

ARBOC Specialty Vehicles

March 24, 2016

To whom it may concern:

The Spirit of Liberty by ARBOC Specialty Vehicles, LLC, is built and successfully tested at the 7 year/200,000 mile category at Altoona. The limited "non-scheduled" issues that resulted during the test were all resolved without further reoccurrence. The validation testing completed for the issues that were discovered was set at an expected design life that will meet and exceed the life cycle criteria of a 10 year/350,000 mile bus. The testing at the 7 year/200,000 mile category allows agencies the flexibility to retire the vehicle in a shorter timeframe if they so desire.

Regards,



Barry Hines
Engineering Manager
ARBOC Specialty Vehicles, LLC

FEDERAL TRANSIT BUS TEST

**Performed for the Federal Transit Administration U.S. DOT
In accordance with CFR 49, Volume 7, Part 665**

**Manufacturer: ARBOC Specialty Vehicles
Model: 3400 Liberty**

**Submitted for Testing in Service-Life Category
7 Year /200,000 Miles**

AUGUST 2015

Report Number: LTI-BT-R1502

PENNSTATE



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FEDERAL TRANSIT BUS TEST

Performed for the Federal Transit Administration U.S. DOT
1200 New Jersey Avenue, SE
Washington, DC 20590

In accordance with CFR 49, Volume 7, Part 665

Manufacturer: ARBOC Specialty Vehicles
Manufacturer's address: 51165 Greenfield Parkway
Middlebury, IN 46540

Model: 3400 Liberty

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Quality Authorization

Director, Bus Research
and Testing Center

Title

8/20/15

Date

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EXECUTIVE SUMMARY

ARBOC Specialty Vehicles submitted a model 3400 Liberty, diesel-powered 34 seat (including the driver) 35-foot bus, for a 7 yr./200,000 mile STURAA test. The odometer reading at the time of delivery was 547 miles. Testing started on January 30, 2015 and was completed on July 29, 2015. The Check-In section of the report provides a description of the bus and specifies its major components.

The primary part of the test program is the Structural Durability Test, which also provides the information for the Maintainability and Reliability results. The Structural Durability Test was started on February 16, 2015 and was completed on July 6, 2015.

The interior of the bus is configured with seating for 34 passengers including the driver. Note: this test bus is not designed to accommodate standing passengers; therefore, GVW and SLW are the same. At 150 lbs. per person, this load results in a measured gross vehicle weight of 23,970 lbs. The first segment of the Structural Durability Test was performed with the bus loaded to a GVW of 23,970 lbs. The middle segment was performed at a seated load weight of 23,970 lbs. and the final segment was performed at a curb weight of 18,930 lbs. Durability driving resulted in unscheduled maintenance and failures that involved a variety of subsystems. A description of failures, and a complete and detailed listing of scheduled and unscheduled maintenance are provided in the Maintainability section of this report.

Effective January 1, 2010 the Federal Transit Administration determined that the total number of simulated passengers used for loading all test vehicles will be based on the full complement of seats and free-floor space available for standing passengers (150 lbs. per passenger). The passenger loading used for dynamic testing will not be reduced in order to comply with Gross Axle Weight Ratings (GAWR's) or the Gross Vehicle Weight Ratings (GVWR's) declared by the manufacturer. Cases where the loading exceeds the GAWR and/or the GVWR will be noted accordingly. During the testing program, all test vehicles transported or operated over public roadways will be loaded to comply with the GAWR and GVWR specified by the manufacturer.

Accessibility, in general, was adequate, components covered in Section 1.3 (Repair and/or Replacement of Selected Subsystems) along with all other components encountered during testing, were found to be readily accessible and no restrictions were noted.

The Reliability section compiles failures that occurred during Structural Durability Testing. Breakdowns are classified according to subsystems. The data in this section are arranged so that those subsystems with more frequent problems are apparent. The problems are also listed by class as defined in Section 2. The test bus encountered no Class 1, 2 or 4 failures. All six reported failures were Class 3.

The Safety Test, (a double-lane change, obstacle avoidance test) was safely performed in both right-hand and left-hand directions up to a maximum test speed of 45 mph. The performance of the bus is illustrated by a speed vs. time plot. Acceleration and gradeability test data are provided in Section 4, Performance. The average time to obtain 50 mph was 26.53 seconds. Top speed obtained on the dynamometer was 63.5

mph. The Stopping Distance phase of the Brake Test was completed with the following results: for the Uniform High Friction Test average stopping distances were 29.51' at 20 mph, 61.26' at 30 mph, 106.95' at 40 mph and 137.92' at 45 mph. The average stopping distance for the Uniform Low Friction Test was 30.23'. There was no deviation from the test lane during the performance of the Stopping Distance phase. During the Stability phase of Brake Testing, the test bus experienced no deviation from the test lane during both approaches to the Split Friction Road surface. The Parking Brake phase was completed with the test bus maintaining the parked position for the full five minute period with no slip or roll observed in both the uphill and downhill positions.

The Shakedown Test produced a maximum final loaded deflection of 0.128 inches with a permanent set ranging between -0.004 to 0.004 inches under a distributed static load of 12,750 lbs. The Distortion Test was completed with all subsystems, doors and escape mechanisms operating properly. No water leakage was observed throughout the test. The handicap ramp was inoperable during the test. All other subsystems operated properly.

The test bus submitted for testing was not equipped with any type of tow eyes or tow hooks; therefore, the Static Towing Test was not performed. The Dynamic Towing Test was performed by means of a front-lift tow. The towing interface was accomplished using a hydraulic under-lift wrecker. The bus was towed without incident and no damage resulted from the test. The manufacturer does not recommend towing the bus from the rear; therefore, a rear test was not performed. The Jacking and Hoisting Tests were also performed without incident. The bus was found to be stable on the jack stands, and the minimum jacking clearance observed with a tire deflated was 4.6 inches.

A Fuel Economy Test was run on simulated central business district, arterial, and commuter courses. The results were 4.37 mpg, 4.99 mpg, and 8.71 mpg respectively; with an overall average of 5.32 mpg.

A series of Interior and Exterior Noise Tests was performed. These data are listed in Section 7.1 and 7.2 respectively.

The Emissions Test was performed. These results are available in Section 8 of this report.

ABBREVIATIONS

ABTC	- Altoona Bus Test Center
A/C	- air conditioner
ADB	- advance design bus
ATA-MC	- The 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)
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 (curb weight plus gross vehicle load)
GVWR	- gross vehicle weight rating
MECH	- bus mechanic
mpg	- miles per gallon
mph	- miles per hour
PM	- Preventive maintenance
PSTT	- Penn State Test Track
PTI	- Pennsylvania Transportation Institute
rpm	- revolutions per minute
SAE	- Society of Automotive Engineers
SCH	- test scheduler
SA	- staff assistant
SLW	- seated load weight (curb weight plus 150 lb for every designed passenger seating position and for the driver)
STURAA	- Surface Transportation and Uniform Relocation Assistance Act
TD	- test driver
TECH	- test technician
TM	- track manager
TP	- test personnel

TEST BUS CHECK-IN

I. OBJECTIVE

The objective of this task is to log in the test bus, assign a bus number, complete the vehicle data form, and perform a safety check.

II. TEST DESCRIPTION

The test consists of assigning a bus test number to the bus, cleaning the bus, completing the vehicle data form, obtaining any special information and tools from the manufacturer, determining a testing schedule, performing an initial safety check, and performing the manufacturer's recommended preventive maintenance. The bus manufacturer must certify that the bus meets all Federal regulations.

III. DISCUSSION

The check-in procedure is used to identify in detail the major components and configuration of the bus.

The test bus consists of an ARBOC Specialty Vehicles, model 3400 Liberty. The bus has a front door equipped with a Ricon model BR2CO2 foldout handicap ramp and is located forward of the front axle. Power is provided by a diesel-fueled, Cummins model ISB 6.7 L engine coupled to an Allison model B220 transmission.

The measured curb weight is 5,570 lbs. for the front axle and 13,360 lbs. for the rear axle. These combined weights provide a total measured curb weight of 18,930 lbs. There are 34 seats including the driver. Note: this test bus is not designed to accommodate standing passengers; therefore, there are no standees. Gross load is $150 \text{ lb.} \times 34 = 5,100 \text{ lbs.}$ At full capacity, the measured gross vehicle weight is 23,970 lbs.

VEHICLE DATA FORM

Page 1 of 7

Bus Number: 1502	Date: 01-30-15
Bus Manufacturer: ARBOC Specialty Vehicles, LLC	Vehicle Identification Number (VIN): 4UZA EJDU6FCGJ3044
Model Number: 3400 Liberty	Chassis Mfr./Mod.#: Freightliner Custom Chassis Corporation / 1A9D02159F6925183
Personnel: T.S. & S.R.	

WEIGHT:

Individual Wheel Reactions:

Weights (lb)	Front Axle		Middle Axle		Rear Axle	
	Curb	Street	Curb	Street	Curb	Street
CW	2,810	2,760	N/A	N/A	6,570	6,790
SLW	3,460	3,400	N/A	N/A	8,400	8,710
GVW	3,460	3,400	N/A	N/A	8,400	8,710

Total Weight Details:

Weight (lb)	CW	SLW	GVW	GAWR
Front Axle	5,570	6,860	6,860	10,000
Middle Axle	N/A	N/A	N/A	N/A
Rear Axle	13,360	17,110	17,110	17,500
Total	18,930	23,970	23,970	GVWR: 25,900

Dimensions:

Length (ft/in)	35 / 7.25
Width (in)	100.5
Height (in)	120.0
Front Overhang (in)	95.5
Rear Overhang (in)	129.25
Wheel Base (in)	202.5
Wheel Track (in)	Front: 84.1
	Rear: 72.3

VEHICLE DATA FORM

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Bus Number: 1502	Date: 01-30-15
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CLEARANCES:

Lowest Point Outside Front Axle	Location: Body at door	Clearance(in): 9.8
Lowest Point Outside Rear Axle	Location: Tailpipe	Clearance(in): 11.0
Lowest Point between Axles	Location: Fuel tank bracket bolts	Clearance(in): 9.3
Ground Clearance at the center (in)	9.3	
Front Approach Angle (deg)	7.8	
Rear Approach Angle (deg)	5.6	
Ramp Clearance Angle (deg)	5.2	
Aisle Width (in)	Front: 23.1 Rear: 23.3	
Inside Standing Height at Center Aisle (in)	77.9	

BODY DETAILS:

Body Structural Type	Integral		
Frame Material	Steel		
Body Material	Fiberglass		
Floor Material	Steel over composite		
Roof Material	Fiberglass		
Windows Type	<input checked="" type="checkbox"/> Fixed	<input checked="" type="checkbox"/> Movable	
Window Mfg./Model No.	CLEER VISION/ Tempered A53 DOT960		
Number of Doors	<u>1</u> Front	<u>0</u> Rear	
Mfr. / Model No.	A & M Systems/ Ser.# Right Door: D126486 Left Door: D126487		
Dimension of Each Door (in)	Front: 36.7 x 80.7	Rear: N/A	
Passenger Seat Type	<input type="checkbox"/> Cantilever	<input checked="" type="checkbox"/> Pedestal	<input type="checkbox"/> Other (explain)
Driver Seat Type	<input checked="" type="checkbox"/> Air	<input type="checkbox"/> Spring	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	USSC / Serial #: 238799		
Number of Seats (including Driver)	34		

VEHICLE DATA FORM

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Bus Number: 1502	Date: 01-30-15
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BODY DETAILS (Contd..)

