

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

7. NOISE

**7.1 INTERIOR 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

#### 7.1-I. TEST OBJECTIVE

The objective of these tests is to measure and record interior noise levels and check for audible vibration under various operating conditions.

#### 7.1-II. TEST DESCRIPTION

During this series of tests, the interior noise level will be measured at several locations with the bus operating under the following three conditions:

1. With the bus stationary, a white noise generating system shall provide a uniform sound pressure level equal to 80 dB(A) on the left, exterior side of the bus. The engine and all accessories will be switched off and all openings including doors and windows will be closed. This test will be performed at the ABTC.
2. The bus will accelerate at full throttle from a stationary position to 35 mph on a level pavement at the PSBRTF. All openings will be closed and all accessories will be operating during the test.
3. The bus will be operated at various speeds from 0 to 55 mph with and without the air conditioning and accessories on. Any audible vibration or rattles will be noted. This test will be performed on the test segment between the PSBRTF and the ABTC.

All tests will be performed in an area free from extraneous sound-making sources or reflecting surfaces. The ambient sound level as well as the surrounding weather conditions will be recorded in the test data.

#### 7.1-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.

#### 7.1-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

##### 1. Test Equipment

- a. Tape measure (50 ft) or a wheeled distance meter
- b. Sound level meter with microphone and windscreen

Note: The sound level meter must meet or exceed Type 1 or S1A requirements of American National Standard Specification for sound level meters. The windscreen shall not affect the microphone response more than  $\pm 1$  dB(A) for frequencies of 20 to 4000 Hz or  $\pm 1 \frac{1}{2}$  dB(A) for frequencies of 4000 to 10,000 Hz.

- c. Sound level calibrator
- d. Sound level meter tripod
- e. White noise generating system
- f. Speaker stands
- g. Wind meter
- h. Thermometer

## 2. Test Facilities

- a. Test condition 1 will be performed on the rear paved area at the Altoona Bus Test Facility. Test condition 2 will be performed on the test track at the PSBRTF. Test condition 3 will be performed on the test segment between the ABTC and the PSBRTF.
- b. The test areas shall be free of reflecting surfaces, such as parked vehicles, trees, or buildings, within 100 ft of the measurement area. The area shall also be free of snow or other sound absorbing material.
- c. The ambient sound level (including wind effects) at the test site shall be at least 10 dB(A) below the sound level of the test vehicle operated in accordance with the test procedures.
- d. The wind speed in the measurement area shall be less than 12 mph.

## 3. Test Personnel - The test personnel consist of the following:

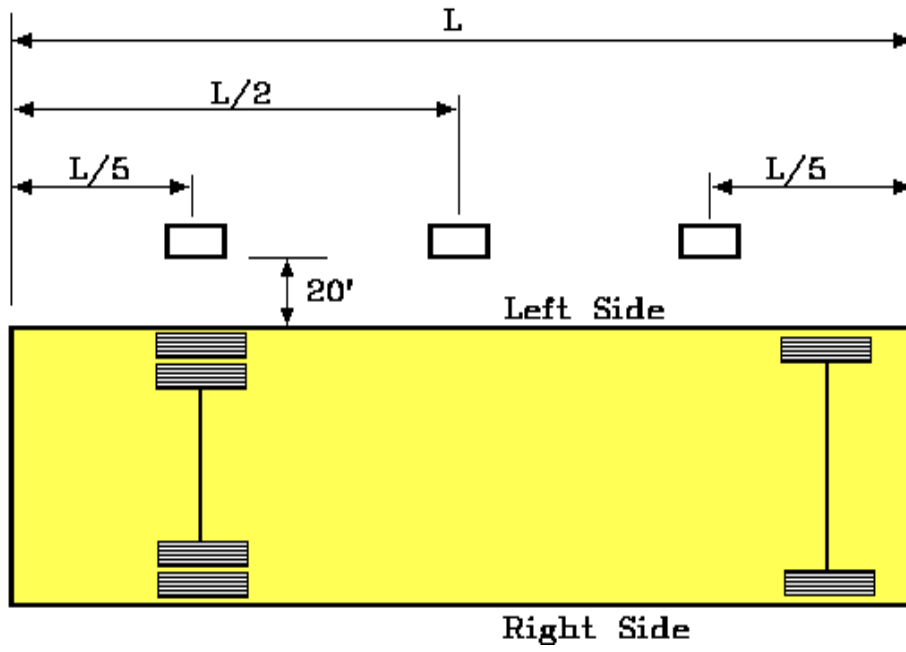
- a. Test driver (TD)
- b. Test Personnel (TP)

