

**CHAPTER 2**  
**STEERING AND SUSPENSION**  
**REVISED FEBRUARY 2008**  
**TABLE OF CONTENTS**

<u>INTRODUCTION</u> .....	2-1
<u>STANDARDS</u> .....	2-1
Source .....	2-1
American Standard .....	2-1
Application .....	2-1
<u>DEFINITIONS</u> .....	2-1
Sideslip (or Scuff) .....	2-1
Wheel Plane .....	2-1
Camber .....	2-1
Caster .....	2-2
Kingpin or Steering Axis Inclination .....	2-2
Toe-In/Toe-Out .....	2-2
<u>SYSTEM OPERATION</u> .....	2-2
Design Criteria .....	2-2
Caster .....	2-3
Steering Axis Inclination .....	2-3
Camber .....	2-4
Wheel Turning Radius (Steering Geometry) .....	2-5
Toe-In .....	2-6
<u>COMPONENT PARTS</u> .....	2-6
<u>INSPECTION PROCEDURE</u> .....	2-9
Preliminary Requirements .....	2-9
Steering Column .....	2-9
Springs .....	2-12
Steering Linkage Play .....	2-12
Tie Rod Ends .....	2-13
Idler Arm .....	2-14
Pitman Arm .....	2-15
Ball Joints and Kingpins .....	2-15
Front Wheel Bearings .....	2-15
Toe-In .....	2-16
Camber and Caster .....	2-16

THIS PAGE INTENTIONALLY LEFT BLANK

## CHAPTER 2

### STEERING AND SUSPENSION

1. INTRODUCTION. This Chapter contains a description of steering systems and component parts and provides a suggested procedure for the inspection<sup>1</sup> of steering and suspension systems.

2. STANDARDS.

a. Source. Standards and definitions contained in this Chapter are consistent with "USA Standard Inspection Procedures for Motor Vehicles, Trailers, and Semitrailers Operated on Public Highways" published by the American Standards Association July 26, 1963, and sponsored by the American Association of Motor Vehicle Administrators and the Insurance Institute for Highway Safety.

b. American Standard. An American Standard implies a consensus of, those substantially concerned with its scope and provisions. An American Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American Standard does not in any respect preclude anyone, whether (s)he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American Standards are subject to periodic review and users are cautioned to obtain the latest editions.

c. Application. Appropriate corrective action should be taken when conditions are at variance with the standards contained herein to such a degree that a violation of the law or an unsafe condition exists or the operation of the vehicle may be adversely affected (Section 24002 VC).

3. DEFINITIONS.

a. Sideslip (or Scuff). The amount of Sidewise tire slippage occurring on the road surface while the vehicle is traveling straight ahead.

b. Wheel Plane. The central plane of the tire, perpendicular to the axis of rotation.

c. Camber. The inclination of the wheel plane to the vertical. It is measured in degrees and considered positive when the wheel leans outward at the top and negative when the wheel leans inward.

d. Caster. Caster is the tilt of the kingpin either toward the front or rear of the vehicle. Tilting the top of the kingpin to the rear is positive caster. Tilting the top of the kingpin to the front is negative caster.

e. Kingpin or Steering Axis Inclination. The outward tilt of the bottom of the kingpin toward the wheel. When the ball joint system is used, the tilt is called steering axis inclination.

f. Toe-In/Toe-Out. When the distance between the tires at the front is less than the distance between the front tires at the rear, measured at, spindle height, the condition is called toe-in. When the distance is greater in front, the condition is called toe-out.

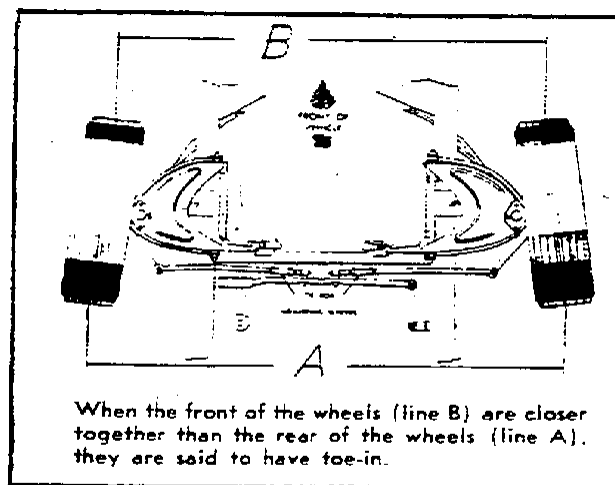


Fig. 2-1. Toe-In

#### 4. SYSTEM OPERATION.

a. Design Criteria. A properly designed, adjusted, and maintained steering system will:

- (1) Provide precise directional control of a vehicle without excessive steering effort.
- (2) Operate without excessive vibration or shimmy.
- (3) Through steering geometry design, minimize tire wear caused by turning.
- (4) Ensure that front wheels will return to the straight ahead position when the steering wheel is released.

b. Caster. A wheel aligns itself to follow the point of load. Caster, or forward inclination of the kingpin at the bottom, moves the point of load forward in relation to the wheel as shown in Figure 2.2.

