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The Maryland Enhanced I/M Program
2013 On-road Remote Sensing Survey

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Prepared for:

Maryland Department of the Environment

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TABLE OF CONTENTS

LISTOF TABLES

LIST OF FIGURES

I. Summary

The Maryland Department of the Environment (MDE) and Motor Vehicle Administration (MVA) are required by the Clean Air Act Amendments of 1990, to supplement Maryland's enhanced Inspection and Maintenance (I/M) program, known as the Vehicle Emissions Inspection Program (VEIP), with an on-road element. The on-road survey will be conducted every two years collecting measurements on 1% of the vehicles. The purpose of the survey is to determine the condition of the VEIP fleet and to evaluate the effectiveness of remote sensing devices in identifying gross polluters.

There were 4.1M registered vehicles in the I/M area and the scope of work required collection of 40,785 valid records (1% of I/M area) from VEIP county-registered vehicles and 10,000 valid records matched from non-VEIP counties. The non-VEIP county records were to be equally divided between the four non-VEIP counties.

Staff from Envirotest, the I/M contractor, conducted the 2013 survey on 31 days between April 22nd and June 6th. Emission measurements were collected from on-road vehicles at 21 sites in 18 jurisdictions (17 counties and Baltimore City). Measurements were made using an RSD-4600 unit capable of measuring hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x). The remote sensing units also measure vehicle speed and acceleration to permit determination of the vehicle operating condition and capture an image of the vehicle plate for identification.

Fleet Emissions

The average emissions of the vehicles measured on-road in Maryland and registered in I/M counties were 0.09% CO, 30 ppm HC hexane and 103 ppm NO_x. Results are sensitive to engine power output, which can vary from site-to-site, and the remote sensing equipment used. The RSD-4000 series of remote sensing equipment has been used since 2003. An RSD-3000 was used in 2001.

The average HC, CO and NO_x emissions by model year for trucks and light passenger vehicles are shown in Figures I-1, I-2 and I-3. The trucks measured are virtually all 10,000 lbs GVWR or less. There were 60 trucks above 10,000 lbs GVWR with emissions measurements[i]

The charts show that newer model year vehicles have substantially lower emissions than older vehicles.

Impact of I/M Testing on Emissions

I/M area vehicles were divided into three groups based on their last identified I/M test result: fail or waiver, unmatched and pass. The dirtiest vehicles on-road were those that failed their most recent test or have obtained a waiver. The results for passenger vehicles and light trucks are provided in Section V.

[i]. Heavy-duty trucks are not measured by RSD without a special set-up to measure elevated exhaust from vertical stacks.

Figure I-1 On-Road Light Passenger Vehicle and Truck HC

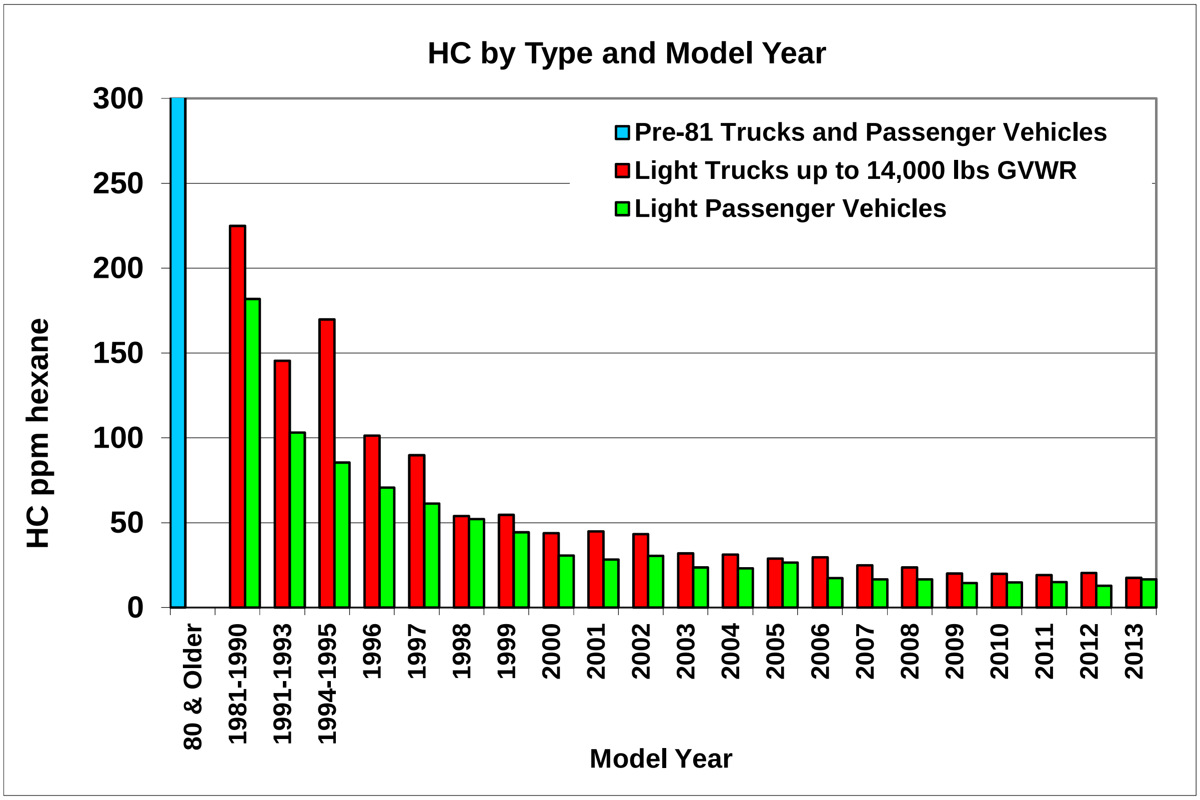


Figure I-2 On-Road Light Passenger Vehicle and Truck CO

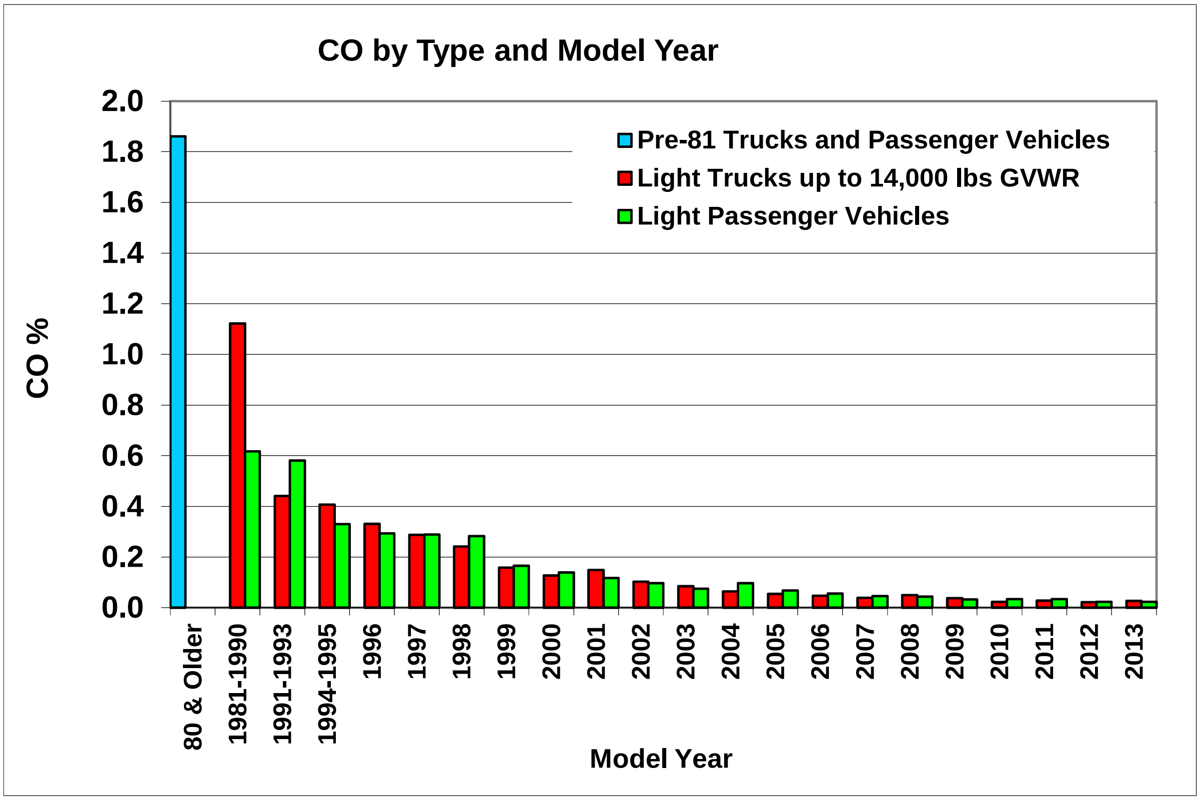
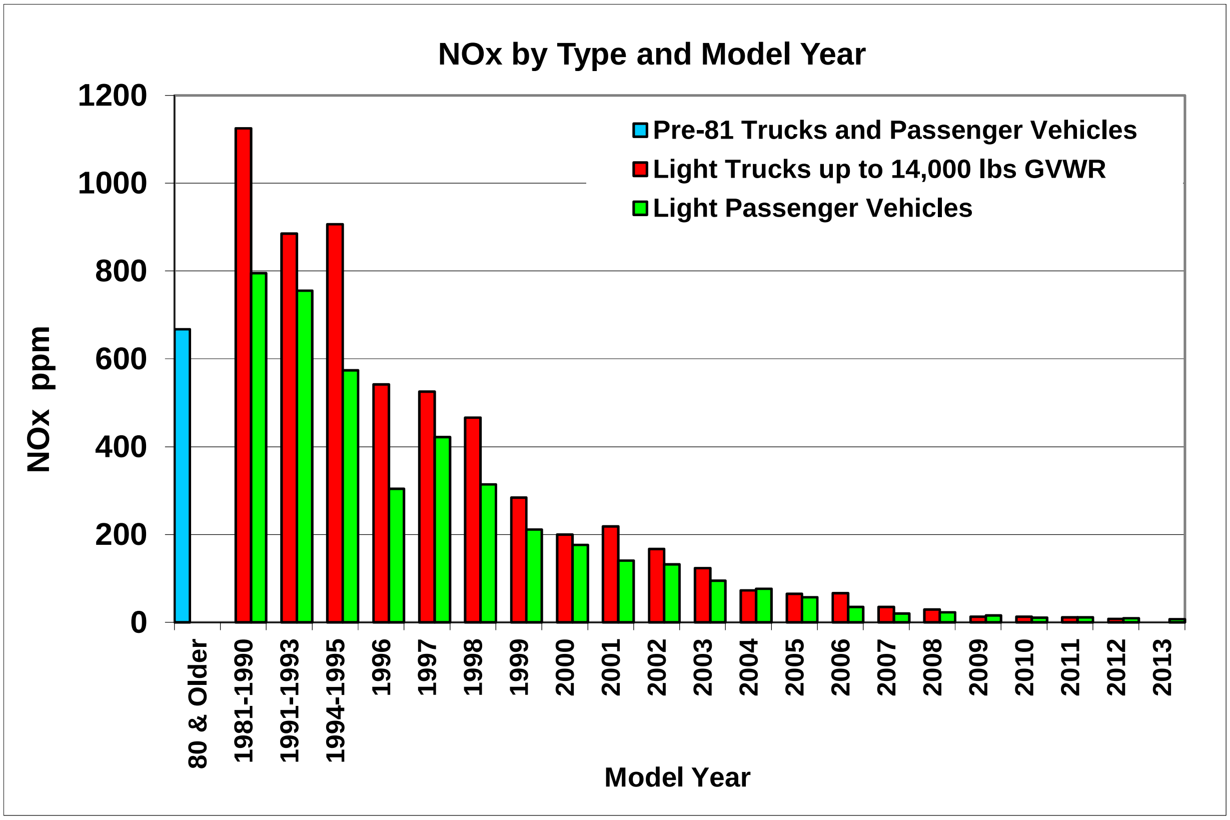


Figure I-3 On-Road Light Passenger Vehicle and Truck NO_x



High Emitters

In order to be considered a high emitter in Maryland, a vehicle must have two or more readings that exceed the standards for the same pollutant on different days. If the standard is exceeded by less than the tolerance of the RSD unit, a third measurement is required for confirmation. Vehicles with out-of-State registrations were not considered in the high emitter analysis because their type and model year was unknown.

Two thousand seven hundred and twenty two vehicles had 2 or more measurements. Of those, 65 (2.4%) had 2 or more valid readings for a pollutant that exceeded the high emitter cutpoints on both readings. Forty of the 65 met the criteria for high emitters with 2 readings that exceeded cutpoints by more than the analyzer tolerance and twenty-five met the criteria for high emitters with 2 readings that exceeded cutpoints by less than the analyzer tolerance. None of the twenty-five that exceeded cutpoints by less than the analyzer tolerance had a third measurement.

Details of high emitters and their identification are provided in section VI.

II. Description of the RSD Project

A. General

1. Project Requirements

The Maryland Department of the Environment (MDE) and Motor Vehicle Administration (MVA) are required by the Clean Air Act Amendments of 1990, to supplement Maryland's enhanced Inspection and Maintenance (I/M) program, known as the Vehicle Emissions Inspection Program (VEIP), with an on-road element to the program. The Clean Air Act Amendments require that a minimum of 0.5% of the eligible motor vehicle population in the enhanced program area be tested. The remote sensing surveys in Maryland are to be conducted every two years and are designed to collect at least a 1% sample on each occasion.

The Code of Federal Regulations *40 CFR, Part 51, Subpart S,* Section 51.371 covering Enhanced I/M programs defines on-road testing as testing of vehicles for conditions impacting emission of HC, CO, NO_x and/or CO_2 emissions on any road or roadside in the non-attainment area or the I/M program area. On road testing is required in enhanced I/M areas.

2. Contractor

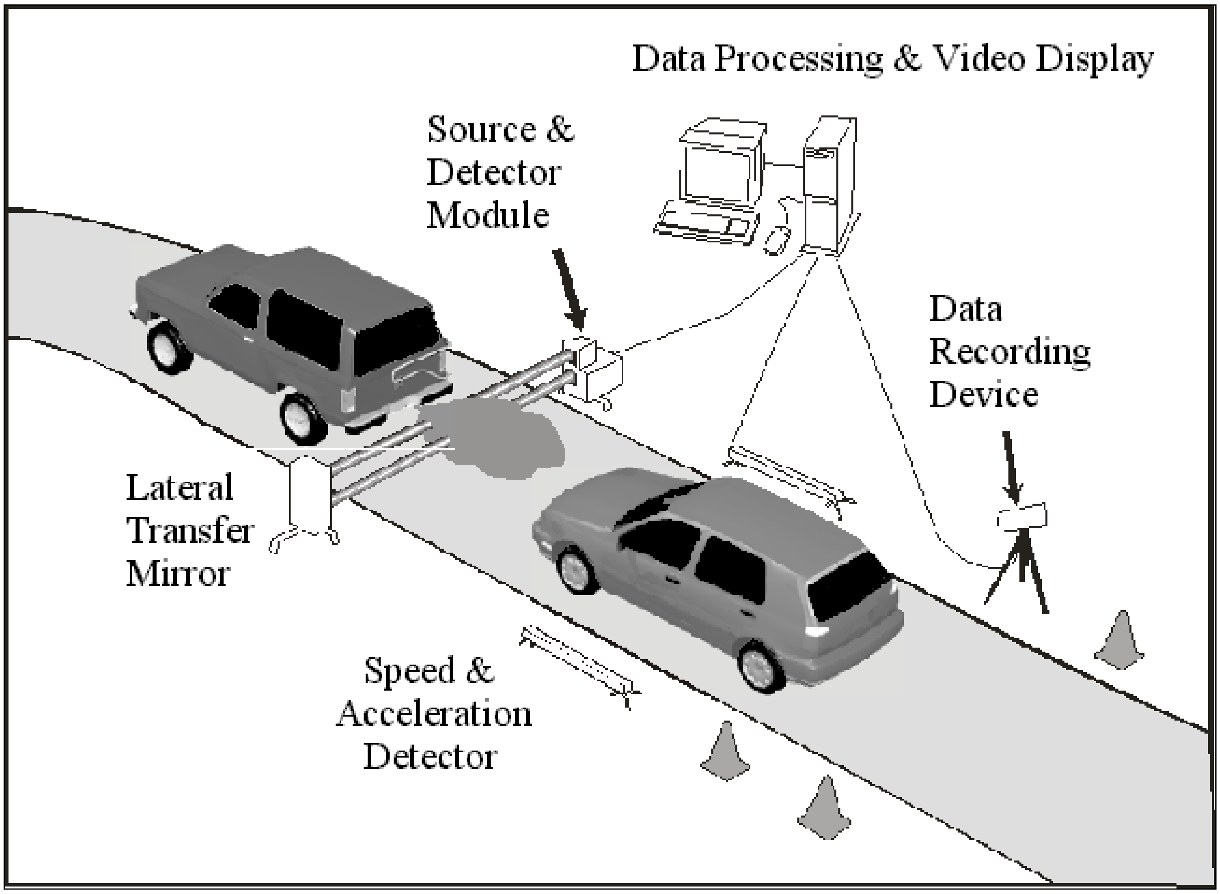
The Remote Sensing division of Envirotest has been responsible for this work. Envirotest has been developing and operating remote sensing equipment for over ten years. Envirotest uses technology derived from that originally developed at the University of Denver with whom Envirotest has a royalty agreement. Envirotest is also the operator of the centralized inspection program in Maryland.

3. Description of RSD

a) Theory of operation

The remote sensing device (RSD) is a system designed for a non-intrusive measurement of vehicle emissions. It generates and monitors a non-dispersive infrared and ultra-violet beam emitted and reflected approximately 10 to 18 inches above ground preferably across a single lane road. Gasoline, diesel, or other fossil fuel powered vehicles drive through this beam and the exhaust interferes with this transmission of the beam. Quantifying the interference enables the calculation of tailpipe concentrations of carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO_2), and nitrogen oxides (NO_x). A camera simultaneously captures a digitized video image of the rear of the vehicle and its license plate. The general arrangement is illustrated in Figure II-1.

Figure II-1 On-road Remote Sensing Setup



b) Equipment

The particular equipment deployed in Maryland in the 2013 study was the RSD-4600 mobile unit also called AccuScan™. The RSD-4600 is the successor to the RSD-3000 (used in the 2001 RSD study) that was based on a technical platform developed at the University of Denver by Dr. Donald Stedman. The RSD-4600 is an improved version of the RSD-3000 with more stable and more sensitive electronic components.

Each mobile unit includes the equipment required to provide measurement of emissions as well as speed and acceleration readings and license plate recognition. Five main components comprise the RSD-4600 system:

- Infrared (IR) and ultraviolet (UV) source detector module (SDM);
- Video system;
- Control console with computer system;
- Laser based speed and acceleration measurement system;
- Specialized license plate image transcription software.

The system captures emissions readings and a camera simultaneously captures a digitized video image of the rear of the vehicle and its license plate. The video and emissions readings taken are stored directly on a removable media disk and can be used for future reference.

c) Emissions Measurements

The primary combustion gases HC, CO, NO_x and CO_2 are measured simultaneously along the same optic path to ensure the proper application of the combustion gas equations. To avoid interference between vehicles, the RSD unit is capable of completing the vehicle emission measurement within 0.5 second and of completing all measurements for a vehicle including emissions, speed, acceleration and plate image within one second.

The RSD unit takes multiple rapid readings of the exhaust plume for each vehicle to evaluate whether a valid measurement of a vehicle's exhaust has been achieved. At least 5 measurements of the plume with CO_2 elevated above ambient by a minimum threshold are required. Up to 48 measurements may be made depending on the exhaust volume, vehicle speed, wind and other factors. The measured values are corrected to account for background concentrations of emissions.

The RSD-4600 continually measures the ambient background. As a vehicle drives by the system, the vehicle blocks the IR/UV beam. When this beam block occurs, the computer stores the current ambient background.

When the exhaust plume is observed by RSD it is already mixing with the surrounding air so that absolute concentrations of exhaust pollutant cannot be measured directly. Rather, it is the ratios of HC/CO_2, CO/CO_2 and NO_x/CO_2 combined with combustion equations that are used to calculate the pollutant concentrations.

RSD units are factory certified to meet accurate measurement of dry calibration gas. Although ambient humidity has an effect on the NO_x emissions performance of vehicles, gaseous H_2O present in the atmosphere and created as a combustion product has no effect on the RSD measurement of emissions.

After every 4,000 operating hours the units are returned to the factory for preventive maintenance and re-certification. A specially modified vehicle dispenses calibration gas blends of CO_2, HC, CO and NO_x past the RSD unit under controlled conditions. Four separate multi-gas blends are used with ten passes per blend. A typical set of certification gases is shown in Table II-1.

Table II-1 Typical Set of Certification Gas Blends

Blend	CO %	CO_2 %	HC ppm propane	NO ppm
1	0.50	15.00	500	3,000
2	1.00	14.50	3,000	2,000
3	2.75	13.00	2,000	500
4	5.00	11.50	6,000	250

The RSD tolerance for each pollutant is:

- Carbon monoxide (CO): ±0.25% CO or ±10% of the expected CO concentration {whichever is greater} for all expected concentrations less than or equal to 3.0%, and ±15% for all CO expected concentrations above 3.0% CO.

- Hydrocarbon (HC): ±150 parts-per-million (ppm) or ±15% of the expected HC concentration {whichever is greater} throughout the range of HC concentrations. In this report Hydrocarbon measurements are reported in their hexane equivalent measurement.

