FEDERAL TRANSIT BUS TEST

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

Manufacturer: Forest River Bus LLC
Model: Ford E-450 Cutaway Shuttle Bus

Partial Test

September 2022

Report Number: LTI-BT-R2022-10-P

Larson Transportation Institute
201 Transportation Research Building
The Pennsylvania State University
University Park, PA 16802
(814) 865-1891

Bus Testing and Research Center
2237 Plank Road
Duncansville, PA 16635
(814) 695-3404

PennState College of Engineering

LTI BUS RESEARCH AND TESTING CENTER

FEDERAL TRANSIT BUS TEST

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

In accordance with 49 CFR Part, 665

Manufacturer: Forest River Bus LLC
Manufacturer's address: 2367 Century Drive
Goshen, IN 46528

Model: Ford E-450 Cutaway Shuttle Bus

Partial Test

Report Number: LTI-BT-R2022-10-P

ACCREDITED
Mechanical Testing Certificate 3172.01

David Klinikowski	Director, Bus Research and Testing Center	September 16th, 2022
Quality Authorization	*Title*	*Date*

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EXECUTIVE SUMMARY

TEST HIGHLIGHTS

The information in this report pertains only to this specific bus, as received from the manufacturer for testing.

The Check-In section of the report provides a description of the bus and specifies its major components. The following table gives the salient specifications.

Manufacturer	Forest River Bus LLC
Model	Ford E-450 Cutaway Shuttle Bus
Chassis Make/Model	Ford Motor Co. / NDC21803
Chassis Modified	Yes
Length	26 feet / 3.2 inches
Fuel	Battery Electric
Service Life	7 Year / 200,000 mile – Partial Test
Number of Seats (including driver)	18 and 1 wheelchair
Manufacturer-Designated Standing Passenger Capacity	No Standees
Gross Vehicle Weight used for testing	14,010 lb.
Gross Vehicle Weight Rating	14,500 lb.
Mileage at Delivery	550 miles
Test Start Date	July 14, 2022
Test Completion Date	September 9, 2022
Report Issuance Date	September 16, 2022

The measured curb weight was 3,920 lb. for the front axle and 6,780 lb. for the rear axle. These combined weights provided a total measured curb weight of 10,700 lb. There are 19 seats including the driver and two wheelchair positions. Two seats are stowable. However, utilizing both wheelchair positions or one wheelchair and all seats results in a load that exceeds the gross vehicle weight rating. Therefore, the gross load represents seated passengers only, for a total of 19 passengers, utilizing 18 seats (including the driver) and one wheelchair position. Gross load is calculated as (150 lb. x 18) + (600 lb. x 1) = 3,300 lb. At full declared capacity, the measured gross vehicle weight was 14,010 lb. A placard shows that standing passengers are not permitted. However, there is free floor space for 14 standing passengers in the above configuration. There is a potential to overload this bus with the available floor space for standing passengers or in any other configuration other than tested.

This bus has a modified chassis. The chassis was modified by adding 16 inches to the rear overhang of the Ford OEM frame.

The FTA determined that this bus be tested for Check in, Accessibility, Selected Maintenance, Safety Double Lane Change, Energy Economy and Range, Interior Noise and Exterior Noise; the baseline full Bus Testing report for this test is PTI-BT-R0518.

ABBREVIATIONS AND ACRONYMS

ABS - anti-skid braking system
ABTC - Altoona Bus Test Center
A/C - air conditioner, or air conditioning
AC - alternating current
ADA - American Disability Act
Ah - Ampere hours
CDCTS - chassis dynamometer test control system
CVS - constant volume sampling
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
DC - direct current
DIR - test director
DR - bus driver
EPA - Environmental Protection Agency
GAWR – gross axle weight rating
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
HD-UDDS – Heavy Duty-Urban Dynamometer Driving Schedule
LTI - Larson Transportation Institute
mpg - miles per gallon
mph - miles per hour
PM - Preventive maintenance
PSTT - Penn State Test Track
rpm - revolutions per minute
SAE - Society of Automotive Engineers
SCF - Standard cubic foot
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)
TD - test driver
TECH - test technician
TM - track manager
TP - test personnel
Wh - Watt hour

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 consisted 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 certified 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 consisted of a Forest River Bus, LLC, Ford E-450 Cutaway Shuttle Bus. The bus has a front, streetside driver's door rear of the front axle and a front, curbside passenger door rear of the front axle. There is a rear curbside passenger door located behind the rear axle that is equipped with a Braun Corporation NCL917FIB345HB electric fold-out lift. Power is provided by a Cascadia iM-225 (HVH250) traction motor with an Oberaigner DTSP1-028 transmission and four Lithium-Nickel-Manganese-Cobalt-oxide (NMC) battery packs totaling nominal energy capacity of 122.4 kWh.

The measured curb weight was 3,920 lb. for the front axle and 6,780 lb. for the rear axle. These combined weights provided a total measured curb weight of 10,700 lb. There are 19 seats including the driver and two wheelchair positions. Two seats are stowable. However, utilizing both wheelchair positions or one wheelchair and all seats results in a load that exceeds the gross vehicle weight rating. Therefore, the gross load represents seated passengers only, for a total of 19 passengers, utilizing 18 seats (including the driver) and one wheelchair position. Gross load is calculated as (150 lb. x 18) + (600 lb. x 1) = 3,300 lb. At full declared capacity, the measured gross vehicle weight was 14,010 lb. A placard shows that standing passengers are not permitted. However, there is free floor space for 14 standing passengers in the above configuration. There is a potential to overload this bus with the available floor space for standing passengers or in any other configuration other than tested.

This bus has a modified chassis. The chassis was modified by adding 16 inches to the rear overhang of the Ford OEM frame.

VEHICLE DATA FORM

Bus Number: 2022-10-P	Date of Check-In: 07/14/22
Bus Manufacturer: Forest River Bus, LLC	Vehicle Identification Number (VIN): 1FDFE4FNXNDC21803
Model Number: E-450	Chassis Mfr./Mod. #: Ford Motor Co. / NDC21803
Personnel: S.R., E.D., T.G. & P.D.	Starting Odometer Reading: 550 miles

WEIGHT:

Individual Wheel Reactions:

Weights (lb.)	Front Axle		Middle Axle		Rear Axle	
	Curb	Street	Curb	Street	Curb	Street
CW	1,940	1,980	N/A	N/A	3,620	3,160
SLW	2,130	2,310	N/A	N/A	5,000	4,570
GVW	2,130	2,310	N/A	N/A	5,000	4,570

Total Weight Details:

Weight (lb.)	CW	SLW	GVW	GAWR
Front Axle	3,920	4,440	4,440	5,000
Middle Axle	N/A	N/A	N/A	N/A
Rear Axle	6,780	9,570	9,570	9,600
Total	10,700	14,010	14,010	GVWR: 14,500 (Declared by Manufacturer)

Dimensions:

Body Length (ft/in)	25 / 11
Length Over Bumpers (ft/in)	26 / 3.2
Overall Length with add-ons (ft/in)	26 / 3.2
Width (in)	97.5 (without mirrors) 139.2 (with mirrors – fully extended)
Height of bus (in)	114.0
Overall Height (in)	123.0
Front Overhang (in)	34.9
Rear Overhang (in)	89.8
Wheelbase (in)	190.5
Wheel Track (in)	Front: 68.3
	Middle: N/A
	Rear: 78.0

Bus Number: 2022-10-P	Date: 07/14/22

CLEARANCES:

Lowest Point Outside Front Axle	Location: Plastic spoiler under bumper	Clearance(in): 8.9
Lowest Point Outside Rear Axle	Location: Battery pack support	Clearance(in): 9.6
Lowest Point between Axles	Location: Curbside battery support	Clearance(in): 9.7
Front Bumper Height (in)	18.7 (does not include the attached spoiler)	
Rear Bumper Height (in)	20.0	
Ground Clearance at the center (in)	9.6	
Front Approach Angle (deg)*	14.3	
Rear Approach Angle (deg)*	12.6	
Ramp Clearance Angle (deg)	5.8	
Aisle Width (in)	18.2	
Inside Standing Height at Center Aisle (in)	79.6	

*Measurements used to calculate approach and departure angles are taken from the centerline of the axles.

