APTA STANDARDS DEVELOPMENT PROGRAM
RECOMMENDED PRACTICE
American Public Transportation Association
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Bus Brake and Chassis Working Group

Aftermarket Disc Brake Pad Evaluation

Abstract: This recommended practice provides guidelines for troubleshooting transit bus air systems, including basic design criteria, preventive maintenance and common problems.

Keywords: ABS tone ring, aftermarket, boot, brake performance, bridge, bushing, caliper, carrier, disc, disc brake maintenance, friction material, hub, original equipment (OE), pads, pin, potentiometer, retaining strap, rotor, seal, slide pin, spring clip, torque plate, wear indicator, wear sensor, wheel seal

Summary: Proper maintenance will ensure the safe and dependable operation of transit vehicles. This document establishes a recommended practice for assessing the selection of friction material for in-service transit buses. It provides information for judging the performance of aftermarket brake pads on air-actuated foundation brakes when performing the dynamometer test and vehicle stopping distance procedures in Federal Motor Vehicle Safety Standard (FMVSS) No. 121, Air Brake Systems, as well as information on lining supplier qualification. Such information will assist fleet operators in choosing aftermarket brake pads that will perform adequately on typical city transit buses.

Scope and purpose: Not all brake systems are included in this document, and the tables and examples it contains are for commonly used transit applications. The purpose of this recommended practice is to provide a uniform method for selecting friction material in order to maintain brake performance.

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Introduction

This introduction is not part of APTA BTC-BC-RP-011-22, "Aftermarket Disc Brake Pad Evaluation."

This recommended practice reflects the consensus of the APTA Bus Standards Program members on the items, methods and procedures that have provided the best performance record based on the experiences of those present and participating in meetings of the program task forces and working groups. APTA recommended practices are voluntary, industry-developed and consensus-based practices that assist equipment suppliers, vehicle and component manufacturers, and maintenance personnel in the construction, assembly, operation and maintenance of transit bus vehicles. They may include test methodologies and informational documents. Recommended practices are nonexclusive and voluntary; they are intended to neither endorse nor discourage the use of any product or procedure. All areas and items included herein are subject to OEMs' and manufacturers' supplemental or superseding recommendations.

APTA recommends the use of this document by:

- Individuals or organizations that inspect and maintain transit buses;
- Individuals or organizations that contract with others for the inspection and maintenance of transit buses; and
- Individuals or organizations that influence how transit buses' brake disc pads are tested and approved for use on their fleets.

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

Aftermarket Disc Brake Pad Evaluation

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 (e.g., brake pads with glass, mineral wool, ceramic, aramid or carbon fibers) is not specifically covered under current OSHA regulations. Although medical experts do not agree about the possible long-term risks of working with and breathing non-asbestos fibers, some believe that long-term exposure could cause pneumoconiosis, fibrosis and cancer. Therefore, it is recommended that workers avoid dust when working on brakes.

Brake pads may also contain crystalline silica, lead, antimony, phenol and other possibly hazardous materials. Refer to the material's 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 or assemblies. 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.
- 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 wrung until nearly dry.
- Never use compressed air or dry sweeping to clean the work area. Use an industrial vacuum with HEPA filters and rags soaked in water and wrung until nearly dry. 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.
- 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. Safety provisions

Failure to comply with the safety provisions may result in personal injury or death.

The following recommended practices and guidelines assume that end users have sufficient skills and knowledge to repair and maintain the related systems at a journeyman level. This must also include a fluent understanding of safe shop working practices, not only for the agency but also OSHA/CCOHS, provincial/state, federal and local safety standards. A familiarity with applicable industries, component and system suppliers, and vehicle manufacturers is also assumed.

3. Background

There may be a variety of reasons for an agency to consider aftermarket lining.

- Noise issues
- Wear issues
- Cost
- Safety
- Performance
- Wear to components such as rotor and pads
- Brake balance
- Availability

The following will outline basic information on brakes components, testing procedures, evaluating, and documenting a procedure for selecting the disk brake pads that best meet your agency's needs. It is important to understand that different fleet types and driving environments may result in different fleets requiring different friction materials. (*This document provides guidelines for evaluating and selecting friction material.*)

See the brake pad evaluation decision parameters in Appendix A.

