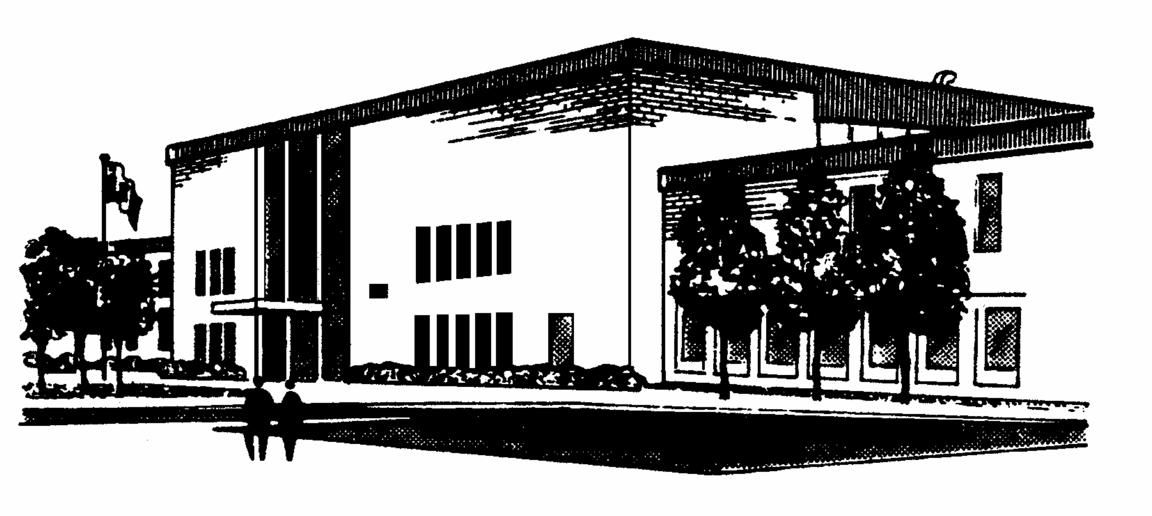
Comparison of Emissions of Conventional and Flexible-fuel Vehicles Operating on Gasoline and E85 Fuels



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Summary

The objective of this project was to determine whether flexible fuel vehicles (FFV), when run on regular gasoline produced increased emissions when compared to E85 and to conventional vehicles.

A pair of Dodge Caravans, one FFV and one conventional and a Chrysler Sebring FFV were used in this study. The Dodge Caravans met the California LEV (low emission vehicle) standard while the Sebring met the California ULEV (ultra-low emission vehicle) standard. The vehicles were tested using standard emissions test procedures as designated in the Canadian Environmental Protection Act (CEPA) 1999, Part 7, Division 5. These testing procedures and requirements are identical to those found in the US EPA Code of Federal Regulations (CFR), volume 40, part 86. The urban dynamometer driving schedule (UDDS) cycle simulates city driving conditions. It has three Phases to capture emissions information on cold engine start (Phase 1), stabilized operation (Phase 2) and hot engine start (Phase 3).

The answers to the specific questions that were posed are summarized below.

1. Do flexible fuel vehicles have higher tailpipe emissions when operated on gasoline when compared to similar normally equipped vehicles?

   From the data presented here on one pair of vehicles, the FFV when operated on regular gasoline showed no statistically significant difference in emissions as compared to the conventional vehicle, except for cold start NOx emissions. These emissions were 20% lower for the FFV compared to the conventional vehicle. As a result, the FTP composite NOx emission rate for the FFV was lower by 22%.

2. Do flexible fuel vehicles have higher tailpipe emissions when operated on gasoline when compared to operation on E85?

   From the data presented here on two FFVs meeting different emission standards, operation on E85 resulted in statistically significantly lower CO and NOx emissions for both vehicles as compared to operation on regular gasoline, but only when engine start was part of the driving cycle. CO emissions were 64% lower while NOx emissions were 55% lower. When the catalyst was at normal operating temperatures there were no statistically significant differences in emissions. For the Caravan there was no statistically significant difference in NMOG (non-methane organic gas) emissions between the two fuels at any time. For the Sebring, NMOG emissions were statistically significantly higher (by 22%) on E85 only during cold engine start (Phase 1), and were then 86% lower during hot engine start (Phase 3) possibly indicating the effectiveness of the catalyst once its operating at optimum temperature.

3. Does the fuel composition sensor impact emissions when it is not reading the fuel composition correctly?

   Yes. The vehicles were tested immediately after the fuel change from gasoline to E85 and again when the fuel sensor appeared to reach a plateau or reached the correct value. For both vehicles, the cold start CO and NOx emissions, immediately after fuel change, were significantly greater than those observed when the fuel sensor had reached its final level. The emissions measured when the catalyst was at normal operating temperature were no different. An unusual effect was the cold start NMOG emissions for the Sebring which increased, by 53% from start to finish, as the fuel sensor reached the correct reading.

4. How long does the fuel composition sensor take to indicate accurate values?

   The Caravan took 22 km to read 53% and 356 km to reach a maximum of 64% as a result of the fuel change from gasoline to E85. The Sebring took 27 km to read 47% and 273 km to reach a maximum of 83% as a result of the fuel change. Due to time constraints, the fuel composition

sensors were not replaced with new ones to determine if properly functioning fuel composition sensors respond any differently.

Observed fuel consumption rates were as expected. Having 29% less energy density than gasoline, the E85 fuel consumption is 26% higher than that of regular fuel.

Other emissions were also characterized during this study, including greenhouse gas emissions, toxic emissions and emissions that lead to the formation of ground level ozone.

In regard to greenhouse gas emissions, tailpipe carbon dioxide emissions were not reduced by the use of E85 as its low energy density results in increased fuel consumption, offsetting the lower carbon content of the fuel. The GHG benefits of E85 result from the lifecycle emissions, compared to fossil fuels, in the balance produced by its carbon sequestration and release cycle. N_2O emissions were significantly reduced for E85 at all Phases, while methane emissions were increased in Phase 1.

Unburned ethanol from the use of E85 fuel was measured. Amounts were detectable for Phase 1 of both vehicles but were below detection limits for Phase 2. The Caravan emitted a small amount of unburned ethanol during Phase 3.

Among the CEPA toxic emissions, total aldehyde emissions increased by 80% for the Caravan and 90% for the Sebring with the use of E85 fuel. This increase was almost entirely in Phase 1 of the test. Benzene, toluene and xylene emissions decreased by 60-80% as a result of displacing gasoline by ethanol in the fuel. 1,3-butadiene emissions were low and as a result, difficult to quantify. No clear trend with fuel composition was observed.

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1.0 Introduction

This report describes the results of an emissions test program undertaken to answer the following questions:

1. Do flexible fuel vehicles have higher tailpipe emissions when operated on gasoline when compared to similar normally equipped vehicles?
2. Do flexible fuel vehicles have higher tailpipe emissions when operated on gasoline when compared to operation on E85?
3. Does the fuel composition sensor impact emissions when it is not reading the fuel composition correctly?
4. How long does a properly operating fuel composition sensor take to read the fuel composition correctly?

2.0 Background

Federal fleet managers in the Federal Vehicles Initiative (FVI) had concerns that flexible fuel vehicles, those vehicles that are equipped to operate on varying blends of ethanol in gasoline ranging from 0% to 85% ethanol, may have higher tailpipe emissions when operated on normal gasoline than when operated on 85% ethanol blends (E85). This possibility has implications with the groups' support of the Alternative Fuels Act and in setting policy direction. The group recommends the purchase of flexible fuel vehicles to federal fleet managers in order to stimulate demand for E85 blends, but in reality, many of the vehicles continue to operate on normal gasoline because the availability of E85 is still very limited.

During a cold temperature drivability study recently conducted by Transport Canada on flexible fuel vehicles operating on E85, it was found that in many vehicles the fuel composition sensor was very slow to respond to changes in actual fuel composition and the final sensor response reached during testing was often incorrect compared to the actual fuel composition. This sensor measurement is used by the engine control computer to set engine parameters according to the fuel composition. Upon further investigation, it was determined that the fuel sensors took a considerable time to accurately sense the correct fuel composition, often on the order of 100 – 200 km of driving. During the Transport Canada study, the vehicles often did not start at the test temperature of –20 °C when the fuel sensor had not reported the correct fuel composition, but did start properly when the fuel sensor had reported the correct fuel composition. There are several possible reasons for this sluggish response to change in fuel composition including sensor contamination by fuel impurities, defects in the sensor itself. According to one vehicle manufacturer's representative, the sensor should nearly instantly sense the fuel composition; it was highly unusual for the sensors to take so long to respond. This sensor performance may result in potentially higher emissions on normal gasoline or when changing fuel composition.

3.0 Testing Details

3.1 Testing Procedure

Two sets of paired, in-use vehicles (4 vehicles total) were provided from various federal department fleets. However, it was determined that one vehicle of one pair did not meet the same emission standards as its intended counterpart, therefore could not render valid comparisons. It was decided to continue the project using three vehicles: one pair, one a flexible fuel vehicle and the other, a vehicle of the same make, model, model year and of similar mileage, but equipped for operation on normal gasoline only, and a solitary flexible fuel vehicle. The three vehicles were tested on the current certification gasoline (Tier 2 reformulated gasoline (RFG)) following the standard chassis dynamometer test procedures for emissions certification of light duty vehicles. In addition, the flexible fuelled vehicles were tested on a commercial E85 blend obtained from a local distributor following similar procedures. A sample of the E85 blend was sent for analysis to determine the parameters required by the emissions measurement procedures.

The vehicles were tested using standard emissions test procedures as designated in the Canadian Environmental Protection Act (CEPA) 1999, Part 7, Division 5. These testing procedures and requirements are identical to those found in the USEPA Code of Federal Regulations (CFR), volume 40, part 86, often referred to as the Federal Test Procedure (FTP). The driving cycle employed was the Urban Dynamometer Driving Schedule (UDDS). This test cycle has three Phases to capture cold engine start, cold stabilized and hot engine start emissions. Fuel exchange procedures were followed to ensure the vehicles were properly purged of the previous fuel used prior to the testing and between test fuels for the flexible fuel vehicles. The vehicles were preconditioned until the fuel composition sensor correctly read the fuel composition, as determined by connection to the on-board diagnostics (OBD) system. In some cases, preconditioning required up to 200 km mileage accumulation on the vehicles. During vehicle preconditioning, the fuel composition sensor was recorded every 20-25 km to track how long the vehicle took to sense the correct fuel composition. Mileage accumulation was done on a road route specifically chosen for this purpose and used in the emissions compliance audit program undertaken by Environment Canada.

The vehicle exhaust was characterized for criteria emissions (carbon monoxide (CO), oxides of nitrogen (NO_X), and total hydrocarbons (THC)), and carbon dioxide (CO_2), ethanol, methane and carbonyl compounds. The measurement of ethanol, methane and carbonyl compounds were required in order to correctly report THC, non-methane hydrocarbon (NMHC), non-methane organic gas (NMOG), and formaldehyde emissions as required by the emissions standards. In addition to methane, nitrous oxide (N_2O) was measured to complete the suite of greenhouse gas (GHG) emissions. Samples were also collected for detailed analysis of the hydrocarbon composition (165 individual hydrocarbons). This information is used to evaluate the ground level ozone formation properties and toxic compound composition of the tailpipe emissions. Fuel consumption (L/100 km) was determined by carbon balance.

To start the program, the three vehicles (one pair and one FFV) were fuel exchanged and the evaporative emissions control system was purged with butane as prescribed in the FTP procedure. The vehicles were preconditioned on the certification gasoline (Tier 2 RFG). Mileage accumulation occurred for the flexible fuel vehicles until the fuel sensor read the correct fuel composition (zero ethanol). The vehicles were tested to obtain three (3) replicate tests that were within the criteria of variability, as summarized in Table 1.

Table 1: Criteria of variability for emissions

Gaseous Emission	Criteria (applied to each Phase of FTP)
CO_2	Ratio highest / lowest < 1.1
CO	Ratio highest / lowest < 1.5
NO_X	Ratio highest / lowest < 1.2
THC	Ratio highest / lowest < 1.2

The two flexible fuel vehicles were then fuel exchanged to E85 and tested for emissions while the fuel sensor was reading incorrectly. They were then tested again on E85 after mileage accumulation to ensure the fuel sensor read correctly. The vehicles were tested to obtain three (3) replicate tests that were within the criteria of variability. These criteria are based on those developed by an industry vehicle emissions testing program (Auto Oil program) conducted in the early 1990's[1] and have been revised based on internal experience with repeatability on current technology vehicles. Additionally, the ratio of maximum difference between two tests to the mean difference between two tests was compared to tabulate statistical critical values to support rejection of outlier tests[2].

The test schedule is outlined in Table 2. As this procedure required a cold engine start, after an 18-hour soak period, only one FTP test could be conducted on each vehicle on a given day, so as a minimum, three test days were required to complete testing on a single vehicle for each test fuel.

Table 2: Test Schedule

	Tasks
Week 1	Check fuel composition sensor on flexible fuel vehicles Fuel exchange flexible fuel vehicles to certification gasoline Evaporative emissions system purge Mileage accumulation with fuel composition sensor monitoring every 25 km
Week 2	Conduct emissions testing of flexible fuel vehicles on certification gasoline with fuel sensor reading correctly Fuel exchange normally equipped vehicles to certification gasoline Evaporative emissions system purge normally equipped vehicles
Week 3	Conduct emissions testing of normally equipped vehicles on certification gasoline Fuel exchange flexible fuel vehicles to E85 Emissions testing on flexible fuelled vehicles with fuel composition sensor reading incorrectly Mileage accumulation and fuel composition sensor monitoring every 25 km
Week 4	Conduct emissions testing of flexible fuel vehicles on E85 with fuel composition sensor reading correctly

3.2 Test Vehicles

Three vehicles of differing technology are tested in this program. A summary of these vehicles can be found in Table 3 and a description of the relevant emission standards in Table 4.

Table 3: Test vehicles

	Emission Standard	Odometer (km)
2004 Chrysler Sebring (FFV)	US EPA Interim Non-Tier 2 Bin 8 and California ULEV 1	51131
2002 Chrysler Caravan (Conventional)	US EPA NLEV LEV LDT and California LEV 1 LDT	45078
2002 Chrysler Caravan (FFV)		53036

Table 4: California Emission Standard for 2001 - 2006 Model Year LEV 1 and ULEV 1 Passenger Cars and Light Duty Trucks[3]

Driving Cycle	Vehicle Type	Time Frame	Non-Methane Organic Gases (g/mi) (NMOG)	Carbon Monoxide (g/mi) (CO)	Oxides of Nitrogen (g/mi) (NO_X)	Particulate Matter (g/mi) (PM)	Formaldehyde (g/mi) (HCHO)
FTP	LEV 1 LDT 3,751 – 5,750 lb LVW (Caravan)	50,000 miles / 5 years	0.1	4.4	0.4	-	0.018
		100,000 miles / 10 years	0.130	5.5	0.5	0.10	0.023
	ULEV 1 Pass. Car ≤3,750 lb LVW (Sebring)	50,000 miles / 5 years	0.04	1.7	0.2	-	0.008
		100,000 miles / 10 years	0.055	2.1	0.3	0.04	0.011

3.3 Test Fuels

Results from emissions testing on two test fuels are reported. They are the current certification gasoline (Tier 2 Reformulated Gasoline) and an E85 blend purchased from a local fuel distributor. Analysis results for the fuels are presented in Table 5. Analysis of the E85 fuel was conducted by the Alberta Research Council's Fuels and Lubricants Group.

Table 5: Fuel Analysis Results

Fuel Property	Units	E85	Tier 2
Specific Gravity	kg/L	0.784	0.743
Net Heating Value	BTU/lb	13867	18132
Energy Density	BTU/L	3408.2	4806.6
Fuel Fraction Carbon	Wt. Fraction	0.575	0.8430
Fuel Fraction Oxygen	Wt. Fraction	0.294	0.018
Sulphur Content	ppm	17	37
Research Octane No.	--	104	96.8
RVP	psi	7.3	5.7

The theoretical volume-based CO_2 emission rates per litre of fuel burned assuming perfect combustion (100% conversion of the fuel carbon to CO_2) can be calculated from the fraction of carbon in the fuel along with the specific gravity. Because the two fuels have differing fuel carbon fractions, as well as differing specific gravities, the theoretical CO_2 emission rates also vary. These theoretical CO_2 emission rates are outlined in Table 6.

Table 6: Theoretical CO_2 Emissions Assuming 100% Conversion (g CO_2 / L fuel)

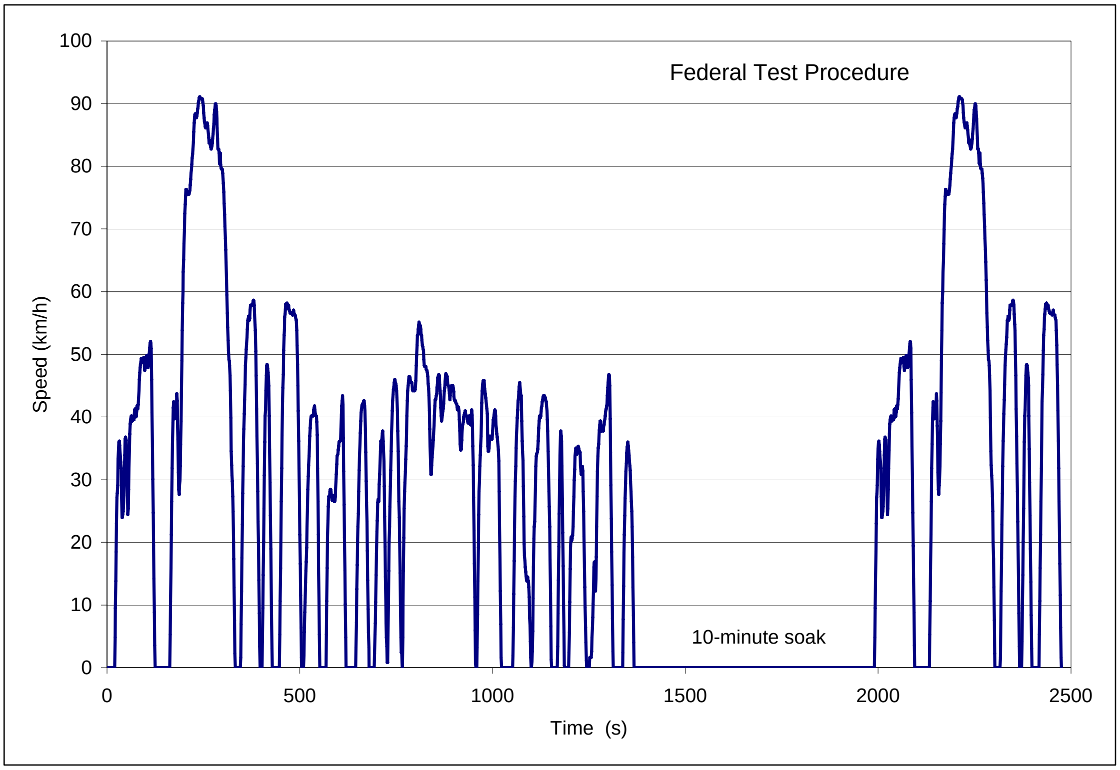
	E85	Tier 2
g CO_2 / L fuel	1646.4	2296.6
% Difference	-28	

Although 28% less CO_2 is emitted per litre of E85 burned as compared to the certification fuel, the E85 fuel has 29% less energy per litre so a larger volume of fuel is needed to cover the same distance. One would expect fuel consumption (L/100km) to be no different between the fuels. There is no CO_2 emission benefit at the tailpipe to using E85 over conventional fuel. Any CO_2 benefit must occur upstream of the vehicle (in production and by the use of a renewable fuel source).

3.4 Driving Cycles

All vehicles were tested over the Federal Test Procedure (FTP) driving cycle to investigate the response of the technology and to obtain comparable results. The FTP allows examination of cold and hot engine start emissions, a non-demanding driving style and city fuel economy. Phases 1 and 3 of the FTP have identical driving schedules but Phase 1 commences with a cold engine start while Phase 3 commences with a hot engine start. The differences in emissions between Phases 1 and 3 are due primarily to the difference in cold engine start and hot engine start and how long the emissions control technology takes to reach operating temperature. Phases 1 and 3 are the same, each 505 seconds in length with an average speed of 41.1 km/h, a maximum speed of 91.1 km/h and cover a distance of 5.8 km. Phase 2 follows immediately from Phase 1. During Phase 2 the emission control technology should be functioning optimally. Phase 2 is 865 seconds in duration with an average speed of 25.8 km/h, a maximum speed of 55.1 km/h and covers a distance of 6.2 km. Phase 3 follows Phase 2 after a 10-minute engine-off soak period. The entire test takes approximately 42 minutes to complete. Emission rates are reported for each Phase and a composite (weighted average) emission rate for the entire test is also computed and reported. The speed vs. time trace of the FTP cycle is shown in Figure 1.

Figure 1: Speed vs. time trace for the FTP cycle



4.0 Sample Collection & Analytical Methods

All of the exhaust produced by the vehicle was collected and diluted using a total exhaust dilution constant volume sampling (CVS) system. The total dilute exhaust volume flow rate was 1160 SCFM (32850 L/min). The dilution air was taken from the test cell.

The CO, CO_2, NO_X, and THC emissions samples were collected on a per Phase basis. For each dilute exhaust sample collected, a corresponding dilution air sample was collected. Samples were collected at a constant rate through a venturied probe to fill large Tedlar™ bags. The bag samples were automatically analyzed at the end of each driving cycle using the automated instruments located in the test cell.

Samples were collected in separate Tedlar™ bags for determining concentrations of methane (CH_4), nitrous oxide (N_2O), ethanol, and for detailed NMHC composition analysis.

Methane determination was by gas chromatography with flame ionization detection following the laboratory's Standard Method #4.03/3.0/M.

N_2O determination was by gas chromatography with electron capture detection following the laboratory's Standard Method #4.08/1.3/M.

For carbonyl compound analysis, dilute exhaust samples were collected from the CVS on a per Phase basis, resulting in three samples. In addition, one dilution air sample was collected over the entire test. The samples were drawn from the dilution tunnel through Sep-Pak silica cartridges coated with 2,4-Dinitrophenylhydrazine (2,4-DNPH), and analyzed by HPLC following the laboratory's Standard Method #4.01/2.0/M.

Oxygenate (ethanol) was determined by a photoacoustic analyzer following the laboratory's Standard Method #4.09/1.2/M.

4.1 Carbon Monoxide (CO)

Dilute exhaust, and dilution air concentrations of CO were determined using a Horiba Non-Dispersive Infra-Red (NDIR) instrument (Model AIA 23). This is a dual-channel instrument for CO and CO_2. It is a dedicated analyzer, specifically used for vehicle emissions testing. The lower detection limit of the CO analyzer is 0.6 ppm. The corresponding distance-based detection limits for CO are out lined in Table 7.