BODY DETAILS:

Body Structural Type	Integral		
Frame Material	Steel		
Body Material	Aluminum		
Floor Material	Plywood		
Roof Material	Fiberglass		
Windows Type	■ Fixed	■ Movable	
Window Mfg./Model No.	Lippert / 080821 (bottoms) / 081521 (top sliders)		
Number of Doors	2 Front (1 Driver – Streetside, 1 Passenger- Curbside) 1 Rear (Curbside – wheelchair lift)		
Mfr. / Model No.	Front –Streetside - Driver – Ford / OEM Front- Curbside - Passenger – A&M Systems / 213382A18G8 Rear- Curbside – Lippert / 07-001-118		
Dimension of Each Door (in)	Front (streetside)- 32 x 54.5 Front (curbside) – 31.7 x 97 (Doors – 31.7, Grabrails 30.0) Rear- 44.6 x 68.3		
Passenger Seat Type	☐ Cantilever	■ Pedestal	☐ Other
Passenger Seat Mfg./ Model No.	Freedman Seating Co. / FW-35628-2MIDRIGSS		
Driver Seat Type	☐ Air	■ Spring	☐ Other
Mfr. / Model No.	Freedman Seating Co. / DRV-71234		
Number of Seats (including Driver)	18 and one wheelchair (as tested)		

Bus Number: 2022-10	Date: 07/14/22

BODY DETAILS (Contd.)

Free Floor Space (ft^2)	N/A
Height of Each Step at Normal Position (in)	Front 1. 11.9 2. 9.5 3. 9.2 4. N/A
	Rear 1. N/A 2. N/A 3. N/A 4. N/A
Step Elevation Change - Kneeling (in)	N/A

ELECTRIC DRIVE SYSTEM

Type	■ Series Battery Electric	☐ Parallel Electric Hybrid
Number of Traction Motor(s)	1	
Mfr. / Model No.	Cascadia / iM-225 (HVH250)	
Location of Traction Motor(s)	Midpoint center underside	
Type	3 phase AC permanent magnet	
Motor Control System Mfr./Model No.	Cascadia / iM-225 (CM200DX)	
Location	Under hood	
Max Rated Power Output (kW)	160	
Nominal Voltage (volts)	350	
Drive Battery Mfr./ Model No.	Romeo Power / A-C6	
Number of Battery Packs	4	
Location of Battery Packs	All battery packs mounted on underside of vehicle – One behind the front axles, two in center (one on either side of vehicle) and one directly behind rear axle.	
Individual Battery Capacity (kWh)	30.6	
Total Nominal Battery Capacity (kWh)	122.4	
Total Usable Battery Capacity (kWh)	100	
Total Nominal Battery Capacity (Ah)	349.7	
Battery Type (Chemistry)	NMC (Lithium-Nickel-Manganese-Cobalt-oxide)	
Nominal Voltage (Vdc)	354	
Low Voltage Battery	■ 12 Volt ☐ 24 Volt	
Low Voltage Battery Mfr./Model No.	Motocraft / ML BXT-65-750	

OTHERS

Air Compressor Mfr. / Model No.	N/A
Maximum Capacity (ft^3 / min)	N/A

Bus Number: 2022-10-P	Date: 07/14/22

TRANSMISSION

Transmission Type*	☐ Manual	■ Automatic	
Mfr. / Model No.	Oberaigner / DTSPI-028		
Control Type	■ Mechanical	☐ Electrical	☐ Other
Integral Retarder Mfr. / Model No.	☐ Yes	■ No	

*Drive motor is connected to a single speed planetary gearbox with a ratio of 2.842:1

SUSPENSION

Number of Axles	2		
Front Axle Type	■ Independent	☐ Beam Axle	
Mfr. / Model No.	Ford Motor Company / BK31-18045-BC		
GAWR (lb.)	5,000		
Axle Ratio (if driven)	N/A		
Suspension Type	☐ Air	■ Spring	☐ Other
No. of Shock Absorbers	2		
Mfr. / Model No.	Ford Motor Company / 8C2Z18124D		
Sway Bar Equipped	■ Front ■ Rear		
Middle Axle Type	☐ Independent	☐ Beam Axle	
Mfr. / Model No.	N/A		
GAWR (lb.)	N/A		
Axle Ratio (if driven)	N/A		
Suspension Type	☐ Air	☐ Spring	☐ Other
No. of Shock Absorbers	N/A		
Mfr. / Model No.	N/A		
Rear Axle Type	☐ Independent	■ Beam Axle	
Mfr. / Model No.	Ford Motor Company / FK41-18080-FA		
GAWR (lb.)	9,600		
Axle Ratio (if driven)	4.10		
Suspension Type	☐ Air	■ Spring	☐ Other
No. of Shock Absorbers	2		
Mfr. / Model No.	Ford Motor Company / F149R1		

Bus Number: 2022-10-P	Date: 07/14/22

WHEELS & TIRES

Front	Wheel Mfr./ Model No.	Fumagalli / 16 x 6
	Wheel Weight Rating	2,500 lbs.
	Tire Mfr./ Model No.	Hankook / Dynapro HT
	Tire Weight Rating	2,680 lb. max load single
Rear	Wheel Mfr./ Model No.	Fumagalli / 16 x6
	Wheel Weight Rating	2,500 lbs.
	Tire Mfr./ Model No.	Hankook / Dynapro HT
	Tire Weight Rating	2,470 lbs. max load dual

BRAKES

Front Axle Brakes Type	☐Cam	■ Disc	☐ Other (explain)
Mfr. / Model No.	Ford Motor Company / BC2Z2C026B		
Middle Axle Brakes Type	☐Cam	☐ Disc	☐ Other
Mfr. / Model No.	N/A		
Rear Axle Brakes Type	☐Cam	■ Disc	☐Other (explain)
Mfr. / Model No.	Ford Motor Company / LC2Z2C026B		
External Parking Brake Mfr. / Model No.	Ford / OEM pedal brake		

HVAC

Driver Heating System Type	☐ Engine Coolant ■ Electric
Capacity (Btu/hr.)	21,496
Mfr./Model No.	Ford / CV68-18K464
Passenger Heating System Type	☐ Engine Coolant ■ Electric ☐Other _____
Capacity (Btu/hr.)	65,000
Mfr./Model No.	ProAir / 50-001-250
Auxiliary Heater	■Yes: Type: Electric ☐ No
Mfr./Model No.	ProAir / SN#EA6168-094
Driver Air Conditioner	■ Yes ☐ No
Location	Dashboard
Capacity (Btu/hr.)	22,150
A/C Compressor Mfr./Model Number	Mitsubishi / AKJ200A114
Passenger Air Conditioner	■ Yes ☐ No

Bus Number: 2022-10-P	Date: 07/14/22

HVAC (cont.)

Passenger Air Conditioner	☐ Engine Driven	■ Electric	☐ Other
Location	Rooftop (Transair)		
Capacity (Btu/hr.)	75,000		
A/C Compressor Mfr./Model No.	Sanden Corp. / SHS33		

STEERING

Steering Gear Box Type	Hydraulic		
Mfr. / Model No.	Ford Motor Company / GU2Z3504A		
Steering Wheel Diameter	15.9”		
Number of turns (lock to lock)	4		
Control Type	☐ Electric	■Hydraulic	☐Other (explain)

OTHERS

ADA Ramps	Location: N/A	Type: N/A
ADA Lifts	Location: Curbside Rear	Type: Electric Fold-out
Mfr. / Model No.	Braun Corporation / NCL917FIB345HB	
Emergency Exit	Location: Windows Doors	Number: 5 2
Fire Suppression System Type	5 lb. fire extinguisher	
Mfr./Model No.	Kidde / FX340SC-2	

CAPACITIES

Fuel Tank Capacity (gallons)	N/A
Engine Crankcase Capacity (gallons)	N/A
Transmission Capacity (gallons)	0.13 (single speed gearbox)
Differential Capacity (quarts)	9.6
Engine Cooling System Capacity (gallons)	8 (shared)
Battery Cooling System Capacity (gallons)	8 (shared)
Electronic Cooling System Capacity (gallons)	8 (shared)
Drive Motor Cooling System (gallons)	8 (shared)
Power Steering Fluid Capacity (gallons)	0.5

Bus Number: 2022-10-P	Date: 07/14/22

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

Part Number	Description	Qty.
8C2Z*1015*G	16” White wheel rims	6
9007-2001831	195/75R16 Hankook Tire blackwall	6
Mount/Bal	Tires mounted on rim and balanced	6
BC2Z*1102*B	Front brake rotor	2
LC2Z*2C026*B	Rear brake rotor	2
8C2Z*2001*C	Front brake pads	2
8C2Z*220*B	Rear brake pads	2
8C2Z*18124*D	Front shocks	2
8C2Z*18125*D	Rear shocks	2
DAP 660 HB	Delta Electronics HV inverter/charger	1
N/A	HV charging cable/port	1
OP3530C/12V/EA25 B-1	EMP smart flow pump	1
WP29-12V-CH-A	EMP smart flow pump	1
N/A	FoMoCo Pump	1
N/A	Assorted heater hose	Multiple
841-007	Net Power DC/DC converter/charger	1
855-004	Coolant pump; 12V; Ford; EV Focus	1
855-005	Coolant pump; 12V; Horizontal; Resistor Address	1
225-001	Pump; Oil; Emp; OP3530	1
N/A	Modified Sensor; LPS; LR-19; Stroke 2 in; 0.5-4V; DT 4POS	N/A
N/A	Harness; LV; E-450; Power steering pump power	N/A
166-505	Hose; Heater; Gates; Safety stripe; ¾ in.	60 in.
166-506	Hose; Heater; Gates; Safety stripe; 1 in.	60 in.
240-027	Hose clamp; constant tension band clamp; 27mm	12
240-036	Hose clamp; constant tension band clamp; 63mm	12

