G1

ASE Study Guide

AUTO MAINTENANCE AND LIGHT REPAIR

AUTO-VIDEO.com

ASE G1
AUTOMOTIVE MAINTENANCE AND LIGHT REPAIR

Disclaimer of Warranties:

This manual contains test procedures and test information obtained by an ASE Master Technician with known good test equipment on real vehicles, your tests may vary due to your test equipment or procedures. No warranty can be made from the ideas presented due to personal testing procedures, nor does the author or anyone connected with him assume any responsibilities or liabilities. The use of this manual is conditional on the acceptance of this disclaimer. If the terms of this disclaimer are not acceptable, please return this manual.

ASE G1
AUTOMOTIVE MAINTENANCE AND LIGHT REPAIR
Test Prep

Contents

2013 ASE G1 Task List

Content Area	Questions In Test	Percent of Test
A. Engine Systems	9	16%
B. Automatic Transmission	4	8%
C. Manual Transmissions & Axles	6	10%
D. Suspension & Steering	13	24%
E. Brakes	11	20%
F. Electrical	8	15%
G. HVAC	4	7%
Total	55	100%

A. Engine Systems (9 questions)

- Verify driver's complaint and/or road test vehicle; determine necessary action. Utilize service manuals, technical service bulletins (TSBs), and product information.
- Inspect engine assembly for fuel, oil, coolant, and other leaks; determine necessary action.
- Check for abnormal engine noises.
- Inspect and replace pans and covers.
- Change engine oil and filter; reset oil life monitor.
- Inspect and test radiator, heater core, pressure cap, and coolant recovery system; determine needed repairs; perform cooling system pressure and dye tests.
- Inspect, replace, and adjust drive belt(s), tensioner(s), and pulleys.
- Inspect and replace engine cooling system and heater system hoses, pipes, and fittings.
- Remove and replace engine thermostat and coolant bypass.
- Inspect and test coolant; drain, flush, and refill cooling system with recommended coolant; bleed air as required.
- Inspect and replace accessory belt driven water pumps.
- Confirm fan operation (both electrical and mechanical); inspect fan clutch, fan shroud, and air dams.
- Verify operation of engine-related warning indicators.
- Perform air induction/ throttle body service.
- Inspect, service, or replace air filter(s), filter housing(s), and air intake system components.
- Inspect and replace crankcase ventilation system components.
- Inspect exhaust system for leaks; check hangers, brackets, and heat shields; determine needed repairs.
- Retrieve and record diagnostic trouble codes (DTCs).
- Remove and replace spark plugs; inspect secondary ignition components for wear or damage.
- Inspect fuel tank, filler neck, fuel cap, lines, fittings, and hoses; replace external fuel filter.
- Inspect canister, lines/hoses, mechanical and electrical components of the evaporative emissions control system (EVAP).
- Check and refill diesel exhaust fluid (DEF).

B. Automatic Transmission/Transaxle (4 questions)

- Road test the vehicle to normal operation; retrieve and record diagnostic trouble codes (DTCs).
- Determine fluid type, level, and condition.
- Inspect transmission for leaks; replace external seals and gaskets.
- Inspect and replace CV boots, axles, drive shafts, U-joints, drive axle joints, and seals.
- Visually inspect condition of transmission cooling system, lines, and fittings.
- Inspect and replace power train mounts.
- Replace fluid and filter(s).

C. Manual Drive Train and Axles (6 questions)

- Inspect, adjust, replace, and bleed external hydraulic clutch slave/release cylinder, master cylinder, lines, and hoses; clean and flush hydraulic system; refill with proper fluid.
- Inspect and replace power train mounts.
- Inspect, adjust, and replace transmission/transaxle external shifter assembly, shift linkages, brackets, bushings/grommets, pivots, and levers.
- Inspect and replace external seals.
- Check fluid level; refill with fluid.

Drive Shaft, Half-Shaft, and Universal Joints/Constant Velocity (CV) Joint (Front and Rear Wheel Drive)

- Road test the vehicle to verify drive train noises and vibration.
- Inspect, service, and replace shafts, yokes, boots, universal/CV joints; verify proper phasing.
- Inspect, service, and replace drive shaft center support bearings.
- Inspect, service, and replace wheel bearings, seals, and hubs, excluding press-type bearings.

Rear Wheel Drive Axle Inspection

- Identify fluid leakage problems.
- Inspect, drain, and refill with lubricant.
- Inspect and replace rear axle shaft wheel studs.
- Inspect axle housing and vent; inspect rear axle mountings.

Four Wheel Drive

- Inspect, adjust, and repair transfer case manual shifting mechanisms, bushings, mounts, levers, and brackets.
- Check transfer case fluid level and inspect condition; drain and refill with fluid.
- Inspect, service, and replace front drive/propeller shaft and universal/CV joints.
- Inspect front drive axle universal/CV joints and drive/half shafts, axle seals, and vents.
- Inspect front wheel bearings, seals, and hubs.
- Inspect transfer case, front differential, and axle seals and vents.
- Inspect tires for correct size for vehicle application; check for wear.
- Retrieve and record diagnostic trouble codes (DTCs).

D. Suspension and Steering (13 questions)

- Disarm airbag (SRS) system.
- Check power steering fluid level; determine fluid type and adjust fluid level; identify system type (electric or hydraulic).
- Inspect, adjust, and replace power steering pump belt(s), tensioners and pulleys; verify pulley alignment.
- Identify power steering pump noises, vibration, and fluid leakage.
- Remove and replace power steering pump; inspect pump mounting and attaching brackets; remove and replace power steering pump pulley; transfer related components.
- Inspect and replace power steering hoses, fittings, O-rings, coolers, and filters.
- Inspect and replace rack and pinion steering gear bellows/boots.
- Flush, fill, and bleed power steering system.

Steering Linkage

- Inspect, adjust (where applicable), and replace pitman arm, center link (relay rod/drag link/intermediate rod), idler arm(s) and mountings.
- Inspect, replace, and adjust tie rods, tie rod sleeves/adjusters, clamps, and tie rod ends (sockets/bushings).
- Inspect and replace steering linkage damper(s).

Front Suspension

- Identify front suspension noises, handling, ride height, and ride quality concerns; disable air suspension system.
- Inspect upper and lower control arms, bushings, and shafts.
- Inspect and replace rebound and jounce bumpers.
- Inspect track bar, strut rods/radius arms, and related mounts and bushings.
- Inspect upper and lower ball joints (with or without wear indicators).
- Inspect non-independent front axle assembly for damage and misalignment.
- Inspect front steering knuckle/spindle assemblies and steering arms.
- Inspect front suspension system coil springs and spring insulators (silencers).
- Inspect front suspension system leaf spring(s), leaf spring insulators (silencers), shackles, brackets, bushings, center pins/bolts, and mounts.
- Inspect front suspension system torsion bars and mounts.
- Inspect and replace front stabilizer bar (sway bar) bushings, brackets, and links.
- Inspect front strut cartridge or assembly.
- Inspect front strut bearing and mount.
- Identify noise and service front wheel bearings/hub assemblies.

Rear Suspension

- Identify rear suspension system noises, handling, and ride height concerns; disable air suspension system.
- Inspect rear suspension system coil springs and spring insulators (silencers).
- Inspect rear suspension system lateral links/arms (track bars), and control (trailing) arms.
- Inspect and replace rear stabilizer bars (sway bars), bushings, and links.
- Inspect rear suspension leaf spring(s), leaf spring insulators (silencers), shackles, brackets, bushings, center pins/bolts, and mounts.
- Inspect and replace rear rebound and jounce bumpers.
- Inspect rear strut cartridge or assembly, and upper mount assembly.
- Inspect non-independent rear axle assembly for damage and misalignment.
- Inspect rear ball joints.
- Inspect and replace rear tie rod/toe linkages.
- Inspect rear knuckle/spindle assembly.
- Inspect and replace shock absorbers, mounts, and bushings.
- Identify noise and service rear wheel bearings/hub assemblies.

Wheel Alignment

- Identify alignment-related symptoms such as vehicle wander, drift, and pull.
- Perform pre-alignment inspection; prepare vehicle for alignment, and perform initial wheel alignment measurements.
- Measure front and rear wheel camber; adjust as needed.
- Measure caster; adjust as needed.
- Measure front wheel toe; adjust as needed.
- Center the steering wheel using mechanical methods.
- Measure rear wheel toe; adjust as needed.
- Measure thrust angle.
- Calibrate steering angle sensor.

Wheel and Tires

- Identify tire wear patterns.
- Inspect tire condition, tread depth, size, and application (load and speed ratings).
- Check and adjust tire air pressure. Utilize vehicle tire placard and information.
- Diagnose wheel/tire vibration, shimmy, and noise concerns; determine needed repairs.
- Rotate tires/wheels and torque fasteners/wheel locks.
- Dismount and mount tire on wheel.
- Balance wheel and tire assembly.
- Identify and test tire pressure monitoring systems (TPMS) (indirect and direct) for operation. Verify instrument panel lamps operation; conduct relearn procedure.

Task 56 – Repair tire according to tire manufacturers' standards.

E. Brakes (11 questions)

- Check for poor stopping, pulling, dragging, noises, high or low pedal, and hard or spongy pedal.
- Check the master cylinder fluid level and condition; inspect for external fluid leakage.
- Inspect flexible brake hoses, brake lines, valves, and fittings for routing, leaks, dents, kinks, rust, cracks, or wear; inspect for loose fittings and supports; determine needed repairs.
- Verify operation of brake warning light and ABS warning light; inspect brake system wiring damage and routing.
- Test parking brake indicator light, switch, and wiring.
- Bleed and/or flush hydraulic system.
- Select, handle, store, and install proper brake fluids.

Drum Brakes

- Remove, clean, inspect, and measure brake drums; follow manufacturers' recommendations in determining need to machine or replace.
- Machine drums according to manufacturers' procedures and specifications.
- Using proper safety procedures, remove, clean, and inspect brake shoes/linings, springs, pins, self-adjusters, levers, clips, brake backing (support) plates, and other related brake hardware; determine needed repairs.
- Lubricate brake shoe support pads on backing (support) plate, self-adjuster mechanisms, and other brake hardware.
- Inspect wheel cylinder(s) for leakage, operation, and mounting; remove and replace wheel cylinder(s).
- Install brake shoes and related hardware.
- Adjust brake shoes and parking brake.
- Check parking brake system operation; inspect cables and components for wear, rust, and corrosion; clean or replace components as necessary; lubricate and adjust assembly.
- Reinstall wheel, torque lug nuts, and make final brake checks and adjustments.

Disc Brakes

- Retract integral parking brake caliper piston(s) according to manufacturers' recommendations.
- Remove caliper assembly from mountings; inspect for leaks and damage to caliper housing.
- Clean and inspect caliper mountings and slides/pins for wear and damage.
- Remove, clean, and inspect pads and hardware; determine needed repairs, adjustments, and replacements.
- Clean caliper assembly; inspect external parts for wear, rust, scoring, and damage; replace any damaged or worn parts; determine the need to repair or replace caliper assembly.
- Clean, inspect, and measure rotors with a dial indicator and a micrometer; determine the need to index, machine, or replace the rotor.
- Remove and replace rotors.
- Machine rotors, using on-car or off-car method.
- Install pads, calipers, and related attaching hardware; lubricate components; bleed system.
- Adjust calipers with integral parking brakes.
- Fill master cylinder with recommended fluid; reset system; inspect caliper for leaks.
- Reinstall wheel, torque lug nuts, and make final brake checks and adjustments.
- Road test vehicle and burnish/break-in pads according to manufacturers' recommendations.

Power Assist Units

- Test brake pedal free travel with and without engine running to check power booster operation.
- Check vacuum supply (manifold or auxiliary pump) to vacuum-type power booster.
- Inspect the vacuum-type power booster unit for operation, and vacuum leaks; inspect the check valve for proper operation.
- Identify operation of electric-hydraulic assist system; check system for leaks and operation.
- Identify operation of hydro-boost assist system; check system for leaks and operation.

F. Electrical (8 questions)

- Disarm/re-enable air bag; verify lamp operation.
- Check voltages, grounds, and voltage drops in electrical circuits; interpret readings.
- Check current flow in electrical circuits and components; interpret readings.
- Check continuity and resistances in electrical circuits and components; interpret readings.
- Perform battery tests (load and capacitance); determine needed service.
- Maintain or restore electronic memory functions.
- Inspect, clean, fill, or replace battery.
- Perform slow/fast battery charge in accordance with manufacturers' recommendations.
- Inspect, clean, and repair or replace battery cables, connectors, clamps, and hold-downs.

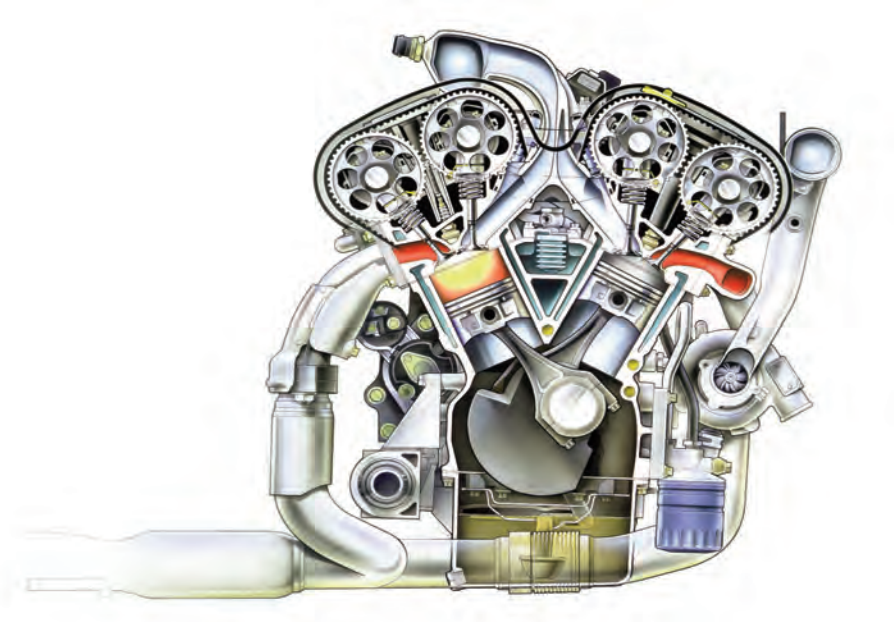
- Jumpstart a vehicle with a booster battery or auxiliary power supply.
- Perform starter current draw test; interpret readings.
- Inspect switches, connectors, and wires of starter control circuits.
- Remove and replace starter.
- Perform charging system output test and identify undercharge, no charge, or overcharge condition.
- Inspect, adjust, and replace generator (alternator) drive belts, pulleys, and tensioners.
- Remove, inspect, and replace generator (alternator).
- Inspect, replace, and aim headlights/bulbs and auxiliary lights (fog lights/driving lights).
- Inspect interior and exterior lamps and sockets; repair as needed.
- Inspect lenses; determine needed repairs.
- Verify instrument gauges, warning/indicator light operation; reset maintenance indicators.
- Verify horn operation; determine needed repairs.
- Verify wiper and washer operation; replace wiper motor, blades, and washer pump as needed.

G. Heating, Ventilation, and Air Conditioning (4 questions)

- Verify HVAC operation (vent temperature, blower and condenser fan, compressor engagement, blend and mode door(s) operation).
- Visually check A/C components for signs of leaks.
- Inspect A/C condenser for restricted air flow.
- Inspect and replace cabin air filter.
- Check drive belt for wear and tension; adjust or replace as needed.
- Inspect and clean evaporator drains.

ASE G1

Engine Systems



It is important to follow instructions from both the vehicle and the test equipment manufacturers when performing engine tests. Some tests require the ignition to be disabled while the starter motor cranks the engine. Others may require bypassing the fuel pump relay, idle speed controller, or some other electrical or electronic component. The proper test equipment, and the knowledge to use it correctly, is essential.

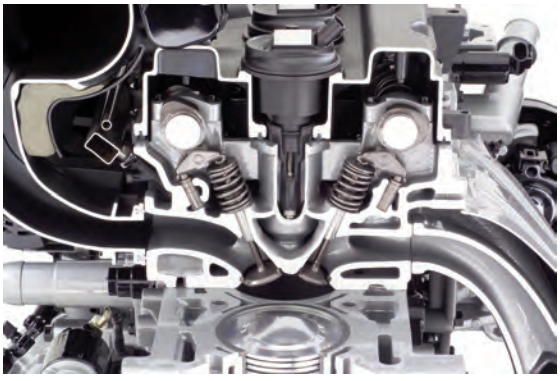
ENGINE NOISES

Engine noises can be divided into two general categories: those that originate in the top end of the engine, and those that originate in the bottom end of the engine. Begin engine noise diagnosis by determining where in the engine the noise is coming from.

Bottom end, or crankcase, noises occur at crankshaft speed, so they tend to produce a high-frequency knock or rumble.

Top end, or valve train, noises occur at a lower frequency because these parts operate at one-half crankshaft speed. A stethoscope is a handy tool for isolating noises. You can also use a timing light to determine whether a noise is from the top or bottom end of the engine. Connect the timing light and listen . If the engine noise cycles in time with the flashing light, the sound is coming from the bottom end. Sounds that are audible with every other flash of the timing light originate in the top end of the engine.

TOP-END NOISES

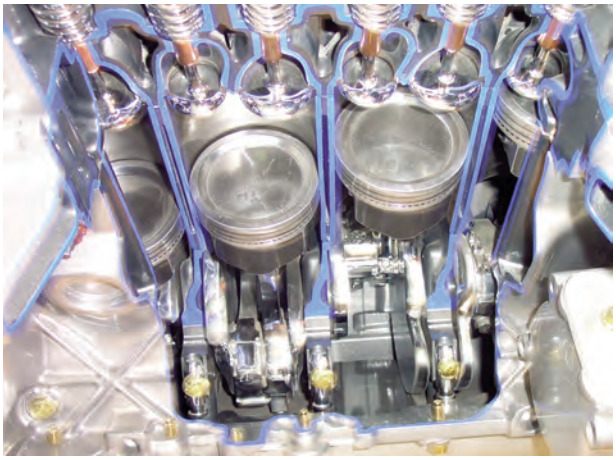


The top end of a healthy engine produces a high pitched, whirring noise with a very rapid and much fainter sewing machine like clicking coming from the valves. The more valves the engine has and the higher the idle speed, the more the individual clicks will blend into a consistent drone. **Any deviation is abnormal and indicates a problem. Listen for:**

- An irregular clacking or knocking noise caused by excessive camshaft endplay
- An irregular slapping or thumping at the front of the engine caused by a loose timing belt. A tight belt makes a whirring, whining, hum that rises and falls in pitch with RPM

•A single, clear clack whenever a particular valve opens can be a collapsed lifter or a broken valve spring.
•A loud, cycling, valve rattle that you can hear over the normal valve noise can indicate either worn valve guides or rocker arm pivots Low pressure or restricted oil flow will produce an excessively loud, rhythmic clatter

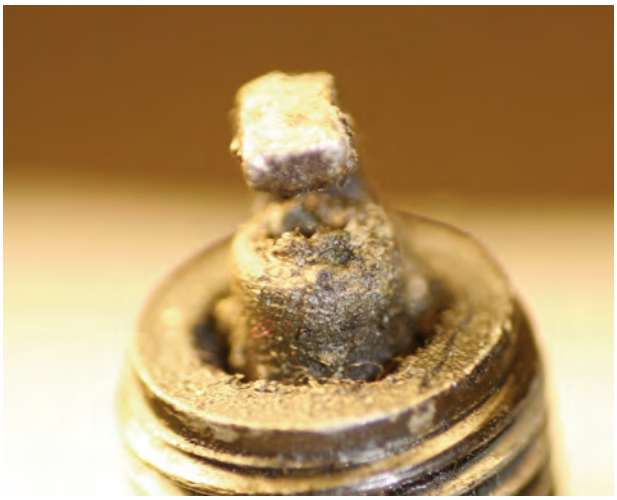
BOTTOM-END NOISES



Healthy engines produce an evenly pitched, rapid, whirring sound and nothing else. Knocking or thumping noises are signs that something is wrong. In general, bottom-end noise can be caused and indicated by:

•An irregular knock at idle that can be made louder or fainter by playing with the clutch pedal indicates too much crankshaft endplay
•A sharp clattering knock that may be continuous at idle or only appear when the throttle closes suddenly, can indicate a bad connecting rod bearing. The noise will diminish if the spark plug for the offending cylinder is grounded
•A hollow metallic clatter that is loudest when the engine is cold may be piston slap caused by too much piston to cylinder wall clearance. Grounding the spark plug of the affected cylinder will often make piston slap louder because it eliminates the cushioning of the extra gas pressure pushing on the piston
•A sharp knocking that stands out most at idle can indicate a wrist pin that is loose in its bore. Grounding the spark plug of the affected cylinder makes the knock audible at top dead center as well as bottom dead center. Retarding the spark decreases wrist pin noise
•A rapid, steady dull pounding that increases with load is typical of worn main bearings

SPARK KNOCK



Pre-ignition can be caused be carbon deposits in the combustion chamber.

Spark knock, which is caused by uncontrolled combustion, sounds like a metallic pinging noise. Spark knock may be heard under a heavy load or on acceleration. Detonation occurs when combustion of the air/fuel mixture in the cylinder starts off correctly in response to ignition by the spark plug, but one or more pockets of the air/fuel mixture explode outside the envelope of the normal combustion. **The collision of the two flame causes a pinging noise. This can be caused by:**

•Fuel with two low of octane rating
•Ignition timing that is to far advanced
•High engine operating temperature
•Excessive carbon build up in the combustion chamber

Pre-ignition and knock can damage the spark plug.

Pre-ignition occurs when the air/fuel mixture prematurely ignites before the spark plug fires. Then the spark plug ignites the remaining mixture at the normal time. When the two portions of burning mixture meet each other, there is a sudden abnormal rise in cylinder pressure causing engine vibration and a pinging noise.

This can be caused by:

- •Hot spots in the combustion chamber
- •Incorrect heat range spark plug
- •Carbon deposits in the combustion chamber

UNUSUAL EXHAUST COLOR AND ODOR

Although a healthy catalytic converter can do a good job of cleaning up the exhaust, you can tell something about the internal engine condition by checking for unusual smoke or smells:

•Black exhaust smoke. This is caused by a rich air/fuel mixture and is often accompanied by the "rotten egg" smell of an overworked catalytic converter

•Blue exhaust smoke indicates excessive oil burning, which gives off a pungent odor

•Cloudy white exhaust is often the result of engine coolant leaking into the combustion chamber. Burning coolant also produces a distinctive chemical odor. Check the temperature gauge for overheating

Oil from the crankcase and connecting rod lubrication holes can be sucked into the combustion chamber if the piston rings are worn. Also, coolant from a leaking gasket can be ingested.

Keep in mind that oil vapor odors are not always the result of an internal engine problem. A clogged or malfunctioning positive crankcase ventilation (PCV) system can not only produce a burning oil smell, but can also cause excessive crankcase vapor and increase oil consumption. Always check all external sources before you condemn the engine.

Intake Manifold Vacuum Tests

Manifold vacuum tests are performed by connecting a vacuum gauge to the intake manifold downstream of the throttle plates. The gauge records the difference between atmospheric pressure and manifold pressure. Vacuum gauge readings can pinpoint manifold and vacuum line leaks, valve and valve guide problems, incorrect ignition and valve timing, exhaust restrictions, and poor combustion chamber sealing.

CYLINDER COMPRESSION TESTS

The compression test reveals how well each cylinder is sealed by the piston rings, valves, cylinder head gasket, and the spark plug. Compression pressure is measured in pounds per square inch (psi), kilopascal (kPa), or bars. The following quantities are equal to each other: 14.5 psi, 100 kPa, and 1 bar. A compression gauge measures the amount of air pressure that a cylinder is capable of producing.

In general, a compression test is performed with the engine at normal operating temperature, all spark plugs removed, the ignition disabled, the battery fully charged, and the throttle held in wide-open position. Interpret compression gauge readings as follows:

- •Compression is normal when the gauge shows a steady rise to the specified value with each compression stroke
- •If the compression is low on the first stroke and builds up gradually with each succeeding stroke, but not to specifications, the piston rings or cylinder walls are probably worn
- •A low compression reading on the first stroke that builds up only slightly on the following strokes indicates sticking or burned valves
- •Two adjacent cylinders with equally low compression indicates a head gasket leak between them
- •A higher than normal compression reading usually means excessive carbon deposits have formed on the piston top or in the combustion chamber. Fluid, such as oil, coolant, or fuel in a cylinder also produces high compression pressure

CYLINDER LEAKAGE TEST

A cylinder leakage tester, or leak-down tester, gives more detailed results than a compression test. **Used as a follow-up to compression testing, a leakage test can reveal:**

- •The exact location of a compression leak
- •How serious the leak is in terms of a percentage of total cylinder compression

The tester forces air into the combustion chamber through the spark plug hole. A gauge installed in the air line indicates how much pressure leaks out of the combustion chamber. The gauge scale is graduated from 0 to 100 percent. Calibrate the leakage tester according to

the equipment instructions before testing. To test a cylinder, the piston must be at TDC of the compression stroke so that both valves are closed. Install the test adapter in the spark plug opening, connect the air hose, and pressurize the cylinder. **Note the percentage reading on the scale and interpret as follows:**

0-10 percent Good
10-20 percent Fair
20-30 percent Poor
30-100 percent Failed!

For cylinders with more than 20-percent leakage, pinpoint the cause of the leaks as follows:

- Air escaping through the air intake indicates a leaking intake valve
- Air escaping through the exhaust indicates a leaking exhaust valve
- Air escaping through the crankcase and PCV system indicates worn or damaged piston rings, worn cylinder walls, or a worn or cracked piston
- Air bubbles in the coolant indicates a leaking head gasket or a crack in the engine block or cylinder head casting
- High readings on two adjacent cylinders indicates head gasket leakage or a casting crack between cylinders

ENGINE OIL & FILTERS

Auto manufacturers, in general, are continuing to reduce vehicle maintenance requirements by extending oil change intervals. But extended oil change intervals are a mixed blessing. On the upside, extended oil change intervals are conserving precious oil and reducing carbon emissions. On the downside, many vehicle owners are forgetting to check their engine's oil level between oil changes.

The most common result is an engine ruined by excess accumulations of varnish and sludge due to using motor oils that are not approved by the engine manufacturer. In less common instances, the engine fails due to low engine oil levels and a subsequent lack of lubrication. Whatever the case, extended oil change intervals are changing how we should recommend and perform scheduled vehicle maintenances.

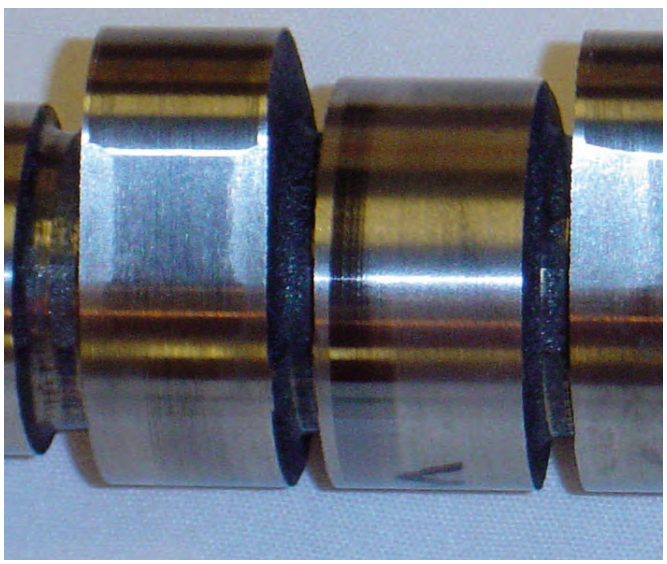
SENSING LEVELS

The oil level sensor obviously warns the driver when the engine oil level is critically low. Although many auto manufacturers install oil level warning systems as standard equipment, many vehicles in the current fleet aren't so equipped. In other instances, the oil level sensor might not function correctly.

Consequently, it's always important for the technician to check the engine's oil level whenever the vehicle is being serviced. If the oil appears very dirty or the oil change interval has nearly expired, an oil change and scheduled service recommendation should be made.

If the oil appears clean, but the level is low, it's important to know the vehicle owner's brand preference for engine oil before adding oil. Most won't know or care, but some owners might prefer using a specific brand of oil. In any case, if the engine oil level is low, always inspect the engine and oil filter for leakage or other signs of oil consumption and make the appropriate service recommendations.

MONITORING OIL LIFE



Oil that has gone past the recommended replacement interval can damage engine surfaces like this camshaft.

Modern oil life monitors use data from the Powertrain Control Module (PCM), such as calculated engine load, trip length, average operating temperature, etc., to measure oil life. It's not unusual for oil life monitors to extend oil change intervals to 10,000 or more miles.

The primary issue in dealing with oil life monitors is to ensure that the replacement engine oil meets the manufacturer's extended mileage requirements. The "generic" 5w-30 oil might, for example, expire at 6,000 miles because neither the base oil nor the additive package meets original equipment (OE) requirements, which results in disastrous consequences.

In a few situations, the oil life monitor might not accurately indicate expected oil life. The evidence might be a varnish or sludge accumulation on internal engine parts. Valve train sludge, for example, can often be observed when the engine oil cap is removed for service. Similarly, rust, varnish and sludge can form on the upper portions of the oil dipstick. If varnishing or sludging is apparent, a shorter oil change interval should be recommended.

CAUSES OF SLUDGING

Neglected oil change intervals can ruin the best engine oils. As engine oil accumulates miles, it becomes contaminated with carbon, water and various acids, all of which are a by-product of internal combustion and which will form a film of black, gooey sludge on the interior parts of the engine.

Cold-engine operation accelerates the formation of sludge because the oil temperatures aren't sufficient to evaporate accumulated moisture. Oil sludging is also aggravated by short-trip, cold-weather driving and by thermostats that are stuck open.

When the engine is operated at high speeds and temperatures, sludge often dislodges and clogs the oil filter. Since most oil filters incorporate bypass valves that allow the lubricating oil to flow around a clogged filter media, the dirty oil can pass directly into the engine and clog small-diameter oil galleries.

In any case, heavily sludged oil will eventually clog the engine's oil pump pickup screen, oil filter and oil galleries. The initial symptoms of oil starvation are engines that become noisy during cold start-up and oil pressure gauges that rise very slowly. Broken timing belts are also symptomatic of oil starvation on overhead camshafts. Because the damage usually includes the crankshaft and piston assemblies, don't be too eager to quote a cylinder head replacement as the cure for a seized camshaft.

All too often, the detergents contained in fresh oil will accelerate the clogging of oil pump screens and oil filters by loosening accumulated sludge. Volumes of engine sludge and dirty engine oil also easily clog today's compact oil filters. If the oil filter bypass valve opens during cold starts, more sludge and dirt will pass into the engine bearings and reciprocating parts. In addition, engine life is drastically shortened when operated at extreme loads and temperatures with badly degraded engine oil.

The problem with any heavily sludged engine is that internal repairs tend to dislodge even more sludge into the oil stream. Because attempting to clean an engine in-chassis is both expensive and risky, you can best address the situation by replacing or rebuilding the engine.

OIL & INTERFERENCE WITH VVT

Most modern engines are very susceptible to lubrication problems because they are equipped with variable valve timing (VVT). A pulse-modulated control valve that meters oil pressure to a hydraulic piston or vane-type camshaft timing phaser controls the amount of advance or retard. A separate valve-timing sensor is used to monitor VVT position.

In addition, you're doing a disservice to your customers if you're exclusively selling low-cost generic engine oils and budget-priced oil filters to meet price-sensitive competition.

OE-specification oils and filters often become the cheaper (and wiser) choice when weighed against a costly engine replacement. If you do the math, it will become clear to you and your customer that using the correct engine oil and filter is the less expensive and far more prudent choice.

OIL FILTERS

The most often replaced filter is the oil filter. It usually gets changed every 3,000 to 7,500 miles on most vehicles (except in Europe where they use different motor oils and typically go for a once-a-year oil change). On many late-model vehicles, oil change intervals have been extended from the traditional 3,000 miles or six months, to 5,000 to 7,500 miles or more.

On vehicles that employ a maintenance reminder light to signal when an oil change is needed, the reminder light may not come on for up to 15,000 miles or more, depending on all the operating variables the software considers

when making its estimate. On some vehicles, additional input from an electrical sensor in the oil pan may help detect oil that is breaking down or is heavily contaminated with moisture.

SPIN-ON OIL FILTERS

In the mid-1950s, the spin-on oil filter design was introduced: a self-contained housing and element assembly which was to be unscrewed from its mount, discarded, and replaced with a new one. Clean the mounting base sealing surface.

Installation:

1. Remove any old gaskets that may be stuck to the base.

2. Apply a thin film of clean engine oil to the new filter gasket. This allows the gasket to turn during tightening.

3. Spin on the new filter until the gasket contacts the mounting base. This does not mean “hand-tighten”. For example, “hand-tighten” to technician “A” might be 1 turn beyond gasket contact, while “hand-tighten” to installer “B” might be 1/2 turn beyond gasket contact.

4. Tighten the filter the required number of turns beyond gasket contact. For most spin-on filters, additional 3/4 to full turn beyond gasket contact to the base to seat the gasket. NOTE: Never use a dented filter.

CARTRIDGE OIL FILTERS

Cartridge filters are becoming increasingly popular in new vehicle applications. Although they are relatively easy to change and dispose of, extra care must be taken when installing a replacement filter. Failure to follow proper Installation procedure may result in oil leakage and engine damage.

Use the right tool to remove the filter housing. Using the wrong tools can damage the cap and housing which may be made of plastic. Always check for how the o-rings are installed and make sure no pieces of the o-rings fall into the housing.

Often the o-ring kit will include a washer seal for the oil pan drain plug. Do not re-use any of the old o-ring(s) as they are not designed for multiple service intervals. Re-use of the old o-ring(s) may lead to oil leakage and possible engine damage.

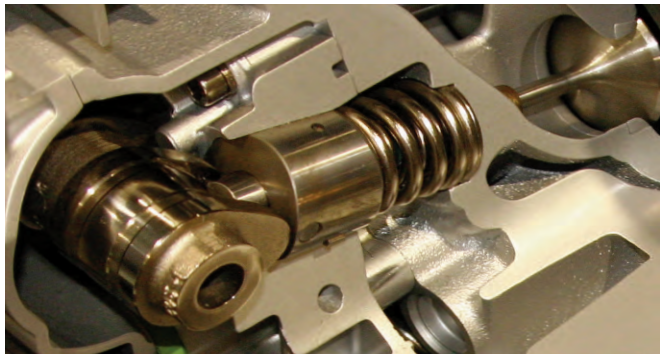
Makes sure the o-rings are properly seated. Reassemble the filter and housing by hand until you feel the o-ring compress. Using an appropriate tool, tighten the housing cap as indicated on the cap or in the owner’s manual. Do not over-tighten the cap. This could force the o-rings out of their grooves.

VALVES

Ideally, an engine should operate with near zero valve lash, or clearance. Under these conditions, valve movement follows the profile of the camshaft lobe exactly to provide efficient operation. Over the life of an engine, valve clearance tends to change as a result of wear on the valve face, valve seat, pushrod, and rocker arm. For many years engines were designed with provisions to make periodic adjustments to correct for this wear.

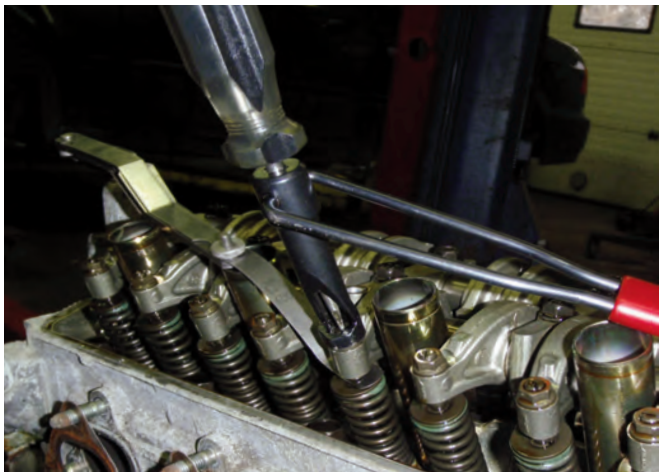
All late-model engines have no scheduled need for and therefore no provision for making a valve clearance adjustment. These engines require precise machining during overhaul to ensure that the proper clearances are met. If valve clearance problems surface diagnosis will reveal a failed component. Follow the Service Manual procedures for repair or replacement of the component or components involved.

VALVE LIFTER DESIGNS



With hydraulic lifters, once engine oil pressure is established, the lifters automatically take up all slack in the valve train to maintain zero clearance. Hydraulic lifters also compensate for metal expansion as the engine

warms up. Hydraulic valve lifters do not require routine adjustment.



Mechanical lifters must be set with a precise amount of clearance so that the valves operate with close to zero lash once the engine is at normal operating temperature. Mechanical lifters must be adjusted periodically to compensate for wear in the valve train. Maintaining the correct clearance is important.

Too much clearance prevents the camshaft from opening the valves fully. This shortens effective camshaft duration causing valves to open late and close early, which reduces engine efficiency and performance. Continued operation stresses valve train parts and can lead to premature failure.

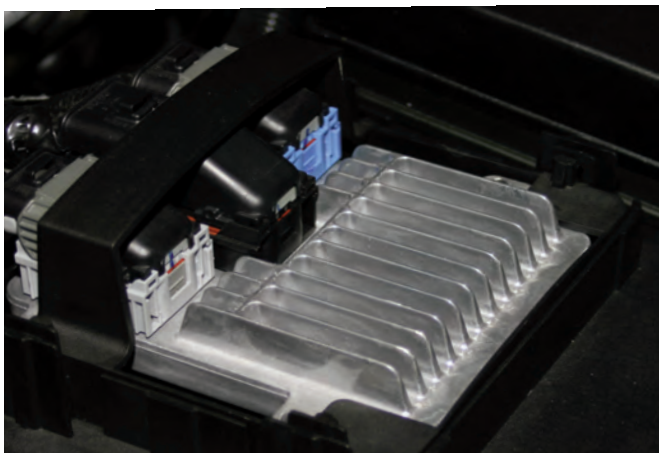
Insufficient clearance causes the valves to open too far. Effective duration is increased so the valves open early and close late. Once the engine warms to operating temperature, the valves might not be able to close completely.

VALVE CLEARANCE

Typical valve clearance specifications range from 0.004 to 0.025 inch (0.10 to 0.64 mm) for intake valves and 0.004 to 0.030 inch (0.10 to 0.76 mm) for exhaust valves. Service Manuals may list valve clearances either as hot or cold specifications, or both. If the valves are to be set cold, check the coolant temperature. It should be about the same as the air temperature, and the valve cover should feel cool to the touch. To use a hot specification, the engine should be warmed to its normal operating temperature. **Common adjustment mechanisms include:**

- An adjustment locknut holding the rocker arm to the rocker stud
- Replaceable adjustment shims located between the camshaft lobes and cam followers
- Selective length pushrods

COMPUTER CONTROL PRINCIPLES



The operation of any computer system is divided into four basic functions: input, processing, storage, and output. A computer operates by converting input voltage signals to other voltage signals that represent combinations of numbers. The numbers represent information about quantities measured by sensors. These include temperature, speed, distance, position, pressure, and other factors of engine and vehicle operation.

The computer processes the voltage signals by computing the numbers they represent and then delivering output commands to actuators that control engine and vehicle operation. Additionally, a computer stores processed information and its own operating instructions in the form of other numerical information. There are four basic functions of any computer system.

1. **Input—**Input information provided as voltage signals from system sensors is received by the computer, or powertrain control module (PCM).
2. **Processing—**The PCM processes, or computes, the input voltage signals into combinations of binary numbers (1 and 0), or bits. It then compares the processed information to instructions and other data in its program to make logical decisions and send output commands to other devices in the system.
3. **Storage—**Every computer has an electronic memory to store its operating instructions, or program. Some computer systems also require that some input signals be stored for later reference. Many systems can "remember" previous operating conditions and adapt their output commands to "learned" characteristics of vehicle operation. All systems have some kind of information storage capability, or memory.
4. **Output—**After receiving and processing input information, the computer sends output commands to other devices to control engine operation. The output devices are actuators such as solenoids and relays. The computer may also send output information to display devices such as electronic instrument panels.

COMPUTER CONTROLLED ENGINE FUNCTIONS

The output commands of an engine control system regulate most, or all, of the following operations:

- •Fuel metering, fuel injection or a carburetor
- •Ignition timing advance
- •Idle speed
- •Electric fuel pump control
- •Exhaust gas recirculation (EGR)
- •Secondary air injection (AIR)
- •Evaporative emissions vapor (EVAP) canister purging
- •Intake mixture preheating, or early fuel evaporation (EFE)
- •Automatic transmission torque converter clutch (TCC) lockup, and transmission shifting
- •Air conditioning (A/C) compressor clutch engagement
- •Electric cooling fan operation
- •Variable Valve Timing Control

SELF-DIAGNOSTIC PROGRAMS

Most engine control systems have a self-diagnostic program that monitors operating signals and records a diagnostic trouble code (DTC) in the event of a communicated failure. Although a DTC does not identify the exact source of a failure, it does isolate the offending circuit and can save a considerable amount of diagnostic time.

To retrieve codes from memory, the powertrain control module (PCM) must be placed in diagnostic mode. Although codes are often displayed as sequential flashes of the MIL, the most accurate method of code retrieval is with a scan tool. In addition to stored codes, a scan tool can display data parameters or parameter identifiers (PID's) transmitted by the PCM on the serial data stream. What information is available to the scan tool varies by the system being tested and the tool itself. Follow procedures from the vehicle and equipment manufacturers.

DIAGNOSTIC TROUBLE CODES

DTCs identify faults in ECM system sensors and circuits or indicate individual system conditions. An OBD II DTC is a five-character, alphanumeric fault identifier. Since a letter is included in every DTC, the only way to retrieve codes is with a scan tool.

The first character of an OBD II DTC is a letter. The second character is a number that indicates if the code is common to all OBD II vehicles (0) or specific to one vehicle manufacturer (1). Remember, only emissions related, P0 codes will activate the MIL. The third character is a number used by all manufacturers to identify which system has a fault. This designation will be the same for P0 (OBD II) or P1 (manufacturer's) codes. Following is the established numbering system:

- •1 - Air/Fuel metering system input faults
- •2 - Air/Fuel metering output faults
- •3 - Ignition system or misfire faults
- •4 - Auxiliary emission controls
- •5 - Vehicle speed control and idle control system
- •6 - Computer output circuit faults
- •7 - Transmission
- •8 - Transmission

The fourth and fifth characters indicate the actual problem associated with the code, (e.g. signal voltage low, system always lean, etc.) The intent of OBD II code designation is to help the technician identify the system at fault, then pinpoint the actual problem or specific circuit causing the fault. Once a problem is identified by code, the technician must use appropriate service manuals to complete the diagnosis and repair.

SYSTEM MONITORS

The OBD II diagnostic system also actively tests some systems for proper operation. While the vehicle is being driven fuel control and engine misfire are checked continuously. Oxygen sensor response, oxygen sensor heater operation, catalyst efficiency, EGR operation, EVAP integrity, variable valve timing, and thermostat operation are tested once or more per trip. When any of the System Monitors detects a failure that will result in emissions exceeding a predetermined level on two consecutive trips, the ECM will store a diagnostic trouble code (DTC) and illuminate the malfunction indicator lamp (MIL). Freeze frame data captured during the first of the two consecutive failures is also stored.

FUEL CONTROL - For many vehicles the monitor will set a DTC if the system fails to enter Closed Loop mode within few minutes of startup, or the Long Term Fuel Trim is excessively high or low anytime after the engine is warmed up, indicating the loss of fuel control. This is always the case when the Long Term Fuel Trim reaches its limits.

ENGINE MISFIRE - For many vehicles, the monitor uses the CKP sensor signal to continuously detect engine misfires both severe and non-severe. If the misfire is severe enough to cause catalytic converter damage, theMIL will blink as long the severe misfire is detected.

CATALYTIC CONVERTER - For many vehicles the monitor compares the signals of the upstream heated oxygen sensors to the signal from the downstream heated oxygen to determine the ability of the catalyst to store free oxygen. If the converter's oxygen storage capacity is sufficiently

degraded, a DTC is set.

EGR SYSTEM - For many vehicles the monitor uses the MAP sensor signal to detect changes in intake manifold pressure as the EGR valve is commanded to open and close. If the pressure changes too little or too much, a DTC is set.

EVAP SYSTEM - For many vehicles the monitor first turns on the EVAP vent solenoid to block the fresh air supply to the EVAP canister. Next, the EVAP purge solenoid is turned on to draw a slight vacuum on the entire EVAP system, including the fuel tank. Then the EVAP purge solenoid is turned off to seal the system. The monitor uses the fuel tank (EVAP) pressure sensor signal to determine if the EVAP system has any leaks. If the vacuum decays too rapidly, a DTC is set. In order to run this monitor, the engine must be cold and the fuel level must be between 1/4 and 3/4 full.

VARIABLE VALVE TIMING - For many vehicles the monitor compares the desired valve timing with the actual timing indicated by the CMP sensors. If the timing is in error, or takes too long to reach the desired value, a DTC is set.

ENGINE THERMOSTAT - This monitor confirms that the engine warms up fully within a reasonable amount of time. If the coolant temperature remains too low for too long, a DTC is set.

OXYGEN SENSORS - This monitor checks the maximum and minimum output voltage, as well as switching and response times for all oxygen sensors. If an oxygen sensor signal remains too low or too high, switches too slowly, or not at all, a DTC is set.

OXYGEN SENSOR HEATERS - This monitor checks the time from cold start until the oxygen sensors begin to operate. If the time is too long, a DTC is set. Battery voltage is continuously supplied to the oxygen sensor heaters whenever the ignition switch is on.

An engine that runs too hot or too cold has poor performance, reduced fuel economy, and increased emission levels. Engine temperatures that are too low or too high are often the result of a cooling system problem. However, other problems, such as incorrect ignition timing, overloading the engine, long periods of idling or slow speed operation, and other factors, can cause overheating as well.

Check the coolant level and test the concentration using a hydrometer. Look for signs of oil and combustion contamination. Engine oil escaping into the coolant will not mix. The oil will float on top of the coolant. Combustion gases will chemically react with coolant to rapidly break it down turning it a rust-brown color. The presence of combustion gases cannot be visually verified.

COOLANT

A mixture of water and antifreeze circulates inside the engine and radiator. There are two basic types of antifreeze: ethylene glycol (EG), which is the most common, and propylene glycol (PG), which is less toxic to animals. Antifreeze is usually mixed in equal parts (50/50 mix) with water. With EG antifreeze, this provides freezing protection down to -34 degrees F and boilover protection up to 265 degrees F with a 15 PSI radiator cap.

Coolant needs to be changed periodically to renew the chemical additives that protect the cooling system against corrosion. The recommended change interval for traditional antifreeze (green and yellow) is two years/30,000 miles, and up to five years or 150,000 miles (whichever comes first) for long-life coolants.

Vehicle manufacturers use long-life coolants to reduce maintenance. Corrosion inhibiting additives and colors can vary depending on the application and model year.

GM has used an orange colored coolant called Dex-Cool since 1996. Dex-Cool contains “Organic Acid Technology”(OAT) inhibitors. Since 2002, Ford has been using a yellow-colored “Hybrid Organic Acid Technology” (HOAT) formula with silicates, but is not switching some models over to OAT coolants. Chrysler has its own HOAT formula coolant called G-05, which is dyed orange like Dex-Cool but is different. Asian and European automakers also have their own formulas and colors.

As long as a vehicle is under warranty, a coolant should be used that meets the vehicle manufacturer’s specifications. Ordinary green antifreeze should not be mixed with long-life coolants as doing so will shorten the service life of the coolant.

Rust, scale and sediment can be removed from a cooling system by using a chemical cleaner and reverse flushing the system when the coolant is changed. Leaks can be prevent-ed, and small leaks can often be sealed, by adding a sealer

product to the coolant.

COOLANT TESTING

Coolant concentration and effectiveness are tested with a refractometer or cooling system hydrometer. For accurate results, the coolant should be hot when tested. Before testing, draw a coolant sample into the hydrometer and return it to the radiator several times to stabilize the internal thermometer of the hydrometer.

Test as follows:

1. Hold the hydrometer straight and draw enough coolant to raise the float. The float should not touch the sides of the hydrometer.
2. With the hydrometer at eye level, take a reading by noting the top of the letter on the float that is touched by the coolant.
3. Find this letter on the hydrometer scale; read down the column under the letter until you are opposite the thermometer reading.
4. The number shown at this point is the degree of protection given by the coolant in the system.

INSPECTION

Use a pyrometer to monitor actual engine temperature and eliminate the possibility of a faulty gauge, warning lamp, sending unit, or circuitry. Once the problem is verified, inspect the cooling system and make the necessary repairs. Approach diagnosing an overheating problem by first determining when and at what interval the problem occurs. If the owner adds water, find out how much and how often. Secondly, determine whether the problem can be isolated to a specific driving condition. Visually inspect all cooling system hoses and replace any that are worn or damaged.

PRESSURE TEST

Pressure testing the cooling system is a quick and easy way to find an external leak. Perform the test on a cold engine using a hand pump with a gauge:

1. Remove the pressure cap and attach the pressure tester to the filler neck.
2. Pump the tester until the gauge reading matches the specified system pressure.
3. Observe the gauge; the reading should remain steady.
4. If the gauge shows a pressure loss, pump the tester to maintain pressure and check for leaks.

WATER PUMP

A water pump is a belt-driven pump that circulates coolant between the engine and radiator. The pump consists of a steel or plastic impeller mounted on a shaft inside a cast or stamped steel housing.

Failure of the pump shaft seal or bearing can cause noise and coolant leaks. A defective water pump can be replaced with a new or remanufactured replacement pump.

Some water pumps are driven by the timing belt and should be replaced when the belt is serviced.

THERMOSTAT

A thermostat that opens above or below its temperature rating will cause driveability problems. If the thermostat is stuck open, or there is no thermostat installed in the system, the engine may never reach an efficient operating temperature. In many instances, the thermostat is defective and should be replaced. Thermostat function can be checked on a running engine.

Replacement thermostats must be the same temperature

rating as the original. This is extremely important on late model computer-controlled engines that use the temperature reading from the coolant sensor to regulate the fuel mixture, ignition and other emission functions. Some vehicles have thermostats with a “jiggle pin” vent that allows trapped air to escape from the engine when the cooling system is refilled with coolant.

COOLANT FAN

Electric coolant fans, which are designed to operate only when necessary. Several methods are used to control fan operation:

1. A temperature switch that energizes an electrical relay. This switch is usually mounted in the engine.
2. A temperature switch that closes a set of contacts inside the switch to either complete the power or ground side of the circuit for the fan. This switch can be mounted either in the engine or radiator.
3. An air conditioning, or high discharge pressure, switch to energize an electrical relay to turn on the fan.
4. Computer-controlled relays to energize the fans. This system uses the engine coolant temperature sensor to sense engine temperature. The coolant fan turns on when engine coolant temperature reaches about 230°F (110°C). Some systems may have either a two-speed fan or two separate fans. These systems control fan use as needed. The fan is also needed to reduce air conditioning high-side pressures. If the fans are computer controlled, they turn on when the coolant temperature is too high or when the computer does not have a coolant temperature sensor reading. Any diagnosis of the cooling fan begins with an examination of the system wiring diagram. This diagram provides the most accurate and timely understanding of how a particular system should operate.

RADIATOR

A large heat exchanger mounted in front of the engine. Airflow through the radiator provides cooling for the coolant that circulates through it. Most newer radiators are a “crossflow” design where the coolant flows from one end to the other. Older vehicles usually have “downflow” radiators where the coolant flows from the top to the bottom. Most late model radiators are aluminum while many older radiators are copper/brass. Most radiators also contain a loop of pipe in the bottom tank or end tank for cooling automatic transmission fluid. A replacement radiator should have the same hose configuration (location and size) as the original, and provide equivalent (or better) cooling. For towing applications and high-performance engines, a larger, thicker and/or more efficient radiator can be installed to improve cooling.

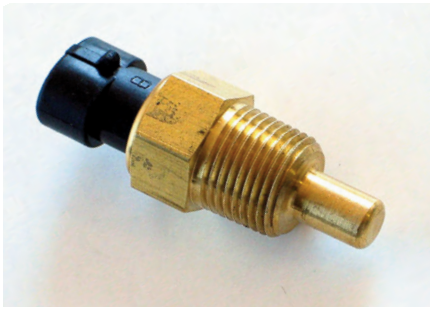
Most early vertical-flow radiators were made of an upper “header” tank soldered to a brass header plate holding the radiator core tubes in place. The lower plate and outlet tank was of similar construction. Unfortunately, vertical-flow brass radiators were heavy, expensive and environmentally challenging due to the liberal use of lead-based solder.

The cooling capacity of most radiators can be increased by adding extra rows of core tubes. While single-row radiators can cool a small-displacement engine, up to four rows of core tubes are required for heavy-duty applications. In terms of increasing cooling capacity, adding more than four rows of core tubes generally produces diminished returns. Consequently, the frontal area of the radiator becomes more important in determining cooling capacity. Additional cooling capacity can be achieved by manipulating the shape and density of the aluminum cooling fins inserted between the core tubes. But, when the cooling fin density becomes too great, air flow through the radiator is reduced at normal road speeds.

RADIATOR CAP

A spring-loaded pressurized cap on the radiator that prevents coolant loss and increases the temperature at which the coolant boils. Pressure ratings vary from 5 to 15 psi. A weak radiator cap may allow the engine to overheat or lose coolant. Caps should be replaced if they do not seal properly or hold their rated pressure. Replacement caps must have the correct pressure rating for the application to prevent overheating.

SENSORS



Monitors the temperature of the coolant. The sensor's resistance changes with the temperature of the coolant. The sensor's output voltage may be used to operate a temperature gauge or warning light, the cooling fan and various emission functions. It is also used by the engine computer to determine when the engine can go into "closed loop" operation (when the computer uses input from the oxygen sensor to regulate the fuel mixture). A defective sensor can prevent the engine from going into closed loop, cause poor fuel economy and higher emissions.

HOSES

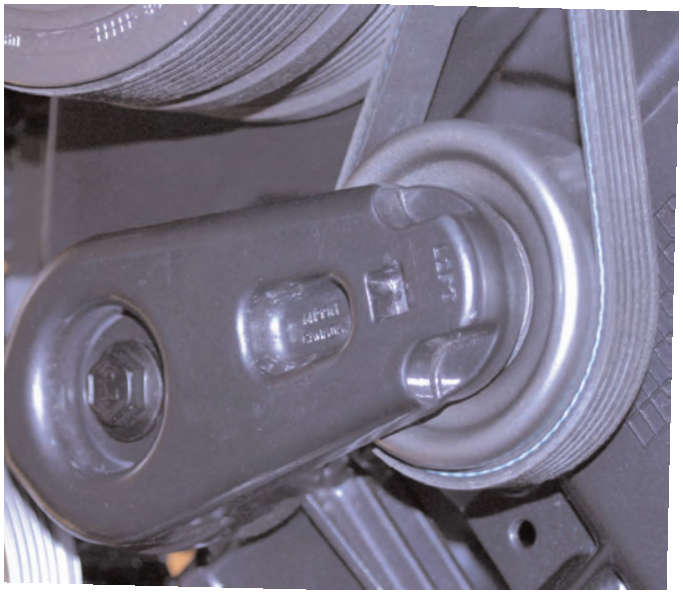
Flexible rubber hoses carry coolant between the engine and radiator, and engine and heater core. Most cooling systems have an upper radiator hose, a lower radiator hose, at least two heater hoses, and possibly other hoses to route coolant to the intake manifold, throttle, turbocharger or elsewhere. Most OEM hoses are "molded" to shape, and some have "branched hoses" where one hose connects directly to another. Hoses deteriorate with age and may leak. Loss of coolant will cause the engine to overheat. Replacement hoses must be the same diameter and length as the original.

REPLACING DRIVE BELTS

Never force or pry a belt over pulley flanges. If the belt cannot be run into the grooves by rotating the pulley, move the driven accessory to obtain closer centers. With the belt removed, examine the pulleys for damage and misalignment. Replace pulleys as required and install the new belt.

Belts should be free from cracks and glazing.

A new drive belt should also be installed when a high-mileage water pump is replaced. Chances are the old belt will have a lot of miles on it and will be badly worn, glazed or



If the belt tensioner is worn, the pump will not work properly.

contaminated with oil, grease or PS fluid that leaked out of the old pump. The automatic belt tensioner also should be carefully inspected and replaced if it is sticking, rusty, wobbling, noisy or can't maintain proper belt tension.

COOLANT FLUSHING

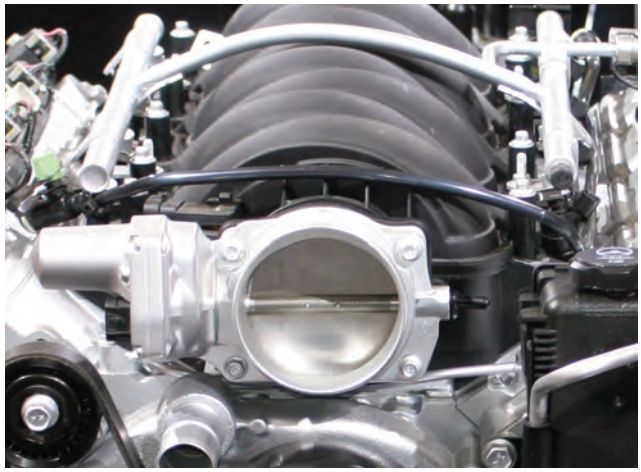
The cooling system should be completely drained and flushed every two year to prevent internal damage. If the sys-tem is regularly serviced and only light contamination is present, the system can be flushed with cleaning water.

1. Drain the old coolant by opening the radiator and engine drain plugs or by disconnecting the lower radiator hose.
2. Remove the cap from the coolant recovery reservoir and use a suction gun to empty the contents
3. Remove the thermostat and reinstall the thermostat housing
4. Place a hose in the radiator filler neck and adjust the water flow to keep the water level at the top of the radiator while water is flowing out of the drains
5. Flush the system for 10 minutes. Run the engine at idle for a more thorough flushing
6. Reinstall the thermostat and close all the drains or

reconnect the lower radiator hose.

7. Fill the system with the recommended amount of coolant to the correct level.
8. Refill the coolant reservoir to the “cold” mark on the side.
9. Start the engine and allow it to reach operating temperature
10. Check for leaks
11. Operate the heater to eliminate all air in the system

AIR INDUCTION & THROTTLE BODY SERVICE



Varnish and carbon can build up in the air induction system. There are products available to clean intakes mani-folds and throttle bodies. But you should always:

1. Check the service information to see if a cleaner of solvent can damage coatings in the throttle plate area or other sensors.

2. Follow the instructions for the product or tool.

3. Solve all other running and drivability issues before performing any type of cleaning service.

4. Make sure all hoses and connections are tight after the service is performed.

5. NEVER use throttle body cleaner on a vehicles with a supercharger. Remove the throttle body before cleaning.

AIR FILTERS

Air filters remove dirt by trapping contaminants as the air flows through the filter media. The percentage of particles removed is a measure of the filter's efficiency. A good quality air filter generally traps upwards of 98.5% of the incoming dirt.

Filter efficiency depends on the type of media used. Most of today's dry paper pleated element air filters are made of a mixture of cellulose and synthetic fibers. Generally speaking, the higher the percentage of synthetic fibers; the better the filter.

As dirt builds up in on the surface and in the fibers of an air filter, it begins to restrict airflow through the filter. Eventually, the point is reached where the increasing restriction begins to affect engine performance, choking the incoming air supply. Ideally, filters should be replaced before they become too restrictive.

This requires inspecting the filter and replacing the filter is it is obviously clogged with debris — but also replacing the filter after so many miles (typically 15,000 to 30,000) regardless of it's outward appearance. Why? Because its often hard to see how much dirt has become embedded within the filter fibers.

The right way to inspect a panel air filter, or a round air filter in an older vehicle, is to remove the filter from its housing and hold a shop light behind it. A little discoloration is normal, but if the filter is dark and blocks the light, it is overdue for a change.

When replacing a filter, it's a good idea to compare the old and new filters to make sure are the same size and thickness. A filter that does not fit the air cleaner housing properly will leak and allow unfiltered air to be sucked into the engine.

Close attention also needs to be paid to the filter housing. Some plastic housings can become distorted as a result of heat exposure, causing them to leak.

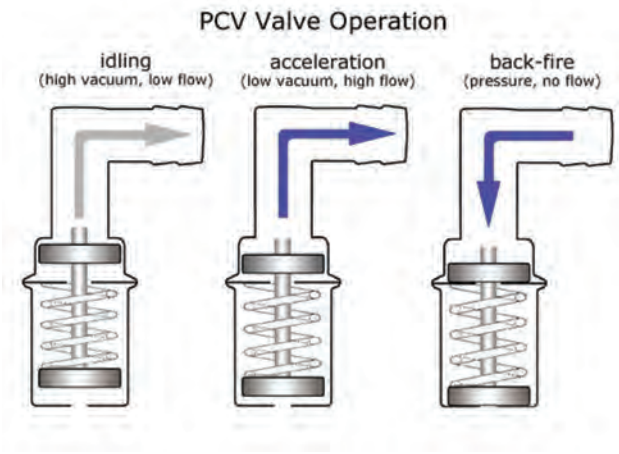
POSITIVE CRANKCASE VENTILATION SYSTEM (PCV)

A flow restriction in the PCV system can result in drivability problems. Improper venting, or scavenging, of the crankcase can result in oil dilution and sludge formation. In extreme cases, oil collects in the air cleaner and

eventually clogs the filter element. Symptoms of a clogged or damaged PCV system include:

- Increased oil consumption
- Diluted or contaminated oil
- Escaping blow by vapors
- Unstable engine operation at idle and low speed

PCV service includes inspection, testing, and component replacement. There are no adjustments possible.



PCV Valves work using a spring calibrated against the force of engine vacuum. The PCV wears out went the spring losses tension or breaks. Also the valve can clog and prevent the valve from seating.

Testing a PVC Valve

Testing the PCV system is relatively easy and can be done a number of different ways:

• **Pinching:** After running the engine up to operating temperature and allowing it to stabilize at idle, pinch or block off the hose between the vacuum source and the PCV valve.

The engine should typically drop 50-80 rpm. If the engine does not change, check the PCV valve and system hoses for blockage.

Replace components as necessary and retest.

• **Vacuum with gauge:** Run the engine up to operating temperature. Shut the engine off and block off the fresh air source to the engine.

This would typically be the hose coming from the air cleaner to the rocker cover.

Remove the dipstick tube and connect a vacuum-pressure gauge to the dipstick tube. Restart the engine and allow it to stabilize at idle. Then take a reading of your vacuum-pressure gauge.

You should read 1-3” of vacuum with a normally operating PCV. If you have 0” of vacuum or even pressure, you have problems.

• **Vacuum without a gauge:** Another way to perform a vacuum test on a PCV valve is to start the engine and bring it to normal operating temperature.

Next, disconnect the hose from the remote air cleaner or air outlet tube.

Place a stiff piece of paper over the nipple or hose end and wait 1 minute. If vacuum holds the paper in place, the system is okay; reconnect the hose.

If the paper is not held in place, the system is plugged or the evaporative emission valve (if equipped) is leaking.

Inspect the PCV valve and grommet for deterioration, and replace if necessary.

Service

Service of the PCV system usually consists of cleaning or replacing the filter, or replacing the connecting hoses or the valve itself.

Filter Replacement

The PCV inlet air is filtered through the engine air filter on some engines. Simply replace the element at the recommended interval. Other designs have a separate PCV filter element that mounts in the air cleaner housing. This may be a foam filter or a wire mesh screen, which unless torn or otherwise damaged can be cleaned and reinstalled. To service, remove the filter, wash with solvent, air dry, then reinstall. Lightly oil a foam type filter with clean motor oil before installation. Filters installed in the oil filler cap are usually made of wire mesh. Remove the filler cap and soak the complete cap and filter in solvent. Allow it to drain and dry in the air. Do not dry with compressed air; this will damage the wire mesh.

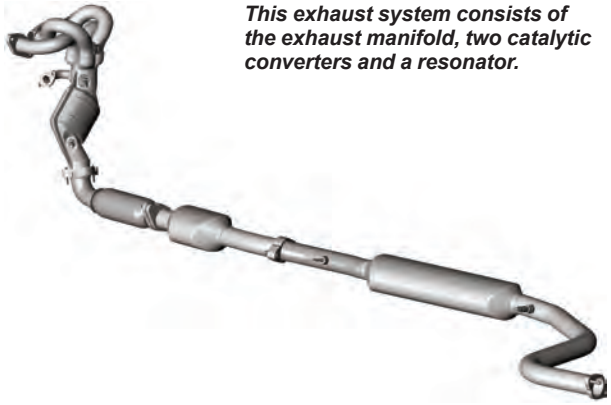
Hose replacement

Any damaged or deteriorated hose must be replaced to ensure proper system operation. Use only hose designed for PCV and fuel system applications. Standard heater hose cannot withstand the blowby vapors and will quickly fail.

PCV Valve Replacement

A PCV valve cannot be distinguished by its appearance; internal valve characteristics are specifically calibrated for each application. Always refer to the part number when replacing a valve. When installing a valve, make sure to fit it with the arrow indicating direction of flow pointing toward the intake manifold. If the valve is mounted in a rubber grommet, it must provide a snug fit. If the grommet is hardened or cracked, replace it.

EXHAUST INSPECTION



This exhaust system consists of the exhaust manifold, two catalytic converters and a resonator.

The exhaust system is a critical emissions component as well as an important part of engine functionality. The exhaust is responsible for evacuating unused mixtures of fuel and air and depositing them through a series of filters and mufflers to ensure it comes out a little cleaner and quieter. The toxic gases are filtered through a catalytic converter located closer to the engine. It uses a ceramic monolith, normally in a honeycomb like structure.

INSPECTION & SERVICE

Servicing the exhaust system consists of inspecting the pipes, brackets, mufflers, and catalytic converters, as well as inspecting and testing the manifold heat control valves. Check each component for damage, exhaust leakage, loose connections, and loose mounting. Tighten where required. The converter or muffler generally is not repaired if damaged, but is replaced with a new one. The replacement procedure essentially is the same for both.

EXHAUST MANIFOLD

Inspect the exhaust manifold to cylinder head area. If signs of leaking exist remove the manifold for further inspection. Check the manifold and head sealing surfaces for:

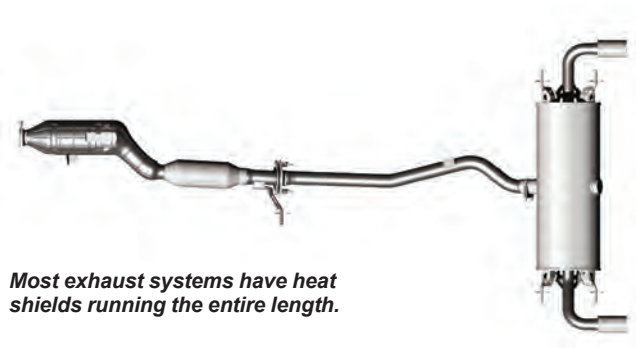
- Warping or distortion
- Erosion
- Cracks
- Pitting

The exhaust manifold or header, must be free of defects so it seals.

If any problems are found, refer to the service manual for applicable repair procedures. Also inspect the seal between the manifolds and the exhaust pipe. Replace or repair as necessary

EXHAUST SYSTEM

Inspect the following components for signs of damage, leaking, corrosion, or other abnormalities:



Most exhaust systems have heat shields running the entire length.

- All exhaust piping
- Muffler(s)
- Resonator(s)
- Heat shields

Repair or replace any components that are defective following procedures outlined in the appropriate Service Manual.

CATALYTIC CONVERTER

Catalytic converters are required by law to give at least 50,000 miles of service. However, if the car is properly tuned and still cannot meet the emissions specifications; perform a vacuum test or backpressure test. These tests indicate only that a restriction exists somewhere in the exhaust system. Check the rest of the system before removing and replacing the converter.

Spark Plugs

The spark plug provides an air gap through which the secondary voltage arcs and ignites the air/fuel mixture in the engine. The basic plug consists of a ceramic insulator and a pair of electrodes. Most plugs have a resistor which, like the wires, reduces current in the secondary sys-

tem. Spark plugs must be the correct size, reach and the heat range for a specific application. It is important to use the spark plug specified for a particular engine.

Spark plug electrodes are subjected to extreme heat, pressure and corrosion. As a result, they should be included in normal maintenance. Arcing tends to deteriorate the electrodes over time, so a higher spark voltage is required to jump the gap. Fouling may provide an alternate path for the spark, which causes misfires. Wetting of the plug may also short out the electrodes. Cracked insulator, carbon tracking, burned electrodes and improper torque can all lead to undesirable performance and premature failure.

SERVICE

Spark plugs are routinely replaced at specific service intervals as recommended by the vehicle manufacturer. However, these intervals are guidelines and actual spark plug service life will vary. Spark plug life depends upon:

- •Engine design
- •Type of driving
- •Kind of fuel used
- •Types of emission control devices

Because the spark plugs are the final component in all secondary circuits, the remainder of the circuit cannot perform properly if they are not in good condition.

INSPECTION

Worn out spark plug with a large gap.

Examining the firing ends of the spark plugs reveals a good deal about general engine conditions and plug operation. The insulator nose of a used plug should have a light brown-to-grayish color, and there should be very little electrode wear. These conditions indicate the correct plug heat range and a healthy engine. Some common spark plug conditions that indicate problems follow.

