

**PARTIAL
STURAA TEST
10 YEAR
350,000 MILE BUS
from
BLUE BIRD
MODEL Q BUS
NOVEMBER 2000
PTI-BT-R2019-15-00-P**

PENNS^{TATE}



The Pennsylvania Transportation Institute

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

Bus Testing and Research Center

6th Avenue and 45th Street (814) 949-7944
Altoona, PA 16602

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EXECUTIVE SUMMARY

Blue Bird Corporation submitted a model Q-Bus, CNG powered 29 seat bus, for Partial STURAA testing in the 10 yr/350,000 mile category. The Federal Transit Administration determined that the following tests would be performed: 1.3 Replacement and/or Repair of Selected Subsystems, 3. Safety, 4. Performance, and 6. Fuel Economy. The Check-In section of the report provides a description of the bus and specifies its major components.

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

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 29.02 seconds.

A Fuel Economy Test was run on simulated central business district, arterial, and commuter courses. The results were 0.73 m/lb, 0.94 m/lb and 1.52 m/lb respectively; with an overall average of .092 m/lb.

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
PSBRTF	- Penn State Bus Research and Testing Facility
PTI	- Pennsylvania Transportation Institute
rpm	- revolutions per minute
SAE	- Society of Automotive Engineers
SCH	- test scheduler
SEC	- secretary
SLW	- seated load weight (curb weight plus 150 lb for every designed passenger seating position and for the driver)
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 has a front door, forward of the front axle, and a rear door between the axles equipped with a Ricon model Mirage F9A wheelchair lift. The engine type is a CNG fueled John Deere Power Systems Power Tech 6.8 L. The transmission is an Allison B 300.

The measured curb weight is 5,675 lbs for the front axle and 16,675 lbs for the rear axle. These combined weights provide a total measured curb weight of 22,350 lbs. There are 29 seats including the driver and room for 20 standing passengers bringing the total passenger capacity to 49. Gross load is $150 \text{ lb} \times 49 = 7,350 \text{ lbs}$. At full capacity, the measured gross vehicle weight is 29,650 lbs. Note: this exceeds the rear axle GVWR (20,500 lbs) by 1,350 lbs.

VEHICLE DATA FORM

Bus Number: 2019	Arrival Date: 9-19-00
Bus Manufacturer: Blue Bird	Vehicle Identification Number (VIN): 1BAGEBNA21F097112
Model Number: Q-Bus	Date: 9-19-00
Personnel: S.C.	

WEIGHT:.

Individual Wheel Reactions:

Weights (lb)	Front Axle		Middle Axle		Rear Axle	
	Right	Left	Right	Left	Right	Left
CW	2,225	3,450	N/A	N/A	8,700	7,975
SLW	2,625	4,100	N/A	N/A	10,275	9,700
GVW	3,150	4,650	N/A	N/A	11,250	10,600

Total Weight Details:

Weight (lb)	CW	SLW	GVW	GAWR
Front Axle	5,675	6,725	7,800	12,000
Middle Axle	N/A	N/A	N/A	N/A
Rear Axle	16,675	19,275	21,850	20,500
Total	22,350	26,700	29,650	GVWR: 32,500

Dimensions:

Length (ft/in)	29 / 8
Width (in)	96.0
Height (in)	126.0
Front Overhang (in)	83.0
Rear Overhang (in)	121.5
Wheel Base (in)	151.5
Wheel Track (in)	Front: 81.0
	Rear: 73.0

Bus Number: 2019	Date: 9-19-00
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CLEARANCES:

Lowest Point Outside Front Axle	Location: Step well	Clearance(in): 10.2
Lowest Point Outside Rear Axle	Location: Muffler	Clearance(in): 9.5
Lowest Point between Axles	Location: Body	Clearance(in): 10.5
Ground Clearance at the center (in)	10.5	
Front Approach Angle (deg)	9.5	
Rear Approach Angle (deg)	6.7	
Ramp Clearance Angle (deg)	8.4	
Aisle Width (in)	19.5	
Inside Standing Height at Center Aisle (in)	77.0	

