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Bus Brake & Chassis Working Group

Transit Bus In-Service Brake System Performance Testing

Abstract: This *Recommended Practice* provides guidelines for testing transit bus air brake system performance.

Keywords: brake performance, brakes, bus brake, deceleration, stopping, transit bus, performance-based brake testers (PBBT)

Summary: This document establishes a recommended practice for transit bus in-service brake performance testing. Individual operating agencies may modify these guidelines to accommodate their specific equipment and mode of operation. Test results must meet or exceed federal, state or other local regulatory agency requirements if different from the recommendations outlined in this document. This document assumes the end users have sufficient skills and knowledge to repair and maintain the related systems at a journeyman level. These skills and knowledge must also 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.

Scope and purpose: This *Recommended Practice* provides system performance testing guidelines for heavy-duty transit buses equipped with air brakes. It covers only the braking force and deceleration aspects of brake testing. The purpose of this *Recommended Practice* is to provide a uniform method and criteria for testing and verification of transit bus brake system performance.

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 system's operations. In cases where this is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal advisor to determine which document takes precedence.

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Introduction

This introduction is not part of APTA BTS-BC-RP-001-05, Rev. 1, "Transit Bus In-Service Brake System Performance Testing."

This *Recommended Practice* reflects the consensus of the APTA Bus Standards Program members on the items, methods and procedures that have provided the best practice based on the experiences of those present and participating in meetings of the program task forces and working groups. *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. *Recommended Practices* may include test methodologies and informational documents. *Recommended Practices* are non-exclusive 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 manufacturers' supplemental or superseding recommendations. APTA recognizes that for certain applications, these practices as implemented by operating agencies may be either more or less restrictive than those given in this document.

Test results must meet or exceed federal, state or other local regulatory agency requirements if different from the recommendations outlined in this document.

APTA recommends the use of this document by:

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

Transit Bus In-Service Brake System Performance Testing

1. Test provisions

1.1 Training

The operating agency and/or its maintenance contractors should develop and execute training programs that provide employees with the knowledge and skills necessary to perform the tasks outlined in this *Recommended Practice* safely and effectively.

1.2 Frequency of testing

The minimum frequency of tasks should comply with original equipment manufacturer (OEM) and operating agency recommendations, as well as local, state and federal requirements. More frequent testing as part of scheduled and diagnostic maintenance by transit agencies is common.

1.3 Tools

A minimum of one of the following tools is recommended for the in-service testing of transit bus brake systems:

- mechanical decelerometer (e.g., Tapley meter)
- electronic decelerometer (e.g., Vericom, Fraser netBrake, Circuitlink Brake Testa)
- performance-based brake testers (PBBTs) approved by the Federal Motor Carrier Safety Administration (FMCSA) (see Appendix C)

Additional tools as recommended by the OEM or as common in the transit industry may also be used.

1.4 Brake performance measurement methods

Brake performance requirements, be they federal, state, local, or internal to the transit authority, may be written in different terms and using different measurement criteria. Commonly used measurement criteria and methods are described in this section, summarized in **Table 1**, and described in more detail in Appendix B.

TABLE 1
 Measurement Criteria

| | 20 mph Stop, Mechanical Deceleration | 20 mph Stop, Electronic Deceleration | Flat Plate Testers | PBBT Roller Brake Tester |
|----------------------------------|---|---|-------------------------------|-------------------------------------|
| Average Deceleration | No | Yes | No | No |
| Peak Deceleration | Yes | Yes | Yes | Yes |
| Individual Wheel End Performance | No | No | Yes | Yes |
| Brake Force Balance | No | No | Yes | Yes |

Measuring the deceleration rate (ft/s², m/s², g) developed during the stop can be a useful criterion for evaluating brake performance. It is important to understand that mechanical deceleration measurement devices usually record the peak (or maximum) deceleration rate developed during the stop, while electronic devices more typically calculate the average deceleration rate developed.

Stopping distance is also (or alternatively) used as a brake performance evaluation criterion. Stopping distances calculated from a decelerometer (mechanical or electronic) commonly ignore the distance traveled prior to the deceleration trigger. Also, since deceleration actually varies during the stop, stopping distance calculations using either peak or average deceleration will vary from the stopping distance measured by a fifth wheel or GPS device (see Appendix B). Some electronic measurement devices (such as Fraser netBrake or Vericom) use the measured deceleration and compensate for the trigger time and in-stop variations to greatly improve the accuracy of the stopping distance calculation.

1.5 Conditions

The following conditions are recommended for the testing of transit bus in-service systems:

- **Passenger load:** Empty
- **Air tank pressure:** Vehicle-governed cutout pressure at the beginning of the test
- **Tire pressure:** Manufacturer-recommended pressure
- **Auxiliary (retarder, regenerative, etc.) braking systems:** Turned off if possible until the entire test is complete
- **Brake temperature:** Operating temperature

1.5.1 Road test

A suitable location for a brake road test is one in which the road surface is reasonably level, dry, and free of road debris, sand or oil, and where traffic conditions will safely permit the required actions. Road conditions different from those noted above may affect results.

1.5.2 Testing using a PBBT

A suitable location for a roller-type PBBT test can be indoors or outside with a straight approach and exit area. The test equipment is not as susceptible to weather conditions. It should be reasonably clean and free of debris.

A performance-based brake tester (PBBT) is a device that can measure vehicle braking performance. The PBBT measures brake force developed at each wheel end and calculates overall vehicle performance.

The two types of performance-based brake testers commonly used for bus maintenance and inspections are roller and flat plate brake testers.

The roller brake tester uses rollers that slowly rotate each wheel end as the driver gradually increases the brake application. The vehicle remains stationary as the rollers rotate the wheels throughout this test. Most brake testers also measure the weight of the wheel end to allow the calculation of brake force developed as a percentage of the measured weight. Additional diagnostics are possible with air pressure monitoring, artificial axle loading and other available options.

The flat plate tester is composed of two or more plates on which a vehicle must stop from a prescribed speed (usually 4–8 mph). The stopping force is measured on each side of the axle. In most cases, the weight is simultaneously measured to allow the calculation of brake force developed as a percentage of the measured weight.

Most PBBTs require annual calibration of the brake force and weight.

1.6 Personal protective equipment

Personal protective equipment, as required by the operating agency, should be worn at all times during testing.

1.7 Safety

Appropriate safety precautions should be followed at all times during testing.

2. Pre-test

The brake system inspection should be done per agency best practices prior to performance testing.

