

4.2 Performance - Bus Braking Performance Test

Test Procedure

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
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

4.2 I. TEST OBJECTIVE

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

4.2 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 be representative of the tires on the production model vehicle

The brake testing procedure comprises three phases:

1. Stopping distance tests
 - i. High friction surface (high-friction, Skid Number within the range of 70-76)
 - ii. Low friction surface (low-friction, Skid Number within the range of 30-36)
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 or low friction surface will be performed in straight line at speed of 20 mph.

The tests will be conducted as follows:

1. **Uniform High Friction Tests:** Four 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:** Four maximum deceleration straight-line brake applications from 20 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 in both directions on the test track. 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 SN 70-76 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. Any deviation from the test lane will be recorded.

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.

4.2 III. TEST ARTICLE

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

4.2 IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

4.2-1 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

4.2-2 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 must be dry and clear of extraneous surface material. The brake test lanes are checked periodically for compliance with the following conditions:
 - i. One high friction surface test lane with skid numbers between 70 and 76 as determined by ASTM E-274 at 40 mph, omitting water delivery as specified in paragraph 4.2 of that method.
 - ii. One low friction surface test lane with skid numbers between 30 and 36 as determined by ASTM E-274 at 25 mph, omitting water delivery as specified in paragraph 4.2 of that method.
5. The brake slope consists of a clean dry Portland cement concrete surface and has a grade of 20%.

4.2-3 Test Personnel

The PTI personnel consist of the following:

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

4.2 V. TEST DATA

The test data consist of the completed attached data forms (Tables 4.2 6-8). Upon completion of this test, data shall be forwarded to the Test Manager.

4.2 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 brakes temperature should be between 150 °F and 200 °F.
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 4.2-1-3. The braking test data should be recorded in Table 4.2-6. After completing the tests, the post-test procedure given in Table 4.2-5 will be performed, and any brake system faults or required repairs will be recorded in Table 4.2-7. Test results will be recorded in tables 4.2-8.1 and 2.

Table 4.2-1 Braking Test Procedure.

<p align="center">DETAILED TEST PROCEDURES TITLE:4.2 Braking Performance Test - Stopping Distance and Stability</p>		
<p align="center">Procedure 4.2-1</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 PREPARATION AT ABTC</p>
1	TP	<p>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.</p>
2	TP	<p>Install a digital speedometer if one has not been previously installed. Mount the speed indicator in plain view of the bus driver.</p>
3	TP	<p>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.</p>
4	TP	<p>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.</p>

Table 4.2-1. Braking Test Procedure (Cont' d).

<p style="text-align: center;">DETAILED TEST PROCEDURES</p> <p style="text-align: center;">TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability</p>		
<p>Procedure 4.2-1</p>		<p style="text-align: center;">NOMENCLATURE: Stopping Distance and Stability</p>
<p>OPER STEP</p>	<p>ACTION BY</p>	<p style="text-align: center;">TEST PREPARATION AT PSBRTF</p>
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"> 1. Fuel to at least 90% of total capacity. 2. All accessories off, except the defroster, heater, and ventilation when needed. 3. All windows and doors closed except those necessary for instrumentation purposes.
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"> 1. Ambient air temp between 32 °F & 90 °F 2. Wind speed less than 12 mph 3. Brake test lanes are clear of extraneous material 4. One high friction brake test lane (SN 70-76) 5. One low friction brake test lane (SN 30-36)
6	TP	Delay the test if any of the above conditions are not met; correct the condition if possible.

Table 4.2-2. Braking Test Procedure.

