Phase II RFG

Report on Performance Testing

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Acknowledgment

This report was peer reviewed by the Phase II RFG Implementation Workgroup's technical steering committee. Members of the technical steering committee are listed in Appendix C.

This report was also reviewed by John Hornback, director of the Kentucky Department for Environmental Protection's Division for Air Quality and co-chair of the workgroup, and by Marlin Gottschalk, manager of the Georgia Department of Natural Resources's Mobile Sources and Area Sources Program.

I. Executive Summary

The federal reformulated gasoline (RFG) program was introduced in January 1995. RFG is a specially blended gasoline that burns cleaner, reducing vehicle emissions of air pollutants that cause smog. Congress requires the RFG program in those cities with the worst smog problems. Other areas may choose to participate in the program. Seventeen states and the District of Columbia currently use RFG. About 30 percent of the U.S. gasoline supply is reformulated.

The second phase of the RFG program will begin in January 2000. Phase II RFG will achieve even greater vehicle emission reductions than Phase I, although the gasoline blend will be similar in many ways. To ensure that any vehicle performance problems with Phase II RFG would be identified before the fuel is introduced to the public, the U.S. Environmental Protection Agency (EPA) conducted a fleet testing program in 1998.

EPA tested 374 in use vehicles in three cities over a period of three to five months. Conditions during testing included subfreezing temperatures in the north and record heat in the south. The combined test fleets drove over one million miles with Phase II RFG. No performance problems with Phase II RFG were reported.

Fleets that participated in the testing program include the Boston Police Department, Elk Grove Village in suburban Chicago, and the Houston Lighting & Power Company. Vehicles in these fleets were generally well maintained.

Well maintained vehicles should experience no unusual performance problems with Phase II RFG. Of course, as vehicles age, parts wear out, so maintenance is the key to good performance with any fuel.

In a separate study by Southwest Research Institute, fuel economy with Phase II RFG was compared to Phase I RFG with 12 vehicles of various makes, ages, and mileage under normal driving conditions. The results indicate no statistically significant difference between the fuels. The results are consistent with other fuel economy studies which show that fuels of equivalent energy content will produce equivalent fuel economy.

Testing was also conducted with small engines, including 177 pieces of utility, lawn, and garden equipment, and with marine and motorcycle engines. No performance problems were reported.

In summary, no difference in vehicle performance or fuel economy is expected when Phase II RFG replaces Phase I RFG. In addition, no difference in performance is expected with small engines, marine engines, or motorcycles.

II. Background

A. RFG Program

Section 211(k) of the Clean Air Act (CAA) directs EPA to issue regulations establishing a reformulated gasoline program that will significantly reduce vehicle emissions that contribute to smog. On February 16, 1994, EPA published a final rule establishing various content and emission reduction standards for RFG, including provisions for enforcement of RFG standards (59 FR 7716). The purpose of the RFG program is to improve air quality by requiring that gasoline sold in certain areas of the U.S. be reformulated to reduce emissions of toxics and smog-forming compounds from motor vehicles.

Section 211(k) mandates that RFG be sold in the nine specific metropolitan areas with the most severe summertime ozone levels as measured during the period 1987 through 1989; RFG must also be sold in any ozone nonattainment area subsequently reclassified as a severe area. Other ozone nonattainment areas may choose to participate or "opt in" to the program. Ground level or tropospheric ozone is the primary ingredient of smog. Ground level ozone results from a reaction between such gases as volatile organic compounds (VOCs) and oxides of nitrogen (NOx) that are emitted from vehicles and other sources.

The Act mandates certain requirements for the RFG program. Section 211(k)(1) directs EPA to issue regulations that:

> require the greatest reduction in emissions of ozone forming volatile organic compounds (during the high ozone season) and emissions of toxic air pollutants (during the entire year) achievable through the reformulation of conventional gasoline, taking into consideration the cost of achieving such emission reductions, any nonair quality and other air-quality related health and environmental impacts and energy requirements.

Section 211(k) specifies the minimum requirement for reduction of VOCs and toxics for 1995 through 1999, or Phase I of the RFG program; the section specifies that EPA must require the more stringent of a specified fuel formula or an emission reduction performance standard, measured on a mass basis, equal to 15 percent of baseline emissions. Baseline emissions are the emissions of 1990 model year technology vehicles operated on a specified baseline gasoline. Section 211(k) compositional specifications for RFG include a 2.0 weight percent oxygen minimum standard and a 1.0 volume percent benzene maximum standard. Section 211(k) also specifies that emissions of NOx may not increase in RFG over baseline emissions.

For the year 2000 and beyond, or Phase II of the RFG program, the Act specifies

that the VOC and toxic performance standards must be no less than either a specified fuel formula or a 25 percent reduction from baseline emissions, whichever is more stringent. EPA can adjust these standards upward or downward taking into account such factors as technological feasibility and cost, but in no case can the standards be less than 20 percent.

Shortly after passage of the CAA Amendments in 1990, EPA entered into a regulatory negotiation with interested parties to develop specific proposals for implementing the RFG program. In August 1991, the negotiating committee reached consensus on a program outline that would form the basis for a notice of proposed rulemaking, addressing emission content standards for Phase I (1995-1999), emission models, certification, enforcement, and other important program elements.

The regulatory negotiation conducted by EPA did not address the Phase II VOC and toxic standards for RFG, nor did it address a reduction in NOx emissions beyond the statutory cap imposed under section 211(k)(2)(A). The final rule promulgated by EPA closely followed the consensus outline agreed to by various parties in the negotiated rulemaking process. The final rule also adopted a NOx emission reduction performance standard for Phase II RFG, relying on authority under section 211(c)(1)(A).

Reformulated Gasoline Average Emission Reduction Requirements*

	Phase I**	Phase II**
Volatile Organic Compounds	17%	27%
Nitrogen Oxides	2%	7%
Toxics	17%	22%

*Reductions are from 1990 nationwide baseline.
**Complex model averaged standards for VOC-control Region 2 (i.e., northern areas).

The Phase I RFG program is designed to reduce the air pollution that causes smog by 36,000 tons per year in the areas that use RFG, compared to conventional gasoline -- the equivalent of eliminating the emissions from over eight million vehicles. When Phase II RFG replaces Phase I, the program is designed to reduce smog pollutants by an additional 45,000 tons per year in RFG areas, for a combined equivalent of eliminating the emissions from over 16 million vehicles.

Analysis of fuel data submitted to EPA by industry for compliance purposes indicates that in each year since the RFG program's introduction in 1995, VOC and

toxic reductions from the RFG program have exceeded program requirements. Preliminary data analysis for 1998 indicates that, on average, all Phase I emission reduction standards are being met and exceeded. In 1998, most RFG already exceeded the Phase II RFG average performance standard for toxics, and some RFG in the Northeast exceeded Phase II RFG emission reduction standards for NOx in the ozone control season (i.e., the summer months). At this time, refiners are still making incremental investments to produce adequate volumes of compliant Phase II RFG.

Air quality monitoring data for 1995, the first year of the RFG program, shows a 43 percent reduction in benzene in the ambient air in RFG areas, according to EPA's *National Air Quality and Emission Trends Report, 1995.* A greater percentage of monitoring sites in RFG areas showed statistically significant decreases in average benzene than did sites in non-RFG areas. The RFG program limits benzene. Still, to overcome the difficulties inherent in linking changes in the ambient air to particular pollution reduction programs like RFG, an independent analysis of the data was conducted by Sonoma Technology, Inc. The analysis of the 1995 ambient air monitoring data indicates that there is a strong case that the ambient reductions in benzene resulted from RFG.

B. Implementation Workgroup

In April 1997, EPA formed a stakeholder workgroup under the Federal Advisory Committee Act to focus on Phase II RFG implementation issues. The Phase II RFG Implementation Workgroup was established by the Clean Air Act Advisory Committee's Mobile Source Technical Review Subcommittee. The workgroup includes representatives of the automobile and oil industries, environmental and public health groups, and state agencies and associations. The goal of the workgroup is to provide factual information to the public by working together to identify, gather, and analyze data on Phase II RFG. Members of the workgroup are listed in Appendix A. The workgroup formed teams to focus on testing and education activities.

III. Vehicle Performance Test Program

To ensure that any vehicle performance problems with Phase II RFG would be identified before the fuel is introduced to the public, the testing team recommended a fleet testing program with Phase II RFG, compared to Phase I RFG. The fleet testing recommendation was adopted by the workgroup, and the Mobile Source Technical Review Subcommittee. Members of the testing team are listed in Appendix B.

The testing team also recommended formation of a technical steering committee to guide development of the fleet testing program. Members of the technical steering committee are listed in Appendix C.

A. Design

The purpose of the test program was to identify any performance problems that might be associated with Phase II RFG before the fuel is introduced to the public in January 2000 by conducting performance testing in several cities representative of RFG areas. Boston, Chicago, and Houston were selected by the workgroup as test program sites.

The technical steering committee worked with EPA to develop a test plan, "Evaluation of On-Highway Motor Vehicles Operated on Federal Phase II Reformulated Gasoline," included as Appendix D. The plan is similar to the test program conducted by the California Air Resources Board for the introduction of its cleaner burning gasoline program in June 1996, but smaller in scale.

From February to August 1995, the California Air Resources Board conducted a performance and compatibility test program with its cleaner burning gasoline (CaRFG). With a fleet of 1466 vehicles, 829 test vehicles were driven over five million miles with CaRFG. The workgroup believes that the California data is applicable to Phase II RFG since the testing was conducted on a wide mix of vehicle types and ages with a fuel more severely reformulated and designed to burn cleaner than is expected for Phase II RFG. A comparison of the properties of Phase II RFG and CaRFG is included in Appendix E.

California's test results indicate that CaRFG performed as well as conventional fuel in terms of driveability, starting, idling, acceleration, power, and safety. There was no significant difference between the frequency of problems in the test and control fleets. Newer vehicles did not experience problems. Historical maintenance and repair data indicate an increasing rate of failures in fuel system components associated with aging irrespective of the fuel used.

The workgroup determined that the California testing results are relevant for Phase II RFG. However, several data gaps were identified, particularly vehicle performance with ethanol-oxygenated fuels and vehicle performance in cold temperatures and the shoulder season (i.e., the period of time in late spring and early autumn when unseasonably cold temperatures may occur). Therefore, EPA's test program was designed to fill gaps in existing data.

Funding for the test fuel for Boston and Chicago was provided by the American Petroleum Institute, Oxygenated Fuels Association, and American Methanol Institute. Management of fuel distribution for the Boston and Chicago fleets was handled by the Lake Michigan Air Directors Consortium. EPA provided test fuel for Houston. EPA entered into a contract with each participating fleet that covered identification of the test fleet, vehicle inspection, incident reporting, and fuel provisions. An example of a

statement of work for these contracts is included in Appendix F.

To carry out the test plan, EPA technicians from the National Vehicle and Fuel Emissions Laboratory inspected the fuel systems of each test and control vehicle included in the test program. Fuel system inspections were conducted three times over five months in Boston and Chicago, and twice over three months in Houston. For each test and control vehicle inspected, relevant information such as mileage and vehicle description was noted on fuel system inspection forms. Examples of these forms are included with the test plan in Appendix D.

The test plan also includes driveability incident logs that were designed to capture information on vehicle performance measures such as starting, running, and idling. EPA provided copies of the driveability incident log to participating fleets. The driveability incident log is included in Appendix D.

B. Fuel

The technical steering committee developed four formulations of test fuel for the fleet testing program that meet the standards for Phase II RFG: winter fuel oxygenated with MTBE, winter fuel oxygenated with ethanol, summer fuel oxygenated with MTBE, and summer fuel oxygenated with a mixture of MTBE and TAME. The test fuel formulations are equivalent to the average or 50th percentile fuel expected for Phase II RFG. The test fuel property specifications developed by the technical steering committee are shown in the test plan in Appendix D. The technical steering committee also developed allowable ranges of parameters and maximum blending fractions for each test fuel to assure that the test fuels would be representative of actual refinery blends. The fractions and ranges are included in the test plan in Appendix D. The properties of the test fuels used in the fleet testing program are shown in Table 1.

Table 1 - Test Fuel Properties

	Summer MTBE	Summer MTBE + TAME	Winter MTBE	Winter Ethanol
Oxygenate, vol%	11.2	10.81 MTBE 3.288 TAME	11.7	9.74
RVP, psi	6.8	6.75	12.8	13.1
Sulfur, ppm	155	169	298	309
Aromatics, vol%	24.5	23.5	23.85	25.2
Olefins, vol%	12	13	10.5	11
Benzene, vol%	1.0	1.0	0.98	0.999
T10, F	139.7	138.5	106.5	110.4
T50, F	205.7	192.7	190.3	182.7
T90, F	312.5	308.2	331.3	335.3

Test fuel was manufactured by Phillips Chemical Company. Certificates of analysis for the four fuel formulations used in the testing program are included in Appendix G. Fuel property analyses were also performed for verification by EPA's National Vehicle and Fuel Emissions Laboratory (NVFEL) in Ann Arbor. NVFEL analyses confirmed that the fuels fell within acceptable ranges for Phase II RFG, or within test method precision range, which specifies an acceptable range of variability. NVFEL analyses are included in Appendix H.

During the testing program, Boston received five test fuel deliveries totaling 39,914 gallons. Of the total, 23,947 gallons were the winter fuel oxygenated with MTBE, 8,073 gallons were the summer fuel oxygenated with MTBE, and 7,894 gallons were the summer fuel oxygenated with MTBE and TAME.

Elk Grove Village in suburban Chicago received three fuel deliveries totaling 24,432 gallons. Of the total, 16,272 gallons were the winter fuel oxygenated with ethanol, and 8,160 gallons were the summer fuel oxygenated with MTBE.

Houston received three test fuel deliveries totaling 23,448 gallons. All test fuel used in Houston was the summer fuel oxygenated with MTBE.

C. Fleets

Three vehicle fleets in three cities participated in the program. Boston, Chicago, and Houston were selected by the testing team and approved by the workgroup as representative of geographic areas participating in the RFG program. The National Association of Fleet Administrators provided assistance in locating participating fleets.

Testing in Boston and suburban Chicago's Elk Grove Village was conducted from March through July. In Houston, the test period was June through August. Daily minimum and maximum temperatures for the test period for Boston, Chicago, and Houston are listed in Appendix I.

In Boston, the Police Department agreed to participate in the fleet testing program. The fleet was composed of two police precincts; one precinct provided a test fleet and another precinct provided a control fleet. Due to the preexisting sizes of the fleet at each precinct, it was not possible to find a closer match between the number of vehicles in the test and control fleets.

Table 2 - Boston Police Department Test Fleet

					Test Fuel		Control Fuel	
Year	Total	Cars	Trucks		Cars	Trucks	Cars	Trucks
99	1	0	1		0	0	0	1
98	4	3	1		0	1	3	0
97	35	35	0		23	0	12	0
96	9	9	0		8	0	1	0
95	20	17	3		8	2	9	1
94	2	2	0		0	0	2	0
93	10	8	2		5	1	3	1
92	1	1	0		1	0	0	0
91	9	9	0		6	0	3	0
90	2	0	2		0	1	0	1
89	2	2	0		1	0	1	0
88	2	1	1		1	1	0	0
	97	87	10		53	6	34	4

In suburban Chicago, Elk Grove Village agreed to participate in the program. The fleet is composed of vehicles used in the full range of municipal activities, including fire and police protection, and parks and sewer maintenance.

Two motorcycles belonging to Elk Grove Village also used Phase II RFG during the test program. The motorcycles are not included in the table or in the results because of their small number and because there were no control motorcycles. No performance problems were reported with the two motorcycles using Phase II RFG. For further information on motorcycle performance with Phase II RFG, see section VI for a description of the motorcycle testing program conducted by Harley-Davidson.

Table 3 - Elk Grove Village Test Fleet

					Test Fuel		Control Fuel	
Year	Total	Cars	Trucks		Cars	Trucks	Cars	Trucks
97	4	0	4		0	2	0	2
96	14	13	1		6	1	7	0
95	11	10	1		5	0	5	1
94	13	11	2		6	1	5	1
93	14	13	1		6	0	7	1
92	14	13	1		7	0	6	1
91	8	7	1		3	1	4	0
90	3	3	0		2	0	1	0
89	1	1	0		0	0	1	0
88	8	3	5		2	3	1	2
87	1	1	0		0	0	1	0
86	2	0	2		0	1	0	1
83	1	0	1		0	1	0	0
82	1	0	1		0	0	0	1
81	1	0	1		0	1	0	0
79	1	0	1		0	0	0	1
73	1	0	1		0	1	0	0
	98	75	23		37	12	38	11

In Houston, the Lighting & Power Company agreed to participate in the test program. Unlike the Boston and Chicago fleets, most of the vehicles in the Houston fleet are trucks.

Table 4 - Houston Lighting & Power Test Fleet

					Test Fuel		Control Fuel	
Year	Total	Cars	Trucks		Cars	Trucks	Cars	Trucks
97	53	15	38		11	21	4	17
96	12	5	7		3	6	2	1
95	59	1	58		1	30	0	28
94	15	0	15		0	4	0	11
93	10	1	9		0	4	1	5
92	0	0	0		0	0	0	0
91	30	23	7		12	2	11	5
	179	45	134		27	67	18	67

The fleets involved in the testing program were composed primarily of General Motors and Ford cars and trucks, with model years ranging from 1973 to 1999. Trucks include sport utility vehicles, vans, pickups, and step vans. The practicalities of finding fleets of an appropriate size, in the geographic locations desired, at the time needed, necessarily limited potential options in terms of representing all automobile manufacturers. The vehicle technologies tested are generally representative of vehicle technologies employed over the same time period.

D. Vehicle Performance

For the purposes of this fleet testing program, the term "incident" means that a fuel system component was adjusted, repaired, or replaced other than through regular scheduled maintenance. There were six incidents during the course of the testing program involving vehicles using Phase II RFG test fuel.

Boston

During the test program, one fuel pump from a 1988 truck in the Boston Police fleet using Phase II RFG was sent to the vehicle manufacturer for analysis. The pump symptom was a leak at the pump outlet port. The manufacturer determined that the pump's performance was still within specifications. The manufacturer's examination indicated that the cause of the leak was mechanical and not fuel related. It was most likely to have resulted from damage to the fitting that screws into the pump outlet port. The manufacturer's analysis is included in Appendix J. The incident occurred during the use of summer test fuel oxygenated with MTBE and TAME.

Elk Grove Village

Four incidents were reported on vehicles using Phase II RFG test fuel during the course of testing in suburban Chicago's Elk Grove Village. All four incidents occurred with the winter test fuel oxygenated with ethanol.

In three cases, electric fuel pumps failed on police vehicles that ranged in age from 1992 to 1996 with between 56,000 and 85,000 miles. Fuel pumps from the 1995 and 1996 vehicles were sent to the vehicle manufacturer for analysis. The manufacturer determined that the two pumps failed because of severe corrosion of the positive brush shunt wire. According to the manufacturer, the corrosion is typical of previously observed field results during long-term exposure to gasoline containing reactive sulfur compounds that did not meet ASTM specifications. The manufacturer concluded that a high level of corrosion probably was present in both pumps at the start of the testing program, and the failures were unrelated to the use of Phase II RFG. The analysis submitted by the manufacturer is included as Appendix K. The third electric fuel pump, from the 1992 vehicle, was inadvertently disposed of by a fleet mechanic before it could be shipped to the manufacturer for analysis. While it seems likely that the third fuel pump suffered from the same corrosion as the other two, there is insufficient information to determine the cause of the failure.

In response to the findings in the manufacturer's analysis, samples of the winter test and control fuels were analyzed to assess relative corrosivity. Some sulfur compounds that remain in gasoline after refining can have a corroding action on various metals. Copper strip corrosion tests were performed and the results showed both fuels to be non-corrosive. The results of the corrosivity tests support the manufacturer's view that the electric pump failures were unrelated to the use of Phase II RFG.

The fourth fuel pump from the Elk Grove Village fleet was removed from a 1981 step van with 66,000 miles. The manufacturer's analysis indicates that the mechanical pump is an after market part of unknown manufacture and showed no obvious signs of failure except an oil leak and extruded seal. The oil leak was not caused by fuel composition, but the extruded seal could be the result of excessive swell caused by oxygenates or a high aromatic content or a combination, or by an assembly problem. The manufacturer speculated that if the seal extruded because of excessive swell, that could have happened in the short duration of the test program; however, the manufacturer concluded it is more likely that the pump failure was unrelated to Phase II RFG use.

