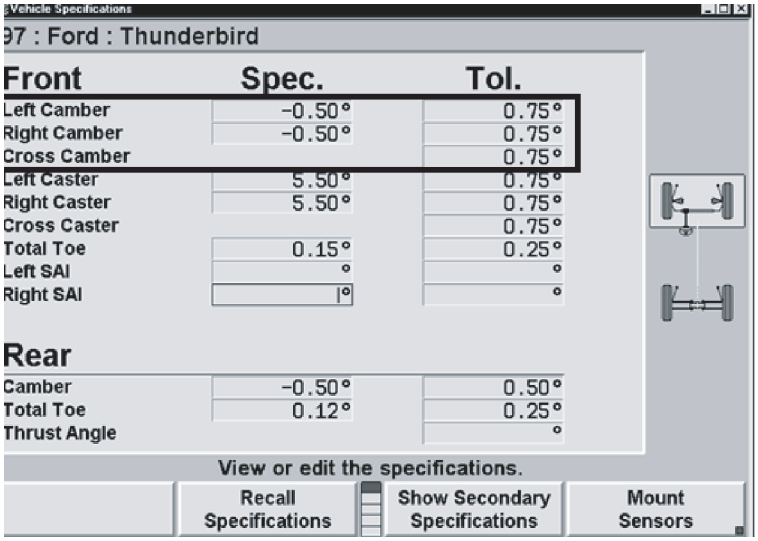


Figure 4-26, Camber Specifications

Excessive camber may cause premature tire wear.

Excessive positive camber wears the outer shoulder of the tread surface.

Excessive negative camber wears the inner shoulder of the tread surface.

Cross camber is the front camber measurements side to side. Cross camber greater than 0.5° may cause a pull or drift to the side with the most positive camber setting.

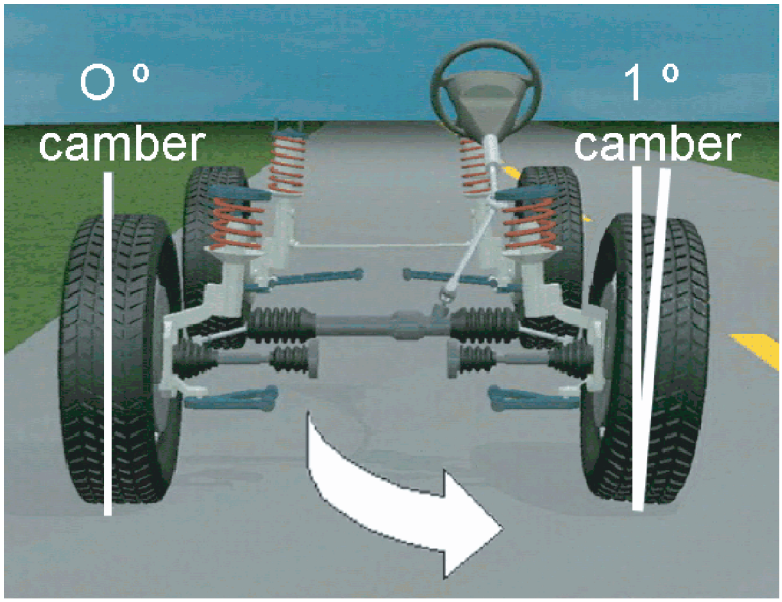
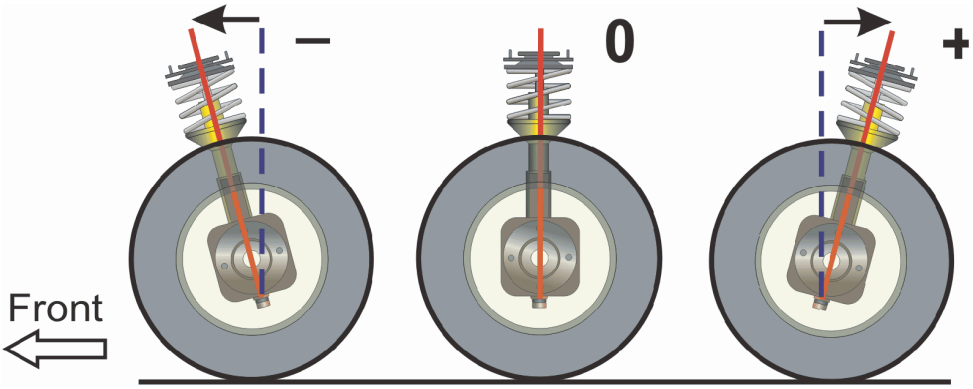


Figure 4-27, Excessive Cross Camber Causes A Pull To The Most Positive Side

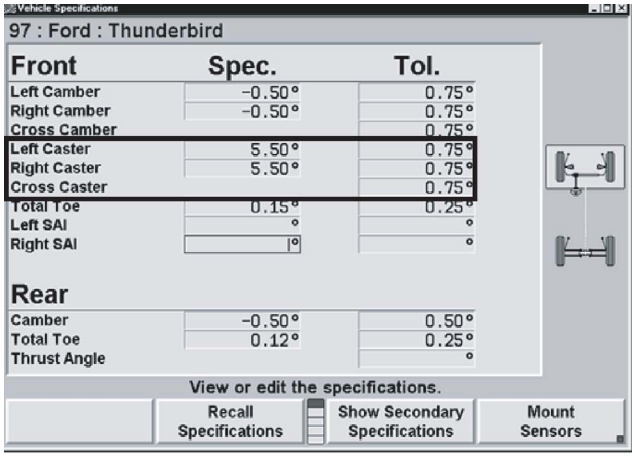
Caster

Caster is the angle formed by the forward or rearward tilt of the steering axis in reference to a vertical line drawn from the center base of the wheel and viewed from the side.



Caster is measured and displayed in degrees.

Caster is specified for each wheel separately.



Cross caster is the front caster measurements side to side. Cross caster greater than **0.5°** may cause a pull or drift to the side with the least positive caster setting.

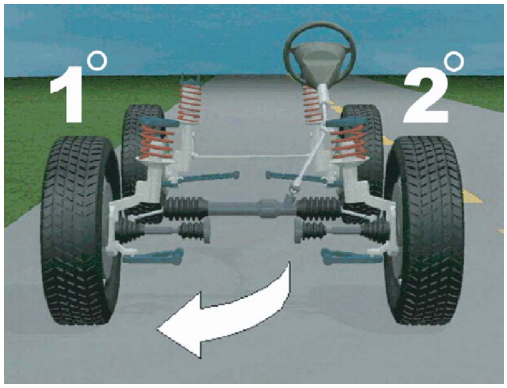


Figure 4-28, Excessive Cross Caster Causes a Pull to the Least Positive Side

Caster causes the camber to change as the wheels are steered left and right. This is known as "camber roll."

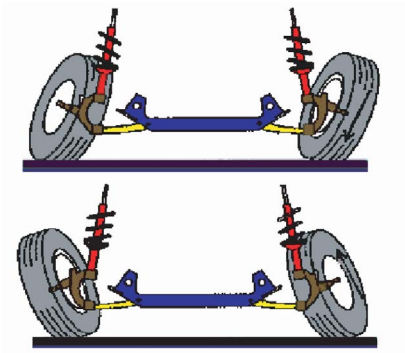


Figure 4-29, Caster Causes Camber to Change as the Wheels are Steered Left or Right

Caster must be calculated by steering the front wheels in a 20° turn and measuring the camber roll.

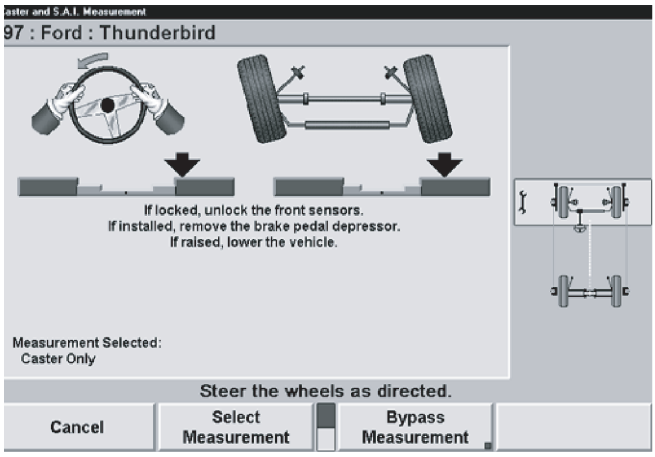


Figure 4-30, Caster is Measured by Steering the Front Wheels

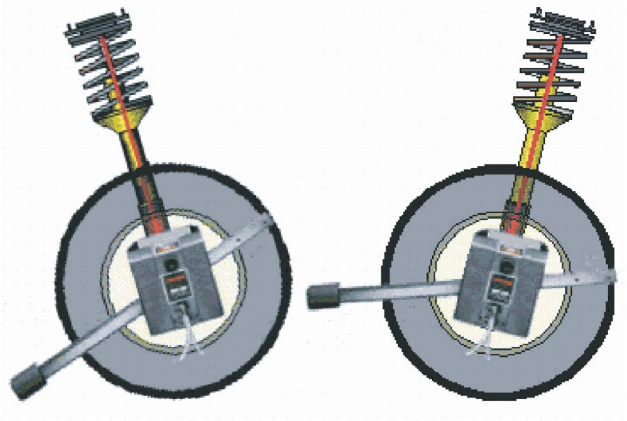


Figure 4-31, Real Time Caster Adjustment Procedure

As caster is adjusted in a negative direction, the sensor will tilt forward. The bar graph will display the negative caster change.

As caster is adjusted in a positive direction, the sensor will tilt rearward. The bar graph will display the positive caster change.

Toe

Total toe is the difference in distance between the front of the tires and the rear of the tires of a same axle.

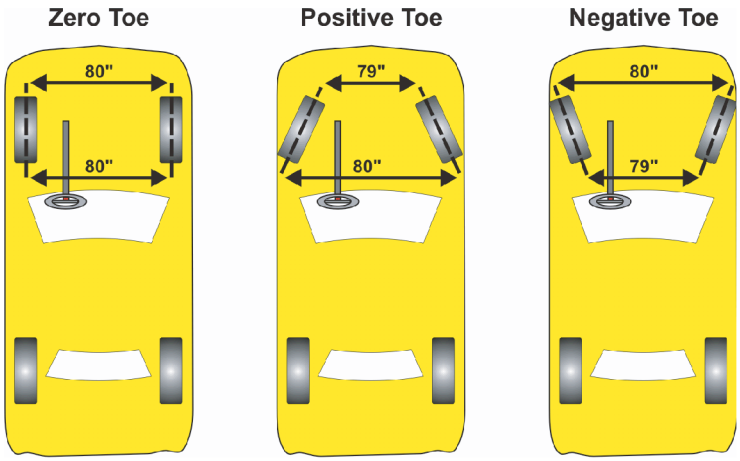


Figure 4-32, Total Toe

Toe specifications are given as "total toe." The individual toe specification is ½ the total toe specification.

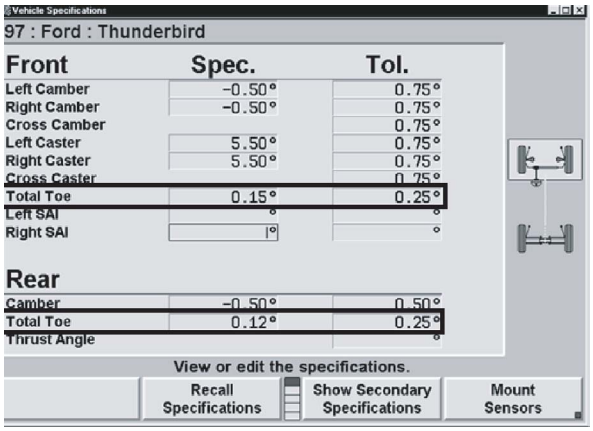


Figure 4-33, Total Toe Specifications

Excessive toe will cause shoulder wear on the tire's tread.

Figure 4-34, Excessive Toe Causes Shoulder Wear on the Tire's Tread

Excessive positive toe wears the outer shoulder of the tread surface.

Excessive negative toe wears the inner shoulder of the tread surface.

Individual toe is the difference in distance of the front and rear of one tire in reference to a centerline.

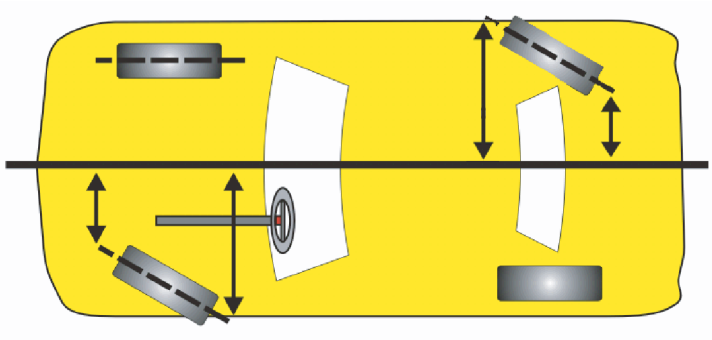


Figure 4-35, Individual Toe

Unequal front individual toe causes a crooked steering wheel.

Unequal rear individual toe causes "dog tracking" and tire wear.

Unequal individual toe on the rear axle may cause the rear tires' tread to squirm as the vehicle goes down the road.

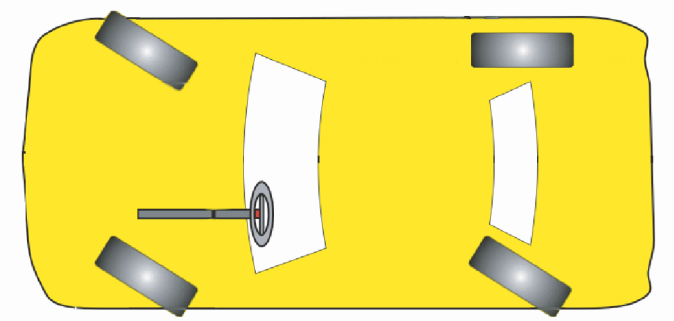


Figure 4-36, Unequal Rear Toe Causes Tire Squirm

This squirming will cause the rear tires to develop a diagonal cupping pattern on the tread surface.

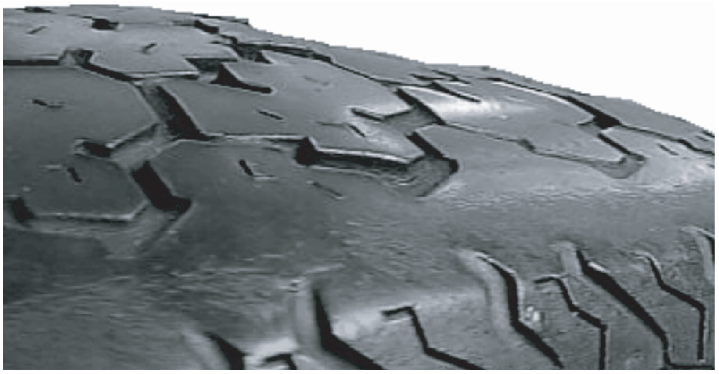


Figure 4-37, Diagonal Wipe

Toe Related Geometry

Geometric centerline is a line drawn though the midpoint of both front wheels and both rear wheels.

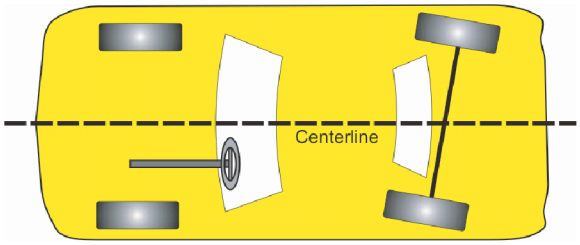


Figure 4-38, Geometric Centerline

Thrustline is defined as a line bisecting the rear total toe angle-the direction the rear wheels point.

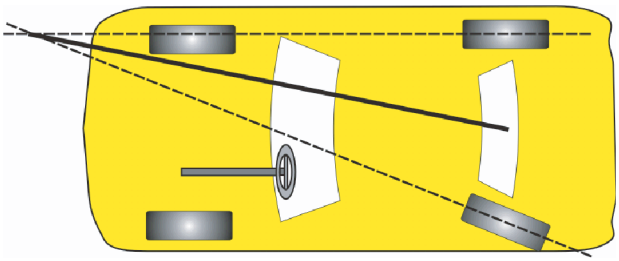


Figure 4-39, Thrustline

Thrust Angle is the angle formed by the intersection of the geometric centerline and the thrustline.

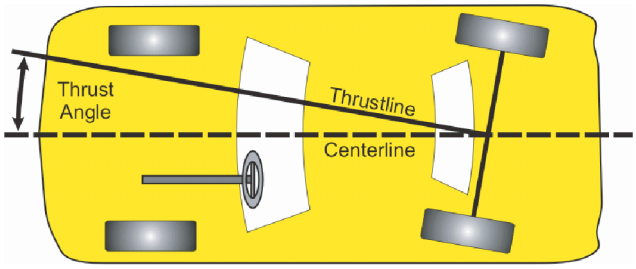


Figure 4-40, Thrust Angle

Positive thrust angle is when the rear wheels point to the right of the geometric centerline.

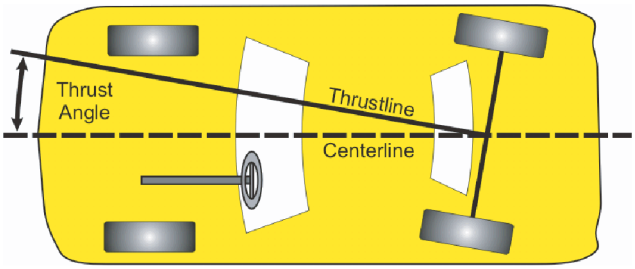


Figure 4-41, Positive Thrust Angle

Negative thrust angle is when the rear wheels point to the left of the geometric centerline.

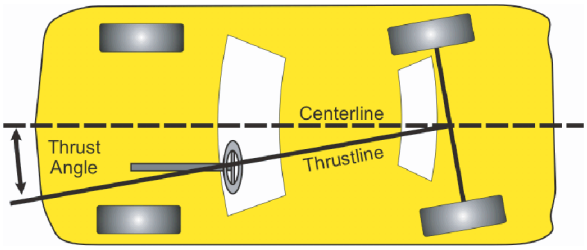


Figure 4-42, Negative Thrust Angle

A thrust angle greater than 0° may cause the vehicle to "dog track" as it goes down the road.

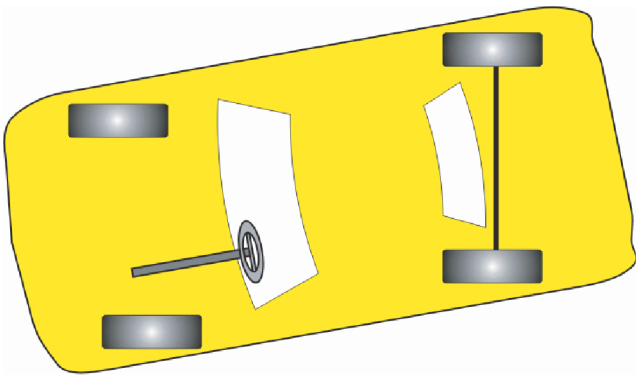


Figure 4-43, Dog Track

Alignment Procedures

A centerline alignment aligns the front wheels to the geometric centerline.

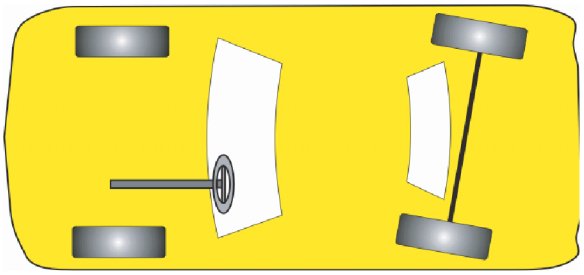


Figure 4-44, Centerline Alignment – Compensate Front Sensors Only

Result:

- The vehicle dog tracks as it goes down the road.
- The steering wheel is not centered.

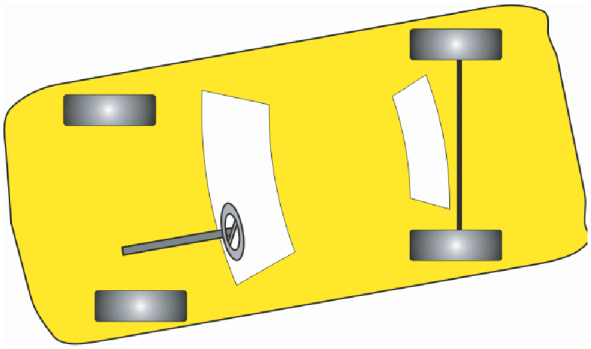


Figure 4-45, Centerline Results

A thrustline alignment aligns the front wheels to the rear thrustline.

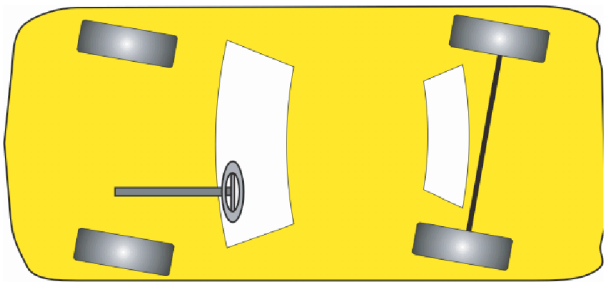


Figure 4-46, Thrustline Alignment – Compensate All Four Sensors

Result:

- The vehicle dog tracks as it goes down the road.
- The steering wheel is centered.

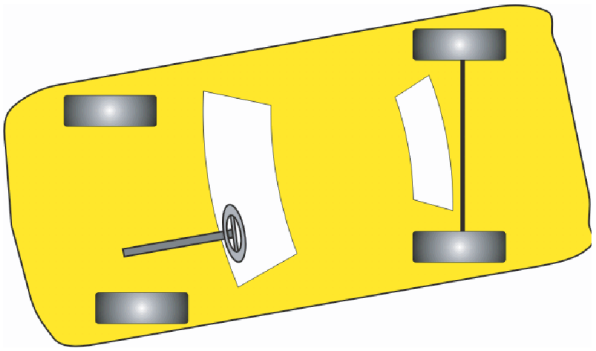


Figure 4-47, Thrustline Results

A total 4-wheel alignment aligns the rear wheels to the geometric centerline and the front wheels to the rear thrustline.

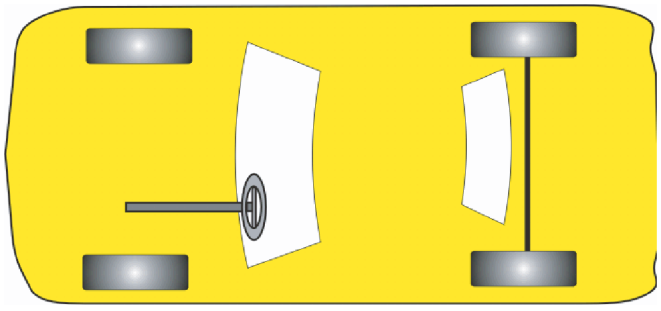


Figure 4-48, Total 4-wheel Alignment – Compensate All Four Sensors

Result:

- The vehicle's body goes straight down the road.
- The steering wheel is centered.

Using "Softkeys"

The "Softkeys" located on the keyboard of the aligner provide operator control of the program.

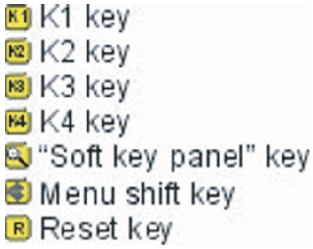


Figure 4-49, Softkeys

The four menu labels that appear at the bottom of each screen are referred to as the "softkey labels." These labels indicate the action the program will take when the corresponding K1 K2 K3, or K4 key is pressed.

The vertically stacked squares between the K2 and K3 labels indicate how many levels of menus are available. Up to six levels of menus are possible. The highlighted box indicates the menu level that is currently displayed.

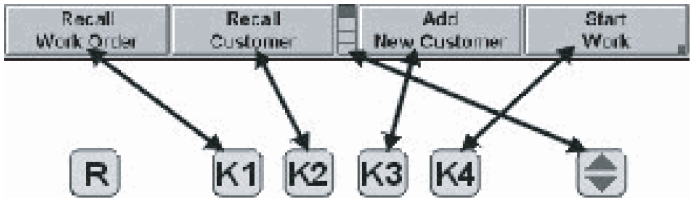


Figure 4-50, Softkey Labels

The menu level is changed by pressing the menu shift softkey. When this key is pressed, the menu labels will change to the next level "down." If the last menu level is currently displayed, the next step will be to the first menu level. Pressing Shift + will display the next level "up."

Pressing , or pressing and holding the lightpen on the menu level indicator, will cause all of the menus available to appear. This "softkey" panel is commonly known as the "Tool Box." The green background indicates the active menu level. Pressing again will cause the menu to return to the original position.

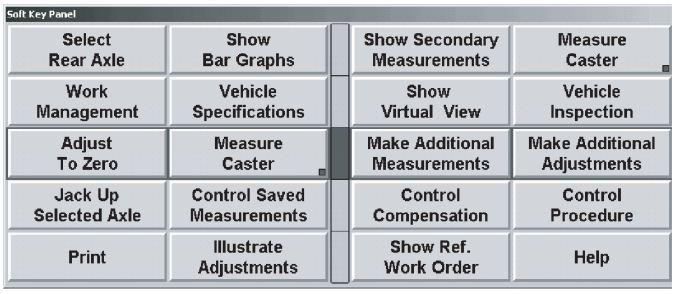


Figure 4-51, Softkey Panel

The remote control provides operation of the WinAlign program from a distance by duplicating the five softkeys.

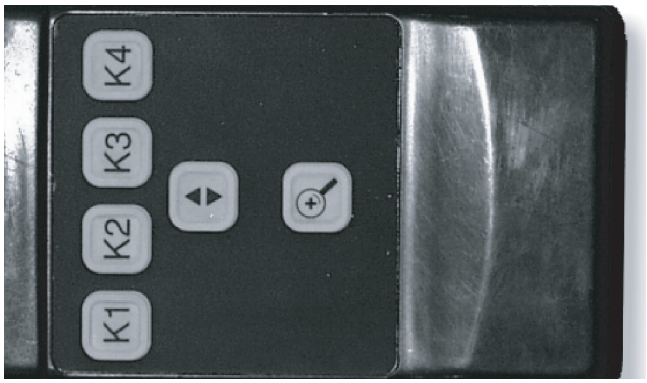


Figure 4-52, Remote Control

The key on the remote control zooms the current softkey menu level.

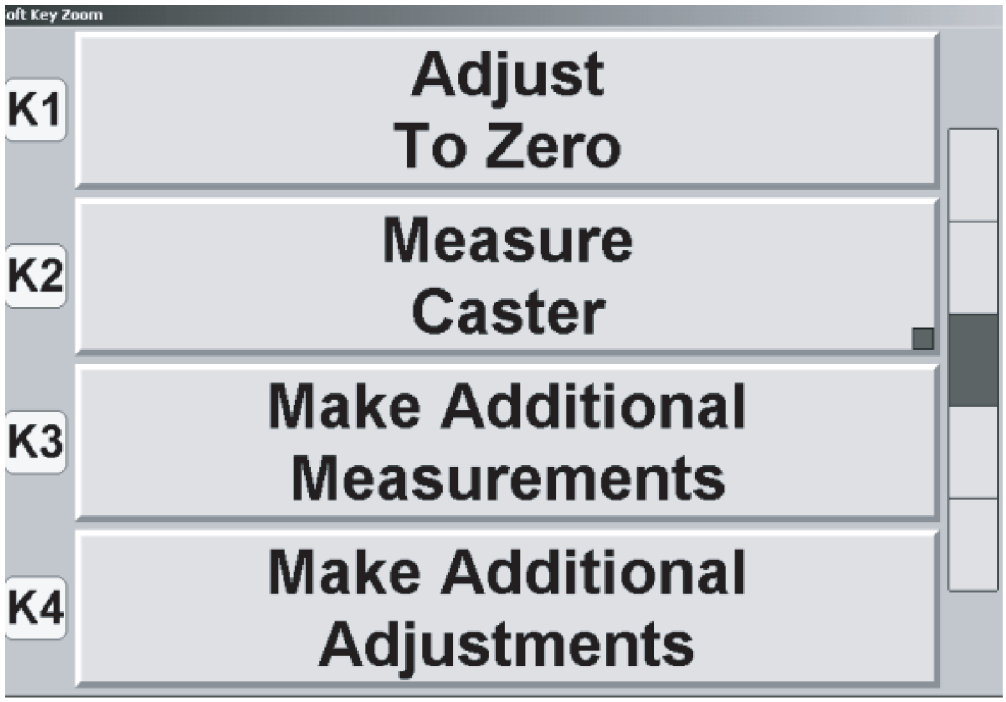


Figure 4-53, Softkeys Zoomed

The remote indicator displays alignment measurements and provides operation of the WinAlign program from a distance by duplicating the five softkeys. The key on the remote zooms the current softkey menu level.

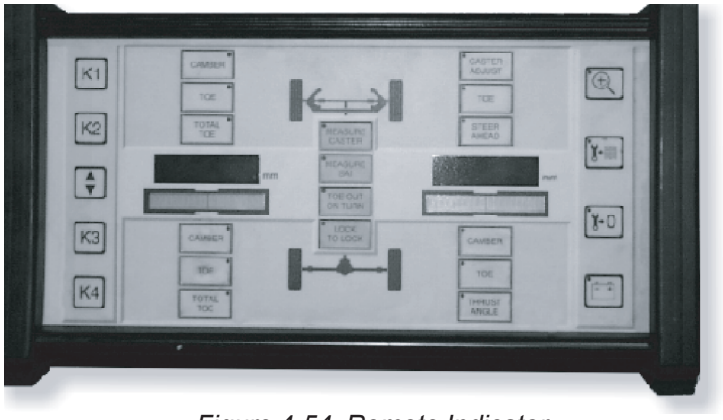


Figure 4-54, Remote Indicator

Some softkey labels have a green square in the lower right corner. Generally, the softkey with the green square (usually K4) is the appropriate key to press to continue with the procedure being performed.

The alignment program may be reset at anytime during an alignment by pressing the R key, located at the upper left corner of the keyboard. A confirmation screen will appear to verify that the "Reset" button was pressed intentionally.

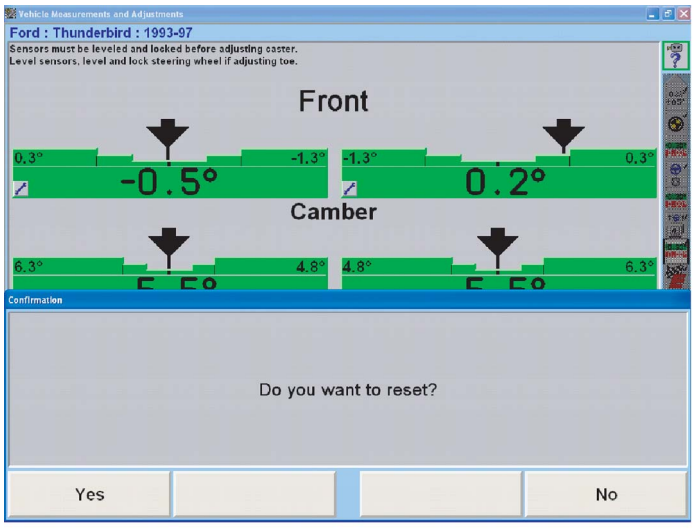


Figure 4-55, Reset Confirmation Screen

When this screen appears, press "Yes" to reset the program or "No" if the program should not be reset.

When then aligner is reset, the information collected for the alignment in progress will be erased and the display will return to the "Logo" screen.

Sample Alignment

Performing an alignment using the Hunter aligner is easy.

You follow 4 basic steps:

1. Enter specifications
2. Measure the vehicle
3. Adjust the vehicle
4. Verify the adjustments.

A 1994 Chevrolet Beretta is in the shop today for an alignment.

Press "Reset" to go the starting screen.

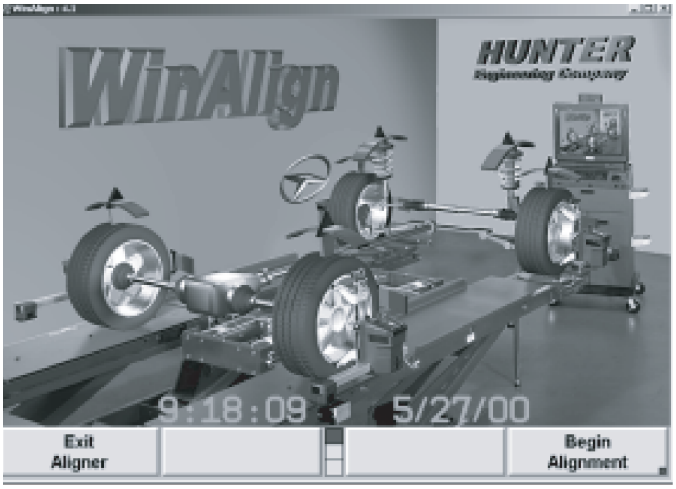
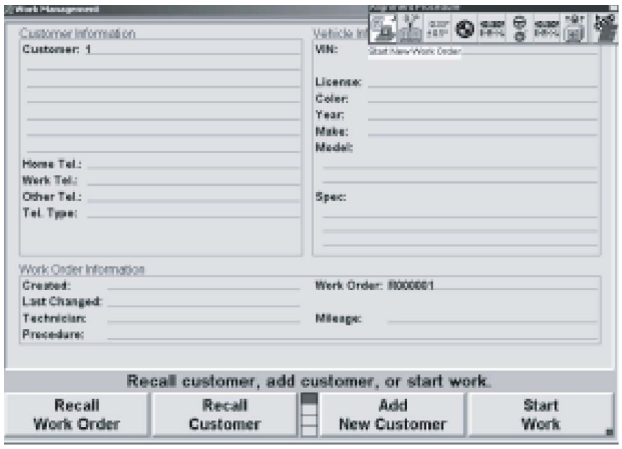


Figure 4-56, Starting Screen

Press "Begin Alignment" to start the alignment.

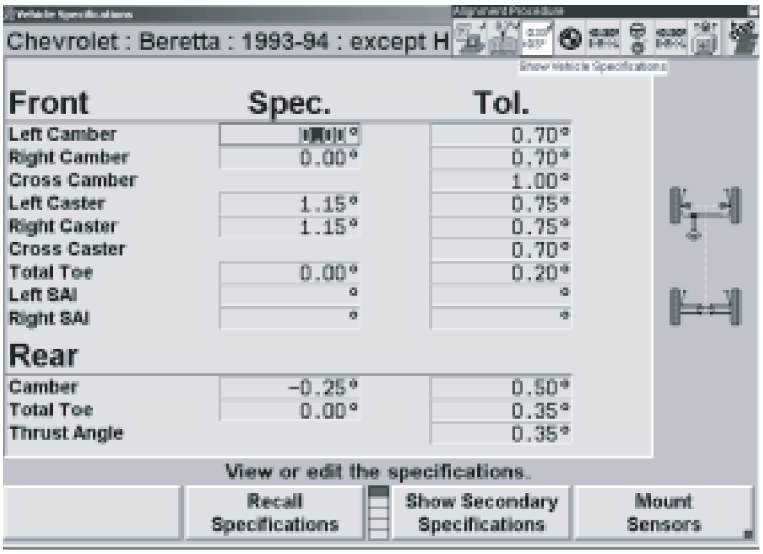
The "Work Management" screen now appears.



"Recall Work Order" recalls a previously saved alignment from the hard disk. "Recall Customer" recalls saved customer ID information.

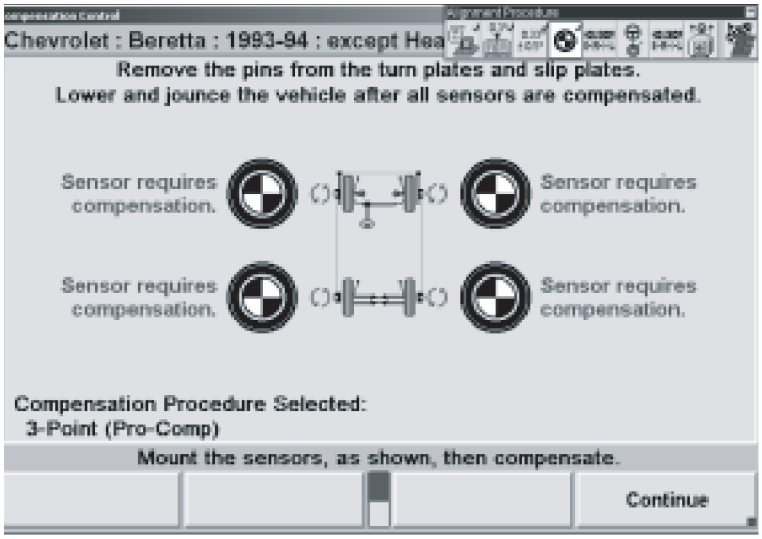
This is the first time we aligned this Beretta so we'll choose "Start Work" to continue. We'll have a chance to save this customer's data once the alignment is complete.

Enter specifications by selecting "Chevrolet, Beretta, 1993-1994, except HD suspension."

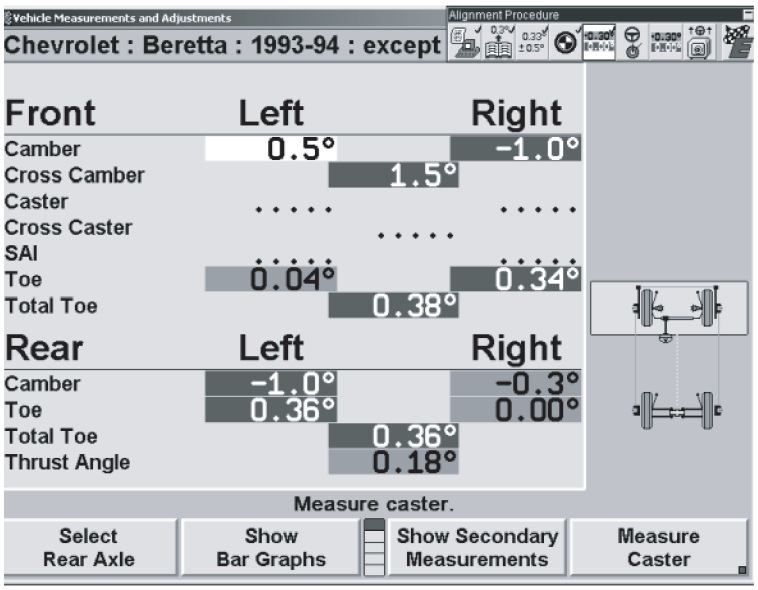


The Beretta's specifications are now displayed.

Jack up the vehicle. Rotate each wheel until the valve stem is at the one o'clock position. Attach the safety cable to the valve stem. Compensate each sensor for wheel and adapter runout.

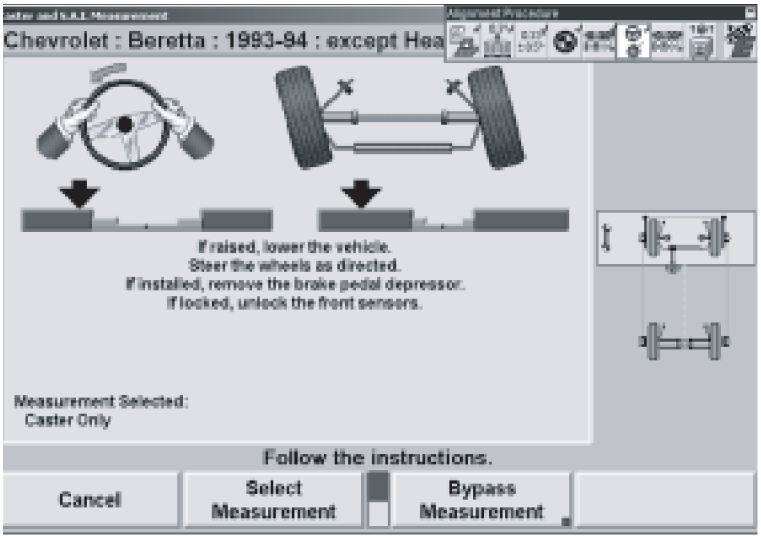


Pull the pins from the front turnplates and rear slip-plates and lower the vehicle onto the alignment rack.



Jounce the vehicle front and rear to settle the suspension.

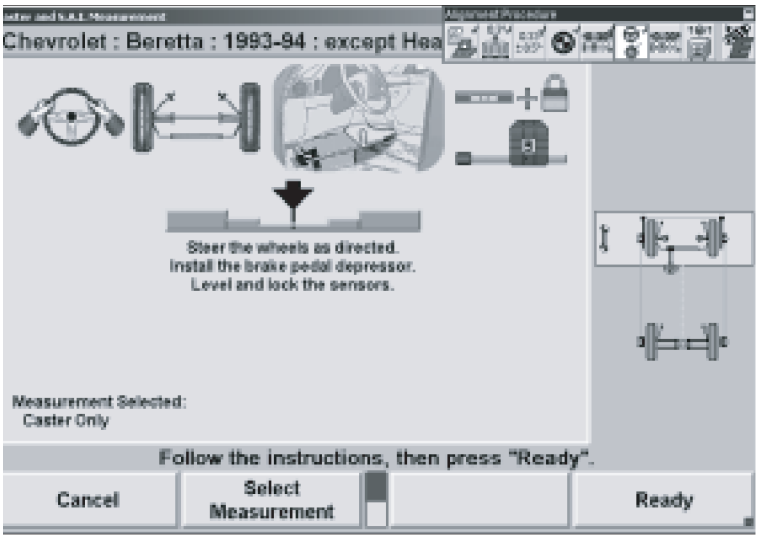
Proceed to measure caster.



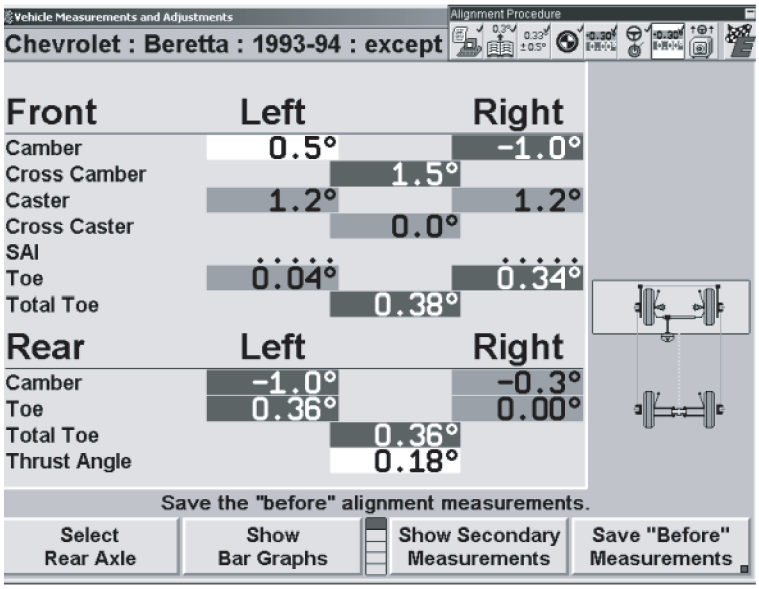
Steer the wheels as directed on the screen. Hold the arrows in the lower valley of the bar graphs until the bar graphs disappears.

Apply the brake depressor and level and lock the front sensors.

These two steps enable the aligner to track caster adjustment.



The initial alignment measurements are now displayed.

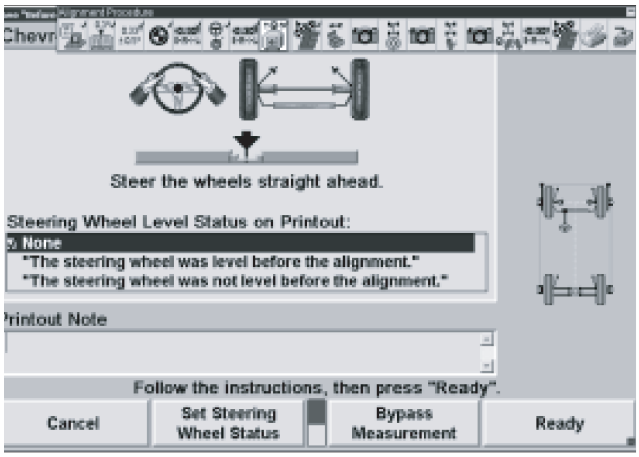


Items shaded with a **green** background are within one half of the manufacturer's specification tolerances.

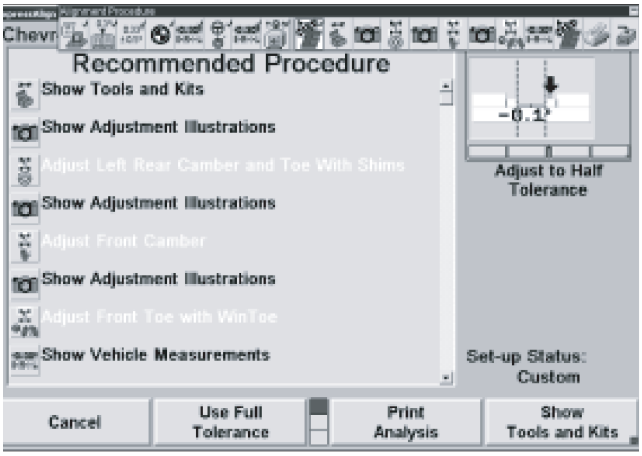
Items shaded with a **yellow** background are within manufacturer's specification tolerances but may need adjustment.

Items shaded in **red** are outside manufacturer's specifications and should be corrected if possible.

Press "Save 'Before' Measurements" and steer the front wheels as directed. Press "Ready" to continue.

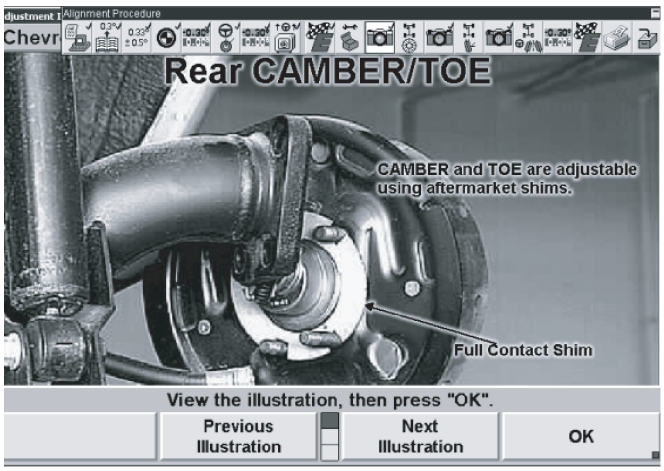


Express Align (if enabled) displays the necessary adjustments in yellow. Press "Print Analysis" to print the before measurements and adjustments required.

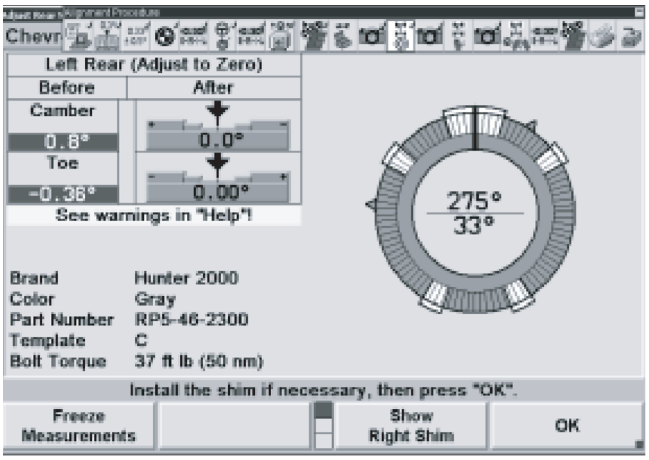


Select "Show Adjustment Illustrations" to display the rear adjustment methods.

The adjustment illustrations for rear camber and toe are displayed.



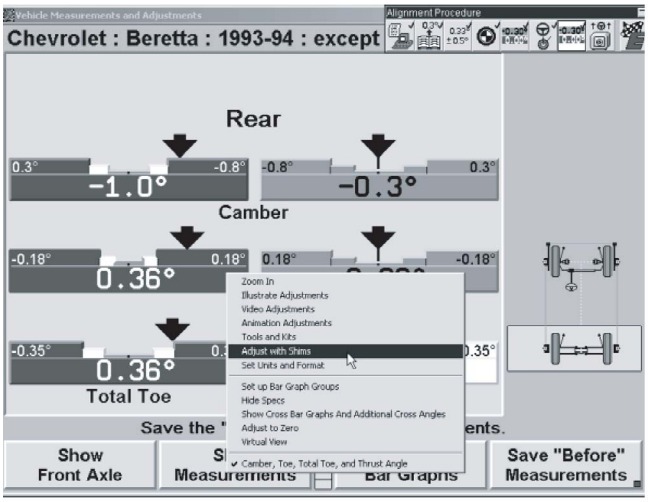
Select "Adjust Left Camber and Toe With Shims."



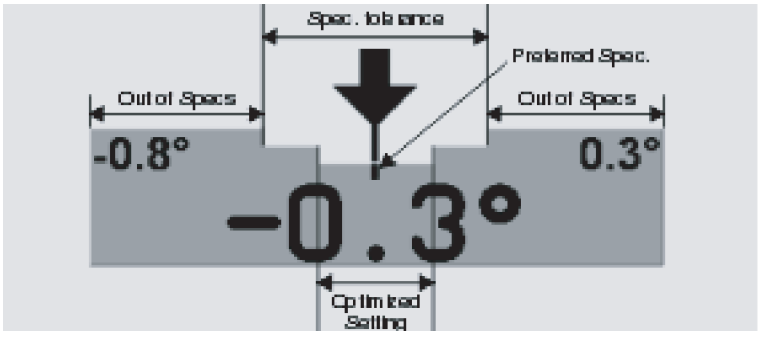
Cut and install the needed shims. Be sure to recompensate the sensor after the installation is complete.

You can also access the specific "Power Tool" and adjustment illustration for an angle directly from a bar graph.

Position the cursor on the angle's bar graph and hold down the left mouse button for 2 seconds.

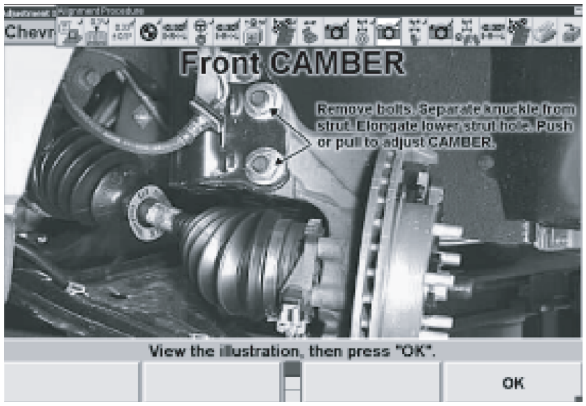


The adjustment bar graphs display both the distance and the direction the measurement is from specifications.



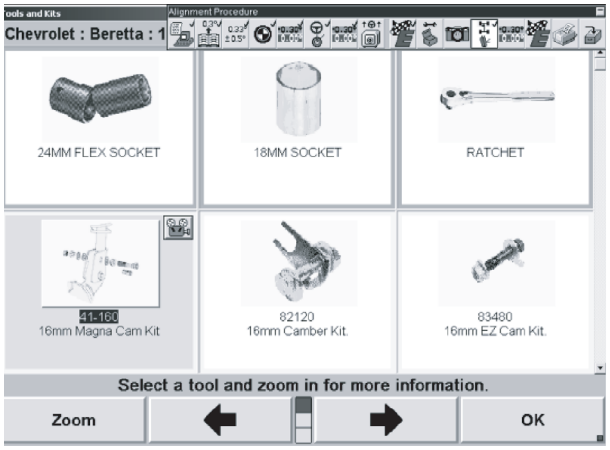
Verify the adjustment is ok.

You have to separate the strut and knuckle and slot the lower strut mounting hole to adjust camber.

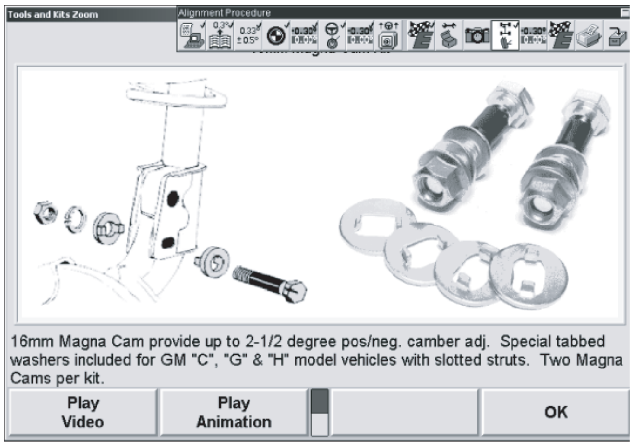


Select "Tools and Kits" to see if an alignment kit is available to make the job easier.

The needed tools and available aftermarket kits are displayed.

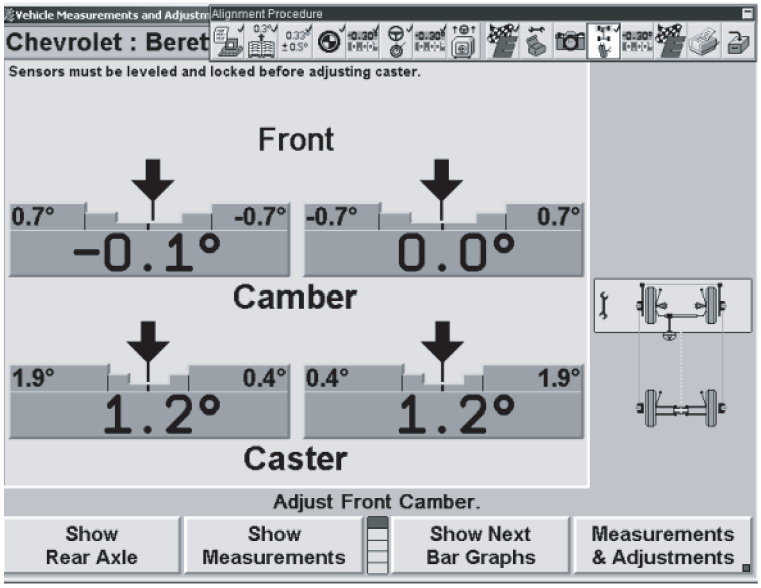


Click on a tool or kit to get a zoomed image.

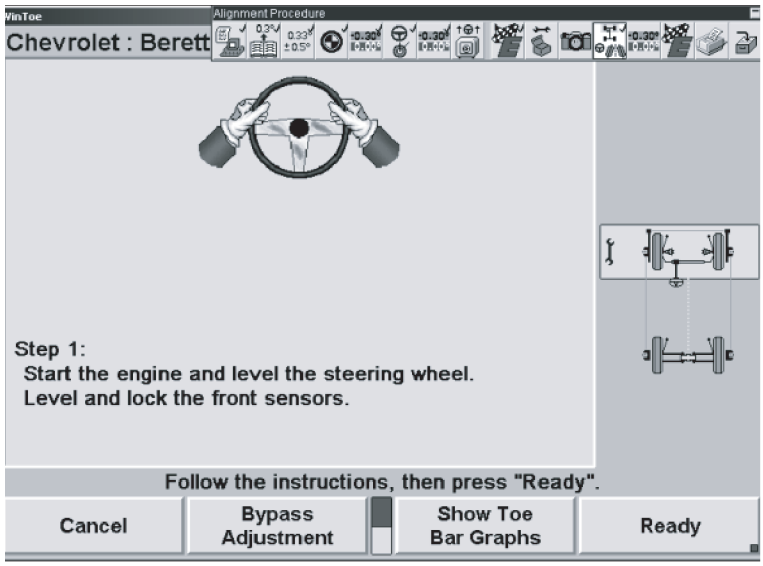


Note: Pressing will play a video of the procedure.

Verify the adjustment is ok.

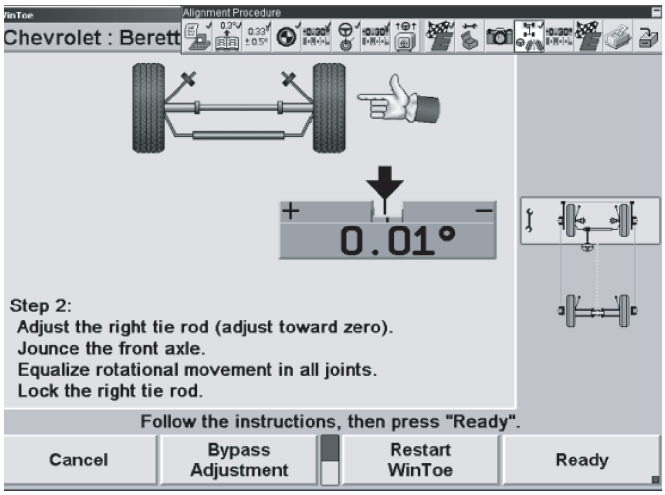


Press "Adjust Front Toe with Win Toe."

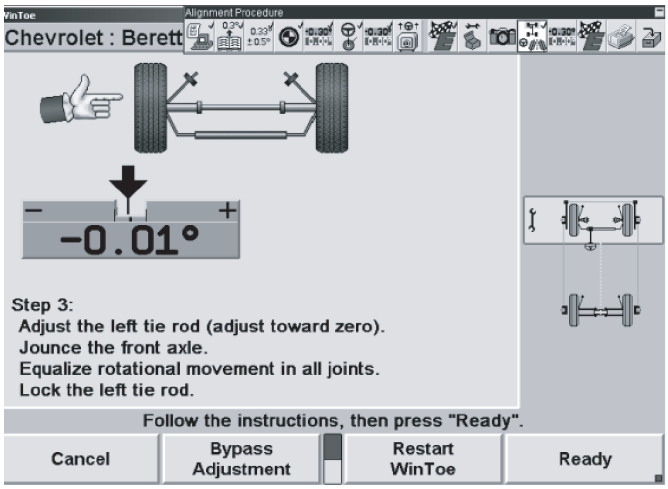


Center the steering wheel then level and lock the front sensors. Press "Ready."

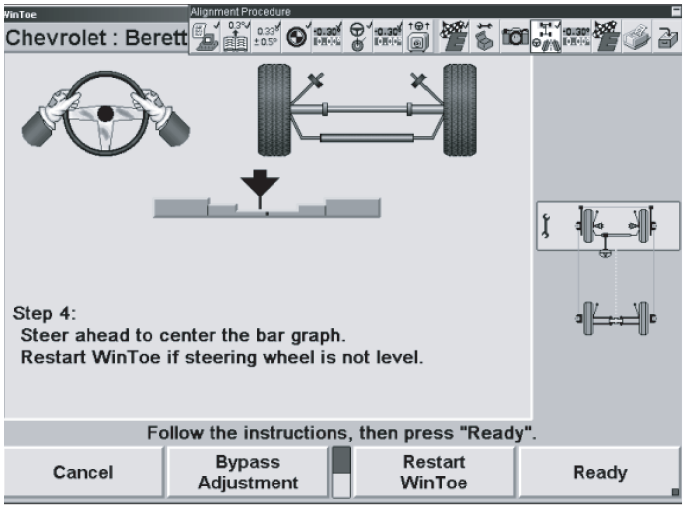
Adjust the right wheel. Press "Ready."



Adjust the left wheel. Press "Ready."

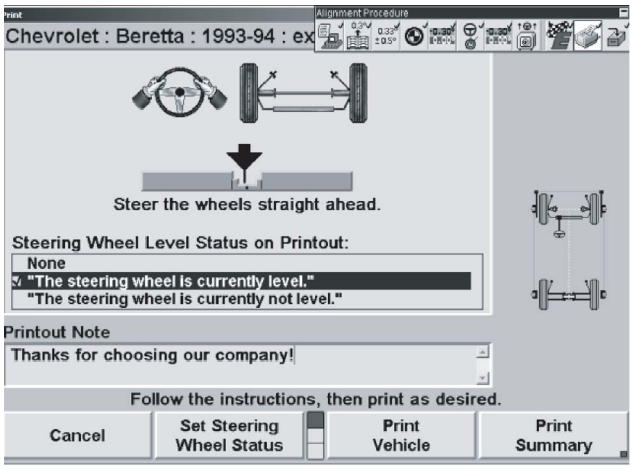


Turn the front wheels straight ahead until the target is centered. Verify the steering wheel is straight.



Press "Print" to continue.

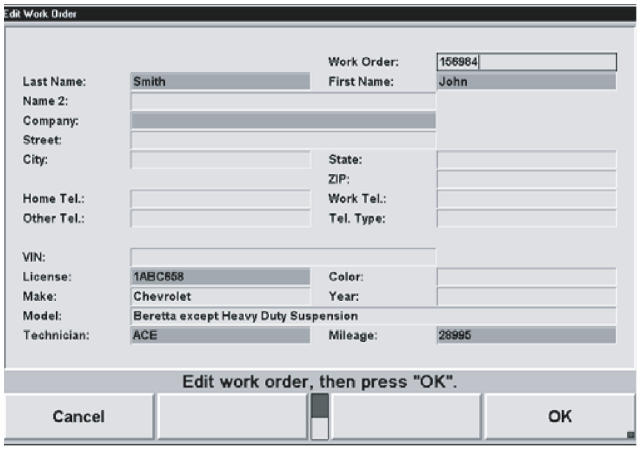
If you wish, type in a note to appear on the printout.



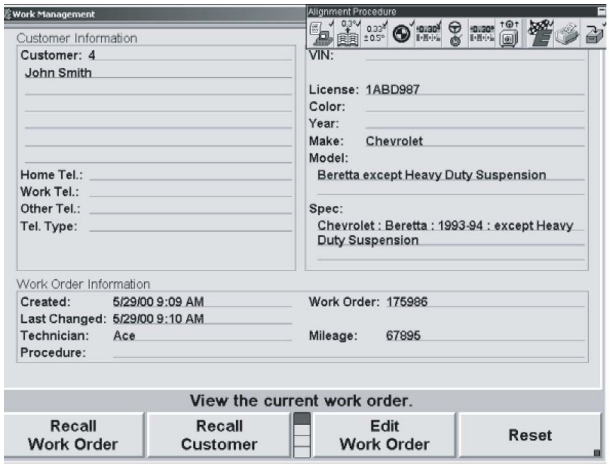
Press "Print Summary" or "Print Vehicle" to print measurements.

Save the alignment to the hard drive.

Enter the required information (indicated in dark grey) by using the keyboard. Press "OK" to save the alignment.



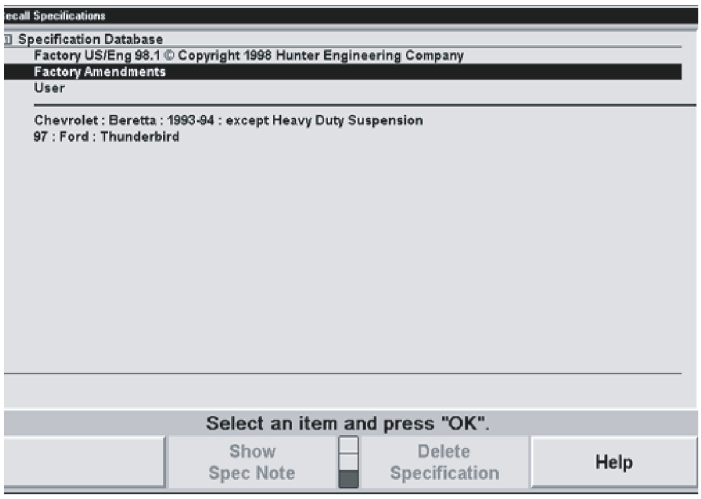
The alignment is complete. Press "Reset" to prepare the aligner for the next car.



Vehicle Specifications

You can recall specifications from 3 different databases in WinAlign.

1. **Factory Specifications**
2. **Factory Amendments** - Specifications you add based on production vehicles.
3. **User** - Specifications you add that are not based on production vehicles such as race cars.



Adding New Specifications

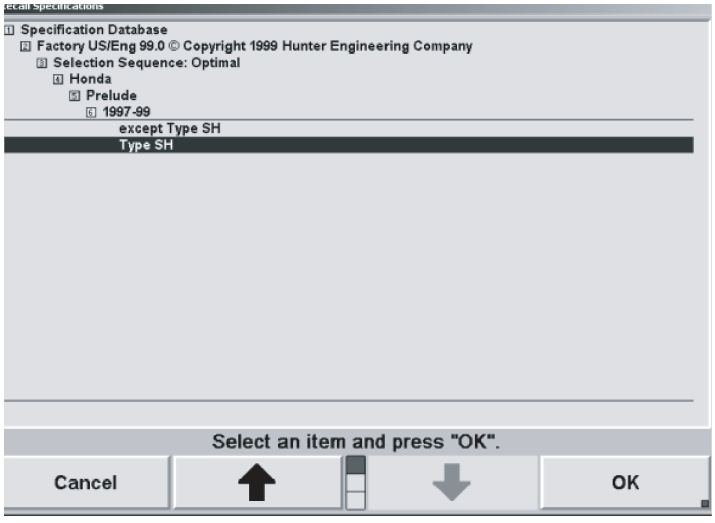
We're going to add specifications for a 1999 Honda Prelude that has been lowered 2 inches.

Select "Honda"

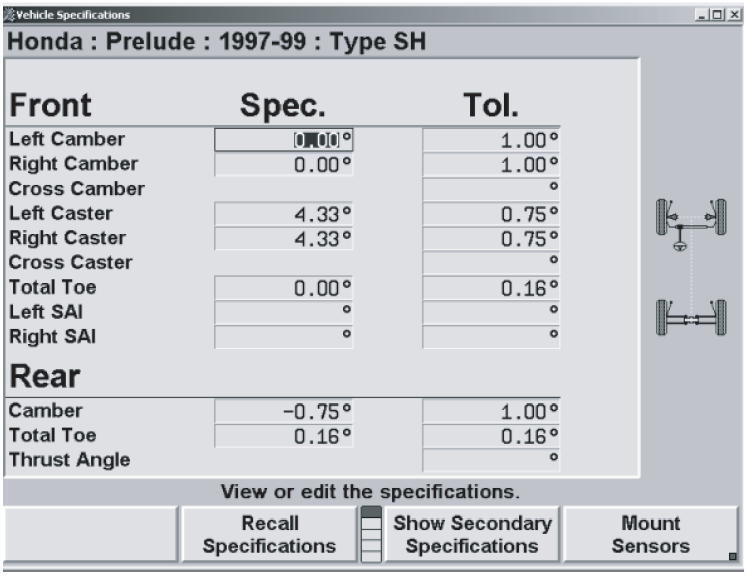
Select "Prelude"

Select "1997-99"

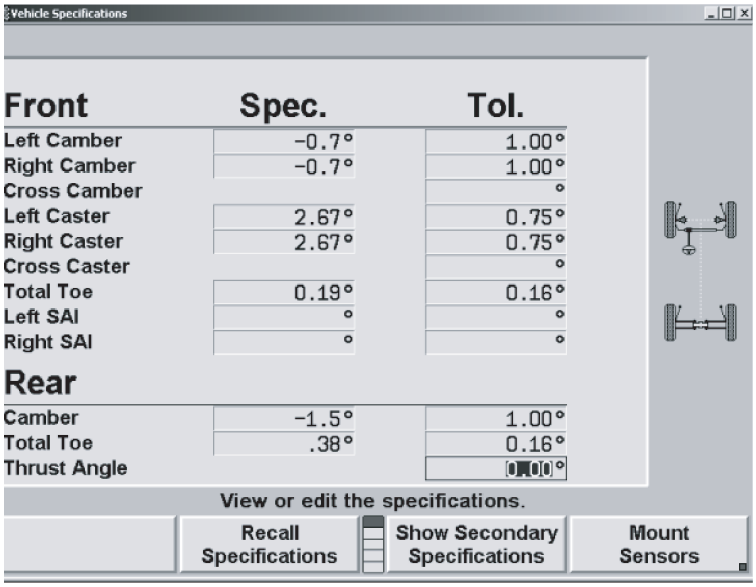
Select "Type SH"



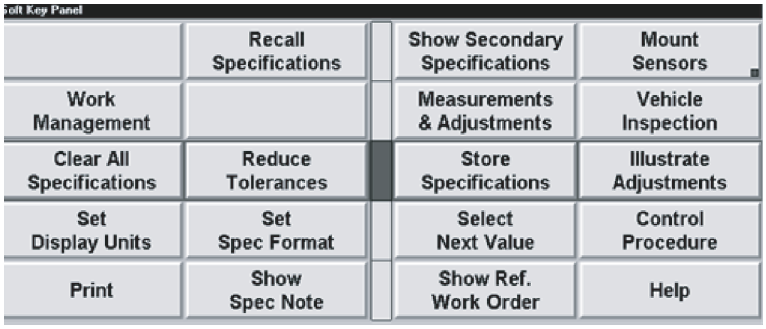
The 99 Preludes's specifications are now displayed.



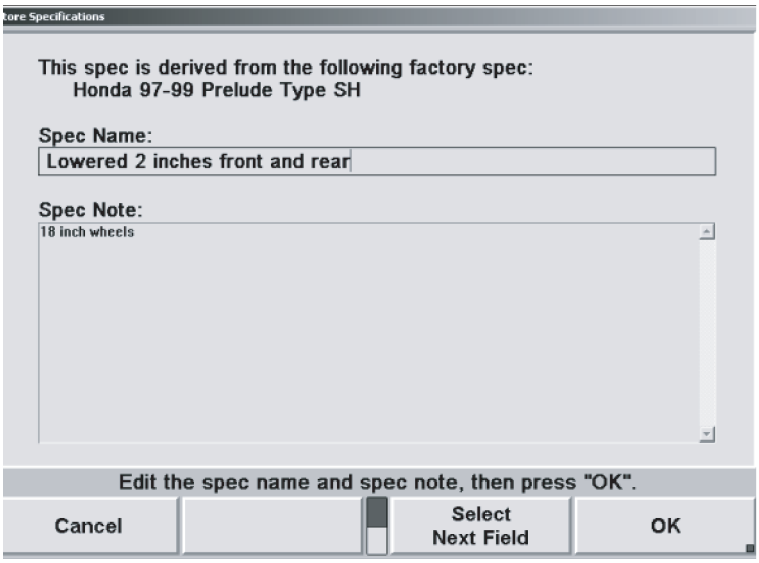
Enter the lowered Prelude's specifications on screen.



To save these specifications as an "amended" specification select "Store Specifications" from the softkey menu.

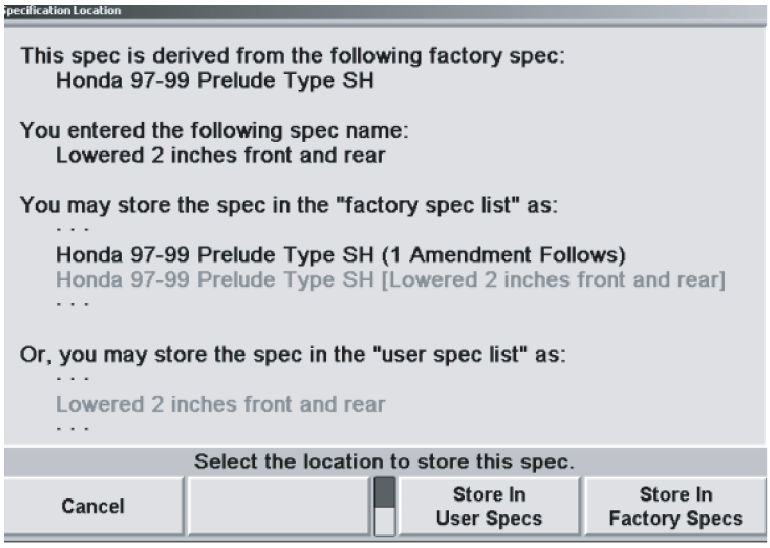


Enter additional information on this screen.



Since this Prelude is based on a production vehicle, we'll choose "Store in Factory Specs."

The specifications are now stored.



Steering Axis Inclination and Included Angle

The term **Steering Axis** describes the relationship of the two pivot points of the steering knuckle.

Steering Axis Inclination or **S.A.I.** for short is the angle formed by a line drawn through the upper and lower pivot points of the spindle and a vertical line drawn from the lower pivot point.

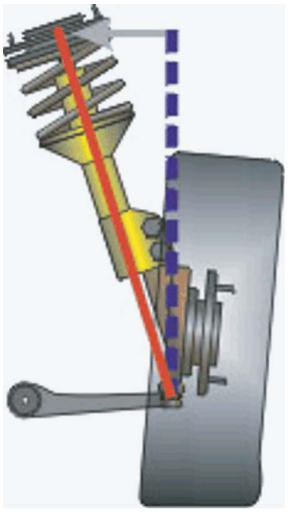


Figure 4-57, Steering Axis Inclination (SAI)

Large differences (usually over 1°) in SAI generally indicate a damaged component at one or both of the two pivots of the steering knuckle.

S.A.I. helps to increase **directional stability** due to the arc the spindle travels when steered. This arc forces the vehicle's weight to be lifted since the spindle turns downward when steered left or right.

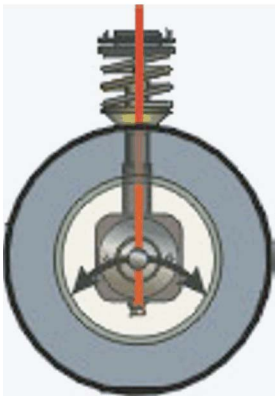


Figure 4-58, Directional Stability

The vehicle's weight helps return the front spindles to a straight ahead position when steering wheel pressure is released.

Included angle, or **I.A.** for short, is the combination of S.A.I. and camber.

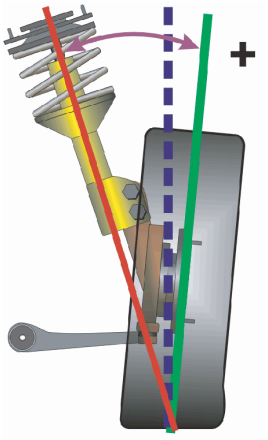


Figure 4-59, Included Angle (IA)

Unequal I.A. Angles May Indicate Damaged Steering or Suspension Components.

Large differences (usually over 1°) in included angle may indicate a damaged component between the two pivots of the steering knuckle.

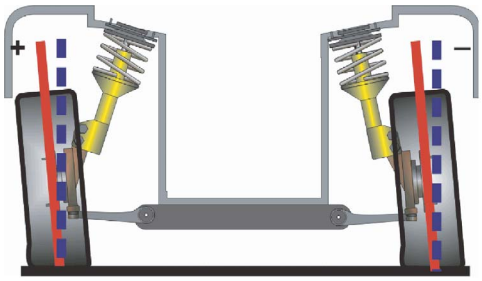


Figure 4-60, Unequal Angle (IA)

Press "Measure Caster" on the "Vehicle Measurements and Adjustments" primary screen. The "Caster and S.A.I. Measurement" pop-up screen will appear.

Press "Select Measurement." The "Caster Measurement Selection" pop-up screen will appear.

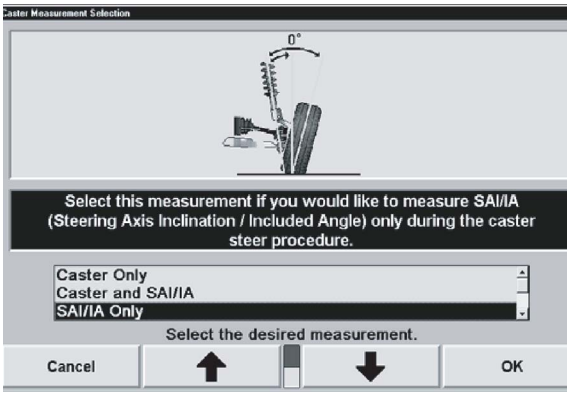


Figure 4-61, Vehicle Measurements and Adjustments Screen

Select "S.A.I./I.A. Only".

