REPORT OF THE VIRGINIA DEPARTMENT OF TRANSPORTATION ON

STUDY OF COMPRESSED NATURAL GAS VEHICLE PILOT PROJECTS

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

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PREFACE

The 1991 General Assembly passed HJR 481/ SJR 206 which requested that the Virginia Department of Transportation (VDOT) undertake three pilot projects involving alternative motor fuels: one project in Northern Virginia, one in the greater Richmond area, and one in the Hampton Roads area.

The Equipment Division was the VDOT division responsible for the projects. The late J. E. Melone, who laid much of the groundwork for these projects, was the Equipment Engineer. He has been succeeded by E. W. Potter. This report was prepared primarily by C. E. Delbridge, Jr. and F. H. Williams, Jr. of the Equipment Division. Many other employees contributed to the information contained in this report, including District Equipment and Facilities Managers, District Equipment Repair Managers, Equipment Repair Technicians and the operators of the pilot project vehicles.

For contributing the fueling stations and for assisting our technicians with correcting conversion problems, we wish to acknowledge the three gas utility companies that worked with us during the projects: Washington Gas, Commonwealth Gas Services, and Virginia Natural Gas.

EXECUTIVE SUMMARY

In 1991, the Virginia General Assembly requested the Virginia Department of Transportation to study alternative motor fuels. Three pilot projects were undertaken using compressed natural gas (CNG) as a vehicle fuel. The primary objectives of the projects were to increase the familiarity and acceptance of clean fuels by the general public and local governments, and to determine any operational and cost differences between CNG powered and gasoline powered vehicles. It is believed the first objective was accomplished because of the publicity given the projects, the visibility of VDOT vehicles to the public, and the interest shown by local governments. The operational and cost differences are reported here, although they are somewhat immaterial due to the rapid changes in CNG vehicle technology.

The projects were developed as a result of the 1991 General Assembly passing HJR 481/ SJR 206. A total of 50 vehicles were selected for conversion and 50 corresponding control vehicles were selected as comparisons. Six dedicated CNG pickups were purchased in 1994 and added to the project.

Project sites were selected on the basis of the availability of the vehicles and the availability of a natural gas line nearby. Of the 50 vehicles selected, there were 20 passenger cars, 29 pickup trucks, and one van. Specifications for conversions were developed based on the latest information available from industry sources. Conversion prices ranged from approximately $2800 for cars to $4500 for some of the pickup trucks. Data was collected from VDOT's computerized Equipment Management System, weekly forms sent in by operators, fuel records, oil analysis and periodic emissions tests.

Fuel costs were compared using 120 cubic feet of natural gas as an equivalent to one gallon of gasoline, and monitored throughout the projects. Since VDOT does not pay federal or state fuel taxes, in some cases the cost of CNG exceeded the cost of gasoline.

Three converted vehicles and three control vehicles were chosen to have emission tests performed by the IM240 process. It was found that on our conversions the air/fuel adjustment was critical to emission output.
Repair history was evaluated for all vehicles in the project by reviewing the work orders generated throughout the projects. In the categories of no-start and driveability, the CNG vehicles exceeded the gasoline vehicles by as much

as three to one. In most cases there was substantially higher repair costs to the converted vehicles.

Periodic oil analysis was performed on each of the 50 converted vehicles as well as the 50 control vehicles. These were reviewed, concentrating on iron contamination and soot contamination. It was found the CNG vehicles had slightly more iron contamination, indicating slightly more internal wear, but much less soot contamination, indicating that CNG vehicles could require less frequent oil changes than gasoline vehicles.

Vehicle performance was tested on VDOT's chassis dynamometer and by timed acceleration tests. The CNG vehicles had less power and slower acceleration than the control vehicles.

As expected in any project of this magnitude, problems arose. Probably the most troublesome was the conversion companies' performance. Many instances of poor wiring connections, loose and leaking lines, and component failures were encountered. Throughout all this the gas companies were very helpful and assisted with correcting problems. The gas companies additionally had their own problems to deal with because of problems with the fueling stations.

CNG conversion technology has improved so much in the last few years that many of the results of these projects are not applicable to the type of conversions available today. However, at least partly as a result of these projects, there is a small but growing infrastructure of CNG stations including several commercial stations.

The experience gained from these projects will aid VDOT in complying with upcoming federal clean fuel fleet regulations. Both the Clean Air Act and Energy Policy Act will require large percentages of the VDOT fleet to be alternatively fueled in the near future. VDOT is working with other agencies to develop a plan so that the Commonwealth's fleet purchases will meet the criteria of both laws.

INTRODUCTION

Study Mandate

The 1990 General Assembly passed HJR 113 which established the Joint Subcommittee to Study the Use of Vehicles Powered by Clean Transportation Fuels. The subcommittee's primary purpose was to study the emissions, economic, safety and other benefits of clean transportation fuels in motor vehicles used by state agencies, school divisions and local transit authorities.

The 1991 General Assembly passed HJR 481/ SJR 206 which requested "...the Virginia Department of Transportation (VDOT) undertake three pilot projects involving alternative motor fuels: one project in Northern Virginia, one in the greater Richmond area, and one in the Hampton Roads area. In choosing a fuel or fuels for such projects, the Department shall limit consideration to those which are produced in the United States, which address the air pollution difficulties of the region in which the project is conducted, and whose use by government fleets is economically feasible, and which can be used in passenger vehicles presently equipped with conventional gasoline engines."

Project Funding

A 1991 budget amendment allowed the Central Garage (upon approval by JLARC) to assess fees in the amounts necessary to pay for vehicle and operating costs of the projects. HJR 481 stipulated that no project could proceed unless private contributions were made to cover the full capital costs of filling stations and related equipment.

Fuel Selection

When the project was initiated, natural gas was considered the least expensive, most abundant and cleanest type of the available fuels. It was available through existing gas utility lines, and did not require truck deliveries like other fuels did. A disadvantage of compressed natural gas (CNG) is the high cost of the facility required to compress the natural gas, which was estimated at the time to be approximately $150,000. However, the gas utility companies supplied the station equipment with VDOT responsible only for site preparation.

Subsequently, VDOT started three pilot projects to study the use of CNG as a vehicle fuel. The pilot projects focused on the three regions in Virginia that were faced with air pollution problems, Northern Virginia, Richmond and Hampton Roads. Fifty vehicles were converted to compressed natural gas operation. Washington Gas Co., Virginia Natural Gas Co. and Commonwealth Gas Services provided the fueling station equipment for the projects, which were to last 18 months after the station startup dates. The study focused on fuel costs, exhaust emissions, and maintenance costs of the 50 converted vehicles as compared to 50 control vehicles.

The CNG fueled vehicles were paired with similar gasoline fueled "control" vehicles. Pairing of vehicles and maintaining cost records provide a comparison of operating expenses between CNG vehicles and gasoline vehicles. This comparison shows the fuel and maintenance costs differentials between CNG and gasoline.

Additionally, in 1994, six dedicated CNG powered pickup trucks were purchased and placed into service by the Department, two each for the three pilot project areas. These trucks are not original equipment manufacturer dedicated CNG vehicles as we originally had planned. After we placed our order, General Motors stopped selling CNG powered trucks due to problems encountered with gas cylinders. The dealer then decided to provide converted trucks in their place. The operation of these vehicles has been monitored, and essentially has been added to the scope of the original projects.

This report outlines the results of these projects.

PROJECT DESCRIPTION

Vehicle Selection

VDOT was selected to perform these projects primarily because of the large size of its equipment fleet. At the time these projects were implemented, there were approximately 90 different types of equipment in the fleet. As shown in Figure 1, VDOT's Equipment Division fleet consisted of 7,573 units with 61% of the fleet being diesel powered, and 39% being gasoline powered. The gasoline units consisted primarily of pickup trucks, but also included vans, 3/4 ton, and 1 ton trucks. The diesel units consisted mostly of large dump trucks and off-road equipment.

No diesel conversion kits were available that were effective in reducing vehicle emissions; therefore, only gasoline powered units were chosen for conversion to use an alternate fuel.

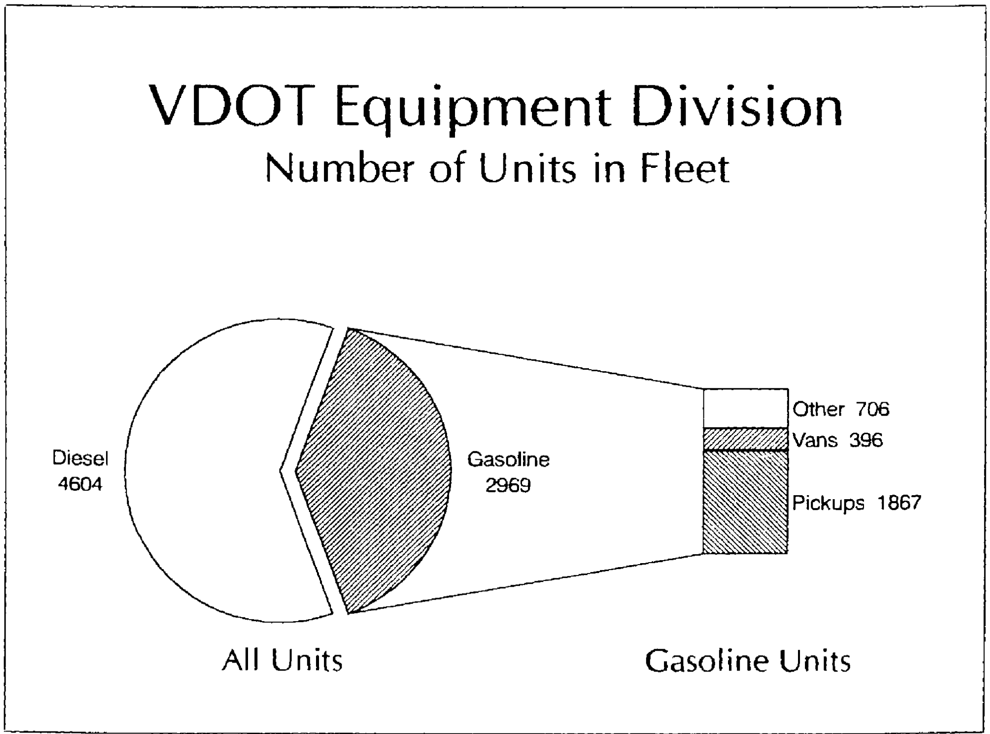


Figure 1

Site Selection

Because VDOT has the greatest number of vehicles at its district headquarters, Suffolk District Headquarters and Richmond District Headquarters were selected for the Hampton Roads and Richmond area pilot project sites. The Newington Area Headquarters was selected In Northern Virginia because the Safety Patrol is stationed there and a natural gas line ran nearby.

One of the first steps in these projects was the selection of vehicles to be converted. Because the vehicles chosen needed to be fueled at a central location in each district, vehicles that traveled throughout the state were excluded. VDOT chose to convert vehicles that use large amounts of fuel, either because of poor fuel economy, or because of high use because these factors will magnify any benefits gained by using the alternate fuel. Efforts were made to select new or almost new vehicles to avoid maintenance problems normally caused by age and mileage.

Because vehicles fueled by CNG were expected to show an approximate 10% power loss, vehicles with large displacement engines (over 2 liters) were selected to minimize the effects of this loss. However, because experience using CNG in a variety of vehicles was desired, some small sedans were also chosen for the projects.

To provide statistically appropriate data for comparison to CNG, other vehicles that represent a cross-section of the fleet were also selected.

Table 1 lists the vehicles converted to CNG. The 50 include 20 passenger cars, 29 pickup trucks, and 1 van.

Table 1 - Vehicles Selected for Conversion

Year	Model	No. Va	Richmond	Suffolk
'86	Dodge Van	1	0	0
'87	Chevrolet Pickup	2	0	1
'88	Dodge Pickup	0	3	6
'89	Dodge Pickup	2	0	2
'90	Chevrolet Pickup	5	7	1
'89	Chevrolet Cavalier	0	2	0
'90	Chevrolet Cavalier	0	2	3
'91	Ford Tempo	0	6	5
'92	Dodge Shadow	0	0	2
TOTALS		10	20	20

Some of the pickup trucks located in the Northern Virginia area are the Safety Patrol vehicles that are run almost continuously, 24 hours a day. Because of the high mileage that these vehicles are driven, only 10 were selected. One of these vehicles was wrecked early in the project, and was not replaced.

