PARTIAL

STURAA TEST

12 YEAR

500,000 MILE BUS

from

THOMAS BUILT BUSES

MODEL SLF 200 / 35'

SEPTEMBER 2001

PTI-BT-R0117

The Pennsylvania Transportation Institute

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

Bus Testing and Research Center

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EXECUTIVE SUMMARY

Thomas Built Buses submitted a model SLF 200 / 35', diesel -fueled, 32 seat/35-foot bus, for a Partial STURAA Test in the 12 yr/500,000 mile test category. The Federal Transit Administration determined that the following tests would be performed; 3. Safety, 4. Performance and 6. Fuel Economy. Testing started on July 30, 2001 and was completed on August 10, 2001. The Check-In section of the report provides a description of the bus and specifies its major components.

The interior of the bus is configured with seating for 32 passengers including the driver. Free floor space will accommodate an additional 23 standing passengers, resulting in a potential capacity of 55 persons. At 150 lbs per person, this load results in a total gross vehicle weight of 27,390 lbs. SLW for the test vehicle is 23,990 lbs and CW for the test vehicle is 19,350 lbs.

The Safety Test, a double-lane change (obstacle avoidance) test, was performed safely 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 30.37 seconds.

A Fuel Economy Test was run on simulated central business district, arterial, and commuter courses. The results were 4.82 mpg, 5.54 mpg, and 10.08 mpg respectively; with an overall average of 5.92 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
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 consists of a Thomas Built Buses, model SLF 200 / 35'. The test bus has a front door equipped with a Ricon model PF5-3641 R handicap ramp located forward of the front axle and a rear door located forward of the rear axle. Power is provided by a diesel-fueled, Cummins ISB 260 engine coupled to an Allison B-300 transmission.

The measured curb weight is 6,120 lbs for the front axle and 13,230 lbs for the rear axle. These combined weights provide a total measured curb weight of 19,350 lbs. There are 32 seats including the driver and room for 23 standing passengers bringing the total passenger capacity to 55. Gross load is 150 lb x 55 = 8,250 lbs. At full capacity, the measured gross vehicle weight is 27,390 lbs.

VEHICLE DATA FORM

Bus Number: 0117	Arrival Date: 7-30-01
Bus Manufacturer: Thomas Dennis Co.	Vehicle Identification Number (VIN): SFD121AL1YGU10101
Model Number: SLF 235	Date: 7-30-01
Personnel: S.C.	

WEIGHT: * Values in parentheses indicate the adjusted weights necessary to avoid exceeding the GAWR. Theses values were used for all dynamic testing.

Individual Wheel Reactions:

Weights (lb)	Front Axle		Middle Axle		Rear Axle	
	Right	Left	Right	Left	Right	Left
CW	2,890	3,230	N/A	N/A	6,750	6,480
SLW	3,390	4,000	N/A	N/A	8,250	8,350
GVW	4,290	4,950	N/A	N/A	8,980	9,170

Total Weight Details:

Weight (lb)	CW	SLW	GVW	GAWR
Front Axle	6,120	7,390	9,240	9,880
Middle Axle	N/A	N/A	N/A	N/A
Rear Axle	13,230	16,600	18,150	18,700
Total	19,350	23,990	27,390	GVWR: 28,580

Dimensions:

Length (ft/in)	35 / 0.75
Width (in)	95.00
Height (in)	120.25
Front Overhang (in)	93.00
Rear Overhang (in)	113.00
Wheel Base (in)	214.75
Wheel Track (in)	Front: 79.50

	Rear: 47.50

Bus Number: 0117	Date: 7-30-01

CLEARANCES:

Lowest Point Outside Front Axle	Location: Rub bar Clearance(in): 7.0
Lowest Point Outside Rear Axle	Location: Body Clearance(in): 7.0
Lowest Point between Axles	Location: Frame Clearance(in): 7.0
Ground Clearance at the center (in)	7.0
Front Approach Angle (deg)	Normal ride - 7.5 High ride - 9.9
Rear Approach Angle (deg)	Normal ride - 7.4 High ride - 9.2
Ramp Clearance Angle (deg)	Normal ride - 3.7 High ride - 4.5
Aisle Width (in)	Front - 31.7 Middle - 18.7 Rear - 16.6
Inside Standing Height at Center Aisle (in)	Front - 95.5 Rear - 77.3