- (1) Proper caster will cause the wheels to align themselves in the direction in which the vehicle is traveling, which increases directional control.
- (2) Too much caster causes hard steering, excessive road shock, and shimmy.
- (3) Too little caster provides easy low speed steering, high speed instability, and wander.
- (4) The amount of caster required, and whether it is positive or negative, can be influenced by another angle - steering axis inclination.

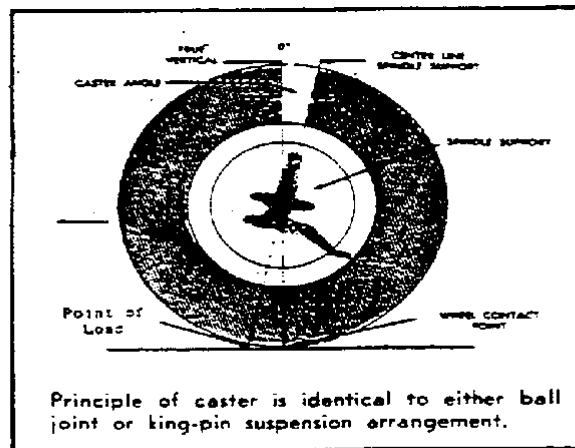


Fig. 2-2. Caster Angle

c. Steering Axis Inclination. Steering axis inclination helps position the load point under the tire as shown in Figure 2-3.

- (1) The camber angle required is reduced by steering axis inclination.
- (2) The load point is brought under the tire reducing steering effort.
- (3) This angle causes the spindle to rise when the wheel is turned. Vehicle weight causes the wheels to return to a straight ahead position, contributing to directional stability.

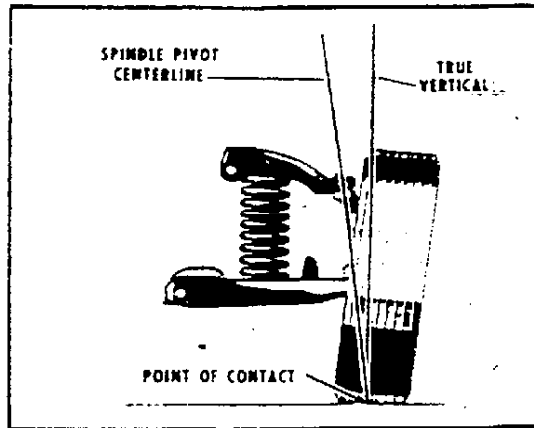


Fig. 2-3. Steering Axis Inclination

- d. Camber. Camber brings the tire under the load point as shown in Figure 2-4.
- (1) Camber, in conjunction with the steering axis inclination, provides ease of steering and increased directional control.
  - (2) Camber, when proper, reduces tire wear by properly positioning the load point under the tire.
  - (3) Excessive camber increases tire wear by causing varying diameters between the two sides of the tires as shown in Figure 2-5. Tire wear increases as tire width increases.

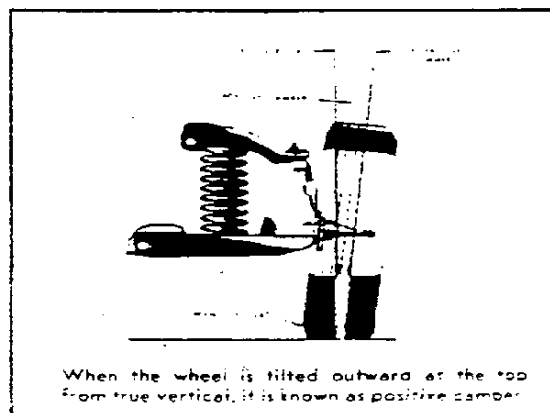


Fig. 2-4. Camber Angle

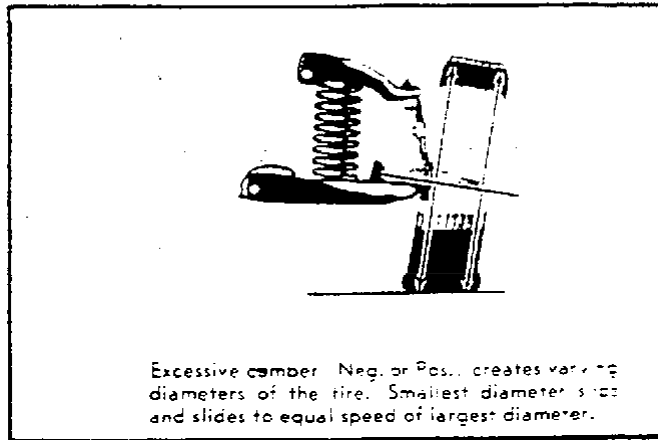


Fig. 2-5.  
Tire Diameter Change from Camber Angle

e. Wheel Turning Radius (Steering Geometry). Each front wheel negotiates different arc when the vehicle is turned.