Conversion Specifications

VDOT developed specifications for conversion of the pilot project vehicles. The Department consulted a number of gas utility companies as well as several conversion kit manufacturers in order to ensure quality installations and competitive price bidding. The specifications required that the conversions meet all known industry standards, i.e. being American Gas

Association certified, and compliant with the National Fire Protection Association's NFPA 52 standard. Appendix B lists the conversion specifications for the project vehicles in the Hampton Roads area.

On each of the passenger cars a CNG cylinder with a capacity of 700 cubic feet (equivalent to approximately 5.8 gallons of gasoline) was installed. The CNG tank was located in the trunk, and the spare tire was relocated. The tank provided a range of approximately 120 miles when full. There was little storage space left over for luggage or other items.

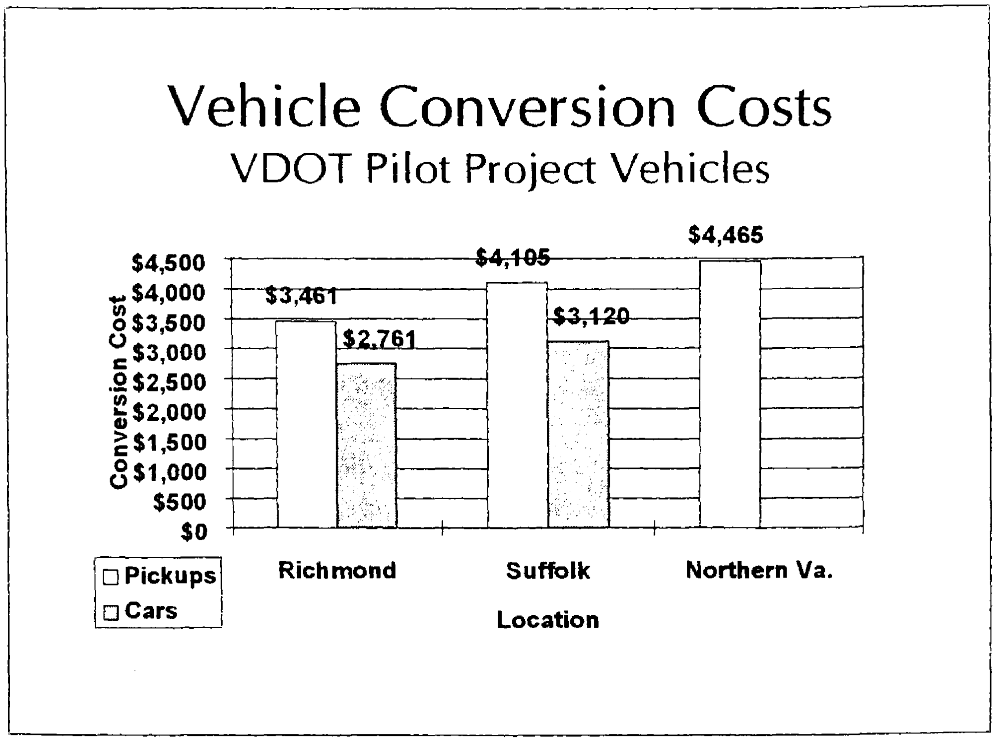
The pickups in Northern Virginia District each had four CNG cylinders of 508 cf (approximately 4.2 gal equivalent) installed. The pickups in Richmond and Suffolk Districts each had two CNG cylinders of 950 cf (approximately 7.9 gal equivalent) installed. The range provided is approximately 255 and 240 miles respectively. The tanks take up a significant amount of bed space. The safety patrol pickup trucks in Northern Virginia District had to be configured differently than the pickup trucks in the other districts because of the amount of emergency equipment that they carry in their beds.

To fill the vehicle with compressed natural gas, the operator connects the dispenser hose to a fitting located under the hood of the vehicle. The fuel is metered into the vehicle tanks until they reach a pressure of 3000 psi. Ideally, the entire process takes approximately 10 minutes. An auxiliary fuel gauge mounted on the dash indicates the amount of CNG stored in the vehicle tank.

Because the vehicles were bi-fuel conversions, they were capable using gasoline as well. An automatic fuel switching device was installed to switch the vehicle to gasoline operation when the CNG cylinders become empty. This bi-fuel operation gave the vehicles an extended range when needed; however, it was intended that the converted vehicles operate only on CNG. Dual hourmeters indicated the amount of time the vehicles operated on each fuel.

Conversion Costs

Figure 2 shows the actual cost of converting vehicles in the pilot projects to CNG. The higher cost in Northern Virginia is due to the use of four CNG tanks on each Safety Patrol truck. Trucks in the other pilot projects each received two tanks.



Vehicle Conversion Costs
VDOT Pilot Project Vehicles
Conversion Cost
$4,500
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
$3,461
$2,761
$4,105
$3,120
$4,465
Pickups
Cars
Richmond
Suffolk
Northern Va.
Location

Figure 2

New Vehicle Costs

Figure 3 compares the cost of the six dedicated CNG powered vehicles to the six identical gasoline powered comparison vehicles. VDOT purchased 180 diesel powered pickups that year, and the unit cost for those is also shown on the chart.

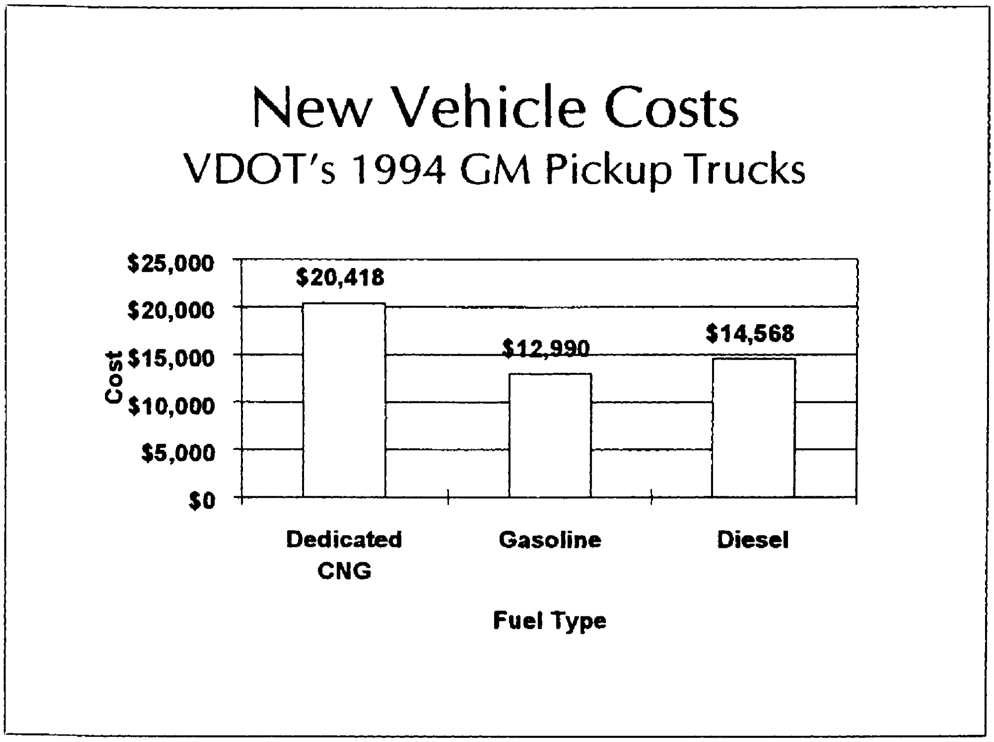


Figure 3

Data Collection

Data pertaining to the operation of the vehicles was collected throughout the project.

Each week the vehicle operators were required to send in a form on which they recorded every fueling of the vehicle and any maintenance performed. The information gathered from these forms was used to compare the fuel costs of the CNG and gasoline powered vehicles. A copy of a fuel and maintenance form is included in Appendix C. Early in these pilot projects, VDOT implemented a computerized statewide equipment management system which offered a more complete and accurate record of maintenance. It is the computerized records, and not the operator forms, that were used in the vehicle maintenance comparisons.

Additionally, an oil analysis program was established to indicate any change in engine oil life and compare engine wear.

Prior to operating the vehicles on CNG, an electronic engine analysis and tune-up was performed on each vehicle.

To determine the air quality impacts of the converted vehicles, periodic emissions testing of all 100 vehicles was conducted using VDOT shop exhaust analyzers. In order to obtain accurate readings of reactive hydrocarbons and nitrogen oxides, an outside vendor was used to test a few of the vehicles. These outside tests cost approximately $250 each.

RESULTS

Fuel Costs

It is difficult to compare the fuel costs of the CNG vehicles with that of the gasoline powered vehicles. First, CNG is a gaseous fuel and gasoline is liquid. The unit of measurement is different, (cubic feet for CNG and gallons for gasoline) and a conversion factor must be used. The conversion factor was calculated as shown below.

According to *Mark's Standard Handbook for Mechanical Engineers*, a typical heating value of pipeline natural gas is 1071 BTU per cubic foot. This value can vary up to 20%, depending on the composition of the natural gas. A typical heating value of gasoline is 20,750 BTU per pound and the density is 6.152 pounds per gallon. Using these values, the equivalent energy of 1 gallon of gasoline is approximately 120 cubic feet of natural gas. This is calculated as follows:

$$1\,gallon \times \frac{20{,}750\,BTU}{lb} \times \frac{6.152\,lb}{gallon} \times \frac{cf}{1071\,BTU} = 120\,cf$$

Another difficulty arose because of the natural gas dispensers. At first, some of our stations' dispensers did not have a readout for the amount dispensed. Instead, amounts had to be estimated based on the fuel tank size, beginning tank pressure, ending tank pressure, and ambient temperature.

With the dispensers that did have a readout for amount, there were freeze-ups where the gas stopped flowing while the meter kept running. In addition, the vehicles were bi-fuel, operating part of the time on gasoline. For these reasons, it was decided that the most accurate way to compare fuel costs was to assume equal energy efficiency between the CNG and gasoline powered vehicles, and compare the costs of equal amounts of energy, i.e. the cost of 120 cubic feet of CNG vs. the cost of 1 gallon of gasoline.

Figure 4 shows a comparison of fuel costs at the three areas. The cost of gasoline is largely uniform between the three areas, although gasoline in Northern Virginia is several cents higher during the winter months due to oxygenated fuel requirements.