COMPONENT/SUBSYSTEM INSPECTION FORM

Bus Number: 2022-10-P	Date: 07/14/22

Subsystem	Checked	Initials	Comments
Air Conditioning Heating and Ventilation	✓	S.R.	None noted.
Body and Sheet Metal	✓	S.R.	None noted.
Frame	✓	S.R.	None noted.
Steering	✓	S.R.	None noted.
Suspension	✓	S.R.	None noted.
Interior/Seating	✓	S.R.	None noted.
Axles	✓	S.R.	None noted.
Brakes	✓	S.R.	None noted.
Tires/Wheels	✓	S.R.	None noted.
Exhaust	N/A	S.R.	None noted.
Fuel System	N/A	S.R.	None noted.
Transmission	✓	S.R.	None noted.
Drive Motors / Axle	✓	S.R.	None noted.
Engine	N/A	S.R.	None noted.
Accessories	✓	S.R.	None noted.
ADA Accessible Lift System	✓	S.R.	None noted.
ADA Accessible Ramp System	N/A	S.R.	None noted.
Interior Fasteners	✓	S.R.	None noted.
Batteries	✓	S.R.	None noted.
Emergency Exits	✓	S.R.	None noted.
Fire Suppression System	N/A	S.R.	5 lb. fire extinguisher is provided.

CHECK - IN

FOREST RIVER BUS LLC
FORD E-450 CUTAWAY SHUTTLE BUS

CHECK – IN

FOREST RIVER BUS LLC
FORD E-450 CUTAWAY SHUTTLE BUS

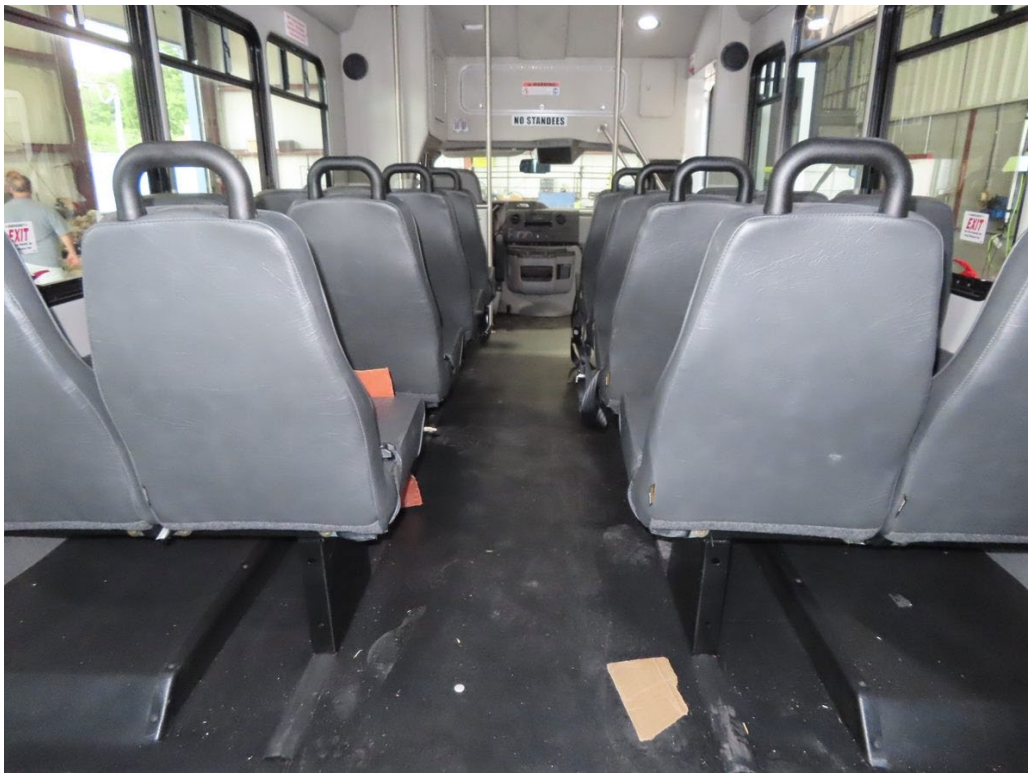
CHECK - IN CONT.

BRAUN CORPORATION / NCL917FIB345HB
ELECTRIC FOLD-OUT LIFT

OPERATOR'S AREA

CHECK - IN CONT.

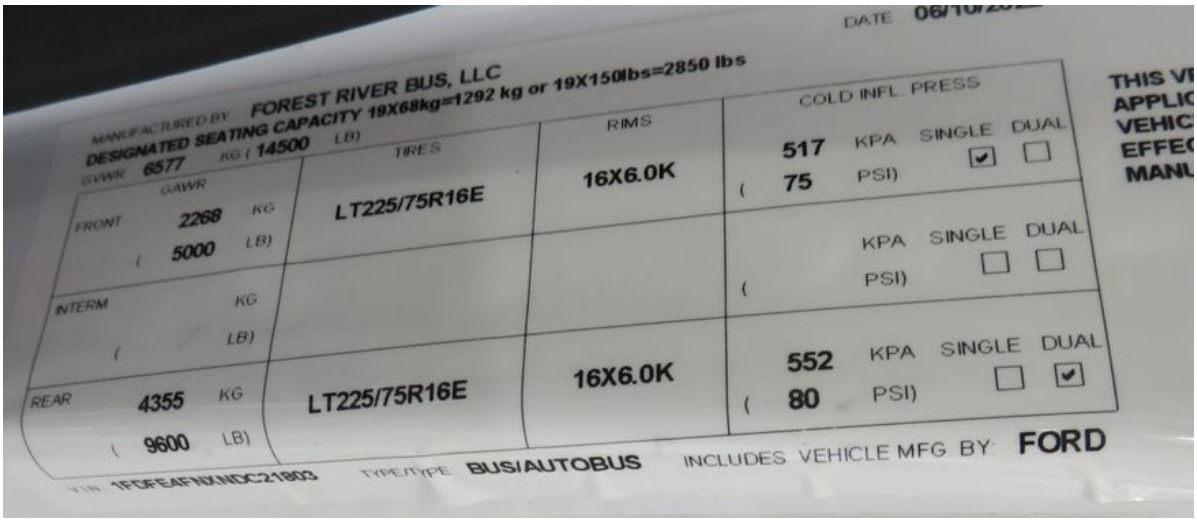
INTERIOR FROM FRONT



INTERIOR FROM REAR

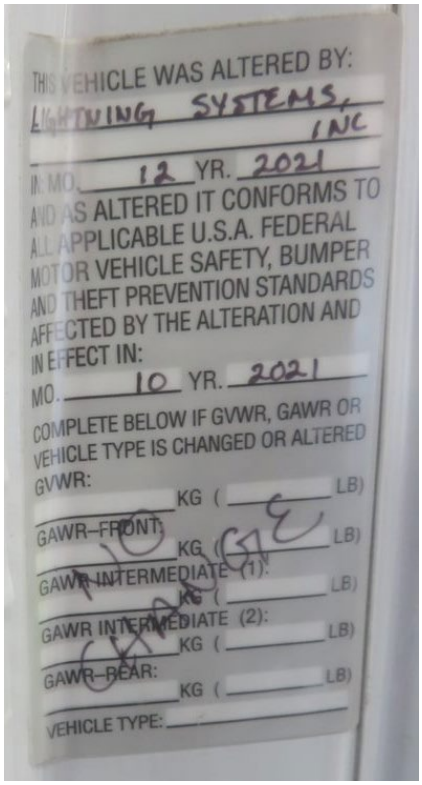
CHECK - IN CONT.

INCOMPLETE VEHICLE CHASSIS TAG FROM FORD MOTOR COMPANY



MANUFACTURER'S TAG

CHECK - IN CONT.

