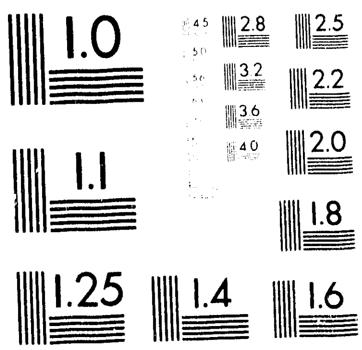
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DOE/EE-0004

Federal Alternative Fuel Program Light Duty Vehicle Operations

Second Annual Report to Congress for Fiscal Year 1992

July 1993

U.S. Department of Energy
Office of Transportation Technologies
Office of Energy Efficiency and Renewable Energy
Washington, DC 20585

MASTER

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ACKNOWLEDGEMENT

The United States Department of Energy gratefully acknowledges the cooperation of the three participating Government agencies in the Alternative Motor Fuels Act of 1988 Federal light duty vehicle program—the General Services Administration, the National Highway Traffic Safety Administration, and the Environmental Protection Agency. The Department also acknowledges the participation and cooperation of General Motors Corporation, Ford Motor Company, Chrysler Corporation, the authorized alternative fuel (methanol, ethanol, and natural gas) vehicle service centers, and the alternative fuel suppliers.

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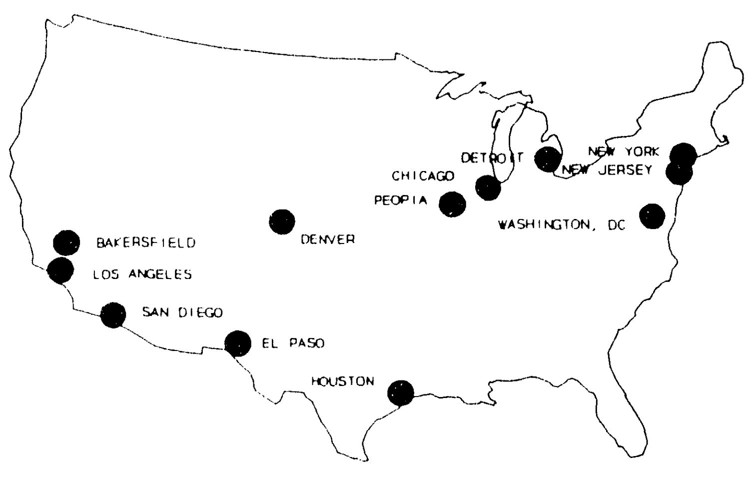
1.0 EXECUTIVE SUMMARY

This annual report to Congress details the second year of the Federal light duty vehicle operations as required by Section 400AA(b)(1)(B) of the Energy Policy and Conservation Act, as amended by the Alternative Motor Fuels Act of 1988, Public Law 100-494. In 1992, the Federal alternative fuel vehicle fleet expanded significantly, from the 65 M85 (85 percent methanol and 15 percent unleaded gasoline) vehicles acquired in 1991 to an anticipated total of 3,267 light duty vehicles. Operating data are being collected from slightly over 20 percent, or 666, of these vehicles. The 601 additional vehicles that were added to the data collection program in 1992 include 75 compressed natural gas Dodge full-size (8-passenger) vans, 25 E85 (85 percent denatured ethanol and 15 percent unleaded gasoline) Chevrolet Lumina sedans, 250 M85 Dodge Spirit sedans (planned to begin operation in fiscal year 1993), and 251 compressed natural gas Chevrolet C-20 pickup trucks. Figure ES-1 illustrates the locations where the Federal light duty alternative fuel vehicles that are participating in the data collection program are operating. The primary criteria for placement of vehicles will continue to include air quality attainment status and the availability of an alternative fuel infrastructure to support the vehicles. This report details the second year of the Federal light duty vehicle operations, from October 1991 through September 1992.

Figure ES-1. Locations of Federal Light Duty Alternative Fuel Vehicles Participating in Data Collection Program



1.1 Program Participants

Alternative fuel vehicles supplied by three United States automotive manufacturers, General Motors Corporation, Ford Motor Company, and Chrysler Corporation, have been procured by the General Services Administration for use in the Alternative Motor Fuels Act program. These alternative fuel vehicles are capable of operating on M85, E85, and compressed natural gas. Currently, five vehicle models are represented in the Alternative Motor Fuels Act program. While these vehicles outwardly appear no different than conventional gasoline vehicles, they incorporate various fuel system and engine modifications in order to operate on methanol/gasoline, denatured ethanol/gasoline, and compressed natural gas fuel. The M85 vehicles are capable of operating on any mixture of gasoline and methanol, up to a mixture of 85 percent methanol. The addition of gasoline to methanol improves vehicle cold-starting and adds visibility to methanol flames, which by themselves are invisible in direct sunlight. The E85 vehicles are capable of operating on any mixture of unleaded gasoline and denatured ethanol, up to a mixture of 85 percent denatured ethanol. The compressed natural gas vehicles are dedicated vehicles, i.e., they operate only on natural gas.

Currently, M85 is being supplied by six oil companies at over 40 public refueling facilities throughout the United States. The six participating oil companies are ARCO, Chevron, Exxon, Mobil Oil Company, Shell Oil Company, and SUNOCO. Compressed natural gas is being supplied by various natural gas utilities throughout the United States. Currently, there are over 500 compressed natural gas refueling facilities in the United States. In Washington, DC, there is one public AMOCO compressed natural gas refueling station located at 823 Pennsylvania Avenue, SE. E85 is available in the Chicago and Washington areas. In Washington there is one public E85 refueling station located at 1248 Pennsylvania Avenue, SE, which is owned and operated by SUNOCO. E85 is available at the Argonne National Laboratory, near Chicago, where three of the six Chevrolet Lumina alternative fuel vehicles are assigned to the area.

Data from these fleets have been collected and analyzed by the National Renewable Energy Laboratory since 1991, and the initial findings have been reported in the first annual report to Congress for fiscal year 1991.[1] The M85, E85, and compressed natural gas vehicles procured by the General Services Administration were incorporated into Government agency fleets throughout the United States in 1992. Overall vehicle operational information for the additional M85, E85, and compressed natural gas vehicles operating in 1992 is discussed in this report, however additional and more quantitative information for the vehicles introduced in 1992 will not be presented. The third annual report to Congress should provide more detailed operational data for these additional M85, E85, and compressed natural gas vehicles.

1.2 Overall Vehicle Operation

The implementation of the alternative fuel vehicles (M85, E85, and compressed natural gas) in 1992 has highlighted a number of challenges that face owners and operators of these vehicles. In 1992, a total of 192 M85 Dodge Spirits were delivered to fleet locations in Washington, DC, Los Angeles, and San Francisco, California. However, problems with the fuel sensor that measures the relative proportions of methanol and gasoline have caused a delay in implementation of these vehicles until a replacement sensor is available. These M85 Dodge Spirits should begin fleet operation

[1] U.S. Department of Energy, Office of Transportation Technologies, *Federal Alternative Fuel Program Light Duty Vehicle Operations - First Annual Report to Congress for Fiscal Year 1991*, DOE/CE-0351, March 1992.

in fiscal year 1993. A total of 675 compressed natural gas vehicles were delivered to various locations and fleets throughout the United States in 1992. One important characteristic noticed of the compressed natural gas vehicles during fleet operations is that they have a shorter operating range than the same model vehicle using gasoline. The purchase specifications for the compressed natural gas vehicles requested a 200-mile operating range. However, a more practical operating range for these vehicles, based on fleet operating experience, is only 80 to 140 miles. There are various factors that conspire to reduce compressed natural gas vehicle operating range which are not factors for conventional liquid fuel vehicles. These factors are the delivery pressure to which the compressed natural gas cylinders are refueled, gas/energy content, operator inexperience, and fuel overheating. These vehicle problems are illustrative of those affecting most alternative fuel vehicles upon initial introduction. All of the 25 E85 Chevrolet Lumina vehicles were delivered to fleet locations in Washington and Chicago. However, one E85 Chevrolet Lumina was destroyed in transit. Currently, the 24 E85 vehicles are operating without any reported problems. With the implementation of alternative fuel vehicles in Federal fleets, the Alternative Motor Fuels Act is acting as a catalyst to the vehicle manufacturers and fuel supply industry to solve these unique problems and make alternative fuel vehicles viable for the general public. While these problems currently cause consternation and inconvenience for their operators, a path is being paved on which solutions can be developed and implemented.

For purposes of this report and to gain a more thorough understanding of alternative fuel vehicle operation in comparison to conventional vehicle operation, the initial 81 vehicles (1991 Chevrolet Lumina and Ford Taurus) were categorized into three separate groups. The first group is designated as the 57 alternative fuel vehicles that operate on M85 and gasoline fuel; however these vehicles refuel a significant percentage of the time on M85 fuel. Therefore, this group of vehicles will be referred to as the M85 alternative fuel vehicles. The second group is designated as the 8 control alternative fuel vehicles that operate almost exclusively on gasoline; this group of vehicles will be referred to as the gasoline alternative fuel vehicles. The third group is designated as the 16 conventional vehicles that operate only on gasoline and are considered control vehicles. Therefore, the third group will be referred to as the conventional gasoline vehicles. The conventional gasoline vehicles normally operate on unleaded gasoline and are not designed to operate on M85 fuel.

Since the introduction of vehicles in January 1991 and through September 1992, the initial 81 vehicles have accumulated about 1,000,000 miles of operation. The Detroit test fleet has accumulated over 300,000 miles, the San Diego fleet about 250,000 miles, and the Los Angeles fleet just over 225,000 miles. The 27 car test fleet in Washington reported a total of nearly 200,000 miles accumulated through September 1992.

1.3 On-Road Fuel/Energy Economy

A summary of the on-road cumulative average fuel and energy economies of the Federal vehicle fleet for fiscal year 1992 is shown in Table ES-1. The Washington M85 alternative fuel vehicles have the lowest average fuel economy of the four sites. This lower average fuel economy was attributable to the greater than average amount of city

Table ES-1. On-Road Fuel/Energy Economy Summary[a]

Federal Fleet Sites/Vehicles	Fuel Economy		Energy Economy
	miles/gallon	miles/gallon—gasoline energy equivalent[b]	BTUs/mile
Washington, DC			
M85 Alternative Fuel Vehicles	11.7	20.7	5,580
Gasoline Alternative Fuel Vehicles	14.3	--	8,060
Conventional Gasoline Vehicles	22.8	--	5,060
Detroit, Michigan			
M85 Alternative Fuel Vehicles	15.9	28.1	4,110
Gasoline Alternative Fuel Vehicles	19.4	--	5,940
Conventional Gasoline Vehicles	24.9	--	4,640
Los Angeles, California			
M85 Alternative Fuel Vehicles	13.9	24.5	4,710
Gasoline Alternative Fuel Vehicles	22.1	--	5,230
Conventional Gasoline Vehicles	25.5	--	4,530
San Diego, California			
M85 Alternative Fuel Vehicles	15.8	27.9	4,140
Gasoline Alternative Fuel Vehicles	20.2	--	6,710
Conventional Gasoline Vehicles	24.3	--	4,750

a Based on 115,400 BTUs/gal for gasoline and 65,400 BTUs/gal for M85.

b Gasoline energy equivalent miles per gallon is the M85 alternative fuel vehicle fuel economy adjusted for the difference in fuel energy content between gasoline and M85 (e.g, M85 has 56 percent of the energy of unleaded gasoline).

driving the M85 alternative fuel vehicles in Washington experience, therefore, reducing their average fuel economy. In addition, due to the limited amount of refueling data collected from the gasoline alternative fuel vehicles in the Washington area, the fuel and energy economies of this vehicle group type may not provide a good representation of varied on-road operation.

1.4 Laboratory Emissions

In order to characterize the emission levels of the fleet vehicles, laboratory tests were performed on 17 vehicles from the Washington and Detroit areas. The exhaust emission results for each vehicle group type (M85 alternative fuel vehicles tested on M85/gasoline, gasoline alternative fuel vehicles tested only on gasoline, and conventional gasoline vehicles) represent an average of 4 to 15 tests from all three test laboratories. Also, the vehicle exhaust and evaporative emission test results for each vehicle group type were averaged from vehicles with odometer mileages ranging from about 200 to 16,000 miles. The M85 alternative fuel vehicles met the Federal standards for total hydrocarbons, organic material hydrocarbon equivalent, carbon monoxide, and oxides of nitrogen when tested on both gasoline and M85. The conventional gasoline vehicles met the Federal emissions standards. Conversely, the gasoline alternative fuel vehicles tested on gasoline were able to meet all applicable Federal emissions standards except for the Federal carbon monoxide standard. The average formaldehyde emissions from the M85 alternative fuel vehicles on M85 were over four times higher than those of the conventional gasoline vehicles. While specific Federal standards do not currently exist for formaldehyde exhaust emissions, these emissions will be important because formaldehyde is one of a number of air toxics being considered for future Federal and state regulations. The average composite Federal Test Procedure evaporative emission test results for the test vehicles revealed a high average evaporative emission level measured for the gasoline alternative fuel vehicles relative to the other vehicle groups, while the M85 alternative fuel vehicles (operating on both gasoline and M85) and the conventional gasoline vehicles exhibited average evaporative emission levels that were much lower than the Federal standard of 2.0 grams/test. The gasoline alternative fuel vehicle test result of 4.72 grams is an average of only three tests, therefore this result is not considered a good representation of the gasoline alternative fuel vehicles evaporative emissions. Based on the limited number of emission tests from the light duty vehicle fleet to date, it is not possible to accurately determine emission trends for the vehicle types and fuels used in the program. However, a test plan has been established for extensive and comprehensive emissions testing of the light duty vehicle fleet for fiscal year 1993.

1.5 Laboratory Fuel/Energy Economy

Fuel/energy economies of selected fleet vehicles from the Washington and Detroit areas were determined based on laboratory testing during fiscal year 1992. The average laboratory fuel/energy economies for each vehicle group/fuel type are shown in Table ES-2. The fuel and energy economy results for each vehicle group type represent an average of 10 to 13 tests from all three test laboratories. The conventional gasoline

Table ES-2. Laboratory Fuel/Energy Economy Summary

Vehicle Group Type	Test Fuel	Fuel Economy, miles/gallon - (gasoline energy equivalent)		Energy Economy, BTUs/mile	
		City[a]	Highway[b]	City[a]	Highway[b]
M85 Alternative Fuel Vehicles	M85	10.6 (18.6)	16.4 (28.9)	6,190	3,980
M85 Alternative Fuel Vehicles	Indolene	17.8	26.8	6,490	4,310
Gasoline Alternative Fuel Vehicles	Indolene	18.4	27.8	6,280	4,160
Conventional Gasoline Vehicles	Indolene	18.9	27.6	6,120	4,170

a City fuel/energy economy data were reduced 10% for comparison with on-road data.
b Highway fuel/energy economy data were reduced 22% for comparison with on-road data.

vehicles had the highest city fuel economy at 18.9 miles/gallon while the M85 alternative fuel vehicles tested on Indolene had the lowest at 17.8 miles/gallon. The city fuel economy (gasoline energy equivalent) of the M85 alternative fuel vehicles tested on M85 was only 2 percent lower than the conventional gasoline vehicles. The M85 alternative fuel vehicles tested on M85 had the highest highway fuel economy (gasoline energy equivalent) at 28.9 miles/gallon while the M85 alternative fuel vehicles tested on Indolene had the lowest at 26.8 miles/gallon. The highway fuel economy (gasoline energy equivalent) of the M85 alternative fuel vehicles tested on M85 was about 5 percent greater than the conventional gasoline vehicles.

1.6 Driveability

During alternative fuel vehicle operation in fiscal year 1992, various driveability difficulties were reported on some of the vehicles, including rough engine idling, hesitation upon acceleration, "check engine" light on, and engine stalling. A portion of both the M85 Chevrolet Lumina and Ford Taurus vehicles experienced some driveability problems during the second year of operation. Installation of upgraded hardware and the issuance of dealer service bulletins appear to have reduced the number of driveability problems experienced by a portion of the alternative fuel vehicles during fiscal year 1992. However, the number of reported driveability difficulties experienced by the M85 alternative fuel vehicles is still greater than the number of difficulties reported by the conventional gasoline vehicles. These vehicle driveability difficulties are illustrative of those affecting most alternative fuel vehicles upon initial introduction.

The Detroit area offers the opportunity to operate fleet vehicles at a cold weather location, in order to test the cold-start capabilities of the M85 alternative fuel vehicles. During the second reported year of vehicle operation, various reported driveability difficulties were reported during the winter months concerning the M85 alternative fuel vehicles in the Detroit area. However, based on dealership repair order information, none of the M85 alternative fuel vehicles in the Detroit area had repairs completed to their cold-start systems.

1.7 Operating Costs

The M85 alternative fuel vehicles in the Los Angeles area had the highest average operating cost (labor, parts, gas/oil/lube, discounts, and total) per vehicle compared to the other fleet locations at nearly $200/vehicle, whereas the Washington area had the lowest at $50/vehicle. However, the maximum overall operating cost was for the gasoline alternative fuel vehicles in the Detroit area at $200/vehicle. The operating costs for the conventional gasoline vehicles in the Detroit, Los Angeles, and San Diego areas were nearly the same at about $50/vehicle, however in the Washington area the operating cost was only about $15/vehicle. The average cost for a scheduled maintenance (lube, oil, and filter only) was greatest in the Detroit area for the M85/gasoline alternative fuel vehicles at over $55; however, the average costs at the other three fleet locations were nearly the same at about $43. The average cost for a scheduled maintenance for an M85 alternative fuel vehicle was about twice the cost of a conventional gasoline vehicle in the Washington and Detroit areas, whereas in Los Angeles the average cost was much less due primarily to discounts. The major cost of a scheduled maintenance on an M85/gasoline alternative fuel vehicle is the cost of the oil. The oil used in the M85/gasoline alternative fuel vehicles is approved by the vehicle manufacturers and contains a special additive package designed specifically for M85 use. The operating cost information was obtained from copies of authorized dealership repair orders at the four fleet locations.

1.8 Safety

In fiscal year 1992, three collision-related accidents were reported involving operation of the light duty vehicles participating in this program. On October 10, 1991, an M85 alternative fuel vehicle was involved in a frontal collision with a non-Federal vehicle in the Detroit area. On December 23, 1991, an M85 alternative fuel vehicle was involved in a collision with a non-Federal vehicle in the Washington area. Also, on April 2, 1992, an M85 alternative fuel vehicle was involved in a collision with a non-Federal vehicle in the Washington area. All of these collision-related accidents had no reported damages to the M85 fuel system and no personnel injuries were reported. No other known safety- or health-related incidents have resulted concerning refueling, maintenance, or servicing.

1.9 Future Activities

Planned activities of the Alternative Motor Fuels Act of 1988 light duty vehicle program include additional alternative fuel vehicles to be added in fiscal year 1993. Secondly, the Energy Policy Act of 1992 makes a number of amendments to the Alternative Motor Fuels Act program, including the repeal of the termination date of September 30, 1997 for the Alternative Motor Fuels Act programs on data collection for light duty vehicles, alternative fuel truck commercialization, and alternative fuel buses. The amended version of the Alternative Motor Fuels Act also allows for all alternative fuel types (e.g., propane, electricity, etc.) to be acquired for the program. Thirdly, the Department has developed an expanded emissions test plan for the light duty vehicle fleet for fiscal year 1993. The overall objective is to ensure the accurate measurement, collection, dissemination, and analysis of mass emissions data from the fleet so that differences in vehicle emissions when using alternative fuels and conventional fuels can be determined. In addition, the Energy Policy Act adds a statutory requirement for the wide adoption of alternative fuel vehicles in normal Federal fleet operations. This has been amplified by Executive Order 12844, signed by President Clinton on April 21, 1993, which directs agencies to exceed the Energy Policy Act alternative fuel vehicle acquisition requirements by 50 percent if possible.

2.0 INTRODUCTION

This annual report to Congress details the second year of the Federal light duty vehicle operations as required by Section 400AA(b)(1)(B) of the Energy Policy and Conservation Act. Section 400AA(b)(1) states:

> *"(A) The Secretary, in cooperation with the Environmental Protection Agency and the National Highway Traffic Safety Administration, shall conduct a study of the vehicles acquired under subsection (a), which shall at a minimum address—*
>
> *"(i) the performance of such vehicles, including performance in cold weather and at high altitude;*
>
> *"(ii) the fuel economy, safety, and emissions of such vehicles; and*
>
> *"(iii) a comparison of the operation and maintenance costs of such vehicles to the operation and maintenance costs of other passenger automobiles and light duty trucks.*
>
> *"(B) The Secretary shall provide a report on the results of the study conducted under subparagraph (A) to the Committees on Commerce, Science, and Transportation and Governmental Affairs of the Senate, and the Committee on Energy and Commerce of the House of Representatives, within one year after the first such vehicles are acquired, and annually thereafter."*

The Alternative Motor Fuels Act of 1988 encourages the use and production of alternative fuel vehicles. The Congress has recognized that displacement of energy derived from imported oil with alternative fuels will help to achieve energy security and improve air quality. In implementing this Act, the Federal Government is assisting clean-burning, non-petroleum transportation fuels to reach a threshold level of commercial application and consumer acceptability at which they can successfully compete with petroleum-based transportation fuels. The objectives of the program are to demonstrate the environmental, economic, and performance characteristics of alternative fuel fleet vehicles and to provide information for engine/vehicle manufacturers as well as the general public.

