Training Solutions

A Snap-on Services Group

The information in this program is based on technical data and tests, and is intended for use by persons having technical skill, at their own discretion and risk. Since conditions of use are outside of the control of Training Solutions, Training Solutions we assumes no liability for the use of such information, or any damages resulting from its use or application. Nothing contained in such programs and publications is to be construed as contractual or providing any form of warranty.

Training
Solutions
A Snap-on Services Group

Contents

Training Solutions
A Snap-on Services Group

Contents

Training Solutions
A Snap-on Services Group

Contents

Contents

I

INTRODUCTION: WHO SHOULD TAKE THIS COURSE

This course is an advanced level course. It is strongly recommended that you complete the ***Four-Wheel Alignment*** course before proceeding with this one. If you understand the general alignment theories and procedures covered in that course, you'll be ready to tackle some of the more advanced aspects of alignment service.

One of the areas covered in depth in this material relates to alignment angles that are considered "non-adjustable" by OE manufacturers. Most of the time, you'll find these angles can be adjusted once you're familiar with the broad range of aftermarket alignment products. From shims, and cam and crank bolts to more recent advances like the smart arm, these products will help you tackle some of the tougher, "real world" issues.

Understanding the use of these aftermarket products can often make the difference between correcting a vehicle's problem and having a "problem vehicle."

This course provides specific examples and recommendations, giving it a real "hands-on" feel. You'll be able to test your knowledge, section by section, and practice service techniques while you learn.

In developing this material, it is our sincere desire to make you the best you can be at your trade.

USING ALL THE TOOLS IN THIS COURSE

The training materials in front of you - this course book, the videotape, the pre-course test, and the final course test- are all the tools you'll need to get the most benefit from this course. Each of the tools play an important role in the total training process, so make sure you have all of them ready before beginning. If you're missing one or two tools, you won't be able to complete the training job.

Here is how to use them. Begin with the pre-course test. The objective of this test is to help identify the subjects you'll want to pay special attention to as you progress through the course. It is an "open book" test, and only you will see the results. The answers are printed at the end of the test.

Next, read Chapter 1 in this course book. When you come to the video icon, set the course book aside, and watch the videotape. The tape is divided into modules that correspond with the chapters in this course book. A stoplight in the video will direct you back to the course book at the appropriate time. In other words, you'll be going back and forth between the two tools-the video and the course book.

From time to time, you'll find review quizzes in the course book. These, too, are important tools because they help reinforce the information just presented. If you have trouble answering the questions, go back through the course book or videotape. Once again, only you will see the results of these review quizzes.

Shop exercises in the course book let you practice the diagnostic and repair procedures you've just learned. The tools and equipment in your shop may not be the same, as those demonstrated here, so you'll have to adapt what we've shown you to your specific equipment. The shop exercises will help you get the most use from the tools you use every day.

After you've watched the last video module, read the final course book chapter, and completed all the review quizzes and shop exercises, it's time to take the final course test. Use only the answer sheet supplied with the course, and mail it to Training Solutions in the self-addressed envelope. Training Solutions will score the test and mail you the results. A score of 80% or better will earn you a personalized certificate. And, your scores will be recorded by Training Solutions for future reference as you take additional courses. A record of your personal training accomplishments will automatically be updated with each new course you complete.

Good luck as you use these training tools!

PRE-COURSE TEST

1. Total individual movement of the rear wheels is possible with what type of rear suspension?
   a. Beam axle
   b. Live axle
   c. Independent
   d. Semi-independent

2. If, when adjusting toe on the alignment rack, you adjusted the left front wheel 1/8" in and the right front wheel at 0, the most likely problem that will occur when the vehicle is driven is:
   a. Tire wear
   b. Poor handling
   c. The steering wheel is off-center
   d. Front end shimmies

3. Caster and camber on a vehicle are adjusted to exact specifications, yet the vehicle tends to wander on flat, even roads. The likely cause of this is:
   a. Incorrect setback
   b. Incorrect scrub radius
   c. Vehicle ride height problem exists
   d. Incorrect toe adjustment

4. SAI (Steering Axis Inclination) is:
   a. Only a diagnostic measurement
   b. Adjustable
   c. Affected by the installation of offset wheels
   d. Not important to vehicle handling

5. A 1989 Ford Crown Victoria has camber readings of 1/4° positive on the right front and left front, and caster readings of +2° on the left front and +4° on the right front. These settings should:
   a. Pull to the left
   b. Pull to the right
   c. Drift slightly to the left
   d. Drift slightly to the right

6. On a RWD car, when using camber to compensate for road crown, caster should be adjusted:
   a. More negative on the left front
   b. More positive on the left front
   c. Equally
   d. Within 1° side-to-side

7. The front alignment angles that can be affected by front cradle adjustment are:
   a. Camber/toe
   b. Camber/caster
   c. Only Camber
   d. Camber/caster/toe

8. To check a wear indicator ball joint, the vehicle must:
   a. Be raised on a frame contact hoist
   b. Be on the ground with the vehicle's weight on the wheels
   c. Be supported under the lower control arms
   d. Have the brakes locked

9. Broken anti-sway bar link pins will affect:
   a. Toe
   b. Brake torque retention
   c. Body roll
   d. Driveshaft angles

10. When tightening the castle nut on the lower ball joint, you notice that the threads run out before the ball stud is tight. You should:
    a. Use washers to take up the space
    b. Replace the steering knuckle
    c. Replace the ball joint
    d. Weld the ball stud to the knuckle

ANSWERS

1. c 2. c 3. d 4. a 5. a
6. c 7. d 8. b 9. c 10. b

0

COURSE OBJECTIVES

This course is designed for experienced chassis and alignment technicians who must regularly perform inspections, wheel alignments, and repairs on passenger cars, light trucks, and sport utility vehicles.

When you have completed this course, you should be able to:

1. Identify the various types of steering and suspension systems used in both front-wheel and rear-wheel drive vehicles.

2. Determine which alignment angles are out of specification or are causing a handling problem.

3. Select the appropriate methods and parts required for bringing the vehicle into proper alignment.

4. Correctly diagnose steering problems and complete the required serv ice on these components.

5. Identify which angles are considered "non-adjustable" by various original equipment manufacturers, and determine the best method for making adjustments using aftermarket products.

IN ADDITION, YOU SHOULD UNDERSTAND:

1. How wear or damage to a vehicle's steering components can alter alignment angles.

2. Which alignment angles can be adjusted, and which angles can be used for diagnostic purposes.

3. How to select the appropriate alignment products for a variety of applications.

NOTES:

G

Glossary of Technical Terms

ADJUSTING SLEEVE
A connecting device into which the inner and outer tie rod ends are threaded. Rotating the adjusting sleeve allows you to lengthen or shorten the effective length of the tie rod end assembly to alter the toe in/out setting.

ALIGNMENT
The process of measuring and positioning all of the wheels attached to a common chassis.

ALL-WHEEL DRIVE (AWD)
Similar to four-wheel drive, but generally associated with passenger cars. Engine power is provided to both the front and rear axles when needed.

BUMP STEER/TOE CURVE
A directional change in steering that occurs after hitting a bump or dip in the road. Often, this is caused by uneven toe changes that occur as the result of the steering linkage or rack not being parallel with the road.

BUSHING
A component made of metal or synthetic material used to locate or guide interconnected moving parts.

CAMBER
The inward or outward tilt of a tire and wheel, as viewed from the front.

CAM BOLT
A bolt fitted with an eccentric that is turned to change a wheel's camber setting. Cam bolts are commonly used on control arms and lower strut mounts.

CASTER
The forward or backward angle of the steering axis, as viewed from the side.

CENTERLINE
The geometric centerline of the suspension is a line that runs the length of the vehicle and intersects the midpoints of the front and rear axles.

CENTER LINK
A tube or rod used as a connection between the Pitman arm and the idler arm in a parallelogram steering system. The inner tie rod ends of the steering linkage are attached to the tapered holes of the center link.

CROSS STEER
A variation of the single tie rod end steering system. A drag link connects the Pitman arm across the front of the vehicle to the passenger side.

DIRECTIONAL STABILITY
The tendency of a vehicle to maintain a directed path.

DRAG LINK
A tube or rod used as a connection between the Pitman arm and the steering knuckle.

DRY PARK CHECK
An undercar inspection method performed with the full vehicle weight on all tires. The steering wheel is turned left and right while the technician visually inspects the steering and suspension components.

ECCENTRIC CAM
A washer with the hole off-center so that it does not rotate in a perfect circle. It is normally used to adjust camber and/or caster.

ENGINE CRADLE
Part of the frame that reaches side-to-side across the front of the engine compartment. It supports the engine and the transaxle.

FOUR–WHEEL DRIVE (4WD OR 4X4)
Engine power is provided to both front and rear axles to drive a vehicle (normally a light truck or sport utility vehicle). It can provide improved traction on wet, slippery, or icy surfaces.

FRAME ANGLE
The angle of the frame with respect to the ground. For every degree of change in frame angle, front caster also changes by one degree.

FRONT-WHEEL DRIVE (FWD)
The front wheels are used to propel the vehicle. It offers a more compact powertrain, with CV joints and halfshafts, rather than a full driveline.

HALTENBERGER
A steering system consisting of a drag link that connects the passenger side steering arm to the Pitman arm. It is unique to Ford vans and light trucks.

HYTREL®
A thermoplastic material often used for CV and rack and pinion boots. It is flexible, and fatigue-resistant.

INCLUDED ANGLE
The sum of the camber angle and steering axis inclination on a front suspension. It is measured primarily to diagnose bent suspension parts, such as spindles and struts.

JOUNCE
The upward movement of the suspension.

LOW-END MAINTENANCE (LEM)
Tie rod ends; also referred to as metal-to-metal tie rod ends, because both the ball and socket are made of sintered metal.

MEMORY STEER
A condition where the front wheels pull in the direction of the most recent turn rather than returning to the straight ahead position.

ORIGINAL EQUIPMENT MANUFACTURER (OEM)
Vehicle manufacturers, such as Ford, Chrysler, Honda, BMW, etc.

PARALLELOGRAM STEERING SYSTEM
A steering linkage that uses a Pitman arm, an idler arm, and a center link to steer the front wheels. It is commonly found on light trucks and older, rear-wheel drive cars.

PITMAN ARM: A part of the steering linkage that is connected to the steering gear sector shaft. The arm moves side to side to steer the vehicle.

RACK AND PINION STEERING
A type of steering gear that uses a pinion gear to drive the rack, steering the wheels. It is most often used in front-wheel drive cars and minivans.

RADIAL MOVEMENT
Horizontal movement of the ball joint or tie rod end.

REBOUND
The downward movement of a suspension.

RIDE HEIGHT
The distance from a specific point on the vehicle to level ground. The measurement should be equal to specifications before correcting alignment.

RUBBER-BONDED SOCKET (RBS)
A tie rod end used on various Ford light trucks, as well as on the Taurus/Sable. It consists of a tapered stud bonded to a rubber ball socket.

SCRUB RADIUS
The distance between the points where the steering axis inclination line intersects the road, and where the centerline of the tire intersects the ground, as viewed from the front.

SETBACK
Occurs when one wheel is set farther back than the opposite wheel. When the right wheel is farther back, the axle has a positive setback. When the left wheel is farther back, the axle has a negative setback.

SHORT/LONG ARM (SLA)
An independent suspension system that uses upper and lower control arms of unequal lengths. The upper arm is usually the shorter of the two.

SINGLE TIE ROD END
A steering system most often found in Ford and GM four-wheel drive vehicles. It consists of a drag link connecting the Pitman arm to the steering arm on the driver's side.

SMART ARM
An aftermarket alignment product used to correct camber settings. It replaces the original equipment-designed control arms, track bars, or connecting links.

SPORT UTILITY VEHICLE (SUV)
Jeep Cherokee, Ford Explorer, Chevy Blazer, and other similar vehicles, which are typically four-wheel drive.

STABILITY
The ability of a vehicle to maintain a specific course.

STABILIZER BAR
A bar that resists body roll or lean by twisting. The bar is usually connected to the suspension by a connecting link kit.

STEERING AXIS INCLINATION (SAI)
The angle of a line drawn through the wheel spindle pivot points compared to true vertical. It is a non-adjustable angle, typically used with camber and included angle to diagnose a bent frame or worn suspension components.

THRUST ANGLE
The angle created by the thrust line and centerline when the rear axle is cocked to one side. When toe is incorrect on either or both rear wheels, it creates a thrust angle.

THRUST LINE
An imaginary line that runs perpendicular to the rear axle. If the line coincides with the vehicle's centerline, the vehicle should track straight ahead.

TIE ROD
Part of the steering linkage that connects the steering arms on the knuckles to the steering rack or center link.

TIE ROD END
The ball and socket assembly of a tie rod.

TOE
The difference in distance between the front and back of two opposite tires. It has the greatest effect of any alignment angle on tire wear.

TOE–OUT ON TURNS:

The change in toe that occurs when the wheels are steered to either side.

TWIN I-BEAM

An independent front suspension on Ford pick–up trucks using two parallel I–beam axles (one for each wheel).

NOTES:

I

Vehicle Designs

FIXING THE UNFIXABLE

Please watch video module one now.

When rear-wheel drive (RWD) automobiles ruled the roads of America, a basic front end alignment was often enough to keep a car moving straight down the road. However, with today's vehicles, technicians have a lot more to think about. The list of possibilities has grown to include front-wheel drive (FWD), all-wheel drive (AWD), and four-wheel drive (4WD) systems used on a wide variety of cars, light trucks, and sport utility vehicles (SUVs) that come in a sometimes confusing array of sizes and shapes. Is it a car? A truck? You can't always tell.

In spite of these changes, the basic components - frames, suspensions, and steering systems - as well as the basic alignment angles and procedures to adjust them, have seen less change.

Throughout this ***Advanced Automotive Alignment*** course, you'll be introduced to current trends in steering and suspension systems. In addition, you will learn how these design changes may affect the various alignment angles we introduced in ***Four-Wheel Alignment,*** which is a prerequisite to this course. You'll also learn the procedures used to repair these vehicles when they're out of alignment. This includes using a variety of aftermarket parts to correct not only adjustable angles, but also those that are "non–adjustable" from the original equipment manufacturer (OEM).

Before we get started, let's head off one concern you might have as you watch the video and read through this course book. We're going to be referring to specific components here. It's not our intention to turn this course into a sales pitch, but , rather to point out that a lot of work has been done to provide aftermarket alignment technicians with components that solve problems. These components let you adjust systems that the original equipment manufacturers designed to be non–adjustable. They offer you a better way to accomplish difficult tasks, or they solve basic design problems.

Understanding and using these components can make the difference between correcting a customer's problem, and creating a "problem customer." To be an "ace" in the alignment business, you need to know how to use these components. That's one of the main objectives of this advanced steering and suspension course. Because we know the most about our own products, we can speak with authority about their use. In doing so, it's our sincere desire to make you the best you can be at your trade.

FRAME DESIGNS

Vehicle frame designs have changed considerably over the years. At one time, they were quite heavy and bulky and were full perimeter or ladder designs. They evolved to a lighter "X" frame design and then back to perimeter designs again. Today's perimeter frames are high–tech engineering and manufacturing designs, specifically configured to act not only as the mounting points for the various steering and suspension components, but also to distribute force if a vehicle is involved in an accident.

Some full frame designs, like the X-frame, are no longer in production. Others, like the perimeter frame, are still commonly found on today's light trucks and SUVs. And, unibody construction has replaced frames on nearly all passenger cars and minivans worldwide.

Understanding each of these various frame designs is important because the frame is the foundation for the entire vehicle. All other vehicle components are directly or indirectly attached to the frame. When a problem such as a bent frame occurs, it can alter vehicle alignment and cause steering, suspension components, or tires to fail prematurely.

Frames

Unitized body or unibody designs, which became popular in the early 1980s, are now common on most cars. They're usually used with front-wheel drive cars and mini vans. Most sport utility vehicles and trucks still use a perimeter type of frame design. It is important to have a clear understanding of the structural engineering of a vehicle to be able to accurately diagnose worn parts, vehicle handling problems, and wheel alignment needs. This is especially true of all–wheel drive or front-wheel drive vehicles with a contemporary steering and suspension system. Problems can and will occur as components wear and as vehicles encounter potholes, or are damaged because of accidents. Something as simple as hitting a pothole hard enough to blow a tire or damage a wheel can severely alter the vehicle's alignment, causing related handling, alignment, and tire wear problems.

Perimeter frames on vehicles, and on unibody construction, act not only as attaching points for the body, suspension, steering, engine, and transaxle components, but also absorb and dissipate energy if the vehicle is in a collision. Modern vehicles are designed to protect the occupants from injury by crushing or folding under impact. This means, for example, that a vehicle that gets hit in the left front may have some damage to the right rear unibody frame area.

ENGINE CRADLES

Many front-wheel drive cars use a *cradle* assembly, which is similar to the front section of a perimeter frame on older, full-frame vehicles. The lower control arm, which uses MacPherson struts, is attached to the cradle assembly. Other components including the engine, the transaxle, and the rack and pinion steering gear, may also be attached to the cradle assembly.

The engine cradle is a box–shaped frame member reaching from side to side (left to right) and fore and aft, which supports the engine and transaxle (Figure 1-1).

Fig. 1-1. Engine Cradle Assembly

The cradle is mounted to the unitized body, or the *sub-frame* with large, rubber mounts. It may also be directly bolted to the sub–frame using a flange, which is an integral part of the cradle.

Many vehicle cradles are adjustable and can be deliberately shifted left or right, fore or aft to establish the basic alignment reference points. Moving this point will affect all of the vehicle's alignment angles, except for rear camber and rear toe. Adjustable cradles are susceptible to shifting or movement when a vehicle hits a pothole or any other obstruction in the road. Even on vehicles where the cradle is fixed by permanent bolts, it can be shifted slightly, or bent, if a severe enough obstruction is encountered.

In addition to the wheel alignment angles and other geometric reference points of the vehicle, the halfshaft angle will also be changed if a cradle is shifted from its proper position. If the halfshaft angle is shifted excessively, it can result in tire wear and vibration, along with handling problems. Always check the cradle, if it's adjustable, as part of a normal wheel alignment procedure. It should also be adjusted prior to performing any wheel alignment adjustments on the vehicle. By simply adjusting the cradle, you may detect a handling problem that was previously missed.

Cradles and vehicle suspension systems have become very sophisticated over the years. The Audi A6 and A8, for example, have a front cradle and suspension system that is unique. The cradle is adjusted to set front camber and to maintain the steering axis inclination. If the cradle is out of adjustment, tire wear, handling and a bump steer or toe curve condition may result.

The adjusting method is to install positioning bolts at the front of the vehicle to align the cradle with specific reference holes in the body. Audi recommends using a special tool that is installed in the right forward cradle–bolt mounting position to shift the cradle. As an alternative, the sub–frame bolts can be loosened and the cradle shifted with a pry bar to make the necessary camber adjustment.

Front-wheel drive 1996 and 1997 Lincoln Continental, Ford Taurus, and Mercury Sable also use the engine cradle as the basic positioning of the front cradle to set the camber, caster, SAI, setback, scrub radius, and toe. If the front cradle is out of position, it can lead to a variety of tire wear, handling, and vehicle control problems.

Ford states that the cradle must be positioned correctly in reference to the alignment holes of the sub–frame of the unibody prior to drilling out the spot welds and shifting the strut tower. Like the Ford Taurus/Mercury Sable, a strut tower alignment plate is used to adjust caster and camber on the Continental. Sometimes these angles cannot be adjusted properly by shifting the upper tower alone. Because the cradle establishes the base reference points, they must be correct before other wheel alignment angles can be adjusted.

FRONT SUSPENSIONS

Suspension system components, regardless of their design, all perform the same basic functions (Figure 1-2). They:

- Support the vehicle's weight, including passengers and cargo
- Help maintain correct vehicle ride height, provided the vehicle is not carrying a load that exceeds the spring's design capabilities
- Allow the vehicle height to be maintained as a suspension system moves through jounce and rebound motions
- Compensate for shifts in vehicle loading, both front-to-rear and side-to-side
- Assist in dampening road shocks through bushings and linkage configurations, so the vehicle remains controllable and predictable

Perhaps one of the most important functions of the suspension system is to keep the alignment angles and steering linkage within their proper ranges of operation. This keeps the vehicle from darting and diving, or from acting unpredictably or uncontrollably.

Front Suspension Variations

A wide variety of suspension systems are used on the vehicles that come into your shop. Some of these include the:

- Short/long arm (SLA) suspension system, which is used on rear-wheel drive passenger cars, many light duty pickup trucks and a variety of sport utility vehicles
- Single I-beam system used on many 4 X 4 trucks, or twin I-beam system used on Ford trucks for many years, or standard monobeam axle
- MacPherson strut and modified MacPherson strut

A variation of the SLA suspension is the *double wishbone*, also called the *multi-link* suspension. This is the type of suspension found on Hondas, Chrysler LH models, and others. It provides a

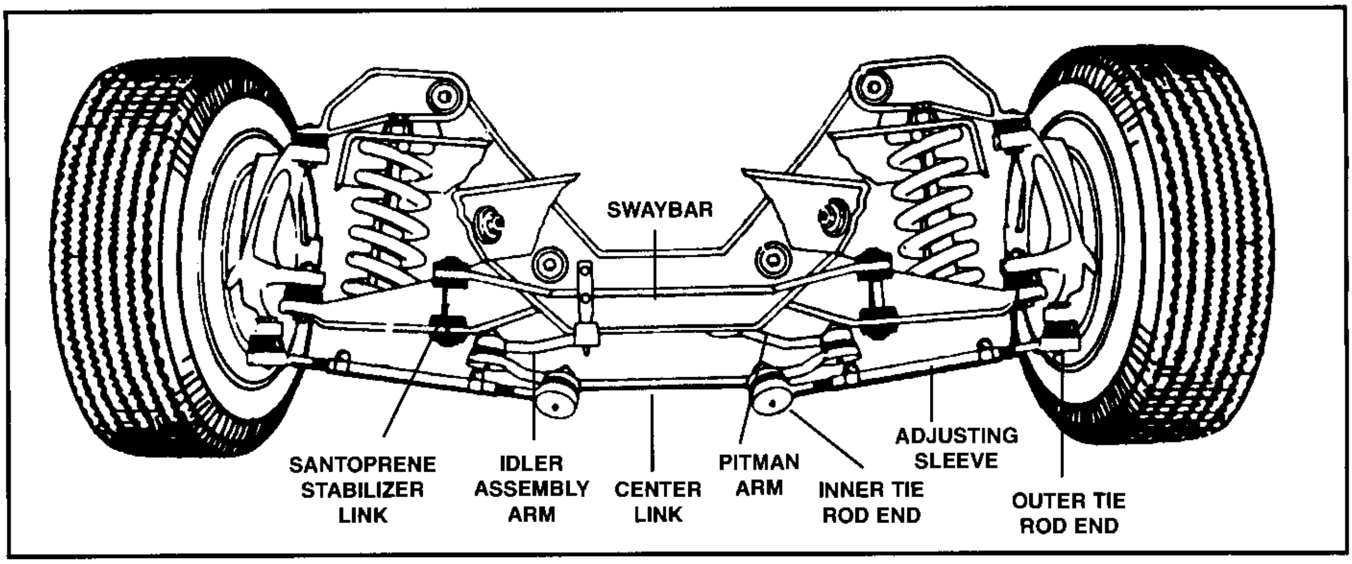

Fig. 1-2. Conventional SLA suspension with parallelogram steering. (Courtesy of DANA).

large degree of control over both handling and alignment angles while the vehicle is being driven.

Variations on these basic systems are becoming common as well. The Audi A6 and A8, mentioned earlier, has a suspension called a *four-link system.* It uses two individual upper links and two individual lower links. The entire weight of the vehicle is carried by one lower, rear control arm on each side. This link also acts as the stabilizer, absorbing all of the road inputs. The other lower link absorbs and controls the inward and outward pressure of the tire on the suspension system as it encounters road forces, bumps, and pot holes. The front arm acts as the locator.

Calculating reference points, such as SAI, is no longer simply a matter of establishing the upper and lower pivot points, and comparing an imaginary line through these points with true vertical. The Audi A4 is engineered to allow very little room for alignment adjustment. Front camber and toe are adjustable, but Audi manuals state that rear camber and toe are not. However, by shifting the rear cradle assembly, a thrust toe adjustment can be made. This will eliminate any thrust angle or thrust steer at the rear of this vehicle.

Wishbones

Many vehicles have adapted a *wishbone or multi-link* suspension system. This system has been used by a few import manufacturers for many years, and it has been adopted by some domestic manufacturers to nearly their entire car line. It requires less room than MacPherson strut suspensions, and offers improved and superior ride, handling and vehicle control. While somewhat more complex, wishbone suspensions can be lighter than MacPherson strut assemblies, and can provide more precise vehicle control.

The wishbone front suspension system is a combination of a strut and a short/long arm suspension system (Figure 1-3). The lower portion of the strut attaches to the lower control arm through a split mounting. This usually is attached by a cross bolt and bushings. In most applications, the CV half shaft passes through the wishbone portion of the lower strut mounting. The steering knuckle is connected to the lower control arm in a conventional manner by a lower ball joint.

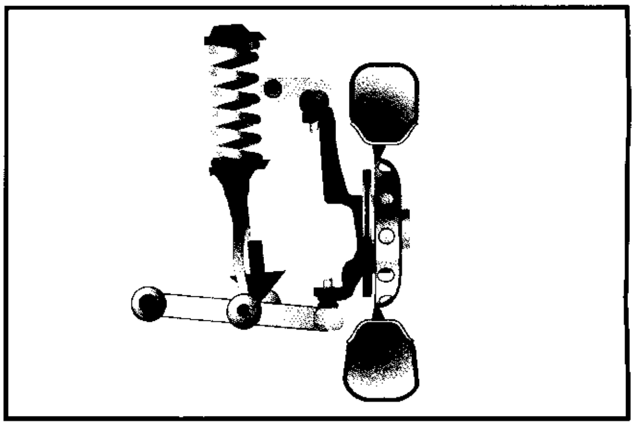

Fig. 1-3. Wishbone Front Suspension is a combination of a strut and SLA Systems

The wishbone suspension also uses an upper control arm. The weight of the vehicle is transmitted through the tire and wheel assembly into the knuckle assembly, through the lower ball joint, into the lower control arm. It is then transmitted through the lower control arm to the wishbone, from the wishbone to the strut tube, the strut tube to the lower spring seat and then into the coil spring, and up into the inner fender liner or upper strut mount, depending on the configuration.

Monobeam

Monobeam suspension systems originated early in the development of the automobile. They are durable and capable of carrying very heavy loads, but they also transmit a harsh ride. Monobeam axles (Figure 1-4) are usually attached by leaf springs and U-bolts. A king-pin attaches the spindle assembly to the axle.

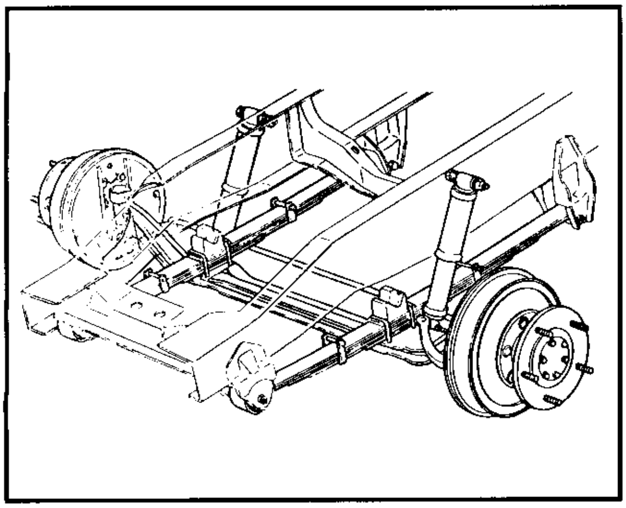

Fig. 1-4. Monobeam Suspension (Courtesy of DANA)

Twin I–Beam

A variation of the monobeam is the *twin I-beam* suspension system used on Ford trucks for many years. It consists of two, individual half beams or I–beams, one for each front wheel. These beams cross paths and have the inner end of each beam assembly attached to the frame. The outer end of the axle assembly is attached by ball joints to the steering knuckle (Figure 1-5).

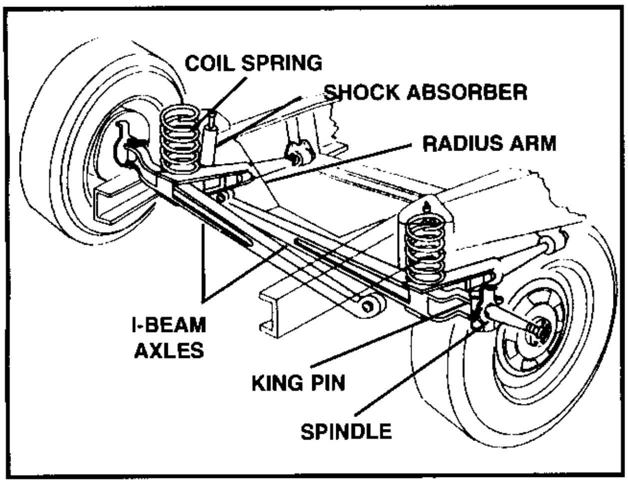

Fig. 1-5. Twin I-beam. (Courtesy of DANA)

Each I–beam has its own coil spring and a radius arm which controls fore and aft motion. This system provides all the advantages of a monobeam axle, including the ability to handle high loads and maintain proper suspension movement. It also offers the advantages of an independent suspension system, so road forces on one wheel do not directly affect the opposite wheel.

MacPherson Strut

MacPhearson strut suspension systems are used on the majority of passenger vehicles sold in the United States, as well as on a limited number of light duty trucks and sport utility vehicles (Figure 1-6).

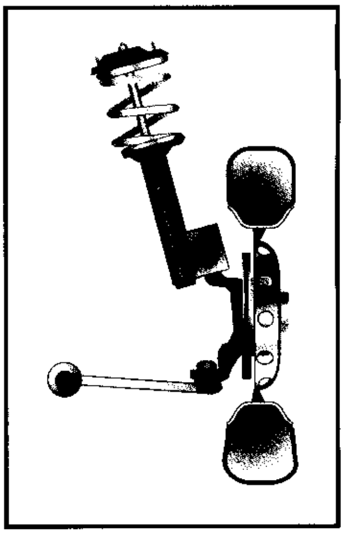

Fig. 1-6 Two Piece Strut Assembly

This system became popular in the late 1970s and has continued to grow in popularity.

MacPherson Strut suspension systems lower the unsprung weight of the vehicle, are less massive or bulky than other systems, and allow engineers to design a vehicle that provides better fuel economy because of its lower overall mass or weight.

The MacPherson strut suspension consists of the strut assembly and coil spring that attaches to the knuckle. The top of the strut is attached to the inner fender liner or structural component. Vehicle load is carried by the tire and wheel assembly. It is passed on to the bearing and knuckle assembly, and up the strut tube to the base of the coil spring.

