

PARTIAL
STURAA TEST
10 YEAR
350,000 MILE BUS
from
ELDORADO NATIONAL
MODEL TM-RE-29

FEBRUARY 1996
PTI-BT-R9601-03-96-P

PENNSSTATE



The Pennsylvania Transportation Institute

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* NOTE: Partial STURAA Testing was performed on this bus. Only those tests that were performed are included in this report. In order to remain consistent with the Time and Fee Schedule, the tests included in this report retain their original numbers and are not numbered sequentially.

EXECUTIVE SUMMARY

EIDorado National submitted a model TM-RE-29, diesel powered 26 seat/29-foot bus, for partial STURAA testing in the 10 yr/350,000 mile category. The Federal Transit Administration determined that the following test would be performed: 3. Safety, 4. Performance, and 6. Fuel Economy Tests. The odometer reading at the time of delivery was 0,134.0 miles. The testing started on January 2, 1996, and was completed on January 22, 1996. The Check-In Section of the report provides a description of the bus and specifies its major components.

The Safety Test, a double-lane change, obstacle avoidance test, was safely performed in both right-hand and left-hand directions up to 40 mph. During the 45 mph phase the test bus had difficulty maintaining a correct profile through the desired lane. Tire/ground patch was maintained throughout testing. 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 29.56 seconds.

A Fuel Economy Test was run on simulated central business district, arterial, and commuter courses. The results were 3.98 mpg, 4.31 mpg, and 7.71 mpg respectively; with an overall average of 4.74 mpg.

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
NBM	- new bus models
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 NBM, assign a NBM number, complete the vehicle data form, and perform a safety check.

II. TEST DESCRIPTION

The test consists of assigning a NBM 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 EIDorado National model TM-RE-29. Power is provided by a diesel fueled, Cummins C8.3 engine coupled to an Allison MTB-643 transmission. The bus is equipped with a walk-in front door, located forward of the front axle, and a dedicated wheelchair access door equipped with a Braun model L911RARS wheelchair lift centered between the front and rear axles.

The measured curb weight is 5,750 lb for the front axle and 15,400 lb for the rear axle. These combined weights provide a total measured curb weight of 21,150 lb. There are 26 seats including the driver, and room for 13 standing passengers bringing the total passenger capacity to 39. The gross load is $150 \text{ lb} \times 39 = 5,850 \text{ lb}$. At full capacity, the measured gross vehicle weight is 27,200 lb. In order to avoid exceeding the GAWR of the rear axle (19,000 lb), 2 standing passengers were eliminated. This reduction from full capacity resulted in an adjusted measured gross vehicle weight of 26,950 lbs and was used for all dynamic testing.

VEHICLE DATA FORM

Bus Number: 9601	Arrival Date: 12-20-95
Bus Manufacturer: Eldorado National Co.	Vehicle Identification Number (VIN): 1N9TBAC84SCO84131
Model Number: TM-RE-29	Date: 1-2-96
Personnel: Bob LaMorte and Stan Crawford	

WEIGHT:

Individual Wheel Reactions:

Weights (lb)	Front Axle		Middle Axle		Rear Axle	
	Right	Left	Right	Left	Right	Left
CW	2,850	2,900	N/A	N/A	7,800	7,600
SLW	3,400	3,400	N/A	N/A	9,150	9,300
GVW	3,900	4,050	N/A	N/A	9,400	9,600

Total Weight Details:

Weight (lb)	CW	SLW	GVW	GAWR
Front Axle	5,750	6,800	7,950	10,000
Middle Axle	N/A	N/A	N/A	N/A
Rear Axle	15,400	18,450	19,000	19,000
Total	21,150	25,250	26,950*	GVWR: 29,000

Dimensions:

Length (ft/in)	29 / 0.5
Width (in)	96
Height (in)	121.5
Front Overhang (in)	92.0
Rear Overhang (in)	117.5
Wheel Base (in)	139.0
Wheel Track (in)	Front: 80.7
	Rear: 72.5