BODY DETAILS:

Body Structural Type	Integral		
Frame Material	Steel		
Body Material	Fiberglass / Aluminum		
Floor Material	Plywood		
Roof Material	Aluminum		
Windows Type	☐ Fixed	☒ Movable	
Window Mfg./Model No.	Alexander / B.S.857		
Number of Doors	1 Front	1 Rear	
Mfr. / Model No.	Deans Powered Door LTD. / 10117		
Dimension of Each Door (in)	Front-48.5 x 77.9	Rear-48.3 x 77.5	
Passenger Seat Type	☐ Cantilever	☒Pedestal	☐ Other (explain)
Mfr. / Model No.	Freedman Seating / Citi Seat		
Driver Seat Type	☒ Air	☐ Spring	☐Other (Cushion)
Mfr. / Model No.	Bostrom / Talladega LS0		

Number of Seats (including Driver)	32 + 2 wheelchair positions

Bus Number: 0117	Date: 7-30-01

BODY DETAILS (Contd..)

Free Floor Space (ft^2)	35.7
Height of Each Step at Normal Position (in)	Front 1. 12.6 2. N/A 3. N/A 4. N/A
	Middle 1. 12.6 2. N/A 3. N/A 4. N/A
	Rear 1. N/A 2. N/A 3. N/A 4. N/A
Step Elevation Change - Kneeling (in)	3.2

ENGINE

Type	☒ C.I.	☐ Alternate Fuel	
	☐ S.I.	☐ Other (explain)	
Mfr. / Model No.	Cummins / ISB 260		
Location	☐ Front	☒ Rear	☐ Other (explain)
Fuel Type	☐ Gasoline	☐ CNG	☐ Methanol
	☒ Diesel	☐ LNG	☐ Other (explain)
Fuel Tank Capacity (indicate units)	100 Gals		
Fuel Induction Type	☒ Injected	☐ Carburetion	
Fuel Injector Mfr. / Model No.	Cummins / ISB 260		
Carburetor Mfr. / Model No.	N/A		
Fuel Pump Mfr. / Model No.	Cummins / ISB 260		
Alternator (Generator) Mfr. / Model No.	Prestolite / AC203RA		
Maximum Rated Output (Volts / Amps)	24 / 180		
Air Compressor Mfr. / Model No.	Wabco / 318		
Maximum Capacity (ft^3 / min)	15.2 CFM		
Starter Type	☒ Electrical	☐ Pneumatic	☐ Other (explain)

Starter Mfr. / Model No.	Prestolite / LNS4524

Bus Number: 0117	Date: 7-30-01

TRANSMISSION

Transmission Type	☐ Manual	☒ Automatic	
Mfr. / Model No.	Allison / B300R		
Control Type	☐ Mechanical	☒ Electrical	☐ Other (explain)
Torque Convertor Mfr. / Model No.	Allison / B300R		
Integral Retarder Mfr. / Model No.	Allison / B300R		

SUSPENSION

Number of Axles	2		
Front Axle Type	☐ Independent	☒ Beam Axle	
Mfr. / Model No.	Spicer- Dana / S46LF		
Axle Ratio (if driven)	N/A		
Suspension Type	☒ Air	☐ Spring	☐ Other (explain)
No. of Shock Absorbers	2		
Mfr. / Model No.	Tenneco (Monroe) / 81.10.25.03		
Middle Axle Type	☐ Independent	☐ Beam Axle	
Mfr. / Model No.	N/A		
Axle Ratio (if driven)	N/A		
Suspension Type	☐ Air	☐ Spring	☐ Other (explain)
No. of Shock Absorbers	N/A		
Mfr. / Model No.	N/A		
Rear Axle Type	☐ Independent	☒ Beam Axle	
Mfr. / Model No.	Eaton / RS404S-00		
Axle Ratio (if driven)	4:88.1		
Suspension Type	☒ Air	☐ Spring	☐ Other (explain)
No. of Shock Absorbers	2		

