

Federal Test Procedure Emissions Test Results from Ethanol Variable-Fuel Vehicle Chevrolet Lumina

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ABSTRACT

The first round of Federal Test Procedure (FTP) emissions testing of variable-fuel ethanol vehicles from the U.S. Federal fleet was recently completed. The vehicles tested include 21 variable-fuel E85 1992 and 1993 Chevrolet Lumina sedans and an equal number of standard gasoline Lumina. Results presented include a comparison of regulated exhaust and evaporative emissions and a discussion of the levels of air toxics, as well as the calculated ozone-forming potential of the measured emissions.

Two private emissions laboratories tested vehicles taken from the general population of Federal fleet vehicles in the Washington, D.C., and Chicago metropolitan regions. Testing followed the standard U.S. Environmental Protection Agency's FTP and detailed fuel changeover procedures as developed in the Auto/Oil Air Quality Improvement Research Program. Variable-fuel vehicles were tested on single respective batches of E85, E50, and California Phase 2 reformulated gasoline (RFG) blended specifically for this test program.

INTRODUCTION

The Alternative Motor Fuels Act of 1988 (AMFA) requires alternative fuel vehicles (AFVs) to be placed in service in U.S. Federal fleets. The U.S. Department of Energy (DOE) is responsible for evaluating the performance of these vehicles. Performance measures include driver acceptance, fuel economy, operational costs, maintenance, and emissions. The alternative fuels being evaluated under AMFA include methanol, ethanol, and natural gas. Light-duty passenger cars, vans, and trucks are part of the AMFA evaluation program along with school buses, transit buses, and heavy-duty trucks. Results from the AMFA fleet test program are reported annually.¹

There is particular interest in using ethanol produced from cellulosic biomass as a renewable fuel. Current commercial production is mainly from corn. Ethanol production from corn has a low net energy yield, but future production methods from cellulosic biomass offer the potential of low cost and favorable net energy yields. In addition, producing ethanol from cellulosic biomass is one of the few methods available for reducing

net carbon dioxide (CO₂) emissions. Unlike fossil fuel sources, producing ethanol from cellulosic biomass essentially recycles the CO₂ from the atmosphere.² Ethanol fuel properties can also provide excellent vehicle performance. All these benefits make ethanol an attractive alternative fuel for reducing energy imports.³

AFV emission performance for light-duty passenger cars, vans, and trucks in the AMFA program is measured at several laboratories located near fleet test sites. Low- and high-altitude laboratories and test sites are part of the AMFA program. The emission results reported here are from two low-altitude laboratories with measurements from 21 variable-fuel passenger cars operating on ethanol and reformulated gasoline (RFG). Emission measurements from comparable dedicated gasoline vehicles are also reported for reference.

The AMFA light-duty emissions test program is designed to evaluate the relative emissions performance of AFVs compared to that of their conventional fuel counterparts. Because ethanol is proposed as a future replacement fuel for gasoline, RFG has been selected as the conventional future fuel baseline. The direct counterpart comparison for emissions performance of ethanol operating in a variable-fuel vehicle (VFFV) is the same vehicle operating on RFG. Emissions results from a similar dedicated gasoline vehicle are of interest for reference only, as it is not equitable to directly compare VFFVs to dedicated vehicles. In other parts of the AMFA program where dedicated AFVs are available, a dedicated conventional fuel vehicle is used for relative performance assessments.

Earlier AMFA emissions testing included a limited number of vehicles.^{4,5} To strengthen the statistical validity of the results, a Phase 2 AMFA test program was initiated in 1994. Phase 2 increased the number of test vehicles to approximately 25 vehicles in each category. Emissions test vehicles are scheduled for emissions measurements at 4,000 miles, 10,000 miles, and each 10,000-mile increment thereafter. The purpose of the test program is to determine relative emissions from vehicles in actual service. By testing at several mileage increments, the deterioration of vehicle emissions with age or use may also be determined. Because of relatively low mileage accumulation to date in the program, emissions deterioration rates are not addressed in this paper.

TEST VEHICLES

The test vehicles were 1992 and 1993 Chevrolet Luminas in the VFV configuration and in the standard dedicated gasoline configuration. Details of the Lumina test vehicles are presented in Table 1. The VFVs are capable of operating on blends of ethanol and gasoline ranging from 85 volume % ethanol to 100 volume % gasoline. Special modifications to the VFVs include different piston rings, fuel tank, engine electronic control module, high-capacity fuel injectors, corrosion-resistant fuel system materials, and an added fuel composition sensor to determine the proportion of ethanol delivered to the engine.

Table 1.
1992/1993 Chevrolet Lumina Test Vehicle Description

Vehicle Type	Four-door sedan
Engine Displacement	3. 1 liter
Engine Configuration	V-6
Cylinder Compression Ratio	8. 8:1
Fuel induction	Multipoint fuel injection

The test vehicles were in regular Federal service in the Chicago and Washington, D. C. areas. Table 2 shows the numbers of vehicles in each location and their average odometer readings. Figure 1 is a photograph of the Chevrolet Lumina VFV.



Figure 1: Chevrolet Lumina VFV

All test vehicles participating in this program are part of the U. S. Federal vehicle pool. The vehicles are leased to various government fleets through the General Services Administration (GSA). Many vehicles have been selected for testing because vehicle usage and care vary from site to site. Vehicle service may vary widely from short delivery routes to highway driving. The degree of adherence to which the original equipment manufacturer's preventive maintenance schedule depends, to a certain extent, on the diligence of the fleet operator. Therefore, throughout the life of the program, variability in the emissions level is expected to be fairly high from vehicle to vehicle. Fleet personnel are notified of upcoming tests and are asked to ensure that the vehicle scheduled for testing has received normal preventive maintenance and that it is in normal operating condition. Nevertheless, each vehicle goes through a general inspection when it arrives in the test laboratory. Based on the general inspection, the vehicle may undergo a minor repair (replace fuel cap, tighten fitting, etc.) at the laboratory, be sent to an authorized dealership for maintenance, be returned to the fleet with notification of a problem, or be prepared for testing.

TEST FUELS

Table 3 describes the three test fuels that were used in the program. The base gasoline reference fuel was California Phase 2 RFG. Ethanol blends of 50 volume % and 85 volume % were prepared by blending neat ethanol with the same California Phase 2 RFG. Phillips Petroleum Company prepared the three fuels and shipped them to the test laboratories in 55-gallon drums. The vapor pressure of each fuel was adjusted by Phillips to achieve a nominal 7-lb Reid vapor pressure. Research and motor octane numbers were measured for RFG and estimated for the ethanol blends. The mass energy content of ethanol is roughly two-thirds that of gasoline; therefore, the ethanol blends reflect a proportionate reduction in their respective net heat of combustion values (see Table 3).

TEST PROCEDURES

Two independent laboratories tested the Federal fleet vehicles in Washington, D. C. , and in the Chicago area, respectively.

Figure 2 outlines the complete procedure for testing a vehicle. As described in the previous section, this was preceded by fleet notification, verification of scheduled maintenance and

Table 2.
Test Vehicle Service Locations and Mileage

	Washington, D. C.	Chicago
VFV Luminas	16	5
Odometer Mileage, miles (km)	9927±1828 (15,972±2,941)	18,354±11,153 (29,532±17,945)
Standard Luminas	16	5
Odometer Mileage, miles (km)	8077±4949 (12,996±7,963)	9267±1101(14,911±1,772)

acceptable vehicle performance, and an inspection of the incoming vehicle at the laboratory. Once the vehicle was approved for testing, an extensive procedure designed to minimize the fuel changeover effects was performed. Each VFV was tested on RFG, E85, and E50, in random order. The fuel changeover procedure was performed before every test, including the first test in the sequence. This process follows the

Auto/Oil Air Quality Improvement Research Program's (AQIRP) vehicle testing procedures.⁶ The main elements of the fuel changeover procedure are a 60-min purge of the vehicle's evaporative canister, several fuel tank drain and fill sequences, a chassis dynamometer driving cycle using the test fuel, and several engine start-up and idle sequences.

Table 3.
Test Fuel Inspections

Tests	RFG	E50	E85
RON ^a	96.9	104.5 (estimated)	109.7 (estimated)
MON ^b	87.9	91.5 (estimated)	93.9 (estimated)
(R+M)/2	92.4	98.0 (estimated)	101.9 (estimated)
Specific gravity 60/60°F (15.6/15.6°C)	0.741	0.767	0.784
MTBE ^c , (vol %)	11	5.5	1.65
Carbon, (wt %)	13.6	13.4	13.2
Hydrogen, (wt %)	84.4	67.7	56.7
Oxygen, (wt %)	2.0	18.9	30.1
Sulfur, (ppm) ^d	36	17	5
Net heat of combustion, (Btu/lb)(MJ/kg)	18,145 (42.21)	14,738 (34.28)	12,486 (29.04)
Reid vapor pressure, (psi) ^e (kPa) ^g	6.85 (47.2)	7.45 (51.4)	6.15 (42.4)
Distillation, (°F)(°C)			
10%	135 (57)	144 (62)	164 (73)
50%	207 (97)	167 (75)	172 (78)
90%	294 (146)	175 (79)	172 (78)
Hydrocarbon type, (vol %)			
Aromatics	24.9	–	–
Olefins	4	–	–
Saturates	67.6	–	–

