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

1. MAINTAINABILITY

1.1 ACCESSIBILITY OF COMPONENTS AND SUBSYSTEMS

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

1.1-I. TEST OBJECTIVE

The objective of this test is to check the general accessibility of components and subsystems. Items that are checked are typically ones that would normally require maintenance or repair during transit service.

1.1-II. TEST DESCRIPTION

Accessibility of components and subsystems will be checked, and where accessibility is restricted then that particular subsystem is to be noted along with the reason for the inaccessibility.

1.1-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.

1.1-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

The equipment and test facilities at the ABTC are used for these tests. Test personnel include:

1. Test personnel(TP)

1.1-V. TEST DATA

The test data consist of the accessibility comments section of the Work Order Forms from all scheduled and unscheduled maintenance and repair. Test data also includes the Accessibility Data Form.

Copies of all records shall be forwarded to the ABTC manager.

1.1-VI. TEST PREPARATION AND PROCEDURE

The detailed test procedures are listed in procedure 1.1-1.

DETAILED TEST PROCEDURES		TITLE: 1. Maintainability
Procedure 1.1-1		**NOMENCLATURE: Accessibility of Components and Subsystems**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	TP	Record the accessibility of all components and subsystems involved in scheduled and unscheduled maintenance and repair on each Work Order Form. Note the part or subsystem and describe any accessibility restrictions.
2	TP	Photograph any accessibility restriction.
3	TP	Fill out the Accessibility Data Form and record comments. Insure all components and subsystems on the form have been checked.
4	TP	Fill out work order for procedure. File completed Accessibility Data Form and work order.

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

ACCESSIBILITY DATA FORM

Bus Number:	Date:

Component	Checked	Comments
ENGINE :		
Oil Dipstick		
Oil Filler Hole		
Oil Drain Plug		
Oil Filter		
Fuel Filter		
Air Filter		
Belts		
Coolant Level		
Coolant Filler Hole		
Coolant Drain		
Spark / Glow Plugs		
Alternator		
Diagnostic Interface Connector		
TRANSMISSION :		
Fluid Dip-Stick		
Filler Hole		
Drain Plug		
SUSPENSION :		
Bushings		
Shock Absorbers		
Air Springs		
Leveling Valves		
Grease Fittings		

ACCESSIBILITY DATA FORM

Bus Number:	Date:

Component	Checked	Comments
HVAC :		
A/C Compressor		
Filters		
Fans		
ELECTRICAL SYSTEM :		
Fuses		
Batteries		
Voltage regulator		
Voltage Converters		
Lighting		
MISCELLANEOUS :		
Brakes		
Handicap Lifts/Ramps		
Instruments		
Axles		
Exhaust		
Fuel System		
OTHERS :		

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

1. MAINTAINABILITY

1.2 SERVICING, PREVENTIVE MAINTENANCE, AND REPAIR AND MAINTENANCE DURING TESTING

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

1.2-I. TEST OBJECTIVE

The objective of this test is to collect maintenance data about the servicing, preventive maintenance, and repair.

1.2.-II. TEST DESCRIPTION

The test will be conducted by operating the bus during the testing period and collecting the following data on Work Order Forms and a Driver Log.

a. Bus number
b. Date
c. Mileage
d. Detailed description of malfunction
e. Repair action and parts used
f. Man-hours required

The bus will be operated in durability service. While typical items are given below, the specific service schedule will be that specified by the manufacturer.

A. Service
   1. Fueling
   2. Consumable checks
   3. Interior cleaning

B. Preventive Maintenance
   4. Brake adjustments
   5. Lubrication
   6. Oil and filter change

C. Periodic Repairs
   1. Brake reline
   2. Transmission change
   3. Engine change
   4. Windshield wiper motor change
   5. Stoplight bulb change

1.2-III. TEST ARTICLE

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

1.2-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

Test equipment and facilities at ABTC are used for this test. In addition, any maintenance done at PSBRTF will be added to the maintenance log. Test personnel include:

1. Test personnel (TP)
2. Bus driver (DR)

1.2-V. TEST DATA

The test data consists of the Work Order Forms for all scheduled and unscheduled maintenance and repair and the Driver Log.

1.2-VI. TEST PREPARATION AND PROCEDURES

The detailed procedures are listed in procedure 1.2-1.

DETAILED TEST PROCEDURES		TITLE: 1. Maintainability
Procedure 1.2-1		**NOMENCLATURE: 1.2 Servicing, Preventative Maintenance, and Repair and Maintenance During Testing**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	TP	Perform all service and maintenance according to the manufacturer's recommended procedures.
2	TP	Fill out Work Order Forms for all servicing, preventative maintenance and repair, and maintenance during testing. Be sure all forms are filled out completely. Provide a detailed description of the failure and repair. In particular, record the parts that are repaired or replaced and the bus mileage at the time of failure. In addition, record diagnostic time, repair time, special tools required, and date.
3	DR	Keep a daily log of all bus activity. In particular, record all bus malfunctions, the date, and the bus mileage at the time of failure. Listen for unusual noises. Record comments on Driver's Log.
4	DR/TP	Note any bus part that is removed from service for an extended period of time for repair or replacement. Attach a tag to any parts that are removed. The tab must include the bus number, date and mileage.
5	TP	Photograph broken or worn parts and any other failures. If new part is available, may want to photograph side by side.
6	TP	File completed test procedure and Work Order Forms.

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

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

1. MAINTAINABILITY

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS

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

1.3-I. TEST OBJECTIVE

The objective of this test is to identify the time required to replace and/or repair selected parts or subsystems.

1.3-II. TEST DESCRIPTION

The test will address components that may be expected to fail or require replacement during the service life of the bus. In addition, any component that fails during the test is included in the data. Components to be included are:

1. Transmission
2. Alternator
3. Starter
4. Batteries
5. Windshield wiper motor

1.3-III. TEST ARTICLE

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

1.3-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

All tests are conducted at the ABTC. Tests are performed by:

1. Test personnel (TP)
2. Driver (DR)

1.3-V. TEST DATA

The Maintainability Evaluation Form is filled out for the items listed in the reliability test procedure section and shall be forwarded to the ABTC manager. When the bus is returned for scheduled or unscheduled maintenance or repair, the form is to be updated for additional repairs and shall be forwarded to the ABTC manager.

1.3-VI. TEST PREPARATION AND PROCEDURES

The detailed test procedures are listed in procedure 1.3-1. This section also includes Maintainability Evaluation Form - 1.3.

DETAILED TEST PROCEDURES		TITLE: 1. Maintainability
Procedure 1.3-1		**NOMENCLATURE: 1.3 Replacement and/or Repair of Selected Subsystems**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	DR	Position the bus into the requested mechanics stall.
2	TP	Record the bus number, date, and test personnel on the Maintainability Evaluation Form. NOTE: Record date, mileage, diagnostic time, repair time, and special tools required, on the Work Order Form for each subsystem. NOTE: Some of the following procedures may need to be performed during the course of testing. If they have been previously evaluated, they do not need to be repeated here as long as all the appropriate information has been recorded on Work Order Forms and the Maintainability Evaluation Form.
3	TP	Remove and replace the transmission. Record the time required and any unusual difficulty.
4	TP	Remove and replace the alternator. Record the time required and any unusual difficulty.
5	TP	Remove and replace the starter. Record the time required and any unusual difficulty.
6	TP	Remove and replace the batteries. Record the time required and any unusual difficulty.
7	TP	Remove and replace the windshield wiper motor. Record the time required and any unusual difficulty.
8	TP	Fill out the Maintainability Evaluation and Work Order Forms.
9	TP	Any time the bus is returned for service or repair, add the components involved to the Maintainability Form.

REVISIONS

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

Revision	Description	Date	Approval

MAINTAINABILITY EVALUATION FORM

Bus Number:

SCHEDULED MAINTENANCE						
Description of Task	Date	Hubodometer Reading	Special Tools Req'd	Diagnostic Time	Repair Time	Total Time

MAINTAINABILITY EVALUATION FORM (continued)

Bus Number:

UNSCHEDULED REPAIRS						
Description of Task	Date	Hubodometer Reading	Special Tools Req'd	Diagnostic Time	Repair Time	Total Time

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

2. RELIABILITY - DOCUMENTATION OF BREAKDOWN AND REPAIR TIMES DURING TESTING

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

2-I. TEST OBJECTIVE

The objective of this test is to evaluate the reliability of the bus by documenting unscheduled breakdowns, repairs, down time, and repair time that occur during testing.

2-II. TEST DESCRIPTION

All breakdowns and repairs that occur during the performance of testing are compiled on the Reliability Data Form. This form summarizes the type of failure, subsystem or part, mileage, and repair time. The failure types will be classified as follow:

1. Class 1: A malfunction that represents a potential crash situation and could lead directly to passenger or driver injury.

2. Class 2: A malfunction that results in test interruption because the bus cannot be operated. Service is discontinued until the bus is repaired at the site of the malfunction or it is towed to a service workshop.

3. Class 3: A malfunction that results in temporary interruption of testing, and the bus must be returned to a service workshop for repair.

4. Class 4: A malfunction that degrades bus operations but does not require immediate removal of the bus from testing.

2-III. TEST ARTICLE

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

2-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

The test facility is the ABTC. Test personnel include:

1. Secretary (SEC)
2. Data Supervisor

2-V. TEST DATA

The type of breakdown, and the accumulated bus mileage at the time of each breakdown will be recorded.

Within each type, breakdowns will be further classified by the specific subsystem or component that failed, e.g., engine, transmission, air conditioning per table 1 in the maintainability procedures. Upon completion of this procedure, all data shall be forwarded to the ABTC manager.

2-VI. TEST PREPARATION AND PROCEDURES

The detailed test preparation and procedures are listed in procedure 2.1-1. This section also includes Reliability Data Form – 2.

DETAILED TEST PROCEDURES		TITLE: 2. Reliability – Documentation of Breakdown and Repair Times During Testing
Procedure 2		NOMENCLATURE: 2. Reliability – Documentation of Breakdown and Repair Times During Testing
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	SEC	Record the bus number, date, and personnel performing the test on the Reliability Data Form.
2	SEC	Fill out the Reliability Data Form on a weekly basis using information obtained from the Work Order Forms for unscheduled repairs and the driver log. Record the down time, man-hours to repair, and the bus mileage at the time of failure under the appropriate subsystem.

REVISIONS

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

Revision	Description	Date	Approval

RELIABILITY DATA FORM

Bus Number:	Date Completed:
Personnel:	

	Failure Type				
	Class 1	Class 2	Class 3	Class 4	
Subsystem	mileage	mileage	mileage	mileage	Manhours
Engine					
Trans-mission					
Air Condi-tioning					
Brakes					
Electrical					

RELIABILITY DATA FORM (page 2)

Bus Number:	Date Completed:
Personnel:	

	Failure Type				
	Class 1	Class 2	Class 3	Class 4	
Subsystem	mileage	mileage	mileage	mileage	Manhours
Steering					
Suspension					
Tires/ Wheels					
Cooling System					
Exhaust System					

RELIABILITY DATA FORM (page 3)

Bus Number:	Date Completed:
Personnel:	

	Failure Type				
	Class 1	Class 2	Class 3	Class 4	
Subsystem	mileage	mileage	mileage	mileage	Manhours

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

3. SAFETY - A DOUBLE-LANE CHANGE (OBSTACLE AVOIDANCE TEST)

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

3-I. OBJECTIVE

The objective of this test is to determine handling and stability characteristics of the bus by measuring the forward speed through a double lane change, obstacle avoidance, course.

3-II. TEST DESCRIPTION

The safety test consists of performing an obstacle avoidance maneuver to evaluate the handling and stability characteristics of a bus. The test is conducted at the PSBRTF on the vehicle dynamics pad. The bus will be driven through a double-lane change course at increasing speeds until the test is determined to be unsafe or a speed of 45 mph is reached. The test will be determined unsafe if the vehicle handling becomes unstable or if any of the tires break contact with the pavement surface.

The layout of the test course will be defined by placing pylons along painted guide lines. The guide lines will mark off two 12 ft center to center lanes with two 100 ft gates, 100 ft apart. The bus will enter the test course in one lane, crossover to the other lane within the 100 ft gate spacing, travel for 100 ft, and then return to the original lane within the next 100 ft gate. This maneuver will be performed standing from both the right-hand and left-hand lanes. The layout of the test course is illustrated in Figure 3.1.

A test run is considered valid if the bus is able to perform the maneuver at a constant speed without deviating from the test course or striking pylons. If the test driver is not able to successfully complete the maneuver because of vehicle instability, the test will be terminated. The highest speed, up to a maximum of 45 mph, at which the maneuver can be successfully performed, will be recorded on the Safety Data Form.

3-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.

3-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

1. Test Equipment

   a. A fifth wheel or non-contacting speed and distance
   b. Ballast to simulate passenger loading to SLW.
   c. Video Camera.

2. Test Facility - The test site is located at the PSBRTF on the vehicle dynamics area. The test site must meet the following conditions:

   a. Dry and free of extraneous surface material
   b. Free of interfering traffic
   c. Wind speed gust < 12 mph
   d. Ambient temperature between 30NF and 90NF

The test site will have two lanes with a 12 ft center to center distance. The test course will be marked with pylons and painted lines as illustrated in Figure 3.1.

3. Test Personnel - This test requires the following personnel:

   a. Test driver (TD)
   b. Test personnel(TP)

3-V. TEST DATA

The test data will consist of the attached Safety Data Form. Upon completion of this test, data shall be forwarded to the ABTC manager.

3-VI. TEST PREPARATION AND PROCEDURES

The detailed test preparation and procedures are listed in procedure 3-1 and 3-2. This section also includes Safety Data Form - 3.

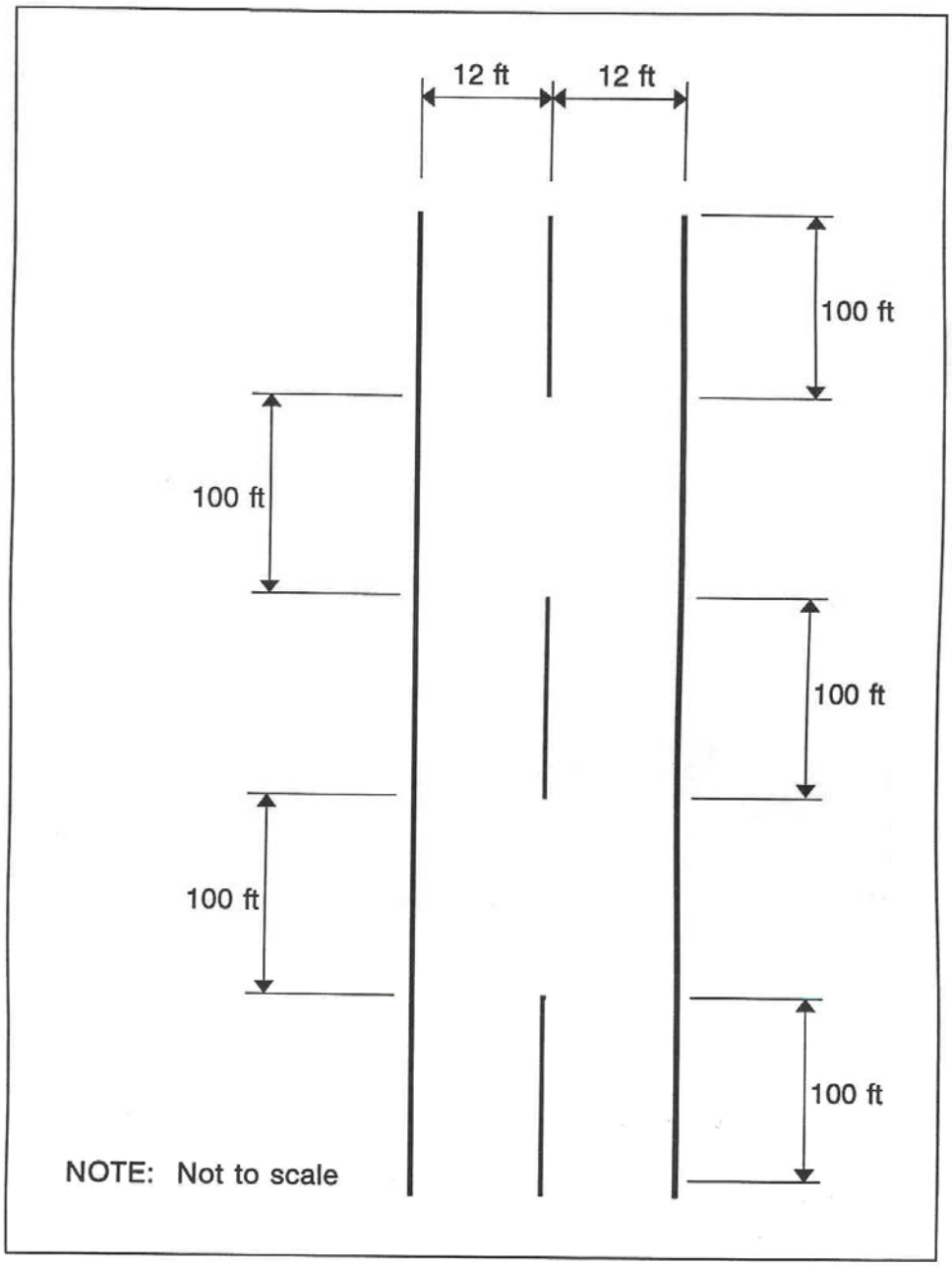


Figure 3.1. Double lane change test course.

