NREL/TP-421-5264 • UC Category: 335 • DE93010047

Data Collection Plan for Phase 2 Alternative Fuels Bus Data Collection Program

Final Report

T. Krenelka
Battelle Columbus Laboratory
Columbus, Ohio

NREL technical monitor: R. Motta

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
Operated for the U.S. Department of Energy
by Midwest Research Institute
under Contract No. DE-AC02-83CH10093

Prepared under subcontract no. YZ-2-12170-1

July 1993

NOTICE

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price: Microfiche A01
Printed Copy A03

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issue of the following publications which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

Printed on recycled paper

Contents

Section 1.0

Introduction

This document constitutes the plan for collecting and reporting data associated with a special set of transit bus demonstrations to be conducted under the Urban Bus Program of the 1988 Alternative Motor Fuels Act (AMFA). This program, called the Phase 2 Bus Data Collection Program, serves as an adjunct to the Phase 1 Bus Data Collection Program. The Phase 1 program collects basic data on many hundreds of buses; this Phase 2 program collects detailed data on just a few buses. This program is intended to augment and enhance the Phase 1 data in fulfilling the urban bus requirements of AMFA. These Phase 2 demonstrations will be conducted at a few transit system locations throughout the United States and will involve a variety of alternative fuels and associated technologies directed toward reducing undesirable transit bus exhaust emissions. Several organizations will be involved in the data collection aspect of this Phase 2 program, and each will have specific roles and responsibilities. The National Renewable Energy Laboratory (NREL) in Golden, Colorado, will manage the program, as well as analyze and store the operating, performance, and emissions data on the vehicles. The data will be made available to the public through the Alternative Fuels Data Center at NREL. The resulting information will enable individual transit agencies, equipment manufacturers, fuel suppliers, and government policy makers to make informed decisions about buying and using alternative fuel buses.

1.1 Background

Congress established the Urban Bus Program as part of AMFA. The program involves the U.S. Department of Energy (DOE), the Environmental Protection Agency (EPA), and the Federal Transit Administration (FTA). Because FTA is the agency most closely involved in urban transit buses through its funding, research, and policy activities, it has been assigned the lead role in the bus program by an interagency agreement between DOE and FTA. The program is closely integrated with FTA's existing Clean Air Program (CAP). The CAP includes the Alternative Fuels Initiative (AFI), which is funding the purchase of more than 1,000 alternative fuel buses nationwide.

Phase 1 of the Urban Bus Program was structured to gain basic information from the CAP demonstrations with a minimal disruption to the normal operations of the transit agencies participating in the study. This Phase 2 program is designed to gather more detailed data from a few selected transit agencies that have agreed to incur somewhat more disruption to participate in this special program.

1.2 Purpose

The purpose of this data collection plan is to define the specific data elements to be collected and the responsibilities of the organizations participating in the Phase 2 Bus Data Collection Program.

1.3 Overview

The Phase 2 program will involve about ten buses at each of four to six demonstration sites. This program will be carried out by transit bus operators participating in FTA's CAP. The bus engine technology and fuel used at the selected sites will provide a current representative sample of the state of the art. Each individual demonstration will consist of a number of alternative fuel test buses operating in regular revenue service under closely monitored conditions. Likewise, a number of diesel buses, also operating in revenue service, will be used as a control population for each demonstration. The operating transit agency will collect and report data from both the test buses and the control buses. Most of the buses will also be tested for emissions and some will be track tested for performance. A subcontractor to NREL will coordinate all activities of the transit agencies as well as the emissions and track testing and report the data to NREL. The transit agencies will receive clerical or other support as required from the subcontractor to help defray the cost of participating in the program.

The program activities are described in Section 2.0 of this plan. The roles and responsibilities of the participants are outlined in Section 3.0. The details of the data reporting activities are given in Section 4.0.

Section 2.0

Program Activities

Data will be collected in four major areas: initial vehicle description, in-service performance, exhaust emissions, and performance in track tests.

2.1 Initial Vehicle Description

At the start of the program, the operator will fill out a complete bus specification sheet, bus route description, and fuel dispenser description (Appendix A). This will be updated any time an item on this sheet changes, or when a major modification is made to the engine/fuel system.

2.2 In-service Data Collection

The test and control buses will be used in normal daily service at the transit agencies. Data will be collected on the buses in service to observe the actual impact of the alternative fuel on maintenance, reliability, cost, emissions, fuel economy, and safety. The data collection activity will be extensive in order to make the results useful to the broader transit and engineering communities.

The transit agencies will collect data from their existing operating, dispatching, maintenance, and fueling systems. These existing systems will be enhanced by a few special data collection procedures. Table 1 shows all the data items that will be collected from the in-service demonstrations. The in-service data will be collected and reported weekly.

2.2.1 Maintenance Data

The data collected will be coded by the subcontractor according to the type of maintenance—scheduled, unscheduled, or road call. The work done and parts replaced will also be coded in a standard format (to be approved by NREL) to facilitate data inquires to the NREL data base. This will allow data retrieval by specific area - for example, a data query into all unscheduled maintenance on the fuel injection system of the methanol versus the diesel buses.