The Alternative Motor Fuels Act directs the Department of Energy to undertake certain tasks to implement alternative fuel projects in the transportation area and to work with other Federal agencies, most notably the General Services Administration, the Department of Transportation, and the Environmental Protection Agency. The Alternative Motor Fuels Act provides for the cooperative efforts of State and local governments as well as an active role for industry. In the vehicle evaluation/ demonstration efforts, three major activities are identified—a Federal light duty vehicle demonstration project, a truck commercial application project, and an alternative fuels bus project. The Department has identified the National Renewable Energy Laboratory, formerly the Solar Energy Research Institute, as the Field Manager to support the alternative fuel evaluation/demonstration efforts. Information on light duty vehicle emissions, fuel economy/consumption, reliability, driveability, operating costs, health/safety, etc., is currently being collected to determine the commercial viability of alternative fuel vehicles in a fleet environment. The Alternative Fuels Data Center established at the National Renewable Energy Laboratory is responsible for storing, displaying, and allowing public access of all available data on alternative fuels. The objectives of the Alternative Fuels Data Center are to:

- Design, implement, and operate a computerized database system for storage and retrieval of available data on alternative transportation fuel demonstration and evaluation efforts and

- Provide user-access to external users in the scientific, industrial, and governmental communities.

In 1991, the Federal vehicles included 65 M85 alternative fuel vehicles and 16 conventional gasoline fuel vehicles totaling 81 vehicles. M85 fuel is a mixture of 85 percent chemical grade methanol and 15 percent unleaded gasoline. The addition of gasoline to methanol improves vehicle cold-starting and adds visibility to methanol flames, which by themselves are invisible in direct sunlight. These 65 M85 vehicles are capable of operating on any mixture of gasoline and methanol up to a mixture of 85 percent methanol. The initial four geographic locations selected for the first 65 M85 vehicles participating in the program were: Washington, DC; Detroit, Michigan; Los Angeles, California; and San Diego, California. The 65 General Motors Lumina and Ford Taurus M85 vehicles were placed in the Federal fleet in January 1991 at Washington (8 Luminas and 15 Tauruses), Detroit (5 Luminas and 15 Tauruses), Los Angeles (6 Luminas and 5 Tauruses), and San Diego (6 Luminas and 5 Tauruses). In addition, four conventional gasoline General Motors Lumina and Ford Taurus vehicles were placed at each of the four locations (16 total) in order to develop comparative operating data between conventional gasoline vehicles and M85 alternative fuel vehicles. Light duty vehicle operations reported in the first year to Congress spanned the period from initial vehicle introduction in January 1991 through September 1991. For the first year, only M85 vehicles began operation into the Federal fleets; however, natural gas and ethanol fuel vehicles began service in fiscal year 1992.

For the period of operation from January 1991 through September 1991, the vehicles accumulated nearly 280,000 miles, an average of 3,450 miles per vehicle. Over 70 percent of these miles were traveled using M85 fuel. The total amount of M85 fuel consumed by the vehicles is estimated at over 15,000 gallons. The vehicle fleet in Washington accumulated nearly 50,000 miles during January through September 1991. In Detroit, the vehicle fleet accumulated nearly 90,000 miles during this same period. The vehicle fleet in Los Angeles and San Diego accumulated 60,000 and 80,000 miles, respectively, during the initial year of operation. Shown in Figure 1 is a monthly summary of miles accumulated by vehicle type for all four cities combined. The limited accumulation of miles during the months of January and February represents the initial implementation of vehicles in the field, with the majority of vehicles beginning service in March and April 1991.

In 1992, the Federal alternative fuel vehicle fleet expanded significantly, from the 65 M85 vehicles acquired in 1991 to an anticipated total of 3,267 light duty vehicles. Operating data is being collected from slightly over 20 percent, or 666, of these vehicles. The 601 additional vehicles that were added to the data collection program in 1992 include 75 compressed natural gas Dodge full-size (8-passenger) vans, 25 E85 (85 percent denatured ethanol and 15 percent unleaded gasoline) Chevrolet Lumina sedans, 250 M85 Dodge Spirit sedans, and 251 compressed natural gas Chevrolet C-20 pick-up trucks.

Figure 2 illustrates the locations where the Federal light duty alternative fuel vehicles that are participating in the data collection program are operating. The primary criteria for placement of vehicles will continue to include air quality attainment status and the availability of an alternative fuel infrastructure to support the vehicles.

This report details the second year of the Federal light duty vehicle operations from October 1991 through September 1992. The following sections discuss the vehicle operation and performance characteristics of the vehicles in a fleet environment.

Figure 1. Light Duty Vehicle Miles Accumulated by Month

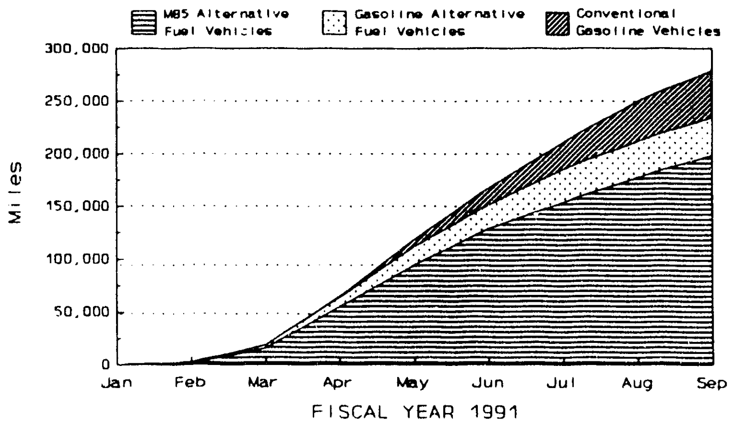
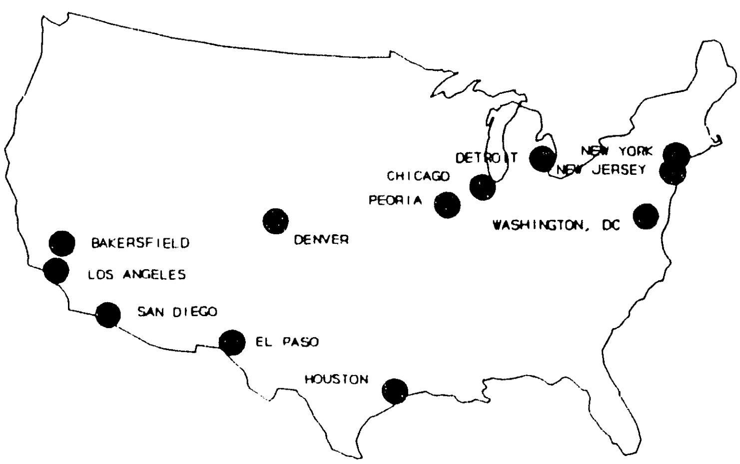


Figure 2. Locations of Federal Light Duty Alternative Fuel Vehicles Participating in Data Collection Program



3.0 ALTERNATIVE FUEL VEHICLE OPERATION

The following sections include discussion of the program participants and summaries of vehicle usage.

3.1 Program Participants

3.1.1 Vehicle Manufacturers

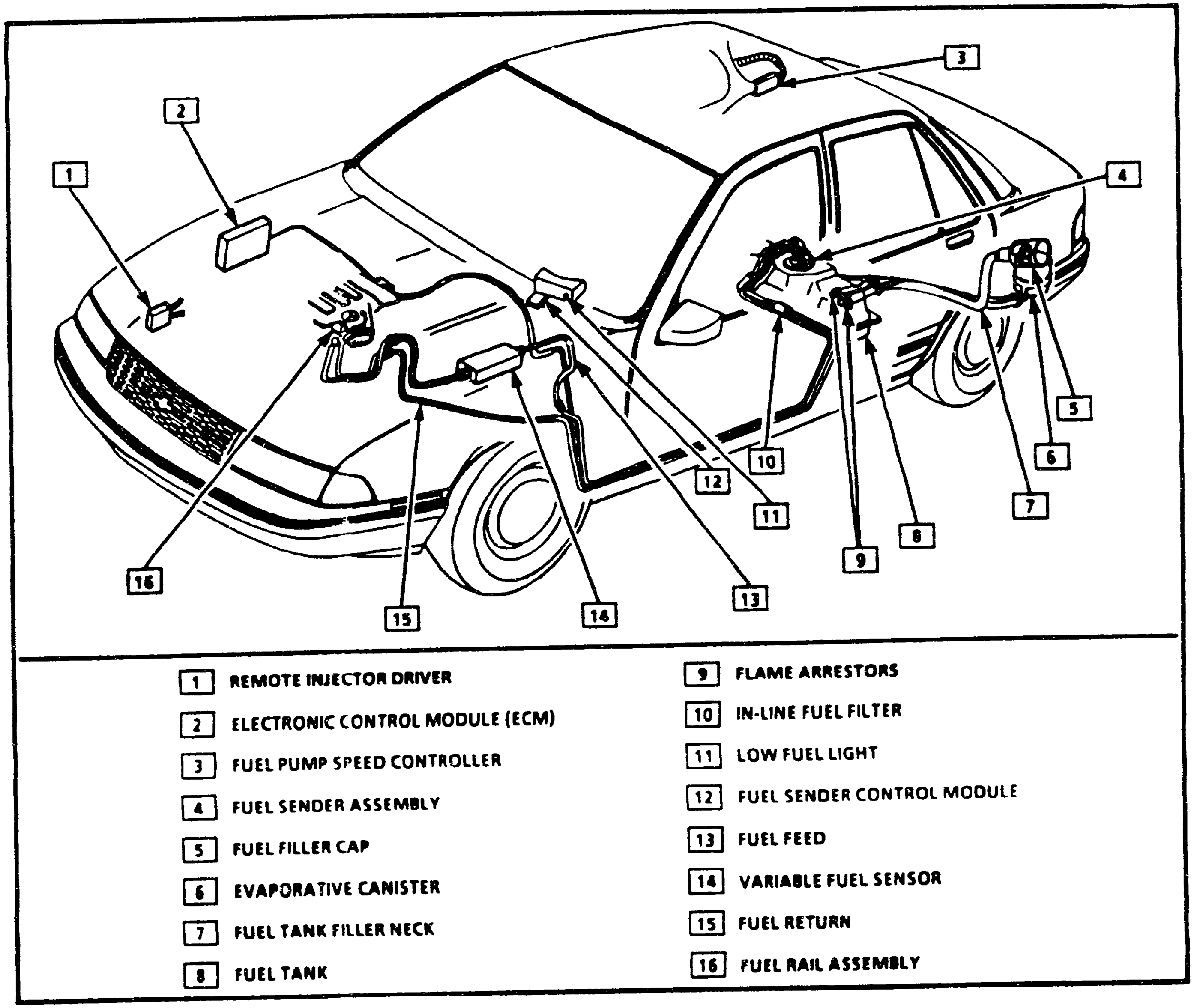
Alternative fuel vehicles supplied by three United States automotive manufacturers, General Motors Corporation, Ford Motor Company, and Chrysler Corporation, have been procured by the General Services Administration for use in the program. These alternative fuel vehicles are capable of operating on M85, E85, and compressed natural gas. The M85 vehicles are capable of operating on any mixture of gasoline and methanol, up to a mixture of 85 percent methanol. By itself, methanol is a clear, colorless liquid that has a very slight alcohol aroma. M85 fuel is a mixture of 85 percent chemical grade methanol and 15 percent unleaded gasoline. The addition of gasoline to methanol improves vehicle cold-starting and adds visibility to methanol flames, which by themselves are invisible in direct sunlight. With the addition of gasoline to methanol, M85 also assumes a brownish tint and a slight gasoline aroma. The E85 vehicles are capable of operating on any mixture of unleaded gasoline and denatured ethanol, up to a mixture of 85 percent ethanol. E85 fuel is a mixture of 85 percent denatured ethanol and 15 percent unleaded gasoline. The compressed natural gas vehicles are dedicated vehicles, i.e., they operate only on natural gas.

Currently, five vehicle models are represented in the program, the 1991/1992 Chevrolet Lumina, 1992 Chevrolet C-20 pickup truck, 1991 Ford Taurus, 1993 Dodge Spirit, and 1992 Dodge B-250/350 van. While these vehicles outwardly appear no different than conventional gasoline vehicles, they incorporate various fuel system and engine modifications in order to operate on methanol/gasoline, ethanol/gasoline, and compressed natural gas fuel.

The unique components of the M85/E85 Chevrolet Lumina for operating on a mixture of methanol/gasoline or denatured ethanol/gasoline are shown in Figure 3. Major changes include different piston rings, fuel tank, electronic control module, and the addition of a fuel sensor to determine the percent of methanol or ethanol in the fuel mixture. The M85 Chevrolet Lumina is able to operate on M85 or gasoline or any mixture of them. Similarly, the E85 Chevrolet Lumina is able to operate on E85 or gasoline, or any mixture of them. The time required to refuel the M85 or E85 Chevrolet Lumina is the same as the conventional gasoline vehicle since the fuel tanks for these vehicles have the same capacity of 17.1 gallons.

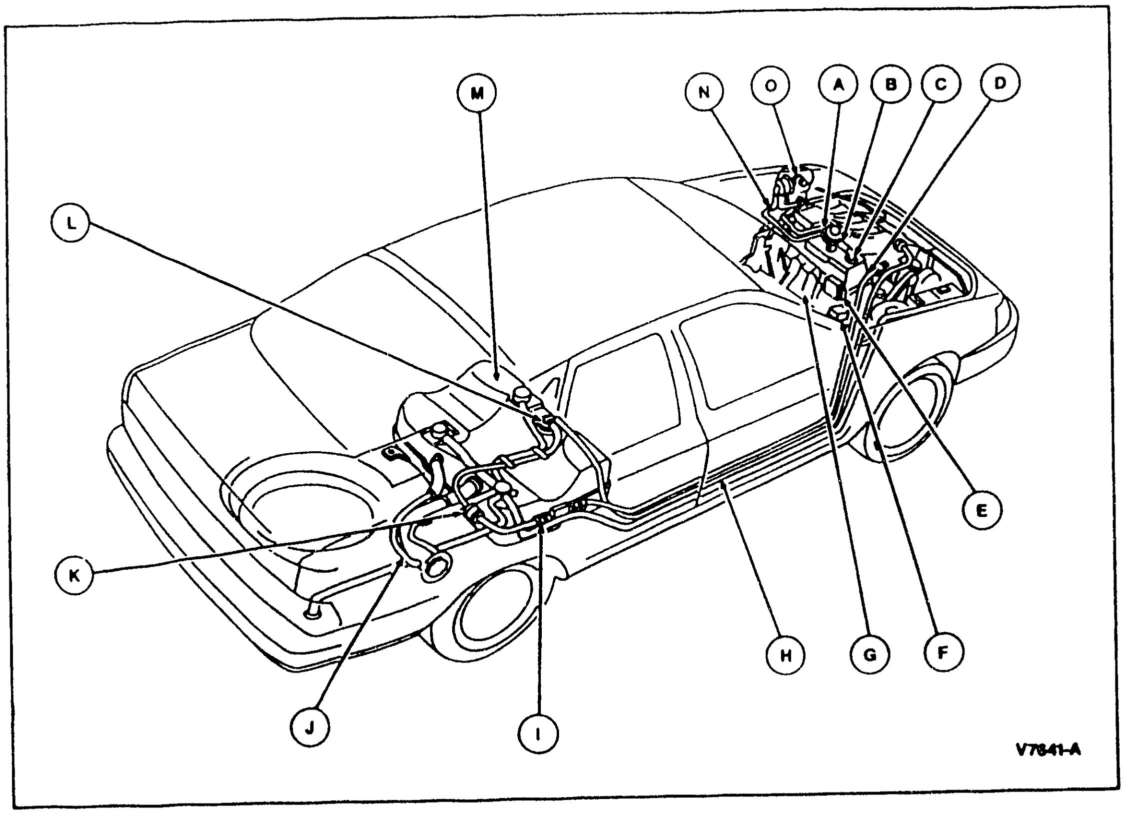
Unique components of the M85 Ford Taurus for operating on methanol and gasoline fuel blends are shown in Figure 4. The major changes include different spark plugs, fuel tank, electronic control module, and the addition of a sensor to determine the percent of methanol in the fuel mixture. The M85 Ford Taurus is able to operate on M85 fuel or

Figure 3. Unique Components of the M85/E85 Chevrolet Lumina



Source: General Motors Corporation

Figure 4. Unique Components of the M85 Ford Taurus



Glossary of Components

A. **Spark Plugs**: The wire electrode is wider for better heat transfer.

B. **Fuel Injectors**: FFV fuel injectors have a higher fuel flow capacity and a modified spray nozzle design.

C. **Fuel Rail** Material changes are made for alcohol fuel compatibility.

D. **Fuel Pressure Regulator**: Material changes are made for alcohol fuel compatibility.

E. **EEC-IV Microprocessor**: A different calibration is utilized to monitor and activate FFV sensors and systems as required.

F. **Wiring Harnesses**: Wiring changes have been made to connect with the Fuel Sensor and Cold Start System.

G. **Engine Oil**: Specially formulated for good engine durability with all of the possible mixtures.

H. **Fuel Supply, Return and Vapor Lines**: Material changes are made for alcohol fuel compatibility.

I. **Fuel Sensor**: This unique FFV component allows the EEC-IV microprocessor to determine the percentage of alcohol in the fuel.

J. **Filler Tube**: Improved coating is applied and anti-siphon screen installed.

K. **Fuel Filter**: Material changes are made for alcohol fuel compatibility.

L. **Fuel Pump Assembly/Fuel Sending Unit**: Nickel plating is applied to non-stainless steel parts. All other parts are of different materials for compatibility with alcohol fuels.

M. **Fuel Tank**: A plastic fuel tank is used for alcohol fuel compatibility and is shielded to reduce evaporation.

N. **Cold Start System**: Allows faster, more reliable starts in very cold weather.

O. **Evaporative Emission System**: Charcoal canister enlarged and vapor vent valves modified to relieve pressure from extended idling and hill climbing.

Source: Ford Motor Company

gasoline or any mixture of them. The time required to refuel the M85 Ford Taurus is slightly longer than the conventional gasoline vehicle since the M85 Ford Taurus fuel tank capacity is 18.6 gallons, 2.6 gallons more than the conventional gasoline vehicle.

Basic operation of either the M85/E85 Chevrolet Lumina or M85 Ford Taurus is unchanged from their conventional gasoline counterparts. Both the Chevrolet Lumina and Ford Taurus alternative fuel vehicle engine control systems continuously adjust the engine for proper performance, regardless of the percent of methanol/ethanol in the fuel. Because these adjustments do not require intervention by the driver, the only difference the driver may notice is a slight increase in vehicle response and acceleration with fuels of a high methanol/ethanol content.

Unique components of the Dodge B-250/350 and Chevrolet C-20 vehicles for operating on compressed natural gas are shown in Figures 5 and 6, respectively. Both the Dodge and Chevrolet vehicles have three pressurized compressed natural gas cylinders in place of the gasoline tank and are dedicated vehicles, i.e., they only operate on natural gas. The time required to refuel the compressed natural gas vehicles is longer than the conventional gasoline vehicle, depending on whether the compressed natural gas vehicles are refueled from a slow-fill or fast-fill refueling station. With fast-fill, refueling occurs in a time period similar to that for conventional liquid fuel vehicles. Slow-fill refueling relies only on the compressor itself and may take several hours to complete, dependent on compressor operating capacity and how many vehicles are being refueled at once. With slow-fill, the vehicles are typically parked and refueled overnight. However, most of the compressed natural gas vehicles participating in the light duty vehicle program are located near refueling facilities which have fast-fill capability.