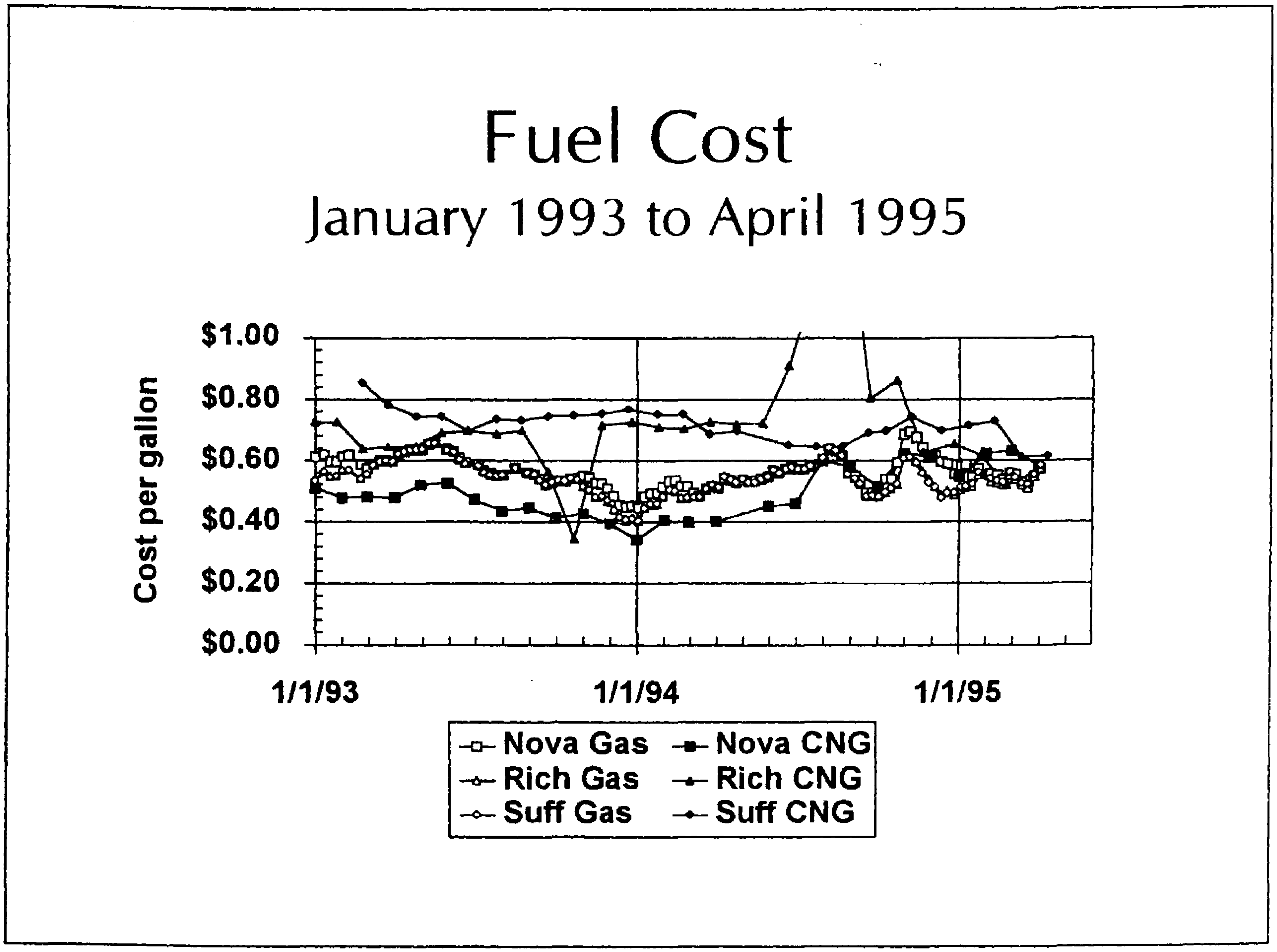


Figure 4

The natural gas costs are more variable. In Northern Virginia CNG is cheaper than gasoline. In Suffolk and Richmond, compressed natural gas generally costs more than gasoline.

The natural gas costs for Richmond District were more erratic than in the other 2 areas, dipping below 40 cents per equivalent gallon one month, and going off the scale another. The price dips largely are due to retroactive rate adjustments. The months where the cost is extremely high, so little gas was used, that the flat monthly service charge had a large effect on the unit cost.

Emissions

Two types of emissions tests were performed on the pilot project vehicles. The first type was performed using a shop type 4 gas analyzer. The shop type test is normally done under no load, and is useful mainly to adjust the fuel/air mixture on the open loop type fuel systems. This type of test does not measure nitrogen oxides (NO_X), which is one of the major emission concerns.

The other, more elaborate, test is called the IM240. These tests were performed for VDOT by EG&G Automotive Research Inc. in Alexandria, Virginia. The IM240 test is performed under load on a dynamometer for a standard simulated driving cycle 4 minutes in length. This test is roughly comparable to the Federal Test Procedures used by the EPA to certify the emissions of new vehicles. The results of the IM240 are given in grams per mile of carbon monoxide (CO), NO_X, and hydrocarbons (HC). The results of the IM240 tests are reported in Figures 5-7.

The following vehicles were tested for exhaust emissions using the IM240:

Table 2 - Vehicles Tested for Emissions

ID	Year	Vehicle	Fuel
R52185	1988	GMC Pickup	Gasoline
R52182	1988	GMC Pickup	Bi-fuel CNG
P01226	1991	Ford Tempo	Gasoline
P01106	1991	Ford Tempo	Bi-fuel CNG
R00540	1994	GMC Pickup	Gasoline
R00534	1994	GMC Pickup	Dedicated CNG

The figures that follow show the results graphically.

Figure 5 shows the results of the emissions tests for two of the safety patrol pickup trucks operating out of Northern Virginia. The bi-fuel vehicle operating on CNG emitted less NO_X, while the gasoline vehicle emitted less hydrocarbons and carbon monoxide. The results for hydrocarbons are somewhat unfair to CNG because it shows total hydrocarbons, not just the reactive hydrocarbons which are the cause of ground level ozone. As a comparison, the 1988 EPA Standards are shown for hydrocarbons, carbon monoxide, and nitrogen oxides. A direct comparison between these standards and our test results is improper because it is based on a different test procedure. It is shown here for a general point of reference.

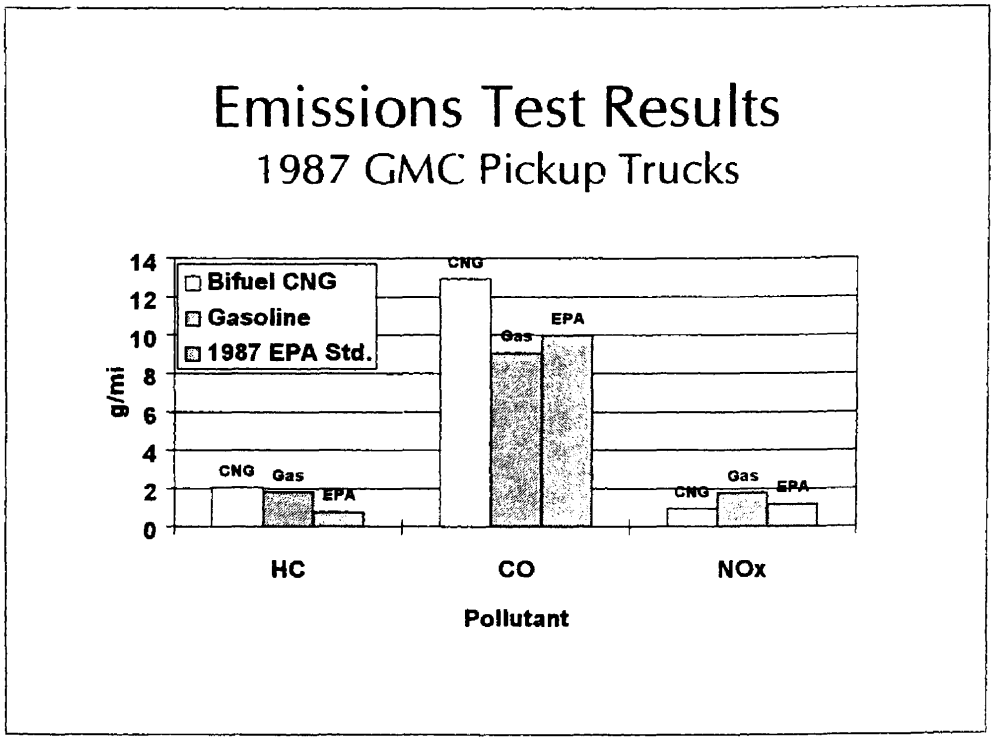


Figure 5

Figure 6 shows emissions tests results for two 1991 Ford Tempos. The one powered by CNG emitted less carbon monoxide and carbon dioxide, but more nitrogen oxides and hydrocarbons. The hydrocarbons shown here reflect only the non-methane hydrocarbons. Again, the EPA standards are shown as a comparison.

The conversions purchased were open loop systems, meaning the system did not use any of the sensors or interface with any on-board computers on any vehicles. At the time of purchase there were no systems available that provided those functions which would result in lower emissions.

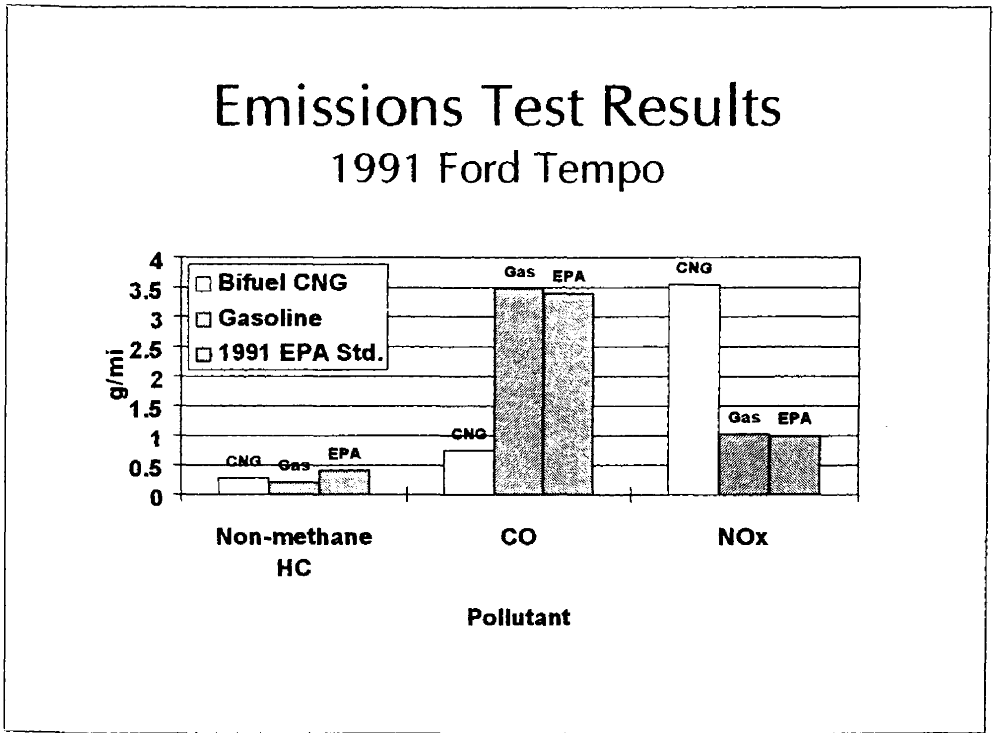


Figure 6

As shown in Figure 7, a new 1994 model dedicated CNG pickup truck was tested for emissions, as was an identical new gasoline truck. The IM240 test was performed by EG&G Automotive Research. The CNG truck showed improved emissions over the gasoline truck for all three pollutants: Non-methane hydrocarbons, carbon monoxide, and nitrogen oxides. The EPA Standard for 1994 pickup trucks is shown as a comparison. Both trucks' emissions fell considerably below the EPA Standards.

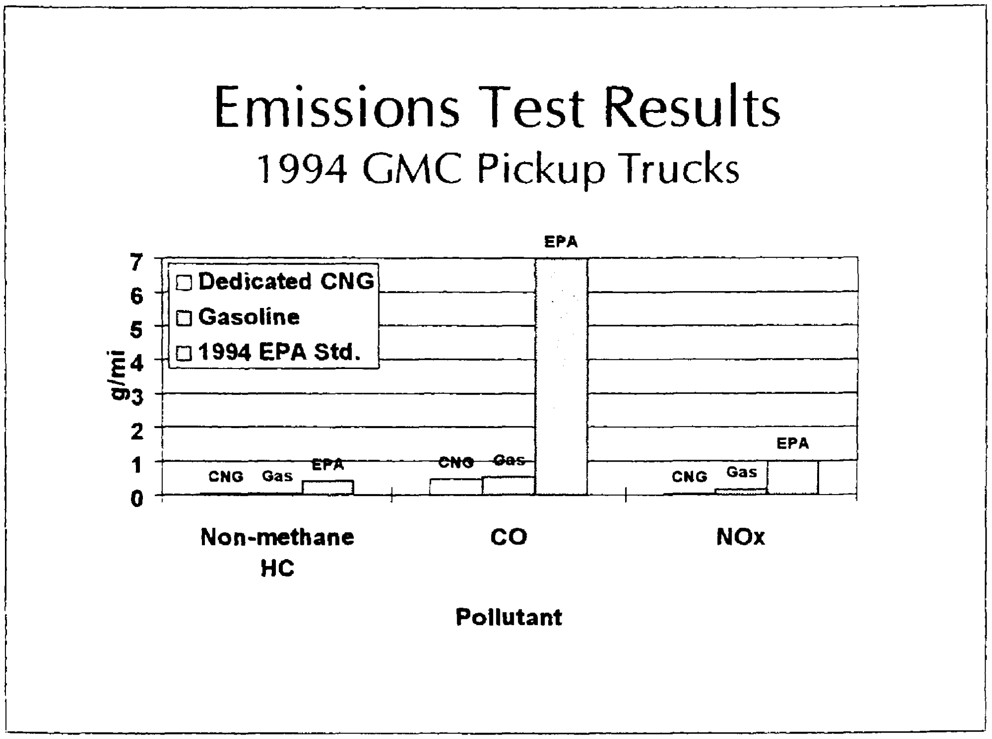


Figure 7

Repair History

A review of work orders generated over a two year period was conducted to evaluate the repairs made to the test vehicles. Two repair categories were chosen; one that indicated a "no start" or "cut off" problem and one that indicated a "driveability" problem. The table below shows the results.

