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AUTOMOTIVE PRODUCTS AND EMISSIONS RESEARCH DIVISION

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

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FINAL REPORT
SwRI Project No. 08-7601-025

Prepared for

Environmental Protection Agency

July 1998

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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.

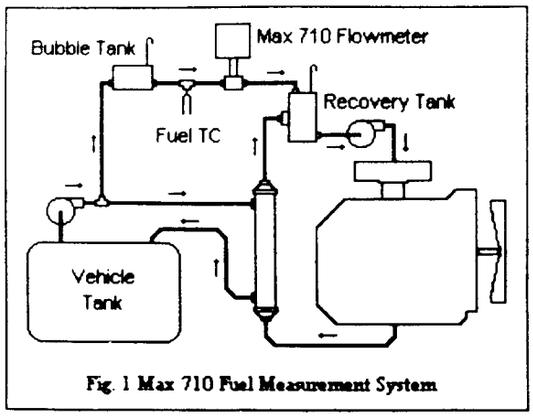


Fig. 1 Max 710 Fuel Measurement System

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.

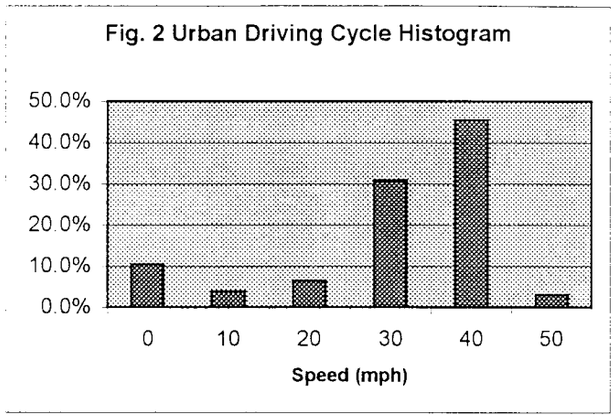
C. Fuel

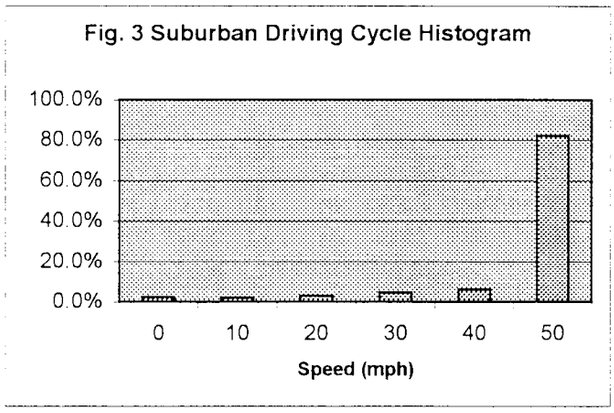
The test fuel used for this program was Phase II RFG (SwRI Code GA-3524). The test fuel was obtained from Phillips Chemical Company and was designated as Oxygenated Test Fuel (MF 6500 Lot D-517). The test fuel was used in EPA's RFG II fleet test program conducted in Boston, Chicago and Houston. The control 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.