DETAILED TEST PROCEDURES		TITLE: Safety – A Double-Lane Change
Procedure 3-1		**NOMENCLATURE: 3. Safety – A Double-Lane Change (Obstacle Avoidance Test)**
OPER STEP	**ACTION BY**	**TEST PREPARATION**
1	TP	Record the bus number, date, and persons performing the test on the data sheet. Retrieve work order form for this test.
2	TD	Fill the fuel tanks.
3	TD	Insure that all tires are properly inflated.
4	TP	Install the speed measuring system on the bus. Install speed indicator in the front of the bus so it is visible to the test driver.
5	TP	Insure that the bus is loaded to SLW minus the weight of TD and equipment.
6	TP	Set up video equipment so that the tire-ground contact patch and the position of the bus can be seen during lane changeover.
7	TD	Drive the bus at least three times around the PSBRTF test track at approximately 45 mph.
8	TP	Make sure the road surface is dry and clean. If not, delay the test until such time that conditions are favorable.
9	TP	Verify the proper configuration of test course and the correct placement of pylons (see figure 3.1).
10	TP	Confirm that all preparations have been completed properly.

DETAILED TEST PROCEDURES		TITLE: Safety – A Double-Lane Change
Procedure 3-1		**NOMENCLATURE: 3. Safety – A Double-Lane Change (Obstacle Avoidance Test)**
OPER STEP	**ACTION BY**	**TEST PROCEDURE**
1	TP	Videotape lane change at an approximately 30 degree angle from the test site at a distance sufficient to capture the tire-ground contact patch as well as the entire bus.
2	TD	Begin in the right lane at 20 mph (as indicated by the speed indicator) and perform the double-lane change maneuver to the left lane and back as marked off by the pylons. Maintain constant speed ($\pm$ 1 mph) throughout the maneuver.
3	TD	Once through the lane change course, safely proceed around the track and return to the beginning of the course at a speed increase of 5 mph from the previous run.
4	TD	Repeat steps 1 and 2 with speed increases of 5 mph until the maneuver is determined to be unsafe by TD and TP or a speed of 45 mph is achieved successfully. NOTE: Do not perform this maneuver at unsafe speeds. The maximum safe speed will be determined by the TD in concurrence with TP.
5	TP	Record the maximum safe speed for the double-lane change to the left on the Safety Data Form.
6	TD	Repeat steps 1 through 3 beginning in the left lane and performing the double-lane change to the right lane and back.
7	TP	Record the maximum safe speed for the double-lane change to the right on the Safety Data Form.
8	TP	Remove all test instrumentation not needed for further testing.
9	TP	Sign the Safety Data Form to indicate completion, including comments on handling braking.
10	TP	File the completed performance data sheet and work order form.

REVISIONS

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

Revision	Description	Date	Approval

SAFETY DATA FORM

Bus Number:	Date:
Personnel:	

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

SAFETY TEST: DOUBLE LANE CHANGE	
Maximum safe speed tested for double-lane change to left	mph
Maximum safe speed tested for double-lane change to right	mph
Comments of the position of the bus during the lane change:	
Comments of the tire/ground contact patch:	

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

4.1 PERFORMANCE - AN ACCELERATION, GRADEABILITY, AND TOP SPEED TEST

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

4-I. TEST OBJECTIVE

The objective of this test is to determine the acceleration, gradeability, and top speed capabilities of the bus.

4-II. TEST DESCRIPTION

In this test, the bus will be operated at SLW on a smooth and level test track. The bus will be accelerated at full throttle from a standstill to a maximum "geared", maximum "governed", or maximum "safe" speed not exceeding 50 mph. The maximum "geared" speed is defined as the limited output capabilities of the test vehicle's engine and drivetrain. The maximum "governed" speed, if applicable, is the top speed as limited by the engine control system. The maximum "safe" speed is defined as the maximum speed that the test course can be traveled without jeopardizing the safety of the test vehicle or its passengers. The test vehicle speed will be measured using a fifth wheel or a non-contacting speed measurement system. The time intervals between 10 mph increments will be measured and recorded using a stopwatch with a lap timer. Time and speed data will be recorded on the performance data form. The recorded data will be used to generate a speed vs time plot and a percent grade versus speed curve. When applicable, the "governed" speed will be recorded. The "ungoverned" speed will be predicted using a hyperbolic curve fit method. The hyperbolic curve fit method will use the speed and time data to extrapolate and to predict the top "ungoverned" speed.

4-III. TEST ARTICLE

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

4-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

1. Test Equipment

    a. A fifth wheel or non-contacting speed and distance measurement system
    b. Ballast to simulate passenger loading (SLW)
    c. Digital stopwatch with lap timer

2. Test Facility - The test site is located at the PSBRTF on the skid pad area and adjoining curves for run in and run out. The test site must meet the following conditions:

    a. Dry and free of extraneous surface material

b. Free of interfering traffic
c. Wind speed gusting less than 12 mph
d. Ambient temperature between 30E F and 90E F

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

a. Test driver (TD)
b. Test personnel (TP)

4-V. TEST DATA

The test data consist of the completed attached Performance Data Form. Upon completion of this test, data shall be forwarded to the ABTC manager.

4-VI. TEST PREPARATION AND PROCEDURES

The detailed test preparation and procedures are listed in procedure 4-1. This section also includes Performance Data Form – 4.

DETAILED TEST PROCEDURES		TITLE: 4. Performance
Procedure 4-1		**NOMENCLATURE: 4. Performance – An Acceleration, Gradeability, and Top Speed Test**
OPER STEP	**ACTION BY**	**TEST PREPARATION**
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 measuring system on the bus at the correct position. Install speed indicator in the front of the bus so it is visible to TP.
3	TP	Load the bus to SLW minus the weight of TP, TD, and equipment.
4	TD	Drive the bus at least three times around the PSBRTF test track at approximately 45 mph.
5	TP	Record the environmental data on the data form. Make sure the road surface is dry and clean. Make sure the temperature is between 30° and 90° F and wind less than 12 mph. If not, delay the test until such time the conditions are favorable.
6	TD	Set the bus accessories as follows: 1. Air conditioning compressor-OFF 2. Ventilation fans-ON HIGH 3. Heater pump motor-OFF 4. Defroster-OFF 5. Exterior and interior lights-ON 6. Windows and doors-CLOSED The driver's window may be left open for comfort. During cold weather, the defroster can be run between tests, but not during test. During warm weather, the A/C may be run between tests, but no during the test.

7	TP	Confirm that all preparations have been completed properly.

DETAILED TEST PROCEDURES		TITLE: 4. Performance
Procedure 4-1		NOMENCLATURE: 4. Performance - An Acceleration, Gradeability, and Top Speed Test
OPER STEP	**ACTION BY**	**TEST PROCEDURE**
1	TP	Turn on the speed measuring instrumentation.
2	TD	With the bus at SLW, drive the bus to the East end of the vehicle dynamics area of the PSBRTF. Position the bus facing west at the beginning of the skid pad. Align front of bus at the pre-designated starting point for the clockwise direction.
3	TP	Reset stopwatch, signal driver to begin test when ready.
4	TD	When the technician signals that he is ready, begin full acceleration from a complete stop. Accelerate at maximum throttle in the bus lane along the skid pad. Continue accelerating along the skid pad until the bus reaches maximum geared speed, maximum safe speed, or maximum governed speed. If maximum geared speed cannot be obtained, continue around the track at a safe speed and enter the skid pad at the last 10mph increment previously obtained and the same gear that was used prior to exiting the skid pad. Accelerate along the skid pad to the next higher 10 mph increment. Decelerate and continue around the track to the beginning of the skid pad; come to a complete stop.
5	TP	Start the stopwatch at the exact moment the bus begins accelerating. Record the elapsed time between 10 mph hour increments on the Performance Data Form.
6	TP/TD	Repeat steps 3 thru 5 twice driving in the same direction (total of three runs). Make sure the starting point is the same for each run.
7	TP/TD	Reverse direction and repeat steps 3 thru 6. Again, start the test with the bus positioned at the predetermined starting point for the counter clockwise direction.
8	TP	Indicate whether the maximum speed was “geared”, “governed”, or “safe” at the bottom of the test data form.
9	SEC	Using the performance computer program, calculate the average time to each speed for each direction from the six test runs and the gradeability calculations.

10	SEC	Using the output from the performance computer program, generate speed vs time plot and the percent grade versus speed curve. Return the output from the performance computer program and plots to ABTC manager.
11	TP	Remove all test instrumentation not needed for future tests.

REVISIONS

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

Revision	Description	Date	Approval

PERFORMANCE DATA FORM

Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Direction:	Wind Speed (mph):
Barometric Pressure (in.Hg):	
Air Conditioning compressor-OFF	_____ Checked
Ventilation fans-ON HIGH	_____ Checked
Heater pump motor-Off	_____ Checked
Defroster-OFF	_____ Checked
Exterior and interior lights-ON	_____ Checked
Windows and doors-CLOSED	_____ Checked

ACCELERATION, GRADEABILITY, TOP SPEED

Counter Clockwise Recorded Interval Times

Speed	Run 1	Run 2	Run 3
10 mph			
20 mph			
30 mph			
40 mph			
Top Test Speed(mph)			

Clockwise Recorded Interval Times

Speed	Run 1	Run 2	Run 3
10 mph			
20 mph			
30 mph			
40 mph			
Top Test Speed(mph)			

The maximum governed speed (mph) obtained from the manufacturer: _____ mph

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 most 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 ^{o}F and 200 ^{o}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.

DETAILED TEST PROCEDURES TITLE:4.2 Braking Performance Test - Stopping Distance and Stability		
Procedure 4.2-1		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.

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

DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability		
Procedure 4.2-1		NOMENCLATURE: Stopping Distance and Stability
OPER STEP	ACTION BY	TEST PREPARATION AT PSBRTF
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: 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. 1. Ambient air temp between 32 ^{o}F & 90 ^{o}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.

DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability		
Procedure 4.2-1		NOMENCLATURE: Stopping Distance and Stability
OPER STEP	ACTION BY	TEST PROCEDURE STOPPING DISTANCE (FULLY LOADED)
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 ^{o}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

DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability		
Procedure 4.2-1		NOMENCLATURE: Stopping Distance and Stability
OPER STEP	ACTION BY	TEST PROCEDURE STABILITY (FULLY LOADED)
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 ^{o}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.

DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Parking Brake		
Procedure 4.2-1		NOMENCLATURE: Stopping Distance and Parking Brake
OPER STEP	ACTION BY	TEST PROCEDURE PARKING BRAKE
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 TP	Shift the vehicle's transmission to neutral. Apply the parking brake. Release the service brake control. 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

DETAILED TEST PROCEDURES TITLE: 4.2. Braking Performance Test - Stopping Distance and Stability		
Procedure 4.2-1		NOMENCLATURE: Stopping Distance and Stability
OPER STEP	ACTION BY	POST TEST PROCEDURE AT ABTC
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 (^{o}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					

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

5. STRUCTURAL INTEGRITY

5.1. STRUCTURAL STRENGTH AND DISTORTION TESTS - STRUCTURAL SHAKEDOWN TEST

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

5.1-I. TEST OBJECTIVE

The objective of this test is to determine certain structural characteristics (e.g., bus frame deflection, permanent structural deformation, etc.) under static loading conditions.

5.1-II. TEST DESCRIPTION

In this test, the bus will be isolated from the suspension by removing the necessary suspension components and blocking the vehicle under the suspension points. The bus will then be loaded and unloaded not more than three times with a distributed load equal to 2.5 times gross load. Gross load is defined as 150 lb for every designed passenger seating position, for the driver, and for each 1.5 sq ft^2 of free floor space. For a distributed load equal to 2.5 times gross load, place a 375 lb load on each seat and on every 1.5 ft^2 of free floor space. The first loading and unloading sequence will "settle" the structure. The second, and third if applicable, loading and unloading sequence will determine the permanent deflection. If the maximum permanent deflection after the second loading and unloading sequence is less than .005 inches, then the third sequence is not needed. Deflections will be measured at various locations during the loading and unloading sequence.

5.1-III. TEST ARTICLE

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

5.1-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

The test will be performed on a smooth level area at the ABTC. The following test equipment is required for this test:

1. Sufficient ballast to provide a distributed load equal to 2.5 times gross load.
2. Displacement gauges with at least .001 inch resolution.
3. Smooth, level area.
4. Support blocks.
5. Three copies of the Structural Shakedown Data Form.

The following personnel are required for this test:

1. Test personnel (TP).

5.1-V. TEST DATA

The test data consist of the Structural Shakedown Data Form. Upon completion of this test, data shall be forwarded to the ABTC manager.

5.1-VI. TEST PREPARATION AND PROCEDURES

Detailed test preparation and procedures are listed in procedure 5.1-1. This section also includes Structural Shakedown Data Form.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.1-1		**NOMENCLATURE: 5.1 Structural Strength and Distortion Tests – Structural Shakedown Test**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	TP	Record the test bus number on the Structural Shakedown Data Form. Retrieve a Work Order Form for this test.
2	TP	Maneuver the bus onto a smooth level surface at the ABTC.
3	TP	Block out the suspension by supporting the bus under the suspension points using the support blocks. Photograph the support blocks in place.
4	TP	Locate and mark at least 10 reference points in a grid pattern covering the entire underside of the bus. Remove dirt and undercoating at each reference point. Indicate the approximate location of the reference points by placing numbers on the data sheet.
5	TP	Record the height of each reference point above the floor on the Structural Shakedown Data Form (A). Photograph the location of each reference point.
6	TP	Load the bus to a distributed load equal to 2.5 times gross load by placing 375 lb at each seating position and on every 1.5 ft^2 of available free floor space.
7	TP	With the bus loaded, measure and record the height of each reference point on the Structural Shakedown Data Form (B). Indicate the loading sequence on data sheet (B).
8	TP	Calculate the deflection at each of the reference points (A-B).
9	TP	Unload the bus.
10	TP	Measure and record the height of each reference point (C).
11	TP	Calculate and record the permanent deflection (A-C).
12	TP	Repeat steps 5 through 11.
13	TP	Repeat steps 5 through 11 if the permanent deflection after the second loading sequence is greater than .005 inches.
14	TP	File the completed Structural Shakedown Data Forms and a Work Order Form.