The lower portion of the coil spring rests in a portion of the strut designed to accept it. At that point, the load is transmitted from the strut assembly to the seat of the coil spring and into the coil spring. It then moves up the coil spring to the upper strut mount, and then to the inner fender liner.

The top mount of the strut is a very important component. It isolates road shock and also allows rotational movement of the strut assembly as the vehicle is steered. The coil spring is mounted directly onto the strut and eliminates the need for any other type of coil spring mount or hardware.

The lower end of the strut is attached to the steering knuckle either by two bolts, by one bolt and one cam, or by a pinch-bolt assembly. On pinch-bolt types, the strut tube fits through an open portion of the knuckle. When the pinch bolt is tightened, it draws the knuckle assembly onto the strut tube so the knuckle moves as part of the suspension system. On GM vehicles, and on many imports that use a bolt and flanges on the strut to attach the strut to the knuckle, camber adjustment is frequently made at this location.

Modified Strut Assembly

A variation of the MacPherson strut is a system called the modified strut. On this system, the vehicle still uses a lower control arm, a knuckle and a strut. However, the coil spring is not mounted on the strut. Instead, it is mounted between the lower control arm and the frame (Figure 1-7).

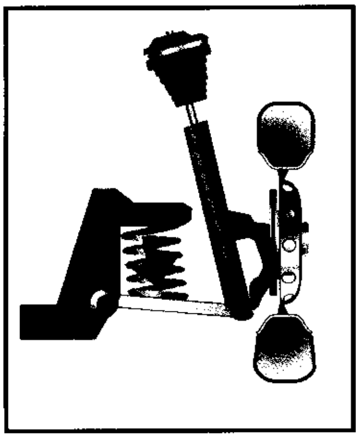

Fig. 1-7 Modified Strut - Spring Mounted Between Frame and Lower Control Arm

The strut acts as an indexing or locating component for the suspension system, but the load is not carried through it. Rather, the load is carried through the tire and wheel assembly to the knuckle assembly, down through the lower ball joint, into the control arm, and up through the coil spring to the frame. The upper strut mount and strut tube are not subjected to the same loads or stresses as a conventional MacPherson strut system. On the modified strut system, the lower ball joint carries the load. On a traditional MacPherson strut suspension system, the lower ball joint is not a load-carrying joint.

In a modified strut assembly, the lower control arm attaches to the frame. The frame acts as a major structural support assembly and controls the inward and outward motion of the lower control arm. Modified strut suspension systems frequently use a stabilizer bar to control body lean during cornering.

REAR SUSPENSIONS

On today's vehicles, the rear suspension is an integral part of the total suspension system. It is designed to keep the rear axle and wheels in the proper position, and to interact with a specific front suspension.

Rear suspension designs include:

- Non-independent solid rear axles that transmit force from one rear wheel to the other whenever one wheel encounters a pothole or bump in the road. This suspension system is commonly found on trucks, vans, RWD passenger cars and many 4WD vehicles.
- Semi-independent rear suspension allows the beam or cross member to act like a sway bar and an axle.
- Independent systems where a wheel that encounters a pothole or bump in the road is moved independently of the other wheel. When a bump or dip is encountered by one wheel, the force is not transmitted to the other rear wheel or other components. This design also helps maintain vehicle control, tire load,

traction and the braking ability of the other wheels. It helps absorb road shock and road input, dampening the input force on that side of the vehicle.

Independent suspension systems can be found on an increasing number of passenger cars, both FWD and RWD, import and domestic.

It is very important that the rear suspension of a vehicle be positioned in the vehicle correctly. If damage, worn or bent parts, or any other cause moves the rear suspension out of position, the vehicle will not handle or steer correctly, even if the front wheels are aligned to specifications. The strut assembly, when used with semi-independent rear suspension systems, usually has the bottom of the strut mounted to the rear of the trailing arm.

The top of the strut is mounted to the inner fender liner on the rear, or inner body panel assembly. This may reach all the way up to underneath the rear package tray behind the back seat, as an integral structural component. There is usually an upper mounting bushing on the strut assembly to isolate road shock, noise and harshness from being transmitted through the body.

Usually on semi-independent rear suspension systems, there is no factory adjustment for camber and toe. Therefore, aftermarket alignment products such full-contact rear shims are used to correct the thrust and toe when necessary.

Independent Rear Suspensions

Independent rear suspensions on front-wheel drive cars offer improved traction and ride comfort over the solid axle rear suspension. Each rear wheel acts independently. If a road force input such as dropping into a hole or hitting an obstruction occurs on one wheel, the force is not transmitted to the other wheel (Figure 1-8). Many independent rear suspensions have a control arm or trailing arm configuration. These units also use lateral arms to control in and out motion.

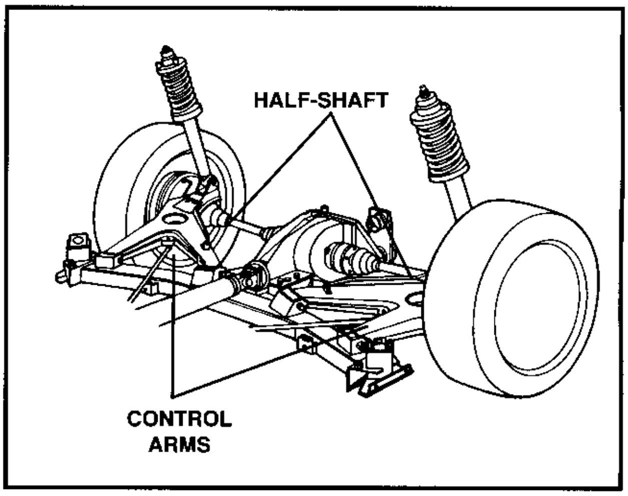

Fig. 1-8. Independent rear suspension. (Courtesy of DANA).

Lateral arms are normally attached from the lower suspension components by a MacPherson strut, which has a coil spring as an integral part of the assembly. Torsion bars may be used, although they are far less common. Rear arms control the fore and aft, and in and out motion of the rear wheels. The most common application of rear control arms are large GM vehicles, such as Cadillacs and the Buick LeSabre.

When an independent rear suspension has trailing arms, the arms are mounted to the frame through bushings and a bolt. The bushings allow vertical, and up and down movement of the assembly, and also act as noise and vibration dampers. When a wheel runs over a rough road or encounters an obstruction, the road shock and vibration is partially absorbed by this bushing. Independent rear suspensions are used not only on MacPherson strut front wheel drive cars, but also on all-wheel drive configurations. In many cases, the all wheel drive systems have basically the same suspensions as a front-wheel drive car with minor alterations to allow for the application of the all-wheel drive components.

Vehicles with independent rear suspensions frequently allow some factory adjustments on the rear. The most common adjustment is for toe. However, even though a toe adjustment is provided from the factory, an aftermarket kit or adjustment procedure is needed for camber. In some cases, the toe adjustment is so severely limited or non–functional that aftermarket kits have been developed to solve factory related toe adjustment problems.

Live Rear Axle

Live rear axle suspensions use a variety of attaching links and spring configurations. The most conventional are leaf springs which not only allow the suspension to move up and down, but also control the fore and aft motion of the axle assembly (Figure 1-9).

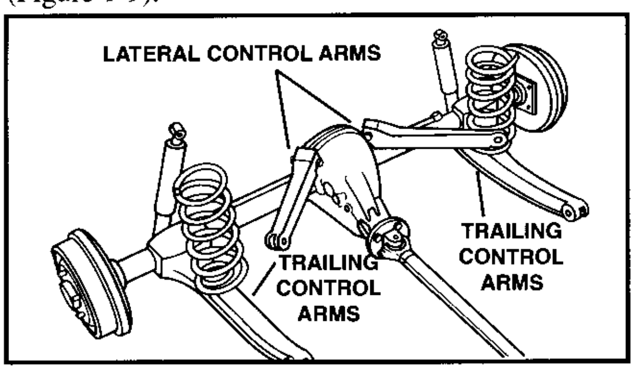

Fig. 1-9. Live axle suspension. (Courtesy of DANA).

Shock absorbers are very important on any live rear axle suspension system. If they are not functioning correctly, you may easily get wheel tramp during braking, acceleration, or when driving over rough roads. Some manufacturers stagger the shock absorbers on opposite sides of the live rear axle to assist in controlling wheel tramp and axle movement.

Forward links used on some live rear axle suspension systems with coil springs are also known as *trailing arms.* These mount to the underside of the axle assembly and run forward in a 90 degree angle from the axle to the brackets on the frame. These trailing arms are mounted to the frame attaching brackets with rubber bushings and a bolt which passes through them. The bushings isolate some of the road shock and harshness, reduce noise and control the axle's position and the vehicle's torque forces.

Rear axle assemblies, regardless of their specific design, may or may not use a stabilizer bar. When they do, it is often smaller than the front bar. This does not make them less effective. Rear stabilizer bars work in tandem, or as part of the overall design of the vehicle suspension system. The rear bar literally balances out the effect of the front bar.

When a live rear axle is used with coil springs, the weight of the vehicle is carried through the axle housing to the coil springs. The top portion of the coil springs mount to a cross member or portion of the frame. The fore and aft positioning of the axle is done by a pair of trailing arms and two lateral control arms, or a tracking bar and trailing arms. These components, or linkage pieces, stabilize he rear axle in its position and provide the means through which the torque is transmitted from the driving force of the wheels to the body.

There is not usually any factory adjustment available on live rear axles using coil springs. Some front–wheel drive vehicles use a standard type of rear axle. On these models, the axle may be mounted either by leaf or coil springs. The axle is positioned with trailing arms, and upper lateral links. A tracking bar may also be used. After-market shims are available to correct camber and toe conditions on some models.

STEERING SYSTEMS AND LINKAGE

Steering systems play a key role in vehicle performance. As a vehicle moves down the road, its

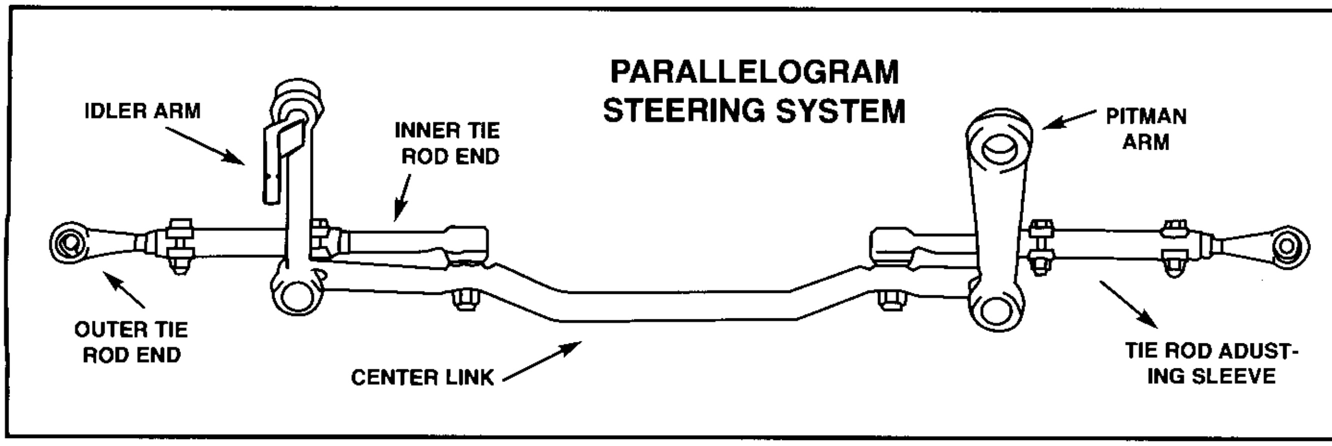

Fig. 1-10. Parallelogram Steering System (Courtesy of DANA).

wheels are constantly changing direction. Worn or loose steering components can alter alignment angles, increasing tire wear and reducing handling ability. The most common steering systems are traditional *parallelogram* and *rack and pinion.* The parallelogram steering linkage is one of the most common designs (Figure 1-10). It consists of two outer and two inner tie rod ends connected with two adjustment sleeves. The tie rod assemblies attach to the center link, which connects to the idler arm and pitman arm. The center link should always remain parallel to the vehicle frame. When set up and adjusted correctly, this system handles and performs very well while maintaining a minimum amount of toe change.

The terms *center link, drag link,* and *relay rod* have become interchangeable in many technicians' vocabularies. Actually, the relay rod or drag link is the portion of the steering linkage used on earlier trucks.

On these vehicles, the steering box was attached on the left-hand side, and a relay rod or drag link went from the steering box forward to the left knuckle assembly. This part consisted of an inner and outer tie rod end, and a long adjusting sleeve. It relayed the motion of the steering box to the left wheel.

The left wheel used a long tie rod end or long sleeve assembly with an inner and outer tie rod end, to force the right wheel to move.

It is very important on parallelogram steering linkages that the steering components be tight and not allow any unusual side to side or up and down motion. If the idler arm is not mounted at the correct height in relation to the Pitman arm, unequal toe change may occur as the vehicle is steered. Likewise, bump steer can also be caused by misaligned or nonparallel steering linkage.

Single Tie Rod End (light trucks and SUVs)

The single tie rod end steering system is normally found in Ford and GM 4WD applications (Figure 1-11) with solid front axles. It consists of a one or two piece drag link connecting the pitman arm to the steering arm on the driver's side. The system also has two outer tie rods connected with a long adjusting sleeve. This assembly spans the width of the vehicle, from steering arm to steering arm, and remains parallel to the front drive axle. The long adjusting sleeve is used to set total toe.

Cross Steer (light trucks and SUVs)

The *cross steer* is a variation of the single tie rod, and consists of the same components. It is most commonly found on 4WD Chrysler/Jeep vehicles

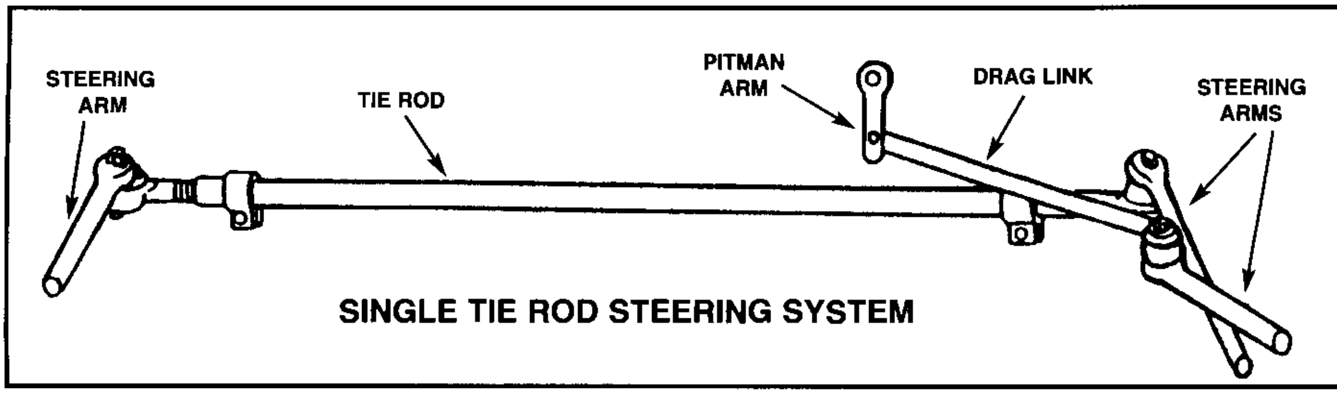

Fig. 1-11. Single Tie Rod End Steering System (Courtesy of DANA)

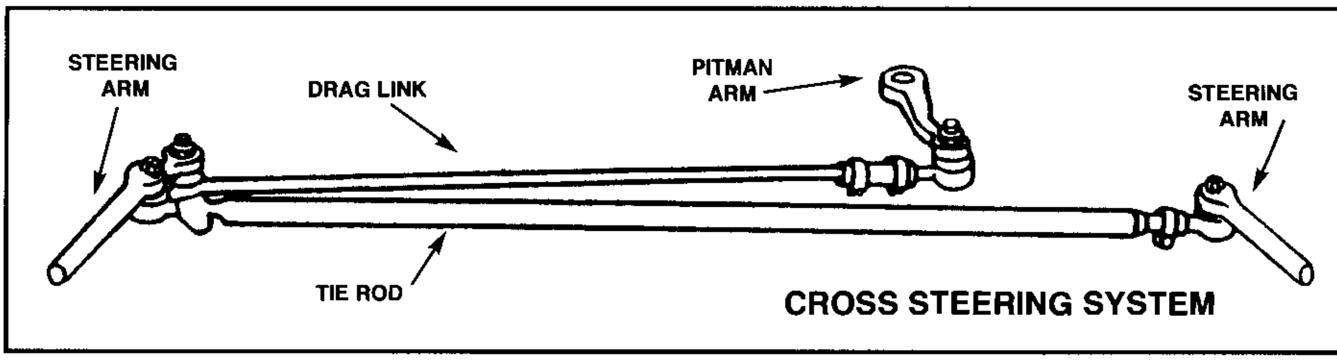

Fig. 1-12. Cross Steering System (Courtesy of DANA)

(Figure 1-12). The major difference is the drag link. On the single tie rod system, the drag link connects the Pitman arm to the steering arm on the driver's side. On the cross steer system, the drag link connects the Pitman arm *across* the front to the passenger side. Adjustments are made in the same manner as the parallelogram system, and other characteristics remain the same.

Haltenberger (Ford)

The Haltenberger steering system is unique to Ford and is used on vans and light duty trucks. This system could be considered the simplest system currently in use. It consists of a drag link connecting the passenger side steering arm to the Pitman arm. This drag link may be a one - or two–piece design. It also uses one outer and one inner tie rod connected by an adjusting sleeve. The assembly (Figure 1-13) connects the driver's side steering arm to a mid-point on the drag link.

STEERING LINKAGES

When a vehicle is driven, the movement of the suspension system also causes the steering linkage to move, normally within its designed range of travel. For this reason, it's critical that all steering parts are tight. If they are worn or loose, and allow uncontrolled inputs into the steering system, handling and alignment angles can be severely altered. If a steering component is worn, toe is normally the alignment angle most affected. Tire wear, safe operation, and the predictability of vehicle handling also may be affected.

Variable Power Assist

Speed sensitive, electronic variable assist power steering systems are being used on a growing number of domestic and import vehicles. They provide drivers with varying levels of power assist based on vehicle speed and steering wheel rotation. Variable power assist systems increase the level of assist to full power under lower speeds or

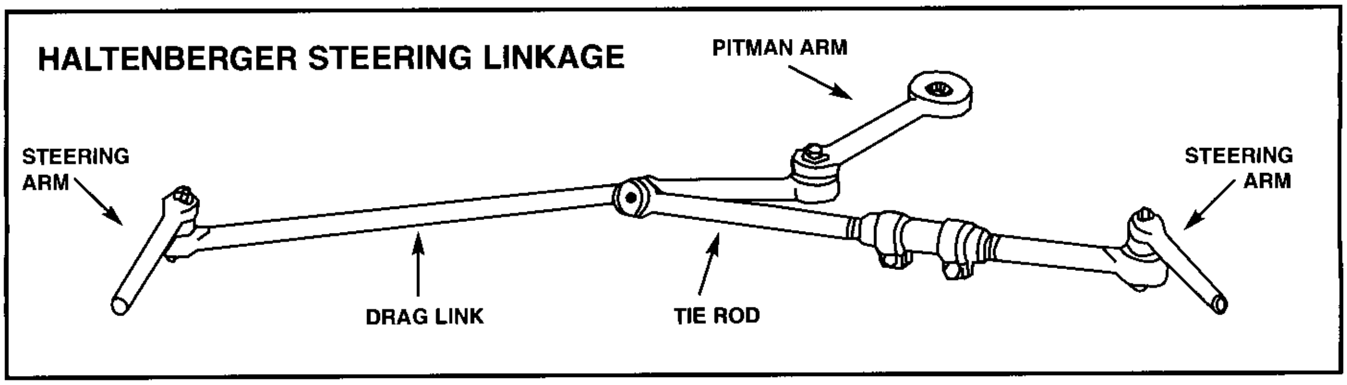

Fig. 1-13 Ford Haltenberger Steering System (Courtesy of DANA)

maneuvering conditions, and reduce it at high speeds, where a driver might require more road feel. Many types of variable assist systems are available including hydraulic, manual, and electronic.

EVO stands for *electronic variable orifice.* It is a specific type of variable power assist system composed of a power steering pump with an actuator assembly, a vehicle speed sensor, a steering sensor, a control module, and a diagnostic connector. It is commonly found on Ford vehicles such as the Mercury Cougar XR7 and the Thunderbird Super Coupe.

Rack and Pinion

The parallelogram system is being replaced by other linkage designs, mainly the rack and pinion system, (Figure 1-14) because of its weight, complexity, and cost benefits.

Rack and pinion steering systems are lighter and have fewer moving components than a parallelogram steering linkage. They are also simpler to install. Outer tie rod ends, similar to parallelogram steering linkages, attach the steering system to the steering arms. In addition, inner tie rod ends, called *inner socket assemblies,* are used.

An adjusting sleeve steers the inner tie rod end farther in or out of the outer tie rod end. A variation of this design features an adjusting sleeve that is screwed into the outer and inner tie rod end. One end has left–hand threads and the other end has right–hand threads. The tie rod expands or contracts in length as it is turned in one direction or the other.

The inner tie rod ends on a rack and pinion steering gear differ from inner tie rod ends on parallelogram steering units. Inner tie rod ends can be attached by a variety of means, including:

- Torque from tightening the units
- Lock type set screws
- Pop rivets
- Hollow roll pins, or other means

The rack gear on a rack and pinion steering unit should always be held when removing an inner socket assembly. Failure to hold the rack gear may cause the seals in the unit to fail because of the unusual twisting that will occur between the rack teeth against the pinion.

Rack and pinion steering units are classified as either front or rear steer. This designation indicates the design of the rack and pinion gear in relation to each other. A *rear steer* rack and pinion system is mounted behind the center line of the wheel assemblies, with the pinion gear located in front of the rack gear assembly.

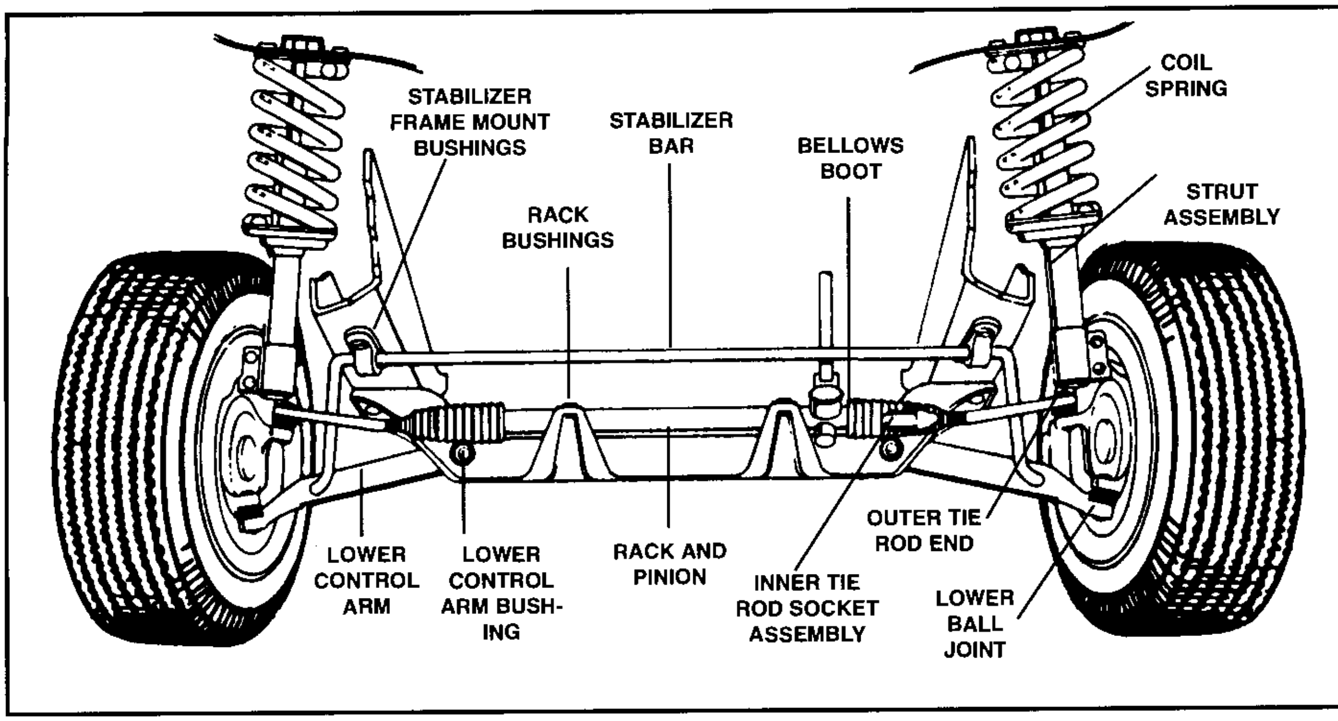

Fig. 1-14. Rack and Pinion Systems Have Replaced Most Linkage System Designs (Courtesy of DANA)

Frequently, designers of vehicles are forced to use front or rear steer because of available space. Front- wheel drive MacPherson strut vehicles usually have a rear steer configuration. The primary reason for this is the space in front of the engine is not sufficient to mount a rack and pinion steering gear.

Many rear drive vehicles also use rack and pinion steering gears. This includes many sport utility vehicles which traditionally have rack and pinion *front steer* systems.

Rear drive vehicles normally have less space behind the engine and transmission to fire wall area to mount a rack and pinion steering gear. The front steer system is mounted in front of the wheel, and the pinion gear is located behind the rack gear.

Either system, when properly designed, responds extremely well to input from the driver. Both are very durable and efficient.

POWER STEERING SERVICE

Power steering problems often appear as one of the following complaints:

- Hard steering
- Erratic assist
- Noisy steering
- Vehicle pulling to one side

The life blood of a power steering system is its fluid. It must be checked regularly, according to the manufacturer's specifications. If the wrong fluid has been used, it may be detected by its color. In many cases, however, there is no way of knowing what fluid is in the vehicle. Try smelling the power steering fluid. If it smells scorched or extremely burnt, it has probably been overheated and no longer provides the correct amount of lubrication to the power steering system.

When diagnosing power steering problems, check the fluid levels (Figure 1-15) with the system at operating temperature according to the manufacturer's specifications. Also, check the system pressure. This will help determine if the pump or the steering gear unit is causing a problem.

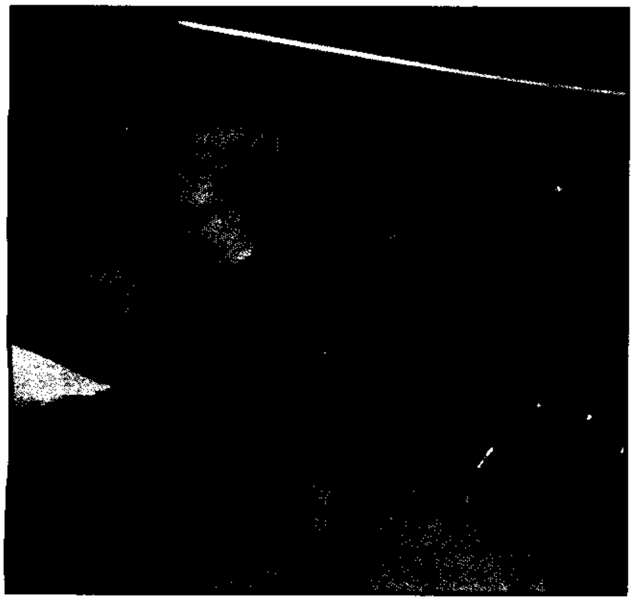

Fig. 1-15 Check Power Steering Fluid.

Rack and Pinion System Service

On rack and pinion steering gears, there are long lines, both high pressure and return, which run from the power steering pump to the rack and pinion steering gear. Some vehicles have had problems with the routing of these lines, which can lead to abrasion and restricted fluid flow to the steering system.

Be sure to check the hydraulic lines and the vent tube to make sure they are not bent, crimped, or otherwise damaged. Always replace any worn or damaged parts, and make sure the reservoir has sufficient fluid in it.

Some vehicles have also had a problem with the stiffness or the diameter of these lines. Undersized lines can cause internal restriction because the limited capacity does not allow the fluid to return properly to the pump or reservoir. Power steering hose movement has also been a problem on some vehicles. The sheer movement and expansion can cause an overall restriction in the system. Any line that shows signs of abrasion, wear, or leakage must always be replaced. A power steering-related problem may be associated with the lines, even if they do not show signs of abrasion and wear or routing difficulty.

The rack and pinion steering gear must also be checked for damage. If it moves left and right before the tie rod ends force the wheels left and right, there will be sloppiness in the steering, bump steer, or other related steering problems.

If the rack is not horizontal, the amount of toe on the left and right wheels will not be the same. This will create a bump steer condition. Racks can also sustain damage from other automotive component service, such as removing the transaxle, or body repair work. Carefully inspect a rack, not only for proper mounting, but also for cracks and other damage which may have occurred.

Check the inner tie rod socket assembly by feeling for movement or play in the inner socket through the protective boot, while you rock the steering wheel back and forth. Also, be sure to inspect units for cracks in the housing or misalignment of the assembly. If the rack has unequal steering geometry due to misalignment or damage, the vehicle could develop a bump steer problem.

FLUSHING AND BLEEDING THE POWER STEERING SYSTEM

Any time contaminants are found in the hydraulic fluid, or when service is performed, flushing and bleeding of the power steering system is recommended to help prevent accelerated wear. For specific information regarding these procedures, consult the *Four-Wheel Alignment* course workbook and video.

Some vehicle manufacturers recommend changing the power steering fluid at specific mileage intervals, while others do not. Feel the fluid to see if it contains grit or small particles. After draining some fluid through a white paper towel, examine the towel to see if particles are present.

In some cases, remanufactured rack and pinion steering gears come supplied with filters and a mandatory recommendation that the system be flushed. Clean fluid must be used, and a filter must be installed in the line. Flushing a power steering system often includes a number of steps, depending on the specific vehicle.

It is important to note that you should always use the type of power steering fluid recommended by the manufacturer. In some cases, this may be a Dexron® fluid. Other vehicle manufacturers may require specially formulated fluids that contain additives to improve fluid flow. After-market fluids can be used to cover more than one OE type of recommendation.

Starting in 1997, many power steering systems recommend vehicle-specific fluids only. The broader, universal coverage of some fluids, such as Dextron ATF, has been eliminated for many of these vehicles. Be very careful of using universal fluids in 1997 and later vehicles

Whenever a rack and pinion steering gear is changed, when hoses are replaced, or when a power steering pump is installed, the entire power steering system must be flushed and refilled with clean fluid. After filling with new fluid, bleed the system according to the manufacturer's recommended procedures. Then, start the vehicle, bring the fluid up to normal operating temperature, and recheck the fluid level.