Table 7: Detection Limits for CO Analysis

	Lower D.L.	
Concentration	0.6	ppm
Phase 1 & 3	0.07	g/mile
Phase 2	0.1	g/mile
Composite	0.1	g/mile

4.2 Carbon Dioxide (CO_2)

Dilute exhaust, and dilution air concentrations of CO_2, were determined using the same dedicated analyzer as for the CO emissions. The samples were measured using a 2% full-scale range, yielding a detection limit of 0.02% CO_2 in dilute exhaust. The corresponding distance-based detection limits for CO_2 are presented in Table 8.

Table 8: Detection Limits for CO_2 Analysis

	Lower D.L.	
Concentration	0.02	%
Phase 1 & 3	40	g/mile
Phase 2	60	g/mile
Composite	50	g/mile

4.3 Oxides of Nitrogen (NO_X)

Dilute exhaust, and dilution air concentrations of NO_X were determined using a Horiba Chemiluminescence instrument (Model CLA-22A). This is a dedicated analyzer, specifically used for vehicle emissions testing. The lower detection limit of the NO_X analyzer is 0.6ppm. The corresponding distance based detection limits for NOx are outlined in Table 9.

Table 9: Detection Limits for NO_X Analysis

	Lower D.L.	
Concentration	0.6	ppm
Phase 1 & 3	0.1	g/mile
Phase 2	0.2	g/mile
Composite	0.1	g/mile

4.4 Total Hydrocarbon (THC)

Dilute exhaust, and dilution air concentrations of THC, were determined using Horiba Flame Ionization instrument (Model FIA-23A). This is a dedicated analyzer, specifically used for vehicle emissions testing. The lower detection limit of the THC analyzer is 0.6 ppm. The corresponding distance-based detection limits for THC are given in Table 10.

Table 10: Detection Limits for THC Analysis

	Lower D.L.	
Concentration	0.6	ppm
Phase 1 & 3	0.05	g/mile
Phase 2	0.09	g/mile
Composite	0.07	g/mile

4.5 Greenhouse Gases (CH_4 and N_2O)

Methane was determined using a Hewlett Packard 6890 gas chromatograph with a flame ionization detector. Its parameters are presented in Table 11. Component identification was made by retention time comparison to the analysis of known standards. The lower detection limit for CH_4 analysis is 10 ng/L. The corresponding distance based detection limits for CH_4 are outlined in Table 13.

Table 11: GC-FID Parameters for Methane Analysis

Column	Agilent 19095P-Q04 270ºC Max, HP-PLOTQ, Capillary 30.0m x 530µm x 40.0µm column
Oven Temp Program	1.10 mins @ 40ºC, 25º/min to 130º; hold for 7.3 min. @ 130ºC; total run time is 12 minutes plus approximately 3 minute cool down period
Carrier gas	Helium: 9.0mL/min. @ 40ºC
Makeup gas	Total of column and make-up flow of 30 mL/min helium
Injector	VICI 6-port gas sampling valve with pneumatic actuator, maintained at 100ºC
Detector	FID, maintained at 180ºC. Fuel gases: hydrogen: 30mL/min air: 400mL/min
Sample size	250 µL

Nitrous Oxide was determined using a Hewlett Packard 5890A Series II gas chromatograph with an electron capture detector. The limit of detection for N_2O analysis using this instrument is 4.2 ppb. The corresponding distance based detection limits for N_2O are outlined in Table 13. The GC-ECD parameters are summarized in Table 12.

Table 12: GC-ECD Parameters for Nitrous Oxide Analysis

Column	HP-PLOT Q column 15m x 0.53 mm, 40 µm film thickness
Oven Temp Program	5 mins @ 40ºC, 40º/min to 120º; hold for 1 min @120ºC
Carrier gas	Helium: 9.7 mL/min @ 40ºC
Makeup gas	56 mL/min 5% Methane in Argon (dual stage regulator)
Injector	VICI 6-port gas sampling valve with electric actuator, maintained at 100ºC
Detector	ECD, maintained at 180ºC
Sample size	250 µL

Table 13: Detection Limits for GHG Analysis

	Lower D.L.
Methane (CH_4)	

Concentration	10 ng/L
Phase 1& 2	1 mg/mile
Phase 2	2 mg/mile
Composite	1 mg/mile
Nitrous Oxide (N_2O)	
Concentration	4.2 ppb
Phase 1 & 3	0.8 mg/mile
Phase 2	1 mg/mile
Composite	1 mg/mile

4.6 Toxic and Reactive Compounds

Compounds listed as CEPA toxic and that contribute to the formation of ground level ozone were also determined.

Carbonyl compounds selectively react with 2,4-Dinitrophenylhydrazine (2,4-DNPH) to form hydrazones. The 2,4-DNPH is coated onto silica cartridges and the hydrazones are retained on the cartridges as the exhaust flows through. The hydrazones were dissolved and removed from the cartridges by elution with acetonitrile. The elute was then analyzed for 17 carbonyl compounds by reverse Phase high performance liquid chromatography with ultraviolet detection, The instrument used for this analysis was an Agilent 1100 Series liquid chromatograph with an ultraviolet-visible (UV-Vis) light diode array detector. Its parameters follow in Table 14.

Table 14: HPLC with UV-Vis Parameters for Carbonyl Compound Analysis

Column	Two Zorbax® Eclipse XBD-C18 narrow-bore columns (2.1 × 150mm, 3.5µm packing)
Guard Column	Eclipse XBD-C18 narrow-bore guard column (2.1 × 12.5mm, 5µm packing)
Solvent flow rate	250 µL/min
Column compartment temp	40ºC
Detector	Agilent G1315B DAD Ultraviolet-visible light diode array equipped with a deuterium lamp
Sample size	5 µL

For determination of 155 non-methane hydrocarbons (NMHC), the samples were first preconcentrated using an Entech Concentrator. They were then analyzed on a Hewlett Packard 6890 gas chromatograph (GC) equipped with a flame ionization detector (FID). Parameters for the GC-FID are listed in Table 15.

Table 15: GC-FID Parameters for Toxic Compound Analysis

Column	50m x 0.32 mm x 1.05 µm film thickness: HP-1 (crosslinked methylsilicone)
Oven Temp Program	3 mins @ -50ºC, 5º/min to 200º, 2 min @200ºC
Carrier gas	UHP Helium, EPC @ 12.3 psig (1.2 ml/min) @ 35ºC
Makeup gas	UHP Helium, total column plus makeup is 45 ml/min
Injector	Entech Instruments Inc. (Model 7100A) automated cryogenic concentrator with a 16 port autosampler
Detector	FID operated at 300ºC. Fuel gases: hydrogen 40 ml/min air 450 ml/min
Sample size	250 mL

In both cases, component identification was made by analysis of certified standards with retention time comparison. From this long list of compounds, those found on the CEPA Priority Substances Lists are listed in Table 16 along with their detection limits and corresponding distance-based detection limits. The discussion will focus on these compounds.

Table 16: Detection Limits for Toxic Compound Analysis

Compound	**Detection Limit**	
Formaldehyde	Concentration	0.005 µg/mL
	Phase 1 & 3	0.2 mg/mile
	Phase 2	0.09 mg/mile
	Composite	0.04 mg/mile
Acetaldehyde	Concentration	0.0004µg/mL
	Phase 1, 2, & 3	0.01 mg/mile
	Composite	0.004 mg/mile
Acrolein	Concentration	0.0004µg/mL
	Phase 1, 2, & 3	0.02 mg/mile
	Composite	0.02 mg/mile
1,3 butadiene	Concentration	0.3 ng/L
	Phase 1 & 3	0.03 mg/mile
	Phase 2	0.05 mg/mile
	Composite	0.02 mg/mile
Benzene	Concentration	0.4 ng/L
	Phase 1 & 3	0.04 mg/mile
	Phase 2	0.07 mg/mile
	Composite	0.03 mg/mile
Toluene	Concentration	0.5 ng/L
	Phase 1 & 3	0.05 mg/mile
	Phase 2	0.08 mg/mile
	Composite	0.03 mg/mile
Ethyl benzene	Concentration	0.5 ng/L
	Phase 1 & 3	0.06 mg/mile
	Phase 2	0.09 mg/mile
	Composite	0.04 mg/mile
m&p-xylene	Concentration	0.5 ng/L
	Phase 1 & 3	0.06 mg/mile
	Phase 2	0.09 mg/mile
	Composite	0.04 mg/mile
o-xylene	Concentration	0.5 ng/L
	Phase 1 & 3	0.06 mg/mile
	Phase 2	0.09mg/mile
	Composite	0.04mg/mile

4.7 Oxygenates (Ethanol)

Ethanol determination was made with an Innova Model 1312 Photoacoustic Multi-Gas Analyzer following ERM Standard Method #4.9. The samples were analyzed on the same day they were received. The detection limit for this analysis is 0.3 ppm. Distance-based limits of detection can be found in Table 17.

Table 17: Detection Limit Ranges for Ethanol Analysis

	Lower D.L.	
Concentration	0.3	ppm
Phase 1 & 3	60	mg/mile
Phase 1	90	mg/mile
Composite	80	mg/mile

Under the emissions standards for these vehicles, non-methane organic gas (NMOG) is the quantity that is regulated. NMOG is obtained by calculation, not directly measured. The quantities that are measured are total hydrocarbons (THC), oxygenate content (in this case ethanol), methane (CH_4), and a group of 16 carbonyl compounds. NMOG is calculated as follows from the measured quantities. The NMHC concentration is obtained by subtracting the contribution of ethanol and methane from the total hydrocarbon concentration for both the dilute exhaust and dilution air samples. Since the THC instrument has different response factors for ethanol and methane, relative response factors (R), are used to account for this difference. The NMHC emission rate is then calculated from these corrected concentrations. The NMOG emission rate is determined by summation of the NMHC, ethanol and total carbonyl emission rates.

$$NMHC = THC - R_{EtOH} * Ethanol - R_{CH4} * CH_4$$

$$NMOG = NMHC + Ethanol + Carbonyls$$

5.0 Data Analysis

5.1 Average & Standard Deviation

The FTP driving cycle was repeated 3 to 5 times for each combination of vehicle and fuel used for this analysis. The number of repeats conducted was determined by the consistency of the emission rate results. The averages of these tests are presented in this report along with the corresponding standard deviations. Outlying data, not meeting the criteria of variability, have been removed from these results.

For both flexible fuel vehicles running on E85, 5 repeat tests were completed. Of these, for each vehicle, 2 were done while the fuel sensor adjusted, and 3 once it stabilized. Of the 3 stabilized repeats, 2 were used in calculations, one did not meet criteria and was discarded. For both flexible fuel vehicles running on regular gasoline, 4 repeat tests were completed. Three were used in these analyses and one was discarded as an outlier. The conventional vehicle was tested on regular fuel 3 times, all of which met criteria and so were used in analysis.

5.2 Statistical Analysis (ANOVA Test)

The potential difference between the various emissions comparisons were evaluated using analysis of variance (ANOVA) tests. For an ANOVA test, the data to be evaluated is divided into two groups (e.g. compare flexible fuel vehicle on E85 and Tier 2 fuels) and the Microsoft Excel “Single-Factor ANOVA” tool was used. The P-value determined by this tool can be interpreted as the probability that the observed differences between the two groups is greater than the differences within each group. In other words, the magnitude of the P-value can be interpreted as the probability that the differences between the two groups is not statistically significant but is due to random error. The P-value is a number between 0 and 1, where 1 equals 100% probability that the differences are due entirely to random error. The higher the P-value, the greater the probability that the differences are due to random error and are not statistically significant.

In this report, the ANOVA test was used to compare various combinations of the vehicles and the fuels used. They include:

- the FFV Caravan with E85 versus the Conventional Caravan with Tier 2 fuel;
- the FFV Caravan versus the Conventional Caravan, both with Tier 2 fuel;
- the FFV Caravan with E85 versus Tier 2 fuel; and
- the FFV Sebring with E85 versus Tier 2 fuel.

For this study, a 95% confidence interval was used, meaning that P-values less than 0.05 were interpreted as a statistically significant difference. Therefore, with a P-value less than 0.05, there was less than 1 chance in 20 that the observed difference between the fuels was actually due to random error.

Comparisons with P-values above 0.05 are considered to have no statistically significant difference (NSD) at the 95% confidence interval. Comparisons that showed a statistically significant difference are discussed in the results section. For such comparisons, the percent difference between the fuels or vehicles was also determined, using the following calculation:

$$\%\ Difference = \frac{Emission\ Rate\ of\ E85\ Fuel - Emission\ Rate\ of\ Tier2\ Fuel}{Emission\ Rate\ of\ Tier2\ Fuel}$$

or

$$\%\ Difference = \frac{Emission\ Rate\ of\ FFV\ Caravan - Emission\ Rate\ of\ Conv\ Caravan}{Emission\ Rate\ of\ Conv\ Caravan}$$

5.3 Fuel Sensors

Being designed as a flexible fuel vehicle, capable of running on ethanol-gasoline blends of up to 85% ethanol, the fuel system incorporates a fuel composition sensor that measures ethanol content in the fuel. This information is then used to adjust the engine parameters to best suit the fuel blend. This sensor can be surveyed through the OBD II (On-Board Diagnostic) technology inside the vehicle to ensure proper operation.

It was observed that the fuel sensors took longer than expected to report the correct ethanol reading. According to one vehicle manufacturer representative, the sensor should nearly instantly sense the fuel composition. Therefore, in addition to the ANOVA tests, emissions at various sensor readings were graphed as the vehicles changed from Tier 2 fuel to E85 to try to determine if, and/or how, the changing engine parameters affect emission rates.

Due to delays in testing resulting from scheduling issues at the lab and having to return the vehicles on a specified date, the fuel sensors could not be replaced and the analysis repeated.

6.0 Results and Discussion

Engine emissions of CO are produced through incomplete combustion, which is most often associated with fuel enrichment. The vehicle 3-way catalyst reduces the amount of CO in the final exhaust stream by oxidising the CO to CO_2, but must be fully heated to perform at optimal conversion efficiency.

CO_2 emissions are largely produced by combustion, while minimal emissions are attributable to the oxidation of combustion by-products such as CO and hydrocarbons in the vehicle's catalytic converter.

Engine NO_X emissions are produced under high temperature and lean air/fuel ratio conditions. The vehicle 3-way catalyst reduces the amount of NO_X in the final exhaust stream, but it must be hot to achieve optimal operating efficiency.

THC emissions are composed of both unburned fuel and of incomplete combustion products. The vehicle 3-way catalyst reduces the amount of hydrocarbon in the final exhaust stream, but again, it must be fully heated to perform optimal conversion of these compounds to carbon dioxide and water.

6.1 FFV Caravan versus Conventional Caravan, both with Tier 2 Fuel

This comparison is used to evaluate the differences between the two vehicles operating on the same fuel prior to comparing differences in emissions between different fuels.

Figure 2 through Figure 7 illustrate the comparison of emissions between the FFV Caravan and the Conventional Caravan both running on Tier 2 (regular) fuel. Each figure is followed by a table representing the P-values from the ANOVA test, and a discussion of the results.

Figure 2: CO Emission Rates - Conventional and FFV Caravans, both with Regular Fuel

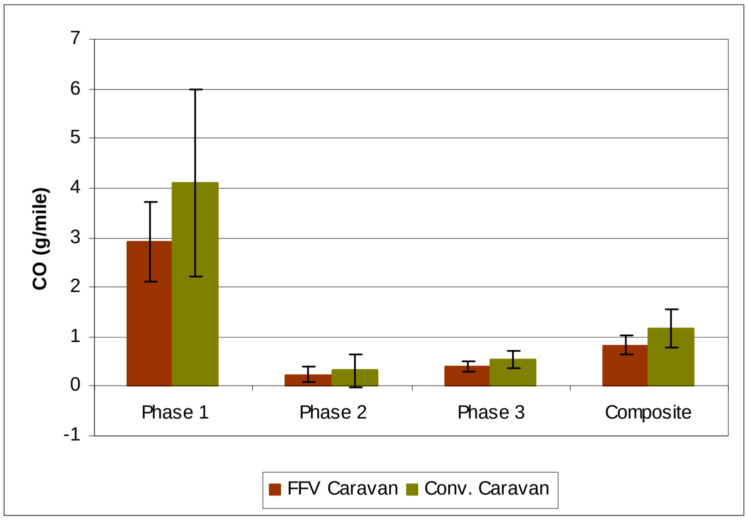


Table 18: Emission rates and P-Values for CO over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	2.9	0.4	4.0	1.0	0.11
Phase 2	0.23	0.08	0.3	0.2	0.47
Phase 3	0.41	0.05	0.54	0.09	0.096
Composite	0.83	0.10	1.2	0.2	0.057

Although the figure might suggest higher CO emissions for the conventional Caravan as compared to the FFV, there is no statistically significant difference in CO emissions at the 95% confidence interval as all of the P-values are less than 0.05.

Figure 3: CO_2 Emission Rates - Conventional and FFV Caravans, both with Regular Fuel

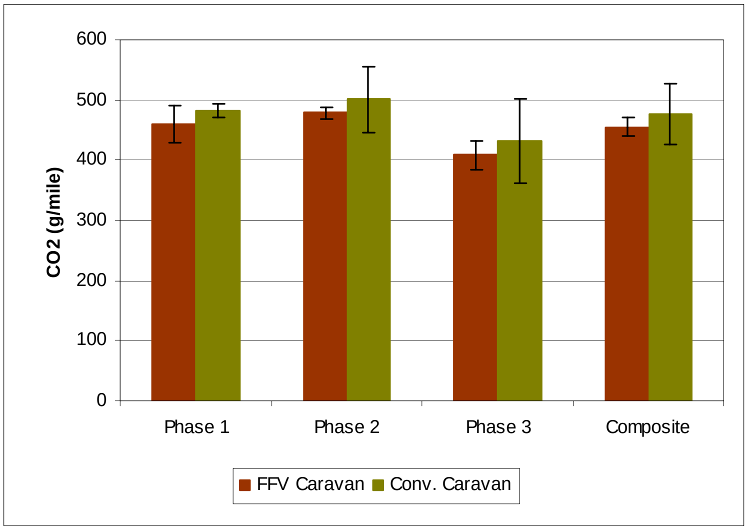


Table 19: Emission Rates and P-Values for CO_2 over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	460	15	481	6	0.087
Phase 2	478	4	501	28	0.25
Phase 3	410	12	431	35	0.35
Composite	456	8	478	25	0.22

There is no statistically significant difference in CO_2 emissions.

Figure 4: NOx Emission Rates - Conventional and FFV Caravans, both with Regular Fuel

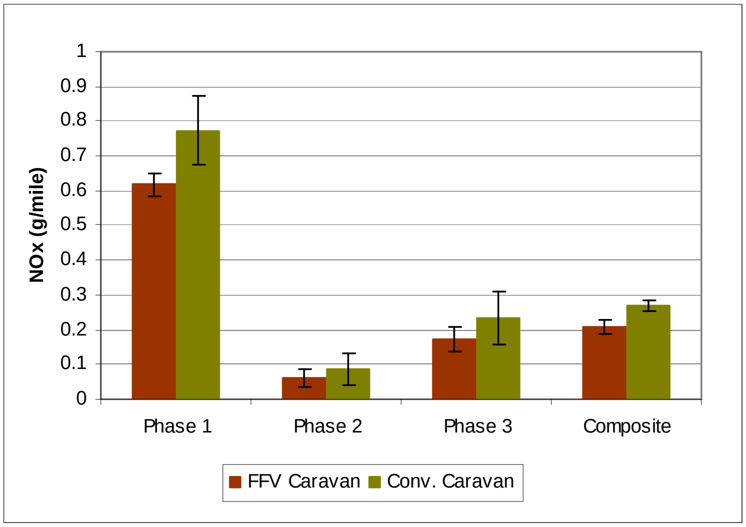


Table 20: Emission Rates and P-Values for NOx over FTP

	FFV Caravan		**Conventional Caravan**		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.62	0.02	0.77	0.05	0.006
Phase 2	0.06	0.01	0.09	0.02	0.14
Phase 3	0.17	0.02	0.23	0.04	0.069
Composite	0.21	0.01	0.27	0.007	0.001

There is a statistically significant difference in NOx emissions during Phase 1 of the FTP and for the composite emission rate. The FFV emissions are 20% lower than the emissions from the conventional Caravan during Phase 1 and 22% lower for the composite emission rate.

Figure 5: THC Emission Rates - Conventional and FFV Caravans, both with Regular Fuel

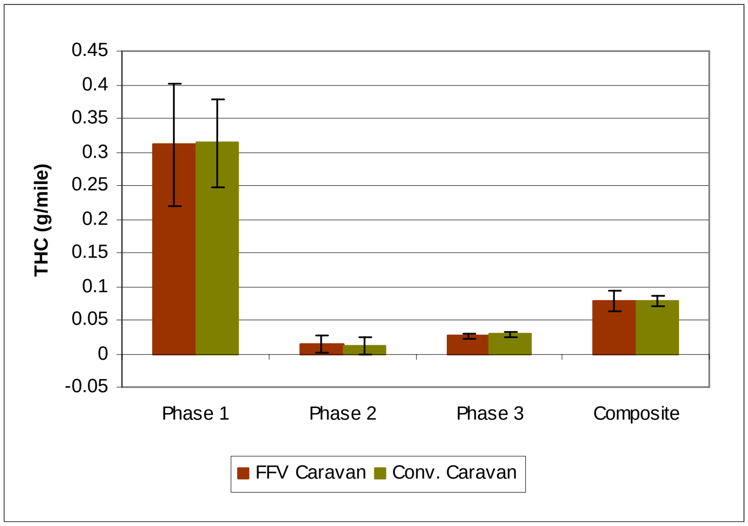


Table 21: Emission Rates and P-Values for THC over FTP

	FFV Caravan		**Conventional Caravan**		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.31	0.05	0.31	0.03	0.95
Phase 2	0.014	0.006	0.011	0.006	0.55
Phase 3	0.026	0.002	0.028	0.002	0.27
Composite	0.079	0.008	0.078	0.003	0.91

There is no statistically significant difference in THC emissions.

Figure 6: NMHC Emission Rates - Conventional and FFV Caravans, both with Regular Fuel

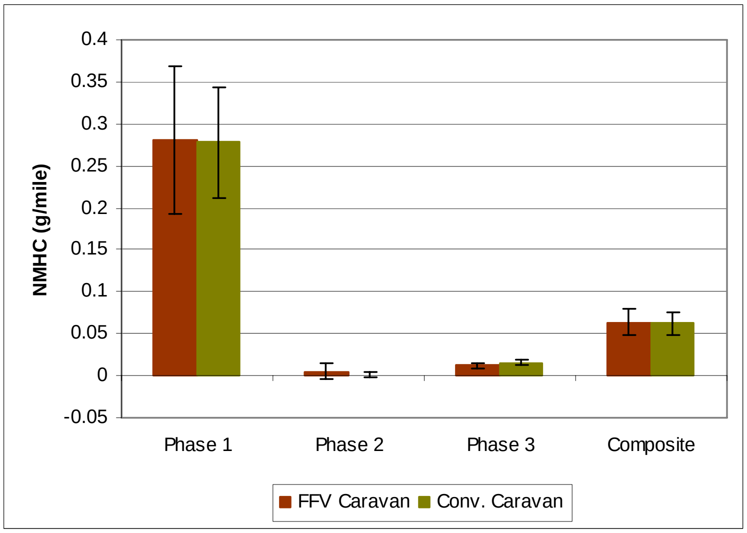


Table 22: Emission Rates and P-Values for NMHC over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.28	0.04	0.28	0.03	0.94
Phase 2	0.0050	0.005	0.00090	0.0016	0.23
Phase 3	0.012	0.001	0.015	0.002	0.052
Composite	0.064	0.008	0.062	0.007	0.78

There is no statistically significant difference in NMHC emissions, although Phase 3 is very close to meeting the 95% confidence interval.