OIL FOULING

Dark, wet deposits on the plug tip are caused by excessive oil entering the combustion chamber. Piston ring, cylinder wall, and valve guide wear are likely causes in a high-mileage engine. Also, a defective PCV valve can draw oil vapor from the crankcase into the intake and oil foul the plugs.

CARBON FOULING

Soft, black, sooty deposits on the plug end indicate carbon fouling. Carbon results from a plug that is operating too cold. Check for spark plugs with an incorrect heat range, an overly rich air-fuel mixture, weak ignition, inoperative manifold heat control valve or thermostatic air cleaner, retarded timing, low compression, faulty plug wires or distributor cap. Carbon fouling may also result from overloading due to excessive stop and- go driving.

ASH FOULING

Certain oil or fuel additives that burn during normal combustion can create ash deposits. Ash deposits are light brownish-white accumulations that form on and around the electrode. Normally, ash deposits are nonconductive, but large amounts may cause misfiring. Splash Fouling

Small dark patches visible on the insulator indicate splash fouling. Deposits breaking loose from pistons and valves and splashing against hot plug insulators cause splash fouling. The condition often occurs after engine servicing that restores engine power and higher combustion temperatures. Splash-fouled plugs can generally be cleaned and reinstalled.

GAP BRIDGING

Gap bridging is usually due to conditions similar to those described for splash fouling. The difference is that deposits form a bridge across the electrodes and cause a short. This condition is common in engines with poor oil control.

INSULATOR GLAZING

Shiny, yellow, or tan deposits are a sign of insulator glazing. Frequent hard acceleration with a resulting rise in plug temperature can cause glazing. The high temperature melts normal plug deposits and fuses them into a conductive coating that causes misfiring.

OVERHEATING

Spark plug overheating is indicated by a clean, white insulator tip, excessive electrode wear, or both. The insulator may also be blistered. Incorrect spark plug heat range, incorrect tightening torque, over-advanced timing, a defective cooling system, or lean air-fuel mixture can cause overheating.

DETONATION

Detonation causes increased heat and pressure in the combustion chamber that exerts extreme loads on engine parts. Fractured or broken spark plug insulators are a sign of detonation. Over-advanced timing, lean fuel/air mixture, low gasoline octane, and engine lugging are contributing factors. An EGR valve that fails to open can also cause detonation.

PRE-IGNITION

Pre-ignition, the air-fuel charge igniting before the plug fires can cause severe damage to the spark plug electrodes. Pre-ignition is usually caused by combustion chamber hot spots or deposits that hold enough heat to prematurely ignite the air-fuel charge. Cross firing between plug cables or a plug heat range much too hot for the engine can also cause pre-ignition. A loose spark plug may also cause pre-ignition.

GAPPING AND INSTALLATION

Spark plugs, both new and used, must be correctly gapped before they are installed. Although a wide variety of gapping tools are available, a round wire feeler gauge is the most efficient for used plugs. Adjust the gap by carefully bending the ground electrode.

- **Do not assume that new plugs are correctly gapped**
- **Do not make gap adjustments by tapping the electrode on a workbench or other solid object**

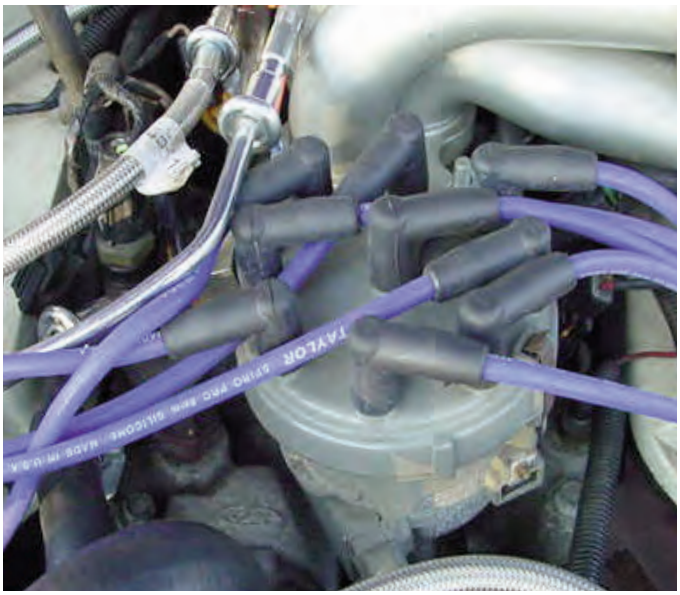
Cleaning the threaded plug holes in the cylinder head with a thread chaser will ensure easy spark plug installation. With aluminum heads, use the tool carefully to avoid damaging the threads.

Some manufacturers recommend using an ant- seize compound or thread lubricant on the plug threads. Use thread lubricant only when specified by the manufacturer. Anti-seize compound is commonly used when installing plugs in aluminum cylinder heads. Be sure to use the specific compound recommended by the manufacturer, as not all are compatible with aluminum. Whenever thread lubricant or antiseize is used, reduce the tightening torque slightly.

The distance across the electrode gap at the end of the spark plug must be within specifications for the engine application. If the gap is too narrow, the spark may not be long enough to ignite the fuel mixture reliably resulting in ignition misfire. If the gap is too wide, there may not be enough available voltage to create a spark also causing ignition misfire. Most spark plugs are pre-gapped at the factory, but the gap should always be checked and readjusted, if necessary, when new spark plugs are installed.

On older vehicles with a distributor, check the distributor cap and rotor for cracks and carbon tracks that can short the spark to ground. Carbon build-up on the terminals inside the cap or on the rotor can cause a misfire.

IGNITION CABLES



Most ignition systems use 7-mm cables. However, others use larger 8-mm cables. The larger cables provide additional dielectric resistance in a system where secondary voltages can exceed 40 kV. Use the proper size cables; they are not interchangeable. Ignition cables generally push-fit into the distributor cap or DIS coil.

Twist and pull up on the boot to remove the cable from the cap. Check the cap tower or DIS terminal for dirt, corrosion, or damage. Clean light deposits in the tower with a wire brush. Replace a cap or coil if there is heavy accumulation. Fit the new cable to the cap so the terminal seats firmly on the tower. Fit the rubber boot seal over the tower, or DIS terminal, and squeeze it to remove any trapped air. Some distributor caps use a male ignition cable terminal that looks much like a spark plug. The cable end snaps onto the terminal instead of fitting down inside the cap tower. When replacing cables, disconnect only one cable at a time from a spark plug and the distributor cap or DIS coil terminal. For distributors, begin with the cable for cylinder number one and work in firing order sequence. Route each cable in the same location as the one removed and secure it into the cable brackets. To prevent the possibility of cross firing, do not route cables in firing order sequence next to each other. Make sure that the cables cannot contact the exhaust manifold or interfere with other electrical wiring.

Water can get past worn boots and rust the terminal. This can cause misfires.

EVAPORATION SYSTEM LEAK DETECTION

The* charcoal canister *is typically located under the hood or on a frame rail.

Check all EVAP system hoses for damage or deterioration and replace as needed. Replacement hose must be designed for fuel system use. Securely tighten all connections. Check that the vapor vent hose leading to the canister is properly routed and positioned. Normally, the hose is routed in a downhill position to prevent liquid gasoline from accumulating in the hose and seeping into the canister. If there is liquid in the line, the canister cannot purge properly. This also creates a potential fire hazard. If you find liquid gasoline in the canister, follow the procedure in the Service Manual to remove and replace the canister.

DIESEL EXHAUST FLUID

Many diesels also add an after-treatment system (Selective Catalytic Reduction or SCR) that injects a water-urea solu-

tion (Diesel Exhaust Fluid or DEF) into the exhaust. At gas stations and truck stops, the fluid is usually marketed as DEF. The level should be inspected every oil change.

Diesel Exhaust Fluid is a solution of 67.5% purified water and 32.5% urea (ammonia). When this type of after-treatment system is used, it reduces the amount of Exhaust Gas Recirculation (EGR) that the engine needs to control NOx. This, in turn, allows the engine to be calibrated for slightly better overall fuel economy.

On vehicles that use a DEF after-treatment system, the fluid is stored in an on-board tank and is sprayed into the exhaust (after the diesel particulate trap) to break down oxides of nitrogen. The storage capacity will vary depending on the vehicle, and usage will depend on how the vehicle is driven. Typically, a gallon of fluid will last about 2,500 miles. The storage tank may hold enough fluid to go the distance of an oil change (7,500 miles up to 15,000 miles). EPA rules require the DEF level to be monitored, and that a warning light be used to signal the driver when the fluid level is low. Furthermore, the engine must power down to a limp-in mode if the after-treatment system runs out of DEF — which can create a real problem for the unwary driver who allows his fluid level to run out.

Another concern with DEF is that the liquid freezes at 12° F

(-11° C). This requires a tank heater to keep the reservoir warm during cold weather, and to thaw frozen fluid following a cold start if the fluid has turned to ice.

Review Questions

1. A possible cause of low oil pressure could be:
a. Worn oil pump
b. Worn engine bearings
c. Bad oil pressure sending unit
d. All of the above

2. The sealing ability of a cylinder with 22% loss of pressure is _____.
a. Good
b. Fair
c. Poor
d. Failed

3. Spark plug overheating , which is indicated by a clean white tip and excessive electrode wear, can be caused by all of the following EXCEPT:
a. Incorrect spark plug tightening torque
b. Over-Advanced timing
c. Lean air fuel mixture
d. Rich air fuel mixture

4. Spark knock can be caused by:
a. Fuel with two low of octane rating
b. Ignition timing that is too far advanced
c. High engine operating temperature
d. all of the above

5. What will oil do when mixed with coolant?
a. Sink to the bottom
b. Dissolve
c. Float to the top

6. A faulty thermostat _____.
a. Should be replaced
b. Can be clean and re-installed
c. Is normal in most vehicles

7. How does the coil know when to ignite the igni-tion?
a. The points
b. Ignition module
c. PCM
d. All of the above

8. Dark/ wet deposits on the spark plugs tip is called
a. Ash fouling
b. Carbon fouling
c. Oil fouling
d. Bridge gapping

9. Shiny, yellow, or tan deposits are a sign of
a. Insulator gazing
b. Carbon fouling
c. Over heating
d. Ash fouling

10. Technician A says that a cooling system pressure test should be performed to find a coolant leak. Technician B says that a cooling system dye and a UV-light should be used to find a coolant leak. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and Technician B
d. Neither A nor B

11. A pressure tester can be used to:

a. Test thermostats
b. Test radiators, pressure caps, and hoses
c. Test for exhaust leaks into the cooling system
d. Test the coolant

12. A V-type drive belt that rides too low and bottoms in the pulley groove causes:

a. Premature wear, glazing, and slippage
b. The belt sides wear excessively and split
c. High belt tension that can lead to bearing damage
d. The belt to bind, seize, and eventually break

13.Technician A says that a thermostat rated at 180 degrees begins to open at 180 degrees. Technician B says that a thermostat rated at 180 degrees is fully open at 180 degrees. Who is correct?

A. Technician A
B. Technician B
C. Both Technician A and Technician B
D. Neither Technician A nor Technician B

14. Technician A says that a cooling system with rust in it may cause the water pump impeller to fail. Technician B says that some water pump impellers are made of plastic. Who is correct?

A. Technician A
B. Technician B
C. Both Technician A and Technician B
D. Neither A nor B

15. Which of the following could cause symptoms of overheating even though the engine temperature is in the normal range?

a. A stuck closed thermostat
b. A defective radiator cap
c. A missing thermostat
d. A defective temperature sending unit

16. An air filter that is plugged with dirt and debris can cause all of the following EXCEPT:

a. Higher fuel economy
b. Poor performance
c. Sluggish acceleration
d. Lower fuel economy

17. The cause of a MIL not lighting during a bulb check when the ignition is switched on can be all of the following EXCEPT:

a. A DTC in memory
b. A burned out bulb
c. An internal PCM failure
d. A faulty circuit

18. A vehicle is equipped with a vented gas cap. Technician A says if a non-vented gas cap is installed on the vehicle, the gas tank could collapse. Technician B says that if a non-vented gas cap is installed, the vehicle could run rich at high speeds. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and Technician B
d. Neither Technician A nor Technician B

19. Technician A says that Diesel Exhaust Fluid (DEF) should be checked and added to the fuel tank every time the vehicle needs to be refueled. Technician B says that Diesel Exhaust Fluid (DEF) should be checked and added to the reservoir every time the vehicle needs to refueled. Who is correct?

a. Technician A
b. Technician B
c. Both Technician A and Technician B
d. Neither Technician A nor Technician B

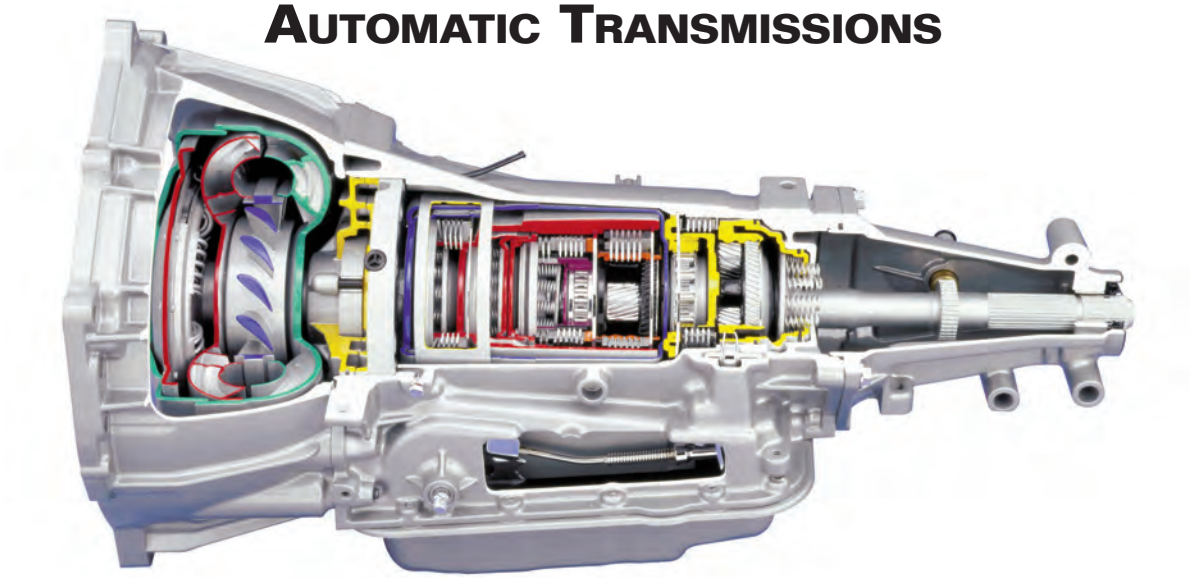
20. A clogged PCV system can cause all of the following EXCEPT:

a. Increased oil consumption
b. Lean fuel mixture
c. Oil dilution
d. Oil leaks

ANSWER KEY: 1) D 2)C 3)D 4)D 5)C 6)A 7)D 8)C 9)A 10)C 11)B 12)A 13)A 14)C 15)D 16)B 17)A 18)A 19)B 20)A

ASE G1

Automatic Transmissions



An automatic is a transmission that shifts itself using engine RPM, load and other inputs to regulate shift points and gear engagement. Late model automatics have electronic/hydraulic controls operated by the Powertrain Control Module (PCM) or its own Transmission Control Module (TCM). Most late model automatics have five or six gears (speeds), though some have as many as eight. Some automatics are actually Continuously Variable Transmissions (CVTs) that vary gear ratios depending on speed and load.

All automatics use a special type of oil for the hydraulic functions as well as lubrication. Due to the complexity of the transmission, internal failures typically require replacing the entire transmission or transaxle with a new or remanufactured unit. Gaskets, filters, sensors, certain control components and other parts are usually available for repairs.

ROAD TESTING

Before the road test, look up the shift speed specifications, also called shift points in the Service Manual. Be aware that shift points differ according to engine, transmission, axle, tire size and model year combination. Make sure specifications are an exact match for the vehicle being tested. During the road test, record the exact shift points for comparison. Also have a clutch and band application chart with you, so you can determine which devices are active at any given time. Depending upon the symptoms, you may also want to connect a pressure gauge to the transmission to monitor hydraulic pressure while driving. During the road test, check for:

- Slippage
- Early, late, or erratic shift timing
- Poor shift quality
- Unusual noise or vibrations
- Torque converter clutch operation

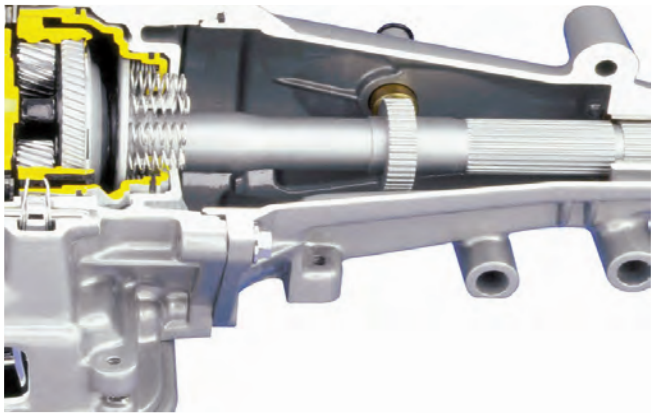
A lightly traveled road is ideal for conducting a road test. Take advantage of any natural features, such as hills and curves, which might emphasize the problem the customer complained about.

DIAGNOSTIC TROUBLE CODE (DTC) CHECKS

Always check both transmission and engine codes, even if the vehicle has only engine data parameters available. On many models, a Malfunction Indicator Lamp or warning lamp will illuminate when a DTC has been detected by the control module. Make sure the system is not operating in limp home mode, or the results of any test you perform may be inconclusive. Some manufacturer's limp home mode will not allow the transmission to either upshift or downshift from the current gear range that it is operating.

If the engine is shut down, while in limp home mode, the Powertrain Control Module (PCM) or Transmission Control Module (TCM) may not allow any gear to engage after restarting. Some systems display codes by a lamp on the instrument panel or gear shift indicator, but the best way to read codes is with a scan tool. Scan tools communicate with the vehicle control modules through a diagnostic connector. Since the inception of onboard electronic controls manufacturers have used a variety of diagnostic connectors to access their control systems. However, with the introduction of Onboard Diagnostics II (OBD II) all late model vehicles use a standard SAE Data Link Connector (DLC) for control system testing. Refer to the appropriate Service Manual for location of the correct diagnostic connector in non-OBD II vehicles.

INPUT SENSORS AND SIGNALS



Electronic automatic transmissions depend upon a complex network of input sensing devices and circuitry. The TCM uses these to determine the operational status of transmission, engine, chassis, and body components. Some sensors transmit signals only to the TCM. Others feed information to both the transmission and engine computers. Switches are digital sensors commonly used to provide signals that indicate:

- Throttle position (at or off idle)
- Basic high or low temperature (above or below the switch set point)
- Gear selector lever position
- Transmission gear ratio
- Power steering and air conditioning pressure

When used as sensors, switches generally install on the ground side of a circuit. The switch receives either system voltage from the vehicle electrical system or a reference voltage from the computer. As the switch opens and closes the circuit to ground, the voltage provided by the computer changes state; it switches from low to high or high to low.

SPEED SENSORS

A number of speed inputs are provided to the TCM by a number of different sensors. These may include engine speed, vehicle speed, transmission input speed, and transmission output speed. These signals are generally transmitted by one of the following types of sensor:

- Pick up coil
- Hall-Effect switch
- Optical Sensor

Automatic Transmission Fluid

Routine maintenance service for an automatic transmission generally includes frequent fluid level checks and an occasional fluid and filter change. Some manufacturers specify a regular mileage interval for fluid replacement. Others recommend fluid replacement only when a major overhaul is per-formed, or when the vehicle is operated under severe service conditions. There are a variety of transmission fluids available, and they are not interchangeable.

Using the wrong fluid can cause clutch engagement problems or a damaging chemical reaction with system components. Consult the appropriate serv-ice literature to determine the proper fluid for each trans-mission you service. Be sure the fluid you add meets the requirements of the transmission manufacturer.

INSPECTION

When checking the automatic transmission fluid (ATF) level, it is important to follow the procedure recommended by the manufacturer. Most require that the level be checked when the fluid is at normal operating temperature, the vehicle is on a level surface, and the engine is running at idle. Dipsticks are often marked for taking readings at different fluid temperatures. Always follow the prescribed procedure.

The transmission fluid that clings to the dipstick can often be used to help determine internal transmission condi-tions.

Analyze the fluid by looking for:

- Unusual color
- Strong odors
- Particles of metal, friction material, and other debris

FLUID COLOR

Most ATF contains red dye to make identification easy. As the fluid ages, the color will change to a reddish brown. This discoloration is normal for some fluids, such as Dexron III, Dexron VI, and Mercon®. Color change is not a cause for concern in itself as long as the fluid is not burnt. If the color on the dipstick is hard to detect, wipe the fluid onto a clean white cloth or paper towel.

This allows the fluid to reflect its true color. Unusual color conditions will include:

- **Dark brown with a pungent odor—brown discoloration may be normal, but the odor indicates overheating, and the fluid should be changed**
- **Dark gray or black—this indicates excessive friction material in the fluid. The particles will separate from the fluid when wiped onto a rag**
- **Milky pink or milky brown—this is an indication of water or coolant contamination. Severe damage will result if the leak is not repaired**
- **Foamy red or reddish-brown—this indicates fluid aeration, often the result of overfilling**

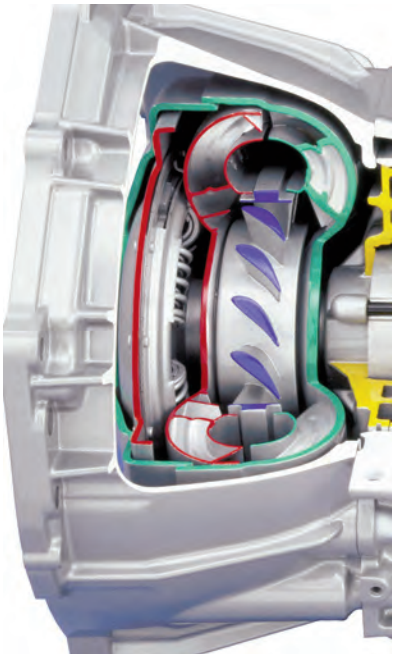
FLUID LEAKAGE

Fluid leaks, a common cause of low fluid levels, are often difficult to locate because the air passing under the vehicle tends to spread the fluid around. To find a leak, first clean off the transmission case; use degreaser or steam cleaning if necessary. Warm the transmission up to operating temperature, lift the vehicle on a hoist, and check for leaks with the engine running. Next, shut the engine off and watch for leaks caused by drain back. **Look for leakage at the:**

- Oil pan gasket
- Oil cooler lines and fittings
- Fluid filler and vent tubes
- Speedometer and throttle valve cable connections
- Output shaft and torque converter seals
- Governor cover
- Downshift control lever shaft and manual shaft seals
- Pressure tap plugs
- Vacuum modulator

With certain transmissions, a leak may result from case porosity. The pressurized fluid actually works its way through the metal of the casting at certain places. Some porosity leaks can be repaired by applying a special epoxy to the affected area of the case.

TORQUE CONVERTER



The torque converter couples the engine to the gear train and multiplies engine torque. Conventional torque converters consist of an impeller, a turbine, and a stator. Lockup torque converters also include a clutch assembly that, when applied, mechanically links the engine to the gear train.

The torque converter holds approximately one third of the total fluid required by the transmission. Draining the fluid from the transmission does not drain the torque converter, so a complete fluid change requires using a fluid exchange machine.

In some lockup converters, clutch application is electronically controlled. Torque converter problems can result in the following conditions:

- Acceleration from a standstill is slow in all ranges
- Acceleration is normal, but high speed performance is poor
- The transmission overheats Converter functions can be checked by pressure testing, stall testing, and road testing.

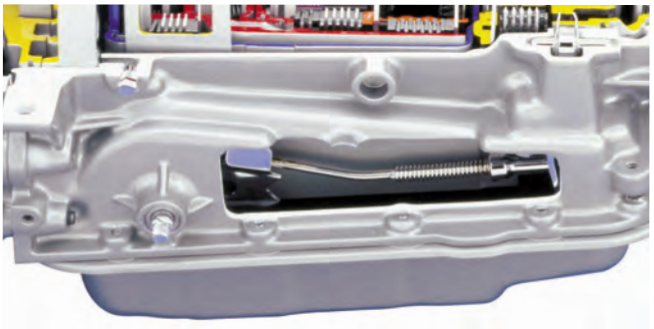
Torque Converter Stator

The torque converter stator and its one-way clutch

may develop two malfunctions. The stator may:

- Freewheel in both directions
- Remain locked up at all times

Both problems tend to show up during a road test. When the clutch is not locking up the stator, the vehicle accelerates slowly at speeds below about 30 or 35 MPH, while at higher road speeds it accelerates normally. A stator that is constantly locked restricts engine RPM and vehicle speed. Often, the vehicle cannot go faster than about 50 MPH. When the vehicle accelerates poorly at lower road speeds, inspect the exhaust system for restrictions and check the state of tune of the engine.



VALVE BODY & CONTROLS

The valve body is located inside the transmission oil pan and regulates gear shifts and clutch pack engagement. Computer-controlled solenoids in the valve body can be replaced if defective. Magnetic sensors are used to monitor the speeds of the transmission input and output shafts. A separate vehicle speed sensor is usually used for speedometer inputs.

Troubleshooting automatic transmission problems requires a scan tool to access diagnostic trouble codes, and a pressure gauge to read internal pressures.

Other shift controls on older automatic transmissions include a vacuum modulator and/or governor that modifies the RPM at which the transmission upshifts when the vehicle is accelerating under load). The modulator is mounted on the side of the transmission, and is connected by a vacuum hose to the intake manifold on the engine. Older transmissions may also use a throttle cable or linkage for kickdown shifts when accelerating.

ATF OIL COOLER

A transmission cooler is a heat exchanger usually mounted inside the radiator to cool the transmission fluid. May have to be replaced if leaking. For towing or hard-use applications, installing an aftermarket auxiliary ATF cooler can help keep ATF temperatures down to prolong the life of the fluid and transmission.

LINKAGE

Most modern transmission shift electronically. On older transmissions, there are four types of linkage involved in transmission operation:

- Accelerator linkage
- Throttle valve linkage
- Downshift linkage
- Gearshift linkage

Not every transmission uses all four types of linkage. Usage depends on the transmission and the vehicle in which it is installed. Symptoms of misadjusted transmission control linkages include:

- Early or late shifts
- Hunting between gears
- Harsh or slipping shifts

Before adjusting, check linkages for binding or bent parts and loose retaining nuts. Adjustment procedures vary; follow instructions provided by the manufacturer. The procedures presented here are general guidelines that apply to most linkage adjustments.

ACCELERATOR LINKAGE

The linkage from the accelerator pedal to the engine must be adjusted correctly on all vehicles. This is especially true on transmissions that use mechanical linkage to control the throttle valve and provide forced downshifts. The procedures for checking and adjusting accelerator linkage differ between manufacturers. However, there are two important points to remember for all vehicles:

1. When the accelerator is depressed all the way to the floor, the throttle plates should be wide open, with the throttle lever against the wide-open throttle stop.
2. When pressure on the accelerator is released, the linkage must return freely and immediately to the idle position.

THROTTLE VALVE LINKAGE

Automatic transmissions use throttle pressure to control mainline pressure and regulate upshifts and downshifts according to the engine throttle position. The throttle valve in the valve body must move in direct proportion to the throttle opening of the engine. This is achieved either mechanically through linkage or cables, or by intake manifold vacuum acting on a vacuum modulator. Mechanical systems, both linkage and

cable, are usually adjustable. Most vacuum operated systems do not need adjustments.

DOWNSHIFT LINKAGE

Downshift linkage, which is also called kick down linkage, is used on some transmissions. Generally, a rod-type linkage is used to connect the downshift valve in the valve body to the accelerator pedal. The rod forces downshifts at wide-open throttle when the accelerator is depressed to the maximum. You can check the kick down shift points by depressing the accelerator through the detent at the appropriate speed during a road test. Kick down shift points are an indication of how the downshift valve is working.

GEARSHIFT LINKAGE

The gearshift linkage, also called manual valve linkage, positions the manual valve in the transmission valve body to direct fluid to the correct circuits for the driving range selected. If the shift linkage is out of adjustment, fluid can leak past the manual valve and cause erratic transmission operation. Under normal circumstances, the gearshift linkage does not need adjustment. Adjustment is required when a transmission is removed and reinstalled or when repairing or replacing worn or damaged linkage components. On some transmissions, the shift lever and its linkage must be removed to provide room for band adjustment, and the linkage will need adjusting on reassembly.

FILTERS AND SCREENS

All automatic transmissions use a filtering device to remove foreign or abrasive particles, varnish, and sludge from the fluid. This filtering device can be either a disposable paper or fabric element or a reusable screen. On transaxles that do not have the valve body mounted to the bottom of the case, the filter is located at the point where fluid leaves the sump rather than at the valve body. The suction side of the pump is connected to the filter, so the fluid is cleaned before it enters the system. Spin-on canister type filters are used on some of the later transmissions; you could see this in a light truck application and or some non-domestic vehicles.

1. All of the following statements about a torque converter are true EXCEPT:

a. It is located between the engine and transmission
b. It is located between the transmission and driveshaft
c. It is filled with automatic transmission fluid
d. It usually has no drain plug

2. Using the wrong type of transmission fluid:

a. May cause shifting problems
b. May cause slipping problems
c. May damage the transmission
d. All of the above

3. Milky pink ATF generally indicates :

a. Clutch or bearing failure
b. Clogged filter
c. Water contamination
d. Low fluid level

4. Technician A says the ATF filter should be replaced when the fluid is changed. Technician B says the ATF filter is located inside the transmission pan. Who is right?

a. Technician A only
b. Technician B only
c. Both Technician A and B
d. Neither one

5. Which of the following conditions would best describe severely overheated transmission fluid?

Choose one answer.

a. Dark brown with particle contamination
b. Dark gray or black with particle contamination
c. Foamy red or reddish-brown with a pungent odor
d. Dark brown with a pungent odor

6. Transmission fluid is leaking from the manual leakage near the transmission case. Technician A says that the shift linkage will need to be disassembled to replace the shift linkage seal. Technician B says that the transmission pan will need to be removed to replace the shift linkage seal. Who is correct?

A. Technician A
B. Technician B
C. Both A and B
D. Neither A nor B

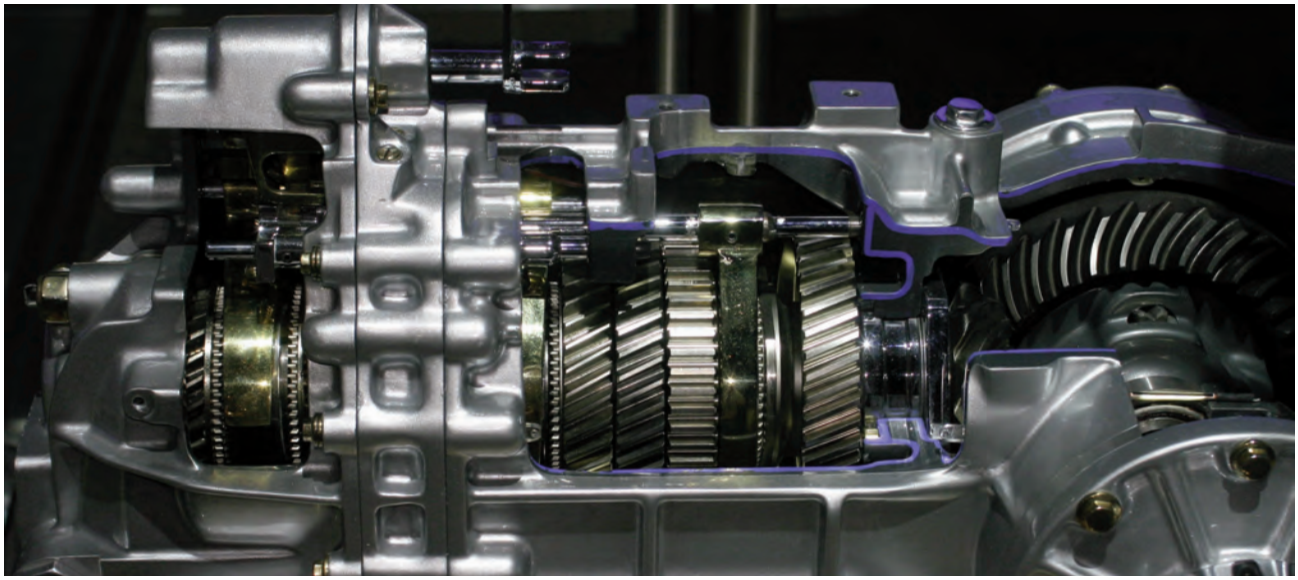
7. A torque converter defect can cause all of the following symptoms EXCEPT:

a. Slow acceleration from a stop
b. Erratic shifting
c. Poor high speed performance
d. Overheating

Answer Key: 1)B 2)D 3)C 4)C 5)D 6)A 7)B

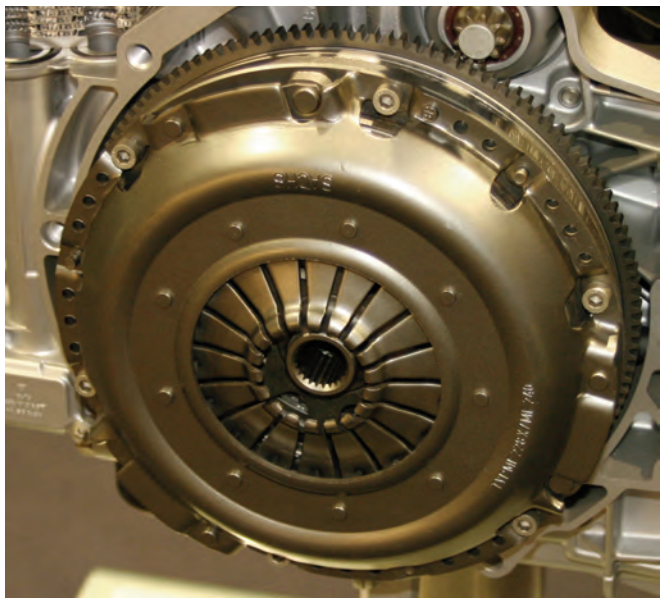
ASE G1

Manual Transmissions



Manual transmissions vehicles use driver selected gears to control the drive ratios to the wheels. While not as complex as an automatic transmission, they can fail several ways that can leave the driver at the side of the road.

Clutch



The number of service operations that can be performed while the clutch assembly is in the vehicle are limited. When you suspect clutch problems, a road test is required to fully evaluate the operation of the clutch assembly.

The symptoms of a clutch problem generally call into four categories:

- Does not release
- Slips
- Grabs or chatters
- Produces excessive noise

CLUTCH FUNCTION

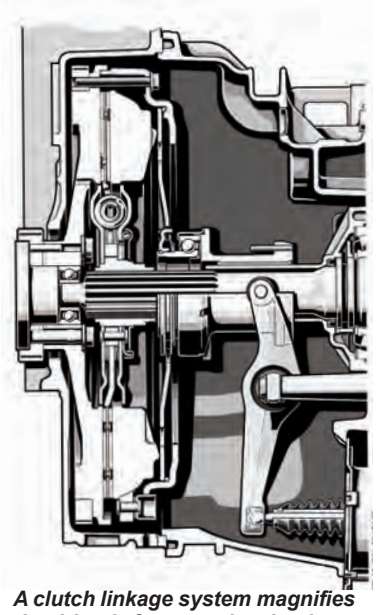
Clutch function refers to how well the clutch operates during a road test. You should evaluate how smoothly the clutch engages and disengages and how well the clutch transmits engine power. A warped pressure plate may possibly cause a pulsating pedal. This condition may be the result of missing springs or misadjusted counterbalance fingers.

A chattering clutch produces a vibration or jerking motion as it engages when the vehicle is accelerated from a stop. A faulty disc, flywheel or pressure plate causes clutch chatter. Both of these conditions would require the clutch to be disassembled to perform repairs. A broken engine or transmission mount can also cause these symptoms, so check mounts before removing the clutch. An increase in engine RPM should be accompanied by an equal increase in road speed as the vehicle is accelerating. If the engine seems to race without propelling the car forward, check for clutch slippage.

CLUTCH LINKAGE

Before attempting to adjust the clutch several components of the release system must be inspected for wear or damage.

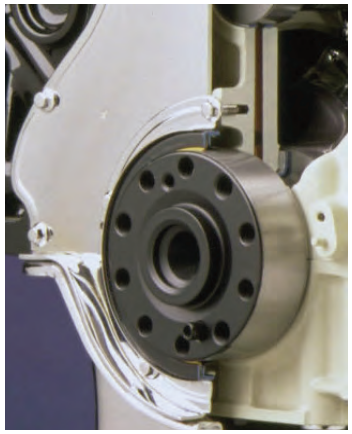
- Linkage pivot points
- Cables
- Bushings
- Shafts
- Mounting brackets
- Automatic or manual adjuster assemblies



A clutch linkage system magnifies the driver's force on the clutch pedal through leavers or hydraulic force, or on some vehicles it will use both.

OIL LEAKS

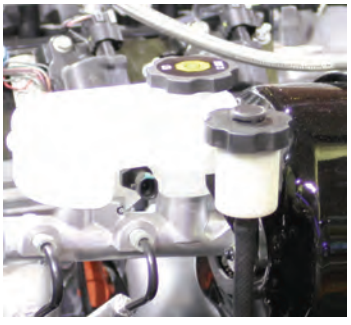
Defective engine crankshaft seals or transmission input shaft seals will allow oil to reach the clutch. If the vehicle has a removable inspection cover, look for traces of oil in the bell housing or on the clutch assembly. The presence of oil requires removal of the clutch assembly to repair the oil leak and to replace the oil soaked clutch.



If a rear main or crankshaft seal is leaking it can contaminate the friction surfaces of the clutch

HYDRAULIC CLUTCH

A hydraulic clutch system consists of a master cylinder and a slave cylinder. The master cylinder is activated by the clutch pedal, and the slave cylinder uses the pressure from the master cyinder to actually operate the clutch fork. Most clutch hydraulic systems generally operate on DOT3 brake fluid, but there are exceptions. Always check service manuals to make sure you install the correct fluid. Handle brake fluid with care to avoid spills, as it will damage painted surfaces.



***A hydraulic clutch may have a separate reservoir mounted next to the brake master cylinder reservoir. Some vehicles pull fluid from the brake system's* reservoir.**

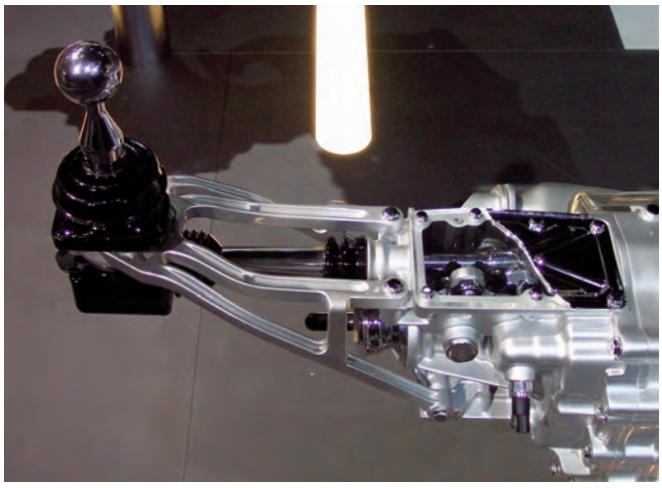
RELEASE BEARING

A bearing that slides around the transmission input shaft and pushes (or in some cases pulls) against fingers or the spring in the pressure plate to disengage the clutch. The bearing is held by a yoke lever attached to the clutch linkage and clutch pedal, or a telescoping hydraulic linkage inside the bellhousing. When the pedal is depressed, the clutch linkage pushes the release bearing forward against the fingers on the clutch plate. This relieves spring tension, allowing the pressure plate to release the clutch. Adjustment of the linkage is important for proper clutch engagement and release, as well as bearing life. A chirping noise that intensifies when the pedal is slowly depressed usually indicates a bad release bearing.

SHIFT LINKAGES

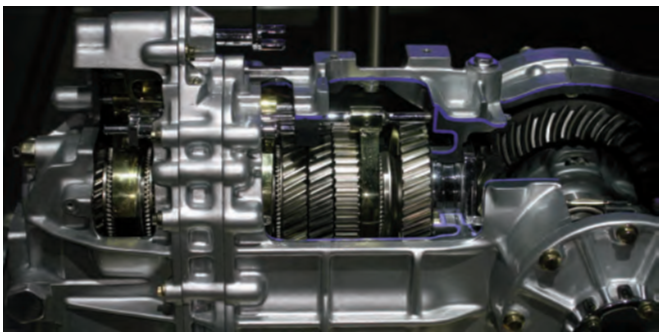
Many customers complaints deal with shift qualities, such as feel and difficulty shifting. You should road test the vehicle to verify the complaint and also check clutch release operation. If the clutch is not operating correctly, you will not be able to shift the transmission properly. Shift linkage adjustments for most manual, RWD transmissions are basically the same.

SHIFT LEVER



On some transaxles, the shift control lever is mounted on an extension rod assembly. If the shaft strokes become short or the gears do not completely mesh, check the shifter control shaft bearings for wear. Always replace worn shifter control shaft bushing before attempting to adjust the shifter.

FINAL DRIVE



Transaxle final drive assemblies incorporate the differential and ring gear into one assembly. The ring gear is driven by a pinion gear on the output shaft. The differential operates in a similar way to the RWD differential assemblies.

BEARING INSPECTION

Thoroughly clean the input and output shaft bearings in solvent and air dry them. Do not spin bearings with compressed air; this can damage them. Carefully inspect the bearing for signs of wear or damage.

Lightly coat each bearing with oil and rotate the outer race by hand. Any roughness means the bearing is bad and must be replaced. Inspect the countershaft needle bearing for damage. If any of the bearings or bushings are sealed, do not attempt to clean or lubricate them. You can place sealed bearings in a vise and load them slightly to check for wear.

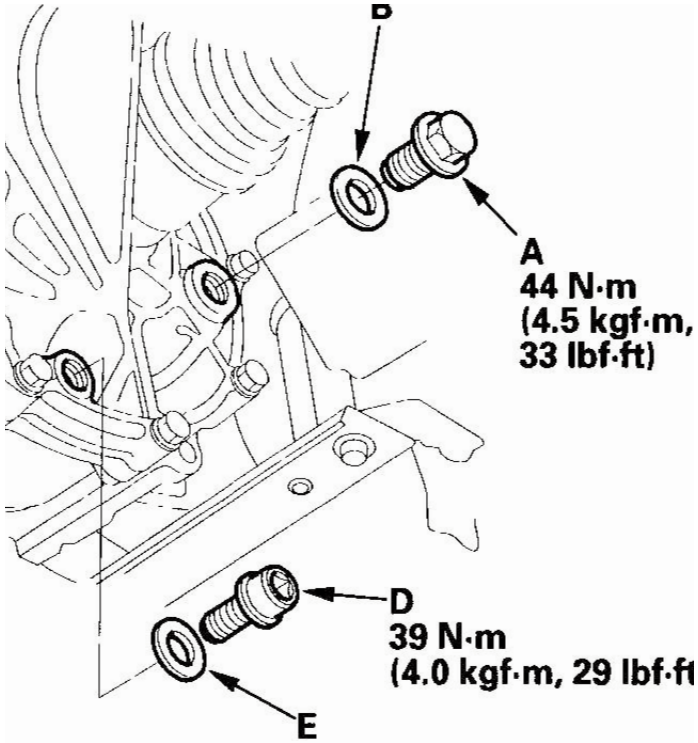
RANGE SWITCHED OR SENSORS

Many transmissions and transaxles are equipped with a multiple contact switch or sensor that sends a signal to the PCM indicating the gear range selected. The input signals are used for adjusting engine timing, fuel injection parameters, and illuminating the backup lamps when reverse is engaged

FLUIDS

In years past, the conventional "90-weight" transmission oil was used in all manual transmission applications. Beginning about 25 years ago, transmission manufacturers began changing over to lower-viscosity oils to reduce rotating friction in their transmissions and to increase fuel economy. In that era, some manufacturers recommended engine oil and even automatic transmission fluid for their manual transmissions.

Most currently recommend synthetic-based oils to improve lubrication and reduce rotating friction. Because



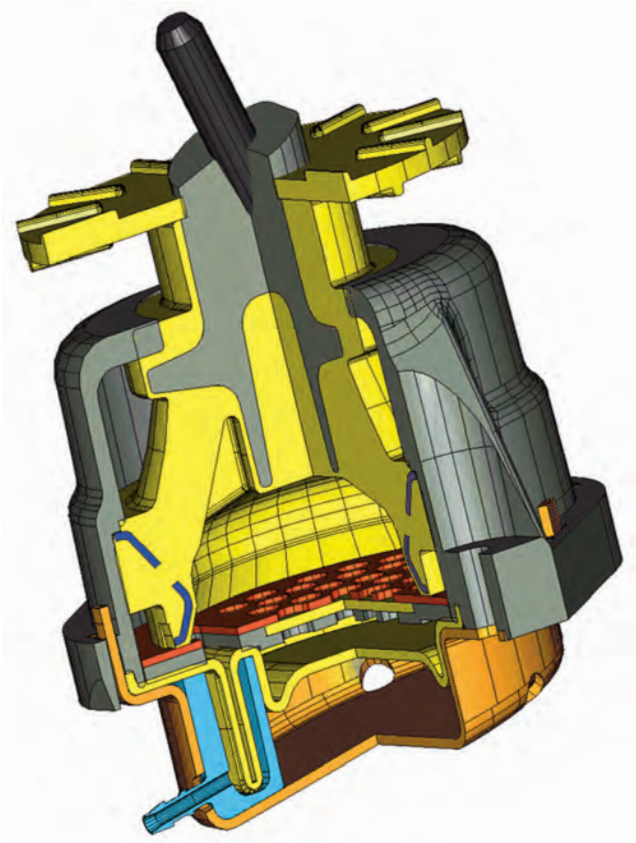
Most manual transmissions have a plug to drain the fluid and fill the fluid. Once the level of fluid has reached the fill hole it is full. But, on some transmissions the service information will ask for a specific volume of fluid, always follow this recommendation.

transmission gear shift synchronizers are designed for specific types of lubricants, a vehicle owner would likely experience hard shifting on cold mornings if a substitute lubricant is installed.

Today, we have very sophisticated five and six-speed, high-performance manual transmissions that require application-specific lubricants. In addition, we also have many automatic transfer cases in 4WD applications that might use friction clutches to engage front drive trains and equalize input and output shaft speeds. Here again, the oil must be formulated to allow smooth 4WD engagement. So the lesson to be learned here is that it's always best to use the recommended fluid for any manual transmission or automatic transfer case application.

MOUNTS

For many years, automakers relied on solid rubber motor mounts to support the engine. The natural flexibility in rubber allows the mounts to absorb vibration. But if the rubber is too compliant, the engine may experience excessive motion under load that could stress and crack exhaust pipes and connections. And with such tight clearances under the hood, there's a risk of something rubbing against something else and causing additional



Some motor and transmission mounts are active and have a vacuum line that controls the stiffness of the mount.

noise or problems. So, the rubber in the mounts has to be relatively stiff to limit compliance so the engine does not rock excessively when it is under load.

Motor mounts support the weight of the engine and transaxle. If a mount fails, it can make the transmission difficult to shift.

Engine vibration is usually most noticeable when the engine is idling, especially if the engine has an odd fire configuration as some V6 engines do. Four-cylinder engines, as well as diesels, can also produce a lot of vibration at idle. Vibrations can be amplified even more when high-load belt-driven accessories, such as the A/C compressor, are engaged while the engine is idling.

HYDROMOUNTS

A little more than 30 years ago, the automakers came up with a solution for reducing Noise, Vibration and Harshness (NVH). It was the glycol-filled "hydromount." Replacing solid rubber motor mounts with ones made of hollow rubber filled with fluid allowed the mounts to absorb more vibration without allowing exces-sive engine motion. It was a totally passive design that did not require any other modifications.

A hydromount that has lost its fluid is somewhat like a

If an engine mount is leaking oil, it is a sign of a failure of the mount.

jelly-filled donut that has lost its filling. It goes flat and can no longer provide the same degree of NVH dampening as it once did. The mount has reached the end of the road and needs to be replaced.

Obviously, the only way to restore the same level of NVH control is to replace bad hydromounts that have lost their fluid with new hydromounts.

In some cases, the original hydromounts (whether they are still good or not) may be replaced with solid motor mounts to stiffen things up. This would be the case with a street performance or racing application where increased engine torque has to be controlled with stronger, stiffer motor mounts.

ACTIVE MOUNTS

Active mounts can be relatively soft at idle to absorb the unwanted shakes produced by widely or unevenly spaced cylinder firings, then stiffen up at higher engine speeds and loads to limit unwanted engine motions. It's the best of both worlds, but it does require some type of external controls and inputs. These mounts are found on a number of late model vehicles including Honda, Hyundai, Jaguar, Lexus, Toyota and others.

On 2005 to 2008 Toyota Camry V6 models, for example, a vacuum-actuated "Active Control Engine Mount (ACM) system is used to reduce NVH. The front engine mount has a hollow chamber inside that allows the stiffness of the mount to change when vacuum is applied. A duty cycle Vacuum Switching Valve (VSV) on the outside of the mount is controlled by the powertrain control module. When the engine is idling, the PCM completes the ground circuit to the VSV solenoid, allowing intake

vacuum to be applied to the mount. This makes the mount more compliant and allows it to absorb more vibration and shake. At higher engine speeds, the PCM reduces the frequency of the pulse signal to the VSV to gradually increase the stiffness of the mount to match engine speed.

On the Toyota application (which is similar to the active mount systems that Honda and Hyundai use), power to the VSV control valve is routed through the fuel injection relay. Vacuum is routed to the active mount through a pair of hoses connected to the engine's vacuum reservoir.

On this system, a noticeable increase in NVH can occur if the active mount leaks vacuum, if the hose connections leak vacuum (or are obstructed), or if there is a problem with the VSV control valve, wiring harness or PCM.

The motor mount can be diagnosed with a handheld vacuum pump to see if it holds vacuum or not. If it leaks, it needs to be replaced. You can also use the vacuum pump gauge or your finger to see if vacuum is reaching the VSV control valve when the engine is idling. No vacuum or weak vacuum would tell you there's a leak in the plumbing somewhere.

TRANSMISSION PROBLEMS

HARD SHIFTING

Hard shifting occurs when the gears engage, but shift effort is excessive. Check the synchronizer hub sleeve for smooth operation. The sleeve should slide freely over the blocking ring and gear teeth. If it will not move easily, disassemble the synchronizer assembly and clean and inspect each part. The hub should be free of burrs and other signs of wear. Use a small file to remove burrs from the hub.

Whenever the synchronizers are disassembled, replace the inserts, also known as detents or dogs, and springs. The sleeve should be cleaned, and internal splines should be inspected for wear. Pay particular attention to the chamfer points at the end of each spine. Assemble the sleeve and hub and check for interference between them. If individual parts are not available, replace the entire synchronizer assembly.

JUMPING OUT OF GEAR

A transmission jumps out of gear when the lever suddenly slips into neutral while the vehicle is being driven. This problem can be caused by excessive wear in the synchronizer inserts and springs, shift forks, shift rails or countershaft. Most manual transaxles do not have a side shift cover containing the shift forks and detent mechanisms. The type of construction in the manual transaxles use shift shafts with the shift forks secured to the shafts with rolls pins. Detent rollers give the feel when shifting and rebuff any attempt to engage two gears at one time. Repair and/or inspection of the shift forks and shift shafts require removal from the vehicle and disassembly of the transaxle.

BLOCKOUT

Blockout occurs when the driver moves the shift lever until the synchronizer sleeve is engaged with the blocking ring and the gear does not immediately engage. When it does engage, the driver feels a double bump at the shift lever. Check the gear cones for worn surfaces, and ensure that the blacking ring is not stuck on the cone. Generally, the gap between the blocking ring and the gear cone should be greater than .024 inches. Replace the blocking ring if it is worn below specifications.

GEAR CLASH

Gear clash is a loud grating or buzzing sound. This occurs if the chamfers on the synchronizer sleeve contact those on the gear before the blocking ring has matched the speeds of the two parts. Check the sleeve chamfers for wear, chipping and burrs. Replace the synchronizer assembly and blocking rings if any damage is present. Also, inspect the clutch gear teeth on the synchronized gear in question. If these teeth are worn, replace the gear.

NOISE

Noise can be caused by worn gears or damaged bearings. The rear output shaft bearing usually causes noise during deceleration. Carefully inspect the gear tooth contact pattern. Pay special attention to the contact between the mina drive gear and the driven gear on the counter gear. The main drive gear bearing produces noise similar to the main drive gear and driven counter gear.

input shaft, as when changing gears or when the transmission is in neutral.

1. Most manual transmissions and transaxles require what type of lubricant?
a. Multi-viscosity gear oil
b. Straight 80W gear oil
c. Automatic transmission fluid (ATF)
d. It depends on the vehicle application

2. The clutch master cylinder is activated by the:
a. Slave cylinder
b. Shift linkage
c. Clutch pedal
d. Clutch fork

3. When a gear engages but the shift effort is excessive is an example of:
a. Gear clash
b. Blockout
c. Hard shifting
d. Jumping out of gear

4. If a motor mount fails, it can make a manual transmission difficult to:
a. Shift
b. Drain
c. Engage the parking brake
d. All of the above

Answer Key: 1)D 2)C 3)C 4)A

ASE G1

Driveshafts, Bearings & Axles

The drivetrain transfers power from the transmission to the wheels. Almost all cars have driveshafts and differentials that transfer and deliver power to the wheels.

Vehicles with All-Wheel-Drive (AWD) and Four-Wheel-Drive can have even more components like center differentials and transfer cases.

Driveshafts and Axles

The driveshaft transfers the rotation of the transmission to the rear wheels through a differential that distributes the energy to both wheels.

General Diagnosis

Driveshaft service for the shafts fitted to rear wheel drive vehicles consists of:

- Visually inspect the driveshaft
- Balancing
- Checking and adjusting driveshaft angles
- Inspecting the slip yoke and slip joint
- Servicing universal joints
- Removing the driveshaft for further inspection

Bent Driveshaft Shafts

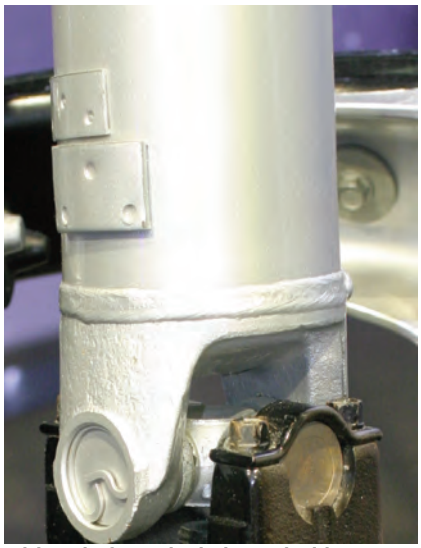
A bent driveshaft can cause vibration in the vehicle. If a bent driveshaft is suspected, the technician will need to perform a runout check on the driveshaft. The dial indicator must be placed at a 90 degree angle from the driveshaft for accurate readings. Measure the run out 3 inches from each yolk weld and verify it is within specifications in the service manual. Then take a second measurement in the center of the driveshaft to verify it is within specifications. If it is not, the driveshaft must be replaced.

Driveshaft Vibrations

Driveshaft vibrations can be classified into three different orders: first, second and third orders. A first-order vibration may be caused by a bent or out-of-balance driveshaft condition. A second-order vibration may be caused by driveshaft angle, U-joint cancellation and bad U-joints. A third-order vibration is often caused by a defective tripod joint on a front wheel drive vehicle.

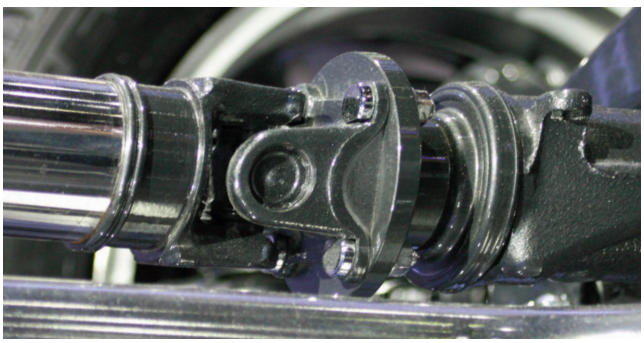
Driveshaft Balancing

Balance the wheels and tires first. If the wheel and tire balancing do not eliminate vibration, inspect the drivetrain. Check the driveshaft for deposits, such as undercoating compounds, and look for dents or other signs of physical damage



A drive shaft can be balanced with weights. If a weight falls off, the driveshaft becomes unbalanced and vibrations could be felt by the driver.

Driveshaft Angles



Incorrect driveshaft angles can also cause vibration, especially during acceleration. The vibration can often be felt but not heard.

Special gauges known as inclinometers are used to measure driveline angles. Several types of inclinometers are available ranging from simple bubble or spirit protractors to more elabo-rate electronic devices. All may be used to measure universal joint angles. To adjust front U-joint angles, add or remove shims under the rear transmission mount. To adjust rear U-joint angles, place tapered shims between the rear lead springs and the axel housing, or adjust the control arm linkages on the coil spring suspensions.

Slip Yoke

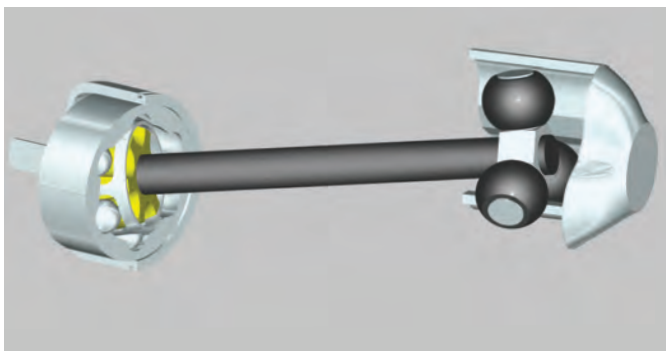
A driveshaft slip yoke generally does not require routine service because the yoke splines and outside surface are lubricated by transmission lubricant. However, some do require periodic lubrication with grease to their splines. Check the service manual specifications for proper grease type and recommended service intervals. Leaks around the output shaft can be caused by a worm seal or output shaft bushing or by damaged to the yoke service.

If the surfaces of the slip yoke are damaged, transmission fluid can get past the seal.

Universal Joints

Most factory-installed universal joints cannot be lubricated unless they are disassembled. Some factory-installed and most aftermarket U-joints have grease fittings, commonly called zerk fittings. Grease should be pumped into the joint until fresh lube appears at each cap. If lube does not appear at each cap, disassemble the joint and inspect for damage or contamination.

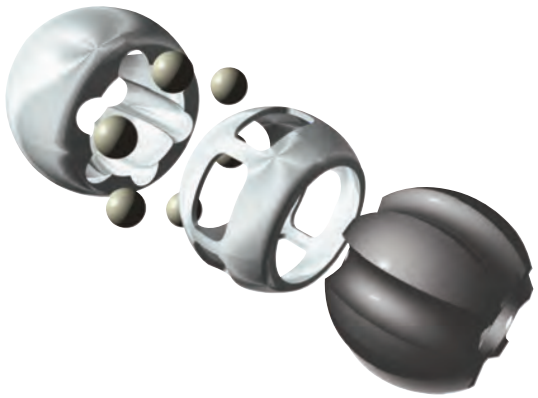
Front Wheel Drive Axles



Front-wheel drive axle inspection and repair involves inspecting and replacing constant-velocity joints and removing and replacing axle shafts.

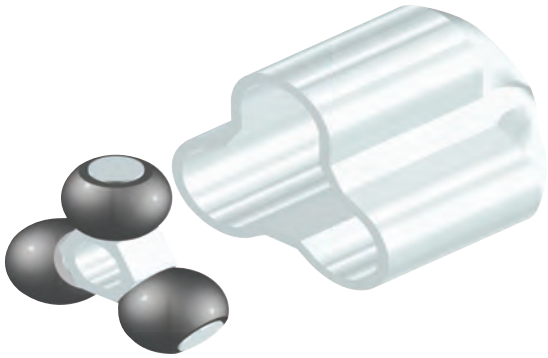
Constant-Velocity (CV) Joints

A modern CV joint can be expected to last about 100,000 miles, but without proper lubrication, it will wear much faster. Most CV joint failures are due to a lack of lubrication and/or contamination caused by a torn boot. Always check CV joint boots for damage to ensure that lubricant remains in the joint. Outer CV joints, at the wheel end of the axel shaft, usually wear more quickly than the inner joints because they are subject to a variety of axel shaft operating angles. The



An outer Constant Velocity (CV) joint can turn at up to a 40º angle. This type of joint is called a repezze joint. If debris gets into the joint it can cause wear on the surfaces. This can cause noise and vibration.

Ball bearing style wheel bearing



An inner CV can only be turned 10-20º. This type of joint is called a tripod. The design allows for the axle to change length.

shaft at the outer CV joint may move as much as 40 degrees to compensate for the suspension and steering angles. Normal operating angles at the inner CV joint are only about 10-20 degrees.

WHEEL BEARING INSPECTION

A body vibration that occurs when the brakes are applied during a road test may be caused by loose wheel bearings. However, a worn wheel bearing makes a growling sound when the vehicle is moving, not only when the brakes are applied. To confirm a wheel bearing problem, swerve the vehicle back and forth to alternately load and unload the bearings on opposite sides of the chassis. The noise from the bad bearing will increase with the load on that side of the vehicle and decrease as the load is reduced. Besides bearing noise, there are three other signs that indicate that a wheel bearing needs attention or replacement: roughness, grease seal leakage, and excessive axial play.

As these contaminants circulate through the grease and between the races and bearings, the components wear. Once a bearing is worn, the wear rate is accelerated by seals that no longer keep out contaminants, and increased heat may breakdown and eventually expel the lubricants. This is a slippery slope that could quickly lead to catastrophic failure.

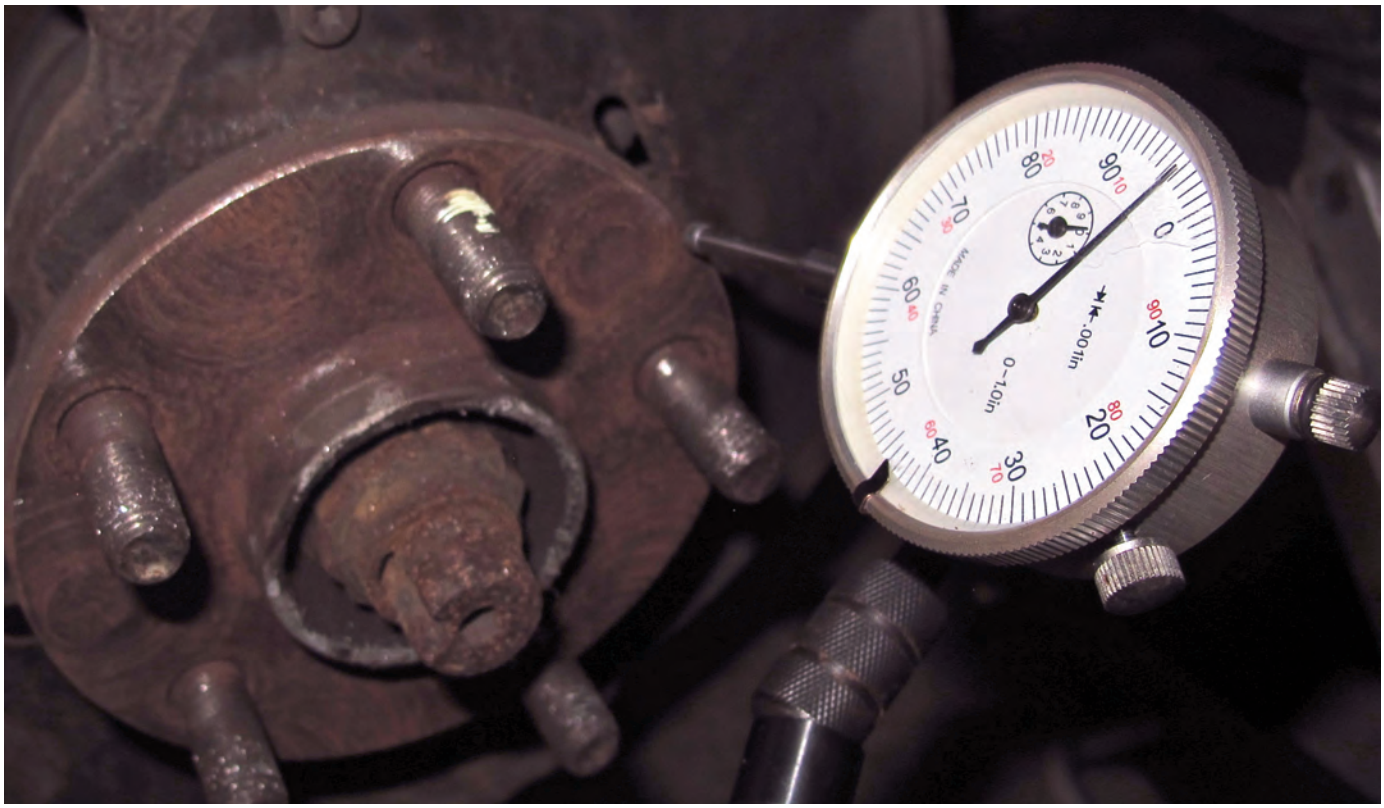
BEARING ROUGHNESS

The same wear that causes bearing noise can also be felt as a roughness if the wheel is rotated with the tire off the ground. If the suspect bearing is not on a driven axle, raise and support the vehicle, then slowly rotate the wheels by hand to check bearing condition. Feel for roughness in the bearing as it turns, and listen for a low-frequency rumbling noise. Compare the results on opposite sides of the vehicle to determine where the problem lies.

Some hub units and sealed bearings are being filled with a special grease that prevents damage while the bear-ing is being shipped. The grease is designed to have a high viscosity during shipping so the balls or rollers do not destroy the surfaces of races. After the bearing is installed, certain elements in the grease break down and the bearing turns normally.

BEARING GREASE SEAL LEAKAGE

Grease leaking from the bearing grease seal can be a sign that excessive bearing play has caused seal damage. Always replace leaking grease seals to prevent



Bearing axial play is measured at the edge of the bearing hub on a dial indicator mounted to the suspension.

contamination of the brake linings. Service the wheel bearings at the same time.

The leading cause of a wheel bearing failing is its seal. The inside of a bearing can be a hot place. When a bearing is cooling off, the contracting metal, air and lubricant can create a vacuum that is hopefully held by the seals. If the seals are worn and can't hold the vacuum, the bearing or sealed hub unit will suck in outside air, debris and water. In some parts of the country that use salt on the roads, it is almost as bad as ocean water on wheel bearings.

BEARING GREASE SEAL LEAKAGE

Grease leaking from the bearing grease seal can be a sign that excessive bearing play has caused seal damage. Always replace leaking grease seals to prevent contamination of the brake linings. Service the wheel bearings at the same time.

The leading cause of a wheel bearing failing is its seal. The inside of a bearing can be a hot place. When a bearing is cooling off, the contracting metal, air and lubricant can create a vacuum that is hopefully held by the seals. If the seals are worn and can't hold the vacuum, the bearing or sealed hub unit will suck in outside air, debris and water. In some parts of the country that use salt on the roads, it is almost as bad as ocean water on wheel bearings.

BEARING AXIAL PLAY

If inward and outward movement of the bearing hub or axle exceeds specifications, the bearings must be serviced. Checking the axial play, or endplay, with a dial indicator is the only accurate means of determining the condition of sealed, double-row bearing assemblies.