According to the Elk Grove Village fleet manager, the number of fuel pump failures during the test program is normal for the fleet's size; in his experience, fuel pump replacement is expected on vehicles that have accumulated more than 60,000 miles. The fleet manager's comments are included in Appendix L.

Houston

One fuel pump using test fuel in Houston failed during the course of the test program. That pump and three pumps from fleet vehicles not participating in the test program were sent to the manufacturer for analysis. All four pumps were from 1993 pickups with mileage ranging from 72,771 to 86,589. Heavy commutator wear coupled with normal brush wear led the manufacturer to believe that all four pumps failed due to operation on peroxidized fuel, also known as sour fuel. Since the failure occurred with both the test and control fuels, the manufacturer theorized that the failures are more likely related to the fuel dispensing system or to vehicle usage and operating factors rather than the composition of either fuel. The manufacturer's analysis is included in Appendix K.

The three pickups using Phase I RFG control fuel that had pump failures, described above, were not assigned to the control fleet. However, fleet personnel alerted EPA to the incidents. Although not assigned to the control fleet, the three pickups were using the same fuel as the control fleet. The incidents are reported here due to their close occurrence in time and similarity to the single test fleet fuel pump failure.

Fuel samples from both the test and control fuel dispensers in Houston were analyzed to determine their levels of peroxide, gum, and acidity, properties related to storage and handling degradation. Both fuel analyses indicated the fuel properties were within acceptable ranges. These analyses suggest that individual vehicle usage and operating factors are more likely related to the incidents than the fuel dispensing system, since peroxidation occurred in individual fuel tanks, not in the fleet's fuel dispensing system. The summer testing in Houston included an extended period of extremely hot weather, a condition conducive to oxidation of gasoline in individual vehicle fuel tanks.

Summary

There were six incidents during the course of the testing program in vehicles using test fuel. Five of the six incidents were deemed unrelated to the use of Phase II RFG by the relevant automobile manufacturer. In the sixth incident, the part in question was lost and the cause of its failure could not be determined.

No problems with starting, running, idling, acceleration, or power were reported by any fleet. One fleet manager described his fleet's use of Phase II RFG as transparent; fleet users and the mechanical staff saw no change or effect (see Appendix L).

IV. Fuel Economy

Another aspect of the testing program recommended by the workgroup involves measuring fuel economy with Phase II RFG compared to Phase I RFG. Two data sets are presented here.

A. Southwest Research Institute Study

EPA hired Southwest Research Institute (SWRI) to conduct a fuel economy study comparing Phase II RFG with Phase I RFG. Fuel economy was measured for 12 vehicles of various makes, ages, mileage, and fuel delivery systems. The vehicles were driven over fixed 50 mile urban and suburban routes. Fuel usage was determined by using a flow meter to precisely measure the total volume of fuel consumed during the 50 mile route. The Phase II RFG summer fuel oxygenated with MTBE was used. The results of this study do not indicate any statistically significant fuel economy difference between the fuels.

The fleet average fuel economy was 21.71 miles per gallon with Phase I RFG and 21.36 miles per gallon with Phase II RFG. The difference in fleet fuel economies was 0.343. Statistical tests indicate that the small difference in fleet fuel economies cannot be attributed to the fuel, and that the difference would have to be almost twice as large to be significant. The difference in fleet fuel economies may be due to variability in the test method. Sources of such test-to-test variability that could not be entirely controlled in the study include differences in driver inputs, traffic patterns, and weather effects.

The outcome of the SWRI study is consistent with other fuel economy studies, and with EPA's analysis of test fleet fuel economy (discussed below). Fuel economy is generally proportional to the energy content of the fuel. During the past few years, studies of the fuel economy effects of reformulated gasolines with oxygenates, including laboratory and on-road studies, have shown that the addition of two percent oxygen, by weight, to gasoline results in a one to three percent fuel economy loss. In this study, both gasolines have essentially the same oxygen content and the same energy content. Since the energy content difference between Phase I RFG and Phase II RFG is expected to be minimal, the absence of an impact on the fuel economy measured in this study was expected.

The SWRI study was designed to minimize the effects of the fuel economy variables that are normally present in driving. The key variables include differences in personal driving habits, weather (temperature, wind effects, and precipitation), traffic patterns (rush hour versus weekend, highway versus city driving), number of passengers, vehicle condition, and changes in tire pressure. The relative effect of many of these variables can be expected to exceed any reduction due to the use of RFG.

The SWRI report is included as Appendix M. The report was reviewed by the technical steering committee and presented to the workgroup.

B. Fleet Average Fuel Economy

Data on fleet average fuel economy for this analysis is limited. The Boston fleet provided no data on fuel economy because the records of fuel usage were not sufficient. Data from the Houston fleet contained gaps and inconsistencies that prevented useful analysis. The Elk Grove Village fleet maintained sufficient fueling records to determine fuel economy for a portion of the fleet, and is included here.

Data obtained from the Elk Grove Village fleet for the test period in 1997 and 1998 indicate that there is no meaningful difference in fuel economy between Phase I RFG and Phase II RFG. For the Elk Grove Village fleet, vehicles using Phase I RFG as control fuel were different than those using Phase II RFG as test fuel, unlike the study performed by SWRI. Also, the routes and driving styles of each individual vehicle differed within each fuel group. Nevertheless, the makes and types of vehicles were essentially the same between each fuel group. The test fleet included seven Caprices and one E250. The control fleet included 12 Caprices, one Mustang, and one Tempo.

For the test period, March through July in 1998, the composite averages in miles per gallon (i.e., total fleet miles driven divided by total fleet gallons used) for the test and control fleets were 9.59 and 9.47 respectively, representing a 1.2 percent difference between the two fuels. The value of 1.2 percent does not represent a meaningful difference in miles per gallon between the two fuels, given the other measures of variability between the two data sets, noted above.

By comparison, during March through July in 1997, when both fleets were using Phase I RFG, the composite averages in miles per gallon for the test and control fleets were 9.48 and 9.47 respectively, representing a 0.1 percent difference between the two fuels. The 95 percent confidence interval for the 1997 control fleet was 9.32 to 11.29 miles per gallon. The mean miles per gallon for the individual vehicles in the test fuel fleet (as opposed to a composite average) was 9.33 miles per gallon, which lies within the confidence interval for the control fleet.

V. Nonroad Test Program

In addition to vehicle testing, the workgroup recommended a testing program to evaluate the performance of Phase II RFG with nonroad engines. The test fuel used for nonroad engine testing was the same as the test fuel used with vehicle fleets. The nonroad test program included 177 pieces of gasoline-powered equipment that encompassed 11 types of utility, lawn, and garden equipment, and included both two-

cycle and four-cycle engine designs. In addition, two-cycle and four-cycle marine engines were tested by Mercury Marine at six sites.

A. Utility, Lawn, and Garden Equipment

The Arlington County, Virginia Department of Parks and Natural Resources provided the equipment and resources to evaluate utility, lawn, and garden equipment. Their equipment fleet consisted of 177 units ranging from three horsepower handheld trimmers to 17 horsepower tractors, with both two-cycle and four-cycle engine designs.

The engines listed in the following table were used for in use testing of Phase II RFG. Most of the engines are used in brush cutters, mowers, gas-powered hedge trimmers, chainsaws, backpack leaf blowers, generators, rototillers, edgers, vacuum blowers, and pruners, and had horsepower ratings between three and eight. Four units are small tractors with horsepower ratings between 12 and 17. Eighteen of the 177 units meet EPA's emission regulations for small handheld engines (40 CFR 90); all 18 units were manufactured by Stihl.

Table 5 - Arlington County Nonroad Engines

Number of Units	Engine Make	Engine Type
60	Stihl	two-cycle
35	Kawasaki	two-cycle
30	Briggs and Stratton	four-cycle
25	Tecumseh	four-cycle
15	Honda	four-cycle
4	Tanaka	two-cycle
4	Yamaha	two-cycle
4*	Kohler	four-cycle

* Tractors

The test fuel for this equipment was the summer fuel oxygenated with MTBE. The fuel was delivered on August 28, 1998 to a storage tank at the County water treatment plant.. To aid equipment refueling, a pickup truck was used as a mobile fueling station. A 100 gallon fuel tank in the back of the truck was used to fuel two-cycle engines, and six five-gallon cans were used to fuel four-cycle engines. The truck tank and cans were refilled at the main storage tank as necessary. Each refill of the 100 gallon tank included the addition of two-cycle engine oil at a gasoline/oil ratio of 40

to one. During the test period, Quaker State Itasca two-cycle engine oil was used.

The performance testing consisted of fueling the engines with Phase II RFG and operating them normally. The fuel was replenished as needed. Any performance problems encountered were to be reported. The testing period began on September 1 and continued until the test fuel was expended during the third week in November. The amount of use for each piece of equipment was not recorded. The primary activities during the testing period consisted of lawn maintenance, leaf removal, and ball field maintenance.

During the testing period, 185 gallons of Phase II RFG were consumed. Assuming a maximum fuel consumption rate of about one-half gallon per hour, testing consisted of more than 370 hours of operation.

No performance-related incidents occurred during the test period. The equipment supervisor reported that there were no perceptible changes in engine performance and no indications of leaks.

B. Marine Engines

Approximately 3,800 gallons of summer fuel oxygenated with MTBE were provided to four Mercury Marine testing facilities in Wisconsin, Florida, and Oklahoma, and two materials testing locations in Illinois and North Carolina. The engines tested ranged from small two-cycle, 25 horsepower outboard engines to large four-cycle, 500 horsepower inboard and stern drive engines.

Small two-cycle outboard engines were tested for startability and running quality, with storage at cool temperatures. Cool temperatures were those lower than are typical for summer fuel. The field testing in November 1998 in Wisconsin with summer fuel captured the temperature conditions that are characterized as the fall shoulder season. Testing consisted of start-up, warm-up, idle quality, and running quality phases. The engines were mounted on a dock for the four-phase test and then moved to an outdoor storage rack for 40 hours to stabilize at ambient conditions, in a temperature range of 35 to 55 degrees. The engines were then returned to the dock and startability testing was conducted. No performance problems with Phase II RFG were reported.

In addition to field testing, engine dynamometer testing was conducted with two-cycle outboard engines. A dynamometer is a device that simulates the resistance the engine would experience under normal operating conditions. The dynamometer tests measured the maximum power produced using the summer test fuel and a baseline fuel known as indolene. No noticeable difference in operating performance was found.

Large four-cycle engines were also tested using both test and baseline fuels. The tests measured power output using an engine dynamometer and found no significant difference between the fuels.

Testing of fuel system materials was done by Airtex and Magnetti Morelli. Gaskets and other fuel system materials were tested. No detrimental effects were reported.

VI. Motorcycle Test Program

Over 1,700 gallons of summer fuel oxygenated with MTBE were provided to Harley-Davidson for laboratory testing of six current model motorcycles, on-road performance testing of six privately-owned motorcycles, and materials compatibility testing. The Harley-Davidson motorcycles listed in the following table were used for laboratory testing of Phase II RFG.

Table 6 - Harley-Davidson Motorcycles Tested in Laboratory

Number	Year	Model	Engine (cc)	Fuel System
2	1997	Sportster	1200	Carburetor
2	1998	FLT/HT	1450	Carburetor
2	1998	FLT/HT	1450	Fuel Injection

The laboratory testing consisted of performance tests on six motorcycles using the test fuel and a baseline fuel known as indolene. Testing was conducted using a chassis dynamometer, a device that allows the motorcycle to remain stationary while the rear wheel turns a drum that provides resistance to simulate the resistance of the motorcycle and rider on the highway. The rider operates the motorcycle as though it were on the highway by shifting gears and adjusting the throttle to follow a graph on a video screen. Acceleration, driveability, and startability were evaluated during these tests. No significant difference in performance was observed between the baseline fuel and Phase II RFG.

On-road testing was conducted by Harley-Davidson employees on their own Harley-Davidson motorcycles. The Harley-Davidson motorcycles listed in the following table were used for on-road testing of Phase II RFG.

Table 7 - Harley-Davidson Motorcycles Tested On-road

Year	Model ID	Model Name	Type	Engine (cc)	Starting Odometer	Accumulated Miles
1998	FLHT	Electra Glide	Touring	1450	675	1,575
1998	FLHTC	Electra Glide Classic	Touring	1450	12,500	1,200
1998	FLHTCUi	Ultra Classic	Touring	1450	1,300	500
1998	FLTR	Road Glide	Touring	1450	9,000	2,500
1998	FLTRI	Road Glide	Touring	1450	2,000	700
1999	FLTR	Road Glide	Touring	1450	150	500

The test period with the summer test fuel was from mid-October until the end of November in the Milwaukee, Wisconsin area, although summer fuel is not provided to retail stations after September 15. The daily temperatures for the on-road testing period are listed in Appendix N. Performance was evaluated using both the test fuel and a commercially available fuel. No performance problems with Phase II RFG were reported.

Materials compatibility tests were done on three sets of fuel system elastomer components. An independent laboratory tested the components by soaking them in both the test fuel and a baseline gasoline and then measuring size changes. Paint finish and decal compatibility tests were also performed using the test fuel and a baseline fuel. Finished fuel tanks were placed in an outdoor rack and each fuel was periodically spilled over a tank during a period of three weeks to determine the effect. No detrimental effects were identified.

VII. Conclusion

All available data indicate that consumers should experience no difference in performance or fuel economy when Phase II RFG replaces Phase I RFG.

EPA tested in use vehicles in three cities over a period of three to five months. The combined test fleet drove over one million miles with Phase II RFG. Out of a combined fleet of 374 vehicles, six component-related incidents occurred during the course of the testing program. Five of the six incidents were deemed unrelated to the use of Phase II RFG by the relevant automobile manufacturer. In the sixth incident, the part in question was lost and the cause of its failure could not be determined.

No problems with starting, running, idling, acceleration, or power were reported by any fleet. One fleet manager described his fleet's use of Phase II RFG as transparent; fleet users and the mechanical staff saw no change or effect (see Appendix L).

Studies have shown that incident rates increase with vehicle mileage, irrespective of the fuel used. Vehicle maintenance is the key to good performance with any fuel.

In a separate study, SWRI compared fuel economy with Phase II RFG to Phase I RFG. Fuel economy was measured for 12 vehicles of various makes, ages, mileage, and fuel delivery systems. The vehicles were driven over fixed 50 mile urban and suburban routes. Fuel usage was determined by using a flow meter to precisely measure the total volume of fuel consumed during the 50 mile route. The results of this study do not indicate any statistically significant fuel economy difference between the fuels.

The outcome of the SWRI study is consistent with other fuel economy studies, and with EPA's analysis of test fleet fuel economy. Fuel economy is generally proportional to the energy content of the fuel. During the past few years, studies of the fuel economy effects of reformulated gasolines with oxygenates, including laboratory and on-road studies, have shown that the addition of two percent oxygen, by weight, to gasoline results in a one to three percent fuel economy loss. In this study, both gasolines have essentially the same oxygen content and the same energy content. Since the energy content difference between Phase I RFG and Phase II RFG is expected to be minimal, the absence of an impact on the fuel economy measured in this study was expected.

The Arlington County, Virginia Department of Parks and Natural Resources provided the equipment and resources to evaluate utility, lawn, and garden equipment. Their equipment fleet consisted of 177 units ranging from three-horsepower handheld trimmers to 17-horsepower tractors with both two-cycle and four-cycle engine designs. Testing began September 1 and concluded the third week in November. During the testing period, 185 gallons of Phase II RFG were consumed. Assuming a maximum fuel consumption rate of about one-half gallon per hour, testing consisted of more than 370 hours of operation. No performance-related incidents occurred during the test period. The equipment supervisor reported that there were no perceptible changes in engine performance and no indications of leaks.

Performance and materials testing was conducted with motorcycles by Harley-Davidson and with marine engines by Mercury Marine. In both cases, outdoor testing in Wisconsin occurred in the autumn with summer test fuel, capturing shoulder season effects. The results indicate no performance problems with Phase II RFG.

In summary, no difference in vehicle performance or fuel economy is expected when Phase II RFG replaces Phase I RFG. In addition, no difference in performance is expected with small engines, marine engines, or motorcycles.

Appendix A

Phase II RFG Implementation Workgroup Members
4/5/99

AUTOMOBILE AND ENGINE COMPANIES AND ASSOCIATIONS

Association of International Automobile Manufacturers
John Cabaniss

Daimler Chrysler Corporation
Reg Modlin
Ann Schlenker

Ford Motor Company
Walt Kreucher
Shelley Scott

General Motors
Gary Herwick

Portable Power Equipment Manufacturers Association
Don Purcell

Tecumseh Products
Roger Gault

Toyota
John Shipinski

AUTOMOBILE AND FLEET ASSOCIATIONS

American Automobile Association
David Van Sickle

National Association of Fleet Administrators
Pat O'Connor

ENVIRONMENTAL AND PUBLIC HEALTH ASSOCIATIONS

American Lung Association
Blake Early

Health Effects Institute
Robert O'Keefe

Natural Resources Defense Council
Janet Hathaway

OIL AND OXYGENATE COMPANIES AND ASSOCIATIONS

BP Amoco
Bob Schaefer

American Methanol Institute
Ray Lewis

ARCO
Dan Hisey

American Petroleum Institute
Paul Argyropoulos
Ed Murphy

Equiva Services
Ron Benton
Mike Kulakowski

Information Resources, Inc.
David Holt

National Petrochemical & Refiners Association
Terry Higgins

Oxygenated Fuels Association
Charlie Drevna

Petroleum Marketers Association of America
John Huber

Renewable Fuels Association
Eric Vaughn

Service Station Dealers Association
Roy Littlefield

Society of Independent Gasoline Marketers of America
Greg Scott

Texaco
Michael Redemer

SERVICE TECHNICIANS

Service Technicians Society
David Solomon

STATES AND STATE ASSOCIATIONS

Arizona Department of Environmental Quality
Ira Domsky

California Air Resources Board
Peter Venturini

Georgia Department of Natural Resources
Marlin Gottschalk

Kentucky Department for Environmental Protection
John Hornback

National Association of State Energy Officials
Frank Bishop

Northeast States for Coordinated Air Use Management
Arthur Marin

Ozone Transport Commission
Bruce Carhart

STAPPA/ALAPCO
Bill Becker

Wisconsin Department of Natural Resources
Dennis Koepke
Bob Lopez

U.S. GOVERNMENT

Department of Energy
Barry McNutt

Environmental Protection Agency
Debbie Wood

Appendix B

Phase II RFG Implementation Workgroup
Testing Team

Paul Argyropoulos
American Petroleum Institute

John Cabaniss
Association of International Automobile Manufacturers

Bruce Carhart
Ozone Transport Commission

Jim Carter
Automotive Testing & Development Services

Bob Dinneen
Renewable Fuels Association

Roger Gault
Tecumseh Products

Larry Haslett
Environmental Protection Agency

Gary Herwick
General Motors

Jim Hyde
New York Department of Environmental Conservation

J. Harold Idell
FedEx Corporation

Bob King
Sun Company, Inc.

Dave Korotney
Environmental Protection Agency

Mike Kulakowski
Equiva Services

Dennis Koepke
Wisconsin Department of Natural Resources

Arthur Marin
Northeast States for Coordinated Air Use Management

Ed Murphy
American Petroleum Institute

Pat O'Connor
National Association of Fleet Administrators

Bob O'Keefe
Health Effects Institute

Tony Pastor
Star Enterprise

Ann Schlenker
Daimler Chrysler Corporation

John Shipinski
Toyota

Shelley Scott
Ford Motor Company

Peter Venturini
California Air Resources Board

Debbie Wood
Environmental Protection Agency

4/5/99

Appendix C

Phase II RFG Implementation Workgroup
Technical Steering Committee

Paul Argyropoulos
American Petroleum Institute

Barry Garelick
Environmental Protection Agency

Larry Haslett
Environmental Protection Agency

Gary Herwick
General Motors

Jim Hyde
New York Department of Environmental Conservation

Dave Korotney
Environmental Protection Agency

Mike Kulakowski
Equiva Services

Dennis Koepke
Wisconsin Department of Natural Resources

Arthur Marin
Northeast States for Coordinated Air Use Management

Ed Murphy
American Petroleum Institute

Pat O'Connor
National Association of Fleet Administrators

Shelley Scott
Ford Motor Company

Peter Venturini
California Air Resources Board

Debbie Wood
Environmental Protection Agency
4/5/99

Appendix D

Evaluation of On-Highway Motor Vehicles Operated on Federal Phase II Reformulated Gasoline

I. INTRODUCTION

The purpose of this test program is to identify performance issues which may be associated with the operation of vehicles on federal Phase II reformulated gasoline (RFG), before the fuel is introduced beginning January 1, 2000. This test program will be supplemented with data gathered in California's Compatibility and Performance Study for California Phase 2 RFG.