Figure 7: NMOG Emission Rates - Conventional and FFV Caravans, both with Regular Fuel

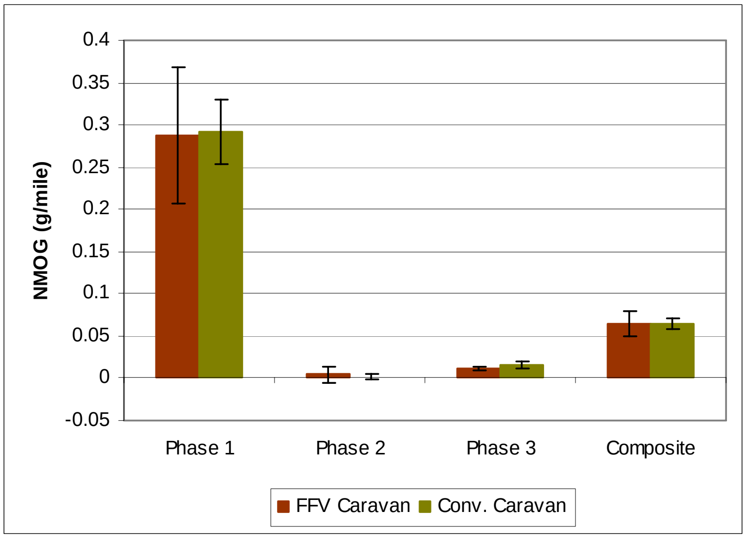


Table 23: Emission Rates and P-Values for NMOG over FTP

	FFV Caravan		**Conventional Caravan**		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.29	0.40	0.29	0.02	0.90
Phase 2	0.0051	0.0048	0.0017	0.0015	0.32
Phase 3	0.012	0.001	0.016	0.002	0.055
Composite	0.065	0.007	0.065	0.003	0.99

As with NMHC, there is no statistically significant difference in NMOG emissions, although Phase 3 is close to meeting the 95% confidence interval.

In summary:

- Comparing the composite emission rates for the two Caravans operating on gasoline to the California LEV 1 LDT emission standard summarized Table 4, it can be seen that both vehicles meet their applicable standard.

- The only difference in emissions between the two vehicles was observed for NOx during Phase 1 and this difference was reflected in the difference in FTP composite NOx emission rate. There were no statistically significant differences for CO, CO_2, THC, NMHC, and NMOG.

- The two vehicles may be considered essentially the same for all emissions but NOx during cold start when operated on the same gasoline fuel.

6.2 FFV Caravan with E85 Fuel versus Conventional Caravan with Tier 2 Fuel

This comparison illustrates the effect of using E85 fuel with the FFV as compared to a conventional vehicle operating on gasoline. Recall that the only difference between the two vehicles was the cold start NOx emissions where the FFV had 20% lower NOx emissions as compared to the conventional vehicle.

Figure 8 through Figure 13 illustrate the comparison of emissions between the FFV Caravan with E85 fuel and the conventional Caravan with Tier 2 (regular) fuel. Each figure is followed by a table displaying the P-values from the ANOVA test, and a discussion of the results.

Figure 8: CO Emission Rates – Conventional Caravan with Regular Fuel versus FFV Caravan with E85

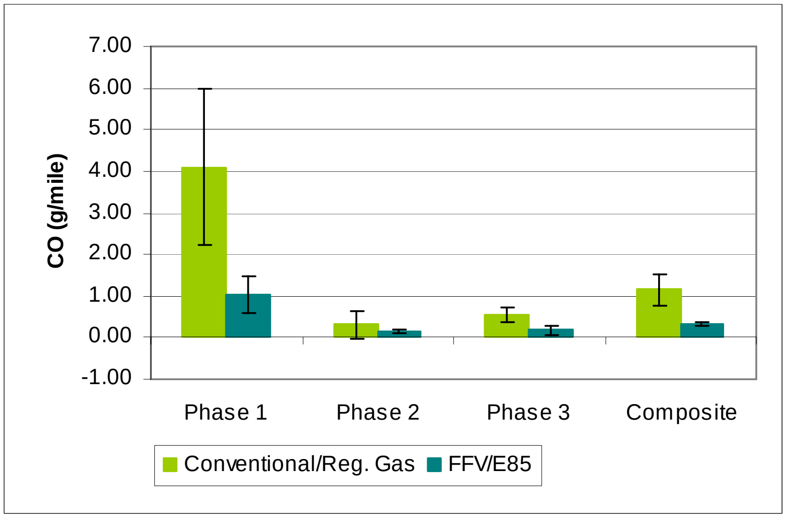


Table 24: Emission Rates and P-Values for CO over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	1.04	0.23	4.1	1.0	0.023
Phase 2	0.15	0.02	0.3	0.2	0.26
Phase 3	0.17	0.06	0.54	0.09	0.015
Composite	0.34	0.02	1.2	0.2	0.010

Comparing CO emission from the two vehicles operating on their intended fuels results in statistically significant differences during Phase 1 and Phase 3 of the FTP. The Phase 1, or cold start, CO emission was reduced by 75 % by using E85 fuel in the flex-fuel vehicle, and the Phase 3, or hot start, CO emission was reduced by 68% by using E85 fuel in the flex-fuel vehicle. There was no statistically significant difference between the vehicles during Phase 2. As a result, the composite emission rate was 72% less for the FFV operating on E85 fuel compared to the conventional vehicle operating on regular gasoline.

Figure 9: CO_2 Emission Rates - Conventional Caravan with Regular Fuel versus FFV Caravan with E85

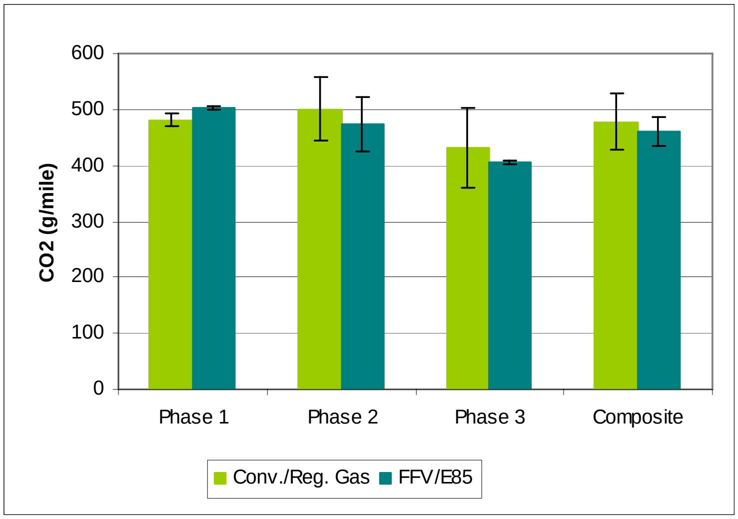


Table 25: Emission Rates and P-Values for CO_2 over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	504	2	481	6	0.015
Phase 2	474	24	501	28	0.35
Phase 3	405	2	431	35	0.40
Composite	461	13	478	25	0.47

The P-values indicate a statistically significant difference in CO_2 emission for Phase 1 (cold start). The CO_2 emission rate is 5% higher for the FFV than for the conventional vehicle. The Phase 2, Phase 3 and the composite CO_2 emission rates do not have a statistically significant difference.

Figure 10: NOx Emission Rates - Conventional Caravan with Regular Fuel versus FFV Caravan with E85

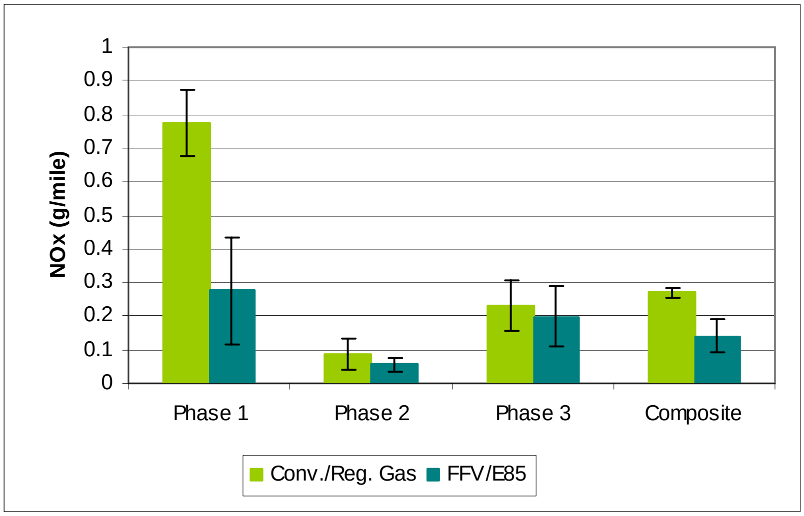


Table 26: P-Values for NOx over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.28	0.08	0.77	0.05	0.003
Phase 2	0.057	0.009	0.09	0.02	0.17
Phase 3	0.20	0.05	0.23	0.04	0.42
Composite	0.14	0.4	0.27	0.007	0.003

The P-Values indicate a statistically significant difference during Phase 1 (cold start). The emission from the FFV is 64% lower than the conventional vehicle during Phase 1. There is no statistically significant difference during Phase 2 or Phase 3 of the cycle. As a result, the FTP composite emission rate is 48% lower for the FFV on E85 as compared to the conventional vehicle on gasoline.

Figure 11: Oxygen Corrected THC Emission Rates - Conventional Caravan with Regular Fuel versus FFV Caravan with E85

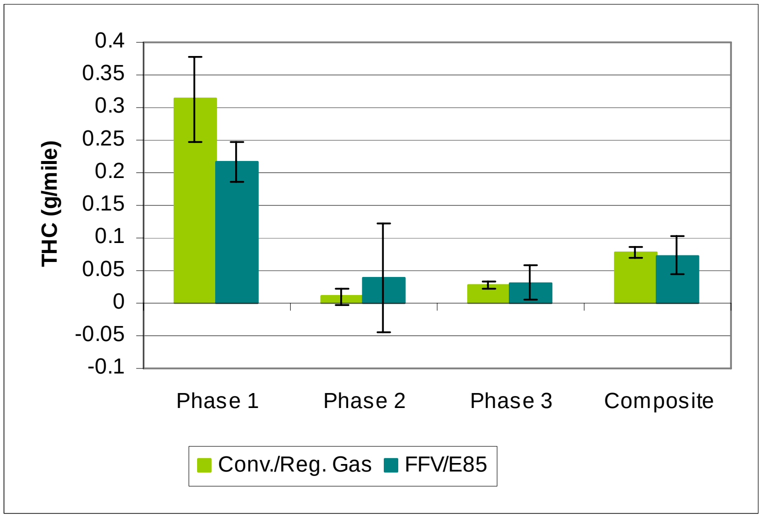


Table 27: Emission Rates for P-Values for oxygenate corrected THC over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.22	0.02	0.31	0.03	0.033
Phase 2	0.04	0.04	0.011	0.006	0.32
Phase 3	0.03	0.03	0.028	0.002	0.69
Composite	0.07	0.07	0.078	0.003	0.57

There is a statistically significant difference for oxygenate-corrected THC during Phase 1. The FFV emitted 31% less than the conventional vehicle. There is no statistically significant difference elsewhere over the cycle.

Figure 12: NMHC Emission Rates - Conventional Caravan with Regular Fuel versus FFV Caravan with E85

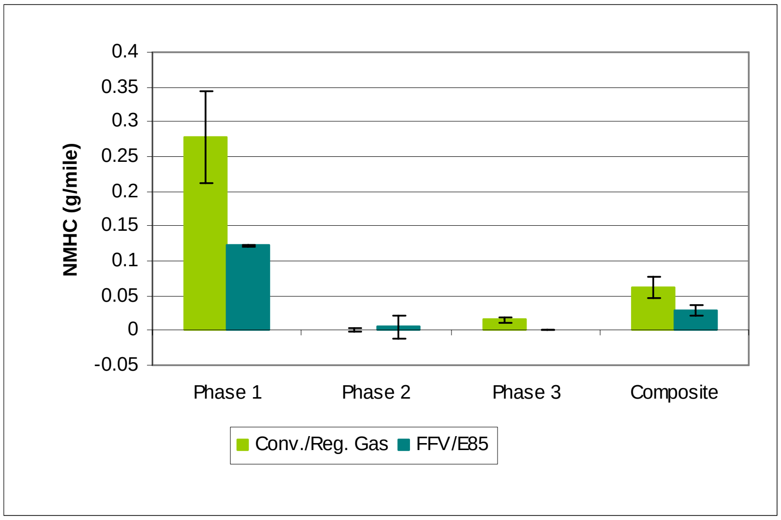


Table 28: Emission Rates and P-Values or NMHC over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.122	0.001	0.28	0.03	0.0077
Phase 2	0.006	0.008	0.0009	0.002	0.35
Phase 3	0.0	0.0	0.015	0.002	0.0010
Composite	0.028	0.004	0.062	0.007	0.010

There is a statistically significant difference in NMHC emissions for Phase 1 and Phase 3 of the FTP and for the FTP composite. The emission from the FFV is 56% lower in Phase 1 than that of the conventional vehicle. The Phase 3 FFV emission rate was below the detection limit of the instruments used to measure it. The resulting composite value is 55% lower for the FFV. There is no statistically significant difference for Phase 2.

Figure 13: NMOG Emission Rates - Conventional Caravan with Regular Fuel versus FFV Caravan with E85

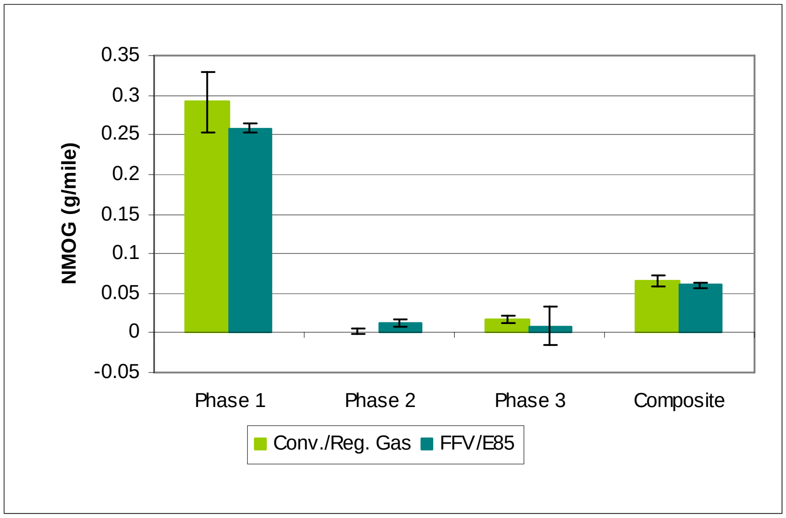


Table 29: Emission Rates and P-Values for NMOG over FTP

	FFV Caravan		Conventional Caravan		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.26	0.003	0.30	0.019	0.10
Phase 2	0.013	0.002	0.0017	0.005	0.01
Phase 3	0.0084	0.0004	0.016	0.002	0.33
Composite	0.060	0.002	0.065	0.003	0.16

There is a statistically significant difference during Phase 2 for NMOG. The NMOG emission from the E85 is 87% higher than from regular gasoline. Recall that neither THC nor NMHC include the unburned ethanol that may present in the exhaust, while NMOG does.

In summary:

- CO emissions are statistically significantly lower for the FFV operating on E85 as compared to the conventional vehicle operating on gasoline. The difference is particularly large during cold start (Phase 1). The extra oxygen in the combustion chamber as a result of the ethanol may contribute to reducing CO emissions with this vehicle.

- The increase in CO_2 emissions for the FFV during Phase 1supports the hypothesis suggested above.

- The difference in NOx emissions observed here are consistent with the results obtained with the FFV operating on the Tier 2 fuel, although the difference is greater. There appears to be both a vehicle and a fuel effect on NOx emissions.

- Overall, comparing the two vehicles with their intended fuels, there is a trend that suggests the flexible fuel vehicles produce less regulated emissions during a cold start than the conventional vehicle on regular fuel possibly indicating earlier catalyst effectiveness or an increase in oxygen in the combustion chamber due to the oxygenated fuel. There was little difference between the two vehicles during other operations.

6.3 FFV Caravan with Tier 2 Fuel versus the Same Vehicle with E85 Fuel

This comparison illustrates the emissions benefits obtained when operating the same flexible fuel vehicle on E85 as compared to gasoline. In this analysis, the sensor read 0% on the regular fuel, but only reached 64% on the E85 fuel.

Figure 14 through Figure 19 illustrate the comparison of emissions between the FFV Caravan with regular fuel and with E85 fuel. Each graph is followed by a table representing the P-values from the ANOVA test, and a discussion of the results.

Figure 14: CO Emission Rates - FFV Caravan with Regular Gas versus E85

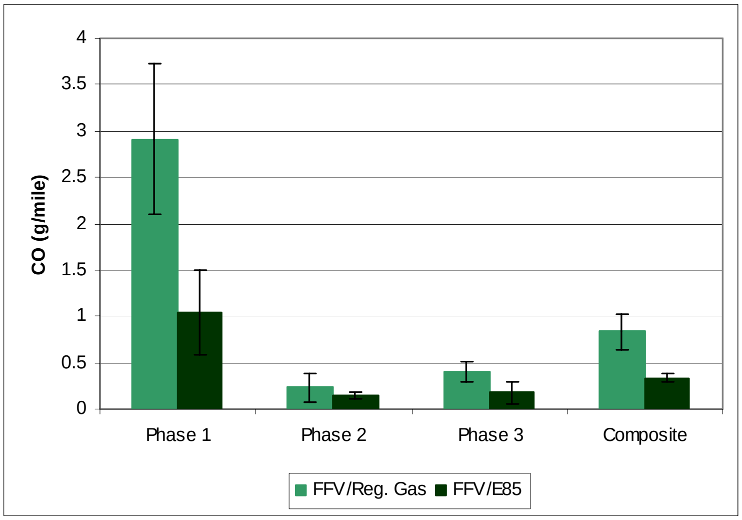


Table 30: Emission Rates and P-Values for CO over FTP

	FFV Caravan/Reg. Gas		FFV Caravan/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	2.9	0.4	1.04	0.23	0.010
Phase 2	0.23	0.08	0.15	0.02	0.26
Phase 3	0.41	0.05	0.17	0.06	0.020
Composite	0.83	0.10	0.34	0.02	0.006

There is a statistically significant difference in the CO emission rates during Phase 1 and Phase 3. The CO emissions are 64% lower in Phase 1 and 35% lower in Phase 3 when using E85 as compared to gasoline. As a result, the FTP composite emission rate is 59% lower.

Figure 15: CO_2 Emission Rates – FFV Caravan with Regular Gas versus E85

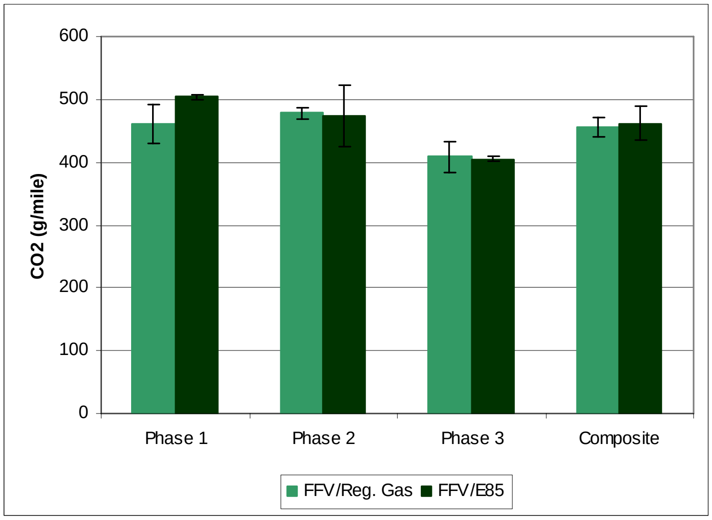


Table 31: Emission Rates and P-Values for CO_2 over FTP

	FFV Caravan/Reg. Gas		FFV Caravan/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	460	0.4	504	2	0.031
Phase 2	478	0.08	474	24	0.75
Phase 3	410	0.05	405	2	0.73
Composite	456	0.10	461	13	0.57

There is a statistically significant difference in CO_2 emission during Phase 1. The CO_2 emission is 9.0% higher from the E85 fuel than it is with regular fuel.

Figure 16: NOx Emission Rates - FFV Caravan with Regular Gas versus E85

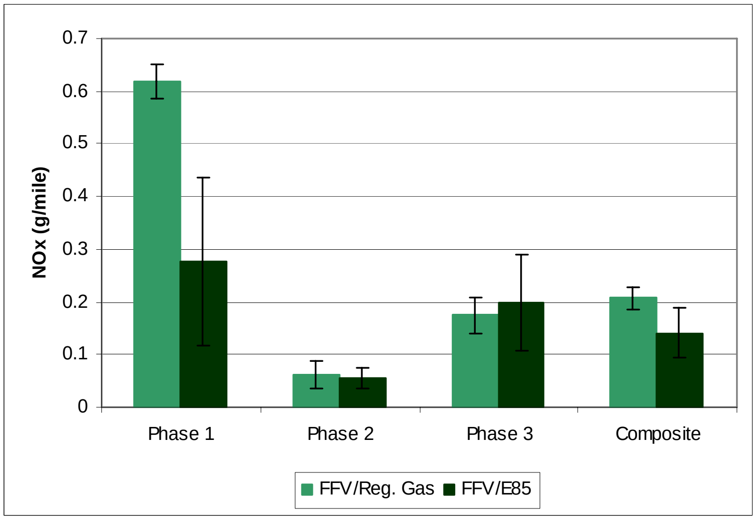


Table 32: Emission Rates and P-Values for NOx over FTP

	FFV Caravan/Reg. Gas		**FFV Caravan/E85**		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.62	0.02	0.28	0.08	0.004
Phase 2	0.06	0.01	0.057	0.009	0.73
Phase 3	0.17	0.02	0.20	0.05	0.43
Composite	0.21	0.01	0.14	0.02	0.021

There is a statistically significant difference in NOx emission during Phase 1 of the FTP. The NOx emission rate is 55% lower on E85 as compared to gasoline. As a result, the FTP composite NOx emission rate is 33% lower.