To check:

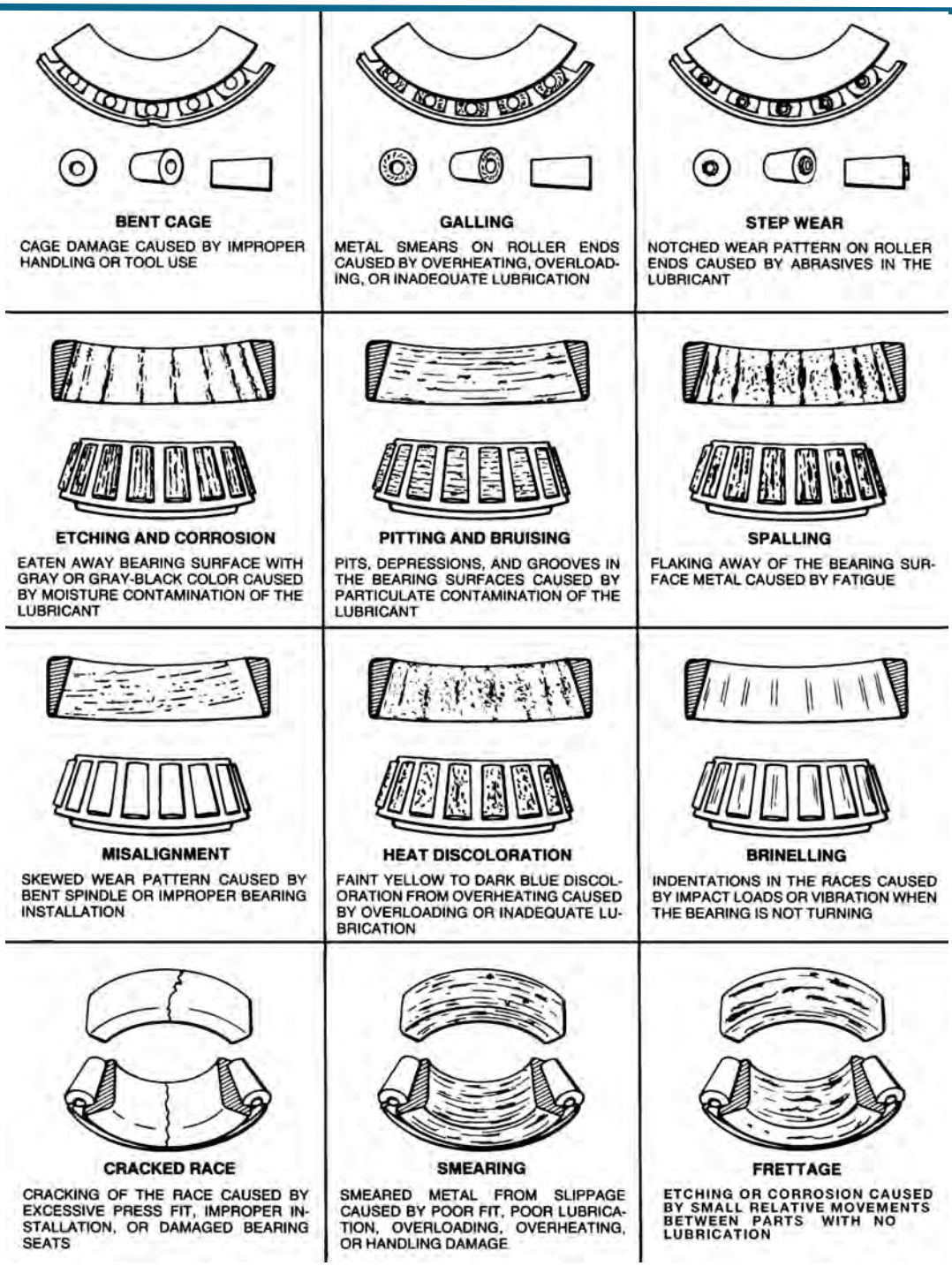
1. Raise and properly support the vehicle, then remove the wheel.

2. If the bearings to be checked are on a wheel equipped with a disc brake, push the caliper pistons into their bores just far enough that the brake pads do not drag against the rotor.

3. Mount a dial indicator on the suspension and position the plunger against the edge of the bearing hub**.**

4. Push the hub inward toward the suspension until it will move no farther. Hold the hub in position and zero the indicator dial.

5. Pull the hub outward away from the suspension until it will move no farther. The dial indicator reading equals the bearing axial play.



Tapered roller bearing inspection guide.

Adjustable dual wheel bearings, or tapered roller bearings, which are used on the front wheels of most rear-wheel-drive (RWD) vehicles and at the rear wheels of most front-wheel-drive (FWD) vehicles, generally operate with 0.001 to 0.005 inch (0.025 to 0.127 mm) of axial play.

FWD vehicles usually have sealed wheel bearings at the front. Typically, sealed ball bearing assemblies are allowed a maximum of 0.002 inch (0.05 mm) of axial play. Consult the factory shop manual to get the proper specifications. If the axial play of a sealed bearing exceeds the amount allowed by the vehicle manufacturer, replace the bearing.

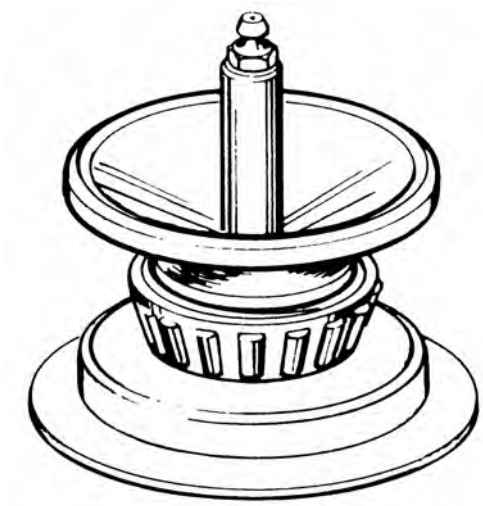
WHEEL BEARING SERVICE

Whenever you replace a tapered roller or ball bearing that has a separate outer bearing race, you must replace the race as well. If you install a new bearing in an old race, it will not fit properly, and premature bearing wear and failure will result. Also, install new grease seals whenever wheel bearings are serviced.

WHEEL BEARING CLEANING

When an unsealed wheel bearing is removed, wipe as much old grease as possible off of the bearing, using dry rags or paper towels. Then, inspect the grease on the towels for metal chips or other indications of bearing wear or damage. Clean bearings with fresh petroleum-base solvent. Wash each bearing individually and keep bearings with detachable outer bearing races separated, so they can be assembled in the same races from which they were removed.

WHEEL BEARING LUBRICATION



A bearing packer uses air or hydraulic pressure to force grease into the bearing.

Always pack a new or used wheel bearing with the type of grease recommended by the vehicle manufacturer. Several different thickening agents are used to formulate greases, and most do not mix. Always clean away every trace of old grease before repacking a wheel bearing, and never add new grease to old.

To pack a wheel bearing, work the grease into the cage and races and between the balls or rollers, so that no air spaces remain. The most effective way to do this is to use a bearing packer, which uses air or hydraulic pressure to force new grease through the entire bearing, **figure 6-3.**

If a bearing packer is unavailable, pack wheel bearings by hand. To hand pack a tapered roller bearing, fill the palm of one hand with grease. Grasp the bearing in your other hand so the large end faces down. Then, draw the bearing across the grease in your palm to force grease into the cage and rollers until it oozes out the opposite side. Repeat this process all around the bearing until it is completely filled with grease. Finish by spreading a medium coating of grease around the outside circumference of the bearing.

TAPERED ROLLER WHEEL BEARING SERVICE

Whenever you replace a tapered roller bearing that has a separate outer bearing race, you must replace the race as well. If you install a new bearing in an old race, it will not fit properly, and premature bearing wear and failure will result. Also, install new grease seals whenever wheel bearings are serviced. Serviceable tapered roller wheel bearings are typically found at the front of RWD vehicles, and at the rear of FWD vehicles.

Over filling a bearing with too much grease can cause excess churning of the grease during operation and high temperatures, resulting in overheating and excess grease purging (leaking). Overheating occurs because the heat generated cannot dissipate correctly, continually building until damage occurs. When a bearing overheats and pushes out the grease, the sealing lip can be damaged and “blown out” in the reverse direction.

To service a set of adjustable dual wheel bearings, follow these steps:

1. Raise and support the vehicle so the wheels with the bearings to be serviced hang free, then remove the wheels.

2. Pull the dust cap from the center of the hub to expose the adjusting nut. Remove the cotter pin, retainer, or any other locking devices from the nut. On vehicles that have a split nut with a pinch bolt, loosen the bolt so the adjusting nut can turn freely

3. Loosen the adjusting nut by backing it off several turns to allow approximately 0.5 inch (13 mm) of play.

4. Pull the drum or rotor outward to free the thrust washer and outer wheel bearing, then push the drum or rotor inward to reseat it on the spindle.

5. Hold the drum or rotor steady to keep it centered, then remove the adjusting nut, thrust washer, and outer wheel bearing from the hub, and set them aside.

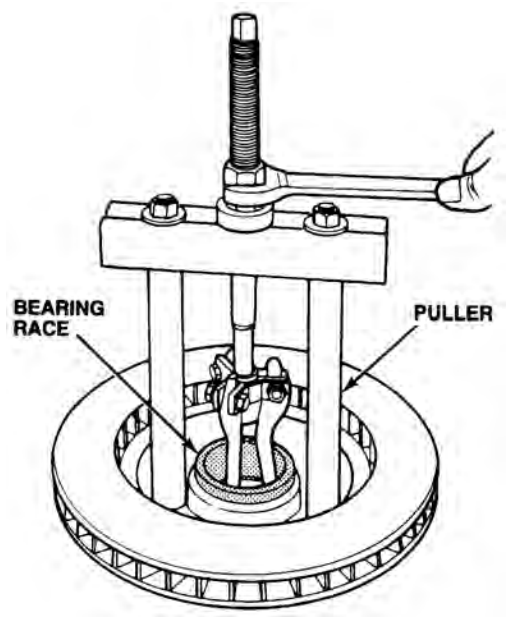
6. Pull the drum or rotor straight outward to slide it off the spindle, taking care not to drag the inner wheel bearing across the adjusting nut threads. The brake adjustment may need to be loosened to remove some drums.

7. Use a seal puller or a pair of pry bars to carefully remove the grease seal and inner bearing.

8. Clean and inspect the bearings and bearing races as described earlier. Also, clean all old grease from the inside of the drum or rotor hub.

9. If installing new bearings, remove the old outer bear-

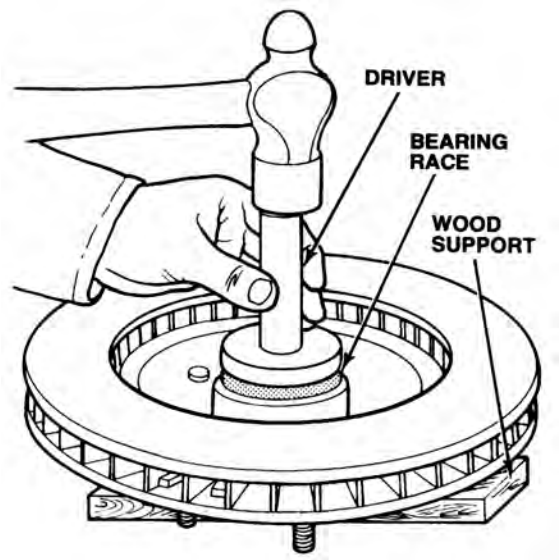
ing races from the drum or rotor hub. There are two methods of removing bearing races:



Using a bearing race puller to remove the old race from the hub.

a. With a bearing race puller pull the races.

b. With a soft-metal (such as brass) drift. Fit the drift through the hub so it firmly contacts the backside of the race. Strike the drift with a hammer while moving it around the race to drive the race from the hub.



Select a suitably sized driver to install bearing races into the hub.

10. New races are pressed or driven into the hub with a bearing race driver or a suitably sized socket. Support the underside of the hub with a block of wood to prevent damage while installing races.

11. Clean and inspect the spindle for rust, scratches, and discoloration. If the spindle is badly scored, cracked, or discolored from overheating, replace it.

12. Lightly coat the spindle with grease.

13. Pack the wheel bearings with grease as described earlier.

14. Place the drum or rotor outer side down on the workbench and lightly coat the inside of the hub with grease to prevent rust.

15. Put a medium coating of grease on the inner bearing race, then place the inner bearing into the race.

16. Use a seal driver to install the grease seal, then apply a light coating of grease on the seal lip.

17. Turn the drum or rotor over and apply a medium coating of grease to the outer bearing race.

18. Fit the drum or rotor squarely over the spindle and slide it straight back into position. Take care to avoid dragging the bearing races across the spindle threads.

19. Hold the drum or rotor in place, fit the outer bearing over the end of the spindle, and slip it into position in the hub. Install the thrust washer over the bearing and thread the adjusting nut onto the spindle finger-tight.

20. Adjust the wheel bearings as described below.

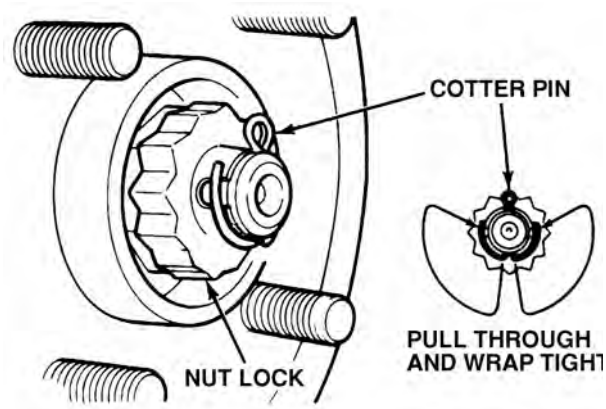
21. If the axle is equipped with disc brakes, install the anchor plate and brake caliper. If the axle has drum brakes and the brake adjustment was loosened, adjust the brakes.

22. Install the wheel and tighten the lug nuts to specified torque following the correct sequence.

TAPERED ROLLER BEARING ADJUSTMENT

There are three ways to adjust tapered roller wheel bearings: by hand, with a torque wrench, or using a dial indicator. Once the axial play is properly set, lock the adjusting nut in place, and install the dust cap with a soft-faced hammer. With a castellated adjusting nut, slots on the nut must align with the hole drilled through the spindle, in order to install the cotter pin. If slots are out of alignment after setting axial play, tighten the nut just enough to insert the cotter pin.

Do not loosen the nut. When a lock nut is used to secure the adjusting nut, place the lock nut over the adjusting nut so the slots in the lock align with the cotter pin hole in the spindle. With either design, insert a new cotter pin and



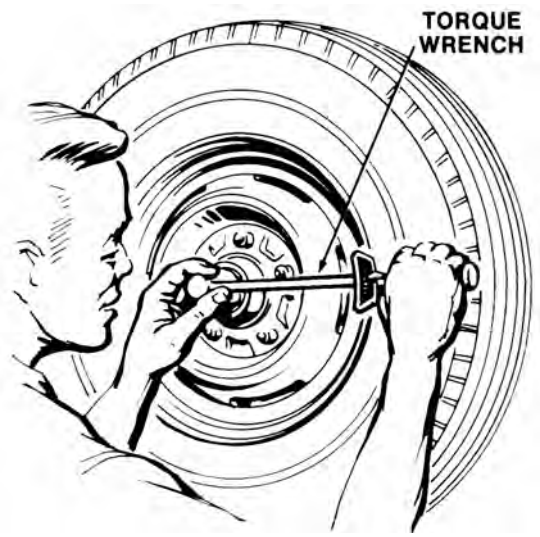
Wrap the tabs of the cotter pin around the nut lock or adjusting nut to secure.

wrap the tabs around the nut lock or adjusting nut to secure it**.** To secure a slotted adjusting nut with a pinch bolt, simply tighten the bolt to the specified torque.

HAND ADJUSTMENT

To adjust the wheel bearings by hand, rotate the wheel while snugly drawing up the adjusting nut with a wrench to seat the bearings. Continue to rotate the wheel and back the adjusting nut off ¼ to ½ turn, or until it is just loose. Then, tighten the nut by hand to a snug fit. Check axial play, then lock the adjusting nut in place.

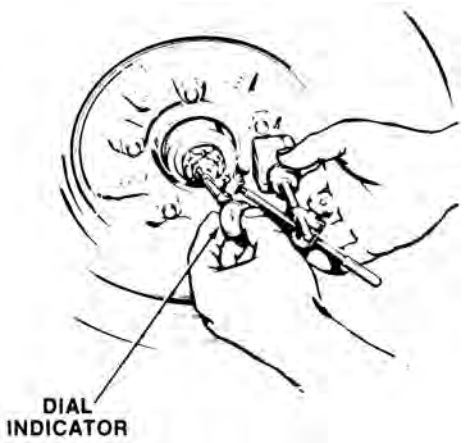
TORQUE WRENCH ADJUSTMENT



Using a torque wrench to adjust tapered roller wheel bearings.

To adjust the wheel bearings with a torque wrench, rotate the wheel and draw the adjusting nut up to the initial tightening torque value specified by the vehicle manufacturer**.** Typically, tapered roller wheel bearings are initially tightened to about 12 to 25 ft-lb (15 to 35 Nm) of torque. Back off the adjusting nut approximately 1/3 turn, then tighten it to the final tightening torque value specified by the vehicle manufacturer. Final torque typically falls in the 10 to 15 in-lb (1 to 1.5 Nm) range. Check axial play and lock the adjusting nut in place.

DIAL INDICATOR ADJUSTMENT



Dial indicator setup for adjusting tapered roller wheel bearings.

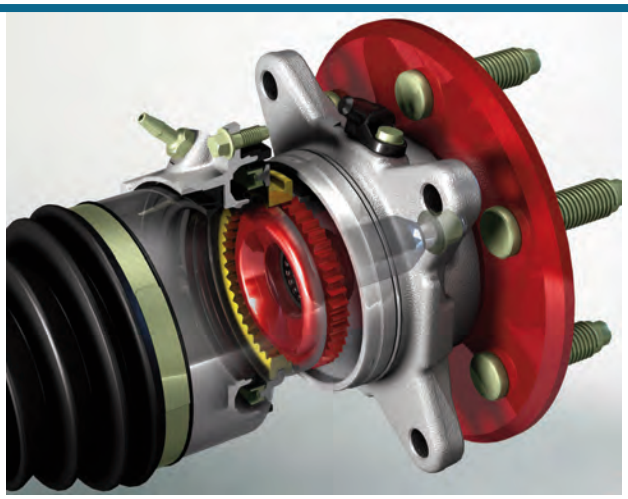
To adjust the wheel bearings with a dial indicator, tighten the adjusting nut to 12 to 25 ft-lb (15 to 35 Nm) of torque while rotating the wheel. Back off the adjusting nut 1/4 to 1/2 turn or until it is just loose, then tighten the nut by hand to a snug fit.

Mount a dial indicator on the wheel and position it so the plunger rests against the end of the spindle. Push the wheel back onto the spindle as far as possible, zero the dial indicator, then pull out on the wheel and read axial play on the dial indicator. Tighten the adjusting nut as needed to obtain the clearance specified by the vehicle manufacturer. Typically, axial play tolerance is in the 0.001 to 0.005 inch (0.025 to 0.127 mm) range. Lock the adjusting nut in place to complete the adjustment.

SEALED WHEEL BEARING SERVICE

The sealed, double-row wheel bearing assemblies used on the front wheels of most FWD vehicles, as well as the driven and non-driven wheels of many late-model vehicles, are serviced by replacing them when their axial play exceeds the recommended specification.

Some sealed wheel bearing designs combine the bearings with the wheel hub assembly, which makes replacement a relatively easy procedure. Simply remove the bearing/hub retaining bolts; then, remove the assembly and replace it. Some models require the use of a thread locking com-



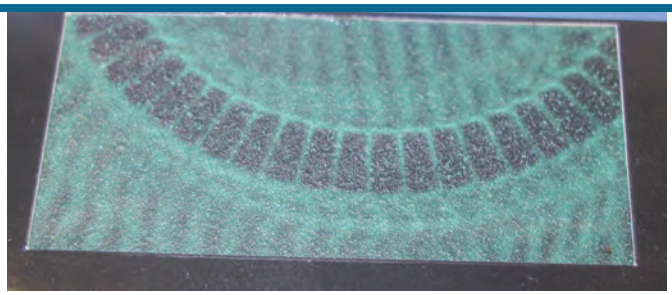
A sealed wheel bearing hub unit is not serviceable. Also, any end-play or runout is a sign of failure.

pound on the bearing and hub mounting fasteners. The mounting fastener threads should be cleaned with a thread cleaner prior to application of the thread locking compound. Use only the type of thread cleaner and thread locking compound recommended by the vehicle manufacturer.

The sealed wheel bearings on some FWD vehicles are press fit to the hub and steering knuckle, so the steering knuckle must be removed from the vehicle to service them.

Replacing a sealed wheel bearing assembly on a driven front axle is more involved. On some designs, the steering knuckle must be removed from the vehicle in order to replace the wheel bearings. A press or special pullers are used to remove the bearings from the steering knuckle, and a press is usually used to install the new bearings**.**

Once the new parts are installed and the fasteners are tightened to specified torque, sealed bearings require no adjustment.



Seals on some of these bearings is that it has a built in magnetic impulse wheel.

The distinctive feature on these bearings is that one of the two seals on some of these bearings is that it has a built in magnetic impulse wheel. Caution should be taken to make sure that the seal with the ABS impulse ring is installed in the correct direction. The side with the impulse ring needs to be installed closest to the ABS sensor. If it is installed backwards, the ABS system will not function.

The side with the ABS ring can be identified either by placing a lightweight metallic object (such as a paper clip) to the magnetic side or by a close visual inspection. The close visual inspection will reveal the ABS impulse ring windows, which can be seen through the seal surface. Care should be used when handling and installing the bearing so that the impulse ring is not damaged. If this occurs the ABS system will not function correctly.

Sample Review Questions:

1. All of the following indicate that wheel bearings need service EXCEPT:
   a. A growling sound that increases with cornering loads
   b. A body vibration that occurs when the brakes are applied
   c. Roughness, grease seal leakage, and excessive axial play
   d. A growling sound that occurs only when the brakes are applied

2. The axial play of a typical tapered roller wheel bearing assembly should be:
   a. 0.001 to 0.005 inch (0.025 to 0.127 mm)
   b. 0.010 to 0.020 inch (0.050 to 0.100 mm)
   c. 0.010 to 0.050 inch (0.50 to 1.0 mm)
   d. Less than 0.002 inch (0.05 mm)

3. Diagnose the condition of sealed, double-row bearings with:
   a. A dial indicator
   b. A seal inspection
   c. A micrometer
   d. A torque wrench

4. Technician A says that the maximum axial play in a sealed front wheel bearing of a typical FWD car is .002 inch. Technician B says that the maximum axial play in a sealed front wheel bearing of a typical FWD car is .005 inch . Who is right?
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

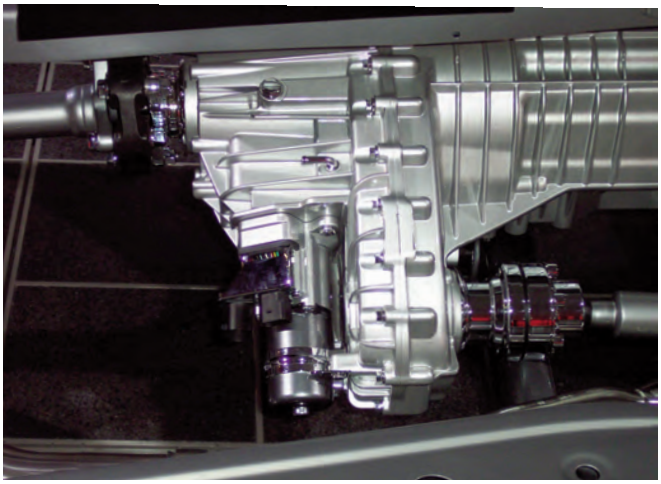
ANSWER KEY

1D, 2D, 3A, 4A

ASE G1

Four Wheel Drive

TRANSFER CASE



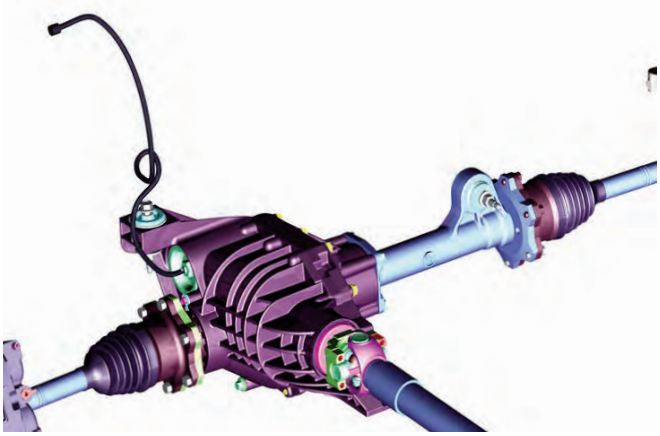
The transfer case splits power between the front and rear axles. Some transfer cases can switch between two-wheel-drive and four-wheel-drive. Some transfer cases include a center differential that can shift torque and power to the axle that needs it the most.

The transfer case distributes power to the front and rear wheels from the transmission by means of drive shafts. Transfer case problem diagnosis begins with a road test to confirm the complaint and experience the symptoms. After the road test, various inspection and adjustment procedures are performed to confirm the diagnosis. The tires need to be the same size front and rear so the transfer case is not damaged.

Transfer cases can be shifted manually or with an electric motor or solenoid mounted on the case. If either mechanism is not adjusted properly, it can cause noise and no engagement.

SHIFT LINKAGE

An inadequately lubricated or incorrectly adjusted shift linkage can be the cause of many transfer case complaints. Symptoms of shift linkage problems include: hard shifting, not being able to engage a desired gear, or have the transmission jump out of gear. The linkage system should be periodically inspected for free movement, proper engage-



A differential on some 4WD systems can be locked using engine vacuum or a electric current.

ment, and secure attachment. Adjust, clean and tighten the linkage system components as necessary.

Noise

A noise complaint is often the result of a lack of lubrication. Check for proper lubricant and fluid levels. Worn transfer case bearings can cause noises similar to those caused by driveline and rear axle problems. If lubricant and fluid levels are correct, you may have to remove and disassemble the transfer case.

GEAR ENGAGEMENT PROBLEMS

Common customer complaints related to gear engagement include hard shifting and not being able to engage a desired gear. These symptoms are often caused by shift linkage problems, shift fork wear, or damaged internal gears or bearings. In some cases, shift linkage adjustment may correct these symptoms. If your inspection verifies shift linkage wear or damaged internal gears or bearings, you will have to remove the transfer case for further inspection. In addition, some transfer cases are shifted electronically or by vacuum-controlled shift mechanisms. Verify that these control systems are functioning properly before removing the transfer case assembly.

ELECTRONIC SHIFT CONTROL

Electronic shift control uses an electric motor mounted on the transfer case to engage and disengage 4WD mode. Diagnostic and service procedures for the electronic shift control can be performed without removing the transfer case from the vehicle. Most electronic transfer cases are regulated by the transmission control modules and have and onboard diagnostic capability within their circuitry.

VACUUM SHIFT CONTROL

A vacuum shift control system switches between 4WD and 2WD on a signal from a dash-mounted or console-mounted switch. This switch controls one or two vacuum motors. If there is one motor, it actuates a front axle disconnect mechanism. When a second motor is used, is disengages the front axle drive chain in the transfer case.

LUBRICANTS

The lubricants that are used in manual transmissions, transaxles, differentials and transfer cases include a variety of different oils. Many transmissions, transaxles and transfer cases use gear oil with viscosities ranging from 75W-90 up to 85W-140. Others use ATF (Dexron II/III, Mercon V, etc.) or even motor oil (10W-30 or 10W-40). Most differentials, by comparison, use hypoid gear oils that also contain extra amounts of “extreme pressure” (EP) additives. Limited slip differentials also require their own special additives.

Most of these lubricants are long-lived and hold up well for tens of thousands of miles. But none will last forever. The combination of heat, shearing action and oxidation eventually breaks down the oil and reduces its ability to lubricate and protect.

VENTS

Transfer cases and differentials typically have a vent that must not be blocked. This tube allows for expansion of the fluid and prevents the case from being pressurized.

It the breather tube is blocked or missing, it can cause damage to the seals.

Review Questions

1. A transfer case is leaking from the front and rear drive shaft seals. What should be inspected first before the seals are replaced?:

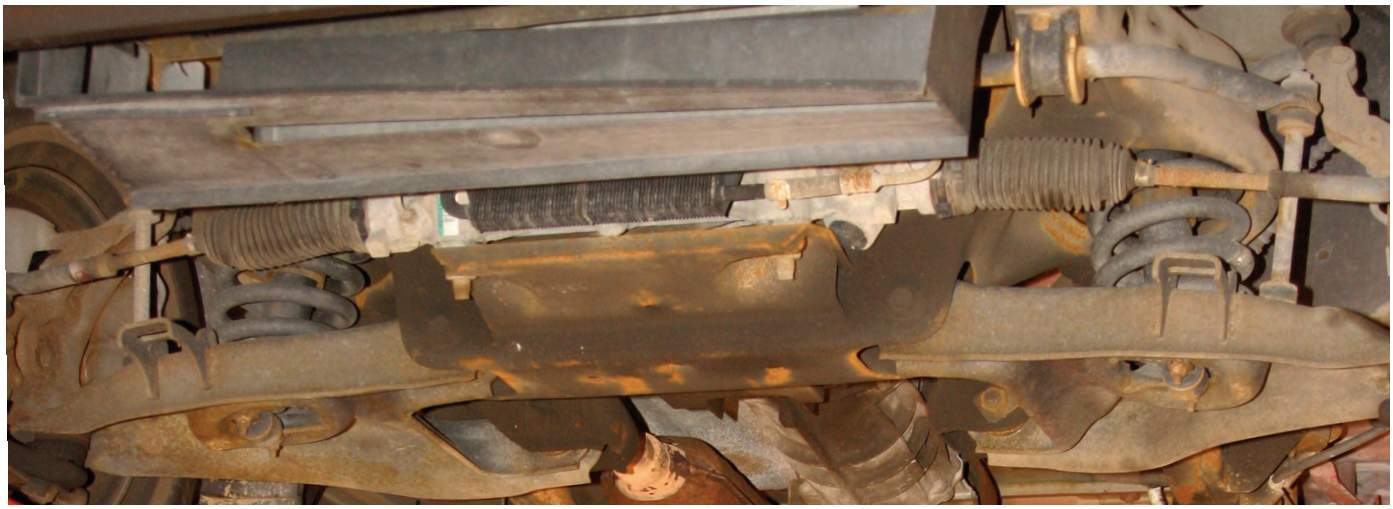
a. Drive shaft angles
b. Vacuum lines
c. Sump guard
d. breather vent tube

Answer Key

1D

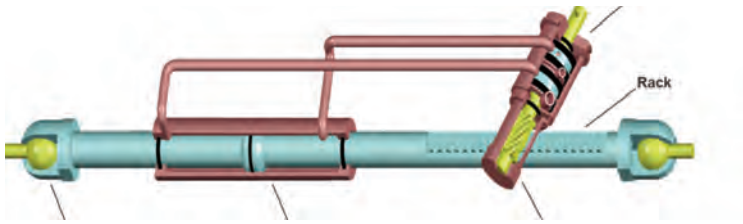
ASE G1

Steering



Chassis parts are usually sold when a customer realizes his vehicle has a tire wear, handling, steering, alignment or suspension problem. Worn chassis parts such as ball joints and control arm bushings can change camber alignment, causing shoulder wear on tires. Worn tie rod ends in the steering linkage can allow toe alignment to change, causing tires to wear rapidly. A worn idler arm in a vehicle that does not have rack and pinion steering can make the steering feel loose and the vehicle to wander on the highway. Even relatively simple parts such as sway bar bushings and links can cause problems, too, such as squeaking and rattling if they are worn, cracked or loose.

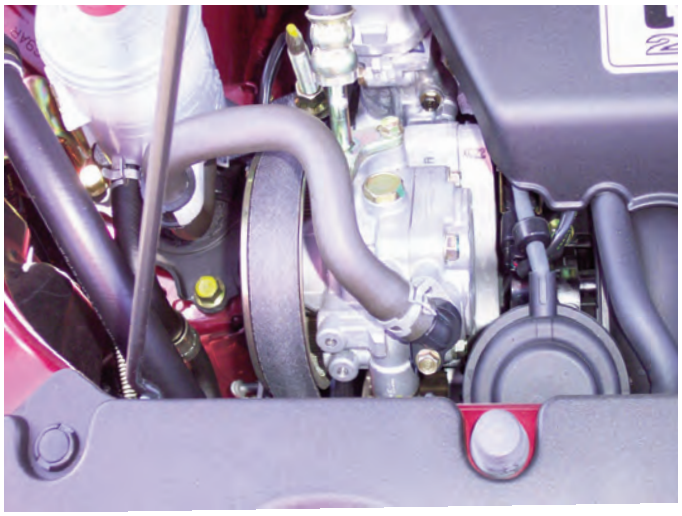
Steering



Hydraulic power steering has been standard equipment on most cars and trucks for many decades, but on many newer vehicles it is being replaced by electric power-assisted steering. Electric steering assist eliminates the belt-driven PS pump, hoses and hydraulic fluid to reduce weight, noise and friction. The change also improves fuel economy and allows steering effort and feel to be better tuned to changing driving conditions. But even if hydraulic power steering disappears entirely, there will continue to be a huge aftermarket for replacement PS pumps, hoses and related components.

PS pumps are fairly durable and often last the life of the vehicle. However, depending on usage and mileage, the pump's shaft bearings and/or pump mechanism can wear out, causing pump noise and/or a loss of steering assist. The pump's pressure relief valve can also stuck or fail causing a loss of power steering assist.

When a PS pump fails as a result of wear or internal damage, metallic debris may pass through the hydraulic lines and damage the power steering unit. Consequently, when a PS pump is being replaced all of the old fluid should be drained from the system and discarded. The hoses and steering gear also should be flushed to remove the contaminants. If this is not done, the new pump may be damaged.



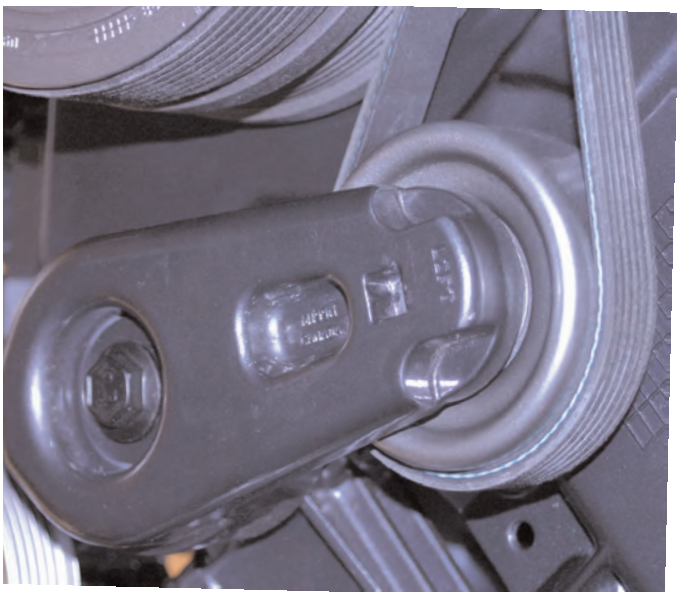
Most replacement power steering pumps do not include the pulley.

Replacement pumps may or may not come with a pulley. If not, the pulley on the old pump must be removed and installed on the new pump. DIY installers should be warned NOT to pound on the pulley or pump shaft as this may damage the pump.

The PS system should be refilled with the type of fluid specified on the pump reservoir or in the vehicle owners manual. Most vehicles can use a universal PS fluid, but some require special fluids or ATF. Using the wrong fluid may damage the pump or steering unit.

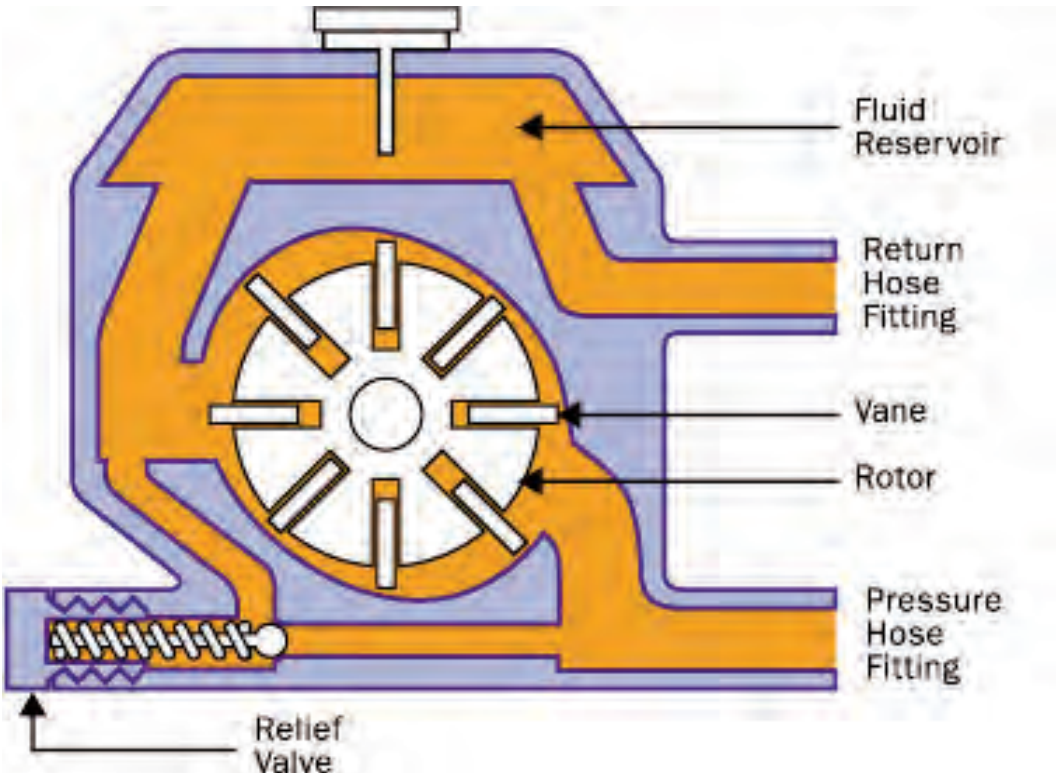
Refilling some PS systems can be tricky because air can become trapped in the steering gear. Air will cause noise and erratic steering assist. Rotating the steering wheel slowly from as far as it will go in one direction to its limit in the opposite direction multiple times will usually allow most of the air to escape. In some cases, it may be necessary to use a special vacuum tool to pull the remaining air out of the system.

Belts should be free from cracks and glazing.



If the belt tensioner is worn, the pump will not work properly.

A new drive belt should also be installed when a high-mileage PS pump is replaced. Chances are the old belt will have a lot of miles on it and will be badly worn, glazed or contaminated with oil, grease or PS fluid that leaked out of the old pump. The automatic belt tensioner also should be carefully inspected and replaced if it is sticking, rusty, wobbling, noisy or can't maintain proper belt tension.



A vane-style power steering pumps have a relief valve that can be operated by a spring or electronic solenoid.

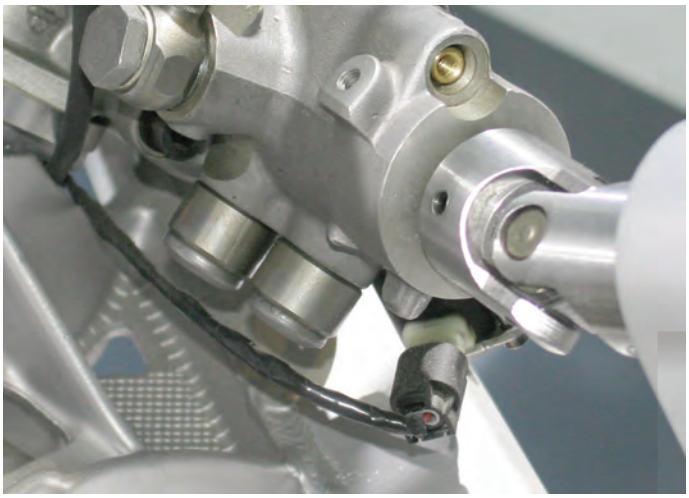
MECHANICAL CONTROLLED SYSTEMS

Mechanical types of variable assist power steering systems use a variable flow rate power steering pump. The flow rate is proportional to engine speed, allowing for more power assist at lower engine speeds than at higher engine speeds. The power steering pump has a special flow control valve that allows for variable oil flow to the steering gear. Oil from the pump flows through an orifice in the valve assembly.

Oil also flows through a pilot port to one side of the valve. At low engine and pump speeds, the oil flow through the pilot port is not enough to move the valve against spring pressure. This keeps the valve in the fully open position, allowing maximum flow for low-speed parking maneuvers. As engine speed increases, the pressure in the pilot port also increases. This moves the valve against spring pressure and reduces the size of the flow orifice. Pump oil flow to the steering gear is reduced, which reduces power steering assist at higher speeds. It is important to remember that variable assist power steering only reduces the amount of pressure that reaches the steering gear at higher road speeds. The only way it could reduce power assist at low speed would be in the unlikely event the actuator or solenoid valve failed in the open position. This could cause a noticeable reduction or loss of power assist.

ELECTRONICALLY CONTROLLED SYSTEMS

Variable assist power steering is provided by controlling power steering fluid pressure at the power steering gear. A solenoid valve, normally located on the steering gear or



Electronically controlled systems have control valves or solenoids on the steering gear or pump to control the amount of assist.

on the power steering pump, is used to control power steering pressure by varying the size of an orifice which the power steering fluid must flow through. The variable

Often the reservoir with have the required fluid imprinted on the top or on the cap. If it can not be found, check the owner's manual or a fluid supplier's catalog.

assist solenoid control valve is controlled by an electronic solenoid control module which may be re-mote mounted or directly attached to the steering gear.

The control module controls the variable assist solenoid control valve, using a vehicle speed signal from the powertrain control module (PCM). Problems with electronic variable-assist systems include all of the same things that can go wrong with a conventional power steering system. Conditions such as fluid leaks, worn gear components, and pump and hose failures, etc.), plus problems with the control electronics including the vehicle speed sensor circuit, the solenoid valve, and control module.

Most of these systems can be diagnosed with a voltmeter, test light, or scan tool to pinpoint the nature of the fault (if the fault is electronic rather than mechanical). If power to the solenoid or control valve actuator is lost, the valve keeps the bypass circuit closed so full power assist is provided under all driving conditions. The only indication of trouble, therefore, might be a loss of road feel and/or increased steering sensitivity at highway speeds.

Check the power steering fluid level and condition at the fluid reservoir. One of two basic reservoir designs are used:

- Integral
- Remote

Many reservoirs or dipsticks have two level indicators to check the fluid level at normal operating temperature and when cold. For the most accurate results many manufacturers suggest checking the level when the fluid is at operating temperature-about 120º to 180ºF (50º to 80ºC). Refer to the Service Manual, Owner's Manual, or instructions stamped on the reservoir or cap.

To inspect the fluid:

1. Park the vehicle on level ground, and locate the power steering fluid reservoir.
2. If fluid is leaking from the reservoir cap, the reservoir may be too full or the cap seal may be damaged. Wipe the cap and around the opening with a clean shop rag to keep dirt from entering the system.
3. Depending on the reservoir design:

- Remove the cap and dipstick assembly, wipe the dipstick with a clean rag, and put the cap back on. Remove it again and see where the fluid level reaches on the dipstick.
- Look where the fluid level reaches on the graduations on the transparent reservoir body.
- If there are no level indicators, remove the cap and look inside. Generally the level should be about 2/3 full for proper operation.

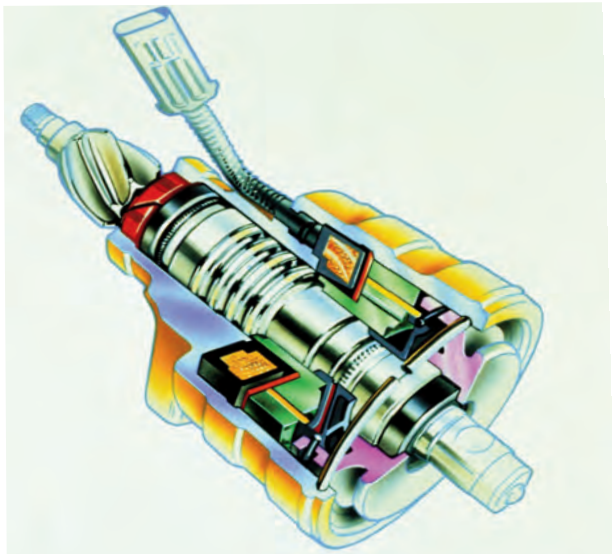
4. Add or remove fluid as needed to correct the level. Often the power steering fluid specification is stamped on the reservoir or cap. If the level is extremely low raise the front of the vehicle off the ground before adding fluid to prevent an air pocket from forming in the gear or pump. Refer to Bleeding the Power Steering System in this Chapter for more information.
5. Once the system is properly filled, wipe up any fluid spilled on the outside of the reservoir, inspect the condition of the cap seal for damage, and if in good condition re-install the cap. If the cap seal is damaged replace as required.
6. Drive the vehicle and check fluid level again. If it is low, look for hydraulic system leaks.

POWER STEERING FLUID CONDITION

While checking the level, also note fluid condition. Dab some on a white paper towel and examine it. The color should be clear and light. If the fluid is brown and thick, and smells like varnish, it may be oxidized. If it contains metal particles, internal damage to the pump or steering gear has occurred. Black particles indicate deteriorating hoses and seals or other contamination. If the fluid is foamy or cloudy, air is in the system, which reduces hydraulic assist. Repair the problems causing fluid deterioration, flush the entire power steering system, add new fluid, and bleed the system.

ELECTRIC POWER STEERING

Electric Power Steering (EPS) is replacing hydraulic power steering in many new vehicles today. One of the advantages of electric power steering is that it eliminates the power steering pump, which can use as much as 8 to 10 horsepower under load. This improves fuel economy while also eliminating the weight and bulk of the power steering pump and hoses. Getting rid of the hydraulics



Electric power steering gets rid of the need for a power steering pump.

also does away with fluid leaks and the need to check the power steering fluid. Electric power steering is also quieter than hydraulic systems because there is no pump noise and no fluid flowing through hoses and valves. But the most noticeable difference is in handling and steering refinement.

Electric power steering can be fine tuned with a precision that is hard to match with hydraulic controls. By monitoring the driver's steering inputs, vehicle speed, and other suspension dynamics, the system can provide just the right amount of steering feel and effort to match rapidly changing driving conditions. EPS can deliver extra effort when you need it, and reduce steering effort when you do not need it. It can even provide steering assist when the engine is off.

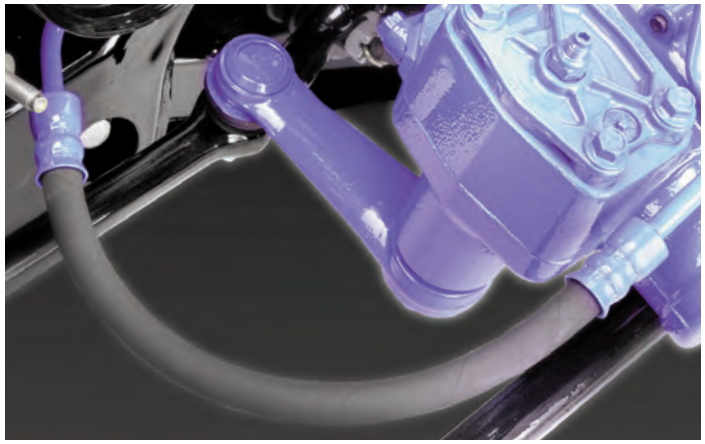
Better yet, because the system is software driven, it is possible to tap into the steering module and modify steering effort and feel. This can be done with a factory scan tool on some applications, and with aftermarket "tuner" scan tools and software.

Though some of the older electric power steering systems were actually "electro-hydraulic," and used an electric motor to drive a conventional hydraulic pump, the latest generation of EPS is all electric/electronic. The steering gear itself is a manual rack with an electric motor mounted on the steering column or the rack.

When the driver turns the wheel, a steering sensor detects the position and rate of rotation of the steering wheel. This information along with input from a steering torque sensor mounted in the steering shaft is fed to the power steering control module. Other inputs such as vehicle speed and inputs from the traction control or stability control systems are factored in to determine how much steering assist is required. The control module then commands the motor to rotate a certain amount, and a sensor on the motor pro-

vides feedback to the control module so it can monitor the motor's position.

LINES AND HOSES



Most power steering hoses deteriorate from the inside out. As the hoses deteriorate from inside, rubber particles begin to flake off from the interior walls. As deterioration advances, more and more particles are pushed through the system. Rubber particles commonly stick the flow control valve in the pump and can cause accelerated wear of the control valve housing in the steering gear or rack and pinion, leading to complete and expensive system failure. If any of the following conditions are found, replace the hoses. Remember, if one hose shows signs of wear, always replace all hoses, as all hoses in the system are subjected to the same conditions and wear. Keep the following in mind when inspecting hoses and lines:

- Check tubing for corrosion, abrasion or cracks
- Check the hose to coupling connection for leaks or drips
- Look for small pinholes or cracks in the hose covers
- The brittleness or hardness of the hose is an early sign that the hose has lost its ability to absorb pressure surges
- A soft, spongy hose is a more serious sign of wear, indicating advanced internal deterioration and probable leakage
- Thick fluid in the pump reservoir indicates internal hose deterioration

POWER STEERING PUMP

The engine drives the power steering pump through a belt and pulleys. There are three major types of pumps in use today:

- Roller
- Vane
- Slipper

SERVICE

While the internal pumping elements are different, there are no significant external service differences between the different pump designs.

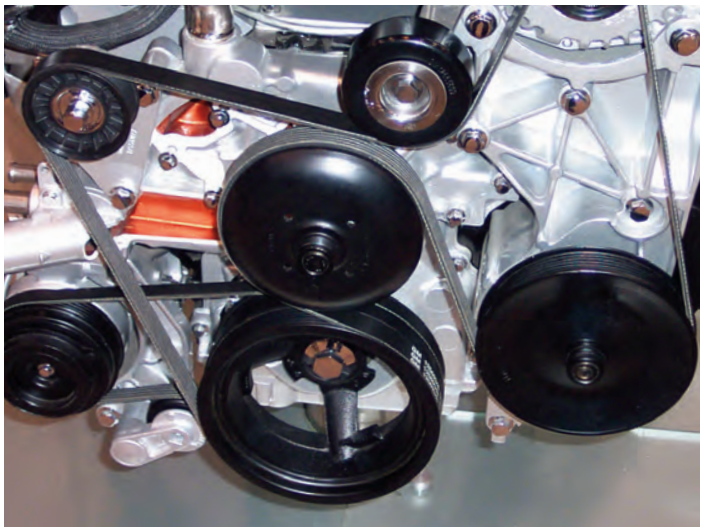
Servicing a power steering pump consists of:

- Inspecting drive belt alignment
- Checking drive belt tension
- Replacing the drive belt tensioner
- Replacing the drive belt
- Checking for noises, vibration, or leaks
- Removing and replacing the pump

Drive Belts

There are two types of belts:

- Drive or V-belts
- Serpentine or Mulit-Rib belts

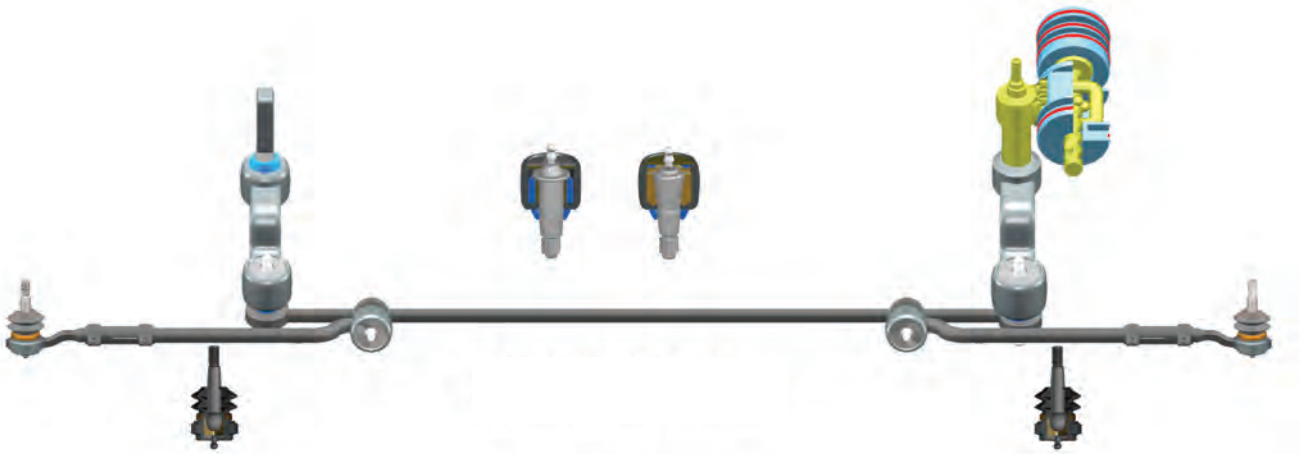


A single serpentine belt will typically drive all the various accessories on the engine, while a drive belt will usually only drive one or two. Most vehicles that use drive belts have more than one belt. Occasionally, vehicles equipped with serpentine belts will have a separate belt which runs the air conditioning compressor alone. Belts need to be replaced when the inside of the belt is badly cracked, glazed, frayed, or when the rubber begins to harden.

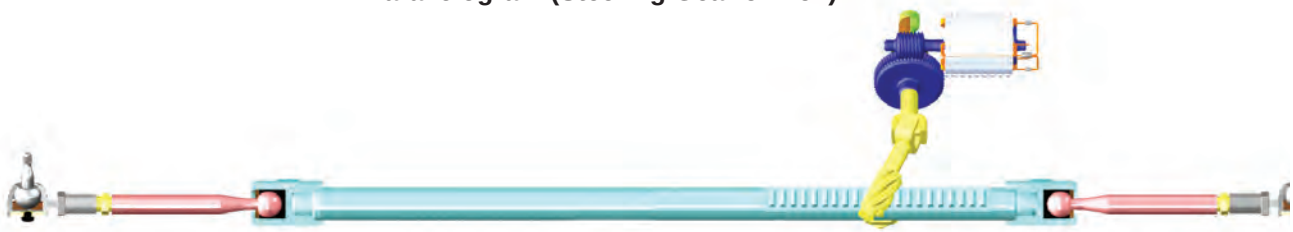
Note: Some applications use multiple V-belts to drive high-load accessories. These belts must be replaced as a matched set to ensure even belt tension and long service life.

Steering Racks

Power racks typically leak at one or both ends where the rack shaft passes through the end seals, at the pinion input shaft seal, or internally in the spool valve housing. Leaky end seals may or may not leave telltale stains on the outside of the rubber or plastic bellows. If the leak is really bad and the bellows are cracked or loose, the fluid will be dripping from the rack and the bellows will be wet. But if the bellows are still intact and tight, you may not see any obvious signs of leakage.



Parallelogram (Steering Gear or Box)



•Rack and pinion

INSPECTION

The end bellows on a steering rack should be dry with no more than a small amount of power steering fluid present. High mileage vehicles may have some fluid seepage into the boots. If the bellows contain a lot of fluid, the rack is leaking and needs to be repaired or replaced. Loosen the bellows clamp and slide the bellows back to check for fluid inside.

To verify rack seal leaks before beginning a repair follow these steps:

1. Raise the vehicle so the front wheels are off the ground.
2. Loosen and push back both bellows on the ends of the rack so you have a clear view of the seals on both ends of the rack.
3. Wipe off any dirt or oil on the rack bar.
4. Start the engine, and with it idling at approximately 1,200 rpm, turn the steering wheel all the way to the right stop and hold under light pressure for about five seconds. Then repeat the process turning the wheel to the left. Repeat the process six to eight times.
5. Recheck the rack for leaks. If you see fluid dripping from the rack, the end seals are leaking and repairs are needed. If no leaks are found at the end seals, check the pinion input shaft seal and the hoses and pump.

FLUSHING & FILLING

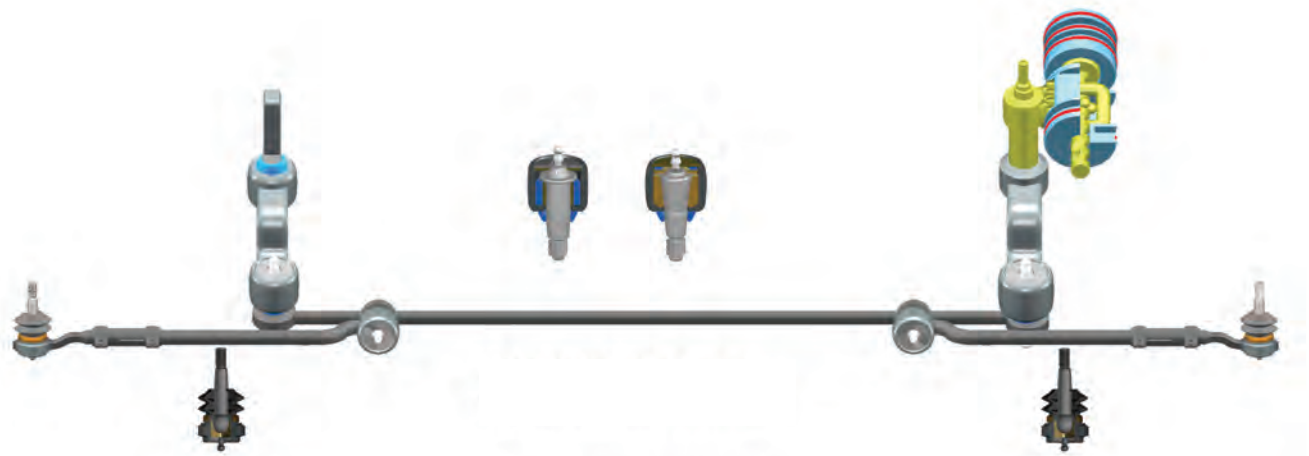
There are several methods and tools to flush a power steering system. But, no matter what tool or method that you use make sure to follow these rules:

1. NEVER let the pump run dry. Even a few seconds of a pump punning without fluid can damage the system.

2. ALWAYS make sure the pump, steering gear and lines have been flushed with a cleaner of solvent if there has been a catastrophic failure.

ASE G1

Steering Linkage



Parallelogram (Steering Gear or Box)

•Rack and pinion

The two most common types of steering linkage are:

• Parallelogram

• Rack and pinion

RACK AND PINION

Rack & pinion steering has been around for quite awhile and remains the most common type of steering system in todays cars and minivans. It is even showing up on some trucks and SUVs. Most are pretty durable and last upwards of 100,000 miles. But, sooner or later, all racks succumb to leaks or wear.

The end bellows on a steering rack should be dry with no more than a small amount of power steering fluid present. High mileage vehicles may have some fluid seepage into the boots. If the bellows contain a lot of fluid, the rack is leaking and needs to be repaired or replaced. Loosen the bellows clamp and slide the bellows back to check for fluid inside.

To verify rack seal leaks before beginning a repair follow these steps:

1. Raise the vehicle so the front wheels are off the ground.

2. Loosen and push back both bellows on the ends of the rack so you have a clear view of the seals on both ends of the rack.

3. Wipe off any dirt or oil on the rack bar.

4. Start the engine, and with it idling at approximately 1,200 rpm, turn the steering wheel all the way to the right stop and hold under light pressure for about five seconds. Then repeat the process turning the wheel to the left. Repeat the process six to eight times.

5. Recheck the rack for leaks. If you see fluid dripping from the rack, the end seals are leaking and repairs are needed. If no leaks are found at the end seals, check the pinion input shaft seal and the hoses and pump.

If a hose connection is leaking first check to see if the fitting is tightened properly. It may also be possible to repair the leak by replacing the seals or O-rings.

PARALLELISM

Parallelogram steering linkage uses the pitman arm and idler arm to support the center link, forming a parallelogram. Tie rods connect a center link to the steering knuckles. In a rack and pinion steering system, the rack takes place of the center link. It moves back and forth across the pinion, and tie rods connect it to the steering knuckles.

In a parallelogram steering linkage, the vehicle steers smoothly when the center link is parallel to the ground. This is called parallelism. If the center link is not parallel, the cause may be a bent or incorrectly positioned idler or pitman arm. This, in turn, affects tie rod position, resulting in bump steer and unequal left and right turning radius. **Check parallelism after you replace parts in the steering linkage.**

1. Position the wheels straight ahead and center the steering gear.

2. Locate the points where the pitman and idler arms connect to the center link and measure the distance from these points to the ground. Some center links have flat machined surfaces for making these measurements.

3. The distance from the pitman arm side and the idler arm side of the center link to the ground should not differ by more than 0.06 inch (1.5 mm). To adjust parallelism, raise the vehicle on a frame-contact hoist. On some vehicles, loosen the idler arm mounting bolts and reposition the arm in the slots on the frame. Another method is to turn a threaded bushing at the base of the idler arm mounting bracket to change idler arm position.

TIE ROD

Tie-rod ends are flexible sockets that connect the steering linkage tie rods to arms on the steering knuckles. If worn, can cause steering looseness and tire wear. Left and right side tie rod ends are usually different and may have reversed threads. Outer tie-rods connect with the knuckle, inner tie-rods connect the outer tie-rod with the rack.

outer tie-rod

As a rule, tie rod ends should show no visible vertical or horizontal play during the dry park check.

inner tie-rod

The inner tie rod sockets on rack & pinion steering gears are enclosed in bellows, making them difficult to inspect. If the bellows are rubber, you can check for looseness by squeezing the bellows and pinching each socket while pushing outward on the wheel or while a helper rocks the steering wheel. If you feel movement, the sockets are loose and need to be replaced. You can't do this check with hard plastic bellows, so lock the steering wheel with a holder and watch for any in or out movement in the tie rod while pulling and pushing on the wheels.

Also pay attention to the rack mounts. Loose, deteriorated or broken mounts may allow the rack housing to move as the wheels are turned. This can cause steering wander and noise.

All tie rod ends should still be checked as per factory guidelines. This bulletin adds a few extra visual checks that must be performed to verify proper performance.

1. Check all tie rods by grasping by hand and check for any movement while applying 25 lbs of force. Do not use channel lock pliers for this procedure. If any movement is noticed, it needs replacement. Additionally, if any rubber boot is torn or worn where water and dirt can enter, replace that part.

2. The next check is called a Dry Park Check. The vehicle should be on a drive on type rack (or ground) to simulate normal part alignment. Have assistant rock steering wheel back and forth from 10 o'clock to 2 o'clock position while you observe tie rod ends. If any movement is noticed, replace that part.

3. This step inspects for any signs of corrosion. Using a wrench, rotate tie rod down to expose boot. Using a putty knife or other dull tool, lift the bottom of the boot up, exposing the stud. If any water escapes from the seal, that tie rod should be replaced. Closely examine the stud for any signs of corrosion. If any corrosion is noted, replace that tie rod end. As always, an alignment is necessary if any parts were replaced.

STEERING KNUCKLES

Loose connections between the steering knuckle and suspension affect steering control and wheel alignment. Check for damage and replace the knuckle as needed. On non-driven wheels, inspect the spindle for bends and wear, especially where the wheel bearings seat.

Check for cracks, rust, and other damage. If the spindle is damaged, replace it if it can be separated from the knuckle, or replace the whole steering knuckle if the spindle and knuckle are a cast piece. If the steering arms are bent, wheel alignment will be incorrect. Check for bends, cracks, or other damage and replace damaged steering arms. On most vehicles, the entire knuckle must be replaced if the steering arm is damaged.

Bent steering knuckle assemblies are easy to ignore simply because they do require extra time and effort to measure and evaluate in today's fast-paced undercar service market. Nevertheless, the symptoms of bent steering knuckles are easy to spot, especially if we do a thorough pre-alignment inspection.

UPPER BEARING PLATE

One mistake to avoid when replacing struts is reusing the original bearing plates. It's like rebuilding an engine with a new crankshaft and reusing the old bearings. Replace the old bearing plates with new ones, or install preassembled struts that come with new bearing plates. The preassembled struts are faster and easier to install than bare struts, and they reduce the risk of comebacks.

Struts may also need to be replaced if the upper strut bearing plate has been hammered to death. The bearing plate serves as both the upper spring support and the steering pivot. The bearings in the plate are sealed assemblies and cannot be lubricated. So if the bearing plate is rusted, loose, worn, noisy, binding or damaged, it has to be replaced.

The symptoms of a bad bearing plate include:

- Steering noise such as snapping, popping, creaking or groaning sounds when turning;
- Suspension noise such as clunking, rattling or popping on rough roads;
- Increased steering effort (most noticeable with manual steering) brought on by binding in the bearing plate;
- Steering snap back after turning caused by a frozen upper strut bearing assembly and spring wind up; and

- "Memory steer" or poor steering return where the car doesn't want to go straight after turning due to binding in the upper mount.

STEERING STABLIZER

Steering stabilizers prevent this jerking action. By absorbing the impact of unexpected jerking, the stabilizers will also prolong the life of ball joints and other components in the steering system. Much like regular shocks that absorb sudden impact on the suspension, steering stabilizers absorb sudden impact on the steering system.

Review Questions

1. Leaky end seals may not leave telltale stains on the outside of the rubber or plastic bellows.

a. true
b. false

2. Servicing a power steering pump consists of:

a. inspecting drive belt alignment
b. replacing the drive belt tensioner
c. replacing the drive belt
d. all of the above

3. A vehicle with rack and pinion steering has a shimmy. Technician A says that worn rack-to-frame mounting bushings could be the cause. Technician B says thata binding steering shaft U-joint could be the cause.

Who is right?

a. A only
b. B only
c. both A and B
d. neither A nor B

4. A pressure test is being performed on a vehicle with power steering. The pressure readings taken when the wheels are at the right and left stops are below specification. The readings are normal when the tester shutoff valve is closed.

Technician A says that these readings could be caused by a failed steering gear. Technician B says that these readings could be caused by a failed pump.

Who is right?

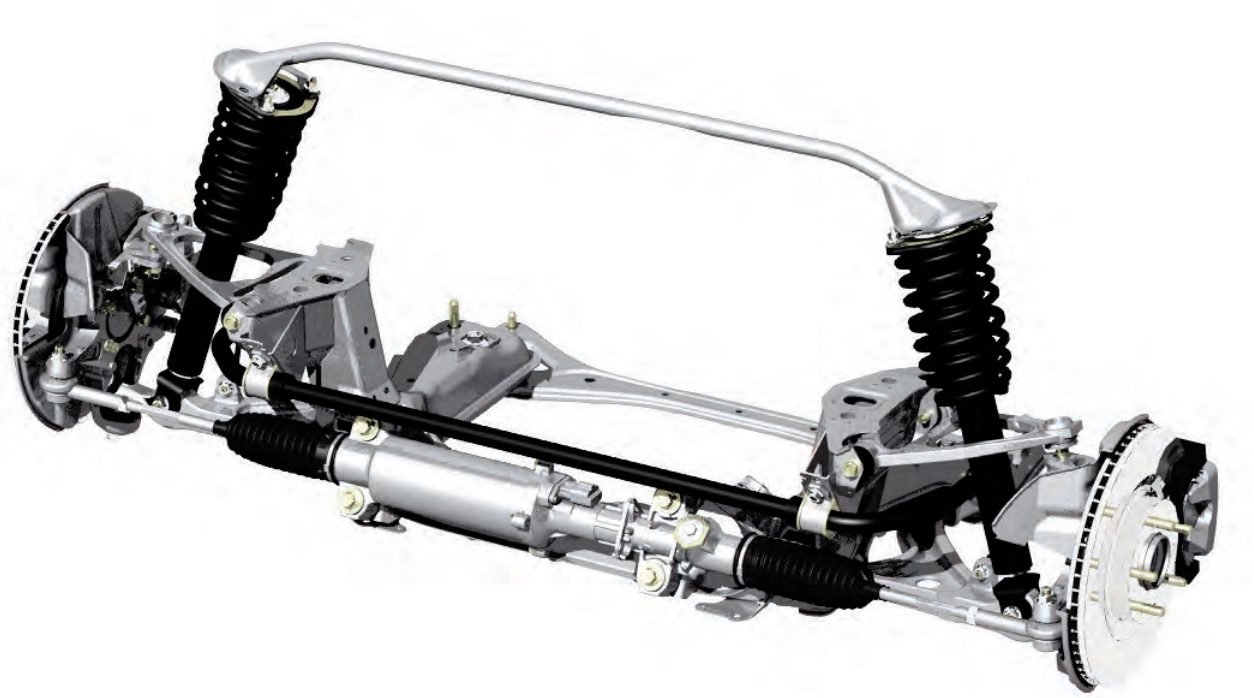
a. A only
b. B only
c. Both A and B
d. Neither A nor B

Answer Key

1A,2D,3A,4A

ASE G1

Front Suspension



Front Suspension

Front suspension components that require service are:

- Control arms and bushings
- Strut rods, radius arms, and bushings
- Antiroll bars and bushings
- Coil springs
- Torsion bars
- Shock absorbers
- Struts
- Ball joints
- Steering knuckles
- Axles

The suspension interacts with the steering and wheels, so along with examining the suspension, check steering system condition, tire inflation, wheel condition, wheel and tire runout and balance, and wheel alignment. Not all vehicles have all the components listed in this inspection:

1. Bounce the vehicle up and down at each corner, then release it and see how soon it settles. If it bounces more than two or three times, the shocks are worn. Listen for unusual sounds such as squeaks or rattles while bouncing the vehicle.
2. Check ride height. If the vehicle is riding low or one side is lower than the other, the springs are worn. Torsion bars can be adjusted to correct slight ride height problems, but springs must be replaced.
3. Raise the vehicle on an alignment rack and have an assistant turn the steering wheel from lock to lock, while you watch the suspension for binding at the ball joints or struts.
4. Inspect ball joint seals and suspension bushings for damage, cracks, or other signs of deterioration.
5. Check ball joint lubrication. The seal should be full of grease, and the grease should not be hardened.
6. Check ball joint play; excess play indicates wear.
7. Push and pull on suspension links to check for looseness, which causes poor handling.
8. Examine coil springs for shiny areas, indicating that the coils clash against each other. Also, examine all types of springs for scratches and damage that can cause metal fatigue and stress risers.
9. Inspect the control arm bushings for signs of deterioration or wear. Also check to ensure that control arm mounting shafts are securely fastened to the vehicle frame or body attachment points.
10. Examine shock absorbers. A light film of oil is normal, but dripping oil means they are damaged. Look for dents in the shock cylinder, which interfere with smooth compression and extension.