Free Floor Space (ft ²)	36.1
Height of Each Step at Normal Position (in)	<div style="display: flex; justify-content: space-between;"> Front 1. <u>14.1</u> 2. <u>N/A</u> 3. <u>N/A</u> 4. <u>N/A</u> </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> Middle 1. <u>N/A</u> 2. <u>N/A</u> 3. <u>N/A</u> 4. <u>N/A</u> </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> Rear 1. <u>N/A</u> 2. <u>N/A</u> 3. <u>N/A</u> 4. <u>N/A</u> </div>
Step Elevation Change - Kneeling (in)	3.4

ENGINE

Type	<input checked="" type="checkbox"/> C.I. <input type="checkbox"/> S.I.	<input type="checkbox"/> Alternate Fuel <input type="checkbox"/> Other (explain)
Mfr. / Model No.	Cummins / ISB 6.7-240	
Location	<input type="checkbox"/> Front	<input checked="" type="checkbox"/> Rear <input type="checkbox"/> Other (explain)
Fuel Type	<input type="checkbox"/> Gasoline <input checked="" type="checkbox"/> Diesel	<input type="checkbox"/> CNG <input type="checkbox"/> LNG <input type="checkbox"/> Methanol <input type="checkbox"/> Other (explain)
Fuel Induction Type	<input checked="" type="checkbox"/> Injected	<input type="checkbox"/> Carburetion
Alternator Mfr. / Mod.No.	Prestolite / A0014944PA Leece Neville / A0014944PA	
Maximum Rated Output (Volts / Amps)	14 / 270	
Air Compressor Mfr. / Model No.	Cummins / 318cc	
Maximum Capacity (ft ³ / min)	30.0	
Starter Type	<input checked="" type="checkbox"/> Electrical <input type="checkbox"/> Pneumatic	<input type="checkbox"/> Other (explain)
Starter Mfr. / Model No.	Delco Remy / 820057129MT	

VEHICLE DATA FORM

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Bus Number: 1502	Date: 01-30-15
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TRANSMISSION

Transmission Type	<input type="checkbox"/> Manual	<input checked="" type="checkbox"/> Automatic	<input type="checkbox"/> Load Sensing Adaptive
Mfr. / Model No.	Allison / B220 Ser.# 6311294497		
Control Type	<input type="checkbox"/> Mechanical	<input checked="" type="checkbox"/> Electrical	<input type="checkbox"/> Other
Integral Retarder	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	

SUSPENSION

Number of Axles	2		
Front Axle Type	<input type="checkbox"/> Independent	<input checked="" type="checkbox"/> Beam Axle	
Mfr. / Model No.	Meritor / MFS10143AMM330		
Axle Ratio (if driven)	N/A		
Suspension Type	<input checked="" type="checkbox"/> Air	<input type="checkbox"/> Spring	<input type="checkbox"/> Other (explain)
No. of Shock Absorbers	2		
Mfr. / Model No.	Bilstein / 700178-13		
Middle Axle Type	<input type="checkbox"/> Independent	<input type="checkbox"/> Beam Axle	<input checked="" type="checkbox"/> N/A
Mfr. / Model No.	N/A		
Axle Ratio (if driven)	N/A		
Suspension Type	<input type="checkbox"/> Air	<input type="checkbox"/> Spring	<input checked="" type="checkbox"/> N/A
No. of Shock Absorbers	N/A		
Mfr. / Model No.	N/A		
Rear Axle Type	<input type="checkbox"/> Independent	<input checked="" type="checkbox"/> Beam Axle	
Mfr. / Model No.	Axle Alliance Company LLC / R19-2N		
Axle Ratio (if driven)	5.13 : 1		
Suspension Type	<input checked="" type="checkbox"/> Air	<input checked="" type="checkbox"/> Spring	<input type="checkbox"/> Other (explain)
No. of Shock Absorbers	2		
Mfr. / Model No.	Bilstein / 700178-15		

VEHICLE DATA FORM

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Bus Number: 1502	Date: 01-30-15
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WHEELS & TIRES

Front	Wheel Mfr./ Model No.	Accuride 19.5 x 6.5
	Tire Mfr./ Model No.	Michelin X 245 / 70R 19.5
Rear	Wheel Mfr./ Model No.	Accuride 19.5 x 6.5
	Tire Mfr./ Model No.	Michelin X 245 / 70R 19.5

BRAKES

Front Axle Brakes Type	<input type="checkbox"/> Cam	<input checked="" type="checkbox"/> Disc	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	Bosch / Dual Piston 66mm		
Middle Axle Brakes Type	<input type="checkbox"/> Cam	<input type="checkbox"/> Disc	<input checked="" type="checkbox"/> N/A
Mfr. / Model No.	N/A		
Rear Axle Brakes Type	<input type="checkbox"/> Cam	<input checked="" type="checkbox"/> Disc	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	Bosch / Dual Piston 70mm		

HVAC

Heating System Type	<input type="checkbox"/> Air	<input checked="" type="checkbox"/> Water	<input type="checkbox"/> Other
Capacity (Btu/hr)	Driver's – 40,000 Passenger's – 65,000		
Mfr. / Model No.	Espar Heater Systems / D5 12V.17100 BTU		
Air Conditioner	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	
Location	Roof		
Capacity (Btu/hr)	Driver's – 40,000 Passenger's – 65,000		
A/C Compressor Mfr. / Model No.	#1 Valeo / 103-56393		

STEERING

Steering Gear Box Type	Hydraulic Gear		
Mfr. / Model No.	TRW / 4C10		
Steering Wheel Diameter	18"		
Number of turns (lock to lock)	4		
Control Type	<input type="checkbox"/> Electric	<input checked="" type="checkbox"/> Hydraulic	<input type="checkbox"/> Other (explain)

VEHICLE DATA FORM

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Bus Number: 1502	Date: 02-03-15
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OTHERS

Wheel Chair Ramps	Location: Front	Type: Fold out
Wheel Chair Lifts	Location: N/A	Type: N/A
Mfr. / Model No.	Ricon / BR2C02	
Emergency Exit	Location: Doors Windows Roof Hatches	Number: 1 4 1

CAPACITIES

Fuel Tank Capacity (gallons)	70.0
Engine Crankcase Capacity (gallons)	4.75
Transmission Capacity (gallons)	3.0
Differential Capacity (gallons)	1.85
Cooling System Capacity (gallons)	11.0
Power Steering Fluid Capacity (quarts)	3.0

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Date: 01-30-15

List all spare parts, tools and manuals delivered with the bus.

[illegible]

COMPONENT/SUBSYSTEM INSPECTION FORM

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Bus Number: 1502	Date: 02-03-15
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Subsystem	Checked	Initials	Comments
Air Conditioning Heating and Ventilation	✓	T.S.	None Noted.
Body and Sheet Metal	✓	T.S.	None Noted.
Frame	✓	T.S.	None Noted.
Steering	✓	T.S.	None Noted.
Suspension	✓	T.S.	None Noted.
Interior/Seating	✓	T.S.	None Noted.
Axles	✓	T.S.	None Noted.
Brakes	✓	T.S.	None Noted.
Tires/Wheels	✓	T.S.	None Noted.
Exhaust	✓	T.S.	None Noted.
Fuel System	✓	T.S.	None Noted.
Power Plant	✓	T.S.	None Noted.
Accessories	✓	T.S.	None Noted.
Lift System	✓	T.S.	None Noted.
Interior Fasteners	✓	T.S.	None Noted.
Batteries	✓	T.S.	None Noted.

CHECK - IN



**ARBOC SPECIALTY VEHICLES
MODEL 3400 LIBERTY**



CHECK - IN CONT.



**ARBOC SPECIALTY VEHICLES
MODEL 3400 LIBERTY EQUIPPED WITH A RICON MODEL
BR2C02 HANDICAP RAMP**



CHECK - IN CONT.



VIN TAG



OPERATOR'S AREA

CHECK - IN CONT.



INTERIOR



ENGINE COMPARTMENT

1. MAINTAINABILITY

1.1 ACCESSIBILITY OF COMPONENTS AND SUBSYSTEMS

1.1-I. TEST OBJECTIVE

The objective of this test is to check the accessibility of components and subsystems.

1.1-II. TEST DESCRIPTION

Accessibility of components and subsystems is checked, and where accessibility is restricted the subsystem is noted along with the reason for the restriction.

1.1-III. DISCUSSION

Accessibility, in general, was adequate. Components covered in Section 1.3 (repair and/or replacement of selected subsystems), along with all other components encountered during testing, were found to be readily accessible and no restrictions were noted.

ACCESSIBILITY DATA FORM

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Bus Number: 1502	Date: 7-28-15
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Component	Checked	Comments
ENGINE :		
Oil Dipstick	✓	N/A
Oil Filler Hole	✓	N/A
Oil Drain Plug	✓	N/A
Oil Filter	✓	N/A
Fuel Filter	✓	N/A
Air Filter	✓	N/A
Belts	✓	N/A
Coolant Level	✓	N/A
Coolant Filler Hole	✓	N/A
Coolant Drain	✓	N/A
Spark / Glow Plugs	N/A	N/A
Alternator	✓	N/A
Diagnostic Interface Connector	✓	N/A
TRANSMISSION :		
Fluid Dip-Stick	✓	N/A
Filler Hole	✓	N/A
Drain Plug	✓	N/A
SUSPENSION :		
Bushings	✓	N/A
Shock Absorbers	✓	N/A
Air Springs	✓	N/A
Leveling Valves	✓	N/A
Grease Fittings	✓	N/A

ACCESSIBILITY DATA FORM

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Bus Number: 1502	Date: 7-28-15
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Component	Checked	Comments
HVAC :		
A/C Compressor	✓	N/A
Filters	✓	N/A
Fans	✓	N/A
ELECTRICAL SYSTEM :		
Fuses	✓	N/A
Batteries	✓	N/A
Voltage regulator	✓	Integral regulator.
Voltage Converters	N/A	N/A
Lighting	✓	N/A
MISCELLANEOUS :		
Brakes	✓	N/A
Handicap Lifts/Ramps	✓	N/A
Instruments	✓	N/A
Axles	✓	N/A
Exhaust	✓	N/A
Fuel System	✓	N/A
OTHERS :		

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

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 NBM and collecting the following data on work order forms and a driver log.

1. Unscheduled Maintenance
 - a. Bus number
 - b. Date
 - c. Mileage
 - d. Description of malfunction
 - e. Location of malfunction (e.g., in service or undergoing inspection)
 - f. Repair action and parts used
 - g. Man-hours required
2. Scheduled Maintenance
 - a. Bus number
 - b. Date
 - c. Mileage
 - d. Engine running time (if available)
 - e. Results of scheduled inspections
 - f. Description of malfunction (if any)
 - g. Repair action and parts used (if any)
 - h. Man-hours required

The buses will be operated in accelerated 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. 3,000 mi (or equivalent) inspection

7. Oil and filter change inspection
 8. Major inspection
 9. Tune-up
- C. Periodic Repairs
1. Brake reline
 2. Transmission change
 3. Engine change
 4. Windshield wiper motor change
 5. Stoplight bulb change
 6. Towing operations
 7. Hoisting operations

1.2-III. DISCUSSION

Servicing and preventive maintenance were performed at manufacturer-specified intervals. The following Scheduled Maintenance Form lists the mileage, items serviced, the service interval, and amount of time required to perform the maintenance. Finally, the Unscheduled Maintenance List along with Unscheduled Maintenance-related photographs is included in Section 5.7, Structural Durability. This list supplies information related to failures that occurred during the durability portion of testing. The Unscheduled Maintenance List includes the date and mileage at which the malfunction occurred, a description of the malfunction and repair, and the time required to perform the repair.

(Page 1 of 2)
SCHEDULED MAINTENANCE
ARBOC #1502

DATE	TEST MILES	SERVICE	ACTIVITY	MAN HOURS	DOWN TIME
02-23-15	658	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00
03-12-15	1,080	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00
03-31-15	2,353	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00
04-20-15	3,386	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00
05-14-15	4,417	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00
06-24-15	5,184	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00
07-02-15	6,324	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00

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SCHEDULED MAINTENANCE
ARBOC #1502

DATE	TEST MILES	SERVICE	ACTIVITY	MAN HOURS	DOWN TIME
07-07-15	7,021	P.M./Inspection Fuel Economy Prep	Linkage, tie rods, universals/u-joints all lubed. Oil changed. Oil, fuel, and air filters changed. Transmission oil and filter changed.	8.00	8.00
07-24-15	7,500	P.M./Inspection	Linkage, tie rods, universals/u-joints all lubed; all fluids checked.	4.00	4.00

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS

1.3-I. TEST OBJECTIVE

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

1.3-II. TEST DESCRIPTION

The test will involve 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 NBM testing is added to this list. Components to be included are:

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

1.3-III. DISCUSSION

During the test, several additional components were removed for repair or replacement. Following is a list of components and total repair/replacement time.

	<u>MAN HOURS</u>
Left & right body supports forward of the rear axle.	12.00
Rear track rod mount.	2.00
Right rear axle U-Bolt & spring bushing.	5.00
Both rear body support mounts. Both rear spring hangers. Both rear springs, shocks & U-bolts.	30.00

At the end of the test, the remaining items on the list were removed and replaced. The transmission assembly took 8.00 man-hours (two men @ 4.00 hrs.) to remove and replace. The time required for repair/replacement of the four remaining components is given on the following Repair and/or Replacement Form.

REPLACEMENT AND/OR REPAIR FORM

Page 1 of 1

Subsystem	Replacement Time
Transmission	8.00 man hours
Wiper Motor	0.75 man hours
Starter	1.00 man hours
Alternator	2.00 man hours
Batteries	0.50 man hours

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS



TRANSMISSION REMOVAL AND REPLACEMENT (8.00 MAN HOURS)



WIPER MOTOR REMOVAL AND REPLACEMENT (0.75 MAN HOURS)

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS CONT.



STARTER REMOVAL AND REPLACEMENT (1.00 MAN HOURS)



ALTERNATOR REMOVAL AND REPLACEMENT (2.00 MAN HOURS)

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

2-I. TEST OBJECTIVE

The objective of this test is to document unscheduled breakdowns, repairs, down time, and repair time that occur during testing.

2-II. TEST DESCRIPTION

Using the driver log and unscheduled work order forms, all significant breakdowns, repairs, man-hours to repair, and hours out of service are recorded on the Reliability Data Form.

