UMTA-IT-06-0219-11-1

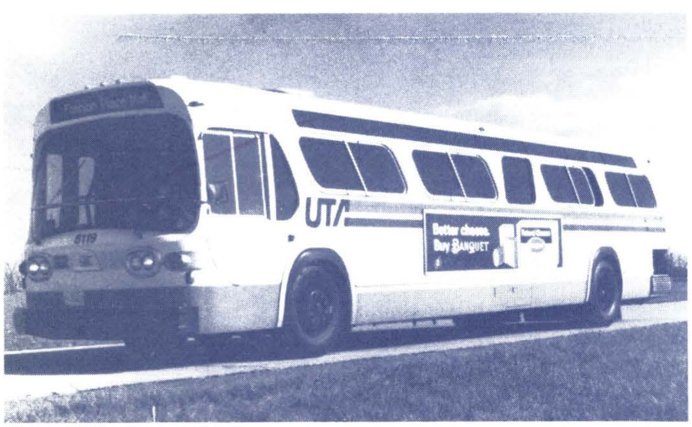
Fuel Economy Testing of Six 40-Foot Transit Buses

U.S. Department of Transportation
Urban Mass Transportation Administration

Office of Technical Assistance
Office of Bus and Paratransit Systems

Prepared by:
Battelle
Columbus Laboratories

March 1983



Technical Assistance - an UMTA Program

FUEL ECONOMY TESTING OF SIX 40-FOOT TRANSIT BUSES

to

DEPARTMENT OF TRANSPORTATION/UMTA
Office of Bus and Paratransit Systems

March 1983

by

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DTUM60-81-C-71103-11-1		

4. Title and Subtitle Fuel Economy Testing of Six 40-Foot Transit Buses	5. Report Date March 1983
	6. Performing Organization Code DTUM60-81-C-71103-11-1
7. Author(s) G.A. Francis, S. R. Nelson	8. Performing Organization Report No.
9. Performing Organization Name and Address Battelle's Columbus Laboratories 505 King Avenue Columbus, Ohio 43201	10. Work Unit No. (TRAIS) DTUM60-81-C-71103
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration 400 Seventh Street, N.W. Washington, D.C. 20590	13. Type of Report and Period Covered Final Report August 1982 to March 1983
	14. Sponsoring Agency Code URT-20

15. Supplementary Notes

16. Abstract

This report documents proving ground fuel economy tests of six transit buses from six manufacturers which were obtained directly from revenue service at six transit authorities. The buses were subjected to tests based on the Advanced Bus Design (ADB) Cycle and SAE J1321 Type II test procedure. The results relate the performance of buses from the six current manufacturers supplying the U.S. transit industry to each other. Drive line configurations, seating capacities, accumulated mileages varied from bus to bus and are documented in the report.

These tests were conducted under contract to UMTA at the Transportation Research Center of Ohio. Battelle Columbus planned, managed, and participated in conducting the tests with excellent cooperation and support from the transit industry.

17. Key Words	18. Distribution Statement
Bus, fuel economy, MPG test planning, test procedures, testing	Available to the Public through the National Technical Information Service Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	70	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

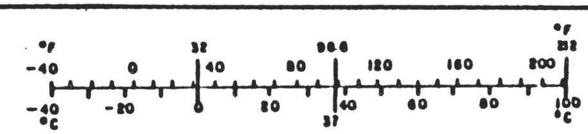
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ACKNOWLEDGMENTS

The authors acknowledge and appreciate the industry's support of this effort. The support included supplying control and test buses, reviewing test plans, consultation during tests, and reviewing test data. Thanks to the following organizations:

Office of Bus and Paratransit Systems, UMTA
American Public Transit Association
Society of Automotive Engineers
Transportation Research Center of Ohio
Transportation Systems Center, Department of Transportation
GMC Truck and Coach Division
Grumman Flxible Corporation
Flyer Industries Limited
Diesel Division General Motors of Canada Limited
Neoplan USA Corporation
Gillig Corporation
Massachusetts Bay Transportation Authority
Utah Transit Authority
Southeastern Pennsylvania Transportation Authority
Intercity Transit (Olympia, WA)
Lincoln Transportation System (NE)
Phoenix Transit System (AZ)
Central Ohio Transit Authority
Detroit Diesel Allison Division
Goodyear Tire and Rubber Company
Firestone Tire Company

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1.0 EXECUTIVE SUMMARY

The importance of life-cycle cost analyses in transit bus procurement is recognized by the industry and has been a Congressional requirement for grantees. In order to assist transit authorities and the industry's suppliers, UMTA's Office of Bus and Paratransit Systems has performed the fuel economy tests described in this report. The tests have two purposes: (1) to produce fuel economy data for use by transit authorities in life-cycle cost procurements, and (2) to provide data to confirm the validity of a computer simulation model (HEVSIM) developed and used at the Transportation Systems Center in Cambridge, MA.

The fuel economy tests during this program provide transit authorities with comparative test track MPG data that may be used in life-cycle cost analyses during bus procurements. The importance of fuel economy to life-cycle cost is based on the recognition of fuel and lubricants as the largest single nonlabor transit bus operating expense. The HEVSIM simulation model is a valuable tool in predicting the fuel economy of transit buses with different options in operating environments and modes of operation that may be encountered in revenue service. HEVSIM could also be valuable to bus manufacturers in designing buses and in preparing bid packages.

The fuel economy tests were conducted at the Transportation Research Center of Ohio (TRC) by TRC and Battelle personnel. Battelle, under contract to UMTA, with assistance from the six bus manufacturers, and the supplying transit authorities planned and conducted the test program. The preparation of the buses, running of the tests, and pickup/return of buses were performed by TRC personnel experienced in bus fuel economy testing.

Planning began in August, 1982 and the consultation with manufacturers, transit properties, and TRC was completed in October, 1982. On October 29 the test plan was released. The technical approach described in detail in Section 4.0 of this report follows the plan and the section describes how it was implemented.

The control buses were received and prepared in September. The GMC Truck and Coach RTS-II-04 control was a reconditioned demonstration unit on a one-year lease. The Grumman 870 control was a new bus built to Baltimore specifications but leased to Battelle for one year. In all respects the preparation of the control buses was identical to that of the test buses. The Grumman control bus was used extensively in driver/observer course familiarization and accumulated 2,000 miles before the beginning of fuel economy runs.

The fuel economy testing started in late October and was completed in mid-January. All test buses were obtained from transit authorities and returned to their owners before the end of January.

Table 1.1 shows the results of this fuel economy test program. The MPG figures in the combined column are accurate to within ± 1 percent as defined by SAE J1321. The other MPG figures are somewhat less accurate due to the fact that less fuel was used on the individual phases so weighing accuracy limits and a small variation in fuel used became important.

In using the data, it is important to recognize that buses in revenue service encounter environmental conditions and modes of operation that are unique to a transit authority and will impact fuel economy. It should also be noted that the buses tested during this program were from revenue service and have different engine powers, axle ratios, accumulated mileages, seating capacities, weights, tires, and ancillary equipment. These facts could be as important or even more important to fuel economy than other design features that distinguish the vehicles of a particular manufacturer.

This report is organized to present an overview of the fuel economy tests in Section 2.0. Results are presented in Section 3.0, and the test plan and tests are described in Section 4.0. The appendices then give detail information on the test facility, the SAE test procedure, and the test data.

TABLE 1.1. FUEL ECONOMY DATA FOR TRANSIT BUSES - SEATED LOAD WEIGHT

Bus Manufacturer*	Transit Authority	Baseline Fuel Economy (MPG) Commuter	Arterial	CBD	Combined	Idle Fuel Consumption (gallon/hour)
Test Buses**						
Flyer Industries	Boston (MBTA)	4.67	3.79	3.85	4.02	0.572
GM of Canada	Salt Lake City (Utah Transit)	4.93	3.94	4.01	4.19	0.536
Neoplan USA	Philadelphia (SEPTA)	5.02	3.70	3.30	3.75	0.616
Gillig	Olympia (Intercity Transit)	5.65	4.13	3.60	4.14	0.608
Grumman Flxible	Lincoln (Lincoln Transportation System)	4.66	3.69	4.06	4.09	0.587
GMC Truck and Coach	Phoenix (Phoenix Transit)	5.03	3.90	3.33	3.81	0.622

* The control buses were a Model 870 supplied by Grumman Flxible Corporation and an RTS II 04 supplied by GMC Truck and Coach Division.

** Buses listed in order tested.

2.0 INTRODUCTION

This report documents a program to determine the fuel economy of six standard-size transit buses. The tests were conducted by Battelle's Columbus Laboratories at the Transportation Research Center of Ohio. TRC was responsible for test execution during the period starting late in October, 1982, and ending in mid-January, 1983. The program was performed under contract to the Urban Mass Transit Administration.

2.1 Purpose of Tests

The primary purpose of this series of tests is to assist transit authorities and bus suppliers by providing accurate comparable fuel consumption data on transit buses produced by different manufacturers. The six bus configurations were selected by the manufacturers and supplied for testing by six transit properties directly from revenue service. This report makes the data available to the industry for discretionary use in estimating life-cycle costs.

2.2 Buses Used in Tests

A total of eight buses were used in this series of fuel economy tests; six test buses and two control buses. A list of the bus manufacturers and the supplying transit system is presented in Table 2.1. Each bus manufacturer was contacted by APTA or Battelle-Columbus, familiarized with the test plan, and asked to suggest a transit authority to supply their test bus. All test buses, except the Grumman, were furnished by the manufacturer's first choice. The second Grumman-recommended transit authority supplied the requested bus.

2.3 Brief Test Description

Each of the six manufacturers of standard 40-foot transit buses sold in the United States as of August 1, 1982 identified test bus sources. The buses were tested over a course based on the Transit Coach Operating Duty Cycle (ADB Cycle) at seated load weight (SLW) using a procedure based on Joint TMC/SAE Fuel Consumption Test Procedure - Type II - SAE J1321 OCT 81. This procedure with unaltered control buses ballasted to SLW allowed the development of comparable fuel economy numbers.

TABLE 2.1. LIST OF BUS MANUFACTURERS AND SUPPLYING TRANSIT AUTHORITIES

Manufacturer	Supplier
	Control Bus
Grumman (Flxible 870)	Grumman Flxible Corporation
General Motors (RTS II-04)	General Motors Corporation Truck and Coach Division
	Test Bus
Flyer Industries Limited	Massachusetts Bay Transportation Authority (Boston, MA)
Diesel Division General Motors of Canada Limited	Utah Transit Authority (Salt Lake City, UT)
Neoplan USA Corporation	Southeastern Pennsylvania Transportation Authority (Philadelphia, PA)
Gillig Corporation	Intercity Transit (Olympia, WA)
Grumman Flxible Corporation	Lincoln Transportation System (Lincoln, NE)
GMC Truck and Coach Division	Phoenix Transit System (Phoenix, AZ)

The two control vehicles were procured directly from their manufacturers and the test vehicles were supplied by properties suggested by manufacturers. Upon arrival at the test track each bus was prepared for test and an acceleration test was performed. If, during the course of testing, any question arose concerning the performance of a bus, a second acceleration test could have been performed and compared to the first in order to identify any changes that could cause invalid test results.

The fuel economy tests were conducted at the Transportation Research Center of Ohio on the inside lane of the 7.5-mile test track described in Appendix A. Signs were erected at carefully measured points which delineate the test course comprised of 8 miles of commuter phase, 8 miles of arterial phase, and 14 miles of CBD phase. An electronic fuel weighing system, developed for this test program, permitted the determination of fuel consumption on each of these three phases. At least one control and one test vehicle were involved in each test run. The test run was repeated until there were three runs in which the fuel used by the test bus divided by the fuel used by the control bus, the T/C ratio, for each 30-mile were run within 2 percent of each other. This set of three valid runs comprised a valid test which then had to be repeated before being accepted as accurately reflecting the fuel economy of the particular test bus.

After the fuel economy tests, idle fuel consumption data was obtained during three hours of idle. The test vehicle was then restored to "as received" condition and returned to the supplying transit authority.

3.0 RESULTS

This section presents the quantitative results of this project; the fuel economy numbers. First, Table 3.1 summarizes the results and Figure 3.1 shows the six test buses. Then, each test bus is described in Figures 3.2 through 3.7 to identify features that could impact fuel economy. The data from which the fuel economy numbers were derived and the calculation of the base line MPG of the control bus are contained in Appendix C. The control bus MPG is based on the average fuel consumption of Grumman control bus No. 626 during the first six valid test runs. T/C ratios are applied to the control bus MPG to produce comparable numbers. The calculation to relate the performance of the two control buses is also shown in Appendix C.

In using the data, it is important to recognize that the buses selected by the manufacturers are from revenue service, have different engine powers, axle ratios, accumulated mileages, seating capacities, weights, tires, and ancillary equipment. Some of the differences in the bus configurations shown in the specification sheets are summarized in Table 3.2. It should also be recognized that the data in Appendix C includes test run times which could be an indication of bus productivity in revenue service.

Using the data presented in Table 3.1, a transit authority may calculate its approximate MPG for transit buses on its own routes. If a particular property knows that its route structure more closely approximates, for example, 30 percent of distance commuter, 40 percent of distance arterial, and 30 percent of distance CBD, then a combined MPG for that property may be calculated as:

$$\frac{\%\text{ Commuter}}{\text{Commuter MPG}} + \frac{\%\text{ Arterial}}{\text{Arterial MPG}} + \frac{\%\text{ CBD}}{\text{CBD MPG}} = \frac{100}{\text{Combined MPG}}.$$

As an example, the Flyer bus on this example property should have a combined MPG of about:

$$\frac{30}{4.67} + \frac{40}{3.79} + \frac{30}{3.85} = \frac{100}{\text{Combined MPG}} = 24.77$$

Therefore,

$$\frac{100}{24.77} = 4.04\text{ MPG.}$$

TABLE 3.1. FUEL ECONOMY DATA FOR TRANSIT BUSES - SEATED LOAD WEIGHT

Bus Manufacturer*	Transit Authority	Baseline Fuel Economy (MPG) Commuter	Arterial	CBD	Combined	Idle Fuel Consumption (gallon/hour)
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Flyer Industries	Boston (MBTA)	4.67	3.79	3.85	4.02	0.572
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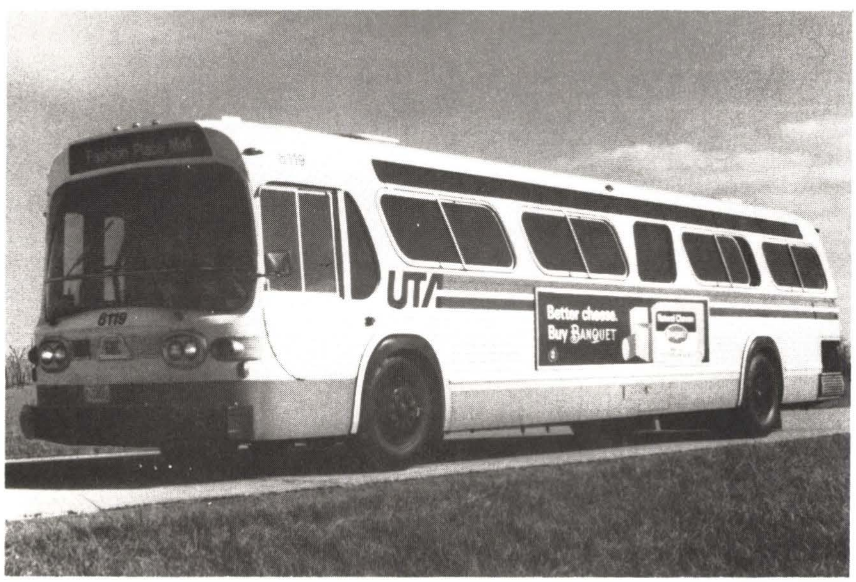
* The control buses were a Model 870 supplied by Grumman Flxible Corporation and an RTS II 04 supplied by GMC Truck and Coach Division.