Table 3 - Vehicle Repair Count

Repair Category	TRUCKS		CARS	
	CNG	Gasoline	CNG	Gasoline
No Start	75 (37%)	27 (35%)	25 (48%)	11 (55%)
Driveability	126 (63%)	50 (65%)	27 (52%)	9 (45%)
Total	201	77	52	20

The 35 trucks operating on CNG required a total of 201 of these types of repairs during the study. 37% of the repairs resulted from "no start" problems, 63% from driveability difficulties. The 35 control trucks (gasoline powered) required 77 repairs with 35% being "no start" and 65% being driveability problems. In total, the CNG trucks required 2.61 times as many repairs as the control trucks.

The 20 CNG cars required 77 of these types of repairs, with 48% in the "no start" category and 52% in the driveability category. The 20 control cars tallied 20 repairs with 55% in the no start category and 45% in the driveability category. The 2.60 ratio of CNG vs. gasoline powered car repairs is nearly identical to the ratio displayed by the pickups.

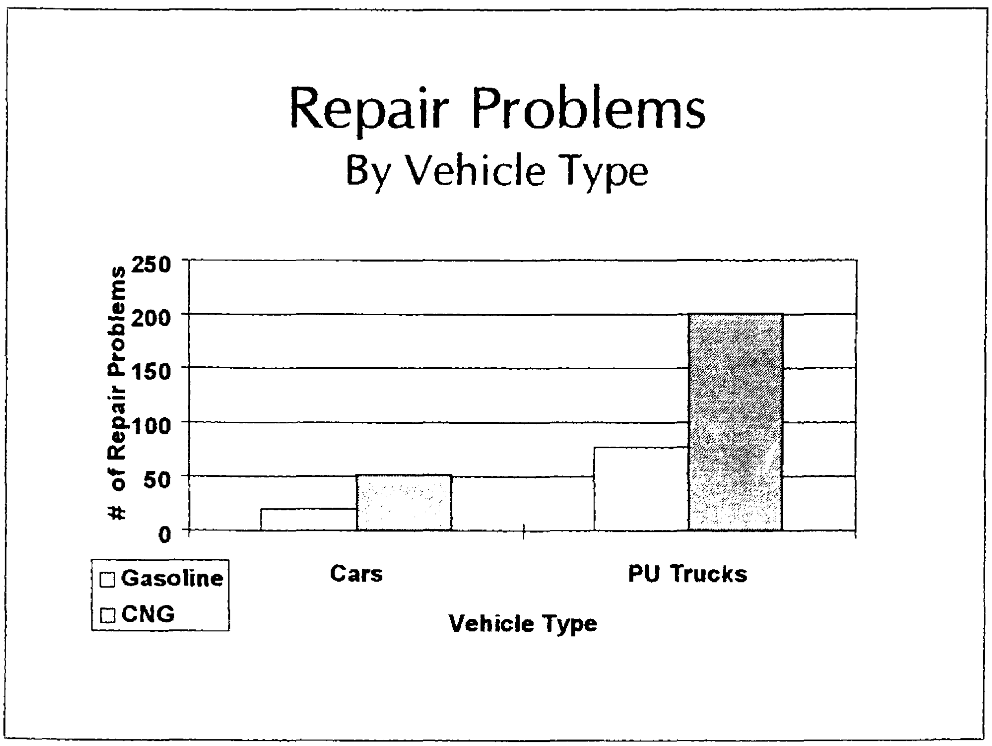


Figure 8

Repair Cost

Repair costs are compared both by district location by vehicle type. The Table in Appendix D provides the cost data used in these comparisons.

Figure 9 displays the average repair cost per mile by District location for both CNG and gasoline powered vehicles. Because the Richmond and Northern Virginia Districts had the same CNG systems installed by the same supplier, the repair cost per mile were expected to be close. However, as Figure 9 indicates repairs on CNG vehicles were much more expensive in Richmond. The only explanation available is that Northern Virginia District asked for and received more assistance from the local utility company (Washington Gas) to troubleshoot problems during the early part of the project. Researching repair histories on some of the vehicles uncovered that some items were being charged as repair parts incorrectly on one of Richmond District's dedicated CNG trucks. This caused some of their figures to be higher than expected. As a result we dropped vehicle number R00537 from the computation. The difference between Northern Virginia District and the other locations in repair cost for gasoline engine trucks could be partially attributed to the labor cost differential for that area.

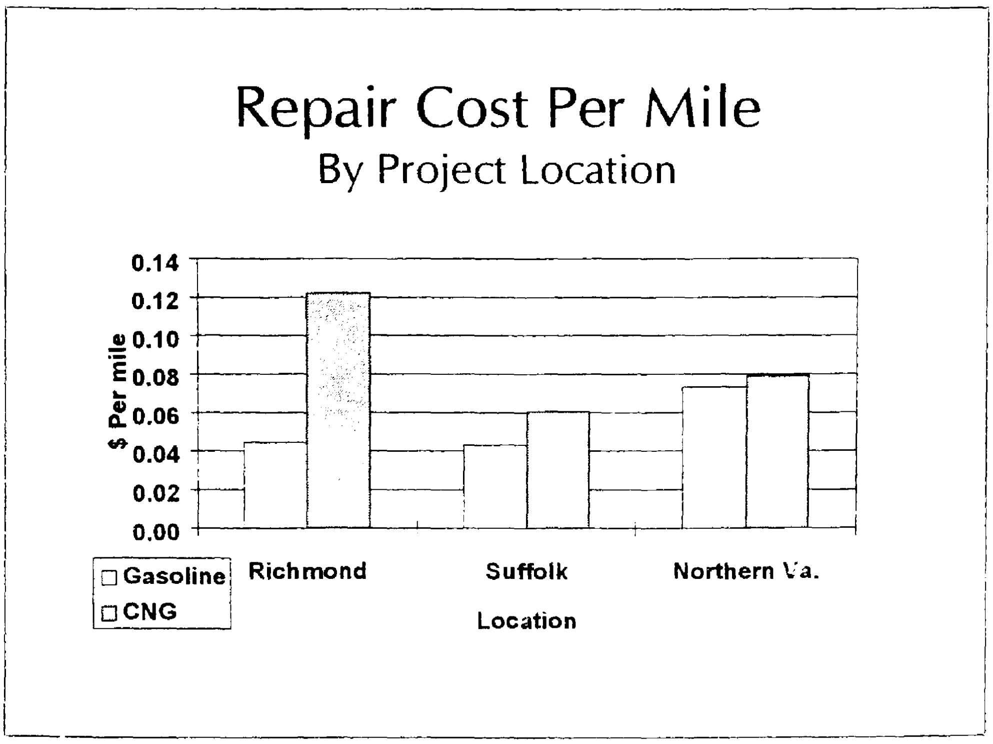


Figure 9

Figure 10 shows comparative repair costs for CNG versus gasoline powered vehicle by vehicle type. Repair costs for CNG powered cars were much higher than their gasoline powered counterparts. The majority of the CNG repairs were related directly to poor installation of the conversion kits and inferior quality parts.

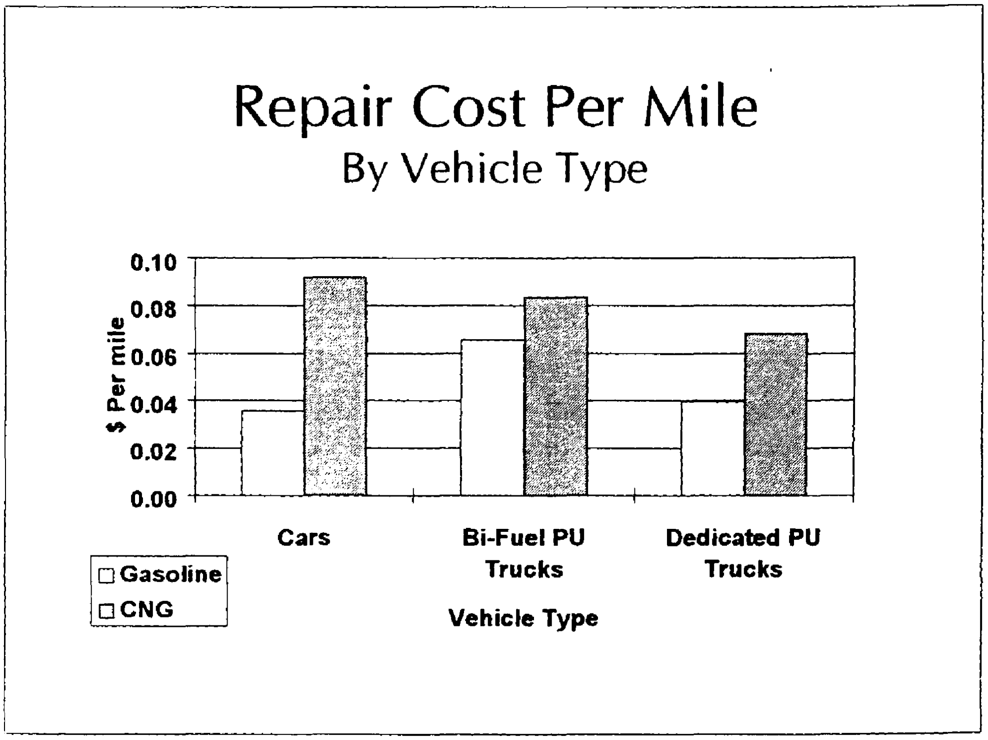


Figure 10

There also was a substantial difference in repair costs between the dedicated CNG pickups and their gasoline engine comparison vehicles. Since General Motors withdrew their dedicated pickups from the market after VDOT ordered these vehicles, we ended up with aftermarket conversions that did not have a local dealer to support them with warranty repairs. Whereas the gasoline engine vehicles could go to any local dealer for warranty repair, our technicians performed the labor on the CNG vehicles for fuel system related repairs. This could account for some of the repair cost difference.

Oil Analysis

Oil was sampled periodically from each of the vehicles and sent to a lab for analysis. Natural gas and gasoline were compared for both wear metals and soot contamination. Although the lab tested for various wear metals, iron was selected as a typical wear metal indicative of the amount of engine wear. Soot contamination is one of the main factors to determine when an oil change is required. Lab results were averaged for dozens of oil samples for the comparisons made in the following two Figures.

Figure 11 shows the average iron parts per million detected in the oil samples. The oil samples taken from the CNG vehicles showed a slightly higher level of iron, indicating slightly more engine wear.

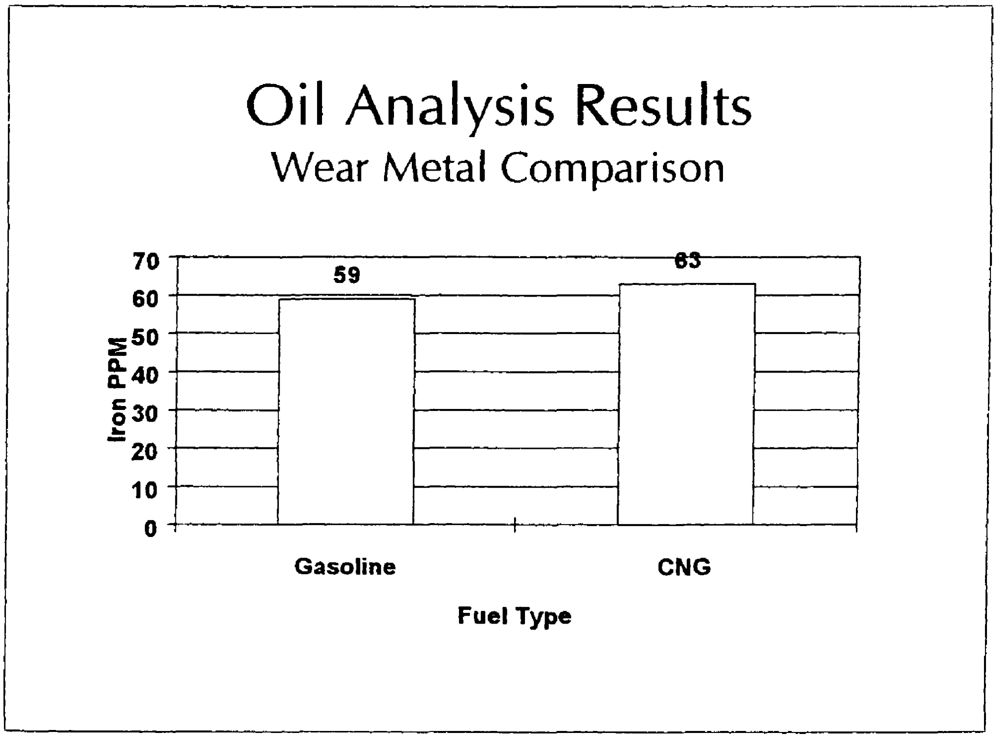


Figure 11

Figure 12 compares the average soot level found in the oil samples. The average soot found in the gasoline vehicles is more than twice the average level found in the CNG powered vehicles. This indicates that CNG vehicles may require oil changes less frequently than gasoline vehicles.