CLASS OF FAILURES

Classes of failures are described below:

- (a) Class 1: Physical Safety. A failure that could lead directly to passenger or driver injury and represents a severe crash situation.
- (b) Class 2: Road Call. A failure resulting in an en route interruption of revenue service. Service is discontinued until the bus is replaced or repaired at the point of failure.
- (c) Class 3: Bus Change. A failure that requires removal of the bus from service during its assignments. The bus is operable to a rendezvous point with a replacement bus.
- (d) Class 4: Bad Order. A failure that does not require removal of the bus from service during its assignments but does degrade coach operation. The failure shall be reported by driver, inspector, or hostler.

2-III. DISCUSSION

A listing of breakdowns and unscheduled repairs is accumulated during the Structural Durability Test. The following Reliability Data Form lists all unscheduled repairs under classes as defined above. These classifications are somewhat subjective as the test is performed on a test track with careful inspections every two hours. However, even on the road, there is considerable latitude on deciding how to handle many failures.

The Unscheduled Repair List is also attached to provide a reference for the repairs that are included in the Reliability Data Forms.

The classification of repairs according to subsystem is intended to emphasize those systems which had persistent minor or more serious problems. There were no Class 1, 2 or 4 failures. Of the six Class 3 failures, four involved the suspension system and two occurred with the body/frame. These failures are available for review in the Unscheduled Maintenance List, located in Section 5.7 Structural Durability.

RELIABILITY DATA FORM

Bus Number: 1502	Date Completed: 7-7-15
Personnel: B.R.	

	Failure Type					
	Class 4 Bad order	Class 3 Bus Change	Class 2 Road Call	Class 1 Physical Safety		
Subsystem	Mileage	Mileage	Mileage	Mileage	Man hours	Down Time
Suspension		2,038			2.00	16.00
		2,400			2.00	208.00
		3,433			11.00	332.00
		4,747			30.00	560.00
Body/Frame		655			12.00	268.00
		1,649			4.00	94.00

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

3-I. TEST OBJECTIVE

The objective of this test is to determine handling and stability of the bus by measuring speed through a double lane change test.

3-II. TEST DESCRIPTION

The Safety Test is a vehicle handling and stability test. The bus will be operated at SLW on a smooth and level test track. The bus will be driven through a double lane change course at increasing speed until the test is considered unsafe or a speed of 45 mph is reached. The lane change course will be set up using pylons to mark off two 12 foot center to center lanes with two 100 foot lane change areas 100 feet apart. The bus will begin in one lane, change to the other lane in a 100 foot span, travel 100 feet, and return to the original lane in another 100 foot span. This procedure will be repeated, starting first in the right-hand and then in the left-hand lane.

3-III. DISCUSSION

The double-lane change was performed in both right-hand and left-hand directions. The bus was able to safely negotiate the test course in both the right-hand and left-hand directions up to the maximum test speed of 45 mph.

SAFETY DATA FORM

Page 1 of 1

Bus Number: 1502	Date: 05-19-2015
Personnel: T.S.,E.D. & C.S.	

Temperature (°F): 79	Humidity (%): 61
Wind Direction: WNW	Wind Speed (mph): 8
Barometric Pressure (in.Hg): 29.95	

SAFETY TEST: DOUBLE LANE CHANGE	
Maximum safe speed tested for double-lane change to left	45 mph
Maximum safe speed tested for double-lane change to right	45 mph
Comments of the position of the bus during the lane change: A safe profile was maintained through all portions of testing.	
Comments of the tire/ground contact patch: Tire/ground contact was maintained through all portions of testing.	

3. SAFETY



RIGHT - HAND APPROACH



LEFT - HAND APPROACH

4.0 PERFORMANCE

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

4.1-I. TEST OBJECTIVE

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

4.1-II. TEST DESCRIPTION

In this test, the bus will be operated at SLW on the skid pad at the PSBRTF. The bus will be accelerated at full throttle from a standstill to a maximum "geared" or "safe" speed as determined by the test driver. The vehicle speed is measured using a Correvit non-contacting speed sensor. The times to reach speed between ten mile per hour increments are measured and recorded using a stopwatch with a lap timer. The time to speed data will be recorded on the Performance Data Form and later used to generate a speed vs. time plot and gradeability calculations.

4.1-III. DISCUSSION

This test consists of three runs in both the clockwise and counterclockwise directions on the Test Track. Velocity versus time data is obtained for each run and results are averaged together to minimize any test variability which might be introduced by wind or other external factors. The test was performed up to a maximum speed of 50 mph. The fitted curve of velocity vs. time is attached, followed by the calculated gradeability results. The average time to obtain 50 mph was 26.53 seconds. Top speed acquired on the dynamometer was 63.5 mph.

PERFORMANCE DATA FORM

Page 1 of 1

Bus Number: 1502		Date: 07-13-15	
Personnel: S.R., T.G. & R.S.			
Temperature (°F): 75		Humidity (%): 55	
Wind Direction: SSW		Wind Speed (mph): 2	
Barometric Pressure (in.Hg): 29.91			
		INITIALS:	
Air Conditioning - OFF	✓Checked	S.R.	
Ventilation fans - ON HIGH	✓Checked	S.R.	
Heater pump motor - OFF	✓Checked	S.R.	
Defroster - OFF	✓Checked	S.R.	
Exterior and interior lights - ON	✓Checked	S.R.	
Windows and doors - CLOSED	✓Checked	S.R.	
ACCELERATION, GRADEABILITY, TOP SPEED			
Counter Clockwise Recorded Interval Times			
Speed	Run 1	Run 2	Run 3
10 mph	3.15	2.90	2.90
20 mph	6.07	5.94	5.93
30 mph	10.38	10.44	10.44
40 mph	17.69	17.63	17.56
Top Test Speed(mph) 50	28.31	27.94	27.56
Clockwise Recorded Interval Times			
Speed	Run 1	Run 2	Run 3
10 mph	2.82	2.90	2.81
20 mph	5.84	5.83	5.88
30 mph	9.51	9.69	9.95
40 mph	16.37	16.40	16.64
Top Test Speed(mph) 50	25.00	25.08	25.31

PERFORMANCE SUMMARY SHEET

BUS MANUFACTURER : ARBOC
 BUS MODEL : 3400 LIBERTY

BUS NUMBER : 1502
 TEST DATE : 07-13-15

TEST CONDITIONS :

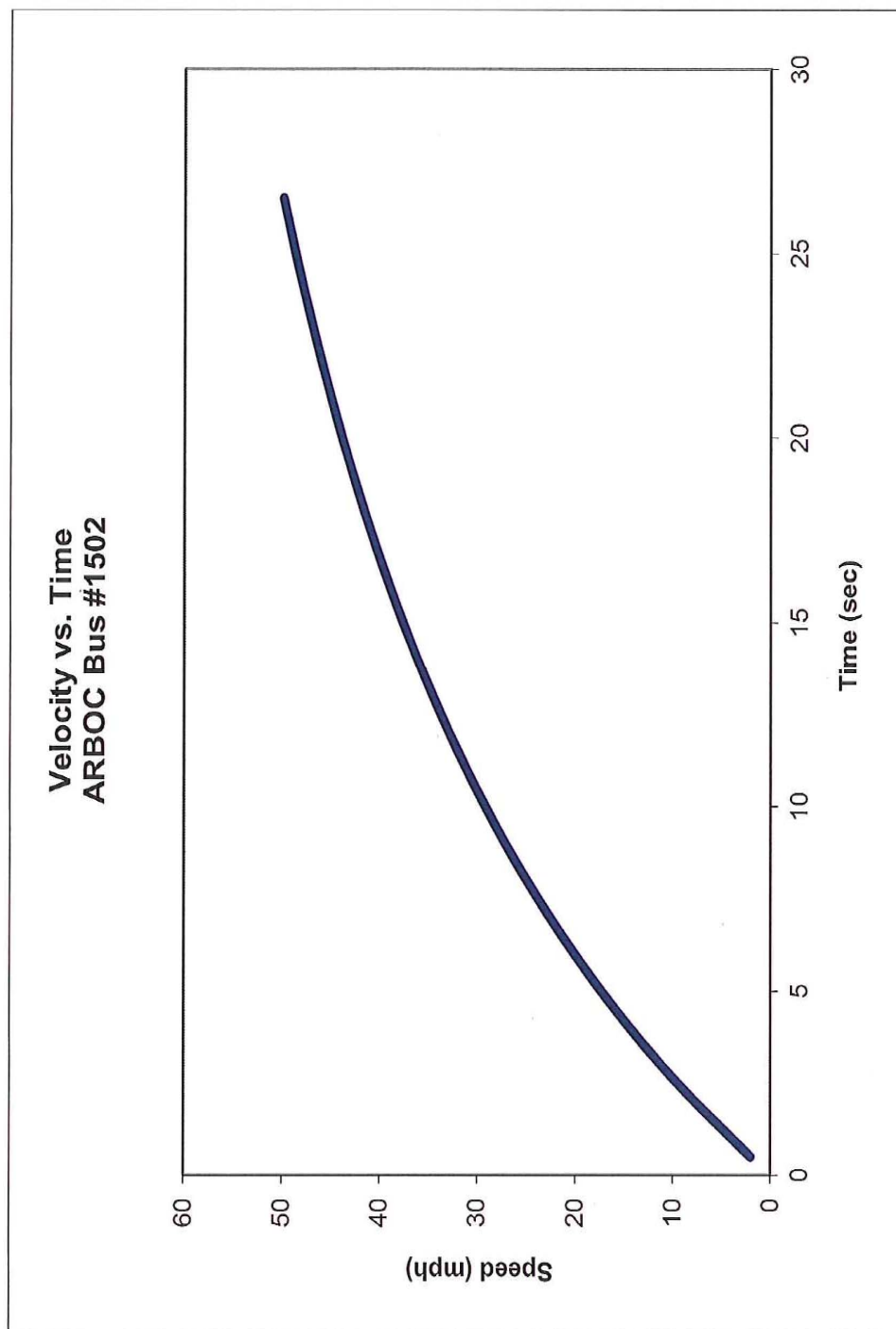
 TEMPERATURE (DEG F) : 75.0
 WIND DIRECTION : SSW
 WIND SPEED (MPH) : 2.0
 HUMIDITY (%) : 55
 BAROMETRIC PRESSURE (IN. HG) : 29.9

(MPH)	AVERAGE TIME (SEC)		
	CCW DIRECTION	CW DIRECTION	TOTAL
10.0	2.98	2.84	2.91
20.0	5.98	5.85	5.92
30.0	10.42	9.72	10.07
40.0	17.63	16.47	17.05
50.0	27.94	25.13	26.53

TEST SUMMARY :

VEHICLE SPEED (MPH)	TIME (SEC)	ACCELERATION (FT/SEC^2)	MAX. GRADE (%)
1.0	.24	6.1	19.2
5.0	1.25	5.6	17.6
10.0	2.63	5.0	15.7
15.0	4.19	4.4	13.8
20.0	5.97	3.8	12.0
25.0	8.03	3.3	10.4
30.0	10.43	2.8	8.8
35.0	13.28	2.3	7.3
40.0	16.75	1.9	5.9
45.0	21.06	1.5	4.7
50.0	26.61	1.2	3.6

NOTE : Gradeability results were calculated from performance
 ----- test data. Actual sustained gradeability performance
 for vehicles equipped with auto transmission may be
 lower than the values indicated here.



4.0 PERFORMANCE

4.2 Performance - Bus Braking

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. Dry surface (high-friction, Skid Number within the range of 70-76)
 - ii. Wet 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 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 four 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. The steering wheel input angle required to keep the vehicle in the lane during the maneuver will be reported.

Parking Brake Test

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

4.2-III. DISCUSSION

The Stopping Distance phase of the Brake Test was completed with the following results; for the Uniform High Friction Test average stopping distances were 29.51' at 20 mph, 61.26' at 30 mph, 106.95' at 40 mph and 137.92' at 45 mph. The average stopping distance for the Uniform Low Friction Test was 30.23'. There was no deviation from the test lane during the performance of the Stopping Distance phase.

During the Stability phase of Brake Testing the test bus experienced no deviation from the test lane during both approaches to the Split Friction Road surface.

The Parking Brake phase was completed with the test bus maintaining the parked position for the full five minute period with no slip or roll observed in both the uphill and downhill positions.

