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ANALYZE EXISTING WEST LA DATA SET FOR ON-ROAD EVAPORATIVE EMISSIONS

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5755 NORTH POINT PARKWAY • SUITE 265 • ALPHARETTA, GA 30022

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Analyze Existing West LA Data set for On-Road Evaporative Emissions

Gary A. Bishop

Department of Chemistry and Biochemistry
University of Denver
Denver, CO 80208

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Prepared for:

Coordinating Research Council, Inc.
5755 North Point Parkway, Suite 265
Alpharetta, Georgia 30022
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Executive Summary

U.S. vehicle fleet emissions have been on a steady decline since the early 90's producing significant improvements in air quality. On-road vehicles can potentially emit carbon monoxide (CO), hydrocarbons (HC) and reactive nitrogen compounds from the tailpipe as well as non-tailpipe (evaporative) HC emissions from the fuel tank and fuel delivery system. As mobile source emissions have decreased the relative contributions of tailpipe and evaporative emissions to the total have been studied and debated. Into the early 2000's measurements and model predictions generally agreed that tailpipe emissions of HC constituted the majority of the mobile source HC emissions. As the total HC emissions have declined the fraction of the total predicted to be contributed by evaporative emissions have grown in the models; yet, analysis of ambient air measurements have disagreed over whether that is the case.

In the spring of 2013 and 2015 the University of Denver collected on-road emission measurements of an in-use fleet that uses the La Brea Ave. and I-10 interchange in West Los Angeles as part of a California Air Resources Board sponsored project. This resulted in two data sets, the first collected between Saturday April 27 through Saturday May 4, 2013 with 33,807 attempted measurements and 27,247 valid and registration matched records. The second set was collected between Saturday March 28 and Friday April 3, 2015 with 27,413 attempted measurements and 22,124 valid and registration matched records. In addition to the fuel specific emission results for each vehicle, the high frequency data which consists of 50 individual voltages from each of the four infrared detectors and concentration data from the ultraviolet spectrometers collected at 100 Hz over the one half second emissions measurement, was also collected for each attempted measurement. These high frequency files contain millisecond level emissions absorption data for each channel and can be used to analyze the changes in an individual species emissions measurement as a function of time during each vehicles tailpipe test.

The high frequency data files were screened for the presence of non-tailpipe hydrocarbons using an evaporative emissions index (EI23) developed by the Eastern Research Group (ERG) in cooperation with the Colorado Department of Public Health and Environment and several of FEAT's additional quality assurance metrics (DeFries et al., 2012). The EI23 index is a method for categorizing the observed noise that exits in the linear least squares fit of supposed exhaust HC emissions for each vehicle. When a vehicle has more than one source of HC emissions there is the potential for this second source of HC to disrupt the correlation with the tailpipe CO_2 emissions. The EI23 index is calculated using the results of the linear least squares fit to the HC to CO_2 correlation graph. The residuals from the fit are then ordered from largest to smallest and the EI23 index is the 90^{th} percentile.

In general testing by ERG it was found that EI23 was linear with the evaporative HC mass emissions flow rate collected in a portable hot soak emissions shed (PSHED). However, the strength of the HC emissions signals observed by the remote sensor were found to be dependent on the location of the leak, the type of leak (vapor or liquid), the speed of the vehicle and the size of the HC emissions signature from the tailpipe. ERG developed a binning criterion to minimize these dependences, which utilizes the tailpipe HC emissions estimate to individually scale the size of the bins for each measurement. The results are eight bins (1 – 8) with 1 being the lowest EI23 index and 8 being the highest. This resulted in a probability distribution where vehicles with and EI23 index bin of 1 - 3 had an 8% chance (9 of 117 measurements) of having a PSHED hot soak emissions of greater than 3 grams VOCs in 15 minutes (the U.S. EPA estimates that Tier 2 vehicles should have less than 0.3g/15 minutes) while an EI23 index of 7 and 8 had an 82% chance (9 of 11) of meeting this timed threshold. Because the measurements were conducted at a Colorado I/M station this generally restricted the fleet sample to vehicles that were at least 7 years old in the summer of 2008. Therefore, when applied to an entire fleet it is expected to find that the PSHED hot soak probability for bins 1 – 3 will drop significantly below 8% while having less effect on the higher bins.

The screening of the Los Angeles remote sensing data resulted in a list of measurements for each year's data set that were considered to potentially have non-tailpipe HC emissions. All of these files were graphically screened and either rejected or assigned a probability rank of 1 to 3 with 1 being less likely but cannot ruled out to 3 the most likely to exhibit evaporative emissions. The rankings are of course, subjective and are based on the EI23 bin classifications and the size of the HC emissions signal. If a vehicle is included in the probability rankings the database was searched for any additional emissions measurements on that vehicle and if found these measurements were also included in the final listing. This process generated a final list that contained 59 measurements (39 unique vehicles with 9 additional measurements with unknown model year) from the 2013 data set (0.17% of the attempts) and 52 measurements (28 unique vehicles with 15 additional measurements with unknown model year) from the 2015 data set (0.19% of the attempted measurements) which are detailed in Table E1.

Table E1. The Original Evaporative Emissions Measurement Probability Rankings for 2013 and the 2015 Data Sets.

Probability Category	Number of 2013 Measurements (% of 59)	Number of 2015 Measurements (% of 52)
3 (Most Likely)	7 (11.9%)	11 (21.2%)
2	32 (54.2%)	13 (25%)
1 (Less Likely)	20 (33.9%)	28 (53.8%)

Table E2 contains a listing of the vehicle model years that are represented in the list for the 2013 and 2015 data sets. The model years are left justified for sequential years and then right justified to indicate when that trend is no longer the case. The "Unknown Model Year" row contains suspected vehicles that were not matched with registration information. This occurs when a plate cannot be matched by the Department of Motor Vehicle Records, the plate was unreadable and

Table E2. Model Year Distribution for the 2013 and 2015 Evaporative Emissions Measurement List and are not unique vehicles.

Model Year	2013 Counts	2015 Counts
2015		5
2014		1
2013	2	
2012	1	
2011	5	
2010	1	
2009	1	
2008		1
2007	1	
2006	1	
2005	2	2
2004	3	3
2003	2	2
2002	4	
2001	6	
2000	5	4
1999	1	4
1998	3	3
1997		3
1996	1	
1995	3	
1994	2	
1993		
1992		2
1991	1	
1990	1	
1989	1	
1986		1
1983		1
1979		1
1978	1	
1974		1
1972		1
1967		1
Unknown Model Year	11	16
Totals	59	52

not entered into the database, the plate was out of state or the plate was not transcribed because the vehicle did not have a valid CO_2 plume.

For the 59 measurements from the 2013 data set 9 (15.3%) were model year 2010 and newer (0.13% of that age group), 25 (42.4%) were model years 2000 to 2009 (0.16% of that age group), 12 (20.3%) were model years 1990 to 1999 (0.26% of that age group), 6 (10.2%) were older than 1990 (1.5% of that age group) and 11 (18.6%) measurements had an unknown model year (0.17% of that group). For comparison the 2013 fleet measured at the La Brea Ave site had 25% of the valid measurements collected from 2010 and newer vehicles, 56.5% from 2000 to 2009 vehicles, 17% from 1990 to 1999 vehicles, 1.5% from vehicles older than 1990 and the unknown vehicles accounted for 19.6% of the 33,807 attempted measurements. The evaporative emissions probability evaluations and rankings assigned 39 of the 59 measurements (66%) to the two highest probability classes meaning indicating a fair level of certainty that the measurements include non-tailpipe HC emissions.

For the 52 measurements from the 2015 data set 6 (11.5%) were model year 2010 and newer (0.07% of that age group), 12 (23.1%) were model years 2000 to 2009 (0.11% of that age group), 12 (23.1%) were model years 1990 to 1999 (0.48% of that age group), 6 (11.5%) were older than 1990 (3.2% of that age group) and 16 (30.8%) measurement had an unknown model year (0.3% of that group). For comparison the 2015 fleet measured at the La Brea Ave site had 40.2% of the valid measurements collected from 2010 and newer vehicles, 47.7% from 2000 to 2009 vehicles, 11.3% from 1990 to 1999 vehicles, 0.8% from vehicles older than 1990 and the unknown vehicles accounted for 31% of the 27,413 attempted measurements. The evaporative emissions probability evaluations and rankings assigned 24 of the 52 measurements (46%) to the two highest probability classes. As previously mentioned these are total measurements and not unique vehicles, for example there were 5 measurements for the 2015 model year which were contributed by only 2 vehicles.

Appendix B gives a detailed listing of the 59 vehicles suspected from the 2013 measurements and the 52 vehicles suspected from the 2015 measurements arranged by probability rank (highest to lowest). There are 7 vehicles ranked in the highest category from the 2013 database and 11 vehicles included from the 2015 database. The 2013 vehicle list includes 1 from the 1970's, 5 from the 1990's and 3 from the 2000's. The 2015 probability 3 vehicles include 3 with unmatched plates, however, 1 is a 1936 Coupe and 1 is an out of state plated compact 4 door sedan which is a mid-2000's manufactured vehicle. There is 1 from the 60's (a 1967 sedan), 1 from the 70's, 2 from the 90's and 4 from the 2000's.

Figure E1 shows the emissions versus time data for a 1990 vehicle that is also a repeat measurement vehicle with a lower ranking. %CO_2 (left axis) and %HC (right axis) emissions are plotted against time for this 1994 SUV with the top panel showing the probability 3 measurements and the bottom panel the repeat measurement given a probability ranking of 1. Both measurements reveal a similar pattern of steadily falling HC emissions after the car passes

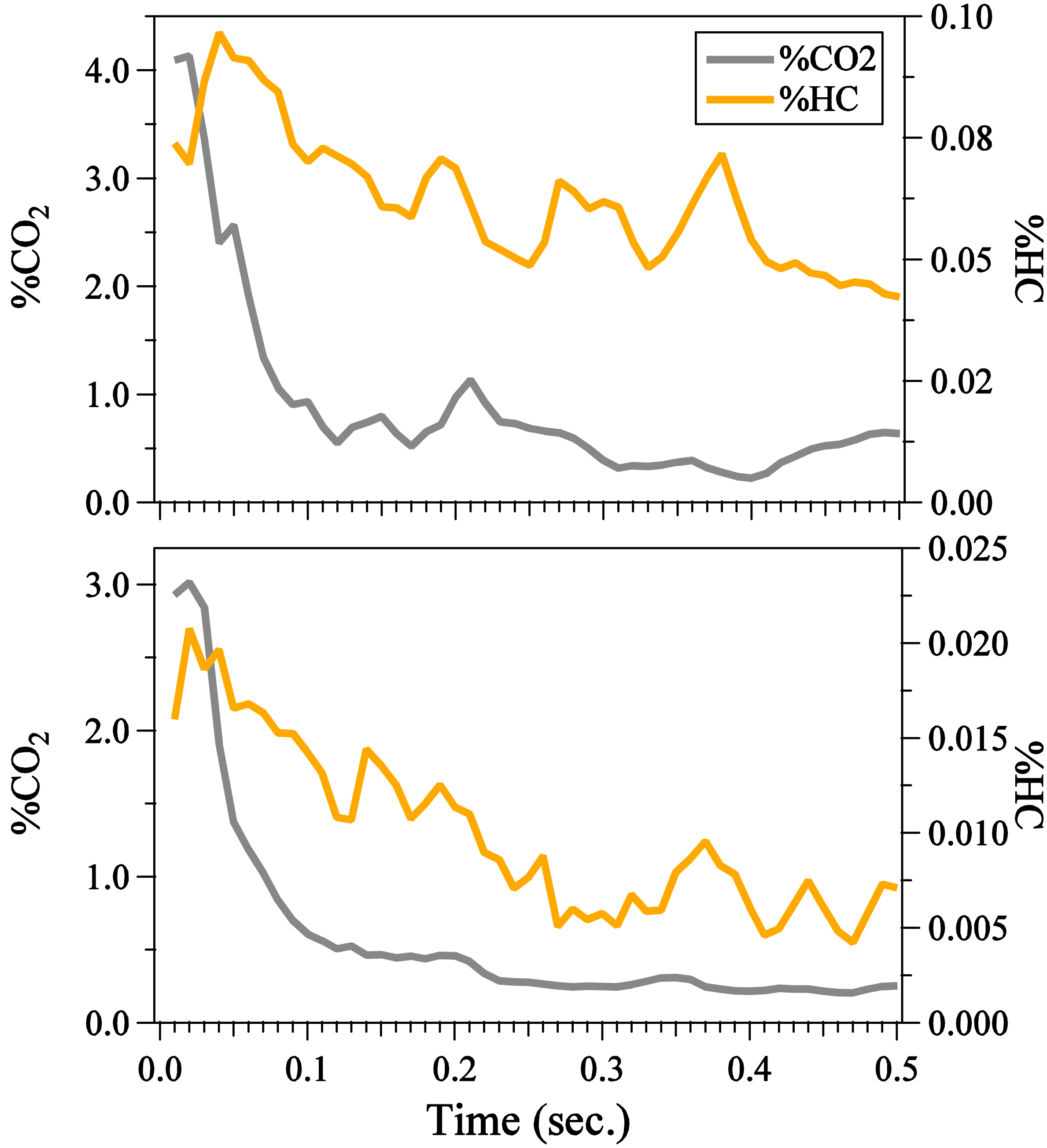

Figure E1. %CO_2 (left axis) and %HC (right axis) versus time for a 1994 SUV measured on May 4, 2013 (top graph) and April 29, 2013 (bottom graph). The top measurement (probability ranking of 3) was found using the EI23 screening with an EI23_bin value of 3. The bottom measurement was included because of multiple measurements and has a probability ranking of 1. Both display a similar pattern with the top panel having a larger Δ%HC.

by with little correlation to the observed exponential decay of the CO_2 plume. The different probability category is influenced by the EI23 bin ranking (3 for the top and 1 for the bottom) and the increased size of the HC emissions plume in the top panel.

Because the probability rankings are entirely circumstantial, one conclusion of this survey is that even with the assumption that all of the vehicles suspected of having non-tailpipe HC emissions do in fact have evaporative or liquid fuel leaks, which is the extreme assumption, the overall number of vehicles found is very small (<~0.2% of the passing fleet for each measurement year). Several vehicles were identified, which likely provides proof of concept that the screening tools can find non-tailpipe HC emissions. Because the high frequency data has not been routinely collected it is unfortunately not possible to screen any older data sets to establish an evaporative emissions trend, however, it is possible to incorporate the EI23 index calculations into the FEAT software which would allow these evaluations to be performed in the future.

Introduction

Since the early 90's U.S. vehicle tailpipe emissions have been on a steady decline. In the Chicago area, for example, carbon monoxide (CO) and total hydrocarbons (HC) have been reduced by a factor of 10 and 20 respectively.[1] Recent fuel based emission inventory estimates for Los Angeles, Houston and New York City have shown that CO and non-methane hydrocarbon emissions decreased by 80 to 90% between 1990 and 2010 though fuel use increased.[2] Over the same time period gasoline engine oxide of nitrogen (NO_x) emissions were estimated to have decreased by 65% in Los Angeles.[3] The California Vehicle Surveillance Program similarly found that tailpipe volatile organic compound emissions decreased by 80% between 1995 and 2003.[4]

Vehicles also can emit HC emissions from non-tailpipe sources. Vehicles are currently certified for evaporative emissions under three modes, running losses, hot soaks and diurnal emissions. Running losses are emissions of vapors when the vehicle is in operation. Hot soak emissions are losses of vapors that are emitted from a fully warmed up vehicle which is subsequently parked with the engine off. Diurnal emissions encompass emissions of vapors from parked vehicles as they experience the 24hr temperature cycle from ambient conditions. Like tailpipe emissions in-use testing of vehicles has demonstrated that vehicle evaporative emissions have also declined significantly. The California Vehicle Surveillance Program found that hot-soak emission rates for most compounds decreased by more than 95% between the 1999 and 2003 California vehicle fleet.[4] The reductions have continued with the introduction of U.S. Tier 2 vehicles as recent research has shown evaporative emission control efficiencies in excess of 98%.[5]

As mobile source emissions have decreased the relative contributions of evaporative and tailpipe emissions to the total have been studied and debated. Into the early 2000's measurements and model predictions generally agreed that tailpipe emissions of HC constituted the majority of the mobile source HC emissions.[6] Since then the fraction of the total HC's predicted to be contributed by evaporative emissions have increased in the models yet analysis of vehicle emissions and ambient measurements have disagreed over whether that is the case.[7, 8] This has created interest in better quantifying the evaporative emissions contribution of mobile source HC emissions.