- Oxides of nitrogen (NO): ±250 parts-per-million (ppm) or ±15% of the expected NO concentration {whichever is greater} throughout the range of NO concentrations.

d) NO vs. NO_x

The vast majority of nitric oxides emitted from the vehicle tailpipe are in the form of NO. The NO is later oxidized to NO_2 and other oxides of nitrogen, which are collectively referred to as NO_x. The RSD unit measures NO. To convert from NO to NO_x, a factor of 1.03 is applied. For simplicity we refer to NO_x measurements when reporting results. Charts in sections IV, V and VI report NO_x values.

e) NO_x and Humidity

Higher humidity reduces vehicle NO_x emissions. When vehicles were inspected (Prior to August 2009) in the I/M program, humidity correction factors were applied to adjust NO_x measurements to values that would have been achieved when the water vapor content was 75 grains per lb. For temperatures above 75 F:

Correction factor = e^(.004977*(H-75) - .004447*(T-75))

For temperatures below 75F:

Correction factor = 1/(1.0 - .0047*(H - 75.0))

Where:

H = absolute humidity in grains of water/lb dry air

T = Temperature (F)

Both of these are capped at 2.19.

The on-road NO_x emissions reported in sections IV, V and VI report the NO_x emissions adjusted for humidity.

Correction factors were calculated using weather information recorded by the weather station attached to the RSD van. Water vapor grains per lb were determined using the temperature, relative humidity and barometric pressure:

Saturated Vapor Pressure = $(-4.14438 \times 10^{-3} + 5.76645 \times 10^{-3} \times [\text{Temp F}] - 6.32788 \times 10^{-5} \times [\text{Temp F}]^2 + 2.12294 \times 10^{-6} \times [\text{Temp F}]^3 - 7.85415 \times 10^{-9} \times [\text{Temp F}]^4 + 6.55263 * 10^{-11} \times [\text{Temp F}]^5)*25.4$

Grains per lb = (43.478 x [Relative Humidity] x [Saturated Vapor Pressure]) / (([Barometric pressure Hg mm])-([Saturated Vapor Pressure]*[Relative Humidity]/100))

4. On-road Puff Calibrations and Puff Audits

Units are equipped with an internal calibration gas cell, which has a specific set of concentrations. As part of standard procedure, the operator must first set up the retro reflector on the far side of the road and conduct a mirror alignment check. The RSD unit sends infrared and ultraviolet beams across the roadway. These beams are reflected by the mirror and detected by the RSD unit. The RSD detectors create a voltage in response to particular infrared and ultraviolet frequencies. The presence of proper voltages across all detectors verifies that the RSD unit and the mirror are properly aligned. Second, the unit is calibrated to the calibration cell values.

The next step is to verify the unit calibration. This is referred to as a puff audit. Calibration gas is introduced into the IR/UV path. This is accomplished through a calibration gas cylinder, a stainless steel gas regulator, fittings and tubing to deliver the calibration gas to the source detector module (SDM). The operator will then introduce the calibration gas into the IR/UV path via a spray nozzle at the end of the tube. The instrument displays the readings on the screen. The RSD unit response is automatically compared to the calibration gas and required to be within specification limits.

Operators are instructed to audit approximately every hour and must audit within two hours or the records will be flagged with a CVA session status of “L” meaning lock out. The records marked with an “L” are not considered valid. Three puffs within specification are required. It may be repeated for verification at operator discretion and depending on traffic conditions. If the audits indicate the unit is operating outside the accuracy specification, then the operator is to recalibrate and re-audit.

5. Speed and Acceleration Measurements

The mobile unit is equipped with a speed and acceleration measurement system that uses extremely accurate low energy lasers to calculate the speed of the vehicle to within +/- 1 mile per hour and acceleration to within +/- 0.5 miles per hour per second at the moment exhaust is measured. The speed and acceleration measurement systems are tested at the time of system certification for functionality, do not contain any moving parts and do not require calibration.

6. Data Collected

For each vehicle the following information is collected:

- Plate number;
- HC, CO, CO_2, and NO emission concentrations;
- Maximum CO_2;
- Speed and acceleration;
- Temperature, barometric pressure, and humidity.

B. Overview of 1.0% Sample

1. Sample Design Criteria

The objective is to obtain the 1.0% sample from sites that will be generally representative of vehicles operating in the I/M program area.

As shown in Table II-2: 'RSD Sites', a total of 21 sites were used to collect RSD data in the state. The intent is to collect tests on a random sample that is representative of all the on-road vehicle traffic. Measurements are distributed both geographically and temporally with no one area or period of the day receiving an undue amount of testing.

2. Description of Sample Site Characteristics

Site selection is critical to obtaining RSD measurements that are representative of vehicle operation. Recommended site attributes include:

- Absence of cold start vehicle operating conditions that would cause atypically high emissions
- Sites where vehicles will generally be accelerating or driving at a steady speed uphill to avoid the highly variable tailpipe emissions that can occur under deceleration. Road grade is considered in order to preclude deceleration and assure light load on the engine.
- Absence of high engine loads that could result in atypically high emissions
- Single lane operation to unambiguously isolate individual vehicles
- High volume traffic for productivity
- Unobtrusive positioning of the remote sensing equipment to avoid motorists braking suddenly
- Multi-year stability in the traffic mix to facilitate evaluation of year-to-year trends
- Adequate median space for safe operation of the RSD equipment.

To improve the chances of multi-year stability in the traffic mix, Envirotest tries to avoid sites that are excessively influenced by temporary operations such as a large development under construction. These can change the traffic and may result in the conversion of the one-lane remote sensing site to a multiple-lane highway that is unsuitable for remote sensing.

The 2013 study had five sites added and three discontinued compared to the 2011 study. Sites BA02, BA03, CL12, HA13, QA03 and QA04 were surveyed in 2013 that were not surveyed in 2011. CL10, HA11 and QA01 were discontinued as recommended in the 2011 report and approved by MDE.

The road grade at each site is measured during the equipment set-up. The measured grade may vary slightly at each site depending on the precise positioning of the RSD equipment along the roadside. At one of the sites used in 2013, BA04, the recorded grade was four degrees less than that recorded in 2011. The site was moved several hundred yards from its 2011 location on Rte. 45 between Loveton Farms and Phoenix Rd to just after Phoenix Rd in 2013 because the original location was widened to two lanes. The new location at BA04 yielded only a 15% valid rate. BA02 and BA03 were subsequently added to make up for the loss of valid records.

The percentages of beam blocks resulting in valid measurements within the desired VSP range are reported in the rightmost column of Table II-2. Sites BA04 and CL12 had low valid rates of 15% and 34% respectively. BA04 in its new location will be dropped from future surveys. CL12 was a modest improvement over CL10, which it replaced.

Table II-2 RSD Sites

Site Code	Location	City	County	Degrees of Grade	Valid RSD in Desired VSP Range	% of Beam Blocks Valid
AA13	Rte 450 West St. and Jennifer Rd SB to Hwy 301 W	Annapolis	Anne Arundel	0.40	6,711	48%
AL12	From Salem St/Center St to I-68 West	Cumberland	Allegany	3.40	3,920	70%
BA02	Eastern Blvd. EB to 702 N	Essex	Baltimore County	0.29	4,694	43%
BA03	Eastern Blvd. WB to 702 N	Essex	Baltimore County	0.40	2,049	70%
BA04	Rte 45 SB near Phoenix Rd.	Cockeysville	Baltimore County	-0.40	1,178	15%
BA20	Eastern Ave. WB to I-95 SB	Baltimore	Baltimore City	1.70	4,026	63%
CE04	Rte 222 South towards I-95	Port Deposit	Cecil	1.00	1,831	56%
CH11	Post Office Rd SB just past Industrial Park Dr	Waldorf	Charles	1.30	1,612	62%
CL12	from MD 4 to MD 260 South	Dunkirk	Calvert	0.70	1,658	34%
CR01	Railroad Ave. NB Just South of Tuc Rd	Westminster	Carroll	2.10	1,931	61%
FR14	From W Patrick St to US 15 Catoctin Mtn Hwy NB	Frederick	Frederick	1.40	4,228	80%
HA13	Riverside Rd (MD 543) North past Brass Mill Rd	Belcamp	Harford	1.80	3,378	69%
HO13	From Rte. 175 EB to I-95 North	Jessup	Howard	0.60	3,534	66%
KE10	Rte. 291 Morgnec Rd. West, just pass Wash. Ave.	Chestertown	Kent	0.13	3,430	49%
MO10	Rte. 198 Spencerville Rd. East before Burtonville Dr.	Burtonville	Montgomery	1.01	8,902	42%
PG10	Rte 197 Collington Rd. North, just pass Lyle Ln.	Bowie	Prince George's	0.70	7,946	50%
QA03	MD 18 (Main St) West past ramp to US 301 (exit 41)	Chester	Queen Anne's	0.10	381	39%
QA04	MD 18 (Main St) East, past ramp to US 301 (exit 41)	Chester	Queen Anne's	0.50	381	43%
SM13	Rte. 5 NB just past Rte. 246	Great Mills	St. Mary's	0.30	3,992	54%
TA01	Rte. 322 Easton Pkwy NB just past Marlboro Ave	Easton	Talbot	0.10	3,704	55%
WA12	US 11 NB, just past Massey Blvd	Hagerstown	Washington	3.10	2,678	83%
					72,164	51%

Appendix A shows the location and layout of each of the RSD sites.

3. *Weather Considerations*

Rain, dense fog, and wet pavement resulting in spray from tires all prevent effective operation of the remote sensing unit since the beam is partially blocked under these conditions. Similarly, cold humid conditions that cause condensation of exhaust plumes are also not productive.

As mentioned earlier, humidity corrections are made to NO_x emissions measurements to account for ambient weather conditions. No corrections are required for HC or CO.

As noted earlier, some data were excluded because of suspected cold starts. These are described in section 3.B.

C. *Sources of Data and Description of Elements*

Data used in the analyses in this report come from three primary sources; the RSD unit measurements, the registration records maintained by the Motor Vehicle Administration, and the I/M test database maintained on the contractor host computer system.

The following description gives a summary of the main tables and data used in the analyses.

1. RSD Measurements

For each measurement record the following information is collected:

RSD unit
Date and time
License plate image
HC, CO, CO_2, and NO measurement
Speed and acceleration
Temperature, barometric pressure, and humidity
Measurement quality indicators: V-valid, X-invalid, E-invalid system exception, O-invalid other, N-NO out of range, S-suspect
Ambients[ii]

2. Data Collection Statistics

Unit
Site
Date
Start time
End time

3. RSD Sites

Site reference
Description of location
Slope of site in degrees

4. Vehicle Registration Data

The license plates of vehicles measured by RSD were matched by plate to registration records maintained by the Motor Vehicle Administration to determine the vehicle identification number (VIN) and additional vehicle information:

Vehicle identification number (VIN)
Vehicle license plate
Model year
Make
Body style
Gross Vehicle Weight Rating (GVWR)
City
County
Zip code

[ii] Ambient background levels of HC, CO, CO2 and NO emissions are measured continuously and are deducted from the emissions levels measured in exhaust plumes of passing vehicles.

The registration vehicle body styles and GVWR values were used to classify vehicles into passenger vehicles, trucks up to 10,000 lbs GVWR and trucks over 10,000 lbs GVWR. This classification scheme is consistent with Maryland's in-use testing standards. For comparison purposes it is useful to classify vehicles using the same scheme to report on-road emissions. The Enhanced I/M test standard truck classes are:

- LDGT1: 0-6,000 lbs GVWR;
- LDGT2: 6,001-8,500 lbs GVWR;
- HDGT1: 8,501-10,000 lbs GVWR;
- HDGT2: 10,001-14,000 lbs GVWR;
- HDGT3: 14,001-26,000 lbs GWVR.

Since 99.8% of trucks were 10,000 lbs GVWR or less, trucks are treated as a single class in most sections of this report. There were 45 trucks between 10-14,000 lbs GVWR and 15 trucks greater than 14,000 lbs.

5. I/M Data

I/M test dates, times and test results were extracted from the VEIP database for VINs matching vehicles measured by RSD. The data were used to identify RSD measured vehicles that had been inspected and their most recent VEIP status prior to the RSD measurement.

D. Data Limitations

1. Remote Sensing Unit Accuracy

As described in Section II.A.4, each remote sensing device is audited periodically each day by dispensing known HC, CO, CO_2 and NO blends into the optical path and comparing the measured values to the known values. If the results are outside the RSD audit tolerances, the unit is re-calibrated and another series of audit measurements are run. Passing traffic can influence individual audit measurements, in which case additional audits may be performed.

The RSD software now includes a computer verified audit (CVA) flag on each record that indicates the RSD unit had successfully completed an audit within the specified audit times. Audit time used for the study was 1-hour; however, the operator has an additional hour of grace time to perform an acceptable audit. Therefore, audit flags of "G" status insure that a successful audit has been performed within the prior two hours. Other values of the CVA flag are 'L' meaning lock out, 'S' meaning start and 'X' meaning the system is not ready to collect data. The 'S' status is used on the last successful audit record that preceded normal data collection.

2. Limitations Due to Registration Process and Data Processing

Using RSD, vehicles are first identified using the vehicle plate, which is then matched to vehicle registration data to determine the vehicle information. In a situation where upon purchase of a new vehicle, an owner may transfer the same plate from the old vehicle to the new vehicle, a data processing delay can result in incorrect identification of the vehicle measured by RSD. This delay is the time between the RSD measurement and the matching of the measurement to the registration data.

III. Summary of Data Collection

A. RSD Sample Quantity

The number of subject vehicles registered in the Enhanced I/M area was estimated to be 4.1M and the scope of work required collection of 40,785 valid records (1% of I/M area) from VEIP county-registered vehicles and 10,000 valid records matched from non-VEIP counties. The non-VEIP county records were to be equally divided between the four non-VEIP counties.

Table III-1 summarizes the number of measurements made. In total, 141,081 measurements were taken. Out of the total measurements, 73,190 (52%) were valid records in the desired operating mode (range). A total of 2 measurements were excluded for CO values less than -0.25% and 5 measurements were excluded for NO_x values of less than -250 ppm. A further 1,038 records were excluded as being possible cold starts. The result was 72,145 (51%) valid records in the desired VSP range. Further screening of the valid records excluded 8,621 records without readable plate images. The net result was 63,524 (51% of total measurements) valid records with readable plates.

The valid records with readable plates were then screened for MD plates only. The result was 56,815 valid MD records. These records were then matched to the MVA registration database. The matching resulted in 55,688 records, or a match of 98% of all valid MD records. Of these, 44,901 were collected in the Enhanced I/M area and the 1% survey goal was therefore satisfied.

Table III-1 Collection Summary

Item	Quantity	%
Beam blocks	141,081	
RSD valid HC, CO, NOx, Speed & Acceleration		
and in desired operating mode (VSP)	73,190	52%
Additional screening:		
CO values less than -0.25 %	2	0.0%
NOx values less than -250 ppm	5	0.0%
Possible cold start	1,038	1%
Valid and in desired VSP range after screening	72,145	51%
Valid with readable plate	63,524	45%
Of which:		
Out of State License Plate	6,709	11%
Maryland License Plate	56,815	89%
Of which:		
Matched to MVA Registration	55,688	98%

Table III-2 shows the measurements collected by county with valid HC, CO, NO, speed, acceleration and a plate. The statistics include multiple results for vehicles measured more than once.

Table III-3 shows for each county:

- The number of vehicles registered in the county;
- The number of valid on-road measurements collected in the county;
- On-road measurements collected in the county as a percentage of registrations;
- The number of on-road measurements collected at any site matching vehicles registered in the county;
- The number of on-road measurements collected at any site matching vehicles registered in the county as a percentage of registrations;
- The collection site;
- The number of on-road measurements collected at the site matching vehicles registered in the state.

The 1% collection goal was achieved for the I/M area. The number of registrations matched in I/M counties was 1.1% of registrations.

Table III-2 RSD Measurements Collected by County

RSD County	Beam Blocks	Valid: Gases, Speed & Accel & in VSP Range	Valid w Readable MD Plate	Valid w Out Of State Plate	Total Complete Records	%	Valid w MD Plate Matched to Registration	Plate Match %
Allegany	5,599	3,920	2,548	979	3,527	63%	2511	99%
Anne Arundel	14,121	6,711	5,258	548	5,806	41%	5137	98%
Baltimore City	6,413	4,026	3,104	245	3,349	52%	3036	98%
Baltimore County	22,040	7,862	6,440	647	7,087	32%	6306	98%
Calvert	4,852	1,658	1,282	162	1,444	30%	1261	98%
Carroll	3,174	1,931	1,534	177	1,711	54%	1501	98%
Cecil	3,272	1,831	1,235	322	1,557	48%	1208	98%
Charles	2,595	1,612	1,403	94	1,497	58%	1378	98%
Frederick	5,313	4,228	3,330	435	3,765	71%	3278	98%
Harford	4,897	3,378	2,555	327	2,882	59%	2505	98%
Howard	5,376	3,534	2,919	302	3,221	60%	2855	98%
Kent	7,057	3,560	2,524	385	2,909	41%	2490	99%
Montgomery	21,251	8,902	7,457	448	7,905	37%	7312	98%
Prince George's	15,885	7,946	6,756	608	7,364	46%	6633	98%
Queen Anne's	1,868	762	597	56	653	35%	584	98%
St. Mary's	7,397	3,992	3,142	248	3,390	46%	3070	98%
Talbot	6,726	3,614	2,787	222	3,009	45%	2716	97%
Washington	3,245	2,678	1,944	504	2,448	75%	1907	98%
Total	141,081	72,145	56,815	6,709	63,524	45%	55,688	98%

Table III-3 On-road Measurements by County as % of Registrations

County	2012 Registered Vehicles	Valid On-Road Measurements Collected	Collected / Registered	Matches to a Registration in This County (Collected Anywhere)	Matched / Registered	Site	Valid Matched to Maryland Registration
Subject to I/M:							
Anne Arundel	481,836	5,806	1.2%	5,562	1.2%	AA13	5,137
Baltimore City	285,286	3,349	1.2%	3,432	1.2%	BA20	3,036
Baltimore County	640,542	7,087	1.1%	5,822	0.9%	BA02	3,881
						BA03	1,565
						BA04	860
Calvert	83,257	1,444	1.7%	1,285	1.5%	CL12	1,261
Carroll	157,609	1,711	1.1%	2,502	1.6%	CR01	1,501
Cecil	84,136	1,557	1.9%	1,208	1.4%	CE04	1,208
Charles	129,902	1,497	1.2%	1,355	1.0%	CH11	1,378
Frederick	210,444	3,765	1.8%	2,917	1.4%	FR14	3,278
Harford	216,770	2,882	1.3%	2,452	1.1%	HA13	2,505
Howard	246,274	3,221	1.3%	2,806	1.1%	HO13	2,855
Montgomery	744,804	7,905	1.1%	5,645	0.8%	MO10	7,312
Prince George's	628,334	7,364	1.2%	7,274	1.2%	PG10	6,633
Queen Anne's	45,427	653	1.4%	1,369	3.0%	QA03	310
						QA04	274
Washington	123,848	2,448	2.0%	2,253	1.8%	WA12	1,907
Subtotal I/M Area	4,078,469	50,689	1.2%	45,882	1.1%		44,901
Non-I/M:							
Allegany	57,328	3,527	6.2%	2,310	4.0%	AL12	2,511
Kent	18,185	2,909	16.0%	1,791	9.8%	KE10	2,490
St. Mary's	95,287	3,390	3.6%	2,981	3.1%	SM13	3,070
Talbot	36,170	3,009	8.3%	1,761	4.9%	TA01	2,716
Other	231,993	n/a	n/a	963	0.4%	n/a	n/a
Total	4,517,432	63,524	1.4%	55,688	1.2%		55,688

B. RSD Sample Description

1. Measurements and Conditions by Site and Time of Day

Table III-4 ‘Measurements by Site and Time of Day’ shows the valid measurements made per hour on each day by each unit and the site measured. The column header shows the hour in which the measurements were made. The hourly counts are for measurements with valid emission, speed, acceleration and a visible plate. Most measurements were made between 6:00 a.m. and 5:00 p.m.

Similarly, Tables III-5 to III-9 show the average hourly speed, acceleration, CO, HC and NO measured each day by each unit.

Table III-8 highlights one hour with HC emissions averaging -1ppm hexane on 5/9/213 and several days had hours of HC emissions averaging over 100ppm hexane. These were reviewed with the following results:

4/23/2013 site KE10 at 17:00 -18:00 only two vehicles were measured and one was a 1997 Ford Ranger with 364ppm HC, which is not unusual;

5/2/2013 site CR01 before 7:00 no vehicles with unusually high HC were identified;

5/6/2013 site BA04 before 7:00 several vehicles were identified as cold starts with temperatures below 15^{o}C and a 2008 Toyota Camry with 720 ppm HC, which was not eliminated as the recorded temperature on this record was over 15^{o}C and the HC/CO_2 correlation r^2 was greater than 0.8.;

5/9/2013 site QA03 before 7:00 there were just two valid measurements, one -24ppm HC and one +22ppm HC that resulted in the average of -1ppm hexane;

5/17/2013 site PG10 after 18:00 thirty-four vehicles measured including a 1987 Chevy Monte Carlo with 2991ppm HC, likely a high emitter;

5/21/2013 site CL12 before 7:00 thirty-four vehicles measured including a 1988 Toyota Tercel with 11% CO and 3709 ppm HC, likely a high emitter;

5/23/2013 site KE10 11:00-12:00 a 1991 Olds Cutlass was measured with 13% CO and 1409 ppm HC and a 1986 FORD F150 was measured with 3423 ppm HC, both likely high emitters;

5/23/2013 site KE10 16:00-17:00 a 1986 Ford F250 was measured with 6088ppm HC and a 2003 Mitsubishi Lancer Evolution AWD was measured with 1.5% CO and 2291 ppm HC, both likely high emitters;

5/29/2013 site BA20 12:00-13:00 a 1995 Dodge Ram B1500 was measured with 46,505 ppm HC, likely a high emitter.

Table III-10 shows the percentage of 2008 and newer models with HC greater than 150 ppm HC hexane[iii]. Few new model vehicles are expected to have high emissions once they have warmed up. If more than 5% of these newer vehicles have high emissions, which occurred on a number of occasions, it is possible there were an excessive number of cold starts or cold temperature effects.