- **For S-cam or wedge:** It is recommended to ensure that brake stroke measurements are within the FMCSR in-service criteria (FMCSR 393.53). This information is also included in **Table 2**.
- **For disc brakes:** It is recommended to inspect the vehicle per the manufacturer's specifications or APTA BTS-BC-RP-006-15, "Transit Bus Air Disc Brake Operation and Wheels-On Inspection."

2.1 Disc brake inspection

Inspect disc brake systems per agency best practices or APTA BTS-BC-RP-006-15.

A visual inspection of the rotor/caliper assembly must be performed prior to testing. A mirror or borescope may be required for a thorough inspection of these components. The inspection must include the following:

- loose or missing hardware
- brake chamber vent hole obstructions
- possible problems with inboard pad (by checking inside rotor surface condition)
- presence and functionality of adjuster cap
- presence of guide pin cap
- rotor surface condition and casting coloration

Additionally, where accessible, grasp the caliper assembly and thrust back and forth to check for appropriate free play.

2.2 S-cam brake power stroke measurement

Prior to road testing, a power stroke measurement of each brake adjuster should be made. The power stroke must not exceed the U.S. DOT readjustment limits for the chamber size as stated in the FMCSR and CVSA out-of-service criteria.

The measurement procedure may be modified for each agency’s requirements but should include the following steps:

1. Measure from the brake chamber face to the center of the clevis pin with the service brake and the parking brake fully released. Repeat at all wheel locations.
2. Make a full-service brake application while maintaining 90–100 psi air system pressure (dash gauge is acceptable) and hold it.
3. While holding the application, remeasure from the brake chamber face to the center of the clevis. Repeat at all wheel locations.
4. The power stroke measurement is the difference between the measurement with the brakes fully applied and the measurement with the brakes fully released. Record calculations.

If the power stroke does not exceed the power stroke limits for the chamber size, then the power stroke inspection is complete.

If the power stroke exceeds the allowable stroke for the chamber size, then the cause of the overstroke condition must be identified and corrected. If the vehicle is equipped with automatic slack adjusters and if measurements exceed the power stroke limits (refer to North American Standard Out of Service Criteria 2018) in **Table 2**, then follow the manufacturer’s recommendations to repair deficiencies. The power stroke should then be retested to confirm compliance.

TABLE 2
Power Stroke Limits

| Chamber Size | Power Stroke Limits (in.) | Power Stroke Limits (mm) |
|--------------|-------------------------------|--------------------------|
| 9 | 1 ³ / ₈ | 35 |
| 12 | 1 ³ / ₈ | 35 |
| 16 | 1 ³ / ₄ | 45 |
| 16LS | 2 | 51 |
| 20 | 1 ³ / ₄ | 45 |
| 20LS | 2 | 51 |
| 24 | 1 ³ / ₄ | 45 |
| 24LS | 2 | 51 |
| 24ELS | 2 ¹ / ₂ | 64 |
| 30 | 2 | 51 |
| 30LS | 2 ¹ / ₂ | 64 |
| 30 DD3 | 2 ¹ / ₄ | 57 |
| 36 | 2 ¹ / ₄ | 57 |

2.3 Burnishing

Burnishing is recommended after replacement or reassembly of foundation brake components. The burnishing procedure may be modified for each agency's requirements. See Appendix A for details.

3. Test

This section contains recommended or common practice performance levels. These performance levels exceed federal, state and local requirements. Each transit authority may have its own required performance criteria.

3.1 Service brake road deceleration test

Each operating agency may determine the number of tests used and the pass/fail criteria for the road deceleration test. Minimum recommended criteria are as follows:

- Find a suitable place to perform the deceleration test (refer to Section 1.5.1).
- If possible, disable auxiliary braking (retarder, regen, dynamics).
- Secure the test equipment per the manufacturer's recommendation.
- When applicable turn on the test equipment and set to Brake mode.
- Accelerate to approximately 20 mph.
- Apply full brake application until the coach comes to a complete stop.
- Record results.

CAUTION: Vehicles may pass the deceleration requirements, but other conditions may affect the total stopping distance, such as the following:

- **Application delay timing.** A brake pedal sensor triggering device can be used to determine the delay time of the brake application, which may vary due to changes in the pneumatic or foundation brake systems. Application delay time is defined as the amount of time from when the brake pedal sensor is triggered until the vehicle reaches the set point deceleration. Comparison of the delay time within similar model buses and the delay time obtained during the test may provide an indication of the status of the air system.
- **ABS system faults.** Crossed wheel sensors, modulator valves, or apply-and-hold wiring of the modulator valves can all increase stopping distances and not trigger fault codes. Care should be taken to check for these problems, in addition to addressing recognized faults.

3.1.1 Mechanical device

When deceleration capability of the service brake system is tested with a mechanical deceleration measurement device, the peak efficiency of 60 percent (0.6 g), as a minimum, should be achieved from an initial speed of approximately 20 mph.

The stopping distance must be less than 20 ft. See Appendix B for more information regarding stopping distance determination methods.

3.1.2 Electronic device

When the deceleration capability of the service brake system is tested with an electronic deceleration measurement device, an average in-stop deceleration rate of at least 52.8 percent (0.528 g), as a minimum, should be achieved from the initial set point until the vehicle makes a complete stop from an initial speed of approximately 20 mph. The deceleration reading may vary with a different initial set point.

The stopping distance must be less than 20 ft.

3.2 Brake system performance test using a PBBT

Transit bus brakes may be tested on a PBBT (that meets the U.S. DOT specifications for such devices) as an alternative to the service brake road deceleration test using a mechanical or electronic decelerometer.

When using a PBBT, the test must be conducted in accordance with the testing procedure outlined in the PBBT OEM technical manual.

On a given axle, the difference in brake forces, left to right, must not exceed 35 percent at 30 psi.

3.2.1 Brake force while measuring weight with a PBBT

When the deceleration capability of the service brake system is tested with a PBBT, a peak efficiency of 58 percent (0.58 g), as a minimum, should be achieved as a percentage of actual total measured vehicle weight.

NOTE: By using gross axle weight rating (GAWR) and gross vehicle weight rating (GVWR) to provide a basis for the requirements in lieu of measured weight, the loaded braking capability of the vehicle is estimated.

3.2.2 Brake force while measuring primary control pressure with a PBBT

During the PBBT test, primary control line service pressure can be measured and each wheel position's foundation brake retardation ratio calculated. These results should meet the criteria indicated in **Table 3** (Appendix C) when calculated as a percent of GAWR.