** Buses listed in order tested.

(a) Flyer Industries Limited



(b) Diesel Division General Motors of Canada Limited

FIGURE 3.1. TEST BUSES

(c) Neoplan USA Corporation

(d) Gillig Corporation

FIGURE 3.1. TEST BUSES (Continued)

(e) Grumman Flxible Corporation

(f) GMC Truck and Coach Division

FIGURE 3.1. TEST BUSES (Continued)

Bus Manufacturer	Flyer Industries Limited
	MBTA Bus No. 2602
Model Number	D901A10240
Date of Manufacture	March 1982
Vehicle Identification Number	D102402602

Length, ft	40
Width, in.	102
Height, in.	120.5
Wheelbase, in.	284.75
Passenger seats, no.	45
Wheelchair lift	No
Engine	6V92TA
Fuel injectors	7G65
Transmission	V730
Torque converter	TC470
Axle ratio	5-1/8
Tires	Goodyear City Cruisers XT 12.5 x 22.5 G
Fuel Tank Capacity, US gallons	140
Air conditioning system	None
Power steering pump	Vickers VT M42-50
Curb Weight:	
Front axle	7,050
Rear axle	16,860
Total	23,910
Seated load weight:	
Front axle	10,640
Rear axle	20,140
Total	30,780

Other factors that could impact fuel economy:

Accumulated mileage at time of test = 30,300

Full-width splash aprons

FIGURE 3.2. SPECIFICATIONS OF FLYER TEST BUS

Bus Manufacturer	Diesel Division General Motors of Canada Limited UTA Bus No. 8119
Model Number	T6H 5307-N
Date of Manufacture	March 1981
Vehicle Identification Number	26HYT82J9B35500551

Length, ft	40
Width, in.	102
Height, in.	116
Wheelbase, in.	285
Passenger seats, no.	48
Wheelchair lift	Yes
Engine	6V92TA
Fuel injectors	7G65
Transmission	V730
Torque converter	TC470
Axle ratio	5-3/8
Tires	Goodyear City Cruisers XT 12.5 x 22.5 G
Fuel Tank Capacity, US gallons	125
Air conditioning system	None
Power steering pump	Vickers
Curb Weight:	
Front axle	7,490
Rear axle	17,020
Total	24,510
Seated load weight:	
Front axle	10,820
Rear axle	21,040
Total	31,860

Other factors that could impact fuel economy:

Accumulated mileage at time of test = 56,700

FIGURE 3.3. SPECIFICATIONS OF DIESEL DIVISION TEST BUS

Bus Manufacturer	Neoplan USA Corporation SEPTA Bus. No. 8322
Model Number	AN-440-A
Date of Manufacture	August 19, 1982
Vehicle Identification Number	IN9TAS2A0CL013068

Length, ft	40
Width, in.	96
Height, in.	129
Wheelbase, in.	272
Passenger seats, no.	42
Wheelchair lift	Yes
Engine	6V92TA
Fuel injectors	7G75
Transmission	HT747
Torque converter	TC495
Axle ratio	4.625
Tires	Goodyear City Cruisers XT 12.5 x 22.5 G
Fuel Tank Capacity, US gallons	125
Air conditioning system	Suetrak Roof-Mounted No. AC-35
Power steering pump	Vickers VTM
Curb Weight:	
Front axle	8,940
Rear axle	17,800
Total	26,740
Seated load weight:	
Front axle	11,460
Rear axle	21,430
Total	32,890

Other factors that could impact fuel economy:

Accumulated mileage at time of test = 10,800

FIGURE 3.4. SPECIFICATIONS OF NEOPLAN TEST BUS

Bus Manufacturer	Gillig Corporation IT Bus No. 407
Model Number	40TA/96-T-6V92
Date of Manufacture	May 24, 1982
Vehicle Identification Number	15GC00816C1080187, Serial No. 80181-80195

Length, ft	40
Width, in.	96
Height, in.	119
Wheelbase, in.	279
Passenger seats, no.	47
Wheelchair lift	Lift U 76-3
Engine	6V92TA
Fuel injectors	7G70
Transmission	HT740
Torque converter	TC495
Axle ratio	4.11
Tires	Goodyear City Cruisers XT 12.5 x 22.5 G
Fuel Tank Capacity, US gallons	125
Air conditioning system	None
Power steering pump	TRW
Curb Weight:	
Front axle	
Rear axle	
Total	26,310
Seated load weight:	
Front axle	12,390
Rear axle	20,930
Total	33,320

Other factors that could impact fuel economy:

Accumulated mileage at time of test = 16,900

FIGURE 3.5. SPECIFICATIONS OF GILLIG TEST BUS

Bus Manufacturer	Grumman Flxible Corporation
	LTS Bus No. 60
Model Number	40102-6T
Date of Manufacture	March 1982
Vehicle Identification Number	1GF4AA6K4CD094395

Length, ft	40
Width, in.	102
Height, in.	119
Wheelbase, in.	299
Passenger seats, no.	48
Wheelchair lift	None
Engine	6V92TA
Fuel injectors	7G75
Transmission	V730
Torque converter	TC490
Axle ratio	5-3/8
Tires	Goodyear City Cruisers XT 12.5 x 22.5 H
Fuel Tank Capacity, US gallons	135
Air conditioning system	Trane-built, GFC design twin compressors
Power steering pump	Vickers VTM-42
Curb Weight:	
Front axle	7,620
Rear axle	17,670
Total	25,290
Seated load weight:	
Front axle	11,040
Rear axle	21,790
Total	32,830

Other factors that could impact fuel economy:

Accumulated mileage at time of test = 18,000; Batteries 2 D8D truck and bus; Engine block heater; Winterfront shutters over radiator (fail open design); AD-2 air dryer.

FIGURE 3.6. SPECIFICATIONS OF GRUMMAN TEST BUS

Bus Manufacturer	GMC Truck and Coach Division
	PTS Bus No. 4560
Model Number	T80204
Date of Manufacture	June 21, 1982
Vehicle Identification Number	

Length, ft	40
Width, in.	102
Height, in.	119
Wheelbase, in.	298.7
Passenger seats, no.	45
Wheelchair lift	None
Engine	6V92TA
Fuel injectors	7G70
Transmission	V730
Torque converter	TC470
Axle ratio	5-1/8
Tires	Goodyear City Cruisers XT 12.5 x 22.5 G
Fuel Tank Capacity, US gallons	125
Air conditioning system	Trane nominal 10 ton system
Power steering pump	Vickers
Curb Weight:	
Front axle	8,780
Rear axle	17,340
Total	26,120
Seated load weight:	
Front axle	12,130
Rear axle	21,210
Total	33.340

Other factors that could impact fuel economy:

Accumulated mileage at time of test = 17,500

FIGURE 3.7. SPECIFICATIONS OF GMC TRUCK AND COACH TEST BUS

TABLE 3.2. SOME TEST BUS DIFFERENCES THAT COULD IMPACT FUEL ECONOMY

Bus Manufacturer	Engine	Fuel Injector	Transmission	Torque Converter	Axle Ratio	Fuel Tank Cap., gallons	Wheel Chair Lift	No. of Box Seats Passenger	SLW, pounds
Flyer	6V92TA	7G65	V730	TC470	5 1/8	140	No	45	30,780
Diesel Division	6V92TA	7G65	V730	TC470	5 3/8	125	Yes	48	31,860
Neoplan	6V92TA	7G75	HT747	TC495	4.625	125	Yes	42	32,890
Gillig	6V92TA	7G70	HT740	TC495	4.11	125	Yes	47	33,320
Grumman	6V92TA	7G75	V730	TC490	5 3/8	135	No	48	32,830
GMC Truck & Coach	6V92TA	7G70	V730	TC470	5 1/8	125	No	45	33,340

4.0 TECHNICAL APPROACH

The program management and technical approach for this fuel economy study was to perform tests under carefully controlled test track conditions and to use the largest practicable body of industry knowledge and experience in planning the tests and presenting the results.

4.1 Program Participants and Supporters

The Urban Mass Transportation Administration (UMTA) through the Office of Bus and Paratransit Systems, was responsible for technical direction of the program. Battelle's Columbus Laboratories (BCL) was responsible for planning, coordinating, and conducting the fuel economy study and for evaluating and reporting the program results. The actual testing was performed by the Transportation Research Center of Ohio (TRC) personnel with BCL staff on-site supporting and monitoring test personnel.

Both General Motors Corporation Truck and Coach Division and Grumman Flxible Corporation supplied control buses and all six coach manufacturers participated by reviewing test plans and test data. Cooperation was excellent.

Six transit authorities also supported the program in an extremely meaningful way by supplying test buses from the manufacturers shown in Table 4.1 from their fleets. The transit authorities in chronological order of test were:

Massachusetts Bay Transit Authority
Utah Transit Authority
Southeastern Pennsylvania Transportation Authority
Intercity Transit
Lincoln Transportation System
Phoenix Transit System.

American Public Transit Association also played an important role in acquainting the manufacturers with the program and acting as a sounding board while the program was underway.

4.2 Test Procedure and Implementation

This series of tests was performed at TRC located at East Liberty, Ohio. The 7.5-mile test track is described in Appendix A.

TABLE 4.1. SOURCES OF BUSES

Control Buses
Grumman Flxible Corporation - Model 870 Transit Coach
General Motors Corporation Truck and Coach Division - RTS II
Test Buses
Flyer Industries Limited (Boston, MA)
Diesel Division General Motors of Canada Limited (Salt Lake City, UT)
Neoplan USA Corporation (Philadelphia, PA)
Gillig Corporation (Olympia, WA)
Grumman Flxible Corporation (Lincoln, NE)
General Motors Corporation Truck and Coach Division (Phoenix, AZ)

4.2.1 Overall Description of Test Procedures

Control buses were provided by manufacturers and test buses were supplied by transit properties as shown in Table 4.1. The buses were driven to the test site by skilled heavy-duty-vehicle drivers. Upon arrival at TRC, the buses received a complete vehicle preparation which included complete service (oil changes, filter changes, brake inspections, etc.), installation of calibrated injectors, vehicle wheel alignment, front wheel balance, chassis dynamometer check at the Central Ohio Transit Authority, and all other necessary preparations for testing. Following vehicle preparation, the rate of acceleration of each bus was tested. This test established an acceleration trace so that if engine or transmission performance proved questionable at a later time a repeat test could be performed and evaluated against the original test run. The test results were so repeatable that it was never necessary to rerun acceleration tests.

After the acceleration test each bus was tested for fuel economy using the test cycle described in Table 4.2 Bus Fuel Economy Test Cycle, and Figure 4.1 Bus Fuel Economy Test Cycle. These fuel economy tests were based on Joint TMC/SAE Fuel Consumption Test Procedure - Type II - SAE J1321 OCT. 81. The test cycle is made up of the individual start, stop, and top speed elements of the ADB Cycle arranged to permit obtaining MPG for each of the three phases. The ADB cycle demands wide open throttle for virtually all buses at SLW. Idle fuel consumption was obtained in a separate test described in Paragraph 4.4.3.

4.2.1.1 Modifications to SAE and ADB Procedure Test. In the course of planning and executing this test program modifications were made in some established procedures. This section describes how we ran the ADB cycle and how we used SAE J1321. The operating cycle described in the "White Book"* is shown by Figures 4.2 and 4.3. The basic acceleration, cruise, and deceleration profiles of the CBD, arterial, and commuter phases shown in Figure 4.3 were maintained for this series of tests. However, the changes were made in the overall sequence of phases to produce compatibility among the ADB cycle, the SAE procedure, MPG data desired, and the test facility. None of the changes made appear to reduce the accuracy of the combined MPG results.

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*Baseline Advanced Design Transit Coach Specification, Urban Mass Transportation Administration, U.S. Department of Transportation, Washington, D.C., November 1978.

TABLE 4.2. BUS FUEL ECONOMY TEST CYCLE

Phase	Stops/ Mile	Top Speed, mph	Miles	Acceleration		Cruise		Deceleration			Dwell Time, sec	Cycle Time, min-sec	Total Stops
				Distance, ft	Time, sec	Distance, ft	Time, sec	Rate, ft/sec2	Distance, ft	Time, sec			
Commuter	1 per 4 mile	55 or maximum, if less than 55	8	5,500	90	15,140	188	6.78	480	12	20	10-20	2
Arterial	2	40	8	1,035	29	1,350	22.5	6.78	255	9	7	18-00	16
CBD	7	20	14	155	10	510 (95) 887 (2)	18.5 32	6.78	90	6	7	65-20	97
Idle*	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals			30									93-40	115

* Fuel consumption at idle will be obtained in a separate test.

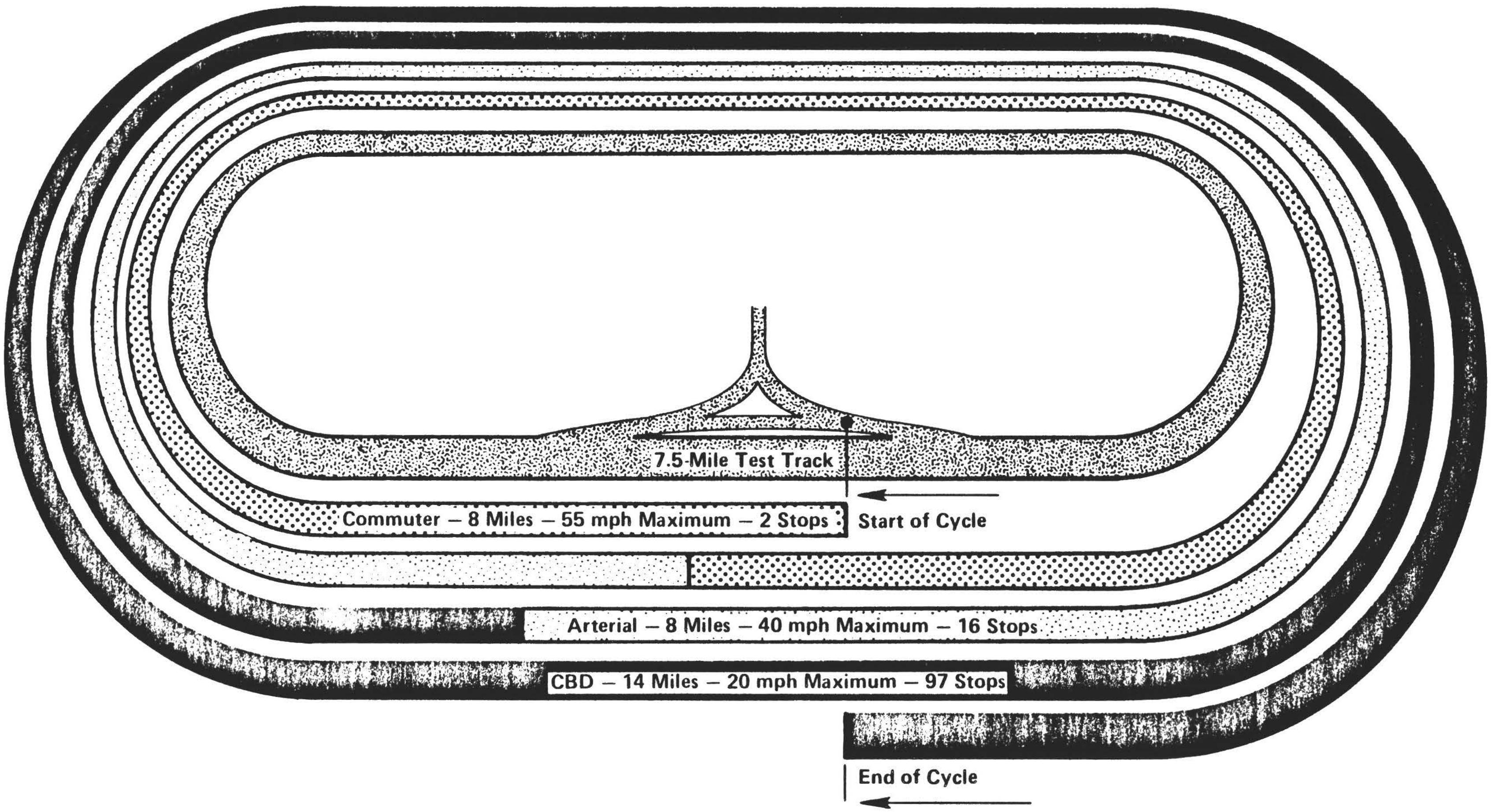


FIGURE 4.1. BUS FUEL ECONOMY TEST CYCLE

Phase	Stops/ Miles	Top Speed (mph)	Miles	Accel. Distance (ft)	Accel. Time (sec)	Cruise Distance (ft)	Cruise Time (sec)	Decel. Rate (fpsps)	Decel. Distance (ft)	Decel. Time (sec)	Dwell Time (sec)	Cycle Time (min-sec)	Total Stops
CBD	7	20	2	155	10	540	18.5	6.78	60	4.5	7	9-20	14
Idle	-		--	-	--	-	-	--	-	-	-	5-0	-
Arterial	2	40	2	1035	29	1350	22.5	6.78	255	9	7	4-30	4
CBD	7	20	2	155	10	510	18.5	6.78	60	4.5	7	9-20	14
Arterial	2	40	2	1035	35	1350	22.5	6.78	255	9	7	4-30	4
CBD	7	20	2	155	10	510	18.5	6.78	60	4.5	7	9-20	14
Commuter	1 stop for phase	Maximum or 55	4	5500	90	2 mile + 4580 ft	188	6.78	480	12	20	5-10	1
Total			14									47-10	51

Average Speed = 17.8 mph

FIGURE 4.2. TRANSIT COACH DESIGN OPERATING DUTY CYCLE

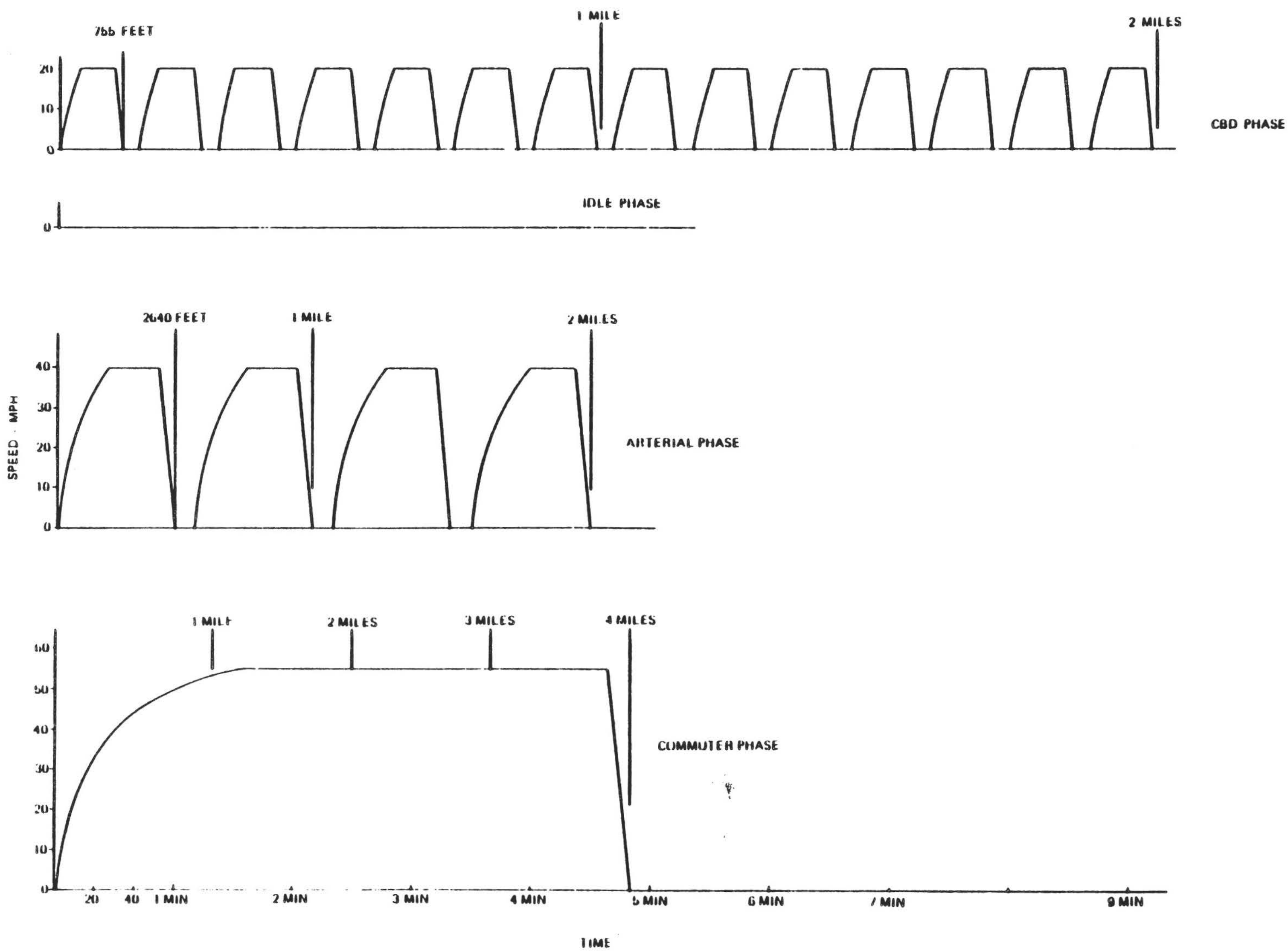


FIGURE 4.3. TRANSIT COACH DESIGN OPERATING PROFILE DUTY CYCLE

There were three modifications that were made to the ADB cycle.