Press "OK" to select the measurement. The "Measure Caster" pop-up screen will appear.

Lock the front brakes using a brake pedal depressor.

Raise the front wheels until they clear the turning angle gauges or rack and support vehicle securely.

Press "Ready."

Perform the S.A.I. turn while observing the bar graphs in the same manner as the caster turn. Refer to "Measure Caster".

When S.A.I. measurements are completed, the CRT will change to the "Vehicle Measurements and Adjustments" primary screen with the S.A.I. and included angle measurements shown.

Lower the Vehicle and View the Measurements

While lowering the vehicle, camber and S.A.I. measurements will change. However, included angle measurements will remain constant.

Turning Angle

Turning angle is the arc a wheel travels during a turn.

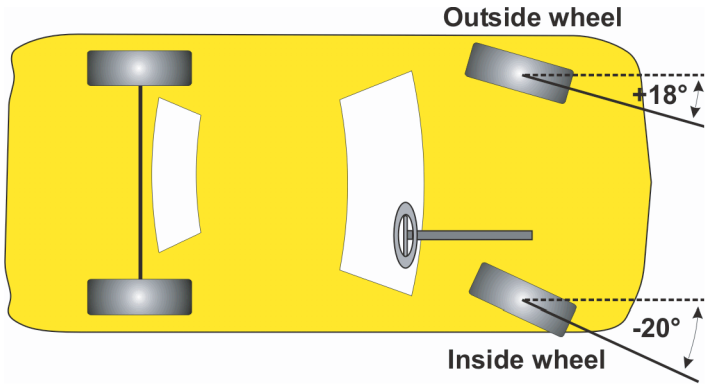


Figure 4-62, Turning Angle

The inside wheel must turn sharper than the outside wheel in order to reduce tire scrubbing in the turn.

The steering arms of the vehicle are designed to predetermine the relationship between the left and right front wheels when the vehicle is steered left or right.

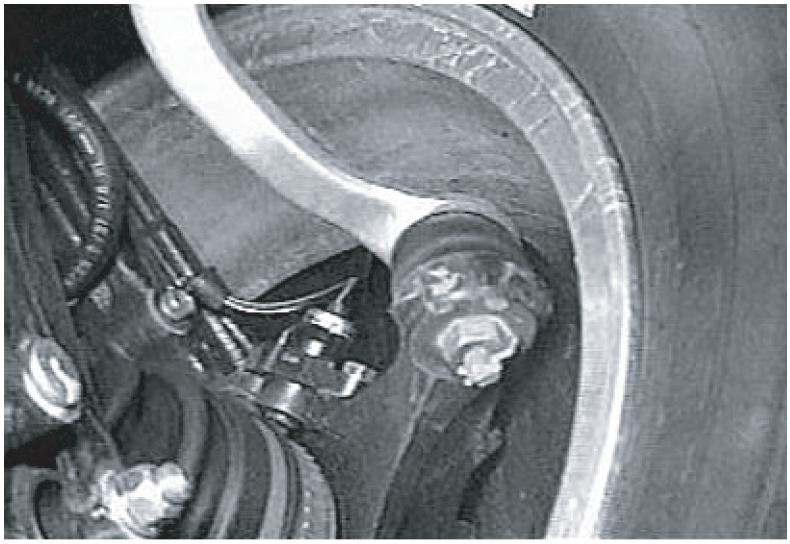


Figure 4-63,

The steering arm connects the outer tie rod to the steering knuckle. The steering arm on most vehicles is an integral part of the steering knuckle.

How Turning Angle Works

The steering arm moves equal distance laterally as the rack moves back and forth. The steering arm must move farther up its curve when the wheel is steered left than when the wheel is steered right.

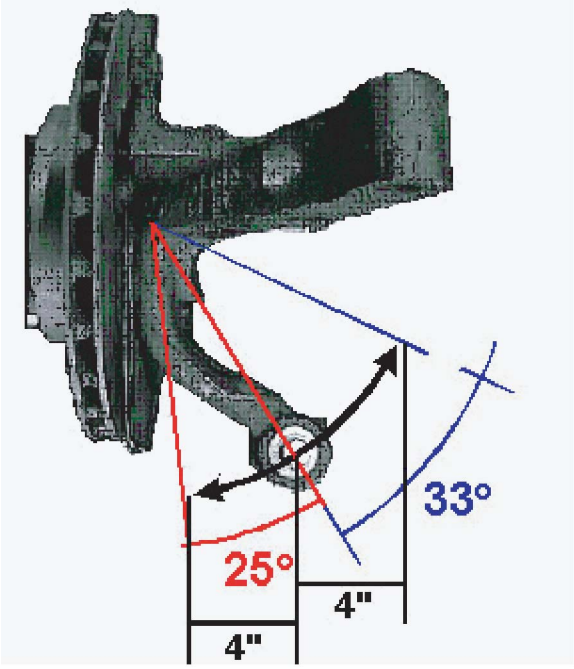


Figure 4-64, Turning Angle

In this example, the rack moves laterally 4" in each direction.

The wheel turns 33° outward as the arm climbs the arc.

The wheel turns only 25° inward as the arm move slightly down and across the arc.

Measuring Turning Angle

Turning angle is measured by steering the inside wheel a specified amount then checking the angle of the outside wheel. The aligner then calculates the total toe ("turning angle difference") in the turn.

Turning angle can be measured with either electronic turnplates, encoders and elastic lines, or the radius gauges on standard Hunter turnplates.

Figure 4-65, Measuring Turning Angle

Setback

Front setback is an angle formed by a line drawn perpendicular to the centerline and a line connecting the centers of the front wheels.

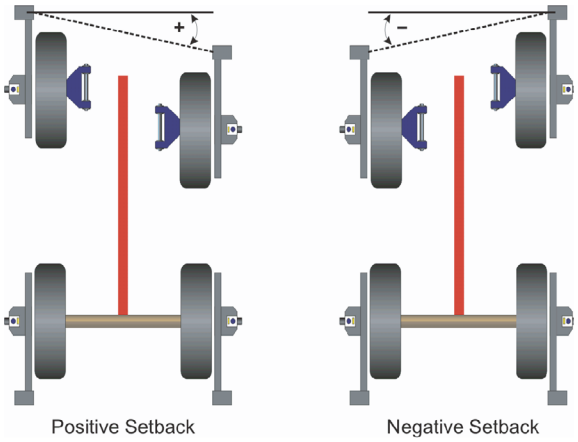


Figure 4-66, Setback

Positive setback indicates the right front wheel is behind the left front wheel.

Negative setback indicates the left front wheel is behind the right front wheel.

Setback is measured as an angle but can be displayed in inches or millimeters if front track width is available in the vehicle specifications.

Front Setback Diagnosis

Front setback is helpful when diagnosing caster problems.

Rear setback is an angle formed by a line perpendicular to the centerline and a line connecting the centers of the rear wheels.

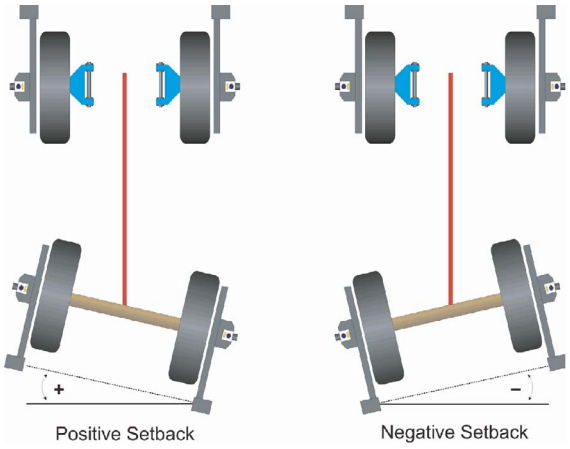


Figure 4-67, Front Setback

Rear setback is positive when the right rear wheel is behind the left rear wheel.

Rear setback is negative when the left rear wheel is behind the right rear wheel.

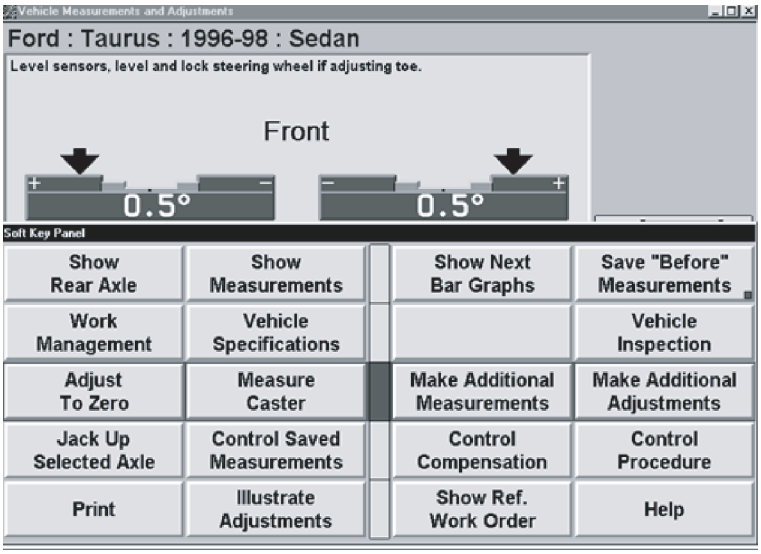
Rear setback is measured as an angle but can be displayed in inches or millimeters if rear track width is available in the vehicle specifications.

Rear Setback Diagnosis

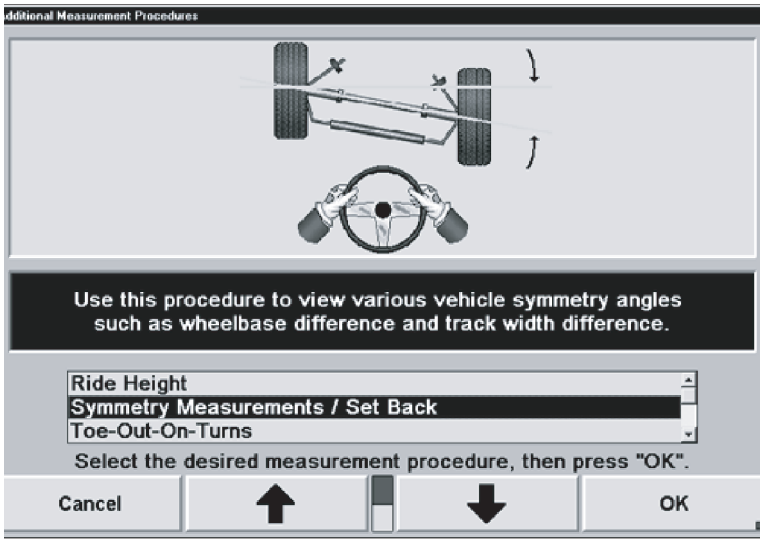
Rear setback is particularly helpful when diagnosing thrust angle problems.

Symmetry / Setback Procedure

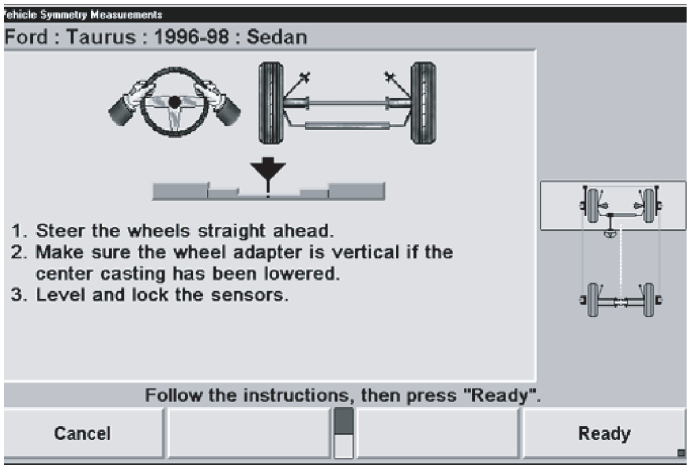
Bring up the "soft key panel" by pressing the light pen against the center of the soft key level indicator (or press the F6 key). Select "Make Additional Measurements."



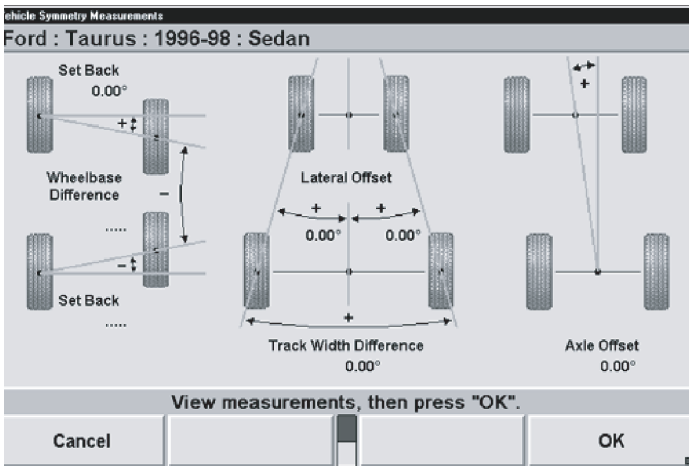
Select "Symmetry Measurements / Set Back."



Follow the instructions, then press "Ready."

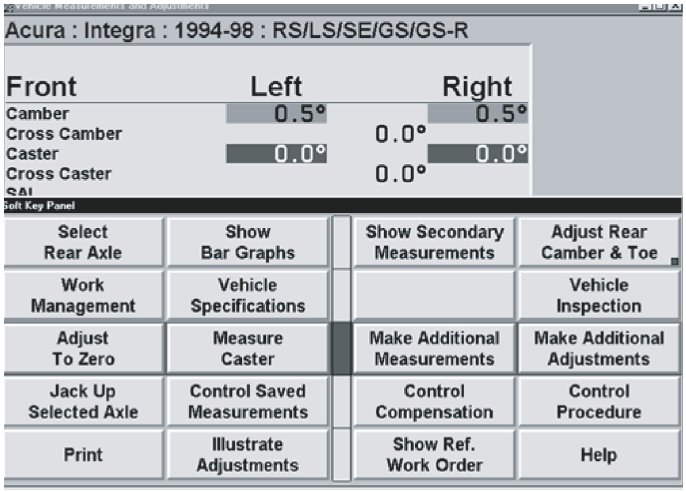


The symmetry/setback measurements are now displayed on screen. Press the "Print Screen" button (upper right on the keyboard) to make a hard copy printout.

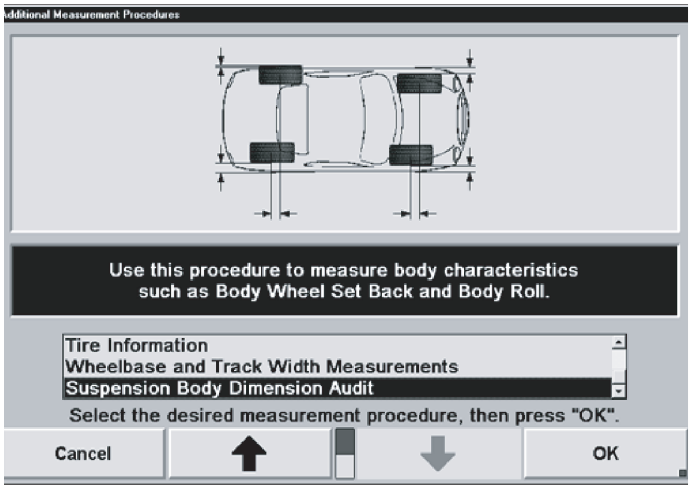


Suspension Body Dimension Audit Procedure

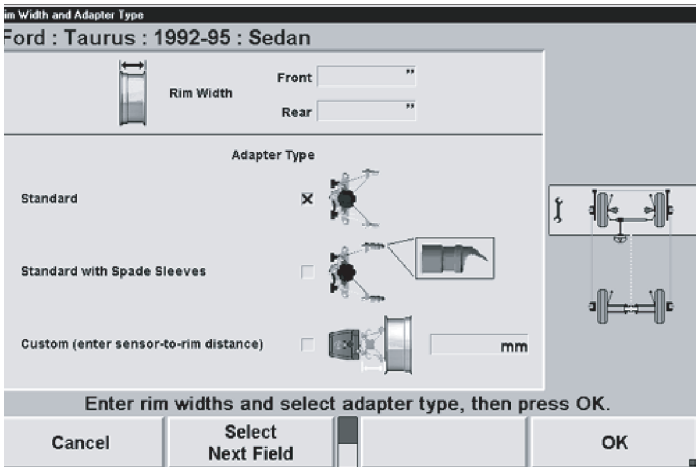
Bring up the tool box by pressing the light pen against the center of the soft key level indicator (or press the F6 key). Select "Make Additional Measurements."



Select "Symmetry Measurements / Set Back."

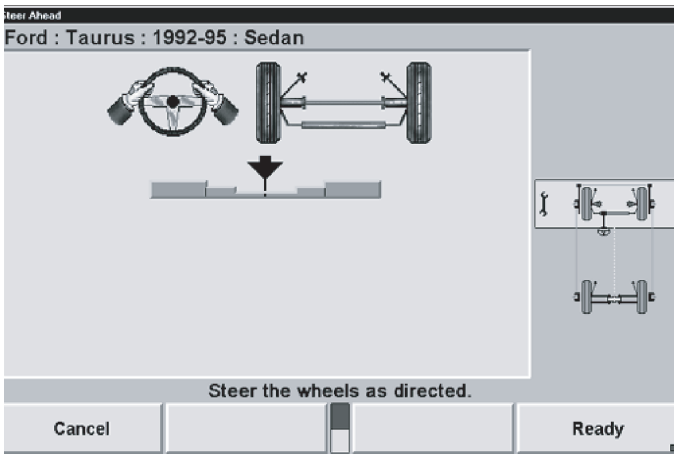


Follow the instructions, then press “OK.”

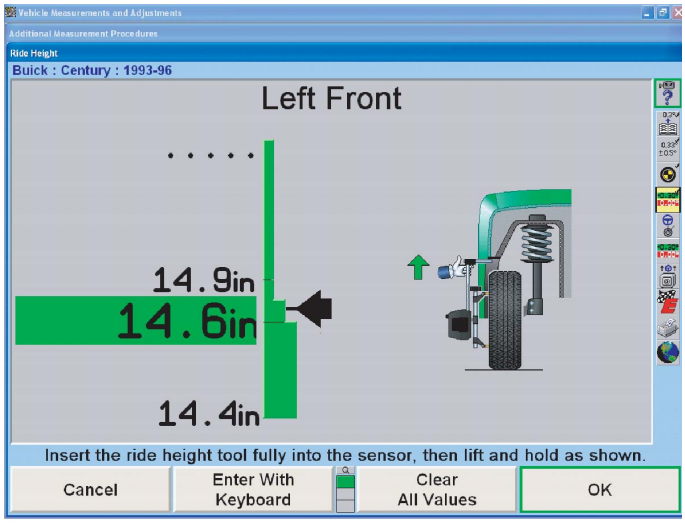


Steer the wheels to line up the bar graph. Press “OK.”

To input the vehicle's right height, raise the ride height tool until the horizontal arm touches the underside of the wheel arch above the center of each wheel.

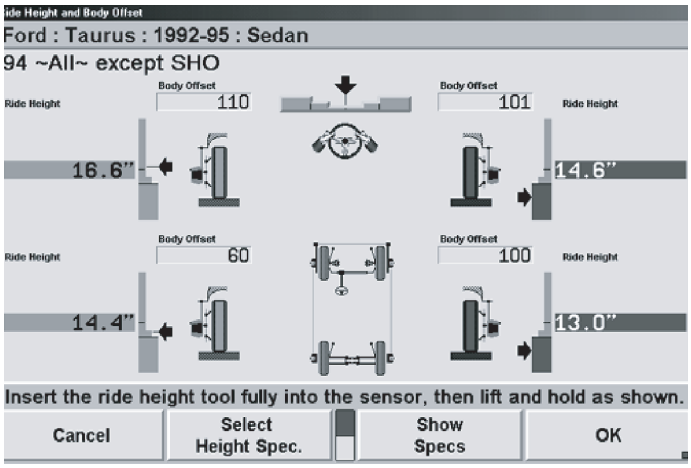


Slide the tip of the ride height tool until it touches the sheet metal above the wheel arch. Locate the number of the scale at the tool's handle.

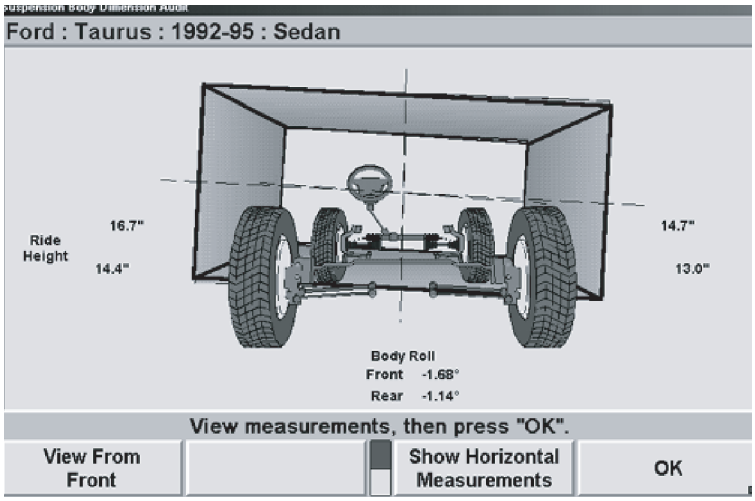


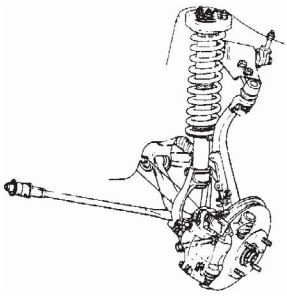
Type the body offset onto the SDBA input screen.

The horizontal measurements screen now appears.



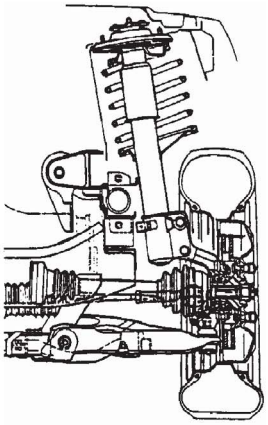
Press "Show Vertical Measurements" to display the vehicles body ride height and body roll measurements.





Short Long Arm (Double Wishbone)

Camber	SAI	IA	Check
Positive	Negative	OK	Bent lower control arm or frame
Negative	Positive	OK	Bent upper control arm or frame
Positive	OK	Positive	Bent knuckle or balljoint
Negative	OK	Negative	Bent knuckle or balljoint
Positive	Negative	Positive	Bent lower control arm or frame and Bent knuckle or balljoint
Negative	Positive	Negative	Bent upper control arm or frame and Bent knuckle or balljoint



Strut

Camber	SAI	IA	Check
Positive	Negative	OK	Bent lower control arm or frame
Negative	Positive	OK	Strut tower in at top
Positive	OK	Positive	Bent strut, knuckle or balljoint
Negative	OK	Negative	Bent strut, knuckle or balljoint
Positive	Negative	Positive	Bent lower control arm or frame and Bent strut, knuckle or balljoint
Negative	Positive	Negative	Strut tower in at top and Bent strut, knuckle or balljoint

Twin I Beam

Camber	SAI	IA	Check
Positive	Negative	OK	Bent axle
Negative	Positive	OK	Bent axle
Positive	OK	Positive	Bent knuckle or balljoint
Negative	OK	Negative	Bent knuckle or balljoint
Positive	Negative	Positive	Bent axle and Bent knuckle or balljoint
Negative	Positive	Negative	Bent axle and Bent knuckle or balljoint

Short Long Arm (Double Wishbone)

Driver Side

Caster	Setback	Check
Negative	Negative	Lower control arm too far back
Negative	Positive	Upper control arm too far forward
Positive	Negative	Upper control arm too far back
Positive	Positive	Lower control arm too far forward

Passenger Side

Caster	Setback	Check
Negative	Positive	Lower control arm too far back
Negative	Negative	Upper control arm too far forward
Positive	Negative	Lower control arm too far forward
Positive	Positive	Upper control arm too far back

Strut

Driver Side

Caster	Setback	Check
Negative	Negative	Lower control arm too far back
Negative	Positive	Strut tower too far forward
Positive	Negative	Strut tower too far back
Positive	Positive	Lower control arm too far forward

Passenger Side

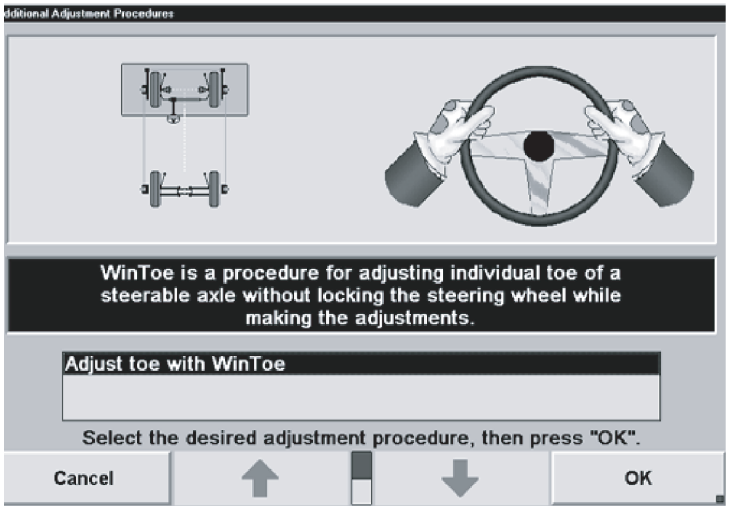
Caster	Setback	Check
Negative	Positive	Lower control arm too far back
Negative	Negative	Strut tower too far forward
Positive	Negative	Lower control arm too far forward
Positive	Positive	Strut tower too far back

"WinToe"

Win Toe is a software feature that allows the adjustment of front toe on vehicles with an independent tie rod adjustment for each wheel. Using WinToe will provide the desired toe settings for each wheel and insure the desired steering wheel position, normally without the need to readjust or touch up settings. Additionally, WinToe eliminates the need to lock the steering wheel during toe adjustments.

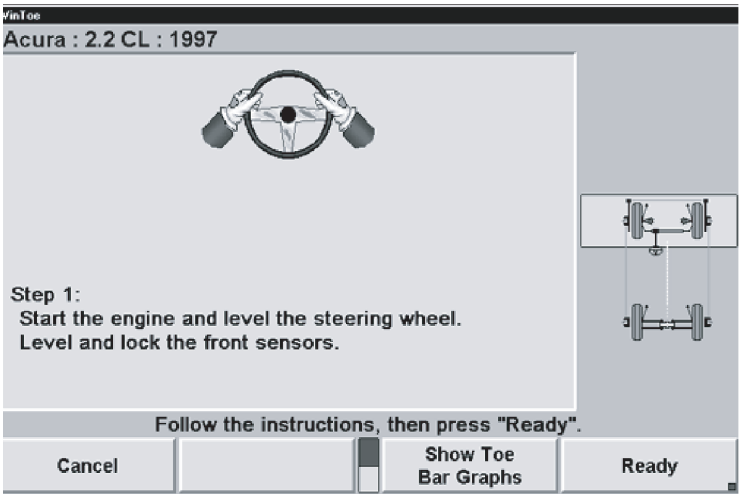
WinToe is only available when the front wheel adjustments are active as indicated by the highlighting of the front of the vehicle plan view at the right hand side of the display.

Select "Adjust Toe With WinToe" under the "Make Additional Adjustments" secondary screen.



To access WinToe directly from the front bar graphs, press and hold the light pen on either the left or right toe bar graph, then highlight "Adjust Toe with WinToe" from the pull-down menu and release the light pen.

The "WinToe" pop-up screen will appear prompting to level the steering wheel in the straight ahead position as indicated by the steering wheel spoke(s).



Center the Steering Wheel

Positioning steering wheel - For vehicles with power steering, place the transmission in park or neutral, lock the brakes, and make sure the wheels are chocked. Start the engine and level the steering wheel.

Steering wheel leveling is important and should be performed as follows:

a) While sitting in the driver's seat, rock the steering wheel back and forth in arcs left and right from the level position. The arcing motion should start out with larger arcs and gradually become smaller arcs with the result being to have the steering wheel be precisely leveled while ensuring the steering system is carefully positioned in the mid-point of any gear lash and power steering valve movement.

b) Use chalk to mark the leveled steering wheel position with the side of the steering column. This easy to see reference mark will save time in final adjustment verification.

c) With the steering wheel centered, turn the engine off and exit the vehicle being careful to not touch or bump the wheel position.

   Note: It is NOT necessary to lock the steering wheel.

d) While being careful not to disturb the position of any wheels or steering linkage, level and lock all four wheel sensors.

Follow the on-screen instructions and press "Ready."

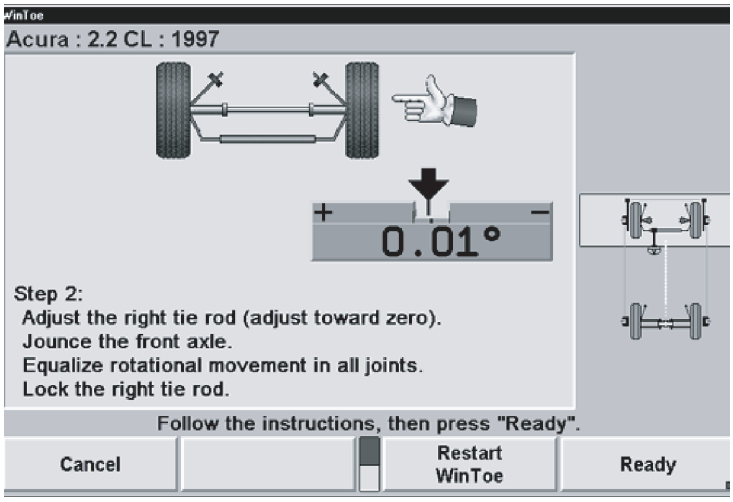
This will allow WinToe to "memorize" each front wheel's position and needed tie rod adjustments relative to the desired steering wheel position. Keep in mind, WinToe's memory will track the needed adjustments for each wheel, even if the steering moves or gets jarred during the adjustment process.

As long as the wheels are within approximately two degrees left or right from straight ahead, WinToe automatically compensates for any movement in the steering system and continues to accurately monitor the adjustments.

The screen will change to display a bar graph prompting to adjust the right toe.

Important:

Before locking each adjustment, lightly **jounce the front end to verify the "relaxed"** position. Lock the adjustment, then again, lightly re-jounce the **suspension to verify adjustment**. As long as the bar graph remains green, with the adjustment locked, you can proceed. The value does not have to read zero. To prevent incorrect adjustments, WinToe does not allow the operator to proceed unless the locked adjustment is green.



Adjust and Lock the Right Tie Rod Assembly

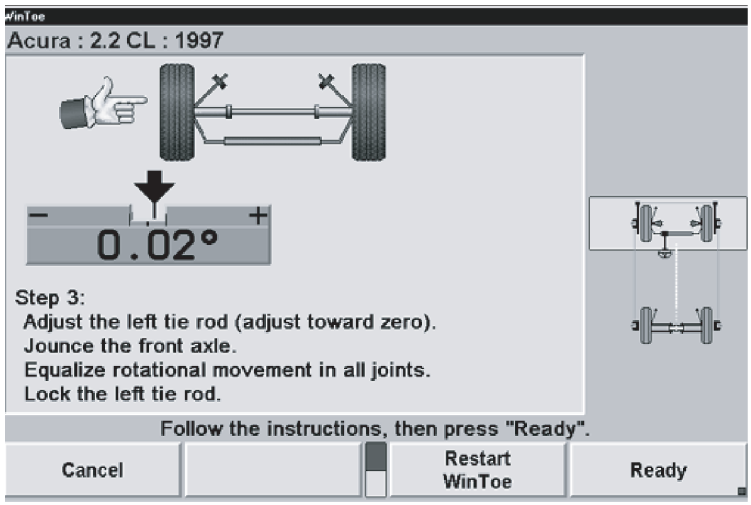
Adjust the right side tie rod until the bar graph is green and the value is near zero.

Before locking the adjustment, lightly jounce the front end.

Lock the adjustment, then lightly jounce the front end again to verify the adjustment. As long as the bar graph remains green, with the adjustment locked, you may proceed. The value does not have to read zero, however, the bar graph must be green.

To prevent incorrect adjustments, WinToe does not allow the operator to proceed unless the locked adjustment is green.

After the right side adjustment is completed and locked, pressing "Ready" will display a bar graph prompting to adjust the left toe.



Adjust and Lock the Left Tie Rod Assembly

Adjust the left side tie rod until the bar graph is green and the value is near zero.

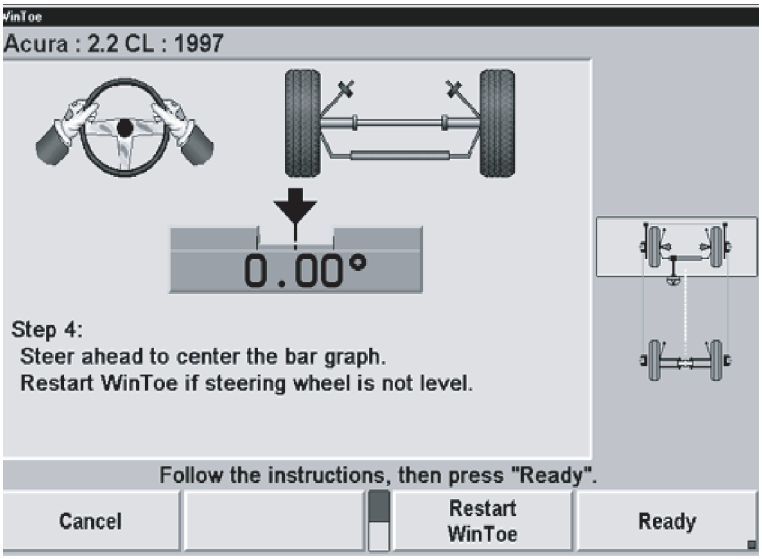
Before locking the adjustment, lightly jounce the front end.

Lock the adjustment, then lightly jounce the front end again to verify the adjustment. As long as the bar graph remains green, with the adjustment locked, you may proceed. The value does not have to read zero, however, the bar graph must be green.

Press "Ready." The screen will change to display the "Steer Ahead" bar graph.

Verify Steering Wheel Adjustment

To verify steering wheel position, steer straight ahead. The arrow should be centered on the bar graph and the steering wheel level.



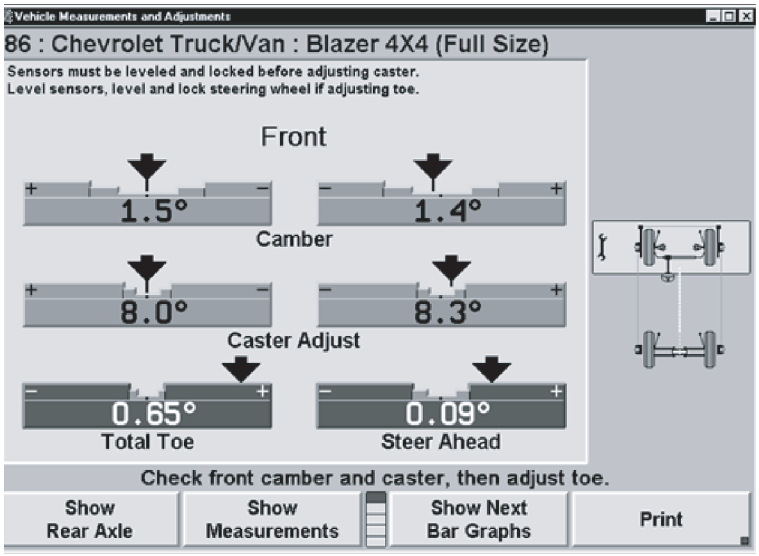
For vehicles with power steering, start the engine, and with a slight rocking motion of the steering wheel, steer the arrow on the bar graph to the center. Observe the final steering wheel position.

Note, you may also use the reference chalk marks, if used earlier, to index the level steering wheel position.

After verification of steering wheel position, the on-screen instructions will prompt you to press "Ready." This will complete the WinToe procedure by returning to the primary "Vehicle Measurements and Adjustments" screen.

Steer Ahead

To verify steering wheel position, steer the front wheels to center the "Steer Ahead" bar graph.



The steering wheel is now in its rest position.

Drag Link Adjustment

Many 4x4 light trucks and sport utility vehicles may use a relay rod steering system.

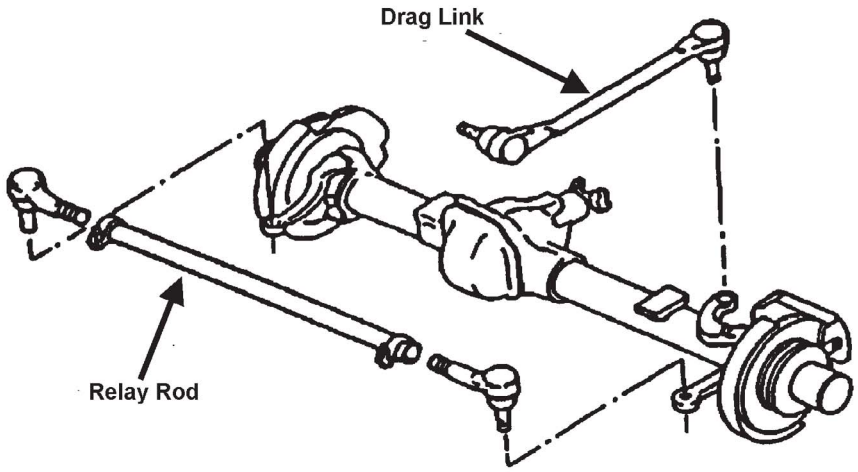
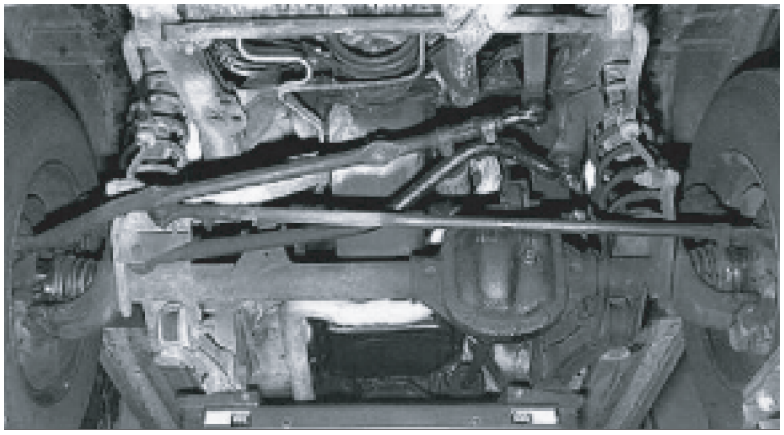


Figure 4-68, Drag Link Adjustment



Select the “Total Toe – Steer Ahead” adjustment screen.

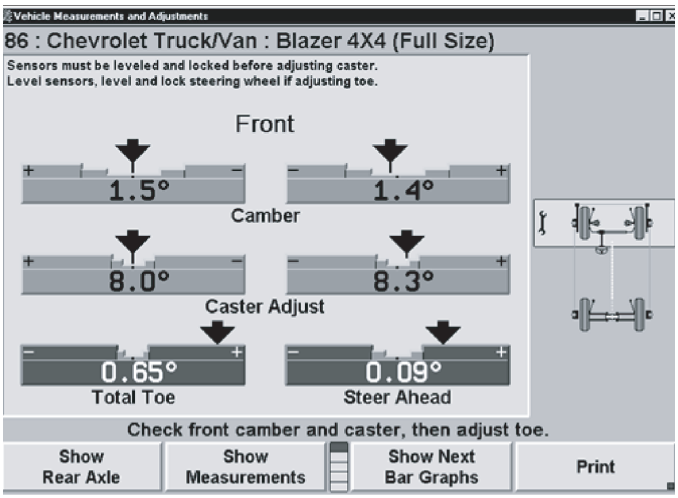


Figure 4-69, Total Toe – Steer Ahead Adjustment Screen

Adjust the relay rod until the "Total Toe" bar graph is centered with the tires on the turnplates.

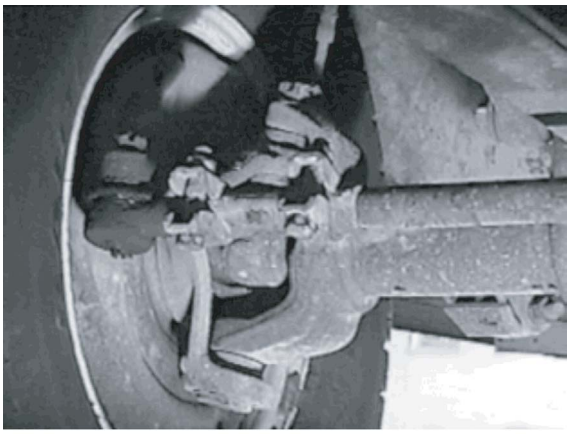


Figure 4-70, Tires on Turnplate

Jack up the axle until the front wheels are off the turnplates.

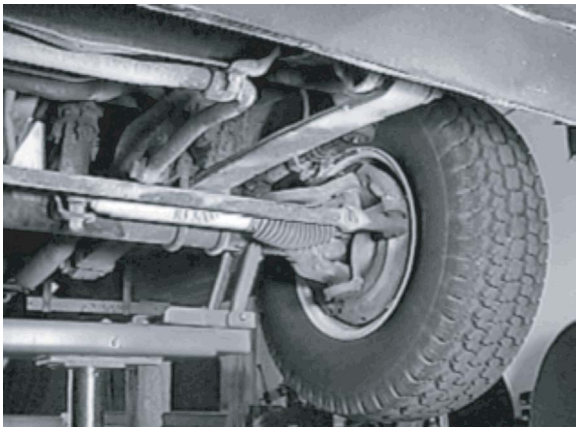


Figure 4-71, Jack Up Axle

Start the engine. Level and lock the steering wheel. Cut the engine off.

Figure 4-72, Start the Engine

Adjust the drag-link to center the steering wheel.

Figure 4-73, Adjust Drag-link to Center Steering Wheel

Adjust until the "Steer Ahead" bar graph is centered.

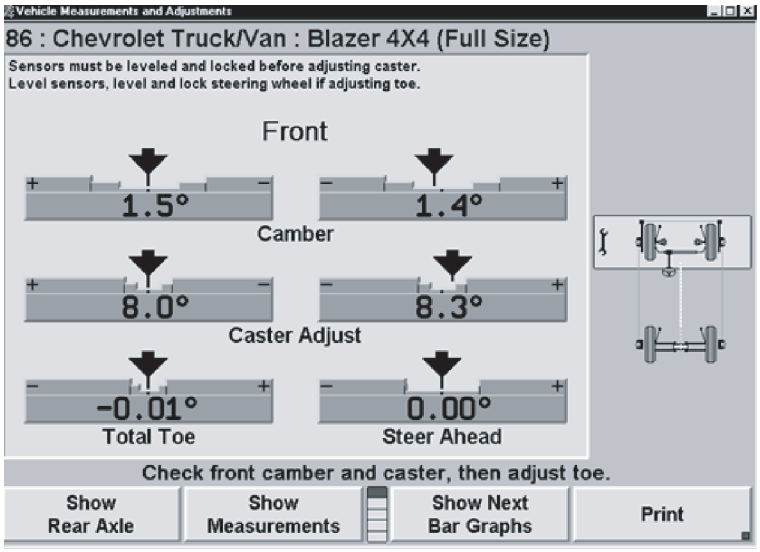


Figure 4-74, Steer Ahead Bar Graph

Zero Adjust

The "Zero Adjust" screen shows the amount and direction (±) the actual measurement is from the preferred specification. Adjusting an angle to zero on this display will cause the actual angle measurement to be exactly equal to the preferred alignment specification.

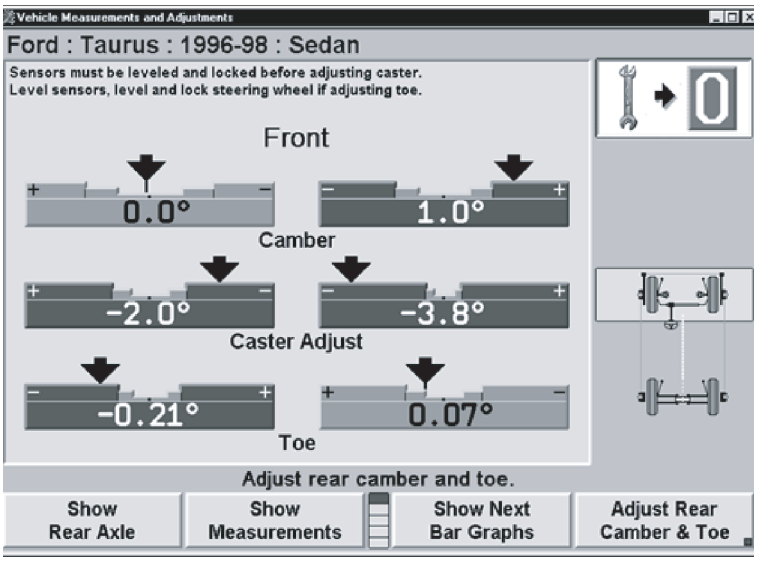


Figure 4-75, Zero Adjust Screen

A red bar graph indicates the adjustment is out of tolerance. Green indicates the adjustment is within tolerance.

"0" indicates the measured angle equals the specification.

If the bar graph is gray, no specification, a zero tolerance, or no tolerance is entered for that angle.

Jack Up Procedure

Jacking up the wheels off the rack or raising the rack to a non-level position may make adjusting rear camber or front camber and caster easier on some vehicles. When the wheels are raised, the sensors will move and the angles will change. If the instructions are followed, the software compensates for the movement of the sensors to allow accurate adjustment.

To adjust the vehicle with the wheels raised:

Press "Jack Up Selected Axle" on the "Vehicle Measurements and Adjustments" primary screen. The "Jack up Selected Axle" pop-up screen will appear.

Lock the service brakes using the brake pedal depressor.

Level and lock the sensors.

Press "Ready." The program will save sensor readings.

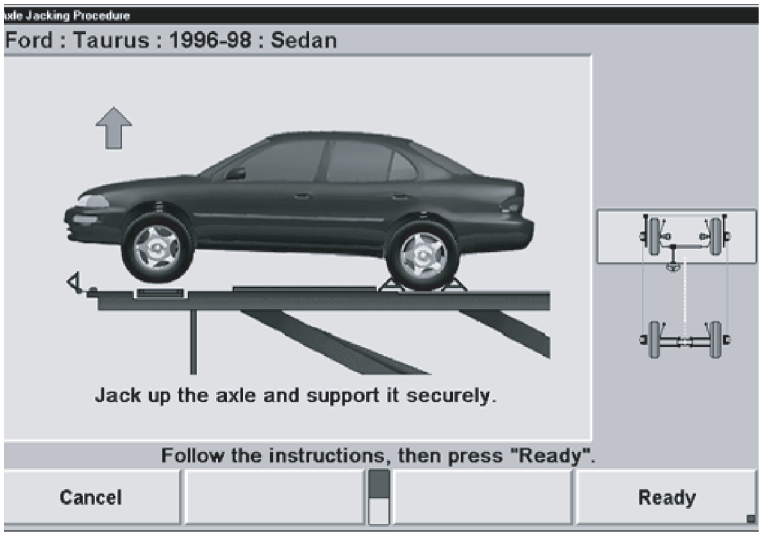


Figure 4-76,

Raise the selected axle and press "Ready." The program will compensate for the difference in sensor readings caused by raising the wheels and return to the "Vehicle Measurements and Adjustments" primary screen.

Make the necessary adjustments while observing the bar graphs or information on the "Zero Adjust" display.

Press "Lower Selected Axle" on the "Vehicle Measurements and Adjustments" primary screen to verify the adjustments are ok.

Control Arm Movements

Camber change without changing Caster.

Move the **front and rear** of the upper control arm **out** equal amounts.

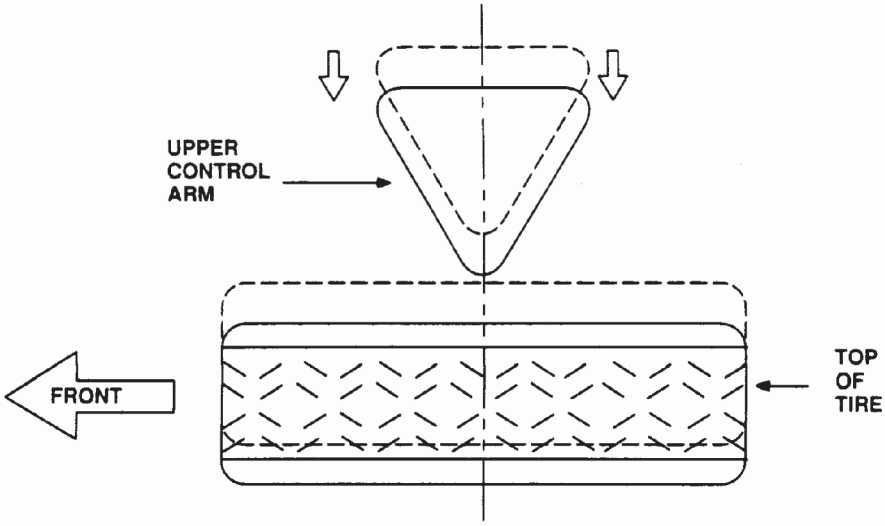


Figure 4-77, Positive Camber Change

Move the **front and rear** of the upper control arm in equal amounts.

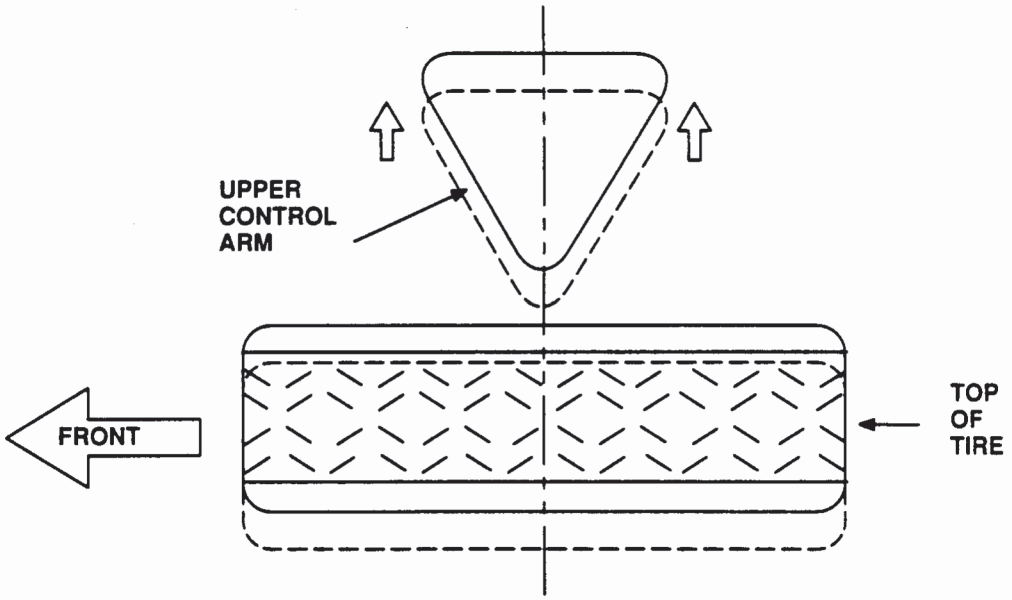


Figure 4-78, Negative Camber Change

Caster Change without Changing Camber.

Move the front of the upper control arm out and the rear in equally.

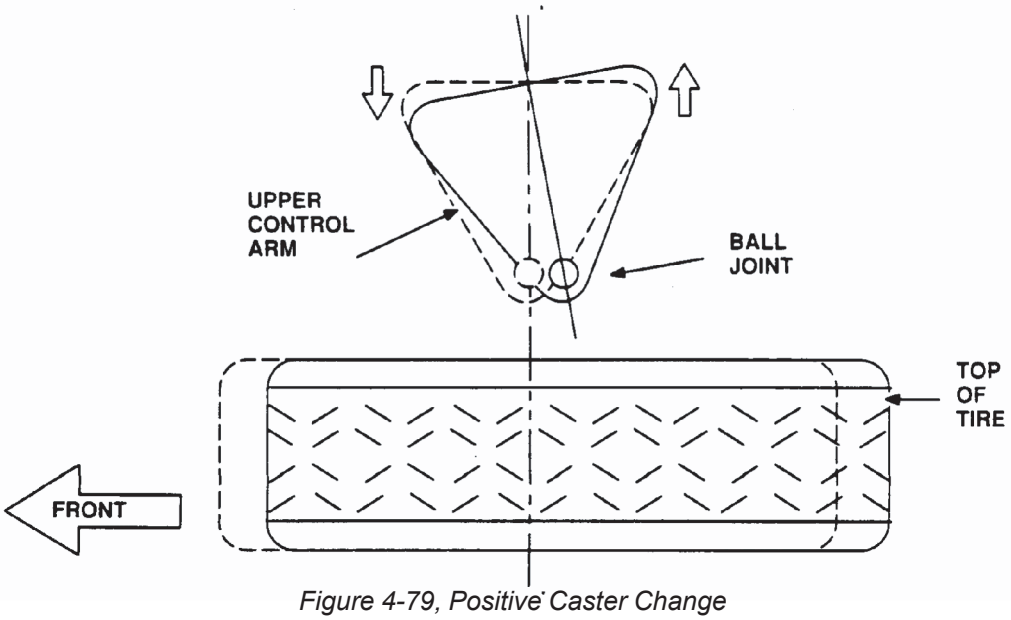


Figure 4-79, Positive Caster Change

Move the **rear** of the upper control arm **out** and the **front in** equal amounts.

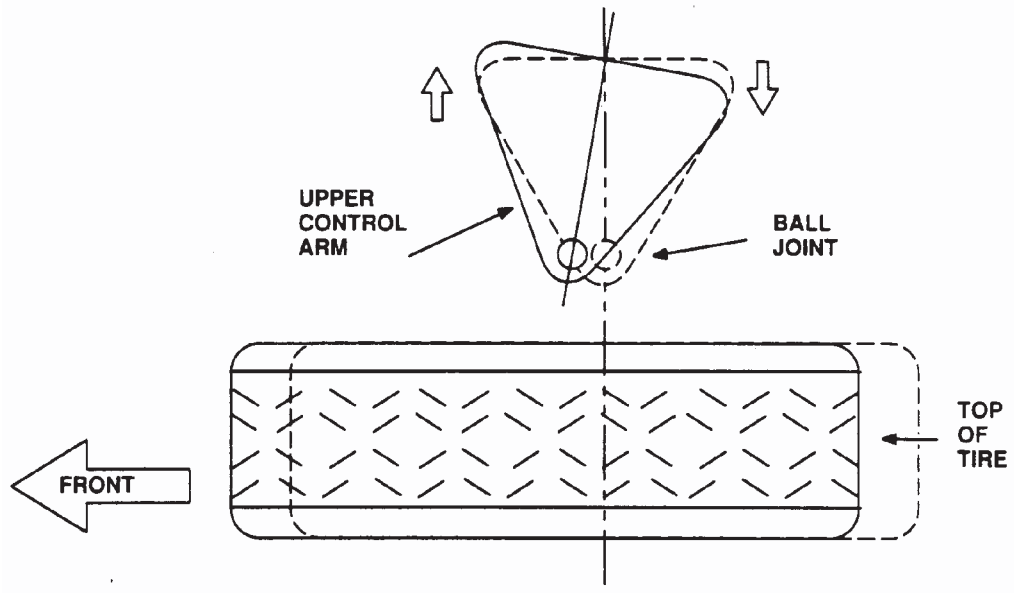


Figure 4-80, Negative Caster Change

Combination Camber and Caster changes.

Move the front of the upper control arm out.

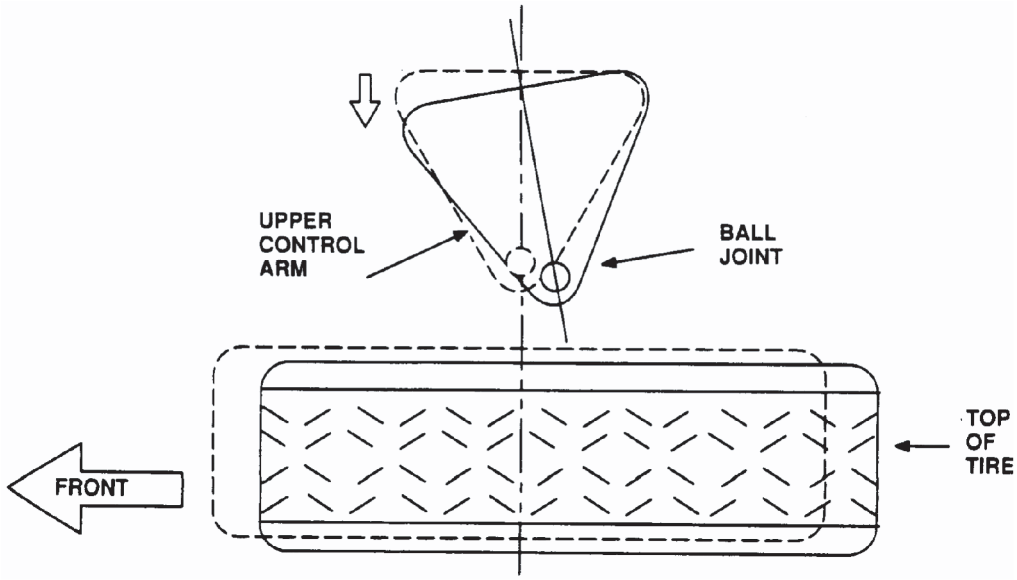


Figure 4-81, Combination Change: +Camber, +Caster

Move the **front** of the upper control arm **in**.

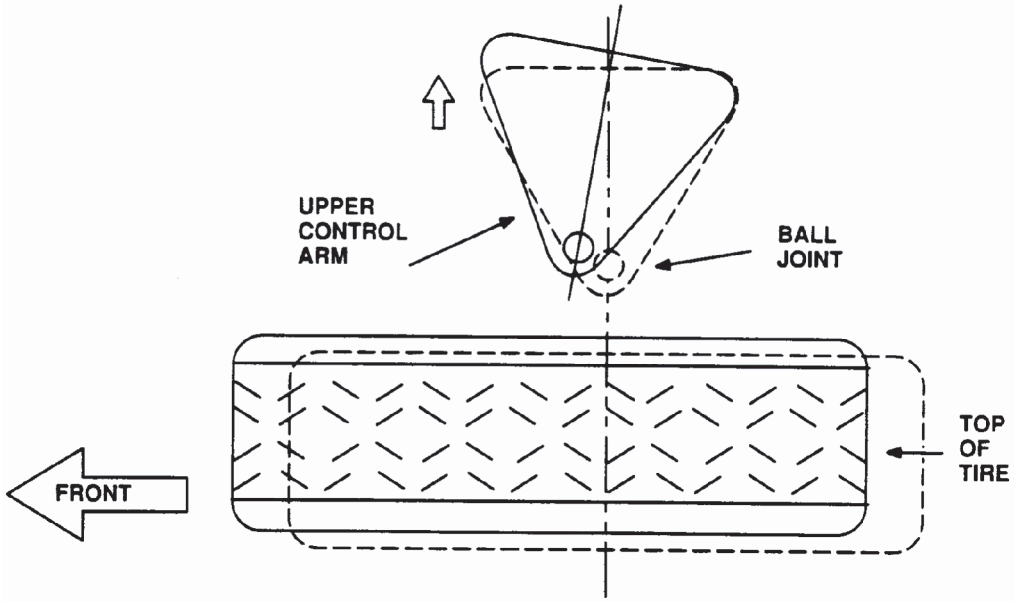


Figure 4-82, Combination Change: -Camber, -Caster

Move the **rear** of the upper control arm **out**.

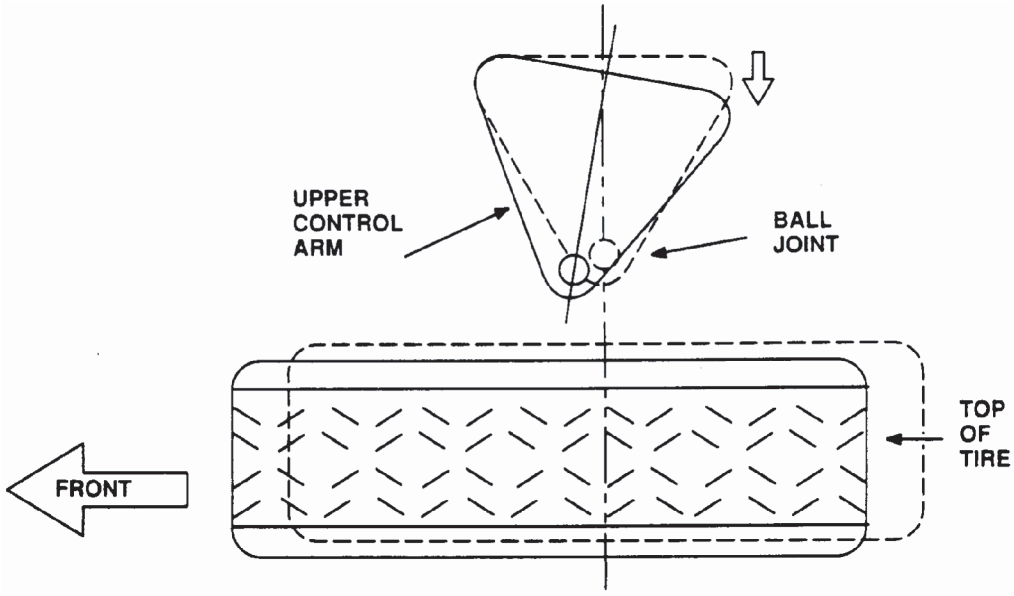


Figure 4-83, Combination Change: +Camber, -Caster

Move the **rear** of the upper control arm **in**.

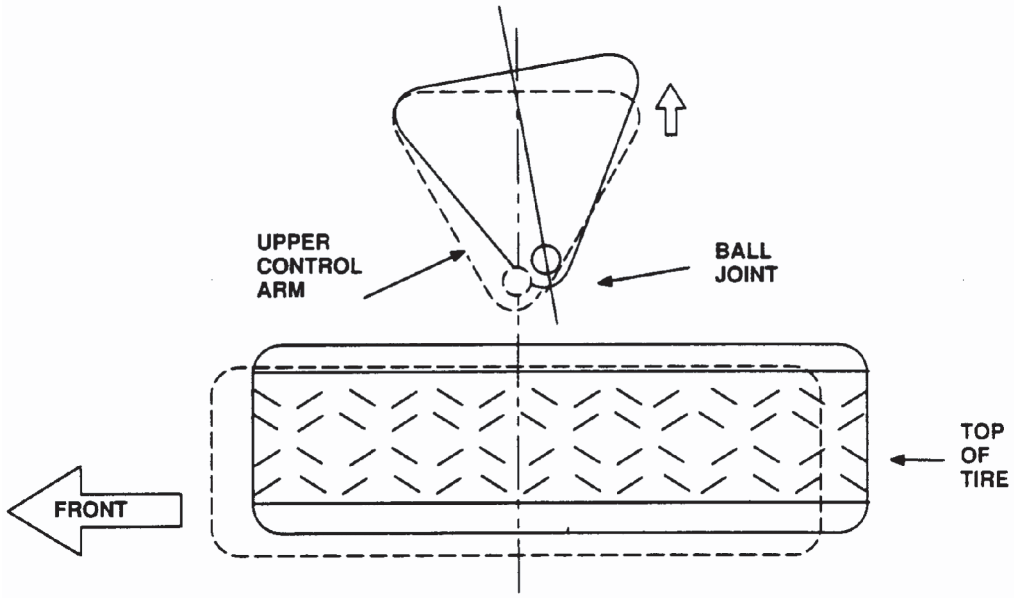


Figure 4-84, Combination Change: -Camber, +Caster

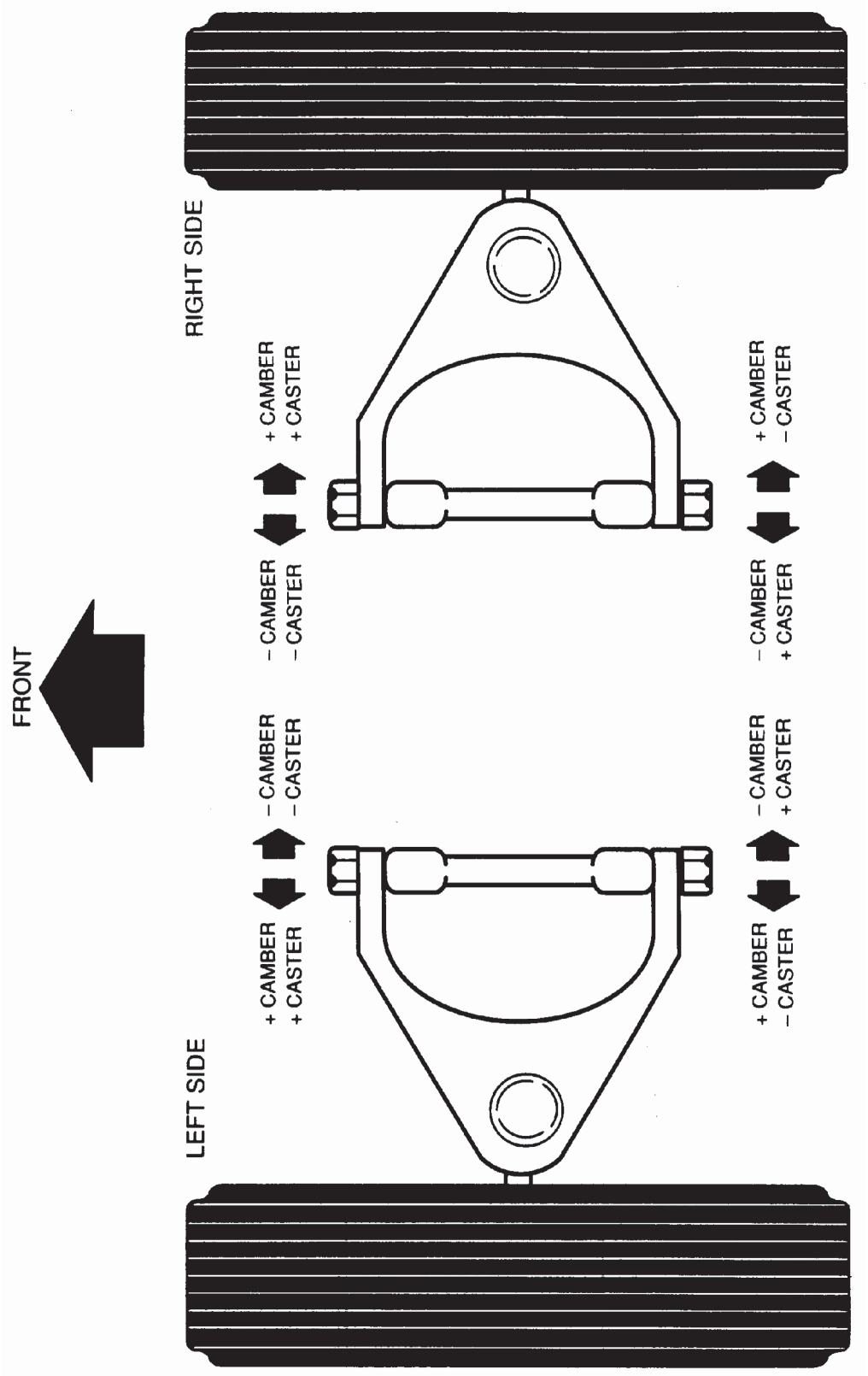


Figure 4-85,

Dual Cam or Slotted Control Arm Adjustment Procedure

Many cars, light trucks, and sport utility vehicles have adjustable control arms. Camber and caster adjustments are made simultaneously by rotating a cam or sliding each end of the control arm one at a time.

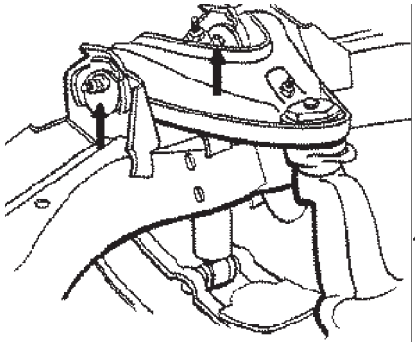


Figure 4-86, Dual Cam Adjustment

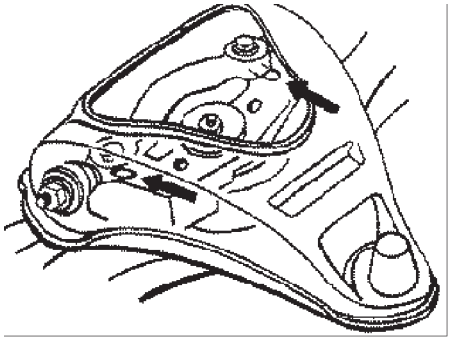
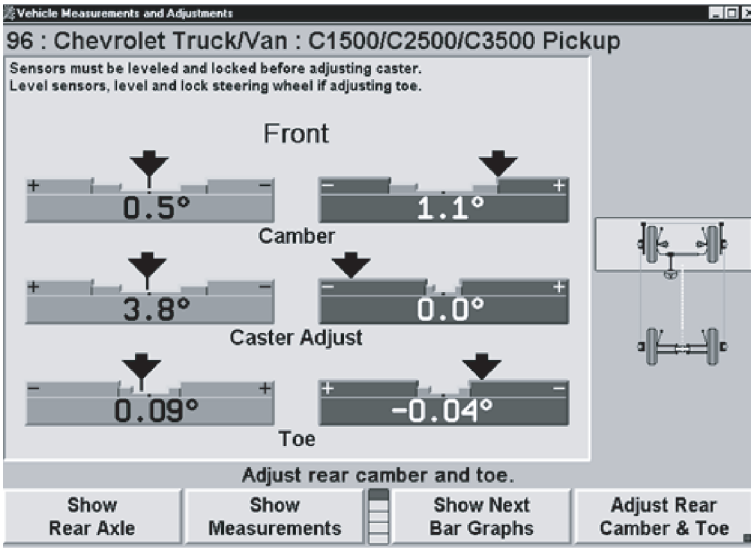


Figure 4-87, Dual Slider Adjustment

Select the adjustment bar graphs for the front wheels.



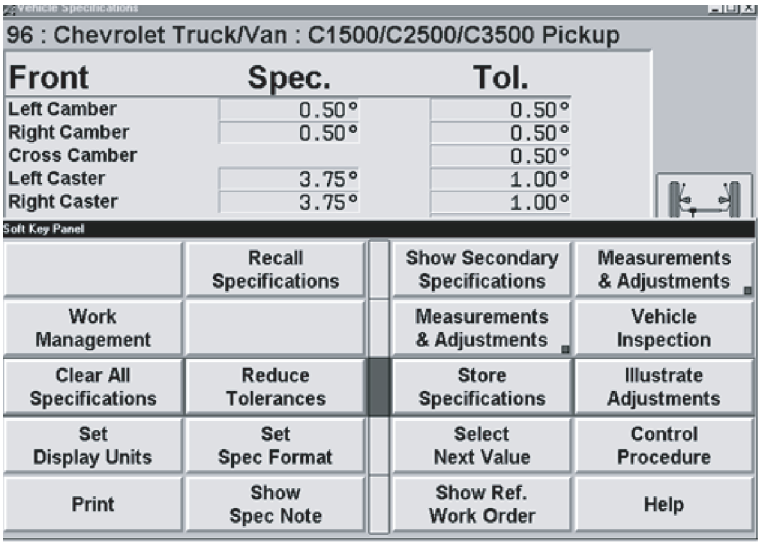
Be sure to apply the front brakes with the pedal depressor then level and lock the front sensors.

Note: Do **NOT** lock the steering wheel!

Adjust camber and caster by following four easy steps:

Step 1 - "Reduce Tolerances"

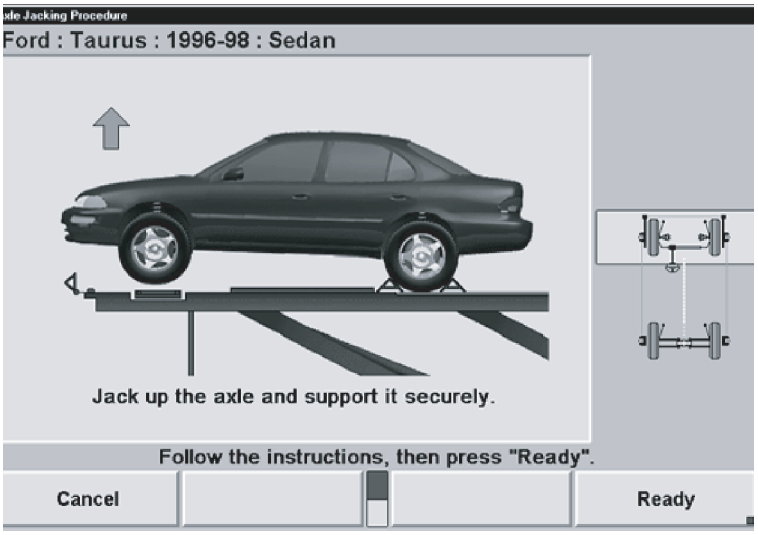
Press the "Reduce Tolerances" button on the "Vehicle Specifications" screen.



Setting the camber tolerance to 0.25° and the caster tolerance to 0.50° makes the camber and caster bar graphs move at the same rate even though caster changes faster than camber.

Step 2 - Jack up the Wheels

Select "Jack Up Selected Axle."

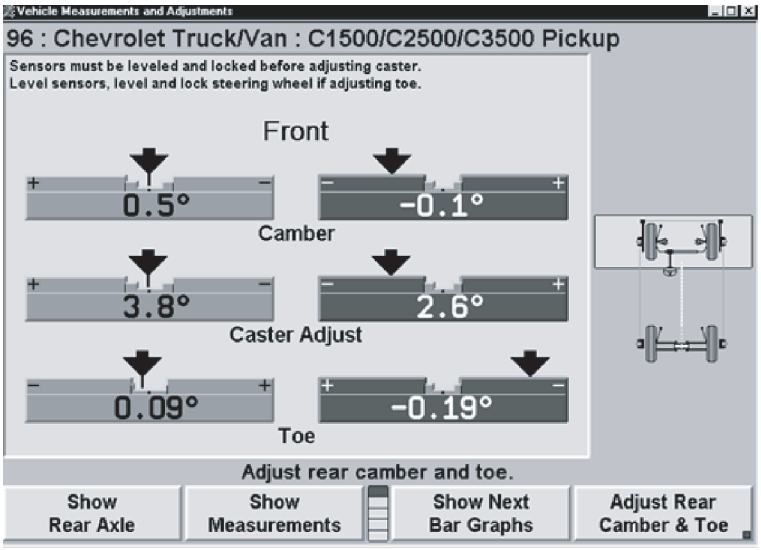


Jack up the vehicle by the lower control arms so the upper control arms can move freely.