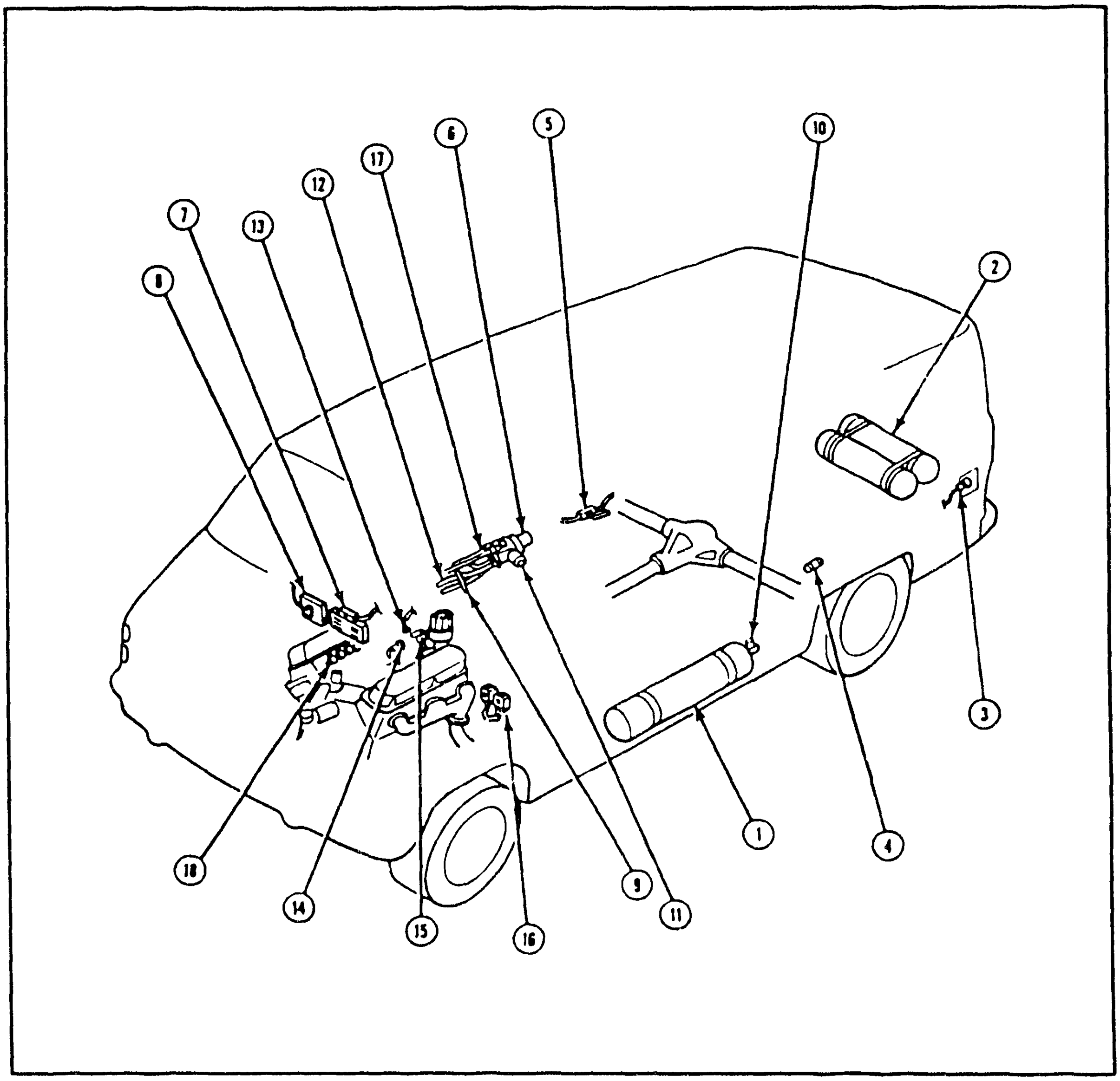
3.1.2 Government Agencies

The primary criteria for placement of vehicles will continue to include air quality attainment status and the availability of an alternative fuel infrastructure to support the vehicles. Some of the Federal agencies currently participating in the program are noted in Table 1. Participation of the Federal agency fleets in the program requires the collection

Table 1. Selected Federal Agencies Participating in the Alternative Fuel Federal Light Duty Vehicle Program

Department of Energy	Department of Transportation	Consumer Product Safety Commission
Department of Agriculture	Office of Personnel Management	Department of Veterans Affairs
Department of Labor	General Services Administration	Department of State
Department of the Interior	Treasury Department	Small Business Administration
Environmental Protection Agency	Department of Justice	Department of Housing and Urban Development
Department of Health and Human Services	Defense Contract Administration	U.S. Army
U.S. Navy	U.S. Marine Corps	U.S. District Court
Defense Logistics Agency	U.S. Air Force	
	U.S. Postal Service	

Figure 5. Unique Components of the Compressed Natural Gas Dodge B-250/350

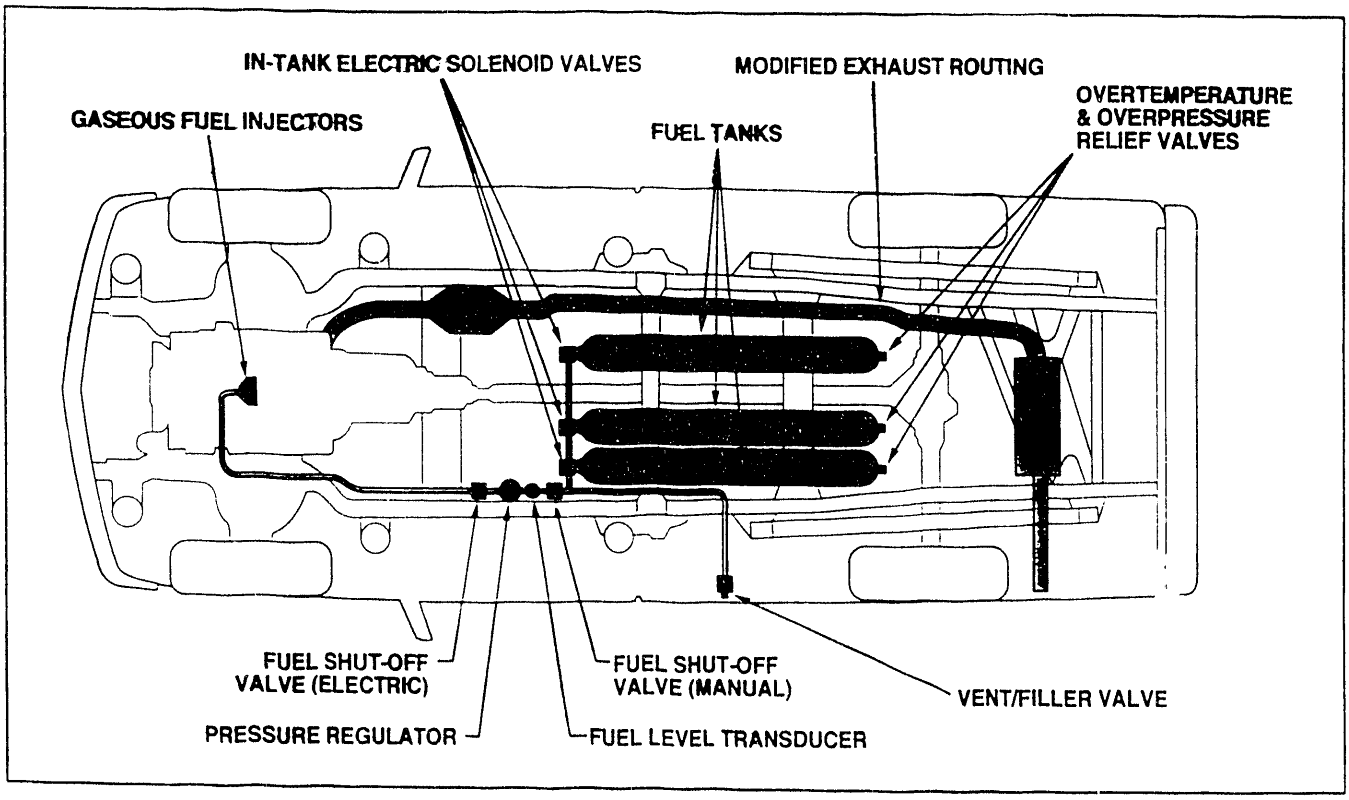


Glossary of Components

1. Fuel Cylinder (Side)
2. Fuel Cylinders (Rear)
3. Fuel Fill Receptacle
4. Check Valve
5. Manual Shut-off Valve
6. Fuel Pressure Regulator
7. Powertrain Control Module
8. Fuel Injector Driver Module
9. Pressure Relief Discharge Tube
10. Fuel Gauge Pressure Sensor
11. High-Pressure Fuel Shut-off Solenoid
12. Engine Coolant Hoses (2)
13. Fuel Temperature Sensor
14. Fuel Pressure Sensor
15. Low-Pressure Fuel Shut-off Solenoid
16. Fuel Shut-off Solenoid Relay
17. Pressure Relief Device
18. Fuel Injectors (8)

Source: Chrysler Corporation

Figure 6. Unique Components of the Compressed Natural Gas Chevrolet C-20



Source: General Motors Corporation

of data specific to vehicle performance. Data from these fleets have been collected and analyzed by the National Renewable Energy Laboratory since 1991, and the initial findings have been reported in the first annual report to Congress for fiscal year 1991.[2] The M85, E85, and compressed natural gas vehicles procured by the General Services Administration, owned and managed by the Interagency Fleet Management System, were incorporated into Government agency fleets throughout the United States in 1992. The Detroit area offers the opportunity to operate fleet vehicles at a cold weather location in order to test the cold-start capabilities of the M85 alternative fuel vehicles, whereas the Denver area offers the opportunity to operate fleet vehicles at a high-altitude location in order to test the emission control system capabilities. However, the impact of altitude on vehicle operation using alternative fuels will not be presented in this report due to insufficient information. The third annual report to Congress should provide additional and more quantitative information on the operation of E85 and compressed natural gas alternative fuel vehicles in the Denver area and other participating locations.

[2] U.S. Department of Energy, Office of Transportation Technologies, *Federal Alternative Fuel Program Light Duty Vehicle Operations - First Annual Report to Congress for Fiscal Year 1991*, DOE/CE-0351, March 1992.

3.1.3 Alternative Fuel Suppliers

Currently, M85 is being supplied by six oil companies at over 40 public refueling facilities throughout the United States. The six participating oil companies are ARCO, Chevron, Exxon, Mobil Oil Company, Shell Oil Company, and SUNOCO.

Compressed natural gas is being supplied by various natural gas utilities throughout the United States. Currently, there are over 500 compressed natural gas refueling facilities in the United States. About 75 percent of these are owned by natural gas utilities, while about 10 percent are publicly owned. In Washington there is one public compressed natural gas refueling station located at 823 Pennsylvania Avenue, SE. This station is owned and operated by AMOCO.

Currently, E85 is available in the Chicago and Washington areas. In Washington, there is one public E85 refueling station located at 1248 Pennsylvania Avenue, SE, which is owned and operated by SUNOCO. E85 is available at the Argonne National Laboratory, near Chicago, where three of the six Chevrolet Lumina alternative fuel vehicles are assigned to the area.

3.2 Overall Vehicle Operation

The implementation of the alternative fuel vehicles (M85, E85, and compressed natural gas) has highlighted a number of challenges that face owners and operators of these vehicles. The following presents an overall description of what these challenges have been.

In 1992, a total of 192 M85 Dodge Spirits were delivered to fleet locations in Washington, Los Angeles, and San Francisco. However, a problem with the fuel sensor that measures the relative proportions of methanol and gasoline has caused a delay in implementation of the M85 Dodge Spirits until a replacement sensor is available. In fiscal year 1993, these M85 Dodge Spirit vehicles should begin fleet operation where M85 refueling facilities already exist, or where plans for M85 refueling facilities are in place. This should provide good access to refueling facilities for the M85 vehicles.

In 1992, all of the 25 E85 Chevrolet Lumina vehicles were delivered to fleet locations in Washington and Chicago. However, one E85 Chevrolet Lumina was destroyed in transit. Currently, the 24 E85 alternative fuel vehicles are operating without any reported problems.

In 1992, a total of 675 compressed natural gas Dodge B-250/350 vans and Chevrolet C-20 pickup trucks were delivered to various locations and fleets throughout the United States. One important characteristic noticed of the compressed natural gas vehicles during fleet operations is that they have a shorter operating range than the same model vehicle using gasoline. The purchase specifications for the compressed natural gas vehicles requested a 200-mile operating range. Neither of the compressed natural gas vehicles purchased was able to meet this requirement (180 miles for the Dodge van and 193 miles for the Chevrolet pickup truck). However, the operating range listed by the vehicle manufacturers represents the maximum range the compressed natural gas vehicle can achieve when all the fuel is consumed under ideal operating conditions. A more practical operating range for these vehicles, based on fleet operating experience, is only 80 to 140 miles. Besides the limitations of an inherently short operating range, there are several factors that further conspire to reduce vehicle operating range which are not factors for conventional liquid fuel vehicles and thus represent a new learning experience for compressed natural gas vehicle operators. The first and most basic is the pressure to which the compressed natural gas cylinders are refueled. Compressed natural gas cylinders are designed to operate at a specified pressure, typically 2,400 psi or 3,000 psi. The range for the compressed natural gas vehicles was based on cylinders completely full of natural gas at 3,000 to 3,600 psi. There are several reasons why the refueling process might result in cylinders which have less fuel than was used to establish the maximum operating range as described below.

- Delivery pressure - Some refueling facilities are only capable of refueling compressed natural gas vehicles to 2,400 psi. Assuming all other things are equal, this results in approximately a 20 to 33 percent reduction in vehicle operating range.

- Driving/route profile - Another important factor to operating range is the type of driving to which the vehicle is subjected. The maximum operating range listed by the vehicle manufacturers is believed to have been developed using the same techniques as is used for conventional liquid fuel vehicles. Those vehicles used in urban environments exclusively will have lower fuel economy and consequently lower operating range - a significant and very noticeable difference when operating range is already very limited.

- Gas/energy content - The heating value of the natural gas is a factor that can adversely affect the compressed natural gas vehicle operating range. The national average heating value for natural gas is about 1,030 BTU/scf, however, there are significant variations across the United States. Operating range will be linearly affected by natural gas heating value. For example, natural gas having 900 BTU/scf will result in approximately a 10 percent reduction in operating range. Likewise, increases in heating value will cause increases in operating range. A further complicating factor is that natural gas heating value may change at any time. Thus, the operator may experience an unexpected decrease in range without warning.

- Operator inexperience - Refueling compressed natural gas vehicles is unlike refueling liquid fuel vehicles in that the refueling rate is not constant. Fuel typically flows from the compressed natural gas refueling facility at a given pressure to the vehicle cylinders. At the beginning of the refueling process, the pressure difference is at its highest and the fuel flow rate is also highest. Near the end of the refueling process, the fuel flow rate is very slow and the operator may mistakenly stop refueling before all the natural gas possible is transferred to the vehicle cylinders. This is understandable because in addition, it usually takes slightly longer to completely refuel a compressed natural gas vehicle compared to the same model vehicle using gasoline. Also, the flow of compressed natural gas through the refueling hose causes vibration of the fuel lines with resultant high-pitched noises. These noises change in pitch and get quieter as the refueling process proceeds, corresponding to a change in fuel flow rate. Some operators have mistaken the change in pitch to represent a problem with the refueling equipment or the end of the refueling process. In some instances, the noise decreases considerably near the end of the refueling process when the refueling rate is very low, and some operators may mistakenly believe refueling to be complete before it really is.

- Fuel overheating - The refueling equipment itself can affect the amount of natural gas that is transferred to the cylinders. There are two types of compressed natural gas refueling systems: fast-fill and slow-fill. Fast-fill uses large storage cylinders to keep natural gas at a pressure higher than what can be stored in the vehicle cylinders. Due to the thermodynamic properties of natural gas, the natural gas entering the vehicle cylinders during fast-fill refueling increases in temperature. This increase in temperature reduces the density of the natural gas at a given pressure, thus reducing the mass of natural gas and the vehicle operating range. Most fast-fill refueling facilities compensate for this temperature increase by allowing the pressure delivered to the vehicle cylinders to be slightly higher than it would normally be. When the natural gas cools to ambient temperature, the pressure should be the fill pressure for that cylinder. Slow-fill refueling does not experience this phenomena because the flow rate is slower which results in smaller temperature increases and because the natural gas typically has sufficient time to cool during the longer time slow-fill refueling requires. However, it has been observed that fast-fill refueling often results in cylinders that contain approximately 10 percent less natural gas compared with slow-fill refueling, with a consequent reduction in vehicle operating range.

- Vehicle accessories - A factor adversely affecting compressed natural gas vehicle operating range is the use of vehicle accessories, the most noticeable one being air conditioning. It is assumed that the operating range specified by the manufacturers was achieved without using the air conditioning, as is the practice for conventional liquid fuel vehicles. Use of the air conditioning and other vehicle accessories will have an adverse impact on vehicle operating range, especially in urban driving environments, as it will for any vehicle.

Limited vehicle operating range has been a very visible and constant source of driver concern when operating the compressed natural gas vehicles. However, there have been several other factors that have affected operation of the compressed natural gas vehicles that have adversely impacted vehicle operator perceptions. Most of these can be characterized as being typical of new technology being used and manufactured in volume for the first time. The following describes these factors observed to date.

- Availability of compressed natural gas refueling facilities - The number of compressed natural gas refueling facilities is currently very limited because the demand for natural gas for use in vehicles is small and because of the high cost of compressed natural gas refueling facilities. The compressed natural gas vehicles bought for the program are dedicated vehicles, i.e., they operate only on natural gas. If compressed natural gas refueling facilities are not available, the vehicles cannot be refueled. The limited number of refueling facilities combined with low operating range puts an additional burden on vehicle operators.

- Driveability problems - Various driveability problems such as stalling, surging and failure to start have been observed when operating the compressed natural gas vehicles. A common problem has been debris in the fuel lines that caused obstructed fuel flow. The debris has included metal chips and strands, and pieces of thread sealant. The metal debris likely come from the cylinders and lines themselves when new, and from assembly, i.e., the process of tightening high pressure fittings can cause metal chips and strands to be created which then can cause obstructions. Liberal use of thread sealant may likewise cause pieces of debris to be created that can lodge in fittings or lines causing obstructions. As a result of debris in the fuel lines, the compressed natural gas Chevrolet pickups have had fuel injector problems and fuel filter replacements. Also, a problem with the pressure regulator on the compressed natural gas Chevrolet pickups has been found that can cause failure to start if the vehicle has not been used for several days. Some driveability problems experienced on the compressed natural gas Dodge vans may have been caused by the engine control computer which was changed to reflect an update on all the compressed natural gas Dodge vans.

- Refueling connector incompatibilities - A standard connector for refueling compressed natural gas vehicles has not been determined yet in the United States (Canada has made such a determination). The compressed natural gas vehicles were delivered with two different refueling connector fittings which did not always match the available refueling dispenser fittings. While many refueling facilities often keep adapters to allow them to refuel compressed natural gas vehicles with different refueling connectors, using adapters is not considered good practice and is discouraged. In some instances, use of adapters has caused very unusual conditions that could only be overcome through a sequence of operations that are beyond the expected comprehension of anyone without extensive knowledge of compressed natural gas refueling facilities and vehicle fuel systems. However, most of the refueling facilities where the compressed natural gas vehicles refuel have retrofitted the dispenser fittings for proper connection.

- Availability of trained mechanics - The compressed natural gas vehicles are being operated in various areas of the United States. This has put a strain on the ability of the vehicle manufacturers to assure that trained mechanics are available everywhere the compressed natural gas vehicles are. Vehicle dealerships have been reluctant to spend the money to train mechanics when they did not sell the compressed natural gas vehicle, there are only a few compressed natural gas vehicles to be serviced, and there is no guarantee that more of the compressed natural gas vehicles will be present in the area for service in the future.

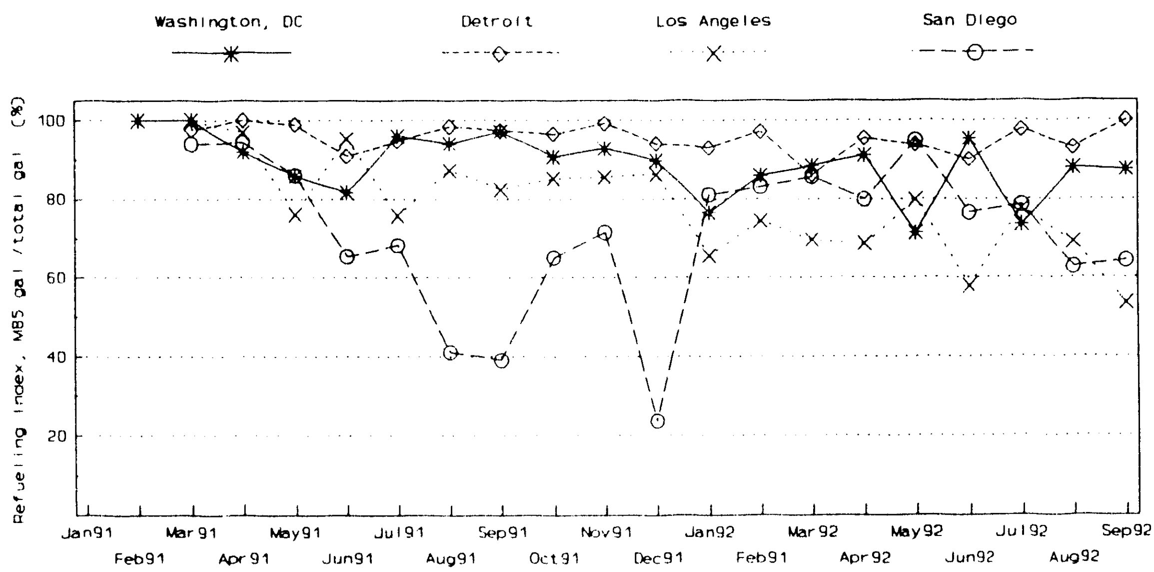
- Availability of parts - There has been a scarcity of replacement parts for the compressed natural gas vehicles. The vehicle manufacturers, in trying to resolve the parts failure problems, have caused a parts backlog until the problems are resolved.

These vehicle and infrastructure problems are illustrative of those affecting most alternative fuel vehicles. The Alternative Motor Fuels Act program is acting as a catalyst to the vehicle manufacturers and fuel supply industry to solve these problems and make alternative fuel vehicles viable for the public. While these problems currently cause consternation and inconvenience for their operators, a path is being paved on which solutions can be developed and implemented.

The third annual report to Congress should provide additional and more quantitative information on vehicle mileage accumulation, fuel economy, maintenance, reliability, vehicle emissions, and comparison of costs in operating the additional M85, E85, and compressed natural gas alternative fuel vehicles during fiscal year 1992.

In order to further understand the amount and apportionment of M85/gasoline fuel used and its relative impact on in-use vehicle operation, a monthly refueling index was computed. The refueling index is the ratio of the amount of M85 fuel used in gallons compared with the total amount (M85 and gasoline fuel) used in gallons, for each of the four initial locations. As shown in Figure 7, the refueling index is consistently above 60 percent for the Washington, Detroit, and Los Angeles areas. This indicates that, of the total amount of fuel used for operating the alternative fuel vehicles, the majority of fuel used was M85 at these three locations. However, in the San Diego area, the relative percentage of M85 fuel used by the fleet vehicles varies from about 95 percent to a low of about 20 percent. This may be attributable to the lack of available M85 refueling facilities since a relatively significant number of alternative fuel vehicles in the San Diego area travel considerable distances. Also, a number of the alternative fuel vehicle operators have reported that the two public M85 refueling stations in the San Diego area have been inoperable and as a result gasoline fuel was used instead.

Figure 7. Vehicle Monthly Refueling Index



Source National Renewable Energy Laboratory

The 65 M85 vehicles (1991 Chevrolet Lumina and Ford Taurus) are capable of operating on any mixture of gasoline and methanol, up to a mixture of 85 percent methanol. In an attempt to quantify comparisons on the commercial and operational viability of in-use fleet operation, 8 of the 65 M85 vehicles (2 at each location) were operated as "control" vehicles. These 8 M85 control vehicles were refueled almost exclusively on gasoline in order to provide data comparing the operation of the remaining 57 vehicles using primarily M85. Due to range limitations and availability of refueling facilities, some M85 vehicles use a significant amount of gasoline in addition to M85. Also, the 16 conventional gasoline vehicles were operated as part of the Federal fleet and are also considered control vehicles. The conventional gasoline vehicles normally operate on unleaded gasoline and are not designed to operate on M85 fuel.