- The ADB cycle is structured as a set number of miles on fixed time in the following order: CBD, idle, arterial, CBD, arterial, CBD, commuter. The cycle used in our test program collected these phases together into the following order: commuter, arterial, CBD and a separate idle fuel consumption. This phase sequence permitted the reporting of MPG for each of these phases separately and should make the data more useful to bus manufacturers and transit properties.

- The ADB cycle is 14 miles long and is usually doubled to 28 miles for SAE J1321 tests. This distance was increased to 30 miles in our test and the percentage of distance traveled on each phase was altered also to:

	Percentage on Phase		
	Commuter	Arterial	CBD
ADB Cycle	28.6	28.6	42.8
Test Program ADB Cycle	26.7	26.7	46.6

  These percentages result from adding two miles to the CBD portion of the total cycle. This change allowed the test to start and end at the same point on TRC's 7.5-mile test track, and allowed enough fuel consumption during a test run to comply with SAE J1321. The increased percentage of the cycle in CBD could give a very small advantage to buses configured for best fuel economy in the CBD phase.

- The individual start-stop cycle in the ADB cycle remained unaltered except for increasing the start-stop cycle length on two of the 97 start-stop cycles of the CBD cycles by 50 percent. The change was made so that separate signs would not be required on the track for the first and the second lap of CBDs. This change reduced the probability of driver error by reducing the number of signs as shown in Figure 4.4.

Four changes were made to the Joint TMC/SAE Fuel Consumption Test Procedure - Type II - SAE J1321 OCT 81: (See Appendix B for procedures as published by SAE.)

- J1321 requires the use of at least a 16-gallon fuel tank. Such a fuel tank when full would weigh about 160 pounds. It was judged that a 12-gallon tank weighing less than 120 pounds would be sufficient for this test and much easier for the driver and observer to handle. The size of the tank is shown in Figure 4.5 with the engineer carrying an empty tank from the Grumman control bus.

- J1321 mentions the use of a mechanical scale or a flowmeter system. This program used a load cell/readout combination which allowed accuracy of 0.5 percent in weight and

FIGURE 4.4. VIEW OF SIGNS AT BEGINNING AND END OF TEST CYCLE

FIGURE 4.5. GRAVIMETRIC TANK AND GRUMMAN CONTROL BUS

permitted onboard weighing of the gravimetric tanks at the end of each phase. This permitted the determination of a fuel economy figure for each phase as well as the overall cycle.

- J1321 recommends that the driver and observer stay with a vehicle throughout the test. This approach is helpful in quickly establishing a valid test (3 T/C ratios within 2 percent) but was found to be unnecessary. Additionally, a philosophical question arises; if the tests are dependent upon a particular driver for repeatable results then can the results be generally applicable? In general, the same driver drove the same bus but when we did change there was no detectable variation in test results.

- J1321 requires run times to be within ±0.5 percent for a valid test. During the course of testing, it was noted that a number of runs which fell outside this time limit were still well within the 2 percent T/C ratio limit. It was concluded that with a cycle as complex as the one used in this program (115 start-stop sequences) the ±0.5 percent time limit is too restrictive. The time limit was, therefore, raised to ±1.0 percent without test accuracy compromise. In fact, runs that were not used because they were outside the ±1.0 percent time limit were still often within the 2 percent T/C fuel consumption ratio limit of the 3 valid runs.

4.2.2 Vehicle Preparation

All incoming buses were prepared for testing in the following manner.

4.2.2.1 Initial Service. After a bus arrived at TRC, mechanics replaced the existing tires with Goodyear City Cruiser XT 12.5 x 22.5 G or H Series, as recommended by the manufacturer or used on the property. All fluids and lubricants were replaced with manufacturer's recommended products and all filters were replaced. Calibrated injectors of the same size that were removed from the bus were installed. The front two wheels were dynamically balanced and the bus was aligned.

4.2.2.2 Dynamometer Check. Each bus was run on the dynamometer at the Central Ohio Transit Authority (COTA) service garage. This test was performed to check a number of parameters including:

- Wheel balance and vibration
- Front axle drag
- Full-throttle horsepower and no-throttle horsepower
- Brake balance
- Speedometer accuracy.

4.2.2.3 Documentation. After the dynamometer test, the make, model, engine, drivetrain components and other features important to fuel economy were documented. This information was cross-checked with descriptive material obtained from the manufacturers and the properties and differences were resolved.

4.2.2.4 Vehicle Preparation. All vehicles were prepared for testing according to the vehicle inspection and preparation sheets shown in Figure 4.6. This was done to insure that the buses tested were in safe and operating condition at the start of the test.

4.2.2.5 Daily Inspection. Each morning before testing, each bus was inspected according to the check list shown in Figure 4.7.

4.2.2.6 Gravimetric Tank System Installation. Gravimetric tanks were used to measure fuel consumptions. The tanks are cylindrical with a radius of 9 inches and a length of 44 inches. These tanks were weighed by utilizing a load cell as a part of the fuel system shown in Figure 4.8. The load cell which supports the tank was secured to a bar running transversely between the hand rails attached to the ceiling and each bus as shown in Figure 4.9. Figure 4.10 shows the remainder of the test fuel system. Support instrumentation included the strain gage amplifier and digital readout unit. Solenoid valves with observer-operated switches directed fuel flow between the gravimetric and main fuel tanks. Whenever fuel flowed from a gravimetric tank, an electronic timer was activated thus assuring an accurate timing of each test. A heat exchanger was installed in a gravimetric tank return line to assure that the fuel temperature remained below 160 F as required by SAE J1321. This fuel temperature was monitored as shown in Figure 4.8. The fuel-weighing system was highly repeatable and accurate. It included the following important components.

- o Load cell: Lebow Model 3397-200
- o Strain gage transducer indicator: Daytronics Model 3270B
- o Boost pump: Holley electric fuel pump Model 12-801.

FUEL ECONOMY TEST VEHICLE PREPARATION Transit Bus

Vehicle ID: Yr.__________ Make__________ Model__________ Type__________ TRC Veh.#______

License No.______________ VIN__________ Engine #__________ Trans. #______________

Seating Capacity____________

1. Fuel System	OK	Date	Initials
a) install gravimetric tank system			
b) replace fuel filter			
c) check for fuel leaks			
d) obtain 4 ounce fuel sample from Pump #7			

Remarks____

____

2. Brakes/Tires			
a) inspect hoses and connections			
b) inspect drums/calipers			
c) inspect linings/pads			
d) inspect drum/rotors			
e) inspect cams & diaphrams			
f) relube bearings			
g) mount test tires			
h) set inflation pressures (mfg. specs.)			

Remarks____

____

FIGURE 4.6. FUEL ECONOMY TEST VEHICLE PREPARATION

	OK	Date	Initials
3. Cooling system			
a) calibrate thermostat			
___°F open ___°F close			
b) install temperature readout			
c) check hoses and connections			
d) pressure test cap _____lb. open			
e) pressure test system for leaks			
f) check coolant freeze point			

Remarks____________________

4. Electrical Systems			
a) check battery			
b) inspect wiring			
c) clean and inspect terminals			
d) check lighting			
e) check and record alternator output			

Remarks____________________

5. Drive System			
a) remove transmission fluid			
b) adjust bands			
c) replace filter/gasket			
d) check hoses and connections			
e) replace fluid			
f) check for leaks			
g) check shifting operation			

FIGURE 4.6. FUEL ECONOMY TEST VEHICLE PREPARATION (Continued)

5. Drive System, cont'd

h) check clutch operation ____________

Remarks As Applicable ____________

____

6. Lubrication

a) drain crankcase ____________

b) replace filters ____________

c) replace oil ____________

d) check for leaks ____________

e) check level ____________

f) lube all chassis joints ____________

g) lube universal joints ____________

h) replace differential lube including axles ____________

Remarks ____________

____

7. Exhaust/Emission System

a) check for exhaust leaks ____________

b) check exhaust system back pressure ____________

Remarks ____________

____

8. Engine

a) replace air filter ____________

b) inspect air compressor and air system ____________

c) inspect vacuum system, if applicable ____________

FIGURE 4.6. FUEL ECONOMY TEST VEHICLE PREPARATION (Continued)

8. Engine, cont'd

d) check and adjust all drive belts ______________

e) check cold start assist ______________

f) disconnect A/C compressor lead ______________

Remarks ____

____

9. Steering System

a) check power steering hoses and connectors ______________

b) service fluid level ______________

c) check power steering operation ______________

d) wheel alignment ______________

Remarks ____

____

10. Ballast bus with 150 lbs. per seat

X ________ seats ______________

11. Test Drive

a) check brake operation ______________

b) check transmission operation ______________

c) calibrate speedometer ______________

d) check for tires/wheel imbalance ______________

FIGURE 4.6. FUEL ECONOMY TEST VEHICLE PREPARATION (Continued)

BATTELLE DAILY MORNING INSPECTION

By: ______________________________ Date: ______________

PRE WARM-UP: If OK, Initial:

1. Tire Pressure

   A. Steering ____________psi ______________

   B. Drive ____________psi ______________

   C. Less than 50% wear ______________

2. Engine oil level ______________

3. Engine coolant level ______________

4. Belt tension ______________

5. Interior and exterior lights on, evap. fan on ______________

6. Instrumentation working properly, including solenoids and fan timer ______________

7. Fuel lines - no leaks or kinks ______________

8. Body free of dents ______________

9. No puddles or drips on pavement ______________

10. Ballast in position ______________

11. Wind speed, temperature, and track condition within client requirements ______________

12. Safety inspection completed ______________

POST WARM-UP:

1. No extensive smoke from exhaust ______________

Comments: ____

____

BL/I-12

FIGURE 4.7. BATTELLE DAILY MORNING INSPECTION

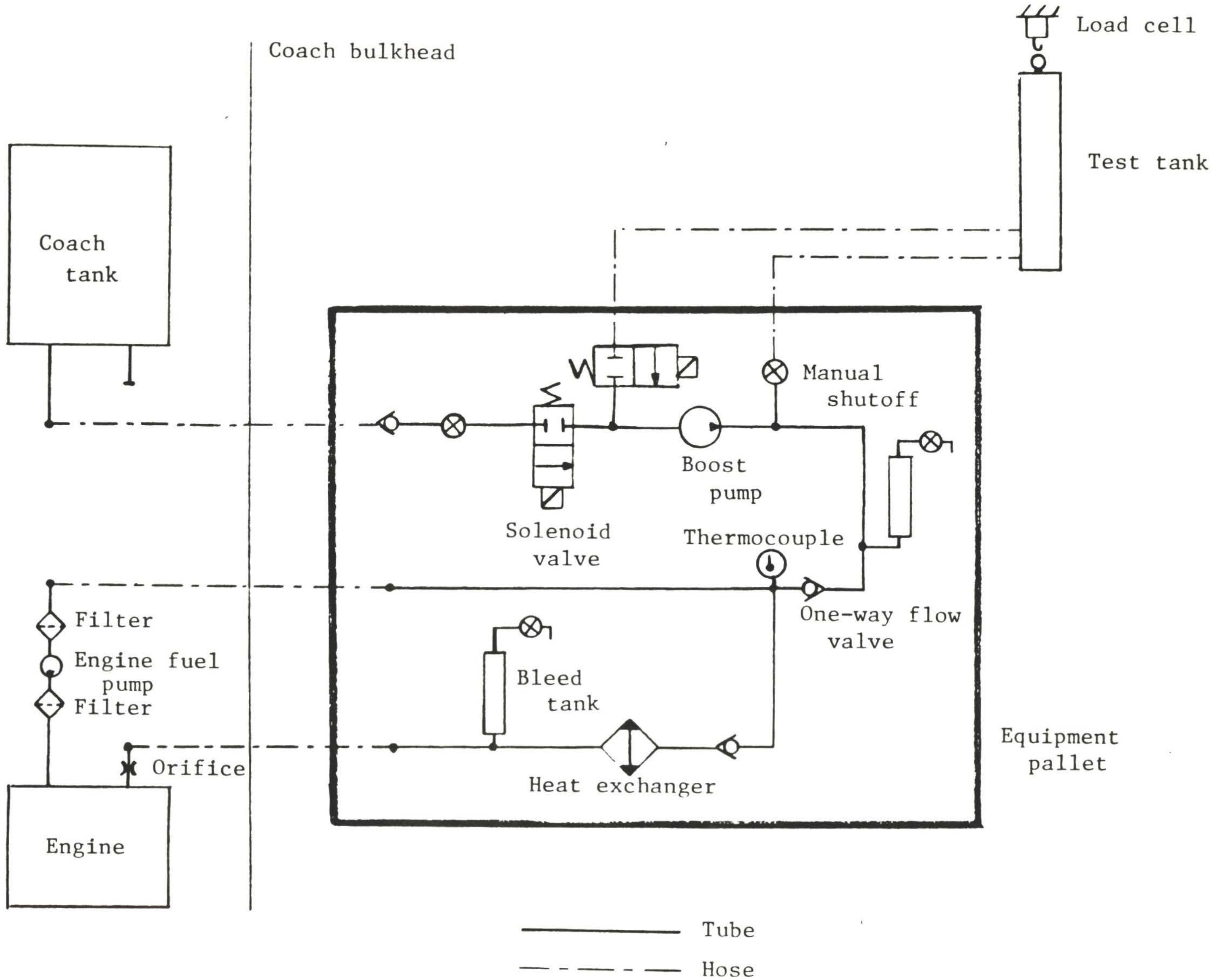


FIGURE 4.8. UMTA BUS FUEL ECONOMY TEST FUEL SYSTEM SCHEMATIC

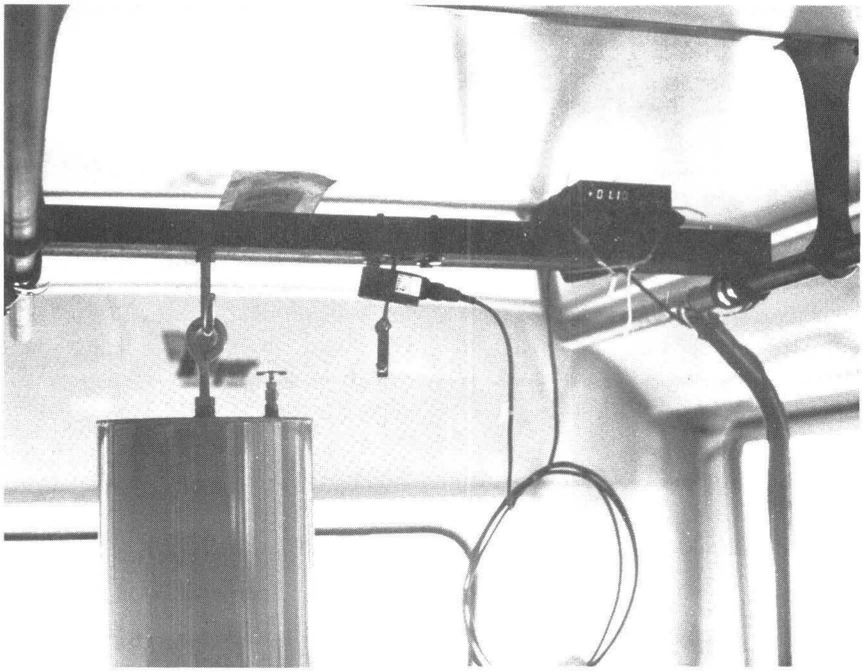


FIGURE 4.9. FUEL WEIGHING SYSTEM

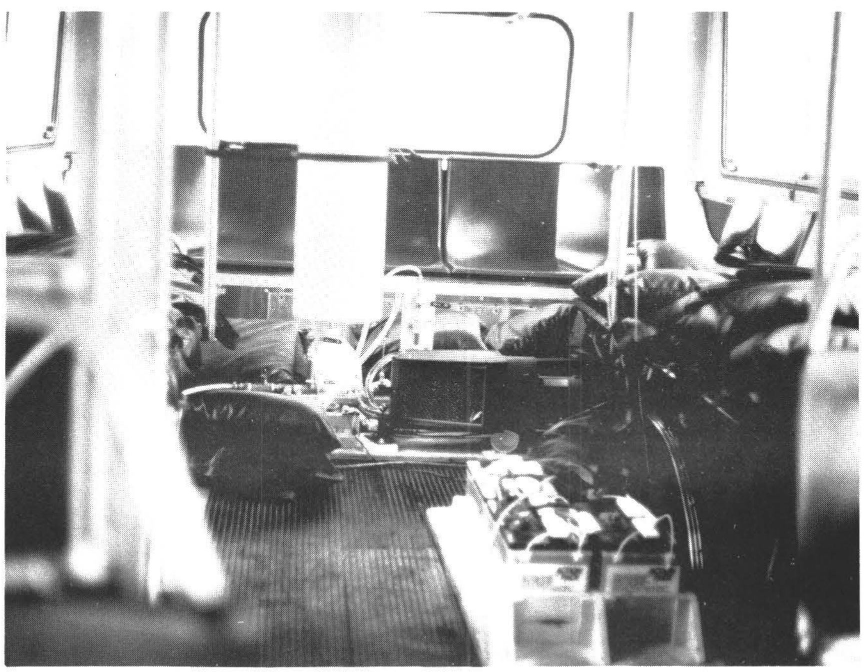


FIGURE 4.10. TEST FUEL SYSTEM INSTALLED IN BUS

4.3 Maintenance

Vehicle maintenance was classified into two categories—scheduled and unscheduled.