Bus Number: 9601	Date: 1-2-96
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CLEARANCES:

Lowest Point Outside Front Axle	Location: Front suspension	Clearance(in): 9.0
Lowest Point Outside Rear Axle	Location: Guard	Clearance(in): 9.9
Lowest Point between Axles	Location: Rear suspension	Clearance(in): 8.2
Ground Clearance at the center (in)	14.0	
Front Approach Angle (deg)	15.0	
Rear Approach Angle (deg)	8.0	
Ramp Clearance Angle (deg)	17.5	
Aisle Width (in)	20.0	
Inside Standing Height at Center Aisle (ft)	80.5	

BODY DETAILS:

Body Structural Type	Integral		
Frame Material	Steel		
Body Material	Fiberglass		
Floor Material	Plywood		
Roof Material	Fiberglass		
Windows Type	<input type="checkbox"/> Fixed	<input checked="" type="checkbox"/> Movable	
Window Mfg./Model No.	ALG / AS-3		
Number of Doors	<u>1</u> Front	<u>1</u> Rear	
Mfr. / Model No.	EMC / 46" swing-out		
Dimension of Each Door (in)	Front 40.0 X 88.5	Rear 43.5 X 70.5	
Passenger Seat Type	<input type="checkbox"/> Cantilever	<input checked="" type="checkbox"/> Pedestal	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	American Seating Co. / 6468		
Driver Seat Type	<input type="checkbox"/> Air	<input type="checkbox"/> Spring	<input checked="" type="checkbox"/> Other cushion
Mfr. / Model No.	Freedman / Hi-back with armrest		
Number of Seats (including Driver)	26		

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BODY DETAILS (Contd..)

Free Floor Space (ft ²)	20.1				
Height of Each Step at Normal Position (in)	Front	1. <u>14.0</u>	2. <u>10.5</u>	3. <u>10.3</u>	4. <u>N/A</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>N/A</u>	2. <u>N/A</u>	3. <u>N/A</u>	4. <u>N/A</u>
Step Elevation Change - Kneeling (in)	9.8				

ENGINE

Type	<input checked="" type="checkbox"/> C.I.	<input type="checkbox"/> Alternate Fuel	
	<input type="checkbox"/> S.I.	<input type="checkbox"/> Other (explain)	
Mfr. / Model No.	Cummins / C8.3 - 250		
Location	<input type="checkbox"/> Front	<input checked="" type="checkbox"/> Rear	<input type="checkbox"/> Other (explain)
Fuel Type	<input type="checkbox"/> Gasoline	<input type="checkbox"/> CNG	<input type="checkbox"/> Methanol
	<input checked="" type="checkbox"/> Diesel	<input type="checkbox"/> LNG	<input type="checkbox"/> Other (explain)
Fuel Tank Capacity (indicate units)	76 gals		
Fuel Induction Type	<input checked="" type="checkbox"/> Injected	<input type="checkbox"/> Carburetion	
Fuel Injector Mfr. / Model No.	Cummins / C8.3		
Carburetor Mfr. / Model No.	N/A		
Fuel Pump Mfr. / Model No.	Nippondenso / 12V		
Alternator (Generator) Mfr. / Model No.	Leece-Neville / BJ0072100A		
Maximum Rated Output (Volts / Amps)	14 / 130		
Air Compressor Mfr. / Model No.	Holset / QE338C		
Maximum Capacity (ft ³ / min)	15		
Starter Type	<input checked="" type="checkbox"/> Electrical	<input type="checkbox"/> Pneumatic	<input type="checkbox"/> Other (explain)
Starter Mfr. / Model No.	Nippondenson / F-type 12V 4KW		

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TRANSMISSION

Transmission Type	<input type="checkbox"/> Manual	<input checked="" type="checkbox"/> Automatic	
Mfr. / Model No.	Allison / MTB-643		
Control Type	<input checked="" type="checkbox"/> Mechanical	<input type="checkbox"/> Electrical	<input type="checkbox"/> Other (explain)
Torque Converter Mfr. / Model No.	Allison / MTB 643 / TC-378		
Integral Retarder Mfr. / Model No.	Allison / MTB 643		

