Investigation of Techniques for High Evaporative Emissions Vehicle Detection:

Denver Summer 2008 Pilot Study at Lipan Street Station - Report Version 5

United States Environmental Protection Agency

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Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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1.0 Introduction

EPA is currently developing the MOVES mobile sources inventory model. As part of that effort, EPA needs to be able to model the evaporative emissions of gasoline-powered on-road vehicles. Evaporative emissions occur when volatile components of gasoline are emitted or when raw gasoline leaks from the fuel system and the evaporative emissions control system. To meet the evaporative emissions modeling needs of the MOVES model, EPA, with the support of the Coordinating Research Council (CRC), is conducting studies to quantify fleet evaporative emissions. Ultimately, EPA would like to know the distribution of the mass of evaporative emissions across all vehicles in the fleet.

This project follows the CRC projects looking at aging enhanced evaporative emission vehicles. E-77 Pilot and E-77-2 were laboratory testing studies which looked at ethanol and RVP fuel effects as well as implanted leak effects on different laboratory test procedures to capture evaporative emissions. The implanted leak data indicates there may be significant effects from small leaks which can multiply in the inventory. This follow-on study can shed light on determining how often the leaks or “High Evap” are found in the fleet.

The effort begins by concentrating on the fleet vehicles that have high evaporative emissions (High Evaps). Initially, the objective is to find the percentage of High Evaps in the average fleet of on-road motor vehicle passenger cars and light-duty trucks. Our initial estimate is that High Evaps are 1% of the gasoline-fueled vehicles in the fleet. The remaining 99% of gasoline-fueled vehicles in the fleet also have evaporative emissions, but their evaporative emissions are low.

This work assignment was in support of the EPA’s National Portable Emissions Measurement System (PEMS) Deployment contract, and is intended to serve as a research project designed to develop methods to estimate evaporative emissions from light-duty vehicles. Innovative methods for measuring and testing real-world evaporative emissions were studied and procedures were developed, to allow the evaporative emission testing of a larger fleet at a later date.

In response to recommendations from the scientific community and interested stakeholders, EPA and the CRC are continuing to collect data designed to improve the methods and tools used to estimate evaporative emissions from the light-duty vehicle fleet. This data collection effort includes this pilot test program, which was designed to develop a quick, inexpensive test procedure to quantify evaporative emissions from the light-duty fleet in an Inspection Maintenance (IM) style setting. The target population for the methodological pilot was 50 to 100 vehicles in the Denver area. Vehicles were screened for high evaporative emissions using a newly developed technique, and then subjected to a battery of evaporative tests to determine both the effectiveness of each short test vis a vis the other proposed short tests, and the standard laboratory evaporative SHED test.

An important focus of this study was to investigate a number of options for measuring evaporative emissions. The primary requirements in the work assignment specified that the screening method be non-intrusive, quick, inexpensive, not require owner cooperation, and correlate well with accepted evaporative measurement techniques, i.e. Sealed Housing for Evaporative Determination (SHED) tests. Given these criteria, the method which appears to hold the most promise is use of remote-sensing devices (RSD).

1.1 Pilot Study Objectives

The goal of the project's initial effort is to estimate the percentage of high evaporative emissions vehicles in the on-road fleet of gasoline-powered passenger cars and light-duty trucks. Specifically, the primary question is:

What fraction of the fleet is made up of high evaporative emissions vehicles?

A large field effort to answer this primary question immediately encounters two problems. First, using the standard method to measure the evaporative emissions of vehicles is expensive, time-consuming, and requires special test facilities – specifically, a standard laboratory SHED. Second, there is not a clear, well-accepted definition of "high evaporative emitters." To make it practical to answer the primary question in a field testing environment, the primary question can be re-stated in terms of two secondary questions:

A. What field method can serve as a practical and substantially accurate method of identifying high-emitting evaporative emissions vehicles (High Evaps)?
B. What fraction of the fleet is made up of High Evaps as defined by the above field method?

The primary focus of this pilot study was to answer Question A. The primary focus of subsequent studies will be to answer Question B. In summary, the effort to determine the percentage of the fleet that is made up of High Evaps is made up of two studies:

1) **The Pilot Study –** The pilot study is the subject of this report. The data from the pilot study will be used to develop the methods, procedures, and design to be used in the main study. The conclusion of this pilot study was the development of a

detailed work plan for a larger study to be conducted in a non-IM area that would use the testing methodology identified in this pilot.

2) **The Main Study –** The main study is the large-scale field study and is the subject of a future work assignment to determine the fraction of High Evaps in the fleet. This kind of study could include the use of Remote Sensing Data (RSD) data from a large on-road program to estimate the fraction of high emitters in the fleet using the relationships developed in the pilot study.

The pilot study was conducted for the purposes of refining procedures for the main study. Specifically, the pilot study was to determine whether the portable SHED should be used in the main study as a field version of the standard laboratory SHED to measure hot-soak and gross liquid leak emissions. The following questions were investigated in the pilot study:

a) How well do the results of the portable SHED method agree with the results of the standard laboratory SHED method? What are the characteristics of portable SHED testing for measuring the evaporative emissions of vehicles in the field? This includes issues such as ease of implementation, cost, number of vehicles tested in the portable SHED per day, level of personnel necessary, and measurement precision and accuracy.

b) Can portable SHED measurements be performed in a way such that the results can be used to estimate the distribution of evaporative emissions of the fleet?

c) What is the approximate fraction of the fleet that is made up of high evaporative emissions vehicles?

d) What are the characteristics of three methods (RSD, modified California method, infrared video camera) for screening vehicles as High Evaps?

    - What are the accuracy characteristics (four-quadrant, true-positive, and false-positive) of the screening methods for identifying high evaporative emitters?
    - What are the practical characteristics of the screening methods? This includes issues such as ease of implementation, cost, time to complete one test, level of personnel necessary (both quantity and skill).

e) Based on the experience of the pilot study, what refinements or modifications would be considered for the design of a larger study?

In order to answer the questions above, a test procedure and sampling plan were developed to characterize the high-emissions tail of the distribution of evaporative emitting vehicles in the relatively new fleet of aging enhanced evaporative emissions on-road light-duty motor vehicles. The current fleet consists of vehicles with newer enhanced evaporative emission technologies, which are now aging and have a potentially different incidence of high evaporative vehicles in the fleet than previous technologies at similar ages. No frequency data currently exists on the range of higher evaporative emission vehicles for these newer technologies.

1.2 Description of Pilot Study Tasks

In this work assignment, ERG conducted a project to develop a sampling plan and test procedures for identifying vehicles with high evaporative emissions. In this pilot study, a number of technologies and ideas were explored, including non-intrusive RSD-style measurements, identification of evaporative leaks using a hydrocarbon sniffer device, and portable SHED (PSHED) measurements. In addition to those intrusive and non-intrusive methods, technologies used in other industries were investigated to determine if other tools could be of use in the measurement of mobile source evaporative emissions.

Field work for this pilot study was conducted in July and August 2008 in Denver, Colorado, in collaboration with the Colorado Department of Public Health and Environment (CDPHE). CDPHE has recently done work measuring evaporative emissions using RSD, and they also have facilities that allowed official laboratory SHED tests to be performed during the pilot study on a subset of the vehicles which had PSHEDs.

This study was preceded by the **Pre-Testing** study. The pre-testing investigation was performed on simulated high evaporative emissions vehicles to develop field methods for detecting High Evaps and measuring their evaporative emissions. This work has been reported separately [1].

This study was a field method evaluation. Testing on 85 vehicles that were recruited from the general public was used to develop and evaluate vehicle selection and emissions measurement. This work is the focus of this report.

The key variables that were surveyed or measured include:

- Vehicle identifiers: License plate and Vehicle Identification Number.
- Vehicle description: Model year, make, model, and odometer reading.
- Vehicle usage and maintenance history through a vehicle owner survey.
- Fuel type was assumed from local area fuels.
- Time trace of cumulative HC concentration of the air inside the portable SHED after a vehicle's engine is turned off and the portable SHED doors are sealed [6]

- Measured values of evaporative emissions vehicle screening methods:
  - Remote Sensing Device HC measurement, and HC concentration relative to CO_2 concentration
  - Modified California Method (Under-hood visual inspection and electronic HC vapor leak detector inspection)
  - Infrared video camera

1.3 Target Population and Coverage

The target population includes all gasoline-powered light-duty vehicles and trucks. Light-duty vehicles have gross vehicle weight ratings of less than 8500 lbs. Light-duty trucks are trucks with gross vehicle weight ratings of less than 8500 lbs. Passenger cars and light-duty trucks form the majority of the on-road motor vehicle fleet. Nationally, they account for 96.6% of the on-road vehicle fleet and 89.0% of the total on-road vehicle miles traveled. Heavy-duty vehicles account for the remainder of the on-road vehicle fleet and the on-road vehicle miles traveled.

The geographical area used for pre-testing and this study was Denver, Colorado. Denver was chosen for several reasons. The Colorado Department of Public Health and Environment, which is located in Denver, operates a laboratory SHED, runs the state's inspection/maintenance (I/M) program, and runs the state's on-road RSD measurement program. Those CDPHE resources were used in the pilot study. The Lipan Street I/M inspection station was used as a convenient source of private vehicles to solicit for the pilot study. Finally, the team that originally developed the RSD technique is located at the University of Denver.

1.4 Funding Partners and Cooperative Participants

Funds were contributed by two government partners and one industry partner. The first government partner is the Assessment & Standards Division within the EPA Office of Transportation and Air Quality (OTAQ) and the second partner is the Colorado Department of Public Health and Environment (CDPHE). The industry advisor is the Coordinating Research Council (CRC), a nonprofit research organization whose members include the American Petroleum Institute (API), the Society of Automotive Engineers (SAE), General Motors, Ford Motor, Chrysler, Toyota, Mitsubishi, Nissan, Volkswagen, and Honda. The Colorado Department of Public Health and Environment supported EPA's test program by providing RSD equipment and staff to operate the equipment to support the RSD portion of the test program.

2.0 Background

Evaporative emissions from gasoline vehicles have been evaluated and regulated since the early 1970s. Gasoline vehicles have evaporative emissions control systems that control excessive evaporative emissions, which are usually gasoline vapors but can also be evaporated liquid gasoline if liquid leaks are present. When these systems or the gasoline delivery system of a vehicle malfunction, excessive evaporative emissions can be emitted. The mass of evaporative emissions from individual vehicles has been quantified in previous studies [2, 3, 4], but the frequency of vehicles in such a condition in the general population has only been estimated based on limited data [2, 4, 5].

The Coordinating Research Council Real World Group has been conducting permeation evaporative emission testing in the E-77 and E-77-2 programs. In the pilot E-77 program the permeation test procedure was refined before using it in a larger program. Most of the vehicles were specifically recruited as aging enhanced vehicles, model years 1996-2000. Three pre-enhanced vehicles and one newer, near-zero emissions vehicle were also tested. A focus was on non-ethanol fuel looking at both 7 and 9 RVP. The program also looked at 24-hour diurnals at the traditional temperature range of 65-105 °F and a higher temperature diurnal of 85-120 °F. A subset of the vehicles was tested for 72-hour diurnals. The higher temperature diurnal data indicated that the predictions that hydrocarbon emissions double every 10 °C was correct and therefore, no further investigative testing was necessary. There were, however, unexpected findings for the influence of fuel volatility (RVP).

One of the aging enhanced vehicles had an implanted leak. The series of tests were run both before and after implanting the leak. This was accomplished by making a small hole in the evaporative control system. The size of the hole, 0.02 inch equivalent diameter, was the minimum detectable size necessary for an on-board diagnostic (OBD) code to flag. The laboratory testing results show the resulting hydrocarbon emissions to be several orders of magnitude larger with the implanted leak. This indicates a potential impact for the emissions inventory, establishing the need to define the rate of occurrence of “leakers” in the in-use fleet. Such implanted leaks can be in liquid or vapor form.

Vapor leaks can also have an impact on the inventory. Traditional evaporative emissions testing, as well as the current E-77 testing, has shown a range of evaporative emissions, particularly with aging vehicles. The higher emission levels (but lower than the gross liquid “leakers”) are associated with slow vapor leaks possibly occurring as the system ages. The enhanced evaporative emission technology is now starting to age, and we do not have information on the number of higher emission vehicles in the fleet. The High Evap occurrence rate is anticipated to be much lower than in the past, but leaks do occur.

Previous E-77 testing has confirmed that leaks, both liquid and vapor, can be an important part of any hydrocarbon inventory. The missing piece of information is how often the leaking vehicles occur. A comprehensive program for finding the quantity of these vehicles in the existing fleet has not been attempted since the American Petroleum Institute "Raw Fuel Leak Survey in I/M Lanes" in 1998 [2], or the California Bureau of Automotive Repair "Evaporative Emission Impact of Smog Check" in 2000 [4]. The current fleet consists of aging enhanced evaporative emissions vehicles which were not part of or still too new in the older studies.

2.1 Findings from California RSD Pilot Project

Recent data collected in the California RSD Pilot project [7] suggest that the tailpipe HC channel of the RSD instrument used in that study, the ESP Accuscan 4000, may be influenced by a vehicle's evaporative emissions, which are HCs.

The RSD instrument uses a light beam shining across the roadway to measure pollutants in a vehicle's tailpipe plume. The instrument has HC, CO, NO and CO_2 channels. In the California study, a few days to several months after vehicles were measured by the on-road RSD instrument, a subset of the vehicles received their regular state inspection program tailpipe emissions test, known as the Acceleration Simulation Mode (ASM) test. Analysis of bins of the 76,982 paired RSD and ASM results showed a quite linear relationship for CO and NO when the logit[1] of the ASM failure rate was plotted against the natural log of the RSD concentration. Figures 2-1 and 2-2 show the relationships for CO and NO. Straight line fits of the trends and 95% confidence limits on the individual points are included. The upward trend in both plots shows that, on the average, vehicles that have higher RSD tailpipe concentrations were more likely to fail their state tailpipe emissions inspection for the same pollutant.

[1] The logit (x) = ln (x/(1-x)), where x is a fraction between 0 and 1. In this case, the logit represents the "log of the odds of failure".

Figure 2-1. ASM CO vs. RSD CO

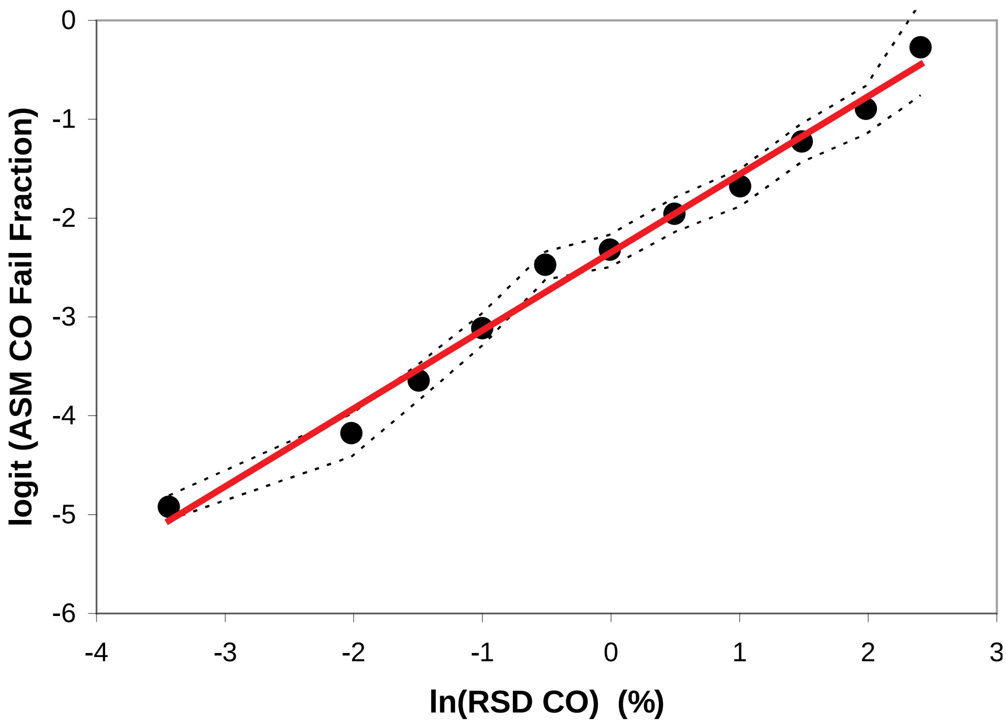


Figure 2-2. ASM NO vs. RSD NO

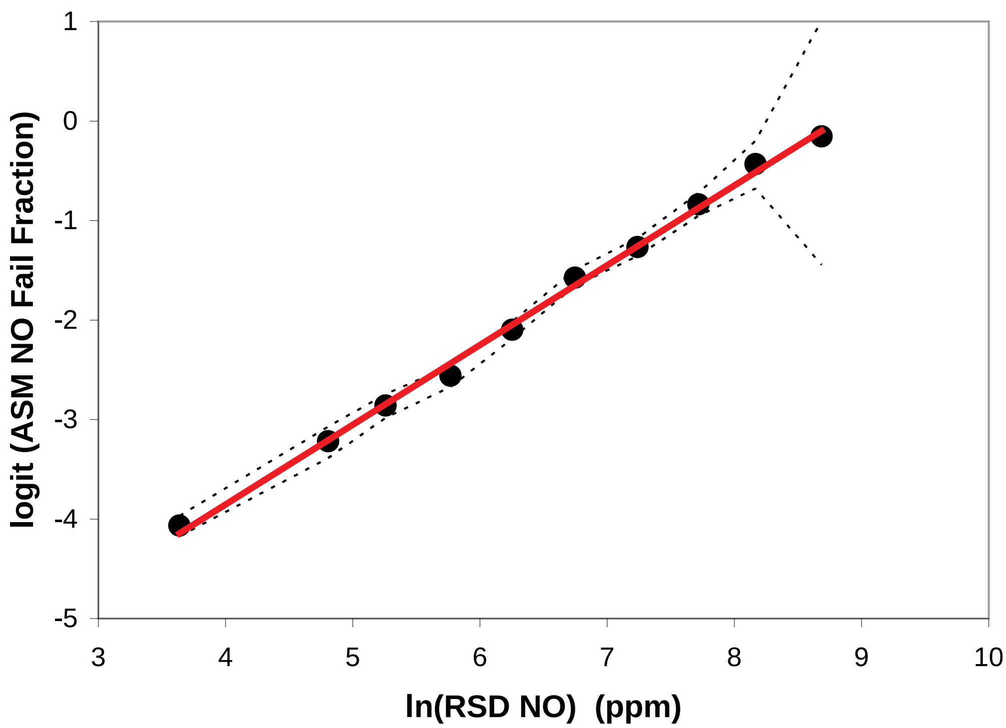
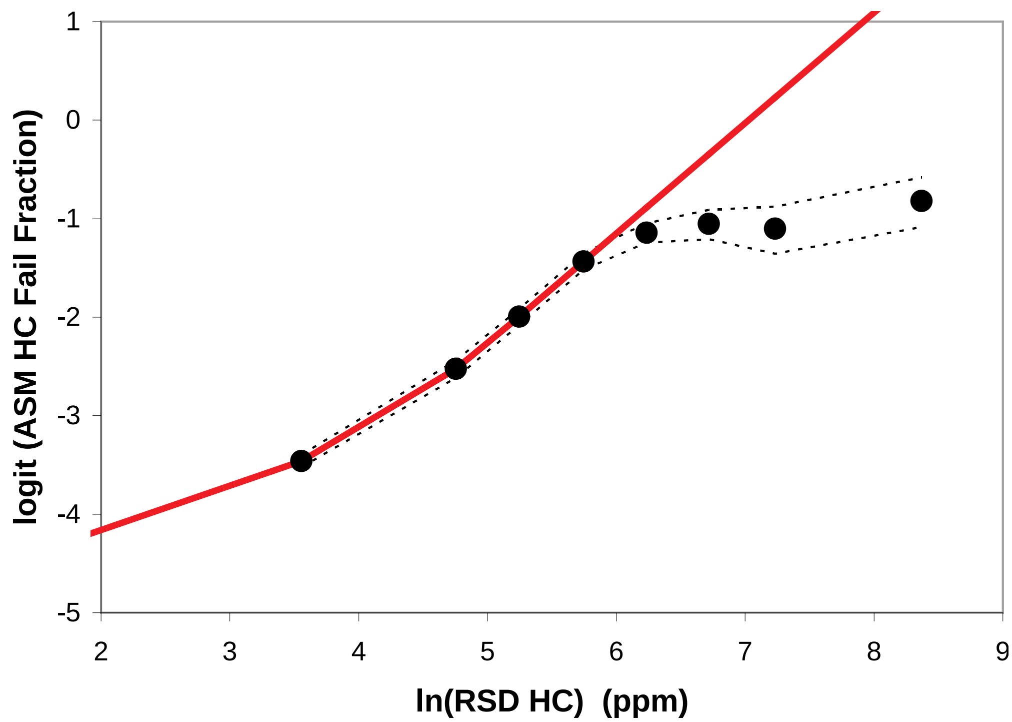


Figure 2-3. ASM HC vs. RSD HC



However, when the same type of plot is made for the analysis of bins of the paired data for HC, two different regions of behavior are observed. See Figure 2-3. In the low RSD HC region (ln RSD HC < 6), the ASM HC fail rate follows the trends seen for CO and NO. That is, vehicles with higher and higher on-road RSD HC concentrations are more and more likely to fail the inspection station ASM HC tailpipe test. The data fall on a relatively linear trend as approximated by the solid red line. However, on the right side of the plot (ln RSD HC > 6), a second, different trend is observed. Here, the data points reach a plateau (logit ASM HC fail fraction = -1), which means that about 27% of the vehicles fail the tailpipe ASM HC tailpipe test even though their on-road RSD HC concentrations range from 400 ppm up to 4000 ppm. That is, in the high RSD HC region, ever increasing RSD HC concentrations do not translate into an ever increasing probability of failing the inspection station ASM HC tailpipe test.

One explanation, but perhaps not the only explanation, for the observed HC behavior is the presence of High Evaps in the fleet sample. High Evaps could pass the inspection station ASM HC test because the ASM test is a tailpipe test, and therefore it is not influenced by evaporative emissions, which are emitted only from the fuel and fuel vapor handling systems of vehicles – not from their tailpipes. However, when a vehicle drives on the road, evaporative emissions can be detected with tailpipe emissions in the plume behind the vehicle. Depending on how the RSD instrument processes the data obtained from its light beam, evaporative emissions could increase the reported RSD HC readings over what one would expect on the basis of tailpipe emissions alone. If the evaporative emissions are very high, the increase could be large enough to cause points on the linear trend in Figure 2-3 to be moved to the right of the expected trend depicted by the red line.

Since evaporative emissions were not measured in the California RSD Pilot study, this explanation of the trends in Figure 2-3 is unconfirmed. Nevertheless, the explanation makes sense. In addition, Don Stedman, the developer of the RSD technique, is familiar with the data processing algorithm of the Accuscan-4000 instrument and believes that its high RSD HC readings may be influenced by High Evaps. Since algorithms of other RSD instruments may be less sensitive to evaporative emissions, this finding, if confirmed, could lead to the development of new RSD processing algorithms that could specifically target the on-road measurement of evaporative emissions.

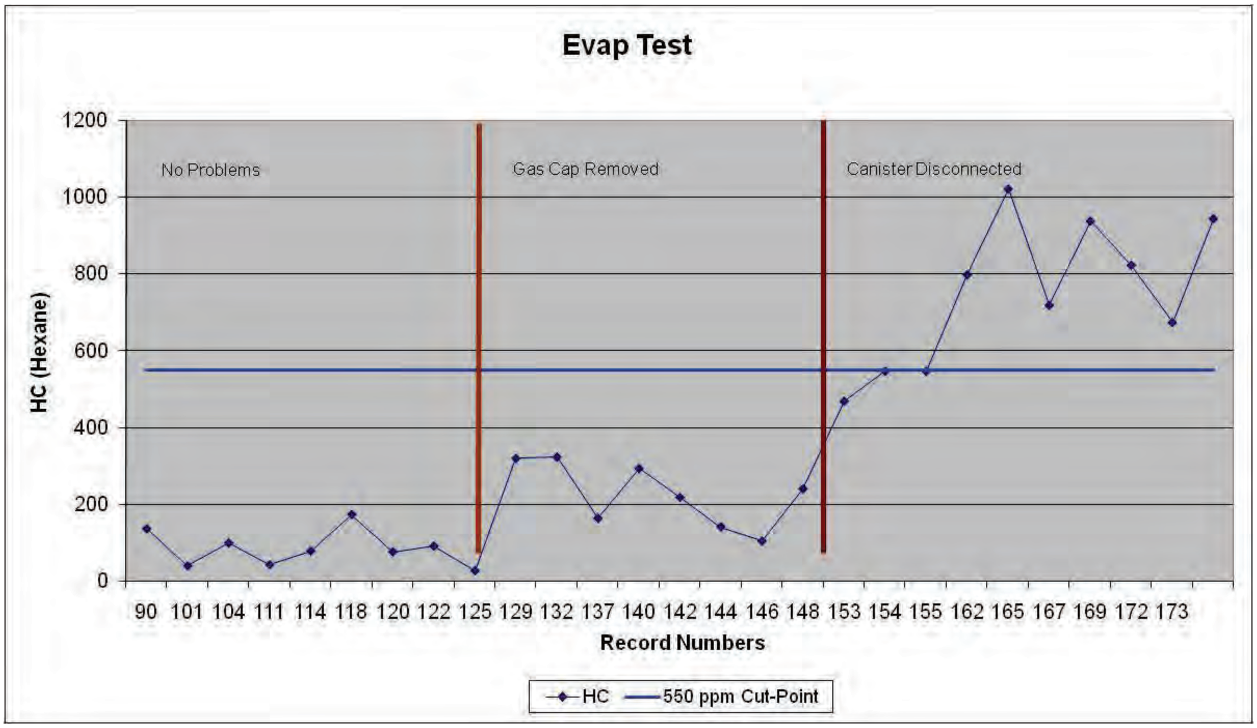
2.2 Findings from Colorado DPHE

CDPHE has empirical evidence that the RSD4000 instrument can detect evaporative emissions and liquid gasoline leaks. CDPHE has been involved with remote sensing devices since 1996. The Department's RSD experience spans several generations of ESP's RSD technology (RSD2000, 3000, 4000, and 4600). In recent years, CDPHE and the Regional Air Quality Council (RAQC) have participated in an RSD-based, high hydrocarbon emitter identification and repair pilot program funded by the Congestion Mitigation and Air Quality Improvement Program (CMAQ). The goal of the study was to use RSD to find vehicles emitting more than 550 ppm HC as hexane from the tailpipe. An unexpected result of the effort was the apparent ability of the RSD4000 instrument to find evaporative emissions and gasoline liquid leakers. Several RSD-identified high HC emitters brought to state IM Tech Centers for an IM240 confirmatory exhaust emissions test easily passed EPA IM240 final standards but were found to have gasoline vapor and/or liquid leaks.

A simple, semi-quantitative follow up experiment by CDPHE staff used an RSD4000 instrument with metered amounts of propane, unmetered amounts of liquid gasoline, and known concentrations of simulated exhaust from an RSD audit truck. This experiment resulted in a small empirical dataset that seemed to corroborate the claim by state IM Technical Center personnel that the RSD was identifying evaporative and liquid leaks. The data shown in Figure 2-4 were obtained using the audit truck. This information illustrates that RSD technology appears to detect evaporative emissions. Both sets of RSD data introducing an evaporative emissions problem, gas cap removal[2] and canister disconnection, are noticeably higher than the "no problem" RSD data. A second, very brief qualitative investigation using unknown amounts of liquid gasoline, an IM240-passing 2000 model year passenger vehicle, and an RSD3000 instrument produced only invalid RSD readings, which indicated there might be something other than high exhaust emissions.

This disparity between the RSD4000 and RSD3000 results prompted an inquiry to Don Stedman of the University of Denver. He clarified that the calculations used by the RSD3000 instrument were specifically designed to see only tailpipe HC, but the RSD4000 instrument and its offspring, the RSD4600, could theoretically see HC from any source.

Figure 2-4. Reported RSD4000 HC on the Audit Truck with Induced Evaporative Emissions



2.3 RSD4000/4600 Data Acquisition and Concentration Calculations

Some background on the operation and calculations of the RSD4000/4600 instrument is useful for understanding the conditions under which RSD might be able to detect vehicle evaporative emissions. While the detailed calculations that are used in RSD instrument software

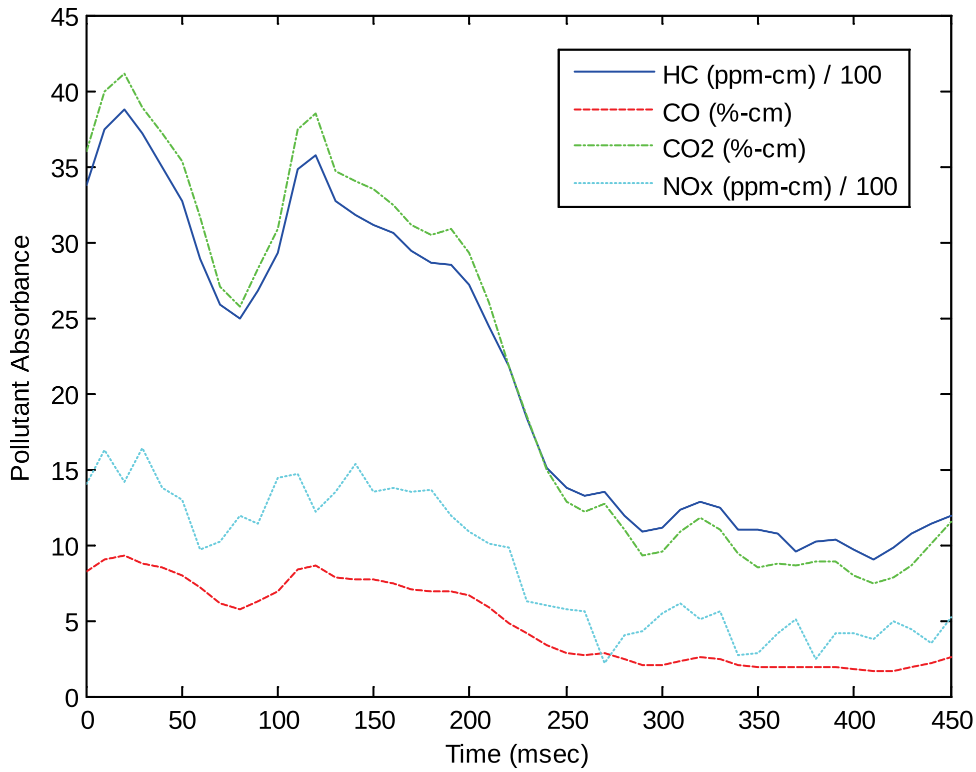
[2] The gas cap removal shows minimal impact on HC concentration levels compared to disconnecting the canister. This compares to the CRC E-77 lab data on implanted leaks. There was a negligible increase in HC emissions when a leak was implanted in a gas cap on an ORVR equipped vehicle compared to one which did not have ORVR or a leak implanted near the canister or the top of the tank.

are proprietary to ESP, ESP personnel have provided some general information about how their current instrument operates and calculates emissions concentrations.

The pollutants in the exhaust gas coming from the tailpipe of a vehicle are assumed to be well mixed and are assumed to be released from only the tailpipe outlet. It is also assumed that after emission from the tailpipe, the HC, CO, NO and CO_2 all disperse into the ambient air at the same rate.