11. Examine bump stops for damage and signs of contact showing the suspension bottoms out due to damaged or worn parts.

FRONT CONTROL ARMS AND BUSHINGS

Control arms link the axle or wheel hub to the vehicle frame. A pivoting bushing at the frame allows the wheel to travel up and down, and a ball joint links the control arm to the front wheel. Ball joints allow both vertical wheel travel and wheel turning in response to steering.

ANTI-ROLL BARS AND BUSHINGS

The anti-roll bar links the left and right sides of a suspension system to transfer rolling force during cornering.
Also known as a stabilizer bar, roll bar, sway bar, or anti-sway bar, the anti-roll bar reduces body roll. Vehicles may be equipped with anti-roll bars on the front, rear, or both ends of the vehicle.

Diagnosis of anti-roll bar issues are the same for all applications. Anytime excessive body roll is detected when cornering a vehicle inspect the anti-roll bar and mounting for damage or missing fasteners.

COIL SPRINGS

The primary cause of coil spring wear is internal friction, resulting from normal operation, which generates heat and weakens the metal. Replace springs in same-axle pairs for even handling. Coil springs mounted between a control arm and the vehicle frame support the weight of the vehicle and exert a considerable amount of force. If you lower the control arm and release the coil spring without compressing it, it will fly out of the suspension, releasing the force of hundreds of pounds of tension, causing severe injury and damage.

To replace coil springs:

1. Raise the vehicle on a hoist and remove the wheels. Disconnect the outer tie rod ends, if necessary, for access.

2. Place a jack under one lower control arm, and lift the control arm until the lower ball joint is unloaded; it moves easily when unloaded.

3. Secure the coil spring with safety clips or compressor plates.

4. Disconnect the ball joints at the lower control arm. Also, disconnect any other suspension components attached to the lower control arm, such as the antiroll bar, shock absorber, or strut rod.

5. Lower the jack and pull the control arm down. Remove the old spring. If the spring insulators are worn or damaged, replace them. Compress a new spring, and secure it with spring clips. Place the new spring in the control arm spring seat.

6. Use the jack to raise the lower control arm. Connect the ball joint.

7. Continue raising the control arm until the spring is compressed enough to remove the clips.

8. Slowly lower the jack to expand on the spring.

9. Connect the shock, antiroll bar, and strut rod.

10. Repeat to replace the opposite spring.

11. Reconnect the outer tie rod ends, if you disconnected them, and install the wheels.

12. Lower the vehicle and bounce it several times to settle the springs. Then, tighten suspension fasteners and wheel lug nuts to specified torque.

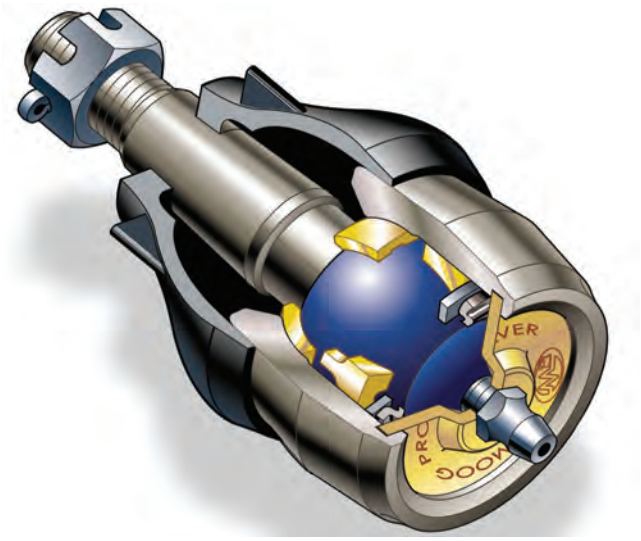
13. Check ride height and adjust wheel alignment.

FRONT LEAF SPRINGS

Older vehicles utilized leaf springs to support the front suspension. Today the only applications still using this design are a few heavy duty four-wheel drive trucks. Inspect the leaf spring insulators, shackles, brackets, bushings, and mounts for wear or damage. Refer to the appropriate Service Manual for specific repair instructions. Leaf springs used on front suspensions are mounted at the front with a hanger and at the rear with a shackle link. Inspect the following components for excessive wear or damage.

- Bushings
- Insulators or silencers
- Shackles
- Mounting brackets
- Axle mounts

BALL JOINTS



To check ball joint wear or play, raise one front wheel at a time off the ground to unload the ball joints on that side. To check for axial play, use a pry bar to move the wheel up and down as you watch for spindle movement. Always check the manufacturer's specification for wear. Excessive or any axial play indicates that the load-carrying ball joint is worn. The load-carrying ball joint is installed into the control arm where the suspension spring is seated. Too much radial play may mean the non-load-carrying joint is worn. Be aware, worn wheel bearings can also cause radial play.

The ball joint is one moveable part of a control arm assembly. The control arm bushings are just as important as the ball joint – if the ball joint is worn, chances are the bushings are just as worn. In the case of a strut suspension, the upper mount can receive as much wear as the ball joint.

There are specific types of ball joints for the different types of suspensions. Read on to learn more about the ball joint and its construction, types, wear and inspection.

TYPES OF BALL JOINTS

A loaded joint is designed to support the weight of the vehicle and a follower joint that positions the control arm or strut assembly.

A lower control arm that is connected to the spring uses a loaded ball joint to connect the steering knuckle to the upper control arm in a short long arm suspension (SLA). The ball joint also allows the steering linkage to rotate the steering knuckle.

Follower ball joints are used in strut suspensions to connect the lower control arm, steering knuckle and the strut. The upper strut mount assembly usually contains a thrust-type bearing to support the weight of the vehicle and allow the steering linkage to rotate the strut and steering knuckle.

A ball joint is made up of a housing, ball stud, bearings, end cover and Belleville washer or spring. A Belleville washer is a conical-shaped spring designed to be loaded in the axial direction. The joint is attached to a control arm by pressing the joint into the arm or riveting the joint to the arm. If the joint is pressed into the arm, it will require a special tool to remove the old joint and install the new one.

Failed pressed joints can be difficult to remove because of corrosion be tween the control arm and joint. This is espe-cially true where a steel ball joint housing is pressed into an aluminum control arm. When the joint is riveted to the control arm the rivets are drilled out or cut with an air chis-el. The new joint is replaced using bolts and locking nuts.

BALL JOINT WEAR

Some ball joints that have a grease fitting use the fitting as a wear indicator. If a grease gun will not couple to the fitting, the joint needs to be replaced. As the joint wears, the Belleville washer or spring ensures the required tension on the bearings to maintain zero axial endplay as the control arms move. Lateral wear causes the ball stud to move inside the bearing. It can affect camber and tire wear. The Belleville washer or spring will not compensate for lateral wear.

INSPECTION

To check a loaded ball joint, place a jack or jack stand under the lower control arm to support the weight of the vehicle. Attach a dial indicator to the lower control arm and place the dial in a vertical position to measure axial runout at the steering knuckle. In the case of an all-wheel-drive front ride strut or independent RWD, it may be necessary to mount the dial at the CV joint. Moving the steering knuckle can check lateral runout.

For a SLA suspension that has the coil spring over the top arm, the upper joint is loaded. To check the joint, the upper control arm is supported to unload the joint. If the ball joint has a built-in wear indicator, joint play should be checked with the vehicle on its wheels.

To check a follower-type joint, the Belleville washer or spring is loaded or compressed to check for axial end play. For a strut-type suspension, place a jack stand under the cradle to allow the strut to fully extend. Attach the dial indicator clamp to the lower control arm and place the dial in a vertical position to measure axial runout at the steering knuckle. Place a jack under the ball joint and load the joint by raising the jack. Turn the steering wheel and observe the ball joint to check lateral runout.

For a SLA suspension, the upper control arm can be blocked and the joint can be compressed. Attach a dial indicator to the steering knuckle and place it in a vertical or parallel position to measure axial runout at the lower control arm. Moving the steering knuckle can check lateral runout.

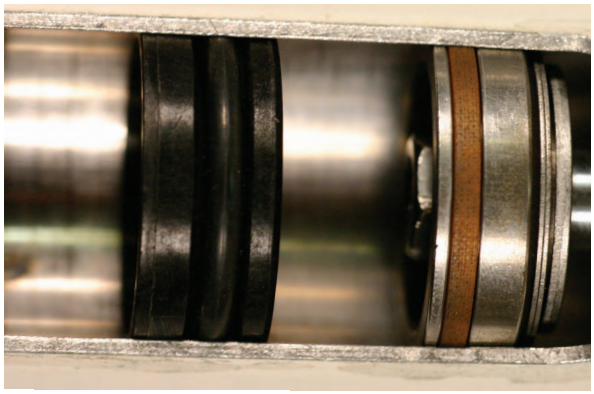
Ride Control

A weak shock absorber or strut does little to dampen bumps and will increase feedback through the steering linkage to the driver. The driver may think he has a steering problem when, in fact, the real problem is poor ride control.

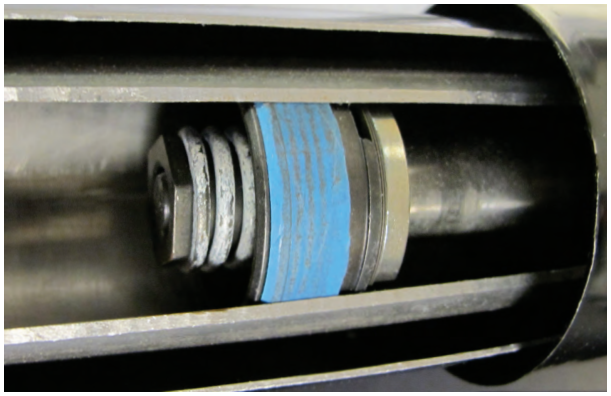
When bad shocks allow tires to leave the road, you obviously can't control the vehicle properly. The driver won't be able to steer, brake or control the vehicle. Furthermore, bad shocks create uneven tire wear and excessive wear on other suspension components.

SHOCK ABSORBERS

A component that dampens suspension motions to improve ride control and handling. The shock absorber is mounted near the wheel and connected to one of the control arms. Inside is an oil-filled cylinder with a piston and valves. Movement of the suspension forces the piston to push against the oil. This creates friction and resistance to dampen the suspension.



Mono-tube shock



Twin-tube shock

Two basic types: twin-tube and monotube. Twin-tube shocks have an oil reservoir around the outside of the piston chamber. Oil moves back and forth from the chamber through valves in the end of the shock. With monotube shocks, there is no outer chamber. One end of the shock is filled with pressurized gas and a floating piston seal separates the gas charge from the oil. Twin-tube shocks also may be pressurized with nitrogen gas (reduces cavitation, foaming and shock fade), but monotube shocks are usually charged at a much higher pressure (up to 360 psi).

Shocks are a wear item and eventually lose their ability to dampen the suspension because of seal wear. A leaky shock must be replaced. Symptoms of worn shocks include a rough, bouncy ride, excessive body sway, bottoming or rocking after hitting bumps and poor handling stability. Worn shocks also can cause a cupped wear pattern on the tires, and may increase stopping distances on rough roads.

An easy way to check the shocks is to do a "bounce test." Rock the suspension several times then release. If the vehicle continues to rock more than once, the shocks are weak and should be replaced.

Replacement shocks with larger piston bores, increased gas pressure, special valving, adjustable valving or other special features can be installed to upgrade ride control performance. Shocks are usually replaced in pairs.

Electronic shocks (and struts) have computer controlled

valving that changes to suit driving conditions. These can be very expensive to replace, so conventional aftermarket shocks and struts are available as a repair alternative.

STRUTS

Shock absorbers that are an integral part of the vehicle's suspension. When used in the front suspension, the strut replaces the upper control arm and ball joint. MacPherson struts have coil springs around them while other struts do not. Like shocks, struts may be twin-tube or monotube and gas charged to improve fade resistance and handling.

At the top of front struts is a bearing plate that allows the strut housing to pivot when the wheels are steered. Looseness in the bearing plate can cause steering noise. Binding may increase steering effort and prevent the wheels from re-centering following a turn. The bearing plate can be replaced separately if necessary.

Struts should be replaced if the shock absorbing element is worn or leaking, or if the strut housing is bent or damaged. A bent strut will upset wheel alignment and may cause uneven tire wear or steering pull.

Replacing a strut that has a coil spring around it requires the use of a spring compressor. A better alternative is a complete strut assembly that comes preassembled with a new spring and is ready to install. It saves time and trouble. Wheel alignment should always be checked after a strut replacement.

STRUT EXTRAS

A new strut or shock is only as good as the parts attached to it. These "required" components (notice I did not say add-ons) should be sold as part of any shock or strut replacement.

BUMP STOPS

Bump stops that fit on the rod of a strut should always be transferred from the old assembly or replaced with new parts. This is cheap insurance against damaging the new unit if it bottoms out. Even if the old strut does not have one, check the parts catalog for a replacement.

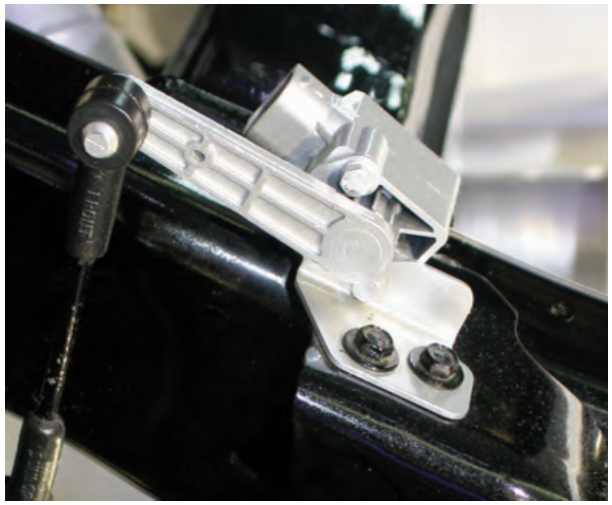
If a strut or shock bottoms out, it can damage the valves in the piston or at the bottom of the bore.

BOOTS

The boot on a shock or strut is critical to the outside and inside of the unit. When a stone hits the chrome shaft of a shock or strut, it will first cause a pit or scratch. This might cause damage to the seal, which might cause a loss of fluid. If the damaged area starts to corrode, it could cause the shaft to lose even more chrome.

Electronically Controlled Ride Operation

Electronically controlled suspension systems use sensors to gather data about driving and road conditions, an electronic control unit (ECU) to process the data and choose the suspension response, and actuators to carry out the response through mechanical action. There are two common methods of regulating the suspension:



- Pneumatic
- Hydraulic

A pneumatic system uses a compressor to develop air pressure, which is used to inflate and deflate air springs or air shocks to regulate suspension stiffness and height. Hydraulic systems generally use an electronic motor, or

actuator, to position the control rod of the variable hydraulic shock absorbers and regulate suspension stiffness.

Some electronic suspension designs use a combination of both air springs and variable shocks. If a vehicle has an electronic suspension system, it is important to disable the system before lifting or towing the vehicle. Some systems automatically shut down when the ignition is switched off, others delay shut down for a preset time interval after the ignition is switched off, and still others only shut down when a switch for the electronic system is manually shut off. Always consult the appropriate Service Manual before beginning to service a vehicle with an electronically controlled suspension.

As for repair, the ECU monitors the system for problems during operation. Should a failure occur, the ECU stores a retrievable diagnostic trouble code (DTC) to let technicians know what type of malfunction occurred. Usually, a warning lamp in the dashboard flashes to let the driver know when a suspension system fault is electronically detected. Most systems transmit suspension system data to a scan tool, but you must count the number and intervals at which the dashboard warning light flashes on others.

Typically, electronic components must be replaced, rather than repaired, if they fail. However, some sensors and actuators are adjustable. A simple but important check is to make sure that all electrical connections are clean and tight, so nothing prevents the flow of electricity. Because electronic system service is not standardized, always check the appropriate Service Manual for instructions before working on an electronically controlled system.

AIR SPRINGS AND SHOCKS

Pneumatic electronically controlled suspensions use air springs or air shocks at the rear wheels, or air springs at all four wheels, to regulate ride height. An air spring takes the place of a coil spring in a suspension. It is a flexible cylinder filled with air. An electronically controlled air shock is a hydraulic shock absorber with an additional air chamber on the top. Some electronic shocks also have an actuator motor that adjusts damping. The ECU responds to suspension height-sensor signals, as well as information from other onboard control systems, to control the air pressure in the springs or shocks. The pneumatic system includes the following:

- Air compressor
- Air dryer
- Airflow control valves
- Air lines and hoses

The motor-driven air compressor draws air into the system and pressurizes it. The air dryer contains a desiccant that draws moisture out of the air to prevent rust or water damage to the system. The ECU controls the airflow solenoid valves to route air to or vent air from the springs and shocks.

Review Questions

1. Which of the following components will cause rapid toe wear on the front tires if worn or loose?

a. Tie rod ends
b. Ball joints
c. Control arm bushings
d. Shocks absorbers or struts

2. Technician A says gas charged shocks contain high-pressure gas to help support the vehicle's weight. Technician B says preassembled MacPherson struts include new upper bearing plates and springs. Who is right?

a. Technician A only
b. Technician B only
c. Both Technician A and B
d. Neither one

3. When Replacing Ball Joints you should NOT

a. Unload the weight-bearing control arm
b. compress the suspension spring
c. use heat to free the ball joint
d. Remove the ball joint cotter pin

4. What links the axle or wheel hub to the vehicle frame

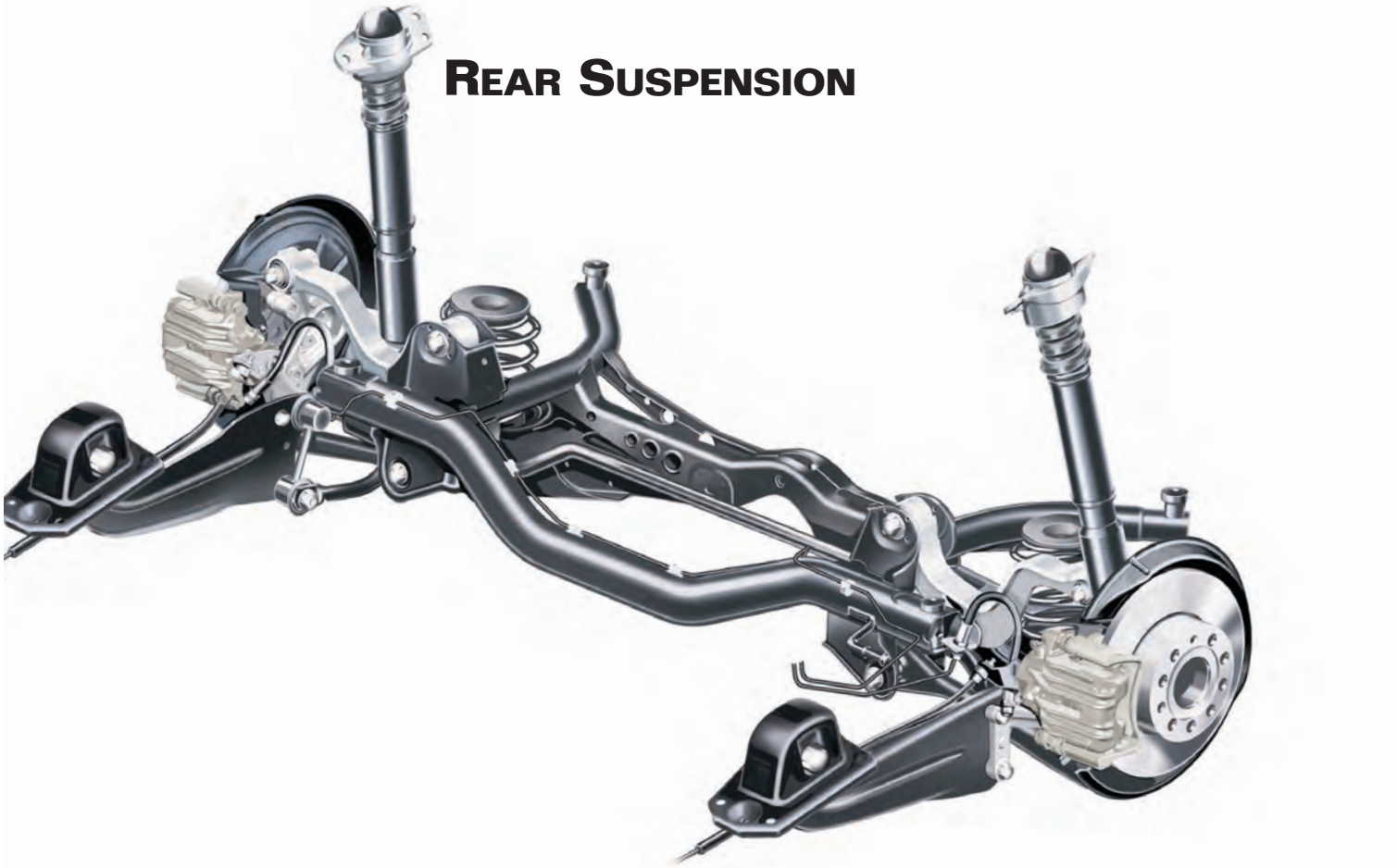
a. Leaf Springs
b. Control Arms
c. ball joints
d. anti-roll bars

Answer Key

1A, 2B, 3C, 4A

ASE G1

Rear Suspension



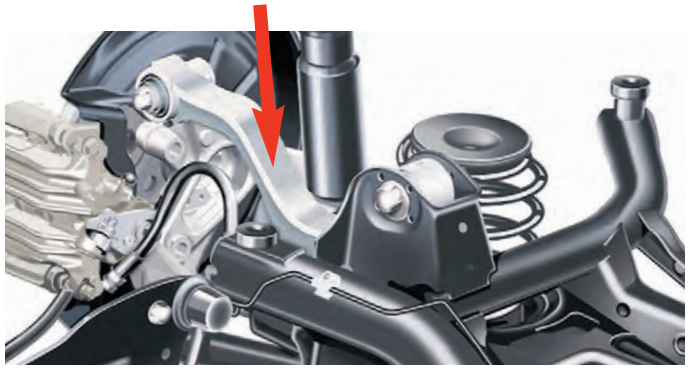
Rear Suspension

Worn rear suspension components can cause steering problems, incorrect wheel alignment, and vibration. Many service procedures for rear suspension components are the same as for the front; but some are different. Service of any rear suspension system should begin with an inspection procedure similar to the one given at the beginning of this Chapter. Check all the suspension components, particularly pivot points, bushings, seals, control arms, and mounting or attaching points. Look for damaged parts, cracks or cuts in rubber parts, bent arms, looseness, and noises or squeaking. Use the guidelines under front suspension service for similar parts, as well as the following paragraphs.

REAR KNUCKLE

Most rear knuckles are made of cast iron and are attached to the upper control arm by a ball joint. Lateral movement is controlled by two lateral arms at the bottom and the upper control arm at the top. Fore and aft movement is controlled by the trailing link. The bottom of the rear shock absorber and spring assembly attaches to the knuckle by a rubber isolated through-bolt.

UPPER CONTROL ARMS



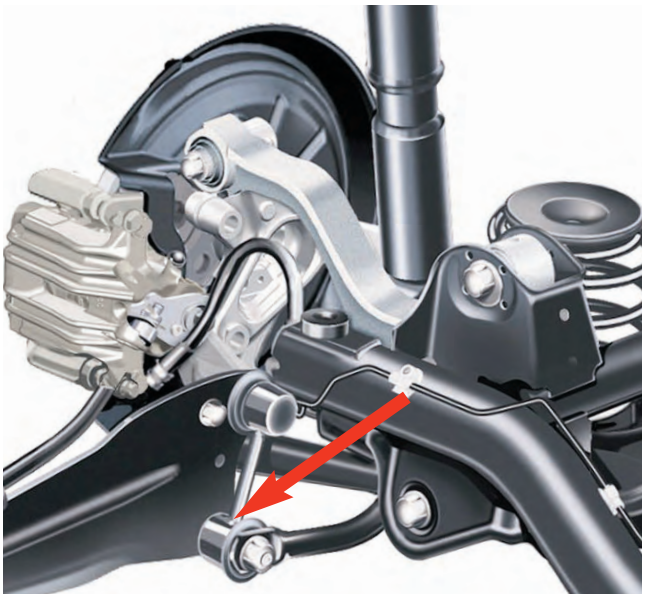
The rear upper control arm is bolted to the rear suspension cross member using a pivot bar, which is rubber isolated from the upper control arm. It is connected to the knuckle by a ball joint.

LATERAL ARMS AND TRAILING LINKS

There is no rear lower control arm. Instead, lateral movement of the knuckle is controlled by lateral arms, while fore-and-aft movement is controlled by the trailing link. Rear toe and camber are adjustable by changing the lengths of the lateral arms. The lateral arms are attached directly to the knuckle.

They are bolted to the rear suspension cross member through two rubber-isolated bushings. The trailing link is mounted between the knuckle and a trailing link bracket, which is connected to the underbody.

STABILIZER BAR



The stabilizer bar connects the forward lateral links. It is mounted to the rear suspension crossmember by rubber isolator bushings. Its function is to control body sway during turns. When one side of the vehicle jounces or rebounds, the sway bar twists to partially send the opposite movement to the other side and keep the body as level as possible.

STRUT REAR SUSPENSION

The strut suspension consists the struts, lateral links, trailing arms, stabilizer bar and cross member. Bolted to each strut is a rear knuckle. Generally four lateral links, two per side, are used between the rear cross member and the knuckle. The lateral links are attached to the cross member and knuckle at each end. The rear-most lateral link is used to adjust rear toe settings. The trailing arm bolts to the knuckle and to a bracket on the body structure or floor pan. A stabilizer bar attaches to each of the rear struts via link assemblies.

SOLID AXLES

Solid rear axles, unless damaged by a collision or underbody impact, generally last the lifetime of the vehicle. If the housing of a solid, rear-wheel drive axle is dented, it may interfere with the axle shafts. Examine a solid axle for dents, bends, or leaking fluid. Check rear camber and toe; if the rear wheels cannot be aligned due to axle damage, either replace the axle, or— if damage and misalignment are minor—align the front wheels to the rear-axle thrust line.

ASE G1

Alignment

Alignment Basics

Correct wheel alignment provides good driving characteristics and keeps tire wear to a minimum. For an alignment to have these effects, the vehicle suspension and steering systems must be in good repair, the wheels must be balanced and not have run out, and the tires must be properly and evenly inflated.

Alignment is measured in angles, according to a system of steering geometry. Traditionally, five alignment angles at the front wheels were checked:

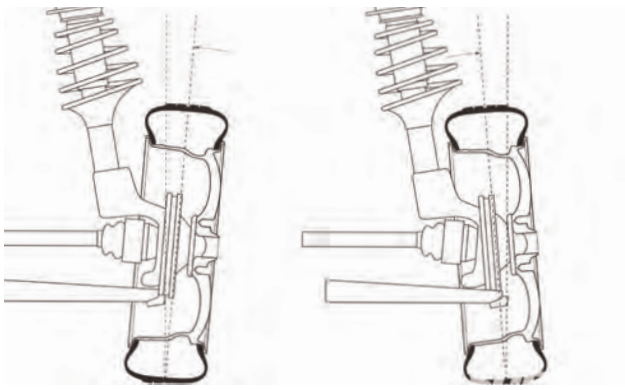
- Camber
- Caster
- Toe
- Steering axis inclination
- Toe-out on turns

Camber, toe, and toe-out on turns are tire wear angles, meaning that if incorrect, the tires wear out quickly. All five traditional angles are directional control angles, which means they affect the steering and vehicle control. Modern suspension geometry demands more precise control to maintain acceptable handling and performance, and two additional measurements are made at the front wheels:

- Thrust angle
- Setback

Many late-model vehicles require a four-wheel alignment, and rear wheel camber and toe must be checked, as well.

CAMBER



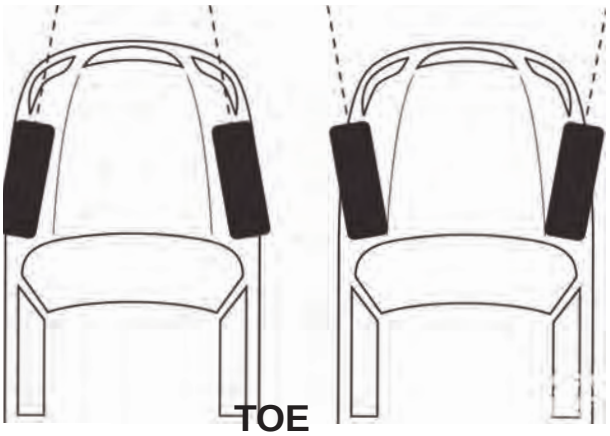
Camber is the tilt of the wheel from true vertical, as seen from the front of the vehicle. Zero camber, a vertical wheel and tire, causes the least tire wear. A positive or negative camber angle causes one side of the tire to squirm on the pavement as the tire rolls, and the tire shoulder wears quickly. When camber angles are unequal, the vehicle pulls toward the side with greater camber. Incorrect camber also places stress on the wheel bearings.

CASTER

Caster is the tilt of the steering axis from true vertical, as seen from the side of the vehicle. Caster affects straight-ahead stability and steering wheel return. High, positive caster makes the front wheels "want" to go straight, so it gives stability and makes the steering wheel return to center after a turn. However, it also increases the amount of effort needed to turn the steering wheel.

Excessive caster causes hard steering, and too little caster can make steering unstable. This instability can cause wheel shimmy, which eventually results in cup wear on the tires. If caster is unequal side-to-side, the vehicle pulls toward the side with less caster.

TOE

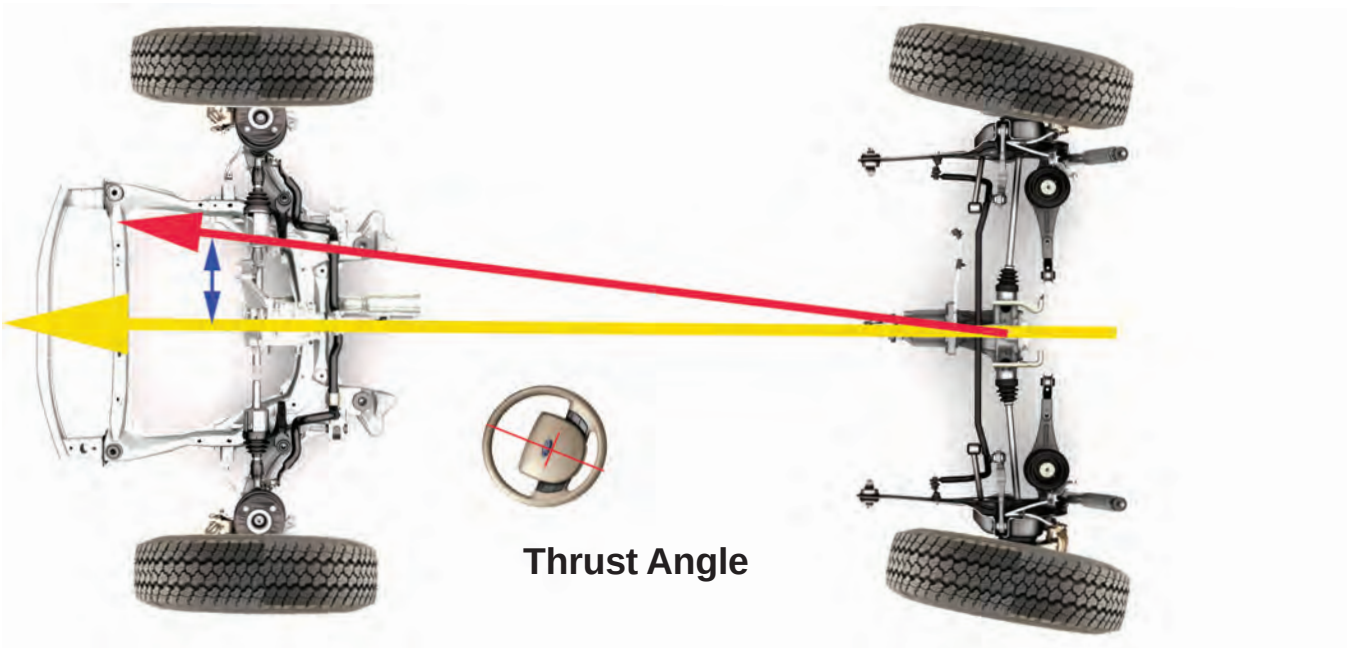


Toe is how the wheels are aimed as seen from above. Wheels aimed inward have toe-in, and wheels aimed outward have toe-out. Zero toe— wheels aimed straight ahead—provides the least tire wear. During straight-ahead driving, toe-in or toe-out causes the wheels to move at an angle to the way they are aimed. This scuffs the tire along the pavement, and the tread wears away very quickly.

Toe-in wears out the outside tire edges, while toe-out wears the inner edges. Toe wear is generally more severe than camber wear. On radial tires, toe wear is smooth, but on older, bias-ply tires, it makes a featheredge wear pattern. Incorrect toe at the rear of a front wheel drive (FWD) vehicle can wear the tires diagonally. Incorrect toe also causes wander and shimmy.

THRUST ANGLE

The thrust angle is the angle between the vehicle centerline and the direction the rear wheels are aimed. If the rear wheels point straight ahead, the thrust line is the same as the geometric centerline of the vehicle, and there is no thrust angle. When a vehicle is driving forward, the rear wheels "steer" it along the thrust line, so zero thrust angle is ideal. Correcting rear toe should correct the thrust angle, but sometimes the rear axle does not allow for toe corrections. If the thrust angle cannot be eliminated, align the front wheels to the thrust line rather than the vehicle centerline. If the front wheels are aligned to the centerline, but



the rear wheels drive along the thrust line, the following problems appear:

- Crooked steering wheel
- Incorrect front camber and toe during driving
- Accelerated tire wear
- Pull

Toe and camber cause similar wear patterns, but toe wear tends to be more severe than camber wear and also tends to occur on both same-axle tires.

RIDE HEIGHT

Ride height problems are not always obvious, and may be overlooked unless a vehicle is leaning like a battleship that's taken a torpedo, or is tilting like the Titanic on its final plunge. It's hard to see variations in ride height if the difference is only an inch or two. You can compare the height of the fender wells on both sides to see if the suspension is leaning or not, but a simple comparison won't tell you if the overall chassis height is correct or not. And with the nose-down aero attitude of so many cars today, it's impossible to tell if the vehicle has the right attitude unless you measure ride height front and rear and compare the results to the factory specifications.

Ride height determines where the control arms operate within their normal range of travel. This is especially important with SLA and wishbone strut suspensions. When a suspension is designed by the vehicle manufacturer, the control arms are positioned to operate at a specified ride height. That position determines the amount and direction of camber change that occurs as the suspension moves from jounce to rebound. If the springs are weak and the suspension has sagged two or more inches below the specified ride height, the arms are forced to operate above their normal plane and beyond their normal range of travel - which can cause undesirable changes in camber and toe. Unequal camber can cause a vehicle to lead to one side.

Differences in ride height front-to-rear can also upset the steering geometry of the front suspension. Raising or lowering the rear of the vehicle will change the angle of the steering axis (caster). Depending on the amount of change, it may have an adverse effect on steering stability, effort and returnability.

There's a safety angle, too. Ride height can also affect the aim of the headlights, which in turn affects nighttime driving safety. A nose high attitude can blind oncoming drivers while a nose low attitude can reduce visibility and the time a driver has to react to a curve or obstacle.

MEASURING RIDE HEIGHT

A vehicle's attitude is difficult to gauge by sight alone unless it is sagging badly or listing to one side. So ride height should always be measured and compared to specifications to determine if it is within an acceptable range. Some manufacturers allow up to an inch or more of sag (but generally no more than two inches) before ride height is considered out of specification.

The point where ride height is measured is critical. Vehicle manufacturers specify various reference points on the frame, body, fender, bumper or suspension. On some applications, ride height may even be specified as a distance between two points on the vehicle's suspension, such as the distance from the frame rail to the axle or a suspension control arm. So make sure you know where the measurement is supposed to be taken.

For conventional ride height checks, a tape measure or ruler is usually all that's needed. Just remember that changes in the wheel and tire size will affect your readings. If tires or wheels on a vehicle have been replaced with ones that are taller or shorter than the originals, it will increase or decrease ride height if you're measuring between some point on the vehicle and the ground. So always check the wheel and tire size on the vehicles prior to taking your measurements.

Aftermarket ride height specification charts are also available that use the distance between the edge of the fender opening and the center of the wheel as a common reference point - which is a much simpler approach. Special aftermarket ride height measuring tools are also available that make this job even easier. The tool snaps on the wheel and helps you find the exact distance between the center of the hub and the lip on the fender.

On some vehicles, the ride height specification is for a loaded vehicle. Adding weight may therefore be necessary to get the correct dimensions. On vehicles with electronic or automatic load leveling suspensions, you may also have to add weight to see if the system is maintaining ride height within the specified range.

Ride height should be measured both front and rear, and on both sides. Comparing the side-to-side ride height dimensions can help you identify sagging springs as well as frame and body misalignment. A difference of more than an inch side-to-side may be enough to cause the vehicle to lead to one side.

Other clues to look for that may tell you a vehicle has a bad ride height problem:

- Caster readings out of spec. Depending on whether the front or rear of the vehicle is low, a certain amount of caster will be added to the front wheels (unless both ends are equally high or low, in which case there is no net change). If the nose is low, negative caster is added to the front wheels. If the rear end is low, positive caster is added to the front wheels.
- Camber readings out of spec. Changes in front or rear ride height can alter front camber alignment (and rear camber on vehicles with independent rear sus-

pensions) especially when there's a difference in ride height side-to-side. How much the camber readings change will depend on the amount of sag and suspension geometry.

- Increased tire wear. Changes in ride height that alter wheel geometry can accelerate tire wear - particularly on suspensions where toe is sensitive to changes in ride height.
- Suspension bottoming. If the suspension has less total travel distance because of weak or sagging springs, it will be more apt to bottom out on bumps or when the vehicle is carrying loads. This, in turn, can accelerate suspension wear and may even damage the suspension stops, shocks, struts or other components. If the suspension stops show evidence of bottoming, and/or the coils on coil springs have been contacting one another, the springs may need replacing.
- Complaints about bottoming, excessive body sway when cornering, nose dive when braking, vehicle instability when towing a trailer or hauling loads, and/or uneven braking or traction may all indicate adverse changes in ride height as a result of weak or sagging springs.

To correct a bad ride height you have to identify the underlying cause and fix it. So anytime ride height is found to be below specs, repairs should be performed before any alignment work is done.

When coil springs are an inch or less below specifications, shims may be installed in or under the springs to restore ride height. But shims do not restore spring rates, so ride harshness may increase with this approach. Installing a shim under a spring to raise ride height also reduces the working range of the spring, which may increase the risk of the spring bottoming. A better way to restore a good attitude is to recommend new springs.

If a vehicle is used for towing or to haul heavier than normal loads, you might also recommend a suspension upgrade such as installing variable rate springs or air springs to boost the vehicle's load carrying capacity.

With leaf springs, longer spring shackles may be installed to compensate somewhat for sag. But the best approach here is also new springs. With torsion bar suspensions, the torsion bars can usually be adjusted to compensate for sag.

For a utility vehicle application, you might also recommend installing some type of helper spring, air spring or elastomer coils that fit between the rear axle and frame to handle the extra weight and to minimize changes in ride height when the vehicle is loaded.

General spring replacement recommendations:

If only one spring is sagging, most experts recommend replacing both springs on an axle to maintain even side-to-side ride height.

Some replacement coil springs have a slightly higher (stiffer) spring rate because they're somewhat shorter than the OE springs. When installed, though, they provide the same ride height and feel as the original springs. Variable rate replacement springs are also available to increase the load carrying capacity of the vehicle without increasing ride harshness.

Handle coated springs with care. The springs on some strut-equipped vehicles have a special coating to protect against corrosion. Use a spring compressor that has soft coated fingers that won't scratch the springs.

Some springs are different side-to-side. Check the markings and make sure you install the correct spring on each side. On some applications, a spacer may also be required under one or both springs to obtain correct ride height.

If ride height is unusually low, a spring may be broken. Breakage may be the result of metal fatigue, overloading and/or corrosion.

Chassis sag may also responsible for a loss of ride height if rust has weakened a strut tower or frame rail. A vehicle in this condition may be unsafe to drive!

If an attitude problem is due to structural damage or misalignment, a trip to a frame shop or body shop may be necessary to make the required corrections.

CORRECTING ALIGNMENT ANGLES

The procedures for measuring wheel alignment angles depend on the alignment equipment used, so we will not detail them here. Some pointers:

- Chock the rear wheels after driving onto the alignment rack; chock the front wheels before raising the rear axle and vice versa
- Lock the wheel turntables and slip plates whenever you are not using them to measure an alignment angle
- Use a brake depressor to hold the brake pedal down when necessary
- Use a steering wheel lock to keep the steering wheel straight during the toe adjustment

Manufacturers provide a number of methods for adjusting wheel alignment, including:

- Placing shims between suspension components and the vehicle frame
- Turning an eccentric cam bolt
- Changing the position of suspension components

- Adjusting the strut rods
- Adjusting tie rod sleeves
- Moving strut mounts

Computerized alignment equipment generally gives onscreen instructions for aligning specific vehicles. Also, illustrated alignment manuals are published yearly. Toe-out on turns, SAI, and setback are non-adjustable angles. When they are out of specifications, it means steering or suspension components are damaged and must be replaced. The thrust angle is not adjusted directly, either. An incorrect thrust angle is a sign of incorrect rear toe. Bringing rear toe into specifications should eliminate the thrust angle. In a four-wheel alignment, always adjust the rear wheels before adjusting the front wheels. If you cannot bring rear wheel toe within specifications, perform a thrust alignment. That is, use the thrust line, instead of the vehicle centerline, as a reference when adjusting the front wheels. Most modern wheel alignment equipment provides for thrust alignments.

ADJUSTING REAR CAMBER AND TOE

On many vehicles, rear alignment angles are not adjustable. Others are only adjustable when aftermarket parts are installed. Vehicles with independent rear suspensions normally allow for a rear camber adjustment. On some vehicles, rear toe adjusts by changing the position of tie rod ends. On vehicles with independent rear suspension, the position of the rear control arms adjusts to set rear-wheel toe. On some vehicles, rear camber and toe are changed by a single adjustment using shims, eccentric bolts, or by repositioning a suspension component.

ADJUSTING FRONT CAMBER AND CASTER

Camber and caster are not adjustable on all vehicles. On a strut suspension, camber is often adjusted by repositioning the top of the strut. Otherwise, the variety of camber and caster adjustment methods includes all those mentioned

earlier. On some vehicles, a single adjustment changes both camber and caster.

ADJUSTING FRONT TOE

Before adjusting toe, center and lock the steering wheel to prevent the steering wheel from being off-center after adjustments are made. Adjust front toe by loosening the lock nut and turning the tie rod to lengthen or shorten it.

On most vehicles, lengthening the tie rod increases toe-in,

and shortening it increases toe-out. On a few vehicles, the tie rods are positioned at the front of the wheels, and the steering arms extend forward from the knuckle. In this case, the effects of tie rod length are reversed.

ALWAYS lengthen the tie rods the same length to avoid geometry problems

CENTERING THE STEERING WHEEL

Before beginning to make adjustments to the vehicle alignment, the steering wheel should be locked in the straight-ahead position. Then then the toe settings are made resulting in a steering wheel that is positioned correctly. If the wheel is not locked the result will be a steering wheel that is turned off center when the vehicle is travelling straight ahead. The steering wheel should only be repositioned after the steering rack or gear and tie rods are centered

and adjusted. These checks are especially important for some cars with power-assisted steering because the system is sensitive to the centered, straight-ahead steering wheel position.

STEERING ANGLE SENSORS (SAS)

Measuring the steering wheel position angle, rate of turn and force of the steering wheel is critical for ESC systems. Often on scan tools they are called Steering Angle Sensors or SAS. The scan tool will typically display the information in degrees.

The SAS is typically is part of a sensor cluster behind the steering wheel. The sensor cluster will have more than one steering position sensor, some sensors have three sensors for redundancy and to confirm the data from the SAS. It is important for the ABS/ESC module to receive two signals to confirm the steering wheel's position. These signals are often out of phase with each other.

RESETING STEERING ANGLE SENSORS

May vehicle require that the SAS is reset or recalibrated after an alignment is performed or parts in the steering system are replaced. There are three types of reset procedures. First, systems that self calibrate on their own. Second, vehicles that require specific wires or grounded or buttons need to be pressed. Third, systems that require recalibration with a scan tool.

Even if the SAS is out of calibration, most vehicles have ways of sensing if it is traveling in a straight line. If the angle is far enough out of range, it might set a trouble code and disable the ESC system.

SELF-CALIBRATION

On some vehicles, to recalibrate the sensor after an alignment or if the battery has died it is just a matter of turning the wheels lock to lock, center the wheel and cycle the key.

This "auto learn" is becoming more common on newer vehicles.

Review Questions

1. Camber on a vehicle can be adjusted on a vehicle with front struts can be adjusted using which of the following methods:

a. Slotting the lower strut mounting bolts
b. Shifting the engine cradle
c. Adjusting the upper strut mounts
d. All of the Above

2. If a vehicle has positive toe, where will tire wear occur?:

a. Inner edges
b. Outer Edges
c. Center
d. None of the above

3. Low ride height can alter:

a. Camber
b. Braking
c. Slip angle

4. Replacing a strut can change ride height.

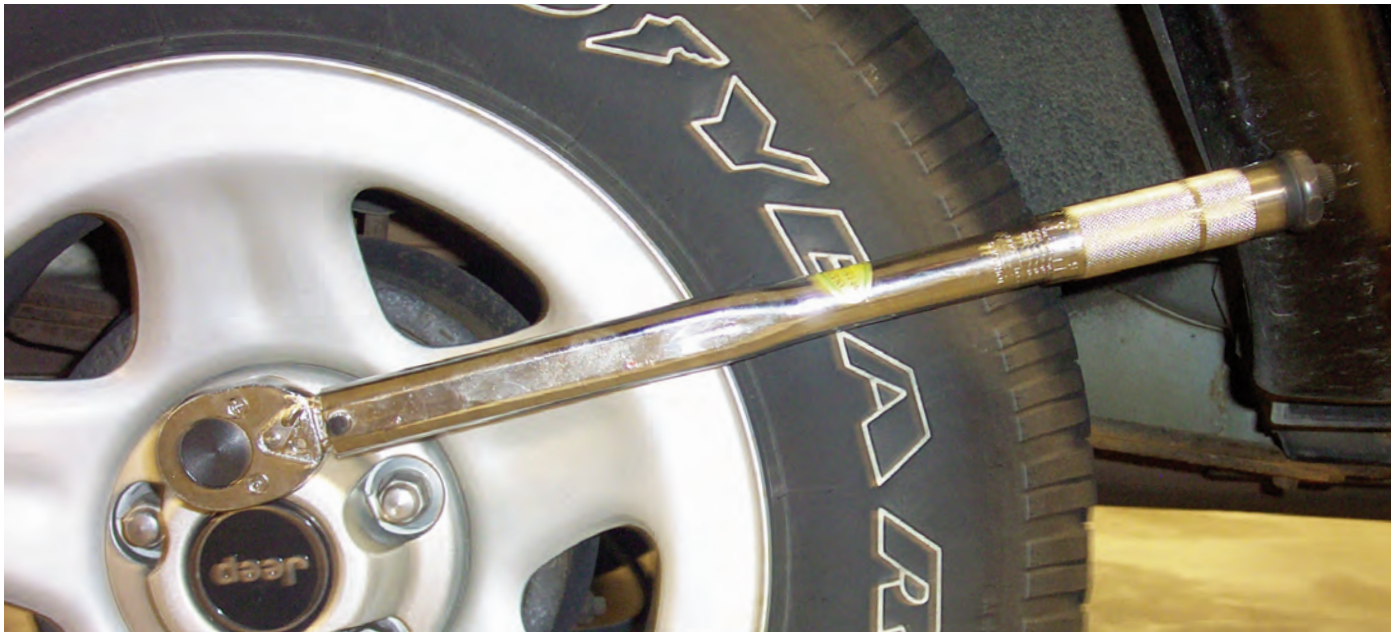
a. True
b. False

Answer Key:

1C, 2B, 3A, 4B

ASE G1

Wheels & Tires



Wheel Service

Wheel removal and installation is an often overlooked aspect of brake service. If wheels are not removed and installed properly, several problems can result. Some of these include:

- **Shortened wheel life**
- **Premature failure of wheel studs**
- **Shortened life of wheel hub and bearing**
- **Warpage of drums and rotors**

Never use lubricants or penetrating fluids on wheel studs, nuts or mounting surfaces. This can raise the actual torque on the nut without a corresponding reading on the torque wrench. Always ensure that wheel studs and nuts are clean and dry. Use of thread-lock, sealant, lubricant, paint or corrosion inhibitor will affect fastener torque and joint clamping force, thereby affecting actual wheel nut torque.

REMOVAL

When removing wheels, never use heat to loosen a seized wheel nut. This could damage the wheel and wheel bearings.

1. Raise and support vehicle.
2. Remove wheel center cap if equipped.
3. Remove wheel nut caps if equipped.
4. Place alignment marks on wheel and hub for installation reference.
5. Remove wheel nuts. If wheel is difficult to remove, install two lug nuts, the tap tire side wall using a suitable mallet.
6. If wheel is still difficult to remove, perform the following steps:
   a. Install and tighten all wheel nuts.
   b. Loosen each wheel nut two turns on affected wheel.
   c. Lower vehicle.
   d. Manually rock vehicle from side to side.
   e. Drive vehicle forward slightly, then apply brakes firmly and quickly.
   f. Drive vehicle backward slightly, then apply brakes firmly and quickly.
   g. Repeat procedure if necessary.
7. Repeat with step one after wheels are loose from mounting surface.

INSTALLATION

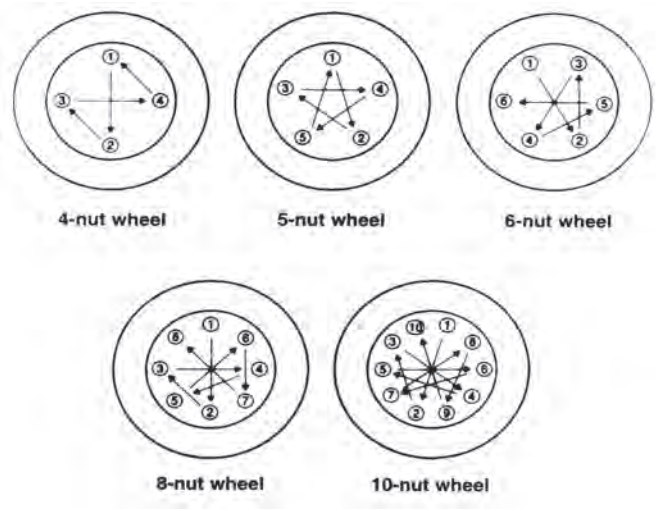
Before installation of wheels, ensure that no penetrating oil is present on vertical surfaces between the wheel and its mounting surface. Remove any corrosion from wheel mounting surfaces using a suitable wire brush. Also ensure that wheel nuts and studs are clean and dry. Never install anti-seize compound to lug nuts or studs unless directed to do so by OEM service literature. Lastly, always follow the proper tightening sequence and tighten lug nuts to specifications. Failure to follow these guidelines when

installing wheels may result in damage to mounting components, poor brake system performance and/or the wheel separating from its mounting surface while the vehicle is being driven.

1. Remove any corrosion or foreign material from wheel and hub mounting surfaces.

2. Clean threads on wheel studs and wheel nuts.

3. Install wheel making sure that reference marks made during removal are aligned.



4. Install wheel nuts. Tighten to specification using a suitable torque wrench in one of the sequences shown above**.**

DIAGNOSING TIRE WEAR:

Toe wear

Toe refers to the parallelism of the wheels to each other. Toe misalignment typically produces a feathered wear pattern across both front tires, and/or inner shoulder wear on both tires (see the photo at the top of the page for an example of extreme toe wear). Front toe wear occurs when the front wheels bow out (too much toe out) as the vehicle is traveling forward. The underlying cause is often worn tie rod ends, but can also be caused by worn or loose inner tie rod sockets on rack and pinion steering gears, worn or deformed control arm bushings, a bent tie rod, bent steering arm or even misalignment in the rear wheels (which throws the steering off-center while driving straight). Measuring toe out with the wheels turned 20 degrees to either side can help you detect a bent steering arm.

If toe wear is accompanied by steering looseness or steering wander, there's a very good chance the tie rod ends are worn. Proceed to the steering checks. If toe wear is accompanied by steering pull or off-center steering, rear wheel toe alignment or axle alignment may be out of specifications.

Toe wear on the inside edges of the REAR tires on a vehicle with an independent rear suspension can also result from toe misalignment (too much toe out). The underlying cause may be rear rod alignment adjustments out of specifications, worn or damaged rear suspension control arm bushings, rear control arm bushings that have too much compliance (give) and allow too much lateral movement of the rear control arms, a bent rear control arm, or worn rear ball joints.

Camber wear

Uneven wear on one side of a tire tread may occur when the tire is leaning due to camber misalignment. The underlying cause may be bad control arm bushings, loose ball joints, a bent spindle or strut, or a strut tower that s out of its normal position (due to factory misassembly, collision damage, body sag or severe corrosion).

Another overlooked cause of camber wear can be a front-wheel drive engine cradle that has shifted out-of-position to one side. A weak or broken spring can also allow camber changes in the suspension that produce camber wear on a tire.

Cupped wear

This may be the result of badly worn shocks or struts, or wheel and tire imbalance.

Diagonal wear

Uneven wear that occurs at an angle across the tread or along the edge of the tread on the REAR tires of a FWD car, minivan or SUV with an independent rear suspension. This type of tire wear can be caused by rear toe misalignment, worn rear control arm bushings, excessive flexing of the rear suspension or not rotating the tires often enough (every 6000 to 7500 miles is recommended). A slight variation is heel-and-toe wear that occurs along the inside edge of the tread. Heel-and-toe wear is caused by unwanted toe and camber changes that occur while driving. The uneven tread wear produced by diagonal wear or heel-and-toe wear makes the surface of the tire rough, which may produce a rumbling or humming noise while driving that sounds like a bad wheel bearing. You can usually feel the undulations and roughness on the tread by rubbing your hand around the circumference of the tire.

MEASURING TIRE WEAR

Tires have wear bars in the tread grooves to visually indicate wear. If the tread is worn down so the wear bars are flush with the surrounding tread, the tire is worn out and needs to be replaced. If you see cords showing through the rubber, the tire is unsafe to drive on and is on the verge of failure. Replace the tire without delay! The same advice goes for any tire that has bulges, deep cracks or the tread is separating from the casing.

Tread wear can be measured using a penny. Place the penny with Lincoln's head upside down in a groove between the treads. If you can't see the top of Lincoln's lead, the tire is okay and still has some wear left in it. But if the top of Lincoln's head is flush with the tread, the tread depth is 2/32-inch (1.6mm) or less, indicating the tire is worn out and needs to be replaced.

Some experts now say the same test should now be done with a quarter. If the top of Washington's head is flush with the tread when you place a quarter upside down in a groove, the tread depth is 4/32-inch (3.2mm). Though the tire still has some tread wear left, braking, traction and handling are significantly reduced on wet pavement compared to a tire with more tread on it. Because of this, many experts now recommend replacing tires when the tread depth is worn down to 4/32-inch or less if you drive in an area that receives a lot of rain or snow.

Tread depth should be checked in the middle of the tread, and in about one inch from each side of the tread.

Tread depth should also be measured at several different locations around the circumference of the tire to check for flat spots.

CAUSES OF TIRE WEAR

Toe or Camber Misalignment

The tires have to roll straight and true, be perpendicular to the road surface (camber) and be parallel to each other (toe) to minimize tread wear. If the wheels are out of alignment, tread wear will increase. Toe misalignment has the greatest effect on tread wear, while camber misalignment causes wear on the inside or outside edge of the tread.

If your tires are wearing unevenly or rapidly, you should have the alignment of all four wheels checked. If toe or camber are out of specifications, the wheels need to be realigned back to factory specifications. This should always be done if you are buying a new set of tires.

Worn Tie Rod Ends

The most common cause of rapid tread wear on the front tires is toe misalignment due to worn tie rod ends in the steering linkage. A bent tie rod or steering arm can also change toe alignment, but in most cases the problem is the tie rod ends are worn out and have too much play.

As a rule, inner and outer tie rod ends should show no visible vertical or horizontal play when rocking the steering back and forth with the full weight of the vehicle on its wheels. If you see any movement in the joint, the tie rod end needs to be replaced.

The inner tie rod sockets on rack and pinion steering gears are enclosed in bellows, making them more difficult to inspect. If the bellows are rubber, you can check for looseness by squeezing the bellows and pinching each socket while pushing outward on the wheel or while a helper rocks the steering wheel. If you feel movement, the sockets are loose and need to be replaced.

You can't do this check with hard plastic bellows, so lock the steering wheel with a holder and watch for any in or out movement in the tie rod while pulling and pushing on the wheels. Also pay attention to the rack mounts. Loose, deteriorated or broken mounts may allow the rack housing to move as the wheels are steered. This can cause steering wander and noise.

With parallelogram steering systems, pay close attention to the amount of play in the idler arm. Looseness here can cause steering wander and toe wear. Pitman arms should show no vertical looseness. Center links should be like tie rod ends and show no vertical or horizontal play.

Underinflated Tires

If the tires are not maintained at the recommended pressure and are underinflated, the tread flexes more than usual as the tire rotates. Over many miles, this will increase tread wear. Check the pressure in each tire with an accurate gauge, and inflate the tires to the pressure recommended in your owner's manual or the inflation decal in the glovebox or door pillar.

Sagging Springs or Bent Suspension Parts

Weak, sagging springs can cause a los of ride height that throws off wheel alignment. Coil and leaf springs sag with age, which can alter camber as well as caster alignment. Measuring ride height will tell you if the springs are still within specifications or not.

If ride height is below specifications, the springs need to be shimmed or replaced. If ride height is okay but camber is out of specifications and a tire shows heavy shoulder wear, a strut or steering knuckle may be bent. This type of damage can be found by having the Steering Axis Inclination (SAI) checked on an alignment machine.

A strut tower that is leaning in or out will affect camber alignment and show a SAI reading that is out of specifications. If the strut tower is pushed back or pulled forward, it will upset caster but SAI will still read within specifications.

A bent spindle can affect either camber or caster or both depending on which way its bent. Also, a bent control arm and/or collapsed control arm bushing can upset camber and/or caster.

Worn Ball Joints

Worn ball joints can also effect wheel alignment and cause uneven tire wear. If the ball joints have built-in wear indicators, joint play should be checked with the weight of the vehicle on the wheels. Ball joints without built-in wear indicators are generally checked by raising the suspension to take the weight off of the joints. But procedures vary.

Worn Control Arm Bushings

Rubber or elastomer bushings are located in the ends of the control arms where they attach to the chassis. The bolt that passes through the bushings serves as a pivot point so the control arm can move up and down with the suspension. If the bushing has deteriorated or deformed with age, it can throw the control arm out of position causing a change in camber alignment. Worn bushings can be replaced to restore proper alignment, but the bushings require special tools or a press to replace. Replacing the stock bushings with firmer aftermarket urethane bushings can reduce compliance and flex for a firmer ride and better control.

Worn Struts or Shock Absorbers

Tire wear can also be caused by worn struts or shock absorbers. The dampers help keep the tires in contact with the road as it encounters bumps and dips. Wear shocks or struts allow the wheels to bounce too much, which typically results in a cupped wear pattern on the tread. You may also feel the steering shudder after hitting a bump if the shocks are worn.

A "bounce test" will usually tell you if your shocks or struts are worn. Rock the suspension up and down several times, then release it. If the shocks are good, the vehicle should stop rocking almost immediately. But if it continues to rock up and down several times, you need new shocks or struts.

TIRE SIZES AND RATINGS

Tires are rated based on the following criteria:

- Size
- Load
- Inflation
- Construction
- Maximum Speed

TIRE SPEED RATINGS

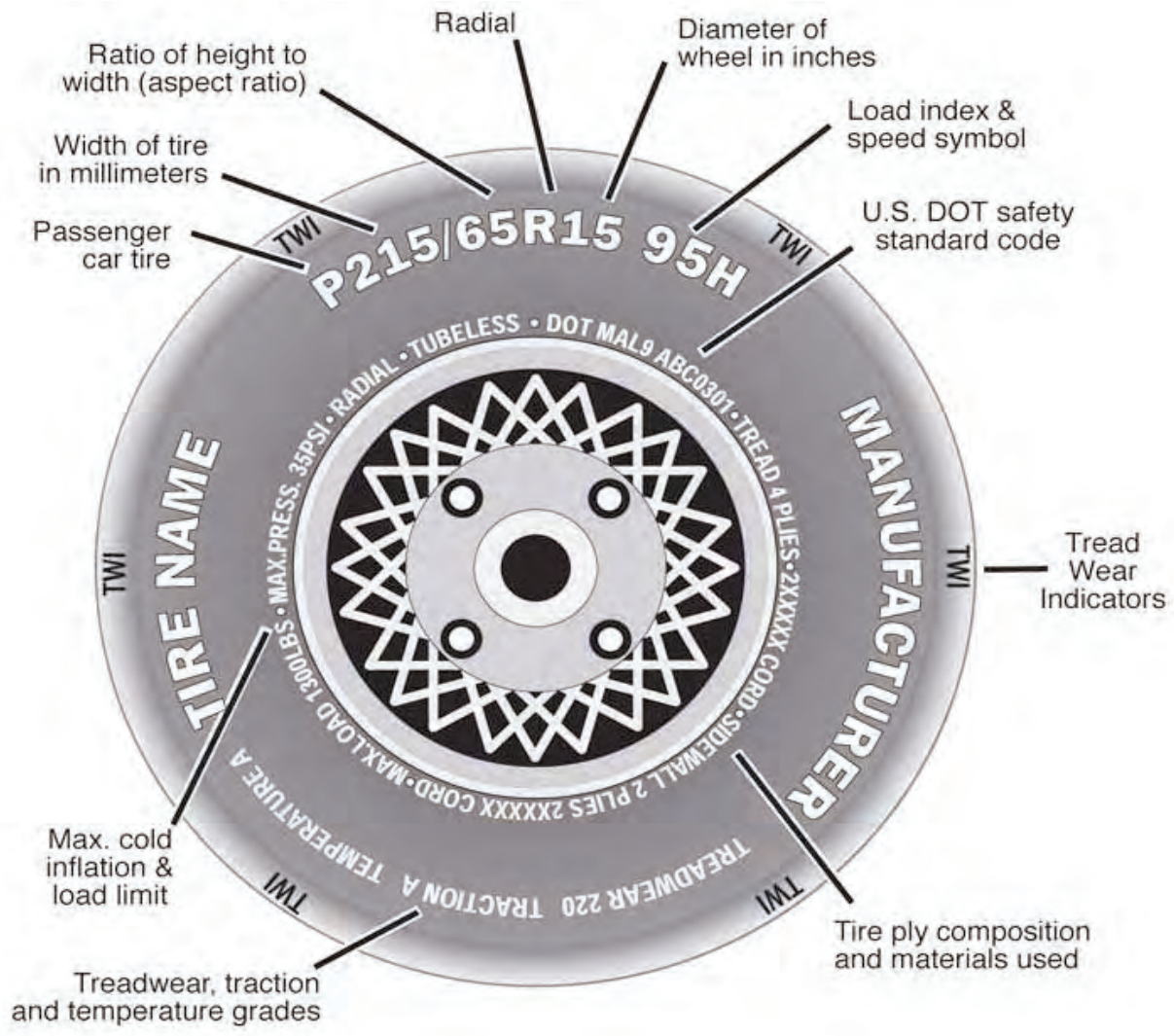
The International Organization for Standardization (ISO) utilizes a load/speed index code, which allows you to determine the correct size of tire for the vehicle's intended use. For instance, a tire speed rating will inform you about the weight or load amount a particular set of tires can hold at high speeds. Tires fall into one of the following grade ratings that are used to indicate the top speed at which a tire can safely operate:

- M - up to 81 mph (130 kph)
- N - up to 87 mph (140 kph)
- P - up to 93 mph (150 kph)
- Q - up to 99 mph (160 kph)
- R - up to 106 mph (170 kph)
- S - up to 112 mph (180 kph)
- T - up to 118 mph (190 kph)
- U - up to 124 mph (200 kph)
- H - up to 130 mph (210 kph)
- V - up to 149 mph (240 kph)
- Z - speeds above 149mph (240 kph)

More recently it was determined that the Z rating turned out to be to vague, and so two more ratings were added:

- W - up to 168 mph (270 kph)
- Y - up to 186 mph (300 kph)

The load/speed index code will usually appear after the size marking on a tire, comprised of two numbers and a letter. For instance, 67H is an example of a load/speed index code. The numbers on this code refer to the maximum load carrying capacity of a particular tire. The letter that is used in conjunction refers to the speed rating, or maximum speed the tire can endure under load and inflation pressure.



A tire's sidewall contians a wealth of information about a tire.

DISMOUNTING AND MOUNTING TIRES

Mounting and dismounting tires improperly can cause personal injury. Always follow all applicable safety precautions when performing tire related service.

Dismounting a Tire

1. Before attempting to dismount a tire from the wheel remove any accumulated mud from the tire and wheel assembly.
2. Place the tire and wheel assembly on the tire service machine.
3. Ensure that the tire valve stem is pointed away from you and others before removing the valve core using a valve core tool.
4. Secure the wheel to the machine using the proper adapter.
5. Follow the machine instructions to break the tire beads free from the wheel rim and removing the tire from the wheel.

Tire mounting machines all have different procedures. Always ready the instruction manual.

Mounting a Tire

1. Lubricate the tire bead and the bead seat on the wheel before installing the tire.
2. Follow the machine instructions to install the tire on the wheel.
3. Loosen but do not remove the adapter securing the wheel to the tire machine.
4. Inflate the tire to the correct pressure and reinstall the valve cap.

WHEEL AND TIRE BALANCE

Wheel balance is the weight distribution of the wheel and tire assembly. If the distribution is uneven, the wheels are out of balance. There are two types of wheel and tire balance:

- Static balance: weight distribution around the hub
- Dynamic balance: weight distribution side to side

When a wheel lacks static balance, it hops, while one lacking dynamic balance wobbles, causing shimmy. Either condition causes steering problems and accelerated tire wear. To correct the unequal weight distribution that causes imbalance, small weights are attached to the wheel rim.

WHEEL WEIGHTS

A wheel balancing weight is made of soft lead, with a steel clip or an adhesive to attach it to the wheel rim. Weights are generally sized in 0.25-ounce (7-gram) increments. Attach a clip-on weight by lightly hammering it onto the rim. Adhesive weights often are a number of 0.25-ounce (7-gram) sections on a single strip; break off as many as needed. Remove the paper covering to expose the adhesive, then press the weight to the wheel. Adhesive weights tend to be less true than clip-on weights. That is, their actual weight may vary slightly. Adhesive weights are also less secure, and typically use is limited to aluminum-alloy wheels, which might develop an electrolytic reaction to a steel clip. If a balancer indicates that several weights are required, consider whether some can be combined to produce the same effect with less total weight added. Too many individual weights begin to act against each other. A computer balancer can usually calculate the most efficient weight placement. Never add more than 6 ounces (170 grams) to the weight of the wheel and tire. If the wheel needs more weight than that to correct balance, it is probably damaged.

Checking and Correcting Balance

There are several methods of balancing the wheel and tire assembly:

- Bubble balancer
- Spin balancer
- On-the-vehicle balancer

SPIN BALANCER

The most typical wheel balancing procedure uses a spin balancer, which also requires removing the wheel and tire assembly from the vehicle. To spin balance a wheel and tire:

1. Remove any old wheel weights and caked-on mud from the wheel.
2. Lift the safety cover on the balancer.
3. Choose an adapter that fits the center of the wheel and place it on the balancer driveshaft.
4. Place the wheel on the driveshaft, and secure it with a threaded clamp. The clamp may have reverse threads.
5. Input wheel dimensions so the computer can calculate correctly. Some machines have dials to set wheel dimensions; others have a keypad. Most balancers need to know:

- Wheel diameter
- Wheel width
- Distance between the wheel and balancer

Wheel diameter is on the tire sidewall. Measure wheel width with the balancer calipers. Use the gauge attached to the balancer to measure the distance between the wheel and balancer cover.

6. Some balancers let you select static or dynamic balance. The dynamic setting checks both.
7. Some balancers have special settings for alloy wheels and steel wheels. Choose the appropriate setting.
8. Close the balancer safety cover and push the start button. The balancer spins the tire and determines

how much weight to add and where.

9. When the wheel stops spinning, open the safety cover and read the display. The computer shows how much weight to add to the outer and inner wheel flanges.
10. Add the weights, close the safety cover on the balancer, and recheck wheel balance. If needed, add weights as indicated by the computer.

TIRE ROTATION

Regularly rotating the tires helps keep wear even and prolongs tire life. Use the schedule and rotation pattern suggested by the vehicle manufacturer. The standard four-tire rotation pattern is to cross non-driven tires to the other axle, and move the driven tires to the other axle on the same side of the vehicle. For example, on a FWD vehicle, cross the rear tires to the front and move the front tires straight back.

For a rear-wheel drive (RWD) vehicle, cross the front tires to the rear and move the rear tires straight forward. In the past, it was believed that crossing radial tires caused tire damage. However, it has been determined that this not true and, unless the vehicle has directional tires, it is an accepted practice to cross radial tires from side to side. To rotate directional tires, switch them front to rear on the same side, and only if the same size tires are used at all four wheels. If the front and rear axles use different-size, directional tires, they cannot be rotated. Most trucks come with a full-size spare and have rotation patterns that include the spare.

