

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Service Category Suspension

Section Alignment/Handling Diagnoses

Market USA

Toyota Supports
ASE Certification 

Applicability

YEAR(S)	MODEL(S)	ADDITIONAL INFORMATION
2002 - 2021	4Runner, 4Runner, 86, Avalon, Avalon HV, Avanza, C-HR, Camry, Camry HV, Celica, Corolla, Corolla BR-Prod, Corolla Hatchback, Corolla HV, Echo, FJ Cruiser, Hiace, Highlander, Highlander HV, Hilux, iA, iM, Land Cruiser, Matrix, Mirai, Mirai (Canada), MR2 Spyder, Prius, Prius C, Prius PHV, Prius Prime, Prius V, RAV4, RAV4 EV, RAV4 HV, RAV4 Prime, Sequoia, Sienna, Solara, Supra, Tacoma, Tundra, Venza, Yaris, Yaris HB MEX-Prod, Yaris R, Yaris SD MEX-Prod, Yaris THAI-Prod	

SUPERSESION NOTICE

The information contained in this bulletin supersedes Service Bulletin Nos. ST005-01, SU001-08, and T-SB-0391-08.

The aforementioned bulletins are obsolete, and any printed versions should be discarded. Be sure to review the entire content of this service bulletin before proceeding.

Introduction

This Service Bulletin provides best practice procedures for vehicle pulling complaint, diagnosis, and repair for 2002 – 2021 model year Toyota vehicles.

This information supplements Repair Manual procedures when the symptoms are:

- Vehicle Pulling: The vehicle moves to the right or left when the driver holds the steering wheel while driving straight ahead without exerting steering effort.
- Steering Wheel Off Center: The vehicle travels straight, but the steering wheel is not pointed straight ahead. The vehicle is not pulling.

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Introduction (continued)

Before repairing a vehicle pulling to one side, it is necessary to clearly identify the cause of the pulling condition. Frequently, pulling to one side is diagnosed as a wheel alignment concern. However, the actual cause may be related to the lateral force generated by the tires, vehicle damage, road crown or worn components. Performing a wheel alignment when tire force is the cause could result in the wheel alignment being set at a value outside of specifications. This could then cause other problems such as uneven tire wear, etc.

A customer may notice a pull to the left when in the left lanes of travel and notice a pull to the right or no pull when traveling in the right lanes of travel on the very same section of roadway. This road crown effect is environmental and cannot be corrected with suspension adjustments or any other wheel or tire modification discussed in this bulletin.

NOTE

Before proceeding with these practices, a vehicle should be thoroughly inspected for damaged or worn components and collision damage. Inspect the tires, wheels, suspension and steering components, as well as the body/frame because these may affect the vehicle handling.

Warranty Information

OP CODE	DESCRIPTION	TIME	OFP	T1	T2
N/A	Not Applicable to Warranty	—	—	—	—

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Contents

Wheel Alignment and Tire Characteristics	4
Road Crown	7
Repair Procedure Flow Chart	8
Road Test.....	9
Repair Procedure	9
Troubleshooting	9
Vehicle Pulling Caused by Tire Conicity	12
Vehicle Pulling Caused by Wheel Alignment.....	14
Steering Wheel Off Center Adjustment	18

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

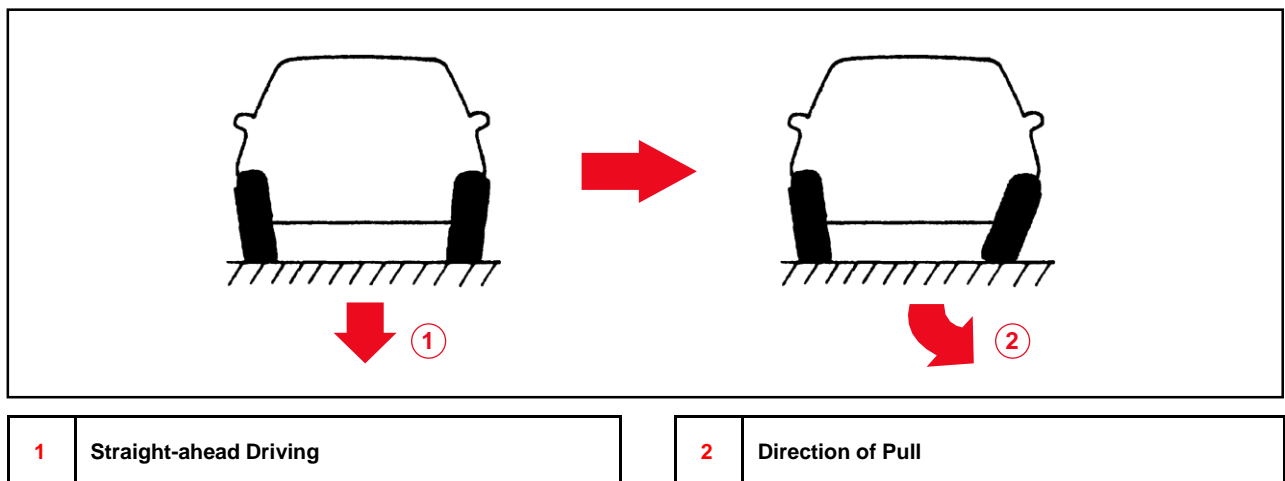
Wheel Alignment and Tire Characteristics

Relationship Between Wheel Alignment and Vehicle Pulling to One Side

When the cross camber or caster of the front wheel alignment is large, it can cause vehicle pulling.