For purposes of this report and to gain a more thorough understanding of alternative fuel vehicle operation in comparison to conventional vehicle operation, the initial 81 vehicles (1991 Chevrolet Lumina and Ford Taurus) were categorized into three separate groups. The first group is designated as the 57 alternative fuel vehicles that operate on M85 and gasoline fuel; however, as explained previously, these vehicles refuel a significant percentage of the time on M85 fuel. Therefore, this group of vehicles will be referred to as the <u>M85 alternative fuel vehicles</u>. The second group is designated as the 8 control alternative fuel vehicles that operate almost exclusively on gasoline; this group of vehicles will be referred to as the gasoline alternative fuel vehicles. The third group is designated as the 16 fleet conventional vehicles that operate only on gasoline and are considered control vehicles. Therefore, the third group will be referred to as the conventional gasoline vehicles. The conventional gasoline vehicles normally operate on unleaded gasoline and are not designed to operate on M85 fuel.

The division of the initial 81 fleet vehicles into three groups facilitates comparisons of M85 alternative fuel vehicle operation and performance with those of conventional gasoline vehicles. For example, comparisons between alternative fuel vehicles and conventional gasoline vehicles will be made on the basis of fuel economy, energy economy, vehicle emissions, driveability, reliability, operating costs, and safety.

3.2.1 Vehicle Distribution by City

The distribution of M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles by city is shown in Figure 8. All of the four cities to date include two gasoline alternative fuel vehicles and four conventional gasoline gasoline vehicles, with the balance of the fleet being M85 alternative fuel vehicles. Both Los Angeles and San Diego include nine M85 alternative fuel vehicles, while Detroit and Washington have 18 and 21 M85 alternative fuel vehicles, respectively.

3.2.2 Vehicle Accumulated Miles

Since the introduction of vehicles in January 1991 and through September 1992, the initial 81 vehicles have accumulated about 1,000,000 miles of operation. Shown in Figure 9 is a monthly summary of miles accumulated by vehicle type for all four cities combined. About 65 percent of these miles were accomplished with alternative fuel vehicles using M85. The limited accumulation of miles during the months of January and February represents the initial implementation of vehicles in the field with the majority of vehicles beginning service in March and April 1991.

A comparison of miles accumulated through September 1992 by city is shown in Figure 10. Since the first vehicle was made available for use, the Detroit fleet has accumulated over 300,000 miles and the San Diego fleet about 250,000 miles. In contrast, short but frequent trips in the Washington and Los Angeles fleets may account for the lower total fleet miles.

3.3 Vehicle Operation by City

3.3.1 Washington, DC

A total of sixteen agencies from the Washington area are participating in the program. The uses for the vehicles at each of the agencies vary, but most vehicles

Figure 8. Vehicle Distribution by City

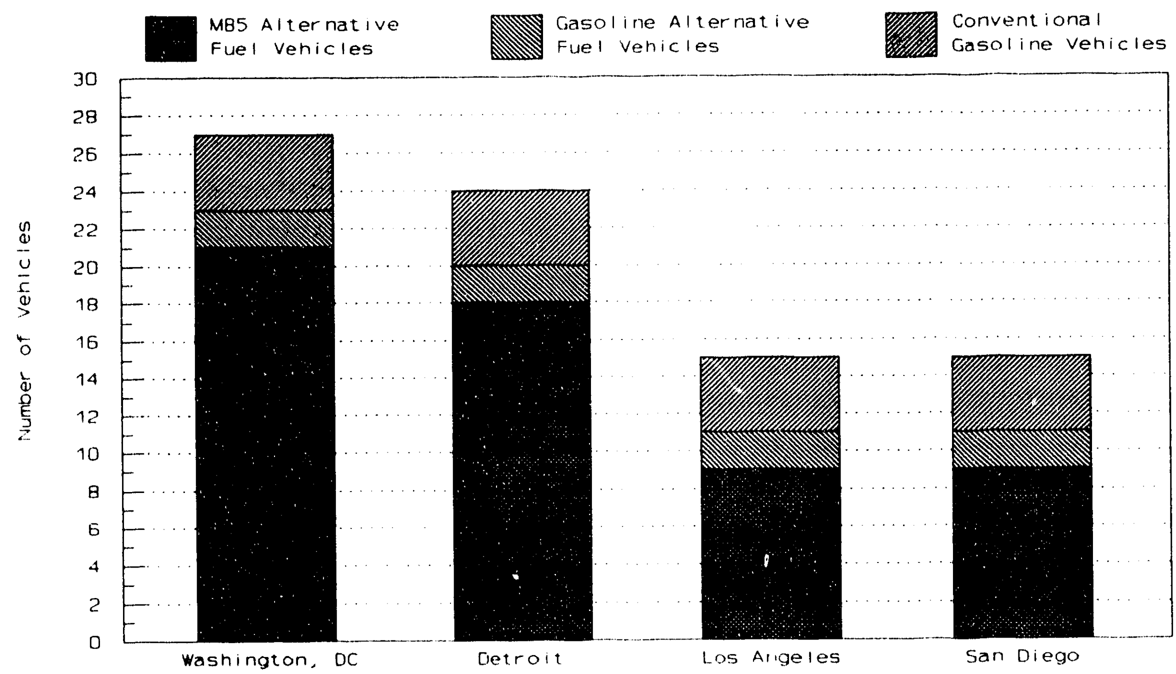
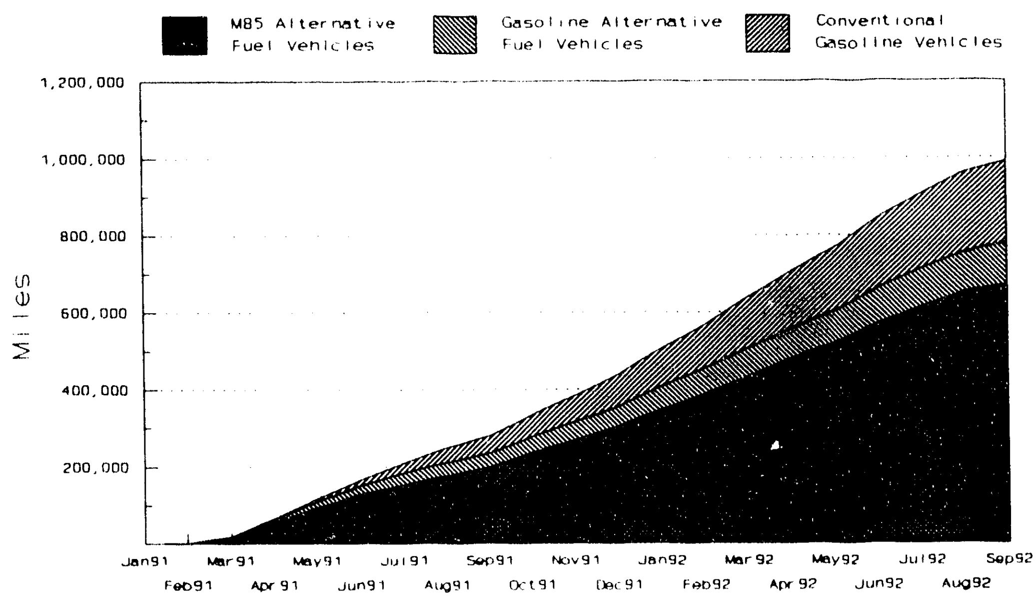
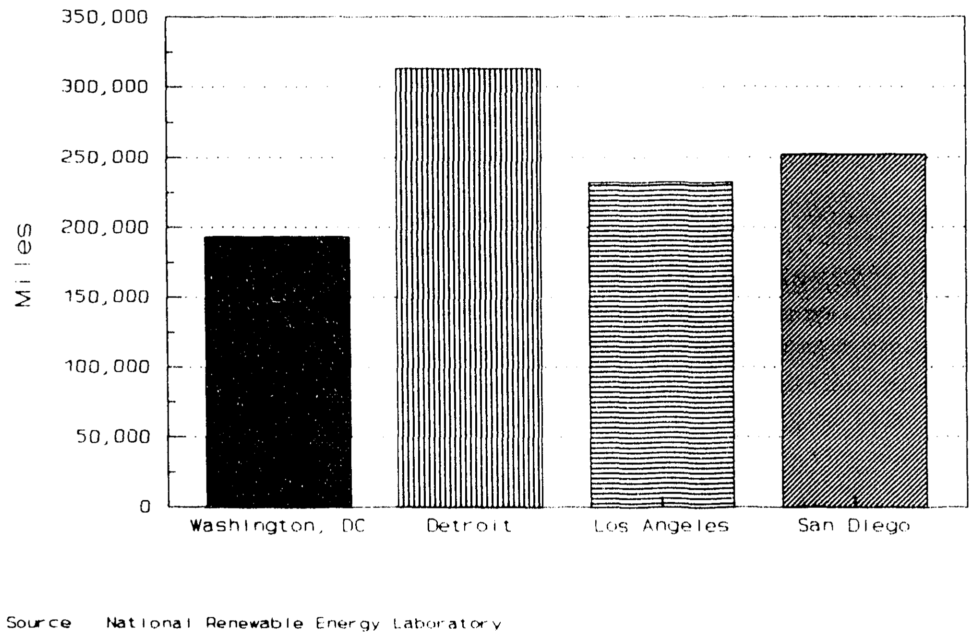


Figure 9. Vehicle Accumulated Miles by Month - All Cities



Source National Renewable Energy Laboratory

Figure 10. Vehicle Accumulated Miles by City



are used for local business-related travel. However, a few vehicles operated by the Department are used for regular shuttle service between Germantown, Maryland, and downtown Washington.

The fleet in Washington is composed of 27 vehicles of which the 2 gasoline alternative fuel vehicles and 4 conventional gasoline vehicles are equally represented by Chevrolet Luminas and the Ford Tauruses. The balance of the fleet are M85 alternative fuel vehicles consisting of 7 Chevrolet Luminas and 14 Ford Tauruses. Figure 11 summarizes the distribution of M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles in Washington.

3.3.1.1 Accumulated Miles

The 27 car fleet in Washington reported a total of nearly 200,000 miles accumulated through September 1992. The miles accumulated January 1991 through September 1992 are shown graphically in Figure 12. The dramatic increase in the rate of miles accumulated per month in March and April 1991 is the result of additional cars introduced into the fleet. While several cars began service in January and February 1991, the vast majority of cars began service in the months of March and April 1991.

Figure 11. Vehicle Distribution in Washington, DC

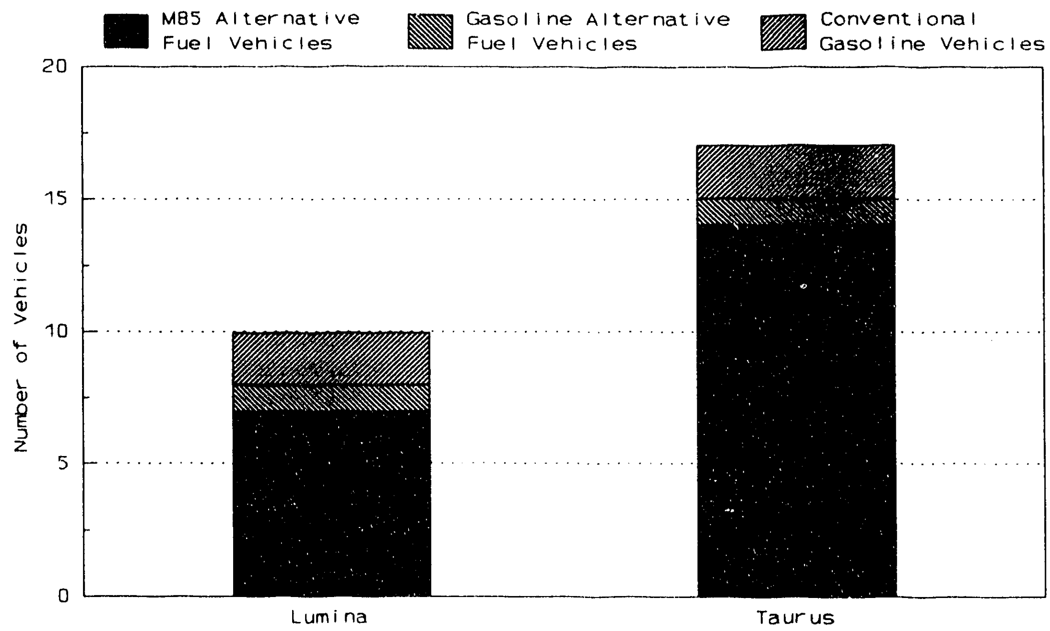
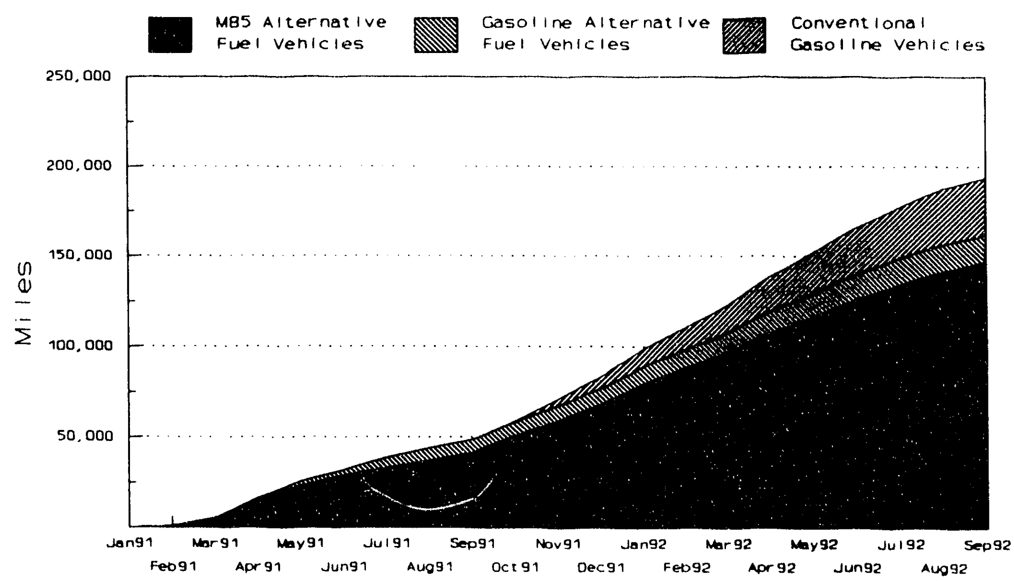


Figure 12. Vehicle Accumulated Miles in Washington, DC



Source National Renewable Energy Laboratory

Washington has the largest fleet of all the sites; however, paradoxically the fleet has the lowest total of accumulated miles. The vehicles in Washington are being used as often as in other cities; however, the average daily mileage is only about half of the other three cities, therefore, reducing the total accumulated miles.

3.3.1.2 Refueling Facilities

Currently, in Washington there is only one public M85 refueling station, which is owned and operated by SUNOCO. The station is located near the intersection of South Capital and M Streets at 50 M Street, SE. In Washington there is only one public E85 refueling station, which is also owned and operated by SUNOCO. The station is located at 1248 Pennsylvania Avenue, SE.

3.3.1.3 Authorized Service Centers

The fleets in each of the four sites are supported by authorized Ford and General Motors dealerships that service and maintain the M85 vehicles. Mike Pallone Chevrolet maintenance personnel have also been trained to service the E85 Chevrolet Lumina alternative fuel vehicles operating in the Washington area. In the Washington area, the authorized service centers are:

Dave Pyles Lincoln Mercury, Inc.
6500 Little River Turnpike
Annandale, Virginia

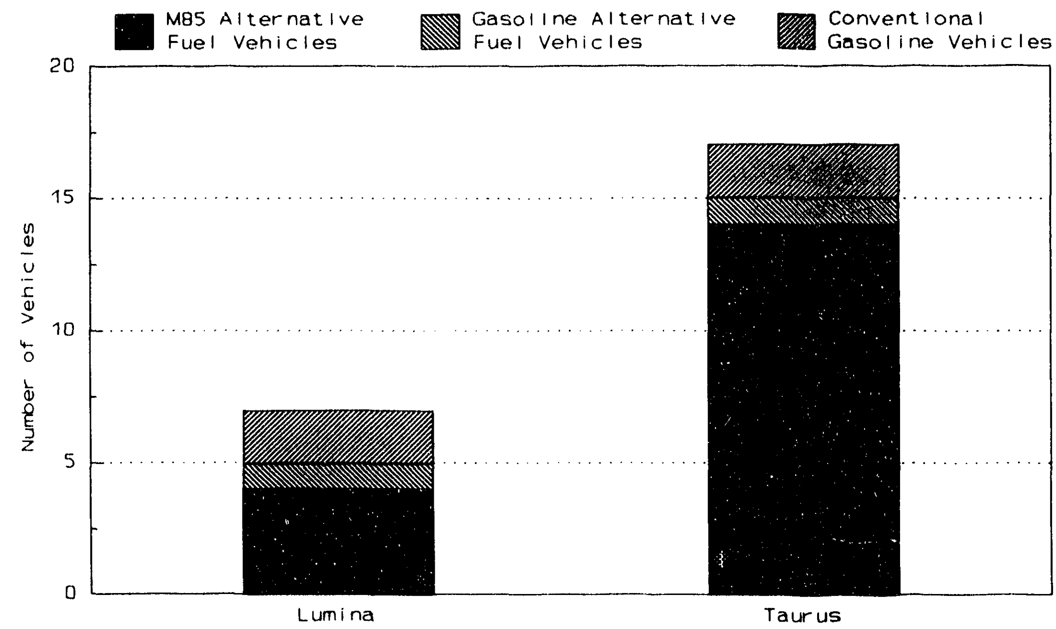
Mike Pallone Chevrolet, Inc.
7722 Backlick Road
Springfield, Virginia

3.3.2 Detroit, Michigan

In the Detroit area, seven Government agencies are participating in the program. The U.S. Environmental Protection Agency National Vehicle and Fuel Emissions Laboratory in Ann Arbor has two Ford Tauruses and two Chevrolet Luminas that are used for emissions and performance testing. The Veterans Administration Hospital in Allen Park uses seven Ford Tauruses for visiting patients in a home care program. The remaining vehicles are used for general business-related travel.

The Detroit area offers the opportunity to operate fleet vehicles at a cold weather location in order to test the cold-start capabilities of the M85 alternative fuel vehicles. Twenty-four vehicles comprise the fleet in Detroit. Four Chevrolet Luminas and 14 Ford Tauruses are M85 alternative fuel vehicles. The remainder of the fleet consists of two gasoline alternative fuel vehicles and four conventional gasoline vehicles equally divided between Chevrolet Luminas and the Ford Tauruses. Figure 13 shows the distribution of M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles in Detroit.

Figure 13. Vehicle Distribution in Detroit, Michigan



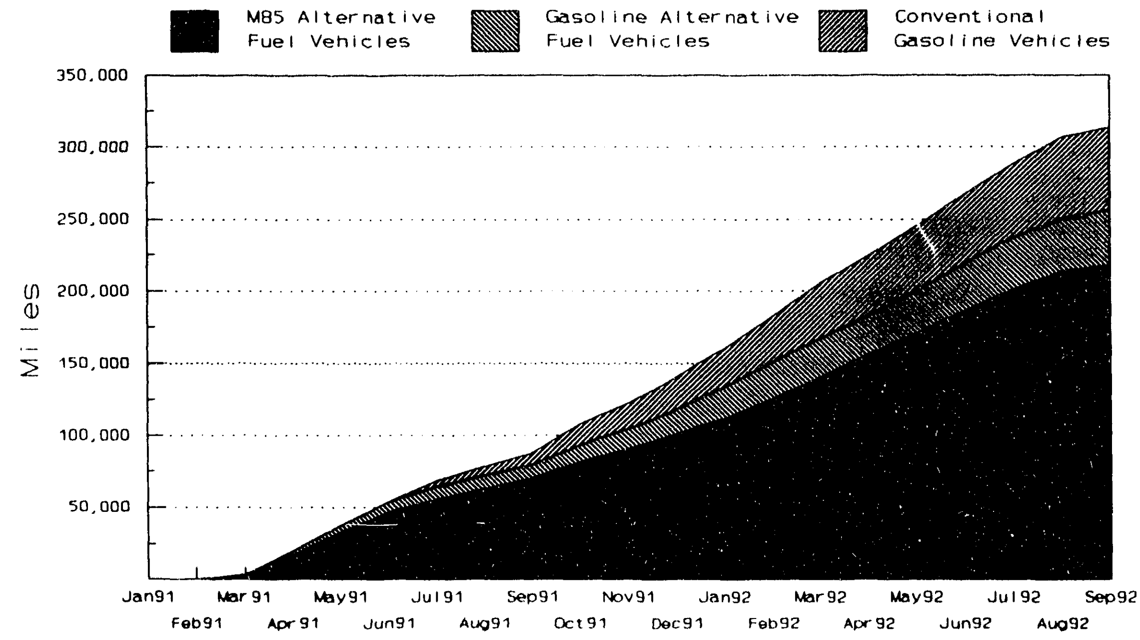
3.3.2.1 Accumulated Miles

In the Detroit area, the 24-car fleet reported a total of over 300,000 miles accumulated through September 1992; this is the highest number reported at the four sites. Figure 14 illustrates the miles accumulated from January 1991 through September 1992. The low mileage accumulated in January and February 1991 is due to the fact that not all the cars were in operation. Also, the conventional gasoline vehicles were not added to the fleet until June 1991.

3.3.2.2 Refueling Facilities

In the Detroit area, there are currently two public M85 refueling stations, which are owned and operated by SUNOCO. The stations are located at the corner of Monroe and Outer Drive at 2740 Monroe in Dearborn and at 1490 East Maple Avenue (and Stevenson Road) in Troy, Michigan.