Because the same two control vehicles will be used for additional tests later in this program, scheduled maintenance was performed. Where possible, maintenance followed the manufacturer's recommended schedule. During this series of tests, items such as tires and brakes were serviced on an as-needed basis. Tires were replaced when 50 percent tread wear conditions existed. Except for tire replacement, test vehicles did not require scheduled maintenance.

Unscheduled maintenance due to unanticipated vehicle failure was provided as required. After testing started, no major unscheduled maintenance was required.

4.4 Test Procedure

Three types of tests were performed on each of the test buses at TRC: acceleration, bus fuel economy test cycle, and idle fuel consumption. These tests were performed with drivers and observers experienced in bus and truck fuel economy testing. All testing was conducted on the first lane of concrete on the 7.5-mile test track described in Appendix A, and was performed on the regular 8:00 a.m. to 5:00 p.m. shift.

4.4.1 Acceleration Test

Following the vehicle preparation described earlier, each transit bus was tested for acceleration. The vehicle was accelerated at wide-open throttle from a stop with the fifth wheel down and instrumentation on to a speed of 55 MPH, held at 55 MPH for a few seconds, and then allowed to coast down to below 10 MPH. The test was performed at least twice, once on each track straightaway, to average out such factors as wind velocity and track grade. The tests were performed so that if at any time during the fuel economy cycle a vehicle's performance were in question because of test run time or driver's complaint, the acceleation test could be repeated to confirm the condition of the vehicle. All vehicles exhibited outstanding stability in maintaining test to control vehicle fuel consumption ratios during the tests so no reruns of the acceleration tests were required.

4.4.2 Fuel Economy Test Cycle

4.4.2.1 Morning Inspection. Each morning before a test run, each bus was inspected according to the daily morning inspection sheet, see Figure 4.7. Some portions of the inspection were performed immediately following warm-up as shown on the sheet.

4.4.2.2 Warm-Up. Warm-up consisted of driving one hour on the bus fuel economy test cycle on the test track. The course layout was prepared by using green, red, and blue signs, respectively, for the commuter, arterial, and CBD portions of the test to indicate changes in speed, cycles, and stop points. The observer coached the driver through the course along with recording cycle run times, fuel temperature, and weather conditions before and after each phase of each cycle using the data sheet as shown in Figure 4.11.

4.4.2.3 Fuel Economy Testing. All six buses were tested at seated load weight (SLW) and three were tested empty load weight. Figure 4.12 shows a control and two test buses. Figure 4.13 shows the second control bus with two test buses. The maximum number of vehicles running at any one time was two control buses and two test buses. The base line fuel economy figures presented in this report are based upon test with

(1) Air conditioning off
(2) Evaporator fan or ventilation fan on
(3) Seated load weight
(4) Diesel No. 2 Supreme fuel, and
(5) Exterior and interior lights on.

Before starting each test, the gravimetric tank was filled, weighed, and documented. The cycle was started adjacent to the entrance of the high-speed pit lane. The cycle is described in Figure 4.1 and Table 4.2. As shown, the cycle has been grouped according to the phase; commuter, arterial, and CBD. Fuel was weighed at the end of each phase without refueling the gravimetric tank. The solenoid valve in the fuel system switched the fuel supply in the gravimetric tank to the main fuel tank at the end of the phase. The graviemtric tank was weighed and fuel flow was switched back to the gravimetric tank before continuing with the next phase.

As described in SAE J1321 (see Appendix B), three cycles were run that fell within a 2 percent window of T/C ratios for a valid test. Our test run times were within $\pm$1.0 percent. The test cycle was then repeated to obtain three more valid T/C ratios falling within 2 percent of each other. The average of these two groupings of T/C ratios fell within 2 percent to show test repeatability.

VEHICLE TYPE____________________ | **BATTELLE INSTITUTE**

VEHICLE NO.____________________ | **TRANSIT BUS FUEL ECONOMY**

TRACK COORDINATOR______________ | DATE__________________

CONFIGURATION__________

DRIVER__________________________ OBSERVER__________________________

TIME		CYCLE	RUN	ZERO READING			FUEL PARAMETERS				RUN TIME	IDLE TIME	FUEL USED	COMMENTS
							WEIGHT (LBS.)		TEMPERATURE (°F)					
START	FINISH	TYPE	NO.	START		FINISH	START	FINISH	START	FINISH	HR/MIN/S	MIN/SEC	LBS.	

FIGURE 4.11. BATTELLE INSTITUTE TRANSIT BUS FUEL ECONOMY DATA SHEET

FIGURE 4.12. GRUMMAN CONTROL BUS WITH FLYER AND GM OF CANADA TEST BUSES

FIGURE 4.13. GMC TEST BUS, GMC CONTROL BUS AND GILLIG TEST BUS

4.4.3 Idle Fuel Consumption

The idle fuel consumption test was done separately with no idle included in our MPG data. Our idle test consisted of a 2-hour warm-up period with the buses at idle, and a further period of 3 hours of idling on fuel from the gravimetric tank. The gravimetric tank was weighed at the beginning of the test and at the end of each hour. This data was considered valid if the hourly weighings did not vary outside of a $\pm$0.1-pound range. A single T/C ratio was determined by dividing the total fuel used by the test bus by the total fuel used by the control bus over the 3-hour period.

4.4.4 Fuel Analysis

4,000 gallons of Standard Oil of Ohio's No. 2 Diesel Supreme was placed in a separate tank at the fuel plaza and used exclusively for control and test buses during these tests. Results of the analysis of the fuel analysis are shown in Figure 4.14.

4.4.5 Weather Conditions

During the fuel economy testing temperatures ranged from 23 to 64 F, maximum wind was 15 MPH gusting to 20 MPH, and the pavement was dry. Precipitation in the form of rain, mist, snow or hail was not occurring to the extent that the driver required the use of windshield wipers for safe operation of the vehicle.

CLEVELAND TECHNICAL CENTER, INC.	CLIENT No. 3045-000 ADVISORY No 143727
FROM 13600 DEISE AVENUE CLEVELAND, OHIO 44110 216-451-6455	UNIT/N No. 628 ENGINE SERIAL No. Diesel Fuel
	SAMPLE DATE 10-29-82 DATE TESTED 11-30-82
SPECTRA - CHECK®	TYPE SERVICE RENDERED: I - II - III ☐ OTHE
TO Kevin R. Boyne Transportation Research Center St.Rt. 33 - Logan County East Liberty, OH 43319	**PHYSICAL TEST RESULTS** FLASH DEGREES F.: ____ VISCOSITY SSU 100°F.: 34.84 H_2O%: ____ VISCOSITY SSU 210°F.: ____ DETERGENCY ____ ANTI-FREEZE ____ INSOLUBLES NAPHTHA % VOL.: ____ OIL MI/HR.: ____ ENG. MI/HR.: ____

I ANALYSIS OF PHYSICAL TESTS:

☐ NO CORRECTIVE ACTION INDICATED BY TESTS PERFORMED.

☐ TEST RESULTS INDICATE OIL CONDITION IS SATISFACTORY.

API Gravity @ 60°F. = 38.0	Distillation:	IBP = 362°F.	90% = 556°F.
Cetane No. = 51.0		10% = 434°F.	End Point = 578°F.
Sulfur = 0.09%		50% = 490°F.	% Return = 98.5%

II SPECTROCHEMICAL ANALYSIS:

☐ NO CORRECTIVE ACTION INDICATED BY ANALYSIS PERFORMED.

☐ TEST RESULTS INDICATE WEAR METAL LEVELS ARE SATISFACTORY.

Carbon Residue on 10% Bottoms = 0.04% Ash (% Wt.) = 0% Flash (COC) = 200°F.

Heating Value = 19,763 BTU/lb. (137,373 BTU/gal.) Cloud Point - -24°F.

Water = Nil Sediment = Trace

NOTE: Results of tests performed are within #2 diesel fuel oil specifications.

WHEN CORRECTIVE ACTION IS INDICATED, PLEASE ADVISE RESULTS OF YOUR FINDINGS AND CORRECTIVE ACTION TAKEN ON ENCLOSED POSTCARD.

Since Spectra-Check services are based on samples and information supplied by others, and since corrective action, if any is necessarily taken by others, these services are rendered without any warranty or liability of any kind beyond the actual amount paid to Cleveland Techni al Center, Inc. for the services

PLEASE DIRECT ANY INQUIRIES YOU MIGHT HAVE TO MANAGER – SPECTRA-CHECK SERVICES.

CTC-106 Rev. 6-75

FIGURE 4.14. ANALYSIS OF TEST FUEL

APPENDIX A

TRACK DESCRIPTION

APPENDIX A

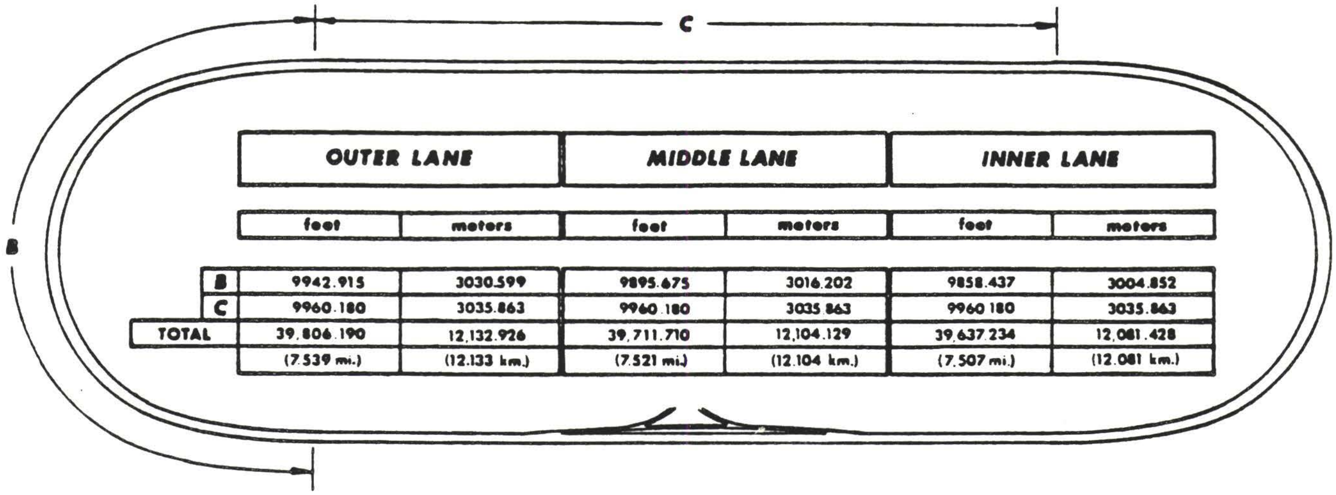
TRACK DESCRIPTION

The 7.5-mile test track at TRC was used for fuel economy testing. It encloses a 1600-acre area, one mile wide, and 3-1/2 miles long (see Figure A-1). The track has a downward grade, north to south, of 0.288 percent and a cross slope in the straightaways of 3/16 inch per foot. The 1.88-mile-long straightaways flow into transition areas 2300 feet in length, and then into 5275-foot-long curves with a constant radius of 2400 feet. The 36-foot-wide straightaways and the 42-foot-wide curves provide three test lanes. Paved berms, 12 feet in width, border the straightaways and the inside of the curves.

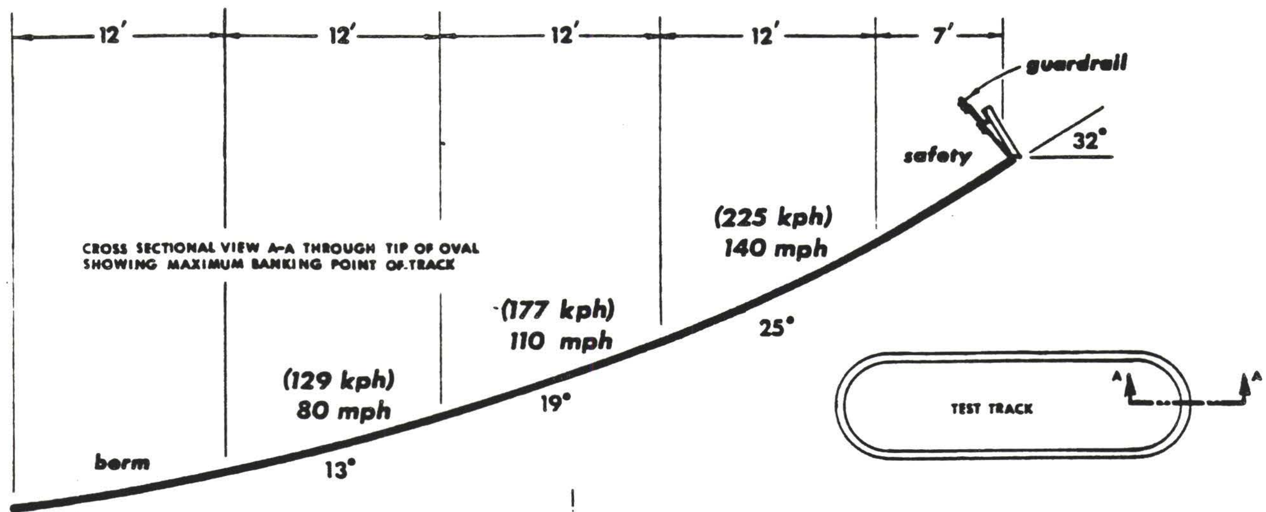
As a vehicle moves toward the outside of the track in the curves, it encounters a progressively steeper bank. The inside lane, which was used in this test program, has a bank of 13 degrees, allowing a neutral speed of 80 mph with no side forces. In the center lane the slope increases to 19 degrees, resulting in a neutral speed of 110 mph. The outside lane's 25-degree bank allows a 140 mph neutral speed. Rimming the outer lane is a 7-foot safety lane culminating in a 34-degree slope at the guardrail.

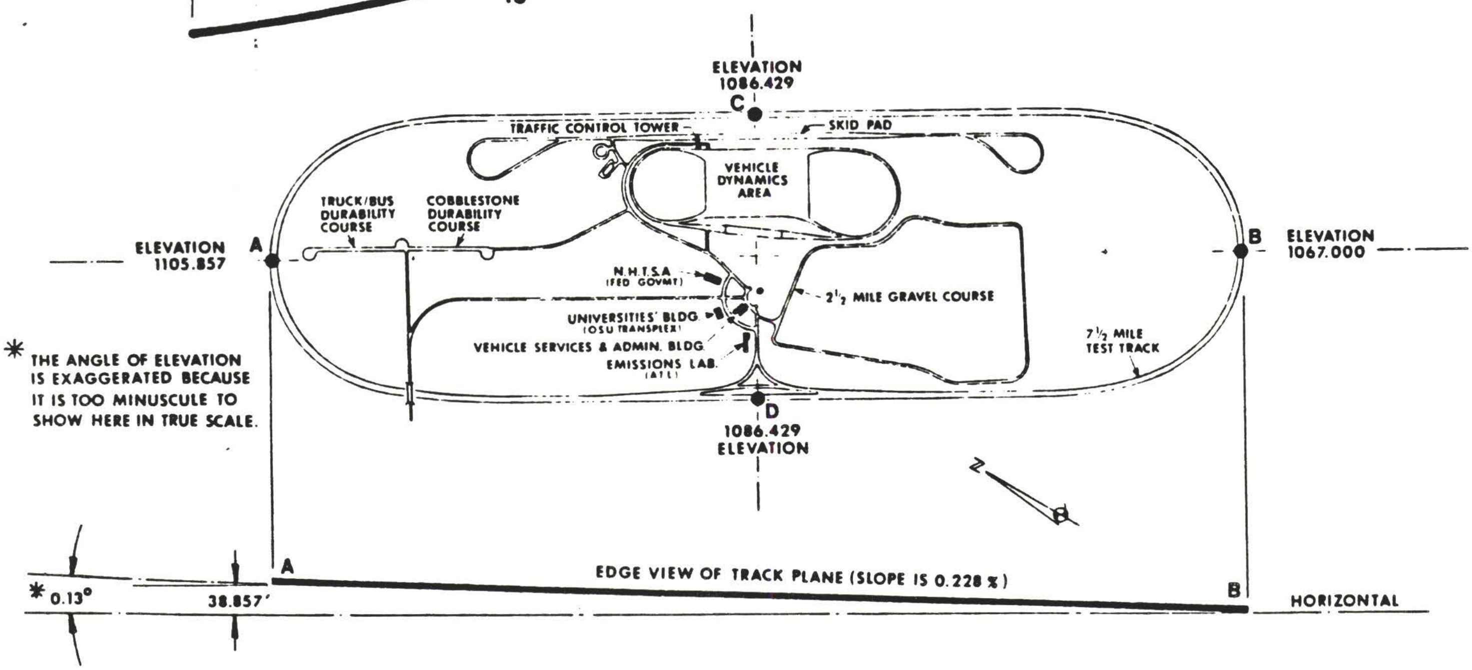
The facility is paved with Portland cement concrete. It carries a maximum single axle load weight of 48,000 pounds.

