

**HEAVY-DUTY ARTICULATED 500,000-MILE BUS
WITH A MINIMUM SERVICE LIFE OF
12 YEARS**

7. NOISE

7.2 EXTERIOR NOISE TESTS

April 2006

ABBREVIATIONS

ABTC	- Altoona Bus Test Center
A/C	- air conditioner
ADB	- advance design bus
CBD	- central business district
CI	- compression ignition
CNG	- compressed natural gas
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
GAWR	- gross axle weight rating
GL	- gross 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 (curb weight plus gross vehicle load)
GVWR	- gross vehicle weight rating
hr	- hour
LNG	- liquefied natural gas
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
SCF	- standard cubic feet
SCFM	- standard cubic feet per minute
SCH	- test scheduler
SEC	- secretary
SI	- spark ignition
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

7.2-I. TEST OBJECTIVE

The objective of this test is to record exterior noise levels when a bus is operated under various conditions.

7.2-II. TEST DESCRIPTION

In the exterior noise tests, the bus will be operated at SLW in three different conditions using a smooth, straight and level roadway:

1. Accelerating at full throttle from a constant speed at or below 35 mph and just prior to transmission upshift.
2. Accelerating at full throttle from standstill.
3. Stationary, with the engine at low idle, high idle, and wide open throttle.

In addition, the buses will be tested with and without the air conditioning and all accessories operating. The exterior noise levels will be recorded.

The test site is at the PSBRTF and the test procedures will be in accordance with SAE Standards SAE J366b, Exterior Sound Level for Heavy Trucks and Buses. The test site is an open space free of large reflecting surfaces. A noise meter placed at a specified location outside the bus will measure the noise level.

During the test, special attention should be paid to:

1. The test site characteristics regarding parked vehicles, signboards, buildings, or other sound-reflecting surfaces
2. Proper usage of all test equipment including set-up and calibration
3. The ambient sound level

7.2-III. TEST ARTICLE

The test article is a heavy-duty articulated transit bus with a minimum service life of 12 years or 500,000 mi.

7.2-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

1. Test Equipment
 - a. Tape measure (100 ft) or a wheeled distance meter
 - b. Road markers (e.g., chalk and highway cones)
 - c. Portable engine speed tachometer.
 - d. Sound level meter - meeting Type 1 or S1A requirements of American National Standard Specification for sound level meters, S1.4-1971 (includes microphone and manual). The sound meter shall be set for fast response and the A-weighting network.
 - e. Sound level calibrator.
 - f. A windscreen that does not affect the microphone response more than ± 1 dB(A) for frequencies of 20-4000 Hz or $\pm 1 \frac{1}{2}$ dB(A) for frequencies of 4,000 - 10,000 Hz.
 - g. Sound level meter tripod that is capable of holding the microphone and meter at 4 ft above ground level.
 - h. Clipboard for data recording
 - i. Speed measurement system.
2. Test Facility - Test site is at the PSBRTF using the skid pad area.
 - a. The measurement area shall be free of tall grass, bystanders, snow or other sound-absorbing materials.
 - b. The ambient sound level (including wind effects) at the test site shall be at least 10 dB(A) below the level of the test vehicle operated in accordance with the test procedures.
 - c. The wind speed in the measurement area shall be less than 12 mph.
3. Test Personnel - The personnel consist of the following:
 - a. Bus driver (DR)
 - b. Test personnel (TP)

7.2-V. TEST DATA

The test data consist of the test procedure and data where requested. On completion of the test, test data shall be forwarded to the ABTC manager.

7.2-VI. TEST PREPARATION AND PROCEDURES

The detailed test preparation and procedures are listed in procedure 7.2-1, 7.2-2, and 7.2-3. This section includes figure 7.2-1 and Exterior Noise Test Data Forms - 7.2-1, 7.2-2, and 7.2-3.