Figure 14. Vehicle Accumulated Miles in Detroit, Michigan



Source: National Renewable Energy Laboratory

3.3.2.3 Authorized Service Centers

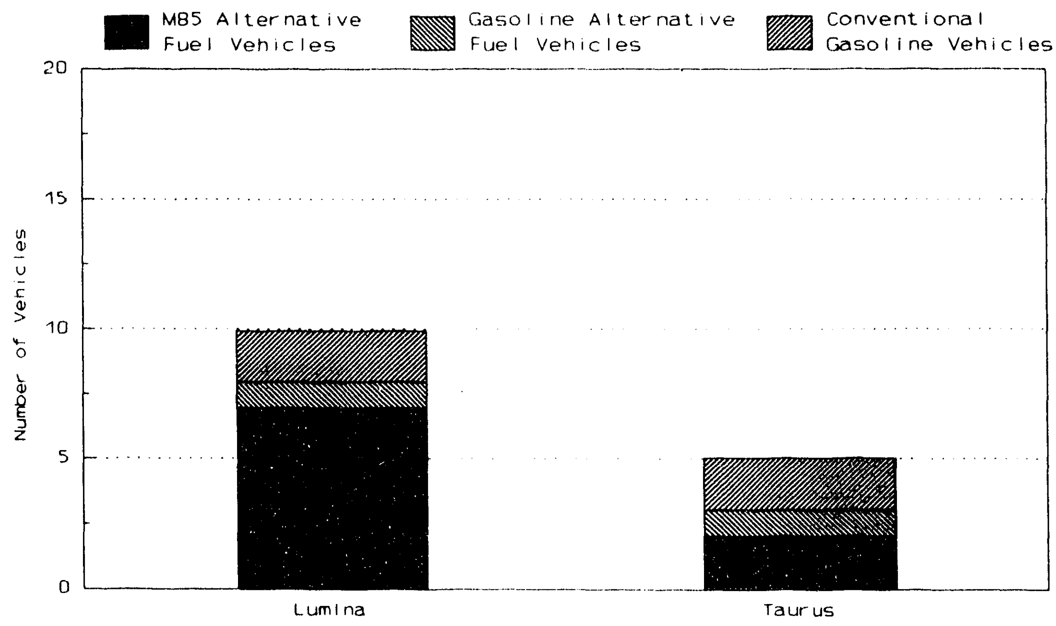
Ford and General Motors have authorized one dealership each in the Detroit area to service and maintain the M85 vehicles. Maintenance personnel in these dealerships have been properly trained in the maintenance and service practices for the M85 vehicles. In addition, there are other Ford dealerships in the Detroit area that are properly trained in the maintenance and service practices for the M85 Ford Tauruses. The authorized service centers for the M85 vehicles are:

Jefferson Chevrolet 2130 East Jefferson Detroit, Michigan	Village Ford, Inc. 23535 Michigan Avenue Dearborn, Michigan

3.3.3 Los Angeles, California

The Los Angeles area has 7 Government agencies participating in the program. The U.S. Army in Los Angeles uses 2 conventional gasoline Luminas for local recruiting. Also, 3 Luminas are used at the U.S. Army Corps of Engineers for visiting sites undergoing general maintenance. Most use is for local business-related travel. In the Los Angeles area, the fleet is composed of 15 vehicles, of which the 2 gasoline alternative fuel vehicles and 4 conventional gasoline vehicles are equally divided between Chevrolet Luminas and the Ford Tauruses. The remainder are M85 alternative fuel vehicles consisting of 5 Chevrolet Luminas and 4 Ford Tauruses. Figure 15 summarizes the distribution of M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles in Los Angeles.

Figure 15. Vehicle Distribution in Los Angeles, California

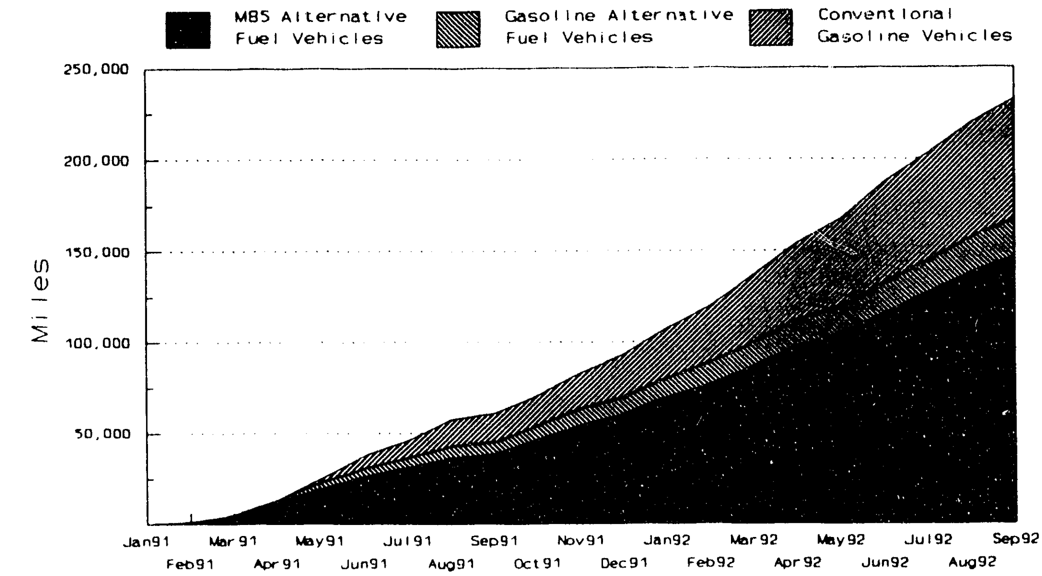


3.3.3.1 Accumulated Miles

The 15-car fleet in the Los Angeles area reported a total of just over 225,000 miles accumulated through September 1992, as shown in Figure 16. While several cars began service in February and March 1991, the vast majority of cars began service in the months of April and May 1991.

Los Angeles has the same size fleet as San Diego but has lower total accumulated miles. The low mileage accumulated in January and February 1991 is due to the fact that not all the cars were in operation. Also, the conventional vehicles were not added to the fleet until April 1991.

Figure 16. Vehicle Accumulated Miles in Los Angeles, California



Source: National Renewable Energy Laboratory

3.3.3.2 Refueling Facilities

In the state of California, there are over 40 M85 refueling stations. Some of these M85 refueling stations in the greater Los Angeles area are at the following locations:

Los Angeles ARCO
3675 Wilshire Boulevard
Los Angeles, California

Pasadena Mobil
392 North Lake Avenue
Pasadena, California

Anaheim Chevron
1801 South Harbor Boulevard
Anaheim, California

Santa Ana ARCO
3414 Main Street
Santa Ana, California

Carson ARCO
20810 South Avalon Road
Carson, California

Simi Valley ARCO
25 West Tierra Rejada Road
Simi Valley, California

Glendale ARCO
3941 San Fernando Boulevard
Glendale, California

Valencia Shell
24301 Valencia Boulevard
Valencia, California

Long Beach ARCO
1785 Bellflower Boulevard
Long Beach, California

3.3.3.3 Authorized Service Centers

Ford and General Motors have authorized various dealerships in the Los Angeles area to service and maintain the M85 vehicles. Maintenance personnel in these dealerships have been properly trained in the maintenance and service practices for the M85 vehicles. In addition, General Motors has trained over 100 Chevrolet dealerships in the state of California for maintenance and service of the M85 Chevrolet Lumina vehicles. Some of these authorized service centers are:

Downey Auto Center
9500 Lakewood Boulevard
Downey, California

Maurice J. Sopp & Son
5801 Pacific Boulevard
Huntington Park, California

Tuttle-Click Ford
43 Auto Center Drive
Irvine, California

3.3.4 San Diego, California

A total of 12 Government agencies in the San Diego area are participating in the program. The General Services Administration uses 2 M85 Lumina vehicles and 1 gasoline alternative fuel Lumina vehicle for facility inspections. The balance of the agencies uses the vehicles for local business-related travel.

The fleet in San Diego is composed of 15 vehicles, of which the 2 gasoline alternative fuel vehicles and 4 conventional gasoline vehicles are equally represented by the Chevrolet Luminas and the Ford Tauruses. The remainder are M85 alternative fuel vehicles consisting of 5 Chevrolet Luminas and 4 Ford Tauruses. Figure 17 summarizes the distribution of M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles in San Diego.

3.3.4.1 Accumulated Miles

The 15-car fleet in the San Diego area reported a total of slightly over 250,000 miles accumulated through September 1992, as shown in Figure 18. The low mileage accumulated in January and February 1991 is due to the fact that not all the cars were in operation. Also, the conventional gasoline vehicles were not added to the fleet until April 1991.

Figure 17. Vehicle Distribution in San Diego, California

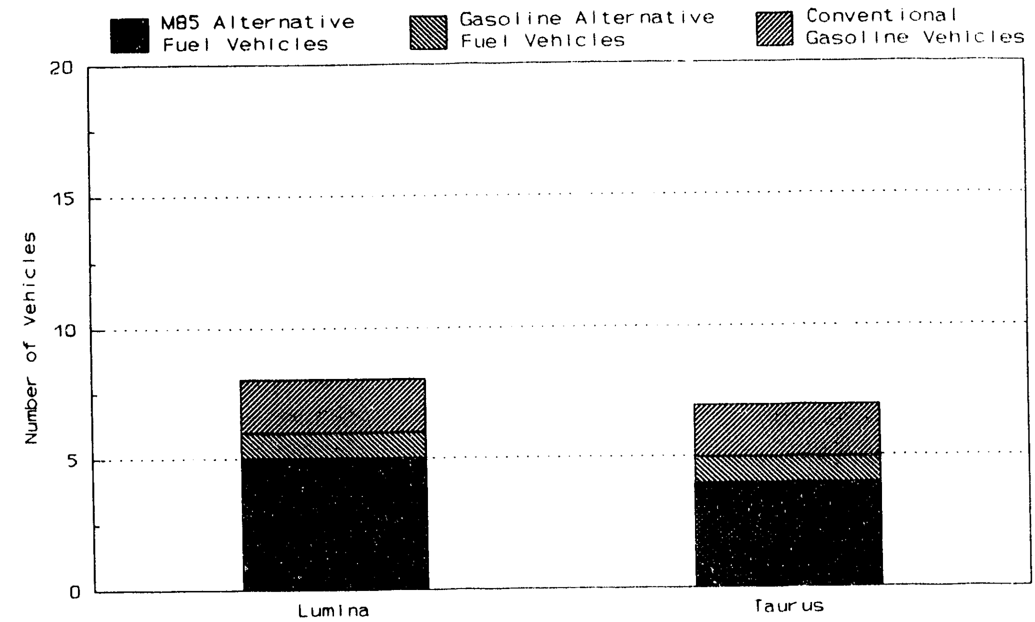
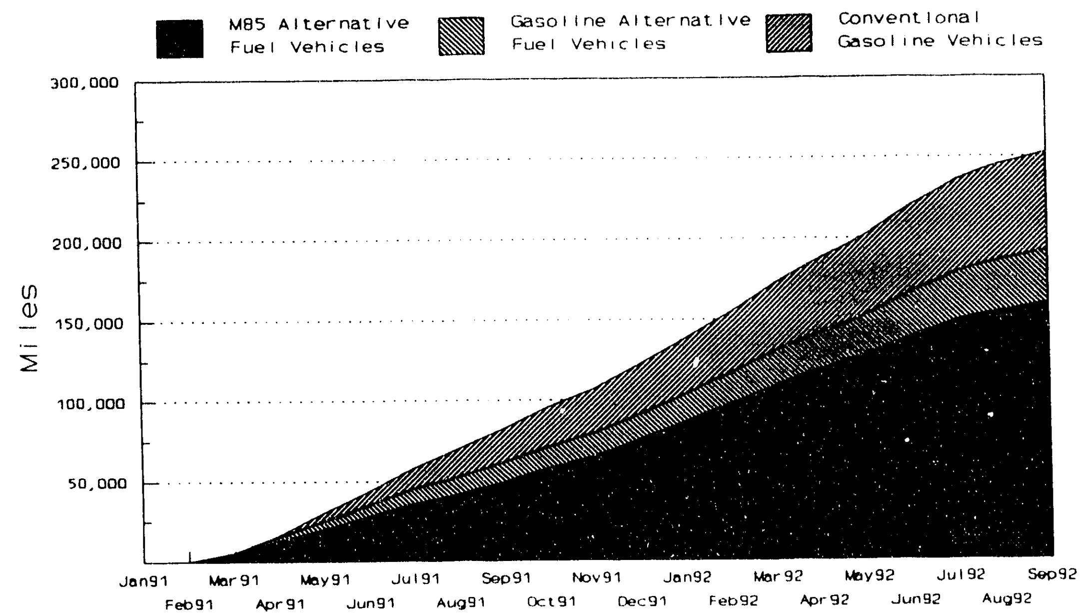


Figure 18. Vehicle Accumulated Miles in San Diego, California



Source: National Renewable Energy Laboratory

3.3.4.2 Refueling Facilities

Of the over 40 M85 refueling stations in the state of California, two are located in the San Diego area. The two public M85 refueling stations are at the following locations:

San Diego ARCO
3205 University Avenue
San Diego, California

San Diego Chevron
1221 11th Avenue
San Diego, California

3.3.4.3 Authorized Service Centers

Ford and General Motors have authorized various dealerships in the San Diego area to service and maintain the M85 vehicles. Maintenance personnel in these dealerships have been properly trained in the maintenance and service practices for the M85 vehicles. Some of these authorized service centers are:

Courtesy Chevrolet
750 Camino Del Rio North
San Diego, California

Drew Ford
8970 La Mesa Boulevard
La Mesa, California

University Ford
730 Camino Del Rio
San Diego, California

4.0 ALTERNATIVE FUEL VEHICLE PERFORMANCE

The following sections include discussions comparing M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles on the basis of fuel/energy economy, vehicle emissions, driveability, reliability, operating costs, and safety.

4.1 On-Road Fuel/Energy Economy

Collection of data concerning fuel usage is an integral part of the Alternative Motor Fuels Act of 1988 program. Drivers of fleet vehicles are required to record odometer readings at the beginning and end of each day. They also record the number of miles traveled and the amount of fuel used between refuelings. This information is recorded by each driver in a weekly log sheet and recorded in the Alternative Fuels Data Center at the National Renewable Energy Laboratory in Golden, Colorado. These records, after being consolidated electronically, eventually are used to calculate the on-road fuel and energy economy.

For purposes of this report and to gain a more thorough understanding of alternative fuel vehicle operation in comparison to conventional vehicle operation, the initial 81 vehicles were categorized into three separate groups. The first group is designated as the 57 alternative fuel vehicles that operate on M85 and gasoline fuel; however, as explained previously, these vehicles refuel a significant percentage of the time on M85 fuel. Therefore, this group of vehicles will be referred to as the M85 alternative fuel vehicles. The second group is designated as the 8 control alternative fuel vehicles that operate almost exclusively on gasoline; this group of vehicles will be referred to as the gasoline alternative fuel vehicles. The third group is designated as the 16 fleet conventional vehicles that operate only on gasoline and are considered control vehicles. Therefore, the third group will be referred to as the conventional gasoline vehicles. The conventional gasoline vehicles normally operate on unleaded gasoline and are not designed to operate on M85 fuel.

4.1.1 Fuel/Energy Economy Analysis Methodology

From January 1991 through September 1992, there were over 7,000 recordings of daily odometer and fuel usage readings. Because these data are used for subsequent fuel and energy economy calculations, it is necessary to assure that the data are as error free as practicable. To eliminate erroneous data entries, the data were examined using a two-step process. First, the data that were obviously incorrect were eliminated. Most appeared to be due to transcription errors that resulted in unrealistically high or low fuel economy values. Secondly, a detailed review of the representativeness of each calculated fuel economy value was conducted. Published Environmental Protection Agency fuel economies (city and highway) for each model were used as general guidelines to frame a range of potential typical fuel economy values that would be expected. The data were then reviewed, vehicle by vehicle, to determine individual vehicle fuel economy trends. Using these trends and the general guidelines, data were determined to be representative or unrepresentative of each vehicle. For example, it was often observed that a very high fuel economy would be directly followed by a very low fuel economy. While the average of the two entries was within the range of expected fuel economy values, these data pairs are possibly a result of short filling or transcription errors and were removed from subsequent fuel economy calculations. Short filling is the process of not filling the fuel tank completely to capacity upon refueling. Once the erroneous data were eliminated, the next step was to eliminate filling switch-over data; refueling an M85 alternative fuel vehicle on gasoline then next on M85, or similarly refueling a gasoline alternative fuel vehicle on M85 then next on gasoline. For example, when an M85 alternative fuel vehicle was refueled once with gasoline then next with M85, the gasoline refueling and the next two M85 refueling data were eliminated. Therefore, by eliminating these data the resultant M85 and gasoline alternative fuel vehicle fuel economies reflected operation almost exclusively on M85 and gasoline fuel, respectively. As stated previously, the 81 vehicles were categorized into three separate groups to compare operation of M85 alternative fuel vehicles on M85 fuel and gasoline alternative fuel vehicles on gasoline fuel to gain a more thorough understanding of alternative fuel vehicle operation in comparison to conventional gasoline vehicle operation. Of the nearly 2,800 refueling data points collected from October 1991 through September 1992, nearly 10 percent were removed through eliminating erroneous and filling switch-over data.

Fuel and energy economies for the four sites are summarized on the basis of monthly average fuel/energy economy, cumulative average fuel/energy economy, and gasoline energy-equivalent fuel economy. Monthly average fuel economy is calculated by dividing the total fleet-accumulated miles for a month by the total fleet-consumed fuel for a month. Cumulative average fuel economy is calculated in the same manner except that the time frame is not fixed. The cumulative average fuel economy includes a running total of all miles traveled and fuel consumed. Energy economy is defined as the fuel energy expended per mile traveled. Energy economy provides for a direct comparison of vehicles when operated on fuels of different energy content. For example, the M85 fuel used by the fleet vehicles has approximately 44 percent less energy per unit volume than does unleaded gasoline. Also, energy economy is indicative of vehicle efficiency. Given two similar vehicles, the one with the lower energy economy is making more efficient use of the fuel it is burning. Because of this difference in energy content, comparisons will also be made on the basis of energy economy. Gasoline energy equivalent miles per gallon is the M85 alternative fuel vehicle fuel economy adjusted for the difference in fuel energy content between gasoline and M85. It is often desirable to compare gasoline fuel economy to M85 fuel economy on an energy-equivalent basis to show relative fuel energy economy.

4.1.2 On-Road Fuel/Energy Economy by City

4.1.2.1 Washington, DC

The monthly average fuel economy of the M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles in Washington is shown in Figure 19, while the cumulative average fuel and energy economies from March 1991 through September 1992 are shown in Figure 20. The cumulative average fuel economy of the M85 alternative fuel vehicles for fiscal year 1992 was 11.7 miles per gallon (20.7 miles per gallon — gasoline energy equivalent). The cumulative average fuel economy of the gasoline alternative fuel vehicles and conventional gasoline vehicles over the same time period was 14.3 and 22.8 miles per gallon, respectively. The average energy economy of the M85 alternative fuel vehicles in the area for fiscal year 1992 was about 5,580 BTUs per mile, while the average energy economy of the gasoline alternative fuel vehicles and conventional gasoline vehicles was about 8,060 and 5,060 BTUs per mile, respectively. The M85 alternative fuel vehicles required approximately 10 percent more energy per mile than the conventional gasoline vehicles.