Figure 17: Oxygenate corrected THC Emission Rates – FFV Caravan with Regular Gas versus E85

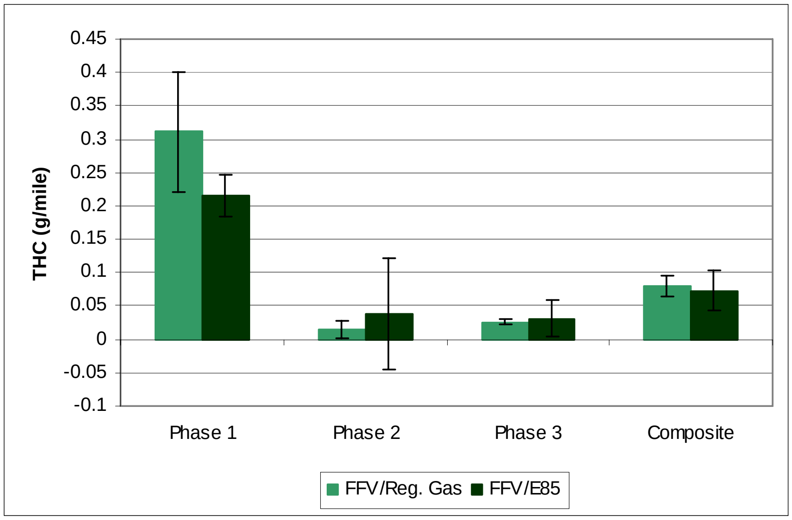


Table 33: Emission Rates and P-Values for oxygenate corrected THC over FTP

	FFV Caravan/Reg. Gas		**FFV Caravan/E85**		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.31	0.05	0.22	0.02	0.073
Phase 2	0.014	0.006	0.04	0.04	0.37
Phase 3	0.026	0.002	0.03	0.01	0.48
Composite	0.079	0.008	0.07	0.01	0.59

There is no statistically significant difference in oxygenate corrected THC emission although Phase 1 comes close to meeting the 95% confidence interval used for this study.

Figure 18: NMHC Emission Rates - FFV Caravan with Regular Gas versus E85

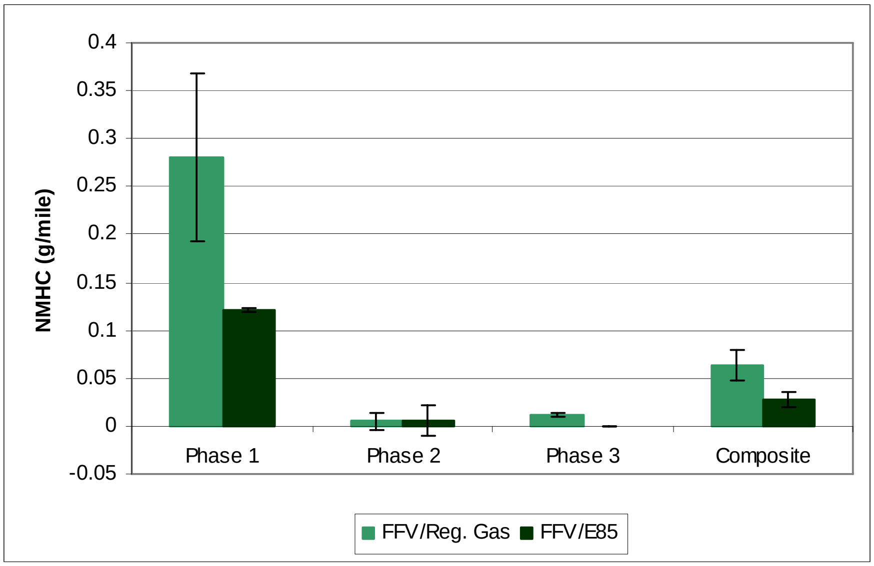


Table 34: Emission Rates and P-Values for NMHC over FTP

	FFV Caravan/Reg. Gas		FFV Caravan/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.28	0.04	0.12	0.001	0.016
Phase 2	0.0050	0.005	0.006	0.008	0.89
Phase 3	0.012	0.001	0.0	0.0	0.001
Composite	0.064	0.008	0.028	0.004	0.011

There is a statistically significant difference in NMHC emissions during Phase 1 and Phase 3. The NMHC emissions were lower during Phase 1, and below detection limits for the FFV Caravan when operating on E85. As a result, the FTP composite NMHC emission rate is 94% lower.

Figure 19: NMOG Emission Rates - FFV Caravan with Regular Gas versus E85

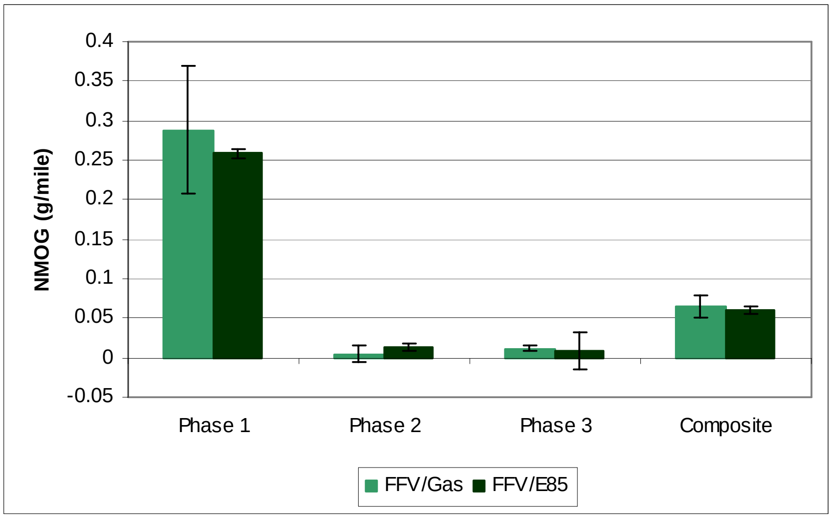


Table 35: Emission Rates and P-Values for NMOG over FTP

	FFV Caravan/Reg. Gas		FFV Caravan/E85		
	(g/mile)	SD	(g/mile)	SD	P-Value
Phase 1	0.29	0.04	0.258	0.002	0.40
Phase 2	0.005	0.005	0.013	0.002	0.12
Phase 3	0.012	0.001	0.008	0.012	0.63
Composite	0.065	0.007	0.060	0.002	0.45

There is no significant difference in the emissions from NMOG.

In summary:

- Emissions from the FFV Caravan were statistically significantly lower for CO (Phase 1 and Phase 3), CO_2 (Phase 1), NOx (Phase 1) and NMHC (Phase 1) while operating on E85 as compared to gasoline.

- The NMHC measurement does not include unburned ethanol which is present in emissions from this vehicle operating on E85. The NMOG measurement includes unburned ethanol thus shows no statistically significant difference.

6.4 FFV Sebring with Tier 2 Fuel versus the Same Vehicle with E85 Fuel

This comparison illustrates the emissions benefits obtained when operating the same flexible fuel vehicle on E85 as compared to gasoline. In this analysis, the sensor read 0% on the regular fuel and reached 83% on the E85 fuel.

Figure 20 through Figure 25 illustrate the comparison of emissions between the FFV Sebring with regular fuel and with E85 fuel. Each graph is followed by a table representing the P-values from the ANOVA test, and a discussion of the results.

Figure 20: CO Emission Rates - FFV Sebring with Regular Gas versus E85

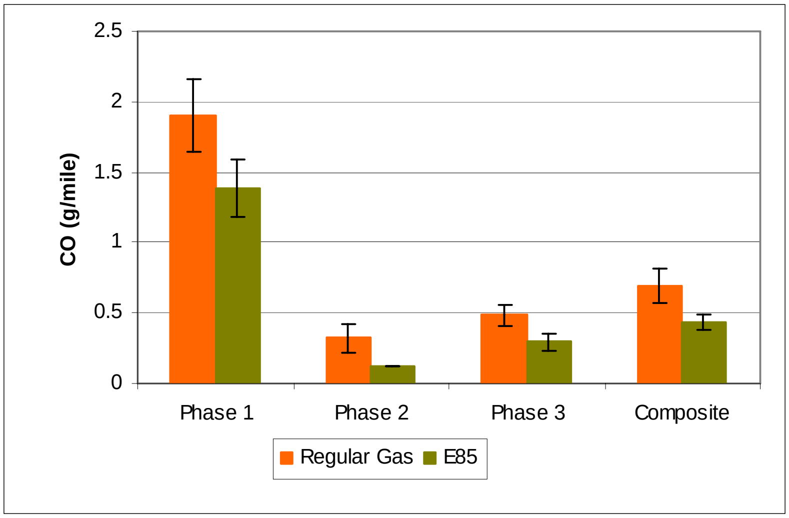


Table 36: Emission Rates and P-Values for CO over FTP

	FFV Sebring/Reg. Gas		FFV Sebring/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	1.9	0.1	1.38	0.10	0.018
Phase 2	0.32	0.05	0.1269	0.0002	0.015
Phase 3	0.48	0.04	0.30	0.03	0.011
Composite	0.69	0.06	0.43	0.03	0.011

There is a statistically significant difference for all Phases of the cycle. The emissions on E85 are 27%, 60% and 38% lower respectively for Phases 1, 2 and 3 on E85 as compared to gasoline. As a result, the FTP composite emission rate is also 38% lower.

Figure 21: CO_2 Emission Rates - FFV Sebring with Regular Gas versus E85

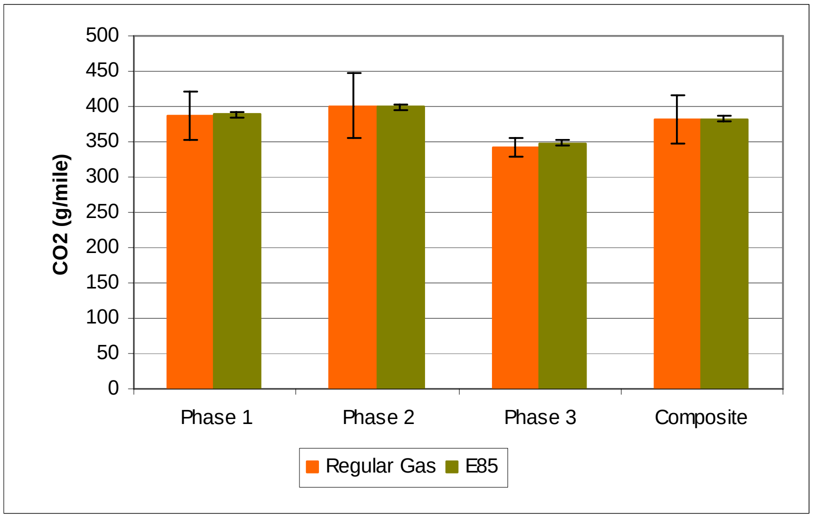


Table 37: Emission Rates and P-Values for CO_2 over FTP

	FFV Sebring/Reg. Gas		FFV Sebring/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	387	17	388	2	0.94
Phase 2	401	23	399	2	0.90
Phase 3	341	6	348	2	0.27
Composite	382	17	383	2	0.95

There is no significant difference in CO_2 emissions from the Sebring with differing fuels.

Figure 22: NOx Emission Rates - FFV Sebring with Regular Gas versus E85

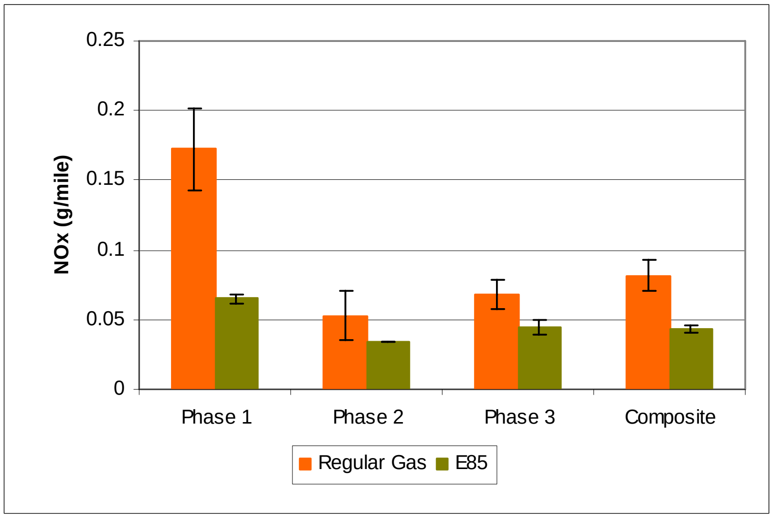


Table 38: Emission Rates and P-Values for NOx over FTP

	FFV Sebring/Reg. Gas		FFV Sebring/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.17	0.01	0.065	0.002	0.002
Phase 2	0.053	0.008	0.0337	0.0001	0.066
Phase 3	0.068	0.005	0.044	0.003	0.010
Composite	0.082	0.006	0.043	0.001	0.003

There is a statistically significant difference in NOx emissions during Phase 1 and Phase 3. Emission rates were 62% and 35% lower on E85 as compared to gasoline. As a result, the FTP composite emission rate was also 48% lower.

Phase 2 comes very close to meeting the 95% confidence level used for determining statistical significance in this study.

Figure 23: Oxygenate corrected THC Emission Rates - FFV Sebring with Regular Gas versus E85

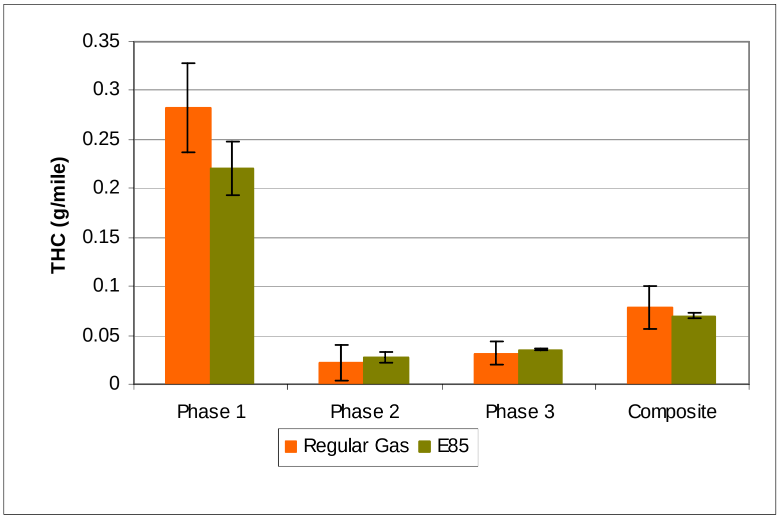


Table 39: Emission Rates and P-Values for Oxygenate corrected THC over FTP

	FFV Sebring/Reg. Gas		FFV Sebring/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.28	0.02	0.22	0.01	0.044
Phase 2	0.022	0.009	0.027	0.003	0.49
Phase 3	0.032	0.006	0.0355	0.0008	0.45
Composite	0.08	0.01	0.070	0.001	0.35

There was a statistically significant difference during Phase 1 for total hydrocarbons. The emission rate was 21% lower for operation on E85 as compared to gasoline. However, the FTP composite emission rate was not statistically significantly different.

Figure 24: NMHC Emission Rates - FFV Sebring with Regular Gas and E85

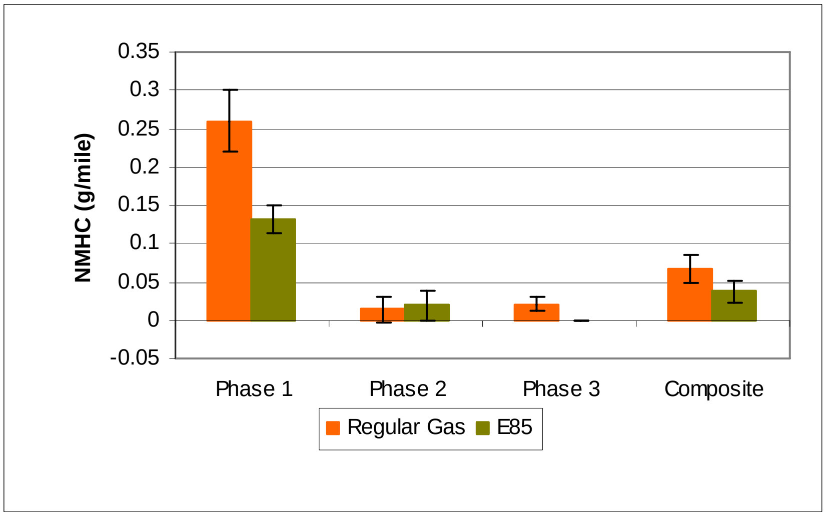


Table 40: Emission Rates and P-Values for NMHC over FTP

	FFV Sebring/Reg. Gas		FFV Sebring/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.26	0.02	0.13	0.009	0.0039
Phase 2	0.014	0.008	0.020	0.010	0.54
Phase 3	0.021	0.005	0.0	0.0	0.008
Composite	0.07	0.009	0.037	0.007	0.032

There was a statistically significant difference during Phase 1and Phase 3 for NMHC. The emission rate on E85 was 50% lower for Phase 1 and below detection limits for the Phase 3 E85 tests. As a result, the composite emission rate was 47% lower when operating on E85.

Figure 25: NMOG Emission Rates - FFV Sebring with Regular Gas versus E85

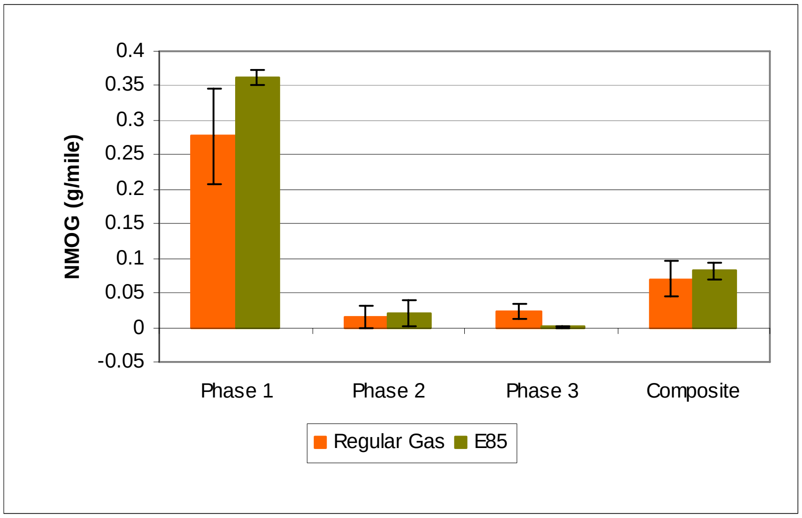


Table 41: Emission Rates and P-Values for NMOG over FTP

	FFV Sebring/Reg. Gas		FFV Sebring/E85		
	(g/mile)	**SD**	**(g/mile)**	**SD**	**P-Value**
Phase 1	0.28	0.03	0.36	0.005	0.046
Phase 2	0.014	0.008	0.020	0.010	0.54
Phase 3	0.022	0.005	0.003	0.0001	0.009
Composite	0.07	0.001	0.082	0.006	0.34

There was a statistically significant difference during Phase 1 and Phase 3 for NMOG. E85 emissions were 22% higher in Phase 1 and 86% lower in Phase 3.

In summary:

- Comparing the composite emission rates for the Sebring operating on gasoline to the California ULEV 1 LDV emission standard summarized Table 4, it can be seen that the vehicle meets the applicable standard except for NMOG, which is 75% (27% if >50K mi, 5 years) above the standard limit.

- Operation on E85 results in lower CO emissions for all Phases, and lower NOx emissions (Phase 1 and Phase 3). Higher NMOG emissions from E85 were observed during Phase 1, however they fell below the gasoline emissions by Phase 3 of the test cycle.

- Overall, the use of E85 yields a larger decrease in emissions, when compared to regular fuel, for the Sebring than it does for the Caravan. The Sebring boasts newer technology and meets a different and more stringent emission standard than the Caravan.

6.5 Effect of Fuel Sensor Reading Incorrectly

The following graphs show the trends which occurred as the FFV Caravan and the FFV Sebring were fuelled with E85 (each following regular Tier 2 fuel testing) and their emissions sampled as the sensors changed. The FFV Caravan's sensor, over 356 km, changed from 0% to 64%. The FFV Sebring's sensor, over 273 km, changed from 0% to 83%. Figure 26 and Figure 27 show the FFVs' sensors changing as mileage accumulated, and indicate where sampling was done. Fuel was topped up during mileage accumulation for both vehicles.

Figure 26: FFV Caravan Sensor Change by Mileage Accumulation

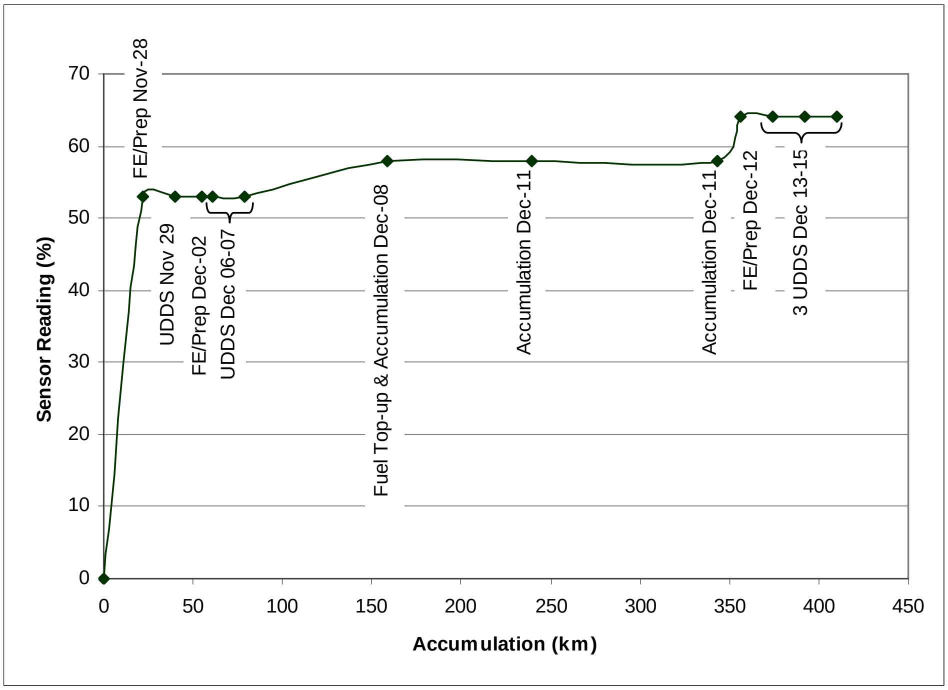


Figure 27: FFV Sebring Sensor Change by Mileage Accumulation

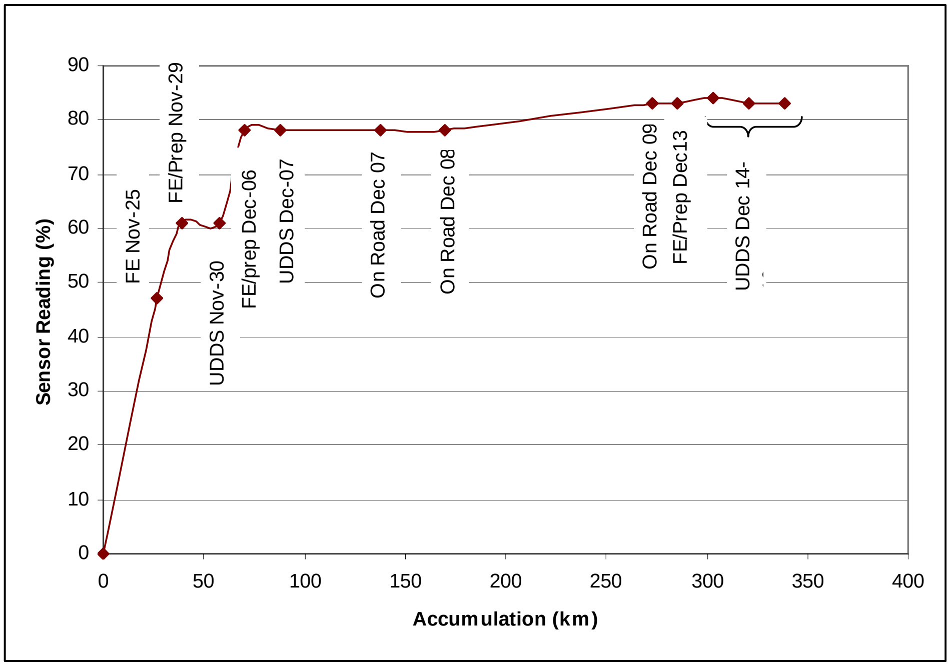


Figure 28 and Figure 29 have linear trend lines to illustrate the change in the emission rate at various sensor readings of ethanol content, over the 3 Phases of the FTP driving schedule. A description of the analysis and its results follows. All tests shown in these figures were conducted on E85 and the sensor reading was recorded at the beginning of the test.