To evaluate the performance of Phase II RFG in current vehicles, in-use studies are proposed. The studies will monitor the use of Phase II RFG in various vehicles driven on their normal daily routes. Control fleets that match the size and make up of the test fleets, operated on market-available gasoline, will also be monitored for comparative analyses. Four methods of data collection will be employed for the purpose of performance evaluation:

(1) Records of incidents related to driveability and performance reported by drivers or users.
(2) Visual inspection surveys taken on a bimonthly basis for each study vehicle.
(3) Maintenance records, both historical and during the study period.
(4) Individual vehicle volumetric fuel consumption and cumulative mileage or actual odometer changes.

All data will be statistically analyzed to quantify impacts which are specific to the use of Phase II RFG. The test program will cover a wintertime fueling period followed by a spring and early summer fueling period with the transition occurring as would normally occur in accordance with existing and future regulatory requirements.

II OBJECTIVE

The objective of this test program is to evaluate the performance of vehicles currently in use, when operated on Phase II RFG, as compared to being operated on currently available Phase I RFG. If performance issues associated with Phase II fuel are identified during the course of the study, the test program will include a more specific investigation of these issues.

III VEHICLES

a. Description of vehicles

Privately and/or publicly-owned fleets of vehicles will be solicited to participate in this test program. These fleets will be located in Boston, Chicago, and Houston. Fleets in each city will be divided into test and control fleets of approximately equal size; there will be approximately 100 vehicles in Boston and Chicago, and 200 vehicles in Houston, for a total of 400. The technology and age distribution of the vehicles will approximate the national distribution, to the extent possible.

b. Vehicle inspections

Before the Phase II RFG performance study begins, each study vehicle shall undergo a visual inspection. As described in the instructions for the various data collection forms, the inspection will verify the identity and classification of the vehicle, as well as identify obvious defects which should be noted and considered during the analysis phase of the study. A "Vehicle Description Log" will be used to record the identity and classification of the test and control vehicles. A preliminary "Fuel System Inspection Log" will also be completed for each study vehicle before testing begins to document the condition of the fuel system components. The Vehicle Description Log and Fuel System Inspection Log will be completed by EPA. EPA inspectors will be trained on how to properly perform vehicle inspections and will be specifically instructed not to disturb or tamper with any of the components under study.

IV FUELS

a. Description of fuels

For these studies the baseline fuels will be the gasolines normally purchased by the fleet operators. The Phase II RFG which will be used in these studies should meet all the standards for Phase II RFG as listed in 40 CFR Part 80, Section 41, and contain detergent additives approved by EPA at commercial doses. The target properties for the test fuels are shown in Table 1 below. The actual test fuel properties will be approved by an executive review committee before the test fuels are produced.

Table 1 - Target Test Fuel Properties

	Summer MTBE	Summer MTBE +TAME	Winter MTBE	Winter Ethanol
Oxygen, wt%	2.1	1.6 (MTBE) 0.5 (TAME)	2.1	3.5
RVP, psi	6.6	6.6	12.8	13.3
Sulfur, ppm	150	150	310	300
Aromatics, vol%	24	24	23	25
Olefins, vol%	11	11	12	12
Benzene, vol%	0.8	0.8	0.9	0.8
T10, °F	133	133	110	108
T50, °F	197	196	195	191
T90, °F	320	320	324	324
(E200, vol%)	(52)	(52)	(53)	(55)
(E300, vol%)	(84)	(84)	(83)	(83)
Octane, (R+M)/2	>87	>87	>87	>87

These fuel properties represent typical properties expected for Phase II RFG complying on average. Each fuel in the table will be used in a different city, and it is possible that not all fuels shown in the table will be required in this study. Also, to ensure that the fuel represents that which will actually be sold in RFG areas, the fuel should be produced from proportions of refinery blending components similar to proportions expected in 2000. These blending proportions are shown in Table 2.

Table 2 - Blendstock blending fractions

	Maximum volume percent of blendstock in final test fuel
Reformate	29
St. run naphtha	15
Isomerate	4
FCC naphtha	35
Hydrocrackate	4
Alkylate	18
Dimate	1
Raffinate	3

Finally, all test fuel properties must fall within prescribed ranges to ensure that the fuels represent expected average Phase II RFG fuels and meet ASTM guidelines. The

allowable ranges for summer and winter fuels are shown in Table 3. No test fuel properties can fall outside the ranges given in Table 3.

Table 3 - Allowable ranges for Test Fuels

	Summer MTBE	Summer MTBE +TAME	Winter MTBE	Winter Ethanol
Oxygen	2.0 +	2.0 +	2.0 +	2.0 +
RVP, psi	6.4 - 6.8	6.4 - 6.8	12.3 -13.3	12.8 - 13.8
Sulfur, ppm	125 - 175	125 - 175	285 - 335	275 - 325
Aromatics, vol%	23 - 25	23 - 25	22 - 24	24 - 26
Olefins, vol%	10 - 12	10 - 12	11 - 13	11 - 13
Benzene, vol%	0.6 - 1.0	0.6 - 1.0	0.6 - 1.1	0.6 - 1.0
T10, °F	125 - 145	125 - 145	100 - 120	100 - 120
T50, °F	190 - 210	190 - 210	190 - 210	180 - 200
T90, °F	305 - 335	305 - 335	305 - 335	305 - 335

A switch from the winter test fuel to the summer test fuel will occur in each area at a time designated by EPA. At that time, the summer test fuel and the summer control fuel will be added to whatever amounts of winter fuels are in the fleet operator's underground tanks.

b. Fuel storage and distribution

A central location may be used to receive and store the test fuel for each test fleet. The test fuel will be shipped by tank truck to the fleet operators. A fuel distributor will be designated to deliver the test fuel to locations where the test fuel is dispensed.

c. Fuel sampling and analysis

EPA-appointed inspectors will obtain samples from the bulk storage tanks of the test fuel and/or control fuel at the fueling facilities. Fuel samples are to be taken using approved EPA procedures whenever fuel is deposited into the fleet operator's storage tanks, or on a bimonthly basis, whichever is more frequent. Test fuel and control (local) fuel will be sampled at the same time.

Whenever a performance-related problem is reported via the Driveability Incident Log, a sample of fuel from the vehicle's tank should be taken. EPA will provide the fleet operators all the equipment needed to collect the fuel samples, as well as protocols for handling and shipping the sample to EPA for analysis.

V DATA COLLECTION

Vehicle operators will be provided with fuel in such a way that they are unaware of which type of fuel (test or control) they are using. This may require that local fuel be added to bulk storage tanks for centralized refueling by each control fleet. Operators will be ordered to refuel only at approved dispensers during the period of the study. Operators will then drive the vehicles on the routes typically followed for that vehicle or fleet.

Four types of data will be collected for both test and control vehicles:

1. EPA inspectors will visually inspect each study vehicle bimonthly. Upon completion of each inspection, the EPA inspectors will complete and submit the Fuel System Inspection Log to document the condition of the vehicle's fuel system. The Fuel System Inspection Log will be completed and submitted by EPA inspectors on a continuous basis so data may be processed as soon as possible.

2. A "Driveability Incident Log" will be completed by the fleet operator's maintenance personnel for any potentially fuel-related performance problems reported by the vehicle operator. Upon a report of an incident (component failure or performance problems) the vehicle will be removed from service and inspected by fleet maintenance personnel to determine if the problem is potentially fuel related. The vehicle will be repaired according to normal procedures, and any replaced parts will be retained. If possible, a fuel sample will also be taken from the gas tank. A copy of the repair invoice should be attached to the "Driveability Incident Log" and submitted to EPA for data retrieval, along with the replaced parts and fuel sample. The "Driveability Incident Log" along with the repair invoice will be used to determine the number and causes for fuel related performance problems.

3. The third method of data collection is the review of historical maintenance and repair records obtained from fleet operators. Electronic retrieval of this data is possible from some of the fleets. Some fleets may have only paper copies of records. Any available historical records should be retrieved and provided to EPA prior to the commencement of the study. Records of maintenance and repairs occurring during the study period should be collected monthly and provided to EPA for processing.

4. The fourth method of data collection will consist of a "Refueling Report" to be completed by the fleet operator's fueling personnel for each test and control vehicle, each time fueling occurs. The Refueling Report will include the date, the odometer reading, and the amount of fuel provided. A summary of

historical data on fuel consumed and the change in odometer readings over a stated period for test and control vehicles will be provided by the fleet operator.

VI DATA ANALYSIS AND REPORTING

Survey data and maintenance records should be provided by the fleet operator every month to EPA. A final report will be issued by EPA following the conclusion of the study. It is envisioned that the final report will include responses totaled for each survey and maintenance field and that each response should be reported as a fraction, or rate, of total responses for each survey and maintenance response category. The data should be analyzed independently for test groups and control groups. At a minimum, study results should be plotted as the incidence rates in the test group versus control group for each response category and each vehicle or equipment classification over the study period.

FLEET DESCRIPTION

(completed by EPA representatives)

Fleet Name: _____ Fleet Code: _____

Fleet contact person: _____

Phone Number: (__) _____

Street address: _____

City: _____ Zip Code: _____

Winter Fueling - Start date: __/__/__ _____ (mm/dd/yy hhmm, i.e. 02/18/98 0645 - 24 hr clock)

Summer Fueling Start: __/__/__ _____ (mm/dd/yy hhmm)

VEHICLE DESCRIPTION

(completed by EPA reps)

Fleet: _____ Date: _____ Inspector: _____ Veh lic #: _____

Veh. year: _____ Mfr: _____ Model: _____ VIN: _____

Odom: _____ Trans: Auto or Man Veh type: Car or Truck or MC Fuel group: D2 or D3

Body: (sticker on door or door jam)

Build Date: _____ GVW: _____

Engine compartment: (sticker under hood)

Engine Family: _____ Emiss Cert yr: ____ # Cyls _____ Dispm't: ____ liters or cu.in.

Fuel System: Fuel inj or TBI or Carb

Emission control device check:

AI: __ DVAS: __ TAC: __ EVP: __ PCV: __ EGR: __ O2S: __

CCO: __ . EWL: __ OC: __ TWC: __ EFE: __ FR: __
Other: __

AI = air inj sys DVAS = diverter valve air sw. TAC = thermostatic air cleaner EVP = evap. emiss sys
PCV = positive c'case vent valve EGR = exh gas recirc valve O2S = oxygen sensor CCO = computer control
EWL = engine warning or check eng light OC = oxidation cat TWC = 3-way cat EFE = early fuel evap sys
FR = fuel filler neck restrictor

Comments: _____

Vehicle fleet records:

Odo: Winter Start: _____ Summer Start: _____ End Test: _____

Fuel quantity used: Winter Test: _____ Summer Test: _____

Fuel Econ: Winter/Test: ____ MPG Winter/Historical: ____ MPG
Summer/Test: ____ MPG Summer/Historical: ____ MPG

Removed from program - reason: _____

Ending date, if removed from program: _____

FUEL SYSTEM INSPECTION LOG

(completed by EPA reps)

Fleet: _____ Date: _____ Inspector: _____ Veh lic #: _____

Veh Year: _____ Make: _____ Model: _____

Odom: _____ Fuel group: D2 or D3 (circle one)

Fuel System Inspection:

	Pass/Fail (circle one)	Severity (seep or drip or run) (circle one)
Fuel Tank	P / F	S / D / R)
Fuel Lines and Hoses	P / F	S / D / R)
Fuel Filter(s)	P / F	S / D / R)
Fuel Pump	P / F	S / D / R)

Fuel in Crankcase, smell dipstick Yes or No

Fuel Odor(s) Yes or No

Comments: _____

Fuel Injection System:

	Pass/Fail	Severity (seep or drip or run)
Fuel Injectors:	P / F	S / D / R)
Throttle body injector unit:	P / F	S / D / R)
Other fuel inj. components:	P / F	S / D / R)

Comments: _____

Carbureted fuel systems: yes / no

	Pass/Fail	Severity (seep or drip or run)
Carburetor	P / F	S / D / R)
Accelerator pump:	P / F	S / D / R)

Comments: _____

DRIVEABILITY INCIDENT LOG

(completed by fleet operator)

Fleet: _____ Date of driveability incident: _____ Driver: _____

Veh lic #: _____ Veh. make: _____ Model: _____ Yr: ___

Odom: _____ Fuel group: D2 or D3 (circle one)

Weather conditions on date of incident: _____

_____

Type of Performance Problems:

If a driveability problem ocurred, please provide a description

Hesitation: _____

Surge: _____

Stall: _____

Odor: _____

Noise: _____

Other _____

Driving Mode - when performance problems occurred:

Highway Driving: Yes or No City Driving: Yes or No

Cold Starting: Yes or No Hot Starting: Yes or No

Morning Driving: Yes or No Afternoon Driving: Yes or No Evening Driving: Yes or No

Idle: Yes or No Acceleration: Yes or No Cruise: Yes or No

Additional Comments: _____

_____

Date of resulting (or next) vehicle inspection: _____ Inspector: _____ Odom: _____

Fuel System Repair Summary

(completed by fleet maintenance personnel)

Fleet: _____ Name: _____ Fuel group: D2 or D3 (circle one)

Veh lic #: _____ Veh. make: _____ Model: _____ Yr: ____

Repair Date: ___/___/____ Odom: _____

Description of malfunction and symptoms: _____

_____

Did the repairs and adjustments involve any of the following components? Yes or No (circle one)

If yes, please describe.

Fuel tank: _____

Fuel lines, hoses: _____

Fuel filter(s): _____

Fuel pump: _____

Fuel injectors: _____

Fuel inj sys: _____

Carburetor: _____

Accel pump: _____

Fuel in Crankcase: _____

Seals: _____

How was the problem diagnosed? _____

_____

_____

Was a repair made to correct the problem? Yes or No

If yes, what repair was made? _____

_____

If repairs were made, were the replaced parts kept? Yes or No or Not applicable

Was a fuel sample taken following the incident? Yes or No

If yes, from which of the following tanks was the sample taken?

From vehicle's tank? Y or N From the dispenser/storage tank where vehicle was last refueled: Y or N

VEHICLE REFUELING REPORT

(completed by driver or other vehicle refuling personnel)

Veh Lic #: _____ Make: _____ Model: _____

Name	Date	Odometer	Gallons added	Gasoline tank/dispenser

BULK STORAGE REFUELING REPORT

(completed by fleet operator)

Name	Date	Gallons added	Storage tank used

Appendix E

Fuels Comparison

Fuel Parameter	Conventional Gasoline[1]	Phase I RFG[2]	Phase II RFG[3]	CaRFG Phase 2 Flat Limits	Ca Phase 2 Marketed[4]
RVP (psi)	8.7/7.8	8.0/7.1	6.7	7.0	7.0
Sulfur (ppm)	339	305	140	40	30
Oxygen (w%)	<0.5	2.1	2.1	1.8-2.2	1.9
Aromatics (vol%)	32	27	25	25	24
Olefins (vol%)	13	12	12	6.0	4.9
Benzene (vol%)	1.5	0.95	0.95	1.0	0.81
E200 (%)	41	49	49		
E300 (%)	83	87	87		
T50 (F)				210	206
T90 (F)				300	298

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[1] Based on statutory baseline.

[2] Estimate used to set standards.

[3] Estimate used to set standards.

[4] March, April, and May 1997 production weighted average.

Appendix F

Phase II RFG Fleet Testing Program
STATEMENT OF WORK

BACKGROUND

One of the requirements of the 1990 Clean Air Act Amendments is the reformulated gasoline (RFG) program. The purpose of the RFG program is to improve air quality by requiring that gasoline sold in certain areas of the country be reformulated to reduce emissions of toxics and tropospheric ozone-forming compounds, as specified by section 211(k). Section 211(k) mandates that RFG be sold in specific metropolitan areas with the most severe summertime ozone levels; RFG must also be sold in any ozone nonattainment area reclassified as a severe area, and in other areas that choose to participate or "opt in" to the program. The Clean Air Act further requires that conventional gasoline sold in the rest of the country not become any more polluting than it was in 1990 by requiring that each refiner's and importer's gasoline be as clean, on average, as it was in 1990. This has resulted in regulatory requirements referred to as the anti-dumping program. Phase I of the RFG program began in January 1995 and will be replaced by Phase II in January 2000. Phase II RFG will achieve even greater reductions in volatile organic compounds (VOCs), oxides of nitrogen (NOx), and toxics than Phase I.

The Phase II RFG Implementation Workgroup has been established by the Clean Air Act Advisory Committee's Mobile Source Technical Review Subcommittee. To ensure a wide range of input on the implementation of Phase II RFG, this workgroup has broad stakeholder representation, including vehicle and fuel users, vehicle and engine manufacturers, the fuel industry, environmental and public health groups, and state agencies and associations. The goal of the workgroup is to ensure the smoothest transition possible to Phase II RFG by working together to gather data and to communicate that data to the public.

The workgroup has recommended a fleet testing program to evaluate performance and fuel economy with in-use vehicles operated on Phase II RFG, compared to being operated on currently available Phase I RFG. The test plan developed by the workgroup for the fleet testing program is included as Attachment A. The purpose of the fleet testing program is to determine whether any vehicle performance issues exist that may be associated with the operation of vehicles on Phase II RFG, compared to Phase I RFG, before the fuel is introduced into commerce by January 1, 2000.

PURPOSE

The purpose of this work assignment is to provide EPA with vehicle performance and fuel economy data from fleet testing conducted according to the plan described in Attachment A.

EPA and the fleet operator expect that the fleet operator will be provided with test fuel by a gasoline manufacturer on an as needed basis up to a quantity consistent with the fleet operator's historical monthly consumption noted below, beginning in June 1998 and ending in August 1998 at the fleet operator's facility located at Houston Power and Light (hereinafter "facility").

EPA will provide to the fleet operator all data collection forms to be used in the fleet testing program. These forms are included in Attachment A. EPA will provide training to the fleet operator regarding the necessary procedures required to complete the "Driveability Incident Log" and "Fueling Report" forms.

EPA, in cooperation with the fleet operator, will complete the "Fuel System Inspection Logs" on a bimonthly basis.

Technical support provided by EPA may include fuel system evaluations, and engineering and engine/fuel system repair consultations.

Task 1 -- Identify appropriate test fleet

The fleet operator shall identify an appropriate test fleet, including test and control vehicles.

Task 2 -- Vehicle inspection

The fleet operator shall make the test fleet vehicles available for inspection by EPA at reasonable times on a bimonthly basis.

Task 3 -- Incident reports

The fleet operator shall provide a completed "Driveability Incident Log" form and related information to EPA for each incident in which a vehicle that is part of this program is removed from service to diagnose a complaint about a condition that is possibly related to fuel. A sample of fuel from the vehicle's tank shall be taken. If a repair is made, a copy of the repair order or invoice shall accompany the log form. Any replaced parts that can be linked with the incident logged shall be tagged and retained by the fleet operator for analysis by EPA.

The fleet operator shall provide access to past and current maintenance records, if available, for each vehicle in the program.

Task 4 -- Fuel economy data

The fleet operator shall provide EPA with fleet aggregate volumetric fuel consumption records on a monthly basis.

The fleet operator shall record individual vehicle fuel consumption and changes in odometer readings. The initial odometer reading shall occur when a vehicle first enters this testing program. The date, odometer reading, and gallons delivered shall be recorded at each fueling.

The fleet operator shall provide a summary of recent historical data (1996 and 1997) related to fuel economy for each test program vehicle for which valid data exists. The data are volumetric fuel consumption and cumulative mileage, or actual odometer changes, both over a stated period.

Task 5 -- Fuel

The fleet operator shall take reasonable measures to ensure that vehicles intended to use test fuel do not receive other fuel. The fleet operator may use other fuels in the event that test fuel is not available, in emergency situations. Likewise, the fleet operator shall take reasonable steps to ensure that participating control vehicles do not receive test fuel.