In the spring of 2013 and 2015 the University of Denver collected on-road emission measurements of an in-use fleet that uses the La Brea Ave. and I-10 interchange in West Los Angeles as part of a California Air Resources Board sponsored project.[9] This site has been visited since 1999 and to date there have been seven data sets collected.[10-12] The 2013 and 2015 data set collection using the Fuel Efficiency Automobile Test (FEAT) included the collection and storage of the high frequency data as part of each vehicle's emissions measurement. These individual measurement files have been used to search the West Los Angeles fleet for high running loss emission vehicles and estimate the size of this fraction of the fleet. Because vehicle emissions are not normally distributed it is expected that evaporative emissions for a fleet will also be dominated by a small number of high emitters. This research is a first step toward establishing the fleet fraction of these vehicles.

Methods

The State of Colorado has a large "clean screen" program as part of its light-duty Inspection and Maintenance (I/M) program. This involves a number of commercially operated remote sensors (RSD4600) measuring a large number of Denver vehicles on a daily basis. The program generally generates more than 8 million readings a year for CO, HC and NO emissions. The Colorado Department of Public Health and Environment (CDPHE) used these measurements in 2006 and 2007 to recruit high on-road emitting HC vehicles for a repair program connected with the state I/M program. Several vehicles were found to not have high tailpipe HC emissions but were discovered to have high evaporative emissions or liquid leaks. This discovery was followed up with a small challenge experiment where a vehicle was measured in a parking lot using metered amounts of propane or unmetered amounts of liquid gasoline in combination with simulated synthetic exhaust from a state audit truck. This test concluded that data sets could be generated with the added HC emissions from the non-tailpipe sources that were noticeably different from the data set with only the tailpipe emissions present.

During the summers of 2008, 2009 and 2011 the Eastern Research Group (ERG) was involved in a research program for the CDPHE which sought to estimate hot-soak evaporative emissions from the Denver I/M fleet utilizing a commercial remote sensor to identify prospective vehicles for testing.[13, 14] As part of this work a numerical method using remote sensing high frequency data was developed for calculating a running loss index which they called EI23, so called because it was the 23rd iteration of the process.

The FEAT exhaust remote sensor correlates the various tailpipe exhaust constituents to carbon dioxide to calculate a fuel specific emissions factor.[15] This process involves collecting 100 Hz data from each of the instruments detectors and performing a least squares fit to the ratio plot for each species measured. Figure 1 is a plot of a 0.5 second of 100 Hz data (50 points) of absorbance measurements from the infra-red detectors versus time behind a light-duty vehicle. These detectors report a voltage that is proportional to the temperature sensed, the higher the voltage the higher the temperature. Each detector only senses an individual species and the reference detector is insensitive to all gases and is used for differentiating gas absorbance from physical blockages such as car parts and road dirt. The sensitivity of each detector is a function of the absorption strength of the gases being monitored. As shown in Figure 1, CO_2 is a very strong absorber and at this scale it is easy to see that as the plume dilutes behind the car the exhaust moves in and out of the remote sensors sensing beam and the voltages change accordingly as the degree of gas absorption of the heat beam lowers or raises the detector temperature. On this scale one can also just notice that the CO detector voltage also changes but changes in the HC signal, whose response is at the millivolt level, is not discernable.

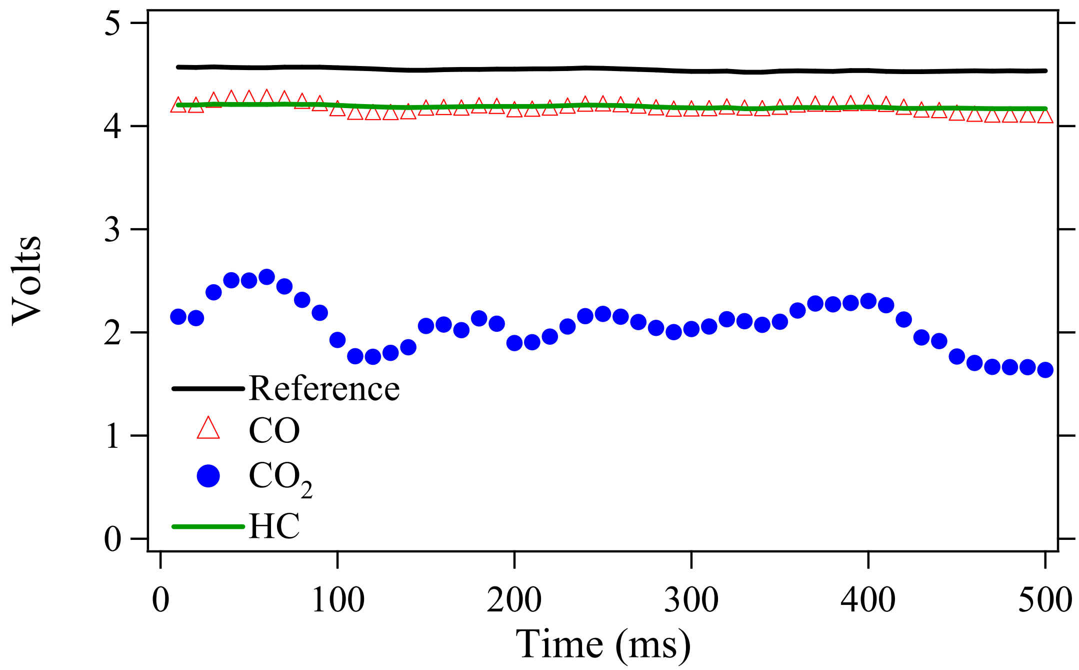

Figure 1. Infrared detector voltages versus time (milliseconds) behind a light duty vehicle.

Figure 2 translates the voltages observed in Figure 1 into concentration values using each detector's calibrated response curves, assuming all of the gas measured is contained in an 8cm cell which is how the response curves are generated in the lab. The CO and CO_2 concentrations are plotted in percent on the left axis and the HC concentrations are plotted as ppm on the right axis. Now it is very easy to see that all of the species move in sync since the gas has been emitted from a single source and it is well mixed. Figure 3 is the final step in the process and shows the correlation plots for CO/CO_2 (left y-axis) and HC/CO_2 (right y-axis) and the least squares lines fit to each. For demonstration purposes this is an extremely high emitting CO (~550 gCO/kg of fuel) and HC (~14 gHC/kg of fuel) vehicle as current on-road fleets have gCO/kg of fuel means around 11 gCO/kg of fuel and gHC/kg of fuel means of 1.4 gHC/kg of fuel. For a vehicle only emitting CO_2 the data points from both of these species would scatter along the x-axis and the least squares slopes would be zero.

The EI23 index developed by ERG is a method for categorizing the observed noise that exits in the linear least squares fit of supposed exhaust HC emissions for each vehicle. When a vehicle has more than one source of HC emissions there is the potential for this second source of HC to disrupt the generally good correlation with the tailpipe CO_2 as seen in Figure 3. Figures 4 and 5 show a 1967 sedan measured in West LA in 2015 where there is an excessively large HC signal early in the data time series that is not well correlated with the tailpipe CO_2, likely indicating that there are multiple HC emission plumes coming from this vehicle.

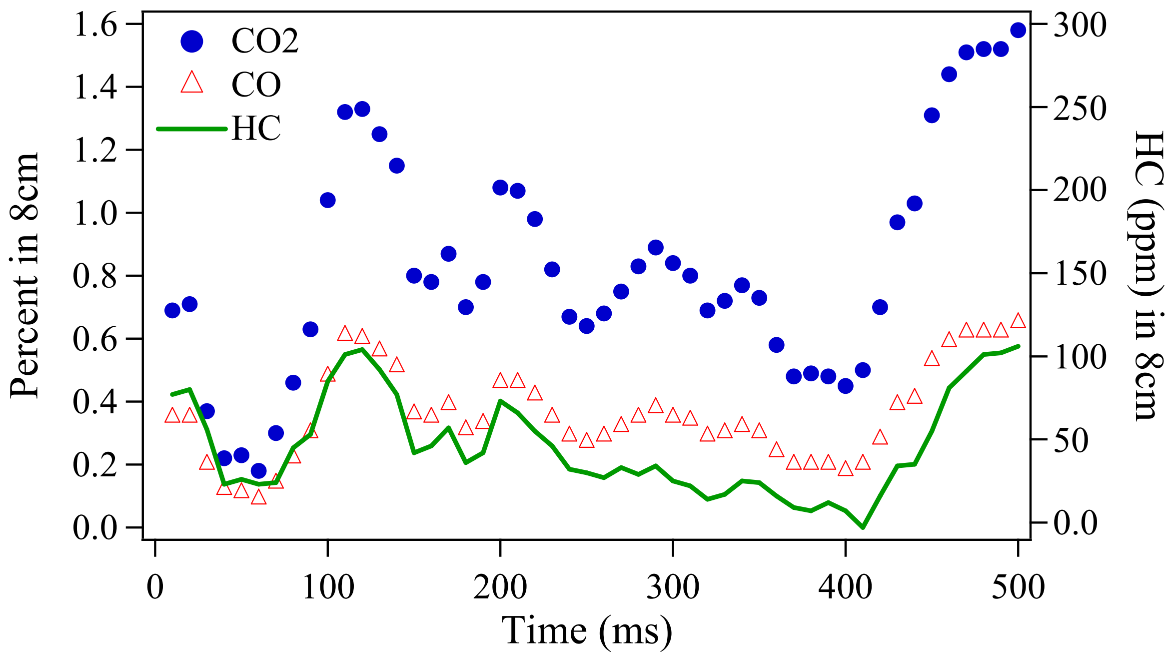

Figure 2. Voltages from Figure 1 converted to concentrations using the individual detectors laboratory determined response curves. CO_2 and CO are graphed as percent on the left y-axis and HC emissions are graphed as ppm on the right y-axis.

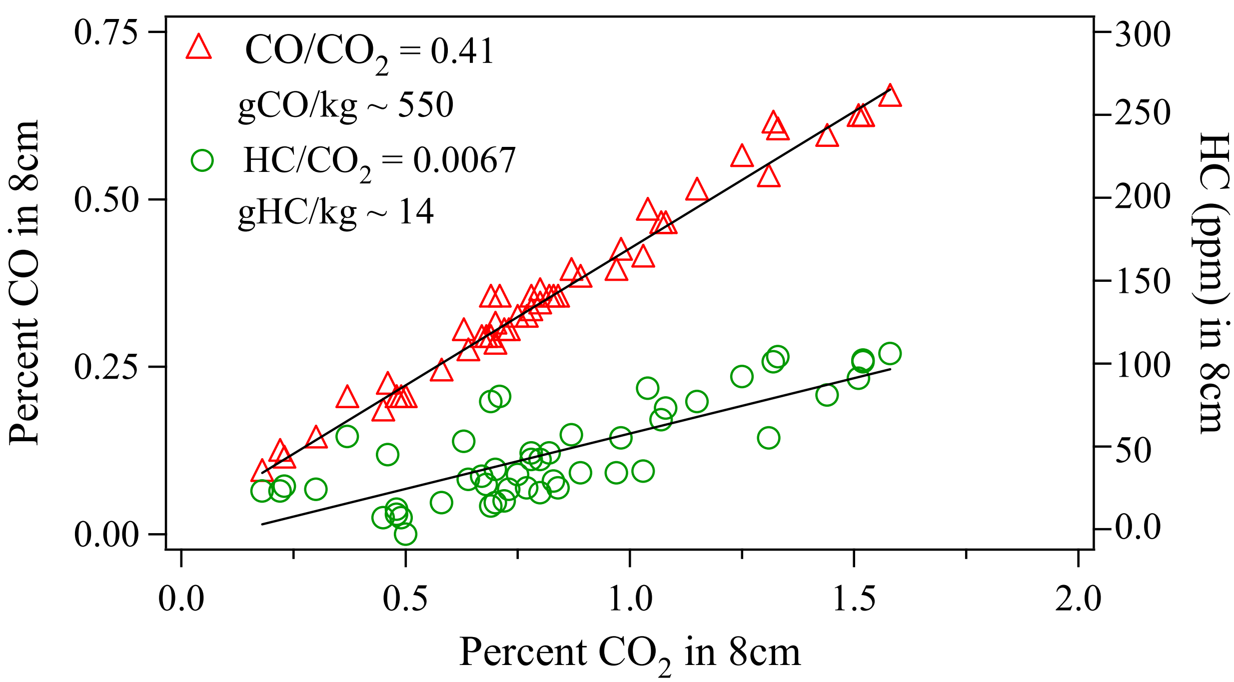

Figure 3. Correlation plots for the CO and HC concentration data plotted in Figure 2 against the CO_2 concentrations from the same figure. Solid lines are the least squares best fit lines with the slope and approximate fuel specific emissions factor in the upper left hand corner of the plot.

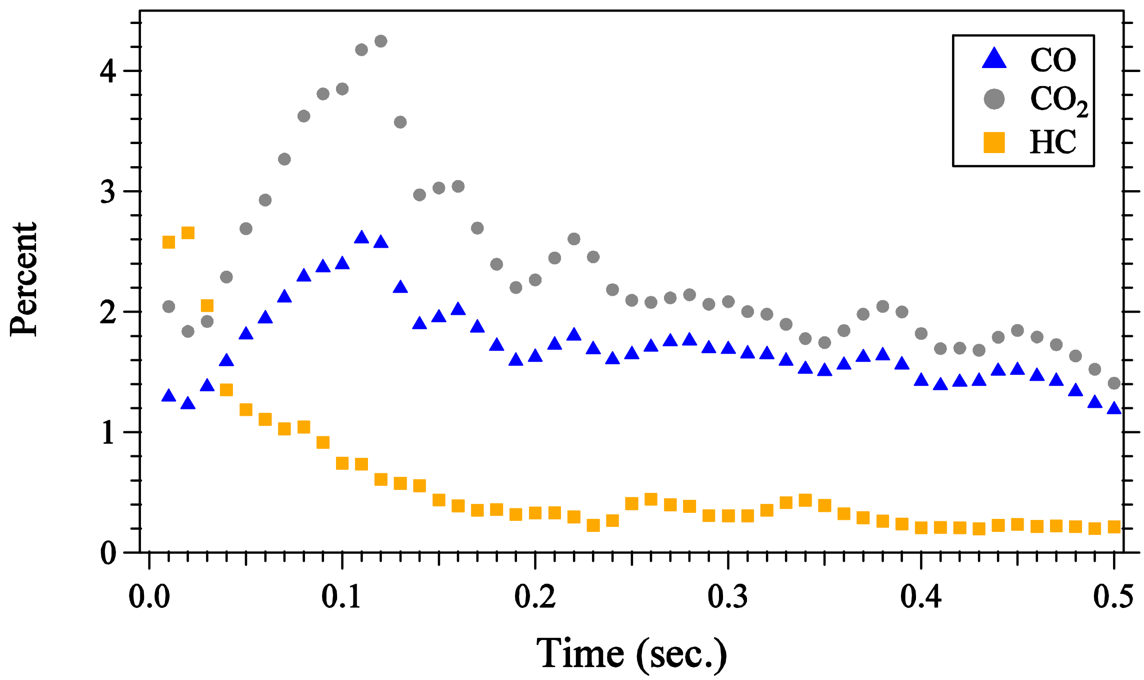

Figure 4. Percent emissions versus time for a 1967 sedan measured at the West LA site on April 1, 2015. Percentages are calculated assuming that all of the exhaust has been compressed into an 8cm cell. HC emissions are not correlated with CO_2 emissions indicating a source other than the tailpipe.

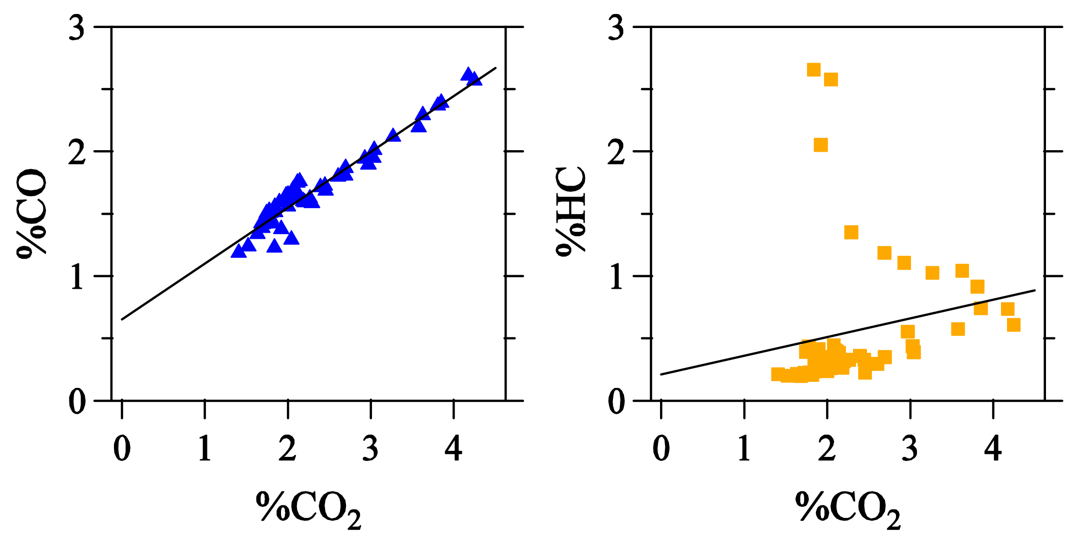

Figure 5. Correlation graphs for %CO versus %CO2 (left panel) and %HC versus $\%CO_2$ (right panel) for a 1967 sedan with least squares best fit line. The lack of correlation between the observed HC and CO_2 emissions resulted in this exhaust measurement being invalidated by the software.