WHEEL ALIGNMENT	DIRECTION OF VEHICLE PULL
Camber	Vehicle Pulls in Direction of Wheel with Large Camber Value (See Figure 1)
Caster	Vehicle Pulls in Direction of Wheel with Small Caster Value (See Figure 2)

Figure 1. Camber

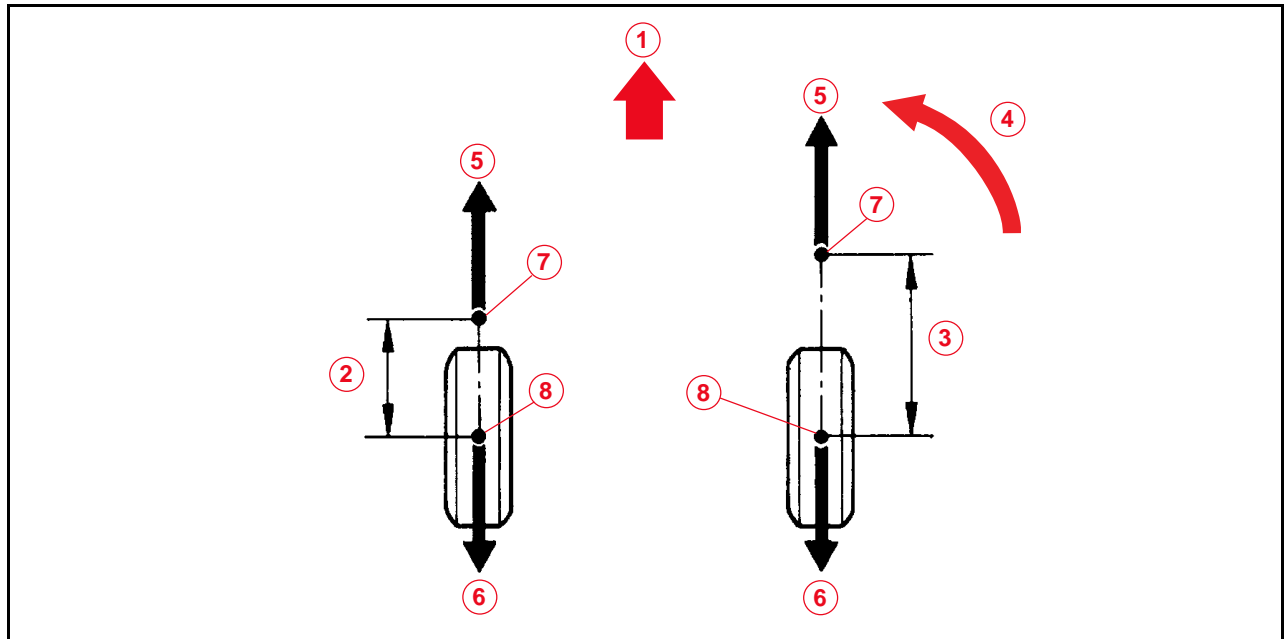


Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Wheel Alignment and Tire Characteristics (continued)

Relationship Between Wheel Alignment and Vehicle Pulling to One Side (continued)

Figure 2. Caster



1	Front
2	Caster Trail (Small)
3	Caster Trail (Large)
4	Direction of Pull

5	Driving Force
6	Reactive Force
7	Steering Axis
8	Center of Tire (Road Contact Area)

If the cross camber or caster is within the specified range (30' or less), noticeable vehicle pulling will not occur due to side-to-side differences in camber or caster.

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Wheel Alignment and Tire Characteristics (continued)

Relationship Between Tire Characteristics and Vehicle Pulling to One Side (continued)

When radial tires are rotating, they have the characteristic of generating force in the lateral direction between the tire and the road surface. This lateral force is comprised of two factors:

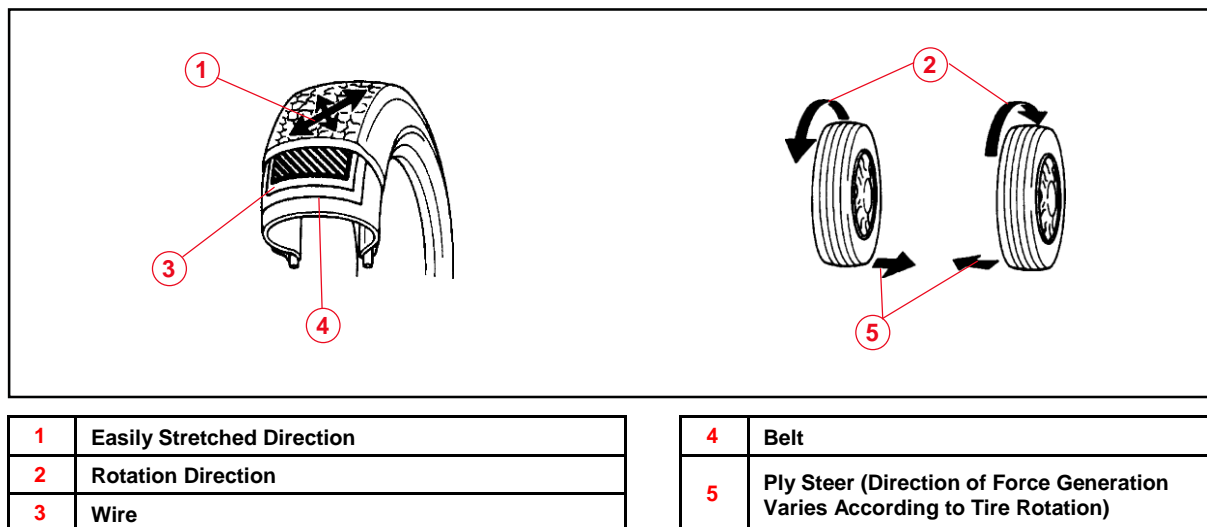
- Ply steer, which changes direction according to the rotation direction of the tires.
- Conicity, which is generated in a fixed direction regardless of the tire rotation direction.

If these lateral forces are too strong, vehicle pulling will occur.

Ply Steer:

Lateral force due to ply steer is produced by the construction of the belts inside the tire tread. With radial tires, the wire of the belt is slanted as shown in the illustration below. Thus, it is in the lateral direction that tire tread easily changes shape (stretches), and lateral force is generated between the tire and the road surface in the lateral direction.

Figure 3. Ply Steer



NOTE

Lateral force from ply steer prevents vehicle drift caused by road crown, so in many cases lateral force to the left is provided to compensate for road crown to the right.