REVISIONS

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

Revision	Description	Date	Approval

STRUCTURAL SHAKEDOWN DATA FORM

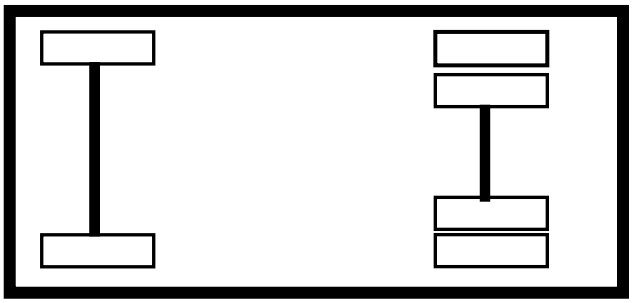
Bus Number:	Date:
Personnel:	Temperature (EF):
Loading Sequence: • 1 • 2 • 3 (check one) Test Load (lbs):	

Indicate Approximate Location of Each Reference Point

Right

Front of Bus

Left



Top View

Reference Point No.	A (in) Original Height	B (in) Loaded Height	A-B (in) Loaded Deflection	C (in) Unloaded Height	A-C (in) Permanent Deflection
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

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

5. STRUCTURAL INTEGRITY

5.2 STRUCTURAL STRENGTH AND DISTORTION TESTS - STRUCTURAL DISTORTION

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

5.2-I. TEST OBJECTIVE

The objective of this test is to observe the operation of various subsystems when the bus is placed in a longitudinal twist (simulating operation over a 6-inch curb or through a 6-inch pothole) and subjected to a water spray mechanism (simulating rain and traffic spray).

5.2-II. TEST DESCRIPTION

With the bus loaded to GVW, each wheel of the bus will be raised (one at a time to simulate operation over a curb) and operation of the following will be inspected:

1. Body
2. Windows
3. Doors
4. Roof vents
5. Special seating
6. Wheelchair lift
7. Engine
8. Service doors
9. Escape hatches
10. Steering mechanism

Each wheel will then be lowered (one at a time to simulate operation through a pothole) and the same items inspected.

5.2-III. TEST ARTICLE

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

5.2-IV. TEST EQUIPMENT/FACILITITES/PERSONNEL

The test will be performed on the structural strength test surface at the ABTC. The area contains a set of ramps, which will be used to alternately raise and lower each of the bus wheels by 6 inches. The following test equipment is needed for this test:

1. The regulated water spray mechanism that simulates rain and traffic spray.
2. Ballast to simulate passenger loading to GVW.

3. Four 6 inch ramps.

4. Ten copies of the Distortion Test Data Form.

Test personnel required for this test include:

1. Test personnel (TP)

5.2-V. TEST DATA

The test data consist of the completed Distortion Test Inspection Form for the ten test orientations. Upon completion of this test, data shall be forwarded to the ABTC manager.

5-2-VI. TEST PREPARATION AND PROCEDURES

The detailed test preparation and procedures are listed in procedure 5.2-1. This section also includes Distortion Test Data Form - 5.2.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.2-1		**NOMENCLATURE: 5.2 Structural Strength and Distortion Tests – Structural Distortion**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE AND PROCEDURE**
1	TP	Record the bus number on the ten separate Structural Integrity Data Forms. Retrieve a Work Order Form for this test.
2	TP	Maneuver the bus onto the structural strength test surface; i.e., all wheels level.
3	TP	Load the bus to gross vehicle weight using ballast. Gross vehicle weight is curb weight plus gross vehicle load.
4	TP	Verify proper operation of the water spray mechanism.
5	TP	Record environmental data on the Distortion Test Inspection Form.
6	TP	Verify that all test prerequisites are satisfied and test preparation steps complete.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.2-1		**NOMENCLATURE: 5.2 Structural Strength and Distortion Tests - Structural Distortion**
OPER STEP	**ACTION BY**	**TEST PROCEDURE**
1	TP	Using a ramp, position the bus so that the left front wheel is 6 inches higher than the other three.
2	TP	Check the appropriate position on a test form.
3	TP	Slowly pass the water spray mechanism over the entire length of the bus.
4	TP	Verify proper operation of the items listed below and record the findings. WINDOWS: Verify that a) All transom windows open and close properly. b) All emergency windows are closed, but will open and close properly c) No windows are cracked or broken. **FRONT DOORS**: Verify that the front doors open and close properly under both normal and emergency controls. **REAR DOORS**: Verify that the rear doors open and close properly under both normal (McKay gate and operator control) and emergency control. **ESCAPE MECHANISMS/ROOF VENTS**: Verify that the roof vents open and close properly. **ENGINE**: Operate the engine in neutral and verify normal operation. **HANDICAPPED DEVICES/SPECIAL SEATING**: Place the special seating in the raised and lowered positions, operate all handicapped equipment and verify proper operation. **UNDERCARRIAGE**: To the extent possible, inspect the undercarriage for cracks, gaps, loose hoses, and other abnormalities.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.2-1		NOMENCLATURE: 5.2 Structural Strength and Distortion Tests – Structural Distortion
OPER STEP	ACTION BY	TEST PROCEDURE
		SERVICE DOORS: Verify that all service doors open and close properly. **BODY:** Inspect the interior and exterior for leaks during the water spray. **WINDOWS/BODY LEAKAGE:** Inspect the interior for leaks during the water spray test. **STEERING MECHANISM:** Verify normal operation.
5	TP	Repeat steps 1 through 4 with the right front wheel 6 inches higher than the other three.
6	TP	Repeat steps 1 through 4 with the right rear wheel 6 inches higher than the other three.
7	TP	Repeat steps 1 through 4 with the left rear wheel 6 inches higher than the other three.
8	TP	Repeat steps 1 through 4 with the left front wheel 6 inches lower than the other three.
9	TP	Repeat steps 1 through 4 with the right front wheel 6 inches lower than the other three.
10	TP	Repeat steps 1 through 4 with the right rear wheel 6 inches lower than the other three.
11	TP	Repeat steps 1 through 4 with the left rear wheel 6 inches lower than the other three.
12	TP	Repeat steps 2 through 4 with all wheels level.
13	TP	File the ten completed Structural Integrity Data Forms and Work Order Form.

REVISIONS

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

Revision	Description	Date	Approval

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number:	Date:
Personnel:	Temperature(EF):

Wheel Position : (check one)		
All wheels level	• before	• after
Left front	• 6 in higher	• 6 in lower
Right front	• 6 in higher	• 6 in lower
Right rear	• 6 in higher	• 6 in lower
Left rear	• 6 in higher	• 6 in lower
Right center	• 6 in higher	• 6 in lower
Left center	• 6 in higher	• 6 in lower

	Comments
• Windows	
• Front Doors	
• Rear Doors	
• Escape Mechanisms/ Roof Vents	
• Engine	
• Handicapped Device/ Special Seating	
• Undercarriage	
• Service Doors	
• Body	
• Windows/ Body Leakage	
• Steering Mechanism	

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

5. STRUCTURAL INTEGRITY

5.3 STRUCTURAL STRENGTH AND DISTORTION TESTS – STATIC TOWING TEST

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

5.3-I. TEST OBJECTIVE

The objective of this test is to determine the strength characteristics of the bus towing fixtures during static loading conditions.

5.3-II. TEST DESCRIPTION

Using a load-distributing yoke, a hydraulic cylinder is used to apply a static tension load equal to 1.2 times the bus curb weight. The load will be applied to both the front and rear (if applicable) towing fixtures at an angle of 20 degrees with the longitudinal axis of the bus. The first test will be a 20 degree pull upward from the longitudinal axis of the bus, and then a 20 degree downward pull from the longitudinal axis of the bus. The bus will then be positioned to one side at an angle of 20 degrees from the longitudinal axis and then to the other. Any deformation or damage to the tow eyes or adjoining structure will be recorded. The bolts that connect the tow eyes and adjoining brackets must be torqued after each test, to the manufactures specification to check for any failure.

5.3-III. TEST ARTICLE

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

5.3-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

This test will be performed on the structural strength test surface at the Test Track. The following test equipment and personnel are required for this test:

1. Static loading fixture
2. Manufacturer provided towing sling
3. Tension measuring load cell apparatus
4. Axle anchoring fixture
5. Test personnel (TP)

5.3-V. TEST DATA

The test data consist of the completed Static Data Test Towing Form. Upon completion of this test, data shall be forwarded to the ABTC manager.

5.3-VI. TEST PREPARATION AND PROCEDURES

Detailed test preparation and procedures are listed in procedure 5.3-1. This section also includes Static Towing Test Data Form - 5.3.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.3-1		NOMENCLATURE: 5.3 Structural Strength and Distortion Tests – Static Towing Test
OPER STEP	**ACTION BY**	**TEST PREPARATION**
1	TP	Record the bus number, date, temperature, and personnel on the data sheet. Retrieve the Work Order Form for this test.
2	TP	Position bus at the proper angle on the structural strength test surface at the ABTC. Consult with NBM manufacturer to determine proper method for anchoring bus. **WARNING:** Make sure bus is properly secured to prevent movement during testing.
3	TP	Attach manufacturer supplies load equalizing towing sling, per manufacturer instructions, to front towing fixtures.
4	TP	Photograph bus in position for tests, also take a close-up photograph of towing sling as attached.
5	TP	Zero the digital readout of the load cell conditioner and check calibration value; adjust if necessary. **WARNING**: Inspect the condition of all cables and towing hardware. Repair or replace any damaged equipment before proceeding with test.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.3-1		**NOMENCLATURE: 5.3 Structural Strength and Distortion Tests – Static Towing Test**
OPER STEP	**ACTION BY**	**TEST PROCEDURE**
1	TP	**WARNING: Stay clear of cable and loading apparatus during test. Failure of loaded mechanism may cause serious personal injury.** Position the bus such that the cable makes angle of 20 degrees upward from the horizontal plane.
2	TP	Inspect towing sling, axle anchoring apparatus, tension measuring device, and tow cable. Ensure that they are secure and properly installed.
3	TP	Using the loading apparatus, slowly apply a load equal to 1.2 times the curb weight of the bus and release. Photograph the procedure (side view).
4	TP	Visually inspect the towing sling, tow eyes, and adjoining structure for damage or permanent deformation. Torque all bolts on tow eyes and adjoining brackets to manufacturer's specifications. Record any deformation, bolt failure, or any structural change that may occur and photograph any damage. **NOTE:** If damage or deformation occurs, terminate test immediately and record observation. If rear towing fixtures are to be tested, then proceed with rear tow test.
5	TP	Reposition the bus such that the cable makes an angle of 20 degrees downward from the horizontal plane.
6	TP	Repeat steps 2 through 4.
7	TP	Reposition the bus such that the cable makes an angle of 20 degrees to the left from the vertical plane.
8	TP	Repeat steps 2 through 4.
9	TP	Reposition the bus such that the cable makes an angle of 20 degrees to the right from the vertical.
10	TP	Repeat steps 2 through 4.
11	TP	Repeat steps 2 through 10 for rear towing fixture when applicable.
12	TP	Complete Static Towing Test Data Form and record observations. File completed data form and work order.

REVISIONS

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

Revision	Description	Date	Approval

STATIC TOWING TEST DATA FORM

Bus Number:	Date:
Personnel:	Temperature (•F):

Inspect right front tow eye and adjoining structure.
Comments:
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments:
Inspect left front tow eye and adjoining structure.
Comments:
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments:
Inspect right rear tow eye and adjoining structure.
Comments:
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments:
Inspect left rear tow eye and adjoining structure.
Comments:
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments:
General comments of any other structure deformation or failure:

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

5. STRUCTURAL INTEGRITY

5.4 STRUCTURAL STRENGTH AND DISTORTION TESTS – 5.5 DYNAMIC TOWING TEST

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

5.4-I. TEST OBJECTIVE

The objective of this test is to verify the integrity of the towing fixtures and determine the feasibility of towing the bus using a heavy-duty wrecker and specified procedures.

5.4-II. TEST DESCRIPTION

This test requires the bus be towed at curb weight using a heavy-duty wrecker and the specified equipment and instructions provided by the manufacturer. The bus will be towed for 5 miles at a speed of 20 mph for each recommended towing configuration. After releasing the bus from the wrecker, the bus will be visually inspected for any structural damage or permanent deformation. All doors, windows and passenger escape mechanisms will be inspected for proper operation.

5.4-III. TEST ARTICLE

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

5.4-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

This test will be performed on the track at the PSBRTF. The following test equipment and personnel are required for this test:

1. Heavy-duty wrecker.
2. Manufacturer supplied towing equipment.
3. Test driver (TD).
4. Test personnel (TP).

5.4-V. TEST DATA

The test data consist of the Dynamic Towing Test Data Form. Upon completion of this test, data shall be forwarded to the ABTC manager.

5.4-VI. TEST PREPARATION AND PROCEDURES

Detailed test preparation and procedures are listed in procedure 5.4-1. This section also includes Dynamic Towing Test Data Form - 5.4.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.4-1		**NOMENCLATURE: 5.4 Structural Strength and Distortion Tests – Dynamic Towing Test**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	TP	Record bus number on the data form. Retrieve the Work Order Form for this test.
2	TP/TD	Attach provided towing fixture to test bus as specified per manufacturer's instructions. Note any difficulty on test data sheet. Photograph fixture as attached (close-up).
3	TP/TD	Attach towing fixture to heavy-duty wrecker and, if required, raise the front wheels of the coach to a height suitable for towing. Note any difficulty on Dynamic Towing Test Data Form. Photograph bus prepared for towing (side view).
4	TP	Remove drive axle shafts or disconnect drive shaft as per manufacturer's recommendations. Ensure brakes are released as per manufacturer's recommendations before towing.
5	TD	Tow bus at a speed of 20 mph for a total of five laps around bus test lane.
6	TP	Repeat steps 2 thru 5 for all other manufacturer recommended towing conditions.
7	TP	Replace drive axle or reconnect drive shaft.
8	TD	Release bus from wrecker.
9	TP/TD	Visually inspect coach for structural damage or permanent deformation.
10	TP/TD	Operate all doors, windows, and escape mechanisms to verify normal operation. Record any malfunctions or damage on test data sheet.
11	TP	File completed Dynamic Towing Test Data Form and Work Order Form.

REVISIONS

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

Revision	Description	Date	Approval

DYNAMIC TOWING TEST DATA FORM

Bus Number:	Date:
Personnel:	

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

Inspect tow equipment-bus interface.
Comments:

Inspect tow equipment-wrecker interface.
Comments:

Towing Comments:

Description and location of any structural damage:

General Comments:

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

5. STRUCTURAL INTEGRITY

5.5 STRUCTURAL STRENGTH AND DISTORTION TESTS - JACKING TEST

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

5.5-I. TEST OBJECTIVE

The objective of this test is to determine the damage caused by a deflated tire, and to determine the feasibility of jacking the bus with a portable hydraulic jack to a height sufficient to replace a deflated tire.

5.5-II. TEST DESCRIPTION

With the bus at curb weight, each tire at one corner of the bus is deflated to simulate a flat tire. A portable hydraulic floor jack is then positioned in a manner and location specified by the manufacturer. The jack is used to raise the bus to a height sufficient to provide 3 inches clearance between the floor and an inflated tire. The deflated tire is then inflated to the tires specification and the jack is lowered. Any structural damage or permanent deformation is recorded on the Jacking Test Data Form. This procedure is repeated for each jacking point on the bus.

5.5-III. TEST ARTICLE

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

5.5-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

This test will be performed on the structural strength test surface at the ABTC. The following test equipment and personnel are required for this test:

1. A floor jack.
2. Tire-valve core tool
3. Tire inflation gauge
4. Air compressor.
5. Test personnel (TP).

5.5-V. TEST DATA

The test data consists of the Jacking Test Data Form. Upon completion of this test, data shall be forwarded to the ABTC manager.

5.5-VI. TEST PREPARATION AND PROCEDURES

Detailed test preparation and procedures are listed in procedure 5.5-1. This section also includes Jacking Test Data Form - 5.5.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.5-1		**NOMENCLATURE: 5.5 Structural Strength and Distortion Tests – Jacking Test**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	TP	With bus at curb weight, position it on the structural strength test surface and apply the parking brake.
2	TP	Record bus number on the Jacking Test Data Form. Retrieve the work order for this test.
3	TP	Remove the tire-valve core and make sure the tire deflates completely. **Note:** The bead on the tire may break, but this is expected. The tire should be sealed and inflated.
4	TP	Check for damage due to the deflated tire and measure the clearance at the jack point.
5	TP	Position jack under right front jacking pad as per manufacturer instructions. **WARNING:** Use extreme caution when jacking or working around raised bus.
6	TP	Jack the bus to a height sufficient to provide 3 inches of clearance between the floor and an inflated tire.
7	TP	Reseal the tire (if applicable) and inflate the tire to the manufacturer’s specifications.
8	TP	Lower jack and remove.
9	TP	Record any difficulty in interfacing the jack with the bus, or in jacking the bus, on the Jacking Test
10	TP	Date Form. Photograph any restrictions.
11	TP	Repeat steps 3 through 7 for left front tire.
12	TP	Repeat steps 3 through 7 for right outside rear tire.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.5-1		**NOMENCLATURE: 5.5 Structural Strength and Distortion Tests – Jacking Test (continued)**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
13	TP	Repeat step 11 for left outside rear tire.
14	TP	Repeat step 12 for both left rear tires.
15	TP	If bus is equipped with an additional axle, repeat steps 11 through 14 as necessary.
16	TP	File completed Jacking Test Data Form and Work Order Form.