The EI23 index is calculated using the results of the linear least squares fit to the HC to CO_2 correlation graph. After the linear equation is determined it is used to calculate the residuals for each of the points used in the fit where the residual is defined as the measured HC value minus the fit predicted HC value. Figure 6 shows the calculated HC residuals for the HC correlation plot shown in Figure 5. The residuals are then ordered from largest to smallest and the EI23 index is the 90th percentile of that list (marked with arrow in Figure 6). For the 1967 sedan that percentile value is 0.573. The EI23 index was designed using ppm as its units and converting the FEAT %HC value into ppm results in the EI23 index value for this vehicle being 5,730.

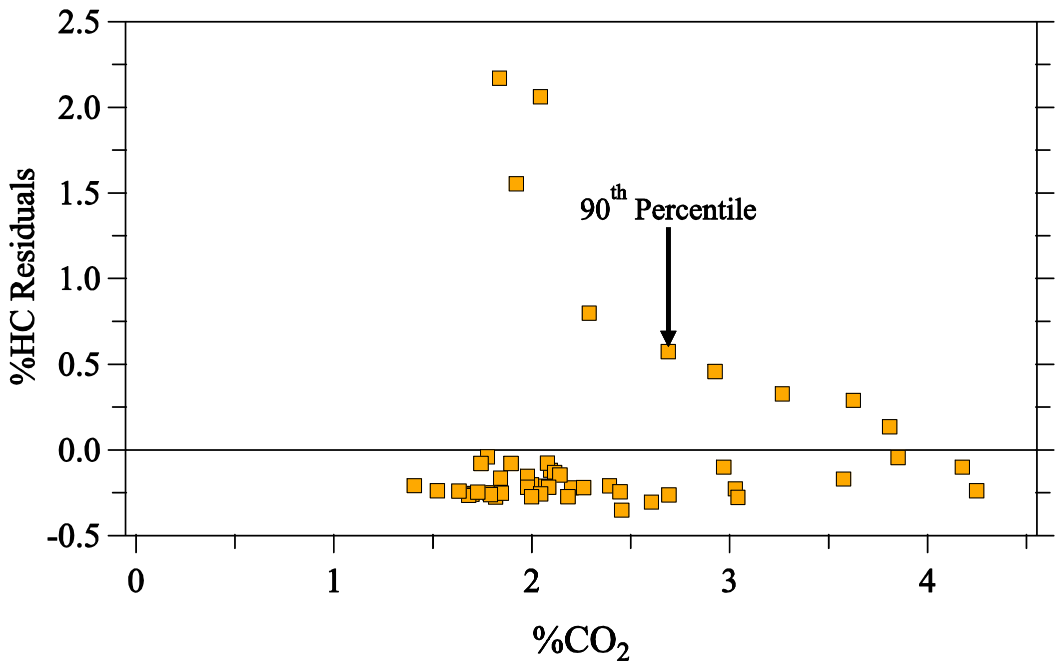

Figure 6. %HC residuals plotted versus %CO_2 for a 1967 sedan measured in Los Angeles in 2015 with the 90th percentile point marked by the arrow. The residuals are calculated using the least squares best fit line shown in Figure 5.

In general testing by ERG it was found that EI23 was linear with the evaporative HC mass emissions flow rate. However, the strength of the HC emissions signals observed by the remote sensor were found to be dependent on several factors beyond just the amount emitted. These included the location of the leak, the type of leak, vapor or liquid, the speed of the vehicle and the size of the HC emissions signature from the tailpipe. As the speed of the vehicle increases the dispersion rate of the leak increases which works to lower its absorption signal. This can be further exacerbated by the location of the leak with leaks located in the front of the vehicle having a longer time to dissipate before reaching the sensing beam. These all work to lower the regression residuals. In addition since the remote sensor only senses HC vapors liquid leaks need time to vaporize in order to be sensed. As vehicle speeds increase these factors limit the size of the evaporative HC emissions emitted that can be detected necessarily requiring a larger emissions signal for detection. It was also found that detection limits decreased as the size of the tailpipe emissions increased. ERG developed a binning criterion to minimize these dependences, which utilizes the tailpipe HC emissions estimate to individually scale the size of the bins for each measurement.

The results are eight bins (1 – 8) with 1 being the lowest EI23 index and 8 being the highest. Vehicles that fall into the highest bins have the highest probability of excess evaporative emissions than those in lower numbered bins but are not to be considered directly proportional to the evaporative emissions. The width of each EI23 bin is approximately one standard deviation of the variability of a single EI23 measurement after accounting for the effects of the exhaust HC concentrations. This means that a difference of two or more bins is likely a statistically significant difference.

In testing in Colorado using a portable hot soak shed (PSHED) a total of 87 vehicles were tested at a local I/M station. Each vehicle was measured remotely as they entered the station and those placed in the desired EI23 bin were recruited for follow up testing using the PSHED. The PSHED testing procedure included driving the vehicle on the road for at least 15 minutes and when complete returning the vehicle to the test locations and collecting two additional RSD measurements on each vehicle for a total of 175 measurements (one vehicle ended up with 3 measurements). After that the vehicle would have the engine shut off and was rolled into the PSHED. The circulation fans were started, the PSHED was sealed and total HC concentration, temperature and barometric pressure measurements were collected for the next 15 minutes.

This resulted in a probability distribution for the vehicles tested. For the vehicles with an RSD measurement that translated into an EI23 index bin of 1 - 3 were found to have an 8% chance (9 of 117 measurements) of having a PSHED hot soak emissions of greater than 3 grams VOCs in 15 minutes (the U.S. EPA estimates that Tier 2 vehicles should have less than 0.3g/15 minutes) while an EI23 index of 7 and 8 had an 82% chance (9 of 11). Because the measurements were conducted at a Colorado I/M station this generally restricted the fleet sampled to vehicles that were at least 7 years old in the summer of 2008. The exception is for vehicles that have changed owners, so generally the vehicle sample consisted of vehicles from 1961 – 2005. Therefore, it is expected that application of these index bins on a real in-use fleet will find that the PSHED hot soak probability for bins 1 – 3 would drop significantly below 8% while having less effect on the two highest bins.

The Data Sets

Generally the FEAT remote sensing setup does not record the high frequency data streams for each individual vehicle. This is due to the fact that it slows down the response time of the instrument and it is generally preferred to be able to attempt measurements on as many passing vehicles as possible. For the 2013 and 2015 West LA measurements, which were collected on the on-ramp from southbound La Brea Ave to eastbound I-10, we were asked by the California

Air Resources Board to collect and store the high frequency data. This resulted in two data sets, the first collected between Saturday April 27 through Saturday May 4, 2013 with 33,807 attempted measurements and 27,247 valid and registration matched records. The second set was collected between Saturday March 28 through Friday April 3, 2015 with 27,413 attempted measurements and 22,124 valid and registration matched records.

Each attempted measurement includes a separate comma delimited file that contains all of the necessary information to reconstruct the measurement process. The file contains the date and time of the measurement, the normalization voltages (these are used for correcting for background concentrations found in front of the car), 50 voltages (every 10ms) for the IR reference, CO, CO_2 and HC channel, 50 molar concentrations for CO, CO_2, and HC along with the 50 concentrations and uncertainty estimates for the species measured by the twin ultraviolet spectrophotometers which include nitric oxide, ammonia, sulfur dioxide and nitrogen dioxide. In addition the file contains the final results of the original analysis, validity flags and the measured speed, acceleration and validity flag. Appendix A contains a sample file listing.

A digital photograph of the rear of each vehicle is saved as well. In normal operation images of vehicles for which there is insufficient exhaust levels to attempt a measurement are not collected and saved. That is the mode that was used for the 2013 data set. This was changed for the 2015 data set to collect plate images for all of the vehicles on which a measurement was attempted.

Results

A program was developed to post process all of the available high frequency data files collected in Los Angeles in the 2013 and 2015 data collection campaigns. This program recalculated the original fits and results for each file, calculated an EI23 index value and representative bins and assigned the EI23 index value to its designated bin. In addition to calculating the EI23 index for the entire data record two additional EI23 index values were also calculated using just the first half of the data set and the second half of the data set. These secondary calculations should be considered as less reliable as all of the quality control processing that is normally done in selecting the data used in the best fit routines was turned off. In addition all of the attempted measurements in each year's data set, including those with insufficient levels of detectable exhaust, were also post processed.

Table 1 shows the distribution of EI23 bin values for the 2013 data set and includes the three data groupings used to calculate the EI23 bin values. For the quality controlled data grouping it was found that more than 99.8% of the measurement attempts are assigned to EI23 bins 1 and 2 and for 2013 only 2 measurements are found beyond bin 4. Note that the data groupings that use only the first or second half of each vehicle's measurements generally increase the number of measurements included in the middle level bins (2 – 4). Table 2 shows the results for the same analysis conducted on the 2015 measurements. The results are similar in the lowest bins with

Table 1. Initial Survey Results Using the EI23 Index as a Screening Value for the Three Data Groupings for the 2013 Measurements.

EI23 Bin	2013 Vehicles (%) All Data	2013 Vehicles (%) First Half	2013 Vehicles (%) Second Half
1	33,146 (98%)	31997 (95%)	32954 (97.8%)
2	593 (1.8%)	1554 (4.6%)	676 (2%)
3	54 (0.16%)	118 (0.34%)	60 (0.17%)
4	12 (0.034%)	14 (0.04%)	11 (0.032%)
5	1 (0.003%)	8 (0.023%)	1
6	0	1	0
7	0	0	0
8	1	1	1

Table 2. Initial Survey Results Using the EI23 Index as a Screening Value for the Three Data Groupings for the 2015 Measurements.

EI23 Bin	2015 Vehicles (%) All Data	2015 Vehicles (%) First Half	2015 Vehicles (%) Second Half
1	26,944 (98.3%)	26476 (96.9%)	26739 (97.8%)
2	369 (1.3%)	603 (2.21%)	400 (1.46%)
3	73 (0.3%)	187 (0.67%)	167 (0.61%)
4	11 (0.04%)	48 (0.17%)	21 (0.08%)
5	11 (0.04%)	6 (0.02%)	2 (0.01%)
6	3 (0.01%)	8 (0.03%)	2 (0.01%)
7	1	0	0
8	1	1	0

more than 99.6 % of the measurement attempts found in bins 1 and 2 for the quality controlled data grouping. In 2015 a few more vehicles were found beyond bin 4 (16 total) but still a very small number of vehicles. The first and second half analysis again indicates an increase in the number of measurements in the mid-level bins.

In addition to calculating the EI23 index values the two data sets were also screened for large changes in HC emission levels during the half-second of data collection (see Figure 4). Records were noted that had valid CO_2 emissions and invalid HC emissions and records with opposite signed first and second half slopes. In the original ERG research vehicle speed was one of the factors which worked against detecting marginal evaporative emitters. Because the original ERG research was conducted at a local I/M station their in-use speeds were generally below 15mph where average speeds at the La Brea Ave. site were 22mph in 2013 (the ramp control light was not working during these measurements) and were 19mph in 2015. Because increased speed is expected to reduce the EI23 index values visual inspections were conducted for all of the measurements assigned to EI23 bins of 2 and larger.

To visually inspect each file a graphical display program was designed that would read each file and display the time series plots and correlation plots that were involved in calculating the EI23 index values for the three data groupings. Figure 7 is a screen shot for a single measurement collected on May 1, 2013. Starting in the upper left hand corner is a voltage time series plot graphing the IR reference channel voltage for the half second measurement. Quality controls restrict changes in the reference channel voltage to less than +/- 2.5% of the before car value (the middle number of the three listed in the bottom right corner of this graph). Large reductions in excess of -2.5% of the before car value indicates some type of physical blockage of the sensing beam by either vehicle parts (most likely) or debris from the roadway. For this vehicle the quality controlled voltage range for valid data is restricted to between ~5.4 to 5.7 volts (see values in lower left corner of this graph) which they are. The middle left graph plots the time series for the measured %CO_2 concentrations (left axis) and the measured %HC concentrations (right axis). The graph in the bottom left hand corner is a replicate time series graph of just the measured %HC concentrations. The graph in the upper right hand corner is the correlation graph of %HC versus %CO_2 with the least squares best fit line for the quality checked data for the entire half-second measurement. The graph in the middle right is the correlation graph of %HC versus %CO_2 with the least squares best fit line for just the first 25 data points that represent half of the measurement. Finally the graph in the lower right hand corner is the correlation graph of %HC versus %CO_2 with the least squares best fit line for the last 25 data points from the last half of the measurement. This vehicle is included in the final list because of the anti-correlation between the %HC and %CO_2 time series plot (left, middle) where high CO_2 levels, indicating the presence of exhaust, find low levels of HC emissions and then when %HC levels are higher CO_2 emissions are moving in the opposite direction.

The process of visually inspecting the measurement files is completely subjective. To that end measurements were assigned to three probability levels (1 to 3) of the likelihood of FEAT detecting non-tailpipe HC emissions with 3 being considered most likely and 1 less likely but cannot be ruled out. Records were excluded that showed no sign of non-tailpipe HC emissions or had mitigating circumstances such as large fluctuations in the IR reference voltage that was responsible for the poor least squares fit.

For example, Figure 8 shows data from a medium duty truck (see photo in Figure 9). At the beginning and in the middle of the data sampling something physically blocked the beam as evidenced by the reduced reference voltage (top graph). From the license plate picture of the vehicle (see Figure 9) it is speculated that because this is a high ground clearance vehicle the data sampling will have begun immediately after the rear wheels and the first blockage is likely the vehicles mud flaps. The blockage in the middle of the graph is more mysterious but if you notice in the picture the rear cargo door of the vehicle has a long rope tied to it. It is possible that the rope is the culprit in the second interference detected by the reference voltage. These areas of

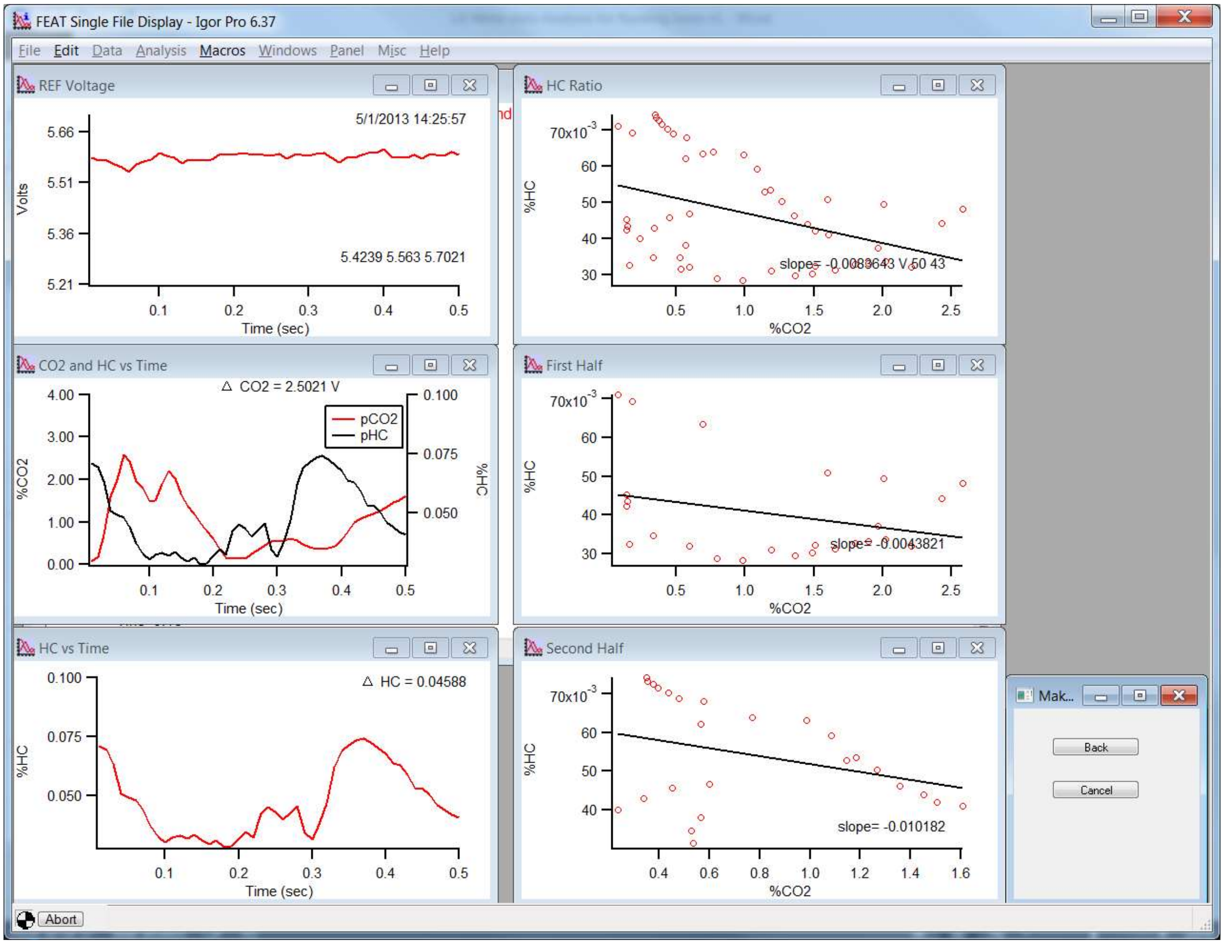

Figure 7. A screen capture of the graphical display program used to visually inspect each of the flagged measurement files.

the time series are marked and excluded from the final correlation graph. The bottom left correlation graph which plots %HC versus %CO_2 shows the quality controlled final ratio calculation where the two regions with elevated CO_2 and elevated and negative HC emissions exist due to the physical blockage of the sensing beam have been excluded resulting in a correlation plot which is a reasonably good fit of the data. The correlation plot in the bottom right uses all of the data points from the first half of the measurement, including the point which is obviously incorrect. This results in a poor fit and an elevated EI23 index which upon visual inspection was excluded for the reasons discussed above.