High Speed Test Track



	OUTER LANE		MIDDLE LANE		INNER LANE	
	feet	meters	feet	meters	feet	meters
B	9942.915	3030.599	9895.675	3016.202	9858.437	3004.852
C	9960.180	3035.863	9960.180	3035.863	9960.180	3035.863
TOTAL	39.806.190	12,132.926	39,711.710	12,104.129	39,637.234	12,081.428
	(7.539 mi.)	(12.133 km.)	(7.521 mi.)	(12.104 km.)	(7.507 mi.)	(12.081 km.)





AB, THE LONG AXIS, IS APPR. 3 1/4 MILES, WITH SLOPE AS SHOWN.
CD, THE SHORT AXIS, IS 5000 FEET; AND THE SLOPE IN THIS DIRECTION IS 0.

FIGURE A-1. HIGH SPEED TEST TRACK

APPENDIX B

JOINT TMC/SAE FUEL CONSUMPTION TEST PROCEDURE - TYPE II - SAE J1321 OCT 81

Joint TMC/SAE Fuel Consumption Test Procedure — Type II — SAE J1321 OCT81

SAE Recommended Practice
Approved October 1981

THIS IS A PREPRINT WHICH IS SUBJECT TO REVISIONS AND CORRECTIONS. THE FINAL VERSION WILL APPEAR IN THE 1983 EDITION OF THE SAE HANDBOOK.

SAE The Engineering Resource For Advancing Mobility

PREPRINT

JOINT TMC/SAE FUEL CONSUMPTION TEST PROCEDURE—TYPE II—SAE J1321 OCT81

Report of the SAE/DOT Advisory Committee, approved October 1981.

1. Scope—This recommended practice provides a standardized test procedure for comparing the in-service fuel consumption of two conditions of a test vehicle or of one test vehicle to another when it is not possible to run the two or more test vehicles simultaneously. An unchanging control vehicle is run in tandem with the test vehicle(s) to provide reference fuel consumption data. This procedure is especially suitable for testing components which require substantial time for removal and replacement or modification, such as engines, transmissions, tag-axles, and cab sheet metal. This procedure may also be used for comparison of entire vehicles and for easy-to-change components (those referenced in the Type I test described in SAE Recommended Practice, SAE J1264). The test may utilize fleet vehicles operating over representative routes.

The result of a test using this procedure is the percent difference in fuel consumption between two test vehicles or the difference in fuel consumption of one vehicle in two different test conditions.

The fuel measurement method is a key factor in determining the overall accuracy achievable with this procedure. If the weighing method is used, overall test accuracy is best and, based on test experience, will be within ±1% (for example, 6% measured improvement can be from 5—7% actual improvement). (See Section 6, Test Accuracy.)

The following four basic rules must be applied to this procedure to insure test result validity:

(a) The test routes and cargo weight should be representative of actual operation.

(b) *A single test is inconclusive regardless of the results. A single test should be taken as an indicator. Test results must be repeatable to have validity.*

(c) The more variables controlled, the more conclusive the results.

(d) All test procedures or methods are accurate within prescribed limits. If the component or system being tested by a given procedure shows a degree of improvement which is equal to or less than the accuracy limit of the procedure, an additional number of tests should be conducted to determine its true value. If a number of such tests do not show consistent results, then one must conclude that the changes caused by the component or vehicle system are less than can be measured by the test procedure.

2. Identification—Sufficient information is to be recorded to identify the vehicles under test and the route over which the test is conducted. Minimum information required is shown on the Type II Test Data Form #1 (Vehicle Identification).

3. Definitions

3.1 **Vehicles "C" and "T"**—The vehicles being used for test purposes are identified "C" and "T." This identification applies to the vehicles and associated equipment, including the trailer, in the case of tractor/trailer combinations. Vehicle "C" is the control and is not modified in any way during the entire test. Control vehicle fuel consumption is used only to generate control data. It is necessary that Vehicle "C" be dedicated to the test and not used for other purposes until the entire series of tests is completed. The singular purpose of Vehicle "C" is to monitor the test route, ambient conditions, and test procedures for each test run. Vehicle "T" is the test vehicle used to evaluate components. The procedure also has the capability to test two test vehicles, comparing one to the other. (See paragraphs 5.12 and 5.13 for explanation of the two-vehicle test.)

3.2 **Test Run**—A test run is a complete circuit of the test route. A test run always starts and ends at a common point. This may be accomplished by using either a closed loop of highways or a single highway with one-half of the test run outbound, a turnaround point, and one-half of the test inbound, or a test track. Each vehicle test run generates one data point. To be usable, a test run must meet the constraints of paragraph 5.9.

3.3 **Data Point**—A data point is the quantity of fuel consumed by a vehicle on a test run.

3.4 **T/C Ratio**—A T/C ratio is the ratio of the quantity of fuel consumed (data point) by the test vehicle to the quantity of fuel consumed (data point) by the control vehicle during one test run.

3.5 **Baseline Segment**—A baseline segment is composed of a minimum of three valid T/C ratios. A baseline segment establishes baseline fuel consumption of the test vehicle or the first of two vehicles to be tested. (See paragraphs 5.10, 5.11, 5.12, and Appendix I, Sample Calculations, for further explanation.)

3.6 **Test Segment**—A test segment is also composed of a minimum of three valid T/C ratios. A test segment establishes the fuel consumption of the test vehicle after modification or the fuel consumption of the second of two vehicles tested. A valid test segment must be compared to a valid baseline segment. (See paragraphs 5.10, 5.11, 5.12, and Appendix I, Sample Calculations, for further explanation.)

3.7 **Complete Test**—A complete test is composed of a baseline segment and a test segment.

4. Test Preparations

4.1 **Test Route Selection**

4.1.1 For Long-Haul Operations—A test route representative of actual operation of not less than 40 miles (64.4 km) should be selected for conducting the test. The route selected must allow high probability of an uninterrupted test. (Record on Test Data Form #1.)

4.1.2 For Other Operations (Pick-up and Delivery (P&D), Construction, Transit Buses, etc.)—A representative test route must be selected which will provide sufficient distance and time to consume a minimum of 30% of the test tank capacity or a minimum of 6 gal (22.7 L) of fuel, whichever is greater. The route selected must allow high probability of an uninterrupted test. (Record on Test Data Form #1.)

4.2 **Vehicle Test Speeds**—The test speeds selected should be representative of average operation as determined by the operator conducting the test and be within the capability of the test vehicles. Vehicles are to be operated according to vehicle, engine, and transmission manufacturers' recommendations (engine speeds and shift points). If the test vehicles can be operated in more than one transmission or differential ratio over any part of the test route at the speed selected, a pre-determined driving procedure must be specified. At no time during the test cycle should one vehicle control the speed or performance of the other vehicle; however, they should be run at basically the same time in order to experience the same ambient operating conditions. (See paragraph 5.4.)

4.3 **Vehicle Type and Configuration**—Vehicles "C" and "T" are not required to be of the same general configuration. However, it may require more test runs to obtain three valid T/C ratios when extreme differences in configuration exist between control and test vehicles. All vehicles must be in proper operating condition as determined by the operator conducting the test. (See paragraph 7.7.) Vehicle "C" need not have the same engine, driveline, axle ratio, or tire size as the test vehicle. (Record on Test Data Form #1.)

4.4 **Cargo Weights**—The cargo weights selected for the test should be representative of the fleet operations and be within the capability of the vehicles under test. Equal gross weights for Vehicles "C" and "T" are not necessary but are desirable. If two test vehicles are being compared, the cargo weights must be the same. Cargo weight must not change during a test unless a change in weight is a factor being tested. (Record measured weights of control and test vehicles on Test Data Form #1.)

4.5 **Driver Selections**—Drivers selected should be sufficiently skilled so that test results are not affected by the driver's technique improvement during the test period. Drivers should also have a strong motivation for unbiased results and excellence of test procedure conduct.

4.6 **Observers**—Observers should be assigned to each vehicle. The observer records the data outlined in paragraph 5.5. Complex driving cycles require observers; simple driving cycles may not require observers.

4.7 **Fuel Measuring**

4.7.1 Portable Weigh Tank Method—This method of fuel consumption measurement requires that a portable tank of at least 16 gal (60.6 L) capacity be installed on each vehicle. The portable tank[1] must have provisions for both supply and return of fuel. The fuel line connections to the portable tank must be fitted with quick-disconnect fittings to allow for removal without spillage. The portable tank weigh method requires a good quality scale[2], accurately calibrated in increments of 0.1 lb (45 g) or 1 oz (28.4 g). (Use Test Data Form #2 for recording data.) When

NOTE: TMC—The Maintenance Council of the American Trucking Association, Inc.

[1] It is strongly recommended that the portable tanks selected have a high degree of mechanical integrity. Temporary installation of an automobile fuel tank is not recommended.

[2] A good scale for this purpose is Accu-weight Model 200 or equivalent.

reading a scale with graduations marked at each ounce, it is a simple matter to interpolate to 1/4 oz. A deadweight of approximately 100 lb (45.4 kg) is required to check scale repeatability immediately preceeding each series of fuel tank weighings. (See paragraph 7.4.)

4.7.2 Flow Meter Method—If vehicles are fitted with on-board flow meters, these meters must be capable of temperature density compensation and must be calibrated to a minimum accuracy of ±1% at a flow rate consistent with the vehicle being tested. (Use Form #2 for recording data.) (See paragraph 6.2 for test accuracy with fuel meter.)

4.7.3 Fuel Temperatures—The fuel temperature in the portable weighing tanks should be kept below 160° F (71°C). Fuel coolers can be used to maintain the temperature below that value but positioning the portable weigh tank in an area of good air flow is an easier solution.

4.8 **Baseline Segment**—Vehicles "C" and "T" must make sufficient test runs to complete a baseline segment. (See Appendix I, Sample Calculations.) After the baseline has been established, modification is made to Vehicle "T". *No change is made to Vehicle "C" for the duration of the test.* Vehicle "C" must remain the same vehicle, without change, and used for test purposes only, even if modification to Vehicle "T" requires several weeks. If trailers are used, the trailers and loads must be used for test purposes only, or be set aside, unchanged, until the test is completed.

4.9 **Test Segment**—Vehicle "C" and modified or new Vehicle "T" must make sufficient test runs to complete a segment. (See Appendix I, Sample Calculations.)

*5. **Test Procedure***

5.1 Vehicles "C" and "T" must follow the same start and warm-up procedures. Warm-up speeds should be at or near test speeds. The time of warm-up must not be less than 1 h. Longer warm-up periods may be required at colder temperatures. Warm-up and driver familiarization with the test route can be accomplished at the same time. This test procedure is structured to measure fuel consumption differences of warmed-up vehicles.

5.2 Record weather, road conditions, traffic conditions, wind velocity, wind direction, temperature, humidity, and barometric pressure for each test run. (Record on Test Data Form #2.) These data are not used in calculation but are useful in evaluation of test results.

5.2.1 Wind velocity may be checked with an inexpensive *marine type*[3] hand held wind indicator.

5.2.2 Weather data may be obtained from a local airport or other weather bureau service.

5.3 Vehicles "C" and "T" are moved to the marked starting point and parked with engines stopped. Portable fuel tanks are topped off, weighed, and the weight recorded. Fuel measuring equipment, if used, and odometers are read and the data recorded. (Use Test Data Form #2.) Vehicles must be fueled from the same dispenser during the entire test to insure consistent fuel grade and quality.

5.4 The driver of Vehicle "T" should start the engine and leave the starting area on a predetermined test route. (Engine start time is recorded on Test Data Form #2-2.) After approximately 5 min, the driver of Vehicle "C" should start the engine and leave on the test route. (Engine start time is recorded on Test Data Form #2-1.) The interval spacing is to insure that one vehicle will not impose an artificial performance limit on the following vehicle and will also allow fueling between runs without disproportionate cooling. Care should be taken to insure that cool-down periods are identical for both vehicles and for all test runs. Cool-down periods at start of test and between runs should not be more than 5 min.

5.5 Observers, if used, should make and record a minimum of ten elapsed time recordings on each run using the Observer's Worksheet. These calculations are made using stopwatches and mile (km) posts. If mile (km) posts do not exist on the test route, measured miles (km) must be laid out prior to conducting the test. Using a stopwatch, observers also record the time the vehicle is stopped at any point on the test route other than at the start and finish point. The time stopped on the course should occur only at stop signs. The vehicle stopped time is subtracted from the total time to obtain running time for each run. (See Form #4, the Observer's Worksheet.)

5.6 If, due to conditions or vehicle specifications, a pre-determined driving cycle is specified for the test, the observer is to coach the driver, making sure that the vehicle is operated as described in the pre-determined driving cycle.

5.7 At the end of each test run, each vehicle must stop at the start (fueling) point. Immediately after full stop, engines are idled for 1 min and then shut down. (Time is recorded using Forms #2-1 and #2-2.) Fuel measurement equipment and odometers are read and recorded. (Use Forms #2-1 and #2-2.)

5.8 The driver of Vehicle "C" should drive that vehicle for the complete test. The driver of Vehicle "T" should drive that vehicle for the complete test. After refueling occurs, repeat paragraph 5.3. (Record weather, road, traffic conditions, wind velocity, and wind direction on Forms #2-3 and #2-4.) Observers should also remain with their respective vehicles throughout the complete test since their instructions may influence driver performance.

5.9 At the conclusion of each test run, all data are recorded and the next test run is started by repeating paragraphs 5.3 through 5.6. Time to complete a test run must be repeated within ±0.5%. For a run which requires 1 h to complete, repeatability must be ±18 s. Fuel consumption data should not be used from runs which failed to repeat time within ±0.5% of other runs in the same segment for the same vehicle. With a 40–50 mile (64.4–80.5 km) long haul course, the use of runs that do not repeat within ±0.5%, excluding time stopped on the test route, will affect the accuracy of the results. The operational events of these runs must be identical. The only allowed variable is time stopped at scheduled stops. More complex test schedules may be less tolerant of variations in stop time.

5.10 A test consists of two segments, a baseline segment and a test segment. Each segment is made up of a minimum of three valid T/C ratios (Test Vehicle Fuel Used/Control Vehicle Fuel Used.) Valid T/C ratios must fit within a 2% band. (See Appendix I, Sample Calculations.) The 2% band means that the lowest T/C ratio cannot be more than 2% below the highest.

5.11 If only one test vehicle is used, a baseline segment is run. The vehicle is then modified and a test segment is run as outlined in paragraphs 4.1 through 4.9 and 5.1 through 5.9. The comparison of the baseline and test segments for the test vehicle gives the test results. (See Appendix I, Sample Calculations.)

5.12 If two complete vehicles are to be compared, the Control Vehicle (C) and Test Vehicle One (T_1) are used in the baseline segment. The Control Vehicle (C) and Test Vehicle Two (T_2) are used in the test segment. Both segments are run as outlined in paragraphs 4.1 through 4.9 and 5.1 through 5.9. The comparison of the baseline and test segments of the test vehicle(s) gives the test results. More than one test vehicle can be run simultaneously in which case the divisor of the ratio is always the Control Vehicle (C). (T_1/C, T_2/C, T_3/C, etc.) (See Appendix I, Sample Calculations.)

5.13 This test procedure is for use when testing a modification to a test vehicle or when comparing two vehicles employing a switch of the complete test vehicle between baseline segment and test segment. For example, when comparing one test tractor to another, the driver and trailer of the baseline segment vehicle are the driver and trailer of the test segment vehicle. The test segment is then comparable to the baseline segment. More than one test can be conducted and several test vehicles can be operated at the same time. When more than one test vehicle is run at the same time, the control vehicle should be run between the test vehicles and as near the middle as possible. A single test is inconclusive regardless of the results. A single test should be taken as an indicator. Test results must be repeatable to have validity.

*6. **Test Accuracy***

6.1 Properly conducted tests using portable tank weigh methods are considered, based on test experience with long-haul test routes, to have an overall accuracy within ±1% (for example, 6% measured difference can be from 5–7% actual difference.)

6.2 The use of on-board meters has not been successfully demonstrated during the validation of this procedure.

*7. **Cautionary Notes***

7.1 Test Route—It has been determined during validation of the procedure that the optimum long haul test route is one that starts and stops at a common point, has a fueling point with easy access to the test route, and has no traffic control lights. The turnaround should be either the cloverleaf type or an off ramp with a stop sign, an overhead (or underneath) crossover, and an on ramp. A turnaround point with traffic control lights must be avoided. A test route that has had mile (km) markers installed is recommended. For other test routes (P&D, construction, transit buses, etc.) experience has shown that this procedure is acceptable. However, care must

[3]Edmund Scientific Co., Barrington, NJ, or Dwyer Instrument, Inc., Michigan City, IN, or equivalent.

be taken in establishing routes and their inherent driving cycles to insure they are representative of the operating parameters of the equipment under test.