Figure 28: FFV Caravan - Emission Changes as Fuel Sensor Changes

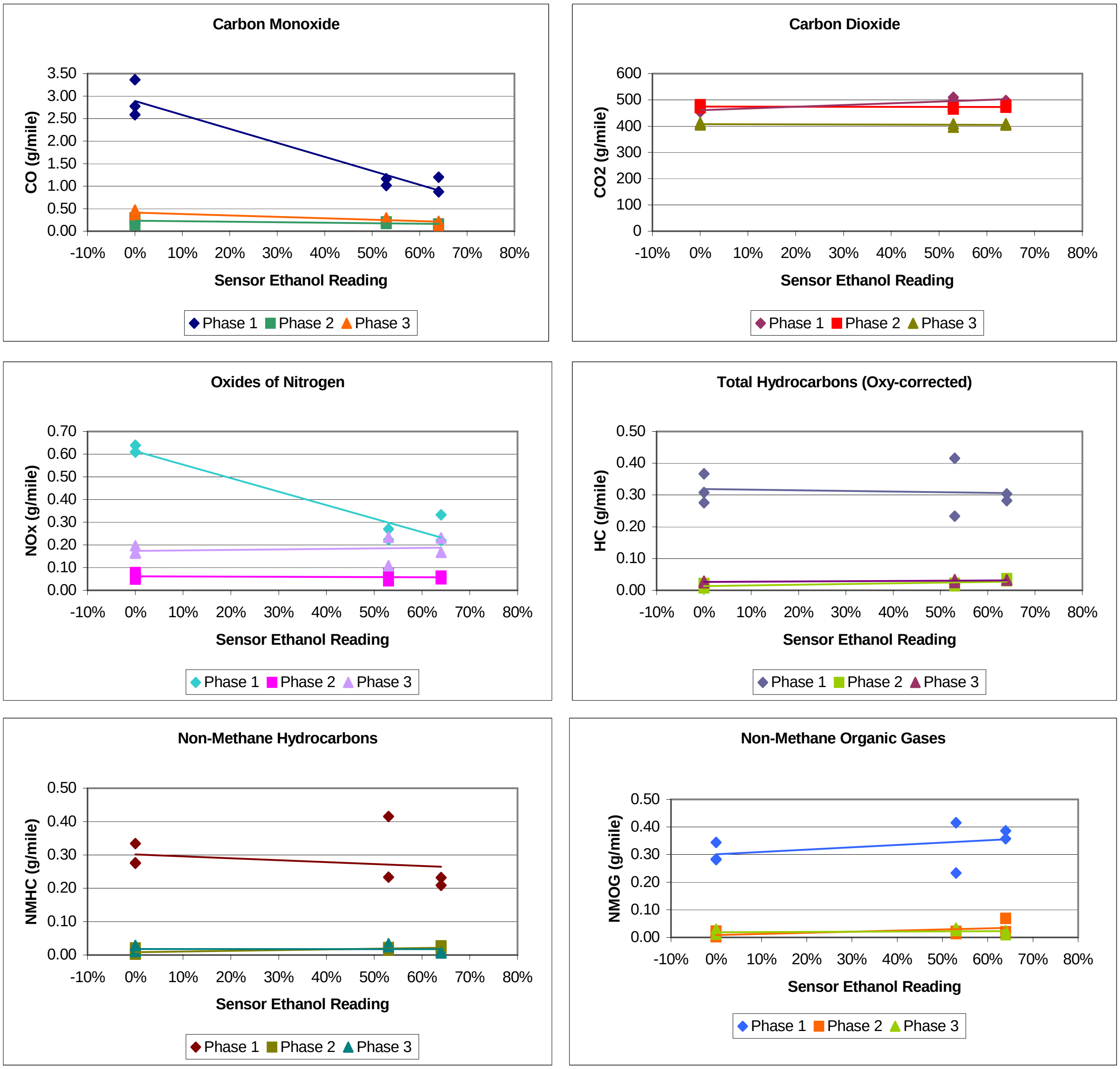
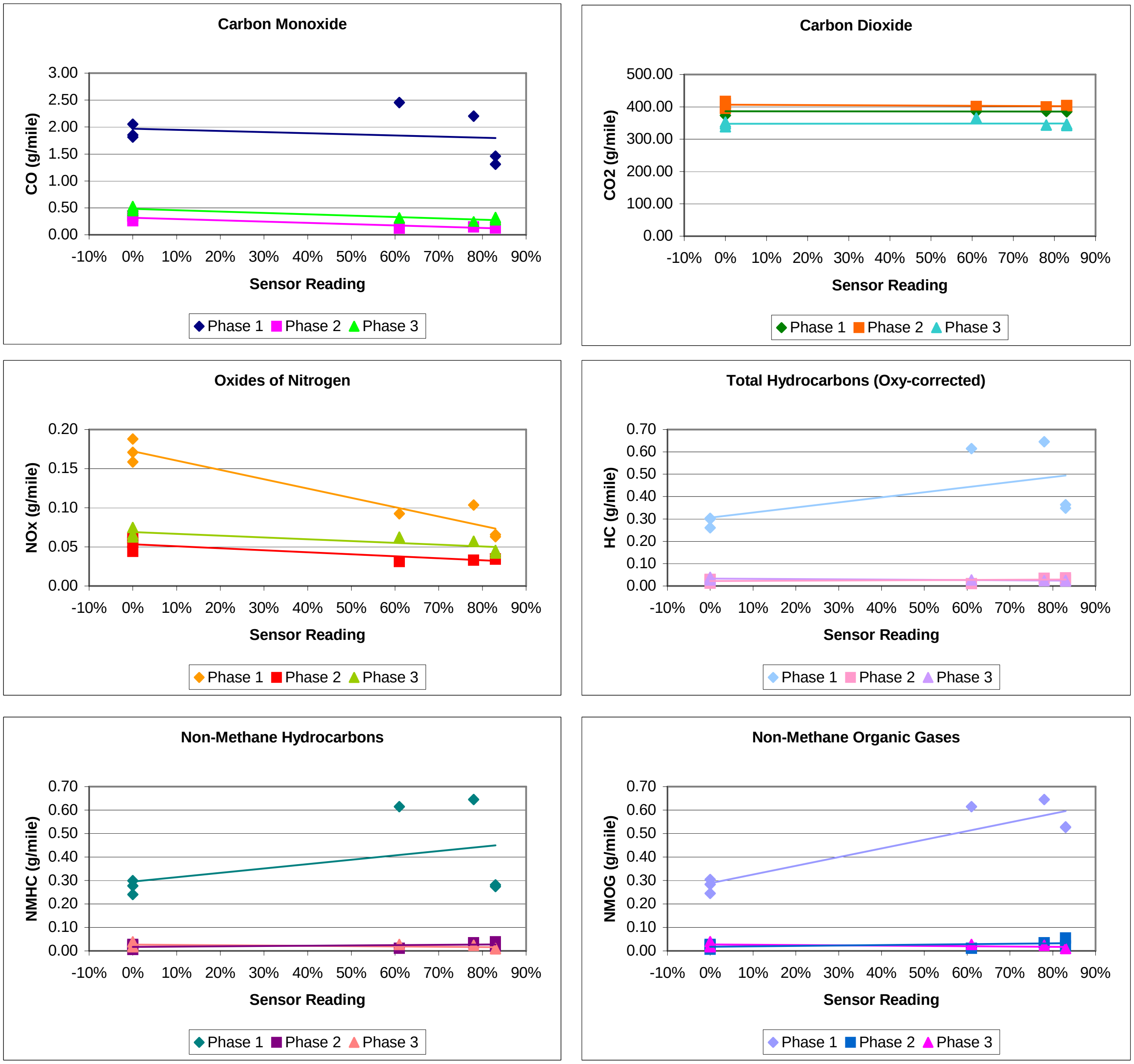


Figure 29: FFV Sebring - Emission Changes as Fuel Sensor Changes



Linear regression is used to illustrate a potential linear trend in the emission rates as the fuel composition sensor reading changes.

For the FFV Caravan, regression analysis showed that carbon monoxide (CO) and oxides of nitrogen (NOx) emissions are affected during Phase 1 of the FTP as the sensor adjusts to the fuel composition. The slope of the regression line is negative, which means that as the sensor reads a higher percentage of ethanol, or as sensor reading increases, CO and NOx levels decrease in a predictable manner.

This regression result also applies to CO during Phase 3 of the FTP. As the sensor reading increases during Phase 3, which is the hot start, CO decreases.

The rest of the regression analyses showed no statistical significance between the sensor readings and the amount of emissions measured.

For the Sebring, CO emission decreased as the sensor reading increased during Phases 2 and 3. The same result was observed for NOx in all three Phases, and total hydrocarbons in Phase 3. For non-methane organic gases (NMOG), linear regression presented a positive slope and statistically significant relationship between the variables during Phase 1. Thus, NMOG increases as the sensor reading increases during cold engine start, in this case by 53% as the sensor went from 0% to 83% ethanol.

Clearly, the emissions are elevated when the fuel composition sensor reading is in error and decrease as it slowly changes to read the correct percentage of ethanol in the fuel.

6.6 Greenhouse Gas Results

The measured CH_4 and N_2O emission rates are summarized in Table 45 in Appendix 1.

Observing GHG measurement results, it can be seen that operation on E85 fuel does not result in a decrease in CO_2 emissions at the tailpipe. The lower carbon content of the E85 is offset by the increased fuel consumption due to lower energy density. The benefit of E85 is the reduced energy demand in the production of ethanol fuel, and the carbon balance between sequestering carbon in the plants used to produce it, and releasing it through burning.

As shown in Figure 30, Phase 1 methane emissions were 40% higher for the FFV Caravan and 53% higher for the FFV Sebring when they ran on E85 compared to E0. Considering measurement uncertainty, Phase 2, Phase 3, and composite values show similar emission patterns across both fuels for both vehicles.

Figure 31 shows nitrous oxide emissions. The FFVs operating on E85 produced less N_2O emissions than when they were operated on E0. For the Caravan, 50%, 50%, 16%, and 33% for Phase 1, Phase 2, Phase 3, and composite values respectively and the Sebring, 54%, 87%, 32%, and 62% for Phase 1, Phase 2, Phase 3, and composite values respectively.

Figure 30: Comparison of Methane Emissions for all Vehicle/Fuel Combinations

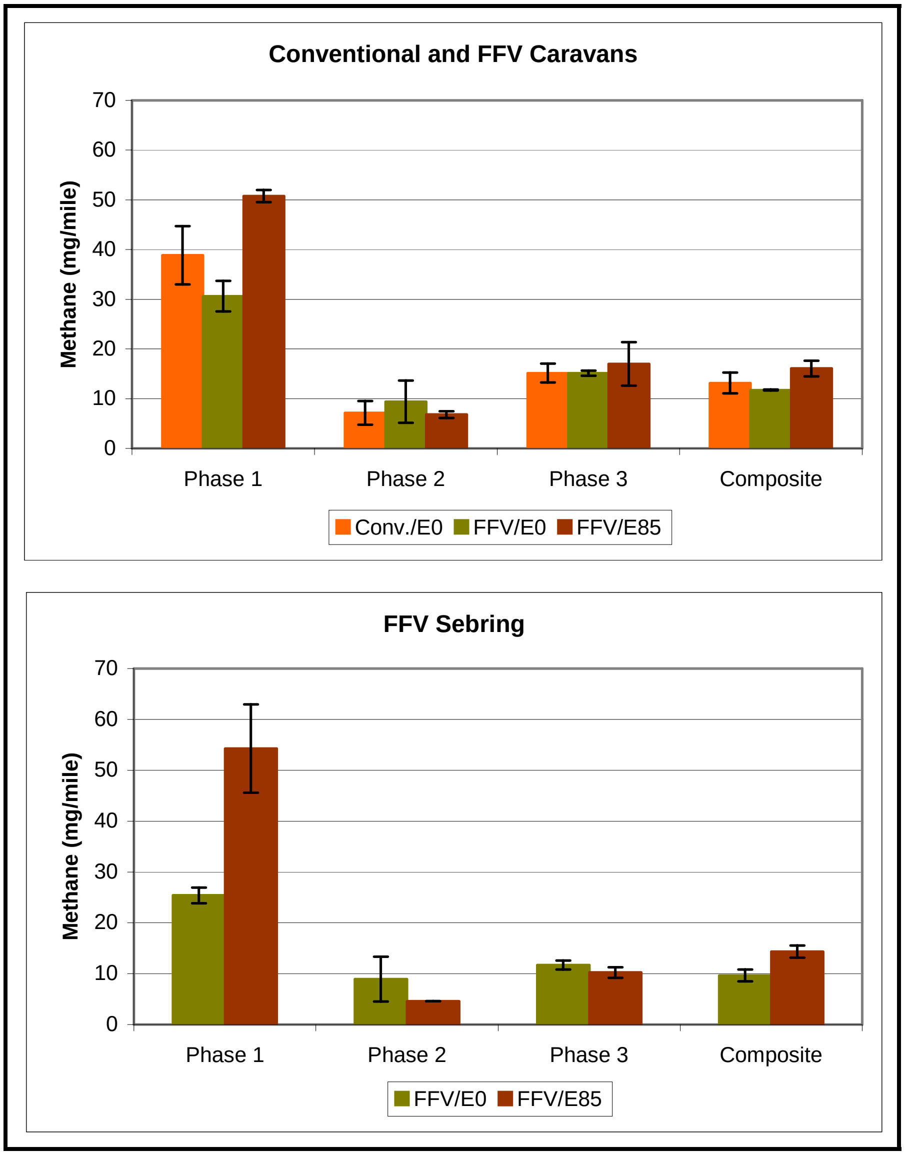
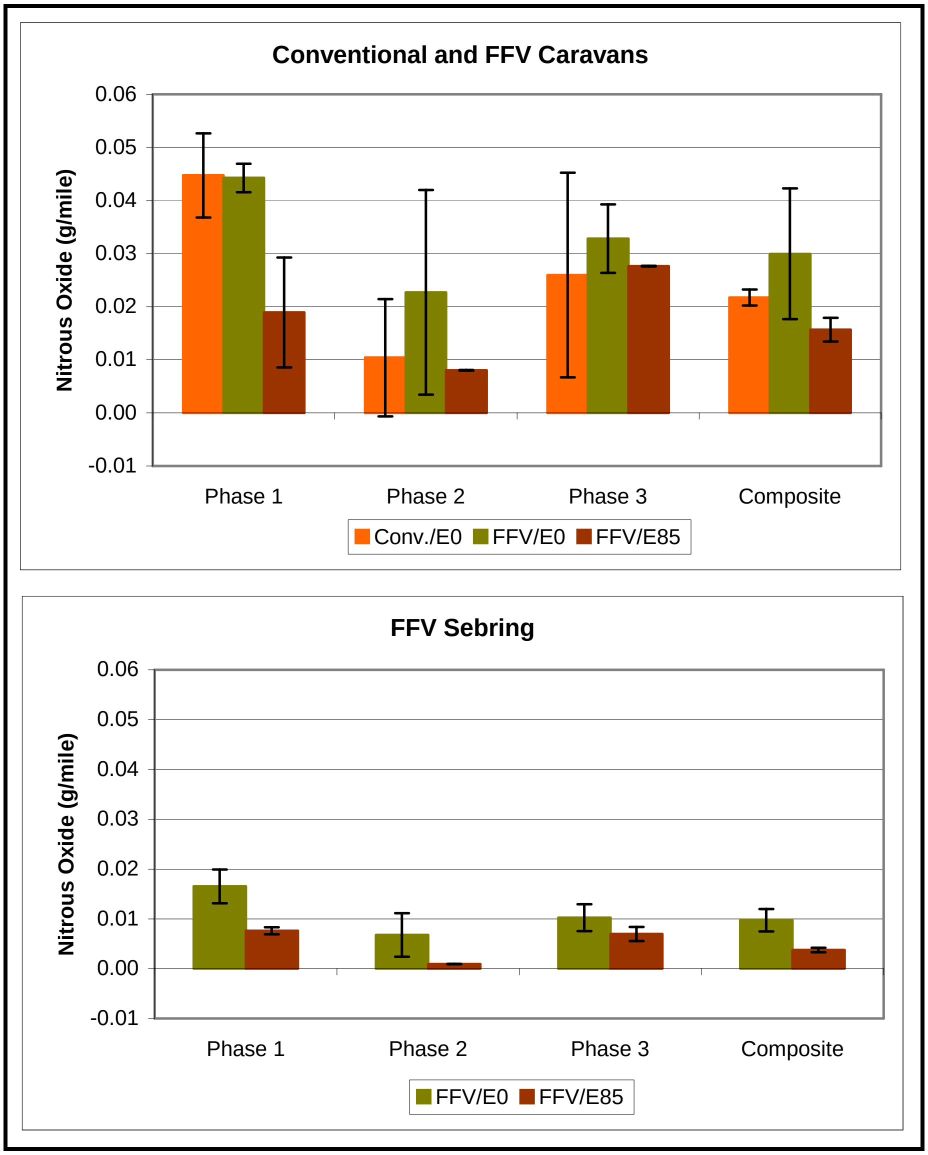


Figure 31: Comparison of Nitrous Oxide Emission for all Vehicle/Fuel Combinations



6.7 Toxic Emissions

Unburned ethanol emissions were measured only for E85 tests and are summarized in Table 42. Ethanol emissions were found primarily in Phase 1, during cold engine start. Emissions during Phase 2, or the stabilized Phase were below the detection limit of the instruments (see Table 17). For Phase 3, a small amount was measured only for the Caravan, which does not meet as high an emission standard as the Sebring.

Those compounds detected in the carbonyl and NMHC analysis that are listed on the CEPA Priority Substances List 1 and 2 are summarized in Table 43. Carbonyl compound emissions, specifically formaldehyde, acetaldehyde and acrolein increased for both vehicles with operation on E85 as compared to gasoline. Formaldehyde emissions increased by 80% for the Caravan and 116% for the Sebring. Acetaldehyde emissions increased by a factor of nearly 13 for the Caravan and by a factor of 50 for the Sebring. Acrolein emissions increased by 50% for the Caravan and by a factor of 16 for the Sebring (from <0.01 mg/mile to 0.17 mg/mile in Phase 1). Nearly all of these increases appear during cold engine start. Benzene, toluene and xylene emissions decreased by 60-80% with operation on E85 as compared to gasoline due to the displacement of the gasoline by ethanol.

The results for the complete suite of compounds is provided in Table 46 through Table 50 in Appendix 2

Table 42: Unburned Ethanol Emissions (mg/mile) measured only for E85 tests

	FFV Caravan E85		FFV Sebring E85	
	Avg*	**St Dev**	**Avg***	**St Dev**
Phase 1	117.22	0.97	205.88	4.24
Phase 2				
Phase 3	16.78			
Composite	26.55	3.48	42.61	0.88

Table 43: CEPA Toxic Emissions (mg/mile)

	FFV Caravan Tier 2		FFV Caravan E85		Conv. Caravan Tier 2		FFV Sebring Tier 2		FFV Sebring E85	
	Avg*	**St Dev**	**Avg***	**St Dev**	**Avg***	**St Dev**	**Avg***	**St Dev**	**Avg***	**St Dev**
Formaldehyde										
Phase 1	1.42	0.15	2.59	0.05	1.80	0.30	0.94	0.12	1.85	0.34
Phase 2										
Phase 3			0.07		0.05					
Composite	0.10	0.01	0.18	0.00	0.13	0.02	0.06	0.01	0.13	0.02
Acetaldehyde										
Phase 1	0.62	0.00	16.17	2.51	0.71	0.07	0.44	0.03	21.98	0.15
Phase 2	0.09									
Phase 3	0.05				0.04				0.23	0.04
Composite	0.08	0.03	1.10	0.17	0.05	0.01	0.03	0.00	1.52	0.01
Acrolein										
Phase 1	0.06		0.09	0.03	0.12				0.17	0.08
Phase 2										

Phase 3			0.01	0.00						
Composite	0.00		0.01	0.00	0.01				0.01	0.01
1,3 butadiene										
Phase 1							1.58	0.56	0.50	
Phase 2			0.57	0.31					0.35	0.05
Phase 3							0.07	0.09		
Composite			0.08	0.04			0.38	0.13	0.10	0.08
Benzene										
Phase 1	10.76	0.78	3.63	0.12	10.72		9.54	0.17	4.62	0.10
Phase 2	0.10	0.08	0.02		0.10		1.02	0.05	0.05	0.06
Phase 3	1.60	0.29	0.01	0.01	1.99		1.00	0.13	0.14	0.02
Composite	2.68	0.07	0.75	0.02	2.78		2.38	0.08	1.00	0.02
Toluene										
Phase 1	26.42	2.46	5.63	0.37	24.95		27.82	0.93	7.68	0.06
Phase 2	0.19	0.10	0.00	0.01	0.21		0.99	0.14	0.02	
Phase 3	1.22	0.22	0.04	0.02	1.63		1.51	0.21	0.18	0.08
Composite	5.83	0.43	1.17	0.08	5.64		6.30	0.27	1.64	0.04
Ethyl Benzene										
Phase 1	8.65	1.58	1.08	0.02	8.26		10.02	0.26	1.48	0.00
Phase 2	0.12	0.01	0.01		0.12		0.26	0.05	0.05	
Phase 3	0.08	0.02	0.01	0.01	0.16		0.35	0.02	0.06	0.02
Composite	1.83	0.32	0.23	0.00	1.77		2.20	0.07	0.33	0.00
m&p-xylene										
Phase 1	17.55	1.74	7.10	6.01	16.17		20.13	0.65	4.55	0.03
Phase 2	0.25		0.06		0.10		0.60	0.08	0.04	
Phase 3	0.50		0.08		0.76		0.74	0.10	0.16	0.04
Composite	3.74	0.44	1.48	1.22	3.57		4.45	0.18	0.99	0.00
o-xylene										
Phase 1	5.84	0.61	1.11	0.14	5.37		6.87	0.25	2.25	0.41
Phase 2	0.08	0.02	0.02		0.00		0.23	0.04	0.29	
Phase 3	0.16	0.01			0.73		0.26	0.03	0.06	0.00
Composite	1.27	0.12	0.23	0.03	1.31		1.52	0.07	0.50	0.06
* where there is no standard deviation reported, avg is a single test value, where there is no value reported, level was below the limit of detection for the instrument (see Table 16)										

7.0 Fuel Consumption and CO_2

Fuel consumption results are summarized in Table 44 and were as expected. As was noted earlier, the energy density of E85 fuel is lower than that of regular fuel. This means that the vehicle must consume more E85 fuel to produce the same amount of energy as regular fuel. The composite L/100 km figures show an average 26% additional E85 fuel by volume is consumed compared to regular fuel consistent with what is theoretically expected (Table 6).

