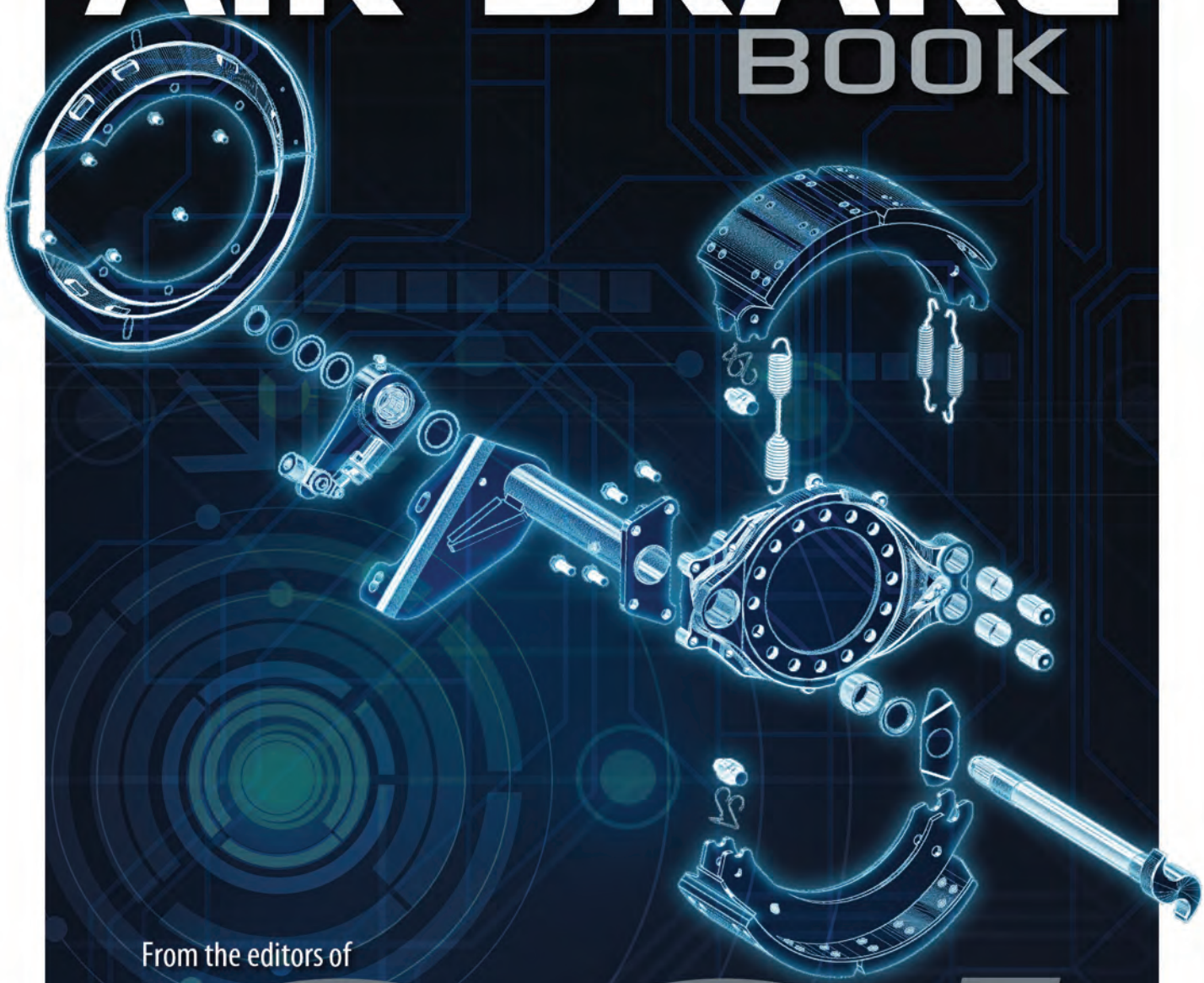
THE AIR BRAKE BOOK

9TH EDITION



From the editors of

COMMERCIAL CARRIER JOURNAL

SINCE 1911

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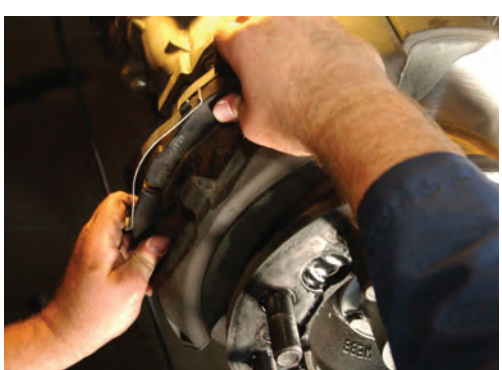

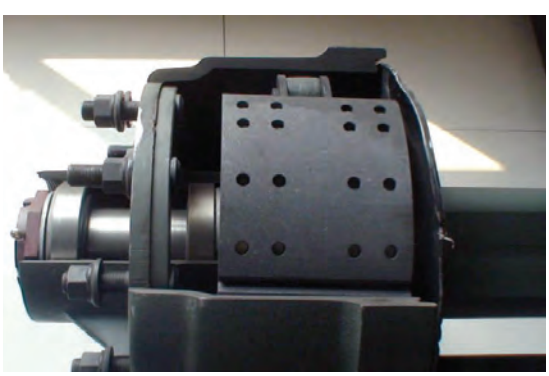

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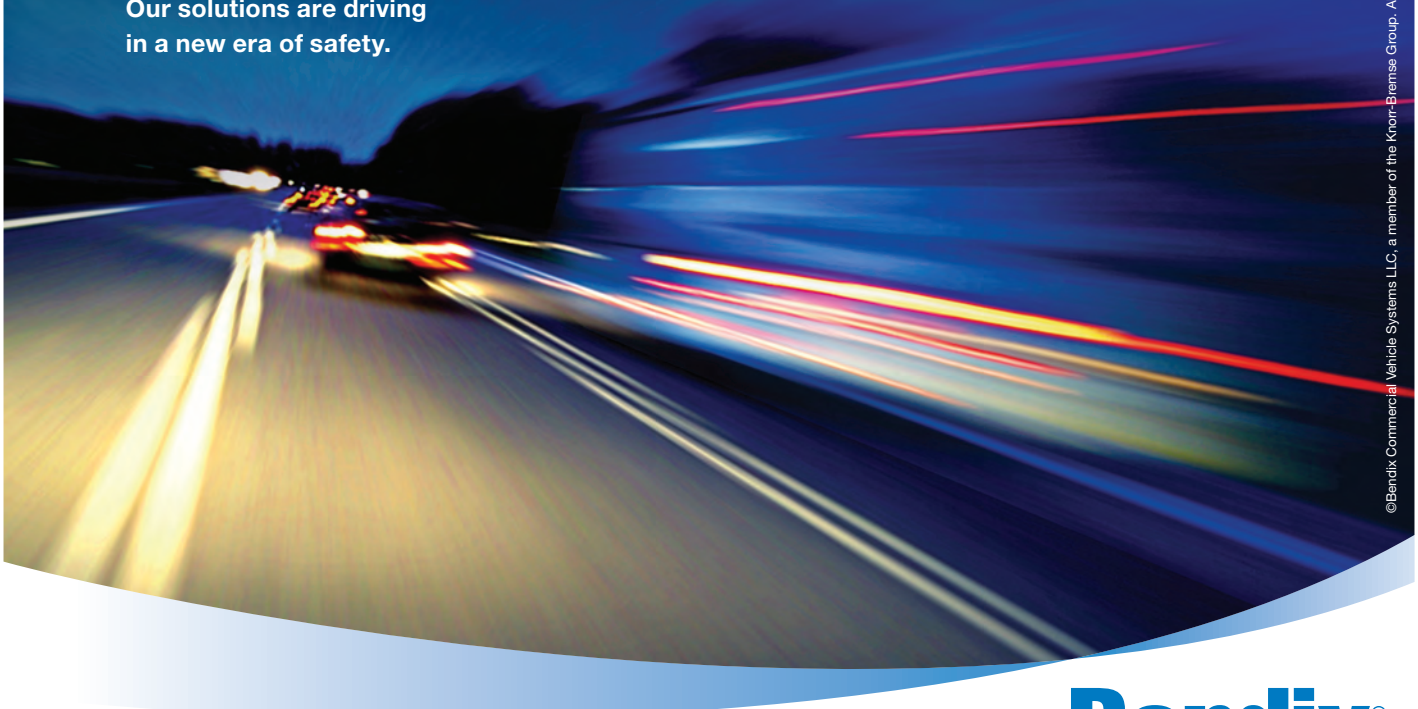

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Brake technology always on the move

Commercial Carrier Journal is proud to bring you the Air Brake Book, 9th Edition. Since we published the last edition in 2009, the industry has seen several regulations and safety initiatives that have impacted the stopping requirements and maintenance practices for commercial vehicle braking systems.

In August 2011, the National Highway Traffic Safety Administration's new stopping distance regulations took effect, mandating a 30 percent reduction in stopping distance requirements for Class 8 commercial vehicles. Several OEMs now provide air disc brakes standard on new trucks, but these systems have their own unique set of maintenance requirements. To that end, we have added a new chapter on air disc brakes as a result of the growth in their popularity and improved performance.

In December 2010, the Federal Motor Carrier Safety Administration went live with its Compliance Safety Accountability program, which replaced the aging SafeStat safety measurement system for identifying at-risk carriers. In CSA's Vehicle Maintenance Behavior Analysis Safety Improvement Category, brakes are one of the most-often cited vehicle-related violations. We have provided a list of the brake-related CSA violations and their corresponding violation severity weights so fleet maintenance managers can get a better picture of how improper brake maintenance procedures can impact a fleet's CSA scores. And we updated all chapters as brake technology continues to evolve and the acceptance of advanced stopping systems such as roll stability control, full electronic stability control and adaptive cruise control with braking continues to improve.

Since 1911, *CCJ*'s mission has been to help our readers be productive and successful. And our goal for the Air Brake Book is to help keep you up to speed on air brake systems — today, and for as long as big wheels are rolling. Let us know how we're doing.

—*CCJ* editorial staff

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CHAPTER 1: The three basics of air brakes

The first step to understanding complex brake problems and repair decisions is basic knowledge of brake system operation.

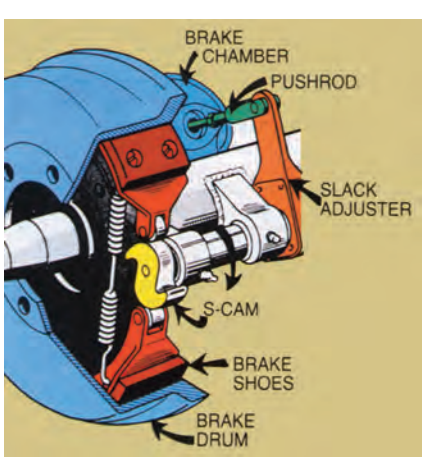
By Jack Roberts

Air brakes operate differently from hydraulic brake systems found on automobiles and light-duty trucks. All air brake systems differ somewhat depending on manufacturer designs and application-specific options. This chapter will detail the three basic systems of air brakes you should be familiar with before attempting maintenance or replacement work.

1. Supply system

The supply system provides the pressurized air that will actuate its components, and is in many ways the heart of any air brake system. An engine-powered air compressor supplies air to a governor, which controls the compressor's output by cycling air into the system as needed or unloading if the system is at its correct pressure – usually between 100 and 120 psi for most vehicles. The vehicle's driver can monitor the air system pressure via a dash-mounted pressure gauge. If pressure in the system falls below 60 psi, a switch in the system must come on and send an electronic signal to a dash light or buzzer in the cab and alert the driver that there is a problem.

Air in the system is stored in air reservoirs – usually three or more per tractor – until it is needed. Check valves prevent pressurized air from passing back through the compressor while it's not running to make sure the air gets to where it is needed. Should the system become over-pressurized with too much air, "pop-off," or safety, valves open to allow air to escape before damaging air lines, the reservoirs or other system components.



Foundation brake operation. When pushrod is extended, brake adjuster, camshaft and S-cam rotate. S-cam spreads brake shoes apart and against brake drum.

The air reservoir nearest the compressor is often called the supply tank (sometimes called a "wet" tank), because that is where atmospheric moisture condenses in the greatest quantities. Moisture is an air brake system's No. 1 enemy, and great care must be taken to ensure a vehicle has the cleanest, driest air possible circulating through its brake system. To that end, reservoirs are equipped with either automatic or manually actuated drain valves allowing water to be purged from the system.

Air dryers then condense and remove any water not drained from the system by forcing air through a canister containing desiccant material. Prior to air dryers, alcohol sometimes was injected into the air system in cold weather to prevent any water from freezing and clogging air lines, but this practice is strongly discouraged today.

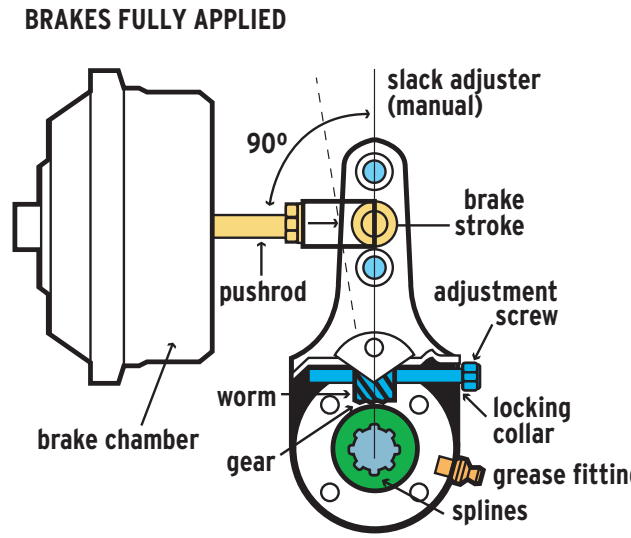
2. Control system

Air in the reservoirs has to be routed to the various components in the system before any braking action can take place. Enter the control system, a series of pneumatic valves that direct and control the air as it flows through the system to make sure it gets to where it's needed. These valves usually are found in a common housing unit on the vehicle, although for simplicity's sake we'll look at them individually here.

The dual-control foot value is the main actuator in the system. It is actually two valves that operate simultaneously in response to input from the driver's foot on the brake pedal. Two valves are needed because after leaving the supply tank, air in the system splits into two separate and protected brake circuits that are divided between the primary and secondary reservoirs. This backup source of air allows the driver to bring the vehicle to a complete stop in the event of a system failure.

When the driver steps on the brake pedal, air flows

from the primary reservoir and through the primary portion of the dual-control foot valve to actuate the rear axle brakes. At the same time, air flows from the secondary reservoir through the secondary portion of the dual-control foot valve to actuate the front axle brakes. A two-way check valve senses the air pressure in both the primary and secondary air systems and allows the system with the higher pressure to actuate the trailer brakes (if present). Primary air also can be manually supplied to the trailer by means of a hand valve, which is usually found near the vehicle's steering wheel. In addition, the two-way check valve actuates the vehicle's stop light switch, thereby ensuring the stop lamps are actuated in the event of a failed circuit.



Action of chamber on brake adjuster (manual type shown). With chamber pushrod fully extended, properly set adjuster forms 90-degree angle with pushrod.

But it takes time to get air through a brake system in order to stop or slow a vehicle. Relay valves are used on trailers and the rear axles of long-wheel-based tractors to ensure faster system reaction times. These relay valves are directly supplied with system pressure and use air from the dual control foot valve as a signal to quickly direct airflow to the brakes they serve. If the vehicle is equipped with an anti-lock braking system, ABS valves are combined with relay valves on a trailer to supply modulated air to the anti-lock brake mechanism.

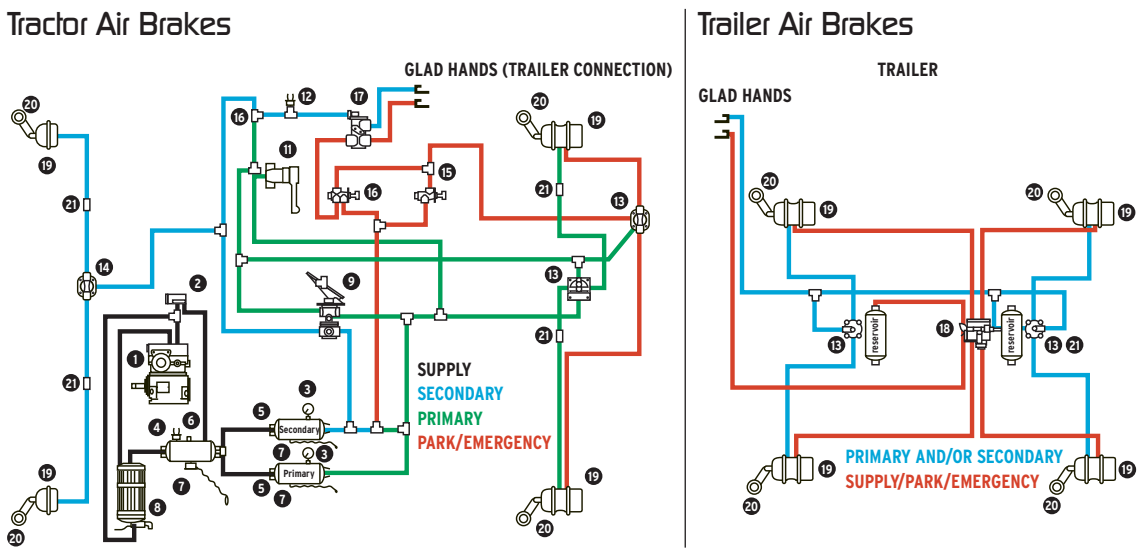
Relay valves' delivery pressures are affected by their respective "crack" pressure setting. Crack pressure is the amount of air pressure required at the input from the foot valve before the relay valve will send air pressure to the brakes controlled by that valve. Crack pressure is an important element of brake timing and balance. It is determined for each axle on the vehicle by how heavily loaded the axle served by the valve is, how big the brakes are and how aggressive the linings are on those brakes.

A valve that cracks at too low a pressure for a given axle can cause that axle's brakes to operate at a lower control pressure while the other axles do not and can lead to a large braking imbalance. Likewise, a valve that cracks at too high a pressure can also cause braking imbalance for the same reasons. Because of incompatibility and wear issues, OEMs and component manufacturers through the Technology & Maintenance Council, the Society of Automotive Engineers and other industry organizations have worked hard to standardize valve crack characteristics. (For more information, refer to SAE recommended practice J1505 for brake balance procedures and J1860 for recommended component labeling practices.)

Once a stopped truck is ready to go, having air travel all the way back through the system would cause a noticeable lag time between the time the driver removed his foot from the brake pedal to when the brakes released. To combat this problem, quick release valves located near the brakes they serve quickly expel air from the system and allow fast brake release times.

Dash-mounted air valves inside the cab control air pressure to the parking brakes. In most cases, these are spring-applied brakes, which are actuated gradually by descending air pressure in the brake system. Conversely, when air is applied by pushing in on the dash control valve (parking control valve), the brakes will be fully released in the 60 to 70 psi range. This provides a fail-safe feature in the event all air is lost; the vehicle can still be parked and can be used as part of an emergency brake system.

Effect of brake chamber type (diaphragm area) on pushrod output force, with constant 60-psi application. Except where noted, illustrations courtesy of Meritor, Bendix and Dana.



The tractor protection valve maintains air pressure in the lines that carry air to the trailer if one is being pulled behind the vehicle. Quick-connect fittings at the rear of the tractor – called "gladhands" – supply air to the trailer. In the event of an emergency – either a substantial leak in the air lines or a trailer breakaway – the tractor protection valve automatically closes to maintain air pressure in the tractor circuit. The valve also works in conjunction with the dash-mounted trailer parking brake valve to shut off air to the trailer circuit before disconnecting the trailer from the tractor.

The trailer spring brake valve – sometimes called the multi-function valve – releases the trailer park brakes and controls the charging of the trailer service reservoirs. It also works with an integral check valve to isolate a failed reservoir, which would otherwise allow the parking brakes to apply automatically – whether they were needed or not.

3. Foundation and parking brake systems

The systems mentioned above exist and work together to supply the proper amount of controlled air pressure to actuate the vehicle's foundation, or service, brakes. When the brakes are applied on a vehicle equipped with air brakes, air pressure is directed to the brake chambers at each wheel end. The brake chamber itself consists of several inter-connected components, including a pressure housing, diaphragm and pushrod.

As the system exerts air pressure on the diaphragm, the pushrod on the other side of the diaphragm extends outward. The force this pushrod exerts as it moves outward is a result of the amount of air pressure applied in psi combined with the area of the diaphragm in square inches. For example, if 100 psi of air pressure is supplied to a pressure chamber with a 16-square-inch diaphragm, then the amount of force generated at the pushrod would be 1,600 pounds. Using the same formula, a 100-psi application of air pressure into a chamber with a 30-square-inch diaphragm will produce 3,000 pounds of pushrod force. Obviously it is very important to make sure brake chambers are properly matched to avoid severe brake imbalance problems.

In an S-cam brake system, the pushrod is connected to a lever called a brake adjuster (also called a slack adjuster). When actuated by air pressure in the brake chamber, the pushrod forces the brake adjuster outward. The brake adjuster is connected to a shaft that runs perpendicular to the plane formed by it and the pushrod. As the pushrod extends outward, it causes the brake adjuster to rotate

the shaft. As the shaft rotates, it turns an "S"-shaped cam located between the brake shoes. This action forces the brake shoes apart, placing them against the inner portion of the brake drum, creating the friction needed to slow the vehicle. The amount of friction produced depends on several factors, most notably the size of the brake shoes, the coefficient of friction (aggressiveness) of the brake lining material and the mass and heat rejection of the drum.

Brake shoes – their lining material, in particular – are self-destructive by nature. In other words, the friction created by pushing the shoe against the brake drum creates heat and naturally wears away the brake lining as it works to slow the vehicle. The brake adjuster is equipped with a slack adjustment mechanism to compensate for constantly wearing brake linings and ensure consistent stopping force when the brakes are applied. This system, as its name implies, automatically adjusts as the brake lining wears away so that the pushrod does not have to travel farther and farther to apply braking pressure. Without the brake adjuster, the pushrod soon would be unable to extend far enough outward to apply the brakes.

Brake adjusters have another important function as well. They are force multipliers – essentially levers that multiply brake forces in proportion to their length. A 5 1/2-inch-long brake adjuster, for example, converts 1,000 pounds of force at the pushrod into 5,500 inch-pounds of torque at the brake camshaft. Because of this, the brake adjuster's length and the brake chamber size are the two components most commonly altered to meet different vehicle braking requirements. ABAs are rated by an "AL factor" — the product of chamber area (type) times the length of the ABA.

Engineers express the product of these two values as the brake system's "AL factor." This factor, when multiplied by 60-psi air pressure, is the industry standard for braking calculations. Using this formula, 60 psi of air pressure applied to an air chamber with a 16-square-inch diaphragm (the "A" portion of the AL factor) creates 960 pounds of pushrod force. This becomes 3,840 pound-feet of torque applied to the brake camshaft when multiplied by a 4-inch brake adjuster.

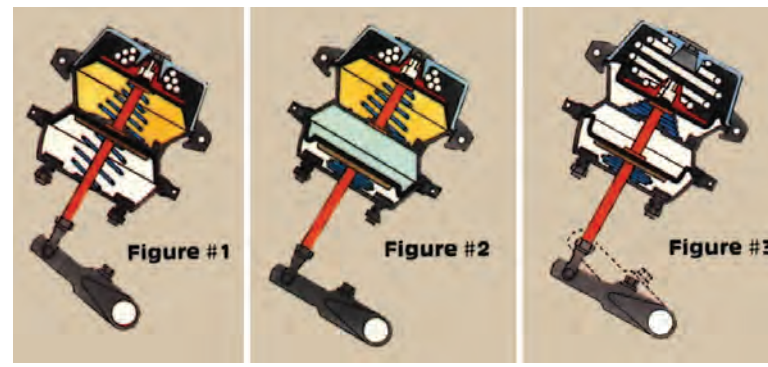


Figure 1: Normal driving position. Hold-off air in rear (yellow) chamber compresses parking spring, releasing parking brake. Service brake is not applied. **Figure 2: Service brake application.** Air pressure in first (light blue) chamber pushes diaphragm and pushrod, rotating slack adjuster. **Figure 3: Parking.** Hold-off air is exhausted from rear chamber, allowing spring to apply parking brake.

Brake chambers do more than simply apply the service brakes in everyday driving. On rear tractor axles and trailer axles, they also apply the parking brakes. These spring brakes use a second chamber with a second diaphragm and a powerful spring. A driver must push in the dash-mounted parking brake valves in order to put a vehicle in normal service. Once these valves are in the "run" (pushed-in) position, air pressure is applied to the spring chamber on the side of the diaphragm opposite the spring itself. Air pressure on the diaphragm compresses the spring, holding the parking brakes off as long as there is adequate air pressure in the system. This does not affect the action of the service brakes in normal vehicle operation.

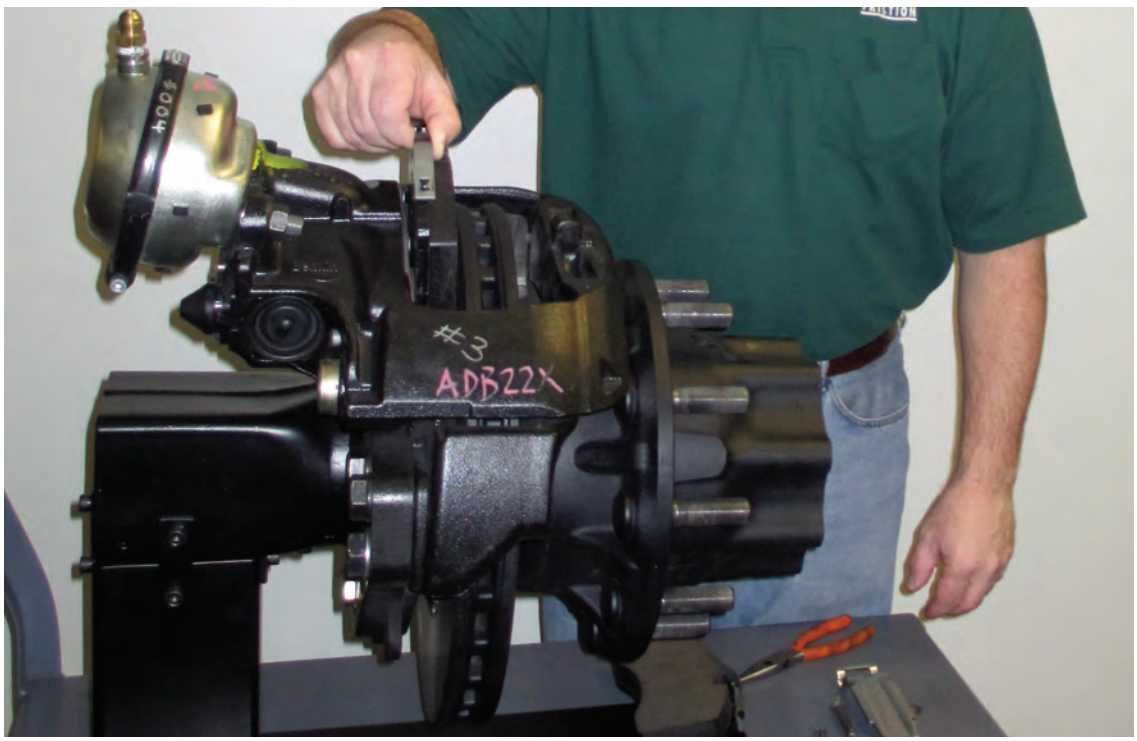
When the vehicle is parked, the driver pulls the dash valves out. This action exhausts the air holding the spring brakes back, allowing them to deploy and hold the vehicle in place. FMVSS 121 typically defines vehicle parking minimum requirements for loaded vehicles.

As a safety precaution, the spring brakes are designed to automatically apply in the event of a loss of air pressure in the brake system. If air pressure is lost for any reason, the parking spring brake overcomes hold-off air pressure in the secondary brake chamber, and the brakes are automatically applied to provide emergency stopping power.

CHAPTER 2: Integrating air disc brakes

Incorporating air disc brakes into your fleet operation can pay dividends down the road.

By John Baxter



Air disc brakes are a different animal than the traditional S-cam drum brake. The good news is that the disc – which replaces the drum as the part that absorbs most of the heat energy generated in braking – cools more effectively than a drum. This is partly a result of the disc-like shape and the fact that air can circulate freely around both sides – unlike the drum, which forms a kind of enclosure.

The discs used on heavy trucks also are ventilated; they consist of two braking surfaces with an open section between them where webbing draws air in at the center and forces it to flow continuously over the inner sides of the surfaces. The disc often can dissipate heat just as fast as it is absorbed. Drum brakes depend, at least in part, on the relatively heavy drum's ability to absorb energy because of its mass of metal.

More disc advantages

The disc also has the advantage that expansion from heat – what Pete Moss, Meritor's brakes product manager, calls "temperature growth" – moves the metal surface closer to the friction surface, and that this surface remains flat, allowing the lining to conform to it easily.

The drum, on the other hand, expands away from the lining, increasing the necessary stroke – and the compression of the return spring inside the brake chamber – while also increasing in diameter. This expansion eventually causes the lining to fit the drum's inside diameter in a less uniform manner, and to be applied with less force due to the additional compression of the return spring.

Because of the differences between the two designs, brake fade is a critical problem with drums but is almost nonexistent with discs. This characteristic becomes valuable on long downgrades, and the more effective cooling means that the disc brake linings will last longer because brake lining wear increases with higher temperatures.

Air disc brakes are easier to maintain than drum brakes.

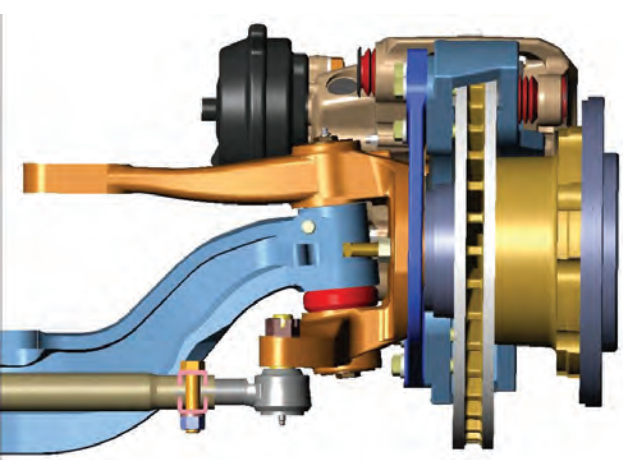
Also, the rotor is vertical and can spin dirt and water off, making it less subject to contamination than the drum, which takes the form of a container that can trap dirt and water. And discs use a smaller chamber and thus use less air, conserving the compressor, air dryer and fuel, says Randy Petresh, vice president of technical services at Haldex.

Disc brakes are constructed differently from S-cam drum brakes, so virtually all maintenance techniques are different. Gary Ganaway, director of marketing and global solutions for Bendix Spicer Foundation Brakes, and his associate, technical service representative Kevin Pfost, both say discs are an advanced technology that do not need the routine greasing of both the slack adjuster and cam bushings required on S-cam brakes. "Air disc brakes are lubed for life and do not require periodic lubrication, so this simplifies the PM," says Ganaway.

As if that wasn't enough good news, pad replacement and other major work take less time than with drums because disc brakes are simpler to service.

According to Federal Mogul, changing an air disc brake takes less than half the time of a drum brake (25 minutes vs. 60 minutes per wheel), reducing vehicle downtime and labor costs.

"That being said, regular brake inspection is very important when servicing air disc pads," says Alesha Erving, commercial markets product manager for Federal Mogul. "Just like a drum brake, it is essential to have a preventive maintenance schedule for these vehicles. Checking for things like pad thickness, pad wear, caliper clearance and inspecting the rotor surface for cracks is key to maintaining a road-ready vehicle."



Acquisition costs are higher for air disc brakes, but lifecycle cost and resale values make up for that in the long run.

Removing the shoes on drum brakes is a lengthy procedure, says Moss. "We have allowed untrained people to replace the pads on our brakes at various industry events while trained technicians replaced brake shoes on drum brakes nearby," he says. "Even without training, those replacing the disc brake pads accomplished the task much faster."

For discs, after removing the wheel and backing off the adjustment, a technician only needs to remove one or, in some cases, two parts that retain the pad, and then remove the pads themselves. For drums, the technician would need to remove the drum, then the springs and rollers, and finally the shoes.

Also, on S-cam brakes, a proper brake job includes not only replacing the shoes, springs and rollers; it also requires checking camshaft and bushing wear. In the event these parts are worn, the bushings will have to be pulled out and new ones pressed into place.

On discs, says Pfost, all that is needed is a simple check to make sure the integral adjuster is functioning. The caliper is not rebuilt but is replaced only as a complete assembly. When replacing the caliper, the technician might, at most, have to rebuild the guide pins and bushings and replace the rubber boots that retain their grease, squeezing a small container of grease into place as this is done. This is a comparatively simple and quick operation, although a set

of tools is required to press the old pins and bushings out and the new ones in.

Disc inspection

One thing that doesn't change when running discs is the need for routine inspections. Brake manufacturers agree that the entire brake system, even with a mix of disc and drum brakes, should be inspected together, and at the normal oil change inspection interval. Technicians should look for anything unusual such as road damage while keeping an eye out for loose fasteners and air leaks.

Another different feature of a disc brake inspection is checking the function of the guide pins that allow the disc to float back and forth and equalize the application pressure of the pads; this is done with the wheels chocked and parking brake released.

Wabco's Hampson describes this as "checking brake free movement." TMC RP 652 (see page 18) points out that this is often a small distance – as little as 0.080 inches, or the thickness of a nickel. A frozen caliper is a problem since only one of the two pads will handle all the braking; movement that is greater than specification also is a problem, and it requires a more extensive inspection and repairs. Technicians need to know the appropriate amount of movement and how to determine it.

Technicians also should check that the rubber boots that protect the caliper tappets, which function as pistons, and the guide pins are in place and undamaged. Brakes that are sealed and don't get periodic greasing depend on undamaged and undeteriorated seals.

Hampson says a wheels-off inspection should be done at least every two years. "This involves a more comprehensive review of the brake and measurement of available pad life by a trained technician," he says. "Should the pads need replacing, this would be done at this point."

An example of the differences in discs can be found by checking the wear of disc brake pads. The technician may be checking the length of a boot, which changes as the pads wear and the caliper moves to one side; or he may be looking for the edges of wear indicators machined into the caliper and brake carrier to see how they are aligned. The specifics differ widely, so it's critical that techs get the manufacturer's training they need.

This image of an air disc brake clearly shows the "squeegee-like" action performed by the brake pads as they press against the rotor to slow and stop the vehicle.

The importance of training

While the work ultimately may be simpler for most operations, training remains important. The most critical part of preparing a maintenance shop to handle disc brake-equipped vehicles is training technicians in the service specifics of the particular discs that are being used.

"Air disc brake training for technicians is highly recommended since the technology, components and function are different from those of drum brakes," says Bendix's Pfost.

Wabco's Hampson agrees that air disc brakes are a different technology and recommends that shops be trained and become familiar with the function and servicing of the products. "Comprehensive service information is available to the fleets through the manufacturer's website," he says.

Haldex's Petresh concurs and stresses that when it comes to preparing a shop for equipment that has disc brakes, the three main principles are "training, training and training." He believes Internet-based training materials are valuable, but only as an adjunct to face-to-face instruction so the technician has a place to recheck details he may have forgotten after personal training.

Technicians will use mostly standard hand tools with a few exceptions. Bendix's Ganaway says the company

provides several sets, including a caliper rebuild toolkit, a tappet and boot replacement toolkit and a guide pin/pin boot service kit; these can be ordered as a set.

Pad replacement can be completed using commonly available tools in the shop, says Fabio Jurchaks, sales & engineering director, NAFTA, for TMD Friction. "A simple box wrench and a pair of pliers are all that is required when replacing brake pads, readjusting pad-to-rotor clearance or removing and replacing the pad retaining plate," he says. "The specialty tools come into play when rebushing the calipers."

In terms of scheduling brake jobs, experts suggest that users are not likely to have both discs and drums on mixed tractors at the same time. "In general, the life of an air disc brake lining is longer than that of a standard drum brake setup," says Hampson. The mileage for scheduled brake work for air disc brakes can be extended in comparison to drum brakes, he says.

"It is not necessary to replace all the brake pads on the tractor and combination at the same time," Hampson says. "The brakes, pads and linings should be serviced when they have reached their specified wear limits or if there is damage to any of the components."

Still, experts say not to replace the pads only on one side of an axle; both sides always must be done simultaneously to guarantee consistent performance and long life.

John Churico, maintenance manager at Bethel, Pa.-based K.L. Harring Transportation, says his fleet has a 2014 Kenworth with front discs that has 20,000 miles on it and has had its first inspection. The fleet does its drum brakes at 120,000 miles, including replacing rather than machining the drums because it has found breakdowns away from home are well worth avoiding. Churico fully expects the need for work on the discs to be extended as compared to drum service.

While the specifics of disc inspection and service are different, the basics of both brakes in terms of what they do and where wear points occur are similar. Few if any fleets have technicians that work only on discs or drums, experts say. "This varies by fleet, maintenance shop, and by maintenance manager," says Bendix's Pfost.

Mike Hasinec, vice president of maintenance systems and support for Reading, Pa.-based Penske Truck Leasing, says his company's experience with air disc brakes over the last few years has been positive.

"We currently have several thousand units with air disc brakes, and with the exception of some component issues on a small percentage of the units, which have since been resolved, air disc brakes have been virtually maintenance-free," Hasinec says. "Customers running the air disc brakes get positive feedback from their drivers about the stopping characteristics and the confidence they provide. Air disc brakes require less routine maintenance, as there are no slack adjusters or S-cam tubes to lube. Roadside inspections are a positive experience for our customers, as you don't need to worry about brakes being out of adjustment.

"Based on measurements we have been taking with one of our key brake component suppliers, we expect to more than double our brake life on this population of Class 8 tractors," he says.

The how, how many, and the why of disc brakes

Because disc brakes resist fade more effectively than drums, they can halt the vehicle quickly during repeated heavy stopping or even on long downgrades. They also produce more uniform stopping power, mainly because the application process is more straightforward.

According to a white paper from Bendix Spicer Foundation Brakes – "The compelling case for air disc brakes in heavy truck braking" – drum brakes are designed to provide a mechanical advantage during the application process. The force generated by the friction participates in forcing the lining against the drum because of the way the lining moves toward its inner diameter. While this helps the brake generate a maximum stopping force in relation to the power produced by the brake chamber, the slack adjuster and the S-cam, it also leads to what the paper terms an "internal amplification." This amplification varies side-to-side on an axle because of the inevitable variations in such factors as the friction coefficient of the linings used, the brake stroke and the condition of the drums; the result is an exaggeration of any variation and a slight pull to one side.

Disc brakes, on the other hand, are applied by two pistons that are balanced in terms of force; the force is applied in a straight line, so there is no such mechanical advantage. The result, according to the paper, is "improved side-to-side

consistency" in brake force, making the front axle an ideal place for discs even when drums are used on the tandem drive axles because the driver is less likely to complain of a pull in the steering.

Randy Petresh, vice president of technical service at Haldex, describes the disc as "a better mousetrap and the brake of choice. Not only does it resist fade, it produces a consistent output torque, including being less sensitive to speed in this respect. Its feel and response are better all around."

Drivers need added skill to manage drum brakes, says Pete Moss, Meritor's brakes product manager. "Driving a truck with disc brakes is like driving a passenger car," Moss says. "The discs take the stress of managing the brakes away from the driver."

Market penetration

The benefits of discs are leading to their penetration into the heavy truck market in spite of their higher initial cost. But just how many brakes are in the U.S. heavy truck market?

Gary Ganaway, director of marketing and global solutions for Bendix Spicer Foundation Brakes, estimates that about 10 percent of the North American Class 8 market has converted to air disc brakes. "Most applications have the air disc brakes on all axles, with a small number of customers spec'ing them on the steer axle only," Ganaway says.

For trailers, with the exception of hazardous material haulers and private fleets with lower tractor-to-trailer ratios, disc brakes make up about 8 percent of the production volume, he says. "In the previously identified applications, we estimate that they are closer to 50 percent."

All major truck OEMs offer a disc brake option, with some available for the front axle only or for the complete vehicle, says Steve Hampson, Wabco sales director. "Trailers are also increasingly being specified with air disc brakes, especially for more demanding applications," Hampson says.

Return on investment depends mostly on application. Hazardous materials haulers were early adopters for safety reasons, says Meritor's Moss. "Any fleet where there is a heavy number of stops per mile can see a good return on investment," he says. "This includes trash haulers and city buses. In linehaul, penetration of our EX-Plus air disc is starting to grow. It extends brake life and performs well."

Although Haldex's Petresh agrees with Moss on the ROI for discs, both allow that for many fleets, drum brakes will last through their trade cycle, especially if they have the versions upgraded for the shorter stopping distance standard.

"Some trucks run coast-to-coast and see 250,000 miles per year," says Petresh. "Most fleets operating in those applications don't see any value (in discs). But obviously in pickup-and-delivery applications, packers, fire trucks, transit and school buses, where they are always doing maintenance, the value is there. In time, when the economics shift and there is parity in pricing, those in linehaul service will switch."

Experts say advantages for discs include fade resistance, stability, consistency, constant output torque, lack of speed sensitivity, better feel, faster response, less sensitivity to contamination and less air consumption.

Petresh says a drum brake with a Type 30 brake chamber would be replaced by a disc brake with a Type 24; smaller chambers – used because the pads don't travel as far toward the disc when applied, as S-cam brake shoes travel toward the drum – mean less air consumption. That, in turn, means less service to the air dryer and fewer air compressor replacements.

Retrofitting: A major challenge

Retrofitting discs is a major challenge: It's rarely done, and the aftermarket is not geared up to supply the parts.

Kevin Pfost of Bendix explained some of the problem. "You would have to pull off the complete wheel end right back to the axle flange," Pfost says. "The aftermarket is almost nonexistent, and so the parts would be very costly."

Also, the truck owner would need considerable help from the OEM truck builder to resolve potential problems with suspension clearances, clocking – ensuring various components are installed at the right angles – and brake timing so the tractor would react properly in a sudden stop and not become unstable.

Meritor's Moss says his company has done this for a few customers. "It is quite expensive to do and quite a difficult task," he says. "You need to replace the entire wheel end, the entire brake assembly and even the brake chambers. It's very difficult to make sure you get the right parts, and the price will be high because the types of parts needed are not widely available in the aftermarket."

Haldex's Petresh sees even more problems. "You practically need to replace the entire axle because the torque plate mounts to the axle, and the carrier mounts to the torque plate," he says. "The axle flanges are welded to the tubes, and you would have to cut them off and replace them with the proper new part. It's just not a reasonable task for the majority of shops."

On the front axle, the steering knuckles, tie rods and suspension attachments are not designed for a disc brake, Petresh says. "You'd have to change the whole steering knuckle," he says. "It's almost like rebuilding the entire chassis." Trailers would be easier because of their simple axles, he says.

It appears the best way to equip all or part of a fleet with disc-braked vehicles is to make the switch at trade-in or when new equipment is purchased.

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TMC Recommended Practice

RP 652

VMRS 013-013-000

SERVICE AND INSPECTION OF AIR DISC BRAKES

PREFACE

The following Recommended Practice is subject to the Disclaimer at the front of TMC's *Recommended Maintenance Practices Manual.* Users are urged to read the Disclaimer before considering adoption of any portion of this Recommended Practice.

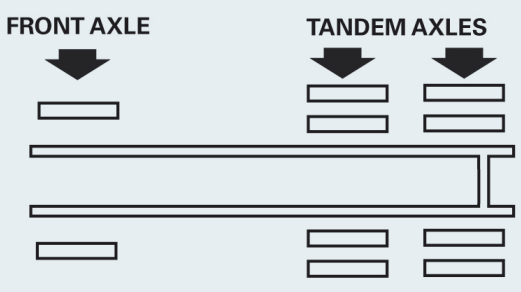
1.0 PURPOSE AND SCOPE

The purpose of this Recommended Practice (RP) is to offer guidelines for the service and inspection of air disc brakes used on medium- and heavy-duty commercial vehicles in North America.

1.1 GENERAL INFORMATION

⚠ **CAUTION** : Air disc brakes are high-performance braking equipment. Consequently, it is strongly recommended that only original equipment (OE) or equivalently performing replacement parts be used when servicing and maintaining air disc brakes. repairs. Otherwise the braking system may not perform as designed or intended.

On vehicles equipped with air disc brakes, both wheel ends of each axle should always be equipped with identical rotors, pads, air chambers, and valve crack pressures. All four wheel ends of tandem axles should also be equipped with identical rotors, pads, and air service chambers; however, it is not necessary for front axle brake equipment to be the same as rear driving axles. Depending upon the vehicle configuration and weight ratings, parking chambers may be used on one or both tandem axles.



Both wheel ends of each axle should have identical rotors and pads.

Figure 1

1.2 BRAKE PADS

⚠ **DANGER**: Although the majority of the brake linings used in the U.S. and Canada today are asbestos-free, the utmost precautions should be taken to eliminate unnecessary exposure to any brake dust from new or used lining materials. There is no easy way to visually identify asbestos-containing pads and the long-term effects of exposure to non-asbestos pads are unknown. The Occupational Safety and Health Administration (OSHA) regulations concerning asbestos exposure levels, testing, disposal of waste, and methods of reducing exposure (including respirators and exhaust systems) are set forth in U.S. Federal Regulations in 29 CFR 1910.1001.

General rules for proper handling of all brake materials include:

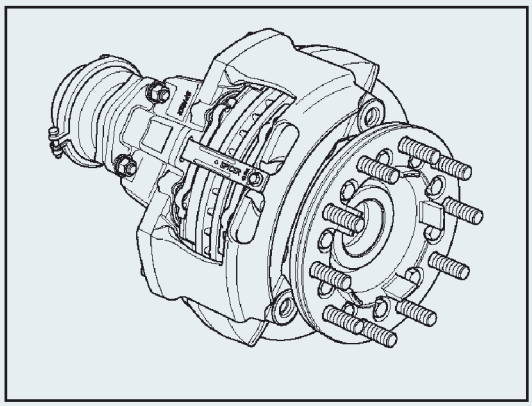
- Use OSHA approved respirators at all times during brake servicing.
- Never use compressed air to clean brake assemblies.
- Always perform brake work in an enclosed cell using filtered vacuums or in a well-ventilated area.

Always follow the vehicle manufacturer's recommended friction guidelines with respect to the pads to be used. Otherwise, adverse conditions could occur. Today's high-performance brake systems must be equipped with proper friction material and these requirements may vary from vehicle to vehicle, depending upon individual system designs. *See TMC RP 606, Brake Lining Procedures*.

Pad thickness should be the same for each pad and on each side of the axle. Some consideration should be given to pads with various performance enhancing profiles.

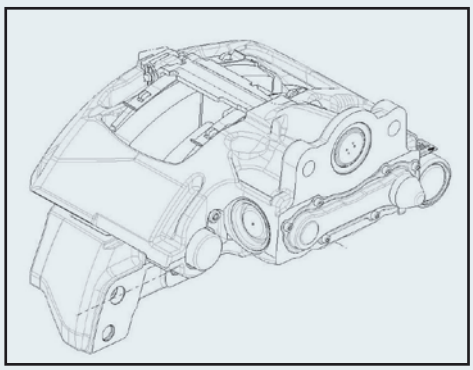
Five air disc brake designs are covered in this RP. (See **Figures 2-6**.) For other types that are not shown, please consult the brake manufacturer.

- Type I—Internal Lever with Internal Auto-



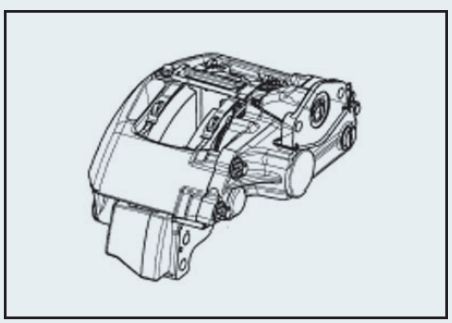
Type I—Internal Lever with Internal Automatic Adjustment (Bendix I - 2002 to present)

Figure 2



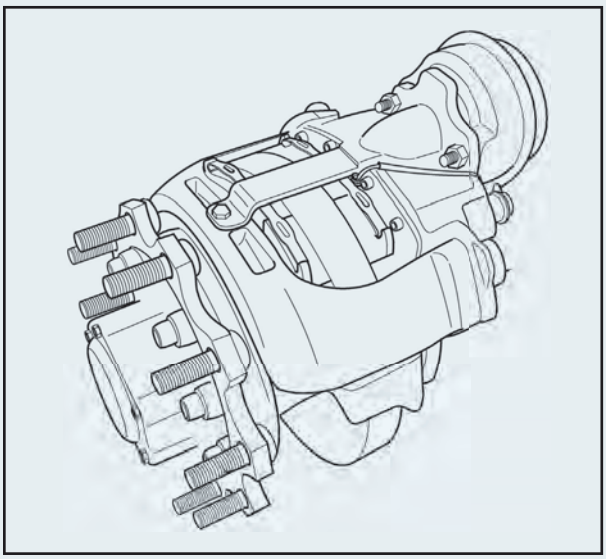
Type II—Internal Lever with Internal Automatic Adjustment (Dana & Bendix II -1994 to present)

Figure 3



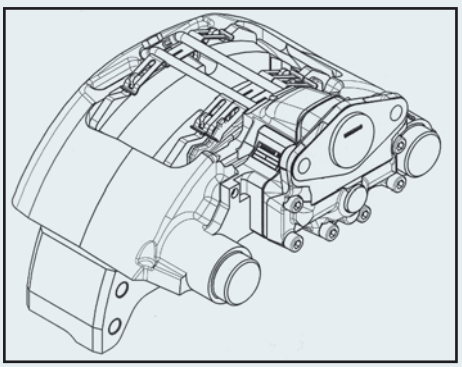
Type III—Internal Lever with Internal Automatic Adjustment (Haldex – 2002 to present)

Figure 4



Type IV—Internal Lever with Internal Automatic Adjustment (Meritor 2003 to present)

Figure 5



Type V—Internal Lever with Internal Automatic Adjustment- Single Piston (WABCO 2002 to present)

Figure 6

matic Adjustment (Bendix I - 2002 to present)
- Type II—Internal Lever with Internal Automatic Adjustment (Dana & Bendix II -1994 to present)
- Type III—Internal Lever with Internal Automatic Adjustment (Haldex – 2002 to present)
- Type IV—Internal Lever with Internal Automatic Adjustment (Meritor 2003 to present)
- Type V—Internal Lever with Internal Automatic Adjustment- Single Piston. (WABCO 2002 to present)

2.0 AIR DISC BRAKE COMPONENTS

Figure 7 illustrates components that are common to all air disc brake systems covered in this RP.

a. Caliper
b. Brake Carrier
c. Pad
d. Air Chamber (Service Chamber Shown)
e. Torque Plate
f. Rotor
g. Hub
h. Slide Pin(s)

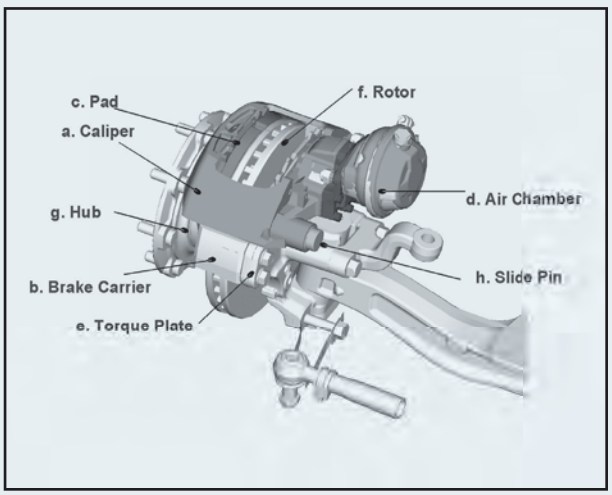
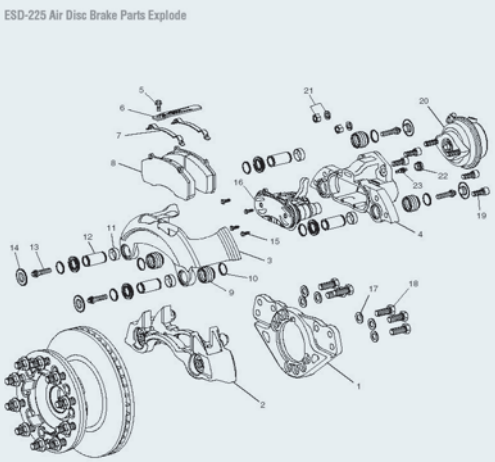


Figure 7

2.1 SPECIFIC AIR DISC BRAKE COMPONENTS FOR EACH BRAKE TYPE

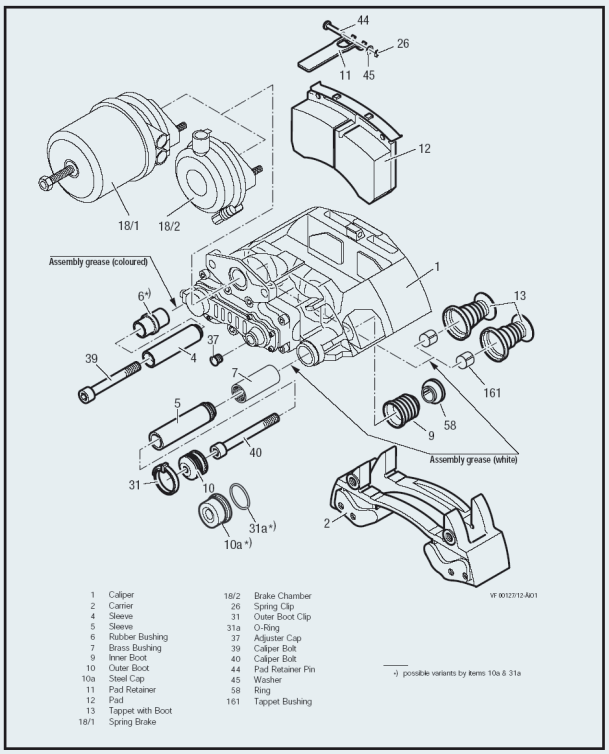
A detailed schematic is provided for air disc brake Types I-V in **Figures 8-13**.



Type I: Bendix I *(Dana)* Air Disc Brake

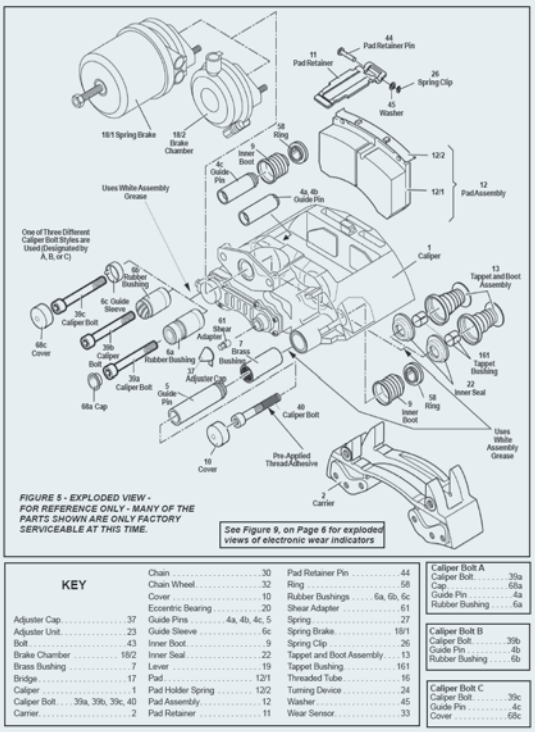
Item	Description Number
1	Torque Plate
2	Frame
3	Caliper Bridge
4	Caliper Housing
5	Retaining Bar Screw
6	Pad Retaining Bar
7	Pad Retaining Spring
8	Pad (Lining)
9	Slider Boot
10	Boot Retaining Ring
11	Slider Bushing
12	Slider Pin
13	Slider Pin Bolt
14	Slider Pin Cap
15	Adjuster Mounting Screw
16	Actuator Assembly
17	Flat Washer (20 mm)
18	Hex Head Screw (M20 x 1.5 50)
19	Socket Head Cap Screw (M16 x 1.5 Bridge Mounting) 4
20	Air Chamber A/R
21	Air Chamber Mounting Nut and Washer
22	Actuator Plug
23	Actuator Extension Assembly

Figure 8



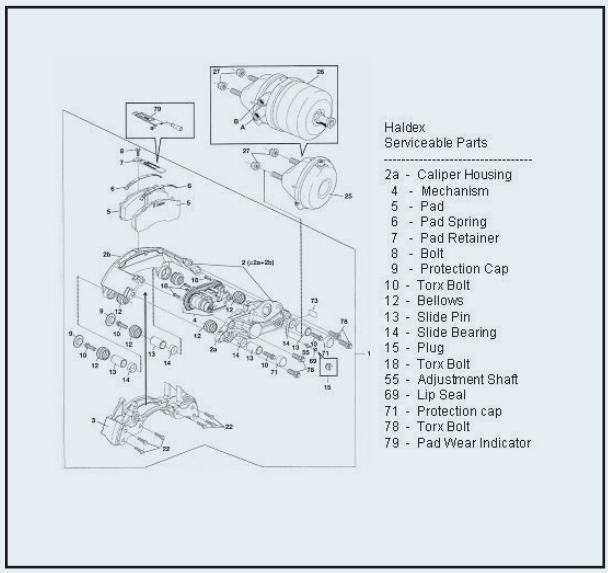
Type IIa: Bendix SB-Series Air Disc Brake

Figure 9



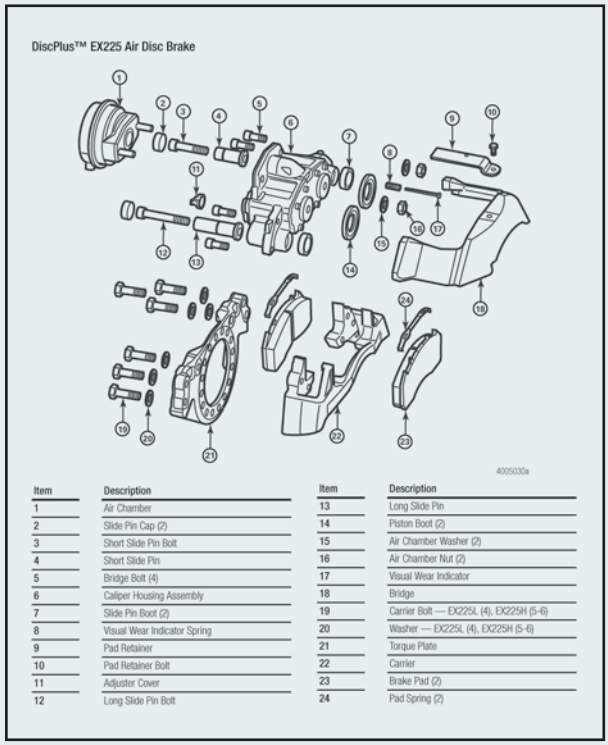
Type IIb: Bendix SN & ADB225™ Air Disc Brake

Figure 10



Type III: Haldex Air Disc Brake

Figure 11



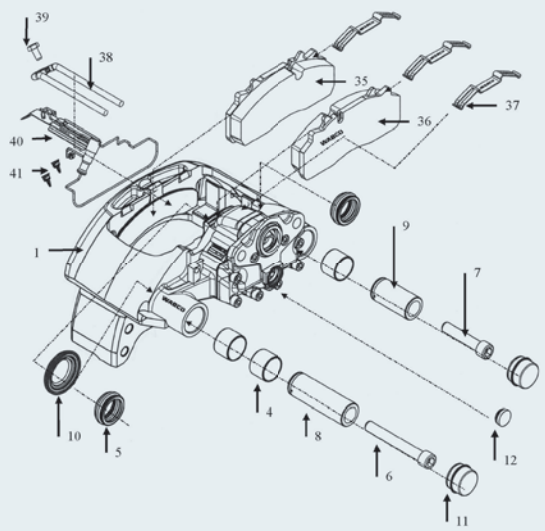
Type IV: Meritor Air Disc Brake

Figure 12

3.0 AIR DISC BRAKE INSPECTIONS

This RP recommends three levels of inspections:

- **Daily Pre-trip Walk-around Inspection**—The intent of this inspection is a pre-trip cursory look at the vehicle and its components by the driver or inspector.
- **Wheels On Inspection**—The intent of this inspection is to be done at the normal vehicle preventative maintenance interval by a qualified maintenance technician.
- **Wheels Off Major Inspection**—This inspection to be performed at each pad reline or a minimum of every two years, whichever occurs sooner by a qualified maintenance technician.



1	Brake Caliper with Brake Carrier
4	Guide Pin Bushes
5	Guide Pin Gaiters
6	Internal Hexagon Bolt (long)
7	Internal Hexagon Bolt (short)
8	Guide Pin (long)
9	Guide Pin (short)
10	Adjuster Screw Gaiter
11	Caps / Covers
12	Plug
35	Brake Pad, Wheel Side
36	Brake Pad, Actuation Side
37	Hold Down Springs
38	Pad Hold Down Hoop
39	Screw
40	Wear Indicator (pre-mounted)
41	Cable Clips

Type V: WABCO PAN 22 Air Disc Brake
WABCO Serviceable Parts

Figure 13

3.1 INSPECTION LEVEL 1: DAILY PRE-TRIP WALK-AROUND INSPECTION

NOTE: Prior to beginning any inspection, first check to make sure that the vehicle is properly parked with the parking brakes applied and wheels chocked.

a. Check for loose parts, broken or cracked air hoses, air system leaks, and damaged components. Check that brake hoses and cables are properly secured, but allow the caliper full movement during normal operation and allow for full pad wear.
b. Check for presence of lining pads. Also check any visual lining wear indicators to insure that pads are not worn beyond specification. Some brakes may have electric wear indicators which are covered in **3.2: Inspection Level 2: Wheels on Inspection**. Each brake has different wear indication systems, these systems are summarized in **Figure 14**.

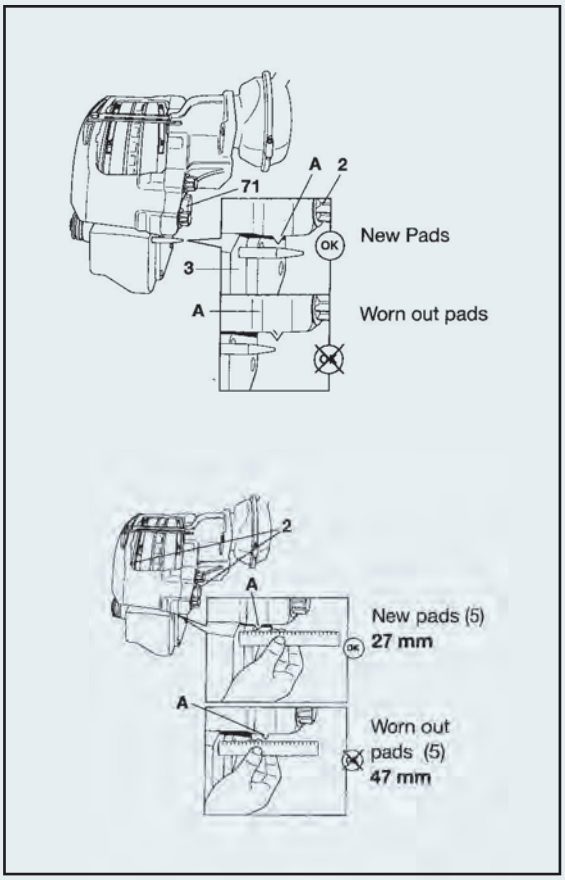


Figure 14

c. Unlike drum brakes, current air disc brake designs do not allow the brake stroke to be easily checked during normal walk around inspections. If it is desired to check brake operation, see guidelines for checking caliper movement in the **Inspection Level 2** instructions.
d. Check for oil or grease contamination of brake assembly.
e. Check that parking springs on parking brake chambers are not caged in the released position with the spring brake dust cover or plug installed, if so equipped.
f. Make sure that the air chamber is not covered with snow, ice, or mud. Air chambers are equipped with breather holes and it is important that they not be obstructed for proper function. See **Figure 18**.
g. Check for presence and condition of rotor ensuring there are no cracks. See Inspection Level 2 for further clarification on acceptable rotor condition.
h. Check that dust cap for manual adjuster access and slide pin boots or caps are in place.
i. Visual Wear Inspection

Visual Wear Inspection – Bendix Type II

- In the SB-series caliper the location of the floating pin with respect to the rubber bushing is in direct relationship to the pad and rotor wear.
- When viewed from the inboard side of the wheel, the floating pin location can be seen as shown below.
- The SB-series caliper and pin location is shown in the first two pictures.
- In new pad and rotor conditions, the pin will be exposed from the rubber bushing 13.6 mm (0.535”). (See **Figure 15a**.)
- With the pads worn to near the replacement thickness and a nearly new thickness rotor, the floating pin will be 4.6 mm (0.181”) below the edge of the rubber bushing. When the rotor is also worn to near the replacement thickness, the floating pin will be 6.6-mm (0.260”) below the edge of the rubber bushing. (See **Figure 15b**.)
- In the ADB225- series caliper the length of the rolling boot is in direct relationship to the pad and rotor wear and is shown in **Figures 15c and 15d**.
- In new pad and rotor conditions, the rolling boot will be extended to a dimension of 27.4 mm (1.08”). (See **Figure 15c**.)
- With the pads worn to near the replacement thickness and a nearly new thickness rotor, the rolling root will have an extension of 16.5 mm (0.650”). When the rotor is also worn to near the replacement thickness, the rolling boot will have an extension of 15.5 mm (0.610”).

Visual Wear Inspection: Meritor Type IV

a. The visual wear indicator shows approximately how much of the lining material is remaining. (See **Figure 16**.)
b. If the indicator extends less than 0.16 inch (4 mm) from the casting the pads require further inspection or replacement.

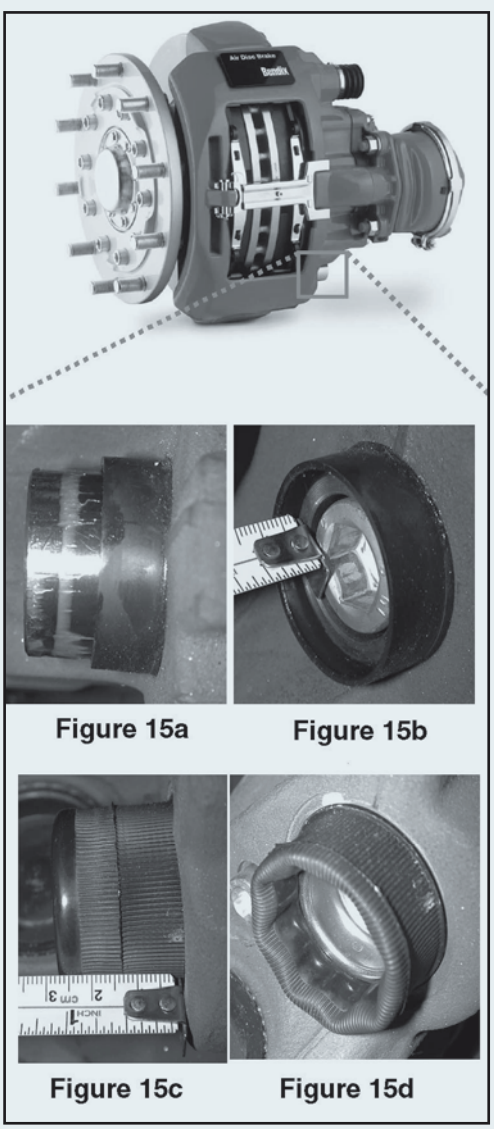


Figure 15

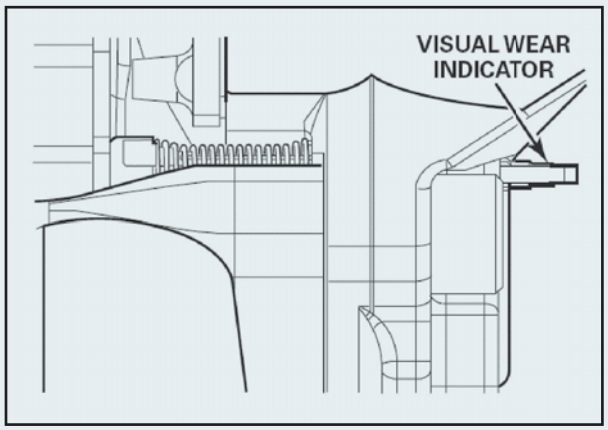


Figure 16

Visual Wear Inspection: WABCO Type V

a. Optical pad wear indication: To provide an optical pad wear indication the brake caliper is equipped with the edge (A) on the rim side. The brake carrier is equipped with the edge (B). The edges (A) and (B) are visible through the rim. The positions of the edges in this picture are only shown to illustrate the visible edges.

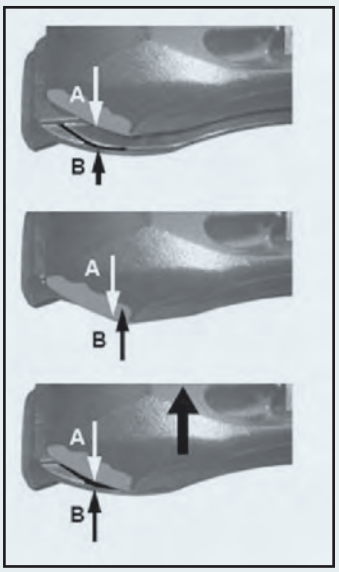


Figure 17

b. Pads in new condition: The edge (A) is positioned in front of edge (B) in the direction of the rim. Edge (B) is not visible.
c. Pads in worn condition: During pad wear the edge in the caliper moves (A) until the same position as the edge (B) in the carrier. In this case the pads have reached their wear limit.

NOTE: These visual inspection parameters are not intended as "out-of-service" criteria. Inspection with wheels removed is required to determine actual pad and rotor thicknesses as specified in **Figure 19**.

If any of the above conditions are not satisfactory, further service is required prior to vehicle operation.

3.2 INSPECTION LEVEL 2: WHEELS ON INSPECTION

NOTE: Prior to beginning any inspection, first check to make sure that the vehicle is properly parked with the parking brakes applied and wheels chocked.

Include all items in Level 1 plus the following:

a. Check for loose parts, broken or cracked air hoses, air system leaks, and damage to components. Check that brake hoses and sensor cables are properly secured, but allow the caliper full movement during normal operation and allow for full pad wear.
b. If possible, visually check the rotor for cracks, grooves, scoring, or hot spots.
c. Check that all brake pad hold-down springs are present and in the correct position.
d. An indication on the degree of pad wear can be obtained without removing the wheels in following manner as pictured in **Figure 17**.
e. With the parking chamber temporarily released and the wheels chocked, check for slight movement of the brake caliper. This very slight movement, less than 2 mm or 0.080" (approximately the thickness of a nickel) in the axial (inboard / outboard) direction, indicates

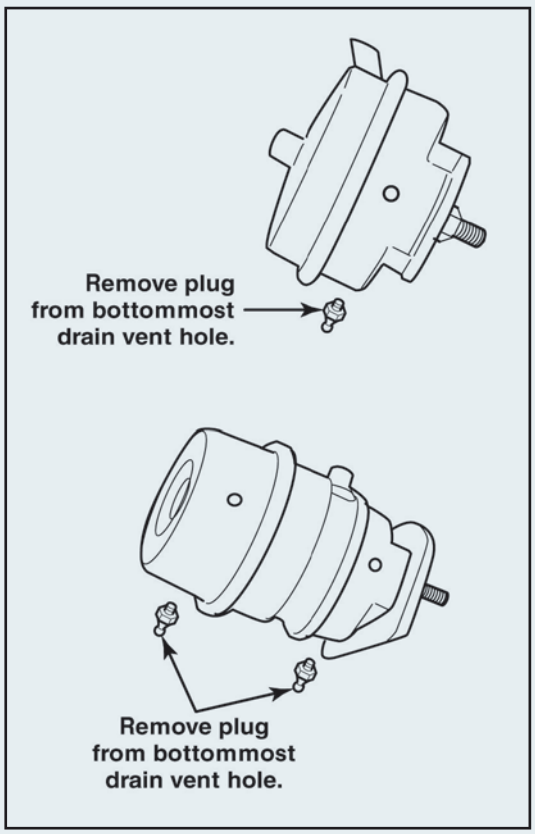


Figure 18

that the brake is moving properly on its slide pins. If the caliper has no movement or appears to move greater than 2 mm or 0.080" other problems may exist – remove the wheels for Level 3 Inspection.

f. The down facing vent hole in the brake chamber or service side of the parking brake chamber must be open and free of any debris. (See **Figure 18.**)
g. The service and parking brake chambers on both wheel ends of each axle must be air disc brake compatible, identical size, type and the same manufacturer.
h. Check that all dust caps and boots are present and that there is no damage visible to either.

3.3 INSPECTION LEVEL 3: WHEELS OFF MAJOR INSPECTION

NOTE: Prior to beginning any inspection, first check to make sure that the vehicle is properly parked with the parking brakes applied and wheels chocked. Please heed the following cautionary notes:

- Do not apply brakes when the pads are removed.
- Take caution that fasteners are installed to the proper torques. Please see individual brake manufactures maintenance manual for specific torque values.
- Wear safe eye protection. Park the vehicle on a level surface. Block the wheels to prevent the vehicle from moving.
- Use a jack to raise the vehicle so that the wheels to be serviced are off the ground. Support the vehicle with safety stands.

Include all items in Levels 1 and 2 plus the following:

a. Pad Inspection

⚠ **CAUTION**: Replace the pads on both brakes of a single axle or all four brakes of a tandem axle at the same time. If all pads are not replaced at the same time, poor brake performance will occur.

- Inspect the brake pads for excessive grooving or cracked friction material or if there is severe damage to the surface of the pad. Check if the friction material is loose or detached from the backing plate. Minor damage to the edge of the pad is permitted. If necessary, replace all brake pad assemblies on the axle(s).
- Measure the friction material thickness at both ends or at the thinnest point on the brake pad. Replace the brake pad assembly at or before the lining thickness reaches 0.12 inch (3 mm) at any point. See Item "E" in **Figure 19 on the next page**.

⚠ **CAUTION**: Consult brake manufacturing for maximum run-out specification.

- Inspect pad material for oil contamination. When pad material is oil soaked, it should be replaced. It is not recommended to "clean" and reuse an oil contaminated disc pad assembly. Follow the guidelines above and replace all wheel ends on the axle(s).

b. Pad Abutment Wear

- Remove the disc pads and pad retainer clips from the disc brake assembly.
- Inspect the disc pads and carrier surfaces for the presence of any dirt or contamination. (See **Figure 20**.)

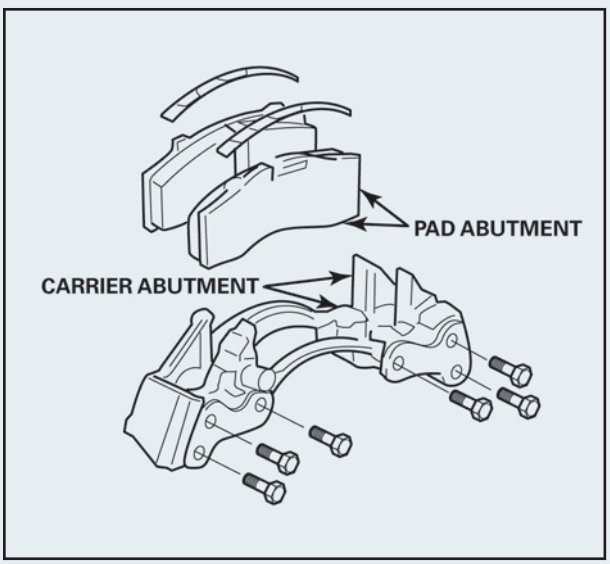
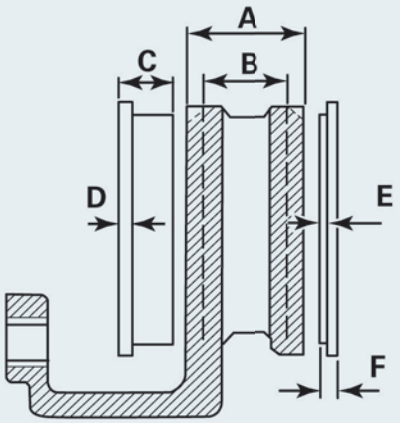


Figure 20

- Clean the disc pads and carrier surfaces as appropriate with a wire brush or similar tool. Take care not to damage boots, seals or other brake assembly components.
- Inspect the edges of the disc pads and the pad abutment surfaces of the carrier (as shown for any indications of noticeable wear, brinnelling or grooving, which would prevent the disc pads from sliding smoothly on the abutment surfaces or the carrier, or which would prevent full contact of the disc pads with the carrier abutment surfaces.



	Dimension					
	Rotor Thickness New Condition (A)	Rotor Thickness Worn Condition (B)*	Overall thickness of Pads New (C)	Backing Plate Thickness (D)	CVSA Minimum Thickness of Friction Material (E)	Minimum Overall Pad Thickness (F)*
Brake Type	**mm/inch**	**mm/inch**	**mm/inch**	**mm/inch**	**mm/inch**	**mm/inch**
Bendix I	45/1.77	41/1.61	30/1.18	8/0.31	3/0.12	11/0.43
Bendix II		37/1.46	30/1.18	9/0.35		12/0.47
Haldex		39/1.54	30/1.18	8/0.31		11/0.43
Meritor		39/1.54	29/1.14	8/0.31		11/0.43
WABCO		37/1.46	32/1.26	9/0.35		12/0.47

Notes:
B: If wear dimension B is within 3 mm of the minimum thickness at the time of reline, then the rotor should be replaced together with pads.*
*B**: Ensure that the wear on both halves of the rotor are approximately even, keeping in mind that they may not be symmetrical.*
F: Consult brake manufacturing for maximum run-out specification.*

Figure 19

- If the edges of the disc pads and the pad abutment surfaces of the carrier are no longer flat, smooth and undamaged, then the disc pads and / or the carrier should be replaced.
- If the edges of the disc pads and the pad abutment surfaces of the carrier are free of noticeable wear, brinnelling, or grooving, reinstall the disc pads in the carrier.
- With the disc pads installed in the carrier, measure the amount of clearance between the disc pads and the carrier abutment surfaces. The maximum permissible clearance due to disc pad wear and/or carrier abutment wear is 2.0 mm max. (See **Figure 21**.)
- If the maximum clearance exceeds 2.0 mm, replace the disc pads, and re-measure the clearance between the pads and the carrier.
- If the maximum clearance still exceeds 2.0 mm, replace the carrier.
- Carrier-to-torque plate fastener torque is important. Consult the brake manufacturer for the proper torque specification.

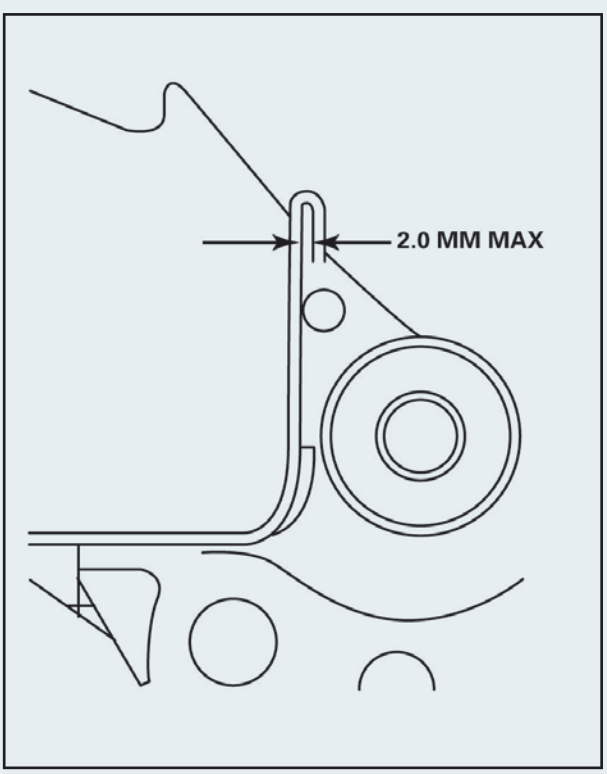


Figure 21

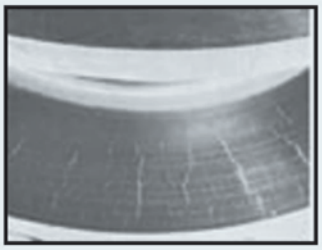
c. Rotor Inspection
- With the pads removed, rotate the wheel and inspect the hub and rotor assembly for damage.
- Inspect both sides of the rotor for cracks and heat checks. Replace the hub, rotor or entire assembly, if necessary.
- Check the hub and rotor assembly for damaged, loose or missing fasteners.

d. Rotor Conditions
- Cracks—When the crack extends through a section of the rotor, replace the rotor.

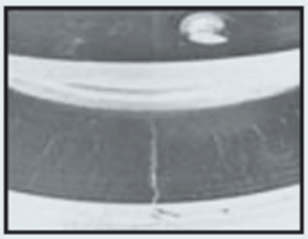
  NOTE: Many heat checks are similar in appearance to cracks. If in doubt, a crack is defined as a "surface split" radiating into or from an edge of the rotor and/or over 75 percent in length.

- Heat checks—Heat checks are short, thin, sometimes numerous, radial interruptions of the rotor braking surfaces. They are the result of disc brake operation. They are caused by the heating and cooling that occurs as the brakes are applied time after time. Heat checks will frequently wear away and reform. They may become braking surface cracks, depending on such factors as the lining and rotor wear rate, brake balance, and how hard the brakes are used. There are two kinds of heat checking: light and heavy. (See **Figure 22**.) If possible, visually check the rotor for cracks, grooves, scoring, or hot spots. (See **Figure 22 on the next page**.)
- **Figure 22** shows possible surface conditions on the rotor.
- Replace the rotor if it reaches the minimum allowable rotor thickness shown in the table below. Damage to components can result.
- Use a micrometer to measure the rotor thickness. If you are replacing the brake pads, the rotor should be replaced if the rotor thickness is less than shown in the table below.

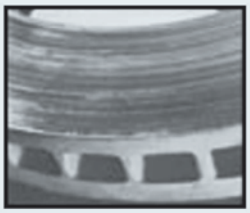
e. Rotor Identification
- The dimensions shown in **Figure 23** should help properly identify the correct replacement rotor for the brake used.



Example A1: Light Heat Checking

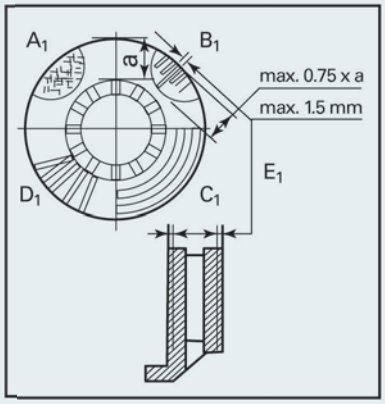


Example: B1/E1
Heavy Cracking greater than 75% of the Braking Surface Width



Example C1:
Deep Grooves or Scores

A1: Small cracks spread over the surface **are allowed**
B1: Cracks less than 0.06 in. (1.5 mm) deep or wide running in a radial direction, **are allowed**
C1: Grooves (circumferential) less than 0.06 in. (1.5 mm) wide **are allowed**
D1: Cracks in the vanes **are not allowed** and the **Rotor MUST BE REPLACED**
E1: Radial crack length cannot exceed 75% of the Braking Surface (a)

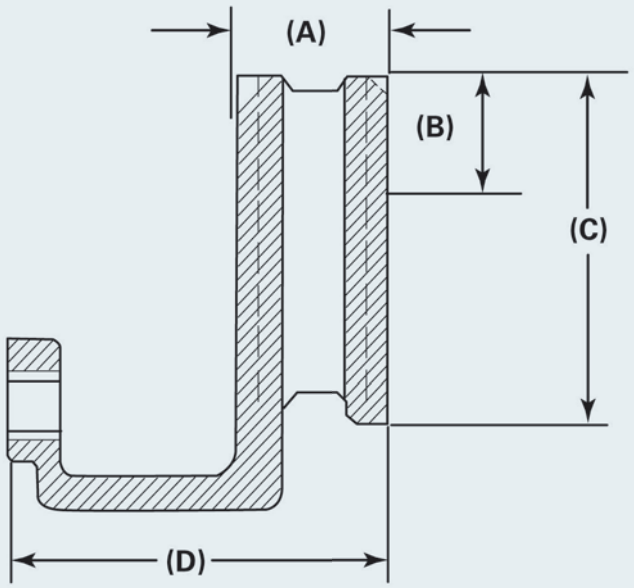


Brake Type	Dimension				
	A_1	B_1	C_1	D_1	E_1
All Disc Brakes	Allowed	1.5 mm (0.06 in.)	1.5 mm (0.06 in.)	Not Allowed	75%

Figure 22

f. Rotor Resurfacing
   - Rotor resurfacing is generally not required or recommended. Please consult your brake manufacturers' service manual for additional information. For additional information on brake rotors, please refer to TMC RP 608, *Brake Drums and Rotors*.

g. Brake Adjustment Inspection
   Brake adjustment is automatic and manual adjustment should not be necessary. Current adjustment condition can be checked with a dial indicator (preferred) or feeler gauge. The following procedures are suggested. For a dial indicator, do the following.



	Dimension			
	Rotor Thickness New Condition (A)	Rotor Width of Braking Surface (B)	Outside Diameter (C)	Overall Depth (D)
Brake Type	**mm/inch**	**mm/inch**	**mm/inch**	**mm/inch**
Bendix I	45/1.77	90/3.60	430/16.93	By Application
Bendix II	45/1.77	87/3.42	430/16.93	By Application
Haldex	45/1.77	90/3.60	430/16.93	By Application
Meritor	45/1.77	90/3.60	430/16.93	By Application
WABCO PAN 19-1	45/1.77	151/5.94	375/14.76	By Application
WABCO PAN 22-1	45/1.77	174/6.85	430/16.93	By Application

Figure 23

- Attach a dial indicator to the torque plate or axle frame. The dial indicator reading should be taken from a point on the backside of the caliper housing. (See **Figure 24**.)
- Check the brake adjustment by sliding the caliper back and forth, by hand, along the slide pins. Normal operating clearance should be between 0.5 mm (0.020") and 1 mm (0.040"). If the caliper slides more than 2 mm (.080") the brake is out of adjustment and requires further inspection or replacement.
- If the adjuster clearance is less or more than the dimensions outlined above, the adjuster may not be functioning correctly. Check adjuster function as noted above.
- For feeler gauge inspection, insert a feeler gage between the pad backing plate and its mating surface. Normal operating clearance should be between 0.5 mm (0.020") and 1 mm (0.040"). If the caliper slides more than 2 mm (0.080") the brake is out of adjustment and requires further inspection or replacement. (See **Figure 21** as shown previously).
- If adjuster clearance is more or less than the dimensions listed above, the adjuster may not be functioning correctly. Check adjuster function as noted previously.

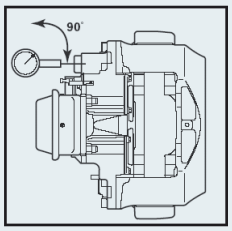


Figure 24

h. Brake Adjuster Function Check
Before beginning this procedure, check the air pressure gauge on the dash to insure that the air system has a minimum 30 psi of pressure.
- Remove protective cap from the adjuster screw.
- De-adjust the brake 1/4-turn with a box end wrench. If the brake does not de-adjust, the adjuster mechanism is not functioning properly and may need replacement. (See **Figure 25**.)
- Leave the wrench on the adjuster stem. Make sure there is adequate clearance for the wrench, and then actuate the brake several times.
- If the wrench rotates and maintains its position when you actuate the brake, the adjuster mechanism is working properly.
- If the wrench does not rotate in the direction of adjustment when you actuate the brake then the adjuster mechanism is not working correctly, the caliper may need replacement—consult the brake manufacturer.
- Make sure the brakes are properly adjusted before returning the vehicle into service.
- Reinstall the protective cap prior to returning the vehicle to service. If damaged, replace the cap.

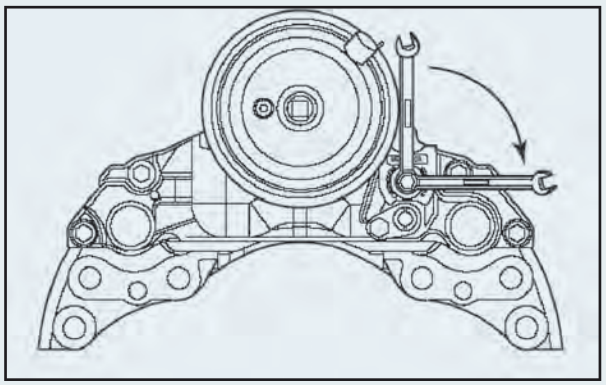


Figure 25

i. Inspection of Brake Assembly
Pad Removal
- Remove pad retainer bolt or pin and pad retainer bar. (See **Figure 26**.)
- Remove pad retainer spring along with the brake pads.
- Inspect brake pads for excessive grooving, cracked or loose friction material. Replace if any of these conditions are present.

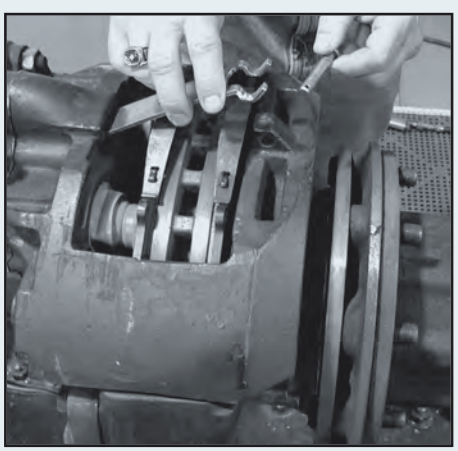


Figure 26

- Check the thickness of the pad material. The minimum dimension is 3 mm. Replace brake pads if necessary.
- Inspect pad springs/retainers for abnormal wear.
- Verify that the caliper moves freely by hand
- Inspect caliper slide pin and piston boots.
- Install new pads. Make sure that the wearable friction material faces the rotor.

Reinstall the retainer bolt or pin and retainer bar.

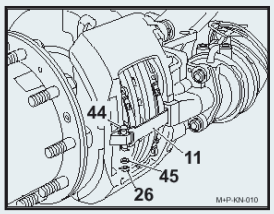


Figure 27

j. Pad Replacement

- Prior to installing new pads, inspect the condition of the piston boots
- Turn the adjuster screw (item 23) as shown in **Figure 28**, clockwise until the boots are clearly visible and inspect.
- If boots are damaged, they should be replaced.

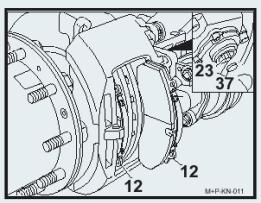


Figure 28

k. Pad Installation

- Turn the adjuster screw counterclockwise to fully retract the pistons to provide space for the new pads.
- Insert new pads and replace the hold down bar, pin, washer and retainer clip.
- Turn the adjuster screw clockwise until the pads are substantially tight against the rotor and back off two audible clicks to provide initial adjustment. Automatic adjustment mechanism will complete proper adjustment.

l. Actuator Piston Boots

- With pistons extended, carefully inspect the piston boots for cuts, tears, or burns; and ensure that they are properly seated. (See **Figure 29**.) If

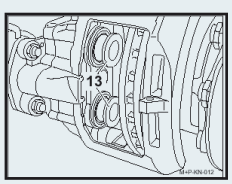


Figure 29

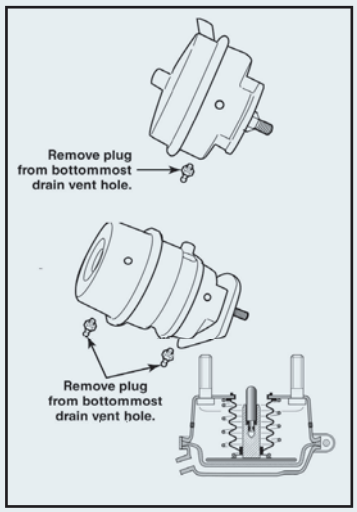


Figure 30

the piston boots are not intact, the caliper internals may have become contaminated. Consult the brake manufacturer's maintenance manual for further inspection and boot replacement instructions.

m. Lubrication

- No periodic lubrication is required for any of the air disc brake designs covered in this manual. Attempting to lubricate air disc brakes is discouraged and could void the manufacturer's warranty.

n. Air Chamber Inspection

NOTE: Service and parking brake chambers on both wheel ends of each axle must be air disc brake compatible and the identical size.

NOTE: To ensure proper performance and sealing, take care when replacing air chambers to make sure that the replacement chamber model and manufacturer are the same as original equipment. Inspect the seal surface of the caliper for signs of corrosion and pitting. (See **Figure 31**.) Consult brake manufacturer for any additional questions.

- Air disc brake chambers are different than drum brake chambers. Air disc brake chambers have an external seal and an internal boot to prevent contaminants from entering the caliper.

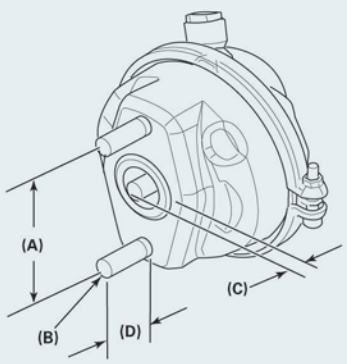
n. Final Inspections and Checks

- The wheel ends must be correctly installed for the proper function of the brak-

ing system. Refer to TMC RP 608 for proper wheel inspection and installation techniques.

- Take care that fasteners are installed to the proper torques. Please see individual brake manufactures maintenance manual for specific torque values.

⚠ **CAUTION**: All wheels and valve stems are not compatible with air disc brakes. Please check to make sure that the wheels being used are compatible with air disc brakes.



			DIMENSION *Metric Units Italicized*		
	Stud spacing (A)	*Stud size (B)*	*Push rod length (C)*	*Nut torque*	*Stud length (D)*
Brake Type	*mm*/inch	*mm*/inch	*mm*/inch	*mm*/inch	*mm*/inch
Bendix I	*120.7+/–0.25* 4.75+/–0.009	5/8"-11 UNC	*15+/–0.5* 0.59+/–0.019	*180-200* 135-150	*43* 1.69
Bendix II		*M16x1.5*			
Haldex		*M16x1.5* 5/8"-11 UNC			
Meritor		*M16x1.5*			
WABCO		*M16x1.5* 5/8"-11 UNC			

Figure 31

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CHAPTER 3: Advanced braking systems

Commercial vehicles are safer than ever, thanks to improved braking technologies

By CCJ Staff

There was a time not too long ago when antilock braking systems were considered advanced, state-of-the-art, top-of-the-line vehicle safety technology. Today, they're only a starting point.

In recent years, increasingly sophisticated systems have been developed to address a variety of truck safety issues from vehicle stability to accident avoidance.

The evolution continues. Today's advanced systems can respond to potential accidents even before the driver is aware of an impending crisis. Drowsy drivers are warned of unintended lane departures. Smart systems take control of braking and throttle to varying degrees to prevent rear-end collisions. Cameras capture video immediately before and after critical safety events.

In retrospect, the introduction of ABS set the stage for the wave of safety advancements. When the federal government mandated ABS on new air-braked tractors in 1997, the goal was simple: prevent a vehicle's wheels from locking in an emergency situation. In a nutshell, an electronic control unit monitors the difference between vehicle speed and wheel speed, and when safety thresholds are exceeded, sends signals that adjust air pressure for individual brake chambers.

Since then, suppliers of braking systems have focused on integrating additional electronic controls

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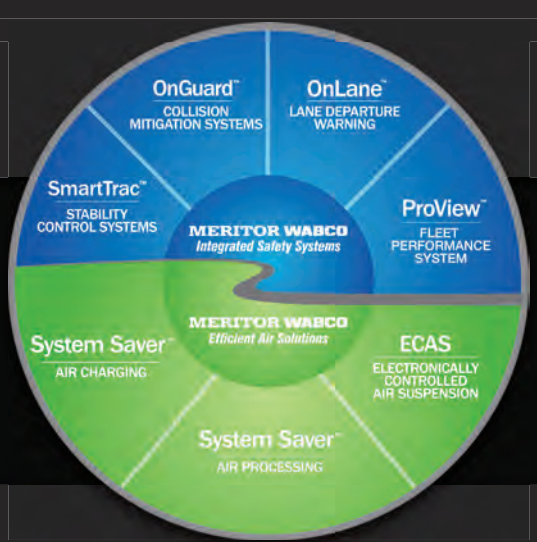
- OnLane™
- SmartTrac™ ESC
- Pneumatic ABS
- Hydraulic ABS

&

Efficiency Smart

- Air Compressors
- System Saver™ Air Dryers
- Brake System Valves
- Brake Actuators
- Electronically Controlled Air Suspension (ECAS)

For the Long Haul



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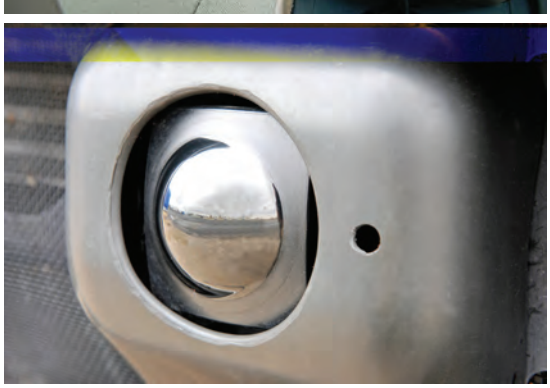


The latest stopping systems to hit the market are active cruise control systems that integrate braking. Meritor Wabco introduced the OnGuard system in 2008, and Bendix rolled out Wingman ACB in 2009. The systems integrate data from forward-looking radar units to provide onboard driver alerts regarding following distance and adjust throttle, the engine retarder and the brakes if necessary.

with basic ABS components. This chapter highlights those developments.

Stability control breakthroughs

The primary goal of ABS was to prevent a loss of vehicle control during emergency braking. That's a major improvement, but it proved to be only the beginning of the ways in which active safety systems can help prevent accidents.

One obvious need for improvement for decades has been in the area of vehicle stability. Due to their weight and high center of gravity, tractor-trailer combinations are susceptible to rollovers in situations involving sudden maneuvers or even while traveling too fast on sharp curves.

The need to curb rollovers and other stability crashes has led the industry toward adoption of stability control systems. Roll stability control is designed to determine when a vehicle is approaching the rollover limit and reduce throttle, apply the engine brake or, finally, apply the service brakes in a uniform manner, slowing the vehicle enough to pre-

vent a rollover. Stability control also adds the ability to apply the power unit brakes selectively, thus enabling it to straighten out a tractor that's starting to jackknife (oversteer) or plow-out (understeer) and may make more powerful emergency braking practical because of its capabilities in keeping the vehicle stable.

These systems build on ABS, adding standard brake apply solenoids, more sensors, processing capacity and sophisticated software. The latter contains the algorithms necessary to produce the right, complex reaction to a given panic-driving situation.

Both Meritor Wabco Vehicle Control Systems and Bendix Commercial Vehicle Systems offer stability control solutions on new tractors from all the major OEMs. Those two companies, as well as Haldex, offer trailer roll stability control. Haldex's trailer system ("TRS," for Trailer Roll Stability Control) can activate the trailer brakes selectively if sensing a rollover is near, or apply all four trailer brakes if slowing the vehicle quickly is essential. TRS – which is available as an aftermarket retrofit – offers an optional premium power cord extension that activates the trailer brake lights when the system is applying the trailer brakes and also records all unstable braking events for later review with optional software.

Bendix's trailer system is available in the aftermarket for retrofit because of "the perpetual existence of trailers," says Rick Conklin, project manager for Bendix ESP, the company's name for its electronic stability control system. The ESP and roll stability control systems apply the appropriate tractor brakes as well as all four trailer brakes through the normal tractor-trailer pneumatic connection, he says.

Mark Melletat, Meritor Wabco's director of marketing and customer service, says his company's tractor-based electronic stability control performs the same function. This means you don't need to have trailer roll stability control for the system to work on a rig; the separate trailer system enhances the performance of the tractor system. In addition, Meritor Wabco's SmartTrac suite of antilock braking, automatic traction control and stability control systems is available as a factory-installed option.

Safety's return on investment

Advanced braking solutions aren't free, and fleets must manage costs to be profitable. How can fleet managers make sure such systems are worth the investment?

The key is to reduce accidents. Insurance companies typically won't offer premium discounts for installation of advanced safety systems. Rather, insurance costs will drop if crashes decline. Besides, many fleets are largely self-insured, and numerous major costs involved in rollovers aren't fully covered by insurance anyway, including deductibles, service failures and, of course, potential loss of life. Several proposals have been drafted as a means for the federal government to encourage the purchase of commercial vehicle safety enhancing systems and products; these include the issuance of grants and Compliance Safety Accountability credits.

The real savings can be measured by tracking the reduction of rollovers and loss-of-ccontrol crashes. Bendix says that one of its customers with 100 trucks saw its rollover rate of about three per year drop to one in three years after installing electronic stability control. From a financial perspective, a trucking company operating on a 5 percent margin needs to generate an additional $2 million in revenue to cover every $100,000 in accident costs.

The benefits of stability control systems were quantified in two studies sponsored by the National Highway Traffic Safety Administration and conducted by the University of Michigan Transportation Research Institute. The first dealt with tractor semi-trailers and found if ESC was installed on all tractors, the result would be a yearly reduction of 4,659 crashes, 126 fatalities and 5,909 injuries. The same type of analysis was conducted on single-unit trucks greater than 10,000 lbs. If ESC was installed on all of these vehicles, the result would be a yearly reduction of up to 5,000 crashes, 1,000 to 2,000 injuries and 136 fatalities.

NHTSA issued a Notice of Proposed Rulemaking in May 2012 that would require all new truck tractors and certain buses greater than 26,000 lbs. to be equipped with electronic stability control systems. These systems must be capable of reducing the likelihood of rollovers and crashes due to a loss of control. The notice contains equipment standards and performance requirements. The U.S. Department of Transportation says a final rule is expected by the end of July 2014 with requirement implementation to follow in approximately two years.

ESP adds a yaw rate sensor and a steer angle sensor to the lateral acceleration sensor needed for roll stability. Conklin says the system measures the angle of the vehicle's turn and compares that to the driver's input. If they don't match, it applies brakes selectively – for example, applying only the right front drive axle brakes – to bring the vehicle into line.

Combining roll directional control capability in stability control is advantageous, says Fred Andersky, Bendix Heavy Vehicle Systems' director of marketing for controls, who cites a National Tank Truck Carriers' instability study conducted by Batelle Institute that found that 53 percent of rollovers occur on straight roads. "The driver slips off the edge of the pavement, and then overcompensates with corrective steering," Andersky says. "You often end up with loss of control and a truck on its side."

Stability control is also starting to be installed on straight trucks in addition to tractors. Straight trucks have different dynamics and are typically less prone to roll than a tractor-trailer combination due to its lower center of gravity. Thus, the direction control capability integrated in stability control systems becomes very important for these types of vehicles.

What changes when stability control is installed? In Bendix's case, in addition to the sensors already mentioned, a different, more powerful electronic control unit (ECU) is installed with the Bendix tractor systems to control both the tractor ABS and the roll stability control or electronic stability control system, rather than adding a separate ECU, Conklin says.

Melletat says that in addition to the inputs from the ABS wheel sensors, modulator valves and data communication, a stability control system includes a lateral accelerometer, yaw rate sensor, steering angle sensor, brake pressure demand sensor and electronic solenoid valves for active brake control.

Meritor Wabco is releasing a new generation of its SmartTrac stability control system called ESCsmart. This new system has the ability to self-learn dynamic vehicle characteristics, decreasing time to market for new applications, reducing the amount of physical testing required, and simplifying calibration and maintenance.

The Haldex TRS uses its own ECU, wheel speed sensors, five pressurized transducers and an integral brake apply function to monitor and assist in controlling the trailer dynamics and speed, with or without driver intervention.

Beyond stability control

Stability control systems work by analyzing data that is limited to the truck or tractor-trailer itself. They instantly measure vehicle dynamics and adjust braking and throttle systems to avoid rollovers, jackknifes and similar loss-of-control events. One thing stability control systems can't do is see what other vehicles are doing. But the newest solutions built on ABS allow the truck to react to other vehicles on the road.

The National Highway Traffic Safety Administration published a study conducted by the University of Michigan Transportation Research Institute in June 2013 that verified the significant benefits of forward collision avoidance and mitigation systems installed on tractor-trailers and straight trucks. Results indicate, if fully implemented, these types of systems are capable of reducing 44 percent of the fatalities and 46 percent of the injuries that occur from rear-end crashes. Future systems with higher levels of active braking could be even more effective.

In 2008, Meritor Wabco introduced the OnGuard system, which combines forward-looking, radar-based forward collision warning with adaptive cruise control and active collision mitigation braking. OnGuard automatically applies foundation brakes, both to alert the driver and to decelerate the vehicle, when it determines a potential forward collision is imminent.

"The driver is still the most important element in maintaining vehicle safety," says Jon Morrison, president and general manager of Meritor Wabco Vehicle Control Systems. "However, the system can provide the additional split-second deceleration needed to maintain control of the vehicle in an emergency situation."

Like other collision warning systems, OnGuard offers visual and audible alarms as alerts to the driver of potentially dangerous situations. OnGuard also

Trailers can overturn so quickly that drivers don't even realize they are in trouble in time to react. Onboard stability systems such as the Meritor Wabco systems installed on this demonstration unit intervene and brake the vehicle before a rollover becomes inevitable.

offers automatic foundation brake intervention, which can be as great as one-half of a full brake application. If the driver reacts, however, his actions will cancel out the automatic intervention. OnGuard further integrates the collision warning and mitigation system with ABS and stability control, allowing various levels of safety control systems using a single ABS electronic control unit.

Meritor Wabco released a new generation of OnGuard in January 2013. The system has a new dual beam radar sensor with the capability of seeing objects up to 650 feet away and detecting objects in parallel lanes. It includes a simplified mounting design with automatic horizontal and vertical alignment, improved object tracking and resolution and the ability to warn of stationary objects (objects that the radar sensor never saw move).

The system quickly coordinates responses from the engine, transmission and antilock braking and stability control systems through communications across the SAE J1939 data network. OnGuard provides feedback to the driver through the in-cab dash display, which includes a progressive audible alert. Meritor Wabco says the sequence of monitoring, warning and intervention is an important part of its strategy to reduce false alarms.

OnGuard is one of the latest elements in what Meritor Wabco calls its "Integrated Safety Systems," which also includes ABS, stability control, Lane Departure Warning and side sensing.

In 2009, Bendix unveiled Wingman ACB, an adaptive cruise control system integrated with braking.

Wingman ACB uses a radar sensor mounted to the front of the vehicle and Bendix ESP full stability technology to actively assist drivers in maintaining set following distances between trucks and forward vehicles. With cruise control on and speed set, Bendix Wingman ACB is designed to warn drivers of vehicles they are approaching too quickly and actively intervene by reducing throttle, engaging the engine retarder and, if needed, automatically applying the foundation brakes to help maintain following distance.

Even when the vehicle is not in cruise control, the driver receives following distance alerts from Wingman ACB, which is a benefit in situations when cruise control should not be used, such as poor weather or congested traffic.

What's next

Collision mitigation systems and stability control are major advances, but there's even more to come from the integration of ABS and vehicle electronics. The

ABS advantages

Antilock braking systems can help fleets lower maintenance costs

Maintaining antilock braking systems properly can help reduce accidents and improve a fleet's inspection record, both of which will help with insurance rates along with reducing downtime. Further enhancing equipment by installing stability control and collision mitigation systems carries the process further.

ABS is designed to be self-diagnosing, which has been a boon when it comes to inspection and troubleshooting, but it also has opened the door for inspectors when it comes to giving out citations. While active testing of ABS with specialized equipment at roadside is impractical, a lit-up ABS malfunction indicator lamp is considered grounds for a citation on any vehicle where ABS is legally required.

A simple system

"ABS maintenance is pretty simple because of the system's self-diagnostic capability," says Mark Melletat, Meritor Wabco's director of marketing and customer service. "There is no preventive maintenance as far as we are concerned except for the wheel speed sensor." The mechanism is self-adjusting, he adds, and if a technician gently pushes it down until it contacts the sensing tone ring, it will adjust itself properly to the proper 0.04-inch gap.

"Always adjust it this way when servicing the brakes," Melletat says. "The holding block is ferrous with a brass spring clip inside. A spring clip provides the holding force." However, if a high dose of magnesium chloride has corroded the block, the sensor may not be able to properly adjust on its own.

"It's thoroughly lubed at the factory and considered to be lubed for life, but tell your technicians to check it," Melletat says. "In a few applications, like city transit, it may be advisable to clean and relube the sensor periodically."

Since ABS valves require clean air to ensure proper operation and prevent corrosion, servicing the air dryer as required will help reduce failures. Air dryers normally work well and provide reliable service unless the air compressor is worn and passing oil, thus contaminating the air dryer desiccant. Check compressor performance with a blot test for the air dryer that's available in the aftermarket, Melletat says.

Fred Andersky, Bendix's director of marketing for controls, says technicians should shut off the vehicle and then turn the ignition back on while listening for the "chuff test," which runs the ABS valves through a full operating sequence. "There will be an audible change in the sound when there is a problem," Andersky says. "If there is a leak, you'll hear air being expelled."

Bendix offers a remote diagnostic unit, or RDU, to

industry is continuing to build tools for fleet managers in the area of diagnostics, monitoring and telematics. Meritor Wabco's latest generation of ABS, for example, allows for the capture of data about braking and stability events, creating a record of accurate, detailed information that fleet managers can use to identify trends and build more effective driver training programs.

Meritor Wabco also notes that using the tractor's data bus, status messages can be relayed to an onboard computer with telematic capabilities. Fleet managers can correlate stability and braking events with precise time and location data, or use exception-based reporting to determine whether a vehicle requires maintenance. In addition, critical event video (before and after the event) can be stored and downloaded from its Lane Departure Warning camera.

"We continue to evolve our vehicle control systems to offer our customers added features and flexibility as well as enhanced performance," says Morrison.

The Meritor Wabco ABS system combines 4-sensor, 4-modulator ABS with an electronic control unit; a lateral accelerometer; a steer axle sensor that measures steering wheel position; and yaw sensors that tell the ECU how the tractor and trailer actually are leaning.

make it easier for technicians to interpret trouble codes and enable them to do so without using a laptop, Andersky says. Also, air dryer performance depends upon proper spec'ing and brake system maintenance, he says. He also warns against using alcohol, which plays havoc with the supply side of the air brake system by washing the lube out of the ABS valves.

Haldex recommends making sure the ABS ECU is connected properly and securely to the trailer wiring harness through the industry standard 5-pin connector.

Also, make sure 7-way connectors are maintained adequately to eliminate corrosion at the connector terminals to ensure proper power flow from the tractor. Ensure that wheel speed sensors are installed properly and functioning on installation, replacement, or upon wheel-end maintenance according to ABS service manuals.

Haldex also recommends use of full-length sensors, rather than short sensors plus extensions, to minimize the number of electrical connections; as well as use of dielectric grease on all electrical sensor and extension connections.

The value of maintenance

That's what fleet owners are supposed to do regarding ABS maintenance. But are they actually doing it?

According to Melletat, most fleets can address the small number of problems that may develop on tractors and trailers. Activated ABS warning lamps are typically caused by a sensor out of adjustment, a faulty valve or an opened circuit. Fortunately, many such problems cause reduced function rather than disabling the entire system. "Use of diagnostic software, maintenance and training information available on the company's website (www.meritorwabco.com) simplify any maintenance issue that results," he says.

Andersky believes most fleets can manage most maintenance challenges and says that Bendix is doing all it can to help that happen. A technician can go to www.bendix.com and download ACom software to help with troubleshooting or request a CD for installation.

Each of the manufacturers offer ABS that can be retrofitted for older trailers. Meritor Wabco and Haldex systems can cost as little as $500. Also, reduced tire flat spotting is an immediate benefit that helps pay for the cost of the system even before it has a chance to improve the fleet's accident record. ABS also serves as a building block that allows easier installation of stability control.

CHAPTER 4: Air brake inspection

Frequent, thorough air brake component inspection can lower risk of brake failure and out-of-service orders

By Jack Roberts

Inspecting air brakes should be done any time a truck or tractor is in the shop as an integral part of a preventive maintenance schedule to ensure safe operation on the road. If you are inspecting brakes, you should become familiar with federal and state periodic inspection requirements as well as those of the Commercial Vehicle Safety Alliance. Anyone performing required periodic inspections must meet specific criteria in terms of experience and training. The CVSA criteria are applied at random roadside inspections in the United States and Canada, and if your vehicle cannot meet these criteria, it will be placed out of service.

Generally speaking, a commercial vehicle air brake system should be visually inspected at least every three months, with more thorough inspections carried out according to application and manufacturer recommendations. This often includes an in-depth inspection for linehaul tractors every six months or 100,000 miles – whichever comes first – and every four months in on-highway linehaul applications when seals are replaced and brakes relined. Bear in mind that

application plays a major role in air brake inspection intervals. Trucks and tractors working in harsh vocational and off-highway environments require more frequent inspections since abrasive materials found in such workplaces will accelerate lining wear and aggressively corrode other brake system components.

Visual inspection should focus on obvious signs of worn or damaged parts. But you should also be alert for more subtle signs of problems: chafed parts, poorly routed air lines or any indication that a component could eminently fail. Experts recommend you inspect the air brake system as a whole entity at one time, starting at the front and systematically working your way toward the back of the vehicle. Since abundant, clean air is the very lifeblood of any air brake system, start your inspection with the compressor under the hood.

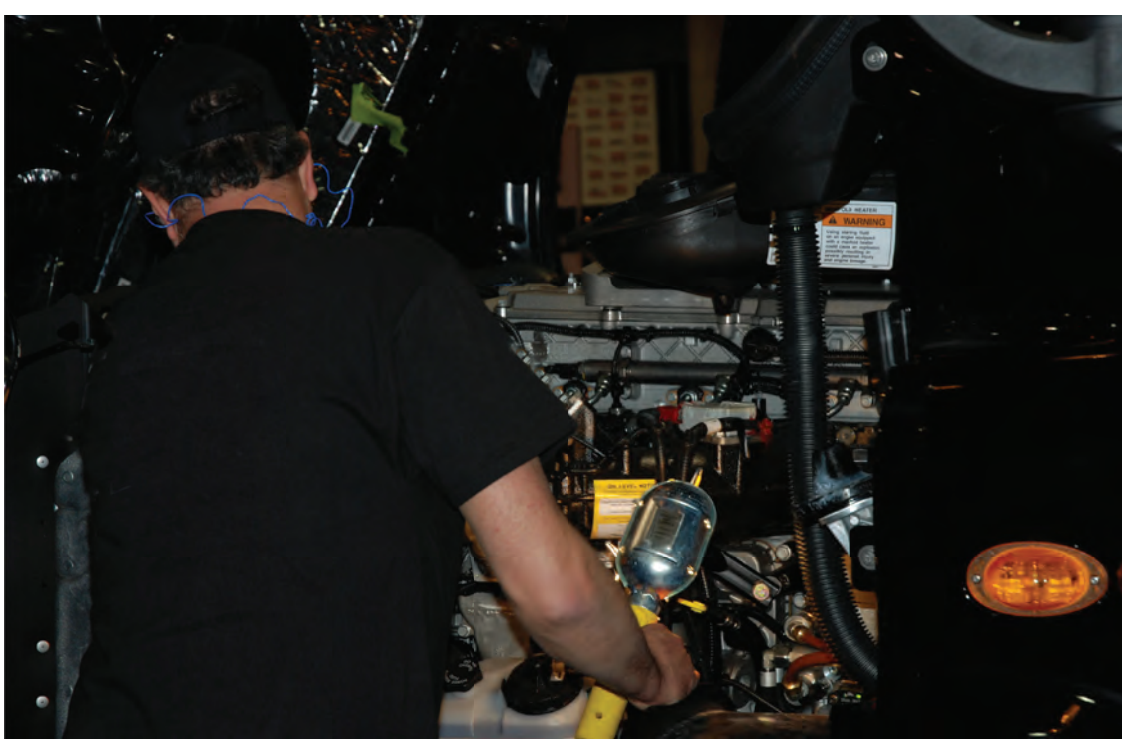
Compressor check

If you're working on an older model truck or tractor, start by inspecting its air compressor drive belt for proper tension, cracking and general wear and tear before you do anything else to the belt. Next, start the engine. According to Bendix, after it is warmed up, run it at full-governed rpm. The air compressor should build pressure in the system from 85 to 100 psi in 40 seconds or less on vehicles with normally sized air reservoirs. If it takes longer than 40 seconds to reach specified pressure levels, you're going to have to check the system for leaks or problems with the air compressor.

During your PM inspection, disconnect the discharge line from the compressor to see if it's clotted up to the point where its inner diameter is noticeably reduced. That's a sure sign the compressor is passing excess oil and needs service. An air compressor can introduce oil into the brake system if its rings are worn. The oil can gum up components and damage brake valves. Following a PM schedule for changing air compressor oil (or engine oil if the compressor uses or shares it for lubrication) is the easiest way of preventing premature ring damage.

Leaks and adjustment

Once the compressor has been checked, it's time to make sure there are no leaks in the air system. Start the engine and run it until the air brake system is fully



Any air brake inspection should start under the hood with brake compressor and air line checks.

pressurized. With the air brakes released, shut off the engine, release the service brakes, and time the resulting air pressure loss. The loss rate should be less than 2 psi per minute for straight trucks and less than 3 psi per minute for combination vehicles.

Next, apply the service brakes to at least 90 psi, and time the pressure drop while holding steady pressure on the pedal. (Don't count the initial air pressure drop that will occur when you apply the brakes.) Here, the air pressure loss rate should be less than 3 psi per minute for straight trucks and less than 4 psi per minute for combination vehicles.

If the pressure on the gauge drops more than that, you've got an air leak to track down. One tried-and-true method of locating air leaks is to paint the air lines and connections with soapy water and watch for bubbles. You can also use an ultrasonic leak detector. Refer to the CVSA guidelines for specific out-of-service criteria.

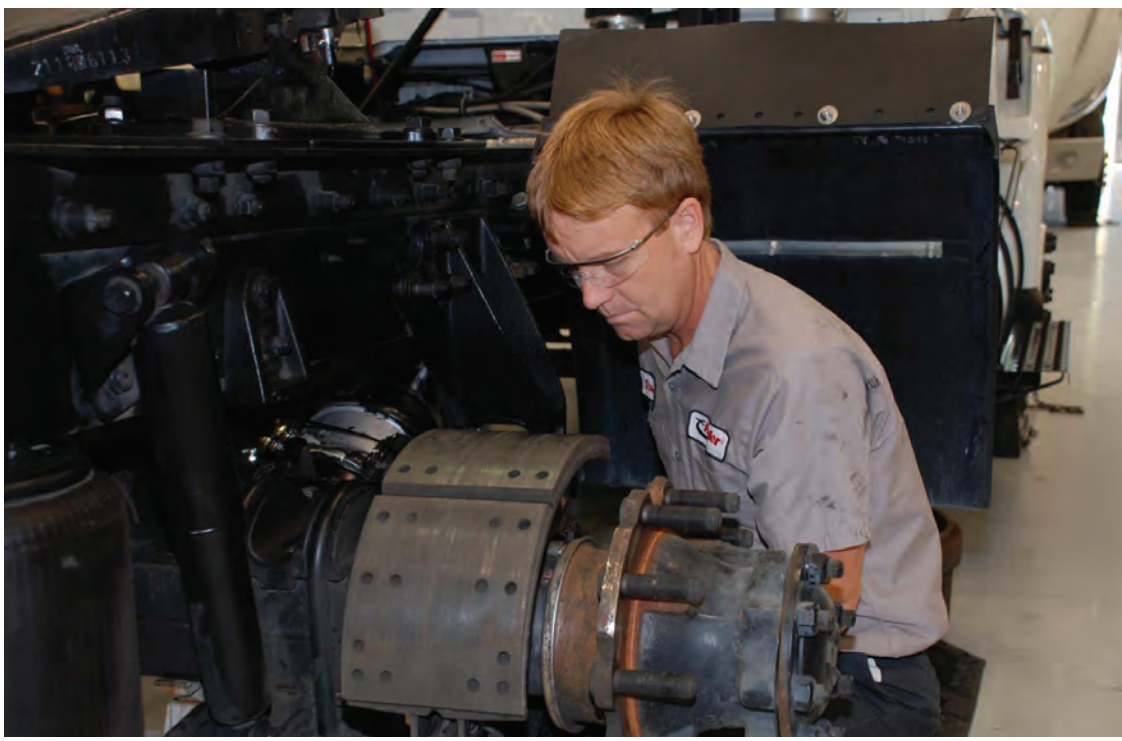
If the system is holding air, you can move on to wheel end and brake component checks. Begin by checking that both wheel ends of each axle have the same linings and drums. All four tandem-axle wheel ends also must have the same linings and drums. Remember that it is not necessary for the front axle brakes to be the same as the rear driving axle brakes.

Now you're ready to check all the brake chambers and make sure the spring brakes are applying and releasing as they're supposed to. Improperly adjusted brakes can cause a host of technical problems, especially when all the brakes on the vehicle are not adjusted to the same degree. When one or more brake assembly is out of adjustment, they're not doing their fair share of the work in stopping the vehicle. This results in brake imbalance and increased stopping distances. Of course, this means that other brake assemblies are doing extra work stopping the vehicle. So bear in mind that while a heat-damaged drum and prematurely worn linings at one or more wheel ends could indicate a dragging brake, it could also be a sign of an out-of-adjustment brake elsewhere on the vehicle.

To start, the return springs must retract the shoes completely when the brakes are released. Likewise, the spring brakes must retract completely when they are released. Then measure brake chamber strokes. To do this, check both the free stroke and the power stroke at each wheel end. Free stroke indicates how far the pushrod moves before the lining contacts the drum. Power stroke indicates how far the pushrod moves when the brake chamber is pressurized to 80-90 psi. Before taking measurements, verify that the parking and service brakes are fully released.

Next, measure the distance from the center of the

Check for air leaks by fully pressurizing the system, applying the brakes and timing any pressure drop. Less than 3 psi per minute for straight trucks and 4 psi per minute for combination vehicles is acceptable.



To avoid imbalance problems, make sure all brake chambers and spring brakes are applying and releasing as they're supposed to.

large clevis pin to the mounting surface of the air chamber while the service brake is released. This is your released, or reference, position. Use a pry bar to move the slack adjuster just enough to bring the linings in contact with the drum, and again measure the distance from the face of the chamber to the center of the large clevis pin. (If it is out of adjustment at 80 to 90 psi, you may be in violation of CVSA out-of-service criteria.) The difference between these two measurements is the free-stroke. Free-stroke should be 0.5-0.625 inch (12.7-15.9 mm) for drum brakes. If the measurement is too short, linings can drag, and damage to components can result. To determine power stroke, start the engine, build reservoir pressure to between 90 and 100 psi and then shut the engine off (if pressure is over 100 psi, pump the service brake to bring it back down into the 90 to 100 psi range). Fully apply the service brake (pedal to the metal) and once more take a measurement from the large clevis pin to the face of the chamber. This part will take two people, one to apply the pedal and one to make the measurement. The difference between this last measurement and the reference or release stroke measurement is your power stroke.

The proper power stroke is a function of the brake chamber type, and you must refer to a table in the manufacturer's literature to obtain the maximum allowable value. If the power stroke is too long, braking power (and vehicle safety) will be reduced, and you can be put out of service at a roadside inspection.

While it is OK to adjust manual slack adjusters to obtain the proper free and power strokes, it is not OK to adjust automatic slack adjusters. The adjusting nut on the automatic slack adjuster is just for setup during initial installation of the adjuster or during brake relines; never use it otherwise. If they are not maintaining the correct strokes, something is either wrong with the adjuster or there is a problem in the foundation brake, and further diagnosis is required.

Lubrication is a crucial aspect of proper brake system maintenance. If you're lubing a truck chassis as part of a scheduled PM check, it's a good idea to make sure brake adjusters, air chamber brackets and anchor pins are properly lubricated as well. Doing so will ensure proper automatic adjuster function and that manual

adjusters are easy to manipulate. It also allows camshafts to rotate freely and reduces wear and tear on components. Always follow manufacturer recommendations when lubricating brake components, and take special care to ensure no grease or oil gets on brake linings.

Relining and component inspection

Sooner or later it will be time to reline the brakes on your commercial vehicles, although a huge number of variables such as weather, operating environment, application and PM schedules make reliably predicting intervals impossible. Careful tracking and experience will give you a general idea of when the vehicles in your fleet are due for brake relining – but remember that the same variables that make broad relining recommendations impossible can and will shorten or lengthen service intervals for individual trucks. This is why a good inspection policy is so important for good brake maintenance programs.

As noted, lining thickness should be measured whenever the vehicle is being serviced – or at least once every three months. If the thinnest part of the brake lining is down to about 1/4-inch thickness, it's time to replace the linings. Most linings today have a wear indicator machined into the friction material. In many cases it's a divot or a line across the material to help you determine if replacement is required. While you're examining lining material depth, it's also a good idea to look for cracks along the edges of the shoe and cracks in the assembly where the rivets are found.

A cracked lining will definitely put that vehicle out of service, so if you find anything amiss, replace the shoes even if the lining material is not worn down to critical levels. You should also check the anchor pins for corrosion and wear, and replace them as needed. Check the brake shoes for rust, expanded rivet holes, broken welds and correct alignment. Replace a shoe with any of the above conditions. Additionally, check the spider for expanded anchor pin holes and cracks. Replace any damaged spiders and anchor pin bushings. Inspect the camshaft bracket for broken welds or cracks, and verify correct alignment. Any damaged brackets must be replaced at this time. (For more detailed information on brake relining, see Chapter 8, page 78.)

Brake drums don't wear as quickly as linings, of course, but now is a good time to inspect them and make sure they are in good operating order, too. You should

Generally speaking, air brakes should be inspected at least every three months. Incorporating brake inspections into your PM checks is a good way to do this.

never allow a vehicle to leave your shop with a brake drum worn or machined beyond the discard dimension indicated on the drum, as this fault may not allow the brake system to operate correctly, causing damage to other vehicle components or resulting in serious injury. Also replace any brake drum if it is out-of-round. Do not turn or re-bore a brake drum, which decreases the strength and capacity of the drum. Check the brake drums for cracks, severe heat checking, heat spotting, scoring, pitting and distortion, and replace them as required.

When replacing brake shoes, you should also adhere to the manufacturer's recommendations. Simply matching the friction letters in the edge code (last two letters in the edge code) does not ensure the part's original friction and wear characteristics will be present in the new part. (For more on brake lining selection, see Chapter 7, page 69.) To get the same characteristics, you must match the entire edge code.

Once you've determined the correct brake shoes, make sure they correspond in size to the parts they're replacing and that all rivets are tight, shoe-to-lining clearances are correct and all slots and holes are the proper shape and size.

Now is a good time to look carefully at cams and camshafts in the brake assemblies. The cam faces should be smooth and free of any pitting, scoring, ridges, cracks or flat spots. Camshaft journals should be smooth, and any cracked or deformed splines should be replaced. Move the S-cam up and down to check for any radial play. Some movement – only a few hundredths of an inch in either direction – is permitted, although excessive movement can cause uneven brake application and chatter. Use a dial indicator if you're not sure.

Check the chamber brackets for cracks, bent areas, looseness or any worn or damaged bushings (or bearings, if so equipped) and seals. All brake chambers should be inspected, keeping an eye out for cracks, clogged vent holes, bent pushrods, loose mountings or air fittings and clamps. Look over the brake adjusters as well. Again, you're looking for cracks, damaged splines, worn clevis pin bushings or sticking adjustment nuts.

Although some technicians opt to inspect return springs and keep them in service, most manufacturers recommend replacing return springs each time the brakes are relined. Return springs are highly stressed in normal driving conditions, and even if they are slightly corroded, there's a good chance they could fail. Before you service a spring chamber, follow the manufacturer's instructions to compress and lock (cage) the power spring. Also verify that no air pressure remains in the service or spring chamber before you proceed, as the sudden release of compressed air can cause serious personal injury and damage to components.

Additional inspection recommendations

Brake system veterans offer the following well-accepted practices for inspecting air brakes:

• Occasionally squeeze rubber hoses to check for soft spots that indicate internal damage. Blisters inside hoses can restrict air flow and adversely affect system performance. Never pinch hoses with pliers or vise grips, as this will initiate such damage.

• Have drivers exercise care when making tractor-trailer air connections. The gladhands should be checked for debris and wiped down or tapped out if necessary. There's no practical way to completely purge an air system, so a lot of what goes in stays in. Accumulated foreign matter will eventually interfere with proper system operation. Also, air lines should be suspended well above deck plates to prevent hose chafing.

• Wherever possible, specify that brakes be mounted so that, as they are applied, S-cams rotate in the same direction as the wheels they serve. When S-cams apply opposite the direction of wheel rotation, hardware and linings wear out more quickly, and brakes are noisier.

• Don't let the compressor unloader be the forgotten component. Once a year, remove and lubricate it and replace all rubber parts.

• Don't mix manual and automatic brake adjusters on a vehicle. That's asking for an adjustment imbalance. If you must do it, never mix them on the same axle.

• Use only recommended air dryer or system anti-freeze chemicals. The wrong ones can attack rubber parts and cause serious system leakage.

• Maintaining brake systems before trouble occurs will prevent lots of problems and minimize ones that crop up. You can always take the "Fix it when it breaks" approach, but in the long run, it's going to cost you.

RP 619B **VMRS 013-010-001**

AIR SYSTEM INSPECTION PROCEDURE

PREFACE

The following Recommended Practice is subject to the Disclaimer at the front of TMC's *Recommended Maintenance Practices Manual*. Users are urged to read the Disclaimer before considering adoption of any portion of this Recommended Practice.

PURPOSE AND SCOPE

This Recommended Practice (RP) provides guidelines for inspecting air systems used on air-braked commercial vehicles.

GENERAL GUIDELINES

Personnel must exercise care to:

- Avoid personal injury to self and others, follow safety rules and use common sense.
- Maintain cleanliness of inspection area and catch contaminants from bleedoffs, etc.
- Use proper tools.

EQUIPMENT

The following equipment will be needed:

1. Two 0-150 psi air gauges with drain cocks.
2. Two 50-cu.in.tank test units (see **Figure 1**).
3. A 0-to-150 psi air gauge with drain cock on a six-foot flexible hose.
4. A 2-1/2 gallon bucket.
5. A 12-inch scale.
6. One set of outside calipers (11-inch minimum diameter).
7. A creeper.
8. Pliers.
9. A 3/8-to-3/4-inch set of open-end wrenches.
10. For trailer only leak tests, a 1450-in^3 reservoir, regulator and shut-off cock.

PROCEDURE

1. When the vehicle first enters the inspection lane, shut off engine and chock wheels fore and aft to prevent movement of the vehicle.
2. Complete the top portion of your company's inspection form.
3. Check for operation of the pressure relief valve. (Start engine and charge the system to full pressure, shut engine off and pull relief valve stem.)

3a. Check the operation of the antilock braking system (ABS) malfunction indicator lamp on each vehicle (model year 1998 to present), including in-cab lamp (model year 2001 to present). With the ignition key cycled on, the lights must turn "on" then go "out" after a few seconds.

4. For combination vehicles only, place the tractor protection control lever or dash knob (trailer air supply or trailer emergency valve) in the emergency (air applied) position and install a 50-cu.in. tank test unit in the supply (emergency) and control (service) lines at the gladhands; open shut-off valves on test units,

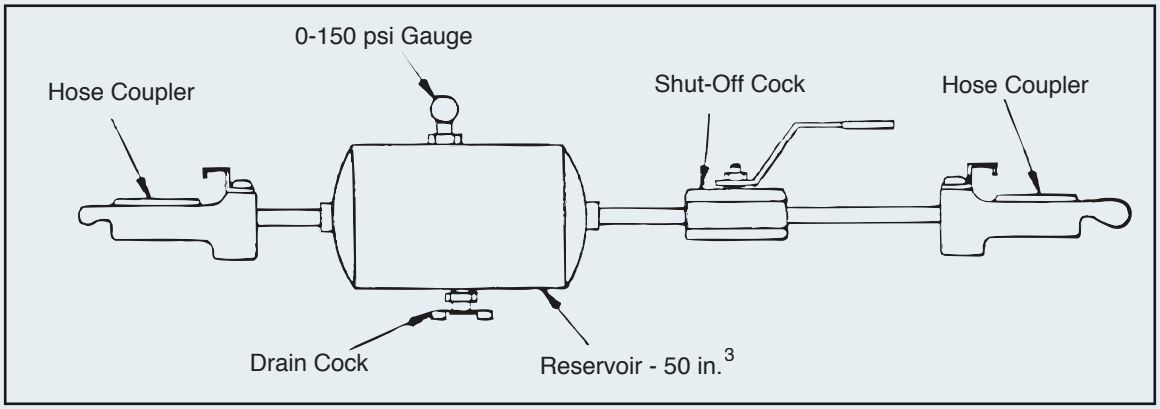


Fig. 1: Diagram of a 50-cu. in. Reservoir Test Unit

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and connect trailer gladhands.

5. For vehicles without an attached trailer, also connect a 50-cu.in. test unit to the supply (emergency) and control (service) lines at the gladhands with the shut-off cocks closed.

5a. For trailer only tests connect a 1450-in^3 test unit to the supply (emergency) line.

6. Place the tractor protection control (trailer air supply or trailer emergency dash valve) back in the normal position (air released) and release any other brakes that may be applied. The transmission of the vehicle remains in neutral throughout the test and all brakes must be in the released position, except as noted.

7. Start engine and charge the system to maximum pressure and shut off engine.

8. Starting upstream (nearest to the air compressor) and using the bucket to catch expelled contaminants, partially open the drain valve on the wet tank and let slowly escaping air remove any contaminants until the air is depleted. Remove the drain cock and install the hose and gauge assembly in the drain port of the wet tank.

⚠ **CAUTION**: Make sure drain valve is not plugged prior to removal.

9. Draining the wet tank should not exhaust the pressure in the supply (emergency) line as noted at the gladhand test gauge. If pressure loss is noted, repair or replace the check valve (at either the primary or secondary reservoir).

10. Repeat the above draining procedure with each protected reservoir, working your way downstream. All reservoirs must be drained even if the system is equipped with an air drier and/or automatic drain valves.

NOTE: If excessive oil or water is evident at any reservoir, steps should be taken to find the cause.

NOTE: Lack of air in any protected reservoir indicates a probable malfunctioning check valve for that reservoir. The check valve must be replaced or repaired. Draining of one protected control (service) reservoir on a power unit equipped with a split air system should not exhaust the pressure in the supply (emergency) line as noted at the gladhand test gauge.

11. Start engine and maintain an engine speed of 1200 to 1500 rpm. Check the air governor cut-out pressure at the wet tank test gauge. Reject if higher than 135 psi. Compare the wet tank test gauge reading and supply (emergency) line gauge reading with that of the vehicle gauge reading. Readings must be within 10 percent of each other.

12. Stop engine. Apply and release brakes with foot valve until wet tank pressure is at 90-100 psi.

13. Check all test hardware for leaks (bubble leak detector) and repair as needed before continuing.

13a. Check the unapplied air loss at the wet tank test gauge for one minute. Loss should not exceed two psi for single vehicles and three psi for combination vehicles.

14. All tests for air loss shall be conducted for a period of one full minute unless it is apparent that there is no air loss or the rate of loss is excessive.

15. Restart engine and bring air pressure up to 90-100 psi

15a. Observe brake operation on all vehicles when the foot valve is fully applied and held. Immediate pressure drop for a combination vehicle shall not exceed 15 percent with an FMVSS 121 towing vehicle or 20 percent with a pre-121 towing vehicle, and for non-towing vehicles shall not exceed 12 percent for am FMVSS 121 vehicle or 15 percent for a pre-121 vehicle.

16. Repeat 15a as required.

16a. Continue full application of the foot valve and record the air pressure drop at the wet tank test gauge over a period of one full minute. The drop shall not exceed three psi for single vehicles and four psi for combination vehicles.

17. Repeat 15a as required.

17a. Release the foot valve and make a full hand valve application. (If the vehicle is not equipped with a hand valve, proceed to the next steps.) Verify brake pressure at control (service) line test gauge. With the hand valve applied, time air loss at the wet tank test gauge for one minute, then release the hand valve. Reject if pressure drop exceeds three psi over a period of one full minute.

18. While making this check with the hand valve, also walk around the vehicle and check for audible leaks and chafed or kinked brake hoses and/or lines. After test gauges stabilize, compare the readings of control (service) and emergency line gauges. The service line must be at least 50 percent of supply (emergency) line pressure. Reject if control (service) line pressure is not within the specified tolerance;

any brake fails to operate smoothly; air leaks are audible; the brake hose or line is chafed to a point where a new color is noted on the nylon tubing; or if wire, fiber, or yarn is visible or if the hose or line is kinked or pinched.

NOTE: Replace defective hose or line and correct cause of damage.

19. Start the engine and crack open the drain cock at the wet tank gauge or the supply (emergency) line gauge for combinations and towing vehicles and record the pressure at which the air governor cuts in. Reject and correct the governor setting if lower than 100 psi (85 psi for bus). Turn off engine, but leave the key in run position and allow the system to bleed down until the low pressure warning signal is noted. Record the pressure. Close the drain cock. Repair or replace the warning signal device if air pressure is lower than 55 psi.

19a. With the compressor cut-in (pumping) and the engine at idle, cycle the service brake pedal again until pressure is between 80 and 90 psi, make a full service brake application and hold. The air compressor is required to maintain or build the system pressure.

20. On combinations and towing vehicles, start engine and charge system to 60 psi. Shut off engine. Open control (service) line gladhand and depress and hold the foot pedal. Record the pressure at the wet tank test gauge at which the tractor protection valve closes off air lines to the trailer. Repair or replace the tractor protection valve or trailer emergency (dash) valve if recorded air pressure is higher than 45 psi or lower than 20 psi. Record the cab gauge and wet tank gauge pressures when air stops escaping from the disconnected tractor gladhand. Repair or replace the tractor protection valve or trailer air supply (trailer emergency) valve if air continues to escape from the disconnected tractor gladhand.

21. Check to see that trailer brakes are applied. Disconnect the supply (emergency) line gladhand and check for air leakage from the trailer gladhands. On vehicles equipped with straight air brakes, this indicates a malfunctioning relay emergency valve (pre-FMVSS 121 trailers) or a malfunctioning check valve, pressure protection check valve, or a charging/parking brake control valve (FMVSS 121 trailers). The malfunctioning valve must be repaired or replaced. On trailers equipped with an air-over-hydraulic system, air escaping from the trailer control (service) gladhand may indicate the presence of a bleed-down relay emergency valve. If so equipped, repair or replace only if air leakage is noted at the open trailer supply (emergency) line.

22. Reconnect all gladhands. Start engine and fully charge system, release parking brakes and shut off engine. On vehicles with S-cam brakes, mark the air chamber push rod at the chamber, with the brakes in unapplied (released) position.

23. Depress and release the service brake treadle until the wet tank is at 90-100 psi and hold. Service brakes on all axles of all vehicles must apply.

24. Measure the amount of push rod travel at each wheel end. Travel should not exceed the limits for corresponding size chambers at an applied pressure of 90 psi shown in **Table 1**.

25. If the stroke exceeds the maximum, there is an issue with the foundation brakes that must be fixed. Determine cause and correct. Start engine and recharge system, mark air chamber push rods (if necessary), apply and hold foot valve, and re-measure stroke.

26. For combination vehicles only, apply and release the trailer emergency brakes or trailer parking brakes by operating the tractor protection control knob (trailer air supply or trailer emergency valve) in the cab. Repair or replace the tractor protection control (trailer air supply or trailer emergency valve) or malfunctioning brake chamber(s) if the trailer brakes do not apply and release in normal manner.

27. Apply and release the parking brakes on the motor vehicle using the applicable control in the cab. Repair or replace the parking control or malfunctioning parking brake chamber(s) if the brakes do not apply and release in a normal manner.

28. On FMVSS 121 tractors and towing trucks, check to see that pulling of the parking valve (yellow diamond knob) applies the parking brakes on the towing vehicle and the emergency or parking brakes on the towed vehicles (exhausts the supply (emergency) line on vehicles without an attached trailer). Depression of the valve should release the parking brakes on the towing vehicle. To release the brakes on the towed vehicle (or to repressurize the supply (emergency) line on vehicles without an attached trailer), it may be necessary to depress the red octagonal tractor protection

control valve knob after the yellow diamond knob has been depressed.

29. On FMVSS 121 semitrailers, charge the system and shut off the engine. Check to ensure that the draining of a trailer control (service) reservoir does not cause the previously released parking brakes to apply. Repair or replace if the parking brakes apply. Place the tractor protection control knob (trailer air supply or trailer emergency dash valve) in the emergency position (released) and check to ensure that the trailer parking brakes apply. Place the tractor protection control (trailer air supply or trailer emergency valve) back in the normal (applied) running position and check to ensure that the trailer parking brakes release once the reservoir is fully charged. Repair or replace if brakes fail to release.
30. If the power unit is so equipped, check for proper operation of the emergency stopping system release (third air tank, spring brake release, pre-FMVSS 121 only).
31. Remove the test gauges and reinstall the drain cock in the wet tank.
32. Make certain that all drain cocks are closed, gladhands are properly recoupled, and all brake systems are operating normally before releasing vehicle.

NOTE: Check for leaks at all test ports using bubble leak detector. Repair as required.

TABLE 1:
READJUSTMENT LIMITS FOR BRAKE PUSH ROD STROKE

	Chamber Type	Overall Diameter	Maximum Stroke at Which Brakes Should be Readjusted *
Bolted Flange Brake Chambers	A (12)	6-15/16"	1-3/8"
	B (24)	9-3/16"	1-3/4"
	C (16)	8-1/16"	1-3/4"
	D (6)	5-1/4"	1-1/4"
	E (9)	6-3/16"	1-3/8"
	F (36)	11"	2-1/4"
	G (30)	9-7/8"	2"
Clamp Ring	9	5-1/4"	1-3/8"
	12	5-11/16"	1-3/8"
	16	6-3/8"	1-3/4"
	20	6-25/32"	1-3/4"
	24	7-7/32"	1-3/4"
	30	8-8/32"	2"
	36	9"	2-1/4"
Long Stroke Clamp Ring	16	6-3/8"	2"
	20	6-25/32"	2"
	24	7-7/32"	2"
	24**	7-7/32"	2-1/2"
	30	8-3/32"	2-1/2"
Rotochambers	9	4-9/32"	1-1/2"
	12	4-13/16"	1-1/2"
	16	5-13/32"	2"
	20	5-15/16"	2"
	24	6-13/32"	2"
	30	7-1/16"	2-1/4"
	36	7-5/8"	2-3/4"
	50	8-7/8"	3"

*** See manufacturer for recommendations concerning wedge brakes.**
**** For 3" max. stroke Type 24 chambers**

33. Collect all tools used during inspection, in, on, around, and under the vehicle, and pull the wheel chocks.
34. A copy of the dated and signed form, showing items corrected or to be corrected, should be distributed as per company policy.

REFERENCES

- Commercial Vehicle Safety Alliance *North American Standard Out of Service Criteria*
- Federal Motor Vehicle Safety Standard (FMVSS) 121
- Federal Motor Carrier Safety Regulation (FMCSR) 393
- FMCSR Appendix G, 49 CFR Subtitle B

CHAPTER 5: 2014 CVSA brake out-of-service criteria

Brake-related criteria for placing vehicles out of service at roadside safety inspections are developed by the Commercial Vehicle Safety Alliance. Out-of-service defects typically must be corrected at the inspection site. But an inspector may require a vehicle to be towed, transported or escorted from the site in order to reduce a hazard to the public. To purchase detailed criteria, contact CVSA at www.cvsa.org.

Defective brakes

A vehicle or combination vehicle is Out-of-Service if 20 percent or more of its service brakes have one of the following defects:

- Any steering-axle brake defect listed in next section.
- Won't actuate effectively or friction material won't contact drum/rotor.
- Audible air leak at chamber.
- Missing brake on any axle required to have brakes.

Drum air brakes

- Broken or missing brake shoe, lining, return spring, anchor pin, spider, cam roller, camshaft, pushrod, yoke, clevis pin, brake adjuster, parking brake power spring or air chamber mounting bolt.
- Loose air chamber, spider or camshaft support bracket.
- Lining has crack/void, observable on edge, wider than 1/16 inch.
- Portion of lining is missing, to the extent that rivet/bolt is exposed.
- Lining has crack, observable on edge, longer than 1 1/2 inch.
- Loose lining segment, permitting about 1/16-inch movement.
- Entire segment of lining is missing.
- Evidence of oil, grease or brake fluid contamination of the friction surface of the brake drum and the brake friction material.
- Lining thickness less than 1/4 inch or to wear indicator, if so marked, at shoe center.

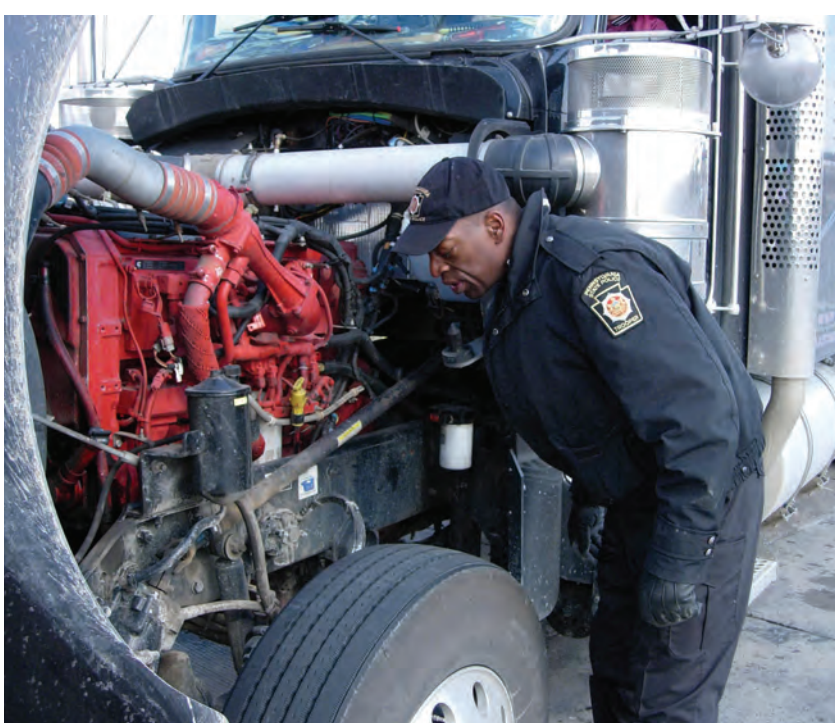
Air disc brakes

- Broken or missing caliper, brake pad, pad retaining component, pushrod, yoke, clevis pin, brake adjuster, parking brake power spring or air chamber mounting bolt.
- Loose or missing brake chamber or caliper mounting bolt.
- Rotor has evidence of severe rusting or metal-to-metal contact over the rotor friction surface or on either side.
- Evidence of oil or grease contamination of the friction surface of the brake rotor and the brake friction material.
- Brake pad thickness is less than 1/16 inch or to wear indicator if pad is so marked.

Brake adjustment limits

- With engine off, reservoir at no more than 90 to 100 psi (dump excess pressure) and brakes fully applied, push rod stroke 1/4 inch or more beyond adjustment limit.
- Counting as one defective brake, two brakes having a stroke less than 1/4-inch beyond adjustment limit. A brake at its adjustment limit is not a violation.
- Clamp-type chamber adjustment limit:

The Commercial Vehicle Safety Alliance has identified the most critical safety violations involving brakes.



  - Type 20 (6 25/32-inch O.D.) = 1 3/4-inch stroke
  - Type 24 (7 7/32-inch O.D.) = 1 3/4-inch stroke
  - Type 30 (8 3/32-inch O.D.) = 2-inch stroke
  - Type 36 (9-inch O.D.) = 2 1/4-inch stroke
- Long-stroke, clamp-type chamber adjustment limit:
  - Type 20 (6 25/32-inch O.D.) = 2-inch stroke
  - Type 24 (7 7/32-inch O.D.) with less than 3-inch maximum stroke = 2-inch stroke
  - Type 24 (7 7/32-inch O.D.) with 3-inch maximum stroke = 2 1/2-inch stroke
  - Type 30 (8 3/32-inch O.D.) = 2 1/2-inch stroke

Note: Brakes found at the adjustment limit are not defective for the purposes of the 20 percent rule.

Hydraulic and electric brakes

- Missing or broken caliper, brake pad, shoe or lining.
- Movement of the caliper within the anchor plate, in the direction of wheel rotation, exceeds 1/8 inch.
- Rotor has evidence of severe rusting or metal-to-metal contact over the rotor friction surface on either side.
- Evidence of oil, grease or brake fluid contamination of the friction surface of the brake rotor and the brake friction material.
- Lining/pad thickness of 1/16 inch or less at the shoe center for disc or drum brakes.

Front steering axle brakes

- Any inoperative or missing brake on either wheel of any steering axle of any vehicle equipped or required to be equipped with steering axle brakes, including the dolly and front axle of a full trailer and tractors required to have steering axle brakes.
- Defects of drum air brakes, air disc brakes and hydraulic brakes in the section above apply to front steering axle brakes with one exception:
  - For drum brakes, lining with a thickness of less than 3/16 inch for a shoe with a continuous strip of lining, or 1/4 inch for a shoe with two lining blocks or to wear indicator, if so marked.
- Mismatched air chamber sizes for drum air brakes and air disc brakes. This excludes long-stroke air chamber versus regular-stroke air chamber; and for drum brakes, differences in design type, such as type 20 clamp versus type 20 rotor chamber. A mismatch on an air disc brake exists only when there is measurable difference in air chamber clamp sizes.
- Mismatched brake adjuster length for drum and air disc brakes.

Spring brake chambers

- Nonmanufactured hole/crack in spring brake housing.

Trailer/breakaway/emergency braking

- Inoperable breakaway braking system on trailer.
- A breakaway system not directly attached to the towing vehicle.
- On any trailer equipped with spring brakes, more than 25 percent of the spring brakes are inoperative.

Parking brake

- No brakes are applied when parking brake control is actuated.

Brake smoke/fire

- Brake malfunction causing smoke or fire to emit from wheel end, not including overheating due to severe brake use.

Drum/rotor

- External crack that is visible or opens upon brake application.
- Rotor with a crack in length of more than 75 percent of the friction surface and passes through the rotor.
- Portion of drum/rotor missing or in danger of falling off.
- A rotor surface is worn to or through center vents.

Hose/tubing

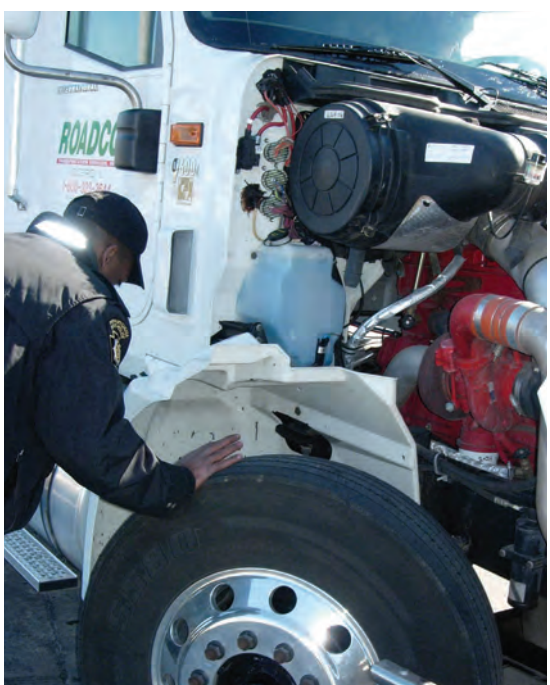
- Damage through outer reinforcing ply. Rubber-impregnated fabric cover is not reinforcement ply. Thermoplastic nylon may have braid reinforcement or color difference between cover and inner tube. Exposure of second color warrants Out-of-Service judgment.
- Bulge/swelling when air applied.
- Audible leak at other than proper connection.
- Cracked, broken or crimped and restricting air flow.
- Improper splice (such as hose ends forced over piece of tubing and secured with hose clamps).

Air loss rate

- 80 to 90 psi reservoir pressure not maintained with governor cut in, with engine idling and with service brakes fully applied.

Tractor protection system

- Missing or inoperative components, including tractor-protection valve and/or trailer supply valve.



Low-air warning device

- Both the audible and visual warning devices fail to operate as required.

Air compressor

- Loose mounting bolts.
- Cracked/broken/loose pulley.
- Cracked/broken mounting bracket/brace/adapter.

Air reservoir

- Separated from original attachment points.

Electric

- 20 percent or more of brakes on vehicle or combination don't work.
- Missing or inoperative breakaway braking device.

Hydraulic

- No pedal reserve, engine running.
- Master cylinder below 1/4 full.
- Inoperative power assist.
- Hose seeps or swells under pressure.
- Any observed brake fluid leak upon full brake application.
- Missing/inoperative breakaway braking device.
- Hydraulic hose worn through outer cover to fabric layer.
- Fluid line/connection is broken, restricted, crimped or cracked.
- Failure/low-fluid warning light is actuated or inoperative.

Vacuum system

- Insufficient reserve for one full-brake application after engine stopped.
- Vacuum hose/line restricted, worn through the outer cover to cord ply, is crimped, cracked or broken or collapses when vacuum is applied.

Performance-based brake tests (PBBTs)

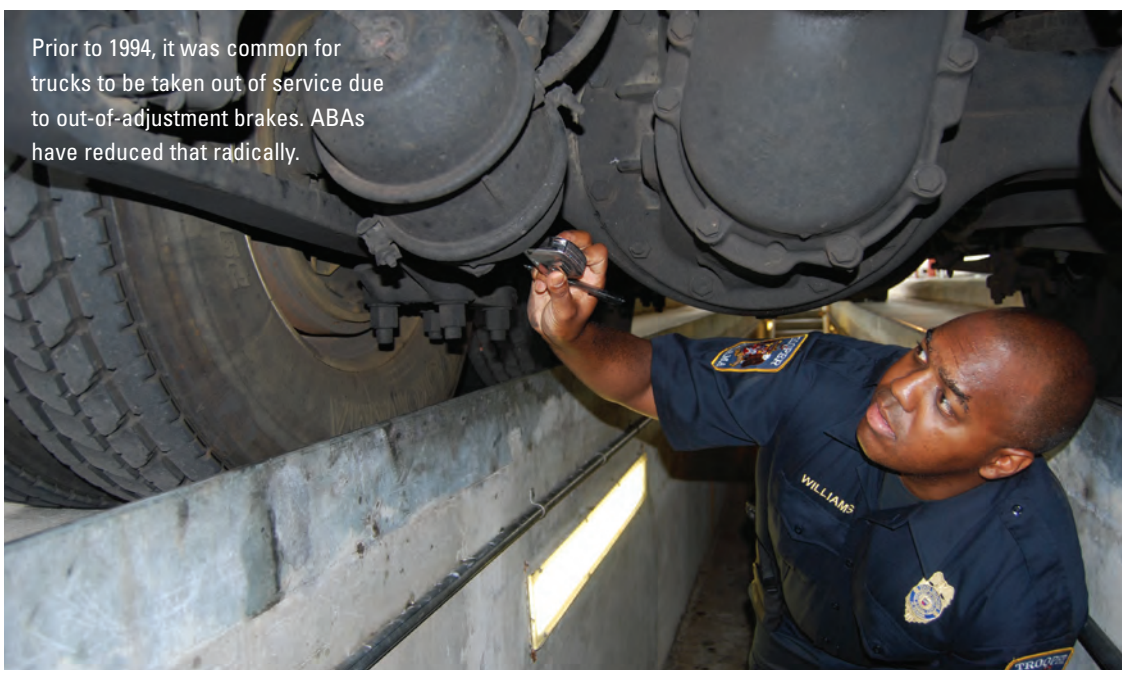
- Failing to develop a total brake force as a percentage of gross vehicle or combination weight of 43.5 or more on an approved PBBT.

Brake-related CSA Vehicle Maintenance BASIC Violations

The following table contains a list of the brake-related violations and severity weights in the Vehicle Maintenance Behavior Analysis and Safety Improvement Category, part of the Federal Motor Carrier Safety Administration's Compliance Safety Accountability program.

Section	Violation Description	Violation Severity Weight
Violation Group Description: Brakes, All Others		
393.40	Inadequate brake system on CMV	4
393.41	No or defective parking brake system on CMV	4
393.42	No brakes as required	4
393.42A-BM	Brake - missing required brake	4
393.42A-BMAW	Brake - all wheels not equipped with brakes as required	4
393.42A-BM-TSA	Brake - missing on a trailer steering axle	4
393.43	No/improper breakaway or emergency braking	4
393.43(a)	No/improper tractor protection valve	4
393.43(d)	No or defective automatic trailer brake	4
393.44	No/defective bus front brake line protection	4
393.45	Brake tubing and hose adequacy	4
393.45PC	Brake tubing and hose adequacy - connections to power unit	4
393.45UV	Brake tubing and hose adequacy - under vehicle	4
393.45(a)(4)	Failing to secure brake hose/ tubing against mechanical damage	4
393.45(b)(2)	Failing to secure brake hose/ tubing against mechanical damage	4
393.45B2PC	Brake hose or tubing chafing and/ or kinking - connection to power unit	4
393.45B2UV	Brake hose or tubing chafing and/ or kinking - under vehicle	4
393.45(b)(3)	Failing to secure brake hose/ tubing against high temperatures	4
393.45(d)	Brake connections with leaks/constrictions	4
393.45DCPC	Brake connections with constrictions - connection to power unit	4
393.45DCUV	Brake connections with constrictions - under vehicle	4
393.45DLPC	Brake connections with leaks - connection to power unit	4
393.45DLUV	Brake connections with leaks - under vehicle	4
393.47	Inadequate/contaminated brake linings	4
393.47(a)	Inadequate brakes for safe stopping	4
393.47(b)	Mismatched brake chambers on same axle	4
393.47(c)	Mismatched slack adjuster effective length	4
393.47(d)	Insufficient brake linings	4
393.47(g)	Insufficient drum/rotor thickness	4
393.48(a)	Inoperative/defective brakes	4
393.48A-BCM	Brakes - hydraulic brake caliper movement exceeds 1/8" (0.125") (3.175 mm)	4
393.48A-BMBC	Brakes - missing or broken components	4
393.48A-BRMMC	Brakes - rotor (disc) metal-to-metal contact	4
393.48A-BSRFS	Brakes - severe rusting of brake rotor (disc)	4
393.48(b)(1)	Defective brake limiting device	4
393.50	Inadequate reservoir for air/vacuum brakes	4
393.50(a)	Failing to have sufficient air/vacuum reserve	4
393.50(b)	Failing to equip vehicle - prevent reservoir air/ vacuum leak	4
393.50(c)	No means to ensure operable check valve	4
393.50(d)	No or defective air reservoir drain valve	4
393.51	No or defective brake warning device	4
393.52(a)(1)	Insufficient braking force as percent of GVW or GCW	4
393.53(a)	Automatic brake adjuster CMV manufactured on or after October 1993 - hydraulic brake	4
393.53(b)	Automatic brake adjuster CMV manufactured on or after October 1994 - air brake	4
393.53(c)	Brake adjustment indicator CMV manufactured on or after October 1994 - external automatic adjustment	4
393.55(a)	ABS - all CMVs manufactured on or after March 1999 with hydraulic brakes	4
393.55(b)	ABS - malfunctioning indicators for hydraulic brake system	4
393.55(c)(1)	ABS - all tractors manufactured on or after March 1997, air brake system	4
393.55(c)(2)	ABS - all other CMVs manufactured on or after March 1998, air brake system	4
393.55(d)(1)	ABS - malfunctioning circuit/signal - truck tractor manufactured on or after March 1997, single-unit CMV manufactured on or after March 1998	4
393.55(d)(2)	ABS - malfunctioning indicator to cab of towing CMV manufactured on or after March 2001	4
393.55(d)(3)	No or defective ABS malfunction indicator for towed vehicles on vehicles manufactured after February 2001	4
393.55(e)	ABS - malfunctioning lamps for towed CMV manufactured on or after March 1998	4
396.3A1B	Brakes (general)	4
396.3A1BC	Brake - air compressor violation	4
396.3A1BD	Brake - defective brake drum	4
396.3A1BL	Brake - reserve system pressure loss	4
Violation Group Description: Brakes Out of Adjustment		
393.47(e)	Clamp/roto-chamber type brake(s) out of adjustment	4
393.47(f)	Wedge type brake(s) out of adjustment	4
396.3A1BA	Brake out of adjustment	4

CHAPTER 6: The ins and outs of automatic brake adjusters



Prior to 1994, it was common for trucks to be taken out of service due to out-of-adjustment brakes. ABAs have reduced that radically.

Understanding the different types of ABAs and how they function is key to proper selection and maintenance

By Jack Roberts

Automatic brake adjusters – also called ABAs or automatic slack adjusters – have dramatically increased the safety of trucks and lowered maintenance concerns since they were made mandatory in 1994 on all new commercial vehicles with air brakes. As a result of the mandate, the percentage of vehicles taken out of service at roadside inspections due to out-of-adjustment brakes has fallen sharply.

There are two basic approaches to ABA technology. The majority of manufacturers, including Bendix Commercial Vehicle Systems, Gunite and Haldex, produce clearance-sensing ABAs, while Meritor produces stroke-sensing adjusters.

Stroke-sensing slack adjusters work by consistently maintaining the total stroke of the air chamber. A clearance-sensing slack adjuster maintains the clearance between the shoe and the drum. The two systems work in a related fashion because the chamber moves out as the slack adjuster is turning, thereby maintaining proper brake adjustment. "But how they function and how they're designed internally are based on two different principles," notes Mark Kromer, engineering manager for specialty and actuation for Bendix Spicer Foundation Brake. "The stroke-sensing adjuster is looking purely to maintain the total stroke of the chamber, and the clearance-sensing adjuster is trying to maintain a specific gap between the linings and the drum."

"All clearance-sensing slack adjusters – no matter who makes them – have some type of a clutch mechanism in them," adds John Hawker, service engineer for Bendix Commercial Vehicle Systems. "These clutches allow a pressure differential slack. So every single time you apply the brake, it's going to try to adjust a very, very small amount to keep the brakes at a constant set height that's built into the slack adjuster." Meritor's stroke-sensing design measures the amount of pushrod travel and says this adjusts for variances when the stroke is out of range. This maintains optimum chamber pushrod stroke.

Meritor ABAs sense the need for adjustment on the apply stroke and make any required adjustment during the end of the brake release stroke. Making adjustments at the end of the release stroke means the ABA adjustment mechanism does not see brake application loads, extending life by minimizing ABA internal wear. Stroke sensing designs also typically adjust faster. Reliability and cost are other advantages Meritor believes are conducive with stroke sensing designs.

"I can't say that one approach is superior to the other," Kromer says. "Both types of adjusters have their pros and cons. From our perspective, it is easier for a fleet or an end user or a truck manufacturer to incorporate a clearance-sensing design into their operations. It relieves them from requiring multiple part numbers and multiple internal components to properly size the slack adjuster for that wheel end, since assembly basically can be used for differing linings, different drums, different camshaft lengths."

Regardless of adjustment philosophy, air chamber stroke is consumed in three ways:

• The chamber free stroke takes up between 1/2 to 5/8 inch of stroke on drum brakes and 3/4 to 7/8 inch on disc brakes.

• Stroke is required to account for system elasticity, which is the result of brake system deflections from the shoes, brake drum, camshaft friction material compression and air chamber mounting brackets.

• To counter dynamic changes that occur to a brake in service requiring more or less chamber pushrod stroke, such as lining or disc pad wear and brake drums or rotors heating and expanding, then cooling and contracting.

"We have a lot of years of experience with the stroke sensing design and the interaction with the S-cam brake assembly," says Joe Kay, chief engineer, Brakes, Meritor. "The design of the S-cam profile is integral to the performance of the ABA."

One concern engineers face when designing any ABA type is maintaining running clearance throughout the life of the brake, as new unburnished brakes must allow for "green lining swell" – larger deflections due to the lining crown – in addition to lining wear and temperature changes brakes see in normal operation.

Most OE-quality replacement shoes and pads are designed in such a way to minimize green lining swell. Low-quality parts are not and may cause a dragging brake problem. All ABAs will adjust regardless of the application pressure applied by your treadle. Most brake applications are low – generally between 10 and 20 psi.

Air disc brakes also are equipped with ABAs. Although they function similarly to those found on drum brake systems, they do not have to compensate for drum expansion. In this application, an ABA's primary purpose is to keep running clearance at a certain level when the brake is cold to prevent brake drag at high temperatures.

"When the brake is hot, obviously the clearance gets less," explains Ron Plantan, principal engineer, Bendix's wheel end group. "Heat effects on running clearance in a disc brake are the opposite of a drum brake. The drum expansion with heat increases the running clearance and corresponding brake chamber stroke. On the other hand, the disc thickness grows with heat, reducing the running clearance and corresponding chamber stroke. The disc brake adjuster is designed to maintain enough running clearance in a cold brake to ensure sufficient running clearance in the worst-case hottest conditions. An inherent advantage of the disc brake is when it heats up under heavy braking – the brake stroke requirement is reduced, giving greater brake chamber reserve stroke along with improved performance.

"Basically, when an air disc ABA senses a larger clearance, it automatically adjusts to maintain to compensate for that amount," says Plantan. "If the brake then gets very hot, the ABA only has to expand over the width of the rotor as opposed to the diameter of the drum. "Because of this, it's easier for an ABA to maintain brake adjustment than on a drum brake system."

Make proper adjustments

Certain features of stroke-sensing and clearance-sensing ABAs can affect fleet operations and should be considered during the spec'ing process. Overheated, expanding brake drums and rotors; cold, contracting ones; warped rotors and out-of-round drums, as well as spongy friction materials and distorted chamber brackets, all can adversely affect proper brake adjustment.

"When ABAs were first introduced, there were certain circumstances where they would overadjust," notes Plantan.

"The automatic adjuster doesn't really know what the temperature of the drum is, or how much it expands. So if the driver pumps his brakes enough going down a long grade, it is possible to adjust the brake to a larger-sized drum."

Plantan says some of the earlier adjusters adjusted in fairly large increments. "On a long grade, if the driver was snubbing his brakes like he's supposed to, the adjuster would overadjust to the thermally expanded drum."

Later, when the truck brakes had cooled down, a dragging brake was a possibility. "It was often described as an overadjustment situation," Kromer says. "When really, it was a misunderstood phenomenon. The component isn't necessarily overadjusting – it's just responding to the high-temperature drum."

Both Plantan and Kromer say that manufacturers today

Tips for spec'ing and maintaining ABAs

The following guidelines, gleaned from fleet managers and field service reps across the country, can help you make better-informed ABA maintenance and purchasing decisions:

When purchasing ABAs:

- Ask for evidence of a potential ABA's performance in different climates, applications, vocations and geographic regions similar to the ones where you operate. Remember that a manufacturer may have more than one ABA offering, including a unit better suited to your operation.
- Because internal contamination is an ABA's number-one enemy, check up on how the ABA you're considering is sealed to keep moisture and contaminants out.
- If your trucks operate in rough or mountainous terrain, pay extra attention to how the manufacturer has addressed overadjustment issues and how the design compensates for them.
- If you're retrofitting, don't buy on price alone. If you're not sure as to which ABA to go with, buy a few, install them, and track their performance before committing to a large purchase.
- Compare preventive maintenance requirements and field serviceability traits among several ABA brands before buying. Some ABAs may require special lubricants to perform properly. If you operate in tough conditions, units with easy field replacement characteristics may be preferred.
- If you're experiencing problems with camshaft corrosion, consider spec'ing an ABA with a lubrication system that sends grease to the splines whenever it is serviced.
- Consider visual stroke indicators to monitor the performance of your ABAs.

When maintaining ABAs:

- Make sure you incorporate ABA inspection procedures into your PM schedule, just like any other component.
- Although manual slack adjusters are becoming increasingly rare, remember that manual and automatic units should never be used together on the same vehicle. Also, some manufacturers caution against using ABAs from different manufacturers on the same vehicle. That being said, there is a general consensus they should never mix on the same axle.
- Keep in mind that improper factory ABA installation can be a problem on new vehicles. So ABA inspection should be a part of your basic predelivery vehicle inspection procedure.
- If you are retrofitting from manual to automatic adjusters on older vehicles, make sure technicians receive thorough training and are familiar with each type of adjuster. Compare installation requirements and interchangeability with the manual adjusters on the vehicles and suspensions you're installing them on. Don't rely on installation diagrams that depict a "typical" vehicle.
- Remember that ABA housings are larger than manual adjuster housings, and make sure there's adequate suspension clearance when the adjuster body is rotated at maximum chamber stroke.
- Bear in mind that some ABAs fit under some suspensions better than others. Some require left- or right-handed versions with an offset clevis or offset arm in order to fit.
- Also remember that switching from manual adjusters to ABAs may reduce some brake maintenance expenses by lowering the incidence of human intervention in the brake adjustment process and by reducing uneven lining wear, wheel-to-wheel. But ABAs do not reduce the need to perform other brake maintenance. In fact, the use of ABAs actually increases the need of optimum brake system maintenance and performance since they tend to amplify weaknesses in brake maintenance practices and procedures. In short, for ABAs to work properly, brakes must be maintained at an optimum level. This many increase brake maintenance expenses in some fleets, but pay dividends in safer vehicles and fewer incidences of unscheduled downtime.
- Always use the same slack type and brand on each axle to prevent side-to-side brake performance issues.

have worked hard to design overcompensation flaws out of their ABA products. ABAs today adjust in increments small enough to allow a driver to snub brakes going down a grade without overadjusting.

"You can get brake drag for a whole variety of reasons," Haldex's Petresh notes. "The things that cause the most amount of problems as it relates to adjustment usually are not associated with ABAs. Brake adjusters will not compensate for poor maintenance practices."

Poor maintenance and general wear and tear can "trick" ABAs into overcompensating and lead to excessive stroke conditions. Wear at quick-connect collars, clevis pin bushings and S-cam splines are common problems. Anchor pin bushings wear. Return springs can lose their tension over time due to heat cycling in the brake, which causes them to weaken and eventually degrades how the shoe returns when the brake is released. As all of these items wear normally during braking operations, the ABA will compensate in small portions, as it is designed to do.

According to Petresh, it is this general wear and tear and degradation of all the other components in the brake wheel and the brake assembly that can be, over time, perceived by technicians as bad ABA adjustment or some sort of change to brake stroke on a particular axle or wheel end. "A lot of people just automatically assume that it's a brake adjuster, so one of the first cardinal sins they commit is they start manually adjusting it to correct the situation," he says. "That's why everybody – all the manufacturers, all the industry organizations such as Team CATA and CBSA – has had strong promotional programs over the last several years to discourage, prevent, train, teach technicians not to manually adjust ABAs."

This is crucially important, Petresh says, because manual ABA adjustments do not solve the initial brake system problem – although doing so may disguise the true nature of the malfunction for a short period of time. But now, he says, on top of the original component problem, the technician has damaged the ABA's internal mechanism. "ABAs are not meant to be manually adjusted," he stresses. "So instead of looking for what's really causing the increase in brake stroke, all you've done is compensate for that condition. But the adjuster will very quickly thereafter revert back to its steady-state condition because it's reacting to how it's designed to react." As a result, Petresh says, the ABA goes back to a long stroke condition because of the other accumulation of wear and tear on the rest of the brake assembly that's causing the stroke to get longer in the first place.

ABA inspection and cleaning

Overall, ABAs are not maintenance-intensive components. As they age in normal service life, they are susceptible to wear and tear that can degrade performance, however. Wear on their tolerance-sensitive surfaces can increase the running clearance they are designed to maintain, resulting in a longer stroke requirement for the friction material to effectively contact the brake drum. In a worse-case scenario, at extended stroke, the amount of friction material coming into contact with the friction surface (the drum) may not be enough to generate adequate braking force.

Water and cold weather also can affect ABAs adversely. Even a small amount of water introduced into an ABA's adjustment mechanism – especially in winter – can allow corrosion to build up inside the component. Additionally, internal tolerance-sensitive surfaces can freeze up, preventing appropriate movement and adjustments until the ice thaws.

That's why Hawker, at Bendix, says the biggest factor affecting the life of any type of ABA is good lubrication practices. "Most technicians simply give the ABAs they service a squirt of grease every 30 days or so and forget about it," he says. "But they need to actually lubricate the ABA in such a way that purges all the contamination out of its internal parts. Automatic brake adjusters need to be lubricated, and they purge the system until clean, new grease comes out, because you want to get rid of all the dirt, debris, water or whatever is inside that component and affecting its performance."

It's also important to remember that just because ABAs are touted as "automatic," they need to be inspected during preventive maintenance checks to ensure proper performance and long life. These checks should include verifying that the physical and operational characteristics of the ABA are in good working order. This includes inspecting its brackets and adjustment mechanisms for visual damage and automatically replacing any ABA that is suspect.

Still Using Old Criteria?

The *North American Standard Out-of-Service Criteria* changes go into effect annually each April 1.

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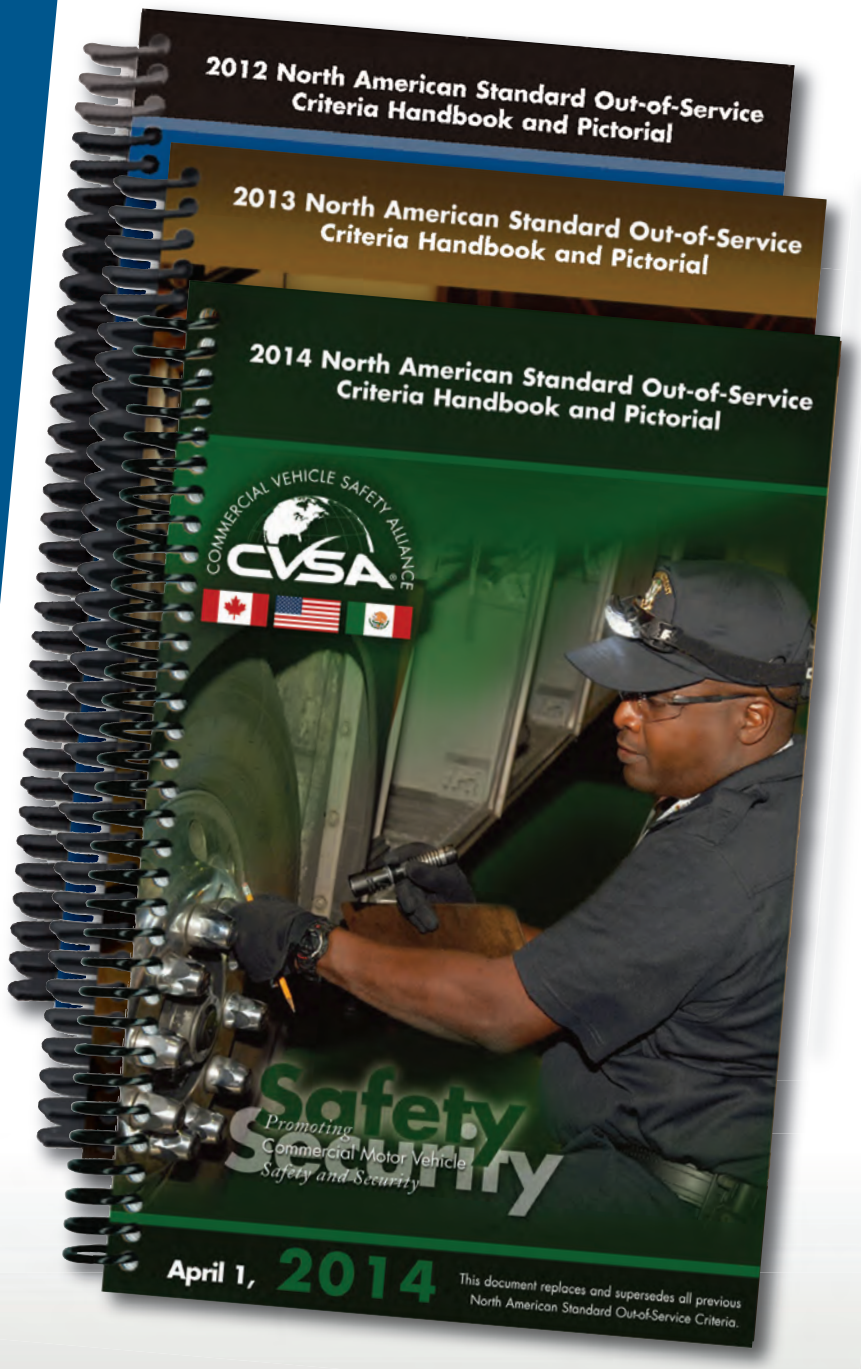

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Recommended Practice

RP 609C VMRS 013-001, 013-002

SELF-ADJUSTING AND MANUAL BRAKE ADJUSTER REMOVAL, INSTALLATION AND MAINTENANCE

PREFACE

The following Recommended Practice is subject to the Disclaimer at the front of TMC's *Recommended Maintenance Practices Manual*. Users are urged to read the Disclaimer before considering adoption of any portion of this Recommended Practice.

PURPOSE AND SCOPE

The purpose of this Recommended Practice (RP) is to provide information regarding the removal, installation, operation, maintenance, and selection of heavy-duty vehicle manual and self-adjusting brake adjusters.

INTRODUCTION

In an S-cam type foundation brake, the final link between the pneumatic system and the foundation brake is the brake adjuster. The arm of the brake adjuster is fastened to the push rod of the chamber with a clevis and the spline end is installed on the brake camshaft. Primarily, the brake adjuster is a lever that converts the linear force of the air chamber push rod into a torque which turns the brake camshaft and applies the brakes.

Two types of brake adjusters are in use: manual type brake adjusters, which periodically require a manual adjustment; and self-adjusting brake adjusters, which automatically adjust during normal service braking applications. All brake adjusters use the worm and gear principle and fundamentally differ only in their torque limit specification.

NOTE: Manual and self-adjusting brake adjusters are for brake adjustment and will not compensate for normal wear characteristics and maintenance requirements associated with foundation brakes.

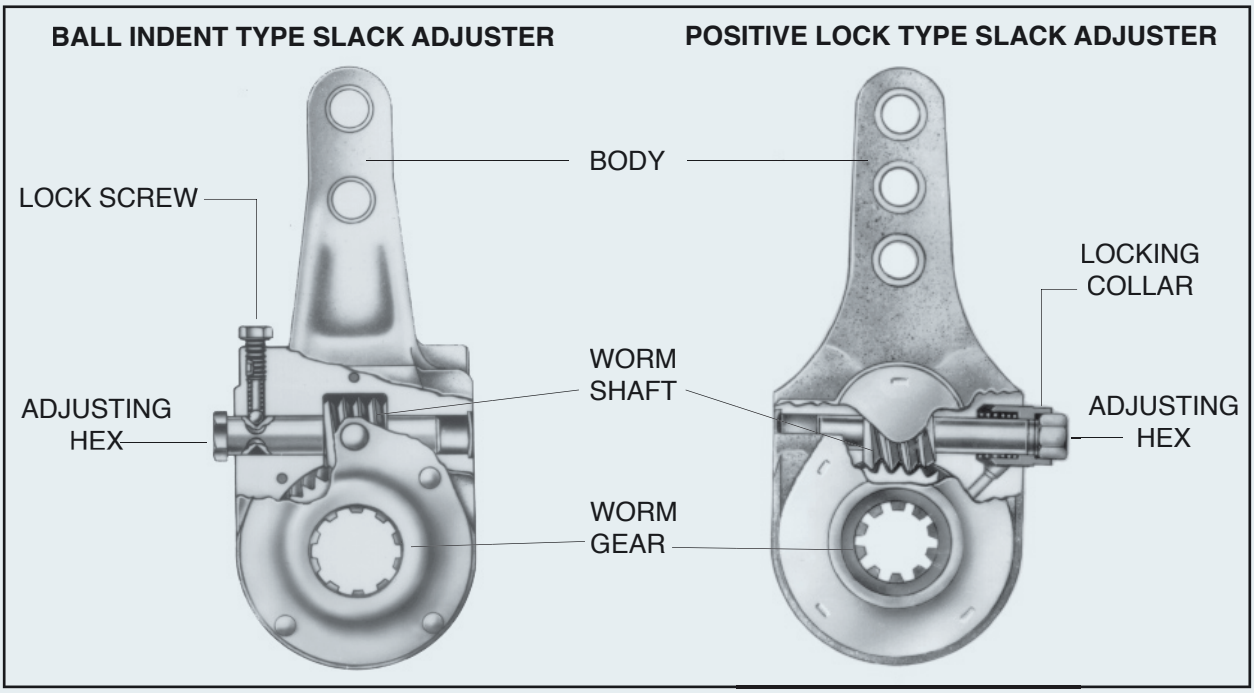

Fig. 1: Manual Brake Adjusters

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MANUAL BRAKE ADJUSTERS

Manual brake adjusters contain four basic components: the body, worm gear, worm shaft, and locking screw or collar. See **Fig. 1.**

The worm shaft of a brake adjuster incorporates an external adjusting hex. Turning the adjusting hex rotates the worm shaft which turns the worm gear and brake cam shaft, thus spreading the brake shoes and reducing drum-to-lining clearance.

Light to medium gross axle weight rating (GAWR) vehicles utilize either a spring-loaded locking sleeve or a lock ball indent adjustment lock to prevent the worm shaft from backing off.

Higher torque-rated brake adjusters use the lock ball or plunger and worm shaft indent principle adjustment lock. The lock ball or plunger must engage the worm shaft indent after the adjustment is completed. An audible metallic click can be heard when engagement is made.

SELF ADJUSTING BRAKE ADJUSTERS

While self-adjusting brake adjuster designs vary in the manner in which they are installed and operate, all are designed to automatically maintain a predetermined drum-to-lining clearance or brake chamber stroke. Some self-adjusting brake adjusters adjust upon the brake application stroke, others adjust upon release. Self-adjusting brake adjusters should not have to be manually adjusted while in service. However, manual adjustments can be made temporarily to get a vehicle to a maintenance facility for inspection and repair, if necessary.

⚠ CAUTION Self-adjusting brake adjusters do not eliminate or reduce the need for periodic inspection and maintenance of the adjuster components and attaching hardware. Self-adjusting brake adjusters should never be operated as a manual adjuster, if the self-adjusting function is not operating properly. Regular adjustment indicates adjuster malfunction; the cause needs to be identified and corrected.

BRAKE ADJUSTER REPLACEMENT

When replacing a brake adjuster, it is recommended that the replacement be of the same size as the original equipment. All self-adjusting brake adjusters on a vehicle should be made by the same manufacturer. To identify the proper replacement, the following slack adjuster key dimensional checks are recommended.

- Arm length (center of spline to center of arm hole to be used).
- Type, width, number, and diameter of splines.
- Clevis pin diameter (do not drive out bushing to accommodate a larger clevis pin).
- Brake chamber push rod size (5/8" or 1/2").
- If offset configuration, determine the offset dimension (right or left side).

BRAKE ADJUSTER REMOVAL AND INSTALLATION

⚠ WARNING: To avoid possible injury, proper precautions must be taken to prevent automatic actuation of the brake chambers while removing or installing brake adjusters. Always block the wheels or mechanically secure the vehicle. Spring brakes must be mechanically caged. All brakes should be fully released.

A. Manual Brake Adjuster Removal—

1. Remove the brake chamber push rod clevis pin.
2. Remove the retaining mechanism from the end of the brake camshaft.
3. Rotate the adjusting hex to back the brake adjuster out of the clevis.
4. Remove the brake adjuster from the spline end of the brake cam shaft.