- (1) To avoid excessive tire wear, the wheel spindles must turn different degrees when the steering wheel is turned.
- (2) This is accomplished by designing the system so that the spindle arms are closer at the tie rod end as shown in Figure 2-6.

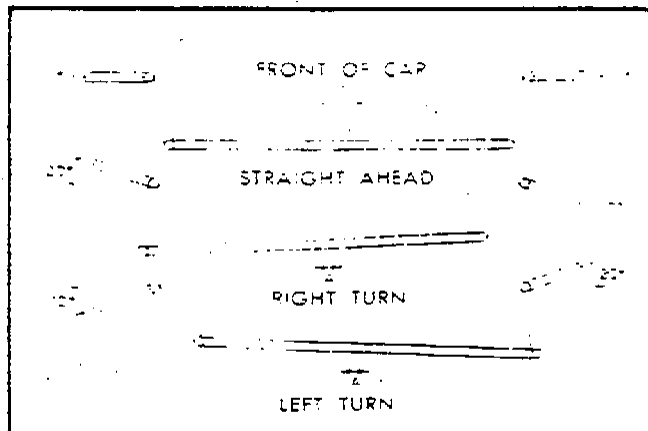


Fig. 2-6. Steering Geometry

f. Toe-In. As a vehicle moves forward, the forces against the wheels tend to compress the steering mechanism. "Toe-In" of the wheels compensates for this and in operation the wheels run straight.