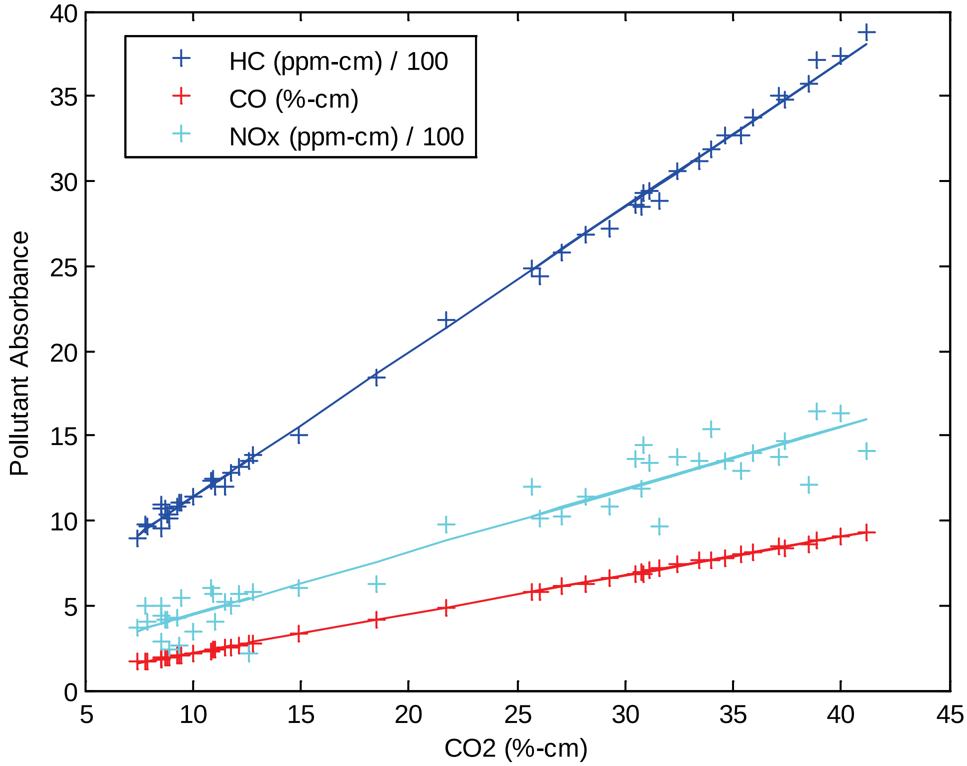
When a vehicle drives past the RSD instrument, the RSD light beam passes through a portion of the dispersing tailpipe plume. The instrument measures the attenuation of IR or UV light caused by the presence of the chemical species in the plume 50 times at 10ms intervals. The size of the attenuation is the product of the concentration and the path length and therefore has units of ppm-cm for HC and NO and %-cm for CO and CO_2. If the only source of the pollutants is the tailpipe exhaust, and if the ambient air has no pollutants, then the ratios of attenuations of any two pollutants will be constant for multiple readings taken in a vehicle's exhaust plume even though the pollutant concentrations change as the plume disperses. Figure 2-5 shows example time traces of the attenuations of HC, CO, NO, and CO_2 as recorded by an RSD instrument for Test Set 18 and VDF 5 from the Summer 2008 Pre-Testing study [1]. The plot clearly shows that for this case, which does not have evaporative emissions, the attenuations move up and down together with time. That is, ignoring the different vertical scales, the time traces of all four pollutants have very similar shapes.

Figure 2-5 Time Histories with Zero Evaporative Emissions and 1100 ppmC_3 Tailpipe HC Emissions



However, the purpose of the RSD instrument is not to determine the time dependence of the pollutant attenuations but instead is to determine the exhaust concentration of the pollutants at a given moment in time. To arrive at an estimate of the pollutant exhaust concentrations requires two steps. In the first step, the instrument uses the assumption that exhaust pollutant gases disperse together from the common exhaust point. If this is true, then plots of the attenuations of one pollutant against the attenuations of any other pollutant should produce a straight line passing through the origin. Figure 2-6 shows the HC, CO, and NO attenuations plotted against the CO_2 absorbance for the data shown in Figure 2-5. The plot shows that the lines are quite straight with little scatter and pass near the origin.

Figure 2-6. Pollutant Attenuations with Zero Evaporative Emissions and 1100 $ppmC_3$ Tailpipe HC Emissions Versus CO_2 with Regression Lines Superimposed



If ambient pollutants are present before the vehicle passes by, then the instrument will also pick up contributions to the attenuations from the background. The RSD4000/4600 instrument attempts to correct for the background by taking a measurement of all four pollutants just before the vehicle blocks the beam. These "front bumper" background attenuation values are subtracted from the raw tailpipe plume attenuation values to arrive at the background-corrected attenuation values that are used to calculate the tailpipe emissions concentrations. The 50 10ms attenuation observations provided with each RSD beam block and those plotted in Figures 2-5 and 2-6 have already had the background correction applied. Thus, if the background correction is accurate, plots of HC, CO, and NO attenuations versus CO_2 attenuation should always pass through the origin. However, we have observed that even for vehicles with no evaporative emissions the regression lines through the data almost never pass through the origin and generally tend to have positive pollutant attenuation intercept values.

Our understanding is that the RSD3000 calculation method (also known as Method B) uses the slope of the regression of the HC attenuation versus CO_2 attenuation to calculate the concentration of HC relative to CO_2. On the other hand, the RSD4000 calculation (also known as Method A) uses the sum of the HC attenuations divided by the sum of the CO_2 attenuations to determine the concentration of HC relative to CO_2.

The second step in the calculation uses combustion stoichiometry. The RSD instrument calculations assume a particular composition for gasoline that contains carbon, hydrogen, and oxygen which when combusted with air will produce a mixture of HC, CO, NO, and CO_2. The balanced chemical equation for this reaction is then used to convert the relative pollutant concentrations as determined from the slopes of the 50 10ms attenuation measurements of the RSD instrument into estimates of the absolute pollutant concentrations by assuming that the gasoline in the vehicle has approximately the same composition as the average gasoline used for the calculations. This second step is used both for Method A and Method B calculations.

The RSD4600 instrument uses the measured attenuations of HC, CO, NO, and CO_2 plus the combustion stoichiometry of the combustion of typical gasoline to arrive at the reported RSD concentrations for the four pollutants. Based on 29,723 RSD measurements made in San Antonio in November 2008, the RSD4600's reported concentrations always obey[A] the following equation:

$$[CO_2] = 150537.66 - 0.7168 * [CO] - 0.3011 * [HC] - 0.3584 * [NO]$$

where: $[CO_2]$ is the CO_2 concentration in ppm,
[CO] is the CO concentration in ppm,
[HC] is the HC concentration in ppmC_3, i.e., ppm Propane, and
[NO] is the NO concentration in ppm.

Now we need to consider the situation when evaporative emissions are present. Evaporative emissions on a vehicle are predominantly HC (some oxygenates may be present if the fuel contains them) and can be emitted from the vehicle from one or multiple sources but the source of evaporative emissions will never be the tailpipe. Accordingly, the characteristics of dispersion of evaporative emissions will be different from the dispersion of the tailpipe emissions. Evaporative emissions can be emitted as vapor or as leaking liquid gasoline. Since the RSD instrument can detect only vapor, liquid leaks must at least partially evaporate for an RSD instrument to detect them. A vehicle's evaporative emissions plume will not necessarily intermingle with its tailpipe plume. However, it may pass through the RSD instrument's light beam at the same time that the tailpipe plume is passing through the light beam. When an evaporative emissions plume does this, it will cause the HC attenuation to be larger than it would be if the evaporative emissions were not present.

Figure 2-7 shows the time series of the attenuations for the audit truck for Test Set 18 and VDF 11 when evaporative and tailpipe emissions were forced to occur. In this case, the shapes of the time series for CO, NO, and CO_2 are similar to each other, but the shape of the time series for HC is different. Comparison of the HC trend with the CO, NO, and CO_2 trends indicates that the HC attenuation has a large increase beginning at about 100ms. This trend is much more obvious when the attenuations for the time series are plotted versus the CO_2 attenuations as shown in Figure 2-8. While the CO versus CO_2 and NO versus CO_2 plots remain as straight lines, the HC versus CO_2 curve shows an increase in HC attenuation relative to CO_2 attenuation and also shows a non-linear behavior. The quantification of this non-linear behavior can be used to develop an RSD evaporative emissions index.

Figure 2-7. Time Histories with 15 scfh Evaporative Emissions and 1100 ppmC_3 Tailpipe HC Emissions

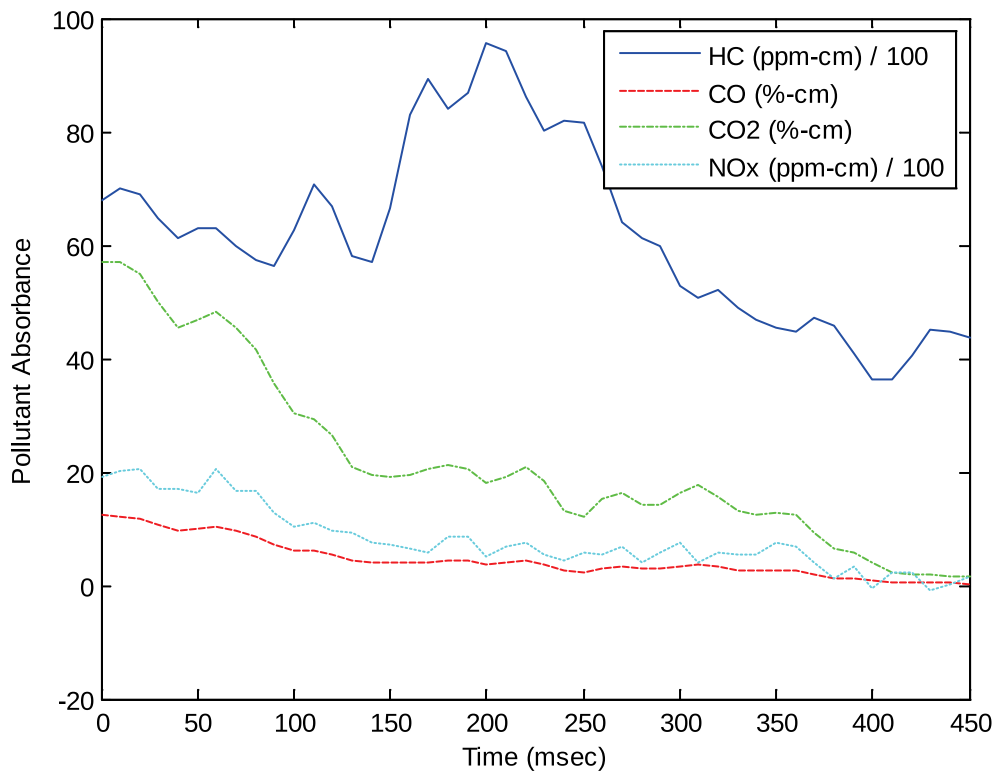
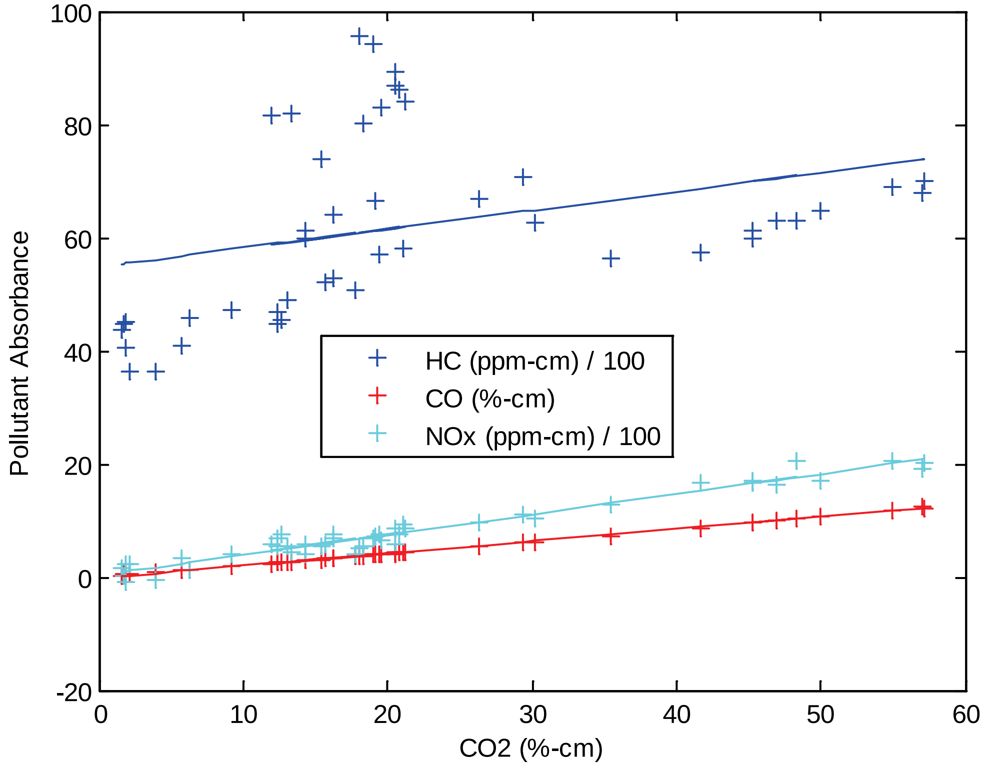


Figure 2-8. Pollutant Attenuations with 15 scfh Evaporative Emissions and 1100 $ppmC_3$ Tailpipe HC Emissions with Regression Lines Superimposed

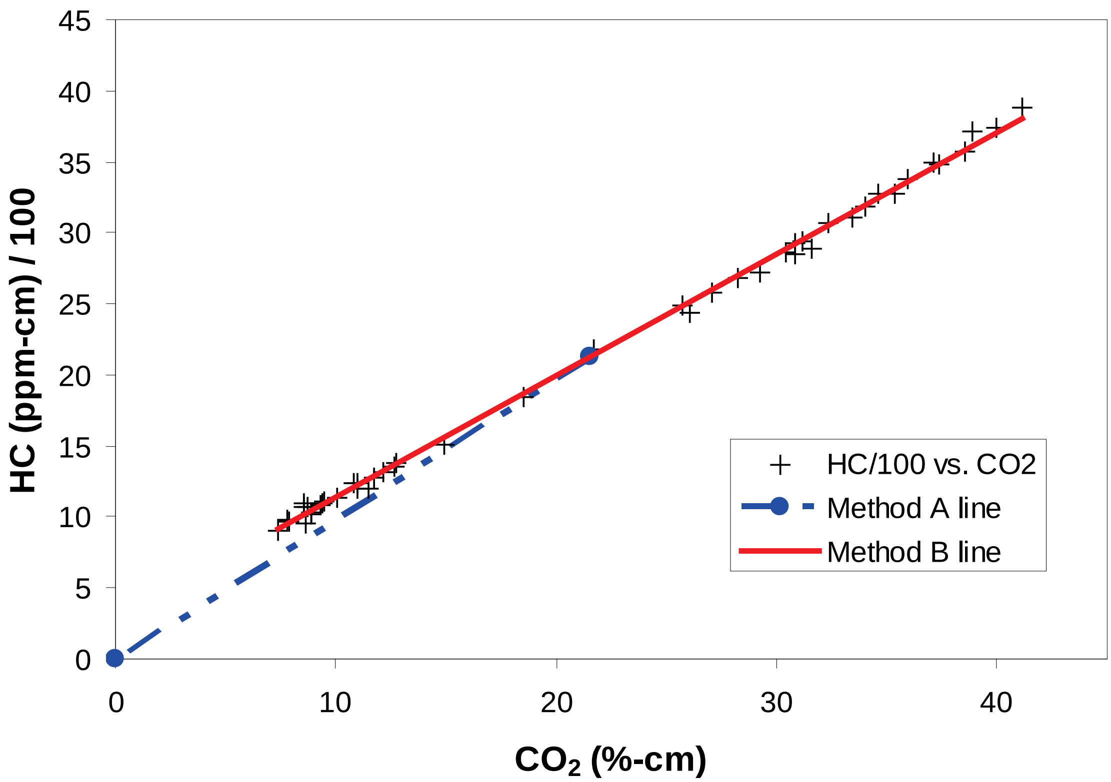


2.4 Influences of Evaporative Emissions on Method A and B Calculations

Methods A and B use two different calculations that are both based on the same 50 10ms absorbance pairs to arrive at different estimates of vehicle HC concentrations. Based on our understanding of the calculations, we believe that the difference between the reported values by the two methods provides an initial RSD evaporative index. This subsection describes why this might be the case.

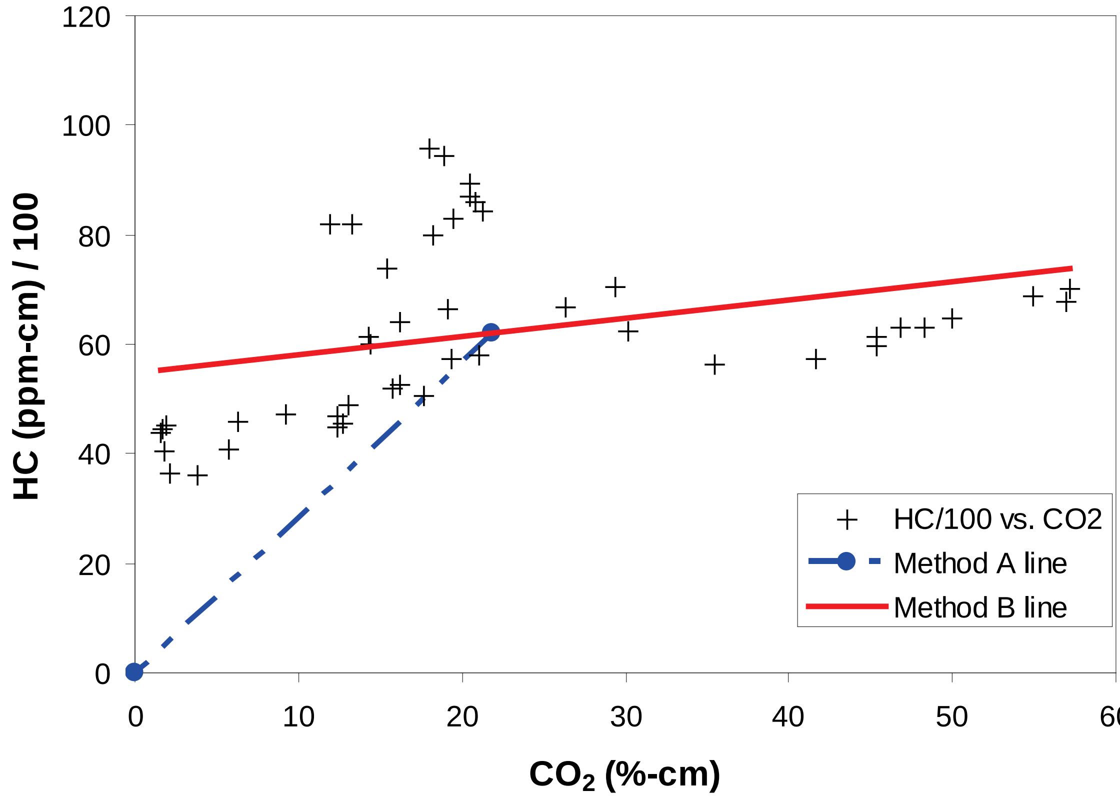
Figure 2-9 contains actual HC and CO_2 attenuation data from an RSD beam block of the audit truck when it was producing simulated exhaust emissions but no simulated evaporative emissions. The slope of the line (blue dashed line) that connects the origin with the centroid of the HC attenuation versus CO_2 attenuation cluster of points represents the Method A result. When the Method B regression line (red solid line) through the string of points passes through or near the origin, as in Figure 2-9, the slopes calculated by Methods A and B will be close to each other and will therefore produce similar RSD HC reported values.

Figure 2-9. Pollutant Attenuations with No Evaporative Emissions and 1100 ppmC$_3$ Tailpipe HC Emissions with Methods A and B Lines Superimposed



On the other hand, consider Figure 2-10 which contains actual RSD attenuation values for a case where the audit truck had simulated exhaust emissions and high artificial evaporative emissions. In this case, for Method A, the slope of the dashed blue line connecting the origin with the centroid of the string of points has a slope that is much larger than the slope of the red solid line through the points by regression. Thus, the reported value of RSD HC by Method A would be substantially larger than the value reported by Method B. The reason that the slope by Method A is larger than the corresponding line in Figure 2-9 is that the HC attenuation values have been shifted higher because of the presence of the evaporative emissions. When evaporative emissions are present but are not extremely high, we would expect that the HC attenuations would be higher than if evaporative emissions were not present but not as high as they are when evaporative emissions are higher.

Figure 2-10. Pollutant Attenuations with 15 scfh Evaporative Emissions and 1100 $ppmC_3$ Tailpipe HC Emissions with Methods A and B Lines Superimposed



Overall, therefore, the Method A calculation produces an RSD HC concentration that tends to be influenced both by the exhaust HC and the evaporative HC emissions. On the other hand, the Method B calculation tends to produce a reported HC concentration that is less influenced by evaporative HC emissions than the Method A calculation. As a consequence of these different sensitivities of Methods A and B to evaporative emissions, the difference between the Method A and Method B reported values could be a useful measure of the level of evaporative emissions that a vehicle produces. In addition, it is possible that this measure of evaporative emissions may be relatively independent of the level of exhaust hydrocarbon emissions from vehicles. We will call Method A minus Method B the RSD Evap Index 0. RSD Evap Index 0 will serve as the starting point for development of future RSD evaporative emissions indices. RSD Evap Index 0 is based on a calculation involving the background-corrected 50 10ms absorbance values from each beam block. Many different RSD evaporative emissions indices could be developed from these 50 10ms observations. Since there is no particular reason to believe that RSD Evap Index 0 is the best index, a search for better performing indices can be made.

3.0 Data Collection

The goal was to perform testing on about 100 vehicles for the purposes of evaluating screening methods that could identify vehicles with high evaporative emissions, to develop and qualify a field method that could distinguish between vehicles with low and high evaporative emissions, and to make an initial estimate of the fraction of high evaporative emissions vehicles in the fleet. Tests were ultimately performed on 85 vehicles by generating data in the pilot study which was performed in Denver, Colorado.

To reduce the time associated with identifying high evaporative emissions vehicles, we tested vehicles in three steps, which are elaborated upon in Sections 3.1 through 3.3:

In the first step, we screened the HC emissions of all vehicles entering the Lipan Street I/M station as they drove by a remote sensing device placed in the station's entrance driveway. Based on their RSD HC emissions levels, these vehicles were categorized into 9 emitter groups that covered the entire range of RSD HC emissions (see Table 3-1).

In the second step, we drew a stratified random sample of vehicles for participation in the field method evaluation (see Section 3.2). This set of vehicles was recruited and tested on site to evaluate three different evaporative emissions screening methods. Each vehicle also had its hot-soak and gross liquid leak emissions measured in the portable SHED (see Section 3.3.3).

In the third step, a fraction of vehicles participating in the field method evaluation were requested to have evaporative emissions measured in CDPHE's laboratory SHED near the recruitment site, and ultimately 23 were tested on both the PSHED and in a laboratory SHED. These data were compared with the portable SHED results to qualify the portable SHED technique for use in subsequent Work Assignments (this portion of the work has been previously reported [6]).

The types of data that were surveyed or measured included:

- Vehicle identifiers and description: license plate, vehicle identification number, model year, make, model, odometer reading, and other identifying information on vehicles that participated in the study. Photographs were taken of each vehicle to assist in data quality control. The vehicle pictures were taken from various angles and included a white board which included the test number assigned to the vehicle. Photos of the VECI label and VIN were also taken.
- Vehicle usage and maintenance: A vehicle owner survey was used to acquire vehicle usage and maintenance history.

- Portable SHED measurements: These include the evaporative emissions measured in the portable SHED environment. These emissions are expressed in terms of the mass evaporative emissions released into the portable SHED, the maximum HC concentration within the SHED, or the time trace of HC concentration of the air inside the portable SHED after a vehicle's engine is turned off and the portable SHED doors are sealed. They are the study's measure of the estimated evaporative emissions from each vehicle.
- RSD HC emissions measurements: These are the exhaust and evaporative emissions measured for the purposes of screening high evaporative emitters.
- Qualitative observations of evaporative emissions: Vehicle observations via HC sniffer and visual inspection and infrared video camera were recorded by on-site technical staff.

The experimental design and results for the Pre-Testing have already been described in a separate report [1], and the Portable SHED Evaluation has also been reported [6]. The procedures used for collecting data for the field evaluation are described in the following sub-sections. The different types of data that were collected are described in Section 3.1. The sampling plan that was used for recruitment of vehicles based on an RSD observation is described in Section 3.2, as well as a description of the test sequence that was performed on each of the sampled vehicles.

3.1 Sequence of Field Testing Procedures for the Pilot Study

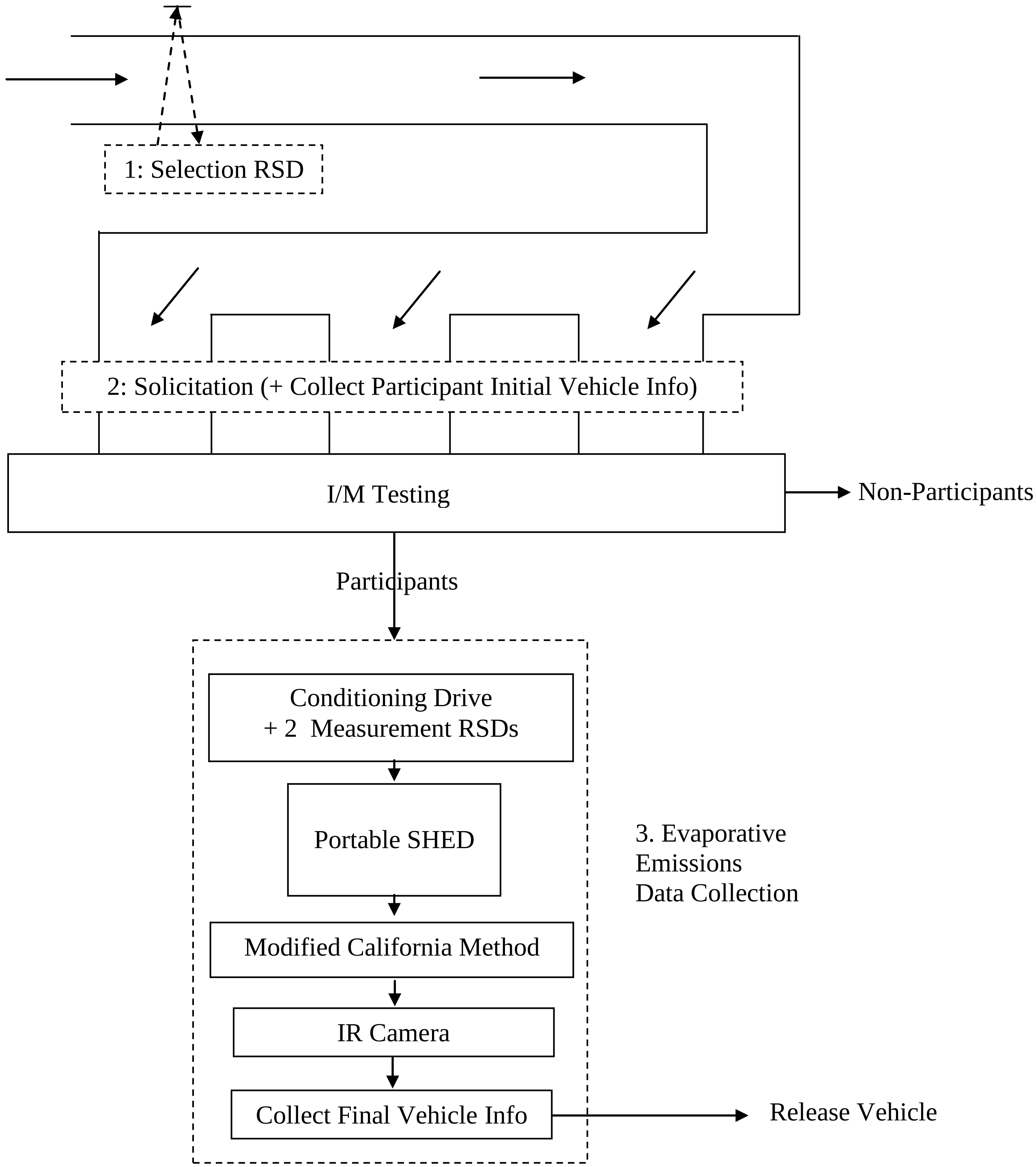
For the pilot study, ERG conducted measurements on vehicles owned by the general public. Vehicles were screened for participation using RSD as they approached an I/M Station. Participating vehicles were subjected to a series of RSD measurements, evaporative emissions measurements, and visual inspection.

The stratified sample system described in Section 3.2 was used to preferentially select higher evaporative emitting vehicles. The owners of vehicles that were identified as potential study participants were solicited by ERG personnel while they waited for their I/M test. They were asked if they would like to participate in the study, allowing their vehicle to undergo additional evaporative emissions testing. Those that agreed to participate were given a questionnaire that would help determine the most recent repairs, re-fuelings, usage patterns, and other information. The additional evaporative emissions tests were then performed on the vehicle.

Solicitors and other testing personnel did not have knowledge of the observed RSD emissions of the candidate or selected vehicles.

The diagram in Figure 3-1 below illustrates how the procedures flowed from the initial RSD HC screening through the various evaporative emissions tests. A total of 85 vehicles were ultimately tested with this test matrix.

Figure 3-1. Vehicle Testing Flow



Flow Diagram Step 1: Screening Using Remote Sensing Device

All vehicles entering the IM station driveway had the emissions plume scanned by an RSD-4600 instrument to measure emissions concentrations. RSD instruments perform these measurements by shining a light beam across the roadway. While the driver could see the equipment, measurements were performed without notifying the vehicle driver that they were being taken. For each vehicle the following quantities were automatically taken as the vehicle passed by the RSD instrument:

- DateTime: The date, hour, minute, and second of the RSD measurement.
- Speed and Acceleration: The speed and acceleration of the vehicle.
- The calculated VSP of the vehicle.
- RSD-4000 Emissions[3]: The concentrations of HC, CO, and NO in the vehicle's plume according to the Method A calculation.
- RSD-3000 Emissions: The concentrations of HC, CO, and NO in the vehicle's plume according to an approximation of the Method B calculation.
- License Plate: A digital image of the rear of the vehicle was recorded so that the license plate could be determined.

3.1.1.1 Flow Diagram Step 2: Solicitation

Based on the screening Method A HC values, the VSP, and the number of vehicles desired for each RSD/age bin in the stratified random plan, a sample of passenger cars and light-duty trucks was approached by the solicitor. The solicitation was usually made as the owner's vehicle was waiting in line for the inspection to begin. The solicitor performed the following activities:

- Introduction: The solicitor explained that a U.S. EPA emissions study was being conducted and measurements would take about one hour. The solicitor explained that the measurements would involve driving the vehicle for about 20 minutes, driving past the RSD unit two times, performing under-hood visual inspections, and testing the air in the portable SHED after the vehicle had sat in it for 15 minutes.
- Ownership: The solicitor asked if the driver owned the vehicle. Only vehicles with their owners driving were eligible for participation. Company vehicles or dealer vehicles were not allowed as participants.

[3] A single instrument was deployed, but the different calculation methods were used to estimate emissions: "RSD-4000" and "RSD-3000".

- Incentive: The solicitor offered a $20 cash incentive. The incentive was provided whether or not the vehicle owner participated.

- Vehicle Information: The solicitor collected an initial vehicle description including license plate, model year, make, model, and color as described in Appendix A.

- Owner Questionnaire: The solicitor administered the owner questionnaire to gather recent vehicle usage and maintenance history information. (Appendix A).

Flow Diagram Step 3: Evaporative Emissions Data Collection

Following completion of the IM inspection, participating vehicles would then undergo the following tests:

- RSD Emissions: A technician conditioned the vehicle for 20 minutes on a set 8-mile route[4], which simulated the Federal Test Procedure (FTP) typically used as preconditioning for a Hot Soak laboratory test. Then drove it past the RSD unit two times to obtain RSD measurements that were independent of the screening RSD used to select the vehicle for participation. The same type of data was recorded as for the screening drive. The technician driver verified with the RSD technician that all RSD results were valid and that the VSP was in range.

- Portable SHED Emissions: With the engine still running, the vehicle was driven just outside the open PSHED door. Upon command from the PSHED technician, the engine was turned off, the vehicle was pushed into the PSHED, and the PSHED door was sealed. The HC emission concentration of the air inside the PSHED was measured continuously with the SEMTECH-G for 15 minutes. Following the measurement, the vehicle was driven out of the PSHED, and the air in the PSHED was flushed.

