

A grayscale photograph of the front of a car, showing the hood, windshield, and front suspension components. The image is slightly faded to serve as a background for the title text.

AUTOMOTIVE CHASSIS SYSTEMS

CHAPTER 34

Alignment Diagnosis and Service



PEARSON

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OBJECTIVES

After studying Chapter 34, the reader will be able to:

1. Prepare for ASE Suspension and Steering (A4) certification test content area “D” (Wheel Alignment Diagnosis, Adjustment, and Repair).
2. List the many checks that should be performed before aligning a vehicle.
3. Describe the proper alignment setup procedure.
4. Explain how to correct for memory steer, torque steer, pull, drift (lead), and wander.
5. Describe the use of unit conversion and diagnostic charts.
6. Discuss tolerance alignment and how to check for accident damage.

KEY TERMS

- Degrees
- Eccentric cam
- Five-wheel alignment
- Four-wheel alignment
- Fractional
- Geometric centerline
- Memory steer
- Minutes
- Prealignment checks
- Ride height
- Shim chart
- Spoke angle
- Thrust line
- Tolerance adjustment
- Torque steer
- Total toe

INTRODUCTION

- Proper wheel alignment of all four wheels is important for the safe handling of any vehicle.
- When all four wheels are traveling the same path and/or being kept nearly vertical, tire life and fuel economy are maximized and vehicle handling is sure and predictable.
- A complete wheel alignment is a complex process that includes many detailed steps and the skill of a highly trained technician.

PREALIGNMENT CORRECTION TECHNIQUES

- There are four basic steps in the correction of any problem:
 - **Verify**
 - **Isolate**
 - **Repair the problem**
 - **Recheck**

PREALIGNMENT CORRECTION TECHNIQUES



FIGURE 34–1 The owner of this Honda thought that all it needed was an alignment. Obviously, something more serious than an alignment caused this left rear wheel to angle inward at the top.

Align and Replace at the Same Time



TECH TIP

- Magnetic bubble-type camber/caster gauges can be mounted directly on the hub or on an adapter attached to the wheel or spindle nut on front-wheel drive vehicles. Besides being used as an alignment setting tool, a magnetic alignment head is a great tool to use whenever replacing suspension components.

Align and Replace at the Same Time



TECH TIP

- Any time a suspension component is replaced, the wheel alignment should be checked and corrected as necessary. An easy way to avoid having to make many adjustments is to use a magnetic alignment head on the front wheels to check camber with the vehicle hoisted in the air *before* replacing front components, such as new MacPherson struts. Then, before tightening all of the fasteners, check the front camber readings again to make sure they match the original setting. This is best done when the vehicle is still off the ground. For example, a typical front-wheel drive vehicle with a MacPherson strut suspension may have a camber reading of 1/4 degree on the ground and 2 degrees while on the hoist with the wheels off the ground. After replacing the struts, simply return the camber reading to 2 degrees and it should return to the same 1/4 degree when lowered to the ground.

Align and Replace at the Same Time

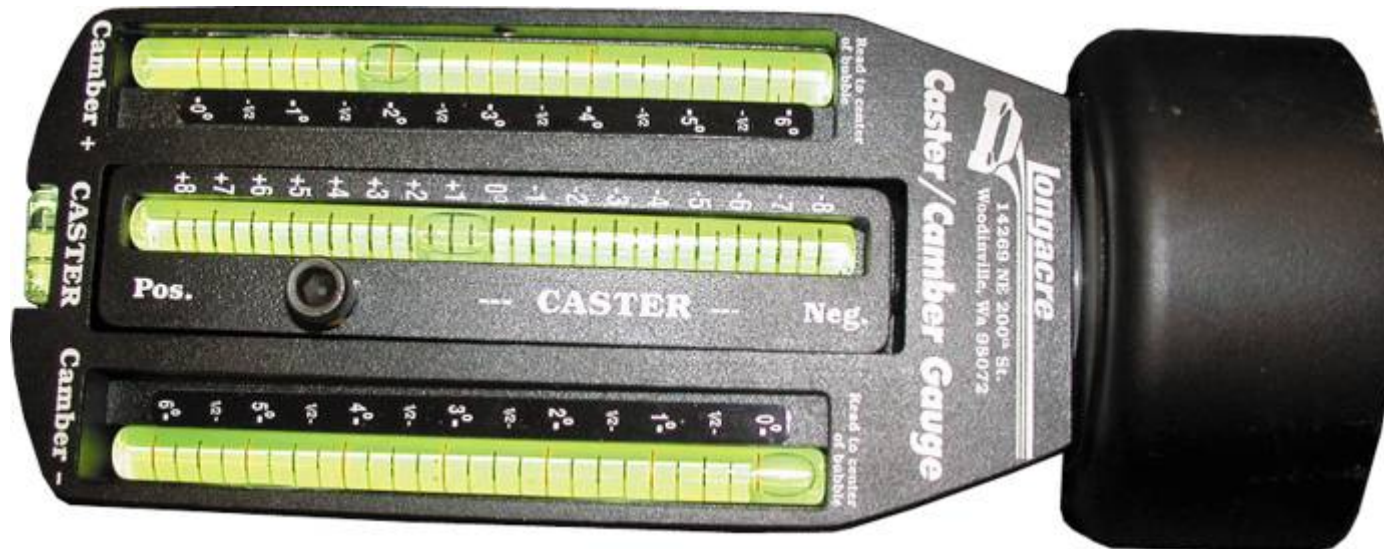


FIGURE 34–2 Magnetic bubble-type camber/caster gauge. To help it keep its strong magnetism, it is best to keep it stored stuck to a metal plate or metal tool box.

PREALIGNMENT CHECKS

- Before checking or adjusting the front-end alignment, the following items should be checked and corrected, if necessary, as part of the **prealignment checks**:
 - Check all the tires for proper inflation pressures
 - Check the wheel bearings for proper adjustment
 - Check for loose ball joints or torn ball joint boots
 - Check the tie rod ends for damage or looseness
 - Check the center link or rack bushings for play
 - Check the pitman arm for any movement
 - Check for runout of the wheels and the tires

PREALIGNMENT CHECKS

- Check for vehicle ride height (should be level front to back as well as side-to-side)
- Check for steering gear looseness at the frame.
- Check for improperly operating shock absorbers.
- Check for worn control arm bushings.
- Check for loose or missing stabilizer bar attachments.
- Check the trunk for excess loads.
- Check for dragging brakes.

PREALIGNMENT CHECKS

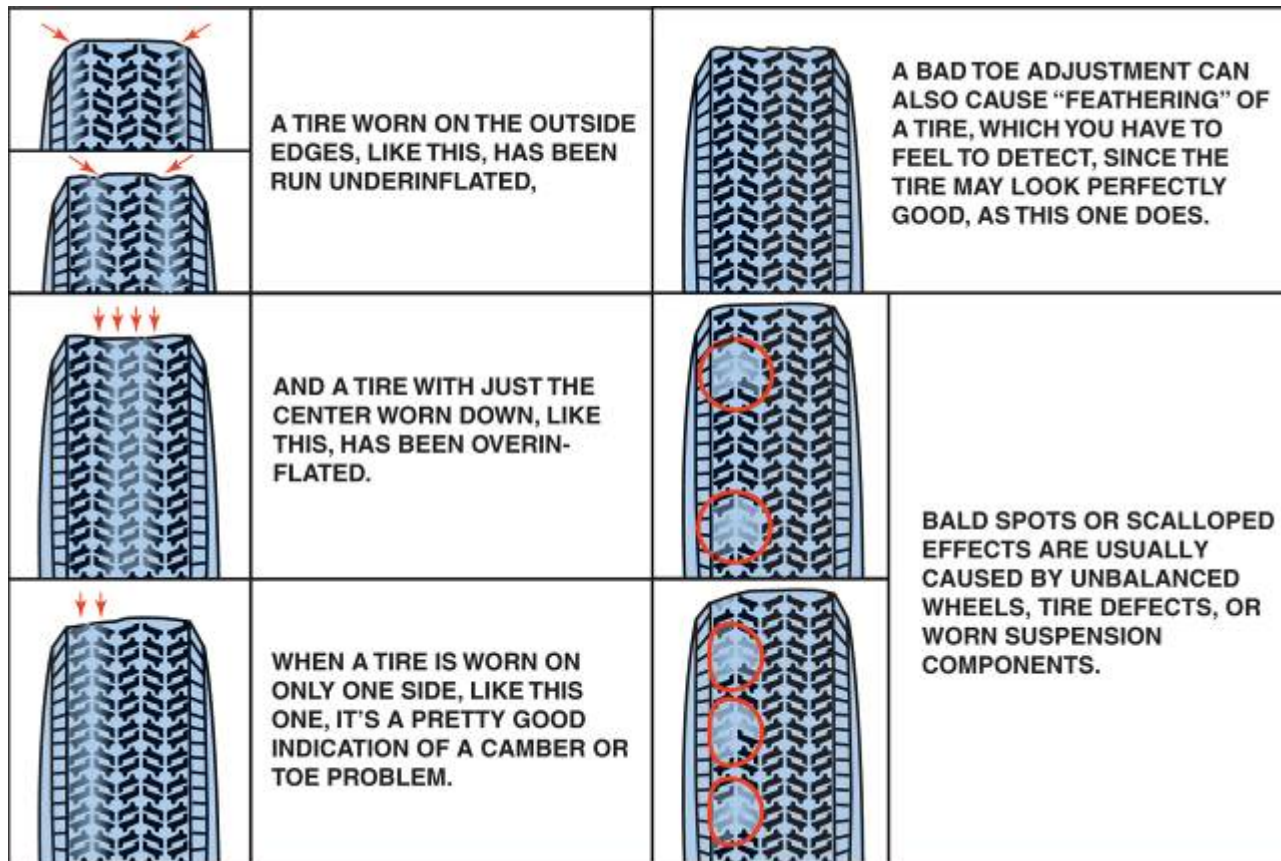


FIGURE 34–3 Typical tire wear chart as found in a service manual. Abnormal tire wear usually indicates a fault in a steering or suspension component that should be corrected or replaced before an alignment is performed.

PREALIGNMENT CHECKS

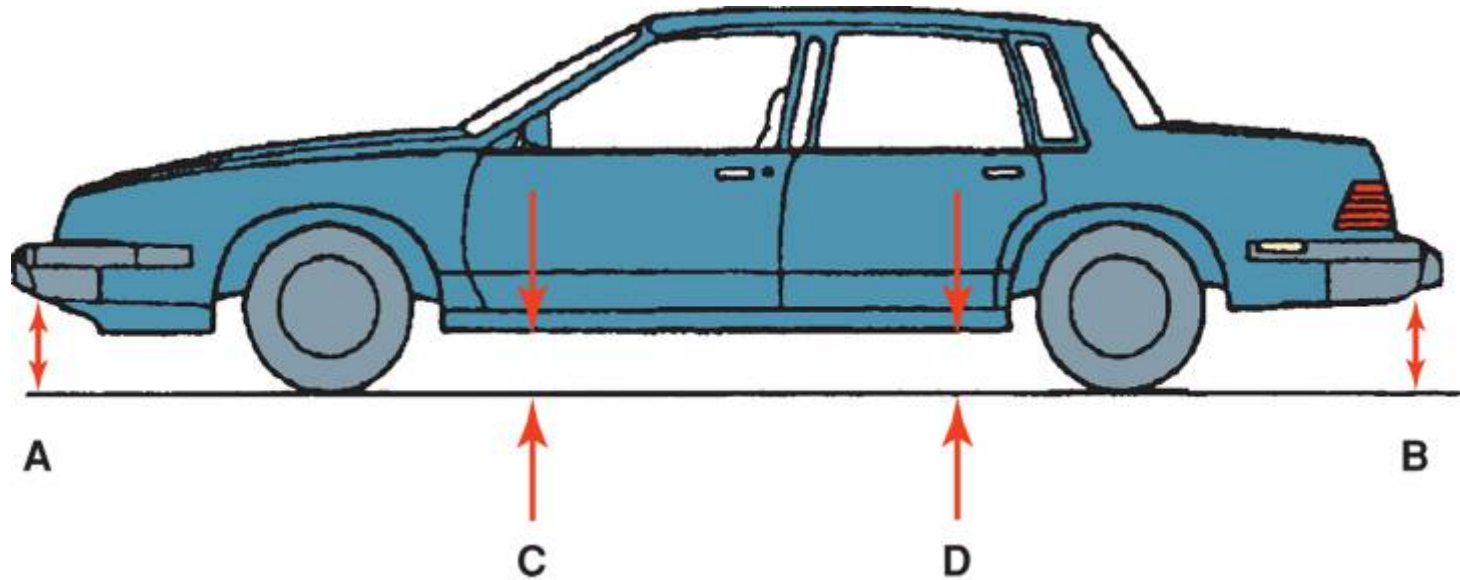


FIGURE 34–4 Measuring points for ride (trim) height vary by manufacturer.
(Courtesy of Hunter Engineering Company)

PREALIGNMENT CHECKS



FIGURE 34–5 Measuring to be sure the left and right sides of the vehicle are of equal height. If this measurement is not equal side-to-side by as little as 1/8 in. (3 mm), it can affect the handling of the vehicle.

LEAD/PULL DIAGNOSIS

- Many alignment requests come from customers attempting to have a lead or pull condition corrected.
- Before aligning the vehicle, verify the customer complaint first, then perform a careful inspection.



FIGURE 34–6 The bulge in this tire was not noticed until it was removed from the vehicle as part of a routine brake inspection. After replacing this tire, the vehicle stopped pulling and vibrating.

MEMORY STEER

DIAGNOSIS

- *Memory steer* is a term used to describe the lead or pull of a vehicle caused by faults in the steering or suspension system.
- Often a defective upper strut bearing or steering gear can cause a pulling condition in one direction after making a turn in the same direction.
- It is as if the vehicle had a memory and pulled in the same direction.

MEMORY STEER

DIAGNOSIS

- To test for memory steer, follow these simple steps during a test drive:
 - With the vehicle stopped at an intersection or in a parking area, turn the steering wheel completely to the left stop and then straighten the wheel without going past the straight-ahead position.
 - Lightly accelerate the vehicle and note any tendency of the vehicle to lead or pull toward the left.
 - Repeat the procedure, turning the steering wheel to the right.

MEMORY STEER CORRECTION

- A binding suspension or steering component is the most likely cause of memory steer.
- Disconnect each wheel from its tie rod end and check for free rotation of movement of each wheel.
- Each front wheel should rotate easily without binding or roughness.
- Repair or replace components as necessary to eliminate the binding condition.

The Five-Wheel Alignment



REAL WORLD FIX

- The steering wheel should always be straight when driving on a straight, level road. If the steering wheel is not straight, the customer will often think that the wheel alignment is not correct. One such customer complained that the vehicle pulled to the right while driving on a straight road. The service manager test drove the vehicle and everything was perfect, except that the steering wheel was not perfectly straight, even though the toe setting was correct. Whenever driving on a straight road, the customer would “straighten the steering wheel” and, of course, the vehicle went to one side. After adjusting toe with the steering wheel straight, the customer and the service manager were both satisfied. The technician learned that regardless of how accurate the alignment, the steering wheel *must* be straight; it is the “fifth wheel” that the customer notices most. Therefore, a **five-wheel alignment** rule includes a check of the steering wheel.

TORQUE STEER

DIAGNOSIS

- Torque steer occurs in front-wheel-drive vehicles when engine torque causes a front wheel to change its angle from straight ahead.