5. COMPONENT PARTS. The component parts of steering and suspension systems are illustrated in Figures 2-7 through 2-13.

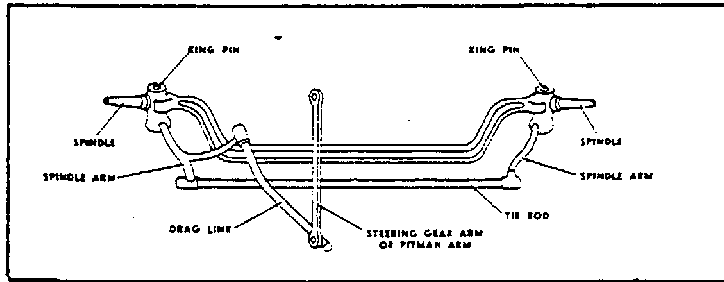


Fig. 2-7.  
Conventional Axle Front Suspension

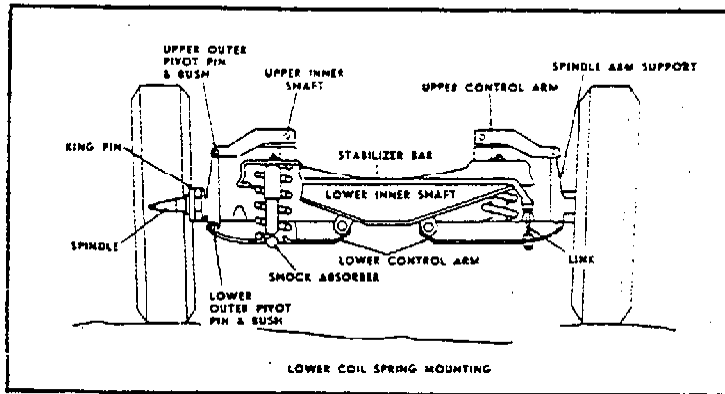


Fig. 2-8.  
Independent Front Suspension

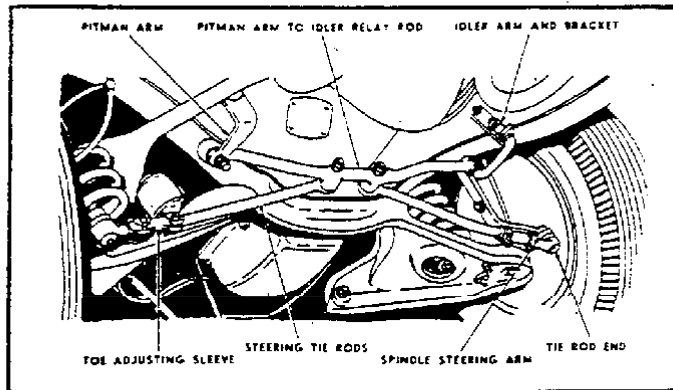


Fig. 2-9.  
Steering Linkage Component Parts

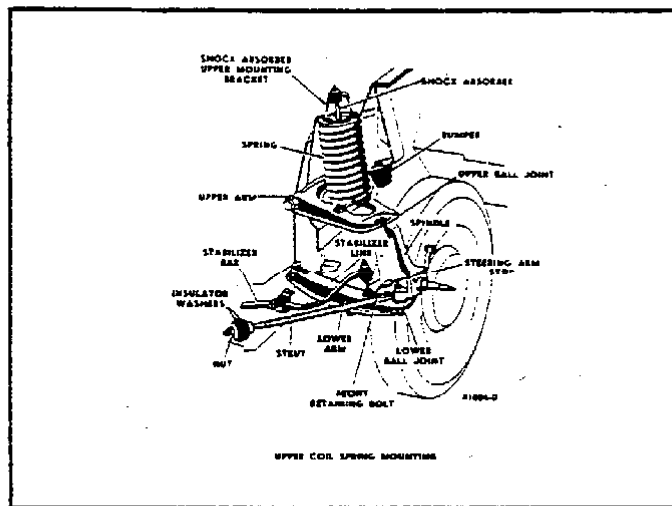


Fig. 2-10.  
Independent Front Suspension

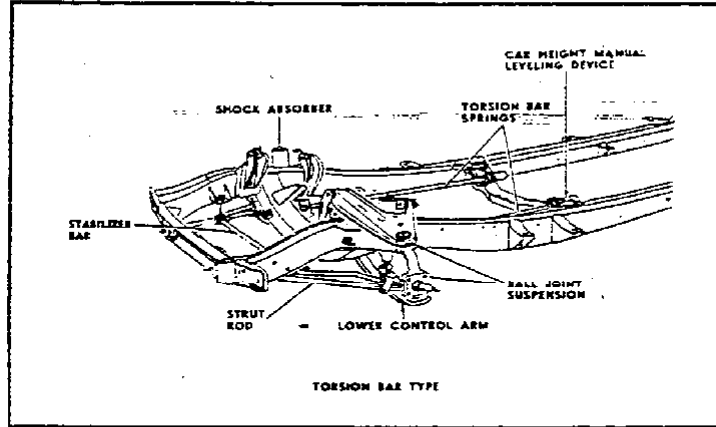


Fig. 2-11.  
Independent Front Suspension

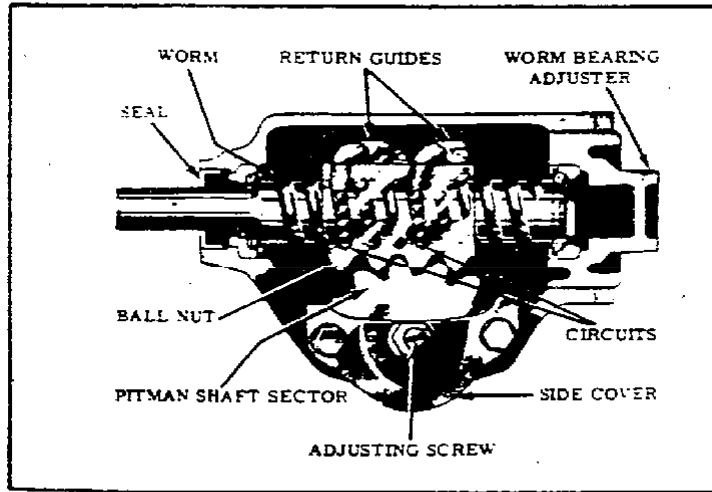


Fig. 2-12. Manual Steering Gear

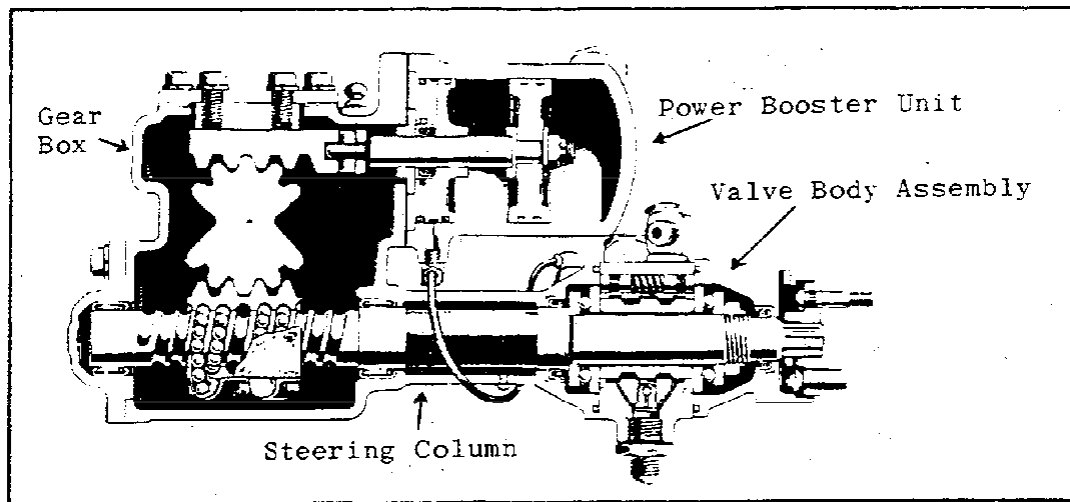


Fig. 2-13. Power Steering Gear (Cross Section)

## 6. INSPECTION PROCEDURE.

a. Preliminary Requirements. Inspection of steering systems should be conducted on a clean, relatively level surface.