Mineral Oil

Some vehicles, like late model Audis, BMWs, and Jaguars, use a mineral oil-based hydraulic fluid in the power steering, hydra-boost, and hydraulic-leveling systems.

Mineral oil has a different operating temperature range, allowing it to retain a thinner viscosity in cold weather. It is also easier on the seals, and allows improved valve functioning.

This is because the oil has greater lubricating properties than other fluids for the internal moving parts. An easy way to determine if a vehicle uses a mineral oil in its hydraulic systems is to check the color. Mineral oil-based fluid has a green tint. (Some Audis use a fluid that is more like an olive color). In addition, power steering reservoirs and systems that use the mineral oil-based fluid are tagged for easy identification.

Mineral oil-based fluids should never be mixed with other types of power steering fluid. Seals on pumps and steering gears that use mineral oil are made from different materials than those that use petroleum-based oil. Mixing or using the wrong fluid can damage the seals.

The valves of the power steering system, and possibly the control valves on the pump, will also function improperly if the wrong fluid is used. If petroleum oil-based power steering fluid is accidentally mixed in a mineral oil-based system, it will be extremely difficult to remove all of it. Some damage to the system is likely to occur, even if the system has not been operated. You must remove and replace any component that contains a seal or a rubber retaining part if the fluids are mixed.

Section One Mini Quiz

1. To correct camber on a FWD Audi A4:
   a. send the vehicle to a frame shop
   b. adjust the cradle
   c. use a crank bolt
   d. slot the strut towers

2. Which of the following steering linkages has a center link?
   a. cross steer
   b. parallelogram
   c. Haltenberger
   d. center point

3. Each rear wheel has total individual movement with what type of rear suspension?
   a. beam axle
   b. live axle
   c. independent
   d. semi-independent

4. The cross steer steering linkage is a variation of the:
   a. single tie rod
   b. EVO steering
   c. Haltenberger
   d. rack and pinion

ANSWERS

1. b 2. b
3. c 4. c

NOTES:

SECTION 1 SHOP EXERCISES

Move to the shop area and perform the following exercise. It is designed to help you better learn and understand the information presented in this section. We are not recommending that you perform any service, disassemble any components, or alter any parts on a customer vehicle while performing this shop exercise.

You will need access to a variety of vehicles and a lift. As vehicles move in and out of the shop you may have to take several trips to find each of the recommended models. Try to find vehicles with the following types of frame, steering and suspension systems:

1. Full perimeter frame
2. Unibody with adjustable front cradle
3. WD MacPherson strut
4. Single I–beam front axle
5. Twin I–beam front suspension
6. Multi–link or four–link FWD
7. FWD with semi–independent rear suspension
8. FWD with independent rear suspension
9. Parallelogram steering
10. Rack and pinion steering
11. Cross steer steering
12. Single tie rod end steering
13. EVO power steering

On vehicles equipped with an adjustable front cradle, identify the type of suspension and steering system. Position the vehicle so that the cradle bolts and body alignment holes can be identified.

Raise and inspect the other vehicles, identifying the various types of frame designs, steering systems and suspension systems. Write down the name of each component, and provide a basic explanation of its function.

NOTES:

2

FOUR-WHEEL ALIGNMENT

Please watch video module two now.

As discussed in the *Four Wheel Alignment* course, there are a number of reasons for maintaining proper alignment. Among them are safety and economy. Problems like poor handling, reduced fuel economy, and increased tire wear can all result from incorrect alignment.

ALIGNMENT ANGLES

Regardless of the vehicle, steering, or suspension system, there are five basic alignment angles that must be measured. Although not all of them are adjustable from the factory, the following angles must be correct:

1. Camber
2. Caster
3. Toe
4. Turning radius (or Toe–out on turns)
5. Steering axis inclination (SAI)

These angles can be classified as tire wear or directional control angles. A tire wear angle helps prevent tire wear when it's correct, and accelerates wear when it's incorrect. Of the five angles, the ones that affect tire wear the most are:

- Camber
- Toe
- Turning radius

Keep in mind that front-wheel camber, caster, and toe, and rear-wheel camber and toe are normally adjustable either through factory installed methods or through aftermarket products.

SAI and turning radius are non-adjustable angles, although camber adjustments can affect SAI. Usually, problems with these measurements indicate a problem within the suspension or steering systems. In these cases, the damaged parts must be repaired or replaced before an alignment can be performed.

Camber

Camber is the inward or outward tilt of a tire and wheel, as viewed from the front. More specifically, it is the angle between the centerline of the tire and a line perpendicular to a level surface (Figure 2-1).

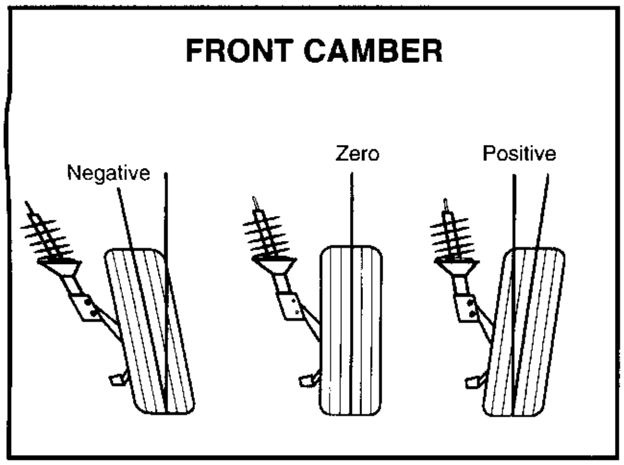

Fig. 2-1. Camber

If camber is unequal side-to-side, the vehicle will pull to the side with the most positive camber. Too much positive camber makes the tire wear out faster on the outside. Too much negative camber makes it wear out faster on the inside. Rear camber is not adjustable on most RWD vehicles. These vehicles are built with zero camber and are strong enough not to flex or bend under normal loads. Most FWD vehicles have a manufacturer's specification usually calling for a small amount of negative rear camber for cornering stability. If the manufacturer's specifications allow, a setting of 0° to -5° is preferred for tire wear and stability. The difference from side-to-side should be no more than 1/2°.

If camber settings change, most vehicles can be adjusted with an aftermarket alignment adjustment kit containing items such as shims, cam bolts, or bushings. Vehicles that do not allow for factory camber or caster adjustments include Honda models with a multi-link front suspension system. An adjustable bushing available from a quality aftermarket supplier can be used to set these angles.

Ford's popular 1986 - 1997 Taurus and Sable sedans use a tri–link type of rear suspension with lateral links attached by rubber bushings (Figure 2-2). The rearward link also has an eccentric metal sleeve in it that allows toe to be adjusted. The factory–installed bushings deteriorate at variable mileage, sometimes as low as 20,000 miles. They are metal, and environmental conditions can cause them to wear and rust. Ford does not allow toe to be adjusted, however an uncontrollable toe change can be transmitted as the vehicle moves through its range of travel and can be caused by wear on this bushing. Suppliers of quality parts has a replacement bushing that eliminates the problems of rust and metal-to-metal contact. It also provides a wider range of camber and toe settings for a more accurate alignment.

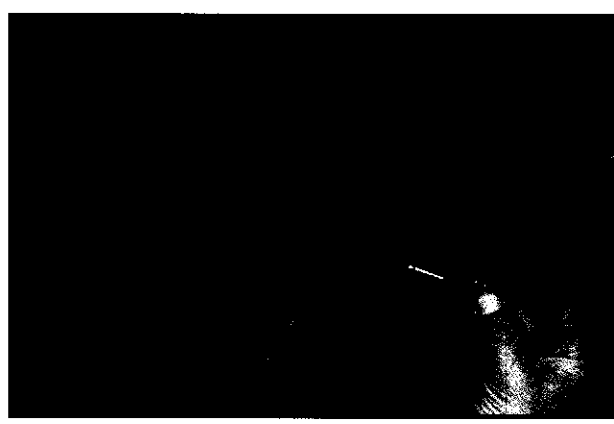

Fig. 2-2. Rear Camber Bushing for Ford Taurus

There is also a kit available that installs a bushing into the forward arm. This enables you to split the amount of change per side between camber and toe, so you can dial in both alignment angles to achieve maximum handling and tire wear.

Caster

Caster is the forward or backward angle of the steering axis, as viewed from the side (Figure 2-3). This angle is formed by the steering axis line and a vertical line running through the center of the wheel and tire. On SLA and strut/SLA suspensions, the steering axis runs through the upper and lower ball joints. On strut suspensions, it runs through the upper strut mount and lower ball joint.

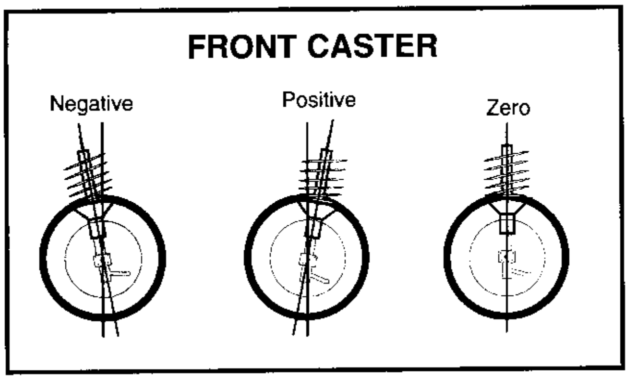

Fig. 2-3. Caster Alignment Angle (Courtesy of DANA)

Generally, caster is measured only on the front wheels because, except in cars with four-wheel steering (4WS), the rear wheels do not have an actual steering axis. On 4WS vehicles, the rear wheels have a steering axis by definition (an imaginary line between two pivot points), how-ever, the steered angle of the rear wheels ranges from 1° to 5°, depending on the manufacturer. This steering axis has no caster value.

Caster is usually recommended to be equal side–to–side, or at least within 1/2°. Some vehicles will call for some caster split. Remember, a vehicle will always drift or go toward the side with the *least* amount of *positive* caster. Another way of thinking about this is, whichever upper pivot point is farther away from the driver, the vehicle will have a tendency to go to that side.

Caster is not generally considered a tire-wearing angle, but if it is excessively high, or if there is a great deal of variance side to side, caster can cause a shimmy. The greater the positive caster, the more camber will change when the vehicle is turned left or right. Therefore, extremely high caster can cause uncontrollable, out of range camber side-to-side changes that may cause tire wear.

If one side has a weak coil spring that allows the body to drop down, the rear axle trailing arm will change, causing a greater caster effect on one rear wheel than the other. This will amplify the rear toe reading and create a thrust problem even though the toe and camber adjustments may be correct. Rear caster amplifies whatever toe reading is present. Therefore, rear toe readings and rear ride height are both critical factors that interrelate with the caster.

On vehicles such as the GM W-bodies, caster can be adjusted by loosening the cradle mounting bolts and shifting the cradle in a fore and aft manner (Figure 2-4). It is *not* adjusted on these models by elongating the upper strut mount holes. This procedure is recommended only to adjust *camber.* Caster should be equalized on the two sides of the vehicle, while maintaining as correct as possible

Fig. 2-4. GM W-Body Cradle Adjustment

alignment of the cradle mounting holes in reference to the body positioning holes.

If a choice is necessary between correct caster alignment and correct mounting hole position, choose the correct caster alignment. Remember, on GM W-bodies, the alignment angles change radically when the wheels are turned from a straight ahead position. Therefore, the correct straight ahead reference angles must always be achieved.

Camber Roll

Caster also affects camber during turning. This motion is known as camber roll (Figure 2-5). As the front wheels turn on a backward-tilted axis (positive caster), the spindle on the outside wheel moves up, and the spindle on the inside wheel moves down. This decreases camber on the outside wheel and increases it at the inside wheel.

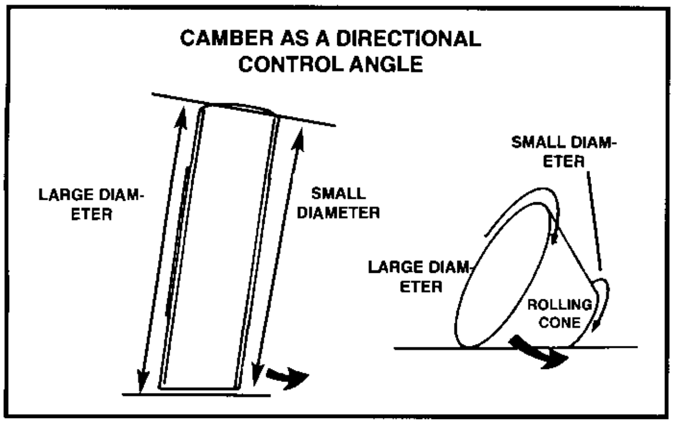

Fig. 2-5. Camber Roll

This means that camber changes when the wheels are steered to either side, even if the camber reading is zero when the wheel is straight ahead. Camber roll wears both edges of the tires because the camber is positive when turning in one direction, and negative when turning in the other direction.

Toe

Toe is the angle between the direction the wheel is aimed and a line parallel to the centerline of the car (Figure 2-6).

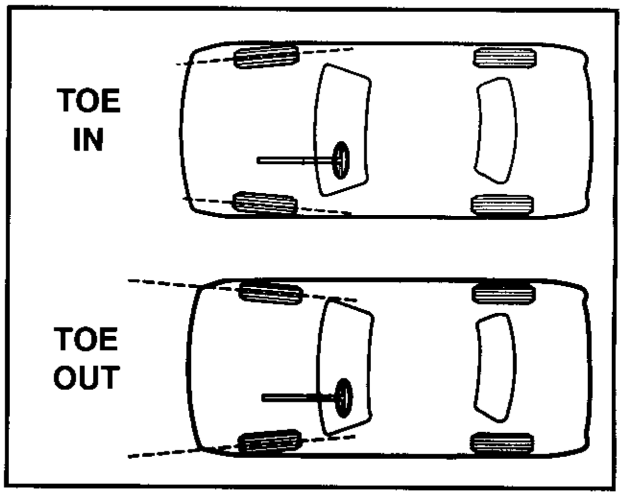

Fig. 2-6. Toe is the Difference Between the Leading and Trailing Center Lines.

Most specifications are for total toe. This is the difference between the leading and trailing centerlines of the tires when compared to each other. It is important to note that although toe has historically been measured in fractions of an inch or decimals, it is becoming more common for vehicle manufacturers to express toe in degrees (Figure 2-7).

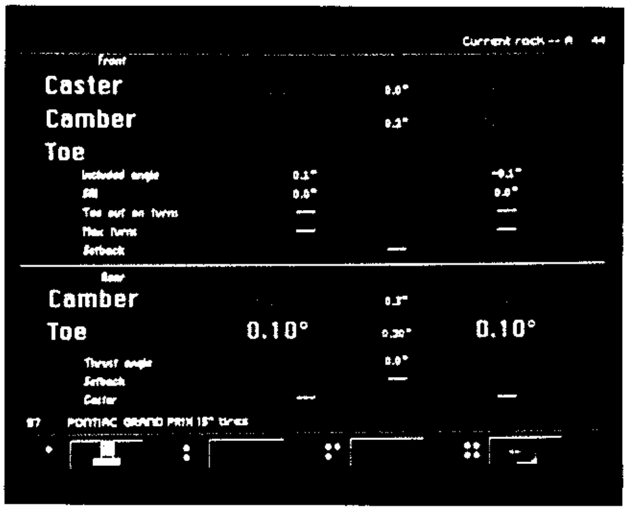

Fig. 2-7. Toe Measured in Degrees

The idea behind this is that the angle, rather than an arbitrary distance, determines the motion of the tire and any resulting tire-wear patterns. Most modern alignment equipment is capable of measuring toe in this manner.

Toe is the most important tire wear angle. Zero toe is ideal for preventing wear. When a wheel is not pointed straight ahead, the tires may scuff sideways along the road as they roll forward. Rear toe is the most critical factor influencing mileage and handling. It is normally adjustable by installing aftermarket shims or kits designed to bring toe into the manufacturer's specifications.

Thrust Line/Thrust Angle

The thrust line is an imaginary line that runs forward from the center of the rear axle and bisects the rear toe at a 90° angle. The geometric centerline is an imaginary line that bisects the front and rear axles of a vehicle.

The angle formed by these two lines is known as the *thrust angle* (Figure 2-8). Thrust angle is important because the rear wheels determine the position of the front wheels during straight driving. This is true on both FWD and RWD vehicles.

In other words, when a car is traveling straight, the rear wheels steer the vehicle, while the front wheels align themselves to the rear. This causes the vehicle to travel along the thrust line.

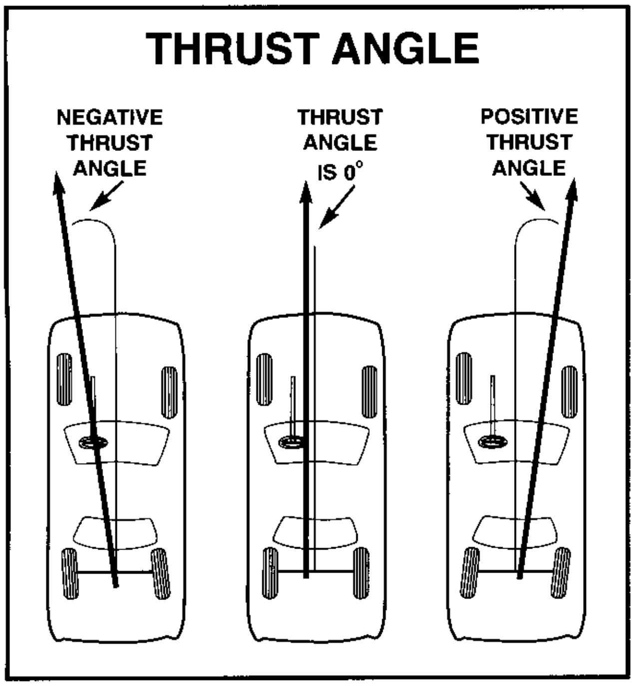

Fig. 2-8. Thrust Angle

An example of how important thrust angle is can be seen in the example of backing up. When backing up, a car will go straight as long as the front wheels are pointing straight ahead. As soon as the wheels are turned, the rear of the vehicle will turn left or right. If the thrust angle is directed to the right, it is called *positive thrust,* and will direct the vehicle in the opposite direction, to the left (Figure 2-9). If the thrust angle is to the left, this is *negative thrust,* and steers the vehicle to the right.

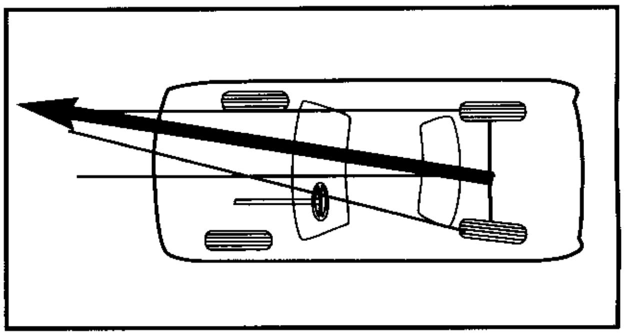

Fig. 2-9. Effect of Positive Thrust

Correcting rear toe may help bring the thrust line and centerline together. However, rear toe may not always be OE-adjustable, as with 1990 and later Saturn models. A rear toe adjusting kit is available for correcting this angle. Installing the kit involves removing and replacing the center mounting bolts on the rear control arms (Figure 2-10).

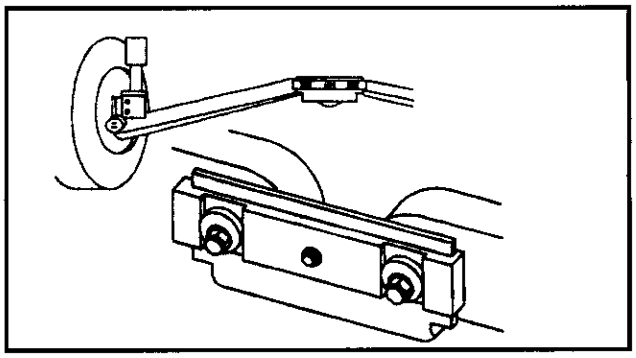

Fig. 2-10. Rear Toe Adjustment Kit for Saturn

Steering Axis Inclination/Included Angle

SAI is not normally adjustable. Alignment technicians often measure this angle when damaged components are suspected. The SAI measurement indicates the position of the ball joints, or ball joint and strut, and the steering knuckle and spindle. If parts are bent or damaged, SAI readings will change. An engine cradle that is damaged or positioned incorrectly may also cause a change in SAI.

Technicians also use SAI and camber to check for bent parts. The SAI angle, plus or minus the camber angle, is known as the *included angle* (Figure 2-11).

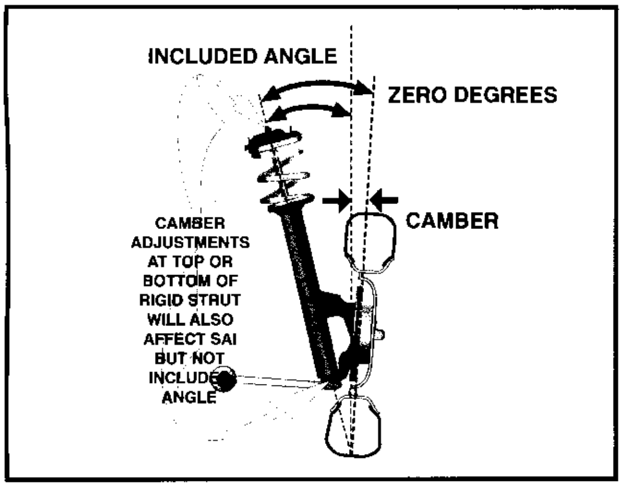

Fig. 2-11. SAI and Included Angle

By comparing these measurements and determining which is incorrect, a technician can more closely pinpoint which steering or suspension component is causing a problem. For example, if an out-of-spec camber angle is needed to make the included angle on both sides identical, a bent spindle or steering knuckle is indicated. If the included angle is more than 1-1/2° different from side-to-side, it is an indication of bent parts.

Scrub Radius

Another angle, known as *scrub radius,* also relates to SAI. Scrub radius is the distance between the point where the SAI line intersects the road and where the centerline of the tire intersects the ground, as viewed from the front. If the SAI line intersects the ground inside the vehicle's tire centerline, the tire has a *positive* scrub radius. If the SAI line crosses over the tire centerline and intersects the ground outside of the tire centerline, the tire has a *negative* scrub radius (Figure 2-12).

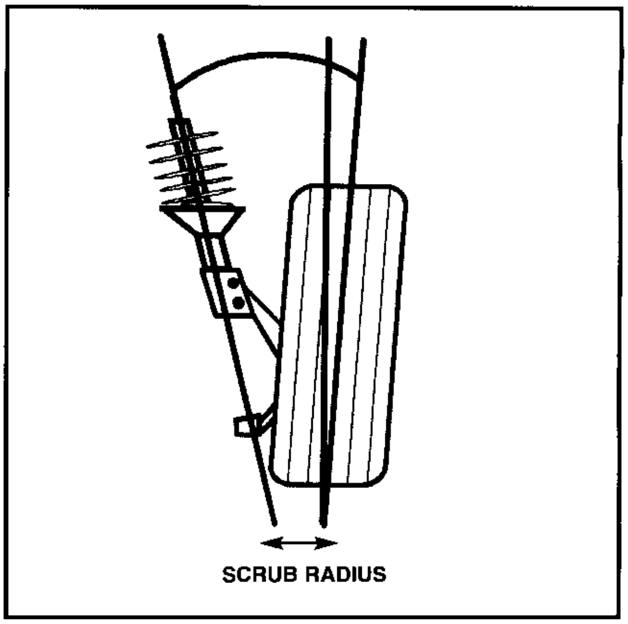

Fig. 2-12. SAI and Scrub Radius

Vehicles are designed to have either a positive or a negative scrub radius. Either is acceptable, as long as the design works properly. However, each makes a vehicle handle differently, particularly while braking. Sports car designers often favor a positive scrub radius. They claim it increases driving enjoyment by increasing the driver's involvement. Designers who use a negative scrub radius favor the ease of handling and safety benefits.

Most FWD vehicles have negative scrub radius to counteract traction differences and to offset the amount of pull if one front brake goes out or the wheel goes flat. Negative scrub radius has a tendency to cause a tire to rotate or tilt inward, offsetting the additional drag caused by a flat tire or a failed brake.

Turning Radius

Turning angle is also known as *toe-out on turns* (Figure 2-13). Like many other alignment angles, this measurement is built into the steering system and is not adjustable. Because of this, if one or both of the steering arms becomes misaligned or bent, the turning angle will change. Readings that are out-of-spec may also indicate a non-parallel steering linkage, a rack that is not level, or a toe adjustment that was made without centering the steering wheel. Normally, the only way to correct toe-out on turns is to replace the defective part or parts.

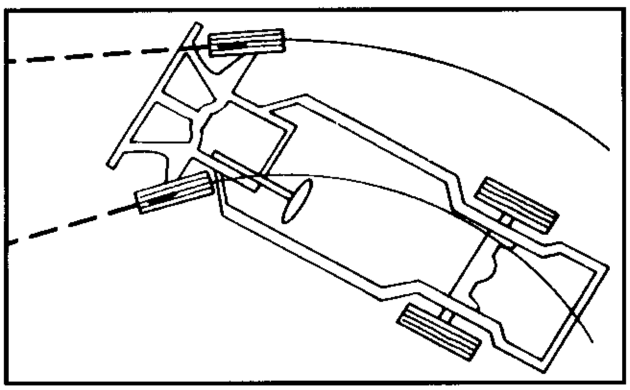

Fig. 2-13. Turning Radius (Toe out on turns)

Bump Steer/Toe Curve

As a vehicle's suspension travels through jounce and rebound, toe change can occur even when toe is correct. Ideally, toe change should be zero. Excessive toe change, often referred to as *bump steer,* or toe curve, normally indicates a problem with the vehicle's idler arm, Pitman arm, or steering arm, and could even indicate a problem with the tie rod (Figure 2-14).

Bump steer causes the same handling problems as incorrect toe. However, bump steer problems occur only during suspension travel (jounce and rebound) and affect steering over bumpy surfaces. In addition, body roll during turns produces similar suspension travel and toe changes. This is commonly referred to as roll steer.

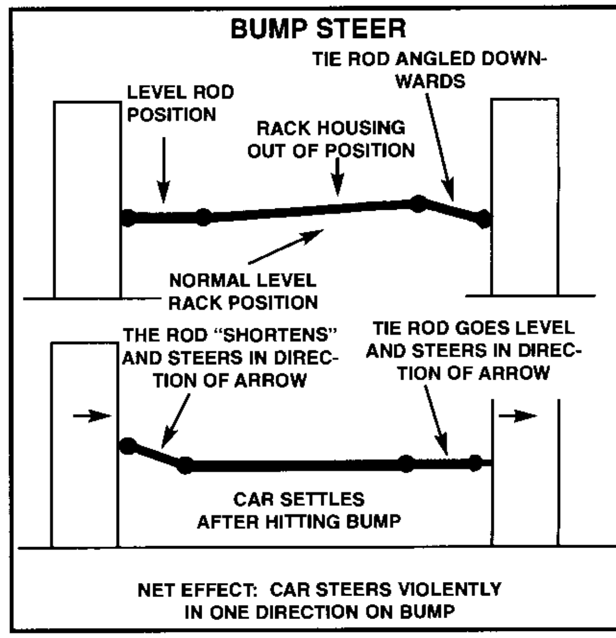

Fig. 2-14. Bump Steer Caused by Tie Rod Position

Memory Steer

Another type of steering pull known as *memory steer,* may occur when the rubber in a rubber-bonded socket (RBS) tie rod end breaks apart, allowing the assembly to shift (Figure 2-15). When this occurs, the vehicle pulls in the direction of the most recent turn, even after the steering wheel is returned to a straight-ahead position.

Fig. 2-15. Check for Tie Rod End Shift.

Setback

Setback occurs when one wheel on an axle is farther back than the other. When the right wheel is farther back than the left, the axle has a *positive* setback. When the left wheel is farther back, the axle has a *negative* setback. Excessive setback of one inch or more can cause an alignment pull to the side with the most setback (Figure 2-16).

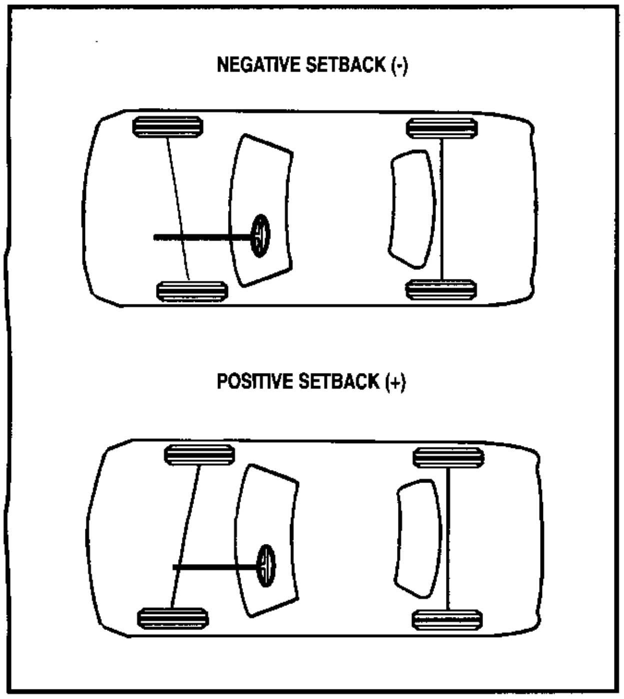

Fig. 2-16. Positive and Negative Setback

Setback is different from wheelbase. Wheelbase is the distance between the center of the front spindle and the center of the rear axle on each side of the vehicle.

The most common problem affecting setback is an accident. If the vehicle is not repaired correctly, the body may look like the wheels are centered in the wheelwells, but a setback condition could exist. It is possible to have zero setback at the front, but still have a wheelbase difference depending on overall design, and whether or not the rear axle has a setback problem.

Front setback is commonly used to diagnose collision damage or cradle misadjustment. The majority of alignment equipment will display a setback condition, but the side with the variance indicated by the equipment is not always the problem side. For example, one side may be farther forward than specifications allow, but the equipment shows that one wheel is back farther than the other. If the cradle is adjusted incorrectly, or if damage is present, it is not unusual to also see a reduced positive caster reading on the side with the setback condition. This will also cause the vehicle to oversteer to the setback side, and understeer to the other side.

Frame Angle

Frame angle is the angle of a frame in relation to the ground (Figure 2-17). This is important because every one degree of change in the frame angle also changes caster by one degree.