TORQUE STEER

DIAGNOSIS

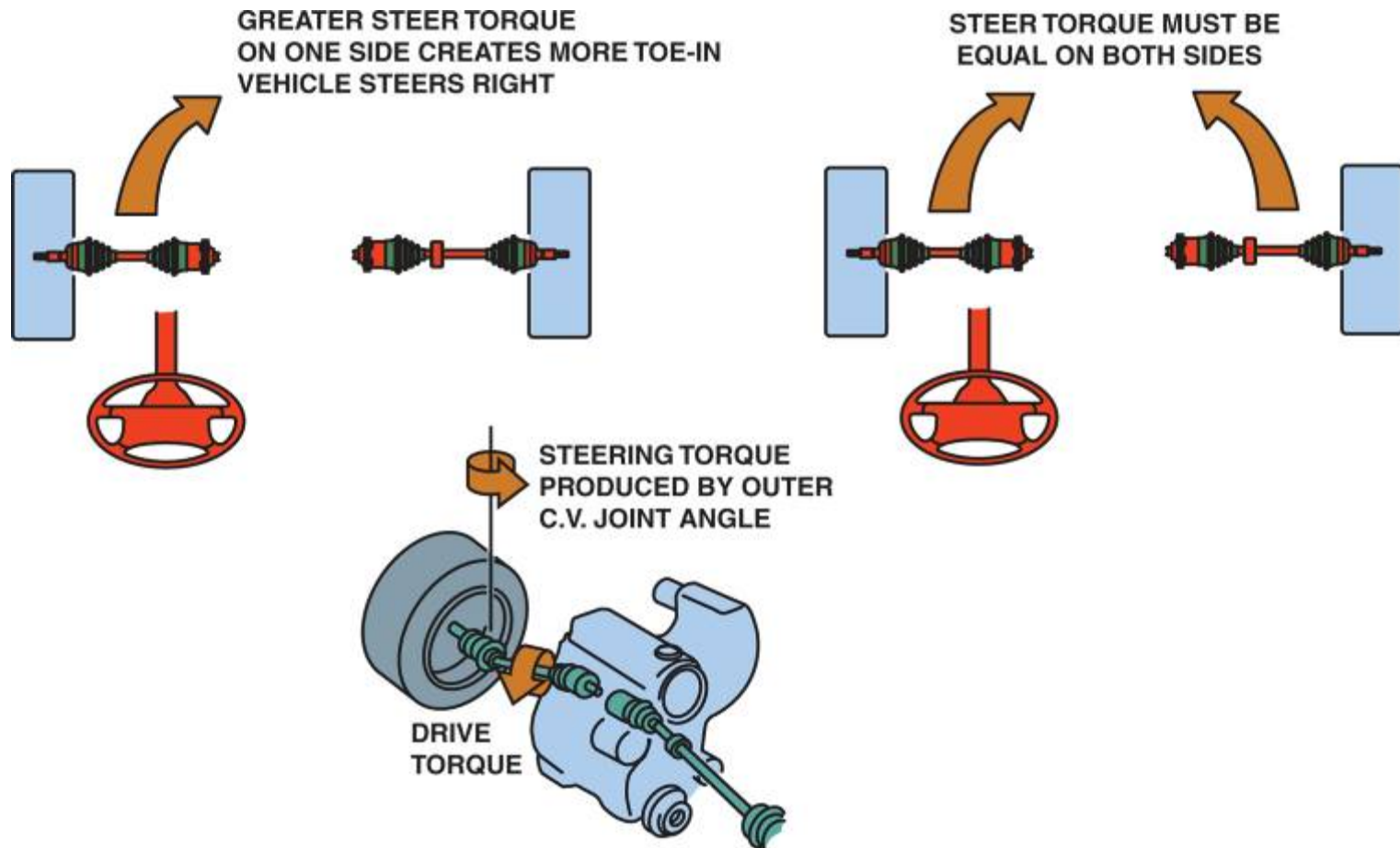


FIGURE 34–7 Equal outer CV joint angles produce equal steer torque (toe-in). If one side receives more engine torque, that side creates more toe-in and the result is a pull toward one side, especially during acceleration.

TORQUE STEER CORRECTION

- The service technician cannot change the design of a vehicle, but the technician can, and should, check and correct problems that often cause torque steer.
- **Check to be sure that the condition is not normal.**
- It is normal for front-wheel-drive vehicles to exert a tug on the steering wheel and steer toward one side (usually to the right) during acceleration.
- This is especially noticeable when the transmission shifts from first to second gear under heavy acceleration.

TORQUE STEER CORRECTION

- To determine how severe the problem is, place a strip of masking tape at the top of the steering wheel.
- Drive the vehicle and observe the amount of movement required to steer the vehicle straight during heavy acceleration.
- Repeat the test with a vehicle of similar make and model.
- If the torque steer is excessive, determine and correct the cause by carefully following the prealignment inspection steps and checking for a level powertrain.

TORQUE STEER CORRECTION

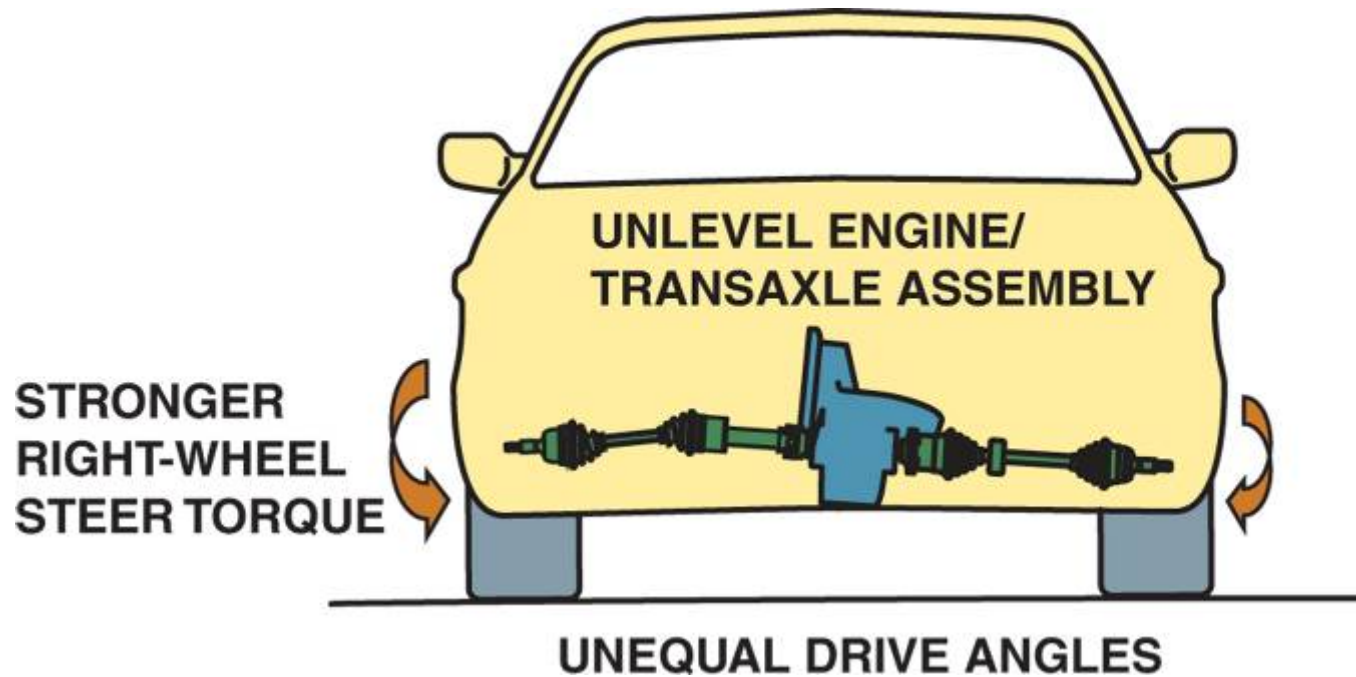


FIGURE 34–8 Broken or defective engine or transaxle mounts can cause the powertrain to sag, causing unequal drive axle shaft CV joint angles.

ALIGNMENT SPECIFICATIONS

- Before attempting any alignment, consider the following:
 - Determine the make, model, and year of the vehicle.
 - Determine if the vehicle is equipped with power steering or manual steering.
 - Check the trunk and with the customer to determine the normal load being carried.
 - Determine the correct specifications
 - Compensate for the lack of a full gas tank by placing an equal amount of weight in the luggage compartment
 - Determine the correct specifications for the *exact* vehicle being checked.

Keep the Doors Closed, but the Window Down



TECH TIP

- An experienced alignment technician became upset when a beginning technician opened the driver's door to lock the steering wheel in a straight-ahead position on the vehicle being aligned. The weight of the open door caused the vehicle to sag. This disturbed the level position of the vehicle and changed all the alignment angles.

Keep the Doors Closed, but the Window Down



TECH TIP

- The beginning technician learned an important lesson that day: Keep the window down on the driver's door so that the steering wheel and brakes can be locked without disturbing the vehicle weight balance by opening a door. The brake pedal must be locked with a pedal depressor to prevent the wheels from rolling as the wheels are turned during a caster sweep. The steering must be locked in the straightahead position when adjusting toe.

ALIGNMENT SPECIFICATIONS

- **READING ALIGNMENT SPECIFICATIONS**
 - **MAXIMUM/MINIMUM/PREFERRED METHOD**
 - **PLUS OR MINUS METHOD**
- **DEGREES, MINUTES, AND FRACTIONS**
- **FINDING THE MIDPOINT OF SPECIFICATIONS**

ALIGNMENT SETUP PROCEDURES

WHEEL ALIGNMENT SPECIFICATIONS

	CASTER	CROSS CASTER (LH-RH)	CAMBER	CROSS CAMBER (LH-RH)	TOE (TOTAL IN) DEGREES	STEERING WHEEL ANGLE	THRUST ANGLE
FRONT	$+3^{\circ} \pm .5^{\circ}$	$0^{\circ} \pm .75^{\circ}$	$+2^{\circ} \pm .5^{\circ}$	$0^{\circ} \pm .75^{\circ}$	$0^{\circ} \pm .3^{\circ}$	$0^{\circ} \pm 3^{\circ}$	--
REAR	--	--	$-.3^{\circ} \pm .5^{\circ}$	$0^{\circ} \pm .75^{\circ}$	$+.1^{\circ} \pm .2^{\circ}$	--	$0^{\circ} \pm .1^{\circ}$

FIGURE 34–9 This alignment chart indicates the preferred setting with a plus or minus tolerance.

ALIGNMENT SETUP PROCEDURES

- After confirming that the tires and all steering and suspension components are serviceable, the vehicle is ready for an alignment.
- Setup procedures for the equipment being used must always be followed.
- Typical alignment procedures include the following:
 - Drive onto the alignment rack straight and adjust the ramps and/or turn plates so that they are centered under the tires of the vehicle.
 - Use chocks for the wheels to keep the vehicle from rolling off the alignment rack.

ALIGNMENT SETUP PROCEDURES

- Attach and calibrate the wheel sensors to each wheel as specified by the alignment equipment manufacturer.
- Unlock all rack or turn plates.
- Lower the vehicle and jounce the vehicle by pushing down on the front, then rear, bumper. This motion allows the suspension to become centered.
- Following the procedures for the alignment equipment, determine all alignment angles.

ALIGNMENT SETUP PROCEDURES



FIGURE 34–10 Using the alignment rack hydraulic jacks, raise the tires off the rack so that they can be rotated as part of the compensating process.



FIGURE 34–11 This wheel sensor has a safety wire that screws to the valve stem to keep the sensor from falling onto the ground if the clamps slip on the wheel lip.

MEASURING CAMBER, CASTER, SAI, TOE, AND TOOT

- CAMBER
- CASTER
- SAI
- TOE
- TOOT

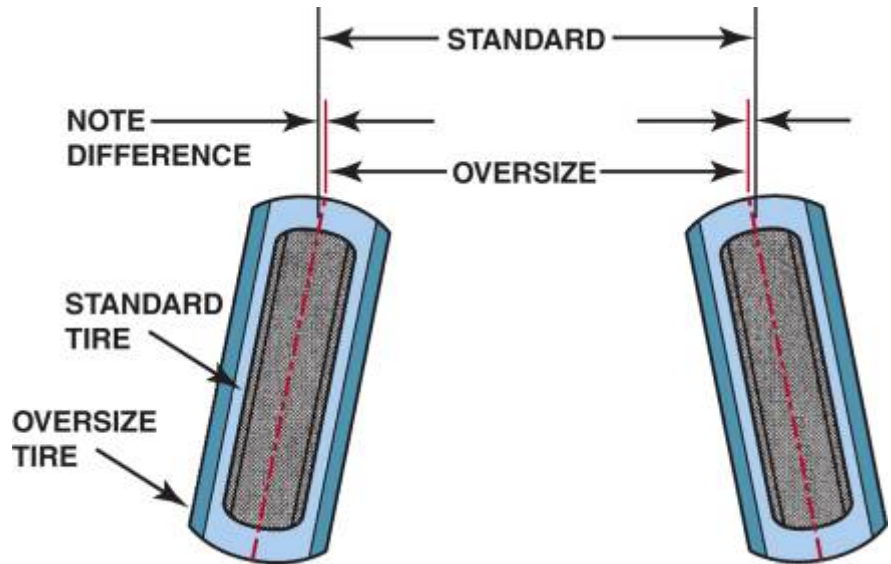


FIGURE 34-12 If toe for an oversize tire is set by distance, the toe angle will be too small. Toe angle is the same regardless of tire size.

MEASURING CAMBER, CASTER, SAI, TOE, AND TOOT

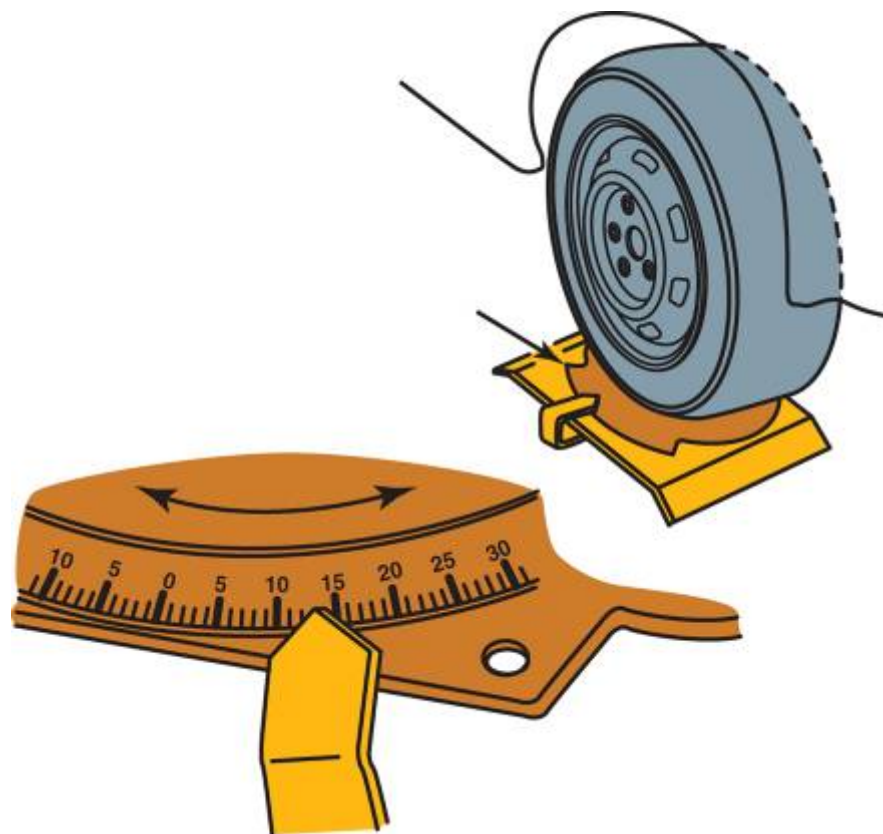


FIGURE 34–13 The protractor scale on the front turn plates allows the technician to test the turning radius by turning one wheel to an angle specified by the manufacturer and observing the angle of the other front wheel. Most newer alignment machines can display turning angle based on sensor readings, and therefore the protractor scale on the turn plate is not needed or used.

SPECIFICATIONS VERSUS ALIGNMENT READINGS

- Secure both the alignment specifications from the manufacturer and the alignment readings and compare the two.
- Before starting an alignment, the smart technician checks the SAI, included angle, setback, and toe-out on turns to make sure that there is no hidden damage such as a bent spindle or strut that was not found during the prealignment inspection.
- *Setback is also a diagnostic angle and should be less than 0.5 in. (13 cm or 1/2 degree).*
- If setback is greater than 0.5 in. (13 cm or 1/2 degree), check the body, frame, and cradle for accident damage or improper alignment.

CHECKING FOR BENT STRUTS, SPINDLES, OR CONTROL ARMS

- Even a minor bump against a curb can bend a spindle or a strut housing.
- Before attempting to correct an alignment, check all the angles and use the appropriate diagnostic chart to check for hidden damage that a visual inspection may miss.