Table III-11 shows the average temperature measured at the RSD van that ranged from 9 degrees Celsius to 41 degrees Celsius.

The results from Tables III-8, III-10 and III-11 flagged a number of hours with suspiciously high HC values. Several sessions of RSD data were selected for further review and exhaust plume measurements of vehicles reported as having high HC were analyzed to determine if they were affected by the presence of condensed water as steam:

4/22/2013 site KE10 before 8:00 A.M., nine vehicles were identified as having water signatures in the plume;

[iii] The percentages of 2008 and newer models with HC greater than 150 ppm HC hexane are shown in Table III-10 only for hours in which more than ten RSD records were available for these models.

4/23/2013 site KE10 before 10 A.M., three vehicles were identified as having water signatures in the plume;

4/26/2013 site SM13 before 7:00 A.M., 17 vehicles were identified as having water signatures in the plume;

5/23/2013 site KE10 no water signatures were identified in the data for the session.

It appeared that plumes affected by water occurred in the mornings when temperatures were below 15 degrees Celsius. Site KE10 had a higher fraction of vehicles that were high emitters and these were more likely to be diesel trucks or flex fuel trucks.

Based on these findings, 1038 measurements were invalidated for hours in which more than 5% of newer models had HC greater than 150 ppm HC and the recorded temperature for the RSD measurement was less than 15 degrees Celsius.

Table III-4 Valid Measurements with Plate by Site and Time of Day

Hourly Valid Measurements with Plates (before cold start screen)															
Date	**Van**	**Site**	**06 & earlier**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18 & later**
4/22/2013	__07064619	KE10	53	82	85	67	57	63	71	77	74	104	72	63	32
4/23/2013	__07064619	KE10	40	61	78	66	46	63	67	56	81	112	74	2	
4/24/2013	__07064619	TA01	97	153	171	134	201	191	212	213	216	217	238	226	112
4/25/2013	__07064619	TA01	78	115	144	153	138	67							
4/26/2013	__07064619	SM13	202	268	312	240	274	278	343	382	383	500	410		
4/29/2013	__07064619	AL12	81	261	247	212	220	257	277	267	299	404	430	309	68
4/30/2013	__07064619	WA12		203	261	210	243	301	303	337	380	210			
5/1/2013	__07064619	FR14		542	578	361	439	420	473	464	483	5			
5/2/2013	__07064619	CR01	113	240	231	197	209	260	259	269	283	3			
5/3/2013	__07064619	HA13	198	187	201	178	190	276	330	234	245	420	411	12	
5/6/2013	__07064619	BA04	61	130	154	99	56	92	122	41	37	53	159	168	
5/8/2013	__07064619	HO13	249	586	461	356	303	333	446	484	3				
5/9/2013	__07064619	QA03	2	68	79	80	70	37							
5/10/2013	__07064619	QA04	14	47	65	79	62	50							
5/13/2013	__07064619	AA13	232	262	271	237	208	255	298	323	253	409	466	477	699
5/14/2013	__07064619	CE04	628	437	307	157	28								
5/15/2013	__07064619	MO10	211	322	341	251	211	219	197	187	212	324	333	302	
5/16/2013	__07064619	MO10	287	416	474	296	217	199	224	235	191	260	362	288	303
5/17/2013	__07064619	PG10	218	451	366	345	394	409	463	384	577	445	514	483	34
5/20/2013	__07064619	CH11	33	75	162	179	165	226	250	275	132				
5/21/2013	__07064619	CL12	31	41	39	32	57	67	79	75	110	190	366	356	1
5/22/2013	__07064619	PG10	228	440	386	329	323	379	196						
5/23/2013	__07064619	KE10		38	85	58	65	69	83	77	84	114	102	93	2
5/28/2013	__07064619	BA02	14	107	84	19	9	182	186	185	214	220	279	303	219
5/29/2013	__07064619	BA20	313	272	195	152	118	104	125	114	139	154	190	171	83
5/30/2013	__07064619	BA03	30	38	58	62	57	93	99	90	144	245	375	312	244
5/31/2013	__07064619	AA13								144	416	457	399		
5/31/2013	__07064619	KE10	64	84	95	83	82	38							
6/3/2013	__07064619	MO10					16	184	223	214	269	137			
6/4/2013	__07064619	BA02	199	297	206	197	161	215	172	196	234	246	127		
6/5/2013	__07064619	AL12	107	88											
6/6/2013	__07064619	BA20	357	302	213	141	95	110	1						
Total			4,140	6,613	6,349	4,970	4,714	5,437	5,499	5,323	5,459	5,229	5,307	3,565	1,797

Table III-5 Average Speed by Site and Time of Day

			Mean Hourly Speed MPH												
Date	**Unit**	**Site**	**06 & earlier**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18 & later**
4/22/2013	__07064619	KE10	27	27	27	27	26	26	26	25	27	27	27	26	27
4/23/2013	__07064619	KE10	28	28	27	26	28	27	27	27	27	27	27	26	
4/24/2013	__07064619	TA01	38	38	38	36	36	36	36	37	36	34	35	36	37
4/25/2013	__07064619	TA01	39	37	37	36	35	36							
4/26/2013	__07064619	SM13	29	30	30	29	29	28	29	28	28	22	25		
4/29/2013	__07064619	AL12	26	25	24	25	25	24	24	25	26	26	25	25	24
4/30/2013	__07064619	WA12		29	28	27	25	26	24	24	24	24			
5/1/2013	__07064619	FR14		28	28	27	27	27	28	27	27	27			
5/2/2013	__07064619	CR01	26	25	25	25	25	25	25	25	25	21			
5/3/2013	__07064619	HA13	29	29	29	29	28	28	27	29	29	28	29	32	
5/6/2013	__07064619	BA04	32	32	30	30	32	31	29	30	29	32	31	29	
5/8/2013	__07064619	HO13	34	31	31	33	33	33	33	32	35				
5/9/2013	__07064619	QA03	30	34	33	32	31	33							
5/10/2013	__07064619	QA04	31	32	32	32	32	32							
5/13/2013	__07064619	AA13	29	30	28	28	28	29	29	27	28	27	26	25	27
5/14/2013	__07064619	CE04	32	32	34	30	34								
5/15/2013	__07064619	MO10	33	31	33	32	34	34	34	33	32	32	32	33	
5/16/2013	__07064619	MO10	32	32	33	34	33	35	33	33	31	33	32	31	34
5/17/2013	__07064619	PG10	36	24	31	32	32	32	31	31	28	21	22	18	13
5/20/2013	__07064619	CH11	31	30	30	29	30	30	30	30	28				
5/21/2013	__07064619	CL12	39	35	38	39	39	39	39	39	39	39	39	38	17
5/22/2013	__07064619	PG10	35	28	30	34	33	33	34						
5/23/2013	__07064619	KE10		29	27	27	27	27	27	28	27	27	27	27	29
5/28/2013	__07064619	BA02	32	35	36	31	33	34	35	35	35	35	34	35	34
5/29/2013	__07064619	BA20	31	31	32	32	32	32	31	33	33	32	32	32	33
5/30/2013	__07064619	BA03	33	33	32	32	33	33	33	33	33	33	33	33	32
5/31/2013	__07064619	AA13								28	27	25	24		
5/31/2013	__07064619	KE10	27	27	28	27	27	28							
6/3/2013	__07064619	MO10					35	34	33	34	32	31			
6/4/2013	__07064619	BA02	39	39	39	39	38	38	38	37	39	38	37		
6/5/2013	__07064619	AL12	26	26											
6/6/2013	__07064619	BA20	32	29	29	32	31	31	33						

Table III-6 Average Acceleration by Site and Time of Day

			Mean Hourly Acceleration MPH/s												
Date	**Unit**	**Site**	**06 & earlier**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18 & later**
4/22/2013	__07064619	KE10	0.6	0.7	0.8	0.7	0.8	0.7	0.8	0.8	0.8	0.7	0.8	0.7	0.7
4/23/2013	__07064619	KE10	0.5	0.5	0.6	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.8	
4/24/2013	__07064619	TA01	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.0	1.0	0.9
4/25/2013	__07064619	TA01	0.9	1.0	1.0	1.1	1.1	1.0							
4/26/2013	__07064619	SM13	1.3	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.3	1.2		
4/29/2013	__07064619	AL12	0.1	0.1	0.1	0.1	0.2	0.3	0.1	0.2	0.2	0.2	0.2	0.2	0.0
4/30/2013	__07064619	WA12		0.0	0.2	0.2	0.5	0.5	0.5	0.6	0.5	0.5			
5/1/2013	__07064619	FR14		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.7			
5/2/2013	__07064619	CR01	0.3	0.4	0.5	0.4	0.4	0.5	0.4	0.5	0.4	-0.0			
5/3/2013	__07064619	HA13	0.8	0.8	0.7	0.8	0.7	0.6	0.8	0.7	0.7	0.8	0.7	0.9	
5/6/2013	__07064619	BA04	0.8	0.9	0.9	0.9	0.9	1.0	1.1	1.0	0.9	0.9	1.0	1.0	
5/8/2013	__07064619	HO13	1.1	1.4	1.2	1.1	1.2	1.2	1.2	1.2	0.6				
5/9/2013	__07064619	QA03	1.3	0.9	0.8	0.7	0.9	0.6							
5/10/2013	__07064619	QA04	0.7	0.8	0.9	0.8	0.9	1.0							
5/13/2013	__07064619	AA13	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.9	0.9	1.0	0.9	1.0	0.8
5/14/2013	__07064619	CE04	0.9	0.9	0.8	1.1	1.0								
5/15/2013	__07064619	MO10	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7	
5/16/2013	__07064619	MO10	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.7	0.8	0.8	0.8	0.6
5/17/2013	__07064619	PG10	0.7	1.1	0.9	0.8	0.9	0.9	0.9	0.9	1.0	1.1	1.2	1.3	1.6
5/20/2013	__07064619	CH11	0.4	0.7	0.7	0.7	0.8	0.8	0.8	0.7	0.7				
5/21/2013	__07064619	CL12	0.9	1.0	1.0	1.1	0.8	1.0	0.9	1.0	0.9	0.9	0.9	1.0	1.9
5/22/2013	__07064619	PG10	0.7	0.9	0.9	0.7	0.8	0.7	0.8						
5/23/2013	__07064619	KE10		0.6	0.5	0.5	0.6	0.7	0.5	0.6	0.6	0.6	0.7	0.7	0.5
5/28/2013	__07064619	BA02	1.1	1.1	1.1	1.1	1.3	1.3	1.2	1.3	1.3	1.2	1.3	1.4	1.4
5/29/2013	__07064619	BA20	0.9	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.9	0.8	0.9	0.7
5/30/2013	__07064619	BA03	1.2	1.2	1.1	1.1	1.1	1.2	1.2	1.1	1.1	1.1	1.2	1.2	1.2
5/31/2013	__07064619	AA13								0.9	1.0	1.0	1.1		
5/31/2013	__07064619	KE10	0.5	0.5	0.5	0.6	0.6	0.7							
6/3/2013	__07064619	MO10					0.2	0.4	0.5	0.5	0.5	0.8			
6/4/2013	__07064619	BA02	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.1	1.2		
6/5/2013	__07064619	AL12	0.5	0.5											
6/6/2013	__07064619	BA20	0.9	0.8	0.7	0.8	0.9	0.9	1.4						

Table III-7 Average CO% by Site and Time of Day

			Mean Hourly CO %												
Date	**Unit**	**Site**	**06 & earlier**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18 & later**
4/22/2013	__07064619	KE10	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.1	0.1	0.0	0.0	0.1	0.1
4/23/2013	__07064619	KE10	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.3	
4/24/2013	__07064619	TA01	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1
4/25/2013	__07064619	TA01	0.1	0.0	0.1	0.1	0.1	0.0							
4/26/2013	__07064619	SM13	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1		
4/29/2013	__07064619	AL12	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
4/30/2013	__07064619	WA12		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1			
5/1/2013	__07064619	FR14		0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2			
5/2/2013	__07064619	CR01	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.9			
5/3/2013	__07064619	HA13	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.4	
5/6/2013	__07064619	BA04	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.4	0.1	0.1	0.1	0.1	
5/8/2013	__07064619	HO13	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0				
5/9/2013	__07064619	QA03	0.2	0.1	0.1	0.2	0.0	0.0							
5/10/2013	__07064619	QA04	0.2	0.0	0.1	0.0	0.0	0.0							
5/13/2013	__07064619	AA13	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5/14/2013	__07064619	CE04	0.1	0.1	0.1	0.1	0.1								
5/15/2013	__07064619	MO10	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
5/16/2013	__07064619	MO10	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5/17/2013	__07064619	PG10	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.1
5/20/2013	__07064619	CH11	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1				
5/21/2013	__07064619	CL12	0.5	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
5/22/2013	__07064619	PG10	0.1	0.0	0.0	0.1	0.1	0.1	0.1						
5/23/2013	__07064619	KE10		0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.1
5/28/2013	__07064619	BA02	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
5/29/2013	__07064619	BA20	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1
5/30/2013	__07064619	BA03	0.1	0.2	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1
5/31/2013	__07064619	AA13								0.1	0.1	0.1	0.1		
5/31/2013	__07064619	KE10	0.2	0.2	0.1	0.3	0.2	0.0							
6/3/2013	__07064619	MO10					0.0	0.1	0.1	0.1	0.1	0.1			
6/4/2013	__07064619	BA02	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1		
6/5/2013	__07064619	AL12	0.1	0.1											
6/6/2013	__07064619	BA20	0.1	0.1	0.1	0.1	0.1	0.1	0.0						

Table III-8 Average HC ppm hexane by Site and Time of Day

			Mean Hourly HC ppm hexane												
Date	**Unit**	**Site**	**06 & earlier**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18 & later**
4/22/2013	__07064619	KE10	81	39	49	24	66	72	47	84	69	47	46	39	58
4/23/2013	__07064619	KE10	60	24	25	28	69	35	51	62	40	43	35	**186**	
4/24/2013	__07064619	TA01	10	16	22	15	22	20	35	27	40	28	20	25	5
4/25/2013	__07064619	TA01	16	15	17	18	25	26							
4/26/2013	__07064619	SM13	83	56	44	43	72	64	96	63	73	75	83		
4/29/2013	__07064619	AL12	65	38	41	27	29	36	24	27	26	26	30	27	27
4/30/2013	__07064619	WA12		39	51	46	36	35	39	37	42	49			
5/1/2013	__07064619	FR14		17	19	23	32	37	34	51	39	75			
5/2/2013	__07064619	CR01	**106**	49	33	36	40	43	40	42	45	37			
5/3/2013	__07064619	HA13	73	26	36	31	26	29	32	36	28	34	31	41	
5/6/2013	__07064619	BA04	**104**	42	67	68	23	23	21	66	33	35	17	6	
5/8/2013	__07064619	HO13	22	18	17	13	20	25	18	19	34				
5/9/2013	__07064619	QA03	-1	31	32	21	21	26							
5/10/2013	__07064619	QA04	18	10	35	24	27	32							
5/13/2013	__07064619	AA13	32	36	38	45	51	50	87	55	40	63	44	34	33
5/14/2013	__07064619	CE04	40	33	67	50	36								
5/15/2013	__07064619	MO10	23	31	22	24	25	41	43	51	59	68	54	41	
5/16/2013	__07064619	MO10	31	27	29	22	44	41	34	34	62	31	27	18	16
5/17/2013	__07064619	PG10	11	23	9	16	15	28	32	34	27	35	34	35	**138**
5/20/2013	__07064619	CH11	5	11	14	19	12	37	50	55	58				
5/21/2013	__07064619	CL12	**146**	56	32	16	77	17	36	43	36	27	27	25	74
5/22/2013	__07064619	PG10	14	22	17	11	17	31	14						
5/23/2013	__07064619	KE10		75	22	22	67	**115**	57	56	57	50	**154**	65	40
5/28/2013	__07064619	BA02	36	15	26	8	9	5	5	7	9	10	5	6	12
5/29/2013	__07064619	BA20	19	58	18	13	61	22	**394**	31	23	27	12	38	8
5/30/2013	__07064619	BA03	24	14	34	32	17	26	28	26	36	28	27	20	50
5/31/2013	__07064619	AA13								40	46	41	36		
5/31/2013	__07064619	KE10	20	31	22	65	64	41							
6/3/2013	__07064619	MO10					39	30	43	35	41	39			
6/4/2013	__07064619	BA02	4	2	1	7	15	19	23	28	30	27	26		
6/5/2013	__07064619	AL12	37	37											
6/6/2013	__07064619	BA20	19	24	26	20	26	37	37						

Table III-9 Average NO ppm by Site and Time of Day

Date	Unit	Site	Mean Hourly NO ppm											
			06 & earlier	07	08	09	10	11	12	13	14	15	16	17	18 & later
4/22/2013	__07064619	KE10	49	100	80	57	198	144	123	119	82	87	68	47	68
4/23/2013	__07064619	KE10	224	78	86	77	107	83	59	174	110	140	108	370	
4/24/2013	__07064619	TA01	113	117	104	124	151	166	167	168	164	123	145	209	173
4/25/2013	__07064619	TA01	208	209	188	156	135	132							
4/26/2013	__07064619	SM13	233	188	158	247	285	245	196	228	157	163	170		
4/29/2013	__07064619	AL12	239	135	124	278	199	192	162	217	203	183	148	148	188
4/30/2013	__07064619	WA12		108	159	207	183	202	133	162	148	145			
5/1/2013	__07064619	FR14		85	105	129	107	128	151	154	154	560			
5/2/2013	__07064619	CR01	136	140	146	171	179	135	118	148	155	263			
5/3/2013	__07064619	HA13	109	160	118	222	123	131	115	153	109	145	125	365	
5/6/2013	__07064619	BA04	53	98	56	80	112	66	99	147	109	74	78	54	
5/8/2013	__07064619	HO13	98	79	83	104	73	104	90	93	57				
5/9/2013	__07064619	QA03	13	106	117	160	117	44							
5/10/2013	__07064619	QA04	110	160	96	74	133	92							
5/13/2013	__07064619	AA13	84	74	99	95	203	125	133	150	97	153	118	145	127
5/14/2013	__07064619	CE04	97	87	126	99	112								
5/15/2013	__07064619	MO10	116	94	92	65	97	92	107	74	122	72	82	80	
5/16/2013	__07064619	MO10	175	105	95	67	99	103	105	71	97	125	59	98	95
5/17/2013	__07064619	PG10	56	55	94	86	123	97	101	91	98	77	61	100	65
5/20/2013	__07064619	CH11	120	119	122	157	148	155	179	125	164				
5/21/2013	__07064619	CL12	316	129	75	124	157	73	178	119	106	72	80	107	-16
5/22/2013	__07064619	PG10	71	71	59	47	69	107	84						
5/23/2013	__07064619	KE10		177	45	80	73	130	157	178	85	149	151	109	1
5/28/2013	__07064619	BA02	156	93	64	68	16	64	53	97	73	105	80	45	71
5/29/2013	__07064619	BA20	227	173	151	157	268	289	279	217	275	149	104	220	128
5/30/2013	__07064619	BA03	145	74	251	132	65	84	65	54	72	88	58	89	78
5/31/2013	__07064619	AA13								70	70	110	99		
5/31/2013	__07064619	KE10	138	62	88	114	130	49							
6/3/2013	__07064619	MO10					68	83	94	82	96	135			
6/4/2013	__07064619	BA02	75	68	59	90	76	66	88	54	114	53	66		
6/5/2013	__07064619	AL12	307	186											
6/6/2013	__07064619	BA20	174	141	115	177	263	193	717						

Table III-10 Average % of New Models with HC Greater than 150ppm Hexane

Hourly percent of MY 2008 and newer with HC GT 150 ppm hexane															
Date	**Unit**	**site**	**06 & earlier**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18 & later**
4/22/2013	__07064619	KE10		4.8%	4.8%	0.0%			0.0%	**7.7%**	0.0%	0.0%		0.0%	
4/23/2013	__07064619	KE10	0.0%	0.0%	0.0%	**7.7%**	0.0%		0.0%		0.0%	0.0%			
4/24/2013	__07064619	TA01	3.3%	2.4%	2.1%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	1.4%	1.5%	0.0%
4/25/2013	__07064619	TA01	0.0%	0.0%	2.6%	0.0%	0.0%	**6.7%**							
4/26/2013	__07064619	SM13	**7.0%**	4.2%	1.2%	0.0%	1.7%	2.6%	**5.4%**	1.1%	**5.4%**	2.5%	4.0%		
4/29/2013	__07064619	AL12	0.0%	4.9%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	
4/30/2013	__07064619	WA12		2.4%	1.9%	2.1%	2.3%	0.0%	0.0%	0.0%	1.3%	2.0%			
5/1/2013	__07064619	FR14		1.1%	0.0%	0.0%	0.9%	1.0%	0.0%	2.6%	0.0%				
5/2/2013	__07064619	CR01	**13.8%**	**5.7%**	1.5%	3.6%	3.2%	1.5%	1.5%	1.4%	1.5%				
5/3/2013	__07064619	HA13	**6.8%**	0.0%	4.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
5/6/2013	__07064619	BA04	**17.6%**	2.7%	**7.1%**	3.3%	0.0%	2.7%	0.0%	0.0%	0.0%	**9.1%**	3.2%	0.0%	
5/8/2013	__07064619	HO13	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%					
5/9/2013	__07064619	QA03		0.0%	0.0%	0.0%	0.0%								
5/10/2013	__07064619	QA04			0.0%	0.0%	0.0%	0.0%							
5/13/2013	__07064619	AA13	1.3%	0.0%	0.0%	2.7%	1.7%	0.0%	1.0%	2.4%	0.0%	1.7%	0.7%	0.0%	0.5%
5/14/2013	__07064619	CE04	0.5%	0.0%	0.0%	2.6%									
5/15/2013	__07064619	MO10	1.7%	1.1%	0.0%	0.0%	0.0%	3.8%	3.8%	3.7%	3.3%	2.3%	2.9%	2.3%	
5/16/2013	__07064619	MO10	1.6%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	1.8%	0.0%	0.0%	1.2%	0.0%
5/17/2013	__07064619	PG10	1.3%	0.7%	0.0%	0.0%	0.9%	0.0%	0.0%	0.9%	0.0%	1.6%	0.7%	0.8%	0.0%
5/20/2013	__07064619	CH11		0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%	3.0%				
5/21/2013	__07064619	CL12			**10.0%**	0.0%	0.0%	0.0%	**5.9%**	0.0%	0.0%	1.9%	0.8%	0.0%	
5/22/2013	__07064619	PG10	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%						
5/23/2013	__07064619	KE10			4.2%		0.0%	**7.1%**	**5.9%**	0.0%	**6.7%**	**5.0%**	**9.5%**	4.0%	
5/28/2013	__07064619	BA02		0.0%	0.0%			0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.0%	1.3%
5/29/2013	__07064619	BA20	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	2.9%	0.0%	0.0%	0.0%	0.0%
5/30/2013	__07064619	BA03		0.0%	0.0%	0.0%	0.0%	3.1%	0.0%	0.0%	2.5%	1.4%	0.9%	0.9%	0.0%
5/31/2013	__07064619	AA13								0.0%	0.7%	0.0%	0.9%		
5/31/2013	__07064619	KE10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%							
6/3/2013	__07064619	MO10						0.0%	0.0%	1.7%	0.0%	3.6%			
6/4/2013	__07064619	BA02	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
6/5/2013	__07064619	AL12	0.0%	**6.7%**											
6/6/2013	__07064619	BA20	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%							