The process of visually inspecting each file resulted in excluding all of the measurements with elevated EI23 index values that were calculated from any of the data fittings including the raw data first and second half fitting correlations that were impacted by reference channel detected interferences. After the visual review each year's data set was also checked for repeat measurements of the same vehicle and if found these repeat vehicle measurements were included in the final list even if they were not flagged as part of the initial survey. This process ended up

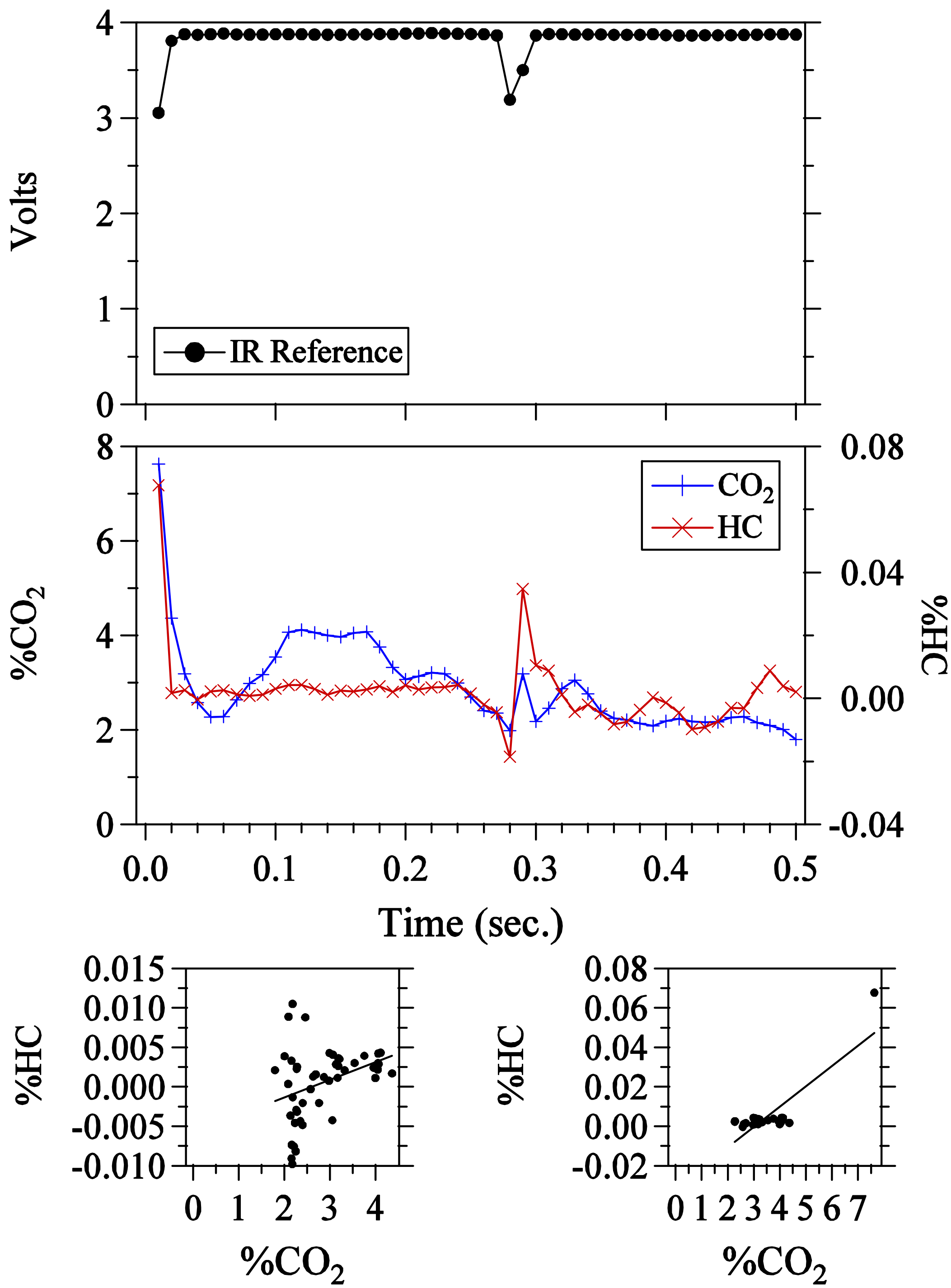

Figure 8. Example measurement data for a vehicle excluded from consideration of non-tailpipe HC emissions. The top panel is the time series of the IR reference voltage. The middle panel is the time series of the calculated $\%CO_2$ (left axis) and %HC (right axis) values for the half second measurement. The bottom left graph is %HC versus $\%CO_2$ for the quality controlled data points and the bottom right graph is a similar plot using all of the first half points. The lines are least squares best fit lines.

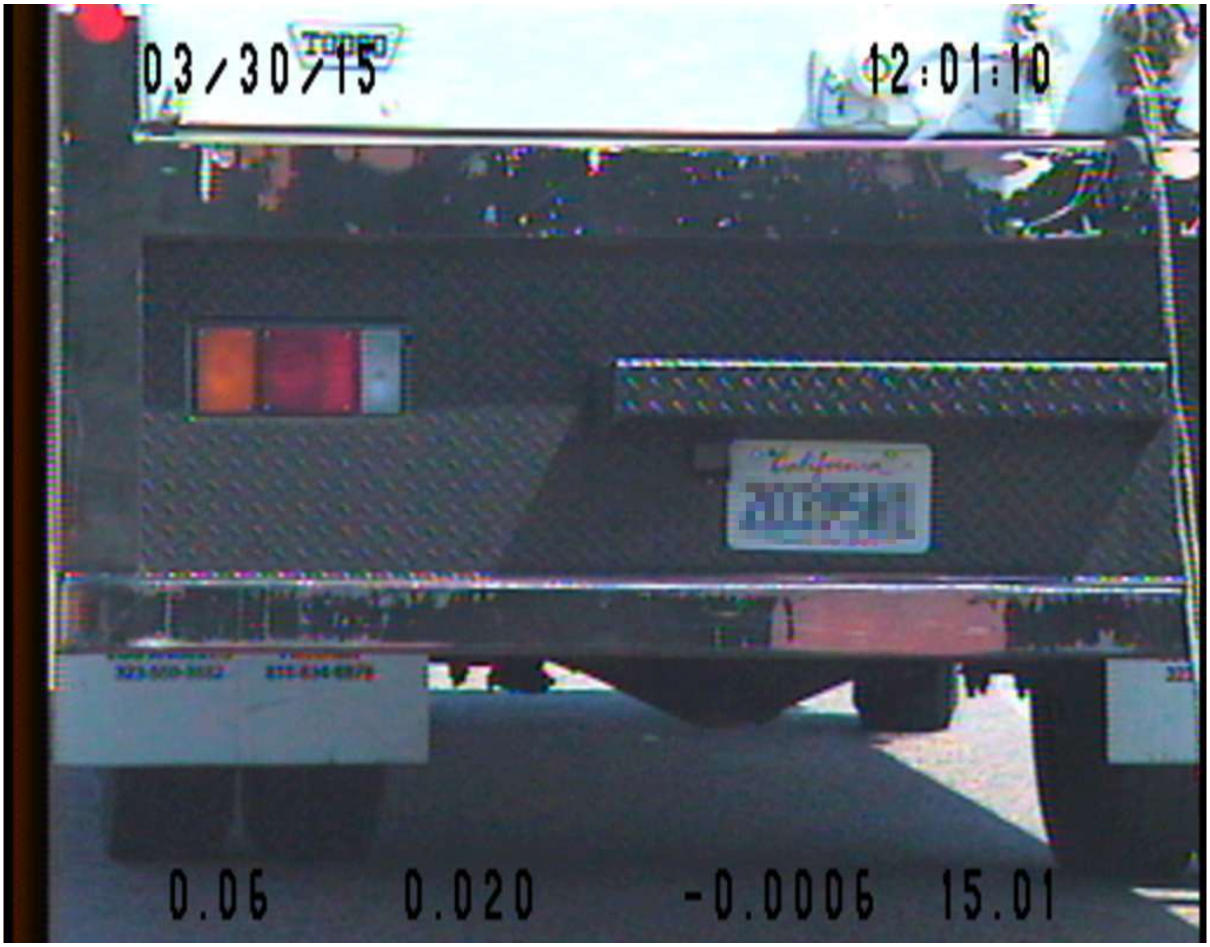

Figure 9. Tag image of the vehicle measured and graphed in Figure 8.

with a list that contained 59 measurements from the 2013 data set (0.17%) and 52 measurements from the 2015 data set (0.19% of the attempted measurements). Even if all of these vehicles were actually vehicles with excess running loss emissions, they are a very small percentage of the passing fleet.

Table 3 contains a listing of the vehicle model years that are represented in the list for the 2013 and 2015 data sets. The model years are left justified for sequential years and then right justified to indicate individual model years. Keep in mind that the same model year vehicles in 2015 are two years older than in 2013. The "Unknown Model Year" row contains suspected vehicles that were not matched with registration information. This occurs when a plate cannot be matched by the Department of Motor Vehicle Records, the plate was unreadable and not entered, the plate was out of state, or the plate was not transcribed because the vehicle did not have a valid CO_2 plume. As previously mentioned unknown records from 2013 have no plate images because they were not collected. Unknown records from 2015 do have a plate image that allows for a basic identification. For the vehicles with matched records there are 15 measurements newer than 2009, 37 between 2000 and 2009, 24 from the 90's, 3 from the 80's, 4 from the 70's and 1

Table 3. Model Year Distribution for the 2013 and 2015 Evaporative Emissions Measurement List and are not unique vehicles.

Model Year	2013 Counts	2015 Counts
2015		5
2014		1
2013	2	
2012	1	
2011	5	
2010	1	
2009	1	
2008		1
2007	1	
2006	1	
2005	2	2
2004	3	3
2003	2	2
2002	4	
2001	6	
2000	5	4
1999	1	4
1998	3	3
1997		3
1996	1	
1995	3	
1994	2	
1993		
1992		2
1991	1	
1990	1	
1989	1	
1986		1
1983		1
1979		1
1978	1	
1974		1
1972		1
1967		1
Unknown Model Year	11	16
Totals	59	52

from the 60's.

Table 4 categorizes the 59 suspected vehicles in 2013 and 52 suspected vehicles in 2015 into the three probability categories where 3 is the most probable and 1 is the least probable. These are the original rankings and does not group the repeat vehicle measurements together.

Table 4. The Original Evaporative Emissions Measurement Probability Rankings for 2013 and the 2015 Data Sets.

Probability Category	Number of 2013 Measurements (% of 59)	Number of 2015 Measurements (% of 52)
3 (Most Likely)	7 (11.9%)	11 (21.2%)
2	32 (54.2%)	13 (25%)
1 (Less Likely)	20 (33.9%)	28 (53.8%)

In addition to scoring the potential evaporative emitters (1 to 3 as previously described) each measurement was categorized as to the emissions pattern observed in the half second of measurement data. Five categories were defined, 1) anti-correlated, 2) exponential decay, 3) high background, 4) consistent rising signal and 5) consistent falling signal that does not look exponential. The anti-correlated pattern exists when the rise and fall of the HC absorbance signal is generally opposite of the rise and fall of the CO_2 absorbance signal (see Figure 7, middle graph left side for an example). Exponential decay is when the HC absorbance signal starts with a large value at the beginning of the half second of data and decreases exponentially (see Figure 4 for an example). High background is an HC absorbance signal that shows little to no correlation with the CO_2 exhaust plume but has a consistently high level of HC absorbance (see top graph Figure 10 for an example). The last two categories, consistent rising (middle graph Figure 10) or falling (bottom graph Figure 10) HC absorbance signal, could be lumped into the anti-correlated category but it was decided to keep them separate because they display a consistent pattern during the half second measurements. Table 5 shows how each year's data sets were categorized by plume shape. Anti-Correlated plumes are the largest in both years and the high background pattern is the smallest.

Table 5. Emissions Measurement Plume Shape Distribution.

Plume Shape	Number of 2013 Measurements (% of 59)	Number of 2015 Measurements (% of 52)
Anti-Correlated	22 (37.3%)	21 (40.4%)
Exponential Decay	5 (8.5%)	10 (19.2%)
Consistently Falling	21 (35.6%)	12 (23.1%)
Consistently Rising	7 (11.9%)	7 (13.5%)
High Background	4 (6.7%)	2 (3.8%)

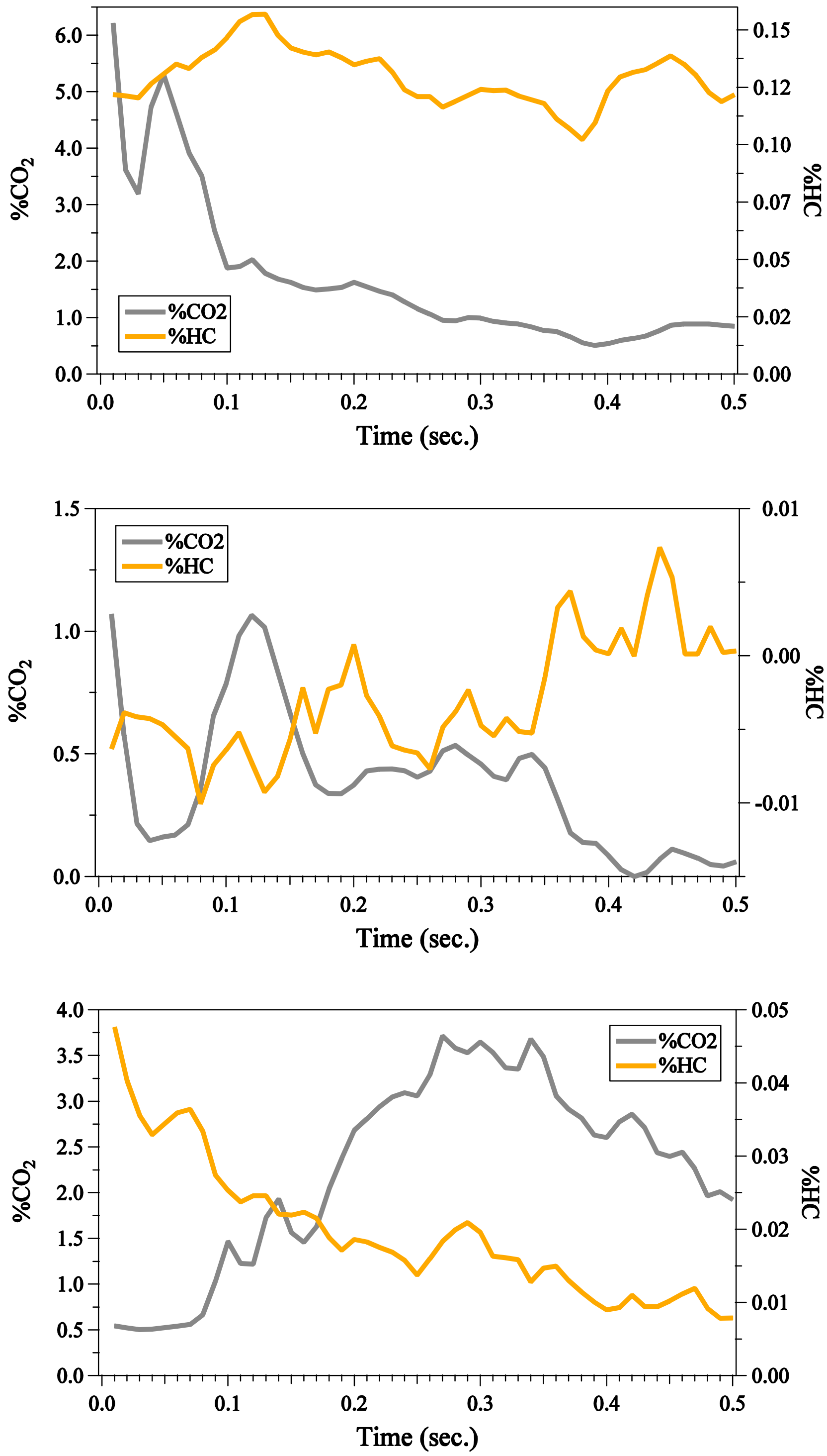

Figure 10. %CO_2 (left axis) and %HC (right axis) emissions versus time for three suspected evaporative emissions plume shapes. The top graph shows an example of a high background plume shape, the middle graph a consistently rising HC plume and the bottom graph a consistently falling plume that is not exponential.