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Wheel Alignment and Tire Characteristics (continued)

Relationship Between Tire Characteristics and Vehicle Pulling to One Side (continued)

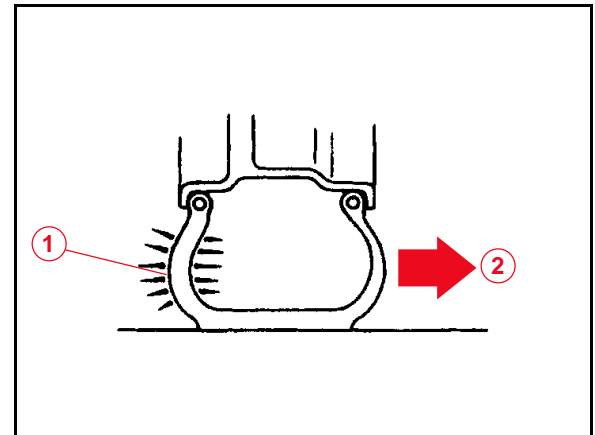
Conicity:

Conicity is lateral force resulting from uneven formation of the left and right sides of the tire. The direction the lateral force is exerted depends on the hardness of the side walls and the difference in height between the left/right sides of the tire. The greatest effect on vehicle pulling is most often the lateral force caused by tire conicity.

NOTE

When vehicle pulling is due to conicity, the amount of drift can be reduced, and the direction of drift can be changed by changing the location of the tire or reversing the tire when installing it on the wheel.

Figure 4.



1	Hard Part
2	Conicity (Direction is Fixed Regardless of Direction of Tire Rotation)

Road Crown

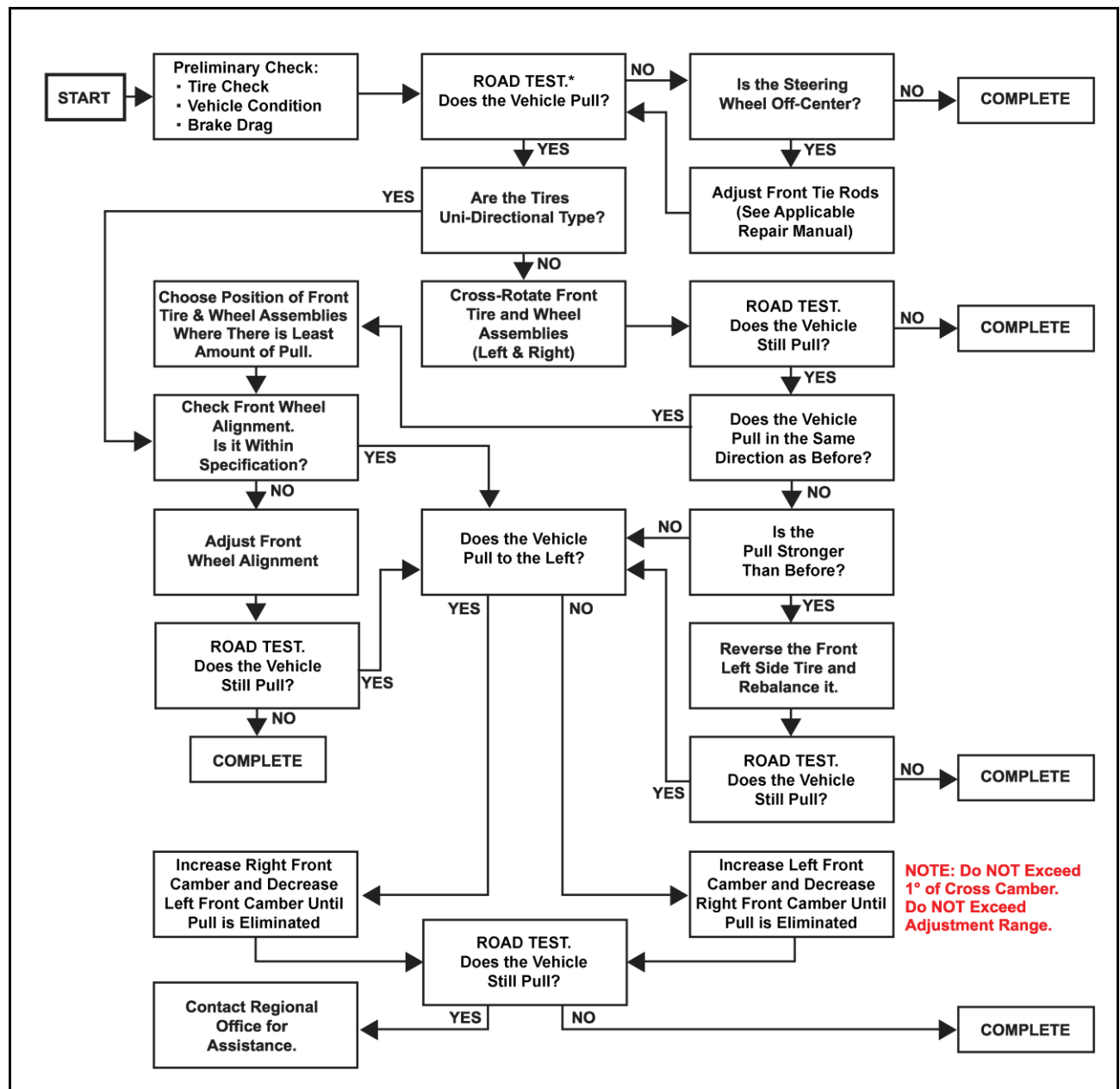
Road crown refers to the 1 – 2% slope built into most roadways for water drainage. It is most commonly toward the right side but may go toward either side, depending on the road design. When operated on crowned roads, many cars that travel straight on a level road (0% road crown) will experience a significant pull, commonly to the right, when operated on crowned roads.