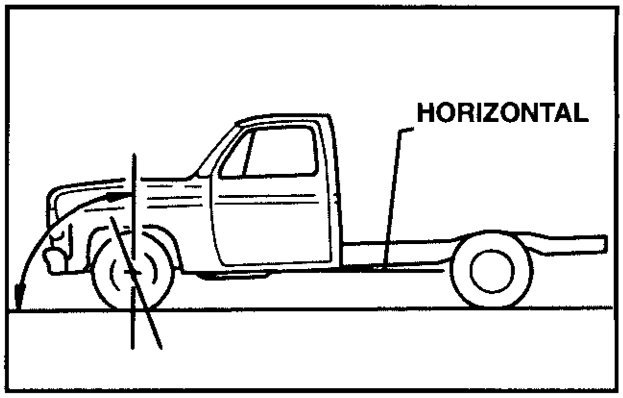

Fig. 2-17. Frame Angle and Effect on Caster

If the frame is higher in the back, it has a *positive* frame angle, while a lower frame in the back results in a *negative* frame angle.

The frame angle is a built–in angle with no factory provisions for change. However, extended shackles or lift kits and, in some cases, shims, may be used between the axle and the leaf springs to alter frame angle.

PRE-ALIGNMENT INSPECTION

Whenever a vehicle is suffering from tire wear, steering and suspension, handling or any other ride control problem, an inspection must be done. Any parts found to be worn, defective or unsafe in this inspection must be replaced to ensure that the vehicle will remain in alignment.

The ***"Four-Wheel Alignment"*** can help technicians conduct a pre-alignment inspection. This course is an excellent reference guide and will prevent you from forgetting or missing any steps in the procedure.

These procedures include:

TOTAL ALIGNMENT SERVICE CHECKLIST

- ❑ Customer Communication
- ❑ Road Testing the Vehicle
- ❑ Inspecting Tires
- ❑ Checking Ride Height
- ❑ Checking for Bent, Broken, or Mis-located Parts

Customer Communication

Communication with the customer is critical. Clarify the details of the problem with the customer and follow through on a complete vehicle inspection. Common customer complaints may include a pull to one side, harsh steering, poor handling or driveability, an off–center steering wheel, or excessive tire wear.

Ask questions to get to the source of the problem. It may save you hours of diagnostic time. Be sure to ask customers how they normally use the vehicle. Wear and tear on the vehicle and its alignment are a lot different if the vehicle is used to carry only the driver than if it's used to regularly haul heavy loads.

Vehicles that are subjected to heavy loads, car pooling with many people, trailer towing, etc., can and do wear tires and handle differently from vehicles that are not subjected to these loads. In some cases, the vehicle may actually be overused, that is, being asked to do more work than it was designed to do safely.

When talking to your customer, some questions to ask should include:

- How would you describe the problem? Is it a noise, a vibration, or a handling problem?
- When did you first notice the problem?
- How long has the vehicle had this problem?
- Under what conditions (type of road, road conditions, weather conditions, etc.) do you notice the problem?
- Has the vehicle been serviced lately? If so, what was inspected or repaired?

Road Testing

Road testing is a very important part of checking the wheel alignment, chassis and suspension systems. If you do not perform a pre- and post-alignment road test, you can miss many problems. Customers get used to various driving and handling conditions that may develop slowly over a period of time. By road testing, you will be able to check for all steering, suspension and handling problems.

Before taking a customer's vehicle for a test drive, get permission from the customer first. Also, make sure you are insured to take a test drive. You should lay out a standard test drive route that you use every time. That way, you'll be able to anticipate how the vehicle will perform on any part of the route.

Road tests should be done over the same section of the road and at a variety of highway and city speeds. By performing a regimented road test on a similar section of the road under similar driving conditions for all vehicles, you will know what normally happens and how the vehicle should react. This will assist you in determining any abnormal conditions that may be present. Be alert for vibrations, shimmies, and other driving conditions at each speed. If a vibration is felt, determining whether it is dominant in the steering wheel or rearview mirror will help you determine whether the front wheels or the rear wheels are causing the problem.

Suspension noises can be extremely difficult to track down. To help determine whether the noise is coming from the front or rear, and the left or right side, drive the vehicle over an object such as a speed bump in a parking lot.

If you have a suspension or steering linkage or part that is binding or making noise, you may be able to isolate the noise between the front and the rear, and in some cases, between the left and right side, by causing one tire at a time to go over the speed bump.

Make several right- and left-hand turns. This will help you determine which side is making noise. When you make a turn, the load is transferred. One wheel will go up and the other wheel will go down. This may also assist you in determining the source of the noise.

Check for noises and other conditions at steady throttle, and when accelerating and decelerating. Pay particular attention to whether the noise is wheel-speed or drive-line related.

Inspecting Tires

One pre-alignment check that's a must is tire inspection, especially inflation. This should be checked while the tires are "cold." Maintaining correct pressure lengthens their life. Checking air pressure is not a visual operation. You must use an air pressure gauge. At least one tire has been found on 40% of vehicles to be at least 15 lbs. low.

Tires that are under inflated can suffer a variety of irregular tire wear patterns and, in some cases, structural damage.Tire inspection is not complicated and, therefore, is frequently over-looked by many technicians. Tires should be inspected for similar sizes, similar tread designs and similar brands. They also should be checked for any irregular wear patterns and tread depth across the face of the tire. Also, check the sidewall for any cuts, abrasions, or other signs of damage.

Tires should be raised off the ground and spun, checking for any irregular runout or separation problems. Also, the tread depth should be checked across the face of the tire with a tread-depth gauge.

Ride Height

Ride height must be checked as a part of the pre-alignment inspection and corrected if it is out of specification (Figure 2-18). Ride height affects the steering and suspension geometry.

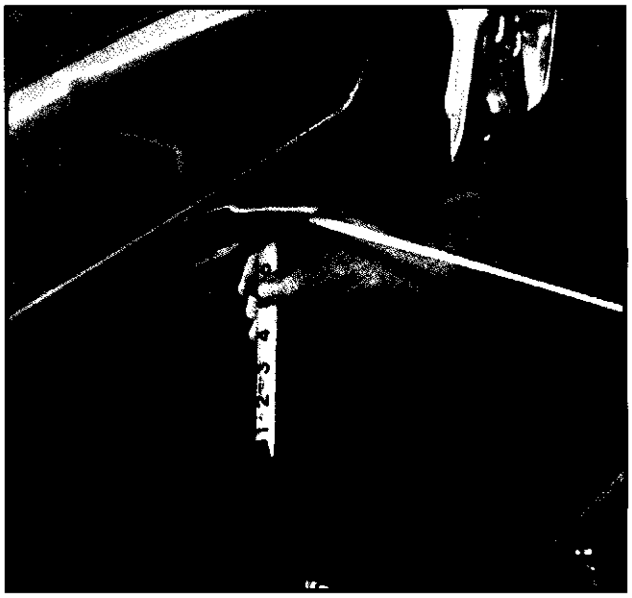

Fig. 2-18 Checking Vehicle Ride Height

The manufacturer designed the steering suspension geometry to operate within a certain ride height range.

If the suspension is higher or lower than spec, the control arms will be mis-positioned with an accompanying suspension geometry change. If ride height differs more than 1" from one side to the other, or front to rear, suspension components should be inspected and replaced as necessary. Be sure to check the ***Specification Manuals*** for the correct specifications for your application.

The usual cause of a ride height problem is a worn or broken spring, although bushings and other parts, depending upon suspension design, may also be the cause. Obviously, worn tires, incorrect tire size, and tire inflation will also affect ride height. Wear on one part can easily lead to wear or handling problems in another portion of the system.

While making alignment adjustments, keep in mind that any vehicle equipped with a rear ride height pressure control valve in the brake system may need an additional adjustment. The valve must be readjusted according to the OE manufacturer's specifications after the vehicle is aligned if the rear alignment changes the setting of the valve.

Bent, Broken, or Mis-located Parts

The final step in the pre-alignment inspection includes checking front suspension, steering, and rear suspension components (Figure 2-19). The steering and suspension systems work as a team, so it's important to remember that wear in one area or on one system can lead to wear on the others.

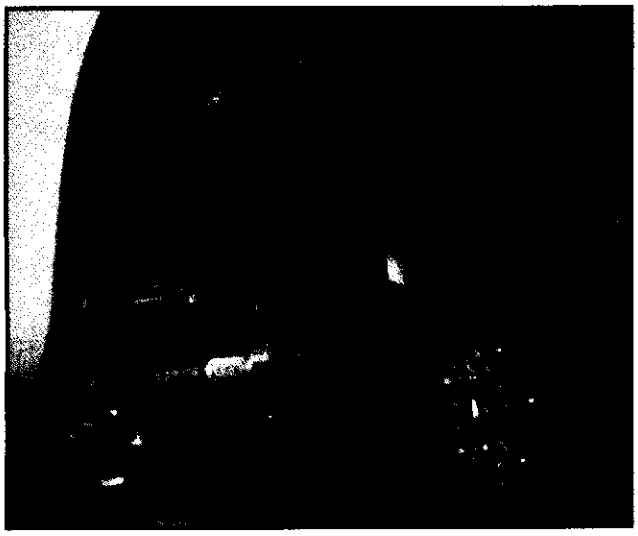

Fig. 2-19 Check Front Suspension System

Some of these inspection steps are discussed briefly in the following section. Additional information on these procedures is available in the ***Four-Wheel Alignment*** course.

Front Suspension Inspection

Shock and strut service mileage will vary considerably, depending upon the manufacturer and use of the vehicle.

The struts should be checked at the upper mounting to see if there is any excessive movement. Make sure that the strut nut and upper bearing plate are held tightly in the inner fender liner.

Check the shocks by jouncing the car at each corner. If the car bounces more than twice after you stop, the shock absorbers should be replaced. A properly functioning shock or strut will allow slight expansion beyond its static height and then immediately settle the suspension.

Inspect the shocks for signs of leakage. Some slight oil film or weeping of the upper seal does not indicate a defective unit. But if oil is running down the side or has leaked enough where it has collected a considerable amount of dirt and oil, it may be defective.

Check the condition of the ball joints according to the specifications found in the wheel alignment service guide. Wear indicator ball joints must be checked with the weight of the vehicle on the tires and while the vehicle is on a level surface. If the wear indicator is recessed or flush with the joint surface, the ball joint must be replaced. Slide a small screw driver or similar tool across the end of the ball joint. If the wear indicator is protruding from the end cap, the ball joint is OK. If it is not, the ball joint is worn *excessively.*

Non-wear indicator, load-carrying ball joints can be checked by measuring vertical and horizontal play. Use a dial indicator and compare the readings against those found in the manufacturer's service guide specifications.To check for wear in non-load carrying ball joints, be sure to follow the manufacturer's instructions. Keep an eye on the joint, and look for movement. However, a dial indicator is the most accurate tool for determining the amount of play in a ball joint. Check the suspension bushings for cracks or other signs of damage.

Also, check the mounting bolts and bushings at the inner ends of the control arms to make sure they are still serviceable. Bushings deteriorate from the inside out. If they show signs of wear, be sure to replace them.

Lower control arm, inner mounting bushings are easy to check. With the weight of the vehicle on the tires, start the engine, and turn the steering wheel until it reaches its lock position.

Next, have an assistant rock the steering wheel back and forth while you inspect the movement of the lower control arm in relationship to the mounting bolt and clamps. If the control arm jumps in and out uncontrollably, the bushing are worn and must be replaced.

On strut suspensions, make sure the pinch bolt and the strut mounting bolts are tight, and that no movement has occurred. The pinch bolt must not have been excessively tightened. If it has, and the ears of the split knuckle flange are touching each other, the knuckle may be stretched or damaged and could break when the pinch bolt is loosened. If there is any indication of bending, the bolt has been excessively tightened and the knuckle should be replaced.

Check to see if there are any signs that the strut tube is shifting in the knuckle. If the bolt is not holding the correct tension on the strut, the strut may move up and down in the split knuckle assembly when the vehicle is driven over rough roads.

Be sure the springs are in good condition and are able to maintain correct ride height. Springs that are in good condition should not show signs of excessive wear, such as cracks or shiny spots caused by coil clash.

If a vehicle has been bottoming excessively, the strike-out bumper, which prevents the lower control arm from making contact with the frame, may be missing, broken, or show signs of excessive bottoming.

Check the rear torsion bar mounts where they mount in the cross member. Deterioration, because of rust or a poor design, may result. In some cases, you can see where the mount has failed and the torsion bar has been striking the cross member when the vehicle makes tight turns. This is a noise that is typically difficult to diagnose.

Steering Linkage Inspection

The entire steering linkage must be carefully inspected. Use a dry park check method prior to greasing the vehicle. A rule of thumb is that any horizontal or vertical movement of components with hand pressure is an indication of loss of preload and possible need for replacement.

Inspect the tie rod and the center link for bends or cracks. Check for damage that may have been caused by striking an object such as a parking curb divider. Grasp the outer tie rod ends and attempt to move them in, up and down. Any movement with normal hand pressure indicates a loss of pre-load.

With the weight of the vehicle on the tires, have an assistant rock the steering wheel left and right. Use your thumb and forefinger to feel between the tie rod, dust boot and steering arm. Any movement or side play indicates an excessive wear condition and the need for replacement.

The boots on the tie rod ends should be checked to make sure they are not cracked, missing, or torn, which would allow contamination to enter the tie rod end socket assembly.

Power steering fluid anyplace on the steering linkage may be a sign that the power steering pump or hoses are leaking, and further inspection is warranted.

Vehicles with a rack and pinion steering gear must have both the inner and outer socket assemblies checked along with the outer tie rod ends. To check the inner tie rod ends, with the weight of the vehicle on the tires, have an assistant rock the wheel left and right while you feel the bellows over the tie rod end. Any clicking or movement indicates a loss of pre-load and the need for replacement.

Next, with the weight of the vehicle off the front suspension, grasp the tire at the 3 and 9 o'clock positions and attempt to move it in and out. Feel the inner bellows assembly for any loss of pre-load on the inner socket. Any indication of excessive movement found during this check also indicates a loss of pre-load on the inner tie rod end and a need for parts replacement. If the rack and pinion steering gear uses a Hytel® boot, you can either remove it or simply feel the boot, pushing downward against the inner socket assembly as much as possible. If an inner socket assembly is excessively loose, you will feel the clicking or looseness.

Check the components that connect the rack to the steering shaft. On some vehicles, this is a "rag" or "universal" joint. These joints can and do wear and may contribute to binding or hard steering problems. On parallelogram type steering linkages, inspect the idler arm by grasping the center link at the idler arm connection while applying approximately 25 lbs. of upward and downward force. Any amount of looseness beyond specification indicates a need for replacement. An idler arm which is loose will allow an uncontrollable toe change as the suspension moves through its jounce and rebound.

To check the Pitman arm to center link connecting pivot point, have the weight of the vehicle on the tires. Have an assistant rock the steering wheel back and forth while you place your thumb and forefinger between the Pitman arm and the center link. Any indication of side motion or play indicates a worn socket assembly and the need for parts replacement.

Inspect the entire steering linkage assembly. Check for any impact damage or other indications that the parts may have been bent. On rack and pinion steering gears, make sure that the rack is mounted securely to the cradle or fire wall by holding your hand over the rack at the fire wall while an assistant rocks the wheel left and right. Feel for any side play of the assembly in its mounting bushings.

On parallelogram steering linkages, check the tie rod ends for lockout. The tapered ball stud must be centered in its housing, and should be able to be swung a slight distance left and right. If the tie rod end is locked out–that is, if the studs are not centered-an over-stressed condition may cause the stud to wear or break. Lockout can occur when toe is adjusted and the tie rod ends are not re-centered in their housing before the sleeve is tightened.

Rear Suspension

Inspection of rear suspension components follows many of the procedures used for front suspension components.

On vehicles with leaf springs, make sure that the axle housing is centered in its proper position. Also, check to see if the U-bolts are broken or loose. If the center indexing end of the leaf spring to axle breaks or becomes distorted, the axle housing may shift forward, back, left, or right, causing a severe axle alignment problem.

Check the rear spring shackles. These may wear and cause an axle misalignment problem.

On front-wheel drive cars with a beam type or U-shaped rear axle-especially those that have a bar welded in the center of the U-shape, or a stabilizer bar that runs down the length of the axle tube-check the control arm connection points.

If the welds are broken, the axle may twist excessively. There may be a noise whenever the axle hits a bump with one wheel. If the welds on the torsion bar are broken, replacement of the rear axle is necessary.

Perform a thorough dry park inspection, paying particular attention to any bushings on the rear axle. On units with a stabilizer bar connected to the lower control arm that runs through the axle housing, the bushings may be replaced if they are deteriorated or allow bar movement.

To determine whether the bushings are worn excessively, inspect the bolt which goes through the center of the bushing. It should be an equal distance from all areas of the bushing. If it appears to be slightly off center, the bushing itself is worn and must be replace.

Inspect the axle beam and control arms for signs of wear, damage, or bending. If any problems are found, the parts should be replaced.

Complete any alignment inspection by keeping in mind the following important areas (Figure 2-20).

DO IT RIGHT THE FIRST TIME: AN ALIGNMENT CHECKLIST

- ❏ Lock down the brakes whenever performing an SAI or caster sweep.
- ❏ Sweep SAI with the weight of the vehicle partially off the tires. This will remove any ball joint or bushing play influence, and give you a true SAI reading.
- ❏ Always lock the steering wheel in place whenever you are performing a toe adjustment.
- ❏ Lock down the alignment heads before taking reading angles. Make sure you do not disturb the heads when you raise the vehicle to do adjustments.
- ❏ If the vehicle is equipped with power steering, start the engine when establishing the initial steering wheel centering reference point, prior to installing the steering wheel lock.

Fig. 2-20. Alignment Checklist

NOTES: ______________________

Section Two Mini Quiz

1. The greater the positive caster, the more camber will change when:
   a. The vehicle is turned left or right
   b. Adjusting a threaded strut rod
   c. Rotating the cam bolts
   d. Shifting the cradle

2. Which of the following statements is true?
   a. Positive caster is the forward tilt of the steering axis
   b. Caster and SAI are the same thing
   c. The rear wheels direct the vehicle
   d. On a RWD vehicle, the thrust line is always the same as the geometric center

3. Negative scrub radius enhances:
   a. Tire wear
   b. Vibrations
   c. Bump steer
   d. Stability

4. When a vehicle pulls in the direction of the most recent turn it has a ________ problem
   a. bump steer
   b. memory steer
   c. camber
   d. setback

ANSWERS
1. a 3. d
2. c 4. b

SECTION 2 SHOP EXERCISES

Move to the shop area and perform the following exercise. This exercise is designed to help you better learn and understand the information presented in this section.

Perform this exercise when you have a GM W-body car on the lift. Raise the vehicle and be sure to take all necessary safety precautions when performing this exercise

1. Locate the engine cradle adjustment bolts. DO NOT ATTEMPT TO LOOSEN as this can result in a realignment of the caster.

2. Locate the adjustment slot.

3. Notice how - if you would move the cradle either forward or aft - you can adjust caster on these types of vehicles.

NOTES:

3

CHASSIS PRODUCTS AND APPLICATIONS

In this section, we'll review basic service procedures for various chassis products and applications.

Please watch video module three now.

BALL JOINTS

4X4 Applications

Today's 4X4 vehicles typically use a short/long arm (SLA) suspension with lower and upper ball joints. The lower ball joint is usually pressed into the control arm, while the upper ball joint is riveted or bolted into the upper control arm. Starting in the late 1980s, Ford and General Motors changed their front suspensions from a solid axle to the more modern, SLA (Figure 3-1). Jeep retained the older, solid axle front suspension on the majority of its 4X4 SUVs. Import manufacturers have a mix of solid front axle and SLA systems.

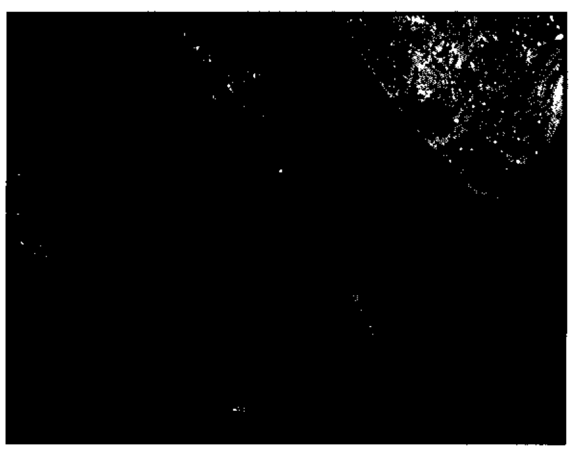

Fig. 3-1. GM SLA Suspension System

Press–In Ball Joints

Press–in ball joints fall into two basic categories: those that are used on solid axle, 4X4applications, and those used as lower ball joints on 4X4s with an SLA suspension. Ball joints on solid axle 4X4's should be replaced in pairs. Both the upper and lower ball joints on each side of the vehicle should be changed at the same time (Figure 3-2).

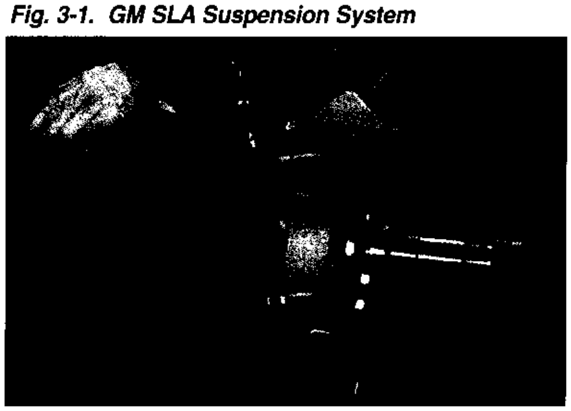

Fig. 3-2. Dana 4X4 Axle

Both ball joints share the load. If one is replaced, and the other were to remain, the new one would carry an additional load because of wear on the older unit. In many cases, it's necessary to remove one ball joint to remove and install the second one. Whenever a ball joint is removed, it should not be reinstalled. In addition, press-in ball joints *must* be installed using a proper ball joint press. If a press is not used, the joint may be cocked, or crooked, when it's installed. This could elongate the hole, causing looseness at a later date, or the next time the ball joint is replaced. A stretched hole can also cause tearing or failure of the metal around the outside edge of the hole, leading directly to control arm failure. A ball joint must have an interference fit when it is pressed into the knuckle or control arm. An improper interference fit means that the ball joint will not be retained correctly in the knuckle or the control arm.

On some press-in ball joint applications, the hole in the control arm may be oversized because the previous ball joint was installed incorrectly, or because a product that was substantially larger than OE dimensions was installed. In these cases, an oversized ball joint must be used, or the control arm must be replaced.

Pinch Bolt

There are two methods of retaining ball joint studs in steering knuckle or spindle assemblies: a tapered stud or a pinch bolt. A tapered stud has threads on the end of it. When tightened, the nut draws the tapered stud into the tapered hole. On a pinch bolt, the stud of the ball joint is straight, not tapered (Figure 3-3). It may also have a machined groove in it that *indexes* the height of the ball joint in the knuckle assembly. This groove does not retain the ball joint in the knuckle assembly. When the pinch bolt is tightened, 100 percent of the surface area of the knuckle comes in contact with the surface area of the ball stud. The friction from this contact retains the ball stud in the knuckle assembly.

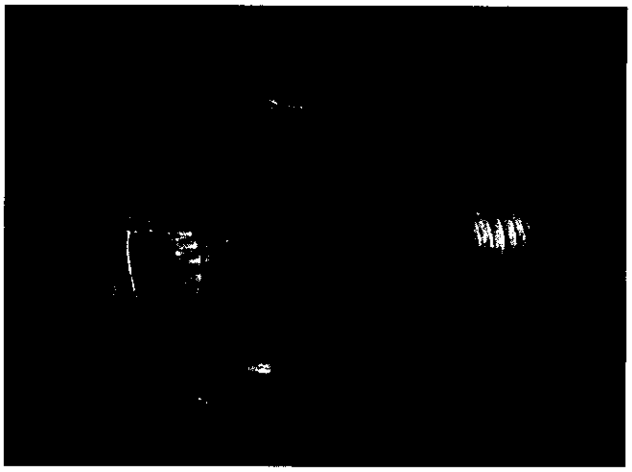

Fig. 3-3. 4X2 Truck with Pinch Bolt Upper Ball Joint

Tightening the pinch bolt must be done carefully. If it is over–tightened, the ears of the knuckle assembly may contact each other. This may cause fatigue in the metal, and could lead to broken or overstressed components. It may also lead to improper contact tension between the steering knuckle and the ball stud. If this happens and the knuckle is distorted, the knuckle assembly must be replaced. Do not attempt to drive a chisel or other device between the split on the end of the knuckle to spread the ears.

Another warning sign that a pinch bolt knuckle assembly has been over-tightened is a distorted bolt that extends through the holes at the end of the knuckle. When removing the ball joint, it may be necessary to completely remove this bolt from the knuckle. If this is the case, put the nut back on the bolt after loosening it. Then, strike the nut and drive the bolt outward.

Note that on the bottom of the bolt head there are serrations that bite into the knuckle. The bolt should be driven through the knuckle carefully, without any binding, and without scraping the knuckle. Inspect the bolt after removal to see if it is bent or distorted (Figure 3–4). A new bolt should fit into the assembly without binding. If it binds, the ears have been distorted. The knuckle assembly must be replaced.

Fig. 3-4. Damaged Pinch Bolt

TIE ROD ENDS

Rubber–Bonded Socket (RBS)

Rubber-bonded socket (RBS) tie rod ends are used on various Ford trucks, and on the Ford Taurus/Mercury Sable passenger cars. On trucks, they are used as outer tie rod ends, and at the right assembly-to-steering gear connecting point. On Taurus/Sable, they are used at the outer tie rod-to-steering arm location only.

Unlike conventional low-end maintenance (LEM) or dual bearing tie rod ends, an RBS tie rod end has no moving parts. The rubber ball socket is slightly larger than the metal housing into which it is pressed. This interference fit creates a torselastic type socket assembly (*torse* meaning torsion or twisting, and *elastic* meaning to spring back.). This means that when rotational force is applied to the tapered stud which is bonded to the rubber ball socket, the socket twists but does not move. When the steering force input from the driver is released, the twisted socket helps to re–center the steering wheel. Because of this type of construction, failures on RBS tie rod ends require specific diagnostic procedures. Inspection procedures for Ford truck RBS tie rod ends consist of looking into the hole in the bottom of the outer shell to see if the bottom of the ball socket is dimpled downward. If it is, the interference fit between the ball socket and the housing is less than the manufacturer's specifications. The ball stud has moved downward, causing the dimple.

The stud should not move when hand pressure is applied to the housing. Also, the stud should be at a right angle to the housing, and the ball socket should not have any loose rubber particles.

Inspection procedures for RBS outer tie rod ends on Taurus/Sable differ from those for the tie rod ends on Ford trucks. On Taurus/Sable, check to see if the tapered stud has swung off–center and is no longer at a right angle to the housing (Figure 3-5).

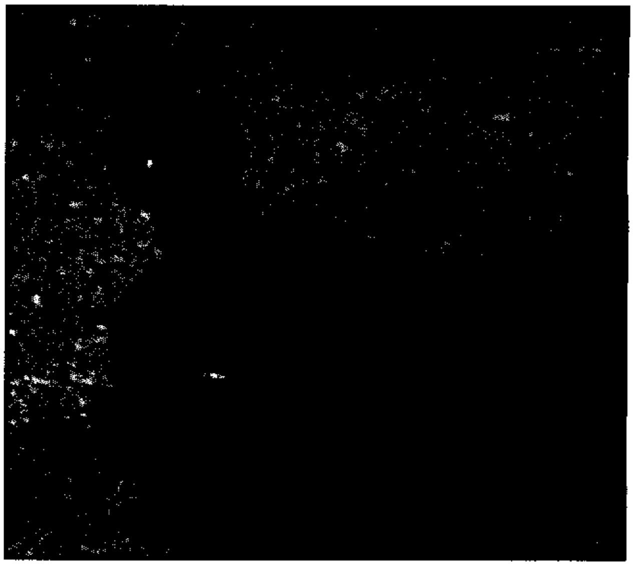

Fig. 3-5. Taurus/Sable RBS Tie Rod End with Off-Center Stud

If it has swung off-center, disconnect the tapered stud from the steering arm, and place two nuts on the threaded end of the stud. The torque required to turn the stud 40° in either direction should not be less than 40lbs. If torque builds, falls off and builds again, the rubber is shifting inside the metal housing and will lead to a memory steer condition. The tie rod end should be replaced.

Even though the ball socket may be held properly in the housing, the tie rod end should be replaced if the metal tapered stud is touching the outer housing. This is because the stud is forced slightly left or right in the housing as the wheels are turned. If it is contacting the housing, it will be forced downward, causing excessive wear on the ball socket. In addition, this may cause a *clunking* noise after centering the wheels following a very tight turn.

Whenever an RBS tie rod end is replaced, it either must be replaced with another RBS tie rod end, or in pairs with conventional metal-to-metal tie rod ends. The dynamic operating conditions of RBS tie rod ends differ from those of conventional tie rod ends. RBS tie rod ends do not allow the same amount of toe compliance (toe change under load) as LEM tie rod ends. If one RBS tie rod end and one conventional tie rod end is used, a handling or dynamic alignment problem may exist.

Inner Socket Assemblies
(Rack and Pinion Steering)

Inner tie rod ends used on rack and pinion (R&P) steering gears are more commonly called *inner socket assemblies* (Figure 3-6). They differ from conventional tie rod ends in that the stud and bearing assembly are not at a right angle to the housing, as it is in a conventional tie rod end. Rather, the stud is a straight, non–tapered rod with threads on one end, and a round bearing surface on the other. The threaded end screws into the outer tie rod end. The inner ball surface is housed within an outer shell/housing, which is part of the inner socket assembly that attaches to the R&P steering unit. The assembly is permanently lubricated and requires no normal maintenance once it is installed.

To remove an inner tie rod end on a Ford rack and pinion steering gear, first raise the vehicle, remove the outer tie rod end from the steering arm, and remove the tie rod end from the inner socket assembly. Next, clean the area around the protective boot and remove it. A set screw, Allen wrench, hollow roll pin, rivet or torque only, inner lock of the threads may be used to attach the tie rod end to the rack. If a set screw is used, simply unscrew it. If a hollow roll pin is used, use an electrician's side-cutters, which is finer and has a sharper blade. Attempt to grasp the top exposed portion of the hollow roll pin and use the tip of the side - cutters as a fulcrum.