BODY DETAILS:

Body Structural Type	Integral		
Frame Material	Steel		
Body Material	Steel / fiberglass		
Floor Material	Plywood		
Roof Material	Steel / fiberglass		
Windows Type	<input type="checkbox"/> Fixed	<input checked="" type="checkbox"/> Movable	
Window Mfg./Model No.	HEHR / AS-3 Dot399 M228G		
Number of Doors	<u>1</u> Front	<u>1</u> Rear	
Mfr. / Model No.	entry: Blue Bird/P/N 1796738 wheelchair: Bode/3279		
Dimension of Each Door (in)	Front-30.0 x 80.5	Rear-45.5 x 93.5	
Passenger Seat Type	<input type="checkbox"/> Cantilever	<input checked="" type="checkbox"/> Pedestal	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	American Seating / 6468 1685221		
Driver Seat Type	<input checked="" type="checkbox"/> Air	<input type="checkbox"/> Spring	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	Recaro / B-100 W		
Number of Seats (including Driver)	29		

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BODY DETAILS (Contd..)

Free Floor Space (ft ²)	30.0				
Height of Each Step at Normal Position (in)	Front	1. <u>13.0</u>	2. <u>8.5</u>	3. <u>8.5</u>	4. <u>8.5</u>
	Middle	1. <u>N/A</u>	2. <u>N/A</u>	3. <u>N/A</u>	4. <u>N/A</u>
	Rear	1. <u>13.0</u>	2. <u>8.8</u>	3. <u>8.2</u>	4. <u>8.1</u>
Step Elevation Change - Kneeling (in)	3.0				

ENGINE

Type	<input type="checkbox"/> C.I.	<input type="checkbox"/> Alternate Fuel	
	<input checked="" type="checkbox"/> S.I.	<input type="checkbox"/> Other (explain)	
Mfr. / Model No.	John Deere Power Systems / Power Tech 6.8 L		
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"/> CNG	<input type="checkbox"/> Methanol
	<input type="checkbox"/> Diesel	<input type="checkbox"/> LNG	<input type="checkbox"/> Other (explain)
Fuel Tank Capacity (indicate units)	6,763 Scf @ 3,600 Psi		
Fuel Induction Type	<input type="checkbox"/> Injected	<input type="checkbox"/> Carburetion	
Fuel Injector Mfr. / Model No.	Woodward / 99230100		
Carburetor Mfr. / Model No.	N/A		
Fuel Pump Mfr. / Model No.	N/A		
Alternator (Generator) Mfr. / Model No.	Leece Neville / A001090836		
Maximum Rated Output (Volts / Amps)	14 / 160		
Air Compressor Mfr. / Model No.	Bendix/550		
Maximum Capacity (ft ³ / min)	13.2		
Starter Type	<input checked="" type="checkbox"/> Electrical	<input type="checkbox"/> Pneumatic	<input type="checkbox"/> Other (explain)
Starter Mfr. / Model No.	Denso / 55800		

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TRANSMISSION

Transmission Type	<input type="checkbox"/> Manual	<input checked="" type="checkbox"/> Automatic	
Mfr. / Model No.	Allison / B 300		
Control Type	<input type="checkbox"/> Mechanical	<input checked="" type="checkbox"/> Electrical	<input type="checkbox"/> Other (explain)
Torque Convertor Mfr. / Model No.	Allison / B 300		
Integral Retarder Mfr. / Model No.	N/A		

SUSPENSION

Number of Axles	2		
Front Axle Type	<input type="checkbox"/> Independent	<input checked="" type="checkbox"/> Beam Axle	
Mfr. / Model No.	Spicer / I 120 S G		
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.	Blue Bird / C0190		
Middle Axle Type	<input type="checkbox"/> Independent	<input type="checkbox"/> Beam Axle	
Mfr. / Model No.	N/A		
Axle Ratio (if driven)	N/A		
Suspension Type	<input type="checkbox"/> Air	<input type="checkbox"/> Spring	<input type="checkbox"/> Other (explain)
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.	Spicer / J 210 S		
Axle Ratio (if driven)	5.38		
Suspension Type	<input checked="" type="checkbox"/> Air	<input type="checkbox"/> Spring	<input type="checkbox"/> Other (explain)
No. of Shock Absorbers	2		
Mfr. / Model No.	Blue / Bird C 1479		