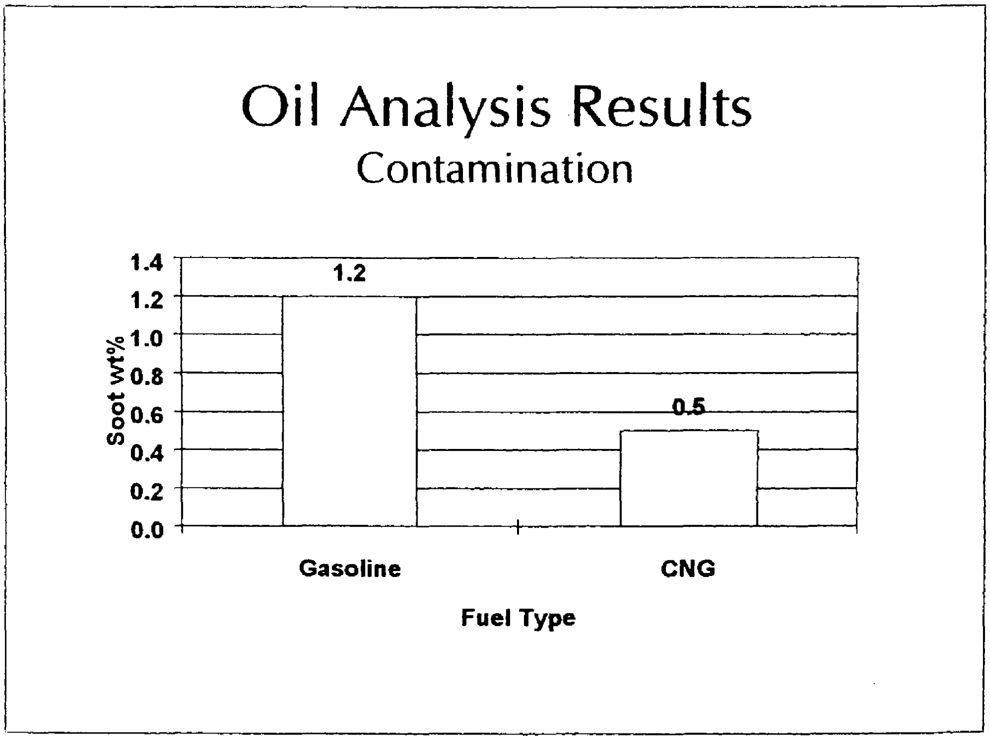


Figure 12

Performance

One of the main concerns the operators had with the natural gas vehicles was their lack of power as compared to their gasoline powered counterparts. A dynamometer was used to measure this power difference.

Figure 13 shows the maximum power obtained at half-throttle for three of the bi-fuel vehicles. The vehicles were tested using natural gas, then switched to gasoline and tested again. The power loss is 28 percent for the pickup truck, and 38 percent for the Cavalier and Tempo when powered by natural gas.

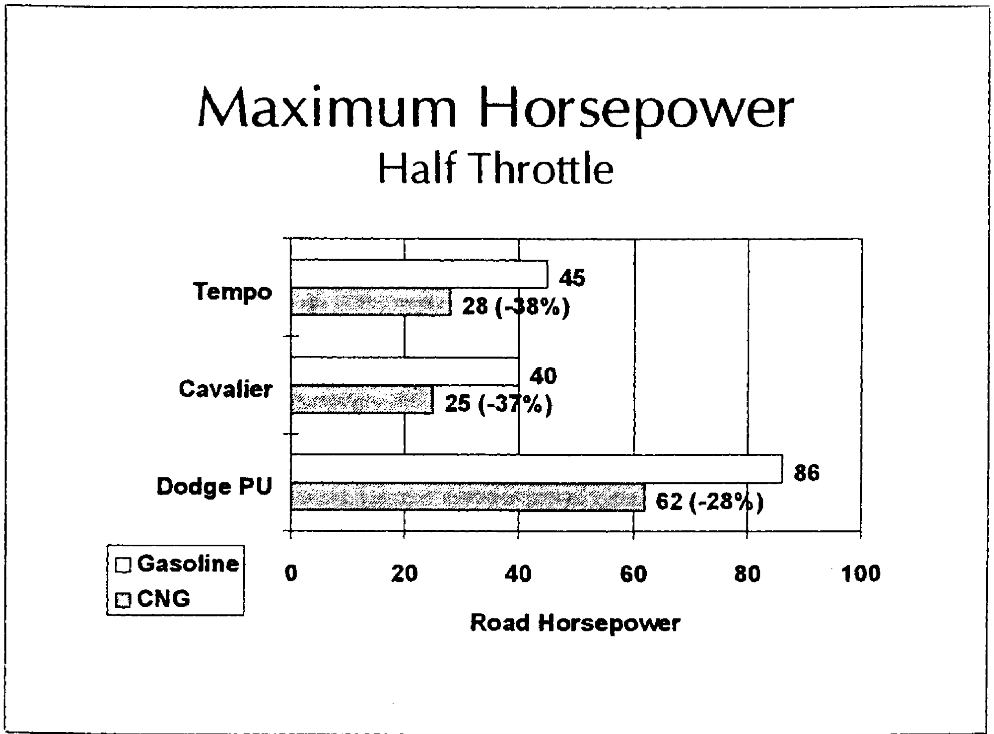


Figure 13

The same procedure was performed at full throttle and the results are shown on Figure 14. The Cavalier lost 25 percent and the Tempo lost 19 percent of its power when operating on CNG. Because of limitations of our dynamometer, the pickup truck wasn't tested at full throttle.

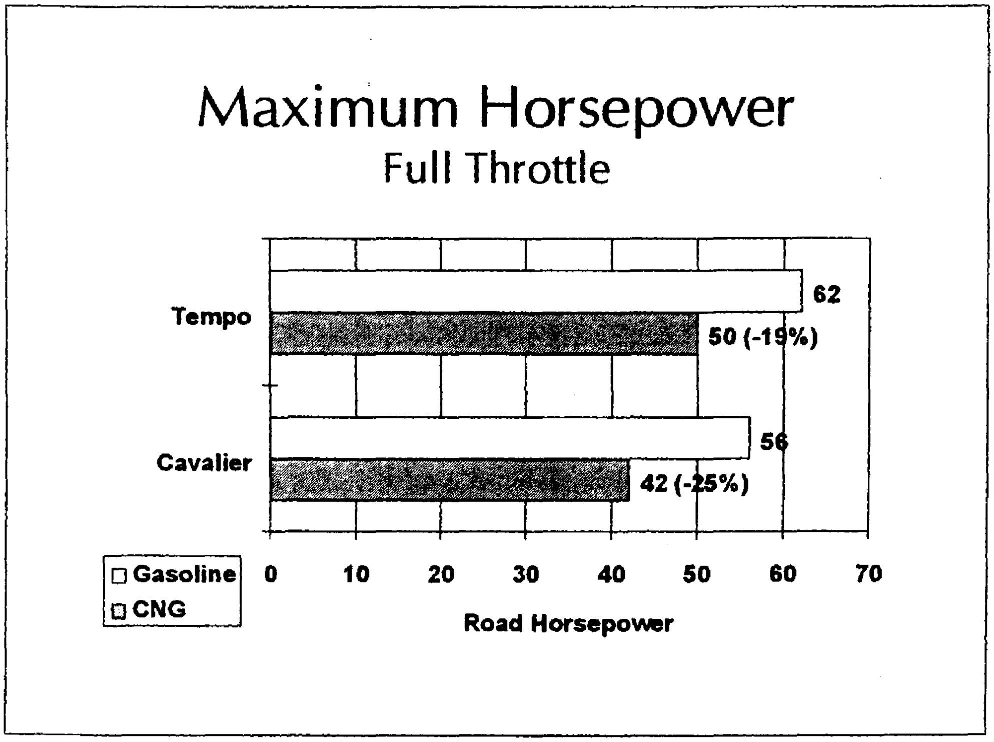


Figure 14

Figure 15 shows the results of the dynamometer tests that were run on two of the 1994 GMC pickup trucks. First, tests were run using VDOT's dynamometer to determine the maximum power output. The CNG truck showed about 41% less horsepower than the gasoline truck. The trucks were then sent to an outside tester where they found a 38% power difference. When we inquired, the company that supplied the trucks informed us that they had tested the vehicles before delivery and had seen a 17% difference. The difference among the three test results could be due to differences in dynamometer calibration, different operators, performing the test in different transmission settings, or differing atmospheric conditions.

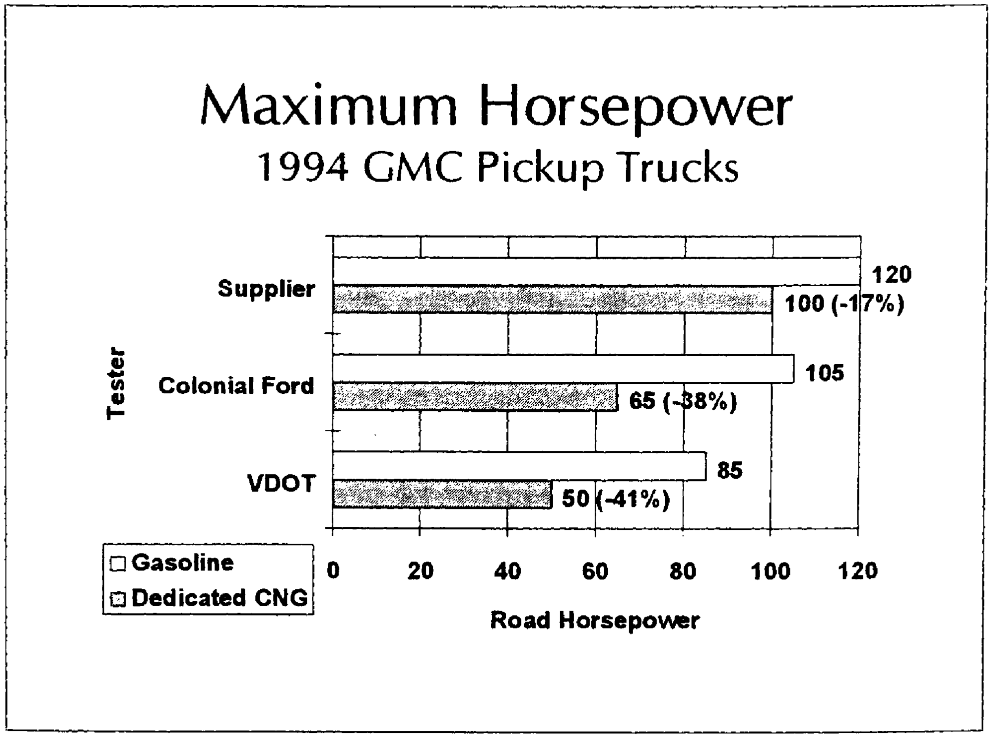


Figure 15

The same three bi-fuel vehicles that were tested on the dynamometer were tested for acceleration while operating on CNG and gasoline. Each vehicle was accelerated from zero to 65 miles per hour at wide open throttle, first using gasoline and then CNG. For all three vehicles, acceleration was quicker when operating on gasoline. The results are shown in Figures 16-18.