Note: Toe dramatically affects camber and caster measurements when the vehicle is in "Jack Up" mode. Simply turn the wheel to keep individual toe on the side you're adjusting less than ± 0.40°

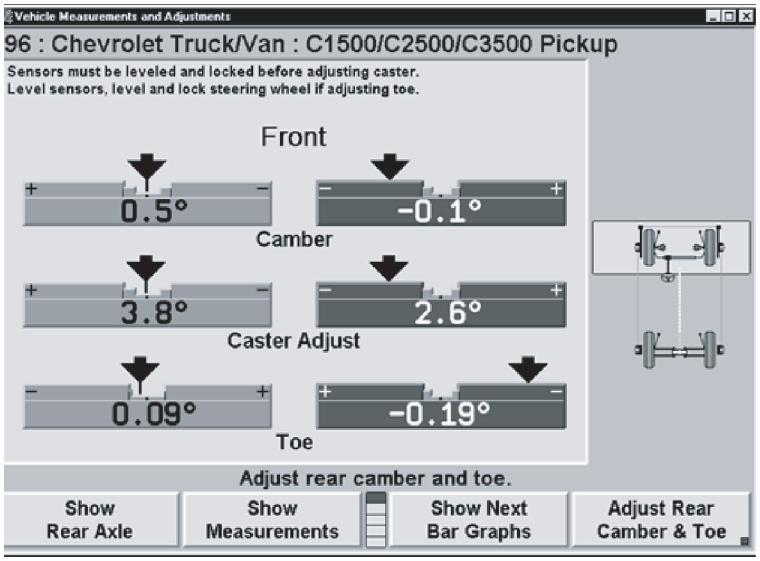
Step 3 - Adjust the Rear.

Move the rear of the control arm-turn the cam or slide the arm-until the camber bar graph's arrow is directly above the caster bar graph's arrow.



Step 4 - Adjust the Front.

Move the front of the control arm-turn the cam or slide the arm-until the camber and caster are in specifications.



General Motors Shim Adjust

Some General Motors passenger cars have shims for adjustment of front wheel camber and caster. The shims are located between the upper control arm pivot shaft and frame.

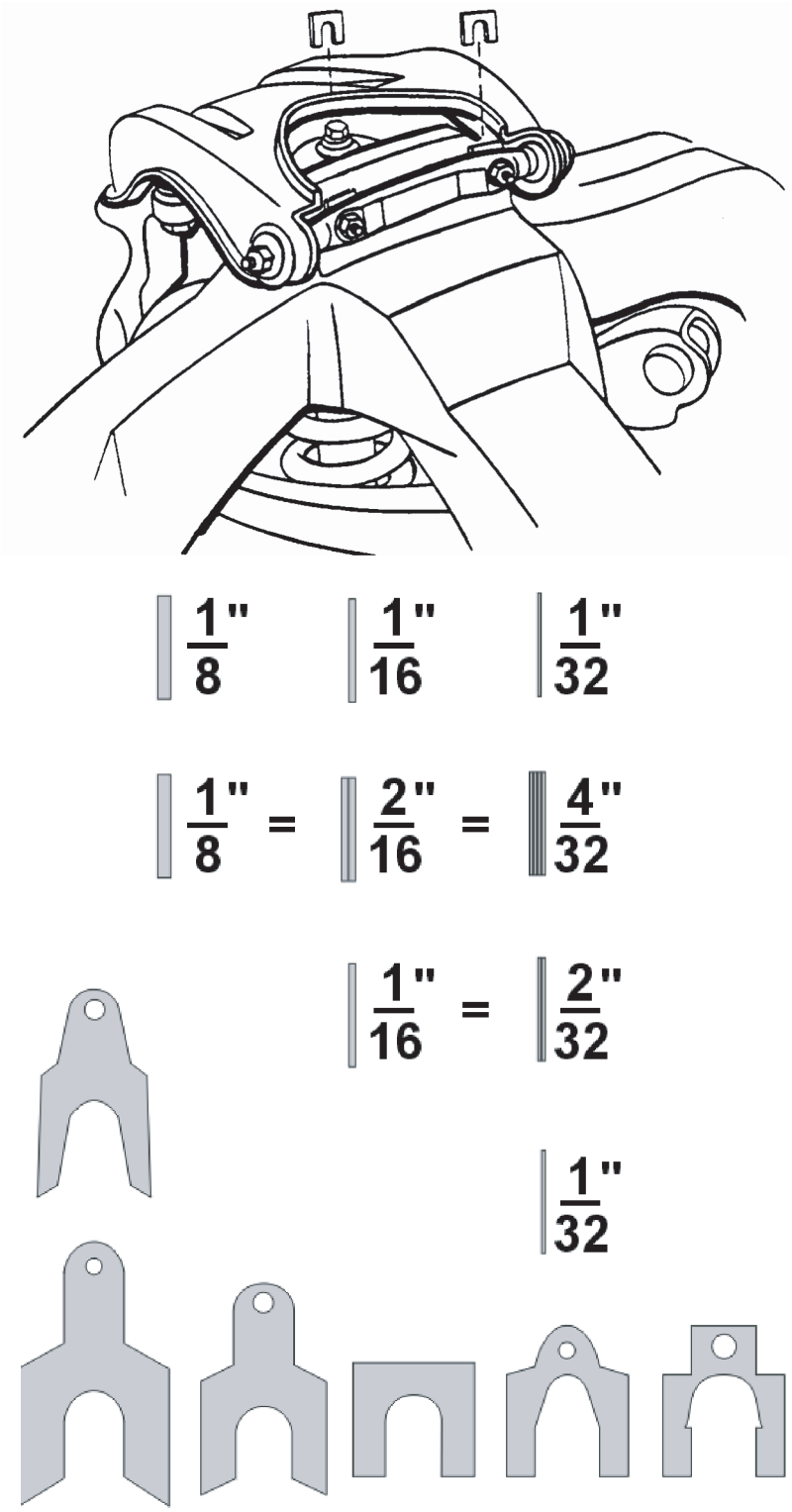


Figure 4-88, Shim Conversion Chart

Positive Camber

Take **shims out** of the **front and rear** equally.

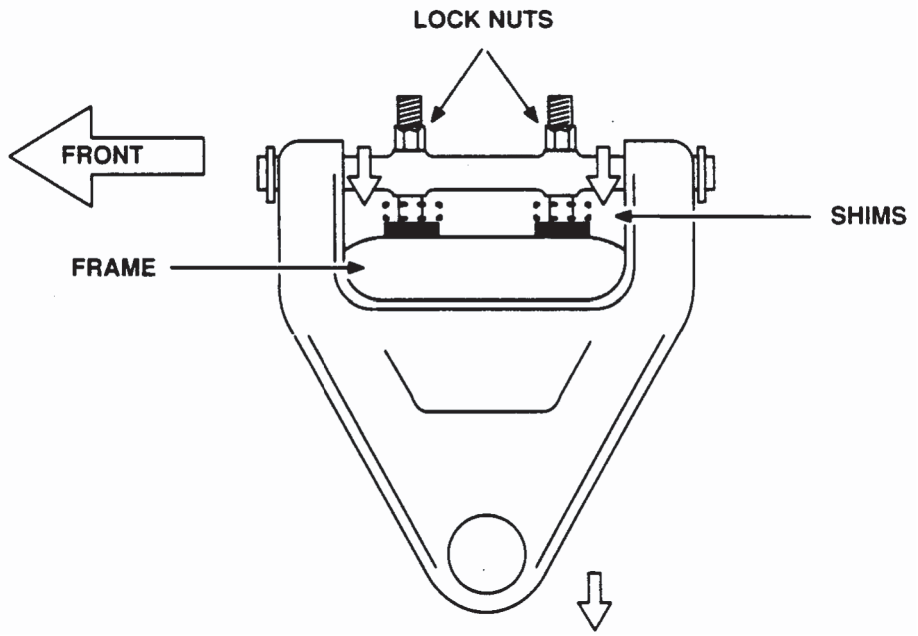


Figure 4-89, Increase Camber: Remove Shims Equally, Front and Rear

Negative Camber

Put **shims** in the **front and rear** equally.

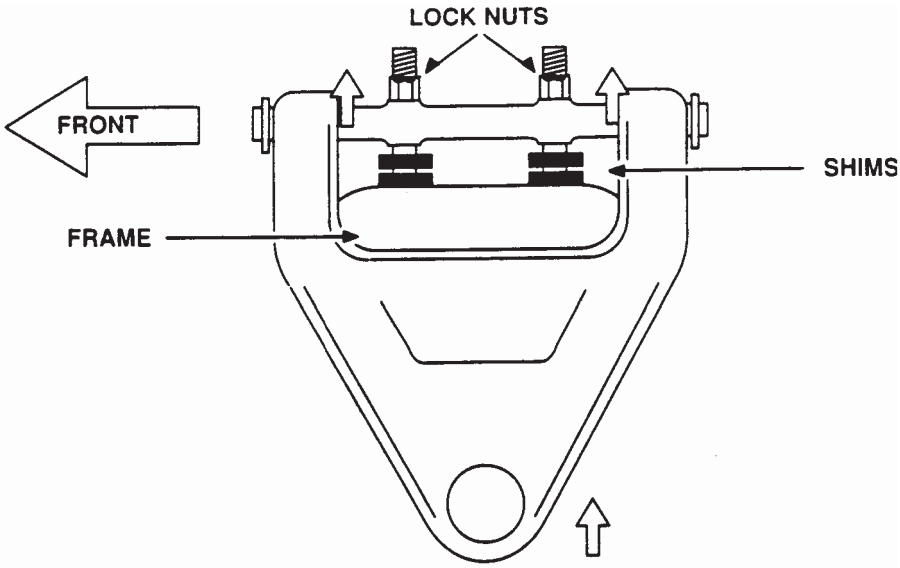


Figure 4-90, Decrease Camber: Add Shims Equally, Front and Rear

Positive Caster

Move shims from the front of the upper control arm to the rear.

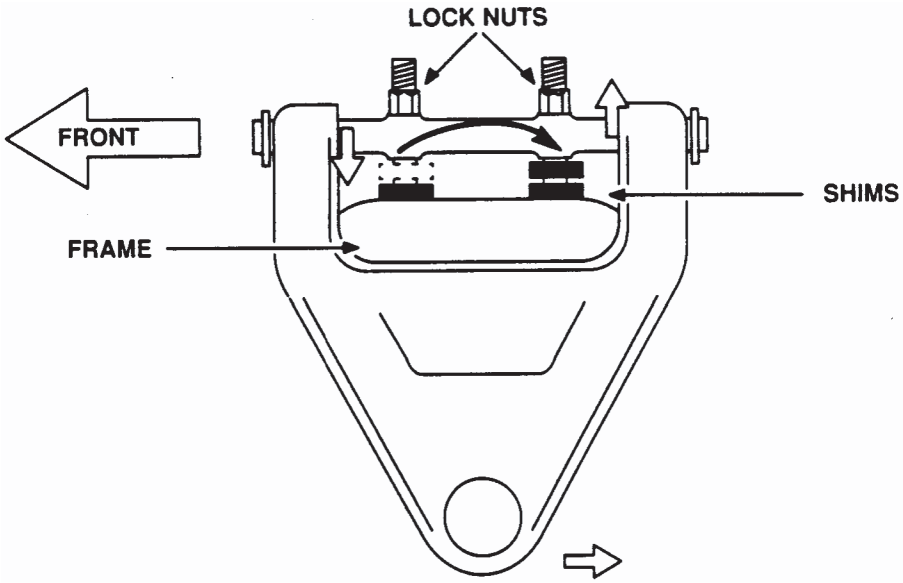


Figure 4-91, Increase Caster: Move Shim Front to Rear

Negative Caster

Move shims from the rear of the upper control arm to the front.

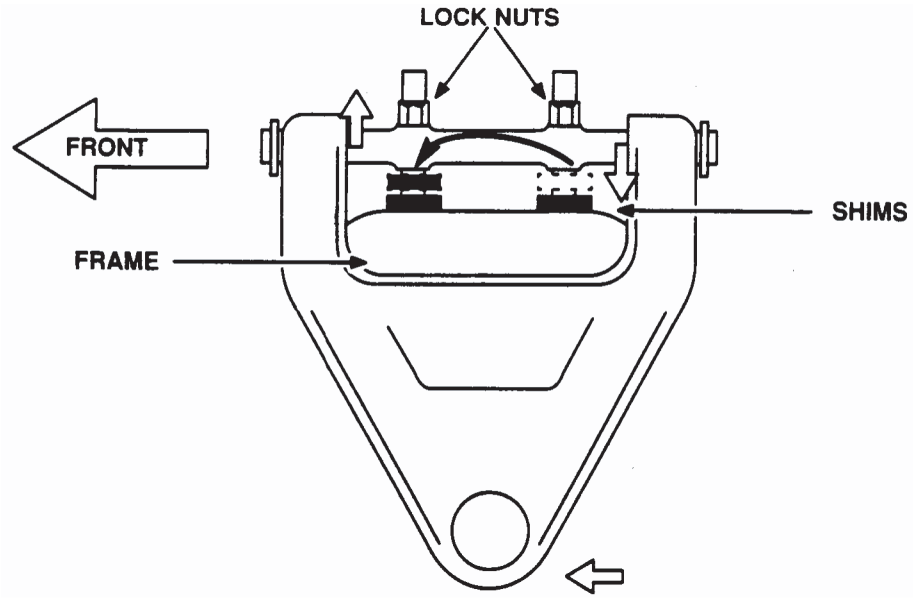
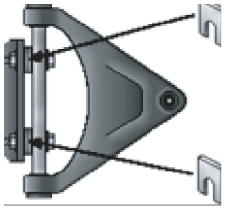


Figure 4-92, Decrease Caster: Move Shim Rear to Front

Front Shim Procedure for Symmetrical Control Arms

Some General Motors passenger cars have shims for adjustment of front camber and caster. The shims are located between the upper control arm pivot shaft and frame.



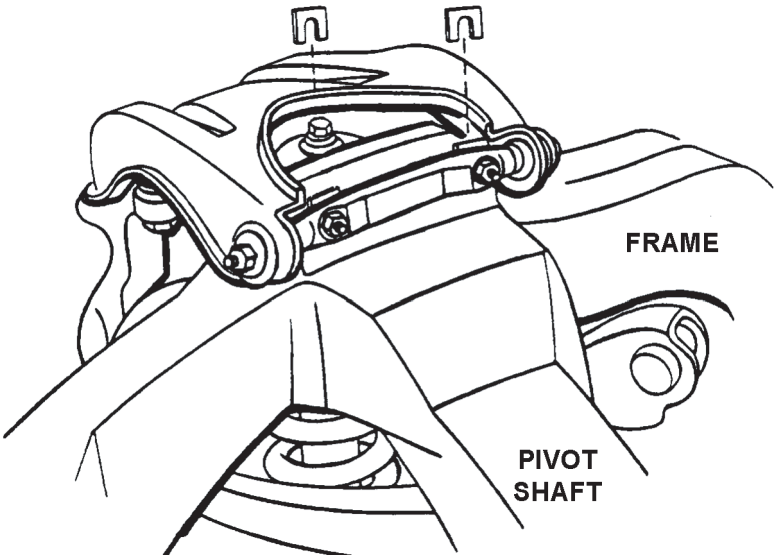
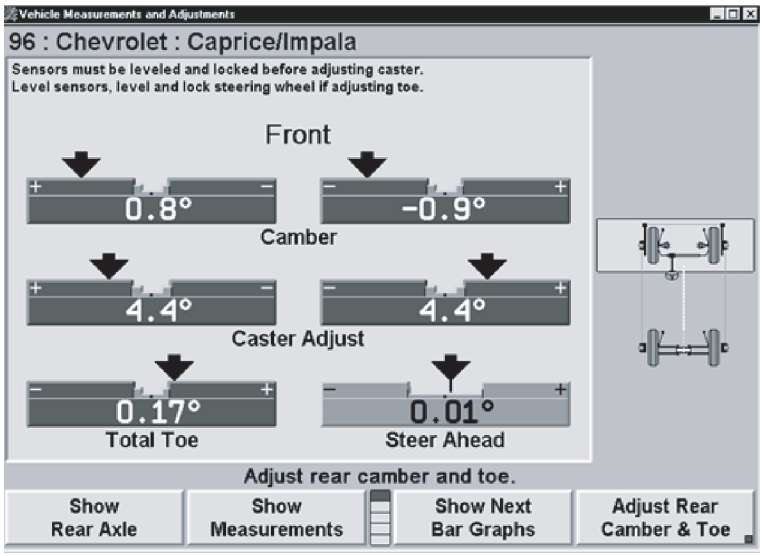


Figure 4-93,

Select the adjustment bar graphs for the front wheels.



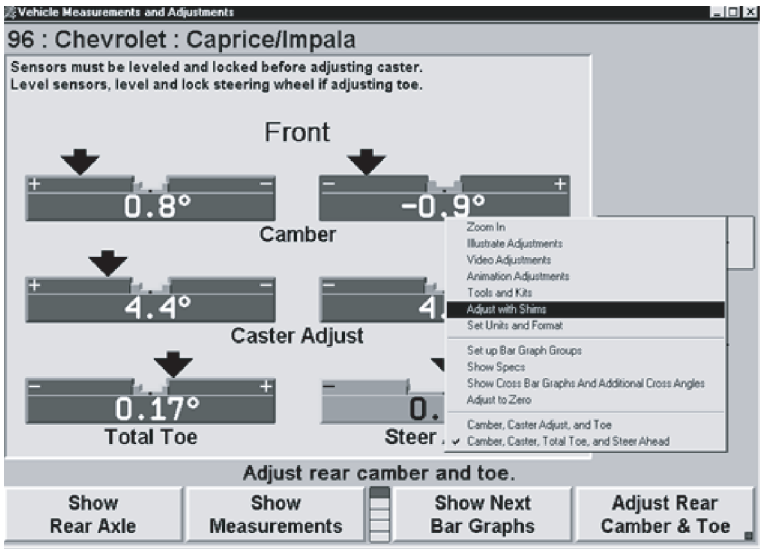
Be sure to apply the front brakes with pedal depressor then level and lock the front sensors.

Note: Do NOT lock the steering wheel!

Step 1 - Select "Adjust with Shims"

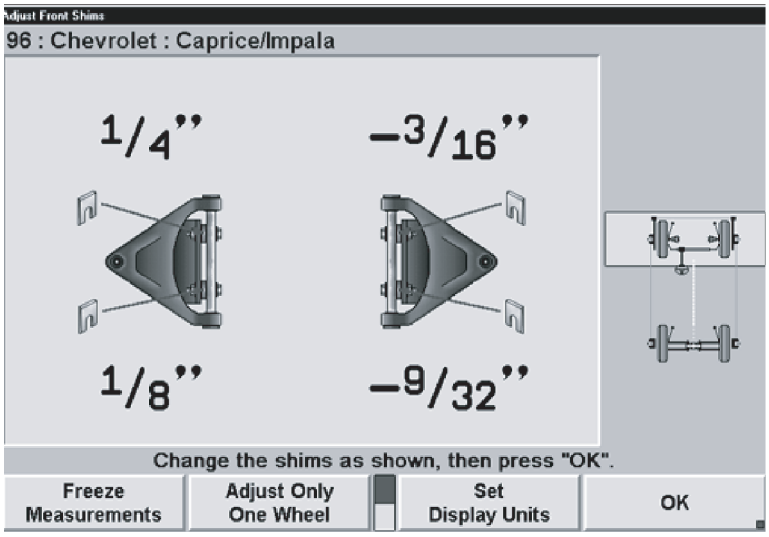
Adjust camber and caster by following two easy steps:

Touch a camber or caster bar graph with the light pen. Choose "Adjust with shims" from the drop down menu.



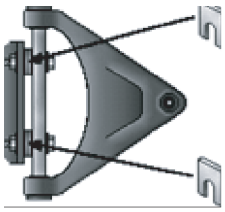
Step 2 - Install or Remove Shims

Press "Freeze Measurements" to save the shim information during adjustment. Add or remove shims as instructed on screen.



Unfreeze measurements after adjustment and remeasure caster to verify camber and caster are in specifications.

Front Shim Worksheet for Symmetrical Control Arms-Inboard Shims



Camber Increase

Change	Front	Rear
+0.3°	Out 1/16"	Out 1/16"
+0.5°	Out 1/8"	Out 1/8"
+0.8°	Out 3/16"	Out 3/16"
+1.0°	Out 2/8"	Out 2/8"
+1.3°	Out 5/16"	Out 5/16"
+1.5°	Out 3/8"	Out 3/8"
+1.8°	Out 5/16"	Out 5/16"
+2.0°	Out 4/8"	Out 4/8"

Camber Decrease

Change	Front	Rear
-0.3°	In 1/16"	In 1/16"
-0.5°	In 1/8"	In 1/8"
-0.8°	In 3/16"	In 3/16"
-1.0°	In 2/8"	In 2/8"
-1.3°	In 5/16"	In 5/16"
-1.5°	In 3/8"	In 3/8"
-1.8°	In 5/16"	In 5/16"
-2.0°	In 4/8"	In 4/8"

Caster Increase

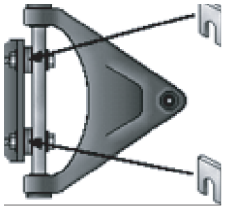
Change	Front	Rear
+0.3°		In 1/32"
+0.5°	Out 1/32"	In 1/32"
+0.8°	Out 1/32"	In 1/16"
+1.0°	Out 1/16"	In 1/16"
+1.3°	Out 1/16"	In 3/32"
+1.5°	Out 3/32"	In 3/32"
+1.8°	Out 3/32"	In 1/8"
+2.0°	Out 1/8"	In 1/8"

Caster Decrease

Change	Front	Rear
-0.3°	In 1/32"	
-0.5°	In 1/32"	Out 1/32"
-0.8°	In 1/16"	Out 1/32"
-1.0°	In 1/16"	Out 1/16"
-1.3°	In 3/32"	Out 1/16"
-1.5°	In 3/32"	Out 3/32"
-1.8°	In 1/8"	Out 3/32"
-2.0°	In 1/8"	Out 1/8"

	Desired Change	Front	Rear
Camber			
Caster			
	Total Move		

Front Shim Worksheet for Symmetrical Control Arms-Outboard Shims (Nissan)



Camber Increase

Change	Front	Rear
+0.25°	In 1/32"	In 1/32"
+0.40°	In 1/16"	In 1/16"
+0.55°	In 3/32"	In 3/32"
+0.75°	In 1/8"	In 1/8"
+0.95°	In 5/32"	In 5/32"
+1.15°	In 3/16"	In 3/16"
+1.30°	In 7/32"	In 7/32"
+1.50°	In 2/8"	In 2/8"
+1.70°	In 9/32"	In 9/32"
+1.90°	In 5/16"	In 5/16"

Camber Decrease

Change	Front	Rear
-0.25°	Out 1/32"	Out 1/32"
-0.40°	Out 1/16"	Out 1/16"
-0.55°	Out 3/32"	Out 3/32"
-0.75°	Out 1/8"	Out 1/8"
-0.95°	Out 5/32"	Out 5/32"
-1.15°	Out 3/16"	Out 3/16"
-1.30°	Out 7/32"	Out 7/32"
-0.75°	Out 2/8"	Out 2/8"
-0.55°	Out 9/32"	Out 9/32"
-1.90°	Out 5/16"	Out 5/16"

Caster Increase

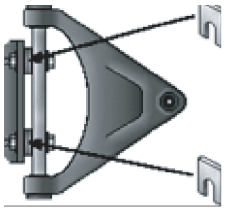
Change	Front	Rear
+0.35°	In 1/32"	
+0.70°	In 1/32"	Out 1/32"
+1.05°	In 1/16"	Out 1/32"
+1.40°	In 1/16"	Out 1/16"
+1.75°	In 3/32"	Out 3/32"
+2.10°	In 1/8"	Out 1/8"

Caster Decrease

Change	Front	Rear
-0.35°		In 1/32"
-0.70°	Out 1/32"	In 1/32"
-1.05°	Out 1/32"	In 1/16"
-1.40°	Out 1/16"	In 1/16"
-1.75°	Out 3/32"	In 3/32"
-2.10°	Out 1/8"	In 1/8"

	Desired Change	Front	Rear
Camber			
Caster			
	Total Move		

Front Shim Procedure for Nonsymmetrical Control Arms



General Motors light trucks manufactured before 1988 had shims placed outside the frame.

Convex Washer and Shim Placement

Make sure the **convex washer** and **shims** are placed properly when making a camber or caster change.

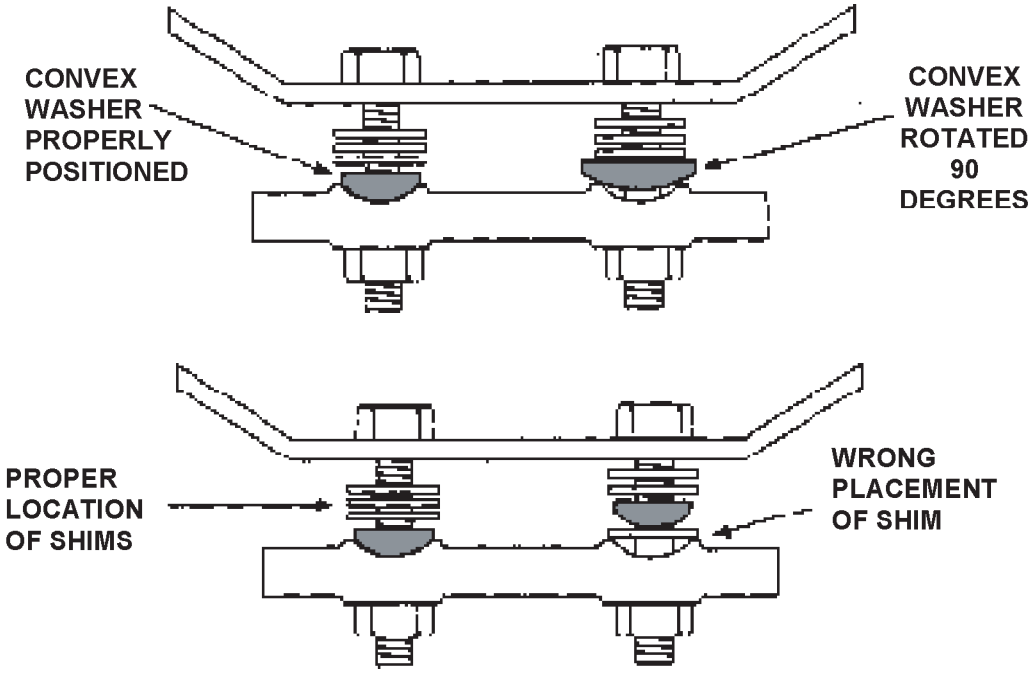
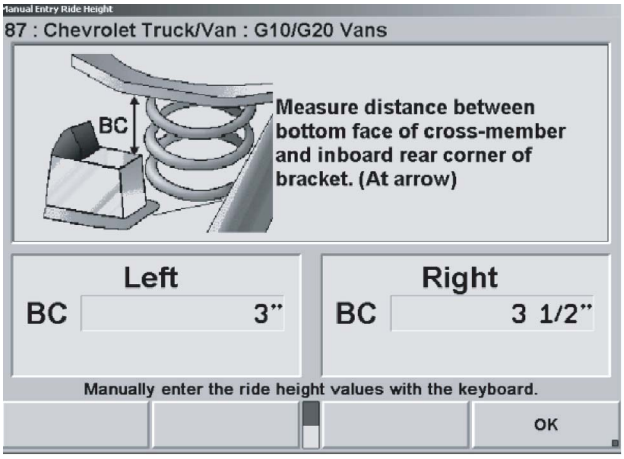


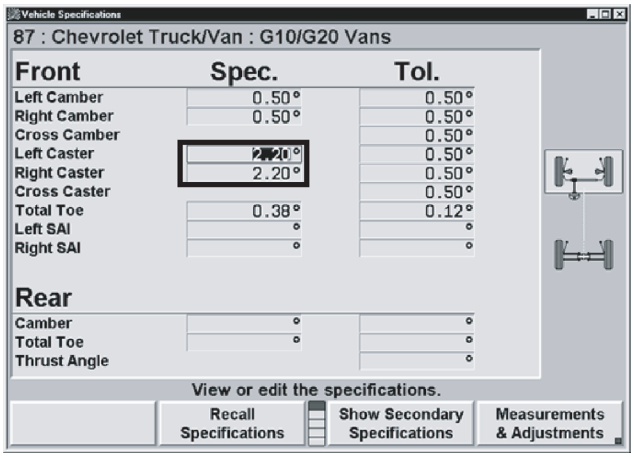
Figure 4-94, General Motors Light Truck Convex Washer and Shims

Step 1 - Enter Ride Height

Caster specifications vary with vehicle ride height. Measure the ride height with a tape measure and enter it on this screen.



The aligner will now add caster specifications to the specifications screen.

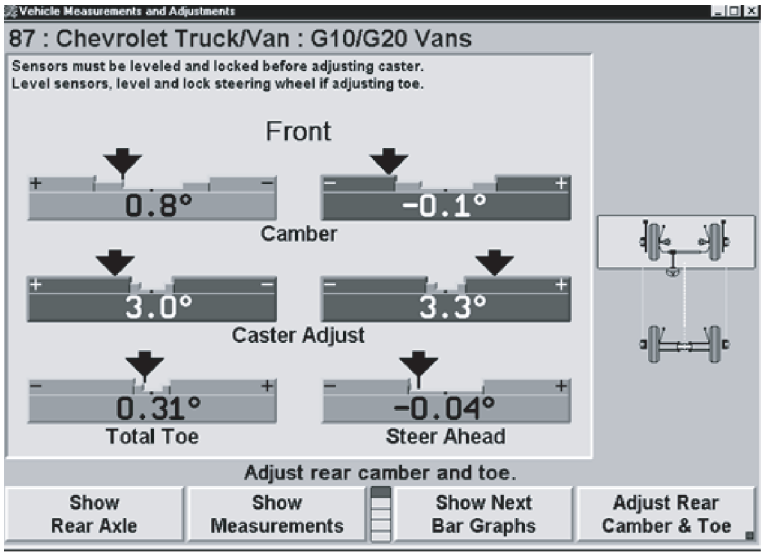


111 Users: Look up the caster specification on the chart below and type it onto your specifications screen.

Caster Chart

Dimension "A" (in.)	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"
Dimension "A" (mm.)	38	45	51	57	64	70	76	83	89	95	102	108	114	121	127
1983-86 C10/1500					3.7°	3.5°	3.2°	2.9°	2.6°	2.4°	2.1°	1.8°	1.5°	1.3°	1.0°
1983-86 C20/C30, C2500,3500					1.5°	1.2°	0.9°	0.6°	0.3°	0.1°	0°	-0.2°	-0.7°	-1.0°	-1.2°
1987-91 R10/1500					3.7°	3.5°	3.2°	2.9°	2.6°	2.4°	2.1°	1.8°	1.5°	1.3°	1.0°
1987-91 R20/R30, R2500/R3500					1.5°	1.2°	0.9°	0.6°	0.3°	0.1°	0°	-0.2°	-0.7°	-1.0°	-1.2°
1983-91 Suburban 10/1500					3.7°	3.5°	3.2°	2.9°	2.6°	2.4°	2.1°	1.8°	1.5°	1.3°	1.0°
1983-91 Suburban 20/2500					1.5°	1.2°	0.9°	0.6°	0.3°	0.1°	0°	-0.2°	-0.7°	-1.0°	-1.2°
1983-84 G10/G20	3.5°	3.3°	3.1°	2.9°	2.7°	2.5°	2.4°	2.2°	2.1°	1.9°	1.8°	1.6			
1983-84 G30	2.8°	2.5°	2.2°	1.9°	1.6°	1.3°	1.0°	0.7°	0.5°	0.2°	0.0°	-0.2			
1985-93 G10/G20	3.4°	3.2°	3.0°	2.8°	2.7°	2.5°	2.3°	2.2°	2.0°	1.8°	1.7°	1.5°	1.4°	1.3°	1.2°
1985-93 G30	3.1°	3.0°	2.7°	2.4°	2.1°	1.8°	1.5°	1.2°	1.0°	0.7°	0.5°	0.2°	0°	-0.2°	-0.5°
1994-95 G10/G20	5.4°	5.2°	5.0°	4.9°	4.7°	4.5°	4.3°	4.2°	4.0°	3.8°	3.7°	3.5°	3.4°	3.3°	3.2°
1994-95 G30	5.1°	5.0°	4.7°	4.4°	4.1°	3.8°	3.5°	3.2°	3.0°	2.7°	2.5°	2.2°	2.0°	1.8°	1.5°

Select the adjustment bar graphs for the front wheels.

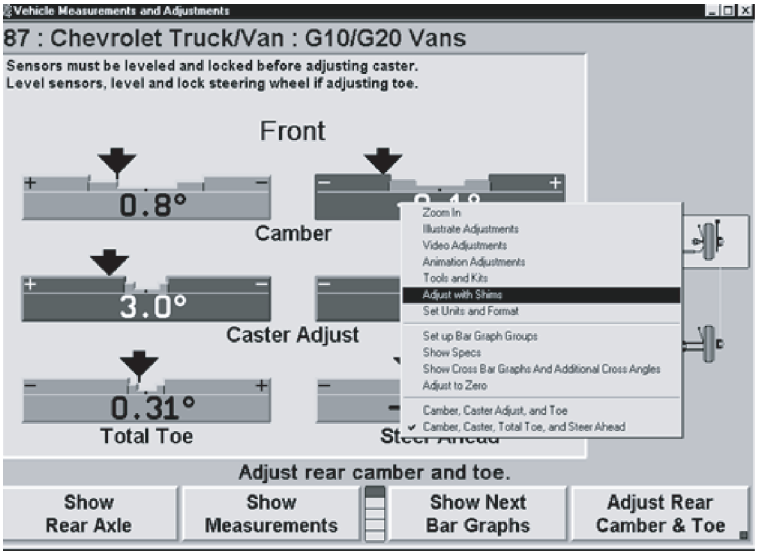


Be sure to apply the front brakes with the pedal depressor then level and lock the front sensors.

Note: Do **NOT** lock the steering wheel!

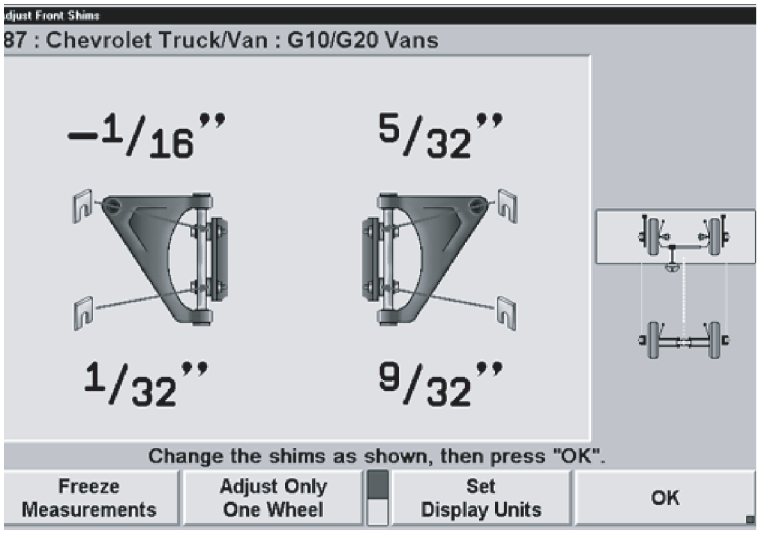
Step 2 - Select "Adjust with Shims"

Touch a camber or caster bar graph with the light pen. Choose "Adjust with shims" from the drop down menu.



Step 3 - Install or Remove Shims

Press "Freeze Measurements" to save the shim information during adjustment. Add or remove shims as instructed on screen.



Unfreeze measurements after adjustment and remeasure caster to verify camber and caster are in specifications.

111 Users: Use the chart below to calculate the shim changes needed.

Camber Increase

Change	Front	Rear
+0.3°	In 1/16"	In 1/16"
+0.5°	In 1/8"	In 1/8"
+0.8°	In 3/16"	In 3/16"
+1.0°	In 2/8"	In 2/8"
+1.3°	In 5/16"	In 5/16"
+1.5°	In 3/8"	In 3/8"
+1.8°	In 5/16"	In 5/16"
+2.0°	In 4/8"	In 4/8"

Camber Decrease

Change	Front	Rear
-0.3°	Out 1/16"	Out 1/16"
-0.5°	Out 1/8"	Out 1/8"
-0.8°	Out 3/16"	Out 3/16"
-1.0°	Out 2/8"	Out 2/8"
-1.3°	Out 5/16"	Out 5/16"
-1.5°	Out 3/8"	Out 3/8"
-1.8°	Out 5/16"	Out 5/16"
-2.0°	Out 4/8"	Out 4/8"

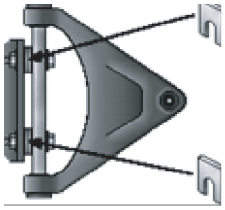
Caster Increase

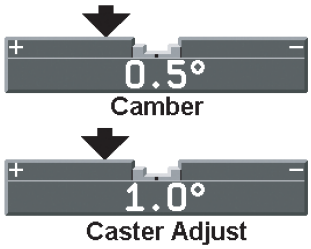
Change	Front	Rear
+0.3°		Out 1/32"
+0.5°		Out 1/16"
+0.8°		Out 3/32"
+1.0°		Out 1/8"
+1.3°		Out 5/32"
+1.5°		Out 3/16"
+1.8°		Out 7/32"
+2.0°		Out 2/8"

Caster Decrease

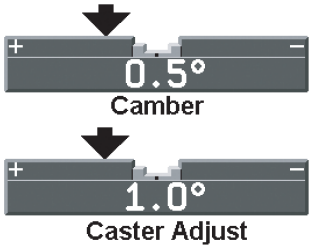
Change	Front	Rear
-0.3°		In 1/32"
-0.5°		In 1/16"
-0.8°		In 3/32"
-1.0°		In 1/8"
-1.3°		In 5/32"
-1.5°		In 3/16"
-1.8°		In 7/32"
-2.0°		In 2/8"

Front Shim Worksheet for Nonsymmetrical Control Arms

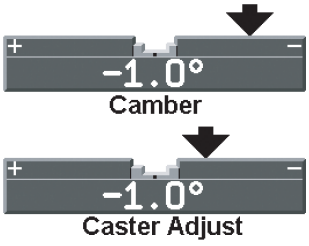




	Desired Change	Front	Rear
Camber			
Caster			
	Total Move		



	Desired Change	Front	Rear
Camber			
Caster			
	Total Move		



	Desired Change	Front	Rear
Camber			
Caster			
	Total Move		

Camber Increase

Change	Front	Rear
+0.3°	In 1/16"	In 1/16"
+0.5°	In 1/8"	In 1/8"
+0.8°	In 3/16"	In 3/16"
+1.0°	In 2/8"	In 2/8"
+1.3°	In 5/16"	In 5/16"
+1.5°	In 3/8"	In 3/8"
+1.8°	In 5/16"	In 5/16"
+2.0°	In 4/8"	In 4/8"

Camber Decrease

Change	Front	Rear
-0.3°	Out 1/16"	Out 1/16"
-0.5°	Out 1/8"	Out 1/8"
-0.8°	Out 3/16"	Out 3/16"
-1.0°	Out 2/8"	Out 2/8"
-1.3°	Out 5/16"	Out 5/16"
-1.5°	Out 3/8"	Out 3/8"
-1.8°	Out 5/16"	Out 5/16"
-2.0°	Out 4/8"	Out 4/8"

Caster Increase

Change	Front	Rear
+0.3°		Out 1/32"
+0.5°		Out 1/16"
+0.8°		Out 3/32"
+1.0°		Out 1/8"
+1.3°		Out 5/32"
+1.5°		Out 3/16"
+1.8°		Out 7/32"
+2.0°		Out 2/8"

Caster Decrease

Change	Front	Rear
-0.3°		In 1/32"
-0.5°		In 1/16"
-0.8°		In 3/32"
-1.0°		In 1/8"
-1.3°		In 5/32"
-1.5°		In 3/16"
-1.8°		In 7/32"
-2.0°		In 2/8"

	Desired Change	Front	Rear
Camber			
Caster			
	Total Move		

Caster Chart for GM Light Trucks

Dimension "A" (in.)	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"
Dimension "A" (mm.)	38	45	51	57	64	70	76	83	89	95	102	108	114	121	127
1983-86 C10/1500					3.7°	3.5°	3.2°	2.9°	2.6°	2.4°	2.1°	1.8°	1.5°	1.3°	1.0°
1983-86 C20/C30, C2500,3500					1.5°	1.2°	0.9°	0.6°	0.3°	0.1°	0°	-0.2°	-0.7°	-1.0°	-1.2°
1987-91 R10/1500					3.7°	3.5°	3.2°	2.9°	2.6°	2.4°	2.1°	1.8°	1.5°	1.3°	1.0°
1987-91 R20/R30, R2500/R3500					1.5°	1.2°	0.9°	0.6°	0.3°	0.1°	0°	-0.2°	-0.7°	-1.0°	-1.2°
1983-91 Suburban 10/1500					3.7°	3.5°	3.2°	2.9°	2.6°	2.4°	2.1°	1.8°	1.5°	1.3°	1.0°
1983-91 Suburban 20/2500					1.5°	1.2°	0.9°	0.6°	0.3°	0.1°	0°	-0.2°	-0.7°	-1.0°	-1.2°
1983-84 G10/G20	3.5°	3.3°	3.1°	2.9°	2.7°	2.5°	2.4°	2.2°	2.1°	1.9°	1.8°	1.6			
1983-84 G30	2.8°	2.5°	2.2°	1.9°	1.6°	1.3°	1.0°	0.7°	0.5°	0.2°	0.0°	-0.2			
1985-93 G10/G20	3.4°	3.2°	3.0°	2.8°	2.7°	2.5°	2.3°	2.2°	2.0°	1.8°	1.7°	1.5°	1.4°	1.3°	1.2°
1985-93 G30	3.1°	3.0°	2.7°	2.4°	2.1°	1.8°	1.5°	1.2°	1.0°	0.7°	0.5°	0.2°	0°	-0.2°	-0.5°
1994-95 G10/G20	5.4°	5.2°	5.0°	4.9°	4.7°	4.5°	4.3°	4.2°	4.0°	3.8°	3.7°	3.5°	3.4°	3.3°	3.2°
1994-95 G30	5.1°	5.0°	4.7°	4.4°	4.1°	3.8°	3.5°	3.2°	3.0°	2.7°	2.5°	2.2°	2.0°	1.8°	1.5°

Front Shim Worksheet

95 Chevrolet Impala-Left side

1.	Reading	Spec.	Change	Front	Rear
Camber	-0.3°				
Caster	2.5°				
			Total Move		

94 Nissan Pathfinder 4X4

2.	Reading	Spec.	Change	Front	Rear
Camber	0.0°				
Caster	3.6°				
			Total Move		

86 Chevy C10 Pickup with 3" ride height and 1.2° frame angle

3.	Reading	Spec.	Change	Front	Rear
Camber	0.2°				
Caster	1.0°				
			Total Move		

85 Olds Delta 88

4.	Reading	Spec.	Change	Front	Rear
Camber	-0.7°				
Caster	2.5°				
			Total Move		

Aftermarket Kits and Procedures

Rear Shims

Full contact shims may be used for rear adjustments on front-wheel drive General Motors, Chrysler, and some import vehicles.

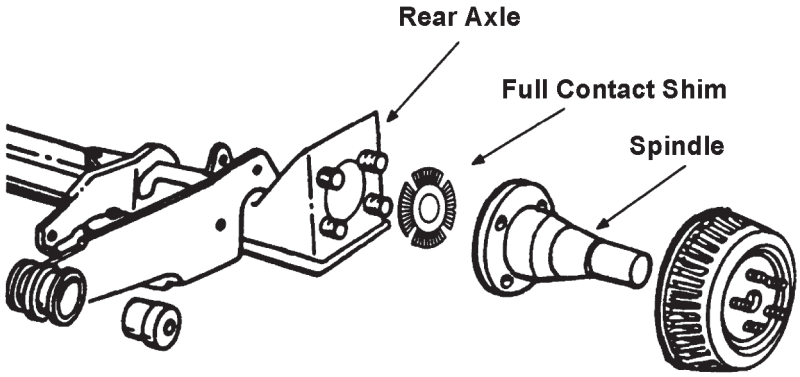


Figure 4-95, Rear Shims

Placement of the shim determines changes in camber, toe or a combination of both.

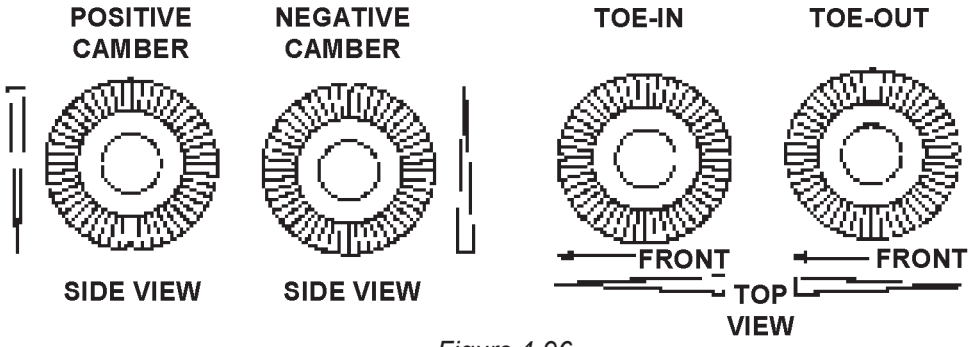


Figure 4-96,

Shim-Select II

The Shim-Select II program can provide assistance in determining the correct full-contact shim and the proper positioning of that shim for the required adjustments.

Press "Make Additional Adjustment," on the "Vehicle Measurements and Adjustments" primary screen. The "Additional Adjustments" pop-up screen will appear.

If necessary, press "Select Rear Axle" to select the rear axle. The available adjustments for the rear axle of the current vehicle are shown.

Select "Adjust camber and toe with full contact shims" (this may be the only selection available), then press "OK." The "Adjust Rear Shim (Shim-Select II)" pop-up screen will appear.

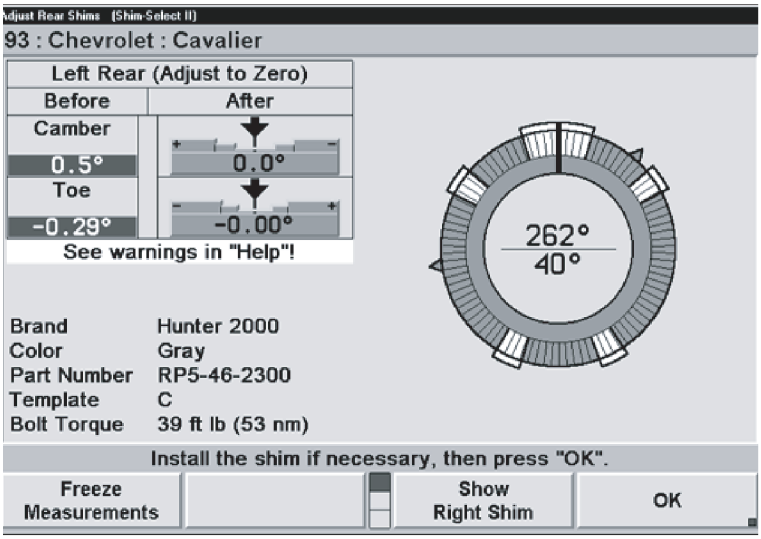


Figure 4-97, Shim-Select II Pop-Up Screen

The screen opens showing the shim requirements for the left rear wheel. Press "Show Right Shim" to toggle to the right wheel, and then "Show Left Shim" to toggle back to the left shim.

The changes required in camber and toe are shown in the "Before" column at the upper left. For example, a change of "0.6°" for camber means "camber must be made 0.6° more positive."

The "After" column at the upper left shows the residual errors that will remain in camber and toe after installing the shim. These residual values are shown in bar graph form so that the quality of the adjustments can be quickly gauged.

The shim required to make the changes is illustrated at the right. In the center of the shim is the size and orientation angle required.

Right Rear (Adjust to Zero)

Before

Camber	0.6°
Toe	-0.43°

After

Camber	0.0°
Toe	0.00°

Shim Required

Brand	Hunter 2000
Color	Gray
Part Number	RP5-46-2300
Template	C
Bolt Torque	37 ft lb (50 nm)

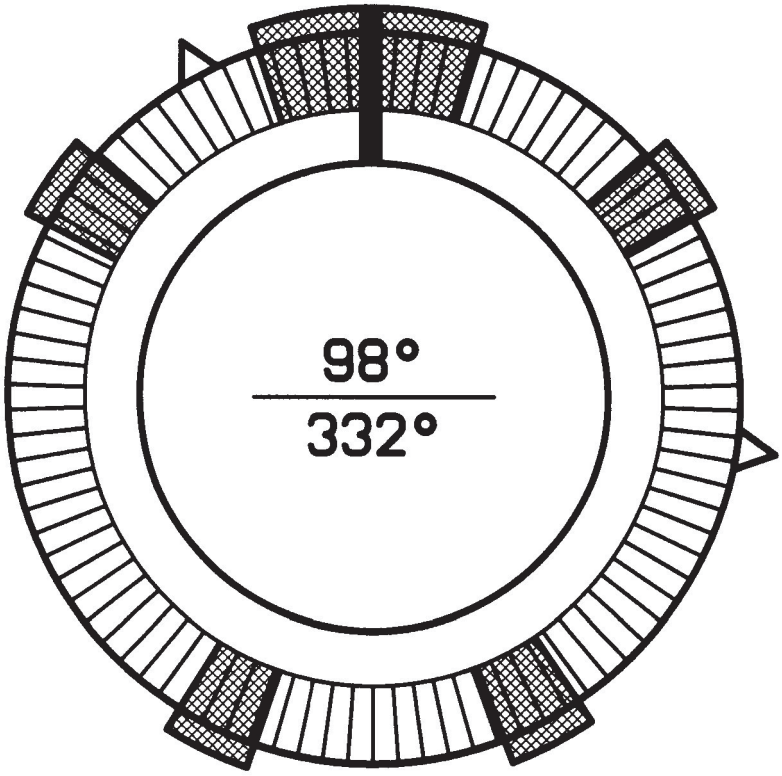


Figure 4-98,

Right Rear (Adjust to Zero)

Before

Camber	0.6°
Toe	-0.43°

After

Camber	0.0°
Toe	0.00°

Shim Required

Brand	Hunter
Color	Gray
Part Number	RP5-46-1203
Template	C
Bolt Torque	37 ft lb (50 nm)

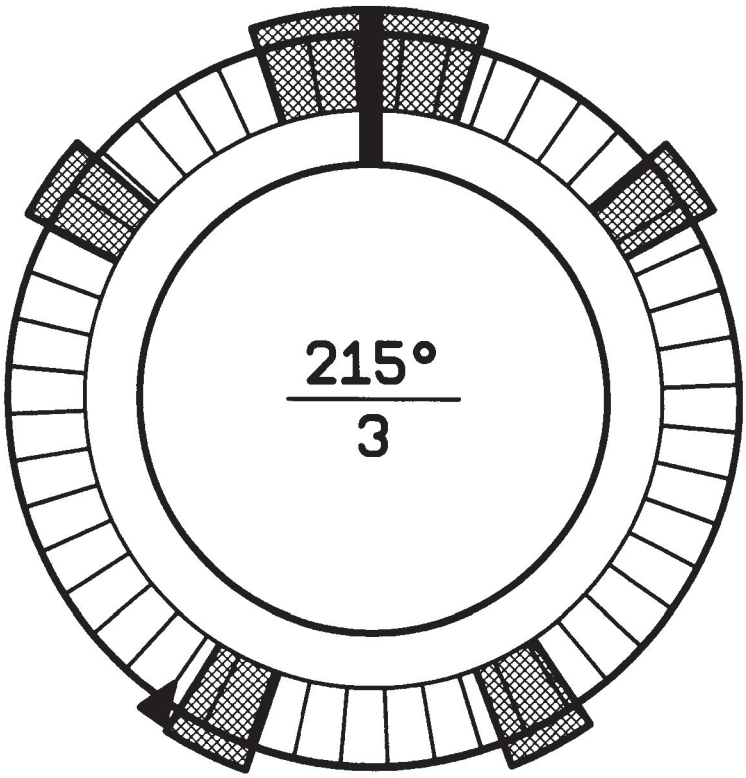


Figure 4-99,

Ford Twin-I-beam

Ford has three different Twin-I-beam axle designs:

- Forged
- Stamped axle
- Cast axle

The forged axle has king pins.

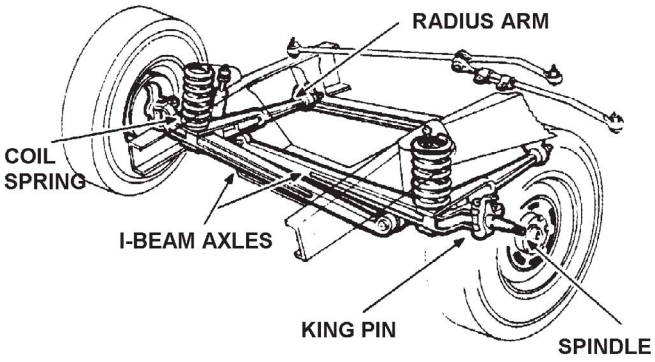


Figure 4-100, Twin-I-Beam Axle

The forged axle is the only Twin-I-beam axle that can be realigned using hydraulic bending equipment to correct camber (with the exception of the Ford Ranger).

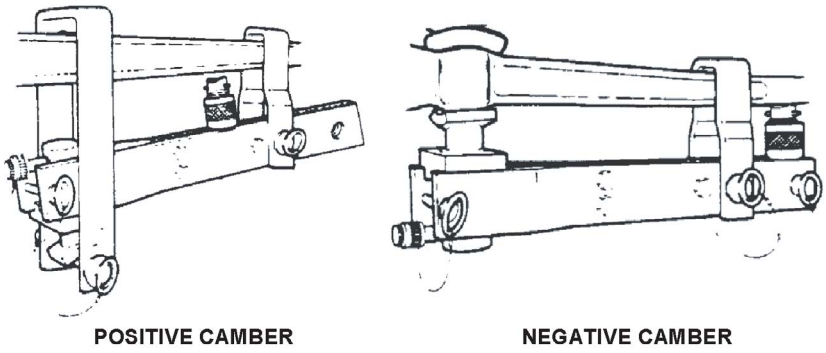


Figure 4-101, Forged Axle

A stamped axle or cast axle uses upper and lower ball joints.

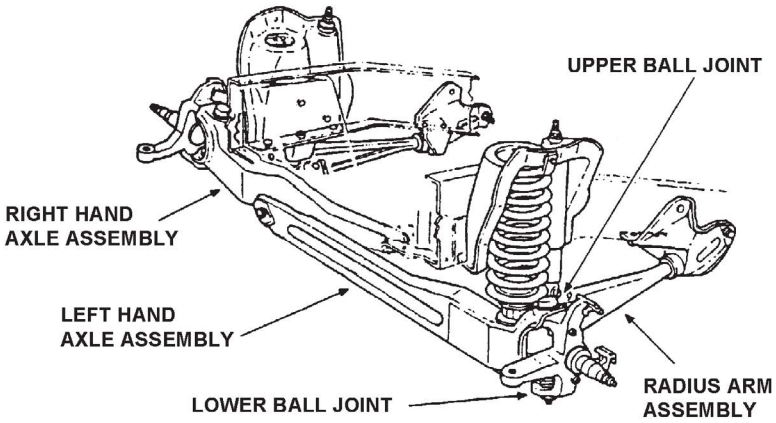


Figure 4-102, Stamped/Cast Axle

Camber can be changed on a stamped or cast axle by replacing an eccentric bushing at the upper ball joint ('82-'86 4x2 trucks).

Camber and caster can be changed on a stamped or cast axle by replacing an eccentric bushing at the upper ball joint ('87 and newer 4x2 trucks, '82 and newer 4x4 trucks).

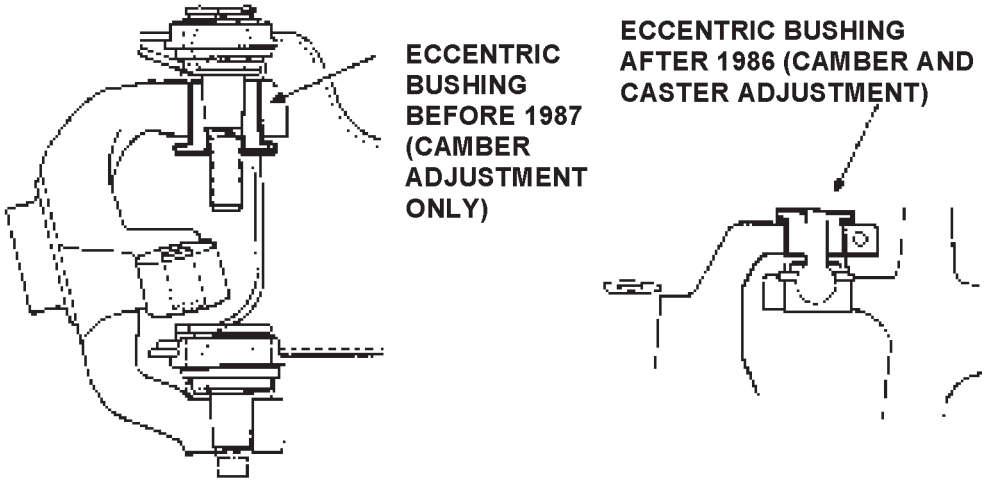


Figure 4-103, Eccentric Bushing

1988 and earlier Ford truck specifications are based on a ride height measurement.

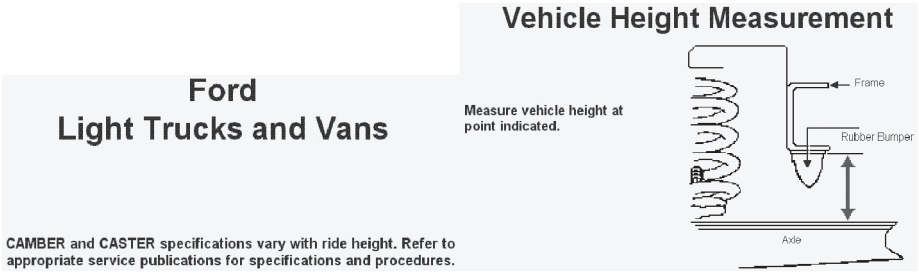
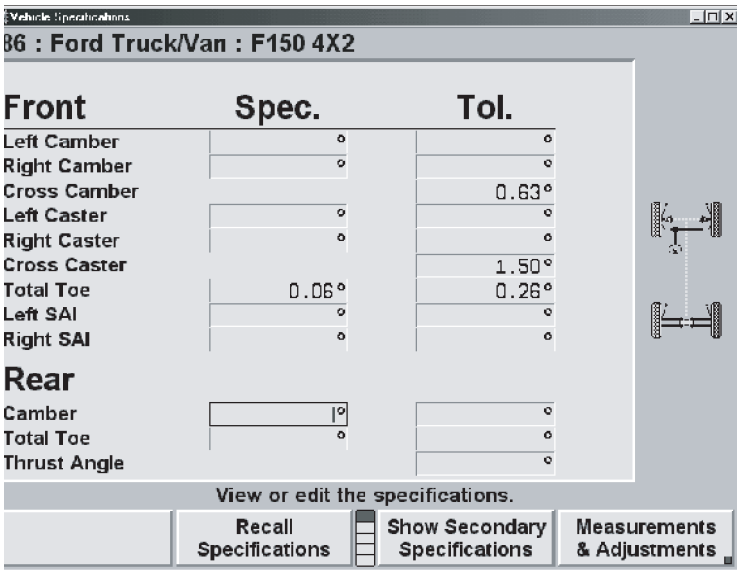
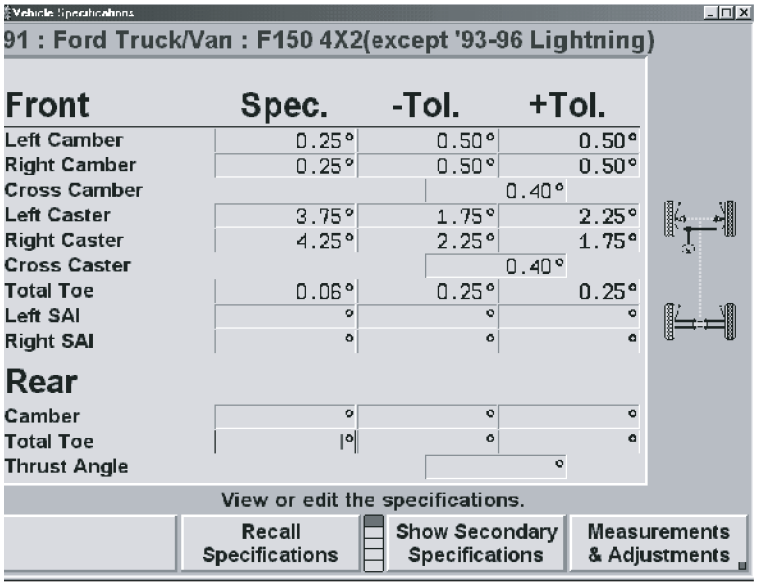


Figure 4-104, Ride Height Measurement

Consult the specification book or shop manual for the location to take this measurement.



1989 and later Ford truck specifications no longer vary with ride height.



Using the Automatic Bushing Calculator

Input the Caster and camber of the bushing currently in the axle.

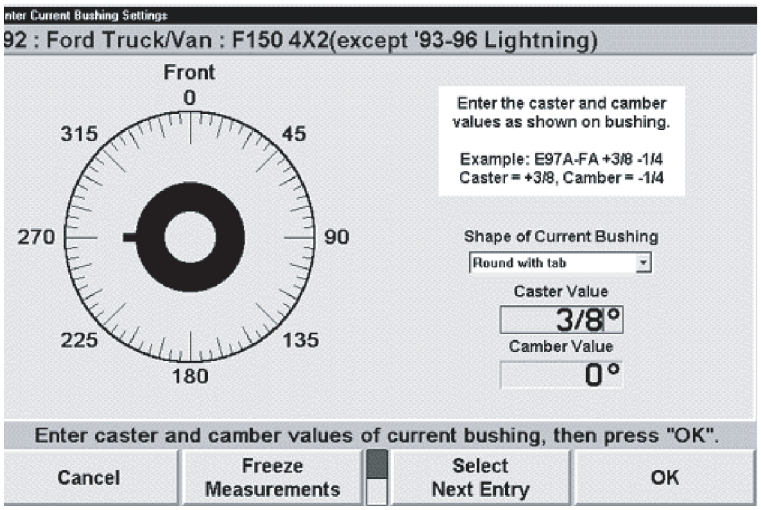
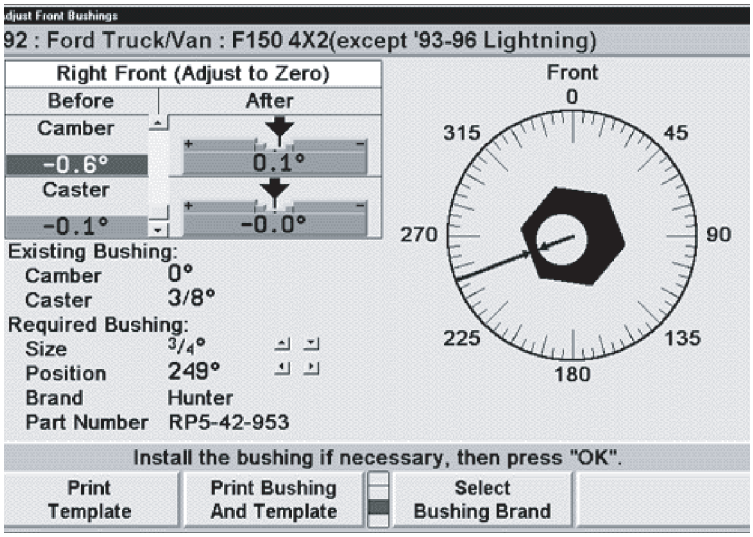


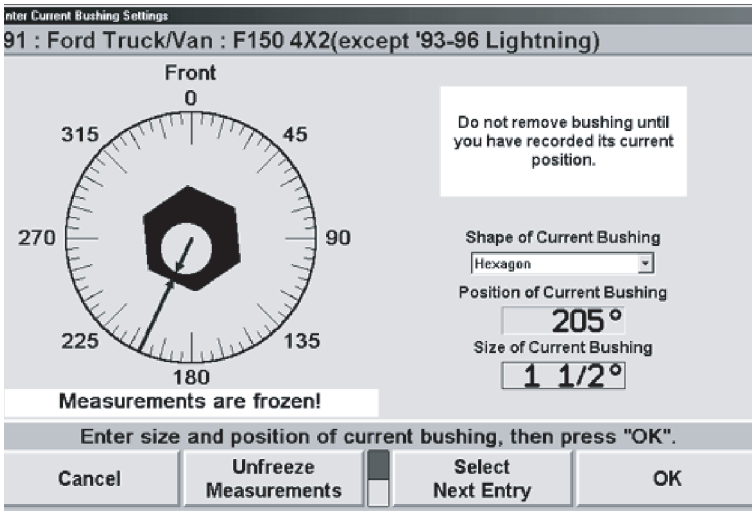
Figure 4-105, Automatic Bushing Calculator

Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing

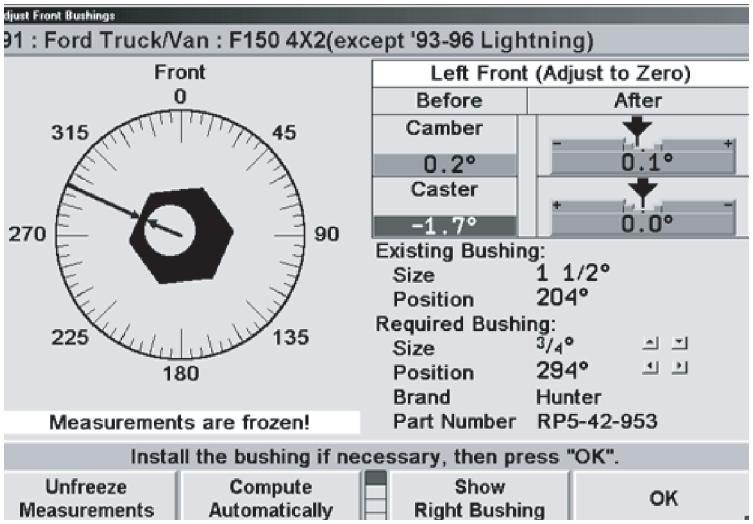


Using the Automatic Bushing Calculator

Input the position and size of the bushing currently installed in the axle.



Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing.