7.1.1 For transit buses, the Transit Coach Operating Profile Duty Cycle[4] may be used.

7.2 **Trailers and Weight Dedication**—If trailers are used, the trailers matched to Vehicles "C" and "T" should stay with their respective tractors throughout the entire test. If this cannot be done with the operator's revenue equipment, consideration should be given to renting trailers for the duration of the series of test segments. Under no circumstances should the trailers be exchanged betweeen Vehicles "C" and "T". The use of revenue cargo for test weight should be avoided to prevent delay of freight or loss of costly test data due to an unavoidable extension of the test period and/or cargo delivery commitments.

7.3 Vehicles "C" and "T" should be operated at test speeds for not less than 1 h, for warmup before test cycles are run, to insure that the vehicles approach temperature stabilization in all components. Invalid test runs may result if higher fuel consumption is caused by temperature-induced frictional resistance in one, but not all, of the vehicles used to conduct the test. If fuel consumption during warm-up is being tested, Vehicles "C" and "T" should not be operated for a minimum of 12 h prior to starting each test run.

7.4 Portable tanks must be weighed on the same portable scales. (See paragraph 4.7.1.) The outside of the portable fuel tanks should be wiped clean of dirt and fuel each time they are weighed. The scale site should be protected from winds. *Scales must be checked with a known deadweight of approximately 100 lb (45.4 kg) before each series of readings.* The portable scales should not be moved between the initial and final weighing of a given test run unless particular attention is paid to checking the scale's repeatability in a second location. (See paragraph 4.7.1, etc.)

7.5 It is strongly recommended that all drivers and observers of Vehicles "C" and "T" be required to drive and ride over the test route at least once before testing. Familiarity with grades, required shifting, braking, speed maintenance, etc., will lead to greater accuracy and repeatability.

7.6 To minimize test variability when driving the warm-up run or first test run, it is recommended that each driver mentally note the precise location on the test route where he applies the brakes and for how long, where he shifts gears, and where he accelerates and decelerates. Each subsequent run should be an exact duplicate of the previous run and no attempt to improve should be made.

The use of stopwatches by observers and/or drivers to facilitate the measurement of time and speed between mile (km) markers has been found to be a valuable aid in meeting the time requirements of this test procedure.

It has also been found useful to select mile (km) marker check points along the route and record the time between markers, the time to negotiate a cloverleaf, and the time elapsed from interstate ramp to ramp. The selected check points should remain the same for each test run. No attempt should be made to compensate for a fast or slow elapsed time between two previous check points.

7.7 To minimize test variability, it is recommended that all vehicles (C and T) being tested be in similar mechanical conditions, be representative of the operator's vehicle(s) involved in the test, and have (except in the case where this is the item being evaluated):

(a) Each engine governor set to manufacturer's recommendation or the operator's standard.

(b) New air cleaner element and new fuel filters. Installation of new air cleaner element can be waived if vehicle's inlet restriction does not exceed 15 in H_2O (3.7 kPa).

(c) Each vehicle reasonably clean and free of sheet metal dents, tears, or missing body parts. Fiberglass hoods should be intact.

(d) Cab side window openings the same in each vehicle, open or closed, for the entire test. For transit buses, all windows should stay the same (open or closed) for entire test.

(e) Accessory load for each vehicle as consistent as possible (for example, by turning air conditioning off, defroster off, heat switch at the same position, and lights on).

(f) Trailer free of damage to exterior surfaces that would affect aerodynamic drag.

(g) Truck/tractor alignment checked and proper. Trailer axle alignment checked and proper.

(h) Each vehicle properly lubricated prior to test. All fluid levels should be checked and be at prescribed levels.

(i) Temperature controlled fan drives and shutters locked in the same operating mode throughout the test.

(j) Cold tire pressures measured and inflated to operator's standard.

(k) A stall check made on vehicles equipped with automatic transmissions and torque converters.

(l) Exhaust system back pressure below engine manufacturer's maximum recommended limit and within 0.5 in Hg (1.7 kPa) between test vehicle engines of the same make and model.

(m) Proper brake adjustment.

7.8 At the end of each warm-up and at the end of each test run, all vehicles must be checked for mechanical changes that would affect test results. Typical checks would include:

(a) Oil pressure and leaks.
(b) Coolant temperature and leaks.
(c) Exhaust gas temperature.
(d) Engine air filter restriction
(e) Electrical load.
(f) Tire pressures.
(g) Brake dragging (i.e. temperature).
(h) Exhaust smoke.
(i) Observed ability to maintain selected test speed.
(j) Transmission or differential leaks.
(k) Intake manifold pressure (turbocharger boost).

7.9 Drivers of Vehicles "C" and "T" should be interviewed between test runs to ascertain any differences in the apparent handling, power, and braking characteristics of their respective vehicles. If changes occur between the test runs of either the baseline segment or the test segment, the test data should be discarded and the test re-run after correction of the problem.

7.10 In order to obtain results which may be considered representative of actual service conditions, it is important to reproduce typical service conditions during the test. This applies to load weights, routes, grades, vehicle speeds, weather, wind conditions, drivers, etc. For example, if the actual service vehicles generally operate in a part of the country where hills exist over a substantial portion of the routes, the test should be conducted on similar terrain in order to obtain the most representative results.

7.11 Because of the special nature of aerodynamic drag reduction equipment (deflectors, body fairings, roof fairings, vortex stabilizers, etc.) comparison tests between brands or types should not be run with two trucks. If comparative results are required, additional test trucks are recommended during any given test. The entire range of results may be either higher or lower than average conditons depending upon the weather (wind velocity and direction) on the days during which the tests were conducted. To minimize the effects of high or low yaw angle wind effects, a circular route or closed loop of highways is recommended.

7.12 The accuracy of odometers and speedometers of Vehicles "C" and "T" should be determined during the warm-up test and compensations made for error during actual test runs. If odometer readings (total miles (km))between two vehicles differ, it is recommended that the two elapsed mileage (km) readings be averaged and this value be used for calculation purposes. Another acceptable method would be to use a vehicle with known speedometer and odometer accuracy and use that distance for calculations of mpg (km/L) conversions.

7.13 If test participants are extremely careful and pay attention to all details of the procedure, it has been found that it is highly unusual that more than five test runs are required to complete a segment. It has also been found that, almost without exception, a procedural error or a mechanical problem can be identified when it is necessary to throw out a test run.

8. Bibliography

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Proposed SAE Information Report, "Bus Advisory Group—Information Report."

SAE Paper No. 810025.

[4] Baseline Advanced Design Transit Coach Specification, Part II, paragraph 1.2 (17), Guideline procurement document for new 30 and 40 ft (10.4 and 12.2 m) coach design. Published by DOT and UMTA.

APPENDIX I

SAMPLE CALCULATIONS

A1. Derivation of Baseline Data

A1.1 Baseline Segment

A.

Test Run No.	Fuel Consumed, lb or kg, Test Vehicle (Data Point)	÷	Fuel Consumed, lb or kg, Control Vehicle (Data Point)	=	T/C Ratio
1	78.94		68.04		1.1602
2	79.41		66.84		1.1881
3	77.50		66.84		1.1595

Check: T/C values must be within 2%[1]:

After three test runs:

B. Highest T/C ratio x .98 = minimum acceptable T/C ratio
1.1881 x .98 = 1.1643

The T/C ratios derived by test runs #1 and #3 are less than the minimum acceptable T/C ratios calculated in B. Therefore, additional baseline data are required. This comparative test to assure T/C ratios within 2% should be made after the third test run and then after each succeeding test run that is required. When three test runs repeated within 2% of each other, as checked in B, have been computed, the baseline segment is complete. In this example, an additional test run is required.

Test Run No.	Fuel Consumed, lb or kg, Test Vehicle (Data Point)	÷	Fuel Consumed, lb or kg, Control Vehicle (Data Point)	=	T/C Ratio
1	78.94		68.04		1.1602
2	79.41		66.84		1.1881
3	77.50		66.84		1.1595
4	78.54		67.84		1.1577

After four test runs:

C.

1. Highest T/C ratio x .98 = minimum acceptable T/C ratio
1.1881 x .98 = 1.1643

2. Second highest T/C ratio x .98 = minimum acceptable T/C ratio
1.1602 x .98 = 1.1370

Because there are three T/C ratios greater than the minimum acceptable T/C ratio as determined by calculation C.2., the requirement that three test runs fall within a 2% band has been met and the baseline segment is complete.

Test runs #1 and #3 were valid when tested by comparison with test run #4. Therefore, run #2 is considered faulty and is deleted as part of the baseline segment. Since test runs #1, #3, and #4 meet the 2% requirement, a #5 test run is not required.

The same procedure shown at A and B is repeated as in C.

If a fifth test is required to get three valid T/C ratios, the determination of those runs is done per item D.

D.

1. Highest T/C ratio x .98 = minimum acceptable T/C ratio
2. Second highest T/C ratio x .98 = minimum acceptable T/C ratio
3. Third highest T/C ratio x .98 = minimum acceptable T/C ratio

Note: If test participants are extremely careful and pay attention to all details of the procedure, it has been found that it is highly unusual that more than five test runs are required to complete a segment. It has also been found that, almost without exception, a procedural error or a mechanical problem can be identified when it is necessary to throw out a test run.

The test segment may now be started.

A1.2 Test Segment—Make similar calculations as in baseline segment. (Typical test segment results are shown in paragraph A2.2.)

A2. Calculation of Results—After finishing a baseline segment and a test segment, calculate the result. That is, compare the baseline segment, performed before the component change was made to the truck, to the test segment, performed after the change. Each segment was run until three T/C ratios of fuel consumption were obtained which met the 2% test. For calculating the results, we must now compare them.

A2.1 Baseline Segment T/C Ratios

Test Run #1	....	1.1602
#3	....	1.1595
#4	....	1.1577
Ave.		3.4774 ÷ 3 = 1.1591

A2.2 Test Segment T/C Ratios—(See A1.2.)

Test Run #2	....	1.0959
#3	....	1.1080
#4	....	1.0936
Ave.		3.2975 ÷ 3 = 1.0992

The T/C ratios derived in each segment are ratios comparing the fuel consumption of the test vehicle (T) to the control vehicle (C). It is by comparing these ratios that we derive the percentage improvement (positive or negative) between the baseline segment (before the component change) and the test segment (after the component change).

A2.3 Percent Fuel Saved

= (Ave. Baseline T/C - Ave. Test T/C) ÷ Ave. Baseline T/C
= (1.1591 - 1.0992) ÷ 1.1591
= (0.0517 x 100) = 5.17% Fuel Saved.

A2.4 Percent Improvement

= (Ave. Baseline T/C - Ave. Test T/C) ÷ Ave. Test T/C
= (1.1591 - 1.0992) ÷ 1.0992
= (0.0545 x 100) = 5.45% Improvement.

A3. mpg (km/L) Conversion—The preferred method of expressing the result of a test is as a percent of fuel saved, as described in paragraph A2.3. If it is desired to see fuel consumption stated in mpg (km/L) it must be emphasized that these values apply to the specific test conditions only. This section of the procedure describes how to state the results in consistent mpg (km/L) values. The fuel consumption of the control vehicle is used, in an arbitrary role, in this calculation. For reasons of consistency, so that the resulting mpg (km/L) values can be compared with each other, it is important that the same control vehicle mpg (km/L) value be used to derive all test vehicles' mpg (km/L) values. Two ways of calculating this representative control vehicle mpg (km/L) are shown and the choice between them is not important. It is important that the precaution be followed of using only one representative control vehicle (including driver) mpg (km/L) value to calculate all mpg (km/L) values which might be compared with each other.

The fuel specific weight of the actual test fuel should be determined and used for this calculation. As an alternative, a value of 7.05 lb/gal (0.84 kg/L) for #2 diesel and 6.0 lb/gal (0.72 kg/L) for gasoline may be used.

A3.1 Representative Control Vehicle mpg (km/L)—The control vehicle representative mpg (km/L) can be obtained from valid fuel consumption for one day or from the valid fuel consumption for every time that control vehicle was used[2]. For this example, the baseline segment valid runs will be used:

68.04	Run #1
66.84	Run #3
67.84	Run #4
202.72 lb for 3 runs	

202.72 lb ÷ 7.05 lb/gal = 28.75 gal
(91.95 kg ÷ 0.85 kg/L = 108.17 L)[3]

50 miles x 3 runs = 150 miles
(80.5 km x 3 runs = 241.4 km)[4]

150 miles ÷ 28.75 gal = 5.22 miles/gal[4]
(241.4 km ÷ 108.17 L = 2.23 km/L)

[1] Use .98 as a multiplier for this purpose.

A3.2 Test Vehicle Baseline mpg (km/L)
Control vehicle representative mpg (km/L) ÷ Ave. Baseline T/C Ratio

5.22 mpg ÷ 1.1591 = 4.50 mpg
(2.23 km/L ÷ 1.1591 = 1.92 km/L)

Test Vehicle Test mpg (km/L)
Control vehicle representative mpg (km/L) ÷ Ave. Test T/C Ratio

5.22 mpg ÷ 1.0992 = 4.75 mpg
(2.23 km/L ÷ 1.0992 = 2.03 km/L)

A3.3 Improvement in mpg (km/L)

Test - Baseline

4.75 - 4.50 = 0.25 mpg improvement
(2.02 - 1.92 = 0.10 km/L improvement)

[2]5.22 mpg (2.23 km/L) has been established as representative of this control vehicle recognizing that tests run on other days under different weather conditions will result in a different mpg (km/L) value for the control vehicle. However, for other tests where this control vehicle is used for the purpose of converting to mpg (km/L) the 5.22 mpg (2.23 km/L) must be used as the representative value if a valid mpg (km/L) conversion is to be made. If a new representative value is used, all previous mpg (km/L) improvements must be recalculated using the new representative value.
[3]To convert lb to kg multiply lb by 0.4536.
[4]To convert miles to km multiply miles by 1.6093.

TYPE II TEST DATA FORM #1 (VEHICLE IDENTIFICATION)

Power Unit

Fleet ______________________ **Date** ______________________ **Test #** ______________________

	Control Vehicle	Test Vehicle
Unit Number	________	________
Make	________	________
Model	________	________
Year	________	________
Number of Axles	________	________
Number of Drive Axles	________	________
Engine Make/Model	________	________
Governed Speed @ No Load (High Idle)	________ RPM	________ RPM
Rated Power (bhp)	________ hp (kw)	________ hp (kw)
Rated Speed	________ RPM	________ RPM
Peak Torque	________ lb-ft	________ lb-ft
Peak Torque Speed	________ RPM	________ RPM
Transmission Make/Model	________	________
Geared For	________ mph (km/h)	________ mph (km/h)
	at ________ RPM	at ________ RPM
	in ________ gear	in ________ gear
Differential Make/Model	________	________
Differential Ratio	________	________
Tire Size/Type/Make/Model	____/____/____	____/____/____
Tire Pressure (Cold)	________ psi (kPa)	________ psi (kPa)
5th Wheel Setting (express in in (mm) the distance 5th wheel fulcrum is ahead or behind the center line of bogie)	________ in (mm)	________ in (mm)

Note: In areas where two units are shown [i.e., hp (kw)] circle the unit used.

TYPE II TEST DATA FORM #1 (VEHICLE IDENTIFICATION) (Continued)

Trailer/Body

Fleet ______________________ Date ______________________ Test # ______________________

	Control Vehicle	Test Vehicle
Unit Number	________	________
Make	________	________
Model	________	________
Year	________	________
Type (Van, Flatbed, Tank, Etc.)	________	________
Type of Side	________	________
Type of Corner	________	________
Height	________	________
Length	________	________
Tire Size/Type/Make/Model	____/____/____	____/____/____
Tire Pressure (Cold)	________ psi (kPa)	________ psi (kPa)
Number of Axles on Trailer(s)	________	________
G.V.W. (Measured on Scale)	________	________
Kingpin Setting	________ in (mm)	________ in (mm)
Cab-to-Trailer Gap	________ in (mm)	________ in (mm)

TYPE II TEST DATA FORM #1 (VEHICLE IDENTIFICATION) (Continued)

Devices, Components, or Systems That Are Incorporated into Control and Test Vehicle Specifications

Fleet ____________ **Date** ____________ **Test #** ____________

	Control Vehicle			Test Vehicle		
	No	Yes	Type	No	Yes	Type
Radiator Shutters (on-off or modulating)						
Engine Cooling Fan Sys. (Describe below—A)						
Aerodynamic Device (Describe below—B)						
Engine Oil						
Transmission Lube						
Differential Lube						
Fuel Heater						
Oil Cooler						
Tag Axle						
Air Lift Axle(s)						
Low Back Pressure Exhaust System						
Other:						

A ____________ / ____________

B ____________ / ____________

TYPE II TEST DATA FORM #1 (VEHICLE IDENTIFICATION) (Continued)

Fleet ______________________ Date ______________________ Test # ______________

Detailed Description of Vehicle, Component, or System Modification Being Tested:

____

____

____

____

____

____

____

____

Length of Test Route from Start to Stop Point: ______________________ miles (km)

Test Route: (Describe in detail number of lanes; type of road surface; type of turnarounds; type, if any, of traffic control devices; type of terrain, hills, cuts, curves; special driving instructions; etc.)