Procedure 7.2-1

NOMENCLATURE: 7.2 Exterior Noise Tests -
Accelerating from Constant Speed

OPER
STEP

ACTION
BY

TEST PREPARATION

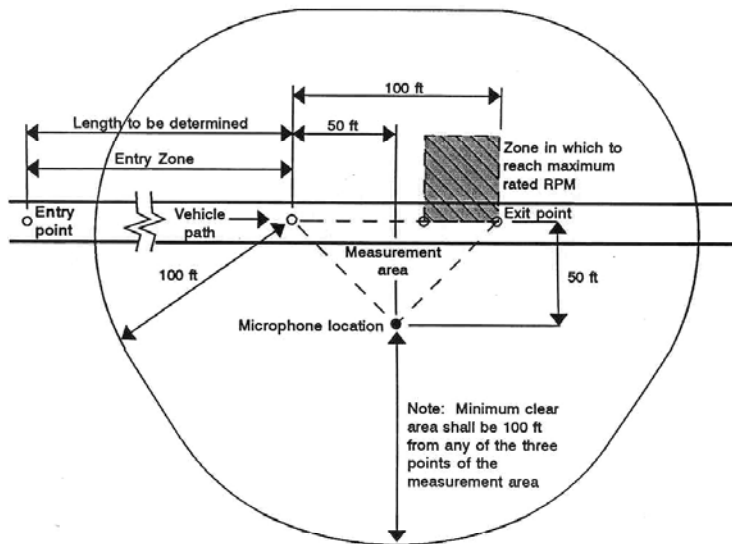


Figure 7.2-1. Test Site - Configured unidirectional for left to right acceleration from constant speed.

Procedure 7.2-1

**NOMENCLATURE: 7.2 Exterior Noise Tests--
Accelerating from Constant Speed**

**OPER
STEP**

**ACTION
BY**

TEST PREPARATION

1	TP	Retrieve work order form for this test.
2	TP	Verify that all test prerequisites defined by 7.2 III, Equipment/Facilities/Personnel are satisfied. NOTE: The following steps will define the layout of the test area. (Refer to figure 7.2-1)
3	TP	Establish an acceleration point by placing a cone at a point along the vehicle path.
4	TP	Establish an end point along the vehicle path by placing a second cone 100 ft from the acceleration point.
5	TP	Establish the microphone location midway between the acceleration point and the end point at a distance of 50 ft to the right from the center line of the vehicle path. Position the height of the microphone 4 ft above the ground plane, pointing horizontally toward the midpoint.
6	TP	Select a transmission ration and entry speed such that at wide-open throttle, the vehicle will accelerate from the acceleration point with the following considerations. a) The entry speed is such that the starting engine speed is no more than two-thirds (66%) of maximum rated or governed engine speed. b) The vehicle reaches maximum rated or governed engine speed before the end point or just prior to transmission upshift. c) The vehicle does not exceed 35 mph before reaching end point. NOTE: Should the maximum rated or governed rpm not be attained until beyond the end point, select lower gear until maximum rpm or transmission upshift is attained before the end point.
7	TP	Select the rear bumper as the vehicle reference point.
8	TP	Turn lights and all accessories on.
9	TP	Operate the engine until the coolant temperature is in the normal operating range.