### 7.1-V. TEST DATA

The test data consist of the Interior Noise Test Data Form. On completion of the test, the test data will be forwarded to the ABTC manager.

### 7.1-VI. TEST PREPARATION AND PROCEDURES

The detailed test preparation and procedures are listed in procedures 7.1-1, 7.1-2, and 7.1-3. This section also includes Interior Noise Test Data Forms - 7.1-1, 7.1-2, and 7.1-3.



$L$  = Length of bus

Speakers 1, 2, and 3 are supported such that their centers are 5 ft above ground level

**DETAILED TEST PROCEDURES**

**TITLE: 7. Noise**

**Procedure 7.1-1**

**NOMENCLATURE: 7.1 Interior Noise  
Condition 1: Stationary**

<b>OPER STEP</b>	<b>ACTION BY</b>	<b>TEST PREPARATION AND PROCEDURE</b>
1	TP	Obtain work order form for this test. Record the bus number, manufacturer and date on the Interior Noise Test Data Form 7.1-1.
2	TD	Position the test bus in the center of the test area.
3	TP	<p>Record the temperature, relative humidity, wind speed, wind direction, and ambient sound level on the Interior Noise Data Form.</p> <p><b>NOTE: Verify that the wind speed is less than 12 mph and the ambient temperature is between 30°F and 90°F.</b></p>
4	TP	<p>Calibrate the sound level meter using the sound level calibrator as per the meter's instruction manual. Set the meter for the A-weighting network and the fast response position. Switch the sound level meter to the "auto" position. Measure and record the ambient sound level at the exterior and interior of the bus.</p> <p><b>NOTE: When taking sound level measurements, position the sound level meter at least arm's length away from the body.</b></p>
5	TP	Position the white noise generating system on the left side of the bus as indicated by figure 7.1. The speaker stands shall position the center of each speaker at 5 ft above ground level.
6	TP	<p>Photograph the test area and setup.</p> <p><b>NOTE: The sound system, as positioned in figure 7.1, must be capable of generating a uniform white noise level of 80 db(A)±2 dB(A) at the left exterior surface of the bus.</b></p>

**DETAILED TEST PROCEDURES**

**TITLE: 7. Noise**

**Procedure 7.1-1**

**NOMENCLATURE: 7.1 Interior Noise  
Condition 1: Stationary**

<b>OPER STEP</b>	<b>ACTION BY</b>	<b>TEST PREPARATION AND PROCEDURE</b>
7	TP	<p>Switch on the noise generating system and set the output to some intermediate level.</p> <p><b>NOTE:</b> The sound level meter should be positioned within 12 inches from the surface of the test bus with the microphone pointing away from and perpendicular to the surface of the bus.</p>
8	TP	<p>Using the sound level meter, check the noise level at the surface of the bus.</p>
9	TP	<p>Adjust the output of the white noise generating system to produce a uniform noise level equal to 80 dB(A) <math>\pm 2</math> dB(A) on the exterior surface of the bus.</p>
10	TP	<p>Sweep the entire left exterior surface of the bus with the sound meter and adjust the output of the noise generating system until the required level has been achieved.</p> <p><b>NOTE:</b> The speakers should not be moved away or toward the bus to obtain the 80 dB(a) noise level. The test personnel should not interfere when trying to obtain the 80 dB(A) noise level.</p>
11	TP	<p>Once 80 dB(A) <math>\pm 2</math> dB(A) has been established, move the meter inside the test bus.</p> <p><b>NOTE:</b> All windows, hatches, doors, and vents shall be in the fully closed position. All accessories and the engine shall be "off."</p>
12	TP	<p>Establish a reference point that approximates the ear-level position of a seated passenger by measuring a distance of 29 inches vertically upward from the predominant surface of the undeflected seat cushion. Using this reference point, position the microphone at the predetermined height by connecting the noise level meter to the tri-pod and adjusting the height of the tri-pod. Record the microphone height (distance from the floor of the bus to the microphone) on the Interior Noise Test Data Form 7.1-1.</p>