The fleet operator shall allow EPA to obtain samples from its bulk storage tanks of the test fuel and control fuel at the fueling facilities whenever fuel is deposited into the fleet operator's storage tanks, or on a bimonthly basis, whichever is more frequent. Refueling receptacles shall be approved vapor recovery systems if required by state law.

Attachment A: Test plan

Appendix G

Certificate of Analysis

PHILLIPS CHEMICAL COMPANY
A DIVISION OF PHILLIPS PETROLEUM COMPANY

SPECIALTY CHEMICALS
P.O. BOX 968
BORGER, TX 79008-0968

DATE OF SHIPMENT
03-06-98

CUSTOMER ORDER NO.
98BO-1

INV./REQN. NO.
480659

TRLR #380

OXYGENATED TEST GAS
LOT D-340

TESTS	RESULTS	SPECIFICATIONS	METHOD
API Gravity	61.85	Report	ASTM D-1298
Specific Gravity, 60/60	0.7318	Report	ASTM D-4052
Sulfur ppm	298	285 - 335	ASTM D-2622
MTBE, LV%	11.7	11.0 - 12.0	ASTM D-4815
Reid Vapor Pressure	12.8	12.3 - 13.3	ASTM D-323
Benzene Content, LV%	0.98	0.6 - 1.0	

DISTILLATION, D-86 °F			ASTM D-86
IBP	86.2		
5%	96.7		
10%	106.5	100 - 120	
20%	122.6		
30%	143.3		
40%	164.8		
50%	190.3	190 - 210	
60%	222.1		
70%	257.1		
80%	291.5		
90%	331.3	305 - 335	
95%	367.9		
EP	409.3		
Loss	1.7		
Residue	0.9		

HYDROCARBON TYPE, VOL. %		SPEC	ASTM D-1319
Aromatics	23.85	22 - 24	
*Olefins	10.5	11 - 13	
*this will be modified for future shipments.			
Research Octane Number	95.5	Report	ASTM D-2699
Motor Octane Number	85.9	Report	ASTM D-2700
Antiknock Index	90.7	Report	

DGD:jam
03/18/98
MF6500

FORM 5526-N D4

Certificate of Analysis

PHILLIPS CHEMICAL COMPANY
A DIVISION OF PHILLIPS PETROLEUM COMPANY

SPECIALTY CHEMICALS
P.O. BOX 968
BORGER, TX 79008-0968

DATE OF SHIPMENT
03-06-98

CUSTOMER ORDER NO.
98EG-1

INV./REQN. NO.
480740

TRLR #334

OXYGENATED TEST GAS
LOT D-368

TESTS	RESULTS	SPECIFICATIONS	METHOD
API Gravity	59.6	Report	ASTM D-1298
Specific Gravity, 60/60	0.7406	Report	ASTM D-4052
Sulfur ppm	309	275 - 325	ASTM D-4294
Ethanol, LV%	9.74	9.5 - 10.5	Chromatography
Reid Vapor Pressure	13.1	12.8 - 13.8	ASTM D-323
Benzene Content, LV%	0.999	0.6 - 1.0	
DISTILLATION, D-86 °F			ASTM D-86
IBP	88.7		
5%	101.6		
10%	110.4	100 - 120	
20%	128.3		
30%	145.2		
40%	155.4		
50%	182.7	180 - 200	
60%	236.9		
70%	266.5		
80%	298.6		
90%	335.3	305 - 335	
95%	374.4		
EP	411.6		
Loss	1.7		
Residue	1.0		
HYDROCARBON TYPE, VOL. %			ASTM D-1319
		SPEC	
Aromatics	25.2	24 - 26	
Olefins	11.0	11 - 13	
Saturates			
Research Octane Number	95.25	Report	ASTM D-2699
Motor Octane Number	85.1	Report	ASTM D-2700
Antiknock Index	90.2	Report	

DGD:jam
03/18/98
MF6500

Certificate of Analysis

PHILLIPS CHEMICAL COMPANY
A DIVISION OF PHILLIPS PETROLEUM COMPANY

SPECIALTY CHEMICALS
P.O. BOX 968
BORGER, TX 79008-0968

DATE OF SHIPMENT

CUSTOMER ORDER NO.

INV./REQN. NO.

MFG DATE: 05-29-98

OXYGENATED TEST GAS
LOT D-517 (AMENDED)

TESTS	RESULTS	SPECIFICATIONS	METHOD
API Gravity	59.4	Report	ASTM D-1298
Specific Gravity, 60/60	0.7414	Report	ASTM D-4052
Sulfur, ppm	155	125 - 175	ASTM D-2622
MTBE, lv%	11.2	11 - 12	ASTM D-4815
Reid Vapor Pressure	6.8	6.4 - 6.8	ASTM D-323
Benzene Content, lv%	1.0	0.6 - 1.0	
DISTILLATION, D-86 °F			ASTM D-86
IBP	105.0		
5%	129.2		
10%	139.7	125 - 145	
20%	154.6		
30%	169.4		
40%	186.1		
50%	205.7	190 - 210	
60%	228.7		
70%	252.1		
80%	279.5		
90%	312.5	305 - 335	
95%	343.2		
EP	388.7		
Loss	1.4		
Residue	0.9		
HYDROCARBON TYPE, VOL. %			ASTM D-1319
Aromatics	24.5	23 - 25	
Olefins	12	10 - 12	
Saturates	-		
Research Octane Number	96.2	Report	ASTM D-2699
Motor Octane Number	85.7	Report	ASTM D-2700

DGD:jam
06/29/98
MF6500

Certificate of Analysis

PHILLIPS CHEMICAL COMPANY
A DIVISION OF PHILLIPS PETROLEUM COMPANY

SPECIALTY CHEMICALS
P.O. BOX 968
BORGER, TX 79008-0968

DATE OF SHIPMENT

CUSTOMER ORDER NO.

INV./REQN. NO.

OXYGENATED TEST GAS (EPA #2)
LOT D-628

TESTS	RESULTS	SPECIFICATIONS	METHOD
API Gravity	60.18	Report	ASTM D-1298
Specific Gravity, 60/60	0.7382	Report	ASTM D-4052
Sulfur ppm	169	125 – 175	ASTM D-2622
MTBE, LV%	10.81	8 - 10	ASTM D-4815
TAME, LB%	3.288	2 – 4	
Oxygen Content	2.4	Report	Chromatography
Oxidation Stability(min)	1440+	1440 min	ASTM D-525
Existent Gums (mg/100ml)	.6	<5 washed	ASTM D-381
Reid Vapor Pressure	6.75	6.3 – 6.9	ASTM D-323
TEL (ml/gal)	0.001	0.005 Max.	ASTM D-3237
Benzene Content, LV%	1.0	0.6 – 1.0	
DISTILLATION, D-86 °F			ASTM D-86
IBP	103.6		
5%	130.0		
10%	138.5	123 - 143	
20%	150.4		
30%	161.9		
40%	175.1		
50%	192.7	186 - 206	
60%	215.2		
70%	242.0		
80%	271.8		
90%	308.2	305 - 335	
95%	335.8		
EP	382.3		
Loss	0.4		
Residue	1.0		
HYDROCARBON TYPE, VOL. %			ASTM D-1319
Aromatics	23.5	22 - 25	
Olefins	13.0	10 - 13	
Research Octane Number	96.3	Report	ASTM D-2699
Motor Octane Number	85.7	Report	ASTM D-2700
Antiknock Index	91	>87	

DGD:teh
08/03/98
MF6500

Appendix H

Appendix H

Fuel Analyses conducted by the EPA National Vehicle and Fuels Emissions Laboratory

Page	Sample location	Date	Season	Test/control	Comments
H1	Elk Grove Village	3/17/98	winter	control	after 1st fuel delivery
H2	Elk Grove Village	5/6/98	winter	control	after 2nd fuel delivery
H3	Elk Grove Village	3/17/98	winter	test	after 1st fuel delivery
H4	Elk Grove Village	5/6/98	winter	test	after 2nd fuel delivery
H5	Elk Grove Village	5/6/98	winter	test	from car 238 at fuel pump change
H6	Phillips/Borger	6/29/98	summer	test	batch D628 MTBE + TAME
H7	Phillips/Borger	6/29/98	summer	test	batch D517 MTBE only
H8	Houston	9/4/98	summer	test	tests include gum and peroxides
H9	Houston	9/4/98	summer	control	tests include gum and peroxides
H10	Houston	9/4/98	summer	control	tests include acidity

NVFEL Fuel Analysis - H1

FTAG: 7768 Village of Elk Grove - control fuel - commercial RFG1 - 3/17/98

CODE	TEST	RESULT	UNITS
552	MTBE by OFID	0.084	Oxy Percent
55	MTBE by OFID	0.46	Volume Percent
56	ETBE by OFID	0	Volume Percent
562	ETBE by OFID	0	Oxy Percent
532	Ethanol by OFID	8.5	Volume Percent
534	Ethanol by OFID	3.178	Oxy Percent
57	TAME by OFID	0	Volume Percent
572	TAME by OFID	0	Oxy Percent
421	Sulfur in Gasoline by ASTM D 2622	219	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	12.21	PSIA
65	Percent Evaporated at 200 Degrees F	49	Volume Percent
66	Percent Evaporated at 300 Degrees F	84.9	Volume Percent
48	Aromatics in Gasoline MSD D5769	26.459	Volume Percent
49	Olefins in by FIA D-1319-93	2.538	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.8479	Volume Percent
63	Benzene in Gasoline by MSD D5769	0.947	Volume Percent
46	Aromatics by FIA D-1319-93	21.3	Volume Percent
531	Ethanol by MSD (Screen)	10.29	Volume Percent
551	MTBE by MSD (Screen)	0.33	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.738829	60/60F
692	Degrees API	60.17	Degrees API
691	Density @ 60 deg F	0.738099	g/cm^3 @ 60 deg F
101	D 86 Initial Boiling Point	88	Degrees F
110	10 Percent	114.2	Degrees F
150	50 Percent	204.4	Degrees F
190	90 Percent	325.69	Degrees F
200	End Point	398.1	Degrees F
201	Residue	1	ml
202	Total Recovery	97.09	ml
203	Loss	1.89	ml
592	Volume Percent Oxygenates by MSD	10.62	Volume Percent
541	Methanol by MSD (Screen)	0	Volume Percent
591	Weight Percent Oxygen by MSD	3.6	Weight Percent
543	Methanol by OFID	0	Volume Percent
533	Ethanol by 4815	8.45	Volume Percent
585	t-Butanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0	Volume Percent
5802	n-Butanol by OFID	0	Volume Percent
593	Volume Percent Oxygenates by OFID	8.97	Volume Percent
59	Weight Percent Oxygen by OFID	3.26	Weight Percent
225	Copper Corrosion D-130-94	1a	Designation

NVFEL Fuel Analysis - H2

FTAG: 7769 Village of Elk Grove - control fuel - commercial RFG1 - 5/6/98

CODE	TEST	RESULT	UNITS
55	MTBE by OFID	0.37	Volume Percent
552	MTBE by OFID	0.067	Oxy Percent
562	ETBE by OFID	0	Oxy Percent
56	ETBE by OFID	0	Volume Percent
534	Ethanol by OFID	3.259	Oxy Percent
532	Ethanol by OFID	8.75	Volume Percent
572	TAME by OFID	0	Oxy Percent
57	TAME by OFID	0	Volume Percent
421	Sulfur in Gasoline by ASTM D 2622	246	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	11.529	PSIA
65	Percent Evaporated at 200 Degrees F	47.6	Volume Percent
66	Percent Evaporated at 300 Degrees F	83	Volume Percent
48	Aromatics in Gasoline MSD D5769	26.285	Volume Percent
49	Olefins in by FIA D-1319-93	2.805	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.8289	Volume Percent
63	Benzene in Gasoline by MSD D5769	0.91	Volume Percent
46	Aromatics by FIA D-1319-93	22.1	Volume Percent
531	Ethanol by MSD (Screen)	10.06	Volume Percent
551	MTBE by MSD (Screen)	0	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.74145	60/60F
692	Degrees API	59.34	Degrees API
691	Density @ 60 deg F	0.74072	g/cm^3 @ 60 deg F
101	D 86 Initial Boiling Point	90.29	Degrees F
110	10 Percent	120	Degrees F
150	50 Percent	210.8	Degrees F
190	90 Percent	333.89	Degrees F
200	End Point	404.89	Degrees F
201	Residue	1.3	ml
202	Total Recovery	96.9	ml
203	Loss	1.8	ml
541	Methanol by MSD (Screen)	0	Volume Percent
592	Volume Percent Oxygenates by MSD	10.06	Volume Percent
591	Weight Percent Oxygen by MSD	3.47	Weight Percent
543	Methanol by OFID	0	Volume Percent
533	Ethanol by 4815	8.87	Volume Percent
585	t-Butanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0	Volume Percent
5802	n-Butanol by OFID	0	Volume Percent
593	Volume Percent Oxygenates by OFID	9.12	Volume Percent
59	Weight Percent Oxygen by OFID	3.32	Weight Percent
225	Copper Corrosion D-130-94	1a	Designation

NVFEL Fuel Analysis - H3

FTAG: 7770 Village of Elk Grove - test fuel - Phillips RFG2 - 3/17/98

CODE	TEST	RESULT	UNITS
552	MTBE bv OFID	0	Oxy Percent
55	MTBE by OFID	0	Volume Percent
56	ETBE by OFID	0	Volume Percent
562	ETBE by OFID	0	Oxy Percent
534	Ethanol by OFID	3.891	Oxy Percent
532	Ethanol by OFID	10.44	Volume Percent
572	TAME by OFID	0	Oxy Percent
57	TAME by OFID	0	Volume Percent
421	Sulfur in Gasoline by ASTM D 2622	308	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	12.599	PSIA
65	Percent Evaporated at 200 Degrees F	52.299	Volume Percent
66	Percent Evaporated at 300 Degrees F	81.4	Volume Percent
48	Aromatics in Gasoline MSD D5769	24.968	Volume Percent
49	Olefins in by FIA D-1319-93	7.967	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.884	Volume Percent
46	Aromatics by FIA D-1319-93	21.1	Volume Percent
63	Benzene in Gasoline by MSD D5769	0.989	Volume Percent
531	Ethanol by MSD (Screen)	11.31	Volume Percent
551	MTBE by MSD (Screen)	0	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.74048	60/60F
692	Degrees API	59.59	Degrees API
691	Density @ 60 deg F	0.73975	g/cm^3 @ 60 deg F 60 deg F
101	D 86 Initial Boiling Point	85.29	Degrees F
110	10 Percent	110.59	Degrees F
150	50 Percent	176	Degrees F
190	90 Percent	328.89	Degrees F
200	End Point	396	Degrees F
201	Residue	1.1	ml
202	Total Recovery	96.59	ml
203	Loss	2.29	ml
592	Volume Percent Oxygenates by MSD	11.31	Volume Percent
541	Methanol by MSD (Screen)	0	Volume Percent
591	Weight Percent Oxygen by MSD	3.91	Weight Percent
543	Methanol by OFID	0	Volume Percent
533	Ethanol by 4815	10.15	Volume Percent
585	t-Butanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0	Volume Percent
5802	n-Butanol by OFID	0	Volume Percent
593	Volume Percent Oxygenates by OFID	10.44	Volume Percent
59	Weight Percent Oxygen by OFID	3.89	Weight Percent
225	Copper Corrosion D-130-94	1a	Designation

NVFEL Fuel Analysis - H4

FTAG: 7771 Village of Elk Grove - test fuel - Phillips RFG2 - 5/6/98

CODE	TEST	RESULT	UNITS
55	MTBE by OFID	0	Volume Percent
552	MTBE by.OFID	0	Oxy Percent
56	ETBE by OFID	0	Volume Percent
562	ETBE by OFID	0	Oxy Percent
532	Ethanol by OFID	10.14	Volume Percent
534	Ethanol by OFID	3.776	Oxy Percent
57	TAME by OFID	0	Volume Percent
572	TAME by OFID	0	Oxy Percent
421	Sulfur in Gasoline by ASTM D 2622	307	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	12.589	PSIA
65	Percent Evaporated at 200 Degrees F	52.799	Volume Percent
66	Percent Evaporated at 300 Degrees F	82	Volume Percent
48	Aromatics in Gasoline MSD D5769	26.158	Volume Percent
49	Olefins in by FIA D-1319-93	9.316	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.889	Volume Percent
63	Benzene in Gasoline by MSD D5769	0.996	Volume Percent
46	Aromatics by FIA D-1319-93	21.8	Volume Percent
531	Ethanol by MSD (Screen)	10.59	Volume Percent
551	MTBE by MSD (Screen)	0	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.74146	60/60F
692	Degrees API	59.33	Degrees API
691	Density @ 60 deg F	0.74073	g/cm^3 @ 60 deg F deg F
101	D 86 Initial Boiling Point	89	Degrees F
110	10 Percent	111	Degrees F
150	50 Percent	175.3	Degrees F
190	90 Percent	330.5	Degrees F
200	End Point	392.6	Degrees F
201	Residue	1.1	ml
202	Total Recovery	97.4	ml
203	Loss	1.5	ml
592	Volume Percent Oxygenates by MSD	10.59	Volume Percent
541	Methanol by MSD (Screen)	0	Volume Percent
591	Weight Percent Oxygen by MSD	3.66	Weight Percent
543	Methanol by OFID	0	Volume Percent
533	Ethanol by 4815	10.09	Volume Percent
585	t-Butanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0	Volume Percent
5802	n-Butanol by OFID	0	Volume Percent
593	Volume Percent Oxygenates by OFID	10.14	Volume Percent
59	Weight Percent Oxygen by OFID	3.77	Weight Percent
225	Copper Corrosion D-130-94	1a	Designation

NVFEL Fuel Analysis - H5

FTAG: 7772 Village of Elk Grove - fuel from vehicle 238 - 5/6/98

CODE	TEST	RESULT	UNITS
55	MTBE by OFID	0	Volume Percent
552	MTBE by OFID	0	Oxy Percent
56	ETBE by OFID	0	Volume Percent
562	ETBE by OFID	0	Oxy Percent
532	Ethanol by OFID	10.14	Volume Percent
534	Ethanol by OFID	3.768	Oxy Percent
57	TAME by OFID	0	Volume Percent
572	TAME by OFID	0	Oxy Percent
421	Sulfur in Gasoline by ASTM D 2622	312	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	12.3	PSIA
65	Percent Evaporated at 200 Degrees F	51.899	Volume Percent
66	Percent Evaporated at 300 Degrees F	81.2	Volume Percent
48	Aromatics in Gasoline MSD D5769	25.669	Volume Percent
49	Olefins in by FIA D-1319-93	9.478	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.896	Volume Percent
46	Aromatics by FIA D-1319-93	22.3	Volume Percent
63	Benzene in Gasoline by MSD D5769	1.008	Volume Percent
531	Ethanol by MSD (Screen)	10.92	Volume Percent
551	MTBE by MSD (Screen)	0	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.74299	60/60F
692	Degrees API	58.94	Degrees API
691	Density @ 60 deg F	0.74226	g/cm^3 @ 60 deg F
101	D 86 Initial Boiling Point	89.79	Degrees F
110	10 Percent	114.09	Degrees F
150	50 Percent	181.8	Degrees F
190	90 Percent	331.3	Degrees F
200	End Point	398.69	Degrees F
201	Residue	0.69	ml
202	Total Recovery	97.2	ml
203	Loss	2.1	ml
541	Methanol by MSD (Screen)	0	Volume Percent
592	Volume Percent Oxygenates by MSD	10.92	Volume Percent
591	Weight Percent Oxygen by MSD	3.79	Weight Percent
543	Methanol by OFID	0	Volume Percent
533	Ethanol by 4815	10.15	Volume Percent
585	t-Butanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0	Volume Percent
5802	n-Butanol by OFID	0	Volume Percent
593	Volume Percent Oxygenates by OFID	10.14	Volume Percent
59	Weight Percent Oxygen by OFID	3.76	Weight Percent
225	Copper Corrosion D-130-94	1a	Designation