- Modified California Method: A visual and olfactory inspection of evaporative emission control system and the fuel system was performed to look for missing, malfunctioning, damaged, or disconnected components. At the same time, a handheld electronic HC vapor detector was used to try to find sources of evaporative emissions by moving the small probe of the detector around components, fittings, and hoses.

- Infrared Video Camera: The infrared video camera recorded video of those areas around the vehicle where evaporative emissions might be present. This included over the engine compartment with the hood opened and closed, and around the gasoline fill pipe.

[4] Turn north on Lipan Street. Drive 200m. Turn east on W. Evans Avenue. Drive 675 m. Turn south on S. Santa Fe Drive. Drive 2875 m. Turn west on W. Hampden Avenue. Drive 2000 m. Turn north on S. Federal Blvd. Drive 3000 m. Turn east on W. Evans Avenue. Drive 2000 m. Turn south on Lipan Street. Drive 200 m.

- Detailed Vehicle Information: Vehicle information was collected including VIN, engine family, evap family, odometer reading, transmission type, and photos as shown in the data packet in Appendix A. Digital photographs of serial numbers and equipment specification tags were taken as indicated, to help correct any inaccurate information recorded during on-site inventories.

- Final Check: After verifying that all items were collected and were complete, the vehicle was released to its owner (unless the vehicle was a candidate for the portable SHED / laboratory SHED evaluation).

Of the 85 vehicles that completed the steps described above, a subset of 23 vehicles participated in a portable SHED / laboratory SHED evaluation. A laboratory-grade 1-hour hot-soak[5] was conducted at CDPHE facilities for these 23 vehicles. Results of the portable SHED / laboratory SHED evaluation have previously been reported [6].

3.2 Stratified Random Sample of Vehicles for Field Testing

During the planning phase of the study, we estimated that 99% of all vehicles are not High Evaps. Since most vehicles are not excessive emitters of evaporative emissions, stratified random sampling was used to seek a preferentially larger number of vehicles that were potential high evaporative emitters. In this pilot study, we used RSD HC to screen vehicles into nine HC emitting categories. We selected vehicles from each of the nine screening RSD HC bins to be solicited for participation in the pilot study. The sample was stratified with allocation among RSD HC emissions bins.

As described in Section 2 (Background), we have circumstantial evidence that the HC channel of certain types of RSD instruments may be able to detect vehicles with high evaporative emissions levels. By preferentially sampling more vehicles from the higher RSD HC bins of screening RSD measurements, we attempted to capture a larger fraction of High Evaps in the pilot study than could be captured by completely randomized sampling from the fleet as a whole.

Design of a stratified sampling strategy to achieve the desired precision required an estimate of the abundance of High Evaps in the fleet as a function of the stratifying variable. Unfortunately, no dataset existed that could clearly define High Evap levels. However, we assumed that the trends in Figure 2-3 were caused by High Evaps. Therefore, the data collected in the California study was used to develop a stratified sampling design for this study.

[5] The lab SHED test was a standard one-hour hotsoak test. It was done with standard pre-conditioning, at standard SHED temperature for a hot-soak, and it was performed using the in-use fuel in the vehicle's fuel tank. The single-value hot-soak result and the minute by minute SHED HC concentrations were both reported for each hot-soak test.

Table 3-1 summarizes the data from the California study that were used to develop a stratified sampling plan for this study. Columns B and C give the bin definitions in terms of the RSD HC as determined by Method A, which is influenced by evaporative emissions and exhaust emissions. Columns D and E give the distribution of vehicles that had an inspection station ASM test that followed the on-road RSD measurement. These columns indicate that the distribution of RSD HC emissions in the fleet is highly skewed with about 83% of the vehicles having RSD HC emissions below 148 ppm. Column F shows the number of High Evaps that we estimated from Figure 2-3. Specifically, we assumed that the gap between the data points and the red line in Figure 2-3 is caused by the presence of High Evaps in the fleet. Column G gives the estimated probability (=F/D) that vehicles in each bin are High Evaps. The fleet estimate from this data suggested 0.75% of the vehicles based on the California data are high evaporative emitters.

Table 3-1. Expected High Evap Fractions Using California RSD Data

A	B	C	D	E	F	G
Bin Definitions: RSD HC (ppm) by Method A			**Vehicle Population**		**High Evap Vehicles (estimated)**	
Bin	**Greater Than**	**Less Than or Equal To**	**Number of Vehicles in Bin**	**Population Fraction in Bin (W_h)**	**Number of High Evaps in Bin**	**Fraction of Vehicles in Bin that are High Evaps (p_h)**
1	-Inf	0	24101	0.3131	0	0.000002
2	0	90	32959	0.4281	1	0.00005
3	90	148	7094	0.0922	3	0.0005
4	148	245	5476	0.0711	15	0.0027
5	245	403	3644	0.0473	49	0.013
6	403	665	2138	0.0278	107	0.050
7	665	1097	917	0.0119	143	0.156
8	1097	1808	365	0.0047	112	0.308
9	1808	Inf	288	0.0037	148	0.513
All			76982	1.0000	578	0.75%

From the information in Columns A through G, we used the technique for optimum stratified sampling, which is described in Appendix B, to develop a plan for achieving the precision target. The optimum plan was modified, however, to meet the objectives of this study and to address the vulnerabilities to sub-optimal sampling.[9]

A random number generator was used to determine whether or not a vehicle observed by RSD entering the Lipan Street IM station would be solicited for the study. A threshold between zero and one was assigned to each of the nine bins, with a higher threshold for the higher RSD HC bins. The random number generator assigned a random number between zero and one to each vehicle that was observed by RSD. The vehicle was then assigned to one of the nine bins, based on its RSD HC value. If the vehicle's random number was below the threshold number for the vehicle's bin, then the vehicle was solicited for the study. These thresholds represented selection probabilities. The random number thresholds for the nine bins were modified at times during the pilot study, as initial results were used to determine whether the actual sampled vehicles were falling into the desired distribution among the nine bins. The random number thresholds that were used and the dates that they were used are listed in Table 3-2.

Table 3-2. Random Number Thresholds for Soliciting at the Lipan Station

A	B	C	D	E	F
Bin Definitions: RSD HC (ppm) By Method A			**Random Threshold**		
Bin	**Greater Than**	**Less Than or Equal To**	**7/28/2008 – 8/7/2008**	**8/7/2008 – 8/12/2008**	**8/12/2008 – 8/30/2008**
1	-Inf	0	0.000883	0.0026	0.0280
2	0	90	.00412	.0124	.0160
3	90	148	.01299	.0361	.093
4	148	245	.0318	.0579	.118
5	245	403	.1535	.2257	.54
6	403	665	.288	.2191	.42
7	665	1097	.480	.2085	.52
8	1097	1808	.622	.2477	1.00
9	1808	Inf	.657	.0627	.30

There are at least two reasons that the rate of occurrence of High Evaps in each of the nine bins might not turn out to be the same as the expected values shown in Column G of Table 3-1. First, our method to determine the rates was based on our interpretation of the trends seen in Figure 2-3 in terms of evaporative emissions. Second, while RSD can estimate the average emissions of a fleet of vehicles, RSD's ability to properly classify individual vehicles in emissions bins is subject to considerable uncertainty caused by the variability of vehicle emissions and by variability in the RSD technique itself.

Vehicles were screened for possible participation in the study based on their first RSD HC emissions measurement. However, RSD HC measurements are subject to large variability. Therefore, because of large expected regression-toward-the-mean effects, it was important to recognize that the RSD HC bin assignments and all data analyses must be based on a second RSD reading. Because the set of vehicles were selected by RSD HC, a measurement subject to error, the second RSD HC measurements, on which the results of the study were based, were, in many cases, different from the first RSD HC measurement.

The final sampling design for the Pilot Study is shown in Table 3-3. Of the 113 vehicles that were to be sampled, nine vehicles were expected to be High Evaps[6] as shown at the bottom of Column H. The primary High-Evap-occurrence results of the pilot study would be the nine High Evap fractions shown in Column I. With these nine values and population fractions for any application population (such as the nationwide fleet), the overall fraction of High Evaps in the application population could be calculated as described in Appendix B.

Table 3-3. Field Method Evaluation Stratified Sampling Design for RSD HC Bins

A	B	C		E	F	G	H	I
Bin Definitions: RSD-4600 HC (ppm)				Planned Allocations in RSD *Screening* Bins		Expected Allocations in RSD *Measurement* Bins		
Bin	Greater Than	Less Than or Equal To	Population Fraction in Bin	Size of Screening Sample Needed to Fill Bin	Number of Vehicles	Number of Vehicles	Number of High Evaps	Fraction of Vehicles in Bin that are High Evaps
1	-Inf	0	*0.3131*	0	0	7	0	0.000
2	0	90	*0.4281*	0	0	15	0	0.000
3	90	148	*0.0922*	0	0	8	0	0.000
4	148	245	*0.0711*	0	0	13	0	0.000
5	245	403	*0.0473*	681	32	18	0	0.000
6	403	665	*0.0278*	737	21	20	1	0.050
7	665	1097	*0.0119*	1647	20	15	2	0.133
8	1097	1808	*0.0047*	7298	34	8	2	0.250
9	1808	Inf	*0.0037*	1514	6	9	4	0.444
All			1.0000		113	113	9	

3.3 New Test Procedures for the Pilot Study

Several of the testing procedures that were used in this pilot study were new to the field of mobile source evaporative emissions, and underwent preliminary testing and validation at the beginning of the study. This included the Modified California Method (see Section 3.3.1) and the IR Camera (see Section 3.3.2). Additionally, the use of the portable SHED (as opposed to the laboratory SHED) was new. The portable shed was tested and results compared to the laboratory SHED as part of separate task under this project, and those results have already been reported [6]. However, since the use of the portable SHED is integral to the pilot study

[6] Note that for this project there was no agreed-upon definition of High Evap. For Table 3-3 a High Evap is defined as any vehicle that would cause the black dots to deviate from the red line in Figure 2-3, which was derived from the California RSD data.

described here, the results of the portable SHED to laboratory SHED comparisons will be summarized in Section 3.3.3.

3.3.1 Modified California Method

We used a modified version of the California IM Liquid Leak Test Procedure. See Appendix C for the standard operating procedure for the California Procedure, which is the visual inspection portion. The procedure was identical to the visual check implemented in January 2008 by the California Bureau of Automotive Repair, with the addition of a HC sniffer to aid in leak detection. California's procedure is as follows:

- The liquid fuel leak inspection shall be conducted with the engine running. Use extreme caution when working around moving parts and ensure the transmission is in "park" or "neutral" with the parking brake on.
- Definition: For the purpose of conducting this inspection, a "Liquid fuel leak" is defined as follows: "Liquid fuel leak" means any fuel emanating from a vehicle's fuel delivery, metering, or evaporation systems in liquid form that has created a visible drop or more of fuel on a component of a vehicle's fuel delivery, metering or evaporation system or has created a fuel puddle on, around, or under a component of a vehicle's fuel delivery, metering, or evaporation system.
- Inspection: With the engine running, the smog check technician shall visually inspect the following components of the vehicle, if they are exposed and visually accessible, for liquid fuel leaks:

  Gasoline Fuel Tanks
  Carburetors
  Fuel Injectors
  Gasoline fill pipes and associated hoses, tanks, connections
  Gas Caps
  Fuel pressure regulators
  External fuel pumps
  Charcoal canisters
  Fuel delivery and return lines
  Any valves connected to any other fuel evaporative component
  Fuel vapor hoses
  Fuel filers

The California procedure was modified by the addition of a HC sniffer. The "sniffing" test was conducted simultaneously with and at the same vehicle locations as the visual inspection. The HC sniffer (see Section 4.3) is a hand held combustible gas detector that has been found useful in locating small liquid and vapor leaks. These units are typically used by home appliance installers to verify gas tight connections and in the automotive trade industry to pinpoint liquid and vapor gasoline leaks.

When the unit detects hydrocarbons it signals the operator by flashing a small red light and creating an audible click. As the concentration of vapors increases, the frequency of the light and audible pulses increases. The sensitivity of the unit is adjusted to just stop pulsing at ambient HC levels. The flexible wand is then used to direct the detector tip to the vicinity of suspected leaks. This unit is extremely sensitive to HC vapor, and has been successfully used in a number of emission laboratory applications. Additional recommended tools are a small flashlight, an extendible inspection mirror, and a mechanic's creeper to view under body fittings and components.

3.3.2 Infrared Video Camera

A technician used an infrared video camera (see Section 4.4) to "film" areas under the hood, around the fuel tank, and around fuel lines. The IR video camera recorded video of those areas around the vehicle where evaporative emissions might be present. This included areas near the engine compartment with the hood opened and closed, and around the gasoline fill pipe.

The IR camera was used to capture evaporative emission images from a vehicle with the fuel cap removed. Again, this was done to establish confidence that the unit is capable of detecting gross level evaporative emissions. The possibility that the background heat from the engine could negatively impact the IR camera performance meant that extra care was taken during this portion of the experiment to develop detailed instructions for how the unit should be used to best capture evaporative images from a vehicle.

3.3.3 Evaluation of the Portable SHED

One of the field methods that was tested as part of this pilot was the use of a portable SHED (Sealed Housing for Evaporative Determination) or PSHED to perform a short hot-soak emission test in an I/M lane setting. The development of this technique included performing regular propane retention and recovery tests to establish the integrity of the PSHED. Additionally, paired hot-soak data on 23 vehicles were obtained to allow the comparison of PSHED measurements to the traditional laboratory SHED (LSHED) measurements. It should be noted that other evaporative emissions tests are commonly performed during EPA's certification testing, such as running loss and diurnal testing; however, these are considerably more complex than a hot-soak test, and therefore these tests were not attempted using the PSHED equipment.

The PSHED is a portable 10' x 20' x 8' sealed enclosure[7]. To determine the evaporative emissions produced by a vehicle, the vehicle is warmed-up by driving it for about 8 miles and is then immediately placed in the PSHED with the engine off, and the enclosure is sealed. During the next 15 minutes the HC concentration in the air inside the PSHED is measured as any evaporative emissions leave the vehicle. At the end of 15 minutes the HC concentration is used to calculate the mass of HC that has been emitted by the vehicle. This PSHED mass is the quantity that is used to determine whether or not the vehicle is a High Evap.

The results of the PSHED evaluation are briefly summarized below; additional detail may be found in the PSHED evaluation report [6].

Recovery and Retention Data - A recovery test consists of injecting a known amount of propane into the PSHED and then measuring the amount of propane detected in the PSHED after a short period of time. This test verifies that the analytical equipment is working and establishes a baseline level of propane above the ordinary ambient background level. The retention test is the measurement of the propane level in the PSHED after 15 minutes, and it establishes the integrity of the PSHED ensuring that there are no major leaks during the time period that a vehicle would be tested.

Both retention and recovery values are presented as a percent of the measured mass of propane injected initially. Values will likely be less than 100% because it is far more likely the propane will be lost from the PSHED (or any enclosure) than introduced into the enclosure by the ambient background or some other mechanism. For the purposes of this study, we believe the retention values reveal information about the accuracy of the PSHED since retention reflects directly on the unit's leak integrity and will inherently capture recovery information. Additionally, the recovery data is superior to the paired vehicle data between the PSHED and the LSHED for evaluating PSHED performance simply due to the inescapable vehicle test-to-test variability.

The average and standard deviation PSHED recovery and 15-minute retention measurements are presented below. This data was collected at the start of each day of vehicle testing and ensured that the analytical equipment was functioning properly and the PSHED had not developed any significant leaks. It can be seen from these values that the unit's performance was good and in fact exceeded expectations for a PSHED unit costing less than $400 plus

[7] Purchased through elitedeals.com. Manufactured by King Canopy, 1730 Five Points Lane, Fuquay-Varina, NC 27526, (800)800-6296, Kingcanopy.com.

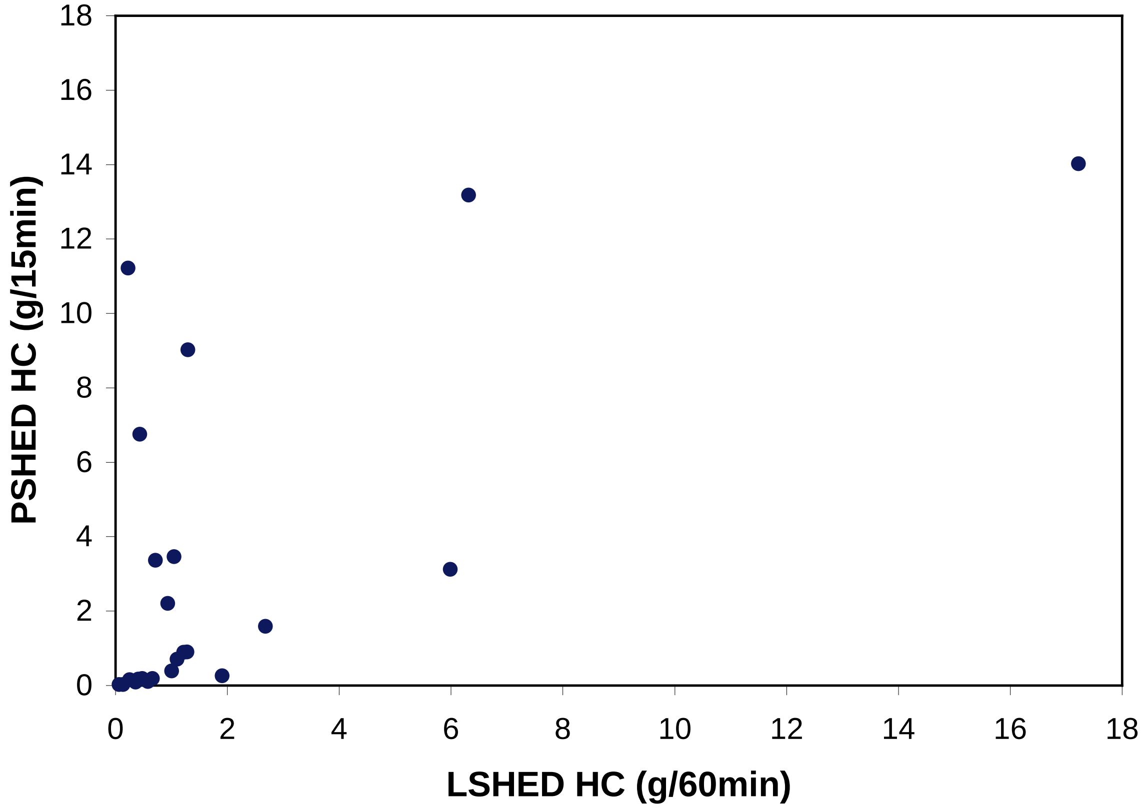
instrumentation and gas costs could provide such accurate and precise retention and recovery values.

Average Recovery	97.6%
Recovery Standard Deviation	3.3%
Average Retention for 15 minutes	95.7%
Retention Standard Deviation	2.3%

PSHED vs. LSHED - The PSHED performed in the IM lane consisted of a 15-minute test that was performed after a test vehicle had been taken on a conditioning drive over a prescribed route. The conditioning drive was important because laboratory SHED hot soak evaporative emissions are measured following a standardized drive cycle on a dynamometer. Therefore, to mimic this procedure with the understanding that future PSHED measurements would likely be performed without any access to a dynamometer, the test vehicles were conditioned on the road over a set route. In addition to the standard dynamometer conditioning drive cycle, an LSHED is also a one hour test, with strict temperature and fuel level controls. Given the objective of developing a quick evaporative test, the PSHED was only 15 minutes in duration and there was no attempt made to control the temperature or the fuel level of the vehicle.

The results of the paired tests are illustrated in Figure 3-2 below. The results are encouraging; however, closer agreement between the PSHED and LSHED measurements was hoped for given the PSHED retention and recovery results. At this time the major cause for this discrepancy is believed to be the non-repeatable nature of a vehicle's evaporative emissions, which can be exacerbated by malfunctioning evaporative emission systems, the variability in the on-road preconditioning driving for the PSHED vs. the dynamometer FTP as well as the widely varying uncontrolled ambient temperatures for the PSHED measurements.

Figure 3-2. Comparison of 15-Minute PSHED and 60-Minute LSHED Measurements



4.0 Analytical Methods

The following instrumentation was used to take the measurements for this study. Each is described in the following sub-sections.

- ESP RSD-4600 remote sensing instrumentation
- SEMTECH-G portable gas analyzer
- SnapOn hand-held combustible gas detector
- FLIR GasFindIR hydrocarbon vapor video camera

4.1 RSD Emissions Instruments

This pilot study used a single RSD-4600 unit for all RSD measurements. RSD systems are designed for non-intrusive measurement of vehicle emissions. They generate and monitor a light beam emitted and reflected approximately 10 to 18 inches above a single lane road. The RSD-4600 detects vehicle emissions when a car drives through an invisible light beam the system projects across a roadway. Figure 4-1 contains a diagram of a typical on-road set-up. The process of measuring emissions remotely begins when the RSD-4600 Source/Detector Module (SDM) sends an infrared (IR) and ultraviolet (UV) light beam across a single lane of road to a Corner Cube Mirror (CCM). The CCM reflects the beam back across the roadway (creating a dual beam path) into a series of detectors in the SDM.

Fuel-specific concentrations of HC, CO, CO_2, NO and smoke are measured in vehicle exhaust plumes based on their absorption of IR/UV light in the dual beam path. During this process, the Speed/Acceleration Module (S/A) measures the speed and acceleration of each vehicle while the Video System Camera captures an image of the rear of the vehicle. Emissions concentration values and other related data are stored in a computer processor monitored by an operator stationed in a mobile unit parked safely along the roadside. This entire process is accomplished in less than a second.

The internal combustion equation assumes a non-oxygenated fuel with a hydrogen to carbon ratio of 1.85 to 1.0. Accuracy specifications apply when the distance between the SDM and the CCM is from 15 ft to 23 ft.

The performance of the RSD-4600 Remote Sensing Device will meet or exceed the absolute and relative accuracy specifications shown in Table 4-1. These data are based on internal instrument specifications, not on-road controlled conditions.

Figure 4-1. Typical On-Road RSD-4600 Set-Up

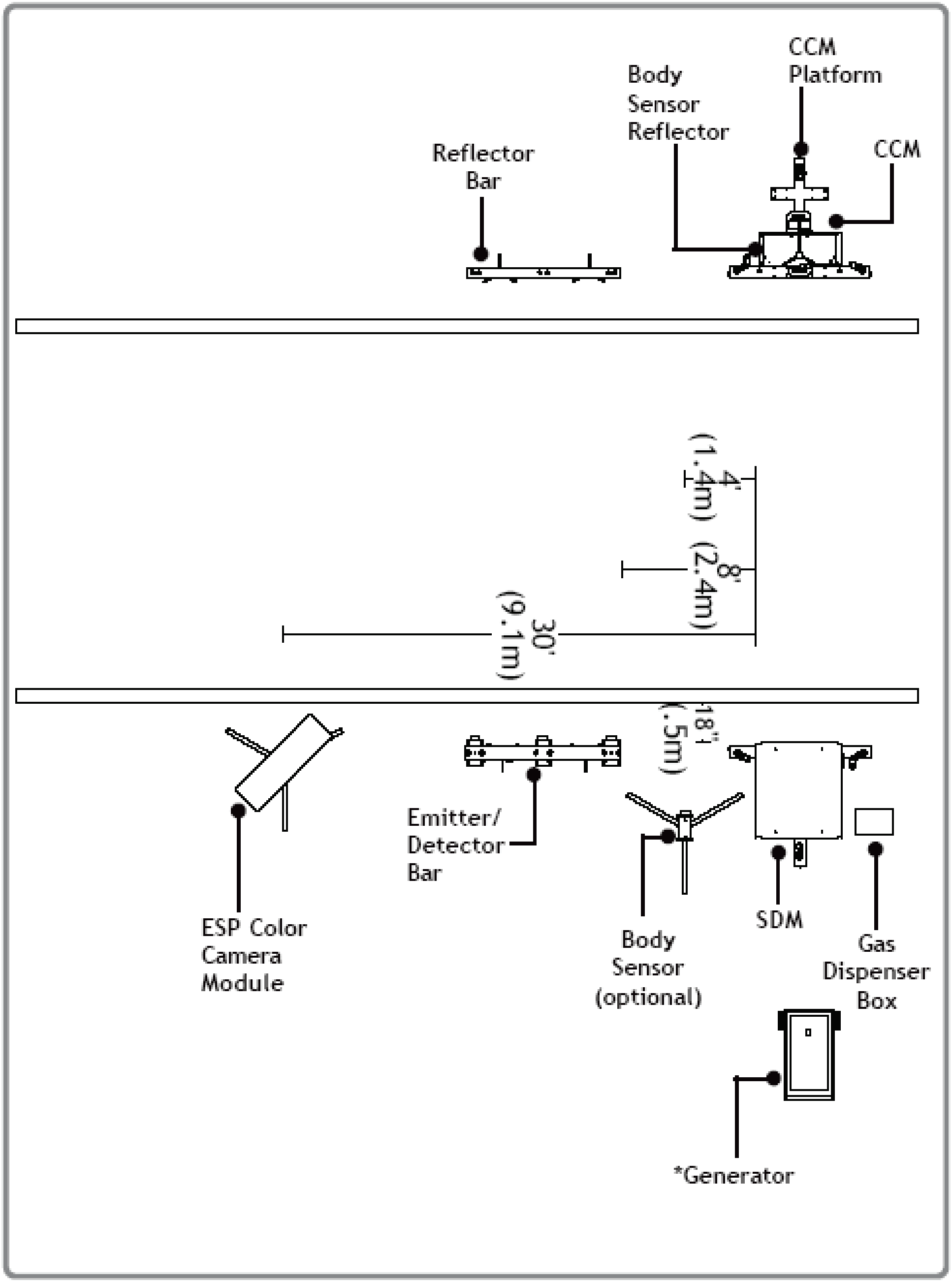


Table 4-1. ESP RSD-4000 Instrument Specifications

RSD-4600 General Specifications

Ambient Temperature	
•Operating:	-7°C to +49°C (20°F to 120°F)
•Storage:	-30°C to 60°C
Ambient Humidity	0 to 95% (non-condensing)
Altitude (operating)	-1000 ft to 10,000 ft (-305 to 305 m)
Speed Accuracy	±1 mph (5 – 70 mph)
Acceleration Accuracy	±0.5 mph/second (5 – 70 mph)

RSD-4600 specifications for CO_2 plume greater than 20%-cm

CO% / **CO_2** %	0.007 or ±10% of reading, whichever is greater
HC ppm / **CO_2** % (propane)	±6.6 or ±10% of reading, whichever is greater
NO ppm / **CO_2** %	±10 or ±10% of reading, whichever is greater
CO%	0.1 or ±10% of reading, whichever is greater
HC (propane) ppm	±100 or ±10% of reading, whichever is greater
NO ppm	±150 or ±10% of reading, whichever is greater
Smoke number	±0.05 or ±10% of reading, whichever is greater

RSD-4600 specifications for CO_2 plume less than 20%-cm

CO% / **CO_2** %	0.015 or ±15% of reading, whichever is greater
HC ppm / **CO_2** % (propane)	±10 or ±15% of reading, whichever is greater
NO ppm / **CO_2** %	±10 or ±15% of reading, whichever is greater
CO%	0.15 or ±15% of reading, whichever is greater
HC (propane) ppm	150 or ±15% of reading, whichever is greater
NO ppm	±225 or ±15% of reading, whichever is greater
Smoke number	0.1 or ±15% of reading, whichever is greater

The usual calculations used by the RSD-4600 instrument are provided by Method A. However, for this pilot study, a special supplemental query was written to also calculate reported emissions concentrations according to an approximation of Method B. Also, a special query was written to bin the Selection RSDs for every vehicle entering the IM station and to randomly select vehicles within each bin for solicitation.

4.2 SEMTECH-G Analyzer for Portable SHED Measurements

The SEMTECH-G analyzer is primarily intended for on-vehicle emission monitoring of gasoline (spark-ignition engine) powered vehicles. The analyzer can also be used for emission monitoring in other mobile applications, and also stationary applications such as engine test cells, where SEMTECH-G can be easily moved from one test cell to another. In this pilot study the SEMTECH-G was used to record the HC concentrations in the PSHED as vehicles produced evaporative emissions.

The SEMTECH® (Sensors Emission Technology) product line is based on a number of modular, stand-alone measurement subsystems. The following is a list of measurement subsystems included in the SEMTECH-G emission analyzer.

- Heated Flame Ionization Detector (FID) for total hydrocarbon (THC) measurement
- Non-Dispersive Ultraviolet (NDUV) analyzer for nitric oxide (NO) measurement
- Non-Dispersive Infrared (NDIR) analyzer for carbon monoxide (CO) and carbon dioxide (CO_2) measurement
- Electrochemical sensor for oxygen (O_2) measurement

All of the SEMTECH subsystems have been designed to match as closely as possible the analytical performance of laboratory grade instrumentation, and yet meet the special requirements of on-vehicle emission monitoring application. This requires a reduction in size, weight, and power consumption combined with reduced sensitivity to vibration and changes in ambient temperature, pressure, and humidity.

In addition to above listed measurement subsystems SEMTECH-G includes following modules:

- Data logger, I/O, and system control module
- Wireless communication module for remote monitoring and control using a personal computer (PC) or a personal digital assistant (PDA)
- Weather probe for ambient temperature and humidity measurement

Total Hydrocarbon Heated FID Analyzer – To accurately measure total hydrocarbons (THC) over the range of 0 to 40,000 ppmC, a high-precision heated FID is used in the SEMTECH-G. A fraction of the sampled gas is routed through the stainless steel heated FID chamber for measurement. The FID chamber is heated to 191 °C.

All aspects of the THC FID are electronically controlled by the SEMTECH-G embedded control software. FID flame ignition and extinction is performed on demand from the user via the host computer software graphic user interface. All internal parameters, such as flow rates and pressures are monitored and controlled automatically by SEMTECH-G.

The user can select a range of 100, 1,000, 10,000, or 40,000 ppmC. All enabled ranges are individually calibrated each time a zero calibration command is given, so the number of enabled ranges is minimized to reduce this process time. The user can also select a data rate of up to 4 Hz through the SENSOR Tech-PC application software.

The THC FID fuel consists of a 40/60 blend of hydrogen/helium. The fuel cylinder is housed inside the SEMTECH-G chassis, and includes an electronic pressure sensor connected to the data acquisition system so the user can monitor the fuel capacity from the SENSOR Tech-PC application software. A warning will occur when the fuel pressure drops too low. The fuel pressure is regulated at the bottle with a two-stage, stainless steel regulator. The bottle holds 105 liters (compressed), which will last approximately eight hours. The bottles are available both in the U.S. and Europe by Scott Gas, and are refillable. There is also an auxiliary FID fuel connection port for external cylinders for use in stationary environments such as test cells.

Table 4-2. SEMTECH-G Measurement HC Specifications

	User Selectable Ranges			
	0 –100 ppmC	**0 –1,000 ppmC**	**0 – 10,000 ppmC**	**0 – 40,000 ppmC**
Accuracy	±2.0 % of reading or ±5 ppmC whichever is greater	±2.0 % of reading or ±5 ppmC whichever is greater	±2.0 % of reading or ±25 ppmC whichever is greater	±2.0 % of reading or ±25 ppmC whichever is greater
Resolution	0.1 ppmC	1.0 ppmC	1.0 ppmC	10.0 ppmC
Linearity	±1.0 % of reading or ±3 ppmC whichever is greater	±1.0 % of reading or ±3 ppmC whichever is greater	±1.0 % of reading or ±10 ppmC whichever is greater	±1.0 % of reading or ±10 ppmC whichever is greater
Repeatability	±1.0 % of reading or ±2 ppmC whichever is greater	±1.0 % of reading or ±2 ppmC whichever is greater	±1.0 % of reading or ±10 ppmC whichever is greater	±1.0 % of reading or ±10 ppmC whichever is greater
Noise	±2 ppmC	±2 ppmC	±10 ppmC	±20 ppmC
Span drift (over 8 hours)	±1.0 % of reading or 3 ppmC whichever is greater	±1.0 % of reading or 3 ppmC whichever is greater	±1.0 % of reading or 15 ppmC whichever is greater	±1.0 % of reading or 20 ppmC whichever is greater
Zero drift (over 2 hours)	5 ppmC	5 ppmC	10 ppmC	20 ppmC
Zero drift (over 8 hours)	10 ppmC	10 ppmC	20 ppmC	40 ppmC
Warm up time	60 minutes	60 minutes	60 minutes	60 minutes
Response time	T90 < 2 seconds	T90 < 2 seconds	T90 < 2 seconds	T90 < 2 seconds
Flow rate	2 lpm	2 lpm	2 lpm	2 lpm
Data rate	Up to 4 Hz, configurable	Up to 4 Hz, configurable	Up to 4 Hz, configurable	Up to 4 Hz, configurable
Operating Temperature	191 °C	191 °C	191 °C	191 °C

Ambient Air Sensors – The standard weather station for the SEMTECH product family consists of a remote mounted temperature and relative humidity sensing device. This package is connected to the SEMTECH-G front panel using the supplied cable. Cables of three meters in length are standard. The ambient pressure sensor is located in the SEMTECH-G unit and is vented through the rear panel.