____

____

____

____

____

____

Driver(s) Interview

Handling, Power, and Braking Characteristics of Vehicle(s) during Test (see paragraph 7.5):

Control Vehicle ____

____

____

____

Test Vehicle ____

____

____

____

TYPE II—FUEL ECONOMY TEST DATA FORM =2-1

BASELINE SEGMENT OF THE CONTROL VEHICLE

Type II Test—Portable Fuel Tank Weighing Method or Fuel Flow Meter Method

Fleet ____________________ Control Tractor = __________ Control Trailer = __________

Driver ____________________ Observer ____________________

Test = ____________________ Date ____________________

Test Speed ____________________ Route ____________________

Test Run =1

Scale Repeatability Check Weight __________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start			
Finish			

Fuel Used __________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run =2

Scale Repeatability Check Weight __________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start			
Finish			

Fuel Used __________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run =3

Scale Repeatability Check Weight __________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start			
Finish			

Fuel Used __________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #4

Scale Repeatability Check Weight ________________

	Fuel Weight/Fuel Meter Reading	**Odometer**	**Time**
Start	________	________	________
Finish	________	________	________

Fuel Used ________________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #5

Scale Repeatability Check Weight ________________

	Fuel Weight/Fuel Meter Reading	**Odometer**	**Time**
Start	________	________	________
Finish	________	________	________

Fuel Used ________________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Control Vehicle MPG Calculation

Total Fuel Used ________ lb/gal kg/L (circle one) ________ Time ________ h ________ m ________ s
Total Fuel Used lb/gal kg/L[2] ________ ÷3 ________ = ________ gal (L)
Total Miles (km) Run ________ ÷ ________ gal (L) used = ________ miles/gal (km/L)
Miles (km) Run ________ ÷ ________ h = ________ miles/h (km/h)

Weather:	Temperature	Humidity	Barometric Pressure	Wind Speed	Wind Direction
Run #1	________	________	________	________	________
Run #2	________	________	________	________	________
Run #3	________	________	________	________	________
Run #4	________	________	________	________	________
Run #5	________	________	________	________	________

[1]Running Time must repeat within ±18 s for 1 h run or ±0.5% of the time required to complete the test run or run data point must not be used. See paragraphs 3.2, 3.3, 5.5, 5.9.

[2]If fuel meter is used record meter readings in this column.

[3]For No. 2 diesel, use 7.05 lb/gal (0.84 kg/L); or for gasoline use 6.0 lb/gal (0.72 kg/L); or actual specific weight of fuel can be used.

TYPE II—FUEL ECONOMY TEST DATA FORM #2-2

BASELINE SEGMENT OF THE TEST VEHICLE

Type II Test—Portable Fuel Tank Weighing Method or Fuel Flow Meter Method

Fleet ______________________ Test Tractor # __________ Test Trailer # __________

Driver ______________________ Observer ______________________

Test # ______________________ Date ______________________

Test Speed ______________________ Route ______________________

Test Run #1

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	______________	__________	__________
Finish	______________	__________	__________

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #2

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	______________	__________	__________
Finish	______________	__________	__________

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #3

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	______________	__________	__________
Finish	______________	__________	__________

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #4

Scale Repeatability Check Weight ________________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	________________	________	________
Finish	________________	________	________

Fuel Used ________________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #5

Scale Repeatability Check Weight ________________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	________________	________	________
Finish	________________	________	________

Fuel Used ________________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Weather:	Temperature	Humidity	Barometric Pressure	Wind Speed	Wind Direction
Run #1					
Run #2					
Run #3					
Run #4					
Run #5					

[1]Running Time must repeat within ±18 s for 1 h run or ±0.5% of the time required to complete the test run or run data point must not be used. See paragraphs 3.2, 3.3, 5.5, 5.9.

TYPE II—FUEL ECONOMY TEST DATA FORM #2-3

TEST SEGMENT OF THE CONTROL VEHICLE

Type II Test—Portable Fuel Tank Weighing Method or Fuel Flow Meter Method

Fleet ______________________ Control Tractor # __________ Control Trailer # __________

Driver ______________________ Observer ______________________

Test # ______________________ Date ______________________

Test Speed ______________________ Route ______________________

Test Run #1

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	______________	__________	__________
Finish	______________	__________	__________

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #2

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	______________	__________	__________
Finish	______________	__________	__________

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #3

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	______________	__________	__________
Finish	______________	__________	__________

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #4

Scale Repeatability Check Weight ________________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	________	________	________
Finish	________	________	________

Fuel Used ________________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #5

Scale Repeatability Check Weight ________________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	________	________	________
Finish	________	________	________

Fuel Used ________________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Control Vehicle MPG Calculation

Total Fuel Used ________ lb/gal kg/L (circle one) ________ Time ________ h ________ m ________ s
Total Fuel Used lb/gal kg/L[2] ________ ÷[3] ________ = ________ gal (L)
Total Miles (km) Run ________ ÷ ________ gal (L) used = ________ miles/gal (km/L)
Miles (km) Run ________ ÷ ________ h = ________ miles/h (km/h)

Weather:	Temperature	Humidity	Barometric Pressure	Wind Speed	Wind Direction
Run #1	________	________	________	________	________
Run #2	________	________	________	________	________
Run #3	________	________	________	________	________
Run #4	________	________	________	________	________
Run #5	________	________	________	________	________

[1] Running Time must repeat within ±18 s for 1 h run or ±0.5% of the time required to complete the test run or run data point must not be used. See paragraphs 3.2, 3.3, 5.5, 5.9.
[2] If fuel meter is used record meter readings in this column.
[3] For No. 2 diesel, use 7.05 lb/gal (0.84 kg/L); or for gasoline use 6.0 lb/gal (0.72 kg/L); or actual specific weight of fuel can be used.

TYPE II—FUEL ECONOMY TEST DATA FORM =2-4

TEST SEGMENT OF THE TEST VEHICLE

Type II Test—Portable Fuel Tank Weighing Method or Fuel Flow Meter Method

Fleet ______________________ Test Tractor = __________ Test Trailer = __________

Driver ______________________ Observer ______________________

Test = ______________________ Date ______________________

Test Speed ______________________ Route ______________________

Test Run =1

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start			
Finish			

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run =2

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start			
Finish			

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run =3

Scale Repeatability Check Weight ______________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start			
Finish			

Fuel Used ______________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #4

Scale Repeatability Check Weight ____________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	____________	____________	____________
Finish	____________	____________	____________

Fuel Used ____________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Test Run #5

Scale Repeatability Check Weight ____________

	Fuel Weight/Fuel Meter Reading	Odometer	Time
Start	____________	____________	____________
Finish	____________	____________	____________

Fuel Used ____________ lb/gal kg/L (circle one)

Time from Start to Finish ______ h ______ m ______ s
Subtract Vehicle Stopped Time ______ h ______ m ______ s

Vehicle Running Time[1] ______ h ______ m ______ s

Weather:	Temperature	Humidity	Barometric Pressure	Wind Speed	Wind Direction
Run #1	______	______	______	______	______
Run #2	______	______	______	______	______
Run #3	______	______	______	______	______
Run #4	______	______	______	______	______
Run #5	______	______	______	______	______

[1] Running Time must repeat within ±18 s for 1 h run or ±0.5% of the time required to complete the test run or run data point must not be used. See paragraphs 3.2, 3.3, 5.5, 5.9.

TYPE II—FUEL ECONOMY TEST DATA FORM #3

CALCULATION SUMMARY SHEET

Fleet ______________________ Date ______________________ Test # ______________________

	Baseline Runs	Test Vehicle Fuel Used, lb/gal kg/L (circle one) Form #2-2	Control Vehicle Fuel Used, lb/gal kg/L (circle one) Form #2-1	T/C Ratio	Check Valid T/C Ratios Used
	1				
	2				
Baseline Data	3				
	4				
	5				

Note: Use only valid T/C ratios for calculation of average T/C.

Sum of valid baseline T/C ÷ No. of valid baseline T/C's = average baseline T/C

______________ ÷ ______________ = ______________

	Test Runs	Test Vehicle Fuel Used, lb/gal kg/L (circle one) Form #2-4	Control Vehicle Fuel Used, lb/gal kg/L (circle one) Form #2-3	T/C Ratio	Check Valid T/C Ratios Used
	1				
	2				
Test Data	3				
	4				
	5				

Note: Use only valid T/C ratios for calculation of average T/C.

Sum of valid test T/C ÷ No. of valid test T/C = average test T/C

______________ ÷ ______________ = ______________

CALCULATION OF T/C LIMITS FORM #3-1

Fleet ____________________ Date ____________________ Test # ____________________

After 3 Runs:

Highest T/C Ratio __________ x 0.98 = __________ minimum acceptable T/C ratio

After 4 Runs:

Highest T/C Ratio __________ x 0.98 = __________ minimum acceptable T/C ratio
Second Highest T/C Ratio __________ x 0.98 = __________ minimum acceptable T/C ratio

After 5 Runs:

Highest T/C Ratio __________ x 0.98 = __________ minimum acceptable T/C ratio
Second Highest T/C Ratio __________ x 0.98 = __________ minimum acceptable T/C ratio
Third Highest T/C Ratio __________ x 0.98 = __________ minimum acceptable T/C ratio

CALCULATION OF % FUEL SAVED FORM #3-2

Fleet ____________________ Date ____________________ Test # ____________________

% Fuel Saved = (Ave. Baseline T/C - Ave. Test T/C) ÷ Ave. Baseline T/C
% Fuel Saved = (__________ - __________) ÷ __________
% Fuel Saved = __________

Calculation of % Improvement:

% Improvement = (Ave. Baseline T/C - Ave. Test T/C) ÷ Ave. Test T/C
% Improvement = (__________ - __________) ÷ __________
% Improvement = __________

Note: See Appendix I, Sample Calculations, to convert to mpg (km/L).

TYPE II—FUEL ECONOMY TEST DATA FORM #3-3

Fleet ______________________ **Date** ______________________ **Test #** ______________________

Test Results:

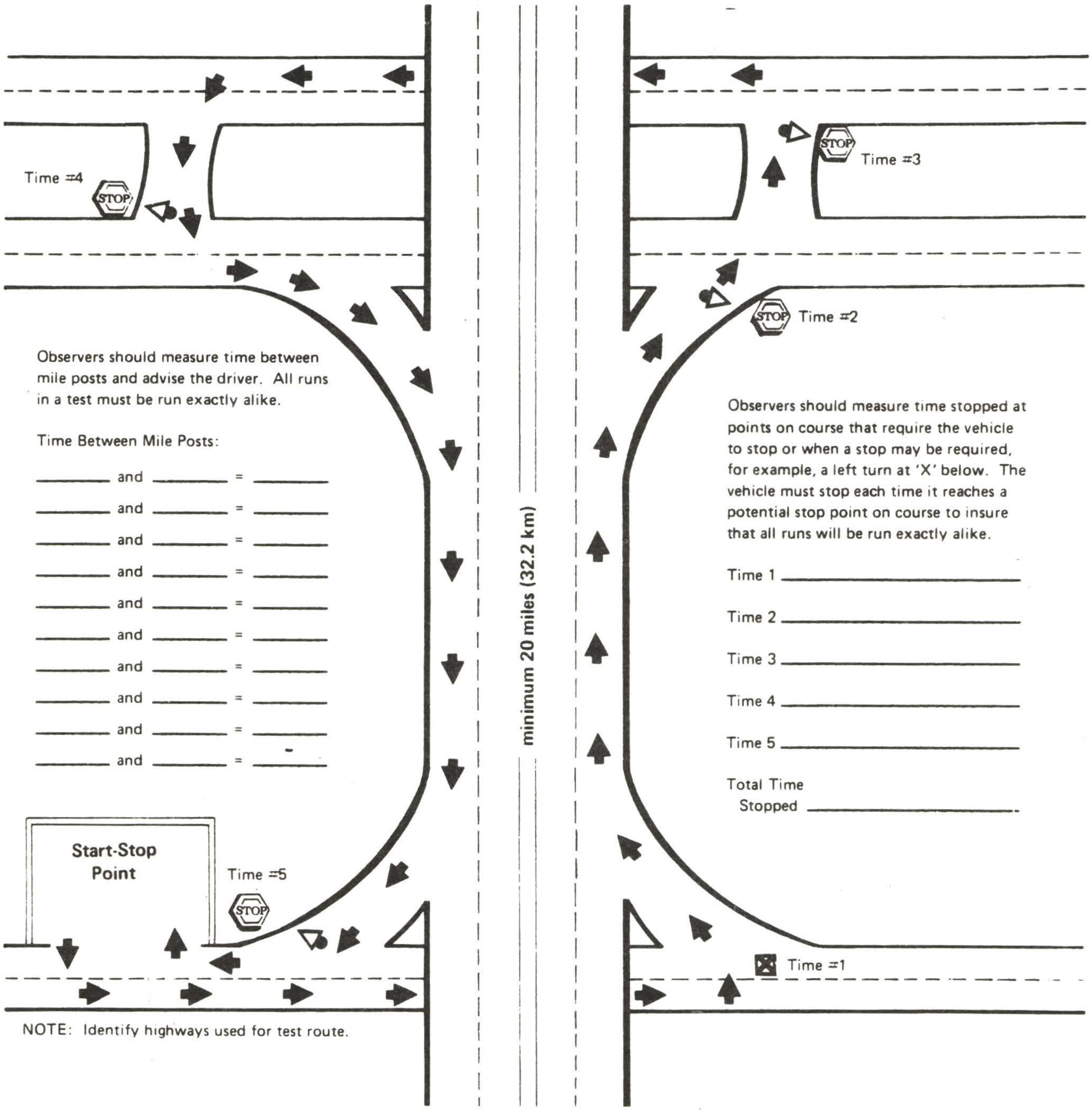
__________ % fuel saved after change

__________ % improvement in fuel economy after change (describe below):

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

TYPE II – FUEL ECONOMY TEST
THE OBSERVER'S WORKSHEET FORM #4

Fleet ______________ Date ______________ Test # ______________



Observers should measure time between mile posts and advise the driver. All runs in a test must be run exactly alike.

Time Between Mile Posts:

______	and	______	=	______
______	and	______	=	______
______	and	______	=	______
______	and	______	=	______
______	and	______	=	______
______	and	______	=	______
______	and	______	=	______
______	and	______	=	______
______	and	______	=	______
______	and	______	=	______

Observers should measure time stopped at points on course that require the vehicle to stop or when a stop may be required, for example, a left turn at 'X' below. The vehicle must stop each time it reaches a potential stop point on course to insure that all runs will be run exactly alike.

Time 1 ______________

Time 2 ______________

Time 3 ______________

Time 4 ______________

Time 5 ______________

Total Time Stopped ______________

NOTE: Identify highways used for test route.

OBSERVER'S NAME ______________________

APPENDIX C

FUEL ECONOMY TEST DATA

APPENDIX C

FUEL ECONOMY TEST DATA

Determination of Reference Fuel Economy

The following calculation establishes a reference fuel economy number to which all subsequent MPGs will be related. The data are that taken from the Grumman Control Bus No. 626 during the six valid runs used to determine the Flyer test bus T/C ratio.

Control Bus No. 626 Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Fuel Used
1	11-08-82	10.05	14.70	23.65	48.40
2	11-08-82	9.80	14.55	23.75	48.10
3	11-08-82	9.95	14.45	24.00	48.40
4	11-15-82	10.10	15.25	24.15	49.50
5	11-15-82	10.00	14.60	24.20	48.80
6	11-16-82	10.15	16.55	22.85	49.55
	Totals (lbs.)	60.05	90.10	142.60	292.75

For Six Runs

Commuter
60.05 lbs. ÷ 6.9667 lbs/gal = 8.62 gallons
8 miles/run x 6 runs = 48 miles
48 miles ÷ 8.62 gallons = 5.57 mpg

Arterial
90.10 lbs. ÷ 6.9667 lbs/gal = 12.937 gallons
8 miles/run x 6 runs = 48 miles
48 miles ÷ 12.93 gallons = 3.71 mpg

CBD
142.60 lbs. ÷ 6.9667 lbs/gal = 20.47 gallons
14 miles/run x 6 runs = 84 miles
84 miles ÷ 20.47 gallons = 4.10 mpg

Total
292.75 lbs. ÷ 6.9667 lbs/gal = 42.02 gallons
30 miles/run x 6 runs = 180 miles
180 miles ÷ 42.02 gallons = 4.28 mpg

During the test of the Gillig bus a total of 13 runs were made with both control buses along with the test bus. Of these 13 runs, 11 generated data such that the ratio of fuel used by Grumann Control Bus No. 626 to that used by the GMC Control Bus No. 627 fell within a 2 percent envelope. These runs were used to generate conversion factors for each phase so that either control bus could be used in later tests. The next two pages show the data used to generate the conversion factors.