Table III-11 Average Hourly Temperature

Mean Hourly Temperature Degrees Celsius															
Date	**Unit**	**Site**	**06 & earlier**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18 & later**
4/22/2013	__07064619	KE10	11	12	12	14	16	18	20	21	22	21	21	21	21
4/23/2013	__07064619	KE10	10	11	13	15	16	18	18	19	21	19	20	21	
4/24/2013	__07064619	TA01	16	21	24	24	25	26	27	27	28	29	29	29	27
4/25/2013	__07064619	TA01	11	12	12	12	13	13							
4/26/2013	__07064619	SM13	11	13	18	24	25	25	26	27	28	28	27		
4/29/2013	__07064619	AL12	17	18	23	26	28	26	22	22	22	23	25	26	25
4/30/2013	__07064619	WA12		16	19	22	22	21	20	20	21	21			
5/1/2013	__07064619	FR14		14	17	19	21	23	26	28	30	31			
5/2/2013	__07064619	CR01	9	10	13	15	17	20	21	22	23	24			
5/3/2013	__07064619	HA13	17	20	23	20	22	22	25	26	27	26	27	26	
5/6/2013	__07064619	BA04	13	12	13	14	19	19	18	20	21	22	23	23	
5/8/2013	__07064619	HO13	19	19	23	25	27	26	26	26	27				
5/9/2013	__07064619	QA03	16	18	18	19	20	21							
5/10/2013	__07064619	QA04	19	21	24	26	28	29							
5/13/2013	__07064619	AA13	15	16	20	24	26	26	24	23	22	22	22	22	22
5/14/2013	__07064619	CE04	12	15	22	24	26								
5/15/2013	__07064619	MO10	17	18	22	26	26	27	28	28	28	29	30	32	
5/16/2013	__07064619	MO10	24	25	27	28	30	30	31	30	30	31	30	30	30
5/17/2013	__07064619	PG10	21	22	24	27	28	29	30	33	33	33	32	31	31
5/20/2013	__07064619	CH11	23	23	24	24	25	26	28	30	31				
5/21/2013	__07064619	CL12	25	25	27	28	28	29	30	31	31	31	31	31	31
5/22/2013	__07064619	PG10	27	28	28	29	30	32	33						
5/23/2013	__07064619	KE10		26	27	27	28	30	32	32	32	32	32	31	31
5/28/2013	__07064619	BA02	18	18	19	20	20	22	23	24	25	27	27	27	27
5/29/2013	__07064619	BA20	25	26	27	29	31	33	35	36	37	36	36	35	34
5/30/2013	__07064619	BA03	24	25	27	30	33	34	35	39	40	40	41	40	39
5/31/2013	__07064619	AA13								35	36	37	36		
5/31/2013	__07064619	KE10	29	31	32	33	34	35							
6/3/2013	__07064619	MO10					29	31	31	31	33	34			
6/4/2013	__07064619	BA02	19	19	21	26	27	29	28	28	30	29	29		
6/5/2013	__07064619	AL12	17	17											
6/6/2013	__07064619	BA20	25	26	26	26	27	29	30						

2. Identification and Treatment of Outliers

Measurements outside expected measurement ranges were flagged invalid as indicated below:

- HC less than minus 150 ppm hexane or greater than 50,000 ppm hexane: 0 records
- CO less than minus 0.25% or greater than 20%: 2 records
- NO less than minus 250 ppm or greater than 20,000 ppm: 5 records

Daily mean values of HC, CO and NO were calculated for 2008 and newer vehicles after removal of the outlying measurements. The results are plotted in Figures III-1 through III-3. Daily average emissions for new models were between 3 and 42 ppm HC, between 0.01 and 0.06 % CO and between -2 and 37 ppm NO.

To further investigate individual vehicle measurement outliers, frequency distributions of HC, CO and NO were determined and plotted in Figures III-4 through III-6. There are small tails of negative values representing measurement noise and large tails of positive values representing high emitters.

Figure III-1 Daily Mean HC for 2008 and Newer Vehicles

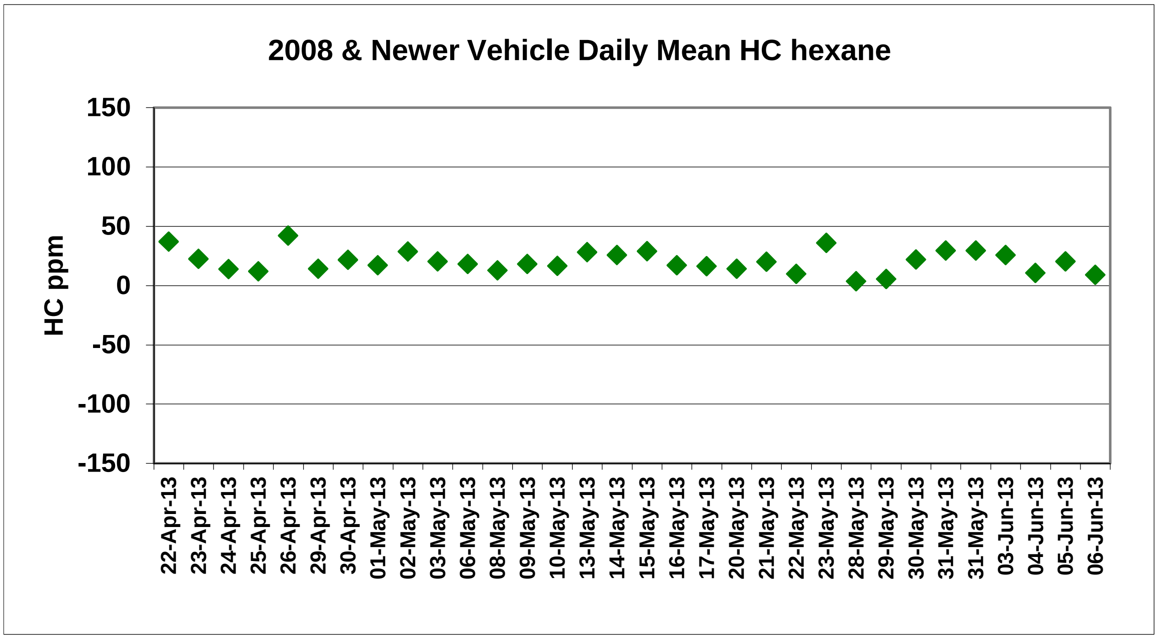


Figure III-2 Daily Mean CO for 2008 and Newer Vehicles

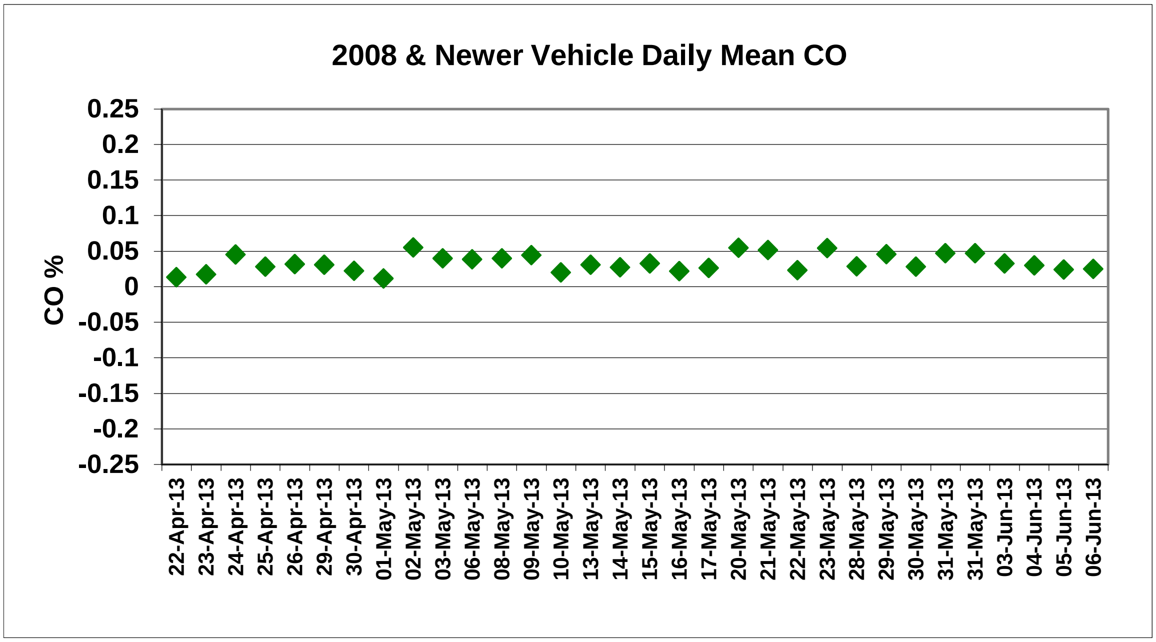


Figure III-3 Daily Mean NO for 2008 and Newer Vehicles

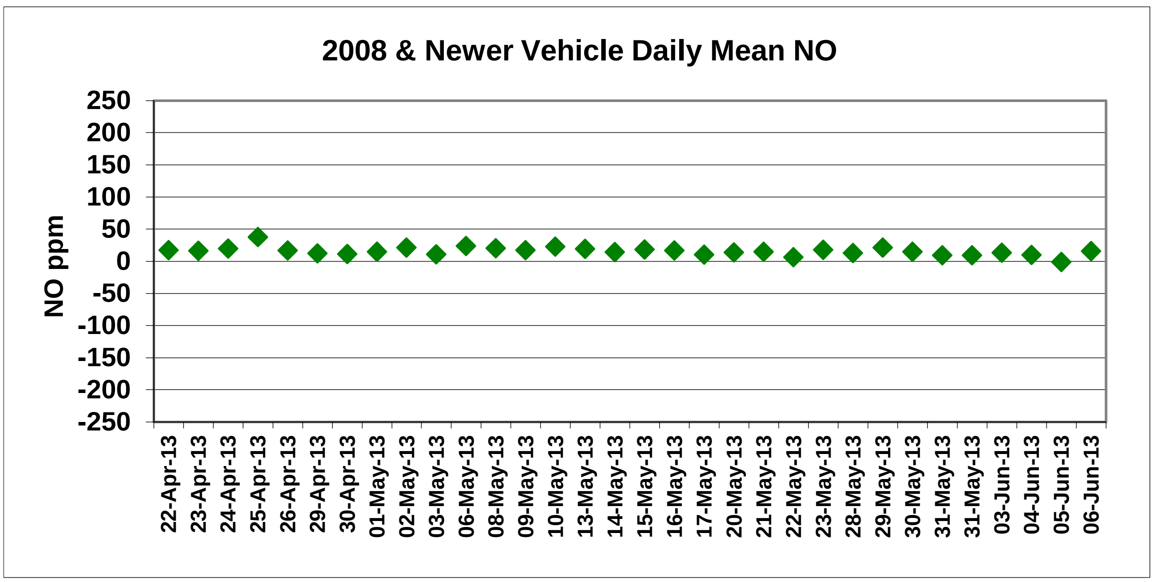


Figure III-4 HC Frequency Distribution

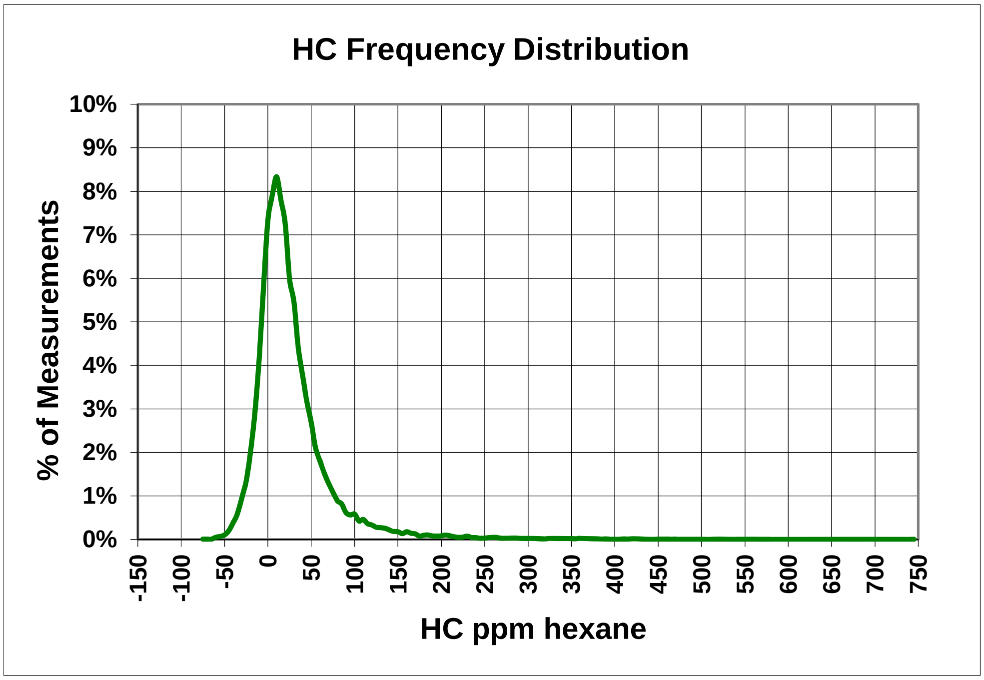


Figure III-5 CO Frequency Distribution

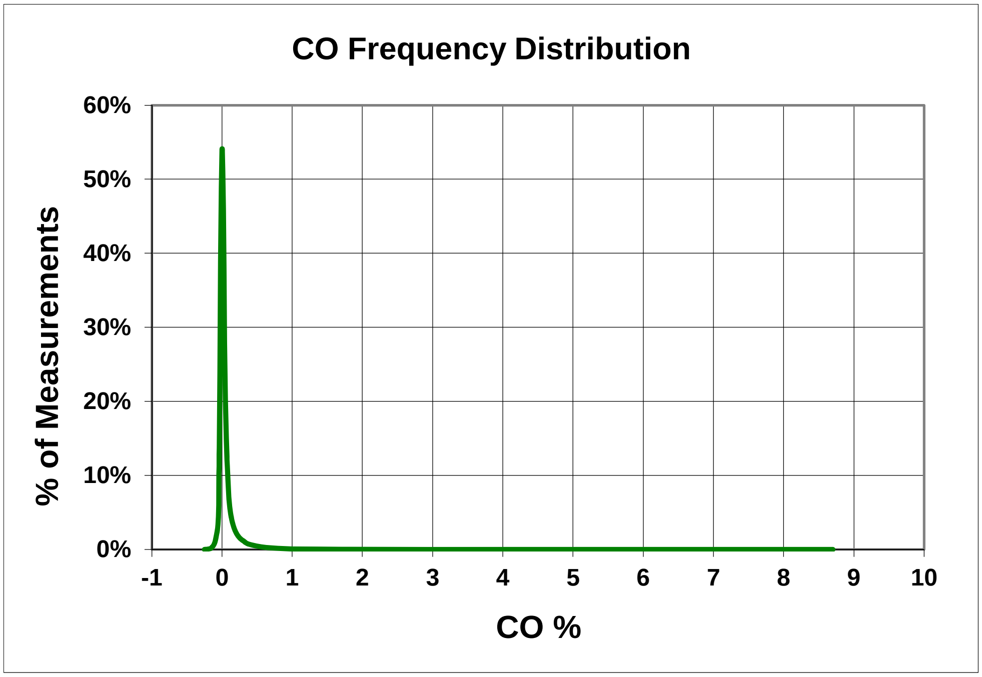
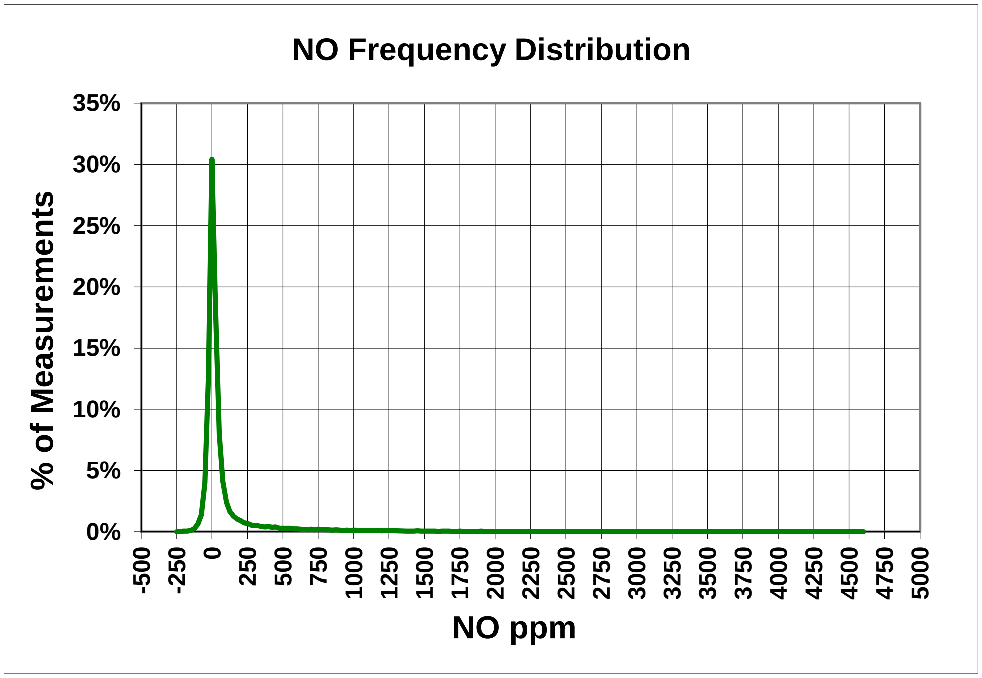


Figure III-6 NO Frequency Distribution



1. Vehicle Mix at Each Site

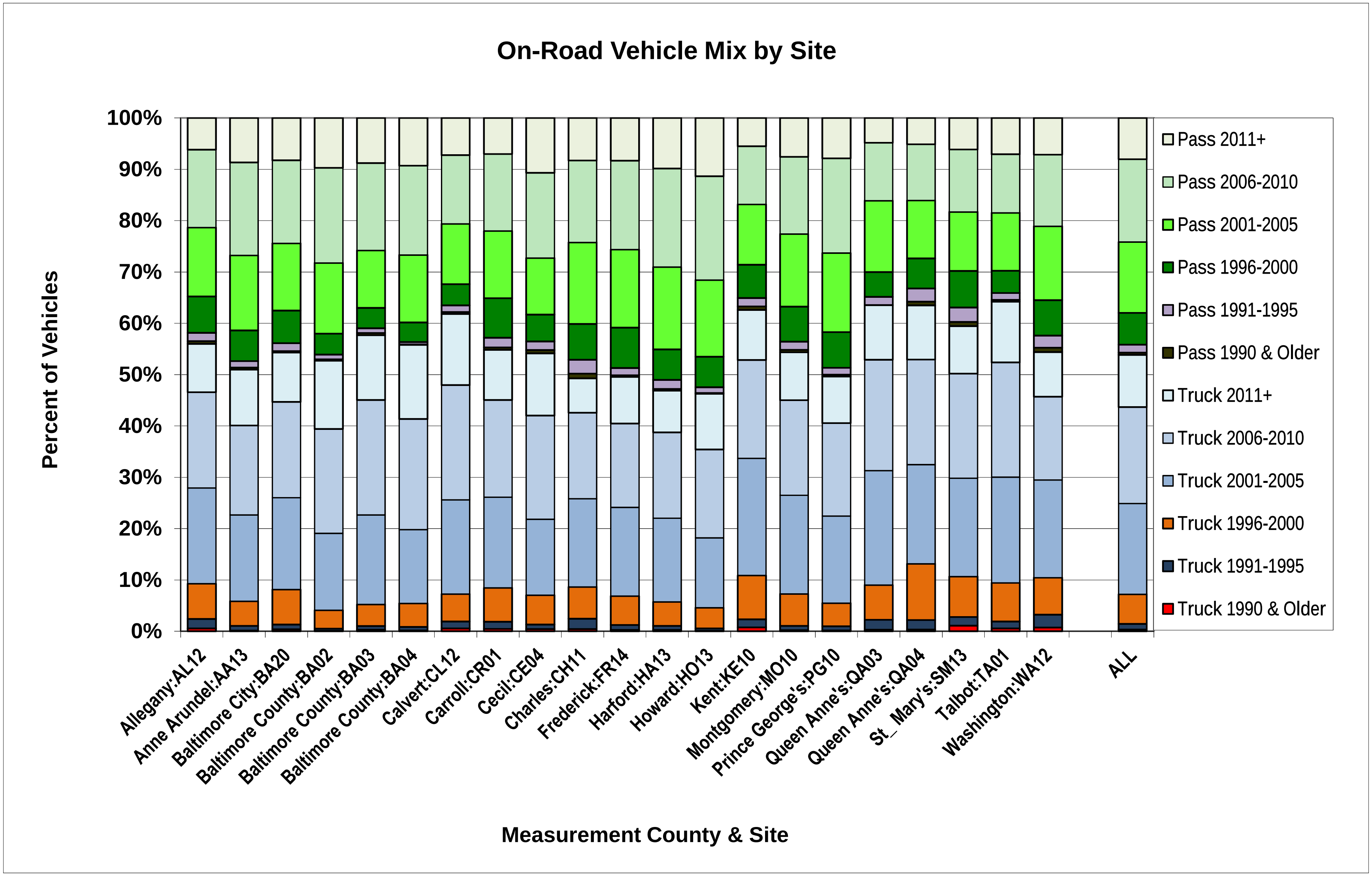
For vehicles matched to registration records, the vehicle type was decoded from the VIN into three groups: T- trucks less than 10,000 lbs GVWR, P – light passenger vehicle, and O – other, which includes heavier vehicles.