On a steer axle, the difference in brake forces, left to right, should not exceed 25 percent at 30 psi. For a drive axle, the difference in left to right brake force should not exceed 35 percent.

When using a PBBT, a brake system test must be conducted in accordance with the testing procedure outlined in the PBBT OEM technical manual. For additional information on performance brake testing, refer to 49 CFR 393 (see References), as published in the Federal Register Rules and Regulations.

3.3 Parking brake road deceleration test

The purpose of the parking brake is to hold the vehicle in a static condition on a grade. However, parking brake effectiveness can be evaluated by means of a low-speed, dynamic stopping test.

3.3.1 Mechanical device

When the deceleration capability of the parking brake system is tested with a mechanical deceleration measurement device, a peak efficiency of 17 percent (0.17 g), achieved from an initial speed of approximately 20 mph, is required.

3.3.2 Electronic device

When the deceleration capability of the parking brake system is tested with an electronic deceleration measurement device, it must achieve an average deceleration rate of at least 15 percent (0.15 g) from an initial speed of about 20 mph. The recommended trigger point for the electronic device is 10 percent (-0.1 g).

NOTE: It may be necessary to adjust the initial set point of the electronic device to -0.1 g.

NOTE: See Appendix C for a more detailed description of bus brake testing while using a PBBT.

3.4 Parking brake test using a PBBT

When the deceleration capability of the parking brake system is tested with a PBBT measurement device, a deceleration rate of at least 15 percent (0.15 g) is required. Deceleration is calculated by adding the parking brake forces measured on a PBBT and then dividing by the GVWR of the vehicle.

3.5 Correction of deficiencies

Deficiencies uncovered during transit bus in-service brake system performance testing should be corrected and documented in accordance with operating agency procedures and/or OEM recommendations.

These additional *APTA Recommended Practices* may also be helpful:

- APTA BTS-BC-RP-006-15, “Transit Bus Air Disc Brake Operation and Wheels-On Inspection”
- APTA BTS-BC-RP-007-15, “Transit Bus Air Disc Brake Operation Wheel-Off Inspection and Reline”
- APTA BTS-BC-RP-004-07, “Transit Bus Front and Rear Axle Disc Brake Reline”
- APTA BTS-SS-RP-005-10, “Troubleshooting Common Transit Bus S-Cam and Air Brake Complaints”
- APTA BTS-SS-RP-006-10, “Troubleshooting Transit Bus Air Systems”

3.6 Documentation

Testing should be documented on a standard form (electronic or paper) and be reviewed and filed in accordance with operating agency procedures.

References

American Trucking Association Technology & Maintenance Council, TMC RP 628, TMC RP 649 and TMC RP 658.

Code of Federal Regulations:

49 CFR §396.17-25, Appendix G to Subchapter B, Subpart C – Brakes.

www.gpo.gov/fdsys/granule/CFR-2011-title49-vol5/CFR-2011-title49-vol5-part393-subpartC/content-detail.html

49 CFR §393.40-53, “Brake Performance Requirements for Commercial Motor Vehicles Inspected by Performance-Based Brake Testers,” 2002. www.gpo.gov/fdsys/granule/CFR-2011-title49-vol5/CFR-2011-title49-vol5-sec393-40/content-detail.html

49 CFR §571.121, “Air Brake Systems,” 2002. www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/fmcsrruletext.aspx?reg=571.121

Commercial Vehicle Safety Alliance (CVSA), Out-of-Service Criteria, April 2012.

New Jersey Transit F&SE, Title 39 16:53-3.20, Brakes, Items 55-60, Paragraph (a).

New York State Department of Transportation, 720.4(z)(1)(b), Service Brakes.

U.S. Department of Transportation, FMCSA-98-3611 (FR 48799), “Functional Specifications for Performance-Based Brake Testers for Commercial Motor Vehicles.”

www.federalregister.gov/articles/2000/08/09/00-19916/guidelines-for-development-of-functional-specifications-for-performance-based-brake-testers-used-to

Definitions

burnishing: A process by which the brake lining surface and brake drum surface are conditioned after reline.

deceleration as measured on a PBBT: Measured brake force divided by the weight.

gross axle weight rating (GAWR): Maximum loaded axle weight allowable by the vehicle manufacturer as stated on the federal certificate.

gross vehicle weight rating (GVWR): Maximum total loaded vehicle weight allowable by the vehicle manufacturer as stated on the federal certificate.

measured weight: Actual weight of the vehicle as tested.

power stroke: The dimensional change in brake chamber stroke between the fully released and fully applied measurements while maintaining 90–100 psi air pressure in the air brake system.

Abbreviations and acronyms

| | |
|--------------|--|
| CCOHS | Canadian Centre for Occupational Health and Safety |
| CFR | Code of Federal Regulations |
| CVSA | Commercial Vehicle Safety Alliance |
| DOT | Department of Transportation |
| FMCSA | Federal Motor Carrier Safety Administration |
| FMCSR | Federal Motor Carrier Safety Regulations |
| FMVSS | Federal Motor Vehicle Safety Standard |
| GAWR | gross axle weight rating |
| GVWR | gross vehicle weight rating |
| NATSA | North American Transportation Services Association |
| OEM | original equipment manufacturer |
| PBBT | performance-based brake testers |
| psi | pounds per square inch |
| SAE | SAE International (formerly the Society of Automotive Engineers) |
| TMC | Technology & Maintenance Council (American Trucking Association) |

Summary of document changes

- Added brake performance measurement methods.
- Added disc brake inspection.
- Updated other items as needed.

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Appendix A: Burnishing

The burnishing procedure establishes the compatibility between the friction material and the disc or drum. This is achieved by driving the vehicle and applying the brakes. Burnishing is also influenced by speed, vehicle weight, brake temperature, brake pressure and the brake material chemistries.

Burnishing advantages

- Gradually eliminates any thermal shock in the drum or rotor.
- Eliminates residue near the friction surfaces.
- Establishes a layer of transfer film a few microns thick on the friction surface.
- Reduces glazing.

Burnishing procedure

Burnishing procedures may be modified for each agency's requirements but should be similar to the following steps:

1. Using the service brake, slow the vehicle from 20 to 5 mph at approximately 0.3 g deceleration, or a moderate brake application. Repeat this process 10 times (snubs) at regular intervals of approximately 500 ft or 0.1 mi without stopping the vehicle.