DETAILED TEST PROCEDURES

TITLE: 7. Noise

Procedure 7.2-1		NOMENCLATURE: 7.2 Test Procedure - Exterior Noise Tests— Accelerating from Constant Speed
OPER STEP	ACTION BY	TEST PROCEDURE
1	TP	Verify that all test preparations have been completed.
2	TP	Record the bus number, date, temperature, relative humidity, wind speed and direction, and barometric pressure on the Exterior Noise Test Data Form 7.2-1.
3	TP	Set the sound level meter for fast response and the A-weighting network and the “auto” position.
4	TP	Check the calibration of the sound level meter.
5	TP	Measure the ambient sound level and record it on the Exterior Noise Test Data Form 7.2-1. NOTE: When taking sound level measurements, position the sound level meter at least 1 meter or arm’s length away from the body.
6	TD	Position the test bus 150 ft from the entry point. Turn on all accessories.
7	TP	Verify that the wind speed is less than 12 mph and the ambient temperature is between 30° F and 90° F.
8	TD	Approach the acceleration point using the entry speed and gear ratio selected in step 6 of the Test Preparation 7.2-1. When the vehicle reference point reaches the acceleration point, apply full throttle and hold until the bus shifts to the next highest gear. Decelerate in a safe manner and return to the starting point.
9	TP	Observe the meter during the period the bus is accelerating. The applicable reading shall be the highest sound level indicated during the run (between the 100 ft span). Record the highest observation on the Exterior Noise Test Data Form. NOTE: The test personnel is cautioned to rerun the test if unrelated peaks occur due to extraneous ambient noises.
10	TP	Repeat steps 7 thru 9 until the three highest readings are within +-2 db(A) of each other or 10 readings are made. Record the average of the two highest observations on the Exterior Noise Test Data Form.

DETAILED TEST PROCEDURES

TITLE: 7. Noise

Procedure 7.2-1		NOMENCLATURE: 7.2 Exterior Noise Accelerating from Constant Speed (continued)
OPER STEP	ACTION BY	TEST PREPARATION AND PROCEDURE
11	TD	<p>Switch the acceleration and end points and position the bus 150 ft from the acceleration point, facing the opposite direction from previous runs.</p> <p>NOTE: Switching the entry points changes the test site of figure 7.2-1 to its mirror image. That is, the acceleration point is on the right and the test zone is on the left. The test site is now ready for right to left motion.</p>
12	TP	<p>Repeat step 10 traveling in the opposite direction. The sound level will be measured for the left side of the bus.</p>
13	TP	<p>Recheck sound level meter calibration.</p> <p>NOTE: If meter calibration has changed by more than ± 0.5 dB(A), recalibrate the meter and repeat test procedure.</p>

EXTERIOR NOISE TEST DATA FORM

Accelerating from Constant Speed

Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Speed (mph):	Wind Direction:
Barometric Pressure (in.Hg):	
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30EF and 90EF: <input type="checkbox"/> checked by	
Initial Sound Level Meter Calibration: <input type="checkbox"/> checked by	
Exterior Ambient Noise Level dB(A):	

Accelerating from Constant Speed Curb (Right) Side			Accelerating from Constant Speed Street (Left) Side		
Run #	Measured Noise Level dB(A)	Actual Noise Level dB(A)	Run #	Measured Noise Level dB(A)	Actual Noise Level dB(A)
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		
Average of two highest actual noise levels = dB(A)			Average of two highest actual noise levels = dB(A)		
Final Sound Level Meter Calibration Check: <input type="checkbox"/> checked by					
Comments:					
NOTE: Actual noise level is corrected for exterior ambient noise level.					

DETAILED TEST PROCEDURES

TITLE: 7. Noise

Procedure 7.2-2

NOMENCLATURE: 7.2 Exterior Noise Tests -
Accelerating from Standstill

OPER STEP	ACTION BY	TEST PREPARATION
1	TP	Retrieve work order form for this test.
2	TP	Verify that all test prerequisites defined by 7.2-III, Equipment/Facilities/personnel are satisfied.
<p>NOTE: The following step will define the layout of the test area. (Refer to figure 7.2-2)</p>		
3	TP	Establish a starting point and exit point by placing two highway cones 80 ft apart, beside the vehicle path.
4	TP	At the point along the center line of the vehicle path, midway between the start and exit points, measure a distance 50 ft perpendicular to the vehicle path and mark the location for the sound level meter.
5	TP	Position the sound level meter at this point, 4 ft above the ground using the sound level meter tripod. Point the microphone toward the midpoint on the vehicle path.
6	TD	Operate the engine until the coolant temperature is in the normal operating range. Turn lights and all accessories on.
7	TP	Select the rear bumper as the vehicle reference point.
<p>NOTE: On vehicles equipped with radiator shutters, the shutter position causing maximum sound level should be determined, and the test conducted with the shutters in such position.</p>		