B. Manual Brake Adjuster Installation—

1. Lubricate the brake cam shaft. Install the brake adjuster on the cam shaft so the adjustment hex and grease fitting (if so equipped) are accessible for servicing.
2. Align the brake adjuster arm with center of the push rod clevis. Install the clevis pin and secure it with a new cotter pin.
3. Check to be sure the angle formed by the brake adjuster arm and the brake chamber push rod is greater than 90° when the brake adjuster is in the released position.
4. Install the brake adjuster retaining mechanism on the end of the brake cam shaft, being sure to shim it to less than 0.060 inch of end play.
5. Tighten the jam nut on the push-rod-to-clevis attachment (1/2 - 20 300-400 in. lbs. 5/8 - 18 400 in. lbs.).
6. After installation, make certain there is adequate clearance in both the fully applied and fully released positions. Check to ensure that all brake adjusters rotate freely and without binding.
7. Adjust the brakes by following the procedure in the section entitled BRAKE ADJUSTMENT PROCEDURE.

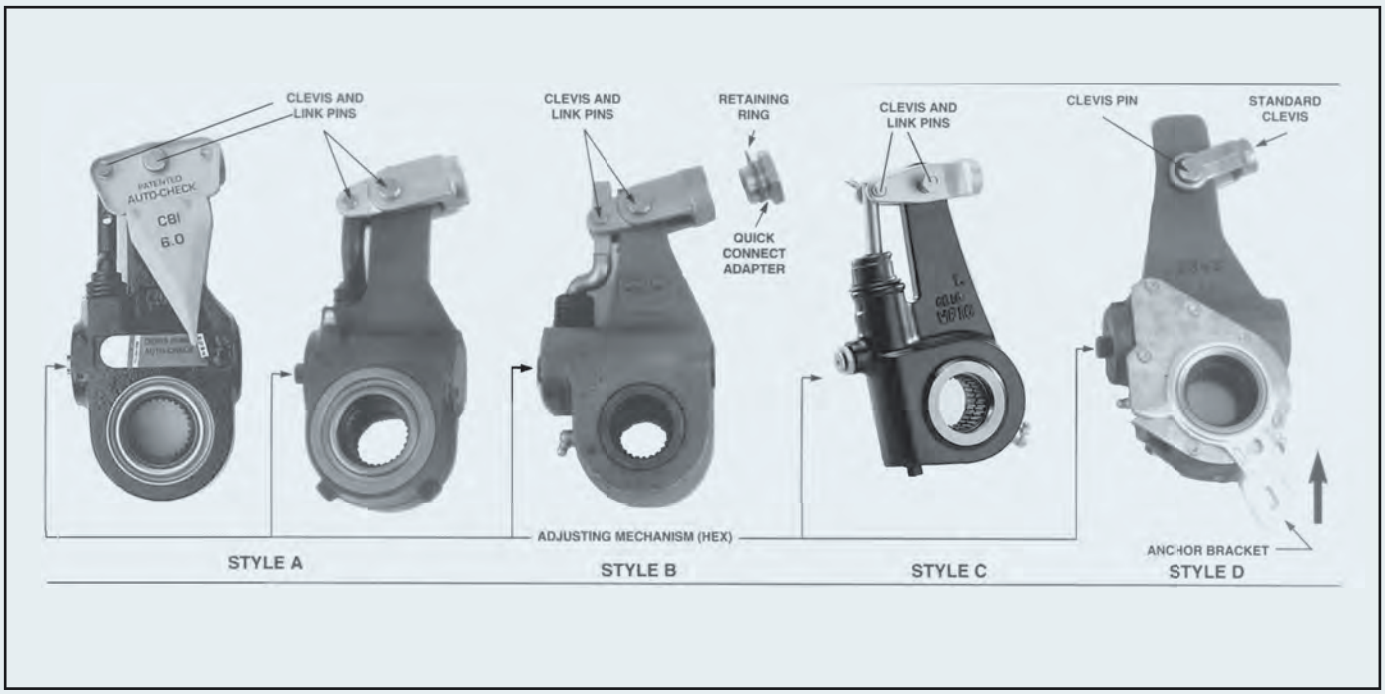


Fig. 2: Self-Adjusting Brake Adjuster Types

C. Self-Adjusting Brake Adjuster Removal—

1. Remove the clevis and link pins and the anchor bracket nut or pawl, if necessary (see **Fig. 2**).
   a. Style A—Remove the clevis and link pins.
   b. Style B—Remove the retaining ring quick connect yoke.
   c. Style C—Remove the pawl, clevis, and link pins.
   d. Style D—Remove the clevis pin and anchor bracket nuts.
2. Remove the retaining mechanism from the end of the brake cam shaft.
3. Rotate the adjusting mechanism to back the self-adjusting brake adjuster out of the clevis, if necessary.
4. Remove the self-adjusting brake adjuster from the spline end of the brake cam shaft.

   NOTE: If a manual brake adjuster is being removed to be replaced with a self-adjusting brake adjuster, the manual or threaded clevis must be removed from the brake chamber push rod (with Style D self-adjusting brake adjuster, the existing clevis is used and additional anchor bracket hardware is required). Leave the jam nut on the push rod.

D. Self-Adjusting Brake Adjuster Installation—

1. Ensure that the brake chamber is installed in the bracket holes appropriate for the self-adjusting brake adjuster arm length.
2. Clean the camshaft splines.
3. Coat the camshaft splines and the end of the brake chamber push rod with an anti-seize type product.
4. Install either a quick connect nut or threaded clevis on the brake chamber push rod per the manufacturer's recommendations. Some manufacturers offer both quick connect and threaded clevises.
5. Install the self-adjusting brake adjuster on the camshaft.
6. Install the self-adjusting brake adjuster retaining mechanism on the end of the brake cam shaft, being sure to shim it to less than 0.060 inch of end play.

7A. Rotate the adjusting mechanism to either install a clevis and link pin or to connect the clevis with a quick connect nut (see **Fig. 2**, Styles A, B, and C).

7B. For Style D, install the anchor bracket loosely and then rotate the adjusting mechanism to install the clevis pin.

8A. Using the correct gauge or template, (see **Fig. 2**, Styles A, B, and C) check for the proper mounting angle. Adjust the clevis for the correct angle, if necessary.

NOTE: The brake chamber push rod may require shortening or replacement to obtain the proper installation length.

8B. Make sure the control arm is bottomed out in the direction of the arrow or if the control arm has a pointer, align with the cut-out gap provided (see **Fig. 2**, Style D) and then secure all anchor bracket hardware.

9. Tighten the jam nut.

10. After installation, make a brake application to make certain there is no interference between the axle and the suspension components in both fully applied and fully released positions. Check to ensure that the brake adjusters rotate freely and without binding.

11. Adjust the brakes following the procedure in the section entitled BRAKE ADJUSTMENT PROCEDURE, below.

BRAKE ADJUSTMENT PROCEDURE

NOTE: All adjustments should be made with cold brake drums and the brakes fully released.

WARNING: To avoid possible injury, proper precautions must be taken to prevent automatic actuation of the brake chambers while adjusting brake adjusters. Always block the wheels or mechanically secure the vehicle. Spring brakes must be mechanically caged or released with air. All brakes should be released.

A. Manual Brake Adjuster

Brake Adjustment Procedure—

1. **Brake adjusters with locking collar (positive lock type)—** Jack up the vehicle. Thoroughly clean the adjusting hex and locking sleeve area. Position a wrench or socket over the adjusting hex and disengage the locking sleeve by depressing it. With the locking sleeve fully depressed, adjust the brakes while rotating the tire and wheel. Use the wrench or socket to turn the adjusting hex until the shoes contact the drum. Then back off the adjusting hex until the tire and wheel turn freely. The actuator stroke should be as short as possible without the brakes dragging.

   If the vehicle cannot be jacked up, thoroughly clean the adjusting hex and locking sleeve area. Position a wrench or socket over the adjusting hex and disengage the locking sleeve by depressing it. With the locking sleeve fully depressed, use the wrench or socket to turn the adjusting hex until it will go no further indicating that either the shoes have contacted the drum or the adjusting hex has been turned in the wrong direction. Pull on the brake adjuster to make sure it will not move. If there is movement, adjustment was made in the wrong direction and the adjusting hex must be turned in the opposite direction until it will go no further. After establishing solid shoe-to-drum contact, back off the adjusting hex 1/4 turn for worn linings and 1/2 turn when relining brakes. The actuator stroke should be as short as possible without the brakes dragging. Measure the chamber power stroke at 90-100 psi as described in subsection “B,” “Self-Adjusting Brake Adjuster Brake Adjustment Procedure,” below. Take a free stroke measurement as outlined in the section entitled FAILURE ANALYSIS. Ensure there is at least

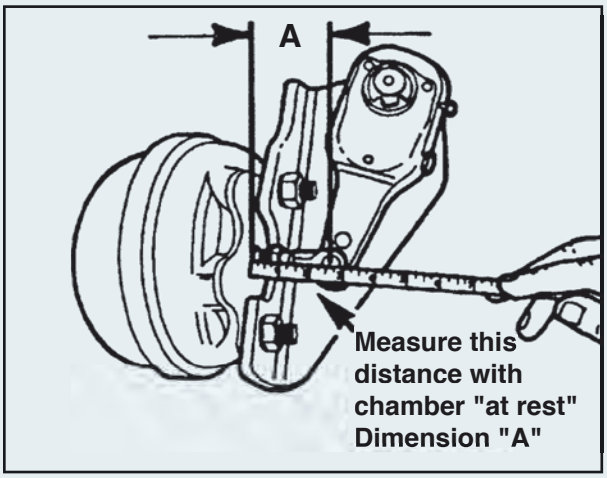


Fig. 3

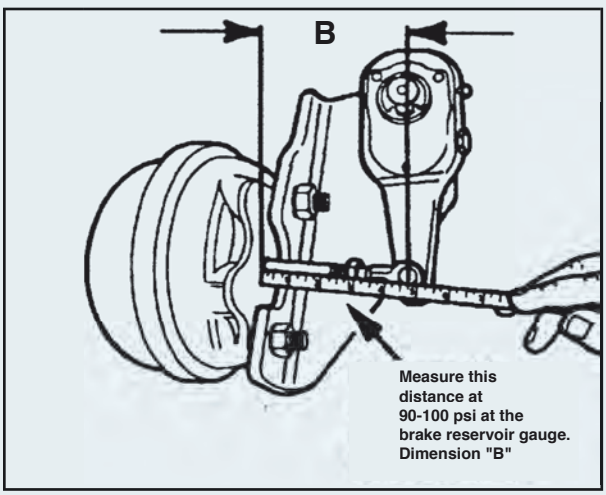


Fig. 4

TABLE 1

CHAMBER TYPE VS. MAXIMUM LEGAL STROKE AT 90-100 PSI BRAKE APPLICATION PRESSURE

Chamber Type	Maximum Legal Stroke
12	1-3/8" or less
12 Long Stroke	1-3/4" or less
16	1-3/4" or less
16 Long Stroke	2.0" or less
20	1-3/4" or less
20 Long Stroke	2.0" or less
24	1-3/4" or less
24 Long Stroke	2.0" or less
24 Extra Long Stroke	2.5" or less
30	2.0" or less
30 Long Stroke	2.5" or less
36	2-1/4" or less

3/8" of free stroke. Free stroke less than 3/8" can cause brake drag. If you can't maintain maximum legal stroke and the free stroke is less than 3/8", contact the brake manufacturer for foundation or brake geometry problems.

⚠ **CAUTION:** When the manual brake adjuster brake adjustment is completed, the adjusting hex should be positioned so the locking sleeve engages it, thus locking it in place. If the locking sleeve does not engage the adjusting hex, the brake adjuster can back itself off.

2. **Brake adjuster with lock screw ball Indent type lock mechanism**—Back off (turn counterclockwise) the worm shaft lock screw (if applicable). Make the necessary adjustment by turning the adjusting hex as described in item number 1 of this section. Following brake adjustment, make certain that the lock ball or plunger engages the worm shaft indent. Without such engagement, the slack adjuster can back itself off.

B. Self-Adjusting Brake Adjuster
Brake Adjustment Procedure—
A self-adjusting brake adjuster should not have to be manually adjusted except for initial installation and at brake reline. Instead of manually adjusting the adjuster, perform the following procedure during inspection:

Chamber Power Stroke: A power stroke at 90-100 psi brake application pressure will check both adjustment and foundation brake condition. Perform the following:

1. Measure from the brake chamber face to the center of the clevis pin at all wheel locations (see **Fig. 3).**
2. Make brake applications until the air reservoir gage reads 90-100 psi. Then have an assistant make a full brake application and hold it.
3. Measure from the brake chamber face to the center of the clevis pin (see **Fig. 4).**
4. The difference between the brakes released and applied measurements is the power stroke measurement. If the stroke is less than the maximum stroke for the chamber size (see **Table 1),** the inspection is complete. If the power stroke is more than the maximum stroke for the chamber size (see **Table 1**), refer to the section entitled FAILURE ANALYSIS.

SELF-ADJUSTING BRAKE ADJUSTER ADJUSTMENT PROCEDURE AT RELINE AND INSTALLATION
A self-adjusting brake adjuster should be manually adjusted after a brake reline and/or installation using the following procedure:

1. Position a wrench or socket over the adjusting mechanism.

   NOTE: If the self-adjusting brake adjuster is equipped with a pawl, remove the pawl for the brake adjustment and then properly reinstall the pawl (see **Fig. 2**, Style C) . Tighten the pawl to 15 - 20 ft.-lbs.

2. Rotate the adjusting mechanism until the brake shoes contact the drum. Pull on the brake adjuster by hand to make sure it will not move. If there is movement, adjustment was made in the wrong direction and the adjusting hex must be turned in the opposite direction until it will go no further.
3. Reverse the rotation, backing the brake adjuster off one-half (1/2) turn.
4. Measure the chamber power stroke at 90-100 psi brake application pressure as described in the previous section.
5. Take a free stroke measurement as outlined in the section entitled FAILURE ANALYSIS. Make sure you have at least 3/8" free stroke. Free stroke of less than 3/8" can cause brake drag. If you cannot maintain the maximum legal stroke and the free stroke is less than 3/8", contact the brake manufacturer for foundation or brake geometry problems.

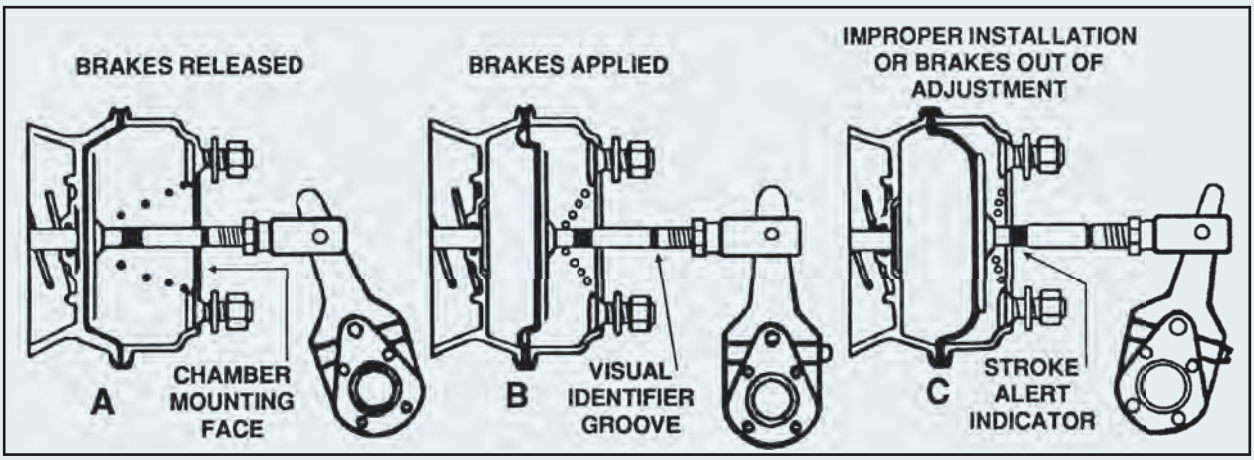


Fig. 5

ROADSIDE BRAKE ADJUSTMENT

If the driver has to adjust brakes on the road, the following procedure is recommended:

If the vehicle is equipped with an self-adjusting brake adjuster, use a pry bar to pull on the brake adjuster. If movement is more than 5/8", a manual adjustment should be made following the same procedure as described below for a manual brake adjuster. If the self-adjusting brake adjuster is equipped with a pawl remove the pawl for the brake adjustment and then properly reinstall the pawl. If the self-adjusting brake adjuster needs adjustment, inform maintenance personnel immediately.

1. Block the wheels or mechanically secure the vehicle. On the brakes to be adjusted, spring brakes must be mechanically caged or released with air.
2. Rotate the adjusting mechanism until the brake shoes contact the drum. Using a pry bar, pull on the brake adjuster by hand to make sure it will not move. If there is movement, adjustment was made in the wrong direction and the adjusting mechanism must be turned in the opposite direction. Tap the brake drum with a wrench; you should hear a dull clunk indicating the brake linings are tight against the drum.
3. Back off the brake adjuster a small amount at a time, while tapping on the brake drum with a wrench in between adjustments. Stop backing off the adjuster when you hear a clear ringing sound from the brake drum when tapped with a wrench.
4. Using a pry bar, pull on the slack adjuster by hand. If movement is more than 5/8", adjustment was not done properly or there is a problem with the foundation brake.

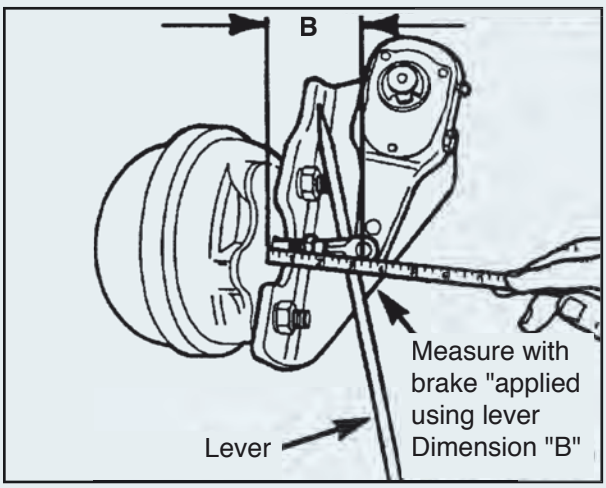


Fig. 6

NOTE: Some brake chamber push rods are marked to warn of an over-stroke condition. While the marking themselves may vary, the marking system has two basic features. They are: There is a mark on the brake chamber push rod near its clevis attachment to signal that it incorporates a stroke alert indicator (see **Fig. 5,** diagram B). There also is a mark on the brake chamber push rod opposite its clevis attachment end which is exposed from the brake chamber wherever over-stroke occurs (see **Fig. 5,** diagram C).

FAILURE ANALYSIS

Manual Brake Adjuster Failure Analysis—Manual slack adjusters should be inspected for gear set wear. To do this, back off the adjusting hex until all spring pressure is relieved from the clevis. Work the

adjusting nut 1/4 turn back and forth while watching for cam rotation. If you have 1/8 to 1/4 turn of play without the cam rotating, the manual brake should be replaced. Repeat this procedure every 1/4 turn of the adjusting nut to check the whole gear set.

Self-Adjusting Brake Adjuster Failure Analysis—If the power stroke is at or more than the maximum stroke, measure free stroke and check/inspect the adjuster components and attaching hardware to determine if the brake adjuster is operational.

FREE STROKE MEASUREMENT

Free stroke is the amount of brake arm movement required to move the brake shoes against the drum. To measure free stroke, perform the following:

1. With the brakes released, measure from the brake chamber face to the center of the clevis pin.
2. With a lever, pry the brake adjuster arm until the brake shoes contact the drum and measure the brake adjuster movement (see **Fig. 6**).
3. The difference between the brake released and applied measurements is the free stroke. The free stroke should be 3/8" - 5/8". If the free stroke is in the correct range, the out of spec stroke is due to a foundation brake problem. Check for missing or worn components, cracked brake drums, or improper lining-to-drum contact. If the free stroke is greater than recommended, a self-adjusting brake adjuster function test should be performed.

SELF-ADJUSTING BRAKE ADJUSTER FUNCTION TEST

1. Remove the pawl (if equipped), then rotate the adjusting mechanism at least one complete turn as if backing off the brake adjustment (see **Fig. 2**, Style C). The pawl must be installed properly and tightened to 15 - 20 ft-lbs after backing off the adjuster.
2. Apply the brakes several times and observe whether the adjustment mechanism is rotating in the direction needed to reduce brake chamber pushrod stroke. If the adjusting mechanism does not rotate, the brake adjuster should be replaced.
3. Check back-off torque by rotating the adjusting hex as follows (see **Fig. 2**):
   - Style A: Minimum 15 ft-lbs counter clockwise (CCW)
   - Style B: Minimum 15 ft-lbs CCW
   - Style C: Less than 45 in-lbs CCW (pawl removed)
   - Style D: Minimum 13 ft-lbs CCW

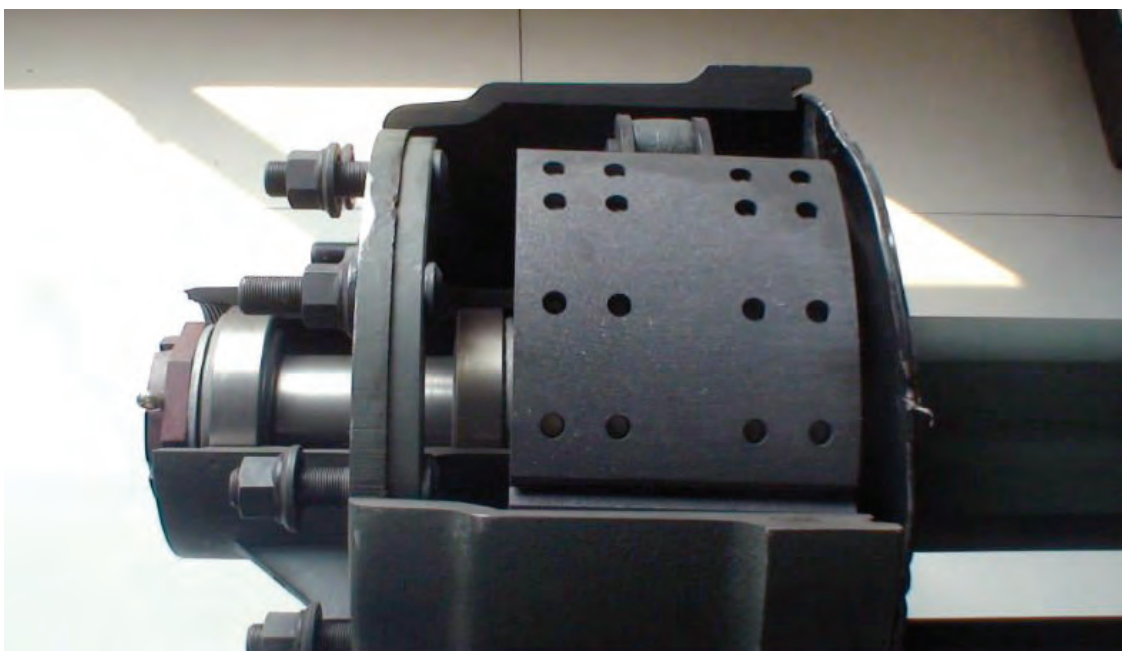
   Consult the manufacturer for more information.

PREVENTIVE MAINTENANCE

Every month, 8,000 miles, or 300 operating hours, check brake chamber push rod travel; chamber stroke should be in compliance with the maximum allowable adjusted strokes indicated in Table 1, without the brakes dragging or the pushrod binding. Adjust manual adjuster if necessary. Due to different operating conditions, adjustments may be necessary at earlier intervals.

Every six months, 50,000 miles, or 1,800 operating hours, lubricate all brake adjusters and clevis pins with manufacturer's recommended lubricant. Check for worn clevises, clevis pins, clevis pin bushings, and worn or broken control arm/attaching brackets. Failure to replace worn, broken, or disconnected components will increase chamber stroke. Lubrication and inspection may be necessary at earlier, intervals due to different operating conditions.

CHAPTER 7: Selecting proper brake linings



Spec'ing the appropriate brake linings is key to optimizing brake performance and lowering maintenance costs

By Jack Roberts

In trucking applications, friction is the force that slows a vehicle down. The brake system is the means by which that force is applied. But the actual component that has to bear the brunt of all the heat, weight, energy and force created during a braking operation? That would be the brake lining on the shoes and pads.

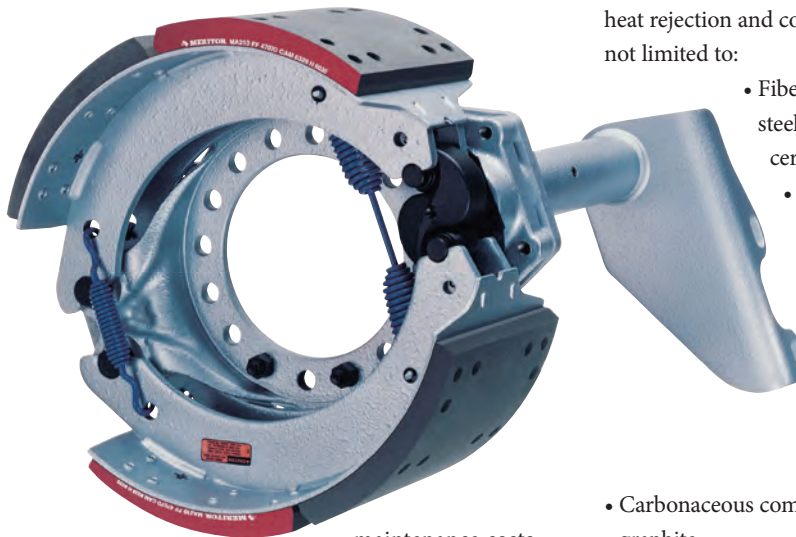
Clearly, brake linings work in a hellish environment. Yet they do so reliably, day in and day out – a testament to the ongoing research and development carried on by manufacturers.

Companies like Haldex carry out extensive laboratory testing to establish performance baselines for new linings. "Then we do field testing in addition to that to make sure they perform as intended, and that field testing can be several years," says Scott Corbett, director of technical service and warranty for Haldex. "Some of the linings have as many as 11 different tests to pass, evaluating factors such as fade, wear characteristics, overall component and material performance and high-temperature performance."

Additionally, Corbett says, tests are conducted on peripheral characteristics such as lining squeal and vibration. In all, he notes, it is not unusual for linings to undergo more than five years of extensive testing before being released into the marketplace. "Whether you're working on a motorcycle or you're working on a severe-duty off-highway vehicle, the concepts are basically the same," says John Hawker, service engineer, Bendix Vehicle Systems. "You're transferring energy and motion – kinetic energy – and converting it to heat. That's what the friction material in a brake pad or shoe does."

To understand exactly how a brake lining accomplishes this, Hawker says it's best to think of the process of applying a brake pedal as a controlled burn. "Just like you burn fuel to make the vehicle go, you wear friction material to make the vehicle slow down," he explains.

Because brake linings are designed to wear as they do their job, it makes sense for manufacturers to design linings to last as long as possible to keep



Brake shoes are almost always sold in kits to ensure replacement of all worn components.

maintenance costs down and assure solid braking performance even in abrasive or severe operating conditions.

Each manufacturer guards the ingredient list for its proprietary brake lining materials with the same sort of zeal that Coca-Cola and KFC guard the ingredients in their products. "Brake linings are made out of many different materials," Corbett notes. "You'll find carbon and fiberglass. And there used to be asbestos until we removed it. But all lining manufacturers have special materials they put in lining, and the higher grade or more expensive the lining is, the more premium materials go into that lining."

Most brake linings consist of different amounts of materials blended together in such a way to maximize heat rejection and component life. These include but are not limited to:

- Fiber materials, usually comprised of steel, carbon, fiberglass, synthetic or ceramics.
- Abrasives such as aluminum oxide, magnesium oxide, zinc oxide and silicon carbide.
- Friction modifiers.
- Fillers – including inorganic, metallic and organic materials.
- Binders – usually phenolic resins and rubber compounds.
- Carbonaceous compounds – coke, carbon and graphite.

Each manufacturer blends these compounds in various amounts under computer control. The mix is pressure-cured in long slabs, then baked, cut and shaped. Rivet holes are drilled, and the lining is affixed to a shoe or pad. Samples are pulled and checked to ensure quality and durability – including analysis of moisture content, acidity, fiber size and ash content, among other tests.

Some states have their own specific requirements for brake materials. Effective Jan. 1, 2014, in California and 2015 in Washington, new OE and replacement brake blocks must feature reduced content of several metals, including cadmium, chromium, lead, mercury and asbestiform fibers. Copper must be cut to 5 percent of material content by weight by Jan. 1, 2021. "Edge codes are specific to the corresponding formulation, so the edge codes will be unique to each formula," says Alesha Erving, commercial markets product manager for Federal Mogul.

Also, Erving says the industry has proposed requirements to designate compliance. There will be suffixes added to the edge code format. Environmental codes will be added (A, B, N), plus the year of manufacture. Each environmental hurdle is designated

Experts stress the importance of always spec'ing brake linings manufactured by well-known OEMs to ensure the highest quality possible.

by the environmental code that will be applied to the edge code and label.

Gauging lining life

Choosing the proper replacement and knowing when to replace brake linings is critical for performance, so manufacturers and industry organizations such as the Technology and Maintenance Council and the Society of Automotive Engineers go to great lengths to simplify the selection process when selecting replacement linings. Common tools are friction thickness or lining thickness gauges built into a shoe or pad to enable technicians to determine at a glance how much useful life the component has left. Many brake wear gauges have a minimum thickness check, but also have a 50 percent checkpoint on them. So they not only will tell you when they need to be replaced, they also can allow you to project the remaining life left on the shoe or pad and schedule the brake maintenance for that vehicle in advance.

Another point worth noting is that the majority of brake shoes are sold in kit form, which typically consists of two shoes with all the applicable wheel-attaching hardware in the box so technicians will replace all of the wear components that are associated to that wheel end – such as anchor pins, springs, retaining springs and bushings – as well as check radial play in the camshaft and others items that are associated to that brake.

All quality brake shoes and pads will be marked with edge codes on the side of the friction material. These codes give crucial data about the part and help technicians ensure they are replacing it with one that will give comparable performance.

Most edge codes start out, typically, by identifying the brand of the material in the pad. Naturally, the manufacturer will be noted as well. If the friction material is designed for extended service, for example, other information such as FMSI identification will follow along with mounting information telling you if the shoe requires single or dual anchor pins. It also will have a coefficient of friction generated by the material; this alphabetical sequence designates the coefficient of friction for that particular lining material. Coefficient of friction can be identified as EE, FF or GG, for example. The higher the alphabet scale gets, the more aggressive the material.

"That coefficient of friction comes from testing in a lab, quality control tests of a 1-inch-square piece of friction at that particular point when coming off a manufacturing batch line," notes a spokesman for Bendix Commercial Vehicles. "It's considered more of a quality control test and was implemented as one of the only tests they had in the marketplace to define an aspect of a brake. Today we have much more in-depth detailed tests that we run, so although the coefficient of friction is still labeled on the edge code of a friction lining material, it is a reference and not indicative of the performance of that particular friction. It's very important for technicians to bear that in mind when comparing edge codes."

A final piece of data on the edge code tells the batch – or specific manufacturing data – pertinent to that particular component. This is so that if there is a failure or performance issue with the material, it can be traced back to its manufacturing date – even down to the exact time of the manufacturing process.

According to Hawker, the most important thing about the edge code of any friction material is the manufacturer's name on it. "You need to know who manufactured that part so you know it's being backed by somebody," he

Edge codes give a variety of important information, including the manufacturer's name, coefficient of friction, anchor pin requirements and service application.

stresses. "There are many 'will fit,' 'could fit,' 'might fit,' copycat and even counterfeit parts out there on the market today. One part may very well look like the one you've just pulled off a truck. But if there's no name on it, I sure wouldn't put it on a vehicle, because I wouldn't want the liability and responsibility that I installed something that's suspect."

A fine line

The alphabetical codes found on the side of a brake pad or shoe also can help you select the appropriate lining material mix for the application at hand, says Haldex's Corbett. "If you have a severe-duty cycle application, like cement mixers, you're going to need a different material grade than you would for a linehaul-type application," he notes. "But don't just depend on edge codes alone." All manufacturers provide weight charts that detail how a particular lining corresponds to the weight your vehicles are hauling. It's an easy way to make sure that you've done your homework and you put the appropriate lining on for the job the vehicle has to do.

But simply increasing the level of friction material aggressiveness to meet more severe duty cycles is not always the best course of action when optimizing brake linings. "It is a balancing act," Bendix's Hawker stresses. "You have to take other factors beyond the friction material into account as well."

Those factors include air valves, drums, slack adjusters and chamber size. Naturally, different working environment or driving conditions may necessitate changes to vehicle brakes. But simply putting an aggressive brake lining on and assuming that will fix everything is a mistake.

One final piece of the puzzle is the driver. As Haldex's Corbett notes, nothing affects lining wear like bad habits behind the wheel. "Excessive braking, running up on stoplights and hitting the brakes at the last minute – all of that takes a toll," he says.

Heat is another critical factor. "Drum-type brakes are effective up to a certain temperature, and then they start to fade away," says Corbett. "If a driver keeps his brakes cool and doesn't abuse them, he's always got that maximum amount of stopping power if he gets into an emergency. If a driver rides the brakes or overheats them and gets into an emergency situation, he may not have enough stopping power to do what he needs, so it's important to coach drivers and get them to help you get the most out of the brake linings on that vehicle."

RP 628B **VMRS 013-001-015; -002-014**

AFTERMARKET BRAKE LINING CLASSIFICATION

PREFACE

The following Recommended Practice is subject to the Disclaimer at the front of TMC's *Recommended Maintenance Practices Manual*. Users are urged to read the Disclaimer before considering adoption of any portion of this Recommended Practice.

PURPOSE AND SCOPE

The purpose of this Recommended Practice (RP) is to provide information for judging the performance of aftermarket brake linings on air-actuated foundation brakes, including testing in accordance with the dynamometer test procedure in Federal Motor Vehicle Safety Standard (FMVSS) 121 and lining supplier qualification information. Such information will assist fleet operators in choosing aftermarket brake linings that will perform adequately on typical combination (tractor/trailer) vehicles and single trucks.

BACKGROUND

While performance of original equipment (OE) brake linings is regulated by FMVSS 121, linings sold as replacements for these friction materials are not. Testing of small lining samples to SAE J661a, producing a two letter "friction identification code" (EE, FF, GH, etc.), is **not** considered accurate in determining performance on a full size brake. **As a result, brakes relined with certain aftermarket materials can have reduced braking output, cause a shift of work to brakes on other axles, and reduce the overall stopping capability of the vehicle.**

NOTE: This RP has been updated in 2009 to include certain additional information on lining performance and suppliers. As a result, some information will not be shown for materials listed prior to this update. As older listings of linings reach their five-year expiration, this additional information will be presented in the listing updates.

The Performance Review Institute (PRI), an affiliate of SAE International, has formed the Brake Lining Performance Review Committee to review results of FMVSS 121 dynamometer performance tests conducted by qualified laboratories, in accordance with the test conditions described in this RP. The **Appendix** represents the most recent results available at the time of this manual's publication. Results are also made available through TMC's website *http://tmc.truckline.com* and PRI's website *www.pri-network.org*/ Brake Lining Program. Readers should visit these websites for the most current list.

LINING TORQUE VALUES

Brake torque output can be compared for linings which have been tested for FMVSS 121 dynamometer performance, using the test conditions of this RP.

Three torque values are listed for each lining at application pressures of 20, 40, and 80 psi. Most vehicle brake applications are typically non-panic stops at low pressures—usually 20 psi or less. Medium braking occurs around 40 psi, while heavy or panic stops can be at 80 psi or higher. Historically, the 40 psi value has been used to match brake torques of aftermarket linings. The 20 and 80 psi values are also now reported for additional fleet operator information. See **Table 1**.

⚠ CAUTION: The torque values of an aftermarket lining should approximately match that of the original equipment lining it is replacing. The vehicle manufacturer should be able to compare such things as lining wear. Brake lining output torque, by itself, should not be used to measure total brake system performance. Due to variability in testing and lining composition, torques shown in the aftermarket lining classification list are approximations only.

BRAKE FADE INDEX

Fade is a characteristic of brakes in which braking torque is reduced as brake temperature increases. Fade can be a concern for vehicle operations in which high brake temperatures are experienced, such as mountainous operation or heavy brake usage in cities.

The RP 628B Brake Fade Index uses the brake power portion of the FMVSS 121 dynamometer test. In this

Issued 3/1995
Revised 10/2009

test, a brake is required to complete 10 snubs from 50 MPH in a timed sequence.

The RP 628B Brake Fade Index is the change in maximum braking force effectiveness from Snub 1 to Snub 10 during the Brake Power portion of the FMVSS 121 dynamometer tests submitted for the given lining and brake listed. A higher brake fade index number indicates a lining with more fade.