**DETAILED TEST PROCEDURES**

**TITLE: 7. Noise**

**Procedure 7.1-1**

**NOMENCLATURE: 7.1 Interior Noise**  
**Condition 1: Stationary (continued)**

**OPER  
STEP**

**ACTION  
BY**

**TEST PREPARATION AND PROCEDURE**

13

TP

Position the microphone at the predetermined height, pointing vertically upward at an angle of about 70 degrees and perpendicular to the left side of the bus. With the microphone in the prescribed position, take noise level measurements at the following six locations:

1. Driver's seat
2. Center aisle, between front passenger seats
3. Center aisle, in line with front speaker
4. Center aisle, in line with center speaker
5. Center aisle, in line with rear speaker
6. Center aisle, between rear passenger seats

Record the highest noise level measured at each location on the Interior Noise Test Data Form 7.1-1.

**NOTE: Unrelated peak readings due to extraneous noises (talking, etc.) should be ignored and omitted from the test data.**

14

TP

Using the sound level calibrator, recheck the calibration of the sound level meter. If the value has changed by more than 0.5 dB(A), recalibrate the meter and repeat all tests since the last calibration.



Procedure 7.1-2

NOMENCLATURE: 7.1 Interior Noise  
 Condition 2: 0 to 35 mph Acceleration Test

OPER STEP	ACTION BY	TEST PREPARATION
1	TP	Obtain work order form for this test. Record the bus number, manufacturer and date on the Interior Noise Test Data Form 7.1-2.
2	TP	Record the temperature, relative humidity, wind speed, and wind direction on the test data form.  <b>NOTE: Verify that the wind speed is less than 12 mph and the ambient temperature is between 30°F and 90°F.</b>
3	TP	Calibrate the sound level meter using the sound level calibrator, as per the meter's instruction manual.
4	TP	Measure the ambient sound level at the exterior and interior of the test vehicle and record the values on the Interior Noise Test Data Form. If the sound level cannot be recorded due to the scale on the sound level meter, then record the lowest reading that is obtainable (34 dB).
5	TP	Establish a reference point that approximates the ear-level position of a seated passenger by measuring a distance of 29 inches vertically upward from the predominant surface of the undeflected seat cushion. Using this reference point, connect the tri-pod to the sound level meter and position the tripod to the predetermined height. Record the microphone height (distance between the microphone and the floor of the bus) on the Interior Noise Test Data Form 7.1-1.
6	TD	Drive the bus, loaded to SLW, on the test track until it has reached normal operating temperature.  <b>NOTE: On vehicles equipped with radiator shutters, the shutter position causing the maximum sound level should be determined prior to the test. The tests should be conducted in such position.</b>
7	TD	Close all windows, doors and other openings.
8	TD	Start the engine and place the transmission in "Drive." Do not move the vehicle. Switch all accessories on, except air conditioning.
9	TP	Position the microphone at the predetermined height, pointing vertically upward at 70 degrees, in the rear most passenger seating position.