Table 4-3. SEMTECH-G Ambient Air Specifications

Sensor	Temperature	Relative Humidity	Pressure
Range of measurement	-39 °C to 60 °C	0.8% to 100% RH	15 to 115 kPa
Accuracy	±0.2 °C	±2% RH at 0 to 90% RH ±3% RH at 90 to 100% RH	±1.5% 0 to 85 °C
Response time		T90 < 10 seconds at 20 °C	T90 < 4 seconds

4.3 HC Sniffer for Modified California Procedure

Another evaporative emissions test was conducted using a handheld combustible gas detector that has been found useful in locating small liquid and vapor leaks. The unit used in this pilot study is the Combustible Gas Detector (Stock# ACT790) sold by SnapOn tools for $299.99, and shown in Figure 4-2. According to Snap-On, the unit can be used to find leaks in fuel and exhaust systems. Detectable compounds include acetylene, isobutane, methane, ethane, propane, hydrogen, acetone, methanol and gasoline. The battery-operated unit uses a solid electrolyte to detect hydrocarbons with a propane sensitivity of < 10 ppm.

Figure 4-2. HC Sniffer

4.4 Infrared Video Camera

Open-path gas detection units, or IR cameras, are used to detect leaks in industrial settings, and it is possible they may be useful in detecting evaporative leaks from vehicles as well. Although there is no standard test procedure for detecting HC leaks from vehicles, the oil and gas industry routinely monitors VOC leaks, and some of the methods used in that setting may prove promising for vapor and liquid leak detection in vehicles.

In this pilot study, the FLIR (Forward Looking InfraRed) Systems[8] GasFindIR video camera was used for about two weeks to evaluate its efficacy for detecting the evaporative emissions of light-duty gasoline vehicles. A photo of the GasFindIR unit is shown in Figure 4-3. According to FLIR, the unit is a hand portable, battery-powered open-path gas monitor providing fast response and broad dynamic range. They are permanently calibrated, small and light (less than 5kg). Alignment is easy and stable. Monitor response does not depend on path length, so a series of paths of different lengths (between 1m and 1000m) can be measured in quick succession. These systems are typically used to provide exceptional detection capability of gas/vapor concentrations ranging from as low as ppm levels to Lower Explosive Limit levels in a wide range of hazardous conditions and ambient air monitoring applications. The device forms an image using infrared radiation, similar to a common video camera that forms an image using visible light. Instead of the 450–750 nanometer range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm).

According to the flir.com website, independent laboratory testing confirms that the GasFindIR cameras can see the following gases at the minimum detected leak rate (MDLR):

1-Pentene - 5.6g/hr
Benzene - 3.5g/hr
Butane -0.4g/hr
Ethane - 0.6g/hr
Ethanol - 0.7g/hr
Ethylbenzene - 1.5g/hr
Ethylene - 4.4g/hr
Heptane - 1.8g/hr
Hexane - 1.7g/hr
Octane - 1.2g/hr
Pentane - 3.0g/hr
Propane - 0.4g/hr
Propylene - 2.9g/hr
Toluene - 3.8g/hr
Xylene - 1.9g/hr

[8] 25 Esquire Road, N. Billerica, MA, 01862, (978) 901-8000, www.flir.com.

Figure 4-3. FLIR GasFindIR Gas Detection Video Camera

In infrared photography, the film or image sensor used is sensitive to infrared light. The part of the spectrum used is referred to as near-infrared to distinguish it from far-infrared, which is the domain of thermal imaging. Wavelengths used for photography range from about 700 nm to about 900 nm. Usually an "infrared filter" is used; this lets IR light pass through to the camera but blocks all or most of the visible light spectrum (and thus looks black or deep red). There are two different methods employed by IR cameras, one is known as Backscatter Absorption Gas Imaging (BAGI) and the other Image Multi-Spectral Sensing (IMSS). The former views the area illuminated by the IR source light and the camera images the reflected light. Volatile Organic Compound vapors absorb IR light, so the image produced is a negative. The cameras using the IMSS method capture an image using the full light spectrum and the optics separate and recombine selected wavelengths to create an image.

Studies indicate that the BAGI style IR camera can detect VOC leaks from 6 to 17 feet away with leak rates ranging from 3-60 grams/hr. Work in the area of refinery leak detection has progressed to the point that emission factors have been developed for various piping components and Monte Carlo simulation methods have been employed to aid in the estimation of VOC fugitive emission releases.

4.5 Management of Field Data

Vehicle information was collected on hardcopy forms similar to the "Vehicle Data Collection Forms" included in Appendix A. VINs, make, model, model year numbers and other information was also collected, as available. Photographs were taken of unique identifiers such as VINs to serve as conformation information and to correct or clarify transcription errors and discrepancies. Vehicle information was transmitted to an ERG office for entry into a spreadsheet or database.

5.0 Analysis

This section of the report will present an initial analysis of the data collected in this pilot study. The main goal here is to describe the general trends in the data. Data observations are shown in Appendices D through K for participating vehicle information, selection RSDs, conditioning drives, measurement RSDs, PSHED results, modified California method results, driver interviews, and I/M gas cap inspection results.

In this study the reference method for determining the evaporative emissions of vehicles was the measurement of hot-soak emissions produced by a vehicle while it soaked in the PSHED for 15 minutes. Three methods were evaluated as candidate methods for detecting vehicles that have high PSHED values:

IR video camera – This qualitative method uses a special IR detector coupled to a video recorder that can see the motion of HC vapors as they are emitted. The results of these tests are reported in Section 5.1.

Modified California Method – This qualitative method supplements a visual and olfactory inspection of the gasoline liquid and vapor handling systems of a vehicle (the California Method) with a hand-held electronic HC vapor detector. The results of this testing is reported in Section 5.2.

RSD – This quantitative method uses the detailed absorbance information from an RSD beam block to calculate an "index" that is related to evaporative emissions.[9] Section 5.3 describes the relationship between RSD Evap Index 1[10] and the PSHED measurements in this pilot study. Note that since better RSD evaporative emissions indices will probably be developed in the future, this analysis is just an early look at the potential for RSD to detect evaporative emissions.

Section 5.4 demonstrates how to estimate the fraction of High Evap vehicles in a sample of a fleet. In this calculation, fleet on-road RSD measurements are used to calculate RSD Evap Index 1, which is in turn used to estimate each vehicle's probability of being a High Evap.

[9] Since RSD instruments were developed with the goal of detecting vehicles with elevated exhaust emissions, finding an index that is sensitive to evaporative emissions without being influenced by exhaust HC emissions is a challenge. We expect that no theory can be used to determine the perfect index. Instead, evap index development is a signal analysis problem. Consequently, ever improved indices can be developed as index developers get more inventive.

[10] Developed by H.J. Williamson [11] using the Summer 2008 PreTesting data.

5.1 Evaluation of Using the Infrared Video Camera to Detect High Evaps

FLIR Systems, Inc. has developed an infrared video camera for the detection of a variety of hydrocarbon gases. The camera used in the pilot study was the FLIR ThermaCAM GasFindIR Infrared Camera. This camera features a high resolution video image based on an indium antimonite (InSb) focal plane array. The visual detection of hydrocarbon gases is provided by a narrow band pass cold filter specifically centered in the spectrum to detect various hydrocarbon gases. The camera is a hand held package weighing less than five pounds and uses a separate video recorder with an LCD screen. The camera was designed to find fugitive emissions such as those that might be present as small hydrocarbon vapor leaks in the piping of a refinery or chemical plant.

The IR video camera was used in this pilot study from August 1 through 15, 2008. To initially test the ability of the IR camera to see evaporative emissions, we removed the gas cap of a vehicle after it had been driven on the 8-mile conditioning drive. Since the ambient temperature was hot, we expected that the fuel tank temperature at the end of the drive would be especially elevated, and therefore a substantial amount of gasoline vapor should be emitted from the open fuel fill pipe. When the gas cap was removed the vehicle, the video camera showed quite clearly the hydrocarbon emissions coming from the opening. Thus, this first test was encouraging. The features that made the hydrocarbon emissions visible in the video were the relative motion of the darkly colored image of hydrocarbon vapors compared with the stationary background of the fender of the vehicle. If the vehicle fender was light colored, then it was easy to see the hydrocarbon emissions. However, if the fender of the vehicle was darkly colored, then it was difficult or impossible to see the motion of the hydrocarbon emissions.

During the routine testing of private vehicles during the two weeks that we had rented the IR camera, we used the camera to search for evaporative emissions from the fuel cap, under the hood, and under the vehicle near the fuel tank. We found that when the background was complex (e.g., under the hood) or was dark (e.g., under the vehicle, in the fender well, or under the hood) the video camera operator would probably not be able to see the wisps of hydrocarbons that might be being emitted as evaporative emissions. It was also rather difficult to aim the camera at the fuel system or evaporative emission system components under the vehicle and under the hood and at the same time watch the video screen for wisps of hydrocarbon with the complex background and poor lighting conditions. Those difficulties hampered the ability of the operator to interpret the video. We found that the use of the hand-held hydrocarbon sniffer with its audio clicking was a far better tool for detecting and locating evaporative emissions leaks. Therefore, after about one week of attempting to use the IR video camera, we abandoned it.

5.2 Evaluation of the Modified California Method to Detect High Evaps

In this subsection, the modified California method (MCM), which includes visual, olfactory, and hand-held electronic HC vapor sniffer inspection components, was evaluated against the PSHED results (g HC / 15 minutes) for the 85 vehicles participating in the evaporative emissions testing at the Lipan Street station.

The sequence of the PSHED and MCM tests is important to the interpretation of the results. Participating vehicles were given an 8-mile on-road conditioning drive and two IM station driveway RSDs. Then, the vehicle was driven to the PSHED door, the engine was shut down, and the vehicle was pushed into the PSHED for the 15-minute test. During this 15 minutes the vehicle cooled somewhat. At the end of the PSHED test the vehicle was started in the PSHED and backed out of the enclosure approximately 50 feet, but the vehicle was still inside the IM station. The MCM inspection was then performed. For the first part of the MCM the engine was left running. For the last part the engine was off. Because of the 8-mile conditioning drive immediately before the PSHED test but not immediately before the MCM test and the 15-minute cooling during the PSHED test, it is likely that the MCM test was conducted under less severe evaporative emissions conditions than the PSHED test. This may mean that in some cases the MCM test may not have detected evaporative emissions that might have occurred if the vehicle had been just as severely conditioned as for the PSHED test.

In addition to the different conditioning used for the PSHED test and for the MCM test, there was another factor that could have affected the MCM results. Personnel conducting the MCM test always knew the PSHED test result. Therefore, if the PSHED result was high, the MCM inspectors worked hard to try to find the source of the HC emissions. In fact, we instructed the MCM inspectors to try to find the exact source of the emissions on high-PSHED vehicles. On the other hand, it would only be human nature that an inspector would not look so hard to find a leak on a vehicle that he knew to have a low PSHED result.

In this study the PSHED result was treated as the true evaporative emissions of each vehicle. In reality, the PSHED result is closest to a hot-soak evaporative emissions result and may be only a crude estimate of diurnal, running losses, resting losses, or fugitive evaporative emissions. The PSHED results, which are given in the last column of the table in Appendix H, are repeated in Table 5-1.

Table 5-1. Comparison of PSHED and MCM Overall Results[B]

PacketID	PSHED (g / 15 minutes)	MCM (1=Detected, 0=NotDetected)	PacketID	PSHED (g / 15 minutes)	MCM (1=Detected, 0=NotDetected)
10	0.130	0	191	0.087	0
11	14.022	1	193	11.219	0
16	0.538	1	194	24.073	0
19	14.809	1	200	0.171	0
22	1.301	0	203	0.022	0
24	11.194	1	213	0.890	1
29	0.088	1	217	0.066	0
35	15.472	1	218	0.354	0
46	11.998	.	220	1.094	0
50	0.903	1	221	0.133	0
60	0.109	1	222	2.795	0
61	0.079	0	223	2.022	1
62	0.082	0	225	0.335	0
63	0.186	0	226	0.174	0
65	0.177	0	229	3.438	1
70	0.040	0	236	1.047	1
72	0.186	0	240	0.109	0
78	0.312	1	242	9.021	1
79	0.021	0	245	0.134	0
84	0.153	0	247	2.203	1
89	0.385	1	248	1.115	0
98	0.032	0	250	0.709	1
108	0.705	0	251	0.027	0
110	3.121	1	254	0.333	0
116	6.753	1	256	2.181	0
117	0.256	0	257	0.076	0
118	9.364	1	258	0.028	0
123	0.209	0	266	0.133	0
124	0.152	0	270	1.062	1
128	3.461	0	271	1.292	1
130	0.156	0	272	1.365	0
131	1.940	1	274	0.022	0
132	1.516	0	281	0.262	0
137	0.285	0	283	0.068	0
138	0.046	0	284	0.067	0
146	1.589	1	286	13.180	1
151	0.354	0	287	2.988	0
157	0.178	1	290	1.227	0
161	3.366	1	294	0.064	0
165	0.262	1	298	0.045	0
169	2.998	0	299	0.323	0
174	0.048	0	300	0.266	0
177	0.068	0	304	0.167	1
184	0.044	0			

The detailed results of the MCM inspection as reported on the data packets are shown in Appendix I. When the MCM inspection found evidence of evaporative emissions, various types of comments were recorded.

In many cases, especially for the newer vehicles, it was difficult to access much of the fuel system with a sniffer. Vehicle designs are much more tightly packed and without invasive diagnostics (i.e. hoisting the vehicle and pulling down the fuel tank and fuel lines), the technicians were unable to determine the source of leaks in even high PSHED readings as can be seen in Table 5-1.

5.3 Evaluation of Using RSD to Detect High Evaps

5.3.1 RSD Evap Index 1 Description

The RSD instrument uses a light beam shining across the roadway to measure pollutants in a vehicle's tailpipe plume. The instrument has HC, CO, NO, and CO_2 channels. When a vehicle drives past the instrument, the light beam shines through the emissions plume behind the vehicle and takes 50 10-millisecond-spaced measurements for each of these channels.

For vehicles with zero evaporative emissions, the 50 data points in the HC-versus-CO_2 plot tend to fall on a straight line. As described in Section 2.3, the exhaust HC emissions concentration is closely related to the slope of the line. This method used to calculate exhaust HC concentration from the 50 10ms RSD data is a standard method and has been known for many years. However, the Denver pilot study also found that for vehicles with high evaporative emissions, the 50 data points in the HC-versus-CO_2 plot tend to not fall on a straight line. We believe this is a consequence of the HC evaporative emissions plume, which is produced by non-tailpipe sources on the vehicle, wafting into the light beam at the same time as the tailpipe plume is in the light beam. Thus, the degree to which the 50 data points deviate from a straight line in the HC-vs-CO_2 plot is a measure of the amount of evaporative emissions produced by the vehicle at the time that it passes through the RSD light beam. The evaporative emissions that may be observed by RSD represent the "running losses" of the vehicle, that is, the evaporative emissions that take place while the vehicle is being driven.

We investigated several measures of the characteristics of the deviations from the straight line as they relate to evaporative emissions. The statistical measures that were investigated included the average deviation from the straight line, correlation coefficient, principal component analysis, and spectral analysis. Each approach has advantages and disadvantages, but using the average deviation from the straight line outperforms the other measures in most cases. Therefore, this measure was used in this study, and is referred to as the RSD Evap Index 1.

For the analysis of the data in this pilot study, we used the RSD Evap Index 1, which is the best second generation evap index that we have developed. It is an improvement over the RSD Evap Index 0, which was simply the difference between the Method A and Method B RSD HC values. The following text, which was taken from H.J. Williamson's report [11] on the development of RSD evaporative emissions indices, provides a description of the RSD Evap Index 1:

> Each RSD beam block typically produces 50 attenuations (concentration times path length) with 10 ms spacing for each pollutant. The attenuations generally decrease with time after the vehicle has passed the RSD unit because of the dispersion of the plume in ambient air. The light beam for the RSD unit is placed so that it is at tailpipe elevation. The above-mentioned gasses [HC, CO, NO_x, CO_2] emitted from the tailpipe are well mixed and disperse together. Therefore, the [RSD optical] path length for each tailpipe pollutant is the same, and the RSD attenuations reflect only the ratios of the tailpipe pollutant concentrations.
>
> On the other hand, evaporative gasses (only HC) are emitted from non-tailpipe sources – even multiple sources. Therefore, evaporative emissions do not disperse in the same way the tailpipe emissions do. The difference in dispersion between evaporative and tailpipe emissions is the key quality that can be used to detect evaporative emissions. The evaporative emissions can waft into and out of the RSD's light beam.
>
> If hydrocarbon fuel is being burned, the CO_2 emissions will be above the detection limit. Thus, CO_2 is an effective tracer for the tailpipe dispersion effect in any case of interest. This is not guaranteed to be the case with CO, NO_x, or HC.
>
> Thus, consider the following. Suppose we perform a regression analysis of the 50 attenuations for HC on CO_2. If the HC measurements are above the detection limit, this regression analysis will account for the tailpipe-related part of the trend in the HC measurements. The residuals, that is, the observed minus predicted values, contain what is left after the trend associated with the tailpipe effect has been mathematically removed.
>
> If there are no evaporative emissions, the residuals should be at the noise level. If there are significant evaporative emissions, the residuals will typically contain a remaining trend that is larger than the noise level. The evaporative trend may not be strictly independent of the tailpipe trend, but the evaporative trend is not expected to be the same as the tailpipe trend. Differences between the

time histories for tailpipe emissions and evaporative emissions produce the remaining trend that allows us to detect evaporative emissions.

If the HC measurements are below the detection limit, they will be essentially noise. If the HC measurements are this low, both the tailpipe and evaporative emissions are probably quite low. There will be no tailpipe trend to remove, and the residuals will be at the noise level.

Now suppose the car has very low tailpipe emissions but has significant evaporative emissions. For reasons discussed above, we do not expect the time history for the HC evaporative emissions to have the same characteristics as the tailpipe CO_2 emissions. Thus, as in the case with measurable tailpipe emissions and significant evaporative emissions, we expect the residuals to have a remaining trend that is larger than the noise level.

Therefore, using the residuals appears to satisfy our need to remove the tailpipe HC trend if it is present. Whether the tailpipe emissions are measurable or not, the residuals are characteristic of noise in the absence of evaporative emissions. Further, the residuals typically have a remaining trend above the noise level if there are significant evaporative emissions. Therefore, the residuals appear to provide an avenue for calculating measures that have a common meaning in different scenarios.

The residuals have other characteristics that we can exploit. If the residuals are characteristic of noise alone, they are likely to oscillate back and forth about zero fairly rapidly. But, if present, the evaporative plume probably does not waft into and out of the RSD's light beam with high frequency. The influence of the evaporative plume is likely to produce sustained periods when the residuals are positive and sustained periods when the residuals are negative. Again, the residual is the HC value after the trend associated with tailpipe emissions has been mathematically removed.

We have experimented with various measures that are based on the properties discussed above. The measure, which we call RSD Evap Index 1,that is related to the presence or absence of evaporative emissions can be described as follows:

1) First, discard the first four HC and CO_2 attenuations. These typically contain noise that can degrade the sensitivity of the index to evaporative emissions.

2) Second, regress the remaining HC attenuations on the CO_2 attenuations using ordinary least squares regression, and calculate the 46 regression residuals.

3) Third, exclude the smallest residual and the largest residual (some would say the most negative and most positive residuals). This step eliminates isolated outliers, if present.

4) Finally, average the absolute values of the remaining residuals. This is the value of the RSD Evap Index 1.

5.3.2 Paired RSD and PSHED Observations

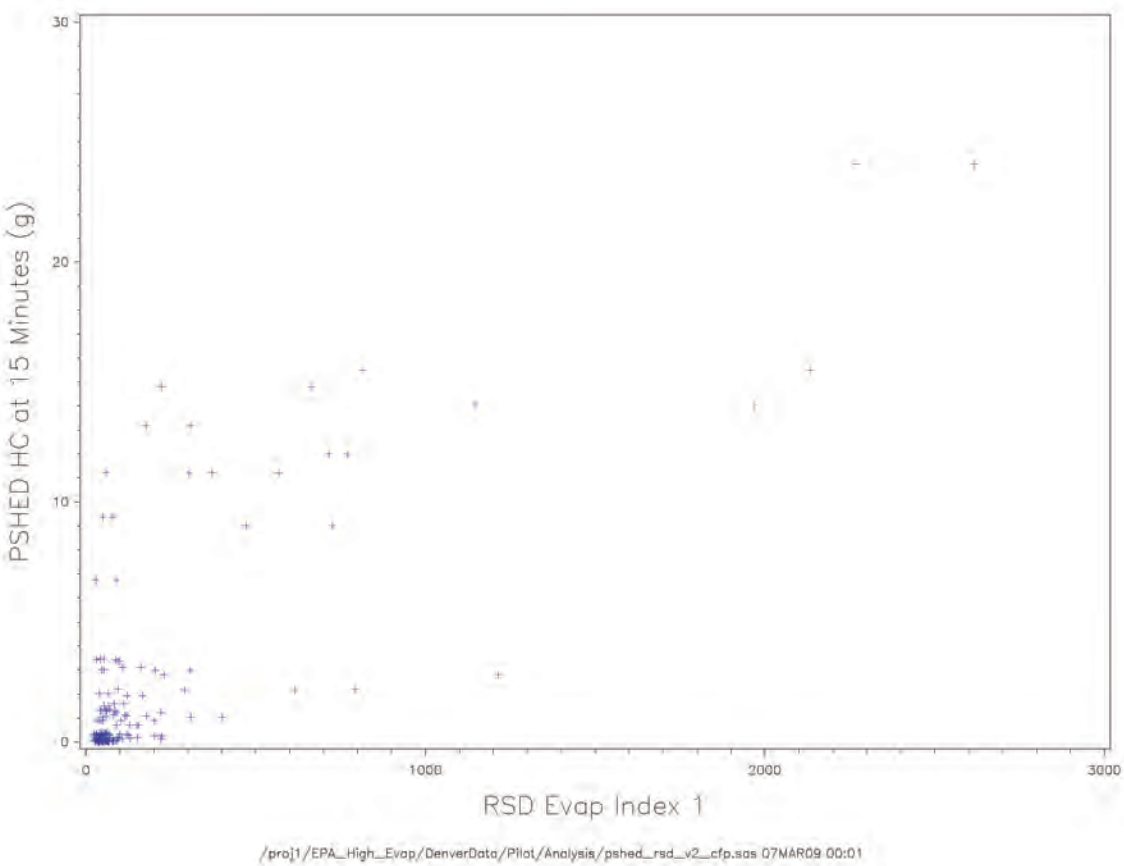
While RSD observes the running losses of a vehicle, the PSHED test measures the "hot-soak" evaporative emissions of a vehicle. However, we expect that a vehicle with a malfunctioning evaporative emissions control system could be expected to have elevated PSHED hot-soak emissions and elevated RSD running loss emissions.

Accordingly, we examined the correlation between the RSD Evap Index 1 and the PSHED test using the 175 observations of the Denver pilot study. Each of 85 PSHED tests was paired with two (and in several cases, more than two) RSD observations, for a total of 175 paired observations. Each RSD measurement produced the 50-sample-point data, which in turn was used to calculate the RSD Evap Index 1 value for the RSD beam block. In this study, all RSD measurements were made in the driveway entrance to the I/M station. Speeds were about 12 mph.

The 85 vehicles tested in this pilot study were selected using a stratified random sampling plan. Therefore, the measured PSHED and RSD results do not directly represent the Colorado fleet; the results would need to be de-stratified. However, the relationship between the RSD and the PSHED results is an estimate of the relationship that the Colorado fleet follows.

Figure 5-1 shows a plot of the 175 observations. The vertical axis is the PSHED result, and the horizontal axis is the RSD Evap Index 1. The plot shows widely scattered data with positively skewed values on both axes. The skewed nature of the PSHED values is derived from the fact that most vehicles (even those in this stratified sample) have low evaporative emissions; only a few vehicles are "High Evaps." In spite of the scatter of the data points, the plot shows that at low values of the RSD Evap Index, most vehicles have low PSHED emissions. In addition, the group of data points with the highest PSHED values increase with increasing RSD Evap Index 1. Thus, it is reasonable to conclude that vehicles with higher RSD Evap Index 1 tend to have higher PSHED values. The relationship between RSD Evap Index 1 and PSHED value needed to be quantified so that it can be used as a predictive tool.

Figure 5-1. RSD Evap Index 1 and PSHED Values (Speed is approximately 12 mph)



Two different approaches may be used to quantify the relationship between the PSHED and RSD values. Because the RSD observations of evaporative emissions represent running losses, while the PSHED test measures hot soak evaporative emissions, the two tests do not actually measure the same type of evaporative emissions. Therefore, a logical correlation between the two tests would seek to determine whether or not there is a gross problem with the evaporative emissions system of a vehicle, rather than attempting to use evaporative emissions observed by RSD to predict a specific level of the different type of evaporative emissions that are measured in a PSHED test. Nevertheless, we want a quantitative relationship to predict if a vehicle is likely to be a High Evap.

In one approach, the PSHED HC mass is regressed against the RSD Evap Index 1 value, to identify an equation to estimate the PSHED HC mass based on a measured RSD Evap Index 1 value. This approach is explored below in Section 5.3.3. Alternatively, each PSHED value can be compared to a high-evap PSHED benchmark value to classify each PSHED measurement as a low-evap or a high-evap value. Then, the classifications are compared to the RSD Evap Index 1 using logistic regression to arrive at a model that calculates the probability that a vehicle is a High Evap based on its measured RSD Evap Index 1. This approach is described in Section 5.3.4.

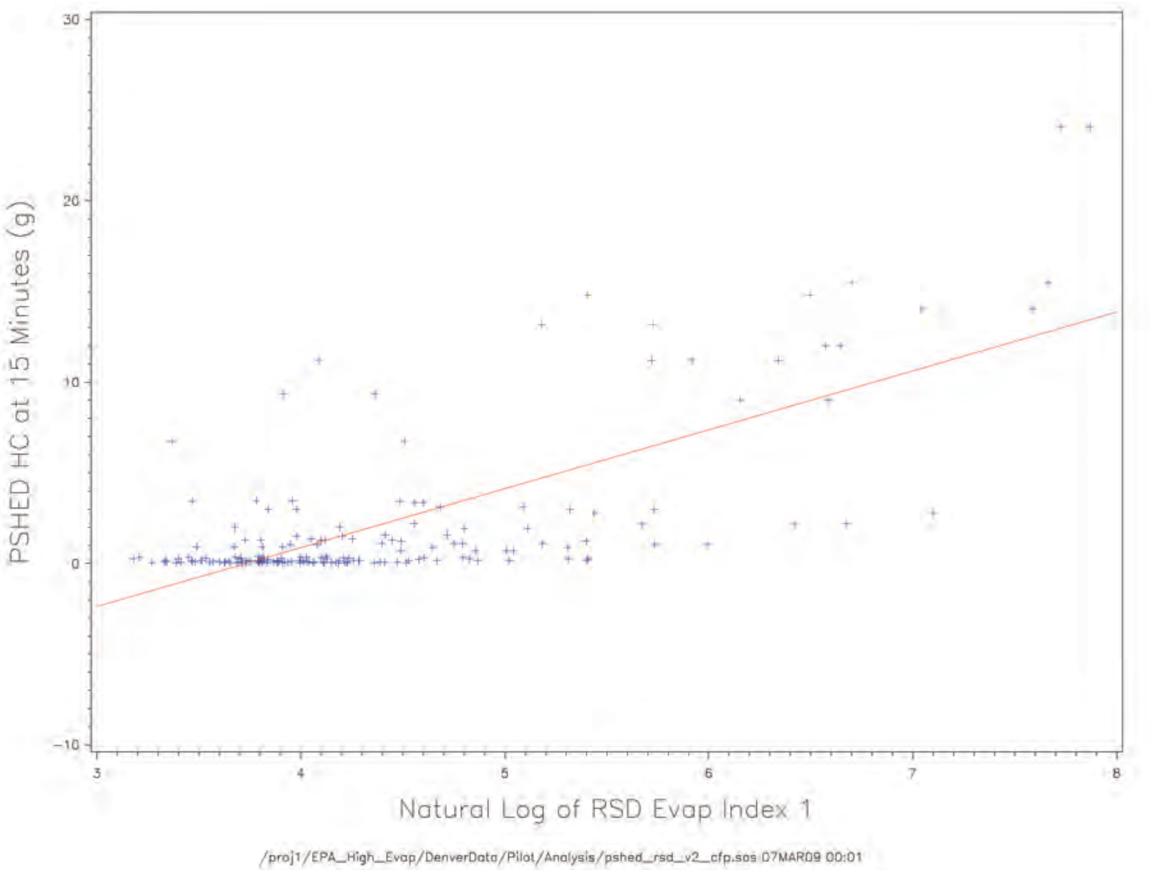
5.3.3 Prediction of PSHED Value Using RSD Evap Index 1

To quantify the relationship between the PSHED value and the RSD Evap Index 1, we performed a linear regression. First, we found that the natural log of the RSD Evap Index 1 was an advantageous transformation. It caused the variances of the RSD Evap Index 1 to be more nearly homogeneous. Using the log transformation, the PSHED value was predicted from the RSD Evap Index 1 as:

$$PSHED\_g = -12.1209 + 3.24789 * \ln(RSD\ Evap\ Index\ 1)$$

The r^2 for the regression was 0.52, indicating that the data include a substantial amount of scatter. The 175 paired data points and the linear correlation are shown in Figure 5-2.

Figure 5-2. Linear Correlation of PSHED and Transformed RSD Evap Index 1



5.3.4 Prediction of PSHED "High Evap" Probability Using Evap Index 1

For the purposes of this analysis, we used a PSHED value of 3 grams was used as the standard for "High Evaps" when measured in the PSHED. Accordingly, the 175 paired RSD and PSHED data points are shown again in Figure 5-3 with a dashed horizontal reference line at 3 grams. Points above this line represent "High Evaps." High-evap PSHED HC mass values other than 3 grams could also be used as the definition of a High Evap.

Rather than attempt to predict the PSHED value based on the RSD Evap Index 1, here we choose to calculate the probability that a vehicle with a given RSD Evap Index 1 is likely to be a High Evap. To help visualize the trend in probability, vertical dashed lines at 80, 270, and 900 in Figure 5-3 are used to divide the plot into four RSD Evap Index 1 bins. The count of the number of observations within each of these bins and the number of "High Evaps" within each of the bins is given in Table 5-2. The table shows a monotonically increasing High Evap fraction as the RSD Evap Index 1 increases.