NVFEL Fuel Analysis - H6

FTAG: 7661 Phillips fuel sample D-628 - RFG2 - 6/29/98

CODE	TEST	RESULT	UNITS
55	MTBE by OFID	10.6	Volume Percent
552	MTBE by OFID	1.946	Oxy Percent
562	ETBE by OFID	0	Oxy Percent
56	ETBE by OFID	0	Volume Percent
534	Ethanol by OFID	0	Oxy Percent
532	Ethanol by OFID	0	Volume Percent
57	TAME by OFID	2.94	Volume Percent
572	TAME by OFID	0.485	Oxy Percent
421	Sulfur in Gasoline by ASTM D 2622	90	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	9.919	PSIA
65	Percent Evaporated at 200 Degrees F	54.899	Volume Percent
66	Percent Evaporated at 300 Degrees F	88.599	Volume Percent
48	Aromatics in Gasoline MSD D5769	25.574	Volume Percent
49	Olefins in by FIA D-1319-93	13.004	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.915	Volume Percent
46	Aromatics by FIA D-1319-93	19.19	Volume Percent
63	Benzene in Gasoline by MSD D5769	1.018	Volume Percent
531	Ethanol by MSD (Screen)	0	Volume Percent
551	MTBE by MSD (Screen)	13.13	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	3.58	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.73804	60/60F
692	Degrees API	60.22	Degrees API
691	Density @ 60 deg F	0.73732	g/cm^3 @ 60 deg F
101	D 86 Initial Boiling Point	101	Degrees F
110	10 Percent	137.3	Degrees F
150	50 Percent	190.4	Degrees F
190	90 Percent	303.3	Degrees F
200	End Point	368.3	Degrees F
201	Residue	1	ml
202	Total Recovery	98.09	ml
203	Loss	0.9	ml
541	Methanol by MSD (Screen)	0	Volume Percent
592	Volume Percent Oxygenates by MSD	16.71	Volume Percent
591	Weight Percent Oxygen by MSD	2.79	Weight Percent
543	Methanol by OFID	0	Volume Percent
585	t-Butanol by OFID	0.04	Volume Percent
587	sec-Butanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0.01	Volume Percent
5802	n-Butanol by OFID	0.04	Volume Percent
593	Volume Percent Oxygenates by OFID	13.59	Volume Percent
59	Weight Percent Oxygen by OFID	2.44	Weight Percent
32	Weight Fraction Carbon ASTM D 3343-95	0.8598	Weight Fraction
73	Net Heat of Combustion ASTM D 3338-92	18605	BTU per Pound

NVFEL Fuel Analysis - H7

FTAG: 7662 Phillips fuel sample D-517 - RFG2 - 6/29/98

CODE	TEST	RESULT	UNITS
55	MTBE by OFID	11.34	Volume Percent
552	MTBE by OFID	2.068	Oxy Percent
56	ETBE by OFID	0	Volume Percent
562	ETBE by OFID	0	Oxy Percent
532	Ethanol by OFID	0	Volume Percent
534	Ethanol by OFID	0	Oxy Percent
572	TAME by OFID	0	Oxy Percent
57	TAME by OFID	0	Volume Percent
421	Sulfur in Gasoline by ASTM D 2622	121	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	6.66	PSIA
65	Percent Evaporated at 200 Degrees F	46.899	Volume Percent
66	Percent Evaporated at 300 Degrees F	87.4	Volume Percent
48	Aromatics in Gasoline MSD D5769	28.285	Volume Percent
49	Olefins in by FIA D-1319-93	11.335	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	1.0689	Volume Percent
46	Aromatics by FIA D-1319-93	21.3	Volume Percent
63	Benzene in Gasoline by MSD D5769	1.181	Volume Percent
531	Ethanol by MSD (Screen)	0	Volume Percent
551	MTBE by MSD (Screen)	13.45	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.742779	60/60F
692	Degrees API	59	Degrees API
691	Density @ 60 deg F	0.742049	g/cm^3 @ 60 deg F
101	D 86 Initial Boiling Point	100.29	Degrees F
110	10 Percent	140.59	Degrees F
150	50 Percent	206.3	Degrees F
190	90 Percent	311.19	Degrees F
200	End Point	372.39	Degrees F
201	Residue	0.69	ml
202	Total Recovery	98.09	ml
203	Loss	1.19	ml
541	Methanol by MSD (Screen)	0	Volume Percent
592	Volume Percent Oxygenates by MSD	13.45	Volume Percent
591	Weight Percent Oxygen by MSD	2.24	Weight Percent
543	Methanol by OFID	0	Volume Percent
585	t-Butanol by OFID	0.05	Volume Percent
587	sec-Butanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0.01	Volume Percent
5802	n-Butanol by OFID	0.05	Volume Percent
593	Volume Percent Oxygenates by OFID	11.39	Volume Percent
59	Weight Percent Oxygen by OFID	2.08	Weight Percent
32	Weight Fraction Carbon ASTM D 3343-95	0.8613	Weight Fraction
73	Net Heat of Combustion ASTM D 3338-92	18570	BTU per Pound

NVFEL Fuel Analysis - H8

FTAG: 7870 Houston test fuel - sample A - RFG2 - 9/4/98

CODE	TEST	RESULT	UNITS
552	MTBE by OFID	2.045	Oxy Percent
55	MTBE by OFID	11.22	Volume Percent
562	ETBE by OFID	0	Oxy Percent
56	ETBE by OFID	0	Volume Percent
534	Ethanol by OFID	0	Oxy Percent
532	Ethanol by OFID	0	Volume Percent
572	TAME by OFID	0	Oxy Percent
57	TAME by OFID	0	Volume Percent
421	Sulfur in Gasoline by ASTM D 2622	133	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	7.059	PSIA
62	Vapor Pressure by Appendix E Method 3	7.03	PSIA
65	Percent Evaporated at 200 Degrees F	46.2	Volume Percent
66	Percent Evaporated at 300 Degrees F	86.7	Volume Percent
48	Aromatics in Gasoline MSD D5769	24.283	Volume Percent
49	Olefins in by FIA D-1319-93	12.042	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.9939	Volume Percent
46	Aromatics by FIA D-1319-93	21.89	Volume Percent
63	Benzene in Gasoline by MSD D5769	1.125	Volume Percent
531	Ethanol by MSD (Screen)	0	Volume Percent
551	MTBE by MSD (Screen)	7.75	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.74319	60/60F
692	Degrees API	58.89	Degrees API
691	Density @ 60 deg F	0.74246	g/cm^3 @ 60 deg F deg F
101	D 86 Initial Boiling Point	104.7	Degrees F
110	10 Percent	143.4	Degrees F
150	50 Percent	207.69	Degrees F
190	90 Percent	311.19	Degrees F
200	End Point	382.5	Degrees F
201	Residue	1.1	ml
202	Total Recovery	98	ml
203	Loss	0.9	ml
592	Volume Percent Oxygenates by MSD	7.75	Volume Percent
541	Methanol by MSD (Screen)	0	Volume Percent
591	Weight Percent Oxygen by MSD	1.4	Weight Percent
543	Methanol by OFID	0.07	Volume Percent
585	t-Butanol by OFID	0.05	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0.01	Volume Percent
5802	n-Butanol by OFID	0.05	Volume Percent
593	Volume Percent Oxygenates by OFID	11.35	Volume Percent
59	Weight Percent Oxygen by OFID	2.09	Weight Percent
227	Gum Content Washed	0.2	mg/100ml
228	Gum Content Unwashed	17.6	mg/100ml
229	Peroxides	0	Weight Percent

NVFEL Fuel Analysis - H9

FTAG: 7871 Houston control fuel - sample B - commercial RFG1 - 9/4/98

CODE	TEST	RESULT	UNITS
552	MTBE by OFID	1.626	Oxy Percent
55	MTBE by OFID	8.94	Volume Percent
56	ETBE by OFID	0	Volume Percent
562	ETBE by OFID	0	Oxy Percent
534	Ethanol by OFID	0	Oxy Percent
532	Ethanol by OFID	0	Volume Percent
572	TAME by OFID	0.082	Oxy Percent
57	TAME by OFID	0.5	Volume Percent
421	Sulfur in Gasoline by ASTM D 2622	165	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	7.12	PSIA
62	Vapor Pressure by Appendix E Method 3	7.11	PSIA
65	Percent Evaporated at 200 Degrees F	51.899	Volume Percent
66	Percent Evaporated at 300 Degrees F	80.599	Volume Percent
48	Aromatics in Gasoline MSD D5769	24.271	Volume Percent
49	Olefins in by FIA D-1319-93	18.604	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.4829	Volume Percent
46	Aromatics by FIA D-1319-93	23.69	Volume Percent
63	Benzene in Gasoline by MSD D5769	0.52	Volume Percent
531	Ethanol by MSD (Screen)	0	Volume Percent
551	MTBE by MSD (Screen)	6.85	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0.5	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.744839	60/60F
692	Degrees API	58.47	Degrees API
691	Density @ 60 deg F	0.744099	g/cm^3 @ 60 deg F
			deg F
101	D 86 Initial Boiling Point	103.4	Degrees F
110	10 Percent	137.69	Degrees F
150	50 Percent	195.69	Degrees F
190	90 Percent	344.39	Degrees F
200	End Point	420.1	Degrees F
201	Residue	0.8	ml
202	Total Recovery	98.09	ml
203	Loss	1.1	ml
592	Volume Percent Oxygenates by MSD	7.62	Volume Percent
541	Methanol by MSD (Screen)	0	Volume Percent
591	Weight Percent Oxygen by MSD	1.4	Weight Percent
543	Methanol by OFID	0.06	Volume Percent
585	t-Butanol by OFID	0.05	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0.01	Volume Percent
5802	n-Butanol by OFID	0.05	Volume Percent
593	Volume Percent Oxygenates by OFID	9.57	Volume Percent
59	Weight Percent Oxygen by OFID	1.75	Weight Percent
227	Gum Content Washed	0.59	mg/100ml
228	Gum Content Unwashed	10	mg/100ml
229	Peroxides	0	Weight Percent

NVFEL Fuel Analysis - H10

FTAG: 7872 Houston control fuel - sample C - commercial RFG1 - 9/4/98

CODE	TEST	RESULT	UNITS
55	MTBE by OFID	8.96	Volume Percent
552	MTBE by OFID	1.631	Oxy Percent
56	ETBE by OFID	0	Volume Percent
562	ETBE by OFID	0	Oxy Percent
534	Ethanol by OFID	0	Oxy Percent
532	Ethanol by OFID	0	Volume Percent
572	TAME by OFID	0.079	Oxy Percent
57	TAME by OFID	0.48	Volume Percent
421	Sulfur in Gasoline by ASTM D 2622	105	Parts Per Million
62	Vapor Pressure by Appendix E Method 3	7.08	PSIA
62	Vapor Pressure by Appendix E Method 3	7.08	PSIA
65	Percent Evaporated at 200 Degrees F	52.399	Volume Percent
66	Percent Evaporated at 300 Degrees F	81.599	Volume Percent
48	Aromatics in Gasoline MSD D5769	25.009	Volume Percent
49	Olefins in by FIA D-1319-93	17.828	Volume Percent
64	Benzene in Gasoline by ASTM D 3606	0.4769	Volume Percent
63	Benzene in Gasoline by MSD D5769	0.519	Volume Percent
46	Aromatics by FIA D-1319-93	23.1	Volume Percent
531	Ethanol by MSD (Screen)	0	Volume Percent
551	MTBE by MSD (Screen)	6.86	Volume Percent
561	ETBE by MSD (Screen)	0	Volume Percent
571	TAME by MSD (Screen)	0.53	Volume Percent
69	Specific Gravity @ 60 Degrees F	0.7449	60/60F
692	Degrees API	58.45	Degrees API
691	Density @ 60 deg F	0.744169	g/cm^3 @ 60 deg F
101	D 86 Initial Boiling Point	104.09	Degrees F
110	10 Percent	135.69	Degrees F
150	50 Percent	194.5	Degrees F
190	90 Percent	343.89	Degrees F
200	End Point	415.5	Degrees F
201	Residue	0.8	ml
202	Total Recovery	97.7	ml
203	Loss	1.5	ml
592	Volume Percent Oxygenates by MSD	7.67	Volume Percent
541	Methanol by MSD (Screen)	0	Volume Percent
591	Weight Percent Oxygen by MSD	1.4	Weight Percent
543	Methanol by OFID	0.06	Volume Percent
585	t-Butanol by OFID	0.05	Volume Percent
586	n-Propanol by OFID	0	Volume Percent
588	DIPE by OFID	0	Volume Percent
589	Isobutanol by OFID	0.01	Volume Percent
5802	n-Butanol by OFID	0.05	Volume Percent
593	Volume Percent Oxygenates by OFID	9.57	Volume Percent
59	Weight Percent Oxygen by OFID	1.75	Weight Percent
226	Acidity as Acetic Acid	0.001	Weight Percent

Appendix I

Temperatures at Boston/Logan airport: March - August 1998

Date	Min	Max	Date	Min	Max	Date	Min	Max	Date	Min	Max	Date	Min	Max	Date	Min	Max
March			April			May			June			July			August		
10	38	61	1	39	71	1	54	72	1	57	79	1	63	77	1	63	75
11	21	35	2	39	45	2	50	66	2	53	73	2	61	82	2	62	82
12	17	27	3	41	55	3	48	58	3	52	74	3	60	82	3	66	84
13	10	36	4	37	49	4	45	54	4	48	65	4	66	80	4	65	85
14	28	39	5	36	45	5	51	63	5	52	72	5	64	74	5	64	79
15	29	40	6	39	54	6	51	59	6	52	71	6	63	76	6	64	81
16	27	37	7	43	64	7	52	59	7	55	69	7	63	76	7	66	78
17	27	37	8	41	59	8	52	57	8	53	65	8	64	72	8	66	82
18	32	41	9	40	53	9	50	55	9	52	72	9	62	75	9	68	88
19	32	41	10	34	54	10	48	55	10	57	79	10	66	81	10	68	88
20	35	37	11	34	54	11	46	54	11	54	75	11	63	77	11	69	88
21	30	36	12	37	50	12	46	53	12	54	65	12	62	77	12	61	73
22	28	34	13	41	57	13	43	49	13	57	64	13	63	86	13	59	71
23	30	41	14	40	59	14	41	52	14	55	72	14	70	90	14	63	82
24	34	46	15	41	56	15	46	66	15	61	80	15	70	91	15	62	84
25	30	46	16	44	59	16	46	68	16	55	64	15	70	91	16	77	84
26	36	59	17	48	61	17	50	66	17	55	64	16	70	91	17	64	78
27	46	79	18	45	64	18	54	82	18	59	72	17	73	90	18	64	86
28	55	85	19	44	65	19	54	83	19	59	70	18	72	88	19	59	73
29	55	85	20	45	54	20	54	77	20	59	70	19	63	81	20	57	72
30	46	79	21	43	64	21	59	81	21	59	68	20	70	84	21	64	75
31	64	88	22	41	65	22	50	70	22	57	70	21	72	90	22	63	79
			23	45	63	23	54	75	23	62	73	22	73	93	23	64	81
			24	43	57	24	57	81	24	68	82	23	71	93	24	70	91
			25	43	59	25	55	77	25	70	88	24	71	92	25	69	92
			26	39	53	26	55	80	26	70	88	25	63	81	26	70	82
			27	39	52	27	55	79	27	64	83	26	63	81	27	71	82
			28	39	61	28	59	85	28	57	66	27	64	82	28	64	77
			29	46	72	29	66	90	29	60	75	28	64	85	29	64	78
			30	57	79	30	64	86	30	60	76	29	73	88	30	64	84
						31	57	80				30	68	82	31	65	85

Note: All temperatures in degrees Fahrenheit

Temperatures at Chicago/O'Hare airport: March - August 1998

Date	Min	Max	Date	Min	Max	Date	Min	Max	Date	Min	Max	Date	Min	Max	Date	Min	Max
March			April			May			June			July			August		
10	13	23	1	38	49	1	52	65	1	51	74	1	59	80	1	59	84
11	13	22	2	38	50	2	51	63	2	47	78	2	60	86	2	63	84
12	10	26	3	37	45	3	49	56	3	48	61	3	69	88	3	72	84
13	19	38	4	32	49	4	48	72	4	47	65	4	63	75	4	68	80
14	22	33	5	29	52	5	54	69	5	42	58	5	62	78	5	71	81
15	22	32	6	33	62	6	58	77	6	43	64	6	68	87	6	72	82
16	24	36	7	44	60	7	55	59	7	45	70	7	67	77	7	72	78
17	33	39	8	43	52	8	52	71	8	43	69	8	66	81	8	70	81
18	38	52	9	41	45	9	50	65	9	58	64	9	64	85	9	70	84
19	34	39	10	35	57	10	48	68	10	60	75	10	64	81	10	72	88
20	33	36	11	34	66	11	49	72	11	60	76	11	60	81	11	64	79
21	31	43	12	55	73	12	47	79	12	64	84	12	57	84	12	64	77
22	26	46	13	55	68	13	56	79	13	60	78	13	60	86	13	64	81
23	31	45	14	48	68	14	52	84	14	58	76	14	66	90	14	61	82
24	28	52	15	44	61	15	64	86	15	61	78	15	70	88	15	66	79
25	42	59	16	36	48	16	62	82	16	60	80	16	72	88	16	77	82
26	60	75	17	34	55	17	50	86	17	62	84	17	66	84	17	66	82
27	56	77	18	39	60	18	62	90	18	64	89	18	66	88	18	70	80
28	49	65	19	41	62	19	66	91	19	64	82	19	70	91	19	61	79
29	44	79	20	39	65	20	54	75	20	64	91	20	67	91	20	61	86
30	66	79	21	47	53	21	51	77	21	69	88	21	76	94	21	72	88
31	45	72	22	43	63	22	53	60	22	61	86	22	70	81	22	72	84
			23	40	72	23	54	68	23	61	87	23	65	81	23	70	90
			24	49	75	24	54	67	24	71	94	24	62	82	24	66	87
			25	43	68	25	51	72	25	70	95	25	57	82	25	70	84
			26	41	54	26	47	78	26	70	87	26	56	83	26	64	84
			27	37	52	27	50	83	27	69	95	27	64	83	27	64	81
			28	34	57	28	60	90	28	68	88	28	63	89	28	64	77
			29	46	62	29	64	83	29	67	86	29	63	86	29	66	84
			30	50	59	30	58	87	30	64	83	30	65	79	30	64	81
						31	57	82				31	62	79	31	57	81

(Note: All temperatures in degrees Fahrenheit)

Temperatures at Houston Hobby airport: June - September 1998

Date	Min	Max	Date	Min	Max	Date	Min	Max	Date	Min	Max
June			July			August			September		
1	75	99	1	79	97	1	76	101	1	73	92
2	74	97	2	77	94	2	77	100	2	75	94
3	81	93	3	77	86	3	81	100	3	79	97
4	81	95	4	79	93	4	75	99	4	75	93
5	82	94	5	77	95	5	80	99	5	73	93
6	71	87	6	75	97	6	77	95	6	75	88
7	72	88	7	75	96	7	73	86	7	73	89
8	79	92	8	77	95	8	78	96	8	75	88
9	79	93	9	79	97	9	77	99	9	75	90
10	81	95	10	78	99	10	76	98	10	73	81
11	81	95	11	77	99	11	77	98	11	75	86
12	81	97	12	78	99	12	77	97	12	75	82
13	78	100	13	79	97	13	78	99	13	75	87
14	79	100	14	73	99	14	75	86	14	78	90
15	79	100	15	75	99	15	75	90	15	77	82
16	78	98	16	77	100	16	85	90			
17	81	93	17	79	102	17	75	93			
18	82	95	18	71	96	18	78	89			
19	80	97	19	77	95	19	75	94			
20	79	97	20	77	95	20	77	94			
21	76	99	21	76	94	21	73	86			
22	75	96	22	78	95	22	77	82			
23	77	97	23	77	97	23	77	88			
24	77	97	24	77	97	24	77	91			
25	77	96	25	78	96	25	78	93			
26	79	91	26	76	97	26	78	94			
27	79	95	27	80	98	27	76	96			
28	73	86	28	77	95	28	78	97			
29	75	93	29	77	98	29	78	99			
30	79	93	30	77	97	30	79	90			
			31	75	100	31	75	91			

(Note: All temperatures in degrees Fahrenheit)

Appendix J

Fuel Economy and Quality
Vehicle Environmental Engineering
Tel (313) 594 3179
Fax (313) 390 0382

