

# **Bus Braking Performance Test**

## **Test Procedure**

**BRAKING - STOPPING DISTANCE AND STABILITY TESTS**

Draft January 2006

## ABBREVIATIONS

ABTC	Altoona Bus Test Center
ABS	anti lock brake system
A/C	air conditioner
ADB	Advance design bus
ATA-MC	Maintenance Council of the American Trucking Association
CBD	central business district
CW	curb weight (bus weight including maximum fuel, oil, and coolant; but without passengers or driver)
dB(A)	decibels with reference to 0.0002 microbar as measured on the "A" scale
DIR	test director
DR	bus driver
EPA	Environmental Protection Agency
FFS	free floor space (floor area available to standees, excluding ingress/egress areas, area under seats, area occupied by feet of seated passengers, and the vestibule area)
FTA	Federal Transit Administration
GVL	gross vehicle load (150 lb for every designed passenger seating position, for the driver, and for each 1.5 sq ft of free floor space)
GVW	gross vehicle weight rating (curb weight plus gross vehicle load)
MECH	bus mechanic
mpg	miles per gallon
mph	miles per hour
NBM	new bus models
PFC	Peak Friction Coefficient
PSBRTF	Penn State Bus Research and Testing Facility
PTI	Pennsylvania Transportation Institute
rpm	revolutions per minute
SAE	Society of Automotive Engineers
SCH	test scheduler
SEC	Secretary
SLW	seated load weight (curb weight plus 150 lb for every designed passenger seating position and for the driver)
TD	test driver
TM	track manager
TP	test personnel
UMTA	Urban Mass Transportation Administration

## I. TEST OBJECTIVE

The objective of this test is to provide, for comparison purposes, braking performance data on transit buses produced by different manufacturers.

## II. TEST DESCRIPTION

The testing will be conducted at the PTI Test Track skid pad area. Brake tests will be conducted after completion of the GVW portion of the vehicle durability test. At this point in testing the brakes have been subjected to a large number of braking snubs and will be considered well burnished. Testing will be performed when the bus is fully loaded at its GVW. All tires on each bus must have a minimum tread depth of 3/16-inch, and be representative of the tires on the production model vehicle

The brake testing procedure comprises three phases:

1. Stopping distance tests
  - i. Dry surface (high-friction, having a PFC of 0.9)
  - ii. Wet surface (low-friction, water delivery for the surface with PFC of 0.5)
2. Stability tests
3. Parking brake test

### **Stopping Distance Tests**

The stopping distance phase will evaluate service brake stops. All stopping distance tests on dry surface will be performed in a straight line and at the speeds of 20, 30, 40 and 45 mph. All stopping distance tests on wet surface will be performed in straight line at speed of 30 mph.

The tests will be conducted as follows:

1. **Uniform High Friction Tests:** Three maximum deceleration straight-line brake applications each at 20, 30, 40 and 45 mph, to a full stop on a uniform high-friction surface in a 3.66-m (12-ft) wide lane.
2. **Uniform Low Friction Tests:** Three maximum deceleration straight-line brake applications from 30 mph on a uniform low friction surface in a 3.66-m (12-ft) wide lane.

When performing service brake stops for both cases, the test vehicle is accelerated on the bus test lane to the speed specified in the test procedure and this speed is maintained into the skid pad area. Upon entry of the appropriate lane of the skid pad area, the vehicle's service brake is applied to stop the vehicle as quickly as possible. The stopping distance is measured and recorded for

both cases on the test data form. Stopping distance results on dry and wet surfaces will be recorded and the average of the three measured stopping distances will be considered as the measured stopping distance. Any deviation from the test lane will be recorded.

### **Stability Tests**

This test will be conducted with the vehicle loaded to GVW. The test consists of four maximum deceleration, straight-line brake applications on a surface with split coefficients of friction (i.e., the wheels on one side run on high-friction PFC 0.9 or more and the other side on low-friction where the lower coefficient of friction should be less than half of the high one at initial speed of 30 mph).

(I) The performance of the vehicle will be evaluated to determine if it is possible to keep the vehicle within a 3.66m (12 ft) wide lane, with the dividing line between the two surfaces in the lane's center. The steering wheel input angle required to keep the vehicle in the lane during the maneuver will be reported.

