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Delaware 2014 Remote Sensing Survey

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Department of Natural Resources and Environmental Control

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Glossary of Terms and Abbreviations

ADT	Average Daily Traffic
ASM	Acceleration Simulation Mode
Basic I/M	A set of vehicle I/M program inspection requirements defined by the U.S. EPA that may be used in areas not required to implement an Enhanced I/M program; the inspection procedure usually involves idle testing
Clean Screening	The process of identifying vehicles with low emissions that are then exempt from emission inspection at an inspection station
CO	Carbon monoxide
CO2	Carbon dioxide
Cutpoint	An emissions level used to classify vehicles as having met an emissions inspection requirement
DNREC	Department of Natural Resources and Environmental Control of the State of Delaware
Enhanced I/M	A set of more rigorous vehicle I/M program inspection requirements defined by the U.S. EPA that usually involves IM240 testing
EPA	United States Environmental Protection Agency
Excess Emissions	Vehicle emissions that exceed an I/M cutpoint
FTP	Federal Test Procedure
g/mi	Grams per mile, the units of measurement for FTP and IM240 tests
GIT	Georgia Institute of Technology
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
High Emitter Identification	The on-road identification of vehicles with high emission levels
I/M	Inspection and maintenance program
Idle Test	A tailpipe emission test conducted when the vehicle is idling and the transmission is not engaged
IM240 Test	A loaded-mode transient tailpipe emission test conducted when the vehicle is driven for up to 240 seconds on a dynamometer, following a specific speed trace that simulates real world driving conditions

KW/t	Kilowatts per metric ton, the units of measurement for vehicle specific power
LDGV	Light-duty Gasoline-powered Vehicle
LDGT	Light-duty Gasoline-powered Truck
NO_X	Oxides of nitrogen, usually measured as nitric oxide (NO)
OBDII	On board diagnostic system to detect emissions related problems that is required on all 1996 and newer light–duty vehicles
Repairable Emissions	The emission reductions that can be obtained by repairing a vehicle. The amount of repairable emissions is equal to or greater than the amount of excess emissions
RSD	Remote Sensing Device
VIN	Vehicle Identification Number
VDR	Vehicle On-road Record
VMT	Vehicle Miles Traveled
VSP	Vehicle Specific Power; estimated engine power divided by the mass of the vehicle
VTR	Vehicle Test Record

1. INTRODUCTION

The 1990 Federal Clean Air Act Amendments require that I/M Programs be implemented in urbanized areas in certain areas to help achieve or maintain attainment of national air quality standards.

Delaware currently operates a test-only, centralized Low enhanced Inspection and Maintenance Program (LEIM) in New Castle and Kent Counties and an I/M program in Sussex County. Motor vehicle emissions tests are performed on all light-duty vehicles weighing up to 8,500 pounds gross vehicle weight at the Delaware Division of Motor Vehicles. Biennial inspections are required for model years 1968 and newer light duty passenger vehicles and model years 1970 and newer light duty trucks with the exception of the five most recent model years. OBD inspections are performed on all 1996 and newer light-duty vehicles and light-duty trucks equipped with certified on-board diagnostic systems (OBD). The exhaust of non OBD equipped vehicles is inspected with Idle or Two Speed Idle tests that measure HC and CO. Evaporative tests are also performed.

The Clean Air Act Amendments of 1990 require Enhanced I/M program areas to supplement emissions testing at stations with on-road testing. The Department of Natural Resources and Environmental Control (DNREC) contracted Envirotest to conduct a remote sensing device (RSD 0.5%) survey to meet this requirement.

Fleet Emissions

Emissions of 15,615 vehicles were measured on-road in Delaware with visible plates and of these, 13,137 (84%) were identified as Delaware registrations.

Average hot running emissions of the Delaware registered vehicles were 25 ppm HC hexane, 0.10% CO and 142 ppm NO. Average emissions were influenced upward by old vehicles and a small percentage of high emitters. Cold weather may have increased cold start HC emissions. Median emissions were lower with approximately zero HC, 0.02% CO and 6 ppm NO. Delaware registered models 2002 and older accounted for 21% of Delaware registered vehicle on-road activity and emitted up to 51%, 45% and 61% of Delaware registered vehicle HC, CO and NO emissions.

Average hot running HC and NOx emissions by model year for Delaware registered trucks and light passenger vehicles are shown in Figures 1-1 and 1-2. The trucks measured with visible plates were virtually all 10,000 lbs GVWR or less[i]

The charts show that newer model year vehicles have far lower emissions than older vehicles. HC & CO emissions were highest among 1992 and older models. NO emissions were highest among 1995 and older models.

High Emitters

Two hundred and forty vehicles with on-road emissions exceeding 500 ppm HC hexane or 3% CO or 2000 ppm NO were identified as high emitters. These were 2.3% of the

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

vehicles measured but emitted up 33%, 19% and 30% of light vehicle HC, CO and NO respectively. Details of these high emitters are provided in section VI.

FIGURE 1-1 AVERAGE ON-ROAD HC EMISSIONS

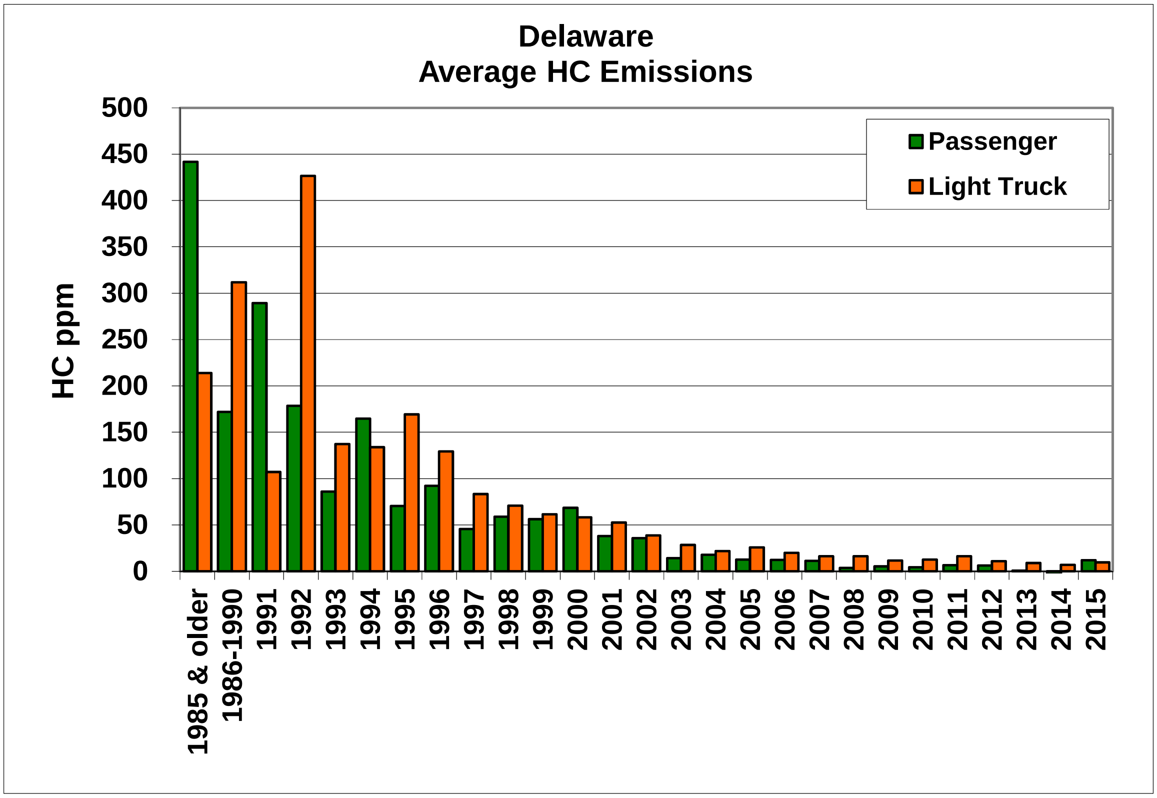
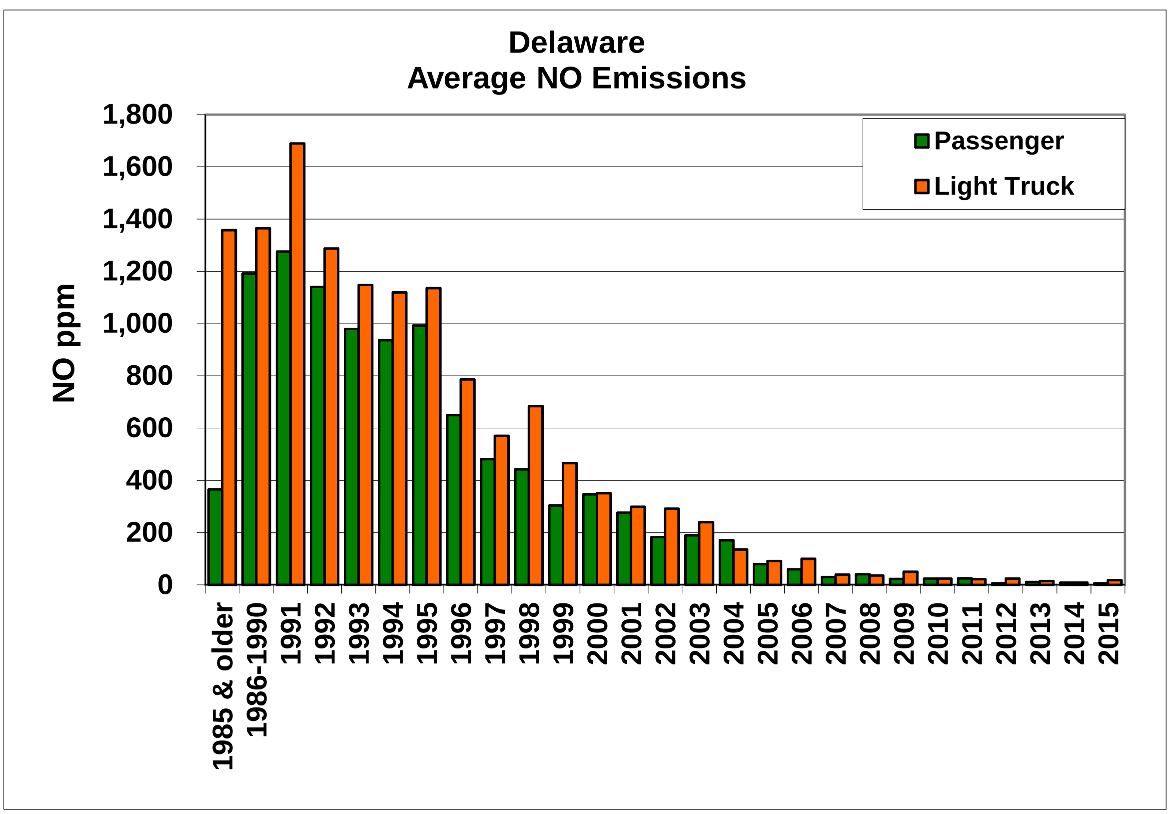


FIGURE 1-2 AVERAGE ON-ROAD NO EMISSIONS



2. STUDY DESIGN

Section 51.371 of the Code of Federal Regulation (CFR) covering Enhanced I/M programs defines on-road testing as the measurement of HC, CO, NOx and/or CO2 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 and is an option for basic I/M areas.

The general requirements specified in CFR 51.371 are:

- On-road testing is to be part of the emission testing system, but is to be a complement to testing otherwise required.
- On-road testing is not required in every season or on every vehicle but shall evaluate the emission performance of 0.5% of the subject fleet, including any vehicles that may be subject to the follow-up inspection provisions of paragraph 4 (below), each inspection cycle.
- The on-road testing program shall provide information about the emission performance of in-use vehicles by measuring on-road emissions through the use of remote sensing devices or roadside pullovers including tailpipe emission testing. The program shall collect, analyze and report on-road emissions data.
- Owners of vehicles that have previously been through the normal periodic inspection and passed final retest and found to be high emitters shall be notified that the vehicles are required to pass and out-of-cycle follow-up inspection; notification may be by mailing in the case of remote sensing on-road testing or through immediate notification if roadside pullovers are used.

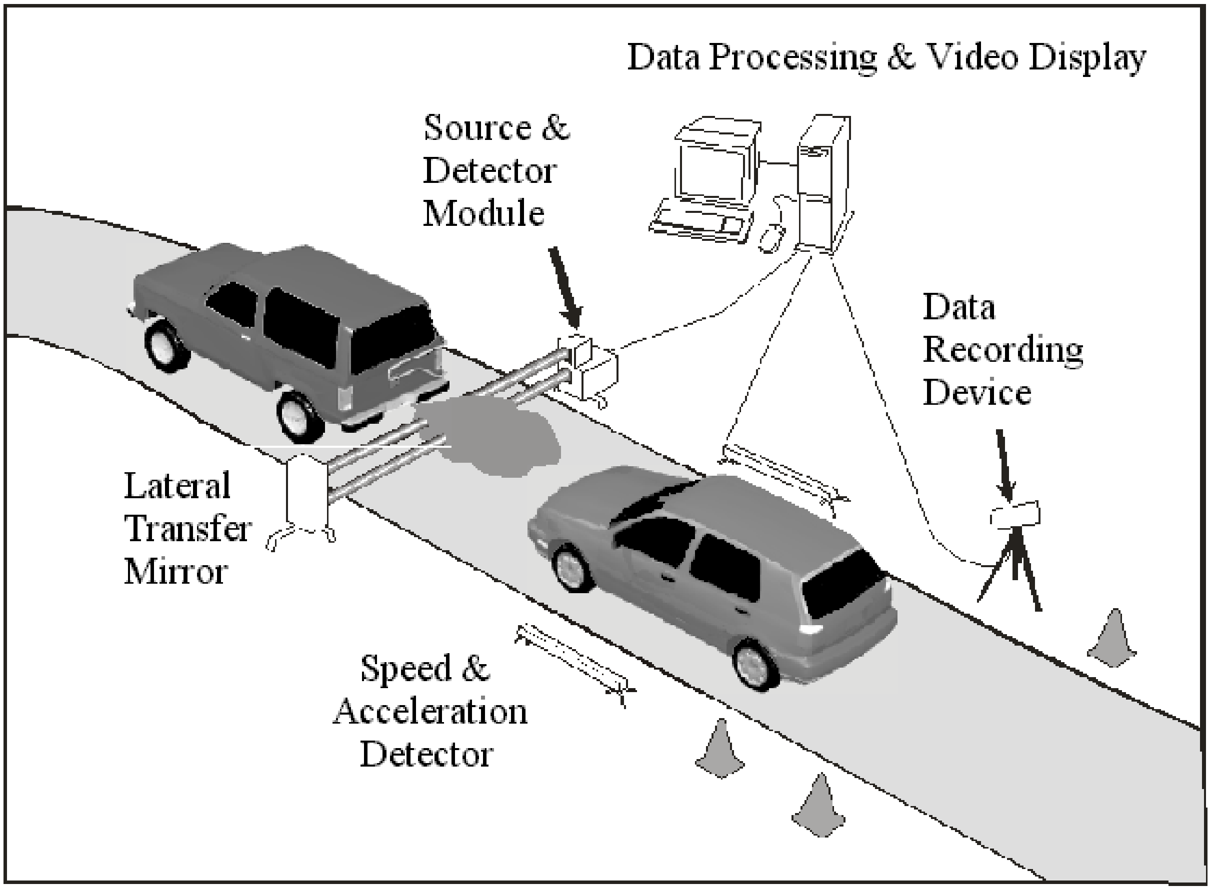
Following sections describe how these requirements have been fulfilled.