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

JACKING TEST DATA FORM

Bus Number:	Date:
Personnel:	Temperature (EF):

Record any permanent deformation or damage to bus as well as any difficulty encountered during jacking procedure.

Deflated Tire	Jacking Pad Clearance Body/Frame (in)	Jacking Pad Clearance Axle/Suspension (in)	Comments
Right front			
Left front			
Right rear--outside			
Right rear--both			
Left rear--outside			
Left rear--both			
Right middle or tag--outside			
Right middle or tag--both			
Left middle or tag--outside			
Left middle or tag--both			

Additional comments of any deformation or difficulty during jacking:

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

5. STRUCTURAL INTEGRITY

5.6 STRUCTURAL STRENGTH AND DISTORTION TESTS - HOISTING TEST

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

5.6-I. TEST OBJECTIVE

The objective of this test is to determine possible damage or deformation caused by the jack stands on the jacking pads.

5.6-II. TEST DESCRIPTION

With the bus at curb weight, the front end of the bus is raised to a height sufficient to allow manufacturer-specified placement of jack stands under the axles or jacking pads independent of the hoist system. The bus will be checked for stability on the jack stands and for any damage to the jacking pads or bulkheads. The procedure is repeated for the rear end of the bus. The procedure is then repeated for the front and rear simultaneously.

5.6-III. TEST ARTICLE

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

5.6-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

This test will be performed on a smooth level surface at the ABTC. The following test equipment and personnel are required for this test:

1. Mobile post hoists as required.
2. Heavy-duty jack stands.
3. Test personnel (TP).

5.6-V. TEST DATA

The test data consist of the Hoisting Test Data Form. Upon completion of this test, data shall be forwarded to the ABTC manager.

5.6-VI. TEST PREPARATION AND PROCEDURES

Detailed test preparation and procedures are listed in procedure 5.6-1. This section also includes Hoisting Test Data Form - 5.6.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.6-1		**NOMENCLATURE: 5.6 Structural Strength and Distortion Tests – Hoisting Test**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
1	TP	Record bus number on data form. Retrieve the work order for this test.
2	TP	With the bus at curb weight, position the bus on a smooth level test surface.
3	TP	Place hoists under each of the front wheels. **WARNING:** Use extreme caution when hoisting bus. Beware of possible instability.
4	TP	Using the hoists, raise the bus to a height sufficient to allow placement of jack stands under the jack pads or axles as specified by the manufacturer.
5	TP	Check the entire bus for possible instability while on the hoist.
6	TP	Place jack stands under the axles or jacking pads as specified by the manufacturer.
7	TP	Using the hoists, lower the bus onto the jack stands.
8	TP	Inspect the jack stand/bus contact; check for instability, structural deformation, or damage to the jacking pads or axles. Photograph bus on jack stands.
9	TP	Raise the bus and remove the jack stands.
10	TP	Lower the bus and remove the mobile hoist.
11	TP	Place a mobile hoist under each of the rear wheels.
12	TP	Repeat steps 4 through 10.
13	TP	Place mobile hoist under all wheels and repeat steps 4 thru 10.
14	TP	Record any problems or comments on the Hoisting Test Data Form. File the completed Hoisting Test Data Form and Work Order Form.

REVISIONS

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

Revision	Description	Date	Approval

HOISTING TEST DATA FORM

Bus Number:	Date:
Personnel:	Temperature (EF):

Comments of any structural damage to the jacking pads or axles while both the front wheels are supported by the jack stands:
Comments of any structural damage to the jacking pads or axles while both the rear wheels are supported by the jack stands:
Comments of any structural damage to the jacking pads or axles while both the front and rear wheels are supported by the jack stands:

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

5. STRUCTURAL INTEGRITY

5.7 STRUCTURAL DURABILITY TEST

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

5.7-I. TEST OBJECTIVE

The objective of this test is to perform an accelerated durability test that approximates up to 25 percent of the service life of the vehicle.

5.7-II. TEST DESCRIPTION

The test article is driven a total of 15,000 miles; approximately 12,500 miles on the PSBRTF durability test track and approximately 2,500 miscellaneous other miles. The durability test track consists of seven different stress elements that subject the bus to the types of events expected to be encountered during transit service. Figures 5.7-1 through 5.7-8 provide a detailed profile for each stress element located on the durability test track. The test will be conducted with the bus operated under three different loading conditions. The first segment will consist of approximately 6,500 miles with the bus operated at GVWR. The second segment will consist of approximately 2,000 miles with the bus operated at SLW. The remainder of the test, approximately 6,500 miles, will be conducted with the bus loaded to CW. If GVWR exceeds the axle design weights, then the load will be adjusted to the axle design weights and the change will be recorded. All subsystems are run during these tests in their normal operating modes. All recommended manufacturers servicing is to be followed and noted on the vehicle maintainability log. Servicing items accelerated by the durability tests will be compressed by 10:1; all others will be done on a 1:1 mi basis. Unscheduled breakdowns and repairs are recorded on the same log as are any unusual occurrences as noted by the driver. Once a week the test article shall be washed down and thoroughly inspected for any signs of failure.

5.7-III. TEST ARTICLE

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

5.7-IV. TEST EQUIPMENT/FACILITIES/PERSONNEL

This test is run on the durability facility and high speed lane at the PSBRTF. Test personnel consist of the following:

1. Test track manager (TM)
2. Bus driver (DR)
3. Test personnel (TP)

5.7-V. TEST DATA

The test data consists of keeping the vehicle log for miles and hours driven on the durability or high-speed lanes. In addition the vehicle maintainability log is updated with Work Order Forms when any breakdown or any maintenance is required. Data shall be forwarded to the ABTC manager on a weekly basis.

5.7-VI. TEST PREPARATION AND PROCEDURES

The detailed test preparation and procedures are listed in procedure 5.7-1.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.7-1		**NOMENCLATURE: 5.7 Structural Durability Test**
OPER STEP	**ACTION BY**	**TEST PREPARATION**
1	TP	Record the test bus number on the vehicle log.
2	TP	Record the bus mileage as delivered on the vehicle log.
3	TP	Load the bus with a distributed load appropriate for the particular test segment.
4	DR	Deliver the bus to the PSBRTF and record the mileage on the vehicle log.

DETAILED TEST PROCEDURES		TITLE: 5. Structural Integrity
Procedure 5.7-1		**NOMENCLATURE: 5.7 Structural Durability Test**
OPER STEP	**ACTION BY**	**TEST PROCEDURE**
	TP	Take photographs of the bus on the durability lane (both side view and head on view).
1	TM	Check bus logs each day. Determine whether the required mileage has been reached for the particular load, and if so, arrange to change load.
2	TM	Check bus logs to see if bus must be scheduled for servicing, and, if so, fill out a Work Order Form and arrange for the bus to be taken to ABTC.
3	DR	Inspect the bus at the beginning of each shift or as necessary for safety, all subsystems operational, and signs of structural failure. Inspect ballast and adjust as necessary to ensure proper weight distribution. Record descriptions on the vehicle log and any repairs on a Work Order Form.
4	DR	Operate the bus as per the established driving schedule, running at 20 mph except for the 4 by 4 sections that are run at 5 mph, the staggered bumps that are run at 10 mph, and the 6-in high full-width bump that is run at 8 mph.
5	DR	In accordance with the established driving schedule, operate all subsystems; e.g., open and close all doors, operate all lights, windshield washer and wipers, chairlifts, etc., depending on the equipment on the bus. Check the suspension components. Photograph any damage that occurs.
6	DR	Repeat steps 3 thru 5 each time you drive again.
7	DR	After turning the bus over to the next driver, fill out your driving log and note anything unusual.

REVISIONS

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

Revision	Description	Date	Approval

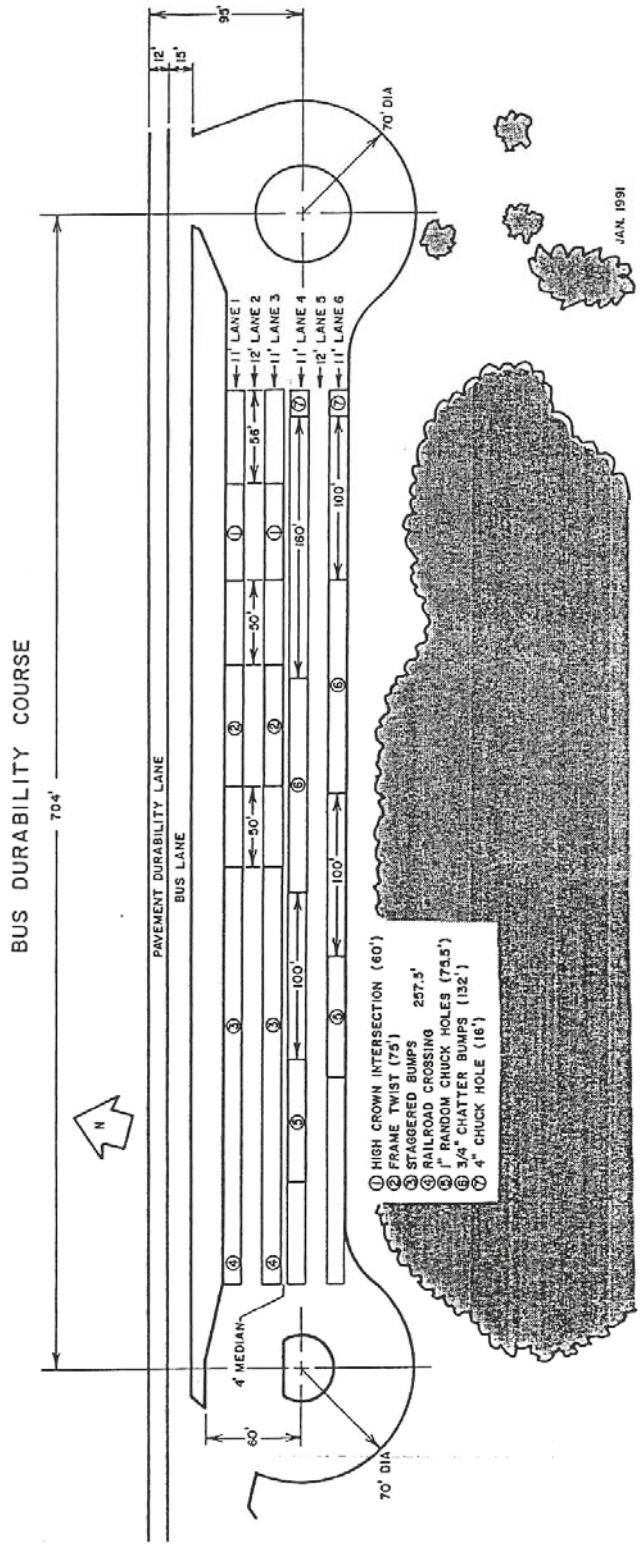


Figure 5.7-1. Plan view of the PSBRTF durability test track.

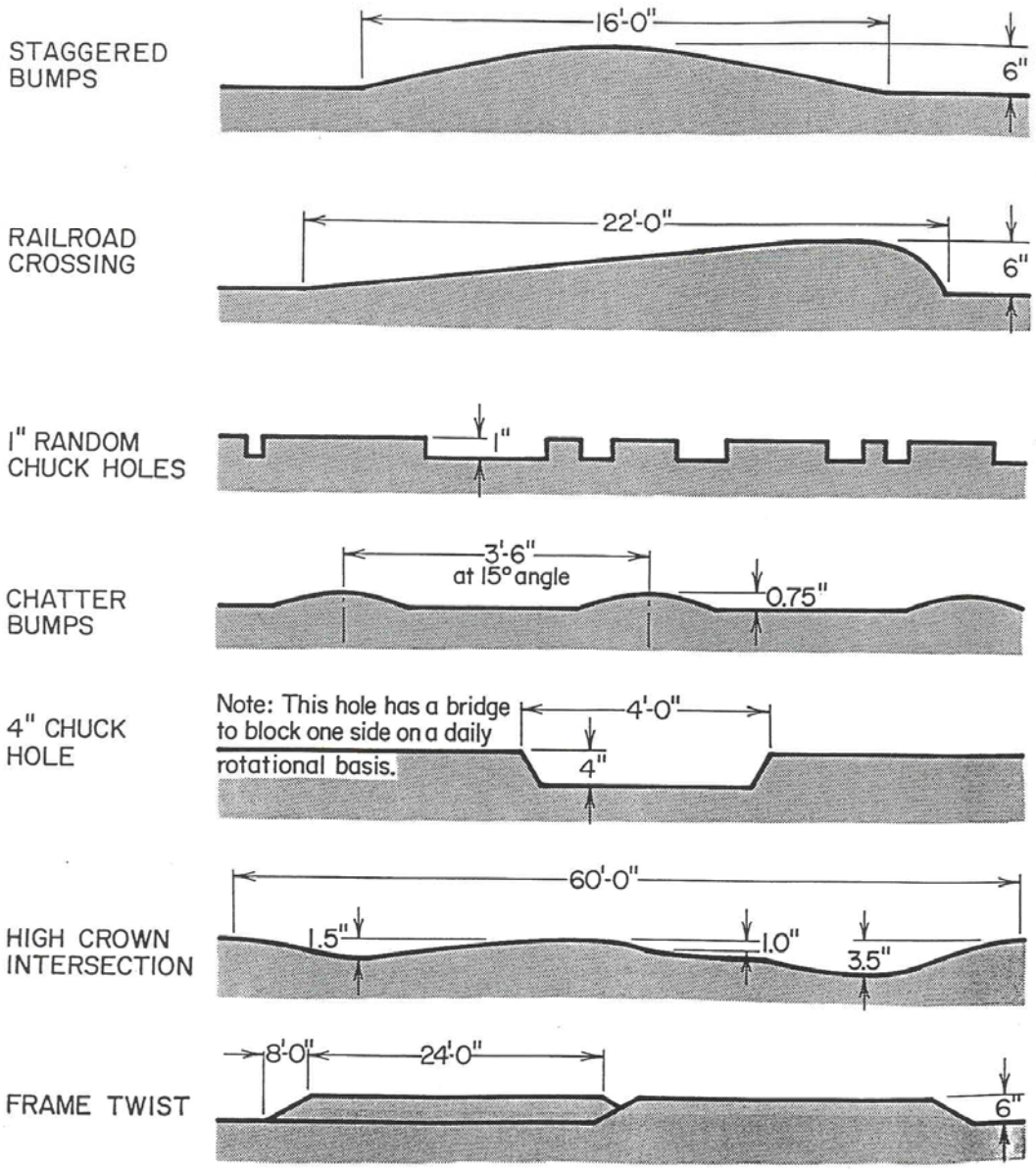


Figure 5.7-2. Side view of stress elements.