### **Parking Brake Test**

The parking brake phase utilizes the brake slope, which has a 20% grade. The test vehicle, at its GVW, is driven onto the brake slope and stopped. With the transmission in neutral, the parking brake is applied and the service brake is released. The test vehicle is required to remain stationary for five minutes. The parking brake test is performed with the vehicle facing uphill and downhill.

### **III. TEST ARTICLE**

The test article is a transit bus equipped with an anti lock brake system.

### **IV. TEST EQUIPMENT/FACILITIES/PERSONNEL**

#### **9.1 Test Equipment**

1. Speed and distance sensor system
2. Ballast to simulate passenger loading at GVW
3. Video recorder with playback capability
4. Non-contacting digital thermometer

#### **9.2 Test Facility**

The test site is located at the PTI Test Track using the bus test lane=s skid pad area. The test site must meet the following conditions:

1. Ambient temperature between 32°F and 90°F and pavement temperature above 32°F.
2. Wind speed less than 12 mph.
3. Brake-test lanes are clearly marked, 12 feet wide, and flat within 1% grade in all directions.
4. Brake-test lanes are clear of extraneous surface material. The brake test lanes are checked periodically for compliance with the following conditions:
  - i. One dry surface test lane with PFC of 0.9 as determined by ASTM E-274 at 40 mph, omitting water delivery as specified in paragraph 9.1 of that method.
  - ii. One wet surface test lane with PFC of 0.5 as determined by ASTM E-274 at 40 mph, with water delivery as specified in paragraph 9.1 of that method.
5. The brake slope consists of a clean dry Portland cement concrete surface and has a grade of 20%.

#### **9.3 Test Personnel**

The PTI personnel consist of the following:

1. Test Driver (TD)
2. Two Test personnel (TP)

## **V. TEST DATA**

The test data consist of the completed attached data forms. Upon completion of this test, data shall be forwarded to the Test Manager.

## **VI. TEST PREPARATION AND PROCEDURES**

All stopping distance brake tests will be conducted according to the following sequence of events.

1. Check the brakes temperature using a non-contacting laser digital thermometer. The initial brake temperature should be between 150EF and 200EF.
2. Accelerate to and maintain a speed exceeding the specified test speed by 4 to 8 mph.
3. Close the throttle and coast in gear to approximately 2 mph above the test speed.
4. Shift the transmission to neutral and coast until the test speed is reached, then initiate the stop by means of the service brake control. The service brake is to be applied at +0 or -1 mph of the specified test speed.

The details of the stopping distance and stability test procedures are given in tables 8.1-3. The braking test data should be recorded after completing the tests. The post-test procedure given in Table 8.4 will be performed, and any brake system faults or required repairs will be recorded.

## Braking Test Procedure.

DETAILED TEST PROCEDURES TITLE: 8 Braking Performance Test - Stopping Distance and Stability		
Procedure 8-1		NOMENCLATURE: Stopping Distance and Stability
OPER STEP	ACTION BY	TEST PREPARATION AT ABTC
1	TP	Check the tire inflation pressure that is to be as specified by the vehicle manufacturer for the gross-vehicle-weight rating and is to be established cold. Correct the inflation pressure, if necessary, and record the correct pressure and tires specifications on the test data form.
2	TP	Install a digital speedometer if one has not been previously installed. Mount the speed indicator in plain view of the bus driver.
3	TP	Inspect the braking system for proper operation and adjustment to manufacturer specification. Inspect the service brake system and the connections of the ABS for detachment or fracture of any components, such as brake springs, brake shoes, houses, control unit and sensors. Record on the test data form any faulty braking components, and make any necessary repairs.
4	TP	Load the bus to GVWR minus the weight of TD, TP, and test equipment. Check the axle loads and record them on the test data form.