CHECKING FOR BENT STRUTS, SPINDLES, OR CONTROL ARMS

DIAGNOSING SAI, CAMBER, AND INCLUDED ANGLE			
SLA AND STRUT/SLA SUSPENSIONS			
SAI	CAMBER	INCLUDED ANGLE	DIAGNOSIS
CORRECT	LESS THAN SPECS	LESS THAN SPECS	BENT STEERING KNUCKLE OR SPINDLE
LESS THAN SPECS	GREATER THAN SPECS	CORRECT	BENT LOWER CONTROL ARM
LESS THAN SPECS	GREATER THAN SPECS	GREATER THAN SPECS	BENT LOWER CONTROL ARM AND STEERING KNUCKLE OR SPINDLE
GREATER THAN SPECS	LESS THAN SPECS	CORRECT	BENT UPPER CONTROL ARM
STRUT SUSPENSIONS			
SAI	CAMBER	INCLUDED ANGLE	DIAGNOSIS
CORRECT	LESS THAN SPECS	LESS THAN SPECS	BENT SPINDLE AND/OR STRUT
CORRECT	GREATER THAN SPECS	GREATER THAN SPECS	BENT SPINDLE AND/OR STRUT
LESS THAN SPECS	GREATER THAN SPECS	CORRECT	BENT CONTROL ARM OR STRUT TOWER OUT AT TOP
LESS THAN SPECS	GREATER THAN SPECS	GREATER THAN SPECS	BENT CONTROL ARM OR STRUT TOWER OUT AT TOP, ALSO
LESS THAN SPECS	LESS THAN SPECS	LESS THAN SPECS	BENT SPINDLE AND/OR STRUT BENT CONTROL ARM OR STRUT TOWER OUT AT TOP, ALSO
GREATER THAN SPECS	LESS THAN SPECS	CORRECT	BENT SPINDLE AND/OR STRUT STRUT TOWER IN AT TOP
GREATER THAN SPECS	GREATER THAN SPECS	GREATER THAN SPECS	STRUT TOWER IN AT TOP AND BENT SPINDLE AND/OR BENT STRUT
KINGPIN TWIN I-BEAM SUSPENSION			
SAI (KPI)	CAMBER	INCLUDED ANGLE	DIAGNOSIS
CORRECT	GREATER THAN SPECS	GREATER THAN SPECS	BENT SPINDLE
LESS THAN SPECS	GREATER THAN SPECS	CORRECT	BENT I-BEAM
LESS THAN SPECS	GREATER THAN SPECS	GREATER THAN SPECS	BENT I-BEAM AND SPINDLE
GREATER THAN SPECS	LESS THAN SPECS	CORRECT	BENT I-BEAM

FIGURE 34–14 By checking the SAI, camber, and included angle, a damaged suspension component can be determined by using this chart.

CHECKING FRAME ALIGNMENT OF FRONT-WHEEL-DRIVE VEHICLES

- Many front-wheel-drive vehicles mount the drive train (engine and transaxle) and lower suspension arms to a subframe or cradle.
- If the frame is shifted either left or right, this can cause differences in SAI, included angle, setback, and camber.

CHECKING FRAME ALIGNMENT OF FRONT-WHEEL-DRIVE VEHICLES

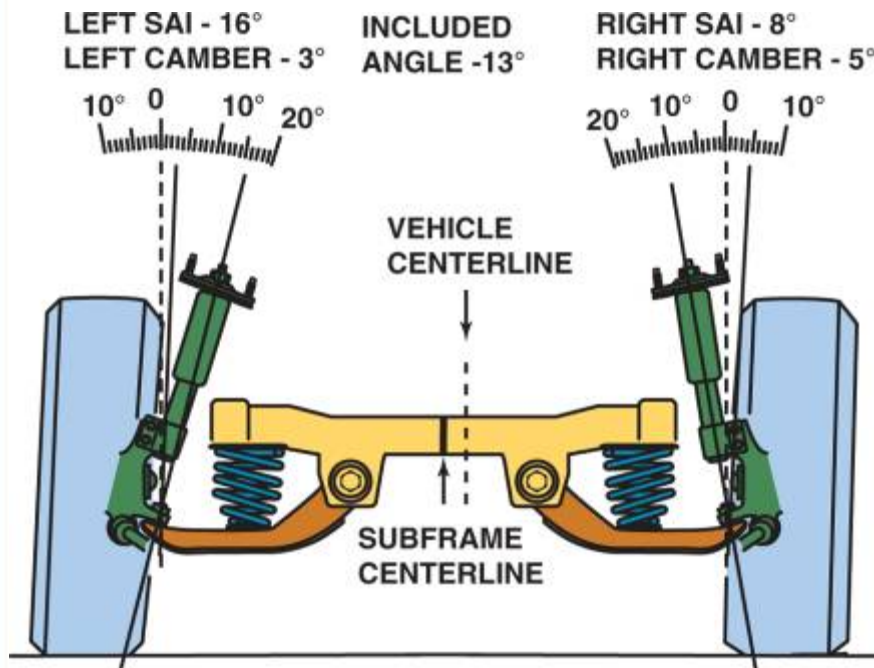


FIGURE 34-15 In this example, both SAI and camber are far from being equal side-to-side. However, both sides have the same included angle, indicating that the frame may be out of alignment. An attempt to align this vehicle by adjusting the camber on both sides with either factory or aftermarket kits would result in a totally incorrect alignment.

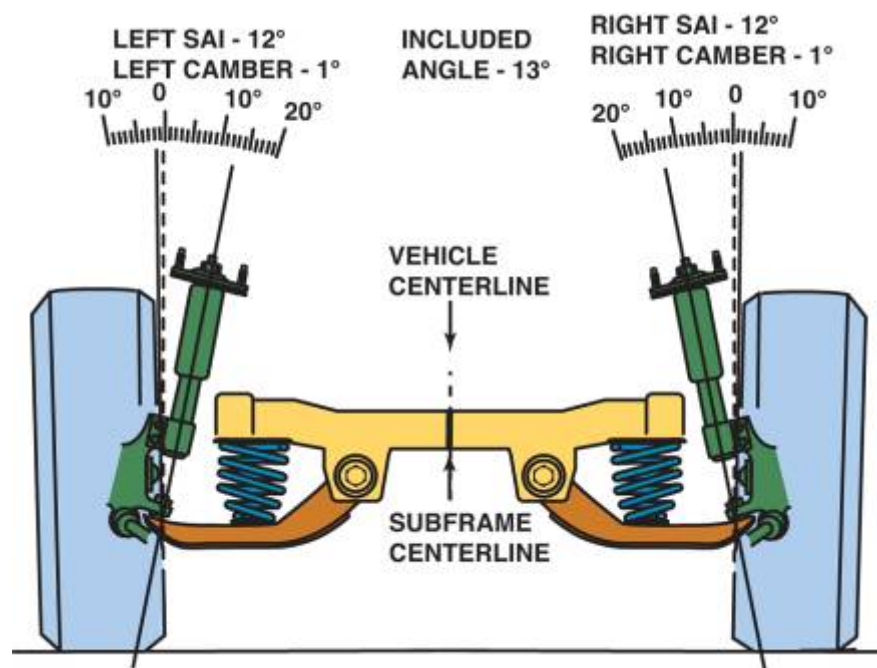


FIGURE 34-16 This is the same vehicle as shown in Figure 18-15, except now the frame (cradle) has been shifted over and correctly positioned. Notice how both the SAI and camber become equal without any other adjustments necessary.

Damage Analysis Tips



TECH TIP

- To check if a vehicle has been in a collision, technicians should look for the following:
 - Drive the vehicle through a water puddle to see if the tire marks are wider than the tires. If they are, then the front and rear wheels are not tracking correctly.
 - If the setback is out of specifications, then the front of the vehicle may be damaged.
 - If the thrust angle is out of specifications, then rear suspension damage is likely.

TYPES OF ALIGNMENTS

- There are three types of alignment: geometric centerline, thrust line, and four-wheel alignment.
 - **GEOMETRIC CENTERLINE**
 - **THRUST LINE**
 - **FOUR-WHEEL ALIGNMENT**

TYPES OF ALIGNMENTS

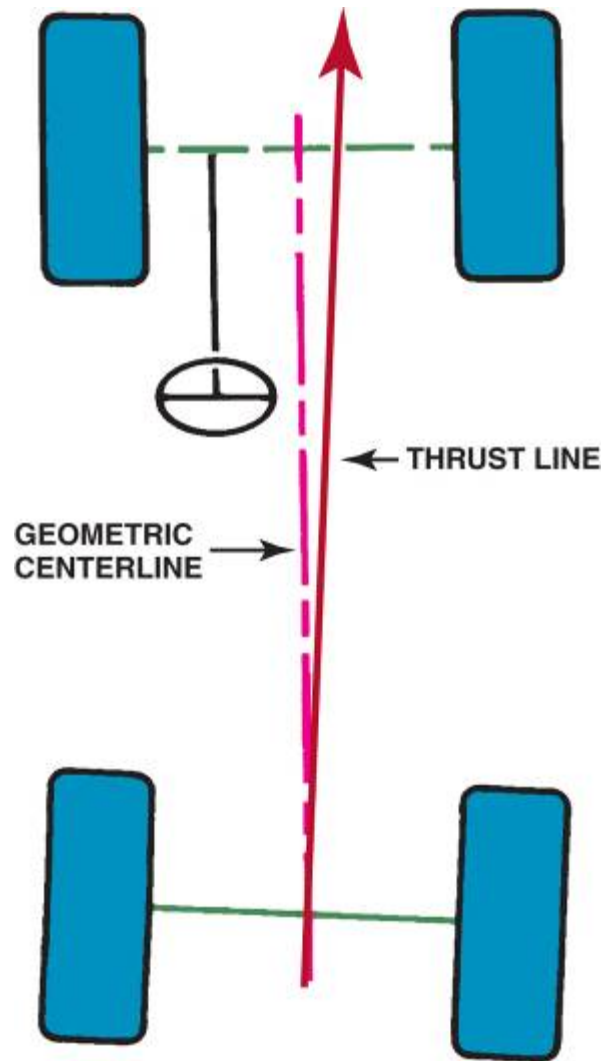


FIGURE 34–17 Geometric-centerline-type alignment sets the front toe readings based on the geometric centerline of the vehicle and does not consider the thrust line of the rear wheel toe angles. *(Courtesy of Hunter Engineering Company)*

TYPES OF ALIGNMENTS

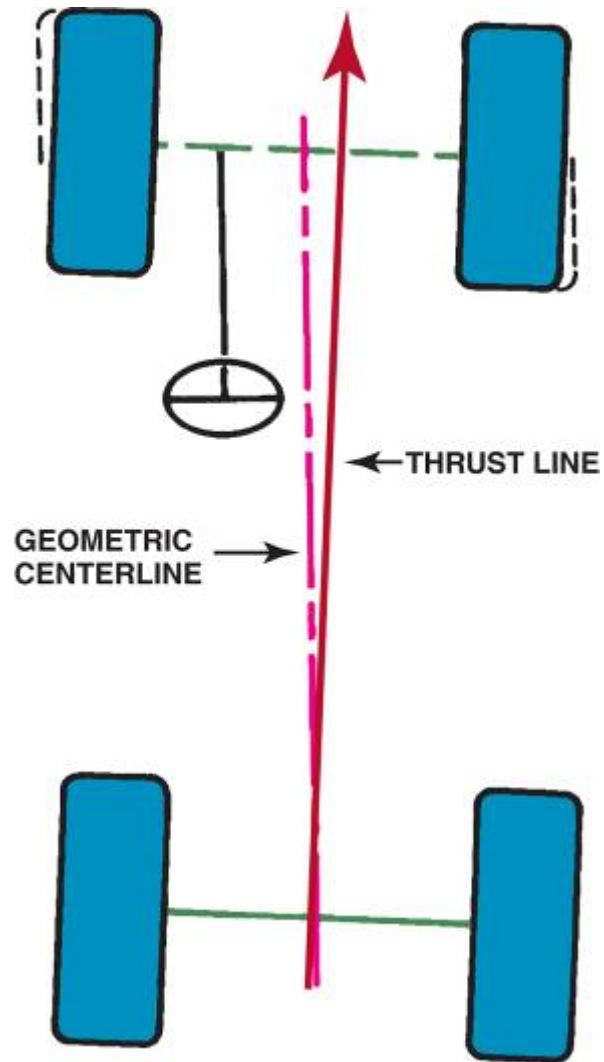


FIGURE 34–18 Thrust line alignment sets the front toe parallel with the rear-wheel toe. *(Courtesy of Hunter Engineering Company)*

TYPES OF ALIGNMENTS

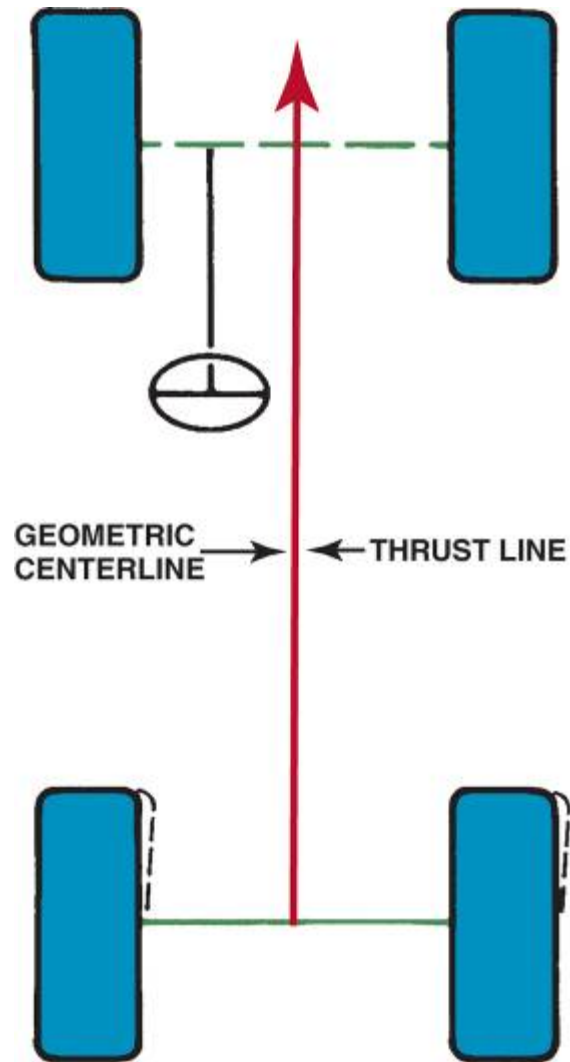


FIGURE 34–19 Four-wheel alignment corrects for any rearwheel toe to make the thrust line and the geometric centerline of the vehicle both the same. *(Courtesy of Hunter Engineering Company)*

Ask Yourself These Three Questions



TECH TIP

- An older technician told a beginning technician that the key to success in doing a proper alignment is to ask yourself three questions about the alignment angles:
 - Question 1. **“Is it within specifications?”**
 - Question 2. **“Is it within 1/2° of the other side of the vehicle?”**
 - Question 3. **“If the camber and caster cannot be exactly equal side-to-side in the front, is there more camber on the left and more caster on the right to help compensate for road crown?”**

How does normal wear affect the alignment angles?



FREQUENTLY ASKED QUESTION

- As a vehicle ages, the springs sag and steering and suspension components wear.
 - When springs sag the ride height changes and the camber usually is reduced and often becomes negative compared to slightly positive when the vehicle was new in most cases.
 - When tie rod ends and other steering components wear, the front wheels tend to toe out.
 - Worn suspension components can cause excessive play making the vehicle unstable and cause the tires to wear abnormally.

ADJUSTING REAR CAMBER

- Adjusting rear camber is the first step in the four-wheel alignment process.
- Rear camber is rarely made adjustable, but can be corrected by using aftermarket alignment kits or shims.
- If rear camber is not correct, vehicle handling and tire life are affected.

ADJUSTING REAR CAMBER

- Before attempting to adjust or correct rear camber, carefully check the body and/or frame of the vehicle for accident damage, including the following:
 - Weak springs, torsion bars, or overloading (check ride height)
 - Bowed rear axle, trailing arm, or rear control arm
 - Suspension mount or body dimension not in proper location
 - Incorrectly adjusted camber from a previous repair

ADJUSTING REAR CAMBER

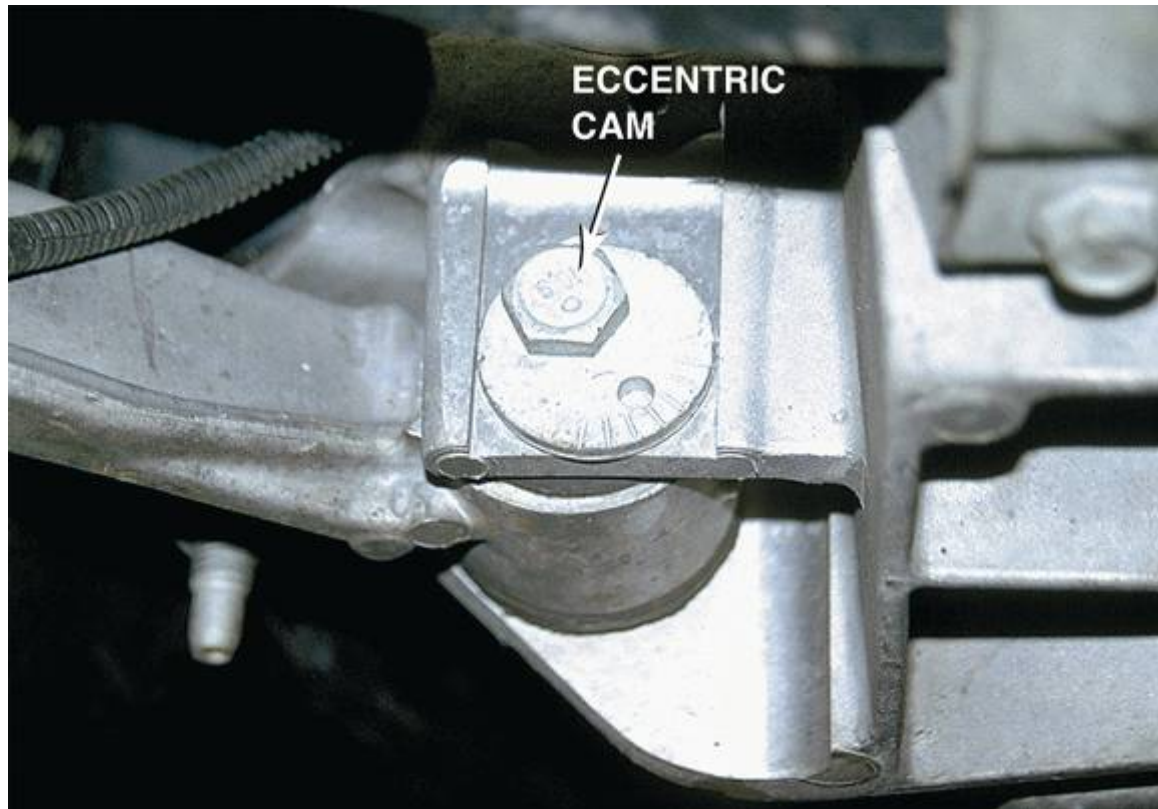


FIGURE 34–20 The rear camber is adjustable on this vehicle by rotating the eccentric cam and watching the alignment machine display.