2.2.2 Fuel Data

In addition to fuel fill data being recorded, one sample of each alternative fuel and one sample of the diesel fuel will be taken from the fuel dispenser and tested each month. Tests will be selected from those shown in Appendix B.

2.2.3 Oil Data

Oil samples will be taken from at least one of each type of alternative fuel vehicle and one control vehicle from each site. Each time the oil is changed, a sample of oil will be taken and tested. Tests will be selected from those shown in Appendix C. Oil samples will be taken within 15 minutes of engine shutdown and in mid-stream during the oil drain.

Table 1. In-service Data Collection

Type of Data	Frequency Recorded	Data Items
Maintenance data	For each work order:	Shop order number
		Repair description
		Type of maintenance - Scheduled - Unscheduled - Road call
		Labor hours
		Date of repair
		Odometer reading
		Parts replaced - code
		Parts cost
		Work done - code
		Date removed from service
		Date returned to service
Fuel data	Each time a bus is fueled:	Type and amount of fuel
		Odometer reading
		Date
	Each month:	One sample of alternative fuel and diesel fuel analyzed per Appendix B
Oil data	Each time oil is added:	Make, type, and viscosity of oil
		Amount of oil
		Odometer reading
	Each time oil is changed:	Make, type, and viscosity of oil
		Amount of oil
		Odometer reading
		Oil sample (select vehicles only)
Vehicle deficiency report	At each problem occurrence:	Standard driver report completed

Table 1. In-service Data Collection (concluded)

Type of Data	Frequency Recorded	Data Items
Bus route and operating cycle data	Each day:	Daily route assignments for each bus
	Each week: (select buses only)	Data from an on-board computer (supplied by the subcontractor, installed by transit agency with engineering support from the subcontractor and vendor)
Safety data	As needed:	Number and nature of each accident or incident involving the test or control buses, including collisions, maintenance incidents, etc.

2.2.4 Vehicle Deficiency Report

The use of a vehicle deficiency report form is to be determined. If appropriate, the bus driver will fill out a driver's report form only on days when a performance problem is experienced. The contents of this report will be decided between the transit agencies, the subcontractor, and NREL.

2.2.5 Bus Route and Operating Cycle Data

Each day the route number will be recorded for each bus in the program. On-board data acquisition systems that provide more precise bus route/duty cycle data will be tested in Houston and may be expanded to other transit agencies based on the results there.

2.2.6 Safety Data

All safety incidents involving accidents, maintenance, refueling, or operation of the buses will be recorded and coded by incidence type for ease of retrieval. A description of the incident should also be included.

2.3 Emissions Testing

West Virginia University (WVU) has developed a transportable emissions testing facility that will be used to measure the exhaust emissions of the buses in this Phase 2 program. Both alternative fuel buses and diesel control buses will be tested. WVU is under contract to DOE to operate this facility for the AMFA program.

The facility consists of a chassis dynamometer built into a flatbed semitrailer, and a laboratory trailer containing the emissions measurement equipment. WVU will drive the emissions test facility to the transit agency site and provide a staff to operate the equipment. The facility must be used indoors. The equipment is designed so that the bus is parked perpendicular to the

flatbed in a "tee" shape. As a result, the equipment occupies the equivalent of three bus lanes when in use.

The facility is capable of testing one bus each day. Considering set-up time and the desired number of buses, testing will require approximately 3 weeks at each site. Testing will be performed approximately once each year at each site. WVU will determine the schedule for testing at each site in cooperation with the transit agencies.

NREL will determine test fuel specifications later. The subcontractor will procure the test fuel and arrange for a fuel analysis if required.

The emissions test will measure carbon monoxide, particulates, oxides of nitrogen, hydrocarbons, methane, carbon dioxide, and formaldehyde. WVU will report the test results to the host transit agency and to this Phase 2 program through the NREL Alternative Fuels Data Center.

2.4 Track Testing

During the 3-year course of this Phase 2 program, some of the alternative fuel buses and control buses will be track tested. The buses will be transported to the Transportation Research Center (TRC) of Ohio test track. The TRC staff will test the buses under tightly controlled conditions for some or all of the following tests: acceleration, fuel economy, noise, and stability in a lane change. In general, stability tests will only be run on buses where major modifications have been made that would significantly alter the center of gravity of the bus. The subcontractor's engineers will supervise track testing at TRC in order to verify compliance with testing protocols and to make any minor adjustments to standard test protocols that may be required. The subcontractor will pay all expenses related to shipping and testing the buses, using NREL funds for this program. The test results will be reported to the transit agency and NREL.

2.4.1 Track Test Protocols

The protocols for track testing of the alternative fuel buses are based on Society of Automotive Engineers (SAE) procedures and FTA guideline specifications. The protocols have been used successfully by the subcontractor to evaluate a compressed natural gas (CNG) bus in 1991.