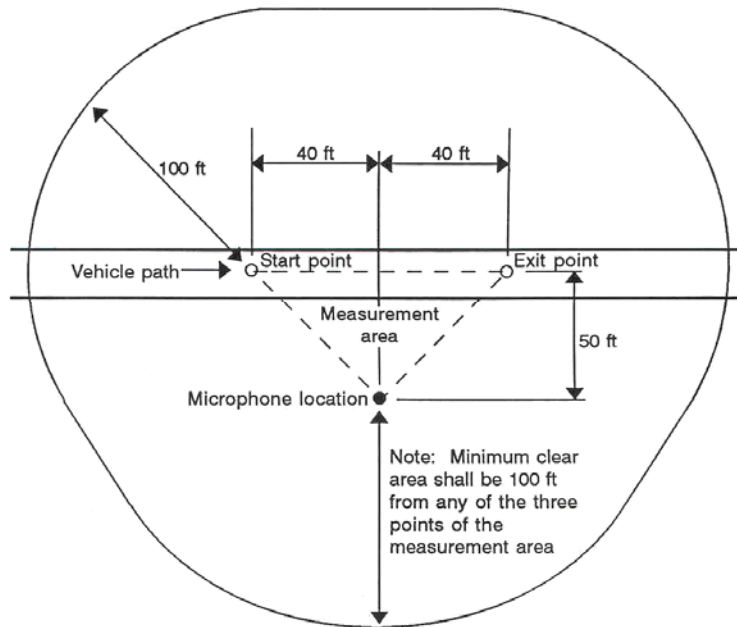
Procedure 7.2-2

NOMENCLATURE: 7.2 Exterior Noise Tests - Accelerating from Standstill (Continued)

OPER
STEP

ACTION
BY

TEST PREPARATION



Right side measurement shown. Start Point and Exit Point interchange for left side measurement.

Figure 7.2-2. Test Site - configured for acceleration from standstill.

DETAILED TEST PROCEDURES		TITLE: 7. Noise
Procedure 7.2-2		NOMENCLATURE: 7.2 Exterior Noise Accelerating from Standstill
OPER STEP	ACTION BY	TEST PREPARATION AND PROCEDURE
1	TP	Record the bus number, date, temperature, relative humidity, wind speed and direction, and barometric pressure on the Exterior Noise Test Data Form 7.2-2.
2	TP	Set the sound level meter for fast response and the A-weighting network in the "auto" position. NOTE: Because bystanders have an appreciable influence on meter response, position all persons out of the measurement area, behind the sound level meter.
3	TP	Check the calibration of the sound level meter.
4	TP	Measure the ambient sound level and record it on the Exterior Noise Test Data Form 7.2-2.
5	TP	Verify that the wind speed is less than 12 mph and the ambient temperature is between 30° F and 90° F.
6	TD	Position the test bus so that is centered in the vehicle path, with the left side of the rear bumper next to the starting cone.
7	TD	Turn all accessories on.
8	TD	With the transmission in "Drive," rapidly establish full throttle. When the rear bumper has passed the exit cone, decelerate and return to the starting point.
9	TP	The sound level meter shall be observed during the period when the bus is accelerating. The applicable reading shall be the highest sound level obtained for the run (between the 80 ft span). NOTE: The test personnel is cautioned to rerun the test if unrelated peaks occur due to extraneous ambient noises.
10	TD	Repeat steps 6 thru 9 until the two highest readings are within 2 dB(A) of each other or 10 readings are made. Record all observations and the average of the two highest on the Exterior Noise Test Data Form.