(1) Caster, camber, toe-in, and steering axis alignment can be inspected only with the use of wheel aligning equipment.

(2) Ball joints, kingpins, and kingpin bushings can be inspected only when the joint is unloaded. (Front end raised off the ground.)

\*b. Steering Column. Inspect the steering column and steering gear box for proper mounting, securement, and operation (Section 24002(a) VC).

(1) Turn steering wheel through a full right and left turn and feel for binding or jamming conditions.

(2) Care should be taken at the extreme ends of the turn to avoid deflecting the mechanism against stops.

(3) Steering shaft should turn through full range in both directions without binding or hard pull and be free of any rough spots.

(a) Binding indicates misaligned steering gear on mountings or coupling.

(b) Rough spots indicate damaged bearings or parts. Hard pull indicates excessive preload adjustment.

(4) With road wheels in straight ahead position, turn steering wheel until first movement of the road wheels to the left can be observed. Select a reference point on outer rim of steering wheel and note its exact position. Turn steering wheel to the left, then to the right until first movement of road wheels can be observed in each direction. Total lash is the maximum movement of the steering wheel reference point measured along its arc of travel between the points where the road wheels begin to move in either direction. Total lash measured at the rim should not be greater than shown in Figure 2-14.

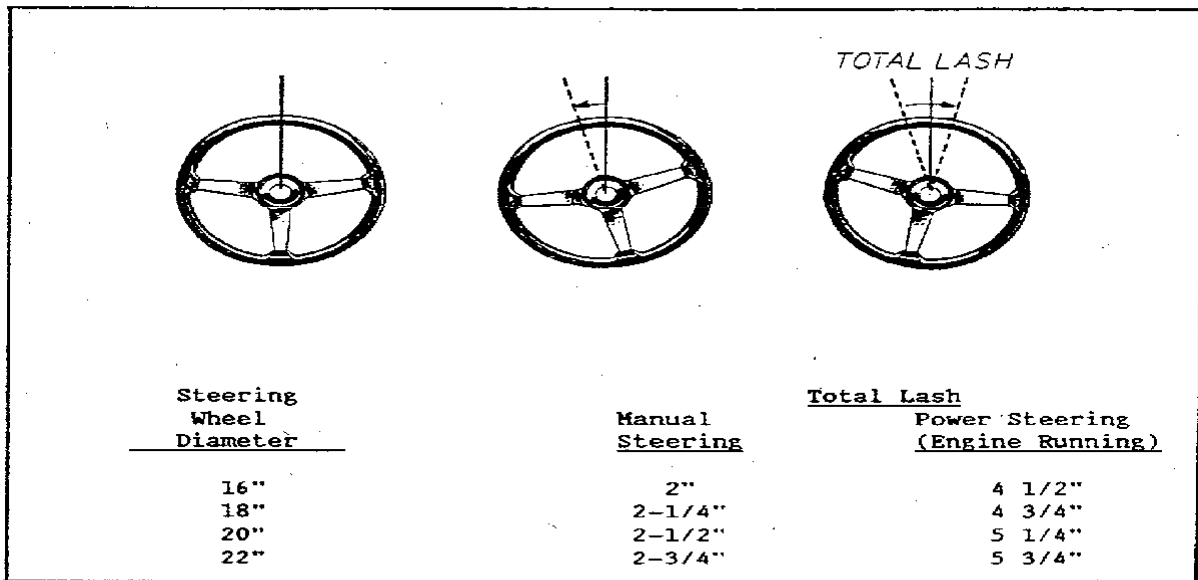
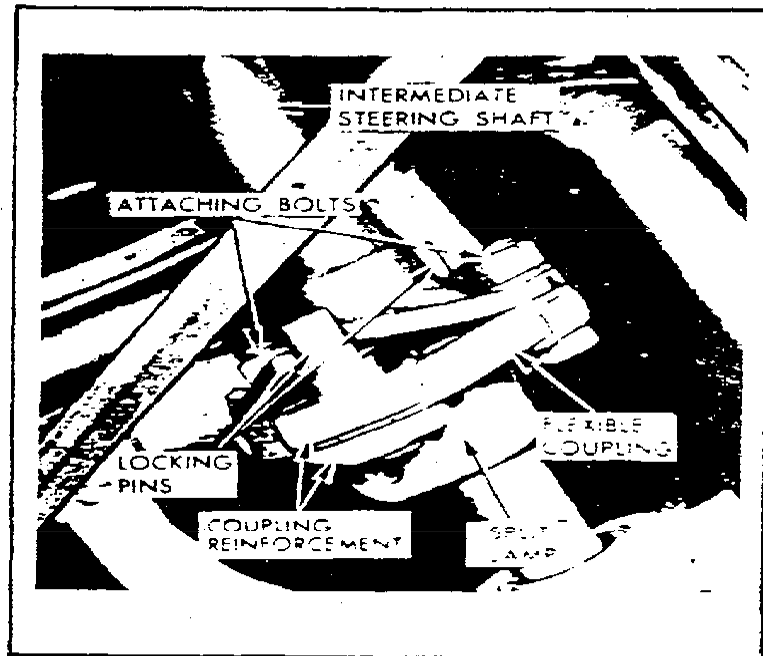