CAUTION: Do not permit wheel lockup.

2. After the 10th brake application (snub), make one complete stop from 20 to 0 mph.
3. Compare brake temperature differential immediately after burnishing. Any that is significantly cooler (approximately 50 °F side to side, 100 °F front to rear) than the others indicates a lack of braking effort. Inspect the vehicle for brake defects and perform necessary repair. After repairs have been made, repeat the burnishing procedure.

Appendix B: Comparison of measuring devices

In order to put the braking performance (i.e., stopping distances) of a transit bus in the proper perspective, it is important to understand the differences among the various instruments used to measure stopping distance. The stopping distance determined with an electronic brake tester (such as Vericom or Fraser NetBrake) will always be greater than that recorded by a mechanical brake tester (such as a Tapley meter) and less than that recorded by a fifth wheel. Testing on transit buses at LINK Engineering have indicated that the Tapley meter using peak deceleration gave 20 mph stopping distance estimates 5 to 9 ft shorter than the electronic brake tester using average deceleration, and the electronic brake tester gave 20 mph stopping distance estimates 3 to 5 ft shorter than the fifth wheel.

These differences are related to how the three devices determine stopping distance. The fifth wheel measures stopping distance as specified by federal regulations (FMVSS 121, FMCSR 393.52) and SAE Recommended Practices, which all define stopping distance as the distance traveled from first movement of the brake pedal until the vehicle reaches a stop. The fifth wheel system counts revolutions of a trailing wheel that has a known circumference. The system triggers (starts counting distance) when the pedal is first moved. A switch on the brake pedal senses this movement. The system also determines vehicle speed from the rate of trailing wheel rotation when the pedal is first moved and throughout the stop. Initial speed information is then used to provide a “corrected stopping distance,” or the distance that would result if the vehicle was traveling at exactly some speed (20 mph in this case). The formula in SAE Recommended Practice J299 is used to make this correction.

Electronic brake testers measure braking rate (deceleration) with an electronic accelerometer, a device that senses rate of speed change, and then uses this data to calculate stopping distance. It does not measure stopping distance directly but uses a mathematical process known as double integration to compute the distance. It does not start recording data until the deceleration reaches the threshold setting and as such does not measure what happens at the beginning of the stop (i.e., from first movement of the pedal until the vehicle braking rate reaches the threshold setting).

The mechanical brake tester is a pendulum device that measures deceleration, but it saves (records) only a value that represents the maximum deceleration reached during the stop. The scale of the mechanical brake tester is calibrated in percent g and stopping distance in a side-by-side fashion, but the distance that corresponds to a given percent g value assumes that the peak deceleration is maintained during the entire stop and that there is no application time to reach this level.

In summary, the fifth wheel measures stopping distance directly, while the electronic and mechanical brake testers measure deceleration and then compute stopping distance from this deceleration information. Because the electronic brake tester records deceleration over most of the stop and uses all this data in the computation process, it provides a more accurate measure of actual stopping distance than does the mechanical brake tester, but the electronic tester does miss the distance traveled at the beginning of the stop until the vehicle reaches the threshold setting.

The fact that the three devices produce different results does not mean they are not useful for measuring or comparing brake performance. In the testing conducted at LINK, they all ranked different levels of braking performance in the same way, indicating that they do provide good relative measures of braking performance. The problem arises in comparing the absolute values of their measurements. Since the electronic and mechanical testers actually measure deceleration, it makes more sense to report their measurements in terms of deceleration and not stopping distance, as they do not measure “true” stopping distance. Furthermore, the mechanical tester measures peak deceleration, whereas the electronic tester measures both peak and average deceleration. Peak and average are both good measures of braking performance, but they are different values

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and cannot be compared. However, the average deceleration more accurately predicts the actual stopping distance.

New Jersey Transit’s Title 39 regulation (see References) has a stopping distance requirement that a bus must stop from 20 mph in less than 22.5 ft. This distance was originally established when the DOT and transit properties were using Tapley meters and represents a peak deceleration reading of 0.6 g. Since testing at LINK has shown that a Vericom, using average deceleration, will give 5 to 9 ft longer stopping distance than a Tapley on the same vehicle with the same brakes, vehicles that would meet the requirement using the Tapley meter might be marginal or not meet the requirement when an electronic tester is used to determine stopping distance. This does not mean the brakes are defective, only that the test instrument being used is producing a different number.

A more reasonable approach would be to use peak deceleration rate or average deceleration rate as the pass-fail criteria, rather than stopping distance. New York State has actually changed its brake regulations for buses to take into account the differences in mechanical devices that measure peak deceleration and electronic devices that measure average deceleration. Under 720.4 (Z)(1)(b) Service Brakes of the New York State DOT regulations, a mechanical device (like a Tapley) must measure a peak efficiency of at least 60 percent (0.6 g) from an initial speed of approximately 20 mph. If an electronic device (like a Vericom or a Fraser) is used, then an average deceleration rate of at least 0.528 g must be obtained from an initial speed of approximately 20 mph.

LINK has recently tested several transit buses used in New York and New Jersey. Below are three figures showing the stopping distance comparison between a fifth wheel, Vericom 2000, Vericom 3000 and Tapley meter for three different transit buses with three different wheelbases under several test configurations. Also included are average deceleration and peak deceleration charts. Data was recorded from the fifth wheel, Vericom and Tapley simultaneously during each stop. The target speed for all the stops was 20 mph. The buses were at empty weight for all the stops. The value plotted is the average of six stops.