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WHEELS & TIRES

Front	Wheel Mfr./ Model No.	Accuride / 8.25 x 22.5
	Tire Mfr./ Model No.	Michelin / 11R 22.5 XZA2
Rear	Wheel Mfr./ Model No.	Accuride / 8.25 x 22.5
	Tire Mfr./ Model No.	Michelin / 11R 22.5 XZA2

BRAKES

Front Axle Brakes Type	<input checked="" type="checkbox"/> Cam	<input type="checkbox"/> Disc	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	Spicer-Eaton / ES1656D		
Middle Axle Brakes Type	<input type="checkbox"/> Cam	<input type="checkbox"/> Disc	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	N/A		
Rear Axle Brakes Type	<input checked="" type="checkbox"/> Cam	<input type="checkbox"/> Disc	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	Spicer-Eaton / ES1657D		
Retarder Type	N/A		
Mfr. / Model No.	N/A		

HVAC

Heating System Type	<input type="checkbox"/> Air	<input checked="" type="checkbox"/> Water	<input type="checkbox"/> Other
Capacity (Btu/hr)	Front - 90,000 Rear-2 units @ 50,000 each		
Mfr. / Model No.	Hurri-Hot / Front - 90 Rear - 50		
Air Conditioner	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	
Location	Roof mount		
Capacity (Btu/hr)	130,000		
A/C Compressor Mfr. / Model No.	Carries / 05KB324400		

STEERING

Steering Gear Box Type	Hydraulic gear
Mfr. / Model No.	Ross / TRW
Steering Wheel Diameter	18.0
Number of turns (lock to lock)	4.75

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OTHERS

Wheel Chair Ramps	Location: N/A	Type: N/A
Wheel Chair Lifts	Location: Right center	Type: Platform
Mfr. / Model No.	Ricon / Mirage F9A	
Emergency Exit	Location: Windows Roof hatch Doors	Number: 7 1 2

CAPACITIES

Fuel Tank Capacity (units)	6,763 Scf @ 3,600 Psi
Engine Crankcase Capacity (gallons)	4.75
Transmission Capacity (gallons)	5.0
Differential Capacity (gallons)	8.0
Cooling System Capacity (gallons)	10.5
Power Steering Fluid Capacity (gallons)	15 quarts (shared system with hydraulic cooling fan)

COMPONENT/SUBSYSTEM INSPECTION FORM

Bus Number: 2019	Date: 9-19-00
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Subsystem	Checked	Comments
Air Conditioning Heating and Ventilation	✓	
Body and Sheet Metal	✓	Doors needed adjustments.
Frame	✓	
Steering	✓	
Suspension	✓	
Interior/Seating	✓	
Axles	✓	
Brakes	✓	
Tires/Wheels	✓	
Exhaust	✓	
Fuel System	✓	
Power Plant	✓	
Accessories	✓	
Lift System	✓	
Interior Fasteners	✓	
Batteries	✓	

CHECK - IN



BLUE BIRD CORPORATION'S MODEL Q-BUS



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

At the end of the test, the items on the list were removed and replaced. The transmission assembly took 18.0 man-hours (two men 9.00 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

Subsystem	Replacement Time
Transmission	18.00 man hours
Wiper Motor	0.50 man hours
Starter	1.00 man hours
Alternator	0.50 man hours
Batteries	0.50 man hours

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

Bus Number: 2019	Date: 9-27-00
Personnel: S.C.	