ADJUSTING REAR CAMBER

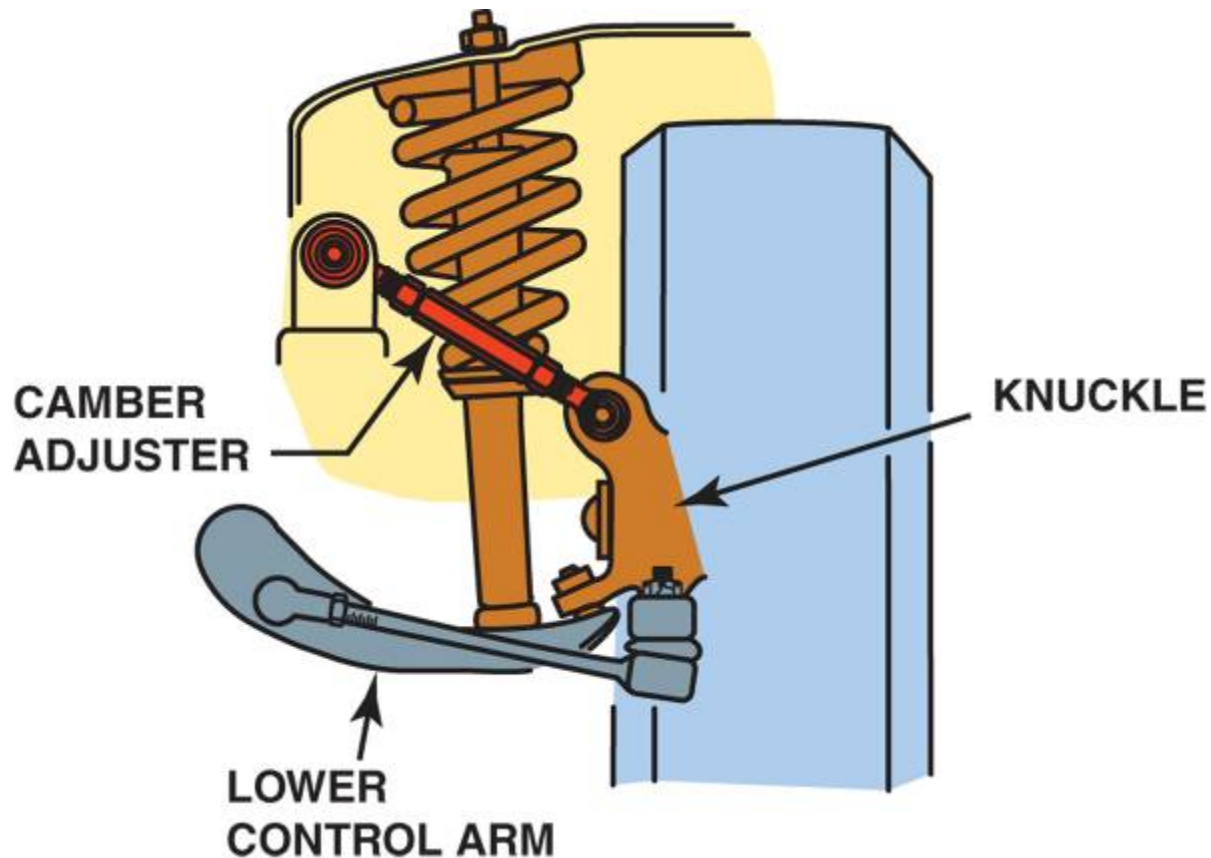


FIGURE 34–21 Some vehicles use a threaded fastener similar to a tie rod to adjust camber on the rear suspension.

ADJUSTING REAR CAMBER

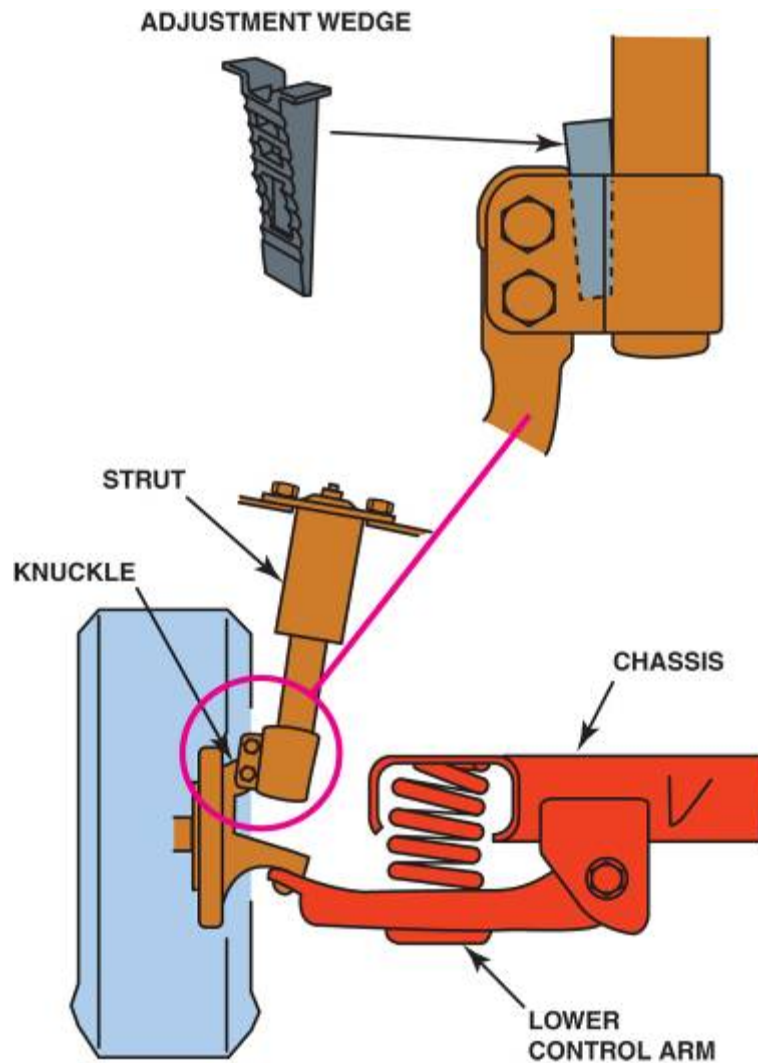


FIGURE 34–22 Aftermarket alignment parts or kits are available to change the rear camber.

The Gritty Solution



TECH TIP

- Many times it is difficult to loosen a Torx bolt, especially those used to hold the backing plate onto the rear axle on many GM vehicles. A technique that always seems to work is to place some valve grinding compound on the fastener. The gritty compound keeps the Torx socket from slipping up and out of the fastener, and more force can be exerted to break loose a tight bolt. Valve grinding compound can also be used on Phillips head screws as well as other types of bolts, nuts, and sockets.

The Gritty Solution

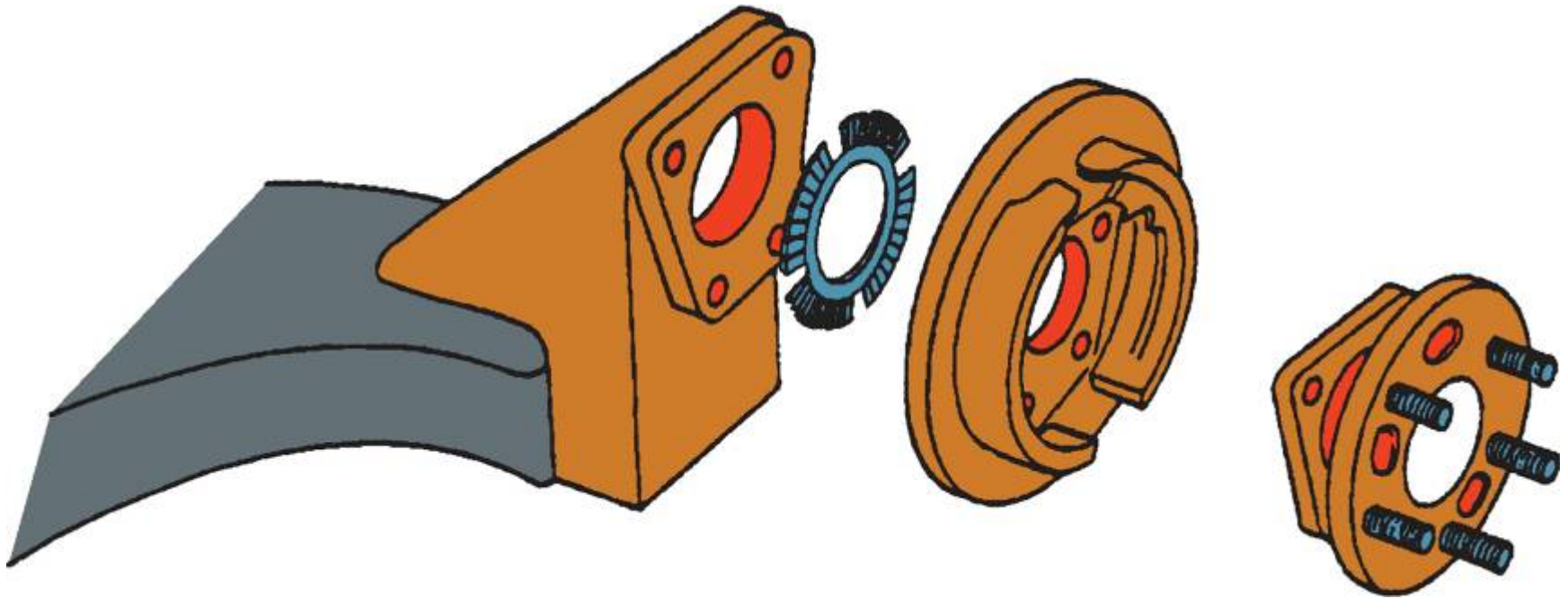


FIGURE 34–23 Full-contact plastic or metal shims can be placed between the axle housing and the brake backing plate to change rear camber, toe, or both. *(Courtesy of Northstar Manufacturing Company, Inc.)*

ADJUSTING REAR CAMBER

- **USING PLASTIC OR METAL ALIGNMENT SHIMS**
- **ADJUSTING REAR TOE**

ADJUSTING REAR CAMBER

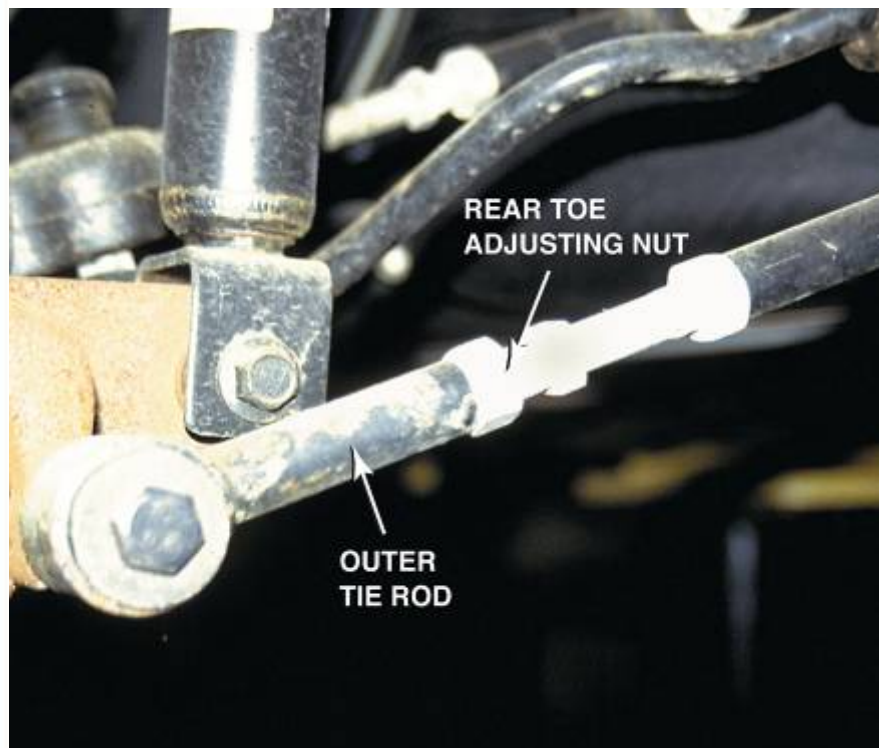


FIGURE 34-24 The rear toe was easily set on this vehicle. The adjusting nuts were easy to get to and turn. Adjusting rear toe is not this easy on every vehicle.

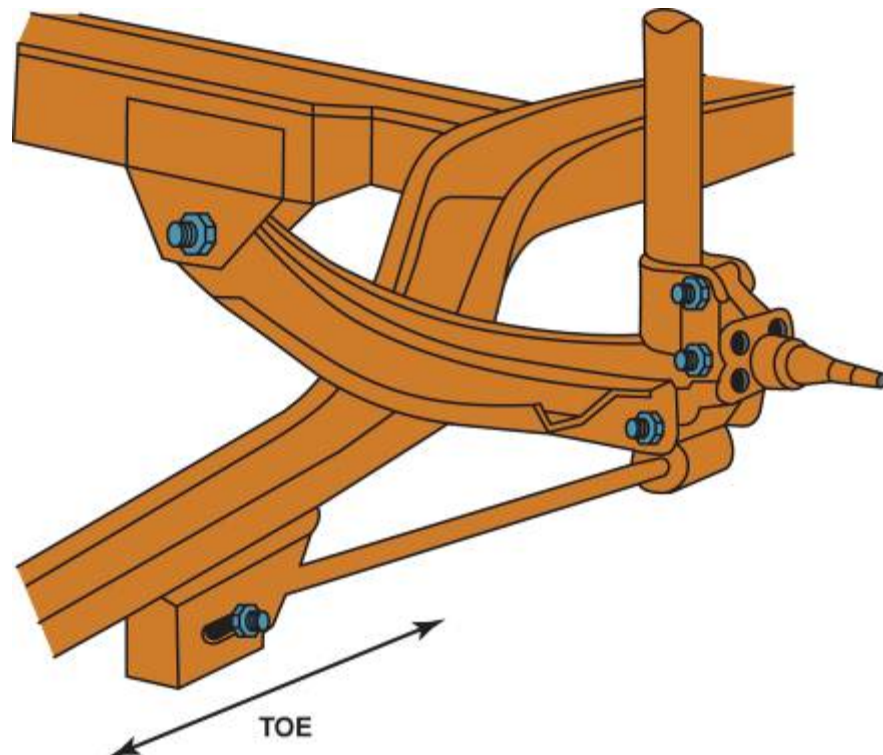


FIGURE 34-25 By moving various rear suspension members, the rear toe can be changed.

ADJUSTING REAR CAMBER

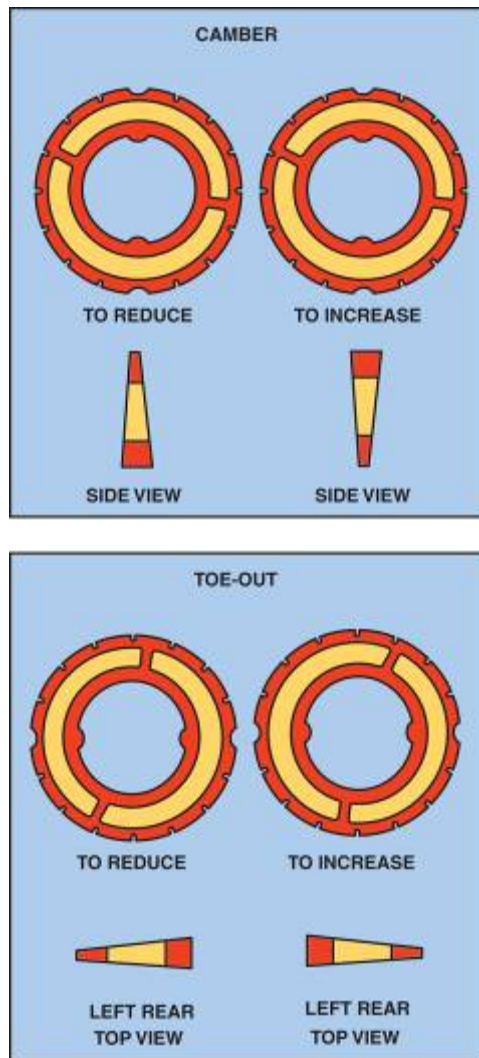


FIGURE 34–26 The use of these plastic or metal shims requires that the rear wheel as well as the hub assembly and/or backing plate be removed. Proper torque during reassembly is critical to avoid damage to the shims.