2.1 EQUIPMENT DESCRIPTION

The Delaware survey was performed using a remote sensing RSD4600 system. The RSD4600 detects vehicle emissions when a car drives through an invisible light beam the system projects across a roadway.

Figure 2-1 illustrates the remote sensing equipment set-up. The process of measuring emissions remotely begins when the RSD4600 Source & Detector Module (SDM) sends an infrared (IR) and ultraviolet (UV) light beam across a single lane of road to a lateral transfer mirror. The mirror reflects the beam back across the street (creating a dual beam path) into a series of detectors in the SDM.

FIGURE 2-1 ON-ROAD REMOTE SENSING SET-UP



Fuel specific concentrations of HC, CO, CO2, NOx 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 data-recording device captures an image of the rear of the vehicle, while the Speed & Acceleration Detector measures the speed of each vehicle.

The RSD units are housed in fully outfitted vans equipped with heating/cooling, a generator, and adequate storage for all components. The vans carry a full complement of road safety equipment and tools for making small repairs. The vans are equipped with additional lighting for testing during pre-dawn and post dusk hours. The new RSD4600 includes the following features:

- Simple and easy setup with laser alignment aids
- Alignment platforms to facilitate a fast and secure alignment result
- Continuous automatic CO2 for background compensation that minimizes the need for field calibration. (Only one or two calibrations are generally required during a full day of data collection.)
- Fourth generation real-time measurement validation
- Signal sensitivity and accuracy that significantly exceed 2002 California BAR certification standards
- A multi-tasking Windows operating system

- A fuel specific smoke measurement using a UV wavelength that senses the fine particles invisible to traditional visible light opacity meters
- Rugged assemblies that result in high availability.

2.2 EQUIPMENT QA/QC AUDITS:

2.2.1 FACTORY TESTING AND CERTIFICATION

When an RSD system is built at the Tucson Technology Center, it undergoes several steps to ensure accuracy. First, the source detector module is bench calibrated. It is then audited using several blends of gas. When the system is fully calibrated and assembled, it is tested again in the parking lot using an audit truck. The unit tests are based on the BAR OREMS specification.

An audit truck is a modified vehicle that uses a long exhaust stack to direct the vehicle engine exhaust upwards and away from the roadway. Audit gases of known concentrations are dispensed through a simulated tailpipe routed to the rear of the audit truck. When the truck is driven past a roadside remote sensing SDM/VTM set of modules, the system measures the pollutant concentrations in the dispensed test gas instead of the vehicle engine exhaust.

The remote sensing unit is setup in a parking lot to avoid interference from other traffic. The auditor drives the audit truck through the remote sensing system 40 times for each gas blend during acceptance testing. Envirotest detector accuracy, including speed and acceleration, will meet the detector accuracy tolerances shown below for at least 97.5% (39/40) runs for each gas. Six different audit gas blends are used to verify the unit accuracy over a range of pollutant concentrations.

2.2.1.1 DETECTOR ACCURACY:

The carbon monoxide (CO %) reading will be within ± 10% of the Certified Gas Sample, or an absolute value of ± 0.25% CO (whichever is greater), for a gas range less than or equal to 3.00% CO. Negative values shall be included and will not be rounded to zero. The CO% reading will be within ± 15% of the Certified Gas Sample for a gas range greater than 3.00% CO. Negative values will be included and will not be rounded to zero.

The hydrocarbon reading (recorded in ppm propane) will be within ± 15% of the Certified Gas Sample, or an absolute value of ± 250 ppm HC, (whichever is greater). Negative values will be included and will not be rounded to zero.

The nitric oxide reading (ppm) will be within ± 15% of the Certified Gas Sample, or an absolute value of ± 250 ppm NO, (whichever is greater). Negative values shall be included and will not be rounded to zero.

2.2.1.2 SPEED AND ACCELERATION ACCURACY:

The vehicle speed measurement will be accurately recorded within ± 1.0 mile per hour.

The vehicle acceleration measurement will be accurately recorded within ± 0.5 mile per hour / second.

2.2.2 DAILY SET-UP AND CALIBRATION

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.

Calibration for the RSD4600 occurs once at the beginning day and at mid-day if conditions warrant.

2.2.3 EQUIPMENT AUDITS

After each daily calibration, the Operator is required to perform an audit to verify an optimal calibration. This is done in the same manner as the calibration except the audits are "earmarked" in the data file with an "A". If the audit passes a predetermined pass/fail tolerance, the operator is allowed to begin testing vehicles. If not, the operator is required to realign and recalibrate the system until it passes the audit process. The Operator thereafter is prompted by the system to perform an audit every two (2) hours to verify the calibration.

2.2.4 QUARTERLY AUDITS (DRIVE-BY AUDITS)

An Audit Truck is used to conduct an on-road audit of the RSD4600 system approximately every three months. The audit truck is outfitted with a gas cylinder rack that holds a maximum of 6 compressed gas cylinders. Each gas cylinder is equipped with a high flow regulator, a high flow solenoid and a Tygon hose, which is adapted to a simulated tailpipe. Inside the truck cab, the audit truck operator has the ability to switch power from solenoid to solenoid to select the appropriate audit gas cylinder for drive-by audits. A traffic cone is placed 60-70 feet preceding the test site. This is used

as a mark to begin the flow of gas to ensure there is an adequate plume of audit gas as the truck passes the RSD4600. The typical gas blends used in the audits are show below:

	HC (ppm)	CO	CO2	NO_X (ppm)
Blend # 1	500	0.5%	14.70%	3000
Blend # 2	3000	1.00%	14.38%	2000
Blend #3	2000	2.75%	13.10%	500
Blend #4	6000	5.00%	11.55%	250

In addition to the equipment, the operator is also audited for following procedures: site setup, calibration, camera alignment, traffic safety and documentation.

2.2.5 NO VS. NOX

The vast majority of nitric oxides emitted from the vehicle tailpipe are in the form of NO. The NO is later oxidized to NO2 and other oxides of nitrogen, which are collectively referred to as NOx. The RSD unit measures NO. To convert from NO to NOx, a factor of 1.03 can be applied. For simplicity we refer to NO measurements when reporting results. Charts in sections III and IV report NO values.

2.2.6 NOX AND HUMIDITY

Higher humidity reduces vehicle NO and NOx emissions. For loaded mode dynamometer tests, humidity correction factors are usually applied to adjust the NOx measurements to values that would have been achieved when the water vapor content is 75 grains per lb.

Sections III and IV report actual on-road NO emissions. They have not been adjusted for humidity. Correction factors can be calculated using the weather information recorded by the weather station attached to the RSD van.

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.

Water vapor grains per lb are 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))

2.3 SITE LOCATIONS

Envirotest selected nine sites in Delaware. The sites were selected to:

- Provide a representative sampling of the I/M area fleet.
- Obtain measurements in each county.

Table 2-1 lists the set of site locations visited during the study and the days the site was used. Table 2-2 list the number of passing vehicles measured, valid measurements, active collection hours, valid measurements per hour and the percentage of attempted measurements that were successful. Vehicles that are decelerating often have insufficient exhaust volume for a valid emissions measurement. Between 5,000 and 7,000 valid measurements were obtained in each county.

Figure 2-2 displays the locations of the sites.

Table 2-1: Site Locations

Site	Description	City	County	Slope
DE01	SR 2 (Kirkwood Hyw) to SR 141 N/S	Wilmington	New Castle	0.7
DE03	SR 4 (Market St) EB to SR141 SB	Wilmington	New Castle	2.4
DE05	US 13 (S Dupont Blvd) to SR 1 Korean War Memorial N/	Smyrna	Kent	0.2
DE09	US 9 (W Market St) East, after US 113 (Dupont Blvd)	Georgetown	Sussex	0.4
DE10	US 9 (Savana Rd) West, just pass Wescoats Rd	Lewes	Sussex	0.5
DE11	US 40 / US 13 North to I-295 North	New Castle	New Castle	0.6
DE12	US 13 North to DE 1 North	Dover	Kent	0.5
DE13	DE 20 West, just past US 9	Seaford	Sussex	0.1
DE14	DE 20 East, just past US 9	Seaford	Sussex	0.1

Table 2-2: Daily Measurements

Date	SDM	Site	Start	End	Active Hours	Beam Blocks	Valid Emissions and Speed	Valid %
12-Dec-14	4619	DE01	12:44:47 PM	3:00:18 PM	2.3	1,059	897	85%
15-Dec-14	4619	DE03	9:19:37 AM	2:59:58 PM	5.7	3,532	3,069	87%
17-Dec-14	4619	DE03	9:32:18 AM	1:30:18 PM	4.0	2,499	2,145	86%
11-Dec-14	4619	DE05	5:42:26 AM	12:16:54 PM	6.6	2,310	1,796	78%
18-Dec-14	4619	DE05	5:29:13 AM	1:30:12 PM	8.0	2,550	1,849	73%
03-Dec-14	4619	DE09	5:31:13 AM	3:29:46 PM	10.0	2,666	1,145	43%
05-Dec-14	4619	DE09	5:43:10 AM	1:44:49 PM	8.0	2,397	895	37%
04-Dec-14	4619	DE10	5:17:40 AM	6:45:13 PM	13.5	6,515	3,616	56%
12-Dec-14	4619	DE11	9:17:05 AM	11:30:12 AM	2.2	1,089	299	27%
08-Dec-14	4619	DE12	6:14:40 AM	5:55:27 PM	11.7	4,009	1,382	34%
10-Dec-14	4619	DE12	11:13:18 AM	6:01:29 PM	6.8	2,482	806	32%
01-Dec-14	4619	DE13	6:12:00 AM	10:44:28 AM	4.5	709	489	69%
01-Dec-14	4619	DE14	12:48:33 PM	4:00:23 PM	3.2	489	336	69%
Total					86.4	32,306	18,724	58%

FIGURE 2-2 SITE LOCATIONS IN DELAWARE

2.3.1 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.

2.4 SOURCES OF DATA AND DESCRIPTION OF ELEMENTS

Data used in the analyses in this report come from two primary sources; the RSD unit measurements and the vehicle registration records.

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

2.4.1 RSD MEASUREMENTS

For each measurement record the following information is collected:

RSD unit

Date and time

License plate image

HC, CO, CO2, 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[i]

2.4.2 DATA COLLECTION STATISTICS

Unit

Site

Date

Start time

End time

[i] 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.

2.4.3 VEHICLE REGISTRATION DATA

The license plates of vehicles with Delaware plates measured by RSD were matched by plate to registration records provided by the department to determine the vehicle identification number (VIN) and additional vehicle information, e.g.:

Vehicle identification number (VIN)

Vehicle license plate

Fuel Code

Model year

Make

Body style

EPA vehicle type (LDGV, LDGT1, etc)

County

Zip code

2.5 DATA SCREENING

Envirotest applied the following screening checks to the RSD measurements to ensure the data used for fleet evaluation and fleet comparisons are reasonable and consistent:

- Screening of exhaust plumes
- Screening of hourly observations to check for cold starts;
- Screening of high values
- Screening of day-to-day variations in emissions values
- Screening for Vehicle Specific Power (VSP) range

The first four of these screening procedures are described in the following paragraphs. The VSP screening is described in section 3.2.

2.5.1 SCREENING OF EXHAUST PLUMES

The RSD4600 unit takes many measurements of each exhaust plume in the one half second after each vehicle passes the equipment.

The basic gas record validity criteria applied are:

- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO2 and CO gas exceed 10%-cm[i]; or
- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO2 and CO gas exceed 5%-cm and the background gas values are very stable (not changing faster than a specified rate) at the time the front of the vehicle breaks the measurement beam.

2.5.2 SCREENING OF HOURLY OBSERVATIONS

Vehicles operating in cold start mode or under conditions when exhaust plumes condense to steam can appear to have high HC emissions. Spray from wet roads can have a similar effect. Envirotest tabulated for each site and hour the percentage of 2008 and newer vehicles that exceeded 150 ppm HC hexane. The percent of 2008 and newer vehicles that exceed 150 ppm HC is normally low unless temperatures are below 40F when vehicles can trail steam plumes or the road was wet. Higher than normal percentages of 2008 and newer vehicles exceeding 150 ppm HC were observed on most days during the study (Table 2-3). Envirotest used an exhaust plume analysis algorithm to detect and flag as invalid 737 plumes affected by a water signature and a visual review eliminated a further 20 plumes. Table 2-4 shows the result after removal of plumes affected by water.

Average hourly temperature and relative humidity at the RSD van are shown in tables 2-5 and 2-6.

Measurements were also screened for the presence of unusually high values or unusually low values.

Table 2-3: Percentage of 2008 and Newer Models with HC > 150 ppm hexane

Day	RSD Unit	Site	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1-Dec-14	__07064619	DE13		3%	0%	0%										
1-Dec-14	__07064619	DE14									0%	0%	0%			
3-Dec-14	__07064619	DE09			3%	13%	10%	8%	3%	13%	7%	7%	8%			
4-Dec-14	__07064619	DE10			17%	7%	5%	5%	1%	3%	4%	0%	7%	12%	7%	5%
5-Dec-14	__07064619	DE09			3%	0%	5%	0%	6%	3%	0%					
8-Dec-14	__07064619	DE12		5%	7%	15%	13%			0%		4%	5%	8%	11%	
10-Dec-14	__07064619	DE12							4%	4%	0%	0%	2%	0%	3%	
11-Dec-14	__07064619	DE05	3%	3%	3%	2%	3%	6%	15%	65%						
12-Dec-14	__07064619	DE01								14%	12%	13%				
12-Dec-14	__07064619	DE11					0%	4%								
15-Dec-14	__07064619	DE03					14%	13%	10%	11%	9%	9%				
17-Dec-14	__07064619	DE03						16%	8%	0%	0%					
18-Dec-14	__07064619	DE05	11%	4%	1%	6%										

[i] The unit of measurement 10%-cm is a measurement of the amount of a gas in the optical path. In this case, if all the molecules of the gas in the path were collected together into just one centimeter of the path then the concentration of the gas in the one-centimeter would be 10%.