Table 44: Fuel Consumption Data for Five Vehicle/Fuel Combinations

	MPG		**L/100 km**	
	Avg	**St Dev**	**Avg**	**StDev**
Conventional Caravan Tier 2				
Phase 1	21.72	0.28	13.01	0.17
Phase 2	21.22	1.15	13.34	0.74
Phase 3	24.68	1.96	11.50	0.94
Composite	22.17	1.14	12.77	0.67
FFV Caravan Tier 2				
Phase 1	22.81	0.73	12.39	0.40
Phase 2	22.17	0.20	12.74	0.12
Phase 3	25.95	0.76	10.89	0.32
Composite	23.23	0.38	12.16	0.20
FFV Sebring Tier 2				
Phase 1	27.17	1.16	10.41	0.45
Phase 2	26.48	1.46	10.69	0.60
Phase 3	31.04	0.59	9.10	0.17
Composite	27.74	1.20	10.20	0.45
FFV Cara E85				
Phase 1	14.82	0.04	19.07	0.05
Phase 2	15.84	0.81	17.86	0.91
Phase 3	18.49	0.08	15.28	0.07
Composite	16.24	0.47	17.40	0.50
FFV Sebring E85				
Phase 1	19.17	0.10	14.74	0.08
Phase 2	18.79	0.11	15.03	0.09
Phase 3	21.53	0.12	13.12	0.08
Composite	19.56	0.11	14.45	0.08

8.0 Conclusions

When comparing regular and FFVs, in this case the Caravans, both on their intended fuels, statistically significant differences occurred primarily during the cold start portion of the test cycle.

Comparing the two vehicles, both on gasoline, shows statistically significant differences only for NOx emissions in Phase 1. This variation could be due to differences in catalyst function, or if the catalysts are functioning identically, lower NOx emissions from the FFV could be at the engine out stage due to a slightly richer air/fuel ratio.

Comparing emissions from the FFV while operating on regular and E85 fuels showed that E85 resulted in lower emissions of CO in Phases 1 and 3, and for NOx, CO_2, and NMHC in Phase 1

Operating the FFV Sebring on the two different fuels resulted in larger differences than the FFV Caravan. This could be due to the Sebring's newer technology and more stringent regulated emission standard. Use of E85 fuel consistently reduced CO and NOx emissions for this vehicle, likely due to differences in combustion.

Linear regression analysis of the emissions during fuel sensor adjustment was done to determine if a relationship existed between sensor readings and emissions. For the Caravan, CO emissions were reduced during Phase 1 and Phase 3 as the sensor reading rose, and NOx emissions were reduced during Phase 1 for the same conditions. The Sebring showed reduced emissions during Phases 2 and 3 for CO, for the entire test for NOx, and for Phase 3 THC. NMOG emissions increased as the sensor reading increased.

In regard to greenhouse gas emissions, carbon dioxide emissions were not reduced by the use of E85 as its lower energy density results in increased fuel consumption. The benefits of E85 result from the ease of its production (less energy intensive) compared to fossil fuels, and in the balance produced by its carbon sequestration and release cycle. NOx emissions were significantly reduced for E85 at all Phases, while methane emissions were increased in Phase 1.

Among the CEPA toxic emissions, unburned ethanol from the use of E85 fuel was measured. Amounts were detectable for Phase 1 of both vehicles but were below detection limits for Phase 2. The Caravan emitted a small amount of unburned ethanol during Phase 3 most likely due to its low emission standard compared to the Sebring. Carbonyl compound emissions were substantially increased with the use of E85 fuel.

Observed fuel consumption rates were as expected. Having less energy density, E85 fuel consumption is higher than that of regular fuel.

Acknowledgements

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- Scott Dey, and Shannon Furino for sample collection; and
- Diane Dey, Kerri Longlade, Trevor Connolly, and Ingrid Popesku for the detailed chemical analysis of the emissions samples.

References

[1] Painter, L.J., J.A. Rutherford, Statistical Design and Analysis Methods for the Auto/Oil Air Quality Research Program, SAE **920319**, 1992.

[2] Wernimont, G.T., Use of Statistics to Develop and Evaluate Analytical Methods, Association of Official Analytical Chemists, Arlington, Va., 1993.

[3] United States Environmental Protection Agency, Federal and California Exhaust and Evaporative Emission Standards for Light-Duty Vehicles and Light-Duty Trucks, EPA420-B-00-001, February 2000.

Appendix 1: Greenhouse Gas Data

Table 45: Greenhouse Gas Emissions

	FFV Caravan Tier 2		FFV Caravan E85		Conv. Caravan Tier 2		FFV Sebring Tier 2		FFV Sebring E85	
	Avg	**St Dev**	**Avg**	**St Dev**	**Avg**	**St Dev**	**Avg**	**St Dev**	**Avg**	**St Dev**
Methane (CH_4) mg/mile										
Phase 1	31	1	50.8	0.6	37	2	25.4	0.8	54	4
Phase 2	9	2	6.8	0.3	14	10	9	2	2	3
Phase 3	15.1	0.3	17	2	14	2	11.7	0.4	10.2	0.5
Composite	11.74	0.05	16.1	0.8	13	0.3	9.6	0.6	14.3	0.6
Nitrous Oxide (N_2O) mg/mile										
Phase 1	44	1	19	5	45	4	17	2	8	0
Phase 2	23	10	8	0	10	5	7	2	1	1
Phase 3	33	3	28	0	26	10	10	1	7	1
Composite	30	6	16	1	22	1	10	1	4	0
Carbon Dioxide (CO_2) g/mile										
Phase 1	463	20	504	2	481	6	389	24	388	2
Phase 2	478	6	474	24	501	28	404	31	399	2
Phase 3	415	6	405	2	431	35	340	9	348	2
Composite	458	9	461	13	478	25	384	23	383	2

Appendix 2: Hydrocarbon Speciation Details (Mass Emission (mg / mile))

Table 46: Vehicle 021 – FFV Sebring, Regular Fuel

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
formaldehyde	0.94	0.12			0.00		0.06	0.01
acetaldehyde	0.44	0.04					0.03	0.00
acrolein	0.00	0.00						
acetone	0.44	0.10			0.08		0.03	0.01
propionaldehyde	0.05	0.03			0.00		0.00	0.00
crotonaldehyde	0.07	0.00					0.00	0.00
methacrolein	0.20	0.01					0.01	0.00
methyl ethyl ketone	0.13	0.03			0.03		0.01	0.00
isobutyraldehyde & butyraldehyde	0.06	0.01					0.00	0.00
benzaldehyde	0.16	0.02					0.01	0.00
isovaleraldehyde								
valeraldehyde								
o-tolualdehyde								
m&p-tolualdehyde								
hexanaldehyde								
2,5-dimethylbenzaldehyde								
ethylene	15.40	0.68	0.00	0.00	1.21	0.21	3.52	0.08
acetylene	7.66	0.60					1.58	0.12
ethane	4.90	0.17	1.68	0.18	1.87	0.22	1.75	0.07
propylene	10.42	0.58					2.16	0.12
propane	0.09		0.88				0.14	
propyne	0.67						0.14	
isobutane	0.53	0.74	0.08		0.17	0.01	0.16	0.16
isobutene/1-butene	15.05	0.12	0.45	0.18	0.92	0.19	3.42	0.10
13-butadiene	1.58	0.56	0.47		0.07	0.09	0.38	0.13
n-butane	2.14	0.39	0.35		0.45	0.01	0.59	0.05
t2-butene	1.54	0.02	0.02		0.04	0.01	0.33	0.00
1-butyne	0.05	0.00					0.01	0.00
c2-butene	1.38	0.04	0.02		0.03	0.00	0.30	0.01
12-butadiene	0.06	0.00					0.01	0.00
3m1-butene	0.43	0.02	0.01		0.02	0.01	0.09	0.00
2m-butane	14.55	0.33	1.05	0.07	2.13	0.32	3.73	0.03
14-pentadiene			0.75	0.03	0.57	0.04	0.26	0.01
2-butyne	0.06	0.01					0.01	0.00
1-pentene	0.49	0.01	0.01		0.02	0.00	0.11	0.00
2m1-butene	1.20	0.07	0.02		0.05	0.01	0.26	0.01
n-pentane	2.53	0.08	0.10	0.07	0.22	0.04	0.60	0.01
2m-13-butadiene (isoprene)	0.73	0.10	0.06		0.07	0.00	0.17	0.03
t2-pentene	0.90	0.02	0.01	0.00	0.03	0.00	0.20	0.00
c2-pentene	0.50	0.01	0.01		0.02	0.00	0.11	0.00
2m2-butene	2.06	0.06	0.03	0.01	0.06	0.02	0.45	0.02
t-13-pentadiene	0.22	0.19	0.01		0.02		0.05	0.04

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
cyclopentadiene	0.17	0.17	0.01		0.01	0.00	0.04	0.04
22-dm-butane/c13-pentadiene	0.70	0.02	0.06	0.01	0.11	0.01	0.18	0.01
cyclopentene	0.37	0.00	0.00		0.01		0.08	0.00
4m1-pentene	0.25	0.00	0.01		0.01	0.01	0.06	0.00
cyclopentane	0.50	0.08	0.10	0.01	0.08	0.01	0.14	0.02
23-dm-butane	3.07	0.12	0.59	0.56	0.35		0.76	0.03
2m-pentane	8.90	0.01	0.45	0.06	1.04	0.18	2.19	0.06
c/t-4m2-pentene	0.23	0.00			0.01	0.00	0.05	0.00
3m-pentane	4.93	0.01	0.29	0.03	0.60	0.09	1.22	0.03
2m1-pentene								
1-hexene	0.24	0.00	0.01		0.01	0.00	0.05	0.00
n-hexane	2.22	0.01	0.13	0.01	0.25	0.04	0.54	0.01
t2-hexene	0.39	0.02	0.01		0.01	0.00	0.08	0.00
2m2-pentene	0.55	0.02	0.01		0.02	0.00	0.12	0.01
t-3m2-pentene	0.40	0.05	0.01		0.02	0.00	0.09	0.01
c2-hexene	0.20	0.00	0.00		0.00	0.00	0.04	0.00
c-3m2-pentene	0.49	0.04	0.01		0.02	0.00	0.11	0.01
22-dm-pentane	0.08						0.02	
m-cyclopentane	1.51		0.07		0.09	0.11	0.19	0.26
24-dm-pentane	6.33	0.19	0.41	0.05	0.76	0.13	1.57	0.08
223-tm-butane	0.11	0.03	0.02		0.02	0.00	0.03	0.01
1m-cyclopentene	0.14	0.02	0.00	0.00	0.01	0.00	0.03	0.00
benzene	9.54	0.17	1.02	0.05	1.00	0.13	2.38	0.08
33-dm-pentane	0.38				0.05	0.02	0.05	0.06
cyclohexane	0.23	0.02	0.01		0.02	0.01	0.05	0.00
2m-hexane	2.71	0.07	0.15	0.01	0.39	0.16	0.69	0.06
23-dm-pentane	12.75	0.36	0.81	0.10	1.42	0.09	3.13	0.12
11-dm-cyP	0.10	0.01	0.00		0.01	0.01	0.02	0.00
cyclohexene	0.09	0.01			0.00		0.02	0.00
3m-hexane	3.16	0.10	0.16	0.03	0.33	0.05	0.76	0.04
c-13-dm-cyP	0.42	0.02	0.02		0.03	0.01	0.10	0.01
3e-pentane/t-13-dm-cyP	0.79	0.02	0.04		0.06	0.05	0.18	0.02
t-12-dm-cyP/1-heptene	0.45				0.03		0.05	0.06
224-tm-pentane	25.21	0.66	1.89	0.21	3.35	0.55	6.38	0.32
t3-heptene	0.15	0.02	0.00		0.00	0.00	0.03	0.00
n-heptane	2.52	0.12	0.12	0.02	0.23	0.04	0.60	0.04
c3-heptene	0.35	0.03	0.00		0.01		0.07	0.01
t2-heptene	0.15	0.02					0.03	0.00
c2-heptene			0.01		0.01		0.00	0.00
m-cyclohexane/22-dm-hexane	0.88	0.10	0.03	0.01	0.09	0.00	0.21	0.02
25-dm-hexane/e-cyP	2.06	0.08	0.07	0.02	0.18	0.04	0.49	0.03
24-dm-hexane/223-tm-pentane	3.26	0.13	0.20	0.03	0.36	0.06	0.80	0.05
33-dm-hexane/ctc124-tm-cyP	0.33	0.02	0.02		0.04	0.00	0.08	0.01
ctc123-tm-cyP	0.16	0.01	0.01		0.01	0.01	0.04	0.00
234-tm-pentane	7.01	0.31	0.44	0.07	0.79	0.12	1.72	0.11
toluene/233-tm-pentane	27.82	0.93	0.99	0.14	1.51	0.21	6.30	0.27
23-dm-hexane	2.16	0.10	0.12	0.02	0.22	0.02	0.52	0.03
2m3e-pentane	0.23	0.01	0.01		0.02	0.02	0.05	0.01

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
2m-heptane/1m-cyclohexene	2.22	0.09	0.10	0.02	0.20	0.03	0.53	0.03
4m-C7/3m3e-pentane	0.89	0.02	0.05		0.09	0.01	0.21	0.01
34-dm-hexane	0.56	0.03	0.03		0.05	0.01	0.13	0.01
3m-heptane/3e-hexane	2.93	0.06	0.16	0.02	0.28	0.04	0.71	0.03
cct-124-tm-cyP/t-13-dm-cyH	0.26	0.02			0.02		0.06	0.00
t-14-dm-cyH	0.10	0.00	0.00		0.01	0.00	0.02	0.00
225-tm-hexane	1.23	0.07	0.12		0.13	0.03	0.30	0.03
1-octene	0.27	0.02	0.01		0.02	0.00	0.06	0.01
1e1m-cyP	0.14	0.00	0.00				0.03	0.00
n-octane/t12-dm-cyH	2.17	0.07	0.10	0.03	0.18	0.02	0.51	0.02
t2-octene	0.14	0.01	0.03		0.00	0.00	0.03	0.00
ccc-123-tm-cyP	0.25	0.00	0.02		0.02	0.00	0.06	0.00
244-tm-hexane	0.04	0.02			0.02		0.01	0.00
c2-octene								
ip-cyP	0.14	0.01	0.02		0.02	0.00	0.04	0.00
235-tm-hexane	0.25	0.01	0.01	0.00	0.02	0.00	0.06	0.00
24-dm-heptane	0.33	0.02	0.03		0.02	0.02	0.08	0.01
26-dm-heptane/c12-dm...	0.44	0.02	0.02		0.03	0.01	0.10	0.01
np-cyP	0.11	0.00	0.02				0.02	0.00
ccc-135-tm-cyP	0.16	0.01	0.00		0.01		0.03	0.00
25-dm-heptane/35-dm-heptane	0.70	0.12	0.00		0.04		0.15	0.02
33-dm-heptane	0.13	0.11	0.05	0.07	0.14		0.05	0.06
114-tm-cyH	0.10	0.05			0.02	0.01	0.03	0.01
e-benzene	10.02	0.26	0.26	0.05	0.35	0.02	2.20	0.07
cct-124-tm-cyH	0.09	0.01	0.00		0.00		0.02	0.00
35-dm-heptane	0.19		0.01	0.00	0.03	0.01	0.03	0.02
m&p-xylene/34-dm-heptane	20.13	0.65	0.60	0.08	0.74	0.10	4.45	0.18
2m-octane	1.53	0.01	0.09		0.14	0.01	0.36	0.01
3m-octane	1.13	0.00	0.08		0.10	0.02	0.27	0.01
styrene/ctc-124-tm-cyH	1.54	0.13	0.07	0.05	0.09	0.00	0.35	0.03
33-de-pentane	0.56	0.02	0.05		0.07	0.01	0.14	0.00
o-xylene	6.87	0.25	0.23	0.04	0.26	0.03	1.52	0.07
1-nonene/112-tm-cyH	1.16	0.02	0.10		0.12	0.02	0.28	0.01
t3-nonene	0.10	0.03	0.01		0.01		0.02	0.01
c3-nonene/ib-cyP	0.11	0.02	0.01		0.01	0.00	0.03	0.01
n-nonane	0.81	0.02	0.06		0.07	0.01	0.19	0.01
t2-nonene	0.57	0.03	0.03	0.02	0.05	0.01	0.14	0.01
c2-nonene	0.10	0.02			0.01	0.01	0.02	0.01
ip-benzene	0.72	0.01	0.07		0.05	0.01	0.17	0.01
22-dm-octane	0.42	0.00	0.01		0.07	0.00	0.11	0.00
ip-cyH	0.03	0.00			0.00	0.00	0.01	0.00
nb-cyP	0.35	0.01	0.04	0.03	0.05	0.02	0.09	0.01
33-dm-octane	0.03						0.01	
n-propylbenzene	1.58	0.01	0.06	0.00	0.05	0.00	0.35	0.00
3e-toluene	5.52	0.14	0.23	0.00	0.20	0.00	1.23	0.03
4e-toluene/23-dm-octane	2.64	0.07	0.12	0.00	0.09	0.01	0.59	0.01
135-tm-benzene	2.19	0.07	0.14	0.02	0.11	0.02	0.50	0.02
2m-nonane	0.22	0.03	0.01		0.03		0.05	0.01

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
3e-octane	0.05	0.01	0.03	0.02	0.10	0.11	0.04	0.03
3m-nonane								
2e-toluene	1.97	0.03	0.10	0.01	0.08	0.00	0.44	0.00
124-tm-benz/tb-benz/1-decene	6.00	0.35	0.33	0.03	0.26	0.03	1.36	0.08
ib-cyH	0.06	0.05			0.21		0.04	0.05
n-decane	0.35	0.02	0.03		0.02	0.02	0.08	0.01
ib-benzene/t-1m-2p-cyH	0.15	0.01	0.01		0.01	0.00	0.03	0.00
sb-benzene	0.13	0.00					0.03	0.00
3-ip-toluene								
123-tm-benzene	0.75	0.04	0.02		0.03	0.02	0.17	0.00
4-ip-toluene	0.04	0.01					0.01	0.00
indan	0.47	0.05	0.07	0.08	0.16		0.13	0.03
2-ip-toluene	0.12				0.07	0.01	0.03	0.02
13-de-benzene	0.49	0.01			0.01	0.00	0.10	0.00
3-np-toluene	0.74	0.03	0.04	0.01	0.03	0.00	0.17	0.01
14-de-benzene	0.35	0.23			0.06		0.08	0.06
4-np-toluene/nb-benz/13dm5e-benzene	1.16	0.06	0.09	0.01	0.02		0.25	0.02
12de-benzene	0.07	0.01	0.00				0.02	0.00
2-np-toluene	0.24	0.03	0.01		0.01	0.00	0.05	0.01
14dm-2e-benzene	0.57	0.04	0.04		0.03	0.02	0.13	0.01
13dm-4e-benzene	0.43	0.03	0.05		0.03	0.02	0.10	0.01
12dm-4e-benzene	0.70	0.06	0.06		0.04	0.02	0.16	0.01
13dm-2e-benzene	0.12		0.01				0.03	
n-undecane	0.11	0.03	0.02	0.00	0.02		0.03	0.00
12dm-3e-benzene	0.12	0.01	0.01		0.01		0.03	0.00
1245-ttm-benzene/2mb-benzene	0.25	0.02	0.03		0.01	0.01	0.06	0.00
tb-2m-benzene	0.12	0.01	0.01	0.00	0.02		0.03	0.01
npentyl-benzene	0.10	0.06	0.01	0.01	0.03		0.02	0.02
t-1m-2-(4mp)cyP	0.27		0.10		0.10	0.00	0.06	0.05
tb-35dm-benzene	0.10	0.07	0.05		0.01	0.00	0.03	0.01
tb-4e-benzene			0.01		0.00		0.00	
naphthalene	0.15	0.02	0.07		0.02	0.01	0.04	0.00
n-dodecane	0.05	0.01			0.03	0.03	0.02	0.01

Table 47: Vehicle 021 – FFV Sebring, E85

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
formaldehyde	1.85	0.34					0.13	0.02
acetaldehyde	21.98	0.15			0.23	0.04	1.52	0.01
acrolein	0.17	0.08					0.01	0.01
acetone	0.24				0.14		0.01	0.00
propionaldehyde	0.06	0.01					0.00	0.00
crotonaldehyde								
methacrolein	0.09	0.01					0.01	0.00
methyl ethyl ketone								
isobutyraldehyde & butyraldehyde	0.04	0.00			0.00		0.00	0.00

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
benzaldehyde	0.09	0.04					0.01	0.00
isovaleraldehyde								
valeraldehyde								
o-tolualdehyde								
m&p-tolualdehyde								
hexanaldehyde								
2,5-dimethylbenzaldehyde								
ethylene	23.17	2.77	1.01		0.63		4.95	0.36
acetylene	1.14	0.84	0.86		0.19		0.32	0.06
ethane	4.84	0.78	1.34		0.62		1.17	0.08
propylene	3.01	0.39					0.62	0.08
propane	1.02	0.27	1.18		0.41	0.12	0.40	0.14
propyne								
isobutane	0.94	0.16			0.10	0.02	0.22	0.03
isobutene/1-butene	1.43	0.79	0.00		0.09		0.31	0.15
13-butadiene	0.50		0.35	0.05			0.10	0.08
n-butane	2.62				2.75	3.81	1.03	0.66
t2-butene	0.50	0.00	0.01		0.01	0.01	0.11	0.00
1-butyne								
c2-butene	0.36	0.01	0.00	0.00	0.01	0.01	0.08	0.00
12-butadiene	0.02	0.00					0.00	0.00
3m1-butene	0.14	0.00	0.00	0.00	0.02	0.02	0.03	0.01
2m-butane	6.13	0.09	0.05	0.01	0.45		1.34	0.10
14-pentadiene					0.72		0.20	
2-butyne	0.02						0.00	
1-pentene	0.32	0.01	0.00	0.00	0.01		0.07	0.00
2m1-butene	0.46	0.00	0.00	0.00	0.01		0.10	0.00
n-pentane	4.02	0.30	0.07	0.05	0.23	0.03	0.90	0.06
2m-13-butadiene (isoprene)	0.32	0.04	0.02		0.05	0.04	0.08	0.02
t2-pentene	0.67	0.04	0.00	0.00	0.01		0.14	0.01
c2-pentene	0.31	0.02	0.00	0.00	0.01		0.06	0.00
2m2-butene	0.87	0.06	0.01	0.00	0.01		0.18	0.02
t-13-pentadiene	0.10	0.03	0.00		0.02		0.02	0.01
cyclopentadiene	0.24	0.06	0.00	0.00	0.02		0.05	0.02
22-dm-butane/c13-pentadiene	0.68	0.02	0.00	0.00	0.04	0.02	0.15	0.01
cyclopentene	0.20	0.01	0.00	0.00	0.02	0.02	0.05	0.00
4m1-pentene	0.10		0.03	0.02	0.03	0.00	0.02	0.02
cyclopentane	0.55	0.05	0.27	0.13	0.20	0.04	0.20	0.04
23-dm-butane	0.98	0.06			0.39	0.02	0.31	0.01
2m-pentane	2.96	0.11	0.01	0.00	0.09	0.11	0.64	0.05
c/t-4m2-pentene	0.10	0.01			0.02	0.02	0.02	0.00
3m-pentane	1.82	0.06	0.01	0.01	0.06	0.05	0.40	0.03
2m1-pentene	0.11		0.01		0.04		0.03	
1-hexene	0.19	0.09	0.00		0.02	0.02	0.05	0.03
n-hexane	2.01	0.15	0.02	0.01	0.11	0.00	0.45	0.03
t2-hexene	0.25	0.01	0.01		0.05	0.05	0.06	0.01
2m2-pentene	0.29	0.02	0.00	0.00	0.03	0.03	0.07	0.00
t-3m2-pentene	0.19	0.01	0.00	0.00	0.02	0.03	0.04	0.00