FIGURE 1
Long Wheelbase Transit Bus

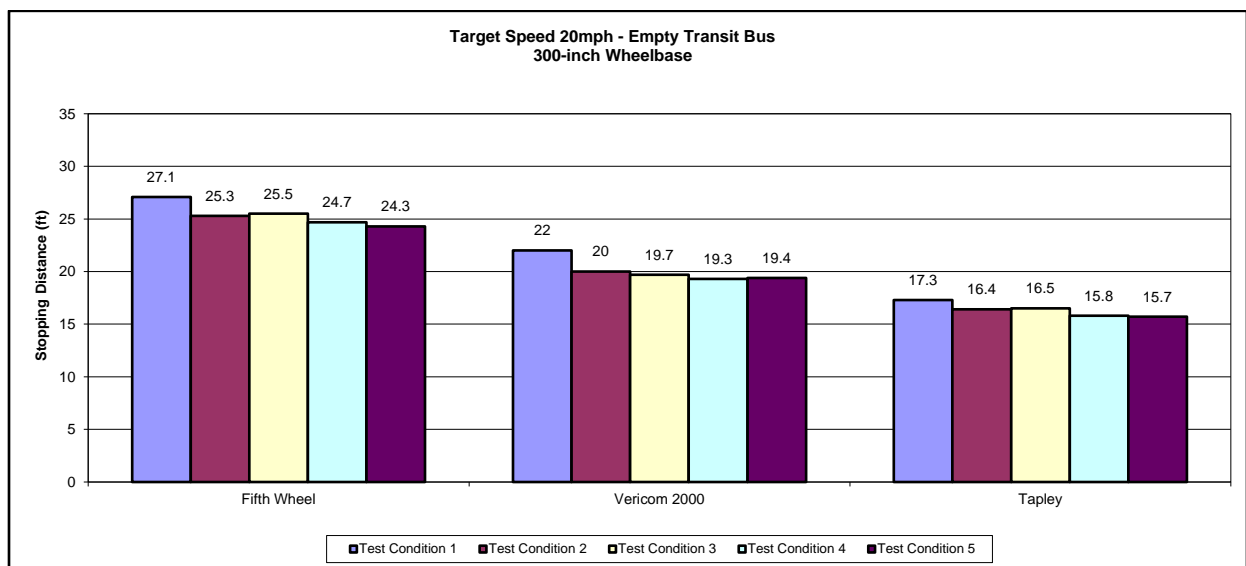
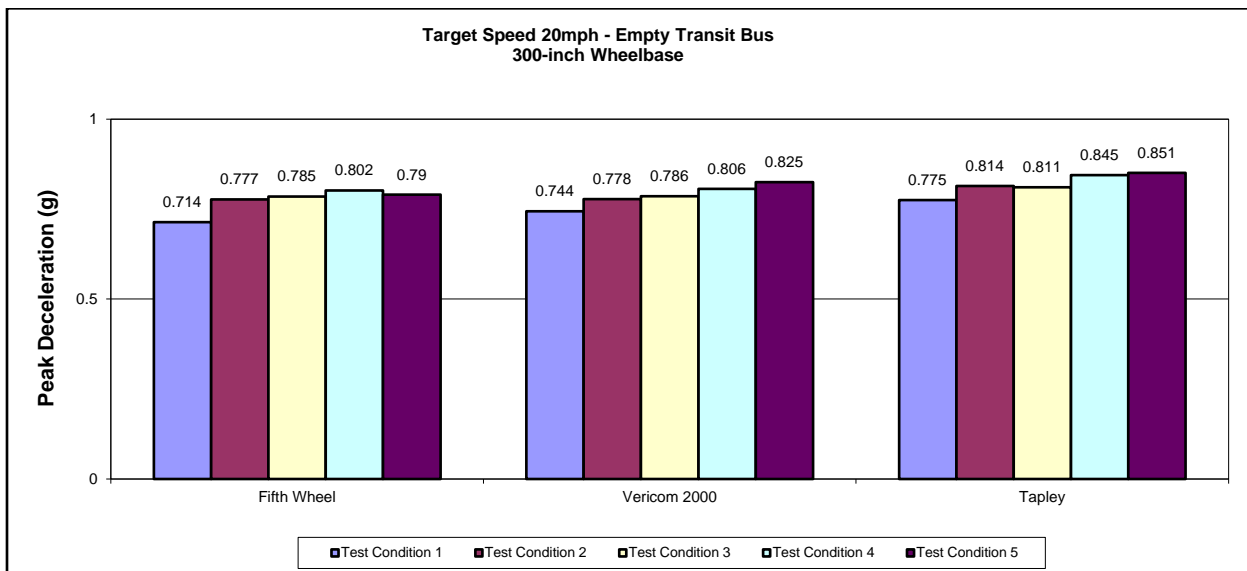
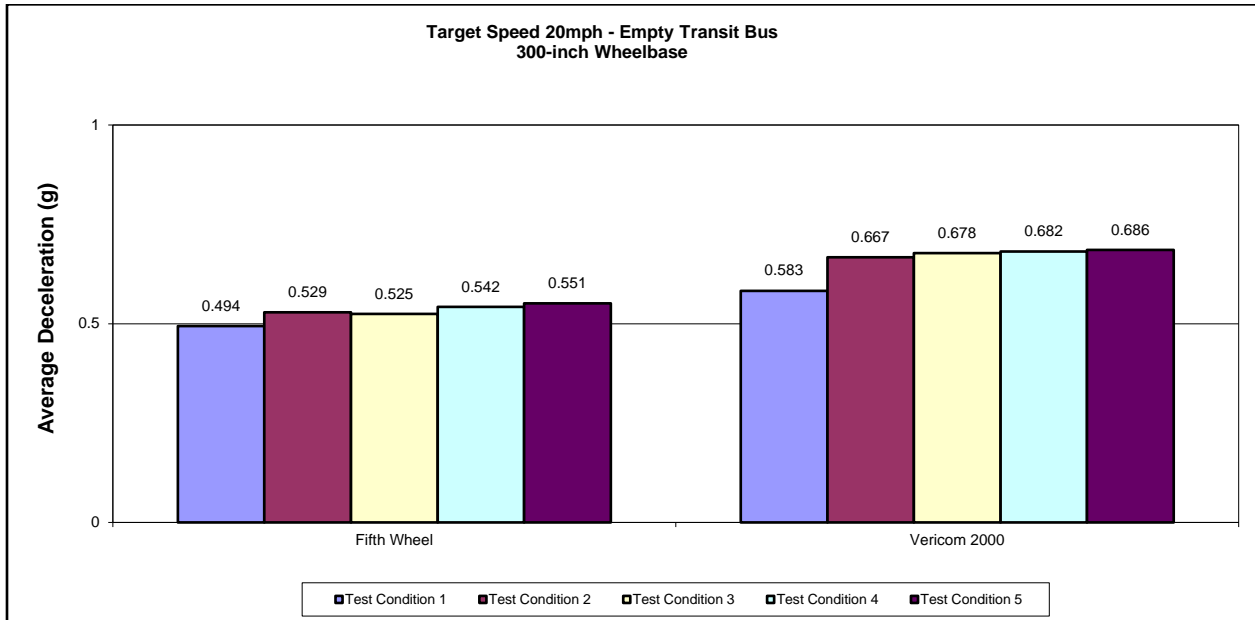


FIGURE 1 (continued)
 Long Wheelbase Transit Bus



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FIGURE 2
 Medium Wheelbase Transit Bus