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

Appendix B

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

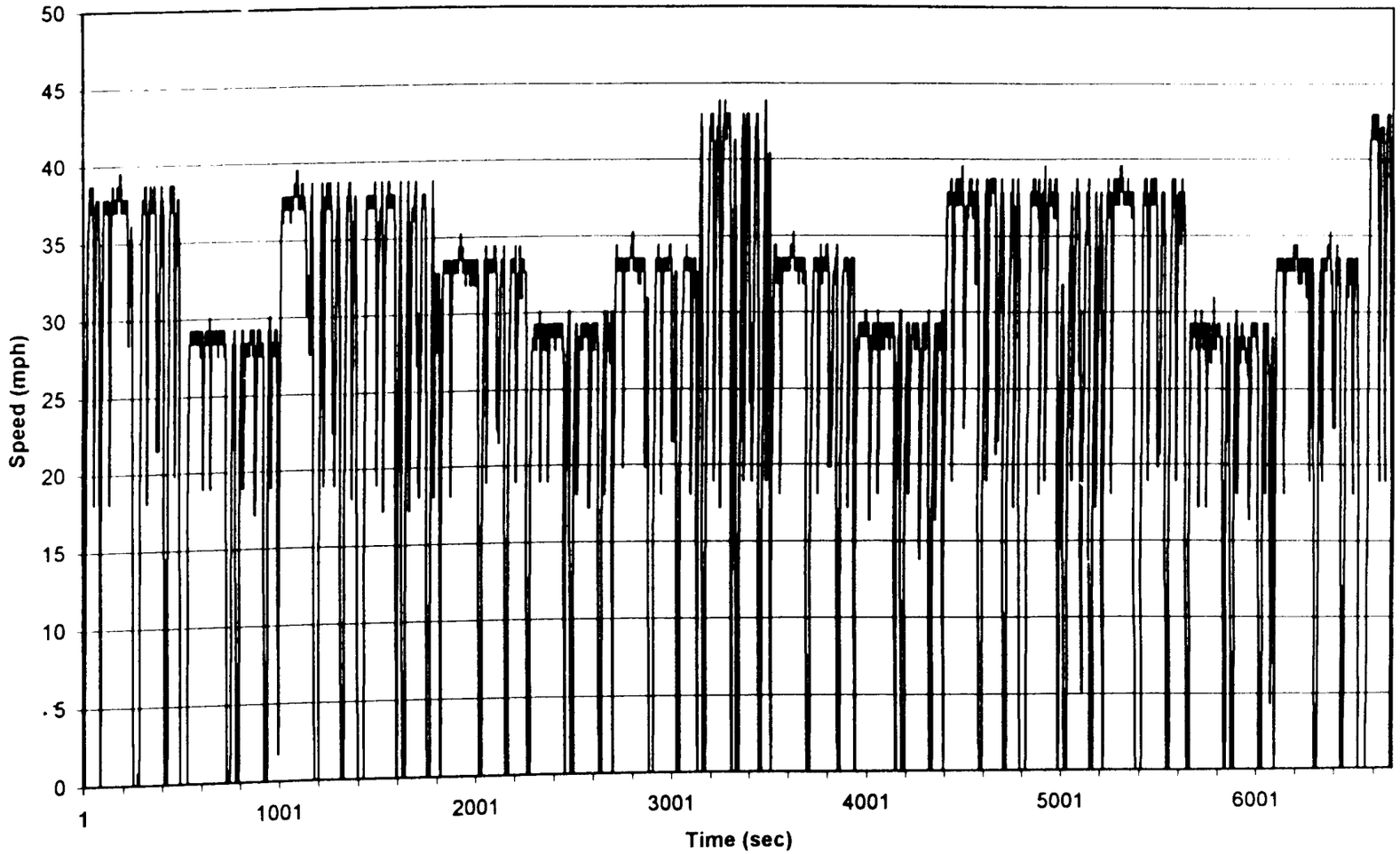
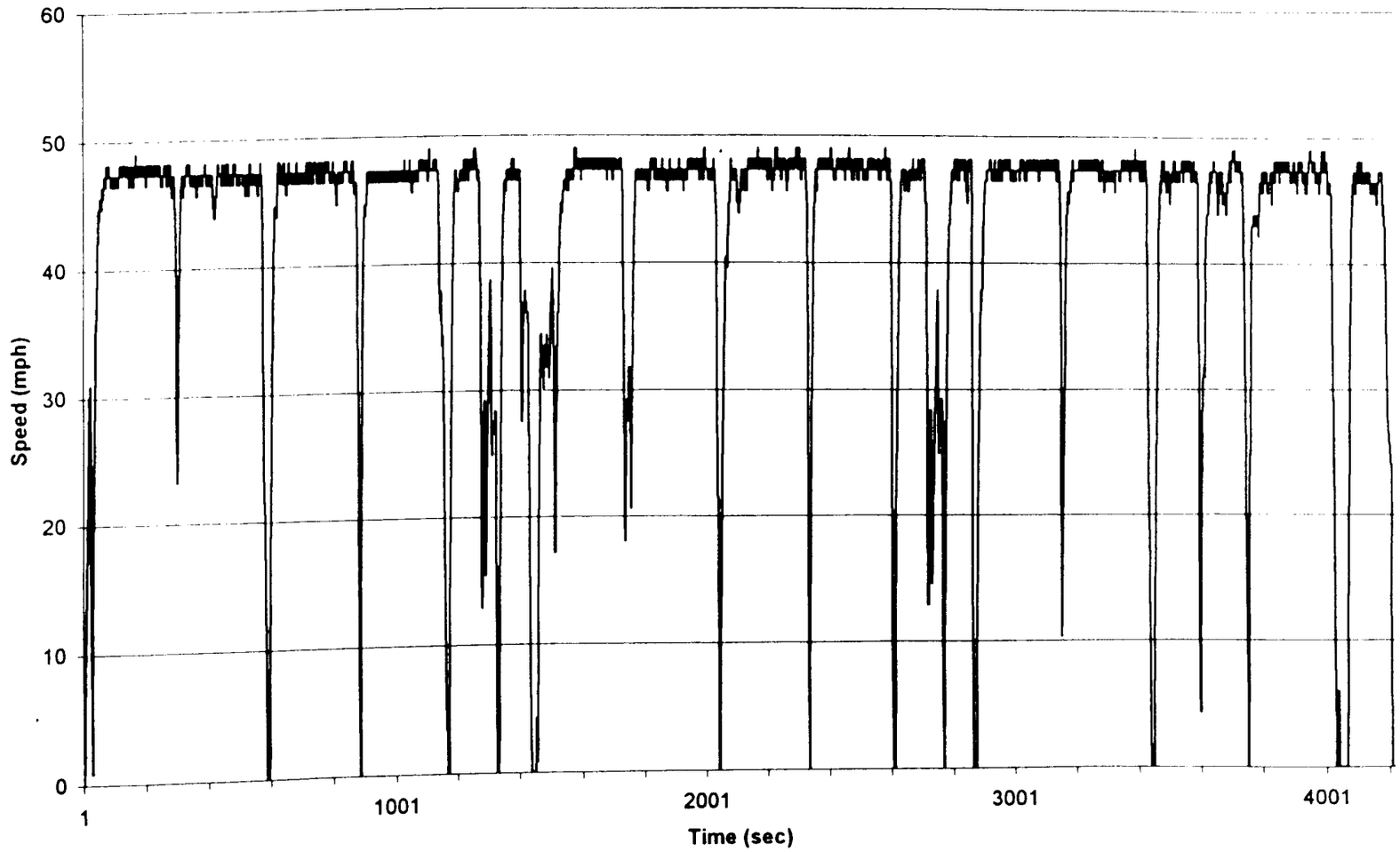


Figure 5 Typical Suburban Driving Cycle



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	
				cm^3	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.