Mfr. / Model No.	Tenneco (Monroe) / 81.10.25.04

Bus Number: 0117	Date: 7-30-01

WHEELS & TIRES

Front	Wheel Mfr./ Model No.	Alcoa / 19.5 x 6.75
	Tire Mfr./ Model No.	Michelin / XZE 245/70R 19.5
Rear	Wheel Mfr./ Model No.	Alcoa / 19.5 x 6.75
	Tire Mfr./ Model No.	Michelin / XZE 245/70R 19.5

BRAKES

Front Axle Brakes Type	☐ Cam	☐ Disc	☒ Other (Wedge)
Mfr. / Model No.	Perrot / Simplex		
Middle Axle Brakes Type	☐ Cam	☐ Disc	☐ Other (explain)
Mfr. / Model No.	N/A		
Rear Axle Brakes Type	☐ Cam	☐ Disc	☒ Other (explain)
Mfr. / Model No.	Perrot / Simplex		
Retarder Type	Integral		
Mfr. / Model No.	Allison / B300		

HVAC

Heating System Type	☐ Air	☒ Water	☐ Other
Capacity (Btu/hr)	116,000		
Mfr. / Model No.	Thermo King / LRT-1		
Air Conditioner	☒ Yes	☐ No	
Location	Roof		
Capacity (Btu/hr)	109,000		
A/C Compressor Mfr. / Model No.	Thermo King / X430		

STEERING

Steering Gear Box Type	Hydraulic gear

Mfr. / Model No.	ZF / 8095
Steering Wheel Diameter	18.0
Number of turns (lock to lock)	3.75

Bus Number: 0117	Date: 7-30-01

OTHERS

Wheel Chair Ramps	Location: Right front	Type: Ramp
Wheel Chair Lifts	Location: N/A	Type: N/A
Mfr. / Model No.	Ricon / PF5-3641R	
Emergency Exit	Location: Roof hatch Windows Doors	Number: 2 4 2

CAPACITIES

Fuel Tank Capacity (units)	100 gals
Engine Crankcase Capacity (gallons)	4.75
Transmission Capacity (gallons)	6.5
Differential Capacity (gallons)	4.5
Cooling System Capacity (gallons)	12.0
Power Steering Fluid Capacity (gallons)	3.5

VEHICLE DATA FORM

Bus Number: 0117	Date: 7-30-01

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

Part Number	Description	Qty.
Michelin XZE 245/70R 19.5	Tire	1

COMPONENT/SUBSYSTEM INSPECTION FORM

Bus Number: 0117	Date: 7-30-01

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	✓	

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: 0117	Date: 8-8-01
Personnel: S.C. & B.S.	

Temperature (°F): 88	Humidity (%): 33
Wind Direction: NW	Wind Speed (mph): 8
Barometric Pressure (in.Hg):	

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 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 33.14 seconds.

PERFORMANCE DATA FORM

Bus Number: 0117	Date: 8-8-01
Personnel: S.C., B.S. & C.S.	

Temperature (°F): 90	Humidity (%): 33
Wind Direction: NW	Wind Speed (mph): 8
Barometric Pressure (in.Hg): 30.10	

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	4.33	4.31	4.18
20 mph	8.02	7.65	7.49
30 mph	12.86	12.37	12.24
40 mph	20.45	19.81	19.55
Top Test Speed(mph) 50	30.25	31.71	31.55

Clockwise Recorded Interval Times

Speed	Run 1	Run 2	Run 3
10 mph	4.86	4.18	3.99
20 mph	7.68	7.40	7.14
30 mph	10.74	11.08	11.50
40 mph	18.71	18.68	18.08

Top Test Speed(mph) 50	30.21	30.11	28.36

0117.ACC

PERFORMANCE SUMMARY SHEET

BUS MANUFACTURER :THOMAS DENNIS
BUS MODEL :SLF 200/35'
BUS NUMBER :0117
TEST DATE :08-0-01

TEST CONDITIONS :