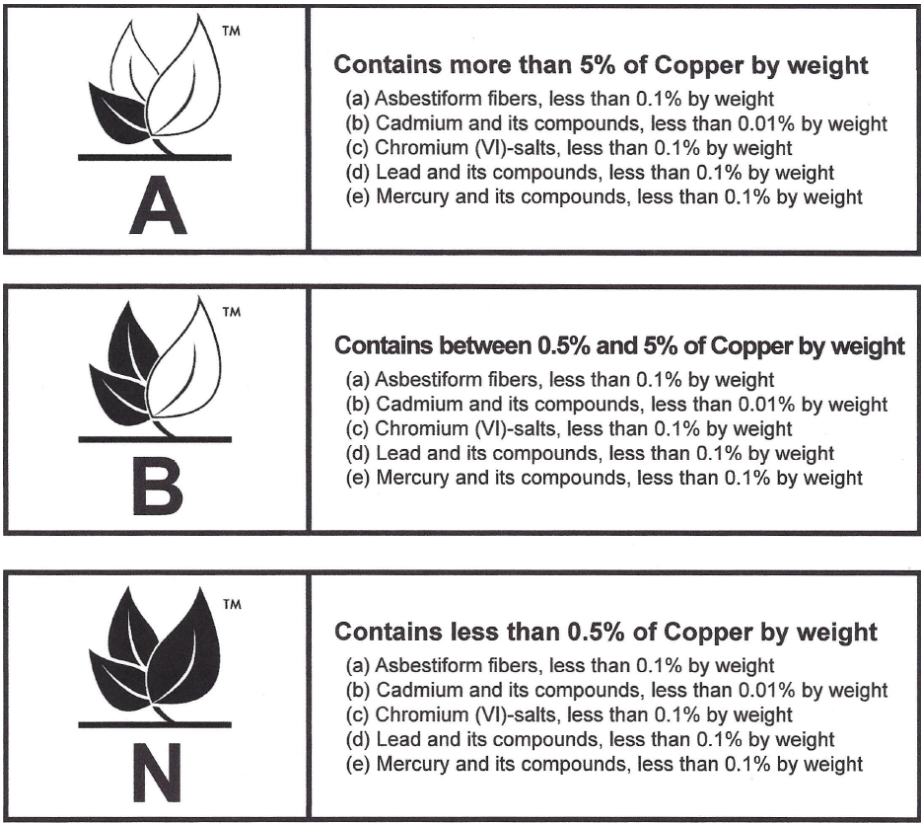
While performance of original equipment (OE) brake pads is regulated by FMVSS 121, pads sold as replacement friction materials are effectively not required to meet any legal standard. As a result, changes in friction materials can affect braking output, causing a shift of work to brakes on other axles, and impact the overall stopping capability of the vehicle. It is upon each agency to insure that all friction material used meets or exceeds federal and agency's braking efficiencies requirements.

3.1 Chemical composition

Some states have imposed limits to reduce and eventually eliminating the amount of copper produced in friction materials due to runoff into bodies of water. Other heavy metals are also included in this LeafMark standard, as detailed in **Figure 1**.

- Compliance to **A** is acceptable to 2021.
- Compliance to **B** is acceptable to 2025.
- Compliance to **N** fully complies with the standard.

FIGURE 1
LeafMark Standards



4. FMVSS 121

FMVSS 121 is a U.S. federal requirement that includes performance-based vehicle and dynamometer test procedures. Designed for on-highway trucks and motor coaches, this rule also applies to city transit buses under an all-encompassing commercial motor vehicle rule. The vehicle test measures complete vehicle stopping distance from 60 mph. The dynamometer evaluates individual wheel ends and includes stops from 50 mph, as well as high-temperature stops.

The FMVSS 121 vehicle and dynamometer tests are the primary means for evaluating brake performance. However, since the vehicle and dynamometer FMVSS 121 tests are not completely representative of city bus brake operations, it is recommended that additional tests be performed to evaluate other important criteria, such as wear, cost, noise, durability, and deceleration performance.