Fig. 2-14. Lash

(5) Inspect flexible coupling in steering column (if the vehicle is so equipped) for excessive misalignment; tightness of adjusting screw or nut; flexible disc worn, torn or frayed; elongated bolt or rivet holes; and missing bolts, nuts, or rivets.



**Fig. 2-15.**  
**Flexible Steering Coupling**

- (6) Check the securement of the steering gear box to the frame. Determine that there are no loose or missing mounting bolts.
- (7) Examine the power steering valve body and hose connections for leaks.
- (8) Check steering column shaft upper bearing for excessive wear and on a remote type check lower bearing for defects as shown in Figure 2-16.

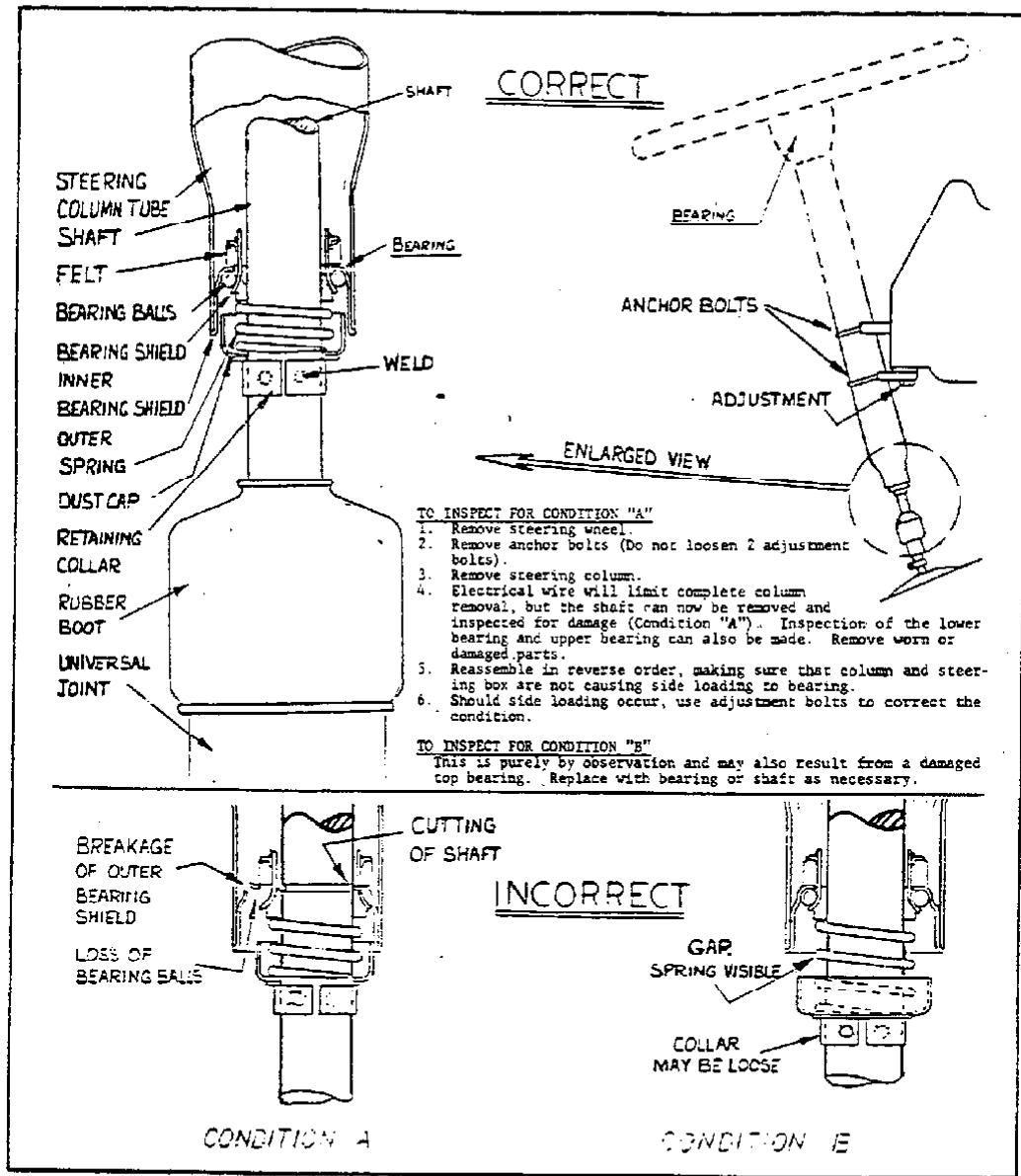


Fig. 2-16. Steering Column Inspection

(9) Check the top mounting bracket for looseness.

c. Springs. Inspect for coil springs and spring leaf suspension components that are weakened, displaced, or broken.

d. Steering Linkage Play. The combined wear of the steering linkage components as shown in Figures 2-7 and 2-9 is determined as follows (Section 24002 VC).

- (1) Raise one wheel off the ground.
- (2) Grasp front and rear of tire and attempt to turn assembly right and left.
- (3) Grasp top and bottom of the tire and attempt to rock in and out. (4) Record movement at extreme front and rear - top and bottom of tire.
- (5) A bar for leverage may be required for heavy wheels. Make sure the bar does not contact any part of the vehicle except the tire during this inspection procedure.
  - (a) Do not use any tool to apply force to any parts whose sole purpose is to steer the wheels. These parts include steering columns, pitman arms, drag links, tie rods, idler arms, and spindle arms.

<u>Movement</u>	<u>Wheel Diameter</u>
1/4-inch	16" or less
3/8-inch	17" and 18"
1/2-inch	over 18"

- (6) Movement should not exceed that specified in the following table.

e. Tie Rod Ends. Inspect all spherical joints on tie rod ends and steering linkage for excessive wear and looseness (Section 24002 VC). Do not use tools to apply force to these parts.

- (1) To check steering linkage ball joints, have an assistant rock the steering wheel back and forth while you watch for signs of looseness at each ball joint. If looseness is observed at a stud nut, a defect exists. If looseness is observed at a ball joint, closer inspection will be necessary before deciding that a defect exists. Return the wheels to the straight ahead position and shut off the engine, if it was running. Using one hand, grasp the linkage near the ball joint and attempt to move the bottom of the ball joint toward the stud nut along the center axis of the ball stud (up and down for a vertical ball stud, etc.) as shown in Figure 2-16a.