Pivot the side cutters upward, lifting the hollow roll pin out. If a rivet is used, use either a screw

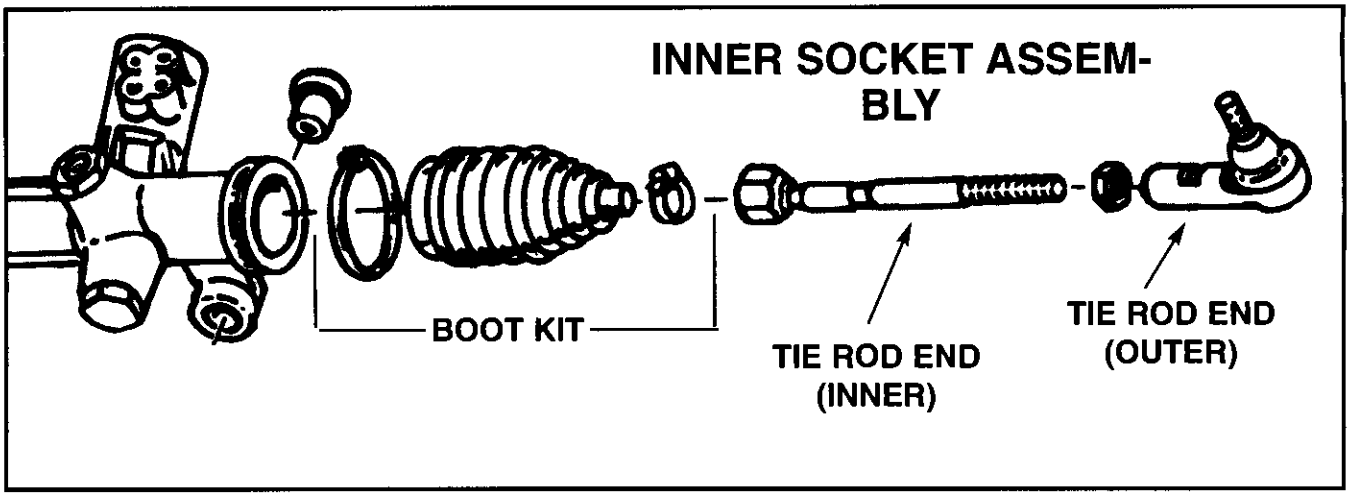

Fig. 3-6. Inner Socket Assembly

driver or semi-sharp chisel to tap underneath the rivet head. This should lift the rivet up and out of the tie rod end.

When installing a new tie rod end socket, hold the rack, applying pressure in the direction opposite to the tightening motion. This will keep the rack from being jammed against the pinion, possibly causing internal seal failure.

On inner tie rod end assemblies that use a torque only specification for tightness, use a torque wrench to achieve the correct lock of the inner socket assembly to the rack gear. After installing a new tie rod end, place some grease around the ball socket where it is retained in the housing. Next, install a new boot kit. Be sure that no dirt or contamination enters the area. Check the power steering unit and flush the assembly. Refill the power steering unit with the lubricant specified by the manufacturer.

On Ford Taurus/Mercury Sable, the inner socket assemblies are attached to the rack by an inner housing that is threaded onto the rack ends. After the inner socket assembly is tightened to the proper torque, a set screw, roll pin, or rivet is inserted into a small hole in the inner housing. These secondary locking devices act as a safety attachment, retaining the inner tie rod end on the rack assembly. Another method for this secondary safety attachment uses torque only, or torque and Loctite® on the rack threads.

Inner Socket Assembly Service (Ford R&P Steering) for Taurus/Sable

After raising the vehicle and removing the outer tie rod end from the steering arm, clean any dirt or contamination and remove the protective bellows (boot). Determine how the inner tie rod end is attached to the rack. If a set screw is used, be sure to use the correct size Allen wrench, and unscrew the set screw. If a rivet is used, take a long, semi-sharp chisel and tap under the head of the rivet, lifting it up and out of the inner socket assembly. If necessary, raise the rivet enough to grasp it with sharp side-cutters, and then finish lifting it out of the inner socket.While removing the old socket and installing the new socket assembly, place an adjustable wrench over the ends of the exposed rack teeth. This helps hold the rack gear and helps prevent rotation and damage to the gear teeth while you are removing and reinstalling the new assembly.

Install the new socket assembly and torque to the manufacturer's recommended specifications. When installation is completed, a new boot kit should be installed. Whenever an inner socket assembly and boot kit is installed, flush and refill the system with new fluid. Always follow the manufacturer's specifications for the correct type of fluid.

IDLER ARMS

Idler arms are defined as assisting in *maintaining proper toe geometry while the wheels are steered by duplicating the motion of the Pitman arm.* An idler arm holds the linkage on the right–hand side of the vehicle in a configuration similar to the action of the Pitman arm on the left–hand side. If an idler arm is loose, toe will change as the suspension goes through its normal jounce and rebound motions.

Some vehicles today, especially some of the smaller minivans, use two idler arms. The diagnostic procedures, whether they are used on one or two idler arms, are the same. There should be no movement beyond the manufacturer's specifications, or an accompanying toe change problem will be the result (Figure 3-7). In addition, if only one idler arm on a two-idler arm vehicle is worn beyond specifications, both should be replaced. If only one is replaced, the older idler arm will take the majority of the load. The new idler arm, which is tight and stable, transmits very little motion. However, the older one will take more of the stress

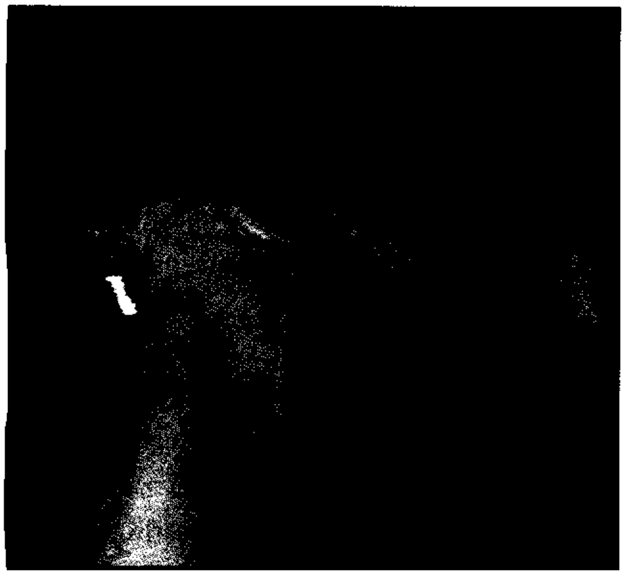

Fig. 3-7. Procedure for Diagnosing Idler Arm Wear

than it did previously. This means that it will have accelerated wear and load characteristics applied to it that could lead to failure.

Threaded Bushing Idler Arm

Prior to the mid-1990s, General Motors used an idler arm called a threaded bushing idler arm (Figure 3-8). In this configuration, a bushing threads into the idler arm, and the idler arm bracket then threads into the bushing. This type of idler arm literally screws and unscrews itself as it is turned left and right. When new, it has a considerable amount of play. On Astro vans with this type of idler arm, it is possible to mount the left–hand replacement idler arm incorrectly. If it is, the steering linkage may bind or have a substantial amount of toe change as the vehicle is driven down the road. An excessive amount of force is applied against the idler arm bracket. This usually tears
the idler arm bracket at the mounting holes.

Fig. 3-8. Threaded Bushing Idler Arm

Reverse installation of the idler arm brackets is not uncommon and may occur with many designs. Some aftermarket idler arms often have a step or bump forged into the bracket that prevent them from being installed backward. After the mid-1990s, General Motors changed its idler arms to a new design that is considerably tighter than the previous unit. It also stabilizes toe and does not cause the accompanying tire wear problems of the earlier design.

When checking idler arms on GM Astro vans, it is important to follow the OE recommendations if OE idler arms are on the vehicle (Figure 3-9).

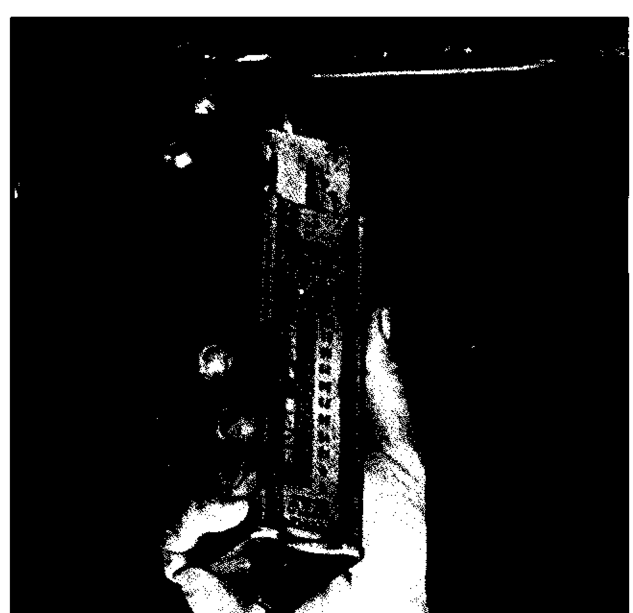

Fig. 3-9. OE Method for Checking GM Idler Arms

GM specifically states not to grasp the tire in the three and nine o'clock positions with the wheels hanging and then move the tire inward and out-ward watching for the idler arm to move up and down.

GM's recommendations for checking idler arms are as follows:

1. **Raise and support the vehicle underneath the lower control arms**
2. Make sure that the supports do not interfere with tire movements.
3. With the wheels in a straight–ahead position, use a spring scale to apply 25 lbs. of force to check the up and down movement of the idler arm.
4. If movement exceeds a 1/8" up and a 1/8" down (1/4" total play), the idler arm is worn and should be replaced. If the total movement does not exceed these measurements, the idler arm meets GM specifications.

Despite meeting OE specs for looseness, the idler arm may still allow toe change as the suspension travels up and down. Therefore, even though the idler arm is within specifications, you may still recommend replacing the unit to stabilize toe, maximize handling, and enhance tire wear.

Idler Arm Bracket

Ford's LTD Crown Victoria uses a parallelogram steering system. The idler arm on this unit contains a bracket which is an integral part of the arm (Figure 3–10). The end of the idler arm attaches to the center link, and contains a bushing with a hole in it. The center link is a non-wear item. There are no moving or wearable parts. The center link stud attaches to the idler arm bushing and, as the idler arm turns on its bracket, it allows for rotational movement.

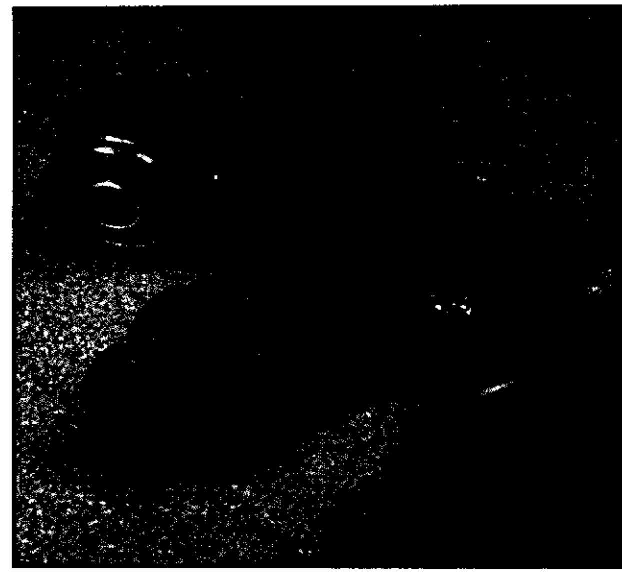

Fig. 3-10 Ford Crown Victoria Idler Arm

This bushing can and does wear. If the idler arm-to-idler arm bracket wear point is still within tolerances and the bushing-to-center link attachment shows signs of wear, you can use a separate bushing and replace only that part of the idler arm.

Depending on the vehicle's use and the amount of wear on the various chassis and steering parts, replacing only the bushing may be done if it is the only part of the assembly that is worn.

Idler arms wear most rapidly. Generally, looseness is determined by grasping the center link at the attachment point and, with reasonable pressure (approximately 25 lbs.), attempting to move it up and down. If toe change occurs when the idler arm is moved, idler arm replacement is recommended. The idler arm may continue to function even though toe change is taking place, but maximum handling, tire wear, and vehicle stability will all be affected.

Design Variations

Idler arm designs can take several different shapes. The most common design has an integral bracket.

The stud may be part of the idler arm and placed in the tapered hole of the center link, or the center link may have a stud in the idler arm containing the tapered hole into which the stud is inserted.

Other idler arm designs include an arm that has a bushing in both ends that mounts onto an idler arm bracket and a stud in the center link.

Idler arm mounting brackets may be straight with two bolts on them, have a flange with three or more mounting bolts, or some other design. Regardless, the overall inspection procedures, operations, and functions are all the same. The brackets support the steering linkage on the right–hand side and should travel in an identical arc to the Pitman arm.

Some vehicles have an idler arm that can be moved up or down on their mounting bolts. To correctly install one of these idler arms, OE procedures should be followed. In some cases, this may include turning the wheel left and right a certain number of degrees, and measuring the idler arm height in relationship to the Pitman arm height. There is a quick check for adjustable mounting idler arms with the wheels straight ahead.

First, measure from the end cap of the Pitman arm to a known reference point, such as the air jack on an alignment rack. Then, measure the idler arm height (Figure 3-11) at the same point from the end cap to the air jack. These measurements should be identical. If measurements vary, loosen the mounting bracket bolts on the idler arm and move the arm up and down so that the center link travels in a perfect, horizontal fashion. It should not travel up and down as the vehicle is steered left and right. Idler arm height mis-adjustment is the prime cause of bump steer and toe change under load, and could cause serious handling difficulties on a vehicle.

Fig. 3-11 Idler Arm Adjusted in Height

CENTER/DRAG LINKS

GMC Center Link: Troubleshooting & Diagnostics

The terms *center link* and *drag link* have become interchangeable in today's steering and suspension service industry. Technically, the part should be called a *center link.* It is the forged metal piece that connects the Pitman and idler arms. The inner tie rod ends are also attached to the center link. A center link is used with a parallelogram steering linkage.

RWD vehicles, especially from GM with parallelogram steering linkages, have an arm that attaches to the output shaft of the steering box. This is called the *Pitman arm.* It is the component connecting the steering box to the center link. The connection socket, including the tapered stud and the hole in which the tapered stud fits, varies in design depending on the specific vehicle manufacturer. In some cases, the wearable sockets, the ball stud, and the tapered connecting stud may be part of the Pitman arm. In this design, the tapered hole receives the tapered stud in the center link.

In other cases, the wearable socket may be built into the center link. Here, the center link has a ball socket and the tapered stud. The hole in which the tapered stud is inserted is part of the Pitman arm.

Regardless of which part contains the hole or the wearable socket, this particular connection is perhaps the highest loaded steering component in the entire vehicle. This also makes it one of the fastest wearing parts.

All changes in vehicle direction are controlled by the steering box, and they are relayed through the Pitman arm-to-center link connection. The inspection procedures for this connecting point consist of checking for side-to-side play and up and down movement. The majority of the play will be side-to-side.

To check the connecting point, place the weight of the vehicle on the tires and have an assistant rock the steering wheel sharply left and right, loading the steering system. At the same time, place your thumb and forefinger to the left and right of the area where the stud passes through the tapered hole. No side play or rocking should be felt. The stud should immediately start to rotate within its housing, prior to any jumping or sideways motion.

If you see or feel any movement before the stud rotates, the unit is worn and the center link or Pitman arm should be replaced, depending on which part has the wearable socket in it.

Another center link related problem is the end cap blowing off when the unit is greased. This is especially common if there is no allowance for grease to move into the dust boot where the center link connects to the Pitman arm.

There should not be any noticeable movement of the center link-to-Pitman arm connection when the unit is lubricated. If any is detected, carefully check the part for side play, up and down movement, or binding.

Haltenberger Toe Change

Haltenberger steering linkage is used on Ford trucks. This system consists of a steering box and a Pitman arm. The Pitman arm hooks onto a bar that is attached to the right–hand steering arm on the other end.

This part is sometimes referred to as the *right-hand assembly* (Figure 3-12). On early model Ford trucks, it was a one–piece unit consisting of a solid bar with a pivotable, wearable link on both ends, and a hole located approximately in the middle.

Fig. 3-12 Ford Haltenberger Right-Hand Assembly

On later models, it became a three-piece assembly. One part attaches to the Pitman arm, which attaches to an adjusting sleeve. The adjusting sleeve is attached to an outer tie rod end (Figure 3-13). On both early and late models, the left-hand tie rod end crosses from the right-hand assembly to the left–hand side. On early model vehicles, toe was adjustable by rotating the left–hand sleeve only. This meant that you could adjust "total" toe. Because toe could not be evenly divided between the two wheels, the steering wheel was frequently off-center after toe was adjusted. Ford trucks were among the few vehicles that allowed the steering wheel to be removed and repositioned to align and center the spokes.

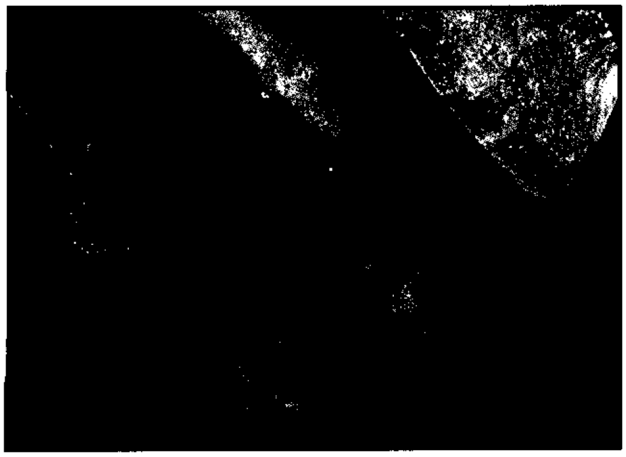

Fig.3-13. Three-Piece Haltenberger Tie Rod End

Note that the three piece, right hand tie rod end assembly can be retrofitted in many applications to the older model Ford trucks. This means that total toe as well as individual toe, on each side, can be adjusted, allowing the steering wheel to be more easily centered.

Outer tie rod ends on Haltenberger steering linkages may take an offset, or the housing may not operate at a right angle to the ball studs.

Whenever toe is being adjusted on one of these trucks, the bottoms of the outer and inner tie rod ends on both the right and left sides should be marked. These marks should point directly down. After the adjusting sleeves are turned, the tie rod ends should be repositioned so that the marks are again pointing down. This will allow toe to be set in the same dynamic mode in which it operates. Toe change takes place on these trucks as the tie rod ends swing off-center. Therefore, if toe is set with the outer tie rod in a centered position, the dynamic toe change may result in an off-center steering wheel or an inaccurate toe setting.

Some aftermarket parts have an outer tie rod end that has been specifically designed to greatly reduce this problem. The tie rod end has an anti-tilt washer under the dust boot that helps it remain centered. It also has an improved bearing-to-housing contact area that allows the unit to remain centered during operation.

BUSHINGS

Bushings are far more technical than most technicians realize. They can be made harder or softer by the density of the rubber, the diameter of the sleeve that is inserted into its center, the method of attaching the sleeve to the rubber, the thickness and diameter of the outer housing, and many other factors. Generally they're manufactured from rubber, urethane, polymers (plastic), or some other non–metal material.

On older vehicles, bushings may be metal–to–metal. Inner control arm bushings on some vehicles manufactured into the late '70s were designed metal–to–metal. When bushings are manufactured of rubber or polymers, and allow rotational pivot or movement, they are referred to as *torselastic*. Therefore, torselastic bushings allow for the movement of components. They have the ability to return to their original shapes after they are twisted or moved. There are other bushing variations that simply act as sound deadeners or vibration dampers.

Ford Radius Arm Bushing

Up until the mid–1990s, Ford used an axle and suspension system on its light duty trucks and SUVs known as a twin I–beam. This system was composed of two axle halves, which were pivoted off-center from the middle of the vehicle. To control the fore and aft motion of the axle, a radius arm extended to the rear from near the outer portion of the axle. The arm was mounted to the frame bracket with a bushing (Figure 3-14). There has been a considerable number of wear and heat related problems with these bushings caused by the routing of the exhaust pipes. The problem was most prevalent on the right sides of downsized Ford trucks.

Fig. 3-14. Ford Radius Arm Bushing

Aftermarket bushing made from Santoprene®, are a significant improvement over the rubber type of bushings used at the factory, or even rubber bushings with increased or more durable cup or strengthening washers (Figure 3-15). This bushing, while maintaining all the properties of the OE unit, is far more durable in stabilizing the control arm movement, and it is not affected by heat, road salt, or other corrosive or deteriorating elements.

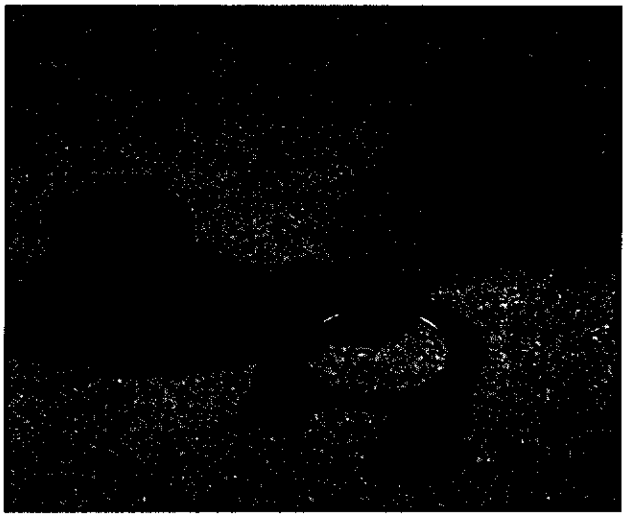

Fig. 3-15. Caster Radius Arm Bushing

In addition, it can provide a caster adjustment point for the vehicle, if needed. Ford radius arm bushings are normally replaced by removing the bracket from the frame. *Do not* replace the bushings by lowering the axle and moving it forward. This usually cuts the rivet heads, causing the rivets to punch through the hole. In some cases, the brackets are bolted on the vehicle, although riveting is more common.

Once the bracket is removed, the radius arm can be separated from the bracket by using an impact wrench and a large socket. Then, the radius arm nut is removed, and the bushing and its attaching hardware are easily replaced. Before the radius arm nut is re-tightened, the bracket is raised into position and bolted to the frame with grade 10 hardware.

After the bracket is bolted in place, put the weight of the vehicle on the tires before tightening the radius arm nut, which secures the bushing to the bracket. If the weight of the vehicle is not on the tires, the bushing will be overstressed. This is not a serious problem for a rubber bushing, but it is when a Santoprene® bushing is used. The bushing will take a set if the front axle is hanging. Then, when the axle is lowered, the bushing will be overstressed, leading to premature deterioration and failure.

If a bushing is used that also affects caster, the vehicle should be lowered with the radius arm nut barely snug. At that point, take the caster reading with the equipment set in a live alignment reading mode.

When the bushing is turned, caster can be read correctly. This eliminates the need for making constant caster sweeps to see the differences in the unit. It also enables the caster to be quickly adjusted on each side of the vehicle.

Note: Even though the radius arm bushings operate independently of each other, they should be replaced in pairs. This is especially true if you use the premium Santoprene® bushing. If you replace radius arm bushings on one side of the vehicle and not the other, the side that was not replaced may allow caster change during braking and acceleration. For example, the vehicle may pull to one side during braking and acceleration if bushings on only one side of the vehicle are replaced.

GM Center Take-Off Bushings

GM center take-off bushings on R&P steering gears that use the center steer system must be checked during any dry park pre-alignment inspection (Figure 3-16). These bushings may fail on certain GM models. If they're worn, they will allow the inner eyelet of the tie rod assembly to move left and right before the motion of the R&P gear is transferred to the wheels.

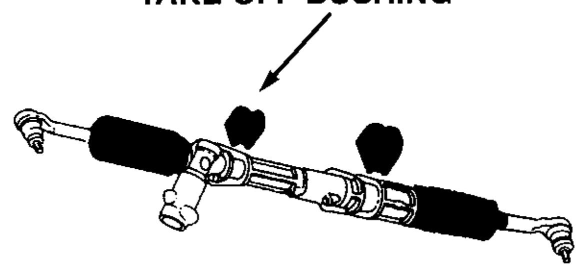

Fig. 3-16. GM Center Take-Off Bushing

Likewise, as the wheels hit bumps or dips in the road, or if other load forces from the road are placed on the bushings, the individual toe will change on each side of the vehicle that has a worn center take-off bushing. This can create a bump steer condition, looseness in the steering wheel, uncontrollable toe change, and a variety of other handling or tire wear problems.

If the center take-off bushings on a GM R&P steering unit are worn, the vehicle will act very much like the steering gear is not secured properly.

To determine if center take–off bushings are worn, or if rack bushings are loose, place the weight of the vehicle on the tires. With the vehicle on pinned turntables or a solid floor, have an assistant turn the steering wheel left and right. Place your thumb and forefinger completely over the rack assembly, feeling the firewall. As the steering wheel is turned, feel for any rack motion. If none is present, grasp the portion attaching the inner tie rod end. Feel the inner tie rod end eyelet/bushing assembly for sideways motion or clicking as the steering wheel is turned slightly left or right. The unit should not jump sideways or allow sideways motion before turning the wheels. If it does, the bushings are worn and should be replaced.

Replacement bushings are designed to be installed much like the OE bushings. These allow you to quickly and easily install replacement parts, eliminating the time-consuming OE method that was used in the factory.

Again, as with dual idler arms and other configurations, whenever inner rack bushings are worn, the entire bushing assembly should be replaced.

Do not attempt to partially fix inner GM tie rod and take-off assemblies. In some cases, the locking tabs, bushing support plates, or other parts of the new assembly kit have been engineered to handle the problem. Therefore, only a complete assembly kit should be installed.

Note: It is important to correctly install the inner tie rod ends to the center take–off area. Washers for the center housing cover must be mounted between the inner tie rod end and the rack. If these washers are not installed, the bolt may protrude too far through the steering rack and contact the housing, eventually causing the housing to crack and fail.

Ford/Chrysler Stabilizer Frame Mount Bushings
Stabilizer or sway bar frame mount bushings are critical. The bar must only twist, not rock forward or backward (Figure 3-17). If it does, the efficiency of the bar rapidly decreases. Some OEM stabilizers or sway bar bushings are one–piece units that cannot be removed without destroying it.

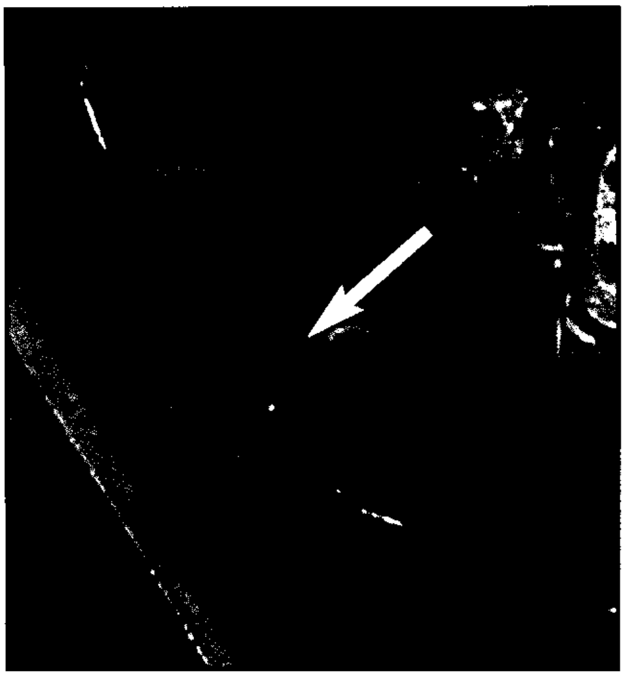
Fig. 3-21. Stabilizer Bar Bushing

When these bars are manufactured, the bushings are slipped on when they are still round. Then, the ends of the bar are flattened, along with the hole for the link kit attachment position. To remove a one-piece bushing, use a hack saw.

The replacement bushing will always have a split so that it can be opened and slipped over the bar. Be sure to note which side of the bushing the bar presses against, and position the split to the opposite side.

The stabilizer bar bushing should be lubricated either before or after it is installed. This is especially true in regions where there is a considerable amount of splash or road salt.

Grit and salt may cause a squeaking problem when the vehicle is operated for a period of time. Some replacements have a Teflon® lining to prevent noise.

Stabilizer bar bushings should also always be replaced in pairs. If a single stabilizer bar bushing is replaced, and the bushing on the other side is not, the remaining bushing will take a higher than normal load level and may allow the bar to shift rather than just rotate on its pivot point. This motion will counteract the basic design of the bar and will destroy the bushings' effectiveness. It may even cause excessive body lean during turns.

Stabilizer Link Pin Kits (for Optimal Performance)
Stabilizer link pin kits consist of mounting grommets, a center spacer, another set of mounting grommets, and a long bolt and nut. A stabilizer link pin should never have any play in it. If it does, the body may lean considerably before the motion of the stabilizer bar is transmitted to the lower control arm, where the link pin is usually attached.

Link pin replacement kits frequently use bushings with an improved durometer or hardness as compared to OE bushings. Likewise, the washers that support the bushing cups are heavier than the OE components.

Whenever a stabilizer link pin kit is installed, check that the height of the stabilizer bar from the control arm is the same on both sides. If it is not, a severe ride height problem may exist, one portion of the frame may be elevated above the other, or some other condition may be present that indicates a more serious vehicle problem.

Care must also be taken when installing stabilizer link pin kits. Do not use an impact wrench to tighten up the nut of the stabilizer link bolt. The proper amount of torque on the assembly compresses the bushings slightly, but does not place so much pre-load on them that they are distorted.

Remember, the purpose of the bushings is to provide an insulated, shock absorbing link between the stabilizer bar and the control arms. If the bushings are too hard or brittle, or are tightened excessively, a reaction that is too abrupt may be present.

When the stabilizer link pin kits are serviced, the stabilizer bar frame mounting bushings should be serviced at the same time. This will ensure that the whole stabilizer bar system has been restored to like-new condition.

If link pin kits are installed and frame bushings are worn, you will actually diminish handling. The link pins and frame mounting bushings work as a unit. Service them as an assembly.

NOTES:

Section Three Mini Quiz

1. When installing an inner tie rod bushing on a GM center take-off rack and pinion, be sure all the spacers are in place. If one is missing, most commonly, the mounting bolt will:
   a. Work itself loose and fall out.
   b. Touch the back of the rack housing, causing a bind.
   c. Make a loud rattling noise in the steering system.
   d. Cause an incorrect toe setting.

2. Inner tie rod socket assemblies should be replaced when an inspection reveals _______ in the socket.
   a. Any movement
   b. 1/16" movement
   c. 1/18" movement
   d. No movement

3. On 4X4 trucks with solid axles, the ball joint(s) that carries the load is:
   a. The upper
   b. The lower
   c. Both the upper and lower
   d. Neither the upper nor lower

4. When tightening the castle nut on the lower ball joint, you notice that the threads run out before the ball stud is tight. You should:
   a. Use washers to take up the space
   b. Replace the steering knuckle
   c. Replace the ball joint
   d. Weld the ball stud to the knuckle

ANSWERS
1. b 3. c
2. a 4. b

SECTION 3 SHOP EXERCISES

Move to the shop area and perform the following exercise. You will need access to a variety of vehicles and an alignment rack.

Ford pickup trucks (1997 or newer). Raise the truck and inspect the pinch bolt on the knuckle that holds the upper ball joint. Determine if the ears have been over-tightened.

Ford truck equipped with RBS tie rod ends Raise the truck and inspect the tie rod ends for serviceability.

FWD vehicle equipped with rack and pinion steering. Perform an inner socket looseness check. Determine the amount of toe change that is occurring due to the looseness in the inner socket assemblies.