Temperature (°F): 60	Humidity (%): 51
Wind Direction: W	Wind Speed (mph): 7 - 8
Barometric Pressure (in.Hg): 30.15	

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. 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 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-III. DISCUSSION

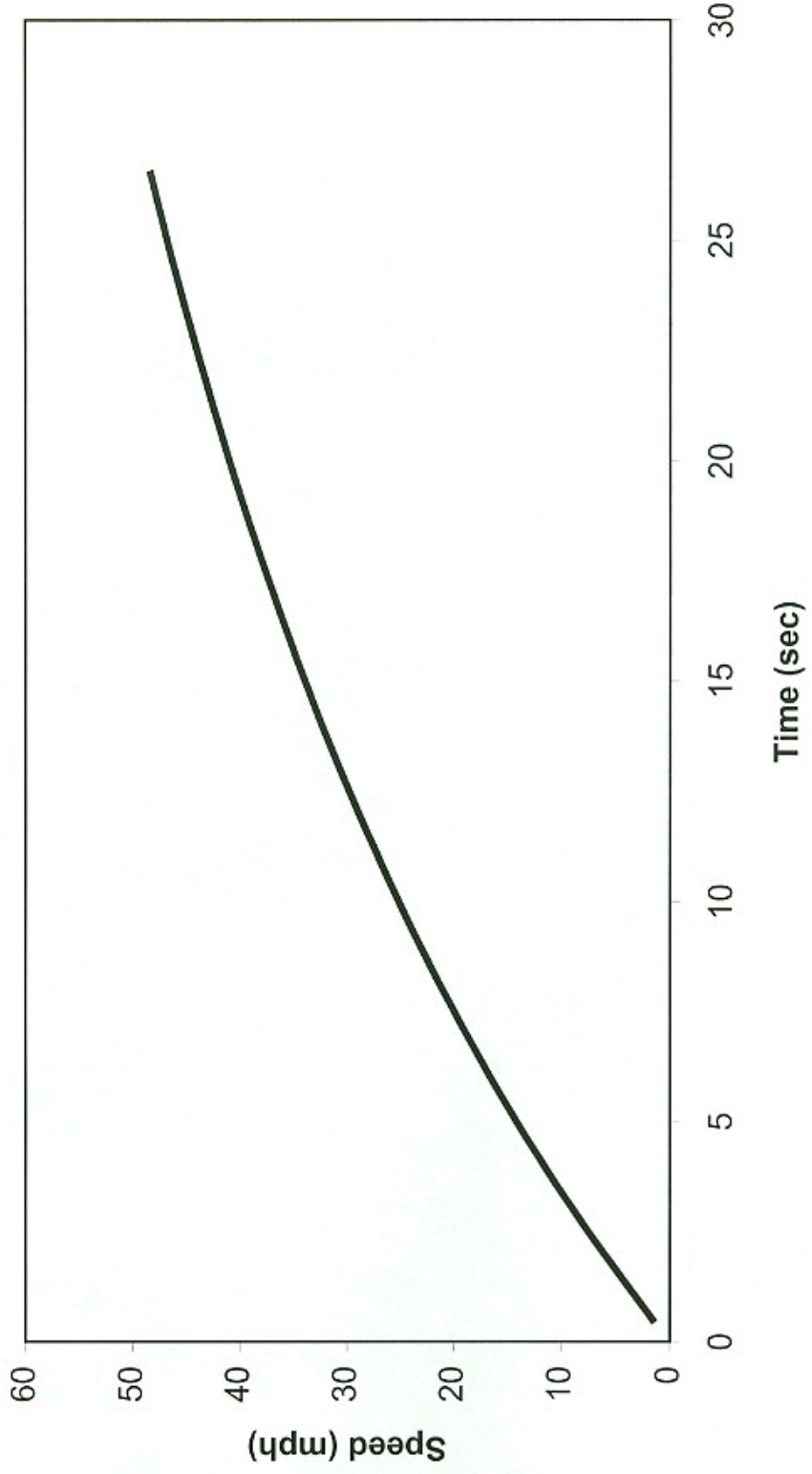
This test consists of three runs in both the clockwise and counterclockwise directions on the PSBRTF Test Track. Velocity versus time data is obtained for each run and results are averaged together to minimize any test variability which might be introduced by wind or other external factors. The test 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 29.02 seconds.