Discussion

The vehicle measurements that were suspected of having evaporative emissions were visually classified into three categories from most likely to less likely. Table 4 provides the distribution for the three levels for the 2013 and 2015 data sets. All of the vehicles in the three categories possess emission patterns that suggest the presence of evaporative emissions. The subjective determination of probability levels is influenced by the magnitude of the change in HC emissions observed during the 0.5 second measurement in addition to the other metrics used. Table 6 shows the average, minimum and maximum Δ%HC values by probability rank and by measurement year. In general, but not for every case, the higher the probability rank the larger the Δ%HC change.

Table 6. Average, Minimum and Maximum Δ%HC by Probability Rank and Measurement Year.

Measurement Year	Probability Rank	Average Δ%HC	Minimum Δ%HC	Maximum Δ%HC
2013	3	0.35	0.02	2.20
	2	0.04	0.01	0.49
	1	0.045	0.009	0.21
2015	3	0.33	0.035	2.46
	2	0.11	0.024	0.38
	1	0.08	0.006	0.52

Appendix B gives a detailed listing of the 59 vehicles suspected from the 2013 measurements and the 52 vehicles suspected from the 2015 measurements arranged by probability rank (highest to lowest). Vehicles with repeat measurements have been grouped together in its highest probability ranking, so that if a vehicle was identified with a probability rank of 2 and 1, both measurements have been included in the probability rank 2 appendix listing. Vehicles with an "Unknown" license number comprise vehicles that were either not successfully measured, had out of state plates or had no visible plate. The vehicles in each of the probability rankings from the highest to the lowest will be briefly discussed.

Probability Rank 3 Vehicles (Highest)

There were 7 vehicle measurements ranked in the highest category from the 2013 database and 11 vehicles included from the 2015 database (see Appendix B for details). Two additional vehicle repeat measurements from the 2013 data are included in the Appendix B listing which received a lower score bringing the total for 2013 to 9 measurements. The 2013 vehicles includes 1 from the 1970's, 5 (3 original with 2 repeats) from the 1990's and 3 from the 2000's. One of the 1990 vehicles with repeat measurement emissions is shown in Figure 11. $\%CO_2$ (left axis) and %HC (right axis) emissions are plotted against time for this 1994 SUV. The measurement in

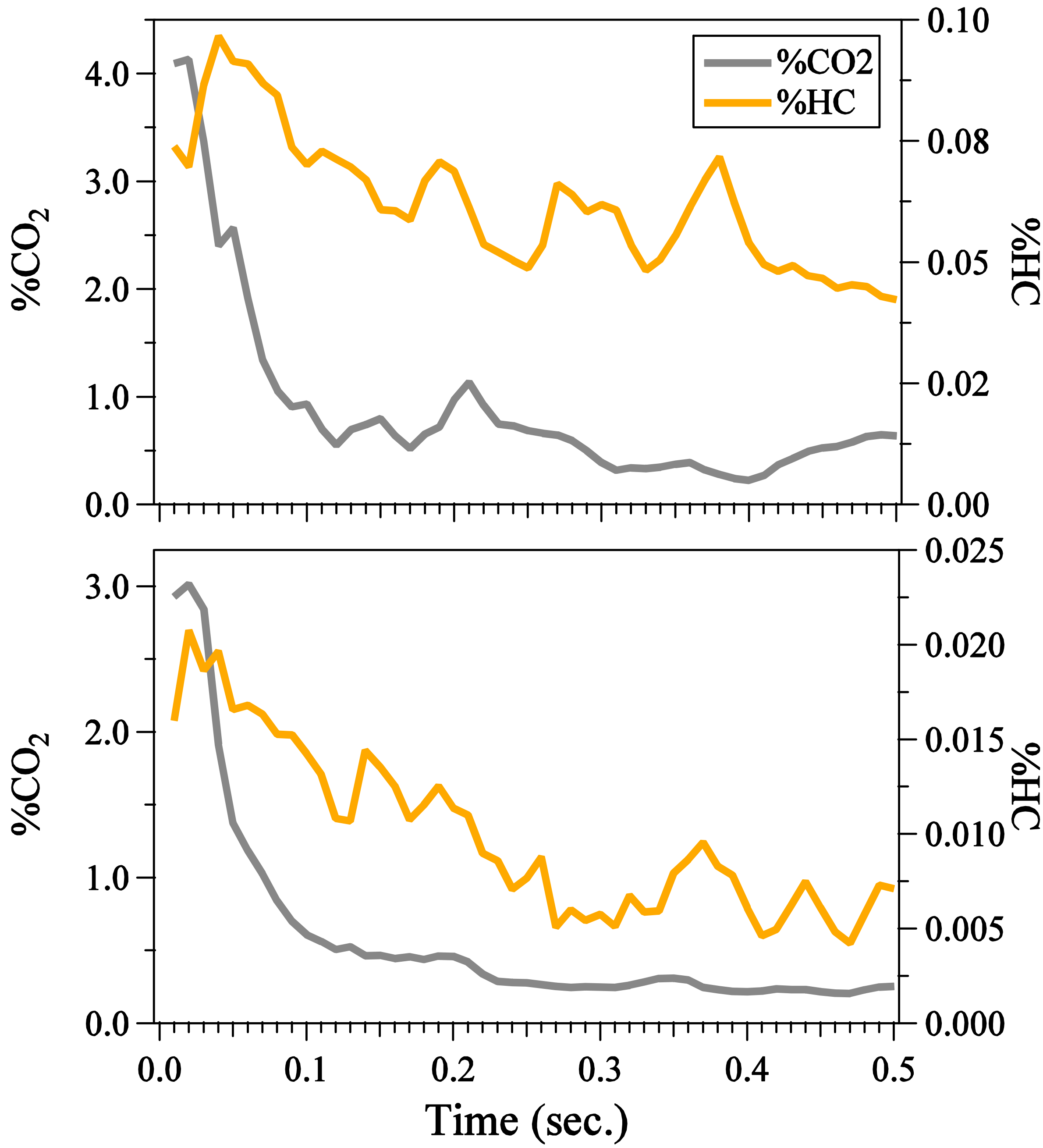

Figure 11. %CO_2 (left axis) and %HC (right axis) versus time for a 1994 SUV measured on May 4, 2013 (top graph) and April 29, 2013 (bottom graph). The top measurement (probability ranking of 3) was found using the EI23 screening with an EI23_bin value of 3. The bottom measurement was included because of multiple measurements and has a probability ranking of 1. Both display a similar pattern with the top panel having a larger Δ%HC.

the top panel was originally classified as a probability 3 candidate with the repeat measurement in the bottom panel showing the lower probability 1 measurement. Both measurements reveal a similar pattern of steadily falling HC emissions after the car with little correlation to the observed exponential decay of the CO_2 plume. The different probability category is influenced by the EI23 bin ranking (3 for the top and 1 for the bottom) and the increased size of the HC emissions plume in the top panel which corresponds with the probability 3 ranking.

The 2015 probability 3 vehicles include 3 vehicle measurements with unmatched plates, however, 1 is a very old antique car which has been identified as a 1936 coupe and 1 is an out of state plated compact sedan which is a mid-2000's manufactured vehicle. For the eight vehicles with known model years there is 1 from the 60's (the 1967 sedan, see Figure 4), 1 from the 70's, 2 from the 90's and 4 from the 2000's. Figure 12 are plots for the mid-2000's compact with the top graph showing the %CO_2 (left axis) and %HC (right axis) emissions plotted versus time and the bottom graph showing the resultant %HC versus %CO_2 correlation graph and the least squares best fit line to those points. The vehicle was identified with the EI23 screening algorithm and was placed in EI23 bin 6. The plume correlation observed is strictly due to both gases being high at the beginning and low at the end.

The final vehicle to be discussed for the probability 3 vehicles is shown in Figure 13. The 1936 coupe (identified by a colleague) that was measured during the 2015 campaign but was not originally identified because of the lack of a visible plate. It is expected that this vehicle will have a vented tank and therefore should be an evaporative emitter and was identified through the EI23 screening and assigned to bin 4. This HC plume shows an elevated background with a definite tailpipe signal on top of the background which at times correlates well with the CO_2 plume. Though note that the time registration is not always accurate.

Probability Rank 2 Vehicles (Middle)

The probability ranking of 2 contains the largest combined number of vehicles with 47 originally identified in total, 33 from the 2013 data set and 14 from the 2015 data set. However, the Appendix B listing contains a total of 52 measurements for both years with the 2013 listing having 36 measurements (4 additional repeat vehicles and one measurement that was moved to the probability 3 listing) and the 2015 listing having 16 measurements (2 additional repeat vehicle measurements). Including the repeat vehicle measurements in the 2013 listing there are 6 with unknown model year status, 9 that are 2010 and newer, 18 from the 2000 to 2009 model year grouping and 3 from the 90's. Also including the repeat vehicle measurements the listing for the 2015 data set has 6 with unknown model year status, 1 from the 2000 to 2009 group, 7 from the 90's, 1 from the 80's and 1 from the 70's.

Figure 14 contains a three panel graph of measurements collected in 2015 on a 1998 pickup over three different days. Each graph is %CO_2 (left axis) and %HC (right axis) versus time. The top panel was screened and assigned an EI23 bin of 7 and was scored as a probability 2 evaporative

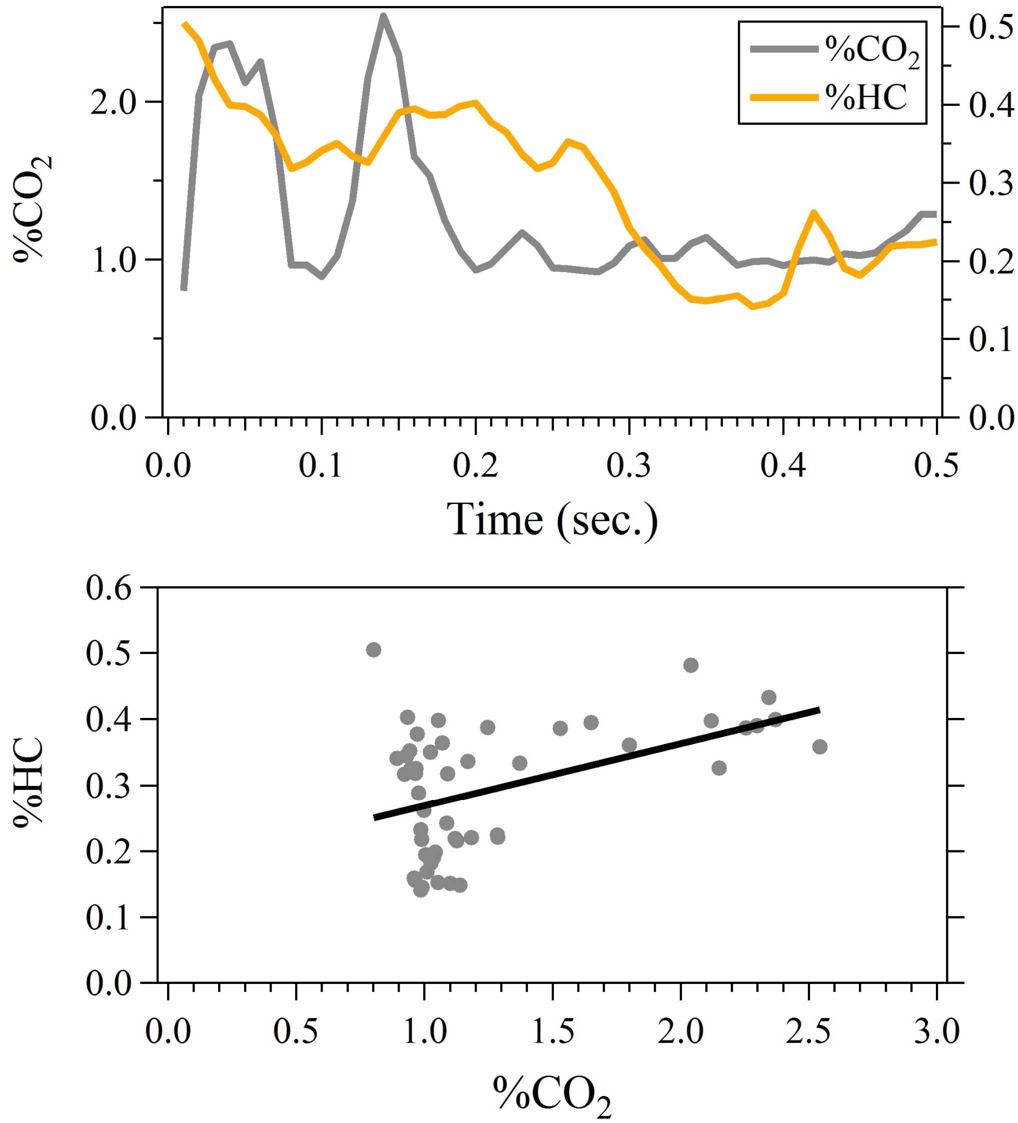

Figure 12. $\%CO_2$ (left axis) and %HC (right axis) emissions versus time (top panel) and %HC versus $\%CO_2$ correlation graph (bottom panel) for a mid-2000's compact sedan measured in 2015.

emitter. The middle panel was assigned an EI23 bin of 4 and was individually scored as a probability 1 evaporative emitter. The bottom panel was included as a repeat measurement as its EI23 bin was only a 1 but because it displays the same anti-correlation pattern between the CO_2 and HC emissions it was scored a probability 1 evaporative emitter. Collectively this vehicle likely belongs in the category 3 as "Most Likely" due to the multiple suspicious measurements but the data was graded individually and is listed in its highest individual ranking which was a 2.