Interstate and other multi-lane highways also have road crown. They may be crowned to drain water toward the center divider to the left, as well as toward the shoulder to the right. A customer may notice a pull to the left when in the left lanes of travel and a pull to the right or no pull when traveling in the right lanes of travel on the same section of roadway. This road crown effect is environmental and cannot be corrected with suspension adjustments or any other wheel or tire modification discussed in this bulletin. Road crown and its effects should be explained to the customer.

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure Flow Chart

Figure 5.



*See the Road Test section on the following page.

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Road Test

Select a flat road (See the Road Crown section) where the vehicle can be driven in a straight line for 109 yards (100 m) at a constant speed of 35 mph (56 km/h), about 6.5 seconds. Please confirm safety and set the steering wheel to its straight position. Drive the vehicle in a straight line for 109 yards (100 m) at a constant speed of 35 mph (56 km/h) without exerting steering effort on the steering wheel. This road test may also be performed at a constant speed of 62 mph (100 km/h), about 3.5 seconds, if road conditions, speed limits, and availability permit. (Before road testing, turn off driving support systems, if equipped, such as Lane Keep Assist and Lane Tracing Assist.)

- Steering wheel off center: The vehicle goes straight (e.g., drifts less than 5 feet [1.5 m]) during the road test, but the steering wheel has some angle. The vehicle is not pulling.
- Vehicle pulls to one side: The vehicle deviates laterally more than 5 feet (1.5 m) during the road test.
- If the vehicle deviates laterally 5 feet (1.5 m) or less, it is within Toyota specifications.

Repair Procedure

IMPORTANT NOTICE

BEFORE repairing a vehicle pulling to one side, it is necessary to clearly identify the cause of the pulling condition. Frequently, the cause of the vehicle pulling to one side is diagnosed as wheel alignment. However, the actual cause may be lateral force generated by the tires. Performing wheel alignment when tire force is the cause could result in the wheel alignment being set at a value outside of specifications. This would then cause other problems such as uneven tire wear, etc.

Troubleshooting

First determine why the vehicle is pulling to one side and then decide which repairs to make.

1. Perform the following checks and correct as necessary:
 - A. Check the tires for size, wear, and proper inflation pressure.
 - B. Check the vehicle for conditions that could cause pulling such as collision damage, impact damage to wheels or tires, bent or worn suspension or steering parts, aftermarket parts, vehicle modifications, etc.

NOTE

Tilting of the vehicle produces a left/right difference in the camber and caster and can cause vehicle pulling to one side.

- C. Check the brakes for dragging.

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

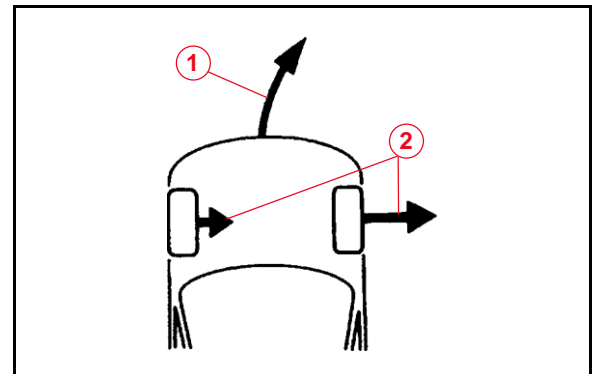
Repair Procedure (continued)

Troubleshooting (continued)

2. Confirm problem symptoms.
 - A. With the customer accompanying you, drive the vehicle to confirm if the customer's complaint involves vehicle pulling to one side or an off-center steering wheel.
 - B. Is the problem an off-center steering wheel?
 - **YES** — Go to the Steering Wheel Off Center Adjustment subsection.
 - **NO** — Continue to step 3.

3. Decide if vehicle pulling is due to wheel alignment or tires.
 - A. Switch the left and right front tires (if the tires are non-unidirectional).
 The direction of lateral force from tire conicity becomes reversed when the left and right tires are switched. Therefore, if the pulling direction changes when the tires are switched, it can be concluded that vehicle pulling is caused by tire conicity.
 - The vehicle is pulled to the right by the lateral force exerted to the right.

Figure 6. Original Tire Positions



1	Vehicle Pulling Direction (Right)
2	Lateral Force by Conicity

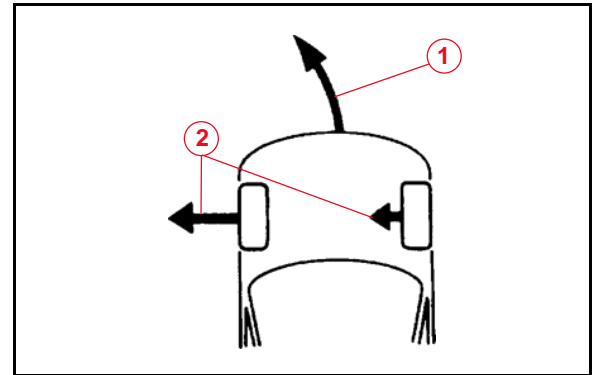
Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Troubleshooting (continued)

- The direction of the tires which exerted lateral force to the right has been changed. The tires now exert lateral force to the left, and the vehicle now pulls to the left.

Figure 7. Tires Switched



1	Vehicle Pulling Direction (Left)
2	Lateral Force by Conicity

If the pulling direction does NOT change AFTER the front tires are switched, the cause of vehicle pulling is NOT tire conicity. In this case, the likely cause is a front wheel alignment condition.

- B. Conduct a road test to check whether the direction that the vehicle pulls has changed.

Table 1.

SYMPTOM	PROBABLE CAUSE	CORRECTIVE ACTION
Vehicle Pulling Is Eliminated	Tire Conicity	The Repair Procedure is Complete, Vehicle Pulling is Caused by Tire Conicity
Vehicle Pulling Direction Is Reversed		Continue to the Vehicle Pulling Caused by Tire Conicity Subsection
No Change in the Vehicle Pulling Condition	Front Wheel Alignment	Go to the Vehicle Pulling Caused by Wheel Alignment Subsection

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Vehicle Pulling Caused by Tire Conicity

When it is determined by troubleshooting that the vehicle pulling to one side is caused by tire conicity, perform repairs according to the following procedures.