Table 4.2-6. Braking Test Data Forms

Page 1 of 3

Bus Number: 1502	Date: 07-10-15
Personnel: S.R., E.D., T.G. & C.S.	
Amb. Temperature (°F): 74	Wind Speed (mph): 2
Wind Direction: N	Pavement Temp (°F) Start: 103.7 End: 109.2

TIRE INFLATION PRESSURE (psi)				
Tire Type: Front: Michelin XZE 245 / 70R 19.5 Rear: Michelin XZE 245 / 70R 19.5				
	Left Tire(s)		Right Tire(s)	
Front	120		120	
	Inner	Outer	Inner	Outer
Rear	N/A	N/A	N/A	N/A
Rear	120	120	120	120

AXLE LOADS (lb)		
	Left	Right
Front	3,400	3,460
Rear	8,710	8,400
Rear	N/A	N/A

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

Page 2 of 3

Date	Fault/Repair	Description
07-10-15	None Noted.	N/A

Table 4.2-8.1. Stopping Distance Test Results Form

Page 3 of 3

Stopping Distance (ft)					
Vehicle Direction	CW	CW	CCW	CCW	
Speed (mph)	Stop 1	Stop 2	Stop 3	Stop 4	Average
20 (dry)	30.70	31.29	26.83	29.25	29.51
30 (dry)	63.96	61.53	57.95	61.63	61.26
40 (dry)	110.76	109.58	106.43	101.05	106.95
45 (dry)	145.33	140.38	137.62	128.37	137.92
20 (wet)	30.78	31.45	28.63	30.06	30.23

Table 4.2-8.2. Stability Test Results Form

Stability Test Results (Split Friction Road surface)			
Vehicle Direction	Attempt	Did test bus stay in 12' lane? (yes/no)	Comments
Drivers side on high friction	1	Yes	None noted.
	2	Yes	None noted.
Drivers side on low friction	1	Yes	None noted.
	2	Yes	None noted.

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
Front up	1	5:00	None	None	X	
	2	N/A	N/A	N/A	N/A	N/A
	3	N/A	N/A	N/A	N/A	N/A
Front down	1	5:00	None	None	X	
	2	N/A	N/A	N/A	N/A	N/A
	3	N/A	N/A	N/A	N/A	N/A

4.2 Performance - Bus Braking



20% UPHILL GRADE HOLDING



20% DOWNHILL GRADE HOLDING

5.1 STRUCTURAL INTEGRITY

5.1 STRUCTURAL STRENGTH AND DISTORTION TESTS – STRUCTURAL SHAKEDOWN TEST

5.1-I. DISCUSSION

The objective of this test is to determine certain static characteristics (e.g., bus floor 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 blocking the vehicle under the suspension points. The bus will then be loaded and unloaded up to a maximum of three times with a distributed load equal to 2.5 times gross load. Gross load is 150 lb for every designed passenger seating position, for the driver, and for each 1.5 sq ft 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 sq ft of free floor space. The first loading and unloading sequence will “settle” the structure. Bus deflection will be measured at several locations during the loading sequences.

5.1-III. DISCUSSION

This test was performed based on a maximum passenger capacity of 34 people including the driver. The resulting test load is $(34 \times 375 \text{ lb.}) = 12,750 \text{ lbs.}$ The load is distributed evenly over the passenger space. Deflection data before and after each loading and unloading sequence is provided on the Structural Shakedown Data Form.

The unloaded height after each test becomes the original height for the next test. Some initial settling is expected due to undercoat compression, etc. After each loading cycle, the deflection of each reference point is determined. The bus is then unloaded and the residual (permanent) deflection is recorded. On the final test, the maximum loaded deflection was 0.128 Inches at reference point 4. The maximum permanent deflection after the final loading sequence ranged from -0.004 Inches at reference point 7 to 0.004 inches at reference points 9 and 10.

STRUCTURAL SHAKEDOWN DATA FORM

Page 1 of 2

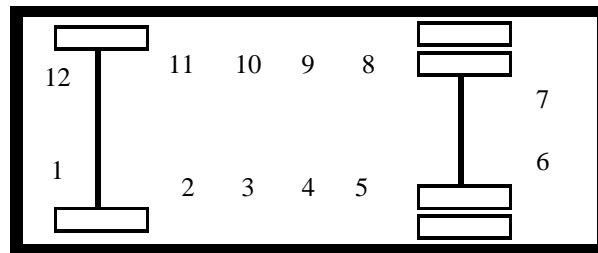
Bus Number: 1502	Date: 02-09-15
Personnel: T.S., S.R., E.D., E.L., T.G., P.D. & J.P.	Temperature (°F): 67
Loading Sequence: <input checked="" type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 (check one)	
Test Load (lbs.): 12,750	

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	B-A (in) Loaded Deflection	C (in) Unloaded Height	C-A (in) Permanent Deflection
1	0	.049	.049	.007	.007
2	0	.034	.034	.001	.001
3	0	.101	.101	.008	.008
4	0	.140	.140	.013	.013
5	0	.108	.108	.017	.017
6	0	-.051	-.051	-.005	-.005
7	0	-.021	-.021	-.021	-.021
8	0	.106	.106	.020	.020
9	0	.127	.127	.008	.008
10	0	.105	.105	.011	.011
11	0	.044	.044	.006	.006
12	0	.003	.003	.005	.005

STRUCTURAL SHAKEDOWN DATA FORM

Page 2 of 2

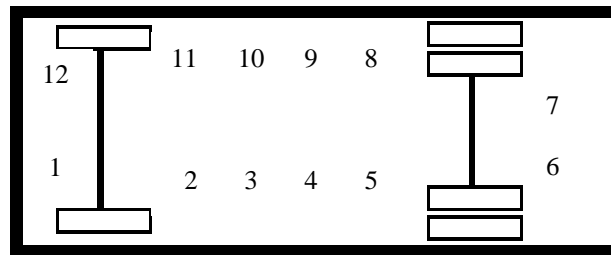
Bus Number: 1502	Date: 02-10-15
Personnel: T.S., S.R., E.D., E.L. & T.G.	Temperature (°F): 71
Loading Sequence: <input type="checkbox"/> 1 <input checked="" type="checkbox"/> 2 <input type="checkbox"/> 3 (check one)	
Test Load (lbs.): 12,750	

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	B-A (in) Loaded Deflection	C (in) Unloaded Height	C-A (in) Permanent Deflection
1	.007	.053	.046	.006	-.001
2	.001	.034	.033	.002	.001
3	.008	.103	.095	.011	.003
4	.013	.141	.128	.016	.003
5	.017	.110	.093	.020	.003
6	-.005	-.055	-.050	-.008	-.003
7	-.021	-.025	-.004	-.025	-.004
8	.020	.109	.089	.023	.003
9	.008	.125	.117	.012	.004
10	.011	.107	.096	.015	.004
11	.006	.045	.039	.008	.002
12	.005	.002	-.003	.006	.001

5.1 STRUCTURAL SHAKEDOWN TEST



DIAL INDICATORS IN POSITION



**BUS LOADED TO 2.5 TIMES GVL
(12,750 LBS)**

5.2 STRUCTURAL STRENGTH AND DISTORTION TESTS - STRUCTURAL DISTORTION

5.2-I. TEST OBJECTIVE

The objective of this test is to observe the operation of the bus subsystems when the bus is placed in a longitudinal twist simulating operation over a curb or through a pothole.

5.2-II. TEST DESCRIPTION

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

1. Body
2. Windows
3. Doors
4. Roof vents
5. Special seating
6. Undercarriage
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. DISCUSSION

The test sequence was repeated ten times. The first and last test is with all wheels level. The other eight tests are with each wheel 6 inches higher and 6 inches lower than the other three wheels.

All doors, windows, escape mechanisms, engine and steering operated normally throughout the test. The handicap ramp was inoperable during the test. No water leakage was observed during the test. The results of this test are indicated on the following data forms.

DISTORTION TEST INSPECTION FORM

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

Page 1 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 40

Wheel Position : (check one)		
All wheels level	<input checked="" type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 2 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 40

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input checked="" type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 3 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 40

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input checked="" type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 4 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 40

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input checked="" type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 5 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 40

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input checked="" type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 6 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 41

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input checked="" type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 7 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 41

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input checked="" type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 8 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 41

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input checked="" type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 9 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 41

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input checked="" type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

DISTORTION TEST INSPECTION FORM

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

Page 10 of 10

Bus Number: 1502	Date: 03-09-15
Personnel: E.D.,E.L.,T.G.,J.P. & P.D.	Temperature(°F): 41

Wheel Position : (check one)		
All wheels level	<input type="checkbox"/> before	<input checked="" type="checkbox"/> after
Left front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right front	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left rear	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Right center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower
Left center	<input type="checkbox"/> 6 in higher	<input type="checkbox"/> 6 in lower

	Comments
Windows	No Deficiencies
Front Doors	No Deficiencies
Rear Doors	No Deficiencies
Escape Mechanisms/ Roof Vents	No Deficiencies
Engine	No Deficiencies
Handicapped Device/ Special Seating	Inoperable
Undercarriage	No Deficiencies
Service Doors	No Deficiencies
Body	No Deficiencies
Windows/ Body Leakage	No Deficiencies
Steering Mechanism	No Deficiencies

5.2 STRUCTURAL DISTORTION TEST



RIGHT FRONT WHEEL SIX INCHES HIGHER



LEFT REAR WHEEL SIX INCHES LOWER

5.3 STRUCTURAL STRENGTH AND DISTORTION TESTS - STATIC TOWING TEST

5.3-I. TEST OBJECTIVE

The objective of this test is to determine the characteristics of the bus towing mechanisms under static loading conditions.

5.3-II. TEST DESCRIPTION

Utilizing 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, first to one side then the other in the horizontal plane, and then upward and downward in the vertical plane. Any permanent deformation or damage to the tow eyes or adjoining structure will be recorded.

5.3-III. DISCUSSION

The test bus submitted for testing was not equipped with any type of tow eyes or tow hooks, therefore the Static Towing Test was not performed.

5.4 STRUCTURAL STRENGTH AND DISTORTION TESTS - DYNAMIC TOWING TEST

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 under manufacturer specified procedures.

5.4-II. TEST DESCRIPTION

This test requires the bus be towed at curb weight using the specified equipment and instructions provided by the manufacturer and a heavy-duty wrecker. 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. DISCUSSION

The bus was towed using a heavy-duty wrecker. The towing interface was accomplished by incorporating a hydraulic under lift. A front lift tow was performed. Rear towing is not recommended. No problems, deformation, or damage was noted during testing.

DYNAMIC TOWING TEST DATA FORM

Page 1 of 1

Bus Number: 1502	Date: 05-26-2015
Personnel: T.S. & S.R.	

Temperature (°F): 78	
Wind Direction: S	Wind Speed (mph): 5

Inspect tow equipment-bus interface.
Comments: A safe and adequate connection was made between the tow equipment and the bus.
Inspect tow equipment-wrecker interface.
Comments: A safe and adequate connection was made between the tow equipment and the wrecker.
Towing Comments: A front lift tow was performed incorporating a hydraulic under lift wrecker.
Description and location of any structural damage: None noted.
General Comments: No problems with the towing interface or towing procedures were encountered.

5.4 DYNAMIC TOWING TEST



TOWING INTERFACE



TEST BUS IN TOW

5.5 STRUCTURAL STRENGTH AND DISTORTION TESTS – JACKING TEST

5.5-I. TEST OBJECTIVE

The objective of this test is to inspect for damage due to the deflated tire, and 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, the tire(s) at one corner of the bus are replaced with deflated tire(s) of the appropriate type. A portable hydraulic floor jack is then positioned in a manner and location specified by the manufacturer and used to raise the bus to a height sufficient to provide 3-in clearance between the floor and an inflated tire. The deflated tire(s) are replaced with the original tire(s) and the jack is lowered. Any structural damage or permanent deformation is recorded on the test data sheet. This procedure is repeated for each corner of the bus.

5.5-III. DISCUSSION

The jack used for this test has a minimum height of 8.75 inches. During the deflated portion of the test, the jacking point clearances ranged from 4.6 inches to 10.4 inches. No deformation or damage was observed during testing. A complete listing of jacking point clearances is provided in the Jacking Test Data Form.

JACKING CLEARANCE SUMMARY

Condition	Frame Point Clearance
Front axle – one tire flat	8.5"
Rear axle – one tire flat	10.0"
Rear axle – two tires flat	7.3"

JACKING TEST DATA FORM

Page 1 of 1

Bus Number: 1502	Date: 02-05-15
Personnel: S.R., T.S. & E.D.	Temperature (°F): 68

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	10.8 " I 8.8 " D	7.2 " I 4.6 " D	Body & Axle
Left front	10.5 " I 8.5 " D	7.4 " I 4.8 " D	Body & Axle
Right rear—outside	10.9 " I 10.0 " D	10.3 " I 9.8 " D	Body & Suspension
Right rear—both	10.9 " I 7.3 " D	10.3 " I 8.0 " D	Body & Suspension
Left rear—outside	11.2 " I 10.4 " D	10.5 " I 9.9 " D	Body & Suspension
Left rear—both	11.2 " I 7.7 " D	10.5 " I 8.0 " D	Body & Suspension
Right middle or tag—outside	N/A	N/A	N/A
Right middle or tag—both	N/A	N/A	N/A
Left middle or tag—outside	N/A	N/A	N/A
Left middle or tag—both	N/A	N/A	N/A
Additional comments of any deformation or difficulty during jacking:			
None noted.			

5.6 STRUCTURAL STRENGTH AND DISTORTION TESTS - HOISTING TEST

5.6-I. TEST OBJECTIVE

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

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. DISCUSSION

The test was conducted using four posts of a six-post electric lift and standard 19 inch jack stands. The bus was hoisted from the front wheel, rear wheel, and then the front and rear wheels simultaneously and placed on jack stands.