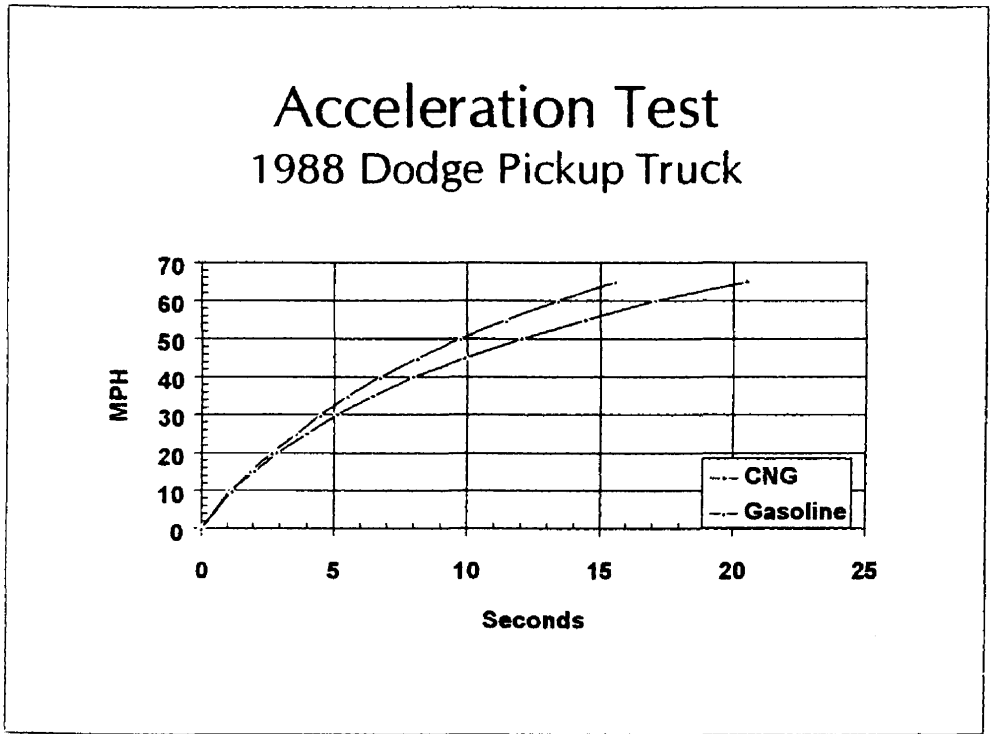


Figure 16

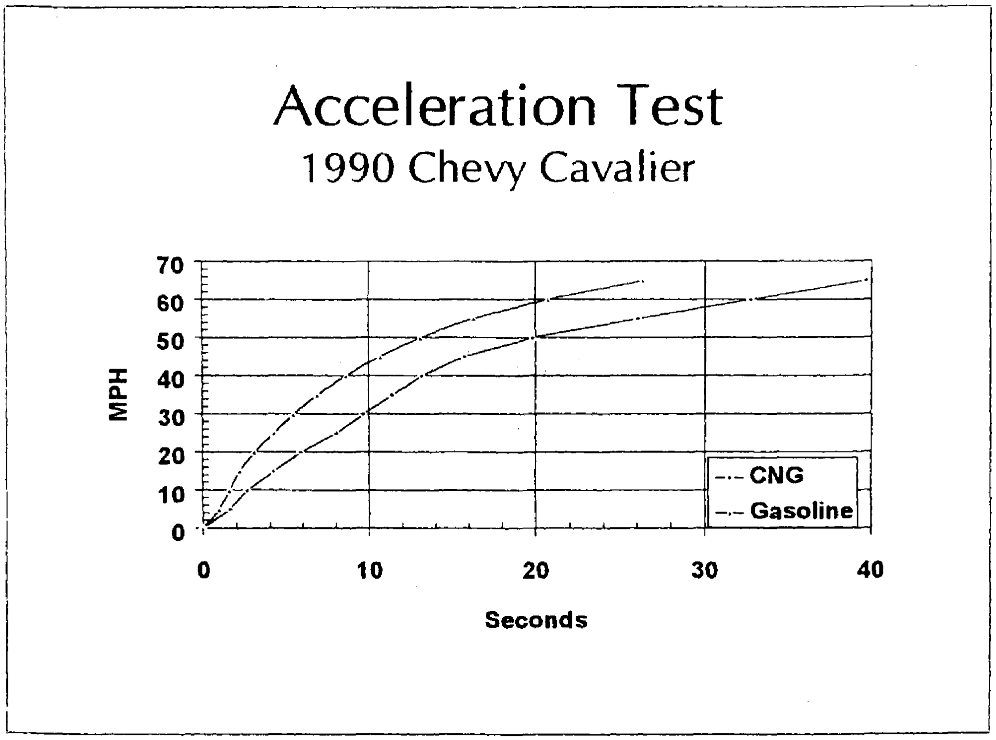


Figure 17

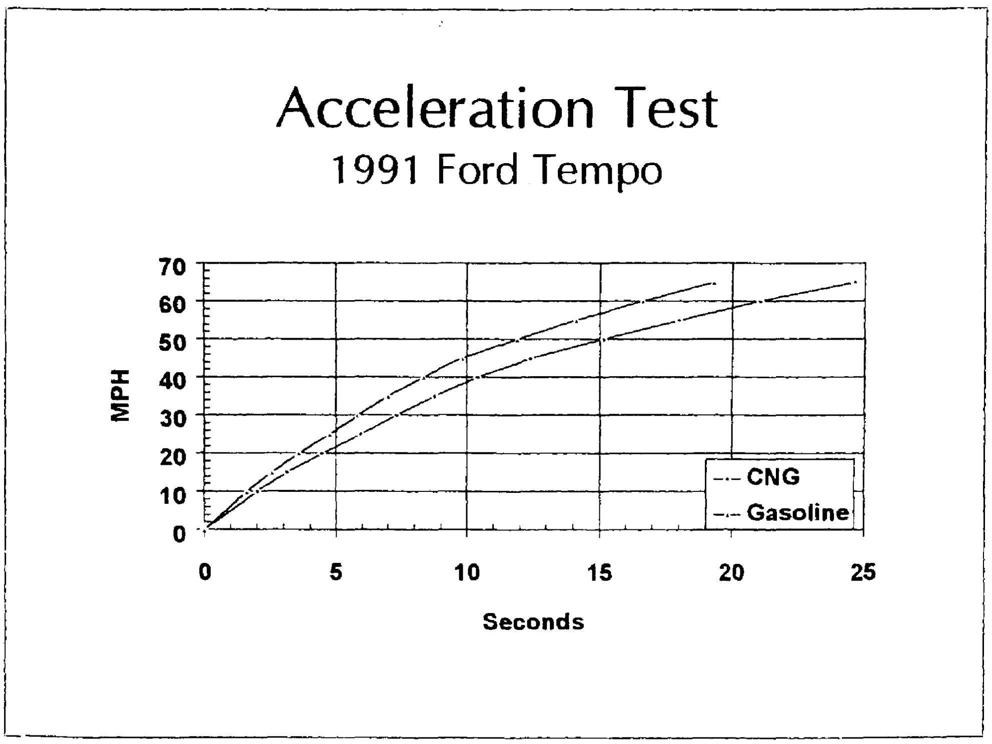


Figure 18

Poor acceleration is probably noticed most when merging onto a crowded Interstate. As expected, when operating on CNG the vehicles took considerably longer to accelerate up to speed. The end of a typical acceleration lane is 1000 feet. As indicated in Figure 19, only the pickup truck operating on gasoline is able to get up to speed before the 1000 foot mark. The Cavalier, which appears to be under-powered to begin with, takes more than twice the distance to get up to speed.

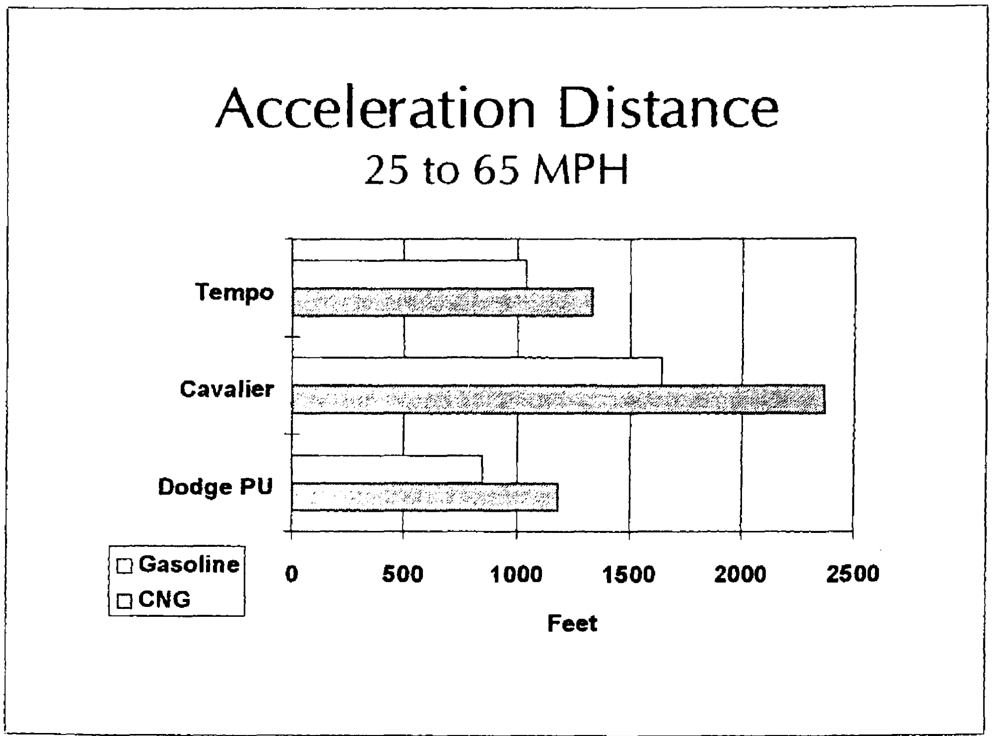


Figure 19

A commonly used measure of vehicle acceleration is the 0 to 60 time. Figure 20 compares the time it took each of the three tested vehicles to reach 60 mph. Again, all the vehicles took longer during CNG operation than during gasoline operation, with the Cavalier showing the greatest difference. The difference between CNG and gasoline acceleration time to 65 MPH ranged from 26 percent longer for the Tempo, to 54 percent longer for the Cavalier.

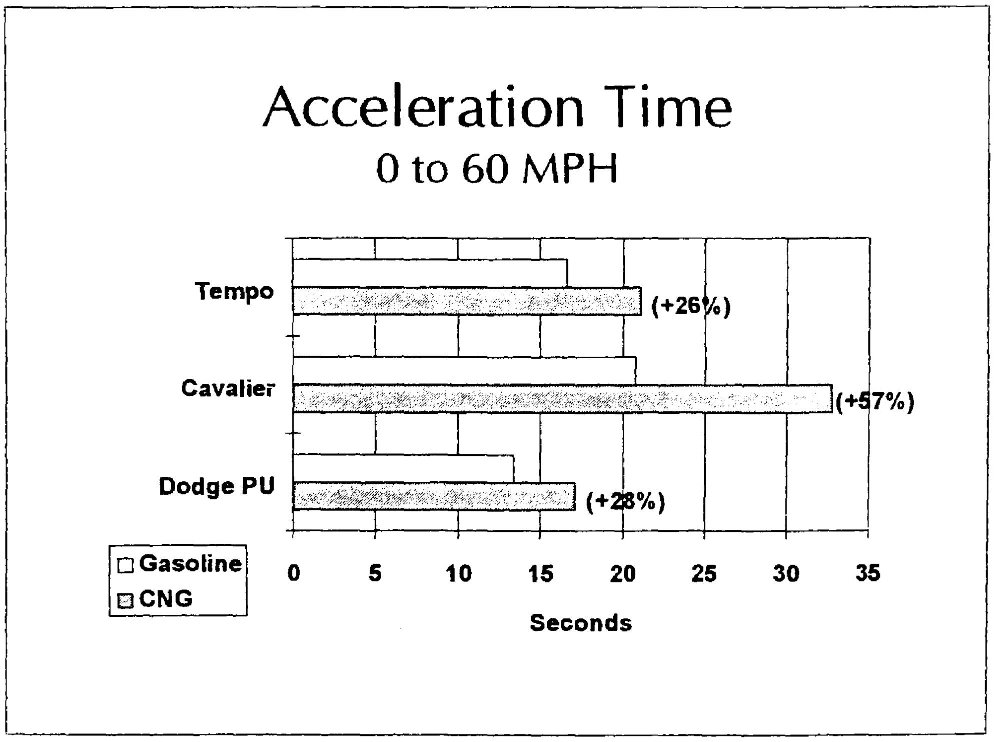


Figure 20

DIFFICULTIES ENCOUNTERED

As would be expected with a project of this nature, there were some problems. Problems were encountered with the conversion companies, conversion hardware, fueling stations and vehicle operations.