Table III-12 and Figure III-7 Vehicle Mix by Site show the percentage of each type/model year range measured at the sites in each county. The fleet is divided between 46% light passenger vehicles (green and purple) and 54% trucks less than 10,000 lbs GVWR (blue and red). Sites in Calvert, Kent, Queen Anne's and Talbot counties measured more than 60% light trucks.

Table III-12 Vehicle Mix by Site

Site	Pass 1990 & Older	Pass 1991-1995	Pass 1996-2000	Pass 2001-2005	Pass 2006-2010	Pass 2011+	**Total Passenger**	Truck 1990 & Older	Truck 1991-1995	Truck 1996-2000	Truck 2001-2005	Truck 2006-2010	Truck 2011+	**Total Truck**
Allegany:AL12	1%	2%	7%	13%	15%	6%	**44%**	1%	2%	7%	19%	19%	9%	**56%**
Anne Arundel:AA13	0%	1%	6%	15%	18%	9%	**49%**	0%	1%	5%	17%	17%	11%	**51%**
Baltimore City:BA20	0%	2%	6%	13%	16%	8%	**46%**	0%	1%	7%	18%	19%	10%	**54%**
Baltimore County:BA02	0%	1%	4%	14%	18%	10%	**47%**	0%	0%	4%	15%	20%	13%	**53%**
Baltimore County:BA03	0%	1%	4%	11%	17%	9%	**42%**	0%	1%	4%	17%	22%	13%	**58%**
Baltimore County:BA04	0%	0%	4%	13%	17%	9%	**44%**	0%	1%	5%	14%	22%	14%	**56%**
Calvert:CL12	0%	1%	4%	12%	13%	7%	**38%**	1%	1%	5%	18%	22%	14%	**62%**
Carroll:CR01	0%	2%	8%	13%	15%	7%	**45%**	0%	1%	7%	18%	19%	10%	**55%**
Cecil:CE04	1%	2%	5%	11%	17%	11%	**46%**	0%	1%	6%	15%	20%	12%	**54%**
Charles:CH11	1%	3%	7%	16%	16%	8%	**51%**	0%	2%	6%	17%	17%	7%	**49%**
Frederick:FR14	0%	1%	8%	15%	17%	8%	**50%**	0%	1%	6%	17%	16%	9%	**50%**
Harford:HA13	0%	2%	6%	16%	19%	10%	**53%**	0%	1%	5%	16%	17%	8%	**47%**
Howard:HO13	0%	1%	6%	15%	20%	11%	**54%**	0%	0%	4%	14%	17%	11%	**46%**
Kent:KE10	1%	2%	7%	12%	11%	5%	**37%**	1%	2%	9%	23%	19%	10%	**63%**
Montgomery:MO10	0%	2%	7%	14%	15%	8%	**46%**	0%	1%	6%	19%	19%	9%	**54%**
Prince George's:PG10	0%	1%	7%	15%	18%	8%	**50%**	0%	1%	5%	17%	18%	9%	**50%**
Queen Anne's:QA03	0%	2%	5%	14%	11%	5%	**36%**	0%	2%	7%	22%	22%	11%	**64%**
Queen Anne's:QA04	1%	3%	6%	11%	11%	5%	**36%**	0%	2%	11%	19%	20%	11%	**64%**
St_ Mary's:SM13	1%	3%	7%	11%	12%	6%	**40%**	1%	2%	8%	19%	20%	9%	**59%**
Talbot:TA01	0%	1%	4%	11%	11%	7%	**36%**	1%	1%	8%	21%	22%	12%	**64%**
Washington:WA12	1%	2%	7%	14%	14%	7%	**46%**	1%	3%	7%	19%	16%	9%	**54%**
ALL	**0%**	**2%**	**6%**	**14%**	**16%**	**8%**	**46%**	**0%**	**1%**	**6%**	**18%**	**19%**	**10%**	**54%**

Figure III-7 Vehicle Mix by Site



2. *Screening by VSP for Emissions Analysis*

Range Vehicle Specific Power

Research[1] has shown that vehicle specific power (VSP) has an important effect on tailpipe emissions. VSP is the power needed to overcome forces acting on the vehicle. In order to compare RSD measurements taken at different sites and at different times, it is necessary to ensure the sets of measurements have similar distributions of vehicle engine load. RSD measurements have been screened to identify those collected when vehicles were operating within a moderate load range of from 3 kilowatts per ton (kW/t) to 22 kilowatts per ton (kW/t). This is a range within the scope of the IM240 and Federal Test Procedure (FTP) tests and over which tailpipe emission concentrations are more stable. Results from vehicles measured outside this range are excluded from the charts and tables of emission values as their results are not comparable to I/M test results.

Vehicle Specific Power (VSP) is the vehicle engine power per unit mass required to overcome gravitational force, inertia, aerodynamic drag and rolling resistance[2]. Expressed in kilowatts per ton it is the sum of:

- Gravitational force: 4.39 x sin(Road grade degrees/57.3) x Speed mph
- Inertial force: 0.22 x Speed mph x Acceleration mph/s
- Aerodynamic drag: 0.0000272 x Speed^3 mph
- Rolling resistance: 0.0954 x Speed mph

The rate of fuel consumption is approximately proportional to VSP. At negative values of VSP, the inertia of the vehicle is greater than the opposing forces and power is either dissipated through the vehicle driving the engine or through braking and very little fuel is being used. This situation typically occurs on downhill grades or during deceleration. When a vehicle engine transitions from producing power to absorbing power, the tailpipe emissions concentrations can vary widely.

To avoid using measurements that are not representative of vehicle emissions performance within the power range contained in the federal certification test, measurements made below a vehicle specific power (VSP) of 3 kW/t or above 22 kW/t have been screened. These measurements are excluded from the emissions analyses presented in following sections.

IV. On-Road Emissions

A. Emissions by Model Year

Figures IV-1 through IV-3 show emissions by model year for I/M area vehicles. Trucks are treated as a single class and 99.8% of trucks measured were less than 10,000 lbs GVWR. There were 45 trucks between 10-14,000 lbs GVWR and 15 trucks greater than 14,000 lbs.

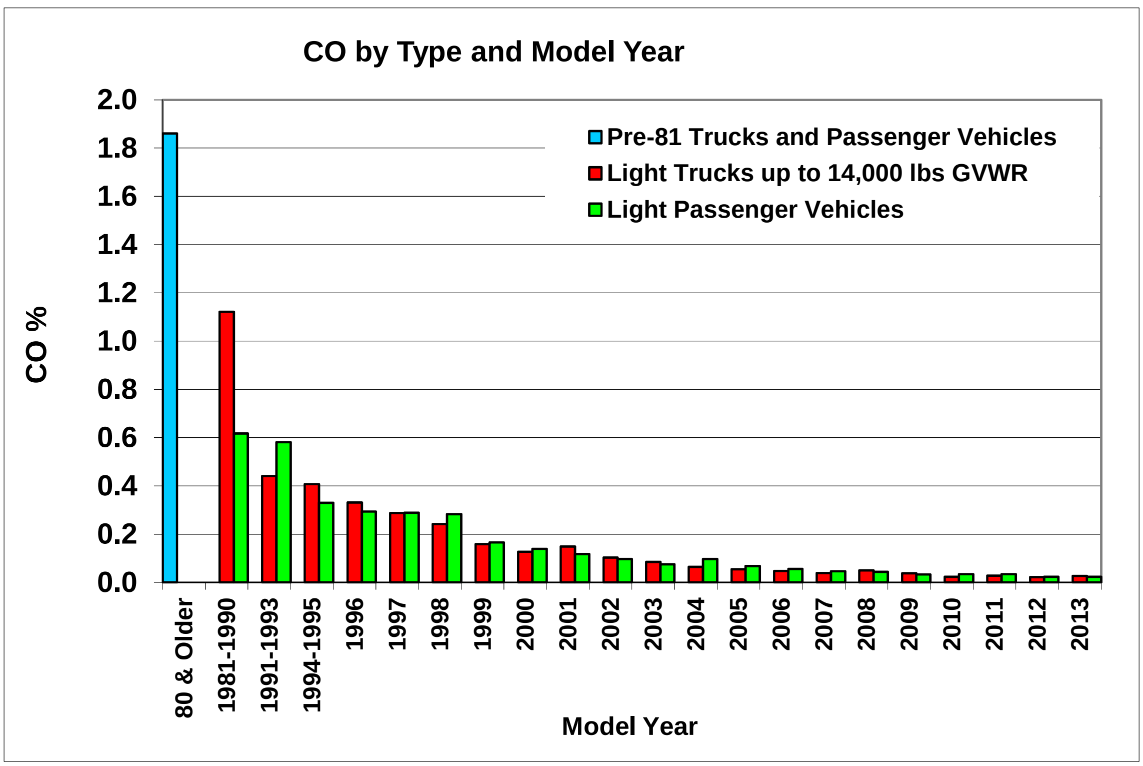
Figure IV-4 shows the number of RSD measurements by model year. Lower numbers of 2009 and 2010 models were evident. The percentage of trucks among light vehicle models peaked at 58% among 2006 models then dipped through 2010 models before rising to 59% in 2011 models and falling to 52% of 2012 models. Sales of 2013 models were not complete at the time of the survey.

Early model years were combined to ensure each bin contained at least 100 measurements. The exception was 29 measurements of 1980 and older models, which were kept separate because their vehicle type was unknown.

The emissions follow the typical patterns for HC, CO and NO_x[iv]. Newer vehicles had lower tailpipe concentrations than older vehicles. Model year 2000 and newer vehicles had low HC and CO emissions. Model year 2007 and newer vehicles had low NO_x emissions.

Trucks had higher HC and NO_x emissions than passenger vehicles.

Figure IV-1 Average RSD CO Emissions by Model Year



[iv] The I/M humidity correction factor has been applied to NOx values reported in this and subsequent sections.

Figure IV-2 Average RSD HC Emissions by Model Year

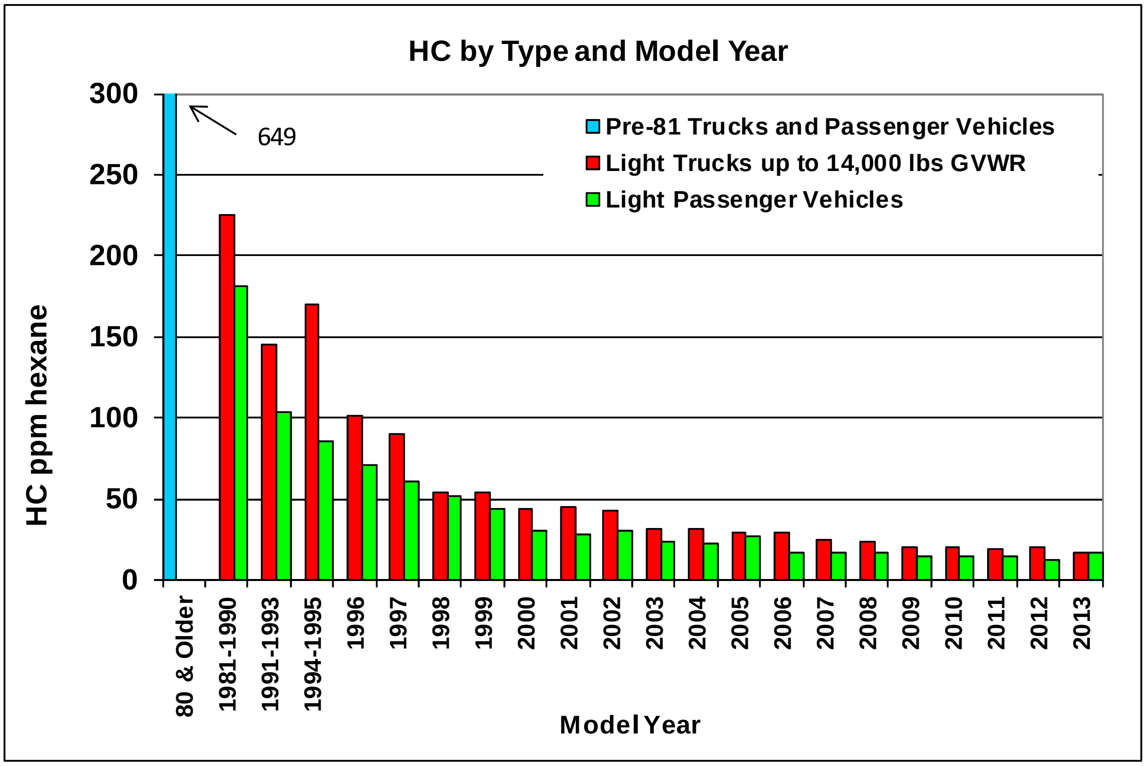


Figure IV-3 Average RSD NO_x Emissions by Model Year

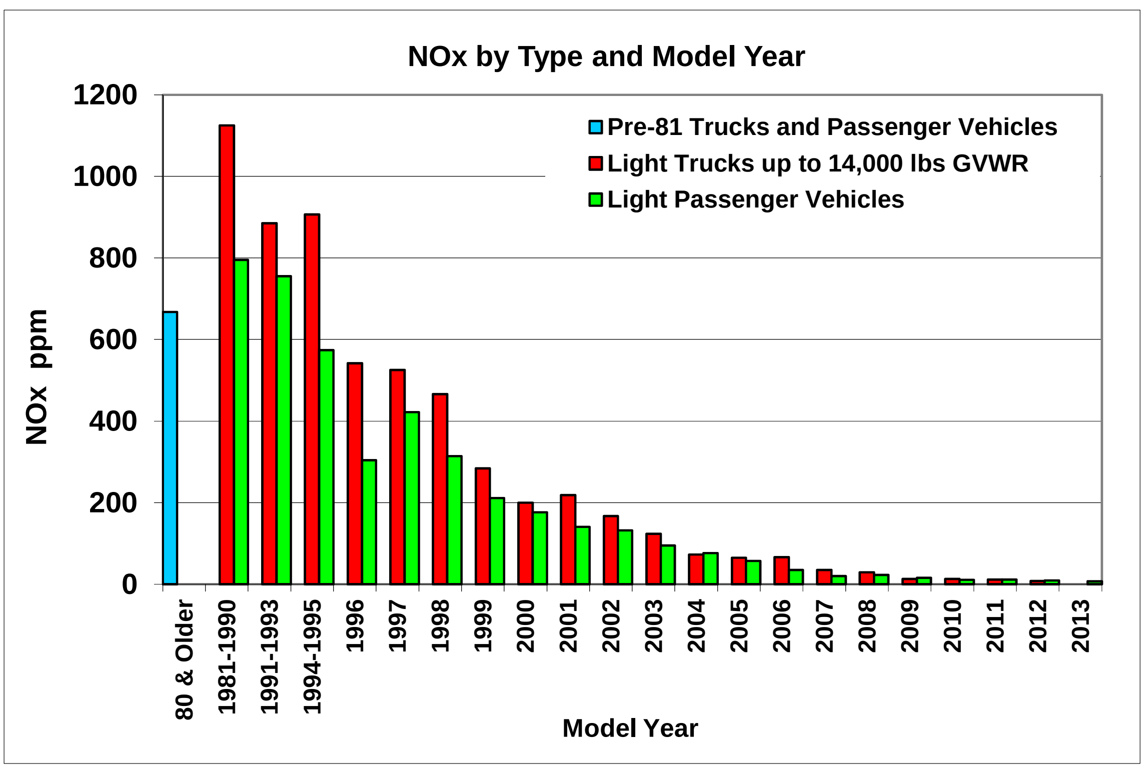
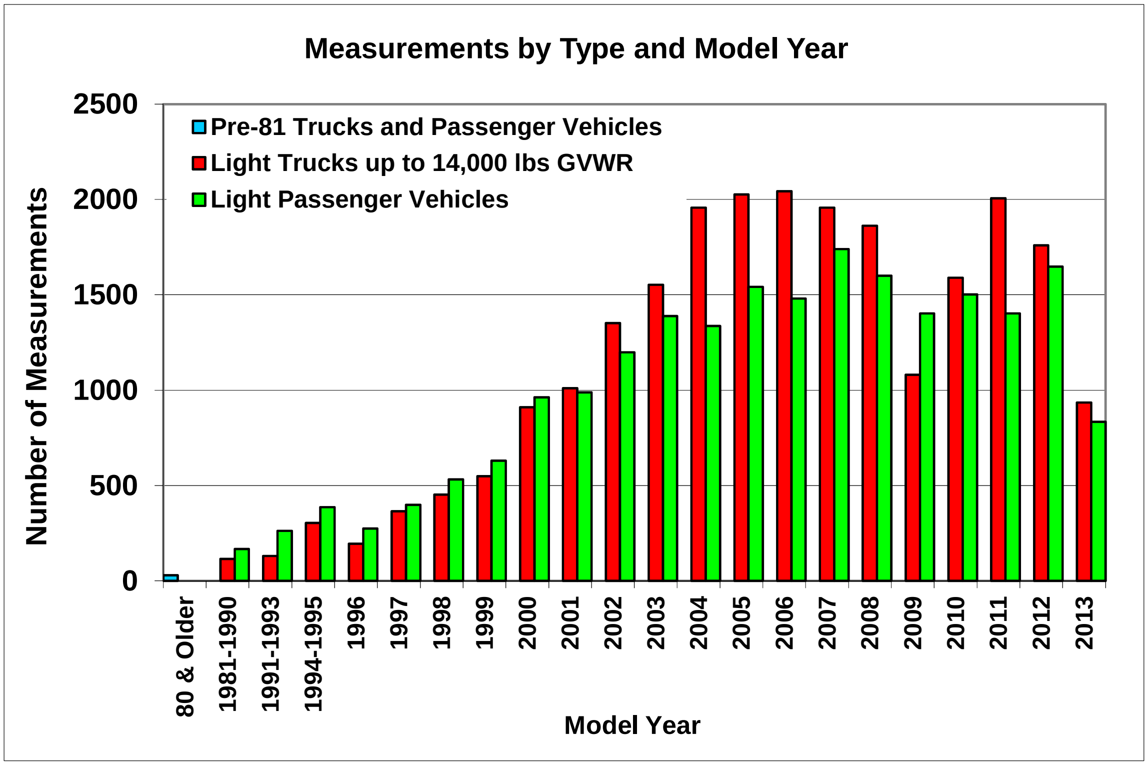


Figure IV-4 Measurements by Model Year



B. Emission Deciles by Model Year

The emission deciles for vehicles are shown in the following charts. These charts illustrate that high HC and CO emissions are more likely to occur among the oldest vehicles and are extremely high across a small portion of the fleet.

NO_x emissions, although also highly skewed, are somewhat less skewed than HC and CO among pre-OBD models.