NOTE

An indication of tire conicity as a cause: When the front tires are switched, the pulling direction changes.

1. Remove the front left tire from the wheel and reverse the tire, if the tire is not unidirectional. Then, perform a road test and check for changes in the pulling direction.

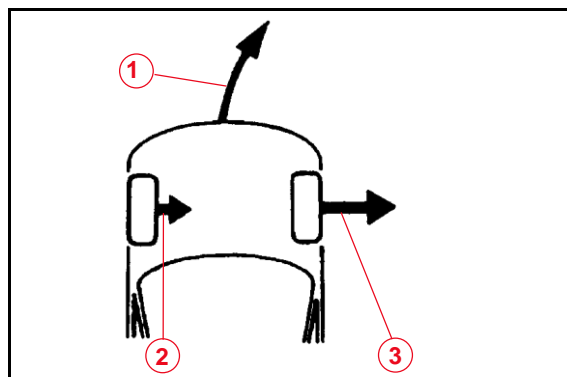
HINT

By performing this operation, it can be checked whether the left or right tire exerts a stronger lateral force. Either tire can be reversed. Shown below is an example of the left tire reversed.

- A. If the vehicle pulls in the same direction, go to step 2.

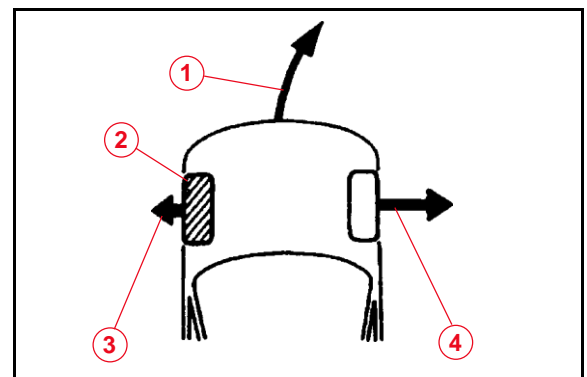
The lateral force generated by the right front tire is greater than the left tire, so the vehicle is pulling due to the lateral force of the right tire.

Figure 8. Original Tire Positions



1	Vehicle Pulling Direction
2	Lateral Force by Conicity (Smaller)
3	Lateral Force by Conicity (Larger)

Figure 9. Left Tire Reverse Installation



1	Vehicle Pulling Direction (Same Direction)
2	Reversed
3	Lateral Force by Conicity (Smaller)
4	Lateral Force by Conicity (Larger)

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

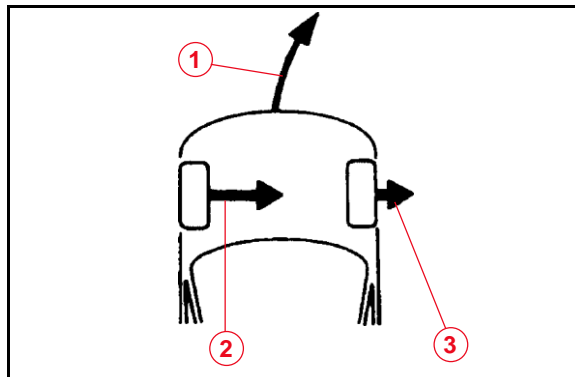
Repair Procedure (continued)

Vehicle Pulling Caused by Tire Conicity (continued)

- B. If the vehicle pulls in the opposite direction, go to step 2.

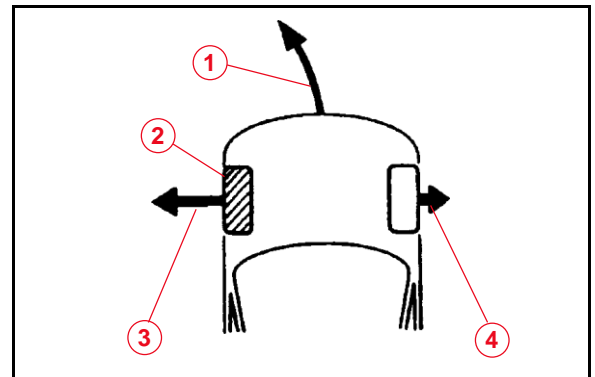
The lateral force generated by the left front tire is greater than the right tire, so the vehicle is pulling due to the lateral force of the left tire.

Figure 10. Original Tire Positions



1	Vehicle Pulling Direction
2	Lateral Force by Conicity (Larger)
3	Lateral Force by Conicity (Smaller)

Figure 11. Left Tire Reverse Installation



1	Vehicle Pulling Direction (Opposite Direction)
2	Reversed
3	Lateral Force by Conicity (Larger)
4	Lateral Force by Conicity (Smaller)

- C. Has the vehicle pull been eliminated?

- **YES** — The repair is now complete. The lateral force generated by the left and right front tires is virtually the same, so the lateral force is neutralized, and the vehicle travels straight ahead.
- **NO** — Continue to step 2.

2. Rotate the LARGER lateral force front tire with the rear tire and check the change in the vehicle pulling if the front and rear wheel and tire assemblies are the same size.

NOTE

By shifting the front tire with the larger lateral force to the rear, the vehicle pulling level is usually reduced.

Has the vehicle pull been eliminated?

- **YES** — The repair is now complete.
- **NO** — Continue to the Vehicle Pulling Caused by Wheel Alignment subsection.