Vehicle equipped with idler arm. Raise the vehicle on an alignment rack and determine if the idler arm meets OE specifications. Perform a toe change test by moving the center link up and down, noting toe change. Compare your results with the OE specification for looseness.

NOTES:

Training Solutions
A Snap-on Services Group

4

ALIGNMENT PRODUCTS AND APPLICATIONS REVIEW

ALIGNMENT SHIMS

Please watch video module four now.

Full Contact and Adjustable Shims

The shims covered in this section are specifically for rear camber and rear toe adjustments. Rear wheel alignment shims were originally designed as half shims (Figure 4-1). They covered the area between two bolts on a four-bolt rear spindle assembly. Using these shims for compound camber and toe adjustments required a high degree of luck, because the thickness of the metal, the predictability of the change, and several other factors were somewhat less than desirable. As a result, shims evolved from the half shim into today's full-contact shim.

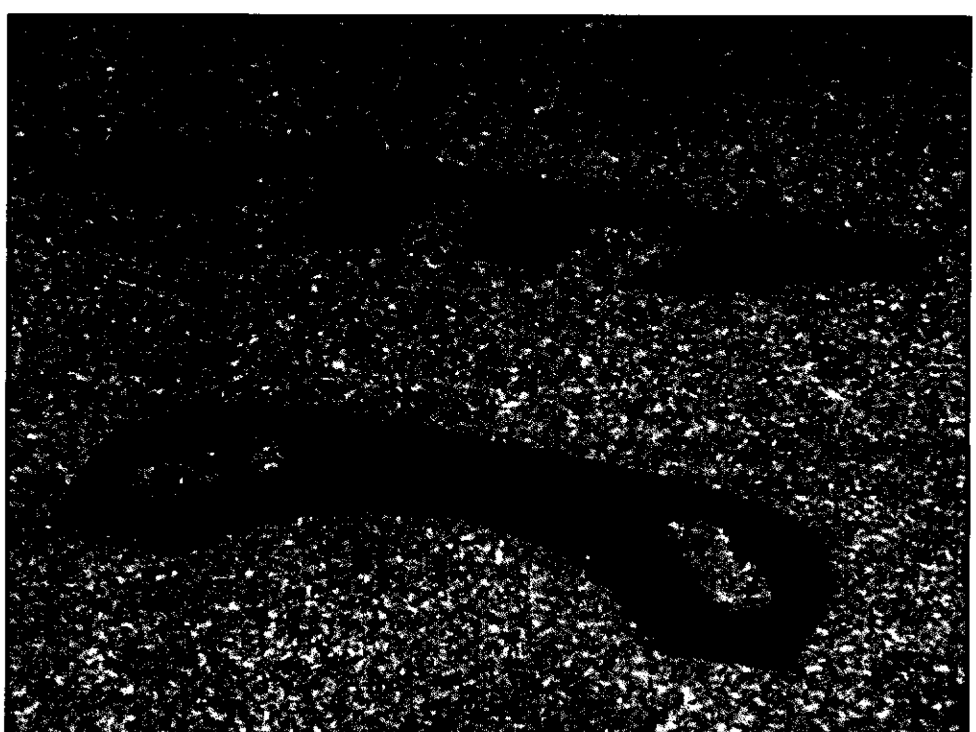

Fig. 4-1. Half Shim

Full-contact shims (Figure 4-2) come in contact with the entire outer perimeter of the rear hub or rear spindle assembly. It has a tapered shape and, by using a built–in angle, it affects the camber and/or toe. Full contact shims provide a full wedge to support the load of the hub and the bearing assembly, or the spindle to axle connection. They do an outstanding job of allowing torque to be applied to the spindle, or hub and bearing assembly when, they are tightened to the axle flange.

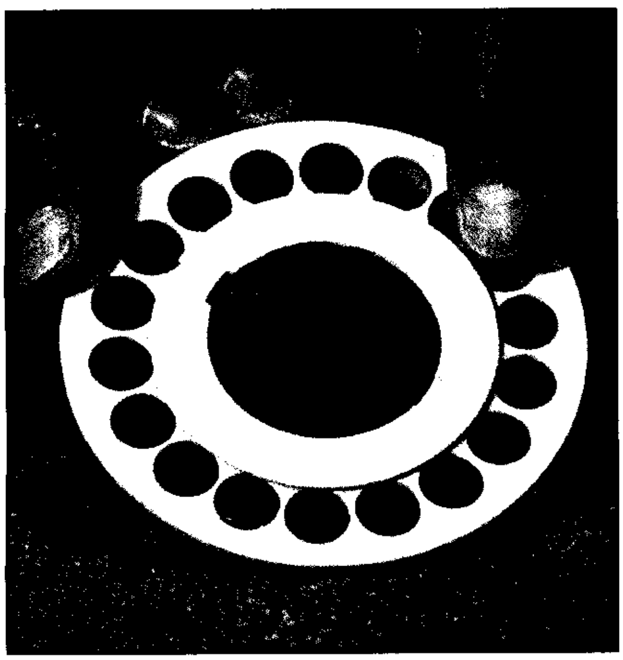

Fig. 4-2. Full-Contact Shim

These shims are installed at a set position. While better than half shims, full-contact shims do not offer a full range of adjustability, and do not always allow the technician to select the specific toe or camber settings needed. At times, compromises are made between camber and toe, and between the amount of change allowed in each area.

Half shims were traditionally manufactured from metal. Full contact shims can be both steel and aluminum, as well as synthetic such as composite nylon, or polyester based, nylon filled materials.

Full-contact shims allow an adjustment range of 0° to 1-1/2°. In some cases, they can be stacked to obtain more than 1-1/2° of change, but the manufacturer's instructions must be followed.
If the manufacturer states that shims cannot be stacked, do not stack them under any circumstances. There may be a seating problem between the two halves of the shim when they contact each other, or the bolts holding the spindle, or hub and bearing assembly to the axle flange may not be long enough. This may weaken the bolts, causing them to fatigue and break.

Full-contact shims also must be installed in a clean environment. Be sure there is no rust, scale, corrosion, or build-up between the parts. If the axle flange is corroded, if rust and scale are present, or if grit falls between the axle flange and shim, or between the shim and hub and bearing assembly, a false reading or false torque will be given when the unit is tightened. If grit is between the shim and the metal part, the grit may crush when the unit is tightened. If this occurs, the attaching bolts may loosen, leading to inaccurate alignment readings.

Prior to taking rear alignment readings, the axle flange-to-backing plate, or axle flange-to-hub bearing assembly should be inspected carefully to see if any shims are already present. If they are, proceed with the alignment reading. If an align-ment change is needed, it is best to remove the existing shims and take the readings again. It is virtually impossible to calculate the amount of alignment change that was made with a previously installed shim. Therefore, it's important to return to a base reading before installing a shim.

Adjustable, full contact shims have minimized the inventory requirements of alignment shops and have allowed alignment technicians to more accurately select the specific amount of toe and camber needed on each rear wheel. These shims can be rotated to select one of 1,008 possible settings, ranging from 1/8° to 1-1/2° for both camber and toe. This means that a specific amount of camber and a specific amount of toe can be dialed in. There is no need to live with a preset amount of alignment change.

All of the installation tips, procedures, and techniques for full contact shims also apply to adjustable, full contact shims.

NOTE: A number of GM vehicles that use torx bolts to hold rear hub and bearing assemblies onto axles, or to hold rear, unitized bearing assemblies onto rear disk brake systems, often have severe corrosion problems. In such cases, the torx socket tends to break or back out of the head of the torx bolt without loosening the bolt. Applying a small amount of valve grinding compound to the torx socket before it is inserted in the bolt head will help the bolts to be removed more easily.

Torx bolt/nut removal tools that fit into an air hammer are also available to make the job easier. These tools have 3/8" square hex ends that fit into the torx socket. They also have larg er hexes that are higher on the shoulder near the area where the air hammer blade fits into the air gun.

Place a box-end wrench over the large hex near the air gun opening. With the torx bit attached and installed into a torx socket, rotate the box-end wrench. Along with the valve grinding compound on the tip of the torx socket, this will loosen up even the most stubborn torx bolts in 99.9 percent of the cases. (Figure 4-4)

Never use heat on torx bolts for rear alignment shims. The heat could easily pass through the

Fig. 4-4. Using an Air Hammer to Remove Components

wheel cylinder or hub and bearing assembly. Heating the wheel cylinder will cause the brake fluid to boil and overstress the wheel cylinder cups. In addition, it may create enough internal pressure to blow off the dust cap. When this happens, the grease is too thin, and subsequent failure of the hub and bearing assembly may occur.

Rear Wheel Shims

The rear wheels on some vehicles have built-in factory toe adjustments that can include an eccentric bushing or a sliding type of connection. On these vehicles, camber adjustments are usually not possible. In some cases, camber can be adjusted by installing a full-contact or an adjustable full-contact shim. If an adjustable shim is used, select the amount of camber change needed and set the shim for 100 percent camber change. If the OE adjuster is frozen or cannot be easily moved to change toe, you may be able to use a shim to adjust camber and toe, ignoring the non–functioning toe adjuster from the OEM.

Some vehicles have built-in rear toe adjustments and fixed camber. Toe can be adjusted by moving or turning eccentrics or tie rod end sleeves. Full-contact shims allow toe and camber adjustments to improve handling and help extend tire mileage.

BUSHINGS

Bushing wear is a very critical factor in determining wheel alignment angles and serviceability. Bushings get old and fatigue. They also fail because of oil or petroleum contamination. Frequently, when a bushing gets old enough that its metal sleeve moves off-center, the pre-load, or stress, that is placed on the bushing will allow alignment to change because of the repositioning of the part.

One example of this is a lower control arm inner mounting point. When the bushing fails, the pressure is inward on the control arm. The control arm will shift, causing an alignment angle change because of the movement of the lower ball joint. As the suspension goes through jounce, rebound, and turns, an alignment change will take place because of the movement. An additional problem is the shifting or movement of a cradle assembly because of impact damage.

If a vehicle drops into a pothole hard enough to blow a tire and damage a wheel, the cradle may shift on its mount. This is especially true on cradles that are adjustable. When a cradle moves, the lower control arm and lower ball joint base reference point will move. This can change camber, caster, toe, scrub and steering axis inclination. The front geometric center point, which is the basis of the rear thrust angle, can also change. If an adjustable cradle has shifted, it should be readjusted.

Aftermarket wheel alignment products are designed to fine-tune rear chassis and suspension systems to enable proper wheel alignment. They are not designed to make up for cars that are not structurally sound, or that do not have their basic geometric reference points within OE tolerances. On vehicles such as FWD GMs with a beam type rear axle, if there is a severe camber problem, carefully inspect the vehicle to determine the true cause. Any camber or toe reading that is exceedingly far out of specifications should require a detailed analysis of the vehicle to determine the cause.

If you have a problem such as a bent axle on a GM front-wheel drive vehicle, the correct repair procedure is to first to replace the axle assembly, then set-up and check the four-wheel alignment. The basic alignment reading should be correct so that camber and rear toe can be adjusted by the installation of a single shim. No manufacturer of dual angle adjustable shims recommends stacking them. You should be able to bring the wheel alignment in by the installation of a shim, and not have to use a shim and crank bolt combination, if it is available for the vehicle. That would be the same as stacking shims.

If your alignment product does not offer the range of adjustment needed, again, check the vehicle for incorrect basic reference points. It is common for dual angle adjustable rear wheel alignment shims to have an adjustment range between 0 and 1-1/2 degrees. As a rule of thumb, any adjustment of more than 1-1/2 degrees should require a more detailed inspection to determine the true cause. Sometimes the damage is very slight and cannot be seen. Other indications, such as signs of impact, concrete marks on tracking arms or axle assemblies, etc., will lead you to the correct analysis that damage has occurred.

Do not attempt to make up for damaged parts by installing aftermarket kits. If damage is done to a non-replaceable part such as the sub-frame assembly on a unitized body, that section must be pulled or brought into proper dimensional referencing prior to replacing any damaged parts.

Eccentric

Bushings are available for a number of applications that require front camber and caster adjustments, or rear camber and toe adjustments. Some bushings offer fixed adjustments and affect the pre-determined alignment angle, such as camber only or caster only (Figure 4-5). Other bushings are double eccentrics (Figure 4-6). These can be turned or adjusted to dial in a specific amount of camber and caster, or camber and toe.

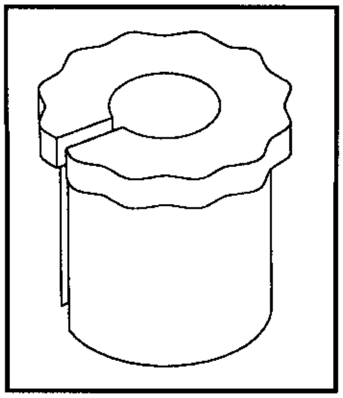

Fig. 4-5. Ford Camber "Stock" Bushings

Bushings are manufactured from a variety of materials. In many cases bushings for the front ends of Ford trucks and other heavier service vehicles are manufactured from a powdered metal, then pressed into a pre-formed mold. This allows the degree of change and the predictability in the manufacturing process to be extremely accurate because all bushings are consistent. Bushings used for the rear of vehicles such as the Taurus/Sable and some other FWD Ford products, are either metal or synthetic. Some rear camber/toe bushings are made of urethane to maintain a high degree of cushioning or flexibility with the companion OE bushings. In other cases, the bushings are manufactured from metal or other higher durometer products to eliminate some of the softness and limited wear properties that may have been present.

Always follow the manufacturer's instructions for installing eccentric bushings. In many cases, the bushing must be lubricated prior to installation, while in other cases, the bushing must be installed dry so it doesn't affect the torque on an attaching bolt or mechanism.

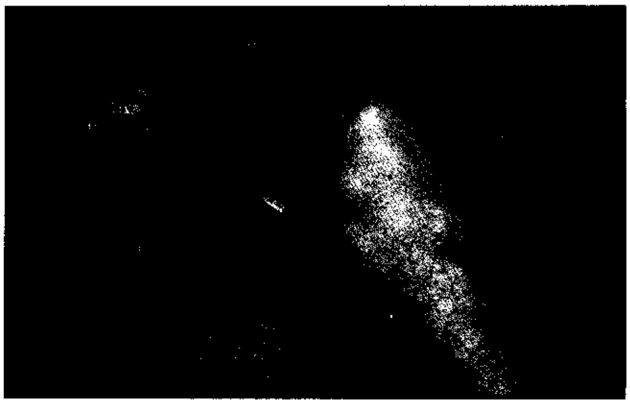

Fig. 4-6. Ford Double Eccentric Bushing

One of the more popular bushings is used on the front end of Ford light trucks. A fixed angle bushing may be installed to change the alignment angle by a specific number of degrees. A double eccentric bushing also may be used. This bushing allows a technician to dial in a combination of camber and camber/caster change, depending on the vehicle. It also allows the bushing to be reset for a different degree of change at a later date if another wheel alignment is needed.

Other bushing styles are sometimes used on the rear of vehicles. These bushings replace OE bushings, which sometimes have a tendency to bind into the metal sleeve, causing them to fail. The aftermarket replacement alignment bushing maintains all the flexible pivot point characteristics of the OE bushing.

CAMBER SOLUTIONS

Cam Bolts

Cam bolts are perhaps the second oldest alignment products available. (The oldest are the standard caster/camber shims for the front ends.) Cam bolts, while used on some cars in the '40s and '50s, started to become popular in the 1960s and were used on a wide variety of vehicles. In many cases, they are installed at the factory and provide a method of adjustment. Cam bolts may need to be replaced because of age, overstressing, or if the cam can turn on the bolt itself. If the unit can no longer be turned because of rust or corrosion, it will also need to be replaced.

On many modern vehicles, cam bolts have been eliminated. If the cam bolt was installed as the attaching mechanism, it may no longer rotate or turn, affecting adjustment. Many Chevrolet trucks, for example, have a cam bolt installed at the factory (Figure 4-7). A plug in the control arm mounting bracket provides a fixed reference point in the upper control arm mounting area. This plug prevents the cam bolt from being turned within the mounting ears, affecting camber and caster.

A variation of this has been used for some Ford truck suspension systems, such as the '94 and later Explorers, and '97 and later F-150s. On these vehicles, a cam bolt is installed at the factory, but the cam on the nut end is square (Figure 4-8). This cam, which is locked on the bolt by the traditional D or double-D flat area, does not allow the cam to be turned. To make this cam bolt functional, it must either be replaced in its entirety, or a cam disk must be installed on the nut end.

Don't assume that because a cam bolt is in the vehicle it can be turned. In fact, just the opposite is usually true. Read the alignment method instructions for the equipment being used. A number of different computer programs and equipment instructions can be used to help determine, what, specifically, must be done to make the cam bolt operational.

Beginning in '88, GM light trucks used a fixed alignment cam. A knock-out plug in the frame mounting pocket must be removed to elongate the mounting hole so the cam can be rotated to allow the control arm to move inward or outward. To do this, first remove the OE cam. A special tool can

Fig. 4-7. Chevrolet Truck Cam Bolts

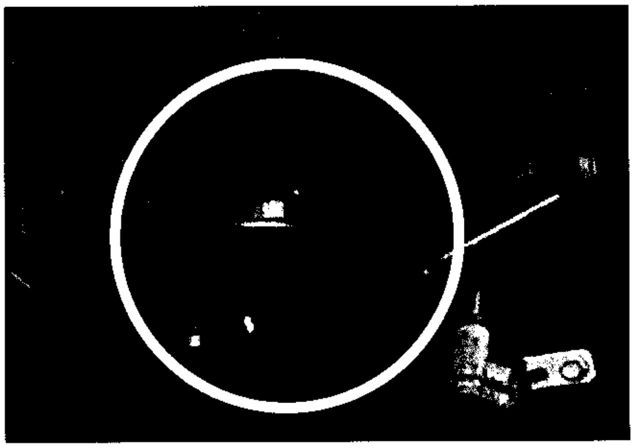

Fig. 4-8. Ford 2X4 Truck with Nut End Cam

be used to remove the knock-out plug from the control arm forward and rearward mounting pockets. Then, reinstall the alignment cam and measure wheel runout, if needed. Supporting the vehicle under the control arm, use the raised vehicle mode on the alignment equipment. The alignment equipment can now read dynamic camber and caster.

Turning the cam bolt when the weight of the vehicle is on the tire is difficult, and on certain vehicles, will flatten or round out the area of the frame that retains the cam bolt. When this occurs, it is a serious problem, making the vehicle very difficult to adjust.

With the vehicle's weight off the tires, turn the alignment cams until you have the correct alignment readings for camber and caster. After the alignment angles are obtained, lock down the nuts on the cambolts, lower the vehicle back on the turntables, and proceed with the toe adjustment.

In some cases you may remove cam bolts from a GM truck expecting to find knock-out plugs, only to find that the hole is already elongated. There are two reasons why this may be present: First, the truck may have been previously aligned, and second, the frame mounting pockets from the left-hand side and right-hand side are different. That is, the knock-out plug is in the forward portion of the frame mounting pocket. If a left hand side frame mounting pocket is installed on the right hand side of the frame, the knock-out plug will be on the rearward portion. Check this whenever you find a forward mounting hole that is already elongated. It would be extremely embarrassing to think that the knock-out plugs were already removed when attempting to rotate an alignment cam, only to find that you could not obtain your proper adjustment and had to go back in and re-do the job. It is rare to find incorrectly mounted frame mounting pockets on both sides of the vehicle, but always check whenever the front knock-out area has been previously elongated after removing a cam. Some late 1997 vehicles have alignment cams mounted from the factory in a normal manner, but a spot weld or tag weld has been placed between the alignment cam and the frame mounting bracket. This weld is removed with an air chisel blade or a die grinding tool. The cam and knock-out plug can be removed next. You may want to check for this tag weld on the alignment mounting frame assembly, since a vehicle that has one will take you longer to repair.

Fastcams

Fastcams are simply a variation of the cam bolt. The major difference is that a fastcam does not have an external eccentric. Instead, the internal portion of the bolt has an eccentric on it. The non-threaded shoulder area of the bolt is machined to contain the eccentric. It is very similar in appearance to the lobe on a camshaft.

Fastcams are used in applications where no cam bolt was installed at the factory. In these applications, the OE bolt is removed (Figure 4-9).

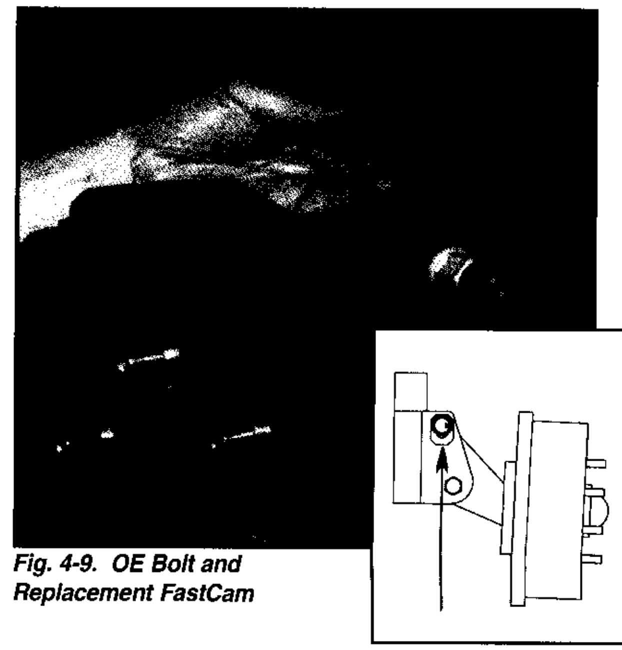

Fig. 4-9. OE Bolt and Replacement FastCam

Frequently, this is the upper bolt on a two-bolt strut-to-knuckle connection. Then, a fastcam is installed. The fastcam contains a slotted washer that fits under the fastcam bolt head. This washer locks into the strut flange area. Once the fastcam bolt is installed, it acts as a reference or pivot point for the bolt head.

After the fastcam is installed, either the lower strut bolt, or the other strut bolt may loosen. On some models, the bolt may be partially driven out. This is because many bolts that attach the strut to the knuckle have serrations or splined shoulders underneath the bolt head that bite into the strut and, in some cases, into the strut end knuckle, preventing movement.

If the serrations on this bolt lock the unit together, the fastcam will not move the upper portion of the knuckle assembly inward and outward on the strut bolt, thus affecting camber.

Fastcams are a quick, easy, and accurate way to obtain camber adjustment on the front and rear ends of some vehicles. It is quicker than elongating holes or grinding out strut hole areas to adjust camber. It is more accurate because the fastcam provides a predictable and accurate transitional amount of camber change as the bolt head is turned.

Camber is most easily adjusted with the weight of the vehicle off the tires. Support the vehicle underneath the lower control arm. Set the alignment equipment in the live reading mode, and read camber as the fastcam is turned.

After obtaining the correct reading, lock down the nut. Then, lower the vehicle onto the turntable, jounce it down, and complete the alignment.

Crank Bolts

Crank bolts are another variation of cam bolts (Figure 4-10). They are similar to fastcams in application, and they fit in the strut area where the upper bolt is held. In some cases, a crank bolt is used in place of the lower bolt.

Fig. 4-10. Crank Bolt

All the installation tips and procedures for fastcams also apply to crank bolts. However, crank bolts vary in design by using a small tab underneath the bolt head, and a washer that has protrusions or points on it to lock into the strut.

After making the initial alignment reading, install the crank bolt at the strut-to-knuckle connecting point. Follow the instructions for removing the lower serrated bolt. The upper serrated bolt may need to be removed when the crank bolt is installed in the lower location.

With the weight of the vehicle off the tires, and the crank bolt installed, be sure that the tab underneath the bolt head is lined up with the pin on the crank bolt. Snug the unit against the strut flanges. If the shoulder is serrated, loosen the lower strut bolt and drive it partially out. Turn the hex head of the bolt until a correct reading is made. Then torque the crank bolt nut, and drive in the lower strut-to-flange bolt if it has a serrated shoulder. If the shoulder is not serrated, simply tighten the nut, lower the vehicle onto the turntable, and proceed with the alignment.

ALIGNMENT KITS

About 95% of the vehicles on the road today can have the most critical angle, toe, adjusted, either on the front or both the front and rear ends using either factory-installed products or an aftermarket kit.

Toe is adjustable on the front end of all vehicles. Toe on the rear end is not always adjustable from the factory. If it is, it may be adjustable on only one side, or it may have a very limited adjustment range.

Rear camber is also seldom adjustable on newer vehicles. Likewise, front camber and front caster are frequently not adjustable.

Aftermarket alignment kits now make these angles adjustable. They have made many vehicles more driveable, and provide excellent tire life and handling. Aftermarket suppliers have combined many of these alignment products into one assortment that covers numerous passenger car and light truck applications. The assortment provides quick and easy access to the right alignment products when you need them, without carrying an extensive inventory of parts. This saves both time and money.

Honda

An alignment kit that provides a real benefit to the aftermarket is the front (Figure 4-11) and rear camber adjuster kits for Honda vehicles. This kit consists of an off-set bushing assembly that replaces the upper control arm to fender liner mounting assembly. A major advantage of this kit is that once it is installed, control arm camber adjustments-including future camber adjustments can be made by simply loosening the nut and rotating each hex head equal amounts in the same direction. This means that as the vehicle's suspension ages and receives some wear, future camber adjustments can be made easily, making this vehicle truly alignable when only toe is adjustable from the factory.

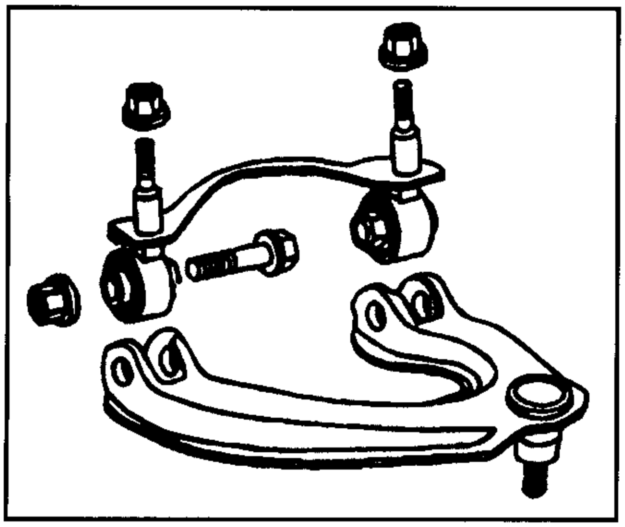

Fig. 4-11. Honda Camber Kits Allow Adjustments Beyond Factory Settings

Other vehicles that have kits available for them include the Nissan 300ZX and 200ZX. These models have a rear camber plate on the lower control arm that allows camber to be adjusted up to 1-1/2 degrees. This vehicle can now have a rear camber adjustment, so this kit solves a real problem.

Subaru

Another example is for various Subaru models. This kit allows the Subaru to have caster adjusted or equalized between the two front wheels. Caster is adjusted with a moveable nut on the end of the strut rod that attaches to the frame bracket.

To install this kit, simply remove the OE strut rod. This can be done easily with the weight of the vehicle on the tires. Be sure the turntables on the alignment rack are pinned. Failure to pin the turntables may allow enough movement to cause the suspension system to shift. Remove the front nut on the strut rod and remove the front bushing.

Next, remove the two bolts and nuts that hold the rod to the lower control arm, and remove the strut rod. Install the replacement strut rod by mounting the most inward nut, and the washer and the bushing. Next, mount the strut rod over the control arm and install the two bolts and nuts holding the strut rod to the lower control arm. Install the bushing on the front of the strut rod. It should come into contact with the frame bracket. Install the washer and the nut next. Repeat the process on the other side of the vehicle if needed. Next, unblock the front wheels, remove the pins from the turntable and re-sweep caster. Adjust caster as needed by simply loosening and tightening the two nuts on the end of the strut rod, alternately allowing the length of the strut rod to change. This moves the lower control arm forward or backward. Jounce the vehicle, tighten all nuts to specifications, and adjust toe.

Ford Trucks

Ford light duty pickup trucks frequently need an alignment because of the variety of spring ride height and wear. An eccentric bushing is available to adjust camber and caster on these vehicles. The same style bushing can be used on both two- and four-wheel drive trucks.

You'll find that they come from the factory with a bushing already installed. This bushing may be one that is changing the alignment, or it may be a zero-reference bushing. To make adjustments on these vehicles, the original equipment bushing is removed and an aftermarket double eccentric bushing replaces it. This bushing works best when both camber and caster need to be adjusted. A camber and caster combination adjustment is the most commonly needed adjustment on these vehicles. First, check the basic alignment reference angles. Determine the amount of change needed to bring the vehicle into specifications. Dial in the bushing according to the instructions, and install the bushing into the axle. You may find a wide variety of original equipment bushings have been used. It is extremely difficult to calculate the amount of change that this bushing is truly affecting on the vehicle.

The easiest way to align one of these vehicles is to install a zero degree bushing. This can be done without the nut or pinch bolt being fully tightened on the unit. Simply install it, lower the vehicle onto the alignment turntables and retake the alignment readings of camber and caster. Next, determine the amount of change from the zero reference point and select a correct bushing. Remove the zero degree test bushing and install the eccentric bushing, referencing the installation point according to the instructions. Then proceed with the alignment in a normal manner.

NOTES:

Section Four Mini Quiz

1. When a vehicle requires shims on both rear wheels, you should install:
   a. Both rear shims and take a new reading.
   b. The right rear shim, take a reading, and then install the left rear shim.
   c. The left rear shim, take a reading, and then install the right rear shim.
   d. The side most out of adjustment, take a reading, and then install the remaining shim if needed.

2. Which of the following items is NOT a means of adjusting camber?
   a. Cam bolt assembly.
   b. Shim.
   c. Strut rod.
   d. Sliding control arm.

3. To correct camber on a 4WD Bronco with independent front suspension, use a camber:
   a. Wedge.
   b. Shim.
   c. Cam bolt.
   d. Bushing.

4. Front camber on a Ford Escort is considered non-adjustable. To adjust camber, _________ is necessary.

   a. A frame shop
   b. Strut bending
   c. A camber plate
   d. A camber wedge

ANSWERS

1.d 2.c 3.d 4.c

SECTION 4 SHOP EXERCISES

Move to the shop area and perform the following exercise. You will need access to a variety of vehicles and an alignment rack. The vehicles you will need include models that use a shim to correct rear camber and toe, a fastcam or crank bolt to adjust camber, and an eccentric bushing to adjust front camber and caster.

1. Obtain the existing alignment readings

2. Determine the amount of correction needed

3. Write down the type of shim, crank bolt or other adjustment device needed to bring the vehicle back to safe operating conditions

4. Determine the installation procedures for each adjustment device

NOTES:

5

NON-ADJUSTABLE CONDITIONS

Please watch video module five now.

Alignment technicians around the country know that OEs and OE manuals often state that specific alignment angles are not adjustable. This often occurs because of changes in vehicle designs and components, as well as manufacturer's specific production needs.

The aftermarket provides a wide range of products and, in many cases, more than one product to do the same job. This allows technicians to use the product that works best or the product that is the easiest for them to use. Most are designed to replace existing components without requiring cutting, bending, or drilling.