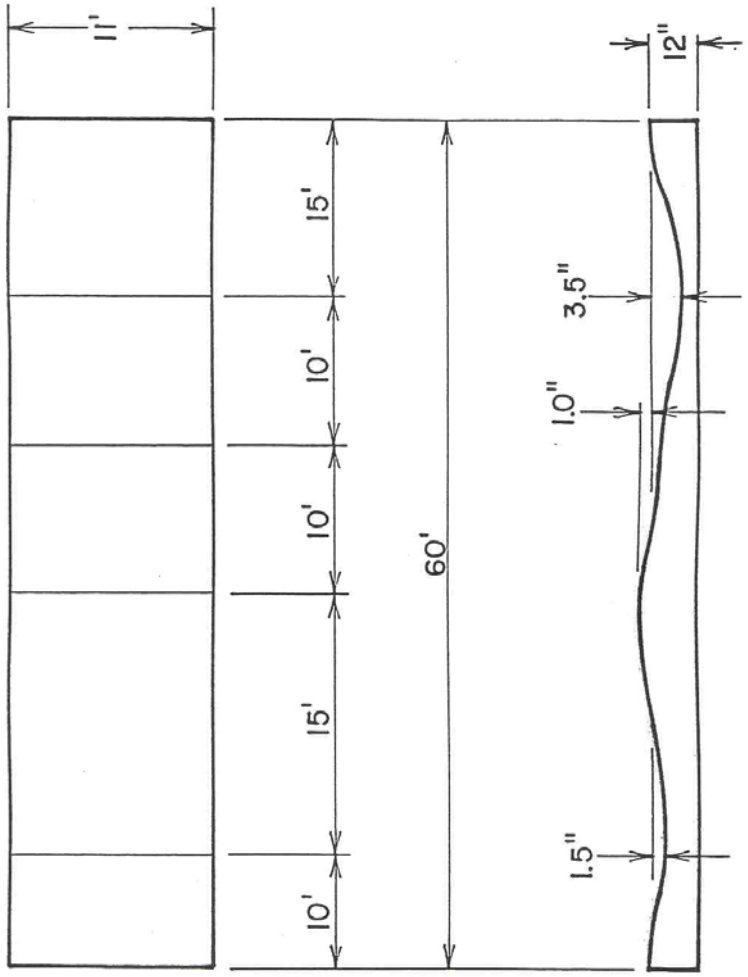

11'
12"
15'
10'
10'
15'
10'
60'
3.5"
1.0"
1.5"
ELEMENT 1 -- HIGH CROWN INTERSECTION

Figure 5.7-3

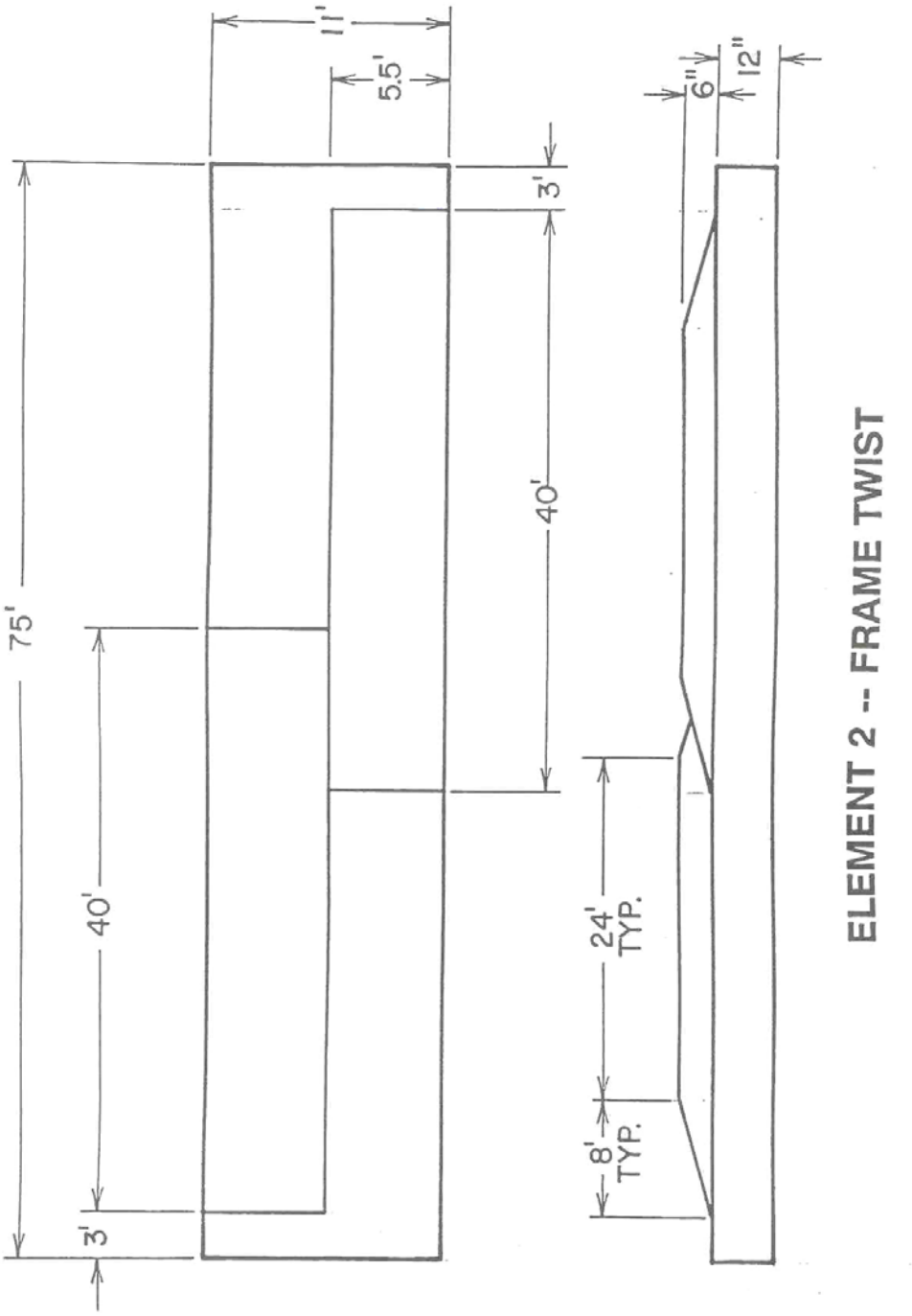


Figure 5.7-4.

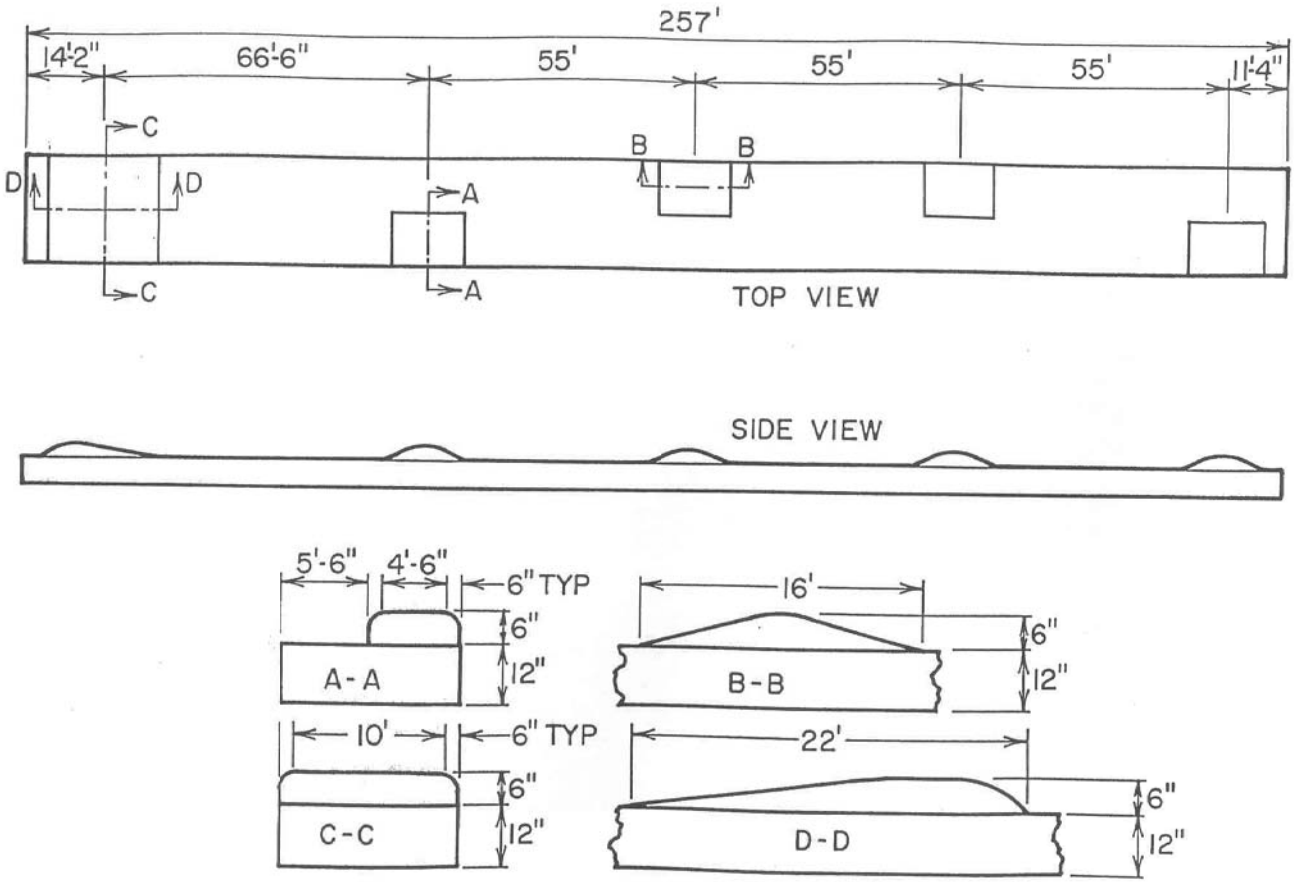
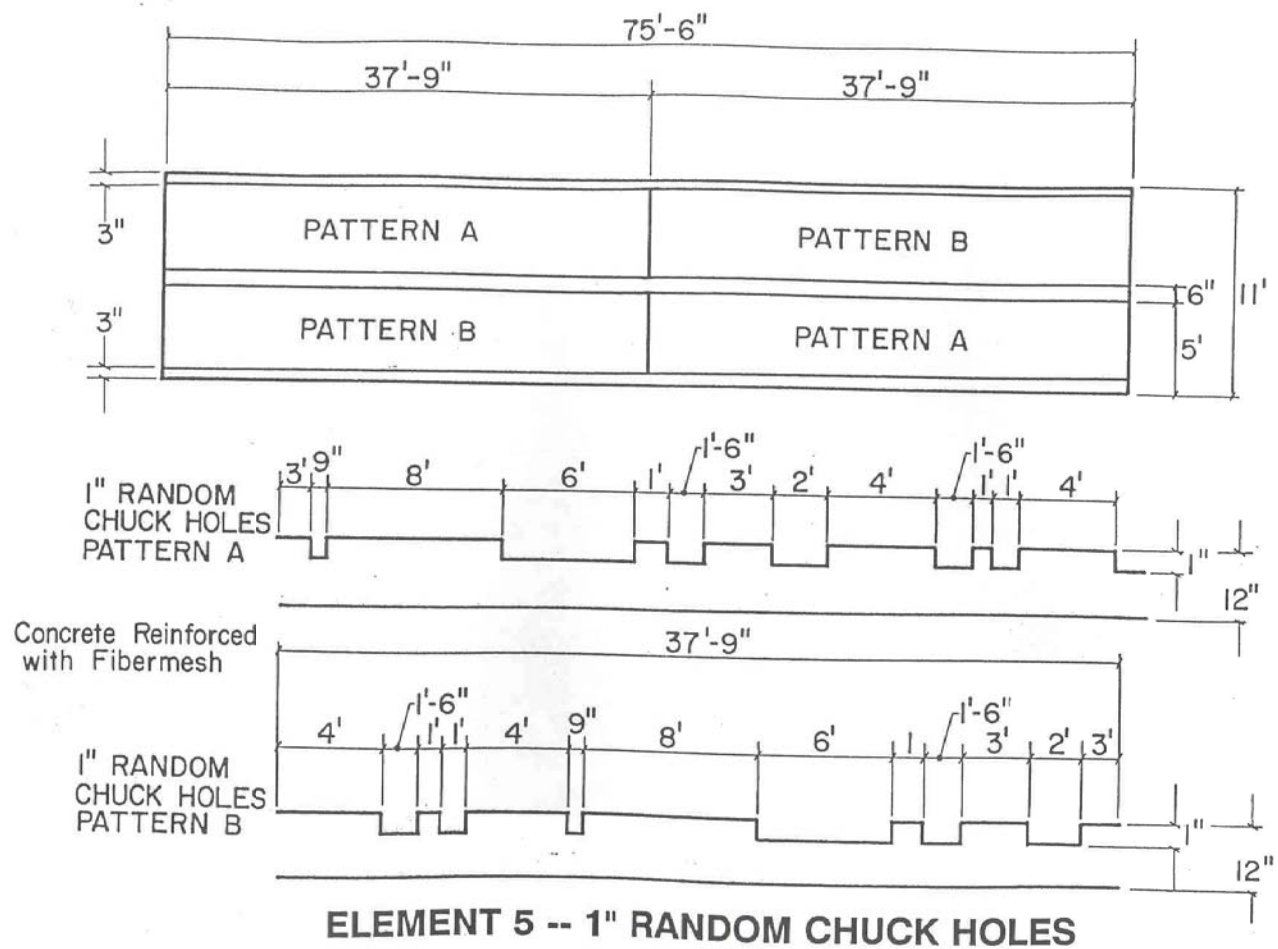


Figure 5.7-5.

ELEMENT 3 -- STAGGERED BUMPS
ELEMENT 4 -- RAILROAD CROSSING



ELEMENT 5 -- 1" RANDOM CHUCK HOLES

Figure 5.7-6.

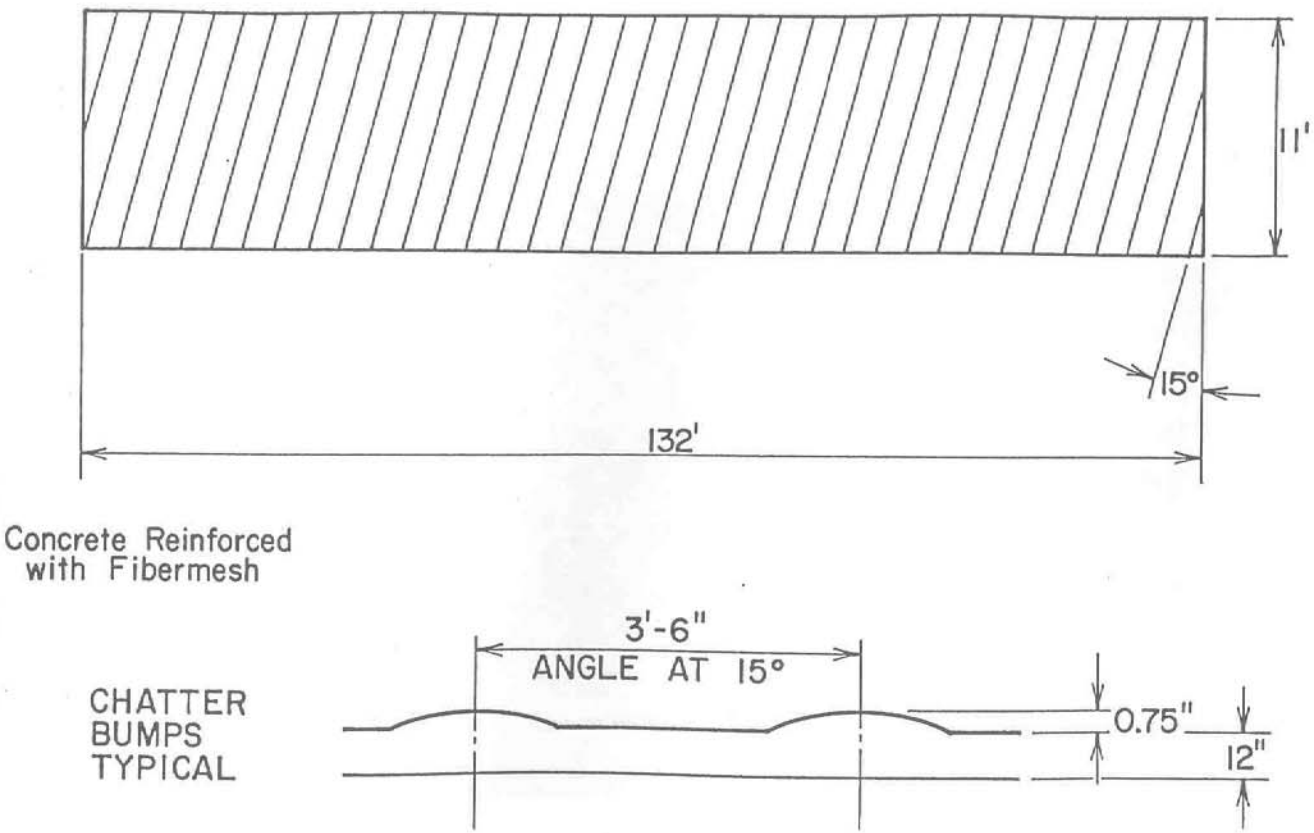


Figure 5.7-7.