TPMS

A tire pressure monitoring system (TPMS) is an electronic system designed to monitor the air pressure inside the pneumatic tires on various types of vehicles. TPMS report real-time tire-pressure information to the driver of the vehicle, either via a gauge, a pictogram display, or a simple low-pressure warning light.

The light should illuminate when a tire is low, and should eventually go out after the low tire has been inflated to its recommended pressure. If the light remains on after checking/inflating the tires, or if it flashes and remains illuminated, it may signal a TPMS problem that will require further diagnosis.

All vehicles manufactured after 2007 will have TPMS and can be identified with a lighted universal symbol on the dash that will illuminate when the ignition is turned to the “on” position. If this doesn’t work, try using the “learn and test” procedure with a TPMS tool.

TPMS problems can include any of the following:

- A TPMS sensor that has stopped functioning because the battery has died.
- A TPMS sensor that is working intermittently due to a weak or failing battery.
- The TPMS module is not receiving a signal from one or more sensors because of an antenna or wiring fault.
- The TPMS module itself is not functioning properly or has failed because of a voltage supply, wiring or internal electronics fault.
- The tires were serviced or rotated recently and the relearn procedure was not done correctly.
- The vehicle owner does not understand how their TPMS system actually works.

IN-DIRECT SYSTEMS

Indirect TPMS do not use physical pressure sensors but measure air pressures by monitoring individual wheel rotational speeds and other signals available outside of the tire itself. First generation indirect systems utilize the effect that an under-inflated tire has a slightly smaller diameter (and hence lower tangential velocity) than a correctly inflated one.

These differences are measurable through the wheel speed sensors of ABS/ESC systems. Second generation iTPMS can also detect simultaneous under-inflation in up to all four tires using spectrum analysis of individual wheels, which can be realized in software using advanced signal processing techniques. The spectrum analysis is based on the principle that certain eigenforms and frequencies of the tire/wheel assembly are highly sensitive to the inflation pressure. These oscillations can hence be monitored through advanced signal processing of the wheel speed signals.

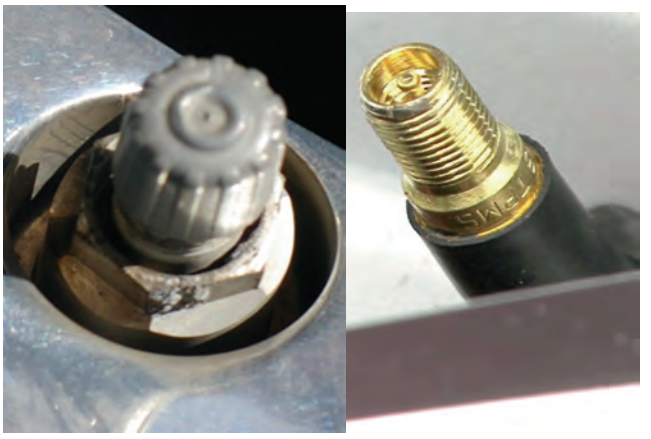
Indirect TPMS cannot measure or display absolute pressure values, they are relative by nature and have to be reset by the driver once the tires are checked and all pressures adjusted correctly. The reset is normally done either by a physical button or in a menu of the on-board computer. iTPMS are, compared to dTPMS, more sensitive to the influences of different tires and external influences like road surfaces and driving speed or style. The reset procedure, followed by an automatic learning phase of typically 20 to

60 minutes of driving under which the TPMS learns and stores the reference parameters before it becomes fully active.

PROPER INFLATION

The inflation pressure shown on the door jamb placard or in the owner's manual is for cold tires (sitting for at least three hours). If you have a customer who brought their vehicle in for an oil change and is waiting for the service to be completed, you may not have the time necessary to properly inflate and check their tires. You can try adding 2-4 psi to the recommended placard inflation because the tires are hot, and ask the customer to check their inflation pressures the following morning. This can prevent the light from coming on after the tires cool down.

STEM IDENTIFICATION



In the past three years, there has been a shift to rubber valve stems by Ford, GM and other carmakers. At first glance, they look just like the valve stems from a non-TPMS vehicle. But, the cap will be longer and the stem will have more threads when compared to a conventional stem. This can help a tech avoid damaging a sensor by accidentally pulling the stem. But regardless of the valve stem's appearance, every model year 2007 and later vehicle has a TPMS system.

SENSOR SERVICE

The grommets around the base and nut of the sensor must be replaced every time the sensor is removed from the wheel. The material in the seals has a "memory" of where it was placed and the amount of clamping force. When the old seal is taken off the rim, it's deformed and will not properly reseal if it's retightened.

Service packs provide the sealing components for each applicable sensor (clamp-in or snap-in) and can be replaced just as valve stems are today. Each time a clamp-in sensor is removed from the valve hole, the grommet, nut, nickel-plated core, cap and any other components supplied in the service pack should be replaced. Snap-in sensors should also have their rubber insert replaced each time the sensor is removed from the valve hole.

Every time a sensor is serviced, the valve core should be replaced with the valve in the service kit. The valve core is nickel-plated to prevent galvanic corrosion and to ensure integrity of the primary seal. To prevent galvanic corrosion, never use a brass valve core with an aluminum TPMS sensor. Instead, always use a nickel-plated valve core with an aluminum-bodied TPMS sensor.

Clamp-on Sensors

Anytime a Clamp-On TPMS sensor is reused or replaced on a wheel, it is necessary to install new seals and valve stem nut to ensure proper sealing around the sensor valve stem.

1. Wipe the area clean around the sensor/valve stem mounting hole in the wheel. Make sure the surface of the wheel is not damaged. Pieces of the old seal can cause a slow leak. Do not lubricate or use a sealant in this area. This can change the torque values and cause you snap the stem.
2. If the valve core is removed, it must be replaced with a new valve core in order to avoid Galvanic corrosion issues, which may cause the valve core to fail.
3. Insert the sensor through the wheel keeping pressure against the rear of the metal valve stem. The potted side of the sensor is to be positioned toward the wheel. Mounting the sensor upside down can cause relearn and transmission problems. The two grommets seal the sensor and nut to the wheel.

Grommets conform to the mating surface of the wheel. The instant the nut is torqued, the seal/grommet starts to take on the shape of the surfaces it is sealing against. This memory cannot be erased. If the seal is reused, it could cause a slow leak.

Never reuse these nuts. The nut is made of a softer metal than the stem, so it will be damaged, and not the sensor, if it is over tightened. The material of choice is typically aluminum. If the nut is over tightened, it will develop hairline cracks. The new nut may have coatings on the threads that prevent corrosion and leaks.

Before tightening the sensor nut, push downward on the sensor housing in an attempt to make it flush with the interior contour of the wheel. Some clamp-in stems have the ability to change the angle of the sensor by loosening a fastener that holds the sensor on the stem. Other sensors should assume the correct position when the nut is torqued.

4. While holding the sensor in position, tighten the sensor nut with a torque wrench. Typical torque values for the base nuts on a TPMS valve stem range from as low as 35 in.-lbs. of torque to as much as 80 in.-lbs. of torque. That's quite a range. This does not mean that any torque value within this range is acceptable. It means that the torque specifications for the base nut on one car might require 44 in.-lbs., another might require 62 in.-lbs. exactly, another might specify 71 in.-lbs. exactly, and so on. Don't guess. Look up the torque specifications for the vehicle you are servicing to make sure you use the correct torque. Over-torquing the sensor nut by as little as 12 Nm (106 in.-lbs.) may result in sensor separation from the valve stem.

Leaks cannot be eliminated by tightening the nut more. Sealing grommets are engineered to work at a specific torque. Any torque above the specified value will cause the seal to leak. Also, extra force may damage the nut or valve stem, or fracture the sensor body.

5. Mount the tire on the wheel following the tire changer manufacturer's instructions, paying special attention not to damage the tire pressure sensor.

Snap-In Sensors

Snap-in sensors can look like regular rubber valve stems. But, the molded rubber on the snap-in valve stem does not reach the threads and there is a tapered shoulder. These valves have a longer cap than a non-TPMS valve stem.

Behind the stem is a mounting point for a self-tapping screw that holds the sensor to the stem. There are two installation methods depending on the type of snap-in valve stem you are installing. Always check the instructions or the manufacturer's recommendation.

The first method is installing the valve stem in the rim and then attaching the sensor. The second method is to attach the sensor to the valve stem and then insert into the wheel. Why? On some stems, the sensor could come in contact with the wheel as the stem is pulled with the sensor attached.

When attaching a new valve to the sensor body, always use a preset torque screwdriver with the correct torx head or hex nut. Most tool suppliers package two preset torque drivers in a set. Due to different manufacturers, the torque settings may differ. The screw is self tapping and can only be used once, the same also applies to the stem.

When tightening the screw, be mindful of stress on the sensor and the alignment of the sensor. Start the screw for the

first couple of threads and make sure the sensor and stem are aligned. When performing the final tightening sequence, stop when the tool clicks indicting the proper torque has been reached.

Before installing the valve stem, it is acceptable to lubricate the seating surfaces with an approved tire lubricant. Do not use chassis grease or grease with petroleum distillates. These types of lubricates can degrade the stem over time and cause a leak. Lubricating the stem can help in the alignment of the sensor on the flats.

When using a tire valve stem installation tool, pull the valve stem straight through the valve hole and not at an angle.

Some valve stems have a tab on the body of the valve that can help in the alignment of the sensor.

The rubber bulb of the valve should be resting against the rim and the sensor body should not be touching the rim for most applications.

RELEARN

When the tires are rotated or sensors replaced, the sensor IDs and postion must be re-learned by the vehicle. Relearn procedures differ from vehicle to vehicle. Some require activition with a magnet that energizes the sensor's transmission, some systems self calibrate and other require a scan tool to connect to the OBDII connector.

When a relearn process is started, vehicles want only one sensor talking at a time. Sometimes all of the sensors are active and sending out signals because the vehicle was repositioned or there is radio interference. For the sensors to go into a sleep mode, the car has to be still for a set amount of time (which varies from vehicle to vehicle). If you are having a difficult time with a relearn procedure, let the vehicle sit for 20 minutes. This should put the sensors into sleep mode, and then you can turn the sensors on one at a time so the IDs and positions can be read by the TPMS system.

Even if the TPMS light is out when the vehicle leaves the service bay, it does not mean the light will not come on later. Usually, this happens when the customer is driving home. According to NHTSA TPMS rules, once a vehicle is started, it can take up to 20 minutes before the TPMS system activates and is ready to alert the driver there is an inflation problem. The "problem" could be air loss, system errors or a sensor that was damaged, perhaps during a demount/mount. This is why looking up the service procedure is required if you are performing any TPMS work, and you will need to perform a little bit of quality control after the repair.

Spares

Before you start a relearn procedure on TPMS sensors, check to see if the spare tire has a sensor. Often, the service information will make the relearn procedures generic so it can be used for a variety of models. Usually the spare is the last sensor to be tested in a relearn procedure. This can be frustrating because it may seem like the vehicle will not relearn the new positions, when actually it is waiting to get information from the spare.

Record Sensor IDs

If you are installing new tires with new sensors, it is a good idea to record the sensor ID numbers and positions before the new tires are mounted. Some vehicle makes – including Nissan, Toyota and Honda vehicles – require that the sensor IDs be entered into the TPMS module through the DLC. This can really save time if something goes wrong during the relearn process and a sensor is not showing up in the memory.

ASE G1

Brake Systems

MASTER CYLINDER SERVICE

The master cylinder generates force and pressure in a brake system. It does this by magnifying brake pedal force into hydraulic pressure by displacing fluid. The master cylinder can be divided into three sections.

At the top is the cap and reservoir. They hold brake fluid before it enters the ports in the cylinder. A swollen reservoir cap seal indicates that petroleum-based lubricants or solvents have been introduced in the system. A replacement of all rubber parts or major components in the conventional hydraulic and anti-lock braking systems is usually required to repair this condition.

A swollen reservoir cap seal indicates that petroleum-based lubricants or solvents have been introduced in the system. A replacement of all rubber parts or major components in the conventional hydraulic and anti-lock braking systems is usually required to repair this condition.

The next component is the cylinder. This component is a round cylinder with ports cut into it that pull brake fluid from the reservoir and other ports that deliver pressure to the wheels or other hydraulic components that measure and distribute the pressure to the wheels. Inside the cylinder's bore is the piston that transfers the force from the brake fluid to the individual wheels.

The piston is machined to precisely fit in the bore and uses seals to prevent leaks to other ports of chambers.

The piston uses cup seals to seal fluid in the pressure chamber. As the seal moves past the replenishing or "compensating" port it begins to create pressure in the pressure chamber, through the lines, and onto the braking units.

A return spring forces the piston back to its resting position. This action allows the brake fluid to return from the brake lines and piston chamber into the reservoir. If the brake pedal is over adjusted or there is debris blocking the compensation port the fluid will not be able to return to the reservoir. This can result in residual and excess pressure in the braking system. This residual pressure can cause brake lock up. Loosening the flare nut at the master cylinder port will often relieve this excess pressure, but will not fix the underlying cause.

DUAL MASTER CYLINDERS

Dual master cylinders are configured to operate two separate braking systems. This was mandated in 1966 as a safety feature to prevent the total loss of brakes if there was a leak in the system.

On a dual-diagonal system, the left front/right rear and right front/left rear brakes operate as separate systems. Dual diagonal systems usually provide better stopping power and steering control when hydraulic pressure is lost in one of the two braking systems. Some systems will do a front rear split.

Master cylinder service begins with a visual inspection:

1.Ensure fluid is at the proper level.

2. Make sure the reservoir cover vent holes are clean and unrestricted.

3. Look over the master cylinder diaphragm, if there is one, for any cracks, tears, or other damage.

4. Check for external leaks at line connections or at the pushrod.

5. Inspect dust boots, if used; they must be soft and

without cracks, and there should be no fluid behind them.

MASTER CYLINDER TESTING

A number of special tests can pinpoint whether a problem is with the master cylinder or elsewhere in the system. First, apply the brake pedal to make sure there is the correct amount of freeplay, **figure 1-1.** Most systems require between 0.13 and 0.50 inch (3 and 13 mm) of freeplay.

EXTERNAL LEAK TEST

A low master cylinder fluid level indicates either normal brake lining wear or a hydraulic system leak. Make sure the cylinder is at least half full, and note the exact level. If the cylinder has run dry, bleed the system first. Apply the brake several times, then check the level again. If the fluid level dropped, there is an external leak. If the external leak is not obvious, have an assistant pump the brakes while you inspect the system for leaks. Be sure to inspect around all fittings and hoses, calipers, wheel cylinders and master cylinder.

INTERNAL LEAK TEST

An internal leak test, also called a bypass test, checks the integrity of the primary seals on the master cylinder piston. The cylinder reservoir must be at least half full for testing. To test, watch the fluid in the reservoir as an assistant slowly applies and releases the brake pedal. If the fluid level rises as the pedal is applied and falls as it is released, the seals are leaking. The fluid is bypassing the seals and rising into the reservoir.

PEDAL LINKAGE ADJUSTMENT

It is essential to adjust the pushrod on a new or reconditioned master cylinder to establish the correct brake pedal free play. If correct pushrod adjustment is not obtained, excessive pedal travel or dragging brakes may result. To adjust the pushrod:

1. If the vehicle has a power booster, pump the brake pedal until the reserve is exhausted and the pedal feel hardens.

2. Place a ruler along the axis of brake pedal travel, then slowly apply the pedal by hand until all the slack in the linkage is eliminated. This amount of travel is the freeplay.

3. Adjust the freeplay by shortening or lengthening the brake pedal pushrod. Loosen the locknut on the pushrod. Rotate the pushrod until you get the specified free play, then tighten the locknut.

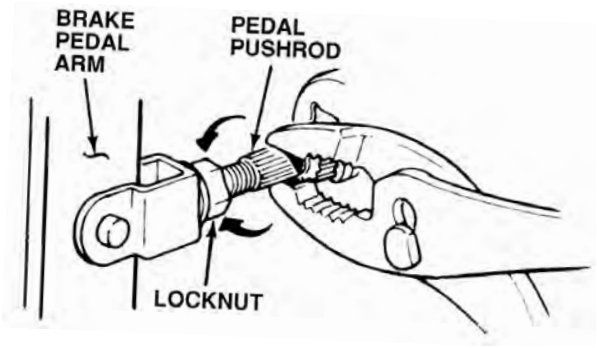


figure 1-1 Brake pedal freeplay is usually adjusted by loosening a locknut and turning the pushrod to obtain the proper length.

Clean the entire cylinder with brake parts cleaner, alcohol, or fresh brake fluid.

BRAKE LINE & HOSES

Brake lines include both the rubber hoses and double-wall steel tubing that transport fluid through the system. Most manufacturers recommend that brake hoses be inspected twice a year or any time the brakes are serviced. Steel brake tubing should be inspected yearly or any time the brakes are serviced. Brake lines that are not in perfect condition must be replaced.

Most brake tubing is a double-walled low-carbon steel tube. It is manufactured by rolling a copper-coated strip and heating to 720 degrees, while the seam resistance brazed by a process called a Bundy weld.

This produces a seamless tube that can be easily flared. The manufacturing process is still used today. The original anti-corrosive coatings were a hot-dip lead-tin coating to both internal and external surfaces followed by zinc-rich paint applied to the exterior. Only use replacement brake lines that are specifically made for brake systems.

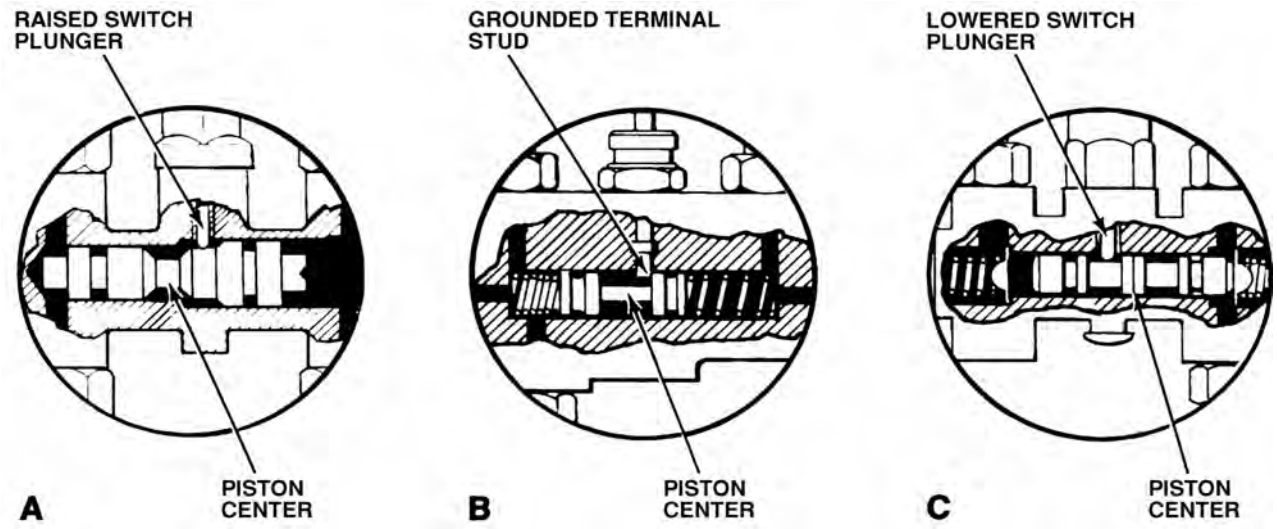


Fig. 2 A unique procedure is needed to recenter the piston in each of the three differential switch designs.

The There are three types of flare and flare nut used on brake tubing. The most common is the SAE 45º flare, which can have both U.S. and Metric threaded nuts. The 37º AN/JIC flare is used on many performance applications. The ISO flare can have both U.S. and Metric type flare nuts. It is referred to as the bubble flare.

Hard brake lines can fail due to corrosion and mechanical damage. Corrosion occurs when the bare metal of the lines is exposed to the water, air and often road salt or deicers. Corrosion can also happen internally if the anti-corrosion additives break down in the brake fluid.

Hard brake lines can be damaged by impacts with objects or by chaffing of the line on other components. If a line is replaced or moved, it is essential that all the clips and holds are reattached.

BRAKE HOSE INSPECTION

Flexible brake hoses are used to connect steel tubing to the calipers or cylinders at the wheels. All vehicles have a hose at each front wheel to permit the wheels to move freely without damaging the brake lines. Vehicles with independent rear suspension have a hose at each rear wheel as well, while vehicles with a live, rear axle generally have a single, rear hose between the axle and the chassis.

Visually inspect brake hoses for swelling, blisters, leaks, stains, cracks, and abrasions. Swelling and blisters are signs of internal fluid leakage that has penetrated to the outer hose covering, **figure 1.** Obvious leaks or stains from leaks may appear on the surface of the hose and around the fittings on the hose ends. Cracks can appear anywhere on the hose, as can signs of abrasion. Finally, check the hose mounting hardware and locating brackets for damage and tightness.

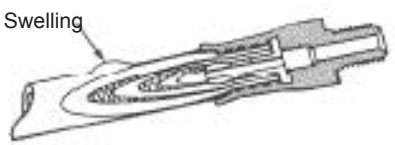


Fig. 1 Internal leakage, which causes a brake hose to swell or blister, is cause for replacing the hose.

Swelling, which can cause poor braking performance, is not always obvious, and may only be noticeable when the brakes are applied. To check, wrap your hand around the suspect hose and have an assistant slowly depress the brake pedal. If you can feel the hose expand in your hand, it is leaking internally and must be replaced.

Pulling to one side while braking and poor stopping performance may be due to blocked or clogged brake hoses. Also, if one front brake exhibits a blued rotor and has worn out its linings in a short time, suspect a hose clogged with deposits that allows high apply pressure into the caliper, but restricts the flow back up to the master cylinder, thus resulting in drag.

BRAKE TUBING INSPECTION

Visually inspect brake lines, beginning where they attach to the master cylinder, and follow them along their paths to the wheels. Look for rust and corrosion along the frame rails, at the mounting clips, or any place where water, dirt, and road salt accumulate. Also, check tubing for kinks, dents, abrasions, and other distortion and damage. Make sure the tubing is properly fastened to the chassis. Loose mounting brackets permit the tubing to vibrate, which results in cracks that lead to fluid leakage. Physical damage is most likely in the areas directly behind the wheels, or where the tubing crosses below an axle or frame member.

RECENTERING PRESSURE DIFFERENTIAL SWITCHES

After the brake system has been bled, the pressure differential switch may have to be recentered in order to switch off the warning light. Opening a bleeder valve creates a pressure differential between the circuits of the hydraulic system, and the switch interprets this as a fluid loss or partial system failure. In response, the piston inside the switch body moves to one side and completes the circuit to switch on the warning light.

There are three types of pressure differential switches, and each requires a different procedure to recenter it, **figure 2.** To recenter a single-piston pressure differential switch without centering springs, first determine if the brake hydraulic system is split diagonally or front to rear, **figure 2A.** Then, open a bleeder valve in the circuit of the system opposite that which was last bled, slowly depress the brake pedal until the warning light goes out, maintain pedal pressure, and close the bleeder valve.

Single-piston pressure differential switches equipped with centering springs illuminate the warning light only when the brakes are applied and a pressure difference exists between the two circuits of the brake system, **figure 2B.** The switch recenters itself automatically when the brakes are released, unless the piston sticks in position against the terminal stud. If the warning light remains illuminated after the brake system has been repaired, apply the brake pedal with moderate to hard force. Hydraulic pressure should free the stuck piston and the centering springs will position it properly in the bore. The warning light will then go out.

A two-piston pressure differential switch with centering springs locks the warning light on until it is recentered, **figure 2C.** Remove the switch plunger assembly from the switch body, then apply the brake pedal with medium to hard force. This allows the centering springs to reposition the piston. Once the piston is centered, reinstall the switch plunger assembly.

BRAKE WARNING LAMPS

The red brake warning lamp can indicate a severe brake system failure. If the brake warning lamp circuit is working correctly, it should prove out by turning on when the ignition switch is turned on, then turning off once the engine is started.

When the red brake warning lamp is illuminated, verify proper functioning of the brake system before operating the vehicle. In most cases, the problems you will diagnose will be due to the lamp being illuminated. In some cases though, you may see a lamp that will not work at all. In this section, we will discuss some common ways in which you can diagnose both problems.

On a typical brake system, there are two switches or sensors that can cause the red brake lamp to illuminate. One is located on the master cylinder and the other is located on the parking brake lever.

On these systems, application of the parking brake or low brake fluid level will cause the red brake lamp to illuminate. Of course, there are circuit problems that can occur that would cause the lamp to turn on. These include: shorted indicator circuit, ABS system failure (if equipped) or instrument cluster printed circuit board failure.

On some models, the instrument cluster is controlled by an electronic control unit (ECU). If a problem exists on one of these systems, some of the basic principles discussed here can be applied to help diagnose the red brake warning lamp circuit, but more than likely, a factory shop manual along with a wiring diagram manual will have to be consulted. Many factory shop manuals outline very in-depth pinpoint tests that should be followed to quickly lead you to proper diagnosis of the red brake warning lamp.

BRAKE WARNING LAMP CIRCUIT TESTING

Preliminary Inspection

When diagnosing the brake warning lamp, first check the brake fluid level. If it is low, determine the cause of low fluid level, then fill and recheck the system. If fluid level is ok, inspect the parking brake system to ensure they are fully released. If the parking brake system does not release inspect all parking brake cables and mechanisms to determine the cause of failure. Repair and recheck warning lamp operation. If fluid level and parking brake operation are ok, suspect a faulty switch, shorted circuit or ABS malfunction (if equipped).

Fluid Level Switch Test

To test the fluid level switch, disconnect the switch, then measure resistance of the switch using a suitable digital volt-ohmmeter. When the fluid level switch is in the full position, the ohmmeter should indicate open circuit, **figure 3.** When the fluid level switch is in the low position, the ohmmeter should indicate continuity.

Parking Brake Switch Test

To test the parking brake switch, disconnect the switch, then measure resistance when parking brake is not applied. The ohmmeter should indicate open circuit. When the parking brake is applied, the ohmmeter should indicate continuity.

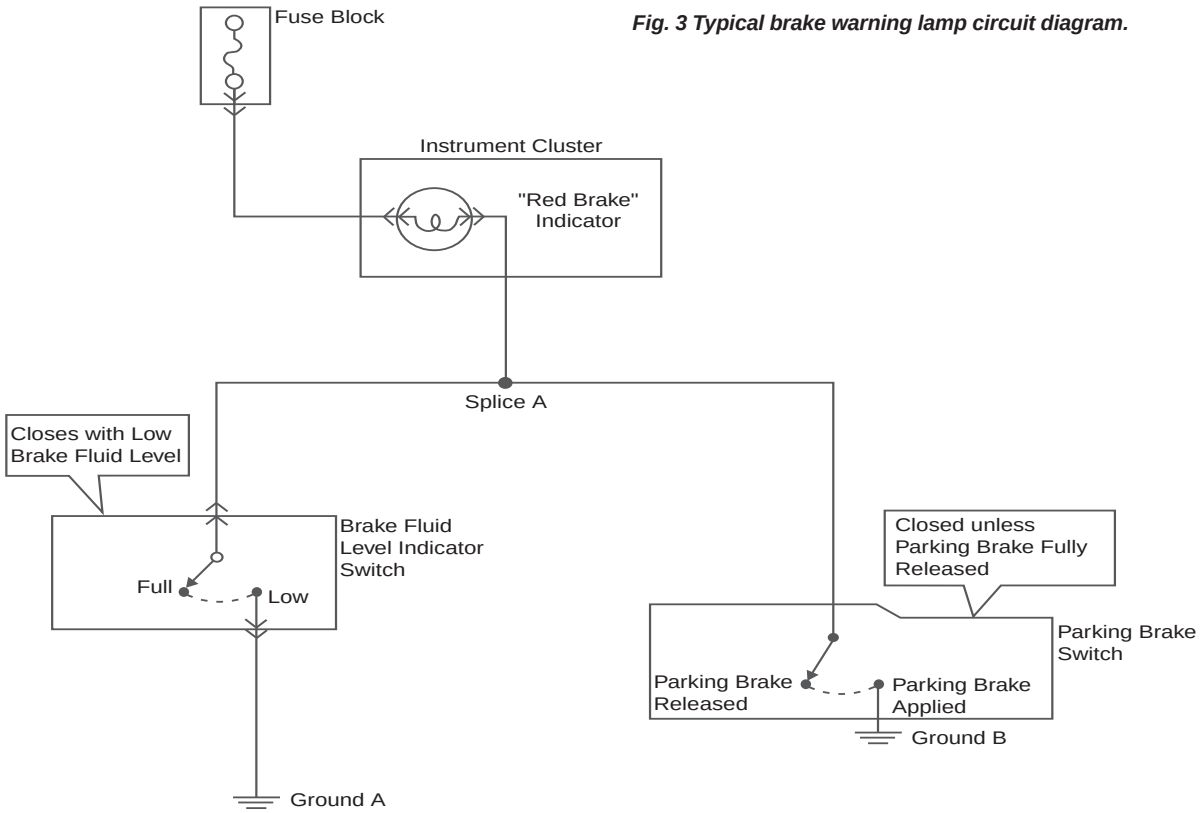


Fig. 3 Typical brake warning lamp circuit diagram.

WARNING LAMP CIRCUIT WIRING INSPECTION

Unwanted Ground

The wiring diagram shown in **figure 3** shows three different areas of the circuit where an unwanted ground might occur. If an unwanted ground occurred in any of these areas, the red brake warning lamp would illuminate. In the circuit shown, one way to tell if there is an unwanted ground would be to disconnect the fluid level switch and the parking brake switch. If the lamp is still on, suspect an unwanted ground that exists before the switches.

To check for an unwanted ground in the circuit shown in **figure 4,** first remove the fuse supplying the circuit with power. Next, disconnect both the brake fluid level switch and the parking brake switch. Using a suitable digital volt-ohmmeter, check the resistance of the harness to ground at several points throughout the circuit. If continuity is indicated by the ohmmeter, suspect that portion of the circuit for the unwanted ground.

Open Circuit

The wiring diagram shown in **figure 5** shows four places where the circuit is open. If an open occurred at point “A” of the circuit, the indicator would not work at all. If an open occurred at points “B” or “C”, the brake fluid level indicator portion of the circuit would not work at all. If an open occurred at points “D” or “E”, the indicator would not illuminate if the parking brake were applied.

Short Circuit

If the circuit shown in **figure 5** were grounded at point “A”, you would have a short circuit. This condition would cause the fuse supplying the circuit to open. If the fuse were replaced, it would immediately open again if the short were present. To find the short circuit, a careful examination of the wiring harness would be necessary.

BRAKE FLUID: BLEEDING, FLUSHING & LEAK TESTING

When topping off the brake fluid, always use the type and DOT grade of brake fluid recommended by the manufacturer. Most vehicles use polyglycol brake fluid, either a DOT 3 or DOT 4 grade fluid.

To avoid mixing the three types, federal law requires that each be a specific color: polyglycol fluids are clear to amber, silicone fluids are purple, and hydraulic mineral oils are green. Keep in mind that today, many manufacturers recommend routine replacement of brake fluid at specific scheduled intervals. Consult OEM maintenance guides to determine these intervals.

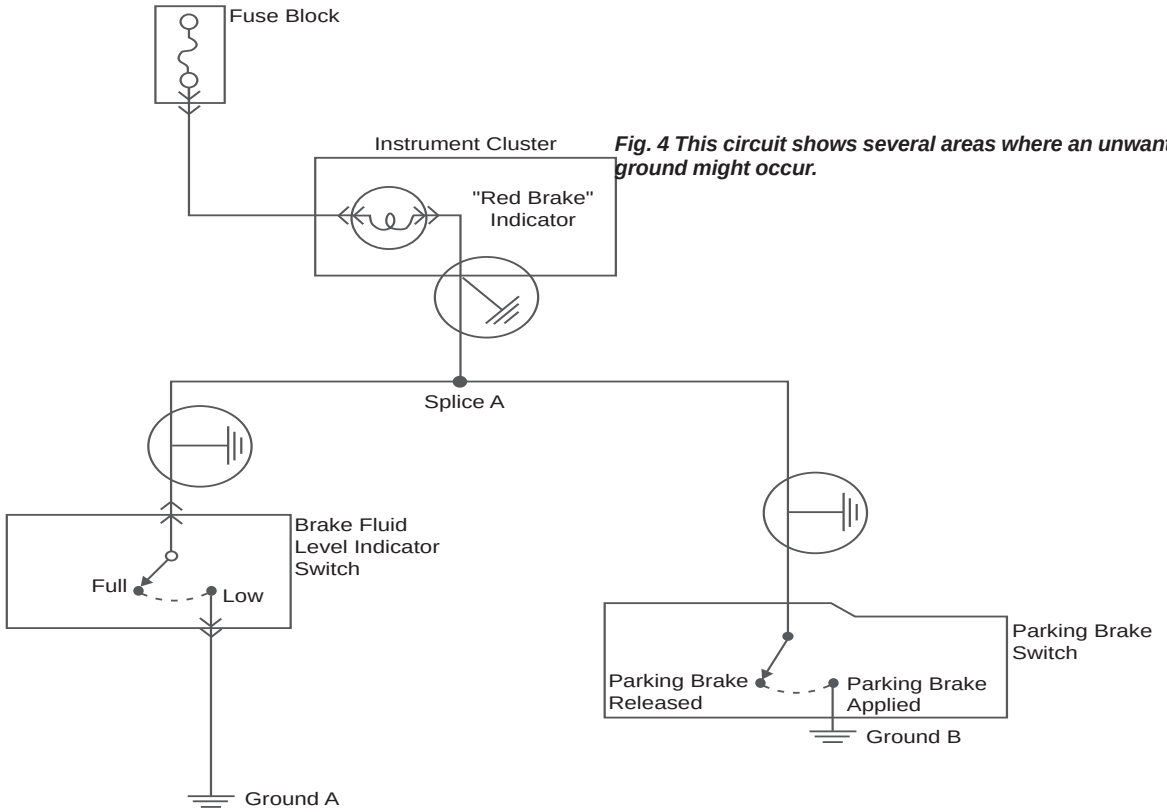


Fig. 4 This circuit shows several areas where an unwanted ground might occur.

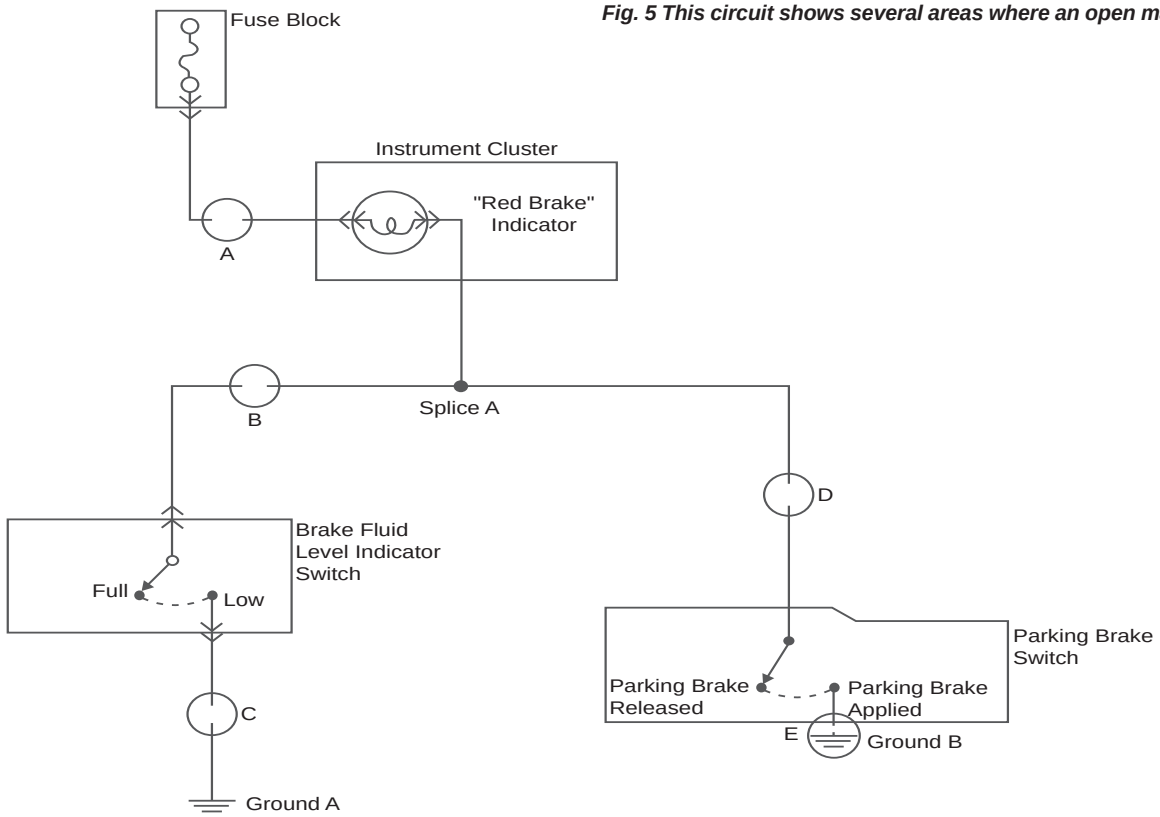


Fig. 5 This circuit shows several areas where an open may occur

SYNTHETIC AND DOT 5.1

Both synthetic and conventional brake fluids start from the same "polyethylene glycol" stock. But, to make synthetic brake fluid the manufacturer will "synthesize" the original base stock and make the molecules better and more consistent. They could make the chains longer or add other molecules to enhance the performance. Almost every synthetic brake fluid manufacturer does it different.

To the base stock they add the additive package. This is a mixture of anti-corrosion, anti-foaming and other secret chemicals that give the fluid the desired performance characteristics for operation in vehicles.

DOT 5.1 is a high-performance certification (higher temps than DOT 5). To meet the performance criteria, it takes a synthetic or really good conventional base stock.

Silicone is a synthetic substance. But, don't confuse Dot 5 with synthetic polyethylene glycol-based fluids like DOT 5.1.

DOT 5 brake fluid should never be used on a daily driver. Moisture is not absorbed by DOT 5 brake fluid. The moisture will collect in the calipers and wheel cylinders. All DOT 3, 4 and 5.1 brake fluids are compatible with each other and with all systems. All polyethylene glycol-based fluids will not harm healthy rubber parts. Also, the additive packages will not damage or distort any rubber parts. Even if an older rubber part that has a high concentration of natural rubber, they will not be damaged by new DOT rated brake fluids.

Polyethylene glycol-based fluids (conventional or synthetic) will not mix with silicone fluid (DOT 5). It will lump together somewhere in the system. Also, they will not react when it is mixed. So, if you perform a good flush, the rubber parts and the system should be OK.

CONTAMINATION

Brake fluid that is contaminated with water, rust, dirt, mineral oil, or compounds derived from overheated glycol can cause various system performance problems. For instance, moisture lowers the boiling point, which can allow bubbles to form in the lines that can result in loss of stopping power, especially at high altitudes. Moisture also contributes to corrosion, which may cause caliper or wheel cylinder pistons to seize, resulting in loss of braking at that wheel and a subsequent pull toward the opposite side. Mineral oil softens and destroys rubber seals, causing catastrophic leaks. Other contaminants can clog valves or the ABS hydraulic control unit. Brake fluid care and maintenance are important for both safety and economy.

STORAGE AND HANDLING

Storage and handling precautions for brake fluid depend on the type of fluid being used. Polyglycol fluid has a very limited storage life. Once a can of polyglycol fluid has been opened, its entire contents should be used as soon as possible because it immediately begins to absorb moisture that degrades its performance. In contrast, silicone brake fluid and HSMO can be stored almost indefinitely. They are not hygroscopic, and there is no limit to the length of time they retain their original properties.

When handling a polyglycol fluid, remember that it is a powerful solvent that can rapidly damage paint. If you spill any, immediately flush the area with plenty of clean water. Neither silicone nor HSMO brake fluids harm paint.

BRAKE FLUID CONDITION

Whenever you check the brake fluid level, also inspect the fluid for dirt, moisture, or oil contamination. Fluid in good condition should be relatively clear. A cloudy appearance indicates moisture contamination, while a dark appearance indicates contamination by rust, dirt, corrosion, or brake dust. A layered appearance can mean a silicone brake fluid was mixed with a polyglycol fluid. The two fluids do not mix, and the entire system should be completely flushed, then refilled with the recommended fluid.

BRAKE BLEEDING SEQUENCE

Brake bleeding is a process that pushes new brake fluid through the brake system to force out contaminated fluid and trapped air. Air can enter the brake lines whenever the system is opened for service. Brake system bleeding must be done in a particular sequence:

1. Master cylinder
2. Combination valve
3. Wheel cylinders and brake calipers
4. Load-sensing proportioning valve
5. Antilock brake system (ABS) hydraulic modulator or pump motor.

Combination valves, load-sensing proportioning valves, and ABS hydraulic modulators or pump motors are only bled when present in the system and equipped with bleeder valves. The correct bleeding sequence at the wheels varies from vehicle to vehicle. In some cases, you may have to recenter the pressure differential switch after bleeding the wheel brakes.

The centering procedure is detailed in this chapter on page 17. Also, some disc brake systems have a metering valve or combination valve that demands special attention if power bleeding the system. Since the operating pressure of power bleeders is within the range where the metering valve blocks fluid flow to the front brakes, you must deactivate the valve. Special override tools are used to hold the valve open for pressure bleeding, **figure 6.**

MASTER CYLINDER BLEEDING

Bleed new or rebuilt cylinders on the workbench before installing them. This practice eliminates trapped air pockets and greatly speeds bleeding the rest of the brake system.

Master cylinder bench bleeding

1. Clamp the cylinder in a vise.

2. Use a drain pan to catch any fluid leakage from the outlet ports, or fit hoses to the ports to route fluid back to the reservoir. Fill the cylinder with the correct type and grade of new brake fluid.

3. Use the cylinder pushrod, or other round-ended rod, to slowly stroke the cylinder pistons inward until they both bottom.

4. If the fluid outlets are open, plug them with your fingertips. Then, slowly allow both pistons to fully return on the back stroke and remove your fingers from the outlets. If the fluid outlets are connected to the reservoir with hoses, make sure the connections are airtight. Then, slowly allow both pistons to fully return.

5. Repeat steps 3 and 4 until the fluid coming from the outlets is air-free, and bubbles no longer emerge from the compensating and replenishing ports in the reservoir.

Wheel Brake Bleeding

When bleeding the wheel brakes, follow the bleeding sequence recommended by the manufacturer for the particular vehicle being serviced. Sequence can vary not only by manufacturer, but also by year, model, and equipment. Special procedures may be required for vehicles with ABS. Generally, the wheel cylinder or caliper furthest from the master cylinder is bled first, followed by the next closest caliper or cylinder, and so on. Be sure to check the recommendations for the specific vehicle you are working on, as sequences will vary. In all types of wheel brake bleeding, fill the master cylinder with fluid and ensure that it stays at least half full during the entire procedure.

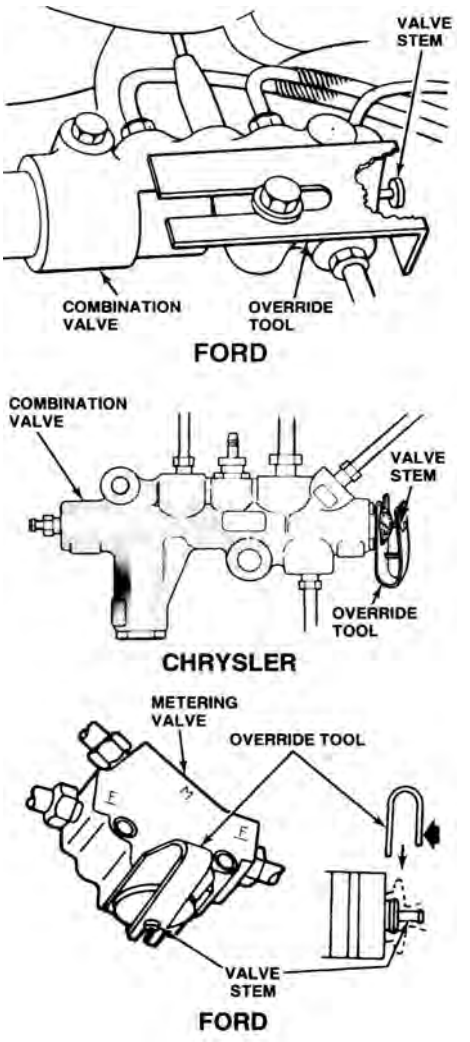


Fig. 6 Override tools hold the combination or metering valve open to allow for pressure bleeding the hydraulic system.

MANUAL BRAKE BLEEDING

This method requires two people: one person to press the brake pedal, while the other opens and closes the bleeder valves. The brake pedal will sink toward the floor as the valve is opened. Upon signal, the bleeder valve is tightened and the operation repeated until all the air is expelled. To manually bleed a system:

1. If the vehicle has a vacuum or hydraulic power booster, discharge it by pumping the brake pedal with the ignition OFF until the pedal feel hardens.

2. Slip a length of clear plastic hose over the bleeder valve of the first wheel cylinder or caliper in the bleeding sequence, and submerge the open end of the tube in a

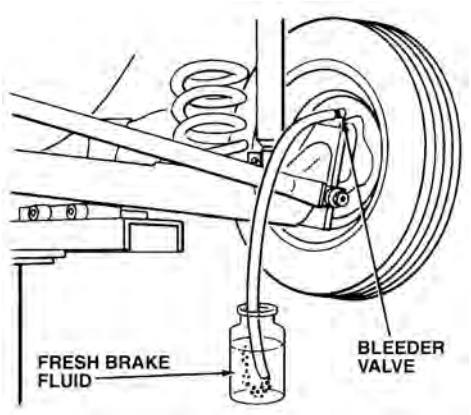


Fig. 7 Using clear hose and a partially filled bottle of fresh brake fluid makes it easy to spot air bubbles and prevents spills when bleeding the system.

partially filled container of fresh brake fluid, **figure 7.**

3. Loosen the bleeder valve approximately one-half turn, then have your assistant slowly depress the brake pedal and hold it to the floor. Air bubbles leaving the bleeder valve will be visible in the hose to the container.

4. Tighten the bleeder valve, then have your assistant slowly release the brake pedal.

5. Repeat steps 3 and 4 until no more air bubbles emerge from the bleeder valve.

6. Transfer the plastic hose to the bleeder valve of the next wheel cylinder or caliper in the bleeding sequence, and repeat steps 3 and 4. Continue around the vehicle in the specified order until the brakes at all four wheels have been bled.

PRESSURE TANK BLEEDING

Pressure bleeding drum brake systems is a straight-forward procedure, but some disc brake systems have a metering valve or combination valve that demands special attention. Since the operating pressure of power bleeders is within the range where the metering valve blocks fluid flow to the front brakes, you must deactivate the valve. An override tool is sometimes used to hold the valve open for pressure bleeding, **figure 6.**

Follow the correct sequence when pressure bleeding a brake system. Be aware, some manufacturers recommend one sequence for manual and another for pressure bleeding. To pressure bleed a system:

1. Make sure the pressure bleeder tank is filled with the proper type and grade of brake fluid. Consult the instructions for the equipment being used.

2. With the bleeder properly sealed and the fluid supply valve closed, use compressed air to charge the bleeder to approximately 30 psi (207 kPa) of pressure.

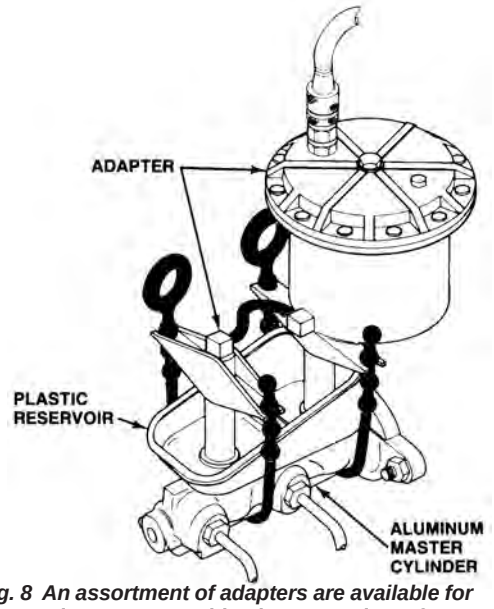


Fig. 8 An assortment of adapters are available for connecting a pressure bleeder to a variety of master cylinders.

3. On vehicles with a metering or combination valve, override it with the appropriate tool.

4. Clean the top of the master cylinder, remove the reservoir cover, and clean around the gasket surface. Be careful not to allow any dirt to fall into the reservoir.

5. Select the appropriate pressure bleeder adapter and install it on the master cylinder, **figure 8.**

6. Connect the pressure bleeder fluid supply hose to the adapter, making sure the hose fitting is securely engaged.

7. Open the fluid supply valve on the pressure bleeder to allow pressurized brake fluid to enter the vehicle brake system. Check carefully for fluid leaks that can damage the vehicle finish.

8. Slip the plastic hose over the bleeder valve of the first wheel cylinder or caliper to be bled, and submerge the open end of the tube in a container partially filled with fresh brake fluid.

9. Open the bleeder valve approximately one-half turn, and let the fluid run until air bubbles no longer emerge from the tube. Then, close the bleeder valve.

10. Transfer the plastic hose to the bleeder valve of the next wheel cylinder or caliper in the bleeding sequence. Repeat steps 8 and 9. Continue around the vehicle in the specified order until the brakes at all four wheels have been bled.

11. Remove the metering valve override tool.

12. Close the fluid supply valve on the pressure bleeder.

13. Wrap the end of the fluid supply hose with a rag, then disconnect it from the master cylinder adapter. Be careful not to spill any brake fluid on the vehicle finish.

14. Remove the master cylinder adapter, adjust the fluid level to the full point, and install the fluid reservoir cover.

VACUUM BLEEDING

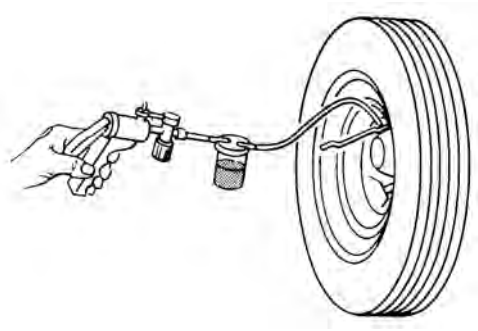


Fig. 9 Vacuum bleeding creates a low-pressure zone at the bleeder valve, which draws fluid through the system.

Vacuum bleeding uses a special suction pump that attaches to the bleeder valve. The pump creates a low-pressure area at the bleeder valve, which allows atmospheric pressure to force brake fluid through the system when the valve is opened**, figure 9**.

Vacuum bleeding requires only one technician; however, it can only be used on wheel cylinders with cup-type expanders and brake calipers with O-ring seals. On wheel cylinders without cup expanders and calipers with stroking seals, the low pressure can pull the lips of the seals away from the bore and allow air to enter the system. To vacuum bleed a brake system:

1. Attach the open end of the vacuum pump to the bleeder valve of the first wheel cylinder or caliper in the bleeding sequence. If necessary, use one of the adapters provided with the vacuum bleeding kit to connect to the bleeder valve.

2. Squeeze the pump handle 10 to 15 times to create a partial vacuum in the catch bottle.

3. Loosen the bleeder valve approximately one-half turn. Brake fluid and air bubbles will flow into the bottle. When the fluid flow stops, tighten the bleeder valve.

4. Repeat steps 3 and 4 until no more air bubbles emerge from the bleeder valve.

5. Transfer the vacuum bleeder to the next wheel cylinder or caliper in the bleeding sequence, and repeat steps 2 and 3. Continue in the specified order until the brakes at all four wheels have been bled.

GRAVITY BLEEDING

Gravity brake bleeding used the force of gravity and ambient air pressure to flush out air. For this method to work, the fluid must have a clear path from the replenish port in the master cylinder to the bleeder to work. It may not work on vehicles with residual pressure valves or other valves that require pressure in the system to make the fluid flow.

1. Clean all dirt from the master cylinder filler cap, then remove the cap and fill the brake master cylinder reservoir with clean, specified brake fluid.
2. If the vehicle has a combination, metering or load-sensing valve, deactivate this item.
3. Bleed the rear disc brake calipers:

A. Place a box-end wrench on the RH rear disc brake caliper bleeder screw. Attach a rubber hose to the RH rear disc brake caliper bleeder screw and submerge the free end of the hose in a container partially filled with clean, specified brake fluid.
B. Open the bleeder screw and leave open until clear bubble-free brake fluid flows into the container.
C. Repeat for the LH rear disc brake caliper.

4. Tighten the rear disc brake caliper bleeder screws.
5. Bleed the front disc brake calipers:

A. Place a box-end wrench on the RH front disc brake caliper bleeder screw.
B. Attach a rubber hose to the RH front disc brake caliper bleeder screw and submerge the free end of the hose in a container partially filled with clean, specified brake fluid.
C. Open the bleeder screw and leave open until clear bubble-free brake fluid flows.
D. Repeat for the LH front disc brake caliper.

6. Tighten the front disc brake caliper bleeder screws.

Surge Bleeding

Surge bleeding is a method of manual brake bleeding that involved pumping the brake pedal rapidly for 8 to 12 strokes and opening the bleeder on the downward stroke up pressure. This method breaks up large bubbles in the fluid. This can be effective in bleeding smaller bore items like master cylinders and wheel cylinders.

Bleeding ABS Brake Systems

As a rule, the brake circuits on most vehicles with anti-lock brakes can be bled in the usual manner — provided no air has gotten into the ABS modulator assembly. If the only components you replaced were down-

stream of the modulator (calipers, wheel cylinders, brake hoses or lines), chances are normal bleeding procedures will clear the lines of any unwanted air.

If the modulator has been replaced or the system has been run dry of brake fluid, it will require the use of a scan tool to bleed the system. If not, the first time the ABS system is used it could introduce air to the system that was trapped in the modulator.

Brakes can be bled manually, with a power bleeder, injector tool or vacuum bleeder. It doesn't make any difference which method you use as long as all the lines and components are flushed with enough fluid to remove any trapped air bubbles or air pockets.

1. Which of the following statements is NOT true?

a. Some imports use HSMO, a green colored oil, as brake fluid
b. Silicone, or DOT 5 brake fluids, contain a purple dye
c. All DOT approved brake fluids are hygroscopic
d. None of the above

2. The first component in a brake system bleeding sequence is the:

a. Master cylinder
b. Wheel cylinder
c. Combination valve
d. Proportioning valve

3. Generally speaking, which of the wheel brakes should you bleed first?

a. The one farthest from the master cylinder
b. The one closest to the master cylinder
c. The one closest to the driver
d. The one closest to the passenger

4. What special tool is required to pressure bleed a system equipped with a metering valve?

a. An adjustment gauge
b. A torque wrench
c. A vacuum tool
d. An override tool

5. After bleeding brakes:

a. The pressure differential switch may need to be recentered.
b. The metering valve may need to be adjusted
c. The proportioning valve may need to be recentered
d. The pressure differential switch may need to be adjusted.

6. Technician A says that the a shorted indicator lamp circuit may cause the red brake lamp to illuminate. Technician B says that an ABS system failure could cause the red brake lamp to illuminate. Who is right?

a. Technician A
b. Technician B
c. Neither
d. Both

7. Technician A says that the first thing to do when diagnosing a red brake warning lamp is to check the brake master cylinder fluid level. Technician B says that the first thing to do is inspect the parking brake system. Who is right?

a. Technician A
b. Technician B
c. Neither
d. Both

8. True or False? An unwanted ground may cause the red brake warning lamp to illuminate, even if there are no other problems in the system.

a. True
b. False

Answer Key:

1D, 2A, 3A, 4D, 5A, 6B, 7A, 8A

ASE G1

Drum Brakes

DRUM BRAKES

A drum brake is a brake that uses friction caused by a set of shoes or pads that press against a rotating drum-shaped part called a brake drum.

The term drum brake usually means a brake in which shoes press on the inner surface of the drum. When shoes press on the outside of the drum, it is usually called a clasp brake. Where the drum is pinched between two shoes, similar to a conventional disc brake, it is sometimes called a pinch drum brake, though such brakes are relatively rare. A related type called a band brake uses a flexible belt or "band" wrapping around the outside of a drum.

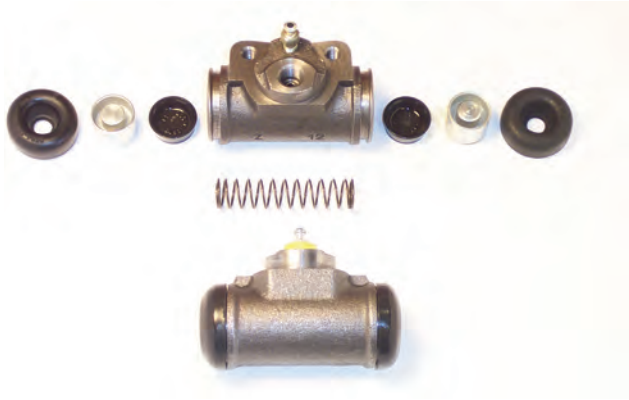
The shoes in drum brakes wear thinner, and brakes required regular adjustment until the introduction of self-adjusting drum brakes in the 1950s. In the 1960s and 1970s, disc brakes gradually replaced drum brakes on the front wheels of cars. Now practically all cars use disc brakes on the front wheels, and many use disc brakes on all wheels. However, drum brakes are still often used for handbrakes, as it has proven very difficult to design a disc brake suitable for holding a parked car. Moreover, it is very easy to fit a drum handbrake inside a disc brake so that one unit serves as both service brake and hand-brake.

DRUM BRAKE DIAGNOSTICS

Begin brake drum diagnosis with a road test. When applying the brakes, listen for unusual noises coming from the rear of the vehicle, pay attention to how the brake pedal feels as the brakes activate, and note if the vehicle pulls to one side or shudders as it comes to a stop.

Excessive pedal travel before the brakes apply is often the result of incorrect adjustment, probably due to an inoperative self-adjusting mechanism; the shoes must move too far before contacting the drum. This is a very common cause of low-pedal complaints. A vehicle that pulls to one side is the result of uneven shoe-to-drum clearance from side to side, or a shoe that is hanging up or binding. Pulling due to a drum brake problem is subtle on a vehicle with front disc and rear drum brakes, and the direct cause is often undetectable without removing the drums and inspecting the brake assembly.

DRUM BRAKE HYDRAULIC PROBLEMS



Drum brake wheel cylinder deterioration can result in several braking performance problems. If a wheel cylinder's internal seals are leaking, brake fluid will find its

way past the dust boots and eventually contaminate the friction material on the shoes. This will not only reduce stopping power at that wheel, but it often causes grabbing and a grunting or groaning noise when the brakes are applied. Also, since brake fluid is hygroscopic (meaning it absorbs moisture), its presence on the drum brake components, especially the self-adjustment mechanism, will promote rapid corrosion that will lead to malfunction.

If a wheel cylinder's pistons become seized either from an internal fluid leak, or from the infiltration of salt water from outside, that wheel brake will be inoperative. Obviously, this will reduce stopping power, but it can also cause pulling or even skidding due to uneven braking. If the pistons are seized in the extended apply position, the brake will fail to retract completely causing a dragging condition, overheating, and premature lining/drum wear.

Equipment exists that can compare the dynamic braking capabilities of all four wheels, but it is not common. So, diagnosis becomes a very straightforward matter.

In cases where your test drive leads you to suspect that there is a problem with the rear drum brakes, raise the rear wheels safely off the ground and spin them by hand. If there is a heavy drag, suspect sluggish or seized wheel cylinder pistons. Have an assistant apply the brakes very gently and slowly while you spin each wheel to make sure that it stops.

The next step is visual inspection. First, look at the outside of the backing plates and the inner side of the tires for evidence of fluid leakage. Next, remove each wheel/tire assembly and drum to see if fluid is present on the hardware and the inside of the backing plate. Next, peel back the wheel cylinder dust boots to see if fluid has collected inside them. If there is any whatsoever, the wheel cylinder must be either reconditioned or replaced.

In some cases, the master cylinder may contain residual check valves to prevent air from being drawn past the wheel cylinder cup seals when the shoes are retracted by the return springs.

DRUM BRAKE MECHANICAL PROBLEMS

Lack of self-adjustment, which allows the shoe-to-drum clearance to become excessive, resulting in a low brake pedal and poor stopping performance, is one of the most common drum brake mechanical problems. Others include noise, pedal pulsation, and parking brake malfunctions.

A grinding or scraping noise coming from the rear of the car when the brakes are applied is typically the result of worn-out brake shoe linings. The sound comes from the rivets or the metal shoe surface making contact with the brake drum. Direct inspection is required to determine the cause of the noise.

Pulling to one side during braking is much less an issue with rear brakes than with fronts, but it can still be noticeable and may contribute to skidding. This may occur if the drum brake on one side has a malfunctioning self-adjusting mechanism. Again, drum removal and direct inspection is required.

Pedal pulsation or shudder not due to front disc brake rotor thickness variation is almost always caused by out-of-round drums. The only other possibility is a cracked drum.

While coasting at low speed on an uncrowded roadway, apply the parking brake slowly. If you feel pulsation, shudder, or hitching, the problem is in the rear drums and not the front discs. Removal and careful measurement and inspection will be needed in order to detect either an out-of-round or a cracked drum.

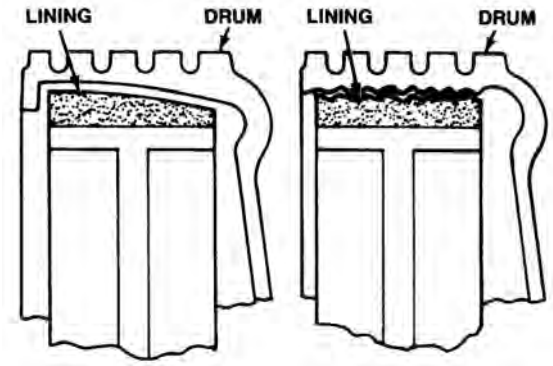
A leaking rear axle seal that permits gear lubricant from the differential to contaminate the shoes will reduce stopping power and is likely to cause grabbing and a grunting noise during brake application.

In some cases, the master cylinder may contain residual check valves to prevent air from being drawn past the wheel cylinder cup seals when the shoes are retracted by the return springs.

BRAKE DRUM REMOVAL

To service a drum brake, you must first remove the drum to gain access to the friction assembly.

The removal procedures differ for fixed and floating drums. With either design, it is sometimes necessary to back off the drum-to-lining adjustment and loosen the parking brake before the drum can be removed. This is because wear at the open edge of the drum, or scoring of the brake linings and drum friction surface creates a ridge or several interlocking grooves that hold the drum in place**.** If the drums are not going to be machined, mark them with their original location so that they can



Brake lining and friction surface wear make it difficult to remove a drum unless the parking and service brake adjustments are loosened.

be returned to the same axle and the same side of the vehicle.

FIXED DRUM REMOVAL

Fixed brake drums are usually found at the rear of front-wheel drive (FWD) vehicles (it has been over two decades since drum brakes have been used at the front of any car). In most applications, the nut that retains a fixed brake drum also secures and preloads the wheel bearings in the hub.

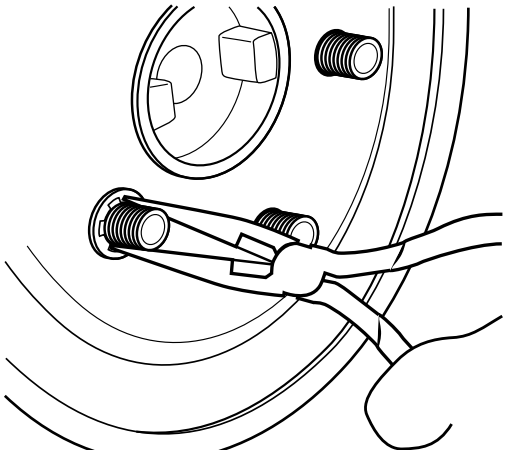
To remove a fixed drum, remove the dust cap from the center of the hub. Most designs have either a castellated nut or a castellated retainer that fits over a standard nut. Both are secured by a cotter pin. Remove the cotter pin along with any other locking devices, then remove the nut. Pull outward on the drum to slide it off the spindle. Take care not to let the thrust washer and outer wheel bearing fall on the ground as they clear the spindle. Also, avoid dragging the inner wheel bearing and grease seal across the retaining nut threads on the spindle.

Once the drum is removed, inspect the grease in the hub and on the wheel bearings. If the grease is relatively fresh and in good condition, set the drum on the bench, open side down, and cover the outer bearing and hub opening so the bearings will not become contaminated. If the grease is old and dirty, repack the wheel bearings before you reinstall the drum. Always repack the wheel bearings when performing a complete brake job. This includes removing all the old grease from the hub.

FLOATING DRUM REMOVAL

Most floating brake drums are held in place by the wheel and lug nuts, although some designs have small bolts or screws that fit through a hole on the face of the drum and into a threaded hole on the axle flange. These must be removed before the drum can be removed. Some drums may also be retained by speed nuts or Tinnerman nut, which fit over the wheel studs that protrude through the drum from the hub or axle flange. To remove speed nuts, grasp them with a pair of pliers and thread them off the studs. Once removed, speed nuts can be discarded because their only purpose is to keep the drum in place on the assembly line. Now, the drum should move freely on the hub or axle and slip off over the brake shoes.

BRAKE DRUM INSPECTION



Speed nuts, which hold a floating drum in place on the assembly line, can be removed and discarded during service.

Two inspections are made on a brake drum, a visual inspection followed by careful measurements. After completing a thorough inspection, you will know if the drum is in serviceable condition or is beyond saving and must be replaced. A serviceable drum can be machined to restore the friction surface, then reinstalled in its original position on the vehicle.

VISUAL INSPECTION

To inspect a drum, first wash its friction surface with detergent and a scrub brush, and rinse with water. If you see any problems that will require the drum to be machined, immediately measure the drum as described in this chapter. Visually inspect the drum for:

- **Scores and grooves**
- **Cracks**
- **Heat checks**
- **Hard spots**

Scores and grooves on the drum friction surface increase brake wear and noise. To determine the depth of any scores or grooves, use a micrometer with a pointed anvil designed for this purpose. As a general rule, any score or groove deeper than 0.010 inch (0.25 mm) requires turning the drum.

Cracks can occur anywhere, but drums usually crack near the bolt circle or web and at the open edge of the friction surface**.** Do not confuse small surface checks with cracks that reach deeply into the structure of the drum. If any cracks are visible, replace the drum.

Heat checking appears as many small, interlaced, cracks on the friction surface. Heat checks can cause a slight pedal pulsation, increase brake lining wear, and make noise. If the heat checking is minor and the drum checks out in other respects, machine the drum. If heat checking is widespread, replace the drum.

Hard spots are round, bluish/gold, glassy appearing areas that develop on the friction surface, **figure 4**. Hard spots can cause pedal pulsation, brake chatter, and increased lining wear. Since grinding down hard spots requires special equipment and is time-consuming and not always successful, it is common practice to replace drums with hard spots.

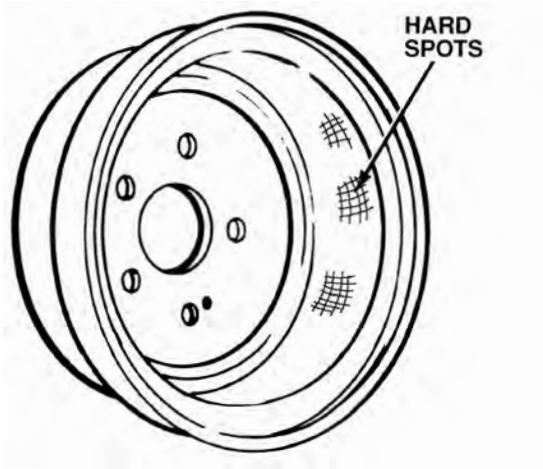
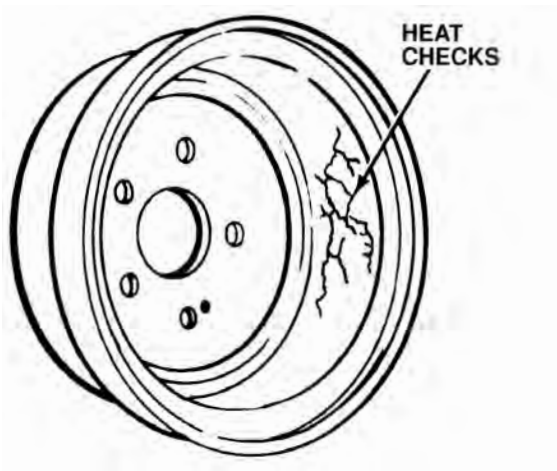


Fig. 4 Hard spots, which appear where extreme heat has hardened the iron in the drum, can cause pedal pulsation, chatter, and increase lining wear.



Heat checks, which are a series of small, interlaced cracks on the friction surface of the drum, can be machined out if they are minor and localized.

MEASUREMENT

Brake drums are measured to identify wear and distortion that is not visually apparent. When drums wear, they become oversized, tapered, or barrel-shaped. Distorted drums become bell-mouthed, out-of-round, or eccentric. Most of these problems can be detected using either a drum micrometer or an inside micrometer.

However, some forms of drum wear and distortion cannot be identified until the drum is actually turned in a brake lathe.

Drum inside diameter

Any time a brake drum is removed from the vehicle, inside diameter should be measured to check for wear. To measure, first note the discard diameter stamped or cast into the drum**.** Then, position the drum so the open side is facing up.