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
c2-hexene	0.11	0.01	0.00	0.00	0.01	0.02	0.03	0.00
c-3m2-pentene	0.23	0.01	0.00	0.00	0.02	0.02	0.05	0.00
22-dm-pentane	0.08	0.03	0.02		0.02		0.02	0.00
m-cyclopentane	1.34	0.15	0.03	0.01	0.05	0.01	0.30	0.03
24-dm-pentane	0.43	0.01	0.01	0.00	0.02		0.09	0.01
223-tm-butane	0.08	0.03					0.02	0.01
1m-cyclopentene	0.05	0.00	0.02		0.01		0.01	0.00
benzene	4.62	0.10	0.05	0.06	0.14	0.02	1.00	0.02
33-dm-pentane	0.15	0.05	0.01		0.05	0.03	0.04	0.00
cyclohexane	0.60	0.04	0.00	0.00	0.02	0.01	0.13	0.01
2m-hexane	1.20	0.06	0.01	0.01	0.05	0.01	0.26	0.02
23-dm-pentane	0.57	0.04	0.01	0.00	0.03		0.12	0.00
11-dm-cyP	0.07	0.00	0.02		0.01		0.02	0.00
cyclohexene	0.10	0.00					0.02	0.00
3m-hexane	1.29	0.07	0.02		0.04	0.03	0.28	0.02
c-13-dm-cyP	0.24	0.01	0.00	0.00	0.03	0.02	0.06	0.00
3e-pentane/t-13-dm-cyP	0.32	0.12	0.01	0.01	0.03	0.03	0.08	0.02
t-12-dm-cyP/1-heptene	0.21		0.02	0.01	0.05	0.00	0.04	0.03
224-tm-pentane	1.33	0.10	0.02		0.04		0.28	0.03
t3-heptene	0.07	0.00	0.00		0.01		0.02	0.00
n-heptane	1.20	0.05	0.02	0.00	0.05	0.02	0.26	0.01
c3-heptene	0.15	0.02	0.01		0.02		0.04	0.01
t2-heptene	0.09	0.01	0.01		0.01	0.01	0.02	0.00
c2-heptene	0.07				0.02		0.02	
m-cyclohexane/22-dm-hexane	0.77	0.16	0.02		0.03	0.00	0.17	0.03
25-dm-hexane/e-cyP	0.34	0.01	0.01		0.06	0.06	0.09	0.02
24-dm-hexane/223-tm-pentane	0.31	0.00	0.00	0.00	0.02		0.07	0.00
33-dm-hexane/ctc124-tm-cyP	0.12	0.01	0.00		0.02	0.01	0.03	0.00
ctc123-tm-cyP	0.09	0.00	0.03	0.04	0.02	0.02	0.03	0.01
234-tm-pentane	0.47	0.00	0.01	0.00	0.02		0.10	0.00
toluene/233-tm-pentane	7.68	0.06	0.02		0.18	0.08	1.64	0.04
23-dm-hexane	0.26	0.00	0.01		0.04	0.04	0.07	0.01
2m3e-pentane	0.08	0.00					0.02	0.00
2m-heptane/1m-cyclohexene	0.53	0.01	0.01	0.00	0.06	0.06	0.13	0.01
4m-C7/3m3e-pentane	0.19	0.01	0.00	0.00	0.02	0.02	0.05	0.00
34-dm-hexane	0.09	0.00			0.01	0.01	0.02	0.00
3m-heptane/3e-hexane	0.57	0.08	0.01		0.06	0.07	0.13	0.00
cct-124-tm-cyP/t-13-dm-cyH	0.14				0.01		0.03	
t-14-dm-cyH	0.07	0.00			0.00		0.01	0.00
225-tm-hexane	0.12	0.00			0.02	0.03	0.03	0.01
1-octene	0.15	0.00			0.01	0.01	0.04	0.00
1e1m-cyP	0.06	0.01			0.00		0.01	0.00
n-octane/t12-dm-cyH	0.51	0.02	0.01		0.02	0.01	0.11	0.01
t2-octene	0.05	0.02			0.01		0.01	0.01
ccc-123-tm-cyP	0.11	0.01			0.01		0.02	0.00
244-tm-hexane	0.07	0.01					0.01	0.00
c2-octene								
ip-cyP	0.05	0.01	0.03				0.01	0.00

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
235-tm-hexane	0.05	0.00					0.01	0.00
24-dm-heptane	0.06	0.00	0.00		0.01	0.00	0.01	0.00
26-dm-heptane/c12-dm...	0.11	0.00			0.01	0.01	0.03	0.00
np-cyP	0.04	0.02					0.01	0.00
ccc-135-tm-cyP	0.09	0.04			0.01		0.02	0.01
25-dm-heptane/35-dm-heptane	0.10	0.02			0.01		0.02	0.00
33-dm-heptane	0.03						0.01	
114-tm-cyH	0.19						0.04	
e-benzene	1.48	0.00	0.05		0.06	0.02	0.33	0.00
cct-124-tm-cyH	0.05	0.00	0.03		0.01	0.01	0.01	0.01
35-dm-heptane	0.05	0.02					0.01	0.00
m&p-xylene/34-dm-heptane	4.55	0.03	0.04		0.16	0.04	0.99	0.00
2m-octane	0.30	0.00	0.02		0.05	0.04	0.08	0.01
3m-octane	0.21		0.01	0.00	0.03	0.03	0.03	0.02
styrene/ctc-124-tm-cyH	0.39	0.03	0.17		0.07		0.10	0.04
33-de-pentane	0.03	0.01	0.19	0.27	0.00		0.03	0.04
o-xylene	2.25	0.41	0.29		0.06	0.00	0.50	0.06
1-nonene/112-tm-cyH	0.19	0.06	0.17	0.21	0.03	0.01	0.07	0.04
t3-nonene	0.06	0.01	6.89		0.01	0.00	0.47	0.65
c3-nonene/ib-cyP	0.05	0.01					0.01	0.00
n-nonane	0.26	0.03	1.37		0.01		0.15	0.12
t2-nonene	0.03	0.01					0.01	0.00
c2-nonene	0.07		0.01		0.05		0.01	0.00
ip-benzene	0.18	0.03	0.05		0.03	0.04	0.05	0.00
22-dm-octane	0.06		0.03		0.02	0.01	0.01	0.01
ip-cyH	0.05	0.01	0.01		0.01	0.01	0.01	0.00
nb-cyP	0.08	0.08			0.06	0.05	0.03	0.00
33-dm-octane	0.04		0.02		0.04	0.03	0.02	0.00
n-propylbenzene	0.42	0.01	0.01		0.01	0.01	0.09	0.00
3e-toluene	1.48		0.71				0.40	
4e-toluene/23-dm-octane	0.65	0.08	0.04		0.06		0.15	0.02
135-tm-benzene	0.68	0.14	0.08		0.05	0.06	0.16	0.04
2m-nonane	0.03						0.01	
3e-octane	0.03	0.00	0.03		0.03		0.01	0.01
3m-nonane								
2e-toluene	0.61	0.08	0.03		0.03		0.13	0.02
124-tm-benz/tb-benz/1-decene	2.27	0.36	0.06	0.00	0.09	0.02	0.50	0.08
ib-cyH	0.38		0.14	0.03	0.09		0.07	0.04
n-decane	0.26	0.03			0.02		0.06	0.00
ib-benzene/t-1m-2p-cyH	0.04	0.01			0.01	0.00	0.01	0.00
sb-benzene	0.04	0.01			0.03	0.00	0.01	0.00
3-ip-toluene			0.09		0.06		0.03	
123-tm-benzene	0.36	0.06			0.05	0.01	0.09	0.01
4-ip-toluene	0.03	0.01	0.00		0.02		0.01	0.00
indan	0.18		0.02		0.13		0.04	0.05
2-ip-toluene	0.22	0.22	0.09		0.05	0.04	0.07	0.03
13-de-benzene	0.17	0.00	0.01		0.05		0.04	0.01
3-np-toluene	0.25	0.00	0.02		1.78	2.46	0.54	0.68

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
14-de-benzene	0.14	0.07	0.01		0.86	1.21	0.27	0.32
4-np-toluene/nb-benz/13dm5e-benzene	0.38	0.02	0.02		0.13	0.18	0.12	0.05
12de-benzene	0.05	0.05	0.01	0.01	0.04	0.04	0.02	0.02
2-np-toluene	0.04	0.04	0.00		0.03	0.00	0.02	0.01
14dm-2e-benzene	0.20	0.07	0.02		0.04	0.01	0.05	0.01
13dm-4e-benzene	0.15	0.09	0.01	0.01	0.02	0.00	0.04	0.02
12dm-4e-benzene	0.24	0.07	0.03		0.05	0.03	0.07	0.00
13dm-2e-benzene			0.04		0.02	0.01	0.01	0.00
n-undecane	0.26	0.06	0.03		0.10	0.10	0.08	0.02
12dm-3e-benzene	0.06	0.01	0.01		0.01		0.01	0.00
1245-ttm-benzene/2mb-benzene	0.15	0.01	0.02		0.04	0.03	0.04	0.01
tb-2m-benzene	0.03	0.02	0.00		0.01		0.01	0.00
npentyl-benzene	0.01	0.01			0.01	0.00	0.01	0.00
t-1m-2-(4mp)cyP	0.28	0.38					0.06	0.08
tb-35dm-benzene	0.05	0.01	0.01		0.01	0.00	0.01	0.00
tb-4e-benzene			0.01		0.01	0.02	0.00	0.01
naphthalene	0.08	0.05	0.01		0.02	0.02	0.02	0.00
n-dodecane	0.13	0.08	0.03		0.03	0.04	0.04	0.00

Table 48: Vehicle 022 – FFV Caravan, Regular Fuel

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
formaldehyde	1.42	0.15					0.10	0.01
acetaldehyde	0.62	0.00	0.09		0.05		0.05	0.01
acrolein	0.03	0.05					0.00	
acetone	0.67	0.18					0.05	0.01
propionaldehyde	0.07	0.06					0.00	0.00
crotonaldehyde	0.11	0.02					0.01	0.00
methacrolein	0.27	0.00					0.02	0.00
methyl ethyl ketone	0.12	0.05			0.05		0.01	0.01
isobutyraldehyde & butyraldehyde	0.06	0.03			0.01		0.00	0.00
benzaldehyde	0.26	0.01					0.02	0.00
isovaleraldehyde								
valeraldehyde								
o-tolualdehyde								
m&p-tolualdehyde	0.15	0.01					0.01	0.00
hexanaldehyde								
2,5-dimethylbenzaldehyde								
ethylene	19.91	4.17			1.03	0.28	4.41	0.94
acetylene	4.44	1.61					0.92	0.33
ethane	6.01	0.45			1.65	0.29	1.70	0.17
propylene	13.45	1.55			0.97		2.92	0.13
propane	0.81				0.70		0.36	
propyne	0.66						0.14	
isobutane	0.84	0.12	0.02		0.05	0.03	0.19	0.01
isobutene/1-butene	17.30	2.71	0.21	0.24	0.72	0.11	3.81	0.62

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
13-butadiene								
n-butane	1.04	0.47	0.10		0.17		0.25	0.06
t2-butene	1.88	0.38	0.00	0.01	0.06	0.01	0.41	0.08
1-butyne	0.08						0.02	
c2-butene	1.32	0.28	0.01	0.00	0.05	0.03	0.29	0.05
12-butadiene	0.07	0.03					0.01	0.01
3m1-butene	0.44	0.13	0.00	0.00	0.01	0.02	0.09	0.03
2m-butane	12.04	1.15	0.15	0.18	0.70	0.22	2.71	0.15
14-pentadiene	0.28		0.50	0.38	0.63	0.06	0.27	0.03
2-butyne	0.04	0.01					0.01	0.00
1-pentene	0.40	0.08	0.00	0.00	0.00		0.08	0.02
2m1-butene	1.16	0.12	0.00		0.02	0.00	0.25	0.02
n-pentane	1.81	0.34	0.05		0.09	0.04	0.40	0.06
2m-13-butadiene (isoprene)	0.15	0.13	0.04				0.03	0.03
t2-pentene	0.77	0.16	0.01		0.01	0.00	0.16	0.03
c2-pentene	0.41	0.07	0.00	0.00	0.01		0.09	0.01
2m2-butene	0.51	0.50	0.00	0.01			0.11	0.10
t-13-pentadiene			0.02				0.00	
cyclopentadiene								
22-dm-butane/c13-pentadiene	0.60	0.04	0.01	0.01	0.04	0.01	0.14	0.00
cyclopentene	0.43	0.21	0.00				0.09	0.04
4m1-pentene	0.22	0.07	0.00	0.00			0.05	0.02
cyclopentane	0.15		0.19	0.14	0.40		0.10	0.12
23-dm-butane	2.45	0.33			0.40	0.05	0.62	0.05
2m-pentane	7.38	0.65	0.01		0.28	0.10	1.61	0.10
c/t-4m2-pentene	0.22	0.02					0.04	0.00
3m-pentane	4.05	0.36	0.04		0.18	0.05	0.89	0.06
2m1-pentene					0.06		0.02	
1-hexene	0.12	0.05	0.01	0.00			0.02	0.01
n-hexane	1.68	0.18	0.02	0.02	0.08	0.02	0.37	0.03
t2-hexene	0.27	0.05	0.00	0.00	0.00		0.06	0.01
2m2-pentene	0.18	0.07	0.00	0.00			0.04	0.01
t-3m2-pentene	0.02	0.01	0.00	0.00			0.00	0.00
c2-hexene	0.14	0.02	0.00	0.00	0.00	0.00	0.03	0.01
c-3m2-pentene	0.08		0.00				0.01	0.01
22-dm-pentane			0.02				0.00	
m-cyclopentane			0.01		0.06		0.01	0.01
24-dm-pentane	4.91	0.38	0.04	0.03	0.22	0.07	1.08	0.06
223-tm-butane	0.05	0.00					0.01	0.00
1m-cyclopentene	0.09	0.01			0.00		0.02	0.00
benzene	10.76	0.78	0.10	0.08	1.60	0.29	2.68	0.07
33-dm-pentane					0.02		0.00	
cyclohexane	0.20				0.01		0.04	
2m-hexane	2.23	0.02	0.01	0.01	0.10	0.01	0.49	0.01
23-dm-pentane	9.73	1.01	0.08	0.04	0.44	0.10	2.15	0.17
11-dm-cyP	0.07	0.00	0.02		0.01	0.00	0.02	0.00
cyclohexene	0.07	0.01					0.01	0.00
3m-hexane	2.45	0.21	0.01		0.10	0.03	0.53	0.03

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
c-13-dm-cyP	0.32	0.03	0.00	0.00	0.01	0.01	0.07	0.00
3e-pentane/t-13-dm-cyP	0.46	0.25	0.04	0.01	0.03	0.04	0.11	0.04
t-12-dm-cyP/1-heptene	0.26		0.04		0.01	0.01	0.03	0.03
224-tm-pentane	19.45	1.56	0.17	0.13	0.96	0.24	4.32	0.24
t3-heptene	0.11	0.03	0.01	0.01	0.00		0.03	0.01
n-heptane	1.77	0.14	0.02	0.00	0.05	0.00	0.38	0.03
c3-heptene	0.10	0.03	0.00	0.00	0.00		0.02	0.01
t2-heptene	0.10	0.02					0.02	0.00
c2-heptene	0.10						0.02	
m-cyclohexane/22-dm-hexane	0.71	0.19			0.03	0.02	0.15	0.03
25-dm-hexane/e-cyP	1.54	0.14			0.10	0.12	0.35	0.00
24-dm-hexane/223-tm-pentane	2.44	0.22	0.02	0.00	0.11	0.03	0.54	0.04
33-dm-hexane/ctc124-tm-cyP	0.25	0.03	0.03	0.03	0.02	0.00	0.06	0.01
ctc123-tm-cyP	0.11	0.02			0.01		0.02	0.01
234-tm-pentane	5.04	0.42	0.04	0.01	0.22	0.05	1.11	0.07
toluene/233-tm-pentane	26.42	2.46	0.19	0.10	1.22	0.22	5.83	0.43
23-dm-hexane	1.59	0.15	0.02	0.01	0.08	0.00	0.35	0.03
2m3e-pentane	0.17	0.02					0.04	0.00
2m-heptane/1m-cyclohexene	1.60	0.13	0.01	0.01	0.06	0.02	0.35	0.02
4m-C7/3m3e-pentane	0.72	0.07	0.00	0.00	0.03	0.00	0.16	0.01
34-dm-hexane	0.41	0.03	0.02		0.02	0.00	0.09	0.01
3m-heptane/3e-hexane	2.12	0.18	0.02		0.11	0.00	0.47	0.03
cct-124-tm-cyP/t-13-dm-cyH	0.12	0.02					0.02	0.00
t-14-dm-cyH	0.07	0.02					0.02	0.00
225-tm-hexane	0.88	0.08	0.01	0.00	0.05	0.01	0.20	0.01
1-octene	0.19	0.02	0.01		0.01		0.04	0.01
1e1m-cyP	0.08	0.03	0.01		0.00		0.02	0.01
n-octane/t12-dm-cyH	1.54	0.15	0.01	0.00	0.06	0.02	0.34	0.03
t2-octene	0.08	0.03					0.02	0.01
ccc-123-tm-cyP	0.18	0.04	0.01	0.02	0.00		0.04	0.01
244-tm-hexane								
c2-octene	0.19	0.09			0.03	0.00	0.05	0.02
ip-cyP	0.07	0.01					0.01	0.00
235-tm-hexane	0.19	0.02	0.00		0.02	0.00	0.04	0.00
24-dm-heptane	0.23	0.02	0.00		0.00	0.00	0.05	0.00
26-dm-heptane/c12-dm...	0.31	0.03	0.00	0.00	0.01	0.00	0.07	0.01
np-cyP	0.08	0.01	0.00		0.01		0.02	0.00
ccc-135-tm-cyP	0.10	0.02	0.01	0.01	0.00		0.02	0.01
25-dm-heptane/35-dm-heptane	0.50	0.05	0.33	0.41	0.11		0.16	0.02
33-dm-heptane	0.04	0.06	0.31				0.03	0.02
114-tm-cyH	0.14	0.09	0.04		0.03		0.03	0.02
e-benzene	8.65	1.58	0.12	0.01	0.08	0.02	1.83	0.32
cct-124-tm-cyH	0.04		0.00	0.00			0.00	0.01
35-dm-heptane	0.16	0.07					0.03	0.01
m&p-xylene/34-dm-heptane	17.55	1.74	0.25	0.07	0.50		3.74	0.44
2m-octane	1.04	0.13	0.01	0.01	0.04	0.00	0.23	0.03
3m-octane	0.76	0.10	0.03		0.03	0.00	0.17	0.02
styrene/ctc-124-tm-cyH	1.24	0.46			0.01		0.26	0.10

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
33-de-pentane	0.35	0.03			0.03		0.08	0.01
o-xylene	5.84	0.61	0.08	0.02	0.16	0.01	1.27	0.12
1-nonene/112-tm-cyH	0.76	0.05	0.02	0.01	0.03	0.00	0.17	0.01
t3-nonene	0.05						0.01	
c3-nonene/ib-cyP	0.06		0.00				0.01	
n-nonane	0.57	0.07	0.01	0.01	0.02	0.01	0.12	0.01
t2-nonene	0.37	0.04	0.01	0.01	0.01	0.00	0.08	0.01
c2-nonene	0.07	0.02	0.01				0.02	0.00
ip-benzene	0.54	0.08	0.02	0.02			0.12	0.02
22-dm-octane	0.26	0.06	0.02		0.01		0.06	0.01
ip-cyH	0.07	0.05	0.01				0.02	0.01
nb-cyP	0.33	0.05	0.08	0.09	0.01		0.08	0.00
33-dm-octane	0.03		0.01		0.01		0.01	0.00
n-propylbenzene	1.08	0.17	0.16	0.16			0.25	0.01
3e-toluene	4.56	0.73	0.38	0.27	0.07	0.02	1.01	0.11
4e-toluene/23-dm-octane	2.10	0.40	0.11		0.03	0.02	0.45	0.10
135-tm-benzene	1.74	0.24	0.06	0.07	0.05	0.04	0.38	0.07
2m-nonane	0.19	0.01	0.03		0.01		0.04	0.00
3e-octane	0.25	0.30	0.05				0.05	0.07
3m-nonane								
2e-toluene	1.55	0.23	0.05	0.02	0.02	0.02	0.33	0.05
124-tm-benz/tb-benz/1-decene	4.79	0.41	0.18	0.02	0.12	0.02	1.05	0.08
ib-cyH	0.18		0.72				0.13	
n-decane	0.18	0.03	0.04	0.05	0.01	0.01	0.05	0.01
ib-benzene/t-1m-2p-cyH	0.10	0.03	0.01	0.00	0.00		0.02	0.01
sb-benzene	0.04	0.01					0.01	0.00
3-ip-toluene								
123-tm-benzene	0.62	0.06	0.03	0.01	0.03		0.14	0.01
4-ip-toluene			0.00		0.00		0.00	0.00
indan	0.39	0.02	0.24	0.17	0.09	0.13	0.14	0.01
2-ip-toluene								
13-de-benzene	0.43	0.03	0.12		0.02		0.10	0.01
3-np-toluene	0.47	0.07	0.05	0.07			0.10	0.02
14-de-benzene	0.24	0.02	0.23		0.08		0.08	0.04
4-np-toluene/nb-benz/13dm5e-benzene	0.90	0.12	0.08	0.10	0.07		0.21	0.00
12de-benzene	0.06	0.02	0.10		0.00		0.02	0.01
2-np-toluene	0.04		0.05	0.06	0.02		0.01	0.00
14dm-2e-benzene	0.38	0.04	0.10	0.04	0.00	0.00	0.09	0.01
13dm-4e-benzene	0.34	0.07	0.13	0.11	0.00		0.09	0.03
12dm-4e-benzene	0.52	0.10	0.19		0.02	0.02	0.13	0.04
13dm-2e-benzene	0.06		0.02		0.02		0.02	
n-undecane	0.11	0.03	0.07	0.08	0.04	0.04	0.05	0.03
12dm-3e-benzene	0.10	0.02	0.04	0.05	0.02	0.02	0.03	0.02
1245-ttm-benzene/2mb-benzene	0.58	0.42	0.10		0.05	0.02	0.14	0.10
tb-2m-benzene	0.09	0.04	0.03		0.03		0.02	0.02
npentyl-benzene	0.09	0.00	0.05	0.04	0.03		0.03	0.01
t-1m-2-(4mp)cyP	0.06		0.12	0.01			0.02	0.01
tb-35dm-benzene	0.05	0.03			0.00		0.01	0.01