The M85 alternative fuel vehicles in the Washington area have the lowest cumulative average fuel economy of the four participating sites. This lower average fuel economy was attributable to the greater than average amount of city driving the M85 alternative fuel vehicles in Washington experience, therefore, reducing their average fuel economy. In addition, the gasoline alternative fuel vehicle fuel and energy economies

Figure 19. Monthly Average Fuel Economy for Washington, DC

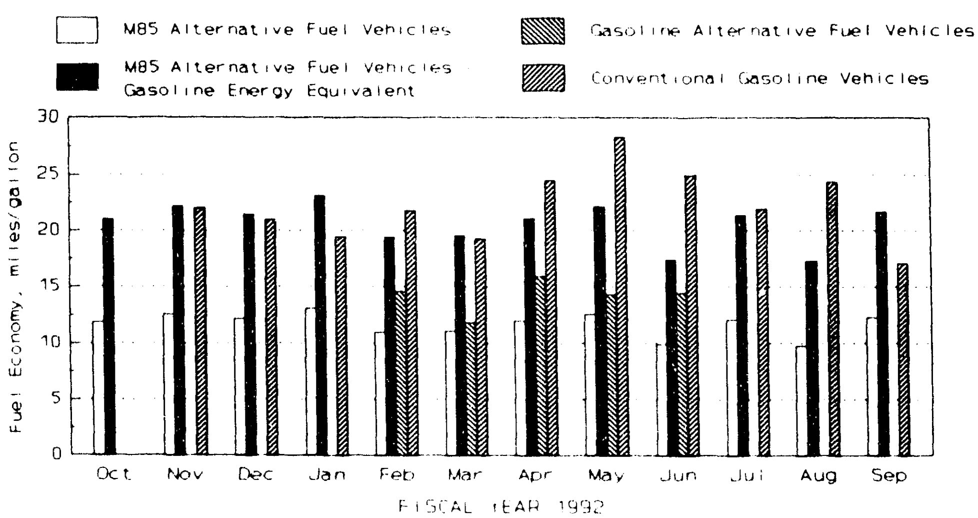
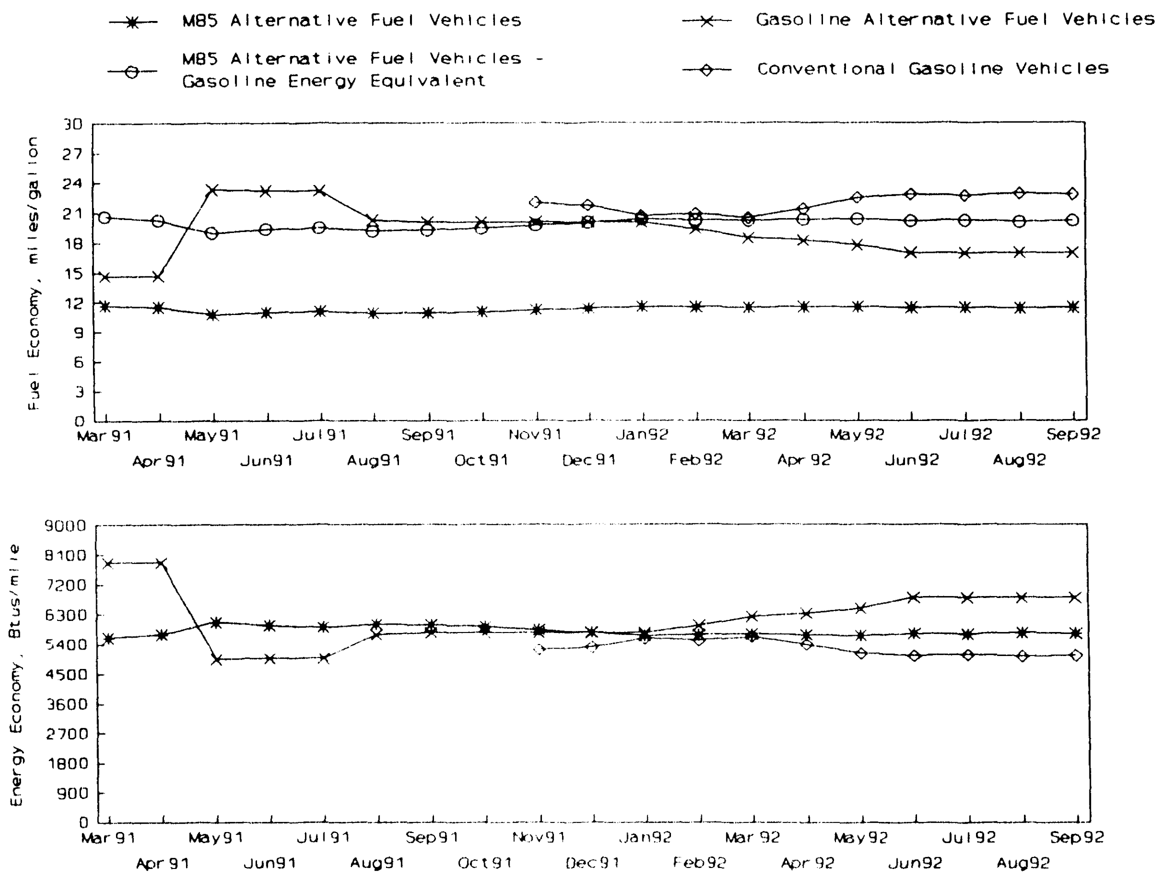


Figure 20. Cumulative Average Fuel/Energy Economy for Washington, DC



represent only five months of refueling data on one of the two gasoline alternative fuel vehicles located in the Washington area.

4.1.2.2 Detroit, Michigan

Shown in Figure 21 is the monthly average fuel economy of the fleet vehicles in the Detroit area for fiscal year 1992. The difference in monthly average fuel economy is about ten miles per gallon between the conventional gasoline vehicles and the M85 alternative fuel vehicles. This difference in average fuel economy is largely reflected by the difference in chemical energy available in a gallon of gasoline versus a gallon of M85. Shown in Figure 22 are the cumulative average fuel and energy economies of the fleet vehicles from March 1991 through September 1992. The cumulative average fuel

Figure 21. Monthly Average Fuel Economy for Detroit, Michigan

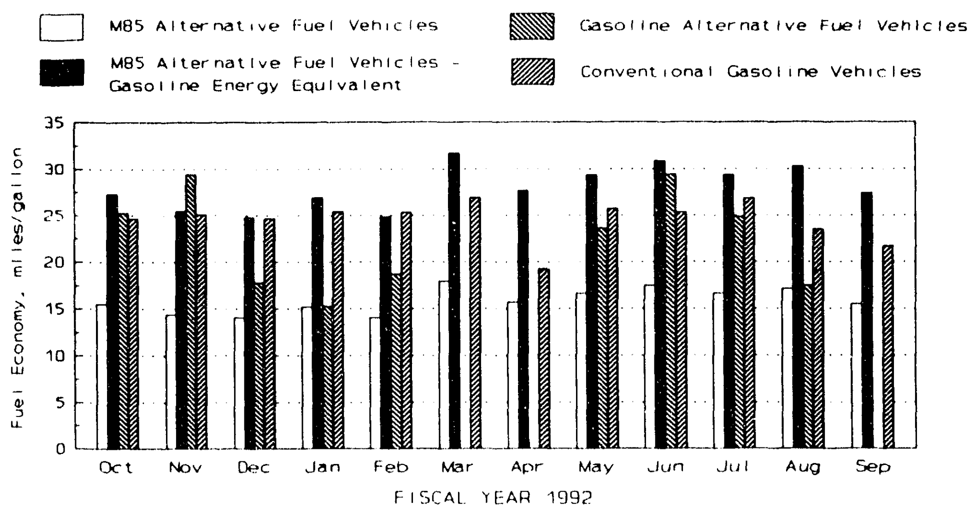
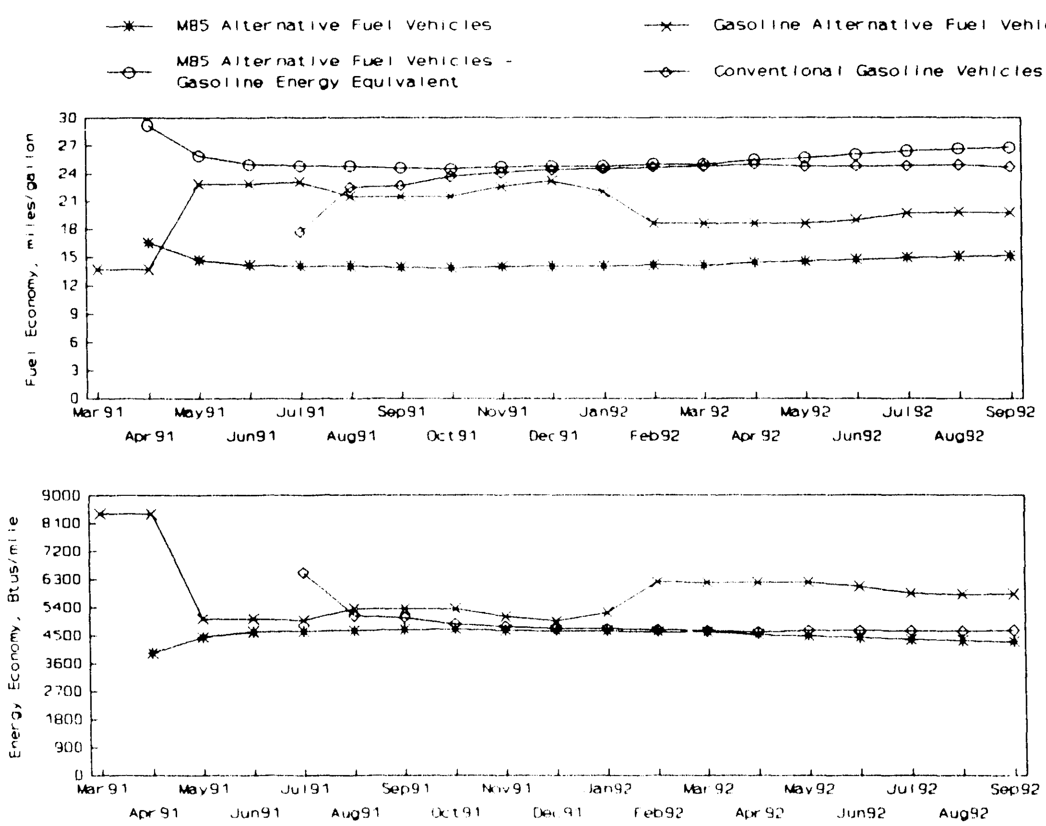


Figure 22. Cumulative Average Fuel/Energy Economy for Detroit, Michigan



economy of the M85 alternative fuel vehicles in Detroit for fiscal year 1992 was 15.9 miles per gallon (28.1 miles per gallon — gasoline energy equivalent), while the cumulative average fuel economy of the gasoline alternative fuel vehicles and conventional gasoline vehicles over the same time period was 19.4 and 24.9 miles per gallon, respectively. For fiscal year 1992, the average energy economy of the M85 alternative fuel vehicles in the Detroit area was about 4,110 BTUs per mile, while the average energy economy of the gasoline alternative fuel vehicles and conventional gasoline vehicles was about 5,940 and 4,640 BTUs per mile, respectively. The M85 alternative fuel vehicles in the Detroit area required approximately 11 percent less energy per mile than the conventional gasoline vehicles.

4.1.2.3 Los Angeles, California

The monthly average fuel economy of the fleet vehicles in the Los Angeles area is shown in Figure 23. The difference in monthly average fuel economy is about eleven miles per gallon between the conventional gasoline vehicles and the M85 alternative fuel vehicles. In the Los Angeles area, the cumulative average fuel economy, shown in Figure 24, of the M85 alternative fuel vehicles for fiscal year 1992 was 13.9 miles per gallon (24.5 miles per gallon — gasoline energy equivalent). The cumulative average fuel economy of the gasoline alternative fuel vehicles and conventional gasoline vehicles during the same time period was 22.1 and 25.5 miles per gallon, respectively. The fuel economy (gasoline energy equivalent miles per gallon) of the M85 alternative fuel vehicles is approximately 4 percent lower than the conventional gasoline vehicles for fiscal year 1992. When expressed on an energy economy basis, the cumulative average energy economy of the M85 alternative fuel vehicles in Los Angeles during fiscal year 1992 was about 4,710 BTUs per mile, while the gasoline alternative fuel vehicle and conventional gasoline vehicle energy economy was 5,230 and 4,530 BTUs per mile, respectively. The energy economy of the M85 alternative fuel vehicles is about 4 percent higher than the conventional gasoline vehicles during this time period.

4.1.2.4 San Diego, California

Shown in Figure 25 is the monthly average fuel economy of the M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and the conventional gasoline vehicles in the San Diego area. The difference in monthly average fuel economy for fiscal year 1992 is about nine miles per gallon between the conventional gasoline vehicles and M85 alternative fuel vehicles. Shown in Figure 26 are the cumulative average fuel and energy economies of fleet vehicles in the San Diego area. The cumulative average fuel economy of the M85 alternative fuel vehicles in the San Diego area for fiscal year 1992 was 15.8 miles per gallon (27.9 miles per gallon — gasoline energy equivalent), while the cumulative average fuel economy of the gasoline alternative fuel vehicles and conventional gasoline vehicles during the same period was 20.2 and 24.3 miles per gallon, respectively. The average energy economy of the San Diego M85 alternative fuel vehicles was 4,140 BTUs per mile, while the gasoline alternative fuel vehicle and

Figure 23. Monthly Average Fuel Economy for Los Angeles, California

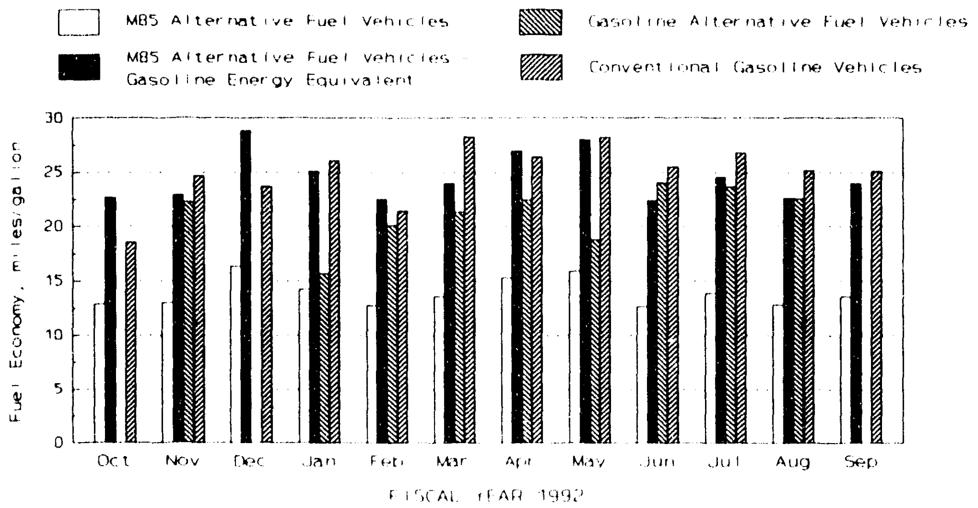


Figure 24. Cumulative Average Fuel/Energy Economy for Los Angeles, California

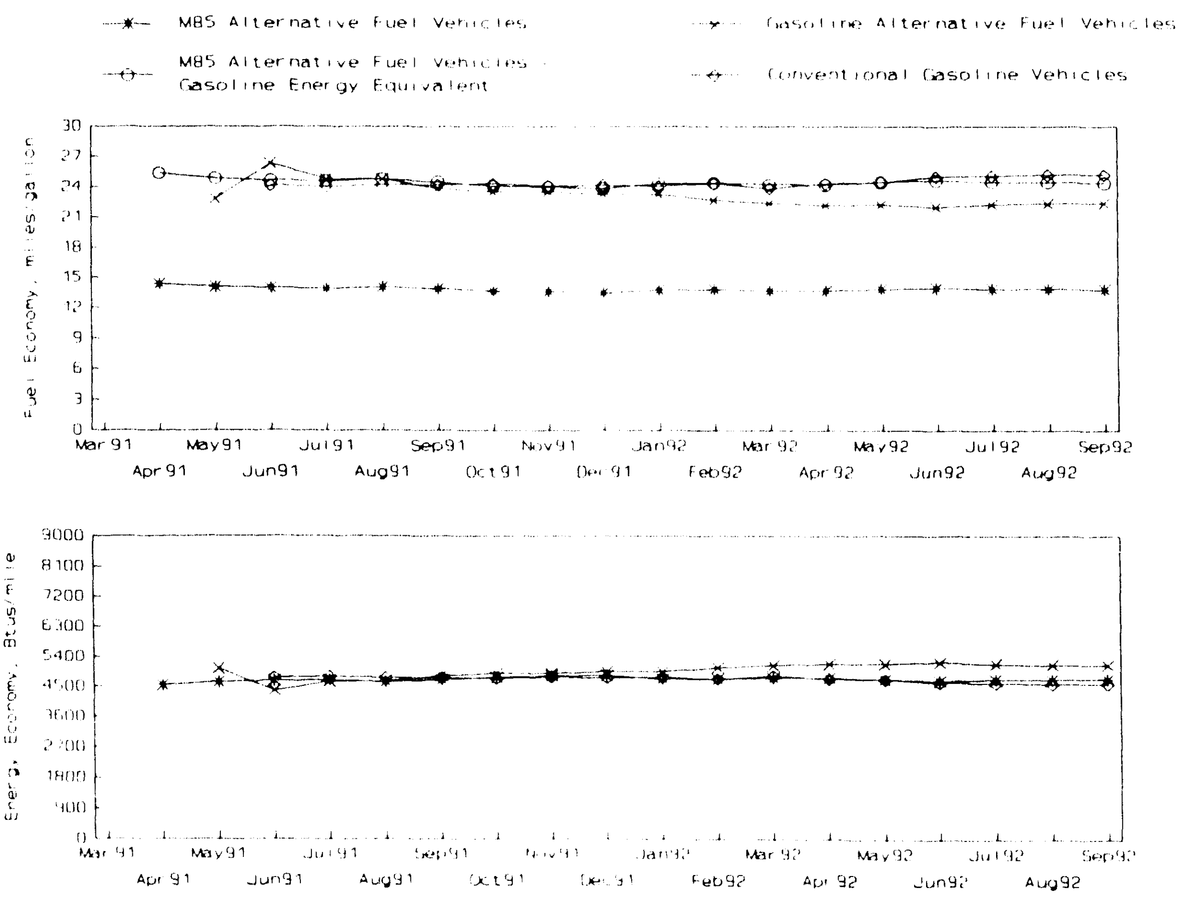


Figure 25. Monthly Average Fuel Economy for San Diego, California

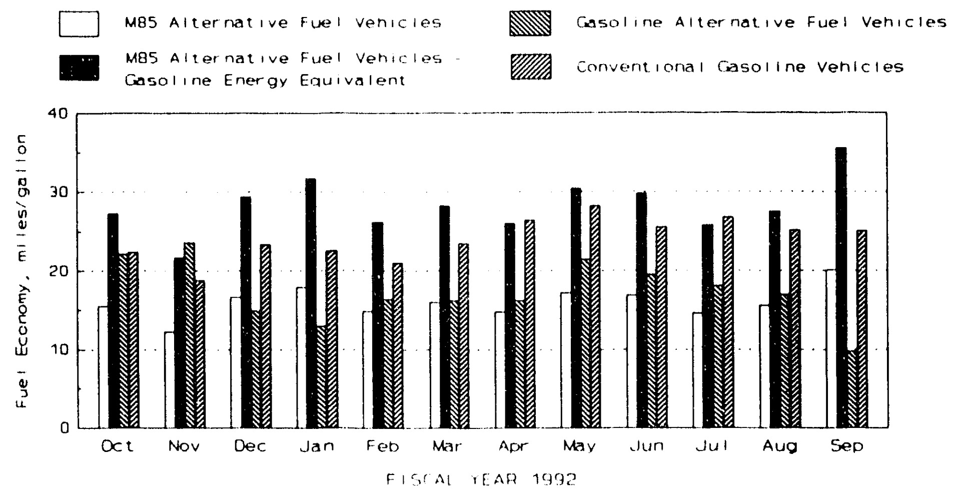
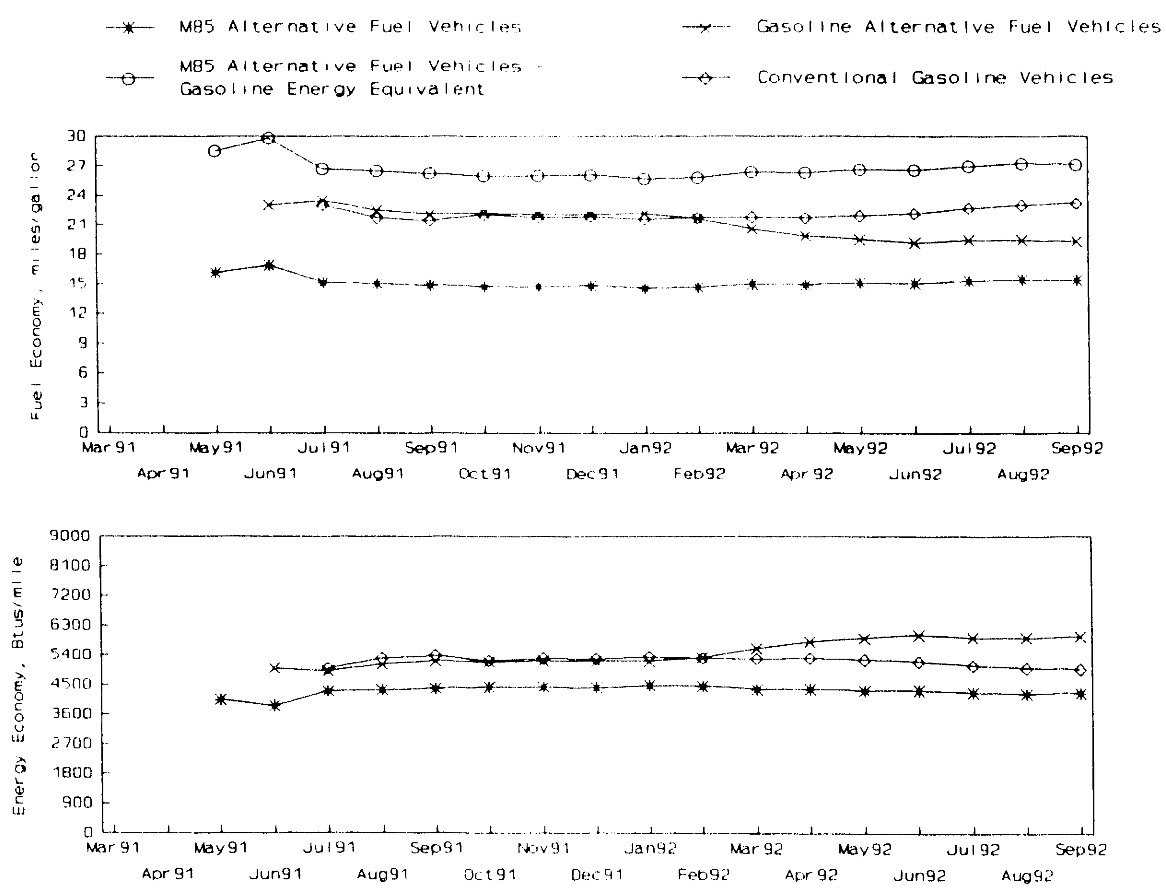


Figure 26. Cumulative Average Fuel/Energy Economy for San Diego, California



conventional gasoline vehicle energy economy was 6,710 and 4,750 BTUs per mile, respectively. The energy economy of the M85 alternative fuel vehicles is about 13 percent lower than the conventional gasoline vehicles during this time period.