Adjust a drum micrometer to the nominal drum diameter, fit it into the drum, and take measurements at two or three locations. Compare the largest micrometer reading to the discard diameter stamped on the drum.

If the inside diameter is smaller than the drum discard diameter, the drum may be returned to service. If it has defects that require machining, however, now is the time to determine with careful measurement whether or not the amount of metal that must be removed will put the drum beyond the discard diameter.

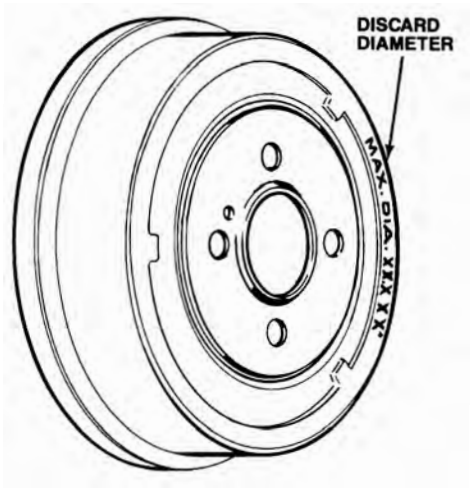
The amount of additional metal sometimes required to allow for wear in service varies by manufacturer, so check the shop manual for the vehicle in question for the exact value.

OUT-OF-ROUND DRUM DISTORTION

The diameter of an out-of-round drum varies when measured at several points around its circumference. This causes a pulsating brake pedal, brake vibration, and sometimes grabby, erratic braking. To check for an out-of-round drum, use a brake drum micrometer to measure the drum inside diameter at four locations 45 degrees apart from one another. If the highest and lowest measurements vary by more than 0.006 inch (0.15 mm), correct by machining the drum. Remember, final diameter must be 0.030 inch (0.75 mm) smaller than discard diameter.

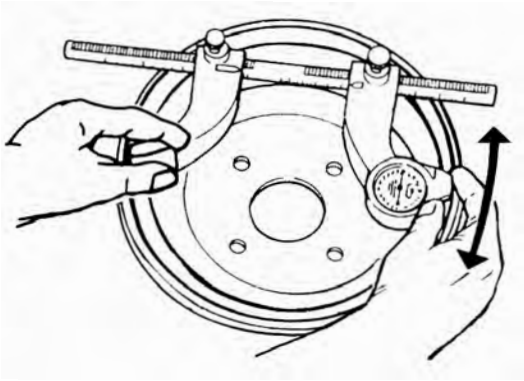
DRUM TAPER WEAR, BARREL WEAR, AND BELLMOUTH DISTORTION

Taper wear, barrel wear, and bellmouth distortion are problems that cause variations in brake drum diameter between



Discard diameter, which is stamped or cast into the face of the drum, shows the machining and wear limits of the drum.

the open and closed edges of the friction surface. A drum with taper wear has a larger diameter at the closed edge than at the open edge, while a drum with barrel wear has a larger diameter at the center than at either edge. A drum with bellmouth distortion has a larger diameter at the open edge than at the closed edge**.**



Use a drum micrometer to take diameter measurements at several locations around the drum.

Taper wear can sometimes cause a spongy brake pedal, but barrel wear and bellmouth distortion have no symptoms that are obvious to the driver. These problems can sometimes be spotted by ridges or lips worn into the drum friction surface; other times, unusual wear patterns on the brake linings will reveal the problem.

You can also identify these wear patterns by measuring the drum inside diameter at several points across the friction surface. A drum micrometer cannot reach deeply enough into the drum to make these measurements, so you must use an inside micrometer instead.

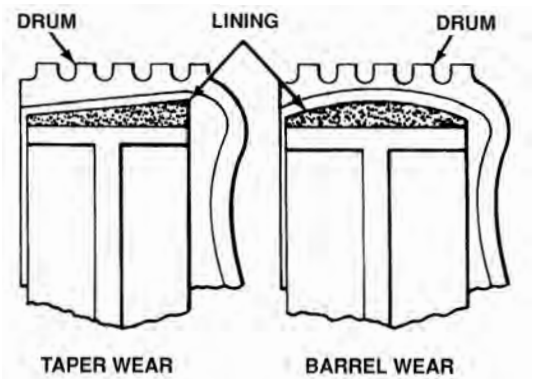
Position the inside micrometer in the drum and take three measurements, one at the open edge of the drum, one at the center of the friction surface, and one at the closed edge of the drum. If the highest and lowest of these measurements vary by more than 0.006 inch (0.15 mm), machine the drum. Replace the drum if machining will not leave the inside diameter at least 0.030 inch (0.75 mm) smaller than the discard diameter.

OUT-OF-ROUND DRUM DISTORTION

The diameter of an out-of-round drum varies when measured at several points around its circumference. This causes a pulsating brake pedal, brake vibration, and sometimes, grabby, erratic braking. To check for an out-of-round drum, use a brake drum micrometer to measure the drum inside diameter at four locations 45 degrees apart from one another. If the highest and lowest measurements vary by more than 0.006 inch (0.15 mm), correct by machining the drum. Remember, final diameter must be 0.030 inch (0.75 mm) smaller than discard diameter.

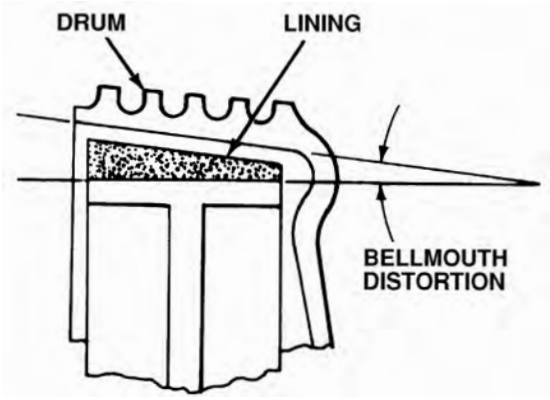
ECCENTRIC DRUM DISTORTION

Eccentric brake drum distortion exists when the geometric center of the friction surface is different from that of the hub. This makes the drum rotate with a cam-like motion, which causes the shoe contact pads on the backing plate



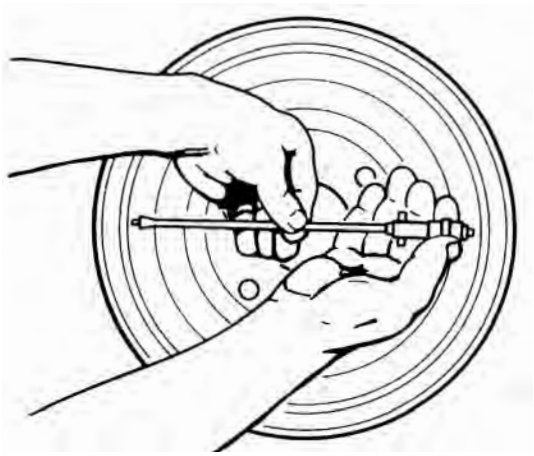
Taper wear, the largest, inside diameter at the closed edge of the friction surface, and barrel wear, the largest, inside diameter at the center of the friction surface, are common in brake drums.

t o



Bellmouth wear, the largest, inside diameter at the open edge of the friction surface, occurs less frequently than other types of brake drum wear patterns.

wear and creates noise whenever the brakes are applied. Since eccentric drum distortion does not affect inside diameter, it cannot be detected visually or with common measuring tools. This condition is identified while a drum is being turned on a lathe and the tool bit contacts the friction surface on only one side of the drum.



Take three inside micrometer readings, at the closed edge, center, and open edge of the friction surface, to check a drum for taper, barrel, and bellmouth wear.

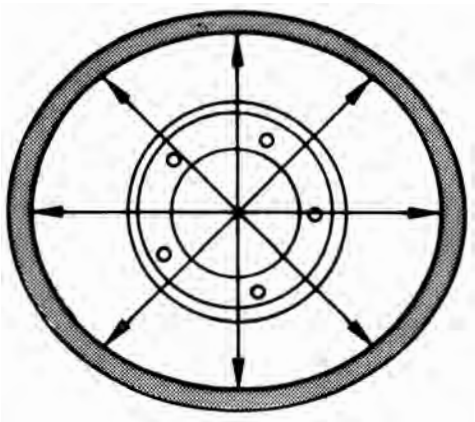
BRAKE DRUM MACHINING

Brake drum machining, also called turning, uses a brake lathe and a carbide tool bit to remove metal from the friction surface of the drum**.** Turning can repair most forms of wear, damage, and distortion. When turning a drum, only remove the minimum amount of metal necessary to restore the friction surface. This helps ensure the longest possible service life for the drum.

In the past when drum brakes were used on the front wheels, it was important to always machine both sides to the same diameter to keep braking force and fade resistance equal from side to side, thus preventing brake pull. Modern vehicles, however, have drums at the rear only where pulling is much less of a concern. Therefore, it is no longer considered necessary to machine a new drum to the diameter of the worn drum on the other side.

While it is not the function of this study guide to instruct you in the exact procedures required by every brake lathe available, a few guidelines are generally agreed upon within the industry:

- **Lathe arbor runout should not exceed .001 in.**
- **The tool bit should be sharp and properly shaped.**



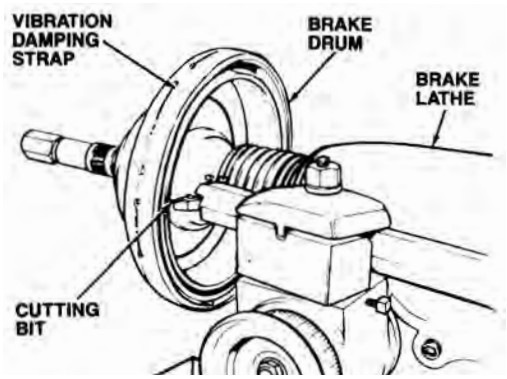
Take four micrometer readings at 45 degree increments around the circumference to check a brake drum for out-of-round distortion

- **The feed should be slow.**
- **Do not take one deep cut. Instead, take enough smaller ones to eliminate the scoring.**

BRAKE SHOE REPLACEMENT

The thickness of the lining material is the main factor that determines whether brake shoes should be replaced. The brake shoe friction linings must be at least 0.030 inch (0.75 mm) above the lining table or rivet heads.

Brake shoes are sold and serviced as axle sets. An axle set consists of four shoes; one pair for the friction assembly at each wheel. Shoes from different manufacturers should never be mixed. Although they will fit and may appear the same, the friction coefficients of the linings may be quite different. Even if only one shoe of an axle set is badly worn, the entire set should be replaced after the problem causing uneven wear has been repaired.



The turning process uses a tool-steel cutting bit to remove metal from the friction surface as the drum rotates on a brake lathe.

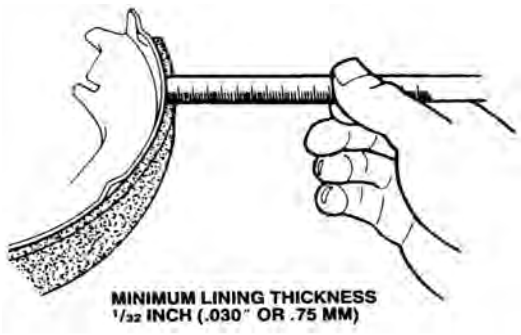
The exact procedure used to replace a set of brake shoes varies with the design of the friction assembly and the hardware used to mount and activate shoes. The sections below describe a general procedure that includes the common operations required to disassemble, inspect, and reassemble drum brakes.

DRUM BRAKE DISASSEMBLY

The order in which the many parts of the friction assembly are disassembled varies from one brake to another. However, once the drum is removed, removing the shoe return springs is often the next step. Avoid injury by always wearing eye protection when removing and installing springs.

Springs that hook over an anchor post are removed with a special brake spring tool**.** Place the tool over the post and hook the flange under the end of the spring. Rotate the tool to lever the spring up and off the anchor. Once the springs are free, remove the anchor plate and adjuster cable or linkage, if fitted, from the anchor post.

Return springs that install between two brake shoes can be removed with a pair of brake spring pliers. However, this is often unnecessary because once the shoes are removed from the anchor, they can be collapsed together by hand to release the tension on the shoe-to-shoe spring.



Measure the thickness of the brake shoe friction lining with a machinist scale to determine wear.

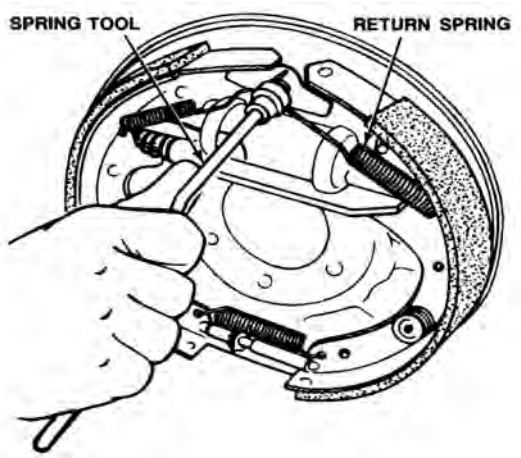
Once the springs are off, remove the brake shoe hold-downs. Although most hold down devices can be removed by hand or with common hand tools, there are special tools available that make the job easier**.**

After removing the return springs and shoe hold downs, the friction assembly can be lifted free of the backing plate. In most cases, simply reposition the brake shoes as needed so the shoe-to-shoe return springs, auto-matic adjusting mechanism, and parking brake linkage, can be disconnected.

DRUM BRAKE INSPECTION

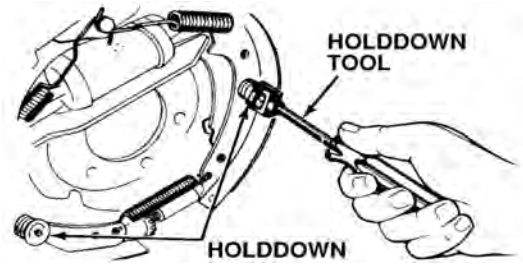
Inspect the brake backing plate and its mounting bolts. If the plate is bent or cracked, replace it. If the mounting bolts are loose, tighten them to the torque specification recommended by the manufacturer. Also, check the shoe support pads for grooves, notches, or any other signs of wear. Although minor wear is considered normal, smooth the pads by filing or grinding to provide a good surface for the new shoes to ride on. If the pads are deeply grooved, replace the backing plate. Then, inspect the wheel cylinder as described in the next section.

Most vehicle manufacturers recommend that the shoe return springs, shoe hold down hardware, and automat-ic adjuster cables be replaced whenever a new set of brake shoes are installed. This is because it is difficult to determine the condition of these parts by inspection.



A special brake spring tool is used to lever return springs off the anchor post.

The automatic adjusting mechanism and parking brake linkage can generally be reused if they pass a visual inspection. To inspect, look for bent components and wear at the points where the parts contact one another. If the brake assembly has starwheel adjusters, disassemble the adjuster assembly and clean it thoroughly**.** Replace the adjuster if the starwheel teeth are rounded, chipped, or broken. Use a wire brush to clean the adjuster threads, lubricate the threads with brake grease, then assemble the adjuster and thread it through its full range of travel. If the threads bind at any point, repair the problem or replace the adjuster.



Special tools make removing spring-and-pin brake shoe holddowns easy.

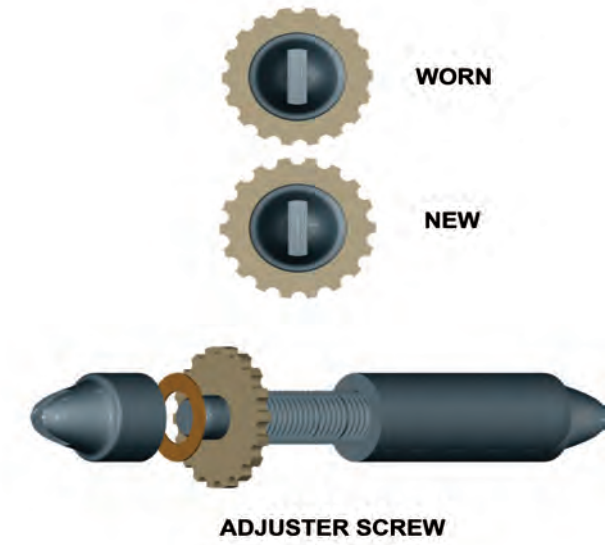
Drum Brake Assembly

Drum brake assembly is essentially the reverse of disassembly, making sure that all parts are reinstalled in their proper locations. There are also a few special techniques used to install specific brake components.

To begin, compare the replacement brake shoes to the original equipment parts. They should have the appropriate holes in the shoe webs, and the linings should be the same basic size and shape as those on the originals.

Next, determine where the shoes belong on the vehicle. For example, the primary shoe on a dual-servo brake generally has a smaller lining than the secondary shoe, and the friction materials used for the two linings may differ as well. Always install the primary shoe so it is pulled away from the anchor when the brakes are applied, with the wheel turning in the direction of forward rotation. Some leading-trailing brakes are also designed to use shoes that have different friction characteristics. In these applications, install the replacement shoes in the same relative locations as the original equipment parts.

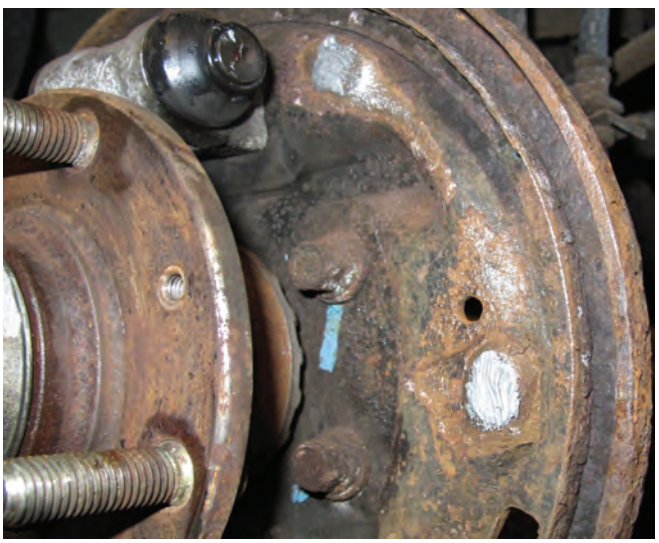
Remove any parking brake linkage pieces or similar parts



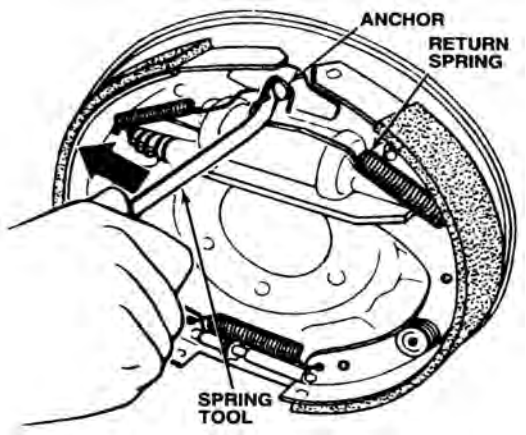
Disassemble, clean, and inspect starwheel adjusters. If they pass inspection, they can be lubricated, assembled, and reinstalled.

from the old shoes. Transfer these parts to the appropriate replacement shoes and install them using new fasteners. Lubricate the shoe support pads on the backing plate with a thin coat of high-temperature brake grease. Avoid excess lubrication, as grease liquifies at high temperatures. If too much grease is applied, it can run and be absorbed by the friction material, which results in braking problems.

Assemble the shoes onto the backing plate. The procedure varies with the design of the friction assembly; basically, reposition the shoes as needed until the parking brake linkage, brake adjuster, and the shoes themselves



Apply a thin coat of high-temperature brake grease to the shoe contact pads on the backing plate.



Using a brake spring tool to install a return spring on an anchor post.

are all fitted together in their proper positions.

Once the shoes are assembled in position, install the hold downs to secure the shoes in place. On pin and spring hold downs, insert the pin through the holes in the backing plate and brake shoe web. Then, while holding the pin in place from the backside of the backing plate, use the special tool to compress the spring and retaining washer over the end of the pin. Rotate the washer as needed to lock it onto the flattened end of the pin. Where a spring clip is used with a hold down pin, compress the clip by hand and slip it into position under the flattened end of the pin. To install a coil-spring "beehive" hold down, hold the retaining clip in place from the backside of the backing plate, then use a Phillips screwdriver to push the spring inward, engaging its hook into the retaining clip.

The final step in drum brake assembly is to install the shoe return springs. It is very important to install the return springs facing in the proper direction and in the correct location. Some springs can be installed only one way, and their proper position is easy to identify. Different paint colors are often used to distinguish similar springs that have different tensions. Certain springs have a longer straight section and attachment hook at one end than other. These springs must be installed facing a specific direction, or the coiled section of the spring will interfere with another part of the friction assembly. Sometimes, there are several holes in the shoe web where a spring can be attached. If you install a spring in the wrong hole, it will affect the rate at which the brake shoes apply and release.

Return springs are installed in two basic ways, and both methods require a special tool. To install a spring that fits over an anchor post, attach the appropriate end of the spring into the hole in the shoe web. Then, place the notched end of the spring tool on the anchor post, and drape the hook end of the spring over the tool shaft**.** Take care not to overstretch the spring as you lever the tool back, so the spring slides down the shaft and into place on the anchor.

Shoe-to-shoe return springs are installed using brake spring pliers. Fit one end of the spring into the correct hole in the brake shoe web and place the other end of the spring over the hooked arm of the brake spring pliers.

Position the pliers over the shoe the spring is to be attached to so that the pointed arm of the plier contacts the lining at the same level as the hole the spring is to engage. If possible, position the pointed arm on a lining rivet. Otherwise, position it directly on the lining and use extra caution to prevent damage. Squeeze the handle of the pliers to stretch the spring to the appropriate length, then insert the end of the spring into the hole in the web. Remove the plier, and make sure both ends of the spring are fully engaged in the web holes.

WHEEL CYLINDER INSPECTION

Grasp the wheel cylinder and attempt to move it. If any movement is detected, make sure all of the mounting hardware is in place and properly tightened. Some import vehicles have wheel cylinders that slide in a slot on the backing plate. These cylinders are designed to move, so simply make sure the mounting clips are present and properly installed. The dust boot that seals the slot must be in good condition.

Once the dust boots are removed, most wheel cylinders can be disassembled, inspected, and serviced without removing them from the vehicle.

Inspect the outside of the wheel cylinder for leaks. Minor stains caused by fluid seepage are considered normal. Fold back the cylinder dust boots and look for liquid. If you find more than a slight amount of dampness, rebuild or replace the cylinder.

Next, check for free movement of the wheel cylinder pistons. With the brake drum from only a single wheel removed, have an assistant gently apply and release the brake pedal while you verify that both brake shoes move outward and return smoothly to their stops.

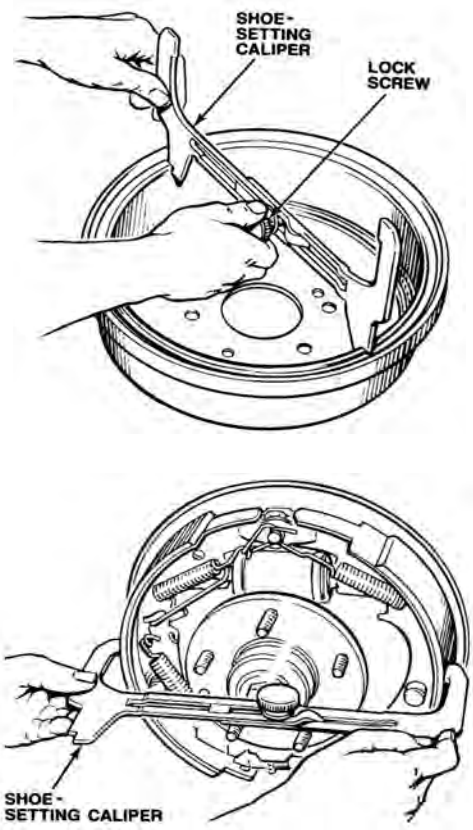
On brakes without piston stops, use two large screwdrivers to make sure the pistons are not pushed out of the cylinder bore. Insert the tips of the screwdrivers under the lip at the edge of the backing plate, then lever the screwdriver shafts against the brake shoes to prevent them from moving outward too far.

On some brake designs, a frozen wheel cylinder piston can prevent one or both of the brake shoes from applying. A sticking piston that slows or prevents full return of the brake shoes will cause the brakes to drag, resulting in rapid lining wear and possibly brake fade.

WHEEL CYLINDER SERVICE

Many wheel cylinders can be taken apart, internally inspected, and rebuilt while they are still mounted on the backing plate. Disassemble a wheel cylinder simply by removing the shoe links and the rubber boots from the ends of the cylinder. Then, press out the pistons, cup seals, spring, and cup expanders. Inspect, hone, and measure the bore of a wheel cylinder using the same techniques detailed in chapter one for servicing a master cylinder.

INITIAL BRAKE ADJUSTMENT



Transfer the drum diameter to the shoes by fitting the opposite jaws of the caliper over the brake friction assembly.

Once the brake is assembled, adjust the initial lining-to-drum clearance so the brake pedal travel will be satisfactory. With starwheel brake adjusters, initial adjustment is usually done before the drum is installed.

Both manual and automatic starwheel brake adjusters make their adjustments in very small increments. If you attempt to adjust the brakes manually after the drum is installed, a considerable number of adjuster clicks may be required to get the proper clearance. This is both tiring and time consuming. When you make the initial adjustment before you install the drum, final manual adjustment will be quick and easy, or you can use the automatic adjusters to make the final adjustment during the test drive.

To perform the initial adjustment, place a shoe setting caliper inside the brake drum and slide the tool back and forth as you spread the jaws until they span the drum at its widest point**.** Then, tighten the lock screw to fix the caliper at this setting. Depending on the brand of tool being used, the opening on the opposite side of the caliper is now set to either equal the drum diameter or at approximately 0.020 inch (0.50 mm) smaller than the drum diameter, providing a clearance of 0.010 inch (0.25 mm) between the drum and each brake shoe.

Remove the caliper from the drum and place the open side over the brake shoes**.** If the caliper opening matches the drum diameter, rotate the starwheel adjuster as needed until there is approximately 0.020 inch (0.50 mm) clearance between the caliper opening and the shoes at their widest point. If the caliper setting includes the desired lining-to-drum clearance, rotate the starwheel, adjuster as needed until the caliper just slides over the shoes at their widest point. Hold the automatic adjuster pawl out of the way while turning the starwheel so it does not become burred. On brakes with dual starwheel adjusters, rotate each starwheel an equal amount.

BRAKE DRUM INSTALLATION FIXED DRUM

The procedure for installing a fixed drum is a very general procedure. Most drum installations are the same, but depending on what vehicle you are working on, the bearing adjustment procedure may be different. In any case, a factory service manual should be consulted for bearing adjustment.

Wheel bearings should be inspected and lubricated as necessary. This is outlined under chapter 6. Clean spindle and install a thin coat of wheel bearing grease. Install brake drum with wheel bearings to spindle. Install washer and adjusting nut and tighten finger tight. Tighten nut while rotating drum. This will seat the bearings. Loosen adjusting nut. Tighten adjusting nut to specifications. Since each application will be different, a factory service manual should be consulted for tightening specifications. Install adjusting nut retainer, then the cotter pin. Bend ends of cotter pin around retainer flange. Ensure drum rotates freely, then install grease cap.

FLOATING DRUM

Install drum to hub making sure that reference marks made during removal are aligned.

Brake Self Adjusters :
-Dual-Servo
-Bendix Wagner
-Wagner

The front disc brake and rear drum brake combination has been used on vehicles since the 1970s. Disc brakes use brake fluid to compensate for pad wear and are self-adjusting. The only hardware involved is to secure and locate the caliper to its bracket. In the case of the floating caliper, there are usually bushings, anti-rattle clips and bridge bolts.

Opposing piston calipers are bolted to the knuckle and have pins to position the pads. Drum brakes have return springs to return the shoes to a rest position and hardware to hold the shoes to the backing plate. The shoes return to a fully retracted or rest position when the master cylinder releases pressure to the wheel cylinder. There is no compensation for lining wear.

In some cases, the master cylinder may contain residual check valves to prevent air from being drawn past the wheel cylinder cup seals when the shoes are retracted by the return springs.

Before 1955, drum brakes required periodic adjustment. As the linings wore, the piston in the wheel cylinder would have to travel further to engage the shoe with the drum friction surface. The return springs would retract the wheel cylinder piston to its rest position. This caused the brake pedal to move closer to the floorboard when the brakes were applied. This was commonly referred to as low pedal.

Adjusting the brakes would move the shoes closer the drum friction surface and reduce the travel of the wheel cylinder piston. It also required more fluid in the wheel cylinder to apply the brakes. Adjustments were made by manually turning the notched wheel on the adjuster with a brake spoon for the self-energizing type.

DUAL-SERVO

The dual-servo drum brake with leading and trailing shoes requires a wrench to adjust the eccentric adjusting cams located on the backing plate. It took a good “sense of feel” to adjust the brakes evenly. The process was to tighten the adjuster or eccentric adjusting cam to a point where the shoes contact the drum friction surface and backing off the adjuster or eccentric adjusting cam to where the shoes just cleared the drum. It’s all in the “feel” as you turn the wheel and move the adjuster or eccentric cam.

Dual Servo brakes use two primary shoes and two anchor pins. The pistons of the wheel cylinder apply both of the shoes. The adjuster is located under the wheel cylinder. The adjuster uses an adjusting screw and notched wheel and lever in the same way as the Bendix/Wagner. A lever is attached to one of the shoes to adjust the notched wheel. The lever is usually part of the parking brake assembly.

There is no pressure on the adjusting screw when the brakes are applied allowing the lever to turn the notched wheel. A return spring is used to contain the adjuster in the same manner as the Bendix/Wagner type. This is different from the Bendix/Wagner type where the adjustment takes place after the brake is released.

BENDIX/WAGNER

The Bendix/Wagner self-energizing brake has a single anchor pin located above the wheel cylinder. The primary shoe is identified by its length and position on the shoe. The lining segment is shorter than the lining segment on the secondary shoe and is positioned toward the adjuster or heals of the shoe. When the brake is applied, the master cylinder applies hydraulic pressure to both wheel cylinder pistons.

The primary and secondary shoes engage the friction surface of the drum. The wrapping motion of the primary shoe transfers pressure through the adjusting screw and drives the secondary shoe against the anchor pin and friction surface of the drum.

The secondary wheel cylinder piston is held in its rest position as the secondary shoe is driven against the anchor pin.

The adjuster mechanism is attached to the secondary shoe. It is a mechanical device that is made up of the three components.

First, an adjusting screw that is a threaded device like a nut and bolt. The head of the bolt is a notched wheel with a cylindrical pin. A washer and slotted cap fits over the pin and engages web section of the secondary shoe. The nut is also a slotted cap that threads onto the bolt and engages the primary shoe.

Second, a lever moves on a pivot to engage and turn the notched wheel.

Third, a cable or linkage is attached to the lever and the anchor pin to move the lever at its pivot point. There are springs and retainers to hold the mechanism in place.

The adjustment takes place when the vehicle is in reverse and the brakes are applied or when the parking brake is engaged. The cable or link attached to the anchor pin pulls the lever mechanism based on the movement of the secondary shoe.

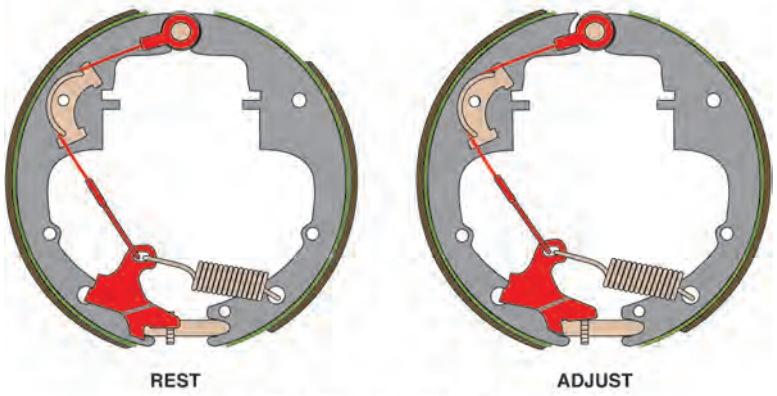
When the brakes are applied, the lever cannot move the adjuster screw because the brake pressure is being used to apply the shoes. The adjuster lever mechanism must store the adjustment and turn the notched wheel when the brake

is released.

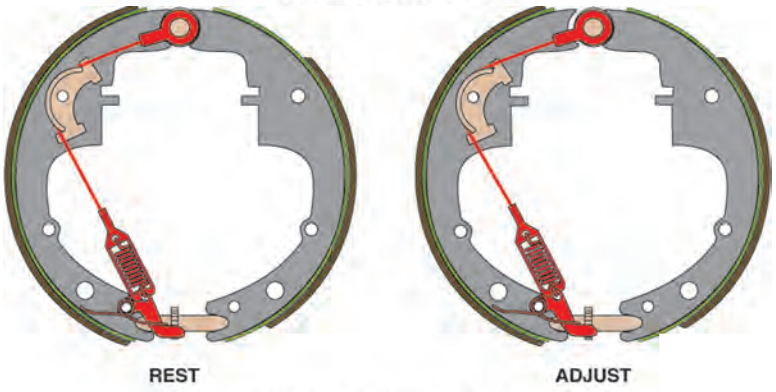
There are two types of Bendix/Wagner self-adjusters. Type 1 uses a cable attached to the anchor pin and hook that is attached to the adjusting lever. A guide holds the cable in place. A spring connects the lever to the primary shoe to contain the adjuster. Type 2 uses a cable attached to the anchor pin with a spring and guide that attaches to the lever.

Type 2 uses the same cable guide as Type 1. On Type 2, the lever is connected to the secondary shoe with a pin and return spring. A spring connects the primary and secondary shoe to contain the adjusting screw.

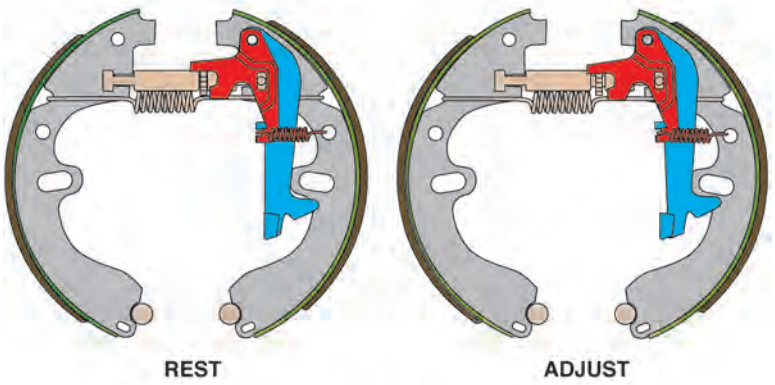
On the Delco Moraine type, the adjuster uses a lever assembly, linkage and adjusting screw. The lever assembly is made up of the adjusting lever with spring-loaded link. The linkage is attached to the anchor pin and spring-loaded link of the assembly. The lever is attached to the secondary shoe at the shoe hold down. A lever return spring is placed between the lever assembly and shoe. A spring connects the primary and secondary shoe to contain the adjuster.



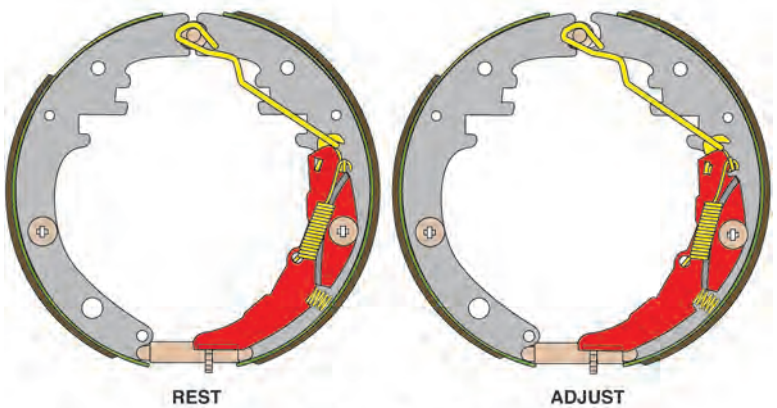
BENDIX / WAGNER TYPE 1



BENDIX / WAGNER TYPE 2



DUAL SERVO / LEADING TRAILING



DELCO MORAINE

1. **Technician A says that a low pedal complaint may be due to inoperative drum brake self-adjusters. Technician B says that a low pedal complaint may be due to weak shoe return springs. Who is right?**
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

2. **A leaky wheel cylinder can cause:**
   a. Grabbing
   b. Loss of stopping power
   c. A grunting or groaning noise when the brakes are applied
   d. All of the above

3. **Technician A says that if wheel cylinder pistons are seized in the extend position, the brake will fail to retract completely causing a dragging condition, overheating, and premature lining/drum wear. Technician B says that seized rear drum brake wheel cylinder pistons will cause a low pedal condition. Who is right?**
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

4. **Pulsation or shudder during braking may be caused by:**
   a. Weak drum brake shoe return springs
   b. A cracked drum
   c. Bellmouthed drum wear
   d. A seized starwheel adjuster

5. **Drums should be visually inspected for all of the following EXCEPT:**
   a. Hard spots
   b. An out-of-round condition
   c. Scoring
   d. Cracks

6. **Which of the following is NOT used to hold floating drums in place?**
   a. Speed nuts
   b. Bolts threaded into the hub
   c. The wheel and lug nuts
   d. A large nut that preloads the wheel bearing

7. Fixed drums are held in place by:
   a. Speed nuts
   b. Bolts threaded into the hub
   c. A large nut that preloads the wheel bearing
   d. The wheel and lug nuts

8. **Technician A says that brake drums should always be replaced if they are cracked. Technician B says that brake drums should be reinstalled on the wheel opposite from where they were removed. Who is right?**
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

9. **Which of the following CANNOT be measured with an inside micrometer?**
   a. Drum inside diameter
   b. Drum taper, barrel, and bellmouth distortion
   c. Out-of-round distortion
   d. Eccentric drum distortion

10. **Technician A says that the shoe with the shorter lining is the primary and should be installed at the rear of the assembly. Technician B says that the shoe with the longer lining is the primary and should be installed at the rear of the assembly. Who is right?**
    a. Technician A
    b. Technician B
    c. Both
    d. Neither

11. **When assembling a drum brake, apply high-temperature brake grease to the:**
    a. Contact pads on the backing plate
    b. Shoe webs
    c. Parking brake cables
    d. Return spring anchors

12. **Set the initial brake adjustment with a:**
    a. Shoe setting caliper
    b. Brake micrometer
    c. Screw driver after the drum is installed
    d. Torque wrench

Answer Key
1. A, 2. D, 3. A, 4. B, 5. B, 6. D, 7. C, 8. A, 9. D, 10. D, 11. A, 12. A

ASE G1

Disc Brakes

A disc brake assembly consists of:

- cast−iron disc (disc rotor) that rotates with the wheel.
- caliper assembly attached to the steering knuckle.
- friction materials (disc pads) that are mounted to the caliper assembly.

When hydraulic pressure is applied to the caliper piston, it forces the inside pad to contact the disc. As pressure increases the caliper moves to the right and causes the outside pad to contact the disc. Braking force is generated by friction between the disc pads as they are squeezed against the disc rotor. Since disc brakes do not use friction between the lining and rotor to increase braking power as drum brakes do, they are less likely to cause a pull.

The friction surface is constantly exposed to the air, ensuring good heat dissipation, minimizing brake fade. It also allows for self−cleaning as dust and water are thrown off, reducing friction differences.

Unlike drum brakes, disc brakes have limited self−energizing action making it necessary to apply greater hydraulic pressure to obtain sufficient braking force. This is accomplished by increasing the size of the caliper piston. The simple design facilitates easy maintenance and pad replacement.

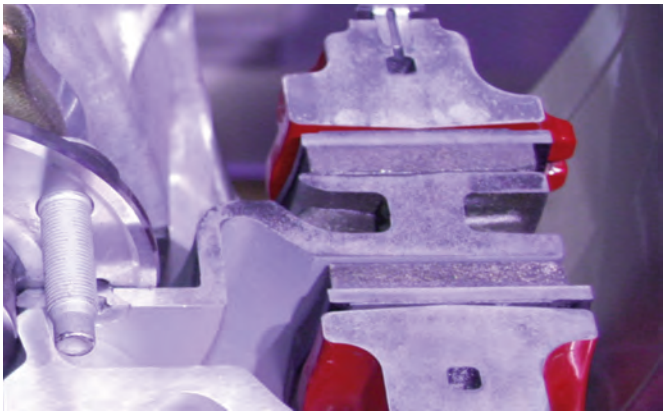
Disc brakes also have the advantage of being self adjusting. The pads are always right next to the spinning rotor. This adjustment is maintained in all models by a square cut piston seal which is seated in a machined groove in the cylinder bore. Any wear of the lining is automatically compensated for by the action of the brake caliper.

Different brake design applications require different kinds of friction materials. Several considerations are weighed in development of brake pads; the coefficient of friction must remain constant over a wide range of temperatures, the brake pads must not wear out rapidly nor should they wear the disc rotors, should withstand the highest temperatures without fading and it should be able to do all this without any noise. Therefore, the material should maximize the good points and minimize the negative points.

Materials which make up the brake pad include friction modifiers, powdered metal, binders, fillers and curing agents. Friction modifiers such as graphite and cashew nut shells, alter the friction coefficient. Powdered metals such as lead, zinc, brass, aluminum and other metals increase a material's resistance to heat fade. Binders are the glues that hold the friction material together. Phenolic resin is the most common binder in current use. Fillers are added to friction materials in small quantities to accomplish specific purposes such as rubber chips to reduce brake noise.

The brake pad material is bonded to a stamped steel backing plate with a high temperature adhesive to which heat and pressure are applied to cure the assembly. A slit is provided on the face of the pad to indicate the allowable limit of pad wear and provide a path for brake dust and gas to escape.

A metal plate, or in some applications multiple plates called anti−squeal shims, are provided on the piston



side of the pad to minimize brake squeal. Various springs and clips are used to reduce rattle as well as reduce brake noise. Shims and plates should be inspected for wear and rust and can be re−used when replacing pads. Fresh approved grease should be applied to the shims prior to installation.

A pad wear indicator has been adopted on some models that produces a high screeching noise when the pad is worn down to a predetermined thickness. The purpose of the indicator is to warn the driver and prevent damage to the rotor should the brake pad wear further. The indicator contacts the rotor while the wheel turns and the brakes are not applied. A customer may comment that the noise stops when the brakes are applied.

There are three main categories of disc brake service:

- pad replacement,
- caliper overhaul,
- rotor machining or replacement.

Although it is impossible to determine what repairs are needed until the brake assemblies are inspected, a preliminary road test can help pinpoint problems.

During the road test, listen for noises and note any pedal pulsation or vehicle pulling when applying the brakes. Noises can indicate brake pad problems among other things, pedal pulsation results from rotor damage, and pulling is due to uneven brake application, which can be caused by a number of things.

DISC BRAKE DIAGNOSIS

BRAKE DRAG

Brake drag is a condition that can be caused by several conditions. These include binding or sticking disc brake caliper pistons, binding caliper slides, parking brake not properly adjusted or hydraulic system concerns. Hydraulic causes of brake drag are described later in this chapter.

BRAKE LOCKUP

Brake lockup can occur for a variety of reasons. Some of these include condensation on brake pads, incorrect tire pressure, worn tires, glazed pads, grease or fluid on pads or a faulty proportioning valve. A thorough inspection of the vehicle is needed in the case of brake lockup.

BRAKE NOISE

Keep in mind that there are some brake noises that are widely considered normal and not a cause for brake service. Such noises include an intermittent squeal or groan when brakes are applied. Sometimes these noises occur only during the first few brake applications in the morning, however they may be heard at any time while braking. These noises are usually aggravated by different conditions such as cold, heat, moisture, road dust, salt or mud. The following noises do not indicate a need for service:

• **Clicking noise during ABS stops.** This noise is usually heard from the ABS pump motor and valves.

• **Morning squeal.** This noise is usually caused by low rotor and pad temperatures and goes away once the pads and rotors are warmed up. If the condition cannot be duplicated after warm-up and does not affect brake performance, it does not require service.

• **Groan when creeping.** If you hear this noise, simply inspect the pads for wear and service as necessary. If pads are not worn out, it does not affect performance or safety. This condition will occur if the vehicle is stopped and the driver slowly releases the brake pedal allowing the vehicle to move along slowly.

• **Wire brush noise.** This noise usually occurs with light braking after the brakes have been replaced. It is caused by new rotors and linings not being “broken in”. Normally this noise will go away within 100 stops.

If you hear a continuous grinding, pad noise, moaning or continuous squeal coming from the brakes, immediate service is required. Inspect the following components at each wheel for wear, damage or improper installation:

- Pads and pad insulators
- Anti-rattle springs and clips
- Calipers and slide mechanisms
- Return springs (parking brake)

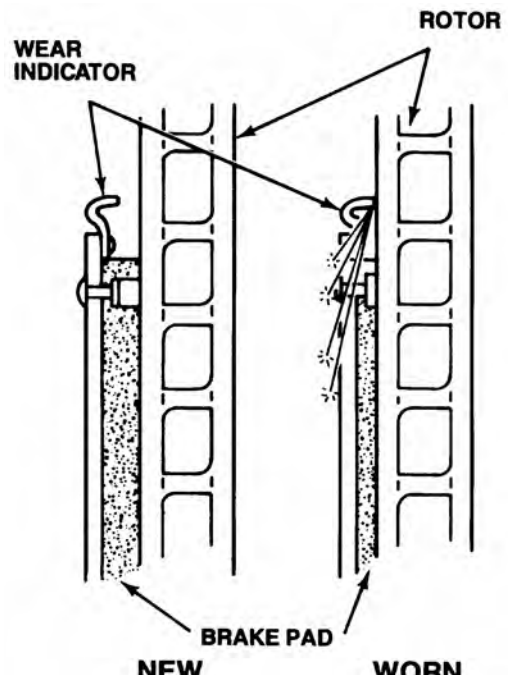


Fig. 1 Brake wear indicators make a "chirping" noise to notify the driver when the friction material is worn and the pads need replacement.

Some common disc brake noises that require immediate service are outlined as follows:

• **Clunking noise.** This can be caused from pads that were not properly fitted to the caliper, loose caliper bracket or loose caliper.

•**Squealing noise during stopping.** This may be the result of an improper disc finish, poor pad isolation, troublesome lining formulations or the wear indicators contacting the rotor surface, **figure 1.**

• Grinding noise. This could indicate that the pad lining material is worn out. When the rivets or the steel backing of the pad make contact with the rotor, damage to the rotor will occur.

HYDRAULIC SYSTEM DIAGNOSIS

Disc brake hydraulic problems typically involve either leakage or an internal hydraulic problem such as a blockage. Leakage will usually appear as wetness around or under the piston dust boot. Sometimes, leakage may not appear evident unless the brakes are under pressure. Other possible sources are a loose or corroded bleeder screw, damaged piston seal or a cracked caliper. Symptoms of leakage will be a low brake pedal, poor stopping, rapidly-falling fluid level in the reservoir, and possibly pulling to one side during braking caused by fluid contamination of the linings. Identification of the problem will require a careful visual examination.

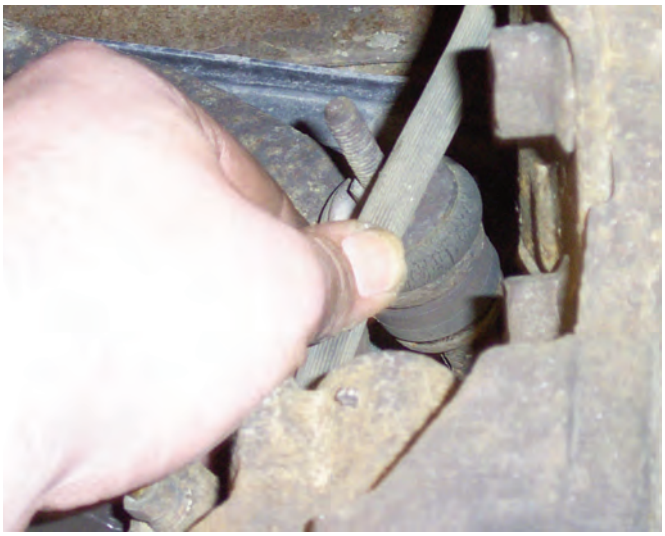


Photo 1: Always inspect brake hoses for crimps, buldges and defects.

Another problem that can be caused by the hydraulic system is brake dragging. This could be the result of trapped hydraulic pressure in the system. It is typically caused by crimped lines and hoses or internal deterioration of the hoses, **photo 1**. If a crimped line is found, the line should be replaced. If internal deterioration of a rubber hose is found to be the problem, always replace the hose instead of trying to clear the blockage.

To check for trapped hydraulic pressure, determine which wheel is dragging by raising vehicle on a hoist and spinning each wheel by hand. Working from the master cylinder to the caliper or wheel cylinder, loosen line and hose connections until the residual pressure is released.

MECHANICAL DIAGNOSIS

Disc brake mechanical problems will usually involve a seized caliper piston, worn parts or calipers that do not move properly on their slides. Each of these problems can be found by doing a thorough visual inspection.

A seized caliper piston will typically show up as hard pulling to the opposite side during brake application. Also, the opposite side brake linings will wear out prematurely. If more than one caliper is seized, poor stopping will result as well.

In cases where you suspect such a failure, raise the car and support it safely, then rotate each wheel by hand as you have an assistant slowly apply the brakes. If you can continue to rotate the wheels while pressure is maintained on the brake pedal, it is likely that the caliper piston on that side is seized. Repair or replace the caliper if you find that the piston is seized.

With typical single-piston calipers, a common mechan-

ical problem is uneven pad wear. Lack of the sliding or floating action that transfers clamping force from the cylinder side of the caliper to the other side results in uneven pad wear and in some cases can result in low or spongy pedal, **Photo 2**. If piston is not moving properly on its slides, inspect slides for damage, then disassemble, lubricate and assemble properly. These procedures are discussed later in this chapter.

Photo 2: Uneven brake wear is a sign the caliper is seized

Rear disc brakes with integral parking brake mechanisms commonly cause a low-pedal condition when the self-adjustment components become sluggish or seize up altogether, or if the driver does not regularly use the parking brake. This will also result in poor stopping power and accelerated front brake wear as the rear brakes will not be doing their fair share of the work. If parking brake mechanism is not functioning properly, repair or replace caliper as necessary. Often the parking brake mechanism is integral to the caliper and cannot be serviced separately.

BRAKE ROUGHNESS

Pedal pulsation, vibration and brake roughness are common disc brake complaints. Most often, these complaints are due to defects in the disc itself – runout, rotor thickness variation, excessive lateral runout, excessive disc thickness variation, lining material transfer, rotor corrosion or cracks. To isolate where the pulsation is coming from, coast at low speed on an uncrowded roadway, hold the steering wheel lightly with your fingers, and apply the brakes gently. If the steering wheel shudders back and forth, the front brakes are at fault.

Rotor lateral runout occurs when the spindle and hub are not parallel to each other, **figure 2**. It is usually not felt in a sliding caliper system, and keep in mind that this condition will lead to disc thickness variation. Runout or rotor warpage may be caused by excessive heat, over torquing lug nuts, or improper mounting of

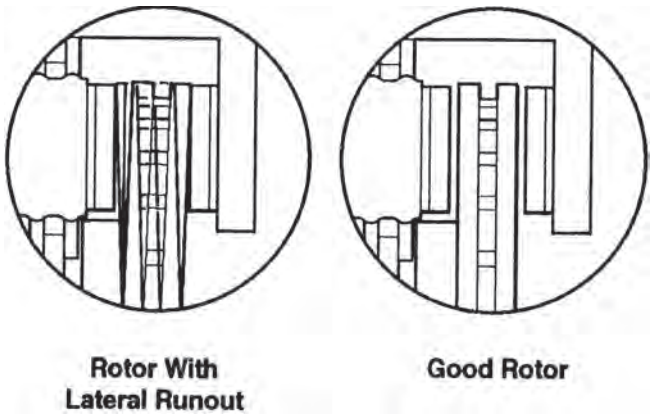


Fig. 2 Disc brake rotor lateral runout.

components.

Lining Material Transfer:

A condition where lining material becomes attached to the rotor. This is a normally occurring condition, but in some cases, the transfer can be uneven or excessive.

Disc thickness variation occurs when the rotor thickness is not the same all the way around the rotor, **figure 3.** Lateral runout will cause thickness variation

Photo 3 Pad material transfer on a rotor.

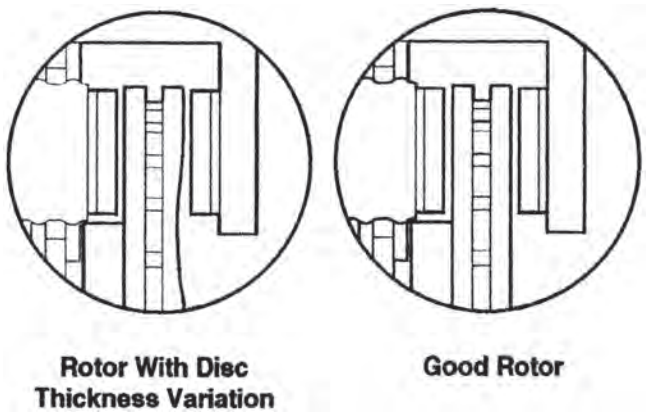


Fig. 3 Comparison between a rotor with excessive disc thickness variation and a normal rotor

then the rotor contacts the brake pad without the brakes being applied as the vehicle is being driven. Eventually the pad will wear the high spot off causing a thin spot to be worn into the rotor. Other causes of thickness variation are pads that do not move properly on their slides or a sticking caliper. When thickness variation becomes bad enough, it may be felt in both the brake pedal and steering wheel. The condition will usually worsen as the rotor gets hot.

Lining material transfer is a condition where lining material becomes attached to the rotor. This is a normally occurring condition, but in some cases the transfer can be uneven or excessive, **Photo 3**. This creates an uneven friction surface on the rotor. The brake pads will tend to grab where material has transferred to the rotor and this is felt in the steering wheel and in the vehicle. If runout and thickness variation are within specifications and roughness complaints are still present, lining material transfer could be the cause.

Rotor corrosion may occur on vehicles that are not driven for long periods of time. The pad material may remove the corrosion when the vehicle is driven, however some pads may remove corrosion better than others. If all corrosion is not removed, thickness variation or excessive lining material transfer could occur. In this case, thickness variation is caused when the area under the pad is not as corroded as the rest of the rotor.

To correct any of the brake roughness complaints described here, machine or replace rotors as necessary. Rotor service procedures including removal, inspection, machining and installation are included in this chapter.

Rotor Types

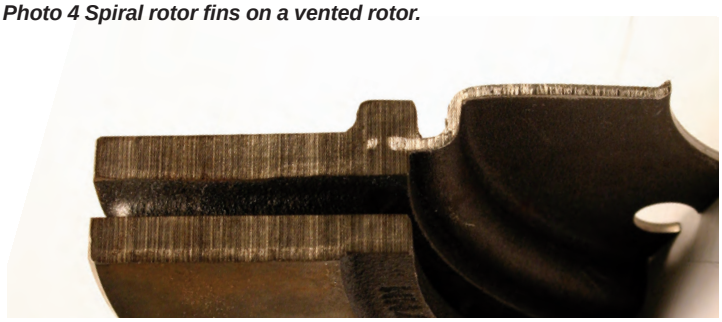
Generally, the disc rotor is made of gray cast iron, and is either solid or ventilated. The ventilated type disc rotor consists of a wider disc with cooling fins cast through the middle to ensure good cooling, **photo 4**. Proper cooling prevents fading and ensures longer pad life. Some Ventilated rotors have spiral fins which creates more air flow and better cooling. Spiral finned rotors are directional and are mounted on a specific side of the vehicle.

The solid type disc rotor is found on the rear of four-wheel disc brake systems and on the front of earlier model vehicles.

A third style rotor can be either the ventilated or solid type which incorporates a brake drum for an internal parking brake assembly, **photo 5**.

Some rotors use a stamped steel hat cast into the plates and fins of the rotor. These were used on some late 1990 model including the Chevrolet Malibu and Jeep Cherokee. These rotors help to save weight.

Photo 4 Spiral rotor fins on a vented rotor.



Composite brake rotor.

Photo 5 Rear rotor with the parking brake in the hat.

ROTOR SERVICE

REMOVAL

Rotors may be of the fixed type made in one piece with the wheel hub, as is found on a typical rear wheel-drive vehicle, or may be of the floating variety, a separate unit that is held against the hub by the wheel and its lugs, and perhaps additional screws or bolts. Some front wheel-drive vehicles have captive rotors. These are integral with the hub and require special pullers and procedures for removal. On-car brake lathes provide the most practical means of machining captive rotors. The removal and installation procedures here are for more common type of rotor, the fixed or floating. Also keep in mind that some rotors are specific to the side of the vehicle that they are installed on. As a general precaution, mark rotors before they are removed to avoid installing them on the wrong side.

1. Inspect fluid in master cylinder. If the retraction of brake caliper pistons will cause fluid overflow, remove appropriate amount of fluid using a suitable tool.

2. Raise and support vehicle, then remove wheels.

3. Retract caliper piston using a suitable c-clamp or

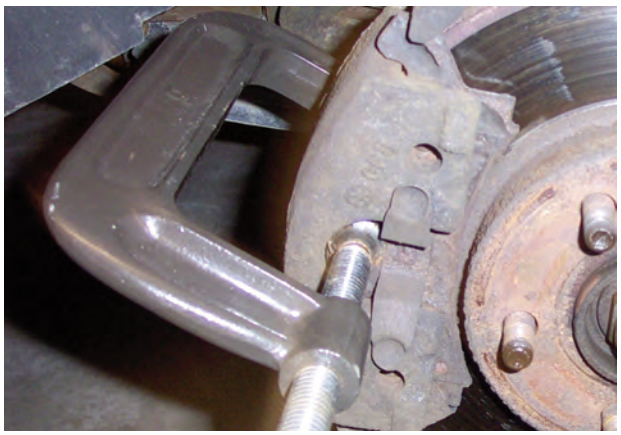


Photo 6 C-Clamp

other tool, **Photo 6**.

4. On models equipped with a caliper bracket, remove caliper bracket bolts, then the caliper with bracket. Support the caliper and bracket using suitable mechanics wire.

5. On models without a caliper bracket, remove caliper attaching bolts, then the caliper. Support the caliper using suitable mechanics wire.

6. If the rotor is of the floating variety, remove rotor holddown screws (if equipped), place an alignment mark on rotor and hub for installation reference, then remove rotor.

7. If rotor is of the fixed variety, proceed as follows:

- On most 2 wheel drive models, you will simply have to remove the dust cap, cotter pin, nut retainer, nut, washer, outer bearing then the rotor.
- On many 4 wheel drive models, the outer hub will need to be disassembled in order to remove the rotor. This procedure will vary depending on the make and model, so consult a factory shop manual when removing 4-wheel-drive fixed rotors.

8. If equipped with serviceable wheel bearings, inspect the grease in the hub and on the wheel bearings. If the grease is relatively fresh and in good condition, set the rotor on the bench and cover the outer bearing and hub opening so the bearings will not become contaminated. If the grease is old and dirty, repack the wheel bearings before you reinstall the rotor/hub. Always repack the wheel bearings when performing a complete brake job. Also, if the rotor is machined, the grease seal must be replaced.

INSPECTION

Brake rotor inspection consists of two parts, a visual inspection followed by one or more careful measurements. A thorough inspection determines if the rotor is in serviceable condition, must be machined to restore its surface, or is beyond saving and must be replaced.

To begin, wipe the rotor surface clean to make it easier to spot problems. Inspect the rotor for problems on the surface, such as:

- Scoring and grooves
- Cracks
- Heat checking
- Hard spots

Generally, rotors must be resurfaced if scoring and grooves are deeper than 0.010 inch. If cracks are visible, replace the rotor. Minor, localized heat checks can be machined out, but if heat checking is widespread, replace the rotor. As with drums, hard spots are difficult to remove, and most manufacturers recommend replacing rotors that have hard spots.

BRAKE ROTOR MEASUREMENT

Brake rotors are measured to identify wear and distortion that is not visually apparent. All types of rotor wear and distortion can be measured using an outside micrometer and a dial indicator.

Rotor thickness

The first step is to measure rotor thickness with an outside micrometer to check for wear. To begin, note the discard dimension stamped or cast into the rotor. Then, take a micrometer reading 1 inch in from the outer edge of the rotor to measure thickness, **figure 4**. For best

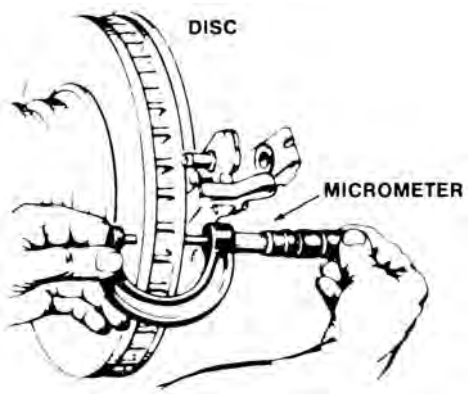


Fig. 4 Use an outside micrometer and take a reading approximately 1 inch in from the outer edge to measure rotor thickness.

results, use a brake micrometer with a pointed anvil that will measure to the bottom of wear grooves. Compare the measured thickness to the discard dimension.

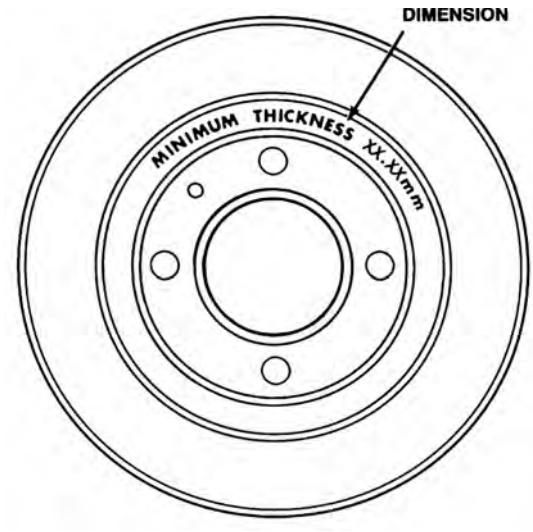


Fig. 5 Rotors must be replaced if they measure less than the specified minimum thickness after turning.

If the rotor thickness is not at least 0.015 to 0.030 inch larger than the rotor discard dimension, replace the rotor. The amount of additional metal required to allow for wear in service varies depending on the manufacturer. Check the shop manual of the vehicle you are servicing for the exact value. If the rotor needs to be turned, there must be sufficient metal remaining, so the thickness will be at least 0.015 to 0.030 inch larger than the discard dimension after machining. Ford Motor Company rotors, and those from some other manufacturers, are marked differently. Replace one of these rotors whenever its thickness is less than the "minimum thickness" stamped or cast into the outside of the rotor, **figure 5**. If you are unsure of what the measurements on a rotor mean, consult a factory shop manual.

Rotor taper variation

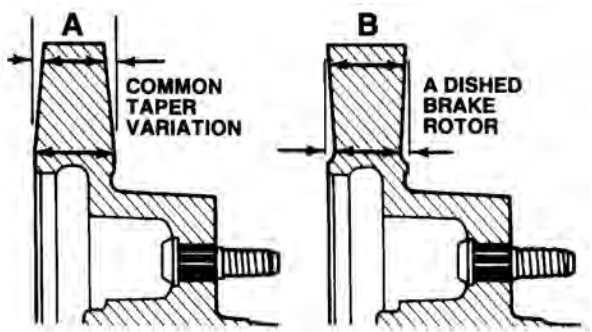


Fig. 6 Taper variation is uneven wear across the friction surface of a rotor.

Rotor taper variation is a difference in thickness across the friction surface of a rotor, **figure 6**. To check for taper variation, use an outside micrometer with a deep frame to measure the rotor thickness at the outer edge just below the ridge. Take a second measurement at the inner edge of the area swept by the brake pads. Subtract the smaller measurement from the larger one to obtain the taper variation. Repeat these measurements at four points around the rotor. If the variation is greater than 0.003 inch at any point, machine the rotor. A rotor with too much taper will not allow the pads to contact the rotor squarely and can cause the caliper pistons to bind in their bores.

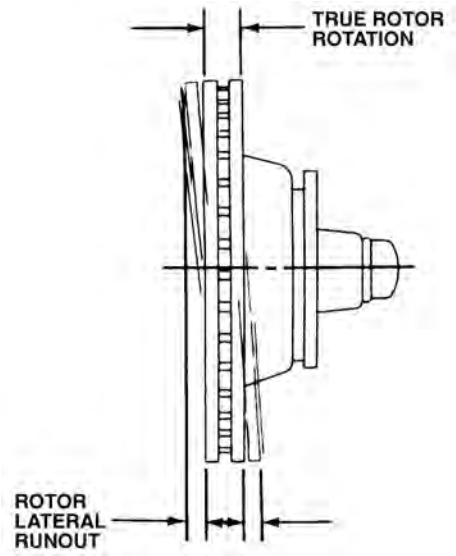


Fig. 7 Lateral runout causes a rotor to move from side to side, or wobble, as it rotates.

Rotor lateral runout

Lateral runout is a side-to-side movement of the rotor as it turns, **figure 7.** Excessive runout can cause brake pedal pulsations, vibration during braking, and increased brake pedal travel from too much pad knockback. Runout is measured using a dial indicator.

For maximum braking performance, lateral runout should be less than 0.003 inch. However, lateral runout tolerances vary by manufacturer and, depending on the vehicle, anywhere from 0.002 to 0.008 inch may be acceptable. It is only necessary to check lateral runout on one side of the rotor; runout never varies significantly between the two sides.

Check for lateral runout while the rotor is mounted on the vehicle and rotating on the wheel bearings. When making this check, it is very important not to mistake bearing play for lateral runout. Adjustable wheel bearings can be tightened to eliminate play as a factor. With non-adjustable wheel bearings, measure and record bearing play, then subtract it from the final reading on the dial indicator to determine the true runout.

To check the lateral runout of a rotor:

1. Raise and properly support the vehicle so the wheel with the rotor to be checked can turn freely, then remove the wheel.

2. If the vehicle has floating rotors, install two lug nuts to hold the rotor tightly on the hub.

3. Either pry the brake pads back, so they do not drag against the rotor, or remove the caliper to access the rotor.

Fig. 8 Dial indicator setup to measure rotor lateral runout.

4. Mount a dial indicator so the plunger contacts the rotor at a 90-degree angle about 1 inch from the outer edge, **figure 8.**

5. Rotate the rotor until the lowest reading shows on the indicator dial, then zero the dial.

6. Rotate the rotor until the highest reading shows on the dial; this is the lateral runout with adjustable wheel bearings. With non-adjustable wheel bearings, subtract the bearing play from this figure to find the true lateral runout.

Compare findings to specifications to determine if the rotor can be salvaged or must be replaced. A rotor with runout can be machined and returned to service unless turning reduces it to less than minimum thickness.

Some manufacturers recommend several ways to correct to correct excessive lateral runout. One is to replace the rotor. Other ways include adding correction plates, indexing the rotor or use of an on-car brake lathe.

The correction plate method involves the addition of a tapered plate between the brake rotor and the hub/axle flange. Correction plates can be used for runout up to .009 inch. The indexing method involves moving the rotor to a different orientation to the hub/axle flange. This method is most effective when runout is out of specifications by a very small amount (.001-.005 inch). The last method involves machining the brake rotors using an on-car brake lathe. An example on-car lathe procedure is described later in this chapter.

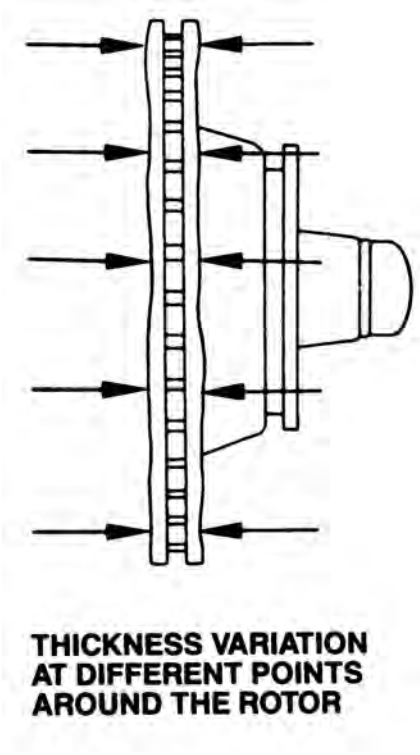


Fig. 9 Lack of parallelism, or thickness variation, is the most common cause of brake pedal pulsation.

ROTOR LACK OF PARALLELISM

A rotor that lacks parallelism varies in thickness at different places around its surface, **figure 9.** Often called warpage, lack of parallelism is the most common cause of brake pedal pulsation and also causes braking vibration.

To check for variations in parallelism, use an outside micrometer to measure the rotor thickness at 6 to 12 equally spaced points around the surface. Make all of the measurements at the same distance in from the outer edge of the rotor, so taper variation will not affect the measurements. If the thickness variation between any two points is greater than 0.0005 inch, and there is noticeable brake pedal pulsation, machine the rotor.

MACHINING

Some carmakers are now recommending that brake rotor machining not be done unless there is a pulsation or shudder complaint. During normal pad replacement, the discs should be used as-is providing the rotor meets all specifications. If the rotor does not meet factory specifications, machine or replace as required.