Table 2-4: Percentage of 2008 and Newer HC > 150 ppm hexane, excl. Water

Day	RSD Unit	Site	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1-Dec-14	__07064619	DE13		3%	0%	0%										
1-Dec-14	__07064619	DE14									0%	0%	0%			
3-Dec-14	__07064619	DE09			2%	3%		0%	3%	4%	0%	0%	0%			
4-Dec-14	__07064619	DE10			2%	1%	2%	1%	0%	3%	3%	0%	2%	2%	3%	1%
5-Dec-14	__07064619	DE09			2%	0%		0%	0%	3%	0%					
8-Dec-14	__07064619	DE12		0%	5%	8%	4%			0%		4%	3%	8%	12%	
10-Dec-14	__07064619	DE12							4%	4%	0%	0%	2%	0%	3%	
11-Dec-14	__07064619	DE05	0%	1%	0%	0%	0%	1%	4%							
12-Dec-14	__07064619	DE01								6%	3%	4%				
12-Dec-14	__07064619	DE11					0%	0%								
15-Dec-14	__07064619	DE03					5%	5%	4%	5%	4%	4%				
17-Dec-14	__07064619	DE03					6%	7%	3%	8%	10%					
18-Dec-14	__07064619	DE05	4%	1%	0%	0%	2%	2%	4%	0%	0%					

Table 2-5: Hourly Temperature

Day	Unit	Site	5	6	7	8	9	10	11	12	13	14	15	16	17
1-Dec-14	__07064619	DE13		13	14	16	18	20							
1-Dec-14	__07064619	DE14								23	24	27	26	26	
3-Dec-14	__07064619	DE09	13	16	17	18	21	22	22	21	22	21	23		
4-Dec-14	__07064619	DE10	8	10	17	22	25	23	25	22	20	20	21	20	19
5-Dec-14	__07064619	DE09	9	12	13	15	16	17	20	18	17				
8-Dec-14	__07064619	DE12		3	5	5	6	7	8	8	7	6	7	9	11
10-Dec-14	__07064619	DE12							7	8	8	8	9	9	8
11-Dec-14	__07064619	DE05	6	9	14	16	13	14	17	16					
12-Dec-14	__07064619	DE01								9	11	15	17		
12-Dec-14	__07064619	DE11					7	8	10						
15-Dec-14	__07064619	DE03					11	16	21	20	20	22			
17-Dec-14	__07064619	DE03					12	17	24	24	22				
18-Dec-14	__07064619	DE05	7	10	11	10	11	11	13	13	10				

Table 2-6: Hourly Relative Humidity

Date	Unit	Site	5	6	7	8	9	10	11	12	13	14	15	16	17
1-Dec-14	__07064619	DE13		68	65	60	55	48							
1-Dec-14	__07064619	DE14								43	42	36	37	37	
3-Dec-14	__07064619	DE09	65	56	52	51	49	48	49	49	48	50	46		
4-Dec-14	__07064619	DE10	53	48	36	28	24	23	21	22	23	24	26	27	27
5-Dec-14	__07064619	DE09	58	50	48	45	43	42	36	40	45				
8-Dec-14	__07064619	DE12		42	41	43	44	43	43	46	48	47	49	45	45
10-Dec-14	__07064619	DE12							54	52	51	49	45	46	46
11-Dec-14	__07064619	DE05	48	43	36	31	31	30	26	30					
12-Dec-14	__07064619	DE01								49	47	41	40		
12-Dec-14	__07064619	DE11					48	46	39						
15-Dec-14	__07064619	DE03					52	47	40	36	38	39			
17-Dec-14	__07064619	DE03					64	57	42	34	34				
18-Dec-14	__07064619	DE05	42	33	29	28	28	28	26	27	32				

2.5.3 SCREENING OF DAY-TO-DAY VARIATIONS IN EMISSIONS VALUES

Day-to-day decile values were compared for 2008 and newer vehicles. Only a small percentage of these vehicles are expected to have high emissions and we expect the intermediate decile emission values should not vary significantly from day-to-day, from site-to-site or between RSD units. In Figure 2-3, the HC decile values for each day of measurements are plotted side-by-side as an example. This comparison revealed median values for the 2008 and newer models that ranged day-to-day from –14 ppm to +56ppm. Although these variations are within the HC specification of the RSD4600 units they are significant compared to average fleet emissions for newer vehicles.

The most likely explanation is that the variation in daily medians represents the limits of accuracy in the daily instrument set-up. For HC, an adjusted set of values was created by direct addition or subtraction of a daily offset that would set the daily median values to zero. We believe this is appropriate since the median I/M test result for new models is normally zero or very close to zero. The results of the correction are shown in Figure 2-4 and analyses shown later in this report used the adjusted HC values.

Day-to-day decile CO, NO and UV smoke values for 2008 and newer vehicles are shown in Figures 2-5 to 2-7. Median values for CO, NOx and smoke were 0.02%, 6ppm and 0.005 respectively. These small positive values appear reasonable and adjustments were not applied to these pollutants.