OE FACTORY DESIGNS

Increasing Fuel Costs Lead to Increased Fuel Efficiency

Since the oil crisis of the 1970s, gasoline prices have skyrocketed. When this happened, consumer demand for more fuel-efficient vehicles also increased dramatically. To meet these demands, manufacturers had to develop newer, lighter weight materials for use in their vehicle suspensions. Frames and control arms were thinned, for example, and new materials were developed to reduce overall vehicle weight.

These components tend to flex and give more readily during normal use, as well as during standard service procedures. For example, a thinner, lighter weight control arm may give or stretch during the removal of a press-in ball joint. As a result, an oversized, replacement ball joint is required, creating the need to re-set the alignment angles.

Production Considerations

In addition, production needs are seemingly at odds with the needs of the aftermarket. One example is the GM C-body. It has two slotted holes in the upper strut mount for caster adjustment. A third hole is marked, but not slotted. The technician must drill out and slot the third hole for caster to become adjustable.

This situation occurs because a fixed reference point is required during production to set vehicle caster so it won't change from side to side or from vehicle to vehicle. Leaving the third hole marked, but not slotted, provides the necessary reference point.

This is true with other vehicles as well, like GM light trucks and vans, where cam bolts are used on the upper control arm to adjust camber (Figure 5-1). However, the plug must be removed before the cam bolt can be rotated to make the necessary adjustment.

Fig. 5-1. GM Upper Control Arm Cam Bolt.

The Ford Taurus/Mercury Sable use spot welds on the upper strut mount plate. These spot welds must be drilled out before any adjustments can be made (Figure 5-2).

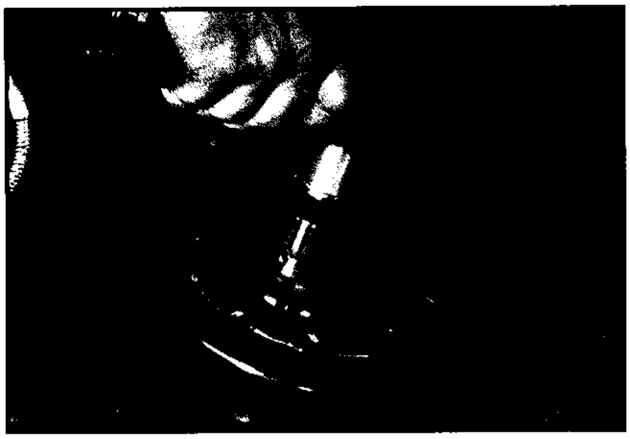

Figure 5-2 Ford Taurus/Mercury Sable Front Strut Tower

Other Ford products may have the upper strut mount plate riveted in place. Regardless of the specific vehicle design, these methods provide a repeatable reference point for the manufacturer. However, none of these "adjustable" angles are truly adjustable until the technician completes the required steps.

Another example of how production costs play a major role in OE manufacturing decisions is the single rear toe adjuster used on the Ford Probe and the 1991 and later Ford Escorts. The initial Ford Escort and Probe had toe adjusters on both sides. The first 400 to 500 of these vehicles were assembled on the line with two rear toe adjusters. However, the assembly evolved to the point that the manufacturer could set a fixed reference toe on the left side, and only the right side contained an adjuster. This allowed Ford to set total rear toe, so it didn't have to be concerned about thrust. Instead, thrust was to be set through the manufacturing tolerances of the vehicle when it was assembled. However, it is possible to adjust total rear toe so it is within specifications and still have a thrust angle problem. Therefore, with these vehicles, it is necessary to install an aftermarket adjustment kit on the left rear. This allows individual rear toe to be adjusted, eliminating any thrust angle problems that may be present on these vehicles.

Factory Settings for Caster

Many FWD vehicles no longer provide for caster adjustment. This is because FWD vehicles are typically designed with a negative scrub radius to provide improved directional control. Vehicle manufacturers often consider this fixed setting to be adequate, so there is no need to adjust caster.

Even though scrub radius on vehicles is preset, many factors can alter it. For example, the ride height on a vehicle can change scrub radius.

Cradle adjustment or offset can also change scrub radius, along with the basic camber settings on some vehicles. This angle is often set at the factory, but it can frequently be disturbed or changed during regular use, causing handling difficulties that the factory never considered.

Effects on the Marketplace

The unibody construction of FWD vehicles is susceptible to the flexing and shifting that normally occurs as a vehicle's age and mileage increase. This flexing tends to move caster enough for it to have an adverse effect on the vehicle's handling characteristics. Shifting of the engine cradle may also occur, leading to the need for cradle alignment and caster adjustment. Therefore, setting caster often requires the use of aftermarket alignment products.

Because so many of today's vehicles are designed with non-adjustable angles, the aftermarket has made significant progress in developing products and methods for making these adjustments.

For example, several Subaru vehicles, including the '80 to '89 DL, GL, GL10, Hatchback, and Brat, and the '90 to '92 Loyale and XT coupe, have no factory provisions for caster adjustment .

Since each of these vehicles may experience a varying degree of handling problems as a direct result of incorrect caster, the aftermarket provides a replacement adjustable strut rod for the OE non-adjustable strut rod (Figure 5-3). This allows the technician to make very accurate caster adjustments.

Other imports using wishbone suspensions, like the Honda Accord, Civic, and Del Sol, and the Acura Integra, provide rear toe adjustment, but not rear camber adjustment. Yet, most wishbone suspension systems will experience tire wear and handling problems as a direct result of incorrect camber.

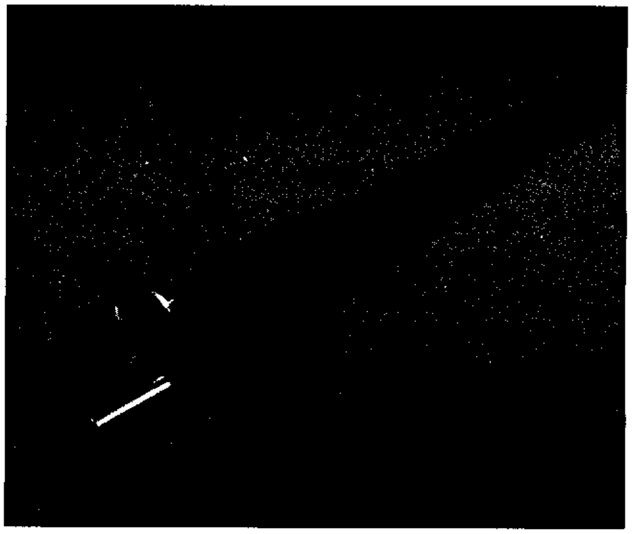

Figure 5-3. Aftermarket Adjustable Strut Rod

Correcting the camber setting on these vehicles requires the use of an aftermarket part known as "smart arm" (Figure 5-4).

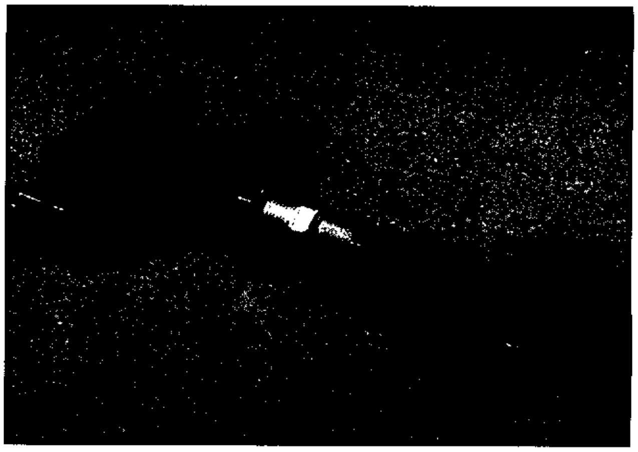

Figure 5-4. Smart Arm for Honda Civic

Smart arms replace OE-designed control arms, track bars, or connecting links. The arms are adjustable to make camber adjustments, and in some other cases, toe settings. The smart arm is also commonly used for the '93 to '97 Dodge Intrepid, Chrysler Concord, LHS, and New Yorker, the Eagle Vision, the Nissan Maxima and Stanza, and the Ford Escort.

FRAME BENDING GUIDELINES

The question of frame bending normally arises in reference to thrust angle alignments. To perform a thrust angle alignment, the technician must first reference the rear axle and adjust front camber, caster, and toe. Depending on the vehicle, factory adjustments may range from all angles to front toe only. This can often mean the technician is stuck with a vehicle that needs an adjustment, but there's no way to do it.

When this happened in the past, a technician would simply send the vehicle to a frame shop. The frame shop technicians would pull, push, and bend the frame or unibody until the angle was close to being correct. While this method will often eliminate the problem at hand, such as a pull to one side, frequently it does not set the angle correctly. In many cases, it may lead to other problems at a later time. This type of repair fatigues the metal and may not correct what caused the vehicle to be out of alignment in the first place.

Unless a vehicle was involved in an accident, it was common for something to be bent, pulled, or pushed to compensate for another problem. But, a vehicle goes out of alignment for many reasons. Just driving a vehicle forces the suspension system to move, so from time to time it will need to be adjusted. Minor, almost unnoticeable wear in bushings, tie rods, and ball joints will not justify their replacement. However, if you add a little play here and a little play there, it's easy to see how this will affect the alignment.

Also, as a bushing gets older, its load-bearing side will often take a set that is off-center. While no looseness or damage will be noticeable, this change in position will affect the alignment. The unibody used on most FWD vehicles is another consideration. This chassis design will shift and twist while driving, in time affecting the alignment. Moreover, simply hitting a pothole or a curb can shift a cradle support. This, again, changes alignment. To pull, push, or bend the frame in these situations would not be in the vehicle owner's best interest. In fact, when the vehicle is due for its next alignment, it may be necessary to unbend what was bent at the last alignment. It won't take much bending for the parts to eventually wear out and break.

In many cases, a cradle support shift may correct these problems (Figure 5-5). However, never shift or move a cradle that is not designed to be an adjustable unit. In addition, do not elongate the holes in the cradle support or remove the cradle indexing pins to allow them to be shifted.

Figure 5-5. Cradle Adjustment

Only a cradle that has been designed to be adjusted should be shifted to deliberately alter the alignment on a vehicle. Some of the more popular vehicles with adjustable cradles include Taurus/ Sable sedans and wagons, Ford Windstar minivans, GM W-cars, the older family of GM X- cars, and the rears of the Chrysler LH and Cirrus automobiles.

Other cars, such as the rears of the Toyota and Probe vehicles, have cradles bolted to the sub-frame assemblies. These cradles are fixed in their positions by indexing pins. Never grind off these indexing pins or elongate the holes into which they fit to correct alignment problems by shifting the cradle left or right. In such a case, you must correct the body or sub-frame condition that caused the cradle to be out of position.

In other cases, however, you may be able to use an aftermarket product that is designed to correct frame problems. For example, an '88 Honda Accord may have rear camber that is out of specification by 1°. This angle has no factory adjustment, but tire wear is a typical customer complaint. This can be corrected by replacing the rear, upper spindle link or control arm with an aftermarket adjustable link (Figure 5-6). Similar to a turn buckle, this replacement link allows adjustments up to 2°. This allows the problem to be corrected with no adverse effect on the suspension system.

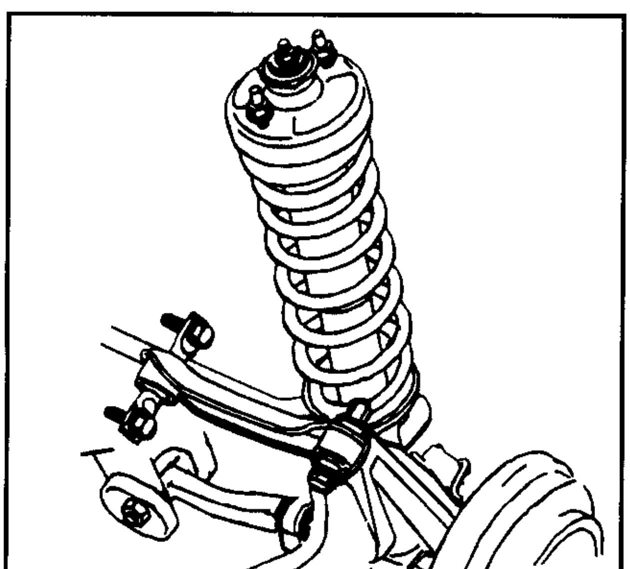

Fig. 5-6. Camber Kitt for '88 Honda

Additionally, the link may be readjusted at the next alignment. The correction is more accurate and a fraction of the cost of frame bending. This product is called a "smart arm" and is only one example of the many designs available for similar situations.

Each product is designed to replace a non-adjustable component with an adjustable one, and all make adjustments with no adverse effects, as well as with greater accuracy, lower cost, and improved flexibility.

However, it's important to know when and how to use these alignment products to avoid misusing them. For example, a customer may come in with a GM FWD vehicle with a beam axle rear suspension.

Camber on one of the rear tires is out of specification by more than 3°. This may be caused by a bend in the rear beam axle. An alignment shim could be used to correct the camber angle on the rear wheel and prevent tire wear, but it may lead to an increased burden on the rear hub mounting bolts.

To properly correct this problem, replace the bent axle and perform a proper four-wheel alignment. An aftermarket shim may be needed to fine-tune the camber angle. However, never stack adjustable, full-contact, dual angle alignment shims. Full-contact synthetic shims may be stacked, but never use more than two shims together.

Also, never use another alignment product with an alignment shim to get more adjustment than the shim allows. Most full-contact, rear-wheel alignment shims have an adjustment range of 0° to 1-1/2°. Never stack two, 1-1/2° shims to get 3° of angle change.

Remember that whenever more than 1-1/2° to 2° of angle change is needed, there usually is a problem other than the alignment. There may be a bent or a worn component or a bent control arm. All such damaged components should be replaced before a proper alignment is performed.

If an alignment is out of specification as a result of accident damage, always replace the damaged components first. If damage was done to the frame or to non-replaceable unibody sections, this would be the time to use a frame shop. Frame bending, pulling, or pushing should be used only as a last resort, but in some cases, such alterations may be the only solution.

Some vehicles require more detailed work and specialized products for setting specific, non-adjustable angles. Some of these are noted in the following pages.

CAMBER

Chrysler LH Bodies (Smart Arm)
Setting rear camber on Chrysler LH bodies (Figure 5-7) requires the use of an aftermarket part known as a "smart arm". The smart arm replaces the OE-designed control arm, and is adjustable to plus or minus 1°.

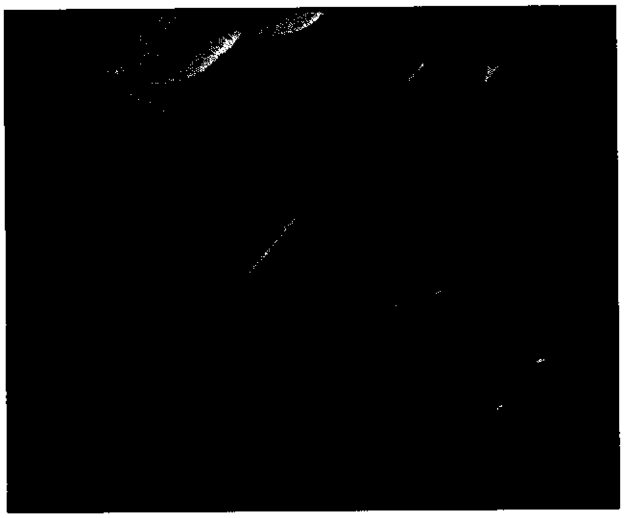

Figure 5-7. Chrysler LH Rear Suspension

To use the smart arm, follow these procedures.

1. After removing the tire and wheel assembly, remove the nut and bolt assembly that attaches the lateral links to the spindle.
2. Remove the nut and bolt assembly that attaches the lateral links to the rear crossmember.
3. Install the new link on the front of the cross-member with the head of the bolt toward the front of the vehicle. Install the nut (Figure 5-8).

Figure 5-8. Installation of Smart Arm

4. Install the rear adjustable link on the cross-member, and reinstall the cross-member.
5. Attach the links to the spindle with the head of the bolt to the front of the vehicle, and install the nut.
6. Torque the lateral link nuts to 105ft.-lbs. (140 NM).
7. Replace the tire and wheel assembly.
8. Adjust the rear camber by loosening the jam nuts and lengthening or shortening the links in equal amounts. Do not exceed more than 3/4" of exposed threads on either side of the bolt.

If an OE arm is replaced with a smart arm on one side of the vehicle, and the OE arm on the other side remains, keep in mind that the length specification for the OE arm is different from the specification for the smart arm. The smart arm instructions for camber adjustment specify no more than 3/4" of exposed threads on either side of the bolt. The OE camber adjusting link specifications state that after the camber adjustment is completed, you should measure from the center of the end bolt to the center of the end bolt. The length should be no more than 391mm.

Remember, there is a difference in the total length specifications of the replacement smart arm and the OE arm. Do not cross the overall specifications, because there are differences in the production of the individual pieces.

GM Cars and Light Trucks (Cam Bolt)

Another alignment product, the cam bolt, is often used with many GM cars. Now it can also be used on the control arms of many GM trucks. The cam bolt kit provides a replacement bolt for the control arm and allows for both camber and caster adjustment. Although some of the newest trucks may already have a cam bolt installed, this cam bolt cannot be rotated because a plug on the inside frame restricts the movement of the bolt.

The first time one of these vehicles is aligned, the cam bolt and plug must be removed. Then, the cam bolt can be reinstalled and turned to make adjustments. This plug is in a very tight area and at a difficult angle to reach.

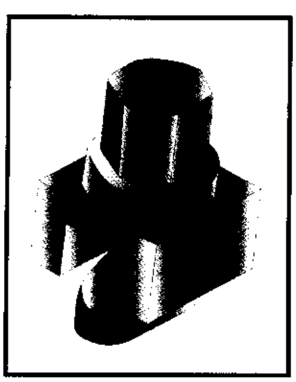

Figure 5-9. Tool Especially Designed to Help Remove Cam Bolt Plugs

A tool has been specifically designed to help remove the plug (Figure 5-9) .

Follow these procedures when using this tool:

1. Back the nut off the end of the tool, and slip off the washers.
2. Slip the plug remover through the plug, going outward.
3. Then, slip the outer bracket over the remover, making sure the plug is centered between the bracket slots.

> **NOTE:** If the plug gets stuck on a bracket edge, it can bend the components. Therefore, perform this step carefully.

4. Install the two washers.
5. Tighten the nut. This draws the plunger in and pops out the plug.

Later model GM trucks may have cam bolts installed at the factory. When these cam bolts are removed, instead of finding a knockout plug on the forward ears of the front and rear control arm mounting pockets, the hole may already be elongated. There are two reasons for this condition: 1) The truck may have been aligned at the factory and the knockout plug was removed, the cam was turned to compensate for an inaccurate alignment reading, and the vehicle was actually adjusted, and 2) The frame pockets may have been reversed. In other words, a right-hand frame pocket may have been used on the left-hand side. If this is the case, the knockout plug will be on the rear portion of the individual mounting pocket on the frame. Check both sides to make sure the front portion of the control arm mounting frame pocket is knocked out. If this is not checked and the rear hole knockout plug isn't removed, any attempts to turn the cam may cause the retaining ears to be rounded off.

Also, late model 1997 vehicles have the cam bolt tag welded to the control arm mounting pocket in some instances. This tag weld must be cut with a chisel or a die grinder, the cam bolt must be removed, and then the knockout plug must be removed from its normal location. It is unknown why factories are tag welding the cam bolts in position on some vehicles, in addition to leaving knockout plugs on the mounting portions of upper control arms. This condition has been reported by various alignment technicians across the country. Just remember, tag welds do not mean that knockout plugs are not present. Cut the tag weld, remove the cam, and look for the knockout plug. In most cases, it will still be present on the vehicle.

Other Solutions

Another product is the front camber adjuster for Honda vehicles (Figure 5-10). This offset adjustable bushing assembly, used on the Accord, Prelude, and Acura Legend, replaces the original bushing in the upper control arm.

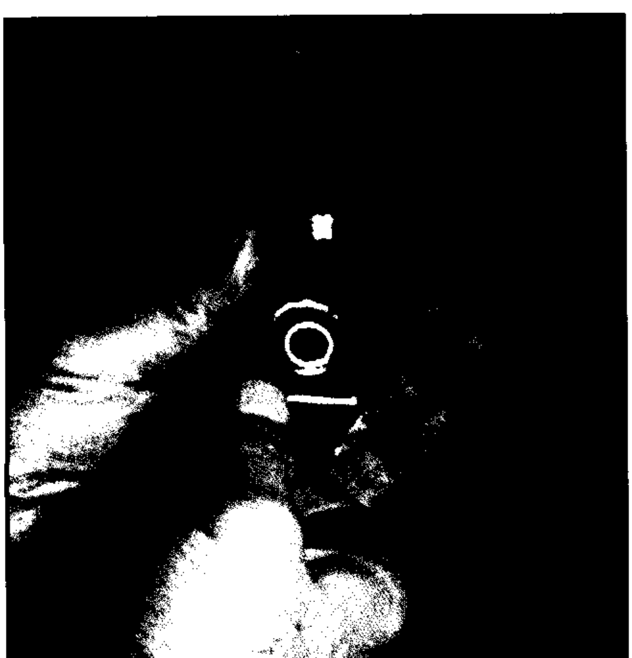

Figure 5-10. Honda Accord Front Camber Adjuster

Once it's installed, camber adjustments can be made by rotating each hex head in the same direction and in equal amounts.

In addition, a rear camber kit for the Nissan 300 ZX and 200SX requires installing a camber plate on the lower control arm to allow camber adjustments up to 1-1/2°.

CASTER

Subaru 4x4s

As stated earlier, Subaru vehicles, including the '80 to '89 DL, GL, GL10, Hatchback, and Brat, and the '90 to '92 Loyale and XT coupe, have no factory provisions for caster adjustment.

Yet, all of these vehicles may experience a varying degree of handling problems as a direct result of incorrect caster. Therefore, the aftermarket provides a replacement adjustable strut rod for the OE non-adjustable strut rod. This allows technicians to make very accurate caster adjustments.

To remove the OE strut rod:

1. Leave the weight of the vehicle on the front wheels. Do not jack up the car.
2. Block the front wheels and set the hand brake so the vehicle cannot move.
3. **CAUTION:** Be sure the turntables on the alignment rack are pinned. Failure to do this will allow the wheel to move when the strut rod is removed.
4. Remove the stock bushing nut first. Then, remove the two bolts and nuts holding the rod to the lower control arm.

To install the aftermarket adjustable rod:

1. Install the rod, reusing the OE rubber bushings, bushing washer, nuts, and bolts.
2. Tighten the two bolts and nuts that hold the rod to the lower control arm.
3. Tighten the bushing nut on the threaded end of the new rod.

4. Move the two nuts back and forth to adjust the caster either positive or negative.
5. Torque all nuts and bolts to OE specifications.

Ford Light Trucks

On Ford light trucks that have a twin I-beam suspension, a bushing assembly on top of the ball joint is used to make camber and caster adjustments (Figure 5-11).

Figure 5-11. Ford Truck Caster / Camber Bushing

This design is used on both 2WD and 4WD trucks. When these trucks come from the factory, the bushing is already installed and set for a specific degree of adjustment. To make future adjustments, the existing bushing can be removed and replaced with an adjustable bushing.

This bushing works best when both camber and caster need to be adjusted. To make the adjustment, first check the alignment angles. Follow the chart included with the bushing, and line up the numbers on the bushing. Then, install the bushing into the axle.

One potential drawback of using this bushing is that the technician must remember to compensate for whatever angles were already set in the truck.

The easiest way around this is to get a set of zero degree bushings that you can use as tools. To use these bushings, first take out the OE bushing and replace it with a zero degree bushing. The entire assembly does not need to be tightened when installing a zero degree bushing. Just snug it enough to hold everything together, and take another alignment reading.

Now you know you're starting from zero, and you don't have to worry about adding or subtracting the original or subsequent settings. This can eliminate a lot of mistakes.Another plus is that adjustable bushings can be reused.

If future adjustments are needed, again replace the bushing with the zero degree bushing to determine the correct reading. Reset the old bushing for the new angles, and reinstall it. These bushings can be used and reused throughout the life of the vehicle.

Saturn Rear Toe Kit

A rear toe kit for Saturn vehicles is available from the aftermarket. To adjust toe up to 1°on these vehicles, adjustable cams and an adjusting plate are installed on the rear trailing arm and trailing arm bracket.

To install the toe kit:

1. Remove the center mounting bolts from the rear arms only.
2. Place one cam on each bolt, and place the bolt head in the slot of the cam.
3. With the two slots in the plate facing outward, place the plate over the trailing arm mounting holes. Insert the bolts through the plate and trailing arm holes. Install the lock nuts on the bolts and snug, but do not tighten them.

4. Drill a 5/32" diameter hole through the trailing arm bracket, using the center hole in the adjusting plate as a guide.
5. Install the self-tapping bolt provided to secure the adjusting plate to the bracket. **DO NOT OVERTIGHTEN** the bolt.
6. Jounce the vehicle and adjust the cams to the desired toe. Torque the nuts to 80-90 ft.lbs.. Make any necessary adjustments to the front of the vehicle and test drive.

Taurus/Sable Bushings

Synthetic bushings for the Ford Taurus/Mercury Sable sedans are available for use on the rear control arms to adjust both camber and toe. The big benefit of a synthetic bushing is that it does not freeze up or rust like a metal bushing.

The new replacement bushing uses the strength of metal-to-metal bushings, with a special synthetic coating so it won't corrode. This metal bushing allows the hole to be offset for a greater degree of adjustment.

In addition, it's a piece that can be reused because it will be able to rotate without freezing up. For these reasons, this particular bushing is far superior to anything else on the market for these vehicles. That is one tip to keep in mind when using these bushings.

Be sure the bushing is exactly square to the hole when it's installed. That's because the lightweight control arm in these vehicles is easily distorted and can become more egg-shaped than round if the bushing is cocked even slightly in the hole. If this happens, the bushing will just spin in the hole.

NOTES:

Section Five Mini Quiz

1. Today's vehicles require more frequent alignments, and advanced repair and adjustment techniques because of:
   a. Poor road conditions, potholes, and soft shoulders
   b. Drivers executing faster starts and stops
   c. Lighter weight materials tending to flex and give more readily
   d. Newer tire technology leading to performance changes

2. Many OE adjustments cannot be made until a pre-approved area is elongated, drilled, or cut. The manufacturers do this to:
   a. Make the technician's job harder
   b. Have a fixed reference point during assembly
   c. Prevent possible angle changes during shipping
   d. Increase aftermarket product profits

3. On the Taurus and Sable, once the spot welds in the upper strut mount are drilled out, camber is adjusted by moving the strut inward or outward. When this does not provide enough adjustment, you can:
   a. Use a cam bolt in the lower strut mount.
   b. Use a full contact shim on the front hub.
   c. Offset caster to compensate.
   d. Use an adjustable strut mount plate.

4. Many FWD vehicles no longer provide for caster adjustments because of:
   a. Negative scrub radius.
   b. Included angle specifications.
   c. Wider wheel bases.
   d. Vehicles travel at high speeds.

ANSWERS
1. c 3. d
2. b 4. a

SECTION 5 SHOP EXERCISES

Move to the shop area and perform the following exercise. You will need access to a vehicle that is in need of frame or structural repair, or has been in an accident and has been improperly repaired.

1. Visually inspect the vehicle for potential problems

2. Set up and take alignment readings

3. Determine the cause of the alignment, frame or structural problems, and if a wheel alignment alone will cure them.

NOTES:

6

CASE STUDIES

Some of the more common problems, along with their solutions, are explained below. Additional information is available on the video that accompanies this workbook.

Please watch video module six now.

NOTE: *Many of the Case Studies described in this section recommend installing a zero degree bushing as part of the pre-alignment service. Newer alignment equipment computer software eliminates the need to install a zero degree bushing. The software automatically calculates the correct angles for you.*

1. 1988 - 1992 CHEVROLET/GMC 1/2-TON AND 3/4-TON ASTRO/SAFARI VAN - HEAVY DUTY IDLER ARMS

General Motors uses a threaded bushing idler arm on these vehicles. This design actually allows the idler arm to be screwed onto the bracket when the vehicle is turned one way, and then screwed off the bracket when it is turned the other way. Because of the basic engineering design, there is a considerable amount of looseness, or sloppiness, in the idler arm-to-idler arm bracket mounting point. This looseness leads to toe-change as the vehicle is driven and as the suspension system goes through its normal range of travel (Figure 6-1).

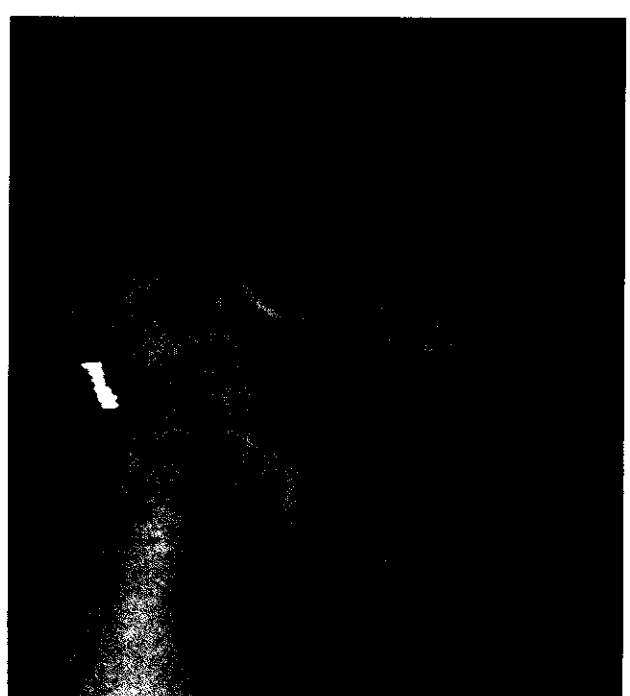

Figure 6–1 GM Idler Arm Being Checked for Looseness

The GM models that have had the most trouble are the 1/2- and 3/4-ton pickup trucks from 1988 to 1992, and the Astro/Safari vans prior to 1996. After 1992 for the trucks, and 1996 for the Astro vans, GM changed its idler arm design, no longer using the threaded bushing idler arm. The factory specification for GM idler arm looseness is 1/4" of total movement. That's 1/8" up and 1/8" down, with 25 lbs. of force applied to the center link-to-idler arm connection. For Astro vans, that specification is applied to both idler arms.

If you are replacing a worn GM idler arm with an OE unit, or with an aftermarket product that uses OE technology, the replacement idler arm may be as loose as the one removed. To determine if the idler arm is definitely causing the toe change problem under dynamic driving conditions, set up the alignment equipment, grasp the center link at the idler arm connection, and move it up and down with normal force. Watch the amount of toe change that takes place. If toe changes, the idler arm is allowing a dynamic change or toe curve as the vehicle is driven, and may be reason for replacement.