It would be impossible to list all instructions for every type of brake lathe in use today, but there are however some general guidelines that do apply to all rotor machining:

• Disc brake rotors should only be refinished if they have enough thickness to still be within specifications after refinishing.

• After a rotor has been separated from the hub, clean any rust or contaminants from the hub flange and brake rotor mating surface. Failure to perform this step will result in increased assembled lateral runout.

• Never machine a rotor unless you also machine the rotor at the other side of the same axle an equal amount. This keeps braking force and fade resistance equal from side to side and prevents brake pull.

• Composite rotors, which combine a steel hub "hat" with an iron wear surface, tend to flex during machining, which makes it difficult to hold tolerances and eliminate chatter marks unless heavy lathe adapters that clamp down on the hub are used.

• Even a well-kept lathe may produce a relatively rough directional finish. In the days of asbestos linings, this was acceptable -- 80-100 RMS was considered fine enough. Today, however, with semi-metallic and ceramic friction material, a very smooth surface on the order of 40 60 RMS is required or squealing and rapid wear will result. A non-directional finish should be obtained if machining rotors. Some manufacturers recommend using 120 grit aluminum oxide sandpaper with a lathe finishing tool, or 150 grit aluminum oxide sandpaper with just a sanding block if a lathe finishing tool is not available. If using the lathe finishing tool, always follow the lathe manufacturer's recommended speed setting for applying a non-directional finish.

• Rotors must be washed after machining or hard particles will become embedded in the new linings and cause noise and scoring. Clean the braking surface with denatured alcohol or other approved brake cleaner.

BENCH LATHE

When using a bench lathe, first consult the instruction manual that pertains to that particular lathe to ensure proper setup and operation. The following instructions pertain to most lathes and are meant as a general outline as to how to use a bench style lathe.

1. Ensure that rotor mounting surfaces are clean.
2. Mount rotor to brake lathe according to manufacturer's instructions.
3. Attach any necessary vibration dampening attachments to the rotor or lathe.
4. Ensure the bits are not damaged in any way.
5. Replace or rotate bits as necessary.
6. Position cutting bits to center of rotor braking surface ensuring that bits do not contact rotor surface.
7. If lathe is equipped to machine drums as well as rotors, ensure that drum feed is not engaged and also ensure that rotor feed is not engaged.
8. Turn brake lathe on, then adjust cutting bits until they just contact the rotor.
9. Observe the witness marks made by the bits. If the mark extends approximately ¾ or more around the rotor braking surface, the rotor is mounted properly. If witness mark is not as just described, remount the rotor to the lathe.
10. Refinish the rotor as outlined under the lathe manufacturer's instructions.
11. After each cut, inspect brake rotor thickness.
12. If rotor exceeds minimum allowable thickness, replace rotor.
13. Remove the rotor from the lathe. If it is within specifications, measure the assembled lateral runout as previously described.

ON-CAR BRAKE LATHE

In recent years, on-car brake lathes have become a popular alternative to traditional bench-style brake lathes. There are several benefits to using the on-car brake lathe. For one, it allows rotor machining on the vehicle spindle center line which is the axis of rotation for the rotor. It also stops the stack-up tolerance of related parts from affecting rotor lateral runout. You will find that some bench-style brake lathes may actually induce lateral runout and instead of machining a rotor to the vehicle spindle center line, it is machined to the centerline of the lathe. Keep in mind that the cutting bits for both the on-car lathe and the bench lathe may not be interchangeable.

Whenever using an on-car lathe, first consult the instruction manual that pertains to that particular lathe to ensure proper setup and operation.

1. Begin setup on the side of the vehicle where the caliper is in on the right side of the spindle centerline when facing the vehicle, **figure 10.** This will make lathe setup easier.

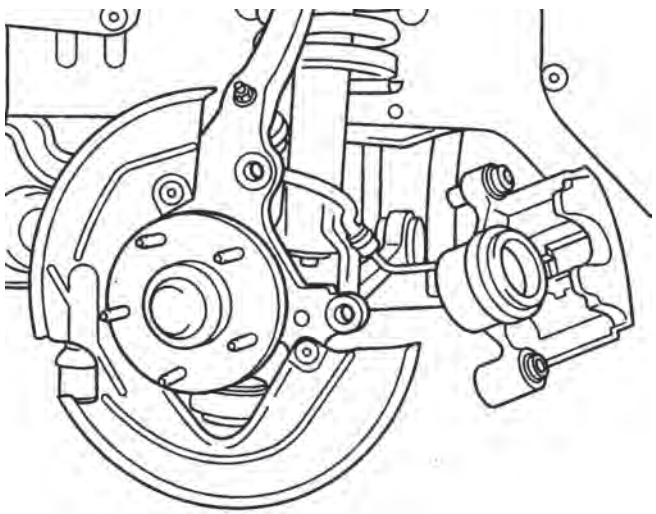


Fig. 10 Choosing to setup the on-car brake lathe according to manufacturer's instructions makes setup easier.

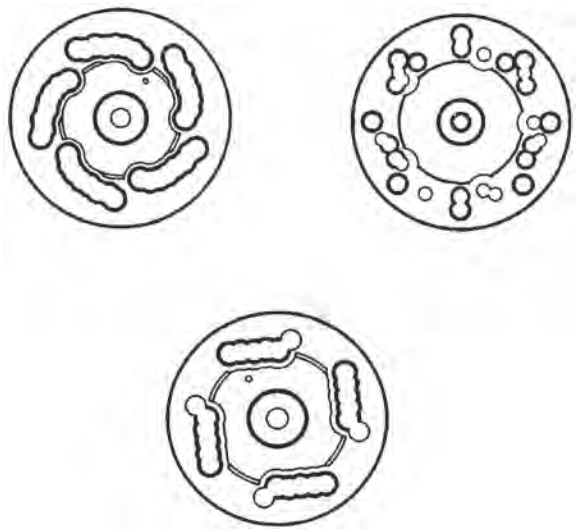


Fig. 11 On-car brake lathe adapter selection.

2. Select the correct adapter for vehicle application by holding the adapter next to the lug pattern and rotating until one of the predrilled patterns matches the vehicle, **figure 11.** Note that a spacer may be needed.
3. Using the lug nuts supplied with the brake lathe, tighten the adapter to 25-30 ft. lbs. Do not use an impact wrench and do not use the vehicle lug nuts for this procedure.
4. Inspect the cutting bits as follows:
   - Ensure the bits are not damaged in any way.
   - Replace or rotate bits as necessary.
5. Ensure cutting bits are correctly installed.
6. Unscrew all lathe lateral runout screws to ensure that they do not protrude through the lathe plate.
7. Adjust the cutting head back to allow the tool head to clear the rotor when the lathe is being attached to the hub.
8. Attach the lathe to the adapter, **figure 12**:

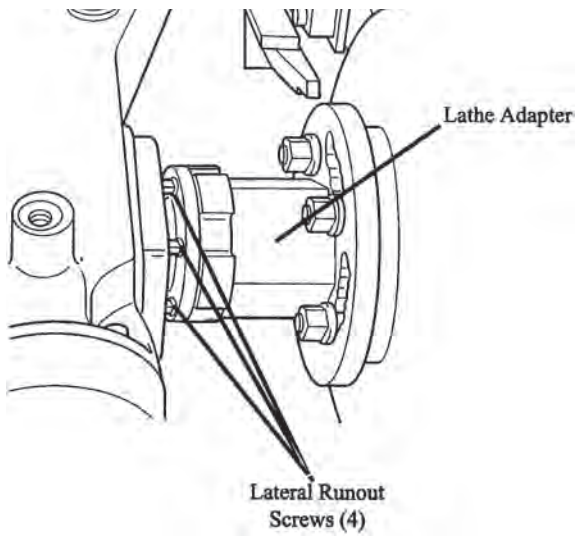


Fig. 12 This view shows the brake lathe being fitted to the adapter.

   - Place lathe so that mounting flange is close to the mating surface on the adapter.
   - The adapter has a dowel pin that must align with one of two holes on the mounting flange.
   - When flange is flush to the adapter, attach shaft of lathe to adapter by rotating large mounting knob.
9. Compensate for lathe runout as follows:
   - Attach a suitable dial indicator to the steering knuckle.
   - Place the dial indicator bit against a flat surface on the outside of the cutting head farthest from the hub, **figure 13.**
   - Tighten the stand handle to prevent lathe from rotating.
   - Pull out feed knob to disengage lathe feed. This will prevent the cutting head from feeding when the motor is in operation.
   - Turn on lathe while observing movement of the dial indicator. Zero the dial indicator.
   - Determine the total needle sweep between the high and low reading on the dial indicator. If the total runout is more than .003 inch, lathe lateral runout must be adjusted. Target range of lathe lateral runout is 0. Maximum is .003 inch.
   - Turn off lathe. Rotate mounting flange until needle reaches highest point of sweep. (The knob on the back of the motor can be used to manually crank the motor to the highest point.
   - Rotate the lateral runout screw closest to the horizontal position on the side of the hub that is opposite of the cutting head (motor side) so that the needle moves half the distance of the total needle sweep, **figure 14.**

     - If the needle does not move toward the center of the needle sweep as the screw is being turned, you are turning the wrong screw.

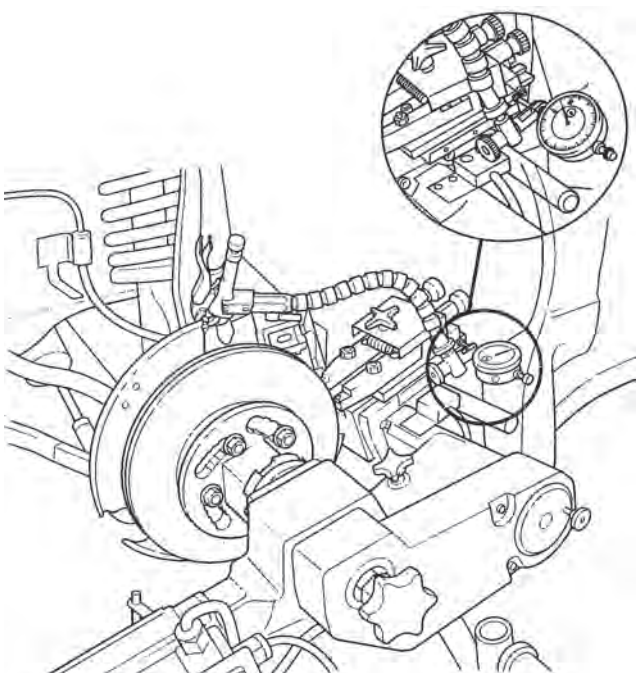


Fig. 13 View of dial indicator position when compensating for lathe runout.

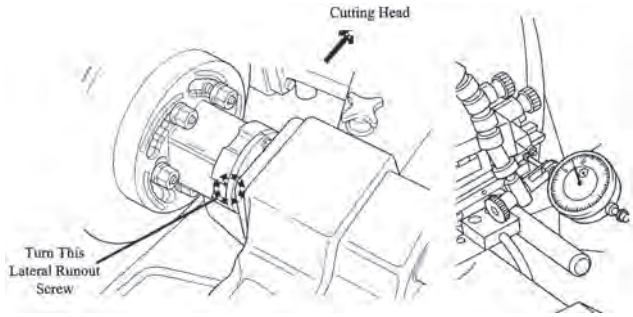


Fig. 14 Lathe lateral runout adjustment.

- Note the number of lateral runout screws that you turned, then turn on lathe and observe the movement of the dial indicator.
- If runout is still not within specifications, a second lateral runout screw may be adjusted.
- Ensure that the second lateral runout screw is not directly across from the first screw that was turned.

10. Center the cutting head with the brake rotor. Move the cutting head into any of the five holes as necessary. Ensure that metal shavings are cleaned from holes and clean dovetail area when changing the cutting head position.
11. Push the cutting head back into the dovetail until it is square, then tighten the setscrew.
12. Adjust feed knob until the cutting bits clear the edge of the rotor. Loosen the shutoff cam screw, then slide the cam back until it contacts the automatic shutoff switch plunger. Tighten the cam screw.
13. Ensure that the feed knob is in the disengaged position, then turn on lathe.
14. Loosen lock knob on top of the cutting head.
15. Adjust cutting bits until they clear both sides of the rotor.
16. Adjust cutting head until it is at the center of the rotor braking surface.
17. Rotate the adjustment dial until the inner cutting bit touches the rotor. You should be able to hear the bit skimming the rotor.
18. Rotate the adjustment dial until the outer cutting bit touches the rotor.
19. Adjust the feed handle until the cutting bits reach the inner edge of the rotor. Be sure not to contact the rotor hat or damage to the holder plate will result.
20. Adjust bits to desired cutting depth on both sides of rotor keeping the following information in mind:

- Inner side of rotor should be set first, then the outer.
- The maximum cut depth for each side of the rotor is .008 inch which would give a total maximum cut of .016 inch for each cut.
- Do not remove more metal than is needed to clean and true the rotor.
- The minimum cut for each side is .004 inch for a total maximum cut of .008 inch.
- A smaller cut causes the bits to get hot and wear out faster. This will result in a poor surface finish.

21. Tighten the lock knob.
22. Install the chip deflector/silencer over the cutting bits.
23. Engage the automatic feed.
24. When the lathe turns off, verify that rotor lateral runout and rotor thickness is within specifications.
25. Clean metal chips before removing the lathe and adapter.
26. Remove lathe and hub adapter from wheel lug nut studs. Clean all remaining metal shavings from adapter and ABS sensor if equipped. Note that special care must be taken to clean metal shavings from exposed 4WD hubs.
27. Repeat procedure on opposite side of vehicle noting the following:

- The cutting head is already centered and the automatic stop is already set.
- Lathe will be turned upside down in order to service opposite side. Remove chip tray, loosen trolley handle and rotate lathe 180°. Reinstall chip tray and tighten handle.
- Back out lateral runout adjustment screws before attaching hub to adapter.
- Adjust for lathe runout.

RESURFACING ISSUES

Once you have collected the data, the following comparisons should be made. Compare bearing flange to rotor runout position. If the shim cannot correct the runout, the bearing should be replaced. Check the rotor thickness. The minimum dimension should be stamped or cast into the rotor. There has to be enough thickness to cover the runout without going below the minimum thickness.

Pulsation comebacks cost technicians and shops parts and lost labor. Rolling the dice every brake job by not eliminating runout or trusting in new rotors will cost you more than the time spent measuring with a dial gauge and micrometer.

In some cases, rotors may not have to be resurfaced when the pads are replaced. If they are relatively smooth with minimal grooving, they may not need to be cut. However, most professional brake technicians won't take a chance on not resurfacing the rotors for fear the brakes may be noisy or not feel right until the pads are fully seated in.

Resurfacing a rotor obviously removes metal, making the rotor thinner and reducing its remaining service life. Because of this, some consumers as well as some vehicle manufacturers say rotors should not be resurfaced every time the pads are replaced (unless the rotors are badly grooved or uneven). Okay, some people are cheap and are trying to save a buck. We'll grant them that. But do they really want to cut corners on their brakes? Resurfacing restores a flat, smooth surface that provides the proper friction characteristics, minimizes noise-producing vibrations and allows for maximum pad contact.

Installing new pads on a grooved rotor causes the pads to ride on the high spots of the rotor. Eventually, the pads will

wear down and make full contact with the rotors as they seat in. But this increases pad wear and decreases overall pad life. So it could also be argued that not resurfacing the rotors is counterproductive to maximizing brake life.

The surface finish on the rotors also is important because it affects the friction characteristics of the brakes, pad seating, break-in, wear and noise. Most new OEM rotors today have a surface finish between 30 and 60 inches RA (roughness average), with many falling in the 40 to 50 RA range. Some OEM specifications say that anything less than 80 RA is acceptable. If rotors are resurfaced, they should be cut to meet these specifications using sharp lathe bits and proper rotation and feed speeds (not too fast!).

INSTALLATION

Photo 7 Clean the hub flange to prevent runout issues.

Pay special attention to the mounting flange. Taking time to clean the mounting flange on the hub can remove corrosion and debris that can cause runout. Also, pay attention to lug nut torque. Often this will alleviate some runout issues, **photo 7.**

You can apply a light coating of anti-seize lubricant to prevent further corrosion and corrosion between the two surfaces. Never put anti-seize on lugs or studs. Some manufacturers recommend applying a high temperature nickel anti-seize lubricant to the inside of the rotor hat to prevent corrosion between the hub and rotor, **figure 15.** If performing this step, be sure to use only factory recommended anti-seize lubricants, apply only a light coat and ensure that no anti-seize compound comes into contact

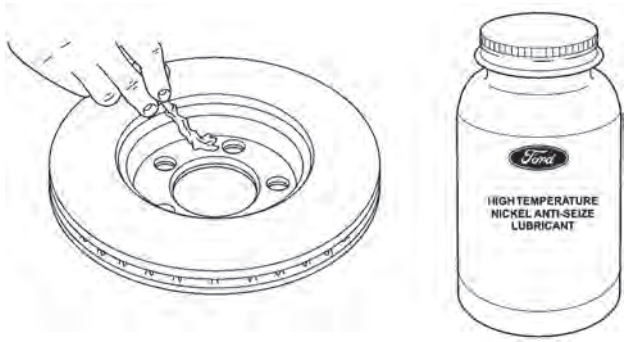


Fig. 3-15 Some manufacturers recommend applying anti-seize compound on the rotor to prevent corrosion between the hub and rotor.

with stud threads. Keep in mind that if you are installing a new rotor, often you will have to remove a protective coating before installation. Note that some rotors are specific to the side of the vehicle that they are installed on as well.

1. On models with the floating rotor design proceed as follows:
   - Ensure that the rotor mounting surfaces are clean.
   - If rotor retaining bolts or screws are used, consult a factory shop manual to determine if a threadlock is needed.
   - Align reference marks made during removal, then install rotor to hub, then the rotor holddown screws if equipped.
2. On models with the fixed rotor design, proceed as follows:
   - Ensure bearings are properly greased
   - Ensure that a new grease seal is installed.
   - Apply a light coating of grease to the spindle.
   - Install the rotor to the spindle.
   - Consult a factory shop manual for final installation instructions as installation and adjustment of bearings will vary between manufacturers.
3. Install brake caliper and/or mounting bracket and tighten to factory specifications.
4. Install wheels as outlined later in this chapter.

BRAKE PAD SERVICE

Brake pads are sold and serviced as axle sets, which consist of four pads, the inner and outer pad for the caliper at each wheel. Never mix pads from different manufacturers, as the friction coefficients of the linings may be different, even though they appear the same. If only one pad of an axle set is badly worn, replace the entire set after repairing the problem that caused the uneven wear.

Most manufacturers recommend that the bushings, O-rings, retaining bolts, retaining clips, and any other caliper mounting hardware be replaced whenever a new set of brake pads is installed. The exact procedure for replacing

a set of

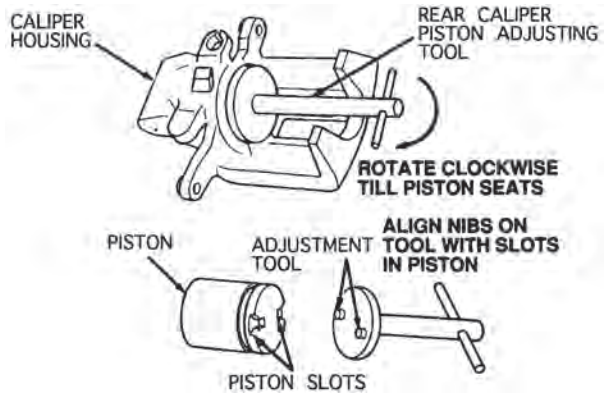


Fig. 16 Some calipers require a special tool to retract the piston back into its bore.

brake pads varies with the design of the caliper. However, there are a number of basic steps common to any pad replacement. For caliper removal instructions, refer to the procedures outlined in this chapter.

Keep in mind that on some rear calipers, there will be are special procedures that need to be followed to retract the piston. Some use an adjusting bolt that will need to be turned in order to retract the piston. On others, a special tool will need to be used to turn the piston back into its bore, **figure 16.** If in doubt, always consult a factory shop manual.

Make sure the pistons are free and go in at the same rate for fixed piston calipers.

REMOVAL

The first step in replacing brake pads is to remove some of the brake fluid from the master cylinder reservoir with a brake fluid syringe. This makes space for the fluid that will be displaced back into the reservoir when the caliper pistons are bottomed in their bores.

On fixed calipers, remove the pad guide pins and retaining spring, then use a pair of pliers to pull the pads straight out of the caliper, **figure 17.** If there is a ridge at the edge of the

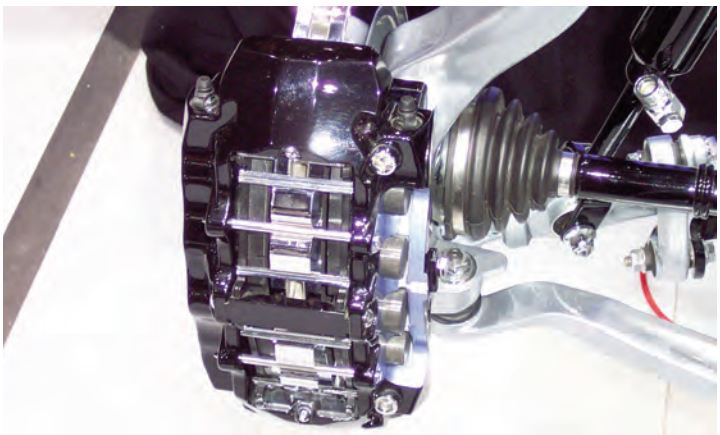


Fig. 17 A fixed caliper rigidly mounts to the chassis. Once the guide pins and retaining spring are removed, the pads can be

Fig. 18 With floating calipers, the anchor plate attaches to the chassis, and the caliper body slides on guide pins connected to the anchor plate as the brakes are applied. To replace the pads, the caliper body must be separated from the anchor plate.

rotor that prevents a pad from being easily removed, insert a screwdriver between the rotor and pad, and carefully pry the caliper piston back into its bore until there is sufficient clearance to remove the pad.

Removing the pads from sliding calipers or floating calipers generally requires that the movable portion of the caliper be separated or pivoted away from the anchor plate, **figure 18.** Whenever you remove a caliper during brake pad replacement, hang it from the suspension by a wire, so there is no strain on the brake hose that might cause internal or external damage.

INSPECTION AND CLEANING

The thickness of the lining material is the main factor that determines whether the pads should be replaced. The brake pads must be at least 0.030 inch above the pad backing plate or rivet heads, **figure 3-19**. Measure friction thickness with a machinist scale.

Fig. 19 Measure the thickness of the friction material on brake pads to determine if they can be returned to service.

Pads should be worn evenly and not tapered. If the pads are tapered, it is a sign the slides or pistons are seizing. The caliper slides should be serviced and the hardware should be replaced

Also, inspect the pads for taper wear, in which the pads are thinner at one end than at the other. Some pad taper wear is normal in floating calipers because the caliper body tends to flex slightly on its mountings. The leading edges of brake pads may also wear faster than the trailing edges because they operate at higher temperatures. However, if there is more than 0.13 inch of taper wear, you should replace the pads and inspect the caliper for possible problems.

Compare the amount of wear on the two pads in each caliper, then compare the amount of pad wear between the two calipers on the same axle. Uneven wear between pads in the same caliper can be caused if the rotor is rough on one side, causing that pad to wear more rapidly. In fixed calipers, a frozen piston will cause uneven wear between the two pads.

All of the pads may not be worn the same amount in sliding or floating calipers because the pad on the piston side usually wears more quickly. However, grossly uneven pad wear occurs in floating and sliding calipers when the mounting hardware rusts or corrodes, causing the caliper to bind as it moves on the guide pins or anchor plate.

Check the friction lining surface for signs of contamination from brake fluid that has leaked past the piston seal and dust boot. Fluid contamination will cause the lining to darken. Brake pads that have been soaked with brake fluid must be replaced.

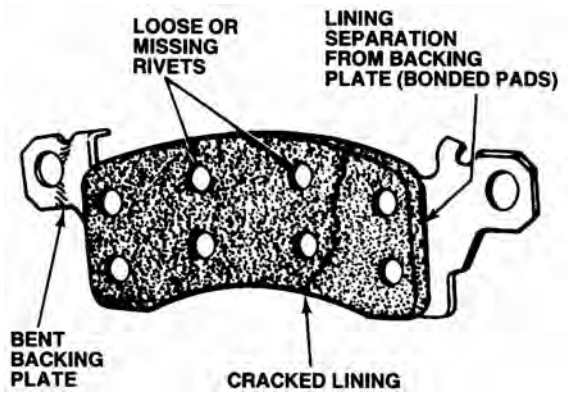


Fig. 20 Inspect brake pads for physical damage, such as lining cracks, loose or missing rivets, backing plate distortion, or separation from the backing plate, as well as wear and fluid contamination.

Inspect the pads for physical damage. Look for large cracks in the lining, loose or missing rivets, a bent backing plate, or a bonded lining that is separating from the backing plate, **figure 20.** If these problems are present, replace the pads.

Installation

Always inspect the brake rotor and the brake caliper, as described in this chapter, before installing new pads. Install the brake pads into the caliper or anchor plate as dictated by the brake design. The pads in fixed calipers slip into place, and a spring retainer on the guide pins prevents the pads from vibrating and causing brake noise. Some designs use shims that fit between the caliper pistons and pad backing plates to reduce vibration and noise, **figure 21**.

Fig. 21 Shims install behind the brake pad backing plates on some vehicles to reduce pad vibration and noise.

The pads in floating and sliding calipers usually have spring clips or bent tabs on the backing plate that lock them securely into the caliper anchor plate. Antirattle spring clips, of which a number of designs are used, attach to the brake pads or caliper anchor plate to reduce pad vibration and prevent brake noise.

Once the pads are in position, secure them in the appropriate manner. With a fixed caliper, install the guide pins and retaining spring. With a sliding caliper, clean the ways and lubricate them using a high-temperature brake grease, **figure 22.** Then, position the caliper body onto the ways over the rotor, and install the retaining hardware. With a floating caliper, lightly coat the caliper bushings and mounting bolts or guide pins with high-temperature brake grease, then position the

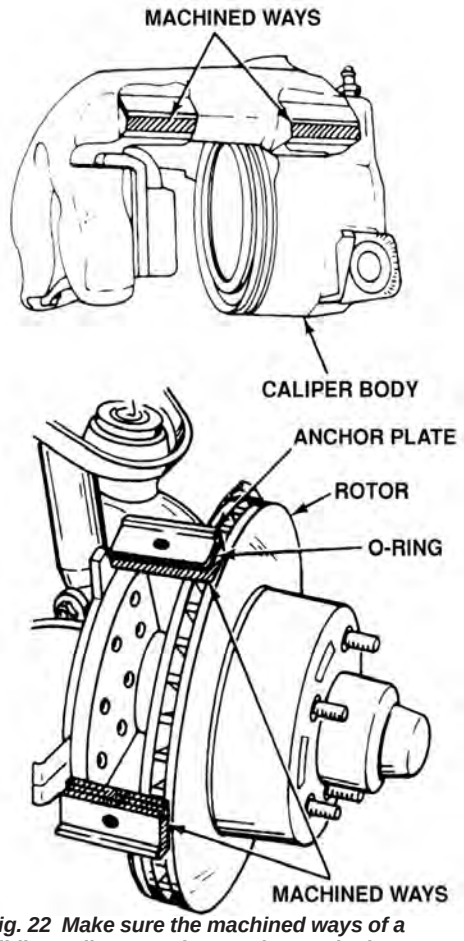


Fig. 22 Make sure the machined ways of a sliding caliper are clean and smooth, then lubricate them with a thin coat of high-temperature brake grease.

caliper body over the rotor. Install the mounting bolts and tighten all fasteners to specified torque.

Heating and cooling cycles can weaken springs and anti-rattle clips. Weak hardware parts can result in excessive caliper/pad movement or binding, causing noise and other related problems. This can lead to uneven and premature pad wear, rotor warpage and pulling.

Some springs and clips can be difficult to install. Some anti-rattle clips may resemble Chinese finger traps when you are trying to reinstall them back on the car. But leaving them out is not an option.

When rust and corrosion build up on a floating caliper's slides or bushings, it can prevent the caliper from centering itself over the rotor when the brakes are applied. Not only does this reduce effective braking force and increase the vehicle's stopping distance, it also causes uneven pad wear. When technicians think of brake hardware, they think springs, clips and slides. But soft parts like dust shields, grommets and bushings need just as much attention.

Most floating brake calipers use a rubber or plastic insulator or shim around the mounting bolts of the caliper. This sleeve of soft material loses resiliency over its lifetime.

Brake lubricants are critical in returning the brake system to optimal operating condition. There are three criteria to remember when selecting a brake lubricant. First, does it say that it's a brake lubricant on the package? If not, don't use it. Some lubricants may say they are a silicone- or molybdenum disulfide-based, but they may not be formulated to work on brakes. Second, look at the effective temperature range of the lubricant. At minimum, a lubricant should be able to handle 400 degrees F. Third, check to see if it contains petroleum distillates or any substance that can be detrimental to soft parts.

Rear disc brake pads that are used for the parking need to have the caliper piston aligned with the tabs or posts on the back of the pad.

ADJUSTMENT

Some rear calipers require an initial adjustment before returning to service. If this adjustment is not performed, damage to the caliper internal parking brake actuator will result when the brakes are first applied.

To adjust the caliper, install the caliper with pads and measure the clearance between the pads and rotor. Typically the clearance should be about .060 inch. If the clearance is not within factory specifications, the caliper piston must be adjusted outward**.** Other designs require you to turn an adjusting nut. Still others require you to remove a plug and turn an allen screw. In any case, consult a factory service manual for the correct procedure. Repeat the adjustment procedure until clearance is within specifications.

When pad clearance has been properly adjusted, apply the parking brake several times until a firm brake pedal is achieved.

TEST DRIVE AND PAD BURNISHING

All brake pads must be bedded-in with the rotor they will be used against to maximize brake performance. The bedding-in process involves a gradual build up of heat in the rotors and pad compound. But, how this gradual heat and bedding process takes place is determined by the manufacturer of the pad.

Taking a vehicle for a test drive after a brake job lays down a thin layer of transfer film on to the rotor surface. Following the bed-in procedures provided by the manufacturer will assure a smooth, even layer of transfer film on the rotor and will minimize brake judders.

The break-in procedure is not to "cure" a pad and harden the resins. If a brake pad set produces an excessive amount of smell or smoke on the initial bedding procedure, chances are that there is something wrong with the pad and how it was manufactured.

There are not any set rules or universal procedure to bedding or breaking-in brake pads. Due to the fact that every manufacturer has different manufacturing processes, each has their own recommended procedure.

Some manufacturers recommend 400 to 500 miles of moderate driving with out hard stops, while some recommend 20 to 30 stops from specific speeds. Most manufacturers are printing the break-in directions and dropping them in the box.

1. Hard pulling to one side during braking may be caused by:
a. Worn pads
b. A seized caliper piston on the opposite side to that of the pull
c. Loose pad mountings
d. Worn sliding ways

2. Check for pedal pulsation in front disc brakes by:
a. Applying the brakes in reverse
b. Braking hard from high speed
c. Coasting and applying the parking brake
d. Feeling for steering wheel rocking while braking lightly at low speed

3. Technician A says that scored rotors cause pedal pulsation. Technician B says that pulsation is caused by disc thickness variation. Who is right?
a. Technician A
b. Technician B
c. Both
d. Neither

4. Brake squeal may be caused by all of the following EXCEPT:
a. A poor rotor friction surface
b. Missing pad shims
c. A leaking caliper piston seal
d. Poor quality linings

5. Slight taper wear on disc brake pads removed from a floating caliper is most likely the result of:
a. A sticking caliper piston
b. A lack of caliper guide pin lubrication
c. Normal wear
d. A lack of rotor parallelism

6. As a general rule, disc brake pads must be replaced if the friction lining thickness measures less than:
a. 0.020 inch
b. 0.030 inch
c. 0.060 inch
d. 0.130 inch

7. To avoid causing damage, remove caliper piston seals with a:
a. Pair of needle-nose pliers
b. Small screwdriver
c. Small steel pick
d. Plastic or wood probe

8. For best results, what drill motor speed should be used when honing a caliper piston bore?
a. 300 rpm
b. 500 rpm
c. 1000 rpm
d. 1200 rpm

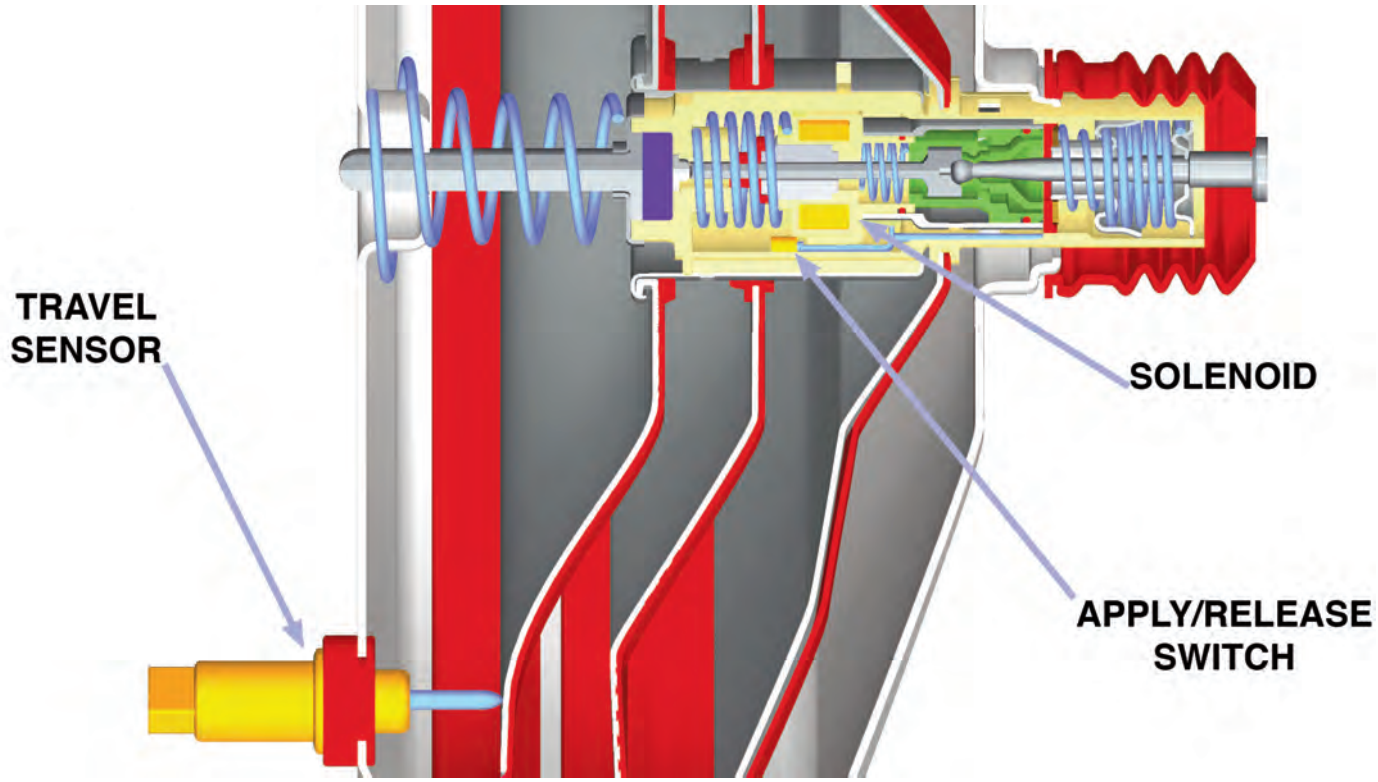
9. Typically, manufacturers allow rotors to be reused if thickness variation does not exceed:
a. 0.005 inch
b. 0.002 inch
c. 0.001 inch
d. 0.0005 inch

10. Use a dial indicator to check a rotor for:
a. Lack of parallelism
b. Taper variation
c. Lateral runout
d. Radial runout

Answer Key: 1. b, 2. d, 3. b, 4. c, 5. c, 6. b, 7. d, 8. b, 9. d, 10. c,

ASE G1

BRAKE POWER ASSIST



VACUUM POWER ASSIST SERVICE

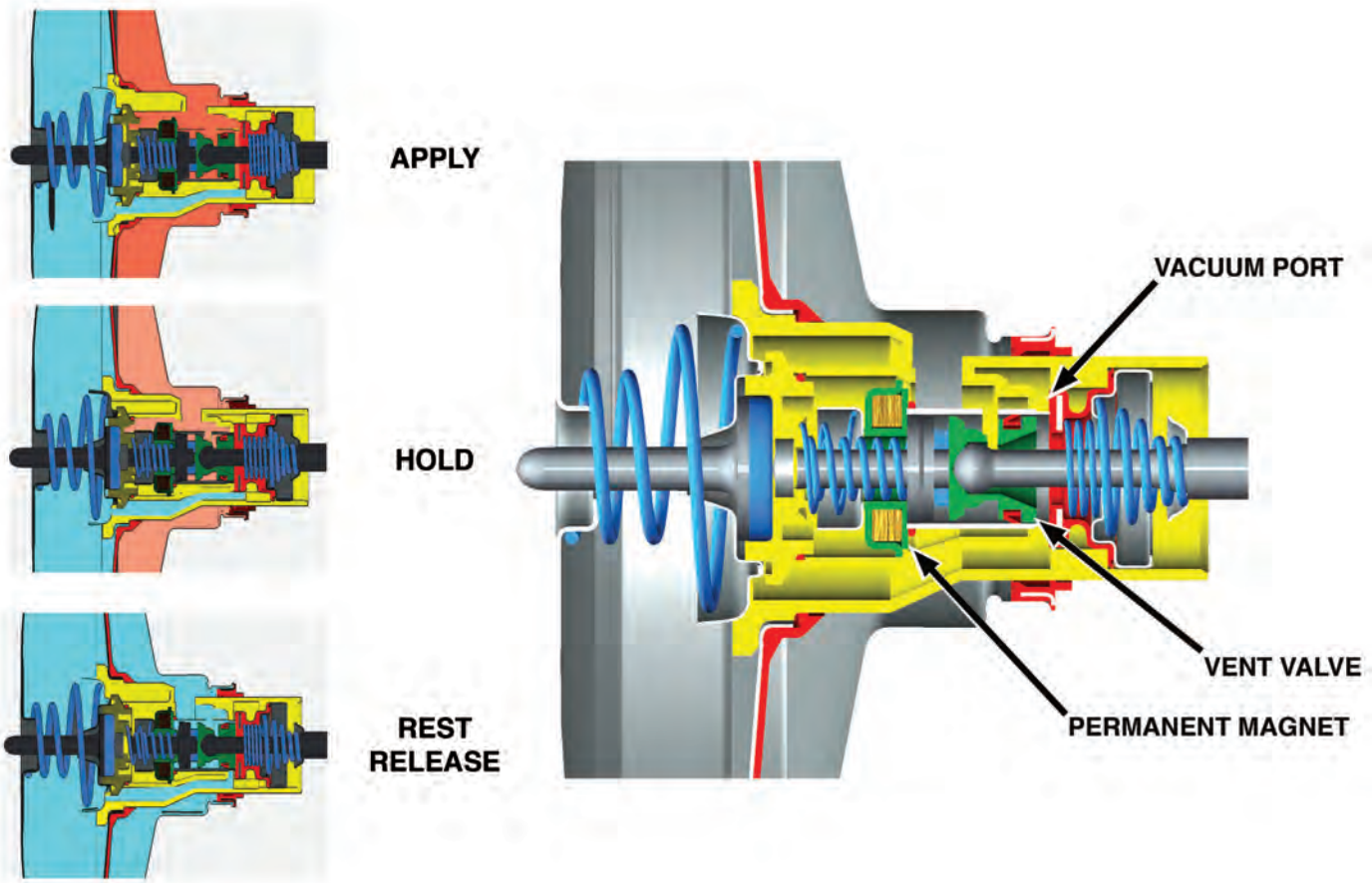
Most late-model vehicles use a vacuum booster to help apply the brakes. The booster is usually located behind the master cylinder on the firewall.

There are four modes of operation for a vacuum brake booster during a brake application. They are rest, apply, hold or balance, and release. In apply mode, the pressure from the brake pedal causes the push rod to move the treadle valve forward and close the vacuum port to the vacuum diaphragm chambers and isolate the vent valve.

As the push rod continues to move forward, it opens the vent valve to atmospheric pressure. This pressurizes the boost chamber(s) to create a force on the diaphragm(s), power piston and the push rod connected to the master cylinder pistons. In hold or balance mode, the pressure generated by the brake pedal push rod and pressure from the master cylinder piston push rod equalize. This causes the treadle valve to close the vent valve.

Release and rest mode are the same. When the pressure generated by the pedal is released, the vacuum valve opens, the pressure from the boost chamber(s) is evacuated, and the power piston is returned to its rest position by the spring in the main vacuum chamber. The vacuum check valve is a key component to the operation of the booster.

A leak in the valve can cause a reduction in the performance of the booster and increase pedal travel. A manifold vacuum of 20” Hg or greater can be achieved during engine deceleration. The booster chambers can be evacuated and retained at this pressure by a properly operating check valve.



VACUUM BOOSTERS REQUIRE THREE BASIC TESTS:

- Operational test
- Vacuum supply test
- Inlet check valve test

BOOSTER FUNCTION TEST

Check pedal feel and vacuum booster function while test-driving the vehicle. With the engine off, apply the brake pedal repeatedly with medium pressure until the booster reserve is depleted. At least two brake applications should have a power-assisted feel before the pedal hardens noticeably. If the pedal feels hard immediately, or after only one brake application, it may indicate a vacuum leak or a low level of engine vacuum. Inspect the vacuum supply hose to the booster for kinks, cracks, or other damage. Check engine vacuum at idle with a vacuum gauge.

To test booster function once the reserve is depleted, hold moderate pressure on the brake pedal and start the engine. If the booster is working properly, the pedal will drop slightly.

BOOSTER VACUUM SUPPLY TEST

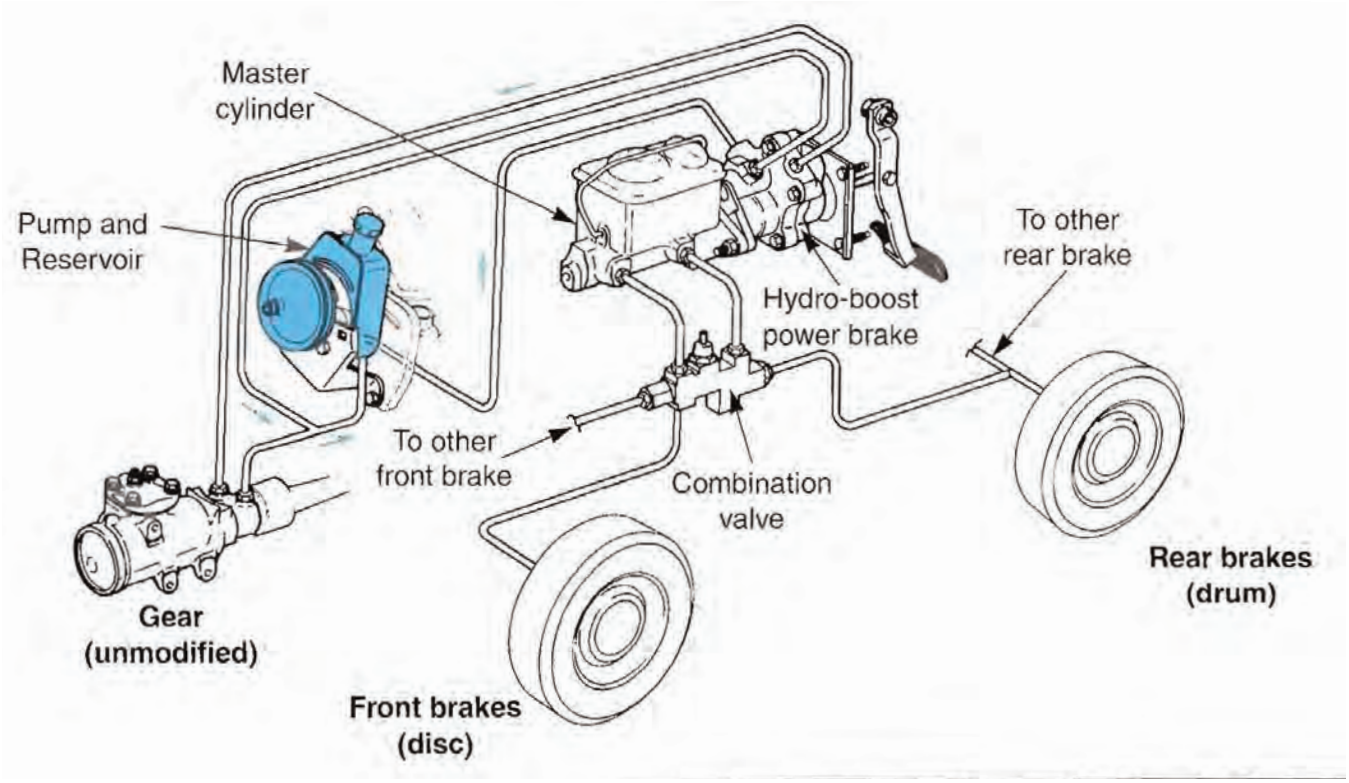
With the ignition OFF, pump the brake pedal to deplete the booster reserve. Disconnect the vacuum supply hose from the booster and connect a vacuum gauge to the hose using a cone-shaped adapter, figure 4-2. Start the engine and allow it to idle while observing the vacuum gauge. Although the amount of vacuum will vary by application, most will register between 15 and 20 in. Hg (50 and 70 kPa) at idle.

Fig. 4-2 Disconnect the vacuum booster supply hose and check for source vacuum with a gauge.

If the reading is low, check to see if the vacuum hose is kinked, clogged, or cracked. If the hose is not at fault, suspect an engine mechanical problem such as leaky valves, worn rings, an intake manifold vacuum leak, improper cam timing, etc.

VACUUM INLET CHECK VALVE TEST

To test the vacuum check valve, disconnect the vacuum supply hose from the intake manifold or vacuum pump, and blow into the hose. If air passes through the valve into the booster, the check valve is defective and should be replaced.



Hydro-Boost Power Assist Service

The Hydro-Boost power assist system performs the same function as the vacuum assist system. The difference is that it uses hydraulic pressure instead of vacuum to provide power assist for the brake system. By using hydraulic pressure, a greater amount of assist can be provided as compared to the vacuum assist system.

The Bendix Hydro-Boost system is used on vehicles, such as those with diesel engines, that produce little or no manifold vacuum. This system is also used on heavy-duty applications, figure 4-3. It uses pressure from the power steering pump to provide braking boost, and includes a high-pressure accumulator that has enough capacity to provide several power-assisted stops in the event that the power steering pump belt breaks or a hose ruptures.

When inspecting the Hydro-Boost system, the inspection must include checking the power steering hoses and pump for leaks, power steering fluid level, drive belt tension. Hydro-Boost operation and accumulator performance must also be tested.

Fluid flow in and out of the hydro-boost is controlled by what is known as a spool valve. Spool valves are used in a variety of hydraulic components, such as the valve body of an automatic transmission. A spool valve is basically a hollow cylinder with a number of rings machined into it. The surface of the spool valve is highly polished to form a sealing surface. The raised portions of the cylinder are called lands while the indentations are called annular grooves.

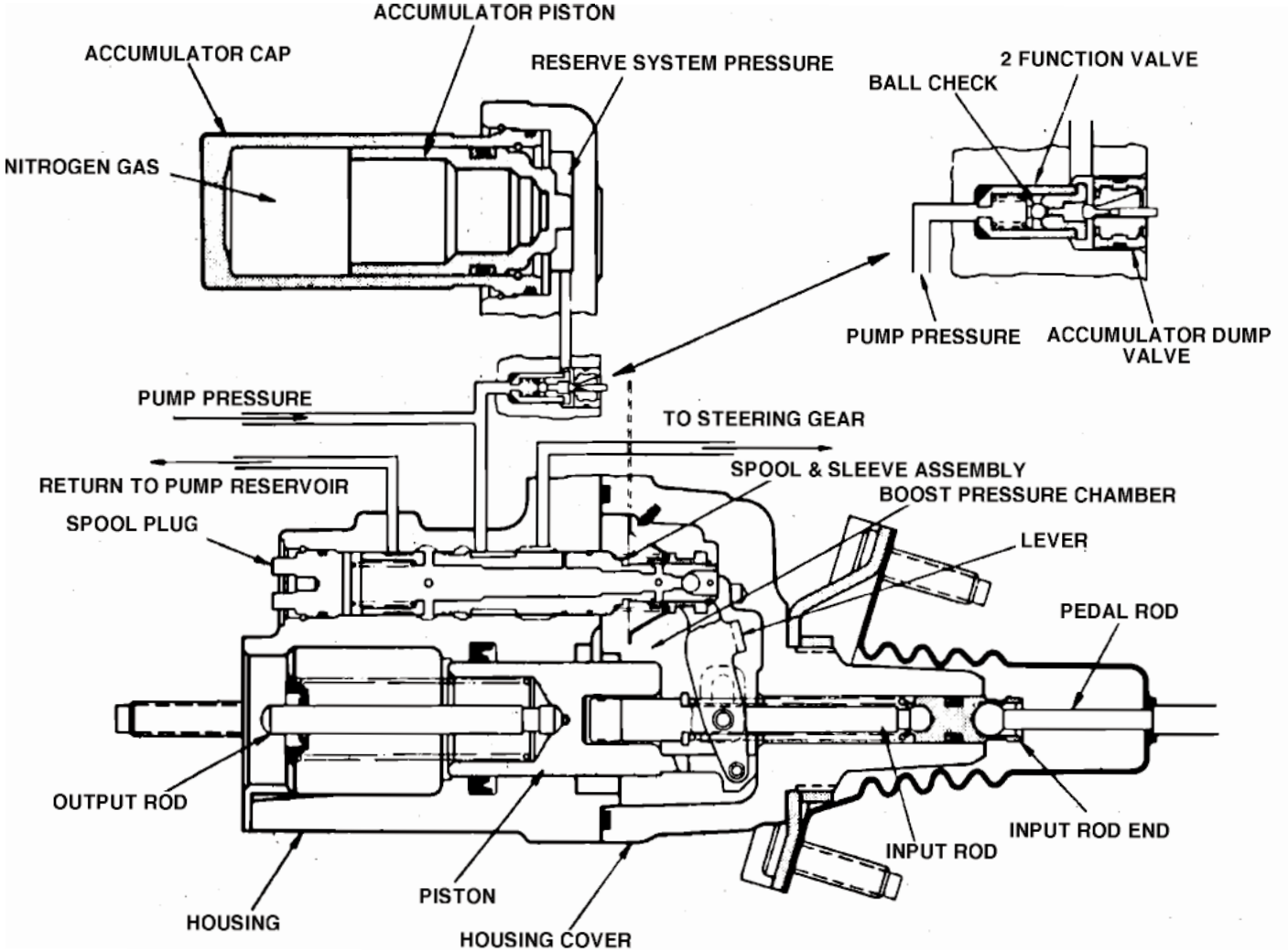
HYDRO-BOOST FUNCTION TEST

With the engine OFF, apply the brake pedal five or more times with medium force to discharge the accumulator. The pedal feel will harden noticeably. Next, apply the brake pedal with medium force, and then start the engine. If the booster is working properly, the pedal will drop toward the floor, and then push back upward slightly. If the booster passes this test, perform the accumulator test as described in this chapter. However, if there is no change in the pedal position or feel, the booster is not working. Check the power steering system to determine whether the problem is in the pump or the booster.

HYDRO-BOOST ACCUMULATOR

Similar to the vacuum booster, the hydro-boost is equipped with a backup or reserve in case the source of pressurized fluid is lost. A failure in the power steering system, such as a broken hose, broken power steering pump drive belt, or failed pump, would result in a loss of pressure to both the hydro-boost and steering gear. The hydro-boost uses a high-pressure accumulator to store power steering fluid under pressure in the event of a failure. There are two types of accumulators used, some hydro-boost units use an external accumulator, while others incorporate the accumulator in the power piston. The accumulator could be either of the spring-loaded variety or nitrogen-gas type.

In the event of a loss of pressurized fluid, the accumula-



tor will provide two to three power assisted stops. Upon the first application of the brakes after an engine stall or loss of power steering, you would find approximately 60 to 75% of the normal assist available. If you were to release and apply the brakes again, you would find approximately 30% to 40% assist, then again approximately 10% to 20%, until you have depleted all stored reserve assist. Once you have depleted all of the stored pressure, the brakes will no longer have power assist and will be manual in their operations.

During normal operation, the accumulator is charged by pump pressure though a check valve assembly. The check valve allows fluid into the accumulator, but prevents it from escaping. When the pressure in the power chamber is lost due to a failure, the input rod linkage will override the power piston linkage and cause the check valve to be opened. The open check valve will release the stored fluid in the accumulator into the power chamber which will provide the power assist.

HYDRO-BOOST ACCUMULATOR TEST

To test the ability of the system to store a short-term high-pressure charge in the accumulator, start the engine and allow it to idle. Charge the accumulator by turning the steering wheel slowly one time from lock to lock; do not hold the steering at full lock for more than five seconds. Switch the engine off, release the steering wheel, and repeatedly apply the brake pedal with medium force. If the accumulator can hold a charge, a Hydro-Boost I unit will provide two or three power-assisted applications, while a Hydro-Boost II unit only provides one or two.

To test the ability of the system to store a long-term charge, start the engine and recharge the accumulator as described above. As the accumulator charges on a Hydro-Boost I system, a slight hissing sound should be heard as fluid rushes through the accumulator-charging orifice. Once the accumulator is charged, switch the engine off and do not apply the brake pedal for one hour. At the end of the hour, repeatedly apply the brake pedal with medium force. Once again, a Hydro-Boost I unit should provide two or three power-assisted applications and a Hydro-

Boost II unit should provide one or two.

If the Hydro-Boost unit fails these tests, it usually means the accumulator of a Hydro-Boost I unit, or the accumulator/power-piston assembly of a Hydro-Boost II unit, is leaking. In either case, the booster must be rebuilt or replaced. However, if a Hydro-Boost I system fails the test but does not make the hissing sound to indicate the accumulator is charging, the fluid in the system is probably contaminated. Simply flushing the Hydro-Boost system may cure the problem.

Never begin any work on a Hydro-Boost system until you have discharged the dangerously high pressure stored in the accumulator by pumping the brake pedal numerous times with the engine off.

Proper diagnosis of hydro-boost related problems requires an understanding of how the system works. A typical hydro-boost is shown in Figure 1. The hydro-boost is plumbed in line with the steering gear. The power steering pump supplies pressurized fluid for both the power steering gear and hydro-boost.

BLEEDING HYDRO-BOOST SYSTEMS

Bleed Technique 1:

1. Replace any hydraulic line showing external damage. Install new seals for all disconnected fittings (as required) and install an in-line power steering filter. Tighten all hose fittings to OE specifications.

2. Flush the entire power steering system using the vehicle manufacturer's recommended fluid. Fill pump reservoir to the proper level.

3. Disable engine to allow cranking without starting. Block wheels, put transmission in neutral or park and set parking brake, then crank engine 5 to 10 seconds (avoid overheating starter motor).

4. Refill pump reservoir as necessary. Repeat step 3 until level is correct.

5. Enable the engine to allow starting. Start engine and let idle. Slowly turn steering wheel from lock-to-lock a number of times.

6. Turn engine off and inspect fluid level and condition. Add or remove fluid as necessary. If fluid is foaming, wait one hour then recheck level. Repeat step 5 and 6 until fluid level is correct and shows no sign of air problem.

NOTE: Many of you are aware that Ford power steering systems are very prone to air-related problems. The most effective way to remove air in these systems is to apply a vacuum to the power steering pump reservoir. This technique can be used on most power steering systems.

Bleed Technique 2:

1. Remove return line from hydro-boost and plug end with appropriate size plug or bolt.

2. Connect two- to three-foot piece of clear hose to return port on hydro-boost unit. Place end of hose into empty container at least 1 gallon in capacity.

3. Fill power steering pump reservoir with correct fluid.

4. Disable engine to allow cranking without starting. Block wheels, put transmission in neutral or park and set parking brake, then crank engine 5 to 10 seconds (avoid overheating starter motor) while applying and releasing brake pedal slowly.

5. Refill pump reservoir as necessary. Repeat step 4 until no air is seen in return line from hydro-boost.

6. Remove clear hose from return port and reconnect return line from pump.

7. Enable the engine to allow starting. Start engine and let idle. Slowly turn steering wheel from lock to lock a number of times.

8. Turn engine off and inspect fluid level and condition. Add or remove fluid as necessary. If fluid is foaming, wait one hour then recheck level. Repeat step 7 and 8 until fluid level is correct and shows no sign of air problem.

Use either of these bleeding procedures whenever replacing or servicing any component in a hydro-boost system. Normal driving conditions will remove air that remains trapped within the system when components are properly installed and there are no flow restrictions in the system. Always refer to the vehicle service manual for specific installation and testing procedures.

HYDRO-BOOST POWER STEERING FLUSH

In addition to requiring the correct pressure, it is also critical that the fluid be clean. The tolerances in the moving parts inside the hydro-boost are such that only a small amount of contaminates can cause a malfunction. This is especially true of the spool valve. The tolerances necessary to form a metal-to-metal seal are quite small and any contaminates or tarnish buildup can prevent smooth operation of the spool valve. Since the spool valve controls the flow of fluid into and out of the power chamber, it is critical it functions properly.

Any vehicle equipped with a hydro-boost power assist will benefit from a periodic power steering flush. The only thing is you have to perform an additional step to ensure the hydro-boost power chamber and internal parts are flushed. When performing the flush, apply and release the brake pedal slowly to allow the new fluid into the hydro-boost. If you skip this step you will have the large quantity of old fluid in the hydro-boost that will mix with the new fluid once the brake is applied and released a couple of times.

1. **Technician A says that with the engine off you should feel that power assist is present for at least two pedal strokes with a vacuum booster. Technician B says the vacuum in the booster should disappear immediately when the engine is shut down. Who is right?**
   a. Technician A
   b. Technician B
   c. Both
   d. Neither
2. **If a vacuum power booster is in good condition, starting the engine after the booster has been depleted will cause the brake pedal to:**
   a. Sink slightly
   b. Pulse rapidly
   c. Rise slightly
   d. Stay the same

3. **When you blow into a vacuum check valve in the direction of the intake manifold:**
   a. Air should pass through freely
   b. Air should not pass through
   c. Air should pass through with difficulty
   d. You should feel the check valve vibrate

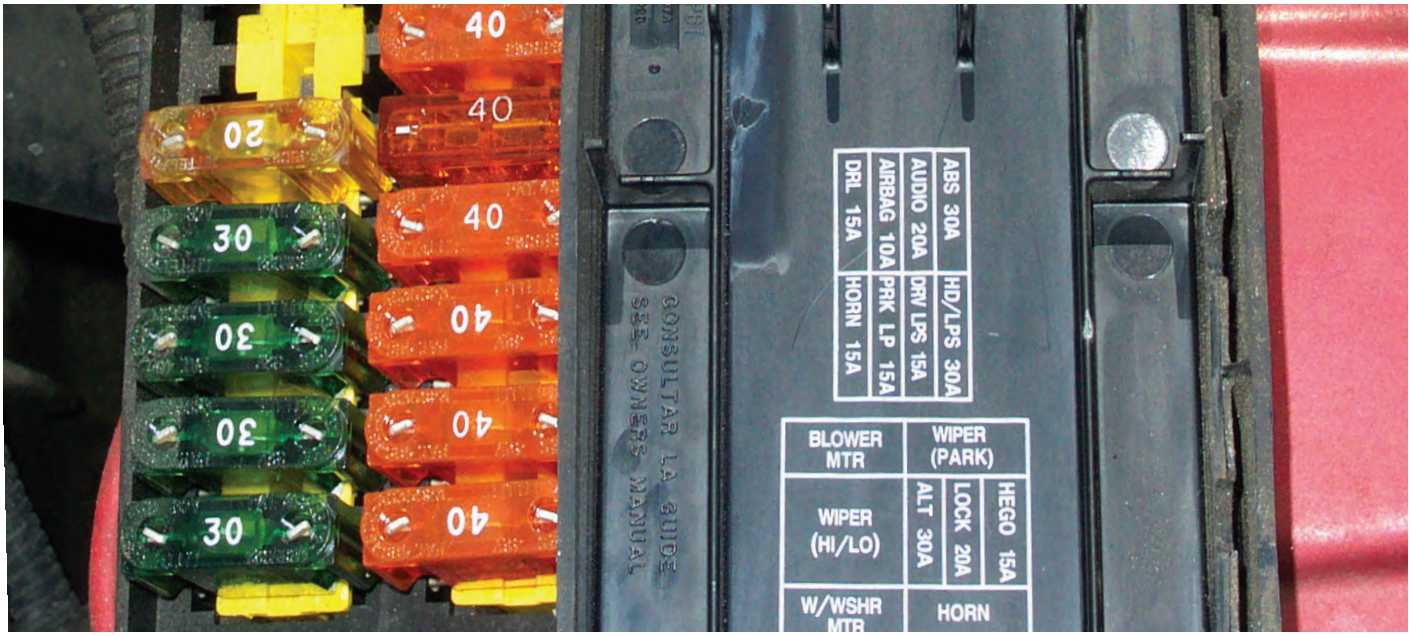
4. **With Hydro-Boost, when you discharge the accumulator, then start the engine, the pedal should:**
   a. Push back
   b. Push back, then sink toward the floor
   c. Sink toward the floor, then push back
   d. Sink toward the floor

5. **Technician A says that the hydro-boost system performs the same function as a vacuum assist system. Technician B says that the hydro-boost accumulator can provide one or more brake pedal applications in the event of a power steering system hydraulic failure. Who is correct?**
   a. Technician A
   b. Technician B
   c. Both
   d. Neither

Answer Key: 1. a, 2. a, 3. a, 4. c, 5. c

ASE G1

Electrical



ELECTRICAL TESTING EQUIPMENT

Self-Powered Test Lamps

Self-powered test lamps are often called continuity lamps and are used to check continuity through a wiring harness or component. Because the self-powered test lamp draws current from its own battery, any circuit or component being tested with the lamp must be disconnected from its voltage source. To use a self-powered test lamp, connect its leads to both ends of the circuit or device. If the lamp lights, the circuit is complete, or there is electrical continuity through the device. A self-powered test lamp cannot be used to check high resistance components, such as suppressor-type ignition cables because of the low available voltage of its battery. However, it is ideal for checking fuses, fusible links, bulb filaments, and wiring harnesses or circuits.

External-Powered Test Lamps

Often called a 12-volt or probe light, this pointed tool with a bulb in its handle or a bulb connected to two leads and alligator clips, is used for voltage-seeking and ground seeking tests. It relies on circuit power for operation. To test for an interruption in the insulated side of a circuit, connect the tester lead to a known good ground. Move the probe from point to point along the insulated side of the circuit until an open circuit is found. To check for ground, connect the tester lead to a known power source and probe the circuit or component to complete the ground path. If ground is present, the lamp will light.

Voltmeter

A voltmeter measures the electrical pressure differential, in volts, between the two points connected by the leads. A voltmeter can be an analog meter with a needle on a scale, or a digital meter with a numerical readout. A voltmeter is connected in parallel, or across, a component or circuit. A very small amount of current passes through the meter, while the rest of the current travels through the normal circuit path. Therefore, the circuit functions normally with the meter connected. Voltage available at the load is less than that produced by the battery due to circuit resistance. A voltage drop test is used to calculate the resistance of circuit components while current is flowing in the circuit. The voltmeter positive lead is connected to the end of the cable that is closest to the power source. The meter negative lead is connected to the cable end that is closest to the circuit ground. The circuit devices must be powered to get a voltage drop reading on the meter. Voltage drop is measured across the device being tested while current is passing through the circuit. Some Service Manuals provide exact specifications for each application.

Ammeters

An ammeter, which measures current in amperes, is connected to the circuit in series. This permits the current in the circuit to pass through the meter for measurement. Unlike a voltmeter, an ammeter has extremely low internal resistance. If connected in parallel, too much current will pass through the meter and damage it. When current draw specifications for a circuit or component are known, an ammeter reading can determine if a short or grounded circuit is present. A reading greater than that specified indicates a short in the circuit. An ammeter also can detect excessive circuit resistance, which causes a low reading. When diagnosing a system to determine why a fuse has blown, knowing the current flow can be helpful. Ammeter testing can determine if the circuit overload is caused by a defective motor, or if two circuits have shorted together. Ammeters equipped with an inductive pickup measure the magnetic field surrounding any current-carrying conductor. The strength of the magnetic field varies directly with current flow, and the meter translates this into a reading in amperes. Because an inductive pickup is clamped around the conductor, the meter cannot be damaged by connecting it incorrectly.

Ohmmeters

An ohmmeter, which measures the resistance to electrical flow in ohms, can be used to determine continuity and the amount of circuit resistance. Unlike a voltmeter or ammeter, an ohmmeter contains its own voltage source. An analog ohmmeter can be destroyed if connected to system voltage, and a digital meter will give incorrect readings when connected to any voltage source. For this reason, it is safest to always disconnect the vehicle battery before using an ohmmeter. Since an ohmmeter does not use circuit voltage, either lead can be connected to any test point unless checking diodes or other solid-state devices. Before using an analog ohmmeter, calibrate, or “zero” it to compensate for its own internal resistance and battery strength. To do this, set the meter control to the desired scale, touch the leads together, and adjust the calibration control on the meter to get a zero reading. Digital ohmmeters do not require calibration, but the resistance of the leads should be tested when measuring low-resistance circuits. If a digital meter is not auto-ranging, begin testing with meter at the highest setting, then decrease the setting to get the most accurate reading. Starting with too low of a setting results in an open circuit reading. It is important to make sure the reading is dis-played correctly; it is easy to misread because of the decimal point settings. When the ohmmeter leads are connected to the circuit or device being tested, current from the internal power source flows through the circuit or device and back to the meter. Because the internal resistance and source voltage of the meter are known, the current flow through the meter depends on the resistance in the circuit or device being tested. With the test leads of an analog meter disconnected, the needle will swing to the opposite end of the scale marked infin-ity. Connect the meter test leads in parallel to the com-ponent or circuit to be tested. Multiply the scale read-ing by the factor indicated on the meter control to determine the resistance. If the reading is high, switch the meter to a higher scale, if available, and recalibrate the meter before taking a new reading. An infinity read-ing indicates an open circuit; a low reading indicates a circuit with little resistance. Since an ohmmeter operates on a low-voltage, low-amperage internal power source, results are not always conclusive when testing circuits designed to carry high current. A damaged circuit may be able to carry the weak signal of the test

meter, but not be able to support the high-current load the circuit normally operates under. For this reason, voltage drop testing is the preferred method of checking circuit continuity.

Oscilloscopes

Another tool used to measure voltage in many applications is the oscilloscope. Oscilloscopes or "scopes" are available in either analog or digital styles. The analog scope incorporates a true live display much like older ignition analyzers. A beam of electrons writes on a phosphorus screen which is laid out in a grid. The analog scope has the advantage of providing a true live display. The disadvantage lies in the fact that it cannot store signals for future review. Inputs to the digital scope are digitized, processed and displayed on the screen for viewing. The digital scope has the advantage of storing the information so that it can be saved; parameters can be calculated, and intermittent glitches can be captured. It also allows for automatic setup and operation. The digital scope does not provide a true live readout and may miss certain short duration voltage variances. Often the digital scope is known as the digital storage oscilloscope or DSO.

Scan Tools

The diagnostic tools discussed to this point rely on making an actual connection to the circuit or component in question to make a reading. In today's vehicles it is often necessary to access information stored within one of the on-board electronic control modules. For this diagnosis a scan tool is used. Scan tools are usually hand-held computers containing programming allowing communication with the control modules. They connect to the vehicle via the data link connector or DLC. The scan tool sends requests for information to the control module and displays the results on its screen. Most scan tools can be used to read operating parameters, read and clear diagnostic trouble codes (DTC's), and commands certain components to operate. The scan tool must always be used in conjunction with the appropriate vehicle service or diagnostic manual. The manuals will provide specific instructions for connecting the tool, reading the information, and interpreting the results. Random use of the scan tool can result in misdiagnosis and wasted diagnostic efforts. Once results are obtained they should be compared to published guidelines and the appropriate repairs completed.

DIRECT VOLTAGE DROP TEST

You can make a voltage drop measurement directly if you can probe both sides of the device with the voltmeter. The voltmeter positive lead is placed on the device side nearest the battery and the negative lead is placed on the side nearest to ground. The voltmeter reading is then the voltage drop across the device. This is because a voltmeter tests the difference in potential directly. That is the definition of a voltage drop. Note that the sum of the voltage drops equals the source voltage applied to the circuit.

VOLTAGE DROP GROUND TEST

A voltage drop test can also be useful to check for excess resistance on the ground side of a circuit or component. The voltmeter positive lead is connected to the cable end that is more positive (closer to the battery positive terminal) than the other end. The negative lead is connected to the cable end closest to ground. The voltmeter reading provides a good test of the battery ground connection.

If there is too much resistance, more voltage is dropped across the cables, limiting the voltage available to the circuit. This is often a problem on the ground side of a circuit where a wire or cable is physically attached to the chassis, such as the negative battery cable. Rust, dirt, or corrosion can create enough resistance to cause a substantial voltage drop. Typically a voltage loss (drop) in a ground circuit of approximately 0.2 volts is acceptable in 12 volt electrical circuits. However, this loss can be a major problem with electronic control systems because they operate at low voltage. These systems normally should not have more than a 0.1 volt drop.