Figure 5-3. RSD Evap Index 1 and PSHED Values

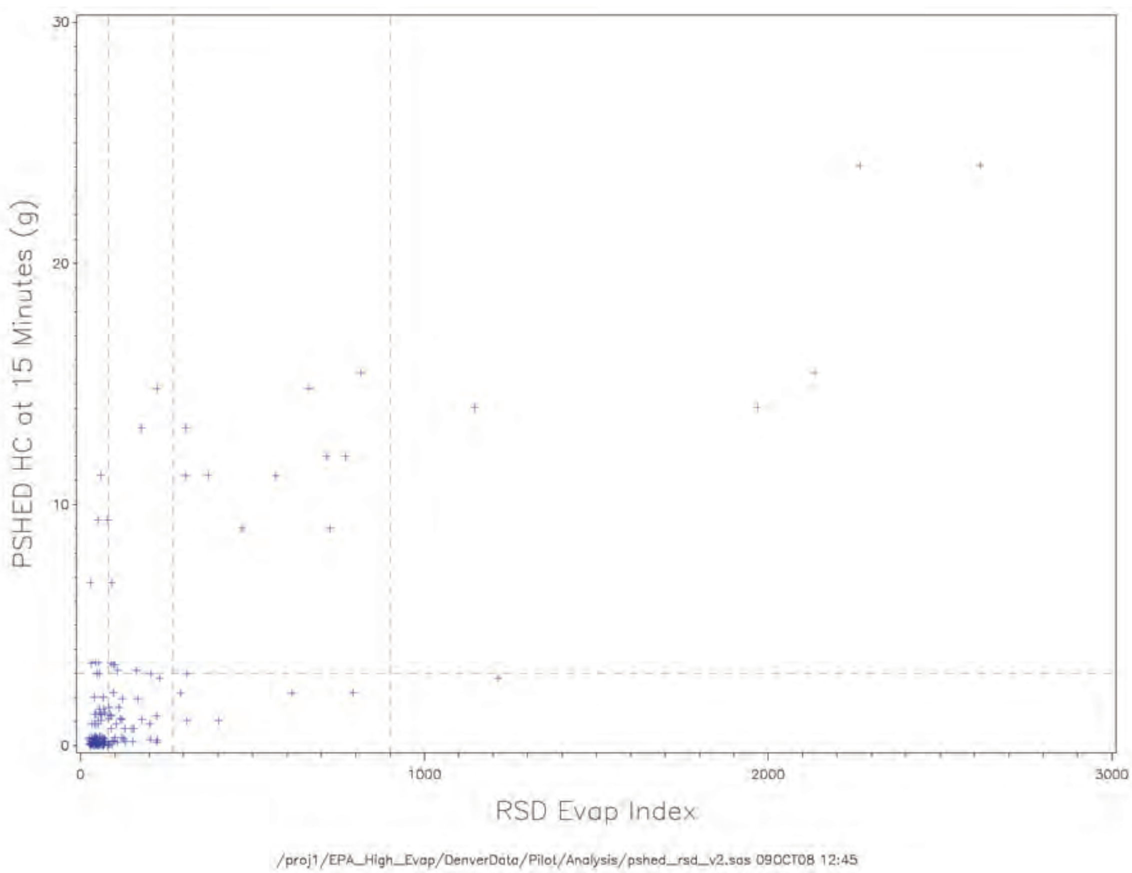


Table 5-2. Counts of High Evap Designations

Range of RSD Evap Index 1		Count		Measured High Evap (fraction)	Modeled High Evap (fraction)
Low	High	PSHED > 3g	Total		
0	80	7	112	0.06	0.054
80	270	8	41	0.20	0.225
270	900	10	16	0.63	0.568
900	Inf	5	6	0.83	0.856

To further quantify the relationship, we performed a logistic regression to predict the probability that the PSHED value would be larger than 3 grams using RSD Evap Index 1 as a predictor. First, we found that the natural log of the RSD Evap Index 1 was an advantageous transformation. It caused the values of the RSD Evap Index 1 to be more nearly homogeneous. The log transformation also was able to predict the PSHED failure probability from a simple expression with no lack of fit, which indicates that the model is an adequate fit to these data:

$$P_{fail} = \exp(arg) / (1 + \exp(arg))$$

Where

P_{fail} = Probability that the PSHED test has a value above 3 grams,

arg = -7.5262 + 1.2582 * ln(RSD Evap Index 1)

During model development, we found that the model had only a small dependence on exhaust emissions level. This means that the RSD Evap Index 1 is largely independent of exhaust emissions influence and therefore a given RSD Evap Index 1 value has the same meaning whether the vehicle has high exhaust emissions or low exhaust emissions. Thus, even though older model year vehicles tend to have higher exhaust emissions, the RSD Evap Index 1 is independent of model year.

The model development also revealed that alternative High Evap definitions (other than a PSHED value of 3 grams in 15 minutes) could also be used to develop a logistic regression models with the same favorable properties. The concordance[11] for the logistic regression was 79.6%.

The PSHED failure probabilities predicted by the model at the center of the ln(RSD Evap Index 1) bins are given in the last column of Table 5-2. The values calculated by the model are reasonably close to the values derived from the counts in Table 5-2.

[11] Concordance is a statistic that evaluates the agreement between the predicted probabilities of a logistic regression model and the pass and fail values of the individual observations in the training set. Concordance can have a value from 0% to 100%. If the predicted probabilities completely agree with the pass and fail values of the response variable, then the concordance is 100%.

6.0 References

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8. R.O. Gilbert, Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York, 1987.

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11. H.J. Williamson, "Measures Useful for Identifying Vehicles with High Evaporative Emissions," CACI, 11211 Taylor Draper Lane, Austin, Texas 78759, CACI-081222, December 22, 2008.

Appendix A
Data Packet

Packet ID__________(give to RSD van)

Date ______________
Time ______________ am/pm

Vdf # ______ /______/______(get from RSD van)

Make_____________ Model___________
MY________________ Color___________

State______Plate_____________ Metal Paper

Participant: Yes No
LSHED: Yes No

Participant First Name ______________________________

Pilot Testing
Lipan Street Station
Denver, Colorado

First Contact

Are you the owner of this vehicle?	Y	N
Is this a Fleet Vehicle?	Y	N
What is the MY of this vehicle?	______	
Is this your normal, every-day car? (no cream puffs, collector's cars, mechanics specials)	Y	N
Your vehicle is eligible for this study. Are you interested in hearing about the project?	Y	N

I, ______________________, would like to participate in this study.
(printed name)

____
Signature

____
Date

I have received $20.00.

____
Signature

____
Date

Driver Questionnaire

I am a contractor for the Environmental Protection Agency. We are conducting a study to understand the evaporative emissions of the vehicle fleet. We would like to do some testing of your vehicle. The testing of your vehicle would take about 1 hour. Your vehicle was randomly selected for this study. Your participation is voluntary.

1. How many miles do you drive in a given year (12,000 is average)?
   (a)< 8,000 (b) 8,000-12,000 (c)12,000-24,000 (d) > 24,000 (e) Don't know

2. How long have you owned your car? ________ months / years Don't know

3. At night, do you park this vehicle:
   (a) Inside a garage (b) Outside (c) Both

4. When was the last time you fueled your vehicle?
   (a) Last 24 hours (b) 2 days ago (c) 5 days ago or greater (d) Don't know

5. Does this vehicle get regular, routine maintenance from you or someone else?
   (a) Yes (b) No (c) Don't know

6. Have you had any of the listed maintenance performed on the vehicle, and if so, how long ago?

		a	b	c	d	e
Oil Change:	Y N ?	///	0-3 months	4-6 months	7 -12 months	Don't Know
Tune Up:	Y N ?	///	0-3 months	4-6 months	7-12 months	Don't Know
NewGasCap:	Y N ?	///	0-3 months	4-6 months	7-12 months	Don't Know
Fuel System:	Y N ?	///	0-3 months	4-6 months	7-12 months	Don't Know
MajEngWrk:	Y N ?	///	0-3 months	4-6 months	7-12 months	Don't Know

7. Have you ever had a gasoline smell around your vehicle? Yes No
   If yes, could you describe the circumstance.
   If yes, have you done anything to fix it?

8. Has the car ever been in an accident to your knowledge?

Copy of I/M Inspection Report

(staple here)

RSD and P-SHED Testing

Start Pre-Condition 7-mile Drive. Time: ____________ am / pm
(Lipan, Evans, 85, 285, Federal, Evans, Lipan)

Drive past RSD #2. Time: ____________ am / pm

Drive past RSD #3. Time: ____________ am / pm

Label Semtech file as: ___ ___ ___ . xml using Data Packet ID

	Time	HC (ppmC)	P_{baro} (mb)	T (°C)
Initial P-SHED				

Put vehicle in SHED and seal the door.

	Time	HC (ppmC)	P_{baro} (mb)	T (°C)
Door Sealed				
Final P-SHED				

Remove vehicle from SHED.

Vehicle Information Sheet 2

Photos:

- Front Quarter View (with white board and Packet ID#)
- All four sides of vehicle
- License plate close-up (rear)
- VECI close-up photo
- VIN close-up photo (windshield or door frame)

VECI label (under hood):

Certification Year: ____________

Engine Family: ____________________________________

Evap Family: _____________________________________

VIN:

Interior:

Transmission Type: Manual Automatic

Fuel Level (circle one) F 3/4 1/2 1/4 <1/4

Odometer Reading __________________________

Odometer Digit Resolution (circle one) 5 6

Modified California Method

⇨ **Locate and identify the source of strong fuel odors.**

Fuel Metering Type: Carburetted Fuel-Injected

Engine warmed up and running
(Check one descriptor for each Location and each of the 3 methods.)

Location	Visual	Sniffer	IR Camera
Underbody fuel lines	0 m S G NP	Y N NP	Y N NP
Bottom of fuel pump	0 m S G NP	Y N NP	Y N NP
Fuel pump to carb	0 m S G NP	Y N NP	Y N NP
In-line fuel filter	0 m S G NP	Y N NP	Y N NP
Fuel rail + connectors	0 m S G NP	Y N NP	Y N NP
All fuel-injectors	0 m S G NP	Y N NP	Y N NP
Ground under vehicle	0 m S G NP	Y N NP	Y N NP

Engine off
(Check one descriptor for each Location and each of the 3 methods.)

Location	Visual	Sniffer	IR Camera
Fuel fill pipe to tank joint	0 m S G NP	Y N NP	Y N NP
Tank: rust,straps,damage	0 m S G NP	Y N NP	Y N NP
Non-OEM installations	0 m S G NP	Y N NP	Y N NP

IR Camera avi file: ____________

General comments:

Descriptors:

- 0 =No visual evidence of liquid fuel leaks
- m =Minor signs of fuel (staining, damp spots), wicking<1"
- S =Significant leaks with single drops of fuel from vehicle to the ground, wicking>1"
- G =Gross leaks, regular flow of drops to the ground, or a large pool of fuel, wicking>1"
- NP =Not Performed
- Y =Positive Instrument Response (Sniffer & IR Camera only)
- N =Negative Instrument Response (Sniffer & IR Camera only)

Permission for Additional Testing

We would like to perform additional testing on your vehicle. This will require overnight laboratory testing at:

Colorado Department of Public Health and Environment
15608 East 18th Avenue
Aurora, Colorado 80011

Your vehicle will be returned to this inspection facility on ___________________ by ___:____am / pm

I give my permission for this testing.

Signature: _____________________________

Name: ________________________________

Street: ________________________________

City/State: _____________________________

ZIP: __________________________________

Circle Primary Phone Number to Contact

Home (_____) ________--____________

Work (_____) ________--____________

Cell (_____) ________--____________

Rental Car Checkout

Staple here:

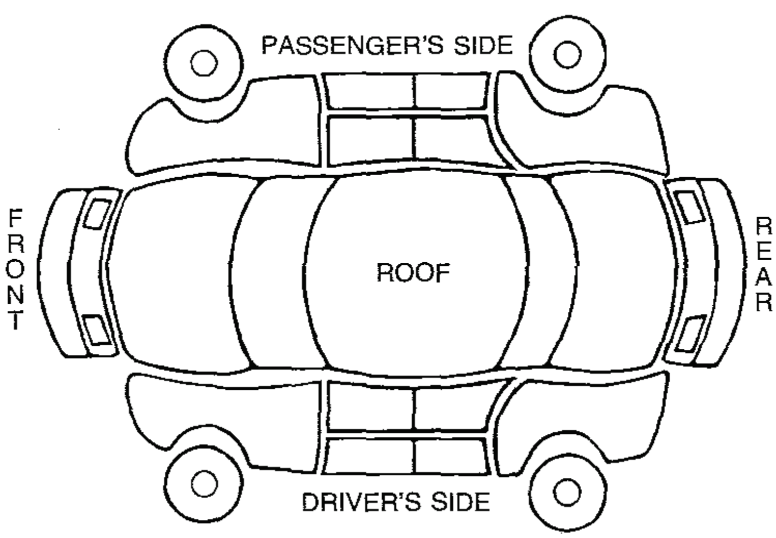
Photocopy of Driver's License (front and back)

Visual Pre-Inspection of Owner's Vehicle
(Use this only when we keep owner's vehicle over night.)

D - Dent

S - Scratch

M - Missing



<u>Colorado Lab SHED Test</u>

Perform a 1-hour hotsoak test with LA-4 pre-conditioning and in-use fuel

Date ________________ Time______________ am / pm

License Plate ____________________

State __________________________

Test Number ____________________

Average SHED Temperature (°F) _________________________

Average SHED Pressure (mm Hg)_________________________

Hotsoak Emissions __________ g during first 15 minutes

__________ g over 1 hour

The name of the file with minute-by-minute hotsoak data is

____

Appendix B
Stratified Sampling

The equations pertaining to stratified sampling discussed in this section are presented by Gilbert [8]. The goal is to determine the number of observations to be taken from each of several strata so that the variability of the mean is minimized. The equation for the optimal sample size for a given stratum is:

$$n_h = \frac{n\,W_h\,\sigma_h}{\sum_{h=1}^{L} W_h\,\sigma_h}$$

where

n_h	=	the sample size in stratum number h,
n	=	the total sample size for all strata,
W_h	=	the fraction of the actual population that falls in stratum h,
L	=	the number of strata, and
σ_h	=	the standard deviation of the distribution from which the individual data values in stratum h are sampled.

This equation follows conceptual guidelines. The number of points taken from a stratum is directly proportional to the fraction of the population comprised of that stratum (the fraction is W_h). Also, the number of points from a stratum is directly proportional to σ_h, which is a measure of the variability in the stratum.

The estimate of the population mean, $\bar{x}_{pop}$, is the weighted mean of the stratum means, $\bar{x}_h$:

$$\bar{x}_{pop} = \sum_{h=1}^{L} W_h\,\bar{x}_h$$

The point here is that the strata are not sampled proportionately to their actual representation in the population. If a simple arithmetic average of the complete stratified sample were calculated, the different strata would be weighted disproportionately to their representation in the population, and a biased average would result. The weighting scheme in the calculation of $\bar{x}_{pop}$ accounts for the nature of the sample and produces an unbiased estimate of the population mean. The formulation here produces the unbiased estimate of the population mean with the minimum error variance, given the total sample size, n. The standard error of the mean is the square root of its error variance. The standard error of this weighted mean estimate is as follows:

$$\bar{x}_{pop} = \sum_{h=1}^{L} W_h\,\bar{x}_h$$

where f_h is the number of data points in stratum h divided by the population size of this stratum.

$$\sigma_{\bar{x}_{pop}} = \sqrt{\sum_{h=1}^{L} W_h^2 \frac{\sigma_h^2}{n_h}(1 - f_h)}$$

The factor $(1-f_h)$ accounts for the finitude of the population in stratum h. If the sample sizes are small compared to the sizes of the strata in the population, this factor can be ignored. The result is somewhat conservative (larger) estimates of the standard errors for the stratified results. The factor $(1-f_h)$ has been ignored (set to 1) in the calculations presented below, so the standard errors for the stratified analysis are somewhat conservative.

In practice the true standard deviations, σ_h, are not known and are estimated on the basis of historical data that exist before the planned stratified sampling effort. The sample standard deviation, s_h, based on a sample, $x_{h,i}$, i=1 to m, is:

$$s_h = \sqrt{\frac{\sum_{i=1}^{m}(x_{h,i} - \bar{x}_h)^2}{m-1}}$$

where $\bar{x}_h$ is the arithmetic mean.

When the individual data values are dichotomous, for example, 1 for a vehicle with high evap and 0 for a vehicle with low evap, then the standard deviation can also be expressed using the probability p_h that the vehicle has high evap:

$$s_h = \sqrt{p_h q_h}$$

where:

p_h is the probability that a vehicle in stratum h has high evap, and
q_h is the probability that a vehicle in stratum h has low evap ($q_h = 1 - p_h$).

Appendix C
California Evaporative Visual Inspection Method

In three CRC studies, signs of some fuel staining were noted on many vehicles. Evidence of liquid fuel including, for example, areas where oil and grease on the engine block had been rinsed away, were noted. Gross liquid leaks were reported on other vehicles. Identification of leaks in this study differentiated between minor signs of fuel (staining, damp spots) and those leaks with certain potential for reduction in evaporative emissions. The latter type of leak results in appreciable pools of liquid fuel or regular drops of fuel from the vehicle to the ground. These leaks are further classified as significant (single drops of fuel) and gross (a regular flow of drops or a large pool of fuel).

A mechanic inspected vehicles using the attached procedure and tools. Vehicles were not to be repaired. Owners were notified if liquid fuel leaks were detected. They were told that the liquid fuel inspection was not a part of the state I/M procedure, but that the liquid fuel presents an extreme hazard that warrants immediate attention.

Inspection results were tabulated to provide statistics regarding major and minor leaks detected by model year inspected. Vehicles were additionally be categorized with respect to carburetion/fuel injection and accumulated odometer at time of inspection. Both cars and trucks were included in the sample.

We estimated that an inspector could inspect up to six vehicles per hour when vehicles were available for inspection.

Inspection Procedure

Tools

Inspection mirror - 2 X 4" typical, extension handle, ball joint
Small flashlight - 6" - to maneuver in and around underhood components
Forceps - 12"
Folded paper towels, blotter paper, or filter paper.
Infrared “snoop” HC analyzer

The corner of a folded paper towel or other blotter will "wick" up fuel from a significant pool, but not a minor drop or a surface stain. Forceps can be used to hold the paper and to approach a suspect area otherwise blocked by vehicle hardware. To differentiate between a "damp" area and a "liquid" area, the corner of the paper was touched to a suspect area. Visual inspection indicated if a significant amount of liquid was absorbed by the paper (more than 1 inch wet spot). A strong gasoline fuel odor would be detected from fuel leaks. Water, antifreeze, oil, windshield washer solvent, or other leaks would result in the strong gasoline odor. The “snoop” analyzer was used to pinpoint the source of HC vapors.

Using the inspection mirror and flashlight, the procedure was to inspect as applicable:

With engine warmed up and running:

Inspect bottom of fuel pump and around pressure line from fuel pump to carb.
Inspect in-line fuel filter
Inspect fuel inlet to carb
Check underbody fuel delivery and return lines.
Check fuel rail, connectors and individual fuel injectors.
Check floor under vehicle for any sign of fuel accumulation.
When strong fuel odors are noted, locate and identify the source.

Additional checks which can be performed with engine off:

Check fuel fill pipe, particularly around joint to tank.
Check bottom of tank, particularly around rust spots, mounting straps, and any spots showing road damage.
Non OEM installations (particularly second fuel tank add-ons) merit close inspection.

The carburetor base plate, fuel pump and other areas will typically show signs of slow fuel seepage (fuel stains or oil deposits washed off). These are not counted as gross leakers unless a measurable pool of fuel or droplets of fuel are detected.

Record model year, make, model, vehicle type (car, pickup, van), fuel injection/carbureted, odometer, and results of inspection.

Appendix D
Participating Vehicle Data[C]

packetID	pi_plate	pi_metalorpaper	pi_state	pi_ModelYear	pi_Make	pi_Model	pi_style	pi_VECICertYear	pi_EngineFamily	pi_EvapFamily	pi_VIN	pi_Transmission	pi_FuelLevel	pi_Odometer	pi_OdoResolution	pi_FuelMetering
Packet Number	**Plate**	**Paper or Metal Plate?**	**State**	**Model Year**	**Make**	**Model**	**Style**	**VECI Cert Year**	**Engine Family**	**Evap Family**	**VIN**	**Trans-mission**	**Fuel Level**	**Odometer**	**Odometer Resolution**	**Fuel Metering**
PIL_010	371416G			1994	Subaru	Legacy	Sedan	1993	RFJ2.2VJGAEK	RFJ1030BYM03		A	.	209748	.	F
PIL_011	137SJM	P	CO	1977	Chevrolet	Pickup	Pickup	1977				A	.	30209	.	C
PIL_016	LUV4LK			1995	Chevrolet	Monte Carlo	Sedan	1995	SIG3.1V8GFEA	SIG1058AYMOA		A	.	160288	.	F
PIL_019	030284F	P	CO	1965	Ford	Mustang	Sedan	1965				M	.	73450	.	C
PIL_022	721IGF			2002	Subaru	Impreza	Sedan	2002	2FJXV02.5JEJ	2FJXR01251BB		M	.	61240	6	F
PIL_024	AC00919		CO	1991	Toyota	Corolla	Sedan	1991	MTY1.6V5FFD5	EV-E		A	.	108957	.	F
PIL_029	921887F	P	CO	1995	Chevrolet	Corsica	Sedan	1995	SIG3.1V8GFEA	SIG1058AYMOA		A	.	114398	.	F
PIL_035				1992	Ford	Explorer	Sedan	1992	NFM4.0T5FYH8	4.0L-0HM			0.25	.	.	F
PIL_046	158EVO	M	CO	1988	Dodge	Pickup	Pickup	.				A	0	50180	5	.
PIL_050	266BZR	M	CO	1994	Subaru	Legacy	Sedan	1994	RFJ22VJGAEK	RFJ1030BYM03		A	0.5	172871	6	F
PIL_060	620722E	P	CO	1984	Lincoln	Towncar	Sedan	1984				A	0.25	94222	6	F
PIL_061	3957796	P	CO	1991	Plymouth	Acclaim	Sedan	.				A	0	221478	6	F
PIL_062	914EXZ	M	CO	1991	Toyota	Camry	Wagon	1991	MTY2.0V5FFF1	EV-E		A	0	223286	6	F
PIL_063	PBT3734	M	CO	1991	Chevrolet	Cavalier	Sedan	1991				M	0.5	102682	6	F
PIL_065	124IOG	M	CO	1996	Mitsubishi	Eclipse	Convertibl	1996				A	0.25	144876	6	F
PIL_070	398718G	P	CO	2000	Chevrolet	Suburban	SUV	2000	YGMXT05.3182	YGMXE0111920		A	0.5	196712	6	F
PIL_072	ADH889	M	CO	1989	Mercedes	190E	Sedan	1989	KMB2.6V6FA12	KMBV62		A	0	90100	6	F
PIL_078	316KWT	M	CO	1991	GMC	Jimmy	SUV	1990	M3G4.3T5XEB2	MBO-3E		A	0.5	190360	6	C
PIL_079	5978395	M	LA	1997	Ford	F150	Pickup	1997	VFM5.458GFEK	VFM1160AYMFD		A	0.25	217264	6	F
PIL_084	185371G	P	CO	1995	Nissan	Maxima	Sedan	1995	SNS3.0VGBEK	SNS1057BYM0A		A	0	121661	6	F
PIL_089	401250G	P	CO	1995	Ford	Contour	Sedan	1995	SFM2.5VJGFEA	SFM1045AYP0A		A	0.5	126863	6	F
PIL_098	524JJX	M	CO	1997	Dodge	Dakota	Pickup	1997	VCR5.928GFGK	VCR1090AYPBB		A	0.5	151552	6	F
PIL_108	549NPA	M	CO	1995	Jeep	Wrangler	SUV	1995	SCR2.578GAEA	SCR1058AYMON		M	0.5	163885	6	F
PIL_110	410451G	P	CO	1987	Chevrolet	Blazer	SUV	1985	FIG2.8T2TRA3			M	0.5	229954	6	F
PIL_116	821HBR	M	CO	1994	GMC	Jimmy	SUV	1994	R3G4.329GFEA	R361053AYMON		A	0.5	142248	6	F
PIL_117	35061AA	M	CO	1992	Ford	F150	Truck	1992	5.0L-OHM	NFM5.8T5HZL1-0L		A	0.5	170483	6	F
PIL_118	803KWW	M	CO	2001	Nissan	Xterra	SUV	2001	1NSXT03.3C5A	1N5XR0120RCA		A	0	105648	6	F
PIL_123	275NFE	M	CO	1992	Dodge	Stealth	Sedan	1992	NMT3.0V5FFD6	IB		M	0.75	109020	6	F
PIL_124	184129G	P	CO	1989	Ford	Bronco	SUV	.	KFM5.875HZZ4			A	0.75	15486	5	F
PIL_128	921NPB	M	CO	1994	Chevrolet	Sierra 1500	Pickup	1994	REG5.785GAEB	R3G1085AYM0A		A	0.5	235330	6	F
PIL_130	404917G	P	CO	1994	Dodge	Ram	Pickup	1990	LCR5.9T5H6F8	LCRTE		A	0.5	194740	6	F
PIL_131	278ITC	M	CO	1994	Jeep	Cherokee	SUV	1994	RCR4.078GAEA	RCR1058AYMON		A	0.25	229501	6	F
PIL_132	401442G	P	CO	1995	Pontiac	Grand Prix SE	Sedan	1995	S1G3.1V8GFEA	SIG1058AYMOA		A	0.25	177033	6	F
PIL_137	938268F	P	CO	1989	Ford	Aerostar	Van	1989	KKFM3.0T5FYK2			A	1	78611	5	F
PIL_138	039302F	P	CO	1999	Infinity	C20	Sedan	1999	XNSXV02.0AZA	XNSXE011OMBA		M	1	91634	6	F
PIL_146	939783F	P	CO	1994	Jeep	Cherokee	SUV	1994	RCR4.078GAEA	RCR1058AYMON		A	0.5	155203.3	6	F
PIL_151	318NAA	M	CO	1986	Chevrolet	Sprint Plus	Sedan	1986	OSK1.0V2FFL5	EV1		M	0.25	88813	5	C
PIL_157	461NOU	M	CO	1989	Chevrolet	Blazer	SUV	1989	K3G5.7T5TYA3	KDO-3C		M	0.25	81287	5	F
PIL_161	679NAZ	M	CO	1991	Subaru	Legacy	Wagon	1991	MFJ2.2V5FFE1	Y-HU		A	.	225480	6	F
PIL_165	801774E	P	CO	1992	Saturn	SL	Sedan	1992	N4G1.9V5JPH5	NAO-4B		A	0.5	64669	6	F
PIL_169	475MPG	M	CO	1987	Porsche	944	Sedan	1987	19HPR151V5FE39?	..K?		M	0.5	163538	6	F
PIL_174	051LIT	M	CO	2000	Toyota	Corolla	Sedan	2000	YTYXV01.8FFA	YTYXR0115AK1		A	0.25	68100	6	F
PIL_177	29262	P	CO	2002	Toyota	Camry	Sedan	2002	2TYXV02.4JJASFI	2TYXR0135AK1		M	0.5	105292	6	F
PIL_184	BLM831	M	CO	1991	Honda	Civic	Sedan	.				M	0.75	165882	6	F
PIL_191	499NXU	M	CO	1994	Toyota	Tercel	Sedan	1994	RTY1.5BHGAFA	RTY1047DYM00		M	0.25	183633	6	
PIL_193	YLL142	M	CO	1998	Ford	Mustang	Sedan	1998		WFMXE0045AAA		A	.	153203	6	F
PIL_194	833GTT	M	CO	1990	Ford	Taurus	Sedan	1990	LFM3.0V5FXG5	TWC-H02J1MPI		A	1	91937	5	F

packetID	pi_plate	pi_metalorpaper	pi_state	pi_ModelYear	pi_Make	pi_Model	pi_style	pi_VECICertYear	pi_EngineFamily	pi_EvapFamily	pi_VIN	pi_Transmission	pi_FuelLevel	pi_Odometer	pi_OdoResolution	pi_FuelMetering
Packet Number	**Plate**	**Paper or Metal Plate?**	**State**	**Model Year**	**Make**	**Model**	**Style**	**VECI Cert Year**	**Engine Family**	**Evap Family**	**VIN**	**Trans-mission**	**Fuel Level**	**Odometer**	**Odometer Resolution**	**Fuel Metering**
PIL_200	51966ML	M	CO	1988	GMC	Sierra	Pickup	1988	1364.3T5TAA0	3F0-3B		A	0.75	145096	6	F
PIL_203	643KCU	M	CO	2000	Ford	Taurus	Sedan	.				A	0.5	151771	6	F
PIL_213	VTTBOTS	M	CO	1987	Toyota	Camry	Sedan	1987	HTY2.0V5FBB4	EV-E		M	1	192201	6	F
PIL_217	028RJT	M	CO	2001	Mercury	Sable	Sedan	2001	1FMXV03.0VF3	3.0L-FMXR011SBA		A	0.5	153356	6	F
PIL_218	850FTE	M	CO	1984	Porsche	944	Sedan	1984	151V5FE03	?H		M	0.75	.	.	F
PIL_220	348AOP	M	CO	1996	Ford	Ranger	Pickup	1996	TFM4.028GKEK	TEM1045AYPBA		M	0	231013	6	F
PIL_221	NO PLATE			1993	Buick	LeSabre	Sedan	1993	PIG3.8V8JGB4	PBO-1R		A	0.5	193041	6	F
PIL_222	034KAT	M	CO	1989	Dodge	Caravan	Van	1989	KCR3.0T5FBL6	KCRTC		A	0.5	225879	6	F
PIL_223	340FUB	M	CO	1994	Mazda	B2300	Pickup	1994	RTK2.318GFEA	2-3L-RTK1065AYP		M	0	151816	6	F
PIL_225	939231F	P	CO	1985	Jeep	CJ7	SUV	1994	P5249610			M	0.5	121987	6	F
PIL_226	NO PLATE			1991	Ford	F250	Pickup	1990	LFM07.585WX	7.5C9HW		M	1	61329	5	F
PIL_229	292AKJ	M	CO	1985	Chrysler	New Yorker	Sedan	.				A	0.25	155701	6	F
PIL_236	401454G	P	CO	1995	Ford	Contour	Sedan	1995	SFM2.5VJGFEA	SFM1045AYP0A		A	0.25	126863	6	F
PIL_240	034366F	P	CO	1997	Isuzu	Rodeo	SUV	1997	VSZ3.22JGKFK	VSZ1095AYMEO		M	0.25	108522	6	F
PIL_242	PAX259	M	CO	1993	Jeep	Wrangler	SUV	1994	RCR4.078GAEA	RCR1058AYMON		M	0	83662	6	F
PIL_245	358NPT	M	CO	1997	Lincoln	Towncar	Sedan	1997	VFM4.6V8GKFL	VFM1090AYMEP		A	0.5	125885	6	F
PIL_247	937581F	P	CO	1992	Cadillac	Deville	Sedan	1992	N2G4.9V8XGA8	NG0-2B		A	0.5	169427	6	F
PIL_248	581LNL	M	CO	1987	Ford	F150	Pickup	1987	HFM5.0Y5HAGX	5.0L-7HM		M	1	46394	5	F
PIL_250	399022G	P	CO	1990	Volvo	740GLE	Wagon	1990	LVV2.3V5F897	E3		A	0.25	182338	6	F
PIL_251	PBN6774	M	CO	1990	Mercury	Topaz	Sedan	.				A	0.25	16238	5	F
PIL_254	371MVY	M	CO	1996	Jeep	Grand Cherokee	SUV	1996	TCRA4.028GKEK	TCR1073AYPBP		A	0.25	117718	6	F
PIL_256	NO PLATE			1999	Oldsmobile	Alero	Sedan	1999	XGMXV03.4042	XGMXR0124912		A	0	124136	6	F
PIL_257	754KCN	M	CO	1990	Chevrolet	S10	Pickup	.				M	0.5	74866	6	F
PIL_258	761JBG	M	CO	2002	Chevrolet	Trailblazer	SUV	2002	2GMXT04.2185	2GMXR0175922		A	0.5	50049	6	F
PIL_266	UFF9944	M	CO	1989	Volkswagen	Golf	Wagon	.				M	0.25	22696	5	F
PIL_270	406626G	P	CO	1992	Jeep	Wrangler	SUV	.				M	1	122720	6	F
PIL_271	842NNA	M	CO	1991	Dodge	Dakota	Pickup	1993	PCR3.9T5FFL7	PTAPF		A	0.5	107371	6	C
PIL_272	665ELF	M	CO	1990	Jeep	Wrangler	SUV	1990	LAM4.2T2HEA4	LAM4.2F-1P		A	0.25	199329	6	F
PIL_274	405028G	P	CO	1999	Dodge	Intrepid	Sedan	1999	XCRV02.7VB0	XCRXR0101GBF		A	0	184036	6	F
PIL_281	PN7271	M	CO	1986	Honda	Accord	Sedan	.				M	0.25	278622	6	F
PIL_283	938NNI	M	CO	1986	Ford	Mustang	Sedan	1986	GFM5.0V5HBF9	5-0L6HM		M	0.75	33505	5	F
PIL_284	403NEV	M	CO	1991	Toyota	Tercel	Sedan	1991	MTY1.5V5FFF1	EV-E		M	0.5	226004	6	F
PIL_286	ADV872	M	CO	1983	Toyota	Landcruiser	SUV	1983	DTY4.2T2AFF3	EV-F		M	0.75	151573	6	C
PIL_287	99051AA	M	CO	1996	Ford	F150	Pickup	1996	TFM4.958GFJK	4.9L-TFM1045AYM		M	0.25	134467	6	F
PIL_290	360GNT	M	CO	1998	Nissan	Altima	Sedan	1998	WNSXV02.433B	WNSXR0110RCA		A	0	123860	.	F
PIL_294	916BPC	M	CO	2001	Subaru	Legacy	Wagon	2002	2FJXV02.5JHM	2FJXR01251CC		A	0.25	144387	6	F
PIL_298	579XBG	M	CO	2002	Mazda	Protege	Sedan	2002	2TKXV02.0GJA	2TKXR0125PMA		A	0.5	67273	6	F
PIL_299	405129G	P	CO	1986	Chevrolet	Chevette	Sedan	1986	G1G1.6V2NEA3	6B5-1A		A	0.5	42044	5	C
PIL_300	551PAU	M	CO	2003	Ford	Focus	Sedan	2003	3FMXV02.0VH1	3FMXR0080BBE		A	0.25	64080	6	F
PIL_304	781NPM	M	CO	1993	Jeep	Cherokee	SUV	.				A	0.25	173573	6	F