	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____

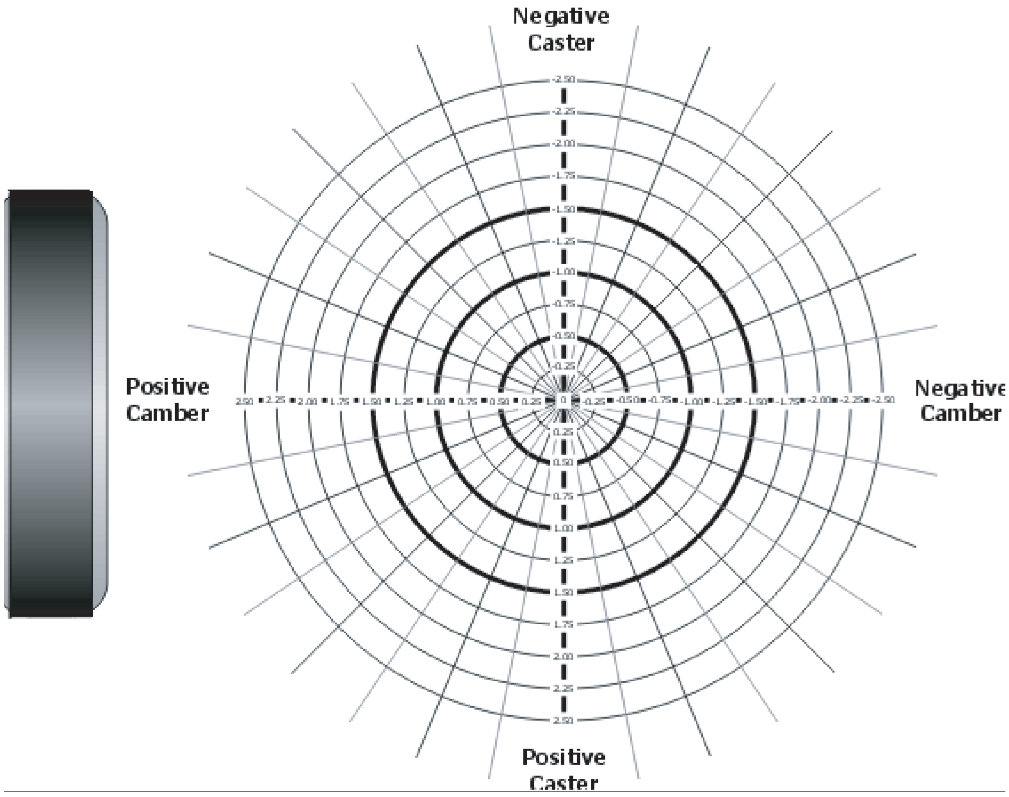


Figure 4-106, Driver Side - Winslow Bushing Calculator

	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size_____

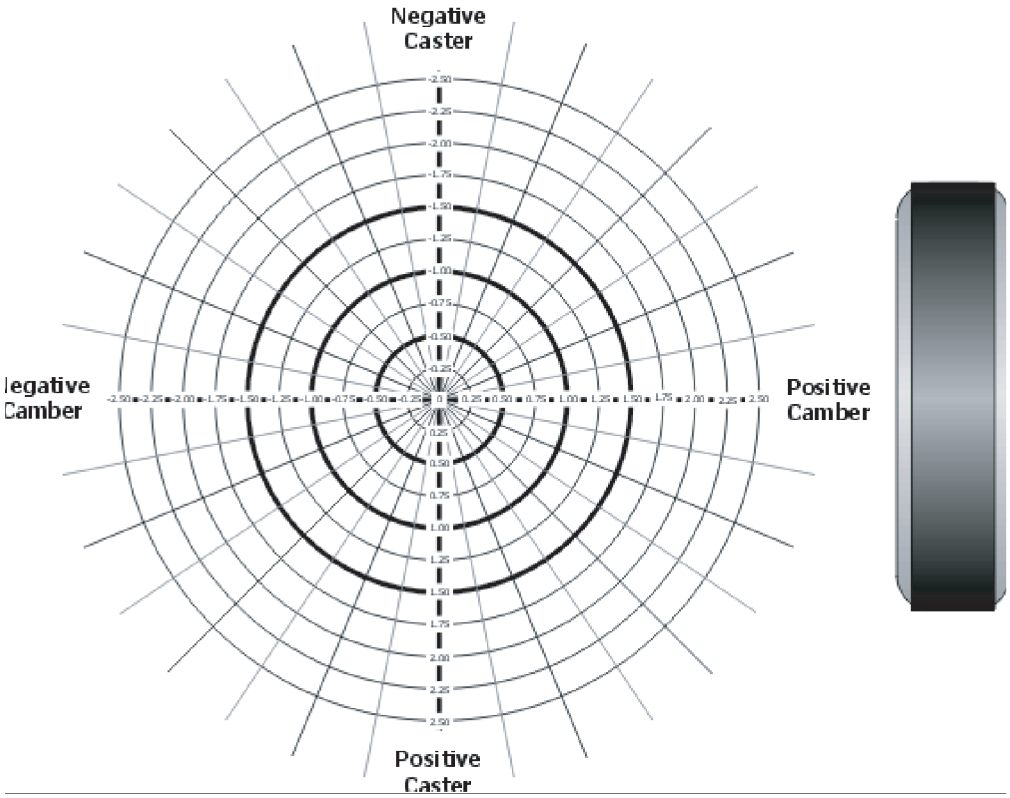


Figure 4-107, Passenger Side - Winslow Bushing Calculator

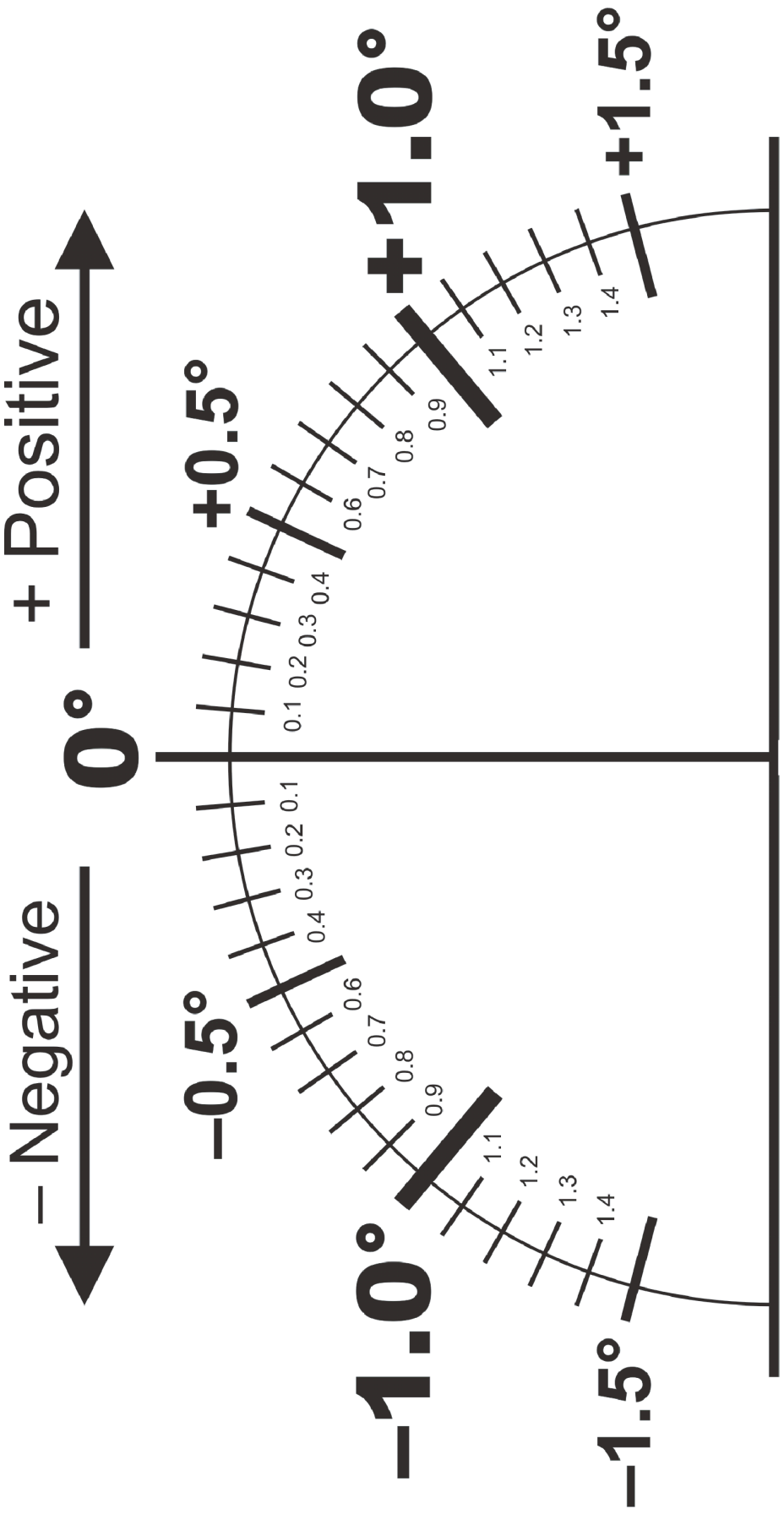


Figure 4-108,

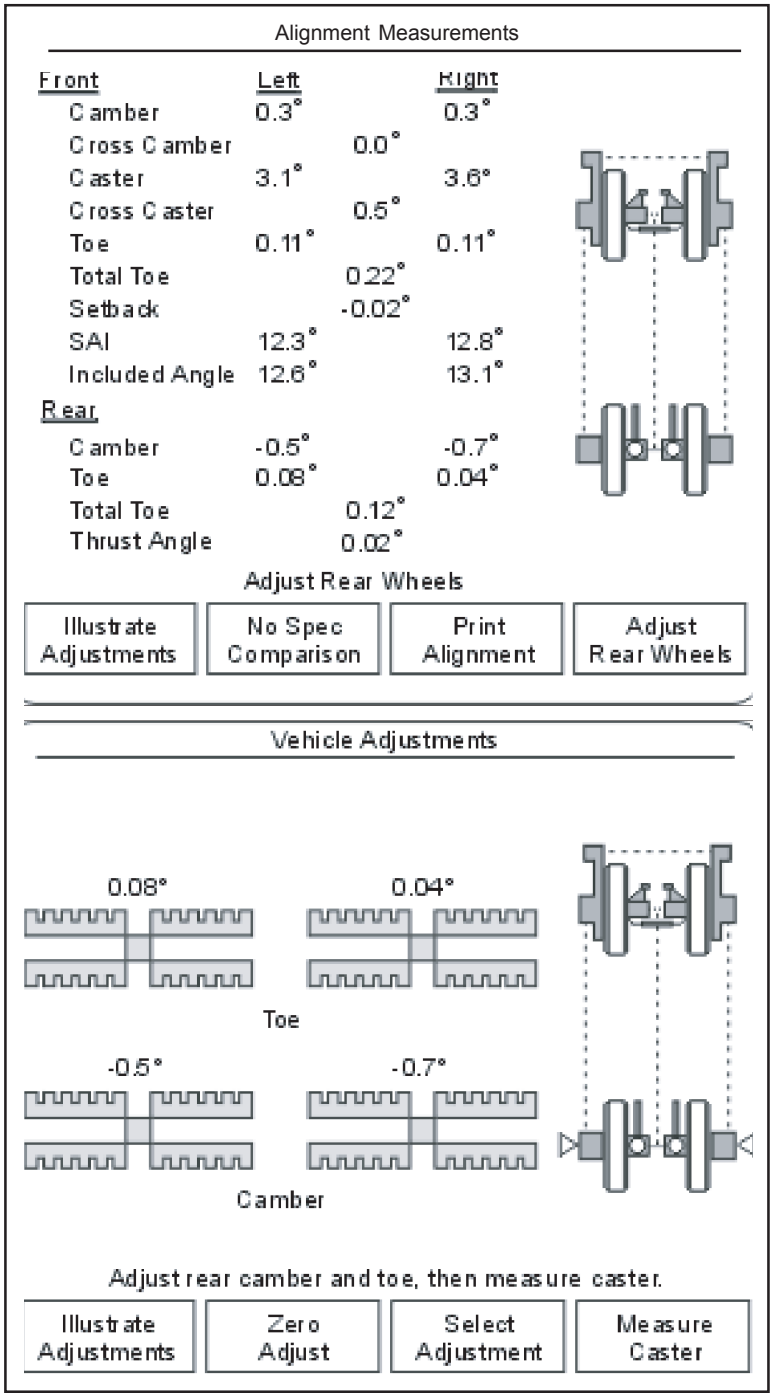


Figure 4-109,

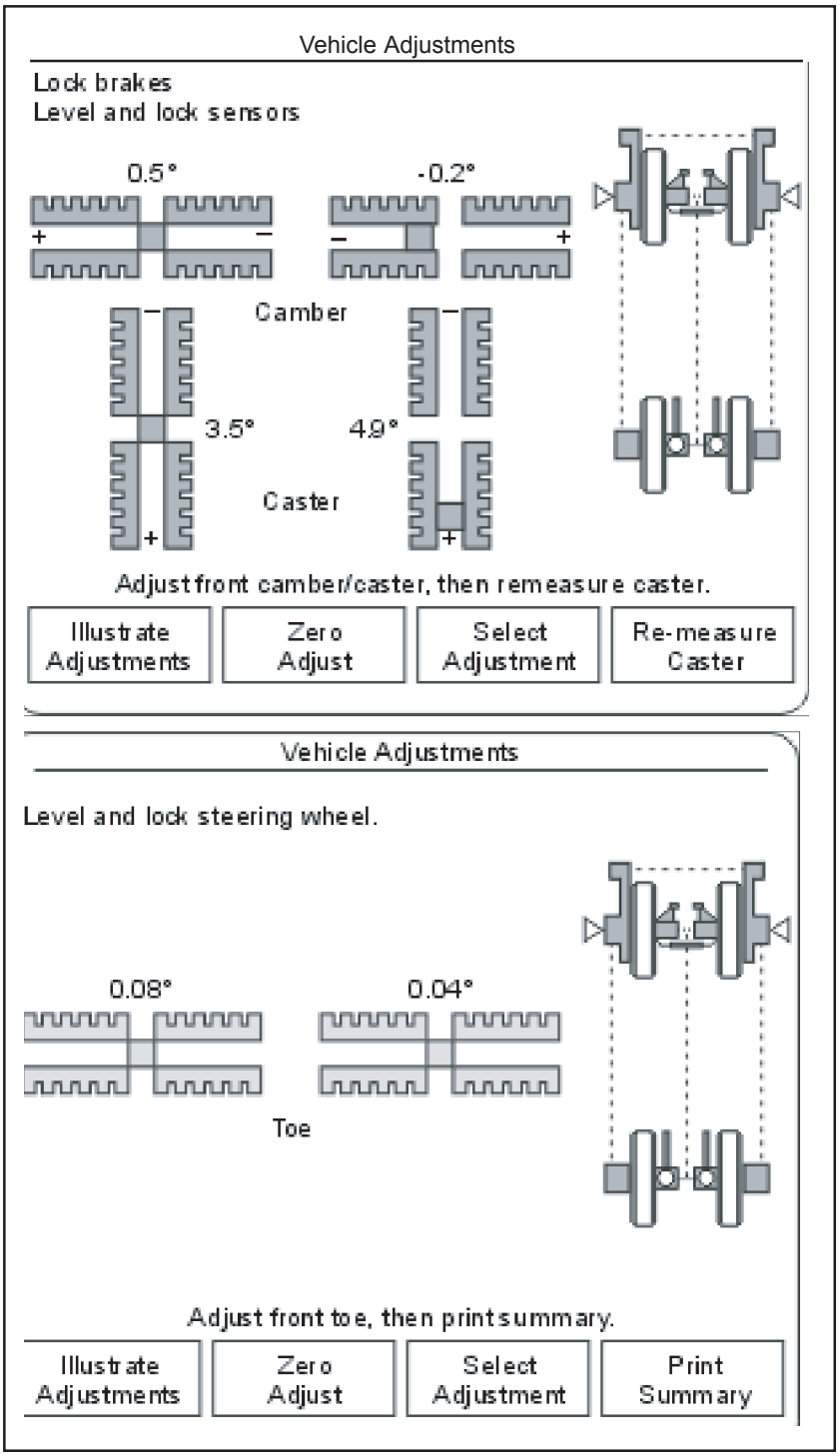


Figure 4-110,

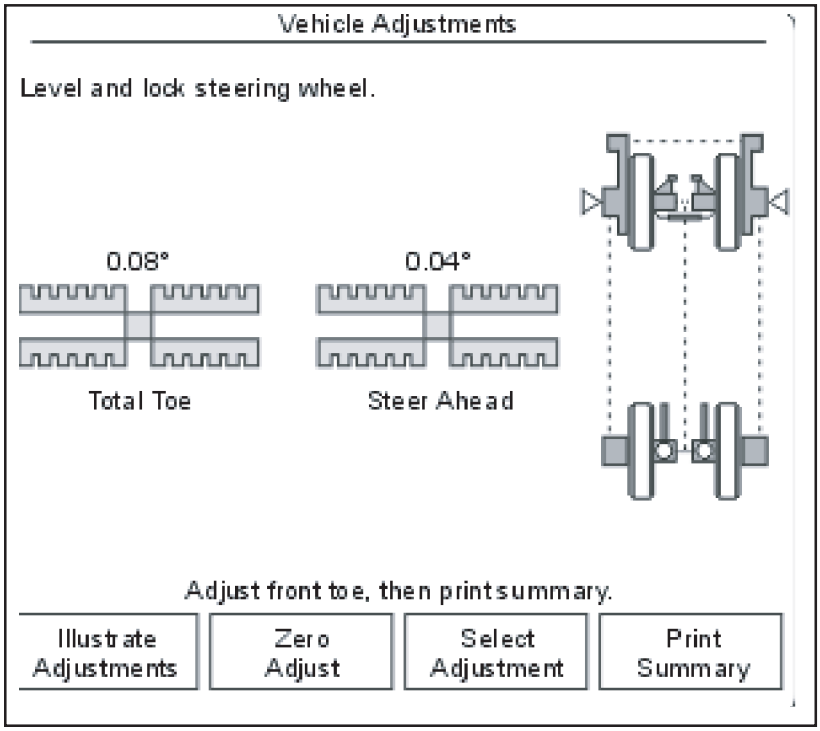


Figure 4-111,

Glossary

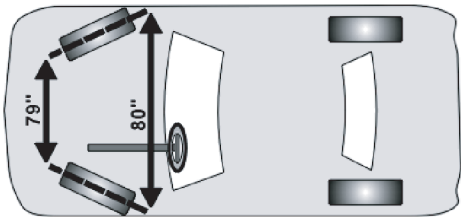
Alignment:	The process of measuring and positioning all wheels attached to a common chassis.
Angle:	Two intersecting lines.
Ball joint:	A connector consisting of a ball and socket. This component allows for simultaneous angular and rotational motion.
Bump Steer:	A directional change in steering during jounce and rebound due to unequal tie rod lengths or angles.
Camber roll:	The changes of camber that occur in a turn due to caster.
Camber:	The inward or outward tilt of the top of the wheel as viewed from the front.
Caster:	The forward or rearward tilt of the steering axis as viewed from the side.
Centerline Steering:	A centered steering wheel with the vehicle in a "straight ahead" course.
Conicity:	A tire irregularity, in that the tire takes the shape of a cone when inflated and loaded.
Cornering:	The ease at which a vehicle travels a curved path.
Degree:	A unit of measurement used to describe an angle.
Directional Stability:	The tendency for a vehicle to maintain a directed path.
Dog Tracking:	The appearance given when the thrustline is not parallel with the centerline of the vehicle.
Dynamic Balance:	An even distribution of weight on each side of the tire/wheel centerline.
Frame Angle:	The angle of a non-level frame.
Geometric Centerline:	A line drawn through the midpoint of both front and rear wheels.
Included Angle:	S.A.I. plus camber

Independent Suspension:	A suspension which provides an isolated mounting for each wheel to the chassis.
Individual Toe:	The angle formed by the intersection of an individual line drawn through the plane of one wheel and the centerline.
Jounce:	A suspension moving upward in its travel.
Lead:	A slight tendency for a vehicle to move away from a given path.
Memory steer:	A condition where the front wheels seek a position other than straight ahead.
O.E.M.	An acronym for Original Equipment Manufacture.
Parallel:	Two lines that stay at the same distance apart and never meet.
Parallelogram Steering:	A linkage design where, if all pivot points are connected by lines, the lines are parallel.
Pull:	The tendency of a vehicle to steer away from a directed course. A constant is maintained at the steering wheel to travel straight ahead.
Rack and Pinion Steering:	A steering system design that utilizes a pinion gear meshed with a rack gear to transmit steering forces to the spindle.
Radial Force Variation:	The difference in the tire sidewall stiffness that can inducean up and down motion in a rotating object.
Rebound:	A suspension moving downward in its travel.
Relay Rod Steering:	A steering design that has a direct bar connection between the tie rods.
Returnability:	The tendency of the front wheels to return to the straight ahead position.
Road crown:	The slope of the lane surface.
Road Isolation: Vibrations.	The ability of the vehicle to absorb or dissipate road

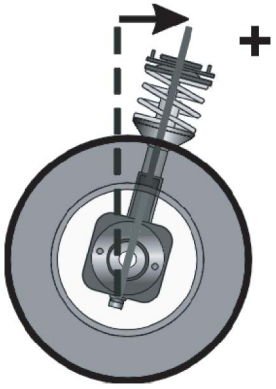
Road Shock:	The transmission of road forces to the passenger compartment.
Setback:	The angle formed by the geometric centerline and a line drawn perpendicular to the front axle.
Shimmy:	A violent side to side motion of an object.
Short/Long Arm	An independent suspension design where the upper and lower suspension: control arms are not equal in length.
Solid Axle Suspension:	A suspension design using an I-beam axle or tubular axle housing extending the width of the vehicle.
Static Balance: Circumference.	An even distribution of weight around the wheel
Steering Axis: of the Spindle.	A line drawn between the upper and lower pivot points
Steering Arm:	A steering component that connects the outer tie rod to the spindle. The angle of the steering arm to the wheel's axis determines turning angle.
Steering Axis Inclination:	The angle formed by a line drawn through the upper and lower pivot (S.A.I.) points of the spindle and a vertical line drawn from the lower pivot point.
Suspension:	An assembly used to support weight, dampen shock, and maintain tire contact and proper wheel to chassis position.
Thrust angle:	The angle formed between the thrustline and the geometric centerline.
Thrust line:	The bisector of rear toe, also described as a line drawn in the direction the rear wheels are pointed.
Torque Steer:	A pull during acceleration or deceleration caused by driveline components.
Torsion Bar:	A wrapped steel spring designed to maintain ride height.

Total Toe (angular):	The angle formed by the intersection of lines drawn through both wheels of a given axle.
Total Toe (linear):	The difference in measurements taken across the front of the tires versus a measurement taken across the rear of the same tires.
Tracking:	The interrelated paths taken by the front and rear wheels.
Turning Angle:	The angle of a wheel during a turn.
Vertical:	Something upright or straight up and down.
Vibration:	The repetitive motion of an object up and down or back and forth.
Wander:	The tendency of a vehicle to drift to either side of a directed course.

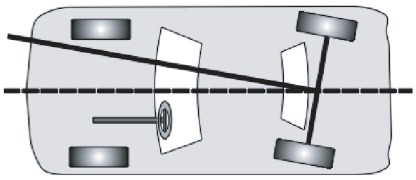
Pretest – Introductory Alignment Course



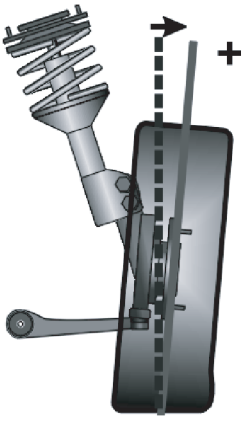
1. This alignment angle is:
   a. Camber
   b. Caster
   c. Total toe
   d. Thrust angle



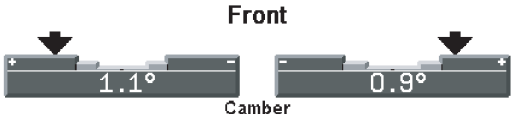
2. This alignment angle is:
   a. Camber
   b. Caster
   c. Total toe
   d. Thrust angle



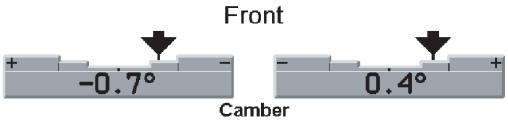
3. This alignment angle is:
   a. Camber
   b. Caster
   c. Total toe
   d. Thrust angle



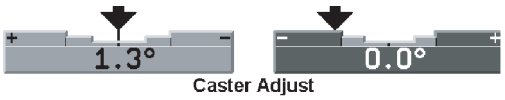
4. This alignment angle is:
   a. Camber
   b. Caster
   c. Total toe
   d. Thrust angle



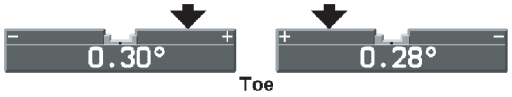
5. Alignment technician A says these readings may cause a pull to the left. Alignment technician B says these readings may cause outside shoulder wear on the front tires. Who is right?
   a. Alignment technician A
   b. Alignment technician B
   c. Both are right
   d. Neither is right



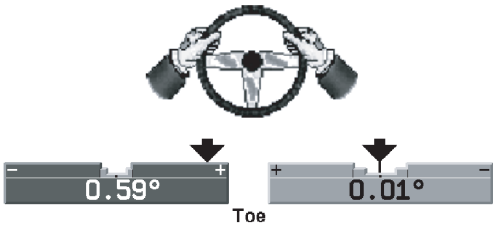
6. Alignment technician A says these readings may cause a pull to the right. Alignment technician B says these readings may cause a pull to the left. Who is right?
   a. Alignment technician A
   b. Alignment technician B
   c. Both are right
   d. Neither is right



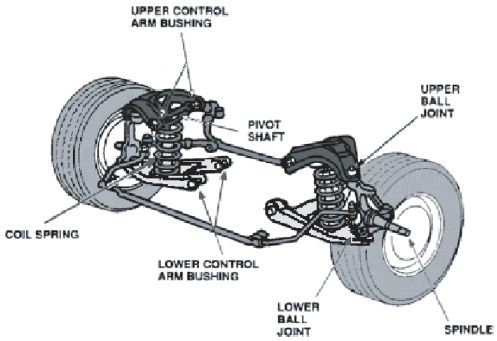
7. Alignment technician A says these readings may cause a pull to the right. Alignment technician B says these readings may cause a pull to the left. Who is right?
   a. Alignment technician A
   b. Alignment technician B
   c. Both are right
   d. Neither is right



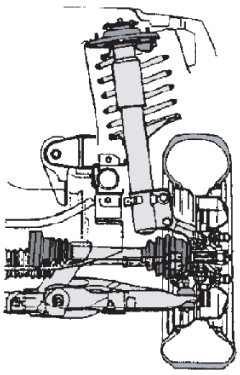
8. Alignment technician A says these readings may cause inside shoulder wear on the front tires. Alignment technician B says these readings may cause outside shoulder wear on the front tires. Who is right?
   a. Alignment technician A
   b. Alignment technician B
   c. Both are right
   d. Neither is right



9. Alignment technician A says these alignment readings may cause a pull right when the steering wheel is held centered. Alignment technician B says these readings may cause outside shoulder wear on the front tires. Who is right?
   a. Alignment technician A
   b. Alignment technician B
   c. Both are right
   d. Neither is right



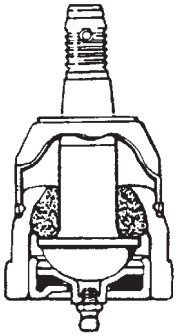
10. Alignment technician A says you should lift this suspension by the lower control arms to check for wear in the non-wear indicator balljoints. Alignment technician B says you should lift this suspension by the frame. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right
    d. Neither is right



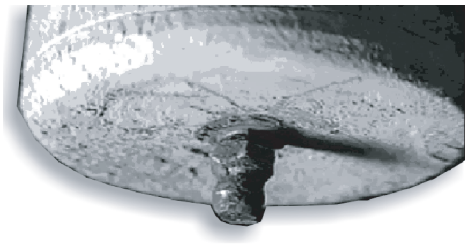
11. Alignment technician A says you should lift this suspension by the lower control arms to check for wear in the non-wear indicator balljoints. Alignment technician B says you should lift this suspension by the frame. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right
    d. Neither is right

12. Alignment technician A says excessive in and out movement in a follower ball joint requires replacement. Alignment technician B says you should check for up and down play with a pry bar and a dial indicator. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right
    d. Neither is right

13. Alignment technician A says excessive in and out movement in a load carrier ball joint requires replacement. Alignment technician B says you should check for up and down play with a pry bar and a dial indicator. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right
    d. Neither is right



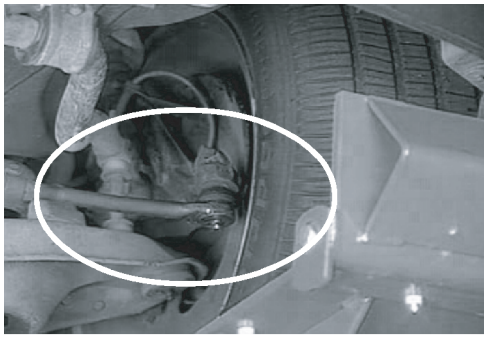
14. Alignment technician A says a "wear indicator" ball joint should be checked with the suspension raised by the lower control arms. Alignment technician B says the tires should be on the rack. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right
    d. Neither is right



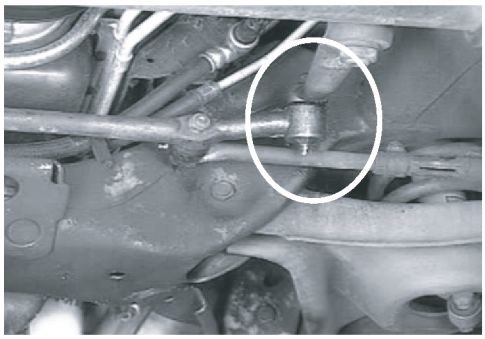
15. Alignment technician A says the ball joint on the left requires replacement. Alignment technician B says the ball joint is ok. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right
    d. Neither is right

16. Alignment technician A says the ball joint on the left requires replacement. Alignment technician B says the ball joint is ok. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right
    d. Neither is right

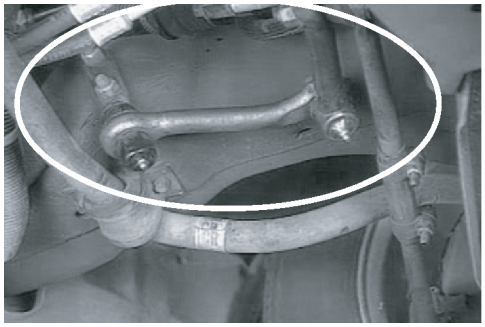
17. Alignment technician A says the inner tie rod shown on the left should be replaced when in and out free play is found. Alignment technician B says some manufacturers allow as much as 0.093” free play before replacement is needed. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right



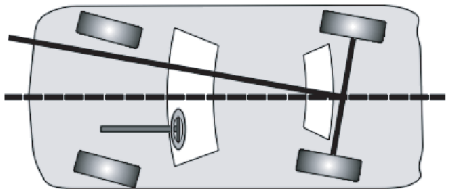
18. Alignment technician A says you should check for side to side play in a tie rod end by shaking the tire. Alignment technician B says you should check for side to side play in a tie rod end by having a helper rock the steering wheel left to right. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right



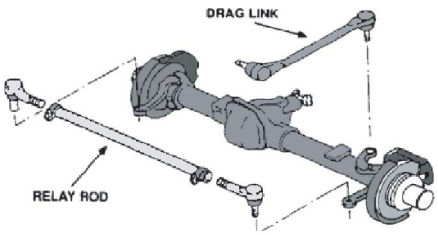
19. Alignment technician A says you should check for up and down movement in the centerlink with a pry bar. Alignment technician B says any side to side movement in centerlink socket requires replacement. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right



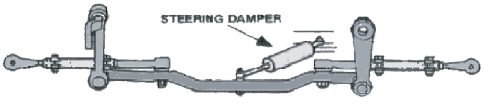
20. Alignment technician A says you should check for up and down movement in the idler arm with a pry bar. Alignment technician B says you should check for up and down movement by jacking up the lower control arms and shaking the right tire in and out. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right



21. Alignment technician A says you have to compensate all 4 sensors to do a Thrustline alignment. Alignment technician B says you only have to compensate the front. Who is right?
    a. Alignment technician A
    b. Alignment technician B
    c. Both are right

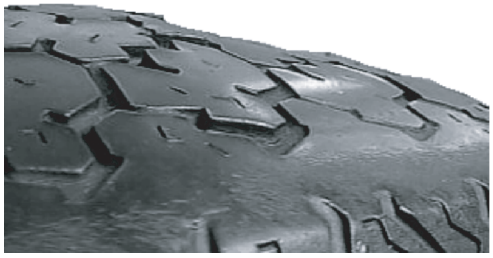


22. What screen is used to adjust this steering system?
    a. Win Toe
    b. Total Toe-Steer Ahead
    c. Individual toe bar graphs



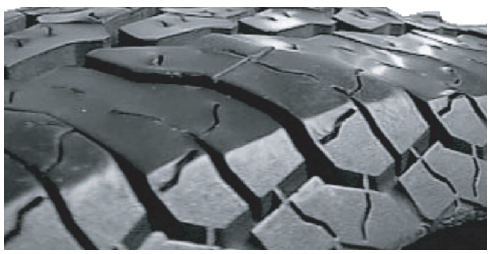
23. What screen is used to adjust this steering system?
    a. Win Toe
    b. Total Toe-Steer Ahead
    c. Individual toe bar graphs

24. All of the following could cause shoulder wear on a tire EXCEPT?
    a. Excessive camber
    b. Excessive total toe
    c. Weak shocks
    d. Frequent cornering by the driver



25. What is the MOST LIKELY cause of diagonal cupping on a rear tire of a front wheel drive car?
    a. Excessive camber
    b. Weak shocks
    c. Unequal rear toe

26. What is the MOST LIKELY cause of the feathering wear problem on this tire?
    a. Excessive camber
    b. Wheel imbalance
    c. Unequal rear toe
    d. Low air pressure



27. What is the MOST LIKELY cause of the cupping wear problem on this rear tire?
    a. Excessive camber
    b. Weak shocks
    c. Unequal rear toe
    d. Lack of rotation

ASE 4 - Suspension and Steering

Module 4b
Advanced Alignment Diagnostics

Acknowledgements

General Motors, the IAGMASEP Association Board of Directors, and Raytheon Professional Services, GM's training partner for GM's Service Technical College wish to thank all of the people who contributed to the GM ASEP/BSEP curriculum development project 2002-3. This project would not have been possible without the tireless efforts of many people. We acknowledge:

- The IAGMASEP Association members for agreeing to tackle this large project to create the curriculum for the GM ASEP/BSEP schools.
- The IAGMASEP Curriculum team for leading the members to a single vision and implementation.
- Direct contributors within Raytheon Professional Services for their support of translating a good idea into reality. Specifically, we thank:

  – Chris Mason and Vince Williams, for their leadership, guidance, and support.
  – Media and Graphics department under Mary McClain and in particular, Cheryl Squicciarini, Diana Pajewski, Lesley McCowey, Jeremy Pawelek, & Nancy DeSantis.
  – For his help on the Steering and Suspension curriculum volume, Subject Matter Expert, John Fisher, for his wealth of knowledge.

Finally, we wish to recognize the individual instructors and staffs of the GM ASEP/BSEP Colleges for their contribution for reformatting existing General Motors training material, adding critical technical content and the sharing of their expertise in the GM product. Separate committees worked on each of the eight curriculum areas. For the work on this volume, we thank the members of the Steering and Suspension committee:

– Jason Hill, Oklahoma State University - Okmulgee
– Marty Kamimoto, Fresno City College
– Tony Marchetti, Camden County College
– Doug Massey, Community College of Baltimore County - Catonsville
– Tom Pease, Florida Community College at Jacksonville
– Daniel Unruh, South Texas Community College
– Vincent Williams, Raytheon

Contents

Module 4b – Advanced Alignment Diagnostics

Diagnostic Process

The first step in the diagnostic process is to collect as much information as possible.

Sources of Information

- Customer interview
- Diagnostic road testing
- Vehicle inspection
- Alignment Measurements

Basic Angles

The following angles should be measured with every alignment:

- Camber
- Cross camber
- Caster
- Cross caster
- Total toe front and rear
- Individual toe front and rear
- Thrust angle

Diagnostic Measurements

Check these additional measurements when a vehicle has been involved in an accident or has unusual handling problems:

Steering Axis Inclination

Used to diagnose structural damage:

- Control arms
- Frame
- Uni-body

Included Angle

Used to diagnose parts damage:

- Steering knuckle
- Spindle
- Strut
- Ball joint studs

Front Wheel Setback

- Used to diagnosis damaged control arms and diamond frames.
- Low caster and high setback often indicate a bent lower arm.

Max. Steer Measurement (Steering Lock- to-Lock)

Used to verify steering wheel to gear alignment.

Checks for:

- Jumped rack teeth
- Bent pitman arm
- Lateral movement of gearbox at frame mounting
- Steering stop adjustment

Turning Angle

- Used to determine if steering arms are damaged.
- May cause tire wear and driveability problems when turning.

Wheelbase

- Used to isolate large thrust angle problems.

What To Ask Before the Alignment

The preferred alignment specifications may not produce the best results in some cases. It is very important to ask the owner how the vehicle is used to determine if any adjustments to factory preferred specifications are needed.

Why did the customer request an alignment?

These are the common reasons given for alignment service:

1. Premature or unusual tire wear
2. Instability problems such as pulls, drifts or wandering
3. Crooked steering wheel
4. Vehicle mishap such as potholes, curbs, or minor accidents
5. Preventive maintenance

Other handling problems may appear so slowly and over a long period of time, the vehicle owner may not realize the problem exists. The mechanic should check for:

1. Excessive road shock
2. Poor returnability of the front wheels after a turn
3. Dog tracking
4. Poor overall stability
5. Excessive or inadequate feel of the road

These and other handling problems may be solved through correcting a vehicle's alignment geometry.

What type of road surface is normally driven on?

1. Four-lane highway
2. Two-lane highway
3. Urban streets
4. Rural roads

Ask this question to determine if the following factors should be considered:

1. Four-lane highways may have road crown in either direction or no road crown at all. The effects of high-speed travel may magnify tire wear due to excessive camber and toe. Caster becomes an important factor in maintaining stability at high speeds.
2. Two-lane highways generally have a road crown that is high in the center of the road. Front camber adjustments may be required to prevent excessive counter steering by the operator. Increased high speed cornering may affect tire and suspension wear.
3. Urban travel suggests frequent starts and stops along with hard, low speed turns. Road crown does not have the noticeable effect on vehicles at low speeds that it does at high speeds. Caster may be adjusted to ease steering and reduce camber roll since the inherent stability offered by high caster is not required at low speeds. Urban travel frequently decreases suspension and steering component life due to frequent starts, stops, and hard turning.
4. Rural road travel suggests low speed travel on gravel or blacktop surfaces. Inspect steering, suspension and brake components for damage due to thrown rock and rough road surfaces. Consider the possibility of high road crown.

What passenger and or cargo weight is normally carried in the vehicle?

Two load imbalances should be considered:

1. Front-to-rear imbalance
2. Side-to-side imbalance

The Original Equipment Manufacturer (OEM) must assume the passenger and/or cargo load will be within the load rating of the vehicle when determining alignment specifications.

This assumption does not always apply. Passenger vehicles and light trucks often carry more weight than originally intended.

This may cause a front-to-rear imbalance.

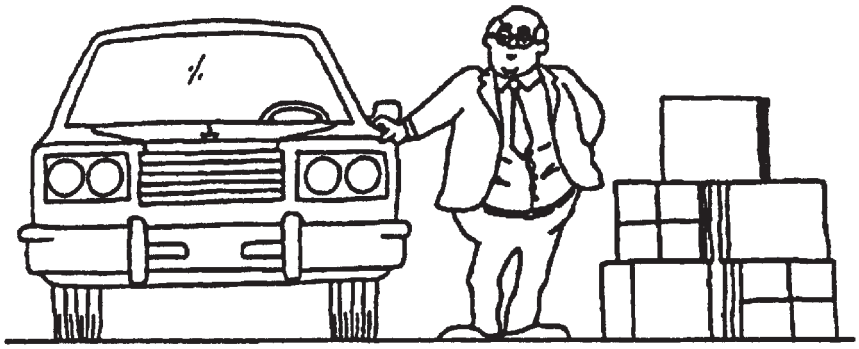


Figure 4b-1, Cargo and Passenger Weight

*Ask the following ques*tions determine if the load should be present during the alignment or if the preferred specifications are still ideal:

1. What, if any, cargo is carried?
2. How often is the vehicle loaded?
3. Is the vehicle used to tow a trailer?
4. What is being towed and how heavy is the tongue weight?
5. How often is the vehicle used for towing?

Weight may be distributed unequally causing an imbalance side-to-side.

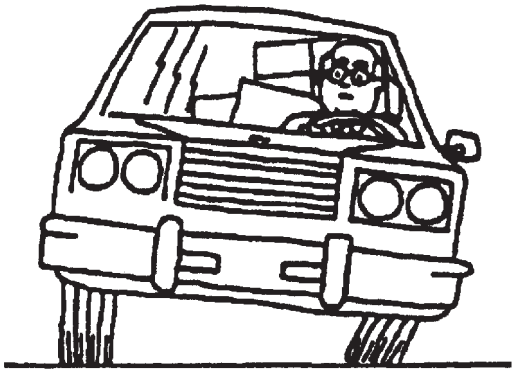


Figure 4b-2, Uneven Weight Distribution

Cargo or passenger weight may cause side-to-side imbalances.

Ask the following questions to determine if the load should be present during the alignment or if the preferred, specifications are still ideal:

1. Do any larger than average people that ride in the vehicle?
2. Is the vehicle equipped with side tool boxes or other containers?
3. How often is the vehicle loaded unevenly?

Weight may cause accelerated tire wear due to two factors?

1. Weight causes alignment angles to change?
2. Weight creates increased tire friction?

Weight may also cause vehicle handling characteristics to change.

Is the vehicle used commercially?

1. Are multiple drivers used for the same vehicle?
2. How is the vehicle used?
3. Is this vehicle part of a fleet of similar vehicles?

These questions are asked to determine if the following factors should be considered:

1. If multiple drivers are involved, it may be necessary to determine if the problem is being experienced by all the drivers. If not, obtain specific information from the driver experiencing difficulty. Individual driver's habits and expectations may differ. This can save you time.
2. Knowing how the vehicle is normally used will help diagnose the problems. Information about how much weight is carried and what type of roads are traveled can determine how the vehicle should be aligned. Differing load placement as well as road contour and crosswinds may be the answer to inconsistent handling problems.
3. If the vehicle is part of a fleet, determine if any similar vehicles are experiencing the same problem.

Is a vehicle maintenance log available?

The maintenance history may be used to take the guesswork out of mysterious problems. If a maintenance log is not available, ask questions to determine the maintenance history of the vehicle.

1. When was the last time the vehicle was aligned?
2. How often have the tires been rotated?
3. Have the tires been replaced recently?
4. Has the vehicle ever been involved in an accident?
5. Have any major repairs ever been made on the vehicle?

Ask these questions to determine if the following factors should be considered:

1. Knowing when and if the vehicle was aligned will establish a platform from which to work. Establish when the handling difficulty or tire wear was noticed and compare it to the date of the last alignment.
2. New tires easily disguise a tire wear problem. If new tires have been installed on the vehicle, ask questions about the wear patterns of the old tires.
3. Vehicles that have been involved in accidents often present a major alignment challenge. Be careful to look at setback, thrust, and SAI/IA. Damaged parts may not be apparent.
4. Major repairs may include the repair or replacement of the engine, transmission, transaxle, drive shaft, drive axle, differential or CV joints. All of these repairs may create alignment problems due to cross-member, cradle or drive axle placement.

Write down all the information you obtain. Don't rely on memory!

Road Test Guidelines

Review the vehicle history and customer concerns. Now, test-drive the vehicle. The road test allows the technician to experience the vehicle's handling and:

- Verify the condition of the vehicle as described by the customer.
- Notice any problems not experienced by the owner. (There may be conditions or problems with the vehicle that have developed so slowly the owner is unaware of them.).

The road test course should consist of the following:

- A flat, straight section of road
- An area to stop and start
- A road with a dip or bump
- A road allowing left and right turns

A Flat, Straight Section of Road

Test directional instability and observe steering wheel position. The road surface should be smooth and flat. The objective is to drive on a surface that will not influence the direction of the vehicle. Note any variance from the straight-ahead course.

A crooked steering wheel may indicate a thrust condition that should be aligned or corrected.

Check for excessive steering wheel play. The vehicle may drift if the steering system is excessively loose. This condition should be repaired before the alignment.

An Area To Stop and Start

This test is used to detect brake pulls, torque steer and worn or loose suspension or steering components.

Check for a brake pull when stopping the vehicle. The owner may think this is an alignment related problem when, in fact, the braking system is at fault. This is usually most noticeable during hard braking.

The vehicle may drift to one side or the other due to dragging brakes. A brake caliper that does not fully release may be at fault.

Note: This problem is often brought about by heat and may not be evident on the alignment rack during compensation of the sensors.

Check for excessive nose-diving during braking. This is not normal and may be caused by worn springs or shocks. Worn springs will affect vehicle ride height and may affect overall vehicle handling.

Check for pulls or drifts when accelerating or decelerating.

This may be due to a condition known as "torque steer." Torque steer is generally associated with FWD vehicles.

An Area With A Dip or Bump

Drive the vehicle over the bump or through the dip and observe the steering wheel position. This is an excellent test to detect weak springs, weak shocks and worn or unlevel steering components.

If the vehicle changes direction or the steering wheel moves excessively, the steering components may be worn, incorrectly adjusted, or unlevel. This condition is commonly known as "Bump Steer." Excessive suspension bouncing may be the result of weak shocks.

Bottoming out of the suspension may be the result of weak springs.

Continue to monitor suspension and steering stability throughout the remainder of the test drive.

An Area for Left and Right Turns

Check the overall handling response through both left and right turns. Front and rear alignment settings as well as steering and suspension components affect cornering capabilities.

Check for steering difficulties that may be the result of mechanical binding or interference. This condition is commonly referred to as "Memory Steer." Check for proper returnability of the steering wheel after a turn. Excessive driver effort should not be necessary.

Note any excessive body sway that could indicate worn springs, shocks or stabilizer assemblies.

Note: Any excessive squealing of tires during turns. This can be caused by incorrect alignment settings or turning angle out of specifications.

Vehicle Inspection

The vehicle inspection is one of the most important steps to assure a successful alignment.

Worn, damaged, incorrectly installed or missing components may cause alignment angles to change and overall handling to be poor.

All vehicles must be thoroughly inspected before alignment. Any worn, damaged or missing parts must be replaced or repaired before starting the alignment. Use a checklist to assure a complete inspection each and every time. It is easy to over-look individual components.

Inspect the following components:

- Tires
- Steering components
- Suspension components
- Frame and cross-members
- Brakes
- Drive-shafts, universal joints and CV joints
- Vehicle ride height

Inspection of Tires

Check air pressure in each tire and inspect for wear patterns.

Adjust the air pressure to factory specifications. The type and size of the tire and wheel should be uniform for a given axle.

It is not a good idea to run a radial and a bias ply tire on the same axle. It is not a good idea to use radial tires on the front and bias ply tires on the rear. Mixing radial and bias ply tires generally cause handling problems.

Wheel rim dimensions should be the same for any given axle. If wheel rim dimensions differ, the alignment equipment may create a false centerline since it basically determines centerline as the midpoint between both sensors.

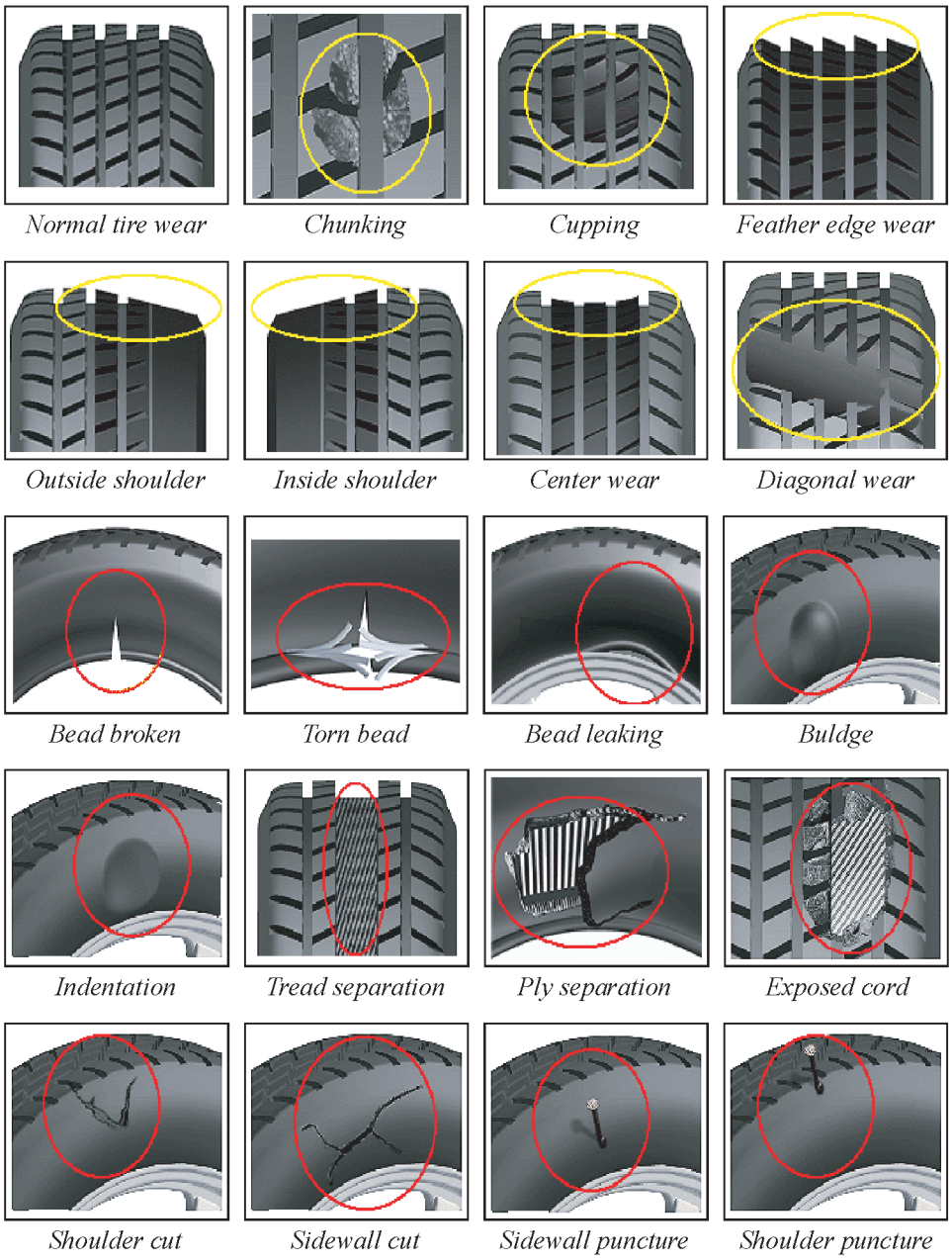


Figure 4b-3, Tire Wear

Tire Rotation Patterns

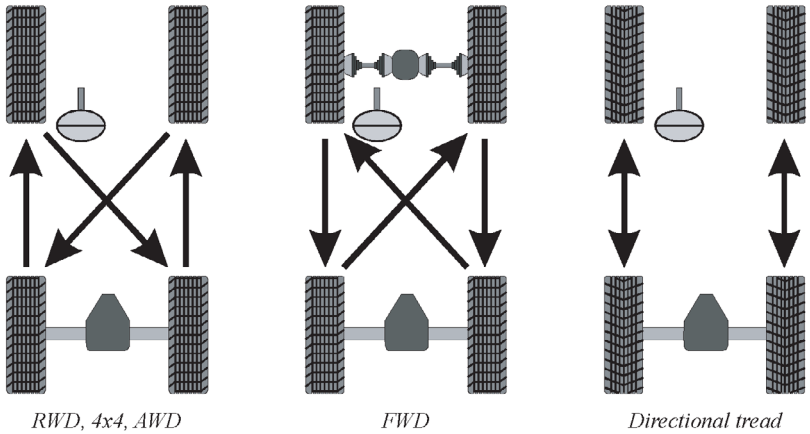


Figure 4b-4, Tire Rotation Patterns

Exceptions

Some vehicles use different size tires or wheels front-to-rear. Some wheels are marked "front" or "rear," "left" or "right.

Figure 4b-5, Camaro's Wheels Use A Different Offset From Front-to-Rear

Figure 4b-6, Rear Wheel Hits the Tie Rod When Mounted on the Front Hub

Inspection of Steering Systems

Three types of steering systems are commonly used:

- Rack and Pinion
- Conventional or Parallelogram
- Relay Rod

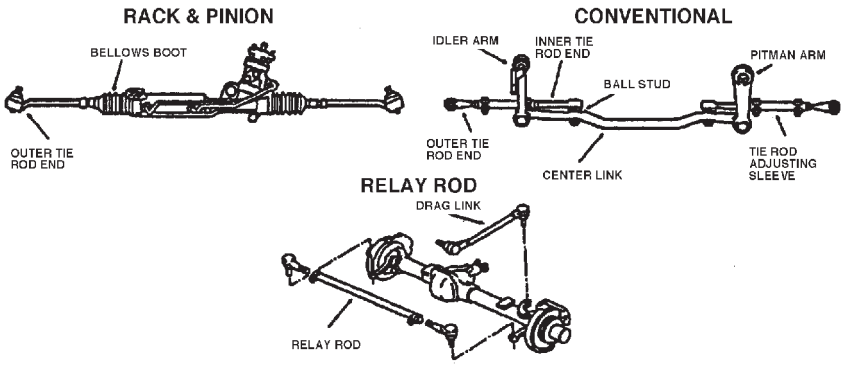


Figure 4b-7, Steering Designs

Perform a "dry park" check.

"Dry park" is a term used to describe a method of inspecting the steering linkage without jacking the front end of the vehicle off the floor or rack. The basic purpose of the dry park method is to inspect the steering linkage for play with the normal weight on the front wheels and the suspension at normal ride height.

When you raise a vehicle, steering components connected through a ball and socket design are pulled out of their normal operating positions. This repositions the wear surfaces of the ball and socket and may tighten the joint thus leaving a marginal component undetected. To perform the "dry park" check, leave the engine off and the steering wheel unlocked.

Flexible Joint

Check the flexible coupling connecting the steering shaft to the steering gear. A rubber disc joint or a universal swivel joint may be used. A rubber disc joint should be replaced if damaged or deteriorated. A swivel joint should be replaced if it binds or is excessively loose. A worn or damaged flexible joint may cause poor steering responsiveness, excessive play, crooked steering wheels or (in the worst case) loss of steering control.

Rack and Pinion Mounting

The rubber insulators that cushion the rack from the mounting surface deteriorate as time passes. Check the rack for looseness by trying to move it side-to-side and up and down. Inspect the insulator bushings and replace them if cracked or damaged.

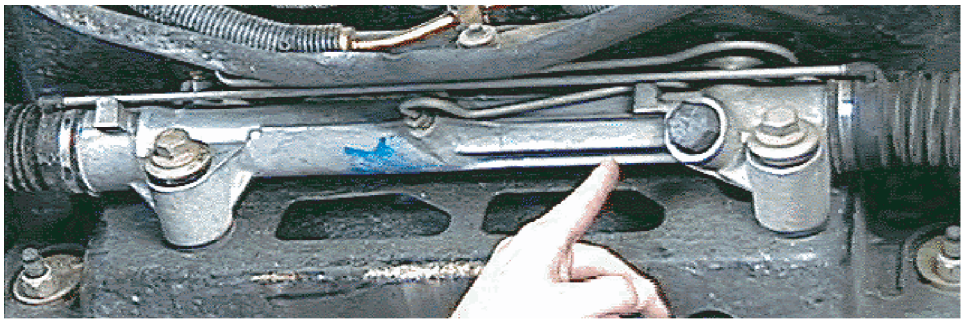


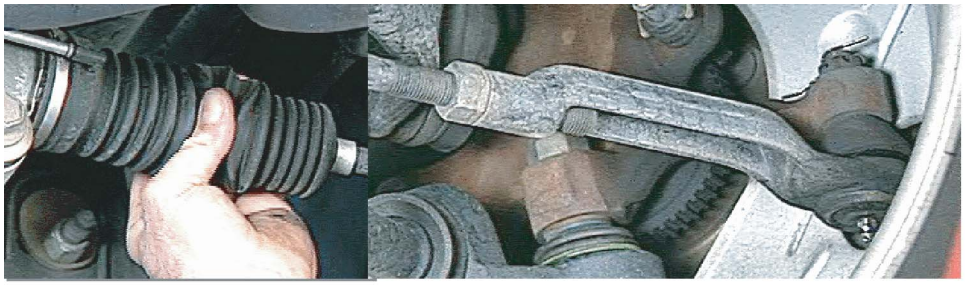
Figure 4b-8, Inspect the Rack Mounting Rubber Insulators

A loose rack and pinion assembly can result in steering wander, overall steering looseness, and unusual noises.

Inspect the rack housing for cracked or broken mounting ears.

Although it may be possible to repair this with a welder, it is a good idea to replace the rack assembly because it is very difficult to keep the heat of the welder localized.

Squeeze the boot and check the inner tie rod for wear by shaking the tire. Be sure to check the outer tie rod for wear also.



Inner tie rod end *Outer tie rod end*

Figure 4b-9,Inner/Outer Tie Rod End

Steering Boxes

Vehicles using parallelogram or relay rod steering systems will have the steering box bolted to a frame member. Check the frame mounting bolts and tighten if needed. Check the frame, especially on 4WD trucks, for fractures where the steering box bolts to the frame. Inspect the connection between the pitman arm and the steering box output shaft. A loose bolt or worn splines may create looseness in the steering system and result in steering wander and overall loose steering.

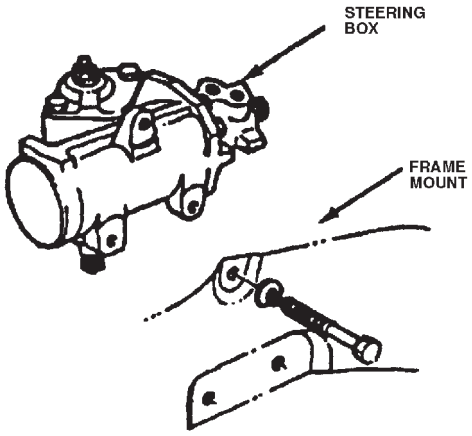


Figure 4b-10, Steering Box Attachment

Twisted splines may be the result of an accident and indicate internal damage to the steering box. A twisted sector shaft may cause binding or turning radius problems.

There are different styles of steering boxes used by the OEMs, which may differ in adjustment techniques and procedures. Do not attempt to adjust a steering box without familiarizing yourself with the manufacturer's procedure.

Two types of adjustments may be possible:

- Sector shaft adjustment
- End-play adjustment

If the steering box cannot be adjusted properly using the manufacturer's procedures, replace the steering box.

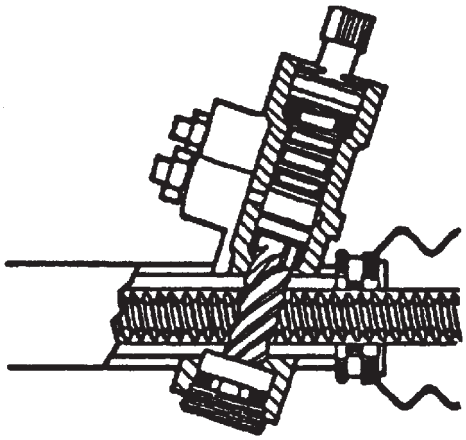


Figure 4b-11, Rack and Pinion Steering Gear

Pitman Arm

The pitman arm connects the output shaft of the steering box to the steering linkage. Check for looseness in the spline connection and the socket connection by steering the wheels back and forth. Improperly installed pitman arms may make it impossible to obtain a straight steering wheel.

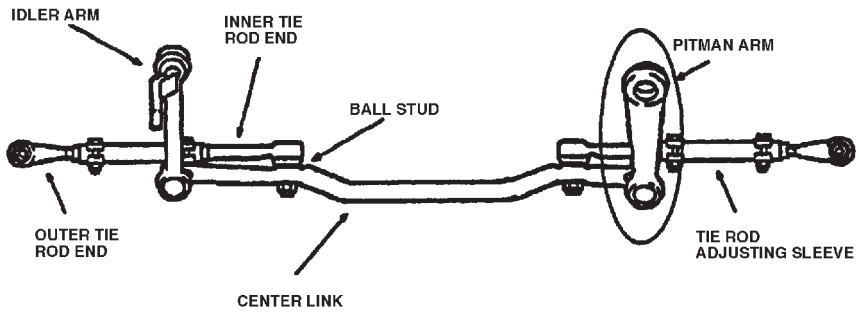


Figure 4b-12, Pitman Arm

Center Link

The center link is used on a parallelogram steering system to connect the pitman arm, idler arm and tie rods together. Steer the front wheels back and forth and observe the center link joints. No looseness is acceptable. Do not use pry bars or pliers to check the joints. The weight of the vehicle on the joints is sufficient to reveal any looseness.

Many GM center links have machined flat spots below the points where the link attaches to the pitman arm and idler arm. With the wheels steered straight ahead, measure from the flat spot to the floor in both locations. Both measurements should be within 1/16" of each other for proper steering geometry. If the center link is not level, loosen the idler arm mounting bolts and adjust the idler arm up or down to level the link.

Idler Arm

The idler arm is designed to support and maintain the level of the steering system. The idler arm should be checked in a loaded condition. The **front wheels should be on the ground**. A worn idler arm allows excessive toe changes producing abnormal tire wear and erratic steering.

Many different idler arms are used although they all are designed to perform the same job. It is also possible to find the wrong idler arm on a vehicle.

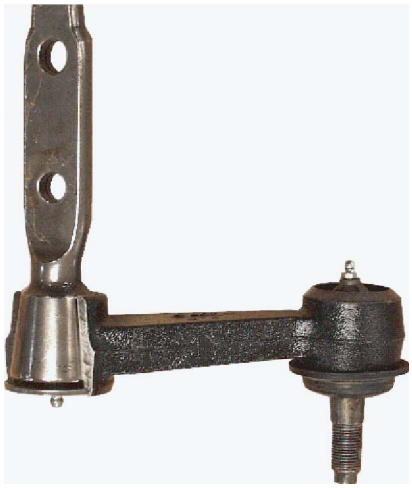


Figure 4b-13, Idler Arm

Check the idler arm mounting bolts and tighten them if necessary. Check the center link for level. Steer the front wheels back and forth and inspect for lateral play either in the pivot bushing or between the idler arm and the center link. Replace the idler arm if lateral play is evident.

Vertical play in the pivot bushing must also be checked. Push the horizontal arm of the idler arm up using approximately 25 ft/lbs. of force and then pull down with 25 ft/lbs. of force. **Do NOT use a pry bar or pliers.** Allowable movement varies from manufacturer to manufacturer. Most manufacturers will not permit more than 1/8" movement at the idler arm pivot bushing. Refer to the manufacturer's specifications.

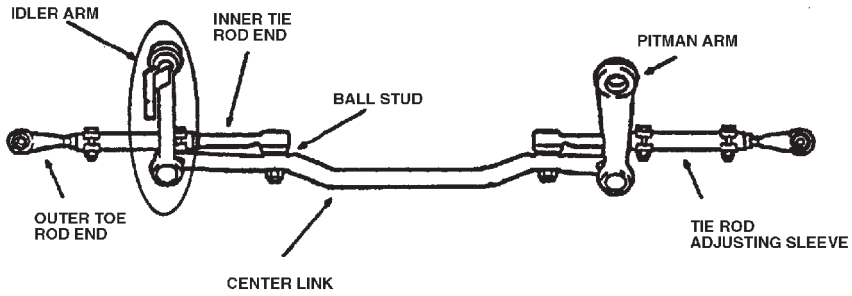


Figure 4b-14, Idler Arm

Conventional Tie Rods

A tie rod assembly consists of an inner tie rod, outer tie rod and an adjustment sleeve. Steer the wheels back and forth and check for side-to-side movement of the ball socket stud. Use your hand to depress the tie rod socket and check for excessive in and out play. Remember that pry bars and pliers should not be used. The tie rod end should be replaced if any movement is detected.

Twist the tie rod to inspect for binding. The tie rod should rotate through the entire operating range without binding. Replace the tie rod if it will not rotate freely. The protective rubber boot should be intact and free of damage. Torn or damaged boots will allow dirt to enter the socket area and destroy the tie rod socket.

Figure 4b-15, Conventional Tie Rod

Inspect the adjustment sleeve. Replace the sleeve if it is bent or damaged. Make sure the sleeve will adjust. This will save time and aggravation later.

Some Ford products are equipped with a rubber bonded tie rod socket (RBS). The inspection procedure is the same as the conventional style. If tightened with the wheels off center, the tie rods will attempt to return to the off center position causing a memory steer condition. Since the rubber twists when the wheels are steered, the tie rods want to remain in the position they were originally installed. It is important when installing an RBS style tie rod that the wheels are steered straight ahead before tightening.

Rack and Pinion Style Tie Rods

The outer tie rod is inspected in the same manner as the parallelogram outer tie rod.

The inner tie rod socket is housed inside a protective boot and is often forgotten. Inspect the inner tie rod for looseness by pinching the bellows boot until you can feel the tie rod then steer the front wheels back and forth. A worn inner socket will allow the tie rod to move back and forth independent of the rack gear.

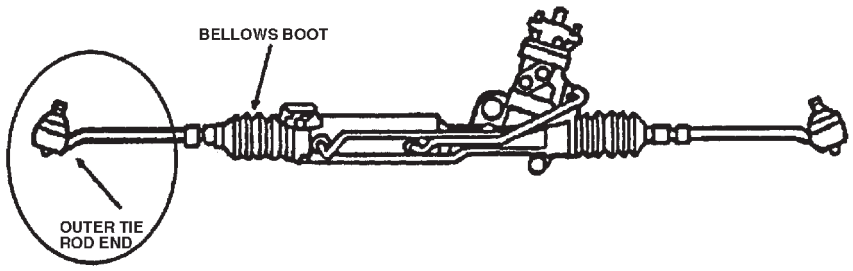


Figure 4b-16, Rack and Pinion Tie Rod

Bellows boots that are torn, cracked or softened from steering fluid should be replaced. The presence of power steering fluid in the bellows boot means the rack is leaking internally. The steering assembly should be replaced or repaired.

Power Steering Systems

The power steering system is capable of causing the vehicle to lead or pull to one side.

Inspect the power steering belt, return hose, pressure hose, pump, fluid level and fluid condition. A power steering belt that slips may cause a jerking sensation at the steering wheel.

A leaking return hose, pressure line or pump may cause a hydraulic imbalance that may cause the centering or spool valve to steer the wheels off center. Low fluid level or contaminated fluid may cause the entire power steering system to fail or work at less than 100% effectiveness.

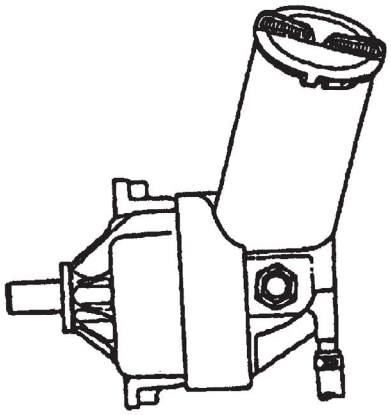


Figure 4b-17, Power Steering System

Variable Assist Power Steering

Variable Assist Power Steering (VAPS) is offered on some vehicles to increase steering performance and safety. The system is designed to increase steering effort at the steering wheel as the vehicle increases speed. The increased steering effort at higher speeds reduces the possibility of over steering. This is a normal function of VAPS, although this may cause some customers to complain of hard steering.

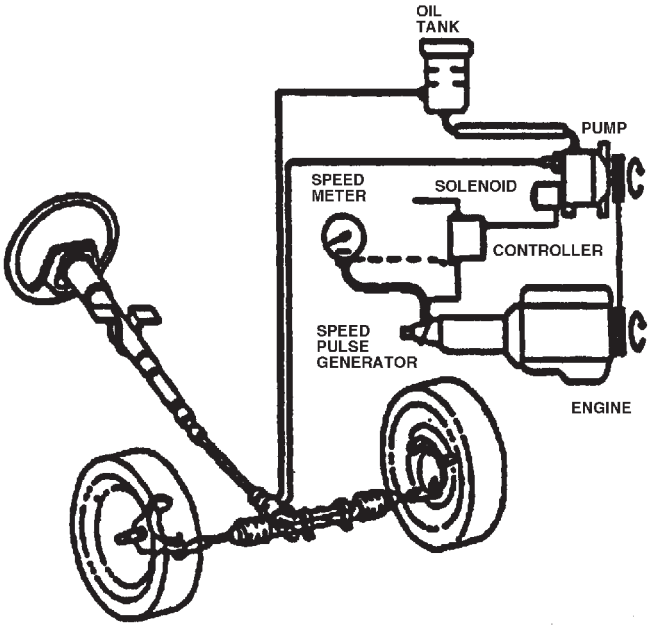


Figure 4b-18, Variable Assist Power Steering

Suspension Inspection

Bushings

All vehicles are equipped with bushings of different sizes, shapes and forms. Although they differ in many ways, they all share the same ultimate goal of isolating vibration, absorbing road shock, and supplying pivot points for the suspension.

Visually inspect bushings made of rubber or some similar substance for cracks, breakage or contamination from oil or other fluids.

Figure 4b-19, Bushing

Metal bushings are also used and should be inspected for wear by determining if any looseness is evident.

Check components using bushings for looseness since they rely on the bushings for a firm fit. Worn, damaged or missing bushings may allow suspension parts to have excessive movement.

Movement may cause alignment angles to change and may cause wheel shimmy, unusual noises, pulls or abnormal tire wear.

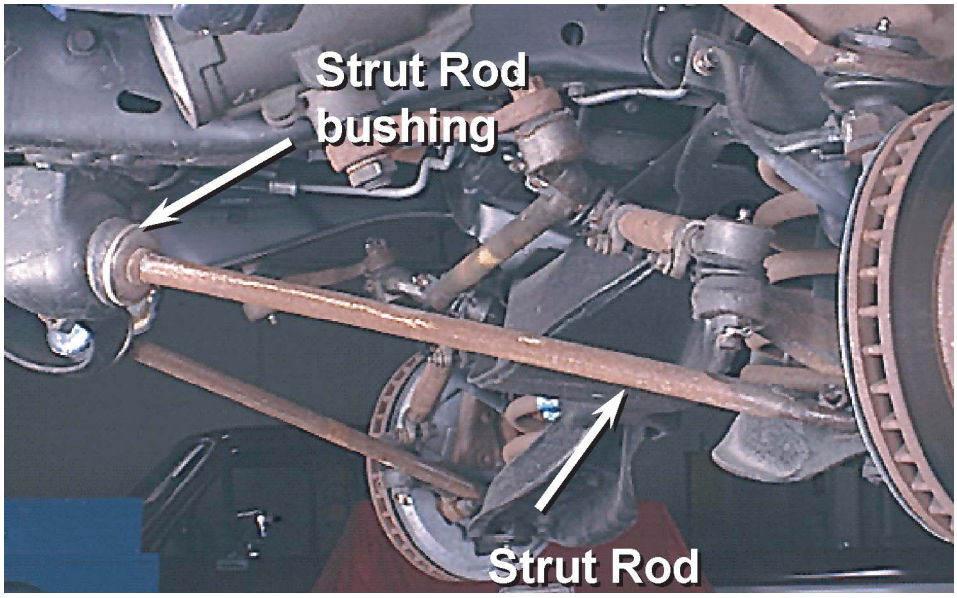


Figure 4b-20, Strut Rod Bushings

The radius arms on many Ford trucks and Range Rover SUV's connect the front axle to the frame and allow for axle articulation. Check the radius arm bushing for wear, many wear from the inside out.

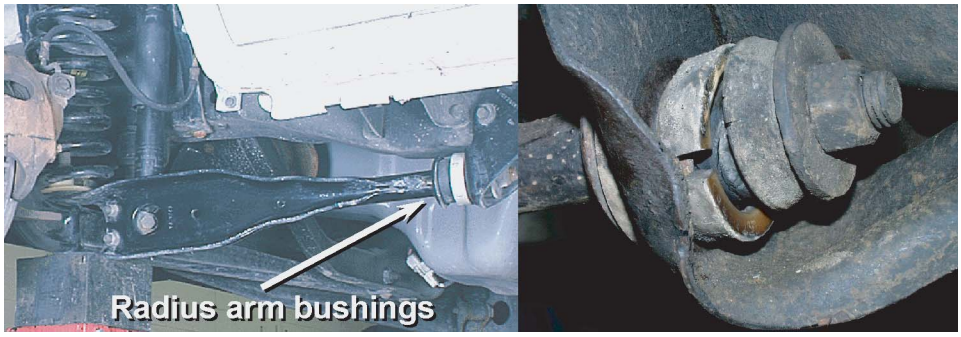


Figure 4b-21, Radius Arm Bushings

The sway bar helps control body roll during turns. The links connect the sway bar to the lower control arms and the frame bushings connect the sway bar to the frame.

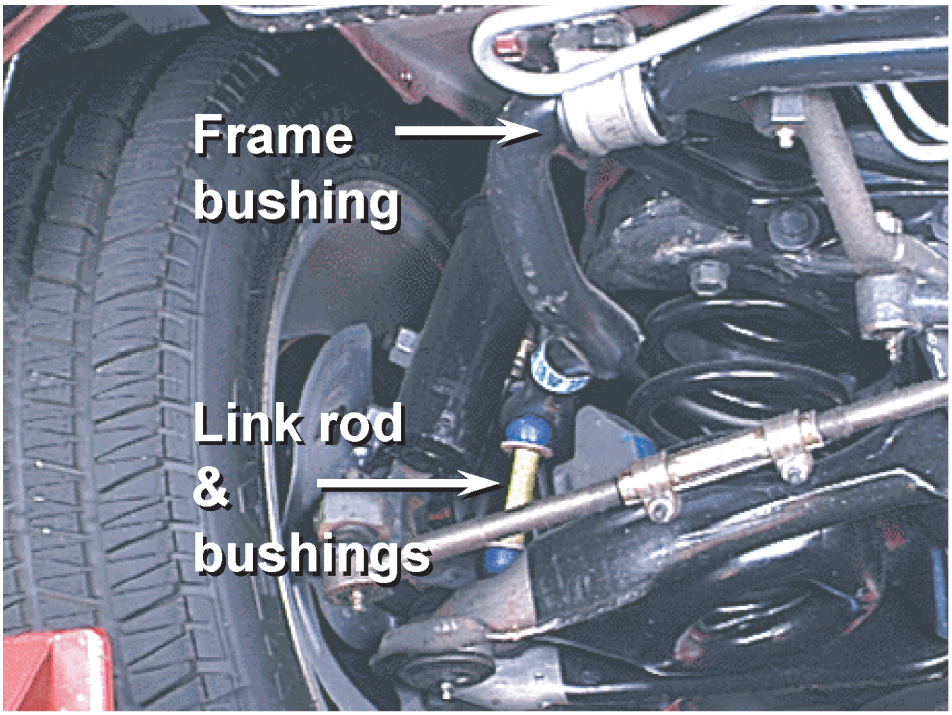


Figure 4b-22, Control Arm Bushings

Excessive cracking or bushing deterioration may cause directional instability during acceleration, cornering, and hard braking.

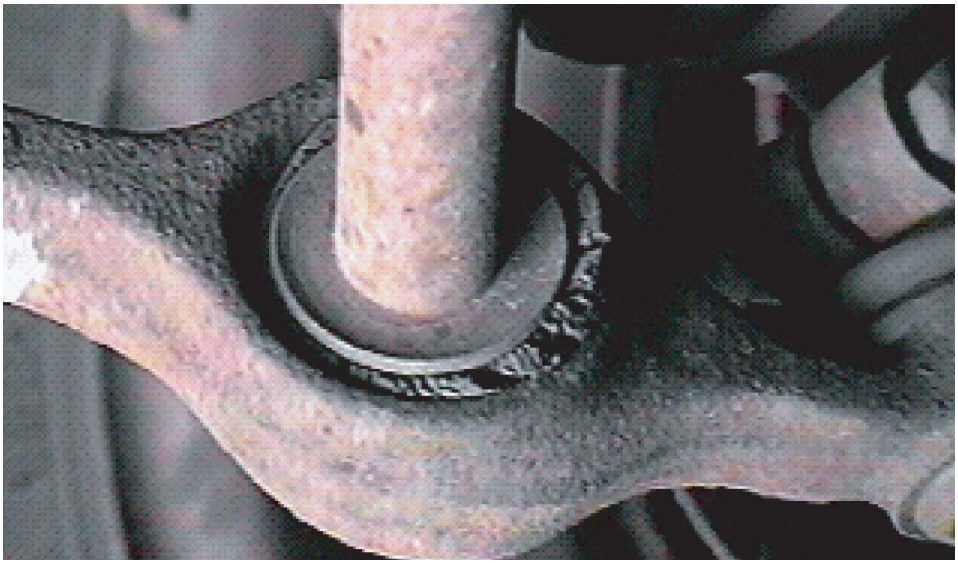


Figure 4b-23, Deteriorated Control Arm Bushing

Springs, Shocks and Struts

Inspect for broken, damaged, or loose springs and shock absorbers

Shock absorbers leaking externally should be replaced. Inspect the shock absorber bushings and bolts for looseness or damage. Check the mounting brackets for damage.

Inspect each spring carefully. Check for proper spring position in the spring holder. Look for signs of the suspension bottoming out on the jounce bumper. Inspect for broken springs. Springs should be replaced in pairs. Worn, damaged or improperly installed springs or shock absorbers will affect overall vehicle handling in an adverse manner.

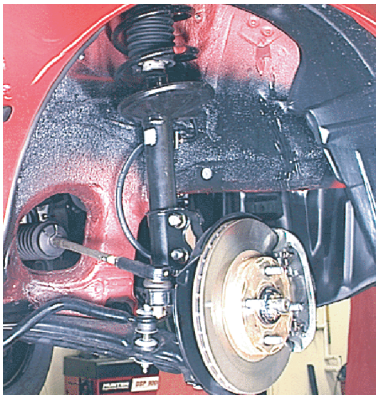


Figure 4b-24, Spring Position

Ball Joints

Ball joints provide a pivot point for the spindle to steer. Some support vehicle weight. Ball joints are designed in a ball and socket configuration. Proper lubrication minimizes friction between the ball and socket, but eventually the components wear and vertical and/or lateral play develops.

Since the ball joint serves as a pivot point for the spindle, vertical or horizontal movement of the ball joints affects alignment angles. Excessive movement may cause abnormal tire wear, instability and handling problems.

Figure 4b-25, Ball Joint

If the front spring rests on the lower control arm, the lower ball joint is the load-carrying ball joint.

*If the spring rests on the upper control arm, the upper ball joint is the load-ca*rrying ball joint.

The vehicle may be equipped with "**wear indicator**" ball joints. This design uses a collar protruding from the base of the ball joint around the grease-fitting inlet. As the ball joint wears, the collar retracts upward into the ball joint housing. *The ball joint is considered good when the collar extends past the ball joint housing.*

Inspect the collar with the weight of the vehicle on the tires.

OK *Worn*

Figure 4b-26,

Conventional ball joints should be checked by raising the front of the vehicle off the resting surface and prying up on the tire with a pry bar.

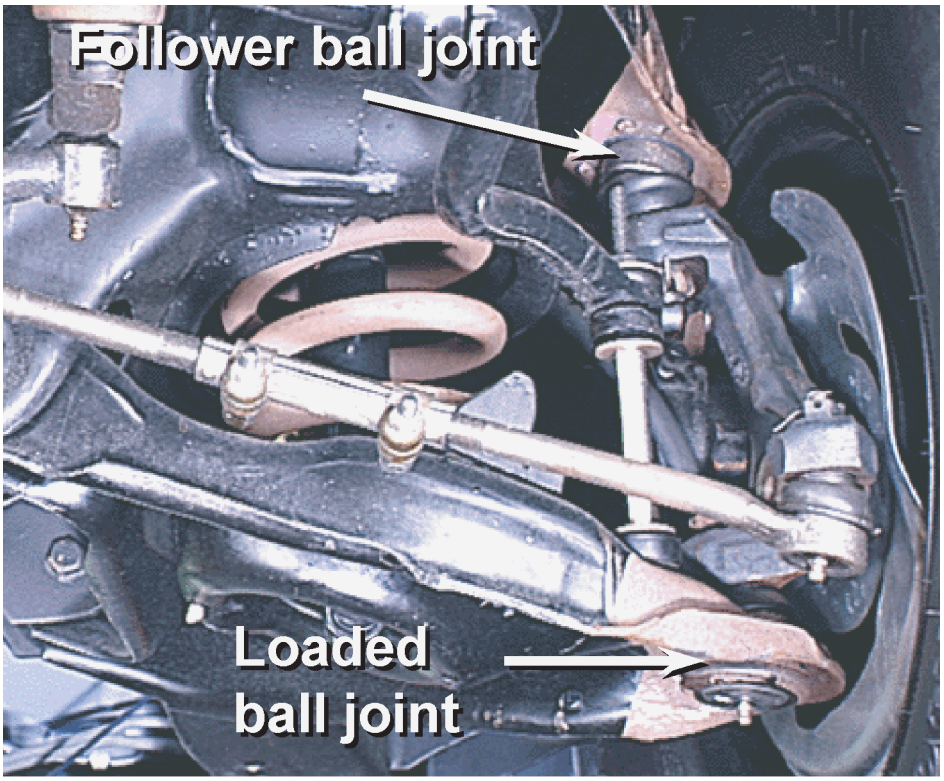
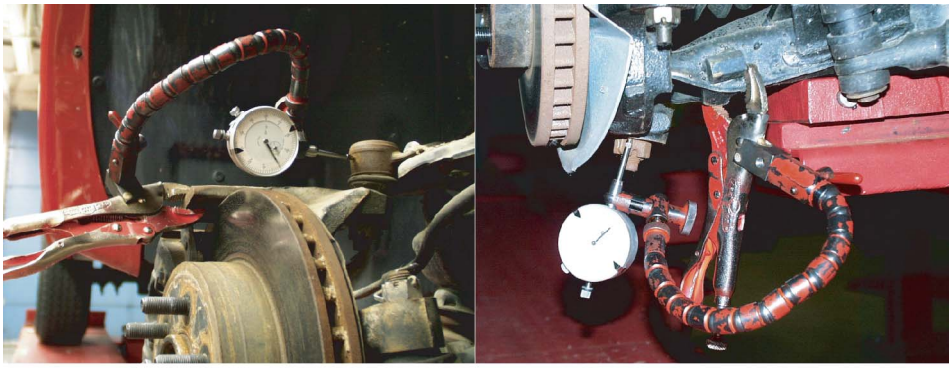


Figure 4b-27, Loaded Ball Joint Carries the Weight of the Spring

Raise the vehicle under the lower control arm if the lower ball joint is the load carrier.

Raise the vehicle by the frame if the upper ball joint is the load carrier.

Each vehicle manufacturer specifies the acceptable amount of lateral or vertical movement.



Axial Check *Radial Check*

Figure 4b-28, Axial/Radial Check

Use the appropriate table and measurement gauge to determine if the ball joint should be replaced. Some vehicles have upper and/or lower ball joints in the rear that must also be checked using the same guidelines.

Wheel Bearings

Wheel bearings should be inspected for looseness. Raise the front of the vehicle and rock the tire in and out at the top. Raise the rear of the vehicle and check the rear wheel bearings in the same manner. Adjust the wheel bearings if needed before checking ball joints, upper strut mounts or king pins.

Sealed wheel bearings are not adjustable and should be replaced if they are excessively loose. Loose wheel bearings may allow alignment angles to change resulting in abnormal tire wear, poor vehicle stability and handling problems.

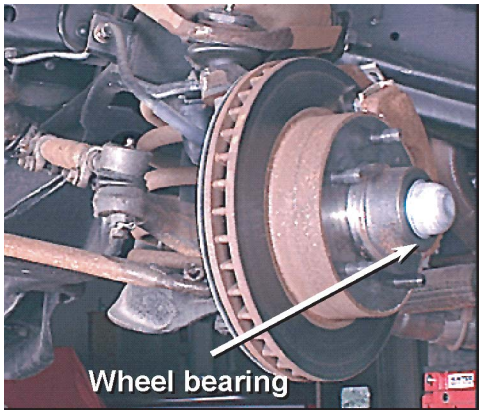


Figure 4b-29, Wheel Bearings

CV Joints

Constant velocity joints and shafts transfer power from the transaxle to the wheels. Check the inner joint for clunking when accelerating or braking.