DETAILED TEST PROCEDURES

TITLE: 7. Noise

Procedure 7.2-2

**NOMENCLATURE: 7.2 Exterior Noise
Accelerating from Standstill (continued)**

OPER STEP	ACTION BY	TEST PROCEDURE
11	TP	Switch the starting and exit points. The test bus will now run in the opposite direction, and noise levels will be recorded for the left side of the bus.
12	TP	Position the test bus so that it is centered in the vehicle path, with the right side of the rear bumper next to the starting cone.
13	TP	Repeat steps 7 thru 9 until the two highest readings are with +- 2 dB(A) of each other or 10 readings are made. Record all observations and the average of the two highest on the Exterior Noise Test Data Form.
14	TP	<p>Recheck sound level meter calibration.</p> <p>NOTE: If meter calibration has changed by more than ± 0.5 dB(A), recalibrate the meter and repeat the test procedure.</p>

EXTERIOR NOISE TEST DATA FORM Accelerating from Standstill

Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Speed (mph):	Wind Direction:
Barometric Pressure (in.Hg):	
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30EF and 90EF: <input type="checkbox"/> checked by	
Initial Sound Level Meter Calibration: <input type="checkbox"/> checked by	
Exterior Ambient Noise Level dB(A):	

Accelerating from Standstill Curb (Right) Side			Accelerating from Standstill Street (Left) Side		
Run #	Measured Noise Level dB(A)	Actual Noise Level dB(A)	Run #	Measured Noise Level dB(A)	Actual Noise Level dB(A)
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		
Average of two highest actual noise levels = dB(A)			Average of two highest actual noise levels = dB(A)		
Final Sound Level Meter Calibration Check: <input type="checkbox"/> checked by					
Comments:					
NOTE: Actual noise level is corrected for exterior ambient noise level.					

DETAILED TEST PROCEDURES

TITLE: 7. Noise

Procedure 7.2-3

NOMENCLATURE: 7.2 Exterior Noise
Stationary

OPER
STEP

ACTION
BY

TEST PREPARATION

1	TP	Retrieve work order for this test.
2	TP	Verify that all test prerequisites defined by 7.2-III Equipment/Facilities/Personnel are satisfied. NOTE: The following steps will define the layout of the test area. (Refer to figure 7.2-3)
3	TP	Place the test bus so that it is centered in the vehicle path with the left side of the rear bumper (if the engine is in the rear end of the test bus) or front bumper (if the engine is in the front end of the bus) next to the center cone.
4	TP	Position the sound level meter 4 ft above the ground, in line with the rear bumper, at a distance of 50 ft from the center line to the right of the vehicle.
5	TD	Operate the bus until the engine coolant temperature is within the operating range. Turn lights and all accessories on. NOTE: On vehicles equipped with radiator shutters, the shutter position causing maximum sound level should be determined and the test conducted with the shutters in such position.

Procedure 7.2-3

NOMENCLATURE: 7.2 Exterior Noise
Stationary (Continued)

OPER
STEP

ACTION
BY

TEST PREPARATION

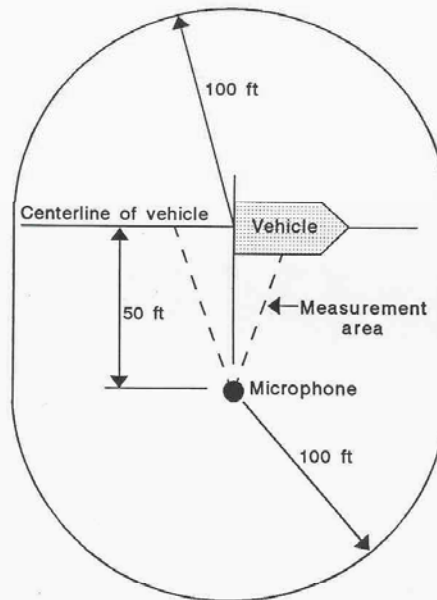


Figure 7.2-3. Test Site - configured for stationary tests.