4.2 Laboratory Emissions and Fuel/Energy Economy

4.2.1 Vehicle Emissions

In order to characterize the emission levels of the fleet vehicles, laboratory tests were performed on 17 vehicles from the Washington and Detroit areas. The test vehicles in Washington included three M85 Chevrolet Luminas, two M85 Ford Tauruses, one Chevrolet Lumina and Ford Taurus gasoline alternative fuel vehicle, and one Chevrolet Lumina and Ford Taurus conventional gasoline vehicle. The test vehicles in Detroit included two M85 Chevrolet Lumina and Ford Taurus vehicles, one Chevrolet Lumina and Ford Taurus gasoline alternative fuel vehicle, and one Chevrolet Lumina and Ford Taurus conventional gasoline vehicle. The nine M85 alternative fuel vehicles were tested on various fuel types including M85, M50, M20, Indolene, and reformulated gasoline in order to determine the variability in vehicle exhaust emissions due to the fuel type used. The four gasoline alternative fuel vehicles and four conventional gasoline vehicles were tested using Indolene fuel only. The vehicles in Washington were tested at two laboratories - Environmental Research & Development Corporation in Gaithersburg, Maryland and U.S. Environmental Protection Agency Research Triangle Park facility in North Carolina. The vehicles in Detroit were tested at the U.S. Environmental Protection Agency National Vehicle and Fuel Emissions Laboratory, formerly the U.S. Environmental Protection Agency Motor Vehicle Emissions Laboratory, in Ann Arbor, Michigan.

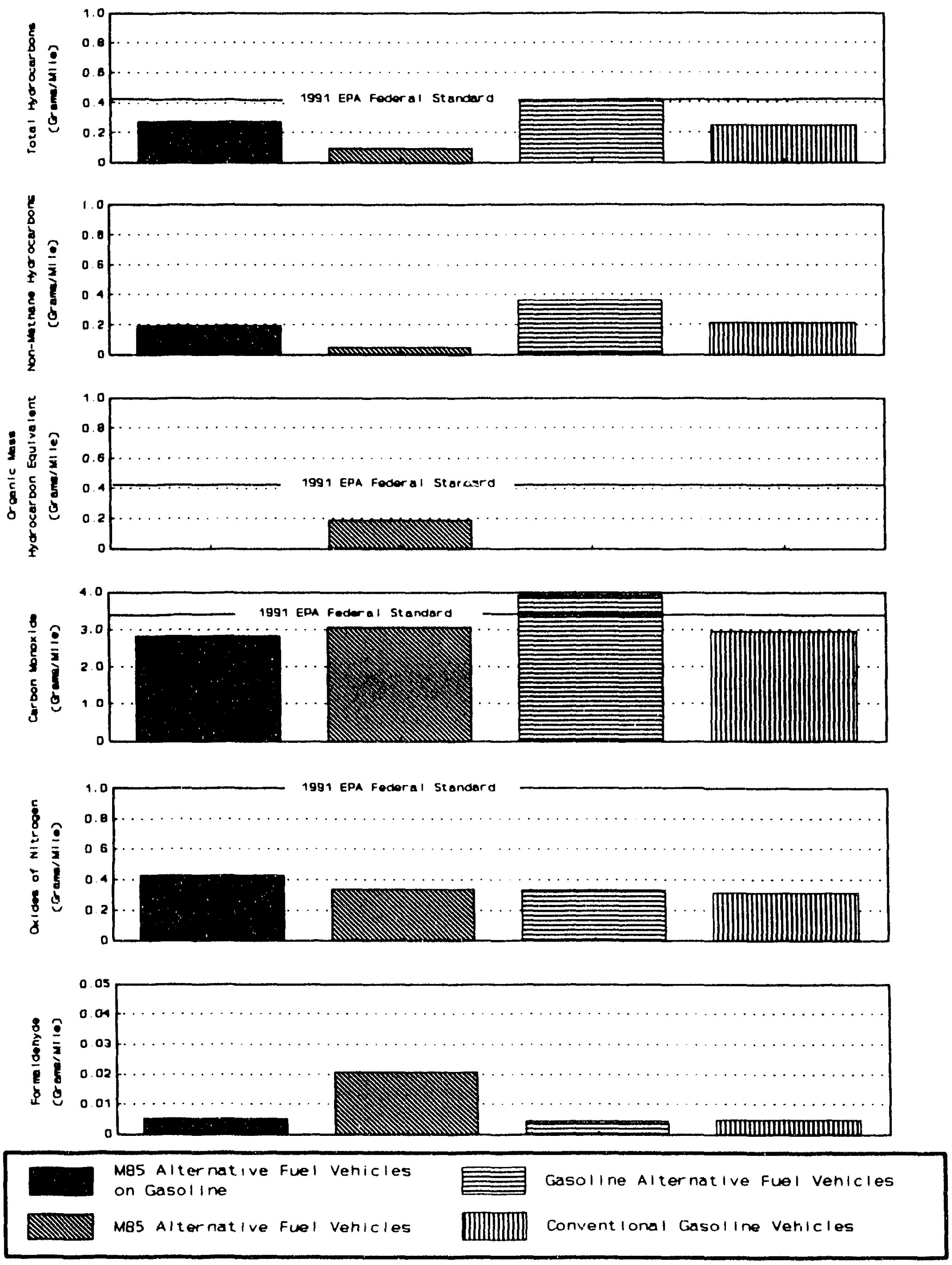
The exhaust and evaporative emissions tests were performed according to the Federal Test Procedure Schedule as detailed in the Code of Federal Regulations Title 40: Part 86 Subpart B - Emission Regulations for 1977 and Later Model Year New Light Duty Vehicles and New Light Duty Trucks; Test Procedures. Indolene is the trade name for gasoline fuel used in performing the Federal Test Procedure Schedule procedures for measuring exhaust and evaporative emissions as certified by the U.S. Environmental Protection Agency. The gasoline (Indolene) fuel specifications are described in Sections 86.113-82 and 86.113-87. The current U.S. Environmental Protection Agency light duty vehicle gasoline exhaust emission standards are 0.41 grams/mile total hydrocarbons, 3.4 grams/mile carbon monoxide, and 1.0 grams/mile oxides of nitrogen. The current U.S. Environmental Protection Agency light duty vehicle gasoline evaporative emission standard is 2.0 grams/test. These standard levels also apply to current light duty vehicles operating on M85. However, instead of reporting total exhaust and evaporative emissions, the M85 emissions test results are reported on an organic material hydrocarbon equivalent basis. Organic material hydrocarbon equivalent accounts for the non-oxygenated portions of traditional hydrocarbon emissions as well as for formaldehyde and methanol emissions. Therefore, in addition to the current carbon monoxide and oxides of nitrogen emission standards, M85 alternative fuel vehicles must meet a 0.41 grams/mile organic material hydrocarbon equivalent exhaust emission standard, and a 2.0 grams/test organic material hydrocarbon equivalent evaporative emission standard.

The average composite urban cycle exhaust emission results for the M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles for fiscal year 1992 are shown in Figure 27. The exhaust emission results for each vehicle group type (M85 alternative fuel vehicle tested on M85/gasoline, gasoline alternative fuel vehicle tested only on gasoline, and conventional gasoline vehicle) represent an average of four to fifteen tests from all three test laboratories. Also, the vehicle exhaust and evaporative emission test results for each vehicle group type were averaged from vehicles with odometer mileages ranging from about 200 to 16,000 miles. From Figure 27, the M85 alternative fuel vehicles met the Federal standards for total hydrocarbons, organic material hydrocarbon equivalent, carbon monoxide, and oxides of nitrogen when tested on both gasoline and M85. Also, the conventional gasoline vehicles met the Federal emissions standards. Conversely, the gasoline alternative fuel vehicles tested on gasoline were able to meet all applicable Federal emissions standards except for the Federal carbon monoxide standard. While specific Federal standards do not currently exist for non-methane hydrocarbons and formaldehyde exhaust emissions, these emissions will be important because formaldehyde is one of a number of air toxics being considered for future Federal and state regulations.

In comparison with the conventional gasoline vehicles, the M85 alternative fuel vehicles emitted lower average levels of non-methane hydrocarbon and carbon monoxide emissions while tested on gasoline and lower average total hydrocarbon and non-methane hydrocarbon emissions while tested on M85. However, the average formaldehyde emissions from the M85 alternative fuel vehicles on M85 were over four times than those of the conventional gasoline vehicles. Compared with the gasoline alternative fuel vehicles, the M85 alternative fuel vehicles while tested on gasoline exhibited noticeably lower average total hydrocarbon, non-methane hydrocarbon, and carbon monoxide emissions.

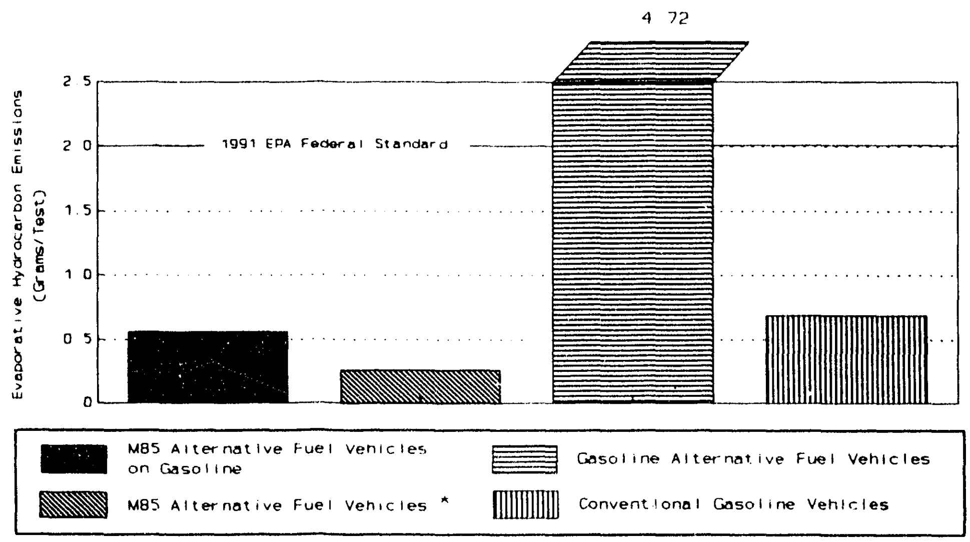
The average composite Federal Test Procedure evaporative emission test results for the test vehicles are shown in Figure 28. The evaporative emission results for each vehicle group type (M85 alternative fuel vehicle tested on M85/gasoline, gasoline alternative fuel vehicle tested only on gasoline, and conventional gasoline vehicle) represent an average of three to nine tests from all three test laboratories. The most obvious result is the very high evaporative emissions for the gasoline alternative fuel vehicles relative to the other vehicle groups, while the M85 alternative fuel vehicles (operating on both gasoline and M85) and the conventional gasoline vehicles exhibited evaporative emissions which were much lower than the Federal standard of 2.0 grams/test. The gasoline alternative fuel vehicle test result of 4.72 grams is an average of only three tests, therefore this result is not considered a good representation of the

Figure 27. Vehicle Exhaust Emissions



Source: National Renewable Energy Laboratory

Figure 28. Vehicle Evaporative Emissions



* Value converted to Organic Mass Hydrocarbon Equivalent for comparison with gasoline vehicles

Source National Renewable Energy Laboratory

gasoline alternative fuel vehicle's evaporative emissions. The evaporative emissions result for the M85 alternative fuel vehicles operating on M85 is shown as a organic material hydrocarbon equivalent value for comparison with conventional gasoline vehicles.

Based on the limited number of emission tests from the light duty vehicle fleet to date it is not possible to accurately determine emission trends for the vehicle types and fuels used in the program. However, a test plan has been established for extensive and comprehensive emissions testing of the light duty vehicle fleet for fiscal year 1993. The emissions test plan for fiscal year 1993 will require emissions tests at various mileage increments over the vehicles' useful lifetimes so that trends in exhaust and evaporative emissions can be accurately determined for the various vehicle and fuel combinations of the fleet.

4.2.2 Laboratory Fuel/Energy Economy

Fuel economies of selected vehicles from the Washington and Detroit areas were determined based on laboratory testing during fiscal year 1992. The vehicles tested included M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles. The vehicles were tested at the Environmental Research & Development Corporation in Gaithersburg, Maryland and the U.S. Environmental

Protection Agency National Vehicle and Fuel Emissions Laboratory, formerly the U.S. Environmental Protection Agency Motor Vehicle Emissions Laboratory, in Ann Arbor, Michigan. The fuel economies of the M85 alternative fuel vehicles were measured on M85 and Indolene in order to determine the difference in vehicle fuel economy on both fuels. The fuel economies of the gasoline alternative fuel vehicles and conventional gasoline vehicles were measured on Indolene only.

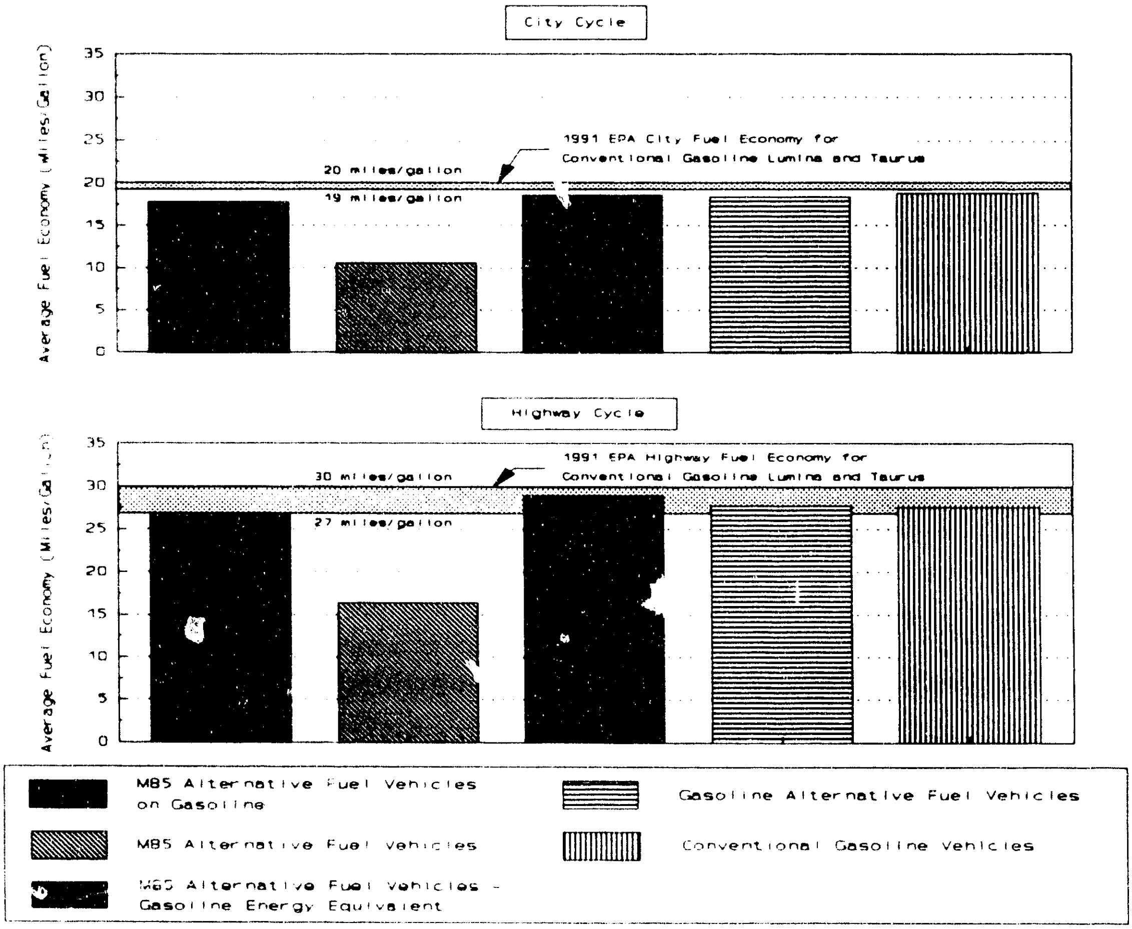
The test procedure used in determining fuel economy for the certification of new vehicles by the U.S. Government is the Federal Test Procedure. The Federal Test Procedure is the same test procedure used to measure emissions. Vehicle fuel economy over the Federal Test Procedure was determined simply by measuring the amount of fuel consumed by the vehicle and the miles traveled by the vehicle over the prescribed "city" or "highway" driving schedules. The 1975 Federal Test Procedure Schedule is used in the calculation of official "city" fuel economy values. The Highway Fuel Economy Test Schedule is used in the United States to obtain the official "highway" fuel economy values. These fuel economy tests were performed to determine fuel economy differences under controlled laboratory conditions using the same driving cycle which rules out influences due to weather, driving habits, and other factors.

The average fuel economy values for the M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles are shown in Figure 29. The fuel economy results for each vehicle group type represent an average of ten to thirteen tests from all three test laboratories. The average Federal Test Procedure city fuel economy values for each vehicle/fuel category were lowered by 10 percent in order to compare with in-use fuel economy information gathered from operation of the light duty vehicle fleet. City fuel economies for the 1991 Chevrolet Lumina and Ford Taurus conventional gasoline vehicles as determined by the U.S. Environmental Protection Agency are provided for comparison. The U.S. Environmental Protection Agency adjusts laboratory test results to account for the difference between controlled laboratory conditions and actual driving on the road. The laboratory fuel economy results are adjusted downward to arrive at the estimates on the labels seen on new vehicles. According to the U.S. Environmental Protection Agency, a downward adjustment in the laboratory fuel economy results make the mileage estimates correspond more closely to the actual fuel economy realized by the average driver.

As shown in Figure 29, the average fuel economy for the M85 alternative fuel vehicles was slightly over half the fuel economy for the M85 alternative fuel vehicles on Indolene, the gasoline alternative fuel vehicles, and the conventional gasoline vehicles. This is largely due to M85's energy content which is only about 56 percent that of unleaded gasoline. However, based on the limited fuel economy testing to date, it is not possible to ascertain fuel economy trends or differences between vehicle types or fuels.

Shown in Figure 30 are the average Federal Test Procedure Schedule city and highway energy economies for each vehicle group type. The conventional gasoline

Figure 29. Vehicle Fuel Economy

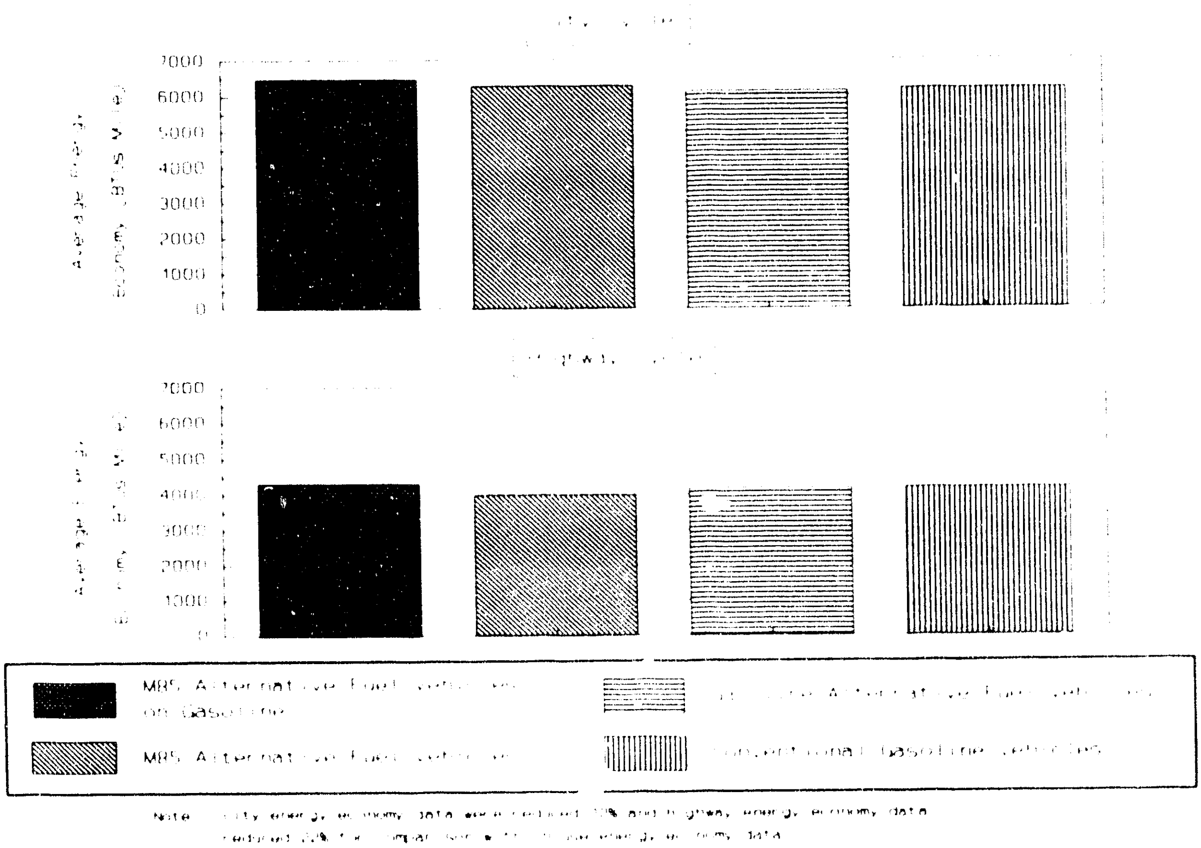


Note: City fuel economy data were reduced 10% and highway fuel economy data reduced 22% for comparison with in-use fuel economy data

Source: National Renewable Energy Laboratory

vehicles had the lowest city energy economy at 6,120 BTUs/mile, while the M85 alternative fuel vehicles tested on Indolene had the highest at 6,490 BTUs/mile. The city energy economy of the M85 alternative fuel vehicles tested on M85 was only about one percent higher than the conventional gasoline vehicles. The M85 alternative fuel vehicles tested on M85 had the lowest highway energy economy at 3,980 BTUs/mile, while the M85 alternative fuel vehicles tested on Indolene had the highest at 4,310 BTUs/mile. The highway energy economy of the M85 alternative fuel vehicles tested on M85 was about five percent lower than the conventional gasoline vehicles.