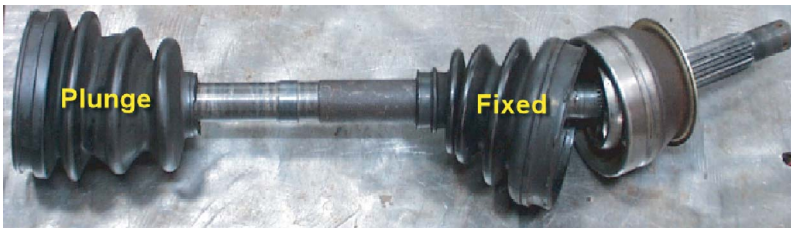


Figure 4b-30, Axle Shaft Assembly

Figure 4b-31, Torn Outer CV Boot

King Pins

King pins are still used on light and medium duty trucks and vans. They should be checked in the same manner as a ball joint with the exception that nominal vertical movement is acceptable. Lateral movement or binding is not acceptable.

Upper Strut Bearings

McPherson strut suspensions do not have an upper ball joint and the spring does not rest on the lower control arm. The upper strut bearing is the load carrying pivot point of the spindle.

Figure 4b-32, Upper Strut Bearing

Raise the vehicle by the frame. Pry under the tire to detect vertical play and move the tire in and out at the top to detect lateral play. Replace the upper strut bearing if excessive play is detected.

Rear Link Rods

Many performance vehicles with independent rear suspensions use link rods to connect the wheels to the chassis. Check each rod for looseness by shaking with firm hand pressure.

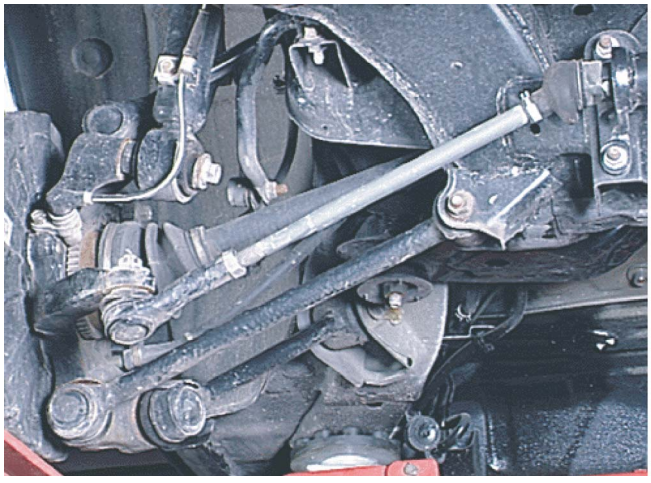


Figure 4b-33, Link Rods

Chassis and Driveline Components

Chassis components such as frame rails, cradles, engine mounts, drive axles, CV joints and bellows boots must also be inspected for damage or wear. Damaged or improperly positioned frame rails or cradles can cause alignment angles to change drastically. Check for signs of damage as well as signs of repair.

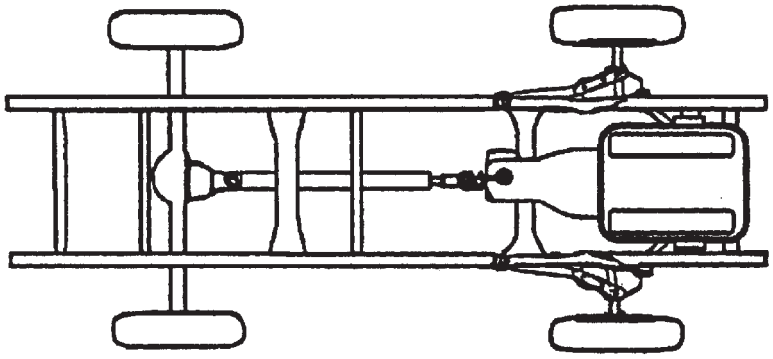


Figure 4b-34, Chassis and Driveline Components

Worn, broken or missing engine mounts may allow the engine to shift during acceleration and deceleration. Front wheel drive driveline angles will change as the engine lifts or lowers causing torque steer. Alignment angles may also change as the engine weight shifts from one position to another.

Drive axles, universal joints, CV joints and bellows boots should be inspected for damage and wear. Worn CV and universal joints may cause driveline misalignment producing vibration. Worn CV joints may bind causing the vehicle to pull due to uneven torque on the front wheels.

Brake Components

Brake components such as calipers, wheel cylinders, brake pads and shoes, rotors, drums and cables must be inspected for damage or wear.

Binding brake calipers or wheel cylinders may leave the brakes applied on a given wheel that may be experienced by the driver as a pull. Rotate each wheel to detect brake drag. Remember, heat causes expansion; so don't be surprised if brake drag is not detected on a vehicle that has not been recently driven.

Brake pads and shoes may become contaminated with brake fluid or axle grease causing the brakes to stay partially applied and create pull.

Rotors and drums that have excessive runout may be the cause of vibrations during braking.

Parking brake cables should operate freely. Verify that the parking brake releases completely and does not cause the brakes to drag.

Ride Height for Passenger Vehicles

Each vehicle is designed with a specific ride height.

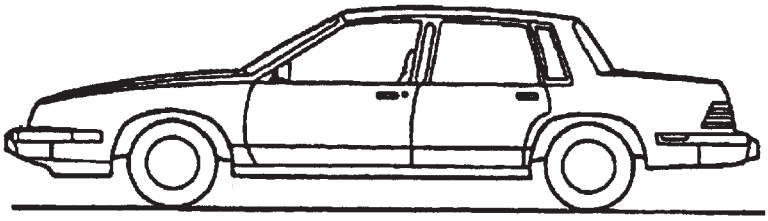


Figure 4b-35, Ride Height

The assigned ride height permits the suspension to move up and down while minimizing caster, camber and toe changes.

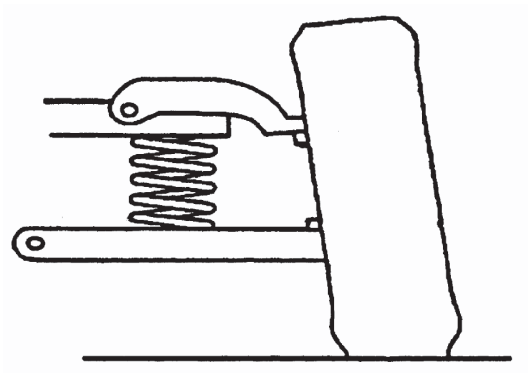


Figure 4b-36, Spring Sag

Spring Sag

Spring sag may cause:

- Front camber, caster and toe changes
- Rear camber and toe changes
- Ride quality changes
- Handling changes
- Premature wear on steering and suspension parts

Use the proper procedure for measuring the ride height of the vehicle.

Don't rely on the naked eye!

Most manufacturers have specific measurement locations.

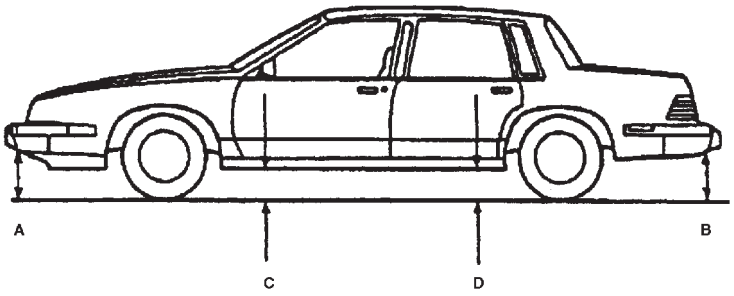


Figure 4b-37, Ride Height Measurements

Before measuring ride height, perform the following steps:

- Adjust tire pressure to OEM specification.
- Inspect for added weight.
- Move front seats to rear most position.
- Fuel tank should be full. If not, estimate the weight that should be added at 6 lbs/gallon.
- If tire size has been altered, corrections to ride height must be made from appropriate charts.

Vehicle must be on a level fixture or floor.

Measurement procedures will vary from one manufacturer to another. The suspension design dictates the ease of ride height corrections.

Inspect spring condition with a jounce and rebound test:

- Jounce the vehicle by pushing down in the center of the front bumper
- Rebound the vehicle by pushing up in the center of the front bumper
- Watch the camber angles when performing the test

Camber should change in a positive direction when jounced on an SLA suspension.

Camber should change in a negative direction when rebounded on an SLA suspension.

Camber should change in a negative direction when jounced on a strut suspension.

Camber should change in a positive direction when rebounded on a strut suspension.

If camber doesn't change or changes in the wrong direction, a spring sag condition may exist.

Factors to consider before recommending spring replacement:

- Most ride height specifications are ± 3/8".
- Be aware of the load demands put on the vehicle.
- Inspect jounce bumpers for signs of bottoming out.
- Is the owner complaining of poor ride quality?
- Have the tire and/or rim sizes been modified?

Coil Spring Design

Although there are aftermarket components such as spring spacers and pads, it must be noted that overall suspension performance may not be adequate unless the springs are replaced.

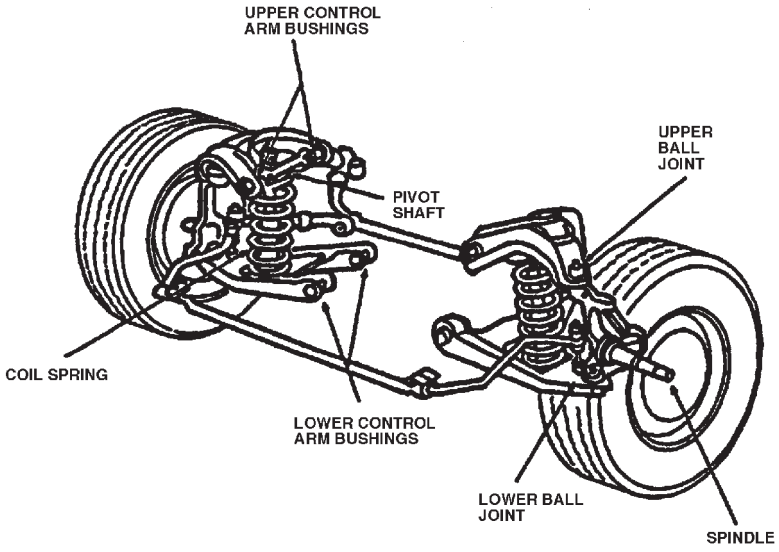


Figure 4b-38, Coil Spring Design

Coil springs should be replaced in pairs to maintain side-to-side level. Inspect new springs carefully. It is common for one of the springs to be marked "DRIVER'S SIDE ONLY," Consult factory procedures for replacing springs.

Leaf Spring Design

Leaf springs are commonly found on the rear of rear wheel drive vehicles and the front of 4 wheel drive trucks. If the ride height is incorrect, the springs should be re-arched or replaced in pairs.

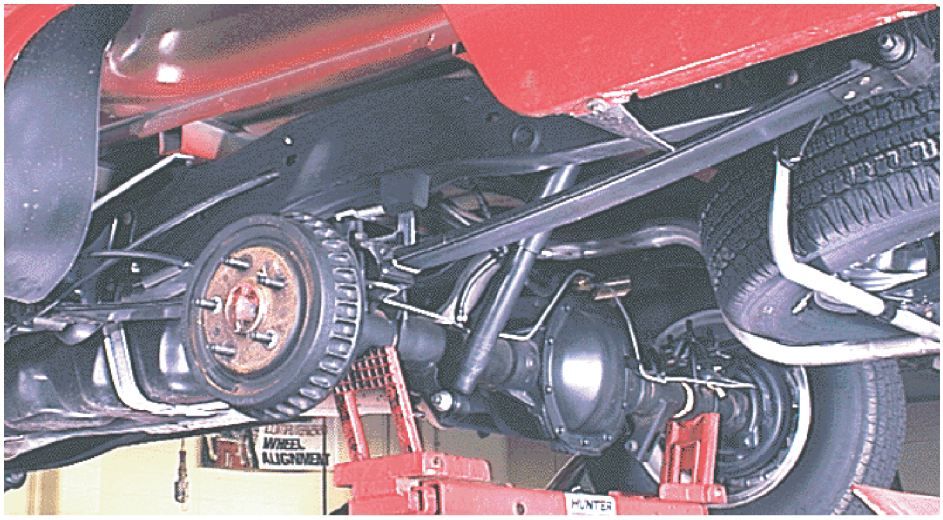


Figure 4b-39, Leaf Springs

The rear axle is located and aligned with a centering pin. A broken centering pin will cause the axle to shift on the spring affecting thrust angle and directional stability.

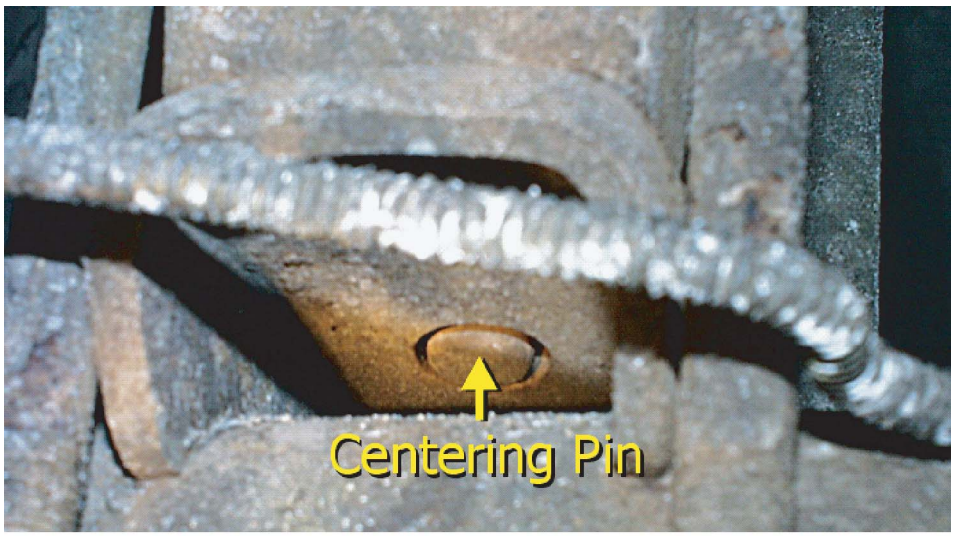


Figure 4b-40, Rear Axle Centering Pin

Some vehicles use rear axles with coil springs. A track bar centers the rear axle to the vehicle. Worn track bar bushings or a bent track bar can affect thrust angle and overall vehicle handling.

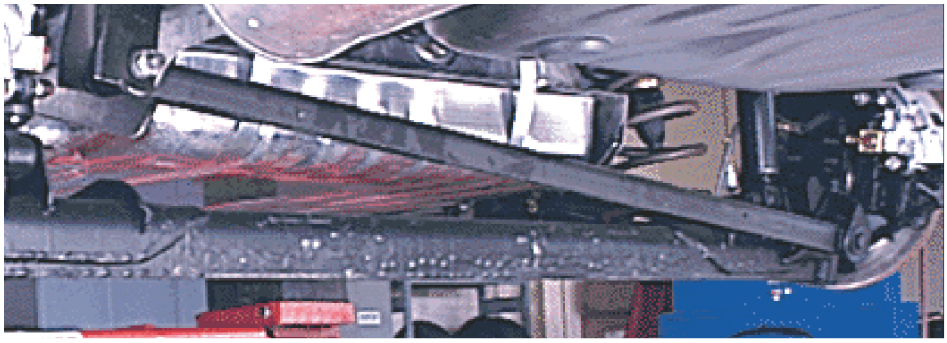


Figure 4b-41, Rear Track Bar

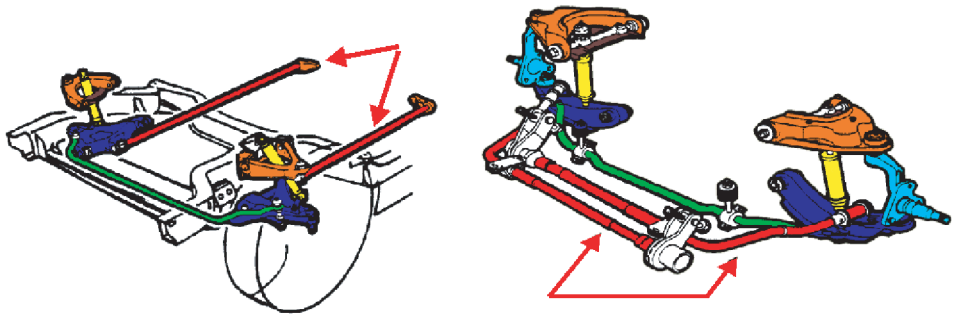
Aftermarket components such as lowering blocks, different length shackles, and overload leafs are available to alter the ride height. These are generally used to customize a vehicle for one particular purpose such as racing, off-road use or shows.

To maintain the ride and handling qualities that were designed into the vehicle, it is a good idea to maintain OEM configurations.

Adding or removing leafs from the shim pack will change the spring stiffness and should be avoided. Consult factory procedures for replacing springs.

Torsion Bar Design

Torsion bars are spring steel bars and may fatigue or break like other styles of springs.



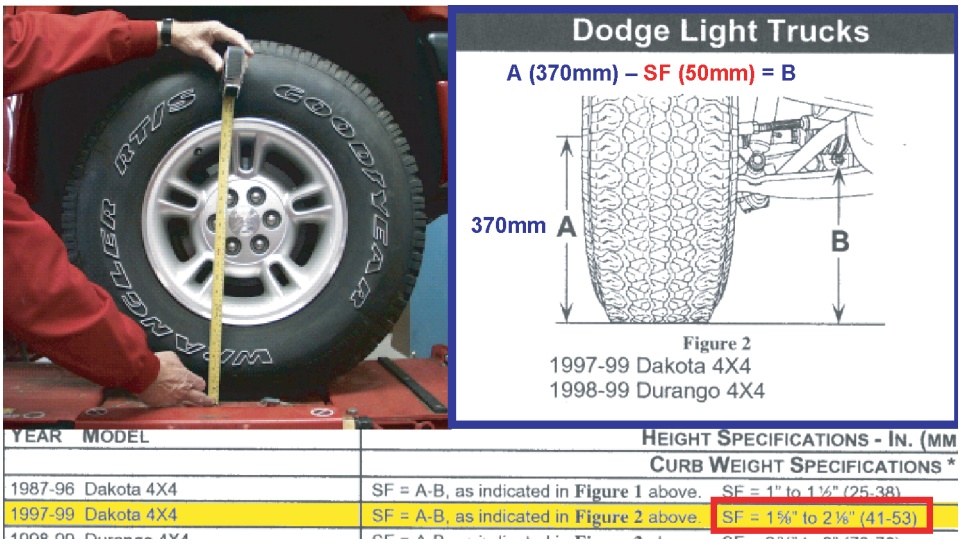
Longitudinal *Transverse*

Figure 4b-42, Torsion Bars

You can restore a vehicle's ride height to specifications by adjusting the torsion bars. Check the shop manual for the correct procedure and measuring locations.

Example: 1998 Dodge Durango 4x4 Pickup

Start by measuring from the center of the wheel to the turnplate.



YEAR MODEL	HEIGHT SPECIFICATIONS - IN. (MM CURB WEIGHT SPECIFICATIONS *	
1987-96 Dakota 4X4	SF = A-B, as indicated in **Figure 1** above.	SF = 1" to 1½" (25-38)
1997-99 Dakota 4X4	SF = A-B, as indicated in **Figure 2** above.	SF = 1⅝" to 2⅛" (41-53)

Figure 4b-43, Measure From The Center of the Wheel to the Turnplate

Adjust the torsion bar until the distance from the center of the lower control arm pivot bolt to the turnplates is 41-53 mm. less than the distance from the center of the wheel to the turnplate.

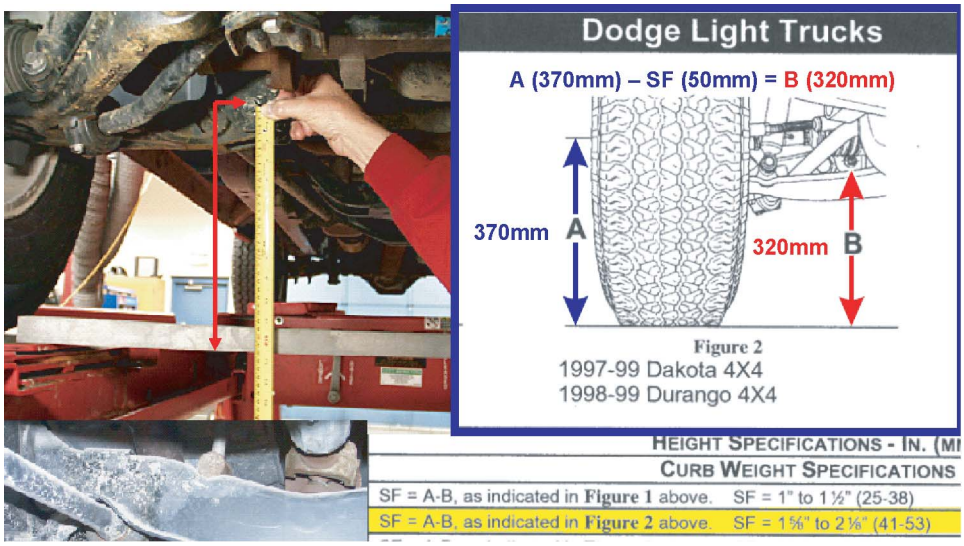


Figure 4b-44, Adjust the Torsion Bar So "B" is 41-53mm Less Than "A."

The following procedures should be followed when measuring ride height on a torsion bar suspension:

- Remove the turnplate pins.
- Jounce the vehicle ten to twelve times before and after ride height measurements on transverse style.
- Jounce the vehicle four to six times before and after ride height measurements on longitudinal style.

Adjust ride height by turning an adjustment bolt near the end of the torsion bar. Consult manufacturer's procedure for spring replacement.

Air Spring Design

Vehicles equipped with automatic level control systems may be equipped with air springs.

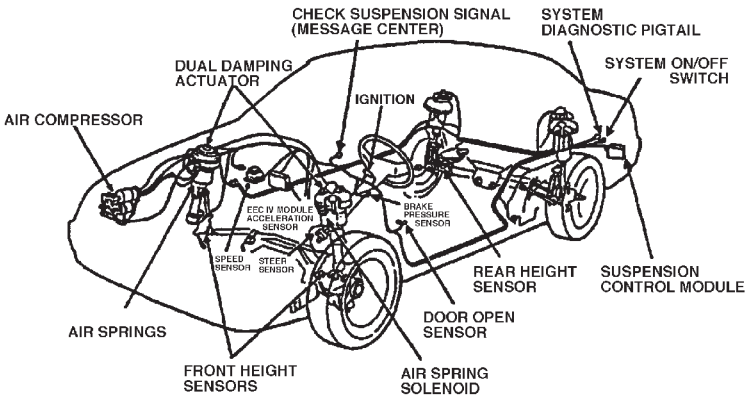


Figure 4b-45, Air Spring Design

Factory Specifications

Each vehicle is assigned factory alignment specifications.

The overall objective is to supply a set of specifications that will provide maximum tire tread life, handling and passenger comfort.

The manufacturer makes assumptions about passenger and cargo weight, driving habits and styles, and vehicle maintenance. Unfortunately, these assumptions are not always correct.

The only assumption that is certain is the customer expects all of these objectives to be met.

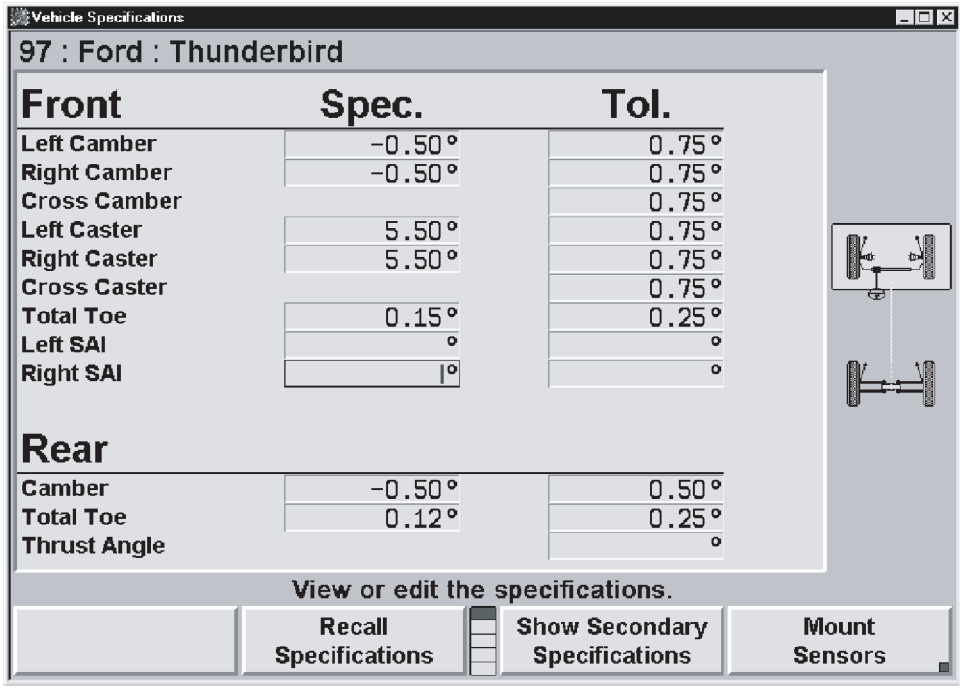


Figure 4b-46, Vehicle Specifications

To contend with real world variables, specifications for each vehicle are supplied with a tolerance. The tolerance allows the alignment technician to vary from the preferred specification without leaving factory constraints.

The tolerance of a specification should be used when the preferred setting produced unsatisfactory results.

It is not a good idea to go beyond the tolerance limits unless authorized to do so by the vehicle's manufacturer.

Modified Vehicles

A vehicle is considered modified when components are added, deleted or altered. This includes tires, wheels, tool boxes, spring alteration, lift kits, larger or smaller engines, etc.

Aftermarket wheels designed with negative offset distribute the weight of the vehicle farther outboard on the spindle than factory stock wheels or positive offset wheels.

Negative *Positive*

Figure 4b-47, Offset Wheels

Lowering a vehicle by cutting the springs changes the relationship between the two pivot points of the spindle. This affects the alignment angles and the adjustment range for camber.

Figure 4b-48, Lowered Vehicle

Raising a truck by over adjusting the torsion bars also changes the relationship between the two pivot points of the spindle.

Figure 4b-49, Lifted Truck

This can radically affect alignment angles, the adjustment range for camber and cause "bump steer."

Adding or removing weight from a vehicle affects ride height.

Alignment angles change in relationship to ride height.

Alignment specifications are not intended to offer preferred alignment settings for modified vehicles.

Use the alignment specifications as a guideline and attempt to stay within factory tolerances if possible. Stay alert to specification differences between different versions of the same body style to help you determine an ideal setting for a modified vehicle.

Explain how vehicle modifications affect alignment angles to the customer and let them be part of the decision process when possible.

Alignment Measurements

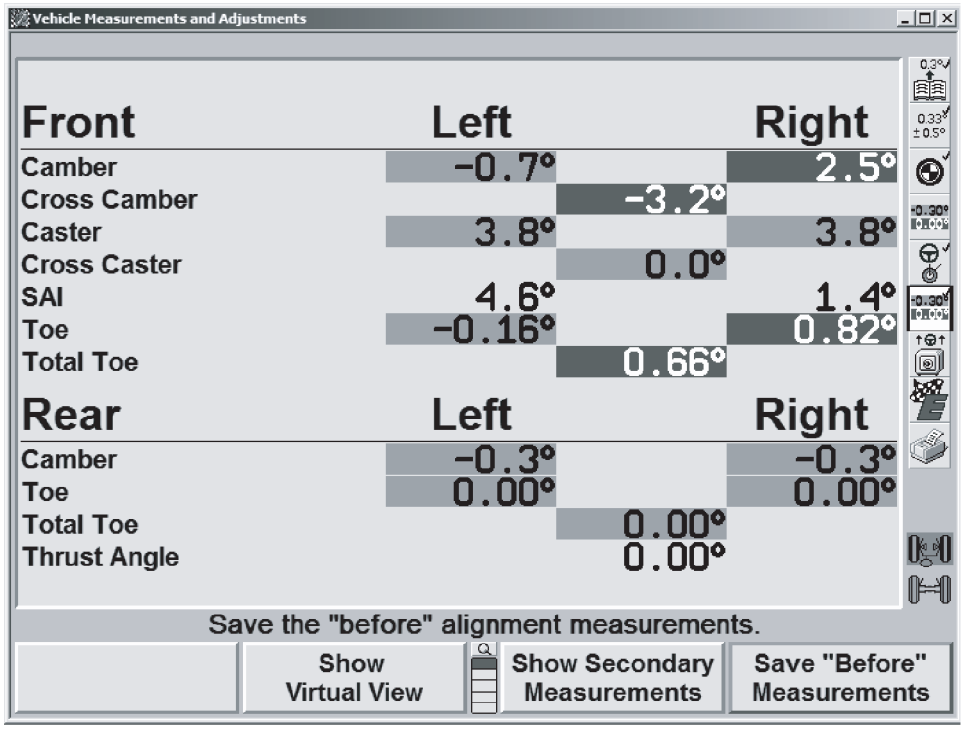


Figure 4b-50, "Primary Alignment Measurements" Screen

Camber

Camber is the angle formed by the inward or outward tilt of the wheel referenced to a vertical line originating from the center base of the tire.

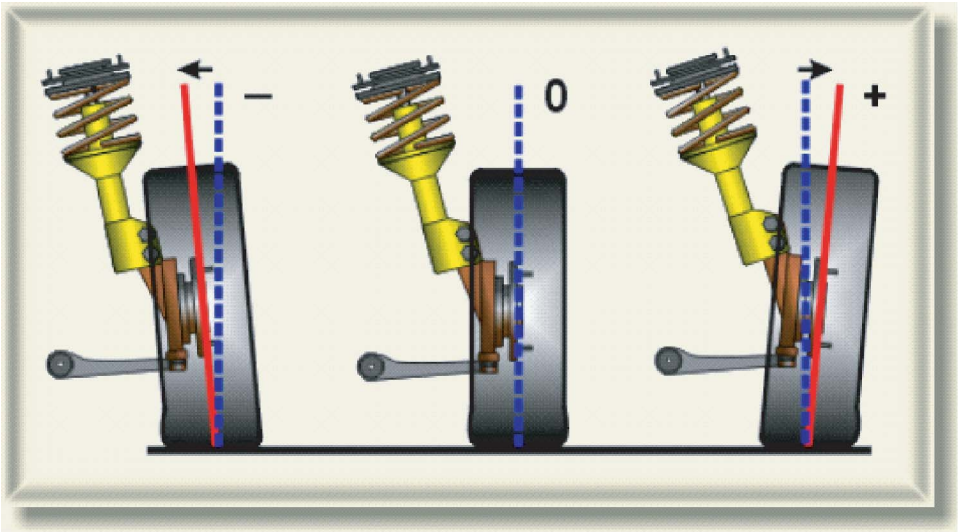


Figure 4b-51, Camber

Camber is measured and displayed in degrees.

Camber specifications are given for each wheel separately.

Camber is measured and displayed in degrees.

Camber specifications are given for each wheel separately.

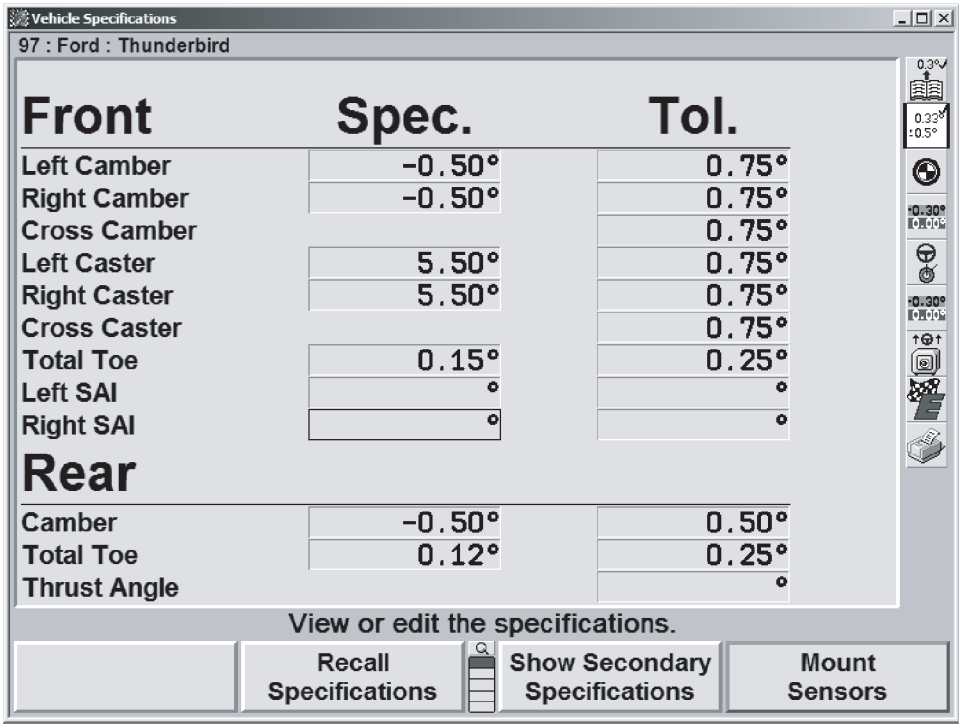


Figure 4b-52, Camber Specifications

Camber angles affect road isolation, ride quality, directional stability and tread life.

Excessive camber may cause premature tire wear.

Excessive positive camber wears the outer shoulder of the tread surface.

Excessive negative camber wears the inner shoulder of the tread surface.

Cross camber is the front camber measurements side to side.

Cross camber greater than **±0.5º** may cause a pull or drift to the side with the **most positive** camber setting.

Figure 4b-53, Excessive Camber May Cause Shoulder Wear on the Tire's Tread

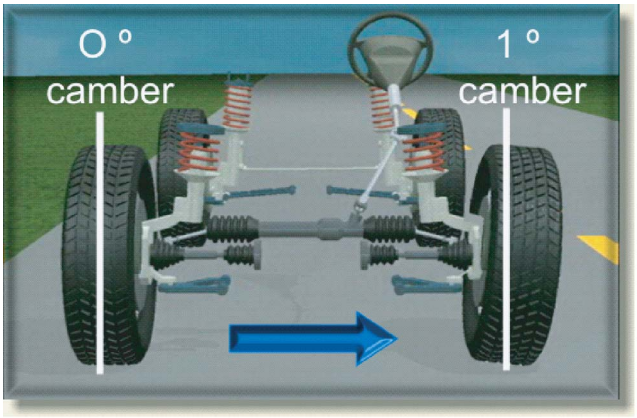


Figure 4b-54, Excessive Cross Camber Causes A Pull to the Most Positive Side

Some vehicles are specified at greater than ±0.5º side-to-side.

This sometimes helps combat torque steer and enhance directional stability.

The primary purpose of positive camber is to maintain vehicle load inboard on the spindle.

With positive camber, the vertical line intersects the spindle near the inner wheel bearing.

With negative camber, the vertical line intersects the spindle near the outer wheel bearing.

The spindle acts much like a lever. The length of the lever is determined by where weight is placed on the spindle. The longer the lever, the greater the leverage and the easier it becomes to move weight.

As the wheel hits a road irregularity, the spindle may generate enough force to move the wheel from straight ahead and affect directional stability.

This may increase road shock, reduce ride quality and increase wear on the outer wheel bearing.

Positive camber reduces the leverage of the spindle. Road isolation, ride quality and directional stability may improve because more force would be needed to move the wheel from straight ahead.

Rear camber is often specified negative to enhance cornering, directional stability or tread life. Some manufacturers do not provide rear camber specifications on rear-wheel-drive vehicles. Some vehicles are specified to have negative camber on front and rear.

Modified vehicles may require variance from the preferred camber specification. The major components to consider are:

- Negative offset wheels
- Wide tires
- Passenger or cargo weight

Combinations of tires and wheels, other than factory-equipped versions, may require different camber settings.

Negative offset wheels place vehicle weight farther outboard on the spindle.

Adjusting camber in a positive direction will move the vehicle weight inward on the spindle.

Wide tires are very susceptible to tire wear due to camber. Most wide tires will wear the longest with camber settings close to zero. This presents a problem because offset wheels are commonly matched with wide tires.

You may have to choose between leaving the spindle loaded outboard or adjusting camber in a positive direction to position the weight inboard on the spindle but most likely cause outside tire wear.

Zero camber will keep the tire wear to a minimum but may leave vehicle weight positioned outboard on the spindle. This will cause excessive strain on the outer wheel bearing, reduced ride quality and possible instability.

Each suspension reacts in its own way to weight added or subtracted.

You may have to modify camber settings if a passenger is an extremely heavy person or if cargo is carried in the vehicle on a regular basis.

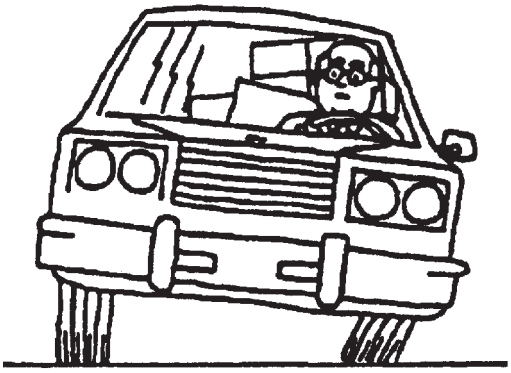


Figure 4b-55, Load Imbalance

Camber will change in a positive direction on short/long arm and strut suspensions on the side that is loaded and in a negative direction on the side that is unloaded. Camber will change in a negative direction on both sides of an I-Beam suspension.

Anticipate the change in camber when side-to-side weight is a factor. Place the weight in the vehicle if possible

Always consult the manufacturer's recommended specifications. Stay within factory tolerances if possible.

Camber on both front wheels will change as weight is added to the rear of the vehicle. The front suspension style dictates how camber will change.

Front camber on McPherson strut or I-beam suspensions will change in a positive direction as the rear of the vehicle is loaded.

Front camber on an SLA suspension will change in a negative direction when the rear of the vehicle is loaded.

The change will be proportional to the amount of weight added to the rear of the vehicle.

Jounce and Rebound Test

Use a jounce and rebound test to determine changes in alignment angles due to added weight in the rear of the vehicle.

Push down in the center of the front bumper to simulate more weight in the front of the vehicle. Observe the alignment angle change.

Push up under the center of the front bumper to simulate more weight in the rear of the vehicle. Observe the alignment angle change.

Note: Some truck specifications are based on front ride height measurements due to varying loads placed in the rear of the truck affecting camber.

Caster

Caster is the angle formed by the forward or rearward tilt of the steering axis in reference to a vertical line drawn from the center base of the wheel and viewed from the side.

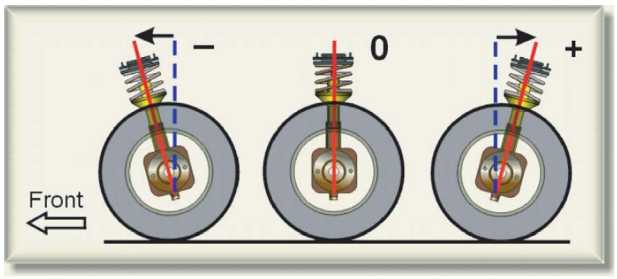


Figure 4b-45, Caster

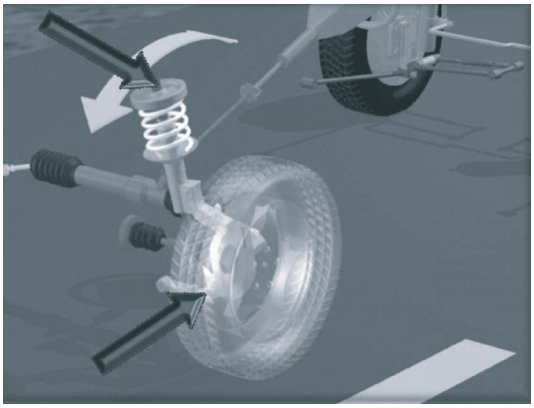


Figure 4b-46, Steering Axis

Caster is measured and displayed in degrees.

Caster is specified for each wheel separately.

Front	Spec.	Tol.
Left Camber	-0.50°	0.75°
Right Camber	-0.50°	0.75°
Cross Camber		0.75°
Left Caster	5.50°	0.75°
Right Caster	5.50°	0.75°
Cross Caster		0.75°

Figure 4b-47, Caster Specifications

Caster is affected by frame angle. Frame angle changes as a vehicle is raised or lowered in the rear.

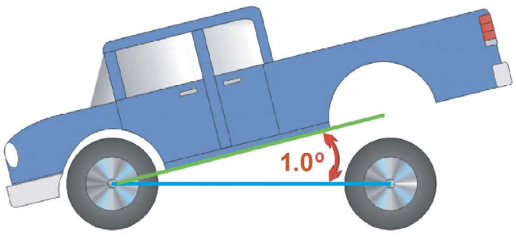


Figure 4b-47 Frame Angle Affects Caster

A vehicle has a **positive** frame angle when the **rear is higher** than the front of the vehicle.

A vehicle has a **negative** frame angle when the **rear is lower** than the front of the vehicle.

Figure 4b-48, Magnetic Protractor

Use a magnetic protractor to measure the amount of frame angle.

Light trucks are generally manufactured with a positive frame angle in anticipation of the load they are designed to carry. Some passenger vehicles are raised in the rear by the owner to accept larger tires and/or wheels.

As the vehicle is raised or lowered, caster will change one degree for every one degree of change in frame angle.

Caster changes one degree in a negative direction for every one-degree the vehicle is raised in the rear. Caster changes one degree in a positive direction for every one-degree the vehicle is lowered in the rear. This can be an alignment factor when vehicles must be aligned without their usual load due to lift capacity restrictions.

Simply subtract one degree of caster from the existing caster specification for every one-degree of positive frame angle. It is possible caster cannot be set to specifications on altered vehicles due to the effect of frame angle on caster. Caster specifications offer tolerances to allow for different driving habits and conditions.

If the vehicle is unloaded and leans forward, be sure to measure the frame's angle and adjust the caster specification accordingly.

Loaded Spec.	-	Frame Angle	=	Unloaded Caster Spec.
3.0°	**-**	**1.0°**	**=**	**2.0°**

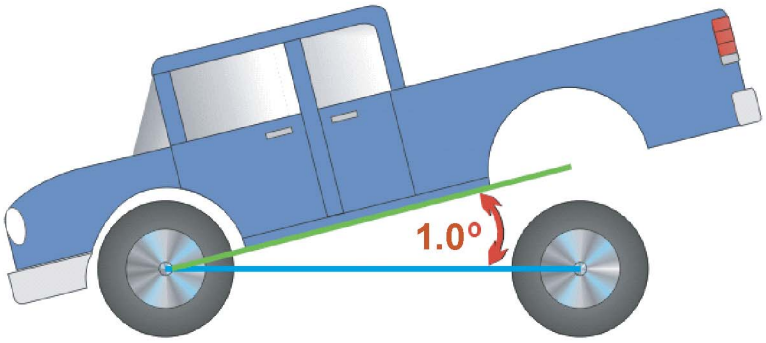


Figure 4b-49, If truck leans forward, subtract the frame angle from the caster specification

Frame leans *forward*: **Subtract** the frame angle from the caster specification

Frames leans *rearward*: **Add** the frame angle to the caster specification

Caster has three primary functions:

- Directional stability
- Returnability
- Enhance cornering

When caster is zero, the spindle moves in a horizontal path as the wheels are steered.

When caster is positive, the spindle moves down when the wheel is steered to the inside of a turn and up when the wheel is steered to the outside of a turn.

The spindle can travel down until the tire and wheel assembly forces vehicle weight to be lifted.

Caster causes weight to be lifted when turning.

Regardless of which way the wheels are steered, weight will be lifted by the wheel turning to the outside.

Since weight is being lifted, steering effort will increase as caster is increased. Steering effort is minimized through gear reduction and power steering.

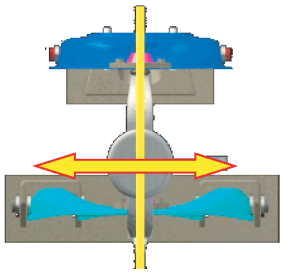
Because caster affects steering effort, more than one specification may be given for the same vehicle. The manual steering model usually has a lower specification.

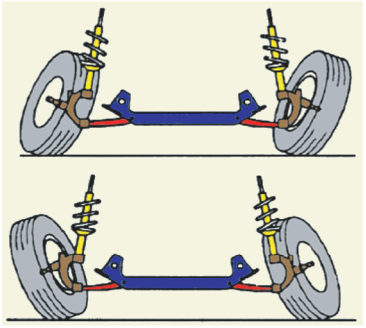
When released from a turn, vehicle weight will help move each spindle back toward a mid-point until load is equal. This is how positive caster provides returnability.

The same spindle movement that supplies returnability also helps to provide directional stability.

Directional stability is enhanced because vehicle weight helps hold the spindles in a straight-ahead position.

Cross caster is the front caster measurements side to side.





Cross caster greater than **±0.5º**, may cause a pull or drift to the side with the **least positive** caster setting.

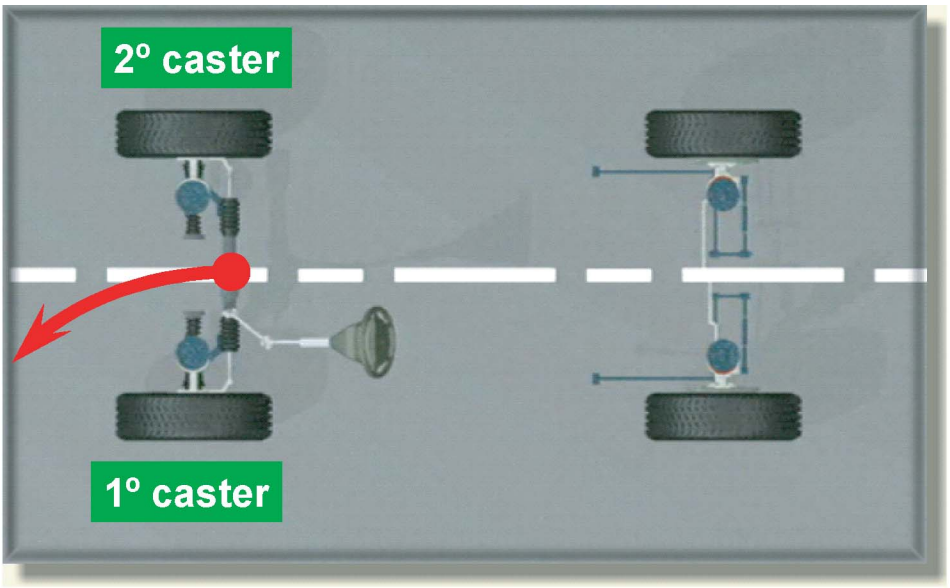


Figure 4b-50, Excessive Cross Caster May Cause A Pull to the Least Positive Side

Do not use caster to compensate for road crown or an existing pull if the vehicle has a caster setting less that 1.5º. A large caster difference side-to-side may create vehicle instability during hard braking.

Now that vehicles are downsized and overall weight has been reduced, caster specifications may be higher than those of years past.

An average caster specification for a vehicle with power steering is approximately 3 degrees. Higher caster settings have advantages and disadvantages.

Advantages of high positive caster:

- Greater directional stability
- Greater returnability

Disadvantages of high caster:

- Steering requires more effort
- Reduced road isolation
- Increased tire wear on turns

Higher positive caster settings require the spindle to turn downward at a more severe angle causing more weight to be lifted.

More weight being lifted places a greater load on the steering system. The increased steering axis angle helps maintain directional stability.

As the steering axis is tilted rearward, road shock has little to stop it from traveling into the driver's compartment.

As caster is increased, returnability is increased. However, higher positive caster may cause the wheels to return to center extremely fast causing the spindle to overshoot center.

A steering dampener is used in some high caster applications to reduce the speed of returnability.

The steering dampener works as a shock absorber to:

- Dampen the snap-back of the spindle
- Prevent a possible shimmy

Camber Roll

Camber roll is the change in camber caused by caster when the wheel is steered.

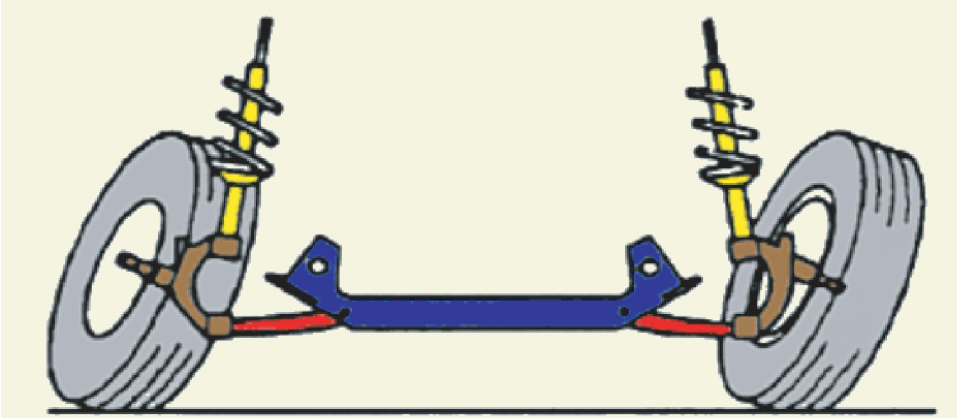


Figure 4b-51, Caster Causes Camber to Change as the Wheels are Steered Left or Right

As the spindle moves downward, camber moves in a positive direction. As the spindle moves upward, camber moves in a negative direction.

Camber roll helps to maintain stability when cornering.

Camber roll may increase scuffing on the shoulders of the tires.

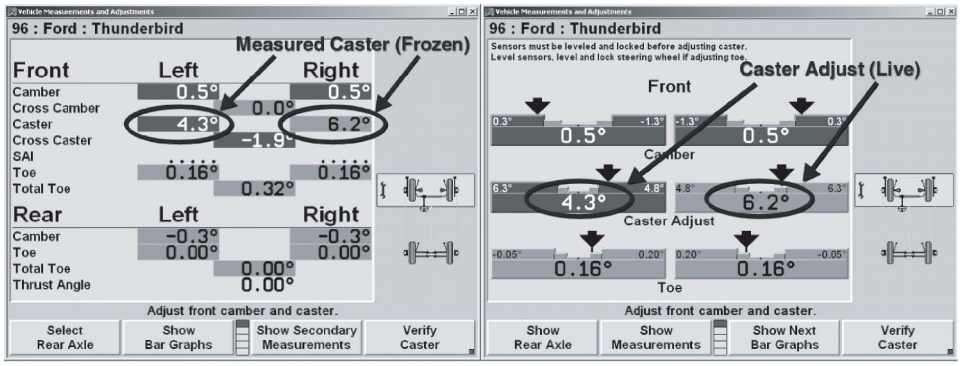
Note: Since camber is so greatly influenced by caster, it is extremely important the front wheels are straight ahead when measuring camber.

Measuring Caster

Caster must be calculated by steering the front wheels in a 20º turn and measuring the camber roll.

Adjusting Caster

To adjust caster, first lock the service brake with the pedal depressor. Level and lock the front sensors.



Alignment measurements screen *Alignment adjustments screen*

Figure 4b-52, Alignment Measurements/Adjustments Screen

Real Time Caster Adjustment Procedure

As caster is adjusted in a negative direction, the sensor will tilt forward. The bar graph will display the negative caster change.

As caster is adjusted in a positive direction, the sensor will tilt rearward. The bar graph will display the positive caster change.

Seven reasons the caster measurements display may not match the caster adjust bar graphs:

1. Technician did NOT lock the brakes with the pedal depressor.
2. Technician did NOT start the vehicle when locking the brakes.
3. Technician did NOT level and lock the sensors when instructed to.
4. Technician bumped the sensor during caster adjustment.
5. Technician keeps re-leveling the sensor during caster adjustment.
6. Technician adjusted caster but has NOT remeasured caster.
7. Technician jacked up the vehicle without selecting "Jack Up Selected Axle."

Toe

Total toe is the difference in distance between the front of the tires and the rear of the tires of a same axle.

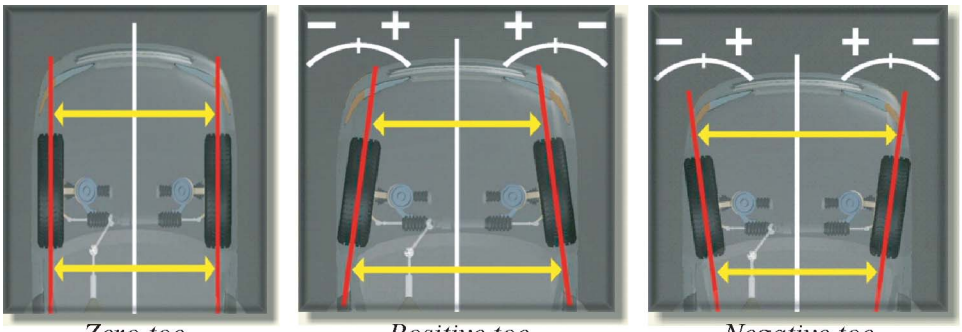


Figure 4b-53, Toe

Toe specifications are given as "total toe." The individual toe specification is ½° the total toe specification.

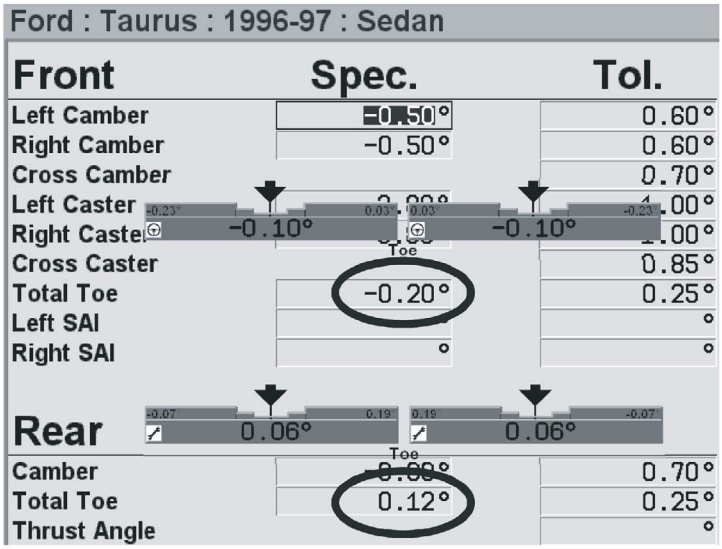


Figure 4b-54, Toe Specifications

Excessive toe will cause shoulder wear on the tire's tread.

Figure 4b-55, Excessive Toe Causes Shoulder War on the Tire's Tread

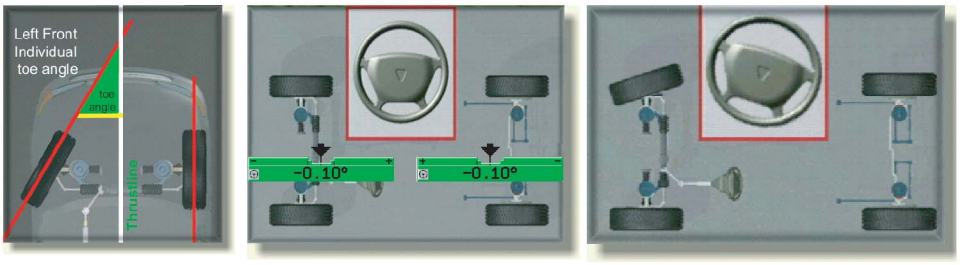
Excessive positive toe wears the outer shoulder of the tread.

Excessive negative toe wears the inner shoulder of the tread.

A saw-tooth or featheredge toe wear pattern is common with bias or bias belted tires.

Front toe will equalize, when the wheels are placed in motion, if there are no mechanical or hydraulic pressures working against it. Therefore, front toe wear will generally be symmetrical on both front tires.

Individual toe is the difference in distance of the front and rear of one tire in reference to a centerline.



Individual toe *Equal toe-level wheel* *Unequal toe-unlevel wheel*

Figure 4b-56,

Unequal front individual toe causes a crooked steering wheel Unequal rear individual toe causes "dog tracking" and tire wear.

Unequal individual toe on the rear axle may cause the rear tires' tread to squirm as the vehicle goes down the road.

This squirming will cause the rear tires to develop a diagonal cupping pattern on the tread surface.

Since rear wheels do not steer freely, rear tires generally develop toe wear on an individual basis.

Toe Related Geometry

Geometric centerline is a line drawn though the midpoints of both front wheels and both rear wheels.

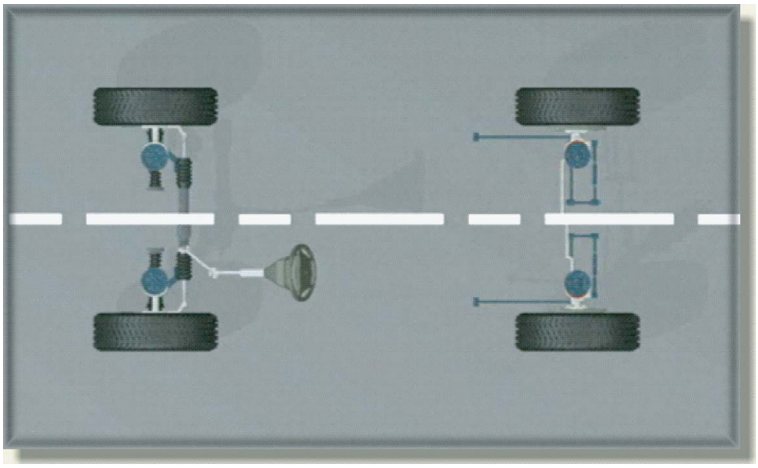


Figure 4b-57, Geometric Centerline

Thrustline is defined as a line bisecting the rear total toe angle-the direction the rear wheels point.

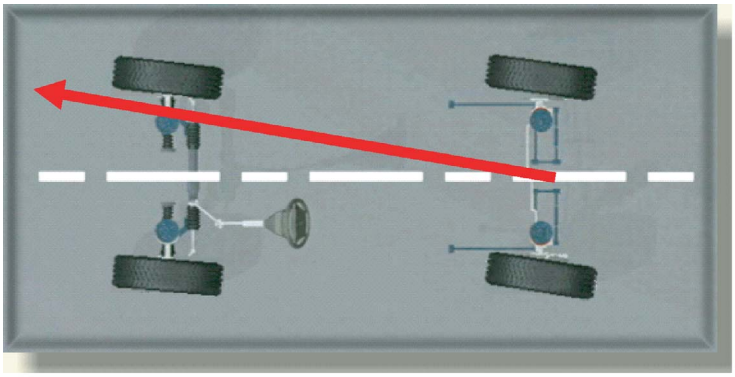


Figure 4b-58, Thrustline

A thrust condition exists when the rear individual toe is not equal.

Thrustline dictates the straight-ahead position of the front wheels; therefore, it is the most accurate reference when measuring or adjusting the front wheels. If thrustline is ignored, there can be no guarantee of alignment accuracy.

Ignoring thrustline is the primary cause of a crooked steering wheel.

As the front wheels steer to align themselves with the rear tires, the steering wheel moves off center.

Using a thrustline reference is preferred when a vehicle has a non-adjustable rear suspension.

Thrust Angle is the angle formed by the intersection of the geometric centerline and the thrustline.

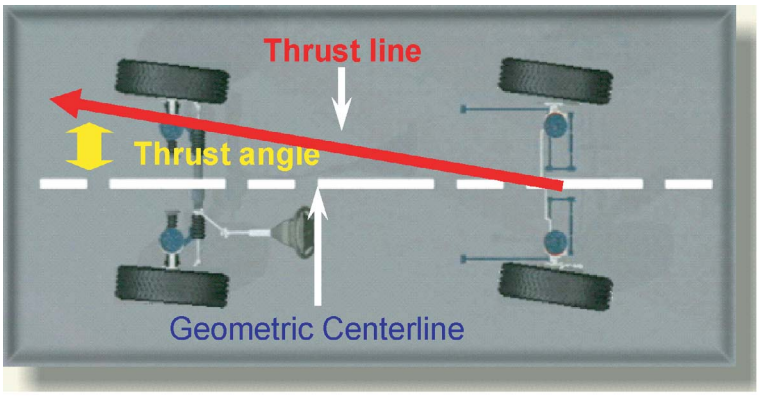


Figure 4b-59, Thrust Angle

Positive Thrust Angle is when the rear wheels point to the right of the geometric centerline.

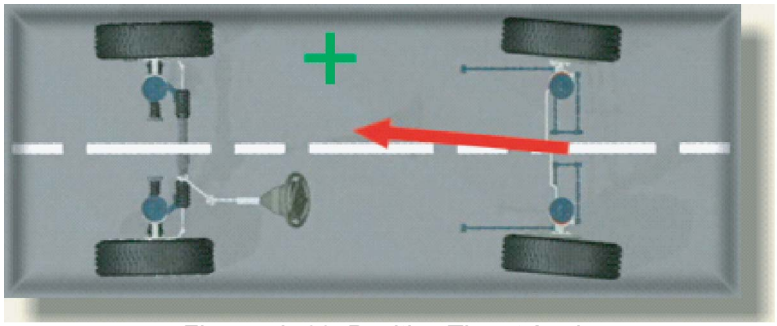


Figure 4b-60, Positive Thrust Angle

Negative Thrust Angle is when the rear wheels point to the left of the geometric centerline.

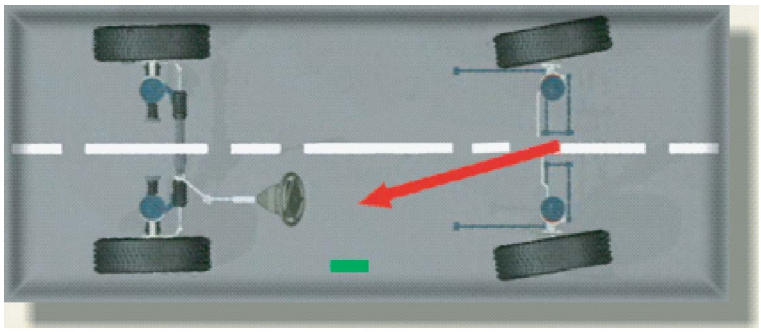


Figure 4b-61, Negative Thrust Angle

A thrust angle greater than 0º may cause the vehicle to "dog track" as it goes down the road.

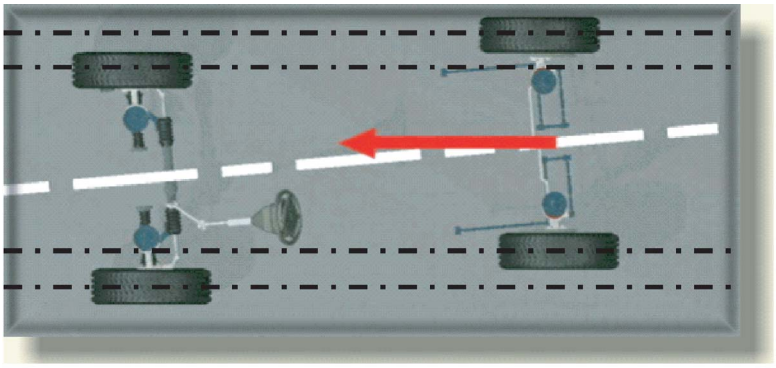


Figure 4b-62, Dog Tracking

Knowing the amount and direction of the thrust angle is necessary when making rear wheel alignment adjustments.

Don't ignore thrust angle on non-adjustable rear suspensions! Thrust angle is an important diagnostic tool.

The major problems associated with excessive thrust are:

- Dog-tracking
- Crooked steering wheels
- Bent or damaged components
- Shifted axles

Thrust angle, rear individual toe and total rear toe measurements are needed to identify the cause of the thrust condition and the necessary adjustment needed to correct it.

As an example, if left rear toe is +0.25º ?and the right rear toe is -0.25º ?on a fixed axle vehicle, it is very possible that the axle has shifted or a frame rail has been damaged.

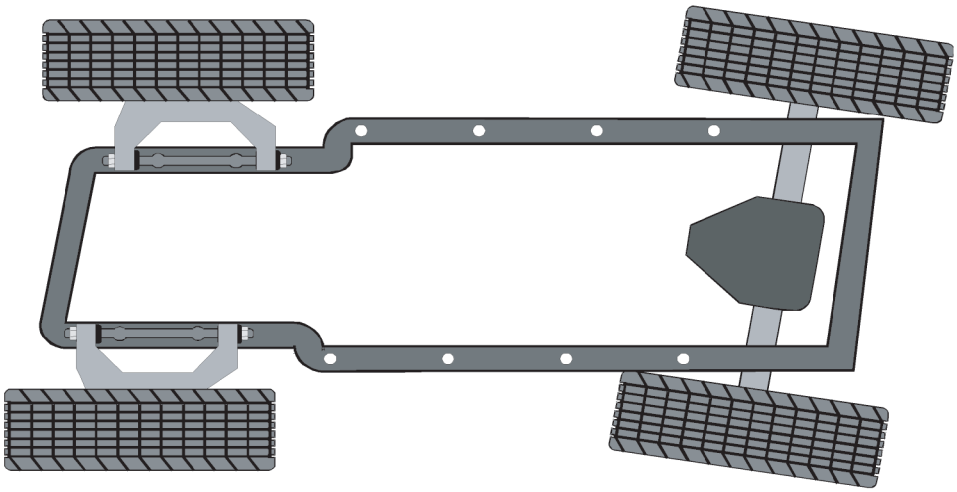


Figure 4b-63, Diamond Frame

As another example, if the left rear toe is +0.06º and the right rear toe is -0.65º, it is very possible the axle housing is bent.

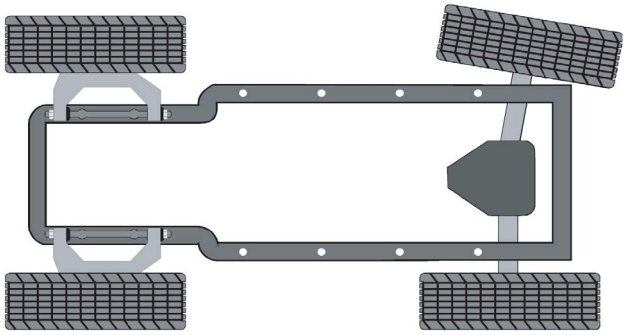


Figure 4b-64, Bent Axle

The total rear toe in the first example is 0.00º, whereas the total rear toe in the second example is -0.59º.

This shows rear total toe is also a useful diagnostic tool.

A proper diagnosis requires gathering as much information as possible. Each angle has an individual importance and an importance in relation to other angles measured on the vehicle.

Adjust rear toe on vehicles where adjustments are possible. After adjusting rear toe to preferred specification, thrustline will be parallel with the geometric centerline and the thrust angle is reduced to zero. This should eliminate any dog tracking.

Centerline steering is defined as the steering wheel being centered while the vehicle is traveling a straight course.

To achieve CENTERLINE STEERING, it is necessary to:

- Lock the steering wheel level.
- Adjust front toe equal to half of the specification with respect to rear wheel thrustline.

Remember, as a four wheel, two axle vehicle is placed in motion, the front wheels assume a direction parallel to the rear wheels.

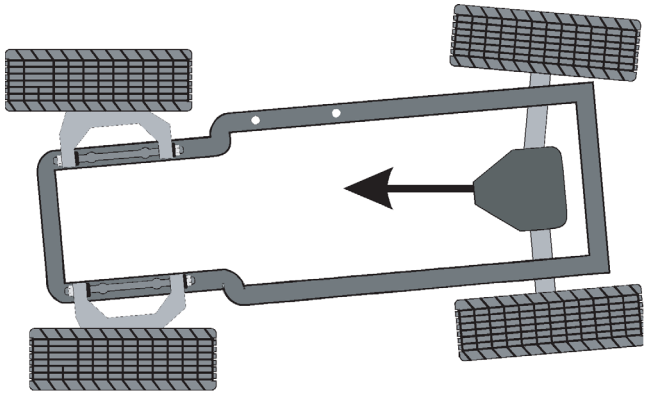


Figure 4b-65, The Rear Wheels Determine Straight Ahead

Alignment Procedures

A centerline alignment aligns the front wheels to the geometric centerline

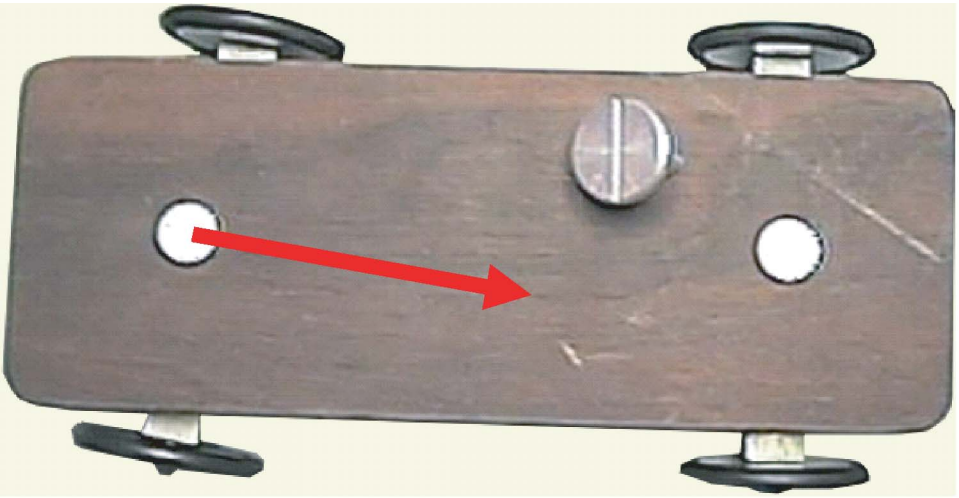


Figure 4b-66, Centerline Alignment – Compensate Front Sensors Only

Result:

- The vehicle dog tracks as it goes down the road
- The steering wheel is not centered

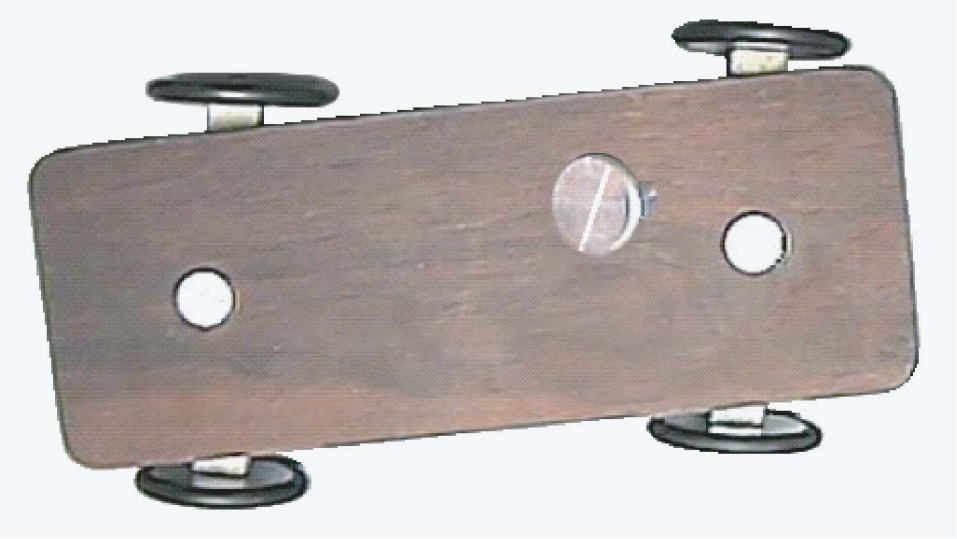


Figure 4b-67, Centerline Results

A **thrustline** alignment aligns the front wheels to the rear thrustline.

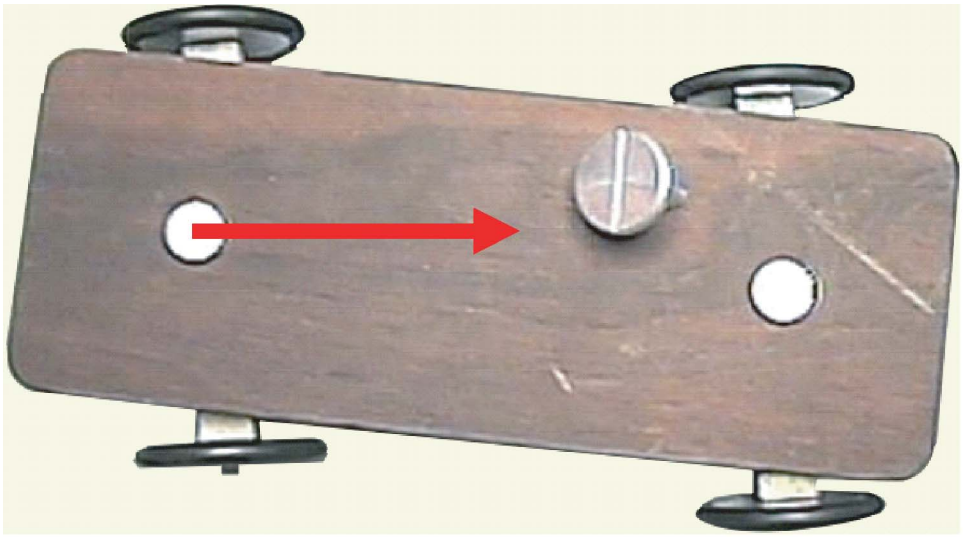


Figure 4b-68, Thrustline Alignment – Compensate All Four Sensors

Result:

- The vehicle dog tracks as it goes down the road
- The steering wheel is centered

A total 4-wheel alignment aligns the rear wheels to the geometric centerline and the front wheels to the rear thrustline.

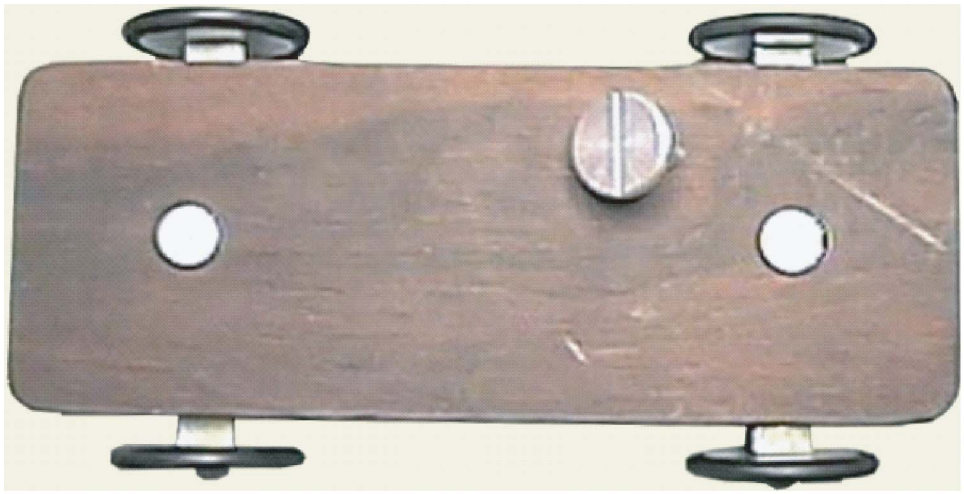


Figure 4b-69, Total 4-Wheel Alignment – Compensate All Four Sensors

Result:

- The vehicle's body goes straight down the road
- The steering wheel is centered.