GUIDELINES FOR ADJUSTING FRONT CAMBER/SAI AND INCLUDED ANGLE

- If the camber is adjusted at the base of the MacPherson strut, camber and included angle are changed and SAI remains the same.
- If camber is adjusted by moving the upper strut mounting location, included angle remains the same, but SAI and camber change.

GUIDELINES FOR ADJUSTING FRONT CAMBER/SAI AND INCLUDED ANGLE

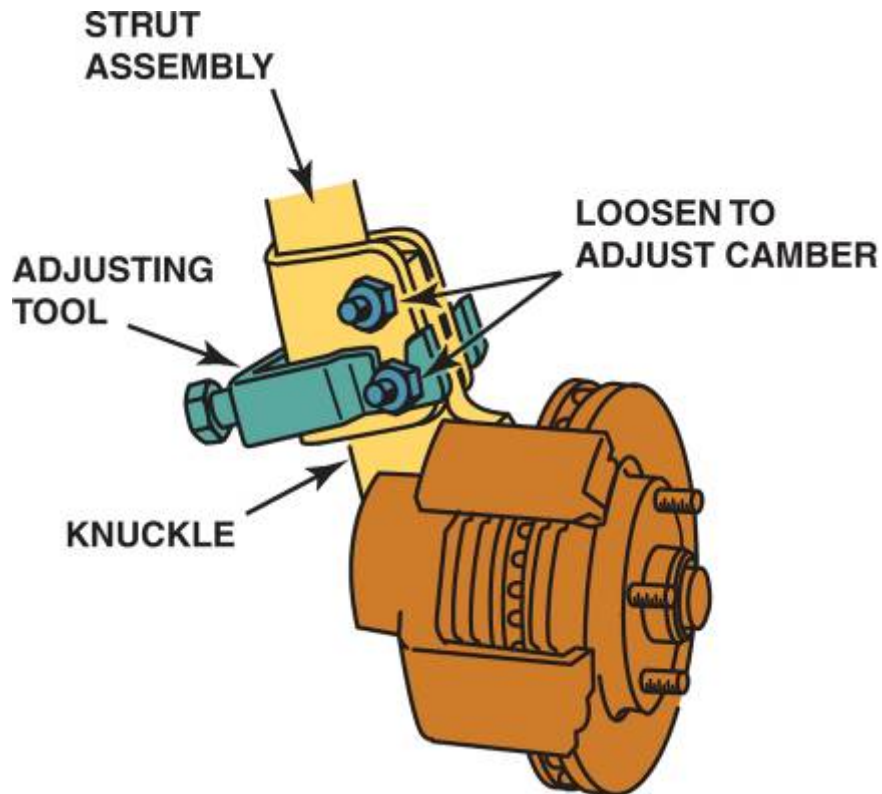


FIGURE 34–27 Many struts allow camber adjustment at the strut-to-knuckle fasteners. Here a special tool is being used to hold and move the strut into alignment with the fasteners loosened. Once the desired camber angle is achieved, the strut nuts are tightened and the tool is removed.

GUIDELINES FOR ADJUSTING FRONT CAMBER/SAI AND INCLUDED ANGLE

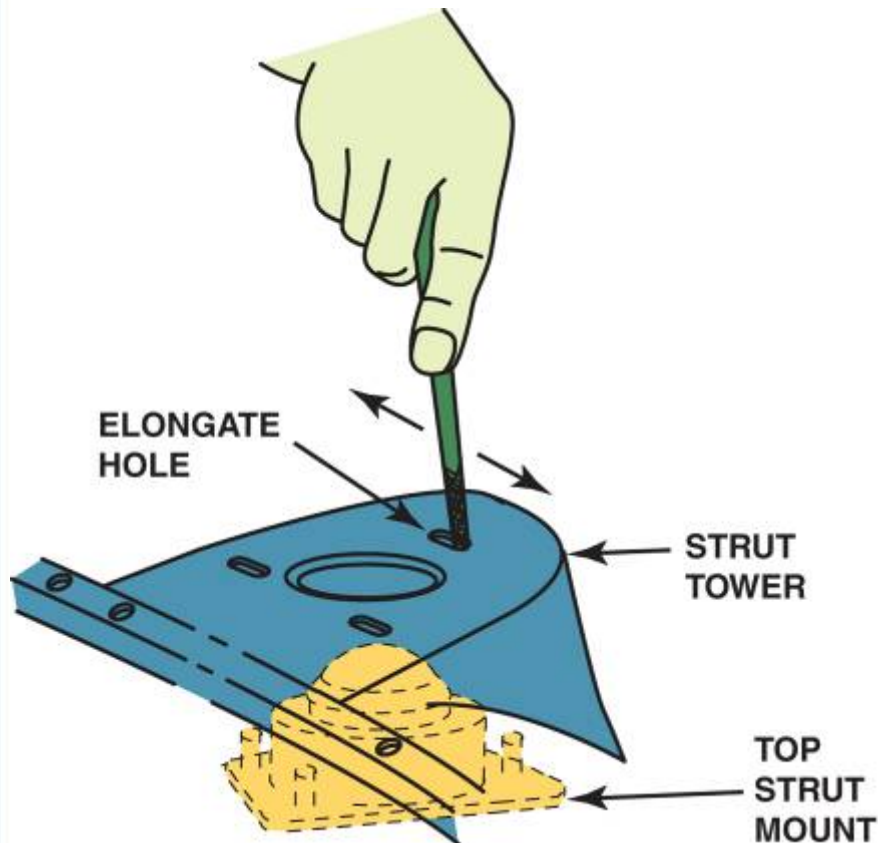


FIGURE 34–28 Some struts require modification of the upper mount for camber adjustment.

FRONT CAMBER/CASTER ADJUSTMENT METHODS

METHODS OF ADJUSTMENT

TOOLS AND ADJUSTMENT DEVICES MAY BE AVAILABLE FROM AFTERMARKET SUPPLIERS TO PERFORM ADJUSTMENTS IN CASES WHERE MANUFACTURERS DO NOT MAKE SUCH PROVISIONS.

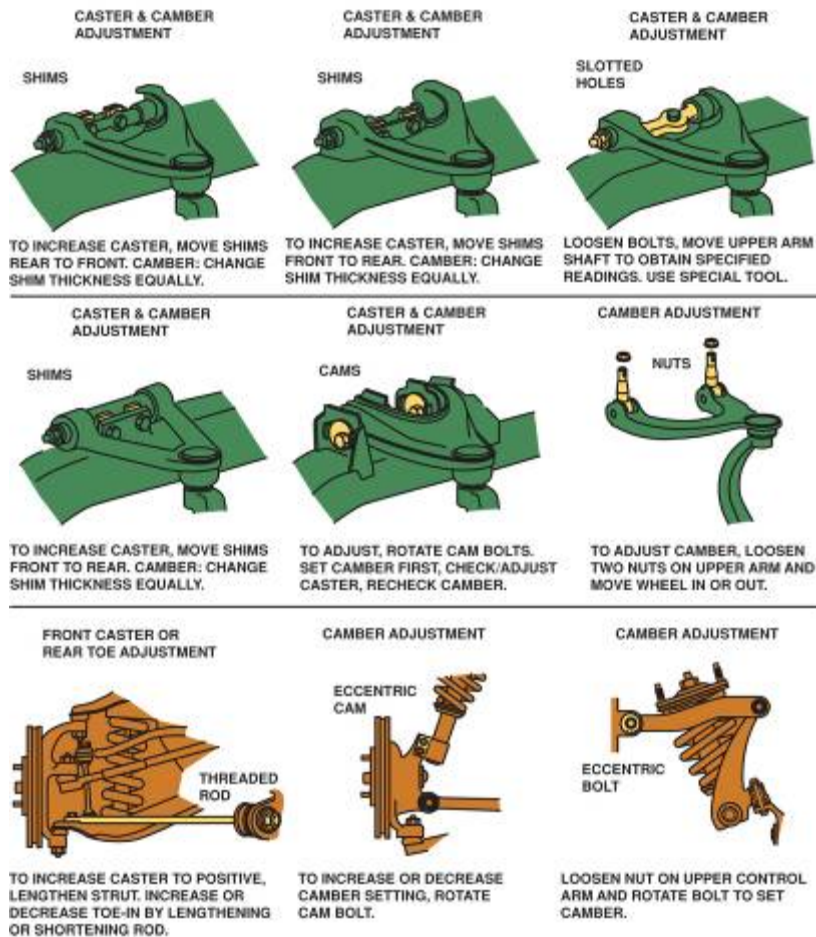


FIGURE 34–29 An example of the many methods that are commonly used to adjust front caster and camber.

ADJUSTING FRONT CAMBER/CASTER

- Most SLA-type suspensions can be adjusted for caster and camber.
- Most manufacturers recommend adjusting caster, then camber, before adjusting the toe.
- As the caster is changed, such as when the strut rod is adjusted, the camber and toe also change.

ADJUSTING FRONT CAMBER/CASTER

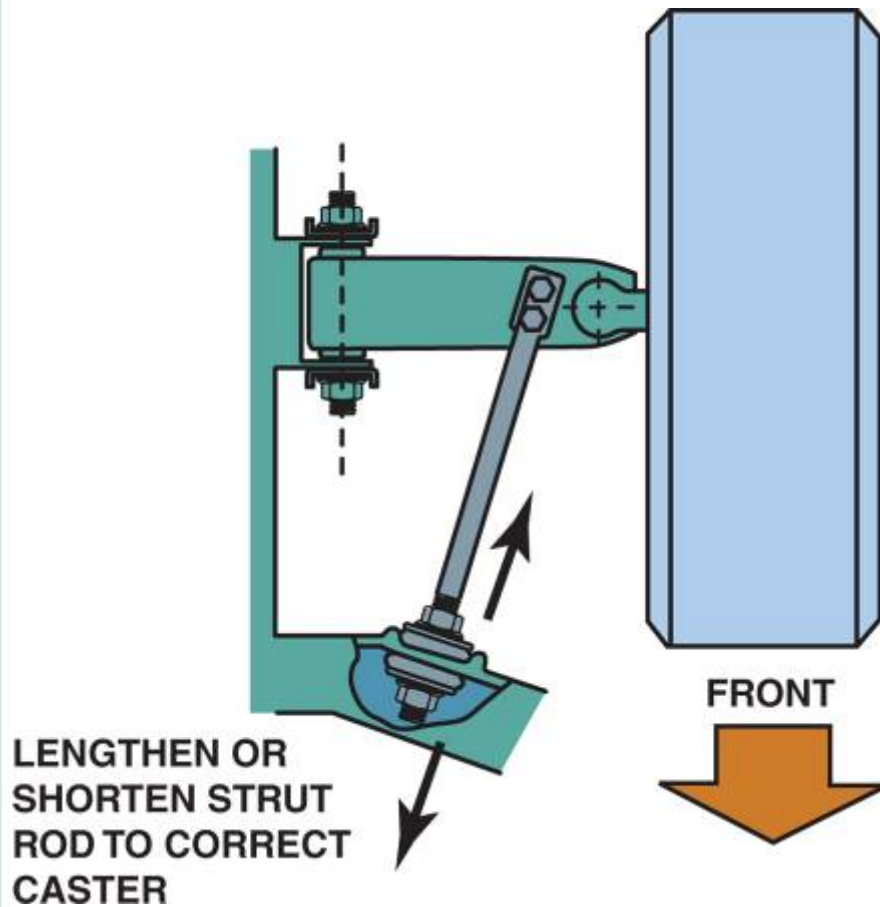
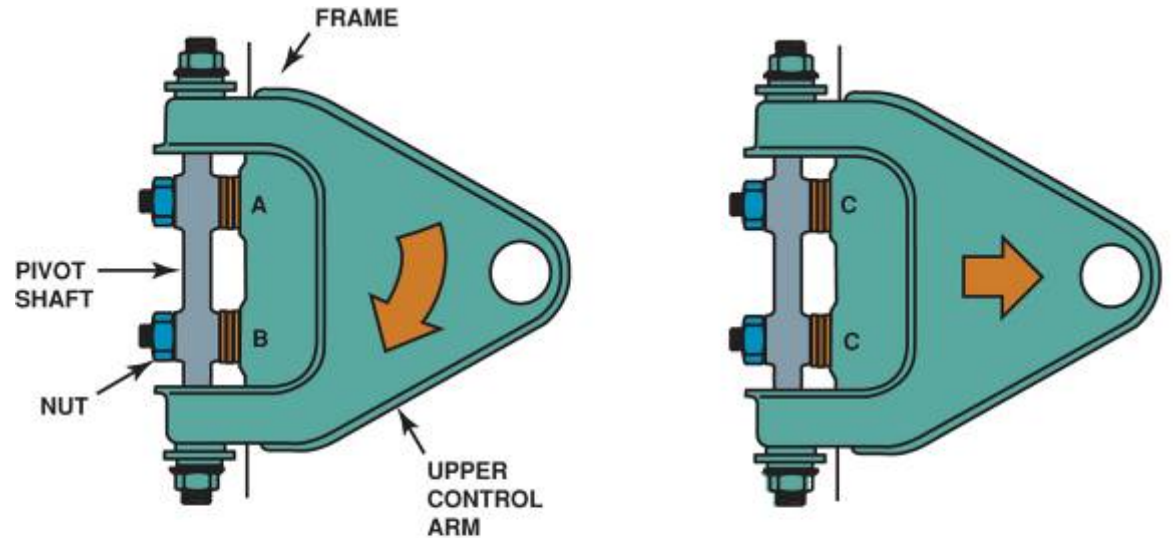


FIGURE 34–30 If there is a nut on both sides of the strut rod bushing, then the length of the rod can be adjusted to change caster.

ADJUSTING FRONT CAMBER/CASTER



A SUBTRACT SHIMS TO INCREASE POSITIVE CASTER

B ADD SHIMS TO INCREASE POSITIVE CASTER

C SUBTRACT SHIMS EQUALLY TO INCREASE POSITIVE CAMBER OR ADD SHIMS EQUALLY TO REDUCE POSITIVE CAMBER

FIGURE 34-31 Placing shims between the frame and the upper control arm pivot shaft is a popular method of alignment for many SLA suspensions. Both camber and caster can be easily changed by adding or removing shims.

ADJUSTING FRONT CAMBER/CASTER

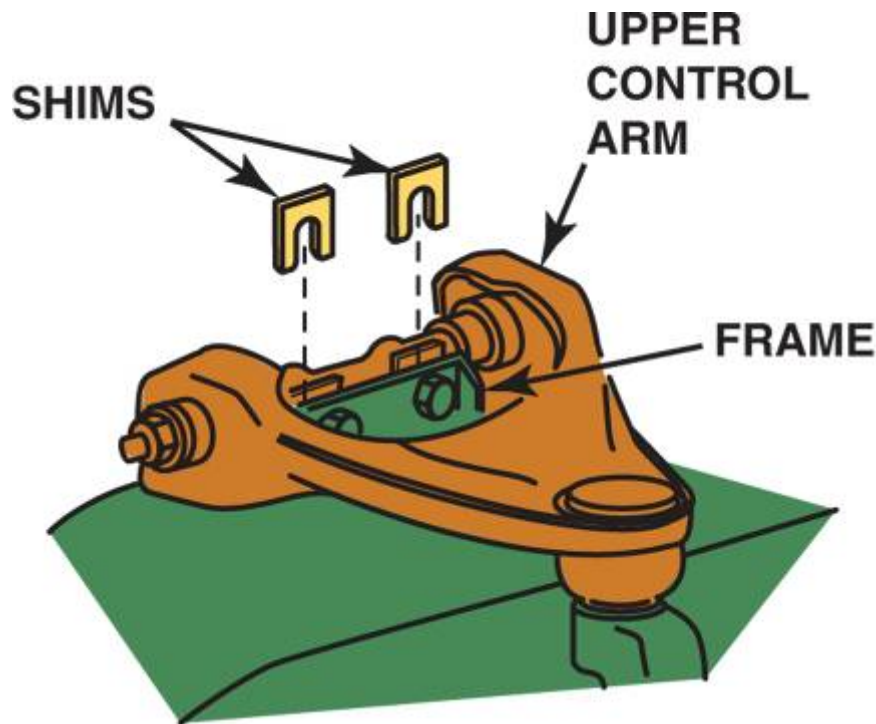


FIGURE 34–32 The general rule of thumb is that a 1/8-in. shim added or removed from both shim locations changes the camber angle about 1/2 degree. Adding or removing a 1/8-in. shim from one shim location changes the caster by about 1/4 degree.