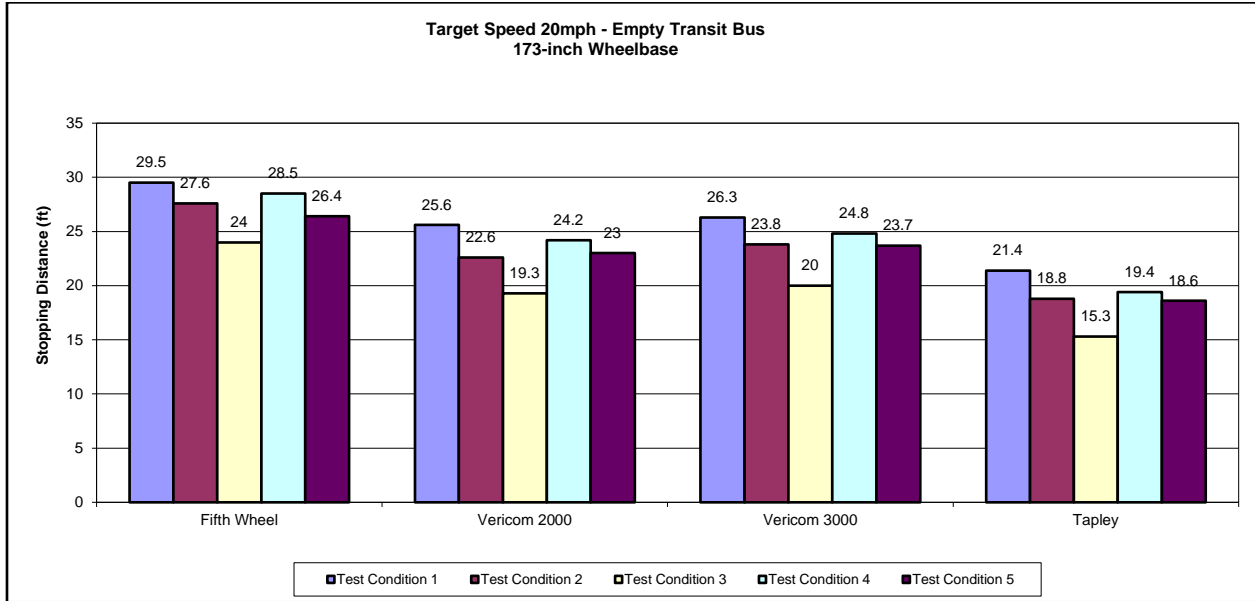


FIGURE 2 (continued)