ELEMENT 6 -- 3/4" CHATTER BUMPS

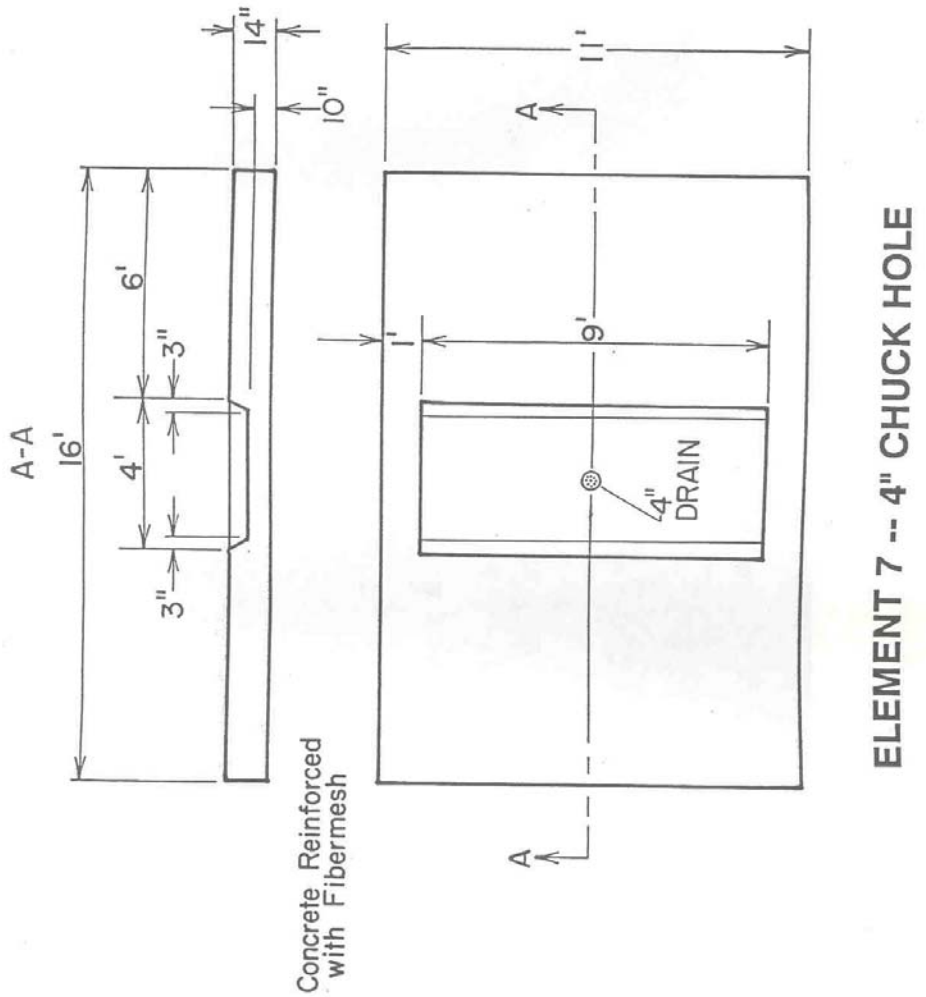

A-A
16'
6'
4'
3"
3"
14"
10"
Concrete Reinforced
with Fibermesh
11'
A
A
1'
9'
4"
DRAIN
ELEMENT 7 -- 4" CHUCK HOLE

Figure 5.7-8.

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

6. FUEL ECONOMY TEST - A FUEL CONSUMPTION TEST USING AN APPROPRIATE OPERATING CYCLE

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

6-I. TEST OBJECTIVE

The objective of this test is to provide accurate comparable fuel consumption data on transit buses produced by different manufacturers. This fuel economy test bears no relation to the calculations done by the Environmental Protection Agency (EPA) to determine levels for the Corporate Average Fuel Economy Program. EPA's calculations are based on tests conducted under laboratory conditions intended to simulate city and highway driving. This fuel economy test, as designated here, is a measurement of the fuel expended by a vehicle traveling a specified test loop under specified operating conditions. The results of this test will not represent actual mileage but will provide data that can be used by recipients to compare buses tested by this procedure.

6-II. TEST DESCRIPTION

This test requires operation of the bus over a course based on the Transit Coach Operating Duty Cycle (ADB Cycle) at seated load weight using a procedure based on the Fuel Economy Measurement Test (Engineering Type) For Trucks and Buses: SAE 1376 July 82. The procedure has been modified by elimination of the control vehicle and by modifications as described below. The inherent uncertainty and expense of utilizing a control vehicle over the operating life of the facility is impractical.

The fuel economy test will be performed as soon as possible (weather permitting) after the completion of the GVW portion of the structural durability test. It will be conducted on the bus test lane at the PSBRTF. Signs are erected at carefully measured points which delineate the test course. A test run will comprise 3 CBD phases, 2 Arterial phases, and 1 Commuter phase. An electronic fuel measuring system will indicate the amount of fuel consumed during each phase of the test. The test runs will be repeated until there are at least two runs in both the clockwise and counterclockwise directions in which the fuel consumed for each run is within ± 4 percent of the average total fuel used over the 4 runs. A 20-minute idle consumption test is performed just prior to and immediately after the driven portion of the fuel economy test. The amount of fuel consumed while operating at normal/low idle is recorded on the Fuel Economy Data Form. This set of four valid runs along with idle consumption data comprise a valid test.

The test procedure is the ADB cycle with the following four modifications:

1. The ADB cycle is structured as a set number of miles in a fixed time in the following order: CBD, Arterial, CBD, Arterial, CBD, Commuter.

A separate idle fuel consumption measurement is performed at the beginning and end of the fuel economy test. This phase sequence permits the reporting of fuel consumption for each of these phases separately, making the data more useful to bus manufacturers and transit properties.

2. The operating profile for testing purposes shall consist of simulated transit type service at seated load weight. The three test phases (figure 6-1) are: a central business district (CBD) phase of 2 miles with 7 stops per mile and a top speed of 20 mph; an arterial phase of 2 miles with 2 stops per mile and a top speed of 40 mph; and a commuter phase of 4 miles with 1 stop and a maximum speed of 40 mph. At each designated stop the bus will remain stationary for seven seconds. During this time, the passenger doors shall be opened and closed.

3. The individual ADB phases remain unaltered with the exception that 1 mile has been changed to 1 lap on the PSBRTF track. One lap is equal to 5,042 feet. This change is accommodated by adjusting the cruise distance and time.

4. The acceleration profile, for practical purposes and to achieve better repeatability, has been changed to "full throttle acceleration to cruise speed".

Several changes were made to the Fuel Economy Measurement Test (Engineering Type) For Trucks and Buses: SAE 1376 July 82:

1. Sections 1.1, and 1.2 only apply to diesel, gasoline, methanol, and any other fuel in the liquid state (excluding cryogenic fuels).

   1.1 SAE 1376 July 82 requires the use of at least a 16-gal fuel tank. Such a fuel tank when full would weigh approximately 160lb. It is judged that a 12-gal tank weighing approximately 120 1b will be sufficient for this test and much easier for the test personnel to handle.

   1.2 SAE 1376 July 82 mentions the use of a mechanical scale or a flowmeter system. This test procedure uses a load cell readout combination that provides an accuracy of 0.5 percent in weight and permits on-board weighing of the gravimetric tanks at the end of each phase. This modification permits the determination of a fuel economy value for each phase as well as the overall cycle.

2. Section 2.1 applies to compressed natural gas (CNG), liquefied natural gas (LNG), cryogenic fuels, and other fuels in the vapor state.

   2.1 A laminar type flowmeter will be used to determine the fuel consumption. The pressure and temperature across the flow element will be monitored by the flow computer. The flow computer will use this data to calculate the gas flow rate. The flow computer will also display the flow rate (scfm) as well as the total fuel used (scf). The total fuel used (scf) for each phase will be recorded on the Fuel Economy Data Form.

3. Use both sections 1 and 2 for dual fuel systems.

6-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.

6-IV. TEST EQUIPMENT

A. The following describes the equipment used for diesel, gasoline, methanol, and any other fuel in the liquid state (excluding cryogenic fuels).

Note: A fire extinguisher must be present during testing.

A fuel flow meter (shown in figure 6-2) is used to measure the fuel consumption. The fuel flow systems calculate fuel flow based on the known displacement of four precision engineered cylinders. Hall sensors located around the crankshaft transform each piston stroke into a pulse signal proportional to fuel consumption. A magnet integrated into the crankshaft works with the non-contact Hall sensors to produce the signals. A data acquisition computer is used to convert the Hall sensors signals to gallons of fuel used. A digital display is mounted on the windshield to display fuel used, speed, distance and test time. A thermocouple is placed inline with the fuel from the tank. The system consists of the following important components.

1. Corrsys-Datron DFL-1 Fuel Flow Meter (Gasoline)
2. Corrsys-Datron DFL-3 Fuel Flow Meter (Diesel)
3. Corrsys-Datron DAQ computer
4. Thermocouple and digital display

B. The following describes the equipment used for CNG, LNG, cryogenic fuels or any other fuel that is stored in the vapor state.

Note: A fire extinguisher must be present during testing.

The methods for storing CNG and LNG on-board a vehicle are vastly different; CNG is stored as a very high pressure gas, and LNG as a cryogenic liquid. These differences and the safety considerations associated with handling the stored fuels render gravimetric measurement systems for CNG and LNG impractical.

Although their methods of storage are quite different, both CNG and LNG systems deliver the fuel to the engine in the vapor state. This

procedure exploits this commonality between the two systems by using a flow measurement device in series with the fuel line, just prior to delivery to the engine. The flow measurement system uses a computer to compensate for pressure and temperature variations. The flow computer uses the ideal gas law to calculate and display the flow rate in standard cubic feet per minute (SCFM) and total fuel consumed in standard cubic feet (SCF). The system consists of the following important components:

1. Laminar flow element: AccuRa Flow Element Model LFE-0100/40 scfm
2. Differential Pressure Transducer: Viatran Model 574-24-0
3. Flow Computer
4. RTD Temperature Sensor

6-V. FACILITIES/PERSONNEL

The fuel economy test is performed on the bus lane of the PSBRTF. This test requires the following personnel:

1. Test driver (TD)
2. Test personnel (TP)

6-VI. TEST PREPARATION AND PROCEDURES

All vehicles are prepared for testing in accordance with the Fuel Economy Pre-Test Maintenance Form. This is done to ensure that the bus is tested in optimum operating condition. The manufacturer-specified preventive maintenance shall be performed before this test. Any manufacturer-recommended changes to the pre-test maintenance procedure must be noted on the revision sheet. The Fuel Economy Pre-Test Inspection Form will also be completed before making a test run. Both the Fuel Economy Pre-Test Maintenance Form and the Fuel Economy Pre-Test Inspection Form are found on the following pages.

Warm-up consists of driving the bus for one hour on the bus lane at the PSBRTF. The course layout is defined by green, yellow, and red signs for accelerate, decelerate, and stop points respectively; while different shaped signs delineate the Commuter, Arterial, and CBD cycles of the test. The test personnel coaches the driver through the course along with recording cycle run times, fuel temperature, fuel consumption data, and weather conditions using the Fuel Economy Data Form.

All buses are tested at SLW. The base line fuel economy data are obtained at the following conditions:

1. Air conditioning off
2. Evaporator fan or ventilation fan on
3. Seated load weight
4. Appropriate test fuel with energy content (BTU/LB) noted on Fuel Economy Data Form
5. Exterior and interior lights on
6. Heater Pump Motor off
7. Defroster off
8. Windows and Doors closed

The test tanks or the bus fuel tank(s) will be filled prior to the fuel economy test with the appropriate grade of test fuel. The fuel economy test is started adjacent to the entrance of the bus lane with the front of the bus aligned with the white triangular sign. After the cycle is complete, the total fuel used will be recorded on the Fuel Economy Data Form.

See figures 6-1, 6-2, and 6-3, and the three forms, which follow.

6-VI. FUEL ECONOMY CALCULATION PROCEDURE

A. For diesel, gasoline, methanol and fuels in the liquid state.

The reported fuel economy is based on the following: measured test quantities--distance traveled (miles) and fuel consumed (pounds); standard reference values--density of water at 60•F (8.3373 lbs/gal) and volumetric heating value of standard fuel; and test fuel specific gravity (unitless) and volumetric heating value (BTU/gal). These combine to give a fuel economy in miles per gallon (mpg) which is corrected to a standard gallon of fuel referenced to water at 60•F. This eliminates fluctuations in fuel economy due to fluctuations in fuel quality. This calculation has been programmed into a computer and the data processing is performed automatically.

The fuel economy correction consists of three steps:

1.) Divide the number of miles of the phase by the number of pounds of fuel consumed

phase	miles per phase	total miles per run
CBD	1.9097	5.7291
ART	1.9097	3.8193
COM	3.8193	3.8193

$$\mathbf{FEo_{mi/lb}} = \text{Observed fuel economy} = \frac{\text{miles}}{\text{lb of fuel}}$$

2.) Convert the observed fuel economy to miles per gallon [mpg] by multiplying by the specific gravity of the test fuel Gs (referred to water) at 60•F and multiply by the density of water at 60•F

$$\mathbf{FEo_{mpg}} = \mathbf{FEc_{mi/lb}} \times Gs \times Gw$$

where **Gs** = Specific gravity of test fuel at 60•F (referred to water)
Gw = 8.3373 lb/gal

3.) Correct to a standard gallon of fuel by dividing by the volumetric heating value of the test fuel (H) and multiplying by the volumetric heating value of standard reference fuel (Q). Both heating values must have the same units.

$$\mathbf{FEc} = \mathbf{FEo_{mpg}} \times \frac{Q}{H}$$

where

H = Volumetric heating value of test fuel [BTU/gal]
Q = Volumetric heating value of standard reference fuel

Combining steps 1-3 yields

$$\Rightarrow \quad FEc = \frac{\text{miles}}{\text{lbs}} \times (Gs \times Gw) \times \frac{Q}{H}$$

4.) Covert the fuel economy from mpg to an energy equivalent of miles per BTU. Since the number would be extremely small in magnitude, the energy equivalent will be represented as miles/BTUx10^6.

Eq = Energy equivalent of converting mpg to mile/BTUx10^6.

$$Eq = ((mpg)/(H))x10^6$$

B. CNG, LNG, cryogenic and other fuels in the vapor state.

The reported fuel economy is based on the following: measured test quantities--distance traveled (miles) and fuel consumed (scf); density of test fuel, and volumetric heating value (BTU/lb) of test fuel at standard conditions (P=14.73 psia and T=60 •F). These combine to give a fuel economy in miles per lb. The energy equivalent (mile/BTUx10^6) will also be provided so that the results can be compared to buses that use other fuels.

1.) Divide the number of miles of the phase by the number of standard cubic feet (scf) of fuel consumed.

phase	miles per phase	total miles per run
CBD	1.9097	5.7291
ART	1.9097	3.8193
COM	3.8193	3.8193

$$\mathbf{FEo_{mi/scf}} = \text{Observed fuel economy} = \frac{\text{miles}}{\text{scf of fuel}}$$

2.) Convert the observed fuel economy to miles per lb by dividing FEo by the density of the test fuel at standard conditions (Lb/ft^3).