4.1 Key dimensions

It is important to evaluate test results using common key dimensions.

- Axle
- Tire
- Brake chamber

Table 1 shows commonly used dimensions for axles and tires in the transit industry.

Table 2 shows disc brake chamber requirements *typical* in the transit industry. (Verify with current vehicle specifications.)

4.2 Static characteristics

- Because tires come in a range of rolling radii, this recommended practice is based on industry average wheel sizes of 22.5 in. Small variations in tire sizes should not significantly change the recommendations within this document.
- Results must apply to fleet and typical service.
- References include similar operating environment and duty cycle.

TABLE 1
GAWR by Disc Caliper Manufacturer[1]

	Meritor	Knorr Bremse
Drive axle	28,660 lbs	28,660 lbs
Steer axle 40 ft transit bus	15,680 lbs	15,873 lbs
Steer axle 60 ft transit bus	15,680 lbs	14,780 lbs
Center axle	22,000 lbs	24,250 lbs
Wheel size: 22.5 in. static loaded radius 18.5 in. rolling radius		

1. Based on currently available data.

TABLE 2
Typical Disc Brake Chamber Requirements

	Meritor	Knorr Bremse
Drive axle	Type 24/30	Type 24/24
Steer axle 40 ft transit bus	Type 24	Type 24
Steer axle 60 ft transit bus	Type 24	Type 24
Center axle	Type 24/24	Type 24/24

Brake caliper available: Meritor EX225, Knorr Bremse SB6,SB7 and SN6,SN7

4.3 FMVSS 121D (dynamometer testing)

The standard requirement is to have a single brake assembly, mounted on a laboratory inertia dynamometer, where it must pass a sequence of burnish, torque/retardation, fade and recovery tests. (See **Figure 2**.)

It is recommended that aftermarket pads for both the steer axle and the drive axle brakes meet or exceed the vehicle's OE braking performance.

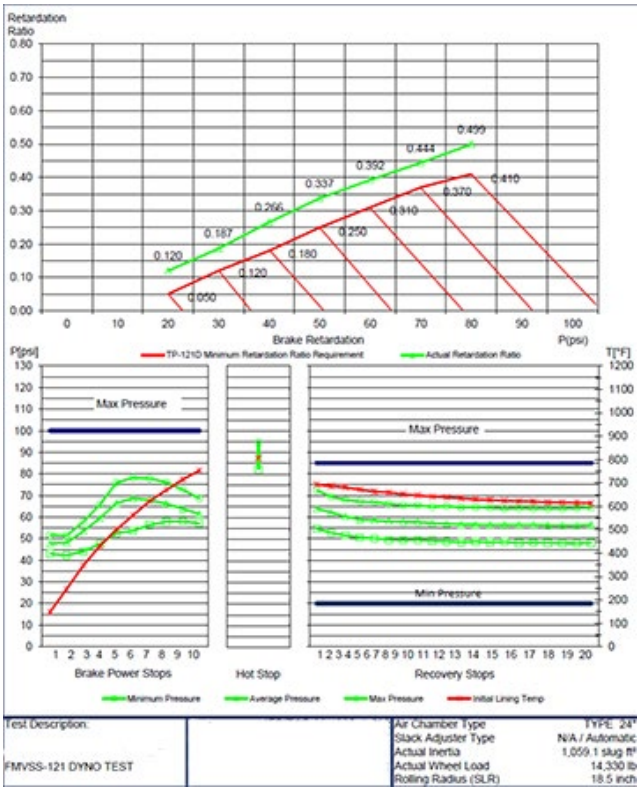
OE FMVSS 121 test data should be compared with the data collected from the test linings. Specifically, retardation ratio, brake fade and recovery data should be compared to ensure that test friction material is

comparable to OE. This comparison testing should be conducted at or above the fleet's specific vehicle parameters as listed in the vehicle specification sheet.