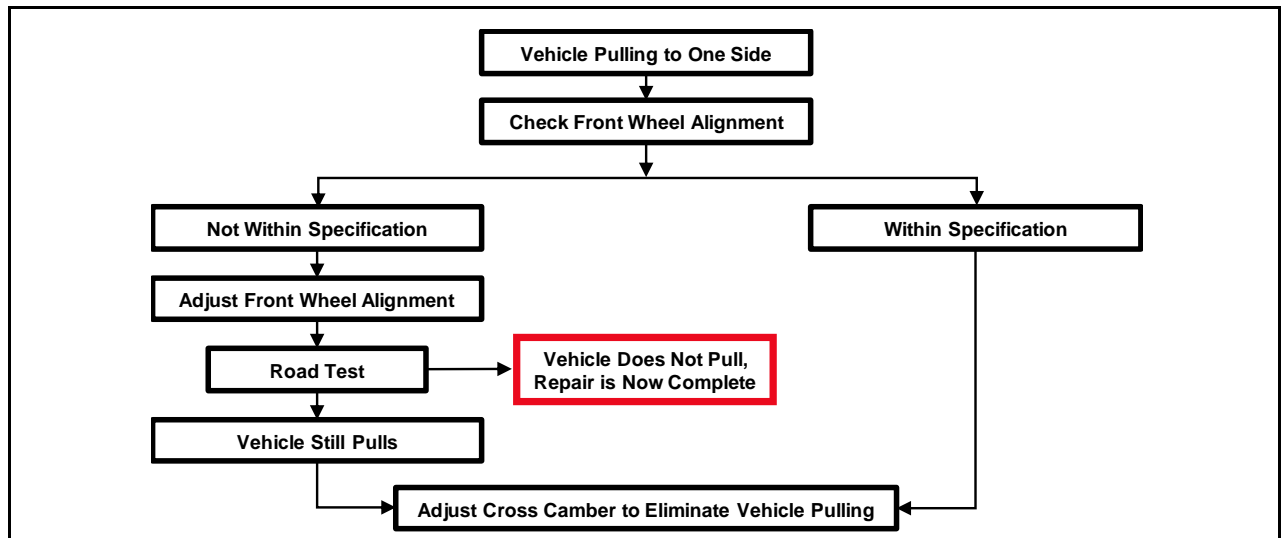
Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Vehicle Pulling Caused by Wheel Alignment

When it is determined by troubleshooting that the vehicle pulling to one side is caused by wheel alignment, perform repairs according to the following procedure.

Figure 12.



Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Vehicle Pulling Caused by Wheel Alignment (continued)

1. Adjust cross camber to eliminate vehicle pulling.

HINT

If the tires are placed in the same positions they were in during tire rotation when the least amount of vehicle pulling occurred, wheel alignment can be performed with a minimal amount of adjustment.

Table 2.

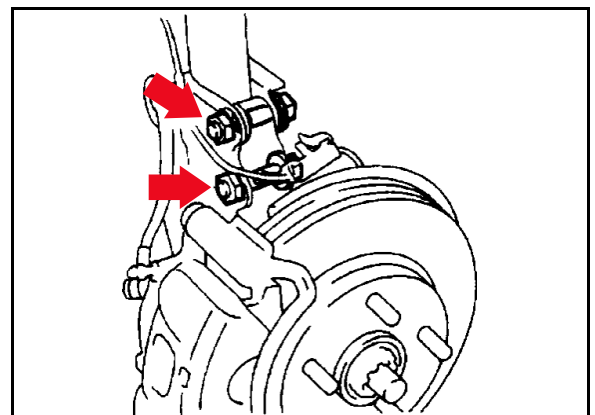
WHEN THE VEHICLE PULLS TO THE LEFT	WHEN THE VEHICLE PULLS TO THE RIGHT
Increase Right Front Camber and Decrease Left Front Camber Until Vehicle Pulling Is Eliminated	Increase Left Front Camber and Decrease Right Front Camber Until Vehicle Pulling Is Eliminated

NOTE

- Keep the cross camber within 1° or less.
- Keep the camber of each wheel within specifications (+/-45' of center value).
- If adjustment exceeds the specifications, uneven tire wear will result.
- AFTER the camber has been adjusted, inspect the toe-in.
- The method of camber adjustment differs for different models, so please refer to the applicable model and model year Repair Manual. Steps 2 – 10 are samples from the [Sienna Repair Manual](#).

2. Remove the front wheels and ABS speed sensor clamp.
3. Remove the two nuts on the lower side of the shock absorber.

Figure 13.



Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Vehicle Pulling Caused by Wheel Alignment (continued)

4. Coat the threads of the nuts with engine oil.

5. Temporarily install the two nuts.

6. Adjust the camber by pushing or pulling the lower side of the shock absorber in the direction in which the camber adjustment is required.

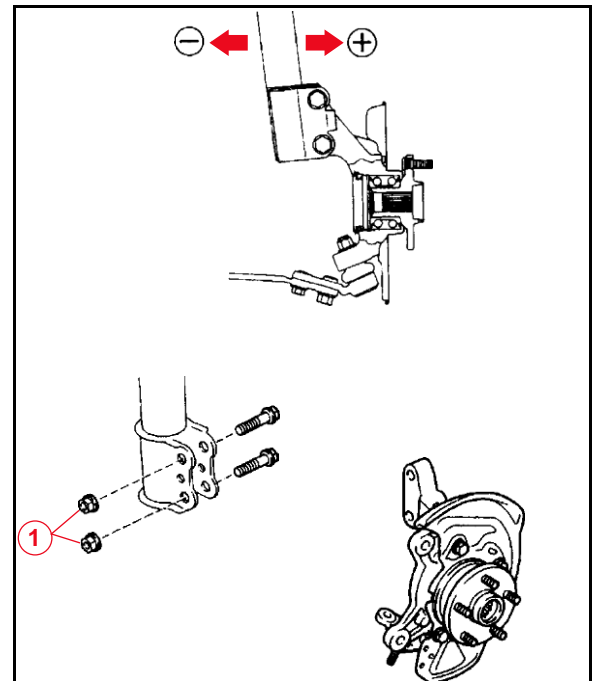
7. Tighten the nuts.

Torque: 210 N*m (2150 kgf*cm, 155 ft*lbf)

8. Install the front wheels.

Torque: 104 N*m (1050 kgf*cm, 77 ft*lbf)

Figure 14.