FIGURE 2-3 DAILY HC DECILES

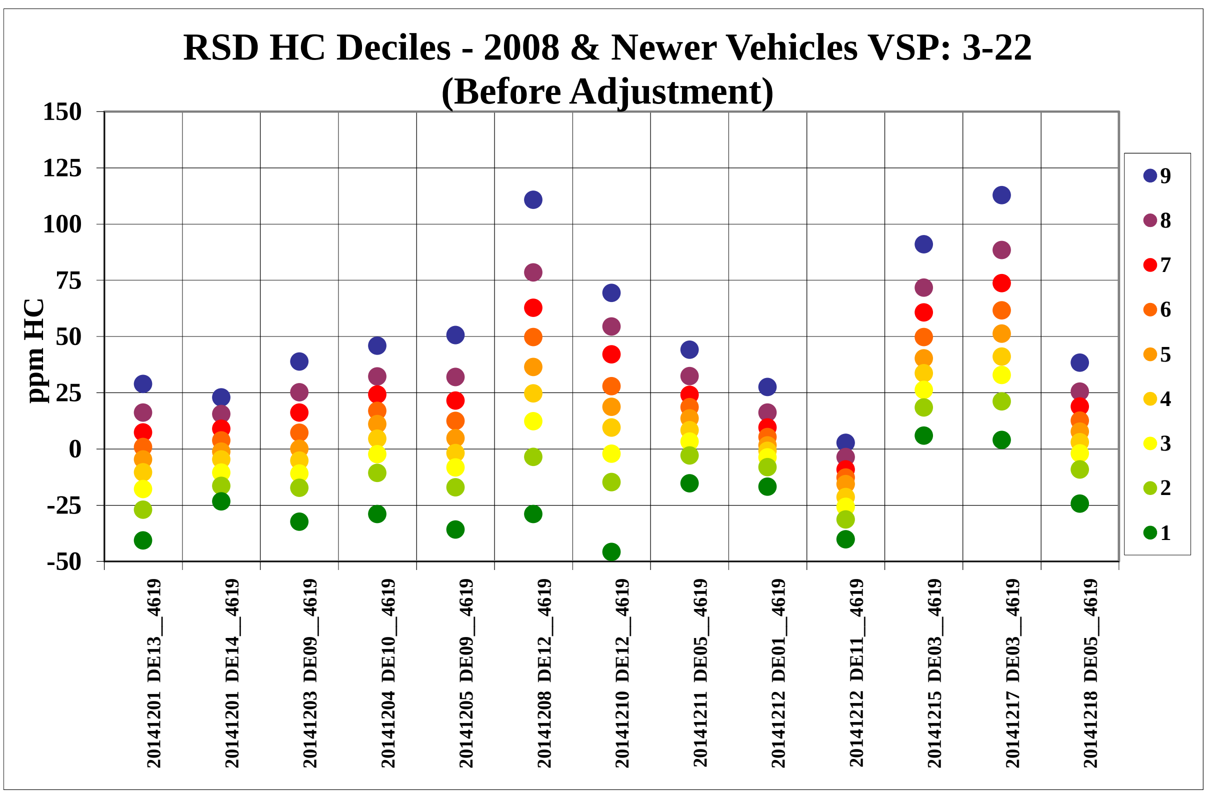


FIGURE 2-4: DAILY HC DECILES – AFTER ADJUSTMENT

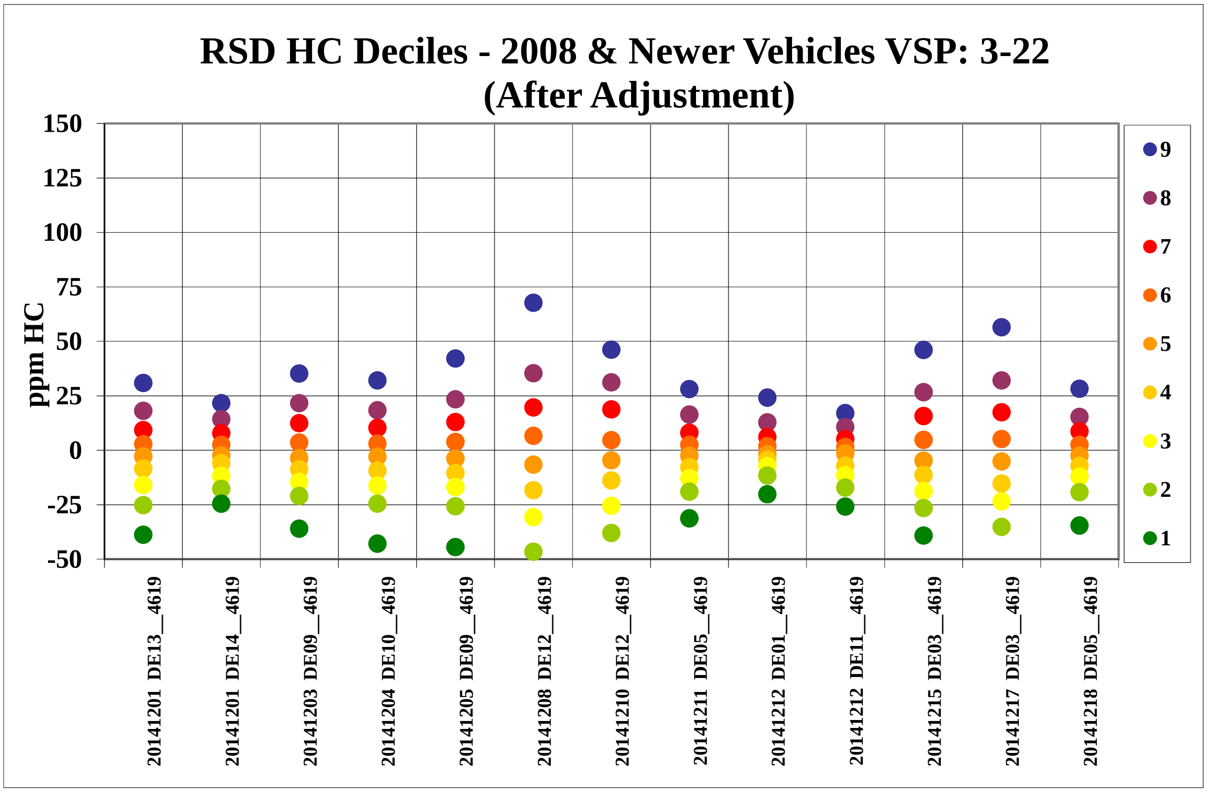


FIGURE 2-5 DAILY CO DECILES

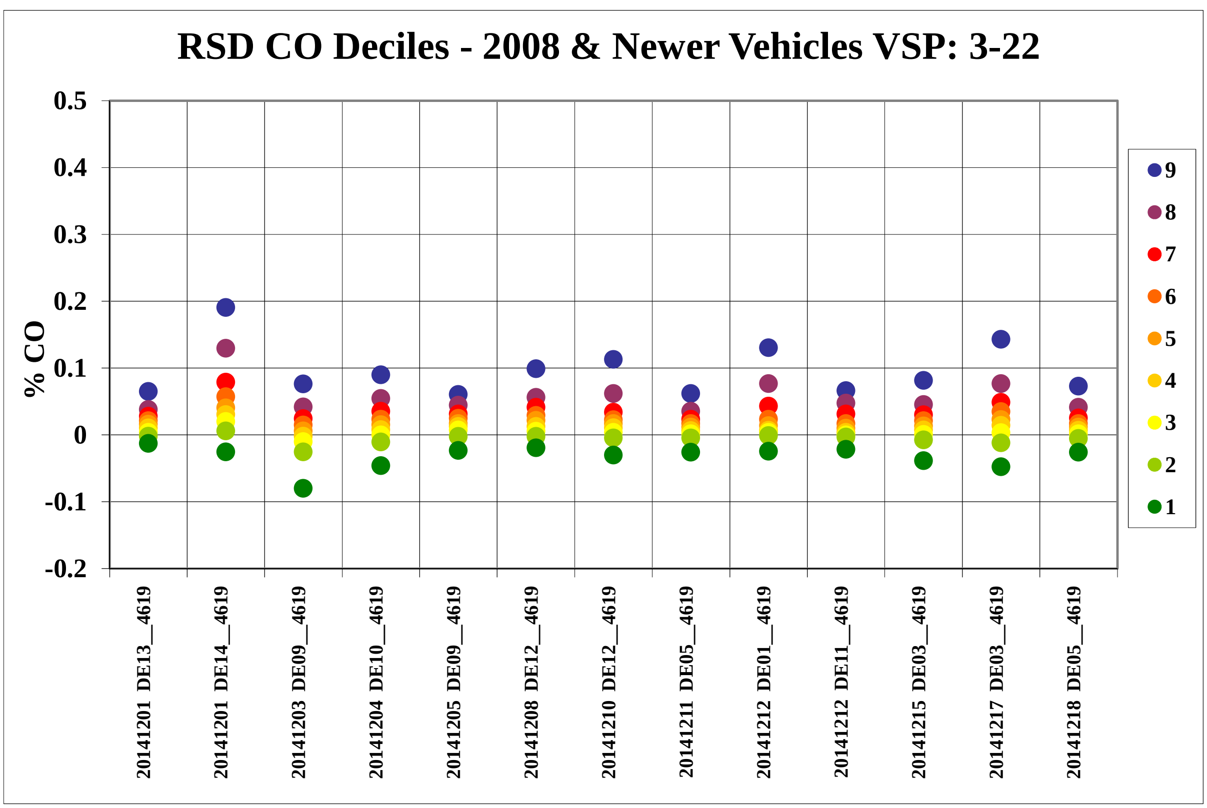


FIGURE 2-6 DAILY NO DECILES

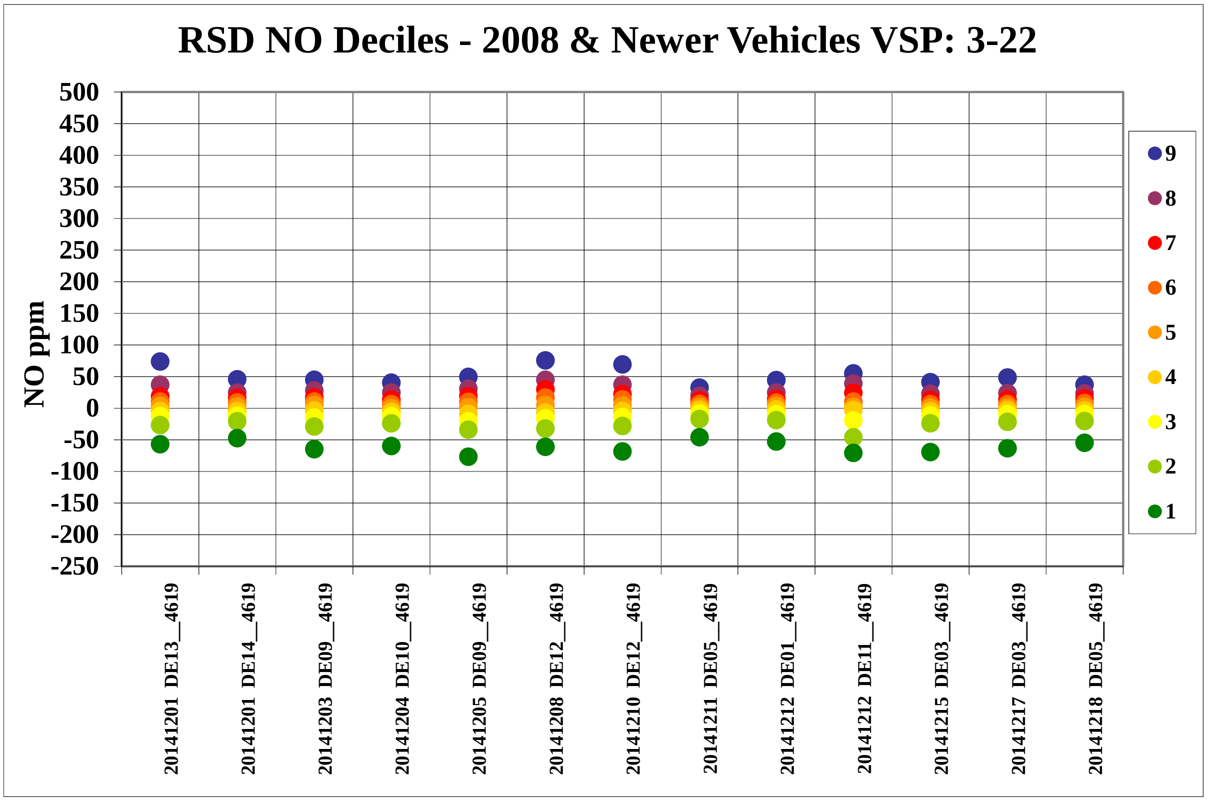
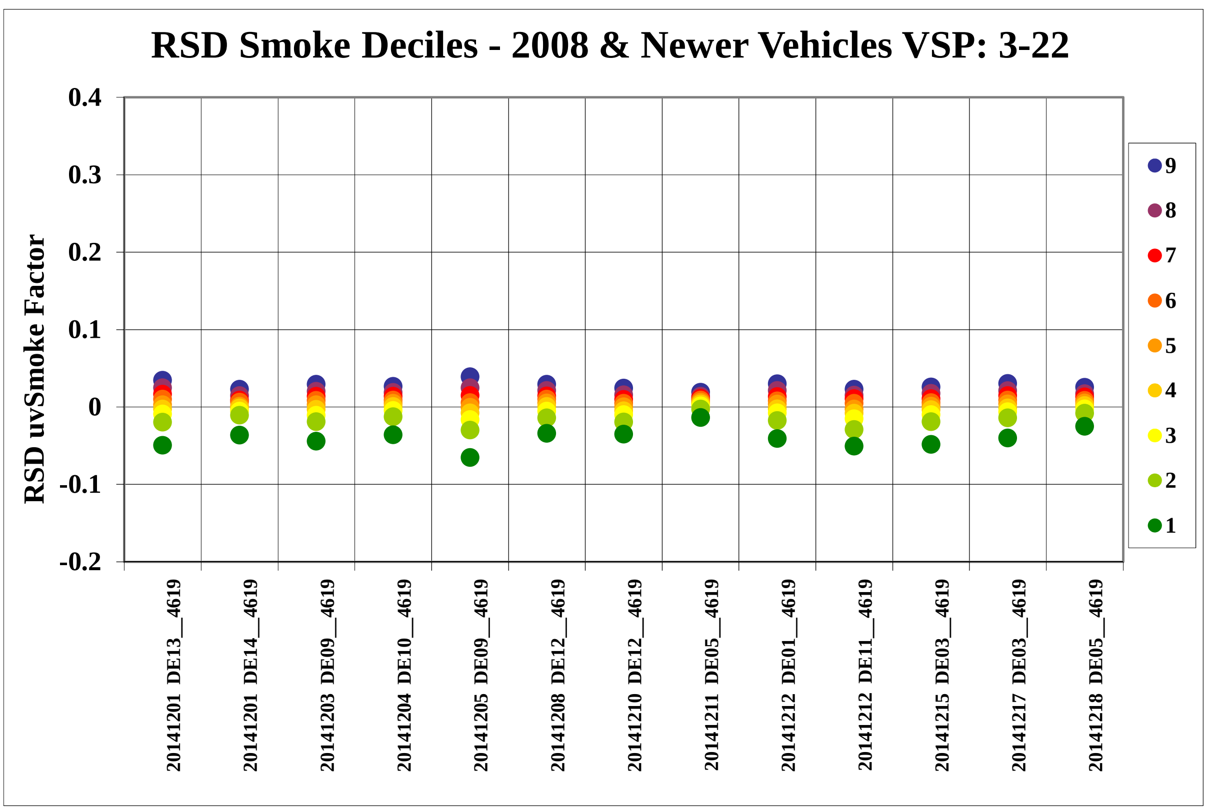


FIGURE 2-7 DAILY SMOKE DECILES



3. ANALYSIS OF DATA COLLECTED

3.1 STATISTICS AND RSD COVERAGE

The study data collection phase lasted from Dec 1st through Dec 18th using RSD4600 system 4619.

Table 3-1 shows the remote sensing measurements made during twelve calendar days of testing in Delaware. Approximately 15,615 measurements were made with complete emissions information (speed, acceleration, emission measurements and a visible plate).

Table 3-2 shows the number of vehicles registered within Delaware and neighboring states. Eighty-four percent of vehicles measured at the survey locations were registered in Delaware, 5% were from Pennsylvania, 4% from Maryland, 3% from New Jersey, 1% from Virginia, and <1% from New York and 2% from other states.

Table 3-1: Number of Remote Sensing Records by License Plate

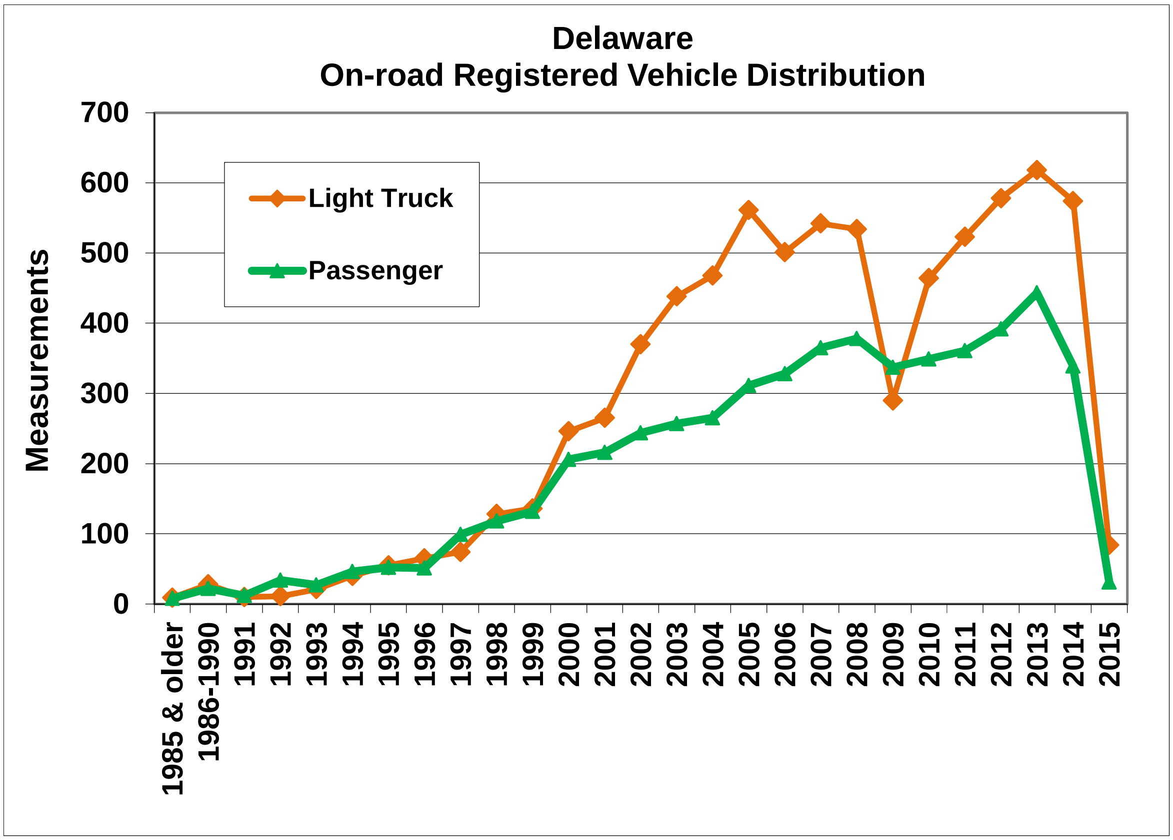
RSD Units	1
Sites	9
Collection-Days	12
Attempted Measurements	32,306
Valid Measurements	17,961
With Valid readings within 3-22 kw/t & Visible Plate	15,595
- Other State Plates	2,458
- Delaware Plates	13,137
Matched to Delaware Registrations	13,049
Unique Delaware Vehicles Identified	11,715
Unique Delaware Vehicles Identified Once	10,496
Unique Delaware Vehicles Identified Twice	1,130
Unique Delaware Vehicles Identified Three Times	74
Unique Delaware Vehicles Identified Four or More Times	15

Table 3-2: Valid Remote Sensing Records by State Plate

State	Count	%
Delaware	13,137	84%
Maryland	682	4%
New Jersey	485	3%
New York	63	0%
Pennsylvania	747	5%
Virginia	144	1%
Other	337	2%
Total	**15,595**	**100%**

Figure 3-1 shows the distribution of the vehicles measured on-road and registered in Delaware that were matched to registration information. The on-road distribution tends to be more skewed towards newer vehicles than the number of registrations. This is because, 1) newer vehicles are more active and 2) there are relatively more inactive older vehicles that still have DMV records. The recession and recovery are clearly visible in registrations of 2008-2013 light trucks. Model year 2014 and 2015 sales were incomplete at the time of the survey.

FIGURE 3-1 MODEL YEAR FRACTIONS OF ON-ROAD LIGHT VEHICLES IN DELAWARE



3.2 VEHICLE SPECIFIC POWER

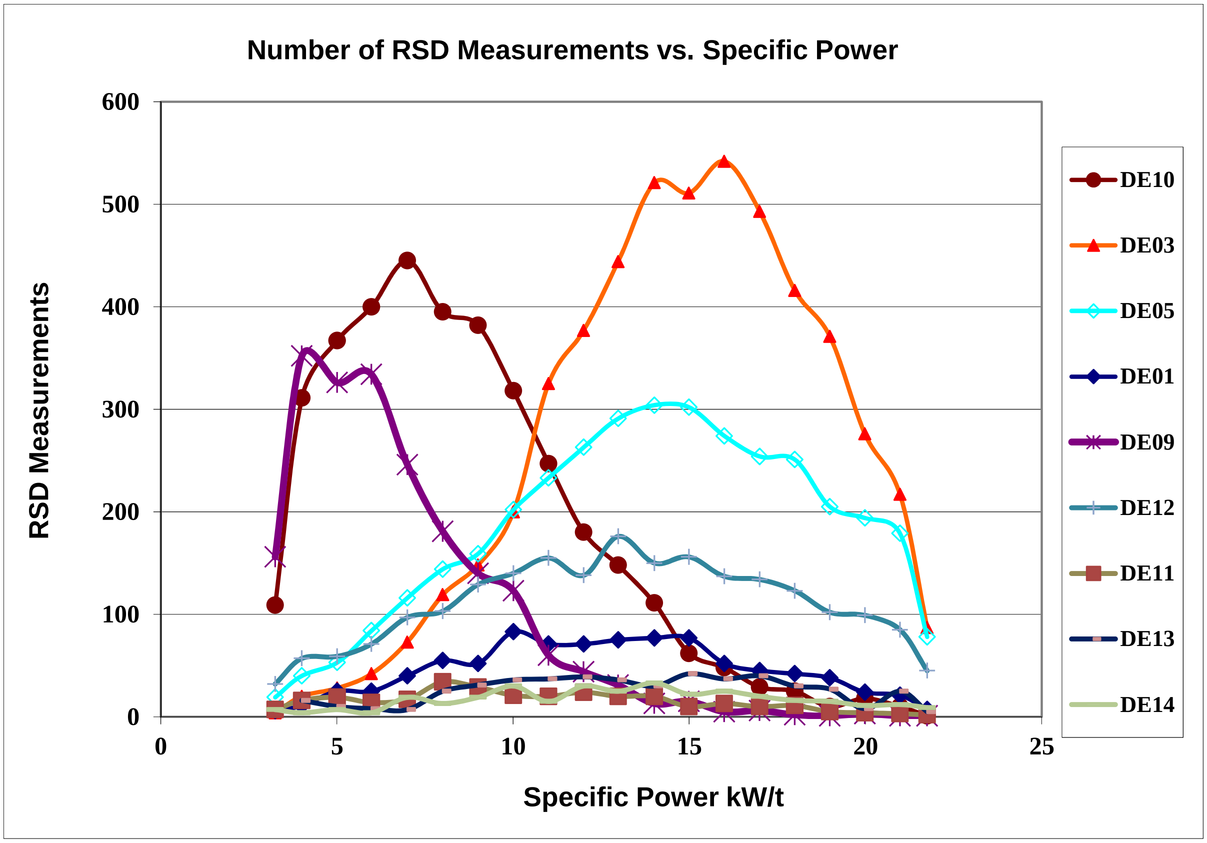
Envirotest used the speed/acceleration and site grade data to determine Vehicle Specific Power (VSP). VSP attempts to normalize the power requirements of the vehicle based upon speed, acceleration and slope at the site. VSP is defined by the following equation:

VSP = 4.364*sin (Grade in Deg/57.3)*Speed + 0.22*Speed*Accel + 0.0657*Speed + 0.000027*Speed*Speed*Speed

Measurements where VSP was between 3 and 22 kW/t were used in subsequent analyses.