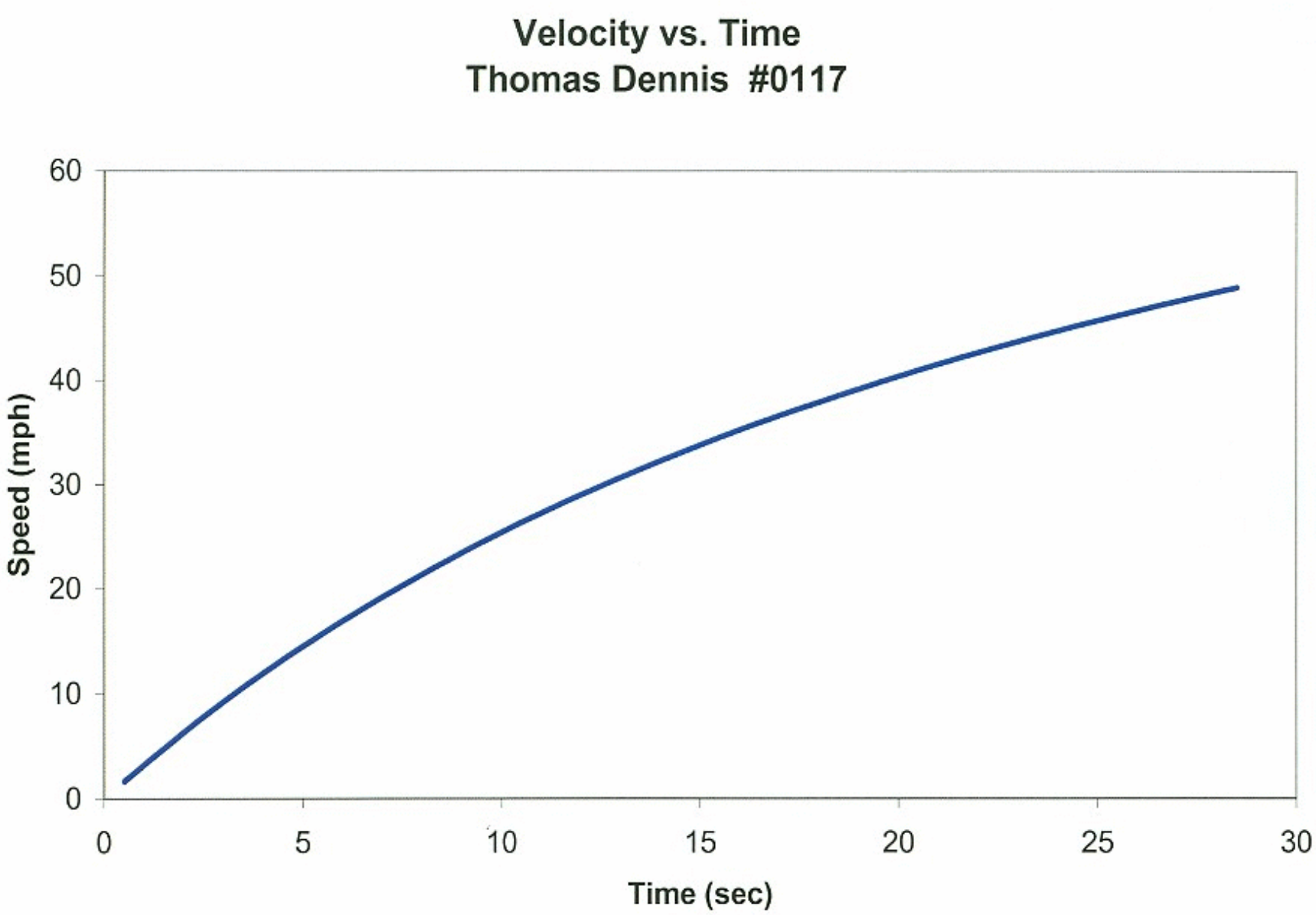
TEMPERATURE (DEG F) : 90.0
WIND DIRECTION : NW
WIND SPEED (MPH) : 8.0
HUMIDITY (%) : 33
BAROMETRIC PRESSURE (IN. HG) : 30.1