Conversion Companies

The conversions were performed by two different companies. One for the Richmond and Northern Virginia District vehicles, and the other for the Suffolk District vehicles. The conversion systems supplied by both companies were certified by the American Gas Association.

The company that converted the Northern Virginia and Richmond District vehicles was from Ohio. Our specifications had required the conversions be done at our district locations. They did not arrive when they had promised, at times they would perform a partial installation on several vehicles and run out of components to complete them. They would then leave and not return for a week or more, leaving the vehicles inoperable. Other times, they could not convert as many vehicles in a day as they had promised, even when they had the parts. The majority of the hardware failures were with this company's conversions.

A Maryland company was selected for converting the Suffolk vehicles. For the Suffolk District conversions the vendor was required to perform the conversions at his shop. There were delays in getting vehicles moved back and forth between VDOT and the vendor's shop, and in completing conversions because of parts unavailability. Driveability problems were encountered, and after about 13 of the 20 were converted the vendor was required to correct the problems before proceeding with the remaining installations.

Poor workmanship on the part of the conversion companies was the source of many problems. After the installations were complete there were numerous instances of wiring connection failures. Most of these were poorly made crimp connections and splices causing intermittant drivability problems. Many vehicles had to be completely rewired, using soldered connections.

Several vehicles experienced natural gas leaks at various fittings throughout the system. These were difficult to catch at first because the conversions were being done before the filling station was in service.

Some vehicles had components that were mounted improperly or inadequately and became loose after the vehicle was in service. Commonly, this problem occurred with the refueling fittings. On many vehicles, the fitting had to be relocated, often requiring fabrication of a new bracket.

Initially, the CNG fuel lines were pinched or kinked, or interfered with tires or suspension parts on some of the vehicles. Some mounted parts were screwed into the upper strut bushings or strut spring causing noise and premature bearing failure. On some of the Ford Tempos, the installer relocated the gasoline filter behind the engine and did not secure it to anything. This resulted in some broken filters, and gasoline leaks. In each of these cases, components had to be relocated and remounted.

It should be noted that throughout all this the gas companies were very helpful and assisted us with finding corrections to many problems.

Conversion Hardware

There also were many failures of automatic fuel selector valves. The valve would not switch when the CNG tank became empty and would leave the vehicle stranded until someone could disable the valve. To resolve this problem, many operators were instructed how to disable the valve so they would not have to wait for help to arrive.

Radio interference sometimes caused problems with the automatic selector valves. When keying the mike, the vehicle would suddenly either switch fuels or shut off altogether. In Suffolk, this could also be caused by transmissions from the I-664 tunnel control tower, causing the operator particular concern when travelling through the tunnel.

Many of the second stage regulators developed gas leaks. Not only is this situation environmentally unfriendly, it was also linked to some operational problems.

In some cases, the regulators, check valves, and automatic fuel selectors were replaced with better, more expensive equipment. However, when this was done, substantial modification of the mounting brackets was often required.

We encountered check valves that failed. This caused problems during refueling due to the pressure being exerted against the refueling port.

We had to add an "O_2 fix" on some vehicles to compensate for the exhaust gas mixture monitored by the vehicle's O_2 sensor.

Some of the vehicles required the battery to be moved from under the hood to the trunk to make space for the conversion hardware. On these vehicles, the cables initially installed were too small, causing starting problems. After determining the cause of this problem, heavier gauge battery cables were installed.

Fueling

The compressors sometimes experienced "freeze-ups" caused by moisture in the lines. When this happened the dispenser meter continued running but no fuel was actually flowing into the vehicle. If the operator happened not to notice this, he got grossly inaccurate readings. If he did notice it and shut off the system, he didn't get a full fuel tank and went away frustrated. The fuel provider installed dryers to help eliminate the problem.

There were complaints from some operators that the fill connectors were difficult to connect, especially when the stations would freeze-up. At the beginning of the pilot projects, there was no standard type of CNG fuel connector, and the VDOT vehicles were fitted with a common type of hydraulic coupler. The CNG industry eventually agreed to the NGV1 coupler standard. VDOT vehicles were retrofitted with various types of couplers, including the NGV1, which helped this problem considerably.

The fuel station at our Richmond District location was repeatedly out of service for such items as oil leaks, engine temperature and oil pressure shut down, thrown belts and dead battery. At the end of the project the compressor was still having operational problems. Suffolk also reported recurring battery problems with their station.

Some of the problems with vehicle check valves and regulators were traced to moisture and dirt in the natural gas. It was also suspected that prolonged station down-time contributed to some of the seized check valves and rotted regulator diaphragms experienced.

Operating

Operators complained of difficulty in starting vehicles on CNG, especially after being parked overnight. Some of this was due to either the leaking second stage regulators which caused the CNG in the system to bleed off, or the regulators being located too far from the mixer. This condition meant that more starting time was needed to get CNG into the engine. In a gasoline powered vehicle, it would be as if the gasoline had been drained from the fuel lines. The regulators had to be replaced and/or relocated.

Some vehicles idled roughly. This was caused by an overly lean air/fuel mixture and was corrected by manually adjusting the system to a richer mixture, but at the expense of increased emissions.

The operators had problems with the lack of power on CNG, especially on the small cars. This problem was partially overcome by using dual curve ignition timing.

CONCLUSIONS

Progress of NGV Technology

It should be noted that increasingly advanced conversion kits continue to come onto the market. VDOT's original 50 pilot project conversions used technology analogous to 1970's era gasoline vehicles. The fuel system is set manually by adjusting screws on the CNG system, just as the old carburetors were adjusted. Even if the adjustments are perfectly set, the engine can not operate optimally under varying operating conditions. There is no oxygen sensor feedback, or computer controls of any kind. In fact, certain computer components of the converted vehicles had to be electronically tricked when operating on CNG so that the "check engine" light on the dash would not glow.

The conversion kits on the six dedicated units that VDOT purchased can be compared to early 1980's gasoline engine technology. They are more advanced than the original bi-fuel conversions in that an oxygen sensor output is used to continuously monitor and adjust the air-fuel ratio.

The newest type of conversions available use even more computerization. All of the sensors used in gasoline operation are used in CNG operation to obtain optimum emissions and performance under all operating conditions. They are capable of adaptive learning and are comparable to current gasoline engine technology. Various VDOT personnel have driven vehicles having this type of conversion, and they do not seem to have the kind of power loss associated with the earlier types of conversions.

Because the technological improvements in CNG conversion kits for vehicles have been so great since the onset of our pilot projects, it is difficult make any conclusions from our pilot projects that have any relevance to today's circumstances. For example, our pilot project vehicles showed a great power loss when operating on CNG. This is not very relevant today, because this great a loss would not occur in a vehicle converted with current technology. Similar improvements have been made with respect to emissions and reliability.

Fuel Cost

If there is one area where our experience is relevant, that would be the area of fuel costs. Much is said of how inexpensive natural gas is. However, most comparisons of fuel price are done on an after tax basis. Because gasoline is taxed at a higher rate than natural gas for most users, the price of natural gas compares favorably with that of gasoline. In Virginia, the combined State and Federal tax burden is 35.9 cents per gallon of gasoline. The corresponding amount for CNG is 15.8 cents per 120 cubic feet. However, for VDOT and other organizations that are not required to pay tax on either fuel, this tax advantage disappears for natural gas. Under this condition, the price of CNG can be higher than that of gasoline.

Project Lessons

When these projects were started, no vehicle users would invest in new alternate fuel vehicles because there was no fuel infrastructure to support them. Similarly, the fuel providers had no motivation to build a fuel infrastructure because there were no vehicles capable of using an alternative fuel. One success of these projects is that this problem was substantially overcome. CNG powered vehicles were brought into service concurrently with fueling stations. By making the stations located on our sites available to vehicles other than our own, it became more attractive for other municipal fleet operators to purchase CNG powered vehicles. There are now several commercially operated CNG fueling stations operating where there were none before. There is now a small but growing CNG fueling infrastructure, partially as a result of these pilot projects. One other success of this project is related to the experience gained. Fleet managers, vehicle operators, and equipment repair technicians have all learned a lot. The Clean Air Act and Energy Policy Act will both require large percentages of our fleet to be alternatively fueled in the near future, and the experience of VDOT personnel with these projects will prove to be invaluable.

It could be argued that VDOT got into alternate fuels too early, and was forced to use inferior technology. However, it was because of our projects and others like them that the shortcomings of the initial technology were exposed. A demand was created for something better. As a result, the technology has rapidly advanced and continues to advance.

One of the main purposes of the pilot projects was to increase the familiarity and acceptance of clean fuels by the general public and local governments. This was a success. As a result, some local governments and federal agencies have joined VDOT in using the CNG filling stations.

Where Do We Go From Here?

There are already regulations in effect through Virginia's Clean Fuels Fleet legislation, which address the Environmental Protection Agency's Clean Air Act of 1990 (CAA). There are impending regulations under the Energy Policy Act of 1992 (EPACT). While the CAA regulations are emissions specific and fuel neutral, the EPACT regulations are fuel specific. Both affect the purchase of new vehicles in certain designated areas.

VDOT is an integral part of the Virginia Clean Fuels Fleet Task Force, which is working to develop a plan to align the Commonwealth's "fleet" purchases with the criteria of both laws. It is conceivable VDOT will purchase a variety of alternate fuel vehicles, such as CNG, LP gas, electric, alcohol and perhaps biodiesel.

Appendix A
Resolutions

HOUSE JOINT RESOLUTION NO. 481

Requesting the Virginia Department of Transportation to undertake certain alternative fuel pilot projects.

WHEREAS, use of domestically produced motor fuels other than gasoline and diesel fuel may have significant benefits not only to the environment, but also to the nation's economy and security; and

WHEREAS, state agencies can perform a useful function in connection with alternative fuels by conducting pilot projects to gain data on and experience with these fuels and also to increase their familiarity to and acceptance by the general public; and

WHEREAS, because one of the primary benefits of alternative fuels is their impact on air pollution caused by motor vehicles, it is appropriate that alternative fuel pilot projects be conducted in the three regions of the Commonwealth with the most significant air pollution difficulties: Northern Virginia, the greater Richmond area, and the Hampton Roads area; and

WHEREAS, among the largest vehicle fleets operated by state government is the central garage fleet of approximately 2,800 vehicles controlled by the Virginia Department of Transportation; nor, therefore, be it

RESOLVED by the House of Delegates, the Senate concurring, That the Virginia Department of Transportation be requested to undertake three pilot projects involving alternative motor fuels; one project in Northern Virginia, one in the greater Richmond area, and one in the Hampton Roads area. In choosing a fuel or fuels for such projects, the Department shall limit consideration to those which are produced in the United States, which address the air pollution difficulties of the region in which the project is to be conducted, whose use by government fleets is economically feasible, and which can be used in passenger vehicles presently equipped with conventional gasoline engines.

After eighteen months of such projects' operation, the Department shall report on fuel cost savings, maintenance cost savings, air quality benefits, and other results of these projects to the Governor and the General Assembly as provided in the procedures of the Division of Legislative Automated Systems for processing legislative documents.

SENATE JOINT RESOLUTION NO. 206

Requesting the Virginia Department of Transportation to undertake certain alternative fuel pilot projects.

WHEREAS, use of domestically produced motor fuels other than gasoline and diesel fuel may have significant benefits not only to the environment, but also to the nation's economy and security; and

WHEREAS, state agencies can perform a useful function in connection with alternative fuels by conducting pilot projects to gain data on and experience with these fuels and also to increase their familiarity to and acceptance by the general public; and

WHEREAS, because one of the primary benefits of alternative fuels is their impact on air pollution caused by motor vehicles, it is appropriate that alternative fuel pilot projects be conducted in the three regions of the Commonwealth with the most significant air pollution difficulties: Northern Virginia, the greater Richmond area, and the Hampton Roads area; and

WHEREAS, among the largest vehicle fleets operated by state government is the central garage fleet of approximately 2,800 vehicles controlled by the Virginia Department of Transportation; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the Virginia Department of Transportation be requested to undertake three pilot projects involving alternative motor fuels; one project in Northern Virginia, one in the greater Richmond area, and one in the Hampton Roads area. In choosing a fuel or fuels for such projects, the Department shall limit consideration to those which are produced in the United States, which address the air pollution difficulties of the region in which the project is to be conducted, whose use by government fleets is economically feasible, and which can be used in passenger vehicles presently equipped with conventional gasoline engines.