DETAILED TEST PROCEDURES		TITLE: 7. Noise
Procedure 7.2-3		NOMENCLATURE: 7.2 Exterior Noise Tests – Stationary
OPER STEP	ACTION BY	TEST PROCEDURE
1	TP	Record the bus number, date, temperature, relative humidity, wind speed and direction, and barometric pressure on the Exterior Noise Test Data Form 7.2-3.
2	TP	Set the sound level meter for fast response and the A-weighting network and switch to the “auto” mode. NOTE: Because bystanders have an appreciable influence on meter response, position all persons out of the measurement area, behind the sound level meter.
3	TP	Check the calibration of the sound level meter.
4	TP	Measure the ambient sound level and record it on the Exterior Noise Test Data Form 7.2-3.
5	TD	Verify that the wind speed is less than 12 mph and the ambient temperature is between 30° F and 90° F.
6	TP	Install the engine tachometer (tape) and verify correct operation. NOTE: Make sure the light reflecting tape is installed on the crankshaft pulley.
7	TD	Turn on all lights, accessories and air conditioning.
8	TD	Set the bus engine to low idle.
9	TP	Measure the engine rpm. With the engine compartment closed, measure the noise level at the specified rpm and record the values on the EXTERIOR NOISE TEST DATA FORM. NOTE: Unrelated peaks due to extraneous ambient noise should be ignored.
10	TD	Set the bus engine to high idle (if obtainable).
11	TP	Repeat Step 9.
12	TD	Establish and hold wide open throttle.
13	TP	Repeat step 9.

DETAILED TEST PROCEDURES		TITLE: 7. Noise
Procedure 7.2-3		NOMENCLATURE: 7.2 Exterior Noise Stationary (continued)
OPER STEP	ACTION BY	TEST PREPARATION AND PROCEDURE
14	TD	Reverse the position of the test bus, such that the bus is centered in the vehicle path with the right side of the rear or front bumper (wherever applicable) next to the center cone. NOTE: Noise measurements will now be made from the left side of the bus.
15	TP	Repeat steps 7 thru 13.
16	TD	Turn off all lights, accessories, and air conditioning.
17	TP	Repeat steps 8 thru 13 to obtain left side measurement with accessories off.
18	TD	Place the test bus so that it is centered in the vehicle path with the left side of the rear bumper or front bumper (wherever applicable) next to the center cone.
19	TP	Repeat steps 8 thru 13 to obtain right side measurement with accessories off.
20	TP	Recheck calibration of sound level meter. NOTE: If meter calibration has changed by more than ± 0.5 dB(A), recalibrate the meter and repeat the test procedure.
21	TP	Return all test equipment to proper location.

EXTERIOR NOISE TEST DATA FORM Stationary

Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Speed (mph):	Wind Direction:
Barometric Pressure (in.Hg):	
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30EF and 90EF: <input type="checkbox"/> checked by	
Initial Sound Level Meter Calibration: <input type="checkbox"/> checked by	
Exterior Ambient Noise Level dB(A):	

Accessories and Air Conditioning ON					
Throttle Position	Engine RPM	Curb (Right) Side dB(A)		Street (Left) Side dB(A)	
		Measured	Actual	Measured	Actual
Low Idle					
High Idle					
Wide Open Throttle					

Accessories and Air Conditioning OFF					
Throttle Position	Engine RPM	Curb (Right) Side dB(A)		Street (Left) Side dB(A)	
		Measured	Actual	Measured	Actual
Low Idle					
High Idle					
Wide Open Throttle					
Final Sound Level Meter Calibration Check: <input type="checkbox"/> checked by					
Comments:					
Note: The actual sound level is corrected for the ambient noise level.					

REVISIONS

All revisions to this test procedure must be identified on this page. Briefly describe each revision in the space provided below.

Revision	Description	Date	Approval
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