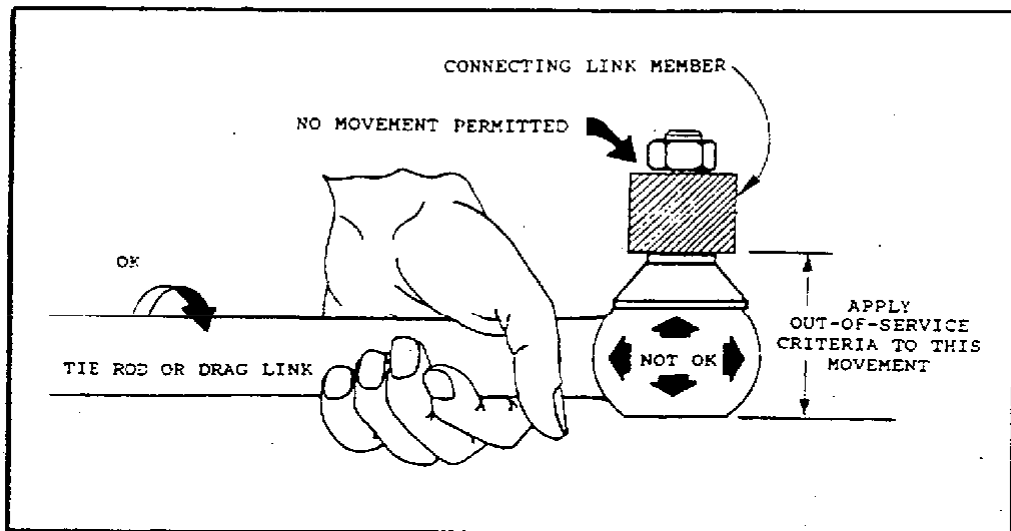


Fig. 2-16a.  
Steering Linkage Ball Joint Inspection

- (2) There should be no relative motion between the ball stud and the member to which it is attached. Ball joints should twist freely but should have no movement up or down along the center axis of the ball stud except as allowed by compression of the ball joint's internal wear-compensating spring. There should be no free movement; that is, movement that is not resisted by a spring or similar internal device.
- (3) Some aftermarket ball joint alignment products may be found installed on or near tie rod or drag link ball joints. These are springs that return a ball joint to its centered position whenever the ball joint is not heavily loaded, as in straight-ahead driving. These springs might tend to hide unacceptable looseness in a tie rod or drag link ball joint that is checked with the steering wheels raised off the ground. However, steering play that is checked by rotating the steering wheel alternately left and right with the front wheels on the ground will still reveal excessively worn joints, even with these devices installed.
- (4) Note condition of sealing boots, particularly on sealed joints without plugs or fittings.
- f. Idler Arm. Inspect idler arm for worn bushing as may be indicated by up-and-down play (Section 24002(a) VC). Do not use tools to apply force to these parts.

g. Pitman Arm. Check pitman arm on steering gear box for looseness. There should be no up-and-down movement of idler or pitman arm (Section 24002(a) VC). Do not use tools to apply force to these parts.

h. Ball Joints and Kingpins. Raise the front end of the vehicle so that the ball joint will not be loaded and check the ball joints and kingpins for excessive looseness (Section 24002(a) VC).

(1) Grasp the tire and wheel assembly at the 11 and 5 o'clock positions on the tire. Work the wheel in and out to detect any looseness. Move hands to the 1 and 7 o'clock positions and repeat. -

(2) Position a pry bar under the front tire and wheel and with a lifting motion move the wheel up and down and observe movement. Make sure the bar does not contact any part of the vehicle except the tire during this inspection procedure.

(3) There should be no perceptible movement of the unloaded ball joint. (The upper ball joint on vehicles where the spring is supported by the lower control arm and the lower joint when the spring is supported by the upper control arm.)

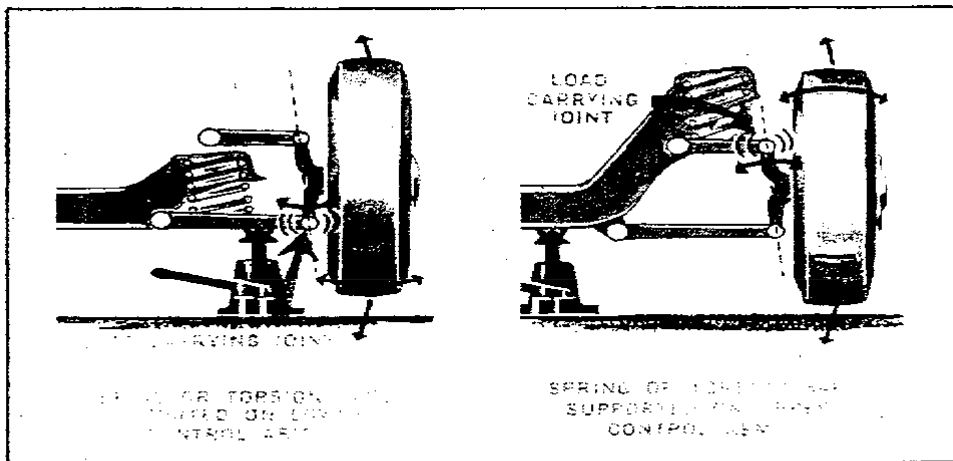


Fig. 2-17.  
Proper Jacking to Unload Ball Joints

i. Front Wheel Bearings. Attempt to move wheel relative to the spindle either by grasping front tire top and bottom or by using a bar for leverage. Make sure the bar does not contact any part of the vehicle except the tire during this inspection procedure.

- (1) Bearing maladjustment or wear is determined by the relative movement between the brake drum (or disc) and the backing plate (or splash shield).
  - (2) Movement between the drum and backing plate should not exceed 1/4-inch measured at the tire tread (Section 24002 VC).
  - (3) Check for overly tightened and defective wheel bearings by rotating the wheel on the spindle.
- j. Toe-In. A measuring device specifically designed for the purpose is normally required for measuring toe-in.
- (1) Measure the distance between tire tread centers at the front and rear of the front tires.
  - (2) The front measurement should be less than the rear measurement and within manufacturers' recommended tolerances.
- k. Camber and Caster. Camber and caster can be measured only with gauges specifically designed for the purpose. Camber and caster should be adjusted to manufacturer's specifications.