4.4 Sample FMVSS 121 test report

- **Brake pad retardation:** This must be above the lower limits set by FMVSS 121 (as shown by the red line in the top chart in **Figure 2**).
- **Brake power stops:** Maximum application pressure must be below 100 psi (as shown by the blue line).
- **Recovery stops:** Application pressure must be between 20 and 85 psi.

FIGURE 2
Sample FMVSS 121 Test Report



4.5 ISO certifications

It is recommended that the manufacture meet ISO 9001-2015 or latest revision for quality certification.

4.6 APTA performance document

For a comprehensive procedure for testing braking performance, refer to APTA-BTS-SS-RP-001-05, "Transit Bus In-Service Brake System Performance Testing."

5. Testing standards

More than one test method should be used to select an aftermarket lining. The more tests a lining meets, the more confidence a fleet can have that the lining will perform adequately on its vehicles.

5.1 Dynamometer

Claims of improved wear characteristics may be initially evaluated with brake dynamometer results, provided the physical dimensions are constant between the friction materials being tested. However, since brake wear is influenced significantly by on-vehicle brake balance and duty cycle, it is recommended that claims of improved wear be evaluated with complete vehicle testing and/or field testing.

Common SAE procedures for comparing friction material:

- **J661:** Brake Lining Friction Analysis (Chase Test)
- **J1505:** Brake Force Distribution Test Procedure-Trucks and Buses
- **J2115**
  - Section 6: Performance
  - Section 7: Wear

5.2 Fleet field testing

Field testing will consist of the periodic inspections of control fleets and test fleets to evaluate wear as well as subjective items, e.g., noise, feel, roughness. Through the course of the test period, inspections will require both wheels-on and a more comprehensive wheel-off inspection. Refer to APTA BTS-BC-RP-007-17 and APTA BTS-BC-RP-006-17 for detailed inspection procedures. Documenting testing results is critical. **Table 3**, In-Service Vehicle Test Reporting Form and **Table 4**, Inspection Checklist Form are examples of forms used to record testing results.

TABLE 3
Sample In-Service Vehicle Test Reporting Form

Unit: _____	**Steer**	**Center (if applicable)**	**Drive**
Date installed			
Mileage installed			
Rotors new (N) or specify thickness			
Caliper new or maintained			
Caliper maintenance performed			
Date inspected			
Mileage inspected			
Date inspected			
Mileage inspected			
Date inspected			
Mileage inspected			
Mileage removed			
Date removed			
Reason removed			

6. Aftermarket brake pad evaluation approval process

6.1 Fleet testing

A minimum of two buses of each fleet are needed for the test, but three or more are recommended. It is also important to limit the variables between the test fleets and control fleets. As much as possible:

- Similar bus type and milage
- Same duty cycle (routes)
- New or newly remanufactured calipers (if used calipers are used, then proper preventive maintenance must be performed {reference APTA BTS-BC-RP-009-19} and operation of calipers verified)
- New rotors. (All rotors shall be from the same manufacturer for test.)
    - Other considerations can be made using used rotors that are within specification.
- New pads install on all axles, including the control fleets

It is also important to mark test components to identify the bus as a test (method determined by testing property; examples would be painting, tagging or other method to identify the test vehicles).

6.2 Burnishing of brakes

After each brake pad change, the brakes must be burnished. This will better ensure the proper seating/mating of the pad to rotor. Failure to burnish can cause in glazing and friction damage, resulting in higher wear and decreased performance.

> **NOTE:** Turning the rotors does not take the place of proper burnishing of the brake.

1. Make 10 stops (snubs) from 15 to 5 mph at regular intervals of approximately a 32% deceleration or approximately 500 ft without stopping the vehicle.
2. Make 10 stops (snubs) from 25 to 5 mph at regular intervals of approximately a 32% deceleration or approximately 500 ft without stopping the vehicle.
3. After the 10th snub, make one complete stop from 20 to 0 mph.

Check the rotor temperatures after the burnish procedure is completed. Check to see if any rotors are noticeably cooler than the others (more than 50 °F front to rear or more than 10 °F across the axle). This indicates a lack of braking effort on the wheel ends with the cooler rotors. If this condition exists after 10 snubs, then repeat the burnish procedure. The overall temperature can vary fleet to fleet and property to property, due to differing climate and operating conditions.