^aRON = Research octane number

^bMON = Motor octane number

^cMTBE = Methyl tertiary butyl ether

^dppm = Parts per million

^eMJ = megajoules

^fpsi = pounds per square inch

^gkPa = kilopascals

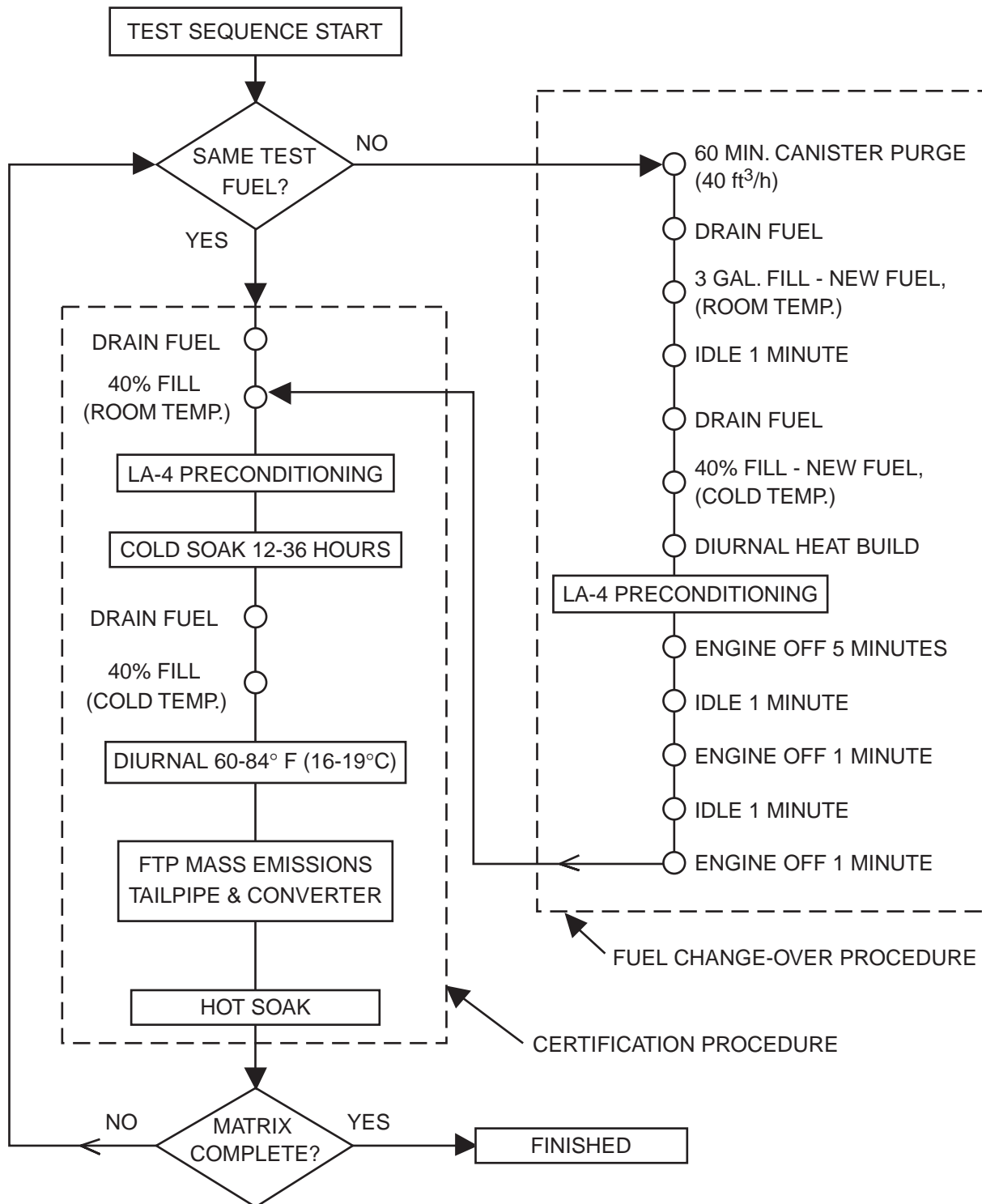


Figure 2: Vehicle Testing Procedure

Once the fuel changeover procedure was complete, the vehicle was tested following the Environmental Protection Agency's (EPA's) FTP for light-duty vehicle chassis dynamometer testing.⁷ This included a complete fuel drain and 40% refill with the test fuel at room temperature, followed by a dynamometer preconditioning driving cycle and a temperature-controlled soak for 12 to 36 hours. After the soak time, the fuel was again drained and filled to 40% capacity with test fuel at 45°–60°F (7°–16°C). The vehicle was then pushed into the sealed housing evaporative enclosure where the EPA diurnal-heat-build, sealed housing evaporative determination (SHED) test was performed. To determine the vehicle's evaporative loss, initial and final hydrocarbon (HC) and ethanol measurements were taken from the evaporative enclosure as the temperature of the vehicle's fuel tank was raised from 60°F to 84°F (16° to 29°C) during a period of 60 min. Within 1 hour of the diurnal SHED test, the vehicle was pushed onto the dynamometer, started, and driven through the three phases of the FTP.

Three samples of dilute exhaust gas from the constant volume sampling system were collected during the FTP corresponding to the cold transient (bag 1) phase, the hot stabilized (bag 2) phase, and the hot transient (bag 3) phase. These "bag" samples were analyzed for HCs, using a flame ionization detector (FID), heated to 235±15°F (113±8°C) for alcohol fuel tests; methane (CH₄), using an FID combined with a gas chromatograph; oxides of nitrogen (NO_x), using a chemiluminescence analyzer; and carbon monoxide (CO) and CO₂, using nondispersive infrared analyzers as prescribed by standard FTP certification. Background ambient samples were also collected and analyzed to correct emissions measurements. Alcohol samples were collected by drawing dilute air and exhaust gas samples through primary and secondary impingers filled with pure water and chilled in an ice-bath to 35°–41°F (2°–5°C). Gas chromatography was used to analyze the alcohol samples. Aldehyde samples were collected on dinitrophenyl-hydrazine (DNPH) coated silica cartridges or impingers filled with an acetonitrile/DNPH solution, and analyzed using high-performance liquid chromatography.

The hot soak evaporative emissions test required by the FTP was performed immediately after the hot transient phase (bag 3) of the exhaust emissions test. Evaporative losses were determined from HC and ethanol analysis of the enclosure atmosphere at the start and end of the 60-minute test period.

Gas chromatography was also used to perform full speciation of the exhaust and evaporative HC from a sample of the vehicles. The HC speciation quantified the concentration of more than 100 HC constituents in the emissions samples. A complete list of the HC species in elution order is given in the Appendix (Table A-1).

Each laboratory performed a complete sequence of duplicate emissions tests (RFG, E85, and E50) on at least two of each vehicle model. Replicate tests were performed on three vehicles at Laboratory 1 and on two vehicles at Laboratory 2. Summary results presented here indicate an average of all tests conducted (26 tests) on 21 vehicles.

EPA audited the test laboratories during in the summer of 1995. The audit reviewed facilities, procedures, and chemical standards used in the AMFA emissions program. Only minor deficiencies were observed, and the data here reflect the minor corrections recommended by EPA.

RESULTS AND DISCUSSION

Detailed results from GSA ethanol Lumina VFV test vehicles and the dedicated control vehicles can be found in the Alternative Fuels Data Center (AFDC) located on the World Wide Web at <http://www.afdc.doe.gov>. Summary results for the data discussed in this report are presented in the Appendix, including total regulated and unregulated exhaust and evaporative emissions, vehicle odometer reading at time of test, and fuel economy calculated from FTP emissions (Tables A-2.–A-5.). The Appendix also summarizes speciated emissions test totals, calculated ozone-forming potential (OFP), calculated specific reactivity (SR), and toxic compound totals from 10 vehicle tests (Tables A-6.–A-7.). Separate results are discussed below for regulated exhaust emissions, evaporative emissions, exhaust toxics as designated in the Clean Air Act Amendments of 1990, fuel economy, CO₂ emissions, and OFP calculated from speciated emissions results. Ethanol vehicle emission performance has been reported elsewhere, but the previous studies evaluated samples of three or fewer vehicles.^{8–13}

REGULATED EXHAUST EMISSIONS - Non-methane hydrocarbon (NMHC), NO_x, and CO results for VFV Luminas operated on RFG, E50, and E85 are summarized in Tables 4, 5, and 6, respectively. Equivalent NMHC emissions for the ethanol fuel blends are expressed as organic material non-methane hydrocarbon equivalent (OMNMHCE). OMNMHCE is calculated by modifying the measured NMHC fraction to account for alcohol and aldehyde emissions as shown here:

$$\text{OMHCE} = \text{FID, corr, (g/mi)} + \frac{13.8756}{46.069} * \text{EtOH(g/mi)} + \frac{13.8756}{46.069} * \text{Acetaldehyde (g/mi)}$$

Table 4.
Lumina VFV NMHC (OMNMHCE) Exhaust Emissions

	RFG		E50		E85	
	g/mi	std. dev.	g/mi	std. dev.	g/mi	std. dev.
Lab 1	0.185	0.047	0.150	0.035	0.139	0.029
Lab 2	0.128	0.042	0.110	0.028	0.100	0.020

Table 5.
Lumina VFV NO_x Exhaust Emissions

	RFG		E50		E85	
	g/mi	std. dev.	g/mi	std. dev.	g/mi	std. dev.
Lab 1	0.173	0.052	0.139	0.026	0.138	0.030
Lab 2	0.268	0.056	0.187	0.050	0.183	0.056

Table 6.
Lumina VFV CO Exhaust Emissions

	RFG		E50		E85	
	g/mi	std. dev.	g/mi	std. dev.	g/mi	std. dev.
Lab 1	3.00	0.78	2.56	0.72	2.29	0.74
Lab 2	2.60	0.87	2.76	1.07	2.29	0.60

The comparative fuel results for NMHC, NO_x, and CO are plotted in Figures 3, 4, and 5 respectively.

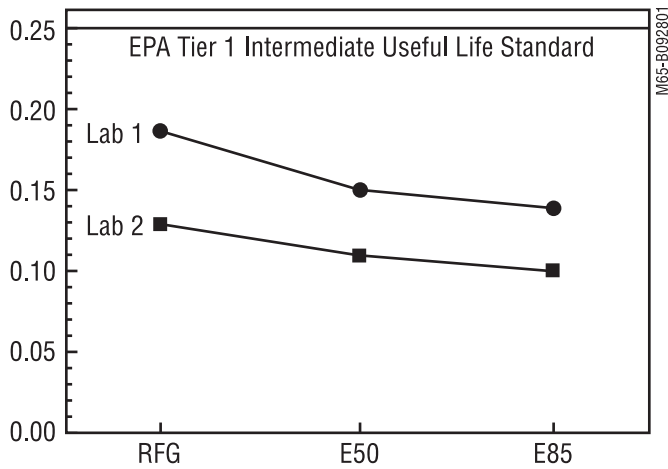


Figure 3: Lumina VFV NMHC (OMNMHCE) Exhaust Emissions

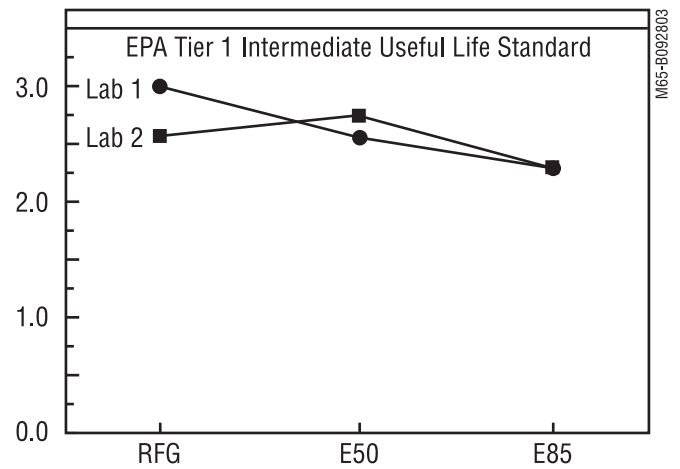


Figure 5: Lumina VFV CO Exhaust Emissions

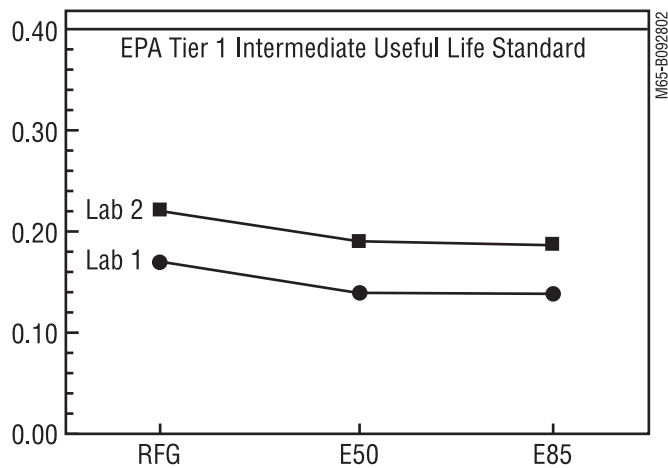


Figure 4: Lumina VFV NO_x Exhaust Emissions (g/mi)