Figure 30. Vehicle Energy Economy



4.3 Driveability

Vehicle driveability for alternative fuel vehicle operation during fiscal year 1992 is discussed in this section. Driveability information recorded on the vehicle weekly survey form summarizes the weekly operation of the participating program vehicles. Vehicle driveability is recorded by the driver for each day of vehicle operation. Driver responses on idle quality, hesitation, hard starting, stalling after starting, pinging, or no problems are recorded.

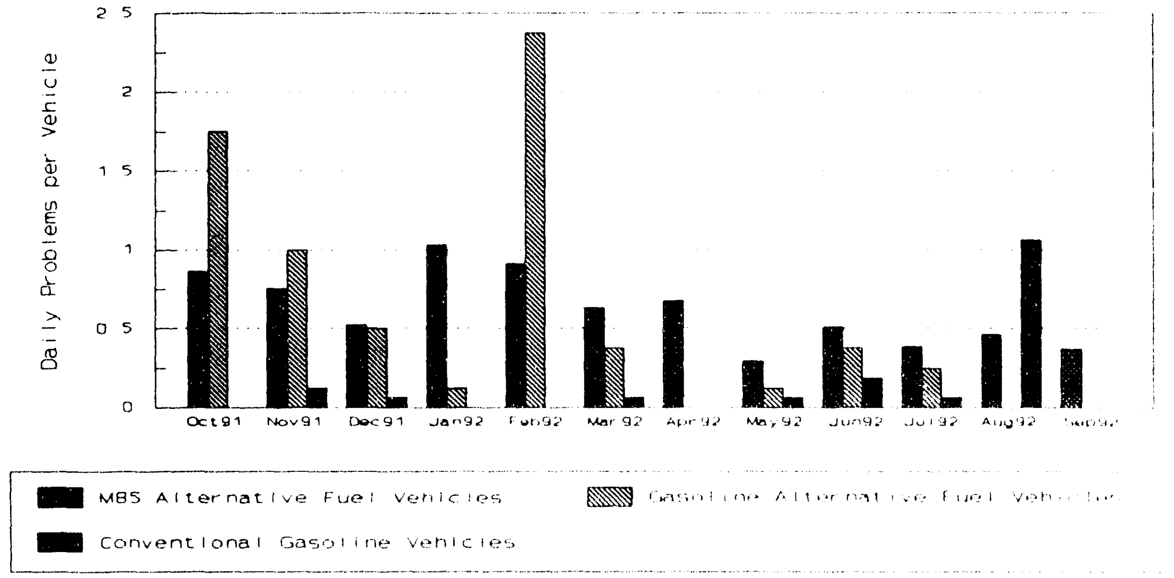
During the second year (October 1991 through September 1992) of alternative fuel vehicle operation, various driveability difficulties were reported on some of the vehicles, including rough engine idling, hesitation upon acceleration, "check engine" light on, and engine stalling. A portion of both the M85 Chevrolet Lumina and Ford Taurus vehicles continued to experience some driveability problems during the second year of operation. The driveability problems that occurred with the M85 Ford Taurus were largely attributed to performance degradation of various unique components of the M85 vehicle such as the EEC-IV engine microprocessor, fuel sending unit, and fuel pressure regulator. However, upgrade kits were delivered to the participating authorized Ford service centers, and the upgraded hardware was installed on the vehicles with the driveability problems. The driveability problems that occurred with the M85 Chevrolet Lumina were largely attributed to performance degradation of the unique fuel injector and fuel pump speed-controller components. However, an updated dealer service bulletin was issued in November 1991 to the participating authorized General Motors service centers, outlining the driveability problems, possible cause, and correct repair procedures (install new service calibration prom and fuel pump speed controller) to follow. As a result of this service bulletin, repairs were performed on all 25 participating M85 Chevrolet Lumina vehicles. Installation of upgraded hardware and the issuance of dealer service bulletins have reduced the number of driveability problems experienced by a portion of the alternative fuel vehicles during calendar year 1992, as shown in Figure 31. However, the number of reported driveability difficulties experienced by the M85 alternative fuel vehicles were still greater than the number of difficulties reported by the conventional gasoline vehicles, except during August 1992 several conventional gasoline vehicles in the Detroit and Washington areas experienced prolonged engine hesitation, "check engine" light on, and poor idle quality problems. The greatest number of problems reported in fiscal year 1992 was from the gasoline alternative fuel vehicles during February 1992, with driveability problems such as engine hesitation, stalled after starting, "check engine" light on, and poor idle quality.

The Detroit area offers the opportunity to operate fleet vehicles at a cold weather location, in order to test the cold-start capabilities of the M85 alternative fuel vehicles. During the second reported year of vehicle operation, various reported driveability difficulties were reported during the winter months concerning the M85 alternative fuel vehicles in the Detroit area. However, based on Ford dealership repair order information, none of the M85 Ford Taurus vehicles in the Detroit area had repairs completed to their cold-start systems.

4.4 Reliability

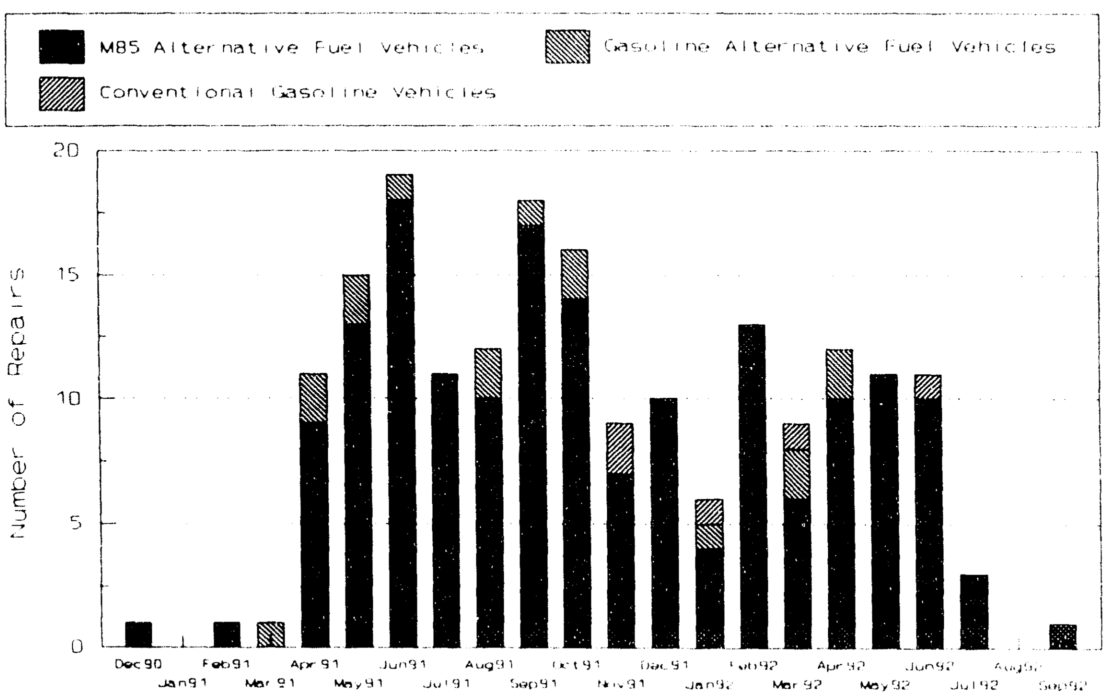
Shown in Figure 32 are the number of unscheduled monthly repairs for the M85 alternative fuel vehicles, gasoline alternative fuel vehicles, and conventional gasoline vehicles from initial vehicle introduction through September 1992. The maximum number of vehicle repairs occurred during the month of June 1991, in which 18 M85 alternative fuel vehicles and one gasoline alternative fuel vehicle had unscheduled maintenance. The three most frequent repairs completed on the alternative fuel vehicles were primarily on the electronic engine control/computer assembly, fuel pump, and fuel injection system, as shown in Figure 33. However, after installation of upgraded hardware and the issuance of dealer service bulletins were conducted at the end of 1991, the number of repairs on the alternative fuel vehicles appear to have reduced during fiscal year 1992.

Figure 31. Frequency of Vehicle Driveability Problems



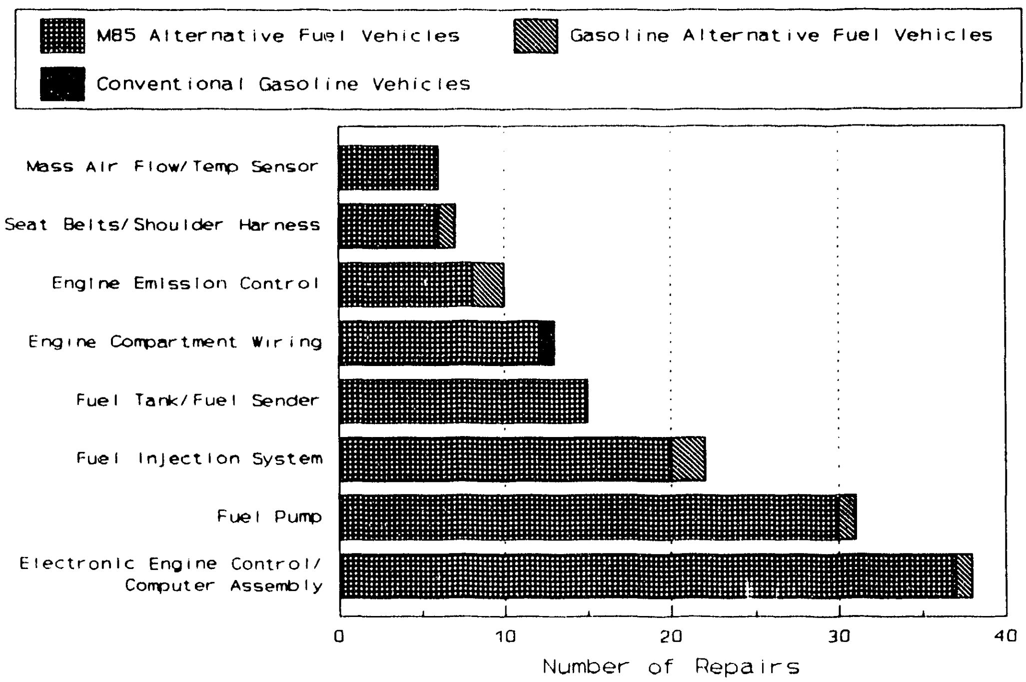
Source: National Renewable Energy Laboratory

Figure 32. Vehicle Repair Frequency



Source: National Renewable Energy Laboratory

Figure 33. Most Frequently Reported Repairs

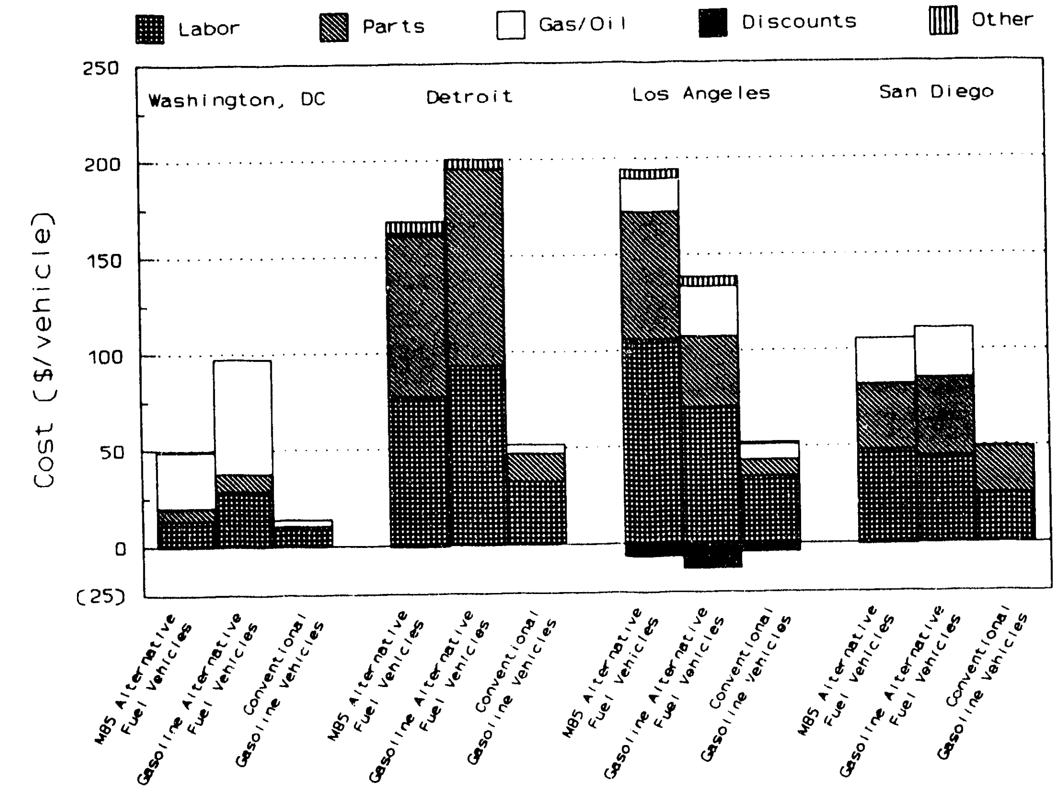


Source: National Renewable Energy Laboratory

4.5 Operating Costs

The average operating costs (labor, parts, gas/oil/lube, discounts, and total) per vehicle are shown in Figure 34 for all four fleet locations and vehicle group types for fiscal year 1992. The M85 alternative fuel vehicles in the Los Angeles area had the highest operating cost compared to the other fleet locations at nearly $200/vehicle, whereas the Washington area had the lowest at $50/vehicle. However, the maximum overall operating cost was for the gasoline alternative fuel vehicles in the Detroit area at $200/vehicle. The operating costs for the conventional gasoline vehicles in the Detroit, Los Angeles, and San Diego areas were nearly the same at about $50/vehicle, however in the Washington area the operating cost was only about $15/vehicle. The average cost for a scheduled maintenance (lube, oil, and filter change only) for an M85 alternative fuel vehicle, gasoline alternative fuel vehicle, and conventional gasoline vehicle for the four fleet locations for fiscal year 1992 is shown in Figure 35. The average cost for a scheduled lube, oil, and filter maintenance was greatest in the Detroit area for the M85/gasoline alternative fuel vehicles at over $55; however, the average costs at the other three fleet locations were nearly the same at about $43. The average cost for a scheduled lube, oil and filter maintenance for an M85 alternative fuel vehicle was about

Figure 34. Vehicle Maintenance Costs



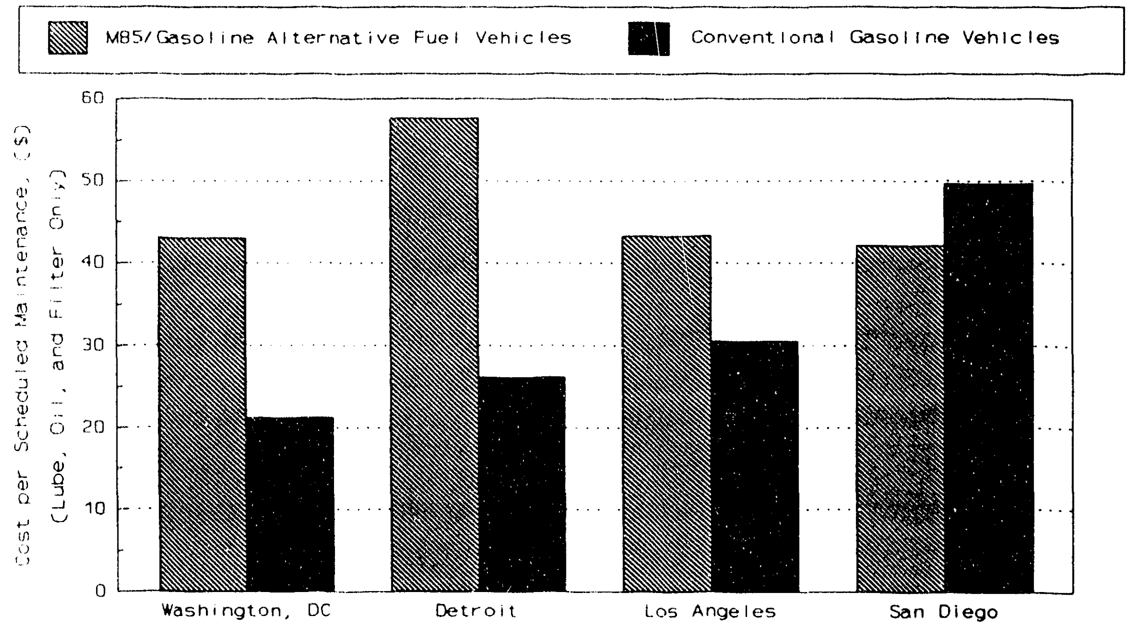
Source: National Renewable Energy Laboratory

twice the cost of a conventional gasoline vehicle in the Washington and Detroit areas, whereas in Los Angeles the average cost was much less due primarily to discounts. The major cost of a lube, oil, and filter maintenance on an M85/gasoline alternative fuel vehicle is the cost of the oil. The oil used in the M85/gasoline alternative fuel vehicles is approved by the vehicle manufacturers and contains a special additive package designed specifically for M85 vehicle use. The operating cost information was obtained from copies of authorized dealership repair orders at the four fleet locations.

4.6 Safety

The safety issues concerning alternative fuel vehicle operation during fiscal year 1992 are discussed in this section. The overall safety assessment of the M85 alternative fuel vehicles is based on information collected from communications with drivers involved in accidents, driver weekly survey forms, and from vehicle maintenance records issued by the authorized service centers.

Figure 35. Vehicle Scheduled Maintenance Costs



NOTES (1) Alternative fuel vehicle costs for all fleet locations included discounts, except Washington, DC.

(2) Conventional gasoline vehicle cost for San Diego was based on only one scheduled maintenance.

Source: National Renewable Energy Laboratory

During the second year of operation (October 1991 through September 1992) various collision-related accidents were reported involving operation of the light duty vehicles participating in the program. On October 10, 1991 an M85 alternative fuel vehicle was involved in a frontal collision with a non-Federal vehicle in the Detroit area. On December 23, 1991 an M85 alternative fuel vehicle was involved in a collision with a non-Federal vehicle in the Washington area. The M85 alternative fuel vehicle was hit in the rear while stopped at a traffic light. Also, on April 2, 1992 an M85 alternative fuel vehicle was involved in a collision with a non-Federal vehicle in the Washington area. The M85 alternative fuel vehicle was hit in the rear while stopped at a stop sign. All of these collision-related accidents had no reported damages to the M85 fuel system and no personal injuries were reported. No other known safety- or health-related incidents have resulted concerning refueling, maintenance, or servicing of the M85 alternative fuel vehicles.

4.7 Consumer Awareness

The promotional activities conducted to educate the public about alternative fuel vehicles and their operation are discussed in this section. The alternative fuel vehicles participating in the program have magnetic decals indicating that they are flexible fuel vehicles that are able to operate on M85 as well as unleaded gasoline fuel. Both vehicle manufacturers have identification on the outside of the 65 alternative fuel vehicles distinguishing them as variable or flexible fuel vehicles. Also, the 65 alternative fuel vehicles have supplements to the original vehicle owner's manual including information such as precautions to be observed when using M85, servicing the vehicle, and proper vehicle operation.

In fiscal year 1992, various publications were prepared and distributed by the Department of Energy/National Renewable Energy Laboratory on the objectives of the Alternative Motor Fuels Act program, current and planned demonstration projects, and technology facts on alternative fuels such as compressed natural gas, liquefied natural gas, methanol, ethanol, and liquefied petroleum gas. During fiscal year 1992, the National Renewable Energy Laboratory has published and distributed quarterly light duty vehicle operational reports titled - "Alternative Motor Fuels Act of 1988 - Light Duty Vehicle Summary Information and Individual Vehicle Graphs." The Department has also published quarterly information updates concerning the initiation, function, and operation of the Alternative Fuels Data Center in Golden, Colorado. The Alternative Fuels Data Center provides information on alternative fuels and alternative fuel vehicles to Government agencies, private industry, research institutions, and other interested organizations. In addition, the Department has established and operates a National Alternative Fuels Hotline. The toll-free number, 1-800-423-1DOE, is available to all callers outside the Washington area; local callers may call (202) 554-5047 to reach the hotline. The hotline is available to callers between 10 a.m. and 6 p.m. eastern standard time on weekdays except Federal holidays.

The public refueling facilities operate M85 fuel pumps and gasoline fuel pumps at each station. However, the M85 fuel pumps have information clearly displayed distinguishing them from the conventional gasoline fuel pumps. The M85 fuel dispensers display information pertaining to the safety precautions of refueling with M85 and warning that M85 fuel should only be used in vehicles that are designed to operate on it.

5.0 FUTURE ACTIVITIES

There are three planned activities of the Alternative Motor Fuels Act of 1988 program. First, additional alternative fuel vehicles are planned to be added to the light duty vehicle program in fiscal year 1993. Secordly, the Energy Policy Act of 1992 makes a number of amendments to the Alternative Motor Fuels Act program, including the repeal of the termination date of September 30, 1997 for the Department's programs on data collection for light duty vehicles, alternative fuel truck commercialization, and alternative fuel buses. The amended version of the Alternative Motor Fuels Act also allows for all alternative fuel types (e.g., propane, electricity, etc.) to be acquired for the program. Thirdly, the Department has developed an expanded emissions test plan for the light duty vehicle fleet for fiscal year 1993. The overall objective is to ensure the accurate measurement, collection, dissemination, and analysis of mass emissions data from the fleet so that differences in vehicle emissions when using alternative fuels and conventional fuels can be determined. In addition, the Energy Policy Act adds a statutory requirement for the wide adoption of alternative fuel vehicles in normal Federal fleet operations. This has been amplified by Executive Order 12844, signed by President Clinton on April 21, 1993, which directs agencies to exceed the Energy Policy Act alternative fuel vehicle acquisition requirements by 50 percent if possible.

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