The solution to this problem is to install a specially designed replacement.

These idler arms are superior in design to the OE idler arms. They use an improved engineered bearing and load carrying assembly that, while maintaining low rotational torque, also maintain a high degree of pre-load, eliminating the looseness found in the OE parts They also have a true rotational pivot point, without any vertical looseness.

When checking the alignment on a GM vehicle that has these idler arms, be sure to use tighter tolerances than those used for the OE design. Also, keep in mind that GM idler arms must be mounted correctly on the vehicle. With OE idler arms, the bracket portion of the idler arm can be mounted with either side toward the frame.

However, the aftermarket idler arms are designed with a bump (Figure 6-2) or a ridge on the bracket end. This was added so the idler arm could not be installed incorrectly. The smooth side of the idler arm must be mounted against the frame. If it is mounted incorrectly, excessive stress or loads are placed on the mounting bolt and mounting bolt bracket. As a result, the bracket may tear due to the incorrect angles between the steering linkage and the idler arm.

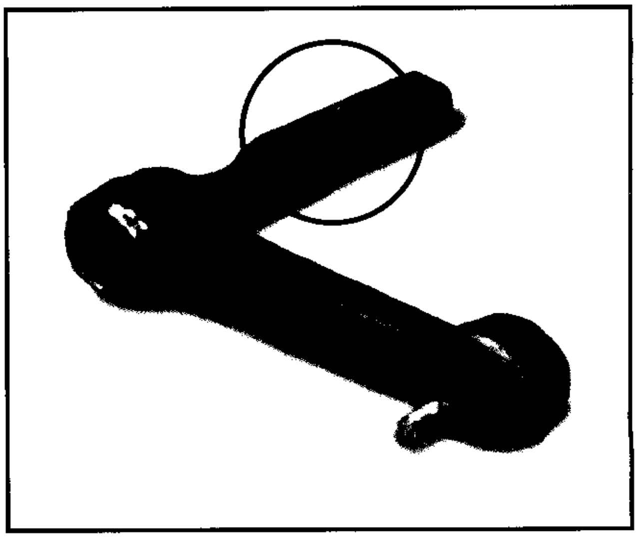

Figure 6-2 Aftermarket Idler Arm

On Chevy Astro vans, it is also possible to mount the left-hand idler arm with the bracket facing in the wrong direction. If this occurs, the linkage could shift, possibly resulting in binding or preventing the steering wheel from returning to center. At the least, it could create a severe toe and dynamic alignment problem. The vehicle should not be driven if the idler arm has been mounted incorrectly. This could lead to stress on the steering linkage and, possibly, broken components.

2. PRE-1997 FORD/MERCURY ESCORT/LYNX, TAURUS/SABLE, TEMPO/TOPAZ - INNER TIE ROD ENDS.

Pre-1997 Ford FWD vehicles have had a tremendous wear problem on the inner tie rod ends or inner socket assemblies of its R&P steering units (Figure 6-3). On some vehicles, such as the Escort/Lynx and the Tempo/Topaz, there is a basic design problem: The angle of the inner tie rod end is not parallel to the angle of the lower control arm. This means the mounting position of the inner tie rod end, when the vehicle is pointed straight ahead, is not in line with the lower control arm inner mounting bushing. This results in pivot binding, and a high degree of load and stress being placed on the inner tie rod ends.

Figure 6-3 Ford Front Suspension

The Taurus and Sable, which run a negative camber setting, are designed with a fairly high steering axis inclination. They also have approximately a 40 to 50 lb. pre-load on the suspension system when it is turned from the straight ahead position. These conditions place a considerable amount of load or stress on the inner tie rod ends. All of these factors place a compression load on the inner tie rod sockets, which are designed as torsion joints.

The aftermarket replacement inner tie rod end, has several engineering features that help eliminate rapid wear. There is a larger bearing surface area, along with an increased ball diameter at the end of the tie rod. The bearing configuration changes these sockets from tension-resistant joints, to tension, compression, and radial force-resistant joints. These features, along with a smoother pre-load torque or swing torque, mean that you can install a tie rod end that will help eliminate the rapid wear common on the OE products. In addition, by maintaining a constant pre-load and smoothing the rotation of the inner tie rod end, toe can be adjusted more accurately and the toe settings will be retained much longer.

3. PRE-1997 FORD PICK-UP TRUCKS - OUTER TIE ROD ENDS

Various models of the pre-1997 Ford pick-up trucks used RBS, or rubber-bonded socket, tie rod ends at the right outer and left outer locations, and also at the point where the right-hand assembly connects to the Pitman arm. They are susceptible to fatigue, deterioration from the elements, and a variety of other conditions that frequently lead to premature failure. When they are replaced with conventional tie rod ends, such as an LEM or dual bearing type, there is a high degree of lateral movement where the inner tie rod end connects to the right-hand assembly. This lateral movement means that when the vehicle is steered, excessive steering wheel and Pitman arm movement occurs before the wheels actually begin moving. It also means that as road forces reach the wheels and steering linkage, there is a looseness or sloppiness in the system. This can create a handling and alignment problem, along with accelerated tire wear.

Certain aftermarket products eliminate the lateral movement that occurs when a non-RBS tie rod end is used. The replacement tie rod end has a limiter washer between the ball socket and the ball stud. Many Ford truck tie rod ends tend to operate at an angle. In other words, the housing does not stay at a right angle to the ball stud portion of the tie rod end. When the ball stud swings from the center position, an accompanying toe change takes place. The limiter washer between the ball stud and the socket puts a pre–load tension on the tie rod end whenever it swings out. This pressure causes the tie rod end to recenter itself, eliminating unwanted toe change.

The tie rod end designed for this application is also greaseable. The original, RBS tie rod end, is not.

4. 1992-1995 FORD E-150, E-250, AND E-350 FULL SIZE VANS-BALL JOINTS.

When Ford's "E" Series vans were switched to a pinch bolt suspension system, the ball joints were similar in design and application to what had been used on the F-150 2WD, pickup trucks.

However, a problem occurred on the van that had not been present on the truck. The new OE ball joints had an unusually high level of dust boot failure, which allowed contaminants to enter the ball joint, causing them to wear out rapidly.

Aftermarket replacement ball joints have an interference fit between the dust boot and the outer shell of the ball joint to provide a superior, moisture-resistant seal.

This ball joint is a low friction design with a tapered stud, a fully polished ball, and a reinforced polymer bearing assembly.

Additional material surrounds the portion of the ball where the tapered stud is attached. This design provides superior wearability and load carrying capacities.

5. PRE-1997 FORD FUL-SIZE PICK-UP AND RANGER 4X4-ALIGNMENT BUSHINGS.

These alignment bushings, unlike the ones installed at the factory, have a removable upper lock ring. That means you can literally dial in the camber/caster split to the exact amount of change needed.

First, remove any bushing that has been installed. It may have an effect on camber and/or caster. Then, install a zero-degree bushing and recheck the readings. Always align the side that needs the most change first. After aligning that side, check the readings on the other side. A substantial change to one side of the Ford truck may shift enough weight or load on the vehicle to slightly change the other side. After obtaining the vehicle's true base reading, determine the amount of camber and caster change needed by referring to a specification chart. This chart lists caster down the left side and camber change across the top (Figure 6-4).

Next, remove the old bushing. It may be easier to loosen the lower ball joint nut and separate the tapers on the lower ball joint, in addition to removing the upper nut and the bushing. After removing the cotter key in the upper ball joint nut, remove the bushing, using a Pitman arm or other puller designed specifically for this work. To separate the tapers of the ball joint from the lower steering knuckle and the upper bushing, strike the steering knuckle near the area where the tapered stud goes through the knuckle.

The most effective way to separate the tapers is to use a dead blow, or negative rebound, ballpeen hammer. This type of hammer has BB shot inside of it and directs the force of the blow. It does not have the same amount of spring–back that a conventional ballpeen hammer has.

> **NOTE:** *You can tell when the tapers are separated, not by the movement of the knuckle, but by the sound of the hammer striking the knuckle assembly. It will have a higher pitched, springy sound when the tapers are still locked in, but a dull or dead sound once the tapers are separated.*

After separating the tapers, attach the Pitman arm puller and remove the upper bushing. If the ears of the bushing break during removal, use an air chisel with a dulled blade.

Approach the bushing at a right angle, and move the handle of the air gun down. This will drive the bushing up and out. The vibrating action of the air chisel will assist in breaking loose any rust scale or binding that may be present between the tapered stud and the bushing. Once the bushing is removed, carefully inspect the knuckle area for any contamination, rust scale, or other debris that may prevent the new bushing from seating properly.

Desired Camber Correction (Positive or Negative)

Desired Caster Correction (Positive or Negative)	0°	1/4°	3/8°	1/2°	3/4°	1°	1-1/8°	1-1/4°	1-1/2°	1-3/4°	2°	2-1/4°	2-3/8°	2-1/2°	2-3/4°	3°	3-1/8°
0°			2782	2782 2783	2783	2783 2784	2784	2784 2785	2785	2785 2786	2786	2786 2787	2787	2787 2788	2788	2788 2789	2789
1/4°		2782	2782	2783	2783	2784	2784	2785	2785	2785 2786	2786	2786 2787	2787	2787 2788	2788	2788 2789	2789
3/8°	2782	2782	2782 2783	2783	2783	2784	2784	2785	2785	2786	2786	2787	2787	2787 2788	2788	2788 2789	2789
1/2°	2782 2783	2783	2783	2783	2784	2784	2784	2785	2785	2786	2786	2787	2787	2788	2788	2789	2789
3/4°	2783	2783	2783	2784	2784	2784	2785	2785	2785 2786	2786	2786 2787	2787	2787	2788	2788	2789	2789
1°	2783 2784	2784	2784	2784	2784	2785	2785	2785	2786	2786	2787	2787	2787 2788	2788	2788 2789	2789	2789
1-1/8°	2784	2784	2784	2784	2785	2785	2785	2786	2786	2786 2787	2787	2787	2788	2788	2789	2789	
1-1/4°	2784 2785	2785	2785	2785	2785	2785	2786	2786	2786	2787	2787	2787 2788	2788	2788	2789	2789	
1-1/2°	2785	2785	2785	2785	2785 2786	2786	2786	2786	2787	2787	2787 2788	2788	2788	2789	2789		
1-3/4°	2785 2786	2785 2786	2786	2786	2786	2786	2786 2787	2787	2787	2787 2788	2788	2788	2789	2789	2789		
2°	2786	2786	2786	2786	2786 2787	2787	2787	2787	2787 2788	2788	2788	2788 2789	2789	2789			
2-1/4°	2786 2787	2786 2787	2787	2787	2787	2787	2787	2787 2788	2788	2788	2788 2789	2789	2789				
2-3/8°	2787	2787	2787	2787	2787	2787 2788	2788	2788	2788	2789	2789	2789					
2-1/2°	2787 2788	2787 2788	2787 2788	2788	2788	2788	2788	2788	2789	2789	2789						
2-3/4°	2788	2788	2788	2788	2788	2788 2789	2789	2789	2789	2789							
3°	2788 2789	2788 2789	2788 2789	2789	2789	2789	2789	2789									
3-1/8°	2789	2789	2789	2789	2789	2789											

TIP: *Keep the upper ball joint nut on the threads when striking the knuckle to separate the tapers. The threads will not be damaged if the hammer glances off the knuckle and hits them. These threads are very difficult to chase or recut because of the taper.*

The installation procedures for the new bushing are:

1. Retighten the lower ball joint nut to approximately half of its torque value, or about 35 to 40 ft. lbs.
2. Lubricate the inside of the new bushing with a light coat of silicone grease or anti-seize compound. Position the slot in the bushing in the direction of change. For example, if a positive caster and a negative camber change are needed, the bushing should be set at approximately the four o'clock position when looking down on the bushing. The slot in the bushing indicates the direction of change.
3. Install the bushing in the upper knuckle assembly, and place the old bushing on top of it.
4. Lightly tap on the old bushing, driving the new one into the knuckle until it is seated. The new bushing will go into place easier if the ball joint stud is centered in the knuckle assembly.
5. Remount the wheel and attach the alignment equipment. Be sure to re–compensate the alignment heads that were removed.
6. Set the alignment equipment in the "live camber and live caster" mode. In this mode, simply rotate the bushing and read the amount of change. Some fine–tuning may be needed after the bushing is installed.
7. After the correct camber and caster readings are set for each wheel, install the upper ball joint nut and tighten it to the correct torque, normally 85 to 100 ft.-lbs. Because this is a castellated nut, ***never*** loosen the nut to align the cotter key holes.
8. After the upper nut is installed, torque it to its correct value and place the cotter key in the hole in the threaded end of the stud.
9. Continue to tighten the lower ball joint nut to its proper torque value, normally 95 to 110 ft. lbs. As with the upper ball joint nut, ***never*** back off the lower castellated nut to install the cotter key. Instead, continue to tighten the nut until the next castellation allows the cotter key to be inserted.

Failure to follow the torque sequence may lead to ball joint binding. This binding may occur even when the torque is applied properly. Always check for binding as described here.

To check for a tight steering condition, disconnect the outer tie rod end from the steering arm. Then swing the wheel and tire assembly left to right, lock to lock, feeling for any excessive pressure, binding, or sticking.

If there is any binding in the knuckle assembly, take a lead or soft brass hammer and strike the upper ball joint stud downward just once. If this does not cure the problem, remove the cotter keys, separate the tapers, and re–torque the ball joint nuts. Check for tight steering as the nut is re-torqued.

An additional problem may occur if the vehicle has exceptionally high mileage. The internal bearing surface of the ball joint may be worn in an irregular pattern. If this is the case, installing a bushing may force the ball stud to operate in a different portion of the bearing surface than it had before, creating a binding condition. The only cure for this is to replace the ball joint.

Repeat the procedure on the other side after checking the alignment readings. Adjust camber, caster, and toe, center the steering wheel, and road test the vehicle.

6. DANA AXLE APPLICATIONS - BUSHINGS NOT DESIGNED TO PRE-LOAD THE BALL JOINT AND GIVE DESIRED CASTER/CAMBER ADJUSTMENT, TILT BEARING BUSHING.

Tilt bearing bushings are used on various open knuckle 4X4 trucks with a screw-in, threaded bushing. This bushing is housed in the top portion of the knuckle and provides the tapered seat for the ball joint. First, take the alignment readings on the vehicle and determine the amount of change needed.

Remove any previously installed alignment bushings, and install a zero-degree bushing. Then, recheck the alignment readings. Perform the normal pre-alignment checks and proceed with the installation of the new bushing. Loosen the lower knuckle-to-ball joint nut. Then, remove the upper ball joint nut. If necessary, strike the knuckle to separate the tapers locking the ball joint tapered stud to the knuckle or to the screw-in bushing on the upper ball joint. Use a negative rebound or dead blow ballpeen hammer to separate the taper.

Next, use a four prong tool (Figure 6-5) to unscrew the bushing that is threaded into the upper knuckle assembly. These bushings rust and corrode, and may be difficult to remove. Therefore, it may be necessary to use some valve grinding compound on the four tips of the tool to make the tool bite into the screw-in bushing. This directs all the force in a rotational direction, preventing the tool from rising up and out of the castellations on the head of the bushing. If the bushing cannot be unscrewed with hand pressure, an impact wrench and socket may be used. Place the socket over the hex head of the tool. Operate the impact wrench at low to moderate pressure, and work the tool back and forth. This usually will free up the bushing and allow it to be removed. *Be careful not to round the castellated ears of the bushing or it will be virtually impossible to remove it from the knuckle assembly.*

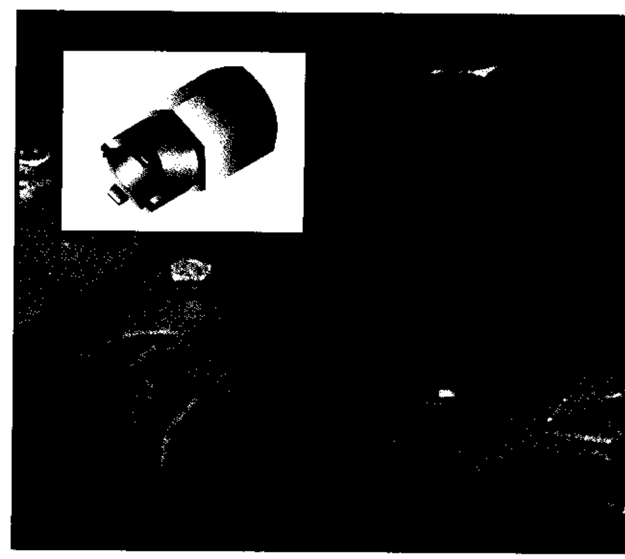

Figure 6-5. Location of Alignment Bushing and Tool to Remove the Bushing

After removing the original bushing, look at the chart and determine the amount of change from the previous alignment reading. After obtaining the correct camber/caster wedge and tilt bearing assembly, clean the top of the knuckle of any rust, scale, or corrosion where the wedge seats. The knuckle cavity into which the threaded bushing is screwed must also be cleaned of any rust, corrosion, or dirt particles that may have fallen into it during disassembly. Use a blow gun to remove any dirt particles.

The lower ball joint nut on this type of knuckle assembly is self-locking. Because it is being reused, apply a few drops of thread locking compound to the threads of the lower ball joint stud and torque it to approximately 40 ft.-lbs. This will ensure that the nut's self-locking properties are retained. Install the new threaded sleeve that comes with the camber/caster wedge bushing into the knuckle assembly. Torque it to 50 ft.-lbs. Then, use a dead blow ballpeen hammer and strike the knuckle assembly around the area where the threaded end bushing is seated.

Next, check the torque again, and re-torque if necessary. It is common to have some additional tightness or bushing movement after it is initially tapped. Repeat this process until the bushing no longer turns. Torque the lower ball joint nut to 80 ft.-lbs. Lubricate the upper assembly with a light coat of silicone grease, and install the wedge, which is part of the camber/caster bushing assembly.

NOTE: *The change will occur in the direction of the thin portion of the wedge. If positive camber and negative caster is needed, place the wedge approximately halfway between the 10 and 11 o'clock positions when looking down on the assembly. Hold the wedge in position, and tighten the upper ball joint nut to its torque value of 100 ft.-lbs. Check to be sure that the wedge is properly seated against the knuckle. If it is not, apply some additional torque to the upper ball joint nut. Make sure that the buttoned end of the wedge is pointed downward and that it is seated correctly in the area of the knuckle that contains the threaded bushing.*

After the unit is seated correctly, and the correct torque value is reached, install the cotter key on the assembly. Check for tight steering by disconnecting the outer tie rod end and swinging the knuckle assembly left and right. If any tightness or binding is felt, use a brass or lead hammer and strike down on the upper ball joint stud. Then, check again for tight steering. If the condition is still present, remove the upper cotter key, loosen the lower ball joint nut, separate the tapers, and re–torque the assembly, feeling for tight steering during the process.

Tight steering must not be present on any vehicle after it is aligned with this or any other type of bushing. If it is, hazardous driving conditions can occur, especially when the vehicle is driven on rough roads. Always check for binding on the steering knuckle after a bushing is installed.

7. CHRYSLER JEEP - ALL DOWNSIZED MODELS (ALIGNMENT BUSHING PROCEDURES ONLY)

Bushings described in this section are available for 1984 to 1989 downsized Jeep Wagoneers, Cherokees, Wranglers, and Scramblers. These vehicles use an alignment bushing which is placed in the lower portion of the knuckle assembly. They also have a unique upper ball joint that has the ability to travel up and down approximately 1-1/2". The bushing must be installed according to the directions, and the service safety notes must be adhered to.

NOTE: *This bushing is for camber only.*

As with other trucks, adjust the side that needs the highest degree of change first. Perform a dry park alignment inspection, along with a road test. Next, take the vehicle's alignment readings to determine the amount of change, and select the correct bushing from the chart.

Install a zero degree bushing, take the reading again, and proceed with the alignment. Raise the vehicle on a suitable lift. Remove the cotter key and nut from the lower ball joint. Strike the steering knuckle with a dead blow ballpeen hammer to separate the tapers of the lower ball joint from the knuckle.

Then use a four prong spanner tool to remove the threaded end bushing. It may be necessary to put some valve grinding compound on the tips of the four prong spanner tool.

Strike the spindle assembly with the dead blow ballpeen hammer, moving it downward.

The upper ball joint may move down when the lower sleeve is removed. To determine if it has, check for a gap between the steering knuckle and the dust boot. Also, look at the stud of the ball joint.

There may be a shiny area that had previously operated on the inside of the dust boot and is now positioned on the outside. Install the set screws into the shoulder head of the new bushing, screwing them in so that they are just flush with the part of the bushing that will contact the steering knuckle.

The slot in the bushing indicates the direction of change. Therefore, if you need positive camber, the slot must point inward. This moves the bottom of the knuckle in and the top of the knuckle out. Reverse the procedure if a negative camber change is required. Make sure that the bushing is fully seated against the knuckle assembly.

Use a suitable spacer, such as the ball joint lower nut, and place it over the grease fitting on the top of the knuckle assembly. Next, use a large C-clamp between the upper ball joint castellated nut and the nut that was placed over the grease fitting. Tighten the C-clamp until a gap of .200-.206 is visible between the shoulder of the new bushing and the lower knuckle assembly. After the correct gap is set, turn the two set screws one turn clockwise in the bushing.

Seat the bushing firmly into the knuckle assembly using a hammer and socket. Torque the replacement hex nut on the lower ball joint to 70 to 85 ft.-lbs. Check the bushing while the nut is tightened to be sure it does not rotate. If the bushing rotates, place a medium, common size screwdriver into the slot. This will help maintain the correct bushing position. Remove the C-clamp on the upper ball joint, and tighten the set screws firmly. Install a new cotter pin, never backing off the hex nut to align the pin. Continue the wheel alignment by adjusting toe and road testing the vehicle.

Whenever ball joint service or knuckle separation is performed on one of these downsized Jeeps, it is possible for the upper ball joint to drop downward. If weight is put on the tires of the vehicle when the ball joint is extended downward, it may receive enough side force to cause it to bind. If this occurs, the ball joint will not return to its original height and may lead to ball joint breakage and/or stud bending.

8. 1989 FORD F-150 4X2 EXCESSIVE TIRE WEAR - CAMBER EXCEEDS SPECIFICATIONS, REPLACE CAMBER ADJUSTER ON UPPER BALL JOINT.

The 1989 Ford F-150 4x2 trucks use Ford's pinch bolt suspension system. The ball joint is contained in the knuckle assembly. The straight–sided stud on the upper ball joint points upward and is held by a bushing that does not have a taper.

The pinch bolt retains the ball joint in the bushing and the bushing in the knuckle. As the pinch bolt is tightened, the split end of the knuckle assembly is driven together.

When an alignment change is needed, perform a dry park check, inspecting all steering and suspension parts. Also, check ride height. Any twin I-beam Ford vehicle is very susceptible to camber changes when ride height is incorrect. If the vehicle carries a heavy load, or has been subjected to heavy service, the springs may be fatigued or weak. In these cases, replace the springs prior to performing an alignment.

Several Ford truck models use different springs on the right and left sides. They may or may not be tagged for use on the right side. The difference in springs is because one axle is longer than the other, so a greater amount of leverage and force is placed on that side of the vehicle.

Check the alignment readings on the vehicle, and determine the amount of change needed. Also, check for a bushing in the vehicle that is already adjusting alignment. In many cases, OE bushings have colored dots or a stamp on the top.

After determining the amount of change needed using a zero- degree bushing, closely follow the directions for installing the replacement bushing. This bushing consists of an eccentric within an eccentric, and it has a series of letters on it. Following the directions, determine the amount of camber and caster change needed, and align these letters with the letters on the outer eccentric.

Then, place the bushing in the knuckle assembly with the specific letter pointing toward the pinch bolt slot (Figure 6-6). Once the bushing is seated and the pinch bolt is re-torqued, the desired alignment is obtained.

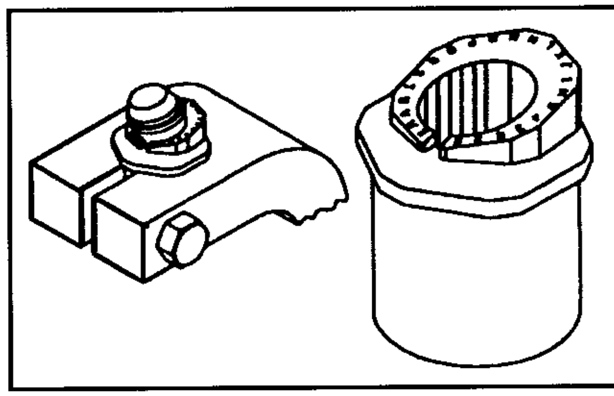

Figure 6-6 Camber Adjuster on Ford Truck

A major advantage of this bushing is that it is re–adjustable at a later time. If an alignment change is needed, the bushing can be turned within its double eccentric configuration to obtain a different degree of camber or caster. If additional changes are needed, the two halves of the bushing can be turned to obtain the zero-degree change reading. This will reestablish a base reference point quite easily.

When installing one of these alignment bushings in a Ford truck, check the area of the pinch bolt prior to removing the original bushing. The ears should be parallel to each other. The pinch bolt should not be so tight that the ends of the ears are touching. If they are, the knuckle may be damaged. When loosening the pinch bolt, if the ears do not return to a parallel position, the knuckle assembly is damaged and may have to be replaced. Do not attempt to re–spread the pinch bolt area by driving in a chisel or a screwdriver to pry the area apart.

When the pinch bolt is removed, it should come out simply by tapping it with a soft-faced hammer after the nut is loosened. If a great degree of force is needed, check to see if it is bent. If it is, carefully inspect the pinch bolt ears to see if they are damaged or cracked.

These and other bushings used on Ford pinch bolt suspension systems are most easily installed in the axle if the ball joint is centered in the area of the opening prior to the bushing being installed.

If the ball joint stud is offset, or tipped to one side or the other, simply move the knuckle assembly, straightening the ball joint stud. Then, hold the hub and rotor assembly so that the ball joint stud is centered in the opening. Place the bushing over the stud and tap it downward, aligning the letter specified on the chart with the slot.

You may find it is easier to put the old bushing on top of the new bushing to tap it down into place. Instead of the old bushing, a large socket over the head of the assembly may also be used. Some alignment bushings use a snap ring. If one is required, it should be installed at this time.

Next, tighten the pinch bolt to 55 to 65 ft.-lbs. Check to see if there is any distortion in the ears of the knuckle assembly. Reinstall the tire and wheel assembly, and install the wheel alignment equipment. Adjust camber/caster on the other side, and then check and adjust the whole as necessary.

Newer model 2WD and 4WD Ford light trucks and vans have SLA suspensions with torsion bars. The 1994 and newer Ford Rangers, and 1997 and newer F-150s, are examples of this suspension design. Alignment adjustments are much like the GM pickups. To adjust camber and caster, cam bolts must be installed in the upper control arm at the frame mounts. Rotating these cam bolts will make both camber and caster adjustments. However, a sliding upper ball joint has been added on the passenger side.

Loosen the two ball joint mounting bolts and slide the upper ball joint forward (toward the front bumper) to decrease caster, and backward (toward the back bumper) to increase caster. This can be done only on the passenger side and may be used for equalizing caster or, possibly, for fine–tuning. However, cam bolts must still be used to make a truly accurate caster adjustment.

9. 1993-1996 CHRYSLER LH BODIES LACK OF CAMBER, REAR LATERAL LINK

The rear lateral links on the Chrysler LH family of automobiles are extremely durable parts and serve a very useful function, but they are not designed to handle high lateral or side forces. They also are not designed to act as a jack pad or a support stand when the vehicle is raised. If the vehicle slides into a curb, is tied down by the lateral links during shipping or towing, or is raised off these lateral links, they most likely will bend. The most obvious sign that they are bent is a radical rear toe change.

If the links are bent, they must be replaced with either OE links or a smart arm. When using a smart arm, there is no need to remove the old OE bushings. Simply remove the entire OE assembly and install the smart arm in its place. The smart arm provides a means for adjusting both toe and camber.

On many of these vehicles, the front link is adjustable for toe, and the rear link is fixed. By replacing the rear link with a smart arm, camber adjustments can be made as well (Figure 6-8).

On Chrysler LH and other Chrysler vehicles that use a similar type of rear suspension system, the rear cradle or cross-member assembly is adjustable. Check it to determine if it is positioned correctly. The cradle is first positioned by aligning the holes in the cross-member with the indexing holes in the body.

Figure 6–9 Installation of Smart Arm on Chrysler LH Vehicle

Next, adjust individual toe and camber. The rear lateral link or smart arm is used for camber adjustment.

The front lateral link adjusts toe. Before performing the camber adjustment, loosen all four jam nuts- two on the front and two on the rear links. After adjusting camber, move to the front link and adjust toe on that side. Some camber change may still exist.

Experienced alignment technicians know to divide the required amount of camber change in half. This will help the job be performed more quickly.

One specification that is not in wheel alignment spec books is performed after adjusting the entire assembly. It is critical that the overall length of the rear (camber) link and the front (toe) link be adjusted.

The length of the rear camber link from the center of the bushing to the center of the bushing should be no more than 391 mm long. Measure from the center of the outer hole to the center of the inner hole on this link. The front lateral link, should be no more than 302 mm long.

The front link has an outward attachment that is slightly different. Determine its center and measure from that point inward to the center of the bolt area.

Failure to check the overall operating length of these links may result in the links being extended excessively. If insufficient adjuster threads remain in the links, the link may separate or break at the adjuster point.

NOTES: ____________________

Section Six Mini Quiz

1. Ford Escort/Lynx and Tempo/Topaz inner tie rod socket assemblies wear at a much faster rate than other FWD vehicles because of:
   a. The alignment angles
   b. Non-greaseable inner socket assemblies
   c. The position of the inner tie rods in relation to the lower control arm
   d. A poorly designed inner tie rod socket assembly

2. Before performing a camber adjustment on a '94 Chrysler LH:
   a. Loosen only front 2 jam nuts
   b. Loosen all 4 jam nuts
   c. Loosen only rear jam nuts
   d. Don't loosen any jam nuts

3. One major cause of Ford's E Series van ball joint failure is:
   a. Contaminants getting past the dust boot
   b. Lack of lubrication
   c. High load forces due to alignment angles
   d. Synthetic bearing designs

4. When using an adjustable camber/caster bushing on many Ford trucks, it is faster and more accurate to first __________, and then take a new camber/caster reading
   a. Install new ball joints
   b. Clean the steering knuckle area
   c. Install a zero bushing
   d. Adjust the front toe

ANSWERS

1. c 2. b 3. a 4. c

CHAPTER 6 SHOP EXERCISES

Move to the shop area and perform the following exercise. You will need access to a GM rear -wheel drive minivan such as the Chevy Astro or GMC Safari.

1. Inspect the idler arms for serviceability and for dynamic toe change.

2. Set up and take alignment readings.

3. Determine what corrections need to be made.

4. Write down the adjustment devices needed to achieve correct alignment angles.

NOTES:

NOTES:

NOTES: