APTA STANDARDS PROGRAM

RECOMMENDED PRACTICE

APTA BTS-BC-RP-012-25

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Bus Brake and Chassis System Working Group

Transit Bus Air Disc Brake Reline

Abstract: This recommended practice provides guidelines for performing complete brake maintenance on a bus with disc brakes. It includes disassembly, cleaning, inspection and assembly. This document is to be used in conjunction with the manufacturer's service manual. It is recommended that all components be replaced equally on both wheel ends of the axle. Failure to do so may affect braking performance.

Keywords: ABS tone ring, boot, bridge, bushing, caliper, carrier, disc, disc brake maintenance, hub, pads, pin, potentiometers, retaining strap, rotor, seal, slide pins, spring clips, torque plate, wear indicator, wear sensors, wheel seals

Summary: This document establishes a recommended practice for transit bus front/rear axle disc brake reline. Individual operating agencies should modify these guidelines to accommodate their specific equipment and mode of operation. The recommended practices and guidelines in this document assume that the end users have sufficient skills and knowledge to repair and maintain the related systems at a journeyman level. This must include a fluent understanding of safe shop working practices, not only for the agency but also OSHA/CCOHS/provincial/federal/state and local safety standards. A familiarity with applicable industries, component/system suppliers and vehicle manufacturers is also assumed.

Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the manual for the APTA Standards Program. This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the Bus Brake and Chassis System Working Group as directed by the Bus Systems Standards Policy and Planning Committee.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any recommended practices or guidelines contained herein is voluntary. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit agency's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This is a new document

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Introduction

This introduction is not part of APTA BTS-BC-RP-012-25, "Transit Bus Air Disc Brake Reline."

APTA recommends the use of this document by:

- individuals or organizations that operate transit systems;
- individuals or organizations that contract with others for the operation of transit systems; and
- individuals or organizations that influence how transit systems are operated (including but not limited to consultants, designers and contractors).

Scope and purpose

This recommended practice provides guidelines for a reline of the typical heavy-duty transit bus disc brake. The components may be different than pictured, and some procedures will vary. The purpose of this document is to provide a uniform standard for heavy-duty transit bus disc brake reline.

Transit Bus Air Disc Brake Reline

1. Hazardous material warning

Most brake pads no longer contain asbestos fibers. However, if working with any component that does contain asbestos, take all the necessary precautions prescribed by OSHA, and follow all federal, provincial/state and local safety requirements. The health impact of non-asbestos fibers (brake pads with glass, mineral wool, ceramic, aramid, carbon, etc.) is not specifically covered under current OSHA regulations. While there is disagreement among medical experts regarding the long-term risks associated with working with and inhaling non-asbestos fibers, some believe that prolonged exposure could lead to the development of pneumoconiosis,[1] fibrosis and cancer.[2] Therefore, it is recommended that workers avoid dust when working on brakes that contain non-asbestos materials.

Brake pads may also contain crystalline silica, lead, antimony, phenol and other possibly hazardous materials. Refer to the material's material safety data sheet (MSDS) for all necessary precautions. Follow the general safety procedures listed below when working with braking components:

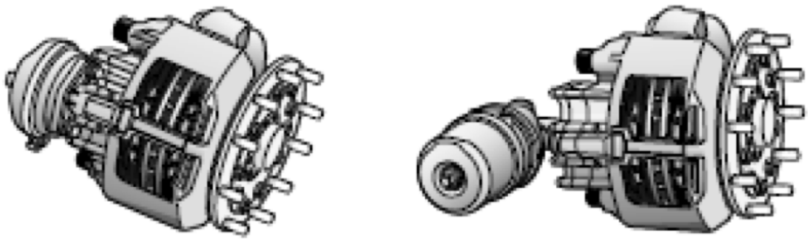
- Whenever possible, work on brakes in a separate area away from other operations.
- Always wear a respirator approved by NIOSH or MSHA during all brake service procedures.
- *Never* use compressed air or dry brushing to clean brake parts, assemblies or the working area. OSHA recommends using cylinders that enclose the brake. The cylinders have vacuums with HEPA filters and arm sleeves. If such equipment is not available, then carefully clean parts and assemblies in the open air. Used rags should be disposed of with care to avoid getting dust into the air. Use an approved respirator when emptying vacuum cleaners and handling used rags.
- During disassembly, carefully place all parts on the floor or in a suitable cleaning station to avoid getting dust into the air. After vacuum cleaning, any remaining dust should be removed using a rag soaked in water-based cleaner and then wrung until nearly dry.
- Workers should wash their hands before eating, drinking or smoking. Work clothes should not be worn home, but should be vacuumed after use and then laundered separately, without shaking, to prevent dust from getting into the air.

2. Operation

The air disc brake consists of an air-operated chamber, two plunger floating calipers, disc brake pads and a rotor. There are two air chamber mounting designs, axial and radial (**Figure 1**), which are mounted directly to the caliper assembly. The disc brake can be installed onto any axle and can be used as a vehicle parking brake when equipped with a spring brake chamber.

1. https://www.ncbi.nlm.nih.gov/books/NBK555902/
2. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1637680/pdf/envhper00313-0064.pdf

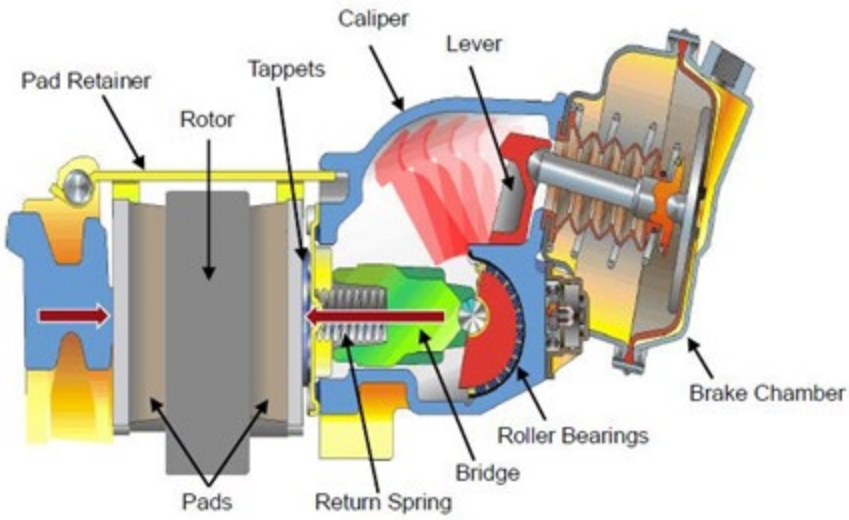
FIGURE 1
Axial and Radial Mounting Designs



Axial Radial

Air disk foundation brakes operate as all foundation brakes. It takes a force, multiplying and applying it to a rotating member (disc or rotor) attached to the wheels such that friction is created that converts energy of motion into heat and slows the vehicle. In the case of air disc brakes, air pressure is applied to a diaphragm, and the pressure on the diaphragm creates a large linear force, which is applied to a lever (internal to the brake caliper), which further increases the actuating force (**Figure 2**).

FIGURE 2
Cross-Section of Knorr-Bremse Caliper Assembly



When the brake chamber is pressurized, the chamber push rod moves forward and acts against a cup in the internal lever. The lever, which has an abutment in the caliper housing, then acts against a pair of tappets, which apply the force onto the inner brake pad. The distances from cup to abutment to tappets are designed to provide a high leverage ratio to apply the required actuation force to the inner brake pad. The inner brake pad moves into contact with the brake rotor. The brake caliper, which is free to slide laterally relative to the brake rotor, then slides on two guide pins, and the reaction force applies an equal and opposite force to the outer brake pad and against the rotor. The rotor now is clamped between the inner and outer pad, and friction is created as the rotor moves across the clamped pads. This results in the creation of a brake torque acting through the wheel and tire, and this torque creates a stopping force acting on the vehicle through the tire contact patch. The higher the clamping force (which is proportional to the brake chamber air pressure), the higher the resulting brake torque.

The brake is released by reducing the chamber pressure, which in turn reduces the force on the internal lever, and thus the clamping force on the rotor. Integrated return springs return the tappets and operating lever back to the starting position, leaving the pads with a defined running clearance to the rotor.

3. Inspection with wheels removed

During a reline, it is recommended to inspect all the brake components on each wheel-end. Removal of wheels will provide complete visual access to the foundation brake system, which includes caliper, rotor, hub, seals, brake chambers, mounting fasteners and other system parts.

The following components should be inspected as part of a disc brake reline and be replaced as necessary:

- brake chambers
- lining thickness
- torque plates
- fastener and mounting
- calipers
- guide pins
- bushings
- carrier and pad abutment
- tappet boots and seals
- rotors
- ABS
- brake wear sensors
- bearings and hubs

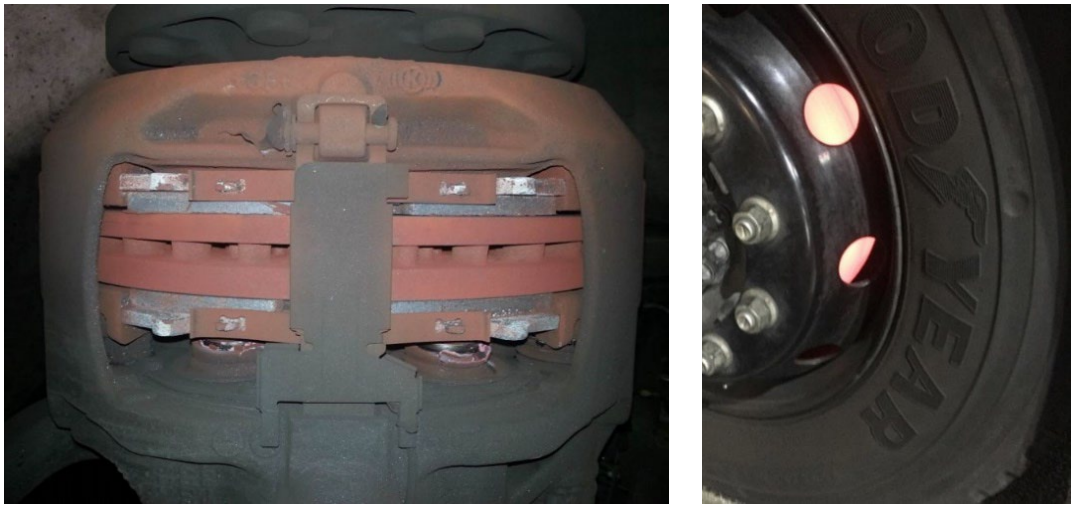
Safely raise and support the bus by the axles at an appropriate working height and remove the wheels (**Figure 3**).

FIGURE 3
Wheels-Off Inspection

Perform a visual inspection of the brake assembly for possible indications of malfunctioning brakes.

For example, a thermal overload (**Figure 4**) is an indication of excessive heat frequently caused by dragging brakes. The cause of the thermal overload must be identified and repaired.

FIGURE 4
Evidence of Thermal Overload



A missing pad retainer strap can allow pads to climb out of the caliper and wear on the rim, resulting in rim and brake failure (**Figure 5**).

FIGURE 5
Other Types of Brake Assembly Damage

Damage caused by a missing pad retainer strap

Damaged rim and brake chamber caused by a missing pad retainer strap

Verify that the bus needs a reline. There are several methods available for estimating pad thickness, such as visual (mechanical) indicators, inspection tools (such as bore scopes, mirrors or cameras), or electronic pad wear indicators (end-of-life or potentiometer sensors). These methods provide only an estimation of the remaining pad life. The only completely accurate way is to remove the pads and measure them.

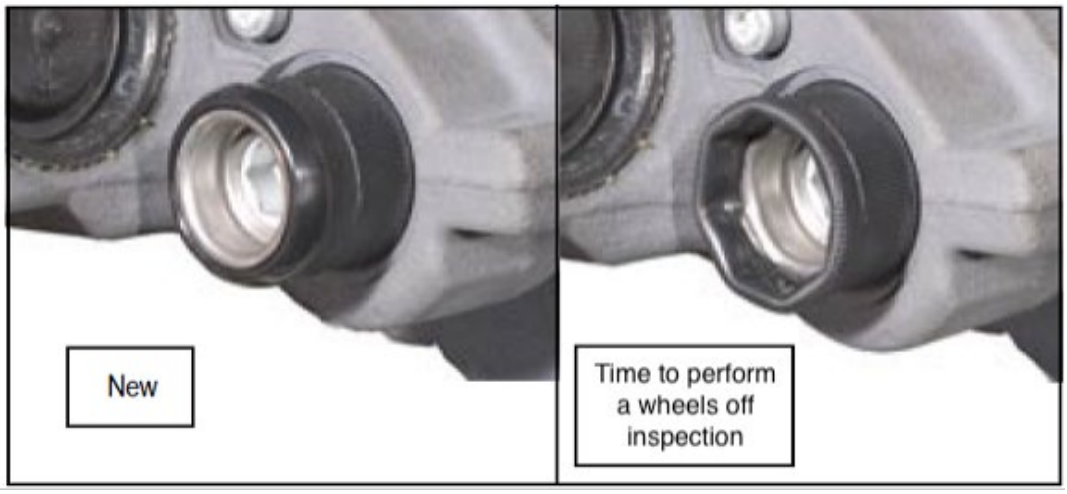
> **NOTE:** Neither style of visual wear indicator can identify uneven pad wear. In the case where one pad is already below the wear limit and the other pad is not, the visual indicator will be misleading. In the extreme case, where one pad is fully worn and the other shows no wear, the Meritor indicator would show 50% remaining, and the Knorr may show 100% or 0% (depending on which pad is fully worn), and either case may result in metal-to-metal contact.

Knorr-Bremse has two styles of wear indicators: a rolling boot style (**Figure 6**), and a solid rubber bushing (**Figure 7**).

> **NOTE:** The Knorr-Bremse mechanical wear indicator measures the relative movement between the caliper body and the caliper bridge casting (the torque plate that straddles the rotor), which indicates only the outboard pad wear—it cannot measure any wear that has occurred on the inboard pad.

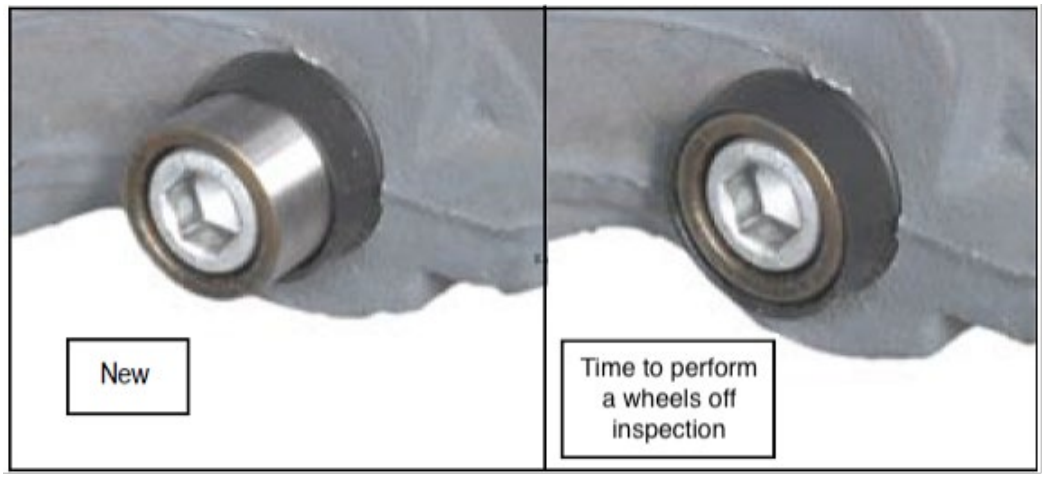
The rolling boot style has a portion of the boot as smooth rubber, while the other portion is ribbed. A more thorough inspection of the pads is necessary when the pin has retracted to the point where only the ribbed portion of the boot is visible.

FIGURE 6
Knorr-Bremse SN/SB Rolling Boot Style Wear Indicator



On the solid boot style, the guide pin extends beyond the bushing. If the pin protrudes less than 0.040 in. (1.02 mm), then a more thorough inspection is necessary.

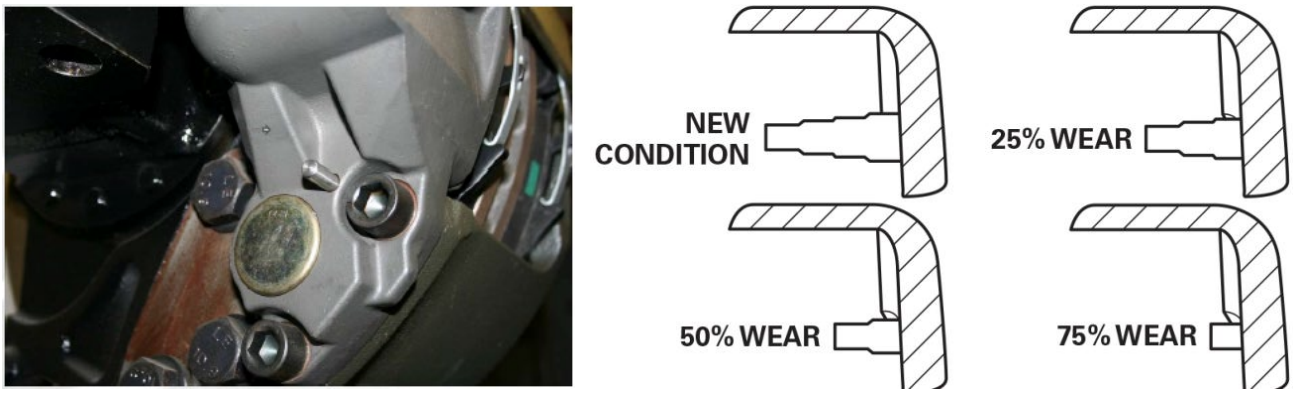
FIGURE 7
Knorr-Bremse SN/SB Solid Rubber Bushing Style Wear Indicator



The Meritor EX225 mechanical wear indicator pin (**Figure 8**) measures the relative travel between the inboard pad backing plate and the inside face of the caliper casting opening. This measures the extension of the tappet assembly, which is the combined wear of both inboard and outboard pads. However, it cannot distinguish whether either pad is worn more than the other.

On the Meritor EX225 setup, the pad/rotor wear can be visually estimated without removing the wheel by viewing the protrusion of the wear indicator pin. If pin protrusion is less than 0.16 in. (4 mm), then the pads require further inspection or replacement.

FIGURE 8
Pin-Style Wear Indicators



On air disc brakes that are equipped with a caliper-to-carrier marking, such as the Knorr setup, (**Figure 9** and **Figure 10**), the pad/disc wear can be visually determined by viewing the position of the caliper and carrier markings ("P" compared with the carrier marking "R"). If caliper and carrier markings are within 1 mm of alignment, then the wheels must be removed to measure pads and rotors on that axle (both sides).

FIGURE 9
Brake Pad/Disc Wear Check Using Caliper-to-Carrier Position Notch

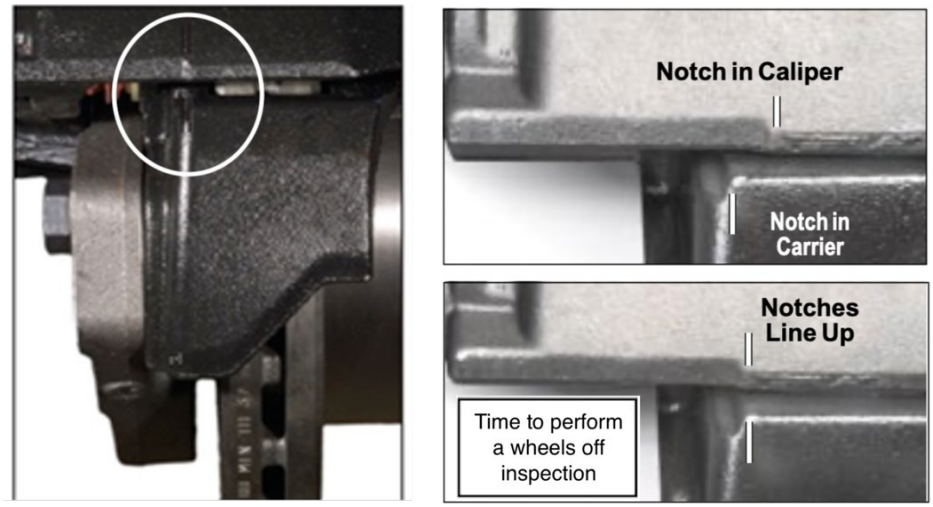
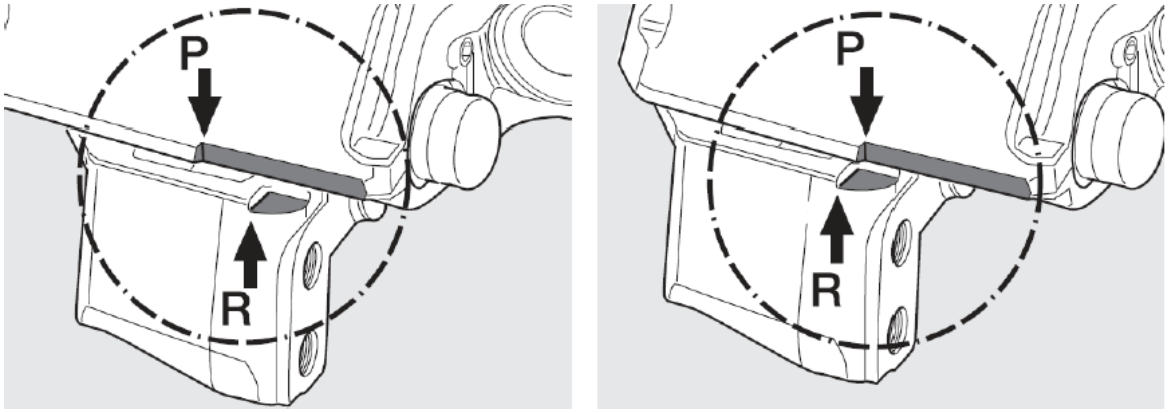


FIGURE 10
Caliper-to-Carrier Markings



Caliper position with new pads/rotor | Pads or rotor require further inspection

CAUTION: In extreme uneven wear conditions, individual pads may wear to their minimum before the visual indicator provides a warning. Visual pad inspection should always accompany running clearance check.

4. Brake chamber inspection and installation

4.1 Inspection

Inspect brake chambers to ensure that the same size is on both ends of the same axle; that mounting fasteners and clamps are properly installed; and that there is no evidence of damage caused by impact or contact with wheels, frame, body or suspension. Also check for proper installation of vent plugs. Inspect air lines in the vicinity of the brake chambers for cracks, leaks, swelling, chafing, etc. With brake system pressures at governor cutout, fully apply service brakes and listen for air leaks. Any leaks at the brake chamber will require the vehicle to be taken out of service for further investigation and correction.

To remove a brake chamber that is not equipped with a spring brake, remove the air line and mounting bolts, and carefully remove the service brake chamber from the caliper. On chambers equipped with a spring brake, follow the chamber manufacturer's instructions to completely cage and release the brake. Then remove the air line and mounting bolts, and carefully remove the chamber from that caliper.

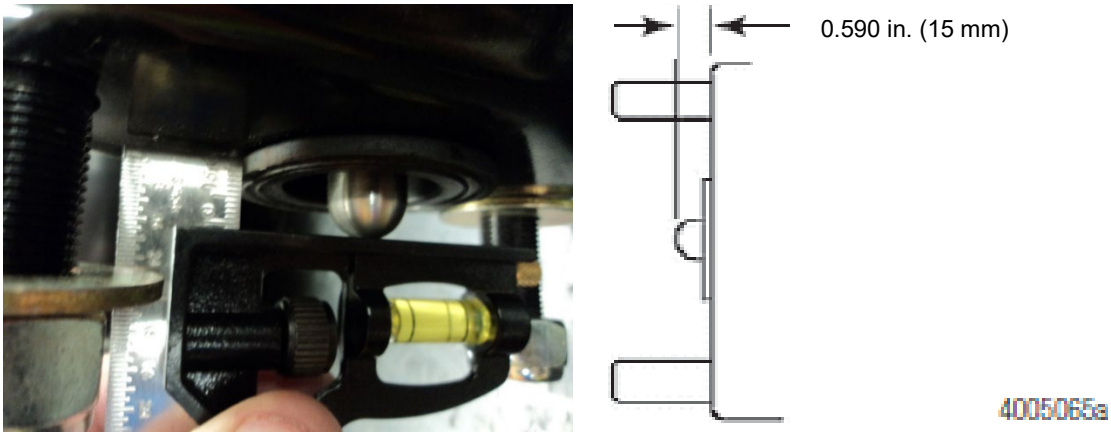
With the air chamber removed, visually inspect for the following:

- mounting hardware (bent or damaged threads)
- push rod protrusion
- push rod not perpendicular to the housing
- seal protrusion
- seal damage
- water intrusion into the caliper

Measure brake chamber push rod protrusion from non-pressure housing to ensure that it is set to 0.590 in. or 15 mm (**Figure 11**). This specification applies to both the Meritor EX225 and Knorr-Bremse.

NOTE: Parking brake actuators need to be fully caged with caging bolt, not just air pressure.

FIGURE 11
Brake Chamber Push Rod Protrusion



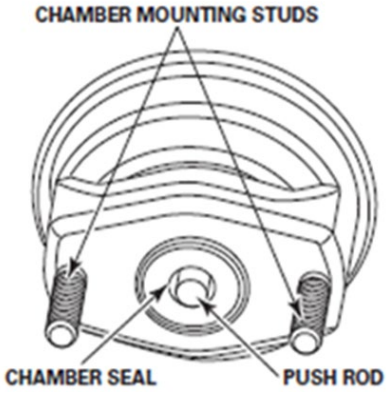
Inspect the push rod for damage and alignment. A failure indicated by a chamber push rod that is not perpendicular to the housing will require a chamber replacement (**Figure 12**).

FIGURE 12
Misaligned Push Rod

Knorr-Bremse calipers do not have a seal on the caliper between the chamber and the caliper. Knorr-Bremse calipers rely solely on the brake chamber seal to prevent water and contaminant intrusion. Meritor EX225 disc brake calipers, on the other hand, frequently have a double seal between the chamber and caliper. The seal pressed into the caliper is serviced as a replaceable seal. The chamber seal is an integral part of the brake chamber and can be serviced only by replacing the brake chamber.

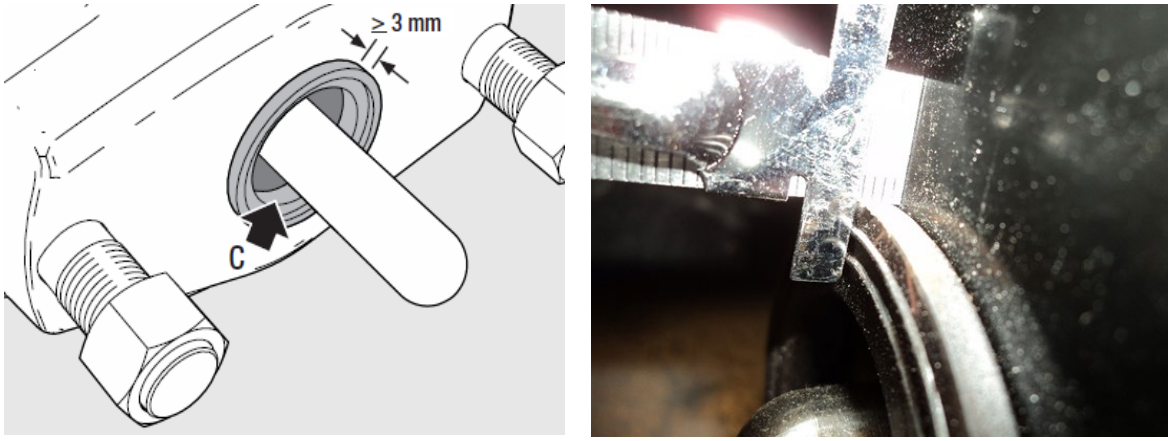
Visually inspect the chamber seal. Replace the brake chamber if the seal or the mating surface of the brake chamber is damaged. See **Figure 13**.

FIGURE 13
Meritor EX225 Brake Chamber Seal Position



For chambers used on the Knorr-Bremse caliper, minimum tolerance is 3 mm of seal protrusion (**Figure 14**). If the seal protrudes less than 3 mm, then the chamber must be replaced.

FIGURE 14
Brake Chamber Seal Protrusion



MGM e-STROKE brake chambers (**Figure 15**) utilize a seal on the sensor pack with the same 3 mm minimum protrusion. If equipped, this seal must be inspected and replaced if worn or damaged.

FIGURE 15
MGM e-STROKE Brake Chamber Inspection

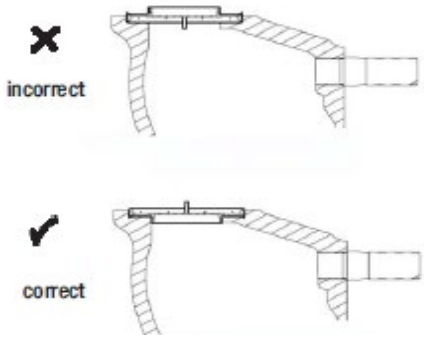
4.2 Installation

Visually inspect the chamber piston, chamber seal and chamber-mounting aperture on the caliper housing assembly. If signs of water entry or corrosion are present, then replace the chamber and caliper assembly.

Check for a light lubrication film on the brake chamber push rod ball end prior to assembly onto the caliper. Refer to Knorr-Bremse or Meritor EX225 maintenance manual for lubricant specifications. Excessive lubrication may result in brake issues, especially on chambers with electronic brake monitoring sensors where reflectivity of the lubricant may cause erroneous faults.

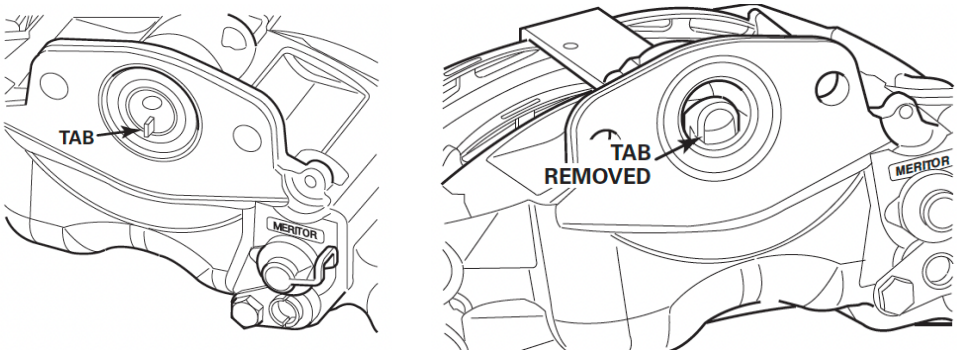
The Meritor EX225 caliper has a seal that rests against the brake chamber seal. Make sure the seal is in good condition and is installed correctly (**Figure 16**).

FIGURE 16
Meritor EX225 Caliper Seal



New Meritor calipers are shipped with a transit plug and should not be confused with the caliper seal (**Figure 17**). The transit plug must be removed before the chamber is installed. Knorr calipers come with a shipping tape that needs to be removed before installation.

FIGURE 17
Meritor EX225 Shipping Plug



Caliper shipping plug | Caliper tab removed

With brake chambers without spring brakes, proceed to the installation procedure below. If the brake chamber has a spring brake, follow the chamber manufacturer's instructions and carefully cage and lock the spring. Typically, new spring brake chambers are shipped caged.

1. Verify that the chamber seal is well-seated, is free of debris and shows no signs of damage. Check the mounting face for corrosion or debris. Do not install a brake chamber that shows signs of debris or excess flash on the seal.
2. Verify that the caliper seal surface and the mounting surface are free of oil, grease and debris and show no signs of damage.
3. If installing the brake chamber on an existing Meritor EX225 caliper, install a new caliper-to-air brake chamber seal on the caliper.
4. Before installing the air chamber onto the caliper assembly, ensure that the perforated transit plug is removed from the caliper by pulling the tab.
5. Position the chamber onto the caliper. Determine which of the two possible brake chamber orientations places the ports in the most accessible position.
6. As the chamber is being positioned onto the caliper, visually check that the chamber push rod is nesting in the pocket of the operating shaft.
7. Firmly hold the chamber onto the caliper by hand. Place the two washers and nuts onto the mounting studs. Do not work from behind the spring brakes; always work from the side and front. Spring brake chambers are under more than 2000 lb (8900 N) of spring force.
8. Use a 24 mm wrench to tighten the nuts in an alternating sequence.
    - Tighten the nuts until the mating surfaces meet. Use minimal torque on the two nuts.
    - Use a torque wrench to tighten each nut to 59 to 75 lb-ft (80 to 100 Nm). Then use a torque wrench to tighten each nut to 133 to 155 lb-ft (180 to 210 Nm).
9. If breather plugs are supplied, locate the bottommost breather plug and remove it from the chamber.
10. Install the air hoses to the chamber ports. Refer to the manufacturer's instructions.
11. If the caliper has a spring chamber, carefully uncage and unlock the spring. Follow the chamber manufacturer's instructions.

4.3 Fasteners and mounting hardware

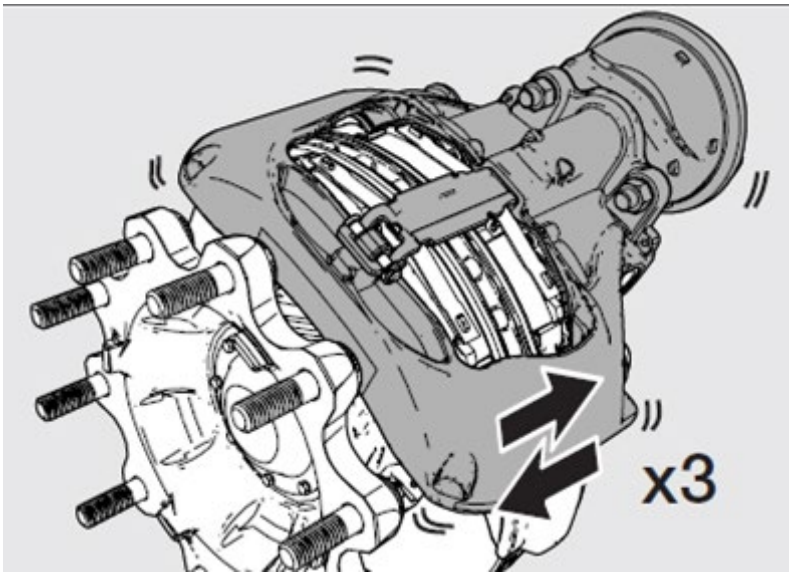
- Fasteners should be replaced every time they are removed.
- Torque per the manufacturer's procedures and specifications upon installation.

5. Caliper inspection, maintenance and replacement

5.1 Knorr-Bremse caliper movement test

The caliper movement test is conducted to make sure that the caliper slides on its pins and that there is sufficient clearance between the rotor and brake pads. To prevent a pressure drop, connect an air line to the bus to maintain air system pressure of at least 95 psi (6.5 bar). With the spring brakes released or caged, push the caliper inboard on its guide pins. Move the caliper in and out three times by hand, and then use a suitable tool and press the inboard pad away from the tappets (**Figure 18**).

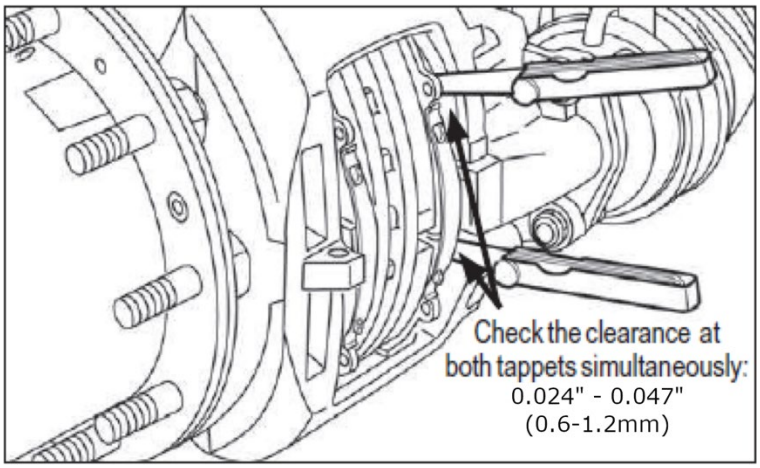
FIGURE 18
Knorr-Bremse Caliper Movement Test



Push and pull caliper by hand three times in an axial direction.

Check that there is no dirt in the gap, and clean if necessary. Use two long feeler gauges to measure over the whole tappet surface. Check the gap between the tappet and the inboard pad backplate. Knorr-Bremse requires the gap to be between 0.024 in. (0.6 mm) and 0.047 in. (1.2 mm). If the gap is within this range, then the test is complete. If the clearance is too wide, then there is a danger of brake failure. If the distance is too small or if there is no gap at all, then there is a danger of the brake overheating. These conditions must be corrected before returning the vehicle to service. See Section 5.2 for the correction procedure. Knorr-Bremse does allow a difference of 0.010 in. (0.25 mm) between the upper and lower tappet and pad measurements (**Figure 19**). If the tappets-to-pad clearance exceeds 0.010 in. (0.25 mm), then the caliper bearing must be checked.

FIGURE 19
Knorr-Bremse Tappets-to-Pad Clearance



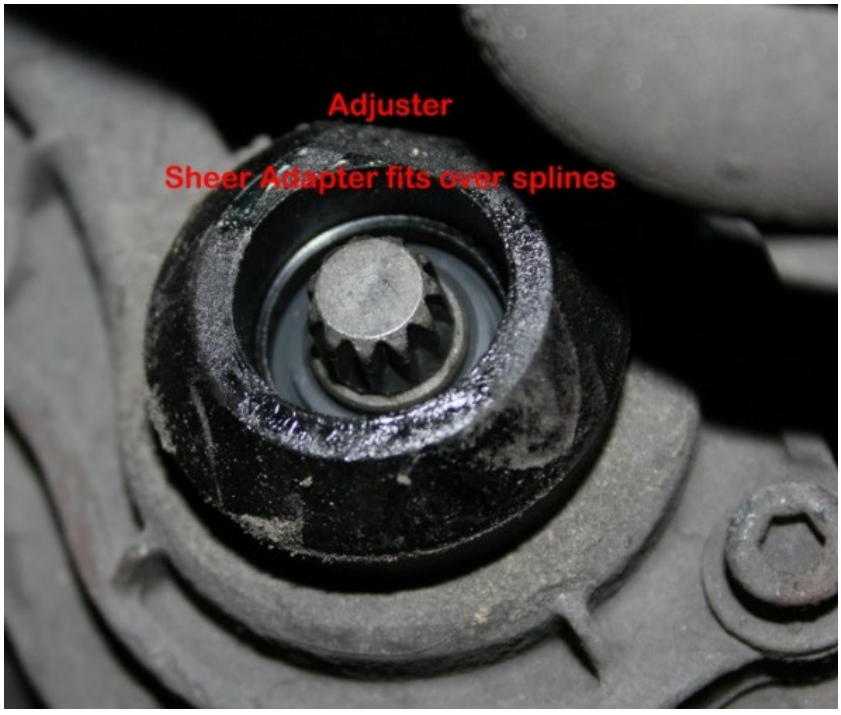
5.2 Knorr-Bremse caliper adjuster test

Check that the adjusting screw cap is properly installed and is not torn or loose. Remove the cap and visually inspect the adjusting screw seal for damage (**Figure 20**).

FIGURE 20
Adjuster Components


Adjuster screw cap


Shear adapter



Adjuster with seal visible

Make sure the bus has at least 95 psi (6.55 bar) air pressure and, if applicable, make sure the spring brake is released. Using the shear adapter, turn the adjuster three clicks counterclockwise, increasing the running clearance. Make sure the shear adapter is used with a box wrench or socket, no power or air tools (**Figure 21**).

Using the wrong wrench or continuing to torque after the tappets are fully retracted will cause the shear adapter to fail.

If the shear adapter fails, check for free movement of the pads and caliper slide pins before attempting a second time. Replace the shear adapter and make a second attempt. If the adapter fails on the second attempt, and the caliper slide pins or brake pads are not stuck, then the adjuster mechanism is seized, and the caliper must be replaced. The shear adapter is designed to shear if excessive torque is required to turn the adjuster (**Figure 22**).

FIGURE 21
Knorr-Bremse Caliper Adjuster Test

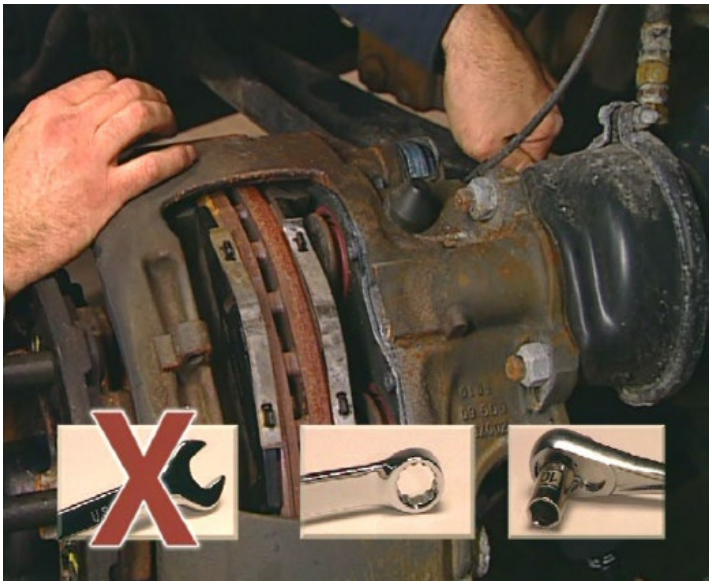
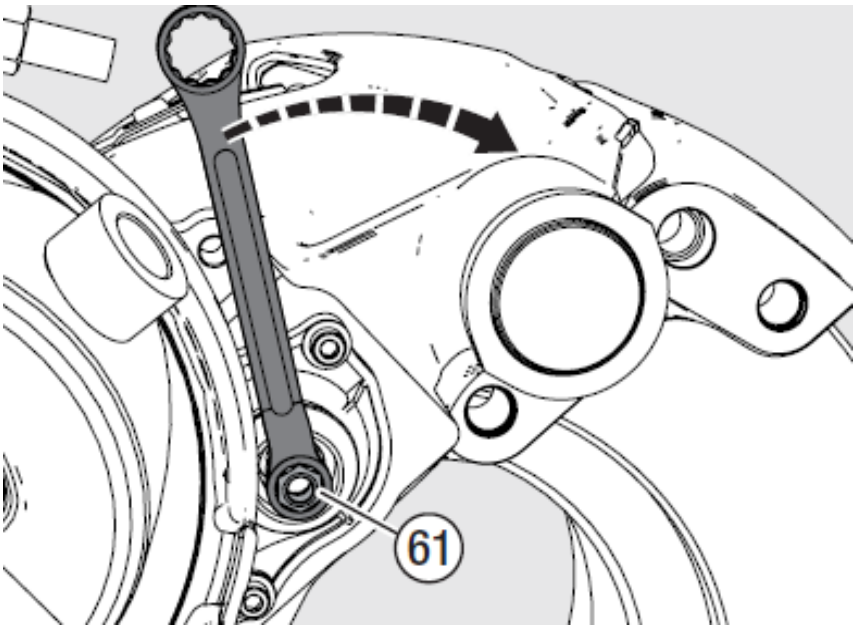


FIGURE 22
Broken Shear Adapter

Leave the box wrench on the shear adapter and make sure it can move in the clockwise direction without obstruction. Apply the brakes with about 30 psi (2 bar) pressure 5 to 10 times. The wrench should turn clockwise as seen from the actuator side (**Figure 23**). If the wrench does not turn, turns only on the first

application, or turns forward and backward with every application, then the automatic adjuster has failed and the caliper must be replaced.

FIGURE 23
Knorr-Bremse Caliper Adjuster Test

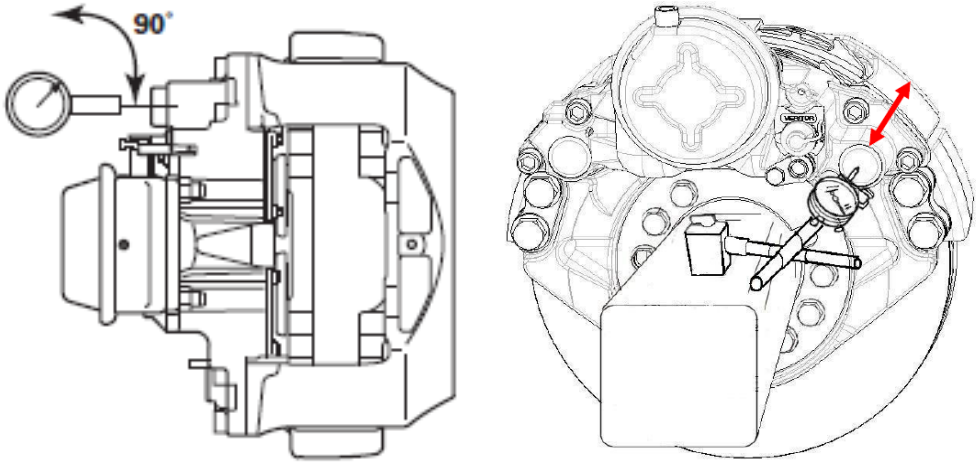


Number 61 is the shear adapter.

5.3 Meritor EX225 caliper brake adjuster test

Slide the caliper fully inboard, and zero the gauge. Move the caliper fully outboard by hand and note the reading (**Figure 24**). The nominal running clearance should be between 0.030 and 0.080 in. (0.76 to 2.03 mm). If the reading is less than 0.030 in. or exceeds 0.080 in., then the brake is out of adjustment and requires further attention. If the gap is within this range, then the test is complete. If the clearance is too wide, then there is a danger of brake failure. See Section 5.5 for the adjustment procedure. If the distance is too small, or if there is no gap at all, then there is a danger of the brake overheating. These conditions must be corrected before returning the vehicle to service. A second caliper test will be done when the pads are removed to check for free movement of the caliper on the guide pins.

FIGURE 24
Meritor EX225 Caliper Movement Test

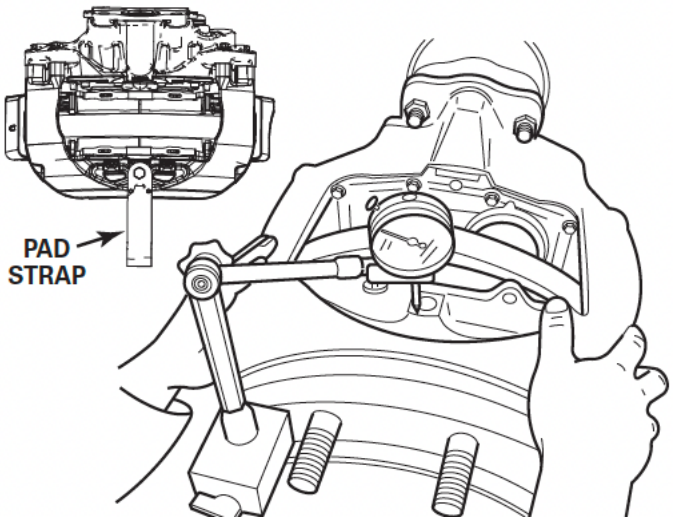


5.4 Meritor EX225 slide pin bushing test

If there is tapered wear on the pads or other pad wear issues, then check the slide pin bushing wear. This check should be performed with the brake assembly installed on the vehicle.

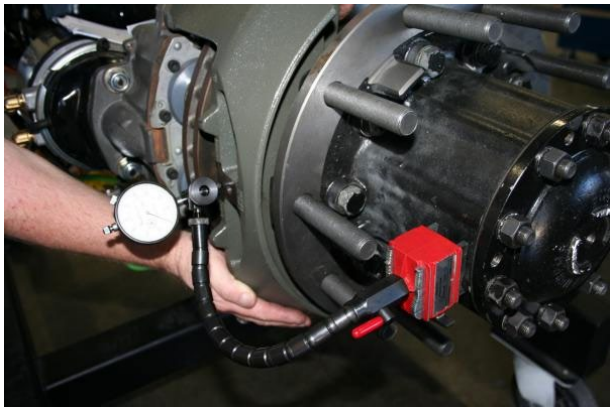
Loosen the pad strap and reposition it 180 deg from the installed position. Retighten the pad strap bolt to 20 lb-ft (27 Nm) so that the strap does not move (**Figure 25**).

FIGURE 25
Radial Test



Attach a dial indicator onto the vehicle hub and set it against the caliper. Position the brake caliper in the center position as it would be when the brake pads are installed. This is set when a gap of approximately 0.8 in. (20 mm) exists between the rotor and the bridge (**Figure 26**). Hold the caliper at the outboard pad edge and by the air chamber. Push the brake caliper down by hand as far as possible with approximately 10 lb of force and set the gauge to zero. Pull the caliper up as far as possible with approximately 10 lb of force without allowing the caliper to slide. The maximum acceptable reading is 0.100 in. (2.5 mm). If the reading is more than 0.100 in. (2.5 mm), then replace the bushings and slide pins, or the caliper assembly.

FIGURE 26
Checking Meritor EX225 Slide Pin Bushing Clearance



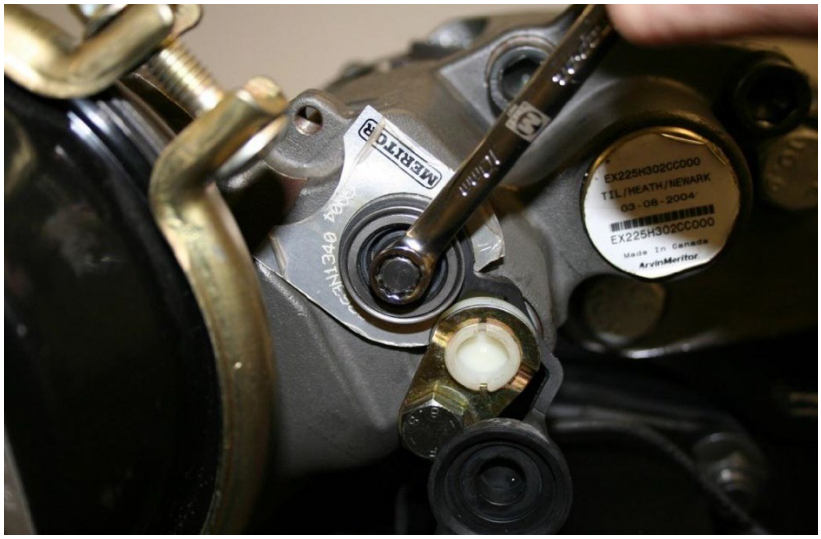
5.5 Meritor EX225 caliper adjuster test

Check that the adjusting screw cap is properly installed and is not torn or loose. Remove the cap and visually inspect the adjusting screw seal for damage (**Figure 27**).

FIGURE 27
Meritor EX225 Dust Cap with Adjuster and Seal Visible

Make sure the bus has at least 95 psi (6.55 bar) air pressure, and if applicable make sure the spring brake is released. Using a 10 mm box wrench, de-adjust the brakes one quarter turn. Do not exceed 30 ft-lb (40 Nm) of torque. Leave the box wrench on the adjuster, and make sure it can move in the clockwise direction without obstruction. Apply the brakes with about 30 psi (2 bar) pressure 5 to 10 times. The wrench should turn clockwise as seen from the actuator side (**Figure 28**). If the wrench does not turn or turns forward and backward with each application, then the automatic adjuster has failed, and the caliper must be replaced.

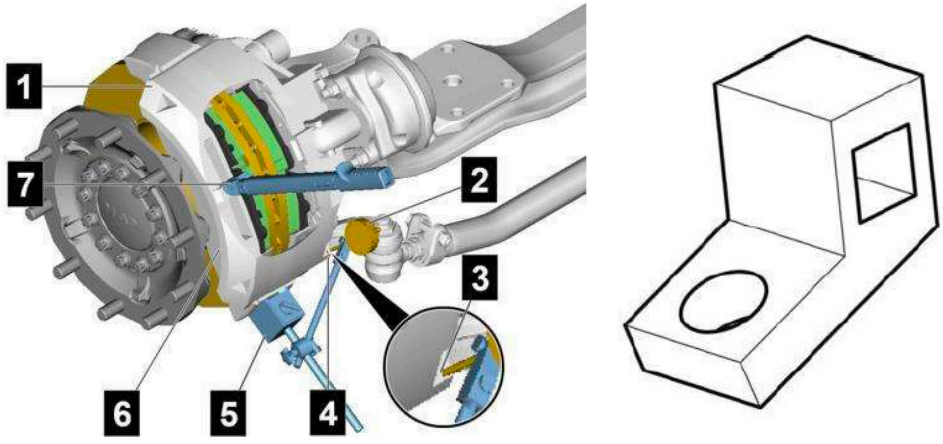
FIGURE 28
Checking Meritor EX225 Adjuster



5.6 Knorr-Bremse guide pin inspection with pads installed

Guide pins and bushings keep the brake caliper perpendicular to the brake rotor and therefore must be maintained to ensure proper brake performance. The guide pin inspection should be conducted after the new brake pads are installed (**Figure 29**), which is described in Section 10 of this document.

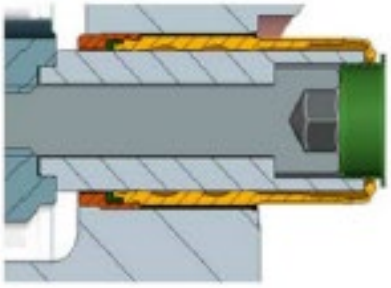
FIGURE 29
Measuring Knorr-Bremse Caliper Guide Pin Wear and Gauge Holder/Adapter



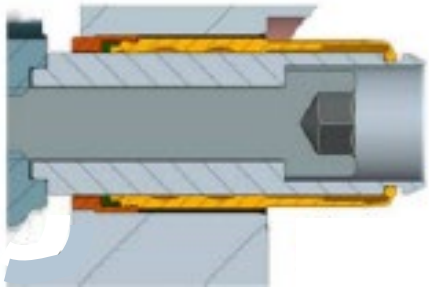
Clean the brake caliper (1) using a steel brush. Place the gauge holder (5 and at right in **Figure 29**) with the dial gauge (2) on brake caliper. Pad retainer must be removed in order to attach the gauge holder/adapter in place of the retainer pin. Position the tip of the dial gauge (3) on the recess (4) of the brake caliper with pre-load. Place the torque wrench (7) with ratchet inserted into the adapter. Push the brake caliper with the torque wrench against the direction of driving and set the dial gauge to zero. Turn torque wrench and apply 18.4 ft-lb (25 Nm) to pry the caliper up. The dial gauge is used to read the movement on the adapter/caliper in relation to the bracket (play in the bushing). If the measured value is over 0.08 in. (2 mm), replace the caliper guides.

The specification for allowable measured movement varies due to the differences in the slide pin bushing design (**Figure 30**). Always confirm which slide pin bushing is installed in the caliper, and refer to the Knorr-Bremse manual for the appropriate specification.

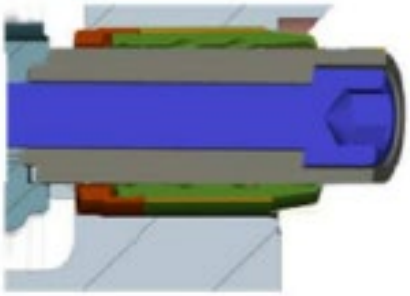
FIGURE 30
Slide Pin Bushing Designs



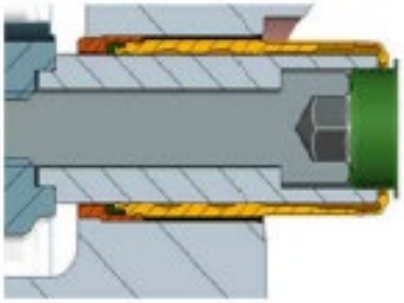
Closed rubber bush bearing with metal hood



Closed rubber bush bearing without metal hood



Open rubber bush bearing



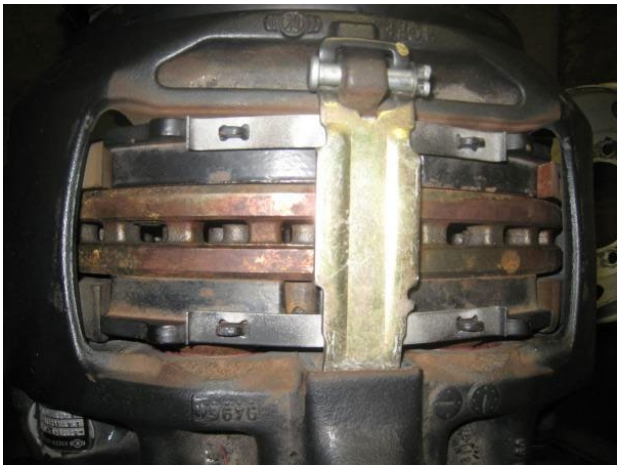
Closed rubber bush bearing with metal hood

5.7 Brake pad removal

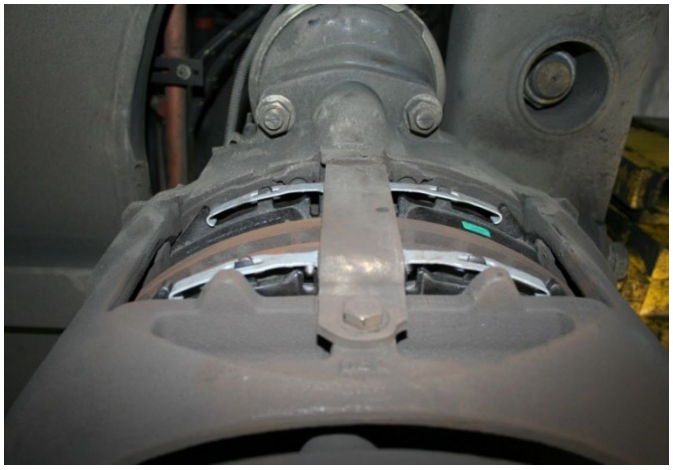
Ensure that the spring brake is caged. Disconnect and remove wear sensors where applicable. Visually inspect the brake pad retainer for damage or wear. Replace if wear or damage is evident and when brake pads are replaced. Remove the brake pad springs (**Figure 31**). Follow the de-adjustment procedures identified previously for the appropriate caliper. Remove the bolt (Meritor) or clevis pin (Knorr-Bremse) securing the pad retaining strap. Remove the retaining strap from the caliper.

> **NOTE:** Some pad springs are permanently affixed to the pads and cannot be removed. Slide the caliper outboard and remove the outer pad. Slide the caliper inboard and remove the inner pad.

FIGURE 31
Brake Pad Removal

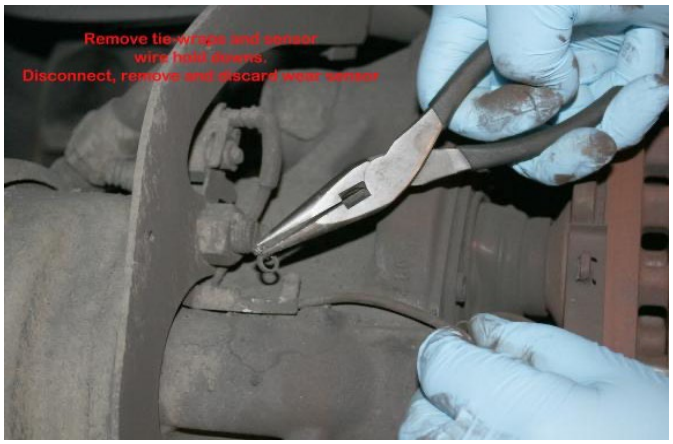


Knorr-Bremse pad retainer with clevis pin



Meritor EX225 caliper pad retainer secured with a bolt

Knorr-Bremse



Remove in-pad sensor components if so equipped

When performing a brake pad replacement, it is important to replace all pads on the same axle (left and right side).

5.8 Caliper guide pin inspection with pads removed

This test is used for both the Meritor EX225 and Knorr-Bremse calipers. Clean the exposed part of the guide pin before moving the caliper in and out to prevent bushing contamination. Using hand pressure only, with the brake pads removed, make sure the caliper slides freely along the whole length of the guide pins (**Figure 32**). Replace the guide pins and bushings if the caliper does not slide freely.

FIGURE 32
Checking for Smooth Caliper Movement on the Guide Pins

When the caliper is removed, visually inspect the caliper slide pin bushings for proper installation and positioning. Some bushings are round, and others are oval. Oval bushings should be installed with the oval shape in the horizontal position. Meritor EX225 has a combination of round and oval bushings, and Knorr-Bremse has round and elastic rubber bushings. On the Knorr-Bremse setup, the long pin is guided with a solid bushing and the short one with an elastic rubber bushing.

FIGURE 33
Meritor EX225 Short Slide Pin with Oval Bushing

5.9 Guide and slide pin boot inspection

All slide/guide pin boots should be free from damage and should be correctly seated. To check boot condition, push the bridge inboard and the boots should collapse (be sucked inward). When the bridge is

moved outboard, the boots should expand. If any whistle or air movement sound is heard, or if the boots do not collapse and expand as described, the boots will need to be replaced. When a damaged or leaking slide pin seal is identified, the caliper should be removed for replacement of the bushings and seals (**Figure 34**). When replacing boots, inspect the guide pin condition. If guide pins show signs of corrosion, then replacement of the pins is recommended.

FIGURE 34
Guide/Slide Pin Boot Inspection

Knorr-Bremse guide pin boot

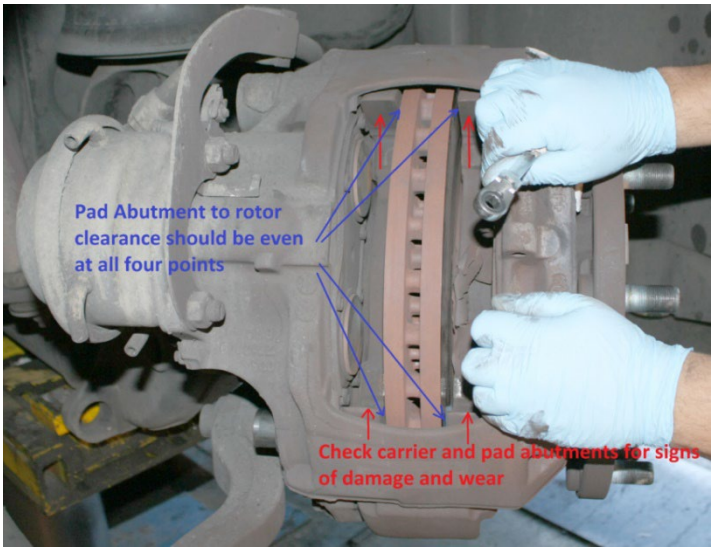
Meritor EX225 slide pin boot and tappet boot

Improperly installed slide pin boot

5.10 Carrier and pad abutment inspection

Carrier and pad abutments should be inspected for signs of wear and damage (**Figure 35**).

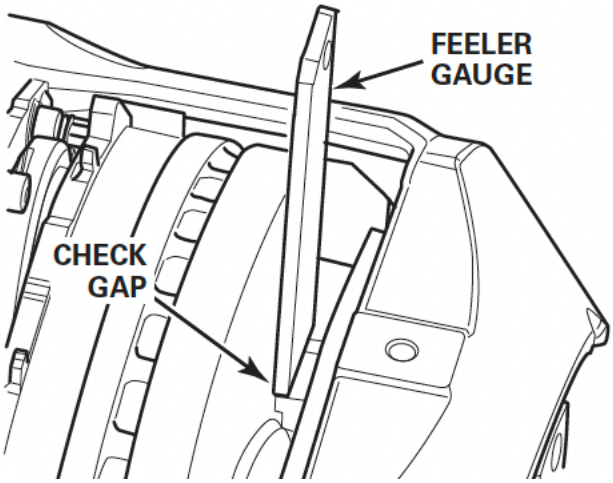
FIGURE 35
Pad Abutment Inspection



Checking pad abutment to rotor clearance and pad abutment wear

Pad abutment to rotor clearance should be approximately equal at all four points. Large variances from side to side can indicate that the hub and rotor position is off-center, caused by uneven rotor wear, incorrectly installed spindle wear ring, or incorrect or out-of-adjustment wheel bearings. Minor abutment wear is normal. Wear that will cause the pads to hang up will require carrier replacement. Meritor notes that grooves in excess of 0.020 in. (0.50 mm) in depth on the abutment surfaces require replacement of the carrier. See **Figure 36**.

FIGURE 36
Maximum Permissible Gap Between the Rotor and Pad Abutment



Max gap, 7 mm (Knorr)
Max gap, 6 mm (Meritor)

5.11 Tappet boot and seal inspection

With the pads removed, rotate the adjuster clockwise until the boots are clearly visible.

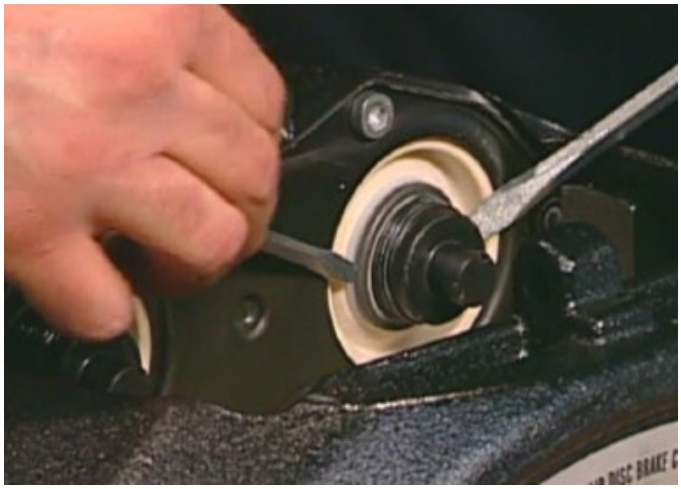
> **CAUTION:** Do not extend the Knorr-Bremse tappets more than 1.18 in. (30 mm). Meritor EX225 pistons can be extended to a maximum of approximately 2 in. (50.8 mm). Extending tappets beyond the maximum will cause a synchronization failure and will require caliper replacement.

Damaged, improperly seated, loose or worn boots and seals (**Figure 37**) can allow moisture and contamination into the internal mechanism of the caliper. These contaminations can cause the caliper to malfunction and not adjust or release properly, resulting in dragging or slack brakes. Inspect all tappet boots and sealing surfaces for damage, looseness and improper seating.

Damaged tappet boots must be replaced prior to installing brake pads. Knorr-Bremse has a replaceable inner tappet seal that is accessible when the tappet and boot are removed (**Figure 38**). Calipers suspected as contaminated must be replaced.

FIGURE 37
Examples of Damaged or Improperly Installed Tappet Boots

FIGURE 38
Knorr-Bremse Inner Tappet Seal Replacement



5.12 Tappet seal replacement

It is recommended that tappet seals be replaced during each wheels-off inspection to improve caliper life and performance (contingent on how often wheels-off inspections are done, or whether calipers are replaced as part of the reline). Tappet and seal assemblies should always be replaced as a set. Replace inner tappet seals on Knorr-Bremse calipers whenever tappets and outer seal assemblies are replaced.

5.13 Tappet inspection

Clean the tappet pad contact surfaces. Using a straight edge, measure tappet height to ensure that both tappets are at equal height (**Figure 39**). Uneven tappet height indicates that tappet synchronization is lost and the caliper must be replaced.

FIGURE 39
Straight Edge Showing Uneven Tappet Height

5.14 Torque plate inspection

- Inspect torque plate for cracks at fastener mounting holes and surfaces.
- Inspect mounting plate fastener holes for oversize, out-of-round and wear.

6. Rotor inspection and maintenance

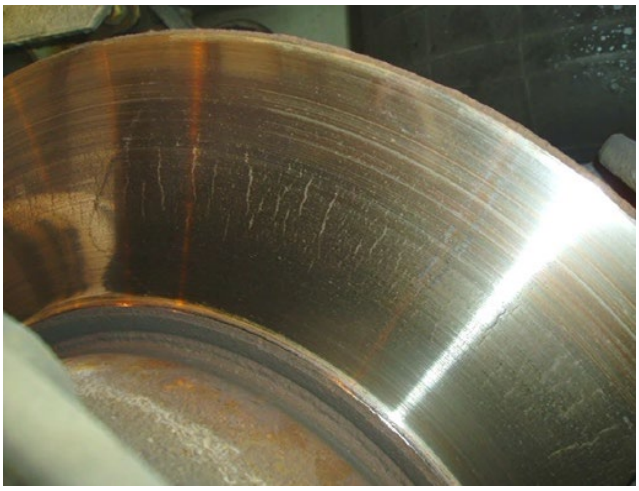
A thorough inspection of the rotors is critical to achieving safe, comfortable and reliable braking. Inspect the rotors for:

- heat checks, cracks, grooving and scoring
- overheating
- thickness
- run-out

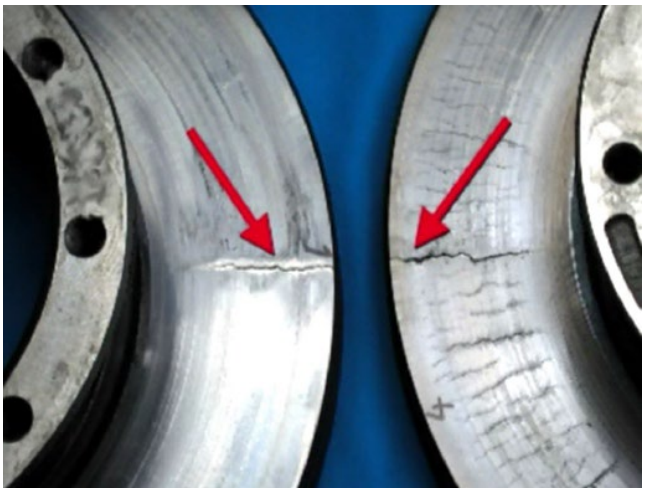
6.1 Heat checks, cracks, grooving and scoring

Heat checks are short, thin, sometimes numerous radial interruptions of the rotor braking surfaces. They are caused by the heating and cooling of the rotor that occurs over time as the brakes are applied. Heat checks will frequently wear away and re-form, or 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 common types of heat checks: light heat checking and heavy heat cracking (**Figure 40**).

FIGURE 40
Heat Checking



Small heat checks (as shown) are allowable. Cracks on the surface of the rotor that result from light heat checking are small and fine and do not require rotor replacement.



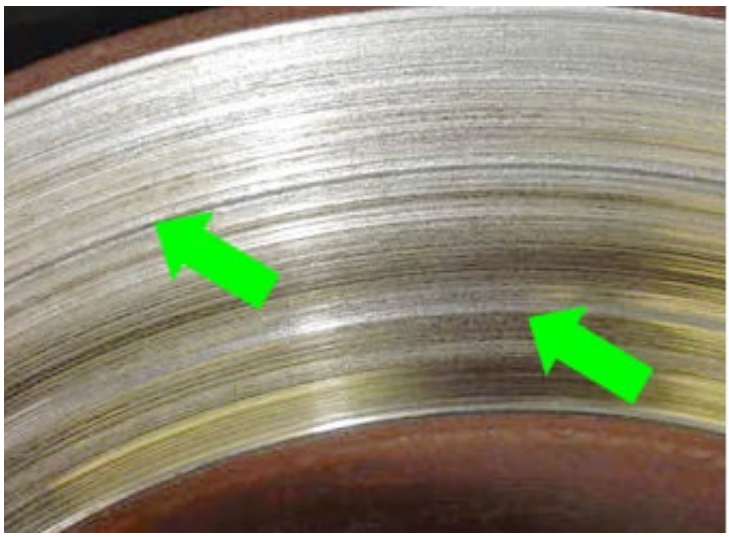
Large cracks creating a split in the rotor are not acceptable and will require the rotor to be replaced. Cracks going through to the cooling fins or into the inner or outer edge of the friction surface are also not allowed, and require the rotor being replaced.

Meritor requirements are to replace the rotor if the heat checks have a width greater than 0.02 in. (0.5 mm), a depth greater than 0.04 in. (1 mm) and extend across the surface more than 75% in the radial direction.

Knorr-Bremse allows radial cracks less than 0.06 in. (1.5 mm) deep or wide if their length is less than 75% of the radial measurement of the friction surface and the cracks do not extend to either end of the friction surface.

Knorr-Bremse allows axial grooves (**Figure 41**) less than 0.06 in. (1.5 mm) deep or wide. Meritor permits axial grooves less than 0.02 in. (0.5 mm) deep or wide. Grooves that exceed manufacturer's specifications will require rotor resurfacing or replacement.

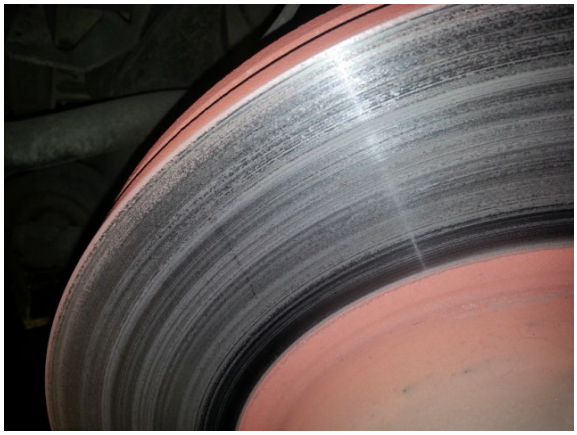
FIGURE 41
Axial Grooves



6.2 Overheating

Blue bands along the swept part of the rotor and rust color on the housing are indicators of a brake that has overheated (**Figure 42**). The cause must be identified and corrected. Rotors and pads must be replaced after identifying and repairing the cause of the hot brakes.

FIGURE 42
Evidence of Overheating



6.3 Rotor thickness

Use a brake rotor micrometer to measure thickness at 90 deg intervals at the thinnest portion of the rotor (**Figure 43**). Avoid measuring near the edge of the rotor, as minor burrs may result in inaccurate measurement. If unsure of the thinnest point, measure at three points. Point one is about 10 mm below the outer friction diameter. Point two is at the friction surface center. Point three is about 10 mm above the inner

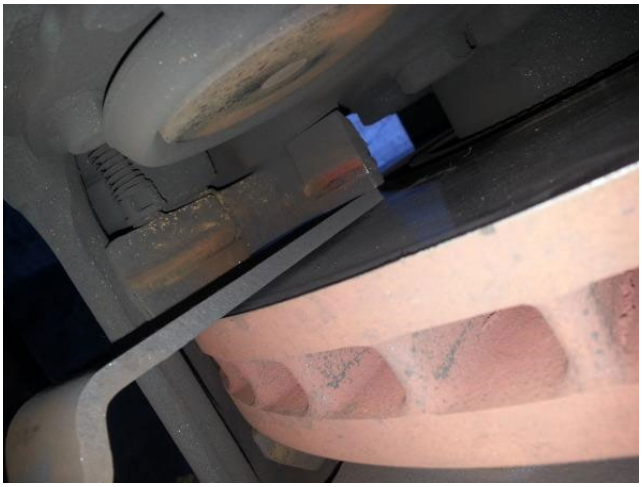
friction diameter. The brake rotor micrometer must be square to the rotor friction surface for accurate measurement. New rotors are typically 45 mm thick. The discard thickness (typically 37 mm) is frequently cast into the rotor hat flange. Rotors must be discarded when the minimum thickness is reached because it is no longer considered safe for operation. Rotor wear must also be taken into account when replacing pads. Minimum thickness is not the minimum brake pad change thickness. New brake pads can be installed with a used rotor, providing that the rotor passes the visual inspection and no portion of the rotor friction surface measures less than 39 mm in thickness.

It is recommended that brake pad wear rate be documented and used to coordinate pad and rotor replacement. Consideration should be taken as brake rotors are worn over the course of brake pad life. Wear rates can be calculated by first installing and measuring new rotors and pads. Then measure both when the pads are worn to their minimum thickness. It is not recommended to install brake pads if rotor wear rates would cause rotor thickness to wear below discard limits during the expected life of the brake pads. Rotors can be resurfaced to acceptable conditions, providing that all other specifications are met.

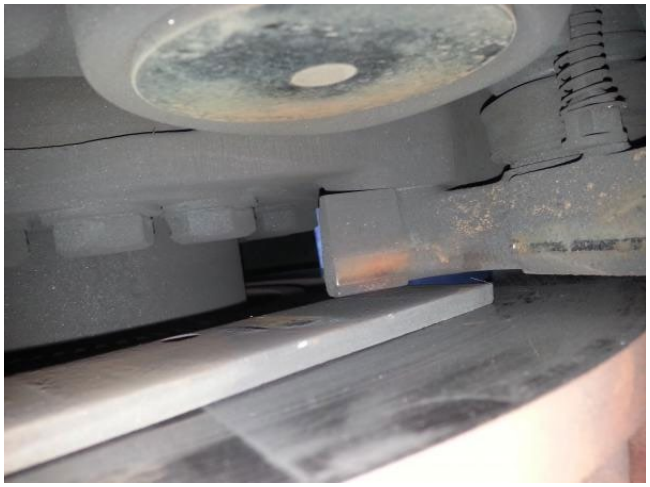
FIGURE 43
Measuring Brake Rotor Thickness with a Brake Rotor Micrometer

Meritor EX225 pad retainers can be used as a gauge to help identify worn rotors. To check wear, place the retainer between the rotor surface and the carrier pad abutment. Make sure that wear is checked on both the inboard and outboard sides of the rotor. See **Figure 44**.

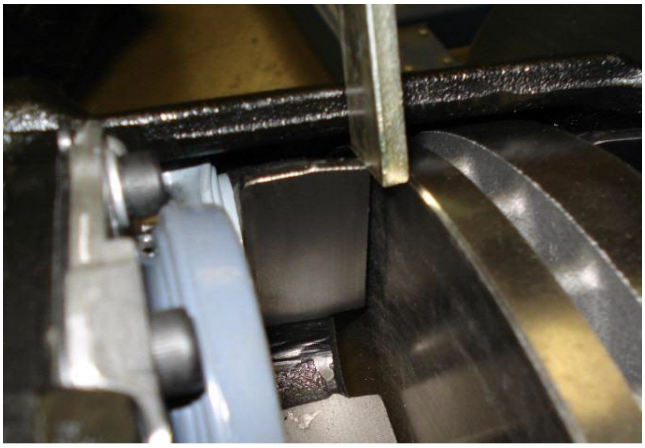
FIGURE 44
Rotor Wear



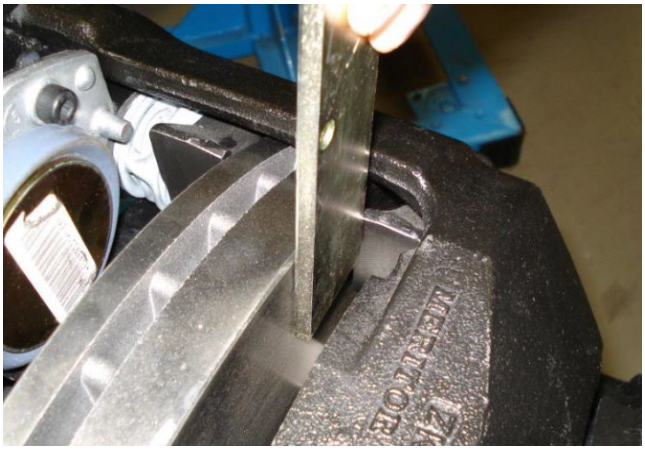
Uneven Meritor EX225 rotor wear indicated by angular gap between pad retainer and carrier. The rotor will need to be replaced.



Worn Meritor EX225 rotor indicated by gap between the pad retainer and the carrier. The rotor will need to be replaced.



Acceptable Meritor EX225 rotor thickness indicated, as the pad retainer will not fit between the rotor and the carrier.



Some Meritor rotors have different inboard and outboard swept area thicknesses. The flange and hub add to brake mass and increase heat transfer.

6.4 Rotor run-out

Check rotor run-out by using a dial indicator mounted on the carrier with the measurement taken at the center of the swept area of the rotor (**Figure 45**). Slowly rotate the rotor by hand one full revolution and note the measurement. The run-out should not exceed 0.020 in. (0.5 mm) for Meritor EX225 and 0.006 in. (0.15 mm) for Knorr-Bremse. Hub bearing end play can also affect rotor run-out. If run-out is greater than specified, check wheel bearings for the correct adjustment.

Thickness can vary, creating the false illusion of run-out. These variances in thickness can also cause wheel vibration during braking. Therefore, it is recommended to check rotor thickness in multiple areas. Mark the rotor on the outside to have a reference point to determine run-out or disc thickness variation.

FIGURE 45
Checking Rotor Run-Out

If rotor run-out is beyond recommended specifications, they will need to be replaced or machined (**Figure 46**). If the rotors fall below 39 mm during machining, they will fall below minimum discard thickness during the life of the new pads, so they will need to be replaced.

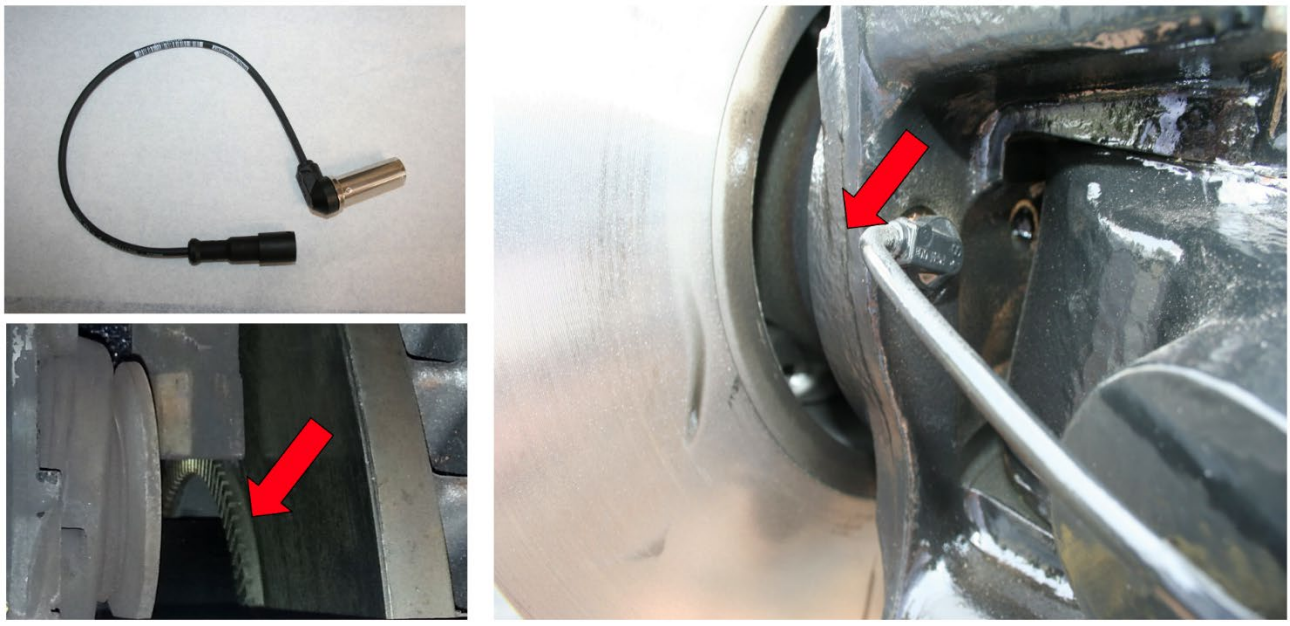
FIGURE 46
Brake Rotor Lathes

Options exist to turn rotors both on and off the vehicle.

7. Antilock braking systems

If the bus is equipped with an antilock braking system (ABS), visually inspect wheel speed sensor (**Figure 47**), sensor mounting, wiring and adjustment. Replace as necessary.

FIGURE 47
ABS Sensor



ABS wheel speed sensor (top left) and mounting location

Using a digital volt ohm meter, test sensor for resistance. Resistance should be between 900 and 2000 Ω. Optimum resistance is approximately 1200 Ω. Anytime the wheel is removed, the sensor depth must be adjusted

8. Electronic brake wear indicators

Some air disc brakes are equipped with electronic pad wear warning indicators or sensors to monitor pad wear. Electronic brake pad wear indicators warn the operator prior to maximum wear limit and end of pad life. Electronic sensors have a sensing wire embedded in the friction material at the minimum service thickness.

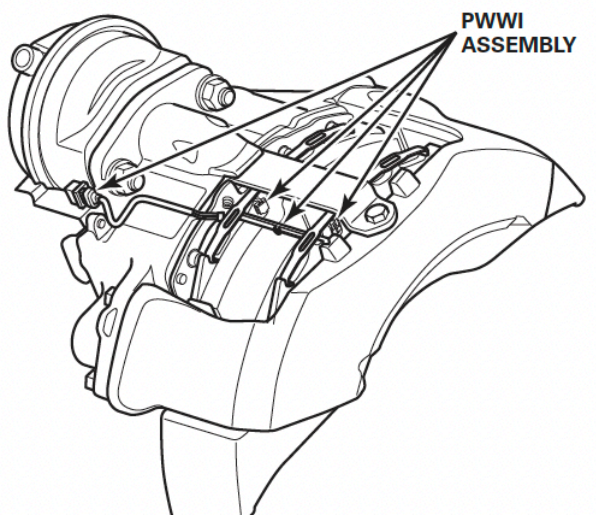
There are two different types of electronic wear indicators: end of life (EOL) wear indicator and continuous wear indicator electronic brake sensor (EBS). EOL sensors have a sensing wire embedded in the friction material at the minimum service thickness (**Figure 48**).

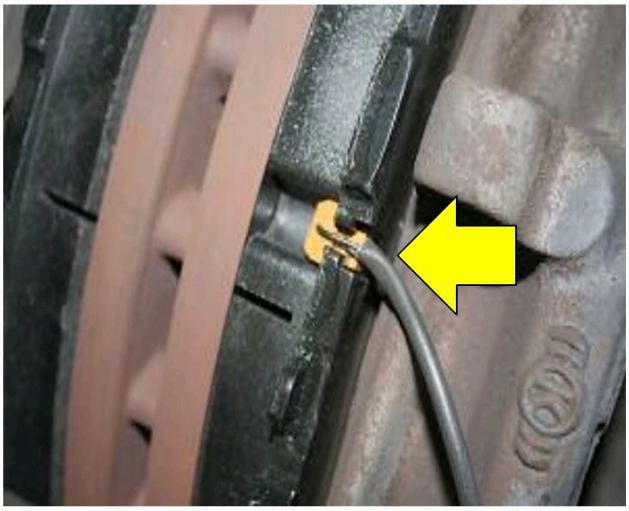
When friction material wears to minimum thickness, the sensor wire contacts the rotor, creating an electrical path to ground and illuminating a service warning requiring further inspection. As the friction material wears further, the sensor wire breaks, creating an open circuit illuminating an end-of-life warning.

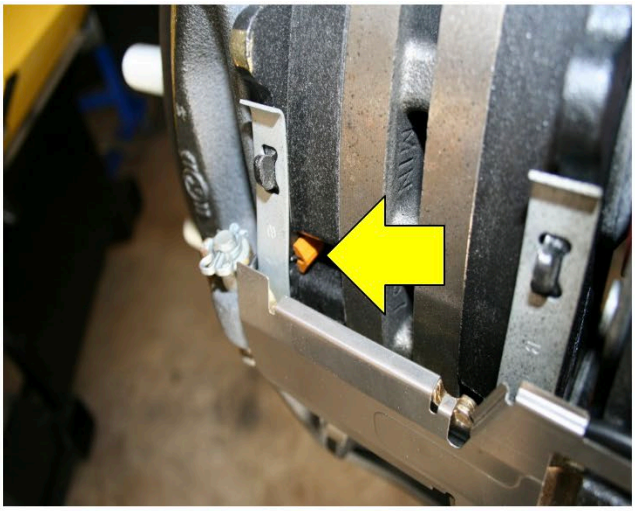
The EBS is embedded into the caliper and continuously checks the gap. Depending on the configuration, the signal can be used to show the percentage of the remaining lining on the dashboard. When the lining thickness wears to a specified value, depending on the vehicle configuration, a warning signal will be given to indicate that a pad change is required.

If either of the two sensors shows signs of wear from a thin brake pad or if the rotor has caused damage to the sensor, the sensor assembly (EOL) must be replaced. Repair of the Knorr caliper EBS is not possible. If the EBS is damaged, the whole caliper needs to be replaced.

FIGURE 48
EOL Indicators

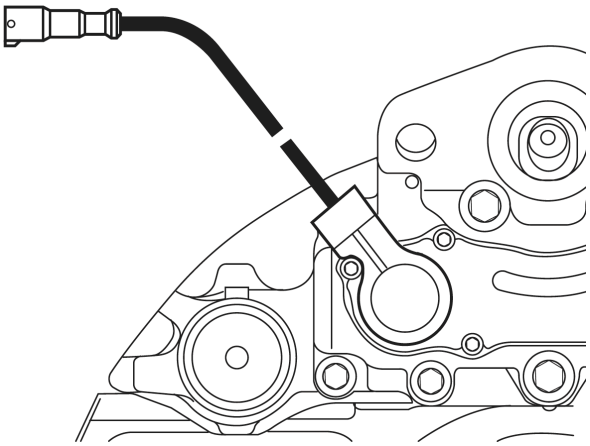






EBS indicators measure pad thickness based on a predetermined rotor thickness of 45 mm. They do not account for rotor wear, and they are less accurate when new pads are installed on used rotors (see **Figure 49**). They provide an alert when the braking system needs to be inspected for wear on the pads and rotor. To get an accurate indication of lining wear, it is important to ensure that the indicator is not seized in the hole. Check the indicator by grasping the indicator and rotating/pulling outward and releasing. If the indicator does not move when pulled on, move it by hand as necessary to free it up.