Figure 3-2 shows the distribution of VSP at each site. A majority of observations fell within the range of 3 to 22 kW/t, which are considered to be valid readings by Envirotest for program evaluation. Measurements outside of the desired VSP window were not included.

FIGURE 3-2: DISTRIBUTION OF VSP AT SITES



3.3 VEHICLE FLEET EMISSION RATES

3.3.1 EMISSION BY JURISDICTION

Envirotest calculated average hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO) emission rates of vehicles registered in Delaware and other states.

Table 3-3 and Figures 3-3 to 3-5 compare emissions of vehicles registered in Delaware to those driving in Delaware but registered in other states. Vertical bars on the charts indicate the 95% confidence intervals for emissions values. As noted in Table 3-3, samples of measurements of out-of-state vehicles observed in Delaware were relatively small and this resulted in wide confident intervals that overlap. Thus differences in mean emissions were not statistically significant. Emissions of vehicles with out-of-state plates were 3%, 5% and 2% lower than Delaware plates for HC, CO and NO respectively.

Also shown in Table 3-3 are emissions of 994 vehicles identified as trucks and 1 motorcycle. The trucks had over three times higher NO and smoke emissions than light vehicles. The motorcycle measured had five to ten times higher emissions concentrations than the average light vehicle.

Table 3-3 Mean Emissions by Jurisdiction

Name	N	HC ppm	CO %	NO ppm	RSD UV Smoke	VSP kw/t
Delaware	**13,137**	**25**	**0.10**	**142**	**0.013**	**12.2**
Maryland	682	34	0.11	159	0.013	11.4
New Jersey	485	25	0.11	110	0.013	13.5
New York	63	22	0.06	37	0.005	15.0
Pennsylvania	747	21	0.09	142	0.010	13.9
Virginia	144	30	0.08	132	0.010	12.0
Other	337	12	0.09	110	0.008	12.4
Total Other States	**2,458**	**25**	**0.10**	**133**	**0.011**	**12.8**
Trucks	994	47	0.09	541	0.066	10.1
Motorcycles	1	126	1.33	659	0.179	7.4
Plates Not Readable	1,377	50	0.15	230	0.031	11.8
Total On-road	**17,961**	**28**	**0.10**	**170**	**0.017**	**12.2**

FIGURE 3-3: MEAN HC BY JURISDICTION

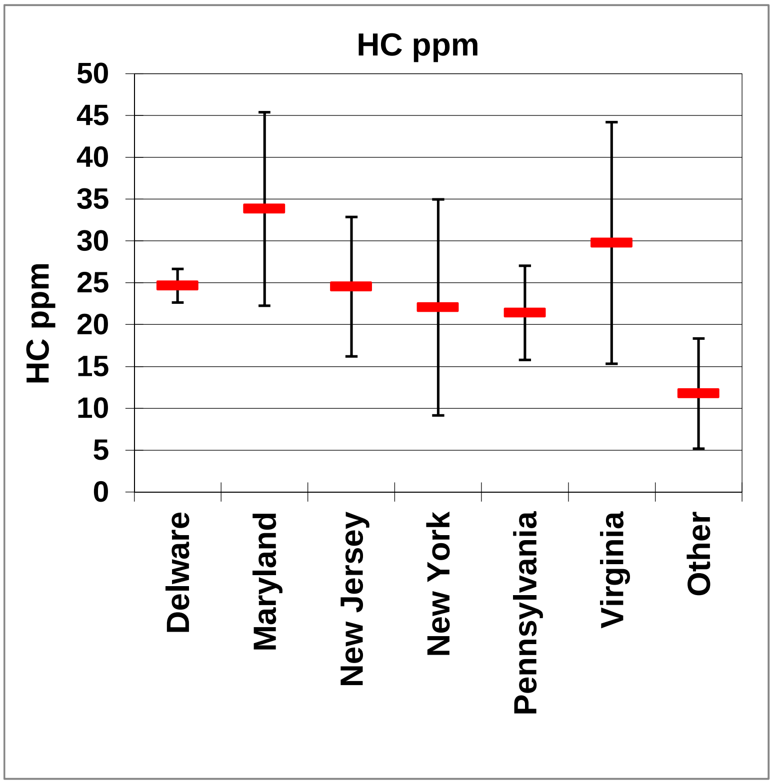


FIGURE 3-4: MEAN CO BY JURISDICTION

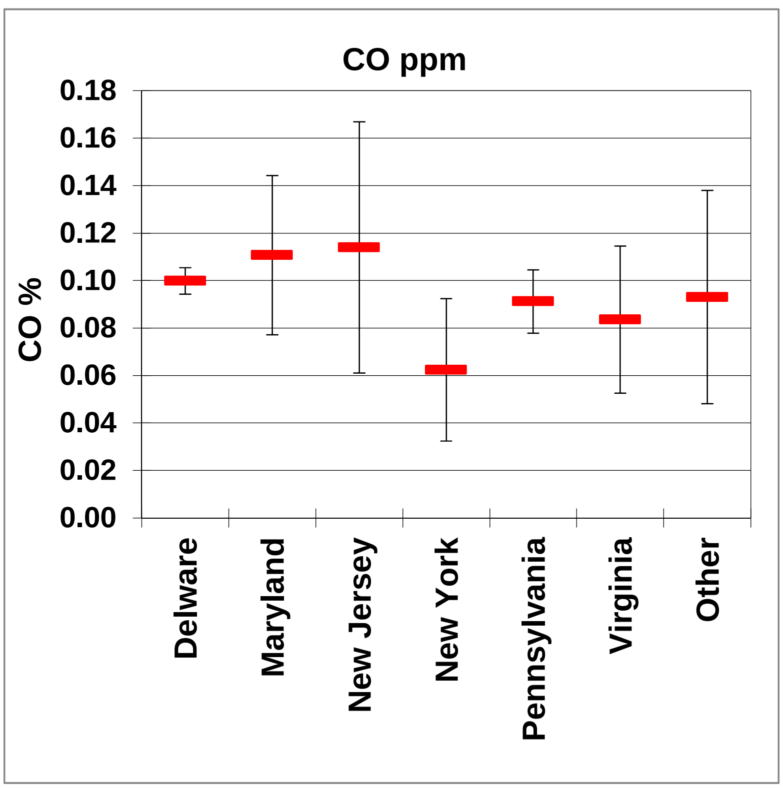


FIGURE 3-5: MEAN NO BY JURISDICTION

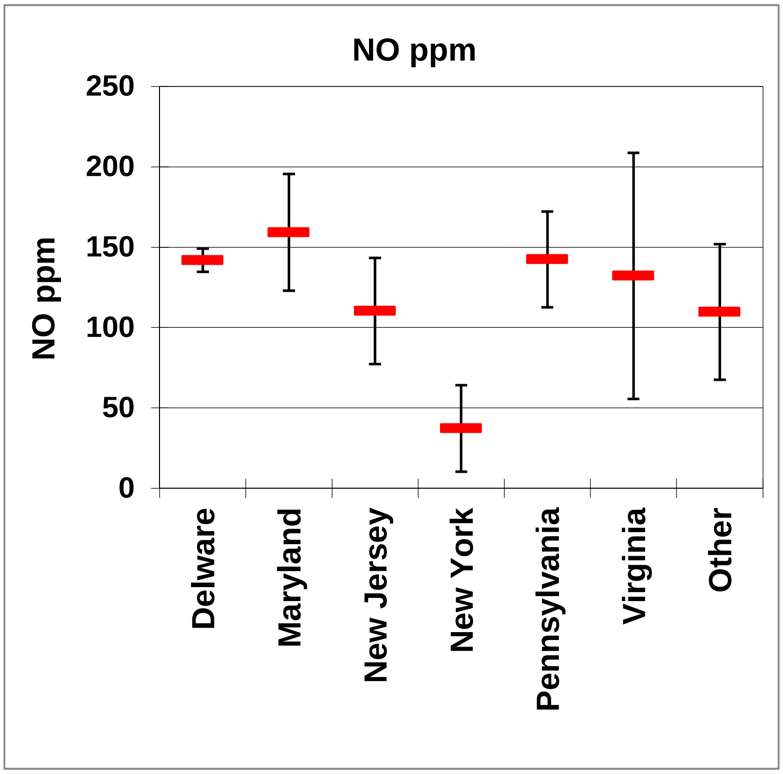
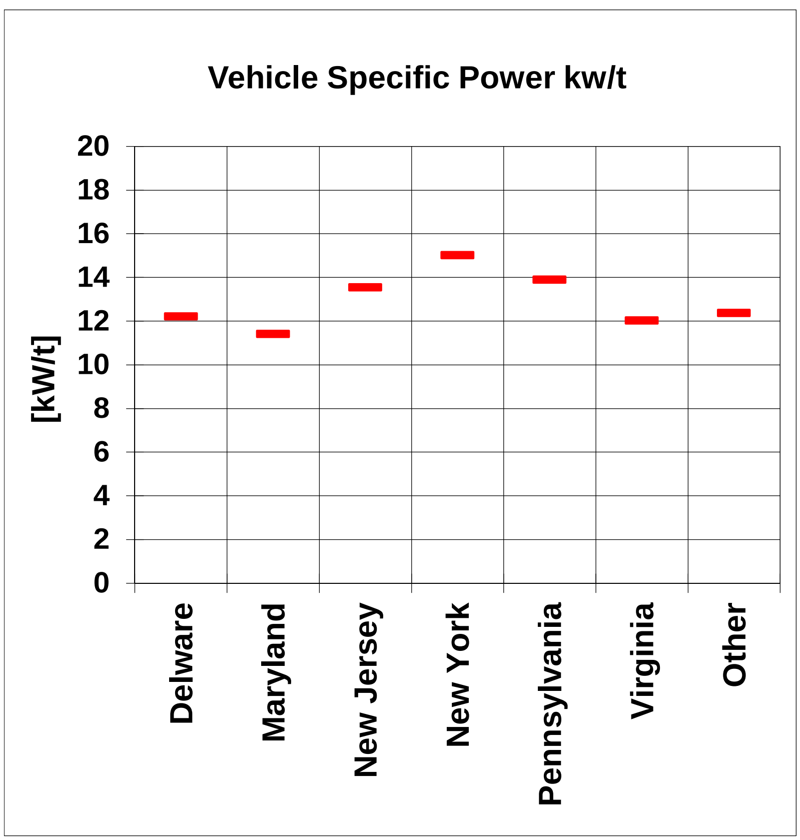


FIGURE 3-6: VSP VS. JURISDICTION



3.3.2 DELAWARE AVERAGE EMISSIONS BY MODEL YEAR

Average emissions by model year are shown in Figures 3-7 to 3-9. A number of vehicles have very high emissions that affect the average values for a particular vehicle type and model year. Thus, there is considerable variation in model year averages. On the whole, however, it is apparent that trucks have higher emissions than passenger vehicles of the same age – especially for NO.

A larger survey would allow more accurate assessment of the average emissions by year of passenger vehicles and light trucks.