1

Nuts

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices





Repair Procedure (continued)

Vehicle Pulling Caused by Wheel Alignment (continued)

9. Check the camber.

NOTE

Adjusting value for the **set bolts** is 6' – 30' (0.1° – 0.5°). When making an adjustment of more than 45', replace the upper and lower steering knuckle set bolts with the **adjusting bolts**. If the camber is NOT within the specification, use the table shown to estimate how much additional camber adjustment will be required, and select the appropriate camber adjusting bolt.

ADJUSTING VALUE	SET BOLT		ADJUSTING BOLT					
			1 DOT 		2 DOTS 		3 DOTS 	
	1	2	1	2	1	2	1	2
15'	X			X				
30'	X					X		
45'	X							X
1°00'			X					X
1°15'					X			X
1°30'							X	X

10. Follow steps 1 – 8 again. Between steps 2 and 3, exchange one or two selected bolts.

HINT

When exchanging the two bolts, exchange one bolt at a time.

11. Road test the vehicle to ensure the vehicle pull has been eliminated.
12. Has the vehicle pull been eliminated?
 - **YES** — The repair is now complete.
 - **NO** — Repeat the steps in the Vehicle Pulling Caused by Wheel Alignment subsection.

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

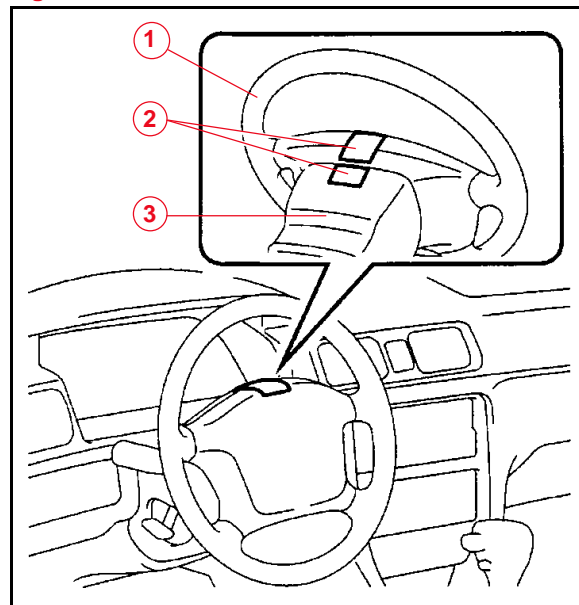
Repair Procedure (continued)

Steering Wheel Off Center Adjustment

This section shows the procedure to correct steering wheel off center for rack and pinion type steering systems. An alignment rack is not needed.

1. Inspect steering wheel off center.
 - A. Apply masking tape to the top center of the steering wheel and steering column upper cover.

Figure 15.



1	Steering Wheel
2	Masking Tape
3	Steering Column Upper Cover

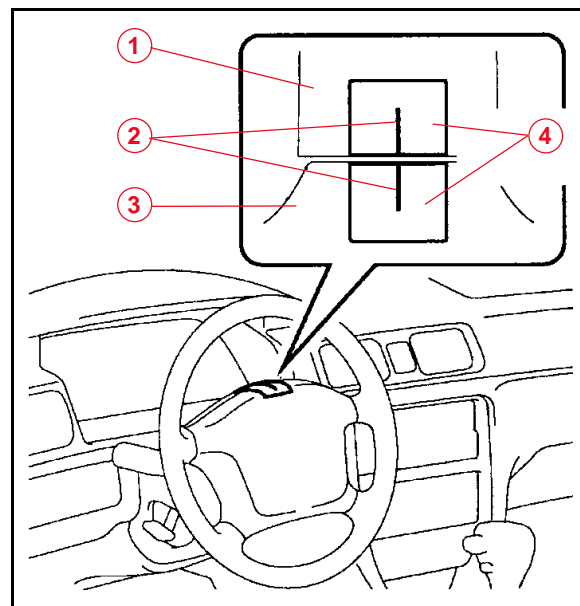
Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Steering Wheel Off Center Adjustment (continued)

- B. Drive the vehicle in a straight line for 330 feet (100 m), at a constant speed of 35 mph (56 km/h) and hold the steering wheel to maintain the course.
- C. Draw a line on the masking tape as shown in Figure 16.

Figure 16.



1	Steering Column Upper Cover
2	Marked Line
3	Steering Wheel
4	Masking Tape

Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Steering Wheel Off Center Adjustment (continued)

- D. Turn the steering wheel to its straight position.

HINT

Use the upper surface of the steering wheel, steering spoke and SRS airbag line (when present) as a reference.

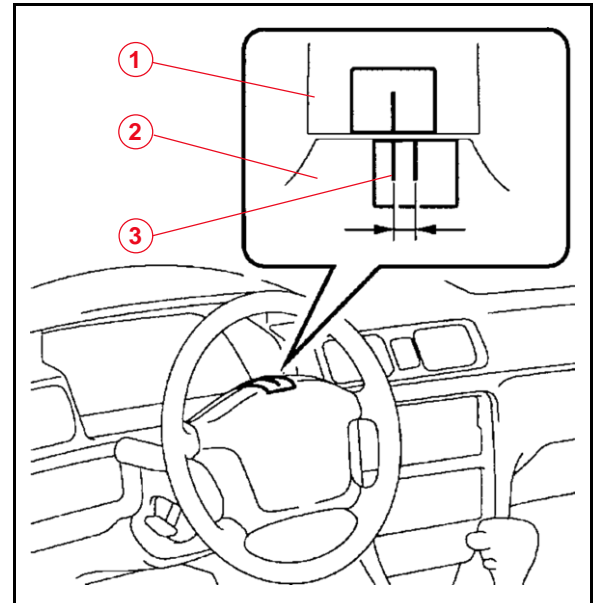
- E. Draw a new line on the masking tape of the steering wheel as shown in Figure 17.

- F. Measure the distance (in millimeters) between the two lines drawn on the steering wheel.

HINT

Make a note of this measurement.

Figure 17.