The newest models tend to show smaller HC emission changes but the changes do appear to be real and several vehicles newer than 2010 were classified as having a probability of 2 (middle

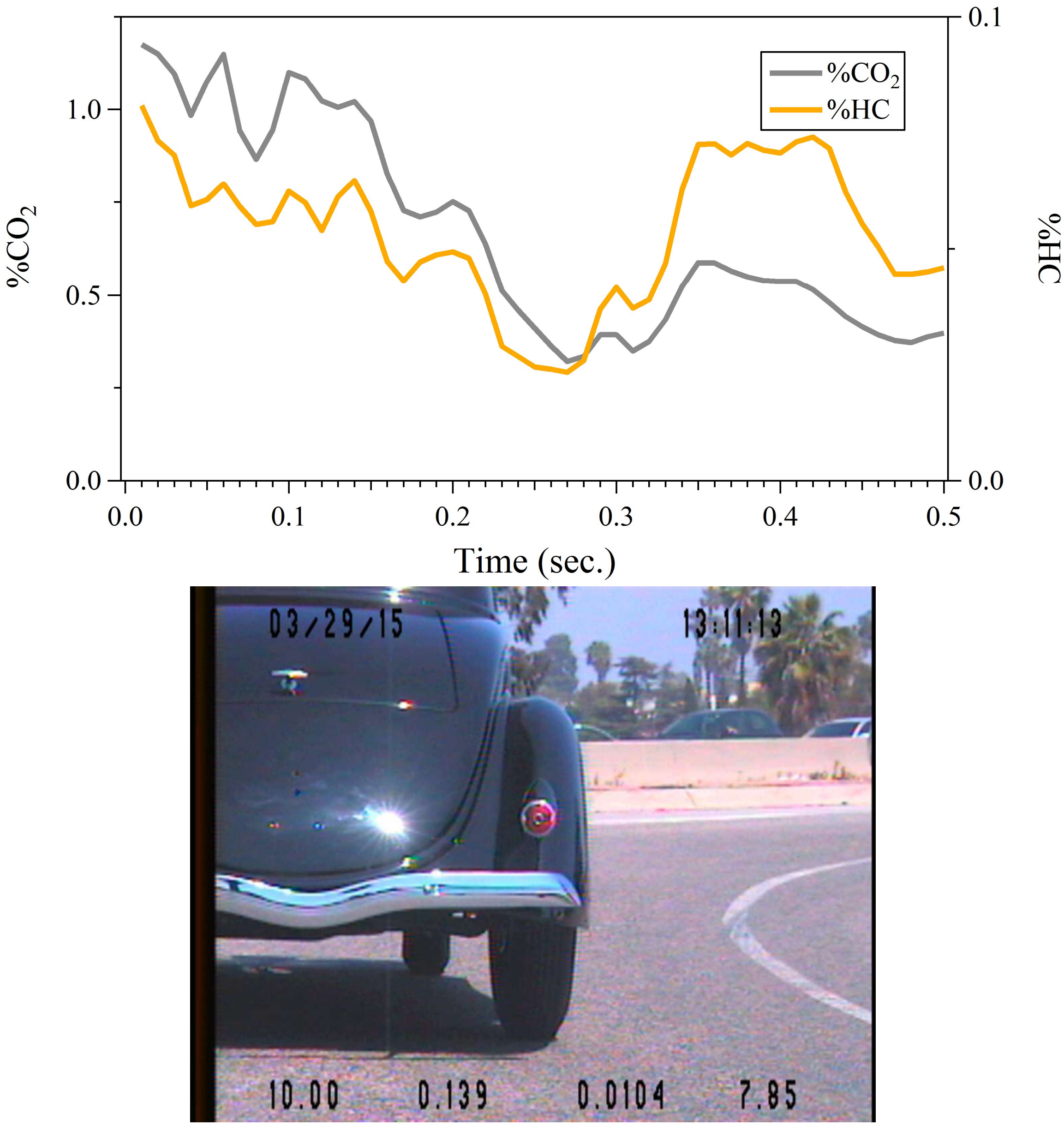

Figure 13. 1936 coupe identified with the EI23 screening from the 2015 data set and assigned to bin 4. The top graph shows the $\%CO_2$ (left axis) and %HC (right axis) versus time for the measurement and the bottom is the plate capture picture of the vehicle.

value) of evaporative emissions. Figure 15 is a two panel plot of $\%CO_2$ (left axis) and %HC (right axis) versus time for the half second measurement. The top graph is from a 2011 sedan and the bottom graph is a 2013 sedan. The changes in HC emissions are small (less than 200ppm over the half second) but are consistent for both vehicles and were therefore not excluded as part of the screening. As previously mentioned the size of the HC emissions measured depends on a number of factors such as placement and type (vapors or liquid).

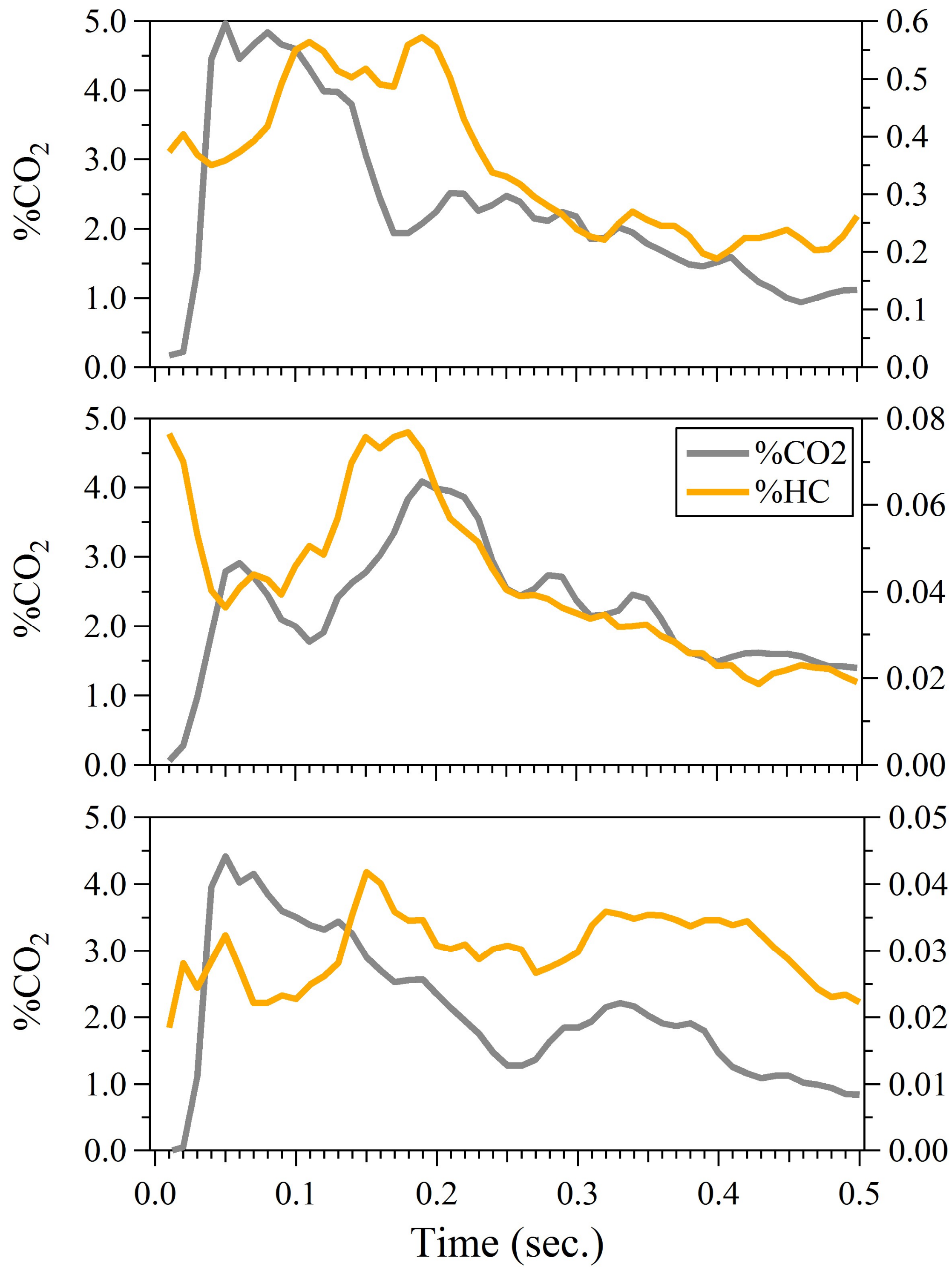

Figure 14. A series of three measurements collected on a 1998 pickup in 2015. $\%CO_2$ (left axis) and %HC (right axis) are plotted against time. The top graph was assigned an EI23 bin of 7, the middle a bin of 4 and the bottom a bin of 1. All display an anti-correlation pattern for all three measurements.

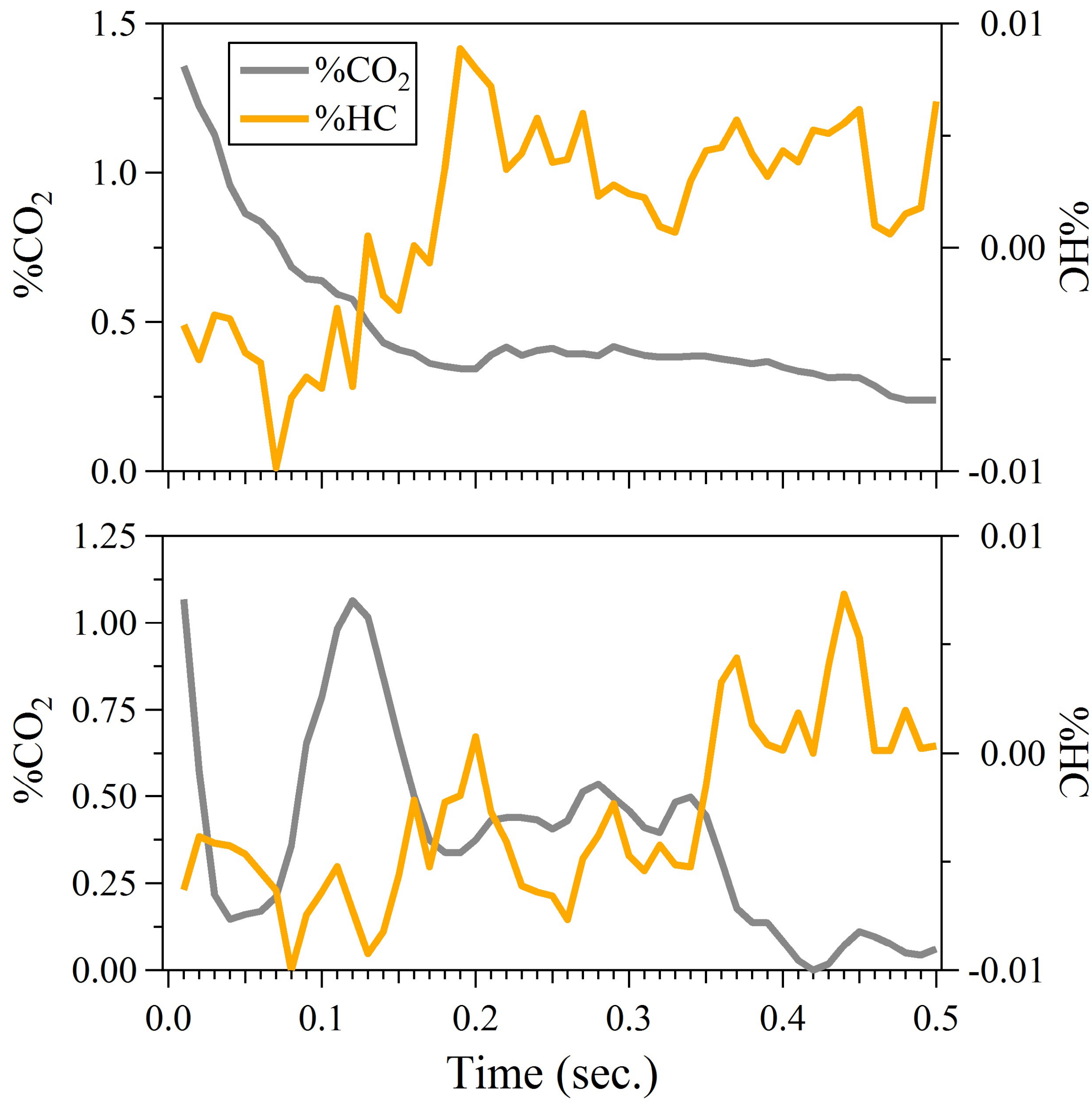

Figure 15. $\%CO_2$ (left axis) and %HC (right axis) versus time for a 2011 sedan (top graph) and a 2013 sedan designated as a probability 2 evaporative emitter. Both have small (~Δ 200ppm) but consistent HC emissions which are rising over time and that are not correlated to CO_2.

Probability Rank 1 Vehicles (Lowest)

The probability ranking of 1 contains a combined number of 39 vehicles in total, 14 identified from the 2013 data set and 25 from the 2015 data set. This category contains the largest number of measurements for the 2015 data set. Appendix B contains a complete listing of all the vehicles with the 2013 having 1 additional repeat vehicle measurement and the 2015 listing containing 5 repeat vehicle measurements. Including the repeat vehicle measurements, from the 2013 data set there are 5 with unknown model year status, 4 from the 2000 to 2009 model year grouping, 4 from the 90's and one from the 80's. Including the repeat vehicle measurements the vehicles identified from the 2015 data set has 7 with unknown model year status, 6 newer than 2010, 7 from the 2000 to 2009 group, 3 from the 90's, 1 from the 80's and 1 from the 70's.

This grouping contains the newest model year vehicles with five measurements on two 2015 models (both SUV's with 3 and 2 measurements each respectively). Each vehicle has one measurement that was originally flagged and for each vehicle it is a consistently rising HC signal after the vehicle. For the additional repeat measurements, which have been added to the group, both have an additional measurement which is largely indistinguishable from instrument noise.

In the Unknown category for measurement year 2015 there are two garbage trucks, likely natural gas powered. What is interesting about these measurements is that the HC signal occurs prior to the tailpipe emissions showing up in the reading. Figure 16 plots the %CO_2 (left axis) and %HC (right axis) versus time for one of the garbage truck measurements. You will notice that there is a significant HC signal that shows up around 0.1 seconds which is well before the tailpipe exhaust emissions show up at 0.3 seconds. Again it is unknown if these trucks are compressed or liquefied natural gas as both types are used in the basin and the type cannot be determined from the plate photograph. If liquefied the leak discovered is likely from the dewar as it is vented directly to the atmosphere to allow the liquefied methane to boil off if pressures become too great, which means it is really not a leak but a design feature in that case.

Conclusions

In the spring of 2013 and 2015 the University of Denver collected on-road emission measurements of an in-use fleet that uses the La Brea Ave. and I-10 interchange in West Los Angeles as part of a California Air Resources Board sponsored project. This resulted in two data sets, the first collected between Saturday April 27 through Saturday May 4, 2013 with 33,807 attempted measurements and 27,247 valid and registration matched records. The second set was collected between Saturday March 28 and Friday April 3, 2015 with 27,413 attempted measurements and 22,124 valid and registration matched records. In addition to the fuel specific emission data, the high frequency data which consists of 50 individual voltage and/or emissions data points collected at 100 Hz over the one half second emissions measurement, was also collected for each attempted measurement. These high frequency files contain millisecond level emissions absorption data for each channel and can be used to analyze the changes in an individual species emissions measurement as a function of time.

The high frequency data files were screened for the presence of non-tailpipe hydrocarbons using an evaporative emissions index (EI23) developed by the Eastern Research Group in cooperation

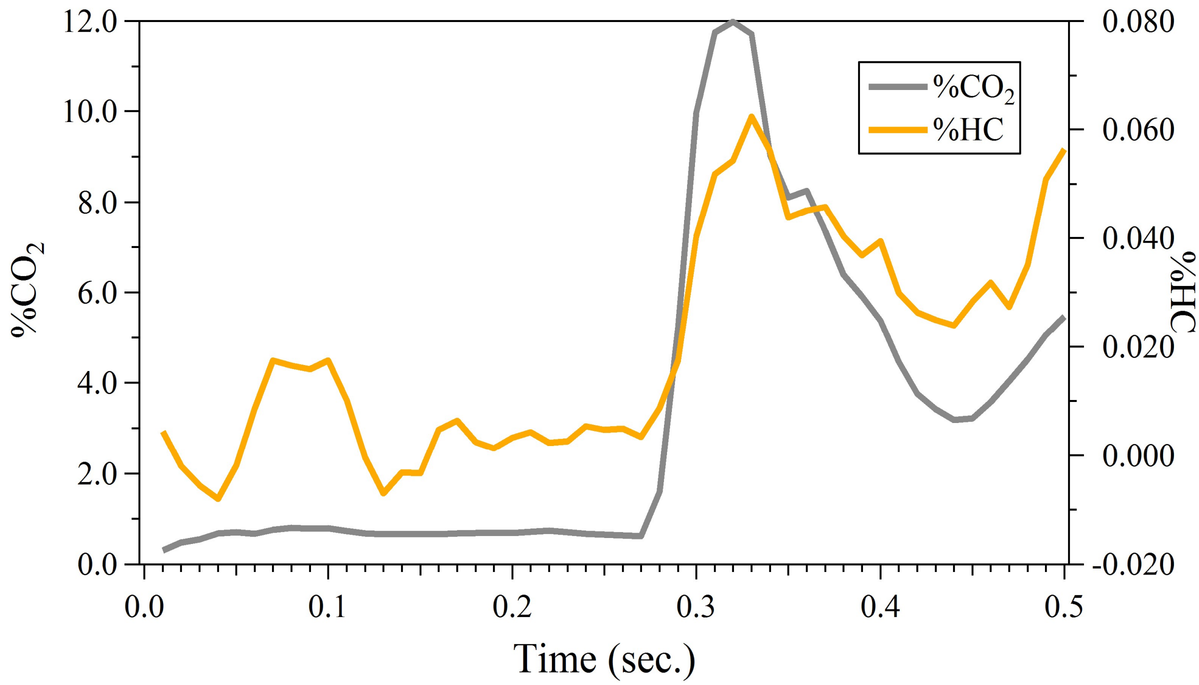

Figure 16. $\%CO_2$ (left axis) and %HC (right axis) versus time for an unidentified garbage truck from the 2015 data set with a probability rank of 1. This truck is believed to be powered by natural gas and the HC signal at 0.1 seconds is likely a methane leak that shows up before the tailpipe exhaust does at 0.3 seconds.

with the Colorado Department of Public Health and Environment and several of FEAT's additional quality assurance metrics. The screening resulted in a list of measurements for each year's data set that were considered to potentially have non-tailpipe HC emissions. All of these files were graphically screened and either rejected or assigned a probability rank of 1 to 3 with 1 being less likely but cannot ruled out to 3 the most likely to exhibit evaporative emissions. If a vehicle is included in the probability rankings the database was searched for any additional emissions measurements on that vehicle and if found these were also included in the final listing. This process generated a final list that contained 59 measurements (39 unique vehicles with 9 additional measurements with unknown model year) from the 2013 data set (0.17% of the attempts) and 52 measurements (28 unique vehicles with 15 additional measurements with unknown model year) from the 2015 data set (0.19% of the attempted measurements).