November 2, 1998

To Debbie Wood - U.S EPA

cc Larry Haslett - U.S EPA
Jim Steiger - AAMA

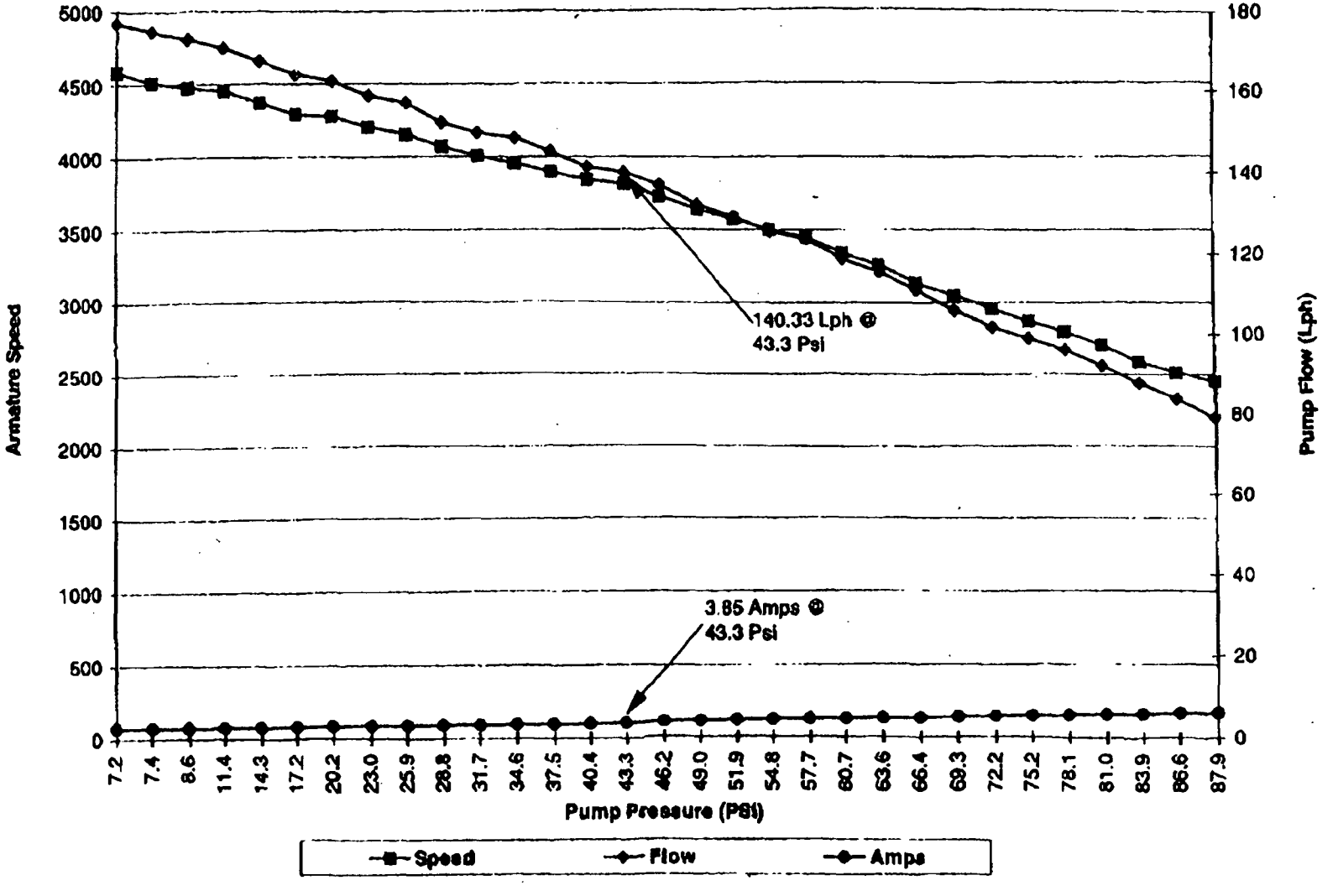
Subject Boston Police Ford Bronco Fuel Pump Failure

Debbie, the Visteon fuel handling department which design and test fuel pumps for Ford have analyzed the returned pump which had operated on Federal Phase 2 gasoline. As the attached test sheet indicates the pump performance is still within our specification and suitable for use.

Further examination of the pump showed that the fitting which screws into the pump outlet tube was damaged and is a likely source of the leak experienced. This in our opinion is a mechanical failure not attributable to the quality of the fuel being used. In summary, Federal Phase 2 gasoline played no part in this failure.

Regards Gary P Smith

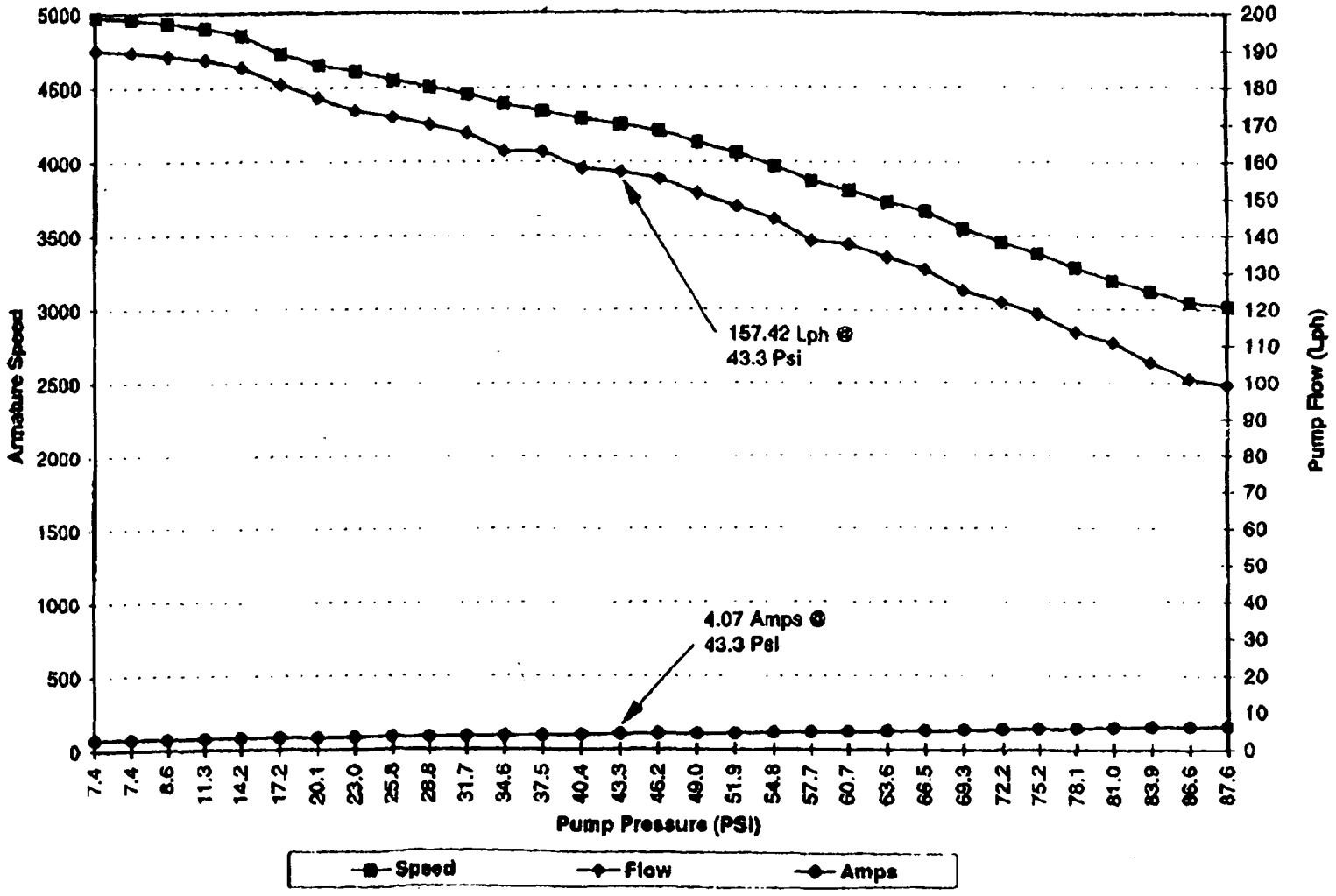
Fleet Return - 88MV Bronco/ Bosch Fuel pump
Part# E7TF-9350-AA
(12 Volt sweep)



Jim Martell
AVT/PCSD- Fuel Delivery

11:48 AM
9/11/98

Fleet Return - 8... Y Bronco/Bosch Fuel pump
Part# E7TF-9350-AA
(13.2 Volt sweep)



Jim Martell
AVT/PCSD Fuel Delivery

11:51 AM
9/11/98

Appendix K

General Motors
Public Policy Center

September 3, 1998
FE-6235

Ms. Deborah K. Wood
Assistant Director, Fuels and Energy Division
Office of Mobile Sources
U.S. Environmental Protection Agency
401 K Street, S.W.
Washington, DC 20460

Dear Ms. Wood:

Re: Fuel Pump Failures During Federal Phase II RFG Testing in Village of Elk Grove, IL, Fleet Vehicles

At the request of your office, General Motors fuel systems personnel examined three fuel pumps that failed during the Federal Phase II RFG test program. The three fuel pumps were from General Motors vehicles operated by the Village of Elk Grove, IL, and were shipped to us from that test fleet.

Two of the pumps were General Motors Delphi rollervane pumps. We were informed that these two pumps were from Chevrolet Caprice police vehicles, a 1995 model with 85,000 miles and a 1996 model with 56,000 miles at the time of failure. It is not known if these pumps were the original production pumps supplied when the vehicle was assembled, but these mileages would indicate that they probably are.

Both rollervane pumps failed because of severe corrosion of the positive brush shunt wire. In both pumps the wire had corroded away entirely leaving the brush spring to carry the pump current, causing the spring to fail eventually because of overheating. The first pump received, from the 1995 vehicle, also displayed severe wear of the copper commutator. The commutator on the other pump was also worn abnormally but not as severely.

The severe positive shunt wire corrosion in the two pumps is typical of previously observed field results during longer-term exposure to gasoline containing reactive sulfur compounds (most often a sulfide, but not exclusively). These compounds corrode copper and, if present, would not allow the gasoline in question to meet ASTM standards for copper strip corrosion. The black deposits on the commutators of both pumps also can be attributed to copper corrosion by reactive sulfur compounds but this was not verified by analysis. The commutator wear was probably also caused by copper corrosion; high levels of peroxides in fuel also can cause the same type of commutator wear, but do not usually cause shunt wire failure. Our conclusion is that a high level of corrosion probably

General Motors Corporation
General Motors Building 3044 West Grand Boulevard Detroit, Michigan 4820
Mail Code 482-112-257 Facsimile # (313) 556-9002 Phone # (313) 556-772

was present in both of these rollervane pumps at the start of the Phase II RFG testing, and the failures are coincidental to the use of reformulated gasoline.

The third pump was a large capacity diaphragm pump used on carbureted fuel systems, which was removed from a 1981 Chevrolet Step Van at 66,000 miles. The diaphragm pump has the markings E L5 and 40987 but is of unknown manufacture, and is not the original equipment component, in our estimation. This pump showed no obvious signs of failure except for an oil leak and possibly an extruded seal. The oil leak was not caused as a result of fuel composition. The extruded seal could be the result of excessive swell; which may be caused by the presence of oxygenates or by excessively high aromatic content or a combination. The apparent extrusion could also be due to an assembly problem. If the seal in question were not sealing properly, it would cause internal fuel leakage and siphoning of the fuel back to the fuel tank. In the most extreme case, the pump would have either reduced or no delivery capacity. If the seal extruded because of excessive swell, this could have occurred in the short duration of the Phase II RFG testing. However, it seems more likely that the failures of both the rollervane and the diaphragm pumps was coincidental to the Phase II RFG use and not related to the use of Phase II RFG.

If I can provide further information, please don't hesitate to call me at (313) 556-7723.

Sincerely,

Gerald J. Barnes

Gerald J. Barnes, Manager
Clean Fuels Activities

General Motors Corporation

General Motors Building *3044 West Grand Boulevard* *Detroit, Michigan 48202*
Mail Code 482-112-257 *Facsimile # (313) 556-9002* *Phone # (313) 556-7[redacted]3*

General Motors
Public Policy Center

September 23, 1998
FE-6239

Ms. Deborah K. Wood
Assistant Director, Fuels and Energy Division
Office of Mobile Sources
U.S. Environmental Protection Agency
401 K Street, S.W.
Washington, DC 20460

Dear Ms. Wood:

Re: Fuel Pump Failures During Federal Phase II RFG Testing in Houston, TX Fleet Vehicles

General Motors fuel systems personnel examined four fuel pumps that failed during the EPA Federal Phase II RFG test program in Houston, TX. All four fuel pumps were of in-tank twin turbine design from 1993 Chevrolet S10 pickups; these vehicles operated on both Phase II RFG test fuel and on the control fuel in the Houston test program, as shown below.

Vehicle #	Mileage	Fuel
1047	82,553	Phase II RFG
1051	72,771	Control
1113	81,998	Control
1249	86,589	Control

Upon receipt, all pumps were checked for free rotation and electrical conductivity before disassembly. No indication of binding was seen in any of the four pumps. However, resistance across the power leads was high for all four samples. This is consistent with the high wear observed on the pump motor commutator upon disassembly. The brushes showed normal wear, however. In addition, the aluminum housing of the pump was covered with fuel gum deposits, imparting a gold color to the pump housing.

The heavy commutator wear coupled with normal brush wear suggest that all four pumps failed due to operation on peroxidized (sour) fuel. The gum deposits on the pump housing are also consistent with this conclusion. This type of failure usually occurs quite quickly, depending on the level the peroxides reach in the fuel in use. Since the failures occurred in both the Phase II RFG and the control fuels, they seem more likely related either to the fuel dispensing system or to vehicle operating factors leading to oxidation of the fuel, rather than to the base composition of either fuel.

General Motors Corporation
General Motors Building *3044 West Grand Boulevard* *Detroit, Michigan 482*
Mail Code 482-112-257 *Facsimile # (313) 556-9002* *Phone # (313) 556-77*

General Motors
Public Policy Center

Peroxidized fuel can result from a number of factors, including poor oxidation stability of the base fuel, long fuel storage time, high storage temperatures, contact with air (such as in a partially filled vehicle or storage fuel tank), or a combination of these factors. Peroxides form by a free radical chain reaction and tend to increase in concentration once present in fuel storage tanks if the right reaction conditions continue to exist. This could lead to a "carry-over" effect in fuel storage systems, if the conditions for peroxide formation continue to exist, even with uncontaminated batches of new fuel. Contact with copper catalyzes the oxidation reaction, and the peroxides produced are very corrosive to copper such as the pump commutator in the failed pumps.

As we discussed with Mr. Haslett, we would suggest that the fleet operator check the current batches of Phase II RFG and control fuels for peroxide, washed gum and acid levels. Levels of peroxides (above 50 ppm by ASTM D 3703) would be of concern, as would washed gum levels above 10 mg/100 ml (ASTM D 381). High acid levels (above about 10 ppm by ASTM D1613) indicate the fuel has probably oxidized even if peroxide levels are relatively low. If high peroxide levels are found in the fuels used in the Houston fleet, it probably is advisable to dispose of the fuel and take steps to reduce the factors that lead to fuel oxidation. The operator may want to consider use of an oxidation inhibitor such as Sta-bil, particularly during the higher temperature summer months.

If I can provide further information, please don't hesitate to call me at (313) 556-7723.

Sincerely,

Gerald J. Barnes

Gerald J. Barnes, Manager
Clean Fuels Activities

c: Lawrence Haslett, EPA

General Motors Corporation

General Motors Building *3044 West Grand Boulevard* *Detroit, Michigan 48202*
Mail Code 482-112-257 *Facsimile # (313) 556-9002* *Phone # (313) 556-77*

Appendix L

February 22, 1999

Deborah K. Wood, Acting Director
Fuels and Energy Division
USEPA (6406)
Washington, DC 20460
Fx: 202-565-2084

Ms. Wood,

During our testing of phase II reformulated gasoline, we experienced four (4) fuel pump failures. Because the test period covered five to six months, I don't consider this number of failures to be out of the ordinary for a fleet of our size. While I do not have detailed records on the historical rate of fuel pump replacements in the Elk Grove Village fleet, it is my opinion, based on my experience, that the number of failures we expected during this program was normal. It is customary to replace fuel pumps on vehicles that have accumulated more than 60,000 miles. While this is not a planned event in the life of any vehicle, experience has shown that it can be expected. Generally, we are not concerned about fuel pump failures that occur after 60,000 miles.

As I have stated previously, the testing of the phase II RFG was basically transparent to our users. Even the mechanical staff saw no change or affect.

I hope these comments will assist you in your endeavor to conclude your report on the testing program. Should you require any further information, data or comments please do not hesitate to call me.

It has truly been a pleasure working with you and the rest of the EPA staff. Thanks again for the opportunity to assist the EPA in this program. If there is an opportunity to participate in any other future testing please keep us in mind.

Respectfully,

Jack Gray

Jack Gray
Superintendent of Building & Fleet Services
Village of Elk Grove Village
1635 Biesterfield Road
Elk Grove Village, IL. 60007
847-734-8080

FEB-22-99 MON 12:41 JACK GRAY - ELK GROVE FAX NO. 8473528953 P. 01/02

Appendix M

SOUTHWEST RESEARCH INSTITUTE
Post Office Drawer 28510, 6220 Culebra Road
San Antonio, Texas 78238

AUTOMOTIVE PRODUCTS AND EMISSIONS RESEARCH DIVISION

ON-ROAD STUDY OF THE EFFECTS OF PHASE II REFORMULATED GASOLINE ON FUEL ECONOMY

Prepared by

Randell Honc

FINAL REPORT
SwRI Project No. 08-7601-025

Prepared for

Environmental Protection Agency

July 1998

Approved:

Kevin Brunner
Manager
Fuel Technology & Product
Development Section

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EXECUTIVE SUMMARY

Southwest Research Institute (SwRI) conducted an on-road study of the fuel economy effects of Phase II reformulated gasoline (Phase II RFG) compared to Phase I reformulated gasoline (Phase I RFG). Fuel economy was measured for a group of vehicles of various makes, ages, mileage, and fuel delivery systems. Twelve vehicles were driven over fixed 50-mile urban and suburban routes. Fuel usage was determined by measuring the total volume of fuel consumed during the 50-mile route using a flow meter to precisely measure volume and temperature. The results in this study do not indicate any statistically significant fuel economy difference between the fuels.

The outcome of this study is consistent with other fuel economy studies. Fuel economy is generally proportional to the energy content of the fuel[1]. During the past few years, studies of the fuel economy effects of reformulated gasolines with oxygenates[123], including laboratory and on-road studies, have shown that the addition of two percent oxygen by weight to gasoline results in a one to three percent fuel economy loss[3]. In this study, both gasolines have essentially the same oxygen content and the same energy content. Since the energy content difference between Phase I RFG and Phase II RFG is expected to be minimal, no impact on the fuel economy measured in this study was expected.

This study was designed to minimize the effects of the fuel economy variables that are normally present in every day driving. The key variables include differences in personal driving habits, weather (temperature, wind effects, and precipitation), traffic patterns (e.g. rush hour versus weekend, and highway versus city driving), number of passengers, vehicle condition, and changes in tire pressure. The relative effect of many of these variables can be expected to exceed any reduction due to using reformulated gasoline[45].

INTRODUCTION

Southwest Research Institute (SwRI) conducted this test program to obtain on-road fuel economy measurements that compare summer-grade Phase II reformulated gasoline (Phase II RFG) with summer-grade Phase I reformulated gasoline (Phase I RFG) at the request of the Environmental Protection Agency (EPA). The Phase II RFG properties are representative of the fuel that will be sold beginning in the year 2000. The Phase I RFG was a commercially available summer-grade gasoline obtained in the Houston area. Both fuels used MTBE as the oxygenate, and the oxygen levels were equivalent.