Appendix E

Selection RSD Data[D]

packetID	HCBinFlagAll	RndThreshAll	sR_1stcontactdate	sR_1stcontacttime	sR_date	sR_vdf	bs_samSpeed	bs_samAccel	VSP	bn_HC3000_ppmC3	bs_HC4000_ppmC3	bs_CO4000_pct	bs_NX4000_ppm	bs_CO24000_pct	RSDEvpIndex0	RSDEvpIndex1
Packet Number	**RSD4000 HC Bin**	**Fraction of Sample Selected**	**First Contact Date**	**First Contact Time**	**Selection RSD Date**	**Selection RSD VDF**	**Speed (mph)**	**Accel (mph/s)**	**VSP (kW/Mg)**	**RSD3000 HC ($ppmC_3$)**	**RSD4000 HC ($ppmC_3$)**	**RSD4000 CO (%)**	**RSD4000 NO (ppm)**	**RSD4000 CO_2 (%)**	**RSD Evap Index 0**	**RSD Evap Index 1**
PIL_010	1	0.000883	07/30/08	11:19	07/30/08	47	14.4	0.2	1.7	-54	-4	0.04	-8	15.03	50	53
PIL_011	9	0.657	07/30/08	13:44	07/30/08	104	5.5	0.1	0.5	12425	11579	3.50	778	12.17	-846	161
PIL_016	7	0.48	07/30/08	16:26	07/30/08	206	12.2	0.6	2.5	489	874	1.91	709	13.63	385	149
PIL_019	8	0.622	07/31/08	12:51	07/31/08	112	11.0	1.9	5.2	927	1133	3.94	324	12.19	206	287
PIL_022	6	0.288	07/31/08	14:40	07/31/08	163	6.6	2.1	3.4	483	617	4.74	75	11.64	134	76
PIL_024	8	0.622	08/01/08	10:39	08/01/08	67	11.9	2.0	6.1	495	1221	0.06	475	14.96	726	96
PIL_029	8	0.622	08/01/08	13:55	08/01/08	175	19.9	0.5	3.7	780	1261	0.74	103	14.48	481	132
PIL_035	9	0.657	08/01/08	16:35	08/01/08	266	14.5	0.5	2.7	6331	4174	0.82	110	14.33	-2157	821
PIL_046	8	0.622	08/04/08	14:50	08/04/08	258	16.0	3.5	13.4	-1943	1757	0.08	1791	14.88	3700	1006
PIL_050	6	0.288	08/04/08	15:17	08/04/08	272	20.1	5.3	24.9	26	453	3.95	602	12.19	428	29
PIL_060	7	0.48	08/05/08	12:52	08/05/08	147	13.7	3.0	9.9	730	789	7.62	57	9.56	59	120
PIL_061	7	0.48	08/05/08	13:19	08/05/08	163	15.0	3.9	14.0	504	700	4.19	1000	11.99	197	64
PIL_062	6	0.288	08/05/08	13:40	08/05/08	173	11.4	2.9	8.0	491	632	0.30	1274	14.77	141	91
PIL_063	5	0.1535	08/05/08	14:14	08/05/08	186	13.5	1.0	4.1	271	298	0.49	168	14.69	26	30
PIL_065	8	0.622	08/05/08	15:16	08/05/08	256	11.3	1.9	5.6	1046	1670	1.36	37	14.03	625	682
PIL_070	8	0.622	08/06/08	13:00	08/06/08	140	13.9	1.8	6.6	1468	1619	1.62	285	13.83	151	42
PIL_072	7	0.48	08/07/08	10:45	08/07/08	69	16.5	6.3	23.9	742	933	8.60	321	8.85	192	42
PIL_078	6	0.2191	08/08/08	9:50	08/08/08	50	14.6	3.2	11.2	381	489	1.08	1451	14.21	108	28
PIL_079	3	0.0361	08/08/08	10:35	08/08/08	71	11.3	1.6	4.7	182	118	0.02	289	15.03	-63	27
PIL_084	2	0.0124	08/08/08	13:39	08/08/08	182	17.4	6.2	25.3	41	69	0.15	666	14.92	28	39
PIL_089	9	0.0627	08/09/08	10:30	08/09/08	64	11.7	2.3	6.8	1786	2052	4.28	-6	11.92	266	107
PIL_098	2	0.0124	08/11/08	13:58	08/11/08	201	12.6	2.0	6.5	-51	31	0.14	323	14.94	81	24
PIL_108	4	0.118	08/12/08	16:19	08/12/08	252	13.1	2.2	7.3	-49	186	0.22	202	14.88	235	42
PIL_110	9	0.3	08/12/08	16:51	08/12/08	266	15.1	3.3	11.9	5820	5599	5.71	332	10.78	-221	228
PIL_116	7	0.52	08/13/08	10:56	08/13/08	72	12.0	1.4	4.6	-1291	725	0.06	69	14.98	2015	162
PIL_117	9	0.3	08/13/08	11:15	08/13/08	81	13.3	1.8	6.3	1871	2137	0.65	1222	14.48	265	128
PIL_118	5	0.54	08/13/08	11:45	08/13/08	92	15.8	3.3	12.7	-69	356	0.24	16	14.87	425	51
PIL_123	1	0.028	08/13/08	15:08	08/13/08	189	14.2	1.2	4.9	-64	-44	0.13	-68	14.97	20	38
PIL_124	3	0.093	08/13/08	15:52	08/13/08	218	10.6	1.2	3.5	34	132	0.05	340	15.00	98	48
PIL_128	7	0.52	08/14/08	9:40	08/14/08	49	9.9	1.5	4.0	1113	983	0.53	1951	14.57	-131	84
PIL_130	6	0.42	08/14/08	11:20	08/14/08	100	15.7	4.2	15.8	467	529	6.05	419	10.69	62	42
PIL_131	8	1	08/14/08	12:30	08/14/08	142	13.2	1.8	6.3	154	1270	0.63	1549	14.51	1116	128
PIL_132	6	0.42	08/14/08	12:45	08/14/08	153	12.8	1.8	6.0	126	495	0.05	133	15.00	368	81
PIL_137	6	0.42	08/14/08	16:45	08/14/08	272	16.6	3.5	13.9	408	494	2.25	1453	13.37	86	43
PIL_138	3	0.093	08/18/08	9:00	08/18/08	16	15.0	4.2	15.0	33	92	0.06	440	14.99	59	38
PIL_146	5	0.54	08/18/08	13:00	08/18/08	151	7.2	1.6	3.1	136	357	0.01	-42	15.04	221	96
PIL_151	5	0.54	08/18/08	15:40	08/18/08	246	10.2	3.0	7.4	234	261	4.16	19	12.06	28	37
PIL_157	7	0.52	08/19/08	11:15	08/19/08	112	14.6	1.4	5.6	997	827	1.80	691	13.72	-169	27
PIL_161	5	0.54	08/19/08	14:34	08/19/08	222	13.6	0.9	3.6	121	324	0.28	110	14.84	203	132
PIL_165	7	0.52	08/19/08	16:48	08/19/08	276	11.6	1.7	5.1	373	757	1.40	39	14.03	384	67
PIL_169	5	0.54	08/20/08	10:34	08/20/08	74	12.4	1.4	4.6	332	358	0.64	1909	14.52	26	32
PIL_174	1	0.028	08/20/08	12:17	08/20/08	129	17.2	4.0	16.5	-31	-12	0.03	342	15.02	19	34
PIL_177	1	0.028	08/20/08	14:41	08/20/08	202	15.7	1.4	6.1	-30	-8	0.01	32	15.05	22	39
PIL_184	5	0.54	08/21/08	9:42	08/21/08	45	13.7	3.7	12.2	-18	261	1.16	464	14.20	279	41

Packet Number	RSD4000 HC Bin	Fraction of Sample Selected	First Contact Date	First Contact Time	Selection RSD Date	Selection RSD VDF	Speed (mph)	Accel (mph/s)	VSP (kW/Mg)	RSD3000 HC ($ppmC_3$)	RSD4000 HC ($ppmC_3$)	RSD4000 CO (%)	RSD4000 NO (ppm)	RSD4000 CO_2 (%)	RSD Evap Index 0	RSD Evap Index 1
packetID	HCBinFlagAll	RndThreshAll	sR_1stcontactdate	sR_1stcontacttime	sR_date	sR_vdf	bs_samSpeed	bs_samAccel	VSP	bn_HC3000_ppmC3	bs_HC4000_ppmC3	bs_CO4000_pct	bs_NX4000_ppm	bs_CO24000_pct	RSDEvpIndex0	RSDEvpIndex1
PIL_191	8	1	08/21/08	13:37	08/21/08	162	17.6	1.1	5.6	1120	1139	3.88	1235	12.19	19	37
PIL_193	3	0.093	08/21/08	14:12	08/21/08	174	16.1	2.4	9.8	63	115	0.18	53	14.92	52	49
PIL_194	8	1	08/21/08	14:25	08/21/08	178	8.4	2.7	5.7	1083	1426	2.32	298	13.34	343	41
PIL_200	6	0.42	08/22/08	9:30	08/22/08	34	15.7	2.5	9.8	413	435	0.41	836	14.71	22	49
PIL_203	4	0.118	08/22/08	11:51	08/22/08	124	19.0	5.2	23.4	189	208	4.92	39	11.52	19	43
PIL_213	8	1	08/23/08	8:23	08/23/08	29	13.1	1.8	6.1	969	1119	0.29	2021	14.74	150	171
PIL_217	5	0.54	08/23/08	10:50	08/23/08	107	8.3	2.7	5.5	198	267	-0.09	-157	15.11	69	90
PIL_218	3	0.093	08/23/08	11:30	08/23/08	120	9.2	4.7	10.0	109	137	0.57	1289	14.59	28	55
PIL_220	4	0.118	08/23/08	12:19	08/23/08	154	16.9	2.1	8.9	-17	170	0.52	42	14.67	186	51
PIL_221	5	0.54	08/25/08	9:10	08/25/08	31	10.5	0.9	2.8	19	373	0.17	377	14.91	354	44
PIL_222	8	1	08/25/08	9:45	08/25/08	50	14.7	1.1	4.6	897	1364	0.35	1159	14.72	467	47
PIL_223	6	0.42	08/25/08	10:31	08/25/08	85	8.2	2.9	5.8	133	575	0.02	44	15.02	442	182
PIL_225	9	0.3	08/25/08	12:05	08/25/08	144	12.8	2.2	7.1	7149	7301	12.24	1268	6.01	152	830
PIL_226	6	0.42	08/25/08	12:15	08/25/08	147	14.5	2.9	10.1	-43	441	1.47	2266	13.91	484	36
PIL_229	4	0.118	08/25/08	15:12	08/25/08	251	12.2	3.5	10.3	172	179	0.46	1241	14.67	6	47
PIL_236	8	1	08/26/08	9:11	08/26/08	37	15.1	0.9	4.2	2140	1684	0.33	818	14.74	-456	88
PIL_240	4	0.118	08/26/08	10:20	08/26/08	76	18.7	5.6	24.5	136	178	2.86	94	13.00	42	61
PIL_242	8	1	08/26/08	12:12	08/26/08	138	15.0	0.5	2.7	993	1106	0.03	32	15.00	112	347
PIL_245	4	0.118	08/26/08	13:40	08/26/08	182	17.9	0.7	4.2	-162	187	0.05	31	15.01	350	53
PIL_247	9	0.3	08/26/08	16:43	08/26/08	273	13.6	3.3	10.9	1830	5098	0.27	454	14.69	3268	271
PIL_248	6	0.42	08/27/08	9:20	08/27/08	31	16.7	4.9	19.1	824	560	1.99	1475	13.56	-264	100
PIL_250	7	0.52	08/27/08	11:20	08/27/08	91	16.8	4.2	16.7	301	705	0.15	436	14.91	404	193
PIL_251	5	0.54	08/27/08	11:55	08/27/08	106	16.3	4.0	15.4	241	379	0.23	3169	14.77	138	33
PIL_254	3	0.093	08/27/08	12:40	08/27/08	135	16.0	3.1	12.1	111	136	0.41	2508	14.66	26	35
PIL_256	4	0.118	08/27/08	13:50	08/27/08	175	13.9	4.5	14.7	210	210	0.03	338	15.01	0	102
PIL_257	1	0.028	08/27/08	14:15	08/27/08	184	14.2	0.9	3.7	-39	-20	-0.05	-12	15.09	19	43
PIL_258	1	0.028	08/27/08	14:30	08/27/08	187	11.6	2.4	7.0	-72	-6	0.01	58	15.05	66	55
PIL_266	8	1	08/28/08	9:55	08/28/08	41	16.7	6.4	24.7	1165	1115	0.81	3724	14.30	-50	67
PIL_271	6	0.42	08/28/08	12:05	08/28/08	105	18.8	5.1	22.6	608	584	5.95	395	10.76	-24	49
PIL_272	7	0.52	08/28/08	12:21	08/28/08	108	12.1	2.6	7.9	724	977	4.50	443	11.78	253	66
PIL_274	6	0.42	08/28/08	12:40	08/28/08	134	11.1	1.4	4.1	377	405	0.18	439	14.90	28	36
PIL_281	5	0.54	08/28/08	16:45	08/28/08	275	13.5	2.7	8.9	242	334	0.94	589	14.35	92	41
PIL_283	5	0.54	08/29/08	9:31	08/29/08	57	13.9	3.6	12.2	207	248	0.24	455	14.86	41	70
PIL_284	5	0.54	08/29/08	9:55	08/29/08	70	11.8	3.0	8.6	322	345	0.41	233	14.74	23	67
PIL_286	7	0.52	08/29/08	11:55	08/29/08	150	12.6	0.8	3.1	467	850	0.96	2114	14.26	383	112
PIL_287	7	0.52	08/29/08	13:00	08/29/08	196	16.5	6.0	23.1	533	900	0.72	245	14.50	366	286
PIL_290	6	0.42	08/29/08	14:05	08/29/08	227	10.1	1.9	5.0	610	561	0.02	31	15.02	-49	181
PIL_294	1	0.028	08/29/08	16:25	08/29/08	346	10.6	1.4	4.0	-53	-20	0.83	-27	14.46	33	81
PIL_298	6	0.42	08/30/08	9:03	08/30/08	29	14.8	2.2	8.2	35	507	0.02	-4	15.03	472	53
PIL_299	5	0.54	08/30/08	9:25	08/30/08	44	12.8	2.9	9.0	98	343	0.09	3722	14.85	244	79
PIL_300	5	0.54	08/30/08	9:45	08/30/08	51	15.7	4.4	16.2	78	298	0.19	67	14.90	220	99
PIL_304	7	0.52	08/30/08	11:42	08/30/08	115	18.9	1.7	8.4	685	708	10.09	300	7.79	24	60

Appendix F
Conditioning Drive Data[E]

packetID	dr_date	dr_time
Packet Number	**Drive Date**	**Drive Time**
PIL_010	07/30/08	11:46
PIL_011	07/30/08	14:01
PIL_016	07/30/08	17:05
PIL_019	07/31/08	13:17
PIL_022	07/31/08	15:22
PIL_022	07/31/08	16:45
PIL_024	08/01/08	11:18
PIL_029	08/02/08	8:17
PIL_029	08/04/08	7:53
PIL_035	08/01/08	17:12
PIL_046	08/04/08	15:35
PIL_050	08/04/08	15:50
PIL_050	08/04/08	16:20
PIL_060	08/05/08	13:22
PIL_061	08/05/08	13:43
PIL_062	08/05/08	14:38
PIL_063	08/05/08	15:19
PIL_065	08/05/08	16:31
PIL_070	08/06/08	13:30
PIL_072	08/07/08	12:25
PIL_078	08/08/08	10:22
PIL_079	08/08/08	11:11
PIL_084	08/08/08	14:12
PIL_089	08/09/08	11:18
PIL_098	08/11/08	14:16
PIL_108	08/12/08	17:10
PIL_110	08/12/08	17:50
PIL_116	08/13/08	13:15
PIL_117	08/13/08	11:42
PIL_118	08/13/08	12:16
PIL_123	08/13/08	15:19
PIL_124	08/13/08	16:14
PIL_128	08/14/08	10:20
PIL_130	08/14/08	11:40
PIL_131	08/14/08	12:55
PIL_132	08/14/08	13:35
PIL_137	08/14/08	17:02
PIL_138	08/18/08	9:37
PIL_146	08/18/08	13:30
PIL_151	08/18/08	16:10
PIL_157	08/19/08	11:52
PIL_161	08/19/08	15:07
PIL_165	08/20/08	8:16
PIL_169	08/20/08	11:27
PIL_174	08/20/08	12:51
PIL_177	08/20/08	15:13
PIL_184	08/21/08	10:14
PIL_191	08/21/08	14:07
PIL_193	08/21/08	14:36
PIL_194	08/21/08	15:12
PIL_200	08/22/08	10:10

packetID Packet Number	dr_date Drive Date	dr_time Drive Time
PIL_203	08/22/08	12:36
PIL_213	08/23/08	8:58
PIL_217	08/23/08	11:23
PIL_218	08/23/08	11:59
PIL_220	08/23/08	12:54
PIL_221	08/25/08	9:44
PIL_222	08/25/08	10:21
PIL_223	08/25/08	11:08
PIL_225	08/25/08	13:30
PIL_226	08/25/08	12:45
PIL_229	08/25/08	15:53
PIL_236	08/26/08	9:56
PIL_240	08/26/08	11:20
PIL_242	08/26/08	12:58
PIL_245	08/26/08	14:29
PIL_247	08/26/08	17:39
PIL_248	08/27/08	9:36
PIL_250	08/27/08	11:41
PIL_251	08/27/08	15:09
PIL_254	08/27/08	13:23
PIL_256	08/27/08	14:29
PIL_257	08/28/08	8:50
PIL_258	08/27/08	16:07
PIL_266	08/28/08	10:34
PIL_270	08/28/08	12:20
PIL_271	08/28/08	13:43
PIL_272	08/28/08	13:01
PIL_274	08/28/08	14:26
PIL_281	08/28/08	17:15
PIL_283	08/29/08	10:05
PIL_284	08/29/08	10:48
PIL_286	08/29/08	13:17
PIL_287	08/29/08	14:10
PIL_290	08/29/08	14:50
PIL_294	08/29/08	16:51
PIL_298	08/30/08	9:37
PIL_299	08/30/08	10:13
PIL_300	08/30/08	10:51
PIL_304	08/30/08	12:15

Appendix G
Measurement RSD Data[F]

packetID	mR_date	mR_time	mR_vdf	bs_samSpeed	bs_samAccel	VSP	bn_HC3000_ppmC3	bs_HC4000_ppmC3	bs_CO4000_pct	bs_NX4000_ppm	bs_CO24000_pct	RSDEvpIndex0	RSDEvpIndex1
Packet Number	**Measurement RSD Date**	**Measurement RSD Time**	**Measurement RSD VDF**	**Speed (mph)**	**Accel (mph/s)**	**VSP (kW/Mg)**	**RSD3000 HC (ppmC3)**	**RSD4000 HC (ppmC3)**	**RSD4000 CO (%)**	**RSD4000 NO (ppm)**	**RSD4000 CO2 (%)**	**RSD Evap Index 0**	**RSD Evap Index 1**
PIL_010	07/30/08	12:02	68	15.8	2.8	10.9	26	21	0.03	901	15.00	-5	38
PIL_010	07/30/08	12:04	70	17.3	3.3	13.9	27	36	0.14	1204	14.91	8	48
PIL_011	07/30/08	15:50	195	16.1	2.7	10.7	11662	10456	11.71	478	6.32	-1206	1969
PIL_011	07/30/08	16:10	205	16.4	2.7	10.9	11635	10705	12.33	607	5.87	-930	1146
PIL_019	07/31/08	13:35	135	15.4	2.8	10.7	834	1252	0.80	1321	14.39	418	665
PIL_019	07/31/08	13:38	138	15.7	3.8	14.2	1151	1384	0.80	2054	14.36	233	223
PIL_022	07/31/08	15:38	197	19.8	4.8	22.5	24	165	0.19	60	14.91	141	42
PIL_022	07/31/08	17:11	247	20.5	5.0	24.3	126	99	0.01	23	15.04	-26	61
PIL_022	07/31/08	17:13	248	19.6	4.9	22.5	25	12	0.03	167	15.03	-13	45
PIL_024	08/01/08	11:32	98	17.3	3.1	13.1	992	1845	0.09	1052	14.90	853	305
PIL_024	08/01/08	11:34	99	16.7	2.6	10.7	927	2268	0.06	1232	14.90	1341	568
PIL_029	08/02/08	8:33	17	19.6	3.7	17.4	-13	42	0.15	49	14.94	54	28
PIL_029	08/02/08	8:35	18	18.5	3.7	16.5	3	37	0.05	69	15.02	34	38
PIL_029	08/04/08	8:09	14	19.3	3.5	16.6	-3	80	0.12	760	14.94	83	49
PIL_029	08/04/08	8:10	15	0.0	0.0	0.0	72	40	0.04	4284	14.87	-32	32
PIL_035	08/01/08	18:12	282	17.5	3.2	13.5	8050	4951	1.57	97	13.77	-3100	815
PIL_035	08/01/08	18:13	283	18.0	3.8	16.2	4109	3975	6.00	29	10.63	-134	2135
PIL_046	08/04/08	15:58	301	15.7	0.6	3.2	-1565	2127	0.06	750	14.92	3692	715
PIL_046	08/04/08	16:00	302	19.9	4.3	20.3	-198	1268	2.74	473	13.03	1466	770
PIL_050	08/04/08	16:05	304	15.3	4.0	14.7	43	296	0.09	361	14.97	252	39
PIL_050	08/04/08	16:08	306	19.6	4.0	18.8	299	473	4.00	298	12.16	174	50
PIL_050	08/04/08	16:40	326	20.5	4.8	23.0	312	428	4.48	286	11.82	116	45
PIL_050	08/04/08	16:42	327	20.2	3.7	18.0	255	445	2.68	430	13.11	189	33
PIL_060	08/05/08	13:35	176	15.6	3.3	12.3	353	399	1.85	105	13.71	46	55
PIL_060	08/05/08	13:42	180	16.3	4.0	15.5	286	323	1.59	334	13.89	38	56
PIL_061	08/05/08	13:57	191	15.4	3.7	13.7	538	557	0.55	2733	14.54	19	45
PIL_061	08/05/08	14:07	196	16.8	3.8	15.4	746	728	2.53	1606	13.16	-18	57
PIL_062	08/05/08	14:53	220	15.9	3.7	14.2	269	285	0.19	2031	14.84	15	50
PIL_062	08/05/08	15:01	232	11.0	42.0	102.6	286	278	0.30	1797	14.77	-7	30
PIL_063	08/05/08	15:36	246	20.7	8.0	37.8	7	222	0.27	1366	14.80	214	46

packetID	mR_date	mR_time	mR_vdf	bs_samSpeed	bs_samAccel	VSP	bn_HC3000_ppmC3	bs_HC4000_ppmC3	bs_CO4000_pct	bs_NX4000_ppm	bs_CO24000_pct	RSDEvpIndex0	RSDEvpIndex1
Packet Number	**Measurement RSD Date**	**Measurement RSD Time**	**Measurement RSD VDF**	**Speed (mph)**	**Accel (mph/s)**	**VSP (kW/Mg)**	**RSD3000 HC (ppmC3)**	**RSD4000 HC (ppmC3)**	**RSD4000 CO (%)**	**RSD4000 NO (ppm)**	**RSD4000 CO2 (%)**	**RSD Evap Index 0**	**RSD Evap Index 1**
PIL_063	08/05/08	15:39	248	20.5	7.6	35.8	132	220	0.27	1791	14.79	87	28
PIL_065	08/05/08	16:52	284	18.9	5.7	24.9	520	579	8.38	38	9.03	59	152
PIL_065	08/05/08	16:57	286	19.2	5.6	25.2	294	315	7.28	94	9.82	21	46
PIL_070	08/06/08	13:46	168	13.9	3.0	10.1	913	988	1.37	37	14.04	75	61
PIL_070	08/06/08	13:50	171	14.7	3.2	11.4	1347	1564	5.66	330	10.94	217	65
PIL_072	08/07/08	12:42	127	17.7	6.6	26.9	973	962	6.59	255	10.29	-11	55
PIL_072	08/07/08	12:45	132	15.5	4.1	15.2	484	498	3.25	261	12.70	14	54
PIL_078	08/08/08	10:35	72	15.9	4.2	15.7	-19	105	0.13	2523	14.87	124	41
PIL_078	08/08/08	10:41	81	15.2	3.6	13.1	202	275	0.33	1117	14.77	73	50
PIL_079	08/08/08	11:27	108	19.1	2.8	13.0	60	90	0.62	243	14.60	31	30
PIL_079	08/08/08	11:29	119	16.7	2.9	11.8	42	22	0.16	71	14.94	-21	41
PIL_084	08/08/08	14:28	214	15.9	3.5	13.4	59	76	0.55	115	14.65	17	48
PIL_084	08/08/08	14:34	220	15.8	4.1	15.3	85	68	0.38	340	14.77	-17	73
PIL_089	08/09/08	11:32	92	14.7	2.9	10.5	1364	1674	2.18	380	13.43	309	62
PIL_089	08/09/08	11:40	105	15.2	4.2	15.2	170	192	3.28	413	12.68	21	44
PIL_098	08/11/08	14:32	225	18.8	5.1	22.4	-171	48	0.16	2126	14.86	219	78
PIL_098	08/11/08	14:35	231	18.9	4.8	21.2	32	-19	0.01	331	15.03	-52	39
PIL_108	08/12/08	17:22	277	16.1	4.0	15.5	271	721	1.76	547	13.75	450	155
PIL_108	08/12/08	17:25	278	15.5	3.4	12.8	180	301	0.45	419	14.71	121	128
PIL_110	08/12/08	18:05	279	19.7	2.0	10.1	2120	2431	6.44	-34	10.36	311	108
PIL_110	08/12/08	18:07	280	17.7	3.3	14.2	1270	1958	9.69	171	8.04	687	162
PIL_116	08/13/08	13:30	141	25.0	1.6	10.9	75	472	0.11	124	14.95	397	29
PIL_116	08/13/08	13:32	144	18.0	5.1	21.4	-129	527	0.06	3313	14.88	656	91
PIL_117	08/13/08	11:55	98	18.5	5.2	22.4	888	984	3.61	589	12.42	96	203
PIL_117	08/13/08	11:58	99	18.6	5.1	22.2	1078	1650	3.76	527	12.29	572	223
PIL_118	08/13/08	12:26	122	23.4	2.8	16.1	-2	61	0.58	0	14.63	62	50
PIL_118	08/13/08	12:30	123	18.8	4.1	18.5	303	276	0.03	124	15.02	-27	79
PIL_123	08/13/08	15:33	208	17.6	3.2	13.8	-81	-47	0.36	219	14.79	33	46
PIL_123	08/13/08	15:35	209	18.5	6.4	27.5	288	351	2.59	754	13.16	63	97
PIL_124	08/13/08	16:31	234	23.2	1.1	7.3	785	920	0.48	1183	14.64	136	106

packetID	mR_date	mR_time	mR_vdf	bs_samSpeed	bs_samAccel	VSP	bn_HC3000_ppmC3	bs_HC4000_ppmC3	bs_CO4000_pct	bs_NX4000_ppm	bs_CO24000_pct	RSDEvpIndex0	RSDEvpIndex1
Packet Number	**Measurement RSD Date**	**Measurement RSD Time**	**Measurement RSD VDF**	**Speed (mph)**	**Accel (mph/s)**	**VSP (kW/Mg)**	**RSD3000 HC (ppmC3)**	**RSD4000 HC (ppmC3)**	**RSD4000 CO (%)**	**RSD4000 NO (ppm)**	**RSD4000 CO2 (%)**	**RSD Evap Index 0**	**RSD Evap Index 1**
PIL_124	08/13/08	16:32	235	24.2	0.7	5.8	3668	2510	1.89	464	13.61	-1157	222
PIL_128	08/14/08	10:37	76	23.4	2.6	15.2	296	626	0.67	2855	14.46	330	44
PIL_128	08/14/08	10:39	79	22.5	2.3	13.3	330	412	0.67	2777	14.46	83	52
PIL_130	08/14/08	11:56	125	20.2	2.8	13.8	382	365	3.77	846	12.31	-17	42
PIL_130	08/14/08	11:58	126	20.8	2.7	14.0	360	431	3.39	1004	12.58	72	44
PIL_131	08/14/08	13:15	170	26.6	0.9	7.6	733	1217	2.76	1400	12.99	484	122
PIL_131	08/14/08	13:16	172	21.1	2.7	14.1	215	966	0.26	2503	14.75	751	166
PIL_132	08/14/08	13:52	187	24.7	4.8	28.3	-49	207	0.03	1602	14.97	256	67
PIL_132	08/14/08	13:55	188	21.8	4.0	20.9	-346	300	0.04	348	15.00	646	53
PIL_137	08/14/08	17:18	282	18.1	4.3	18.4	435	522	1.68	2268	13.76	86	69
PIL_137	08/14/08	17:22	283	17.6	4.0	16.9	507	615	1.59	2542	13.80	109	34
PIL_138	08/18/08	9:52	52	18.5	4.7	20.5	-7	83	0.11	805	14.94	90	68
PIL_138	08/18/08	9:55	55	16.4	4.1	15.9	56	165	0.11	310	14.96	109	44
PIL_146	08/18/08	13:49	190	14.3	3.3	11.4	-504	633	0.08	802	14.95	1137	112
PIL_146	08/18/08	13:51	194	14.6	3.5	12.2	-114	476	0.07	1004	14.95	590	83
PIL_151	08/18/08	16:25	280	14.2	3.3	11.2	30	35	0.20	152	14.91	5	40
PIL_157	08/19/08	12:07	143	12.8	2.5	7.8	274	443	0.20	1641	14.84	169	71
PIL_157	08/19/08	12:08	145	12.7	2.0	6.4	110	209	0.48	1305	14.66	100	34
PIL_161	08/19/08	15:22	243	15.6	4.0	14.8	63	455	0.23	973	14.84	391	99
PIL_161	08/19/08	15:24	244	14.2	3.3	11.4	97	622	0.27	542	14.82	526	95
PIL_165	08/20/08	8:32	11	15.6	3.2	12.2	137	221	0.98	29	14.35	84	24
PIL_165	08/20/08	8:37	18	15.8	2.6	10.1	200	343	1.61	149	13.88	143	40
PIL_169	08/20/08	11:43	115	15.3	3.2	11.8	311	377	0.55	2737	14.55	65	53
PIL_169	08/20/08	11:44	117	15.1	3.2	11.7	341	418	0.63	2915	14.49	77	46
PIL_174	08/20/08	13:05	159	16.1	3.8	14.7	5	0	0.04	68	15.02	-5	58
PIL_174	08/20/08	13:06	160	15.3	4.3	15.6	35	44	0.05	55	15.02	9	46
PIL_184	08/21/08	10:29	66	16.4	2.9	11.7	23	42	0.19	3087	14.81	20	26
PIL_184	08/21/08	10:30	67	15.5	2.9	10.9	169	202	1.45	449	13.99	33	35
PIL_191	08/21/08	14:22	186	5.7	0.4	0.8	437	516	0.17	1210	14.87	79	28
PIL_191	08/21/08	14:23	187	0.0	0.0	0.0	799	860	1.33	1828	14.01	62	37