For the 59 measurements from the 2013 data set 9 (15.3%) were model year 2010 and newer (0.13% of that age group), 25 (42.4%) were model years 2000 to 2009 (0.16% of that age group), 12 (20.3%) were model years 1990 to 1999 (0.26% of that age group), 6 (10.2%) were older than 1990 (1.5% of that age group) and 11 (18.6%) measurements had an unknown model year (0.17% of that group). For comparison the 2013 fleet measured at the La Brea Ave site had 25% of the valid measurements collected from 2010 and newer vehicles, 56.5% from 2000 to 2009 vehicles, 17% from 1990 to 1999 vehicles, 1.5% from vehicles older than 1990 and the unknown vehicles accounted for 19.6% of the 33,807 attempted measurements. The evaporative emissions probability evaluations and rankings assigned 39 of the 59 measurements (66%) to the two highest probability classes indicating a fair level of certainty that the measurements include non-tailpipe HC emissions.

For the 52 measurements from the 2015 data set 6 (11.5%) were model year 2010 and newer (0.07% of that age group), 12 (23.1%) were model years 2000 to 2009 (0.11% of that age group), 12 (23.1%) were model years 1990 to 1999 (0.48% of that age group), 6 (11.5%) were older than 1990 (3.2% of that age group) and 16 (30.8%) measurement had an unknown model year (0.3% of that group). For comparison the 2015 fleet measured at the La Brea Ave site had 40.2% of the valid measurements collected from 2010 and newer vehicles, 47.7% from 2000 to 2009 vehicles, 11.3% from 1990 to 1999 vehicles, 0.8% from vehicles older than 1990 and the unknown vehicles accounted for 31% of the 27,413 attempted measurements. The evaporative emissions probability evaluations and rankings assigned 24 of the 52 measurements (46%) to the two highest probability classes.

Because the probability rankings are entirely circumstantial, one conclusion of this survey is that even with the assumption that all of the vehicles suspected of having non-tailpipe HC emissions do in fact have evaporative or liquid fuel leaks, which is the extreme assumption, the overall number of vehicles found is very small (<~0.2% of the passing fleet for each year). Several vehicles were identified, which likely provides proof of concept that the screening tools can find non-tailpipe HC emissions. Because the high frequency data has not been routinely collected it is unfortunately not possible to screen any older data sets to establish an evaporative emissions trend, however, it is possible to incorporate the EI23 index calculations into the FEAT software which would allow these evaluations to be performed in the future.

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Appendix A: Sample Image of CSV High Frequency FEAT File for the 1967 Sedan

Date	Time	Pic_name	vNorms	Seconds	vREF	vCO	vCO2	vHC	pCO	pCO2	pHC	pNO	NO_err	pSO2	SO2_err	pNH3	NH3_err	pNO2	NO2_err	CO	CO_flag	CO2	CO2_flag	HC	HC_flag	NO	NO_flag	SO2	SO2_flag	NH3	NH3_flag	NO2	NO2_flag	Speed	Speed_flag
4/1/2015	13:26:34	1132634A.jpg	4.531	0.01	4.51	4.414	4.664	2.728	1.2924	2.0436	2.57729	0.01124	0.00981	0.00586	0.00252	0.00402	0.00316	0.00318	0.00089	3.4263	V	12.2177	V	1.2126	X	0.05879	V	0.00486	V	0.00794	V	0.00284	V	16.5	V
			4.755	0.02	4.514	4.429	4.724	2.697	1.2277	1.8373	2.65545	0.0107	0.00948	0.006	0.00244	0.00403	0.00305	0.00317	0.00075	0.15		0.233		0.8963		0.00189		0.00182		0.00164		0.00134		1.929	
			5.373	0.03	4.513	4.402	4.701	2.976	1.3775	1.9208	2.05221	0.01241	0.00801	0.005	0.00206	0.00509	0.00258	0.0025	0.00064	1.6		0		1.51		1.62		1.62		0.93		1.1			
			4.611	0.04	4.506	4.36	4.595	3.378	1.5864	2.2891	1.35103	0.01461	0.00661	0.00461	0.0017	0.00517	0.00213	0.00244	0.00064																
				0.05	4.499	4.318	4.489	3.485	1.8071	2.6897	1.18591	0.01786	0.00593	0.00416	0.00152	0.00428	0.00191	0.00286	0.00061																
				0.06	4.507	4.305	4.441	3.548	1.941	2.9263	1.10603	0.01855	0.00581	0.0041	0.00149	0.00473	0.00187	0.0025	0.00065																
				0.07	4.51	4.283	4.368	3.609	2.1173	3.2659	1.02606	0.02263	0.00539	0.00361	0.00138	0.00428	0.00173	0.00287	0.00059																
				0.08	4.513	4.262	4.295	3.6	2.291	3.6241	1.04193	0.0247	0.00543	0.00355	0.0014	0.00521	0.00175	0.00232	0.00057																
				0.09	4.504	4.243	4.249	3.689	2.3683	3.809	0.91567	0.0268	0.00487	0.00347	0.00125	0.00394	0.00157	0.00204	0.00049																
				0.1	4.507	4.242	4.243	3.834	2.391	3.8507	0.7413	0.02757	0.00412	0.00276	0.00106	0.00328	0.00133	0.00291	0.00068																
				0.11	4.498	4.207	4.172	3.833	2.6076	4.1754	0.73437	0.03114	0.00433	0.00286	0.00111	0.00378	0.00139	0.00232	0.00075																
				0.12	4.492	4.205	4.152	3.937	2.5683	4.2486	0.60858	0.02979	0.00394	0.00271	0.00101	0.00335	0.00127	0.0028	0.00057																
				0.13	4.508	4.27	4.3	3.981	2.1943	3.5747	0.57516	0.02229	0.00359	0.00261	0.00092	0.00317	0.00116	0.0016	0.00053																
				0.14	4.509	4.315	4.433	4.002	1.8939	2.971	0.55445	0.02046	0.00331	0.00215	0.00085	0.00325	0.00107	0.00198	0.00068																
				0.15	4.511	4.308	4.422	4.114	1.95	3.0288	0.43757	0.02304	0.00286	0.00183	0.00074	0.00266	0.00092	0.00108	0.00035																
				0.16	4.5	4.288	4.408	4.152	2.0124	3.0419	0.38927	0.02147	0.00288	0.00188	0.00074	0.00293	0.00093	0.0023	0.0007																
				0.17	4.498	4.308	4.487	4.19	1.867	2.6935	0.35001	0.01793	0.00254	0.00157	0.00065	0.00256	0.00082	0.00149	0.00034																
				0.18	4.502	4.335	4.564	4.184	1.7138	2.3943	0.35864	0.01538	0.00247	0.00161	0.00063	0.00235	0.00079	0.00135	0.00035																
				0.19	4.509	4.362	4.622	4.234	1.5911	2.2001	0.31652	0.01512	0.00211	0.00145	0.00054	0.00181	0.00068	0.00065	0.00034																
				0.2	4.497	4.345	4.593	4.209	1.623	2.2636	0.32966	0.01733	0.00223	0.00146	0.00057	0.00176	0.00072	0.00158	0.00046																
				0.21	4.505	4.336	4.554	4.215	1.7254	2.4453	0.33112	0.01867	0.00226	0.00142	0.00058	0.00208	0.00073	0.0015	0.00045																
				0.22	4.506	4.326	4.516	4.252	1.7985	2.6051	0.29641	0.01881	0.00205	0.00125	0.00053	0.00192	0.00066	0.00181	0.00051																
				0.23	4.501	4.339	4.548	4.321	1.6844	2.4548	0.22673	0.01686	0.0018	0.00114	0.00046	0.00148	0.00058	0.0015	0.00046																
				0.24	4.502	4.353	4.619	4.281	1.6009	2.1824	0.26482	0.01508	0.00198	0.00121	0.00051	0.00199	0.00064	0.00193	0.00049																
				0.25	4.501	4.345	4.641	4.137	1.6456	2.0948	0.40482	0.01286	0.00277	0.00171	0.00071	0.00235	0.00089	0.00175	0.00049																
				0.26	4.482	4.317	4.625	4.082	1.708	2.0786	0.44386	0.01236	0.00294	0.00192	0.00076	0.00259	0.00095	0.00114	0.00048																
				0.27	4.472	4.301	4.606	4.119	1.7505	2.1155	0.39634	0.01404	0.00273	0.00164	0.0007	0.00239	0.00088	0.0012	0.00038																
				0.28	4.481	4.308	4.608	4.139	1.7602	2.1418	0.38452	0.01342	0.00265	0.00167	0.00068	0.00225	0.00085	0.00154	0.00049																
				0.29	4.482	4.319	4.629	4.218	1.6937	2.0632	0.30712	0.01362	0.00223	0.00142	0.00057	0.00193	0.00072	0.00123	0.00043																
				0.3	4.486	4.324	4.628	4.224	1.6871	2.0851	0.3056	0.01307	0.0023	0.00135	0.00059	0.00212	0.00074	0.00122	0.00047																
				0.31	4.486	4.329	4.651	4.223	1.6519	2.0004	0.30591	0.01291	0.0023	0.0016	0.00059	0.00188	0.00074	0.00116	0.00048																
				0.32	4.485	4.33	4.655	4.176	1.6452	1.9795	0.35114	0.01232	0.00257	0.00138	0.00066	0.00244	0.00083	0.00138	0.00045																
				0.33	4.489	4.343	4.683	4.116	1.5913	1.8955	0.41545	0.01107	0.00297	0.00183	0.00076	0.00258	0.00096	0.00164	0.00043																
				0.34	4.498	4.362	4.725	4.105	1.5216	1.7764	0.4344	0.00965	0.00293	0.00195	0.00075	0.00319	0.00094	0.00171	0.00049																
				0.35	4.506	4.373	4.743	4.155	1.5051	1.7444	0.39157	0.00978	0.0026	0.00158	0.00067	0.00236	0.00084	0.0021	0.00056																
				0.36	4.503	4.362	4.712	4.223	1.5567	1.8439	0.32185	0.01222	0.00233	0.00153	0.0006	0.0019	0.00075	0.00163	0.00061																
				0.37	4.502	4.35	4.673	4.256	1.622	1.9795	0.28931	0.01392	0.00223	0.0013	0.00057	0.00188	0.00072	0.00214	0.00048																
				0.38	4.504	4.35	4.657	4.288	1.6342	2.0444	0.26053	0.01422	0.00214	0.00136	0.00055	0.0017	0.00069	0.00172	0.00049																
				0.39	4.496	4.354	4.661	4.306	1.5597	1.9991	0.23631	0.01341	0.00197	0.00126	0.00051	0.00155	0.00063	0.00167	0.00051																
				0.4	4.496	4.377	4.711	4.338	1.4236	1.818	0.20691	0.01182	0.00169	0.00104	0.00044	0.0014	0.00055	0.00141	0.00041																
				0.41	4.497	4.385	4.748	4.337	1.3862	1.6929	0.20874	0.0109	0.00176	0.00106	0.00045	0.00149	0.00057	0.00127	0.00045																
				0.42	4.493	4.376	4.742	4.337	1.416	1.6981	0.20574	0.01069	0.00178	0.00105	0.00046	0.00157	0.00057	0.00099	0.00039																
				0.43	4.495	4.376	4.749	4.348	1.4239	1.6815	0.19662	0.01079	0.00172	0.00095	0.00044	0.00152	0.00055	0.00074	0.00034																
				0.44	4.485	4.353	4.709	4.306	1.5082	1.7886	0.22682	0.01169	0.00203	0.00133	0.00052	0.00167	0.00065	0.00163	0.00044																
				0.45	4.486	4.352	4.693	4.299	1.5131	1.8457	0.23401	0.01137	0.00205	0.00124	0.00053	0.00156	0.00066	0.00227	0.00056																
				0.46	4.498	4.372	4.721	4.328	1.4641	1.7913	0.21814	0.01113	0.00189	0.00133	0.00049	0.00175	0.00061	0.00191	0.00059																
				0.47	4.498	4.379	4.739	4.323	1.4235	1.7277	0.22208	0.01075	0.00192	0.0012	0.00049	0.00138	0.00062	0.00219	0.00052																
				0.48	4.498	4.394	4.766	4.332	1.3376	1.6324	0.21429	0.00974	0.00183	0.00106	0.00047	0.00115	0.00059	0.00241	0.00061																
				0.49	4.505	4.418	4.806	4.354	1.2391	1.5236	0.20001	0.00877	0.00157	0.00096	0.0004	0.00098	0.0005	0.00245	0.00067																
				0.5	4.515	4.438	4.851	4.351	1.1879	1.4068	0.21187	0.00782	0.0017	0.0011	0.00044	0.00118	0.00055	0.00246	0.00069																

Appendix A (cont): Infrared Voltages and Calculated Percent Exhaust Concentrations for the 1967 Sedan

vNorms	Seconds	vREF	vCO	vCO2	vHC	%CO	%CO2	%HC
4.531	0.01	4.51	4.414	4.664	2.728	1.2924	2.0436	2.57729
4.755	0.02	4.514	4.429	4.724	2.697	1.2277	1.8373	2.65545
5.373	0.03	4.513	4.402	4.701	2.976	1.3775	1.9208	2.05221
4.611	0.04	4.506	4.36	4.595	3.378	1.5864	2.2891	1.35103
	0.05	4.499	4.318	4.489	3.485	1.8071	2.6897	1.18591
	0.06	4.507	4.305	4.441	3.548	1.941	2.9263	1.10603
	0.07	4.51	4.283	4.368	3.609	2.1173	3.2659	1.02606
	0.08	4.513	4.262	4.295	3.6	2.291	3.6241	1.04193
	0.09	4.504	4.243	4.249	3.689	2.3683	3.809	0.91567
	0.1	4.507	4.242	4.243	3.834	2.391	3.8507	0.7413
	0.11	4.498	4.207	4.172	3.833	2.6076	4.1754	0.73437
	0.12	4.492	4.205	4.152	3.937	2.5683	4.2486	0.60858
	0.13	4.508	4.27	4.3	3.981	2.1943	3.5747	0.57516
	0.14	4.509	4.315	4.433	4.002	1.8939	2.971	0.55445
	0.15	4.511	4.308	4.422	4.114	1.95	3.0288	0.43757
	0.16	4.5	4.288	4.408	4.152	2.0124	3.0419	0.38927
	0.17	4.498	4.308	4.487	4.19	1.867	2.6935	0.35001
	0.18	4.502	4.335	4.564	4.184	1.7138	2.3943	0.35864
	0.19	4.509	4.362	4.622	4.234	1.5911	2.2001	0.31652
	0.2	4.497	4.345	4.593	4.209	1.623	2.2636	0.32966
	0.21	4.505	4.336	4.554	4.215	1.7254	2.4453	0.33112
	0.22	4.506	4.326	4.516	4.252	1.7985	2.6051	0.29641
	0.23	4.501	4.339	4.548	4.321	1.6844	2.4548	0.22673
	0.24	4.502	4.353	4.619	4.281	1.6009	2.1824	0.26482
	0.25	4.501	4.345	4.641	4.137	1.6456	2.0948	0.40482