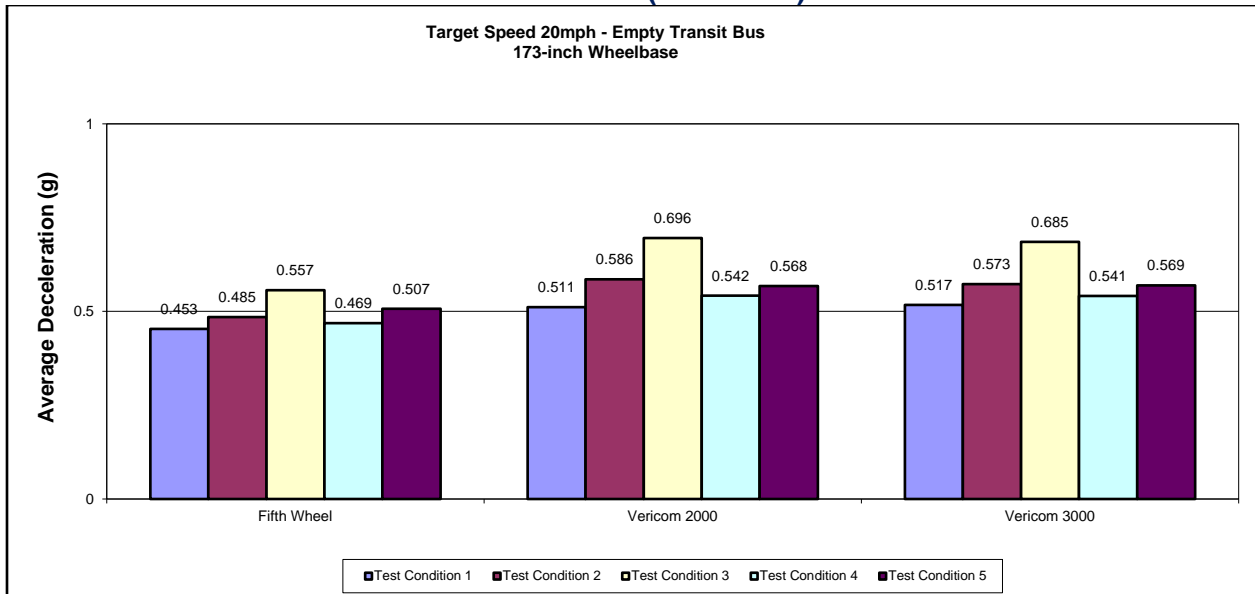


FIGURE 2 (continued)
 Medium Wheelbase Transit Bus

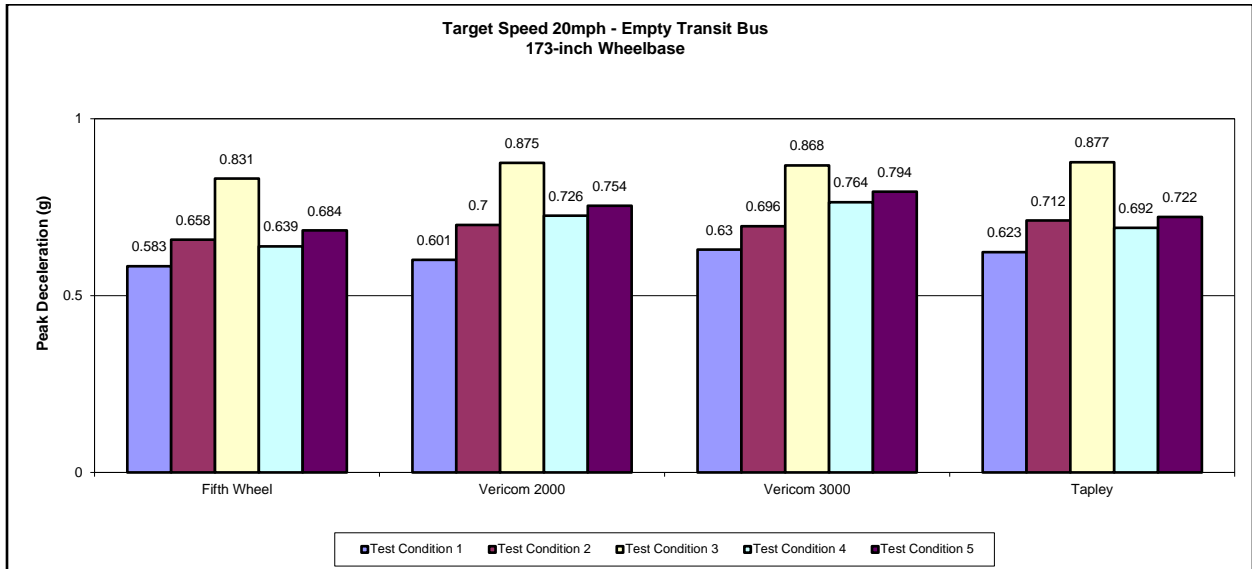


FIGURE 3
 Short Wheelbase Transit Bus

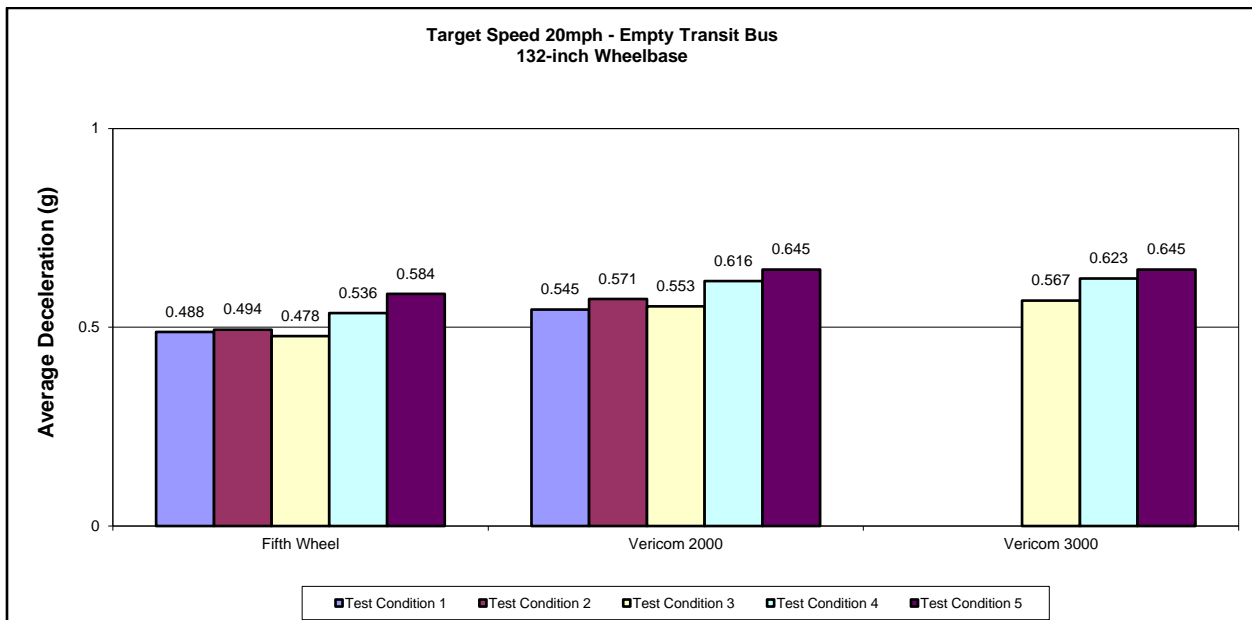
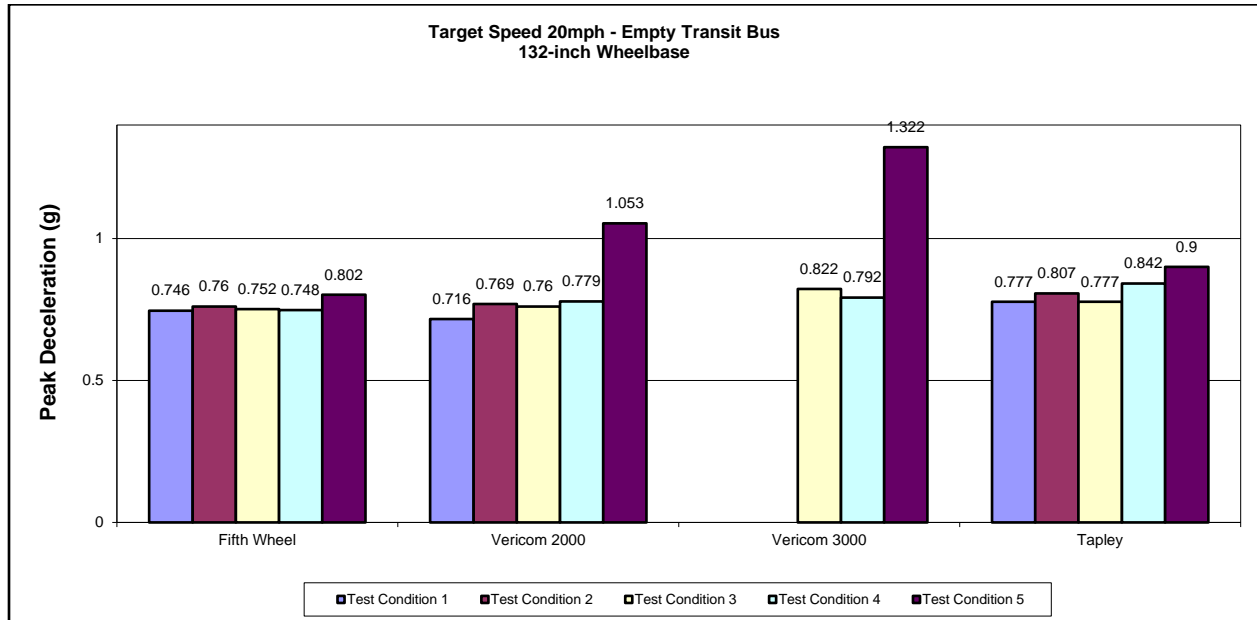


FIGURE 3 (Continued)
Short Wheelbase Transit Bus



Appendix C: Use of PBBTs to verify brake performance

Background

The Federal Motor Carrier Safety Administration (FMCSA) of the U.S. DOT has issued a modification to the Federal Motor Carrier Safety Regulations (FMCSR) that allows the use of a PBBT (that meets certain DOT specifications) to determine compliance with the brake performance requirements of Section 393.52.