SUSPENSION

Number of Axles	2		
Front Axle Type	<input type="checkbox"/> Independent	<input checked="" type="checkbox"/> Beam Axle	
Mfr. / Model No.	Rockwell International / FF943QX646		
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.	Koni / 9410		
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.	Rockwell International / B23320051865		
Axle Ratio (if driven)	4.33		
Suspension Type	<input checked="" type="checkbox"/> Air	<input type="checkbox"/> Spring	<input type="checkbox"/> Other (explain)
No. of Shock Absorbers	2		
Mfr. / Model No.	Koni / 9410		

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WHEELS & TIRES

Front	Wheel Mfr./ Model No.	Accuride / 22 X 7
	Tire Mfr./ Model No.	Goodyear / 255 / 75R 22.5 G159
Rear	Wheel Mfr./ Model No.	Accuride / 22 X 7
	Tire Mfr./ Model No.	Goodyear / 255 / 75R 22.5 G159

BRAKES

Front Axle Brakes Type	<input checked="" type="checkbox"/> Cam	<input type="checkbox"/> Disc	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	System-Bendix / 16" MGM		
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 type="checkbox"/> Cam	<input type="checkbox"/> Disc	<input type="checkbox"/> Other (explain)
Mfr. / Model No.	System-Bendix / MGM 2430		
Retarder Type	Transmission		
Mfr. / Model No.	Allison / MTB-643		

HVAC

Heating System Type	<input type="checkbox"/> Air	<input checked="" type="checkbox"/> Water	<input type="checkbox"/> Other
Capacity (Btu/hr)	90,000 / 70,000-floor / 55,000-driver		
Mfr. / Model No.	Thermo King / ProAir / E4M2		
Air Conditioner	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	
Location	Front & Rear		
Capacity (Btu/hr)	90,000 / 18,500-driver		
A/C Compressor Mfr. / Model No.	Thermo King / X426 comp		

STEERING

Steering Gear Box Type	Hydraulic gear
Mfr. / Model No.	Sheppard / MDL-M80
Steering Wheel Diameter	20.0
Number of turns (lock to lock)	4

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OTHERS

Wheel Chair Ramps	Location: N/A	Type: N/A
Wheel Chair Lifts	Location: Right ctr.	Type: Platform
Mfr. / Model No.	Braun Corp. / L911RARS	
Emergency Exit	Location: Door Windows Roof hatch	Number: 1 7 1

CAPACITIES

Fuel Tank Capacity (units)	76.00
Engine Crankcase Capacity (gallons)	3.50
Transmission Capacity (gallons)	5.00
Differential Capacity (gallons)	4.38
Cooling System Capacity (gallons)	9.00
Power Steering Fluid Capacity (gallons)	6.25

VEHICLE DATA FORM

Bus Number: 9601	Date: 1-2-96
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List all spare parts, tools and manuals delivered with the bus.

Part Number	Description	Qty.
N/A	Manuals	2

COMPONENT/SUBSYSTEM INSPECTION FORM

Bus Number: 9601	Date: 1-2-96
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Subsystem	Checked	Comments
Air Conditioning Heating and Ventilation	✓	
Body and Sheet Metal	✓	
Frame	✓	
Steering	✓	
Suspension	✓	
Interior/Seating	✓	
Axles	✓	
Brakes	✓	
Tires/Wheels	✓	
Exhaust	✓	
Fuel System	✓	
Power Plant	✓	
Accessories	✓	
Lift System	✓	
Interior Fasteners	✓	
Batteries	✓	

CHECK - IN



ELDORADO NATIONAL MODEL TM-RE-29



CHECK - IN CONT.