VEHICLE SPEED	AVERAGE TIME (SEC)		
(MPH)	CCW DIRECTION	CW DIRECTION	TOTAL
10.0	4.27	4.34	4.31
20.0	7.72	7.41	7.56
30.0	12.49	11.11	11.80
40.0	19.94	18.49	19.21
50.0	31.17	29.56	30.37

TEST SUMMARY :

VEHICLE SPEED (MPH)	TIME (SEC)	ACCELERATION (FT/SEC^2)	MAX. GRADE (%)
1.0	.30	4.8	15.1
5.0	1.57	4.5	14.0
10.0	3.29	4.0	12.6
15.0	5.21	3.6	11.3
20.0	7.36	3.2	10.0
25.0	9.81	2.8	8.8
30.0	12.61	2.4	7.6
35.0	15.85	2.1	6.5
40.0	19.68	1.8	5.5
45.0	24.27	1.5	4.5
50.0	29.90	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
Thomas Dennis #0117
Speed (mph)
60
50
40
30
20
10
0
0
5
10
15
20
25
30
Time (sec)

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 PTI test track. 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

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

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

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

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

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

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

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

where

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

Combining steps 1-3 yields

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

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

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

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

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

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

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

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

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

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

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

$FEo_{mi/lb} = FEo / Gm$

where Gm = Density of test fuel at standard conditions

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

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

where

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

6-III. DISCUSSION

This is a comparative test of fuel economy using diesel fuel with a heating value of 20,214.0 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 - 4.82 mpg, ART - 5.54 mpg, and COM - 10.08 mpg. Average fuel consumption at idle was 3.22 lb/hr (0.51 G/hr).

FUEL ECONOMY PRE-TEST MAINTENANCE FORM

Bus Number: 0117	Date: 8-6-01	SLW (lbs): 23,990
Personnel: S.C.		

FUEL SYSTEM	OK	Date	Initials
Install fuel measurement system	✓	8-6-01	S.C.
Replace fuel filter	✓	8-6-01	S.C.
Check for fuel leaks	✓	8-6-01	S.C.
Specify fuel type (refer to fuel analysis)	Diesel		
Remarks:			
BRAKES/TIRES	OK	Date	Initials
Inspect hoses	✓	8-6-01	S.C.
Inspect brakes	✓	8-6-01	S.C.
Relube wheel bearings	✓	8-6-01	S.C.
Check tire inflation pressures (mfg. specs.)	✓	8-6-01	S.C.
Remarks:			
COOLING SYSTEM	OK	Date	Initials
Check hoses and connections	✓	8-6-01	S.C.
Check system for coolant leaks	✓	8-6-01	S.C.
Remarks: None			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 2)

Bus Number: 0117	Date: 8-6-01
Personnel: S.C.	

ELECTRICAL SYSTEMS	OK	Date	Initials
Check battery	✓	8-6-01	S.C.
Inspect wiring	✓	8-6-01	S.C.
Inspect terminals	✓	8-6-01	S.C.
Check lighting	✓	8-6-01	S.C.
Remarks:			

DRIVE SYSTEM	OK	Date	Initials
Drain transmission fluid	✓	8-6-01	S.C.
Replace filter/gasket	✓	8-6-01	S.C.
Check hoses and connections	✓	8-6-01	S.C.
Replace transmission fluid	✓	8-6-01	S.C.
Check for fluid leaks	✓	8-6-01	S.C.
Remarks:			

LUBRICATION	OK	Date	Initials
Drain crankcase oil	✓	8-6-01	S.C.
Replace filters	✓	8-6-01	S.C.
Replace crankcase oil	✓	8-6-01	S.C.
Check for oil leaks	✓	8-6-01	S.C.
Check oil level	✓	8-6-01	S.C.
Lube all chassis grease fittings	✓	8-6-01	S.C.
Lube universal joints	✓	8-6-01	S.C.
Replace differential lube including axles	✓	8-6-01	S.C.
Remarks: None			

FUEL ECONOMY PRE-TEST MAINTENANCE FORM (page 3)

Bus Number: 0117	Date: 8-6-01
Personnel: S.C.	