PERFORMANCE DATA FORM

Bus Number: 2019	Date: 9-27-00
Personnel: S.C., E.D. & G.M.	
Temperature (°F): 61	Humidity (%): 51
Wind Direction: W	Wind Speed (mph): 7 - 8
Barometric Pressure (in.Hg): 30.15	
Air Conditioning compressor-OFF	<input checked="" type="checkbox"/> Checked
Ventilation fans-ON HIGH	<input checked="" type="checkbox"/> Checked
Heater pump motor-Off	<input checked="" type="checkbox"/> Checked
Defroster-OFF	<input checked="" type="checkbox"/> Checked
Exterior and interior lights-ON	<input checked="" type="checkbox"/> Checked
Windows and doors-CLOSED	<input checked="" type="checkbox"/> Checked

ACCELERATION, GRADEABILITY, TOP SPEED			
Counter Clockwise Recorded Interval Times			
Speed	Run 1	Run 2	Run 3
10 mph	3.84	4.90	5.15
20 mph	6.91	7.77	8.24
30 mph	11.00	11.74	12.24
40 mph	17.91	18.71	20.18
Top Test Speed(mph) 50	28.41	30.53	30.28
Clockwise Recorded Interval Times			
Speed	Run 1	Run 2	Run 3
10 mph	5.47	5.10	4.35
20 mph	8.06	8.16	7.56
30 mph	11.75	11.82	10.99
40 mph	17.85	17.98	17.15
Top Test Speed(mph) 50	28.91	28.67	27.34

**Velocity vs. Time
Blue Bird #2019**



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

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

1. The ADB cycle is structured as a set number of miles in a fixed time in the following order: CBD, Arterial, CBD, Arterial, CBD, Commuter. A separate idle fuel consumption measurement is performed at the beginning and end of the fuel economy test. This phase sequence permits the reporting of fuel consumption for each of these phases separately, making the data more useful to bus manufacturers and transit properties.
2. The operating profile for testing purposes shall consist of simulated transit type service at seated load weight. The three test phases (figure 6-1) are: a central business district (CBD) phase of 2 miles with 7 stops per mile and a top speed of 20 mph; an arterial phase of 2 miles with 2 stops per mile and a top speed of 40 mph; and a commuter phase of 4 miles with 1 stop and a maximum speed of 40 mph. At each designated stop the bus will remain stationary for seven seconds. During this time, the passenger doors shall be opened and closed.
3. The individual ADB phases remain unaltered with the exception that 1 mile has been changed to 1 lap on the PSBRTF track. One lap is equal to 5,042 feet. This change is accommodated by adjusting the cruise distance and time.
4. The acceleration profile, for practical purposes and to achieve better repeatability, has been changed to "full throttle acceleration to cruise speed".

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

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

- 1.1 SAE 1376 July 82 requires the use of at least a 16-gal fuel tank. Such a fuel tank when full would weigh approximately 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), liquified 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 60°F (8.3373 lbs/gal) and volumetric heating value of standard fuel; and test fuel specific gravity (unitless) and volumetric heating value (BTU/gal). These combine to give a fuel economy in miles per gallon (mpg) which is corrected to a standard gallon of fuel referenced to water at 60°F. This eliminates fluctuations in fuel economy due to fluctuations in fuel quality. This calculation has been programmed into a computer and the data processing is performed automatically.

The fuel economy correction consists of three steps:

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

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

$$FE_{o_{mi/lb}} = \text{Observed fuel economy} = \frac{\text{miles}}{\text{lb of fuel}}$$

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

$$FEo_{mpg} = FEc_{mi/lb} \times G_s \times G_w$$

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.

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

where

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

Combining steps 1-3 yields

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

- 4.) Convert 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.

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

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.

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

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

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

$$FEO_{mi/lb} = FEO / Gm$$

where Gm = Density of test fuel at standard conditions

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

$$Eq = ((FEOmi/lb)/H) \times 10^6$$

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 CNG fuel with a heating value of 1,008.1 Btu/cf. 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 127,700 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 sheet shows the correction calculation for the test fuel. 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 - 0.73 m/lb, ART - 0.94 m/lb, and COM - 1.52 m/lb. Average fuel consumption at idle was 3.38 lb/hr (80.4 scf/hr).