ADJUSTING FRONT CAMBER/CASTER

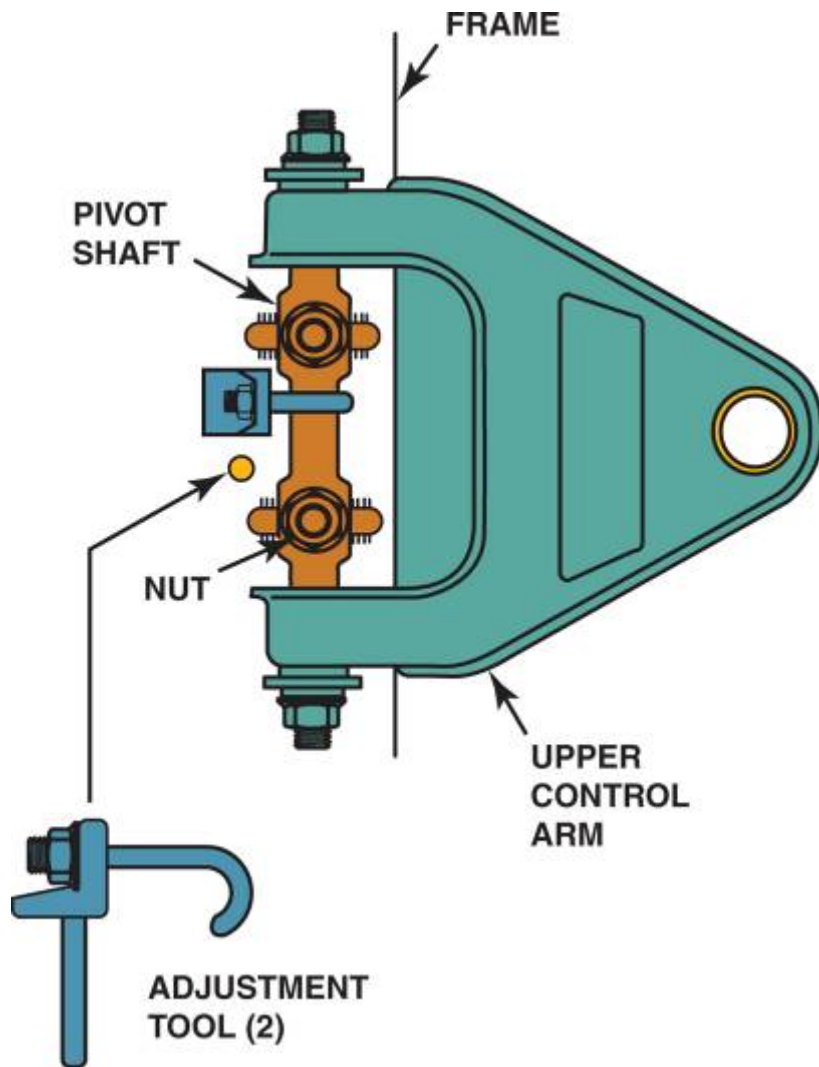


FIGURE 34–33 Some SLA-type suspensions use slotted holes for alignment angle adjustments. When the pivot shaft bolts are loosened, the pivot shaft is free to move unless held by special clamps as shown. By turning the threaded portion of the clamps, the camber and caster can be set and checked before tightening the pivot shaft bolts.

ADJUSTING FRONT CAMBER/CASTER

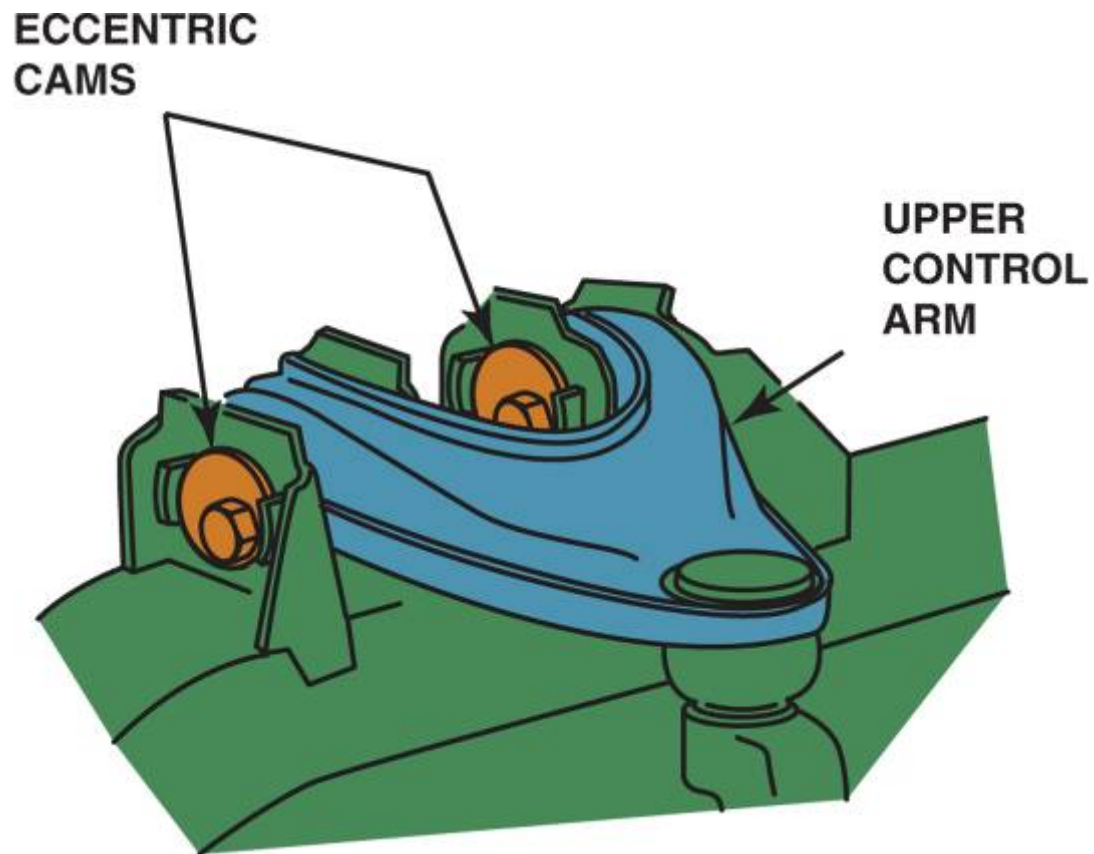


FIGURE 34–34 When the nut is loosened and the bolt on the eccentric cam is rotated, the upper control arm moves in and out. By adjusting both eccentric cams, both camber and caster can be adjusted.

ADJUSTING FRONT CAMBER/CASTER

		DEGREES CASTER															
		+4.9°	+4.7°	+4.5°	+4.3°	+4.1°	+3.9°	+3.7°	+3.5K	+3.3°	+3.1°	+2.9°	+2.7°	+2.5°	+2.3K	+2.1°	
DEGREES CAMBER	BOLT																
	+2.2°	FRONT REAR	+300 +101	+211 +101	+211 +110	+210 +110	+210 +111	+201 +200	+201 +200	+201 +201	+200 +210	+200 +201	+111 +201	+111 +211	+110 +300	+110 +301	+110 +301
	+2.0°	FRONT REAR	+210 +011	+210 +100	+210 +101	+201 +101	+201 +110	+200 +110	+200 +111	+200 +200	+111 +200	+110 +201	+110 +210	+110 +210	+101 +211	+101 +300	+100 +300
	+1.8°	FRONT REAR	+201 +010	+201 +011	+200 +011	+200 +100	+111 +101	+111 +101	+110 +110	+110 +110	+110 +111	+101 +200	+101 +200	+100 +201	+100 +210	+100 +210	+011 +211
	+1.6°	FRONT REAR	+200 +001	+200 +001	+111 +010	+111 +011	+110 +101	+110 +100	+101 +100	+101 +101	+100 +110	+100 +110	+100 +111	+011 +200	+011 +200	+010 +201	+010 +210
	+1.4°	FRONT REAR	+111 +000	+110 +000	+110 +001	+101 +001	+101 +010	+100 +011	+100 +011	+100 +100	+011 +100	+011 +101	+010 +110	+010 +110	+010 +111	+001 +200	+001 +200
	+1.2°	FRONT REAR	+110 -010	+101 -001	+101 +000	+100 +000	+100 +001	+011 +001	+011 +010	+010 +011	+010 +011	+010 +100	+001 +101	+001 +101	+000 +110	+000 +111	+000 +111
	+1.0°	FRONT REAR	+100 -011	+100 -010	+011 -010	+011 -001	+010 -000	+010 +000	+010 +001	+001 +001	+001 +010	+000 +011	+000 +011	+000 +100	+001 +101	+001 +101	+010 +110
	+0.8°	FRONT REAR	+011 -100	+011 -100	+010 -011	+010 -010	+001 -010	+001 -001	+000 -001	+000 -001	+000 +001	-001 -001	-001 +001	-010 +011	-010 +011	-010 +100	-010 +101
	+0.6°	FRONT REAR	+010 -101	+001 -101	+001 -100	+001 -100	+000 -011	+000 -010	+001 -010	+001 -001	-010 -001	-010 +000	-010 +001	-011 +001	-011 +010	-100 +011	-100 +011
	+0.4°	FRONT REAR	+001 -111	+000 -110	+000 -101	+001 -101	+001 -100	+010 -100	+010 -011	+010 -010	+011 -010	+011 -001	+010 -000	+010 +000	+010 +001	+010 +010	+010 +010
	+0.2°	FRONT REAR	-001 -200	-001 -111	-001 -111	-010 -110	-010 -101	-010 -101	-011 -100	-010 -100	-100 -101	-100 -011	-101 -010	-101 -010	-101 -000	-110 +000	-110 +000
	+0.0°	FRONT REAR	-010 -201	-010 -201	-011 -200	-011 -111	-100 -111	-100 -110	-100 -101	-101 -101	-101 -101	-101 -100	-110 -100	-110 -011	-111 -010	-111 -001	-200 -000
	-0.2°	FRONT REAR	-011 -210	-011 -210	-100 -201	-100 -201	-101 -200	-101 -111	-110 -111	-110 -110	-111 -101	-111 -101	-111 -100	-111 -100	-200 -011	-200 -010	-201 -010
	-0.4°	FRONT REAR	-100 -300	-101 -211	-101 -210	-110 -210	-110 -201	-110 -201	-111 -200	-111 -111	-200 -111	-200 -111	-201 -101	-201 -101	-201 -100	-210 -011	-210 -011

FIGURE 34–35 Typical shim alignment chart. As noted, 1/8-in. (0.125) shims can be substituted for the 0.120-in. shims; 1/32-in. (0.0625) shims can be substituted for the 0.060-in. shims; and 1/32-in. (0.03125) shims can be substituted for the 0.030-in. shims.

1. DETERMINE VEHICLE'S CURRENT CASTER AND CAMBER MEASUREMENTS.
2. USING THE CURRENT CASTER READING, READ DOWN THE APPROPRIATE COLUMN TO THE LINES CORRESPONDING TO THE CURRENT CAMBER READING.
3. CORRECTION VALUES WILL BE GIVEN FOR THE FRONT AND REAR BOLTS.
EXAMPLE: CURRENT READING +1.6° CASTER +0.4° CAMBER. BY READING DOWN THE CHART FROM +1.6° CASTER TO +0.4° CAMBER YOU WILL FIND THAT THE FRONT BOLT REQUIRES AN ADJUSTMENT OF -101 AND THE REAR BOLT REQUIRES AN ADJUSTMENT OF +010.

SETTING TOE

- Front toe is the last angle that should be adjusted and is the most likely to need correction.
- This has led to many sayings in the alignment field:
 - “Set the toe and let it go.”
 - “Do a toe and go.”
 - “Set the toe and collect the dough.”

SETTING TOE



FIGURE 34–36 Many procedures for setting toe specify that the steering wheel be held in the straight-ahead position using a steering wheel lock, as shown. One method recommended by Hunter Engineering sets toe without using a steering wheel lock.

SETTING TOE

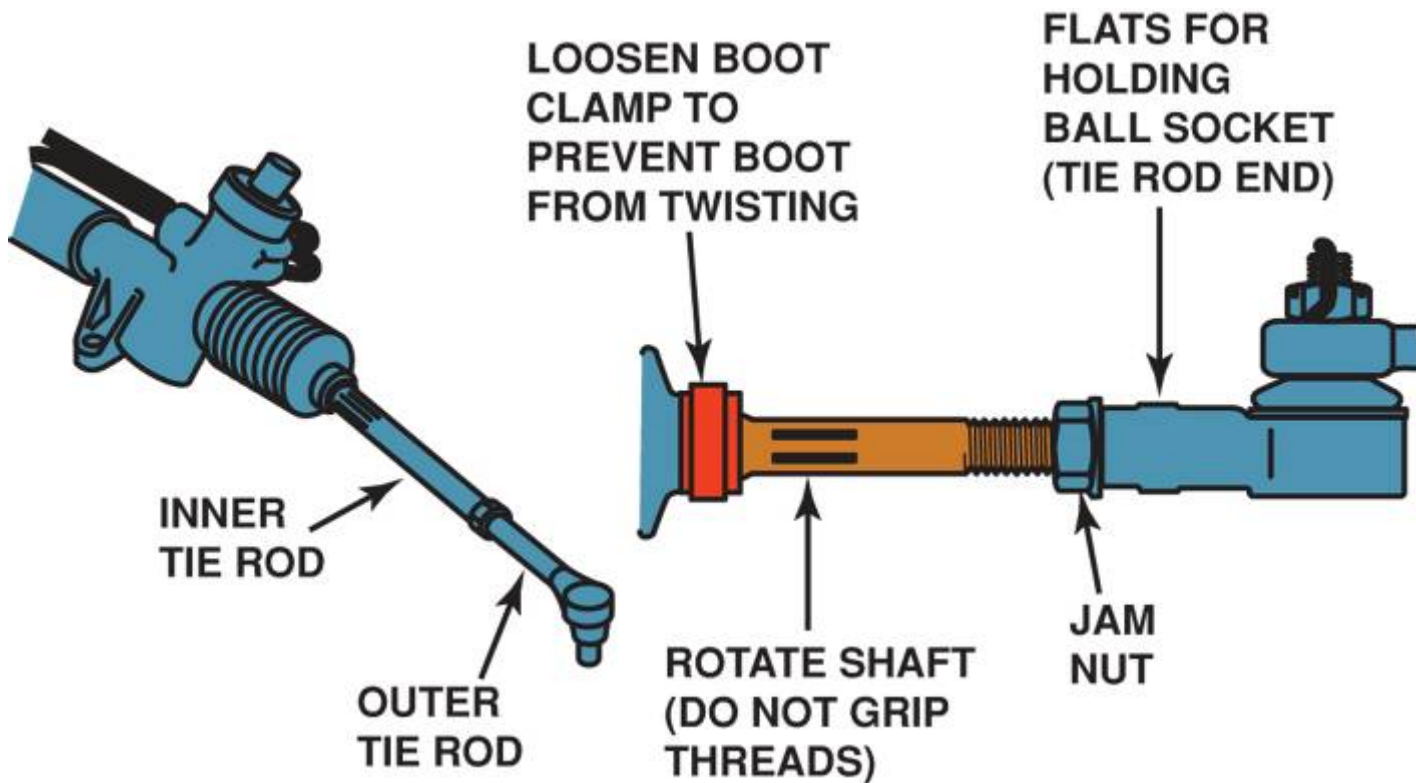


FIGURE 34–37 Adjusting toe by rotating the tie rod on a vehicle equipped with rack-and-pinion steering.