FIGURE 3-7: AVERAGE HC EMISSIONS

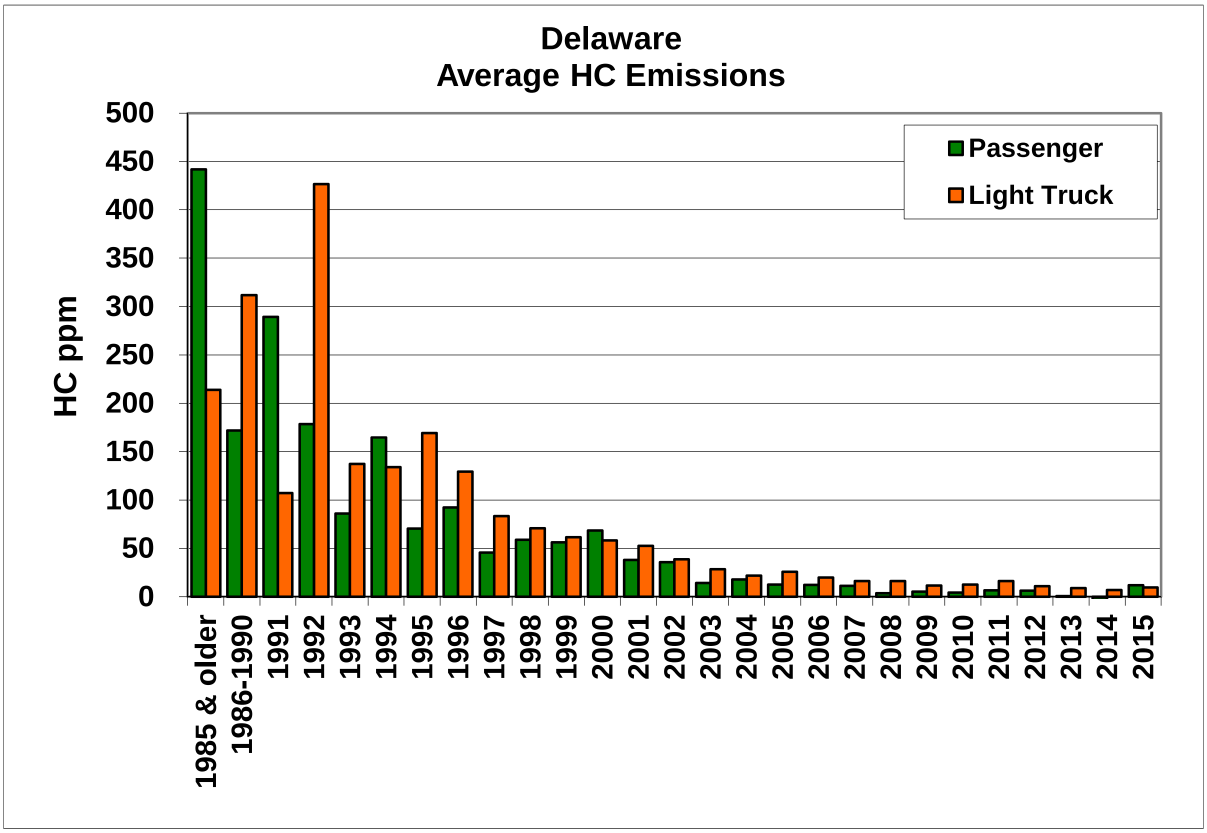


FIGURE 3-8: AVERAGE CO EMISSIONS

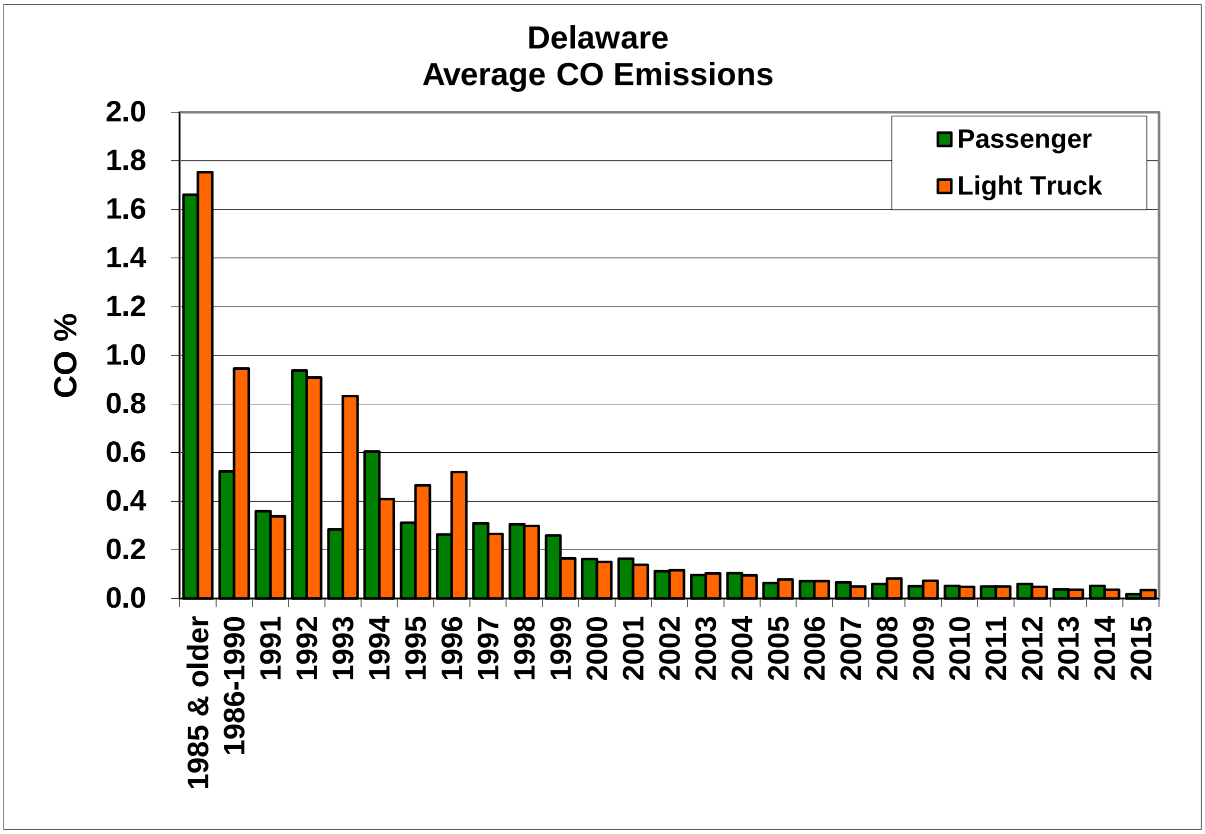
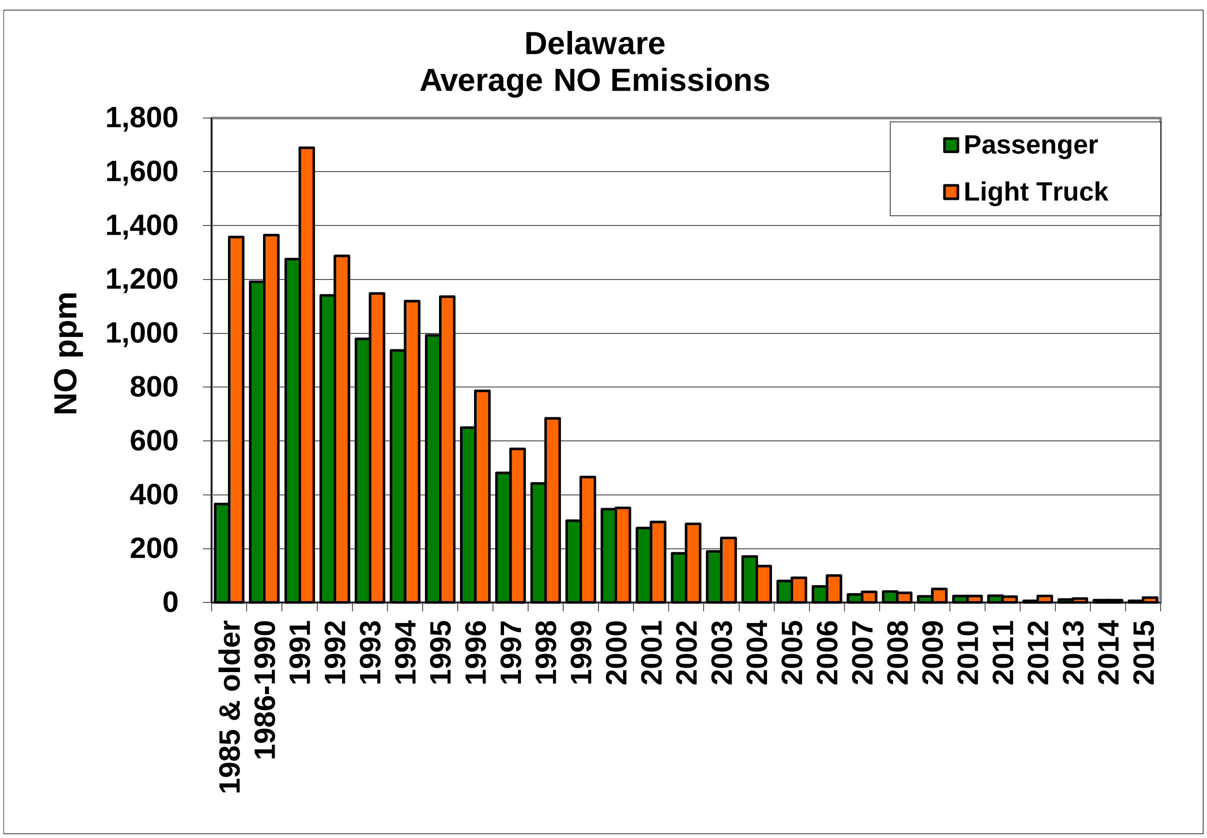


FIGURE 3-9: AVERAGE NO EMISSIONS



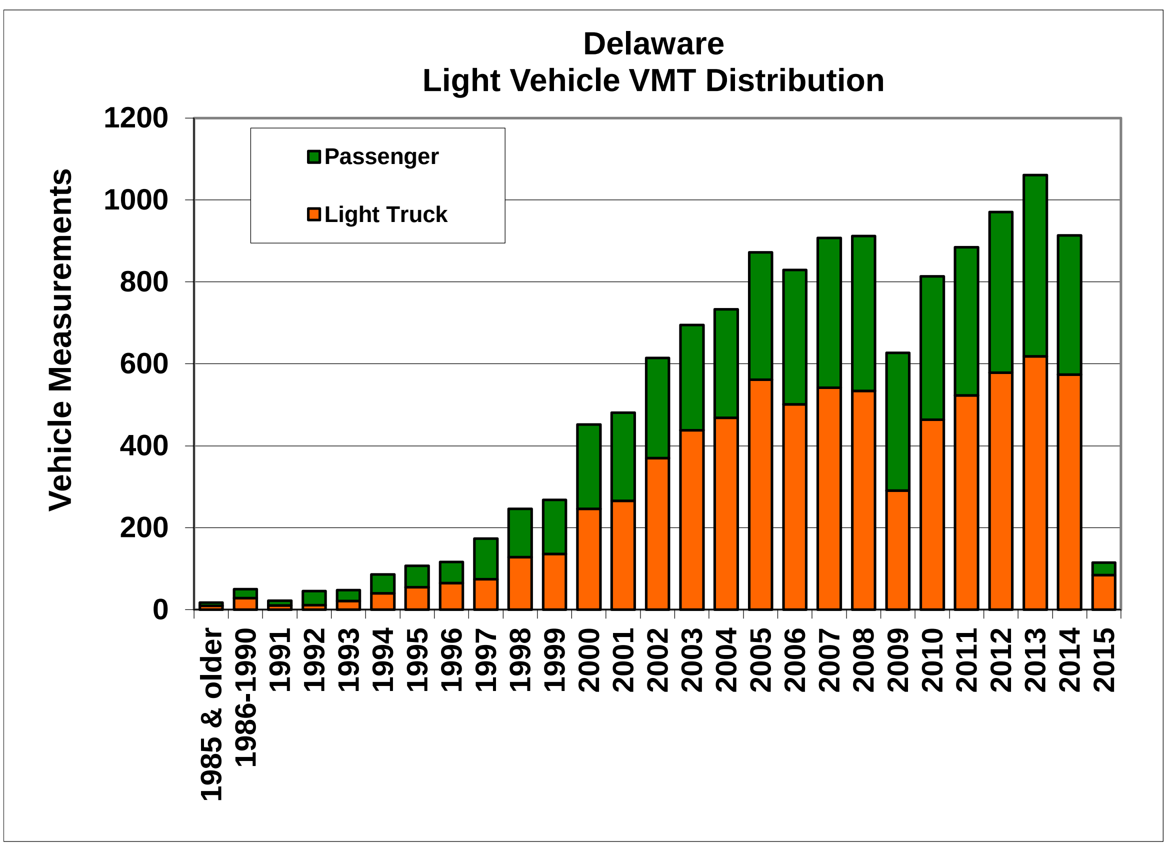
3.3.3 APPROXIMATE EMISSION CONTRIBUTIONS BY MODEL YEAR

Figures 3-10 through 3-13 illustrate the contributions to light vehicle VMT. The number of vehicle measurements is approximately representative of VMT. The exhaust emission contributions are calculated using passenger vehicle and light truck fuel economies reported in the US Department of Transportation Fuel Economy Table 1-20[i]. Starting with 2008-model vehicles, the EPA adopted a new protocol for estimating the MPG figures presented to consumers. The new protocol included driving cycles more closely representative of today's traffic and road conditions, as well as increased air conditioner usage.

Contributions of on-road emissions were skewed towards the older vehicles. 2002 and older models accounted for just 21% of on-road activity and 52%, 45% and 61% of the HC, CO and NO emissions respectively. Therefore, it is important to maintain the effectiveness of I/M programs for the vehicles over ten years old that have emissions many times those of newer vehicles.

Light trucks contributed 58% of VMT and 71%, 63% and 66% of HC, CO and NO respectively. Light truck observations were skewed more towards newer models than observations of light passenger vehicles. 2002 & newer models were 81% of truck observations vs. 77% of observations of passenger vehicles.

FIGURE 3-10: APPROXIMATE VMT CONTRIBUTION



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i http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_20.html

FIGURE 3-11: APPROXIMATE HC CONTRIBUTION

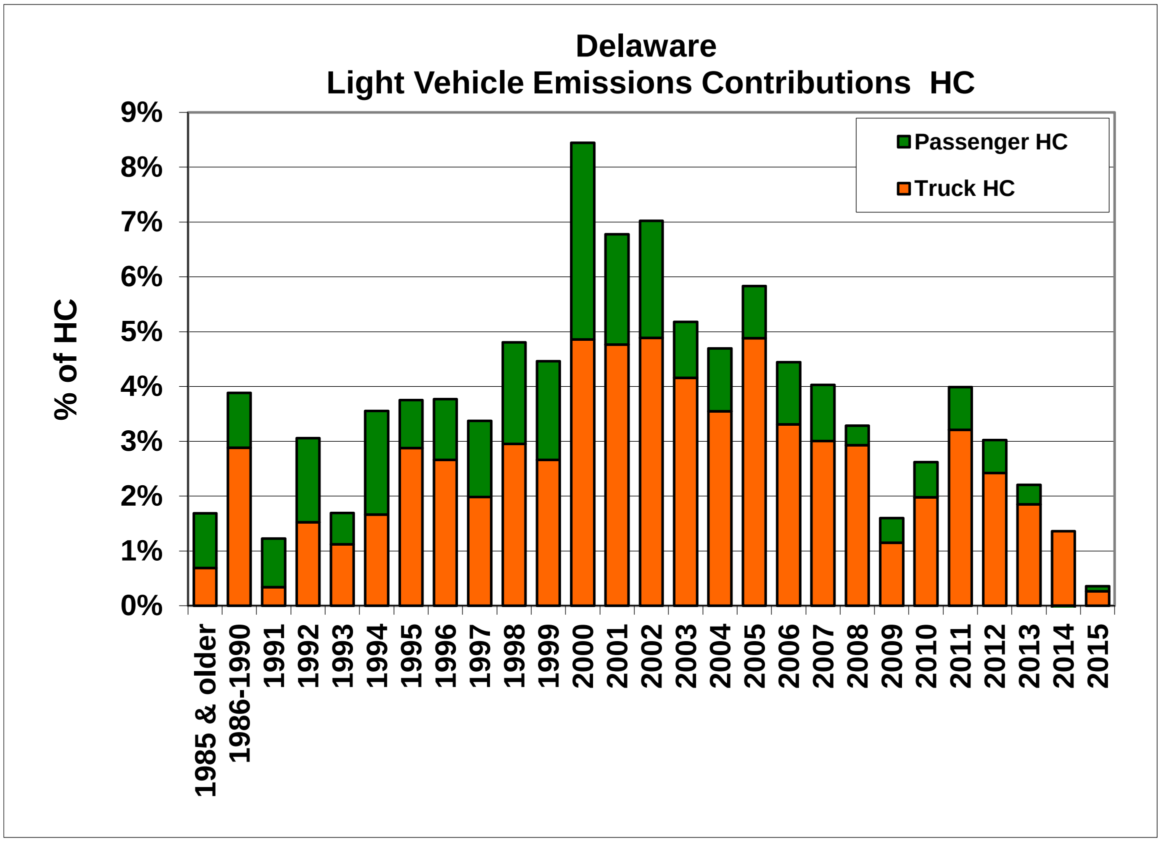


FIGURE 3-12: APPROXIMATE CO CONTRIBUTION

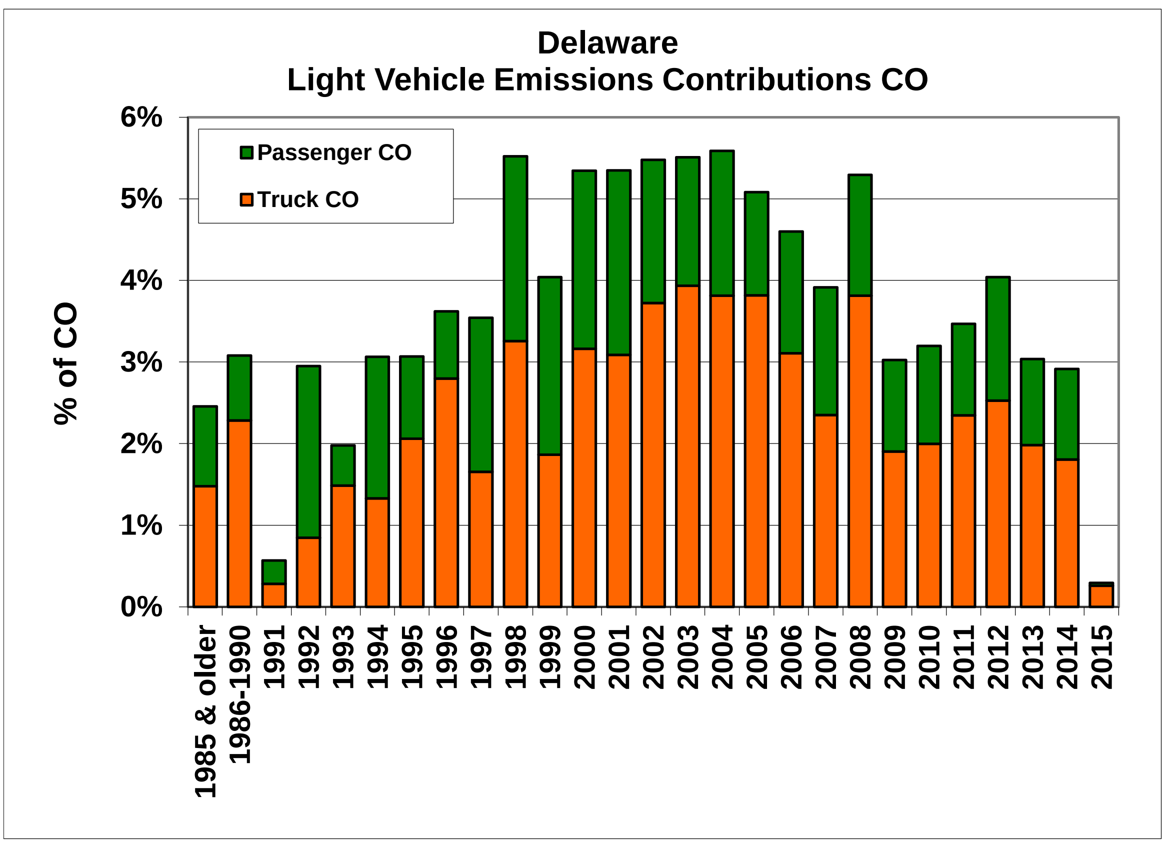
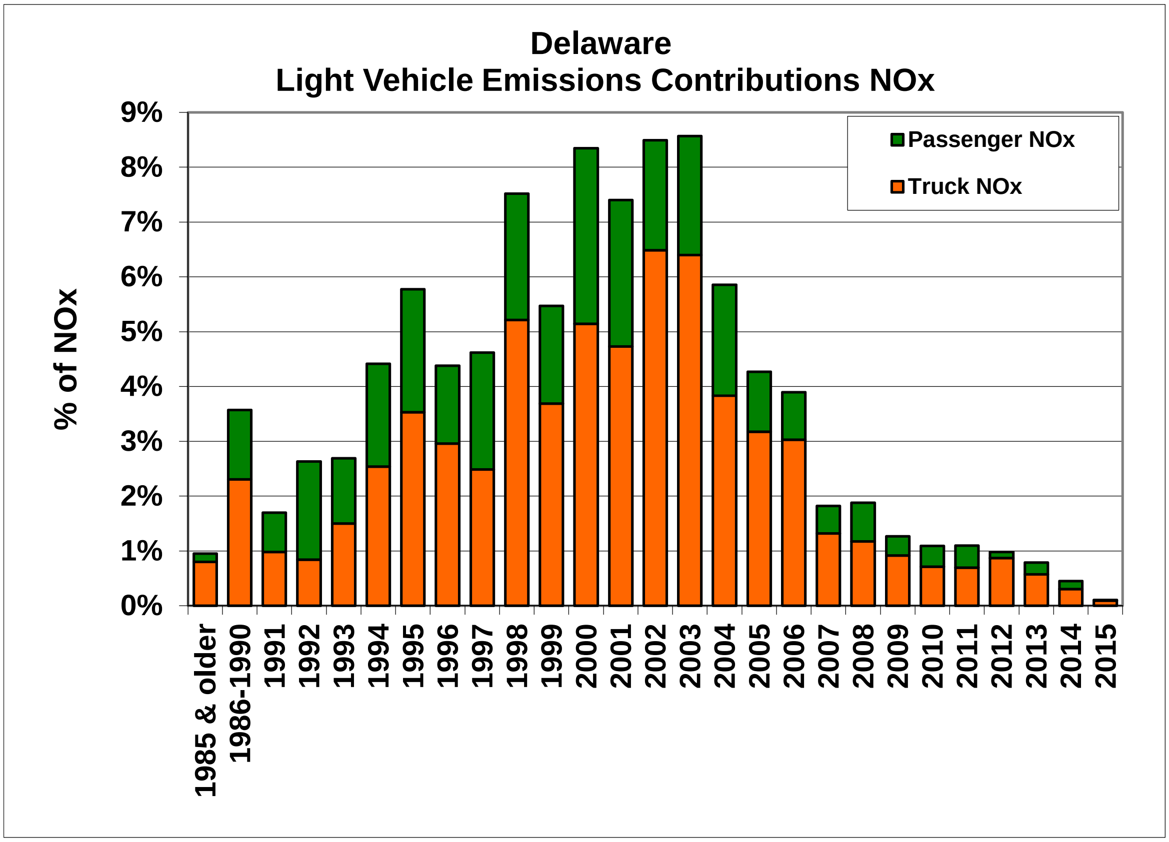


FIGURE 3-13: APPROXIMATE NOX CONTRIBUTION



4. HIGH EMITTERS

High emitters were identified using cutpoints of 500ppm HC, 3% CO, 2,000ppm NO and 0.75 RSD smoke factor. These definitions of high emitters are, admittedly, somewhat arbitrary and use higher values than the standards typically used in an inspection and maintenance program.

Of the vehicles measured on-road that were identified by plate and matched to a Delaware registration, 240 (2.3%) exceeded one or more of the pollutant cutpoints (Table 4-1). However, the 2.3% of vehicles had average emissions of 364ppm HC, 0.9% CO and 2,064 ppm NO – hundreds of times dirtier than the median vehicle. These high emitting vehicles emitted up to 33%, 19% and 30% of all light vehicle HC, CO and NO.

Table 4-2 shows the combinations of cutpoints that were exceeded. With these cutpoints a majority of the vehicles identified as high emitters were selected for high NO.

Nineteen vehicles (8%) were identified for more than one pollutant.

Table 4-1: High Emitters

	Count
Vehicles exceeding one or more cutpoints	240
Emissions cutpoints exceeded:	
HC 500 ppm hexane	58
CO 3%	22
NO 2000ppm	167
UV Smoke Factor 0.75	12
Total Cutpoints Exceeded	259

4.1 HIGH EMITTER CUTPOINTS VS. IN-USE STANDARDS

Figures 4-1 to 4-4 illustrate the relationship of the adopted RSD high emitter cutpoints to vehicle in-use standards. We only show standards through 2003 models. Standards for Tier 2 2004 and newer models are the same or lower.

The precise g/mi equivalents for RSD concentration emissions values depend on vehicle fuel economy. Typical average values of 24 mpg for light passenger vehicles and 20 mpg for light trucks were used in these Figures.

The selected high emitter cutpoints far exceed the in-use standards.

Table 4-2 Higher Emitters by Pollutant

HE Cutpoint Exceedance Combinations	Count
Single pollutant:	
HC Only	44
CO Only	18
NO Only	158
Smoke Only	5
Two Pollutants:	
HC & CO Only	3
HC & NO Only	5
CO & NO Only	0
HC & Smoke Only	2
CO & Smoke Only	0
NO & Smoke Only	1
Three Pollutants:	
HC & CO & NO	0
HC, CO & Smoke	1
HC, NO & Smoke	3
CO, NO & Smoke	0
Jackpot:	
HC, CO, NO & Smoke	0
Total	240