FUEL ECONOMY PRE-TEST MAINTENANCE FORM

Bus Number: 2019	Date: 9-22-00	SLW (lbs): 26,700
Personnel: K.D. & S.C.		

FUEL SYSTEM	OK	Date	Initials
Install fuel measurement system	✓	9-22-00	K.D.
Replace fuel filter	✓	9-22-00	K.D.
Check for fuel leaks	✓	9-22-00	K.D.
Specify fuel type (refer to fuel analysis)			
Remarks: none			
BRAKES/TIRES	OK	Date	Initials
Inspect hoses	✓	9-22-00	K.D.
Inspect brakes	✓	9-22-00	K.D.
Relube wheel bearings	✓	9-22-00	K.D.
Check tire inflation pressures (mfg. specs.)	✓	9-22-00	K.D.
Remarks: none			
COOLING SYSTEM	OK	Date	Initials
Check hoses and connections	✓	9-22-00	K.D.
Check system for coolant leaks	✓	9-22-00	K.D.
Remarks: none			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 2)

Bus Number: 2019	Date: 9-22-00		
Personnel: K.D.			
ELECTRICAL SYSTEMS	OK	Date	Initials
Check battery	✓	9-22-00	K.D.
Inspect wiring	✓	9-22-00	K.D.
Inspect terminals	✓	9-22-00	K.D.
Check lighting	✓	9-22-00	K.D.
Remarks: none			
DRIVE SYSTEM	OK	Date	Initials
Drain transmission fluid	✓	9-22-00	K.D.
Replace filter/gasket	✓	9-22-00	K.D.
Check hoses and connections	✓	9-22-00	K.D.
Replace transmission fluid	✓	9-22-00	K.D.
Check for fluid leaks	✓	9-22-00	K.D.
Remarks: none			
LUBRICATION	OK	Date	Initials
Drain crankcase oil	✓	9-22-00	K.D.
Replace filters	✓	9-22-00	K.D.
Replace crankcase oil	✓	9-22-00	K.D.
Check for oil leaks	✓	9-22-00	K.D.
Check oil level	✓	9-22-00	K.D.
Lube all chassis grease fittings	✓	9-22-00	K.D.
Lube universal joints	✓	9-22-00	K.D.
Replace differential lube including axles	✓	9-22-00	K.D.
Remarks: none			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 3)

Bus Number: 2019	Date: 9-22-00		
Personnel: K.D.			
EXHAUST/EMISSION SYSTEM	OK	Date	Initials
Check for exhaust leaks	✓	9-22-00	K.D.
Remarks: none			
ENGINE	OK	Date	Initials
Replace air filter	✓	9-22-00	K.D.
Inspect air compressor and air system	✓	9-22-00	K.D.
Inspect vacuum system, if applicable	✓	9-22-00	K.D.
Check and adjust all drive belts	✓	9-22-00	K.D.
Check cold start assist, if applicable	✓	9-22-00	K.D.
Remarks: none			
STEERING SYSTEM	OK	Date	Initials
Check power steering hoses and connectors	✓	9-22-00	K.D.
Service fluid level	✓	9-22-00	K.D.
Check power steering operation	✓	9-22-00	K.D.
Remarks: none			
	OK	Date	Initials
Ballast bus to seated load weight	✓	9-22-00	K.D.
TEST DRIVE	OK	Date	Initials
Check brake operation	✓	9-22-00	K.D.
Check transmission operation	✓	9-22-00	K.D.
Remarks: none			