SETTING TOE

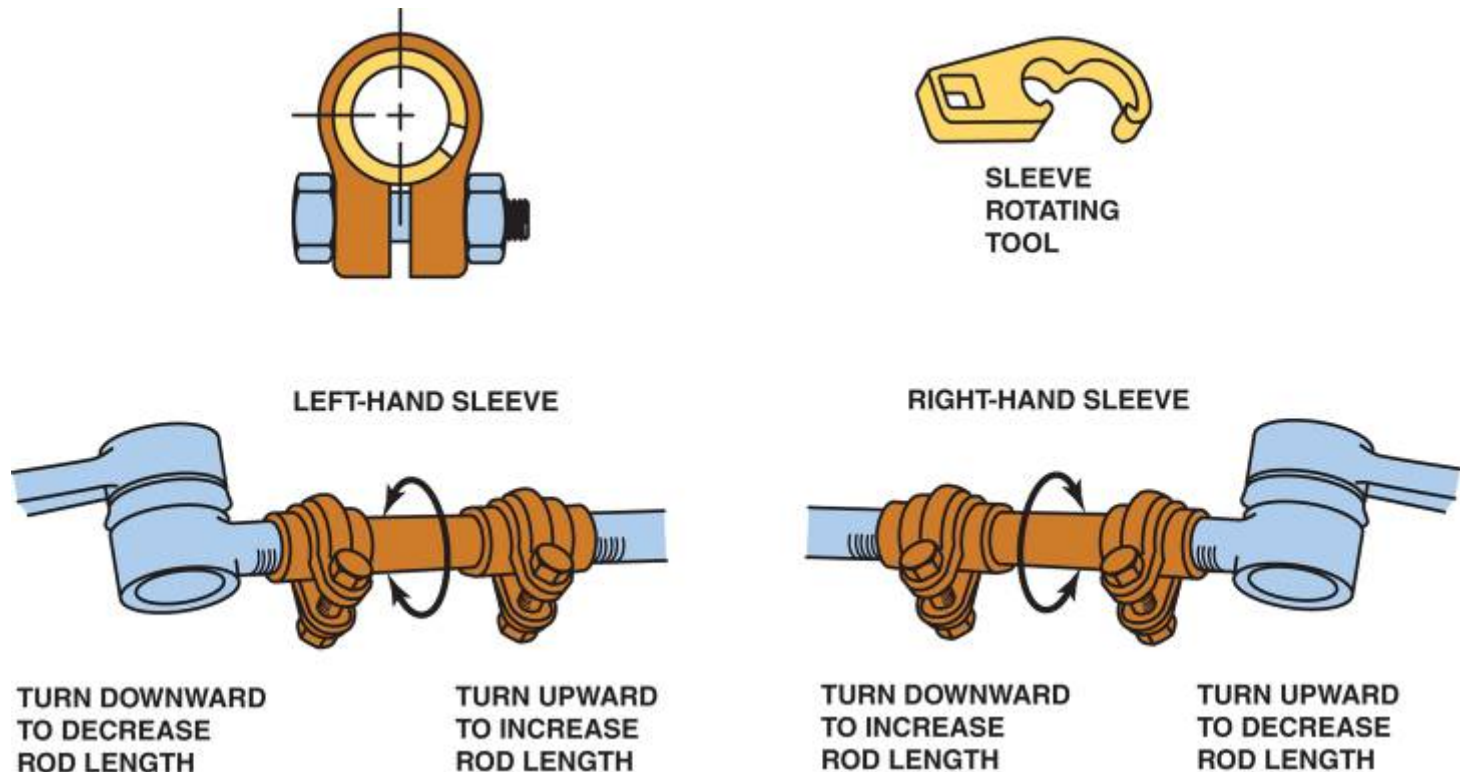


FIGURE 34–38 Toe is adjusted on a parallelogram-type steering linkage by turning adjustable tie rod sleeves. Special tie rod sleeve adjusting tools should be used that grip the slot in the sleeve and will not crush the sleeve while it is being rotated.

Race Vehicle Alignment



TECH TIP

- Vehicles used in autocrossing (individual timed runs through cones in a parking lot) or road racing usually perform best if the following alignment steps are followed:
 - **1. Increase caster (+)**
 - **2. Adjust for 1 to 2 degrees of negative camber**
 - **3. Set toe to a slight toe-out position**

SETTING TOE



FIGURE 34–39 Special tie rod adjusting tools should be used to rotate the tie rod adjusting sleeves. The tool grips the slot in the sleeve and allows the service technician to rotate the sleeve without squeezing or damaging the sleeve.

CENTERING THE STEERING WHEEL

- Centerline steering *should* be accomplished by adjusting the tie rod length on both sides of the vehicle while the toe is set.

STEERING WHEEL REMOVAL

- If the steering wheel *must* be removed, first disconnect the airbag wire connector at the base of the steering column.
- This reduces the chance of personal injury and prevents accidental airbag deployment.
- Remove the center section of the steering column by removing the retaining screws, including the inflator module on vehicles equipped with an airbag.
- After removal of the airbag inflator module, remove the steering wheel retaining nut.
- Note the locating marks on the steering wheel and steering shaft.

STEERING WHEEL REMOVAL

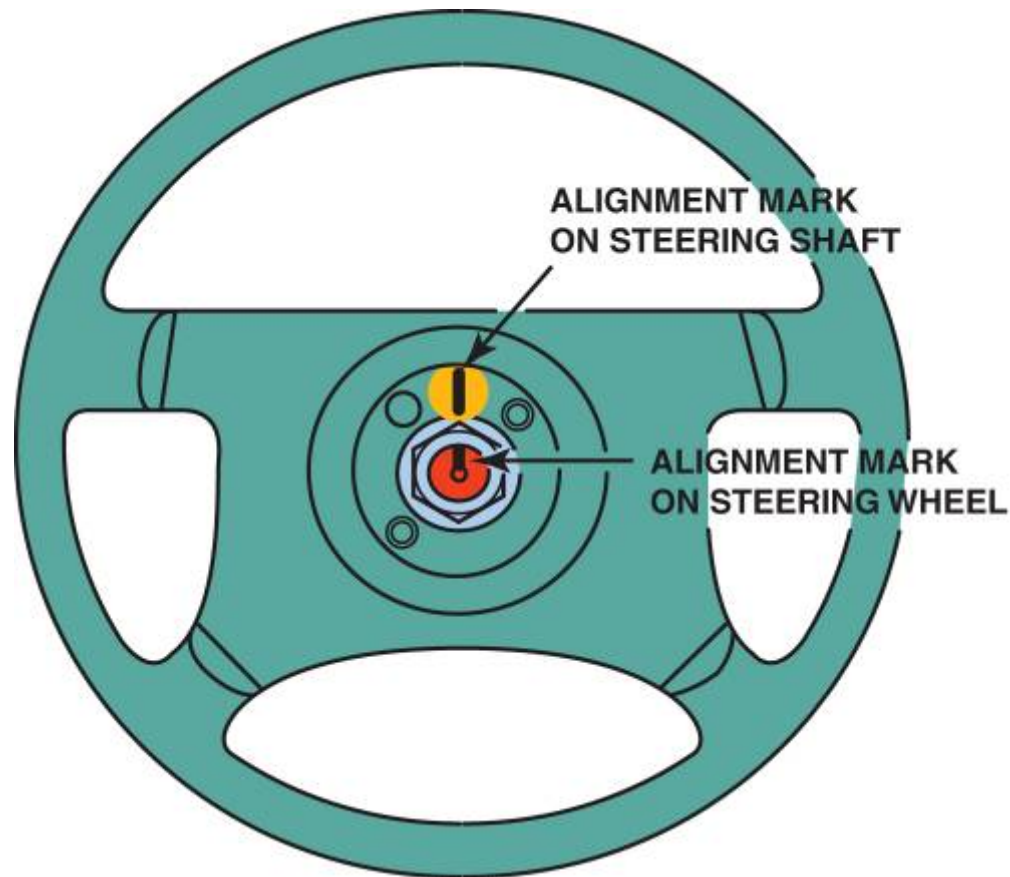


FIGURE 34–40 Most vehicles have alignment marks made at the factory on the steering shaft and steering wheel to help the service technician keep the steering wheel in the center position.

STEERING WHEEL REMOVAL

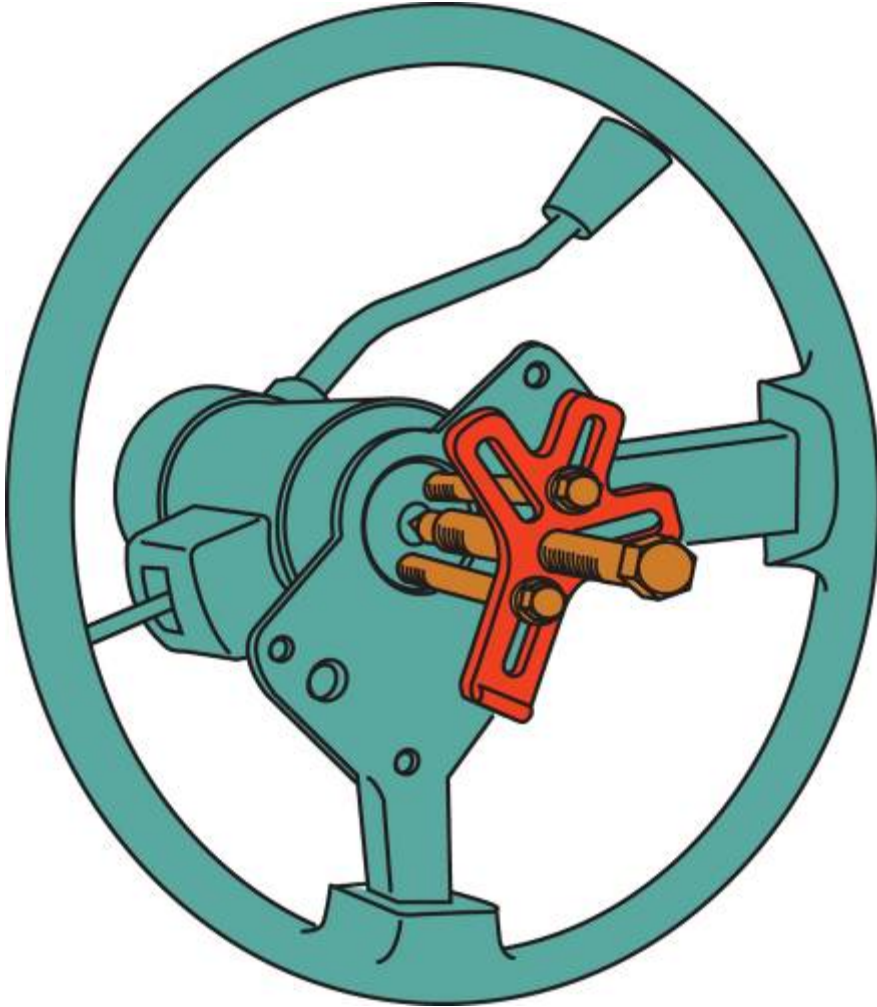


FIGURE 34–41 A puller being used to remove a steering wheel after the steering wheel retaining nut has been removed.

Locking Pliers to the Rescue



TECH TIP

- Many vehicles use a jam nut on the tie rod end. This jam nut must be loosened to adjust the toe. Because the end of the tie rod is attached to a tie rod end that is movable, loosening the nut is often difficult. Every time force is applied to the nut, the tie rod end socket moves and prevents the full force of the wrench from being applied to the nut. To prevent this movement, simply attach locking pliers (Vise Grips®) to hold the tie rod. Wedge the pliers against the control arm to prevent any movement of the tie rod. By preventing the tie rod from moving, full force can be put on a wrench to loosen the jam nut without doing any harm to the tie rod end.

Left Thrust Line, but a Pull to the Right!



REAL WORLD FIX

- A new four-door sport sedan had been aligned several times at the dealership in an attempt to solve a pull to the right. The car had front-wheel-drive and four-wheel independent suspension. The dealer rotated the tires, and it made no difference. The alignment angles of all four wheels were in the center of specifications. The dealer even switched all four tires from another car in an attempt to solve the problem.
- In frustration, the owner took the car to an alignment shop. Almost immediately the alignment technician discovered that the right rear wheel was slightly toed-in. This caused a pull to the right.

Left Thrust Line, but a Pull to the Right!



REAL WORLD FIX

- The alignment technician adjusted the toe on the right rear wheel and reset the front toe. The car drove beautifully.
- The owner was puzzled about why the new car dealer was unable to correct the problem. It was later discovered that the alignment machine at the dealership was out of calibration by the exact amount that the right rear wheel was out of specification. The car pulled to the right because the independent suspension created a rear steering force toward the left that caused the front to pull to the right. Alignment equipment manufacturers recommend that alignment equipment be calibrated regularly.

Left Thrust Line, but a Pull to the Right!

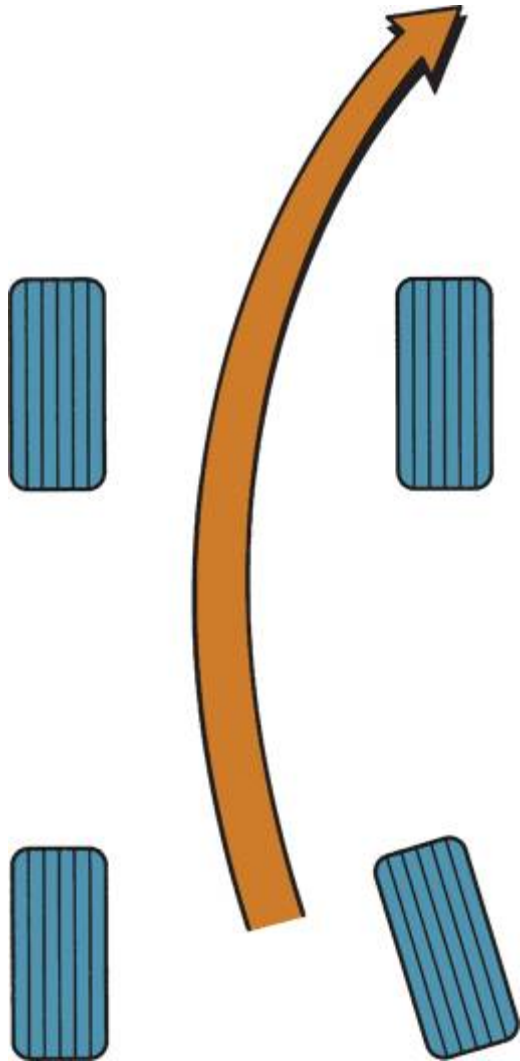


FIGURE 34–42 The toe-in on the right wheel creates a turning force toward the right.

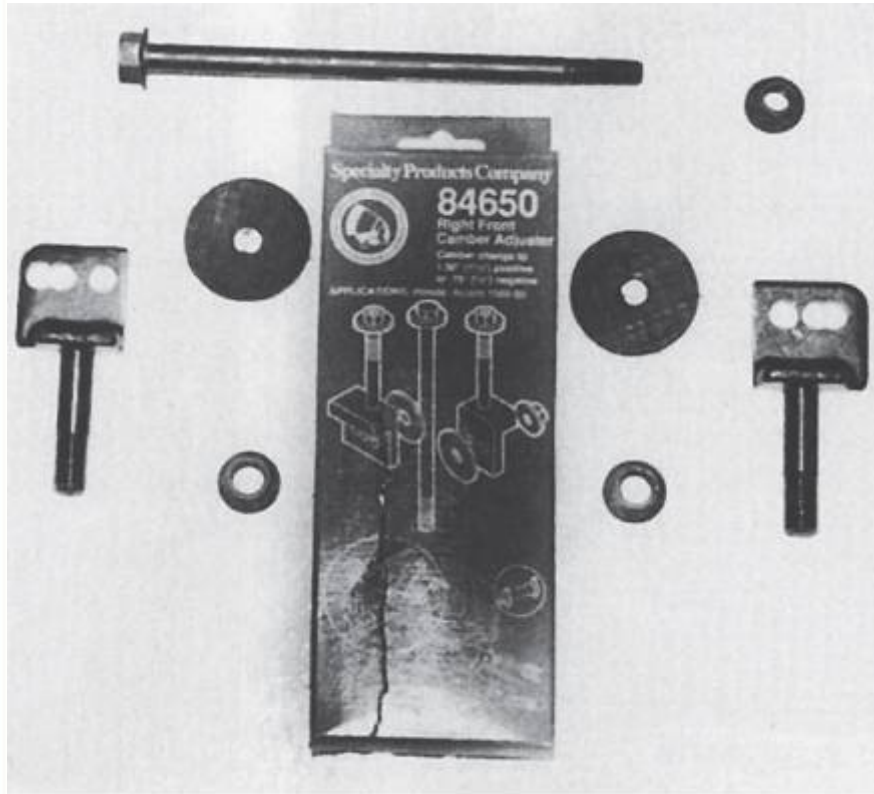
TOLERANCE ADJUSTMENT PROCEDURE

- Many vehicles are designed and built without a method to change caster or camber, or both.
- Before trying an aftermarket alignment correction kit, many technicians first attempt to correct the problem by moving the suspension attachment points within the build tolerance.
- All vehicles are constructed with a slight amount of leeway or tolerance; slight corrections can be made because bolt holes are almost always slightly larger than the bolt diameter, allowing for slight movement.
- When several fasteners are involved, such as where the powertrain cradle (subframe) attaches to the body of the front-wheel-drive vehicle, a measurable amount of alignment change (often over 1/2 degree) can be accomplished without special tools or alignment kits.

AFTERMARKET ALIGNMENT METHODS

- Accurate alignments are still possible on vehicles without factory methods of adjustment by using alignment kits or parts.
- Aftermarket alignment kits are available for most vehicles.
- Even when there are factory alignment methods, sometimes the range of adjustment is not enough to compensate for sagging frame members or other normal or accident-related faults.