packetID	mR_date	mR_time	mR_vdf	bs_samSpeed	bs_samAccel	VSP	bn_HC3000_ppmC3	bs_HC4000_ppmC3	bs_CO4000_pct	bs_NX4000_ppm	bs_CO24000_pct	RSDEvpIndex0	RSDEvpIndex1
Packet Number	**Measurement RSD Date**	**Measurement RSD Time**	**Measurement RSD VDF**	**Speed (mph)**	**Accel (mph/s)**	**VSP (kW/Mg)**	**RSD3000 HC (ppmC3)**	**RSD4000 HC (ppmC3)**	**RSD4000 CO (%)**	**RSD4000 NO (ppm)**	**RSD4000 CO2 (%)**	**RSD Evap Index 0**	**RSD Evap Index 1**
PIL_193	08/21/08	15:02	206	17.4	4.4	18.2	225	312	6.08	63	10.68	87	60
PIL_193	08/21/08	15:03	211	18.3	3.7	16.4	558	1170	6.49	12	10.36	613	371
PIL_194	08/21/08	15:27	228	20.3	1.6	8.7	2224	5476	2.50	63	13.10	3251	2616
PIL_194	08/21/08	15:29	229	18.7	1.4	7.3	1515	10592	2.05	-61	13.27	9077	2268
PIL_200	08/22/08	10:26	68	16.9	3.6	14.6	267	347	0.37	2345	14.70	80	66
PIL_200	08/22/08	10:27	70	16.2	2.1	8.5	443	571	0.34	2145	14.72	128	32
PIL_203	08/22/08	12:53	148	16.7	4.2	16.8	-149	12	0.02	69	15.04	161	54
PIL_203	08/22/08	12:54	149	17.4	4.3	17.7	13	24	0.07	65	15.00	11	66
PIL_213	08/23/08	9:16	67	16.5	4.8	18.7	473	559	0.40	1416	14.70	86	104
PIL_213	08/23/08	9:17	69	15.6	4.5	16.5	588	765	1.46	1782	13.92	178	202
PIL_217	08/23/08	11:39	140	15.9	4.2	15.9	34	65	0.51	72	14.68	31	61
PIL_217	08/23/08	11:40	141	15.6	4.3	15.8	-7	27	0.08	77	14.99	34	81
PIL_218	08/23/08	12:15	155	14.1	3.6	12.2	140	192	0.29	1055	14.81	52	31
PIL_218	08/23/08	12:16	156	14.6	4.3	14.9	103	118	0.23	1165	14.85	14	56
PIL_220	08/23/08	13:09	171	20.8	4.6	22.5	-59	857	0.09	1455	14.91	916	178
PIL_220	08/23/08	13:10	172	20.9	4.7	23.1	117	401	0.42	-51	14.74	284	121
PIL_221	08/25/08	10:02	64	18.5	4.8	20.8	-106	29	0.09	1430	14.94	135	44
PIL_221	08/25/08	10:04	66	18.6	4.7	20.4	26	82	0.06	1221	14.96	55	42
PIL_222	08/25/08	10:37	88	20.2	4.8	23.0	-7967	3758	0.38	3493	14.54	11725	1214
PIL_222	08/25/08	10:38	90	18.7	4.6	20.2	1108	1474	1.47	1795	13.89	366	230
PIL_223	08/25/08	11:24	126	18.2	4.0	17.6	53	291	0.11	43	14.96	237	40
PIL_223	08/25/08	11:26	129	17.5	4.0	16.6	219	279	0.09	112	14.98	60	66
PIL_225	08/25/08	13:45	201	0.0	0.0	0.0	961	1075	10.10	230	7.77	114	121
PIL_225	08/25/08	13:48	204	0.0	0.0	0.0	961	963	7.35	502	9.74	2	25
PIL_226	08/25/08	13:05	177	17.6	5.4	22.4	189	177	0.77	3106	14.38	-12	72
PIL_226	08/25/08	13:07	181	18.8	6.1	26.6	-28	170	0.51	3112	14.57	198	33
PIL_229	08/25/08	16:09	284	16.1	4.7	17.9	82	125	0.73	1568	14.47	43	32
PIL_229	08/25/08	16:11	285	16.0	4.5	16.9	137	190	0.58	1411	14.58	53	89
PIL_236	08/26/08	10:12	77	16.0	4.5	17.0	1139	1460	0.74	987	14.44	321	309
PIL_236	08/26/08	10:14	80	15.0	4.3	15.2	3073	3288	3.59	489	12.37	215	401

packetID	mR_date	mR_time	mR_vdf	bs_samSpeed	bs_samAccel	VSP	bn_HC3000_ppmC3	bs_HC4000_ppmC3	bs_CO4000_pct	bs_NX4000_ppm	bs_CO24000_pct	RSDEvpIndex0	RSDEvpIndex1
Packet Number	**Measurement RSD Date**	**Measurement RSD Time**	**Measurement RSD VDF**	**Speed (mph)**	**Accel (mph/s)**	**VSP (kW/Mg)**	**RSD3000 HC (ppmC3)**	**RSD4000 HC (ppmC3)**	**RSD4000 CO (%)**	**RSD4000 NO (ppm)**	**RSD4000 CO2 (%)**	**RSD Evap Index 0**	**RSD Evap Index 1**
PIL_240	08/26/08	11:36	120	19.6	4.2	19.4	29	63	0.15	1148	14.90	34	32
PIL_240	08/26/08	11:38	123	15.7	4.0	15.0	12	58	0.11	1110	14.93	46	45
PIL_242	08/26/08	13:15	163	14.8	5.2	17.9	-1038	413	0.11	855	14.93	1452	471
PIL_242	08/26/08	13:17	166	14.3	4.6	15.5	-1425	1000	0.11	601	14.92	2426	727
PIL_245	08/26/08	14:43	218	19.9	5.5	25.7	49	113	3.30	-9	12.69	64	49
PIL_245	08/26/08	14:45	219	18.6	5.5	24.1	69	85	4.05	31	12.15	16	43
PIL_247	08/26/08	17:55	292	17.8	5.8	24.0	-849	1486	0.16	1886	14.83	2335	95
PIL_247	08/26/08	17:57	293	17.3	5.7	23.0	-2535	2745	0.14	1866	14.80	5280	793
PIL_248	08/27/08	9:57	44	14.8	3.2	11.3	532	549	0.88	2048	14.34	16	116
PIL_248	08/27/08	9:59	49	15.9	2.5	9.9	409	386	0.14	1922	14.87	-24	81
PIL_250	08/27/08	11:56	109	17.9	5.0	20.9	442	468	0.17	732	14.89	26	89
PIL_250	08/27/08	11:59	111	17.8	5.0	21.0	311	511	0.35	637	14.76	200	150
PIL_251	08/27/08	15:27	232	17.6	4.2	17.4	245	316	1.02	2427	14.23	71	41
PIL_251	08/27/08	15:28	235	16.0	4.1	15.6	199	305	0.95	2459	14.28	105	38
PIL_254	08/27/08	13:39	174	18.3	4.2	18.2	79	173	0.44	3261	14.61	94	45
PIL_254	08/27/08	13:41	176	18.2	3.8	16.6	97	139	0.34	2975	14.70	41	60
PIL_256	08/27/08	14:45	211	19.4	4.8	21.9	776	1015	0.02	623	14.98	239	291
PIL_256	08/27/08	14:47	213	19.9	5.0	23.5	1168	1656	0.03	539	14.97	489	615
PIL_257	08/28/08	9:04	19	16.5	4.3	16.8	79	48	0.14	550	14.93	-32	40
PIL_257	08/28/08	9:06	23	12.1	3.0	8.8	103	44	0.04	2470	14.94	-59	45
PIL_258	08/27/08	16:24	270	19.1	5.2	23.1	-13	9	0.03	12	15.03	22	50
PIL_258	08/27/08	16:26	271	16.6	4.8	18.9	20	47	0.01	3	15.05	27	40
PIL_266	08/28/08	10:48	63	20.1	3.9	18.9	481	567	0.56	2893	14.53	86	52
PIL_266	08/28/08	10:50	64	21.4	2.9	15.2	345	440	0.40	2816	14.65	95	35
PIL_270	08/28/08	12:37	131	14.1	4.1	13.7	-24	60	0.01	2032	14.97	84	59
PIL_270	08/28/08	12:41	136	17.3	3.4	14.0	-1	72	0.03	599	15.01	73	52
PIL_271	08/28/08	13:57	182	18.6	3.8	16.7	567	568	4.47	337	11.82	1	60
PIL_271	08/28/08	13:59	185	18.2	4.9	20.8	390	580	3.52	539	12.49	190	85
PIL_272	08/28/08	13:17	156	18.4	3.4	15.3	511	657	3.15	963	12.74	147	57
PIL_272	08/28/08	13:19	160	13.5	2.2	7.4	833	937	5.99	383	10.72	104	70

packetID Packet Number	mR_date Measurement RSD Date	mR_time Measurement RSD Time	mR_vdf Measurement RSD VDF	bs_samSpeed Speed (mph)	bs_samAccel Accel (mph/s)	VSP VSP (kW/Mg)	bn_HC3000_ppmC3 RSD3000 HC (ppmC3)	bs_HC4000_ppmC3 RSD4000 HC (ppmC3)	bs_CO4000_pct RSD4000 CO (%)	bs_NX4000_ppm RSD4000 NO (ppm)	bs_CO24000_pct RSD4000 CO2 (%)	RSDEvpIndex0 RSD Evap Index 0	RSDEvpIndex1 RSD Evap Index 1
PIL_274	08/28/08	14:43	207	18.2	4.7	20.4	540	549	0.16	1906	14.85	9	42
PIL_274	08/28/08	14:45	210	18.7	4.4	19.5	421	422	0.17	1525	14.86	1	49
PIL_281	08/28/08	17:33	290	19.1	3.4	15.7	83	137	0.27	814	14.83	54	45
PIL_281	08/28/08	17:35	291	22.5	3.4	18.6	292	317	2.08	1220	13.51	25	30
PIL_283	08/29/08	10:23	87	16.3	4.6	17.9	285	317	0.25	1240	14.82	33	82
PIL_283	08/29/08	10:25	88	21.6	4.5	23.0	286	285	0.37	1276	14.73	-1	58
PIL_284	08/29/08	11:06	114	21.6	3.6	18.8	619	703	0.49	1557	14.63	84	69
PIL_284	08/29/08	11:08	116	18.3	3.5	15.6	561	727	0.44	1082	14.68	166	63
PIL_286	08/29/08	13:35	211	21.7	2.3	12.9	133	916	0.17	1867	14.84	783	307
PIL_286	08/29/08	13:37	214	18.6	2.7	12.3	267	340	0.09	2610	14.89	73	177
PIL_287	08/29/08	14:25	252	19.7	3.5	16.7	454	403	0.01	815	15.00	-51	204
PIL_287	08/29/08	14:27	254	20.1	2.9	14.4	417	1153	0.03	231	14.99	736	308
PIL_290	08/29/08	15:07	302	17.0	5.3	20.9	188	263	3.79	52	12.33	76	89
PIL_290	08/29/08	15:10	306	17.7	5.1	21.1	354	492	0.18	49	14.91	138	221
PIL_294	08/29/08	17:11	362	14.6	5.3	18.1	-48	-11	0.02	10	15.04	37	51
PIL_294	08/29/08	17:12	363	16.1	5.3	19.9	60	64	0.07	8	15.00	5	88
PIL_298	08/30/08	9:50	59	18.6	4.9	21.3	-3	8	0.02	-32	15.04	11	68
PIL_298	08/30/08	9:52	60	17.7	4.2	17.8	-13	18	0.02	0	15.04	32	92
PIL_299	08/30/08	10:28	78	14.5	2.1	7.8	263	313	0.05	2467	14.92	49	100
PIL_299	08/30/08	10:30	80	15.8	2.1	8.4	239	299	0.04	2545	14.92	59	67
PIL_300	08/30/08	11:05	98	15.6	3.4	12.8	65	339	0.05	-32	15.01	274	125
PIL_300	08/30/08	11:07	99	15.5	3.0	11.5	15	104	0.03	32	15.03	89	62
PIL_304	08/30/08	12:31	143	17.4	3.6	15.2	737	744	8.96	367	8.59	7	130
PIL_304	08/30/08	12:32	144	18.1	3.9	16.7	799	874	12.00	275	6.42	75	93

Appendix H
PSHED Data[G]

packetID	PS_date	PS_SealTime	PS_DoorSealHC_ppmC	PS_DoorSealP_mb	PS_DoorSealTemp_C	PS_FinalTime	PS_FinalHC_ppmC	PS_FinalP_mb	PS_FinalTemp_C	PS_Min0_g	PS_Min1_g	PS_Min2_g	PS_Min3_g	PS_Min4_g	PS_Min5_g	PS_Min6_g	PS_Min7_g	PS_Min8_g	PS_Min9_g	PS_Min10_g	PS_Min11_g	PS_Min12_g	PS_Min13_g	PS_Min14_g	PS_Min15_g
Packet Number	PSHED Date	PSHED Seal Time	PSHED Seal HC (ppmC)	PSHED Seal Pbaro (mb)	PSHED Seal Temperature (C)	PSHED Final Time	PSHED Final HC (ppmC)	PSHED Final Pbaro (mb)	PSHED Final Temperature (C)	**Cumulative PSHED HC Mass at Minutes Since Door Seal (g)**															
										0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PIL_010	07/30/08	12:05	2	836	34	12:22	8	836	40	0.00	0.02	0.02	0.04	0.04	0.05	0.07	0.07	0.08	0.09	0.09	0.11	0.11	0.11	0.13	0.13
PIL_011	07/30/08	16:13	25	834	38	16:28	850	834	42	0.00	0.27	0.98	1.91	2.16	4.73	4.89	6.20	7.32	7.69	8.67	10.19	10.98	12.20	12.81	14.02
PIL_016	07/30/08	17:43	24	834	36	18:00	28	833	42	0.00	0.42	0.49	0.49	0.50	0.51	0.52	0.52	0.52	0.52	0.52	0.53	0.54	0.54	0.54	0.54
PIL_019	07/31/08	13:44	36	837	35	13:59	729	837	40	0.00	0.46	1.11	1.83	2.54	3.24	3.96	4.81	5.70	6.91	7.96	9.38	10.57	12.44	13.86	14.81
PIL_022	07/31/08	17:14	3	835	36	17:30	.	.	.	0.00	0.03	0.07	0.14	0.24	0.36	0.46	0.57	0.69	0.81	0.93	1.03	1.11	1.19	1.26	1.30
PIL_024	08/01/08	11:38	170	837	36	11:53	529	837	40	0.00	0.32	2.61	4.22	6.09	6.62	7.70	8.60	8.99	9.49	9.90	10.36	10.53	10.78	10.93	11.19
PIL_029	08/02/08	8:37	2	836	31	8:52	6	836	34	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.04	0.04	0.05	0.07	0.07	0.07	0.09	0.09
PIL_029	08/04/08	8:11	2	837	26	8:28	6	.	.	0.00	0.00	0.01	0.02	0.02	0.02	0.04	0.05	0.05	0.07	0.07	0.07	0.07	0.07	0.09	0.09
PIL_035	08/01/08	17:37	.	834	40	17:53	.	834	41	0.00	1.21	4.43	6.07	6.70	7.71	9.01	9.99	10.40	11.63	12.07	12.44	13.15	13.98	14.92	15.47
PIL_046	08/04/08	16:02	41	838	34	.	.	.	.	0.00	0.41	1.01	1.51	2.01	2.69	3.55	4.49	6.10	7.98	8.67	9.40	10.11	10.71	11.35	12.00
PIL_050	08/04/08	16:42	3	838	33	16:59	46	838	37	0.00	0.36	0.44	0.50	0.55	0.61	0.69	0.74	0.78	0.79	0.81	0.83	0.84	0.87	0.89	0.90
PIL_060	08/05/08	13:45	2	842	31	14:01	7	842	37	0.00	0.00	0.01	0.02	0.02	0.04	0.04	0.04	0.06	0.07	0.07	0.08	0.09	0.09	0.11	0.11
PIL_061	08/05/08	14:07	3	840	33	14:23	7	841	34	0.00	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.06	0.07	0.07	0.07	0.07	0.08
PIL_062	08/05/08	15:04	2	841	30	15:19	.	841	.	0.00	0.00	0.00	0.02	0.03	0.02	0.02	0.04	0.04	0.04	0.04	0.06	0.07	0.07	0.07	0.08
PIL_063	08/05/08	15:44	2	841	31	16:00	.	.	.	0.00	0.02	0.03	0.05	0.05	0.08	0.08	0.10	0.10	0.12	0.12	0.14	0.14	0.16	0.17	0.19
PIL_065	08/05/08	16:56	7	842	31	17:12	10	842	35	0.00	0.11	0.11	0.12	0.13	0.13	0.13	0.13	0.15	0.16	0.16	0.16	0.16	0.16	0.18	0.18
PIL_070	08/06/08	13:52	2	841	31	14:09	4	841	40	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.04	0.04
PIL_072	08/07/08	12:45	2	843	27	13:00	10	843	33	0.00	0.02	0.03	0.05	0.07	0.06	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17	0.18	0.19
PIL_078	08/08/08	10:42	1	839	26	10:57	15.4	838	31	0.00	0.01	0.04	0.06	0.10	0.12	0.15	0.17	0.19	0.21	0.24	0.25	0.27	0.28	0.29	0.31
PIL_079	08/08/08	11:40	2	838	27	11:55	2.6	838	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
PIL_084	08/08/08	14:35	3	836	29	14:50	9.3	836	33	0.00	0.02	0.02	0.04	0.05	0.05	0.06	0.07	0.08	0.10	0.10	0.11	0.13	0.13	0.15	0.15
PIL_089	08/09/08	11:42	3	836	29	11:57	20	836	36	0.00	0.07	0.09	0.11	0.14	0.17	0.19	0.22	0.24	0.27	0.29	0.32	0.33	0.35	0.37	0.39
PIL_098	08/11/08	14:36	1	836	32	14:51	2	836	40	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.03
PIL_108	08/12/08	17:28	14	839	32	17:45	.	.	.	0.00	0.13	0.09	0.25	0.27	0.34	0.44	0.52	0.57	0.62	0.66	0.67	0.69	0.71	0.71	0.71
PIL_110	08/12/08	18:11	5	839	32	18:28	171	839	37	0.00	0.12	0.44	0.57	0.80	0.98	1.25	1.48	1.63	1.75	1.88	2.07	2.31	2.56	2.87	3.12
PIL_116	08/13/08	13:34	41	841	32	13:57	314	841	37	0.00	1.03	1.73	2.34	3.18	3.71	4.25	4.74	5.14	5.53	5.95	6.11	6.38	6.48	6.65	6.75
PIL_117	08/13/08	11:59	1	842	31	12:14	13	841	38	0.00	0.02	0.03	0.04	0.05	0.07	0.08	0.10	0.11	0.13	0.15	0.18	0.20	0.21	0.23	0.26
PIL_118	08/13/08	12:38	13	841	32	12:56	465	841	38	0.00	0.28	1.08	2.02	2.67	3.48	4.17	4.87	5.57	6.28	6.94	7.47	7.94	8.52	8.88	9.36
PIL_123	08/13/08	15:38	2	841	32	15:55	13	841	37	0.00	0.02	0.02	0.04	0.04	0.07	0.07	0.09	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21
PIL_124	08/13/08	16:34	2	840	33	16:51	10	840	40	0.00	0.02	0.04	0.04	0.06	0.07	0.07	0.09	0.09	0.11	0.11	0.13	0.13	0.13	0.15	0.15
PIL_128	08/14/08	10:42	29	845	25	10:59	160.1	845	31	0.00	0.39	0.69	1.22	1.56	1.83	2.11	2.38	2.55	2.77	2.98	3.09	3.17	3.31	3.40	3.46
PIL_130	08/14/08	12:01	3	844	27	12:18	9	844	32	0.00	0.03	0.05	0.07	0.09	0.09	0.09	0.11	0.11	0.11	0.11	0.12	0.13	0.13	0.14	0.16
PIL_131	08/14/08	13:18	32	844	27	13:36	89	844	.	0.00	0.17	0.71	1.07	1.38	1.67	1.87	1.96	1.97	1.96	1.96	1.96	1.95	1.95	1.94	1.94
PIL_132	08/14/08	13:57	4	844	27	14:14	87.1	844	31	0.00	0.09	0.16	0.27	0.36	0.45	0.55	0.70	0.80	0.89	1.01	1.10	1.22	1.33	1.43	1.52
PIL_137	08/14/08	17:22	3	843	28	17:39	15	843	33	0.00	0.04	0.05	0.07	0.09	0.11	0.12	0.14	0.16	0.18	0.19	0.21	0.23	0.24	0.26	0.29
PIL_138	08/18/08	9:57	0	845	22	10:12	1	845	28	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.05
PIL_146	08/18/08	13:53	5	845	26	14:08	72	.	.	0.00	0.15	0.44	0.58	0.71	0.81	0.94	1.04	1.13	1.22	1.29	1.37	1.43	1.49	1.55	1.59
PIL_151	08/18/08	16:29	2	844	27	16:44	17	844	31	0.00	0.02	0.05	0.05	0.07	0.08	0.11	0.14	0.16	0.18	0.21	0.24	0.27	0.30	0.34	0.35
PIL_157	08/19/08	12:10	2	842	28	12:25	9	842	34	0.00	0.02	0.02	0.04	0.06	0.07	0.09	0.10	0.11	0.13	0.13	0.15	0.16	0.16	0.17	0.18
PIL_161	08/19/08	15:27	13	841	30	15:42	171.2	841	35	0.00	0.86	1.46	1.97	2.48	2.70	2.92	3.05	3.17	3.21	3.24	3.28	3.28	3.30	3.32	3.37
PIL_165	08/20/08	8:39	2	840	22	8:56	15	840	26	0.00	0.02	0.04	0.05	0.07	0.09	0.10	0.13	0.14	0.16	0.17	0.19	0.21	0.23	0.24	0.26
PIL_169	08/20/08	11:47	5	839	29	12:02	153.2	839	33	0.00	0.07	0.17	0.40	0.58	0.79	1.00	1.25	1.47	1.69	1.94	2.18	2.36	2.62	2.80	3.00
PIL_174	08/20/08	13:11	1	838	31	13:26	3	838	35	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05
PIL_177	08/20/08	15:34	3	839	29	15:51	5	839	30	0.00	0.01	0.02	0.02	0.02	0.02	0.03	0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.07	0.07
PIL_184	08/21/08	10:33	2	839	29	10:54	3	838	32	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04
PIL_191	08/21/08	14:28	2	836	34	14:43	6	836	37	0.00	0.00	0.02	0.02	0.02	0.02	0.04	0.04	0.04	0.05	0.07	0.07	0.07	0.07	0.08	0.09
PIL_193	08/21/08	15:05	200	836	35	15:20	515.4	836	41	0.00	2.34	5.38	7.46	9.13	9.72	10.15	10.60	10.94	11.15	11.19	11.30	11.32	11.32	11.26	11.22

packetID	PS_date	PS_SealTime	PS_DoorSealHC_ppmC	PS_DoorSealP_mb	PS_DoorSealTemp_C	PS_FinalTime	PS_FinalHC_ppmC	PS_FinalP_mb	PS_FinalTemp_C	PS_Min0_g	PS_Min1_g	PS_Min2_g	PS_Min3_g	PS_Min4_g	PS_Min5_g	PS_Min6_g	PS_Min7_g	PS_Min8_g	PS_Min9_g	PS_Min10_g	PS_Min11_g	PS_Min12_g	PS_Min13_g	PS_Min14_g	PS_Min15_g
			PSHED	PSHED	PSHED		PSHED	PSHED	PSHED	Cumulative PSHED HC Mass at Minutes Since Door Seal (g)															
Packet Number	PSHED Date	PSHED Seal Time	Seal HC (ppmC)	Seal Pbaro (mb)	Seal Temperature (C)	PSHED Final Time	Final HC (ppmC)	Final Pbaro (mb)	Final Temperature (C)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PIL_194	08/21/08	15:37	33	835	36	15:52	1151.2	835	42	0.00	8.03	14.41	20.62	24.32	24.31	24.26	24.23	24.22	24.15	24.15	24.15	24.15	24.13	24.07	24.07
PIL_200	08/22/08	10:29	4	842	29	10:45	12	842	34	0.00	0.02	0.04	0.05	0.07	0.09	0.09	0.11	0.11	0.11	0.13	0.13	0.15	0.15	0.15	0.17
PIL_203	08/22/08	12:52	2	842	29	13:07	2	844	35	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PIL_213	08/23/08	9:19	10	849	23	9:35	43.1	849	28	0.00	0.26	0.27	0.35	0.41	0.47	0.53	0.58	0.63	0.68	0.70	0.75	0.79	0.83	0.86	0.89
PIL_217	08/23/08	11:41	4	847	26	11:56	7	847	32	0.00	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.05	0.07	0.07	0.07	0.07
PIL_218	08/23/08	12:19	4	847	27	12:33	20	847	32	0.00	0.03	0.05	0.07	0.09	0.12	0.14	0.17	0.19	0.21	0.24	0.27	0.29	0.31	0.33	0.35
PIL_220	08/23/08	13:11	17	846	28	13:28	54.1	846	32	0.00	0.11	0.20	0.31	0.65	0.75	0.80	0.84	0.88	0.91	0.96	0.98	1.02	1.05	1.08	1.09
PIL_221	08/25/08	10:08	.	.	.	10:23	8	843	33	0.00	0.02	0.02	0.02	0.04	0.05	0.05	0.07	0.07	0.08	0.09	0.09	0.11	0.11	0.13	0.13
PIL_222	08/25/08	10:43	4	843	29	10:58	127	843	33	0.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2.80
PIL_223	08/25/08	11:29	10	843	28	11:44	94	843	34	0.00	0.22	0.28	0.46	0.65	0.81	0.97	1.10	1.23	1.34	1.51	1.61	1.74	1.85	1.93	2.02
PIL_225	08/25/08	13:52	0	841	33	14:11	19	841	38	0.00	0.03	0.05	0.07	0.10	0.12	0.14	0.16	0.19	0.22	0.24	0.26	0.28	0.30	0.32	0.34
PIL_226	08/25/08	13:11	2	842	33	13:26	10	841	39	0.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.17
PIL_229	08/25/08	16:15	30	840	32	16:30	158	840	36	0.00	0.02	0.13	1.01	1.66	2.43	2.95	3.26	3.42	3.46	3.46	3.45	3.44	3.45	3.44	3.44
PIL_236	08/26/08	10:18	4	838	30	10:33	48	838	35	0.00	0.07	0.10	0.13	0.17	0.25	0.34	0.43	0.60	0.70	0.80	0.87	0.93	0.99	1.02	1.05
PIL_240	08/26/08	11:41	1	837	32	11:56	6	837	37	0.00	0.02	0.02	0.03	0.04	0.04	0.05	0.07	0.07	0.07	0.09	0.09	0.09	0.09	0.10	0.11
PIL_242	08/26/08	13:21	50	837	33	13:36	425	837	38	0.00	0.68	1.81	2.72	3.53	4.25	4.94	5.56	6.19	6.77	7.17	7.65	7.94	8.37	8.67	9.02
PIL_245	08/26/08	14:49	3	837	35	15:04	8	836	40	0.00	0.04	0.05	0.07	0.07	0.08	0.09	0.09	0.10	0.11	0.11	0.11	0.13	0.13	0.13	0.13
PIL_247	08/26/08	18:02	30	836	33	18:17	109	837	38	0.00	0.24	0.77	0.96	1.11	1.32	1.48	1.60	1.68	1.78	1.86	1.94	2.01	2.07	2.15	2.20
PIL_248	08/27/08	10:03	5	844	22	10:18	53	844	28	0.00	0.12	0.24	0.35	0.44	0.53	0.60	0.67	0.73	0.79	0.86	0.91	0.97	1.02	1.08	1.12
PIL_250	08/27/08	12:03	6	842	25	12:18	34	841	31	0.00	0.09	0.22	0.31	0.38	0.44	0.48	0.53	0.56	0.59	0.61	0.64	0.65	0.67	0.69	0.71
PIL_251	08/27/08	15:37	0	837	31	15:52	1	837	35	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03
PIL_254	08/27/08	13:45	5	840	28	14:00	16	839	34	0.00	0.07	0.13	0.17	0.20	0.23	0.26	0.28	0.29	0.31	0.31	0.31	0.31	0.31	0.33	0.33
PIL_256	08/27/08	14:51	10	838	30	15:06	100	838	36	0.00	0.22	0.23	0.61	1.07	1.50	1.75	1.94	2.07	2.15	2.18	2.20	2.19	2.20	2.18	2.18
PIL_257	08/28/08	9:11	1	847	22	9:26	4	847	27	0.00	0.02	0.02	0.02	0.03	0.05	0.05	0.05	0.05	0.06	0.07	0.07	0.07	0.07	0.07	0.08
PIL_258	08/27/08	16:30	2	837	33	16:45	3	837	41	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
PIL_266	08/28/08	10:53	2	847	23	11:08	8	847	28	0.00	0.02	0.02	0.04	0.04	0.04	0.06	0.07	0.07	0.09	0.09	0.11	0.11	0.11	0.13	0.13
PIL_270	08/28/08	12:44	2	846	26	12:59	48	846	29	0.00	0.04	0.12	0.22	0.34	0.45	0.53	0.60	0.68	0.75	0.80	0.87	0.91	0.97	1.01	1.06
PIL_271	08/28/08	14:03	4	845	27	14:18	62	845	33	0.00	0.03	0.06	0.09	0.14	0.26	0.40	0.56	0.69	0.84	0.94	1.02	1.09	1.16	1.23	1.29
PIL_272	08/28/08	13:24	3	846	27	13:39	57	846	31	0.00	0.01	0.23	0.39	0.52	0.64	0.75	0.88	0.98	1.02	1.10	1.18	1.23	1.27	1.32	1.37
PIL_274	08/28/08	14:48	2	845	27	15:03	3	845	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02
PIL_281	08/28/08	17:38	0	844	27	17:53	12	843	32	0.00	0.02	0.02	0.03	0.05	0.06	0.08	0.09	0.11	0.13	0.15	0.17	0.19	0.22	0.24	0.26
PIL_283	08/29/08	10:29	2	846	25	10:44	4	846	30	0.00	0.02	0.02	0.02	0.02	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.07	0.07
PIL_284	08/29/08	11:11	3	846	26	11:26	5.5	846	30	0.00	0.01	0.02	0.02	0.02	0.02	0.03	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.06	0.07
PIL_286	08/29/08	13:41	4	844	29	13:56	620	844	36	0.00	0.05	0.19	0.66	1.35	2.38	3.76	4.99	6.48	7.79	8.89	10.11	11.02	11.51	12.68	13.18
PIL_287	08/29/08	14:30	13	844	30	14:45	136	844	38	0.00	0.25	0.82	1.18	1.46	1.69	1.95	2.18	2.34	2.51	2.66	2.78	2.86	2.90	2.94	2.99
PIL_290	08/29/08	15:13	20	843	31	15:28	58	843	35	0.00	0.34	0.58	0.73	0.94	1.06	1.14	1.18	1.19	1.20	1.20	1.21	1.22	1.22	1.22	1.23
PIL_294	08/29/08	17:15	4	842	31	17:30	6	842	35	0.00	0.02	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.06	0.06
PIL_298	08/30/08	9:56	1	842	26	10:11	3	842	30	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.05
PIL_299	08/30/08	10:33	1	842	27	10:48	19	842	31	0.00	0.02	0.04	0.05	0.06	0.07	0.09	0.09	0.12	0.13	0.16	0.19	0.21	0.23	0.27	0.32
PIL_300	08/30/08	11:11	3	841	28	11:26	13	841	33	0.00	0.04	0.06	0.09	0.13	0.15	0.16	0.18	0.18	0.20	0.20	0.20	0.23	0.25	0.26	0.27
PIL_304	08/30/08	12:36	0	840	30	12:51	8	840	37	0.00	0.01	0.02	0.05	0.05	0.07	0.07	0.09	0.09	0.11	0.11	0.12	0.13	0.14	0.15	0.17