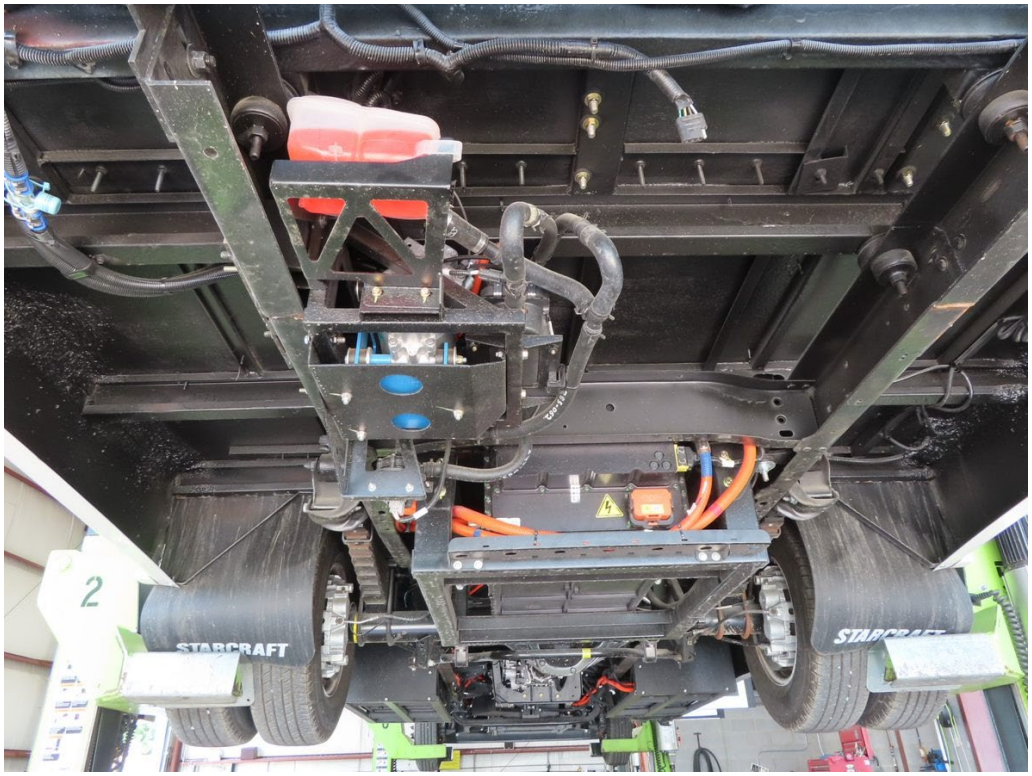


ELECTRIC CONVERSION MANUFACTURER'S TAG

PLACARD SHOWING NO STANDEES PERMITTED

CHECK - IN CONT.

COMPARTMENT UNDER THE HOOD



UNDERSIDE OF BUS REAR TO FRONT

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 was checked, and where accessibility was restricted, the subsystem was 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

Bus Number: 2022-10-P	Date: 08/24/22

Component	Checked	Comments
ENGINE:		
Oil Dipstick	N/A	None noted.
Oil Filler Hole	N/A	None noted.
Oil Drain Plug	N/A	None noted.
Oil Filter	N/A	None noted.
Fuel Filter	N/A	None noted.
Air Filter	N/A	None noted.
Belts	N/A	None noted.
Coolant Level	✓	None noted.
Coolant Filler Hole	✓	None noted.
Coolant Drain	✓	None noted.
Spark / Glow Plugs	N/A	None noted.
Alternator	N/A	None noted.
Diagnostic Interface Connector	✓	None noted.
TRANSMISSION:		
Fluid Dipstick	✓	None noted.
Filler Hole	✓	None noted.
Drain Plug	✓	None noted.
SUSPENSION:		
Bushings	✓	None noted.
Shock Absorbers	✓	None noted.
Air Springs	N/A	None noted.
Leveling Valves	N/A	None noted.
Grease Fittings	N/A	None noted.

ACCESSIBILITY DATA FORM

Bus Number: 2022-10-P	Date: 08/24/22

Component	Checked	Comments
HVAC:		
A/C Compressor	✓	None noted.
Filters	✓	None noted.
Fans	✓	None noted.
ELECTRICAL SYSTEM:		
Fuses	✓	None noted.
Batteries	✓	None noted.
Voltage regulator	✓	None noted.
Voltage Converters	✓	None noted.
Lighting	✓	None noted.
MISCELLANEOUS:		
Brakes	✓	None noted.
ADA Accessible Lifts/Ramps	✓	None noted.
Instruments	✓	None noted.
Axles	✓	None noted.
Exhaust	N/A	None noted.
Fuel System	N/A	None noted.
OTHERS:		
N/A		

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 involved components that may be expected to fail or require replacement during the service life of the bus. In addition, any component that failed during testing of the bus was added to this list. Components to be included are:

1. Drive motor
2. Motor controller
3. Coolant pump
4. High voltage battery
5. Low voltage battery
6. Windshield wiper motor

1.3-III. DISCUSSION

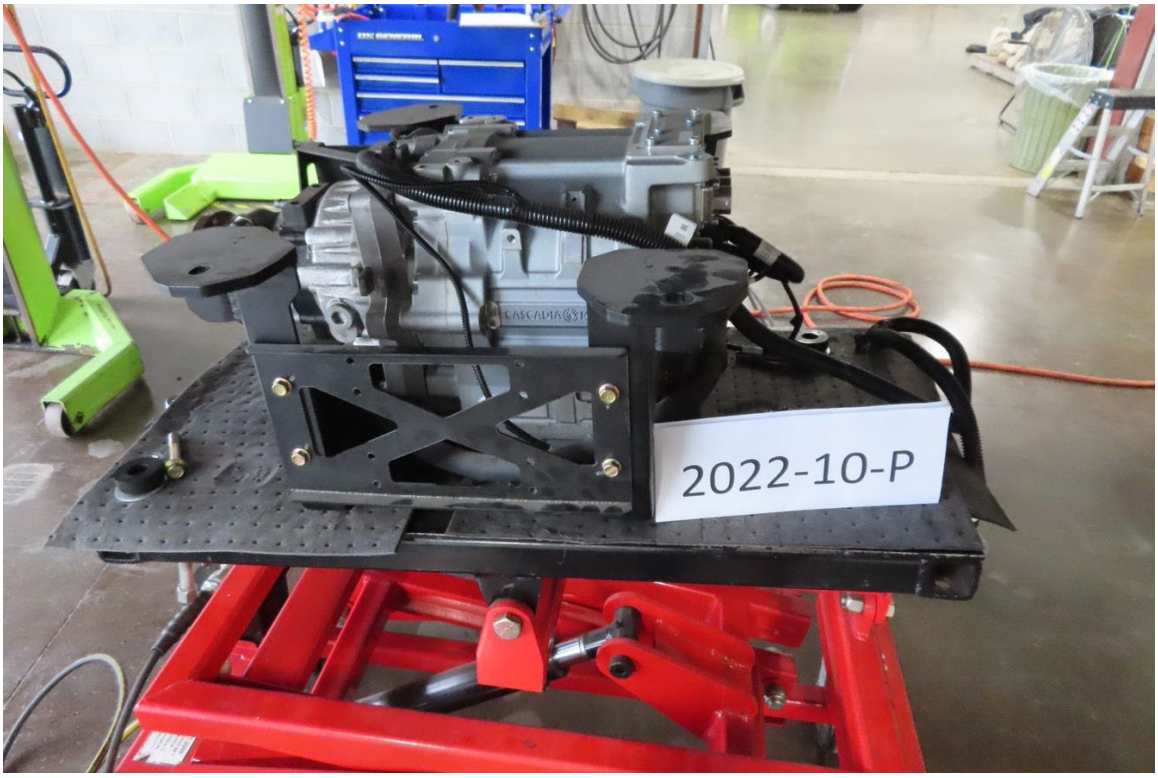
At the end of the test, the items on the list were removed and replaced. The drive motor took 1.33 labor-hours to remove and replace. The time required for repair/replacement of the other five components is given on the following Repair and/or Replacement Form.

REPLACEMENT AND/OR REPAIR FORM

Subsystem	Replacement Time
Drive motor	1.33 labor hours
Motor controller	0.67 labor hours
Coolant pump	0.17 labor hours
High voltage battery	0.50 labor hours
Low voltage battery	0.07 labor hours
Wiper motor	0.17 labor hours

During this portion of the test, it was discovered that there was a slight gear oil leak at the joint where the motor and the single speed gearbox meet.

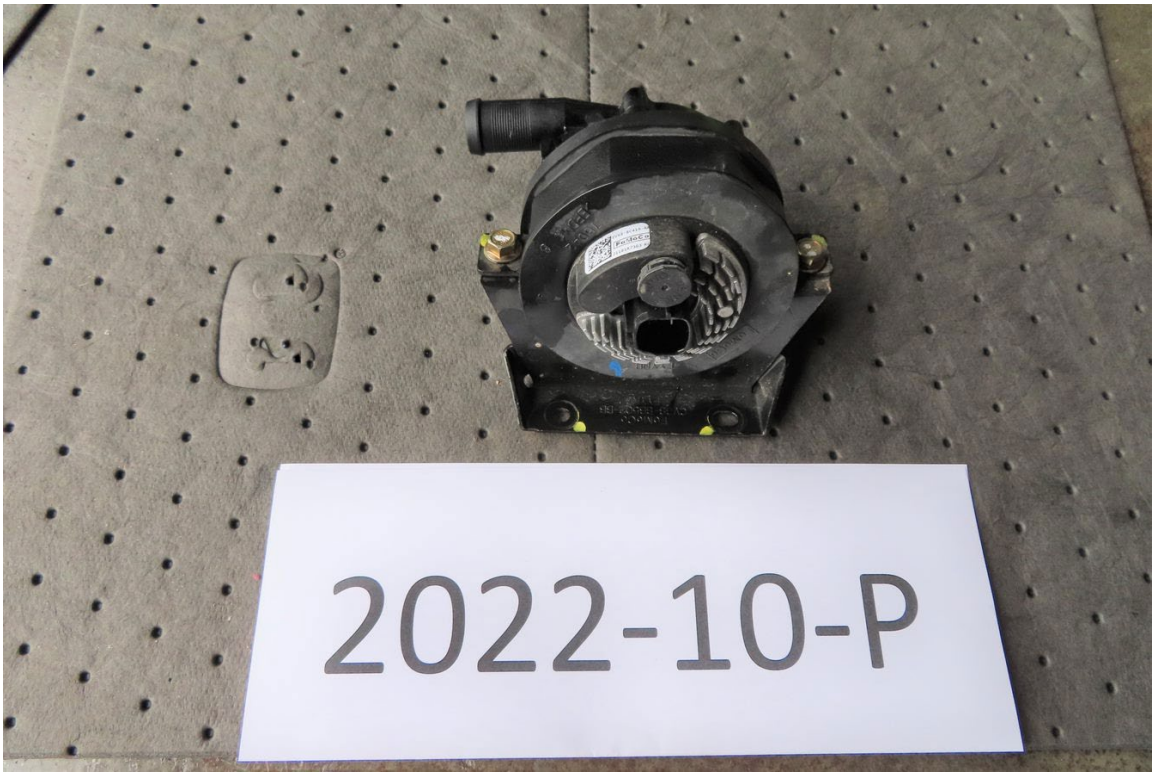
1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS



DRIVE MOTOR REMOVAL AND REPLACEMENT (1.33 LABOR HOURS)

MOTOR CONTROLLER REMOVAL AND REPLACEMENT (0.67 LABOR HOURS)

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS CONT.

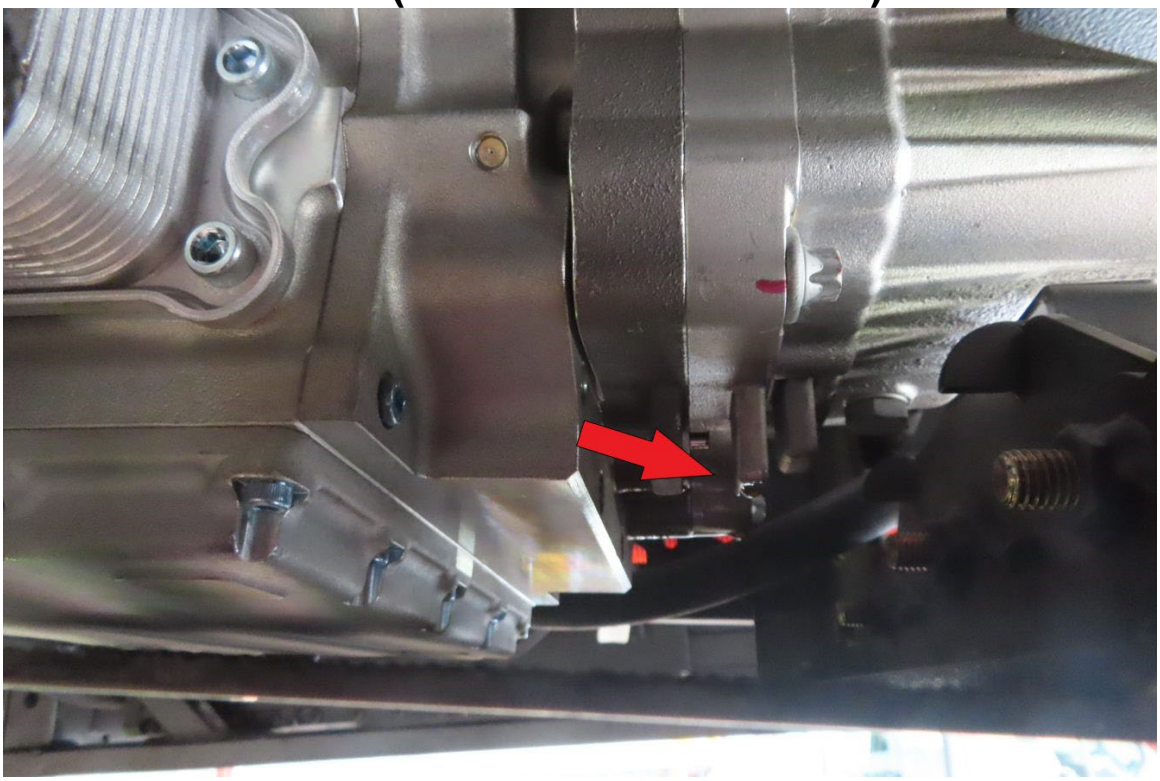


COOLANT PUMP REMOVAL AND REPLACEMENT (0.17LABOR HOURS)

HIGH VOLTAGE BATTERY REMOVAL AND REPLACEMENT (0.50 LABOR HOURS)

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS CONT.

WIPER MOTOR REMOVAL AND REPLACEMENT (0.17 LABOR HOURS)



SLIGHT GEAR OIL LEAK

3.1 SAFETY - A DOUBLE-LANE CHANGE (OBSTACLE AVOIDANCE)

3.1-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.

3.1-II. TEST DESCRIPTION

The Safety Test consisted of an obstacle avoidance maneuver to evaluate the handling and stability of the bus. The test was conducted at the LTI test track on the vehicle dynamics pad. The bus was driven through a double-lane change course at increasing speeds until the test was determined to be unsafe or a speed of 45 mph is reached. The test is determined unsafe if vehicle handling becomes unstable or if any of the tires lose contact with the pavement.

The layout of the test course was defined by placing pylons along painted guidelines that delineated the course. The guidelines marked off two 12-foot center-to-center lanes. Each lane had two 100 foot long gates with a spacing distance of 100 feet between them. The bus entered the test course in one lane, crossed over to the other lane within the 100 foot gate, traveled for 100 feet, and then returned into the original lane within the next 100 foot gate. This maneuver was repeated from 20 mph with speed increasing in increments of 5 mph. The test was performed starting from both the right and left lanes.

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

3.1-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.

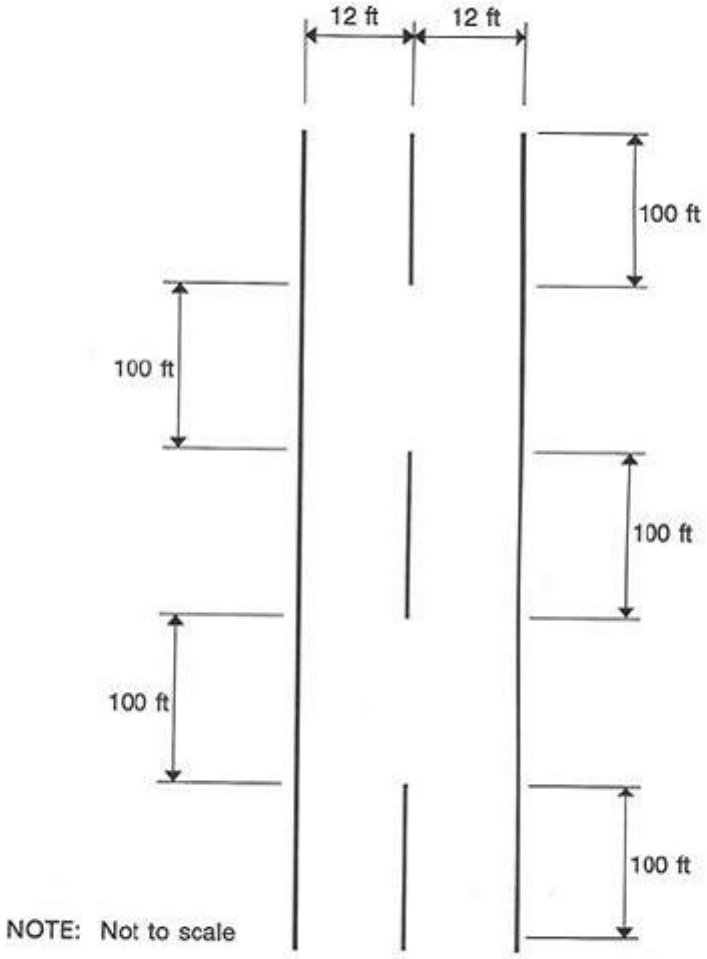


Figure 3.1. Double lane change test course

SAFETY DATA FORM

Bus Number: 2022-10-P	Date: 09/09/22
Personnel: F.T., R.M. & E.L.	

Temperature (°F): 74	Humidity (%): 94
Wind Direction: SE	Wind Speed (mph): 1
Barometric Pressure (inHg): 30.12	

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:	
Bus maintained a proper position during the test.	
Comments of the tire/ground contact patch:	
Bus maintained a proper tire ground contact patch during test.	

3.1 SAFETY

RIGHT - HAND APPROACH

LEFT - HAND APPROACH

4. PERFORMANCE - AN ACCELERATION, GRADEABILITY, AND TOP SPEED TEST

4-I. TEST OBJECTIVE

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

4-II. TEST DESCRIPTION

In this test, the bus was operated at SLW on a chassis dynamometer. The procedure dictates that the test bus be accelerated to a maximum “power-limited”/”governed” or maximum “safe” speed not exceeding 80 mph. The maximum power-limited/governed speed, if applicable, is the top speed as limited by the engine control system. The maximum safe speed is defined as the maximum speed that the dynamometer, the tires, or other bus components are limited to. The test vehicle speed was measured using a speed encoder built in the chassis dynamometer. The time intervals between 10 mph increments were recorded using a Data Acquisitions System. Time-speed data and the top speed attained were recorded on the Performance Data Form. The recorded data was used to generate a percent grade versus speed table and a speed versus time curve. All the above are available in the following pages.

4-III. DISCUSSION

This test consisted of three runs from standstill to full throttle on the chassis dynamometer. Speed versus time data was obtained for each run and results are averaged to minimize test variability. The test was performed up to a maximum governed speed of 63.2 mph. The calculated gradeability results are attached. The average time to reach 30 mph was 7.5 seconds. The maximum gradeablity at 10 mph was 22.9% and at 40 mph was 8.9%.

Prior to the start of the Performance and Energy Economy and Range tests, the manufacturer’s representative installed a software update to fix calibration issues. They also installed a firmware update for the invertor to help eliminate the shudder when pulling out.

PERFORMANCE DATA FORM

Bus Number: 2022-10-P	Date: 08/19/22
Personnel: A.Z. & S.I.	
Temperature (°F): 69.2	Humidity (%): 59.3
Barometric Pressure (inHg): 28.8	

		INITIALS:
Air Conditioning - OFF	✓Checked	A.Z.
Heater pump motor - OFF	✓Checked	A.Z.
Defroster - OFF	✓ Checked	A.Z.
Exterior and interior lights - ON	✓ Checked	A.Z.
Windows and doors - CLOSED	✓ Checked	A.Z.

ACCELERATION, GRADEABILITY, TOP SPEED

Recorded Interval Times

Speed	Run 1	Run 2	Run 3
10 mph	3.0	3.0	3.1
20 mph	5.1	5.1	5.2
30 mph	7.5	7.5	7.6
40 mph	11.4	11.5	11.6
50 mph	18.2	18.3	18.5
60 mph	29.6	29.9	30.2

Maximum Speed (mph): 63.2 maximum governed speed reached

PERFORMANCE SUMMARY SHEET

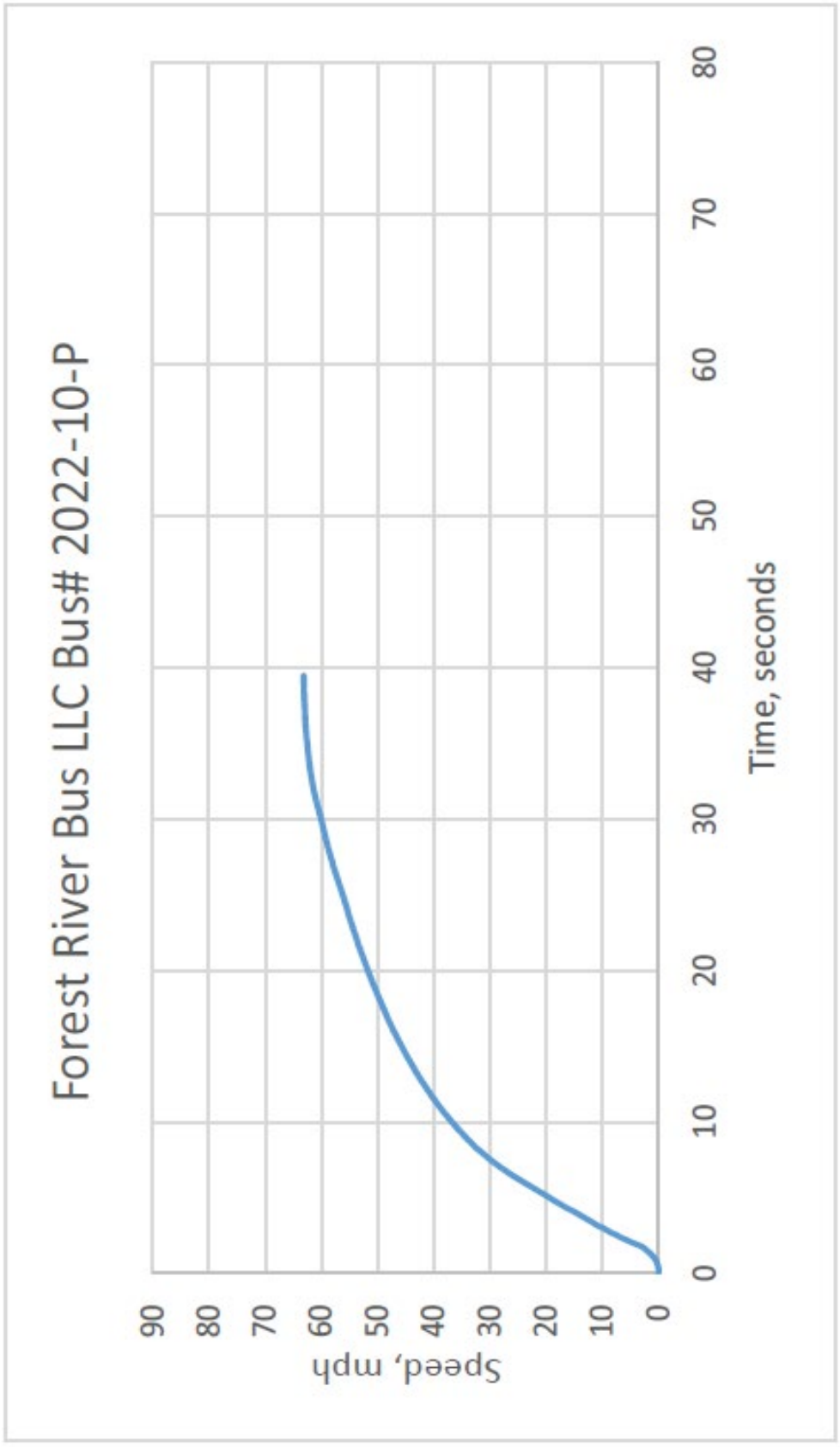
Bus Number: 2022-	Date: 08/19/22
Personnel: A.Z. & S.I.	

Test Conditions:

Temperature (°F): 69.2	Humidity (%): 59.3
Barometric Pressure (inHg): 28.8	

Test Results:

Vehicle Speed (MPH)	Time (SEC)	Acceleration (FT/SEC^2)	Max. Grade (%)
1.0	1.1	3.28	10.2
5.0	2.1	8.04	25.0
10.0	3.0	7.37	22.9
15.0	4.1	6.96	21.6
20.0	5.1	6.60	20.5
25.0	6.2	6.36	19.8
30.0	7.5	4.94	15.3
35.0	9.2	3.69	11.5
40.0	11.5	2.85	8.9
45.0	14.5	2.16	6.7
50.0	18.4	1.65	5.1
55.0	23.5	1.21	3.8
60.0	29.9	0.98	3.0
63.2	39.6	Maximum Speed	


Forest River Bus LLC Bus# 2022-10-P
Speed, mph
0
10
20
30
40
50
60
70
80
90
Time, seconds
0
10
20
30
40
50
60
70
80

6. ENERGY ECONOMY AND RANGE TEST – AN ENERGY CONSUMPTION AND RANGE TEST FOR BATTERY ELECTRIC BUSES USING APPROPRIATE OPERATING CYCLES

6-I. TEST OBJECTIVE

The objective of this test is to provide accurate comparable energy consumption data on battery electric transit buses produced by different manufacturers. This energy 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 energy economy test, as designated here, is a measurement of the energy consumed by a vehicle traveling a specified test operating profile, under specified operating conditions that are typical of transit bus operation. The results of this test will not represent actual energy usage but will provide data that can be used by FTA Grantees to compare buses tested using this procedure.

6-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 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 HD-UDDS Cycle (Figure 3). This test is conducted at seated load weight.

This test is conducted generally as per the methods described in the SAE standard J 1634-2017. The light-duty test cycles specified in this standard are replaced by transit bus test cycles mentioned above.

The Multi-Cycle test (MCT) procedure is adopted for this bus. The end of test is determined when the bus cannot maintain 50 miles per hour or earlier, as recommended by the bus manufacturer. The battery system is recharged to full SOC at the end of the test, following procedures specified in SAE J 1634-2017. During the recharge, the DC energy (into the battery system) and the AC energy (into the charger) are recorded. From these data, the average AC energy consumption, the range (miles) and the charger efficiency for each test cycle are reported.

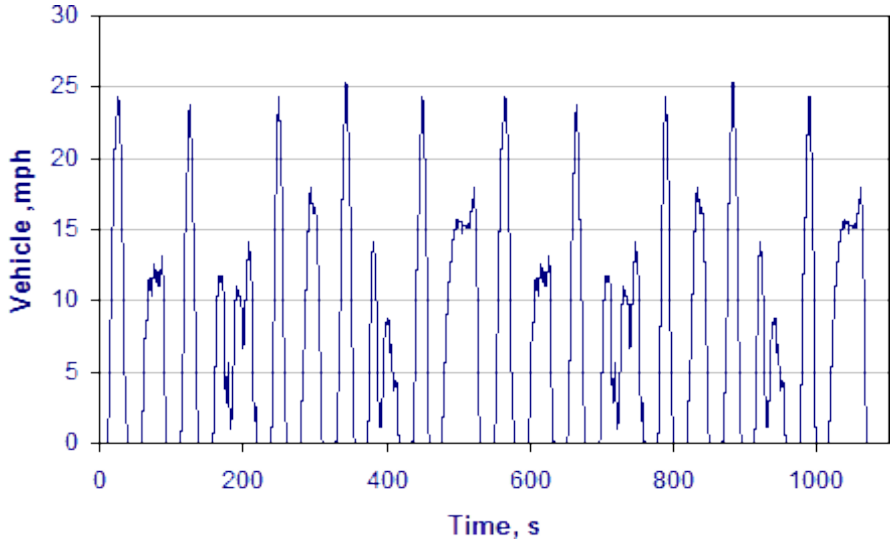


Figure 1. Manhattan Driving Cycle (duration 1089 sec, Maximum speed 25.4 mph, average speed 6.8 mph)

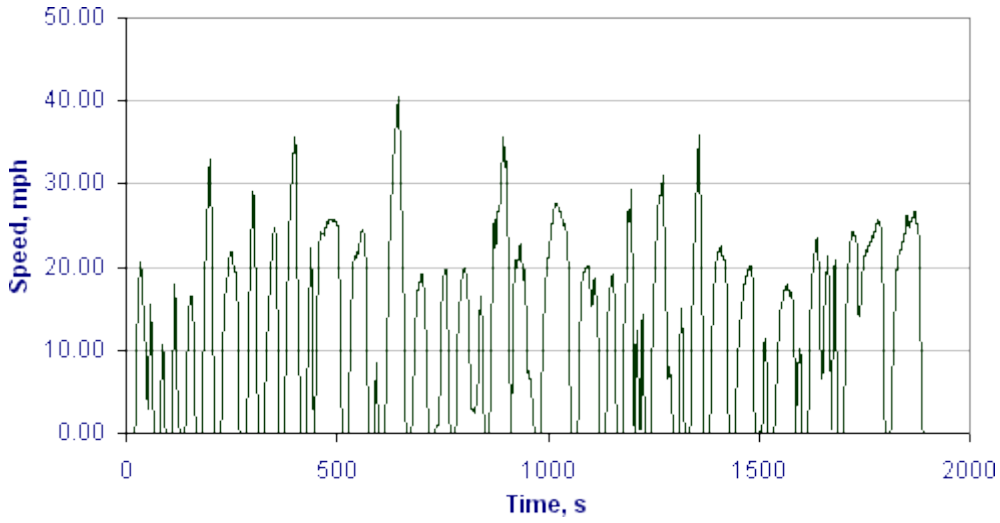


Figure 2. Orange County Bus Cycle (Duration 1909 Sec, Maximum Speed 41 mph, Average Speed 12 mph).

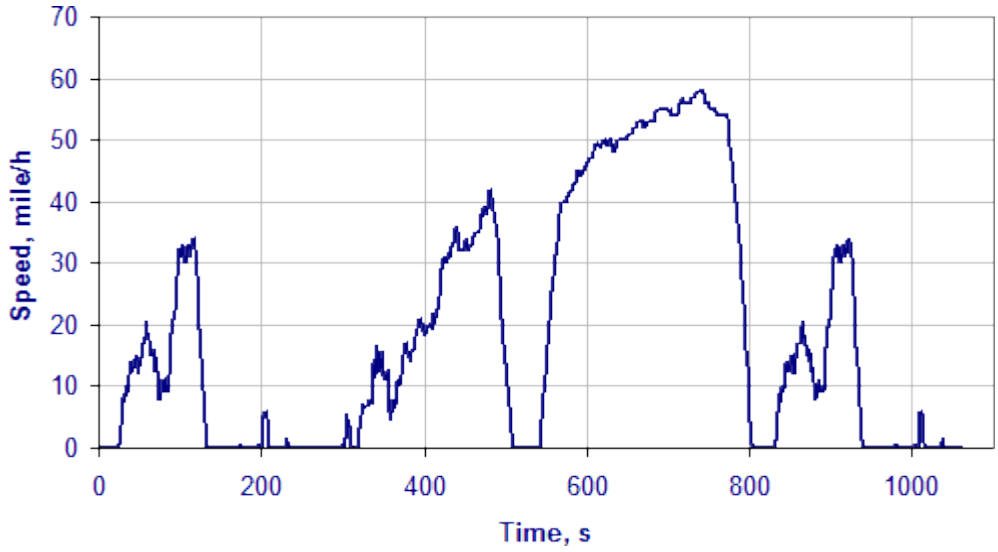


Figure 3. HD-UDDS Cycle (duration 1060 seconds, Maximum Speed 58 mph, Average Speed 18.86 mph).

6-III. DISCUSSION

The driving cycle consists of three simulated transit driving cycles: Manhattan, Orange County Bus Cycle, and the HD-UDDS, as described in 6-II.

An extensive pretest maintenance check is conducted including the replacement of all lubrication fluids, if applicable. The details of the pretest maintenance are given in the first three Pretest Maintenance Forms. The fourth sheet shows the Pretest Inspection Form. Finally, the summary sheet provides the average energy consumption and range of bus for the three test cycles. The test was conducted at a seated load weight of 14,010 lbs. The average AC energy consumption for the Manhattan, OCBC and the HD-UDDS were 1,182 Wh/mile, 939 Wh/mile and 922 Wh/mile, respectively. The range for the three driving cycles were 93 miles, 117 miles and 119 miles, respectively. The charger efficiency was 95%.

This bus was tested using the Manhattan, Orange County and UDDS driving cycles. The energy economy and range results for buses tested using these cycles are not directly comparable to buses tested under the earlier protocol that uses the CBD, Arterial and Commuter driving cycles.

ENERGY ECONOMY PRE-TEST MAINTENANCE FORM

Bus Number: 2022-10-P	Date: 07/28/22	SLW (lb.): 14,010
Personnel: R.M. & E.L.		

ENERGY SYSTEM	OK
Install fuel measurement system	✓
Remarks: None noted.	
BRAKES/TIRES	**OK**
Inspect hoses	✓
Inspect brakes	✓
Check tire inflation pressures (mfg. specs.)	✓
Check tire wear (less than 50%)	✓
Remarks: None noted.	
BATTERY COOLING SYSTEM	**OK**
Check hoses and connections	✓
Check system for coolant leaks	✓
Remarks: None noted.	

ENERGY ECONOMY PRE-TEST MAINTENANCE FORM

Bus Number: 2022-10-P	Date: 07/23/22
Personnel: R.M. & E.L.	

ELECTRICAL SYSTEM	OK
Check battery	✓
Inspect wiring	✓
Inspect terminals	✓
Check lighting	✓
Remarks: None noted.	

DRIVE SYSTEM	OK
Drain transmission fluid	N/A
Replace filter/gasket	N/A
Check hoses and connections	✓
Replace transmission fluid	N/A
Check for fluid leaks	✓
Remarks: None noted.	

LUBRICATION	OK
Lube all chassis grease fittings	✓
Lube universal joints	✓
Replace differential lube including axles	N/A
Remarks: None noted.	

ENERGY ECONOMY PRE-TEST MAINTENANCE FORM

Bus Number: 2022-10-P	Date: 07/28/22
Personnel: R. M. & E.L.	

OTHER ITEMS	OK
Replace air filter	N/A
Inspect air compressor and air system	N/A
Inspect vacuum system, if applicable	N/A
Check and adjust all drive belts	N/A
Remarks: None noted.	

STEERING SYSTEM	OK
Check power steering hoses and connectors	✓
Service fluid level	✓
Check power steering operation	✓
Remarks: None noted.	

	OK
Ballast bus to seated load weight during coast down	✓

TEST DRIVE	OK
Check brake operation	✓
Check transmission operation	✓
Remarks: None noted.	