Note: The density of test fuel must be determined at standard conditions as described above. If the density is not defined at the above standard conditions, then a correction will be needed before the fuel economy can be calculated.

$$\mathbf{FEo}_{mi/lb} = FEo / Gm$$

where Gm = Density of test fuel at standard conditions

3.) Convert the observed fuel economy (FEomi/lb) to an energy equivalent of (miles/BTUx10^6)by dividing the observed fuel economy (FEomi/lb) by the heating value of the test fuel at standard conditions.

$$Eq = ((FEomi/lb)/H)x10^6$$

where Eq = Energy equivalent of miles/lb to mile/BTUx10^6
H = Volumetric heating value of test fuel at standard conditions

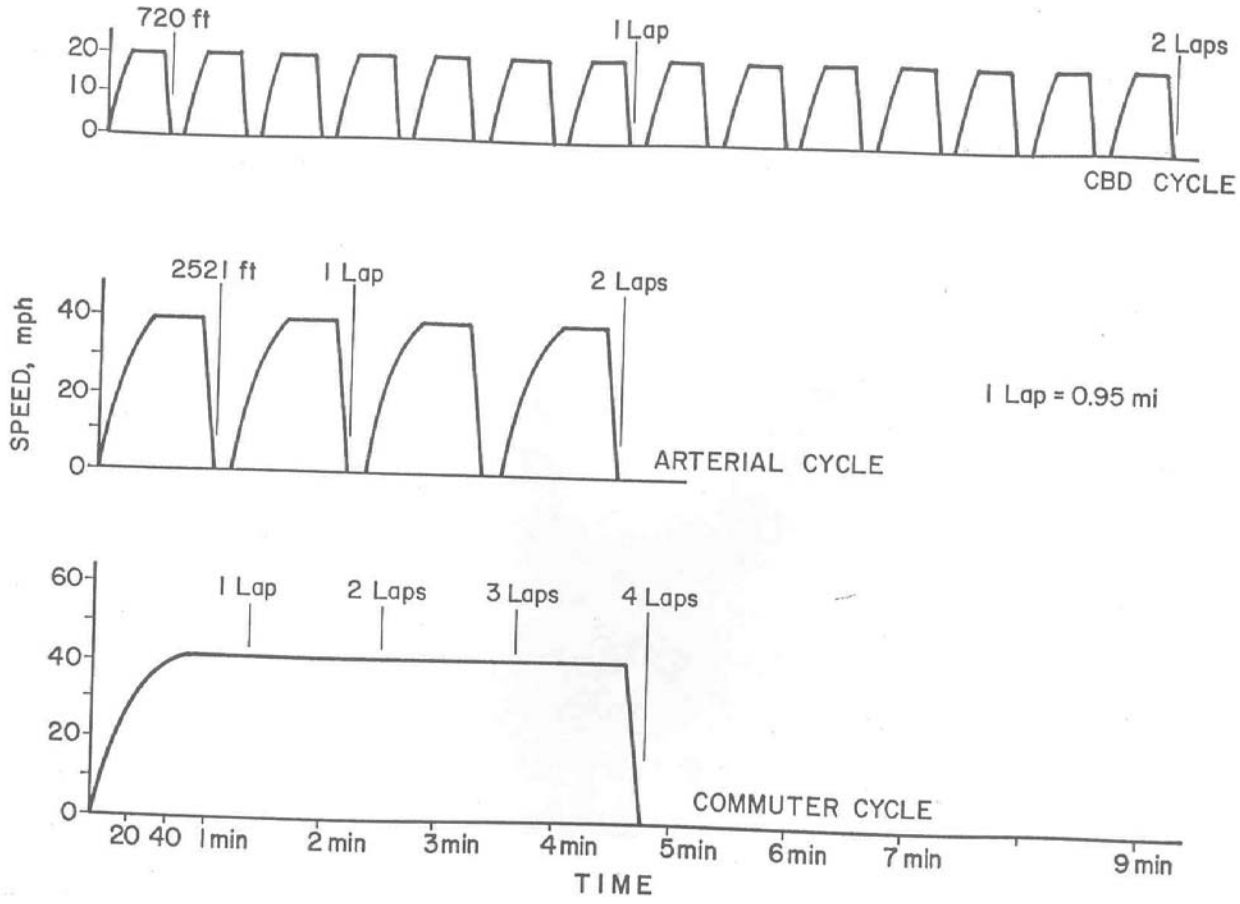
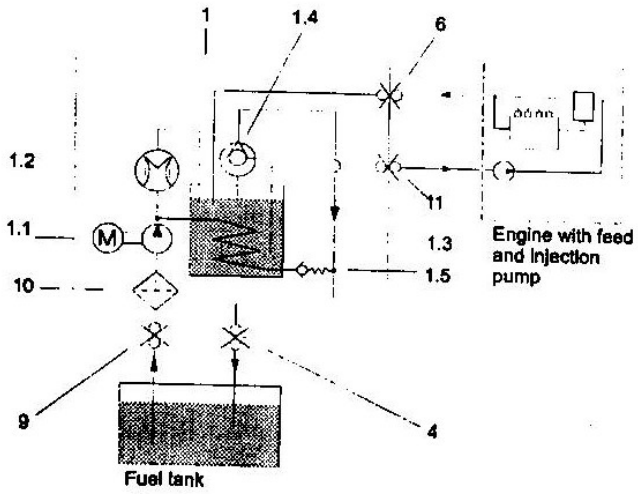
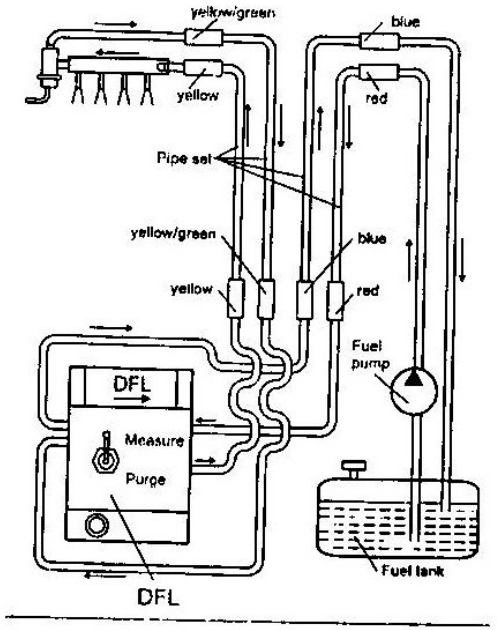


Figure 6-1. Bus Operating Profile.

DIESEL FUEL TEST



GAS



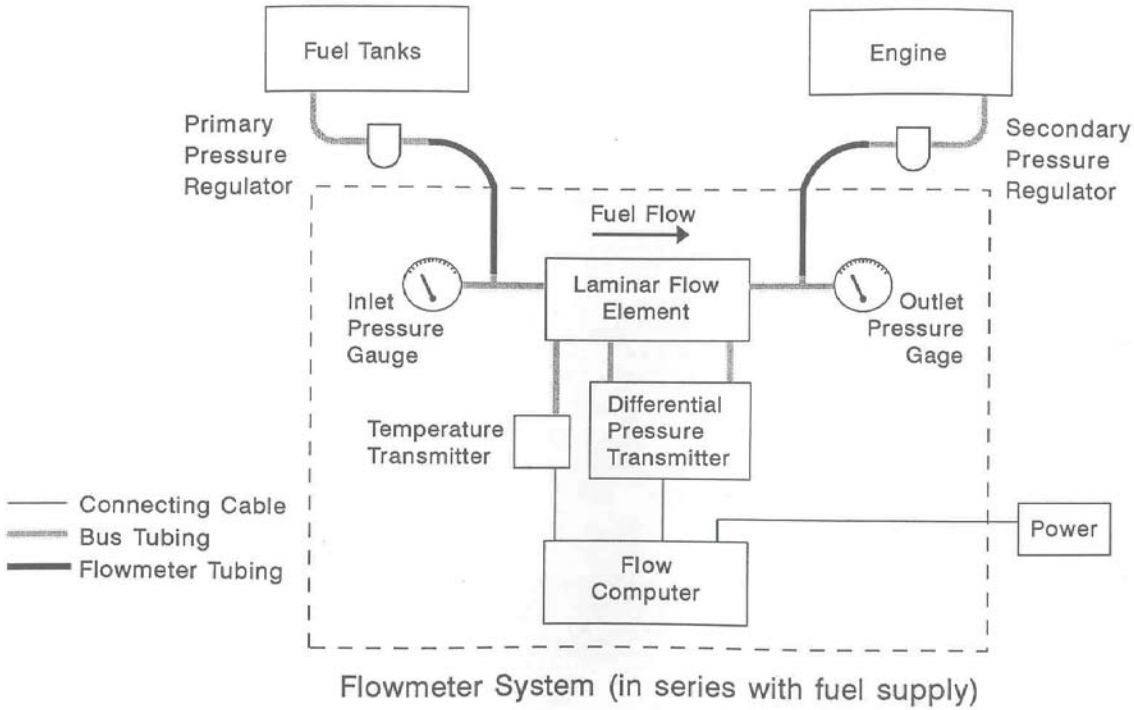


Figure 6-3. Gaseous Fuel Test Schematic.

FUEL ECONOMY PRE-TEST MAINTENANCE FORM

Bus Number:	Date:	SLW (lbs):
Personnel:		

FUEL SYSTEM	OK	Date	Initials
Install fuel measurement system			
Replace fuel filter			
Check for fuel leaks			
Specify fuel type (refer to fuel analysis)			
Remarks:			
BRAKES/TIRES	OK	Date	Initials
Inspect hoses			
Inspect brakes			
Relube wheel bearings			
Check tire inflation pressures (mfg. specs.)			
Remarks:			
COOLING SYSTEM	OK	Date	Initials
Check hoses and connections			
Check system for coolant leaks			
Remarks:			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 2)

Bus Number:	Date:
Personnel:	

ELECTRICAL SYSTEMS	OK	Date	Initials
Check battery			
Inspect wiring			
Inspect terminals			
Check lighting			
Remarks:			
DRIVE SYSTEM	OK	Date	Initials
Drain transmission fluid			
Replace filter/gasket			
Check hoses and connections			
Replace transmission fluid			
Check for fluid leaks			
Remarks:			
LUBRICATION	OK	Date	Initials
Drain crankcase oil			
Replace filters			
Replace crankcase oil			
Check for oil leaks			
Check oil level			
Lube all chassis grease fittings			
Lube universal joints			
Replace differential lube including axles			
Remarks:			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 3)

Bus Number:	Date:
Personnel:	

EXHAUST/EMISSION SYSTEM	OK	Date	Initials
Check for exhaust leaks			
Remarks:			

ENGINE	OK	Date	Initials
Replace air filter			
Inspect air compressor and air system			
Inspect vacuum system, if applicable			
Check and adjust all drive belts			
Check cold start assist, if applicable			
Remarks:			

STEERING SYSTEM	OK	Date	Initials
Check power steering hoses and connectors			
Service fluid level			
Check power steering operation			
Remarks:			

	OK	Date	Initials
Ballast bus to seated load weight			

TEST DRIVE	OK	Date	Initials
Check brake operation			
Check transmission operation			
Remarks:			

FUEL ECONOMY PRE-TEST INSPECTION FORM

Bus Number:	Date:
Personnel:	

PRE WARM-UP	If OK, Initial
Fuel Economy Pre-Test Maintenance Form is complete	
Cold tire pressure (psi): Front____ Middle____ Rear____	
Tire wear: less than 50%	
Engine oil level	
Engine coolant level	
Interior and exterior lights on, evaporator fan on	
Fuel economy instrumentation installed and working properly.	
Fuel line -- no leaks or kinks	
Speed measuring system installed on bus. Speed indicator installed in front of bus and accessible to TP and Driver.	
Bus is loaded to SLW	
WARM-UP	**If OK, Initial**
Bus driven for at least one hour warm-up	
No extensive or black smoke from exhaust	
POST WARM-UP	**If OK, Initial**
Warm tire pressure (psi): Front____ Middle____ Rear____	
Environmental conditions Average wind speed <12 mph and maximum gusts <15 mph Ambient temperature between 30EF(-1EC) and 90EF(32EC) Track surface is dry Track is free of extraneous material and clear of interfering traffic	

DETAILED TEST PROCEDURES		TITLE: 6. Fuel Economy
Procedure 6-1		**NOMENCLATURE: 6. Fuel Economy Test – A Fuel Consumption Test Using and Appropriate Operating Cycle**
OPER STEP	**ACTION BY**	**TEST PROCEDURE: For diesel, gasoline, methanol an other fuels in the liquid state.**
		NOTE: Keep fire extinguisher at hand during test.
1	TD	Drive the bus to the white, triangle sign. Align the front bumper of the bus with the sign.
2	TD/TP	Check that all windows and vents are closed. Driver's window may be open.
3	TD	Set the Bus Accessories as follows: 1. Air conditioning compressor OFF 2. Ventilation fans ON HIGH 3. Heater Pump Motor OFF 4. Defroster OFF 5. Exterior and Interior Lights ON 6. Windows and Doors CLOSED
4	TP	Record the starting fuel temperature(20-minute idle section).
5	TP	Operate the bus for 20 minutes at low idle. After 20 minutes, measure and record the finish temperature and fuel used on LCD.
6	TD	Record starting times, fuel temperature, and fuel used for CBD phase.
7	TP	Signal TD to begin the first, 2-lap CBD (square sign) phase.
8	TD	On signal, accelerate at full throttle to reach 20 mph. Cruise at 20 mph until the yellow, square sign. At the yellow sign, smoothly decelerate to a complete stop at the red square sign. Open and close passenger doors while idling for 7 seconds.
9	TP	Repeat step 10 for remainder of 2 laps.

DETAILED TEST PROCEDURES		TITLE: 6. Fuel Economy
Procedure 6-1		**NOMENCLATURE: 6. Fuel Economy Test – A Fuel Consumption Test Using An Appropriate Operating Cycle (continued)**
OPER STEP	**ACTION BY**	**TEST PROCEDURE: For diesel, gasoline, methanol and other fuels in the liquid state.**
10	TP	After 7-second idle at white sign, at end of 2 laps, record the time.
11	TP	Immediately record fuel temperature and fuel used.
12	TP	Reset clock. Signal TD to begin first, 2-lap, ART (diamond sign) phase.
13	TD	On signal, accelerate at full throttle to reach 40 mph. Cruise at 40 mph until the yellow, diamond sign. At the yellow sign, smoothly decelerate to a complete stop at the red diamond sign. Open and close passenger doors while idling for 7 seconds.
14	TD	Repeat step 16 for remainder of 2-lap ART phase.
15	TP	After 7-second idle at white sign at end of 2 laps, record the time.
16	TP	Immediately record finish fuel temperature and fuel used.
17	TP/TD	Repeat CBD phase, steps 8-13.
18	TP/TD	Repeat ART phase, steps 14-19.

DETAILED TEST PROCEDURES		TITLE: 6. Fuel Economy
Procedure 6-1		**NOMENCLATURE: 6. Fuel Economy Test - A Fuel Consumption Test Using An Appropriate Operating Cycle (continued)**
OPER STEP	**ACTION BY**	**TEST PROCEDURE: For diesel, gasoline, methanol and other fuels in the liquid state.**
19	TP/TD	Repeat CBD phase, steps 8-13.
20	TP	Record the fuel starting temperature and fuel used for the COM phase.
21	TP	Start clock, and signal TD to begin 4-lap, COM (hexagonal sign) phase.
22	TD	On signal, accelerate at full throttle to reach 40 mph. Cruise for 4 laps at 40 mph until the yellow, hexagonal sign. At the yellow sign, begin decelerating to a complete stop at the white sign. Open and close passenger doors while idling for 7 seconds.
23	TP	Immediately record finish time, fuel temperature, and fuel used.
24	TP	Total the times and fuel used during the CBD, ART, and COM phases.
25	TD/TP	Repeat steps 1-27 in the opposite direction around the track. Continue alternating steps 1-27 in a clockwise and a counterclockwise direction until a minimum of two runs in each direction are within $\pm$ 4 percent of the total average fuel used.
26	TP	Repeat idle consumption test, steps 6-7.