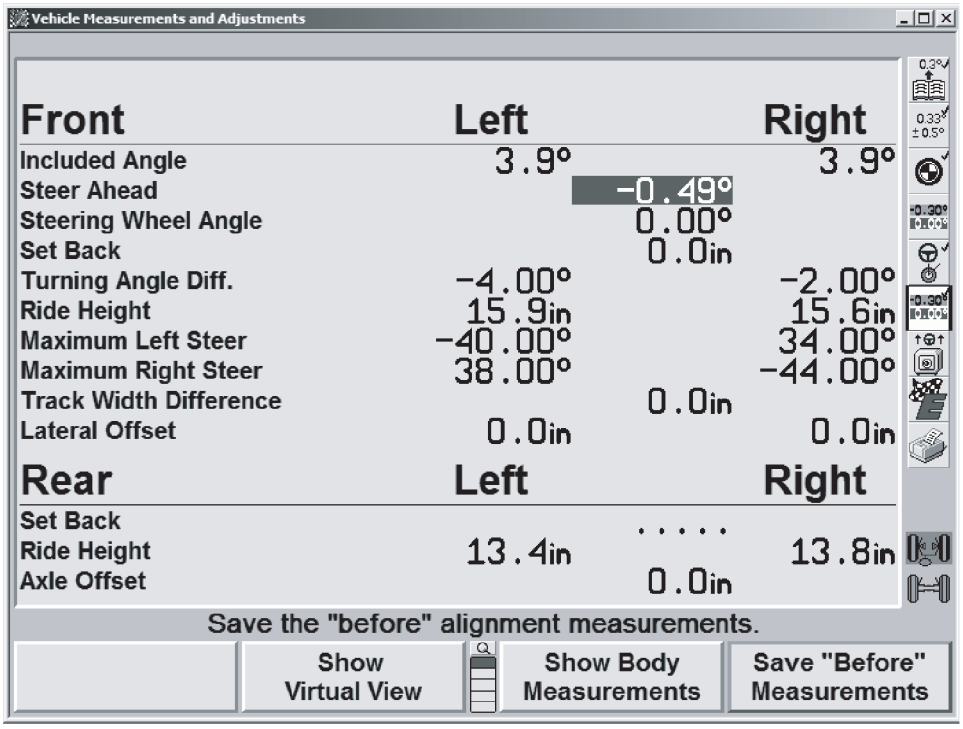


Figure 4b-70, Secondary Alignment Measurements Screen

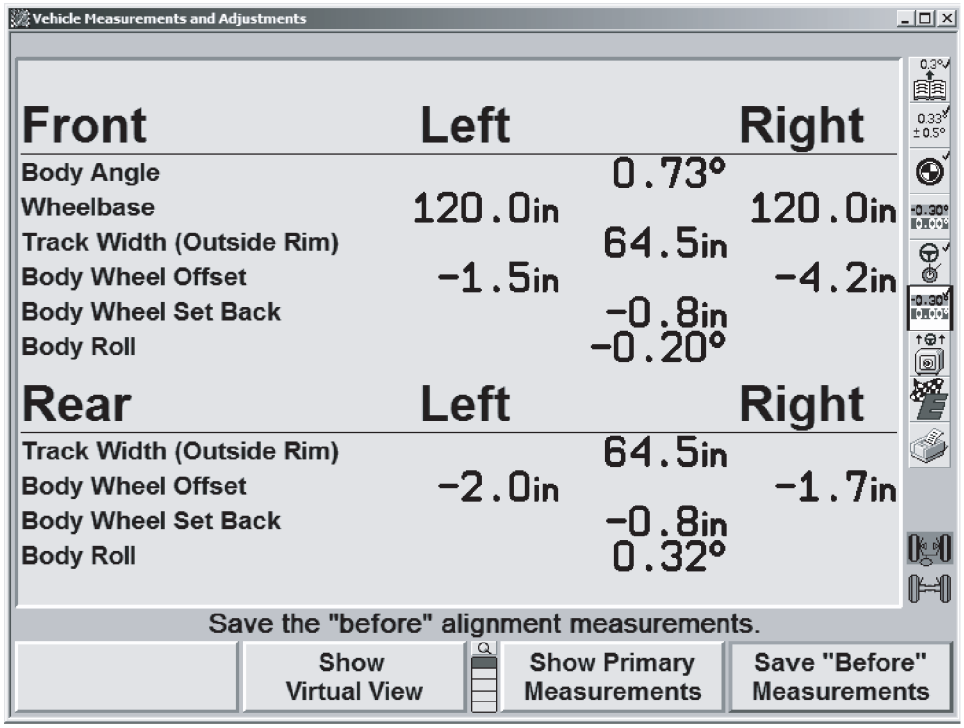


Figure 4b-71, Body Measurements Screen

Steering Axis Inclination and Included Angle

The term **Steering Axis** describes the relationship of the two pivot points of the steering knuckle.

Steering Axis Inclination

Steering Axis Inclination or SAI for short is the angle formed by a line drawn through the upper and lower pivot points of the spindle and a vertical line drawn from the lower pivot point.

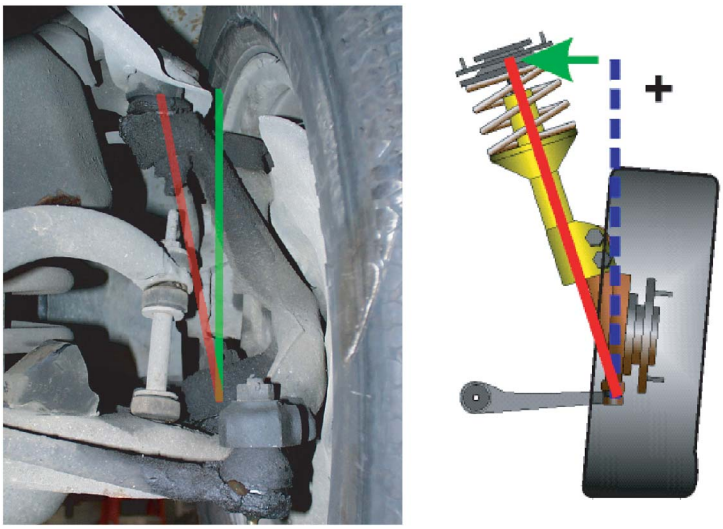
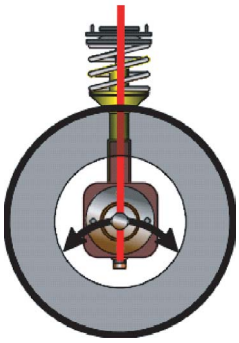


Figure 4b-72, Steering Axis Inclination (S.A.I.)



S.A.I. helps to increase directional stability due to the arc the spindle travels when steered. This arc forces vehicle weight to be lifted since the spindle turns downward when steered left or right.

Returnability is also enhanced because vehicle weight helps return the spindle to the straight-ahead position when steering wheel pressure is released.

S.A.I. Diagnosis

Cross S.A.I. greater than 1.5º may indicate:

- Bent control arm
- Damaged strut tower
- Damaged frame or subframe

Included Angle

Included angle, or **I.A.** for short, is the combination of S.A.I and camber. S.A.I. and I.A. measurements are useful diagnostics tools.

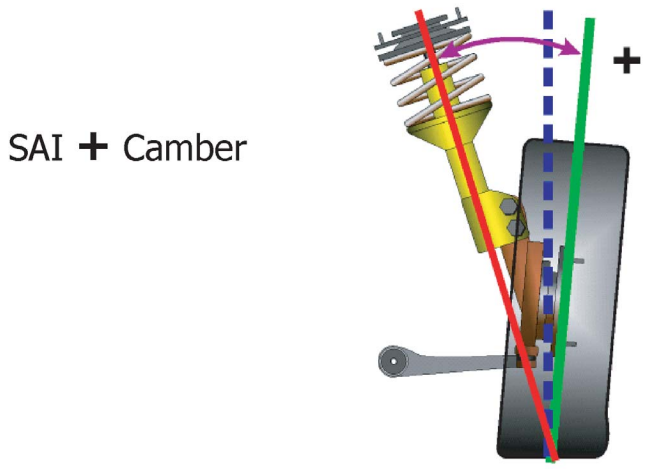


Figure 4b-73, Included Angle (i.A.)

Included Angle Diagnosis

Large differences (usually over 1.5º) in included angle generally indicate a damaged component between the two pivots of the steering knuckle.

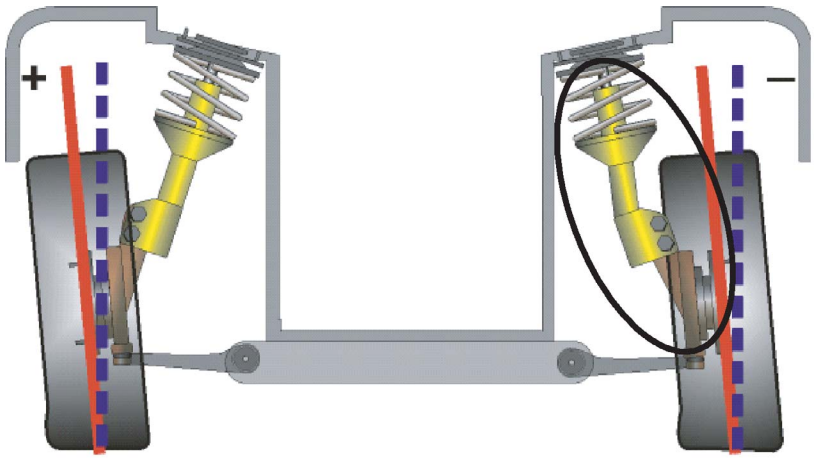


Figure 4b-74, Unequal I.A. Angles May Indicate Damaged Components

S.A.I. and I.A. Diagnostic Examples

In this example, left camber is within specifications. Right camber is -1.8º from specifications and may indicate suspension damage. Cross S.A.I is only 0.2º. The strut tower, lower control arm and frame are probably OK.

	Left	Right	
Camber	0.3º	**-1.5º**	—
SAI	12.0º	12.2º	ok
IA	12.3º	**10.7º**	—

Negative camber and low Included Angle may indicate a bent strut, knuckle or ball joint stud.

Negative camber and low Included Angle may indicate a bent strut, knuckle or ball joint stud.

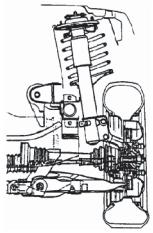
	Camber	SAI	IA	Check
	Positive	Negative	OK	Bent lower control arm or frame.
	Negative	Positive	OK	Strut tower in at top
	Positive	OK	Positive	Bent strut, knuckle, or balljoint
	Negative	OK	Negative	Bent strut, knuckle or balljoint
	Positive	Negative	Positive	Bent lower control arm or frame and Bent strut, knuckle or balljoint
	Negative	Positive	Negative	Strut tower in at top and Bent strut, knuckle or balljoint

Figure 4b-75, S.A.I. I.A. Diagnostic Chart

Check for a Bent Strut Piston Rod

Loosen the strut piston rod nut. The strut piston rod is bent if camber changes as you rotate the strut piston rod 360º.

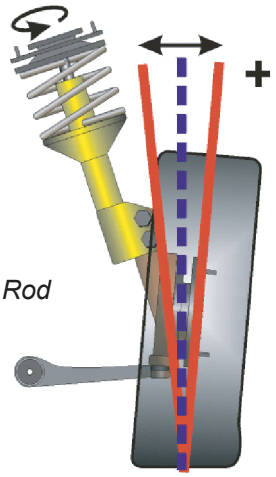


Figure 4b-76, Rotate the Strut Rod Piston to Check for a Bent Rod

Check for a Bent Strut Housing

Place a straight edge against the strut housing. Check for distortion near the bottom of the housing. Look for paint cracks where the strut tube enters the collar.

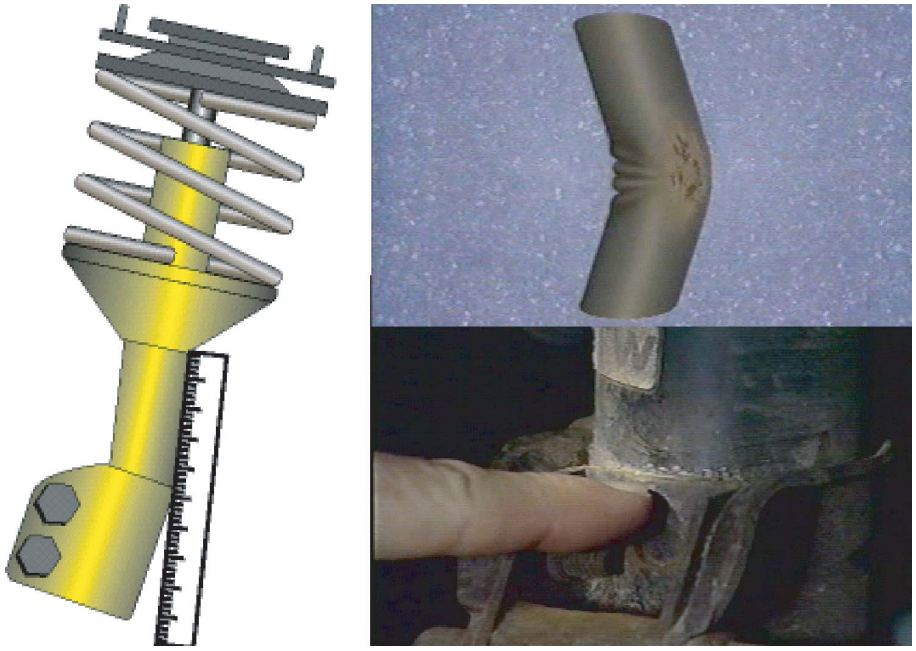


Figure 4b-77, Check for a Bent Strut Housing with a Straight Edge

Check for a Bent Knuckle.

Use a carpenter's square to check for a bent knuckle. Set the base against the brake rotor and slide the ruler until it touches the top of the knuckle. Compare one side to the other.

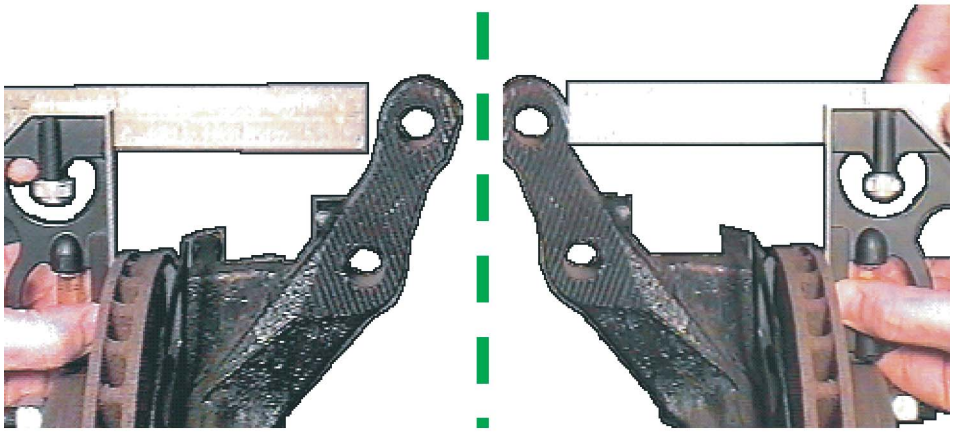


Figure 4b-78, Check the Top of the Knuckle with a Carpenter's Square

Be sure to check the bottom of the knuckle as well. Set the carpenter square's base against the bottom of the knuckle and slide the ruler until it touches the brake rotor. Compare one side to the other.

Check for a Bent Ball Joint Stud

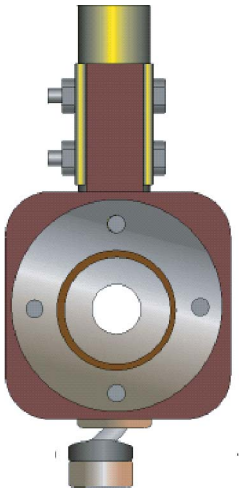


Figure 4b-79, Bent Ball Joint Stud

Disconnect the outer tie rod end from the steering arm. Steer the wheels left and right. Look for back and forth movement between the ball joint and the steering knuckle.

If you find a bent stud, carefully inspect the knuckle. If the knuckle hole is tapered to fit the stud, damage to the stud may have distorted the hole, also. Industry standard is to replace both the stud and the knuckle.

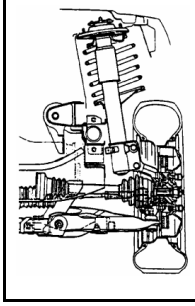
Note: Pinch bolt type knuckles are not machine fitted, so generally damage to one doesn't necessarily affect other."

Large differences in S.A.I. (usually over 1.5º) generally indicate one of the two pivot points of the steering knuckle is out of position.

In this example, left camber is within specifications. Right camber is +2.8º from specifications and may indicate suspension damage. Cross I.A. is only 0.2º. The strut, knuckle and ball joint stud are probably OK.

	Left	Right	
Camber	0.3º	**3.1º**	+
SAI	12.0º	**9.0º**	−
IA	12.3º	12.1º	ok

Positive camber and low S.A.I. may indicate a bent control arm or frame.



Camber	SAI	IA	Check
Positive	Negative	OK	Bent lower control arm or frame.
Negative	Positive	OK	Strut tower in at top
Positive	OK	Positive	Bent strut, knuckle, or balljoint
Negative	OK	Negative	Bent strut, knuckle or balljoint
Positive	Negative	Positive	Bent lower control arm or frame and Bent strut, knuckle or balljoint
Negative	Positive	Negative	Strut tower in at top and Bent strut, knuckle or balljoint

Figure 4b-80, S.A.I. I.A. Diagnostic Chart

Positive camber and low S.A.I. may indicate a bent lower control arm and/ or frame/subframe.

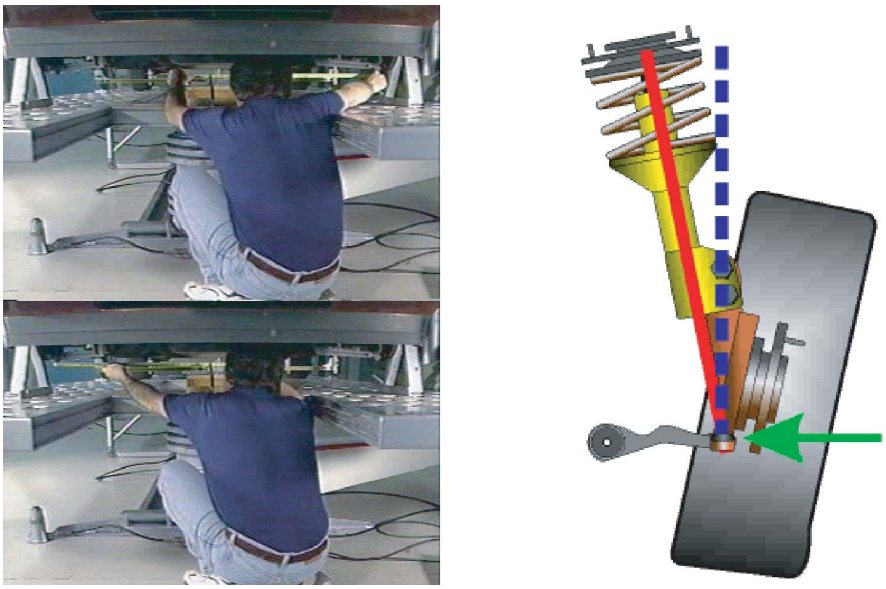


Figure 4b-81, Check for a Bent Control Arm with a Tape Measure

In this example, left camber is within specifications. Right camber is -2.2º from specifications and may indicate suspension damage. Cross I.A. is only 0.2º. The strut, knuckle and ball joint stud are probably OK.

	Left	Right	
Camber	0.3º	**-2.2º**	−
SAI	12.0º	14.3º	+
IA	12.3º	**12.1º**	ok

Negative camber and high S.A.I. may indicate a bent control arm or frame.

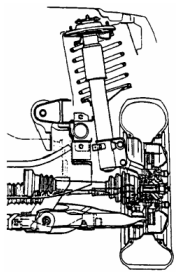
	Camber	SAI	IA	Check
	Positive	Negative	OK	Bent lower control arm or frame.
	Negative	Positive	OK	Strut tower in at top
	Positive	OK	Positive	Bent strut, knuckle, or balljoint
	Negative	OK	Negative	Bent strut, knuckle or balljoint
	Positive	Negative	Positive	Bent lower control arm or frame and Bent strut, knuckle or balljoint
	Negative	Positive	Negative	Strut tower in at top and Bent strut, knuckle or balljoint

Figure 4b-82, S.A.I. I.A. Diagnostic Chart

Negative camber and high S.A.I. may indicate a bent upper control arm on an SLA suspension or a damaged strut tower on a strut suspension.

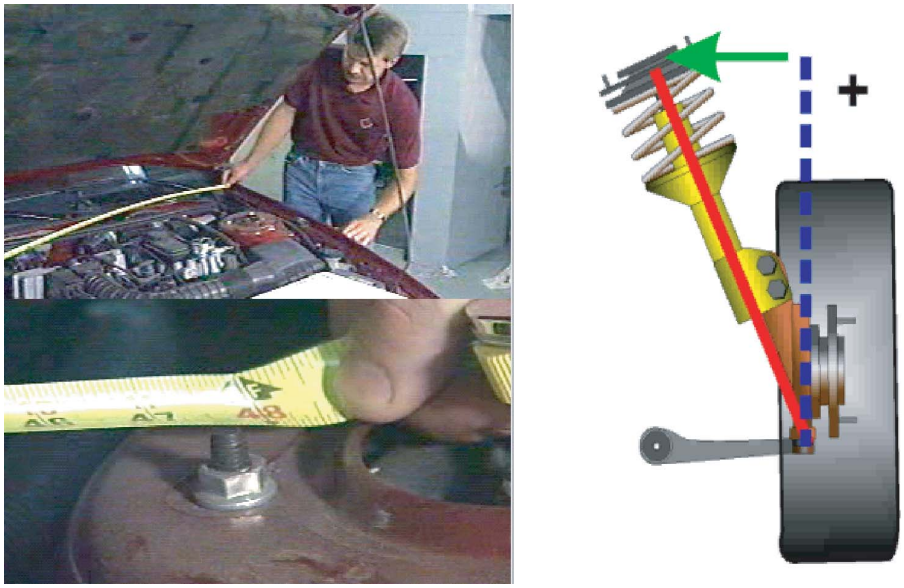


Figure 4b-83, Strut Tower Gauge

Check for a damaged strut tower by measuring across the strut mounts with a tape measure or tram bar. A strut tower gauge provides an easy tower to centerline measurement. Compare measurements side-to-side.

Cradle Shift

If the vehicle's cross-member is positioned improperly, both left and right front camber and S.A.I. will be affected.

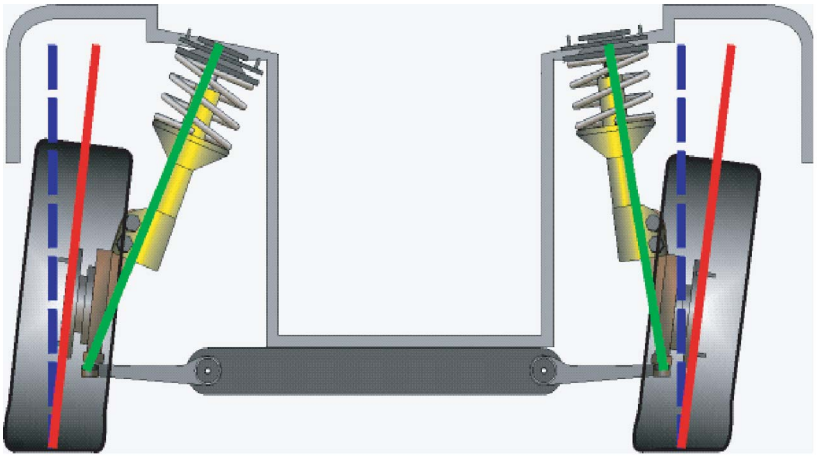


Figure 4b-84, Improperly Positioned Cross-member will Cause Cross Camber and Cross S.A.I. Errors

Shifting the cradle may correct a non-adjustable angle to within specification.

Not all FWD vehicles have cradles that are easily shifted.

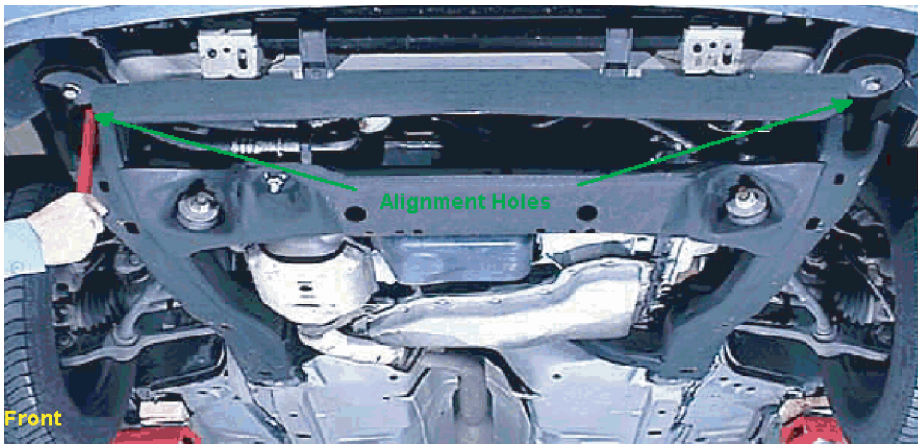


Figure 4b-85, Many Hunter aligners display cradle adjustment information.

Caster and setback measurements may also be affected by cradle placement.

Some FWD vehicles don't have adjustable cradles but do have stabilizer bars, which control the lower control arm position. Adjust caster by loosening the stabilizer bar frame bracket bolts and sliding the bracket forward or rearward to change caster.

You can reposition the front cross member on some "rear-wheel-drive" vehicles to change camber, caster or S.A.I.

SAI / IA Measurement (Preferred)

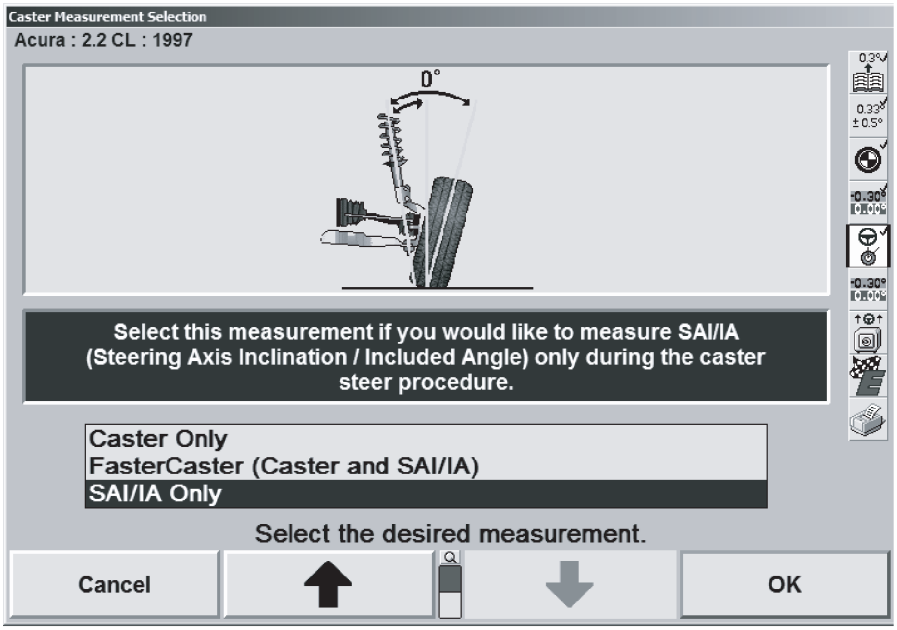


Figure 4b-86, SAI/IA Measurement (Preferred)

Press "Measure Caster" on the "Vehicle Measurements and Adjustments" primary screen. The "Caster and S.A.I Measurement" pop-up screen will appear.

If measuring S.A.I./I.A. only is not the default:

Press "Select Measurement," the "Caster Measurement Selection" pop-up screen will appear.

Select "S.A.I./I.A. Only." This selection will not change the aligner default setting. When the aligner is reset, the default settings will be applied.

Press "OK" to select the measurement. The "Measure Caster" pop-up screen will appear.

Lock the front brakes using a brake pedal depressor.

Raise the front wheels by the frame until they clear the turning angle gauges or rack and support vehicle securely.

Press "Ready." Perform the S.A.I. turn while observing the bar graphs in the same manner as the caster turn. Refer to "Measure Caster."

When S.A.I. measurements are completed, the CRT will change to the "Vehicle Measurements and Adjustments" primary screen with the S.A.I. and included angle measurements shown.

Lower the vehicle.

While lowering the vehicle, camber and S.A.I. measurements will change. However, included angle measurements will remain constant.

Setback

Front Setback

Front setback is an angle formed by a line drawn perpendicular to the centerline and a line connecting the centers of the front wheels.

Positive setback indicates the right front wheel is behind the left front wheel.

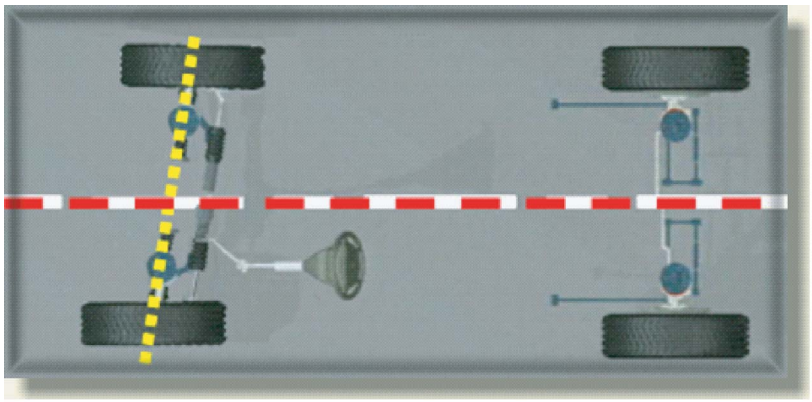


Figure 4b-87, Positive Setback

Negative setback indicates the left front wheel is behind the right front wheel.

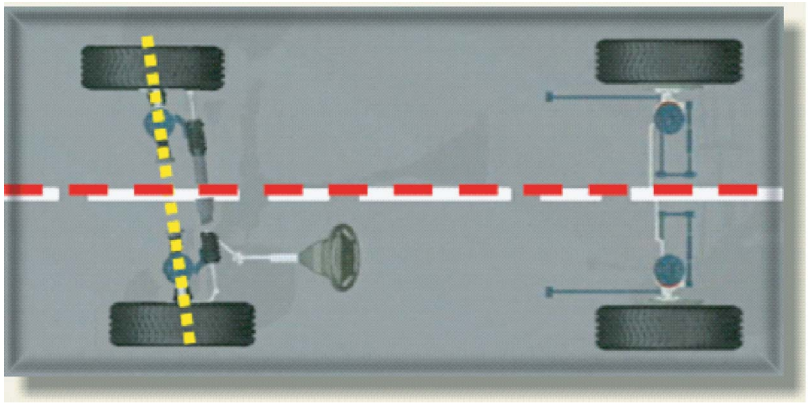


Figure 4b-88, Negative Setback

Setback is measured as an angle but can be displayed in inches or millimeters if front track width is available in the vehicle specifications.

Setback is a diagnostic angle. The preferred setback measurement is assumed to be zero.

Setback may exist because of manufacturing tolerances, collision, frame repair or parts installation.

Setback measurement exceeding ±0.50 ?is a good indication a suspension component is bent or positioned incorrectly. Light trucks are sometimes an exception to this rule.

If the thrust angle and the setback are in the same direction and approximately the same amount, a diamond shaped frame is probably the cause.

Use setback to help determine the cause of side-to-side caster differences and turning radius problems.

Cross caster measurements exceeding ±0.5º ?may be caused by a setback condition. If a lower control arm has been moved rearward, caster is changed in a negative direction.

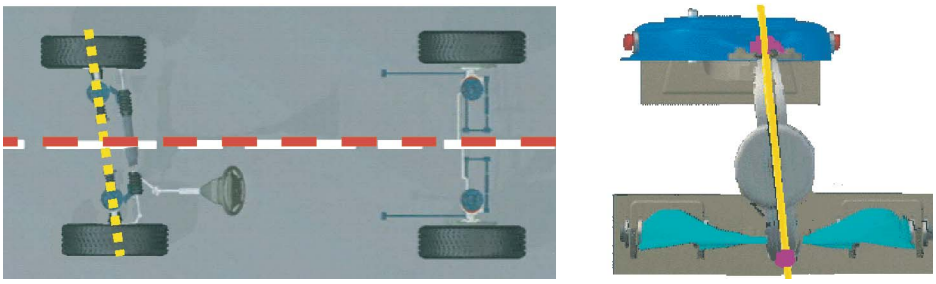


Figure 4b-89, Low Caster and High Setback may indicate a bent lower control arm.

Compare the setback measurement to the caster measurement to determine if the lower control arm may be moved to reduce cross caster and setback measurements.

Extreme setback conditions may affect turning angle due to the repositioning of the steering arm when the lower control arm is moved forward or rearward.

Setback Diagnostic Example

A 1986 Mazda RX7 pulls left after the driver struck a curb. The right front caster is -3.7º from specifications and the front setback is high.

	Left	Right
Caster	.5º	4.2º
Setback		-1.01º

Figure 4b-90, Low Caster and High Setback may indicate a bent control arm.

Many technicians check for accident damage by comparing the distance between the front and rear of the tire to the wheel opening.

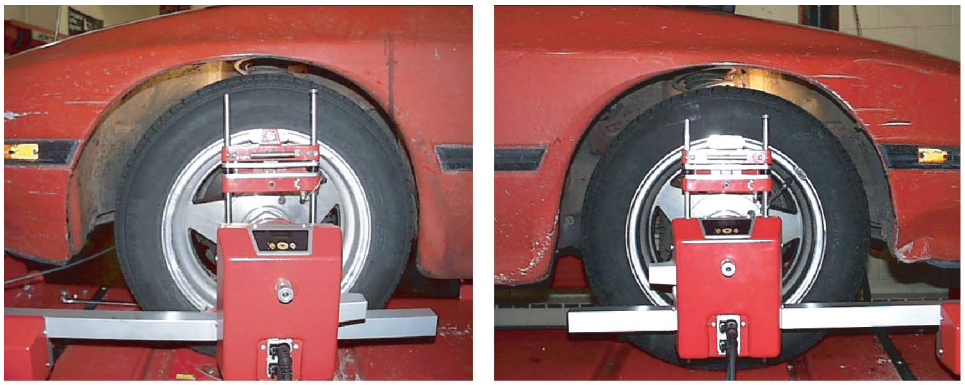


Figure 4b-91, Left Front Wheel is Pushed Back

Verify the left control arm is bent with a tape measure.

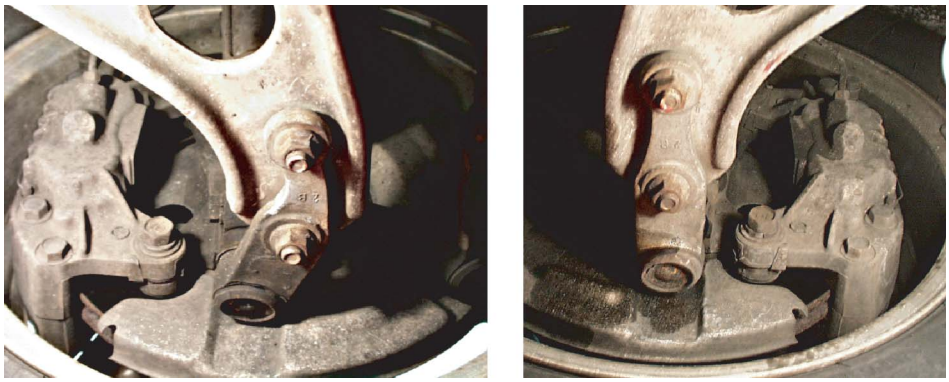


Figure 4b-92, Left Control Arm is Bent

Rear Setback

Rear setback is an angle formed by a line drawn perpendicular to the centerline and a line connecting the centers of the rear wheels.

Rear setback is positive when the right rear wheel is behind the left rear wheel.

Rear setback is negative when the left rear wheel is behind the right rear wheel.

Rear setback is measured as an angle but can be displayed in inches or millimeters if rear track width is available in the vehicle specifications.

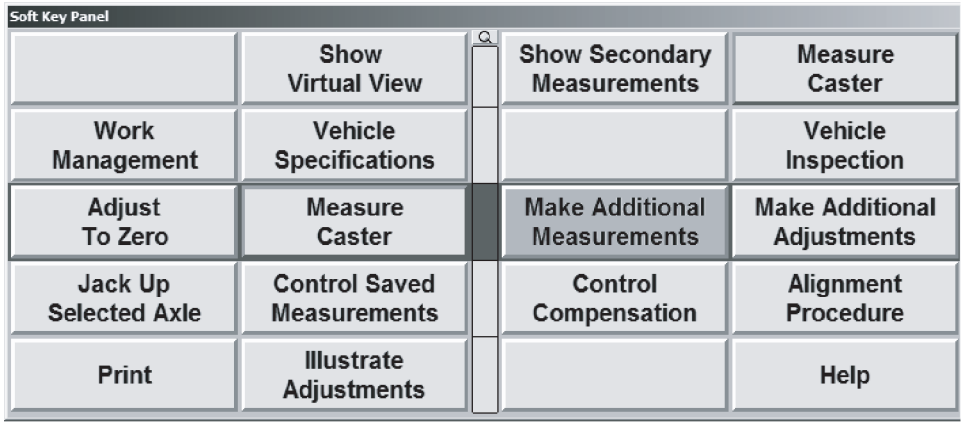
Rear Setback Diagnosis

Use rear setback to help diagnose thrust angle problems.

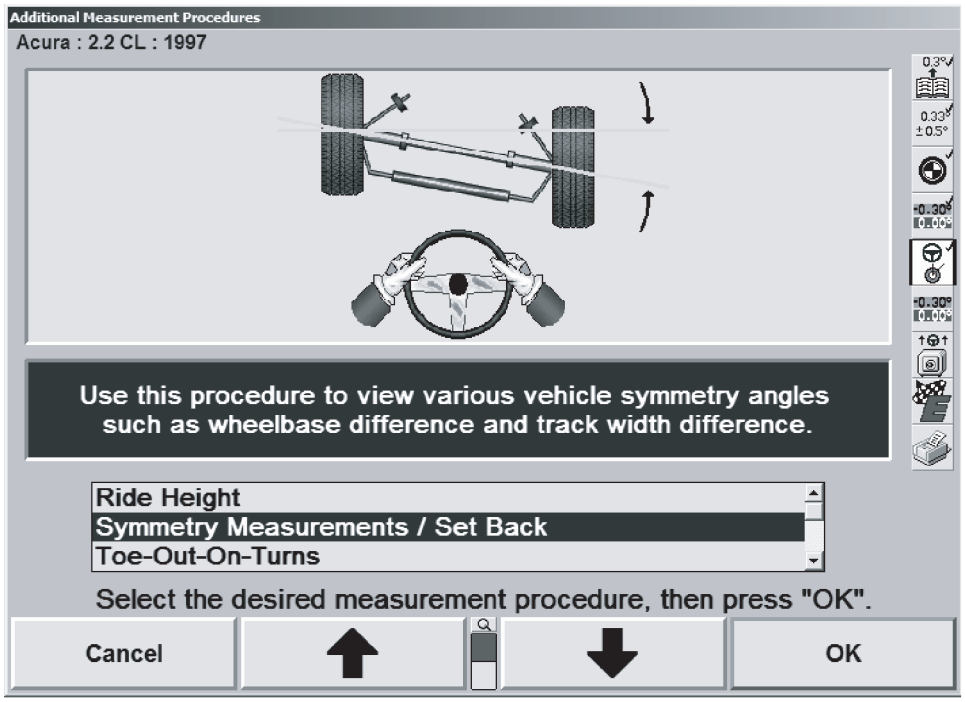
Symmetry / Setback Procedure

Bring up the "Soft-Key Panel" by pressing the light pen against the center of the soft key level indicator (or press the F6 key).

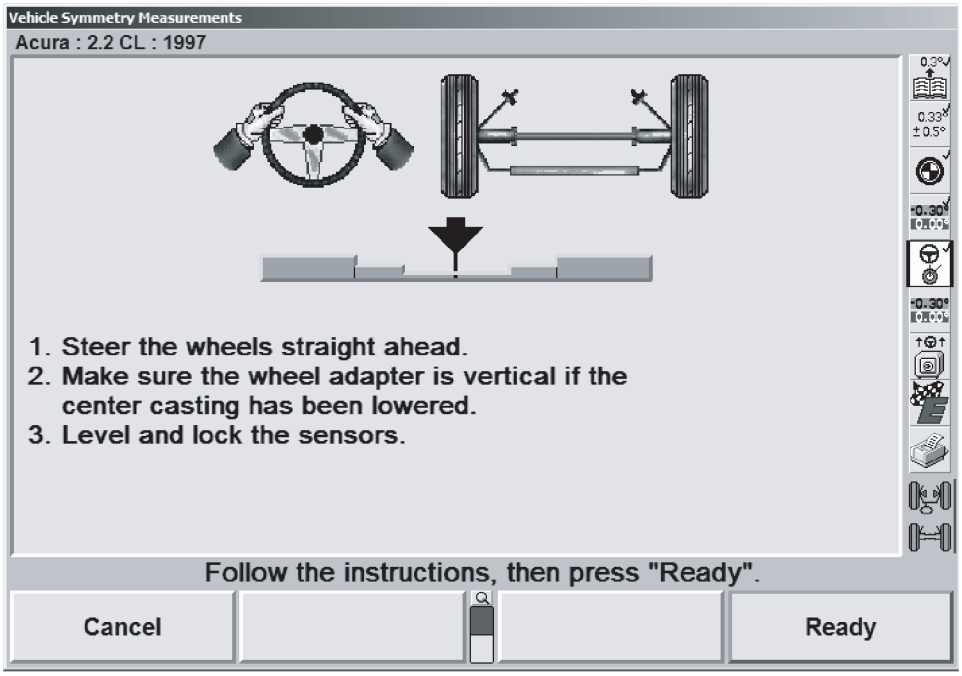
Select "Make Additional Measurements."



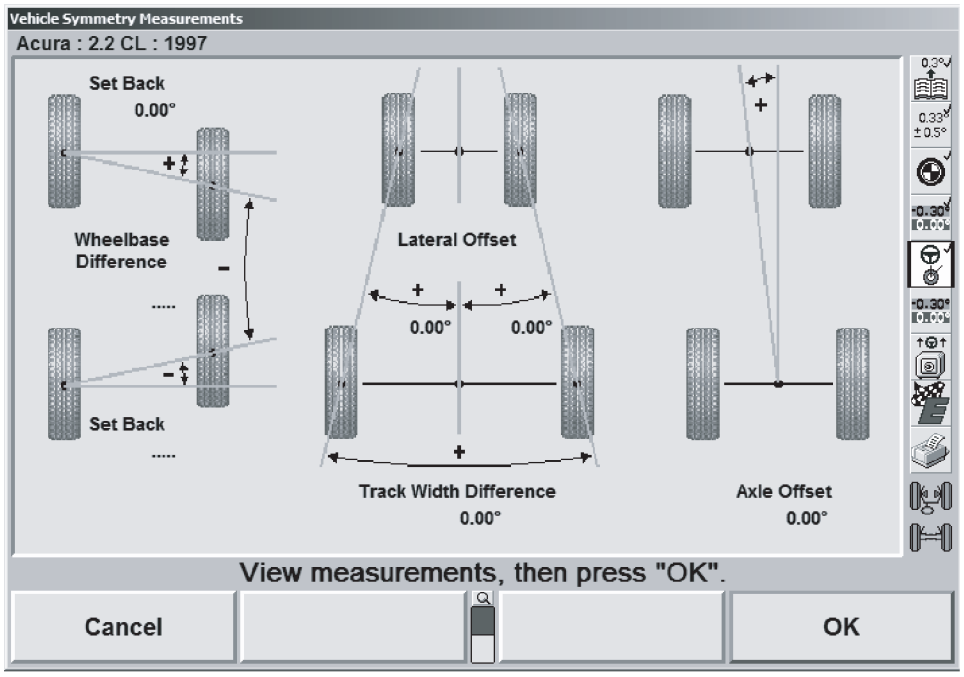
Select "Symmetry Measurements / Set Back" from the menu.



Follow the instructions, then press "Ready."

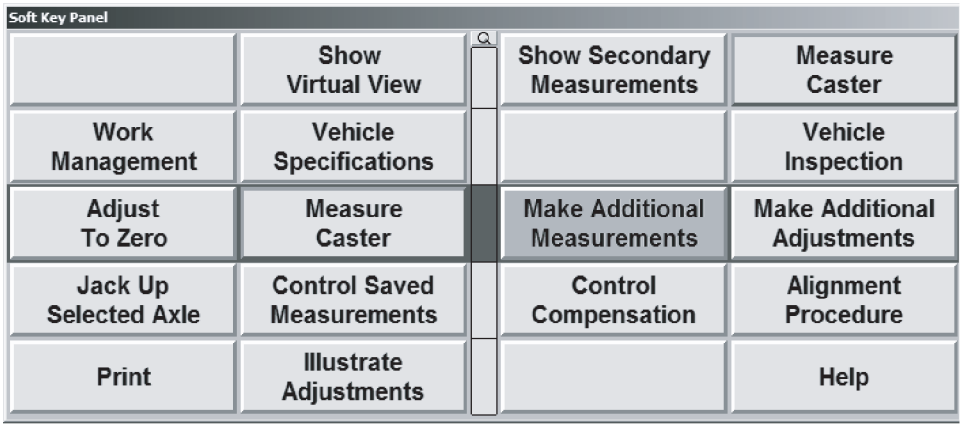


The symmetry/setback measurements are now displayed on screen. Press the "Print Screen" button (upper right on the keyboard) to make a hard copy printout.

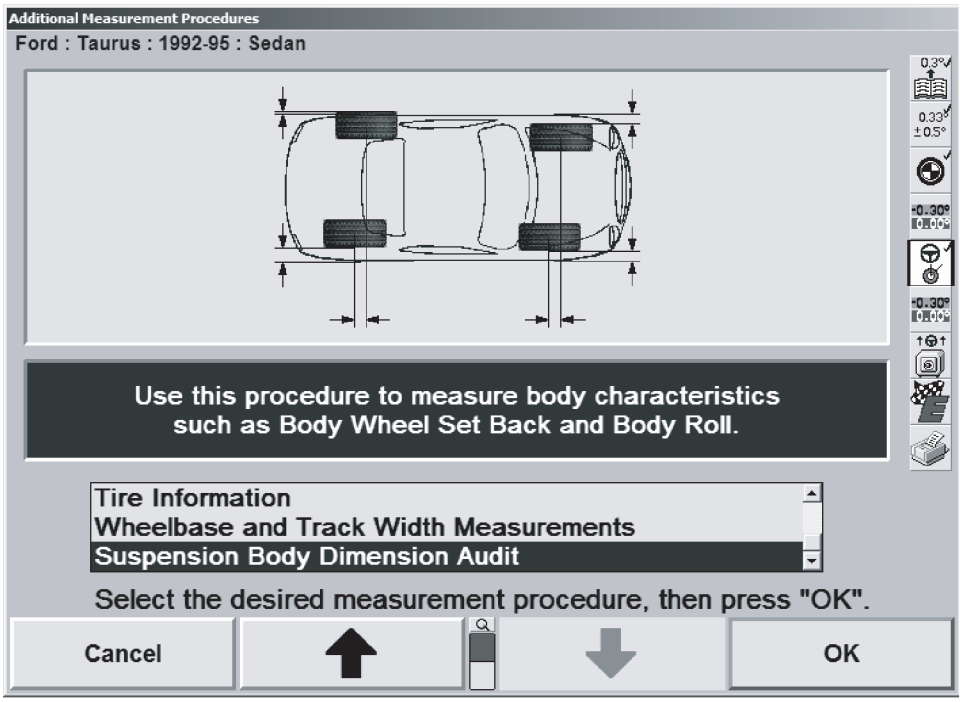


Suspension Body Dimension Audit Procedure

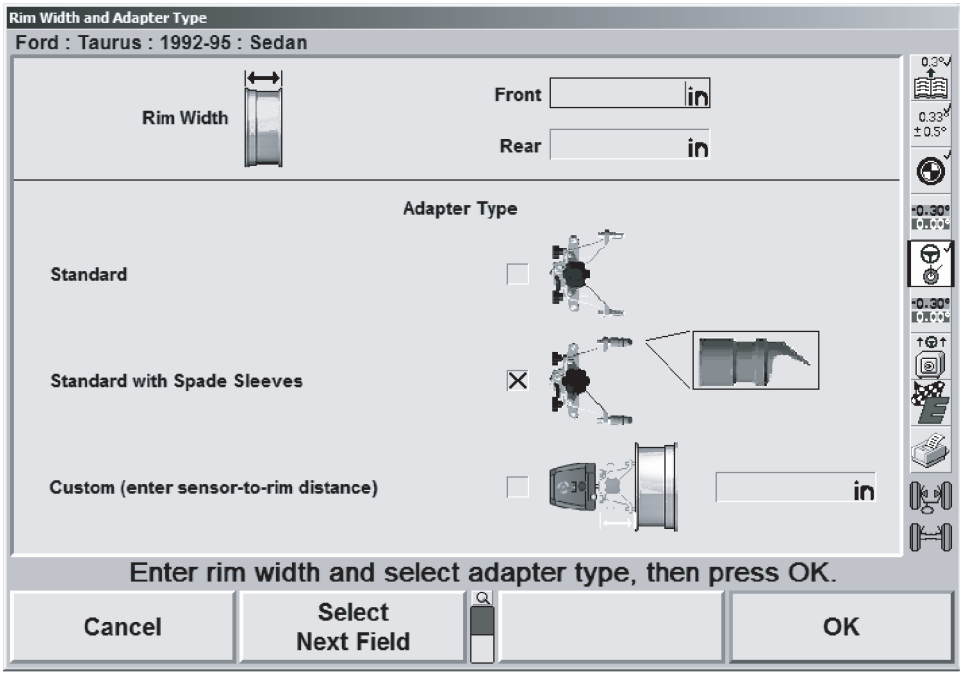
Bring up the "Soft-Key Panel" by pressing the light pen against the center of the soft key level indicator (or press the F6 key). Select "Make Additional Measurements."



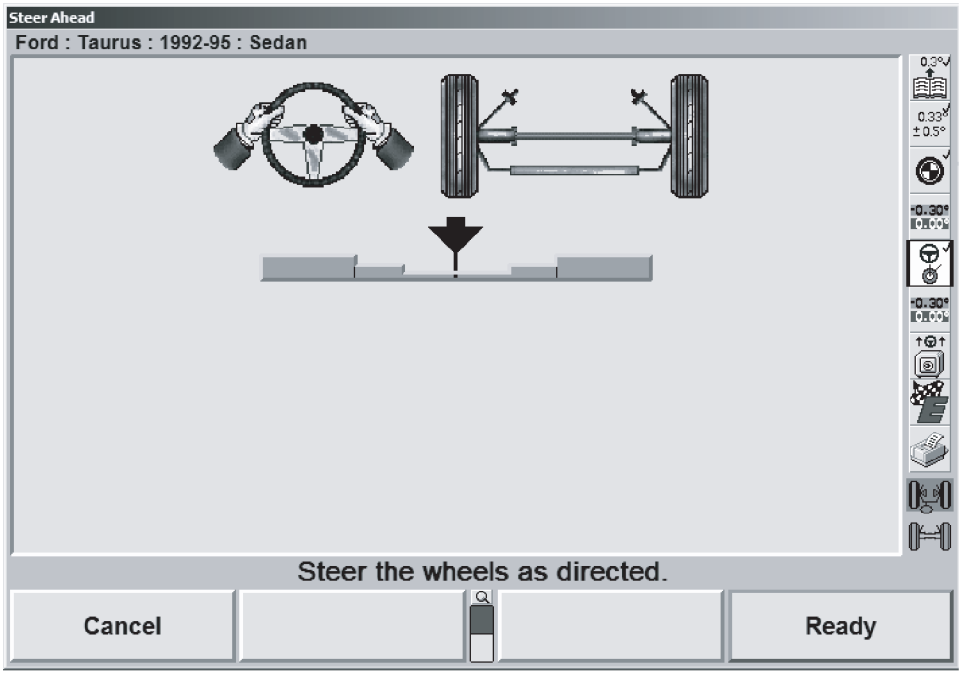
Select "Symmetry Measurements / Set Back" from the menu.



Follow the instructions, then press "OK."



Steer the wheels to line up the bar graph. Press “OK.”



To input the vehicle's ride height, raise the ride height tool until the horizontal arm touches the underside of the wheel arch above the center of each wheel.

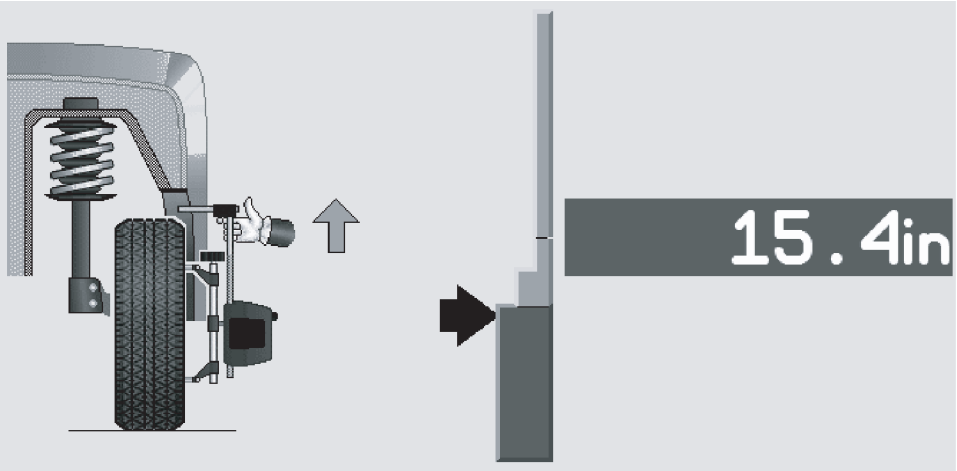


Figure 4b-93, Input Vehicle Ride height with the Ride Height Tool

Slide the tip of the ride height tool until it just touches the sheet metal above the wheel arch. Locate the number of the scale at the tool's handle. Type the body offset onto the SDBA input screen.

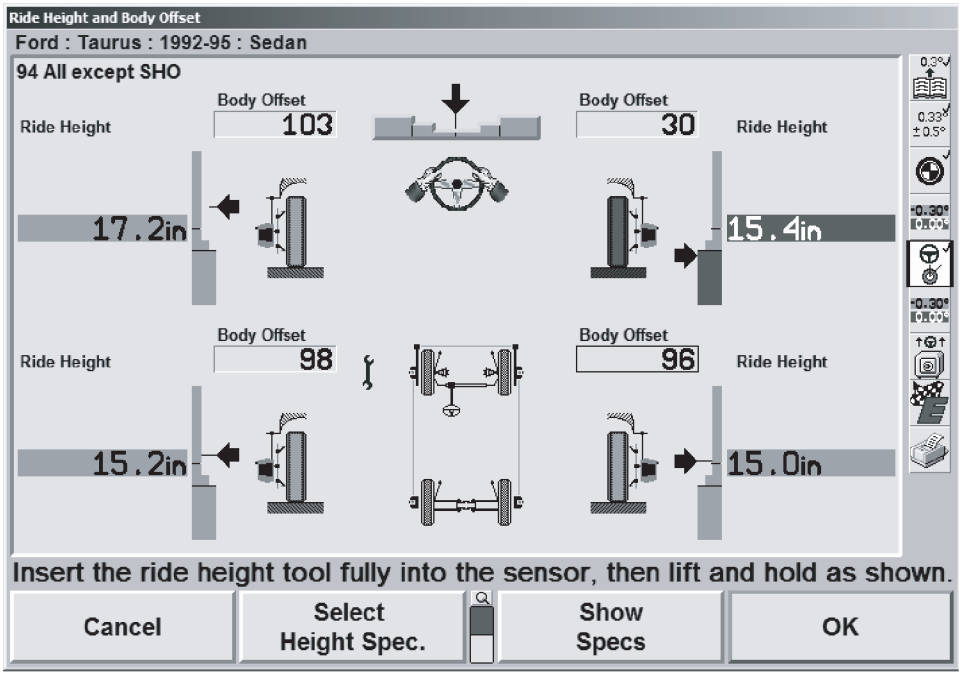


Figure 4b-94, Type the Body Offset onto the SDB Input Screen.

The horizontal measurements screen now appears.

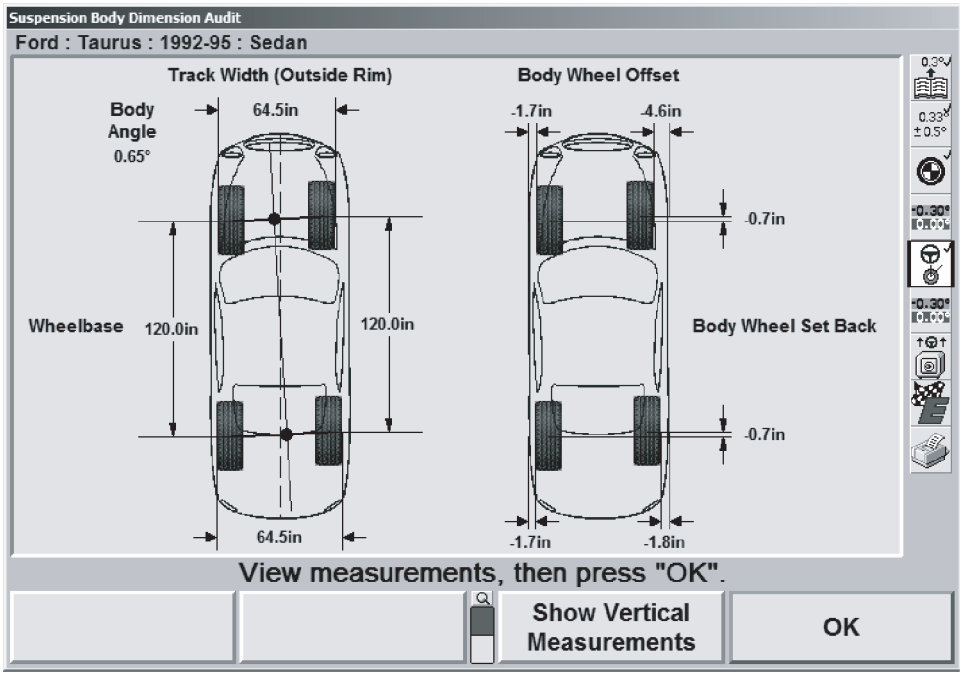


Figure 4b-95, SBDA Horizontal Measurements Screen

Press "Show Vertical Measurements" to display the vehicles body ride height and body roll measurements.

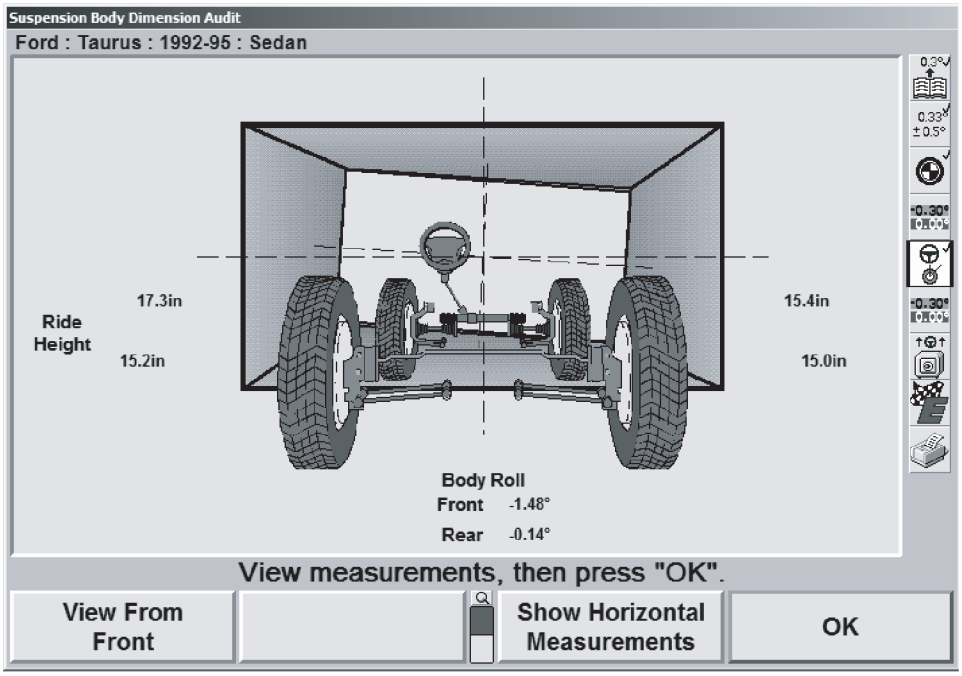


Figure 4b-96, SBDA Vertical Measurements Screen

Turning Angle

Turning angle is the difference in the angles of the front wheels in a turn. The angle difference is determined by the steering arm design.

When turning a corner, the outside wheel must travel a greater distance and a wider turn than the inside wheel.

Turning angle measurements outside manufacturer's specifications may cause front tire shoulder wear and improper handling.

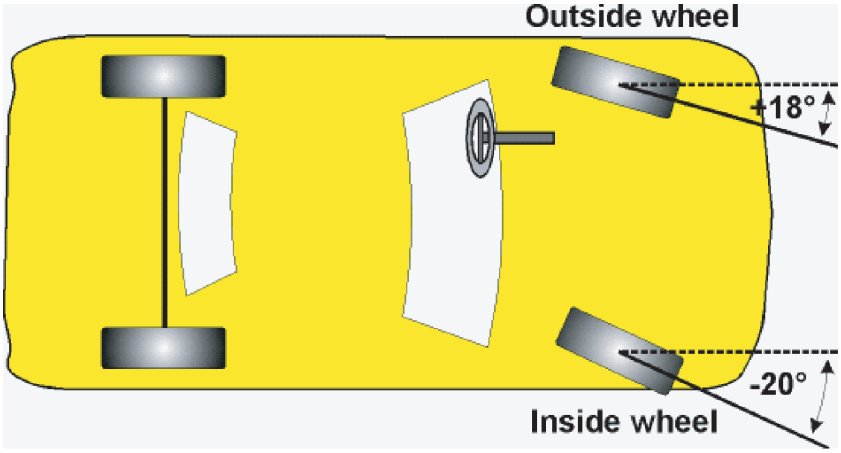


Figure 4b-97, Turning Angle

The most common approach in turning angle design is where the difference in the turning angles is symmetrical (equal).

Example:

When the left wheel is steered into the turn 20º, the right wheel should be at 18º. When the right wheel is steered into the turn 20º, the left wheel should be at 18º.

As a rule of thumb, the turning angle for the wheel on the outside of the turn should not vary more than ±1.5º from specification.

Example: If the left wheel is steered into the turn 20º, the outside wheel should measure 18º ±1.50º.

The non-symmetrical design produces unequal turning angles.

This design is found on various makes and models of vehicles to assist in controlling torque steer and various other problems.

The rules for measuring symmetrical designs also apply to non-symmetrical designs with one exception. Two sets of turning angle specifications are required.

Always use the manufacturer's turning angle specifications if possible.

Turning angle measurements that vary more than 1.5° from specification generally indicate a bent steering arm.

The steering arms of the vehicle are designed to predetermine the relationship between the left and right front wheels when the vehicle is steered left or right.

The steering arm connects the outer tie rod to the steering knuckle. The steering arm on most vehicles is an integral part of the steering knuckle.

Figure 4b-98, The steering arm is part of the knuckle.

How Turning Angle Works

The steering arm moves equal distance laterally as the rack moves back and forth. The steering arm must move farther up its curve when the wheel is steered left than when the wheel is steered right.

In this example, the rack moves laterally 4" in each direction.

The wheel turns 33º ?outward as the arm climbs the arc.

The wheel turns only 25º ?as the arm move slightly down and across the arc.

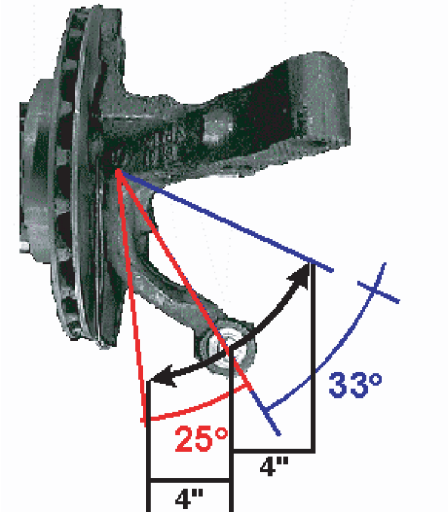


Figure 4b-99, Steering Arm

Turning Angle Measurement

Measure turning angle is accomplished by steering the inside wheel a specified amount then checking the angle of the outside wheel. The aligner calculates total toe ("turning angle difference") in the turn.

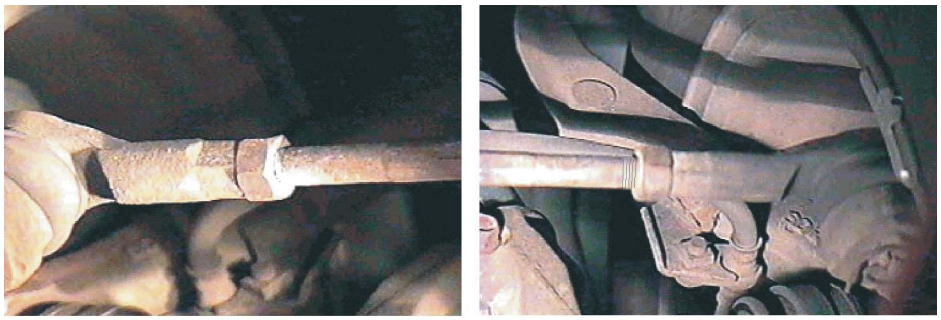
You can measure turning angle with electronic turnplates, encoders and elastic lines, or radius gauges on standard Hunter turnplates.

Turning Angle Diagnosis

A 1992 Honda Prelude 2WS hit a guardrail with the left front wheel and fender. A local body shop replaced the damaged sheet metal and aligned the wheels. The car drives straight and the steering wheel is level; however, when making a left "U-turn", the tires squeal excessively and the car shudders.

Inspect the Steering Linkage

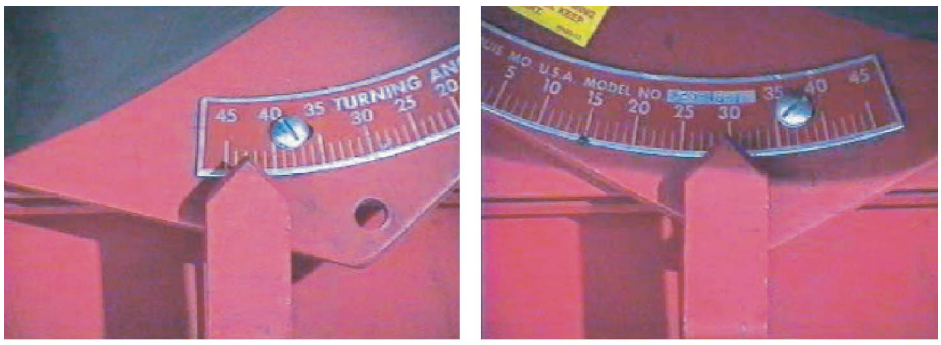
Normally, the exposed tie rod threads on each tie rod should be virtually equal. Note the lack of exposed threads on the left tie rod assembly.



Left side *Right side*

Figure 4b-100, Left Tie Rod No Exposed Tie Rod Threads

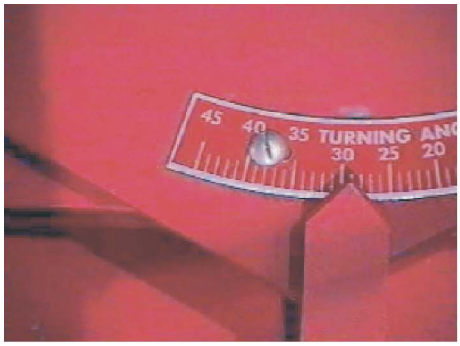
We measured turning angle with the mechanical turning angle gauges first by steering the left wheel first to the outward lock and then to the inward lock. The left wheel turned 43º out and 30º in.



Left wheel turn to the outward lock *Left wheel turned to the inward lock*

Figure 4b-101, Mechanical Turning Angle Gauges

We then steered the right wheel first to the outward lock and then to the inward lock. The right wheel turned 36º out and 29º in.



Right wheel turned to the inward lock

Right wheel turned to the outward lock

Turning Angle Specifications

Honda's specifications say when a wheel is steered 29.67º inward the other wheel should steer 36.6º outward (6.67º further outward). The maximum variance (tolerance) either way is 2º.

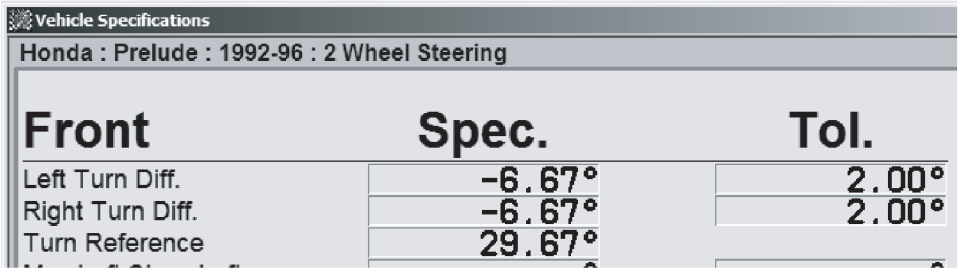


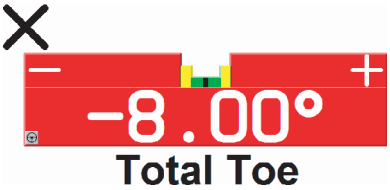
Figure 4b-102, 1992 Honda Prelude Turning Angle Specification

We made this chart and determined the "turning angle difference" for a left and right turn.

	Left Wheel	Right Wheel	Turning Angle Difference
Left Turn	Out 43°	In 29°	**Out 14°**
Right Turn	In 30°	Out 36°	Out 6°

Figure 4b-103, Turning Angle Measurement Results

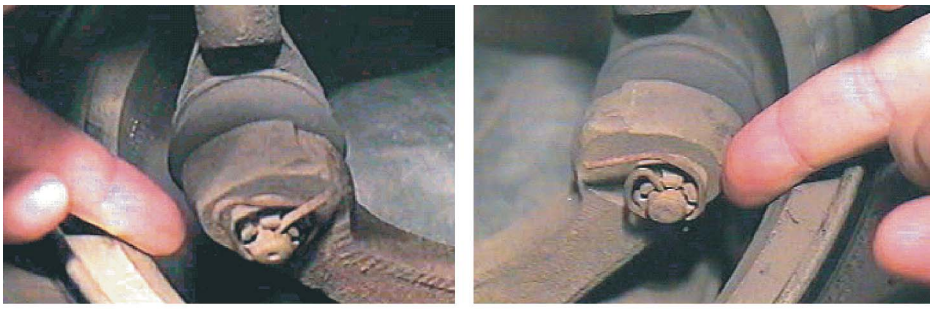
Note: The total toe of the front wheels is -14º in a left turn and -6º in a right turn. Since the specifications call for -6.6º ±2º the right turn is in specifications but the left turn is -8.00º beyond specifications.



The total toe of the front wheels is **-8.00º** outside of specifications! No wonder the tires squeal!

Steering Arm Quick Checks

On symmetrical steering systems, use your fingers to verify the distance from the steering arm to the wheel is equal side-to-side. Note on this Prelude, the left steering arm is bent slightly causes an -8.00º out of specification measurement.

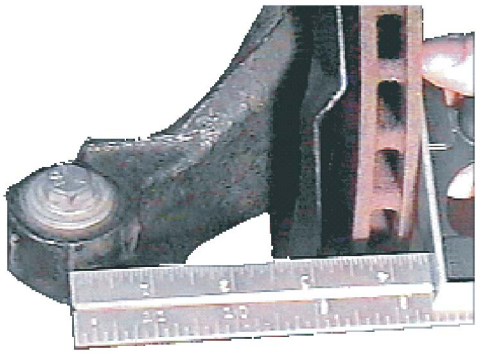


Left side *Right side*

Figure 4b-104, Steering Arm Finger Checks

To be more precise, use a "T-square" to check for a bent steering arm. Compare one side to the other.

Some vehicles have a nonsymmetrical steering system (e.g. 1986 Ford Escort). The length and angle of these steering arms may vary from side-to-side.



Maximum Steering Angle

Maximum steering angle is the angle of the front wheels when turned to the inward and outward lock position.

A wheel that turns beyond the maximum steering angle may create hazardous conditions when driving and cause premature tire wear.

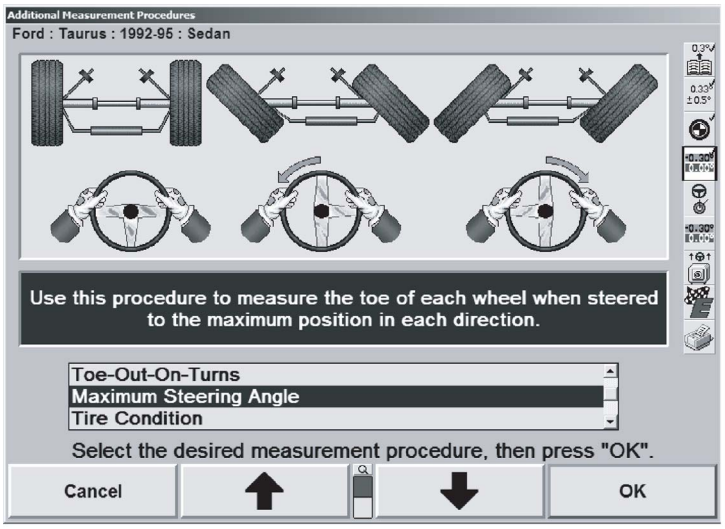


Figure 4b-105, Maximum Steering Angle Measurement

Maximum Steering Angle Diagnosis

Look for symmetrical negative numbers on each side. Large differences side to side (over 2 degrees) may indicate:

- Seering stops out of adjustment
- Steering wheel is not centered on the steering column when the rack or centerlink is centered
- Steering column to gear mismatch at the steering coupler

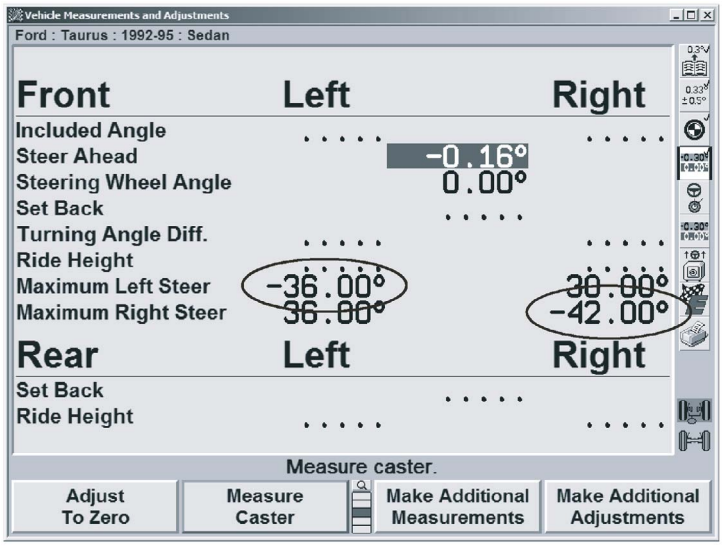


Figure 4b-106, Look for even negative numbers side to side

Maximum Steering Angle Quick Check

Turn the steering wheel left until it reaches the stops. Count the number of turns while turning right until the steering wheel stops.

Turn the steering wheel back to the left ½ the number of turns counted.

The rack or centerlink should now be in the center of its travel.

Verify the steering wheel is level or on the closest available spline on the steering column or coupler.

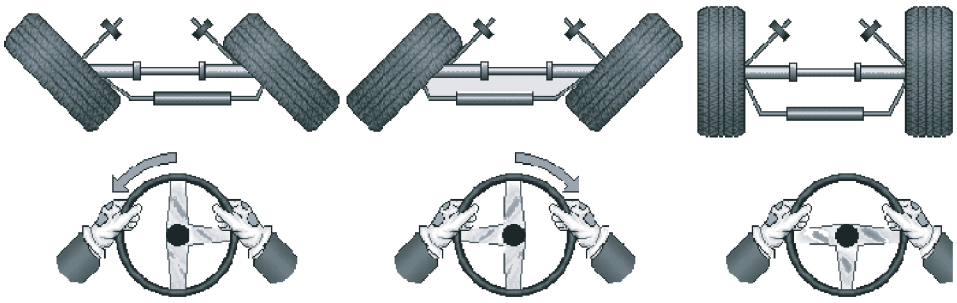


Figure 4b-107, Maximum Steering Angle Quick Check – Count the Turns

Rear Suspension Diagnostic Chart

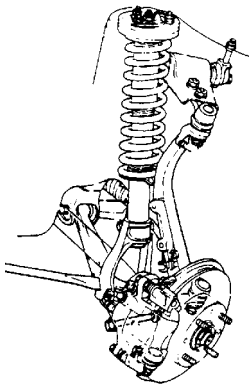
DSP208, 258, 300, 308 Sensors

Thrust Angle	Front Setback	Rear Setback	Check
Positive	OK	Positive	Cocked rear axle Check for wheel base difference with a tape measure
Positive	OK	OK	Offset rear axle
Positive	Positive	Positive	Diamond frame Verify by cross measuring frame holes with tape measure.
Negative	OK	Negative	Cocked rear axle Check for wheel base difference with a tape measure
Negative	OK	OK	Offset rear axle
Negative	Negative	Negative	Diamond frame Verify by cross measuring frame holes with tape measure.

DSP300, 308, 400 Sensors

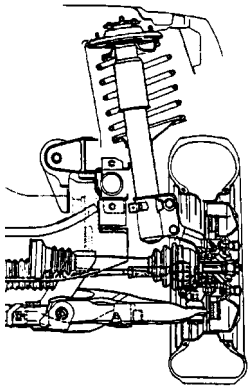
Thrust Angle	Front Setback	Wheel Base	Check
Positive	OK	Longer right side	Cocked rear axle
Positive	OK	Equal	Offset rear axle
Positive	Positive	Equal	Diamond frame Verify by cross measuring frame holes with tape measure.
Negative	OK	Longer left side	Cocked rear axle
Negative	OK	Equal	Offset rear axle
Negative	Negative	Equal	Diamond frame Verify by cross measuring frame holes with tape measure.

Short Long Arm & Double Wishbone



Camber	SAI	IA	Check
Positive	Negative	OK	Bent lower control arm or frame
Positive	OK	Positive	Bent knuckle or ball joint
Positive	Negative	Positive	Bent lower control arm or frame and Bent knuckle or ball joint
Negative	Positive	OK	Bent upper control arm or frame
Negative	OK	Negative	Bent knuckle or ball joint
Negative	Positive	Negative	Bent upper control arm or frame and Bent knuckle or ball joint

Strut

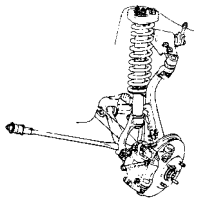


Camber	SAI	IA	Check
Positive	Negative	OK	Bent lower control arm or frame
Positive	OK	Positive	Bent strut, knuckle or ball joint
Positive	Negative	Positive	Bent lower control arm or frame and Bent strut, knuckle or ball joint
Negative	Positive	OK	Strut tower in at top
Negative	OK	Negative	Bent strut, knuckle or ball joint
Negative	Positive	Negative	Strut tower in at top and Bent strut, knuckle or ball joint

Twin I-beam or straight axle with ball joints

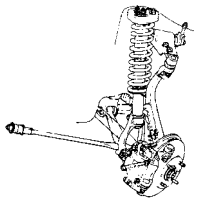
Camber	SAI	IA	Check
Positive	Negative	OK	Bent Axle
Positive	OK	Positive	Bent knuckle or ball joint
Positive	Negative	Positive	Bent axle and Bent strut, knuckle or ball joint
Negative	Positive	OK	Bent Axle
Negative	OK	Negative	Bent knuckle or ball joint
Negative	Positive	Negative	Bent axle and Bent strut, knuckle or ball joint

Caster Diagnostic Chart



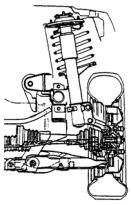
Driver side

Caster	Setback	Check
Negative	Negative	Lower control arm too far back
Negative	Positive	Upper control arm too far forward
Positive	Negative	Upper control arm too far back
Positive	Positive	Lower control arm too far forward



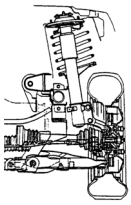
Passenger side

Caster	Setback	Check
Negative	Positive	Lower control arm too far back
Negative	Negative	Upper control arm too far forward
Positive	Negative	Lower control arm too far forward
Positive	Positive	Upper control arm too far back



Driver side

Caster	Setback	Check
Negative	Negative	Lower control arm too far back
Negative	Positive	Strut tower too far forward
Positive	Negative	Strut tower too far back
Positive	Positive	Lower control arm too far forward



Passenger side

Caster	Setback	Check
Negative	Positive	Lower control arm too far back
Negative	Negative	Strut tower too far forward
Positive	Negative	Lower control arm too far forward
Positive	Positive	Strut tower too far back

Non-Alignment Pulling Factors

Non-Alignment Pulling Factors Alignment angles are not always the cause of a pull or drift.

The amount of cross camber or cross caster that may cause a vehicle to pull or drift will vary from one vehicle configuration to another. Therefore, be sure the finished alignment leaves no questions about alignment angles.

Non-alignment pulling factors may include:

- Tires
- Steering components
- Brakes
- Mechanical binding
- Driveline torque

These factors are listed in the order they most commonly occur.

Tires

The term "radial pull" is used frequently. To be more specific, the terms "conicity" and "ply steer" should be used.

Conicity implies that the tire has taken the shape of a cone. Similar to the theory of a cambered wheel, the cone shape will affect the direction of travel by leading the tire to the small end of the cone. The pull will remain in the same direction regardless of forward or reverse travel.

Test for this condition by swapping the front tires from side-to-side and test driving the vehicle. If the vehicle pulls in the opposite direction or does not pull at all, a tire is most likely at fault. If the vehicle continues to pull in the same direction, the tires are most likely not at fault.

Ply steer implies that the outer most plies in a tire are formed in a manner creating lateral forces. Ply steer generally causes a drift instead of a pull.

To test for this condition, test drive the vehicle in both forward and reverse directions. Since the lateral forces are created by the outer plies of the tire, reverse travel will cause the vehicle to drift in the opposite direction. This is not a common problem.

Steering Components

The steering system may cause the following alignment associated conditions:

- Wander
- Pull
- Poor returnability

Wander

Although wander is generally associated with toe or caster, steering components may be at fault. Check the following items:

- Steering gear mounting insulators or bolts
- Column intermediate shaft connecting bolts
- Column intermediate shaft joints
- Steering gear adjustment

Pulls

An imbalance in the power steering system may cause pull or drift. Here are two common diagnostic methods:

1. With the front wheels off the ground, start the vehicle with no restriction on the steering wheel. Imbalance in the steering hydraulics will cause the steering wheel to move as the vehicle is started.
2. While driving, place the transmission in neutral and turn the engine off. If the vehicle does not pull with the engine off, power steering pull is the problem. Repairs to the steering gear valve assembly are necessary.

Poor Returnability

Poor returnability is often considered caster related. If caster is known to be correct, check the following components of the steering system:

- Steering column misalignment
- Column flange rubbing steering wheel column
- Intermediate shaft universal joints binding
- Tie rod ends binding
- Column bearings
- Fluid contamination
- Steering gear adjustment

Brakes

A dragging brake can cause a vehicle to pull. If you suspect brake drag, inspect the following:

- Parking brake cable
- Caliper slides
- Caliper piston travel
- Piston seal condition

Mechanical Binding

Components having the ability to control front wheel position can bind and cause the vehicle to steer in a direction away from straight ahead.

Be aware of prior repairs done to the vehicle you are aligning.

Improperly installed components are the number one cause of pull and drift due to mechanical binding.

Inspect the travel zone of the steering and suspension system for abrasive marks left by components contacting each other.

Proper inspection techniques will generally identify binding problems.

The fastest way to isolate the problem is to separate the possibilities into three areas:

- Suspension system
- Steering linkage
- Gear box and steering column

Disconnect the outer tie rods from the steer arms and steer each front wheel by hand. Observe any binding while steering the wheel from stop to stop. Repeat this step for the steering linkage.

If binding is noticed, disconnect the pitman arm from the steering box output shaft. Test the linkage assembly, and then test the gearbox.

Driveline

Torque steer is a pulling factor more common in some models than in others. Most FWD vehicles have some inherent torque steer when under severe acceleration. This is generally considered normal and additional repairs are not needed. Vehicles with excessive torque steer under mild acceleration or deceleration should be evaluated.

Unequal drive-shaft angles are the primary cause for excessive torque steer. Although this is addressed in the design stage, sagging or broken motor mounts can cause increased torque steer. Inspect motor mounts and keep aware of OEM updates about redesigned replacement parts that may minimize torque steer problems.

Note: Do not attempt to correct for torque steer by increasing cross caster or cross camber unless specifically instructed to do so by the manufacturer.

Crooked Steering Wheel

Vehicles equipped with individual tie rod adjusters generally make it simple to obtain centerline steering if the correct procedures are followed when setting toe. If the steering wheel is not straight after following the correct procedures, check for the following conditions:

- Excessive gearbox play
- Performing a centerline alignment
- Loose steering or suspension components
- Power steering induced pull

You can diagnose power steering induced pull by lifting the front wheels off the rack and starting the vehicle. Watch the steering wheel as the vehicle is started. An unbalanced control valve or spool valve will cause the steering wheel to move in the direction of the pull.

Check each component of the power steering system including the belt. Replace or repair the appropriate component.

A single tie rod adjuster design may be found on domestic light trucks and some European designs such as Volkswagens.

The lack of individual toe adjustment often results in a crooked steering wheel. Although a crooked steering wheel will not affect the alignment, it often affects the customer's perception of the alignment. Customers should be informed of this problem and asked if it is acceptable before the alignment is started.

Some models will allow the steering wheel to be repositioned on the steering shaft splines while others will not. Volkswagen offers an adjustable replacement tie rod for the side of the steering assembly without an adjuster.

Road Isolation

The road isolation characteristic of a parallelogram steering system is considered good as long as all the components are in good condition.

Parallelogram linkage does not offer a direct path for road forces to travel to the passenger compartment.

Rack and pinion and relay rod steering systems offer a more direct path for road forces to travel to the passenger compartment.

Intermittent Directional Instability

Bump steer

The steering system may cause directional stability problems.

Bump steer is when a bump or road irregularity causes the vehicle to change course.

If the steering system is sound and in proper alignment, toe change will be nominal and linear through suspension jounce and rebound. If the steering linkage is not in proper alignment, toe change may be different for each wheel.

This difference in toe change will steer the wheels, altering the direction of travel. Some common causes for misaligned steering systems are:

- Idler arm height adjustment
- Worn steering components
- Loose mounting bolts
- 4WD truck suspension changes without steering conversions
- Collision damage

You can diagnose a bump steer condition by performing a jounce and rebound test:

- Steer the front wheels straight ahead and verify front toe is within tolerances.
- Push down in the center of the front bumper and watch the amount and direction of front toe change
- Individual front toe should change in the same direction, and the amount of change should be nominal
- If the toe changes in opposite directions or an excessive amount (±0.13º), a bump steer condition may exist.

There are several late model GM vehicles with idler arms mounted to the frame with slotted adjustment:

- 1980 - 1985 Cadillac Seville
- 1979 - 1985 Toronado, Riviera, and Eldorado
- 1982 - 1990 Camaro and Firebird
- 1984 1990 Chevy S10 4X4

A collision, hard impact or improper installation may locate the idler arm at the wrong height (regardless if it is designed to be adjusted or not).

Check the idler arm in the following manner:

- Clean both flats on the center link.
- Install a socket onto the front head of the pivot bolt on the lower control arm of the driver's side.
- Place a straight-edge against the flat on the center link near the pitman arm.
- Measure the distance between the bottom of the socket and the top of the straight edge extending from the flat area of the center link.
- Repeat this procedure on the right side of the center link using the flat spot near the idler arm.
- Adjust the idler arm up or down until the measurements on both ends of the center link are within 1/32" of each other.

Memory Steer

Memory steer is a condition where the front wheels remember and seek a set position rather than returning to "straight ahead." This may generate a lead or a drift. Memory steer may be caused by:

- Binding steering linkage
- Binding steering gear
- Unbalanced power assist
- Ball joint, king pin or upper strut bearing that is binding or incorrectly installed

The easiest way to determine if a component is causing a memory steer condition is to isolate it from the rest of the components. Disconnect the pitman arm from the gearbox and the outer tie rods from the steering arms. Test each of the three assemblies for free travel. Each assembly can be broken down farther if necessary.

RBS style tie rods will memorize the position they are installed in as straight ahead. Be certain the front wheels are straight ahead when installing RBS tie rods.

Torque Steer

The rear wheels of a vehicle establish "straight ahead" since they do not have steering flexibility of the front wheels. The front wheels of a vehicle will steer into the path established by the rear wheels as they attempt to take the path of least resistance. However, the front wheels of a FWD vehicle possess a greater self-aligning torque than do the front wheels of a RWD vehicle. This is because the front wheels are steering as well as driving. The amount of self-aligning torque depends on the amount of torque being applied to each wheel.

As a result, the handling characteristics of the vehicle may vary during acceleration and deceleration. This is known as "torque steer."

The primary causes for torque steer are one drive axle being longer than the other or a difference in drive axle angle. A certain degree of torque steer is generally normal for a front wheel drive vehicle. The following factors may cause torque steer to be more apparent on a particular car:

- Tires and wheels have a significant effect on torque steer.
- Inspect the tires for a difference in brand, construction or size on the drive axle. Correct any differences. If the tire and wheel assemblies appear alike, rotate the tires from side to side. Correct any differences in tire pressure.
- Correct any looseness in control arm bushings, steering linkage or steering gear mounting which permits a front wheel to pull forward. Loose suspension components may cause an opposite lead on deceleration.
- Check suspension height. High front suspension height may increase drive axle angle.
- Inspect for a binding or tight drive axle joint. A tight joint or high front suspension height may result in a wobble condition between 15 to 30 mph.
- Incorrect, worn or loose engine mounts may cause drive axle angles to change.

Vehicle manufacturers have offered repairs to reduce torque steer:

- Motor mounts may be shimmed
- The cradle may be realigned
- Replacement motor mounts may be available
- Cross camber specifications may exceed ±0.5º

A two-piece drive shaft was introduced on some vehicles to eliminate drive axle length differences. Consult the manufacturer's procedures and recommended repairs for the vehicle being repaired.

Shimmy

Shimmy is a rapid in and out motion of the front wheels. Front wheel shimmy may occur at any speed.

The following factors may cause front wheel shimmy:

- Extremely low tire pressure
- Loose wheel bearings
- Excessive positive caster
- Bent spindle
- Loose steering or suspension components
- Excessive tire or wheel runout
- Excessive disc brake rotor lateral runout

Vehicles with preferred caster specifications of 5.0º ?or more are candidates for a shimmy condition because of the increased speed of the spindle returning from a steered position.

Most of these vehicles are equipped with a steering dampener to prevent wheel oscillation from starting. Eliminate the obvious, such as loose wheel bearings and low tire pressure before measuring runout and replacing spindles.

Wander

Wander is the tendency of a vehicle to drift to either side of a directed course. The following factors may cause wander:

- Extremely low tire pressure
- Excessive negative front total toe
- Brake drag
- Worn or loose suspension or steering components
- Incorrectly adjusted wheel bearings
- Power steering centering valve sticking
- Mismatched tires
- Extreme negative caster

Remember to eliminate the obvious such as mismatched tires on the same axle, brake drag, low tire pressure and excessive negative toe. Radial tires on the front wheels and bias ply on the rear may cause a vehicle to wander. Most of these problems should be detected during pre-alignment inspection.

Pull Diagnosis Quick Checks

Problem	Diagnosis
1. Tire pull	Check air pressure and wear patterns. Cross rotate the 2 front tires. If the pull switches sides, invert 1 front tire on the wheel or rotate one front tire with a back tire.
2. Brake pull	Check for a dragging wheel. Open the bleeder valve. Drag still present: Repair caliper Drag gone: Check for restricted brake hose.
3. Power steering pull	*Method 1:* Jack up front wheels, start engine. If steering wheel moves suspect defective steering gear. Method 2: Road test car and shut off engine. If pull returns on restart, suspect defective steering gear.
4. Alignment pull Cross Camber pull Cross Caster pull Excessive Thrust Angle	Cross Camber greater than 0.5° will drift to most positive side. Cross Caster greater than 0.5° will drift to least positive side. Excessive Thrust Angle may cause a full time drift and a pull when braking.
5. Road crown	Drive car on a flat road and check for pull. *Solution 1:* Adjust Caster +0.5° on passenger side. Solution 2: Adjust Camber -0.5° on passenger side.
6. Torque steer	Check for tire pull. Check for misaligned suspension cross-member. Check for worn engine and trans-axle mounts.
7. Bump steer	Check for unequal length tie rod assemblies. Check for unequal tie rod angles. Check for unlevel rack or centerlink.

Pull Diagnosis Quick Checks

Problem	Diagnosis
8. Memory Steer	Check for binding ball joints or tie rod ends. Check for binding strut bearings. If vehicle uses rubber strut plates or rubber tie rod ends, center steering wheel, loosen then retorque components.
9. Vehicle loading	Check for unequal or overloading of vehicle. If customer normally carries the load, align vehicle best possible with the weight in the vehicle.

Scenario 1: 1996 Buick Century

Left Front

Min.	Spec.	Max.	Actual	
-0.5º	0.0º	0.5º	-0.5º	Camber
0.7º	3.0º	3.7º	3.0º	Caster
-0.10º	0.0º	0.10º	0.01º	Toe
			12.3º	SAI
			11.8º	Included Angle

Right Front

Actual	Min.	Spec.	Max.
0.2º	-0.5º	0.0º	0.5º
2.8º	0.7º	3.0º	3.7º
0.02º	-0.10º	0.0º	0.10º
12.7º			
12.9º			

Front

	Actual	Min.	Spec.	Max.
Cross Camber	-0.7º	-0.5º	0.0º	0.5º
Cross Caster	0.2º	-1.0º	0.0º	1.0º
Total Toe	0.03º	-0.20º	0.00º	0.20º
Set Back	-0.01º			

Left Rear

Min.	Spec.	Max.	Actual	
-0.3º	0.0º	0.3º	0.2º	Camber
-0.15º	0.00º	0.15º	0.01º	Toe

Right Rear

Actual	Min.	Spec.	Max.
0.0º	-0.3º	0.0º	0.3º
-0.03º	-0.15º	0.00º	0.15º

	Actual	Min.	Spec.	Max.
Total Toe	-0.02º	-0.20º	0.00º	0.20º
Thrust Angle	0.02º			

Complaint: "Vehicle pulls to the right."

Question: "How bad is the pull?"

Answer: "It will take you off the road in less than 100 feet."

Question: "When does it pull?"

Answer: "Most noticeable at highway speeds."

Question: "When did you first notice this pull?"

Answer: "About one month ago."

Question: "Has any mechanical work been done on the car?"

Answer: "No."

Notes:

Scenario 2: 1999 S10 Blazer 4X4

Left Front

Min.	Spec.	Max.	Actual	
-0.5º	0.0º	0.5º	0.1º	Camber
2.5º	3.0º	3.5º	5.1º	Caster
0.00º	0.05º	0.10º	0.05º	Toe
			6.2º	SAI
			6.3º	Included Angle

Right Front

Actual	Min.	Spec.	Max.
-0.1º	-0.5º	0.0º	0.5º
5.3º	2.5º	3.0º	3.5º
0.05º	0.00º	0.05º	0.10º
6.5º			
6.4º			

Front

	Actual	Min.	Spec.	Max.
Cross Camber	0.2º	-0.5º	0.0º	0.5º
Cross Caster	-0.2º	-0.5º	0.0º	0.5º
Total Toe	0.10º	0.00º	0.10º	0.20º
Set Back	0.06º			

Left Rear

Min.	Spec.	Max.	Actual	
			-0.1º	Camber
			0.12º	Toe

Right Rear

Actual	Min.	Spec.	Max.
0.0º			
-0.12º			

	Actual	Min.	Spec.	Max.
Total Toe	-0.00º			
Thrust Angle	0.12º			

Complaint: "Vehicle pulls to the right and may shimmy intermittently."

Question: "When did you notice the shimmy?"

Answer: "After traveling rough roads or sometimes after bridges."

Question: "Has the vehicle been aligned lately?"

Answer: "Yes, I had trouble with the steering wheel returning, but that is fixed."

Question: "Was the shimmy problem present before the alignment?"

Answer: "No."

Question: "Have you noticed any other differences?"

Answer: "Yes, it seems to be a little harder to steer."

Notes:

Scenario 3: 1998 Cadillac Deville FWD

Left Front

Min.	Spec.	Max.	Actual	
-0.5º	0.0º	0.5º	0.2º	Camber
2.0º	3.0º	4.0º	3.1º	Caster
-0.10º	0.00º	0.10º	0.01º	Toe
			12.8º	SAI
			13.0º	Included Angle

Right Front

Actual	Min.	Spec.	Max.
0.2º	-0.5º	0.0º	0.5º
3.0º	2.0º	3.0º	4.0º
0.01º	-0.10º	0.00º	0.10º
12.0º			
12.2º			

Front

	Actual	Min.	Spec.	Max.
Cross Camber	0.00º	-0.75º	0.0º	0.75º
Cross Caster	-0.1º	-0.75º	0.0º	0.75º
Total Toe	0.02º	-0.20º	0.00º	0.20º
Set Back	0.05º			

Left Rear

Min.	Spec.	Max.	Actual	
-0.5º	0.0º	0.5º	-0.4º	Camber
-0.05º	0.05º	0.15º	0.04º	Toe

Right Rear

Actual	Min.	Spec.	Max.
-0.8º	-0.5º	0.0º	0.5º
0.04º	-0.05º	0.05º	0.15º

	Actual	Min.	Spec.	Max.
Total Toe	0.08º	-0.10º	0.10º	0.30º
Thrust Angle	0.00º			

Complaint: "Vehicle pulls to the right."

Question: "How bad is the pull?"

Answer: "I have to steer the other way most of the time."

Question: "When did you first notice the problem?"

Answer: "It has always pulled a little, but seems to have gotten worse in the last year."

Question: "Have any major repairs been done to the car?"

Answer: "The transmission was worked on about a year ago."

Question: "When was the car last aligned?"

Answer: "I think it was aligned after the transmission repair."

Notes:

Scenario 4: 1991 Porsche 944

Left Front

Min.	Spec.	Max.	Actual	
-.2º	0.0º	0.2º	0.0º	Camber
2.3º	2.5º	3.0º	2.7º	Caster
0.04º	0.08º	0.12º	0.10º	Toe
			11.3º	SAI
			11.3º	Included Angle

Right Front

Actual	Min.	Spec.	Max.
0.8º	-.2º	0.0º	0.2º
2.0º	2.3º	2.5º	3.0º
0.11º	0.04º	0.08º	0.12º
9.4º			
10.2º			

Front

	Actual	Min.	Spec.	Max.
Cross Camber	0.8º	-0.3º	0.0º	0.3º
Cross Caster	0.7º	-0.5º	0.0º	0.5º
Total Toe	0.21º	0.09º	0.17º	0.25º
Set Back	0.51º			

Left Rear

Min.	Spec.	Max.	Actual	
-1.3º	-1.0º	-0.7º	-0.8º	Camber
0.08º	0.16º	0.24º	0.08º	Toe

Right Rear

Actual	Min.	Spec.	Max.
-1.0º	-1.3º	-1.0º	-0.7º
0.09º	0.08º	0.16º	0.24º

	Actual	Min.	Spec.	Max.
Total Toe	0.17º	0.16º	0.33º	0.50º
Thrust Angle	-0.01º			

Complaint: "The vehicle continues to wear out front tires rapidly."

Question: "Has rapid front tire wear always been a problem?"

Answer: No, it has only been this way since the accident."

Question: "What happened to the car?"

Answer: "The car slid on wet pavement and hit a median with the right front wheel. They replaced the tire and wheel."

Question: "Are there any other problems other than the rapid tire wear?"

Answer: "No, the car seems to drive alright."

Question: "Have you had the car aligned?"

Answer: "Yes, I've been to two or three shops and they can't seem to solve the problem."

Notes:

Scenario 5: 1996 Ford Escort

Left Front

Min.	Spec.	Max.	Actual	
-0.6º	0.2º	1.0º	0.2º	Camber
0.5º	1.3º	2.0º	1.3º	Caster
-0.05º	0.10º	0.25º	0.08º	Toe
			14.1º	SAI
			14.3º	Included Angle

Right Front

Actual	Min.	Spec.	Max.
0.3º	-0.6º	0.2º	1.0º
1.4º	0.5º	1.3º	2.0º
0.12º	-0.05º	0.10º	0.25º
14.3º			
14.6º			

Front

	Actual	Min.	Spec.	Max.
Cross Camber	-0.1º			
Cross Caster	-0.1º			
Total Toe	0.20º	-0.10º	-0.20º	0.50º
Set Back	0.42º			

Left Rear

Min.	Spec.	Max.	Actual	
-1.5º	-0.5º	0.5º	-1.2º	Camber
-0.05º	0.10º	0.25º	0.16º	Toe

Right Rear

Actual	Min.	Spec.	Max.
-0.9º	-1.5º	-0.5º	0.5º
-0.40º	-0.05º	0.10º	0.25º

	Actual	Min.	Spec.	Max.
Total Toe	0.56º	-0.10º	0.20º	0.50º
Thrust Angle	0.28º	-0.40	0.00	0.40

Complaint: "The vehicle constantly wears out rear tires."

Question: "How long does a tire generally last on the rear?"

Answer: "They seem to last about a year."

Question: "Do you rotate the tires?"

Answer: "They don't last long enough to rotate."

Question: "Have you had the car aligned?"

Answer: "It has been aligned twice, but it doesn't seem to help."

Question: "Do you carry heavy loads in the back?"

Answer: "On occasion, but not as a general rule."

Question: "Do both tires show the same wear pattern?"

Answer: "Yes, they are worn on the inside shoulder with diagonal cupping."

Notes:

Scenario 6: 1995 Ford Taurus

Left Front

Min.	Spec.	Max.	Actual	
-1.1º	-0.5º	0.1º	-0.4º	Camber
2.8º	3.8º	4.8º	4.7º	Caster
-0.23º	-0.10º	0.15º	-0.08º	Toe
			13.8º	SAI
			13.4º	Included Angle

Right Front

Actual	Min.	Spec.	Max.
0.0º	-1.1º	-0.5º	0.1º
2.9º	2.8º	3.8º	4.8º
-0.10º	-0.23º	-0.10º	0.15º
13.4º			
13.4º			

Front

	Actual	Min.	Spec.	Max.
Cross Camber	-0.4º	-0.7º	0.0º	0.7º
Cross Caster	1.8º	-0.9º	0.0º	0.9º
Total Toe	-0.18º	-0.45º	-0.20º	0.30º
Set Back	0.42º			

Left Rear

Min.	Spec.	Max.	Actual	
-1.6º	-1.0º	-0.3º	-0.7º	Camber
-0.06º	0.06º	0.18º	0.07º	Toe

Right Rear

Actual	Min.	Spec.	Max.
-0.9º	-1.6º	-1.0º	-0.3º
0.05º	-0.06º	0.06º	0.18º

	Actual	Min.	Spec.	Max.
Total Toe	0.12º	-0.13º	0.12º	0.37º
Thrust Angle	0.01º			

Complaint: "The vehicle pulls to the right."

Question: "How bad is the pull?"

Answer: "The car will be on the shoulder in less than a minute."

Question: "When did you first notice the pull?"

Answer: "About 3 months ago."

Question: "Has any mechanical work be done to the car?"

Answer: "The engine was worked on recently."

Question: "What type of engine work?"

Answer: "They replaced the engine?"

Notes:

Scenario 7: 1989 Chrysler Conquest

Left Front

Min.	Spec.	Max.	Actual	
-1.0º	-0.5º	0.0º	-0.8º	Camber
5.33º	5.83º	6.33º	5.4º	Caster
-0.20º	0.00º	0.20º	0.20º	Toe
				SAI
				Included Angle

Right Front

Actual	Min.	Spec.	Max.
0.0º	-1.0º	-0.5º	0.0º
6.3º	5.33º	5.83º	6.33º
0.00º	-0.20º	0.00º	0.20º

Front

	Actual	Min.	Spec.	Max.
Cross Camber	-0.8º	-0.5º	0.0º	0.5º
Cross Caster	-0.9º	-0.5º	0.0º	0.5º
Total Toe	0.20º	-0.40º	0.00º	0.40º
Set Back	-0.45º			

Left Rear

Min.	Spec.	Max.	Actual	
-0.8º	-0.3º	0.3º	-0.6º	Camber
-0.08º	0.00º	0.08º	0.04º	Toe

Right Rear

Actual	Min.	Spec.	Max.
0.2º	-0.8º	-0.3º	0.3º
-0.04º	-0.08º	0.00º	0.08º

	Actual	Min.	Spec.	Max.
Total Toe	0.00º	-0.16º	0.00º	0.16º
Thrust Angle	0.04º			

Complaint: "The car drifts to the left."

Question: "When do you notice the drift?"

Answer: "I notice it most at speeds above 40mph."

Question: "How long has this drift been noticeable?"

Answer: "Since I slid into a curb last winter."

Question: "Has the car been aligned recently?"

Answer: "The car was aligned when it was repaired."

Question: "Did the drift exist before the accident?"

Answer: "Yes, but not as bad."

Notes:

Scenario 8: 1996 Honda Prelude 2WS

Left Front

Min.	Spec.	Max.	Actual
-1.0º	0.0º	1.0º	0.1º
1.7º	2.7º	3.7º	1.5º
-0.08º	0.00º	0.08º	-0.16º

Camber
Caster
Toe
SAI
Included Angle

Right Front

Actual	Min.	Spec.	Max.
0.3º	-1.0º	0.0º	1.0º
1.3º	1.7º	2.7º	3.7º
-0.16º	-0.08º	0.00º	0.08º

Front

	Actual	Min.	Spec.	Max.
Cross Camber	-0.2º			
Cross Caster	0.2º			
Total Toe	-0.32º	-0.16º	0.00º	0.16º
Set Back	0.10º			

Left Rear

Min.	Spec.	Max.	Actual
-1.8º	-0.8º	0.3º	-0.8º
0.00º	0.08º	0.16º	0.06º

Camber
Toe

Right Rear

Actual	Min.	Spec.	Max.
-0.9º	-1.8º	-0.8º	0.3º
0.30º	0.00º	0.08º	0.16º

	Actual	Min.	Spec.	Max.
Total Toe	0.36º	0.00º	0.16º	0.32º
Thrust Angle	-0.12º			

Complaint: "The vehicle tends to wander constantly."

Question: "What do you mean by 'wander'?"

Answer: "I constantly have to steer to keep it going straight."

Question: "Has the car been in an accident?"

Answer: "No."

Question: "When was the vehicle align last?"

Answer: "About two years ago."

Question: "Does the problem appear to be worse at any time?"

Answer: "Rough roads seem to make it worse."

Notes:

Scenario 9: 1997 Ford Ranger 4x4

Left Front

Min.	Spec.	Max.	Actual	
-0.3º	0.3º	0.8º	-0.5º	Camber
2.0º	3.6º	6.0º	5.4º	Caster
-0.10º	0.00º	0.16º	0.01º	Toe
				SAI
				Included Angle

Right Front

Actual	Min.	Spec.	Max.
-0.6º	-0.3º	0.3º	0.8º
5.2º	2.0º	4.4º	6.0º
0.02º	-0.10º	0.00º	0.16º

Front

	Actual	Min.	Spec.	Max.
Cross Camber	0.1º	-0.4º	0.0º	0.4º
Cross Caster	0.2º	-1.2º	-0.8º	-0.4º
Total Toe	0.03º	-0.19º	0.06º	0.31º
Set Back	-0.12º			

Left Rear

Min.	Spec.	Max.	Actual	
			-0.1º	Camber
			0.08º	Toe

Right Rear

Actual	Min.	Spec.	Max.
-0.3º			
-0.10º			

	Actual	Min.	Spec.	Max.
Total Toe	-0.02º			
Thrust Angle	0.09º			

Complaint: "I seem to feel every bump in the road."

Question: "Has the ride quality changed or do you just want to improve it?"

Answer: "I think it has changed. It rode better when it was new."

Question: "Was the ride quality change sudden or did it occur over a period of time?"

Answer: "That's hard to say. I want to say it was kind of sudden."

Question: "Have you replaced or added any suspension or steering parts?"

Answer: No, but I did have it in the shop for a wandering problem."

Question: "Have you changed tires or wheels?"

Answer: "I did have larger tires and wheels put on to increase road clearance."

Notes:

Ford Twin I-Beam

Note: 1988 and earlier Ford truck specifications are based on a ride height measurement. Consult the specification book or shop manual for the location to take this measurement.

Ford has three different Twin-I-beam axle designs:

- Forged
- Stamped axle
- Cast axle

Cast axle with balljoints

Hollow stamped axle with balljoints

Forged axles with kingpins

Forged Axle

The forged axle has king pins.

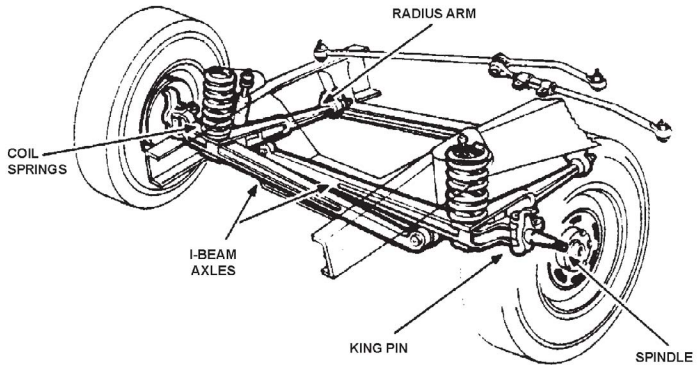


Figure 4b-108, Forged Axle with King Pins

The forged axle is the only Twin-I-beam axle that can be realigned using hydraulic bending equipment to correct camber (with the exception of the Ford Ranger).

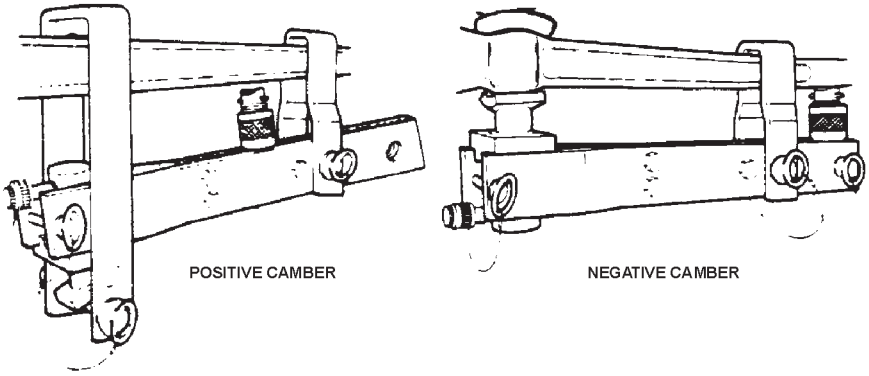


Figure 4b-109, Camber Adjustment Using Hydraulic Bending Equipment

Stamped or Cast Axle

A stamped axle or cast axle uses upper and lower ball joints.

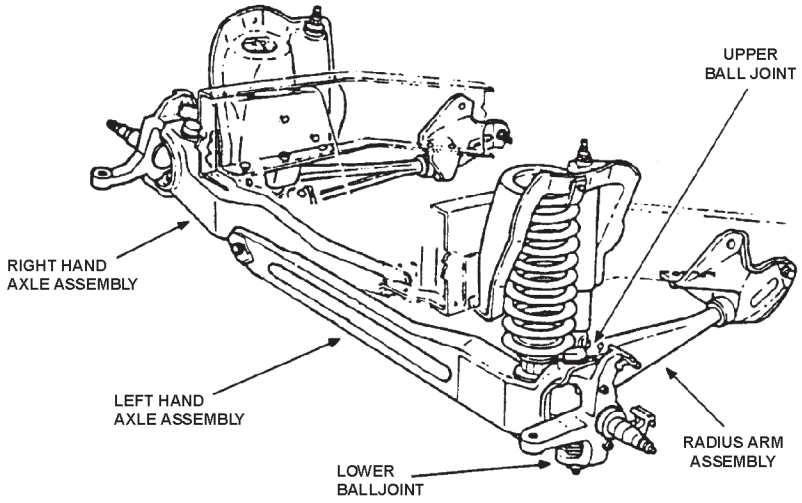


Figure 4b-110, Stamped or Cast Axle

Change camber only on a stamped or cast axle by replacing an eccentric bushing at the upper ball joint ('82-'86 4x2 trucks).

Change camber and caster on a stamped or cast axle by replacing an eccentric bushing at the upper ball joint ('87 and newer 4x2 trucks, '82 and newer 4x4 trucks).

Eccentric Bushings

A stamped axle or cast axle uses upper and lower ball joints.

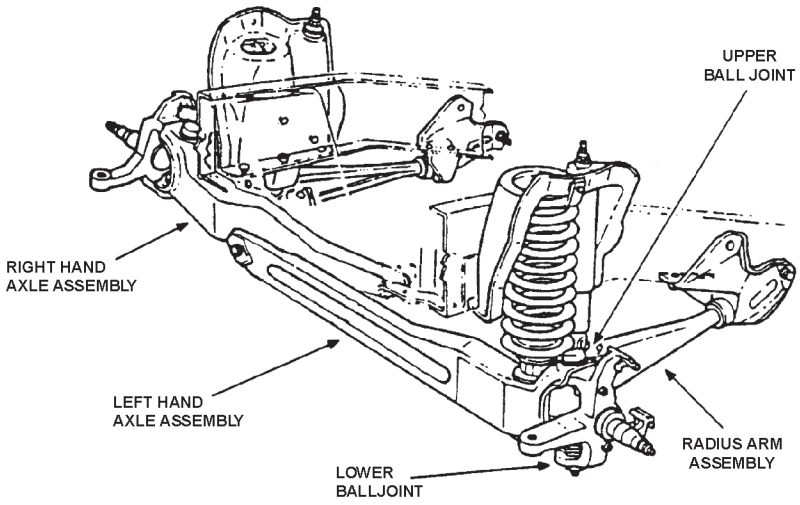


Figure 4b-111, Camber or Caster Adjustment Using Replaceable Eccentric Bushings

Specifications

1988 and earlier Ford truck specifications are based on a ride height measurement. Consult the specification book or shop manual for the location to take this measurement.

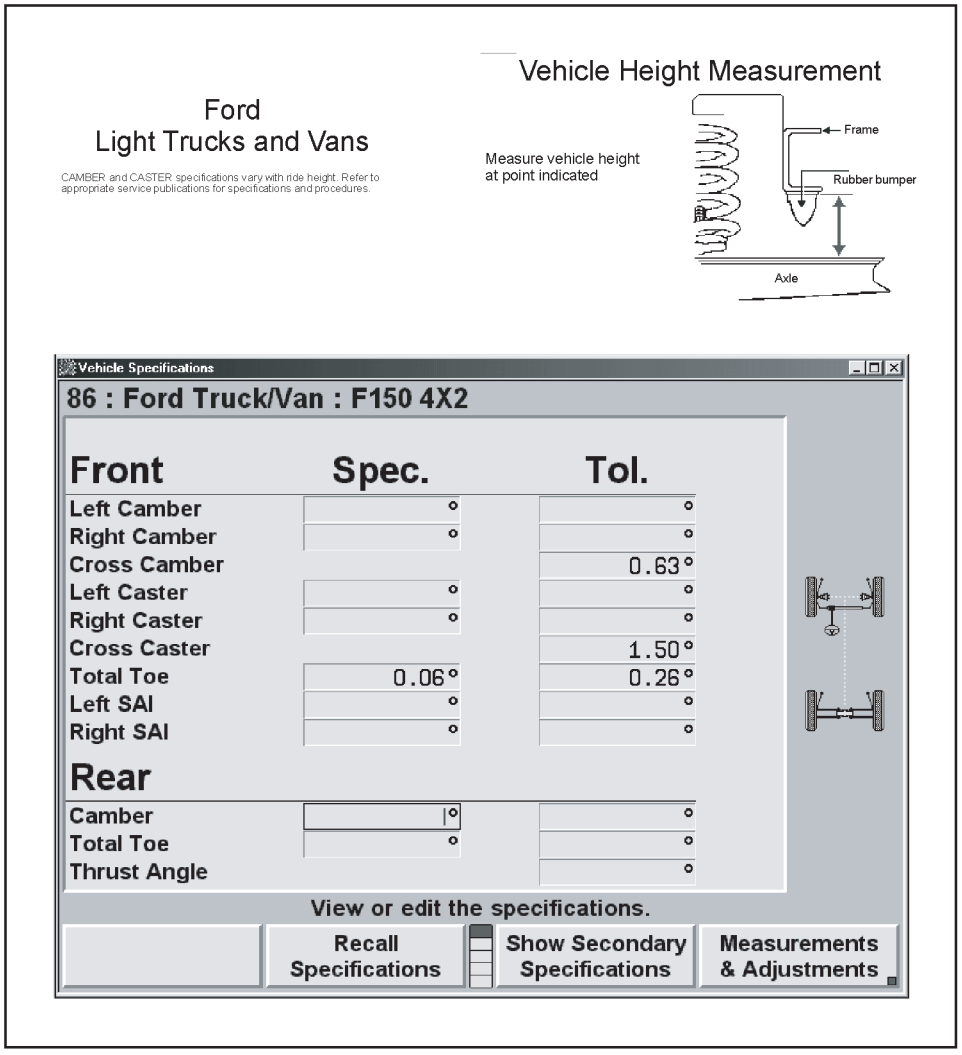


Figure 4b-112, 1986 Ford Truck Specifications

1989 and later Ford truck specifications no longer vary with ride height.

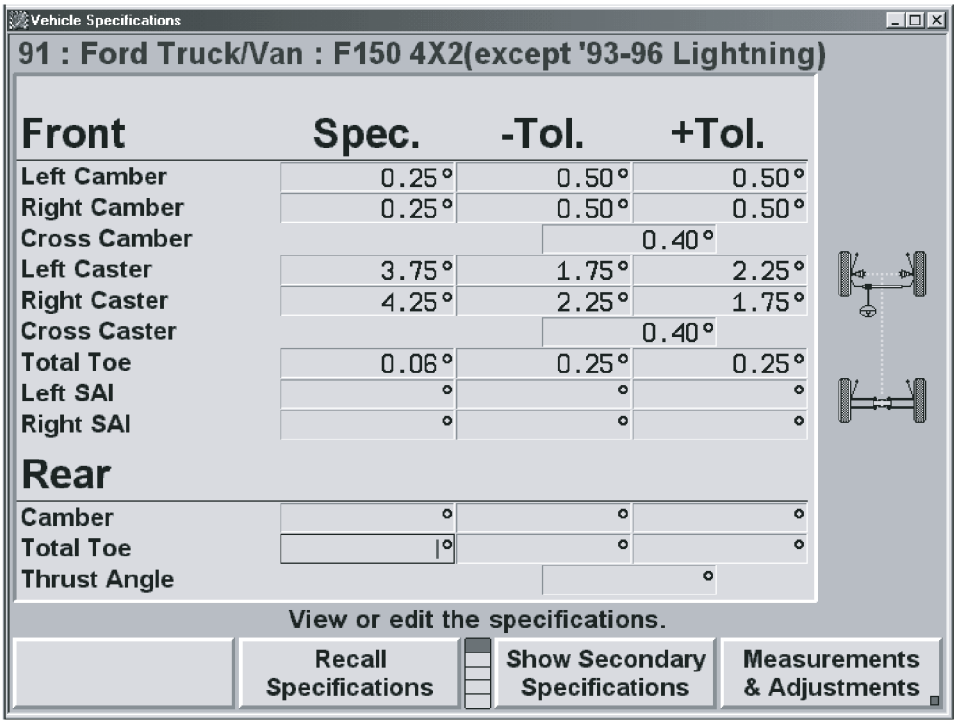


Figure 4b-113, 1991 Ford Truck Specifications

Using the Automatic Bushing Calculator

Automatic Bushing Calculator (ABC) helps determine the correct bushing size and proper positioning for the required adjustments.

Note: Do NOT remove bushings until instructed to do so. The illustrated blue arrow depicts the center of the thin wall. This is NOT always at the bushing crush gap.

Press "Make Additional Adjustments," on the "Vehicle Measurements and Adjustments" primary screen.

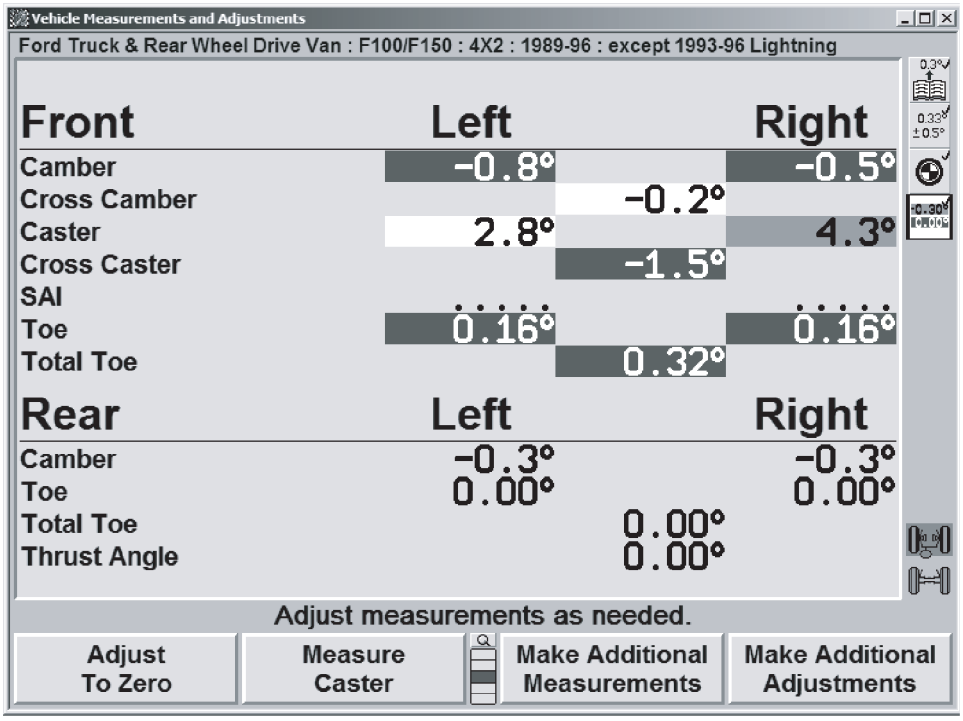


Figure 4b-114, Select “Make Additional Adjustments”

The "Additional Adjustment Procedures" pop-up screen will appear. Select "Adjust camber/caster with bushings."

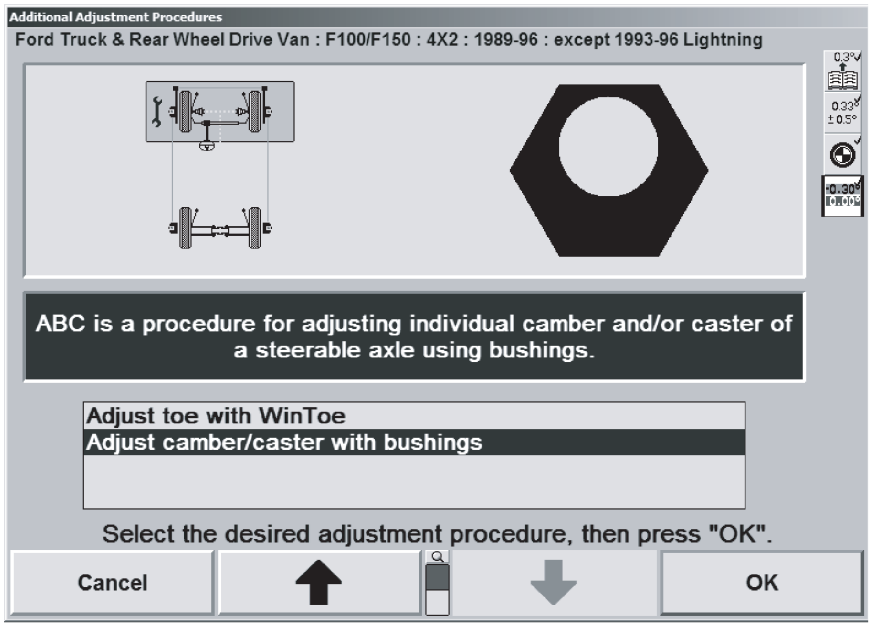


Figure 4b-114, Select "Adjust CamberCaster with Bushings."

Press "OK."

OR

Select "Adjust with Automatic Bushing Calculator" from the context sensitive menu.

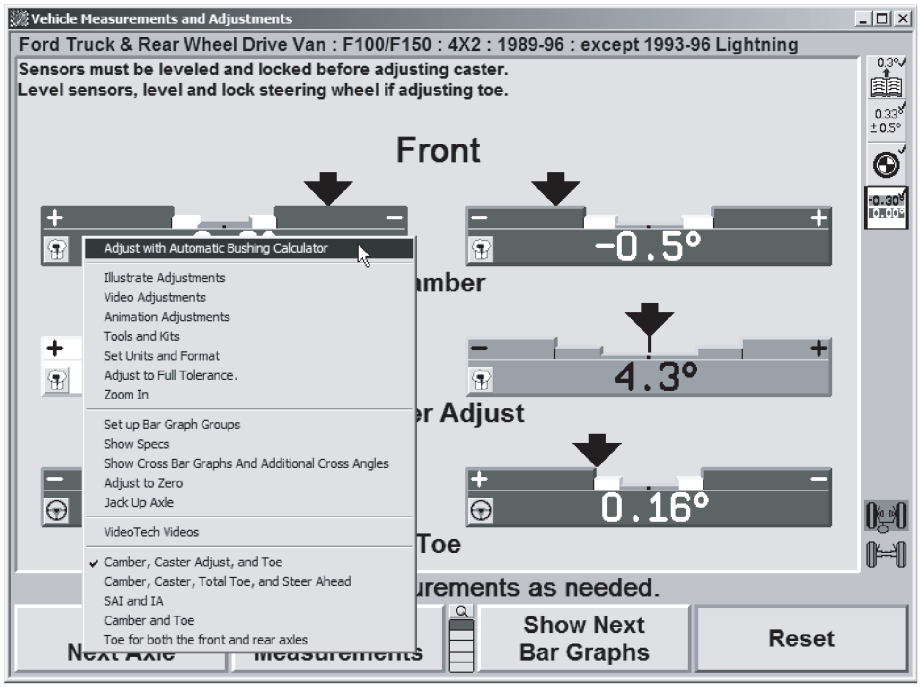


Figure 4b-115, Drop-down Menu

In the left lower corner of each applicable bar graph, there will be a bushing icon to indicate the Automatic Bushing Calculator is available.

When the "Steer Ahead" pop-up screen appears, steer the wheels straight ahead.

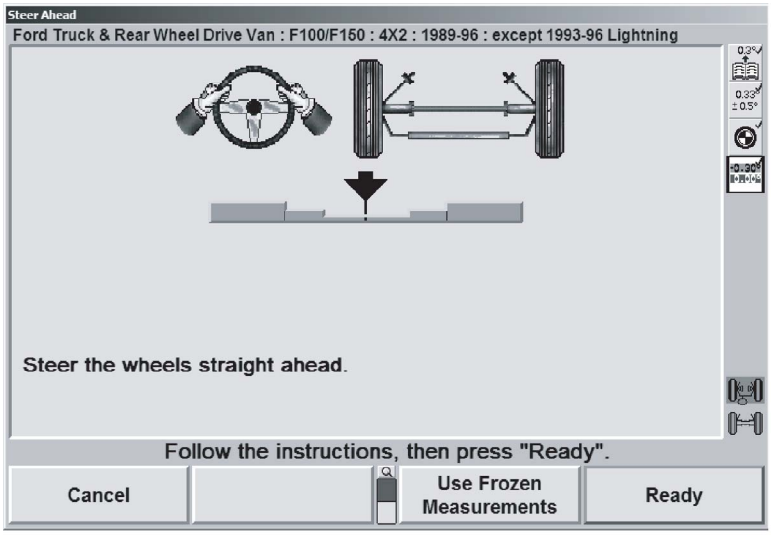


Figure 4b-116, Steer the Wheels Straight Ahead

Press "Ready." Measurements will automatically be frozen.

Do not remove the bushing.

The screen then displays "Measurements are frozen!" Freezing the measurements allows the sensors to be removed from the wheels while the display continues to show the bushing requirements. Press "Unfreeze Measurements" to return the display to normal "live" operation.

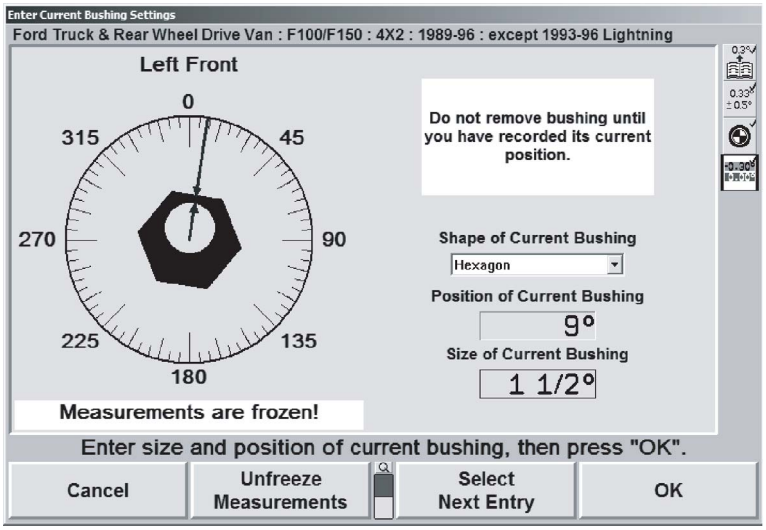


Figure 4b-117, Input the Current Bushing's Position and Size

Identify and enter the shape of the current bushing by pressing "Tab" and or on the keyboard to highlight the desired choice or using the mouse or light-pen.

Record the current position of the bushing into the computer.

Note: The illustrated blue arrow depicts the center of the thin wall. This is NOT always at the bushing crush gap.

Adjust the blue arrow to the center of the thin wall on the illustrated bushing with a light pen or a mouse.

OR

Enter the data manually by pressing "Tab" to highlight the "Position of Current Bushing" data box and entering the degrees using the illustrated bushing as a reference for direction.

Identify the size of the current bushing by looking at the stamped size on the side of the bushing and enter the size into the "Size of Current Bushing" data box.

Note: ABC accepts bushing size values in both decimal degrees and fractional degrees. If the bushing is stamped in degrees and minutes (example 1º30'), you should convert the value to degrees before you enter it.

After you finish entering the existing bushing information, press "OK."

The "Adjust Front Bushings" pop-up screen will appear. The screen opens showing the bushing requirements for the left wheel. Press "Show Right Bushing" to toggle to the right wheel, and then "Show Left Bushing" to toggle back.

Remove the bushing.

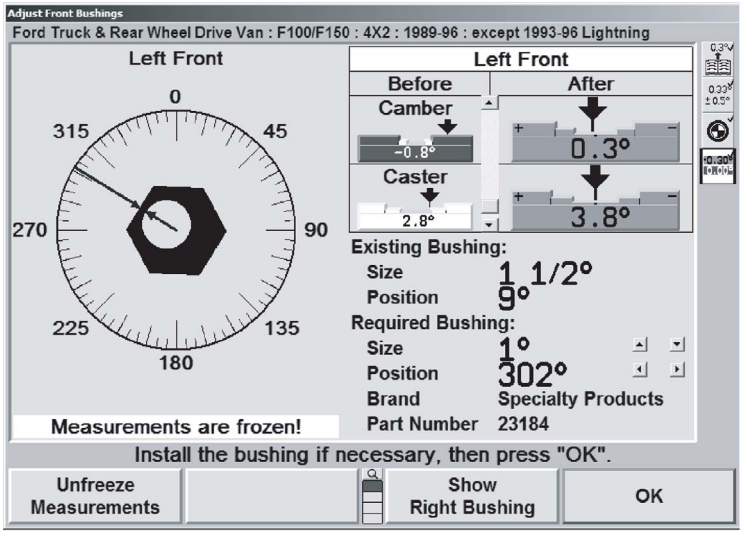


Figure 4b-118, Required Replacement Bushing Position and Size

This screen will display the existing bushing information and the required adjustment bushing information. The changes required in camber and caster are shown in the "Before" column at the upper left. For example, a change of "0.13º" for camber means "camber must be made 0.13° more positive.

The "After" column shows the residual errors that will remain in camber and caster after installing the bushing. These residual values are shown in bar graph form so the quality of the adjustments can be quickly gauged.

The size, installation position, brand and part number for the required bushing will be displayed in the lower left-hand corner of the screen.

The size and position of the required bushing are computed for optimum adjustment, but may be manually overridden by the technician by either selecting the adjustment arrows to the right of the numbers, or by moving the blue arrow to a new placement of the thin wall of the bushing.

Initially, the computer considers both readings to have equal importance, but the scroll bar to the right of the camber and caster readings allows the technician to prioritize the need for either camber or caster adjustment as more or less important.

"Improve Camber" and "Improve Caster" can also be selected to move the scroll bar. For instance, scrolling toward caster increases the importance of caster adjustment and decreases the importance of the camber adjustment. The bushing will be changed accordingly.

Selecting "Change Bushing Brand" will change the bushing manufacturer to the next manufacturer available.

Figure 4b-118, Change Bushing Brand

Selecting "Print Bushing and Template" will print the template of the bushing that can be helpful in placement of the bushing

The bushing is shown actual size so the display may be used as a template.

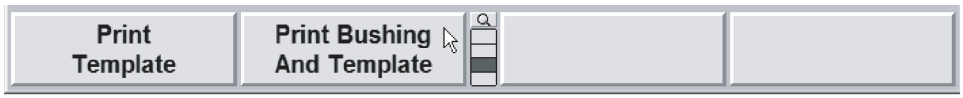


Figure 4b-119, Print Bushing and Template

Selecting "Select Bushing Brand" will present the technician with a list of bushing brands. The desired manufacturer can be selected by pressing or to highlight the manufacturer and selecting "OK."

Figure 4b-120, Select Bushing Brand

When used with "ExpressAlign" the Alignment Bushing Calculator allows for only one wheel to be adjusted when the opposite wheel is within specification.

The pop-up screen provides you with a list of options that allow you to select "Adjust Only One Wheel," "Adjust Both Wheels," or "Adjust to Actual Value."

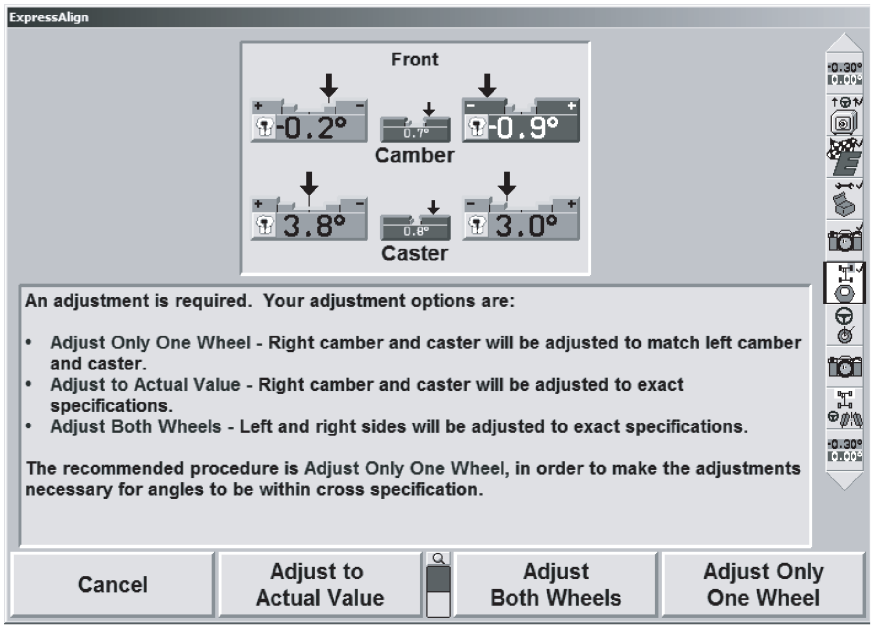


Figure 4b-121, Adjust Only One Wheel

Selecting "Adjust Only One Wheel" when the left wheel is out of specification will set the specification for the left wheel to right value "+" cross spec. If the right side were out of specification, then right wheel would be set to left value "-" cross spec.

Note: This feature is available only when ExpressAlign is enabled from setup.

To adjust both wheels using ABC with ExpressAlign:

Adjust the left wheel first. After adjusting the left wheel, press "OK." Win Align will display the steer ahead screen again. This time, K3 will read "Use Frozen Measurements."

Press "Use Frozen Measurements" to bypass the "steer ahead" screen and use the previously frozen measurements.

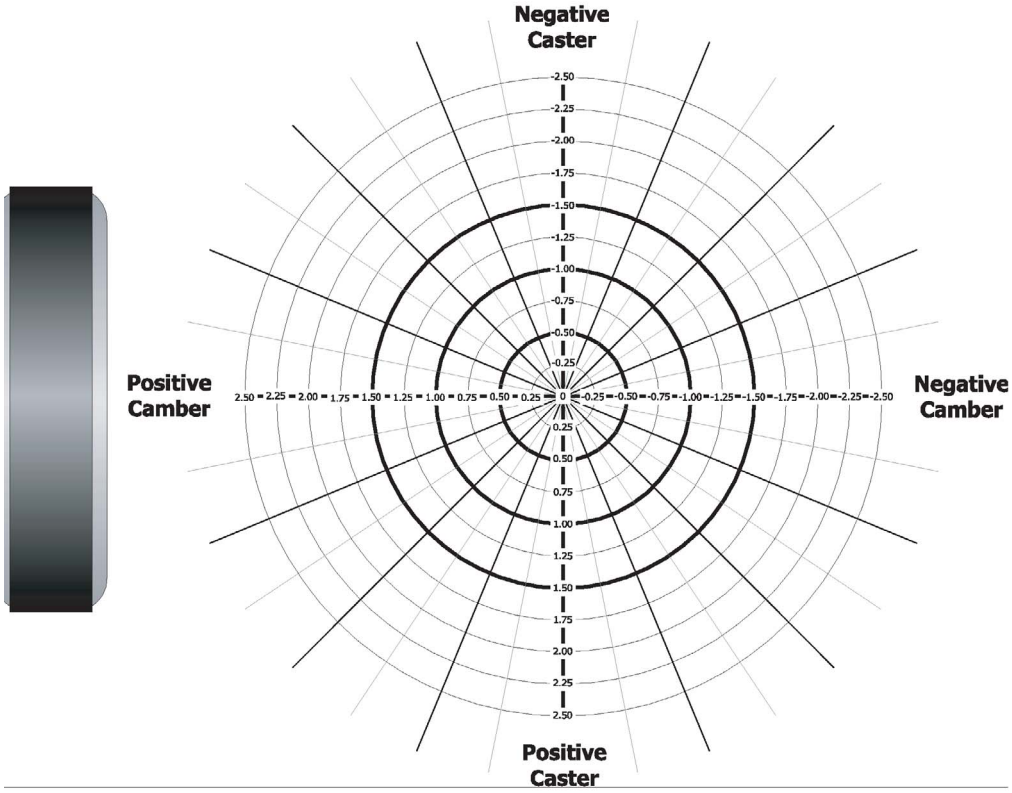
This prevents the user from having to re-mount the wheel and sensors. Lower and jounce the vehicle. Re-compensate the sensors, and steer ahead to re-freeze the measurements.

When the all adjustments are completed, press "OK" to return to the "Vehicle Measurements and Adjustments" primary screen. After adjusting camber and/or caster using ABC, lower and jounce the vehicle, then re-compensate the sensors.

Driver Side - Manual Bushing Calculator

	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

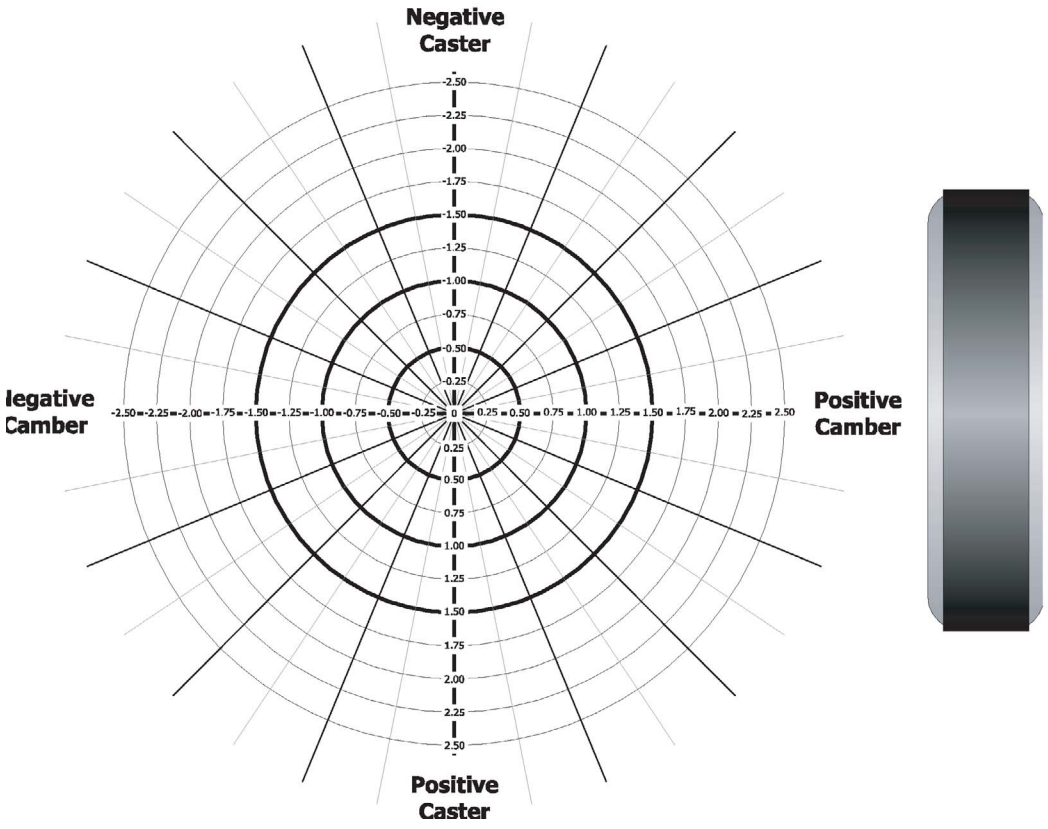
Bushing Size _____



Passenger Side - Manual Bushing Calculator

	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____



Using the Manual Bushing Calculator-OE

Select the "Adjust to Zero" screen ("Zero Adjust on 111 aligners). The align will now display how far camber and caster are from preferred specifications.

Note: When using the "Adjust to Zero" screen, adjust ALL values to Zero!

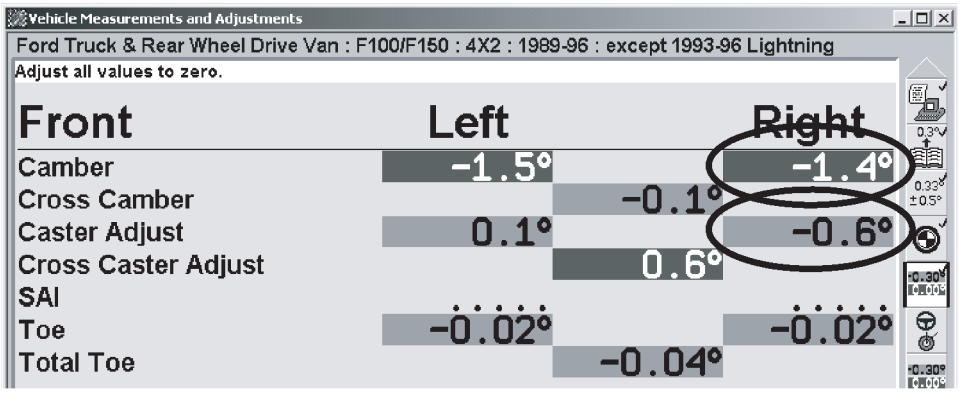


Figure 4b-122, Adjust to Zero Measurements

Record the required camber and caster adjustment (write down the OPPOSITE of the "Adjust to Zero" measurements) on the bushing calculator worksheet.

Passenger Side – Manual Bushing Calculator

	Desired Change		Old Bushing		Total Change
Camber	+1.4°	+		=	
Caster	+0.6°	+		=	

Bushing Size _____

Figure 4b-123, Write Down the Opposite of "Adjust to Zero" Measurements

Record the caster and camber adjustments from the bushing currently in the axle on the bushing calculator worksheet.

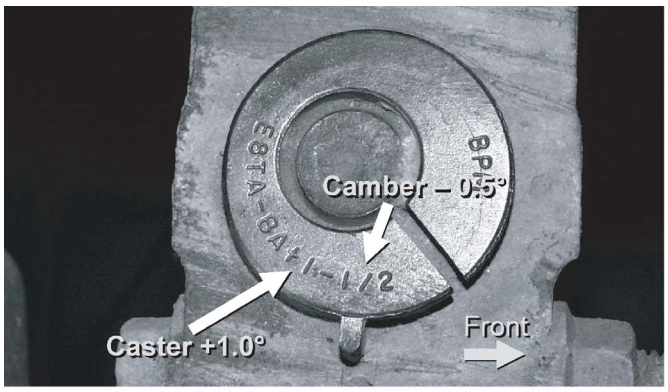


Figure 4b-124, Caster and Camber Adjustment Values Are Stamped on an OE Bushing

Note: The caster adjustment on the DRIVER'S SIDE bushing is the OPPOSITE sign of the actual number stamped on the bushing!

Passenger Side – Manual Bushing Calculator

	Desired Change		Old Bushing		Total Change
Camber	+1.4°	+	- 0.5°	=	
Caster	+0.6°	+	+1.0°	=	

Bushing Size _____

Figure 4b-125, Write Down the Adjustment Values of the OE Bushings

Add the "Desired Change" to the "Old Bushing" to calculate the required camber and caster adjustments for a replacement bushing.

The "Total Change" is the amount of adjustment required as if a Zero offset bushing were installed in the axle.

Passenger Side – Manual Bushing Calculator

	Desired Change		Old Bushing		Total Change
Camber	+1.4°	+	- 0.5°	=	+0.9°
Caster	+0.6°	+	+1.0°	=	+1.6°

Bushing Size _____

Figure 4b-126, Add the "Desired Change" t the "Old Bushing" to compute "Total Change"

Mark the required camber adjustment on the bushing calculator worksheet with a vertical line.

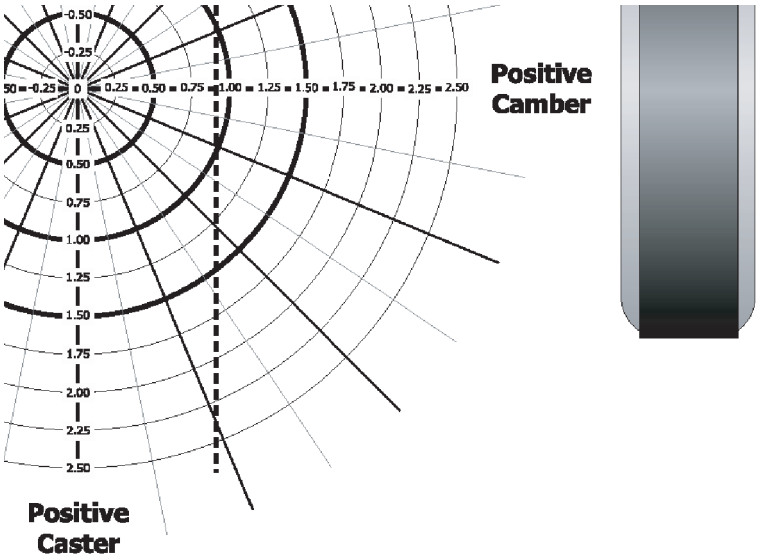


Figure 4b-126, Mark the Required Camber Adjustment

Mark the required caster adjustment on the bushing calculator worksheet with a horizontal line.

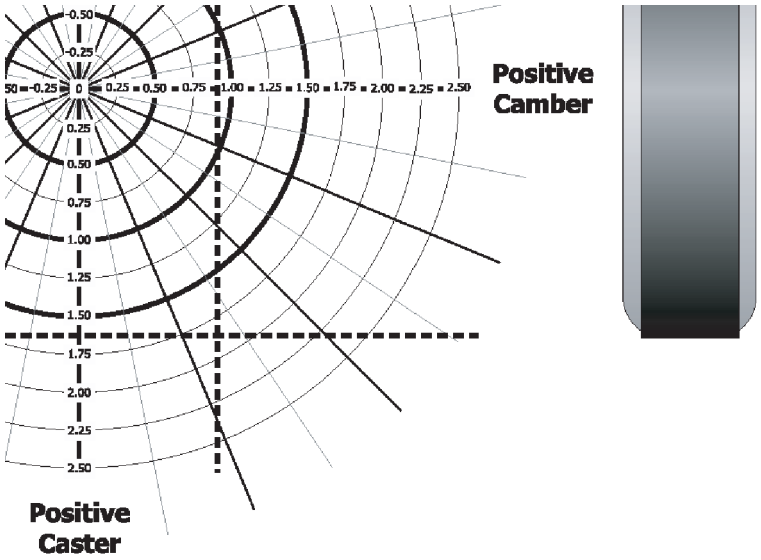


Figure 4b-127, Mark the Required Caster Adjustment

The intersection point of the camber vertical line and the caster horizontal lines displays BOTH the required bushing offset size AND the direction the thin wall of the bushing must face when installed in the axle.

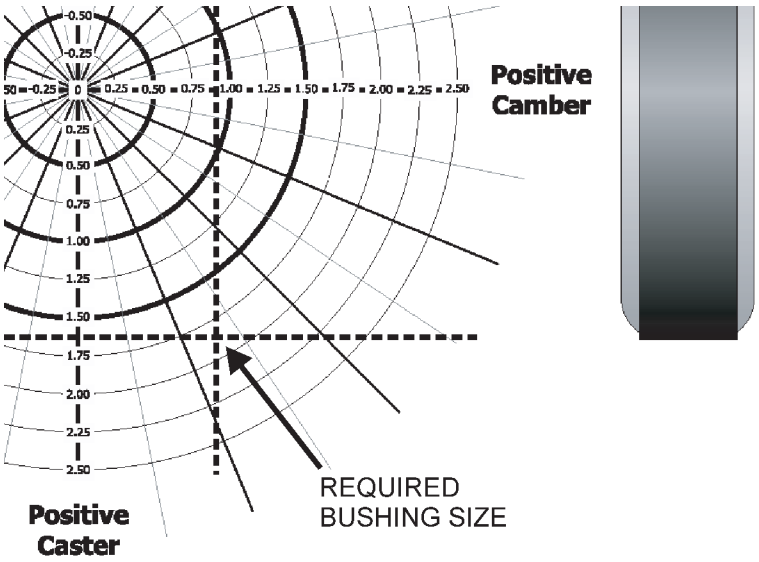


Figure 4b-128, Required Bushing Size is 1.75°

Draw a line from the 0 point (center of chart) through and past the intersection point of the camber and caster lines.