**ELDORADO NATIONAL MODEL TM-RE-29
EQUIPPED WITH A BRAUN MODEL
L911RARS WHEELCHAIR LIFT**

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 up to and including the 40 mph phase. During the 45 mph phase the test bus had difficulty maintaining a correct profile through the desired lane. Tire/ground contact patch was maintained throughout testing.

SAFETY DATA FORM

Bus Number: 9601	Date: 1-25-96
Personnel: Bob LaMorte, Stan Crawford, and Ron Harter	

Temperature (°F): 32	Humidity (%): 58
Wind Direction: N	Wind Speed (mph): 5
Barometric Pressure (in.Hg): 30.08	

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 up to and including 40 mph. The bus was difficult to handle within the desired lane during the 45 mph phase.	
Comments of the tire/ground contact patch:	
Tire/ground contact was maintained.	

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 29.56 seconds.

PERFORMANCE DATA FORM

Bus Number: 9601	Date: 1-25-96		
Personnel: Bob LaMorte, Stan Crawford, and Ron Harter			
Temperature (°F): 32	Humidity (%): 58		
Wind Direction: N	Wind Speed (mph): 5		
Barometric Pressure (in.Hg): 30.08			
Air Conditioning compressor-OFF	✓ Checked		
Ventilation fans-ON HIGH	✓ Checked		
Heater pump motor-Off	✓ Checked		
Defroster-OFF	✓ Checked		
Exterior and interior lights-ON	✓ Checked		
Windows and doors-CLOSED	✓ Checked		
ACCELERATION, GRADEABILITY, TOP SPEED			
Counter Clockwise Recorded Interval Times			
Speed	Run 1	Run 2	Run 3
10 mph	3.63	3.42	3.28
20 mph	7.16	6.89	6.74
30 mph	12.60	12.56	12.43
40 mph	20.09	20.37	19.89
Top Test Speed(mph) 50	31.06	31.16	30.44
Clockwise Recorded Interval Times			
Speed	Run 1	Run 2	Run 3
10 mph	3.88	3.51	3.48
20 mph	7.23	6.82	6.94
30 mph	12.77	12.08	12.13
40 mph	19.99	18.43	18.42
Top Test Speed(mph) 50	28.39	28.24	28.04

PERFORMANCE SUMMARY SHEET

BUS MANUFACTURER : ELDORADO NATIONAL BUS NUMBER : 9601
 BUS MODEL : TM-RE-29 TEST DATE : 1/25/96

TEST CONDITIONS :

 TEMPERATURE (DEG F) : 32.0
 WIND DIRECTION : N
 WIND SPEED (MPH) : 5.0
 HUMIDITY (%) : 58
 BAROMETRIC PRESSURE (IN. HG) : 30.1

VEHICLE SPEED (MPH)	AVERAGE TIME (SEC)		
	CCW DIRECTION	CW DIRECTION	TOTAL
10.0	3.44	3.62	3.53
20.0	6.93	7.00	6.96
30.0	12.53	12.33	12.43
40.0	20.12	18.95	19.53
50.0	30.89	28.22	29.56