The bus easily accommodated the placement of the vehicle lifts and jack stands and the procedure was performed without any instability noted.

HOISTING TEST DATA FORM

Page 1 of 1

Bus Number: 1502	Date: 02-05-15
Personnel: T.S., S.R. & E.D.	Temperature (°F): 69

Comments of any structural damage to the jacking pads or axles while both the front wheels are supported by the jack stands:
None noted.
Comments of any structural damage to the jacking pads or axles while both the rear wheels are supported by the jack stands:
None noted.
Comments of any structural damage to the jacking pads or axles while both the front and rear wheels are supported by the jack stands:
None noted.
Comments of any problems or interference placing wheel hoists under wheels:
None noted.

5.7 STRUCTURAL DURABILITY TEST

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 vehicle is driven a total of 7,500 miles; approximately 5,000 miles on the PSBRTF Durability Test Track and approximately 2,500 miscellaneous other miles. The test will be conducted with the bus operated under three different loading conditions. The first segment will consist of approximately 3,000 miles with the bus operated at GVW. The second segment will consist of approximately 1,500 miles with the bus operated at SLW. The remainder of the test, approximately 3,000 miles, will be conducted with the bus loaded to CW. If GVW 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/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 vehicle shall be washed down and thoroughly inspected for any signs of failure.

5.7-III. DISCUSSION

The Structural Durability Test was started on February 16, 2015 and was conducted until July 6, 2015. The first 3,000 miles were performed at a GVW of 23,970 lbs. and completed on April 14, 2015. Note: this test bus is not designed to accommodate standing passengers; therefore, GVW and SLW are the same 23,970 lbs. The next 1,500 mile SLW segment was performed at 23,970 lbs. and completed on May 19, 2015, and the final 3,000 mile segment was performed at a CW of 18,930 lbs. and completed on July 6, 2015.

The following mileage summary presents the accumulation of miles during the Structural Durability Test. The driving schedule is included, showing the operating duty cycle. A detailed plan view of the Test Track Facility and Durability Test Track are attached for reference. Also, a durability element profile detail shows all the measurements of the different conditions. Finally, photographs illustrating some of the failures that were encountered during the Structural Durability Test are included.

ARBOC #1502

MILEAGE DRIVEN/RECORDED FROM DRIVER'S LOGS

DATE	TOTAL DURABILITY TRACK	TOTAL OTHER MILES	TOTAL
02/16/15 TO 02/22/15	538.00	120.00	658.00
02/23/15 TO 03/01/15	0.00	0.00	0.00
03/02/15 TO 03/08/15	0.00	0.00	0.00
03/09/15 TO 03/15/15	441.00	211.00	652.00
03/16/15 TO 03/22/15	234.00	58.00	292.00
03/23/15 TO 03/29/15	452.00	72.00	524.00
03/30/15 TO 04/05/15	169.00	58.00	227.00
04/06/15 TO 04/12/15	0.00	0.00	0.00
04/13/15 TO 04/19/15	501.00	532.00	1033.00
04/20/15 TO 04/26/15	0.00	0.00	0.00
04/27/15 TO 05/03/15	0.00	0.00	0.00
05/04/15 TO 05/10/15	448.00	496.00	944.00
05/11/15 TO 05/17/15	123.00	54.00	177.00
05/18/15 TO 05/24/15	103.00	23.00	126.00

ARBOC #1502

MILEAGE DRIVEN/RECORDED FROM DRIVER'S LOGS

DATE	TOTAL DURABILITY TRACK	TOTAL OTHER MILES	TOTAL
05/25/15 TO 05/31/15	0.00	58.00	58.00
06/01/15 TO 06/07/15	0.00	0.00	0.00
06/08/15 TO 06/14/15	0.00	0.00	0.00
06/15/15 TO 06/21/15	95.00	57.00	152.00
06/22/15 TO 06/28/15	425.00	66.00	491.00
06/29/15 TO 07/05/15	1303.00	59.00	1362.00
07/06/15 TO 07/12/15	168.00	192.00	360.00
07/13/15 TO 07/19/15	0.00	82.00	82.00
07/20/15 TO 07/26/15	0.00	362.00	362.00
TOTAL	5000.00	2500.00	7500.00

Table 4. Driving Schedule for Bus Operation on the Durability Test Track.

STANDARD OPERATING SCHEDULE

Monday through Friday		
	HOUR	ACTION
Shift 1	midnight	D
	1:40 am	C
	1:50 am	B
	2:00 am	D
	3:35 am	C
	3:45 am	B
	4:05 am	D
	5:40 am	C
	5:50 am	B
	6:00 am	D
	7:40 am	C
Shift 2	7:50 am	F
	8:00 am	D
	9:40 am	C
	9:50 am	B
	10:00 am	D
	11:35 am	C
	11:45 am	B
	12:05 pm	D
	1:40 pm	C
	1:50 pm	B
	2:00 pm	D
Shift 3	3:40 pm	C
	3:50 pm	F
	4:00 pm	D
	5:40 pm	C
	5:50 pm	B
	6:00 pm	D
	7:40 pm	C
	7:50 pm	B
	8:05 pm	D
	9:40 pm	C
	9:50 pm	B
	10:00 pm	D
	11:40 pm	C
	11:50 pm	F

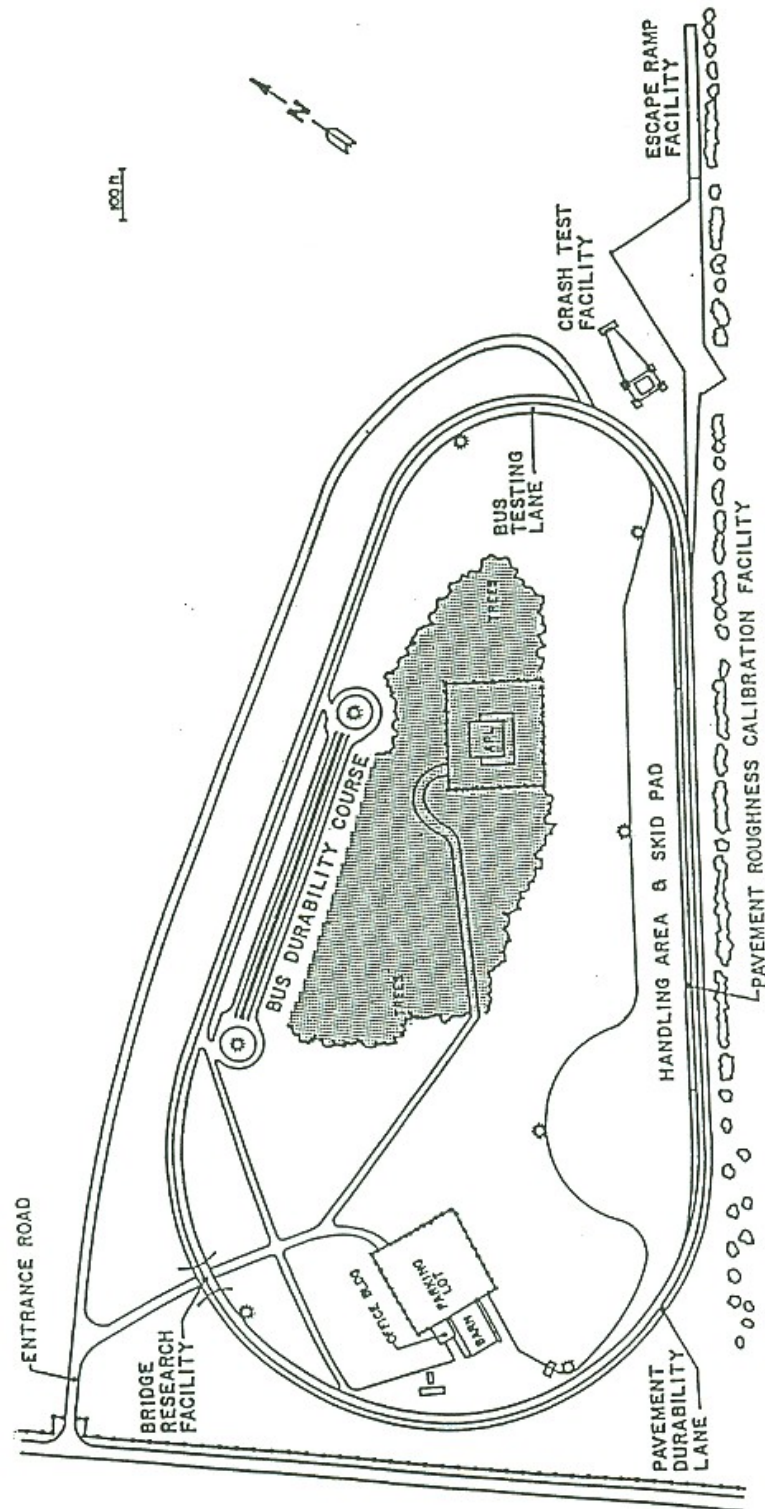
B—Break

C—Cycle all systems five times, visual inspection, driver's log entries

D—Drive bus as specified by procedure

F—Fuel bus, complete driver's log shift entries

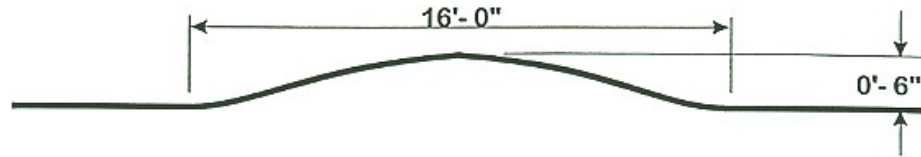
“PLAN VIEW OF PENN STATE BUS TESTING AND RESEARCH FACILITY”



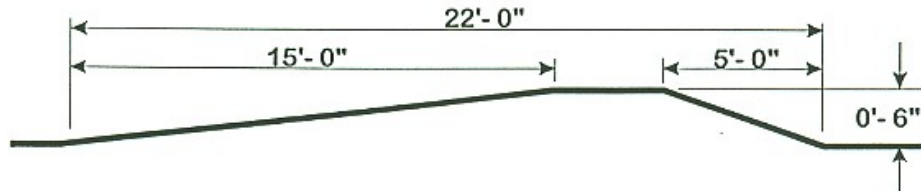
**BUS TESTING AND RESEARCH TEST TRACK
UNIVERSITY PARK, PA**



Staggered
Bumps
(10 mph)



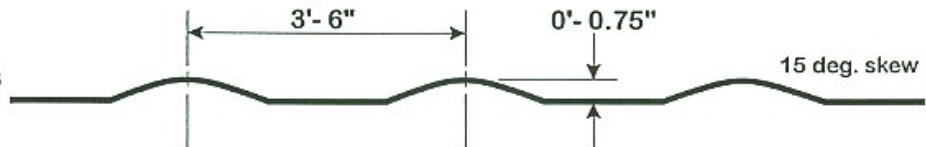
Railroad
Crossing
(8 mph)



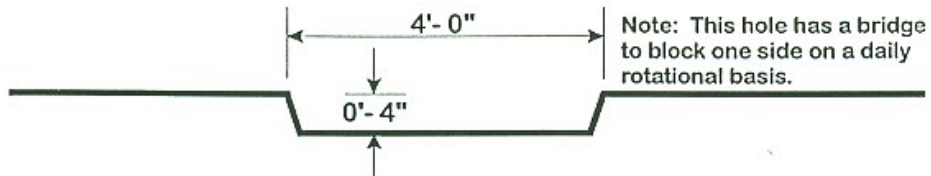
1" Random
Chuck Holes
(20 mph)



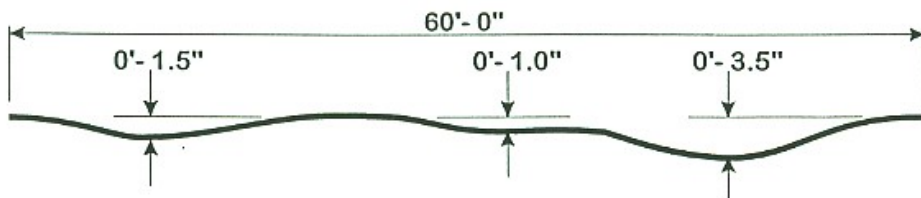
Chatter Bumps
(20 mph)



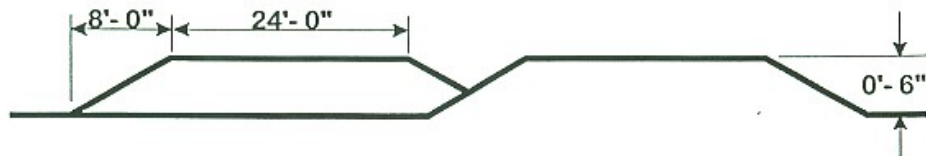
4" Chuck Hole
(5 mph)



High Crown
Intersection
(20 mph)



Frame Twist
(10 mph)