EXHAUST/EMISSION SYSTEM	OK	Date	Initials
Check for exhaust leaks	✓	8-6-01	S.C.
Remarks:			

ENGINE	OK	Date	Initials
Replace air filter	✓	8-6-01	S.C.
Inspect air compressor and air system	✓	8-6-01	S.C.
Inspect vacuum system, if applicable	✓	8-6-01	S.C.
Check and adjust all drive belts	✓	8-6-01	S.C.
Check cold start assist, if applicable	✓	8-6-01	S.C.
Remarks:			

STEERING SYSTEM	OK	Date	Initials
Check power steering hoses and connectors	✓	8-6-01	S.C.
Service fluid level	✓	8-6-01	S.C.
Check power steering operation	✓	8-6-01	S.C.
Remarks:			

	OK	Date	Initials
Ballast bus to seated load weight	✓	8-6-01	S.C.

TEST DRIVE	OK	Date	Initials
Check brake operation	✓	8-6-01	S.C.

Check transmission operation	✓	8-6-01	S.C.
Remarks: None			

FUEL ECONOMY PRE-TEST INSPECTION FORM

Bus Number: 0117	Date: 8-8-01
Personnel: S.C.	

PRE WARM-UP	If OK, Initial
Fuel Economy Pre-Test Maintenance Form is complete	SC
Cold tire pressure (psi): Front 110 Middle N/A Rear 110	SC
Tire wear:	SC
Engine oil level	SC
Engine coolant level	SC
Interior and exterior lights on, evaporator fan on	SC
Fuel economy instrumentation installed and working properly.	SC
Fuel line -- no leaks or kinks	SC
Speed measuring system installed on bus. Speed indicator installed in front of bus and accessible to TECH and Driver.	SC
Bus is loaded to SLW	SC
WARM-UP	**If OK, Initial**
Bus driven for at least one hour warm-up	SC
No extensive or black smoke from exhaust	SC
POST WARM-UP	**If OK, Initial**
Warm tire pressure (psi): Front 112 Middle N/A Rear 115	
Environmental conditions Average wind speed <12 mph and maximum gusts <15 mph Ambient temperature between 30°(-1°) and 90°F(32°C)	SC

Track surface is dry Track is free of extraneous material and clear of interfering traffic	

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 0117	Manufacturer: Thomas Built	Date: 8-8-01
Run Number: 1	Personnel: S.C. & B.S.	
Test Direction: ☐CW or ☒CCW	Temperature (°F): 77	Humidity (%): 41
SLW (lbs): 23,990	Wind Speed (mph) & Direction: 8 / NW	Barometric Pressure (in.Hg): 30.10

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	8:24	8:24	27.7	100.00	97.50	2.50
ART #1	0	4:01	4:01	29.5	97.50	95.25	2.25
CBD #2	0	8:28	8:28	29.8	95.25	92.65	2.60
ART #2	0	4:00	4:00	30.5	92.65	90.45	2.20
CBD #3	0	8:30	8:30	31.0	90.45	87.90	2.55
COMMUTER	0	6:03	6:03	31.1	87.90	85.50	2.40
							Total Fuel = 14.50 lbs

20 minute idle : Total Fuel Used = 1.00 lbs

Heating Value = 20,014.0 BTU/LB

Comments: None

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 0117	Manufacturer: Thomas Dennis	Date: 8-8-01
Run Number: 2	Personnel: S.C. & B.S.	
Test Direction: ☒CW or ☐CCW	Temperature (°F): 79	Humidity (%): 41
SLW (lbs): 23,990	Wind Speed (mph) & Direction: 8 / NW	Barometric Pressure (in.Hg): 30.10

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	8:35	8:35	31.4	85.50	83.10	2.40
ART #1	0	4:02	4:02	31.9	83.10	81.00	2.10
CBD #2	0	8:30	8:30	32.6	81.00	78.50	2.50
ART #2	0	4:06	4:06	33.2	78.50	76.50	2.00
CBD #3	0	8:39	8:39	33.3	76.50	74.00	2.50
COMMUTER	0	6:10	6:10	34.0	74.00	71.65	2.35
							Total Fuel = 13.85 lbs