LINING MANUFACTURER INFORMATION

To further assist fleet operators in selecting aftermarket linings, the following information is also provided for each manufacturer and lining formula:

- Whether or not the manufacturer of the lining has certified the specific lining formula as "asbestos free."
- What quality certification is held by the manufacturing plant(s) that produce the specific lining formula.
- Whether or not the lining has been tested via either FMVSS 121 stopping distance vehicle test or FMVSS 121 parking vehicle test.

TABLE 1:
LINING TEST CONDITIONS AND THE VEHICLE CONFIGURATIONS THEY REPRESENT

Rim Size		Drive/Trailer					Steer		
22.5 In.	Brake Size (Drum - Dia./Width, in., Disc - Rim Size, in.)	16.5x7 Drum	16.5x7 Drum	16.5x7 Drum	22.5 Disc	22.5 Disc	15x4 Drum	16.5x5 Drum	22.5 Disc
	GAWR (lbs.)	20,000	20,000	23,000	20,000	23,000	12,000	14,600	14,600
	Air Chamber Size (type)	30	24	30	Various	Various	20	24	Various
	Cam Brake Slack Adjuster Size (in.) -	5.5	5.5	5.5	Not Req'd.	Not Req'd.	5.5	5.5	Not Req'd.
	Tire Size for Test, Rolling Radius (in.)	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
	Range of Tire Sizes on Vehicle	18.5 - 21.0	18.5 - 21.0	18.5 - 21.0	18.5 - 21.0	18.5 - 21.0	18.5 - 21.0	18.5 - 21.0	18.5 - 21.0
19.5 In.	Brake Size (Drum - Dia./Width, in., Disc - Rim Size, in.)	15x8.625 Drum	15x8.625 Drum	19.5 Disc	Additional brake sizes, linings, axle ratings, etc. can be supplied as special configurations for any wheel size.				
	GAWR (lbs.)	14,500	14,500	14,500					
	Air Chamber Size (type)	30	24	Various					
	Cam Brake Slack Adjuster Size (in.) -	5.5	5.5	Not Req'd.					
	Tire Size, Rolling Radius (in.)	15.3	15.3	15.3					
	Range of Tire Sizes on Vehicle	15.1 - 16.3	15.1 - 16.3	15.1 - 16.3					
17.5 In.	Brake Size (Drum - Dia./Width, in., Disc - Rim Size, in.)	12.25x7.5 Drum	12.25x7.5 Drum	17.5 Disc					
	GAWR (lbs.)	19,200	19,200	19,200					
	Air Chamber Size (type)	30	24	Various					
	Cam Brake Slack Adjuster Size (in.) -	5.5	5.5	Not Req'd.					
	Tire Size, Rolling Radius (in.)	14.6	14.6	14.6					
	Range of Tire Sizes on Vehicle	14.1 - 17.0	14.1 - 17.0	14.1 - 17.0					

The sets of FMVSS 121 test conditions listed above—which depend on gross axle weight rating (GAWR) and air chamber size—can be used to test and evaluate brake lining friction materials. The test conditions simulate vehicle configurations which are commonly used in on-highway tractor-trailer operations.

APPENDIX

AFTERMARKET BRAKE LININGS WHICH MEET FMVSS 121 CRITERIA FOR ORIGINAL EQUIPMENT LININGS AND APPROXIMATE OUTPUT TORQUE VALUES DURING A BRAKE APPLICATION

The Performance Review Institute (PRI)—an affiliate of SAE International—Brake Lining Performance Review Committee has complied this list of aftermarket brake linings that meet the brake dynamometer requirements specified in FMVSS 121. All original equipment foundation brakes must meet these requirements.

Three torque values are listed for each lining at application pressures of 20, 40, and 80 psi. Most vehicle brake applications are typically non-panic stops at low pressures—usually 20 psi or less. Medium braking occurs around 40 psi, while heavy or panic stops can be at 80 psi or higher. Historically, the 40 psi value has been used to match brake torques of aftermarket linings. The 20 and 80 psi values are also now reported for additional fleet operator information.

The linings are listed in descending torque value. Order is not based on brake lining quality. The aftermarket brake lining list is intended to help fleets replace worn OEM linings with replacement linings of similar torque value to help ensure torque balance. The higher the torque value the more aggressive the brake lining.

PRI and TMC stress that the review of this information does not constitute PRI or TMC approval, certification, endorsement, or recommendation of the products; it simply verifies that the brake lining material, as represented by the data presented to the PRI Brake Lining Performance Review Committee, has demonstrated its ability to meet FMVSS 121 dynamometer requirements, when installed on the indicated brake and operated in a configuration specified in TMC RP 628B, *Aftermarket Brake Lining Classification*.

NOTE: Vehicle compliance indicated in a lining's listing does not guarantee vehicle certification under all vehicle configurations. Brake lining products that are not on the list either were not tested, or did not pass. Only successfully tested linings are listed.

TMC permits distribution of this Appendix. However, the preceding preamble must appear in its entirety with any publication of the brake lining list.

Any friction material or foundation brake supplier who wishes to submit lining formulas for review and addition to the RP628B list should visit the website *www.pri-network.org — http://www.pri-network.org/other-programs/automotive-qpl/brake-lining/—* Brake Lining Program or contact PRI for information on how to submit test results. PRI may be reached at 161 Thorn Hill Road, Warrendale, PA 15086; phone: (724) 772-1616.

NOTICE: The material manufacturers provided the information contained in this report. The Performance Review Institute has not tested this material nor verified the manufacturers test results. The review of this information does not constitute an approval by SAE. The listing of these products on the Performance Review Institute Brake Lining Qualified Products List only verifies that the brake lining material, as represented by the data presented by the manufacturer, has demonstrated its ability to meet the established test criteria. It is the sole responsibility of the user to determine whether the material is or is not suitable for a particular application.

The torque of an aftermarket lining should approximately match that of the original equipment lining it is replacing. The vehicle manufacturer should be able to supply the original equipment lining formulation when supplied with the vehicle identification number. Brake lining output torque, by itself, should not be used to measure total brake system performance. Due to variability in testing and lining composition, torques shown in the aftermarket lining classification list are approximations only.

(NEXT PAGE)

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Brake Lining Material Report - Provided to Technology & Maintenance Council (TMC)

Company Name	Address	Market Brand Name	Brake Type	Brake Size	GAWR	Chamber Type	Slack Adjuster Length	Rolling Radius	40 PSI Value	20 PSI Value	80 PSI Value	Brake Fade Index	Lining is Asbestos Free	Quality Certification of Manufacturing Plant	Lining has been Tested to FMVSS 121 Vehicle Test	Review Expiration Date
Carlisle Motion Control	4040 Lewis & Clark Drive Charlottesville, Virginia 22911	MB21	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	54,567	24,967	110,096	-2.10%	Info Not Available	Info Not Available	Info Not Available	30-Apr-2013
Carlisle Motion Control	4040 Lewis & Clark Drive Charlottesville, Virginia 22911	MB23	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	72,390	33,079	145,454	41.70%	Info Not Available	Info Not Available	Info Not Available	30-Apr-2013
Carlisle Motion Control	4040 Lewis & Clark Drive Charlottesville, Virginia 22911	CF2000	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	62,976	31,122	118,978	21.40%	Info Not Available	Info Not Available	Info Not Available	30-Apr-2013
Carlisle Motion Control	4040 Lewis & Clark Drive Charlottesville, Virginia 22911	MB20	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	53,145	24,570	111,887	0.30%	Info Not Available	Info Not Available	Info Not Available	30-Apr-2013
DUROLINE SA	Rua Gerson Andreis 366 Distrito Industrial - 95112 - 130 Caxias do Sul, RS, Brasil	CREST XL	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	42,956	20,876	92,901	20.00%	Yes	ISO 9001:2008	No	28-Feb-2016
DUROLINE SA	Rua Gerson Andreis 366 Distrito Industrial - 95112 - 130 Caxias do Sul, RS, Brasil	ULTRAPEAK BRT	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	53,740	24,220	108,992	16.50%	Yes	ISO 9001:2008	No	28-Feb-2016
DUROLINE SA	Rua Gerson Andreis 366 Distrito Industrial - 95112 - 130 Caxias do Sul, RS, Brasil	ULTRAPEAK FT	Drum	14.5 x 10	26000	30	7"	20.3"	71,792	36,040	122,304	37.40%	Yes	ISO 9001:2008	No	28-Feb-2016
DUROLINE SA	Rua Gerson Andreis 366 Distrito Industrial - 95112 - 130 Caxias do Sul, RS, Brasil	VISTA HP	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	51,284	24,804	102,856	44.40%	Yes	ISO 9001:2008	No	28-Feb-2016
Federal Mogul	1 Grizzly Lane Smithville, Tennessee 37166-2810	OTR SILVER	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	58,995	29,891	112,712	85.00%	Info Not Provided	Info Not Provided	Info Not Provided	31-May-2014
Federal Mogul	1 Grizzly Lane Smithville, Tennessee 37166-2810	OTR BLUE	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	52,446	23,087	107,973	41.60%	Info Not Provided	Info Not Provided	Info Not Provided	31-May-2014
Federal Mogul	1 Grizzly Lane Smithville, Tennessee 37166-2810	OTR ORANGE	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	66,620	32,348	131,261	77.60%	Info Not Provided	Info Not Provided	Info Not Provided	31-May-2014
Federal Mogul	1 Grizzly Lane Smithville, Tennessee 37166-2810	OTR BLACK	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	57,948	26,841	116,755	18.30%	Info Not Provided	Info Not Provided	Info Not Provided	31-Aug-2014
Federal Mogul	1 Grizzly Lane Smithville, Tennessee 37166-2810	OTR GOLD	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	53,659	24,643	117,451	11.60%	Info Not Provided	Info Not Provided	Info Not Provided	31-Aug-2014
Federal Mogul	1 Grizzly Lane Smithville, Tennessee 37166-2810	OTR RED	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	62,587	26,826	126,420	72.40%	Yes	ISO 14001:2004 ISOTS16949:2009	No	31-Aug-2017
Federal Mogul	1 Grizzly Lane Smithville, Tennessee 37166-2810	OTR GREEN	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	61,840	28,679	122,311	69.10%	Yes	ISO 14001:2004 ISOTS16949:2009	No	31-Aug-2017
FRAS-LE North America	37728 Hills Tech Drive Farmington Hills, Michigan 48331	MG1	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	63,469	26,834	133,493	7.40%	Yes	ISO 14001:2004 ISOTS16949:2009	No	31-Oct-2015
TMD Friction, Inc.	1035 Crooks Road Troy, Michigan 48084	Textar T5000	Drum	16.5 x7	17-20000	30	5.5"	19.6"	53,537	26,114	108,215	24.80%	Yes	ISO/TS 16949:2009	Yes	28-Feb-2017
TMD Friction, Inc.	1035 Crooks Road Troy, Michigan 48084	Textar T3070	Disc	225	12000	T18	NR	19.6"	37,058	15,544	83,144	-13.20%	Yes	ISO/TS 16949:2009	Yes	28-Feb-2017

List current as of March 2013

NR=Not Required

Notice: The material manufacturers provided the information contained in this report. The Performance Review Institute has not tested this material nor verified the manufacturers test results. The review of this information does not constitute an approval by SAE. The listing of these products on the Performance Review Institute Brake Lining Qualified Products List only verifies that the brake lining material, as represented by the data presented by the manufacturer, has demonstrated its ability to meet the established test criteria. It is the sole responsibility of the user to determine whether the material is or is not suitable for a particular application. The torque of an after-market lining should approximately match that of the original equipment lining it is replacing. The vehicle manufacturer should be able to supply the original equipment lining formulation when supplied with the vehicle identification number. Brake lining output torque - by itself - should not be used to measure total brake system performance. Due to variability in testing and lining composition, torque shown in the after-market lining classification list is approximate only.

Brake Lining Material Report - Provided to Technology & Maintenance Council (TMC)

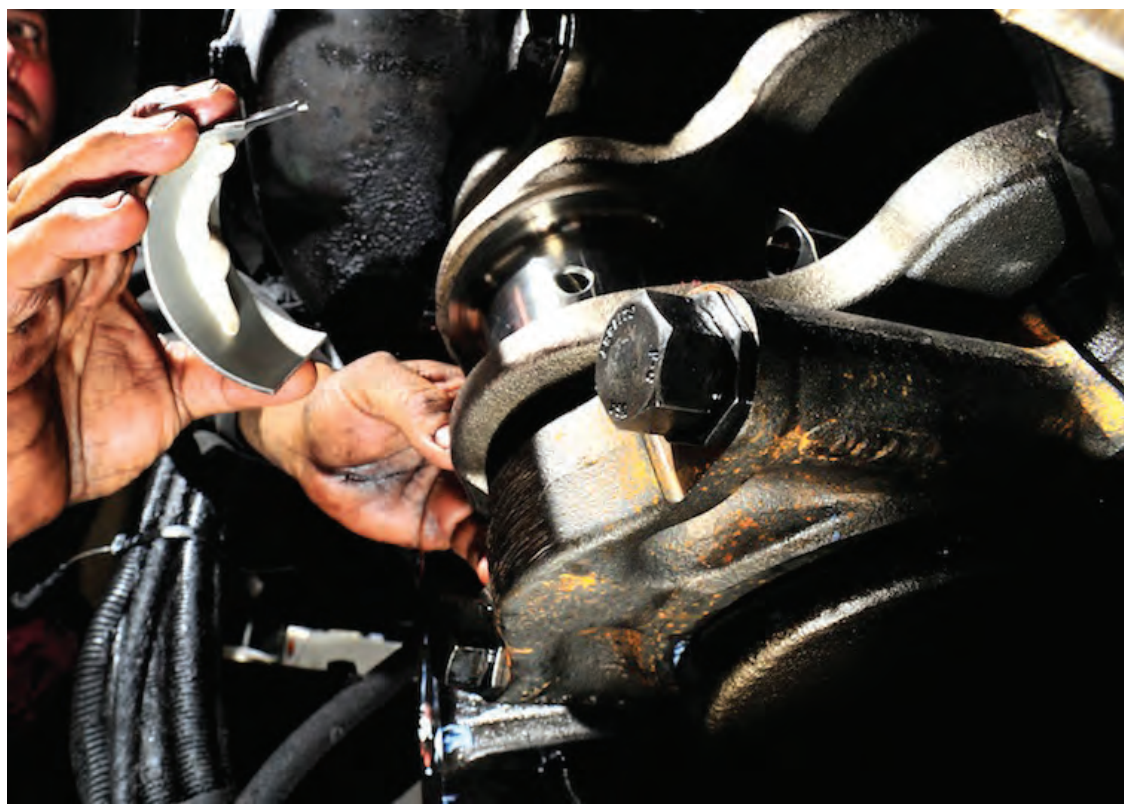
Company Name	Address	Market Brand Name	Brake Type	Brake Size	GAWR	Chamber Type	Slack Adjuster Length	Rolling Radius	40 PSI Value	20 PSI Value	80 PSI Value	Brake Fade Index	Lining is Asbestos Free	Quality Certification of Manufacturing Plant	Lining has been Tested to FMVSS 121 Vehicle Test	Review Expiration Date
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	AR1	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	77,919	35,398	152,545	16.20%	Yes	ISO 9001:2000 ISO/ TS16949:2002 ISO 14001:2004	Yes	31-Aug-2014
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	Armada AR1	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	56,880	25,508	117,044	32.50%	Yes	ISO / TS 16949:2009	No	31-Jan-2018
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	AR2	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	73,797	34,159	140,183	109.80%	Yes	ISO 9001:2000 ISO / TS 16949:2002 ISO 14001:2004	Yes	31-Aug-2014
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	AR3	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	71,045	31,256	143,452	6.80%	Yes	ISO 9001:2000 ISO / TS 16949:2002 ISO 14001:2004	Yes	31-Aug-2014
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	AR4	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	67,674	30,478	128,463	21.20%	Yes	ISO 9001:2000 ISO / TS 16949:2002 ISO 14001:2004	Yes	31-Aug-2014
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	AR5	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	66,408	29,415	132,504	78.30%	Yes	ISO 9001:2000 ISO / TS 16949:2002 ISO 14001:2004	Yes	30-Sep-2015
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	ARSM	Drum	16.5 x 7	22-23000	30	5.5"	19.6"	79,805	36,522	147,360	32.60%	Yes	ISO 9001:2000 ISO / TS 16949:2002 ISO 14001:2004	Yes	30-Sep-2015
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	Armada AR20P	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	51,464	29.956	97,564	49.90%	Yes	ISO/TS 16949:2009	No	31-Jan-2018
TruckPro, Inc.	8110 Cordova Road,Suite 116 Cordova, Tennessee 38018	Armada AR23P	Drum	16.5 x 7	17-20000	30	5.5"	19.6"	64,920	29,604	131,896	73.50%	Yes	ISO/TS 16949:2009	No	31-Jan-2018

NR=Not Required

List current as of March 2013

CHAPTER 8: Brake relining and restoration

Taking time to thoroughly inspect and repair brake components when relining brakes can save money in the long run



By Jack Roberts

Brake linings should be replaced before they completely wear away, resulting in metal-on-metal contact between the brake shoe and the brake drum, causing potentially catastrophic component failures and expensive replacement costs. Replacing linings in a timely fashion also will prevent the possibility of S-cam turnover.

It is widely accepted that brake linings worn down to 1/4-inch thickness are in need of replacement. Carefully measuring lining thickness is always recommended, but if you are performing a visual inspection, look for lining thickness that is slightly higher than the rivet heads that secure it to the brake shoe.

But don't simply slap new shoes on and put the vehicle back in service. Relining time is an excellent opportunity to tune up the entire brake system and ensure safe, efficient stopping power for many miles to come.

Inspecting foundation brakes

It's easy to check over the foundation brakes when the wheel is off an axle. Keep an eye out for excessive deflection or loose and broken parts. You also want to look for excessive component wear – most notably on the cam splines, which can allow lost motion between the automatic brake adjuster and S-cam. Replace the camshaft and the slack adjuster if there is more than .020 inch of free movement between the adjustor and the S-cam. This is also a good time to check the clearance between the slack clevis pin and its bushing. Once again, clearance between the two components should not exceed .020 inch. If the slack adjuster has to

be removed, use an anti-seize compound on the camshaft splines to make it easier to remove next time service work is performed.

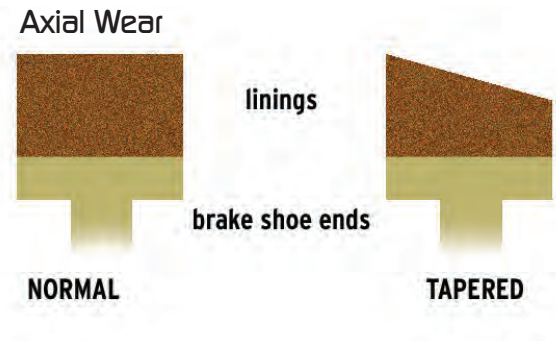
Once removed, closely examine the old brake shoes before you toss them in the core bin. They can tell you a lot about what's going on with the foundation brakes out on the highway. Are any linings cracked? That's a sure sign of additional problems – most likely a shoe that's out of arc, rust buildup on the shoe surface, improper riveting or duty cycle.

Lining wear should be even around the circumference of both brake shoes, from inboard to outboard. Tapered wear patterns – where both shoes show accelerated wear at the top or bottom, or inboard or outboard side – is an indication that peripheral brake hardware is worn. As a result, the brake cannot be properly adjusted. Ideally, you should see uniform wear patterns all the way around the brake linings.

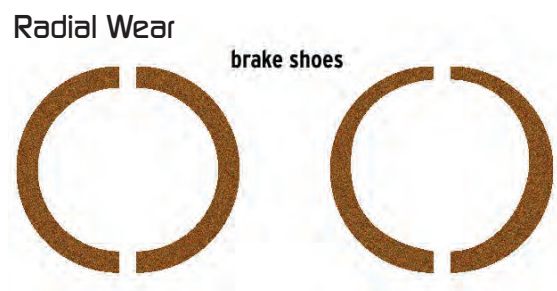
Worn anchor pins, holes and bushings or outer S-cam bushings can allow applied force to push the brake shoes to one side. This not only results in tapered lining wear, but can also cause outer edge abrasion on the brake shoes. (This condition can also be caused by drum deflection at the open side). For those reasons, reusing shoe rollers and anchor pins is not recommended.

Don't confuse a designed-in taper with one caused by unbalanced brake wear. Many brake shoes feature a cam end that is thicker than the anchor end to allow geometry optimization in an effort to gain full contact to the drum. Also don't confuse tapered lining wear with a high ridge on the inside edge of the linings. This is actually beneficial, as it prevents a lip being etched into the drum, and makes drum removal easier while keeping water and contaminants out of the brake assembly.

If you do find uneven lining wear between the leading and trailing ends of a shoe, you'll need to check several components to pinpoint the cause. Such wear may be the result of a weak return spring, a worn outer S-cam bushing, an out-of-arc shoe or a high-energy duty cycle. Attempting to adjust a brake with any of these conditions will result in dragging and high contact pressure at one spot of the lining, leading to rapid lining wear and heat damage to the drum.



Axial tapered wear results from worn anchor pins, holes or bushings, or worn outer S-cam bushings. These allow force to push shoes to one side.



Radial tapered lining wear between the leading and trailing ends of a shoe may mean a weak return spring, a worn S-cam bushing or an out-of-arc shoe.

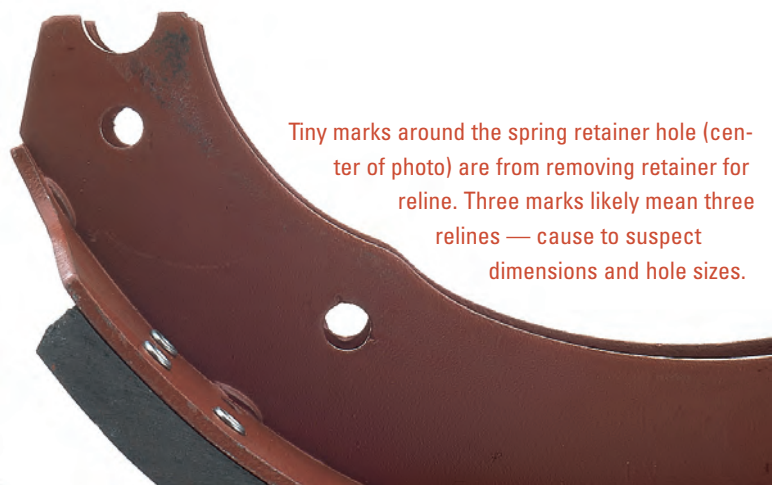
Brake disassembly and repair

If lining wear is unacceptable, it's time to remove the worn brake shoes and replace them. It's also a good time to replace any associated components and check for leaks to ensure safe and reliable braking characteristics.

When removing anchor pins, don't heat the spider and try to hammer them out. Heating removes the metal's temper, and hammering a hot spider will cause permanent distortion, reduced brake performance and abnormal wear. If the anchor pins are stubborn and don't want to come out easily, douse them with a light, penetrating oil and give it time to work in before tapping them out as gently as possible. You can also use a puller specifically designed for that purpose.

Once you've got it out, clean the spider with a solvent and wire brush, and inspect it for broken welds or cracks in the camshaft and anchor pin areas. Check tightness of the spider securing bolts, and be sure the spider is not bent; the anchor pin holes must be parallel to the

Cracked linings likely were loose on the shoe. This is caused by a shoe that's out of arc, rust buildup on the shoe surface or improper riveting.



Tiny marks around the spring retainer hole (center of photo) are from removing retainer for reline. Three marks likely mean three relines — cause to suspect dimensions and hole sizes.

centerline of the axle. Otherwise, the shoes won't track in the drum properly, and tapered wear will result.

If the old liners are covered with oil or grease, you need to identify and correct the cause before putting new shoes on. The problem is almost always a leaking oil seal, too much grease on a grease-type wheel bearing or camshaft bushing or from careless handling. If there is some grease or oil on the old lining — an area no larger than 10 percent of the total lining area – then the spot can be cleaned with brake cleaning solvent (not gasoline or another substitute). However, this isn't the safest option, as it could lead to a brake imbalance condition if done improperly.

Check the cam bearing surfaces for wear before installing the new brake shoes. Replace any cam if wear exceeds .010 inch. You can reuse a cam that's within tolerance but has deep grooves caused by the seals, although Meritor recommends no more than 0.030 inch of total radial play since at that point the seal lip may no longer be effective at keeping contaminants out, resulting in accelerated bearing and cam wear. The cam bearing itself should be replaced each time the brakes are relined.

Carefully examine the S-cam and rollers for flat spots and irregularities. An irregular surface on these parts will cause brake noise and cause brake "grab" and slower release times. It is best to replace the S-cam if you have any doubts about its condition. Return springs are inexpensive, and there's almost no excuse for reusing them. If you must, be sure they're not stretched, broken or corroded. Be sure to lube the cam bearing and seals, and anchor pin bores and bushings when reassembling.

Now you're ready to install new brake shoes. First, make sure the lining is tight and follows the contour of the new shoe. Always check a replacement shoe's dimensions – don't assume it's OK just because it has new lining.

Clean spider with solvent and a wire brush, and inspect for broken welds or cracks in camshaft and anchor pin areas. Check tightness of spider securing bolts, and be sure the spider is not bent. Anchor pin holes must be parallel to axle centerline to avoid uneven lining wear.

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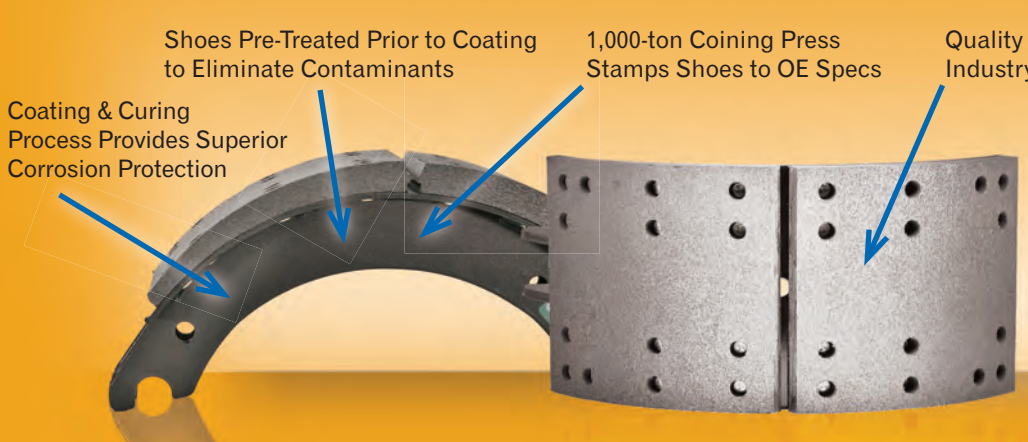

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www.vipar.com

Most experts stress the importance of using known name-brand replacement linings and brake components. A rash of counterfeit and "look-alike" will-fit parts from overseas are readily available today – often at discount prices. But they rarely perform up to the standards of the original parts and may be unsafe to install and use. Worse, they can be a tremendous liability for your fleet if a jury finds you or your technicians knowingly installed counterfeit or substandard parts on a commercial vehicle involved in an accident. (For more on brake lining selection, see Chapter 7: Selecting proper brake linings, page 69.)

Replace cam if bearing surface wear exceeds .010 inch. Deep seal grooves admit abrasive contaminants and accelerate bearing and cam wear.

Always check a replacement shoe's dimensions — don't assume arc is correct.

Inspect the brake drum before you put it back on over the foundation brakes. No matter how good a reline job you've done, the linings must have a smooth, round drum to rub against, or the brakes aren't going to perform properly. Some light scoring and abrasions are OK as long as they haven't cut any deeper than .010 inch into the drum. A drum with surface heat checks should be inspected periodically as the checks may wear away over time. If it's obvious that they are getting worse, discard the drum. Needless to say, any crack through the drum's thickness means the drum should be scrapped.

Heat generated in intense (downgrade) braking situations can distort drums quickly. So it's important to check and make sure the drum's circumference is within tolerances. Use a dial indicator to measure a mounted drum's diameter in the center of the rubbing path. Take another measurement 90 degrees from the first one, again in the center of the rubbing path. If the two measurements are not within .010 inch of each other, the drum can be cut or rotated one bolt hole and rechecked. If severely out of round, the drum should be discarded.

Whether a drum should be cut (turned) is a matter of debate. Turning a drum removes valuable metal and reduces the drum's effectiveness. If you want top performance, replace drums as wear approaches .080 inch.

The key to a good reline is to remember that brakes are a system of components working together to get the job done. For that reason, it is vitally important to replace linings by axle sets rather than individual wheel ends to avoid performance differences. If any part of the system isn't right, the brakes are not right, and the vehicle is unsafe. Wheel seals, bearings, axles – anything you touch during a brake job should be treated with the same respect given the brake components. Bring everything as close as possible to original condition, and you won't be sorry. It costs more upfront, but a thorough job will pay for itself in longer life and trouble-free operation.

CHAPTER 9 : Troubleshooting brake imbalance

A rolling dynamometer (brake tester) can be invaluable when diagnosing brake imbalance, easily exposing left-to-right and steer-versus-drive imbalances.

Diagnosing and correcting brake imbalance issues is critical for vehicle performance and safety over the road.

By Jack Roberts

A balanced brake system is one in which all the vehicle's brakes apply and release at about the same time, with each brake developing the appropriate braking force for its respective load.

Visualizing this concept, it's not hard to imagine the safety and maintenance problems that imbalanced brakes can cause for a commercial vehicle. If a tractor, for example, brakes more aggressively than the trailer it is towing, uneven brake wear will be the most obvious consequence as the linings on the hardest-working brakes will wear faster than the brakes not doing their fair share of the work. Worse, this condition could lead to a trailer bumping into the braking tractor, jackknifing or unintended panic stops as brakes lock up.

The frequency of brake imbalance situations has decreased somewhat thanks to improved brake technology. Today's brake systems are comprised of a

myriad of components that must all work properly and in the correct sequence in order to guarantee safe, efficient stops day in and day out. But if one of those components fails to perform, the vehicle's brake system will begin applying in an unsynchronized manner.

Brake imbalance is an early warning sign that a brake system is not functioning like it's supposed to. Torque imbalance, pressure imbalance and different tire sizes are all common problems that can lead to a brake imbalance problem. Each of those circumstances can be further complicated by the temperature extremes foundation brakes are subjected to during an normal workday. For many technicians, tracking down the source of a brake imbalance problem can be like a forensic investigator trying to figure out a crime scene: Many possibilities have to be examined and discarded before the culprit is identified.

When examining brake imbalance causes, it's worth noting that stopping distances on a vehicle equipped with drum brakes will increase when all brakes on a heavily laden combination vehicle are cool but maladjusted. When these maladjusted brakes become hot, their drums naturally expand, which causes linings to fade and brake-chamber stroke to increase. In these instances, it can take the vehicle up to 75 percent more stopping distance to come to a complete halt. Automatic slack adjusters are supposed to combat this problem, but don't always respond correctly due to worn parts.

Maintaining torque balance

One of the most common brake imbalance scenarios is caused by torque imbalance – a lack of uniform friction material coming into contact with the vehicle's brake drum or rotor. This is common sense: A brake shoe or pad with thicker friction material on it will engage sooner and more aggressively than a shoe or pad on another wheel end with a thinner layer of material.

Other factors can degrade friction material's stopping power as well. These include oil or grease on the pad or shoe, glazed friction material, polished drums or rotors or linings and pads with mixed friction capabilities at one or more wheels. Out-of-spec drums or rotors, incorrectly adjusted brakes, different size brake chambers, improperly installed automatic brake adjusters, inoperative or improperly adjusted antilock brake wheel sensors and incorrectly spec'd axle gross vehicle weight rating all can cause brake imbalance problems as well.

Differences between linings are most likely to sneak up and present you with a nasty surprise when you least expect it. That's because lining friction, fade and recovery characteristics at various temperatures can vary widely. In the early days of nonasbestos linings, some friction materials would swell excessively when exposed to high temperatures. Because of this, the swelled linings often caused tightly adjusted brakes to drag after the treadle was released. However, after the lining cooled down, it could not always be counted on to shrink back to its previous dimensions. In extreme cases, this permanent lining growth required slacks to be backed-off before the brakes could be released.

Other friction-induced imbalance problems remain with us. Consider edge codes, as a prime example, which offer easy identification of a lining's aggressiveness. (For more information on brake lining selection, see Chapter 7, page 69). But edge-code markings often wear off as friction material is worn down during the braking process. That's no great loss, however, because even within the same edge code, friction can vary by as much as 40 percent.

To maintain some degree of consistency, always spec the same brand and type of lining on tractors and trailers, and use the same material for relining. A good guide is TMC's RP 628B "Aftermarket Brake Lining Classification," (see page 73) which provides an ever-changing laundry list of various brands and types of FMVSS-121-compliance linings and their torque ratings.

Understanding torque degradation

Even if tractors and trailers initially are well-matched, torque balance can degrade over time. Friction material can be contaminated by leaky, improperly installed wheel oil seals or ill-advised and

overgenerous greasing of the cam assembly on drum brakes. Leaking oil seals on new equipment demands a spot check of other units on the tractor or trailer, since assembly line errors could be responsible. Leaking seals on older vehicles and equipment could indicate a need to spec higher-quality seals or retrain technicians in proper lubrication procedures. Another option is to consider spec'ing "unitized" (sealed) hubs on new equipment.

Over time, brake drums can become deeply scored or bell-mouthed, and disc brake rotors can become "dished," and prevent even contact with the friction material at one or more wheels. Never assume new or replacement drums are automatically good to go, either. They can come from the manufacturer with flaws, like being bell-mouthed or eccentric, requiring that they be turned true in a lathe. In some cases, radius grinding of linings may be required for a good fit. While mild heat checking is acceptable, any drum or rotor with deep cracks should be scrapped out of hand.

Remember that brake shoe return springs can stretch or even break over time. That's why it's a good idea to replace springs every time brakes are relined, even if they look good. The same rule should apply to rollers that have become flat-spotted.

S-cams can wear down to the point that brake torque is severely affected as well. Likewise, worn camshafts and their splines and bushings can also degrade stopping performance. Pay special attention to the condition of the bushing, as it's responsible for centering the cam and shoe assembly in the drum. Just like springs, bushings should be replaced every time the brakes are relined.

More than one anchor pin has been removed over the years with heat and hammer. But doing so may warp the spider, and bent spiders degrade lining-to-drum contact. Use only light taps, or better yet, use specially designed pullers to remove anchor pins when servicing brakes.

Sliding disc brake calipers can seize, causing accelerated wear of the inner disc brake pad. To combat this problem, make sure caliper pins and sliding surfaces are properly lubricated to assure proper function of the disc caliper.

Gum and carbon buildup from air contaminated with oil and water can, over time, clog valves, causing them to slow down or fail altogether. There's an easy way to avoid this malady – make sure air tanks are drained routinely, and spec an air dryer if you're not using one already.

Retrofitting brake chambers or slack adjusters of the wrong size will change performance and compatibility. Mixing two brands of automatic slack adjusters on the same axle is also not recommended because they will not perform identically and will create uneven brake wear. And although they are highly reliable components, automatic slack adjusters can malfunction or wear out over time. Lubricate them properly, and measure for excessive push rod stroke as brakes are applied. Inspecting the assembly for excessively worn holes in the yolk and slack adjuster, worn clevis pins and general looseness should be a standard maintenance procedure as well. To ensure proper performance, ABAs must be mounted at the correct angle, as determined by use of installation templates that vary by application and brand of slack. In the real world, however, the mounting angle may be compromised by clearance problems experienced by the OEM. For that reason, clearance should be checked before making a change in mounting position. (See Chapter 6, page 56.)

Low-profile tires can save you money at the fuel pump. But not matching low-profile tires on a tractor and trailer can cause brake compatibility issues. And retrofitting tires without reconfiguring the vehicle's brake system is a mistake. A vehicle or tractor with low-profile tires having a radius 18 percent smaller than original-equipment tires can cause a vehicle to be overbraked. In fact, an 18 percent reduction in rolling radius can result in an 18 percent increase in braking force, resulting in the lockup of lightly laden non-ABS-equipped trailers in the course of normal braking. And because smaller tires rotate faster at a given road speed, linings will engage the drums at higher rpm and run hotter, especially when braking on downgrades. If you want to spec low-profile tires, consider spec'ing the next

smallest chamber on the vehicle, which will reduce torque by about 20 percent. And changing to a less aggressive lining – or, with engineering approval, placing some sort of pressure modifier in the system – will help resolve an overbraking issue as well.

Consistent overheating, localized wear from lack of uniform friction material contact, or exposure to abrasive material all can damage drums and rotors. Always inspect rotors and drums during relining jobs. Any friction surfaces with a mirror-like finish should be roughed up with 80-grit emery cloth and, if accompanied by a glazing on the shoes or pads, should trigger a quest for a more suitable friction material.

Foreign abrasive materials also can cause excessive wear along the edges of the trailer lining contact area, or in areas coinciding with lining rivet holes. If this is happening, remove the lower dust shield (if equipped) to provide an exit for the foreign material. Remember when checking a drum for excessive wear that its inner diameter shouldn't be more than .12-inch more than the original spec.