NMHC emissions were reduced using E85 compared to RFG by 20% at Laboratory 1 and by 22% at Laboratory 2. NO_x emissions were reduced by 25% and 32%, respectively, for E85 at the two laboratories, and CO was reduced in the E85 case by 24% and 12%, respectively, at the two laboratories.

Table 7.
Lumina VFV Evaporative Emissions

	RFG		E50		E85	
	g/test	std. dev.	g/test	std. dev.	g/test	std. dev.
Lab 1	0.59	0.40	0.84	0.24	0.57	0.22
Lab 2	0.24	0.29	0.17	0.04	0.24	0.26

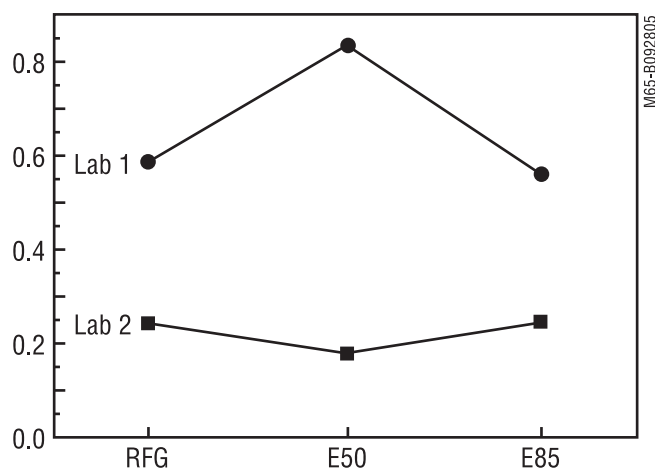


Figure 6: Lumina VFV Evaporative Emissions (g/test)

EVAPORATIVE EMISSIONS - Results for evaporative emissions from VFV Luminas operated on the three test fuels are presented in Table 7 and plotted in Figure 6. As expected from the equivalent Reid vapor pressure blends, little difference was noted. E85 evaporative emissions at Laboratory 1 were only 3% less, and the same emission measurements at Laboratory 2 were nearly identical.

EXHAUST TOXICS - Speciated emission analysis included detecting and quantifying four mobile source toxics—benzene, 1,3-butadiene, formaldehyde, and acetaldehyde—as designated in the Clean Air Act. Acetaldehyde is one of the

primary decomposition products from ethanol combustion and is expected to be higher from ethanol than from other fuels. In relative terms, however, acetaldehyde is the least potent of the four mobile source toxics.^{14,15}

Table 8 presents the mobile source toxics results measured at Laboratory 1. The same results are plotted in Figure 7. E85 operation compared to RFG effected a 79% reduction in benzene emissions and an 80% reduction in 1,3-butadiene. E85 operation resulted in a 20% increase in formaldehyde emissions and nearly a 20-fold increase in acetaldehyde emissions.

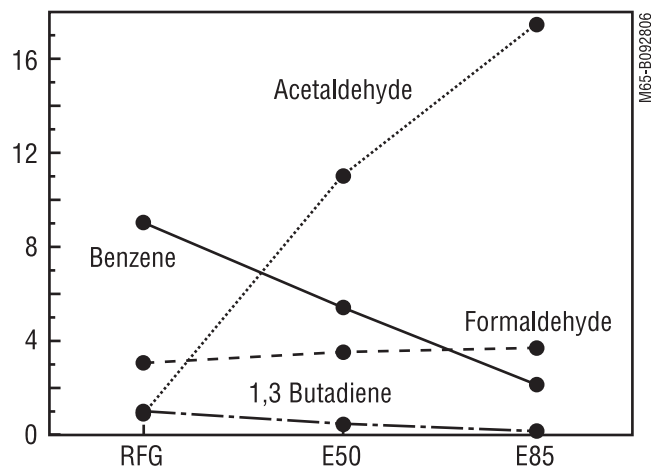


Figure 7: Lumina VFV Exhaust Toxics (mg/mi)

Table 8.
Lumina VFV Exhaust Toxics

	RFG		E50		E85	
	mg/mi	std. dev.	mg/mi	std. dev.	mg/mi	std. dev.
Benzene	8.90	2.26	5.00	1.07	1.83	0.37
1,3-Butadiene	0.87	0.33	0.43	0.17	0.17	0.09
Formaldehyde	2.79	1.01	3.38	1.23	3.36	1.63
Acetaldehyde	0.84	0.31	11.10	3.85	17.21	7.06

Table 9.
Lumina VFV Fuel Economy (miles per equivalent gallons)

	RFG		E50		E85	
	mi/gal	std. dev.	mi/gal	std. dev.	mi/gal	std. dev.
Lab 1	19.97	0.34	19.61	0.15	20.16	0.25
Lab 2	19.05	0.66	17.98	0.62	18.77	0.58

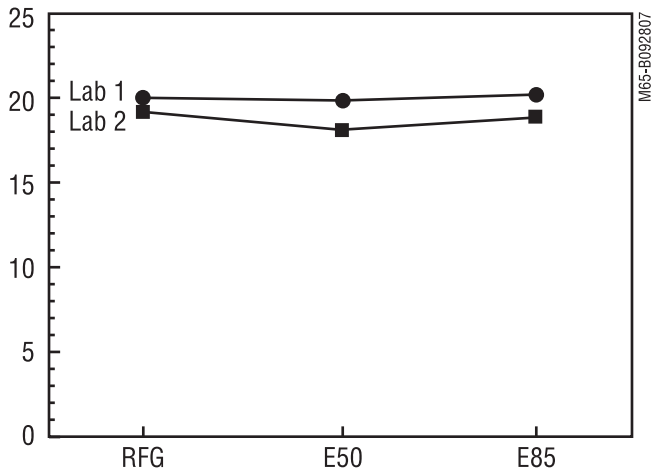


Figure 8: Lumina VFV Fuel Economy (mi/equivalent gallon)

FUEL ECONOMY - Table 9 shows the fuel economy determined as part of the FTP emissions procedure for the three fuels tested. Because ethanol has a lower volumetric energy content, the volumetric fuel economy for ethanol fuels is expected to be lower. The energy-specific fuel economy based on equivalent energy content of gasoline is plotted in Figure 8. On an energy equivalent basis, results from this test program showed essentially identical fuel economy for each fuel. Laboratory 1 indicated a 1% improvement and Laboratory 2 indicated a 1% reduction in energy equivalent fuel economy for E85 compared to RFG.

Theoretical analysis of the combustion properties of ethanol would predict improved energy equivalent fuel economy for ethanol blends.³ Other studies have reported results

similar to the theoretical analysis,^{13,16} but the results from this study and one other study¹⁷ did not show this advantage.

CARBON DIOXIDE EMISSIONS - Emissions of CO₂ are not regulated, but are of interest as a greenhouse gas because of their the estimated contribution to global warming. Measured CO₂ emission results are presented in Table 10 and plotted in Figure 9. A slight reduction is noted for the ethanol fuels. This is expected because of the lower carbon content of ethanol per unit of energy compared to RFG. In a larger sense, however, ethanol produced from renewable resources such as cellulosic biomass can result in near elimination of net CO₂ emissions, because the production cycle would recycle the carbon from the atmosphere.

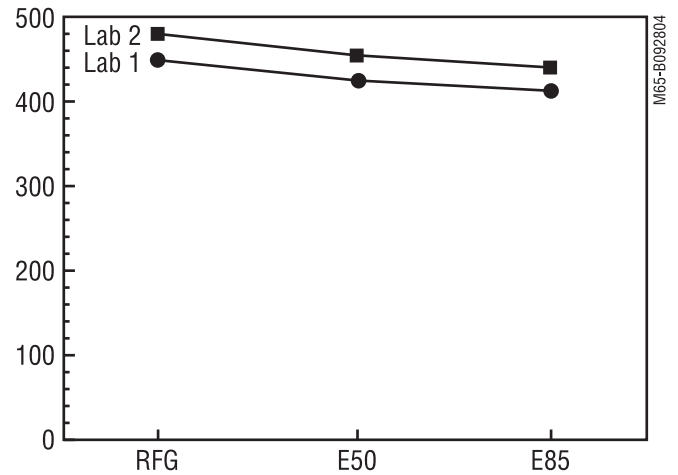


Figure 9: Lumina VFV CO₂ Exhaust Emissions (g/mi)

Table 10.
Lumina VFV CO₂ Exhaust Emissions

	RFG		E50		E85	
	g/mi	std. dev.	g/mi	std. dev.	g/mi	std. dev.
Lab 1	451.3	7.3	432.8	4.7	418.8	5.7
Lab 2	480.4	16.8	464.0	15.8	451.4	14.5

OZONE-FORMING POTENTIAL AND SPECIFIC REACTIVITY - Regulations in California assign a maximum incremental reactivity (MIR) value to individual compounds emitted in exhaust. The MIR value is the predicted contribution of the compound to ozone formation in certain urban atmospheres and is expressed in units of milligrams of ozone per milligram of compound. The MIR value is determined in a laboratory experiment in which a small increment of the compound is added to a simulated urban background mixture and the net increase in ozone is measured. Taking into account the MIR values for all measured exhaust compounds, an OFP for the fuel may be calculated in units of milligrams of ozone per mile. SR for a given fuel may also be calculated by combining the respective mass of compound emissions per mile with the

OFP, which results in units of milligrams of ozone per milligram of total organic emissions. In California regulations, SR is based on non-methane organic gas (NMOG) emissions. SR is usually constant for a given fuel and engine technology.