CALCULATED VOLTAGE DROP TEST

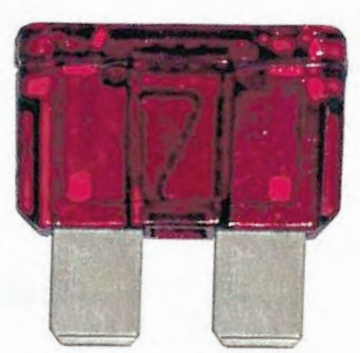
By conducting pinpoint voltage drop tests and some simple math, you can calculate the voltage drop across any part of a circuit. Sometimes this is a preferable method for deter-

mining a voltage drop if you cannot physically reach a portion of the circuit. However, this method works for any circuit as long as all measurements are made from the same reference point (usually ground). You can find a voltage drop by comparing the voltage available on one side of a load to the voltage available on the other side, and calculating the difference.

CIRCUIT PROTECTION DEVICES

Fuses, circuit breakers, and fusible links are circuit protection devices. Each can carry a specified current without damage, but if this predetermined rating is exceeded, they open to prevent circuit damage. Installing a new device will not solve the problems, as whatever caused the first one to open will quickly do the same to the replacement. Always determine and correct the cause of the blown device before installing a replacement.

Fuses



Although fuses are made in a range of standard sizes and types, most domestic and import manufacturers use only blade-type fuses in late-model applications. A miniature version, as well as larger maxi and mega versions, of the standard blade-type fuse have gained popularity in recent years. All fuses are rated by current capacity and the internal filament burns through to open the circuit when current rating is exceeded. A fuse generally can be checked while still in place using a test lamp. If the lamp does not light on either side of the fuse, turn the ignition switch to IGN or ACC, or the headlamp switch to the first or second position, whichever applies. A burned fuse will have a hot side and a dead side. Because a fuse is meant to burn out when current is too high, it should never be replaced with one whose rating is higher than the original equipment. A fuse with too high a rating causes circuit or component damage if an overload occurs.

Circuit Breakers

Circuit breakers are mechanical units that operate on the principle of different rates of expansion in heated metals. Unlike fuses that must be replaced after a single overload, circuit breakers are designed to open and close through repeated use. Circuit breakers are used in circuits where temporary overloads can occur frequently and power must be restored rapidly, such as in the headlamp circuit. Three types of circuit breakers are used on motor vehicles. A cycling or self-resetting circuit breaker opens when current through the contacts is excessive, and closes when the points cool a few seconds later. This off/on action continues until the cause of the excessive current is corrected. The second type is the non-cycling breaker. This type opens like the cycling type but does not reset until power is removed from the circuit allowing the bimetal element to cool and snap back into position closing the contacts. The third and less common type is the manual resetting circuit breaker. It remains open after high current passes through it and must be reset manually. Reset the unit by depressing a button on the case once the source of the problem has been corrected.

Fusible Links

A fusible link is a backup to prevent major harness damage or fire in the event of a serious electrical malfunction. Fusible links are made of a special smaller wire and are part of the main wiring harness. Fusible links also have a special insulation that is designed to melt but not burn when the wire is overloaded. They react much like a fuse but have higher current ratings. Each fusible link normally protects several smaller circuits with lower rated fuses of their own. Many late model vehicles have replaced fusible links with a plug type fuse installed in the under hood fuse box. When replacing a blown wire-type fusible link, be sure the replacement part is the correct size and rated for the circuit load. If possible, use a replacement fusible link supplied by the vehicle OEM. If one is not available choose a fuse link that is four wire sizes smaller than the circuit it protects. To make the repair, cut out the fusible link at the nearest connector on each side. Attach each end of the replacement fuse link wire to the standard wire with a splice sleeve and solder the connection with rosin-core solder.

Diodes

Diodes are semiconductors used in many electrical and electronic circuits. The primary use of a diode is to control the direction of current flow. In simple terms a diode acts as a one-way check valve in the circuit. When the diode is forward biased current is allowed to flow though the circuit. When reversed biased current flow is blocked in the circuit. Diodes are often used in warning lamp circuits. Another use of a diode is that of a clamping diode. In this application a diode is placed across the terminals of a coil such as the AC compressor clutch. The diode provides a path for the spike current generated when the coil is deengerized and induced voltage is generated. Without the clamping diode this spike current could damage sensitive electronic components in the vehicle.

ISOLATING CIRCUIT PROBLEMS

A short circuit can allow current to bypass the intended load, which can increase amperage and damage the electrical circuit. A short circuit can also bypass the control of the circuit so that the circuit cannot operate properly. Short circuits can blow the fuse that protects the circuit.

A wiring diagram of the fuse involved is an important tool in locating the possible problem areas, and in identifying all of the circuits involved. A tool for finding short circuits uses a circuit breaker in place of the blown fuse, and an inductive ammeter to follow the circuit wire. As the circuit breaker closes and opens because of the increased current, the inductive meter needle makes a big sweep as it senses the high current. As the meter goes past the short to ground, the meter movement is reduced. These tools work with circuits that are shorted to bypass the load. If the short circuit bypasses the switches that control the operation, it may be necessary to disconnect connectors to find the problem. An open circuit is one that prevents current from completing its intended path due to infinite resistance. Infinite resistance is a result of an air gap in the circuit that prevents current from moving past it. It can be as simple as a disconnected wire or as complicated as a damaged harness from a previous short circuit. The most important tool for locating an open circuit is a wiring diagram. It is critical to know how the circuit is laid out before testing.

When looking for an open circuit, carefully check for voltage at the switches and ground connectors in the suspect circuit. If testing reveals voltage is present at one connection, but not at the next, the open circuit is located between the two test points. The source of excessive resistance can be confirmed with an ammeter. Locate the problem using an ohmmeter or by performing voltage drop tests.

PHANTOM BATTERY DRAIN

Phantom battery drain, or parasitic draw, is caused by something in the vehicle constantly drawing current from the battery when the ignition is off. Although a certain amount of discharge is normal and can be expected, a fully charged battery in good condition should not lose its charge when left idle for a few days or even weeks. Typical causes of battery drain include:

- Acid, moisture, dirt, or corrosion on top of the battery case
- An accessory, such as a trunk light, glove box light, underhood light, or cigarette lighter, remaining on when the vehicle is not in use
- Parasitic drains required to operate systems that continue to work even when the vehicle is parked and the ignition is off

The most serious of these are the parasitic losses resulting from the advent of computer controls. Virtually all late-model vehicles are equipped with computers that control such things as engine operation, radio tuning, suspension leveling, steering assist, antilock brakes, and more. Each of these microprocessors contain random access memory (RAM) that stores information relevant to its job. Remember: RAM requires a constant power supply that puts a continuous drain on the vehicle electrical system. In addition, many electronic control systems conduct a self-diagnostic test after the engine is switched off.

The combined drain of several computer memories, or diagnostic test routines, can discharge a battery to the point where there is insufficient cranking power after only a few weeks. Due to the higher parasitic current drains on late-model vehicles, the old test of removing a battery cable connection and tapping it against the terminal while looking for a spark is both dangerous and no longer a valid check for excessive current drain. Furthermore, everytime the power source to computer modules is interrupted, module memories are lost. Information programmed into memory by the vehicle owner, such as radio presets, door lock combinations, seat position memories, and climate controls, all have to be reset when the battery is reconnected. On engine management systems with adaptive learning capability, driveability also may be affected until the computer relearns the engine calibration or transmission shift modifications that were erased from memory. A clean battery top prevents any drain from the negative to positive battery terminals.

Periodically clean the battery top and terminals with a mixture of baking soda and water applied with a brush. Do not allow the solution to enter the battery cells. To test for abnormal battery drain, disconnect the negative battery cable and connect an ammeter in series between the negative terminal and the cable. On many late-model vehicles it is necessary to wait up to one hour before taking the reading.

Many onboard computers have timer circuits which must time-out before they shutdown. To isolate the source of a draw, disconnect each accessory system one at a time until the meter reading drops into the normal range. This locates the offending circuit. Consult a wiring diagram to determine how power is routed through the circuit, then systematically eliminate components to determine which one was remaining on and draining the battery.

CHARGING SYSTEMS

Like all electrical circuits, the charging system is subject to four basic electrical failures:

- Short circuits
- Open circuits
- Grounded circuits
- High-resistance circuits

Short circuits are unwanted connections, usually copper-to-copper, in the wiring or components that allow current to bypass part or all of the circuit. An open circuit is one in which a break in the circuit causes extremely high, or infinite resistance; usually no current flows through an open circuit.

Grounding a circuit creates an unwanted connection between the insulated circuit and the ground circuit. This allows current to bypass part or all of the insulated circuit.

High circuit resistance is usually the result of either poor or corroded connections or frayed and damaged wires that impede current. Insight: In 1996, SAE J1930 terminology was adopted to standardize component identification. This standard adopted the name "generator" to refer to the component commonly known as an "alternator." This study guide uses the term generator throughout, however both terms are used interchangeably in the ASE tests.

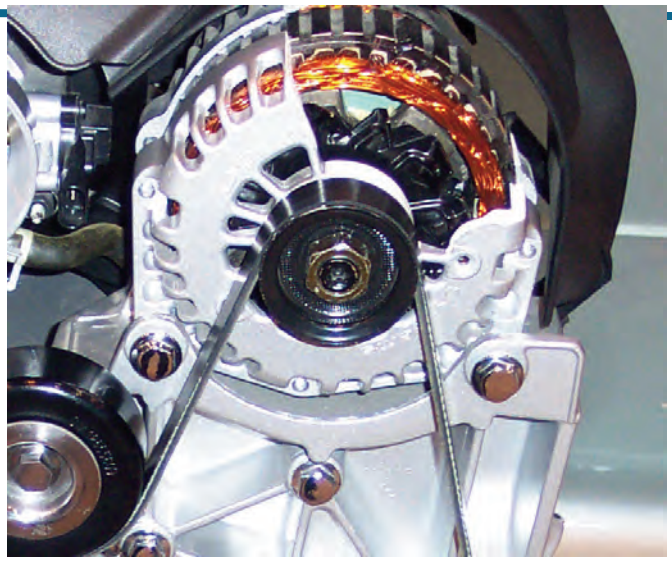
Basic Operation

1. The regulator is energized by the ignition system either by battery voltage or a lower regulated voltage. Some systems use the instrument cluster warning light ground to energize the system.
2. The voltage regulator controls current through the generator field windings. With electronic regulators, this is usually done by pulse-width modulation of the ground side circuit. The longer the ON time, voltage low, the higher the output. An external mechanical regulator varies the voltage on the power side of the field circuit. Replacement regulators of this style are now solid-state, and control the power side, but with pulse-width modulated signal, rather than a contact point set. On these units, the longer the ON time, voltage high, the higher the output.
3. The regulator is connected to battery voltage to sense charging voltage. This circuit is used to tell the voltage regulator to increase or decrease field current. The regulator also has to have a good ground for reference.

System Inspection

Charging system complaints often result from simple and easily corrected problems that become obvious during a quick visual inspection of the system components. To begin:

1. Check the battery electrolyte level, state-of-charge, and capacity. If the battery is worn out or defective, the charging system may not be at fault.
2. Inspect the generator drive belt. Loose belts are a major cause of poor charging system performance. If the belt is loose or damaged remove it for further inspection. Loosen the tension on the belt before attempting to remove it from the engine. Never force or pry a belt over pulley flanges. While the belt is removed, examine the pulleys for damage and misalignment. Replace pulleys as required and install the new belt. Belts must be properly tensioned. A loose belt will slip, and a tight belt can damage bearings. Adjust tension to specifications. . After installing a new drive belt, allow the engine to run for at least 10 to 15 minutes. Switch the engine off, then recheck and adjust belt tension using "used" belt specifications.
3. Check all system wiring and connections. Be sure to closely inspect all fusible links. Even when the fusible



link looks good it may be damaged internally. If in doubt pull on one end of the fusible link. If the insulation stretches replace the link. Disconnect each connector in the circuit and conduct a visual inspection. Look closely for damaged, corroded, or pushed out pins. Use a new terminal pin to check for a snug fit into the plug, If the socket in the plug is loose replace with a new part. Reconnect and ensure the connector is latched properly.

4. Inspect the generator and regulator mountings for loose or missing bolts. Replace or tighten as needed.

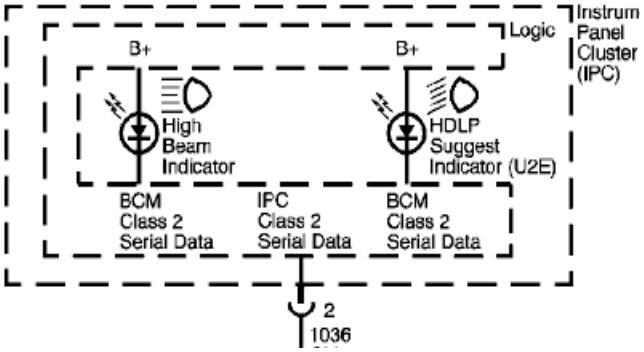
System Testing

On-vehicle generator system tests are essentially the same, regardless of the vehicle. The main differences are meter test points and specifications. This section contains general descriptions of common on-vehicle tests. To check a particular generator or system, use the procedures and specifications from the vehicle manufacturer.

The voltage regulator limits the strength of the magnetic field by changing the current going to the field coil.

Therefore, it regulates the generator voltage output according to the electrical system demand. Bypassing a voltage regulator for test purposes is called full-fielding the generator. Bypassing a voltage regulator supplies maximum output to the field coil. Under these conditions, system voltage can increase above 16 volts, which is an unsafe level. Once you determine that the generator can or cannot produce the required voltage, remove the bypass immediately.

ELECTRICAL SCHEMATICS



The wiring schematic is the cornerstone of electrical diagnosis. Schematics break the entire electrical system into individual circuits, and show the electrical current paths and components. Wiring which is not part of the circuit of interest may be referenced to another page where the circuit is shown complete.

Most schematics use a top (power) to bottom (ground) sequence to present electrical information while others are shown in a horizontal format. Because more than one electrical system is located in each subsection, each electrical system's schematics are broken down further into the individual operating system. Components in the schematic are identified using icons, symbols, or drawings of the internal circuitry. Service publications contain a page identifying the icons and symbols used in that manual.

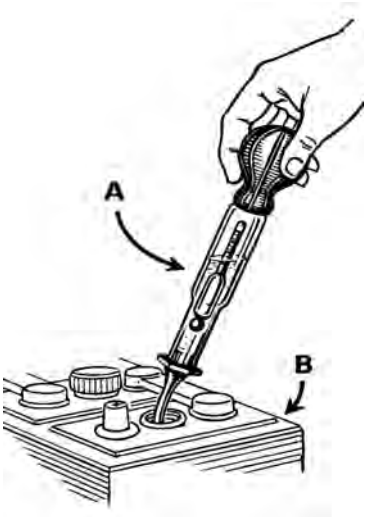
Most service manuals also provide component location information along with connector end-view drawings for reference. Many times a description of the circuit function is also available. Always refer to the correct service manual for the vehicle you are servicing. Using the wrong publication may lead to misdiagnosis and wasted effort. Use the schematics to trace the path of current flow when diagnosing electrical concerns.

BATTERY BASICS

A battery is two or more cells working together to produce electricity through a chemical reaction. In order for the stored electricity to be used a circuit must be completed between the positive and negative poles or terminals of the battery. Electricity generated by this method is called direct current or DC. An automotive battery is made up of approximately 65% purified water and 35% hydrogen sulfide, creating sulfuric acid. The acid reacts with plates made of lead compounds.

BATTERY CHARGING

Charging a battery replaces energy that was drained during service to restore the battery to its full capacity. The more discharged the battery has become, the greater the charge required to revive it. There are no shortcuts when recharging a battery. Typically, a battery is either slow charged at rate of about 3 to 15 amperes, or fast charged at higher rates of up to 50 amperes. Generally, any battery can be charged at any current rate as long as electrolyte gassing and spewing does not occur, and the electrolyte temperature remains below 125°F (52°C). When possible, charge at a slow rate of 5 to 15 amperes for best results. When charging a battery, observe these precautions:

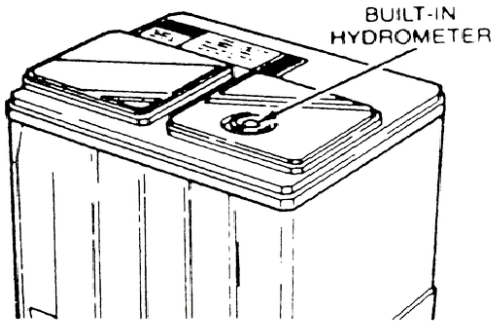


Measuring the specific gravity of a battery requires a hydrometer. Samples should be taken from more than one cell.

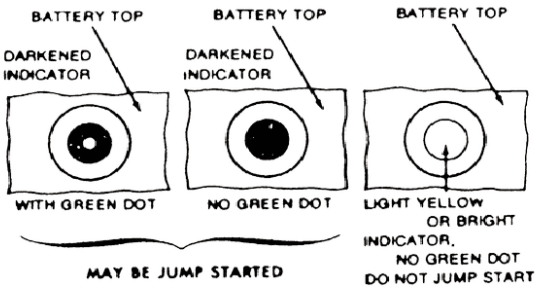
- Charge in a well-ventilated area away from sparks and open flame
- Be sure the charger is off before connecting or disconnecting cables at the battery
- Never try to charge a frozen battery
- Always wear suitable eye protection
- Never fast charge a battery that has failed a 3-minute charge test
- Never fast charge a battery that is sulfated or has plate or separator damage
- Monitor electrolyte temperature closely and stop charging if it rises above 125°F (52°C)

Maintenance-free batteries require special precautions during charging. A battery with a state-of-charge indicator should not be recharged if the eye indicates the electrolyte is below the level of the built-in hydrometer. A high initial charging current heats the electrolyte of a maintenance-free battery and causes it to gas. Since the battery is sealed, venting is minimal and a high charging current can cause internal battery damage and result in an explosion.

A completely discharged battery may not accept a high charging current because the electrolyte is almost pure water and thus a poor conductor of electricity. Since the



Location of Indicator on sealed battery



Check the appearance of the charge indicator on top of the battery before attempting a jump start; if it's not green or dark, do not jump start the car

Some maintenance free batteries have a hydrometer built into one of the cells. Even if there is a green eye, the battery could be malfunctioning because a cell without the green eye could be dead or dry.

weak electrolyte solution is highly resistant to the charger current, the amount of current accepted will be very low at first.

As the battery is charged, more sulfuric acid forms and the electrolyte will eventually accept the full current from the charger. If a load test indicates that the battery is fully dis-charged, watch the initial charging rate and terminal volt-age carefully.

If terminal voltage exceeds 15.5 volts with a high charging current, reduce the current and charge the battery for several hours at a setting low enough to keep terminal voltage under 15.5. Whenever time permits, a battery should be slow charged using a low charging rate of 5 to 15 amperes. It may require 12 to 24 hours to restore the battery to a full charge. After charging, wash, neutralize, and dry the top of the battery to remove any acid condensation due to gassing. Make certain that battery cells are filled to the level marks.

Cell caps should be left in place during slow charging, but make sure the vent holes in the caps are open. Clean battery posts of any corrosion to ensure good electrical contact.

Charge at the recommended rate, checking electrolyte specific gravity with a hydrometer occasionally during the first stage of charging and every hour as the battery approaches full charge. Unless otherwise specified by the battery manufacturer, a battery is fully charged when all cells are gassing, the specific gravity reading is 1.260 to 1.280 when corrected for an electrolyte temperature of 80°F (27°C), and hydrometer readings show no increase during three consecutive hourly readings.

With a maintenance-free battery, follow specifications from the manufacturer for charging rate and time. Determine battery temperature by touch and check the state-of-charge indicator hourly for the green dot. If not visible, gently shake the battery and continue charging. Once the green dot appears and remains visible, the battery is charged and the charger should be switched off and disconnected.

Fast charging a battery delivers a much higher charging rate for a shorter period of time. Normally, fast charging time does not exceed one hour and is usually much less. Equipment operating instructions for charging rate and length of charge should always be followed. However, charge time can generally be estimated based on a preliminary specific gravity reading at an electrolyte temperature of 80°F (27°C).

During charging, check electrolyte temperature frequently and reduce the charging rate if temperature rises above 125°F (52°C). With a battery tester or voltmeter connected across the battery terminals, check voltage. If it exceeds 15.5 volts for a 12-volt battery or 7.75 volts for a 6-volt battery, lower the charging rate until the voltage reading drops below the specified maximum. Whenever possible, follow a fast charge with a slow charge rate for as long as time permits to bring the specific gravity reading to 1.260 at an electrolyte temperature of 80°F (27°C). If the battery terminals are removed for cleaning, charging, or any other reason, power is lost to all of the onboard computer modules.

This may erase diagnostic trouble code records. The vehicle may have to be driven to restore the adaptive memory for idle speed, fuel trim, and transmission shifting. To allow the PCM to relearn lost values drive the vehicle several miles. Stop 3 or 4 times and accelerate back to road speed. Some engine and transmission computers include programs to enhance the relearn procedure. Refer to the appropriate Service Manual for the correct procedures. Other accessory settings, such as the radio, clock, memory power seats, steering wheels, and mirrors can also be

lost as well. It is possible to keep these memories alive by providing power into the cigarette lighter or other circuits. Several special tools are available to supply the necessary power to these modules while the battery is disconnected.

BATTERY INSPECTION AND SERVICE

battery capacity tester

Inspection, cleaning, and replacement are the only services a battery normally requires. To inspect:

1. On a battery with vent caps, check to make sure the electrolyte level is above the tops of the plates or at the indicated level within the cells. Top off the electrolyte with distilled or mineral-free water as needed.
2. Inspect the battery case, terminals, connectors, hold down, and tray for rust, corrosion, or damage.
3. Inspect the battery case for cracks and check for loose terminal posts. Replace the battery if any of this type of damage is found.
4. Look for accumulated dirt and grease on the battery cover that could cause a voltage draw to ground, and for corrosion buildup on the terminals. Clean and neutralize with baking soda as needed.

Automotive batteries are very heavy and awkward to handle. A dropped battery can seriously injure your foot, spill the electrolyte, and ruin the battery. When removing, carrying, or installing a battery, always use an appropriate battery-carrying strap or carrier to make battery handling easier and safer.

Electrolyte can leak from the vent holes at the top of a maintenance-free battery if it is tipped more than 45 degrees in any direction. When handling batteries, use extreme care to avoid spilling or splashing electrolyte. If spilled, the sulfuric acid in the battery electrolyte can damage paint or corrode metal parts.

Battery acid also can destroy clothing, cause severe burns, and permanently injure eyes. Always wear safety glasses and gloves to protect eyes and hands when servicing a battery. If electrolyte contacts your skin or eyes, flush the area with cold water for several minutes, then flood it with a solution of baking soda and water or a neutralizing eyewash.

Never rub the affected area. Get immediate medical attention. When a battery is charging or discharging, it releases highly explosive hydrogen gas. Hydrogen, which is always present in battery cells, escapes through the flame arrester vent and can form an explosive atmosphere around the battery. Since this explosive gas can remain in or around the battery for several hours after charging, make sure the work area is well-ventilated. Any spark or flame can cause the battery to explode violently, disintegrating its case and showering the vicinity with acid. Follow these important safety precautions to prevent accidents:

- Keep sparks, open flame, and smoking materials far away from batteries at all times
- Operate charging equipment only in a well-ventilated area
- Never short across battery terminals or cable connectors
- Never connect or disconnect charger leads at battery terminals while the charger is running; this always causes sparks
- Never wear a wristwatch or rings when servicing a battery or working on or near electrical systems; this reduces the possibility of arcing and burns If the battery terminals and cable connectors are corroded, remove the cables from the battery for a thorough cleaning. Disconnect the negative cable first, then the positive cable from the terminals. Use a cable puller to remove terminals that are stuck on a post. Never pry posts. Be aware: Over tightening side terminal bolts can strip the threads out of the battery. To help prevent corrosion on top terminal batteries, apply a light coat of anticorrosion compound to the terminals and connectors after installation.

BATTERY CABLES

The terminals of the two heavy-gauge battery cables that connect the battery to the starter motor and a chassis ground should be cleaned and inspected whenever the battery tray is cleaned. Because the terminals that connect most cables to the battery can be replaced individually, battery cables seldom require replacement unless their insulation is damaged or corrosion has started to deteriorate the cable strands. Corrosion or other cable damage causes an increase in resistance, which reduces the current carrying capability of the cable.

To replace the battery negative, or ground, cable, disconnect the terminal end from the battery and remove the bolt attaching the other end to the chassis. Tore place the positive cable, first disconnect the negative cable at the bat-

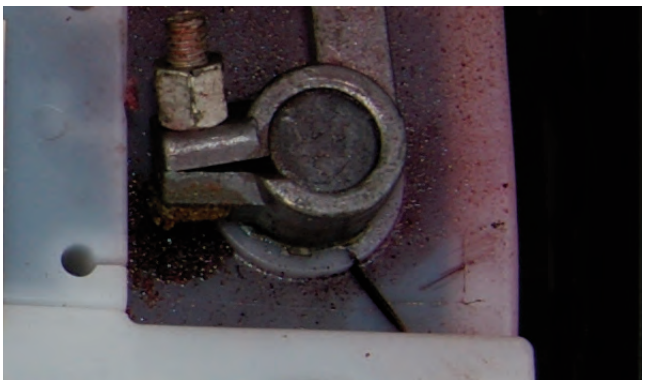
tery. Then, remove the positive cable terminal at the battery and disconnect the opposite end of the cable from the starter solenoid. In addition to the heavy-gauge cable, many designs include one or more smaller-gauge leads for energizing accessory circuits that must be disconnected before the cable can be removed.

Be sure the replacement cable includes all of the necessary leads. Route the new cable along the same path as the old one, making connections in reverse order of removal.

BATTERY CAPACITY TESTING

A battery capacity, or load, test determines how well a battery can perform when under load. Test results indicate the capacity to furnish adequate starting current while maintaining sufficient voltage to effectively operate the ignition system. An instrument called a charging- battery-starter (CSB) analyzer is used to conduct the test. A CSB analyzer consists of an ammeter, voltmeter, and carbon pile, which can be either a fixed or variable resistance. Exact test procedures vary, so refer to the equipment instructions to perform a load test. For most CSB analyzers, perform a load test as follows:

1. Switch the analyzer off and connect the test leads to the battery. Be sure to observe the correct polarity, and make certain the test clip leads make good contact on the battery posts. Special adapters may be needed to connect the unit to a battery with side terminals.
2. If the analyzer has a temperature adjustment, select the setting that matches electrolyte temperature. Use a thermometer in one cell to determine the electrolyte temperature of a battery with vent caps; estimate the temperature on sealed batteries. Minimum capacity test voltages vary significantly with battery temperature.
3. Refer to specifications for the cold cranking amperage (CCA) rating of the battery. This information should be on a label attached to the battery.
4. On a CSB analyzer with a variable resistor, turn the load control knob to draw battery current at a rate equal to one-half the CCA rating of the battery. On a fixed-load tester, set the battery size indicator to the appropriate position.
5. Maintain this load for 15 seconds while watching the voltmeter. Turn off the control knob immediately after 15 seconds of current draw.
6. On a 12-volt battery, voltage should not fall below 9.6 volts after 15 seconds.



If the vents for a battery are clogged, the gas inside a battery can crack the case.

JUMP STARTING

When charging or using a battery booster pack, always connect the terminals and then turn on the machine.

A booster battery and jumper cables can be used to jump start a vehicle with a dead battery. Unless performed properly, jump starting can damage the charging and electronic control systems, or produce sparks that might cause a battery explosion resulting in personal injury. Wear eye protection when jump starting a vehicle, always properly route the jumper cables, and make connections in the correct order. To jump start a disabled vehicle:

1. On the disabled vehicle: Switch off the ignition and all accessories, set the parking brake, and place the shift lever in NEUTRAL or PARK.

2. First, attach one end of a jumper cable to the positive terminal of the discharged battery. Second, connect the other end of the same cable to the positive terminal of the booster battery.
3. Next, connect one end of the other jumper cable to the negative terminal of the booster battery. Attach the remaining jumper cable end to a good ground on the engine block of the disabled vehicle at least 12 inches from the discharged battery. Some vehicles have a remote jump start terminal for this purpose.
4. Make sure that the two vehicles are not touching each other, and that the clamps from one cable do not accidentally contact the clamps on the other cable.
5. Switch on the ignition of the disabled vehicle and attempt to start it.
6. Once the disabled vehicle starts, remove the cable connection to the engine block or remote terminal first, then disconnect the other end of the same cable from the booster battery. Disconnect and remove the cable linking the two positive battery terminals.

In the past, 24-volt booster chargers or other auxiliary power supplies such as portable welders which would quickly spin the starter motor were sometimes used to jump start vehicles with a dead battery. Never use a 24- volt booster charger or other power supply to jump start a late-model computer-equipped vehicle. Immediate failure of the onboard electronic control modules will result. Diesel engine glow plug systems may also suffer immediate, severe, and costly damage.

GENERATORS & ALTERNATORS

When a generator tests bad on the vehicle, and it is going to be repaired, remove and bench test the unit. Before removing the generator, test all of the inputs and the output of the unit. Once the generator is removed from the vehicle, check for:

- Rotor continuity
- Rotor ground
- Stator continuity
- Stator ground
- Shorted capacitor
- Diode function

STARTING SYSTEM

The starting system includes the battery, ignition switch, safety switch, solenoid, starter motor, and all the circuitry that links these components. Starting circuits often contain relays, fuses, fusible links, circuit breakers, or similar devices to protect the wiring and deliver the required current to the starter motor. For an accurate diagnosis, have a wiring diagram handy during troubleshooting.

Starter relays, solenoids and safety switches

The starter relay is an electromechanical switch that connects the battery directly to the starter motor when the starter control circuit is closed by turning the ignition key. A starter solenoid is an electromagnetic device that engages the starter drive with the engine flywheel to crank the engine. The heavy solenoid coil is mounted around a plunger. The plunger connects to a shift lever, which is mechanically attached to the starter drive pinion. Closing the starter control circuit activates the solenoid by energizing the coil. This pulls the plunger in and levers the shift lever out to mesh the gears of the drive pinion with those of the flywheel. As the plunger continues to move, it closes the starter motor switch to energize the starter. A starting safety, or neutral safety, switch, which prevents the starter from cranking when the transmission is engaged, is used on all vehicles with automatic transmissions and on some vehicles with manual transmissions. The safety switch can be mounted on the steering column under the dash panel, on the transmission or transaxle, or on the clutch pedal. Vehicles with a manual transmission often have a safety switch that is activated by the clutch pedal, so the starter will only operate when the clutch pedal is depressed.

System Testing

Almost all starting system tests are performed while the starter motor is cranking the engine. However, if the engine starts and runs during the test, the readings will be inaccurate. Bypass the ignition switch with a remote starter switch to prevent the engine from starting. On vehicles with the ignition starting bypass in the ignition switch or the starter relay, disable the ignition. Disconnect the wiring harness connector from the distributor or coil pack to disable vehicles with electronic ignition or engine management system. Be sure any disconnected wires do not contact a ground. When testing, observe the following precautions:

- Be sure the transmission is out of gear during cranking; use the remote starter switch to bypass the safety switch
- Do not crank the starter motor for more than 30 seconds at a time, and allow two minutes between tests for cooling to prevent overheat damage to the motor
- Disconnect the battery ground cable before making or breaking any connections at the starter motor, solenoid, or relay

CRANKING CURRENT DRAW TEST

The cranking current draw test measures the amount of current, in amperes, that the starter circuit requires to crank the engine. This test, which helps isolate the source of a starting problem, is performed with either a charging-starter-battery (CSB) analyzer, or individual voltmeter and inductive ammeter. To test with inductive ammeter:

1. Bypass the ignition with a remote starter switch.
2. Connect the voltmeter leads to the battery terminals observing correct polarity.
3. Clamp the inductive ammeter pickup around the positive cable.

4. Crank the engine for several seconds and note the voltmeter and ammeter readings.
5. Compare ammeter readings to specifications. With a CSB analyzer, connect the leads and test according to the equipment instructions. Regardless of method, high current draw is caused by a short in the starter circuit or a binding starter motor or engine. Low current draw often results from high resistance in the starting system circuit, but can also be caused by an undercharged or defective battery.

High resistance in the cranking circuit can cause either high or low current draw. To understand how, it is necessary to know that the starter motor requires high current to get up to speed. Once the starter motor is up to speed, it acts like a generator and produces a counter voltage which limits the current. A motor requires high current when turning slowly.

This high resistance can prevent the starter from getting enough current to get up to speed. As a result, the motor turns slowly and does not limit the current. If resistance is high enough, it limits current to the starter. This low current causes the starter motor to turn slowly or not at all. High resistance can be seen on the ammeter when the starter is first engaged. If current momentarily goes high, then settles down to a lower amount suspect high resistance. When high resistance is indicated, perform starter circuit resistance tests as described later in the chapter. If testing indicates a starter motor problem, remove the unit for service.

CRANKING VOLTAGE TEST

This test, which must be performed with a fully charged battery in good condition, measures available voltage at the starter during cranking. Test results are read on a voltmeter. To test:

1. Bypass the ignition switch with a remote starter switch.
2. Connect the negative voltmeter lead to a good ground and connect the positive voltmeter lead to high-current circuit to the starter. Some manufacturers recommend connecting the voltmeter directly to the starter, while others specify testing at the relay or solenoid. Check the Service Manual for exact procedures and specifications. Typical voltmeter connections for performing a cranking voltage test.
3. Crank the engine while monitoring the voltmeter. To interpret test results if the starter motor cranks poorly, and if voltage is:

- 9.6 or more and the amperage is high, the problem is in the motor, ignition timing is too far advanced, the engine is tight and binding, or there is high circuit resistance. The battery is good and the starter motor is getting enough current to operate
- 9.6 or more and the amperage is low, the problem is high resistance. The battery is good but there is not enough current through the starter motor
- 9.6 or less and the amperage is high, the problem is either in the motor, ignition timing is too far advanced, the engine is tight and binding, or there is high circuit resistance. The high amperage draw

pulls down the battery voltage and the battery may be faulty

- 9.6 or less and the amperage is low. The battery should be tested

Perform a cranking test to check for high resistance in the starter circuit. Starter overloading can result from engine seizing, dragging, or pre-ignition.

CIRCUIT RESISTANCE TESTING

If the current draw and cranking voltage tests indicate that the problem lies in one of the starting system electrical circuits, use the following tests to pinpoint the problem. These tests locate the point of high resistance in the circuit that is causing excessive voltage drop. The resistance usually occurs at one of the connections in the circuits, but internally defective wires and cables may also be at fault. As a general rule, acceptable voltage drop standard in starting systems is a maximum of 0.1 volt per connection. A greater voltage drop causes starter motor performance problems.

The starting system has three circuits:

- Insulated
- Ground
- Control

The insulated circuit carries the high current needed to operate the starter motor, the ground circuit provides a return path to the battery for power supplied by the insulated circuit, and the control circuit includes all the low current wiring and devices used to open and close the insulated circuit. To locate the source of high resistance, perform voltage drop tests as described previously in this book at test points recommended by the manufacturer. Take readings while the starter motor is cranking, or use a carbon pile to load the circuit. Momentarily load the circuit to approximately 150 to 200 amps, and switch the load off quickly to prevent draining the battery. Test the starter ground circuit in a similar manner. Perform voltage drop tests on the control circuit as needed.

CHECKING AND REPLACING RELAYS

Many vehicles use a starting circuit relay. To check relay operation, connect one voltmeter lead to the battery terminal of the relay and the other lead to the relay switch terminal. Then, switch the ignition switch to crank the starter. A voltmeter reading that exceeds 2.5 volts indicates excessive resistance in the control circuit. If the voltmeter reading is below 2.5 volts and the relay does not close, connect the voltmeter leads to the switch terminal of the relay and ground.

The starter solenoid is often controlled by a relay. The relay is typically controlled by the engine control computer.

Typically, a relay closes whenever the voltage reaches approximately 7.7 volts on a 12 volt system. Confirm the relay ground by connectingthe voltmeter leads to the relay case and a chassis ground. The voltmeter reading should be less than 0.1 volt when the starter motor is engaged. A relay that does not operate with a 7.7 or higher voltage and a good ground is faulty and must be replaced. Replacing most starter relays is simply a matter of locating the relay, labeling and disconnecting its wires, and removing the attachment screws. On older vehicles, the starter relay is often mounted on the firewall or fenderwell. Newer vehicles generally use a relay that simply plugs into a power distribution center in the engine compartment.

CHECKING AND REPLACING SOLENOIDS

The solenoid is mounted on top of the starter motor. It is a critical junction for the vehicle's electrical system.

Starter motor solenoids are a pull-hold type. When the solenoid is first energized, both the pull-in windings and the hold-in windings are energized to draw in the core. Once the core is pulled in, the pull-in windings are de-energized and the hold-in windings keep the core in position until the cranking circuit is de-energized. Use the same voltmeter test as described for relays to check solenoid operation. To test starters and solenoids:

1. Confirm there are at least 8 volts available at the solenoid when cranking.
2. If voltage is present, check for battery voltage to the solenoid, then battery voltage to the starter.
3. A starter that motor fails to crank when battery voltage is available can indicate either a seized engine or starter motor or an open circuit in the starter or ground. A seized engine or motor produces low voltage and high amperage readings, while an open circuit results in high voltage and low amperage readings. A seized engine, caused by liquid filling the cylinders due to a blown head gasket or leaking fuel injection system is becoming more common. In most cases, replacing a starter solenoid involves removing the starter motor and partially disassembling it to disengage the plunger from the starter shift lever.

STARTER MOTOR SERVICE

Once a system problem is isolated in the starter motor, remove it for further testing or replacement.

- Loosening, relocating, or removing exhaust heat shields, support brackets, or pipes
- Loosening, relocating, or removing suspension components
- Loosening, relocating, or removing intake air hoses, ducts, pipes or manifolds
- Loosening or removing engine mounts or loosening and relocating the engine cradle Label nuts, bolts, and washers removed from the starter motor and other parts to ease reassembly. Also, tag all disconnected wires to prevent circuit failures on assembly.

Starter Removal

The following is a typical starter motor removal sequence. Always consult the repair manual for the vehicle being serviced. To remove the starter:

1. Disconnect the negative battery cable.
2. Raise the vehicle on safety stands or a hoist high enough to access the starter motor.
3. Disconnect tie rods and other suspension links that are likely to interfere with removing the starter from the chassis.
4. Loosen or remove exhaust pipes and other components that interfere with starter motor removal.
5. Disconnect and label all wires and cables to the starter motor or solenoid.
6. Remove any heat shields and brackets covering the starter motor.
7. Remove any mounting bolts and shims securing the starter motor to the engine.
8. Slide the starter free of the bellhousing and guide it out of the chassis.

Starter Installation

When replacing a starter motor, make sure the new unit meets the requirements of the vehicle. Some vehicles require a high-temperature starter with an extra field coil, brush lead, and solenoid winding insulation as well as a high-temperature solenoid cap.

To install a starter motor:

1. Transfer support brackets or other hardware from the old motor to the replacement motor as required.
2. Fit the starter motor into position on the engine and install the mounting fasteners. Be sure to reconnect any ground cables or brackets that install on the starter mounts.
3. Check flywheel-to-starter engagement. Some vehicles require shims to provide correct starter pinion to-flywheel engagement. These shims are placed between the starter drive housing and the engine block. Remove the flywheel cover and check the starter pinion engagement with the flywheel. Add or remove shims to correct.
4. Connect all wires to the solenoid or starter motor terminals.
5. Connect any suspension or exhaust system parts that were loosened or removed.
6. Connect the negative battery cable.

Test starter motor operation by starting the vehicle. Listen for any unusual sounds and check for correct operation of the starting safety switch. Some late-model starters have a special stud in the motor housing. Be sure the short end of the stud, with coarser threads, is threaded into the housing. Incorrect installation damages the field coils.

GENERATOR/ALTERNATOR INSPECTION

Brush any dirt or debris off the outside of the generator housing, then loosen the fasteners adjoining the drive and stator end frames. Mark position of the end frames before separating them so they align easily during assembly. Also, note the location of the brush assembly when separating the end frames. Brushes are generally located in the drive end frame. Check brushes to make sure they slide freely in their holders and are making full contact on the rotor shaft slip rings. Replace the brushes if they are worn to half their original length or less. Remove the stator and rotor from their end frames. As you disassemble the generator, clean each part and inspect it for excessive wear or damage. As part of the overall inspection during disassembly:

- Check bearings for proper clearance, roughness, or galling
- Remove any oil and dirt from insulation
- Check insulation condition

After inspecting and cleaning the generator, test components and replace any defective parts, then reassemble the unit.

Generator Removal

Remove a generator as follows:

1. Disconnect the negative battery cable.
2. Identify, label, and disconnect all leads from the generator. Some are held by nuts on terminal studs; others are plug-in connections. Be sure to release any clips or springs holding the plugs in the generator. 3. Remove the drive belt.
4. Remove the mounting bolt and adjusting bolts and lift the generator free of the mounting brackets.

Disassembly, Cleaning, and Inspection Brush any dirt or debris off the outside of the generator housing, then loosen the fasteners adjoining the drive and stator end frames. Mark position of the end frames before separating them so they align easily during assembly. Also, note the location of the brush assembly when separating the end frames. Brushes are generally located in the drive end frame. Check brushes to make sure they slide freely in their holders and are making full contact on the rotor shaft slip rings. Replace the brushes if they are worn to half their original length or less. Remove the stator and rotor from their end frames. As you disassemble the generator, clean each part and inspect it for excessive wear or damage. As part of the overall inspection during disassembly:

- Check bearings for proper clearance, roughness, or galling
- Remove any oil and dirt from insulation
- Check insulation condition

After inspecting and cleaning the generator, test components and replace any defective parts, then reassemble the unit.

Generator Installation

Before installing the generator, spin the rotor and pulley by hand to be sure there is no drag or binding. Carefully inspect and replace any drive belts that are worn, frayed, or damaged. Then install the generator:

1. Put the generator on its engine mounting brackets and loosely secure the mounting and adjusting bolts.
2. Replace the drive belt and adjust tension.
3. Identify all wiring connections and attach them to their appropriate terminals or sockets.
4. Connect the negative battery cable.
5. Start and run the engine to test the generator. Repeat output tests and listen for noise or vibration coming from the generator or drive belts.

LIGHTING SYSTEMS

The vehicle lighting system circuits on a late-model vehicle can be complex, and often there are a number of variations to accommodate different options on the same model vehicle. Accurate specifications, wiring diagrams, and electrical schematics are important to have on hand when servicing the lighting system.

Schematics

Manufacturers provide electrical wiring diagrams that depict the entire automobile wiring system. An electrical schematic is a portion of the complete wiring diagram that details the operation of an individual circuit. All the electrical information about a complete automotive circuit, including the switches, connectors, loads, and other devices, is included in the schematic. Interpretation

of an electrical schematic is further simplified by circuit numbering, color-coded wires, and representation of components or loads by symbols. The information provided by an electrical schematic makes it easy to trace a circuit during troubleshooting.

HEADLAMPS

Halogen

Halogen sealed-beam headlamps are like conventional headlamps, except for the halogen bulb. There are the same five types of halogen sealed-beam as conventional ones, plus a high and low beam. Composite headlamps use a halogen bulb inside an aerodynamic plastic lens. Composite headlamps also may contain individual halogen bulbs, one for low beam and one for high beam illumination.

Xenon

Xenon headlamps are also known as "High Intensity Discharge" (HID) headlamps. HID lighting systems use a special quartz bulb that contains no filament and is filled with xenon gas and a small amount of mercury and other metal salts. Inside the bulb are two electrodes separated by a small gap (about 4 mm or 3/16th inch). When high voltage current is applied to the electrodes, it excites the gases inside the bulb and forms an electrical arc between the electrodes. The hot ionized gas produces a "plasma discharge" that generates an extremely intense, bluish-white light.

SWITCH, RELAY AND CIRCUIT SERVICE

On most domestic headlamp circuits, the headlamp and dimmer switches are both in series with power to the headlamps. Power goes through the switches, and the bulbs are grounded. A different method is on many import circuits, the headlamp switch turns on the power, but the dimmer switch is on the ground side. On newer vehicles the dimmer switch is part of the column mounted multi-function switch, while older vehicles used a foot-operated dimmer switch. Most vehicles have a three-position main headlamp switch:

- First position—off, no current
- Second position—current flows to parking lamps, tail lamps, and other circuits
- Third position—current flows to both the second position circuits and to the headlamp circuit There are number of variations, but all headlamp switches can be checked in a similar way. To test a headlamp switch:

1. Check for voltage at the headlamp switch source terminal. If power is not available, check the power source circuit.
2. If power is available to the switch, turn on the headlamp switch and check for power at the output terminal wire. If power is not coming from the switch, replace the headlamp switch.

To test the dimmer switch:

1. With the headlamps turned on, check for power at the dimmer switch terminals.
2. If either the high or low beams operate, there should be power through the switch.
3. If there is power through the switch to one terminal but not the other, the dimmer switch is defective.

DAYTIME RUNNING LAMPS

Many vehicles are equipped with Daytime Running Lamps (DRL). Most DRL systems illuminate the high beam headlamps at reduced intensity anytime the ignition switch is in the ON position, the headlamps are switched OFF, and the park brake is released. The circuitry used to reduce the output of the lamps varies by manufacturer.

Many OEM's install a special module or controller that sends a reduced voltage signal to the lamps. Others connect both high beam headlamps in series which cuts the effective voltage to each lamp in half. Vehicles with automatic headlamps generally switch automatically from DRL to regular operation. Another design illuminates the front park lamps or fog lamps for DRL operation. Most vehicles include an indicator lamp on the instrument panel to inform the driver that the system is activated.

BULB DESIGN AND REPLACEMENT

Automotive bulbs and sockets conform to design standards in order to reduce the possibility of installing the wrong bulb. There are different bulb sizes, shapes, and socket connections. Double filaments bulbs are used to accommodate two circuits, such as parking and directional, or stop and tail lamps that use the same bulb. Small bulbs used in exterior lighting systems are usually clear and mount behind colored lenses. Some applications call for a red or an amber bulb, which is indicated by an R or NA in the standards. Bulbs have either a brass or glass wedge base, and are generally replaced from the rear of the lamp assembly.

Bulbs with a brass base fit into a matching socket that contains single or double contacts to route current through the filament and complete the insulated circuit. Double-contact bulbs have an indexed base and fit into the socket in only one way.

Wedge-base bulbs are used in the instrument cluster and other interior lighting applications. The base and optical part of the bulb are a one-piece, formed-glass shell with four filament wires extending through the base and crimped around it to form the external contacts. To replace a non-indexed or wedge-base bulb, pull it from the socket and push in the replacement. Push an indexed bulb into the socket and rotate until the bulb is free, then push the replacement into the socket and rotate until it is secure. If you cannot reach the rear of the lamp assembly, remove the lamp lens to replace the bulb. Screws secure lamp lenses on the outside of the vehicle, nuts on the inside. You may have to remove other trim parts to reach the screws or nuts. When reinstalling the lens, correctly position any gaskets and washers. Replace a socket that is corroded or rusted. In most cases, cut the socket from the wiring harness and splice a new one in place.

PARKING, TAIL, SIDE, DASH, AND COURTESY LAMPS

The tail, parking, and side marker lamps operate when the headlamp switch is at the park or headlamp position on most vehicles. Typically, the parking and tail lamps are on a separate circuit, but share a common switch with the headlamps. Side marker lamps connect in parallel to the parking lamps. Tail lamp circuits generally share a fuse with another circuit, or have a circuit breaker instead of a fuse. The license plate lamp is on the same circuit as the tail lamps.

SIDE MARKER LAMPS

Side markers generally use wedge-type bulbs mounted in insulated sockets. Some bulbs are independently grounded and others ground through the turn signal filaments. Side marker lamps that ground through the turn signal filaments are on whenever the parking lamps are lit. However, the side marker goes out each time the turn signal flashes because the ground circuit opens to switch the turn signal off. The result is parking and side marker lamps that are on at the same time and turn signal and front side markers that flash alternately. With the parking lamps off, the turn signal and side marker lamps flash together. This can make troubleshooting this circuit confusing. For example, a burned-out turn signal filament also prevents the front side marker from operating. However, a burned-out parking lamp filament has no effect on the side marker.

DASH LAMPS

Three categories of bulbs are used in instrument panel displays: indicator, warning, and illumination lamps. Dash panel illumination lamps are part of a series parallel circuit where all the bulbs are connected in parallel with each other and in series with a variable resistor, or rheostat. All instrument panel circuits are grounded with a separate ground circuit. An open in the instrument panel ground circuit affects all electrical components mounted in the instrument cluster.

SWITCHES AND RHEOSTATS

Current to the dash lamps is controlled by contacts within the main headlamp switch. They receive current when the

parking and tail lamps are lit. A rheostat lets the driver control the brightness of the dash lamps. The rheostat may be integral to the headlamp switch or a separate unit mounted in the dash. Intermittent operation of only the instrument lamps may be caused by oxidation build up on the rheostat coils. Troubleshooting these circuits is similar to that of other lighting circuits.

COURTESY LAMPS

Dome and courtesy interior lamps usually have battery voltage at each bulb at all times. Switches installed on the ground side of the circuit regulate current through the bulb. Switches may be located in the door jambs, headlamp switch, or on the light itself. A short to ground on the insulated, or power, side of the circuit can blow the fuse. A short to ground on the ground, or switch, side does not blow the fuse, but the lamps will stay on. Check for a defective fuse if none of the dome or courtesy lamps operate. If any of these lamps operate, the fuse is good, so check the individual lamps that do not operate. Test for battery power at the dome lamp socket. If voltage is available at the socket, check for ground when opening doors or turning on the dome lamp at the headlamp switch. A dome lamp that does not turn off can be caused by a faulty door switch, a short to ground, or possibly the dome lamp is turned on at the headlamp switch.

STOP LAMPS, BACK UP LAMPS, HAZARDS AND TURN SIGNALS

Dome and courtesy interior lamps usually have battery voltage at each bulb at all times. Switches installed on the ground side of the circuit regulate current through the bulb. Switches may be located in the door jambs, headlamp switch, or on the light itself. A short to ground on the insulated, or power, side of the circuit can blow the fuse. A short to ground on the ground, or switch, side does not blow the fuse, but the lamps will stay on. Check for a defective fuse if none of the dome or courtesy lamps operate. If any of these lamps operate, the fuse is good, so check the individual lamps that do not operate. Test for battery power at the dome lamp socket. If voltage is available at the socket, check for ground when opening doors or turning on the dome lamp at the headlamp switch. A dome lamp that does not turn off can be caused by a faulty door switch; a short to ground, or possibly the dome lamp is turned on at the headlamp switch.

Stop Lamp and Turn Signals

On vehicles where the rear directional and stop lamps share bulb filaments, a circuit is complete to the right and left lamps when the stop lamps are on.

Moving the directional switch to the right or left position removes the corresponding rear lamp from the stop lamp circuit and connects it to the directional circuit. Since the bulbs on each side are wired in parallel, each bulb can operate independently of the other bulb on the same side.

When one bulb is not operating, current is reduced and the flasher is calibrated to operate with a specified amount of current. Inoperative bulbs cause the flasher to stay on or cycle slowly. A traditional flasher uses a bimetallic strip to open and close contacts and interrupt current through a directional switch. With the switch turned on, resistance in the strip generates heat that causes the strip to bend and opens a contacts set. As the strip cools, the contacts close and the cycle starts over again.

Many newer vehicles are equipped with electronic flasher devices. These devices time the on and off of the lamps regardless of load. A switch on the brake pedal linkage actuates the stop lamps when the pedal is depressed slightly. Some switches are adjustable, others are not and must be replaced if not working properly. Turn signals are controlled by a switch located in the steering column. To replace a turn signal switch, disassemble the steering column as needed to access the unit. Install and check the operation of the new switch.

Hazard Lamps

A separate switch attached to the directional switch enables directional lamps to be operated at the same time as hazard warning lamps. When the hazard lamp switch is applied, the turn signal flasher is disconnected from the circuit and replaced with a hazard flasher. Unlike the directional lamps, the hazard lamps can be operated with the ignition switch off.

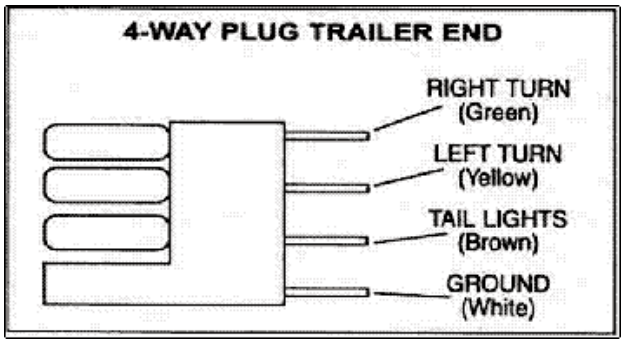
Back Up Lamps

Backup lamps receive voltage from the accessory terminal of the ignition switch and a backup lamp switch connected to the shift linkage or the transmission shift rail controls the ground circuit. The backup lamps switch on when the transmission is in Reverse. The neutral safety switch is combined in an assembly with the backup lamp switch on some vehicles. If the lamp does not operate with the ignition switch on and transmission in Reverse, check for:

- Blown fuse
- Improperly adjusted switch
- Faulty bulb

TRAILER WIRING

Many vehicles are manufactured with trailer towing capabilities. Others have trailer hitches and wiring installed in the aftermarket. In either case the circuits must be capable of safely carrying the additional load of trailer lamps and electric braking systems. Most OEM systems isolate the trailer lighting on a separate circuit to prevent a short circuit from



putting all rear lamps out. When installing trailer lighting circuits follow the vehicle wiring diagram for the correct connection points. Pay special attention to the high-mounted stop lamp circuit when connecting the brake lamp circuit. Failure to make the connection correctly may result in improper operation of the turn signals. Trailer brake wiring is usually a heavier gauge than the lighting circuits. All of the trailer brake actuators are connected to the system in parallel. A short circuit anywhere in the brake circuit will cause all of the brakes to be inoperative.

Review Questions:

1. Technician A says a replacement battery should have the same or higher CCA rating as the original battery. Technician B says a battery's "group size" depends on the CCA rating of the battery and its post configuration. Who is right?

a. Technician A only
b. Technician B only
c. Technician A and B
d. Neither one

2. What is the function of the diodes (rectifier assembly) in an alternator?

a. Convert Direct Current (DC) to Alternating Current (AC)
b. Convert Alternating Current (AC) to Direct Current (DC)
c. Regulate charging voltage
d. Regulate electrical system voltage

3. A gear reduction starter:

a. Uses gears to reduce friction
b. Uses gears to reduce cranking speed
c. Uses gears to increase cranking speed
d. Uses gears to deliver more cranking torque

4. The magnets in a permanent magnet starter do what?

a. Hold the shaft bearings in place
b. Replace the armature
c. Replace the field coils
d. Replace the brushes

ANSWER KEY

1A, 2B, 3D, 4C

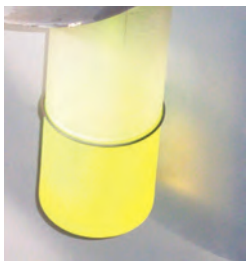
ASE G1

HVAC

REFRIGERANT

Air conditioning refrigerant is constantly changing and being approved upon. R12 is the original refrigerant of choice used in older model vehicles. But with new environmental regulations came new alternatives that are a bit more costly but with a lesser impact on global warming. R134a is currently the most widely used refrigerant and has been used on all new vehicles since 1996. Although R134a is considerably safer than R12, environmental standards are still being challenged with the development of even more environmentally friendly alternatives like 1234yf. No matter which refrigerant you are using, it is illegal to evacuate an air conditioning system into the atmosphere. Always practice safe procedures when handling refrigerants.

Refrigeration Oil



Because the lubricating oil circulates with the refrigerant in an A/C System, discharging refrigerant into a recovery station removes oil from the system as well. Recycling equipment separates the oil from the refrigerant. When recharging the system, add the same amount of fresh oil as was removed. The system also loses refrigerant oil during component replacement. Most shop manuals specify how much oil to add after replacing each part. Remember to add mineral oil to an R-12 system and PAG oil R134 systems, and not to confuse to two. Follow the recommendation of the compressor manufacturer when selecting refrigerant oil.

DISCHARGING AND EVACUATING THE SYSTEM

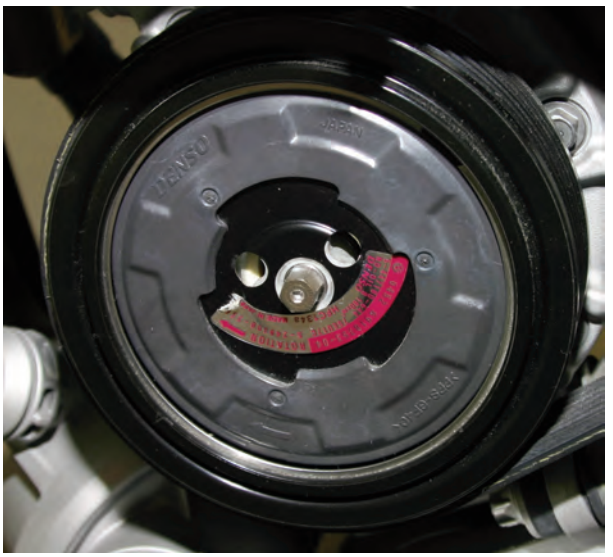
An A/C system must be discharged before fittings are opened for repairs. Once repairs are made, the system must be evacuated and charged to return to working order. Discharge the system before removing or replacing any part. Recover the refrigerant, weather R-12 or R134a, into a recovery tank and later recycle it.

A/C recovery and recycling is required to evacuate, recycle and recharge A/C systems.

Compressor and Clutch

The compressor and clutch work together to develop and maintain optimum service pressures. When either unit fails, the system cannot operate. The clutch, which drives the compressor, is belt driven by the engine crankshaft. A worn or incorrectly adjusted drive belt or a slipping clutch reduces compressor efficiency and system performance suffers.

COMPRESSOR CLUTCH DIAGNOSIS AND REPAIR



The compressor clutch engages to drive the compressor shaft only when there is current through the clutch field winding. If the compressor operates with no current applied to the windings, the clutch is faulty. Another problem that may cause a clutch malfunction is a leaking from compressor seal that allows refrigerant and oil to escape from the system. The oil can contaminate the clutch and cause slippage.

Common compressor clutch failures include:

- Open field windings
- Slippage due to low supply voltage
- A damaged or bent pulley
- A defective bearing

Begin troubleshooting at the field windings. Check the power and ground wire connections leading from the field coil. If they are good, the problem may be open windings in the coil preventing clutch operation or shorted field windings drawing excess current and blowing fuses.

A field coil recovering a low voltage supply does not engage the clutch properly, resulting in slippage. The clutch will also seize if it is damaged or warped or if the clutch plate surface is contaminated.

Check the pull to see if it is bent or damaged. Damage to the clutch hub or pulley can cause slippage, failure to engage or failure to disengage. The clutch bearing should not fail if the drive belt tension is correct and the bearing dust seal is intact. If the bearing wears due to incorrect belt tension or contamination, replace it and the belt.

COMPRESSOR FAULTS

Damaged internal parts can also cause compressor failure. Damage to the pistons, cylinderwalls, swashplates and other parts may be cause by:

- Insufficient refrigerant or lubrication
- Incorrect oil
- Collision damage
- System Contamination
- Debris in the Cylinder
- Incorrect assembly or disassembly

Inadequate lubrication is the most common cause of compressor failure; lack of lubrication causes excessive friction and overheating which results in seized parts. Replace a seized compressor.

Damage to A/C system parts can contaminate the compressor. Also, improper evacuation and charging procedures leave moisture in the system, which forms corrosive acids. If the compressor is contaminated, drain the oil to clean it or replace it.

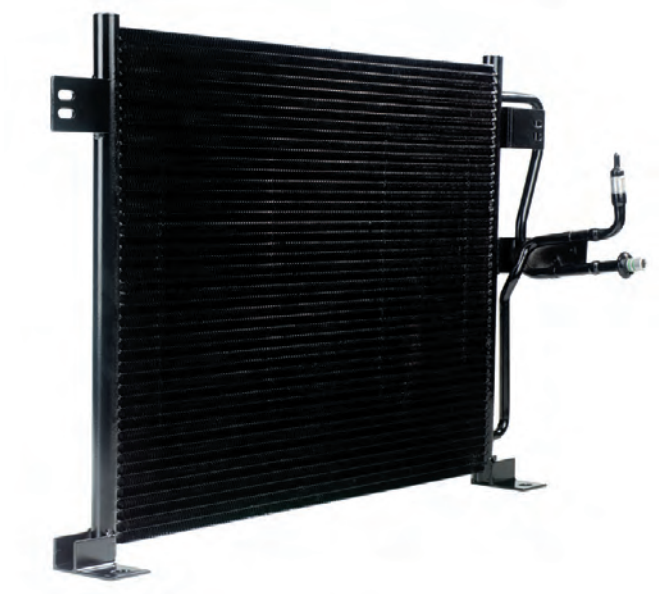
Condenser and Evaporator

The condenser and evaporator are particularly susceptible to collision damage and plugging. Both can leak when cracks develop at seams and other stress points.

Symptoms of a defective condenser or evaporator

- Excessive high-side pressure, possibly with the pressure relief valve venting excess pressure and frost on the discharge line

- Severe compressor damage, suggesting that debris has contaminated to condenser
- Refrigerant loss, indicating possible leaks at the evaporator or condenser
- Areas of localized frost



The condenser is a heat exchanger that sits in front of the radiator. It transfers heat from the cabin to outside the vehicle.

The evaporator core is located inside the vehicle and cools the air. It is also used to remove moisture from the air used to defrost the windows.

RECEIVER-DRIER

The receiver-drier is a high-pressure storage device located between the condenser outlet and expansion valve inlet. A desiccant bag in the receiver-drier is replaced when there is:

- System or component contamination
- Refrigerant leaks
- Collision damage
- Excessive ambient air entering an open system
- Compressor replacement

Signs of a receiver-drier problem

- Loss of refrigerant
- Moisture or debris contamination
- Desiccant particles in the system
- Refrigerant starvation due to receiver-drier blockage
- A significant temperature difference between the receiver-drier inlet and outlet
- Frost on the bottom of the receiver-drier

The receiver-drier is not serviceable and must be replaced when defective.

Receiver-drier

ACCUMULATOR

The accumulator is a device on the low-side of an orifice tube system that performs two functions: It serves as a storage container to hold excess refrigerant, and also prevents liquid refrigerant from returning to the compressor. The accumulator, which is located at the evaporator outlet, receives refrigerant in bother liquid and vapor form. Refrigerant is stored at the bottom of the unit as a liquid and must be vaporized before it can be picked up

Orifice tube

at the top of the accumulator and returned to the compressor. The accumulator also contains a desiccant to remove moisture from the system.

A drain hole at the bottom of the accumulator stand pipe allows oil and some refrigerant to return to the compressor. Because of the large desiccant bag and the considerable amount of oil retained by the accumulator, it is important to accurately measure and replace the lost oil when installing a new accumulator. The accumulator is not serviceable and must be replaced when defective. Also, replace the accumulator whenever a refrigerant hose, compressor, condenser, evaporator or other major component is replaced.

Heating Problems

- Blocked coolant flow through the heater core-if the heater hoses are cool with the engine running the problem may be a plugged heater core, hoses, hose fittings or a faulter heater control valve
- Incorrectly positioned blen doors-If the heater hoses are warm but no heat is delivered to the passenger compartment, check for stuck blend doors, disconnected or broken control cables or damaged ductwork
- Blocked air inlet ducts-If the airflow improves when the mode selector is changed to the RECIRC position, check the ductwork or cowl intake blockage
- Defective blower or reduced current to blower-If the blower runs slowly or not at all, refer to blower service instructions

HEATER CONTROL VALVE

Most heating systems use a heater control valve to regulate coolant flow into the heater core. The valve may be actuated by a cable, vacuum servomotor or electric solenoid. A vacuum-operated heater control valve on a blend door system is usually open until a vacuum signal closes it. Use a vacuum pump to check whether the valve opens smoothly and evenly with the correct amount of vacuum applied.

HEATER CORE

Many problems with the heating system are caused by heater core problems. If the engine coolant level is low but the coolant system is not leaking, check the heater core. Coolant may leak from pinholes in the heater core in the form of steam, which enters the passenger compartment along with the heated air. When the air condenses against the cold windows, the coolant deposits there forming a sticky, sweet-smelling residue.

MECHANICAL OPERATING CONTROLS

Mechanical controls are simple, cable-operated devices that move levers or rotary switches to pull blend doors and mode doors into position. The blend door determines how much of the intake air is directed through the heater core before entering the passenger compartment.

Mode doors direct the airflow to the various ducts. An incorrectly positioned door cannot deliver proper air flow. Blend and mode door position problems may be caused by the doors themselves binding, being blocked by debris or by a control cable that is out of adjustment. Most newer control cables have a self-adjusting clip, but the self-adjustment range is limited.

VACUUM-OPERATED CONTROLS

Vacuum-operated climate control systems use intake manifold vacuum to operate controls and actuators. Many vacuum systems are complex, so it is important to have a vacuum diagram and specifications for the specific vehicle being serviced. In general, take vacuum readings at engine idle speed using a vacuum gage. Often, components can be tested without removing them from the vehicle using a hand-operated vacuum pump.

BLOWER MOTOR

The blower motor pushes air through the HVAC system. This electric motor can be controlled by the driver using a knob on the dash. Some older systems control fan speed by placing specific resistance in the circuit. The resistance is typically placed in the circuit by the switch and a blower motor control unit. This component is a series of resistors connected to cooling fins. When it fails, the blower may only work in one or two speeds.

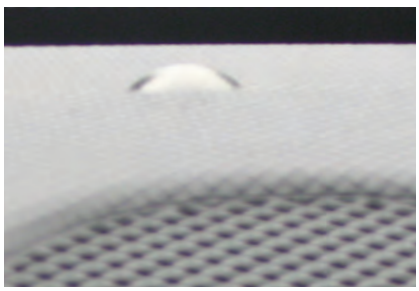
Most automatic temperature control HVAC systems utilize a system to control blower operation until the engine reaches operating temperature. Whenever the

HVAC system is turned on in any mode, except defog, and the coolant temperature is below approximately 28 degrees, blower operation is disabled. During this time the blower will be commanded off, any airflow will be redirected to the front defrost outlets to keep moisture off the windshield. Normal blower operation resumes when the defrost function is selected or after the coolant temperature reaches approximately 110 degrees.

TEMPERATURE SWITCHES AND SENSORS

Temperature switches such as the ambient temperature switch and the engine coolant temperature switch on/off devices that control circuits based on temperature. Most late-model vehicles have replaced temperature switches with temperature sensors. These sensors are generally thermistors, and are used to provide input to various control modules. A typical system uses thermistors to monitor the ambient temperature, evaporator temperature, coolant temperature and passenger compartment temperature.

Vehicle with automatic temperature control measure the interior's ambient temperature. Behind the screen is a small fan and a temperture sensor.



Vehicle with automatic temperature control measure the interior's solar load in order to determine blower and compressor settings.

The ambient temperature sensor is an electronic device that transmits a variable voltage signal to the control unit. The resistance of an ambient sensor varies in proportion to the temperature changes. In addition to controlling compressor clutch operation, and ambient temperature sensor signal may also be used by the control unit to compute the correct blend door position.

1. A/C compressors in most late model vehicles require what type of lubricant?
a. PAG oil
b. POE oil
c. Mineral oil
d. Motor oil

2. All of the following statements about A/C condensers are true EXCEPT:
a. It is usually located in front of the radiator
b. It receives high-pressure refrigerant gas from the compressor
c. It cools the air entering the passenger compartment
d. It cools the refrigerant so the gas will condense into a liquid

3. The orifice tube in an A/C system is located where?
a. In the suction hose
b. Between the evaporator and compressor inlet
c. Between the compressor and condenser
d. Between the condenser and evaporator

4. Technician A says the accumulator should always be replaced if an A/C system has been opened up for repairs. Technician B says a plugged orifice tube is a common cause of compressor failure. Who is right?
a. Technician A only
b. Technician B only
c. Both Technician A and B
d. Neither one

5. Technician A says that the A/C lines before and after the condenser should be the same temperature. Technician B says that the A/C lines before and after the receiver/drier should be the same temperature. Who is correct?
a. Technician A
b. Technician B
c. Both Technician A and Technician B
d. Neither Technician A nor Technician B

6. To locate the source of a foul odor whenever the A/C system is operating, inspect the:
a. Condenser drain
b. Receiver-drier drain
c. Compressor drain
d. Evaporator drain

Answer Key:

1A, 2C, 3D, 4C, 5B, 6D

ASE Study Guides by AVI

ASE Alternative Study Guides available for California: A6, A8 & L1.

- **A1** Engine Repair
- **A2** Automatic Transmission and Transaxles
- **A3** Manual Drivetrains and Axles
- **A4** Suspension and Steering
- **A5** Brakes (also available in Spanish)
- **A6** Electrical and Electronic Systems
- **A7** Heating and Air Conditioning
- **A8** Engine Performance
- **C1** Automobile Service Consultant
- **L1** Advanced Engine Performance Specialist

AUTOMOTIVE VIDEO, INC.
6280 Arc Way • Fort Myers, FL 33966 • (800) 718-7246 • Fax (239) 561-9111 • www.auto-video.com