Appendix I
Modified California Method Data[H]

Legend:

0 No visual evidence of fuel leaks

m Minor visual signs of fuel (staining, damp spots), paper towel wicking < 1 inch

S Significant visual leaks with single drops of fuel from vehicle to the ground, paper towel wicking > 1 inch

G Gross visual leaks, regular flow of drops to the ground, or a large pool of fuel, paper towel wicking > 1 inch

NP Not Performed (usually because component was not present, could not be found, or was hidden)

Y Positive HC sniffer response

N No HC sniffer response

Data entry was missing from data packet

packetID	MCM_Date	MCM_Time	MCM_UnderbodyV	MCM_FuelPumpV	MCM_PumpToCarbV	MCM_FuelFilterV	MCM_FuelRailV	MCM_FuelInjectorsV	MCM_UnderVehicleV	MCM_FillPipeToTankV	MCM_TankV	MCM_NonOEMV	MCM_UnderbodyS	MCM_FuelPumpS	MCM_PumpToCarbS	MCM_FuelFilterS	wMCM_FuelRailS	MCM_FuelInjectorsS	MCM_UnderVehicleS	MCM_FillPipeToTankS	MCM_TankS	MCM_NonOEMS	pi_VideoFileNum	pi_Comments
			Visual										Sniffer											
Packet Number	MCM Date	MCM Time	Underbody	Fuel Pump	Pump to Carb	Fuel Filter	Fuel Rail	Fuel Injectors	Under Vehicle	Fill Pipe to Tank	Tank	Non-OEM	Underbody	Fuel Pump	Pump to Carb	Fuel Filter	Fuel Rail	Fuel Injectors	Under Vehicle	Fill Pipe to Tank	Tank	Non-OEM	Video File Number	Comments
PIL_010	07/30/08	12:22	0	0	0	0	0	0	0	0	0	NP	#	#	#	#	#	#	#	#	#	NP	None	No problems found.
PIL_011	07/30/08	16:28	0	0	0	0	0	0	0	0	0	0	#	#	Y	#	#	#	#	Y	#	#	None	The end of the fuel filler neck is damaged. The flange where the gas cap should seal is smashed. After-market locking gas cap does not seal well. Gas cap almost falls off the vehicle. Non-OEM open air filter. Non-OEM fuel fill pipe is homemade of PVC elbows and rubber to metal connections. Second fuel tank is disconnected and crossover valve is bypassed. Vapor and liquid leaks.
PIL_016	07/30/08	18:00	0	NP	NP	0	0	0	0	0	0	NP	#	#	#	#	#	#	#	#	#	#	None	Bad vapor leak at cap, failed fuel cap IM test. Canister saturated.
PIL_019	07/31/08	13:59	0	0	0	NP	NP	NP	0	0	0	0	#	#	#	#	#	#	#	#	#	#	None	New fuel tank, no liquid leaks, lots of carb vapors, OEM cap is vented, a pre-evap-control vehicle.
PIL_022	07/31/08	17:30	0	0	NP	NP	0	0	0	0	0	NP	#	#	#	#	#	#	#	#	#	#	None	Clean. No sniffer beeps or leaks.
PIL_024	08/01/08	11:53	0	NP	NP	NP	0	0	0	0	0	0	#	#	#	#	#	#	#	Y	#	#	96	Sniffer: trace at fill pipe to tank joint.
PIL_029	08/02/08	8:52	0	NP	NP	0	0	0	0	m	0	0	#	#	#	#	#	#	#	#	#	#	None	No problems found, m=stain at tank.
PIL_035	08/01/08	17:53	0	NP	NP	NP	0	0	#	#	#	#	NP	NP	NP	NP	Y	Y	NP	Y	Y	#	None	No visual signs of fuel. Around fuel rail. Fuel fill pipe at gas cap, bottom of inlet to tank, top of tank. Vapor leak top of tank.
PIL_046	08/04/08	16:19	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	None	Pass I/M and cap.
PIL_050	08/04/08	16:59	0	NP	NP	0	0	0	0	0	0	NP	N	N	N	N	N	N	N	Y	#	#	103, 104, 105	Vapor return at cap trace, trace at vapor return to inside of fuel inlet return. Also vdf 326 and 327 on 8/4/08.
PIL_060	08/05/08	14:01	0	NP	NP	0	0	NP	0	M	M	0	#	#	#	#	#	#	#	Y	N	N	106	Trace fill pipe at tank. Slight by cap, Trace by cap.
PIL_061	08/05/08	14:23	0	NP	NP	0	0	NP	0	0	0	0	N	N	N	N	N	N	N	N	N	N	107	Pass I/M and cap, no problems found.
PIL_062	08/05/08	15:19	0	NP	NP	0	0	0	0	0	0	0	N	NP	NP	N	N	N	N	N	N	NP	108	
PIL_063	08/05/08	16:00	0	NP	NP	0	0	NP	0	0	0	0	N	NP	NP	N	N	NP	N	N	N	NP	109	
PIL_065	08/05/08	17:12	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Bad miss, fail I/M. Could not video. Camera problems.
PIL_070	08/06/08	14:09	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	110	Very clean - recently detailed. Large (40 gal?) tank. No problems found.
PIL_072	08/07/08	13:00	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	N	N	N	NP	115	File corrupted.
PIL_078	08/08/08	10:57	0	NP	0	NP	0	0	0	0	0	NP	Y	NP	N	NP	N	N	N	N	N	#	113	Passed IM, previous IM - cap failed, new cap - no problems found.
PIL_079	08/08/08	11:55	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	#	114	No problems found.
PIL_084	08/08/08	14:50	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	119	Pass IM cap, no defects found.
PIL_089	08/09/08	11:57	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	Y	N	#	120	No gas cap, strong sniff signal at top of tank, leaking oil, overheating, holes punched in catalyst.
PIL_098	08/11/08	14:51	0	0	NP	#	0	0	0	0	0	NP	N	N	NP	N	N	N	N	N	N	NP	None	
PIL_108	08/12/08	17:45	0	0	0	0	0	0	0	0	0	NP	N	N	NP	#	N	NP	N	N	N	NP	None	Rejected from IM240 for drive trace problems.
PIL_110	08/12/08	18:28	S	0	NP	0	S	S	S	#	m	#	Y	N	NP	N	Y	Y	Y	#	Y	#	None	This is definite leaker, smell gas.
PIL_116	08/13/08	13:57	0	NP	NP	0	0	0	0	0	0	0	#	#	#	#	#	#	#	Y	NP	NP	None	Possible leak on top of fuel tank.
PIL_117	08/13/08	12:14	0	0	NP	0	0	0	0	0	0	NP	N	N	NP	N	N	N	N	N	N	NP	N/A	Dual fuel tanks.
PIL_118	08/13/08	12:56	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	N/A	Strong fuel smell, no visual leaks.
PIL_123	08/13/08	15:55	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	N	N	N	NP	None	
PIL_124	08/13/08	16:51	0	0	0	0	0	0	0	0	0	0	N	N	N	N	N	N	N	N	N	N	None	
PIL_128	08/14/08	10:59	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	
PIL_130	08/14/08	12:18	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	#	None	No dyno, unsafe on dyno.

packetID	MCM_Date	MCM_Time	MCM_UnderbodyV	MCM_FuelPumpV	MCM_PumpToCarbV	MCM_FuelFilterV	MCM_FuelRailV	MCM_FuelInjectorsV	MCM_UnderVehicleV	MCM_FillPipeToTankV	MCM_TankV	MCM_NonOEMV	MCM_UnderbodyS	MCM_FuelPumpS	MCM_PumpToCarbS	MCM_FuelFilterS	wMCM_FuelRailS	MCM_FuelInjectorsS	MCM_UnderVehicleS	MCM_FillPipeToTankS	MCM_TankS	MCM_NonOEMS	pi_VideoFileNum	pi_Comments
			Visual										Sniffer											
Packet Number	MCM Date	MCM Time	Underbody	Fuel Pump	Pump to Carb	Fuel Filter	Fuel Rail	Fuel Injectors	Under Vehicle	Fill Pipe to Tank	Tank	Non-OEM	Underbody	Fuel Pump	Pump to Carb	Fuel Filter	Fuel Rail	Fuel Injectors	Under Vehicle	Fill Pipe to Tank	Tank	Non-OEM	Video File Number	Comments
PIL_131	08/14/08	13:36	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	Y	Y	N	N	N	NP	None	#2 and #4 injectors are leaking.
PIL_132	08/14/08	14:14	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	
PIL_137	08/14/08	17:39	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Owner says miles are actual, although vehicle was just purchased used.
PIL_138	08/18/08	10:12	0	0	NP	NP	0	0	0	0	0	NP	N	N	NP	NP	N	N	N	N	N	NP	None	
PIL_146	08/18/08	14:08	0	NP	NP	NP	0	0	0	m	m	NP	N	NP	NP	NP	N	N	N	Y	Y	NP	None	Tank very rusty. Leak on top of fuel tank at fuel pump or fill pipe. Cannot see on top of tank.
PIL_151	08/18/08	16:44	0	NP	0	NP	NP	NP	0	0	0	NP	N	NP	N	NP	NP	NP	N	N	N	NP	None	
PIL_157	08/19/08	12:25	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	N	None	Leak at PCV/Throttle body vacuum line tee fitting.
PIL_161	08/19/08	15:42	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	Y	N	N	N	NP	None	Leaking at injector/intake boss on cylinder number 4.
PIL_165	08/20/08	8:56	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	Y	N	N	N	N	NP	N/A	Fuel leak along intake/fuel rail. Could not pinpoint it.
PIL_169	08/20/08	12:02	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Could not find leak.
PIL_174	08/20/08	13:26	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	No leaks, 3ppm shed.
PIL_177	08/20/08	15:51	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Rained during drive. No 2nd or 3rd RSD. Clean shed.
PIL_184	08/21/08	10:54	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Appears to be Canadian import, gray market, clean, no HC.
PIL_191	08/21/08	14:43	0	NP	NP	NP	0	0	0	NP	0	NP	N	NP	NP	NP	N	N	N	N	N	NP	None	Smokes from tailpipe while running.
PIL_193	08/21/08	15:20	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Could not find leak.
PIL_194	08/21/08	15:52	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	#	None	Unable to find the leak(s). Very high HC emissions, 1200 ppm, no visible leaks detected.
PIL_200	08/22/08	10:45	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	
PIL_203	08/22/08	13:07	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	No emissions labels, very clean. Shed >= 3ppm @ 15 min.
PIL_213	08/23/08	9:35	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	Y	N	NP	None	Filler neck leaks near top and at tank (smoke test).
PIL_217	08/23/08	11:56	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Clean.
PIL_218	08/23/08	12:33	0	NP	0	NP	0	0	0	NP	NP	NP	N	NP	N	NP	N	N	N	NP	NP	NP	None	Questionnaire Driver comment: when tank is topped off there is a leak on the top of filler neck.
PIL_220	08/23/08	13:28	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	No leak found.
PIL_221	08/25/08	10:23	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	Computer bombed when started PSHED. Session file was still open when rebooted.
PIL_222	08/25/08	10:58	0	NP	0	0	0	0	0	0	0	NP	NP	NP	N	N	N	N	N	N	NP	NP	None	Could not find leak. Used smoke test too. Results of smoke test: N; N; NP
PIL_223	08/25/08	11:44	0	NP	NP	0	0	0	0	m	0	NP	N	NP	NP	N	N	N	N	Y	N	NP	None	Leak at filler neck/tank joint area on top of tank.
PIL_225	08/25/08	14:11	0	0	NP	0	0	0	0	0	0	0	N	N	NP	N	N	N	N	N	N	N	None	Aftermarket fuel injection. Emissions label lists as a 1994.
PIL_226	08/25/08	13:26	NP	NP	0	0	0	0	0	0	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	None	No leak.
PIL_229	08/25/08	16:30	0	NP	0	NP	m	0	0	0	0	NP	N	NP	N	NP	N	N	N	N	N	NP	None	Could not find leak. Significant corrosion on underbody fuel lines.
PIL_236	08/26/08	10:33	0	NP	0	0	0	0	0	0	0	NP	N	NP	N	Y	N	N	NP	N	N	NP	None	No I/M due to coolant warning light. New gas cap. Leak at fuel filter (per sniffer).
PIL_240	08/26/08	11:56	0	0	0	NP	0	0	0	0	0	NP	N	N	N	NP	N	N	NP	N	N	NP	None	
PIL_242	08/26/08	13:36	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	NP	Y	N	NP	None	Leaks at gas cap, top of fill neck, and tank/fill neck joint area (top of tank).
PIL_245	08/26/08	15:04	0	NP	NP	NP	0	0	0	0	0	NP	NP	NP	NP	NP	N	N	NP	N	N	NP	None	Very clean.
PIL_247	08/26/08	18:17	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	Y	NP	N	N	NP	None	Small leak in area of injectors, large leak at carbon canister.
PIL_248	08/27/08	10:18	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	NP	N	N	NP	None	Could not find leak.
PIL_250	08/27/08	12:18	NP	NP	NP	NP	0	0	0	0	0	NP	NP	NP	NP	NP	Y	Y	NP	N	N	NP	None	2 Leaks: 3rd injector from front and union of flexible fuel line and fuel rail.

packetID	MCM_Date	MCM_Time	MCM_UnderbodyV	MCM_FuelPumpV	MCM_PumpToCarbV	MCM_FuelFilterV	MCM_FuelRailV	MCM_FuelInjectorsV	MCM_UnderVehicleV	MCM_FillPipeToTankV	MCM_TankV	MCM_NonOEMV	MCM_UnderbodyS	MCM_FuelPumpS	MCM_PumpToCarbS	MCM_FuelFilterS	wMCM_FuelRailS	MCM_FuelInjectorsS	MCM_UnderVehicleS	MCM_FillPipeToTankS	MCM_TankS	MCM_NonOEMS	pi_VideoFileNum	pi_Comments
			Visual										Sniffer											
Packet Number	**MCM Date**	**MCM Time**	**Underbody**	**Fuel Pump**	**Pump to Carb**	**Fuel Filter**	**Fuel Rail**	**Fuel Injectors**	**Under Vehicle**	**Fill Pipe to Tank**	**Tank**	**Non-OEM**	**Underbody**	**Fuel Pump**	**Pump to Carb**	**Fuel Filter**	**Fuel Rail**	**Fuel Injectors**	**Under Vehicle**	**Fill Pipe to Tank**	**Tank**	**Non-OEM**	**Video File Number**	**Comments**
PIL_251	08/27/08	15:52	NP	NP	NP	NP	0	0	0	0	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	None	Ratty, but vapor tight.
PIL_254	08/27/08	14:00	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	N	N	N	NP	None	No leak detected, even at gas cap.
PIL_256	08/27/08	15:06	NP	NP	NP	NP	0	0	0	0	0	NP	NP	NP	NP	NP	N	N	NP	N	N	NP	None	No leak found. Difficult to visual/sniff due to shrouding.
PIL_257	08/28/08	9:26	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	NP	N	N	NP	None	
PIL_258	08/27/08	16:45	NP	NP	NP	NP	0	0	0	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	None	Clean. Difficult to visual/sniff due to shrouding.
PIL_266	08/28/08	11:08	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	NP	N	N	NP	None	Ratty, but no leak found.
PIL_270	08/28/08	12:59	0	NP	NP	NP	0	0	0	m	0	NP	N	NP	NP	NP	N	N	NP	Y	N	NP	None	Gas cap was off during 2nd and 3rd RSD runs and PSHED test.
PIL_271	08/28/08	14:18	0	NP	NP	NP	0	NP	0	0	0	NP	N	NP	NP	NP	N	NP	NP	N	N	NP	None	Leak at carbon canister line connection. Running hot, fan clutch out, boiled coolant before entering PSHED.
PIL_272	08/28/08	13:39	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	NP	N	N	NP	N	N	NP	None	No leak found.
PIL_274	08/28/08	15:03	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	NP	N	N	NP	None	
PIL_281	08/28/08	17:53	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	NP	N	N	NP	None	Rusty body, but solid fuel system.
PIL_283	08/29/08	10:44	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	NP	N	N	NP	None	
PIL_284	08/29/08	11:26	0	0	NP	0	0	0	0	0	0	NP	N	N	NP	N	N	N	NP	N	N	NP	None	
PIL_286	08/29/08	13:56	0	S	0	0	0	NP	0	0	0	NP	N	Y	N	N	N	NP	NP	Y	N	NP	None	Leaks at fuel pump body and top of fill pipe near or at cap.
PIL_287	08/29/08	14:45	0	0	0	NP	0	0	0	0	0	NP	N	N	N	NP	N	N	NP	N	N	NP	None	Rapid screened. No leak found, could not reach into injectors but no visual sign of leak either.
PIL_290	08/29/08	15:28	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	NP	N	N	NP	None	No leak found.
PIL_294	08/29/08	17:30	0	0	0	0	0	0	0	0	0	NP	N	N	N	N	N	N	NP	N	N	NP	None	
PIL_298	08/30/08	10:11	0	NP	NP	NP	0	0	0	0	0	NP	N	NP	NP	NP	N	N	NP	N	N	NP	None	
PIL_299	08/30/08	10:48	0	0	0	0	0	NP	0	0	0	NP	N	N	N	N	N	NP	NP	N	N	NP	None	Rebuilt engine. No leaks found.
PIL_300	08/30/08	11:26	0	NP	NP	0	0	0	0	0	0	NP	N	NP	NP	N	N	N	NP	N	N	NP	None	
PIL_304	08/30/08	12:51	0	0	NP	0	m	m	0	0	0	NP	N	N	NP	N	Y	Y	NP	N	N	NP	None	Leaks at several injectors and carbon canister, some may be false positives because exhaust had enough unburnt fuel to set off the sniffer.

Appendix J
Driver Interview Information[1]

packetID	pi_FleetVehicle	pi_ModelYear_gt1980	pi_EveryDayCar	pi_Eligible	pi_MilesYear	pi_MonthsOwned	pi_ParkingLocation	pi_LastTimeFueled	pi_RegularMaintenance	pi_OilChange	pi_TuneUp	pi_NewGasCap	pi_FuelSystemRepairs	pi_MajorEngineWork	pi_SmelledGasoline	pi_AccidentEver
Packet Number	**Fleet Vehicle?**	**Model Year > 1980?**	**Every-Day Car?**	**Eligible?**	**Miles per year?**	**Months owned?**	**Parking location?**	**Last Time Fueled?**	**Regular Maintenance?**	**Oil Change?**	**Tune-up?**	**New Gas Cap?**	**Fuel System Repairs?**	**Major Engine Work?**	**Smelled Gasoline?**	**Accident ever?**
PIL_010	N	Y	Y	Y	A	1	B	A	Y	B	A	A	A	A	N	N
PIL_011	N	N	Y	Y	B	1	B	C	N	A	A	A	A	A	Y	U
PIL_016	N	Y	Y	Y	C	48	A	C	Y	C	A	B	B	B	Y	Y
PIL_019	N	N	N	Y	A	14	B	C	Y	C	C	A	A	A	Y	N
PIL_022	N	Y	Y	Y	B	72	B	C	N	A	A	A	A	A	N	N
PIL_024	N	Y	Y	Y	C	120	B	B	Y	D	D	A	A	A	N	N
PIL_029	N	Y	Y	Y	E	1	B	A	C	E	E	E	E	E	N	N
PIL_035	N	Y	Y	Y	A	12	B	C	N	A	A	A	A	A	N	N
PIL_046	N	Y	Y	Y	A	108	B	C	Y	D	B	C	D	A	N	Y
PIL_050	N	Y	Y	Y	C	156	B	C	B	B	B	A	A	A	N	Y
PIL_060	N	Y	Y	Y	B	2	B	C	A	B	B	E	A	A	N	N
PIL_061	N	Y	Y	Y	B	1	B	C	A	B	B	A	A	A	N	N
PIL_062	N	Y	Y	Y	B	1	B	B	A	B	B	A	A	A	N	N
PIL_063	N	Y	Y	Y	B	204	B	A	A	B	B	A	A	E	N	Y
PIL_065	N	Y	Y	Y	B	0	B	A	A	C	A	A	A	C	Y	N
PIL_070	N	Y	Y	Y	B	0	B	B	A	C	C	A	A	A	N	N
PIL_072	N	Y	N	Y	A	180	A	C	A	B	D	A	A	A	N	N
PIL_078	N	Y	Y	Y	A	96	B	B	A	B	D	B	A	A	N	N
PIL_079	N	Y	Y	Y	B	1	B	A	A	C	E	A	B	A	N	Y
PIL_084	N	Y	Y	Y	B	1	A	A	A	B	B	A	A	A	N	N
PIL_089	N	Y	Y	Y	C	2	B	A	A	B	B	B	E	E	Y	U
PIL_098	N	Y	Y	Y	B	60	A	A	A	C	D	A	A	A	N	Y
PIL_108	N	Y	Y	Y	A	48	B	C	Y	B	B	A	A	A	N	N
PIL_110	N	Y	Y	Y	C	2	B	A	A	B	B	B	A	A	N	Y
PIL_116	N	Y	Y	Y	B	96	A	C	A	C	C	C	A	A	Y	N
PIL_117	N	Y	Y	Y	B	156	B	C	A	B	C	A	A	A	N	N
PIL_118	N	Y	Y	Y	D	36	A	B	A	B	E	A	A	A	Y	N
PIL_123	N	Y	Y	Y	A	144	A	C	A	B	D	A	A	A	N	N
PIL_124	N	Y	Y	Y	B	0	B	B	C	E	E	E	E	E	Y	U
PIL_128	N	Y	Y	Y	B	144	B	A	A	B	B	A	B	A	N	Y
PIL_130	N	Y	Y	Y	A	3	B	B	A	B	B	B	A	A	N	N
PIL_131	N	Y	Y	Y	B	36	B	A	A	B	A	A	A	A	N	N
PIL_132	N	Y	Y	Y	B	0	B	D	C	B	E	E	E	E	N	U
PIL_137	N	Y	Y	Y	C	1	A	A	C	B	B	A	A	A	N	U
PIL_138	N	Y	Y	Y	B	0	B	A	C	E	E	E	E	E	N	Y

packetID **Packet Number**	pi_FleetVehicle **Fleet Vehicle?**	pi_ModelYear_gt1980 **Model Year > 1980?**	pi_EveryDayCar **Every-Day Car?**	pi_Eligible **Eligible?**	pi_MilesYear **Miles per year?**	pi_MonthsOwned **Months owned?**	pi_ParkingLocation **Parking location?**	pi_LastTimeFueled **Last Time Fueled?**	pi_RegularMaintenance **Regular Maintenance?**	pi_OilChange **Oil Change?**	pi_TuneUp **Tune-up?**	pi_NewGasCap **New Gas Cap?**	pi_FuelSystemRepairs **Fuel System Repairs?**	pi_MajorEngineWork **Major Engine Work?**	pi_SmelledGasoline **Smelled Gasoline?**	pi_AccidentEver **Accident ever?**
PIL_146	N	Y	Y	Y	A	12	B	B	C	B	B	A	B	A	Y	U
PIL_151	N	Y	Y	Y	A	36	B	C	A	B	C	A	A	A	N	N
PIL_157	N	Y	Y	Y	B	36	A	A	A	B	D	C	A	A	N	Y
PIL_161	N	Y	Y	Y	B	24	B	B	Y	D	B	A	A	A	N	Y
PIL_165	N	Y	Y	Y	E	0	A	C	A	B	B	B	A	A	N	Y
PIL_169	N	Y	Y	Y	A	24	B	A	A	C	D	A	A	A	N	N
PIL_174	N	Y	Y	Y	B	36	A	C	A	C	E	A	A	A	N	N
PIL_177	N	Y	Y	Y	C	1	B	C	C	A	A	A	A	A	N	N
PIL_184	N	Y	Y	Y	A	72	A	D	A	D	A	B	A	A	N	Y
PIL_191	N	Y	Y	Y	B	48	B	C	A	B	B	A	A	A	N	Y
PIL_193	N	Y	Y	Y	C	120	A	C	A	C	D	A	A	A	Y	N
PIL_194	N	Y	Y	Y	A	36	B	A	B	D	D	A	B	A	N	Y
PIL_200	N	Y	Y	Y	A	1	B	C	C	B	B	A	E	A	N	N
PIL_203	N	Y	Y	Y	B	72	A	C	A	B	D	B	A	A	N	N
PIL_213	N	Y	Y	Y	A	168	B	A	A	C	E	A	A	A	Y	N
PIL_217	N	Y	Y	Y	E	0	B	B	A	B	B	A	A	A	N	N
PIL_218	N	Y	Y	Y	A	48	B	A	A	B	D	A	A	A	Y	N
PIL_220	N	Y	Y	Y	D	96	B	B	A	B	D	A	A	A	N	N
PIL_221	N	Y	Y	Y	A	3	B	A	A	A	B	A	A	A	N	N
PIL_222	N	Y	Y	Y	A	60	B	A	A	E	A	E	A	A	N	N
PIL_223	N	Y	Y	Y	E	1	B	A	A	A	A	A	A	A	N	Y
PIL_225	N	Y	Y	Y	A	144	A	A	A	B	B	A	A	A	N	N
PIL_226	N	Y	Y	Y	A	1	C	A	A	B	A	A	B	A	N	N
PIL_229	N	Y	Y	Y	A	240	B	C	A	D	D	A	A	A	Y	N
PIL_236	N	Y	Y	Y	B	4	B	A	A	B	B	B	A	A	Y	N
PIL_240	N	Y	Y	Y	A	3	B	C	A	B	E	A	A	A	N	N
PIL_242	N	Y	Y	Y	A	180	B	C	A	B	B	A	A	A	N	Y
PIL_245	N	Y	Y	Y	A	36	A	C	A	C	D	A	A	A	N	N
PIL_247	N	Y	Y	Y	B	0	B	B	A	A	A	A	A	A	N	N
PIL_248	N	Y	Y	Y	D	132	B	C	B	B	B	A	A	A	N	N
PIL_250	N	Y	Y	Y	C	0	B	B	A	A	A	A	A	A	N	N
PIL_251	N	Y	Y	Y	A	204	B	D	B	B	B	A	A	A	N	N
PIL_254	N	Y	Y	Y	A	72	B	A	A	C	C	A	D	A	Y	N
PIL_256	N	Y	Y	Y	B	2	B	B	B	A	A	A	B	A	N	N
PIL_257	N	Y	Y	Y	A	72	B	A	A	B	A	A	A	A	N	N
PIL_258	N	Y	Y	Y	B	72	A	C	A	C	A	A	A	A	N	N

packetID	pi_FleetVehicle	pi_ModelYear_gt1980	pi_EveryDayCar	pi_Eligible	pi_MilesYear	pi_MonthsOwned	pi_ParkingLocation	pi_LastTimeFueled	pi_RegularMaintenance	pi_OilChange	pi_TuneUp	pi_NewGasCap	pi_FuelSystemRepairs	pi_MajorEngineWork	pi_SmelledGasoline	pi_AccidentEver
Packet Number	**Fleet Vehicle?**	**Model Year > 1980?**	**Every-Day Car?**	**Eligible?**	**Miles per year?**	**Months owned?**	**Parking location?**	**Last Time Fueled?**	**Regular Maintenance?**	**Oil Change?**	**Tune-up?**	**New Gas Cap?**	**Fuel System Repairs?**	**Major Engine Work?**	**Smelled Gasoline?**	**Accident ever?**
PIL_266	N	Y	Y	Y	A	144	B	C	A	B	B	E	A	A	Y	Y
PIL_270	N	Y	Y	Y	A	1	B	A	A	B	B	E	E	E	N	N
PIL_271	N	Y	Y	Y	A	204	B	B	A	B	B	A	A	A	N	Y
PIL_272	N	Y	Y	Y	A	104	B	D	A	B	B	D	A	A	N	N
PIL_274	N	Y	Y	Y	A	1	B	C	A	E	E	E	E	E	N	N
PIL_281	N	Y	Y	Y	A	264	B	C	A	B	E	E	E	A	N	Y
PIL_283	N	Y	Y	Y	A	24	A	A	A	B	E	E	A	A	N	N
PIL_284	N	Y	Y	Y	A	72	B	A	A	B	B	D	C	A	N	N
PIL_286	N	Y	Y	Y	B	300	B	C	A	C	B	E	E	A	Y	Y
PIL_287	N	Y	Y	Y	C	96	C	A	A	B	D	B	A	A	Y	N
PIL_290	N	Y	Y	Y	B	12	B	A	A	B	B	B	B	B	N	N
PIL_294	N	Y	Y	Y	B	36	B	B	A	B	B	E	E	E	N	N
PIL_298	N	Y	Y	Y	B	48	B	C	B	D	A	A	A	A	N	N
PIL_299	N	Y	Y	Y	A	264	B	C	A	B	B	A	B	B	N	N
PIL_300	N	Y	Y	Y	A	18	A	D	A	E	E	E	E	E	N	N
PIL_304	N	Y	Y	Y	C	48	B	A	A	C	C	E	A	A	N	N

Appendix K
I/M Gas Cap Inspection Results[J]

packetID	pi_CapResult
Packet Number	**IM Gas Cap Inspection Result**
PIL_010	P
PIL_011	
PIL_016	F
PIL_019	
PIL_022	P
PIL_024	P
PIL_029	P
PIL_035	P
PIL_046	P
PIL_050	P
PIL_060	P
PIL_061	P
PIL_062	P
PIL_063	F
PIL_065	P
PIL_070	P
PIL_072	P
PIL_078	P
PIL_079	P
PIL_084	P
PIL_089	F
PIL_098	P
PIL_108	
PIL_110	P
PIL_116	P
PIL_117	P
PIL_118	P
PIL_123	P
PIL_124	P
PIL_128	F
PIL_130	
PIL_131	P
PIL_132	P
PIL_137	P
PIL_138	P
PIL_146	P
PIL_151	P
PIL_157	P
PIL_161	P
PIL_165	P
PIL_169	P
PIL_174	P
PIL_177	P
PIL_184	P
PIL_191	P
PIL_193	P

packetID	pi_CapResult
Packet Number	**IM Gas Cap Inspection Result**
PIL_194	P
PIL_200	P
PIL_203	P
PIL_213	P
PIL_217	P
PIL_218	P
PIL_220	P
PIL_221	P
PIL_222	P
PIL_223	
PIL_225	P
PIL_226	
PIL_229	P
PIL_236	
PIL_240	P
PIL_242	F
PIL_245	F
PIL_247	P
PIL_248	P
PIL_250	P
PIL_251	P
PIL_254	F
PIL_256	P
PIL_257	P
PIL_258	P
PIL_266	P
PIL_270	P
PIL_271	P
PIL_272	P
PIL_274	P
PIL_281	P
PIL_283	P
PIL_284	P
PIL_286	P
PIL_287	
PIL_290	P
PIL_294	P
PIL_298	P
PIL_299	P
PIL_300	P
PIL_304	P

[A] The regression equation was developed using proj1/EPA_High_Evap/SanAntonio/Fall2008/Analysis/COCO2.sas. The equation has an r^2 of 1.00000.

[B] P:\EPA_High_Evap\DenverData\Pilot\Analysis/MCM+PSHEDdata.xls

[C] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.

[D] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.

[E] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.

[F] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.

[G] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.

[H] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.

[I] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.

[J] /proj1/EPA_High_Evap/DenverData/Pilot/Analysis/Appendix_tables.xls, which was created by mk_appendix_tbls.sas of the same directory.