Table 11 presents the OFP and SR for Lumina VFV operation on the three test fuels. OFP is plotted in Figure 10 and SR results for the three test fuels are plotted in Figure 11. Changing from RFG to E85 operation in the Lumina VFV results in a 25% reduction in OFP and a 30% reduction in SR, indicating benefits for ethanol in controlling urban ozone in some locations. The HC type distribution of compounds found in the speciated emissions data set are plotted in Figure 12 for the three test fuels. The carbon number distribution of speciated HC emissions is presented in Figure 13 for each test fuel.

Table 11.
Lumina VFV Ozone-Forming Potential

	RFG		E50		E85	
	mg O ₃ /mi	std. dev.	mg O ₃ /mi	std. dev.	mg O ₃ /mi	std. dev.
OFP	555	82	490	135	416	115
	gO ₃ /gNMOG	std. dev.	gO ₃ /gNMOG	std. dev.	gO ₃ /gNMOG	std. dev.
SR	3.53	0.06	3.08	0.12	2.48	0.18

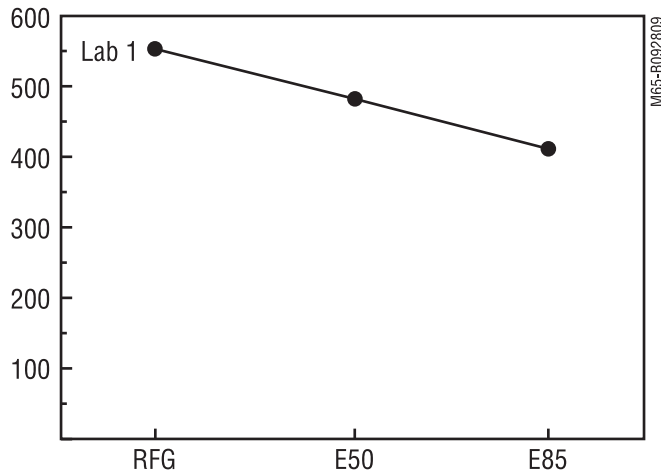


Figure 10: Lumina VFV Ozone Forming-Potential (mg/O₃/mi)

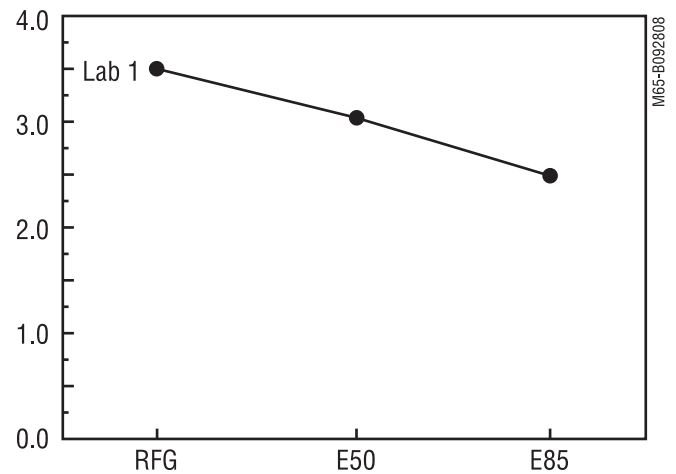


Figure 11: Lumina VFV Specific Reactivity (mg O₃/mg NMOG)

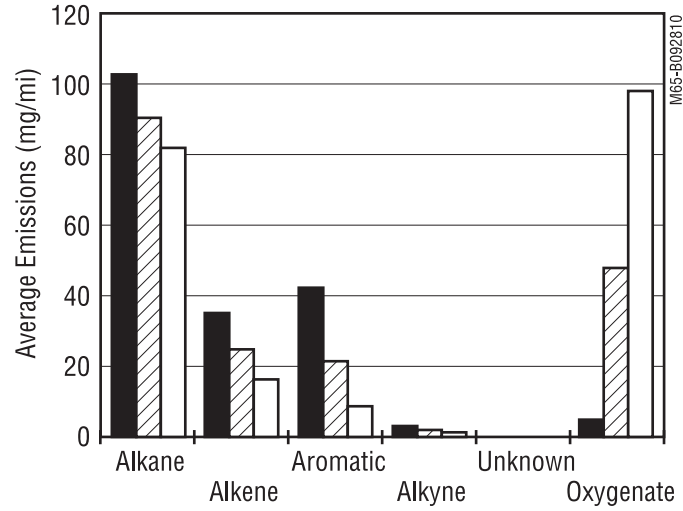


Figure 12: Lumina VFV Speciated Emissions Distribution

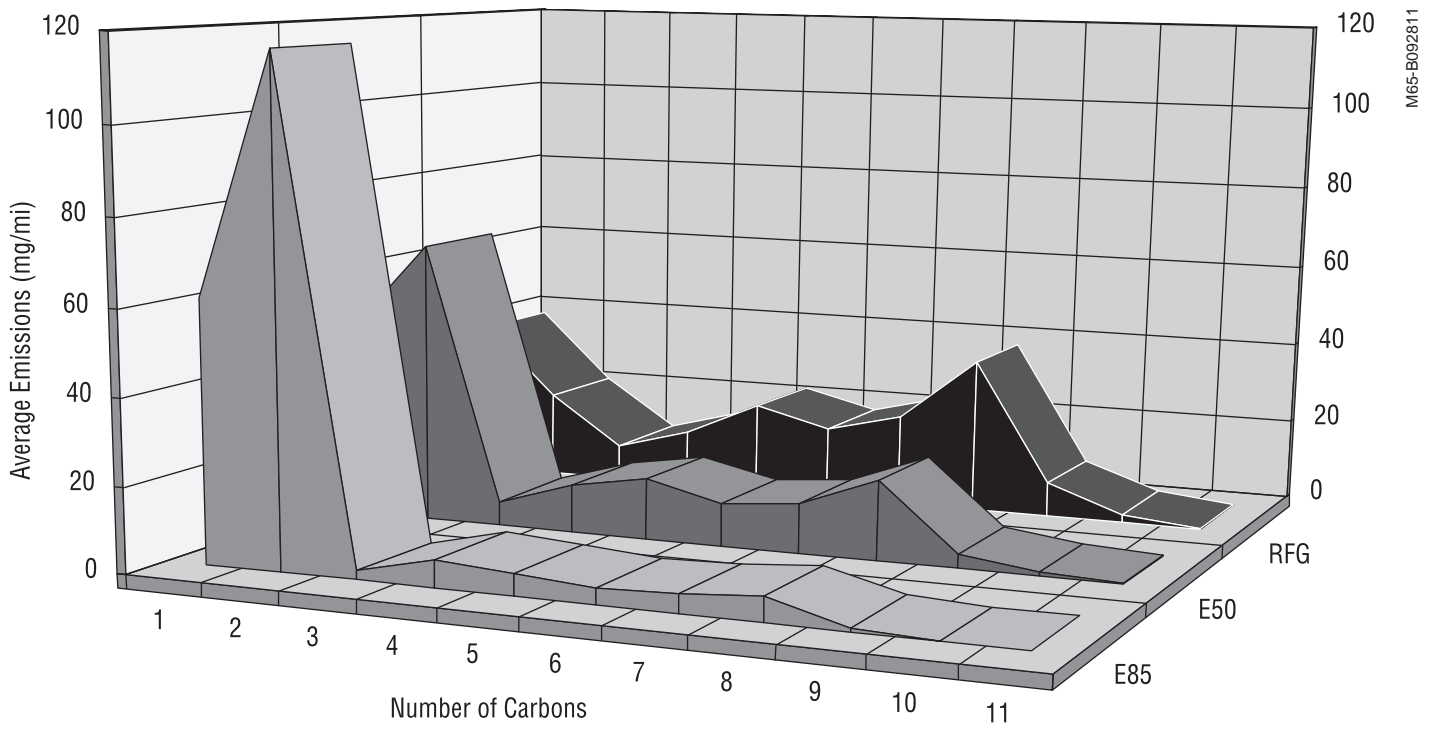


Figure 13: Lumina VFV Speciated HC Emissions Distribution

Table 12.
Summary of Effects for E85 Compared to RFG

	Lab 1	Lab 2
NMHC (OMNMHCE)	-20%	-22%
NO _x	-25%	-32%
CO	-24%	-12%
CO ₂	-7%	-6%
Evaporative emissions	-3%	0%
Fuel economy (equivalent energy basis)	+1%	-1%
Toxics		
- Benzene	-79%	
- 1,3-Butadiene	-80%	
- Formaldehyde	+20%	
- Acetaldehyde	+1949%	
SR	-30%	
OFP	-25%	

SUMMARY AND CONCLUSIONS

Table 12 summarizes the results of the AMFA emission testing of in-service Chevrolet Lumina VFVs operating on ethanol blends and RFG. Conclusions from this test program are preliminary, as the vehicles are still being tested at higher mileage accumulation points. The conclusions to date are:

1. Both independent emissions test laboratories reported reductions in NMHC (OMNMHCE) emissions for E85 compared to RFG operation for the in-service VFV test fleet.
2. Both independent emissions test laboratories reported reductions in NO_x emissions for E85 compared to RFG operation for the in-service VFV test fleet.
3. Both independent emissions test laboratories reported modest reductions in CO emissions for E85 compared to RFG operation in the in-service VFV test fleet.
4. Evaporative emissions were not sensitive to the three test fuels (RFG, E50, E85), which were all blended to the same nominal Reid vapor pressure.
5. E85 demonstrates large reductions in benzene and 1,3-butadiene exhaust emissions. VFV operation on E85 results in slightly higher formaldehyde emissions and in much higher acetaldehyde emissions.
6. VFV fuel economy measured on a chassis dynamometer was similar on an energy equivalent basis for RFG and E85.
7. SR and OFP were less for E85 than for RFG in the in-service VFV test fleet.
8. CO₂ exhaust gas emissions were less for E85 compared to RFG operation in the VFV test fleet.