BACKGROUND

The Fuels and Energy Division (FED) within the Office of Mobile Sources (OMS) is responsible for developing, implementing, and assuring compliance with national programs that reduce air pollution from highway and nonroad sources through fuel and fuel-related emission controls. FED develops regulations, policies, guidance, studies, and reports to Congress. FED provides fuel-related support to other divisions within OMS and to other EPA offices, federal and state organizations, and external groups. FED is responsible for identifying environmental benefits, costs, and other effects (e.g. U.S. trade balance impacts, energy security impacts, fuel safety, vehicle compatibility, full life cycle emissions) associated with fuels. FED performs these assessments for petroleum-based fuels as well as for alternative fuels. FED reviews applications for fuel waiver requests, collaborates with state and regional offices on oxygenated fuel responsibilities, and oversees the registration program. The coordination of energy policy for OMS is also a function of the division.

One of the requirements of the 1990 Clean Air Act Amendments that FED implements is the reformulated gasoline (RFG) program. The purpose of the RFG program is to improve air quality by requiring that gasoline sold in certain areas of the country be reformulated to reduce emissions of toxics and tropospheric ozone-forming volatile organic compounds (VOCs), as specified by section 211(k). Section 211(k) mandates that RFG must be sold in any ozone nonattainment area classified as severe, and in other ozone nonattainment areas that choose to participate or "opt in" to the program. The RFG program was implemented in two phases. Phase I RFG was required to be used in the specified RFG areas beginning in January 1995. It will be replaced by Phase II RFG in January 2000. Phase II RFG is formulated to achieve even greater reductions in VOCs, oxides of nitrogen (NOx), and toxics than Phase I.

TEST PROCEDURES

The objective of the study was to provide on-road fuel economy measurements that compare summer-grade Phase II RFG with summer-grade Phase I RFG. The Society of Automotive Engineers (SAE) standard, Fuel Economy Measurement Test Procedure – SAE J1082, is essentially designed to provide the type of measurements desired. That standard was used as a guide for this study. Certain parameters, such as maximum ambient temperature and test repeatability limits, various vehicle inspection and operating ranges, were not followed because of resource limitations and because they were expected to have a minimal impact on the outcome of this study. The number of vehicles, tests, and variables in this study indicated that the focus of the analysis should be on comparing fleet fuel economies, determined from total fuel consumption of all the vehicles, rather than comparing the fuel economies on individual vehicles. There is insufficient information for robust vehicle-by-vehicle comparisons. The statistical treatment of the data has focused on detecting fleet effects.

A. Vehicle Selection

The test program was conducted on twelve (12) in-use vehicles distributed, subject to availability, to cover the span of model years from 1989 through 1997. Eight of the vehicles were passenger cars, both domestic and imported, compact to full-size, and including four, six, and eight cylinder engines. The remaining four (4) vehicles were utility vehicles, three domestic and one imported model. They included a minivan, a sport utility vehicle, and two light-duty trucks. The engines included four, six, and eight cylinder models. The range of fuel delivery systems, carburetted, throttle-body injected (TBI), and port-fuel injected (PFI) were represented. There were two throttle-body injection, nine port-fuel injection, and one carburetted vehicle. A description of the test vehicles is presented in Appendix A.

Prior to testing, each vehicle was inspected and repaired or adjusted to ensure that the vehicle was in proper running order. The inspections included items specified by the vehicle preparation form in SAE Procedure J1082 "Fuel Economy Measurement Road Test Procedure". Vehicles that failed this inspection were excluded from testing. The maximum tread wear limitation and minimum engine oil age could not be verified in most cases but were checked; the vehicle was excluded if they were deemed inappropriate. A copy of the vehicle inspection form is presented in Appendix B.

B. Vehicle Preparation

Upon successful completion of the inspection, the vehicle was equipped with auxiliary fuel supply lines with quick-disconnects to allow for installation of a Max 710 Fuel Measurement System just prior to testing. The Max 710 Fuel Measurement System uses a positive displacement flow meter capable of measuring fuel consumption with ± 0.5% accuracy and 0.1% repeatability.

A bubble tank removed vapor bubbles to stabilize volumetric delivery to the flowmeter that increased measurement accuracy. Since fuel volume increases slightly as temperature rises, fuel temperature was monitored just prior to measurement by the flowmeter. Fuel consumption was later corrected for changes in density for the given temperatures. A recovery tank collected the return fuel from the engine so the flowmeter only measured make-up fuel as it replaced the fuel consumed by the engine.

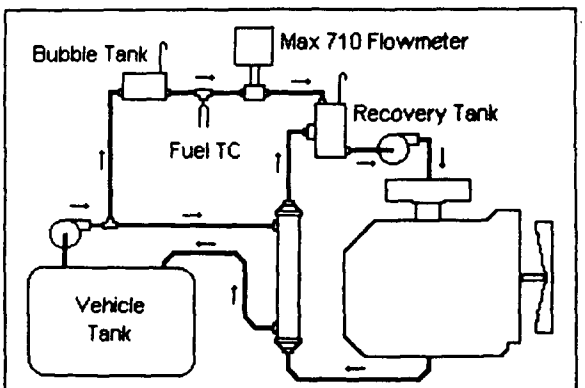


Fig. 1 Max 710 Fuel Measurement System

The vehicle fuel tank was flushed and filled with the test fuel. The vehicle was preconditioned to allow those vehicles with adaptive learn capability to adjust to the test fuel. The preconditioning procedure outlined in CRC Designation E-15-97 "Technique for Determination of Octane Number Requirements of Light-Duty Vehicles" was performed using a Clayton Chassis Dynamometer. The vehicle was driven over the first 505 seconds of the Federal Test Procedure (FTP) emissions test cycle three times in order to achieve a ten-mile warm-up. The preconditioning was initiated with the ignition key turned to the off position for five seconds and returned to the off position for five seconds upon completion of each 505-second cycle. Each vehicle was preconditioned regardless of technology to minimize test variability.

C. Fuel

The test fuel used for this program was Phase II RFG (SwRI Code GA-3524). The test fuel was obtained from Phillips Chemical Company and was designated as Oxygenated Test Fuel (MF 6500 Lot D-517). The test fuel was used in EPA's RFG II fleet test program conducted in Boston, Chicago and Houston. The control fuel was Phase I RFG (SwRI Code GA-3520). The control fuel was obtained from a retail outlet in the Houston area. The fuels were dispensed from drums to the vehicles with a portable pump during the test. Analyses of both fuel properties are presented in Table 2 of Appendix C.

D. Test Routes and Mileage Accumulation

The fuel economy measurements were conducted over fixed road routes that approximate urban and suburban driving patterns. The urban driving cycle is 50 miles of low to moderate speeds with frequent stops. The suburban driving cycle is 50 miles of mostly moderate speeds with infrequent stops. The urban and suburban driving cycles were established using an instrumented vehicle with a calibrated speedometer.

Histograms of the urban and suburban driving cycle speeds are presented in Figures 2 and 3. Typical driving cycles are presented in Appendix D.

Fig. 2 Urban Driving Cycle Histogram

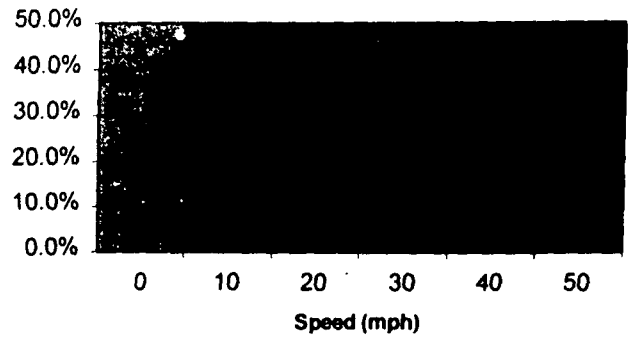
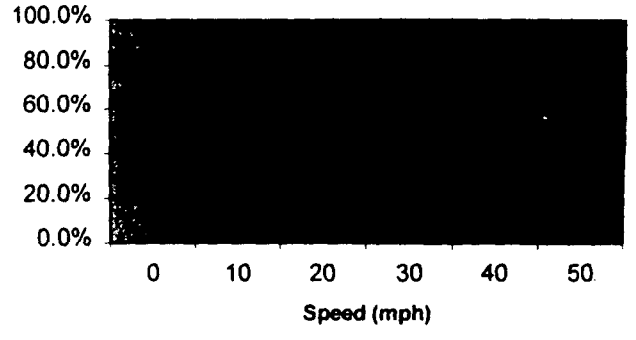


Fig. 3 Suburban Driving Cycle Histogram



Each vehicle was operated for 15 miles just prior to testing to bring the vehicle to operating temperature. Duplicate urban and suburban cycles were driven using each fuel. Driver variability was kept to a minimum by using the same driver for all testing. The vehicle air conditioner was operated at all times during testing since this is typical of summer driving. The air conditioner was turned on in the normal mode, set to a comfortable level, with low fan. Before the start of each driving cycle, the fuel volume meter was reset to zero and the fuel temperature recorded with the engine running. Upon completion of each driving cycle, the fuel volume (totalized) and temperature were recorded.

The vehicles were driven over the 50-mile urban and the 50-mile suburban road route once in the morning and again in the afternoon. Upon completion of each driving cycle, the fuel volume and temperature were recorded. To compensate for temperature effects, the fuel volume for each test was corrected to the standard reference conditions of 15.6 °C (60 °F).

RESULTS

The individual vehicle fuel economy and consumption data, corrected for fuel temperature, are given in Appendix E. Duplicate tests, two urban cycles and two suburban cycles were run using Phase I RFG, the control fuel; the sequence was repeated using Phase II RFG, the test fuel. The fuel consumed by each individual vehicle was added, within fuel types, to provide overall fuel economy numbers for the entire fleet. The fleet-wide fuel consumption data over both urban and suburban test cycles is shown in Appendix F.

Eleven of the twelve vehicles in the test program completed the test schedule, four tests on each of the two fuels. The twelfth vehicle, vehicle L, experienced mechanical problems (clutch failure) during testing and did not complete the eight tests. Five tests for vehicle L are shown in the individual vehicle fuel economy and consumption data tables in Appendix E. The fleet-wide fuel consumption was computed using the values from the first run of the urban and suburban driving cycles. The second run of the urban and suburban driving cycle for vehicle L was not included in the fleet average.

Table 6. Fleet Fuel Economy Results

	RFG I	RFG II
Total Fuel Consumed (Liters)	401.02	407.46
Total Distance Driven (km)	3700.70	3700.70
Fleet Fuel Economy (km/L)	9.23	9.08
Fleet Fuel Economy (mpg)	21.71	21.36
Difference (RFG II - RFG I) (km/L)	-0.146	
Difference (RFG II - RFG I) (mpg)	-0.343	

The difference in fleet fuel economies is the experimental result. In order to determine how closely it represents the true difference in fuel economies, a nonparametric statistical test[6] was used to determine whether the difference is likely to be real or the result of measurement variability.

To test the assumption of no difference in fleet fuel economies, the difference in individual fuel consumption rates (liters per kilometer) were compared in Appendix G, thereby weighting the individual differences in proportion to their overall fuel consumption. These consumption rates were then tested against the null hypothesis of no difference in fleet fuel economies. The hypothesis was not rejected therefore no difference in fleet fuel economy between Phase I RFG and Phase II RFG is indicated.

CONCLUSION

The results of this study show no significant change in fleet fuel economy when switching from Phase I RFG to Phase II RFG. The small difference in the fleet fuel economy cannot be attributed to the change in fuel. It may be due to variability that is inherent in the test method. Sources of such test-to-test variability that could not be entirely controlled in this experiment include differences in driver inputs, traffic patterns, and weather effects.

The *experimental* results produced a very small, statistically insignificant, difference between the fleet fuel economies. The statistical test used to determine significance also indicated that the difference between the fleet fuel economies would have to be almost twice as large to be significant.

The finding that there was no difference in fuel economy was *not* unexpected. Fuel economy correlates with the fuel property of heat of combustion[1]. As indicated on Table 2, the heat of combustion for the test and control fuels were essentially identical.

Table 1. Vehicle Descriptions						
Year	Type	Make	Model	Engine	Fuel System	Mileage
1997	Sedan	Plymouth	Neon	4 cyl, 2.0 L	PFI	28,903
1996	Sedan	Chevrolet	Lumina	6 cyl, 3.1 L	PFI	115,566
1995	Sedan	Mazda	626	4 cyl, 2.0 L	PFI	85,940
1994	SUV	Ford	Explorer	6 cyl, 4.0 L	PFI	46,978
1994	Truck	Chevrolet	Silverado	8 cyl, 5.7 L	TBI	87,232
1993	Sedan	Ford	Taurus	6 cyl, 3.0 L	PFI	59,738
1993	Van	Plymouth	Voyager	6 cyl, 3.0 L	PFI	91,265
1992	Sedan	Audi	100s	6 cyl, 2.8 L	PFI	65,081
1991	Sedan	Chevrolet	Caprice	8 cyl, 5.0 L	TBI	113,413
1990	Sedan	Ford	Probe	4 cyl, 2.2 L	PFI	87,571
1990	Sedan	Toyota	Corolla	4 cyl, 1.6 L	PFI	140,838
1989	Truck	Mazda	B2200	4 cyl, 2.2 L	carb	166,993

EPA FUEL ECONOMY VEHICLE INSPECTION

Year : _____ Make/Model : _____

VIN : _____ Transmission : _____

Mileage : _____ Engine/Disp/Fuel : _____

Optional Power Consuming Equip : _____

Tire Make/ Size : _____ Tires have over 100 miles ? YES / NO

Front Brakes ? DISK / DRUM Brake drag not excessive ? YES / NO
Rear Brakes ? DISK / DRUM Brake drag not excessive ? YES / NO

CHECK LIST

_____	Engine Oil Level OK	Leaks ? YES / NO
_____	Coolant Level OK	Leaks ? YES / NO
_____	Transmission Fluid Level OK	Leaks ? YES / NO
_____	Fuel System OK	Leaks ? YES / NO
_____	Belts and Hoses TIGHT	
_____	Throttle Operation FUNCTIONAL	
_____	Engine Operation OK	
_____	Transmission Operation OK	
_____	Tire Wear EVEN	
_____	Air Cleaner CLEAN	
_____	Fan Clutch FUNCTIONAL	
_____	Air Conditioning FUNCTIONAL	

Diagnostic Codes : _____

Note Scratches/Dents/Hubcaps : _____

_____

Comments : _____

_____

Name : _____ Date : _____

APPENDIX C

FUEL ANALYSIS

Table 2. Fuel Analysis Summary			
Test		Phase I RFG (GA-3520)***	Phase II RFG (GA-3524)*
ASTM D86 - Distillation Temperature (°F)	IBP	103.0	105.0
	5%	124.0	129.2
	10%	135.0	139.7
	15%	142.0	
	20%	149.0	154.6
	30%	165.0	169.4
	40%	185.0	186.1
	50%	213.0	205.7
	60%	245.0	228.7
	70%	271.0	252.1
	80%	296.0	279.5
	90%	328.0	312.5
	95%	353.0	343.2
	EP/FBP	393.0	388.7
	Recovery (vol%)	97.5	
	Residue (vol%)	0.5	0.9
	Loss (vol%)	2.0	1.4
	E-200 (vol%)	45.7	
	E-300 (vol%)	81.5	
ASTM D4052 - Density @ 15.5 °C (60 °F)	API	57.0	59.4
	Specific Gravity	0.7505	0.7414
ASTM D5191 - RVP by Grabner	(psi)	6.89	
ASTM D323 - Reid Vapor Pressure	(psi)		6.8
ASTM D2622 -Sulfur by X-Ray Florescence	(wt%)	0.032	0.016
ASTM D1319 - Hydrocarbon Composition	Aromatics (vol%)	31.5	24.5
	Olefins (vol%)	13.0	12.0
	Saturates (vol%)	55.5	
	Benzene (vol%)	1.22	1.0
ASTM D2699 - Research Octane Number	Research	92.9	96.2
ASTM D2700 - Motor Octane Number	Motor	83.1	85.7
	(R+M)/2	88.0	91.0
	Sensitivity (R-M)	9.8	10.5
ASTM D4815 - Oxygenates	MTBE (vol%)	10.76	11.2
	Oxygen (wt%)	2.00	2.04**
ASTM D240 - Heat of Combustion	Gross (Btu/lb)	19,417.2	19473.4***
	Net (Btu/lb)	18,199.3	18236.3***

* Phillips analysis - Lot D517

** O2 wt% = (0.112 x 0.182) x 100

*** Southwest Research analysis

APPENDIX D

URBAN AND SUBURBAN TEST ROUTES

Figure 4 Typical Urban Driving Cycle

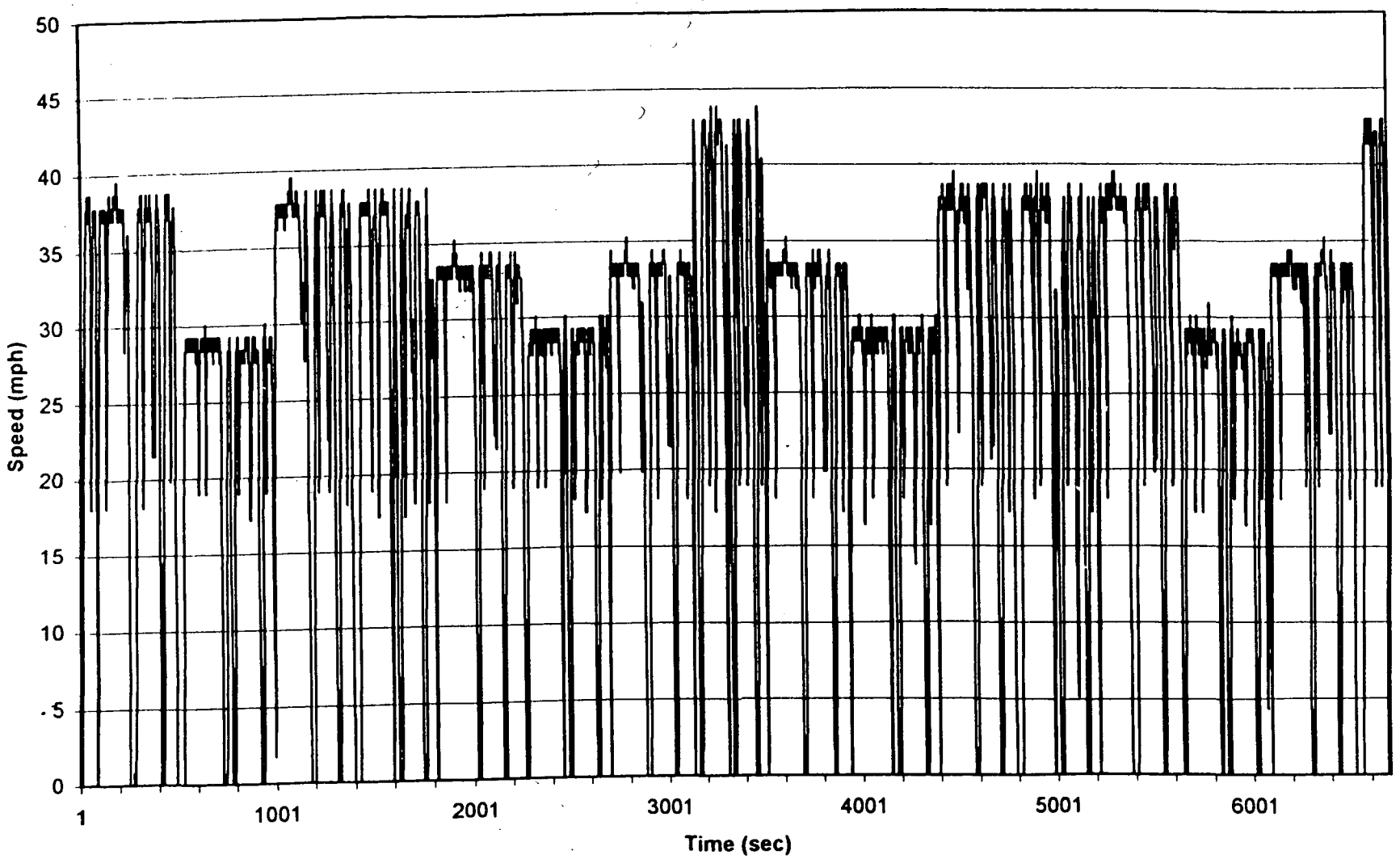
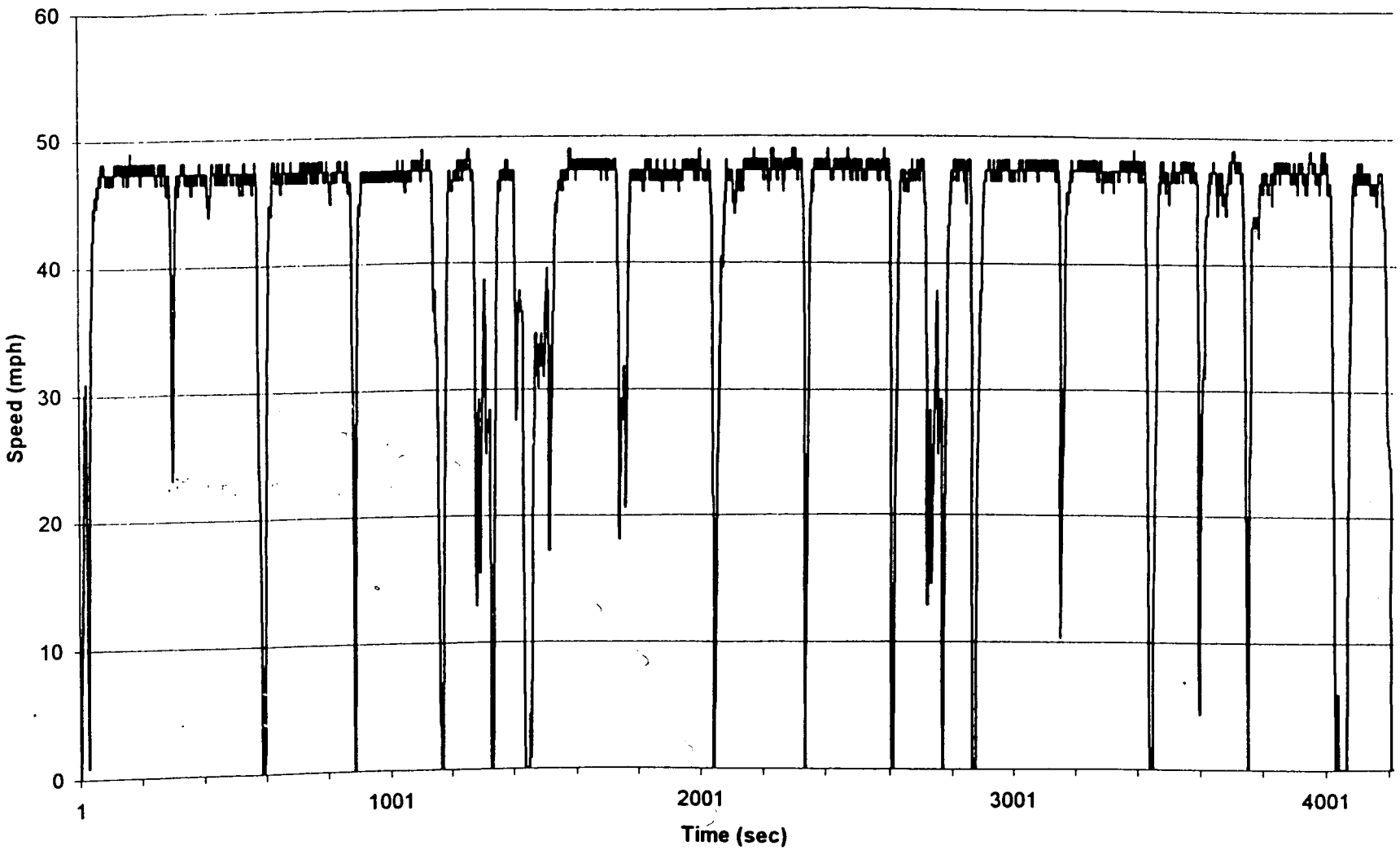