After eighteen months of such projects' operation, the Department shall report on fuel cost savings, maintenance cost savings, air quality benefits, and other results of these projects to the Governor and the General Assembly as provided in the procedures of the Division of Legislative Automated Systems for processing legislative documents.

Appendix B
Vehicle Conversion Specifications

VIRGINIA DEPARTMENT OF TRANSPORTATION

SPECIFICATIONS

Compressed Natural Gas Conversion

GENERAL: Each bi-fuel CNG conversion system must be designed to allow the vehicle to operate on CNG or gasoline. The system must include all necessary components, gauges, fittings and tubing.

The conversion system supplied must be certified by the American Gas Association. Proof of certification must be submitted with each bid.

Installations must comply with NFPA-52, and with AGA requirements.

The successful bidder will provide and install CNG conversion kits for the following vehicles:

Quantity	Make & Model	Engine
1	1987 Chevrolet 1/2 Ton Pickup Truck	5.0
6	1988 Dodge 1/2 Ton Pickup Trucks	5.2
2	1989 Dodge 1/2 Ton Pickup Trucks	5.2
1	1990 Chevrolet 1/2 Ton Pickup Truck	5.0
3	1990 Chevrolet Cavaliers	2.0
5	1991 Ford Tempos	2.3
2	1992 Dodge Shadows	2.2

LOCATION: Bidders are to submit two separate quotes, one for each of the following two options. Each quote is to include the estimated time for completion of installations after receipt of the Purchase Order.

Option 1: The Virginia Department of Transportation (VDOT) will ship the vehicles to and from the bidder's location for conversion.

Option 2: Installations are to be made at the following VDOT facility:

Suffolk District Shop
1700 North Main Street
Suffolk, VA 23434-1070

VDOT welding equipment will be available for fabricating any brackets, etc., that are needed, using vendor's material.

If the CNG fuel facility is not in place by the time of the conversions, the successful bidder shall either provide their own source of compressed gas or return to the conversion site at a later date to pressurize the vehicle systems and perform leak tests and any other testing that is required. The bidders are to submit an additional quote which covers the extra cost incurred if this is required. The bid will be awarded according to the sum of the installation quote and the "extra cost" quote.

<u>CYLINDERS</u>: All cylinders are to be DOT tested, approved and labeled. The minimum operating pressure allowable will be 3000 psi.

The total volume of the cylinder(s) provided for each vehicle shall be according to the following minimums (Standard Cubic Feet at 3000 psi.):

Pickup Trucks
1,900 SCF - (Two - 13" x 54", or equal)

Automobiles
700 SCF - (One - 15" x 32", or equal)

Tanks shall be located in the beds of the pickup trucks and in the trunks of the automobiles.

If necessary, the spare tires shall be relocated so that they remain accessible.

<u>TUBING</u>: All high pressure tubing to be 304 stainless steel with a minimum of 12,000 psi burst strength. Tubing is to be supported at least every 24" and is to have grommets where it passes through metal plates. Manual shut off valves are to be 1/4 turns and are to be installed so they do not protrude below the vehicle frames.

<u>FUELING CONNECTION</u>: All vehicle fill connections shall be female, steel 3/8" hydraulic coupling with rubber dust plug. To be Parker H3-62 or equivalent. The fill connection is to be located under the hood of the vehicle.

A check valve having a KEL-F seat shall be located in the fill line.

GAUGES: Each vehicle will have two hour meters installed in the engine compartment. One hour meter will record only the hours that the engine is operated on CNG and the other will record only the hours that the engine is operated on gasoline. The gauges must be permanently labeled "CNG" or "Gasoline" to show which fuel usage it is recording.

The CNG fuel level shall be indicated on a dash mounted gauge separate from the factory fuel gauge.

A pressure gauge with a minimum read-out of 5000 psi shall be located at the fill connection totally visible to the operator.

FUEL SWITCHING: Fuel injected vehicles shall be equipped with an automatic fuel selector. Automatic switchover from CNG to gasoline shall occur when the cylinder pressure drops below approximately 100 psi. CNG operation shall automatically resume when the cylinder is repressurized.

Vehicle systems shall be vacuum/electric activated to switch operation between fuels. Cable operated systems are prohibited.

Electric fuel pumps and injectors shall be switched off during operation of CNG.

All wire connections are to be soldered with heat shrink tubing insulation.

The installed conversion kit is to be compatible with two-way radios.

The original equipment air cleaner is to be used.

When the system is operating, the gas pressure in the vapor hose is to be less than atmospheric.

To be standard proven model of manufacturer's latest current production with additional features outlined herein. Unit is not to be materially modified or augmented.

Successful bidder shall furnish two manual of instructions and parts lists with each conversion. Parts lists are to include appropriate serial numbers of major components, and tank certification dates and water volume capacity.

The successful bidder shall provide two days of mechanic's training at the site of conversion. Additionally, VDOT mechanics will be allowed to observe and aid with the vehicle conversions in order to become accustomed with the CNG systems.

Installations shall be of the highest quality workmanship. All parts and installations associated with the conversion shall be warranted for a one year period from the date of installation.

Descriptive literature will be required to substantiate the details specified in bid.

Appendix C
Fuel and Maintenance Weekly Report

Fuel and Maintenance
Weekly Report

Vehicle Number or ED Number: ____________

FUEL

Date	Time	Odometer Reading	Hourmeter Gasoline	Hourmeter Nat. Gas	Gallons Gasoline*	Beg Press Nat. Gas	End Press Nat. Gas	Ambient Temp

MAINTENANCE

Date	Odometer Reading	Hourmeter Gasoline	Hourmeter Nat. Gas	Description of Maintenance	Initials

COMMENTS

Indicate problems encountered or any other comments:

Form ED-NG1 (Rev. 8/91) *Report to nearest tenth

Appendix D
Repair Costs

Repair Cost Per Mile									
		Natural Gas Vehicles				Gasoline Vehicles			
Year	District	Vehicle #	Cost ($)	Miles	CPM ($)	Vehicle #	Cost ($)	Miles	CPM ($)
94	NoVa	R00533	1,569.64	26,736	0.0587	R00539	2,353.41	41,919	0.0561
94	NoVa	R00534	1,936.04	22,599	0.0857	R00540	2,065.24	39,805	0.0519
86	NoVa	R50549	4,585.23	41,020	0.1118	R50539	6,929.65	17,809	0.3891
87	NoVa	R52182	5,254.85	95,113	0.0552	R52185	3,407.32	29,764	0.1145
87	NoVa	R52714	8,765.17	132,767	0.0660	R52184	5,366.64	37,892	0.1416
89	NoVa	R58315	6,609.29	53,350	0.1239	R58373	3,187.83	44,755	0.0712
90	NoVa	R61775	22,747.39	217,505	0.1046	R61832	7,286.06	174,014	0.0419
90	NoVa	R61837	11,332.66	154,551	0.0733	R61827	10,356.36	199,913	0.0518
90	NoVa	R61838	13,933.87	157,001	0.0888	R61863	18,120.75	159,780	0.1134
90	NoVa	R61857	8,845.02	145,505	0.0608	R61874	10,333.09	204,164	0.0506
90	NoVa	R61872	10,490.63	170,458	0.0615	R61828	2,883.57	33,274	0.0867
90	Richmond	P00232	4,427.93	40,703	0.1088	P00258	1,546.00	31,392	0.0492
90	Richmond	P00272	3,030.32	25,375	0.1194	P00285	1,459.51	29,372	0.0497
91	Richmond	P01105	4,014.15	34,801	0.1153	P01112	2,230.52	20,379	0.1095
91	Richmond	P01106	6,635.32	36,806	0.1803	P01146	887.44	22,798	0.0389
91	Richmond	P01118	5,947.55	33,047	0.1800	P01226	1,271.28	26,047	0.0488
91	Richmond	P01124	3,609.11	49,425	0.0730	P01235	876.32	32,619	0.0269
91	Richmond	P01163	3,525.02	16,774	0.2101	P01240	1,189.08	56,398	0.0211
91	Richmond	P01209	2,968.29	20,401	0.1455	P01345	1,126.06	30,762	0.0366
89	Richmond	P09128	6,216.86	27,618	0.2251	P09119	800.06	26,770	0.0299
89	Richmond	P09221	3,617.84	21,419	0.1689	P09217	639.77	29,294	0.0218
94	Richmond	R00537	5,507.87	3,347	1.6456	R00543	184.14	9,109	0.0202
94	Richmond	R00538	588.50	3,430	0.1716	R00544	373.75	8,823	0.0424
88	Richmond	R57695	4,511.71	16,535	0.2729	R57694	636.65	15,957	0.0399
88	Richmond	R57765	2,701.68	15,903	0.1699	R57740	1,123.14	24,810	0.0453
88	Richmond	R57818	4,650.27	18,256	0.2547	R57756	1,683.66	30,269	0.0556
90	Richmond	R61789	3,994.15	59,433	0.0672	R61790	1,753.37	60,935	0.0288
90	Richmond	R61791	1,882.94	28,983	0.0650	R61798	2,646.09	64,313	0.0411
90	Richmond	R61907	2,870.97	12,899	0.2226	R61902	1,905.50	16,656	0.1144
90	Richmond	R61908	3,694.53	46,756	0.0790	R61909	790.38	29,476	0.0268
90	Richmond	R61919	3,184.28	26,052	0.1222	R61910	1,553.64	34,556	0.0450
90	Richmond	R61920	3,347.59	67,481	0.0496	R61911	4,357.60	61,820	0.0705
90	Richmond	R61921	3,884.91	45,052	0.0862	R61918	2,485.10	44,593	0.0557
90	Suffolk	P00112	1,365.15	23,299	0.0586	P00119	850.73	21,480	0.0396
90	Suffolk	P00124	2,159.40	30,773	0.0702	P00116	1,689.66	48,143	0.0351
90	Suffolk	P00245	1,147.78	25,371	0.0452	P00238	577.39	35,229	0.0164
91	Suffolk	P01142	1,124.25	30,729	0.0366	P01170	571.52	33,243	0.0172
91	Suffolk	P01243	1,688.48	33,151	0.0509	P01291	438.91	32,362	0.0136
91	Suffolk	P01329	942.12	34,548	0.0273	P01319	628.40	30,548	0.0206
91	Suffolk	P01371	625.76	27,065	0.0231	P01176	1,132.50	46,974	0.0241

Repair Cost Per Mile

Year	District	Natural Gas Vehicles				Gasoline Vehicles			
		Vehicle #	Cost ($)	Miles	CPM ($)	Vehicle #	Cost ($)	Miles	CPM ($)
91	Suffolk	P01372	2,683.76	33,784	0.0794	P01253	4,358.82	34,163	0.1276
92	Suffolk	P02159	547.88	34,493	0.0159	P02377	462.35	46,041	0.0100
92	Suffolk	P02248	822.19	40,355	0.0204	P02254	1,033.78	31,059	0.0333
94	Suffolk	R00535	511.22	13,368	0.0382	R00541	325.90	24,127	0.0135
94	Suffolk	R00536	421.50	7,518	0.0561	R00542	194.48	15,109	0.0129
87	Suffolk	R52042	2,481.62	25,725	0.0965	R52118	2,439.95	29,491	0.0827
87	Suffolk	R52127	2,077.42	19,052	0.1090	R52137	1,494.16	21,780	0.0686
88	Suffolk	R57665	2,096.43	35,341	0.0593	R57627	837.60	28,181	0.0297
88	Suffolk	R57703	4,105.29	38,384	0.1070	R57645	887.30	46,081	0.0193
88	Suffolk	R57782	2,817.69	27,198	0.1036	R57688	1,704.68	17,987	0.0948
88	Suffolk	R57790	2,310.73	34,648	0.0667	R57814	1,044.37	21,395	0.0488
88	Suffolk	R57832	2,506.45	47,544	0.0527	R57827	1,034.32	27,810	0.0372
89	Suffolk	R58367	4,150.76	58,033	0.0715	R58262	6,891.70	58,820	0.1172
89	Suffolk	R58370	1,988.11	27,503	0.0723	R58278	1,953.98	53,383	0.0366
89	Suffolk	R58387	2,752.51	33,342	0.0826	R58388	995.26	29,522	0.0337
Totals			222,208.08	2,548,325	0.0872		135,356.74	2,423,165	0.0559