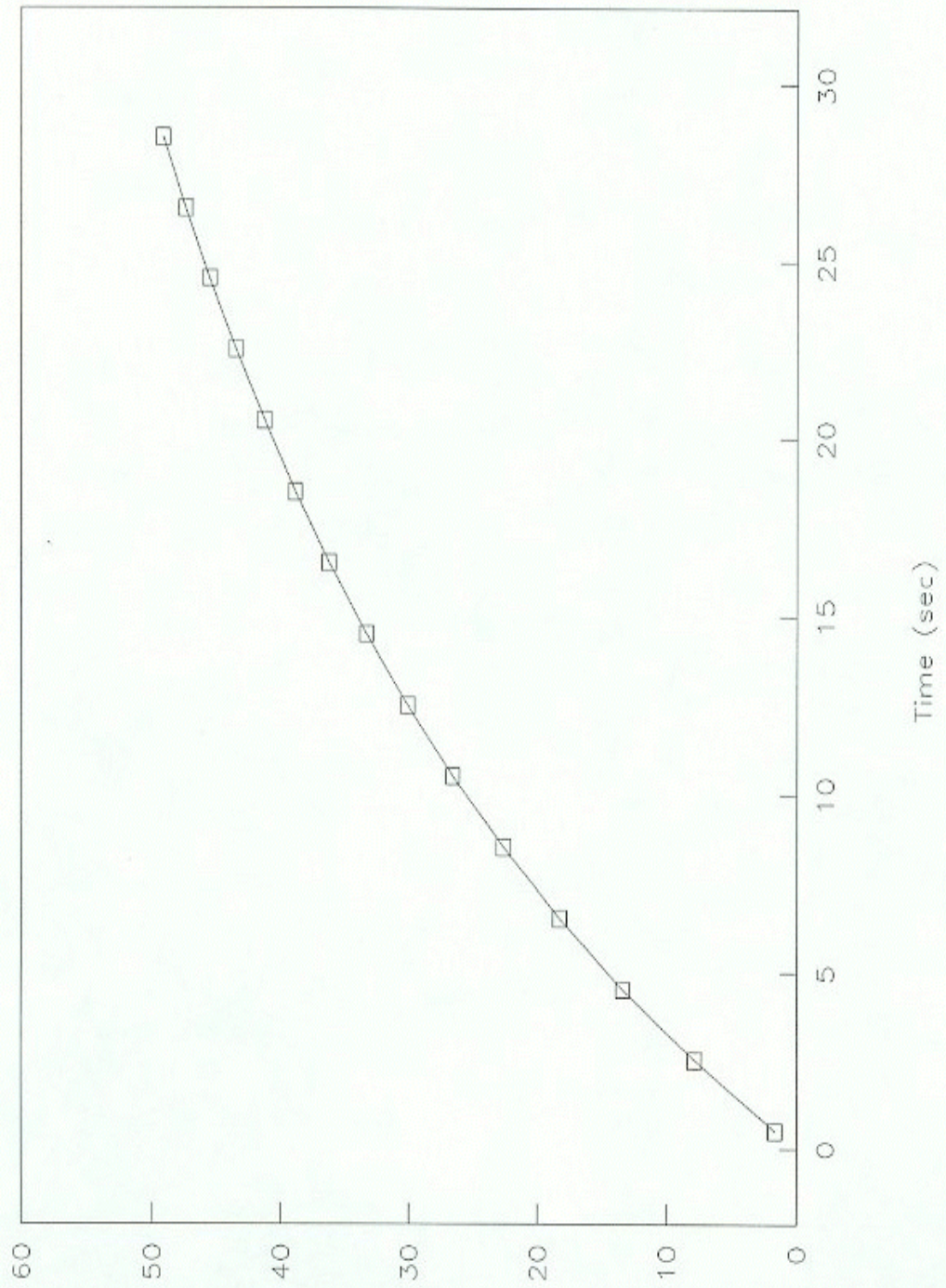
TEST SUMMARY :

VEHICLE SPEED (MPH)	TIME (SEC)	ACCELERATION (FT/SEC ²)	MAX. GRADE (%)
1.0	.30	4.9	15.4
5.0	1.54	4.5	14.3
10.0	3.24	4.1	12.8
15.0	5.13	3.7	11.5
20.0	7.25	3.2	10.1
25.0	9.66	2.8	8.9
30.0	12.43	2.5	7.7
35.0	15.64	2.1	6.6
40.0	19.43	1.8	5.5
45.0	23.99	1.5	4.5
50.0	29.59	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.

Velocity vs Time

Eldorado National 9601



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

FEO_{mi/lb} = Observed fuel economy = miles
 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

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

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.

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

where

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

Combining steps 1-3 yields

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

- 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 number one diesel fuel with a heating value of 19,864.4 btu/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 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 - 3.98 mpg, ART - 4.31 mpg, and COM - 7.71 mpg. Average fuel consumption at idle was 5.70 lb/hr (0.89 gph).