DETAILED TEST PROCEDURES		TITLE: 6. Fuel Economy
Procedure 6-2		NOMENCLATURE: 6. Fuel Economy Test – A Fuel Consumption Test Using An Appropriate Operating Cycle
OPER STEP	ACTION BY	TEST PROCEDURE: For CNG, LNG, cryogenic fuels, and other fuels stored in the vapor state
		NOTE: Keep fire extinguisher at hand during test.
1	TP	Turn on the flow meter system and press the "Total" button on the flow computer.
2	TD	Drive the bus to the white triangle sign. Align the front of the bus with the sign.
3	TD/TP	Check that all doors, windows and vents are closed. Driver's window may be open.
4	TD	Set the Bus Accessories as follows: 1. Air conditioning compressor OFF 2. Ventilation fans ON HIGH 3. Heater Pump Motor OFF 4. Defroster OFF 5. Exterior and Interior Lights ON 6. Windows and Doors CLOSED
5	TP	Press and hold the "Program" button on the flow computer until the "t" is displayed. Record the fuel temperature. Confirm that the flow computer is in the totalize mode by pressing the "Total" button. Press the "Reset" button on the flow computer, and start the clock for the first 20 minute idle.
6	TD/TP	At the end of the 20 min idle record the total fuel used (SCF) on the Fuel Economy Data Form. Press the "Rate" button on the flow computer. Record the flowrate (SCFM) at idle and at full throttle with the buses transmission in neutral/park. Press the "Total" button on the flow computer to re-enter the totalize mode. **NOTE: When in the totalize mode, depressing the depressing the reset button will reset the total to zero and will immediately begin totalizing.**
7	TP	Record starting times. Press and hold the "Program" button on the flow computer and record the fuel temperature.

DETAILED TEST PROCEDURES		TITLE: 6. Fuel Economy
Procedure 6-2		NOMENCLATURE: 6. Fuel Economy Test – A Fuel Consumption Test Using An Appropriate Operating Cycle (continued)
OPER STEP	ACTION BY	TEST PROCEDURE: For CNG, LNG, cryogenic fuels, and other fuels stored in the vapor state
8	TP	Simultaneously press the "Reset" button on the flow computer, start clock, and signal TD to begin the first, 2-lap CBD (square sign) phase.
9	TD	On signal, accelerate at full throttle to reach 20 mph. Cruise at 20 mph until the yellow square sign. At the yellow sign, smoothly decelerate to a complete stop at red square sign. Open and close the passenger door while idling for 7 seconds.
10	TD	Repeat step 10 for remainder of 2 laps.
11	TP	After 7-second idle at white sign, at end of 2 laps, record the total fuel used (SCF) from the display on the flow computer. Record the cycle time.
12	TP	Press and hold the "Program" button on the flow computer and record the fuel temperature for the ART phase.
13	TP	Simultaneously press the "Reset" button on the flow computer, start clock, and signal TD to begin first, 2-lap, ART (diamond sign) phase.
14	TD	On signal, accelerate at full throttle to reach 40 mph. Cruise at 40 mph until the yellow, diamond sign. At the yellow sign, smoothly decelerate to a complete stop at the red, diamond sign. Open and close the passenger door while idling for 7 seconds.
15	TD	Repeat step 14 for remainder of 2-lap ART phase.
16	TP	After 7-second idle at white sign at end of 2 laps, record the total fuel used (SCF) from the flow computer. Record the cycle time.
17	TP	Press and hold the "Program" button on the flow computer and record the fuel temperature for the second CBD phase.
18	TP	Simultaneously press the "Reset" button on the flow computer, start clock, and signal TD to begin the second 2-lap CBD phase.

DETAILED TEST PROCEDURES		TITLE: 6. Fuel Economy
Procedure 6-2		**NOMENCLATURE: 6. Fuel Economy Test - A Fuel Consumption Test Using An Appropriate Operating Cycle (continued)**
OPER STEP	**ACTION BY**	**TEST PROCEDURE: For CNG, LNG, cryogenic fuels, and other fuels stored in the vapor state**
19	TP/TD	Repeat 9-11 for the second CBD phase.
20	TP	Press and hold the "Program" button on the flow computer and record the fuel temperature for the second ART phase.
21	TP/TD	Repeat 13-16 for the second ART phase.
22	TP	Press and hold the "Program" button on the flow computer and record the fuel temperature for the third CBD phase.
23	TP/TD	Repeat 9-11 for the third CBD phase.
24	TP	Press and hold the "Program" button on the flow computer and record the fuel temperature for the COM phase.
25	TP	Simultaneously press the "Reset" button the flow computer, start clock and signal TD to begin 4-lap, COM (hexagonal sign) phase.
26	TD	On signal, accelerate at full throttle to reach 40 mph. Cruise for 4 laps at 40 mph until the yellow, hexagonal sign. At the yellow sign, smoothly decelerate to a complete stop at the white sign. Open and close the passenger door while idling for 7 seconds.
27	TP	After 7 second idle at white sign, record the total fuel used (SCF) from the display on the flow computer. Record the cycle time.
28	TP	Total the fuel used during the CBD, ART, and COM phases.
29	TD/TP	Repeat steps 1-28 in the opposite direction around the track. Continue alternating steps 1-28 in a clockwise and a counterclockwise direction until a minimum of two runs in each direction are within $\pm$4 percent of the total average fuel used.
30	TP	Repeat idle consumption test, steps 5-6.

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

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number:	Manufacturer:	Date:
Run Number:	Personnel:	
Test Direction: GCW or GCCW	Temperature (EF):	Humidity (%):
SLW (lbs):	Wind Speed (mph) & Direction:	Barometric Pressure (in.Hg):

Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (EC)	gallons		Fuel Used (gals)
	Start	Finish		Start	Start	Finish	
CBD #1							
ART #1							
CBD #2							
ART #2							
CBD #3							
COMMUTER							
						Total Fuel =	gls

20 minute idle : Total Fuel Used = gls
Heating Value = BTU/LB
Comments:

FUEL ECONOMY DATA FORM (Gaseous Fuels)

Bus Number:	Manufacturer:	Date:

Run Number:	Personnel:	
Test Direction: GCW or GCCW	Ambient Temperature (EF):	Humidity (%):
SLW (lbs):	Wind Speed (mph) & Direction:	Barometric Pressure (in.Hg):

Cycle Type	Run Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (EF)	Total Fuel Used (SCF)
	Start	Finish		Start	
CBD #1					
ART #1					
CBD #2					
ART #2					
CBD #3					
COMMUTER					
Total Fuel: SCF					

20 minute idle : Total Fuel Used = SCF	
No Load Flow Rate at Idle = SCFM	No Load Flow Rate at Full Throttle = SCFM
Heating Value = BTU/LB	
Comments:	

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 ±1 dB(A) for frequencies of 20 to 4000 Hz or ±1 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:

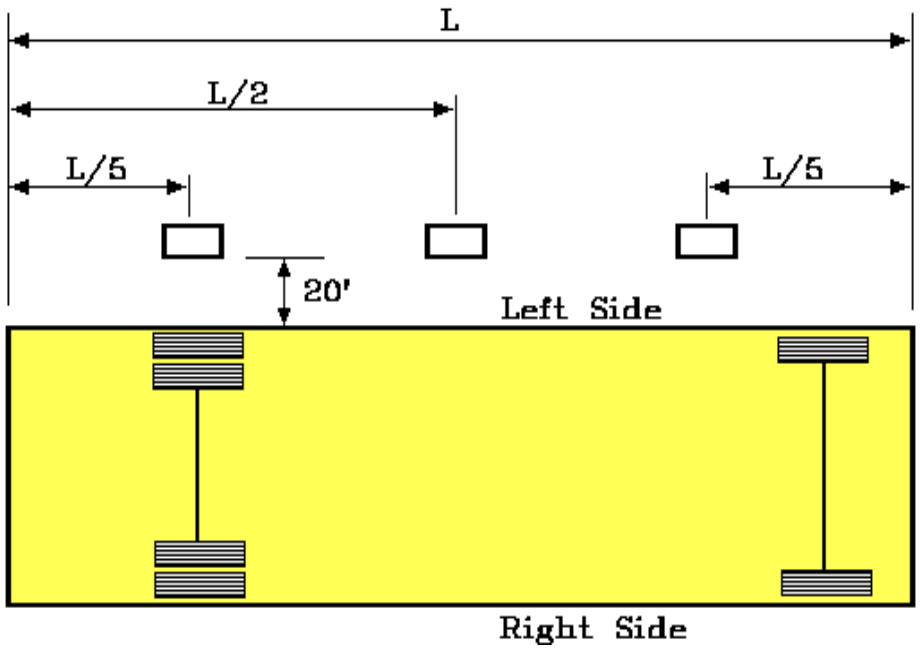
a. Test driver (TD)
b. Test Personnel (TP)

7.1-V. TEST DATA

The test data consist of the Interior Noise Test Data From. 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**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
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	Record the temperature, relative humidity, wind speed, wind direction, and ambient sound level on the Interior Noise Data Form. **NOTE: Verify that the wind speed is less than 12 mph and the ambient temperature is between 30°F and 90°F.**
4	TP	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. **NOTE: When taking sound level measurements, position the sound level meter at least arm's length away from the body.**
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	Photograph the test area and setup. **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.**

DETAILED TEST PROCEDURES		TITLE: 7. Noise
Procedure 7.1-1		**NOMENCLATURE: 7.1 Interior Noise Condition 1: Stationary**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
7	TP	Switch on the noise generating system and set the output to some intermediate level. **NOTE:** 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.
8	TP	Using the sound level meter, check the noise level at the surface of the bus.
9	TP	Adjust the output of the white noise generating system to produce a uniform noise level equal to 80 dB(A) $\pm$2 dB(A) on the exterior surface of the bus.
10	TP	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. **NOTE:** 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.
11	TP	Once 80 dB(A) $\pm$2 dB(A) has been established, move the meter inside the test bus. **NOTE:** All windows, hatches, doors, and vents shall be in the fully closed position. All accessories and the engine shall be "off."
12	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, 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.

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.

DETAILED TEST PROCEDURES		TITLE: 7. Noise
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. **NOTE: Verify that the wind speed is less than 12 mph and the ambient temperature is between 30°F and 90°F.**
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. **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.**
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**
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
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
4	TP	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.

REVISIONS

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

Revision	Description	Date	Approval

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

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

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:

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 ± 1 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.

DETAILED TEST PROCEDURES		TITLE: 7. Noise
Procedure 7.2-1		NOMENCLATURE: 7.2 Exterior Noise Tests - Accelerating from Constant Speed
OPER STEP	ACTION BY	TEST PREPARATION

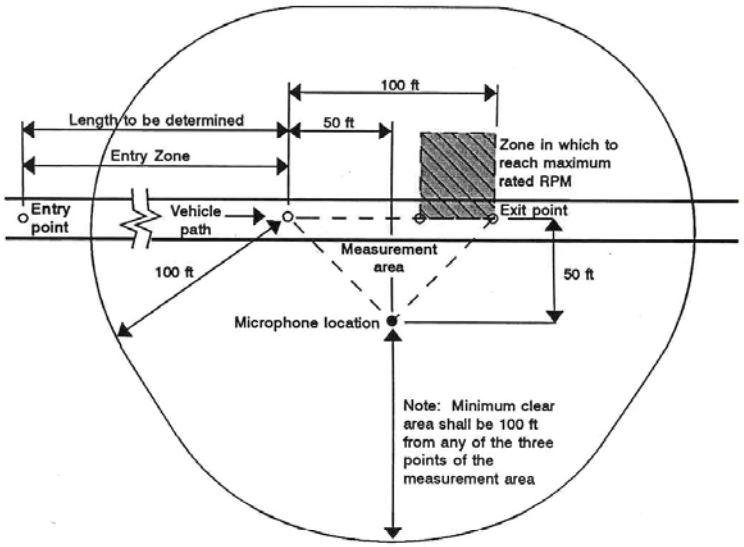


Figure 7.2-1. Test Site - Configured unidirectional for left to right acceleration from constant speed.

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.

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.

Procedure 7.2-1		NOMENCLATURE: 7.2 Exterior Noise Accelerating from Constant Speed (continued)
OPER STEP	**ACTION BY**	**TEST PREPARATION AND PROCEDURE**
11	TD	Switch the acceleration and end points and position the bus 150 ft from the acceleration point, facing the opposite direction from previous runs. **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.**
12	TP	Repeat step 10 traveling in the opposite direction. The sound level will be measured for the left side of the bus.
13	TP	Recheck sound level meter calibration. **NOTE: If meter calibration has changed by more than ±0.5 dB(A), recalibrate the meter and repeat test procedure.**

EXTERIOR NOISE TEST DATA FORM
Accelerating from Constant Speed

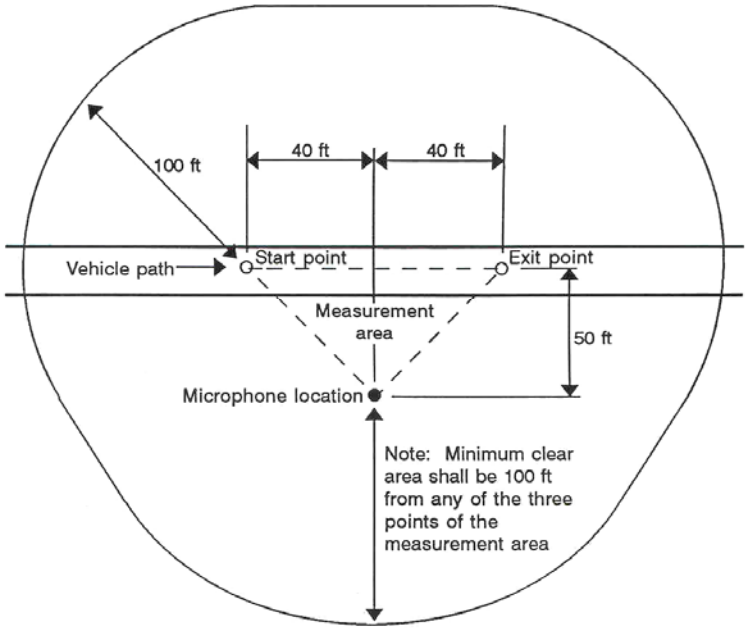
Bus Number:	Date:
Personnel:	
Temperature (EF):	Humidity (%):
Wind Speed (mph):	Wind Direction:
Barometric Pressure (in.Hg):	
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30EF and 90EF: Gchecked by	
Initial Sound Level Meter Calibration: Gchecked 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: Gchecked 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. **NOTE: The following step will define the layout of the test area. (Refer to figure 7.2-2)**
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. **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.**

DETAILED TEST PROCEDURES		TITLE: 7. Noise
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.

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	Recheck sound level meter calibration. **NOTE: If meter calibration has changed by more than ±0.5 dB(A), recalibrate the meter and repeat the test procedure.**

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: Gchecked by	
Initial Sound Level Meter Calibration: Gchecked 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: Gchecked 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.**

DETAILED TEST PROCEDURES		TITLE: 7. Noise
Procedure 7.2-3		NOMENCLATURE: 7.2 Exterior Noise Stationary (Continued)
OPER STEP	ACTION BY	TEST PREPARATION

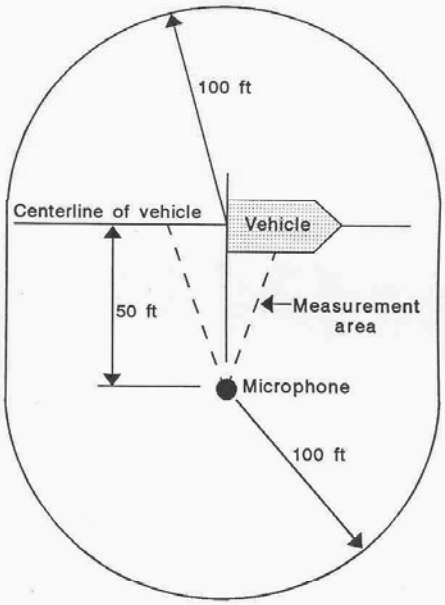


Figure 7.2-3. Test Site - configured for stationary tests.

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 $\pm$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: Gchecked by	
Initial Sound Level Meter Calibration: Gchecked 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: Gchecked 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