FUEL ECONOMY PRE-TEST INSPECTION FORM

Bus Number: 2019	Date: 9-25-00
Personnel: S.C.	
PRE WARM-UP	If OK, Initial
Fuel Economy Pre-Test Maintenance Form is complete	S.C.
Cold tire pressure (psi): Front <u>120</u> Middle <u>N/A</u> Rear <u>120</u>	S.C.
Tire wear:	S.C.
Engine oil level	S.C.
Engine coolant level	S.C.
Interior and exterior lights on, evaporator fan on	S.C.
Fuel economy instrumentation installed and working properly.	S.C.
Fuel line -- no leaks or kinks	S.C.
Speed measuring system installed on bus. Speed indicator installed in front of bus and accessible to TECH and Driver.	S.C.
Bus is loaded to SLW	S.C.
WARM-UP	If OK, Initial
Bus driven for at least one hour warm-up	S.C.
No extensive or black smoke from exhaust	S.C.
POST WARM-UP	If OK, Initial
Warm tire pressure (psi): Front <u>121</u> Middle <u>N/A</u> Rear <u>121</u>	S.C.
Environmental conditions Average wind speed <12 mph and maximum gusts <15 mph Ambient temperature between 30°(-1°) and 90°F(32°C) Track surface is dry Track is free of extraneous material and clear of interfering traffic	S.C.

FUEL ECONOMY DATA FORM (Gaseous Fuels)

Bus Number: 2019		Manufacturer: Blue Bird		Date: 9-25-00	
Run Number: 1		Personnel: S.C. & G.M.			
Test Direction: <input type="checkbox"/> CW or <input checked="" type="checkbox"/> CCW		Ambient Temperature (°F): 49		Humidity (%): 60	
SLW (lbs): 26,700		Wind Speed (mph) & Direction: 5 / NE		Barometric Pressure (in.Hg): 30.05	
Cycle Type	Run Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°F)	Total Fuel Used (SCF)
	Start	Finish		Start	
CBD #1	0	8:25	8:25	76.8	62.9
ART #1	0	4:08	4:08	78.9	49.5
CBD #2	0	8:23	8:23	76.0	62.1
ART #2	0	4:15	4:15	78.9	48.6
CBD #3	0	8:26	8:26	78.7	63.1
COMMUTER	0	6:14	6:14	77.0	59.5
Total Fuel:345.7 SCF					
20 minute idle : Total Fuel Used = 27.2 SCF					
No Load Flow Rate at Idle = 1.8 SCFM			No Load Flow Rate at Full Throttle = 13.9 SCFM		
Heating Value = 1,008.1 BTU/LB					
Comments: none					

FUEL ECONOMY DATA FORM (Gaseous Fuels)

Bus Number: 2019		Manufacturer: Blue Bird		Date: 9-25-00	
Run Number: 2		Personnel: S.C. & G.M.			
Test Direction: <input checked="" type="checkbox"/> CW or <input type="checkbox"/> CCW		Ambient Temperature (°F): 52		Humidity (%): 58	
SLW (lbs): 26,700		Wind Speed (mph) & Direction: 7 / NE		Barometric Pressure (in.Hg): 30.00	
Cycle Type	Run Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°F)	Total Fuel Used (SCF)
	Start	Finish		Start	
CBD #1	0	8:33	8:33	79.1	60.7
ART #1	0	4:07	4:07	81.0	48.3
CBD #2	0	8:30	8:30	78.3	63.2
ART #2	0	4:10	4:10	82.2	48.4
CBD #3	0	8:34	8:34	83.5	63.2
COMMUTER	0	6:18	6:18	82.9	60.2
Total Fuel: 344.0 SCF					
20 minute idle : Total Fuel Used = N/A					
No Load Flow Rate at Idle = N/A			No Load Flow Rate at Full Throttle = N/A		
Heating Value = 1,008.1 BTU/LB					
Comments: none					

FUEL ECONOMY DATA FORM (Gaseous Fuels)

Bus Number: 2019		Manufacturer: Blue Bird		Date: 9-25-00	
Run Number: 3		Personnel: S.C. & G.M.			
Test Direction: <input type="checkbox"/> CW or <input checked="" type="checkbox"/> CCW		Ambient Temperature (°F): 54		Humidity (%): 58	
SLW (lbs): 26,700		Wind Speed (mph) & Direction: 7 / NE		Barometric Pressure (in.Hg): 30.00	
Cycle Type	Run Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°F)	Total Fuel Used (SCF)
	Start	Finish		Start	
CBD #1	0	8:30	8:30	82.2	63.7
ART #1	0	4:12	4:12	84.7	48.6
CBD #2	0	8:33	8:33	85.0	64.3
ART #2	0	4:19	4:19	83.9	48.8
CBD #3	0	8:39	8:39	83.7	61.9
COMMUTER	0	6:20	6:20	85.5	58.8
Total Fuel: 346.1 SCF					
20 minute idle : Total Fuel Used = N/A					
No Load Flow Rate at Idle = N/A			No Load Flow Rate at Full Throttle = N/A		
Heating Value = 1,008.1 BTU/LB					
Comments: none					