Figure IV-5 CO Deciles by Model Year

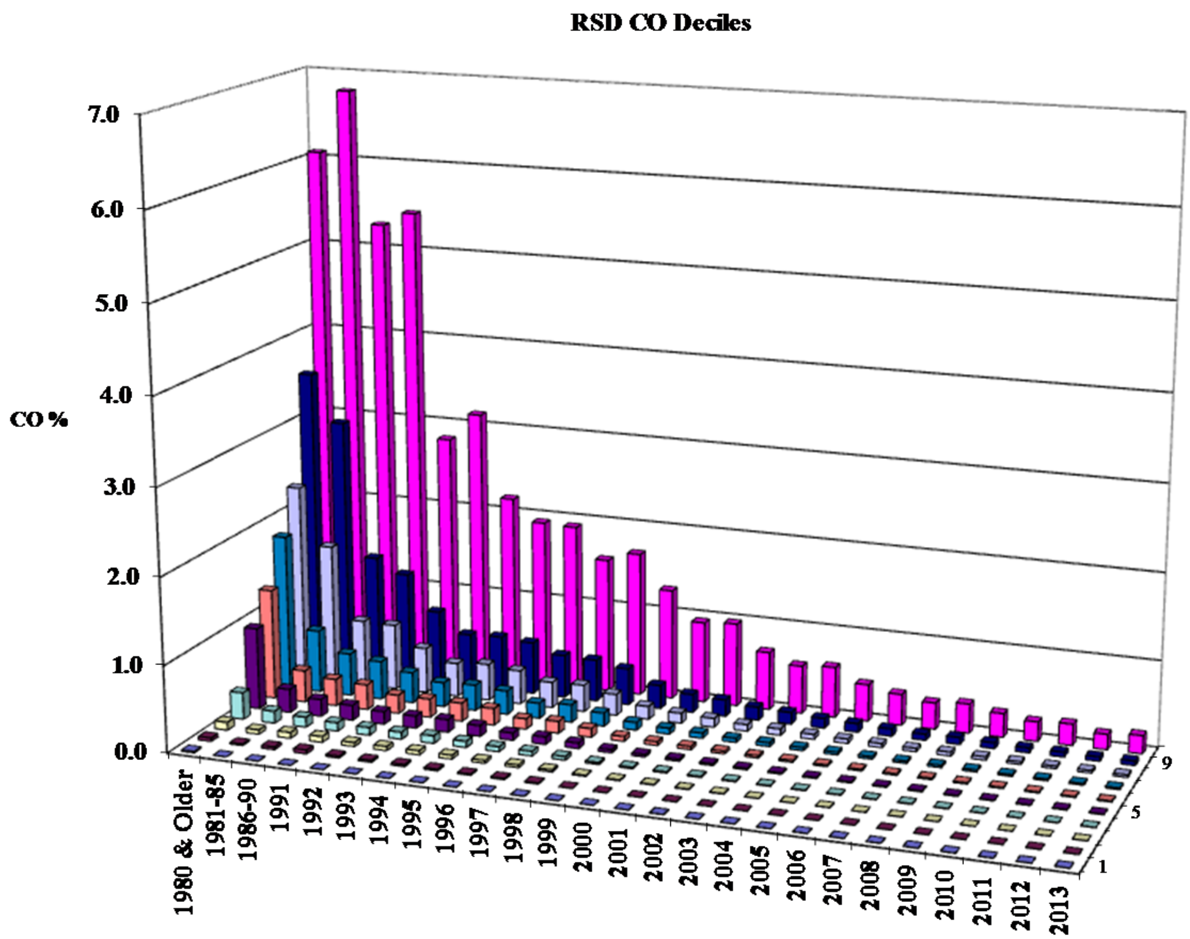


Figure IV-6 HC Deciles by Model Year

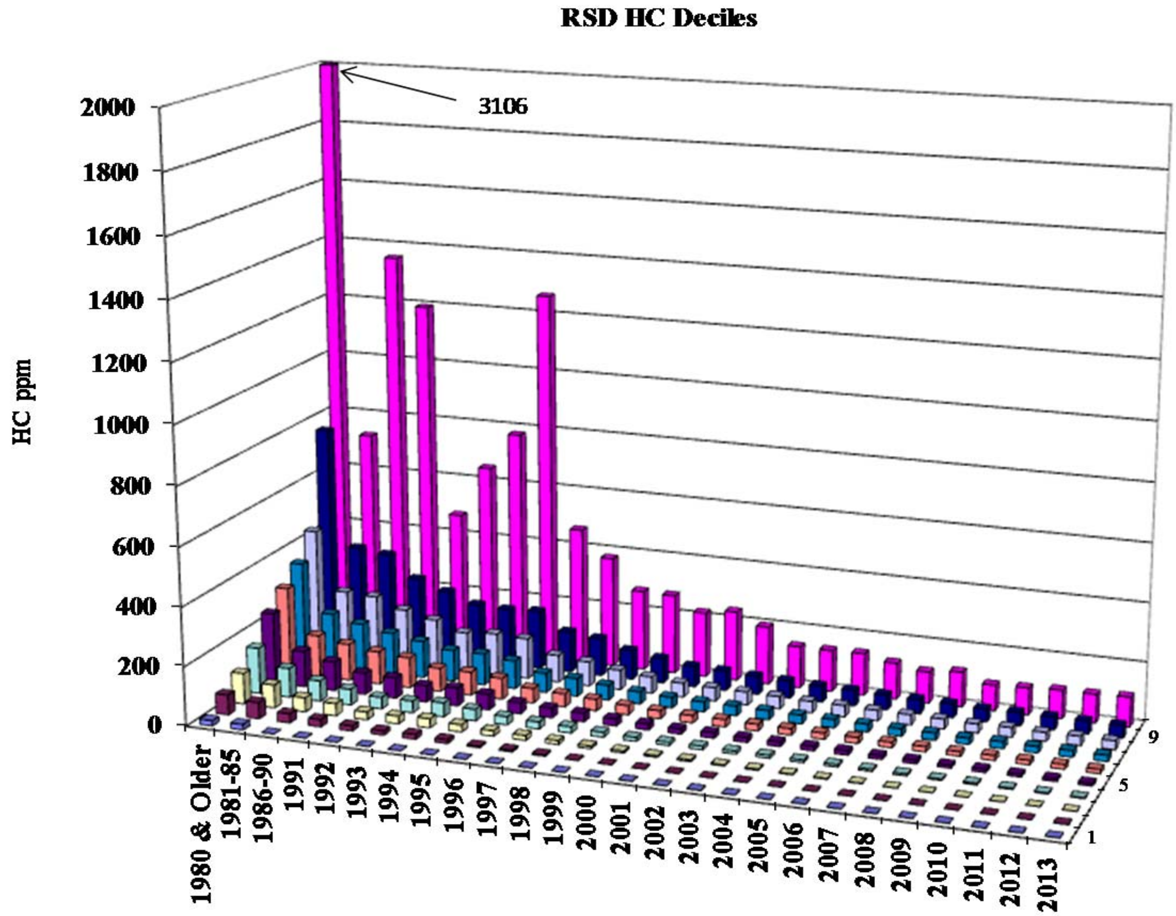
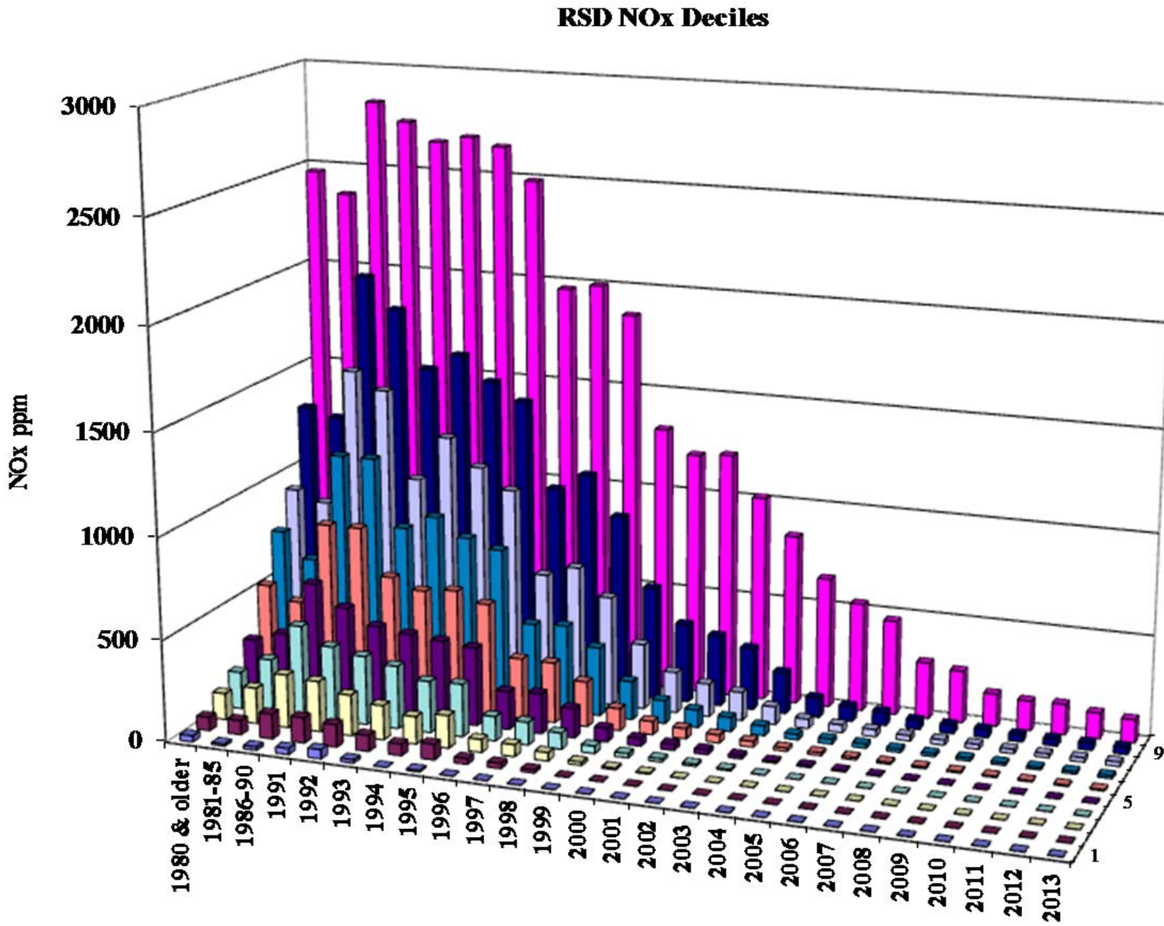


Figure IV-7 NO_x Deciles by Model Year



V. Tested and Untested Vehicles

A. Percent of Vehicles Tested

The on-road vehicles with plates matching Maryland Motor Vehicle Administration registrations were compared against the database of I/M inspection results to determine the percentage of on-road vehicles that have been inspected. Tests from January 2011 through June 2013 were examined. This covers the period from two years three months before the start of the on-road survey in April through the end of the survey in June 2013.

Matching Vehicle Emissions Inspection Program (VEIP) inspection records were identified for 90.2% of the 1981 to 2010 model vehicles less than 10,000 lbs GVWR that were seen on the road and registered in counties subject to the VEIP program and 92.2% of vehicles 10,000 lbs GVWR and over. The trends are shown by vehicle type and model year in Figure V-1. The first two model years are exempt from I/M inspection and 2011 models were part way through the inspection year when the matching tests were queried in July 2013.

Not all vehicles were subject to the program; diesel, solely electric, historic or antique vehicles and some other classes, e.g. farm, fire and ambulance were exempt. Diesel and electric vehicles identified by VIN were excluded but historic, antique and other exempt classes remain. Delayed recording of license plate transfers or address changes, remote sensing tag editing errors, VIN transcription errors, extensions, and late vehicles can all affect the number of vehicles matched to VEIP results.

The results presented in Figures V-1 and V-2 show the percentage of matched VEIP tests for 1981-2010 model vehicles less than 10,000 lbs to be 90.2% and for vehicles 10,000 lbs and over to be 92.2%. However, just because matching VEIP tests were not found does not necessarily mean vehicles were not tested.

The percentage of vehicles positively identified as being tested was greater than the equivalent percentage in the 2011 survey. The 2011 results may have been affected by a program transition. The 2013 percentage was higher than the 89% positively identified as being tested in the 2009 survey.

Figure V-2 shows there is a small variation in the percentage of on-road 1981 to 2010 model vehicles matched to VEIP tests by county of registration. VEIP tests were matched to 3% of vehicles registered in counties outside the I/M inspection program.

Figure V-1 % of Vehicles with I/M Tests

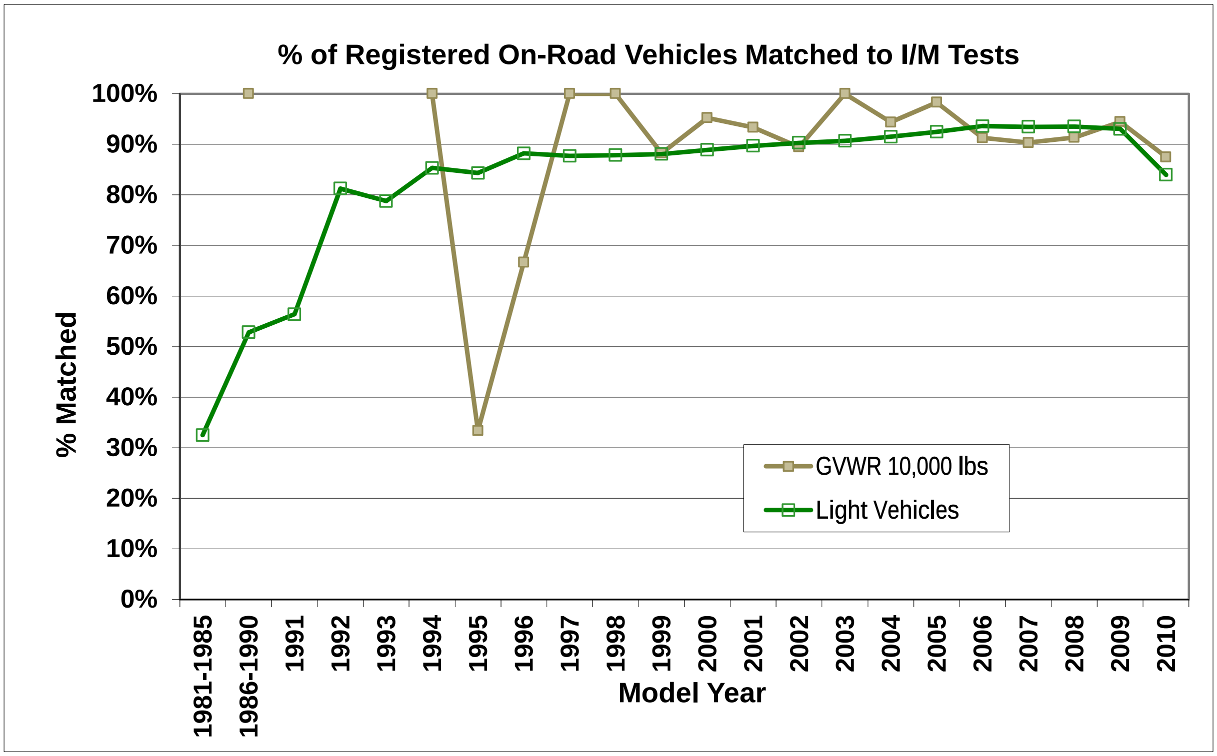
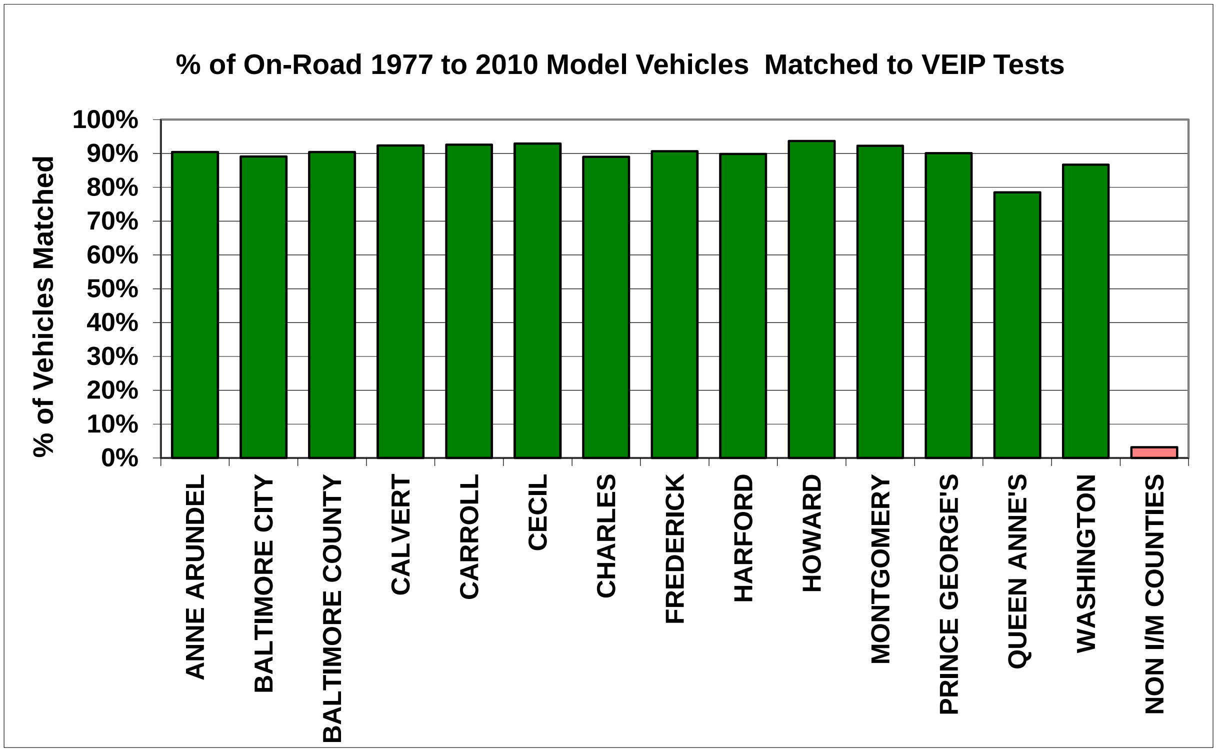


Figure V-2 On-Road Vehicles Matched to VEIP Tests by County of Registration



B. Vehicle Emissions by VEIP Status

The vehicles measured on-road and registered in VEIP counties were separated into three groups:

- Tested WF – vehicles registered to I/M counties for which the last matching VEIP test found was a waiver or a fail
- Unmatched – vehicles registered to I/M counties for which no matching VEIP inspection record was found
- Tested P – vehicles registered to I/M counties for which the last matching I/M test found was a pass

As noted earlier, only part of model year 2011 vehicles had been I/M inspected and model years 2012 and 2013 were exempt at the time of the remote sensing survey. Therefore, only model years 1977 through 2010 were included in this comparison. Diesel and electric vehicles were excluded.

Table V-1 shows the measurements and Figures V-3 through V-8 compare the emissions for these three groups of vehicles. This comparison should be treated with some caution as site-to-site differences have an effect on the emissions levels observed. In addition, the 'Tested WF' bins for '1990 & older' vehicles contained fewer than 10 measurements.

Vehicles whose last test resulted in a waiver or a fail typically had emissions 1.5 to 4 times those of vehicles passing their last test.

Unmatched models typically had higher emissions than those with passing test records.

Table V-1 Light Vehicles Matched to I/M Test Result

Model Years	Unmatched to Test	Tested Waiver or Fail	Tested Pass	Total
Passenger Vehicles				
1990 & older	80	3	72	155
1991-1995	107	22	497	626
1996-2000	351	195	2,190	2,736
2001-2005	623	247	5,439	6,309
2006-2010	727	47	6,742	7,516
Light Trucks				
1990 & older	55	5	50	110
1991-1995	93	27	293	413
1996-2000	257	184	1,943	2,384
2001-2005	628	312	6,681	7,621
2006-2010	612	68	7,514	8,194
Total	**3,533**	**1,110**	**31,421**	**36,064**

Figure V-3 Passenger Vehicle CO by VEIP Status

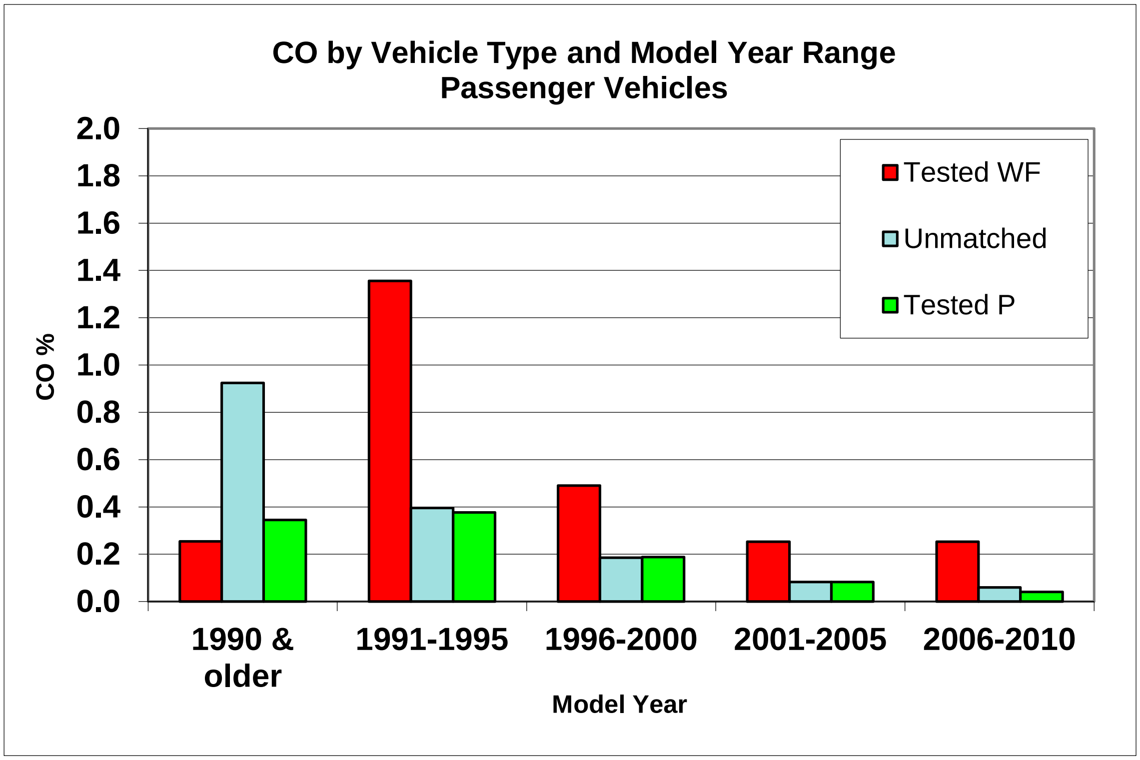


Figure V-4 Light Truck CO by VEIP Status

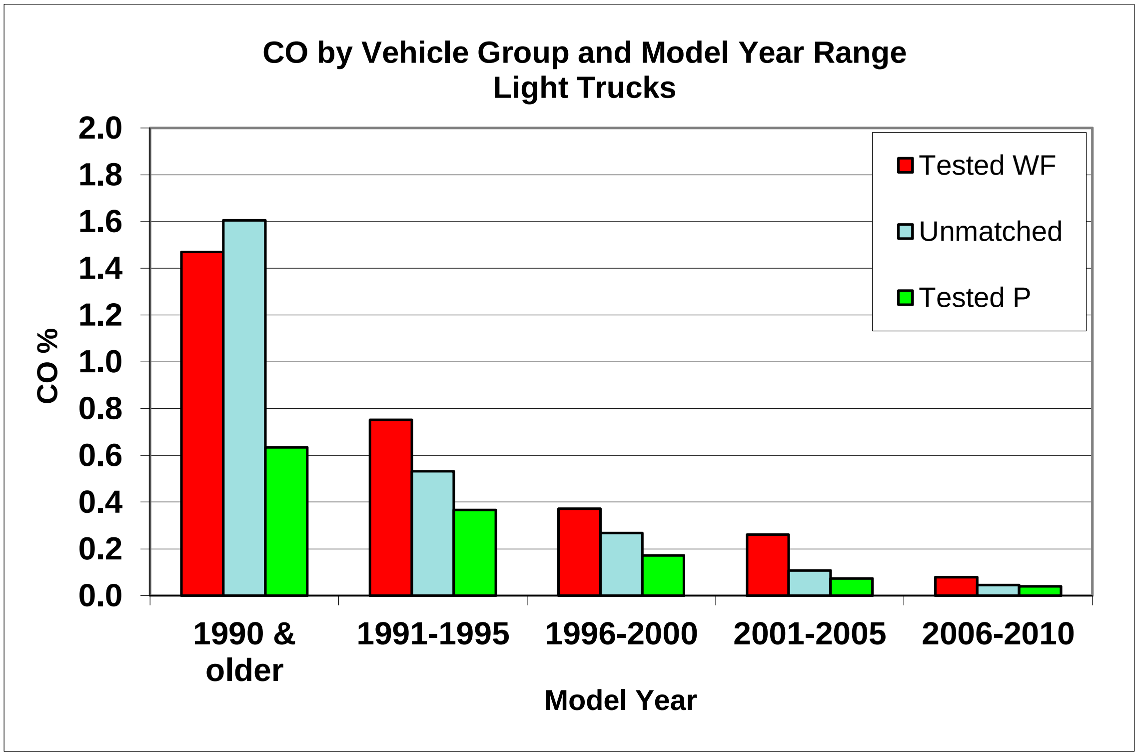


Figure V-5 Passenger Vehicle HC by VEIP Status

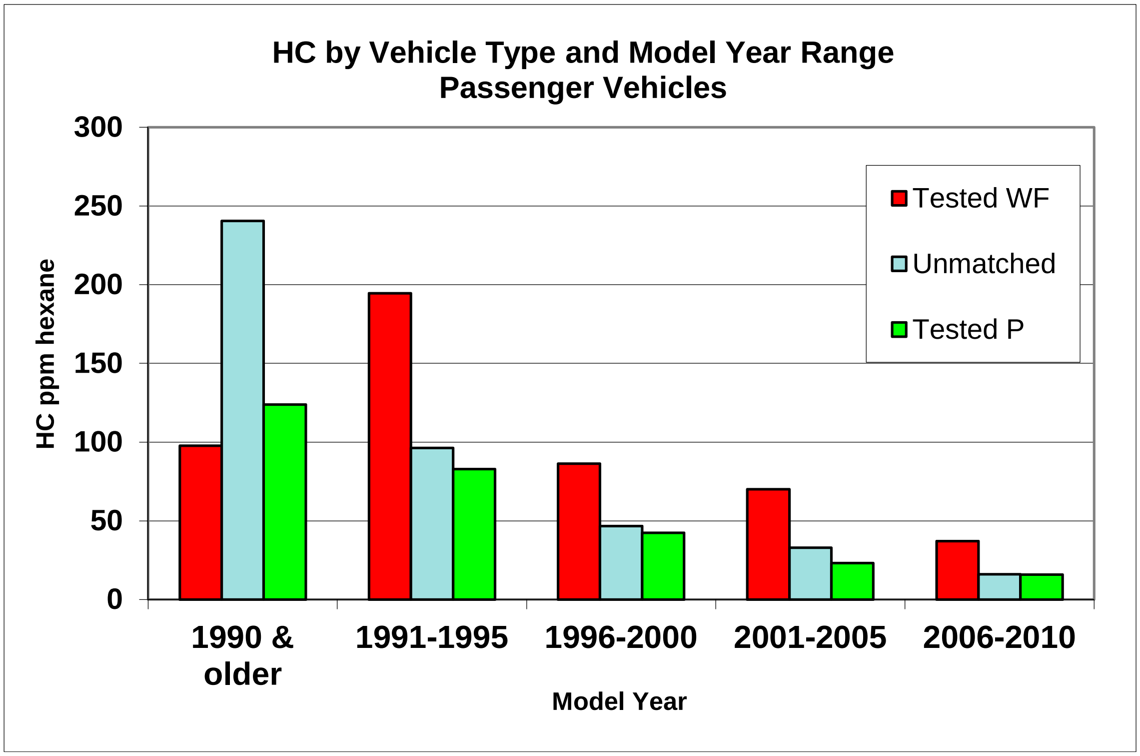


Figure V-6 Light Truck HC by VEIP Status

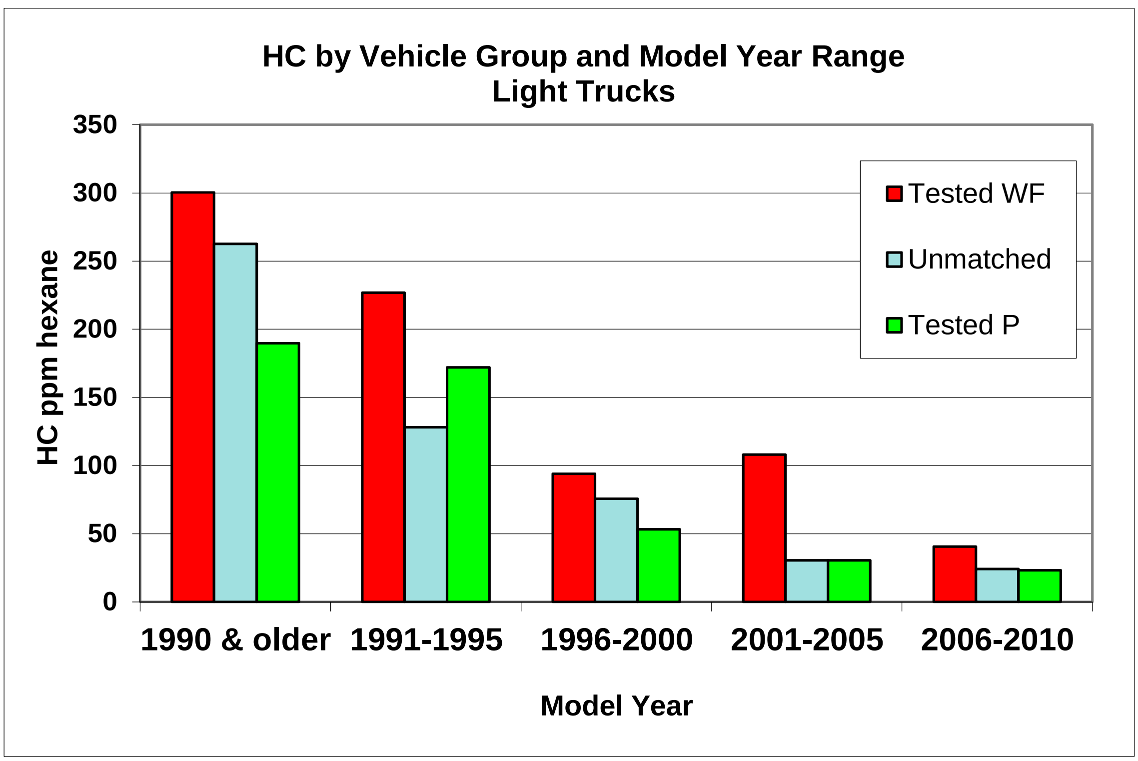


Figure V-7 Passenger Vehicle NO_x by VEIP Status

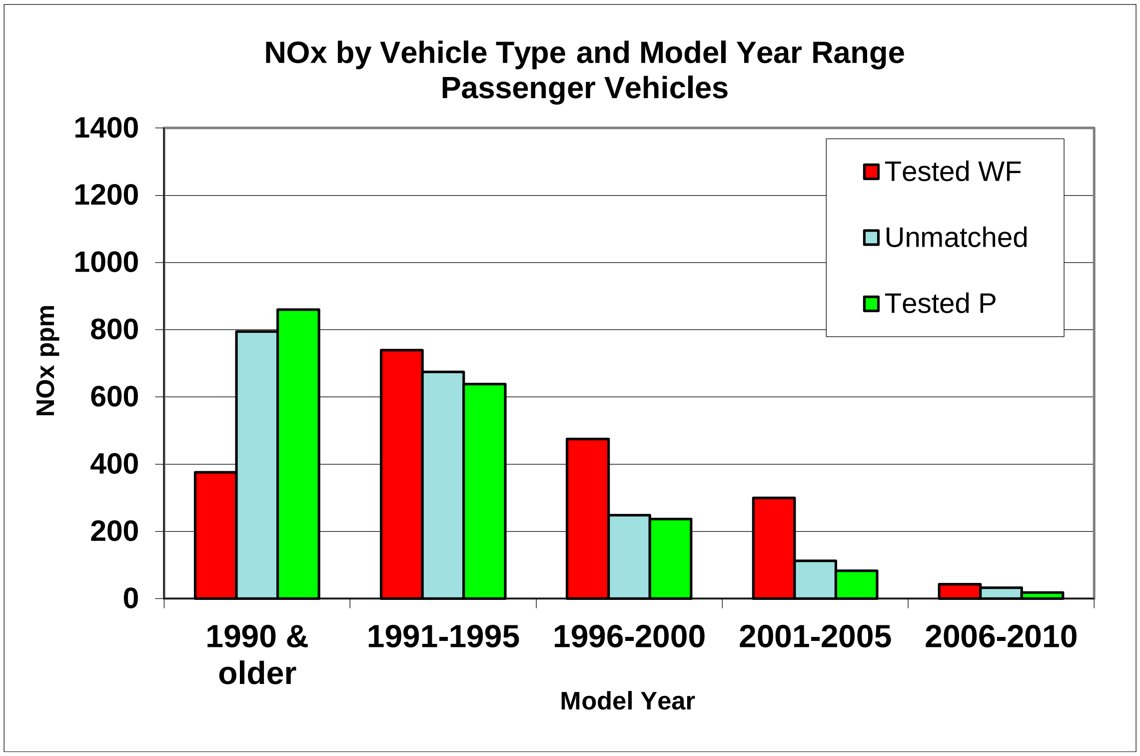
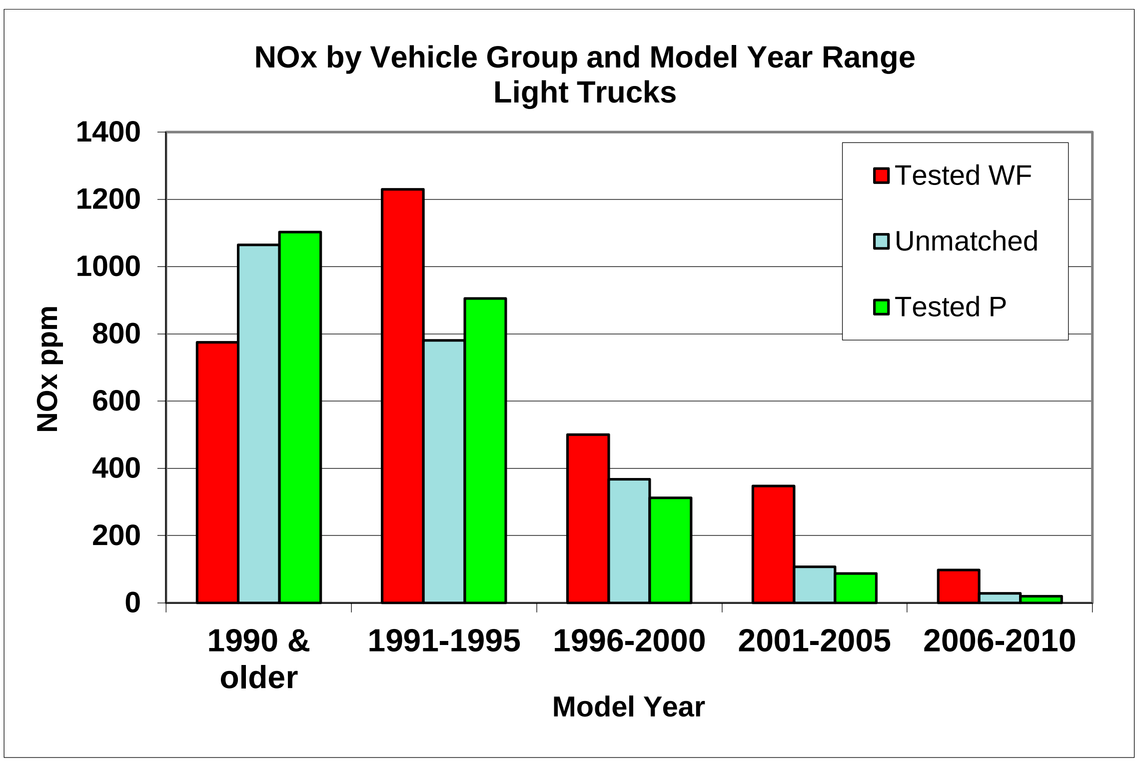


Figure V-8 Light Truck NO_x by VEIP Status



C. I/M and Non I/M Emissions

The vehicles measured on-road were separated into two groups based on their registration county:

- Non-VEIP– vehicles registered to counties outside the VEIP testing area;
- VEIP counties & Baltimore City

The results are plotted in Figures V-9 through V-11. The combined sample of passenger vehicles and light trucks registered in non-I/M counties contains 8,169 measurements. For both passenger vehicles and trucks, the average emissions of I/M registered vehicles are lower than those of non-I/M registered vehicles for HC, CO and NO_x.

Figure V-9 I/M and Non-I/M -CO

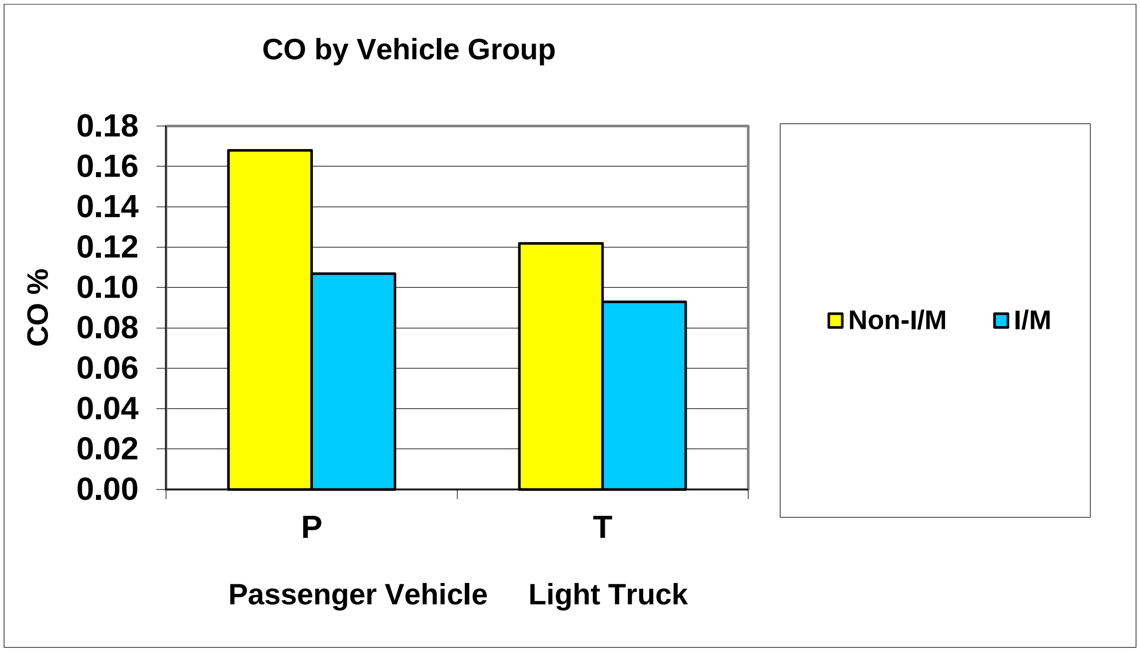


Figure V-10 I/M and Non-I/M - HC

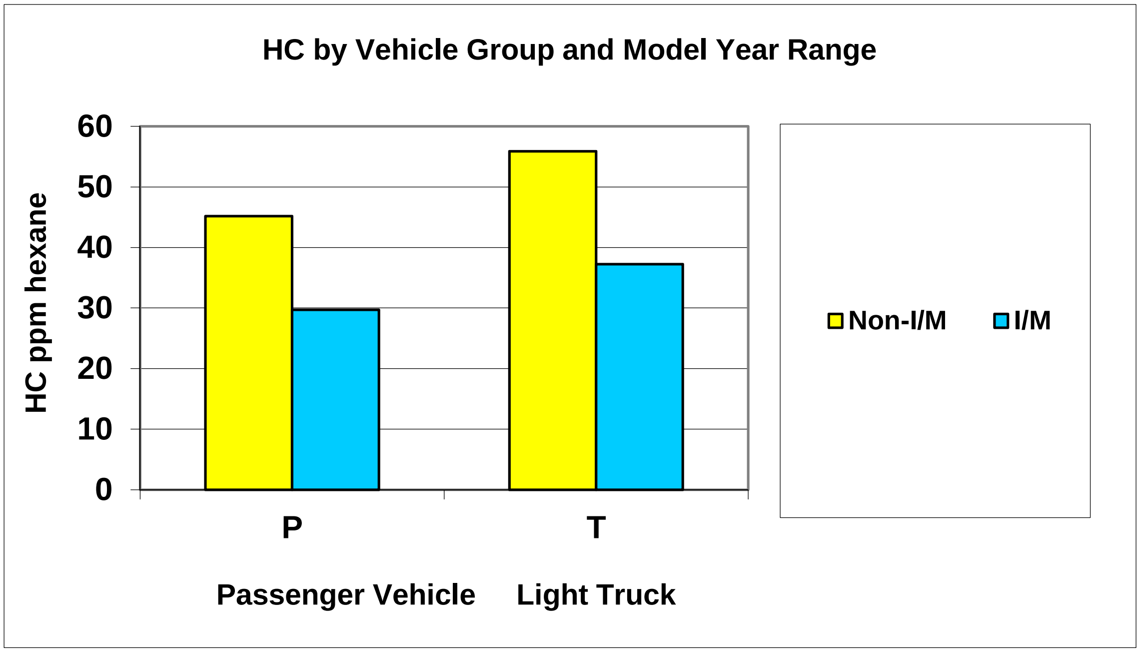
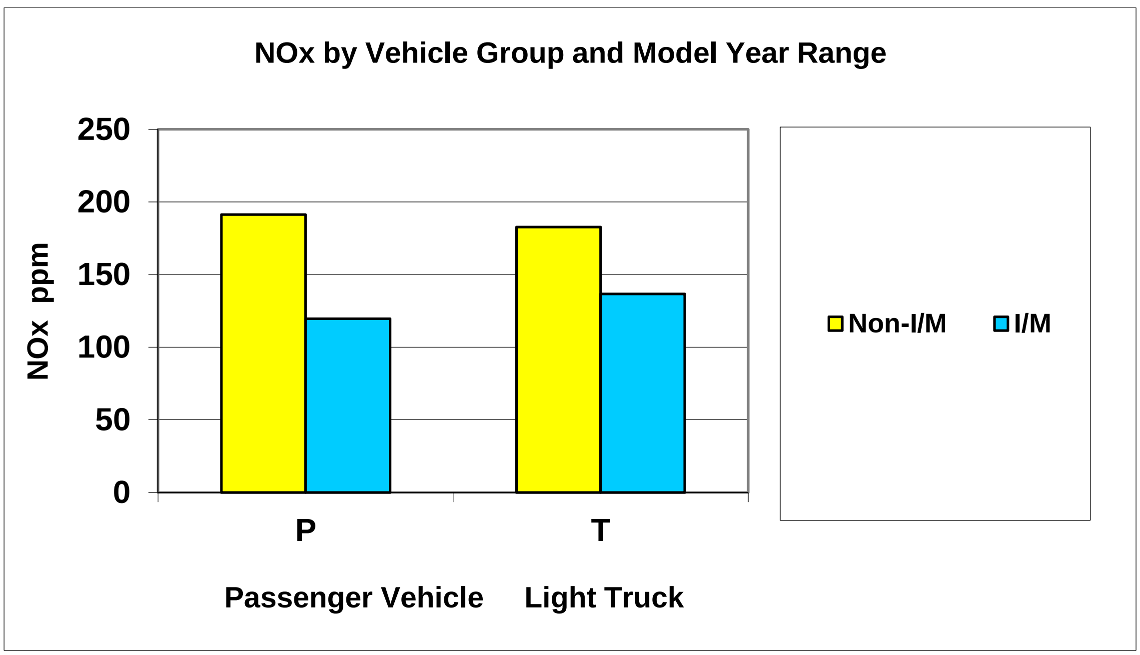


Figure V-11 I/M and Non-I/M - NO_x



D. Non-VEIP Traffic in VEIP Counties

Table V-2 lists the number and percentage of non-VEIP County vehicles observed at VEIP County sites. Approximately 0.9% of light duty vehicle traffic in VEIP counties are registered in non-VEIP counties.

Table V-2 Non-I/M County Registered Vehicles at I/M County Sites

County	Site	City	Non-VEIP Vehicles	Non-VEIP % of Traffic
Anne Arundel	AA13	Annapolis	73	1.4%
Baltimore City	BA20	Baltimore	24	0.8%
Baltimore County	BA02	Essex	12	0.3%
Baltimore County	BA03	Essex	1	0.1%
Baltimore County	BA04	Cockeysville	2	0.2%
Calvert	CL12	Dunkirk	13	1.0%
Carroll	CR01	Westminster	7	0.4%
Cecil	CE04	Port Deposit	2	0.2%
Charles	CH11	Waldorf	56	4.1%
Frederick	FR14	Frederick	20	0.6%
Harford	HA13	Belcamp	11	0.4%
Howard	HO13	Jessup	19	0.7%
Montgomery	MO10	Burtonville	21	0.3%
Prince George's	PG10	Bowie	62	0.9%
Queen Anne's	QA03	Chester	61	19.7%
Queen Anne's	QA04	Chester	16	5.8%
Washington	WA12	Hagerstown	11	0.6%
Total I/M Counties			411	0.9%

VI. High Emitters

For this survey, high emitters were identified using cutpoints listed in Table VI-1. Vehicles have been divided into three classes: 1) 0 to 6,000 lbs, 2) 6,001 to 10,000 lbs, and 3) over 10,000 lbs. The cutpoints for HC in this table are specified in ppm hexane, i.e. concentrations of C_6 molecules, which is consistent with most I/M inspection equipment used to measure tailpipe concentrations. Remote sensing NO_x emissions were corrected for humidity as described in Section III before being compared to the high emitter standards.

Table VI-1 On-Road High Emitter Cutpoints

	GVWR <= 6,000 lbs			GVWR 6,001-10,000 lbs			GVWR 10,001+ lbs		
Year	HC (ppm)	CO (%)	NOx (ppm)	HC (ppm)	CO (%)	NOx (ppm)	HC (ppm)	CO (%)	NOx (ppm)
1977	700	7	2,718	700	7	2,557	700	7	5,000
1978	645	7	2,718	700	7	2,557	700	7	5,000
1979	600	6	2,718	700	7	2,045	700	7	5,000
1980	330	2.6	2,718	525	7	2,045	700	7	5,000
1981	330	1.8	2,718	375	4.5	2,045	700	7	5,000
1982	330	1.8	2,718	330	3.8	2,045	700	7	5,000
1983	330	1.8	2,718	330	2.3	2,045	700	5.3	5,000
1984	264	1.8	2,252	311	1.8	1,969	660	4.5	4,500
1985	264	1.8	2,252	292	1.8	1,969	660	4.5	4,500
1986	264	1.8	2,252	292	1.8	1,969	420	3.8	4,500
1987	264	1.8	2,252	187	1.8	1,969	330	1.8	4,500
1988	264	1.8	1,243	180	1.8	1,917	330	1.8	4,500
1989	264	1.8	1,243	180	1.8	1,917	330	1.8	4,500
1990	264	1.8	1,243	180	1.8	1,917	330	1.8	4,500
1991	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1992	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1993	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1994	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1995	208	1.8	1,087	168	1.8	1,457	330	1.8	4,000
1996+	100	1.0	893	168	1.0	1,457	330	1.8	3,600

In order to be considered a high emitter in Maryland, a vehicle must have 2 or more readings that exceed the standards for the same pollutant on different days. If the standard is exceeded by less than the tolerance of the RSD unit, a third measurement is required for confirmation. Vehicles with out-of-State registrations were not considered in the high emitter analysis because their type and model year was unknown. Correct high emitter cutpoints cannot be selected without this information.

Some 2,722 vehicles had two or more valid remote sensing measurements on different days within the normal VSP operating range of 3 to 22 kW/t. Sixty five (65) of these exceeded the cutpoints on both of their last two measurements for the same pollutant.

Forty (40) vehicles exceeded the standard by more than the tolerance of the RSD unit on their last two measurements and qualify as high emitters. One of these, a 2004 Volvo, had a third measurement and it also exceeded the standard.

Twenty-five (25) suspected high emitting vehicles required additional confirmation by a third measurement. None of these vehicles had a third measurement.

The high emitters and suspected high emitters by pollutant are summarized in Table VI-2.

Table VI-2 High Emitters by Pollutant

Pollutant Exceeded	High Emitter	Suspected	Total
HC only	10	12	22
CO only	1	1	2
NO only	18	8	26
HC & CO	4	0	4
HC & NOx	6	4	10
CO & NOx	0	0	0
All	1	0	1
Total	40	25	65

The high emitters that exceeded the standard by more than the tolerance of the RSD unit on their last two measurements are listed in Table VI- 3. Those requiring a third measurement are listed in Table VI-4.

Table VI-5 shows the emissions of one vehicle with a third measurement that further confirmed the high emitter finding.

Table VI-3 High Emitters

			Registration	Date		HC Values			CO Values			NOx Values		
Year	Make	Body Style	County	Last	Prev	Std	Last	Prev	Std	Last	Prev	Std	Last	Prev
High Emitters (Last two measurements both exceed the emissions standards for at least one pollutant by more than the RSD tolerance).														
1981	CHEV	2S	PG	17-May-13	03-May-13	330	960	418	1.8	4.0	3.5	2,718	220	164
1985	DODG	TK	T	25-Apr-13	24-Apr-13	264	225	193	1.8	2.1	3.6	2,252	755	294
1986	FORD	TK	K	23-May-13	22-Apr-13	292	3,423	2,100	1.8	0.3	0.1	1,969	1,930	1,432
1986	CHEV	4S	PG	03-Jun-13	15-May-13	264	660	1,317	1.8	0.3	1.9	2,252	2,763	461
1988	CADI	2H	BC	06-Jun-13	29-May-13	264	90	601	1.8	0.1	0.0	1,243	2,882	3,818
1992	DODG	4S	BC	06-Jun-13	29-May-13	208	135	147	1.8	0.1	0.3	1,087	2,035	2,143
1992	VOLV	SW	T	25-Apr-13	24-Apr-13	208	360	358	1.8	0.1	0.2	1,087	837	138
1993	CHEV	SU	CAR	30-May-13	28-May-13	208	624	1,061	1.8	0.3	0.4	1,087	625	88
1993	MITS	TK	A	05-Jun-13	29-Apr-13	208	557	458	1.8	0.4	0.6	1,087	1,823	1,321
1995	JEEP	SW	CAR	04-Jun-13	28-May-13	208	122	55	1.8	0.2	0.2	1,087	2,168	1,799
1995	HOND	2S	BC	06-Jun-13	29-May-13	208	225	329	1.8	0.5	0.5	1,087	2,652	2,893
1995	TOYT	4S	HO	16-May-13	15-May-13	208	275	188	1.8	0.3	0.3	1,087	1,589	1,668
1997	NISS	4S	AA	22-May-13	17-May-13	100	56	63	1.0	0.2	0.2	893	2,127	1,196
1997	PONT	VN	T	25-Apr-13	24-Apr-13	100	19	51	1.0	0.3	0.6	893	1,430	1,305
1998	DODG	VN	BC	06-Jun-13	29-May-13	100	97	97	1.0	0.3	0.3	893	2,232	2,893
1998	JEEP	TK	A	05-Jun-13	29-Apr-13	100	150	50	1.0	0.4	0.4	893	2,269	1,870
1998	MERC	TK	AA	06-Jun-13	29-May-13	100	53	23	1.0	0.4	0.2	893	2,056	1,684
1998	TOYT	SU	BA	06-Jun-13	29-May-13	100	68	116	1.0	0.3	0.5	893	1,700	3,424
1998	TOYT	TK	BA	30-May-13	06-May-13	168	411	461	1.0	7.6	7.3	1,457	(25)	75
1998	ACUR	2S	M	31-May-13	13-May-13	100	630	262	1.0	1.9	0.5	893	2,195	1,987
1998	TOYT	4S	AA	31-May-13	13-May-13	100	139	250	1.0	1.1	1.3	893	1,350	1,152
1999	GMC	TK	M	16-May-13	15-May-13	100	192	113	1.0	0.6	0.8	893	1,319	1,311
1999	LEXU	4S	BC	06-Jun-13	29-May-13	100	207	156	1.0	2.1	2.1	893	812	228
1999	MERC	4S	BC	06-Jun-13	29-May-13	100	318	760	1.0	0.5	0.1	893	825	3,830
2000	FORD	TK	K	31-May-13	23-May-13	168	1,727	1,015	1.0	1.4	1.3	1,457	321	56
2000	FORD	CN	K	23-May-13	23-Apr-13	100	253	257	1.0	0.8	0.5	893	344	941
2000	HOND	TK	M	16-May-13	15-May-13	100	250	221	1.0	0.3	0.6	893	2,528	1,787
2000	VOLK	4S	PG	16-May-13	15-May-13	100	256	271	1.0	0.9	0.5	893	689	3,157
2001	HOND	4H	K	31-May-13	23-Apr-13	100	1,466	1,727	1.0	1.2	0.6	893	334	434
2001	JEEP	SW	HO	16-May-13	15-May-13	100	30	50	1.0	(0.0)	(0.0)	893	2,919	1,240
2001	DODG	TK	BC	06-Jun-13	29-May-13	168	94	116	1.0	0.4	0.5	1,457	1,816	2,295
2001	FORD	TK	BC	06-Jun-13	29-May-13	168	21	14	1.0	0.0	0.2	1,457	3,153	4,394
2001	VOLK	4S	K	31-May-13	23-Apr-13	100	(6)	67	1.0	(0.0)	0.0	893	3,411	2,482
2002	CHEV	VN	BA	06-Jun-13	29-May-13	100	125	158	1.0	0.5	0.3	893	2,090	2,047
2002	FORD	TK	M	16-May-13	15-May-13	100	69	57	1.0	0.0	0.0	893	1,196	1,321
2003	NISS	TK	M	03-Jun-13	16-May-13	168	50	153	1.0	0.3	0.5	1,457	1,776	1,967
2004	VOLV	TK	HA	03-Jun-13	16-May-13	100	1,079	904	1.0	0.1	0.0	893	(44)	15
2004	CHEV	TK	BA	04-Jun-13	28-May-13	168	25	82	1.0	0.4	0.6	1,457	2,238	2,713
2005	HOND	2S	PG	22-May-13	17-May-13	100	72	280	1.0	0.3	0.7	893	1,675	1,202
2005	BUIC	4S	M	16-May-13	15-May-13	100	638	354	1.0	(0.2)	0.0	893	(63)	32

Table VI-4 Suspected High Emitters Requiring a Third Measurement

			Registration	Date		HC Values			CO Values			NOx Values		
Year	Make	Body Style	County	Last	Prev	Std	Last	Prev	Std	Last	Prev	Std	Last	Prev
A third reading is needed to verify high emitter status (The last two measurements exceed standard by less than the RSD tolerance).														
1987	BMW	2S	AA	31-May-13	13-May-13	264	313	258	1.8	0.7	0.6	2,252	2,870	2,303
1993	HOND	4S	M	16-May-13	15-May-13	208	118	434	1.8	0.4	1.2	1,087	2,069	1,169
1994	BUIC	2S	BA	17-May-13	13-May-13	208	85	113	1.8	0.1	0.3	1,087	1,248	1,777
1996	CHEV	TK	A	05-Jun-13	29-Apr-13	100	125	135	1.0	0.1	0.3	893	1,453	1,022
1996	PLYM	VN	BC	06-Jun-13	29-May-13	100	156	116	1.0	0.1	0.2	893	690	343
1996	HOND	2S	BC	06-Jun-13	29-May-13	100	67	28	1.0	1.5	1.0	893	162	47
1996	JEEP	SW	BA	28-May-13	06-May-13	100	56	47	1.0	0.3	0.1	893	1,059	1,208
1997	FORD	VN	F	16-May-13	15-May-13	168	194	239	1.0	0.4	2.7	1,457	2,523	984
1997	GMC	TK	K	31-May-13	23-May-13	168	189	184	1.0	1.6	0.9	1,457	45	68
1997	CHEV	2H	M	16-May-13	15-May-13	100	287	154	1.0	0.9	0.4	893	1,214	1,053
1997	MITS	2H	CAL	16-May-13	15-May-13	100	167	117	1.0	0.1	0.1	893	694	567
1997	OLDS	4S	T	25-Apr-13	24-Apr-13	100	153	205	1.0	0.2	0.3	893	355	424
1997	TOYT	4S	BA	04-Jun-13	28-May-13	100	47	89	1.0	0.3	0.2	893	1,099	1,413
1998	TOYT	4S	BA	06-Jun-13	29-May-13	100	53	3	1.0	0.2	0.2	893	944	976
1999	CHEV	TK	K	23-May-13	23-Apr-13	100	285	146	1.0	0.5	0.3	893	1,708	1,134
2001	HOND	2S	AA	16-May-13	15-May-13	100	170	225	1.0	0.8	1.8	893	2,166	823
2003	OLDS	4S	K	23-May-13	23-Apr-13	100	1,766	204	1.0	0.5	1.0	893	753	454
2004	CHEV	4S	K	31-May-13	23-May-13	100	111	212	1.0	0.3	0.4	893	415	483
2004	HYUN	TK	BC	06-Jun-13	29-May-13	100	6	9	1.0	0.1	0.1	893	930	1,015
2005	AUDI	4S	BA	28-May-13	06-May-13	100	104	193	1.0	0.4	0.4	893	2,160	877
2005	CHEV	TK	PG	22-May-13	17-May-13	168	224	169	1.0	0.1	0.4	1,457	(20)	(2)
2005	JEEP	TK	BA	03-Jun-13	16-May-13	100	27	(1)	1.0	0.0	(0.0)	893	900	2,416
2006	ISU	TK	M	16-May-13	15-May-13	168	229	1,010	1.0	0.4	0.3	1,457	1,528	1,316
2007	DODG	4H	BA	06-Jun-13	29-May-13	100	127	181	1.0	0.1	0.8	893	3,441	947
2009	TOYT	5S	BC	06-Jun-13	29-May-13	100	173	126	1.0	0.2	0.8	893	116	69

Table VI-5 Third Measurements of High Emitters

				Date			HC Values				CO Values				NOx Values			
Year	Make	Body Style	Registration County	Last	Prev	2nd Prev	Std	Last	Prev	2nd Prev	Std	Last	Prev	2nd Prev	Std	Last	Prev	2nd Prev
2004	VOLV	TK	HA	03-Jun-13	16-May-13	15-May-13	100	1,079	904	461	1.00	0.07	0.01	0.01	893	(44)	15	132

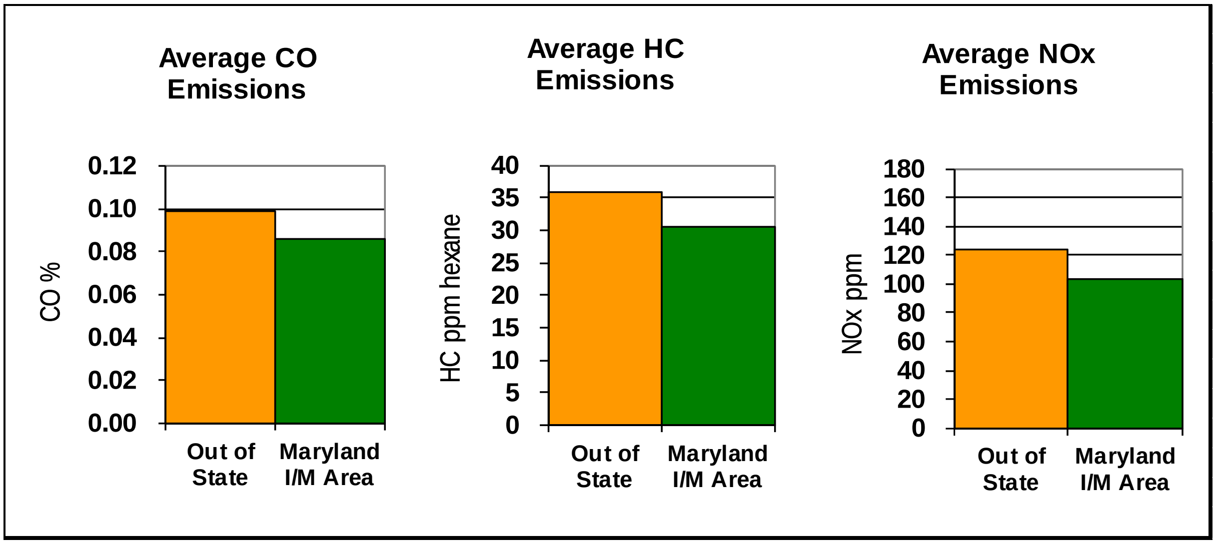
VII. Out of State Vehicles

Valid measurements were obtained on 6,709 vehicles with out of state plates. This is 11% of the surveyed vehicles with valid measurements and a visible plate. Because these vehicles are registered to other states, specific information about the type and age of these vehicles is not available as part of this survey. Compared to the surveyed vehicles registered in the Maryland I/M counties the vehicles from out-of-state had 15% higher CO, 18% higher HC and 20% higher NO_x.

The Maryland vehicles on average were measured at 3% higher vehicle specific power than the out-of-state vehicles.

No conclusions can be drawn as to whether the out-of-state fleet is cleaner or dirtier for equivalent aged vehicles because the age of the out-of-state fleet is unknown. The comparative emissions are shown in Figure VII-1.

Figure VII-1 Maryland I/M and Out-of-state Vehicle Emissions

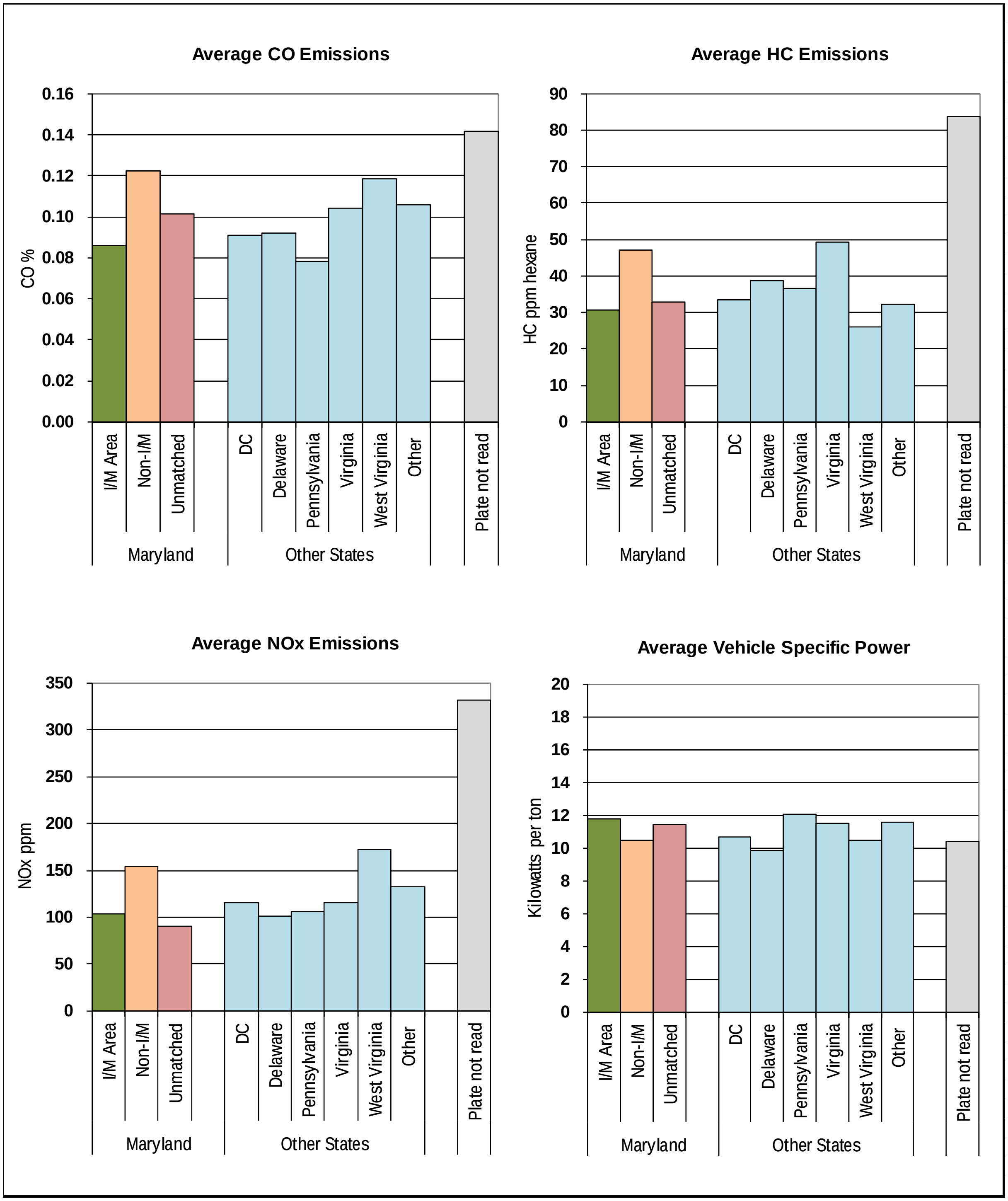


Average emissions and the average measured vehicle specific power are shown by jurisdiction in Figure VII-2. As noted in Section V, vehicles registered in Maryland counties subject to I/M had lower emissions than those registered in counties not subject to I/M. Vehicles registered in Maryland counties subject to I/M also had lower emissions than vehicles with Maryland plates that were not matched to a registration.

Vehicles from Virginia, which has an I/M program in its northern counties, had higher average HC and CO emissions and similar NO_x. Vehicles from West Virginia, which has no I/M program, had higher average emissions of CO and NO_x than both Maryland vehicles registered in I/M counties and vehicles from other states with I/M programs but lower HC.

Vehicles whose plates were not captured or could not be read may be larger vehicles such as medium-duty trucks, vehicles with tow hitches or pulling trailers and vehicles with dirty or obscured plates. These vehicles had the highest average emissions of all pollutants.

Figure VII-2 Emissions by Plate Jurisdiction



References

1 McClintock, P. "The Colorado Enhanced I/M Program 0.5% Sample Annual Report" Prepared for the Colorado Department of Public Health and Environment, 1998.

2 Lindner, J. “Draft Guidance on Use of In-Program Data for Evaluation of I/M Program Performance” EPA, August 2001