ENERGY ECONOMY PRE-TEST INSPECTION FORM

Bus Number: 2022-10-P	Date: 08/19/22
Personnel: R.M., E.L., A.Z. & S.I.	

PRE-WARM-UP	If OK, Initial
Fuel Economy Pre-Test Maintenance Form is complete	R.M.
Cold tire pressure (psi): Front 75 Middle N/A Rear 80	R.M.
Energy economy instrumentation installed and working properly.	R.M./S.I.
Bus is loaded to SLW during coast down	R.M.
WARM-UP	**If OK, Initial**
Interior and exterior lights on, evaporator fan on	A.Z.
Air conditioner off	A.Z.
Defroster off	A.Z.
Windows and doors closed	A.Z.
Do not drive with left foot on brake	A.Z.

ENERGY ECONOMY DATA FORM
(Battery Electric Buses)

Bus Number: 2022-10-P	Manufacturer: Forest River Bus LLC	Date: 08/19/22
Fuel Type: Electric	Personnel: A.Z. & S.I.	
Temperature (°F): 72.1	Humidity (%): 65.1	Barometric Pressure (inHg): 28.9
SLW (lb.): 14,010	Charger: Delta (25kW)	

	Manhattan	**Orange County**	**UDDS**
AC Energy (Wh/mile)	1,182	939	922
Range (miles)	93	117	119
Charger Efficiency (%)	95		

Comments: None noted

6.0 ENERGY ECONOMY

BUS TESTED ON CHASSIS DYNAMOMETER FOR PERFORMANCE AND FUEL ECONOMY

DELTA CHARGER

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 was measured at several locations with the bus operating under the following three conditions:

1. With the bus stationary, a white noise generating system provided a uniform sound pressure level equal to 80 dB(A) on the left, exterior side of the bus. The engine and all accessories were switched off and all openings including doors and windows were closed. This test was performed at the LTI Test Track Facility.

2. The bus was accelerated at full throttle from a standing start to 35 mph on a level pavement. All openings were closed, and all accessories were operating during the test. This test was performed on the track at the LTI Test Track Facility.

3. The bus was operated at various speeds from 0 to 55 mph with and without the air conditioning and accessories on. Any audible vibration or rattles were noted. This test was performed on the test segment between the LTI Test Track and the Bus Testing Center.

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

7.1-III. DISCUSSION

For the first part, the overall average of the six measurements was 47.1 dB(A); ranging from 46.5 dB(A) in line with the middle speaker to 47.9 dB(A) in line with the front speaker. The interior ambient noise level for this test was less than 30 dB(A).

For the second part, the interior noise level ranged from 62.9 dB(A) at the front and middle passenger seats to 63.4 dB(A) at the rear passenger seats. The overall average was 63.1dB(A). The interior ambient noise level for this test was less than 30 dB(A).

No vibrations or rattles were noted during the third part of this test.

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

Bus Number: 2022-10-P	Date: 07/26/22
Personnel: F.T., R.M. & E.L.	
Temperature (°F): 79	Humidity (%): 44
Wind Speed (mph): 5	Wind Direction: W
Barometric Pressure (inHg): 30.02	
Interior Ambient Noise Level dB(A): less than 30	Exterior Ambient Noise Level dB(A): 34.0
Microphone Height During Testing (in): 45.6	

Reading Location	Measured Sound Level dB(A)
Driver's Seat	47.1
Front Passenger Seats	47.0
In Line with Front Speaker	47.9
In Line with Middle Speaker	46.5
In Line with Rear Speaker	47.3
Rear Passenger Seats	46.7

Comments: None noted.

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

Bus Number: 2022-10-P	Date: 07/22/22
Personnel: F.T., R.M & D.B.	
Temperature (°F): 88	Humidity (%): 50
Wind Speed (mph): 9	Wind Direction: SW
Barometric Pressure (inHg): 29.93	
Interior Ambient Noise Level dB(A): 37.9	Exterior Ambient Noise Level dB(A): 48.3
Microphone Height During Testing (in): 45.6	

Reading Location	Measured Sound Level dB(A)
Driver's Seat	63.3
Front Passenger Seats	62.9
Middle Passenger Seats	62.9
Rear Passenger Seats	63.4

Comments: None noted.

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

Bus Number: 2022-10-P	Date: 07/22/22
Personnel: F.T., R.M. & D.B.	
Temperature (°F): 88	

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

Source of Noise	Location	Description of Noise
Drivetrain and Accessories	None noted.	None noted.
Windows and Doors	None noted.	None noted.
Seats and Wheelchair lifts	None noted.	None noted.
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 was operated at a SLW in three different conditions using a smooth, straight and level roadway:

1. Accelerating at full throttle from a constant speed starting from 35 mph.

2. Accelerating at full throttle from standstill.

3. Stationary, with the engine at low idle, high idle, and wide-open throttle, where applicable. In addition, the bus was tested with and without the air conditioning operating.

The test site is at the Larson Transportation Institute Test Track and the test procedures were performed 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 was used to measure the noise level.

During the test, special attention was 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 outside ambient noise level of 38.6 dB(A), the average of the two highest readings obtained while accelerating from a constant speed was 71.2 dB(A) on the right side and 70.6 dB(A) on the left side.

When accelerating from a standstill with an exterior ambient noise level of 39.1 dB(A), the average of the two highest readings obtained were 64.4 dB(A) on the right side and 65.2 dB(A) on the left side.

With the vehicle stationary and the engine, accessories, and air conditioning on, the measurements averaged 54.3 dB(A). With the accessories and air conditioning off, the readings averaged 50.6 dB(A). This battery electric test vehicle had no rpm or throttle positions. The exterior ambient noise level measured during this test was 38.7 dB(A).

EXTERIOR NOISE TEST DATA FORM
Accelerating from Constant Speed

Bus Number: 2022-10-P	Date: 07/22/22
Personnel: F.T., S.R., R.M., T.G. & D.B.	
Temperature (°F): 79	Humidity (%): 68
Wind Speed (mph): 8	Wind Direction: SW
Barometric Pressure (inHg): 29.96	
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30°F and 90°F: ■	
Initial Sound Level Meter Calibration: 93.8 dB(A)	
Exterior Ambient Noise Level: 38.6 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	70.0	1	69.7
2	71.6	2	69.0
3	70.3	3	69.1
4	69.8	4	70.4
5	70.8	5	70.8
6	N/A	6	N/A
7	N/A	7	N/A
8	N/A	8	N/A
9	N/A	9	N/A
10	N/A	10	N/A
Average of two highest actual noise levels = 71.2 dB(A)		Average of two highest actual noise levels = 70.6 dB(A)	

Final Sound Level Meter Calibration Check: 93.8 dB(A)
Comments: None noted.

EXTERIOR NOISE TEST DATA FORM
Accelerating from Standstill

Bus Number: 2022-10-P	Date: 07/22/22
Personnel: F.T., R.M., S.R., T.G. & D.B.	
Temperature (°F): 82	Humidity (%): 62
Wind Speed (mph): 9	Wind Direction: SW
Barometric Pressure (inHg): 29.91	
Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30°F and 90°F: ■	
Initial Sound Level Meter Calibration: 93.8 dB(A)	
Exterior Ambient Noise Level: 39.1 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	64.3	1	65.2
2	63.9	2	64.1
3	64.1	3	65.0
4	63.7	4	65.0
5	64.4	5	65.2
6	N/A	6	N/A
7	N/A	7	N/A
8	N/A	8	N/A
9	N/A	9	N/A
10	N/A	10	N/A
Average of two highest actual noise levels = 64.4 dB(A)		Average of two highest actual noise levels = 65.2 dB(A)	

Final Sound Level Meter Calibration Check: 93.8 dB(A)
Comments: None noted.

EXTERIOR NOISE TEST DATA FORM
Stationary

Bus Number: 2022-10-P	Date: 07/22/22
Personnel: F.T., S.R., T.G., R.M. & D.B.	
Temperature (°F): 82	Humidity (%): 62
Wind Speed (mph): 9	Wind Direction: SW
Barometric Pressure (inHg): 29.91	
Initial Sound Level Meter Calibration: 93.8 dB(A)	
Exterior Ambient Noise Level: 38.7 dB(A)	

Air Conditioning ON

Throttle Position	Engine RPM	Curb (Right) Side dB(A)	Street (Left) Side db(A)
		Measured	Measured
Low Idle	N/A	53.3	55.3
High Idle	N/A	N/A	N/A
Wide Open Throttle	N/A	N/A	N/A

Air Conditioning OFF

Throttle Position	Engine RPM	Curb (Right) Side dB(A)	Street (Left) Side db(A)
		Measured	Measured
Low Idle	N/A	50.5	50.7
High Idle	N/A	N/A	N/A
Wide Open Throttle	N/A	N/A	N/A

Final Sound Level Meter Calibration Check: 93.8 dB(A)

Comments: None noted.

7.2 EXTERIOR NOISE TESTS

TEST BUS UNDERGOING EXTERIOR NOISE TESTING