Figure 5 Typical Suburban Driving Cycle



APPENDIX E

INDIVIDUAL VEHICLE FUEL ECONOMY DATA

Table 3. Fuel Economy Results for the Urban Driving Cycle									
Vehicle	Fuel	Date	Time	Fuel Consumed	Observed Fuel Economy	Average Fuel Temp.	Corrected Fuel Economy	Corrected Fuel Consumed	
				cm³	km/L	°C	km/L	Liters	(gallons)
A	RFG I	08-Jun-98	8:00	14,074	5.72	28.3	5.80	13.88	(3.67)
			12:00	13,597	5.92	38.6	6.07	13.25	(3.50)
	RFG II	09-Jun-98	8:00	13,491	5.96	29.4	6.06	13.29	(3.51)
			12:00	13,473	5.97	36.9	6.11	13.16	(3.48)
B	RFG I	10-Jun-98	8:00	11,197	7.18	32.8	7.32	10.99	(2.90)
			12:00	11,023	7.30	40.6	7.50	10.72	(2.83)
	RFG II	11-Jun-98	11:00	10,928	7.36	31.4	7.49	10.74	(2.84)
			16:00	11,119	7.24	42.2	7.45	10.79	(2.85)
C	RFG I	12-Jun-98	8:00	7,058	11.40	33.3	11.62	6.92	(1.83)
			12:00	6,845	11.75	42.5	12.11	6.64	(1.76)
	RFG II	13-Jun-98	8:00	7,443	10.81	33.1	11.02	7.30	(1.93)
			12:00	7,513	10.71	44.2	11.06	7.28	(1.92)
D	RFG I	15-Jun-98	12:00	10,000	8.05	39.2	8.26	9.74	(2.57)
			16:00	10,397	7.74	51.1	8.05	9.99	(2.64)
	RFG II	16-Jun-98	8:00	10,601	7.59	30.8	7.72	10.42	(2.75)
			12:00	11,340	7.09	43.1	7.31	11.00	(2.91)
E	RFG I	17-Jun-98	9:00	10,941	7.35	29.7	7.47	10.77	(2.85)
			13:00	11,293	7.12	40.3	7.32	10.99	(2.90)
	RFG II	18-Jun-98	10:00	12,055	6.67	34.2	6.81	11.81	(3.12)
			14:00	11,812	6.81	43.6	7.03	11.45	(3.03)
F	RFG I	19-Jun-98	8:00	9,080	8.86	33.9	9.04	8.90	(2.35)
			12:00	9,491	8.48	45.8	8.77	9.18	(2.42)
	RFG II	20-Jun-98	8:00	8,842	9.10	33.3	9.28	8.67	(2.29)
			12:00	9,345	8.61	46.9	8.92	9.02	(2.38)
G	RFG I	22-Jun-98	9:00	10,839	7.42	34.2	7.58	10.62	(2.81)
			13:00	10,808	7.44	45.3	7.69	10.46	(2.76)
	RFG II	23-Jun-98	8:00	10,571	7.61	30.8	7.74	10.39	(2.75)
			12:00	10,826	7.43	42.5	7.66	10.51	(2.78)
H	RFG I	24-Jun-98	11:00	8,026	10.02	41.1	10.31	7.80	(2.06)
			15:00	7,994	10.06	47.8	10.43	7.71	(2.04)
	RFG II	25-Jun-98	8:00	7,936	10.14	31.7	10.32	7.80	(2.06)
			12:00	8,162	9.86	44.4	10.18	7.90	(2.09)
I	RFG I	26-Jun-98	8:00	8,636	9.32	35.8	9.53	8.44	(2.23)
			12:00	8,726	9.22	53.3	9.62	8.36	(2.21)
	RFG II	27-Jun-98	8:00	8,731	9.21	35.3	9.42	8.54	(2.26)
			12:00	9,598	8.38	53.9	8.75	9.19	(2.43)
J	RFG I	29-Jun-98	9:00	8,965	8.97	34.2	9.16	8.78	(2.32)
			13:00	9,065	8.87	45.8	9.18	8.76	(2.32)
	RFG II	30-Jun-98	8:00	8,529	9.43	34.2	9.63	8.36	(2.21)
			12:00	8,263	9.74	47.2	10.09	7.98	(2.11)
K	RFG I	02-Jul-98	10:00	11,539	6.97	35.8	7.13	11.28	(2.98)
			14:00	11,745	6.85	45.0	7.08	11.37	(3.00)
	RFG II	03-Jul-98	8:00	11,957	6.73	31.4	6.85	11.75	(3.10)
			12:00	11,946	6.73	39.7	6.92	11.63	(3.07)
L*	RFG I	08-Jul-98	11:00	8,823	9.12	33.9	9.31	8.65	(2.28)
			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	RFG II	09-Jul-98	8:00	9,106	8.83	28.1	8.96	8.98	(2.37)
			12:00	9,258	8.69	40.3	8.93	9.01	(2.38)

* Vehicle L experienced mechanical problems on the last suburban driving cycle using Phase II RFG. In addition, there was only enough Phase I RFG to perform one urban and one suburban driving cycle.

Table 4. Fuel Economy Results for the Suburban Driving Cycle									
Vehicle	Fuel	Date	Time	Fuel Consumed	Observed Fuel Economy	Average Fuel Temp.	Corrected Fuel Economy	Corrected Fuel Consumed	
				cm^3	km/L	°C	km/L	Liters	(gallons)
A	RFG I	08-Jun-98	10:00	11,108	7.24	32.8	7.38	10.90	(2.88)
			14:00	11,578	6.95	43.1	7.16	11.23	(2.97)
	RFG II	09-Jun-98	10:00	10,702	7.52	32.8	7.66	10.50	(2.77)
			14:00	11,069	7.27	41.4	7.48	10.76	(2.84)
B	RFG I	10-Jun-98	10:00	8,159	9.86	36.9	10.10	7.97	(2.11)
			14:00	8,414	9.56	44.7	9.88	8.14	(2.15)
	RFG II	11-Jun-98	13:00	8,234	9.77	37.5	10.01	8.04	(2.12)
			18:00	8,018	10.03	42.2	10.34	7.78	(2.06)
C	RFG I	12-Jun-98	10:00	5,807	13.85	38.9	14.22	5.66	(1.50)
			14:00	5,660	14.21	42.2	14.64	5.49	(1.45)
	RFG II	13-Jun-98	10:00	6,393	12.58	39.7	12.93	6.22	(1.64)
			14:00	6,360	12.65	47.5	13.11	6.14	(1.62)
D	RFG I	15-Jun-98	14:00	8,717	9.23	46.7	9.56	8.42	(2.22)
			18:00	9,068	8.87	50.0	9.22	8.73	(2.31)
	RFG II	16-Jun-98	10:00	8,992	8.95	37.2	9.16	8.78	(2.32)
			14:00	8,930	9.01	46.7	9.33	8.63	(2.28)
E	RFG I	17-Jun-98	11:00	9,725	8.27	35.6	8.46	9.51	(2.51)
			15:00	10,133	7.94	43.6	8.19	9.82	(2.60)
	RFG II	18-Jun-98	12:00	10,023	8.03	41.9	8.27	9.73	(2.57)
			16:00	10,207	7.88	46.4	8.16	9.86	(2.61)
F	RFG I	19-Jun-98	10:00	6,656	12.09	40.0	12.42	6.48	(1.71)
			14:00	7,032	11.44	50.6	11.90	6.76	(1.79)
	RFG II	20-Jun-98	10:00	6,574	12.24	40.8	12.59	6.39	(1.69)
			14:00	7,084	11.36	51.7	11.83	6.80	(1.80)
G	RFG I	22-Jun-98	11:00	6,783	11.86	40.3	12.19	6.60	(1.74)
			15:00	7,632	10.54	47.8	10.93	7.36	(1.95)
	RFG II	23-Jun-98	10:00	7,581	10.61	37.2	10.87	7.40	(1.96)
			14:00	7,670	10.49	45.8	10.85	7.42	(1.96)
H	RFG I	24-Jun-98	13:00	6,409	12.55	45.6	12.98	6.20	(1.64)
			17:00	6,565	12.25	48.9	12.72	6.32	(1.67)
	RFG II	25-Jun-98	10:00	6,337	12.70	39.4	13.04	6.17	(1.63)
			14:00	6,640	12.12	48.6	12.57	6.40	(1.69)
I	RFG I	26-Jun-98	10:00	6,653	12.09	47.2	12.53	6.42	(1.70)
			16:00	6,832	11.78	57.5	12.34	6.52	(1.72)
	RFG II	27-Jun-98	10:00	6,667	12.07	46.4	12.49	6.44	(1.70)
			14:00	7,082	11.36	59.4	11.94	6.74	(1.78)
J	RFG I	29-Jun-98	11:00	6,786	11.86	42.2	12.21	6.59	(1.74)
			17:00	6,132	13.12	38.9	13.46	5.98	(1.58)
	RFG II	30-Jun-98	10:00	6,547	12.29	41.7	12.65	6.36	(1.68)
			14:00	6,558	12.27	52.2	12.78	6.29	(1.66)
K	RFG I	02-Jul-98	13:00	9,542	8.43	42.5	8.69	9.26	(2.45)
			17:00	9,525	8.45	46.4	8.74	9.20	(2.43)
	RFG II	03-Jul-98	10:00	9,709	8.29	36.9	8.48	9.48	(2.51)
			14:00	9,826	8.19	40.3	8.42	9.56	(2.53)
L*	RFG I	08-Jul-98	13:00	7,499	10.73	43.9	11.07	7.27	(1.92)
			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	RFG II	09-Jul-98	10:00	7,771	10.35	34.4	10.57	7.61	(2.01)
			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

* Vehicle L experienced mechanical problems on the last suburban driving cycle using Phase II RFG. In addition, there was only enough Phase I RFG to perform one urban and one suburban driving cycle.

APPENDIX F

FLEET FUEL CONSUMPTION DATA

Table 5. Corrected Fuel Consumed (Liters)							
Vehicle	Fuel	Urban Run 1	Urban Run 2	Suburban Run 1	Suburban Run 2	Total	
						RFG I	RFG II
A	RFG I	13.88	13.25	10.90	11.23	49.26	
	RFG II	13.29	13.16	10.50	10.76		47.70
B	RFG I	10.99	10.72	7.97	8.14	37.82	
	RFG II	10.74	10.79	8.04	7.78		37.35
C	RFG I	6.92	6.64	5.66	5.49	24.72	
	RFG II	7.30	7.28	6.22	6.14		26.94
D	RFG I	9.74	9.99	8.42	8.73	36.88	
	RFG II	10.42	11.00	8.78	8.63		38.83
E	RFG I	10.77	10.99	9.51	9.82	41.09	
	RFG II	11.81	11.45	9.73	9.86		42.85
F	RFG I	8.90	9.18	6.48	6.76	31.31	
	RFG II	8.67	9.02	6.39	6.80		30.89
G	RFG I	10.62	10.46	6.60	7.36	35.03	
	RFG II	10.39	10.51	7.40	7.42		35.72
H	RFG I	7.80	7.71	6.20	6.32	28.04	
	RFG II	7.80	7.90	6.17	6.40		28.27
I	RFG I	8.44	8.36	6.42	6.52	29.75	
	RFG II	8.54	9.19	6.44	6.74		30.92
J	RFG I	8.78	8.76	6.59	5.98	30.11	
	RFG II	8.36	7.98	6.36	6.29		28.98
K	RFG I	11.28	11.37	9.26	9.20	41.11	
	RFG II	11.75	11.63	9.48	9.56		42.42
L*	RFG I	8.65	#N/A	7.27	#N/A	15.91	
	RFG II	8.98	#N/A	7.61	#N/A		16.59
						401.02	407.46

* The fleet-wide fuel consumption was computed using the values from the first run of the urban and suburban driving cycles. The second run of the urban and suburban driving cycle was not included in the fleet average

APPENDIX G

STATISTICAL ANALYSIS

Table 7. Corrected Fuel Economies (L/km)								
Vehicle	Fuel	Urban Run 1	Urban Run 2	Suburban Run 1	Suburban Run 2	Average	Difference	Rank
A	RFG I	0.172	0.165	0.135	0.140	0.1531	-0.00485	7
	RFG II	0.165	0.164	0.131	0.134	0.1482		
B	RFG I	0.137	0.133	0.099	0.101	0.1175	-0.00145	3
	RFG II	0.133	0.134	0.100	0.097	0.1161		
C	RFG I	0.086	0.083	0.070	0.068	0.0768	0.00690	10
	RFG II	0.091	0.090	0.077	0.076	0.0837		
D	RFG I	0.121	0.124	0.105	0.108	0.1146	0.00605	9
	RFG II	0.130	0.137	0.109	0.107	0.1207		
E	RFG I	0.134	0.137	0.118	0.122	0.1277	0.00547	8
	RFG II	0.147	0.142	0.121	0.123	0.1332		
F	RFG I	0.111	0.114	0.081	0.084	0.0973	-0.00132	5
	RFG II	0.108	0.112	0.079	0.085	0.0960		
G	RFG I	0.132	0.130	0.082	0.092	0.1089	0.00212	2
	RFG II	0.129	0.131	0.092	0.092	0.1110		
H	RFG I	0.097	0.096	0.077	0.079	0.0871	0.00073	1
	RFG II	0.097	0.098	0.077	0.080	0.0878		
I	RFG I	0.105	0.104	0.080	0.081	0.0924	0.00364	4
	RFG II	0.106	0.114	0.080	0.084	0.0961		
J	RFG I	0.109	0.109	0.082	0.074	0.0936	-0.00349	11
	RFG II	0.104	0.099	0.079	0.078	0.0901		
K	RFG I	0.140	0.141	0.115	0.114	0.1278	0.00407	6
	RFG II	0.146	0.145	0.118	0.119	0.1318		
L*	RFG I	0.107	#N/A	0.090	#N/A	0.0989	0.00423	#N/A
	RFG II	0.112	#N/A	0.095	#N/A	0.1031		

* Vehicle L was excluded from the statistical analysis.

REFERENCES

1. A. M. Hoochhauser, J. D. Benson, V. R. Burns, R. A Gorse, Jr., W.J. Koehl, L. J. Painter, R. M. Reuter, and J. A. Rutherford, "Fuel Composition Effects on Automotive Fuel Economy – Auto/Oil Air Quality Improvement Research Program", SAE Paper No. 930138(1993).

2. S. Aceves, R. Glaser, and J. Richardson, "Assessment of California Reformulated Gasoline Impact on Vehicle Fuel Economy", Lawrence Livermore National Laboratory (January 1997).

3. "California Reformulated Gasoline: Performance and Compatibility Test Program: Report of the Performance Subcommittee of the California Reformulated Gasoline Advisory Committee", California Environmental Protection Agency, Air Resources Board (March 1996).

4. M.W. Thomson, A. R. Frelund, M. Pallas, and K. D. Miller, 1987, "General Motors 2.3L Quad 4 Engine", SAE Paper 870353

5. Environmental Protection Agency, 1995, "Fuel Economy Impact Analysis of RFG", Report EPA 420-F-95-003, EPA Office of Mobile Sources

6. Wilcoxon signed-rank test.

Appendix N

Temperatures at Milwaukee Mitchell airport: October - December 1998

Date	Min	Max
October		
1	44	60
2	39	56
3	50	55
4	54	61
5	57	63
6	55	70
7	48	58
8	48	57
9	43	62
10	43	64
11	43	64
12	51	64
13	41	58
14	39	52
15	45	59
16	57	70
17	64	72
18	46	66
19	41	61
20	41	55
21	45	52
22	34	54
23	43	64
24	43	64
25	48	66
26	53	72
27	57	65
28	54	63
29	48	55
30	54	57
31	52	55

Date	Min	Max
November		
1	50	54
2	45	52
3	37	45
4	32	43
5	28	41
6	28	43
7	28	45
8	33	39
9	36	45
10	41	61
11	36	45
12	34	43
13	25	50
14	39	55
15	36	50
16	37	52
17	34	45
18	34	49
19	36	54
20	30	35
21	27	39
22	36	55
23	46	57
24	37	51
25	43	54
26	41	59
27	28	64
28	45	64
29	55	64
30	45	66

Date	Min	Max
December		
1	36	57
2	46	61
3	53	64
4	46	59
5	45	61
6	34	55
7	34	39
8	27	43
9	28	46
10	32	39
11	30	46
12	30	46
13	27	44
14	21	46
15	39	48
16	33	44
17	26	35
18	25	48
19	27	47
20	28	34
21	12	32
22	1	13
23	7	23
24	-	-
25	-	-
26	18	30
27	19	39
28	16	39
29	23	36
30	-	-
31	-	-

(Note: All temperatures in degrees Fahrenheit)