## Braking Test Procedure (Cont=d).

DETAILED TEST PROCEDURES TITLE: 8 Braking Performance Test - Stopping Distance and Stability		
Procedure 8-1		NOMENCLATURE: Stopping Distance and Stability
OPER STEP	ACTION BY	TEST PREPARATION AT PTI Test Track
1	TP	Record the bus number, date, and persons performing the test on the data sheet. Retrieve work order form for this test.
2	TP	Install the speed and distance measuring systems on the front of the bus. Install the speed/distance indicator in the front of the bus, so it is accessible to TP.
3	TP	Set vehicle conditions as follows: <ol style="list-style-type: none"> <li>1. Fuel to at least 90% of total capacity.</li> <li>2. All accessories off, except the defroster, heater, and ventilation when needed.</li> <li>3. All windows and doors closed except those necessary for instrumentation purposes.</li> </ol>
4	TP/TD	Drive the bus at 45 mph for 15 min around the bus lane at the PTI Test Track. Calibrate or verify the calibration of the digital speedometer.
5	TP	Record the environmental data and verify surface conditions. <ol style="list-style-type: none"> <li>1. Ambient air temp between 32EF &amp; 90EF and pavement temperature above 32EF.</li> <li>2. Wind speed less than 12 mph</li> <li>3. Brake test lanes are clear of extraneous material</li> <li>4. One dry brake test lane (PFC 0.9)</li> <li>5. One wet brake test lane (PFC 0.5)</li> </ol>
6	TP	Delay the test if any of the above conditions are not met; correct the condition if possible.

**Table 8.1 Braking Test Procedure.**

<p align="center">DETAILED TEST PROCEDURES                      TITLE: 8. Braking Performance Test - Stopping Distance and Stability</p>		
<p align="center">Procedure 8-1</p>		<p align="center">NOMENCLATURE:                      Stopping Distance and Stability</p>
<p align="center">OPER STEP</p>	<p align="center">ACTION BY</p>	<p align="center">TEST PROCEDURE                      STOPPING DISTANCE</p>
1	TD	Drive the bus on the bus test lane at the PTI Test Track and make 4 consecutive stops from 20, 30, 40, and 45 mph. Then check if all the instrumentations is working and also check the driver=s response observations and record his comments at each speed (if he observed any unusual behavior during braking).
2	TP	Turn on the distance measuring system. Stop the bus and check all brake temperatures using the non-contacting laser thermometer. Initial Brake temperature between 150EF and 200EF.
3	TD/TP	Drive the bus on the bus test lane at the PTI Test Track. Accelerate to and maintain a speed 4 to 8 mph greater than the specified test speed. Maintain this speed into the brake test run in area. Close the throttle at first marker of the run in area. Coast to the second marker when the transmission is to be shifted to neutral. Coast into the appropriate brake test lane and apply full, rapid brake applications at 20 mph.
4	TP	Videotape the braking runs.
5	TP	Record the stopping distance on the test data form.
6	TP/TD/TP	Repeat steps 3 thru 5 three times for each condition listed below: 1. Brake from 20, 30, 40 and 45 mph on dry brake test lane. 2. Brake from 20 mph on wet brake test lane.

**Table 8.2 Braking Test Procedure**

<p align="center">DETAILED TEST PROCEDURES                      TITLE: 8. Braking Performance Test - Stopping Distance and Stability</p>		
<p align="center">Procedure 8-2</p>		<p align="center">NOMENCLATURE:                      Stopping Distance and Stability</p>
<p align="center">OPER STEP</p>	<p align="center">ACTION BY</p>	<p align="center">TEST PROCEDURE                      STABILITY</p>
1	TD	<p>Drive the bus on the bus test lane at the PTI Test Track and make 4 consecutive stops from 20, 30, 40, and 45 mph. Then check if all the instrumentations are working and also check the driver=s response observations and record his comments at each speed (if he observed any unusual behavior during braking).</p>
2	TP	<p>Turn on the distance measuring system. Stop the bus and check all brake temperatures using the non-contacting laser thermometer. Initial Brake temperature between 150EF and 200EF.</p>
3	TD/TP	<p>Drive the bus on the bus test lane before entering the split-friction lanes. Accelerate to and maintain a speed 4 to 8 mph greater than the specified test speed. Maintain this speed into the brake test run in area. Close the throttle at first marker of the run in area. Coast to the second marker when the transmission is to be shifted to neutral. Coast into the appropriate brake test lane, where the right side on the wet test lane and the left side on the dry test lane and apply full, rapid brake applications at 30 mph. Measure the steering- wheel angle and record the maximum correction required to maintain the vehicle in straight-line motion.</p>
4	TP	<p>Videotape the braking runs.</p>
5	TP	<p>Record the maximum steering wheel angle stopping distance on the test data form.</p>
6	TP/TD	<p>Repeat steps 3 thru 5 two times each for each condition listed below:                      1. Braking when vehicle=s right side is on wet test lane and left side on dry test lane.                      2. Braking when vehicle=s left side is on wet test lane and right side is on dry test lane.</p>