Durability Element Profiles

The Pennsylvania Transportation Institute
Penn State

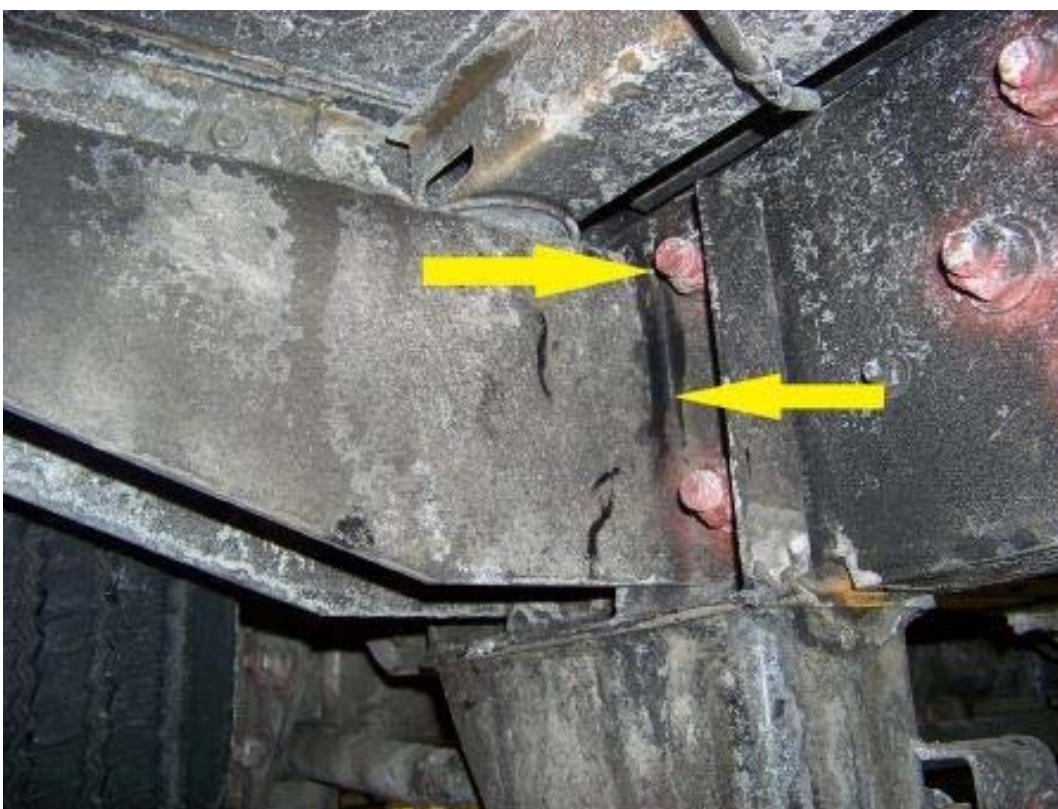
(Page 1 of 1)
UNSCHEDULED MAINTENANCE
ARBOC #1502

DATE	TEST MILES	SERVICE	ACTIVITY	MAN HOURS	DOWN TIME
03-03-15	655	The left and right side body supports forward of the rear axle are cracked in the radius near the mounting bolts.	Both body supports replaced.	12.00	268.00
03-24-15	1,649	Both rear out riggers are cracked.	Cracks cleaned, prepped and welded/repaired.	4.00	94.00
03-26-15	2,038	Rear axle lateral bar mounting bracket; of four bolts one is missing and one is broken.	Two bolts replaced on the rear axle lateral bar mounting bracket.	2.00	16.00
04-10-15	2,400	The rear track rod mount assembly is broken at the attaching bolts.	Track rod mount replaced.	2.00	208.00
04-21-15	3,433	The right rear axle U-bolt is broken.	Disassemble right rear road spring and shock. Spring bushing is damaged spring bolt hole and locator hole are damaged. Parts ordered.	6.00	6.00
05-05-15	3,433	Reference 4/21/15 failure.	Parts arrived. Right rear U-bolt replaced spring bushing replaced and suspension reassembled.	5.00	326.00
06-16-15 to 06-18-15	4,747	The left rear, spring eye bolt broke. The axle has shifted to the rear. The right side spring hanger, spring mounting holes are worn oblong.	Parts ordered for left & right rear spring hangers. Removed the left and right rear springs, spring hangers and body support mounts for replacement. Parts arrived. Left and right rear spring hangers, body mounts, springs replaced. Both rear shocks and U-bolts replaced.	30.00	560.00

UNSCHEDULED MAINTENANCE



**CRACKED BODY MOUNT FORWARD OF REAR AXLE
(655 TEST MILES)**



UNSCHEDULED MAINTENANCE CONT.



**CRACKED REAR OUTRIGGER
(1,649 TEST MILES)**



**CRACKED REAR AXLE LATERAL BAR MOUNT
(2,038 TEST MILES)**

UNSCHEDULED MAINTENANCE CONT.



**BROKEN RIGHT REAR AXLE U-BOLT
(3,433 TEST M,ILES)**



**DAMAGED RIGHT REAR SPRING
(3,433 TEST MILES)**

UNSCHEDULED MAINTENANCE CONT.



**DAMAGED SPRING BOLT HOLE
(3,433 TEST MILES)**



**DAMAGED SPRING BUSHING
(3,433 TEST MILES)**

UNSCHEDULED MAINTENANCE CONT.



**WORN SPRING MOUNTING HOLE
(4,747 TEST MILES)**

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

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 Penn State Test Facility. 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, and 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 Penn State Test 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 160 lb. It is judged that a 12-gal tank weighing approximately 120 lb will be sufficient for this test and much easier for the technician and 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.

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 60EF (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 60EF. 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

$$\text{Fem}_{i/lb.} = \text{Observed fuel economy} = \frac{\text{miles}}{\text{lb of fuel}}$$

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

$$FE_{\text{mpg}} = FE_{\text{mi/lb}} \times G_s \times G_w$$

where G_s = Specific gravity of test fuel at 60°F (referred to water)
 G_w = 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.

$$FE_c = FE_{\text{mpg}} \times \frac{Q}{H}$$

where

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

Combining steps 1-3 yields

$$\Rightarrow FE_c = \frac{\text{miles}}{\text{lbs}} \times (G_s \times G_w) \times \frac{Q}{H}$$

- 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/BTUx10⁶.

Eq = Energy equivalent of converting mpg to mile/BTUx10⁶.

$$Eq = ((\text{mpg})/(H)) \times 10^6$$

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/BTUx10⁶) 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.

<u>phase</u>	<u>miles per phase</u>	<u>total miles per run</u>
CBD	1.9097	5.7291
ART	1.9097	3.8193
COM	3.8193	3.8193

$$\text{FEo}_{\text{mi/scf}} = \text{Observed fuel economy} = \frac{\text{miles}}{\text{scf of fuel}}$$

- 2.) Convert the observed fuel economy to miles per lb by dividing FEO by the density of the test fuel at standard conditions (Lb/ft³).

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.

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

where Gm = Density of test fuel at standard conditions

- 3.) Convert the observed fuel economy (FEomi/lb) to an energy equivalent of (miles/BTUx10⁶) by dividing the observed fuel economy (FEomi/lb) by the heating value of the test fuel at standard conditions.

$$\text{Eq} = ((\text{FEomi/lb})/\text{H}) \times 10^6$$

where

Eq = Energy equivalent of miles/lb to mile/BTUx10⁶

H = Volumetric heating value of test fuel at standard conditions

6-III. DISCUSSION

This is a comparative test of fuel economy using diesel fuel with a heating value of 19,568 but/lb. The driving cycle consists of Central Business District (CBD), Arterial (ART), and Commuter (COM) phases as described in 6-II. The fuel consumption for each driving cycle and for idle is measured separately. The results are corrected to a reference fuel with a volumetric heating value of 126,700.0 btu/gal.

An extensive pretest maintenance check is made including the replacement of all lubrication fluids. The details of the pretest maintenance are given in the first three Pretest Maintenance Forms. The fourth sheet shows the Pretest Inspection. The next four Fuel Economy Forms provide the data from the four test runs. Finally, the summary sheet provides the average fuel consumption. The overall average is based on total fuel and total mileage for each phase. The overall average fuel consumption values were; CBD – 4.37 mpg, ART – 4.99 mpg, and COM – 8.71 mpg. Average fuel consumption at idle was 0.67 gph.

FUEL ECONOMY PRE-TEST MAINTENANCE FORM

Page 1 of 3

Bus Number: 1502	Date: 7-7-15	SLW (lbs.): 23,970
Personnel: S.R., T.S. & E.D.		

FUEL SYSTEM	OK
Install fuel measurement system	✓
Replace fuel filter	✓
Check for fuel leaks	✓
Specify fuel type (refer to fuel analysis)	Diesel
Remarks: None noted.	
BRAKES/TIRES	OK
Inspect hoses	✓
Inspect brakes	✓
Relube wheel bearings	✓
Check tire inflation pressures (mfg. specs.)	✓
Check tire wear (less than 50%)	✓
Remarks: None noted.	
COOLING SYSTEM	OK
Check hoses and connections	✓
Check system for coolant leaks	✓
Remarks: None noted.	

FUEL ECONOMY PRE-TEST MAINTENANCE FORM

Page 2 of 3

Bus Number: 1502	Date: 7-7-15
Personnel: S.R., T.S. & E.D.	
ELECTRICAL SYSTEMS	OK
Check battery	✓
Inspect wiring	✓
Inspect terminals	✓
Check lighting	✓
Remarks: None noted.	
DRIVE SYSTEM	OK
Drain transmission fluid	✓
Replace filter/gasket	✓
Check hoses and connections	✓
Replace transmission fluid	✓
Check for fluid leaks	✓
Remarks: None noted.	
LUBRICATION	OK
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: None noted.	

FUEL ECONOMY PRE-TEST MAINTENANCE FORM

Page 3 of 3

Bus Number: 1502	Date: 7-7-15
Personnel: S.R., T.S. & E.D.	
EXHAUST/EMISSION SYSTEM	OK
Check for exhaust leaks	✓
Remarks: None noted.	
ENGINE	OK
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: None noted.	
STEERING SYSTEM	OK
Check power steering hoses and connectors	✓
Service fluid level	✓
Check power steering operation	✓
Replace transmission fluid	✓
Remarks: None noted.	
TEST DRIVE	OK
Check brake operation	✓
Check transmission operation	✓
Remarks: None noted.	

FUEL ECONOMY PRE-TEST INSPECTION FORM

Page 1 of 1

Bus Number: 1502	Date: 7-15-15
Personnel: S.R., T.G. & M.H.	
PRE WARM-UP	If OK, Initial
Fuel Economy Pre-Test Maintenance Form is complete	S.R.
Cold tire pressure (psi): Front <u>120</u> Middle <u>N/A</u> Rear <u>120</u>	S.R.
Engine oil level	S.R.
Engine coolant level	S.R.
Interior and exterior lights on, evaporator fan on	S.R.
Fuel economy instrumentation installed and working properly.	S.R.
Fuel line -- no leaks or kinks	S.R.
Speed measuring system installed on bus. Speed indicator installed in front of bus and accessible to TECH and Driver.	S.R.
Bus is loaded to SLW	
WARM-UP	If OK, Initial
Bus driven for at least one hour warm-up	S.R.
No extensive or black smoke from exhaust	S.R.
POST WARM-UP	If OK, Initial
Warm tire pressure (psi): Front <u>125</u> Middle <u>N/A</u> Rear <u>125</u>	
Environmental conditions Average wind speed <12 mph and maximum gusts <15 mph Ambient temperature between 30°F(-1C°) and 90°F(32°C) Track surface is dry Track is free of extraneous material and clear of interfering traffic	S.R.

FUEL ECONOMY DATA FORM (Liquid Fuels)

Page 1 of 4

Bus Number: 1502		Manufacturer: ARBOC		Date: 7-15-15			
Run Number: 1		Personnel: S.R., T.G. & M.H.					
Test Direction: <input type="checkbox"/> CW or <input checked="" type="checkbox"/> CCW		Temperature (°F): 69		Humidity (%): 90			
SLW (lbs.): 23,970		Wind Speed (mph) & Direction: 2 / N		Barometric Pressure (in. Hg): 29.71			
Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Flow Meter Reading (gals)		Fuel Used (gals)
	Start	Finish			Start	Finish	
CBD #1	0	8:47	8:47	34.1	0	.346	.346
ART #1	0	4:02	4:02	36.7	0	.340	.340
CBD #2	0	8:47	8:47	38.8	0	.384	.384
ART #2	0	4:13	4:13	39.6	0	.347	.347
CBD #3	0	8:55	8:55	38.5	0	.395	.395
COMMUTER	0	5:55	5:55	39.3	0	.397	.397
Total Fuel = 2.209 gals							
20 minute idle : Total Fuel Used = .204 gals							
Heating Value = 19,568 BTU/LB							
Comments: None noted.							