2.4.1.1 Test Vehicle Preparation. The vehicles will be prepared for testing by performing routine maintenance checks of fluid levels and tire pressures, installing and calibrating test instruments, and ballasting the coach to the manufacturer's seated load weight. The bus will be warmed up for approximately 1 hour prior to the first test run of the day.

2.4.1.2 Fuel Economy Test. Fuel economy will be measured by operating over the Advanced Design Bus (ADB) duty cycle. The length of the TRC 7.5-mile test track is not an even fraction of the 14-mile ADB cycle. The SAE J1321 test usually doubles the ADB cycle to 28 miles. Accurate execution of the cycle would require four partial laps of the TRC track, each starting and stopping at a different point. By adding 2 miles to the SAE J1321 procedure, the complexity of the markers for the start-stop cycles is greatly reduced, and the probability of driver error is greatly reduced. The change is accomplished by increasing the start-stop cycle length of 2 of the 97 central business district (CBD) cycles by 50%.

For gaseous fuel vehicles, the procedure will be to install a removable portable fuel tank for use in the test. The tank will be weighed before and after each test run. Pressure measurements will be made at the connecting lines to account for fuel in the lines. Previous tests of CNG buses have shown that the fuel in the connecting lines has about a 1% effect on the fuel economy results. This effect will be measured so that a correction can be applied to remove the 1% error.

2.4.1.3 Acceleration. The bus acceleration will be tested on the straightaways of the TRC 7.5-mile test track. The test will be performed at seated load weight, at full throttle, and at operating temperature. Procedures will be used to avoid torque converter stall. The test track section has a grade of 0.228% (2.75 inches in 100 feet). Runs will be made upgrade and downgrade and the results averaged, which will compensate for the slope.

2.4.1.4 Top Speed. Top speed will be measured during the acceleration test. Full throttle will be maintained for each test run until a steady speed is achieved.

2.4.1.5 Gradeability. Gradeability will be calculated from acceleration curves. The acceleration test data above 20 mph will be used, and the gradeability acceleration data will be used below 20 mph. The gradeability acceleration runs use a different throttle/brake procedure. This is done to eliminate throttle decay effects. The gradeability is calculated by the instantaneous acceleration at various speeds. A 3% mass correction is applied to account for rotational inertias.

2.4.1.6 Steady-state Cornering. The test will be performed by driving a 100-foot radius circle and a 400-foot circle on the TRC Vehicle Dynamics Area (skid pad). The test will be performed at seated load weight, in both steering directions. The bus will be kept centered on the painted circle and vehicle speed will be gradually increased until the maximum safe speed is reached. The results show vehicle speed, steering wheel angle, lateral acceleration, and roll angle.

2.4.1.7 Transient Cornering. This test uses the results of the steady-state cornering test. The steering wheel angle found in the 100-foot radius test is used here. The test will be performed at the TRC Vehicle Dynamics Area. The vehicle is stabilized at 22.5 mph, then the driver applies the steering wheel angle as quickly as possible. The steering wheel angle and speed will be held constant for at least 5 seconds. Results measured will be speed, steering wheel angle, lateral acceleration, roll angle, roll rate, and yaw rate. The test will be repeated using a speed of 45 mph and the steering wheel angle from the 400-foot radius steady-state cornering test.

2.4.1.8 Obstacle Avoidance. This test will be a double lane change maneuver performed at the TRC Vehicle Dynamics Area. The lane width will be 12 feet and the gate spacing will be 100 feet. The test will be performed at seated load weight and at constant speed. The speed will be gradually increased on successive runs to determine the maximum speed at which the vehicle can negotiate the course. The result is the maximum speed.

2.4.1.9 Exterior Noise. This test will be performed at the TRC Noise Pad. This surface complies with the requirements of SAE J366 Exterior Sound Level for Heavy Trucks and Buses Test Procedure. The test will be performed with all vehicle accessories running, with no ballast added to the vehicle. Noise will be measured at 50 feet from the vehicle, perpendicular to its longitudinal centerline, on both sides of the vehicle.

2.4.1.10 Stationary High Idle Noise. This test will place the sound meter directly beside the rear bumper of the vehicle. The vehicle will be stationary with the transmission in neutral, with noise measured when the engine idle switch is in both the "low" and "high" positions.

2.4.1.11 Full Throttle Pull-away Noise. This test will be performed with the sound meter directly beside the front bumper of the vehicle, with the vehicle stationary. The vehicle will be accelerated past the meter at full throttle and the maximum sound level recorded.

2.4.1.12 Full Throttle Upshift Noise. This test will be performed using the course described in SAE J366. The vehicle will be accelerated from a standstill at full throttle. The course will be arranged so that the rear bumper passes the sound meter just as the transmission shifts from first gear to second gear. The maximum noise level will be recorded.

2.5 Engineering and Scientific Support

Throughout the 3-year duration of this Phase 2 program, there will be an ongoing need for engineering and scientific services. This support will be provided by the subcontractor to NREL in two areas: fast-response problem solving and analysis, and reporting on program results. Fast-response problem solving is expected to be needed for any of several reasons. The transit agencies may require assistance in solving small technical problems, as might TRC in its track testing or WVU in its emissions testing. The subcontractor will provide this support as needed to facilitate all aspects of this program. This may include laboratory analysis of fuel samples; electron microscopy of used parts; analysis of parts failure; or expert engineering comment on designs or testing protocols.

The subcontractor will analyze the program results and write technical reports about the program for NREL's review. Technical presentations and briefings will be provided as requested by NREL.

2.6 Data Analysis Reports

Throughout the duration of the Phase 2 program, the subcontractor will prepare biannual data analysis reports for NREL. These reports will summarize all of the data available; present comparisons for reliability, safety, fuel economy, and cost; discuss the vehicle configurations; explain and describe any unusual phenomenon observed at each site; and present findings and conclusions. In cooperation with the subcontractor, NREL will determine the exact content of the reports. Table 2 shows the measures that will be used to characterize the vehicles in the Phase 2 program.

2.7 Data Base Services

The detailed results of this Phase 2 program will be stored by NREL in the Alternative Fuel Data Center (AFDC). The data center is the focus for all data archiving activities. All the data generated by AMFA activities are stored at the data center, including the results of this Phase 2 program.

Table 2. Measures Used to Characterize Test and Control Vehicles

Safety Profile

Incidents classified by

- Severity (minor, moderate, serious)
- Location (road, station)
- Activity (maintenance, driving, refueling storage)
- Hazard type (spill, fumes, fire, skin exposure)

Number of incidents (per million miles), number of injuries, and effect on operations will be reported. Results of track tests will also be discussed for safety implications.

Maintenance Profile

Labor hours per unscheduled work orders
Unscheduled labor hours per 1,000 miles
PM[(a)] labor hours per 1,000 miles
Labor hours per PM action
Total maintenance labor hours per 1,000 miles
Schedule maintenance cost per 1,000 miles
Total maintenance cost per 1,000 miles

Reliability Profile

Number of in-service breakdowns
Miles between breakdowns
Miles between unscheduled work orders
Number of unscheduled work orders
Rank order of failure modes and parts replacements
Miles between particular failures
Vehicle availability (down time)
Fuel analysis

Performance Profile

Operational performance

- Results from drivers' surveys
- Route performance
- Fuel consumption and cost

Duty cycles

- Route characterization by trip recorder and route activity reports

Durability Profile

Engine oil analyses

Emissions Profile

- Chassis dynamometer test results

[(a)]PM = Preventive Maintenance

Section 3.0

Roles and Responsibilities

The roles and responsibilities of the primary participants in the Phase 2 program are described below and summarized in Figure 1.

3.1 U.S. Department of Energy

DOE is responsible for carrying out the activities mandated by AMFA. DOE is the major source of funding for the Phase 2 data collection activity and will provide technical information and support for the use of alternative fuels in transit buses. The DOE Office of Transportation Technologies is the focal point for the DOE efforts in this program.

3.1.1 National Renewable Energy Laboratory

NREL is supporting DOE by managing and administering this Phase 2 program. NREL will also include the data from this program in its AFDC. NREL, therefore, has two major roles in this Phase 2 program. First, it is the government's program manager for this effort. Second, it maintains the results of this effort in its data bases at the data center.

The technical contact for this program at NREL is:

Mr. Robert C. Motta
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
Phone: (303) 231-7882
FAX: (303) 231-7815

3.1.2 Subcontractor

The subcontractor to NREL is responsible for planning and accomplishing the data collection activities as well as analyzing and reporting the data to NREL. To carry out this role, the subcontractor will interact directly with the transit agencies involved in this program. The subcontractor will be responsible for assembling all program data collected by the transit agencies, analyzing that data, preparing technical reports, and disseminating information as requested by NREL. The subcontractor will provide the reduced data as well as all raw data to NREL on a weekly basis. The subcontractor will conduct some special studies and tests that are planned for the buses. The subcontractor will also provide general engineering and scientific services to the transit agencies and other program participants as needed to solve technical problems with the buses; install and use special measuring instruments; and explain unusual phenomenon observed in the demonstration. The subcontractor, therefore, has the major role of principal investigator in this Phase 2 effort. As such, the subcontractor is responsible for planning and coordinating the data collection activities, ensuring the timely delivery of high quality data to NREL's AFDC, analyzing data and reporting results, and controlling the work of TRC and other Phase 2 lower tier subcontractors.

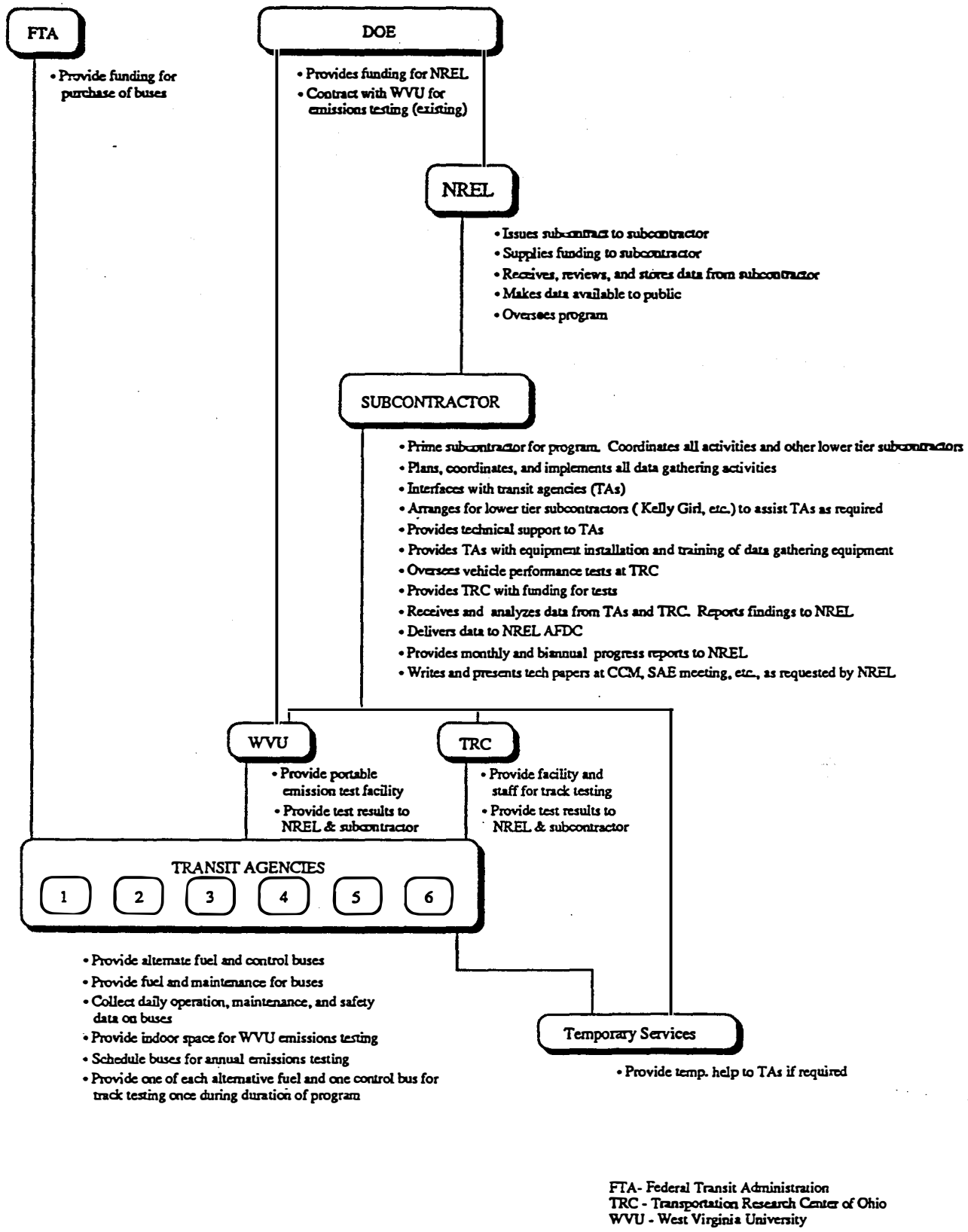

Figure 1. Functional organization of the Phase 2 program

3.2 Transit Agencies

Four to six transit agencies will be involved in this Phase 2 program. These transit agencies have two major roles. First, they will provide the buses, facilities, and staff to operate the alternative fuel test buses and the diesel control buses in revenue service. Likewise, the transit agencies will provide all service and maintenance of the buses and related equipment and facilities. Second, the transit agencies will be responsible for collecting the daily operational data on the buses and reporting it to the subcontractor each week. In addition, the transit agencies are responsible for making the demonstration buses available to DOE for emissions testing and for accommodating the portable emission test facility once a year. The transit agencies are also responsible for making one alternative fuel bus, as well as one control bus, available for track testing on one occasion.

3.3 Federal Transit Administration

Through its existing CAP, FTA will provide funds for capital acquisition of buses and facilities needed for the demonstrations and participation in the Phase 2 program. The focal point within FTA for these activities is the Office of Engineering Evaluations.

Section 4.0

Data Reporting

Data will be collected and reported in four streams. First, the transit agencies will collect detailed data on their demonstration buses and report these data to the subcontractor each week. Second, the subcontractor will compile and process the transit agency data each week and report them to NREL in a standard format to be approved by NREL. Third, WVU will report emissions test data to the subcontractor and NREL as they become available. Fourth, NREL, and the subcontractor, if requested by NREL, will provide data and reports back to the government, the transit industry, the technical community, and the public.

NREL will maintain on file the original data submission documents sent to the subcontractor by the transit agencies.

4.1 Transit Agency Data Reporting

Each transit agency participating in the Phase 2 program will submit detailed data about its demonstration. These data will be submitted in two basic types of reports: an initial demonstration description report, and weekly in-service reports. Data concerning both the alternative fuel test buses and the diesel control buses must be reported by individual bus, not by summaries of the demonstration fleet.

4.1.1 Data Reporting Schedule

The participating transit agencies will submit their initial demonstration description report at the beginning of the demonstration period. The subcontractor will assist the transit agencies in this effort as needed. These are one-time submittals unless revisions are made to the demonstration fleet, facilities, or procedures. In such case, the nature of the revisions will be reported at the time they are implemented in the next weekly report.

The weekly in-service reports are to be submitted to the subcontractor within 3 days following the end of the week being reported.

4.1.2 Data Reporting Format

The format for the weekly data report will be defined later by mutual agreement between NREL and the transit agencies.

4.1.3 Data Reporting Items

Two types of data will be reported: an initial description and weekly in-service data.

4.1.3.1 Initial Demonstration Description Report. The transit agency will complete Appendix A describing the buses (the subcontractor will assist as required). The transit agency will also provide a description of the refueling facility as well as a description of the bus routes and preventive maintenance schedule.

4.1.3.2 Weekly In-service Data Reporting Items. The data to be reported by the transit agencies in their weekly reports are contained in Table 1. These are primarily related to normal operations and maintenance data of the demonstration buses, including usage of consumables and maintenance activities.

4.1.4 Data Reporting Points of Contact

The subcontractor will designate a single primary point of contact for interacting with the transit agencies.

Each transit agency is to designate a single primary point of contact for all data reporting associated with its demonstration. This contact will serve as the interface between the transit agency and other program participants.

4.2 Subcontractor Data Reporting to NREL

The information received by the subcontractor from the transit agencies and others participating in the program will be reviewed for quality and put into a standard electronic format suitable as input to the NREL data center. Any feedback to the transit agencies on poor quality data will also be conveyed to NREL. All raw data supplied by the transit agencies will also be forwarded to NREL. The subcontractor will also submit a brief (one page) monthly status report to NREL covering data collection progress to date and any outstanding issues.

4.2.1 Data Reporting Schedule

The subcontractor will report data to NREL on a weekly basis. Each report will cover a calendar week of data collection and reporting by the participating transit agencies. These will be submitted within 7 days following the subcontractor's receipt of the data from the transit agency.

The reporting of special tests will be accomplished by the subcontractor as soon as practical after the tests.

4.2.2 Data Reporting Format

The subcontractor will provide weekly reports to NREL electronically and in writing in a format that NREL will supply. The electronic report will be transmitted to NREL by cc:mail. The files will be in the PARADOX format, with one file for each reporting period. In addition, a text file will be transmitted, which contains a list of the data file names transmitted and their size. Every data file will have the same format and field names. Changes to the format will only be made with NREL's approval.

4.2.3 Data Reporting Items

Corresponding copies or originals of all data obtained in this program will be sent to NREL along with the electronic data. The subcontractor will release data obtained only to NREL.

4.2.4 Data Reporting Points of Contact

The subcontractor to NREL will designate a primary contact for interacting with NREL.

NREL's point of contact for the AFDC is:

Mr. Kenneth J. Kelly
National Renewable Energy Laboratory
Alternative Fuels Data Center
1617 Cole Boulevard
Golden, CO 80401-3393
Telephone: (303) 231-1165
FAX: (303) 231-7815

4.3 Emissions Data Reporting

WVU staff will provide data to NREL and the subcontractor about the vehicle emissions tests that they will conduct throughout the duration of the Phase 2 program. These tests are expected to encompass a variety of alternative fuel and diesel buses.

4.3.1 Emissions Testing Schedule

WVU will test the Phase 2 buses approximately once each year. The exact testing schedule will be set by WVU in cooperation with the transit agency.

4.3.2 Data Reporting Schedule

WVU's submittal of emissions testing results to the subcontractor will be made as soon as practical following the completion of testing at each transit agency. We recognize that WVU will require time to collect the raw data from the field and review and process it to determine vehicle emissions levels.

4.3.3 Data Reporting Format

WVU will choose the format it uses to report emissions test results to the subcontractor. The format used by the subcontractor to report the data to NREL will be defined by NREL and the subcontractor at the time of the first submission.

4.3.4 Data Reporting Items

The data reported must address three basic areas of interest: a description of the buses, engines, or other equipment tested; the conditions and protocols of the specific tests conducted; and the results of the tests.

Appendix A

Initial Demonstration Description

Engine Lubricating Oil

Transit Agency_____
Bus Number_____
Bus Manufacturer_____ Model_____
Vehicle Identification Nu ber (VIN)_____
Date of Purchase_____
Accumulated Mileage at Start of Demonstration_____

Bus Dimensions	
Length, feet	
Width, inches	
Height, inches	
Wheel base	
Gross vehicle weight rating, pounds	
Front axle	
Rear axle	
Total	
Curb weight, pounds	
Front axle	
Rear axle	
Total	
Seated load weight	
Front axle	
Rear axle	
Total	
Passenger Seats	
Number of passenger seats with no wheelchairs on board	
Number of wheelchair positions	
Number of passenger seats with all wheelchair positions occupied	
Maximu nu ber of standees	
Fuel	
Type(s):	
Necessary additives:	

Engine	
Original equipment or retrofit?	
Manufacturer	
Model number	
Year of manufacture	
2-cycle or 4-cycle?	
Compression ratio	
Ignition aids used? (yes/no)	
Type of ignition aid (spark plug, glow plug, pilot charge, other)	
EPA certified? (yes/no)	
Power rating	
Maximum bhp	
RPM of maximum bhp	
Maximum torque (foot pounds)	
RPM of maximum torque	
Blower? (yes/no)	
Turbocharger? (yes/no)	
Liquid fuel delivery systems:	
Mechanical or electronic fuel injectors?	
Injector manufacturer	
Injector model number	
Number of fuel filters	
Fuel filter manufacturer	
Fuel filter model	
Gaseous fuel delivery systems:	
Direct injection or fumigation?	
Throttle for intake air? (yes/no)	
Original equipment or retrofit?	
Engine Accessories:	
Generator:	
Output at normal idle	Amps____ Volts____
Maximum rating	Amps____ Volts____

Starter type (electrical/air):	
Manufacturer	
Model	
Hydraulic pump:	
Manufacturer	
Model	
Output (gpm @ psi)	
Heating and air conditioning:	
Heating system type:	
Capacity, Btu/h	
Air conditioning:	
Manufacturer	
Model	
System capacity, Btu/h	
Air compressor:	
Manufacturer	
Model number	
Capacity, cubic ft/min	
Drive Train:	
Transmission:	
Manufacturer	
Model number	
Year of manufacture	
Number of forward speeds	
Torque converter multiplication	
Optional features	
Retarder:	
Manufacturer	
Model number	
Brakes, Type:	
Manufacturer	
Drive axle:	
Manufacturer	

Model number	
Axle ratio(s)	
Tires:	
Manufacturer	
Model	
Size	
Fuel Storage System:	
Number of tanks:	
Maximum working pressure: (Gaseous fuels only)	
Total useful amount of fuel:	
Tank manufacturer:	
Tank model(s):	
Total empty weight of tank(s):	
Safety Equipment:	
Fire detection:	
Manufacturer	
Model number	
Year of manufacture	
Sensor type	
Number of sensors	
Fire Suppression:	
Manufacturer	
Model number	
Year of manufacture	
Amount of agent	
Type of agent	
Number of discharge points	
Vapor detection:	
Manufacturer	
Model number	
Year of manufacture	
Amount of agent	

Sensor type	
Number of sensors	
Alarm threshold (% lower explosive limit)	
Other attributes or features: (Wheelchair lifts, wheelchair position, bicycle racks, any items that make this bus different from the other test or control buses)	

Bus Route Description

- Route number
- City, highway, or mixed
- Flat, hilly, or mixed
- Distance
- Number of scheduled bus stops
- Estimated average route time
- Calculated average speed
- Estimated average passenger loading (20, 40, etc.)

Refueling Station Description

- Fuel
- Fueling rate (gal/min, scfm/min)
- On-site facility (Y/N)
- Ownership (transit agency, fuel company, etc.)
- Address
- Date in service (if known)
- Type of nozzle connection (CNG/LNG* only)
- Filtering equipment description (if any)
- Name and phone number of contact person
- Operating pressure (CNG only)
- Fuel storage capacity

* LNG: liquefied natural gas

Appendix B

Fuel Analysis Testing Procedures

Diesel Fuel[1]

ANALYSIS	TEST PROCEDURE
Flash point	ASTM D 93
Cloud point	ASTM D 2500
Water and sediment content	ASTM D 1796
Carbon residue	ASTM D 524
Ash	ASTM D 482
Distillation	ASTM D 86
Viscosity	ASTM D 445
Sulfur content	ASTM D 129
Corrosion	ASTM D 130
Cetane number	ASTM D 613
Color	ASTM D 1500
Gravity/density	ASTM D 287 or D 1298
Pour point	ASTM D 97
Wax point	ASTM D 3117
Oxidation stability	ASTM D 2274
Rust protection	ASTM D 605

[1] These analyses are described in greater detail in "Specification for Diesel Fuel Oils," ASTM D 975. See also "Diesel Fuels," SAE J313.

Methanol, Ethanol, 85% Blends[1]

ANALYSIS	TEST PROCEDURE
Total acids	ASTM D 1613
Suspended solids	ASTM D 2276
Vapor pressure	ASTM D 4814
Copper content	ASTM D 1688
Phosphorus content	ASTM D 3231
Manganese content	ASTM D 3831
Water and sediment	ASTM D 1796
Lead content	ASTM D 3237
Gravity/density	ASTM D 287 or D 1298
Hydrocarbon content[2]	ASTM D 1319
Chlorine	ASTM D 808 or D 1317
Sodium	ASTM D 811

1 See also "Specification for Spark-Ignition Automotive Engine Fuel," ASTM D 4814; "Alternative Automotive Fuels," SAE J1297, and "Impacts of Alternative Fuels on Engine Test and Reporting Procedures," SAE J1515.

2 For alcohol/hydrocarbon blends.

Note: Specifications and analytical test procedures for 99.85% pure methanol are given in "Standard Specifications for Methyl Alcohol," ASTM D 1152. However, this standard has apparently been made without special consideration of methanol as an automotive fuel and thus should not be used instead of, but in addition to, ASTM D 4814.

Methane (Natural Gas)[1]

ANALYSIS	TEST PROCEDURE
Heating value	ASTM D 1826
Total sulfur content	ASTM D 3031
Specific gravity	ASTM D 1070
Hydrogen sulfide and mercaptan sulfur	ASTM D 2385, D 2727, or D 4084
Non-condensible gases	ASTM D 2504
Methane, CO_2, N_2, He, C_2, C_3, and higher hydrocarbon contents	ASTM D 1945
Water content	ASTM D 1142

[1] See "Alternative Automotive Fuels," SAE J1297, and "Impacts of Alternative Fuels on Engine Test and Reporting Procedures," SAE J1515.

Appendix C

Oil Analysis Testing Procedures

Engine Lubricating Oil[1]

ANALYSIS	TEST PROCEDURE
Solids (percent volume)	ASTM D 893
Glycol content	ASTM D 2982
Fuel dilution	ASTM D 322 or D 3525 (gasoline), ASTM D 3524 (diesel fuel)
Engine oil viscosity and viscosity index	SAE J300; ASTM D 445 and D 2161; ASTM D 2270
Total base number (TBN)/total acid number (TAN)	ASTM D 2896
Spectrochemical analyses (wear metals, solubles)[2]	no ASTM or SAE method
Flash point	ASTM D 92
Water dilution	ASTM D 95
Cloud point	ASTM D 2500
Carbon residue	ASTM D 524
Appearance and odor	Chevron (see "Testing Used Engine Oils")
API gravity	ASTM D 287/API 2544
Pour point	ASTM D 97
Ash content	ASTM D 874

[1] See "Specification for Automotive Engine Oils," ASTM D 4485, and "Physical and Chemical Properties of Engine Oils," SAE Information Report J357, for more detailed information about the purpose of the tests and how they are to be conducted.

[2] This includes Fe, Cr Pb, Cu, Sn, Al, Ni, Ag, Mn, Si, B, Ba, Mg, Ca, Ba, P, Zn, Mo, Ti, V, and Cd.

Appendix D

Conversion Factors

Converting American Units to SI Units

TO CONVERT FROM	TO	MULTIPLY BY
Btu/h	watts	0.2931
horsepower	watts	745.7
cubic feet	cubic meters	0.02832
feet	meters	0.3048
foot pounds	kilogram meters	0.1383
inches	centimeters	2.540
miles	kilometers	1.609
pounds	kilograms	0.4536
psi	kilogram/square meter	703.1

Document Control Page	1. NREL Report No. TP-421-5264	2. NTIS Accession No. DE93010047	3. Recipient's Accession No.

4. Title and Subtitle
Data Collection Plan for Phase 2 Alternative Fuels Bus Data Collection Program

5. Publication Date
July 1993

6.

7. Author(s)
T. Krenelka

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Battelle Columbus Laboratory
505 King Avenue
Columbus, Ohio 43201

10. Project/Task/Work Unit No.
FU311010

11. Contract (C) or Grant (G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401

13. Type of Report & Period Covered
Subcontractor report

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This document constitutes the plan for collecting and reporting data associated with a special set of transit bus demonstrations to be conducted under the Urban Bus Program of the Alternative Motor Fuels Act (AMFA) of 1988. This program, called the Phase 2 Bus Data Collection Program, serves as an adjunct to the Phase 1 Bus Data Collection Program, collecting detailed data on just a few buses to augment and enhance the Phase 1 data in fulfilling the urban bus requirements of AMFA. Demonstrations will be conducted at a few transit system locations throughout the U.S. and will use alternative fuels and associated technologies to reduce undesirable transit bus exhaust emissions. Several organizations will be involved in the data collection; NREL will manage the program, analyze and store vehicle data, and make these data available through the Alternative Fuels Data Center. This information will enable transit agencies, equipment manufacturers, fuel suppliers, and government policy makers to make informed decisions about buying and using alternative fuels.

17. Document Analysis

a. Descriptors
alternative fuels, alternative fueled vehicles, transit buses, Alternative Motor Fuels Act

b. Identifiers/Open-Ended Terms

c. UC Categories 335

18. Availability Statement
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

19. No. of Pages
30

20. Price
A03

Form No. 0069E (6-30-87)