**Table 8.3 Braking Test Procedure.**

<p align="center">DETAILED TEST PROCEDURES                      TITLE: 8. Braking Performance Test - Stopping Distance and Stability</p>		
<p align="center">Procedure 8-3</p>		<p align="center">NOMENCLATURE:                      Stopping Distance and Stability</p>
<p align="center">OPER STEP</p>	<p align="center">ACTION BY</p>	<p align="center">TEST PROCEDURE                      PARKING BRAKE</p>
1	TD	Drive the bus onto the parking brake ramp facing uphill. Stop and hold the bus by means of the service brake control.
2	TP	Mark the interface between tires and ramp surface with chalk.
3	TD	Shift the vehicle's transmission to neutral. Apply the parking brake. Release the service brake control.
	TP	Start the stopwatch when the service brake control is released.
4	TP	Visually observe whether the vehicle remains stationary, slides, or rolls.
5	TP	After duration of at least 5 min, measure the vehicle movement, if any. Record the time of hold and vehicle movement on the test data form. Use the previously made chalk mark to measure vehicle movement.
6	TD/TP	If the vehicle did not remain stationary, steps 1 through 6 may be repeated until it remains stationary or a maximum of three times.
7	TD/TP	Repeat steps 1 through 6 with the vehicle facing downhill. Record data.

**Table 8.4 Braking Test Procedure**

<p align="center">DETAILED TEST PROCEDURES                      TITLE: 8. Braking Performance Test - Stopping Distance and Stability</p>		
<p align="center">Procedure 8-1</p>		<p align="center">NOMENCLATURE:                      Stopping Distance and Stability</p>
<p align="center">OPER STEP</p>	<p align="center">ACTION BY</p>	<p align="center">POST TEST PROCEDURE                      AT ABTC</p>
1	TP	Disconnect and remove the instrumentations.
2	MECH	Inspect the braking systems for detachment or fracture of any components, such as brake springs and brake shoes. Record on the test data form any faulty braking components and make any necessary repairs.
3	MECH	Adjust the brakes to the manufacturer=s specification.
4	MECH	Inspect all brake system, including control units and sensors fittings that were disassembled and reassembled. Repair any leaks or disconnections that are found.
5	MECH/ TD/TP	Verify that the braking system and ABS are operating properly.

## Braking Test Data Forms

Bus Number:	Date:
Personnel:	
Amb. Temperature (EF):	Wind Speed (mph):
Wind Direction:	

TIRE INFLATION PRESSURE (psi)				
Tire Type: Front:		Rear:		
	Left Tire(s)		Right Tire(s)	
Front				
	Inner	Outer	Inner	Outer
Rear				
Rear				

AXLE LOADS (lb)		
	Left	Right
Front		
Rear		

Rear

FINAL INSPECTION	
Bus Number:	Date:
Personnel:	

**Record all Braking System Faults/Repairs.**

Date	Personnel	Fault/Repair	Description

### Stopping Distance Test Results Form

Stopping Distance (ft)				
Speed (mph)	Stop 1	Stop 2	Stop 3	Average
20 (dry)				
30 (dry)				
40 (dry)				
45 (dry)				
20 (wet)				

### Stability Test Results Form

Stability Test Results (Split Friction Road surface)		
Vehicle Direction	Attempt	Maximum Steering Wheel Angle correction (deg) & Remarks
Right Side on Wet Lane	1	
	2	
Left Side on Wet lane	1	
	2	

### Parking Brake Test Form

PARKING BRAKE (Fully Loaded) - GRADE HOLDING						
Vehicle Direction	Attempt	Hold Time (min)	Slide (in)	Roll (in)	Did Hold	No Hold
Facing Uphill	1					
	2					
	3					
Facing Downhill	1					
	2					
	3					