When resurfacing drums, the finished ID shouldn't be over .08 inch beyond original spec. And runout shouldn't exceed .01 inch. The same goes for disc brake rotors. When checking rotor thickness, they shouldn't be more than .12 inch less than the original spec, and don't resurface more than .08 inch less than the original spec. Lateral runout shouldn't exceed .01 inch. In any event, it is important to follow individual manufacturer turning and finish requirements.

Pneumatic imbalance

Pneumatic or air pressure imbalance occurs when a tractor-trailer's air system delivers air pressure to the vehicle's brake chambers improperly. This is often caused by incorrectly spec'd or malfunctioning relay valves, although quick-release valves can also upset air pressure balance. Other common air pressure imbalance causes include air leaks, air system contamination, a front-axle-limiting valve and excessive use of the trailer hand control valve. (Refer to SAE J1505 and 1860 for further information.)

Timing imbalance occurs when some brakes receive air faster than others. Common causes include oversized control lines (found on pre-1991 trailers), which impede brake application; poor plumbing design or improper installation; and failure to use booster valves where appropriate.

Most manufacturers say that maintaining good pneumatic balance is crucial in improving brake response. Ideal pneumatic balance is achieved when the air delivered to each axle doesn't vary by more than 2 psi during a 10-40 psi application. (An exception to this rule would be the ill-advised mating of an S-cam-equipped tractor with a wedge-braked trailer. Because wedge brakes have smaller chambers and require more psi than S-cams to make linings contact the drum, the wedge-braked trailer would require higher air pressure than the tractor for balanced braking during low-pressure applications.)

Low-pressure imbalance

Brake system engineers say about 95 percent of braking involves application pressures for linehaul applications below 20 psi. And approximately 84 percent of braking is done at application pressures of 15 psi or less. When Federal Motor Vehicle Safety Standard 121 took effect in 1975, it required trailers to be compatible with a tractor simulator delivering a massive slug of air. To achieve timing requirements, trailers needed 1⁄2-inch OD (3⁄8-inch ID) control lines instead of the 3⁄8-inch OD (1⁄4-inch ID) lines. But during normal braking procedures, a tractor doesn't deliver enough air to fill a trailer's oversized control line. As a result, trailer braking is delayed – and the problem is magnified on multiple-trailer combinations.

In some cases, this delayed air delivery gives drivers a noticeable thump from behind as the trailer pushes the power unit forward. In extreme cases, that bump can quickly become a full-blown shove when braking in slippery conditions or in a curve, causing a jackknife.

Seeking to eliminate the delay, the National Highway Traffic Safety Administration modified the tractor simulator and changed maximum application/release times for trailers built on or after May 3, 1991,

and has specified air-delivery times for control-line gladhands at the rear of tractors, trailers and dollies built on or after May 3, 1991, and should, theoretically, be a rare occurrence today. But if you're working with older tractors and trailers, trailer bumping can be eliminated by retrofitting a smaller control line to the trailer and by making changes to the tractor that would speed gladhand timing. This causes trailer brakes to apply faster during normal brake applications without any degradation of stopping distance during panic stops.

High-pressure imbalance

Conversely, if a tractor's brakes are doing most of the work, a combination vehicle can't slow down quickly without the driver applying heavy pressure on the brake pedal.

And while ABS prevents overbraked wheels from locking up, it's not a substitute for a properly balanced brake system. Sustained high-pressure braking of an ABS-equipped tractor is not advisable since a non-ABS-equipped trailer (or one with nonfunctional ABS) may receive enough air to lock its brakes, perhaps causing it to swing rapidly out of its traffic lane. Worse, a tractor with a nonfunctioning ABS is likely to jackknife during full and sustained braking. For those reasons, NHTSA advises drivers not to change their normal braking habits when driving ABS-equipped combination vehicles.

Air disc brakes provide more efficient braking on tractors, which could be a problem when paired with trailers still equipped with drum brakes. Trailer drum brakes have a tendency to develop heat fade faster when paired with tractor air disc brakes. As a result, the tractor brakes work harder to slow the rig down, resulting in imbalanced brakes.

The key to solving this high-pressure imbalance lies with the crack pressure on the trailer. Crack pressure, expressed in psi, is the air required to force a valve open when air brakes are applied. Some tractors fire air quickly to their own brakes before passing it along to the trailer(s) behind them. But some trailers resist accepting air from a tractor because they have a relay valve set with a relatively high crack pressure.

As a general rule, valve character, including crack pressure, has minimal effect on high-pressure braking and primarily influences low-pressure braking and wear.

Remember that retrofitting remanufactured or aftermarket air valves can destroy pneumatic balance because the crack pressure of relay or quick-release valves fitted with aftermarket springs can vary considerably. Just because a valve "looks right" or "will fit" doesn't mean it's a suitable replacement for original equipment. Even where valves of the same make and model are used as replacements, crack pressures and pressure differentials may vary because of differences in bore size and manufacturing tolerances. (Refer to SAE 1860 for more information.)

Correcting overspec'd brakes

A final yet relatively simple problem causing brake imbalance is a tractor with axles that have been overspec'd for the loads it usually carries. Some fleets do this to boost the tractor's resale value or to extend axle life by using larger gearsets and bearings. But the safety aspects far outweigh any payload or durability gains because the tractor always will overbrake if axle loading is substantially less than its rated capacity. The same rule applies to trailers with overspec'd axles. This can lead to compatibility, wear and maintenance issues.

One option to resolve an overspec'd tractor or trailer is to switch to less-aggressive brake linings. Another option (not always possible) is to attach chamber pushrods to a different slack adjuster hole, thereby reducing braking force. Keep in mind, though, that spacing between slack adjuster holes varies by make. So it's wise to ask your vehicle OEM or brake component supplier for technical advice before making changes.

It's also a good idea to conduct an onsite brake-torque-balance test before making any fleetwide modifications. A suitable procedure is offered by Recommended Practice (RP) 613 "Brake System Torque Balance Test Procedure," which is offered by the Technology and Maintenance Council of the American Trucking Associations.

CHAPTER 10: Resources

The following are selected original equipment and aftermarket suppliers of air brake system parts and components.

AIR COMPRESSORS, BRAKING

Bendix Commercial Vehicle Systems
www.bendix.com

Bepco, Inc.
www.bepco.biz

Brake Systems, Inc.
www.brakesystemsinc.com

FleetPride, Inc.
www.fleetpride.com

Haldex
www.haldex.com

HD America, Inc.
www.hdamerica.com

Meritor, Inc.
www.meritor.com

Precision Rebuilders
www.precisionrebuilders.com

S & S Truck Parts Inc.
NewStar Parts Component Group
www.sandstruck.com

Transaxle LLC
www.transaxle.com

Truck Pride Marketing
www.truckpride.com

Vipar Heavy Duty
www.vipar.com

Wholesale Truck Parts
www.wholesaletruckparts.com

AIR DRYERS

Alliance Brand Parts
www.alliancebrandparts.com

Automann Inc.
www.automann.com

Bendix Commercial Vehicle Systems
www.bendix.com

Bepco, Inc.
www.bepco.biz

Brake Systems, Inc.
www.brakesystemsinc.com

D&D Instruments
www.ddinstruments.com

Haldex
www.haldex.com

HD America, Inc.
www.hdamerica.com

Meritor, Inc.
www.meritor.com

PDC
Power Products
www.e-pdc.com

Precision Rebuilders
www.precisionrebuilders.com

S & S Truck Parts Inc.
NewStar Parts Component Group
www.sandstruck.com

SKF Vehicle Service Market
www.vsm.skf.com

Truck Pride Marketing
www.truckpride.com

Vipar Heavy Duty
www.vipar.com

Wholesale Truck Parts
www.wholesaletruckparts.com

ANTILOCK BRAKING SYSTEMS

Air Brake Systems, Inc.
www.absbrakes.com

Bendix Commercial Vehicle Systems
www.bendix.com

Haldex
www.haldex.com

Meritor, Inc.
Meritor Wabco
www.meritor.com
www.meritorwabco.com

Mico, Inc.
www.mico.com

Road Equipment Parts Center
www.roadparts.com

Robert Bosch Corp.
www.bosch.com

BRAKE ADJUSTERS

Automann Inc.
www.automann.com

Bendix Commercial Vehicle Systems
www.bendix.com

Bendix Spicer Foundation Brake
www.foundationbrakes.com

Gunite Corp.
www.gunite.com

Haldex
www.haldex.com

Meritor, Inc.
www.meritor.com

PDC
Power Products
www.e-pdc.com

S & S Truck Parts Inc.
NewStar Parts Component Group
www.sandstruck.com

Sirco Industries, Inc.
www.sircoind.com

Transaxle LLC
www.transaxle.com

Vipar Heavy Duty
www.vipar.com

Wanxiang America Corp.
www.wanxiang.com

BRAKE DRUMS AND ROTORS

Accuride Corp.
www.accuridecorp.com

Alliance Brand Parts
www.alliancebrandparts.com

Automann Inc.
www.automann.com

Bendix Commercial Vehicle Systems
www.bendix.com

Bendix Spicer Foundation Brake
www.foundationbrakes.com

Brake Systems, Inc.
www.brakesystemsinc.com

Consolidated Metco (Con Met)
www.conmet.com

DuraBrake Co.
www.durabrake.com

East Coast Brake Rebuilders
www.eastcoastbrake.com

Express Brake International, Inc.
www.expressbrake.com

Federal Mogul Corp.
www.federalmogul.com

FleetPride, Inc.
www.fleetpride.com

Gunite Corp.
www.gunite.com

HD America, Inc.
www.hdamerica.com

KIC Holdings Inc.
www.kic-group.com

Meritor, Inc.
www.meritorinc.com

Motor Wheel CVS
www.motorwheelcvs.com

New Life Transport Parts Center
www.newlifeparts.com

SAF-Holland
www.safholland.us

Transaxle LLC
www.transaxle.com

Webb Wheel Products, Inc.
www.webbwheel.com

BRAKE LINING & BLOCK

Automann Inc.
www.automann.com

Bendix Commercial Vehicle Systems
www.bendix.com

Bendix Spicer Foundation Brake
www.foundationbrakes.com

Carlisle Corp.
Motion Control Industries
www.carlisle.com

DuraBrake Co.
www.durabrake.com

East Coast Brake Rebuilders
www.eastcoastbrake.com

Federal-Mogul Corp.
Abex Friction
www.federal-mogul.com

Fras-Le North America
www.fras-le.com

Gorilla Brake & Components, Inc.
www.gorillabrake.com

Haldex
www.haldex.com

HD America, Inc.
www.hdamerica.com

I.M.T. Corp.
www.imtcorporation.com

Marathon Brake Systems
www.marathonbrake.com

Meritor, Inc.
www.meritor.com

Roadranger Parts Marketing
www.roadranger.com

Southwest Trailers & Equipment
www.swtrailer.com

Stemco Duroline
www.stemcoduroline.com

TMD Friction, Inc.
www.tmdfriction.com
Truck Pride Marketing
www.truckpride.com

Vipar Heavy Duty
www.vipar.com

BRAKE SERVICE EQUIPMENT

Bendix Commercial Vehicle Systems
www.bendix.com

Bendix Spicer Foundation Brake
www.foundationbrakes.com

Brake Machinery Sales
www.brakemachinery.com

Brake Tech Tools
www.braketechtools.com

Central Tools, Inc.
www.centraltools.com

Equipment Supply Co.
www.esco.net

Hennessy Industries, Inc.
www.ammcoats.com

Hommer Tool & Mfg., Inc.
www.hommer.com

Hunter Engineering Co.
www.hunter.com

Kiene Diesel Accessories
www.kienediesel.com

KleenTec/Kleer-Flo
www.kleentec.com

Kwik-Way Products
www.kwik-way.com

LS Industries
www.lsindustries.com

MotorVac Technologies, Inc.
www.motorvac.com

Safe Shop Tools
www.safeshop.com

SPX Service Solutions
www.spx.com

Tiger Tool International Inc.
www.tigertool.com

Unique Truck Equipment
www.uniquetruck.com

Van Norman
www.van-norman.com

Vehicle Inspection Systems
www.vischeck.net

BRAKE SHOES

American Isuzu Motors
www.isuzucv.com

Automann Inc.
www.automann.com

Bendix Commercial Vehicle Systems
www.bendix.com

Bendix Spicer Foundation Brake
www.foundationbrakes.com

Carlisle Corp.
www.carlisle.com

East Coast Brake Rebuilders
www.eastcoastbrake.com

Express Brake International, Inc.
www.expressbrake.com

Federal-Mogul Corp.
www.federalmogul.com

FleetPride, Inc.
www.fleetpride.com

Gorilla Brake & Components, Inc.
www.gorillabrake.com

Haldex
www.haldex.com

HD America, Inc.
www.hdamerica.com

I.M.T. Corp.
www.imtcorporation.com

Marathon Brake Systems
www.marathonbrake.com

Meritor, Inc.
www.meritor.com

Napa Truck Parts
www.napaonline.com

Road Equipment Parts Center
www.roadparts.com

Roadranger Parts Marketing
www.roadranger.com

Rome Heavy Duty
www.rometool.com

TMD Friction, Inc.
www.tmdfriction.com

Truck Pride Marketing
www.truckpride.com

Vipar Heavy Duty
www.vipar.com

BRAKE VALVES

Automann Inc.
www.automann.com

Bendix Commercial Vehicle Systems
www.bendix.com

Bepco, Inc.
www.bepco.biz

Brake Systems, Inc.
www.brakesystemsinc.com

Crawford Machine, Inc.
www.crawfordmachineinc.com

D&D Instruments
www.ddinstruments.com

Di-Pro Inc.
www.di-pro.com

FleetPride, Inc.
www.fleetpride.com

Fontaine PartSource
www.fontainepartsource.com

Haldex
www.haldex.com

HD America, Inc.
www.hdamerica.com

Meritor, Inc.
www.meritor.com

Parker Hannifin
www.parker.com

PDC
Power Products
www.e-pdc.com

Precision Rebuilders
www.precisionrebuilders.com

S & S Truck Parts Inc.
NewStar Parts Component Group
www.sandstruck.com

Sloan Transportation Products
www.sloantrans.com

Tectran Mfg., Inc.
www.tectran.com

Tramec
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Truck Pride Marketing
www.truckpride.com

Velvac Inc.
www.velvac.com

Vipar Heavy Duty
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BRAKES, AIR SYSTEM PARTS

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Bendix Commercial Vehicle Systems
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Brake Systems, Inc.
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Brass Craft Industrial Products
www.brasscraft.com

Coronet Parts Mfg. Co. Inc.
www.coronetparts.com

Crawford Machine, Inc.
www.crawfordmachineinc.com

Dayton Parts LLC
www.daytonparts.com

Di-Pro Inc.
www.di-pro.com

DuraBrake Co.
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Tramec
www.tramec.com

TSE Brakes, Inc.
www.tsebrakes.com

U.S. Trailer Parts & Supply
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Vipar Heavy Duty
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Wholesale Truck Parts
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Brake Systems, Inc.
www.brakesystemsinc.com

Carlisle Corp.
www.carlisle.com

Consolidated Metco (Con Met)
www.conmet.com

DuraBrake Co.
www.durabrake.com

Federal-Mogul Corp.
www.federalmogul.com

Fras-Le North America
www.fras-le.com

Gunite Corp.
www.gunite.com

Haldex
www.haldex.com

Hendrickson
Trailer Suspension Systems
www.hendrickson-intl.com

Marathon Brake Systems
www.marathonbrake.com

Meritor, Inc.
www.meritor.com

Midwest Remanufacturing
www.pwrsteering.com

Performance Friction Corp.
www.performancefriction.com

Precision Rebuilders
www.precisionrebuilders.com

Robert Bosch Corp.
www.bosch.com

Ryder Fleet Products
www.RyderFleetProducts.com

SAF-Holland
www.safholland.us

TMD Friction, Inc.
www.tmdfriction.com

Webb Wheel Products, Inc.
www.webbwheel.com

CHAPTER 11: Glossary

ABA: The abbreviation for automatic brake adjuster. Also called an automatic slack adjuster (ASA), this is a lever connecting the brake chamber pushrod with the foundation brake camshaft. It provides torque to rotate the brake camshaft when the brake treadle is depressed. It also provides a means of adjusting clearance between brake shoes and the drum to compensate for lining wear. Some brake adjusters require manual adjustment.

ABS: The abbreviation for "antilock braking system." ABS electronically monitors wheel speed and prevents wheel lockup by rapidly cycling the brakes during panic stops and when stopping on low-friction surfaces.

ABS control valves: Control valves that are actuated by the ABS electronic control unit (ECU) to ensure wheels are optimally braked. On a tractor, they are called ABS modulator valves. On a trailer, they're called ABS relay valves.

Actuate: To initiate mechanical motion of a brake system component.

Actuator: A device which physically initiates mechanical motion of a brake system component.

Aftercooler: Optional device that condenses and eliminates water from air pressurized by the compressor.

Aggressiveness (pertaining to brake linings): The brake output torque developed based on the friction coefficient and the input pressure. Brake torque output can be increased with higher friction coefficients. Typically the friction coefficient is varied by the friction block or pad material rather than the rotor or drum. Changing friction coefficients changes the energy distribution proportionally. The vehicle needs to be balanced to avoid creating overly aggressive stopping performance that may occur when a vehicle is lightly loaded.

Air buildup: Process of compressor building (increasing) pressure to a predetermined maximum level (usually 100-120 psi) within the brake system air tanks.

Air compressor: Engine-driven via a belt or direct gear, the compressor pressurizes the air tank.

Air compressor cut-out: Predetermined point at which the air governor halts compression of air by the compressor.

Air disc brakes: Air-actuated brakes which, upon application, employ a caliper to clamp two brake pads against a rotor. Air discs, compared with drum-type brakes, have superior ability to resist fade.

Air dryer: A filter, typically containing a desiccant, which is installed between the compressor and service reservoir to remove water and vapor plus oil blow-by from the compressor.

Air gauge: Dash-mounted gauge indicating air pressure in terms of pounds per square inch (psi).

Air governor: Controls the compressor unloader mechanism and also maintains system air pressure between predetermined minimum and maximum levels (usually between 90-120 psi).

Air tank: A reservoir for compressed air. Typically, a combination vehicle has several tanks: three in the tractor and one per trailer. The tractor's supply air tank (formerly "wet tank") receives air from the compressor and delivers it to the primary and secondary air tanks in the tractor. A check valve on each tank prevents total air loss in the event of a leak.

Alcohol evaporator: Optional device, installed in compressor discharge line between the compressor and supply air tank, which injects alcohol mist into the air flow to reduce the risk of freezeup. It's not normally used in a vehicle with an air dryer.

AL factor: A mathematical expression of the brake adjuster and brake chamber combination. "A" equals the effective area, in square inches, of the brake chamber (e.g., Type 30 chamber has effective area of 30 square-inches). "L" equals the effective length, in inches, of the slack adjuster. For example, 30 x 6 inches = 180 AL factor.

Analog processing: A method of processing information used in older ABS control units. Today's electronic control units (ECUs) use digital processing, which is many times faster and more reliable.

Anchor pin: A pin or pins used to retain brake shoes within the brake assembly.

Anti-compounding: Basically, an optional system that prevents application of service brakes from compounding (adding to) the force exerted by parking brakes. Functionally, this guards against brake cracking and lining damage.

Antilock: A safety-oriented system which senses wheel rotation (at one or more axles) during braking and cycles the brakes to prevent locking those wheels.

Application time: Time elapsed between depression of the brake treadle and engagement of the linings with the drums (or, per FMVSS 121, the point at which all service chambers reach 60 psi).

Application valve: Air valve, such as foot valve or trailer control valve, which controls

the pressure delivered to brake chambers.

Automatic slack adjuster: See **ABA.**

Automatic traction control (ATC): Also called ASR, it's an optional system that is available on 4- and 6-channel ABS systems. Automatic traction control minimizes wheel slipping during acceleration by controlling both the engine throttle and brake pressures. Can also be used to enhance vehicle roll stability.

Bell-mouthed drum: Drum with variation of inner diameter (i.e., greater at open end), preventing full contact with brake lining.

Blue drum: Brake drum with friction surface blued from high temperature. High temperature may result, for example, from dragging of brakes caused by weak return springs. Blue drum also may result from lack of brake balance.

Brake adjuster: See **ABA.**

Brake balance: Is achieved when all brakes on all axles do their fair share of the work. It is an optimized timing when all the vehicles' brakes (including trailers) turn on and turn off. Brake balance is desirable to assure good wear, proper energy distribution during braking and stable vehicle handling.

Brake block: Friction material or lining attached to a brake shoe. Disc brakes use pads with friction material.

Brake chamber: Device inside which a diaphragm converts air pressure to mechanical force, via a push rod, for brake actuation.

Brake chamber diaphragm: Bellows-type device within brake chamber that converts air pressure to mechanical force via a push rod.

Brake drag: Failure of one or more brakes to release immediately or completely after a driver removes his foot from the brake treadle. (See **Quick release valve.**) Constant drag, unrelated to a brake application, also can exist.

Brake fade: There are many types and causes of braking fade. Fade may result, for example, from a reduction in friction between linings and drums caused by exposure to water. Most typically, however, fade involves a reduction in braking force experienced when dragging brakes on a long grade. If brakes are maladjusted, an overheated drum may expand to the degree that pushrod travel is insufficient to fully actuate the brakes. This is one example of mechanical fade, which also may result from various mechanical defects (e.g., scored drums) within the foundation brake system. In contrast, heat fade occurs when linings overheat and become less aggressive. Gradual and predictable fade is desirable as a warning.

Brake proportioning: Optional safety-oriented system, often called "bobtail proportioning," for limiting drive-axle brakes while a tractor is operated without a trailer. Also, a system that varies individual axle braking effort in response to weight or other variable.

Brake treadle: Functionally, the brake pedal; a mechanical lever attached to the foot brake valve.

Breakaway valve: Upon accidental separation of trailer(s), a tractor protection system which prevents air loss from the power unit. (See **Tractor protection valve.**)

Burnish: The conditioning or "seasoning" of a brake lining by wear and temperature via a test procedure or in-service operation.

Caliper: In an air disc brake system, the clamping device containing friction material mounted to pads. When actuated, the caliper applies braking force to both sides of the rotor.

Channel/ABS: The number of channels in an ABS system refers to the number of valves its electronic control unit (ECU) is capable of independently controlling.

1-Channel ABS: A system design that uses two wheel-speed sensors and one control valve (2S/1M). This is the most popular system for most trailers. It is called tandem control.

2-Channel ABS: A system design that uses two or four wheel-speed sensors and two control valves (2S/2M or 4S/2M). The ABS monitors wheel speed and avoids wheel lockup on one axle while braking on low-friction surfaces or in emergency situations by rapidly cycling the brakes on the wheel ends of two axles. Commonly used on trailers.

4-Channel ABS: A system design that uses four wheel-speed sensors and four ABS control valves (4S/4M) on a two-axle truck or tractor. A 4-channel system can also be used on a three-axle vehicle, controlling the left- and right-side drive axle wheels in pairs. This popular system, which offers an optimum blend of performance and economy, is the most common system on trucks, tractors and buses.

6-Channel ABS: A system design that features six wheel-speed sensors and six ABS control valves (6S/6M) to individually monitor and control all six wheels of a three-axle truck or tractor. This type of system provides the highest available level of ABS control. It's commonly used on vehicles with lift or tag axles.

Check valve: A one-way check valve is used, for example, to prevent air from bleeding back out of a reservoir. A two-way check valve activates selectively: for instance, by drawing air for brake application from the most-highly-pressurized reservoir (primary or secondary).

Clevis pin: Pin connecting the arm of a slack adjuster to a brake chamber push rod yoke.

Connectors/ABS: Sealed, corrosion-resistant plugs that link the ABS wiring system to the electronic control unit (ECU), wheel-speed sensors and modulator or relay valves using a shielded wiring harness.

Control algorithm: The computer commands programmed into the electronic control unit (ECU) to control brake actuation under impending wheel lockup.

Cracked drum: Brake drum cracked all the way through by excessive heat buildup (perhaps signifying inadequate drum weight, driver abuse or resurfacing of a drum beyond the manufacturer's limit).

Crack pressure: Minimum air pressure, expressed in pounds per square inch (psi), required to open an air valve.

Diagnostics/ARS: A component-by-component self-check performed each time the truck's ignition is turned on. An independent microprocessor also checks the system continuously during vehicle operation.

Diagonal system/ABS: A brake system design that divides the ABS into two circuits (front wheel on one side with rear on the other side, and vice versa) to allow partial system function should one diagonal malfunction.

Digital processing/ABS: The latest processing technology that is many times faster and more reliable than analog processing.

Drain valve: Used to drain oil and water from air reservoirs. Valve may be manual or automatic in operation. Automatic versions, which may be heated electrically to prevent the valve freezing open, often are referred to as spitter valves.

Dual brake system: A redundant air system (primary and secondary) designed to retain braking ability in the event one system fails.

Duplex gauge: Essentially, a diagnostic device incorporating two separate air gauges with a common housing and utilizing indicator needles of different colors. Device is used to diagnose brake system imbalance within a combination vehicle via simultaneous connection to two points (such as the tractor gladhand and a trailer brake chamber). It's also used as a dash gauge for dual reservoirs.

Dust shield: Plate made of metal or polyethylene that's mounted behind a brake drum to minimize entry of dirt and road splash.

EBS: Electronic braking system, or brake-by-wire. A system in which the control signal is sent electronically, rather than pneumatically, although the actual service application is still made by air pressure.

ECU/ABS: Electric control unit is a microprocessor that evaluates how fast a wheel is rotating. The electrical signals generated by the inductive sensors pick up impulses from toothed rings that spin with the wheel.

Edge codes: Developed by Friction Materials Standards Institute, a double letter code (e.g., EE, FF, GG, FG) printed on the edge of a brake block to designate its range of aggressiveness.

Emergency brake system: Not a separate system, emergency braking (in the event of air loss) involves various portions of the parking and service brake systems. (See **Spring brake.**)

Engine brake: One type of retarder. An optional device that converts a diesel engine into a power-absorbing air compressor to slow a vehicle on downgrades.

Exhaust brake: One type of retarder. An optional device that uses engine exhaust back pressure to slow a vehicle on downgrades.

Fail-safe/ABS: If antilock brake system should fail during vehicle operation, a dash light warns driver that ABS is disengaged. Meanwhile, the tractor's pneumatic system returns to normal relay valve functions and maintains standard air brake performance.

Fault codes/ABS: A series of codes displayed by the self-diagnostic portion of the ABS unit, isolating the section of the system that has malfunctioned.

Foot valve: A foot-operated valve controlling air pressure delivered to the brake chambers.

Foundation brake system: Term inclusive of mechanical components involved in providing braking force (i.e., brake chambers, slack adjusters, brake drums and brake linings).

Front axle limiting valve: See **Ratio limiting valve.**

GCWR: Gross combination weight rating is the total weight capacity of a combination vehicle (tractor and trailer) as determined by axle ratings. It includes the weight of the vehicle and payload.

Gladhand: Mechanical connector used to attach a tractor's or converter dolly's service (i.e., control) and emergency (i.e., supply) air lines to those on a trailer.

Greased-stained drum: A brake drum with discoloration of friction surface caused by, for example, improper greasing of brake camshaft.

GVWR: Gross vehicle weight rating is the total weight capacity of a single vehicle, as determined by axle ratings.

Hand valve: See **Trailer control valve.**

Heat-checked drum: Brake drum with hairline cracks on friction surface caused by thermal cycling. Mild checking normally does not require drum replacement.

Heat-spotted drum: Brake drum with a pattern of hard, slightly raised dark spots

of martinsite on its friction surface. Caused by localized overheating and sudden cooling, those spots should be ground off to prevent drum cracking, uneven lining wear and loss of braking efficiency. If spots cannot be removed, the drum should be discarded. Heat spotting is promoted by light and steady braking on downgrades.

Hold-off spring: A spring within a relay valve or quick release valve designed to retard valve operation until a predetermined amount of air pressure is exerted. (See **Crack pressure.**)

Hysteresis: Difference between the amount of pressure needed to open a valve and the pressure drop needed to close it.

Inversion valve: Valve used on trucks to release air from the parking brake chambers and apply the rear brakes if the rear air reservoir fails.

Jackknife: Uncontrollable articulation of a tractor-trailer typically resulting from lock-up or spinning of tractor drive axles. The risk of jackknife is greatest on a slippery road with an empty or lightly-laden trailer in tow.

Jake Brake: Trademark of engine brakes by the Vehicle Equipment Division of The Jacobs Manufacturing Co.

Leak-down test: A common method of checking for air leaks. With the engine off, vehicle stationary, the air system at maximum governed pressure and all service brakes fully applied, there should be no more than a 3 psi/minute air loss noted on the dash-mounted pressure gauge for straight trucks; 4 psi/minute for combination vehicles.

Lining growth: Permanent swelling of brake lining resulting from heat exposure.

Long-stroke chamber: A brake chamber designed to permit longer-than-normal pushrod travel without exceeding its readjustment limit. For example, a regular, clamp-type, Type 30 chamber has a readjustment limit of 2 inches. A long-stroke version of that chamber has a readjustment limit of 2½ inches.

Low pressure warning device: Pressure-sensitive electrical switch that actuates an in-cab buzzer and warning light when air pressure falls below a predetermined level (typically, 60 psi).

Multiplexing: A means of sending discreet electrical signals to multiple devices along a common pair of wires.

Out-of-round drum: Brake drum with variations in its inner diameter, causing reduced braking efficiency. An out-of-round drum often can be machined, within manufacturer's limits, to restore concentricity.

Oversized drum: Refers to a brake drum having an inner diameter greater than the discard diameter marked on the drum by its manufacturer.

Parking brake: See **Spring brake.**

Parking brake priority: A type of trailer brake control valve which prioritizes delivery of air for quick release of a trailer's parking brakes after being hooked to a tractor. Charging a trailer's service reservoirs, to provide braking ability, is a secondary concern.

Pawl: A mechanical device allowing rotation in only one direction. One type consists of a hinged tongue, the tip of which engages the notches of a cogwheel, preventing backward motion.

PLC: Power-line carrier; a form of multiplexing wherein a discreet electrical signal is sent along a wire already carrying power for another purpose. PLC technology is used in tractor/trailer communications, allowing more utility than the standard J-560 7-pin connector could otherwise afford.

Pneumatic balance: Achieved when individual air chambers receive the air pressure required for each brake in the system to do its fair share of the work. Lack of pneumatic balance is most likely at low brake application pressures, rarely during panic stops.

Pneumatic timing balance: Achieved when individual air chambers sequentially receive air within a timeframe that ensures each brake in the system will do its fair share of the work. In a combination vehicle, lack of proper timing is likely to occur because tractor brakes receive air faster than trailer brakes. (See **Trailer push.**)

Polished drums: A brake drum with a friction surface polished to a mirror-like finish by unsuitable brake linings. Remove gloss from drum with 80-grit emery cloth.

Pop-oil valve: Jargon for a pressure-relief valve, installed in the service reservoir or wet tanks as insurance against over-pressurization.

Pressure differential: Difference between the inlet and outlet air pressure of an open brake valve. Also, difference in air pressure between any two points within a brake system.

Pumping the brakes: Phrase denoting a rapid series of brake applications (a.k.a. fanning) used to avoid locking brakes on axles during sudden stops. Phrase also may apply to a slower series of heavy brake applications (a.k.a. snubbing) used in an attempt to prevent brake overheating and resultant fade on long downgrades.

Pushrod: A rod, protruding from a brake chamber, which is connected to the arm of a slack adjuster via a clevis pin.

Quick release valve: Designed to reduce the chance of brake drag, a valve that speeds the process of exhausting air from

brake chambers when driver releases the brake treadle.

Radio frequency interference (RFI): External interference or false signals from such sources as radar, citizens band radio, other types of radio transmissions and television signals. While the effects of this interference on ABS was a concern during the 1970s, today's technology has virtually eliminated the problem.

Ratio limiting valve: Prevents locking of front brakes by automatically limiting application pressure to steer axle during normal braking. Progressively harder braking, however, will progressively increase steer-axle braking until maximum torque is applied.

Relay valve: Valve located near a reservoir that is activated by a control signal from another valve that usually is farther away. It's used to speed the application of brakes on drive and trailer axles.

Release time: Time between release of brake treadle and total disengagement of brake linings and brake drums. Or, per FMVSS-121, that time required to reduce pressure to 5 psi from 95 psi within all service chambers.

Retarder: Auxiliary braking device such as engine brake, exhaust brake, hydraulic retarder or electric retarder.

Return springs: Springs which retract brake shoes upon release of the brake treadle.

Roll-over: Jargon denoting that an S-cam has traveled beyond its designed stopping position during brake application.

S-cam brake: Type of brake where mechanically-induced rotation of an S-shaped cam forces brake linings against the brake drum.

Scored drum: Brake drum with a grooved friction surface, resulting in excessive lining wear. Severe scoring requires that a drum be machined, within manufacturer's limits, before replacing the linings.

Service brake priority: A type of trailer brake control valve which prioritizes delivery of air to a trailer's service reservoirs, to provide braking ability, after being hooked to a tractor. Releasing a trailer's parking brakes is a secondary concern.

Service brakes: As opposed to parking brakes, that portion of the brake system used for normal brake applications.

Slack adjuster: Also called a brake adjuster, this is a lever connecting the brake chamber push rod with the foundation brake camshaft. It provides torque to rotate the brake camshaft when the brake treadle is depressed. It also provides a means of adjusting clearance between brake shoes and the drum to compensate for lining wear. Some models are automatic, while others require manual adjustment. (See **ABA.**)

Speed sensor/ABS: An electromagnetic device that, in conjunction with a rotating toothed wheel, generates an electrical signal proportional to the wheel speed and transmits the information to the ABS electronic control unit (ECU).

Spider (on a brake shoe): Foundation component that attaches all the drum brake components such as brake shoes, camshaft, etc. to the axle. It transfers brake torque from the wheel end to the axle/suspension.

Spitter valve: Slang for automatic drain valve. (See **Drain valve.**)

Split-coefficient surface: Also called split-Mu, a road condition where one side of a lane has low friction and the other has high friction (example, the left side of the lane is ice-covered, the right side is dry). A 2-, 4- or 6-channel ABS system (antilock brake system) with individual wheel control will provide optimum stability and stopping-distance performance under these conditions.

Spring brake: Generally refers to a tandem-chamber brake actuator that incorporates an air-applied service brake chamber and an air-release/spring-applied parking or emergency brake chamber. Spring brakes apply upon sudden air loss (emergency mode) or activation of a dash-mounted parking brake control. Spring brakes remain applied until that chamber is recharged with air or the spring is manually compressed or caged. DISASSEMBLY OF A SPRING BRAKE IS DANGEROUS. SO ONLY TRAINED MECHANICS SHOULD ATTEMPT THE PROCEDURE. The spring portion often is referred to as the piggy-back.

Stopping distance: The distance traveled by a vehicle on a road between the initial brake pedal movement and a full stop.

Stopping time: The time elapsed between the initial brake pedal movement and a full stop.

Stroke: Refers to a total distance traveled by a brake chamber pushrod or slack adjuster arm during brake application.

Supply air tank: The air reservoir immediately downstream of the air compressor. (See **Wet tank.**)

Threaded drum: Brake drum improperly resurfaced on a lathe, resulting in a friction surface akin to that of a scored drum.

Tire loaded rolling radius: Distance, expressed in inches, from the center of a tire/wheel assembly to the pavement, measured when mounted on a vehicle and loaded to its maximum rated capacity.

Torque balance: Achieved when individual brakes exert the degree of braking

force required for each brake in the system to do its fair share of the overall work.

Tractor protection valve: Isolates tractor air system in event of a trailer breakaway or dangerous decrease in the tractor's reserve air, but is typically applied (via dash-mounted control) before disconnecting a trailer.

Trailer control valve: Hand-operated valve, located on (or adjacent to) the steering column, which permits independent control of the trailer brakes. Also known as the trolley valve or the hand valve.

Trailer push: Caused by the tractor braking prior to the trailer and/or with greater torque. Even with "perfect" brake balance, the trailer pushes the tractor to some extent since the tractor brakes absorb part of the trailer's load.

Trailer swing: Articulation of the trailer caused by locking the trailer brakes.

Treadle valve: Foot-operated brake actuation valve.

Trolley valve: See **Trailer control valve.**

Turned drum : A brake drum that has been resurfaced on a lathe to remove scoring or other defects. Stay within manufacturer's limits.

Warning light/ABS: An indicator light on the truck or tractor instrument panel that illuminates to indicate the status of the ABS system. On trailer ABS, the indicator light may be located on the trailer body where the driver or maintenance personnel can easily see it.

Wedge brakes: As opposed to a brake applied by an S-cam, this type of brake is applied by a single or double wedge-type mechanism. This type of brake is self-adjusting and, as such, does not utilize a slack adjuster.

Wet tank: Also known as the supply air tank, that reservoir nearest to the air compressor where water and oil are most likely to accumulate (assuming the lack of a functional air dryer).

Worm gear: Component of slack adjuster. The worm and worm gear provide for adjusting lining-to-drum clearance.

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