FUEL ECONOMY PRE-TEST MAINTENANCE FORM

Bus Number: 9601	Date: 1-22-96	SLW (lbs):
Personnel: Ken Defibaugh		

FUEL SYSTEM	OK	Date	Initials
Install fuel measurement system	✓	1-19-96	KJD
Replace fuel filter	✓	1-19-96	KJD
Check for fuel leaks	✓	1-19-96	KJD
Specify fuel type (refer to fuel analysis)	#1 diesel		
Remarks:			
BRAKES/TIRES	OK	Date	Initials
Inspect hoses	✓	1-19-96	KJD
Inspect brakes	✓	1-19-96	KJD
Relube wheel bearings	✓	1-19-96	KJD
Check tire inflation pressures (mfg. specs.)	✓	1-19-96	KJD
Remarks:			
COOLING SYSTEM	OK	Date	Initials
Check hoses and connections	✓	1-19-96	KJD
Check system for coolant leaks	✓	1-19-96	KJD
Remarks:			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 2)

Bus Number: 9601	Date: 1-19-96		
Personnel: Ken Defibaugh			
ELECTRICAL SYSTEMS	OK	Date	Initials
Check battery	✓	1-19-96	KJD
Inspect wiring	✓	1-19-96	KJD
Inspect terminals	✓	1-19-96	KJD
Check lighting	✓	1-19-96	KJD
Remarks:			
DRIVE SYSTEM	OK	Date	Initials
Drain transmission fluid	✓	1-19-96	KJD
Replace filter/gasket	✓	1-19-96	KJD
Check hoses and connections	✓	1-19-96	KJD
Replace transmission fluid	✓	1-19-96	KJD
Check for fluid leaks	✓	1-19-96	KJD
Remarks:			
LUBRICATION	OK	Date	Initials
Drain crankcase oil	✓	1-19-96	KJD
Replace filters	✓	1-19-96	KJD
Replace crankcase oil	✓	1-19-96	KJD
Check for oil leaks	✓	1-19-96	KJD
Check oil level	✓	1-19-96	KJD
Lube all chassis grease fittings	✓	1-19-96	KJD
Lube universal joints	✓	1-19-96	KJD
Replace differential lube including axles	✓	1-19-96	KJD
Remarks:			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 3)

Bus Number: 9601	Date: 1-19-96		
Personnel: Ken Defibaugh			
EXHAUST/EMISSION SYSTEM	OK	Date	Initials
Check for exhaust leaks	✓	1-19-96	KJD
Remarks:			
ENGINE	OK	Date	Initials
Replace air filter	✓	1-19-96	KJD
Inspect air compressor and air system	✓	1-19-96	KJD
Inspect vacuum system, if applicable	✓	NA	KJD
Check and adjust all drive belts	✓	1-19-96	KJD
Check cold start assist, if applicable	✓	NA	KJD
Remarks:			
STEERING SYSTEM	OK	Date	Initials
Check power steering hoses and connectors	✓	1-19-96	KJD
Service fluid level	✓	1-19-96	KJD
Check power steering operation	✓	1-19-96	KJD
Remarks:			
	OK	Date	Initials
Ballast bus to seated load weight	✓	1-19-96	KJD
TEST DRIVE	OK	Date	Initials
Check brake operation	✓	1-19-96	KJD
Check transmission operation	✓	1-19-96	KJD
Remarks:			