**DETAILED TEST PROCEDURES****TITLE: 7. Noise****Procedure 7.1-2****NOMENCLATURE: 7.1 Interior Noise  
Condition 2: 0 to 35 mph Acceleration Test**

<b>OPER STEP</b>	<b>ACTION BY</b>	<b>TEST PREPARATION AND PROCEDURE</b>
10	TD	Accelerate the bus at full throttle from a stationary position to a speed of 35 mph. Visually notify the test personnel when a speed of 35 mph has been reached. Proceed around the test track to the starting position and stop the bus.
11	TP	Observe the sound level while the bus is accelerating to 35 mph. Record the highest measured level, while the bus is accelerating from 0 to 35 mph, on the Interior Noise Test Data Form.
12	TP	Position the microphone at the predetermined height pointing vertically upward at 70 degrees, in the middle of the passenger compartment.
13	TD	Repeat Step 10
14	TP	Repeat Step 11
15	TP	Position the microphone at the predetermined height, pointing vertically upward at 70 degrees, in between the front most passenger seats.
16	TD	Repeat Step 10
17	TP	Repeat Step 11
18	TP	Position the microphone at the predetermined height, pointing vertically upward at 70 degrees, at the driver's position.
19	TD	Repeat Step 10
20	TP	Repeat Step 11
21	TP	Using the sound level calibrator, recheck the calibration value of the sound level meter. If the value has changed by more than $\pm 0.5$ dB(A), recalibrate the meter and repeat all tests since the last calibration.
22	TP	Verify that all test requirements have been completed.

**DETAILED TEST PROCEDURES**

**TITLE: 7. Noise**

**Procedure 7.1-3**

**NOMENCLATURE: 7.1 Interior Noise  
Condition 3: Audible Vibration Test**

**OPER  
STEP**

**ACTION  
BY**

**TEST PROCEDURE**

1

TP

Obtain work order form for this test. Record the bus number, date, temperature, and relative humidity on the Interior Noise Test Data Form 7.1-3.

**NOTE: This test is an "over the road" test. The test segment consists of the sections of roadway between the ABTC and the PSBRTF.**

2

TD

Cycle the air conditioning, and all accessories on and off every 15 minutes during the course of travel.

3

TD

While the bus is operating over the test course, observe the relative magnitude of any resonant vibrations or rattles, giving a description of the location and the conditions under which the event(s) occurred. Record all observations and comments on the Interior Noise Test Data Form 7.1-3.

4

TP

**REVISIONS**

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

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Revision	Description	Date	Approval
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**INTERIOR NOISE TEST DATA FORM**  
**Test Condition 1: 80 dB(A) Stationary White Noise**

Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Speed (mph):	Wind Direction:
Barometric Pressure (in.Hg):	
Initial Sound Level Meter Calibration:    Gchecked by	
Interior Ambient Noise Level dB(A):	Exterior Ambient Noise Level dB(A):
Microphone Height During Testing (in):	

Measurement Location	Measured Sound Level dB(A)	Actual Sound Level dB(A)
Driver's Seat		
Front Passenger Seats		
In Line with Front Speaker		
In Line with Middle Speaker		
In Line with Rear Speaker		
Rear Passenger Seats		

Final Sound Level Meter Calibration:    Gchecked by
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Comments:
Note: Actual sound level is corrected for inside ambient noise level.

**INTERIOR NOISE TEST DATA FORM**  
**Test Condition 2: 0 to 35 mph Acceleration Test**

Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Speed (mph):	Wind Direction:
Barometric Pressure (in.Hg):	
Initial Sound Level Meter Calibration:      Gchecked by	
Interior Ambient Noise Level dB(A):	Exterior Ambient Noise Level dB(A):
Microphone Height During Testing (in):	

Measurement Location	Measured Sound Level dB(A)	Actual Sound Level dB(A)
Driver's Seat		
Front Passenger Seats		
Middle Passenger Seats		
Rear Passenger Seats		

Final Sound Level Meter Calibration:      Gchecked by
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Comments:
Note: Actual sound level is corrected for ambient inside sound level.

**INTERIOR NOISE TEST DATA FORM**  
**Test Condition 3: Audible Vibration Test**

Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Speed (mph):	Wind Direction:
Barometric Pressure (in.Hg):	

Describe the following possible sources of noise and give the relative location on the bus.

Source of Noise	Location	Description of Noise
Engine and Accessories		
Windows and Doors		
Seats and Wheel Chair lifts		

Comment on any other vibration or noise source which may have occurred that is not described above: