CleanFleet

FINAL REPORT

December 1995

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Glossary

AFV	=	Alternative fuel vehicle
ARB	=	California Air Resources Board
Btu	=	British thermal unit
C	=	Degrees Celsius
CAAA	=	Clean Air Act Amendments of 1990
CFM	=	Cubic feet per minute
CNG	=	Compressed natural gas
CO	=	Carbon monoxide
Control vehicle	=	A CleanFleet van using regular unleaded gasoline for daily operations or RF-A gasoline for emissions tests. Control vehicles are the baseline for the CleanFleet project
EPA	=	U.S. Environmental Protection Agency
EPACT	=	Energy Policy Act
EV	=	Electric vehicle
FFV	=	Flexible fuel vehicle
Fleet	=	A unique combination of vehicle manufacturer and fuel in the CleanFleet project
GEQ	=	Gasoline equivalent gallons
GVWR	=	Gross vehicle weight rating
HC	=	Hydrocarbons
kg	=	Kilograms
kPa	=	KiloPascal. 6.895 kPa = 1 psi.
kWh	=	Kilo-Watt-hour
L	=	Liter
Lbs	=	Pounds

Glossary
(Continued)

LEV	=	Low emission vehicle (LEV emission standard)
M-85	=	Fuel consisting of 85 percent methanol and 15 percent RFG by volume
Max	=	Maximum
Mi	=	Mile
Min	=	Minimum
MJ	=	MegaJoules
Ni-Cd	=	Nickel-cadmium
NO_x	=	Nitrogen oxides (sum of nitric oxide and nitrogen dioxide)
OEM	=	Original equipment manufacturer
PRO	=	Propane gas or liquefied petroleum gas
Psi	=	Pounds per square inch
RAF	=	Reactivity adjustment factor
RF-A	=	Unleaded gasoline used in CleanFleet control vans only for the emissions tests to serve as a baseline. RF-A is an industry average gasoline
RFG	=	California Phase 2 reformulated gasoline blended for the CleanFleet project
Therm	=	100,000 Btu
TLEV	=	Transitional low emission vehicle
ULEV	=	Ultra-low emission vehicle
UNL	=	Regular unleaded gasoline sold commercially and used to power CleanFleet control vans in daily operations
Vol	=	Volume
Wt	=	Weight
ZEV	=	Zero emission vehicle

PROJECT DESIGN AND IMPLEMENTATION

The CleanFleet alternative fuels demonstration project evaluated five alternative motor fuels in commercial fleet service over a two-year period. The five fuels were compressed natural gas, propane gas, California Phase 2 reformulated gasoline (RFG), M-85 (85 percent methanol and 15 percent RFG), and electric vans. Eight-four vans were operated on the alternative fuels and 27 vans were operated on gasoline as baseline controls. Throughout the demonstration information was collected on fleet operations, vehicle emissions, and fleet economics. In this volume of the CleanFleet findings, the design and implementation of the project are summarized.

Introduction

Alternative motor fuels are viewed by some policy makers as potentially viable options for addressing two problems facing the transportation sector of the United States economy. First, they are said by some to be “clean burning” fuels; and, as such, they could be used to reduce emission levels significantly from vehicles optimized to operate on them. Dramatic reductions in emissions are being mandated in urban areas across the nation that are not in compliance with the health-based national ambient air quality standard for ozone. Standards for carbon monoxide and concerns for greenhouse gases and “air toxic” emissions also must be addressed. Second, alternative fuels that are not derived from petroleum could provide more diversity for energy sources and reduce the country's dependence upon foreign oil. In spite of this potential, in the early 1990s a dearth of objective, practical information existed on the operational, emissions, and economic effects of using the leading available alternative fuel options.

Introducing alternative motor fuels into the economy requires the availability of reliable supplies of the fuels and vehicles built to use them. Both fleet operators and individuals must have confidence in the safety, reliability, and performance of the vehicles. Also, alternative fuel vehicles (AFVs) and the fuels themselves must be economically viable. In the 1990 time frame when the CleanFleet project was developed, the requisite conditions cited above did not exist; several critical gaps existed in the information base available to policy makers, fleet operators, vehicle manufacturers, and fuel suppliers. Among these gaps were the following:

- Objective, comparable data on the operations, emissions, and economics of several alternative fuel technologies

- Comprehensive sets of detailed operations and speciated emissions data on a significant number of vehicles over a sufficient period of time to provide meaningful results

- Consistent information on employee acceptance, training requirements, and safety practices; and on local building code and fire marshall practices.

To address these needs, the CleanFleet project was designed to demonstrate and document the operational, emissions, and economic status of alternative fuel, commercial fleet delivery vans in the early 1990s for meeting air quality regulations in the mid to late 1990s. The project was designed to provide information on “daily, real-world, commercial operations” using AFV technologies that could be put into FedEx delivery service for a two-year period.

Six fuels were initially considered for study in CleanFleet as alternative fuels capable of being used in FedEx operations in the 1992 to 1994 time frame: compressed natural gas (CNG), propane gas (also called liquefied petroleum gas), California Phase 2 reformulated gasoline (RFG), methanol (M-85, 85 percent methanol and 15 percent RFG), ethanol (E-10, E-85, or ethyl tert-butyl ether (ETBE and RFG)), and electric vehicles (EVs). Five fuels were demonstrated (the ethanol industry declined to support the demonstration of an ethanol fuel). The choice of these fuels reflects the status of AFV technology and the driving forces of air quality and energy diversity.

Definitions of alternative fuels vary depending upon whether the driving force is primarily environmental or energy diversification. The Clean Air Act Amendments (CAAA) of 1990 delineate federal emission standards and clean fuel requirements.[(1)] Emission standards are set to prescribed levels without specifying motor fuels. The CAAA also provide for introduction of clean-fueled vehicles in the regions of the country classified as serious, severe, and extreme non-attainment areas for ambient ozone. The CAAA define the following fuels as clean alternative fuels: methanol, ethanol, other alcohols, reformulated gasoline, reformulated diesel (for trucks), natural gas, propane gas, hydrogen, and electricity. California's Low Emission Vehicle program sets a series of emission standards that are stricter than the federal standards.[(2)] California defines alternative fuels as including methanol, ethanol, natural gas, propane gas, electricity, or other clean-burning fuels.

Energy diversity drives alternative fuels from the federal level. The Alternative Motor Fuels Act (AMFA) of 1988 promotes demonstrations of alternative fuels and provides credits to determination of corporate average fuel economy (CAFE) for vehicle manufacturers for every AFV produced.[(3)] AMFA defines alternative fuels as methanol, ethanol, and natural gas.

Subsequently the Energy Policy Act (EPACT) of 1992 provides mandates for acquisition of AFVs by the federal government.[(4)] Provisions for other fleets in state government, alternative fuel providers, and companies in the energy business are also specified. Municipal and private fleets may be covered later. EPACT defines alternative fuels as including natural gas, propane gas, alcohol (methanol, ethanol, other alcohols), blends of alcohols with gasoline or other fuels in which the blend contains at least 85 percent alcohol by volume, hydrogen, fuels derived from biomass, liquid fuels derived from coal, and electricity.

Thus the five alternative fuels demonstrated in CleanFleet are a subset of alternative fuels defined in environmental and energy legislation. They are those fuels that both vehicle manufacturers and fuel organizations agreed to support in FedEx operations in the 1992 to 1994 time frame prior to the effective dates of regulations in the mid to late 1990s.

PROJECT DESIGN AND IMPLEMENTATION

This volume of the CleanFleet Findings describes the project design and implementation.[5,6] Information is provided on the following topics in this volume of report:

- Project Design

  — Experimental design
  — Fuels
  — Vehicles.

- Implementation

  — Fueling infrastructure
  — Building facilities
  — Training
  — Vehicle activity
  — Types of data collected
  — Public outreach
  — Close-out.

Results on operations, emissions, and economics are provided in the remaining volumes, Volumes 3 through 8.

PROJECT DESIGN AND IMPLEMENTATION

Experimental Design

The experimental design for the demonstration had several important features. For fleet operations, they are (1) geographic centralization of vehicles operating on each alternative fuel, (2) number of vehicles, (3) control fleets, (4) treatment of EVs, (5) time frame, and (6) treatment of variables. For emissions tests, they are the substances measured, number of vans tested, effect of mileage, and baseline fuel.

Fleet Operations

The geographic extent of the demonstration is shown in Figure 1. CleanFleet vehicles were operated by FedEx throughout the four counties comprising the South Coast Air Quality Management District. Each fuel was headquartered at a single FedEx location: CNG in Irvine, propane gas in Rialto, RFG in south central Los Angeles, M-85 in Santa Ana, and EVs in Culver City. The restrictions of demonstrating only one alternative fuel per site and only one site per alternative fuel were forced principally by limitations on funding for fueling infrastructure and by the need to simplify business operations for FedEx and for conducting the project.

The experimental design called for demonstrating a sufficient number of vehicles to achieve statistical credibility in findings of the project. In addition, all three major domestic vehicle manufacturers, which had ongoing dealings with FedEx, were invited to participate. As a result of a statistical design process, a minimum of seven identical liquid or gaseous fueled vans from each participating original equipment manufacturer (OEM) was called for.

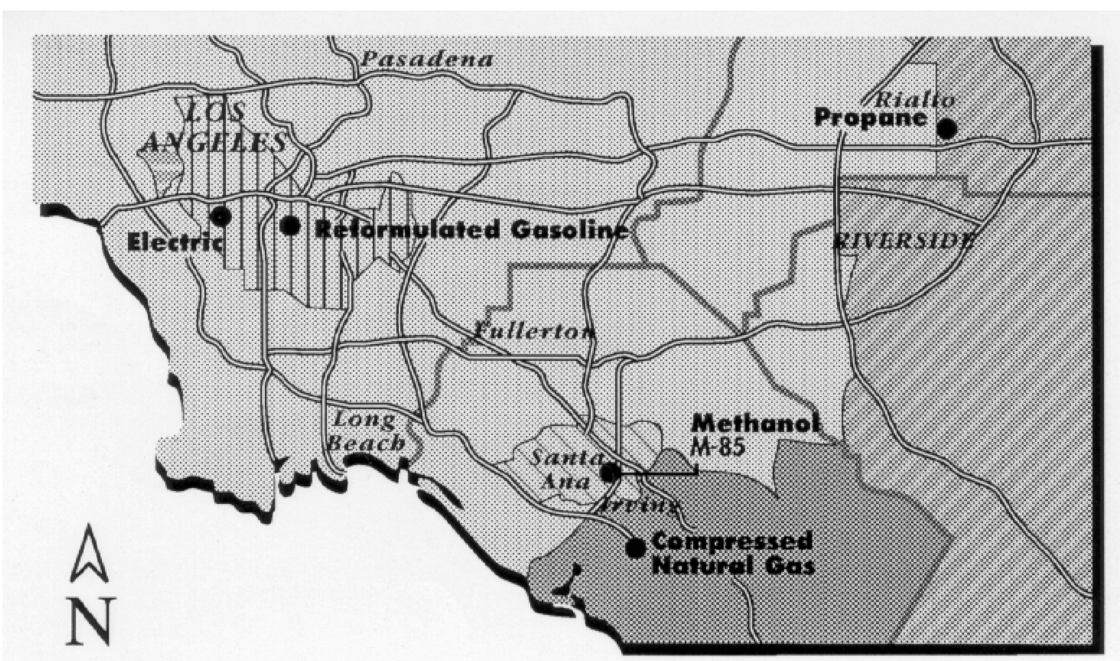


Figure 1. CleanFleet vehicles operated in the South Coast Air Quality Management District.

PROJECT DESIGN AND IMPLEMENTATION

Along with the liquid and gaseous alternative fuel vans from each OEM, control fleets of three standard gasoline vans were used at each site for each OEM to provide a baseline for comparison. The principal comparisons in evaluating results of operations, emissions, and economics were to be for individual alternative fuel fleets compared to their counterpart control fleets. (A fleet is defined in this report as a group of vans from a particular OEM operating on a particular fuel at a particular site.)

Because of the early development status of EVs (both the vans themselves, as well as the chargers), coupled with their cost, only two EVs were evaluated in CleanFleet. Control vans were not used as a baseline in a comparative study of EVs. Rather the EV demonstration was designed to provide information on how well early prototype EVs could meet the needs of a fleet operator in the delivery service business.

All CleanFleet vans were evaluated over about a 24-month period from April 1992 through September 1994. The various fleets were phased into operation as the vehicles and fuels became available. This period of time was judged to be sufficiently long to provide credible information from the project. During this period, information was gathered on operations, emissions, and economics.

Finally, the experimental design addressed the variables that would affect project results. Principal variables to be studied were (1) fuels, (2) vehicle technologies, and (3) daily use (with distance traveled, or mileage, as the indicator of vehicle use). Ancillary variables included effects of weather, site location (e.g., different FedEx practices or delivery and pickup route structures), routes and drivers, and baseline fuel for emissions measurements.

Weather could affect operation of vehicles because of ambient temperatures. As one example, of the five demonstration sites, only vans at Rialto were equipped with air conditioning because of the prevailing temperature differences across the basin. Also, different grades of gasoline are sold in the South Coast Air Basin in summer and winter months. Daily temperatures and precipitation across the South Coast Air Basin were documented from published information in *The Los Angeles Times*. By demonstrating the vehicles over a 24-month period, two annual cycles of weather were encountered; and this was judged to be sufficient to document any important effects of weather on the project results.

Site location was another ancillary variable to be dealt with. Because each alternative fuel was demonstrated at only one site, differences in site characteristics (including FedEx operational practices) could confound comparisons among fuels or even make the project results site-specific. These potential effects were ameliorated by FedEx's uniform business practices across the sites and by use of control vans. Results for the control vans were compared across sites to investigate the possible influence of site characteristics on results. Also, it is important to remember that the principal comparisons were designed to be between alternative fuel fleets and their control fleets at a particular site, not between alternative fuel fleets at different sites.

The effects of different driving routes and drivers were expected to be a significant ancillary variable. The experimental design called for the liquid and gaseous fuel vans to be rotated among delivery routes and drivers at each demonstration site throughout the 24-month demonstration. This was done to even out differences in the effects of different duty cycles on the vans. Each van was driven by from 3 to 6 of drivers on different routes during the demonstration.

The baseline fuel for operations over the 24 months was regular unleaded gasoline purchased according to normal FedEx practice. This fuel varied seasonally, by supplier, and also changed as oxygenate was added to gasoline sold in Los Angeles during the project. The use of this fuel as a "baseline" reflected the practical nature of the project.

Emission Tests

The emission tests were designed to provide information on emissions from in-use vehicles as the vehicles accumulated mileage during the course of the demonstration. Details of the experimental design for the emission tests are provided in Volume 7 of the CleanFleet Findings.

Four classes of substances were measured in vehicle exhaust and evaporative emissions. They were regulated emissions, ozone precursors, air toxics, and greenhouse gases. These measurements provided a comprehensive data set on emissions from all liquid and gaseous fuel vehicles. Because the EVs are classified as zero-emission vehicles, they were not tested for emissions.

Three vans from each fleet were tested for emissions by the California Air Resources Board (ARB) in three rounds of tests as they accumulated mileage. Thus, for each fleet, the tests provided data on emission levels versus mileage. Tests on each vehicle at a particular mileage level were, in general, performed in duplicate to obtain information on the variability of the results due to testing. (As noted in the discussion on the experimental design for fleet operations, regular unleaded gasoline was used in daily operations for the baseline fuel.)

While this variability was deemed acceptable for daily operations, the project sponsors recognized that a more steady baseline would be needed to evaluate changes in emissions from vans over time. Consequently, a standard fuel was selected to be used in the control vans for emissions measurements. This fuel was the industry average fuel (designated as RF-A) used in the Auto/Oil Air Quality Research Improvement Program.[(7)] It is also the standard gasoline used by the ARB for emission measurements. The AFVs were tested with the fuels used in daily operations.

PROJECT DESIGN AND IMPLEMENTATION

Fuels

The objectives of the fuel supply activity of the CleanFleet project were to provide a reliable supply of each alternative fuel to the various vehicle fleets, to monitor key fuel properties for fuel quality and consistency, to gather the data necessary to determine the energy content, and to allow for collection of data on the quantity of fuel dispensed into each van.

Fuel Supply Strategies

The fuel supply strategies were chosen first and foremost to maintain a reliable supply for FedEx operations. Towards this end a secondary source of supply was identified for each alternative fuel, which would allow FedEx to maintain fleet operations in case the primary source of supply was interrupted. This was particularly important for the CNG and propane gas fleets because these AFVs were dedicated vehicles; they only could operate on the fuel they were built for. Consistent with FedEx custom, all CleanFleet vehicles at the demonstration sites were fueled on the premises.

The fuel supply strategies were also chosen to fulfill CleanFleet requirements. These requirements included maintaining the desired fuel specifications and allowing the collection of fuel data for CleanFleet reporting.

Natural Gas

The natural gas supplied to the compressor was pipeline quality gas as supplied by the Southern California Gas Company. After the CleanFleet project began, the ARB established a specification for natural gas used as a transportation fuel. The major gas composition limits of the ARB specification are given in Table 1. The natural gas delivered to the CleanFleet project met this specification. Characteristics of the natural gas used in the demonstration are provided in Table 2.

Table 1. Major ARB Composition Limits for Compressed Natural Gas Fuel

Fuel Property	Specification Value (Volume Percent)
Methane	88 min.
Ethane	6.0 max.
C_3 and higher HC	3.0 max.
C_6 and higher HC	0.2 max.
Sum of CO_2 and N_2	1.5 - 4.5 range

Table 2. Characteristics of CNG

Parameter	Units	Mean	Relative Standard Deviation (%)[c]
Methane	Vol %	94.62	1.49
Ethane	Vol %	2.09	NR
Propane	Vol %	0.48	NR
n-butane	Vol %	0.11	NR
Isobutane	Vol %	0.10	NR
Pentanes	Vol %	0.06	NR
Hexanes	Vol %	0.07	NR
Nitrogen	Vol %	1.39	NR
CO_2	Vol %	1.08	NR
Heating value, net	MJ/kg	47.3	1.28
Density	kg/m^3	0.722	1.36
Specific gravity [a]		0.589	2.52
Wobbe Index[b]	MJ/m^3	44.4	1.13

[a] With respect to air.
[b] Calculated from heating value and specific gravity.
[c] Relative standard deviation is reported for major components and parameters. NR means not reported.

Propane Gas

The propane gas supplied to the FedEx fleet was HD-5 specification propane gas. Table 3 shows major points of the HD-5 propane fuel specification. The complete HD-5 specification is contained in the American Society for Testing and Materials (ASTM) Standard D 1835.

Table 3. Major HD-5 Specifications for Propane Gas Fuel

Fuel Property	Specification Value
Vapor pressure at 38 C	1,430 kPa max.
Propene content	5 vol. % max.
Butane and heavier	2.5 vol % max.

The average composition of propane gas over the course of the demonstration met the project specifications (Table 4). During the first three months of the demonstration the composition was more variable than during the rest of the demonstration, as illustrated in Figure 2.

Table 4. Propane Gas Characteristics

Parameter	Units	Mean	Relative Standard Deviation (%)
Methane	Vol %	0.20	NR
Ethane	Vol %	5.43	NR
Propane	Vol %	91.88	4.86
Propene	Vol %	0.76	NR
Butanes	Vol %	1.48	NR
C5+[a]	Vol %	0.02	NR
Inerts[b]	Vol %	0.23	NR
Liquid density	kg/L	0.501	1.03
Heating value, net	MJ/kg	46.3	0.49
Wobbe Index[c]	MJ/m^3	69.3	1.29

(a) C5+ is hydrocarbons with five or more carbon atoms.
(b) Inerts include nitrogen, oxygen, and carbon dioxide.
(c) Calculated from heating value and liquid density.

Phase 2 RFG

The reformulated gasoline used in the CleanFleet project was blended by Phillips for Chevron and ARCO to meet California Phase 2 RFG specifications. Table 5 shows the specifications for Phase 2 RFG. Although the CleanFleet RFG blends met California specifications for Phase 2 gasoline, they were not produced entirely from refinery streams expected to be used for production in 1996 and beyond. Consequently, some differences in effects of their use are possible.

The average composition of RFG during the demonstration is shown in Table 6. The two batches produced for CleanFleet differed slightly in composition, but both batches met specifications for Phase 2 gasoline. Selected parameters of the two batches are shown in Table 7.

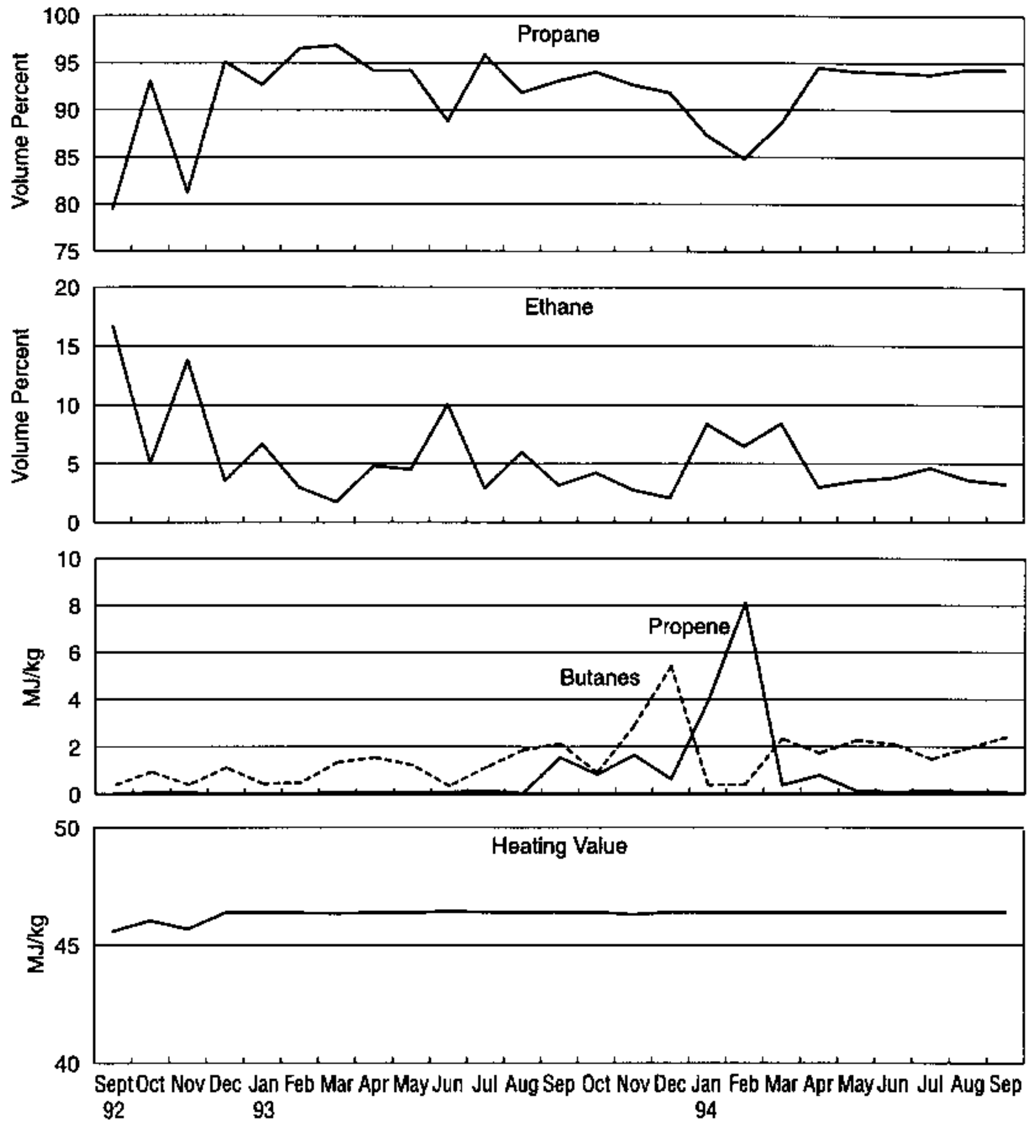


Figure 2. Characteristics of propane gas varied over the course of the demonstration.

M-85

The methanol portion of the M-85 blend was obtained from the California methanol reserve. Fuel in the methanol reserve is intended to meet ARB specifications for M-100 fuel (100 percent methanol). Table 8 summarizes major ARB specifications for fuel methanol. The gasoline portion of the M-85 blend consisted of reformulated gasoline as used by the RFG fleet. CleanFleet was the first demonstration of M-85 with Phase 2 RFG as the 15-percent gasoline (G-15) component. Previous studies involving M-85 used regular gasoline for the G-15 component. Properties of the M-85 throughout the demonstration are summarized in Table 9.

Table 5. Major RFG Fuel Property Specifications

Fuel Property	Specification Value
Reid vapor pressure	48 kPa, max.
Sulfur	40 ppm, max.
Olefins	5 vol. %, max.
Aromatics	20 vol. %, max.
Benzene	1.0 wt. %,, max.
Oxygenate	1.8 - 2.2 wt. % oxygen
T50	100 C, max.
T90	150 C, max.

Table 6. Average Characteristics of RFG

Parameter	Units	Mean	Relative Standard Deviation (%)
Density	kg/L	0.738	0.43
Methanol	Vol %	0.0	NR
Ethanol	Vol %	0.0	NR
MTBE[(a)]	Vol %	10.5	3.94
TBA[(b)]	wt %	0.0	NR
Carbon	wt %	83.9	1.19
Hydrogen	wt %	13.7	2.40
Heating value, net	MJ/kg	42.3	1.73
Reid vapor pressure	kPa	47.5	2.01

(a) MTBE is methyl tert-butyl ether.
(b) TBA is tert-butyl alcohol.

Table 7. Measured Values of Selected Parameters for the Two Batches of RFG

Parameter	Units	Batch 1	Batch 2
Toluene	wt %	14	8.2
Sulfur	ppm	17	36
T90	C	143	148
MTBE	wt %	10.31	10.81
Reid vapor pressure	kPa	47.2	45.5

Table 8. Major ARB Specifications for M-100 Fuel (Methanol)

Fuel Property	Specification Value
Methanol	96 vol. percent min.
Distillation temperature	4.0 C range (must include 64.6 C)
Other alcohols and ethers	2 mass percent max.
Hydrocarbons (gasoline or diesel fuel derived)	2 mass percent max.
Specific gravity	0.792 ± 0.002 at 20 C

Table 9. Characteristics of M-85

Parameter	Units	Mean	Relative Standard Deviation (%)
Density	kg/L	0.787	0.27
Methanol	Vol %	85.4	1.27
Hydrogen[(a)]	wt %	12.7	0.40
Heating value, net	MJ/kg	23.5	2.29
Reid vapor pressure	kPa	50.3	2.52
Particulate loading	mg/L	0.373	NR

[(a)] Calculated from hydrogen content of pure methanol and the measured hydrogen content of RFG.

Vehicles

The delivery vans used in the project were all full-size panel vans. A typical CleanFleet van is shown in Figure 3. The gasoline vans had a gross vehicle weight rating (GVWR) of from 7,200 pounds (Ford) to 7,500 pounds (Dodge) to 8,600 pounds (Chevrolet).

Figure 3. CleanFleet vans were full-size panel vans outfitted for FedEx operations.

The vehicle technologies that were demonstrated were those that the project sponsors agreed to support over a two-year period and that were judged to be sufficiently reliable for the rigors of daily commercial delivery service operations. The 111 CleanFleet vans were comprised of 84 vans operating on alternative fuels and 27 vans operating on a baseline gasoline for purposes of comparison. Each van was dedicated to a particular fuel.

The vehicle technologies represented various stages of development and optimization for the fuel each operated on. They represented a "snap-shot" in time in terms of technology development. As summarized in Table 10, the 111 CleanFleet vans can be categorized broadly into three groups: OEM production vans, OEM-modified vans, and after-market modified vans. OEM-modified vans refer to vans modified by the OEMs to operate on an alternative fuel and sold to FedEx as AFVs. After-market modified vans refer to vans sold to FedEx by the OEMs as gasoline vans (although equipped with gaseous-fuel-compatible engines) and then modified with alternative fuel systems by other organizations for the project. For this project, the OEMs played an active role in selecting the organizations to modify the vans. The electric vans were owned by Southern California Edison and leased to FedEx for a nominal sum for use in the project.

Table 10. Number of Vehicles Demonstrated in Different Vehicle Technology Classifications

Fuel	OEM	After-Market Modified With IMPCO Systems ADP	AFE	OEM-Modified	OEM-Production
CNG	Ford			7	
	Chevrolet		7		
	Dodge				7
Propane Gas	Ford	13			
	Chevrolet		7		
RFG	Ford				7
	Chevrolet				7
	Dodge				7
M-85	Ford			20	
Unleaded Gasoline	Ford				12
	Chevrolet				9
	Dodge				6
Electric[a]	Vehma G-Van				
	Lead-acid	2			
	Nickel-cadmium	1			

[a] There were two EVs in the project. Each began the demonstration equipped with lead-acid batteries. One van was removed from service, and nickel-cadmium batteries were installed in it.

The 21 CNG vans included seven vans from each category of development. The 20 propane gas vans were all after-market modifications. The 21 RFG and 27 control (i.e., unleaded gasoline) vans were all OEM production vans. The 20 M-85 vans were prototype vans modified under Ford's direction. Finally, the two EVs, one of which was evaluated with two types of batteries, were vans modified to operate as EVs. Thus, the assortment of vans demonstrated in CleanFleet represents a variety of technologies both in terms of development and optimization for the fuels they operated on.

Vehicle Specifications

All CleanFleet vans met FedEx's normal specifications for its fleet, including ancillary equipment such as communications systems. All Ford vans were Econoline E-250 panel vans with 4.9-liter, in-line, six-cylinder engines. The Chevrolet vans were all G30 vans with either 5.7-liter, V-8 engines for the two gaseous fuels or 4.3-liter, V-6 engines for the gasoline vans. The Dodge vans were all model B350 vans equipped with 5.2-liter, V-8 engines. Specifications for the vans are summarized in Appendix A. In

Table 11. Characteristics of Engines and Fuel Systems in the CleanFleet Vans

Vehicle Manu-facturer	Engine					Fuel Delivery[d]	Special Materials[g]
	Fuel[a]	Displace-ment (liters)	Type[b]	Horse-power[c]	Compression Ratio		
Ford	M-85	4.9	I6	N/A	8.8	SMPI	HVS
	Propane Gas	4.9	I6	N/A	8.8	TB[e]	HV, HESI
	CNG	4.9	I6	N/A	11	SMPI	HVSI
	RFG/UNL	4.9	I6	150	8.8	MPI	None
Dodge	CNG	5.2	V8	200@ 4,000 rpm	9.08	SMPI	HVSI
	RFG/UNL	5.2	V8	230	9.08	SMPI	None
Chevrolet	Propane Gas	5.7	V8	N/A	8.6	TB[f]	HVS, CCR
	CNG	5.7	V8	N/A	8.6	TB[f]	HVS, CCR
	RFG/UNL	4.3	V6	155 @ 4,000 rpm	8.6	TBI	None

(a) CNG = Compressed natural gas, RFG = California Phase 2 reformulated gasoline, UNL = Unleaded gasoline.
(b) I6 = Inline, 6 cylinder.
(c) N/A - Not available, rpm = engine speed in revolutions per minute.
(d) TBI = Throttle body fuel injection, MPI = multiport electronic fuel injection, SMPI = sequential MPI.
(e) IMPCO ADP system provides fuel to the engine through the throttle body.
(f) IMPCO AFE system provides fuel to the engine through the throttle body.
(g) HVS = Hardened valves and seats
HV = Hardened valves
HESI = Hardened exhaust seat inserts
CCR = Chrome compression rings
HVSI = Hardened valve seat inserts.

addition, characteristics of the engines and fuel systems are listed in Table 11. Table 12 contains a summary of the capacity of the various fuel storage systems on board the vehicles. Figures 4 and 5 provide plots of the physical volume and energy equivalent storage on board the vans. Table 13 summarizes the measured weight of the vans. The emission control equipment and status of its certification for each type of van is summarized in Table 14. Pertinent characteristics of the CleanFleet vans are summarized by type of fuel in the remainder of this section.

Compressed Natural Gas. The 21 CNG vans included OEM production vans, OEM-modified vans, and after-market-modified vans. The technology in these vans is summarized below.

Ford. The Ford CNG vans were built especially for CleanFleet. They featured a 4.9-liter, in-line, six-cylinder engine having a limited calibration of a sequential, multi-port, electronic fuel injection system (see Table 11). The compression ratio was 11:1 compared to a value of 8.8:1 for gasoline Ford vans.

Table 12. Characteristics of Fuel Storage On Board the CleanFleet Vehicles

Vehicle Manufacturer	Fuel	Fuel Tank Capacity (liters)
Ford	CNG Propane Gas RFG/UNL M-85	188 98 132 132
Chevrolet	CNG Propane Gas RFG/UNL	249 105 125
Dodge	CNG RFG/UNL	198 132
G-Van	Lead-Acid Nickel-Cadmium	14.7[a]

[a] Volume of the battery pack.

Table 13. Average Measured Weight of CleanFleet Vehicles

Vehicle Manufacturer	Fuel	Weight (kg)	Weight (lbs)
Ford	CNG Propane Gas RFG M-85 UNL	2,623 2,421 2,516 2,506 2,490	5,782 5,337 5,546 5,526 5,490
Chevrolet	CNG Propane Gas RFG UNL	2,478 2,326 2,259 2,248	5,462 5,128 4,980 4,956
Dodge	CNG RFG UNL	2,257/2,323 2,189 2,183	4,975/5,122[a] 4,826 4,812
G-Van	Electric Lead-Acid Nickel-Cadmium	 3,518 3,135	 7,756 6,910

[a] The production Dodge vans weighed about 4,975 pounds after upfitting for FedEx. After the addition of the fourth fuel tank, these vans weighed, on average, 5,122 pounds.

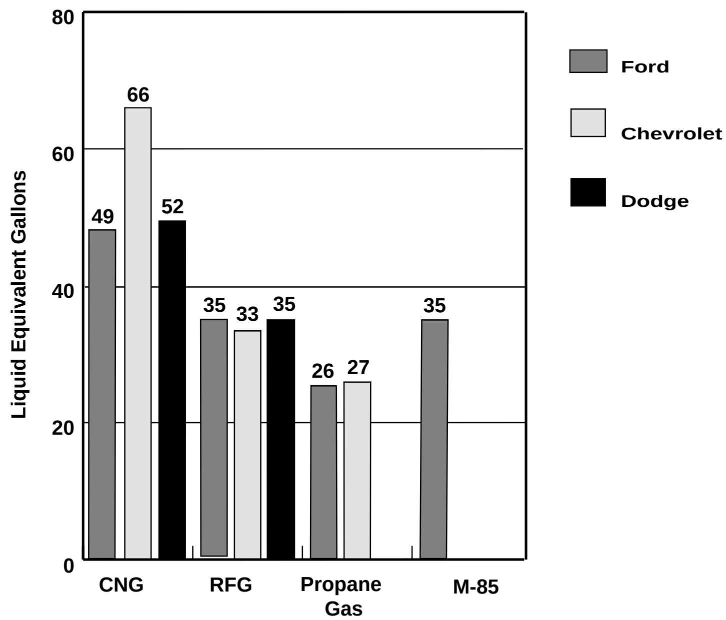


Figure 4. The physical volume of fuel stored on board the CleanFleet vehicles ranged from 26 to 66 gallons.

Fuel capacity was 188 liters (49 gallons) in three steel gas cylinders (see Table 12). The gas cylinders were manufactured by Pressed Steel, and were capable of storing CNG at 3,000 pounds-per-square inch (psi) gauge pressure. Ford provided a steel covering plate underneath the gas cylinders to protect them from damage in case they came in contact with an obstacle (such as a curb) or road debris. This fuel storage capacity was equivalent to 14 gallons of unleaded gasoline on an energy equivalent basis (GEQ). The Ford CNG vans weighed, on average, about 133 kg (292 pounds) more than the Ford gasoline control vans.

The Ford CNG vans were equipped with a standard gasoline catalyst system (see Table 14). The vehicles were operated under an experimental permit from the California ARB.

Chevrolet. The Chevrolet vans were built originally to operate on gasoline, although they featured V8, 5.7-liter engines that were compatible with gaseous fuel in anticipation of their use. Subsequently, these vans were modified to operate on CNG using IMPCO Technologies Inc.'s advanced fuel electronic (AFE) system (see Table 10). This is a microprocessor-based engine management system that controls fuel flow and mixture, spark advance, and exhaust gas recirculation (EGR) functions to provide optimum engine performance. AFE's operational functions interact with the vehicle's OEM on-board computer. The AFE strategy allows the OEM on-board diagnostic routines to remain operational at all times. Fuel was provided to the engine through the throttle body (see Table 11). The compression ratio was not changed during the modification process; it remained at 8.6:1.

A schematic of IMPCO's AFE system is shown in Figure 6. High pressure (up to 3,000 psig) CNG is drawn from the tank through the primary regulator and lockoff valve to the secondary regulator. Natural gas exits the secondary regulator at a pressure of 3.5 inches water column (w.c.). The gas moves through the gas mass sensor to the gas ring, which injects the natural gas into the throttle body and into the engine.

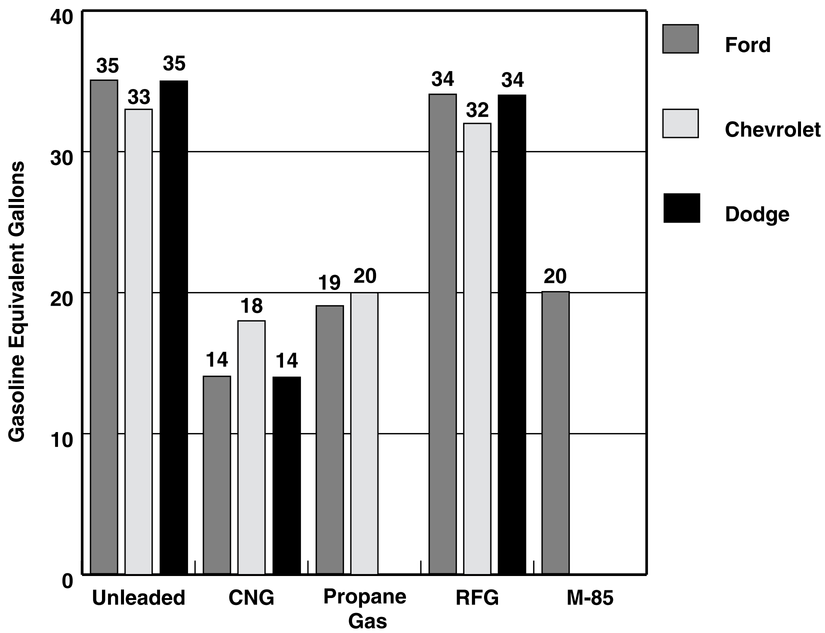


Figure 5. The combined effects of physical storage volume for fuel and energy content yielded a range of equivalent energy storage on board the CleanFleet vehicles.

Table 14. Emission Control Catalysts and Certification Status of CleanFleet Vehicles

Vehicle Manufacturer	Fuel	Catalyst System[(a)]	Class[(b)]	Certification Status
Ford	M-85 Propane Gas CNG RFG/UNL	Gasoline Gasoline Gasoline Gasoline	MD MD MD MD	Exper[(c)] Mod[(d)] Exper 1992[(e)]
Dodge	CNG RFG/UNL	Natural Gas Gasoline	MD MD	1992L[(f)] 1992
Chevrolet	Propane Gas CNG RFG/UNL	Propane Gas[(g)] Natural Gas[(g)] Gasoline	HD HD HD	Exper Exper 1992

(a) Three-way catalyst systems optimized for the fuels listed.
(b) MD = vehicles in California medium-duty class. HD = engines in heavy-duty class.
(c) Vehicles were operated under experimental permits from the ARB. Prior to modification to run on the alternative fuel, the vehicles were a model certified to California 1992 standards for gasoline vehicles (MD) or engines (HD).
(d) Gasoline vehicle modified with ARB-approved kit to run on propane gas.
(e) Certified to California 1992 standards.
(f) Dodge model year 1992 vans were certified to California 1992 standards. The same technology in model year 1993 was certified to low-emission vehicle (LEV) standards.
(g) Engelhard catalysts.

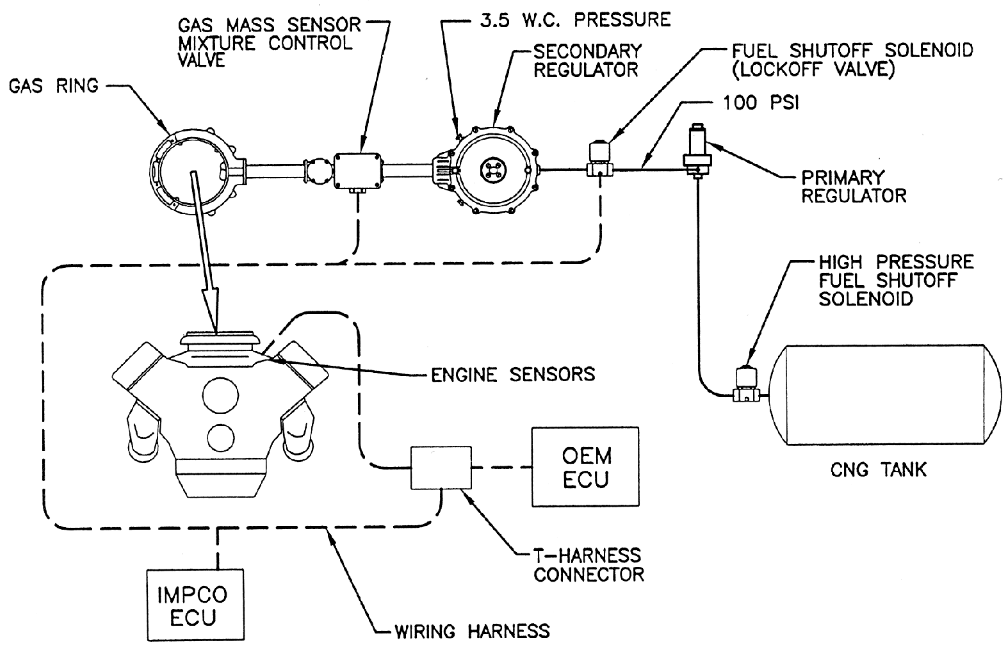


Figure 6. IMPCO's AFE system was used on CleanFleet's Chevrolet CNG vans.

Fuel capacity was 249 liters in three aluminum, fiber glass-wrapped, cylinders. The gas cylinders were manufactured by CNG Cylinders and were capable of storing CNG at 3,000 psig. This fuel storage capacity was equivalent to 18 gallons of unleaded gasoline on an energy equivalent basis. On average, the Chevrolet CNG vans equipped with 5.7-liter V-8 engines weighed about 230 kg (506 pounds) more than the Chevrolet control vans equipped with 4.3-liter V-6 engines.

The Chevrolet CNG vans were equipped with Engelhard catalysts that had been chosen for use with natural gas exhaust. These vans were operated on experimental permits from the ARB.

Dodge. The Dodge CNG vans were among the first production CNG vans offered for sale by Dodge.[(8)] They employed sequential, multi-port fuel injection to the 5.2-liter, V-8 engine.

Fuel was stored in three fully wrapped (Fiberglas), aluminum gas cylinders in the production vans for an equivalent storage capacity of 11 GEQ at 3,000 psig. These cylinders, manufactured by Comdyne, were capable of storing CNG at 3,600 psig, but fuel was stored at 3,000 psig for CleanFleet. This permitted the natural gas fuel compressor and dispenser to operate at the same pressure for vehicles from all three OEMs. On average, the Dodge production vans with three gas cylinders weighed about 74 kg (163 pounds) more than the Dodge control vehicles. Because these vans were found to have a driving range in FedEx operations of only about 80 miles, a fourth fuel storage cylinder was added to them with Chrysler's approval (see Table 12). With the addition of the fourth cylinder, from CNG Cylinders, the fuel storage was increased to 198 liters or 14 GEQ.

The Dodge CNG vans had a catalyst tailored for natural gas exhaust. These vans were certified to California model year 1992 emission standards. A year later the same technology was certified to California's LEV standards (see Volume 7, Vehicle Emissions).

PROJECT DESIGN AND IMPLEMENTATION

Propane Gas. The twenty propane gas vans were all after-market modifications to gasoline vans from Ford and Chevrolet (Table 10) that had been built with engines that were compatible with gaseous fuels (see Table 11). Two generations of IMPCO fuel system technology were used on the vans. The Ford vans were equipped with IMPCO's ADP system, and the Chevrolet vans were equipped with IMPCO's AFE system (which was the same engine management system used on the Chevrolet CNG vans).

Ford. The thirteen Ford propane gas vans had 4.9-liter, in-line, six-cylinder engines that had been prepared for use with a gaseous fuel (Ford's "LP prep package"). IMPCO's adaptive digital processor (ADP) system was added to these vans. The ADP system is a stand-alone, alternative fuel, electronic, closed-loop feedback controller. An electronic controller with a 16-cell block learn memory is designed to provide stoichiometric fuel mixtures when used in conjunction with IMPCO's air/fuel mixer. The ADP controller cannot interact with the OEM's on-board computer. The compression ratio was not changed in the modification process—it remained at 8.8:1.

A schematic diagram of the ADP system is shown in Figure 7. Liquid propane is drawn from the fuel tank through a fuel filter and lock-off valve to the convertor, where it is changed to a gaseous state, and two stages of pressure regulation occur. The first stage regulator reduces the gas pressure to 1.5 to 2 psig, and the second stage reduces it to -1.5 inches of water (-0.05 psig). The propane gas is drawn into the vehicle's throttle body by IMPCO's air/fuel mixer.

The ADP controller uses manifold absolute pressure (MAP) and engine speed (RPM—revolutions per minute) to control gas pressure within the alternative fuel system. The ADP system also uses oxygen sensor input to update fuel system data stored in the adaptive memory. By using stored stoichiometric mixture data, the ADP can instantly adjust the fuel system to meet the required combustion characteristics. The fuel adjustment function is accomplished by sending a duty cycle signal back

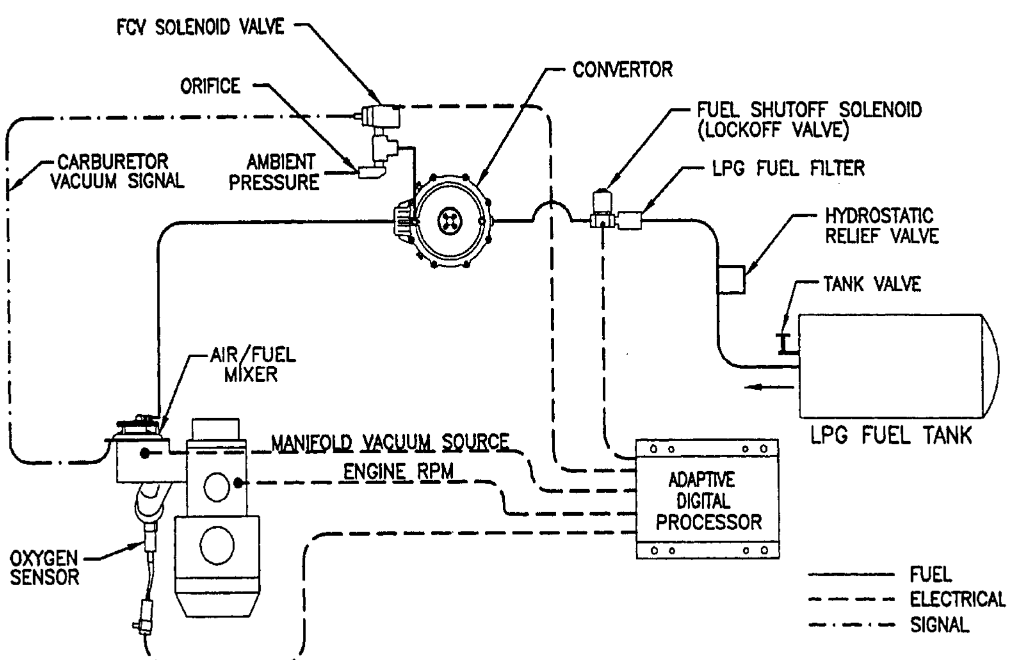


Figure 7. IMPCO's ADP system was used on the Ford Propane gas vans.

from the ADP to the fuel control valve that varies the fuel pressure to the IMPCO feedback mixer. This process will continuously readjust the air/fuel ratio over the entire service life of the vehicle. Block learn memory is also used to compensate for engine wear and degradation.

The Ford propane gas vans were equipped with one steel tank for fuel storage providing 116 liters of gross storage capacity. The fuel tanks were filled to about 85 percent of gross capacity to account for the vapor in the tank, yielding an effective capacity of 106 liters or 19 GEQ. On average, these vans weighed about 69 kg (153 pounds) less than the Ford control vans. The catalyst on these vans was a standard 1992 gasoline catalyst system for California. These vans were operated on permits for the ARB-certified ADP system.

Chevrolet. The seven Chevrolet propane gas vehicles were all 5.7-liter, V-8 engines. IMPCO's AFE system was added to these vehicles during the after-market modification (see Figure 8). The AFE system was described previously in the discussion of the Chevrolet CNG vans.

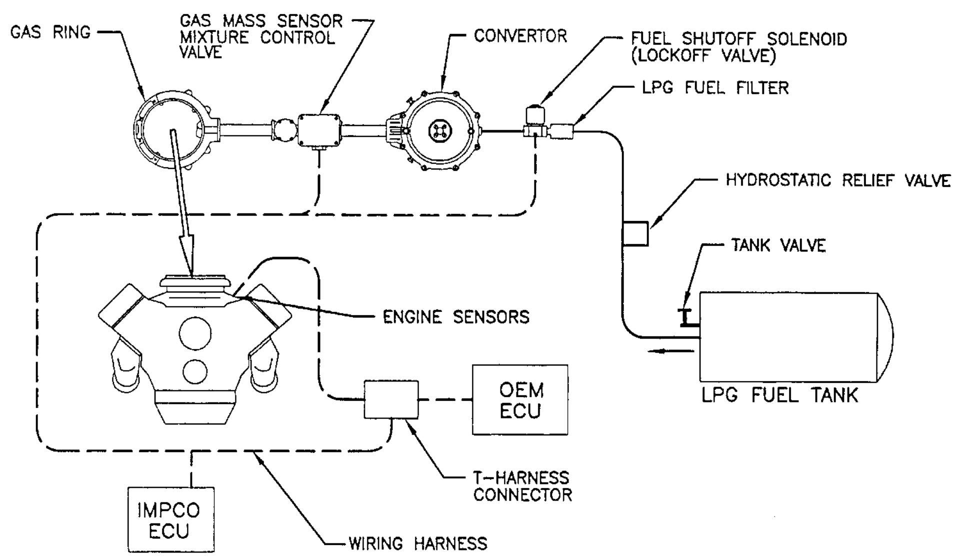


Figure 8. IMPCO's AFE system was used on the Chevrolet propane gas vans.

The Chevrolet vans had twin steel fuel tanks providing 122 gross liters of fuel storage and 21 GEQ of storage capacity at 85 percent of gross volume. On average, the vans, with 5.7-liter engines, weighed about 78 kg (172 pounds) more than the Chevrolet control vans, with 4.3-liter engines. The Engelhard catalyst was chosen specifically for treating exhaust from propane gas. These vans were operated on experimental permits granted by the ARB.

RFG and Unleaded Controls. The vans operating on gasoline were all standard model year 1992 production vans from Ford, Chevrolet, and Dodge. The RFG and control vans from each manufacturer were identical. Differences in average weight between the RFG and control vans are indicative of the variability of the measurements, principally differences in upfitting FedEx equipment and supplies in the individual vans.

The catalysts on these vans were standard model year 1992 catalysts for California. The emission control systems were not optimized for future California LEV standards.

M-85. The twenty Ford M-85 vans were all flexible fuel vehicles (FFVs), and they were a portion of about 200 such vans built by Ford for a California Energy Commission program. They had 4.9-liter, in-line, six-cylinder engines. As FFVs, they could operate on a blend of methanol and gasoline ranging from 85 percent methanol by volume down to zero percent methanol, i.e., gasoline. For the CleanFleet project they were operated on a steady supply of M-85, in which the 15-percent gasoline component was the RFG used in this project.

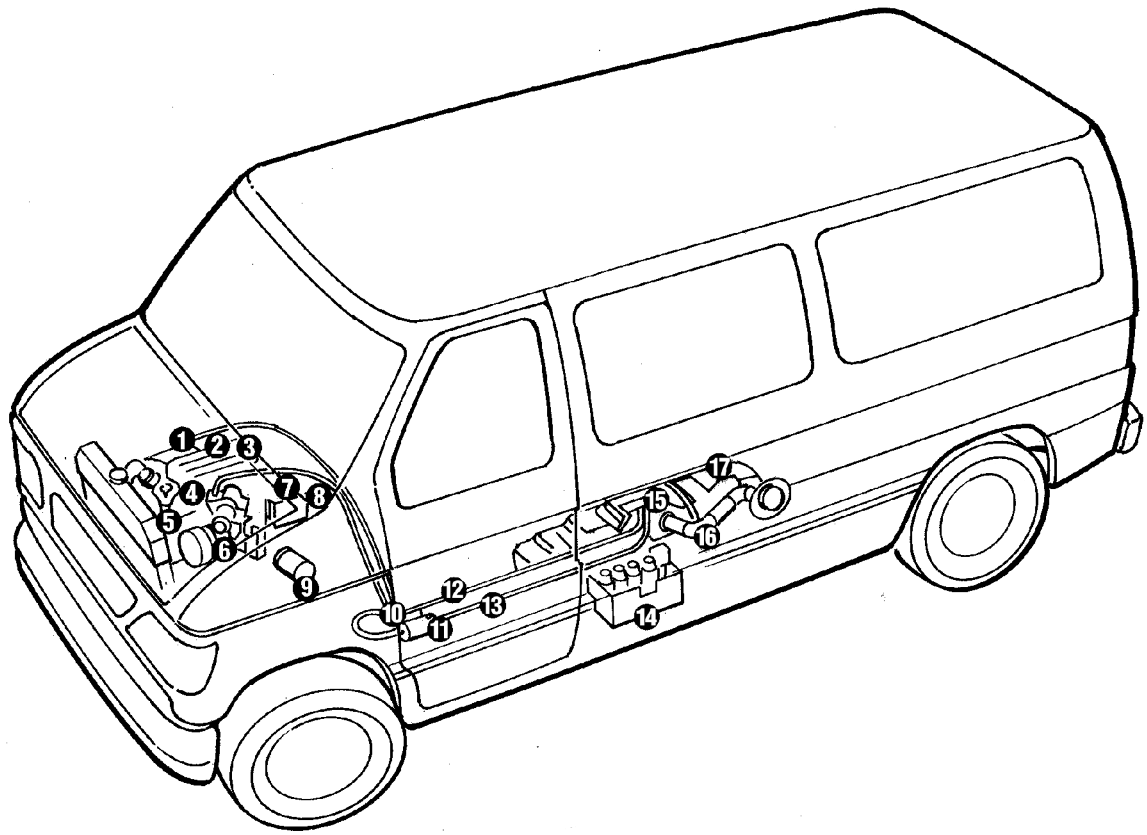
These vans were built as gasoline vans then modified in California to become FFVs. Changes to the vehicles are shown in Figure 9, adapted from Ford.

On average, the M-85 vans weighed about 16 kg (36 pounds) more than the Ford control vans. The M-85 fuel tank had the same capacity as for Ford gasoline control vans--132 liters. For M-85 this was equivalent to 22 GEQ. The catalyst on these vans was a standard model year 1992 catalyst for gasoline exhaust. A catalyst specifically designed to remove formaldehyde in exhaust during cold-start conditions was not used in these vans.

Electric Vehicles. The EVs were full-size vans with a General Motors body style (one-ton Vandura) that had been modified for electric propulsion by Conceptor Corporation, a subsidiary of Vehma International, Inc.[(9)] A schematic of the EVs is shown in Figure 10. They had a GVWR of 8,600 pounds. Note in the figure that these EVs were equipped with an auxiliary heater powered by diesel fuel. These vans were prototype EVs owned by Southern California Edison (SCE) and leased to FedEx for the project. Prior to introduction into service at FedEx they were outfitted with technology current in 1991.

The two EVs began the demonstration equipped with lead-acid batteries from Chloride (3ET205 batteries). The battery pack contained 36, six-volt, lead-acid monoblocks, with a nominal capacity of 205 ampere-hours at a five-hour rate of discharge.[(10)] The battery pack weighed about 1,140 kg, and it had a volume of 14.7 liters. The lead-acid EVs averaged 3,518 kg (7,756 pounds).

A critical component of the EVs was the battery charger. Chargers and batteries are often considered separately; however, for optimum performance these need to be designed and used as a system. Each lead-acid EV was charged using a Chloride Spegel Charger, single-phase, type SIP/108/35. This charger used single-phase AC power between 200 and 250 volts, 50 A nominal, 60 Hertz frequency. The direct current (DC) output current was 35 A. The charger provided a refreshening charge for 10 minutes every four hours. For the CleanFleet project, the battery chargers were considered “part of the demonstration vehicle.” The Chloride batteries were charged using two Chloride chargers that were hung from the ceiling of FedEx facility near the EVs. Figure 11 shows a FedEx employee plugging in the charger cord from the ceiling-mounted Chloride charger to the G-Van. The lead-acid battery pack is shown on the bottom of a G-Van in the lower portion of Figure 11.



1. **Fuel Injectors**
2. **Fuel Pressure Regulator**
3. **Mass Air/SEFI**
4. **Spark Plug**
5. **Engine**
6. **Cold Start System**
7. **EEC-IV Microprocessor**
8. **Wiring Harnesses**
9. **Engine Oil**
10. **Fuel Sensor**
11. **Fuel Filter**

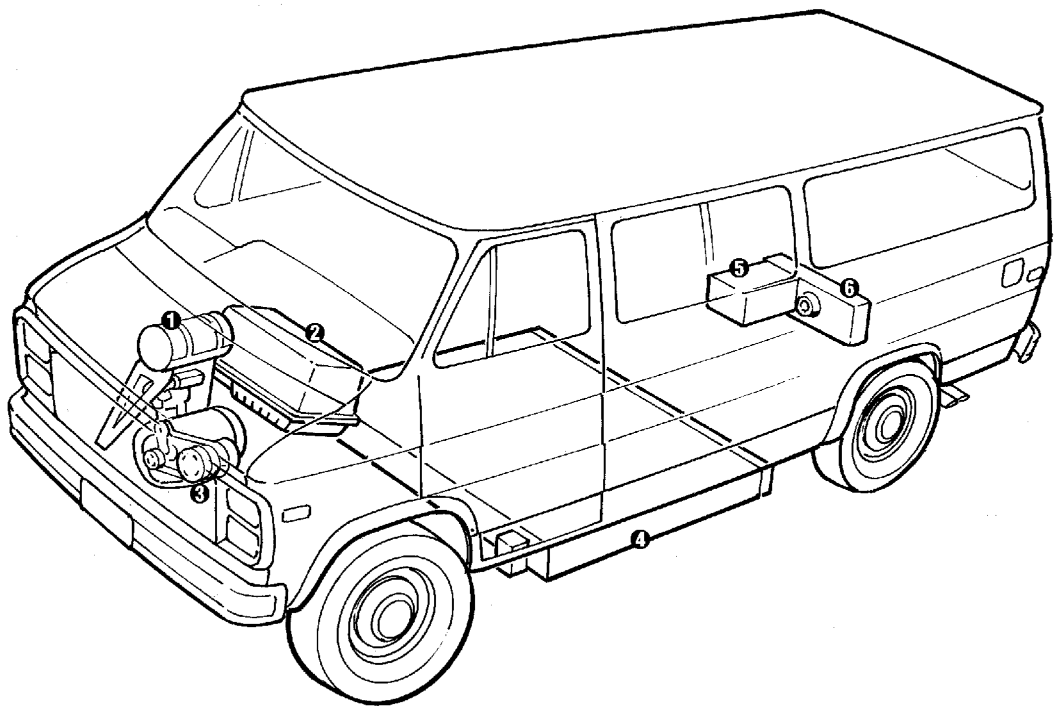
12.&13. Fuel Supply, Return, and Vapor Lines

14. **Evaporative Emission System**
15. **Fuel Pump Assembly/ Fuel Sending Unit**
16. **Filler Tube**
17. **Fuel Tank**

Figure 9. Several components of the Ford M-85 vans were changed for operation as a FFV (after Ford).

In January 1993, one lead-acid EV was removed from FedEx service; and it was outfitted with nickel-cadmium (Ni-Cd) batteries.(11) This EV returned to service in November 1993. The Ni-Cd battery pack was composed of 34 SAFT STM5-200 Ni-Cd monoblocks. Each monoblock weighs 55 pounds, is rated at a nominal voltage of six volts, and has a 200 Ah capacity at the five-hour (C/5) discharge rate (1.2 kWh). The monoblocks were installed in a special stainless steel tray. The weight of the batteries themselves was 850 kg (1,870 pounds). The combined weight of the battery pack, tray, intercell connectors, fans, watering system, and insulating blanket was 1,018 kg (2,240 pounds).

The Ni-Cd battery pack required a charging profile that differed from the lead-acid batteries: an overcharge of 120 to 125 percent. A LaMarche charger (Model A70B-45-108L-BD1) was used. This charger uses single-phase AC power at 208 volts at 155 A, 60 Hz. The DC output is 46 A. The charger was programmed with an EPROM to meet the SAFT charging profile. The charger was suspended from the ceiling of the FedEx facility.



1. Heater
2. Controller
3. Power Steering
4. Battery Pack (36 Six-Volt Batteries)
5. Traction Motor (60 HP)
6. Transmission

Figure 10. CleanFleet G-Vans were prototype EVs (after Southern California Edison).

SCE installed a state-of-charge device in the Ni-Cd EV to provide FedEx couriers with a user-friendly read-out of the net energy (kWh) used. This unit was installed in response to requests from FedEx to have a gauge that provided a reliable indication of the quantity of "charge" used or remaining.

Experience with Vehicle Procurement

With the exception of the two EVs leased by FedEx for the project, all CleanFleet vans were purchased by FedEx from Ford, Chevrolet, and Dodge. FedEx used the specifications for these vans that were customary for its normal fleet operations. No significant issues arose in procuring the OEM production vans from the three manufacturers. Likewise, no significant issues arose while procuring the OEM-modified vans. The only class of vans for which issues arose during procurement were the after-market modified vans.

Figure 11. Lead-acid batteries were recharged from ceiling-mounted chargers.

PROJECT DESIGN AND IMPLEMENTATION

Liability issues arose for the Ford propane gas vans and Chevrolet CNG and propane gas vans (which FedEx had purchased from Ford and Chevrolet) while the vans were being modified by other organizations prior to their delivery to FedEx. After discussion among the various parties, it was agreed that the organizations modifying the vans were responsible during the modification process. This was uncharted territory for the OEMs, FedEx, and the organizations that modified the vans. Ironing out the details resulted in several days of delay.

Ford assisted FedEx and Battelle in locating a suitable organization to modify 13 Ford vans to operate on propane gas. An experienced organization was selected to modify the Ford vans with a proven propane gas fuel system technology kit (IMPCO's ADP kit). The modification itself proceeded smoothly. Early problems with the fuel lockoff valve are summarized in Volume 3 (vehicle maintenance).

Chevrolet selected IMPCO's AFE technology for its CNG and propane gas vans. This technology was relatively new in 1992 for CNG and had not previously been used for propane in a commercial fleet. IMPCO contracted the modifications.

Upon inspection of the propane gas vans, Battelle, FedEx, and Chevrolet determined that the installation was not satisfactory for safety reasons. Another organization was brought in, and the original modifications were changed. The alterations included adding an auto-stop feature to the fuel tanks to prevent overfilling, making the fuel shut-off valve more accessible, installing a vent line to the outside of the vehicle body, installing a heat shield for exhaust near the fuel tank, relocating fuel lines within the vehicle frame, and moving the pressure regulator for improved accessibility, service life, and safety.

The Chevrolet vans were modified to permit operation on CNG without significant problems. An individual experienced with natural gas systems made the modifications.

After-market vehicle modifications for CleanFleet involved (1) no significant problems for procuring OEM-production vans that were for sale and (2) problems with the modifications if the organization responsible was not well-versed in the business or if the technology was not fully proven.

Fueling Infrastructure

Fueling infrastructure was a key element of CleanFleet for two reasons. First, the CleanFleet AFVs had to be fueled reliably to power them for FedEx business and for the demonstration. Second, experience gained with the fueling facilities provided valuable information on the use of alternative fuels in fleet operations. These elements of the demonstration are the focus of this section of the report. For each fuel, information is summarized on permitting, fuel storage and dispensing equipment, recording the quantity of fuel dispensed, and operation requirements experience.

CNG

The CNG fuel supply strategy was based on taking pipeline gas from the existing local distribution system line, compressing the gas, and storing it on site. The design intent was that the on-site storage (the "cascade") would be sufficient to fuel the CNG fleet, with the compressors replenishing the fuel in the cascade over a longer period of time. The compressors were driven by electric motors. Supplying power to these motors required installing a new breaker panel and electrical metering equipment.

Permitting Requirements. All permitting for the CNG fueling installation in Irvine as well as the installation itself was handled by Southern California Gas (SoCalGas) Company. No unusual permitting requirements were noted, but the fire department did require installation of a flashing red warning light to indicate compressor station malfunction.

Fuel Storage and Dispensing Equipment. The CNG fuel storage and dispensing equipment consisted of a meter set, an electrical panel, two compressors, a cascade, and a fuel dispenser.

The meter set measured the amount of gas delivered to the compressor from the local distribution line. The gas meter was a large bellows-type meter typical of a utility installation for a commercial gas user. The compressor inlet pressure was regulated to 100 kPa.

A separate electrical panel provided an electrical disconnect, circuit breaker protection, and metering for the compressor station. The compressor station had two compressors, each with a 50 horse-power electric motor. A typical current draw was about 40 amperes per compressor at a nominal 480 volts.

The compressor station had two nominal 50 cfm Ariel compressors (see Figure 12). Two 50-cfm compressors were used rather than a single 100-cfm compressor to provide redundancy of fuel supply. The compressor station was not enclosed. There was a wall on three sides for visual screening.

The cascade consisted of nine gas bottles with a total storage capacity of 450 normal cubic meters.

Figure 12. The natural gas fueling station had two compressors, cascade storage, and a dispenser.

The fuel dispenser was located on an island adjacent to the gasoline fueling island. The dispenser had two fuel delivery hoses. Each dispenser hose was equipped with a vented Sherex 1000 nozzle connection. This fueling connector captured the gas that would have been released at the nozzle when the connection was broken and conveyed it to a vent stack on the fueling island.

Recording Fuel Dispensed. The quantity of fuel dispensed into each van was recorded electronically by the Ward system, which was activated by a magnetic card specific to each CleanFleet CNG van. The dispenser measured mass of natural gas dispensed, but it reported the quantity of fuel dispensed in nominal terms using a constant conversion factor (4.61 lbs/therm). A Micromotion sensor was used to measure the quantity of natural gas moving through the line in the dispenser. SoCalGas calibrated the system periodically, adjusting the system to provide the constant factor between pounds and terms as necessary. SoCalGas performed these regular calibration checks by weighing a test cylinder before and after filling it.

Operational Experience. The natural gas compressor, storage, and dispensing station required preventive and unscheduled maintenance, as would be expected for a mechanical system of this complexity. Over the course of the first year, a local firm under contract to SoCalGas had a person at the site at least weekly. Throughout the demonstration, the system provided fuel to the vans each evening.

Two technical problems with the installation surfaced that were ameliorated by SoCalGas. First, early in the demonstration, the injectors of one of the Ford vans were fouled by lubricant from the compressor. Lubricant was found in the regulators of vans from all three manufacturers. About a year into the demonstration, about 30 milliliters of lubricant were found in one of the natural gas cylinders on board a vehicle. SoCalGas changed the lubricant and reduced the quantity used in the compressor. No further problems were encountered. Second, FedEx personnel found that, when fueling all 21 natural gas vans in succession, the first 17 vans could be filled to 3,000 psig, but the remaining vans could only be filled to about 2,700 psig. The last vehicles to be fueled required several minutes to fill to the 2,700 psig instead of about four minutes to fuel each of the first vehicles to 3,000 psig. SoCalGas changed the plumbing in the system to direct compressed gas directly to the dispenser and vehicles when the pressure of the stored gas in the cascade system fell below a specific level. This change helped, but the system was never able to fill all 21 vans in rapid succession.

During the course of the demonstration, maintenance was required a number of times to restore the system to operation. For example, a relief valve on the cascade tanks stuck open on two occasions. On another occasion, vibration of the compressors caused a fitting on a supply line to become loose. A fault condition shut down the compressor. Halfway through the demonstration, an electrical short caused a valve to malfunction in one of the compressors. That unit was out of service for two days before it could be brought back on line. In this instance the use of dual compressors for redundancy proved to have been a wise decision. Once a power outage to the telephone system forced the magnetic card reader system at this location and others to become inoperable for a short period of time. Finally, the reference cylinder in the dispenser, which was filled to a reference pressure, lost pressure on a few occasions. When this occurred, the dispenser would only fill vehicles to a pressure equal to the pressure in the reference cylinder, and a full fill would not be obtained. When this occurred, SoCalGas had to replenish the gas in the reference cylinder.

Propane Gas

Propane gas for the propane-fueled fleet at Rialto was supplied from a 4,000-liter on-site propane tank. The tank was equipped with a fuel pump, a standard volume-metering dispenser, and fuel delivery hose.

Permitting Requirements. The propane gas supply tank and dispenser were installed by a local propane distributor. No unusual permitting requirements were noted.

Fuel Storage and Dispensing Equipment. The 4,000-liter propane storage tank was located on an island in the parking lot (see Figure 13). A standard propane fuel pump and a volume-metering dispenser were used to deliver the fuel. The fuel hose was equipped with a trigger-type nozzle

Figure 13. The propane gas fueling facility was located on an island in the parking lot.

whose action was similar to a gasoline dispenser nozzle. The nozzle was connected to the vehicle with a 1-1/4 inch Acme thread and knurled nut. This is a common connection for propane dispensing.

The vehicle fuel tanks were equipped with an auto-stop fill mechanism that automatically stopped the flow of fuel to the tank when the tank was approximately 80 percent full. In addition to the auto-stop fill mechanism, the propane fuel tanks on the vehicles were equipped with traditional dip-tube fill indicators. The dip tubes were attached to a small vent valve that remained open during fueling. In order for the auto-stop device on the vehicle fuel tanks to work correctly, it was necessary to level the asphalt pad in front of the dispenser. This was done by adding a layer of asphalt paving to one end of the pad. Prior to leveling the pad at the fuel dispenser, FedEx found that the vans were filled only to within 2 to 3 gallons of the "full-fuel" level. This caused reduced driving range, which was a problem on some of the longest FedEx routes.

Recording Fuel Dispensed. A mechanical key-lock system with totalizers was used to control access to fueling vans and to record the quantity of fuel dispensed into each van. Before the dispenser would provide propane to the vans, the person fueling the van had to insert a key into the proper key hole. The key holes were numbered sequentially on a panel. This panel had to be placed some distance (at least 20 feet) from the dispenser because the panel was not rated as electrically explosion proof (as required by the National Fire Protection Association for the dispenser).

The tank truck that brought propane gas to the site was sealed by local weights and measures. The quantity of fuel delivered was documented to verify that the calibration of the dispenser was correct. The dispenser itself was also calibrated using a standard meter supplied by the propane industry.

Operational Experience. Over the course of the demonstration there were no significant problems with the propane storage tank or dispenser.

Phase 2 RFG

The downtown Los Angeles location chosen for the RFG fleet had two 5,000-gallon, underground storage tanks, each connected to a fuel pump and dispenser. Prior to the CleanFleet project, both were used for unleaded gasoline. One of these storage tanks was pumped out, cleaned, and used for storing RFG. The RFG, which was blended and stored in bulk by Phillips in Borger, Texas, was delivered to the demonstration site in tank trucks.

There were no additional permitting requirements for the RFG supply over and above those already in place for unleaded gasoline. However, the use of this facility to load the gasoline component of the M-85 meant that the fuel dispenser hose had to be longer than normal. To maintain the efficiency of the Stage II vapor recovery system, twin hoses, rather than coaxial hoses were used.

Fuel Storage and Dispensing Equipment. The fuel storage and dispensing equipment were not modified from the existing gasoline installation. However, because the fuel pump dispenser on the RFG tank was relatively old, it was replaced with a newer unit to ensure reliability.

Recording Fuel Dispensed. The quantity of RFG dispensed into the vans was recorded using a key-lock system similar to that used for propane gas. An automated fuel management system was evaluated at this site. The CleanFleet vans were equipped with transponders that provided information on vehicle identification and odometer. Only vans identified by the fuel management system as CleanFleet RFG vans were allowed to be fueled with RFG. Other vans at the site were fueled with regular unleaded gasoline at a pump a few feet away. From the beginning of the installation, the automated system experienced problems with the hardware and software. Vendor support of the system was inadequate, and FedEx employees soon learned not to trust the automated system. If a problem appeared, they quickly manually bypassed the system. This automated system never provided useful data.

The RFG and unleaded gasoline dispensers were calibrated using standard weights and measures procedures.

Operational Experience. No problems were experienced with the RFG dispenser during the demonstration.

PROJECT DESIGN AND IMPLEMENTATION

M-85

Methanol for the M-85 was obtained from the California methanol reserve. The methanol was carried by tank truck from the terminal in Long Beach to the FedEx station in downtown Los Angeles, where the RFG fleet was kept. Here, 15 percent RFG by volume was added to the tank truck. The tank truck then proceeded to Santa Ana where the entire load was emptied into the M-85 storage tank, the fuel being splash-blended during the trip.

Permitting Requirements. The installation of the 4,000-gallon, aboveground, storage tank triggered extensive permitting requirements in Santa Ana. Altogether, over a dozen city departments were involved. In this jurisdiction, installing an aboveground fuel tank requires a conditional-use permit. The chief concerns to be addressed during the tank permitting process were:

1. **Fire.** The fire department required that the tank be set back from the property line, but also be easily accessible from the street for possible fire fighting operations.

2. **City Planning.** This planning commission was concerned with the aesthetics of the installation and with appropriateness for the commercial, light-industrial neighborhood. This commission wanted the tank located toward the rear of the property and as far from public view as possible.

3. **FedEx Operations.** FedEx operations required that tractor trailer trucks be able to maneuver on the property. Inasmuch as there was limited room on the site, installation of the fuel tank could not interfere with these operations.

As it turned out, the only location on the property acceptable to all parties was close to a fire hydrant. Thus, this fire hydrant had to be moved prior to installing the tank. Moving the hydrant triggered additional permitting requirements, including pressure testing of the new piping. The pressure testing process was complicated by a lack of adequate shut-off valves in the fire water distribution system and the need to maintain continuous service to a sprinkler system on an adjacent property that was fed from the same water supply.

As part of the fuel tank permitting process, Battelle and FedEx also agreed to:

- Replace the chain link fence in front of the tank with a wall to provide architectural screening of the installation

- Replace an existing chain link truck gate near the tank with an opaque steel gate to provide additional visual screening.

Figure 14 shows the M-85 fueling facility. Experience with this permitting process suggests that, if a fleet operator implements an alternative fuel into the fleet and plans to store the new fuel on site, local code officials may evaluate all aspects of the property, not just those pertaining specifically to the fuel itself.

Fuel Storage and Dispensing Equipment. Once the permit was obtained, installation of the fuel storage and dispensing equipment was relatively straightforward. The tank vendor installed the tank, fuel dispenser, and associated plumbing as part of a turn-key contract.

However, after an initial period of use, fuel contamination was noted. This was traced to several materials compatibility problems with the tank and dispenser installation. These included

- In some cases the installers had used galvanized pipe fittings rather than the required black iron fittings.
- The fuel pump and dispenser were listed by the vendor as “methanol compatible.” However, this equipment turned out to be suitable only for gasoline with small amounts of methanol. The pump and dispenser unit were replaced with a more robust model from another vendor.
- The hose initially installed on the fuel dispenser was not methanol-compatible. This resulted in the carbon filler in the hose being released into the fuel. In an effort to “flush the system,” the tank vendor’s crew pumped contaminated fuel into the fuel tank.

Figure 14. An above-ground tank and dispenser were installed for the M-85 fueling facility.

After this hose and the dispenser were replaced, the tank was pumped, cleaned, and then put back into service.

- The originally installed fuel filters were not of a methanol-compatible design. During the first month or so, methanol compatible filters were not yet available from the manufacturer.

After fixing these installation problems, no further difficulty with methanol fuel quality was noted during the balance of the two-year demonstration.

Recording Fuel Dispensed. The quantity of fuel dispensed into each vehicle was recorded by a key-lock system with mechanical totalizers similar to propane and RFG. The fuel dispenser was calibrated using weights and measures procedures.

Operational Experience. After the initial problems with material compatibility were ironed out, no problems were experienced with the tank or dispenser.

Electric Vehicles

Electricity for electric vehicles was obtained through the local electrical utility (Southern California Edison) to the FedEx facility in Culver City. The numbers of electric vehicles and their associated requirements for charging were such that the existing electrical distribution service to the FedEx facility and to the main breaker panel was adequate. Therefore, the only change required was adding a separate circuit for the electric vehicle chargers.

Permitting Requirements. There were no special permitting requirements for the use of the electric vehicles in Culver City. An eyewash station was installed close to the battery chargers. The wiring for the electric chargers was installed by a local electrical contractor according to standard electrical code specifications.

Battery Chargers. Fuel (electricity) was stored on board the vehicles in batteries. The battery chargers were located within the facility, not on board the vehicles. The vehicle connection to the battery chargers was located under the hood in front of the vehicle. Because of the need to back the trucks up to a conveyer belt for loading and unloading, and also to have an unobstructed driving lane in front of the trucks, the chargers were mounted on the ceiling of the facility, with a lanyard to pull down the charging cords when needed.

Recording Electric Energy. Two digital meters were installed in the circuit to record the electrical energy provided to each charger. Information from these meters was recorded manually, as well as sent automatically to Southern California Edison.

Operational Experience. One of the original chloride chargers malfunctioned and had to be replaced. Otherwise FedEx experienced no problems with the chargers themselves.

PROJECT DESIGN AND IMPLEMENTATION

Building Facilities

FedEx brings delivery vehicles indoors each day to load and unload packages. Figure 15 shows CleanFleet vans parked indoors at the sorting belt at the propane gas demonstration site. Vehicles are kept indoors each night for security. Each FedEx host site in the CleanFleet project also had an indoor vehicle maintenance area where light maintenance was performed. Prior to commencing the demonstration, local building code officials and fire marshals were contacted to inform them about the project and to ensure adherence to all applicable codes and regulations.

An architecture and engineering (A&E) firm, under subcontract to Battelle, worked with Battelle and the fuel organizations involved in the project to obtain approval from the local code officials and fire marshals for conducting the demonstration. In some cases, modifications to the buildings (e.g., ventilation systems) were required to accommodate the use of alternative fuels in trucks that were brought indoors. Building modifications are described in Volume 6 in the discussion of safety issues under the heading "Facility Safety Modifications."

Figure 15. CleanFleet vans were stored indoors at each demonstration site. (The propane gas site is shown.)

Training

Because alternative fuels were new to the FedEx operation in Southern California it was necessary to provide basic information to all FedEx employees associated with the CleanFleet demonstration project. An alternative fuels training program was developed to fill this need. This program was developed according to the following philosophy:

- Direct training and training materials to a group of employees who are generally motivated, intelligent, and interested. Material of interest mainly to engineers and equipment designers was eliminated.

- Provide extensive general background information. Many employees are quite interested in alternative fuels and appreciate more detailed information.

- In addition to general information on alternative fuels, provide specific job procedures and behaviors.

- Make the training materials and the training program as interesting as possible.

- Verify that what was taught was actually learned.

The training procedures consisted of formal training sessions, printed training materials, computerized information assessment, and one-on-one assistance.

Formal Training Sessions

Formal training sessions were developed for each of the five alternative fuels used on the CleanFleet project. These training sessions are described below.

At each FedEx demonstration site, a training session was organized for all employees. While not all employees were directly involved in driving CleanFleet vans, it was important that, not only should FedEx have the operating flexibility associated with training all employees, but also that the curiosity of other employees with regard to the fuels used on the CleanFleet project should be satisfied. These training sessions were taught jointly by a subject matter expert and an expert in organizational training.

For each alternative fuel, the course content consisted of

- An introduction to the properties of the fuel
- An indication of why the fuel was desirable as an alternative fuel
- A review of special handling precautions associated with the fuel
- Specific procedures for fueling, driving, and repairing alternatively fueled vans
- Procedures for CleanFleet data collection.

PROJECT DESIGN AND IMPLEMENTATION

Training Materials

Along with the training course, training materials were developed. These training materials were used with the training course and were kept by each employee as a reference. The training materials were arranged for visual interest and text appropriate to the audience. For maximum effectiveness, the training materials were specific to each of the five fuels demonstrated and also to the FedEx and CleanFleet work environments.

Computerized Training Verification

The CleanFleet training was also incorporated into the FedEx ScholarTeach program. The ScholarTeach program is a computerized system that allows FedEx employees to receive information and also record an individual assessment of their understanding of that information. The ScholarTeach was already in place and used by FedEx for a variety of topics from package sorting to driving skills. The integration of alternative fuels training information into this system allowed normal management tracking of which employees had received the training.

One-on-One Assistance

Throughout the demonstration project, Battelle had a local staff member make frequent visits to each demonstration site. These visits provided an opportunity for fielding questions, observing whether procedures were being followed, and providing follow-up training.

CleanFleet Experiences

The CleanFleet project found that most employees were genuinely appreciative of information transfer efforts. Many employees have a keen interest in air quality and/or automotive technology. Information on how their vehicles work and how they differ from traditional vehicles is of great interest.

Some employees have concerns about new fuels technology. Sometimes people within this group complain that they are being used to test new technology. Sharing information on the successful use of alternative fuels at other locations was generally reassuring to this group, as was detailed information on safety plans and procedures.

Vehicle Activity

During the period from April through September 1992, the 111 CleanFleet vans were introduced into FedEx package delivery operations at the five demonstration sites. Data collection began as soon as the vans entered service and continued until September 30, 1994. Initially, the liquid and gaseous fueled vans were randomly assigned to a subset of FedEx couriers (drivers) who were responsible for daily pickup and delivery service on specific routes. The EVs were placed in service on routes of less than 25 miles in length at the Culver City location.

Two vans from each liquid and gaseous fuel fleet were equipped with trip recorders for a portion of the demonstration to record data on vehicle use and engine duty cycle. The average hours each vehicle was driven each month were 161 for CNG, 188 for propane gas, 146 for RFG, 195 for M-85, and 205 for the control vans.

Most FedEx couriers remain on the same delivery routes for a long period of time (i.e., many months or years). To ensure that the CleanFleet vans would be driven on a variety of routes and by different drivers, the vans were periodically rotated among available delivery routes and couriers within each demonstration site. The rotation plan attempted to even out the total miles each vehicle was driven, as well as the distribution of duty cycles experienced by each vehicle. It also ensured that there would be an adequate pool of couriers who drove both the alternative fuel and control fuel vans from each manufacturer. These couriers provided valuable user information through the employee attitude assessment survey (see Volume 5).

Table 15 lists the average number of service days, average total miles driven, and average daily mileage achieved for each fleet of vans. Differences in the average number of service days resulted from phasing in the vehicles over an eight-month period and from different service requirements at each site. For example, at some sites, FedEx did not use all available vans for deliveries on Saturdays. Among the liquid and gaseous alternative fuel vans, the average miles accumulated during the demonstration ranged from 18,200 to 42,700.

Because most FedEx vans were used on similar pickup and delivery schedules, the average daily mileage is a descriptive measure of vehicle activity. Longer routes include more highway driving and involve fewer stops. As shown in Table 15, the average daily vehicle miles ranged from about 30 miles per day at the Los Angeles site to about 80 miles per day at Rialto. CleanFleet vans were generally limited to routes of less than 120 miles.

The only exception to the rotation plan occurred early in the demonstration. FedEx requested that the CNG vans not be assigned to the longer routes out of Irvine until an additional fuel tank was added to each Dodge CNG van and more accurate fuel pressure gauges were installed on the Ford and Dodge vans (such gauges were installed on the Chevrolet vans during their modification to operate on CNG). The fuel tanks were installed in March 1993, and the pressure gauges were installed during the fourth quarter of 1993.

Afterward, the CNG vans were assigned to longer routes. Because the control vans began service several weeks before the CNG vans, it was not possible to equalize the total vehicle miles driven between the CNG and control vans. However, the Chevrolet and Ford CNG vans experienced nearly the same average daily mileage as the corresponding control vans.

Table 15. Summary of Number of Vehicles and Activity by Fleet

Location	Fuel Type	Vehicle Manufacturer	Number of Vehicles	Average Number of Service Days	Average Total Miles Per Vehicle	Average Miles Per Day
Irvine	CNG	Chevrolet	7	441	26,812	61
		Dodge	7	460	22,639	49
		Ford	7	455	29,533	65
	UNL	Chevrolet	3	573	39,663	69
		Dodge	3	544	42,685	78
		Ford	3	630	39,439	63
Rialto	Propane Gas	Chevrolet	7	432	35,519	82
		Ford	13	522	39,521	76
	UNL	Chevrolet	3	502	38,758	77
		Ford	3	572	42,452	74
Santa Ana	M-85	Ford	20	521	24,969	48
	UNL	Ford	3	595	25,221	42
Los Angeles	RFG	Chevrolet	7	608	19,740	32
		Dodge	7	605	18,246	30
		Ford	7	648	20,984	32
	UNL	Chevrolet	3	660	16,176	24
		Dodge	3	607	25,697	42
		Ford	3	647	18,944	29
Culver City	Electric[a]	G-Van	2	179	2,606	15
	Electric[b]	G-Van	1	76	1,406	18

[a] Lead-acid batteries.
[b] Nickel-cadmium batteries. One van used lead-acid batteries at the beginning of the demonstration and nickel-cadmium batteries later. Two G-Vans were used in CleanFleet.

Figure 16 demonstrates how the vehicle rotation plan achieved its goal of equalizing the distribution of duty cycles among fleets at each demonstration site. The “box and whisker” plots show the distribution of average daily miles driven by CleanFleet vans within a rotation cycle. For example, each of the seven Chevrolet CNG vans were assigned to five different routes during the demonstration—a total of 35 route assignments. The “box” indicates that 50 percent of the daily routes assigned to the Chevrolet vans averaged between 50 and 70 miles per day. The median value is indicated by the bar in the middle of the box. The ends of the “whiskers” indicate that the minimum route length was 10 miles per day, and the maximum was 120 miles. Overall, the distributions of route lengths are very consistent within a site.

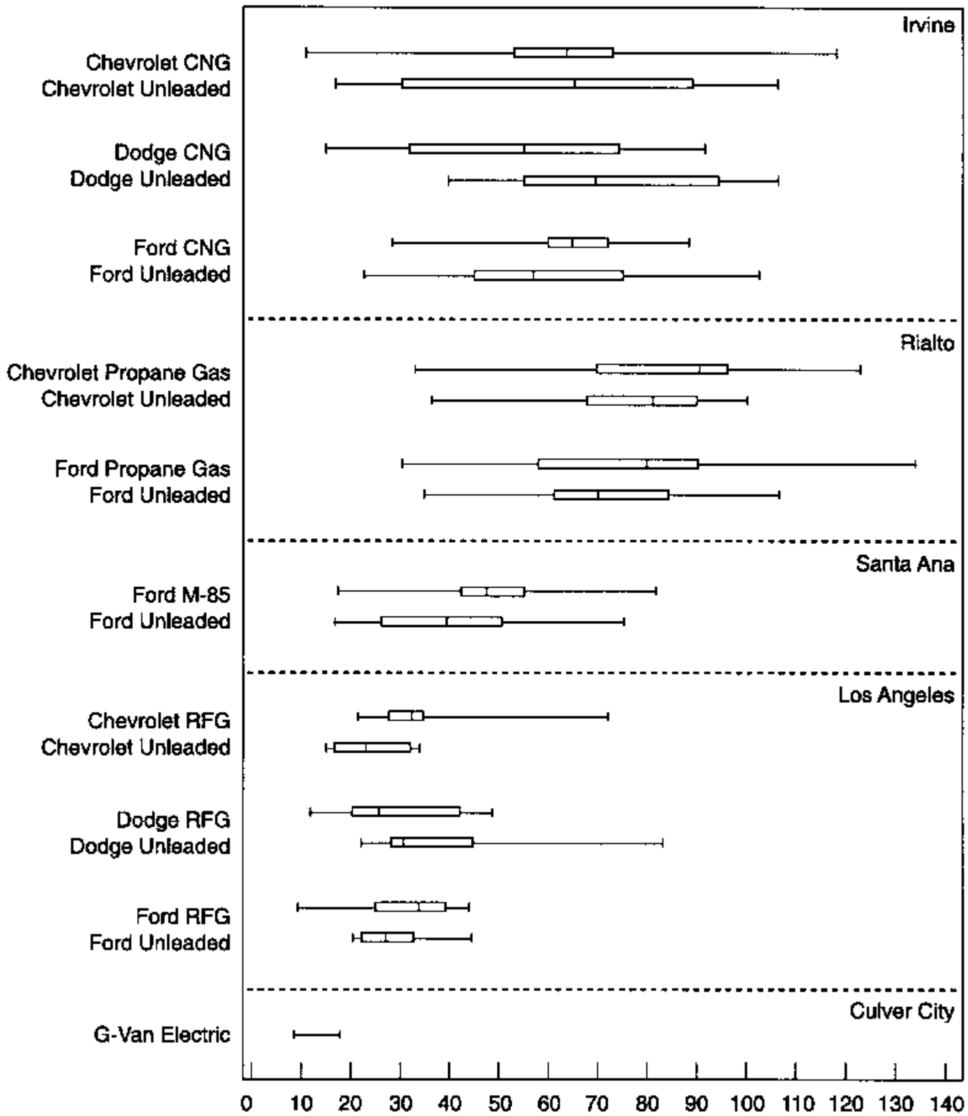


Figure 16. A vehicle rotation plan equalized the distribution of duty cycles among fleets.

The potential effects of the site-to-site differences in duty cycles (as well as other operational factors, such as maintenance practices) on specific performance measures were investigated by comparing results among control fleets at each site. Significant effects were dealt with by restricting the comparison of results to those obtained at the same site (e.g., Ford propane gas versus Ford unleaded at Rialto). For example, in evaluating fuel economy, the mean fuel economy of individual fleets was found to be linearly related to average daily mileage. The fuel economy of alternative fuel fleets and control fleets differed among and within sites. However, the marginal dependence of fuel economy on average mileage was found to be the same for all fleets at a site, but different among sites (see Volume 4 and Reference 12). This is an example of the way the rotation plan evened out differences within a site, while the data analysis accounted for differences among sites (the alternative fuel vans could not be rotated among sites).

Types of Data Collected

The scope of the project encompassed fleet operations, vehicle emissions, and fleet economics. A number of topics were addressed within each of these three major categories. They are listed in Table 16.

Table 16. Topics Addressed in the Project

Fleet Operations	Vehicle Emissions	Fleet Economics
Vehicle	Regulated Emissions	Infrastructure Costs
Maintenance	Ozone Precursors	Owning Costs
Reliability	Air Toxics	Operating Costs
Fuel Economy	Greenhouse Gases	
Durability		
Safety		
Facilities		
Fueling		
Vehicle Housing		
Employee Attitudes		
Training		
Occupational Hygiene and Safety		
Operational Impacts		

Data for the CleanFleet demonstration were collected from several sources as illustrated in Figure 17. Battelle developed the data collection protocols in collaboration with FedEx, the California ARB, and other members of the Working Group. All of these organizations participated in data collection. This section provides brief descriptions of the various types of data collected during the two-year demonstration. The descriptions are organized according to the principal topics addressed in the CleanFleet findings.

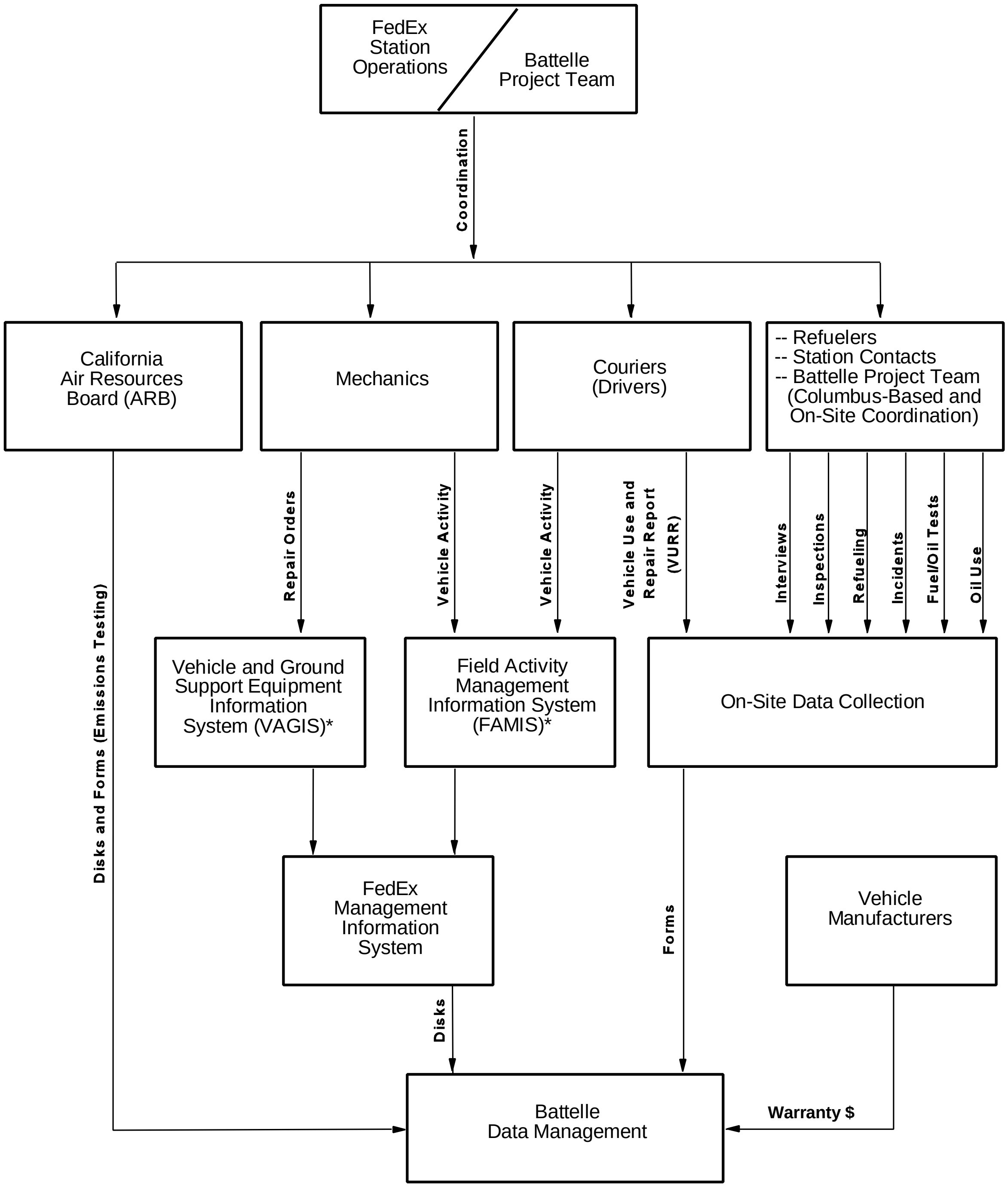


Figure 17. Data were collected from several sources during the CleanFleet data collection process.

Vehicle Activity

Vehicle activity data were collected to monitor vehicle utilization in terms of average daily mileage, routes driven, number of service days, and total miles driven. The types of data collected include

- Information recorded by FedEx couriers and mechanics
- Data from trip recorders installed on selected vehicles.

The primary source of information on vehicle activity is data reported by FedEx couriers (i.e., drivers). Couriers reported vehicle identification numbers and odometer readings as they performed various tasks throughout the day. The data were maintained by FedEx in the Field Activity Management Information System (FAMIS). The activity data collected by couriers participating in the demonstration were periodically extracted from FAMIS by FedEx and sent to Battelle in electronic form. Battelle converted the data to create a working database on vehicle activity. The database, containing nearly 67,000 records, specifies the date, driver, route driven, and beginning and ending odometer readings each time the demonstration vehicles were driven. The data were used for routine data tracking and data validation procedures, characterizing the duty cycles of the test vehicles in terms of daily mileage and number of delivery stops, and monitoring vehicle utilization (number of service days) and mileage accumulation.

FedEx mechanics also report data on vehicle activity. Each time they performed maintenance on a vehicle, they reported the vehicle identification number, time, and date. These data were used to cross-check the information received on vehicle repair orders.

More detailed information on route characteristics and courier driving patterns was obtained by equipping selected vehicles with Rockwell Tripmaster trip recorders. Information obtained included number of engine starts and stops, total road time, and road time at selected speeds and engine rpm. These data were used to further characterize routes driven by demonstration vehicles.

Fuel Consumption and Analysis

Fuel consumption and analysis data include

- Refueling data recorded each time the vehicles were refueled
- Data obtained from totalizers, which track the total amount of alternative fuel dispensed to demonstration vehicles
- Analyses of monthly fuel samples.

Fuel consumption for all demonstration vehicles was recorded on refueling forms each time the vehicles were refueled (usually daily). The data collected by FedEx employees included vehicle and employee identification numbers, amount of fuel dispensed, date and time, and vehicle odometer reading. Over 44,800 vehicle refuelings were reported.

In addition to recording data on individual refuelings, the dispensers for all of the alternative fuels tracked the total fuel dispensed to each vehicle, as described earlier. Data from the dispensers and refueling forms were periodically compared to ensure data quality. For the entire demonstration, 96 percent of the refueling data collected for the alternative fuel vans and 89 percent of the refueling data collected for the unleaded control vans were accurate and complete.

Every month fuel samples were collected from each of the fuel dispensers used to fuel demonstration vehicles. The samples were analyzed to determine chemical composition, heating value, density, specific gravity, and other fuel-specific properties. The results were used to ensure that the fuels met the specifications agreed to by the Working Group and to monitor the consistency of the fuel supplies throughout the demonstration.

Maintenance and Reliability

Vehicle maintenance data include:

- FedEx vehicle repair orders
- Warranty and maintenance data obtained from local dealers, vehicle manufacturers, and Southern California Edison (for electric vehicles)
- Daily Vehicle Use and Repair Reports (VURR).

FedEx maintains an information management system on all repairs to its fleet vehicles. The system is called the Vehicle and Ground Support Equipment Information System (VAGIS). Maintenance data from VAGIS on all demonstration vehicles were periodically transferred to Battelle in electronic form and placed into the CleanFleet database. The data include date of repair, repair order number, mechanic employee number, party responsible for the repair (vendor or FedEx), reason for repair (e.g., scheduled, breakdown, driver report), type of repair, labor performed, parts replaced, and costs of labor and parts. All labor and parts replaced are reported using standard ATA (American Trucking Associations) codes. Data from VAGIS were used to assess the reliability and maintenance costs of the vehicles and to monitor preventive maintenance activities.

In addition to the data obtained from FedEx, Battelle also received data from the local dealers and other organizations who performed certain warranty repairs. Information on manufacturer warranty repairs were received directly from the manufacturers. Two of the three vehicle manufacturers (Ford and Dodge) provided costs on all fuel-related warranty repairs. Maintenance data on the electric vehicles were obtained from Southern California Edison. The data received from FedEx, local vendors, and vehicle manufacturers were reviewed by Battelle for accuracy and completeness. After reconciling any differences, the data were combined into a single maintenance database. The maintenance database contains approximately 6,500 repair orders. This is an average of 59 repair orders per vehicle, or 2.5 repair orders per vehicle per month, during the two-year demonstration.

Each time a FedEx employee drove a fleet vehicle, he or she was required to record its use and report any problems encountered on a VURR. Mechanics reviewed the VURRs daily and recorded any maintenance performed. Battelle received copies of all VURRs to monitor this communication between drivers and mechanics. The data maintained in the CleanFleet database included date of use, vehicle identification number, and a description of problems reported. These data were primarily used to monitor oil consumption as it was reported by couriers during their early morning vehicle check.

Performance

Vehicle performance data include

- Periodic field acceleration tests
- Fuel economy (discussed in "Fuel Consumption and Analysis" section)
- Interviews with FedEx employees (discussed in "Employee Attitude" section).

Field acceleration tests were performed three times during the demonstration. The data include the time and distance required to achieve various speeds. The purposes of these acceleration tests were to establish the relative baseline performance of the vehicles and to monitor their performance throughout the demonstration. The tests were performed on all of the vehicles at the beginning and end of the demonstration and on half of the vehicles at approximately the middle of the demonstration. These data were intended to be used solely to guide objective evaluation of vehicle performance.

Vehicle performance was also assessed through the analysis of vehicle fuel economy and employee attitudes. The process of collecting these data is discussed in the "Fuel Consumption and Analysis" and "Employee Attitudes" sections, respectively.

Employee Attitudes

The employee attitude study involved collection of data through printed questionnaires, personal interviews, and focus group discussions involving FedEx employees. Four groups of employees from each of the five demonstration locations (Los Angeles, Irvine, Santa Ana, Culver City, and Rialto) participated in the study. The four employee groups were the couriers who drove the vehicles, operations managers who were responsible for the personnel and the routes on which the CleanFleet vans were in service, mechanics who maintained and serviced the vehicles, and handlers who managed the refueling process.

The printed questionnaire included background information (current position, years with FedEx, age, prior experience with alternative fuels), questions about safety and health concerns, opinions regarding vehicle performance, and general attitudes about alternative fuel vehicles. Questionnaire results were used to prepare questions for the personal interviews and discussion topics for the focus groups. Questionnaires were completed by 114 employees across the five sites. Approximately 80 employees were randomly selected from the population and divided into two groups (40 each) for participation in the interviews and focus groups. Employees selected for participation in the attitude study were identified through the vehicle activity database, which contains identification numbers for drivers of the CleanFleet vehicles and information provided by FedEx operations managers.

PROJECT DESIGN AND IMPLEMENTATION

Emissions

Emissions data included

- Pre-emissions test inspection
- Exhaust and evaporative emissions tests
- Detailed fuel analyses.

The pre-emissions test inspection included a visual assessment of the vehicle and checks of critical engine and fuel systems and emissions control devices. Any noteworthy observations were recorded on a pre-emissions checklist. The history of maintenance performed on the vehicles prior to the emissions test was available through the VAGIS maintenance database.

Speciated exhaust and evaporative emissions tests were performed by the California ARB at its test facility in El Monte, California. Three vehicles from each of the 12 fleets (i.e., combinations of fuel type and vehicle manufacturer, except electric) were tested for exhaust emissions as the vehicles reached approximately 4,000 miles, 14,000 miles, and at the end of the demonstration (approximately 24,000 miles). Duplicate tests were performed at the 4,000 and 24,000 mileage levels. Of the 219 exhaust emissions tests preformed, 196 included speciated emissions. Evaporative tests were also performed at approximately 14,000 miles. ARB analytical methods were used to determine methanol and ethanol (ARB Method 1001); C_2 through C_5 hydrocarbons (ARB Method 1002); methyl tert-butyl ether, ethyl tert-butyl ether, and C_6 through C_{12} hydrocarbons (ARB Method 1003); and C_1 through C_8 carbonyls (ARB Method 1004). Fourier transform infrared spectroscopy (FTIR) was employed on an experimental basis to determine methyl nitrite, nitrous acid, and nitrous oxide. On-line instruments measured total hydrocarbons, methane, carbon monoxide, carbon dioxide, nitric oxide, and nitrogen dioxide. Species were reported in emissions units of mg/mile. Following the tests at the ARB, the data were sent to Battelle and stored in the CleanFleet database. The ARB and Battelle collaborated on reviewing the data for accuracy and completeness.

The ARB performed periodic analyses of the fuel from CleanFleet vehicles during the time each fleet of vehicles underwent emissions testing. The measured properties and chemical composition of the fuel were compared with the results from the monthly fuel samples collected at each of the demonstration sites.

Safety and Occupational Hygiene

Safety data include

- FedEx accident reporting systems
- Information from Battelle's on-site project representative
- On-site emissions and fuel vapor measurements.

FedEx employees are required to report significant safety incidents on an incident information report. These reports identify staff involved in the incident, date and time, and location. A description of the incident and the corrective action taken are also provided. Incident reports are kept on file at each FedEx facility. Battelle received copies of all incident reports involving refueling systems or demonstration vehicles.

In addition to reviewing safety incidents identified through the formal reporting systems, Battelle's on-site project representative often learned of safety incidents through discussions with FedEx mechanics and drivers. Such events were investigated in the same manner as those identified through the formal reporting systems.

The occupational hygiene study involved taking multiple fuel vapor (methane, propane, methanol, and gasoline) measurements during the refueling process at each of the FedEx facilities (except electric). Measurements were made in or near the breathing zone of the fuelers using a MIRAN 1B gas analyzer. Fuel vapor levels in the vicinity of the fuel storage facilities were also measured. Formaldehyde and carbon monoxide measurements were made inside the FedEx facilities during the early morning period when the vans were started up and began their delivery routes. Concentrations of fuel vapors and carbon monoxide were made using infrared spectroscopy. Formaldehyde was measured using wet chemistry techniques.

Durability

Data related to vehicle durability include

- Oil consumption and analysis
- Engine inspections.

Oil consumption was reported by FedEx mechanics each time they added or changed the oil in the demonstration vehicles. The amount of oil consumed was calculated from the amount of oil added and the level indicated on the oil dipstick prior to adding or changing oil.

Used oil samples were collected each time the mechanics performed routine oil changes. The samples were sent to an independent laboratory for analysis of composition including metals such as iron, chromium, nickel, aluminum, lead, copper, tin, silver, and titanium. During the two-year demonstration, data from 918 oil changes and 858 oil analyses have been reported.

At the end of the demonstration, engines from two vehicles from each of the Ford and Dodge fleets were disassembled to examine the wear of selected parts. The examination focused on deposits, pistons, valve stems, valve seats, valve guides, piston rings, cylinder bores, and main and connecting rod bearings.

PROJECT DESIGN AND IMPLEMENTATION

Fleet Economics

The fleet economic analysis identified costs that are likely to be incurred by a fleet operator using alternative fuel vehicles in a package delivery service similar to FedEx in the 1996 time frame. Three categories of cost factors were identified: infrastructure costs (e.g., training, fueling and maintenance facilities, vehicle storage), owning costs (e.g., vehicle price, modifications, residual value), and operating costs (e.g., fuel, refueling labor, maintenance, insurance). Cost data were obtained from three sources: actual CleanFleet experience, information provided by vehicle manufacturers and fuel organizations, and the literature.

Public Outreach

The importance of public outreach and communication was recognized early in the project design stage by the sponsoring organizations, particularly the federal and state agencies with public involvement mandates. The size of the demonstration (111 vehicles, five alternative fuels), its links to two key federal laws and California's LEV regulations, objectives, comprehensive scope, potentially interested groups, and commitment to objectivity were predictors that the project would have high visibility and broad interest.

Planning and Implementation

A formal Public Affairs Plan was developed to ensure that the variety of audiences and interests would be considered as project design decisions were made and the project's progress and results were communicated. These audiences ranged from internal project participants to external groups and individuals affected by the federal, regional, and state clean air mandates.

For example, the representatives of the co-sponsoring organizations, who had "corporate review" responsibilities, were expected to prefer frequent and tailored reporting methods. The potential results of, for example, emissions tests and fleet economics studies were anticipated to be of major interest to government officials and business leaders, particularly in the fuels, automotive, and fleet operations segments. The heightened awareness among media representatives and environmental leaders of alternative fuel requirements for fleets and the imminent dates for implementing those requirements meant that CleanFleet would have high visibility, both in the Los Angeles area and in other affected major metropolitan areas.

This section describes the public outreach program conducted for the CleanFleet demonstration. Key elements of the plan and implementation are summarized as follows.

Audiences. Possible audiences identified in the plan included representatives of the 19 sponsoring organizations; decision makers in federal and state government, e.g., U.S. Congress, state assembly, and cognizant agencies; staff of those agencies and the host fleet (FedEx); local agencies with permitting responsibilities; affected business interests, including fleet owners and managers, auto manufacturers, vehicle modification vendors, and fuel suppliers; the public; and the media.

Internal Communications. Several methods were used to communicate with designated representatives of co-sponsoring groups and their staffs. A formal reporting process was developed for the sponsoring organizations' representatives (called the Working Group). Periodic Working Group meetings were held to provide project status updates and review data summaries, project reports, and plans. Members received for review and comment advance copies of all printed materials, including reports, newsletters, and briefing packages.

During the period when new vehicles were being phased into the demonstration (i.e., April to October 1992), weekly teleconferences were scheduled for technical staff from FedEx, the vehicle manufacturers, supporting vendors, and Battelle.

Similar methods were used to communicate with and link the co-sponsors' public affairs representatives. These methods included establishing a CleanFleet Public Affairs Subgroup; seeking the subgroup's comments on drafts, major announcements, and events; inviting members to attend Working Group meetings and major project events; and involving them in media and public interactions.

External Communications. A CleanFleet mailing list was developed that, over the term of the project, grew to approximately 1,000. The list included representatives of all the identified audiences. Those interested in receiving all project information (approximately 700 people) were mailed copies of all technical data reports and analysis reports, as well as the general CleanFleet information noted below. A separate media list included key trade publications and environmental and energy reporters for print and electronic outlets in the Los Angeles area and major metropolitan centers nationwide. Lists were coded to facilitate selective mailings based on interests. For those needing additional information, a Battelle contact person was identified on all printed materials.

For people in the South Coast Air Basin served by FedEx, the demonstration was highlighted by marking the CleanFleet vans with project decals. These markings (e.g., Figures 3 and 18) announced that alternative fuels can be used successfully in daily business operations. In addition, at the start of the demonstration, flyers about the demonstration were distributed by FedEx drivers to each customer served by a CleanFleet van.

Communications Materials. CleanFleet provided general information as well as materials designed for specific audiences. General materials included the *CleanFleet Newsletter*, issued six times during the two-year demonstration and distributed to the entire mailing list; fact sheets describing the project and defining alternative fuels; information packets; reprints of presentations at project and technical conferences; a background video featuring the launch of the vehicles; exhibits at project activities; and briefing packages.

Various audience-specific materials and activities were provided. For example, at the October 1994 events signalling the end of field operations, a lessons-learned symposium for fleet operators was provided. Other examples were periodic “Experiences” fact sheets highlighting lessons learned throughout the demonstration; Congressional briefing packages; and monthly issues (nine) of the *CleanFleet TeamNews*, designed for FedEx staff at the host stations. *TeamNews* issues were placed in special binders containing all CleanFleet project reports and publications at each FedEx host site. To keep FedEx employees informed about the demonstration’s progress and reinforce the sense of commitment to the project, banners were displayed at each site (Figure 19 shows information for the propane site). Monthly data on the progress of the demonstration were posted.

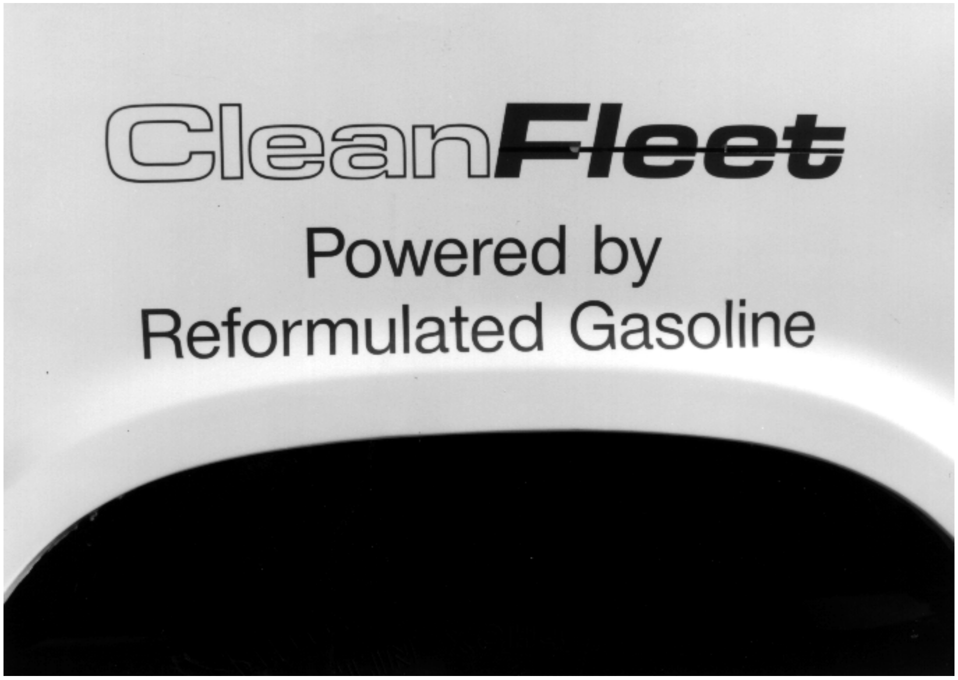
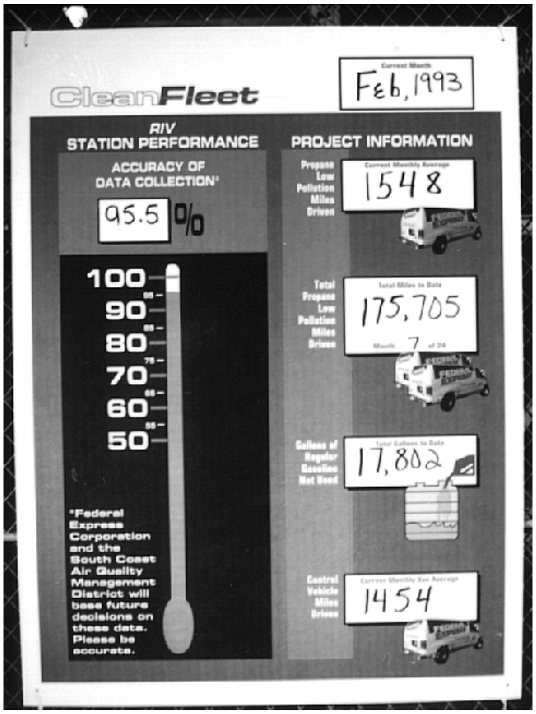


Figure 18. CleanFleet vans were marked to alert the public that clean fuels were being demonstrated in daily FedEx operations.

Communications Activities. Communications activities were linked to important milestones in the technical schedule. Audiences for each activity were identified and materials needed to communicate with those audiences were planned. For example, a news conference was held when the demonstration was launched in June 1992, followed by a project Working Group meeting. Interim project results, such as early emissions analyses, were announced via briefings for all interested groups, including the media. At the end of the demonstration's field operations, in October 1994 (see Figure 20), preliminary results were provided at a news conference, followed by a symposium for fleet owners and local officials.

New Communications Needs. New materials were developed as new communications needs surfaced during the demonstration. For example, as key technical experience was gained, fact sheets describing the lessons learned were made available. To ensure consistency in providing information, protocols were agreed to by members of the Working Group and Public Affairs Subgroup. Special communications materials were provided to FedEx employees at the host stations.



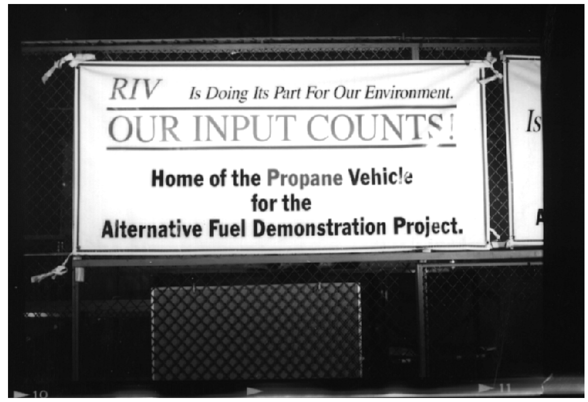


Figure 19. At each demonstration site, monthly data were displayed on percent data completeness, average miles driven on alternative fuel, total cumulative miles driven, gallons of regular gasoline not used, and average miles driven in control vans.

Applicable Lessons Learned

This section provides examples of lessons learned from a public affairs perspective that may aid a fleet operator in communicating to employees and other interested groups, including news media representatives, about plans to use alternative fuel vehicles.

Good News. Depending upon the timing—i.e., whether your company is the first to use alternative fuels for its fleet in a community or the fourth--introducing AFVs into the fleet can be a positive local news story. If the vehicles are identified as using clean-burning fuels, for example, with a decal or placard, they become a visible daily message about the company's commitment to a better environment, thereby enhancing the company's image.

> CleanFleet anecdote. Those driving the CleanFleet vans, which had decals identifying them, found out early that people notice such things. When a CleanFleet van powered by electricity was stuck in a traffic jam, the policeman directing traffic spotted the license plate (SMOGFREE) and motioned for the driver to move around the jam and continue on his route. The policeman commented that vehicles cleaning the air

Figure 20. The CleanFleet Demonstration concluded in September 1994. Representatives of the five fuels and the chairman of the South Coast Air Quality Management District attended the "finish event."

deserved special attention. CleanFleet drivers who participated in an attitude survey toward the end of the demonstration expressed surprise and pleasure at the high level of interest of the public and customers.

Employee Motivation. Good internal communications about the alternative fuels changeover can build enthusiasm among employees, especially improving the morale of those personally involved with the new fuels. This can help soften possible reactions to any concerns or added inconveniences the new fuels may cause (e.g., safety questions, required training, new procedures).

CleanFleet anecdote. In the attitude survey conducted among FedEx employees involved with CleanFleet vehicles, the majority said their contribution to improving air quality was both important and credible. The three major areas of concern expressed by employees involved in the demonstration were health, safety, and vehicle performance. One mechanic who admitted to being skeptical initially turned into a supporter for keeping the AFVs at his station.

Spread the Word. The first two examples confirm that doing the right thing goes a lot further if you communicate it, externally and internally. Here are some ideas that worked in the CleanFleet and may be useful to fleet operators and managers:

- Announce the company's plans with a news release and employee handout about the selection of alternative fuel(s) and a commitment statement from the company to cleaner air (as well as to meeting statutory requirements).

- Form a small employees' alternative fuels or "clean the air" committee with representatives from various job categories. The purpose is to get the message out via these company opinion leaders and to tap their ideas on how best to communicate about this new initiative.

- Use the employees' committee to start things off on a high note. Invite all employees to submit a nickname for the alternative fuel vehicles and let the committee select the winner. Encourage the committee to recommend other ways to increase visibility and promote the new vehicles, such as special paint, logo, placard, or a flyer enclosed with deliveries.

- Have a ceremony to launch the new fleet and invite employees, media representatives, and local leaders. Feature employees involved with the new vehicles.

- Encourage committee members to develop contacts with all company staff in the alternative fuels decision chain and operations (e.g., management, technical, training, purchasing, accounting, workforce). The committee can act as a two-way channel, giving information to those responsible for vehicle purchasing and related operational decisions about employee concerns and suggestions about the new fuels.

- Keep the communications going with periodic progress reports to all employees and by asking those using or servicing the new alternative fuel vehicles: "How are we doing?" Periodically interview employees about their concerns and suggestions to improve operations and communications.

- Routinely post or print notices for employees about the number of "clean air miles" driven, suggestions implemented, and other good news. For large fleets, periodic news releases about, for example, smog-free miles driven may be well received by local media representatives.

Close-Out

Project close-out activities included transitioning from Battelle support of FedEx AFV operations to complete responsibility by FedEx, restoring facilities to their original condition, as appropriate for each site, and disposing of vehicles.

The control vans remained in service at FedEx operating on gasoline. The Dodge CNG vans also remained in service until such time as FedEx disposed of them in its normal course of business operations.

Ford worked with FedEx to replace experimental prototype vans with production vehicles at the conclusion of the demonstration. The M-85 vans were modified by Ford to contain only production components designed for gasoline. The CNG vans were returned to Ford. The propane gas vans continued to operate out of Rialto until such time as FedEx disposed of them in the normal course of operations.

The Chevrolet CNG and propane gas vans, which had been equipped with IMPCO's AFE system, were removed from service.

The electric charging equipment, fueling facility for M-85, and project-related dispensing equipment for RFG were removed from FedEx property. The Southern California Gas Company and the propane industry kept the fueling facilities on site in Irvine and Rialto as long as FedEx continued to operate vehicles on the respective fuels.

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APPENDIX A

Specifications for CleanFleet Vehicles

Specifications for Reformulated Gasoline and Control Vehicles in CleanFleet Project

MANUFACTURER	CHEVROLET	CHRYSLER CORPORATION	FORD MOTOR COMPANY
Vehicle Model Name / Number	1992 H.D. Chevrolet Van CG31305	B 350	Econoline, E-250
Assembly Plant Name / City / State	Lordstown Assembly Plant, Lordstown, Ohio	Windsor, Ontario, Canada	Lorain Assembly Plant Lorain, Ohio
Modifications		None: Production vehicle.	None: Production vehicle.
General Description of Modificationn	None	None	None
Notes about vehicle	Standard production vehicle	None	None
FUNCTIONAL EQUIPMENT — Powertrain			
Engine	Displacement and type: 4.3L V-6 BHP @ RPM: 155 @ 4,000 RPM (SAE NET Horsepower) Ft / Lb torque @ RPM: 230 @ 2,400 RPM CR: 8.6:1	Displacement and type: 5.2 L V-8 EFI BHP @ RPM: 230 Ft / Lb torque @ RPM: 250 HP CR: 19.08:1	Displacement and type: 4.9 L I-6 EFI BHP @ RPM: N / A Ft / Lb torque @ RPM: N / A CR: 8.8:1
Transmission	4-speed automatic with overdrive (4L80E)	4-speed automatic	Ford 4-speed E40D
Battery	Delco 630 cold cranking amps @ 0 F	No change	Maintenance-free. 12 volt. 72 amp / hr.
FUNCTIONAL EQUIPMENT — Chassis			
Frame	Type of construction: All-welded integral body frame	Type of construction: All-welded integral body frame	Type of construction: Single channel, 5 cross members
Front Suspension	Type: Independent Springs: Coil Axle capacity: 3,880 lb.	Type: Independent Springs: Coil Axle capacity: 3,600 lb.	Type: Independent Springs: Coil 4"ID Axle capacity: 3,700 lb.
Rear Suspension	Type: Semi-elliptic, 2-stage leaf Springs: Multi-leaf (8 leaves) Axle capacity: 5,360 lb.	Type: Multi-leaf Springs: N / A Axle capacity: 4,700 lb.	Type: Multi-leaf / two-stage Springs: 55" x 3.0", 5 leaves Axle capacity: 5,345 lb.
Steering	Type: Integral power Ratio: 17.2:1	Type: Power Ratio: N / A	Type: Recirculating ball, XR-50 Gear Ratio: 17.0:1 - 15.5"
Brakes	Front, type: Disc, power assisted Front, size: 47.12 sq. in. pads, Rotor 12.5" x 1.28" Rear, type: Drums, rear wheel anti-lock, 13.0" x 2.5" wide Rear, size: 116.73 sq. in. Power-assist booster, size: 9.5" x 8.0" tandem diaphragm	Front, type: Disc, self-adjusting, hydraulic Rear, type: Drum and shoe type, self-adjusting Power-assist booster, size: 13.46" effective diameter, dual diaphragm type	Front, type: Disc, self-adjusting, hydraulic Front, size: 12.56 Rear, type: Drum and shoe type, self-adjusting Rear, size: 12" x 3" Power-assist booster, size: 13.46" effective diameter, dual diaphragm type
Wheels	Type and size: Painted steel 16.0" x 6.5"	Type and size: 16" x 6.0"	Type and size: 8-hole disc, 16" x 7.0"
Body	Construction: Steel unibody Doors: Sliding side door, regular front and rear	Construction: Cargo van Doors: Side and rear	Construction: Cargo van Doors: Side and rear
Dimensions	Overall length: 202.2 (in.) Wheelbase: 125 (in.) Overall width: 79.5 (in.) Cargo volume: 260 (cu. ft.) Curb weight: 4,722 (lb.) Maximum load weight: 3,280 (lb.)	Wheelbase: 127 (in.) Curb weight: approx. 4,615 (lb.) Maximum load weight: 2,885 (lb.)	Overall length: 211.8 (in.) Wheelbase: 138 (in.) Overall width: 79.5 (in.) Cargo volume: 255 (cu. ft.) Curb weight: N / A (lb.) Maximum load weight: 2,245 (lb.)
FUELING SYSTEMS			
Description of Fuel Delivery Systee	Standard production unit	Individual port fuel injection with tuned intake manifold.	Individual port fuel injection with tuned intake manifold.
Fuel Storage	Tank type: Standard steel Capacity: 33 gallons Tank location: Behind rear axle Filler fittings: Left rear	Tank type: Twin steel with manifold connection Capacity: 32 gallons Tank location: Rear of axle	Tank type: Coated steel Capacity: 35 gallons Tank location: Mid-ship
Other Significant Modifications	None	None	None

Excerpted from CleanFleet Quarterly Data Report,
Report No. 1, April 1992, Inception -- December 1992.

Specifications for CNG Vehicles in CleanFleet Project

MANUFACTURER	FORD MOTOR COMPANY	CHEVROLET	CHRYSLER CORPORATION
Vehicle Model Name/Number	Econoline, E-250	1992 Chevrolet H.D. Van (CG31305)	B 350
Assembly Plant Name/City/State	Lorain Assembly Plant, Lorain,Ohio	Lordstown Assembly Plant, Lordstown, Ohio	Windsor, Ontario, Canada
Modifications	Ford Motor Company	Fuel system-IMPCO, Cerritos, California	Fuel system: Southern California Gas Company
General Description of Modifications	Fuel storage and delivery changes; chassis modifications and engine changes. Unique electronic engine control calibration.	IMPCO "AFE" fuel injection system, three aluminum cylinders (fiberglass wrapped) and a methane catalyst	Additional fuel tank
Notes about vehicle	Powerplant and components not yet available. Mid-90s offering planned.	This vehicle uses a specially equipped alternative fuels compatible 5.7 liter V8 engine. The engine is equipped with hardened valves and exhaust valve seats, chrome compression rings, valve rotators and a higher capacity oil pan. This engine is available as an option on many Chevrolet trucks for 1993 for those customers desiring an engine which can be fueled with CNG or LPG and carries a full manufacturer's warranty.	
FUNCTIONAL EQUIPMENT — Powertrain			
Engine	Displacement and type: 4.9 L I-6 EFI BHP @ RPM: N/A Ft/Lb torque @ RPM: N/A CR:11.0:1	Displacement and type: 5.7 (350 cubic inch) V8 BHP @ RPM: 190 @ 4,000 RPM Ft/Lb torque @ RPM: 300 @ 2,400 RPM CR: 8.6:1	Displacement and type: 5.2 L V8 EFI BHP @ RPM: 200 @ 4,000 RPM Ft/Lb torque @ RPM: 250 @ 3,600 RPM CR: 9.08:1
Transmission	Ford 4-speed E40D	4-speed automatic with overdrive (4L80E)	No change
Battery	Maintenance-free, 12 volt, 72 amp/hr.	Delco-630 cold crank, amps @ 0 F	No change
FUNCTIONAL EQUIPMENT — Chassis			
Frame	Type of contruction: Single channel, 5 cross members Special modifications to accommodate changes from standard-fueled vehicles: Aft 2 cross members have been changed. Exhaust tail pipe has been modified.	Type of construction: All-welded integral body frame	Type of construction: All-welded integral body frame
Front Suspension	Type: Independent Springs: Coil 4" ID Axle capacity: 3,700 lb.	Type: Independent Springs: Coil Axle capacity: 3,880 lb.	Type: Independent Springs: Coil Axle capacity: N/A
Rear Suspension	Type: Multi-leaf/2-stage Springs: 55" x 3.0", 5 leaves Axle capacity: 5,345 lb.	Type: Semi-elliptic, 2-stage leaf Springs: Multi-leaf (8 leaves) Axle capacity: 5,360 lb.	Type: Multi-leaf Springs: N/A Axle capacity: N/A
Steering	Type: Recirculating ball, XR-50 Gear Ratio: 17.0:1–15.5"	Type: Internal power Ratio: 17.2:1	Type: N/A Ratio: N/A
Brakes	Front, type: Disc, self-adjusting, hydraulic, power assisted Front, size: 12.56 Rear, type: Drum and shoe type, self adjusting Rear, size: 12" x 3" Power-assist booster, size: 13.46" effective diameter dual diaphragm type	Front, type: Disc, power assisted Front, size: Rotor 12.5" x 1.28" - 47.12 sq. in. pads Rear, type: Drum - Rear wheel anti-lock Rear, size: Drum - 13.0" x 2.5" wide (116.73 sq. in. surface) Power-assist booster, size: 9.5 x 8.0 tandem diaphragm	Front, type: Disc, self-adjusting, hydraulic Rear, type: Drum and shoe type, self-adjusting Power-assist booster, size: 13.46" effective diameter, dual diaphragm type
Wheels	Type and size: 8-hole disc, 16" x 7.0"	Type and size: Painted steel 16.0" x 6.5" wide	Type and size: N/A
Body	Construction: Cargo van Doors: Side and rear	Construction: Steel unibody Doors: Sliding side door, regular front and rear	Construction: Cargo van Doors: Side and rear
Dimensions	Overall length: 211.8 (in.) Wheelbase: 138 (in.) Overall width: 79.5 (in.) Cargo volume: 255 (cu. ft.) Curb weight: N/A (lb.) Maximum load weight: 2,245 (lb.)	Overall length: 202.2 (in.) Wheelbase: 125 (in.) Overall width: 79.5 (in.) Cargo volume: 260 (cu. ft.) Curb weight: 4,950 (lb.) Maximum load weight: 3,050 (lb.)	Wheelbase: 127 (in.) Curb weight: 4,615 (lb.) Maximum load weight: 2,885 (lb.)
FUELING SYSTEMS			
Description of Fuel Delivery System	Stainless steel fuel lines, two fuel pressure regulators, manual shutoff valve, high flow fuel rail (single pass design). Fuel injectors are high-flow, low-impedance. In-tank solenoid valves are normally closed and are controlled by fuel pump relay and inertia switch.	IMPCO "AFE" fuel system using a first- and second-stage regulator to reduce pressure from 3,000 psi to approximately 0.25 psi at the throttle body. IMPCO "AFE" computer interacts with the Chevrolet electronic control module. "AFE" uses mass fuel flow sensor to monitor fuel flow and adjust the amount of fuel delivered to the engine.	Individual port fuel injection.
Fuel Storage	Tank type: Steel, fiberglass hoop wrapped Capacity: 1,686 SCF Tank location: 1 mid-ship, 2 aft-of-valve Filler fittings: Sherex	Tank type: Aluminum-fiberglass wrap (3 tanks) Capacity: All total 21 gallon equivalent Tank location: 2 mounted parallel to driveshaft, 1 in place of gasoline tank Filler fittings: Production filler door	Tank type: Aluminum, fully wrapped with fiberglass Capacity: 11 gallon equivalents from factory Tank location: 3 tanks, 1 large tank lying front to rear and 2 smaller tanks behind rear axle across the vehicle. An additional large tank, lying front to rear on opposite side, added by the project to increase total volume to 15.3 gallons. Filter fittings: Sherex
Other Significant Modifications	Engine cooling system: Engine coolant used to heat pressure regulator Engine combustion system components: Hardened valve seat inserts, 11.0:1 CR pistons Exhaust system components: Tail pipe modified Emissions control system components/design: Mass air/SEFI, nonthermactor air	Engine cooling system: Heater hose is spliced to the pressure regulator to heat the regulator Engine combustion chamber components: None Exhaust system components: Muffler moved forward and to right side to make room for tanks Emissions control system components/design: Methane catalyst replaces production catalytic converter	Engine combustion chamber components: Valve seat inserts, valve guide lubrication

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Specifications for Propane Gas Vehicles in CleanFleet Project

MANUFACTURER	CHEVROLET	FORD MOTOR COMPANY
Vehicle Model Name / Number	1992 Chevrolet H.D. Van (CG31305)	Econoline, E-250
Assembly Plant Name / City / State	Lordstown Assembly Plant, Lordstown, Ohio	Lorain Assembly Plant, Lorain, Ohio
Modifications	Fuel System: IMPCO, Cerritos, California	Suburban Petrolane; IMPCO
General Description of Modifications	IMPCO "AFE" fuel injection system, two manifold connected tanks and a methane catalyst	Modifications include: fuel storage and delivery changes. Unique electronic engine control calibration. IMPCO ADP closed-loop system.
Notes about vehicle	This vehicle uses a specially equipped alternative fuels compatible 5.7 liter V8 engine equipped with hardened exhaust valves and seats, chrome compression rings, valve rotators and a higher-capacity oil pan. This engine is available as an option on many Chevrolet trucks for 1993 for those customers desiring an engine which can be fueled with CNG or propane and carries a full manufacturer's warranty.	LP Prep Engine Powerplant and components are available on the commercial market.
FUNCTIONAL EQUIPMENT — Powertrain		
Engine	Displacement and type: 5.7 liter (350 cu. in.) V8 BHP @ RPM: 190 @ 4,000 RPM Ft / Lb torque @ RPM: 300 @ 2,400 RPM CR: 8.6:1	Displacement and type: 4.9 L I-6 EFI BHP @ RPM: N / A Ft / Lb torque @ RPM: N / A CR: 8.8:1
Transmission	4-speed automatic with overdrive (4L80E)	Ford 4-speed E40D
Battery	Delco-630 cold crank amps @ 0 F	Maintenance-free, 12 volt, 72 amp / hr.
FUNCTIONAL EQUIPMENT — Chassis		
Frame	Type of construction: All-welded integral body frame	Type of construction: Single channel, 5 cross members Special modifications to accommodate changes from standard-fueled vehicles: Aft 2 cross members have been changed. Exhaust tail pipe has been modified.
Front Suspension	Type: Independent Springs: Coil springs Axle capacity: 3,880 lb.	Type: Independent Springs: Coil 4" ID Axle capacity: 3,700 lb.
Rear Suspension	Type: Semi-elliptic, 2-stage leaf Springs: Multi-leaf (8 leaves) Axle capacity: 5,360 lb.	Type: Multi-leaf / two-stage Springs: 55" x 3.0", 5 leaves Axle capacity: 5,345 lb.
Steering	Type: Integral power Ratio: 17.2:1	Type: Recirculating ball, XR-50 Gear Ratio: 17.0:1 – 15.5"
Brakes	Front, type: Disc, power assisted Front, size: 47.12 sq. in. pads, rotor 12.5" x 1.28" Rear, type: Drums, rear wheel anti-lock, 13.0" x 2.5" wide Rear, size: 116.73 sq. in. Power-assist booster, size: 9.5 x 8.0 tandem diaphragm	Front, type: Disc, self-adjusting, hydraulic, power assisted Front, size: 12.56 Rear, type: Drum and shoe type, self-adjusting Rear, size: 12" x 3" Power-assist booster, size: 13.46" effective diameter dual diaphragm type
Wheels	Type and size: Painted steel 16.0" x 6.5"	Type and size: 8-hole disc, 16" x 7.0"
Body	Construction: Steel unibody Doors: Sliding side door, regular front and rear	Construction: Cargo van Doors: Side and rear
Dimensions	Overall length: 202.2 (in.) Wheelbase: 125 (in.) Overall width: 79.5 (in.) Cargo volume: 260 (cu. ft.) Curb weight: approx. 4,850 (lb.) Maximum load weight: 3,150 (lb.)	Overall length: 211.8 (in.) Wheelbase: 138 (in.) Overall width: 79.5 (in.) Cargo volume: 255 (cu. ft.) Curb weight: N / A (lb.) Maximum load weight: 2,245 (lb.)
FUELING SYSTEMS		
Description of Fuel Delivery System	IMPCO "AFE" fuel system using a pressure regulator to reduce fuel tank pressure from 150 psi to approximately 0.25 psi at the throttle body. The IMPCO "AFE" computer interacts with the Chevrolet electronic control module. "AFE" uses a mass fuel flow sensor to monitor and adjust the amount of fuel delivered to the engine.	In-tank mounted manual shutoff with excess flow. Flexible stainless steel braided fuel hose. Vacuum filter lockoff mounted adjacent to the service valve. Vacuum controlled electric lockoff, demand regulator / converter. Feedback mixer, mixture control by ADP processor. IMPCO ADP closed-loop system.
Fuel Storage	Tank type: Twin steel with manifold connection Capacity: 32 gallons Tank location: Rear of axle (replaces original gas tank) Filler fittings: Standard fuel filler door	Tank type: 1 steel tank Capacity: 98 liters (about 22 gal.) based on 85% full Tank location: 1 mid-ship Filler fittings: Standard fuel filler door
Other Significant Modifications	Engine cooling system: Heater hose routed to pressure regulator for heat Engine combustion chamber components: None Exhaust system components: See below Emissions control system components / design: Methane catalyst replaces production catalytic converter.	Engine cooling system: Header hose routed to pressure regulators for heat engine combustion.

Excerpted from CleanFleet Quarterly Data Report,
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Specifications for Methanol and Electric Vehicles in CleanFleet Project

MANUFACTURER	FORD MOTOR COMPANY	CONCEPTOR A DIVISION OF VEHMA, INT.
Vehicle Model Name / Number	Econoline, E-250	Electric G-Van, based on General Motors Vandura Van
Assembly Plant Name / City / State	Lorain Assembly Plant, Lorain, Ohio	New Market Ontario, Canada
Modifications	Ford Motor Company	
General Description of Modifications	Flexible fuel vehicle (FFV), changes to fuel supply, storage and engine at Rancho Cucamonga, California.	Installation of battery pack, traction motor and controller, rear axle, transmission, interior heating system
Notes about vehicle	FFV Econoline not currently available on the commercial market.	Commercially available. Serviced by GM dealers.
FUNCTIONAL EQUIPMENT — Powertrain		
Engine	Displacement and type: 4.9 L I-6 EFI BHP @ RPM: N / A Ft / Lb torgue @ RPM: N / A CR: 8.8:1	Motor: DC, 38 KW, transistorized control with DC-DC convertor to charge control battery.
Transmission	Ford 4-speed E40D	Single speed transfer. Fuel storage: Main
Battery	Maintenance-free, 12 volt, 72 amp / hr.	6 V, tubular plate. Lead acid (36 monoblocs, total 216 V). Regenerative braking. Chloride Corporation charger. Recharges in about 8 hours.
FUNCTIONAL EQUIPMENT — Chassis		
Frame	Type of construction: Single channel, five cross members	Type of construction: All-welded integral body frame
Front Suspension	Type: Independent Springs: Coil 4" Axle capacity: 3,700 lb.	Type: Independent Springs: Coil Axle capacity: N / A
Rear Suspension	Type: Multi-leaf / 2-stage Springs: 55" x 3.0", 5 leaves Axle capacity: 5,345 lb.	Type: Semi-elliptic, 2-stage leaf Springs: Multi-leaf (8 leaves) Axle capacity: N / A
Steering	Type: Recirculating ball, XR-50 gear Ratio: 17.0:1 15.5"	Type: Internal power Ratio: 17.2:1
Brakes	Front, type: Disc, self-adjusting, hydraulic Front, size: 12.56 Rear, type: Drum and shoe type, self adjusting Power-assist booster, size: 13.46" effective diameter, dual diaphragm type	Front, type: Disc, power-assisted Front, size: 12.5" x 1.28"—47.12 sq. in. pads Rear, type: Drum Rear, size: 13.0" x 2.5" wide (116.73 sq. in. surface) Power-assist booster, size: 9.5" x 8.0" tandem diaphragm
Wheels	Type and size: 8-hole disc, 16" x 7.0"	Type and size: Painted steel 16.0" x 6.5"
Body	Construction: Cargo van Doors: Side and rear	Construction: Steel unibody Doors: Sliding side door, regular front and rear
Dimensions	Overall length: 211.8 (in.) Wheelbase: 138 (in.) Overall width: 79.5 (in.) Cargo volume: 255 (cu. ft.) Curb weight: N / A (lb.) Maximum load weight: 2,245 (lb.)	Overall length: 202.2 (in.) Wheelbase: 125 (in.) Overall width: 79.5 (in.) Cargo volume: 260 (cu. ft.) Curb weight: 7,100 (lb.) Maximum load weight: 1,500 (lb.)
FUELING SYSTEMS		
Description of Fuel Delivery System	Fuel sensor in-line for percentage methanol. Methanol compatible fuel lines. Larger fuel injectors plus 7th cold start injector.	One G-Van is operating on lead-acid batteries. In the second G-Van, Southern California Edison (SCE) is installing a nickel-cadmium battery pack. If approved by Federal Express, when a Ford Ecostar is available late this year, SCE will substitute it for the G-Van operating on lead-acid batteries. The Ecostar uses sodium-sulfur batteries.
Fuel Storage	Tank type: Methanol-compatible, plated steel with insulator Capacity: 35 gallons Tank location: Mid-ship	
Other Significant Modifications	Engine combustion chamber components: Hardened block for improved wear	None

Excerpted from CleanFleet Quarterly Data Report,
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