CONTROL BUS NO. 627 - CONTROL BUS NO. 626

COMPARISON ANALYSIS
FUEL ECONOMY

Fuel Consumption - Control Bus No. 627 (lbs)

Run No.	Date	Commuter	Arterial	CBD	Total
1	12-14-82	12.85	15.95	31.05	59.85
2	12-14-82	12.80	15.75	31.10	59.65
3	12-14-82	13.10	16.40	29.50	59.00
4	12-16-82	13.00	16.90	30.35	60.25
5	12-16-82	12.50	15.70	31.05	59.25
6	12-17-82	12.90	15.65	31.15	59.70
7	12-17-82	12.65	15.55	30.50	58.70
8	12-21-82	12.80	15.70	30.55	59.05
9	12-21-82	12.75	15.75	31.15	59.65
10	12-22-82	12.95	15.60	30.70	59.25
11	12-22-82	12.60	15.60	30.80	59.00

Fuel Consumption - Control Bus No. 626 (lbs)

Run No.	Date	Commuter	Arterial	CBD	Total
1	12-14-82	10.45	14.65	24.10	49.20
2	12-14-82	10.45	14.85	24.00	49.30
3	12-14-82	9.85	14.70	24.10	48.65
4	12-16-82	10.25	14.60	24.40	49.25
5	12-16-82	9.75	14.60	23.65	48.00
6	12-17-82	10.20	14.75	23.85	48.80
7	12-17-82	10.15	14.55	23.30	48.00
8	12-21-82	10.25	14.55	23.95	48.75
9	12-21-82	10.20	14.80	23.95	48.95
10	12-22-82	10.00	14.55	24.05	48.60
11	12-22-82	10.10	14.80	23.80	48.70

CONTROL BUS NO. 627 - CONTROL BUS NO. 626

COMPARISON ANALYSIS
FUEL ECONOMY

Control Bus No. 626 Control Bus No. 627 (Ratios of Fuel Consumed)

Run No.	Date	Commuter	Arterial	CBD	Total
1	12-14-82	.8132	.9185	.7762	.8221
2	12-14-82	.8164	.9429	.7717	.8265
3	12-14-82	.7519	.8963	.8170	.8246
4	12-16-82	.7885	.8639	.8040	.8174
5	12-16-82	.7800	.9299	.7617	.8101
6	12-17-82	.7907	.9425	.7656	.8175
7	12-17-82	.8024	.9357	.7639	.8177
8	12-21-82	.8008	.9268	.7840	.8256
9	12-21-82	.8000	.9397	.7689	.8206
10	12-22-82	.7722	.9327	.7834	.8202
11	12-22-82	.8016	.9487	.7727	.8254
Average		.7925	.9252	.7790	.8207

If Control Bus No. 627 is used to obtain valid runs, the following numbers must be used to convert each phase to the comparable Control Bus No. 626 used as the standard for this program:

Commuter- Multiply the test bus fuel economy relative to Bus No. 627 by .7925

Arterial- Multiply the test bus fuel economy relative to Bus No. 627 by .9252

CBD- Multiply the test bus fuel economy relative to Bus No. 627 by .7790

Total- Multiply the test bus fuel economy relative to Bus No. 627 by .8207

Sample Calculation for Fuel Economy

To calculate the commuter MPG:

(1) Divide the fuel used by the test bus by that used by the control bus; this gives the T/C ratio.

(2) Continue Step (1) for all of the commuter runs.

(3) Average the values obtained in Steps (1) and (2).

(4) Divide the previously determined commuter reference MPG by the answer in Step (3).

The Flyer Fuel Economy Determination sheet was used for this sample calculation. Referring to the underlined data on the sheet:

$12.00 \div 10.05 = 1.1940$

$(1.1940 + 1.2245 + 1.1709 + 1.2129 + 1.1800 + 1.1724) \div 6 = 1.1925$

$5.57 \div 1.1925 = 4.67$

Flyer commuter fuel economy = 4.67 MPG

The following sheets present the data taken for the cycle fuel economy calculations, the idle fuel consumption calculations, and the results of those calculations.

FLYER FUEL ECONOMY DETERMINATION

Seated Load Weight

Flyer Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	11-08-82	12.00	14.80	25.50	52.30	1:35:21
2	11-08-82	12.00	14.45	25.00	51.45	1:34:52
3	11-08-82	11.65	14.65	25.25	51.55	1:35:03
4	11-15-82	12.25	14.80	25.50	52.55	1:33:51
5	11-15-82	11.80	14.55	25.05	51.40	1:33:57
6	11-16-82	11.90	14.65	25.50	52.05	1:33:49

Control Bus No. 626 Fuel Consumption (lbs)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	11-08-82	10.05	14.70	23.65	48.40	1:37:19
2	11-08-82	9.80	14.55	23.75	48.10	1:37:08
3	11-08-82	9.95	14.45	24.00	48.40	1:36:40
4	11-15-82	10.10	15.25	24.15	49.50	1:36:23
5	11-15-82	10.00	14.60	24.20	48.80	1:36:55
6	11-16-82	10.15	16.55	22.85	49.55	1:36:44

Valid T/C Ratios

Run No.	Date	Commuter	Arterial	CBD	Total
1	11-08-82	1.1940	1.0068	1.0782	1.0806
2	11-08-82	1.2245	.9931	1.0526	1.0696
3	11-08-82	1.1709	1.0138	1.0521	1.0651
4	11-15-82	1.2129	.9705	1.0559	1.0616
5	11-15-82	1.1800	.9966	1.0351	1.0533
6	11-16-82	1.1724	.8852	1.1160	1.0505
Average		1.1925	.9777	1.0650	1.0635

Flyer MPG Adjusted to Control Bus No. 626

Commuter - 5.57 mpg ÷ 1.1925 = 4.67 mpg
Arterial - 3.71 mpg ÷ .9777 = 3.79 mpg
CBD - 4.10 mpg ÷ 1.0650 = 3.85 mpg
Total - 4.28 mpg ÷ 1.0635 = 4.02 mpg

This was the first bus tested. The runs shown above are 6 out of a total of 15.

FLYER IDLE FUEL CONSUMPTION

Date: 11/19/82

	Fuel Consumption (pounds per hour)		
Run No.	Flyer	Control Bus	T/C
1	4.00	3.80	1.0526
2	4.00	3.75	1.0667
3	3.95	3.75	1.0533
Average	3.92	3.77	1.0575

Control Bus Idle Fuel Consumption

3.77 lbs/hour ÷ 6.9667 lbs/gal. = 0.541 gallon/hour
This number will be used on all subsequent tests.

Flyer Adjusted Idle Fuel Consumption

0.541 gallon/hour x 1.0575 = 0.572 gallon/hour

DIESEL DIVISION FUEL ECONOMY DETERMINATION

Seated Load Weight

GM of Canada Fuel Consumption (lbs)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	11-15-82	11.00	13.55	25.00	49.55	1:35:59
2	11-15-82	11.25	14.00	24.70	49.95	1:34:17
3	11-17-82	11.10	13.90	24.60	49.60	1:35:10
4	11-17-82	11.15	14.20	24.35	49.70	1:35:03
5	11-18-82	11.55	14.05	24.15	49.75	1:34:25
6	11-18-82	11.10	13.85	24.05	49.00	1:33:48

626 Control Bus No. Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	11-15-82	10.00	14.60	24.20	48.80	1:36:55
2	11-15-82	10.15	15.00	23.85	49.00	1:36:08
3	11-17-82	9.85	14.75	24.10	48.70	1:37:15
4	11-17-82	10.00	14.60	23.85	48.45	1:36:50
5	11-18-82	9.80	14.95	23.70	48.45	1:37:00
6	11-18-82	9.60	14.80	23.80	48.20	1:35:29

Valid T/C Ratios

Run No.	Date	Commuter	Arterial	CBD	Total
1	11-15-82	1.1000	.9281	1.0331	1.0154
2	11-15-82	1.1084	.9333	1.0356	1.0194
3	11-17-82	1.1269	.9424	1.0207	1.0185
4	11-17-82	1.1150	.9726	1.0210	1.0258
5	11-18-82	1.1786	.9398	1.0190	1.0268
6	11-18-82	1.1562	.9358	1.0105	1.0166
Average		1.1308	.9420	1.0233	1.0204

Diesel Division MPG Adjusted to Control Bus No. 626

Commuter - 5.57 mpg ÷ 1.1308 = 4.93 mpg
Arterial - 3.71 mpg ÷ .9420 = 3.94 mpg
CBD - 4.10 mpg ÷ 1.0233 = 4.01 mpg
Total - 4.28 mpg ÷ 1.0204 = 4.19 mpg

This was the second bus tested. The runs shown above are 6 out of a total of 12.

DIESEL DIVISION IDLE FUEL CONSUMPTION

Date: 11/22/82

	Fuel Consumption		
Run No.	GM of Canada	Control Bus	T/C
1	3.65	3.70	0.9865
2	3.65	3.70	0.9865
3	3.70	3.70	1.0000
Average			0.9910

Control Bus Idle Fuel Consumption

0.541 gallon/hour

Diesel Division Adjusted Idle Fuel Consumption

0.541 gallon/hour x 0.9910 = 0.536 gallon/hour

NEOPLAN FUEL ECONOMY DETERMINATION

Seated Load Weight

Neoplan Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	12-07-82	11.20	14.35	29.65	55.20	1:34:46
2	12-07-82	10.85	14.95	29.40	55.20	1:35:25
3	12-07-82	11.85	13.15	29.20	54.20	1:34:15
4	12-08-82	10.75	14.25	29.90	54.90	1:35:36
5	12-14-82	11.10	14.50	30.00	55.60	1:35:38
6	12-16-82	11.40	16.05	27.80	55.25	1:36:11

Control Bus No. 626 Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	12-07-82	9.80	14.55	23.65	48.00	1:37:07
2	12-07-82	10.25	14.35	23.45	48.05	1:36:38
3	12-07-82	9.85	14.30	23.30	47.45	1:37:40
4	12-08-82	10.10	14.35	23.25	47.70	1:37:13
5	12-14-82	10.45	14.85	24.00	49.30	1:36:12
6	12-16-82	10.15	14.65	23.80	48.60	1:35:44

Valid T/C Ratios

Run No.	Date	Commuter	Arterial	CBD	Total
1	12-07-82	1.1429	.9862	1.2537	1.1500
2	12-07-82	1.0585	1.0418	1.2537	1.1488
3	12-07-82	1.2030	.9196	1.2532	1.1423
4	12-08-82	1.0644	.9930	1.2860	1.1509
5	12-14-82	1.0622	.9764	1.2500	1.1278
6	12-16-82	1.1232	1.0956	1.1681	1.1368
Average		1.1090	1.0021	1.2441	1.1428

Neoplan MPG Adjusted to Control Bus No. 626

Commuter - 5.57 mpg ÷ 1.1090 = 5.02 mpg
Arterial - 3.71 mpg ÷ 1.0021 = 3.70 mpg
CBD - 4.10 mpg ÷ 1.2441 = 3.30 mpg
Total - 4.28 mpg ÷ 1.1428 = 3.75 mpg

This was the third bus tested. The runs shown above are 6 out of a total of 13.

NEOPLAN IDLE FUEL CONSUMPTION

Date: 12/15/82

Run No.	Fuel Consumption: Neoplan	Control Bus	T/C
1	4.30	3.75	1.1467
2	4.25	3.75	1.1333
3	4.25	3.75	1.1333
Average			1.1378

Control Bus Idle Fuel Consumption

0.541 gallon/hour

Neoplan Adjusted Idle Fuel Consumption

0.541 gallon/hour x 1.1378 = 0.616 gallon/hour

GILLIG FUEL ECONOMY DETERMINATIONS

Seated Load Weight

Gillig Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	12-14-82	9.95	13.40	27.40	50.75	1:36:02
2	12-14-82	10.40	13.45	27.60	51.45	1:35:22
3	12-14-82	10.10	13.20	27.45	50.75	1:36:11
4	12-16-82	9.90	13.30	27.00	50.20	1:35:07
5	12-16-82	9.90	13.40	27.35	50.65	1:33:37
6	12-16-82	9.85	13.30	27.00	50.15	1:33:12

Control Bus No. 627 Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	12-14-82	12.85	15.95	31.05	59.85	1:32:02
2	12-14-82	12.80	15.75	31.10	59.65	1:31:55
3	12-14-82	13.10	16.40	29.50	59.00	1:32:06
4	12-16-82	13.00	16.90	30.35	60.25	1:31:40
5	12-16-82	12.75	15.80	31.50	60.05	1:31:30
6	12-16-82	12.50	15.70	31.05	59.25	1:31:39

Valid T/C Ratios

Run No.	Date	Commuter	Arterial	CBD	Total
1	12-14-82	.7743	.8401	.8824	.8480
2	12-14-82	.8125	.8540	.8875	.8625
3	12-14-82	.7710	.8049	.9305	.8602
4	12-16-82	.7615	.7870	.8896	.8332
5	12-16-82	.7765	.8481	.8682	.8435
6	12-16-82	.7880	.8471	.8696	.8464
Average		.7806	.8302	.8880	.8490

Gillig MPG Adjusted to Control Bus No. 626

Commuter - (5.57 mpg ÷ .7806) x .7925 = 5.65 mpg
Arterial - (3.71 mpg ÷ .8302) x .9252 = 4.13 mpg
CBD - (4.10 mpg ÷ .8880) x .7790 = 3.60 mpg
Total - (4.28 mpg ÷ .8490) x .8207 = 4.14 mpg

This was the fourth bus tested. The runs shown above are 6 out of a total of 6.

GILLIG IDLE FUEL CONSUMPTION

Date: 12/15/82

	Fuel Consumption		
Run No.	Gillig	Control Bus	T/C
1	4.15	3.75	1.1067
2	4.25	3.75	1.1333
3	4.25	3.75	1.1333
Average			1.1244

Control Bus Idle Fuel Consumption

0.541 gallon/hour

Gillig Adjusted Idle Fuel Consumption

0.541 gallon/hour x 1.1244 = 0.608 gallon/hour

GRUMMAN FLXIBLE FUEL ECONOMY DETERMINATION

Seated Load Weight

Grumman Flxible Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	01-03-83	11.90	14.45	23.80	50.15	1:35:36
2	01-03-83	12.15	14.35	23.70	50.20	1:35:44
3	01-03-83	11.70	14.45	23.55	49.70	1:35:40
4	01-04-83	11.90	14.30	24.20	50.40	1:34:57
5	01-04-83	11.95	14.40	24.40	50.75	1:35:28
6	01-04-83	11.85	14.30	24.35	50.50	1:35:19

Control Bus No. 627 Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	01-03-83	13.30	15.50	29.85	58.65	1:32:37
2	01-03-83	12.40	15.40	30.40	58.20	1:32:36
3	01-03-83	12.35	15.40	30.45	58.20	1:32:00
4	01-04-83	12.55	15.55	30.80	58.90	1:31:50
5	01-04-83	12.55	15.45	30.95	58.95	1:31:38
6	01-04-83	12.35	15.45	30.50	58.30	1:31:52

Valid T/C Ratios

Run No.	Date	Commuter	Arterial	CBD	Total
1	01-03-83	.8947	.9323	.7973	.8551
2	01-03-83	.9798	.9318	.7796	.8625
3	01-03-83	.9474	.9383	.7734	.8540
4	01-04-83	.9482	.9196	.7857	.8557
5	01-04-83	.9522	.9320	.7884	.8609
6	01-04-83	.9595	.9256	.7984	.8662
Average		.9470	.9299	.7871	.8591

Grumman Flxible MPG Adjusted to Control Bus No. 626

Commuter - (5.57 mpg ÷ .9470) x .7925 = 4.66 mpg
Arterial - (3.71 mpg ÷ .9299) x .9252 = 3.69 mpg
CBD - (4.10 mpg ÷ .7871) x .7790 = 4.06 mpg
Total - (4.28 mpg ÷ .8591) x .8207 = 4.09 mpg

This was the fifth bus tested. The runs shown above are 6 out of a total of 6.

GRUMMAN FLXIBLE IDLE FUEL CONSUMPTION

Date: 12/31/82

Fuel Consumption

Run No.	Grumman Flxible	Control Bus	T/C
1	4.10	3.70	1.1081
2	4.05	3.80	1.0658
3	4.10	3.80	1.0790
Average			1.0843

Control Bus Idle Fuel Consumption

0.541 gallon/hour

Grumman Flxible Adjusted Idle Fuel Consumption

0.541 gallon/hour x 1.0843 = 0.587 gallon/hour

GMC TRUCK AND COACH FUEL ECONOMY DETERMINATION

Seated Load Weight

GMC Truck and Coach Fuel Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	01-06-83	11.75	12.90	28.80	53.45	1:29:35
2	01-06-83	10.85	13.70	29.10	53.65	1:29:26
3	01-11-83	11.85	13.70	29.50	54.05	1:29:28
4	01-11-83	10.75	13.65	29.25	53.65	1:28:42
5	01-13-83	10.65	13.70	29.00	53.35	1:28:27
6	01-13-83	10.50	13.50	29.50	53.50	1:28:09

Control Bus. No. 627 Consumption (lbs.)

Run No.	Date	Commuter	Arterial	CBD	Total	Run Time
1	01-06-83	12.25	15.40	30.20	57.85	1:31:53
2	01-06-83	12.50	15.25	30.05	57.80	1:31:52
3	01-11-83	12.70	15.65	30.75	59.10	1:31:56
4	01-11-83	12.65	15.50	30.45	58.60	1:31:32
5	01-13-83	12.05	15.15	30.55	57.75	1:31:19
6	01-13-83	12.30	15.20	30.50	58.00	1:31:22

Valid T/C Ratios

Run No.	Date	Commuter	Arterial	CBD	Total
1	01-06-83	.9592	.8377	.9536	.9239
2	01-06-83	.8680	.8984	.9684	.9282
3	01-11-83	.8543	.8754	.9594	.9146
4	01-11-83	.8498	.8806	.9606	.9155
5	01-13-83	.8838	.9043	.9493	.9238
6	01-13-83	.8537	.8882	.9672	.9224
Average		.8781	.8808	.9598	.9214

GMC RTS MPG Adjusted to Control Bus 626

Commuter - (5.57 mpg ÷ .8781) x .7925 = 5.03 mpg
Arterial - (3.71 mpg ÷ .8808) x .9252 = 3.90 mpg
CBD - (4.10 mpg ÷ .9598) x .7790 = 3.33 mpg
Total - (4.28 mpg ÷ .9214) x .8207 = 3.81 mpg

This was the sixth bus tested. The runs shown above are 6 out of a total of 12.

GMC TRUCK AND COACH IDLE FUEL CONSUMPTION

Date: 12/31/82

	Fuel Consumption		
Run No.	GMC RTS	Control Bus	T/C
1	4.30	3.70	1.1622
2	4.35	3.80	1.1447
3	4.35	3.80	1.1447
Average			1.1505

Control Bus Idle Fuel Consumption

0.541 gallon/hour

GMC Truck and Coach Adjusted Idle Fuel Consumption

0.541 gallon/hour x 1.1505 = 0.622 gallon/hour