1	Steering Column Upper Cover
2	Steering Wheel
3	New Marked Line

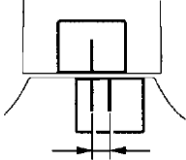

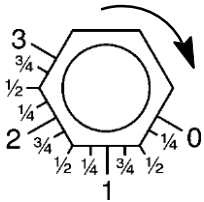
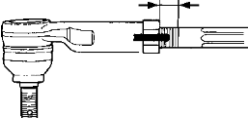
Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Steering Wheel Off Center Adjustment (continued)

2. Determine the amount and direction of tie rod adjustment.
 - A. Use the measurement made in step 1F to determine the amount of adjustment necessary to the tie rod ends.

Table 3.

DISTANCE MEASURED BETWEEN TWO LINES DRAWN ON STEERING WHEEL	APPROXIMATE ANGLE STEERING WHEEL IS OFF CENTER (BASED ON MEASURED VALUE)	AMOUNT OF ROTATION OF EACH TIE ROD END (ROTATE EACH ROD END SAME AMOUNT BUT IN DIFFERENT DIRECTIONS)		CHANGE IN LENGTH OF TIE ROD END (ONE GETS LONGER, THE OTHER GETS SHORTER)
				
MEASUREMENT (mm)	APPROXIMATE ANGLE (deg)	STARTING POSITION	ENDING POSITION	VERIFICATION MEASUREMENT (mm)
1.0	1.0	0	1/2	±0.125
2.0	2.0	0	1	±0.2
3.0	3.0	0	1-1/2	±0.375
4.0	4.0	0	2	±0.5
5.0	5.0	0	2-1/2	±0.625

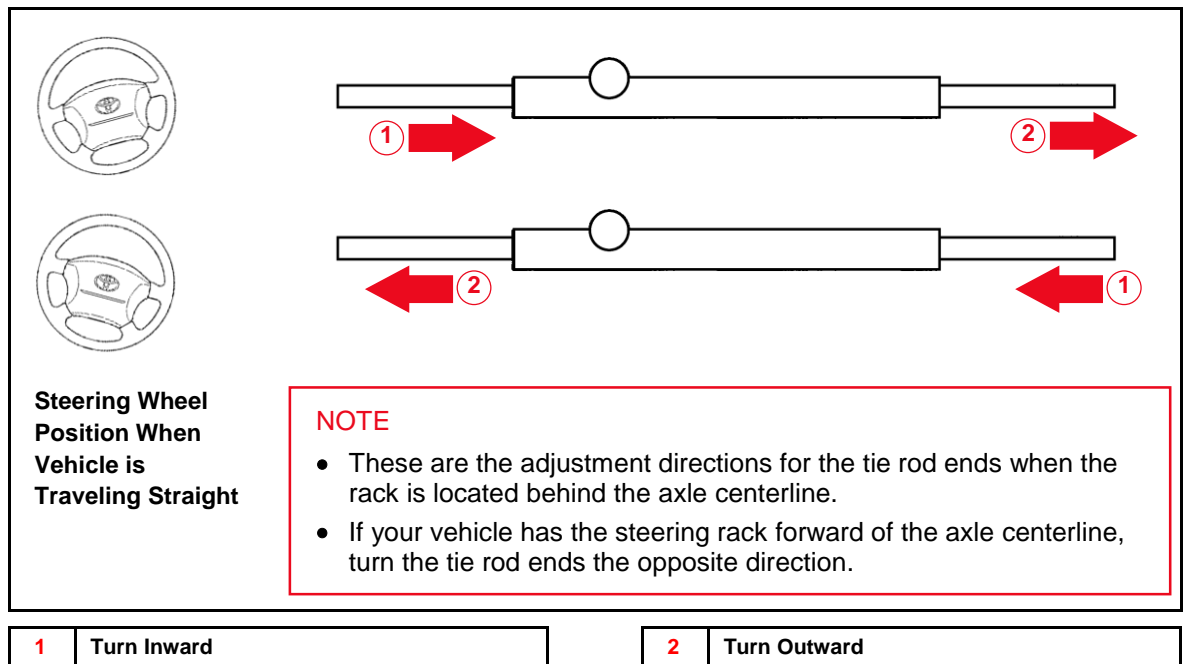
Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Steering Wheel Off Center Adjustment (continued)

B. See the figure below for the direction of adjustment.

Figure 18.



Vehicle Pull, Steering Wheel Off Center, and Alignment Best Practices

Repair Procedure (continued)

Steering Wheel Off Center Adjustment (continued)

3. Adjust the steering angle.
 - A. Lift the vehicle.
 - B. Draw a line on the right and left-hand tie rods and rack ends where it can be easily seen.
 - C. Measure the distance from the right and left-hand tie rod ends to the rack end screws.

NOTE

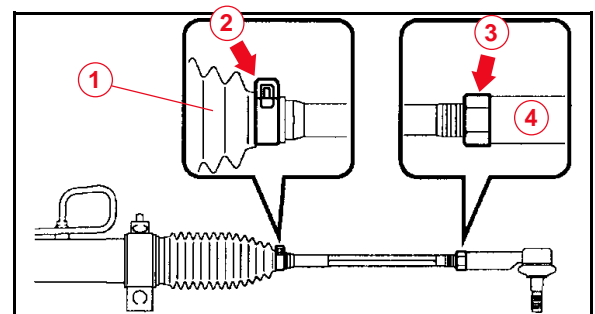
- Measure the right and left-hand sides.
- Make a note of the measured values.

- D. Remove the right and left-hand boot clips from the rack boots.
- E. Loosen the right and left-hand lock nuts.
- F. Turn the right and left-hand rack ends by the same amount (but in different directions) according to the steering angle.
- G. Tighten the right and left-hand lock nuts to the specified torque.

NOTE

Make sure that the difference in length of the threaded portion of the right- and left-hand tie rod ends and rack ends are within 1.5 mm (0.059 in.).

Figure 19.



1	Rack Boot
2	Boot Clip
3	Lock Nut
4	Rack End

- H. Install the right- and left-hand boot clips.
- I. Is the steering wheel centered when driving?
 - **YES** — The repair is complete.
 - **NO** — Repeat the steps in the Steering Wheel Off Center Adjustment subsection.