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
tb-4e-benzene								
naphthalene	0.15	0.08	0.06	0.03			0.04	0.02
n-dodecane	0.08		0.06	0.05			0.02	0.01

Table 49: Vehicle 022 – FFV Caravan, E85

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
formaldehyde	2.59	0.05			0.07		0.18	0.00
acetaldehyde	16.17	2.51					1.10	0.17
acrolein	0.09	0.03			0.01	0.00	0.01	0.00
acetone	0.31						0.02	
propionaldehyde	0.07	0.02			0.01	0.01	0.01	0.00
crotonaldehyde								
methacrolein	0.10	0.02					0.01	0.00
methyl ethyl ketone								
isobutyraldehyde & butyraldehyde	0.05	0.02					0.00	0.00
benzaldehyde	0.12	0.03					0.01	0.00
isovaleraldehyde								
valeraldehyde								
o-tolualdehyde								
m&p-tolualdehyde								
hexanaldehyde								
2,5-dimethylbenzaldehyde								
ethylene	30.08	0.86					6.22	0.17
acetylene	4.41	2.00					0.91	0.41
ethane	5.85	0.38			1.69	0.03	1.67	0.09
propylene	2.39	0.01					0.50	0.00
propane					0.54		0.15	
propyne								
isobutane	0.77	0.10					0.16	0.02
isobutene/1-butene	0.72	0.03			0.04		0.15	0.01
13-butadiene			0.57	0.31			0.08	0.04
n-butane	2.11	0.25	0.10		0.03	0.01	0.45	0.04
t2-butene	0.57	0.01	0.00		0.05	0.06	0.13	0.01
1-butyne								
c2-butene	0.95	0.56	0.01		0.05	0.05	0.21	0.13
12-butadiene	0.04						0.01	
3m1-butene	0.11	0.01			0.01	0.01	0.03	0.01
2m-butane	5.17	0.32	0.09	0.08	0.15	0.02	1.12	0.05
14-pentadiene					0.03		0.01	
2-butyne	0.03						0.01	
1-pentene	0.20	0.00	0.01		0.05	0.07	0.05	0.02
2m1-butene	0.38	0.00	0.00				0.08	0.00
n-pentane	3.39	0.12	0.04	0.05	0.11		0.72	0.00
2m-13-butadiene (isoprene)	0.14	0.10			0.09		0.04	0.00
t2-pentene	0.66	0.02	0.01	0.01	0.00		0.14	0.00

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
c2-pentene	0.29	0.01	0.01		0.04	0.06	0.07	0.02
2m2-butene	0.46	0.46	0.02				0.10	0.10
t-13-pentadiene	0.06		0.01	0.00			0.01	0.01
cyclopentadiene	0.06		0.01				0.01	
22-dm-butane/c13-pentadiene	0.51	0.00	0.00		0.02	0.00	0.11	0.00
cyclopentene	0.20	0.02	0.00		0.01	0.01	0.04	0.01
4m1-pentene	0.10		0.03	0.04	0.01	0.01	0.02	0.02
cyclopentane	0.53	0.16	0.33	0.18	0.29	0.04	0.23	0.04
23-dm-butane	1.14	0.49	0.01	0.01	0.15	0.19	0.28	0.15
2m-pentane	2.42	0.20			0.05	0.02	0.51	0.05
c/t-4m2-pentene	0.09	0.01			0.02		0.02	0.00
3m-pentane	1.40	0.05	0.02		0.03	0.00	0.30	0.01
2m1-pentene	0.11		0.04	0.05			0.02	0.01
1-hexene	0.10	0.00	0.00		0.02	0.01	0.03	0.00
n-hexane	1.53	0.04	0.04		0.05	0.00	0.33	0.00
t2-hexene	0.21	0.01	0.00		0.06		0.05	0.01
2m2-pentene	0.23	0.02	0.00	0.00	0.02		0.05	0.00
t-3m2-pentene	0.13	0.05					0.03	0.01
c2-hexene	0.09	0.00			0.01	0.01	0.02	0.00
c-3m2-pentene	0.14	0.08	0.00		0.01		0.03	0.01
22-dm-pentane	0.06		0.00				0.01	
m-cyclopentane	1.00	0.08	0.00		0.02		0.21	0.02
24-dm-pentane	0.26	0.00	0.01	0.00	0.01		0.06	0.00
223-tm-butane	0.10	0.08	0.00				0.02	0.02
1m-cyclopentene	0.04	0.00			0.00		0.01	0.00
benzene	3.63	0.12	0.02		0.01	0.01	0.75	0.02
33-dm-pentane	0.12	0.08	0.05				0.03	0.02
cyclohexane	0.41	0.01	0.00		0.02	0.00	0.09	0.00
2m-hexane	0.79	0.00	0.01		0.02	0.01	0.17	0.00
23-dm-pentane	0.32	0.01	0.00	0.00	0.01	0.00	0.07	0.00
11-dm-cyP	0.05	0.01			0.00		0.01	0.00
cyclohexene	0.06	0.01			0.00		0.01	0.00
3m-hexane	0.84	0.01			0.01	0.01	0.18	0.00
c-13-dm-cyP	0.16	0.01	0.00		0.02	0.02	0.04	0.01
3e-pentane/t-13-dm-cyP	0.24	0.03	0.00	0.00	0.04	0.02	0.06	0.01
t-12-dm-cyP/1-heptene	0.12	0.01			0.02		0.03	0.00
224-tm-pentane	0.64	0.00	0.04	0.04	0.05	0.03	0.15	0.01
t3-heptene	0.05	0.00	0.03		0.01		0.01	0.00
n-heptane	0.71	0.02			0.01	0.00	0.15	0.00
c3-heptene	0.12	0.00	0.01	0.01	0.01		0.03	0.00
t2-heptene	0.06	0.03	0.01	0.01	0.00		0.01	0.01
c2-heptene	0.05		0.01				0.01	
m-cyclohexane/22-dm-hexane	0.44	0.05	0.02	0.02	0.07	0.08	0.11	0.02
25-dm-hexane/e-cyP	0.19	0.01			0.03	0.04	0.05	0.01
24-dm-hexane/223-tm-pentane	0.19	0.02	0.00	0.00	0.04	0.05	0.05	0.01
33-dm-hexane/ctc124-tm-cyP	0.06	0.01	0.00		0.01		0.01	0.00
ctc123-tm-cyP	0.05	0.00	0.03		0.01	0.01	0.02	0.00
234-tm-pentane	0.25	0.03	0.00		0.01	0.00	0.05	0.01

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
toluene/233-tm-pentane	5.63	0.37	0.00	0.01	0.04	0.02	1.17	0.08
23-dm-hexane	0.11	0.01	0.00		0.05		0.03	0.01
2m3e-pentane	0.03	0.00	0.02				0.01	0.00
2m-heptane/1m-cyclohexene	0.27	0.00	0.00		0.04	0.05	0.07	0.01
4m-C7/3m3e-pentane	0.10	0.01	0.00	0.00	0.01	0.01	0.02	0.01
34-dm-hexane	0.04	0.01	0.00		0.00		0.01	0.00
3m-heptane/3e-hexane	0.27	0.01	0.00	0.01	0.09		0.07	0.02
cct-124-tm-cyP/t-13-dm-cyH	0.05	0.00			0.12		0.03	0.02
t-14-dm-cyH	0.03	0.00					0.01	0.00
225-tm-hexane	0.06	0.00	0.00		0.02		0.01	0.00
1-octene	0.06	0.01	0.02		0.01		0.01	0.01
1e1m-cyP	0.02	0.00	0.00		0.00		0.00	0.00
n-octane/t12-dm-cyH	0.23	0.02	0.00		0.10		0.06	0.02
t2-octene	0.03						0.01	
ccc-123-tm-cyP	0.06	0.00					0.01	0.00
244-tm-hexane	0.03	0.00					0.01	0.00
c2-octene	0.13				0.03	0.00	0.02	0.02
ip-cyP	0.01	0.00	0.00				0.00	0.00
235-tm-hexane	0.03	0.00	0.00				0.01	0.00
24-dm-heptane	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01
26-dm-heptane/c12-dm...	0.06	0.02	0.00	0.00	0.01	0.01	0.02	0.01
np-cyP	0.03	0.01					0.01	0.00
ccc-135-tm-cyP	0.05	0.01	0.00	0.00	0.02		0.01	0.01
25-dm-heptane/35-dm-heptane	0.05	0.02	0.01	0.00	0.02		0.01	0.01
33-dm-heptane	0.02	0.00			0.02		0.01	0.00
114-tm-cyH								
e-benzene	1.08	0.02	0.01		0.01	0.01	0.23	0.00
cct-124-tm-cyH	0.02		0.02		0.01	0.00	0.01	0.00
35-dm-heptane	4.34						0.90	
m&p-xylene/34-dm-heptane	7.10	6.01	0.06		0.08		1.48	1.22
2m-octane	2.28	3.09	0.01		0.08	0.03	0.49	0.63
3m-octane	0.05	0.01	0.01		0.24	0.28	0.08	0.08
styrene/ctc-124-tm-cyH	0.39	0.11	0.03		0.30		0.12	0.08
33-de-pentane			0.04	0.01	0.11		0.02	0.02
o-xylene	1.11	0.14	0.02				0.23	0.03
1-nonene/112-tm-cyH	0.01				4.17	5.86	1.14	1.61
t3-nonene	0.05		0.01				0.01	
c3-nonene/ib-cyP								
n-nonane	0.08	0.02			0.18	0.14	0.07	0.04
t2-nonene					0.11		0.03	
c2-nonene	0.01		0.02	0.01	0.11	0.14	0.03	0.04
ip-benzene	0.02	0.03	0.05	0.05	0.11	0.11	0.04	0.03
22-dm-octane	0.01		0.03		0.03	0.02	0.01	0.01
ip-cyH	0.02	0.01	0.02	0.01	0.01		0.01	0.00
nb-cyP	0.17	0.09	0.05		0.03	0.03	0.05	0.02
33-dm-octane			0.01	0.00	0.08		0.01	0.02
n-propylbenzene	0.16		0.01	0.00	0.00	0.00	0.02	0.02
3e-toluene	1.07						0.22	

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
4e-toluene/23-dm-octane	0.38	0.03			0.01		0.08	0.01
135-tm-benzene	0.32	0.05	0.01		0.05		0.07	0.00
2m-nonane	0.08		0.02		0.02		0.02	
3e-octane	0.03		0.09	0.06	0.09	0.02	0.04	0.02
3m-nonane								
2e-toluene	0.30	0.01	0.01		0.03		0.07	0.01
124-tm-benz/tb-benz/1-decene	1.05	0.12	0.04		0.11	0.11	0.25	0.00
ib-cyH	0.04	0.04	0.22		0.13		0.04	0.01
n-decane	0.08	0.03	0.01	0.00	0.02	0.00	0.02	0.01
ib-benzene/t-1m-2p-cyH	0.02	0.02	0.00	0.00	0.01		0.01	0.00
sb-benzene	0.01	0.00	0.00		0.03		0.01	0.00
3-ip-toluene								
123-tm-benzene	0.13	0.02			0.05	0.06	0.04	0.02
4-ip-toluene					0.01	0.00	0.00	0.00
indan	0.12		0.05				0.02	0.01
2-ip-toluene	2.55				0.05		0.54	
13-de-benzene	0.05	0.04			0.04	0.02	0.02	0.01
3-np-toluene	0.07	0.04	0.01		0.01		0.02	0.01
14-de-benzene	0.04				0.04	0.03	0.01	0.01
4-np-toluene/nb-benz/13dm5e-benzene	0.22	0.11	0.02	0.01			0.05	0.02
12de-benzene	0.02	0.02			0.02		0.01	0.00
2-np-toluene	0.02	0.00	0.01		0.02		0.01	0.00
14dm-2e-benzene	0.06	0.03	0.01		0.04	0.05	0.02	0.02
13dm-4e-benzene	0.03	0.03	0.00		0.05		0.01	0.01
12dm-4e-benzene	0.08	0.03			0.05	0.07	0.03	0.03
13dm-2e-benzene			0.02		0.07		0.02	
n-undecane	0.07	0.00			0.02		0.02	0.00
12dm-3e-benzene	0.02	0.01	0.00		0.01	0.01	0.01	0.00
1245-ttm-benzene/2mb-benzene	0.11	0.10	0.02		0.09	0.08	0.05	0.04
tb-2m-benzene	0.02	0.02	0.02	0.02	0.02	0.00	0.01	0.01
npentyl-benzene	0.01		0.03		0.02	0.02	0.01	0.01
t-1m-2-(4mp)cyP					0.06		0.02	
tb-35dm-benzene	0.01				0.02		0.01	
tb-4e-benzene			0.00	0.00	0.02	0.01	0.00	0.00
naphthalene	0.08	0.03	0.03		0.03	0.02	0.03	0.01
n-dodecane	0.06	0.01	0.01		0.06		0.02	0.02

Table 50: Vehicle 024 – Conventional Caravan, Regular Fuel

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
formaldehyde	1.98	0.37			0.05		0.14	0.02
acetaldehyde	0.71	0.07			0.04		0.05	0.01
acrolein	0.12						0.01	
acetone	0.95	0.25			0.06		0.07	0.02
propionaldehyde	0.08	0.02					0.01	0.00
crotonaldehyde	0.10	0.01					0.01	0.00

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
methacrolein	0.27	0.03					0.02	0.00
methyl ethyl ketone	0.12	0.03			0.03	0.01	0.01	0.00
isobutyraldehyde & butyraldehyde	0.06	0.03					0.00	0.00
benzaldehyde	0.27	0.04					0.02	0.00
isovaleraldehyde								
valeraldehyde								
o-tolualdehyde	0.09	0.03					0.01	0.00
m&p-tolualdehyde	0.19	0.04					0.01	0.00
hexanaldehyde								
2,5-dimethylbenzaldehyde								
Remainder were sampled only once for this vehicle/fuel combination								
ethylene	21.66				1.54		4.91	
acetylene	3.28						0.68	
ethane	5.93		0.29		2.10		1.84	
propylene	14.53						3.01	
propane								
propyne								
isobutane	0.83		0.01		0.09		0.20	
isobutene/1-butene	17.55				0.74		3.84	
13-butadiene								
n-butane	1.23				0.16		0.30	
t2-butene	1.98		0.00		0.09		0.44	
1-butyne	0.05						0.01	
c2-butene	1.35		0.01		0.11		0.31	
12-butadiene	0.11						0.02	
3m1-butene	0.46						0.10	
2m-butane	11.73		0.13		0.96		2.71	
14-pentadiene			0.82				0.11	
2-butyne	0.06				0.03		0.02	
1-pentene	0.42						0.09	
2m1-butene	1.32		0.00		0.03		0.28	
n-pentane	1.91		0.02		0.16		0.44	
2m-13-butadiene (isoprene)	0.07		0.02		0.01		0.02	
t2-pentene	0.80		0.01		0.01		0.17	
c2-pentene	0.42		0.00		0.01		0.09	
2m2-butene	0.37		0.00				0.08	
t-13-pentadiene								
cyclopentadiene								
22-dm-butane/c13-pentadiene	0.51		0.01		0.04		0.12	
cyclopentene	0.48		0.00				0.10	
4m1-pentene	0.24				0.01		0.05	
cyclopentane			0.13		0.16		0.06	
23-dm-butane	2.25		0.03		0.16		0.51	
2m-pentane	6.99				0.41		1.56	
c/t-4m2-pentene	0.22						0.04	
3m-pentane	3.84		0.03		0.25		0.87	
2m1-pentene								
1-hexene	0.07		0.01		0.03		0.03	

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
n-hexane	1.69		0.02		0.10		0.38	
t2-hexene	0.25				0.00		0.05	
2m2-pentene	0.09						0.02	
t-3m2-pentene	0.07						0.01	
c2-hexene	0.12				0.02		0.03	
c-3m2-pentene								
22-dm-pentane								
m-cyclopentane					0.09		0.02	
24-dm-pentane	4.67		0.05		0.29		1.05	
223-tm-butane	0.07						0.01	
1m-cyclopentene	0.10						0.02	
benzene	10.72		0.10		1.99		2.78	
33-dm-pentane								
cyclohexane			0.01		0.00		0.00	
2m-hexane	1.98		0.01		0.13		0.45	
23-dm-pentane	9.39		0.11		0.58		2.12	
11-dm-cyP	0.08						0.02	
cyclohexene	0.07						0.02	
3m-hexane	2.31		0.00		0.13		0.52	
c-13-dm-cyP	0.29		0.00		0.03		0.07	
3e-pentane/t-13-dm-cyP	0.25		0.07		0.03		0.07	
t-12-dm-cyP/1-heptene	0.31						0.06	
224-tm-pentane	18.31		0.28		1.29		4.18	
t3-heptene	0.08						0.02	
n-heptane	1.62		0.02		0.08		0.36	
c3-heptene	0.06		0.02				0.01	
t2-heptene	0.08						0.02	
c2-heptene					0.26		0.07	
m-cyclohexane/22-dm-hexane	0.66		0.00		0.03		0.15	
25-dm-hexane/e-cyP	1.44				0.05		0.31	
24-dm-hexane/223-tm-pentane	2.28		0.02		0.14		0.51	
33-dm-hexane/ctc124-tm-cyP	0.24		0.02				0.05	
ctc123-tm-cyP	0.11		0.01				0.02	
234-tm-pentane	4.69		0.06		0.29		1.06	
toluene/233-tm-pentane	24.95		0.21		1.63		5.64	
23-dm-hexane	1.45		0.02		0.09		0.33	
2m3e-pentane	0.18						0.04	
2m-heptane/1m-cyclohexene	1.49		0.00		0.09		0.33	
4m-C7/3m3e-pentane	0.69		0.02		0.04		0.16	
34-dm-hexane	0.38		0.01		0.02		0.09	
3m-heptane/3e-hexane	1.99		0.01		0.15		0.45	
cct-124-tm-cyP/t-13-dm-cyH	0.10						0.02	
t-14-dm-cyH	0.08						0.02	
225-tm-hexane	0.81		0.01		0.06		0.19	
1-octene	0.15						0.03	
1e1m-cyP	0.07						0.01	
n-octane/t12-dm-cyH	1.44		0.02		0.09		0.32	
t2-octene	0.06						0.01	

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
ccc-123-tm-cyP	0.17		0.02				0.04	
244-tm-hexane								
c2-octene	0.20				0.02		0.05	
ip-cyP	0.06						0.01	
235-tm-hexane	0.15				0.02		0.04	
24-dm-heptane	0.21				0.00		0.04	
26-dm-heptane/c12-dm...	0.27				0.01		0.06	
np-cyP	0.07						0.02	
ccc-135-tm-cyP	0.11						0.02	
25-dm-heptane/35-dm-heptane	0.29		0.05		0.12		0.10	
33-dm-heptane	0.04						0.01	
114-tm-cyH	0.13						0.03	
e-benzene	8.26		0.12		0.16		1.77	
cct-124-tm-cyH	0.06						0.01	
35-dm-heptane	0.17						0.04	
m&p-xylene/34-dm-heptane	16.17		0.10		0.76		3.57	
2m-octane	1.01		0.00		0.06		0.23	
3m-octane	0.75		0.02		0.04		0.17	
styrene/ctc-124-tm-cyH	1.06				0.09		0.24	
33-de-pentane	0.39		0.01				0.08	
o-xylene	5.37		0.00		0.73		1.31	
1-nonene/112-tm-cyH	0.70		0.02		0.03		0.16	
t3-nonene	0.02		0.03				0.01	
c3-nonene/ib-cyP	0.05		0.02				0.01	
n-nonane	0.55		0.02		0.03		0.13	
t2-nonene	0.35		0.03		0.02		0.08	
c2-nonene	0.04		0.01				0.01	
ip-benzene	0.52		0.03				0.11	
22-dm-octane	0.27		0.08				0.07	
ip-cyH	0.09		0.01				0.02	
nb-cyP	0.25		0.26		0.01		0.09	
33-dm-octane	0.02		0.00				0.01	
n-propylbenzene	0.99		0.00		0.00		0.21	
3e-toluene	4.20		0.10		0.11		0.91	
4e-toluene/23-dm-octane	1.99		0.04		0.07		0.44	
135-tm-benzene	1.64		0.03		0.11		0.37	
2m-nonane	0.15				0.09		0.06	
3e-octane			0.11				0.02	
3m-nonane			0.10				0.01	
2e-toluene	1.42		0.05		0.02		0.31	
124-tm-benz/tb-benz/1-decene	4.24		0.14		0.16		0.94	
ib-cyH	0.06		0.23				0.04	
n-decane	0.16		0.05		0.04		0.05	
ib-benzene/t-1m-2p-cyH	0.08						0.02	
sb-benzene	0.10						0.02	
3-ip-toluene								
123-tm-benzene	0.54		0.07		0.03		0.13	
4-ip-toluene								

	Phase 1		Phase 2		Phase 3		Composite	
	Avg	St Dev	Avg	St Dev	Avg	St Dev	Avg	St Dev
indan			0.38				0.05	
2-ip-toluene	0.44						0.09	
13-de-benzene	0.39		0.01				0.08	
3-np-toluene	0.48		0.02				0.10	
14-de-benzene	0.22						0.05	
4-np-toluene/nb-benz/13dm5e-benzene	0.92		0.02				0.19	
12de-benzene	0.04						0.01	
2-np-toluene	0.05						0.01	
14dm-2e-benzene	0.39		0.12				0.10	
13dm-4e-benzene	0.38		0.07				0.09	
12dm-4e-benzene	0.52		0.08		0.00		0.12	
13dm-2e-benzene	0.05		0.48				0.07	
n-undecane	0.07				0.00		0.01	
12dm-3e-benzene	0.08		0.02				0.02	
1245-ttm-benzene/2mb-benzene	0.74		0.05		0.10		0.19	
tb-2m-benzene	0.07		0.03				0.02	
npentyl-benzene	0.07		0.03				0.02	
t-1m-2-(4mp)cyP	0.03		0.33		0.07		0.07	
tb-35dm-benzene	0.05						0.01	
tb-4e-benzene								
naphthalene	0.07		0.03		0.01		0.02	
n-dodecane			0.15		0.01		0.02	