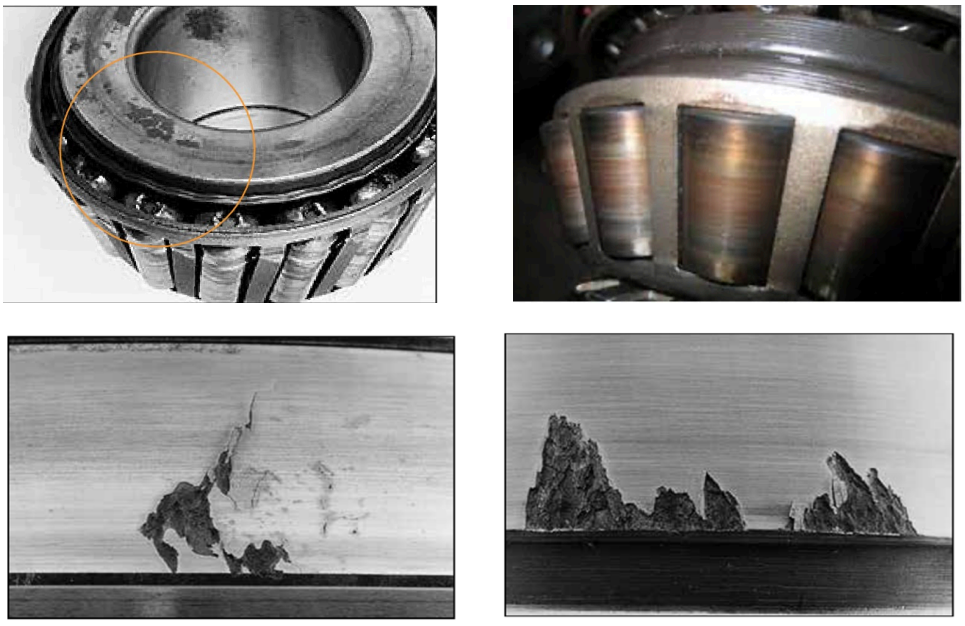
FIGURE 49
Example of a Knorr Bremse Continuous Brake Wear Indicator (EBS)



9. Bearings

Inspect the cup, cone, rollers and cage of all tapered roller bearing assemblies. Bearing wear and failure are usually a case of inadequate lubrication, faulty installation or improper adjustment. Lubrication failure can occur if the wrong lubricant is used, if not enough lubricant is applied, or if the bearing has been exposed to excessive temperatures that have caused the lubricant to degrade. Overheated roller bearings (**Figure 50**) show evidence of bluing, discoloration and wear. If any defects are found, replace the complete bearing assembly.

FIGURE 50
Overheated Bearings



Point Surface Origin (PSO) spalling

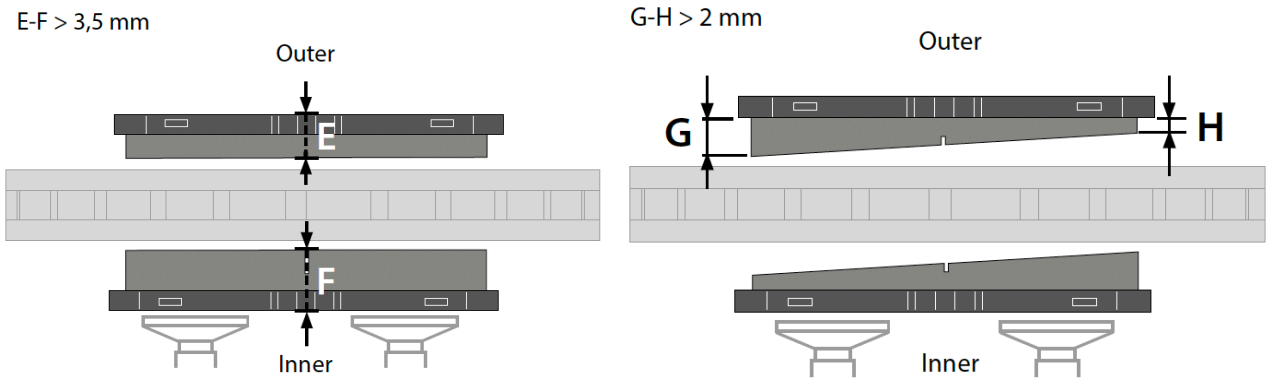
Geometric Stress Concentration (GSC) spalling

Spalling is the result of metal fatigue and also associated with improper lubrication.

10. Brake pad installation and adjustment

Inspect the old brake pads for abnormal wear. If the thickness difference between the two pads is greater than 3.5 mm or if the wear on either pad is tangential oblique (more than 2 mm between two ends of a pad), check the bearing clearance, ensure that the pads move freely in the caliper, and make sure there is not excessive dirt/grime in the brake system. See **Figure 51**.

FIGURE 51
Brake Pad Wear Measurements



Cracking on the pad surface is typical of normal wear and is not always an indication of a faulty product or grounds for replacement, assuming that the following conditions apply:

- The cracks do not appear within the pad binding area (2 mm above the pad back plate).
- Cracks on the pad surface do not run through to the back plate.

Brake pads must be changed as an axle set and not individually. Before installing the pads, make sure that the tappets are fully retracted and that all surfaces are clean. Install the new pads so the friction material faces the rotor. Note that on Knorr Bremse SYNACT calipers, the brake lining and the longer friction surface must be fitted in the outer brake lining cavity and the brake lining with the shorter friction surface in the inner brake lining cavity (**Figure 52**).

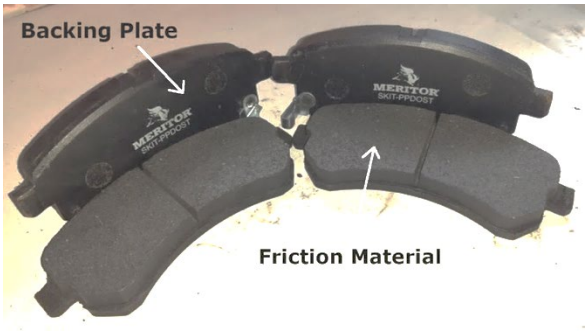
FIGURE 52
SN7 vs. SYNACT Caliper

SN7 caliper | SYNACT caliper

After the brake pads are installed, install new pad retainers, springs and hardware to complete the installation. Knorr-Bremse permits the use of a light lubricant film (refer to manual for specific lubricant for each setup)

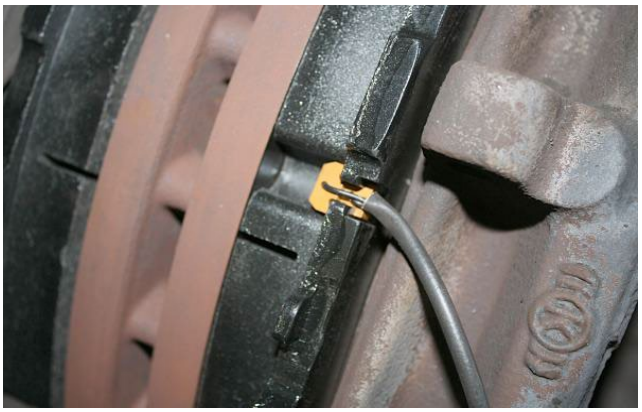
on the backing plate of the brake pad with no excess lubricant evident. Make sure there is no lubricant on the friction material surface of the brake pad (**Figure 53**). Anti-seize must not be used.

FIGURE 53
Brake Pad Backing Plates and Friction Material

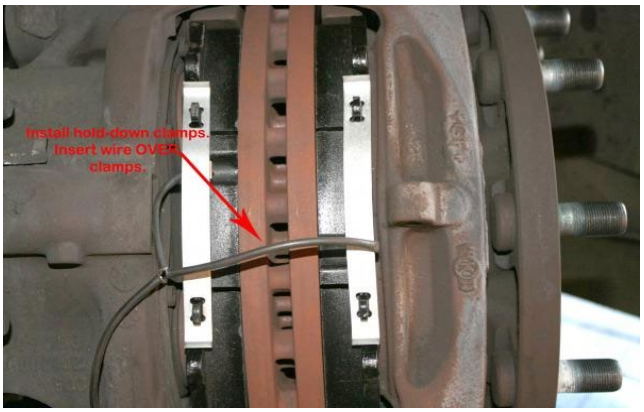


If required, connect and fit cable/sensor guides. Make sure harnesses are secured per the manufacturer's recommendations to prevent chafing against the rotor or rim (**Figure 54**).

FIGURE 54
Brake Pad Installation and Adjustment



Install sensors as required

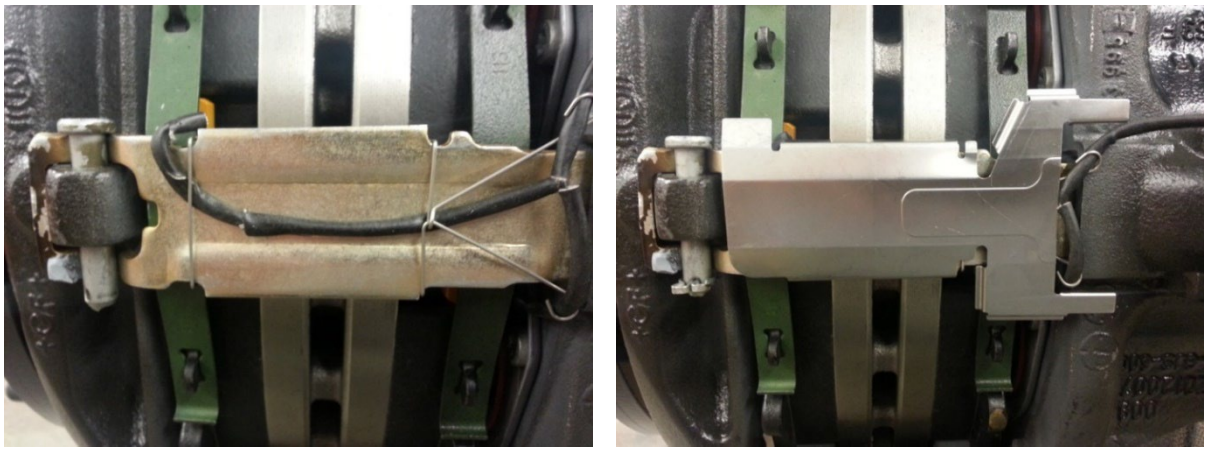


Knorr-Bremse wear sensor harness routing

Make sure the pad retainer straps are installed per manufacturer's recommendations (**Figure 55**).

FIGURE 55
Pad Retainer Straps

Knorr-Bremse pad retainer installation

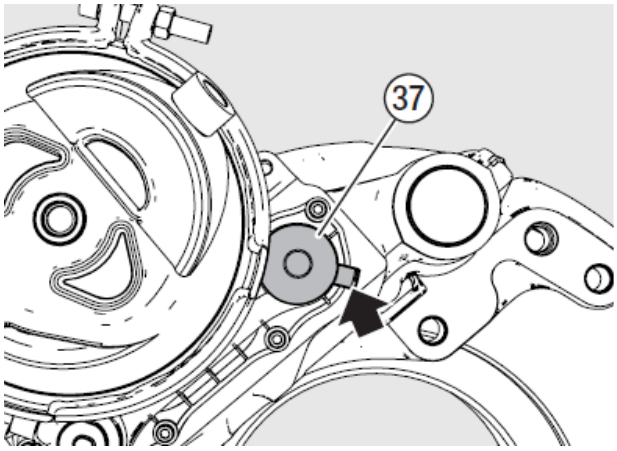


If equipped, properly secure Knorr-Bremse wear sensor harness.

For Knorr-Bremse calipers, turn the shear adapter clockwise until the pads come in contact with the rotor. Then back off the adjuster three clicks and check the running clearance. Clearance should be between 0.0275 and 0.047 in. (0.7 and 1.2 mm). Apply and release the brake, making sure the hub turns easily by hand. Put a small amount of grease in the adjuster stem sealing cap and install, noting the orientation of the tab. See **Figure 56**.

FIGURE 56
Setting Initial Clearance

Adjusting the brakes to set the initial clearance



Adjuster stem cap position

To set the initial running clearance on Meritor EX225 calipers, use a 10 mm socket and turn the adjuster clockwise until both pads contact the rotor. Turn the adjuster back one half turn to create a running clearance. Apply the brakes 5 to 10 times with the bus at minimum 95 psi (6.55 bar) air pressure to set the correct running clearance. Check that the rotor is free to turn and confirm that the brake-pad-to-rotor clearance is within specification. Nominal total pad-to-rotor clearance should be 0.030 in. (0.75 mm). Install the adjuster stem cap.

Complete a final visual inspection to ensure that all components are properly installed. Check for air leaks.

Install wheels, follow the agency's break-in recommendations and perform a brake performance test to verify satisfactory operation of the brakes (refer to APTA BTS-BC-RP-001-05, "Transit Bus In-Service Brake System Performance Testing").

Related APTA standard

APTA BTS-BC-RP-001-05, "Transit Bus In-Service Brake System Performance Testing"

References

This recommended practice is to be used in conjunction with the OEM and disc brake manufacturer service manuals.

Definitions

disc brake assembly: Consists of the brake pads, rotor and caliper assembly.

These terms are interchangeable:

- **Brake pad:** friction material, brake lining
- **Bearing cups:** bearing races
- **Brake chamber:** air chamber
- **Machining:** turning, reboring, grinding, sanding and cutting of components

Abbreviations and acronyms

Ω	ohm
ABS	antilock braking system
CCOHS	Canadian Centre for Occupational Health and Safety
EBS	electronic brake sensor
EOL	end of life
ft-lb	foot-pounds
HEPA	high-efficiency particulate air
MSDS	material safety data sheet
MSHA	Mine Safety and Health Administration
Nm	Newton-meters
NIOSH	National Institute for Occupational Safety and Health
OEM	original equipment manufacturer
OSHA	Occupational Safety and Health Administration
psi	pounds per square inch
PWWI	pad wear warning indicator

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