This indicates the direction the thin wall of the bushing must face when installed in the axle.

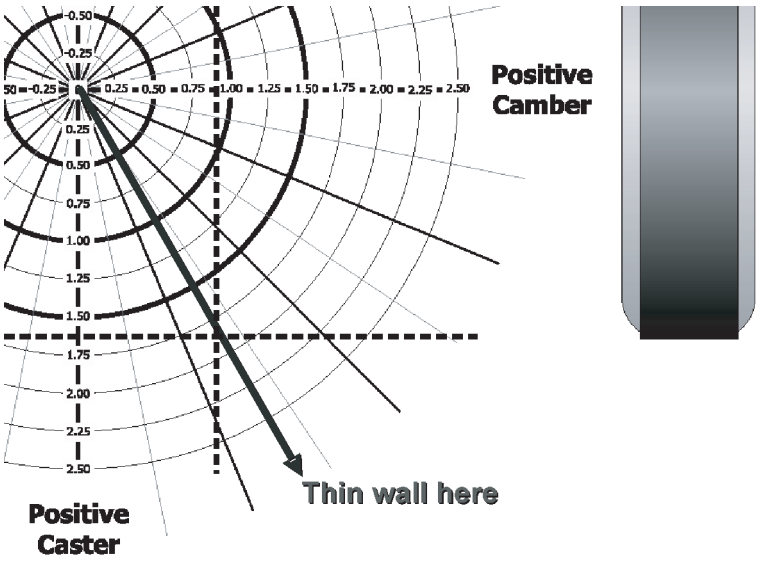


Figure 4b-129, Thin Wall Faces this Direction

Place the required bushing on the bushing calculator worksheet with the bushing's thin wall facing as indicated above.

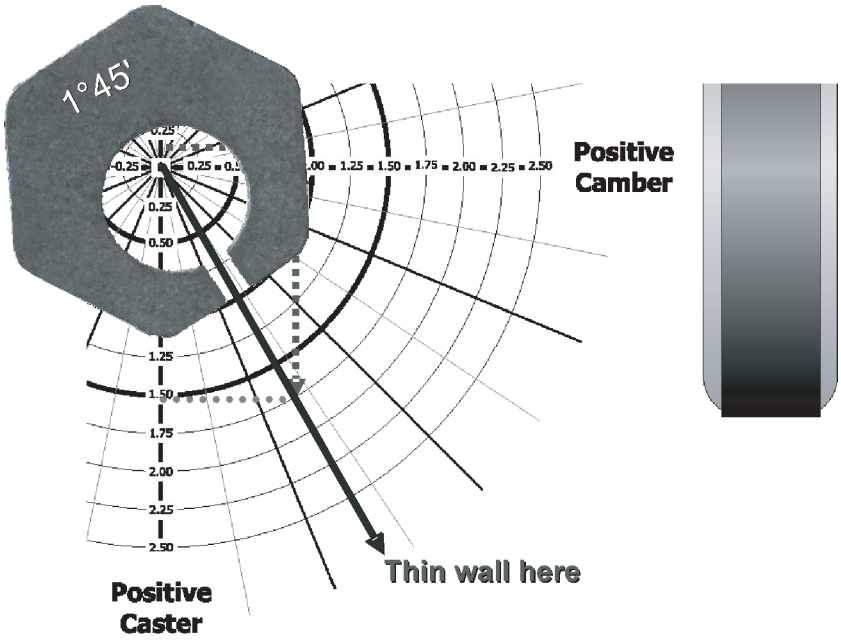


Figure 4b-130, Place Bushing on Chart with Thin Wall Correctly Positioned

Mark the bushing at "12 o'clock". This mark represents the FRONT of the truck.

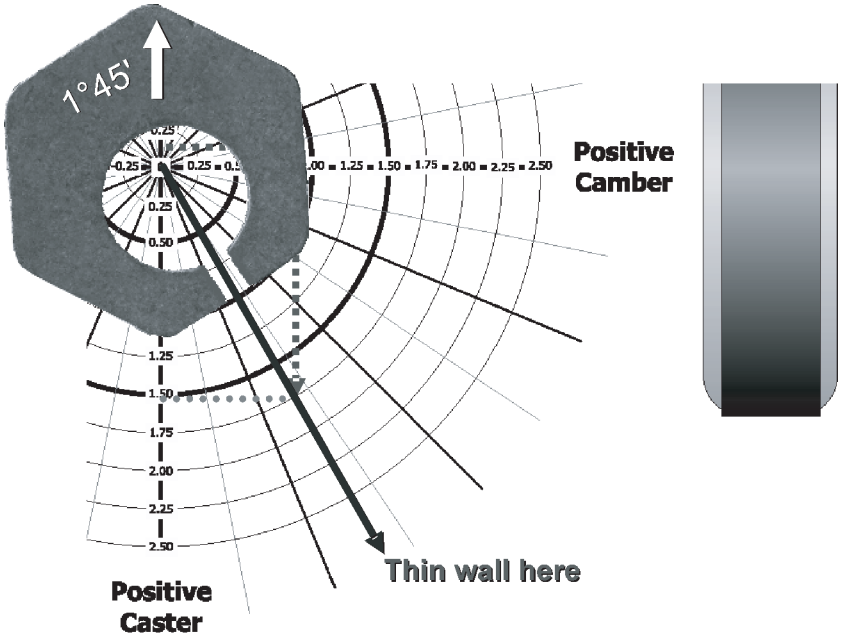
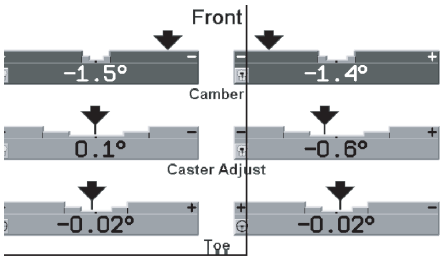


Figure 4b-131, Mark the Bushing at FRONT

Install the new bushing with the FRONT mark facing the front bumper of the truck.



"Adjust to Zero" Measurements

	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____

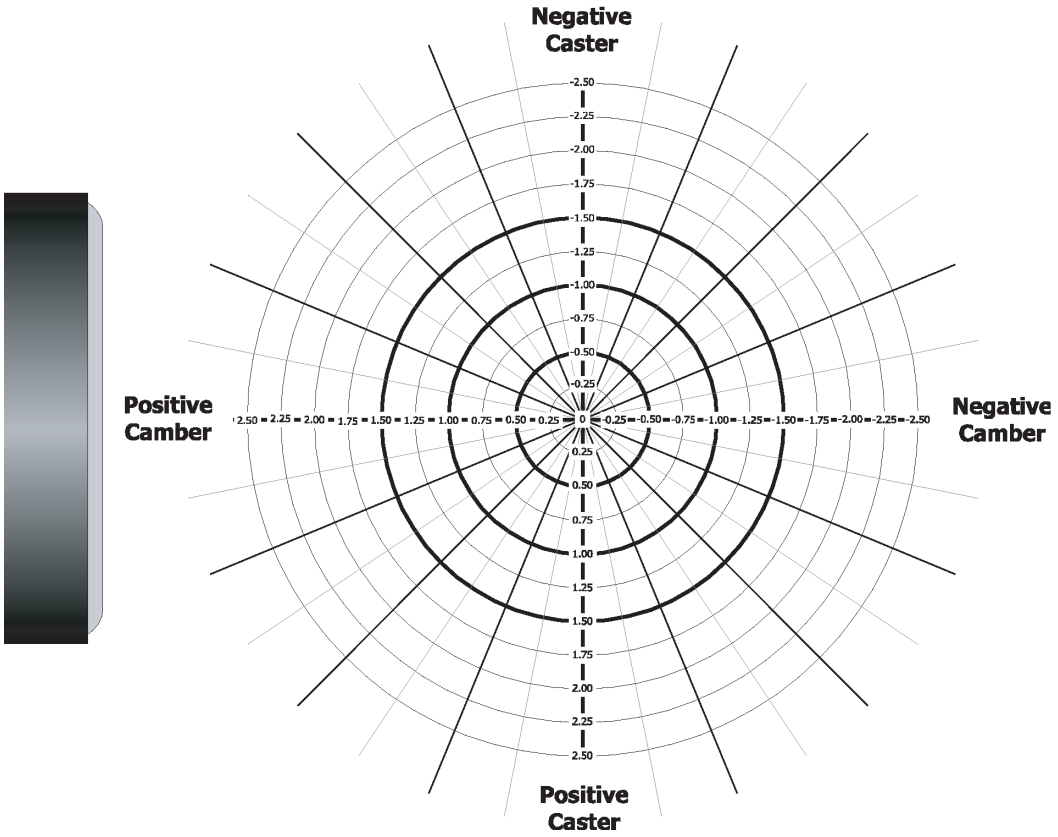


Figure 4b-132,

Automatic Bushing Calculator Solution

Input the position and size of the bushing currently in the axle.

Note: Do NOT reverse the sign of the driver side bushing's caster value when using the Automatic Bushing Calculator.

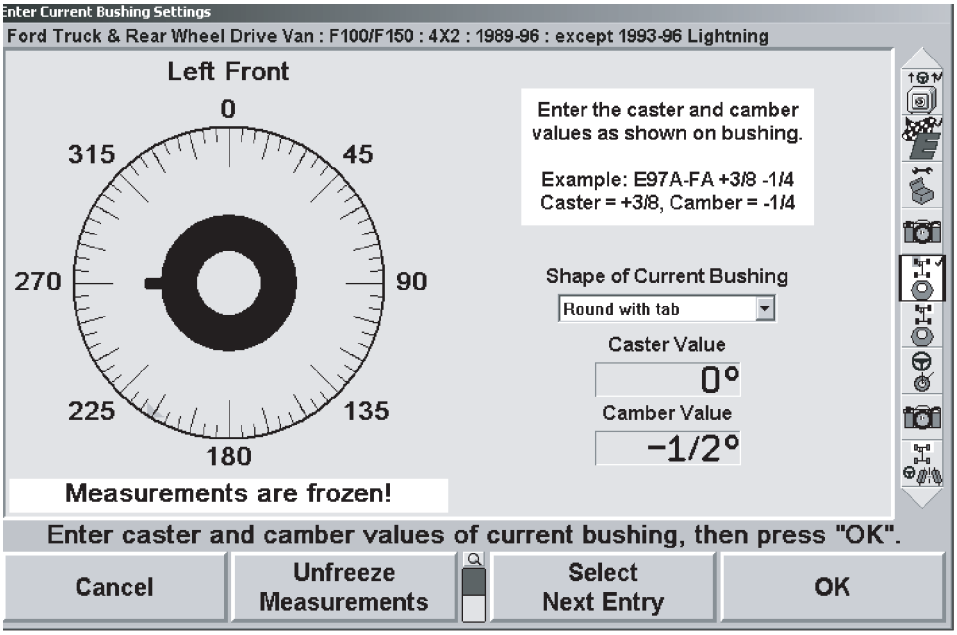


Figure 4b-133, Input the Old Bushing on the ABC Screen

Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing.

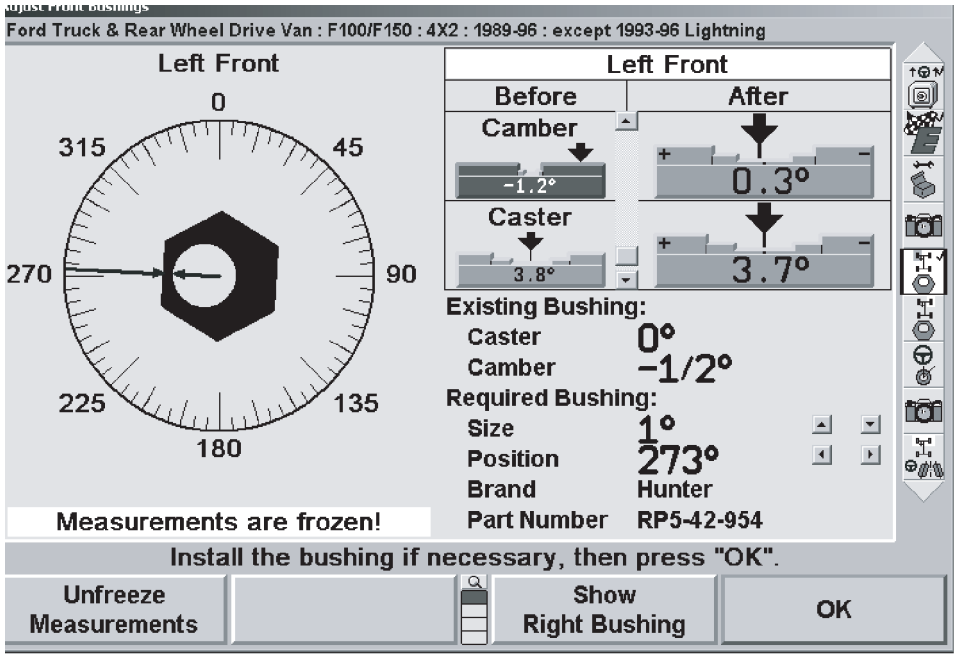
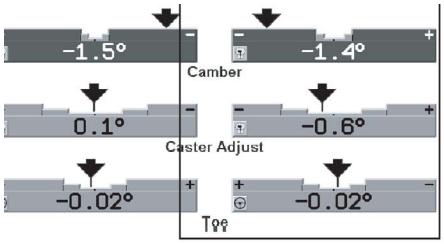


Figure 4b-134, Automatic Bushing Calculator Solution



"Adjust to Zero Measurements"

Present bushing

	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____

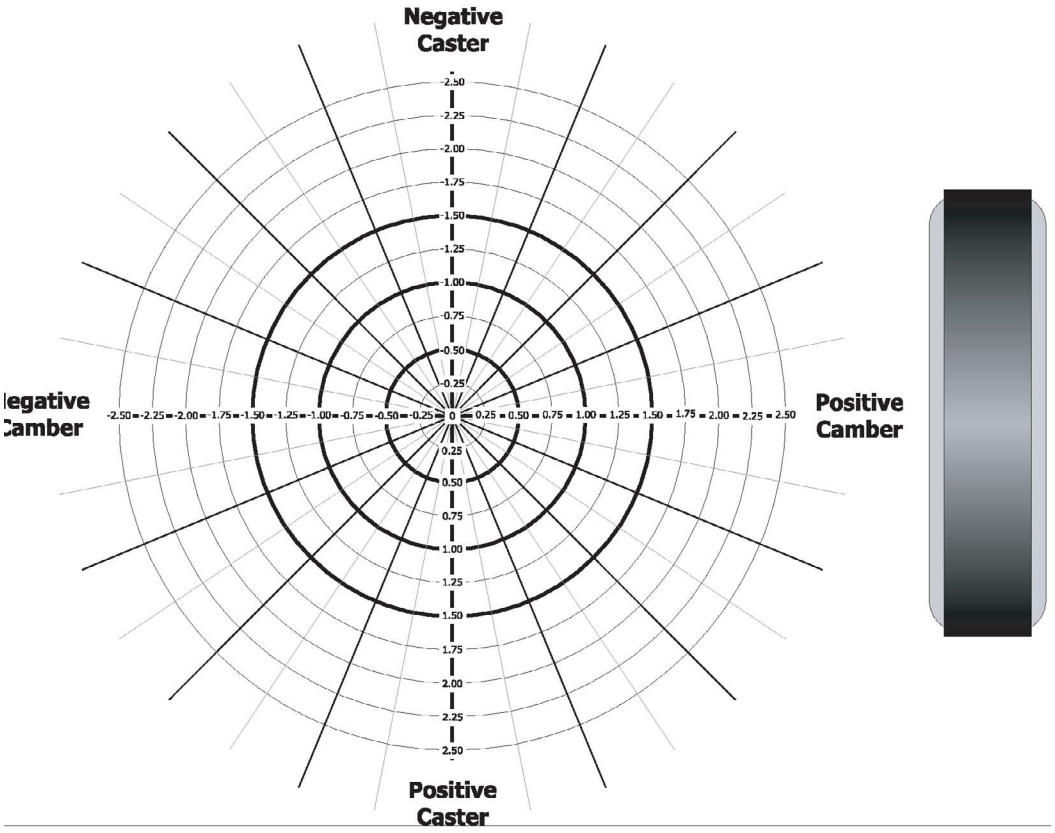


Figure 4b-135,

Automatic Bushing Calculator Solution

Input the position and size of the bushing currently in the axle.

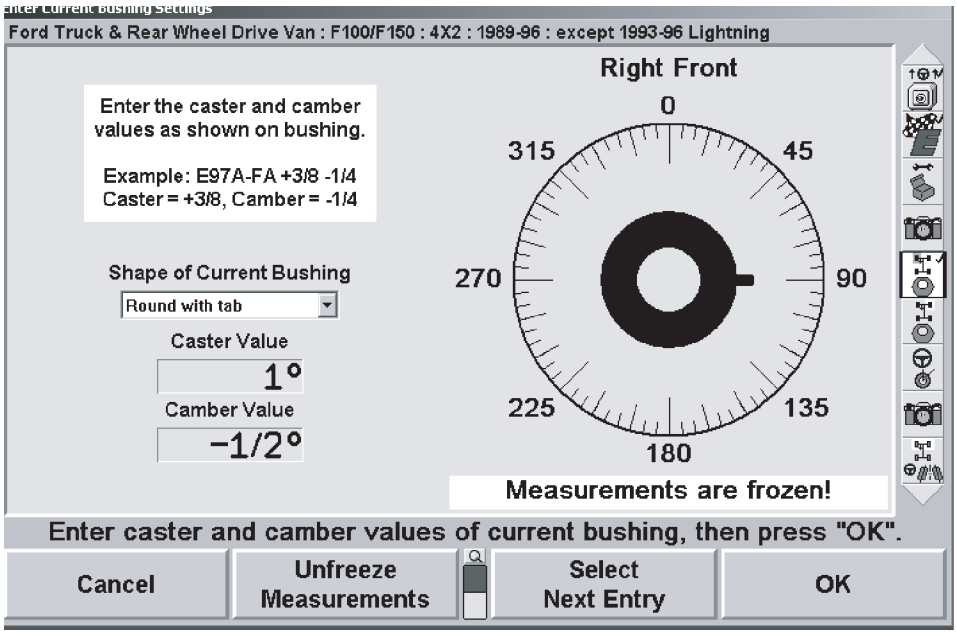


Figure 4b-136, Input the Old Bushing on the ABC Screen

Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing.

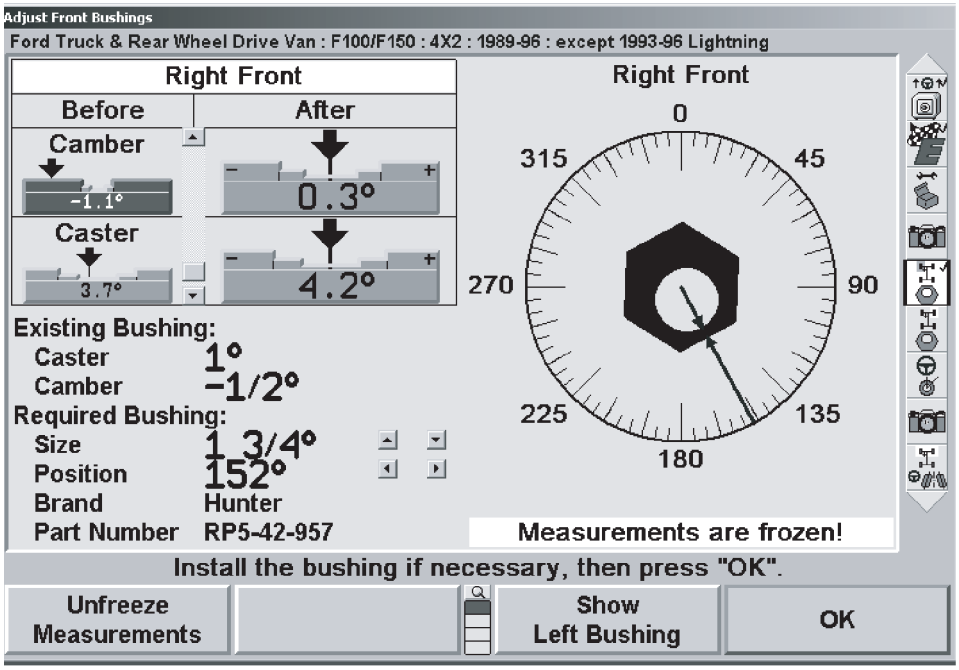
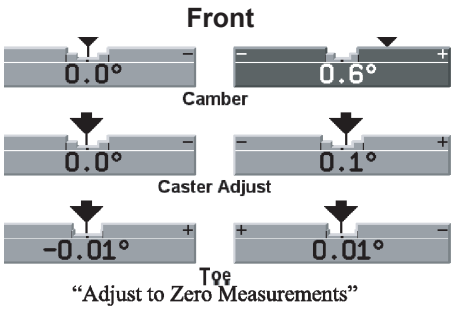
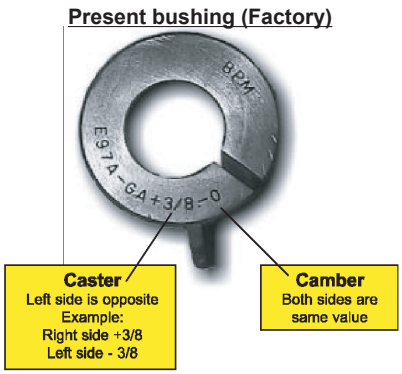


Figure 4b-137, Automatic Bushing Calculator Solution





	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____

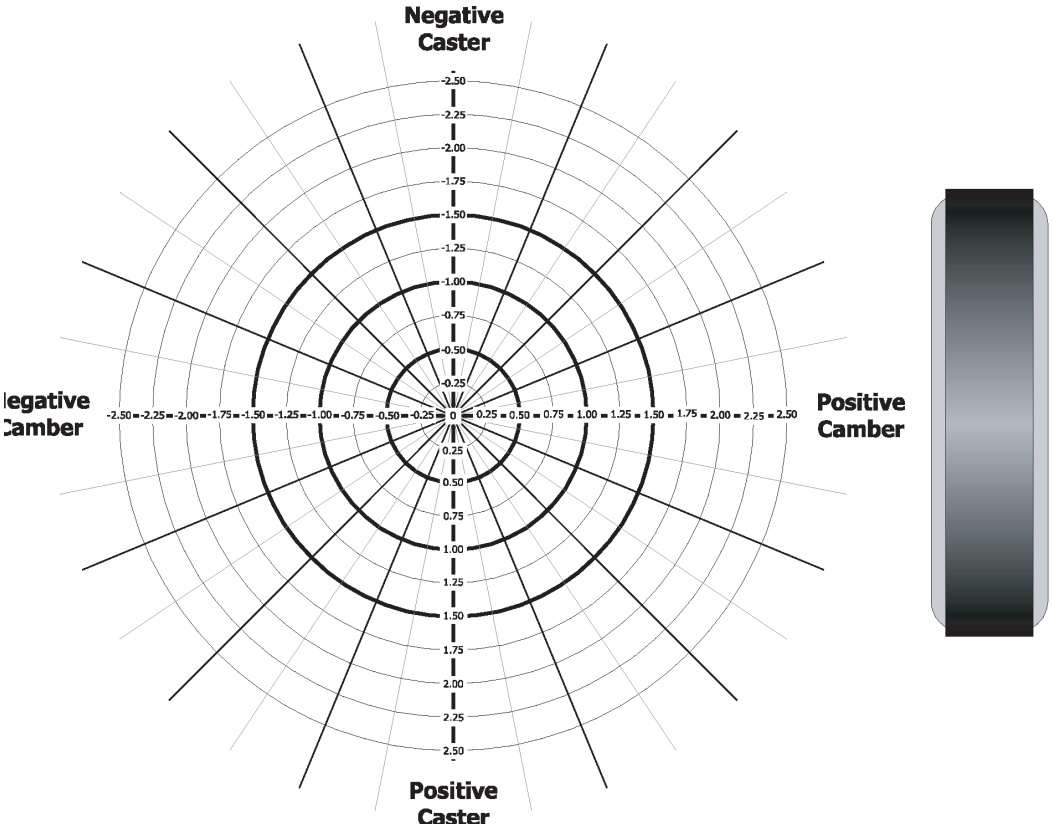


Figure 4b-138,

Automatic Bushing Calculator Solution

Input the position and size of the bushing currently in the axle.

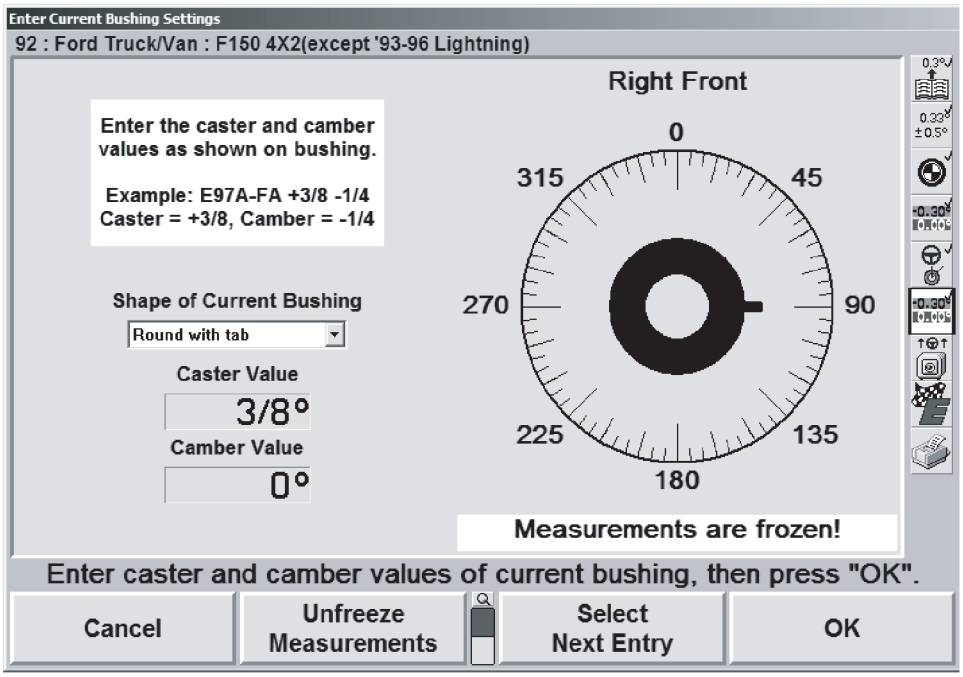


Figure 4b-139, Input the Old Bushing on the ABC Screen

Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing.

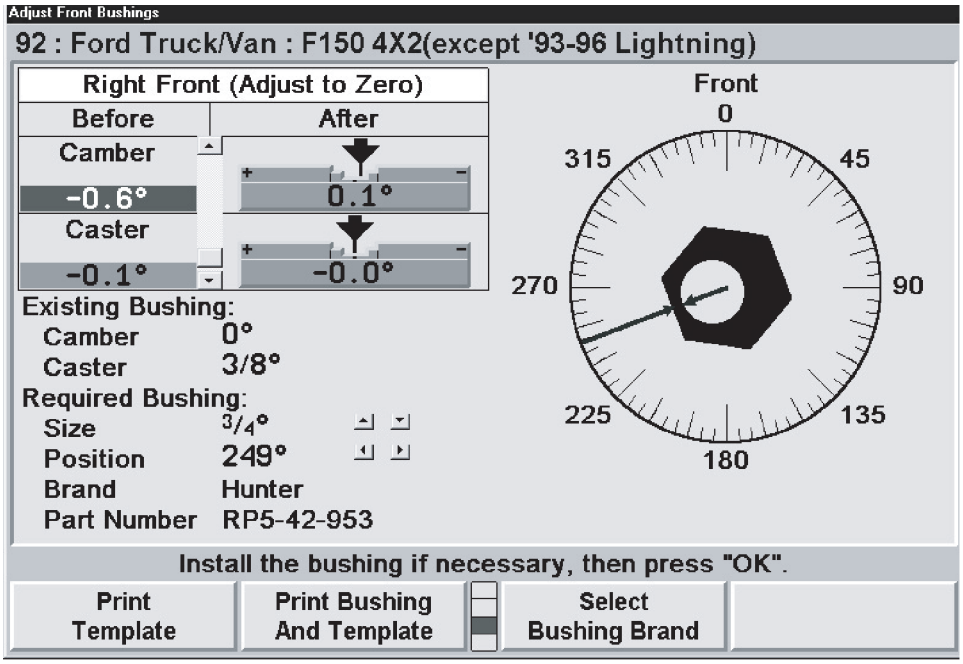
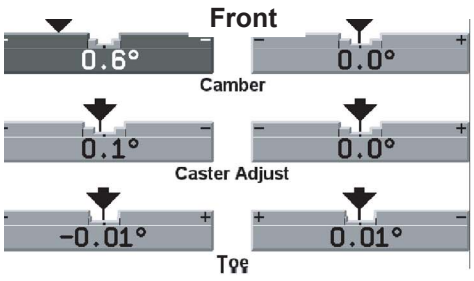
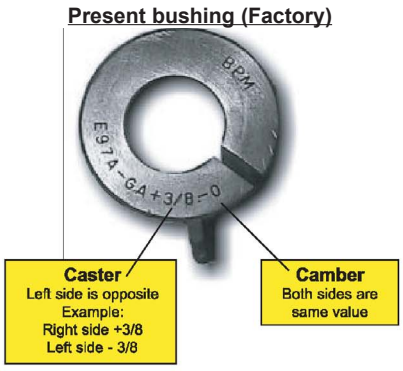


Figure 4b-140, Automatic Bushing Calculator Solution



"Adjust to Zero" Measurements



	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____

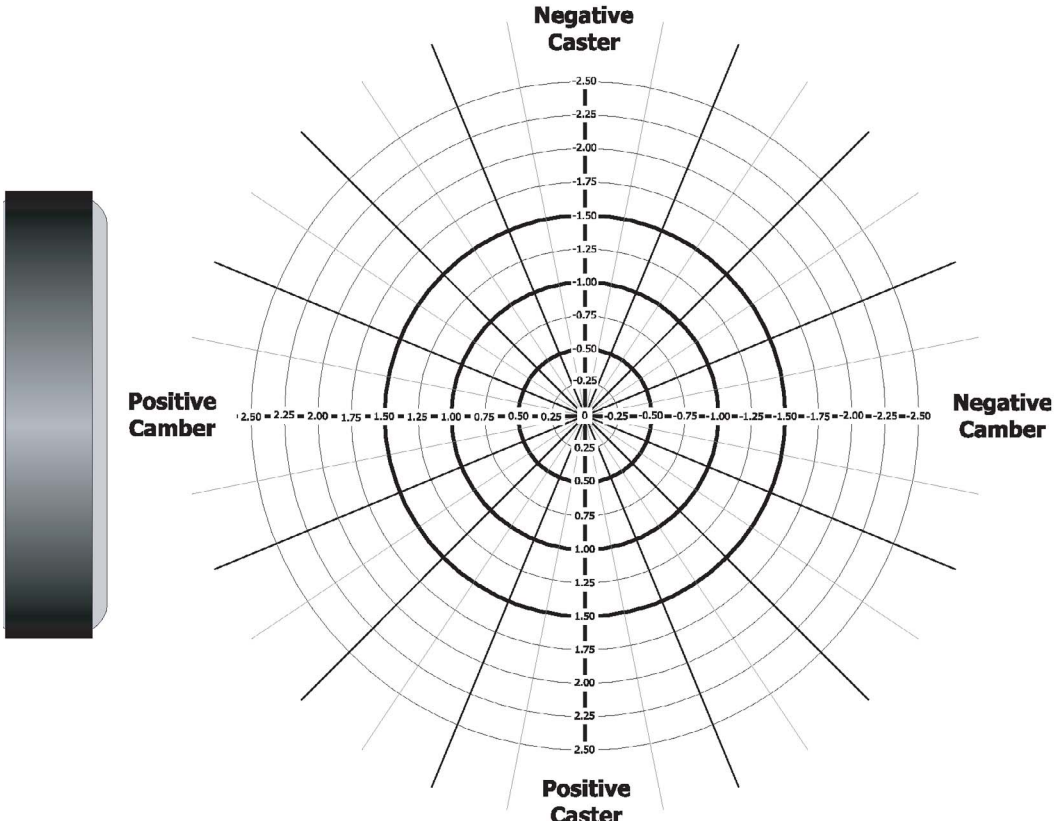


Figure 4b-141,

Automatic Bushing Calculator Solution

Input the position and size of the bushing currently in the axle.

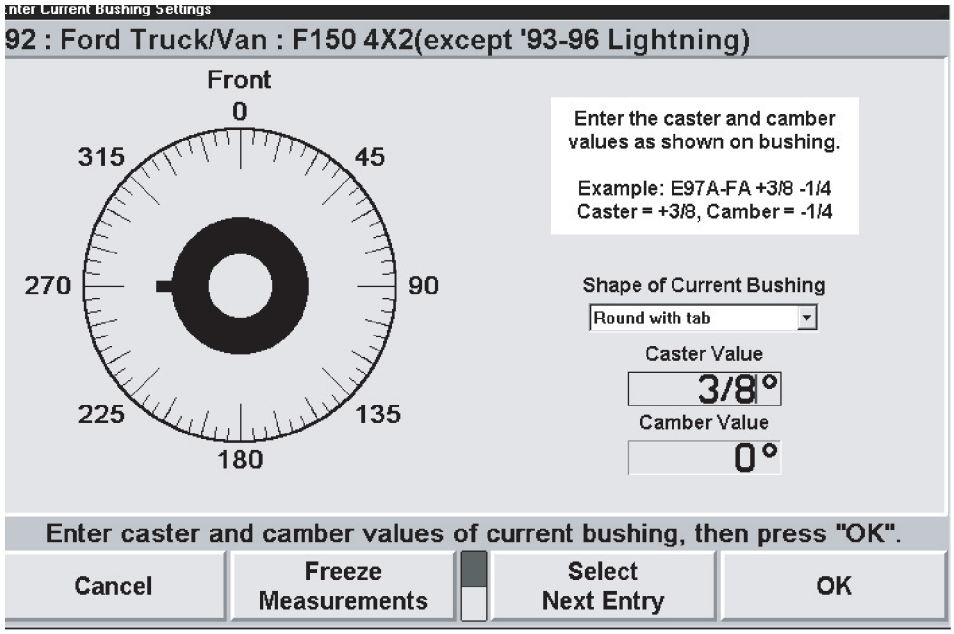


Figure 4b-142, Input the Old Bushing on the ABC Screen

Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing.

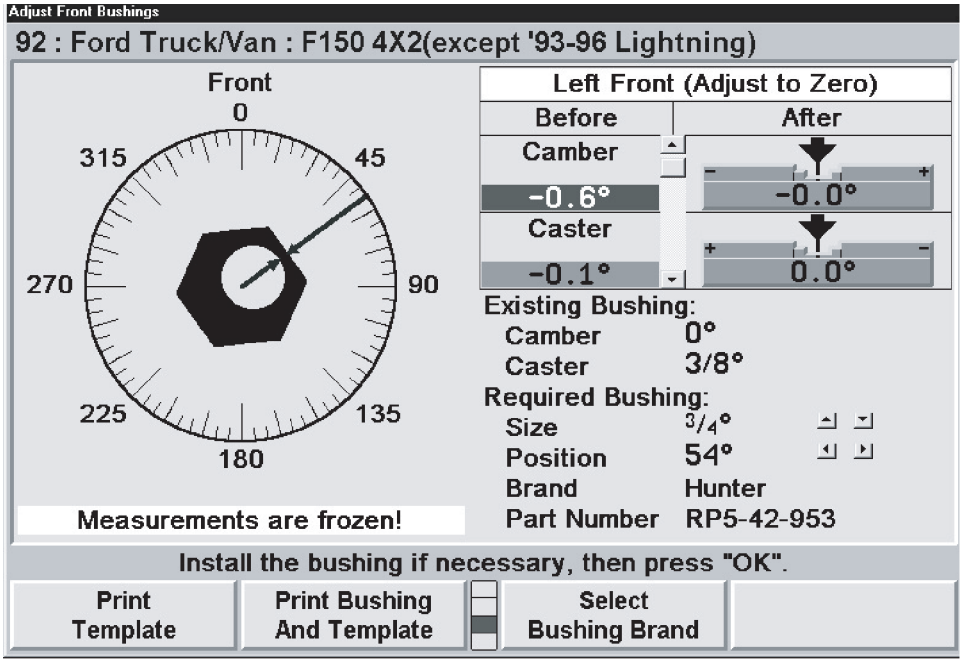


Figure 4b-143, Automatic Bushing Calculator Solution

Manual Bushing Calculator-Aftermarket

Select the "Adjust to Zero" screen ("Zero Adjust on 111 aligners). The align will now display how far camber and caster are from preferred specifications.

Note: When using the "Adjust to Zero" screen, adjust ALL values to Zero!

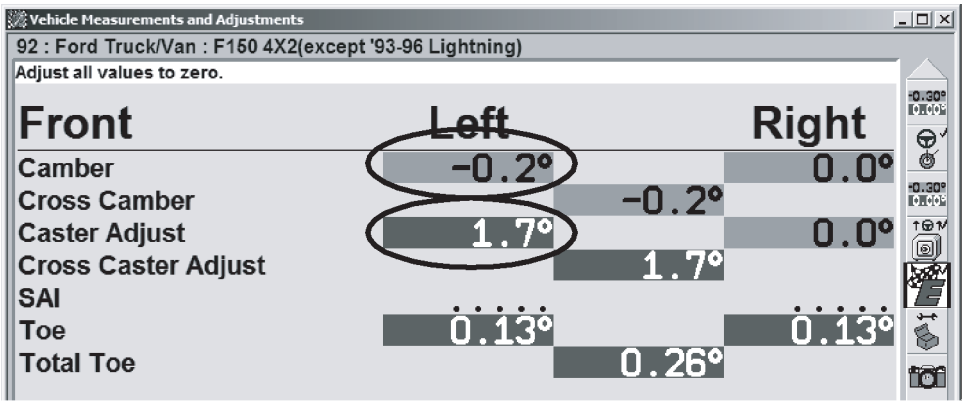
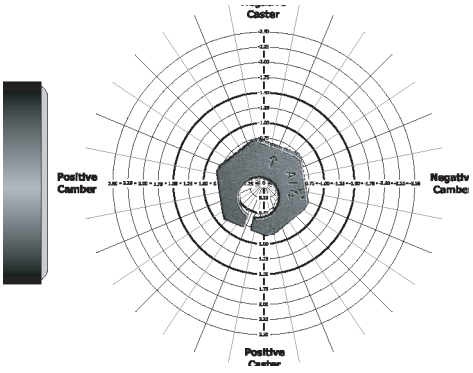


Figure 4b-144, "Adjust to Zero" Measurements

Record the required camber and caster adjustment (write down the OPPOSITE of the "Adjust to Zero" measurements) on the bushing calculator worksheet.

	Desired Change		Old Bushing		Total Change
Camber	**+0.2°**	+		=	
Caster	**-1.7°**	+		=	

Figure 4b-145, Write Down the Opposite of "Adjust to Zero" Measurements



Mark the old bushing at the front location with a chisel mark. Remove the old bushing and place it on the Manual Bushing Calculator with the front chisel mark facing the top of the page (negative caster direction).

Note the direction of the thin wall (offset) of the bushing. Draw a line from the center of the chart (0) to the circle representing the offset amount stamped on the bushing in the direction of the thin wall. Since this bushing is a 1.5° bushing and the thin wall faces toward 7 o'clock, we drew the line from 0 to the 1.5° circle facing 7 o'clock.

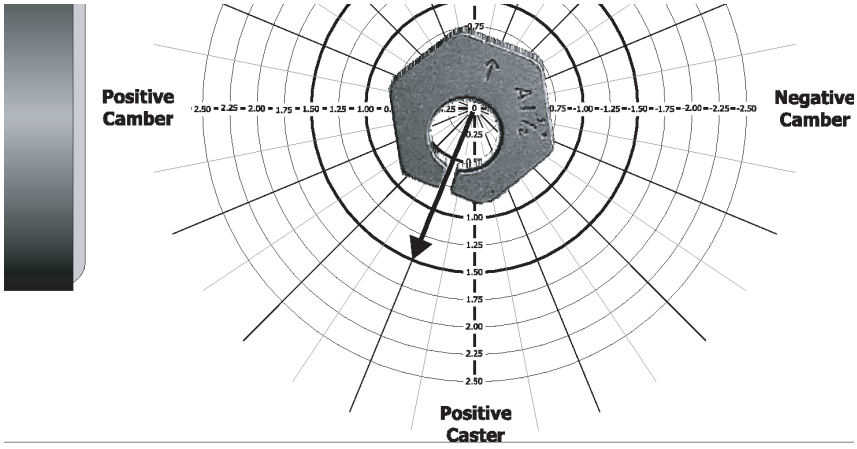


Figure 4b-146, Mark the Direction and Offset Amount of the Old Bushing

Mark the intersection point of your line and the 1.5° circle with a dot.

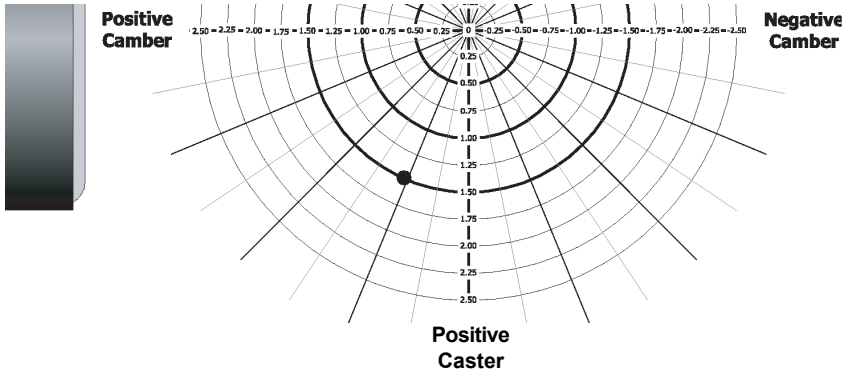


Figure 4b-147, Mark Intersection Point with a Dot

Draw a *vertical* line from your dot to the camber axis. Note the camber correction value of the old bushing.

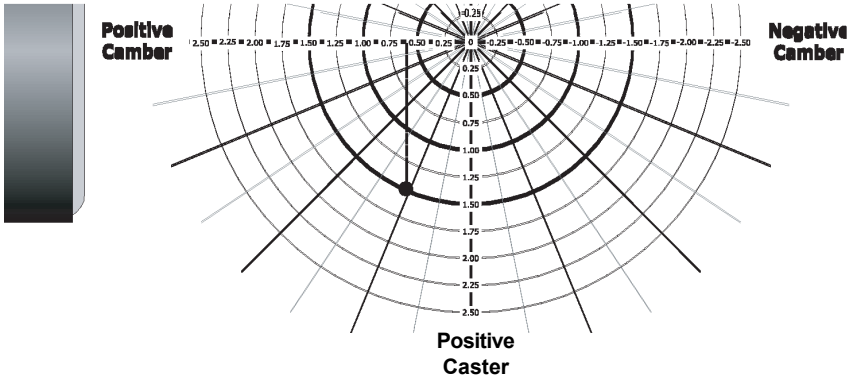


Figure 4b-148, Draw a Vertical Line to the Camber Axis

Record the camber correction value of the old bushing on the Manual Bushing Calculator.

	Desired Change		Old Bushing		Total Change
Camber	+0.2°	+	+0.6°	=	
Caster	-1.7°	+		=	

Draw a *horizontal* line from your dot to the caster axis. Note the caster correction value of the old bushing.

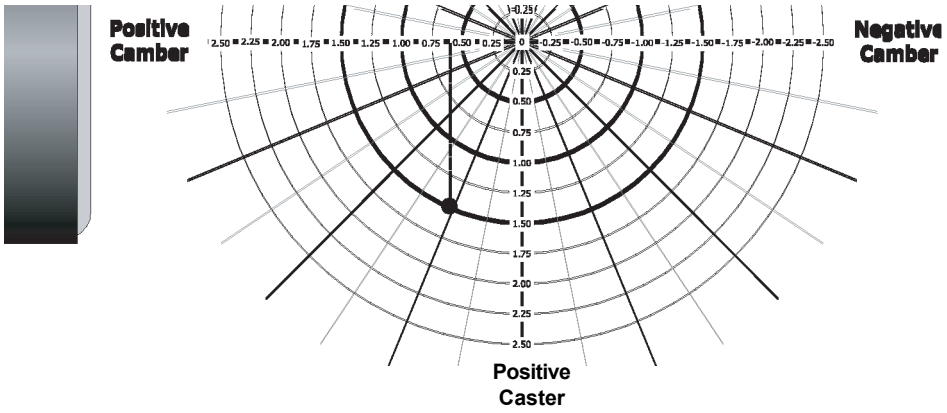


Figure 4b-149, Draw a Horizontal Line to the Caster Axis

Record the caster correction value of the old bushing on the Manual Bushing Calculator.

	Desired Change		Old Bushing		Total Change
Camber	+0.2°	+	+0.6°	=	
Caster	-1.7°	+	+1.3°	=	

Add the "Desired Change" to the "Old Bushing" to calculate the required camber and caster adjustments for a replacement bushing.

	Desired Change		Old Bushing		Total Change
Camber	+0.2°	+	+0.6°	=	+0.8°
Caster	-1.7°	+	+1.3°	=	-0.4°

Add the "Desired Change" to the "Old Bushing" to compute "Total Change."

The "Total Change" is the amount of adjustment required as if a Zero offset bushing were installed in the axle.

Mark the required camber adjustment on the bushing calculator worksheet with a vertical line.

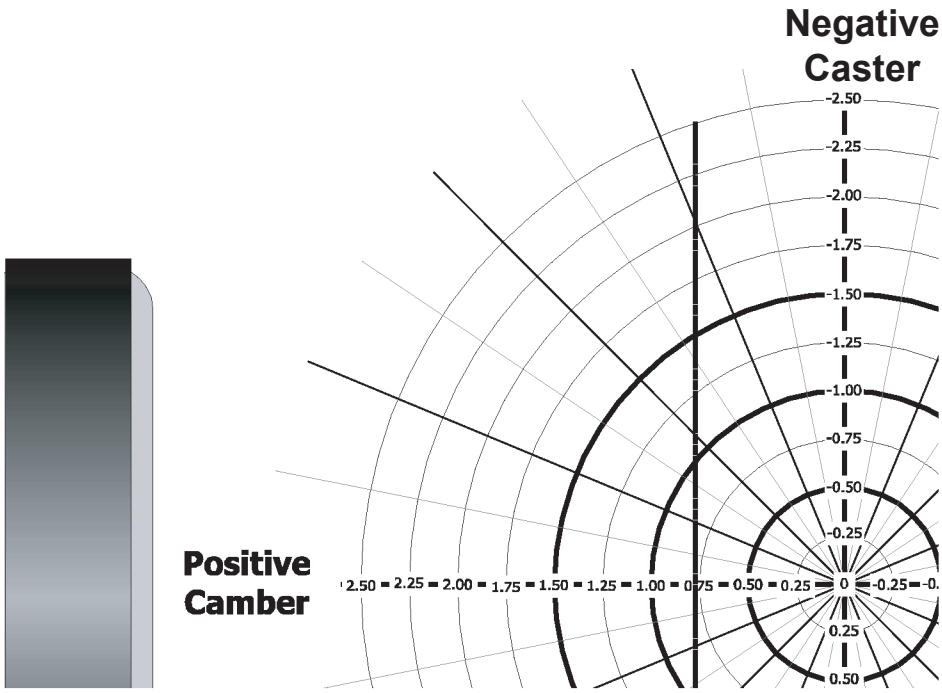


Figure 4b-150, Mark the Required Camber Adjustment

Mark the required caster adjustment on the bushing calculator worksheet with a horizontal line.

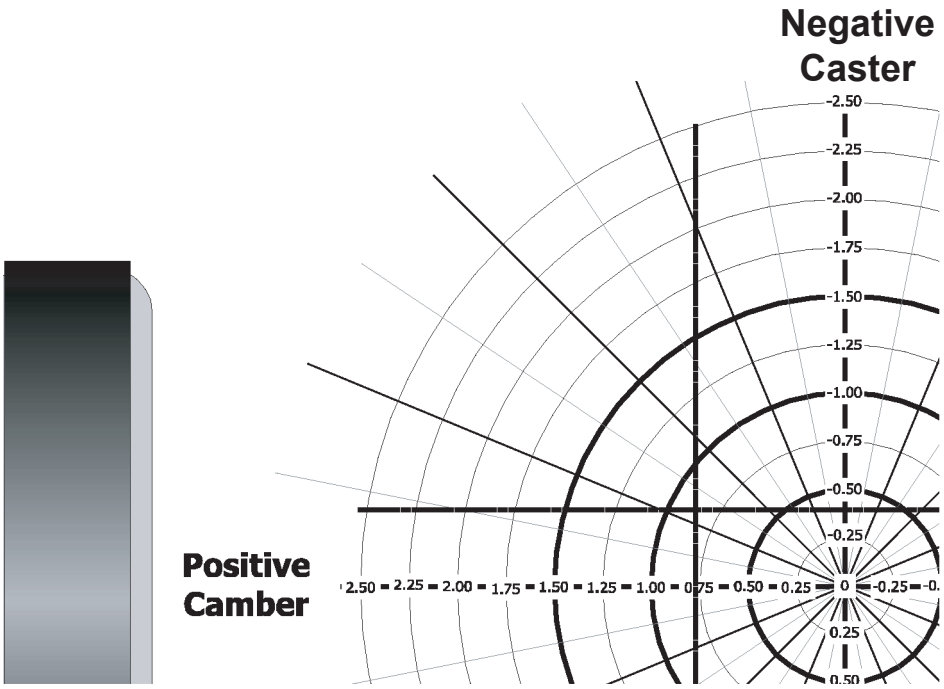


Figure 4b-151, Mark the Required Caster Adjustment

The intersection point of the camber vertical line and the caster horizontal lines displays BOTH the required bushing offset size AND the direction the thin wall of the bushing must face when installed in the axle.

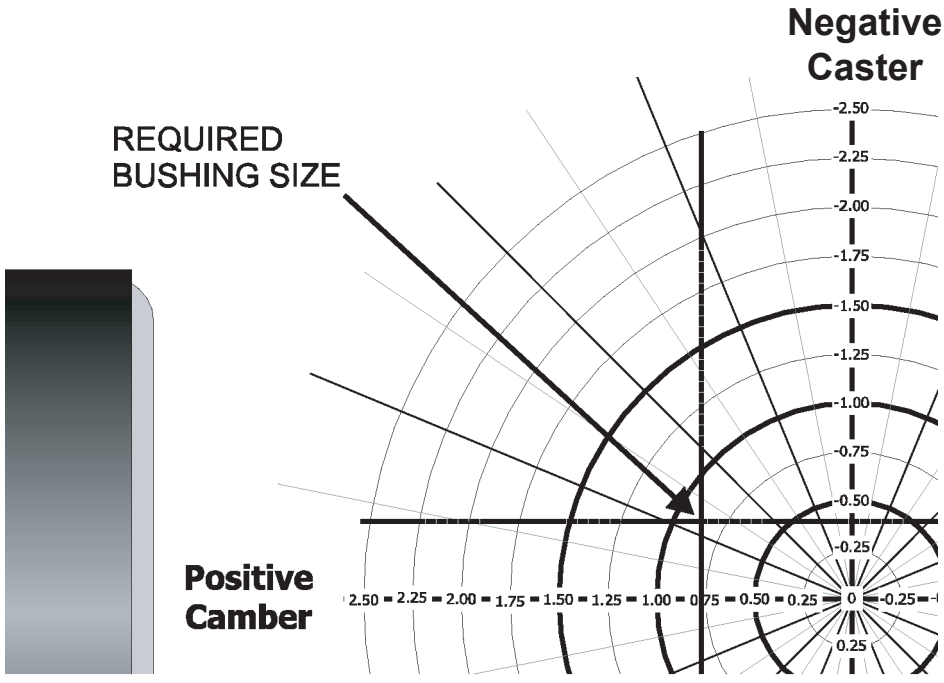
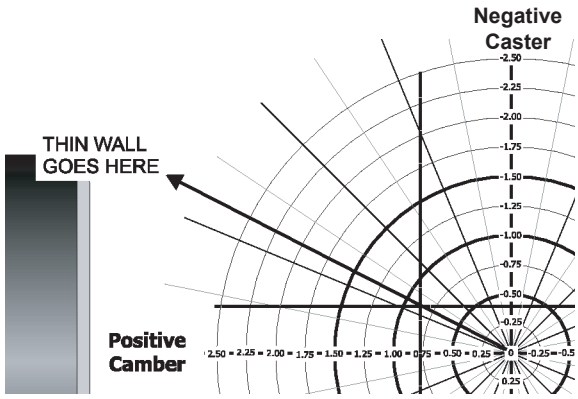


Figure 4b-152, Required Bushing Size is 1.0°

Draw a line from the 0 point (center of chart) through and past the intersection point of the camber and caster lines.

This indicates the direction the thin wall of the bushing must face when installed in the axle.

Place the required bushing on the bushing calculator worksheet with the bushing's thin wall facing as indicated above.



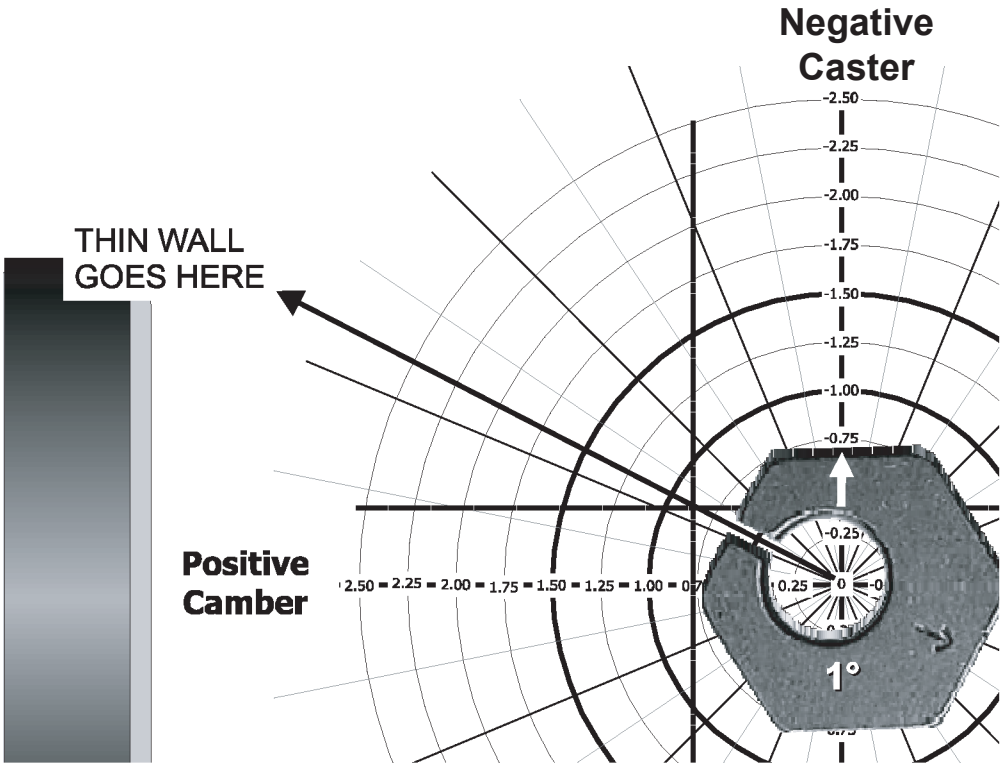
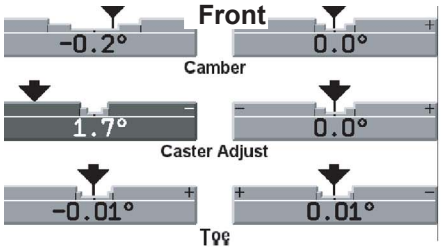


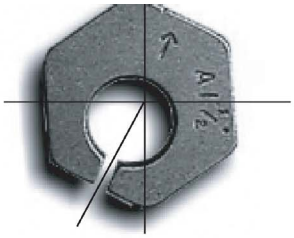
Figure 4b-153, Place Bushing on Chart with Thin Wall Correctly Positioned

Mark the bushing at "12 o'clock". This mark represents the FRONT of the truck.

Install the new bushing with the FRONT mark facing the front bumper of the truck.



"Adjust to Zero" Measurements



Present bushing

	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____

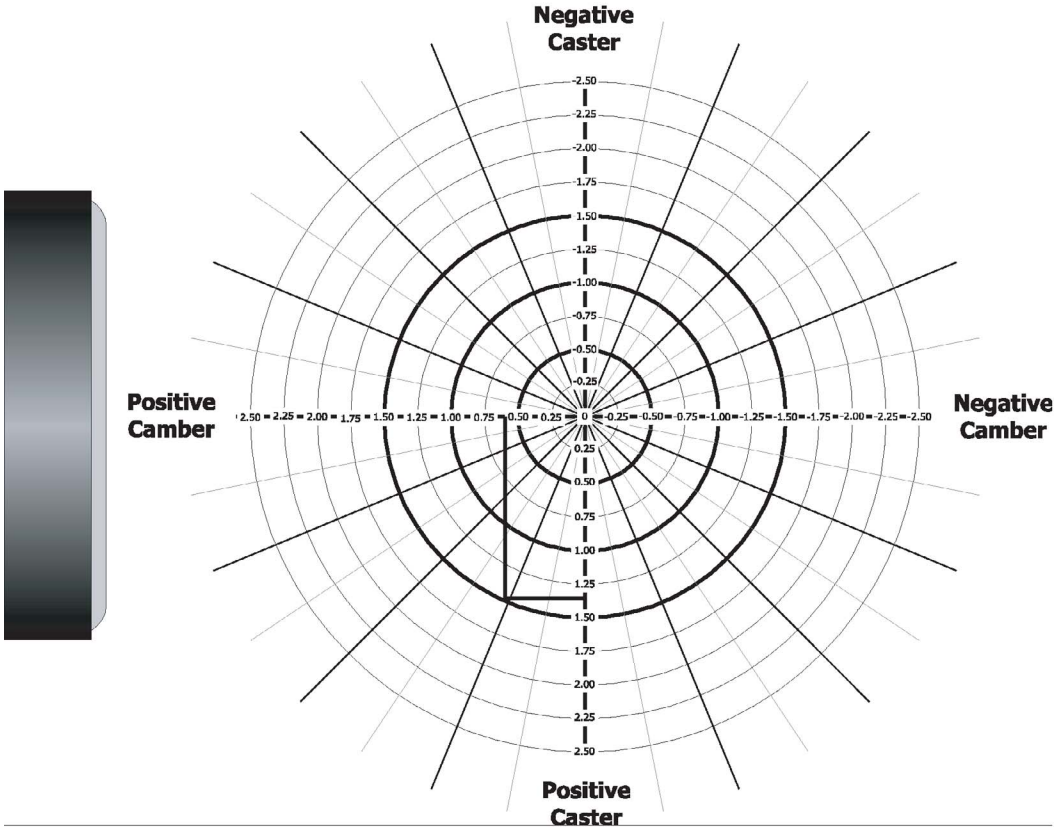


Figure 4b-154,

Automatic Bushing Calculator Solution

Input the position and size of the bushing currently in the axle.

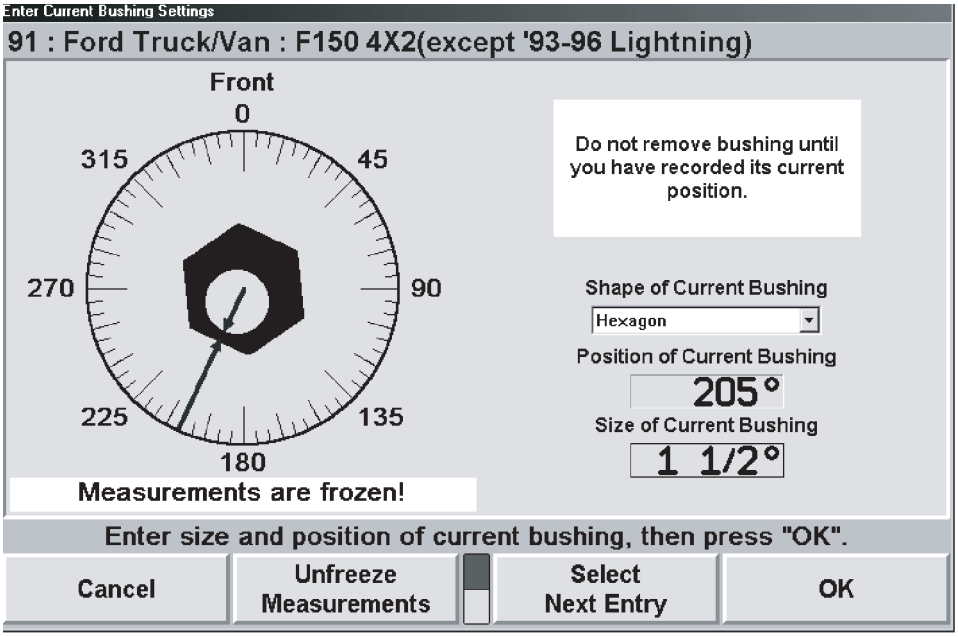


Figure 4b-155, Input the Old Bushing on the ABC Screen

Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing.

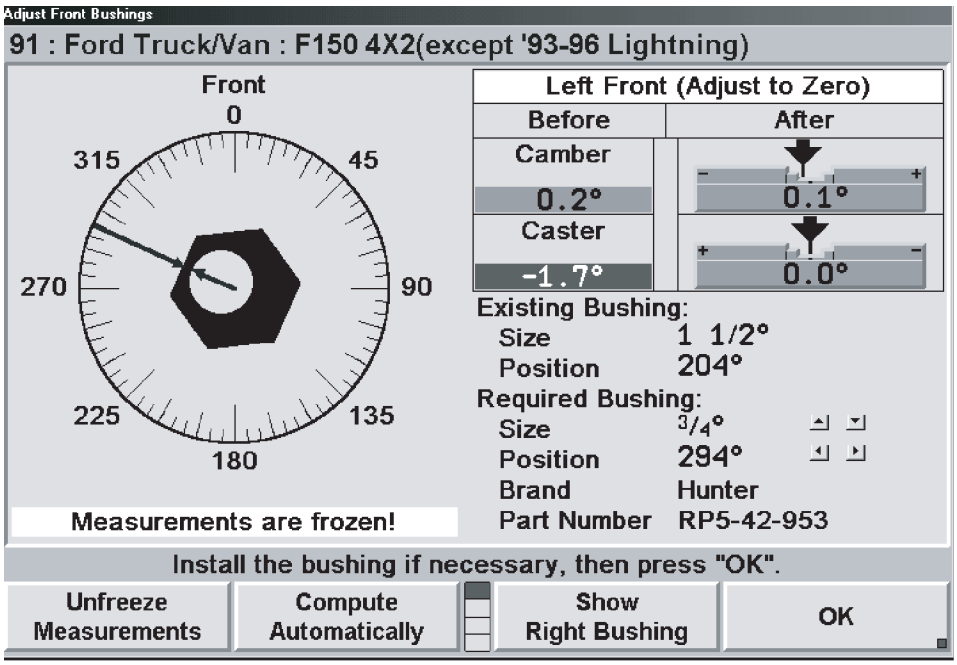
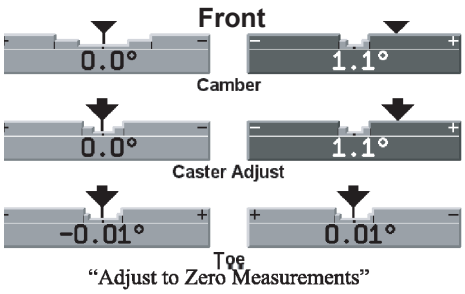
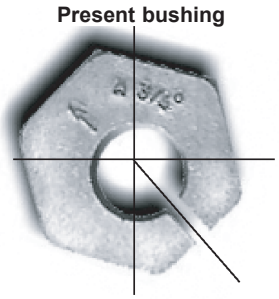


Figure 4b-156, Automatic Bushing Calculator Solution





	Desired Change		Old Bushing		Total Change
Camber		+		=	
Caster		+		=	

Bushing Size _____

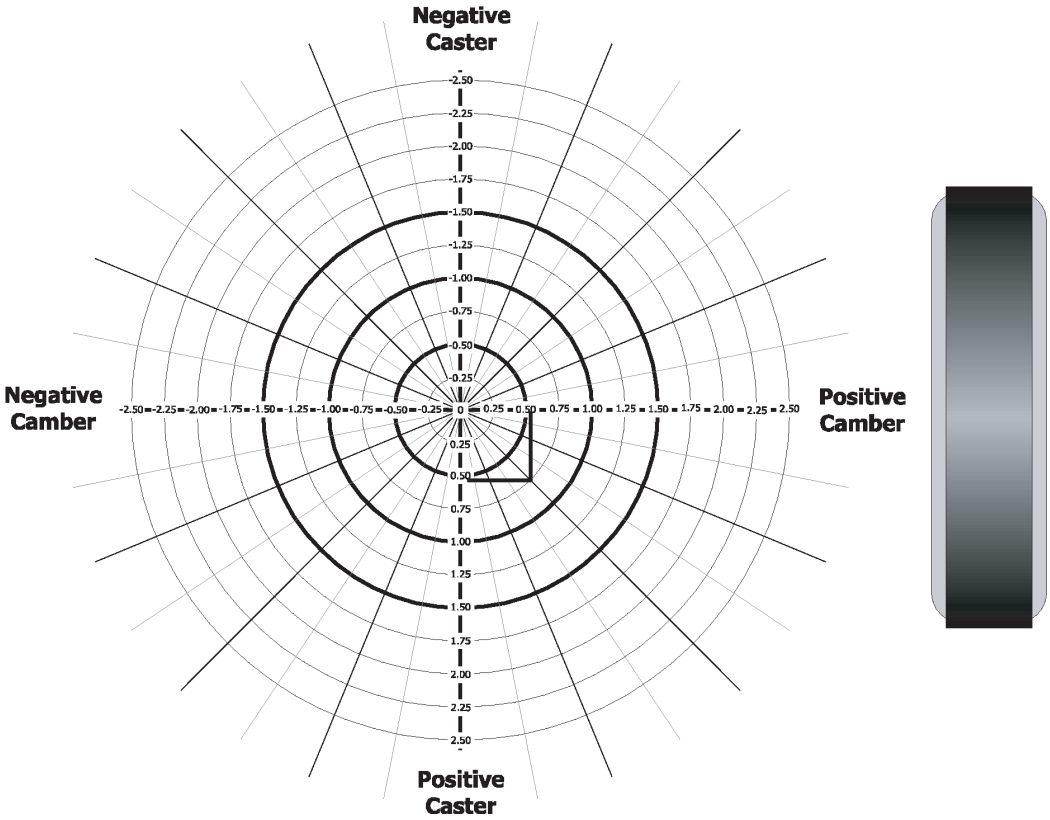


Figure 4b-157,

Automatic Bushing Calculator Solution

Input the position and size of the bushing currently in the axle.

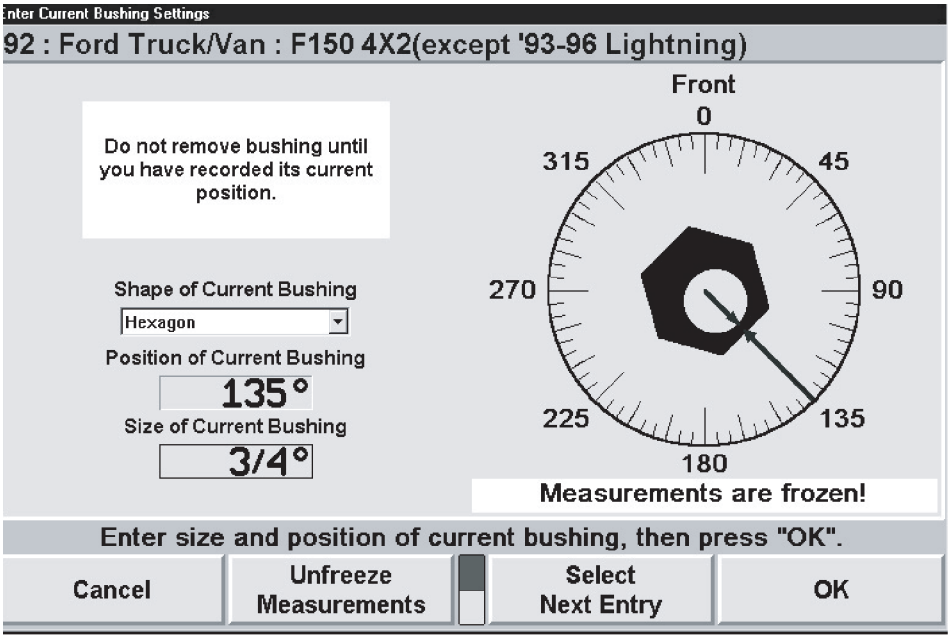


Figure 4b-157, Input the Old Bushing on the ABC Screen

Automatic Bushing Calculator's solution displays the position and size of the needed replacement bushing.

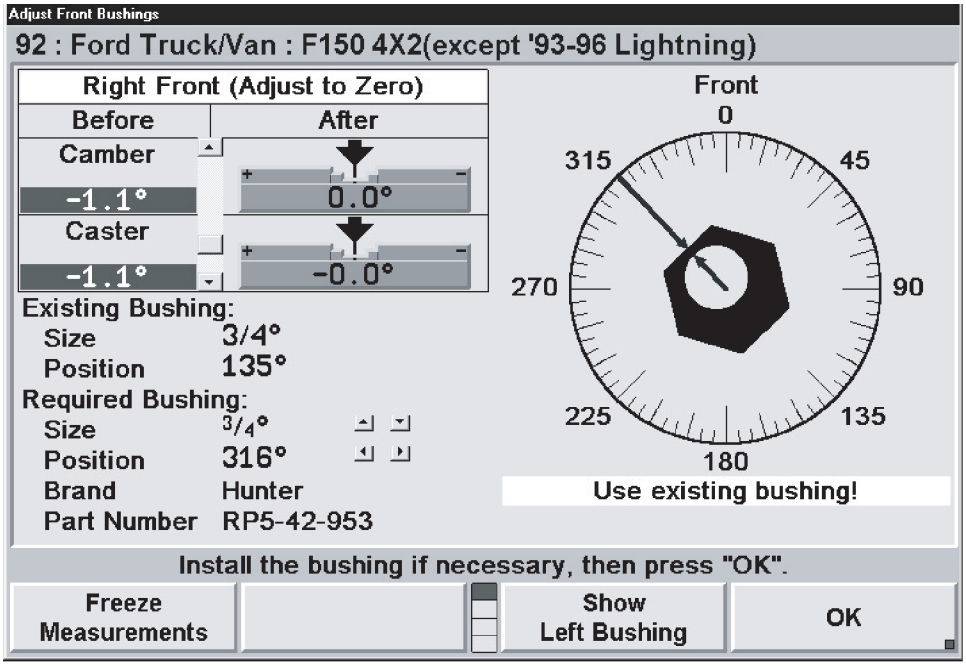


Figure 4b-158, Automatic Bushing Calculator Solution

Glossary

Alignment:	The process of measuring and positioning all wheels attached to a common chassis.
Angle:	Two intersecting lines.
Ball Joint:	A connector consisting of a ball and socket. This component allows for simultaneous angular and rotational motion.
Bump Steer:	A directional change in steering during jounces and rebound due to unequal tie rod lengths or angles.
Camber Roll:	The changes of camber that occur in a turn due to caster.
Camber:	The inward or outward tilt of the top of the wheel as viewed from the front.
Caster:	The forward or rearward tilt of the steering axis as viewed from the side.
Centerline Steering:	A centered steering wheel with the vehicle in a "straight ahead" course.
Conicity:	A tire irregularity, in that the tire takes the shape of a cone when inflated and loaded.
Cornering:	The ease at which a vehicle travels a curved path.
Degree:	A unit of measurement used to describe an angle.
Directional Stability:	The tendency for a vehicle to maintain a directed path.
Dog Tracking:	The appearance given when the thrustline is not parallel with the centerline of the vehicle.
Dynamic Balance:	An even distribution of weight on each side of the tire/wheel centerline.
Frame Angle:	The angle of a non-level frame.
Geometric Centerline:	A line drawn through the midpoint of both front and rear wheels.
Included Angle:	S.A.I. plus camber

Independent Suspension:	A suspension that provides an isolated mounting for each wheel to the chassis.
Individual Toe:	The angle formed by the intersection of an individual line drawn through the plane of one wheel and the centerline.
Jounce:	A suspension moving upward in its travel.
Lead:	A slight tendency for a vehicle to move away from a given path.
Memory Steer:	A condition where the front wheels seek a position other than straight ahead.
O.E.M.	An acronym for Original Equipment Manufacture.
Parallel:	Two lines that stay at the same distance apart and never meet.
Parallelogram Steering:	A linkage design where, if all pivot points are connected by lines, the lines are parallel.
Pull:	The tendency of a vehicle to steer away from a directed course. A constant is maintained at the steering wheel to travel straight ahead.
Rack and Pinion Steering:	A steering system design that utilizes a pinion gear meshed with a rack gear to transmit steering forces to the spindle.
Radial force Variation:	The difference in the tire sidewall stiffness that can induce an up and down motion in a rotating object.
Rebound:	A suspension moving downward in its travel.
Relay Rod Steering:	A steering design that has a direct bar connection between the tie rods.
Returnability:	The tendency of the front wheels to return to the straight ahead position.
Road Crown:	The slope of the lane surface.
Road Isolation:	The ability of the vehicle to absorb or dissipate road vibrations.
Road Shock:	The transmission of road forces to the passenger compartment.

Setback:	The angle formed by the geometric centerline and a line drawn perpendicular to the front axle.
Shimmy:	A violent side-to-side motion of an object.
Short/Long Arm	An independent suspension design where the upper and lower suspension: control arms are not equal in length.
Solid Axle Suspension:	A suspension design using an I-beam axle or tubular axle housing extending the width of the vehicle.
Static Balance: Circumference.	An even distribution of weight around the wheel
Steering Axis:	A line drawn between the upper and lower pivot points of the spindle.
Steering Arm:	A steering component that connects the outer tie rod to the spindle. The angle of the steering arm to the wheel's axis determines turning angle.
Steering Axis Inclination:	The angle formed by a line drawn through the upper and lower pivot (S.A.I.) points of the spindle and a vertical line drawn from the lower pivot point.
Suspension:	An assembly used to support weight, dampen shock, and maintain tire contact and proper wheel to chassis position.
Thrust Angle:	The angle formed between the thrustline and the geometric centerline.
Thrust Line:	The bisector of rear toe, also described as a line drawn in the direction the rear wheels are pointed.
Torque Steer:	A pull during acceleration or deceleration caused by driveline components.
Torsion Bar:	A wrapped steel spring designed to maintain ride height.
Total Toe (Angular):	The angle formed by the intersection of lines drawn through both wheels of a given axle.

Total Toe (Linear):	The difference in measurements taken across the front of the tires versus a measurement taken across the rear of the same tires.
Tracking:	The interrelated paths taken by the front and rear wheels.
Turning Angle:	The angle of a wheel during a turn.
Vertical:	Something upright or straight up and down.
Vibration:	The repetitive motion of an object up and down or back and forth.
Wander:	The tendency of a vehicle to drift to either side of a directed course.