Section 393.52 requires that the brake forces on the vehicle must be capable of producing a vehicle deceleration of at least 0.435 g (14 ft/s²). If the total of the maximum brake forces for individual wheels measured on a PBBT are greater than 0.435 times the vehicle's weight, then the vehicle meets the deceleration requirement of Section 393.52. (Vehicle deceleration is calculated using measured weight. Lightly loaded or empty vehicles will usually achieve higher deceleration values than vehicles loaded to their rated capacity.)

Historically, the transit industry has also used deceleration as a measure of brake performance, but the requirements that are typically implemented require a deceleration greater than that specified in FMCSR 393.52.

Some properties use a Tapley meter with a 22.2 ft requirement. This actually corresponds to a peak deceleration of 0.6 g or peak brake efficiency of 60 percent. Others use a Fraser or Vericom or some other electronic decelerometer with a requirement of 0.528 g average deceleration. In either case, this is significantly higher deceleration and brake performance than required by the FMCSR. (Transit vehicles are empty when tested and should be able to achieve those greater deceleration values.)

Advantages of using a PBBT to measure brake performance

PBBTs offer a number of advantages over road tests:

- They can be run indoors and are not affected by weather.
- They are safer (no moving vehicles or traffic issues).
- There is no damage to the tires or suspension.
- They can measure performance at each individual wheel and can identify exactly where a problem is located.
- They are fast and can check service brakes, parking brakes and ABS function, all in less than 10 minutes.
- They can measure front-to-rear brake force balance and threshold pressures in order to assess wear balance issues.
- They can measure left/right balance in order to determine the source of steering pull complaints.
- They can measure rolling resistance in order to identify dragging brakes or bad wheel bearings.

Discussion of braking requirements when using a PBBT

Service brake effectiveness

The current deceleration requirement of 0.435 g in the FMCSR 393.52 has historically been considered too lenient by transit operators, and the requirement to be used with PBBTs needs to be higher to satisfy transit needs. European countries generally require that deceleration be at least 0.5 g based on PBBT measurements, but this is for annual inspections as opposed to random roadside inspections, where the FMCSR apply (and must therefore allow for some degradation between annual inspections).

FMVSS 121, the brake standard for new vehicles, requires that each brake on a vehicle meet certain dynamometer requirements using a laboratory device known as an inertia dynamometer. **Table 3** shows the brake effectiveness requirements from FMVSS 121.

TABLE 3
FMVSS 121 Requirements (Brake Effectiveness at 50 mph)

| Pressure (psi) | Retardation Ratio |
|----------------|-------------------|
| 20 | 0.05 |
| 30 | 0.12 |
| 40 | 0.18 |
| 50 | 0.25 |
| 60 | 0.31 |
| 70 | 0.37 |
| 80 | 0.41 |

Retardation ratio is simply the brake force divided by the rated wheel load (GAWR/2). If all the wheels on the vehicle developed a retardation ratio of exactly 0.41 at 80 psi, then the deceleration of the vehicle at 80 psi would be 0.41 g.

It is recommended that the FMVSS 121 requirements in **Table 3** be used with a PBBT to serve as one of the pass-fail criteria for service brake force at each wheel. Since the FMVSS 121 requirements are for a 50 mph stop and the measurements on a PBBT are usually made at 5 mph or less, using such criteria on a PBBT actually allows for some degradation from the new-vehicle requirement. This is because brake force increases as speed is reduced, and the PBBT would be expected to produce a higher brake force than the inertia dynamometer. Some degradation from the new-vehicle requirements is reasonable, and in addition FMVSS 121 requires that brakes be burnished to a very specific temperature-controlled procedure that may not be representative of transit operations.

Side-to-side (left/right) balance on service brake forces

Experience has shown that left-to-right brake force differences across an axle that exceed 25 percent steer and 25 percent drive may indicate that something is wrong with the brake that has the lower force. European-based PBBT requirements use 30 percent as the pass-fail threshold, and in fact some countries set this limit at 20 percent for the steering axle.

It is recommended that the 25 percent threshold for steer axles and 35 percent for drive axles be used to identify a brake problem in the transit requirements for PBBTs. The difference can be measured at two points, when the first wheel on an axle reaches 1200 and 2400 lb or at 30 psi of control line air pressure.

Parking brake forces

FMVSS 121 requires that a vehicle at full load (GVWR) must hold on a 20 percent slope. It is recommended that for transit, this value be set at 15 percent to allow for some degradation, which is normal for the spring brake assemblies.

Grade holding is calculated by adding the parking forces measured on a PBBT and then dividing by the GVWR of the vehicle.

Specific recommendation

Transit bus brakes may be tested on a PBBT (that meets the U.S. DOT specifications for such devices) as an alternative to a 20 mph vehicle test with a decelerometer.

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During the PBBT test, each service brake must develop brake forces that exceed those values shown in the table of retardation values in FMVSS 121 (see Table 1 in Section D.5.1) when measuring control line pressure or a peak retardation value of 0.41 g, as a minimum when not measuring control line air pressure. These required retardation values must be based on rated wheel weight (GAWR/2).

On a steer axle, the difference in brake forces, left to right, should not exceed 25 percent at 1200 and 2400 lb of individual wheel brake force or at 30 psi control line application pressure. For a drive axle the difference in left-to-right brake force should not exceed 35 percent. Percent difference is equal to the difference in brake forces divided by the higher of the two forces times 100.

The total of the brake forces developed by the parking brakes must be equal to or exceed 15 percent of the GVWR.

NOTE: By using GAWR and GVWR to provide a basis for the requirements, the loaded braking capability of the vehicle is determined. It is then not necessary to actually measure the weight of the bus with the PBBT. Eliminating the need for weight measurement reduces the initial cost of the equipment and also reduces the cost for maintenance and calibration. GAWR and GVWR are the parameters used when designing brakes.

Measurement of brake pressure is necessary during the test in order to give a measure of brake effectiveness. The FMCSR PBBT test does not measure pressure and as such may miss brake problems that result in driver complaints. Pressure can be easily measured in the primary control line by installing a quick coupler and leaving it in place (if the bus does not already have one). Each time the bus is tested, the pressure transducer provided with the brake tester is installed during the test. Both wireless and cable style transducers are available.