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APPENDIX

Appendix A-1. Speciated Compounds

Compound Number	Compound Name	CAS	
		Number	Formula
1	METHANE	74828	CH4
2	ETHYLENE	74851	C2H4
3	ETHANE	74840	C2H6
4	ACETYLENE	74862	C2H2
5	PROPANE	74986	C3H8
6	PROPYLENE	115071	C3H6
7	PROPADIENE	463490	C3H4
8	METHYLACETYLENE	74997	C3H4
9	ISO-BUTANE	75285	C4H10
12	ISO-BUTYLENE	115117	C4H8
13	1,3-BUTADIENE	106990	C4H6
14	N-BUTANE	106978	C4H10
15	2,2-DIMETHYLPROPANE	463821	C5H12
16	TRANS-2-BUTENE	624646	C4H8
18	1-BUTYNE	107006	C4H6
19	CIS-2-BUTENE	590181	C4H8
20	*** UNKNOWN ***		C4H8
22	3-METHYL-1-BUTENE	563451	C5H10
23	ISO-PENTANE	78784	C5H12
24	1,4-PENTADIENE	591935	C5H8
25	2-BUTYNE	503173	C4H6
29	2-METHYL-1-BUTENE	563462	C5H10
30	N-PENTANE	109660	C5H12
31	ISOPRENE	78795	C5H8
32	TRANS-2-PENTENE	646048	C5H10
33	3,3-DIMETHYL-1-BUTENE	558372	C6H12
34	CIS-2-PENTENE	627203	C5H10
35	2-METHYL-2-BUTENE	513359	C5H10
36	TRANS-1,3-PENTADIENE	2004708	C5H8
37	CYCLOPENTADIENE	542927	C5H6
38	2,2-DIMETHYLBUTANE	75832	C6H14
42	CYCLOPENTENE	142290	C5H8
44	4-METHYL-1-PENTENE	691372	C6H12
46	CYCLOPENTANE	287923	C5H10
51	2-METHYLPENTANE	107835	C6H14
58	3-METHYLPENTANE	96140	C6H14
59	2-METHYL-1-PENTENE	763291	C6H12
63	N-HEXANE	110543	C6H14
64	CIS-3-HEXENE	7642093	C6H12
65	TRANS-2-HEXENE	405045	C6H12
66	2-METHYL-2-PENTENE	625274	C6H12
67	CIS-3-METHYL-2-PENTENE	922623	C6H12
69	CIS-2-HEXENE	7688213	C6H12
72	TRANS-3-METHYL-2-PENTENE	616126	C6H12
72.501	2,2-DIMETHYLPENTANE	590352	C7H16
73	METHYLCYCLOPENTANE	96377	C6H12
76	2,4-DIMETHYLPENTANE	108087	C7H16
76.501	2,3-DIMETHYL-2-BUTENE	563791	C6H12
77	2,2,3-TRIMETHYLBUTANE	464062	C7H16
78	C6H8		C6H8
81	1-METHYLCYCLOPENTENE	693890	C6H10
82	BENZENE	71432	C6H6
83	4,4-DIMETHYL-2-PENTENE	26232984	C7H14
84	3,3-DIMETHYLPENTANE	562492	C7H16
85	TRANS-2-METHYL-3-HEXENE	692240	C7H14
86	CYCLOHEXANE	110827	C6H12
92	2-METHYLHEXANE	591764	C7H16
93	2,3-DIMETHYLPENTANE	565593	C7H16
96	3-METHYLHEXANE	58934	C7H16
98	CIS-1,3-DIMETHYLCYCLOPENTANE	2532583	C7H14
100	TRANS-1,2-DIMETHYLCYCLOPENTANE	822504	C7H14
102	ISO-OCTANE	540841	C8H18
105	N-HEPTANE	142825	C7H16
106	CIS-3-METHYL-3-HEXENE	491489	C7H14

Compound Number	Compound Name	CAS	
		Number	Formula
112.5	2,2-DIMETHYLHEXANE	590738	C8H18
113	METHYLCYCLOHEXANE	108872	C7H14
118	2,5-DIMETHYLHEXANE	592132	C8H18
119	2,4-DIMETHYLHEXANE	589435	C8H18
120.501	3,3-DIMETHYLHEXANE	563166	C8H18
124	2,3,4-TRIMETHYLPENTANE	565753	C8H18
125.502	2,3,3-TRIMETHYLPENTANE	560214	C8H18
126	TOLUENE	108883	C7H8
127	2,3-DIMETHYLHEXANE	584941	C8H18
128	2-METHYLHEPTANE	592278	C8H18
129	4-METHYLHEPTANE	589537	C8H18
130	3,4-DIMETHYLHEXANE	583482	C8H18
131	3-METHYLHEPTANE	589811	C8H18
131.501	3-ETHYLHEXANE	619998	C8H18
134	1,3-DIMETHYLCYCLOHEXANE		C8H16
135	2,2,5-TRIMETHYLHEXANE	3522949	C9H20
136.501	TRANS-1-ETHYL-3-METHYLCYCLOPENTANE	2613652	C8H16
137	CIS-1-ETHYL-3-METHYLCYCLOPENTANE	2613663	C8H16
141	N-OCTANE	111659	C8H18
148	2,3,5-TRIMETHYLHEXANE	1069530	C9H20
160	2,4-DIMETHYLHEPTANE	2213232	C9H20
162	2,6-DIMETHYLHEPTANE	1072055	C9H20
165.501	3,5-DIMETHYLHEPTANE	926829	C9H20
168	ETHYLBENZENE	100414	C8H10
169	2,3-DIMETHYLHEPTANE	3074713	C9H20
171	M&P-XYLENE		C8H10
174	3-METHYLOCTANE	2216333	C9H20
176	C9H18		C9H18
177.501	STYRENE	100425	C8H8
178	1-NONENE	124118	C9H18
178.501	2-NONENE		C9H18
179	O-XYLENE	95476	C8H10
187	N-NONANE	111842	C9H20
188	C9H18		C9H18
195	ISOPROPYLBENZENE	98828	C9H12
196	C10H22 ?		C10H22
200	C10H22		C10H22
204	N-PROPYLBENZENE	103651	C9H12
206	1-METHYL-3-ETHYLBENZENE	620144	C9H12
207	1-METHYL-4-ETHYLBENZENE	622968	C9H12
209	1,3,5-TRIMETHYLBENZENE	108678	C9H12
212	C10H22		C10H22
213	1-METHYL-2-ETHYLBENZENE	611143	C9H12
216	C10H20		C10H20
217	o-METHYLSTYRENE	100801	C9H10
218	1,2,4-TRIMETHYLBENZENE	95636	C9H12
219	N-DECANE	124185	C10H22
222.503	p-METHYLSTYRENE		C9H10
223	1,2,3-TRIMETHYLBENZENE	576738	C10H14
225	2,3-DIHYDROINDENE(INDAN)	496117	C9H10
226	C10H20		C10H20
227	1,3-DIETHYLBENZENE	141935	C10H14
229	1-METHYL-3-n-PROPYLBENZENE	1074437	C10H14
230	1,2-DIETHYLBENZENE	135013	C10H14
233	1-METHYL-2-n-PROPYLBENZENE	1074175	C10H14
235	1,3-DIMETHYL-4-ETHYLBENZENE	874419	C10H14
236	1,2-DIMETHYL-4-ETHYLBENZENE	934805	C10H14
237	1,3-DIMETHYL-2-ETHYLBENZENE	2870044	C10H14
241.501	C11H16		C11H16
245	1,2,4,5-TETRAMETHYLBENZENE	95932	C10H14
246	1,2,3,5-TETRAMETHYLBENZENE	527537	C10H14
268	NAPHTHALENE	91203	C10H8
269	n-DODECANE	112403	C12H26
330	MTBE	1634044	C5H12O
341	ETHANOL	108101	C2H6O

Table A-2. VFV Chevrolet Lumina - RFG Emissions Tests

VFV CHEVROLET LUMINA - RFG TESTS AT LAB 1

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)
AR202EL	1992	ATL	3/14/94	14699	RFG	18.32	0.0011	0.0520	4.0900	470.5000		0.0035	0.2620	0.1400			0.3040	0.0620	0.1970	0.2590
AR202EL	1992	ATL	3/17/94	14774	RFG	19.20	0.0011	0.0480	3.8500	449.1000		0.0035	0.1830	0.1300			0.2210	0.0820	0.2940	0.3760
AR201EL	1992	ATL	3/18/94	12121	RFG	19.51	0.0010	0.0480	1.7900	445.4000		0.0038	0.1430	0.1400			0.1810	0.1790	1.3560	1.5350
AR204EL	1992	ATL	3/22/94	10276	RFG	19.16	0.0009	0.0400	2.7800	451.9000		0.0031	0.1660	0.1700			0.1980	0.1180	0.3390	0.4570
AR201EL	1992	ATL	3/23/94	12226	RFG	19.08	0.0009	0.0590	3.4700	452.5000		0.0028	0.2650	0.1600			0.3120	0.1830	0.8590	1.0420
AR202EL	1992	ATL	3/25/94	14939	RFG	19.37	0.0010	0.0470	3.7800	445.2000		0.0035	0.1990	0.1500			0.2360	0.0870	0.3950	0.4820
AR204EL	1992	ATL	3/25/94	10379	RFG	19.22	0.0012	0.0420	2.6700	450.8000		0.0033	0.1560	0.1600			0.1880	0.0500	0.3940	0.4440
VO016EL	1993	ATL	12/2/94	20520	RFG	19.28	0.0004	0.0240	1.9800	450.6000		0.0014	0.1230	0.2000			0.1430	0.0700	0.1940	0.2640
AR301EL	1993	ATL	12/6/94	46034	RFG	19.41	0.0005	0.0340	2.6300	446.1000		0.0018	0.1700	0.3100			0.1980	0.0700	0.3900	0.4600
COUNT						9	9	9	9	9		9	9	9			9	9	9	9
AVERAGE						19.1722	0.0009	0.0438	3.0044	451.3444		0.0030	0.1852	0.1733			0.2201	0.1001	0.4909	0.5910
STD DEV						0.3265	0.0003	0.0097	0.7845	7.2653		0.0008	0.0466	0.0521			0.0529	0.0468	0.3573	0.3981
CV						0.0170	0.2963	0.2219	0.2611	0.0161		0.2654	0.2517	0.3004			0.2405	0.4672	0.7279	0.6736
MAX						19.5100	0.0012	0.0590	4.0900	470.5000		0.0038	0.2650	0.3100			0.3120	0.1830	1.3560	1.5350
MIN						18.3200	0.0004	0.0240	1.7900	445.2000		0.0014	0.1230	0.1300			0.1430	0.0500	0.1940	0.2590