FUEL ECONOMY DATA FORM (Liquid Fuels)

Page 2 of 4

Bus Number: 1502		Manufacturer: ARBOC		Date: 7-15-15			
Run Number: 2		Personnel: S.R., T.G. & M.H.					
Test Direction: <input checked="" type="checkbox"/> CW or <input type="checkbox"/> CCW		Temperature (°F): 75		Humidity (%): 88			
SLW (lbs.): 23,970		Wind Speed (mph) & Direction: 3 / N		Barometric Pressure (in.Hg): 29.76			
Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Flow Meter Reading (gals)		Fuel Used (gals)
	Start	Finish			Start	Finish	
CBD #1	0	8:58	8:58	38.2	0	.393	.393
ART #1	0	4:13	4:13	38.2	0	.338	.338
CBD #2	0	8:56	8:56	38.6	0	.394	.394
ART #2	0	4:13	4:13	38.7	0	.338	.338
CBD #3	0	9:00	9:00	38.4	0	.396	.396
COMMUTER	0	6:05	6:05	38.6	0	.390	.390
Total Fuel = 2.249 gals							
20 minute idle : Total Fuel Used = N/A gals							
Heating Value = 19,568 BTU/LB							
Comments: None noted.							

FUEL ECONOMY DATA FORM (Liquid Fuels)

Page 3 of 4

Bus Number: 1502		Manufacturer: ARBOC		Date: 7-15-15			
Run Number: 3		Personnel: S.R., T.G. & M.H.					
Test Direction: <input type="checkbox"/> CW or <input checked="" type="checkbox"/> CCW		Temperature (°F): 72		Humidity (%): 88			
SLW (lbs.): 23,970		Wind Speed (mph) & Direction: 5 / N		Barometric Pressure (in. Hg): 29.77			
Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Flow Meter Reading (gals)		Fuel Used (gals)
	Start	Finish			Start	Finish	
CBD #1	0	8:53	8:53	39.6	0	.398	.398
ART #1	0	4:13	4:13	38.9	0	.347	.347
CBD #2	0	9:00	9:00	39.4	0	.396	.396
ART #2	0	4:13	4:13	40.3	0	.345	.345
CBD #3	0	8:52	8:52	40.8	0	.400	.400
COMMUTER	0	6:04	6:04	40.9	0	.397	.397
Total Fuel = 2.283 gals							
20 minute idle : Total Fuel Used = N/A gals							
Heating Value = 19,568 BTU/LB							
Comments: None noted.							

FUEL ECONOMY DATA FORM (Liquid Fuels)

Page 4 of 4

Bus Number: 1502		Manufacturer: ARBOC		Date: 7-15-15			
Run Number: 4		Personnel: S.R., T.G. & M.H.					
Test Direction: <input checked="" type="checkbox"/> CW or <input type="checkbox"/> CCW		Temperature (°F): 72		Humidity (%): 82			
SLW (lbs.): 23,970		Wind Speed (mph) & Direction: 8 / NE		Barometric Pressure (in. Hg): 29.80			
Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Flow Meter Reading (gals)		Fuel Used (gals)
	Start	Finish			Start	Finish	
CBD #1	0	8:54	8:54	40.4	0	.397	.397
ART #1	0	4:10	4:10	40.8	0	.345	.345
CBD #2	0	8:48	8:48	40.2	0	.398	.398
ART #2	0	4:13	4:13	40.7	0	.340	.340
CBD #3	0	8:45	8:45	40.4	0	.400	.400
COMMUTER	0	6:04	6:04	39.7	0	.387	.387
Total Fuel = 2.267 gals							
20 minute idle : Total Fuel Used = .196 gals							
Heating Value = 19,568 BTU/LB							
Comments: None noted.							

FUEL ECONOMY SUMMARY SHEET

BUS MANUFACTURER :ARBOC
 BUS MODEL :SPIRIT OF LIBERTY
 BUS NUMBER :1503
 TEST DATE :07/15/15

FUEL TYPE : DIESEL
 SP. GRAVITY : .8505
 HEATING VALUE : 19568.00 BTU/Lb
 FUEL TEMPERATURE : 99.00 deg F
 Standard Conditions : 60 deg F and 14.7 psi
 Density of Water : 8.3373 lb/gallon at 60 deg F

CYCLE	TOTAL FUEL USED(GAL)	TOTAL MILES	FUEL ECONOMY MPG(Measured)	FUEL ECONOMY MPG (Corrected)
-------	-------------------------	-------------	-------------------------------	---------------------------------

Run # :1, CCW				
CBD	1.125	5.73	5.093	4.56
ART	.687	3.82	5.560	4.98
COM	.397	3.82	9.622	8.61
TOTAL	2.209	13.37	6.053	5.42

Run # :2, CW				
CBD	1.183	5.73	4.844	4.34
ART	.676	3.82	5.651	5.06
COM	.390	3.82	9.795	8.77
TOTAL	2.249	13.37	5.945	5.32

Run # :3, CCW				
CBD	1.194	5.73	4.799	4.30
ART	.692	3.82	5.520	4.94
COM	.397	3.82	9.622	8.61
TOTAL	2.283	13.37	5.856	5.24

Run # :4, CW				
CBD	1.195	5.73	4.795	4.29
ART	.685	3.82	5.577	4.99
COM	.387	3.82	9.871	8.84
TOTAL	2.267	13.37	5.898	5.28

IDLE CONSUMPTION (MEASURED)

First 20 Minutes Data : .20GAL Last 20 Minutes Data : .20GAL
 Average Idle Consumption : .60GAL/Hr

RUN CONSISTENCY: % Difference from overall average of total fuel used

Run 1 : 1.9 Run 2 : .1 Run 3 : -1.4 Run 4 : -.7

SUMMARY (CORRECTED VALUES)

Average Idle Consumption : .67 G/Hr
 Average CBD Phase Consumption : 4.37 MPG
 Average Arterial Phase Consumption : 4.99 MPG
 Average Commuter Phase Consumption : 8.71 MPG
 Overall Average Fuel Consumption : 5.32 MPG
 Overall Average Fuel Consumption : 38.31 Miles/ Million BTU

7. NOISE

7.1 INTERIOR NOISE AND VIBRATION TESTS

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 accelerating at full throttle from a standing start to 35 mph on a level pavement. All openings will be closed and all accessories will be operating during the test. This test will be performed on the track at the Test Track Facility.
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 Test Track and the Bus Testing Center.

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. DISCUSSION

This test is performed in three parts. The first part exposes the exterior of the vehicle to 80.0 dB(A) on the left side of the bus and the noise transmitted to the interior is measured. The overall average of the six measurements was 52.5 dB(A); ranging from 50.8 dB(A) at the rear passenger seats to 54.7 dB(A) in line with the middle speaker. The interior ambient noise level for this test was < 30.0 dB(A).

The second test measures interior noise during acceleration from 0 to 35 mph. This noise level ranged from 71.3 dB(A) at the driver's seat to 74.7 dB(A) at the rear passenger seats. The overall average was 73.0 dB(A). The interior ambient noise level for this test was < 34.0 dB(A).

The third part of the test is to listen for resonant vibrations, rattles, and other noise sources while operating over the road. Squeaking was noted in the wheelchair ramp.

INTERIOR NOISE TEST DATA FORM
Test Condition 1: 80 dB(A) Stationary White Noise

Page 1 of 3

Bus Number: 1502	Date: 6-26-15
Personnel: T.S. & S.R.	
Temperature (°F): 70	Humidity (%): 72
Wind Speed (mph): 4	Wind Direction: E
Barometric Pressure (in.Hg): 30.02	
Initial Sound Level Meter Calibration: dB(A): 93.8 S.R.	
Interior Ambient Noise Level dB(A): < 30.0	Exterior Ambient Noise Level dB(A): 44.7
Microphone Height During Testing (in): 46.3" average from floor	
Initial Reading at Speaker: 81.5 dB(A)	Final Reading at Speaker: 81.3 dB(A)

Measurement Location	Measured Sound Level dB(A)
Driver's Seat	51.6
Front Passenger Seats	53.4
In Line with Front Speaker	53.4
In Line with Middle Speaker	54.7
In Line with Rear Speaker	51.2
Rear Passenger Seats	50.8

Final Sound Level Meter Calibration: 93.8 dB(A) S.R.
--

Comments: This test was audited.

INTERIOR NOISE TEST DATA FORM
Test Condition 2: 0 to 35 mph Acceleration Test
Page 2 of 3

Bus Number: 1502	Date: 03-13-15
Personnel: S.R., E.D. & M.H.	
Temperature (°F): 36	Humidity (%): 34
Wind Speed (mph): Calm	Wind Direction: N-Calm
Barometric Pressure (in.Hg): 30.50	
Initial Sound Level Meter Calibration: 93.8 dB(A)	
Interior Ambient Noise Level dB(A): < 34.0	Exterior Ambient Noise Level dB(A): 41.8
Microphone Height During Testing (in): 29.0" above seat	

Measurement Location	Measured Sound Level dB(A)
Driver's Seat	71.3
Front Passenger Seats	71.6
Middle Passenger Seats	74.4
Rear Passenger Seats	74.7

Final Sound Level Meter Calibration: 93.8 dB(A)

Comments: None noted.

INTERIOR NOISE TEST DATA FORM

Test Condition 3: Audible Vibration Test

Page 3 of 3

Bus Number: 1502	Date: 03-13-15
Personnel: S.R., E.D. & M.H.	
Temperature (°F): 36	

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	None Noted.	None Noted.
Windows and Doors	None Noted.	None Noted.
Seats and Wheel Chair Lifts	Wheelchair ramp	Squeaking in ramp is noticeable.
Other	None Noted.	None Noted.

Comment on any other vibration or noise source which may have occurred that is not described above: None noted.
Comments: None noted.

7.1 INTERIOR NOISE TEST



**TEST BUS SET-UP FOR 80 dB(A)
INTERIOR NOISE TEST**

7.2 EXTERIOR NOISE TESTS

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 a 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 up shift.
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. DISCUSSION

The Exterior Noise Test determines the noise level generated by the vehicle under different driving conditions and at stationary low and high idle, with and without air conditioning and accessories operating. The test site is a large, level, bituminous paved area with no reflecting surfaces nearby.

With an exterior ambient noise level of 44.4 dB(A), the average test result obtained while accelerating from a constant speed was 78.0 dB(A) on the right side and 77.2 dB(A) on the left side.

When accelerating from a standstill with an exterior ambient noise level of 44.6 dB(A), the average of the results obtained were 78.0 dB(A) on the right side and 78.0 dB(A) on the left side.

With the vehicle stationary and the engine, accessories, and air conditioning on, the measurements averaged 64.6 dB(A) at low idle, 69.2 dB(A) at high idle, and 72.4 dB(A) at wide open throttle. With the accessories and air conditioning off, the readings averaged 1.9 dB(A) lower at low idle, 0.7 dB(A) lower at high idle, and 0.2 dB(A) lower at wide open throttle. The exterior ambient noise level measured during this test was 43.8 dB(A).

EXTERIOR NOISE TEST DATA FORM

Accelerating from Constant Speed

Page 1 of 3

Bus Number: 1502		Date: 03-13-15	
Personnel: S.R., E.D. & M.H.			
Temperature (°F): 35		Humidity (%): 40	
Wind Speed (mph): Calm		Wind Direction: Calm	
Barometric Pressure (in.Hg): 30.50			
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30°F and 90°F: ■ E.D.			
Initial Sound Level Meter Calibration: 93.8 dB(A)			
Exterior Ambient Noise Level: 44.4 dB(A)			
Accelerating from Constant Speed Curb (Right) Side		Accelerating from Constant Speed Street (Left) Side	
Run #	Measured Noise Level dB(A)	Run #	Measured Noise Level dB(A)
1	76.3	1	76.2
2	76.6	2	76.2
3	76.3	3	76.0
4	78.0	4	76.5
5	77.9	5	77.8
6		6	
7		7	
8		8	
9		9	
10		10	
Average of two highest actual noise levels = 78.0 dB(A)		Average of two highest actual noise levels = 77.2 dB(A)	
Final Sound Level Meter Calibration Check: 93.8 dB(A)			
Comments: None noted.			

EXTERIOR NOISE TEST DATA FORM

Accelerating from Standstill

Page 2 of 3

Bus Number: 1502		Date: 03-13-15	
Personnel: S.R., E.D. & M.H.			
Temperature (°F): 36		Humidity (%): 40	
Wind Speed (mph): Calm		Wind Direction: N-Calm	
Barometric Pressure (in.Hg): 30.50			
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30°F and 90°F: ■ E.D.			
Initial Sound Level Meter Calibration: 93.8 dB(A)			
Exterior Ambient Noise Level: 44.6 dB(A)			
Accelerating from Standstill Curb (Right) Side		Accelerating from Standstill Street (Left) Side	
Run #	Measured Noise Level dB(A)	Run #	Measured Noise Level dB(A)
1	77.4	1	77.8
2	77.8	2	77.4
3	78.1	3	77.6
4	77.9	4	77.2
5	77.6	5	78.1
6		6	
7		7	
8		8	
9		9	
10		10	
Average of two highest actual noise levels = 78.0 dB(A)		Average of two highest actual noise levels = 78.0 dB(A)	
Final Sound Level Meter Calibration Check: 93.8 dB(A)			
Comments: None noted.			