7. Pre-service performance testing

Prior to returning the vehicle into service, a performance testing should be completed. See APTA-BTS-SS-RP-001-05, “Transit Bus In-Service Brake System Performance Testing.”

- The data should be collected using a certified decelerometer, such as the Fraser Gauge, netBrake, Tapley meter or Vericom.
    - Speed: 20 mph (if equipment capability will not jeopardize the accuracy of the results)
    - Passenger load: 0
    - Air tank pressure: At vehicle-governed cut out pressure
    - Tire pressure: Manufacturer-recommended pressure
    - Pavement: Clean and dry

- Tests: It is recommended that three deceleration tests be performed (results must meet the stopping distance requirements)
- Stopping distance: As required by law and/or operating agency

When a transit bus brake system needs to be tested, the tests cannot always be conducted at the traditional 20 mph deceleration due to weather, space availability and/or safety considerations. In that event, the task force recommends that a test procedure include the following:

- Visual inspection
- Temperature balance
- Road test

8. Post-installation vehicle test reporting

The duration, goals, testing (wheels-on and/or wheels-off) and reporting of the test should be predetermined with the vendor prior to the beginning of the test. The test should not exceed a predetermined time frame unless an undesirable result is identified or unforeseen exceptions occur (e.g., bus on hold for another maintenance issue, accident.). Testing for comparison should be done at the same interval for both the control and test fleets.

The information in **Table 4** should be collected prior to a bus going into service and during wheel-off inspections to ensure that all appropriate steps have been taken to ensure a valid test and that the vehicle is properly operating at peak efficiency.

TABLE 4
Inspection Checklist Form

BUS NUMBER: _____	**Front Axle**		**Center Axle**		**Rear Axle**	
DATE: _____	**Curb Side**	**Street Side**	**Curb Side**	**Street Side**	**Curb Side**	**Street Side**
Wheels-off inspection						
Rotor thickness						
Rotor run out						
Pad thickness						
Visual indicator protrusion						
Tappet clearance						
Burnish/completed						
Stopping distance	Test 1:		Test 2:		Test 3:	
Decel G-force	Test 1:		Test 2:		Test 3:	
Rotor temperature						

The table requires some measurements to be entered; areas in gray require only the technician's initials.

Related APTA standards

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

References

SAE International standards:

J661: Brake Lining Friction Analysis (Chase Test)
J1505: Brake Force Distribution Test Procedure-Trucks and Buses

Definitions

brake pad: Consists of friction material, brake lining.

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

Abbreviations and acronyms

CCOHS	Canadian Centre for Occupational Health and Safety
CVSA	Commercial Vehicle Safety Alliance
FMVSS	Federal Motor Vehicle Safety Standard
GAWR	gross axle weight rating
HEPA	high-efficiency particulate air
MSDS	material safety data sheet
MSHA	Mine Safety and Health Administration
NATSA	North American Transportation Services Association
NIOSH	National Institute for Occupational Safety and Health
OE	original equipment
OSHA	Occupational Safety and Health Administration
psi	pounds per square inch

Document history

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First published	March 2, 2022	April 20, 2022	July 22, 2022	August 22, 2022	Sept. 9, 2022

Appendix A: Brake pad evaluation decision parameters

1. Would obtaining equal brake lining wear, axle to axle, be important to your fleet?

☐ Yes ☐ No

2. Would the ability to perform an all-wheel brake lining replacement at each brake job be an important result?

☐ Yes ☐ No

3. Are you willing to trade rotor life for extended pad life?

☐ Yes ☐ No

4. Do you have a brake noise issue?

☐ Yes ☐ No

5. Do you have a rotor wear issue?

☐ Yes ☐ No

6. Do you need an alternate supplier of brake pads?

☐ Yes ☐ No

7. Are you satisfied with the price you are paying for your brake pads?

☐ Yes ☐ No

8. What is your current experience of mileage between brake jobs in your fleet?

Make	Model	Front Mileage	Center Mileage	Rear Mileage

Property: _____

Name: _____

Title: _____