VFV CHEVROLET LUMINA - RFG TESTS AT LAB 2

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)
DC215EL	1992	ERD	5/6/94	11045	RFG	19.29	0.0012	0.0404	2.9064	453.8632		0.0054	0.1421	0.2655			0.1743	0.0473	0.1303	0.1776
DC215EL	1992	ERD	5/14/94	11211	RFG	19.46	0.0012	0.0398	2.9499	449.8355		0.0046	0.1322	0.2760			0.1639	0.0549	0.1430	0.1979
DC206EL	1992	ERD	6/14/94	8296	RFG	18.12	0.0011	0.0428	3.3068	483.1241		0.0060	0.1356	0.1967			0.1697	0.0558	0.1133	0.1691
DC206EL	1992	ERD	6/20/94	8400	RFG	18.27	0.0009	0.0330	2.1223	481.1516		0.0043	0.1252	0.2361			0.1515	0.0450	0.1056	0.1506
DC213EL	1992	ERD	7/21/94	10621	RFG	19.31	0.0010	0.0345	2.0911	454.7956		0.0046	0.1118	0.2390			0.1393			
DC221EL	1993	ERD	7/29/94	10293	RFG	18.06	0.0004	0.0282	1.9395	487.4542		0.0038	0.0860	0.3324			0.1085	0.0351	0.0708	0.1059
DC211EL	1992	ERD	7/29/94	10376	RFG	18.63	0.0014	0.0418	3.0465	469.9074		0.0065	0.1429	0.2311			0.1762	0.0501	0.1006	0.1507
DC222EL	1993	ERD	8/1/94	9129	RFG	18.62	0.0011	0.0284	2.7162	471.0995		0.0046	0.1192	0.1794			0.1418	0.0694	0.0624	0.1318
DC227ELC	1993	ERD	8/15/94	11081	RFG	18.24	0.0006	0.0260	2.6576	481.1846		0.0039	0.0942	0.2248			0.1149	0.0382	0.0500	0.0882
DC231EL	1993	ERD	8/24/94	12444	RFG	18.05	0.0005	0.0278	2.0050	487.4208		0.0031	0.1036	0.1927			0.1257	0.0651	0.1552	0.2203
DC218ELC	1993	ERD	8/30/94	10849	RFG	17.79	0.0006	0.0282	2.8616	492.5368		0.0027	0.1007	0.2686			0.1232	0.0938	0.1082	0.2020
DC229EL	1993	ERD	9/21/94	10067	RFG	18.21	0.0007	0.0223	1.3119	484.3811		0.0023	0.0781	0.2455			0.0971	0.0774	0.1148	0.1922
DC208EL	1992	ERD	12/30/94	11673	RFG	18.39	0.0009	0.0497	4.3769	473.6721		0.0054	0.1914	0.3255			0.2331	0.0456	0.1222	0.1678
DC201EL	1992	ERD	1/6/95	6365	RFG	18.07	0.0011	0.0482	3.9600	483.4096		0.0042	0.2430	0.2428			0.2841	0.0641	0.1129	0.1770
DC207EL	1992	ERD	1/6/95	5902	RFG	16.82	0.0010	0.0381	3.8022	519.8427		0.0036	0.1912	0.3748			0.2236	0.0625	0.1166	0.1791
DC209EL	1992	ERD	1/11/95	13058	RFG	18.39	0.0009	0.0353	1.9759	477.8521		0.0075	0.1099	0.3570			0.1393	0.0699	0.1039	0.1738
DC219ELC	1993	ERD	1/17/95	10544	RFG	18.03	0.0006	0.0264	1.2194	489.3387		0.0072	0.0964	0.2995			0.1188	0.1021	0.1785	0.2806
DC225EL	1993	ERD	1/24/95	8904	RFG	17.40	0.0006	0.0225	1.6005	505.6165		0.0046	0.0952	0.3280			0.1148	0.0900		
COUNT						18	18	18	18	18		18	18	18			18	17	16	16
AVERAGE						18.29	0.0009	0.0341	2.6028	480.3603		0.0047	0.1277	0.2675			0.1555	0.0627	0.1118	0.1728
STD DEV						0.63	0.0003	0.0082	0.8719	16.8220		0.0014	0.0416	0.0559			0.0478	0.0189	0.0316	0.0434
CV						0.03	0.3046	0.2405	0.3350	0.0350		0.2995	0.3261	0.2090			0.3075	0.3009	0.2827	0.2512
MAX						19.46	0.0014	0.0497	4.3769	519.8427		0.0075	0.2430	0.3748			0.2841	0.1021	0.1785	0.2806
MIN						16.82	0.0004	0.0223	1.2194	449.8355		0.0023	0.0781	0.1794			0.0971	0.0351	0.0500	0.0882

Table A-3. VFV Chevrolet Lumina - E50 Emissions Tests

VFV CHEVROLET LUMINA - E50 TESTS AT LAB 1

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)		
AR204EL	1992	ATL	3/16/94	10178	E50	16.26	0.0170	0.0740	3.3500	437.8000	0.0603	0.0040	0.1850	0.1100	0.2720	0.2080	0.2500	0.1050	0.5290	0.6340		
AR201EL	1992	ATL	3/17/94	12086	E50	16.37	0.0142	0.0620	1.3600	438.2000	0.0407	0.0046	0.1080	0.1400	0.1750	0.1220	0.1600	0.1680	0.9700	1.1380		
AR201EL	1992	ATL	3/21/94	12156	E50	16.33	0.0146	0.0610	1.4900	439.1000	0.0535	0.0046	0.1260	0.1400	0.1950	0.1420	0.1800	0.1510	1.1450	1.2960		
AR202EL	1992	ATL	3/22/94	14869	E50	16.66	0.0149	0.0600	3.1700	427.6000	0.0539	0.0041	0.1740	0.1100	0.2470	0.1950	0.2270	0.1280	0.6410	0.7690		
AR202EL	1992	ATL	3/23/94	14896	E50	16.55	0.0126	0.0530	3.0200	430.8000	0.0490	0.0044	0.1450	0.1300	0.2050	0.1590	0.1920	0.2430	0.6590	0.9020		
AR204EL	1992	ATL	3/23/94	10309	E50	16.47	0.0121	0.0620	2.8800	433.2000	0.0492	0.0038	0.1440	0.1400	0.2130	0.1590	0.1980	0.0960	0.5320	0.6280		
VO016EL	1993	ATL	12/5/94	20555	E50	16.58	0.0058	0.0360	2.2700	428.3000	0.0318	0.0017	0.0910	0.1400	0.1300	0.0990	0.1240	0.1000	0.6190	0.7190		
AR301EL	1993	ATL	12/8/94	46074	E50	16.57	0.0060	0.0440	2.9000	427.4000	0.0398	0.0018	0.1080	0.2000	0.1560	0.1180	0.1490	0.1010	0.5270	0.6280		
COUNT						8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
AVERAGE						16.4738	0.0122	0.0565	2.5550	432.8000	0.0473	0.0036	0.1351	0.1388	0.1991	0.1503	0.1850	0.1365	0.7028	0.8393		
STD DEV						0.1314	0.0039	0.0111	0.7154	4.6699	0.0086	0.0011	0.0310	0.0262	0.0434	0.0354	0.0385	0.0472	0.2151	0.2379		
CV						0.0080	0.3175	0.1967	0.2800	0.0108	0.1828	0.3095	0.2293	0.1888	0.2179	0.2356	0.2082	0.3460	0.3060	0.2834		
MAX						16.6600	0.0170	0.0740	3.3500	439.1000	0.0603	0.0046	0.1850	0.2000	0.2720	0.2080	0.2500	0.2430	1.1450	1.2960		
MIN						16.2600	0.0058	0.0360	1.3600	427.4000	0.0318	0.0017	0.0910	0.1100	0.1300	0.0990	0.1240	0.0960	0.5270	0.6280		

VFV CHEVROLET LUMINA - E50 TESTS AT LAB 2

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)		
DC215EL	1992	ERD	5/11/94	11114	E50	15.94	0.0109	0.0495	2.7426	439.1572	0.0515	0.0065	0.0978	0.1920	0.1595	0.1168	0.1406	0.0483	0.1364	0.1847		
DC215EL	1992	ERD	5/12/94	11141	E50	15.88	0.0132	0.0593	3.0576	440.0991	0.0532	0.0073	0.1018	0.1958	0.1732	0.1220	0.1530	0.0569	0.1389	0.1958		
DC206EL	1992	ERD	6/13/94	8261	E50	15.13	0.0107	0.0456	2.5545	463.4216	0.0491	0.0065	0.0830	0.1457	0.1406	0.1012	0.1224	0.0545	0.1362	0.1907		
DC206EL	1992	ERD	6/21/94	8434	E50	15.07	0.0111	0.0410	1.8101	465.6977	0.0443	0.0055	0.0862	0.1786	0.1385	0.1030	0.1217	0.0736	0.1125	0.1861		
DC213EL	1992	ERD	7/18/94	10536	E50	15.82	0.0091	0.0404	1.6291	444.1592	0.0417	0.0052	0.0727	0.1876	0.1231	0.0882	0.1076	0.0865	0.1419	0.2284		
DC211EL	1992	ERD	7/28/94	10342	E50	15.57	0.0106	0.0579	3.0801	448.5488	0.0307	0.0066	0.1137	0.1795	0.1763	0.1263	0.1637	0.0738	0.1041	0.1779		
DC221EL	1993	ERD	7/28/94	10258	E50	15.03	0.0068	0.0465	2.6824	465.9131	0.0395	0.0046	0.0811	0.1961	0.1353	0.0951	0.1213	0.0242	0.0416	0.0658		
DC222EL	1993	ERD	8/4/94	9199	E50	15.42	0.0068	0.0403	2.6460	454.2177	0.0323	0.0039	0.0806	0.1098	0.1273	0.0925	0.1155	0.0999	0.0702	0.1701		
DC227ELC	1993	ERD	8/16/94	11115	E50	15.28	0.0073	0.0343	2.8564	458.1014	0.0246	0.0041	0.0846	0.1217	0.1240	0.0943	0.1143	0.0321	0.0599	0.0920		
DC231EL	1993	ERD	8/25/94	12479	E50	14.36	0.0091	0.0841	6.2908	481.9250	0.0350	0.0042	0.1321	0.1124	0.2182	0.1455	0.2047	0.0642	0.1140	0.1782		
DC218ELC	1993	ERD	8/29/94	10813	E50	14.97	0.0067	0.0370	2.6821	468.4686	0.0200	0.0029	0.0811	0.1499	0.1212	0.0892	0.1131	0.0883	0.1003	0.1886		
DC229EL	1993	ERD	9/19/94	9998	E50	14.94	0.0077	0.0326	1.3666	470.7301	0.0236	0.0045	0.0689	0.2274	0.1065	0.0784	0.0970	0.0723	0.1331	0.2054		
DC208EL	1992	ERD	12/29/94	11638	E50	15.20	0.0131	0.0574	3.5453	459.2228	0.0523	0.0058	0.1277	0.2611	0.1972	0.1476	0.1774	0.0544	0.1089	0.1633		
DC207EL	1992	ERD	1/5/95	5867	E50	13.80	0.0154	0.0605	3.5940	505.5787	0.0497	0.0065	0.1547	0.2904	0.2268	0.1745	0.2070	0.0523	0.1274	0.1797		
DC201EL	1992	ERD	1/10/95	6434	E50	14.88	0.0155	0.0520	2.9039	469.6100	0.0438	0.0055	0.1397	0.2150	0.2026	0.1577	0.1846	0.0432	0.1105	0.1537		
DC209EL	1992	ERD	1/10/95	13023	E50	15.02	0.0099	0.0473	2.2000	467.3118	0.0336	0.0047	0.0815	0.2665	0.1356	0.0947	0.1224	0.0544	0.0915	0.1459		
DC219ELC	1993	ERD	1/18/95	10578	E50	14.97	0.0079	0.0305	1.3110	470.0536	0.0331	0.0101	0.0638	0.1653	0.1027	0.0763	0.0902	0.0635	0.1215	0.1850		
DC225EL	1993	ERD	1/23/95	8870	E50	14.56	0.0096	0.0341	2.7980	481.0415	0.0403	0.0055	0.0962	0.1778	0.1409	0.1114	0.1257	0.0703	0.1582	0.2285		
COUNT						18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
AVERAGE						15.10	0.0101	0.0472	2.7639	464.0699	0.0388	0.0055	0.0971	0.1874	0.1528	0.1119	0.1379	0.0618	0.1115	0.1733		
STD DEV						0.52	0.0027	0.0129	1.0699	15.7511	0.0100	0.0016	0.0254	0.0498	0.0368	0.0276	0.0346	0.0188	0.0296	0.0395		
CV						0.03	0.2694	0.2733	0.3871	0.0339	0.2585	0.2810	0.2615	0.2658	0.2407	0.2463	0.2511	0.3036	0.2653	0.2279		
MAX						15.94	0.0155	0.0841	6.2908	505.5787	0.0532	0.0101	0.1547	0.2904	0.2268	0.1745	0.2070	0.0999	0.1582	0.2285		
MIN						13.80	0.0067	0.0305	1.3110	439.1572	0.0200	0.0029	0.0638	0.1098	0.1027	0.0763	0.0902	0.0242	0.0416	0.0658		