FUEL ECONOMY PRE-TEST INSPECTION FORM

Bus Number: 9601	Date: 1-19-96
Personnel: Ken Defibaugh	
PRE WARM-UP	If OK, Initial
Fuel Economy Pre-Test Maintenance Form is complete	RLL
Cold tire pressure (psi): Front <u>100</u> Middle <u>N/A</u> Rear <u>100</u>	RLL
Tire wear:	RLL
Engine oil level	RLL
Engine coolant level	RLL
Interior and exterior lights on, evaporator fan on	RLL
Fuel economy instrumentation installed and working properly.	RLL
Fuel line -- no leaks or kinks	RLL
Speed measuring system installed on bus. Speed indicator installed in front of bus and accessible to TECH and Driver.	RLL
Bus is loaded to SLW	RLL
WARM-UP	If OK, Initial
Bus driven for at least one hour warm-up	RLL
No extensive or black smoke from exhaust	RLL
POST WARM-UP	If OK, Initial
Warm tire pressure (psi): Front <u>101</u> Middle <u>N/A</u> Rear <u>102</u>	RLL
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	RLL

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 9601		Manufacturer: Eldorado National		Date: 1-22-96			
Run Number: 1		Personnel: Bob LaMorte, Stan Crawford & Ron Harter					
Test Direction: <input type="checkbox"/> CW or <input checked="" type="checkbox"/> CCW		Temperature (°F): 34		Humidity (%): 55			
SLW (lbs): 25,250		Wind Speed (mph) & Direction: 7 W		Barometric Pressure (in.Hg): 30.33			
Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Load Cell Reading (lb)		Fuel Used (lbs)
	Start	Finish		Start	Start	Finish	
CBD #1	0	8:55	8:55	17.8	101.40	98.10	3.30
ART #1	0	4:06	4:06	17.9	98.10	95.25	2.85
CBD #2	0	8:55	8:55	18.4	95.25	92.15	3.10
ART #2	0	4:10	4:10	21.0	92.15	89.20	2.95
CBD #3	0	8:56	8:56	21.4	89.20	86.10	3.10
COMMUTER	0	5:58	5:58	22.9	86.10	82.95	3.15
Total Fuel = 18.45 lbs							
20 minute idle : Total Fuel Used = 2.00 lbs							
Heating Value = 19,864.4 BTU/LB							
Comments:							

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 9601		Manufacturer: EIDorado National		Date: 1-22-96	
Run Number: 2		Personnel: Bob LaMorte, Stan Crawford & Ron Harter			
Test Direction: <input checked="" type="checkbox"/> CW or <input type="checkbox"/> CCW		Temperature (°F): 36		Humidity (%): 55	
SLW (lbs): 25,250		Wind Speed (mph) & Direction: 5 W		Barometric Pressure (in.Hg): 30.33	

Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Load Cell Reading (lb)		Fuel Used (lbs)
	Start	Finish		Start	Start	Finish	
CBD #1	0	8:50	8:50	21.5	82.95	79.95	3.00
ART #1	0	4:14	4:14	24.5	79.95	77.10	2.85
CBD #2	0	8:55	8:55	25.0	77.10	74.10	3.00
ART #2	0	4:11	4:11	25.7	74.10	71.25	2.85
CBD #3	0	9:00	9:00	25.9	71.25	68.25	3.00
COMMUTER	0	5:58	5:58	26.5	68.25	65.05	3.20
Total Fuel = 17.90 lbs							

20 minute idle: Total Fuel Used = N/A
Heating Value = 19,864.4 BTU/LB
Comments:

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 9601		Manufacturer: EIDorado National		Date: 1-23-96			
Run Number: 3		Personnel: Bob LaMorte, Stan Crawford & Ron Harter					
Test Direction: <input type="checkbox"/> CW or <input checked="" type="checkbox"/> CCW		Temperature (°F): 32		Humidity (%): 60			
SLW (lbs): 25,250		Wind Speed (mph) & Direction: 2 NW		Barometric Pressure (in.Hg): 30.09			
Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Load Cell Reading (lb)		Fuel Used (lbs)
	Start	Finish			Start	Finish	
CBD #1	0	8:48	8:48	10.0	92.85	89.80	3.05
ART #1	0	4:07	4:07	15.2	89.80	87.00	2.80
CBD #2	0	8:51	8:51	18.1	87.00	83.90	3.10
ART #2	0	4:08	4:08	21.0	83.90	81.05	2.85
CBD #3	0	8:50	8:50	22.4	81.05	78.05	3.00
COMMUTER	0	5:53	5:53	24.3	78.05	74.85	3.20
Total Fuel = 18.00 lbs							
20 minute idle: Total Fuel Used = N/A							
Heating Value = 19,864.4 BTU/LB							
Comments:							