Seconds	vREF	vCO	vCO2	vHC	%CO	%CO2	%HC
0.26	4.482	4.317	4.625	4.082	1.708	2.0786	3.0322
0.27	4.472	4.301	4.606	4.119	1.7505	2.1155	0.39634
0.28	4.481	4.308	4.608	4.139	1.7602	2.1418	0.38452
0.29	4.482	4.319	4.629	4.218	1.6937	2.0632	0.30712
0.3	4.486	4.324	4.628	4.224	1.6871	2.0851	0.3056
0.31	4.486	4.329	4.651	4.223	1.6519	2.0004	0.30591
0.32	4.485	4.33	4.655	4.176	1.6452	1.9795	0.35114
0.33	4.489	4.343	4.683	4.116	1.5913	1.8955	0.41545
0.34	4.498	4.362	4.725	4.105	1.5216	1.7764	0.4344
0.35	4.506	4.373	4.743	4.155	1.5051	1.7444	0.39157
0.36	4.503	4.362	4.712	4.223	1.5567	1.8439	0.32185
0.37	4.502	4.35	4.673	4.256	1.622	1.9795	0.28931
0.38	4.504	4.35	4.657	4.288	1.6342	2.0444	0.26053
0.39	4.496	4.354	4.661	4.306	1.5597	1.9991	0.23631
0.4	4.496	4.377	4.711	4.338	1.4236	1.818	0.20691
0.41	4.497	4.385	4.748	4.337	1.3862	1.6929	0.20874
0.42	4.493	4.376	4.742	4.337	1.416	1.6981	0.20574
0.43	4.495	4.376	4.749	4.348	1.4239	1.6815	0.19662
0.44	4.485	4.353	4.709	4.306	1.5082	1.7886	0.22682
0.45	4.486	4.352	4.693	4.299	1.5131	1.8457	0.23401
0.46	4.498	4.372	4.721	4.328	1.4641	1.7913	0.21814
0.47	4.498	4.379	4.739	4.323	1.4235	1.7277	0.22208
0.48	4.498	4.394	4.766	4.332	1.3376	1.6324	0.21429
0.49	4.505	4.418	4.806	4.354	1.2391	1.5236	0.20001
0.5	4.515	4.438	4.851	4.351	1.1879	1.4068	0.21187

Appendix A (cont): Ultraviolet Measured Species Calculated Percent Exhaust Concentrations for the 1967 sedan

Seconds	%NO	NO_err	%SO2	SO2_err	%NH3	NH3_err	%NO2	NO2_err
0.01	0.01124	0.00981	0.00586	0.00252	0.00402	0.00316	0.00318	0.00089
0.02	0.0107	0.00948	0.006	0.00244	0.00403	0.00305	0.00317	0.00075
0.03	0.01241	0.00801	0.005	0.00206	0.00509	0.00258	0.0025	0.00064
0.04	0.01461	0.00661	0.00461	0.0017	0.00517	0.00213	0.00244	0.00064
0.05	0.01786	0.00593	0.00416	0.00152	0.00428	0.00191	0.00286	0.00061
0.06	0.01855	0.00581	0.0041	0.00149	0.00473	0.00187	0.0025	0.00065
0.07	0.02263	0.00539	0.00361	0.00138	0.00428	0.00173	0.00287	0.00059
0.08	0.0247	0.00543	0.00355	0.0014	0.00521	0.00175	0.00232	0.00057
0.09	0.0268	0.00487	0.00347	0.00125	0.00394	0.00157	0.00204	0.00049
0.1	0.02757	0.00412	0.00276	0.00106	0.00328	0.00133	0.00291	0.00068
0.11	0.03114	0.00433	0.00286	0.00111	0.00378	0.00139	0.00232	0.00075
0.12	0.02979	0.00394	0.00271	0.00101	0.00335	0.00127	0.0028	0.00057
0.13	0.02229	0.00359	0.00261	0.00092	0.00317	0.00116	0.0016	0.00053
0.14	0.02046	0.00331	0.00215	0.00085	0.00325	0.00107	0.00198	0.00068
0.15	0.02304	0.00286	0.00183	0.00074	0.00266	0.00092	0.00108	0.00035
0.16	0.02147	0.00288	0.00188	0.00074	0.00293	0.00093	0.0023	0.0007
0.17	0.01793	0.00254	0.00157	0.00065	0.00256	0.00082	0.00149	0.00034
0.18	0.01538	0.00247	0.00161	0.00063	0.00235	0.00079	0.00135	0.00035
0.19	0.01512	0.00211	0.00145	0.00054	0.00181	0.00068	0.00065	0.00034
0.2	0.01733	0.00223	0.00146	0.00057	0.00176	0.00072	0.00158	0.00046
0.21	0.01867	0.00226	0.00142	0.00058	0.00208	0.00073	0.0015	0.00045
0.22	0.01881	0.00205	0.00125	0.00053	0.00192	0.00066	0.00181	0.00051
0.23	0.01686	0.0018	0.00114	0.00046	0.00148	0.00058	0.0015	0.00046
0.24	0.01508	0.00198	0.00121	0.00051	0.00199	0.00064	0.00193	0.00049
0.25	0.01286	0.00277	0.00171	0.00071	0.00235	0.00089	0.00175	0.00049

Seconds	%NO	NO_err	%SO2	SO2_err	%NH3	NH3_err	%NO2	NO2_err
0.26	0.01236	0.00294	0.00192	0.00076	0.00259	0.00095	0.00114	0.00048
0.27	0.01404	0.00273	0.00164	0.0007	0.00239	0.00088	0.0012	0.00038
0.28	0.01342	0.00265	0.00167	0.00068	0.00225	0.00085	0.00154	0.00049
0.29	0.01362	0.00223	0.00142	0.00057	0.00193	0.00072	0.00123	0.00043
0.3	0.01307	0.0023	0.00135	0.00059	0.00212	0.00074	0.00122	0.00047
0.31	0.01291	0.0023	0.0016	0.00059	0.00188	0.00074	0.00116	0.00048
0.32	0.01232	0.00257	0.00138	0.00066	0.00244	0.00083	0.00138	0.00045
0.33	0.01107	0.00297	0.00183	0.00076	0.00258	0.00096	0.00164	0.00043
0.34	0.00965	0.00293	0.00195	0.00075	0.00319	0.00094	0.00171	0.00049
0.35	0.00978	0.0026	0.00158	0.00067	0.00236	0.00084	0.0021	0.00056
0.36	0.01222	0.00233	0.00153	0.0006	0.0019	0.00075	0.00163	0.00061
0.37	0.01392	0.00223	0.0013	0.00057	0.00188	0.00072	0.00214	0.00048
0.38	0.01422	0.00214	0.00136	0.00055	0.0017	0.00069	0.00172	0.00049
0.39	0.01341	0.00197	0.00126	0.00051	0.00155	0.00063	0.00167	0.00051
0.4	0.01182	0.00169	0.00104	0.00044	0.0014	0.00055	0.00141	0.00041
0.41	0.0109	0.00176	0.00106	0.00045	0.00149	0.00057	0.00127	0.00045
0.42	0.01069	0.00178	0.00105	0.00046	0.00157	0.00057	0.00099	0.00039
0.43	0.01079	0.00172	0.00095	0.00044	0.00152	0.00055	0.00074	0.00034
0.44	0.01169	0.00203	0.00133	0.00052	0.00167	0.00065	0.00163	0.00044
0.45	0.01137	0.00205	0.00124	0.00053	0.00156	0.00066	0.00227	0.00056
0.46	0.01113	0.00189	0.00133	0.00049	0.00175	0.00061	0.00191	0.00059
0.47	0.01075	0.00192	0.0012	0.00049	0.00138	0.00062	0.00219	0.00052
0.48	0.00974	0.00183	0.00106	0.00047	0.00115	0.00059	0.00241	0.00061
0.49	0.00877	0.00157	0.00096	0.0004	0.00098	0.0005	0.00245	0.00067
0.5	0.00782	0.0017	0.0011	0.00044	0.00118	0.00055	0.00246	0.00069

Appendix A (cont): Calculated Results for the 1967 sedan

CO	CO_flag	CO2	CO2_flag	HC	HC_flag	NO	NO_flag	SO2	SO2_flag	NH3	NH3_flag	NO2	NO2_flag
3.4263	V	12.2177	V	1.2126	X	0.05879	V	0.00486	V	0.00794	V	0.00284	V
0.15		0.233		0.8963		0.00189		0.00182		0.00164		0.00134	
1.6		0		1.51		1.62		1.62		0.93		1.1	

Speed	Speed_flag
16.5	V
1.929	

Appendix B: Vehicle Information by Data Collection Year and Evaporative Emissions Probability.

Table B1. Listing of 2013 Vehicles Rated with the Highest Evaporative Emissions Probability of 3.

License	Date	Time	Year	Model	EI23 Value	EI23_bin	Leak Shape	Leak Probability
	5/4/2013	15:24:12	2005	UT	81	2	E	3
	5/1/2013	15:01:43	2005	PK	41	1	F	3
	5/3/2013	17:43:00	2003	4D	147	3	E	3
	5/2/2013	17:19:19	1995	VN	100	4	E	3
	4/29/2013	18:01:34	1995	VN	23	1	H	2
	5/4/2013	08:33:36	1994	4D	149	3	F	3
	4/29/2013	08:15:52	1994	4D	41	1	F	1
	5/3/2013	10:26:15	1991	PK	5898	8	A	3
	5/1/2013	14:25:57	1978	PK	186	4	A	3

Note: Shaded entries are repeat identified vehicles kept together with the highest probability

Leak Shape Definitions
A - Anti-correlated
E – Exponential decay
F – Consistently falling
R – Consistently rising
H – High background

Table B2. Listing of 2015 Vehicles Rated with the Highest Evaporative Emissions Probability of 3.

License	Date	Time	Year	Model	EI23 Value	EI23_bin	Leak Shape	Leak Probability
	4/3/2015	09:14:54	2005	VN	92	3	F	3
	4/3/2015	12:28:24	2005	VN	273	5	E	3
	3/28/2015	12:47:23	2004	2H	186	4	E	3
	3/30/2015	11:46:35	2004	4D	528	5	E	3
	3/28/2015	12:48:47	1997	SW	645	6	E	3
	3/30/2015	11:39:34	1997	UT	293	4	E	3
	3/31/2015	10:52:09	1979	VN	146	3	F	3
	4/1/2015	13:26:34	1967	4D	5731	8	E	3
Unknown	3/28/2015	11:14:18		VN	23	1	A	3
Unknown	3/29/2015	13:11:13	1936	CP	213	4	A	3
Unknown	4/3/2015	12:00:43	2006?	CP	1111	6	F	3

Table B3A. Listing of 2013 Vehicles Rated with the Mid-level Evaporative Emissions Probability of 2.

License	Date	Time	Year	Model	EI23 Value	EI23_bin	Leak Shape	Leak Probability
	4/28/2013	16:03:06	2013	4D	35	1	R	2
	5/3/2013	15:17:12	2013	4D	36	1	R	2
	4/29/2013	15:56:49	2012	SD	24	1	A	2
	4/27/2013	12:34:24	2011	4D	25	1	F	2
	4/29/2013	13:45:42	2011	4C	43	1	A	2
	5/1/2013	16:52:06	2011	4D	37	1	R	2
	5/3/2013	10:26:22	2011	4D	32	1	A	2
	5/4/2013	10:10:38	2011	4D	25	1	F	1
	4/27/2013	11:18:35	2010	4D	52	1	F	2
	4/29/2013	13:41:30	2009	4D	28	1	A	2
	4/30/2013	08:19:59	2007	SW	110	3	F	2
	5/4/2013	14:41:38	2006	UT	59	2	A	2
	4/28/2013	15:59:35	2004	4D	29	1	A	2
	5/1/2013	11:20:34	2003	VN	34	1	A	2
	4/29/2013	09:16:53	2002	UT	32	1	H	2
	5/3/2013	09:33:31	2002	UT	113	3	F	1
	4/30/2013	17:37:28	2002	SW	33	1	F	2
	4/30/2013	10:02:40	2001	4D	33	1	F	2
	5/3/2013	15:48:49	2001	4D	34	1	R	2
	4/30/2013	13:20:25	2001	4D	598	5	E	2
	4/30/2013	12:57:16	2001	VN	35	1	F	2
	5/2/2013	12:57:58	2001	VN	99	3	F	1
	5/3/2013	14:09:56	2001	SN	61	2	A	2
	4/28/2013	14:57:29	2000	4D	28	1	A	2
	4/30/2013	10:43:52	2000	4D	49	1	F	2
	5/1/2013	11:28:48	2000	4D	32	1	A	2
	5/2/2013	10:17:50	2000	4D	27	1	A	2

Table B3B. Listing of 2013 Vehicles Rated with the Mid-level Evaporative Emissions Probability of 2 (Continued).

License	Date	Time	Year	Model	EI23	EI23_bin	Leak Shape	Leak Probability
	4/28/2013	18:06:20	1998	CP	260	4	F	2
	5/3/2013	14:06:42	1998	SV	41	1	R	2
	4/30/2013	18:21:36	1998	SV	36	1	F	1
	4/29/2013	14:35:00			24	1	F	2
	4/30/2013	12:01:56			42	1	A	2
Unknown	4/28/2013	15:30:25			37	1	R	2
Unknown	4/28/2013	18:05:33			44	1	A	2
Unknown	4/29/2013	15:19:39			39	1	R	2
Unknown	5/4/2013	09:45:39			97	3	A	2

Table B4. Listing of 2015 Vehicles Rated with the Mid-level Evaporative Emissions Probability of 2.

License	Date	Time	Year	Model	EI23	EI23_bin	Leak Shape	Leak Probability
	4/2/2015	08:20:10	2003	4D	224	4	H	2
	3/28/2015	15:28:50	1999	SV	80	2	F	2
	3/30/2015	14:02:54	1999	SV	145	3	A	2
	3/30/2015	15:54:17	1999	4D	24	1	E	1
	3/28/2015	12:25:59	1998	PK	1619	7	A	2
	4/1/2015	09:01:37	1998	PK	246	4	A	1
	4/3/2015	07:52:52	1998	PK	54	1	A	1
	4/3/2015	14:45:49	1997	VN	128	3	F	2
	3/28/2015	16:43:27	1986	CP	174	5	A	2
	4/1/2015	06:55:13	1974	2D	952	5	E	2
Unknown	3/30/2015	09:19:08		WRK	541	6	R	2
Unknown	3/30/2015	11:56:30		PK	400	5	R	2
Unknown	3/31/2015	09:54:35		PK	392	5	R	2
Unknown	3/31/2015	13:59:51		PK	292	5	R	2
Unknown	3/31/2015	16:26:41		PK	31	1	F	2
Unknown	4/1/2015	12:29:30		UT	51	2	E	2

Table B5. Listing of 2013 Vehicles Rated with the Lowest Evaporative Emissions Probability of 1.

License	Date	Time	Year	Model	EI23 Value	EI23_bin	Leak Shape	Leak Probability
	5/1/2013	16:05:31	2004	2L	61	2	F	1
	5/2/2013	16:07:44	2004	2L	30	1	F	1
	4/28/2013	18:14:13	2002	CV	136	3	E	1
	5/1/2013	17:09:54	2000	4D	93	3	A	1
	4/29/2013	14:10:09	1999	LL	114	3	A	1
	4/27/2013	12:19:11	1996	SW	82	2	A	1
	5/2/2013	16:06:23	1995	PK	148	3	H	1
	4/28/2013	14:35:41	1990	CP	102	3	A	1
	5/1/2013	11:41:41	1989	PK	170	4	A	1
Unknown	4/29/2013	07:36:43			118	3	F	1
Unknown	4/29/2013	10:27:38			163	3	F	1
Unknown	5/1/2013	07:59:33			22	1	F	1
Unknown	5/1/2013	09:45:09			134	4	H	1
Unknown	5/2/2013	16:08:24			110	3	A	1

Table B6. Listing of 2015 Vehicles Rated with the Lowest Evaporative Emissions Probability of 1.

License	Date	Time	Year	Model	EI23 Value	EI23_bin	Leak Shape	Leak Probability
	3/28/2015	14:11:08	2015	4D	19	1	F	1
	3/30/2015	16:11:29	2015	4D	22	1	A	1
	4/3/2015	14:42:10	2015	4D	97	3	R	1
	4/2/2015	12:39:46	2015	UT	28	1	A	1
	4/3/2015	08:58:15	2015	UT	87	2	A	1
	4/3/2015	12:00:51	2014	4D	169	4	H	1
	3/31/2015	08:22:55	2008	2D	112	3	A	1
	3/28/2015	10:13:15	2004	VN	44	1	F	1
	4/3/2015	12:12:15	2003	VN	257	4	F	1
	4/2/2015	08:04:50	2000	SUV	152	3	A	1
	4/3/2015	08:11:44	2000	UT	12	1	A	1
	4/2/2015	13:22:33	2000	PK	47	1	A	1
	4/3/2015	12:51:35	2000	PK	135	3	R	1
	4/3/2015	14:46:52	1999	3C	400	5	E	1
	4/3/2015	10:49:10	1992	4D	119	3	A	1
	4/2/2015	16:12:38	1992	CP	163	3	A	1
	4/3/2015	12:38:25	1983	VN	339	5	A	1
	4/1/2015	14:46:53	1972	CP	198	5	F	1
Unknown	3/28/2015	13:06:53			113	3	A	1
Unknown	3/30/2015	14:01:42		GT	103	3	A	1
Unknown	3/31/2015	13:50:22		MC	17	1	F	1
Unknown	4/1/2015	10:12:06		MD	98	3	A	1
Unknown	4/1/2015	13:41:26		PK	345	5	F	1
Unknown	4/2/2015	08:40:13			9	1	R	1
Unknown	4/2/2015	10:50:19		GT	75	2	A	1