Table A-4. VFV Chevrolet Lumina - E85 Emissions Tests

VFV CHEVROLET LUMINA - E85 TESTS AT LAB 1

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)				
AR201EL	1992	ATL	3/16/94	12051	E85	14.46	0.0428	0.0890	1.5100	426.0000	0.1093	0.0082	0.1180	0.1400	0.2360	0.1590	0.2000	0.1680	0.8240	0.9920				
AR202EL	1992	ATL	3/18/94	14809	E85	14.71	0.0272	0.0600	2.6000	417.1000	0.1119	0.0057	0.1260	0.1100	0.2120	0.1600	0.1860	0.0740	0.1970	0.2710				
AR204EL	1992	ATL	3/18/94	10221	E85	14.63	0.0338	0.0740	2.6700	419.2000	0.1255	0.0060	0.1420	0.1300	0.2430	0.1790	0.2140	0.1170	0.4250	0.5420				
AR201EL	1992	ATL	3/22/94	12191	E85	14.59	0.0306	0.0590	1.0300	423.2000	0.1150	0.0065	0.1010	0.1300	0.1840	0.1340	0.1600	0.1190	0.7210	0.8400				
AR204EL	1992	ATL	3/24/94	10344	E85	14.69	0.0274	0.0650	2.3600	418.2000	0.1301	0.0056	0.1270	0.1700	0.2160	0.1600	0.1920	0.1150	0.4630	0.5780				
AR301EL	1993	ATL	12/2/94	46000	E85	15.08	0.0122	0.0550	2.4700	407.2000	0.0642	0.0028	0.0860	0.2000	0.1500	0.1030	0.1380	0.0810	0.3910	0.4720				
VO016EL	1993	ATL	12/7/94	20597	E85	14.73	0.0121	0.0790	3.6400	414.8000	0.1020	0.0020	0.1030	0.1100	0.1930	0.1250	0.1800	0.0800	0.3890	0.4690				
VO016EL	1993	ATL	12/8/94	20624	E85	14.49	0.0123	0.0550	2.0600	424.6000	0.0776	0.0024	0.0740	0.1100	0.1380	0.0920	0.1260	0.0680	0.3490	0.4170				
COUNT						8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8		
AVERAGE						14.67	0.0248	0.0670	2.2925	418.7875	0.1045	0.0049	0.1096	0.1375	0.1965	0.1390	0.1745	0.1028	0.4699	0.5726				
STD DEV						0.18	0.0107	0.0116	0.7373	5.6878	0.0213	0.0021	0.0213	0.0303	0.0355	0.0287	0.0287	0.0314	0.1912	0.2192				
CV						0.01	0.4334	0.1736	0.3216	0.0136	0.2042	0.4265	0.1944	0.2204	0.1808	0.2068	0.1643	0.3058	0.4068	0.3828				
MAX						15.08	0.0428	0.0890	3.6400	426.0000	0.1301	0.0082	0.1420	0.2000	0.2430	0.1790	0.2140	0.1680	0.8240	0.9920				
MIN						14.46	0.0121	0.0550	1.0300	407.2000	0.0642	0.0020	0.0740	0.1100	0.1380	0.0920	0.1260	0.0680	0.1970	0.2710				

VFV CHEVROLET LUMINA - E85 TESTS AT LAB 2

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)				
DC215EL	1992	ERD	5/10/94	11080	E85	14.32	0.0337	0.0723	2.3218	430.2792	0.1357	0.0104	0.0603	0.1765	0.1743	0.1117	0.1228	0.0442	0.1303	0.1745				
DC215EL	1992	ERD	5/13/94	11176	E85	14.40	0.0273	0.0662	2.5911	426.5329	0.1384	0.0077	0.0750	0.2294	0.1825	0.1253	0.1323	0.2333	0.1872	0.4205				
DC206EL	1992	ERD	6/16/94	8338	E85	13.69	0.0262	0.0549	1.6729	451.3690	0.0768	0.0087	0.0643	0.1792	0.1432	0.0957	0.1118	0.0443	0.0902	0.1345				
DC206EL	1992	ERD	6/17/94	8365	E85	13.85	0.0240	0.0504	1.5266	446.4997	0.0991	0.0082	0.0532	0.2191	0.1342	0.0906	0.0968	0.0526	0.1060	0.1586				
DC213EL	1992	ERD	7/19/94	10571	E85	14.25	0.0212	0.0547	1.7062	433.0396	0.0700	0.0064	0.0686	0.1735	0.1436	0.0963	0.1158							
DC221EL	1993	ERD	7/27/94	10224	E85	13.80	0.0134	0.0752	3.2155	444.9234	0.1143	0.0079	0.0766	0.1684	0.1803	0.1153	0.1417	0.0232	0.0500	0.0732				
DC211EL	1992	ERD	8/1/94	10411	E85	13.93	0.0227	0.0594	2.4520	441.6985	0.0929	0.0076	0.0637	0.1994	0.1501	0.0988	0.1150	0.0675	0.0959	0.1634				
DC222EL	1993	ERD	8/2/94	9164	E85	13.75	0.0125	0.0726	3.5794	446.4056	0.0993	0.0058	0.0559	0.1111	0.1525	0.0897	0.1187	0.0593	0.0627	0.1220				
DC227ELC	1993	ERD	8/17/94	11151	E85	13.80	0.0135	0.0598	2.7002	445.5640	0.0612	0.0070	0.0633	0.1340	0.1377	0.0860	0.1150	0.0588	0.1138	0.1726				
DC231EL	1993	ERD	8/22/94	12409	E85	13.24	0.0149	0.0613	2.0248	466.2806	0.0758	0.0057	0.0789	0.1249	0.1594	0.1064	0.1319	0.1607	0.1685	0.3292				
DC218ELC	1993	ERD	8/26/94	10778	E85	13.40	0.0146	0.0635	2.7832	459.3021	0.0727	0.0044	0.0682	0.1196	0.1496	0.0947	0.1231	0.0565	0.0648	0.1213				
DC229EL	1993	ERD	9/20/94	10033	E85	13.50	0.0173	0.0460	1.4359	457.5390	0.0779	0.0055	0.0317	0.1802	0.1003	0.0605	0.0714	0.0696	0.1320	0.2016				
DC230EL	1993	ERD	10/7/94	8218	E85	13.53	0.0185	0.0681	1.9388	455.8625	0.0650	0.0051	0.0497	0.1170	0.1340	0.0751	0.1086	0.0691	0.0901	0.1592				
DC208EL	1992	ERD	1/3/95	11708	E85	13.79	0.0243	0.0789	3.2724	444.8443	0.1085	0.0089	0.0872	0.2522	0.1957	0.1276	0.1554	0.0448	0.0860	0.1308				
DC201EL	1992	ERD	1/9/95	6399	E85	13.52	0.0355	0.0523	2.6016	454.7243	0.1090	0.0089	0.1002	0.2025	0.1894	0.1442	0.1454	0.0561	0.1155	0.1716				
DC207EL	1992	ERD	1/9/95	5937	E85	12.62	0.0339	0.0570	1.8433	489.1651	0.1201	0.0105	0.0752	0.3174	0.1714	0.1221	0.1246	0.0589	0.1337	0.1926				
DC209EL	1992	ERD	1/12/95	13096	E85	13.73	0.0276	0.0635	1.9992	448.6821	0.1539	0.0146	0.0331	0.2961	0.1430	0.0882	0.0880	0.0569	0.1187	0.1756				
DC219ELC	1993	ERD	1/19/95	10613	E85	13.37	0.0196	0.0523	1.7598	461.9094	0.0644	0.0093	0.0566	0.1295	0.1274	0.0822	0.1018	0.0661	0.1236	0.1897				
DC225EL	1993	ERD	1/25/95	8939	E85	13.07	0.0182	0.0303	2.1375	471.9018	0.0797	0.0076	0.0519	0.1523	0.1078	0.0816	0.0780	0.0610	0.1380	0.1990				
COUNT						19	19	19	19	19	19	19	19	19	19	19	19	19	19	18	18	18		
AVERAGE						13.66	0.0220	0.0599	2.2927	451.3960	0.0955	0.0079	0.0639	0.1833	0.1514	0.0996	0.1157	0.0713	0.1115	0.1828				
STD DEV						0.42	0.0070	0.0112	0.6038	14.4741	0.0269	0.0023	0.0164	0.0577	0.0254	0.0201	0.0213	0.0473	0.0344	0.0764				
CV						0.03	0.3201	0.1868	0.2633	0.0321	0.2817	0.2924	0.2569	0.3148	0.1679	0.2019	0.1843	0.6642	0.3089	0.4181				
MAX						14.40	0.0355	0.0789	3.5794	489.1651	0.1539	0.0146	0.1002	0.3174	0.1957	0.1442	0.1554	0.2333	0.1872	0.4205				
MIN						12.62	0.0125	0.0303	1.4359	426.5329	0.0612	0.0044	0.0317	0.1111	0.1003	0.0605	0.0714	0.0232	0.0500	0.0732				