FUEL ECONOMY DATA FORM (Gaseous Fuels)

Bus Number: 2019		Manufacturer: Blue Bird		Date: 9-25-00	
Run Number: 4		Personnel: S.C. & G.M.			
Test Direction: <input checked="" type="checkbox"/> CW or <input type="checkbox"/> CCW		Ambient Temperature (°F): 54		Humidity (%): 54	
SLW (lbs): 26,700		Wind Speed (mph) & Direction: 8 / ENE		Barometric Pressure (in.Hg): 29.97	
Cycle Type	Run Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°F)	Total Fuel Used (SCF)
	Start	Finish		Start	
CBD #1	0	8:35	8:35	83.3	62.5
ART #1	0	4:13	4:13	84.6	48.3
CBD #2	0	8:40	8:40	82.3	61.5
ART #2	0	4:20	4:20	85.1	47.8
CBD #3	0	8:39	8:39	85.5	61.7
COMMUTER	0	6:20	6:20	86.3	59.8
Total Fuel: 341.6 SCF					
20 minute idle : Total Fuel Used = 26.4 SCF					
No Load Flow Rate at Idle = 1.3 SCFM			No Load Flow Rate at Full Throttle = 13.8 SCFM		
Heating Value = 1,008.1 BTU/LB					
Comments: none					

FUEL ECONOMY SUMMARY SHEET

BUS MANUFACTURER :Blue Bird
 BUS MODEL :Q-Bus
 BUS NUMBER :2019
 TEST DATE :9/25/00

FUEL TYPE : NATURAL GAS
 SP. GRAVITY : .5770
 HEATING VALUE : 1008.10 BTU/cf
 Standard Conditions : 60 deg F and 14.7 psi
 Density of Air : 0.0729 lb/scf

CYCLE	TOTAL FUEL USED (Scf)	TOTAL MILES	FUEL ECONOMY M/Scf (Measured)	FUEL ECONOMY M/Lb (Corrected)
Run # :1, CCW				
CBD	188.1	5.73	.03	.72
ART	98.1	3.82	.04	.93
COM	59.5	3.82	.06	1.53
TOTAL	345.7	13.37	.04	.92
Run # :2, CW				
CBD	187.1	5.73	.03	.73
ART	96.7	3.82	.04	.94
COM	60.2	3.82	.06	1.51
TOTAL	344.0	13.37	.04	.92
Run # :3, CCW				
CBD	189.9	5.73	.03	.72
ART	97.4	3.82	.04	.93
COM	58.8	3.82	.06	1.54
TOTAL	346.1	13.37	.04	.92
Run # :4, CW				
CBD	185.7	5.73	.03	.73
ART	96.1	3.82	.04	.95
COM	59.8	3.82	.06	1.52
TOTAL	341.6	13.37	.04	.93

 IDLE CONSUMPTION

First 20 Minutes Data : 27.2 Scf Last 20 Minutes Data : 26.4 Scf
 Average Idle Consumption : 80.4 Scf/Hr

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

 Run 1 : -.4 Run 2 : .1 Run 3 : -.5 Run 4 : .8

SUMMARY

Average Idle Consumption : 3.38 LB/Hr
 Average CBD Phase Consumption : .73 M/Lb
 Average Arterial Phase Consumption : .94 M/Lb
 Average Commuter Phase Consumption : 1.52 M/Lb
 Overall Average Fuel Consumption : .92 M/Lb
 Overall Average Fuel Consumption : 38.52 Miles/ Million BTU