AFTERMARKET ALIGNMENT METHODS



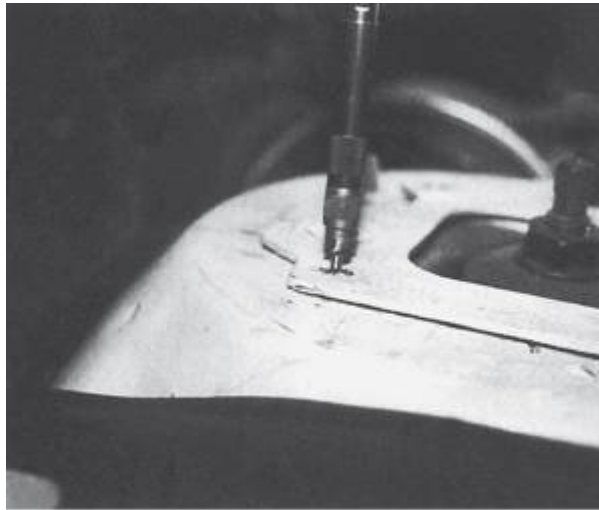
(a)



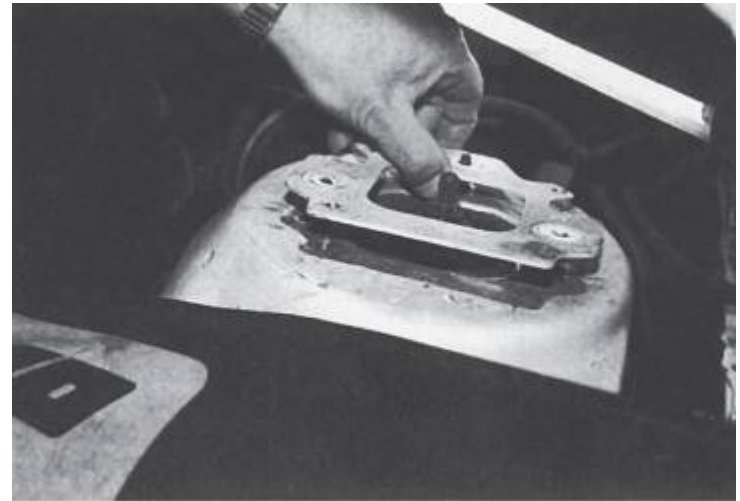
(b)

FIGURE 34–43 (a) Aftermarket camber kit designed to provide some camber adjustments for a vehicle that does not provide any adjustment. (b) Installation of this kit requires that the upper control arm shaft be removed. Note that the upper control arm was simply rotated out over the wheel pivoting on the upper ball joint.

AFTERMARKET ALIGNMENT METHODS



(a)



(b)



(c)

FIGURE 34–44 (a) The installation of some aftermarket alignment kits requires the use of special tools such as this cutter being used to drill out spot welds on the original alignment plate on a strut tower. (b) Original plate being removed. (c) Note the amount of movement the upper strut bearing mount has around the square openings in the strut tower. An aftermarket plate can now be installed to allow both camber and caster adjustment.

ALIGNING ELECTRONIC-SUSPENSION VEHICLES

- When aligning a vehicle equipped with an electronic suspension, several additional steps may be required.
- Always check service information and read carefully all on-screen instructions on the alignment machine.
- Some examples of the steps that may be needed include:
 - Verify the exact type of electronic suspension. This step could include checking the regular production order (RPO) code.
 - Check that the ride height (suspension height) is within factory specifications.
 - The steering wheel angle, as well as the radar cruise control sensor, will often need to be recalibrated using a scan tool.

ALIGNING MODIFIED VEHICLES

- If different springs were installed which in turn changes the suspension height, or if larger or smaller wheels and tires were installed, many alignment shops would reject doing an alignment.
- If a shop attempted to align a vehicle, handling and tire wear problems were common.
- Because the ride height is changed from stock factory setting, the following can occur:
 - The steering axis inclination (SAI) is now incorrect.
 - Because the steering linkage and the control arms are no longer parallel, bump steer can occur. Bump steer causes the vehicle to dart to one side when a wheel hits a bump.
 - Because the ride height changed, camber and toe also changed. The camber change is often enough to prevent it from being able to be adjusted to within specifications.

ALIGNING MODIFIED VEHICLES

- Alignment alone will not correct these concerns.
- To allow for proper handling, the following aftermarket kits and parts are available:
 - **Camber kits**
 - **Bump steer kits**

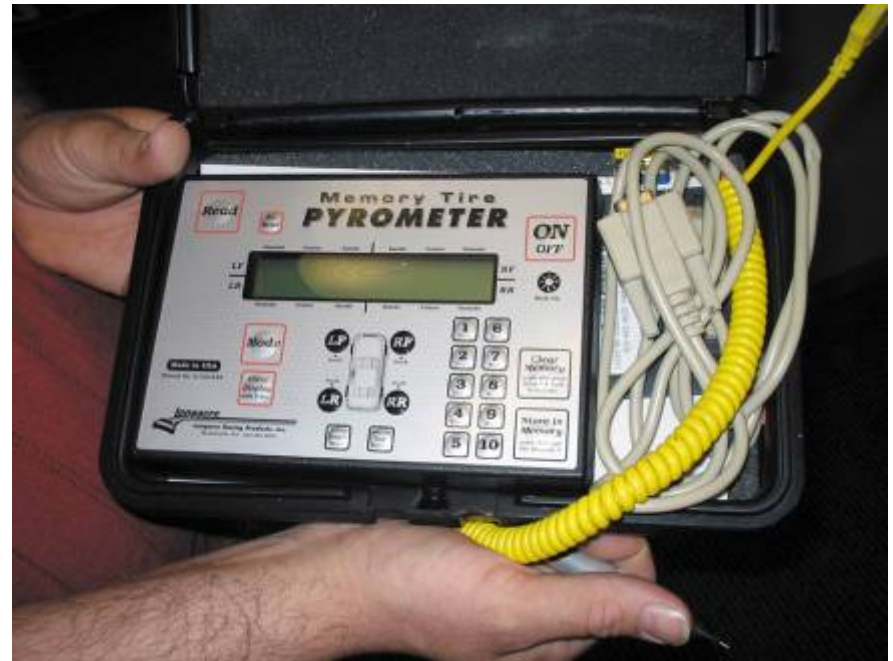


FIGURE 34–45 A typical tire temperature pyrometer. The probe used is a needle that penetrates about 1/4 inch (7 mm) into the tread of the tire for most accurate readings.

HIDDEN STRUCTURAL DAMAGE DIAGNOSIS

- Many accidents result in hidden structural damage that can cause alignment angles to be out of specification.
- If alignment angles are out of specification tolerances, then accident damage should be suspected.
- Look for evidence of newly replaced suspension parts, body work, or repainted areas of the body.
- While a body and/or frame of a vehicle can be straightened, it must be done by a knowledgeable person using bodymeasuring equipment.
- The first thing that must be done is to determine a *datum plane*.
- *Datum* means a basis on which other measurements can be based. The datum plane is the horizontal plane.

HIDDEN STRUCTURAL DAMAGE DIAGNOSIS

- **FRAME/BODY DIAGONALS**

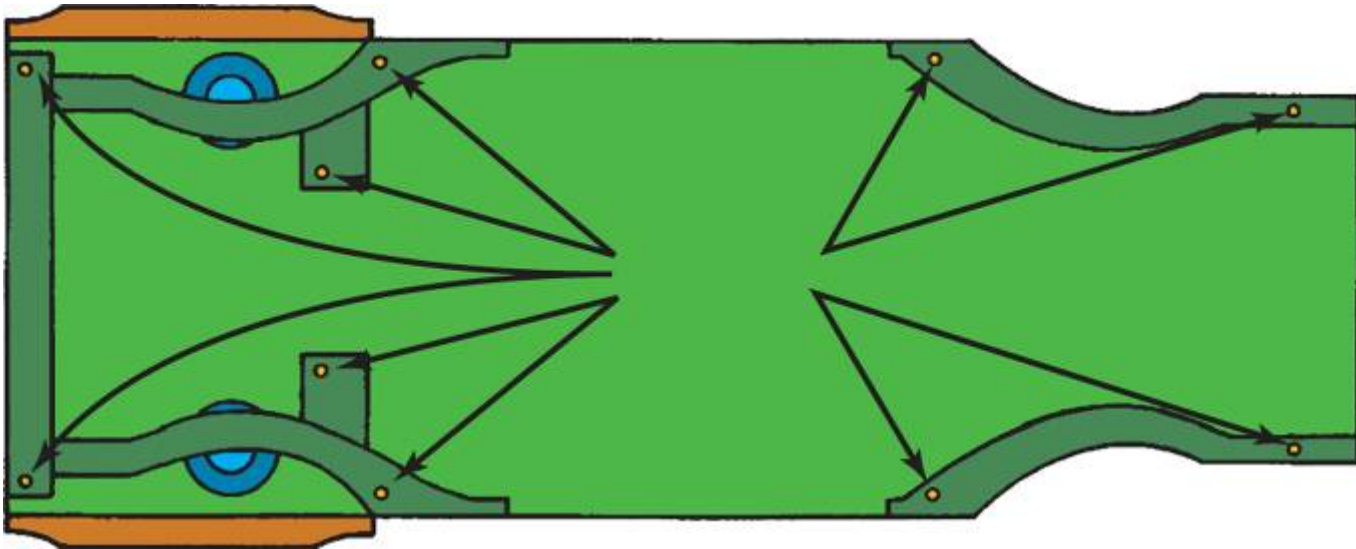


FIGURE 34–46 Jig holes used at the assembly plant to locate suspension and drivetrain components. Check service information for the exact place to measure and the specified dimensions when checking for body or frame damage.

TSBs Can Save Time



TECH TIP

- Technical service bulletins (TSBs) are issued by vehicle and aftermarket manufacturers to inform technicians of a situation or technical problem and give the corrective steps and a list of parts needed to solve the problem.
- TSBs are often released by new vehicle manufacturers to the dealership service department. They usually concern the current-year vehicle of a particular model. While many of these TSBs concern minor problems covering few vehicles, many contain very helpful solutions to hard-to-find problems.

TSBs Can Save Time



TECH TIP

- Most TSBs can be purchased directly from the manufacturer, but the cost is usually very high. TSBs can also be purchased through aftermarket companies that are licensed and available on a web site. Go to the National Automotive Service Task Force (NASTF) web site (www.NASTF.org) for a list of the web addresses for all vehicle manufacturer's sites where TSBs can be purchased directly. Factory TSBs can often save the technician many hours of troubleshooting.

ALIGNMENT GUIDE

Symptom-Based Alignment Guide

Problems	Probable Causes
Pull left/right	Uneven tire pressure, tire conicity, mismatched tires, unequal camber, unequal caster, brake drag, setback, suspension/frame sag, unbalanced power assist, bent spindle, bent strut, worn suspension components (front or rear), rear suspension misalignment.
Incorrect steering wheel position	Incorrect individual or total toe, rear wheel misalignment, excessive suspension or steering component play, worn rack-and-pinion attachment bushings, individual toe adjusters not provided.
Hard steering	Improper tire pressure, binding steering gear or steering linkage, low P/S fluid, excessive positive caster, lack of lubrication, upper strut mount(s), worn power steering pump, worn P/S belt.
Loose steering	Loose wheel bearings, worn steering or suspension components, loose steering gear mount, excessive steering gear play, loose or worn steering coupler.
Excessive road shock	Excessive positive caster, excessive negative camber, improper tire inflation, too wide wheel/tire combination for the vehicle, worn or loose shocks, worn springs.
Poor returnability	Incorrect camber or caster, bent spindle or strut, binding suspension or steering components, improper tire inflation.
Wander/instability	Incorrect alignment, defective or improperly inflated tires, worn steering or suspension parts, bent spindle or strut, worn or loose steering gear, loose wheel bearings.
Squeal/scuff on turns	Defective or improperly inflated tires, incorrect turning angle (TOOT), bent steering arms, excessive wheel setback, poor driving habits (too fast for conditions), worn suspension or steering parts.
Excessive body sway	Loose or broken stabilizer bar links or bushings, worn shocks or mountings, broken or sagging springs, uneven vehicle load, uneven or improper tire pressure.
Memory steer	Binding steering linkage, binding steering gear, binding upper strut mount, ball joint, or kingpin.
Bump steer	Misalignment of steering linkage, bent steering arm or frame, defective or sagged springs, uneven load, bent spindle or strut.
Torque steer	Bent spindle or strut, bent steering arm, misaligned frame, worn torque strut, defective engine or transaxle mounts, drive axle misalignment, mismatched or unequally inflated tires.

SUMMARY

1. Before attempting to align any vehicle, it must be checked for proper ride height (trim height), tire conditions, and tire pressures. A thorough inspection of all steering and suspension components must also be made.
2. Memory steer is a condition that causes the vehicle to lead or pull to the same direction it was last steered. Binding steering or suspension components are the most frequent causes of memory steer.
3. Torque steer is the pull or lead caused by engine torque being applied to the front wheels unevenly on a frontwheel-drive vehicle. Out-of-level drivetrain, suspension components, or tires are the most common causes of excessive torque steer.

SUMMARY

4. Lead/pull diagnosis involves a thorough road test and careful inspection of all tires.
5. There are three types of alignment: geometric centerline, thrust line, and four-wheel alignment. Only an a four-wheel alignment should be used on a vehicle with an adjustable rear suspension.
6. The proper sequence for a complete four-wheel alignment is rear camber, rear toe, front camber and caster, and front toe.

REVIEW QUESTIONS

1. List 10 prealignment checks that should be performed before the wheel alignment is checked and/or adjusted.
2. Describe the difference between a lead (drift) and a pull.
3. Explain the causes and possible corrections for torque steer.
4. Explain the causes and possible corrections for memory steer.
5. List the necessary steps to follow for a four-wheel alignment.

CHAPTER QUIZ

1. If the tie rod ends become worn, which angle is most affected?
 - a. Camber
 - b. Caster
 - c. Toe
 - d. SAI

CHAPTER QUIZ

2. Technician A says that a vehicle will pull (or lead) to the side with the most camber (or least negative camber). Technician B says that a vehicle will pull (or lead) to the side with the most positive caster. Which technician is correct?
- a. Technician A only
 - b. Technician B only
 - c. Both Technicians A and B
 - d. Neither Technician A nor B

CHAPTER QUIZ

3. Technician A says that the front toe determines the thrust angle. Technician B says that the rear toe angle determines the thrust angle. Which technician is correct?
- a. Technician A only
 - b. Technician B only
 - c. Both Technicians A and B
 - d. Neither Technician A nor B

CHAPTER QUIZ

4. Strut rods, if they are adjustable, can be used to adjust which angle?
- a. Toe
 - b. Camber
 - c. Caster
 - d. Toe-out on turns

CHAPTER QUIZ

5. If metal shims are used for alignment adjustment in the front, they adjust _____.
- a. Camber
 - b. Caster
 - c. Toe
 - d. Both a and b

CHAPTER QUIZ

6. Which angle is largest?

- a. 0.55 degrees
- b. $\frac{1}{4}$ degree
- c. 45 minutes
- d. $\frac{1}{2}$ degree

CHAPTER QUIZ

7. The vehicle above will _____.
- a. Pull toward the right and feather-edge both tires
 - b. Pull toward the left
 - c. Wear the outside of the left tire and the inside of the right tire
 - d. None of the above

Use the following information to answer question 7:

Specifications:	Min.	Preferred	Max.
Camber (degree)	0	1.0	1.4
Caster (degree)	.8	1.5	2.1
Toe (inch)	-.10	.06	.15
Results:	L	R	
Camber (degree)	-.1	.6	
Caster (degree)	1.8	1.6	
Toe (inch)	1.12	+.12	

CHAPTER QUIZ

8. The vehicle above will _____.
- a. Pull toward the left
 - b. Pull toward the right
 - c. Wander
 - d. Lead to the left slightly

Use the following information to answer questions 8 and 9:

Specifications:	Min.	Preferred	Max.
Camber (degree)	- 1/4	+ 1/2	1
Caster (degree)	0	+2	+4
Toe (inch)	- 1/16	1/16	3/16
Results:	L	R	
Camber (degree)	-0.3	-0.1	
Caster (degree)	3.6	1.8	
Toe (inch)	- 1/16	+ 1/32	

CHAPTER QUIZ

9. The vehicle above will _____.
- a. Wander
 - b. Wear tires, but will not pull
 - c. Will pull, but not wear tires
 - d. Pull toward the left and cause feather-edge tire wear

Use the following information to answer questions 8 and 9:

Specifications:	Min.	Preferred	Max.
Camber (degree)	- 1/4	+ 1/2	1
Caster (degree)	0	+2	+4
Toe (inch)	- 1/16	1/16	3/16
Results:	L	R	
Camber (degree)	-0.3	-0.1	
Caster (degree)	3.6	1.8	
Toe (inch)	- 1/16	+ 1/32	

CHAPTER QUIZ

10. Which alignment angle is most likely to need correction and cause the most tire wear?

- a. Toe
- b. Camber
- c. Caster
- d. SAI/KPI