20 minute idle : Total Fuel Used = N/A lbs

Heating Value = 20,214.0 BTU/LB

Comments: None

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 0117	Manufacturer: Thomas Dennis	Date: 8-8-01
Run Number: 3	Personnel: S.C. & B.S.	
Test Direction: ☒CW or ☐CCW	Temperature (°F): 82	Humidity (%): 33
SLW (lbs): 23,990	Wind Speed (mph) & Direction: 8 / NW	Barometric Pressure (in.Hg): 30.10

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	8:30	8:30	29.0	100.25	97.75	2.50
ART #1	0	3:48	3:48	30.5	97.75	95.45	2.30
CBD #2	0	8:35	8:35	30.5	95.45	92.90	2.55
ART #2	0	4:02	4:02	30.7	92.90	90.65	2.25
CBD #3	0	8:35	8:35	31.0	90.65	88.15	2.50
COMMUTER	0	5:55	5:55	31.3	88.15	85.70	2.45
							Total Fuel = 14.55 lbs

20 minute idle : Total Fuel Used = N/A lbs

Heating Value = 20,214.0 BTU/LB

Comments: None

FUEL ECONOMY DATA FORM (Liquid Fuels)

Bus Number: 0117	Manufacturer: Thomas Dennis	Date: 8-8-01
Run Number: 4	Personnel: S.C. & B.S.	
Test Direction: ☐CW or ☒CCW	Temperature (°F): 84	Humidity (%): 33
SLW (lbs): 23,990	Wind Speed (mph) & Direction: 8 / NW	Barometric Pressure (in.Hg): 30.10

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	8:46	8:46	32.2	85.70	83.25	2.45
ART #1	0	4:09	4:09	32.7	83.25	81.05	2.20
CBD #2	0	8:50	8:50	33.1	81.05	78.55	2.50
ART #2	0	4:11	4:11	33.5	78.55	76.35	2.20
CBD #3	0	8:50	8:50	33.9	76.35	73.80	2.55
COMMUTER	0	6:08	6:08	34.2	73.80	71.40	2.40
							Total Fuel = 14.30 lbs

20 minute idle : Total Fuel Used = 1.15 lbs

Heating Value = 20,214.0 BTU/LB

Comments: None

0117.FUL
FUEL ECONOMY SUMMARY SHEET

BUS MANUFACTURER :Thomas Dennis BUS NUMBER :0117
BUS MODEL :SLF 200/35' TEST DATE :8/08/01

FUEL TYPE : DIESEL
SP. GRAVITY : .8095
HEATING VALUE : 20014.00 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 USED (Lb)	TOTAL MILES	FUEL ECONOMY M/Lb(Measured)	FUEL ECONOMY MPG(Corrected)
Run # :1, CCW				
CBD	7.65	5.73	.75	4.74
ART	4.45	3.82	.86	5.43
COM	2.40	3.82	1.59	10.08
TOTAL	14.50	13.37	.92	5.84
Run # :2, CW				
CBD	7.40	5.73	.77	4.90
ART	4.10	3.82	.93	5.90
COM	2.35	3.82	1.63	10.29
TOTAL	13.85	13.37	.97	6.11
Run # :3, CW				
CBD	7.55	5.73	.76	4.80
ART	4.55	3.82	.84	5.31
COM	2.45	3.82	1.56	9.87
TOTAL	14.55	13.37	.92	5.82
Run # :4, CCW				
CBD	7.50	5.73	.76	4.84
ART	4.40	3.82	.87	5.50
COM	2.40	3.82	1.59	10.08
TOTAL	14.30	13.37	.93	5.92

IDLE CONSUMPTION

First 20 Minutes Data : 1.00 Lb Last 20 Minutes Data : 1.15 Lb
Average Idle Consumption : 3.22 Lb/Hr

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

Run 1 : -1.4 Run 2 : 3.1 Run 3 : -1.7 Run 4 : .0

SUMMARY

Average Idle Consumption : .51 G/Hr
Average CBD Phase Consumption : 4.82 MPG
Average Arterial Phase Consumption : 5.54 MPG
Average Commuter Phase Consumption : 10.08 MPG
Overall Average Fuel Consumption : 5.92 MPG
Overall Average Fuel Consumption : 43.84 Miles/ Million BTU