Table A-5. Standard Gasoline Chevrolet Lumina - RFG Emissions Tests

STANDARD GASOLINE CHEVROLET LUMINA - RFG TESTS AT LAB 1

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)	
AR203GLC	1991	ATL	4/1/94	8349	RFG	20.07	0.00098	0.033	2.58	431.5		0.00334	0.164	0.49			0.19	0.458	0.3460	0.458	
AR204GLC	1991	ATL	4/8/94	8800	RFG	19.84	0.00093	0.03	1.79	438		0.00291	0.153	0.47			0.177	0.918	0.3190	0.918	
AR205GLC	1991	ATL	4/5/94	8948	RFG	19.92	0.00119	0.027	2.04	435.7		0.00368	0.158	0.59			0.179	0.401	0.3120	0.401	
AR205GLC	1991	ATL	4/4/94	8922	RFG	19.89	0.00111	0.027	2.01	436.4		0.00377	0.175	0.65			0.197	0.581	0.4450	0.581	
AR206GLC	1991	ATL	4/7/94	7267	RFG	20.05	0.00045	0.035	2.41	432.2		0.00123	0.173	0.41			0.2	0.418	0.2780	0.418	
AR207GLC	1991	ATL	3/31/94	9646	RFG	20.17	0.00085	0.034	2.98	428.6		0.00261	0.197	0.48			0.224	0.388	0.2780	0.388	
AR207GLC	1991	ATL	4/1/94	9673	RFG	20.57	0.00103	0.028	2.22	421.5		0.00319	0.161	0.53			0.183	0.402	0.3050	0.402	
AR208GLC	1991	ATL	4/5/94	10912	RFG	20.49	0.00099	0.031	2.98	421.9		0.00312	0.191	0.46			0.215	1.359	1.0380	1.359	
AR208GLC	1991	ATL	4/1/94	10886	RFG	20.35	0.00081	0.037	2.87	425.1		0.00253	0.185	0.55			0.214	1.293	1.0930	1.293	
COUNT						9	9	9	9	9		9	9	9				9	9	9	9
AVERAGE						20.15	0.00	0.03	2.43	430.10		0.00	0.17	0.51				0.20	0.69	0.49	0.69
STD DEV						0.25	0.00	0.00	0.42	5.85		0.00	0.01	0.07				0.02	0.37	0.31	0.37
CV						0.01	0.22	0.11	0.17	0.01		0.25	0.08	0.13				0.08	0.54	0.63	0.54
MAX						20.57	0.00	0.04	2.98	438.00		0.00	0.20	0.65				0.22	1.36	1.09	1.36
MIN						19.84	0.00	0.03	1.79	421.50		0.00	0.15	0.41				0.18	0.39	0.28	0.39

STANDARD GASOLINE CHEVROLET LUMINA - RFG TESTS AT LAB 2

NREL ID	MODEL YEAR	LAB	TEST DATE	TEST ODOM	TEST FUEL	MPG	CH ₃ CHO	CH ₄	CO	CO ₂	ETOH	HCHO	NMHC	NO _x	OMHCE	OMNMHCE	THC	EVAP DI THC	EVAP HS THC	EVAP THC(total)	
DC209GLC	1993	ERD	5/27/94	2903	RFG	20.14	0.0012	0.0336	2.5792	435.1320		0.0071	0.1804	0.7100			0.2072	0.0322	0.0818	0.1140	
DC209GLC	1993	ERD	5/31/94	2930	RFG	19.83	0.0018	0.0335	2.5577	442.4679		0.0093	0.1582	0.6091			0.1849	0.1069	0.1011	0.2080	
DC207GLC	1993	ERD	6/13/94	9405	RFG	19.43	0.0014	0.0348	3.3318	449.6017		0.0064	0.1719	0.4758			0.1996	0.0959	0.0897	0.1856	
DC207GLC	1993	ERD	6/14/94	9432	RFG	19.45	0.0012	0.0502	5.4649	445.8709		0.0051	0.2044	0.3807			0.2444	0.1024	0.0875	0.1899	
DC215GLC	1993	ERD	6/28/94	3385	RFG	19.36	0.0008	0.0302	3.1609	451.9486		0.0036	0.1659	0.4850			0.1899	0.1476	0.0980	0.2456	
DC202GLC	1993	ERD	7/7/94	2981	RFG	19.18	0.0008	0.0377	3.1927	456.0654		0.0045	0.1655	0.8232			0.1955	0.9657	0.1317	1.0974	
DC214GLC	1993	ERD	7/19/94	11027	RFG	19.86	0.0009	0.0393	3.3542	439.5714		0.0045	0.1760	0.4995			0.2073	0.0236	0.0596	0.0832	
DC216GLC	1993	ERD	8/5/94	9097	RFG	18.95	0.0008	0.0398	3.6472	460.6140		0.0060	0.1944	0.5211			0.2260	0.4786	0.0684	0.5470	
DC218GLC	1993	ERD	9/2/94	10713	RFG	18.76	0.0012	0.0386	4.1363	464.5914		0.0060	0.1940	0.4660			0.2247	0.0587	0.0858	0.1445	
DC205GLC	1993	ERD	9/12/94	4379	RFG	18.42	0.0010	0.0437	4.5333	472.5647		0.0046	0.2089	0.4146			0.2464	0.0638	0.0705	0.1343	
DC211GLC	1993	ERD	12/28/94	5906	RFG	18.44	0.0016	0.0331	3.6526	473.6169		0.0055	0.1739	0.6723			0.2019				
DC208GLC	1993	ERD	1/5/95	3098	RFG	18.21	0.0012	0.0363	3.5554	480.3867		0.0059	0.1908	0.4593			0.2214	0.0714	0.0858	0.1572	
DC210GLC	1993	ERD	1/23/95	8767	RFG	18.94	0.0013	0.0365	3.7953	460.7321		0.0066	0.1834	0.5661			0.2143	0.0990	0.1013	0.2003	
DC206GLC	1993	ERD	1/24/95	7996	RFG	18.62	0.0012	0.0409	4.3710	468.0472		0.0070	0.2188	0.6438			0.2536	0.0801	0.0935	0.1736	
DC220GLC	1993	ERD	2/7/95	4947	RFG	18.65	0.0012	0.0383	4.5250	467.1101		0.0063	0.2054	0.5629			0.2392	0.0610	0.0970	0.1580	
DC219GLC	1993	ERD	2/13/95	22151	RFG	18.01	0.0016	0.0522	5.6495	482.3362		0.0068	0.2551	0.6243			0.3003	0.0753	0.1077	0.1830	
DC203GLC	1993	ERD	2/20/95	10253	RFG	19.33	0.0012	0.0506	3.9845	451.4917		0.0119	0.2149	1.3760			0.2580	0.1273	0.0936	0.2209	
DC213GLC	1993	ERD	3/22/95	16021	RFG	19.84	0.0011	0.0457	4.2917	438.6032		0.0069	0.1920	0.6519			0.2303	0.0300	0.0970	0.1270	
COUNT						18	18	18	18	18		18	18	18				18	17	17	17
AVERAGE						19.08	0.00	0.04	3.88	457.82		0.01	0.19	0.61				0.22	0.15	0.09	0.25
STD DEV						0.60	0.00	0.01	0.82	14.08		0.00	0.02	0.22				0.03	0.23	0.02	0.23
CV						0.03	0.22	0.16	0.21	0.03		0.29	0.12	0.36				0.13	1.47	0.18	0.95
MAX						20.14	0.00	0.05	5.65	482.34		0.01	0.26	1.38				0.30	0.97	0.13	1.10
MIN						18.01	0.00	0.03	2.56	435.13		0.00	0.16	0.38				0.18	0.02	0.06	0.08

Table A-6. Speciation Analysis Test Result Summary

Make Model Model year Decal ID Test Fuel	GMC- Chev LUMINA 1992 AR202EL E50	GMC- Chev LUMINA 1992 AR202EL E50	GMC- Chev LUMINA 1993 VO016EL E50	GMC- Chev LUMINA 1992 AR202EL E85	GMC- Chev LUMINA 1993 VO016EL E85	GMC- Chev LUMINA 1993 VO016EL E85	GMC- Chev LUMINA 1992 AR202EL RFG	GMC- Chev LUMINA 1992 AR202EL RFG	GMC- Chev LUMINA 1991 AR204GLC RFG	GMC- Chev LUMINA 1993 VO016EL RFG
Test Number	1029	994	3918	973	3932	3946	952	1155	1551	3911
Total VOC, milligrams/mile	254.51	218.84	140.87	267.65	236.83	174.82	228.07	225.85	158.44	128.76
Total NMOG, milligrams/mile	198.41	169.14	106.27	210.25	161.43	124.62	181.57	179.35	130.24	107.66
Total MIR speciated NMOG, mg/mile	198.41	169.04	106.27	210.15	161.43	124.62	180.77	178.75	129.64	107.46
Percent MIR accounted	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	99.6%	99.7%	99.5%	99.8%
OFF, mgO ₃ /mile	639.58	519.24	312.41	573.18	372.13	301.29	670.74	643.42	484.41	351.94
SR, mgO ₃ /mgNMOG	3.22	3.07	2.94	2.73	2.31	2.42	3.71	3.60	3.74	3.28

Table A-7. Average OFF, SR and Toxic Compound Emissions

	E50	std. dev.	E85	std. dev.	RFG	std. dev.	RFG C Dedicated	Std. Dev. (one sample)
OFF	490.41	135.11	415.53	115.16	555.37	82.16	484.41	0
SR	3.08	0.12	2.48	0.18	3.53	0.06	3.74	0
Benzene	5.00	1.07	1.83	0.37	8.90	2.26	5.50	0
1,3 Butadiene	0.43	0.17	0.17	0.09	0.87	0.33	1.20	0
Formaldehyde	3.38	1.23	3.36	1.63	2.79	1.01	2.91	0
Acetaldehyde	11.10	3.85	17.21	7.06	0.84	0.31	0.93	0