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 9601		Manufacturer: EIDorado National		Date: 1-23-96	
Run Number: 4		Personnel: Bob LaMorte, Stan Crawford & Ron Harter			
Test Direction: <input checked="" type="checkbox"/> CW or <input type="checkbox"/> CCW		Temperature (°F): 34		Humidity (%): 60	
SLW (lbs): 25,250		Wind Speed (mph) & Direction: 2 N		Barometric Pressure (in.Hg): 30.11	

Cycle Type	Time (min:sec)		Cycle Time (min:sec)	Fuel Temperature (°C)	Load Cell Reading (lb)		Fuel Used (lbs)
	Start	Finish		Start	Start	Finish	
CBD #1	0	9:02	9:02	24.0	74.85	71.85	3.00
ART #1	0	4:04	4:04	24.6	71.85	69.10	2.75
CBD #2	0	9:09	9:09	25.5	69.10	66.00	3.10
ART #2	0	4:08	4:08	26.1	66.00	63.30	2.70
CBD #3	0	8:50	8:50	27.0	63.30	60.30	3.00
COMMUTER	0	6:00	6:00	24.4	60.30	57.20	3.10
Total Fuel = 17.65 lbs							

20 minute idle : Total Fuel Used = 1.80 lbs
Heating Value = 19,864.4 BTU/LB
Comments:

FUEL ECONOMY SUMMARY SHEET

BUS MANUFACTURER : ELDORADO NATIONAL BUS NUMBER : 9601
 BUS MODEL : TM-RE-29 TEST DATE : 1/22/96

FUEL TYPE : DIESEL
 SP. GRAVITY : .8095
 HEATING VALUE : 19864.40 BTU/Lb
 Standard Conditions : 60 deg F and 14.7 psi
 Density of Water : 8.3373 lb/gallon at 60 deg F

 CYCLE TOTAL FUEL TOTAL MILES FUEL ECONOMY FUEL ECONOMY
 USED (Lb) M/Lb (Measured) MPG (Corrected)

Run # : 1, CCW
 CBD 9.50 5.73 .60 3.85
 ART 5.80 3.82 .66 4.20
 COM 3.15 3.82 1.21 7.73
 TOTAL 18.45 13.37 .72 4.62

Run # : 2, CW
 CBD 9.00 5.73 .64 4.06
 ART 5.70 3.82 .67 4.27
 COM 3.20 3.82 1.19 7.61
 TOTAL 17.90 13.37 .75 4.76

Run # : 3, CCW
 CBD 9.15 5.73 .63 3.99
 ART 5.65 3.82 .68 4.31
 COM 3.20 3.82 1.19 7.61
 TOTAL 18.00 13.37 .74 4.74

Run # : 4, CW
 CBD 9.10 5.73 .63 4.02
 ART 5.45 3.82 .70 4.47
 COM 3.10 3.82 1.23 7.86
 TOTAL 17.65 13.37 .76 4.83

 IDLE CONSUMPTION

First 20 Minutes Data : 2.00 Lb Last 20 Minutes Data : 1.80 Lb
 Average Idle Consumption : 5.70 Lb/Hr

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

Run 1 : -2.5 Run 2 : .6 Run 3 : .0 Run 4 : 1.9

SUMMARY

Average Idle Consumption : .89 G/Hr
 Average CBD Phase Consumption : 3.98 MPG
 Average Arterial Phase Consumption : 4.31 MPG
 Average Commuter Phase Consumption : 7.71 MPG
 Overall Average Fuel Consumption : 4.74 MPG
 Overall Average Fuel Consumption : 35.35 Miles/ Million BTU