<p style="text-align: center;">DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability</p>		
<p>Procedure 4.2-1</p>		<p style="text-align: center;">NOMENCLATURE: Stopping Distance and Stability</p>
<p>OPER STEP</p>	<p>ACTION BY</p>	<p style="text-align: center;">TEST PROCEDURE STOPPING DISTANCE (FULLY LOADED)</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. None of the brakes temperature should be higher than 200 °F.
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 of the bus.
5	TP	Record the stopping distance on the test data form (Table 4.2-8.1.)
6	TP/TD/TP	Repeat steps 3 thru 5 four times for each condition listed below: 1. Brake from 20, 30, 40 and 45 mph on skid number 70-76 2. Brake from 20 mph on skid number 30-36

Table 4.2-3. Braking Test Procedure

<p style="text-align: center;">DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability</p>		
<p>Procedure 4.2-1</p>		<p style="text-align: center;">NOMENCLATURE: Stopping Distance and Stability</p>
<p>OPER STEP</p>	<p>ACTION BY</p>	<p style="text-align: center;">TEST PROCEDURE STABILITY (FULLY LOADED)</p>
1	TP	Turn on the distance measuring system. Stop the bus and check all brake temperatures using the non-contacting laser thermometer. None of the brakes temperature should be higher than 200 °F.
2	TD/TP	Drive the bus on a uniform high friction surface 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 curb side on the low friction lane and the driver side on the high friction lane and apply full, rapid brake applications at 30 mph. Record if bus stayed in 12 foot lane.
3	TP	Videotape the braking runs of the bus.
4	TP	Record the maximum steering wheel angle stopping distance on the test data form (Table 4.2-8.2.)
5	TP/TD	Repeat steps 4 thru 6 two times for each condition listed below: 1. Braking when vehicle's driver side on skid number 70-76 (High friction) 2. Braking when vehicle's driver side on skid number 30-36 (Low friction)

Table 4.2-4. Braking Test Procedure.

<p style="text-align: center;">DETAILED TEST PROCEDURES</p> <p style="text-align: center;">TITLE: 4.2. Braking Performance Test - Stopping Distance and Parking Brake</p>		
<p>Procedure 4.2-1</p>		<p style="text-align: center;">NOMENCLATURE: Stopping Distance and Parking Brake</p>
<p>OPER STEP</p>	<p>ACTION BY</p>	<p style="text-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 7 with the vehicle facing downhill. Record data in Table 4.2.8.3.

Table 4.2-5. Braking Test Procedure

<p style="text-align: center;">DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability</p>		
<p>Procedure 4.2-1</p>		<p style="text-align: center;">NOMENCLATURE: Stopping Distance and Stability</p>
<p>OPER STEP</p>	<p>ACTION BY</p>	<p style="text-align: center;">POST TEST PROCEDURE AT ABTC</p>
1	TP	Disconnect and remove the instrumentations.
2	TP	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	TP	Adjust the brakes to the manufacturer' s specification.
4	TP	Inspect all brake system, including control units and sensors fittings that were disassembled and reassembled. Repair any leaks or disconnections that are found.
5	TD/TP	Verify that the braking system and ABS are operating properly.

Table 4.2-6. Braking Test Data Forms

Bus Number:	Date:
Personnel:	
Amb. Temperature (°F):	Wind Speed (mph):
Wind Direction:	Pavement Temperature: Start: End:

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		

FINAL INSPECTION	
Bus Number:	Date:
Personnel:	

Table 4.2-7. Record of All Braking System Faults/Repairs.

Date	Personnel	Fault/Repair	Description

Table 4.2-8.1. Stopping Distance Test Results Form

Stopping Distance (ft)					
Vehicle Direction					
Speed (mph)	Stop 1	Stop 2	Stop 3	Stop 4	Average
20 (dry)					
30 (dry)					
40 (dry)					
45 (dry)					
20 (wet)					

Table 4.2-8.2. Stability Test Results Form

Stability Test Results (Split Friction Road surface)			
Vehicle Direction	Attempt	Did Bus stay in 12' Lane (Yes/No)	Comments
Driver side on high friction	1		
	2		
Driver side on low friction	1		
	2		

Table 4.2-8.3. Parking Brake Test Form

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