EXTERIOR NOISE TEST DATA FORM

Stationary

Page 3 of 3

Bus Number: 1502		Date: 03-13-15	
Personnel: S.R., E.D. & M.H.			
Temperature (°F): 36		Humidity (%): 36	
Wind Speed (mph): Calm		Wind Direction: N	
Barometric Pressure (in.Hg): 30.50			
Initial Sound Level Meter Calibration: 93.8 dB(A)			
Exterior Ambient Noise Level: 43.8 dB(A)			
Accessories and Air Conditioning ON			
Throttle Position	Engine RPM	Curb (Right) Side dB(A)	Street (Left) Side db(A)
		Measured	Measured
Low Idle	800	60.4	68.8
High Idle	1,200	65.6	72.7
Wide Open Throttle	2,500	71.2	73.6
Accessories and Air Conditioning OFF			
Throttle Position	Engine RPM	Curb (Right) Side dB(A)	Street (Left) Side db(A)
		Measured	Measured
Low Idle	800	59.8	65.5
High Idle	1,200	67.2	69.7
Wide Open Throttle	2,500	71.4	73.0
Final Sound Level Meter Calibration Check: 93.8 dB(A)			
Comments: None noted.			

7.2 EXTERIOR NOISE TESTS



**TEST BUS UNDERGOING
EXTERIOR NOISE TESTING**



8. EMISSIONS TEST – DYNAMOMETER-BASED EMISSIONS TEST USING TRANSIT DRIVING CYCLES

8-I. TEST OBJECTIVE

The objective of this test is to provide comparable emissions data on transit buses produced by different manufacturers. This chassis-based emissions test bears no relation to engine certification testing performed for compliance with the Environmental Protection Agency (EPA) regulation. EPA's certification tests are performed using an engine dynamometer operating under the Federal Test Protocol. This emissions test is a measurement of the gaseous engine emissions CO, CO₂, NO_x, HC and particulates (diesel vehicles) produced by a vehicle operating on a large-roll chassis dynamometer. The test is performed for three differed driving cycles intended to simulate a range of transit operating environments. The cycles consist of Manhattan Cycle, the Orange County Bus driving cycle, and the Urban Dynamometer Driving Cycle (UDDS). The test is performed under laboratory conditions in compliance with EPA 1065 and SAE J2711. The results of this test may not represent actual in-service vehicle emissions but will provide data that can be used by recipients to compare buses tested under different operating conditions.

8-II. TEST DESCRIPTION

This test is performed in the emissions bay of the LTI Vehicle Testing Laboratory. The Laboratory is equipped with a Schenk Pegasus 300 HP, large-roll (72 inch diameter) chassis dynamometer suitable for heavy-vehicle emissions testing. The dynamometer is located in the end test bay and is adjacent to the control room and emissions analysis area. The emissions laboratory provides capability for testing heavy-duty diesel and alternative-fueled buses for a variety of tailpipe emissions including particulate matter, oxides of nitrogen, carbon monoxide, carbon dioxide, and hydrocarbons. It is equipped with a Horiba full-scale CVS dilution tunnel and emissions sampling system. The system includes Horiba Mexa 7400 Series gas analyzers and a Horiba HF47 Particulate Sampling System. Test operation is automated using Horiba CDTCS software. The computer controlled dynamometer is capable of simulating over-the-road operation for a variety of vehicles and driving cycles.

The emissions test will be performed as soon as permissible after the completion of the GVW portion of the structural durability test. The driving cycles are the Manhattan cycle, a low average speed, highly transient urban cycle (Figure 1), the Orange County Bus Cycle which consists of urban and highway

driving segments (Figure 2), and the EPA UDDS Cycle (Figure 3). An emissions test will comprise of two runs for the three different driving cycles, and the average value will be reported. Test results reported will include the average grams per mile value for each of the gaseous emissions for gasoline buses, for all the three driving cycles. In addition, the particulate matter emissions are included for diesel buses, and non-methane hydrocarbon emissions (NMHC) are included for CNG buses. Testing is performed in accordance with EPA CFR49, Part 1065 and SAE J2711 as practically determined by the FTA Emissions Testing Protocol developed by West Virginia University and Penn State University.

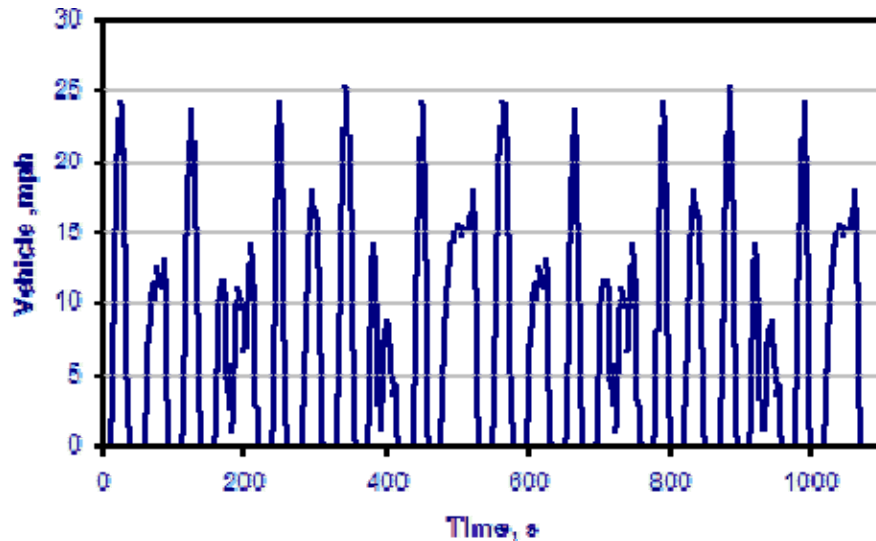


Figure 1. Manhattan Driving Cycle (duration 1089 sec, Maximum speed 25.4mph, average speed 6.8mph)

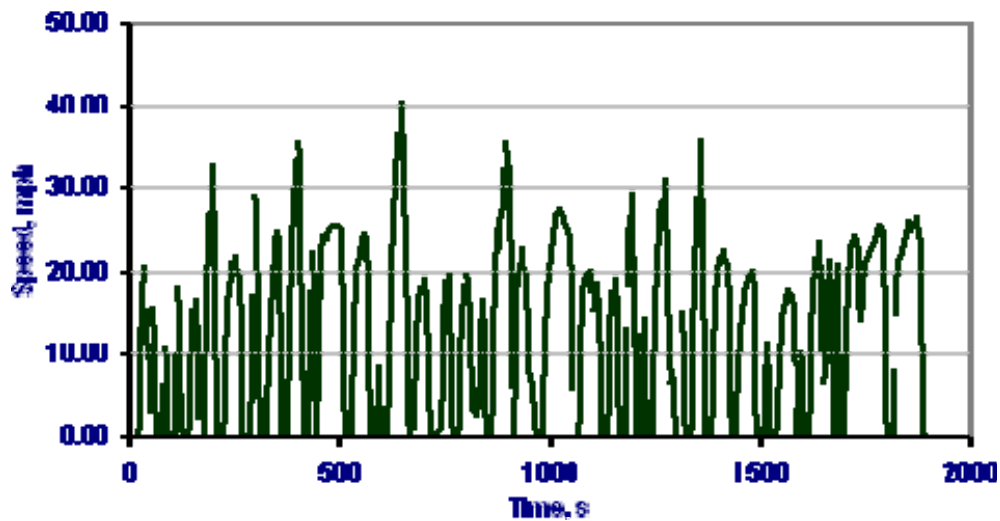


Figure 2. Orange County Bus Cycle (Duration 1909 Sec, Maximum Speed 41mph, Average Speed 12mph)

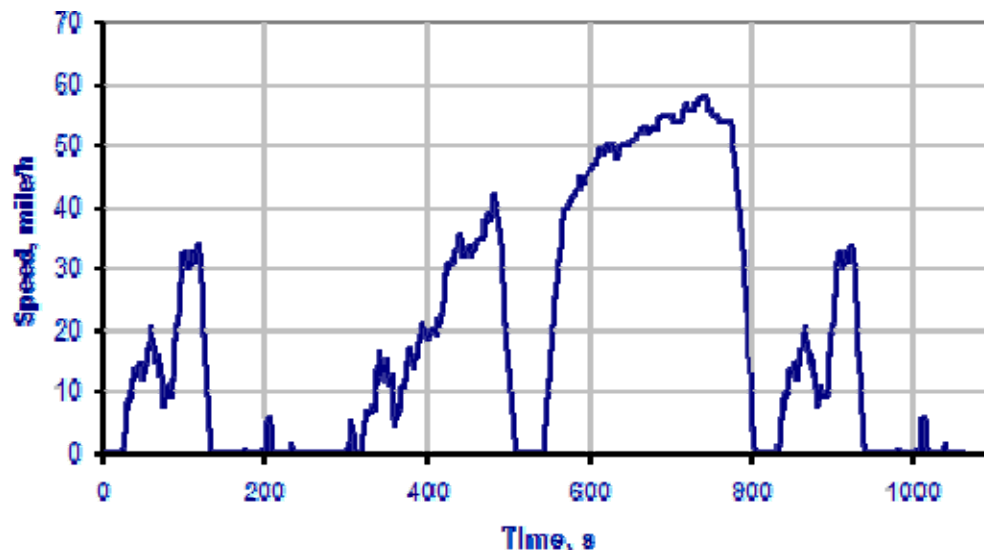


Figure 3. HD-UDDS Cycle (duration 1060seconds, Maximum Speed 58mph, Average Speed 18.86mph)

8-III. TEST ARTICLE

The test article is a ARBOC model 3400 Liberty transit bus equipped with a diesel fueled Cummins model ISB 6.7 engine. The bus was tested on July 22, 2015.

8-IV. TEST EQUIPMENT

Testing is performed in the LTI Vehicle Testing Laboratory emissions testing bay. The test bay is equipped with a Schenk Pegasus 72-inch, large-roll chassis dynamometer. The dynamometer is electronically controlled to account for vehicle road-load characteristics and for simulating the inertia characteristics of the vehicle. Power to the roller is supplied and absorbed through an electronically controlled 3-phase ac motor. Absorbed power is dumped back onto the electrical grid.

Vehicle exhaust is collected by a Horiba CVS, full-flow dilution tunnel. The system has separate tunnels for diesel and gasoline/natural gas fueled vehicles.

In the case of diesel vehicles, particulate emissions are measured gravimetrically using 47mm Teflon filters. These filters are housed in a Horiba HF47 particulate sampler, per EPA 1065 test procedures.. Heated gaseous emissions of hydrocarbons and NOx are sampled by Horiba heated oven analyzers. Gaseous emissions for CO, CO2 and cold NOx are measured using a Horiba Mexa 7400 series gas analyzer. System operation, including the operation of the chassis dynamometer, and all calculations are controlled by a Dell workstation running Horiba CDCTS test control software. Particulate Filters are weighed in a glove box using a Sartorius microbalance accurate to 1 microgram.

8-V. TEST PREPARATION AND PROCEDURES

All vehicles are prepared for emissions testing in accordance with the Fuel Economy Pre-Test Maintenance Form. (In the event that fuel economy test was performed immediately prior to emissions testing this step does not have to be repeated) 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. The ABS system and when applicable, the regenerative braking system are disabled for operation on the chassis dynamometer. 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 performing. Both the Fuel Economy Pre-Test Maintenance Form and the Fuel Economy Pre-Test Inspection Form are found on the following pages.

Prior to performing the emissions test, each bus is evaluated to determine its road-load characteristics using coast-down techniques in accordance with SAE J1263. This data is used to program the chassis dynamometer to accurately simulate over-the-road operation of the bus.

Warm-up consists of driving the bus for 20 minutes at approximately 40 mph on the chassis dynamometer. The test driver follows the prescribed driving cycle watching the speed trace and instructions on the Horiba Drivers-Aid monitor which is placed in front of the windshield. The CDCTS computer monitors driver performance and reports any errors that could potentially invalidate the test.

All buses are tested at half seated load weight. The base line emissions data are obtained at the following conditions:

1. Air conditioning off
2. Evaporator fan or ventilation fan on
3. One Half Seated load weight
4. Appropriate test fuel with energy content (BTU/LB) noted in CDTCS software

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.

8-VI DISCUSSION

The following Table 1 provides the emissions testing results on a grams per mile basis for each of the exhaust constituents measured and for each driving cycle performed.

TABLE 1 Emissions Test Results

Test Completed at Half SLW: <u>21,450</u>			
Driving Cycle	Manhattan	Orange County Bus	UDDS
CO₂, gm/mi	2,720	1,817	1,617
CO, gm/mi	0.13	0.07	0.05
THC, gm/mi	0.20	0.13	0.08
NMHC, gm/mi	0.17	0.11	0.07
NO_x, gm/mi	3.5	2.91	1.62
Particulates. gm/mi	0.025	0.021	0.022
Fuel consumption mpg	3.44	5.63	6.28