FIGURE 4-1 HIGH EMITTER HC VS. IN-USE STANDARDS

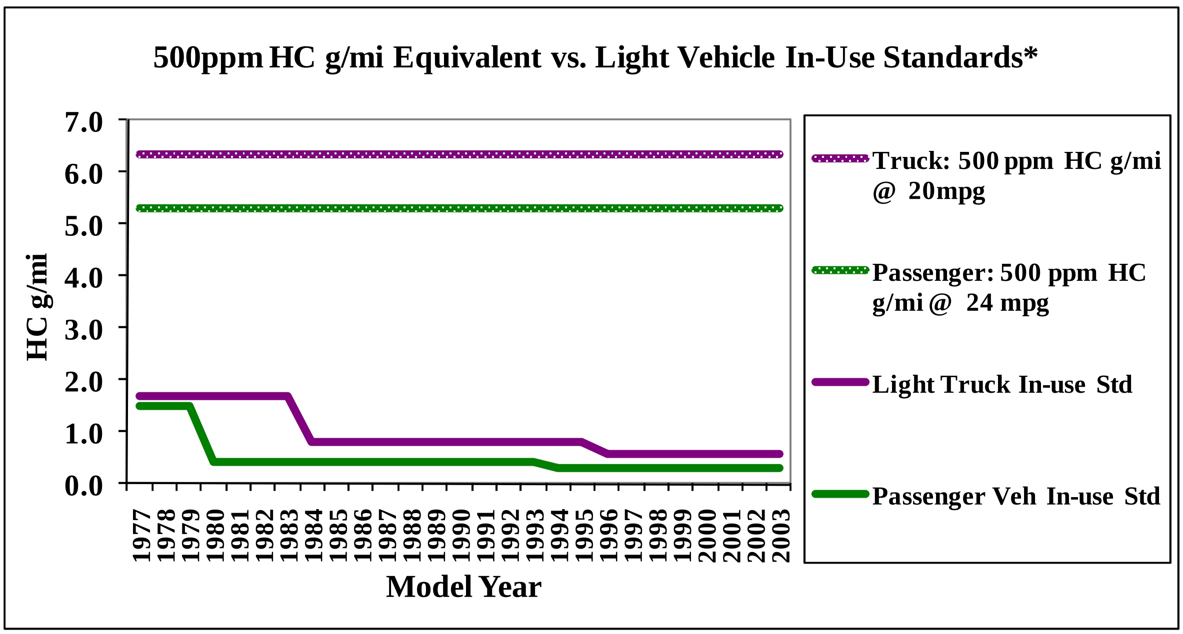


FIGURE 4-2 HIGH EMITTER CO VS. IN-USE STANDARDS

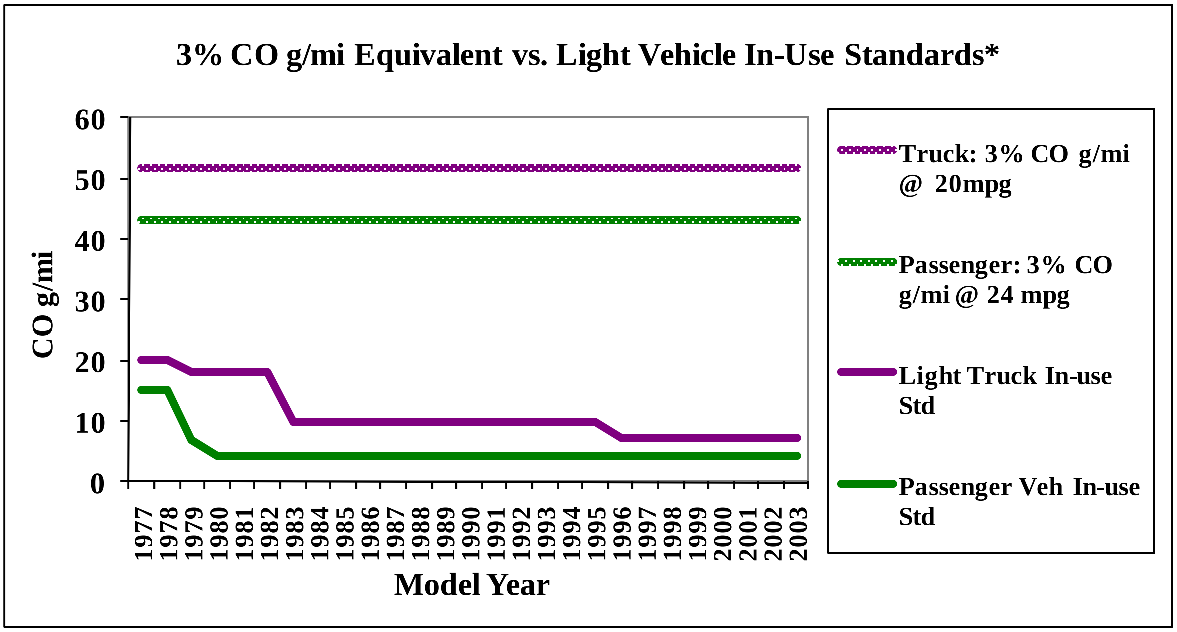
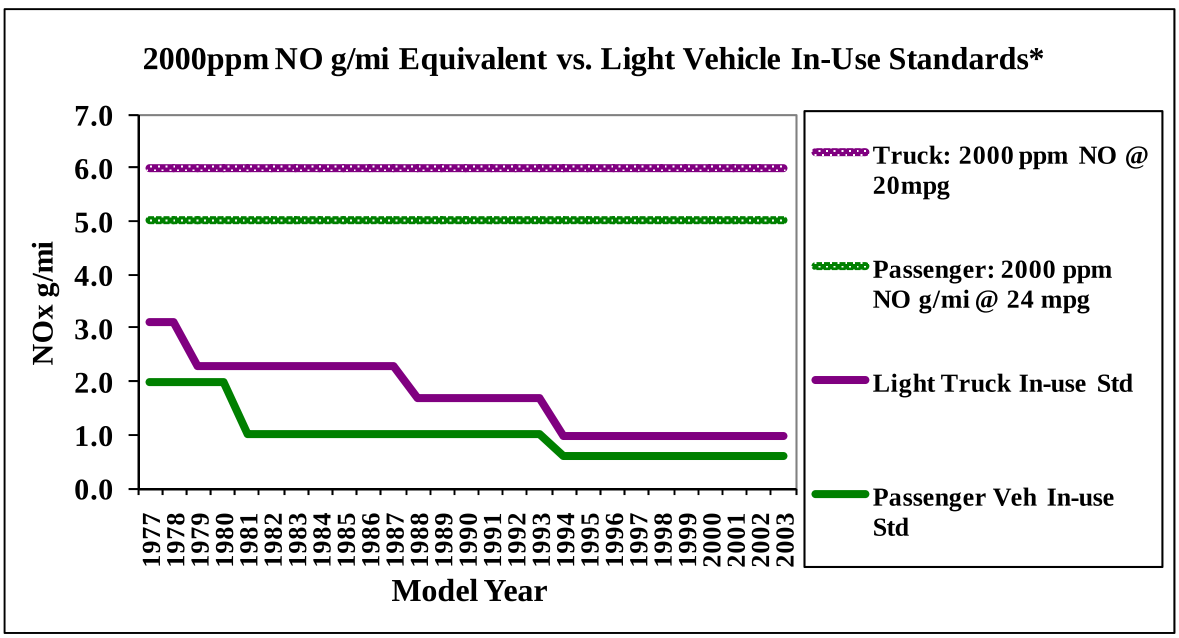
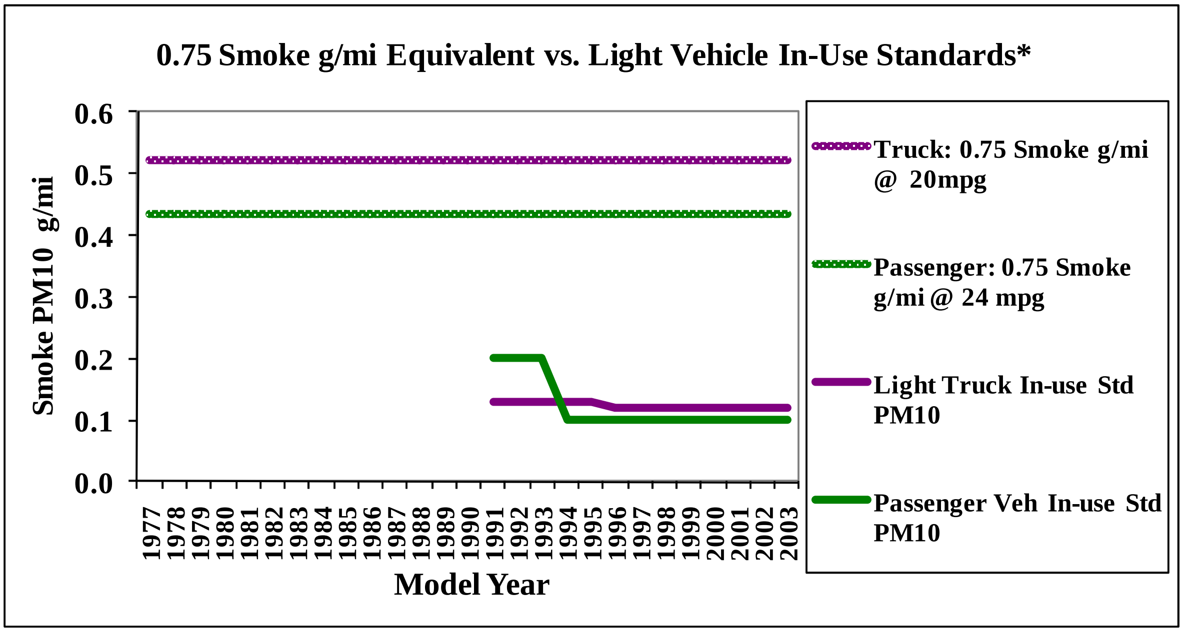


FIGURE 4-3 HIGH EMITTER NOX VS. IN-USE STANDARDS





4.2 HIGH EMITTER RATES

High emitter rates varied dramatically by model year, with the oldest models having rates of over 30% and 2006 and newer models having virtually no high emitters (Figure 4-5). Fortunately, relatively few of the oldest models remain in operation. On a positive note, high emitter rates among models less than twelve years old remained low – an average of 0.5% vs. 8.6% for older models. Models 2002 and older were 21% of vehicles measured and 83% of high emitters. Manufacturers improved component quality considerably to meet OBD-II requirements. These improvements, combined with the engine warning light that alerts owners to emissions problems, are responsible for the low rates of high emitters observed in vehicles up to ten years old at the time of the survey.

Figure 4-6 shows the number of high emitters by model year. The greatest numbers of high emitters were 1992-2003 models. A larger dataset is required to confirm more precise rates of high emitters by model year. Two thirds of the high emitters were flagged only for high NOx.

Twelve vehicles with high smoke factors are listed in Table 4-3. Although diesel fueled vehicles were only 6% of measurements they were half of the smokers. The gasoline smokers also had very high HC emissions and most had high CO or high NO. The diesel smokers were not high NO emitters.

4.3 HIGH EMITTERS WITH MULTIPLE MEASUREMENTS

Table 4-4 lists RSD measurements for the eleven high emitters with two measurements. In all cases, vehicles exceeded the same pollutant cutpoints on both measurements.

FIGURE 4-5: PERCENT OF HIGH EMITTERS BY MODEL YEAR

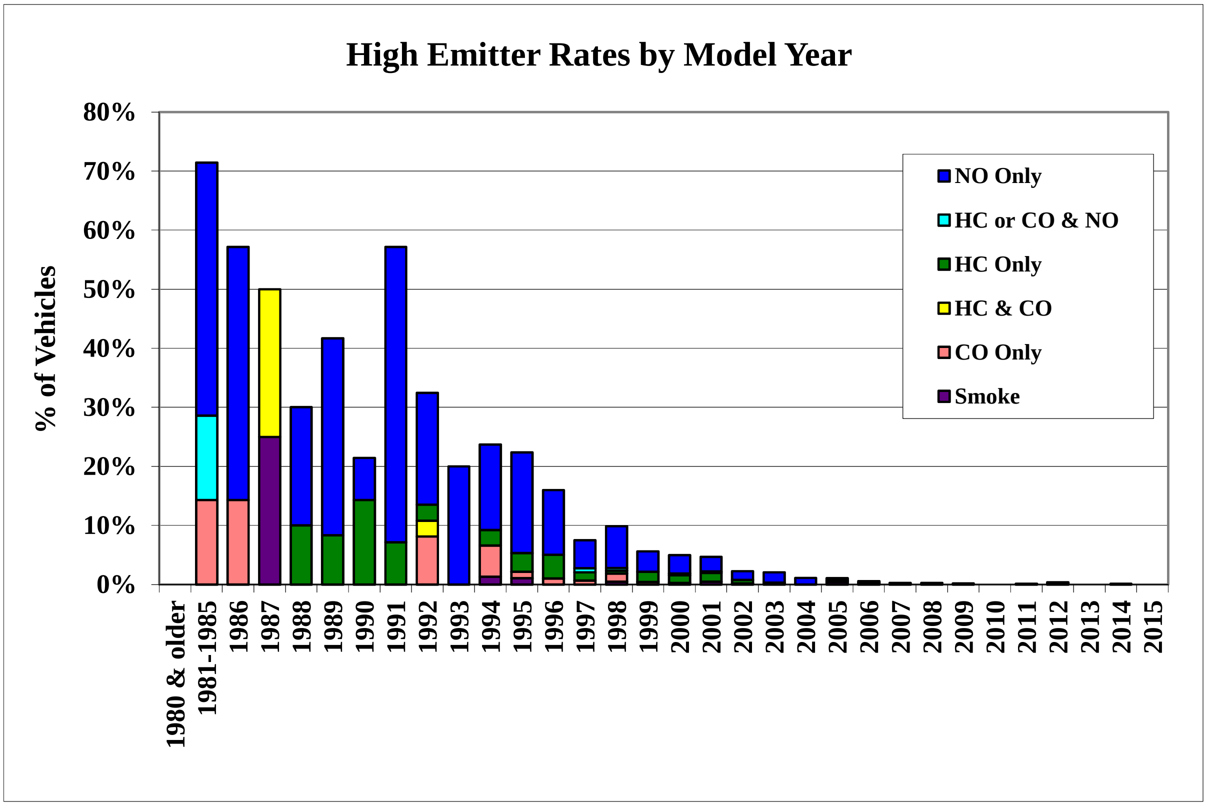


FIGURE 4-6: NUMBER OF HIGH EMITTERS BY MODEL YEAR

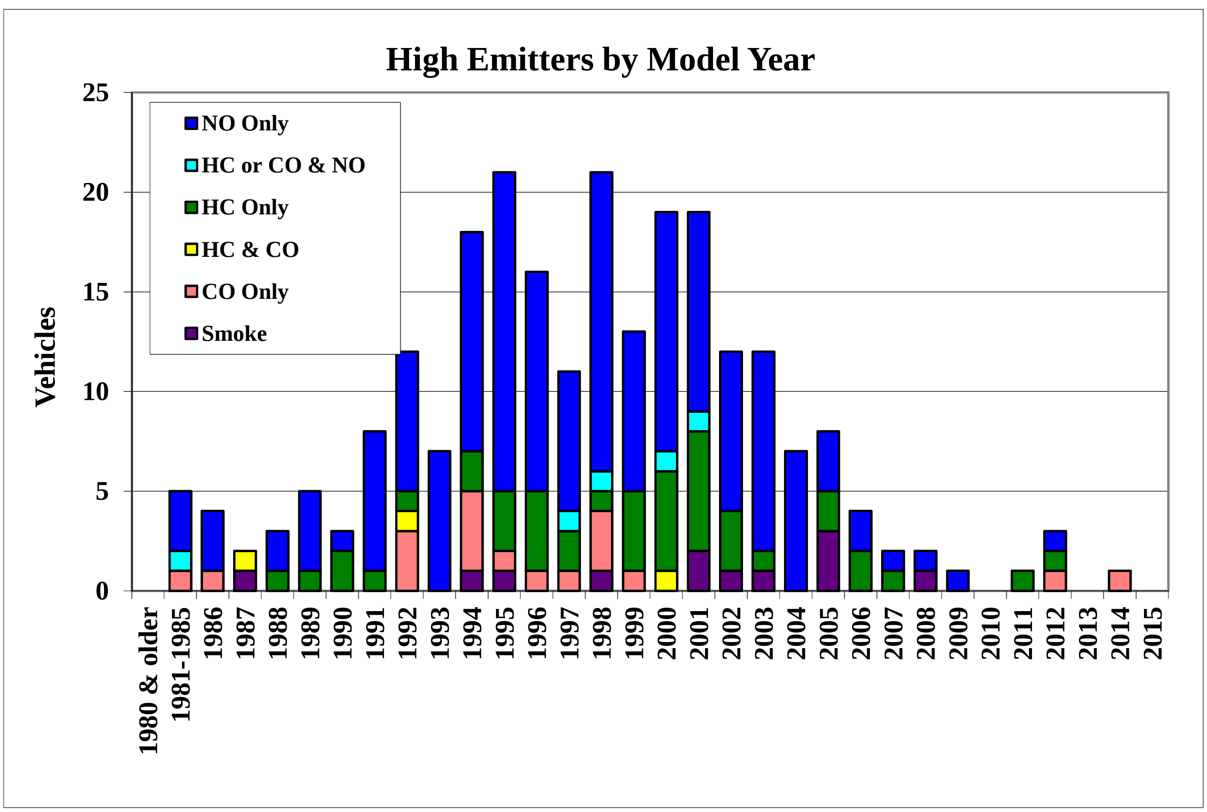


Table 4-3: Smoking Vehicles

VIN	MY	Make	Mod	Fuel	HC Cutpoint	HC ppm	CO Cutpoint	%CO	NO Cutpoint	ppm NO	Smoke Cutpoint	UV Smoke
JS4JC51CXH4165072	1987	SUZI	SAM	G	500	516	3	0.8	2000	282	0.75	2.89
1FTCR14U0RPA78191	1994	FORD	RNG	G	500	699	3	1.2	2000	3982	0.75	1.54
1GCGK24K9SE278840	1995	CHEV	GM4	G	500	1551	3	1.5	2000	2688	0.75	1.71
1C3EJ56H4WN263783	1998	CHRY	CIR	G	500	1087	3	0.7	2000	2310	0.75	5.15
1HGCG55481A092277	2001	HOND	ACC	G	500	598	3	6.8	2000	441	0.75	0.85
3VWRP29M41M077017	2001	VOLK	JET	D	500	74	3	-0.1	2000	167	0.75	0.87
JA3AJ36E02U008261	2002	MITS	LAN	G	500	445	3	0.3	2000	2097	0.75	1.19
1GCHC231X3F147017	2003	CHEV	SLV	D	500	261	3	0.1	2000	662	0.75	0.98
1FDSS34P35HA61102	2005	FORD	EC3	D	500	559	3	0.1	2000	856	0.75	1.07
1GCHK23295F847125	2005	CHEV	SLV	D	500	208	3	0.1	2000	760	0.75	0.76
1J8GL58575W663503	2005	JEEP	LIB	D	500	138	3	-0.1	2000	191	0.75	0.82
1FTSS34P08DB48181	2008	FORD	EC3	D	500	475	3	0.6	2000	368	0.75	1.30

One of eleven vehicles with two measurements was a smoking diesel. The remaining ten were high NO or high HC emitters. Nine were 1999 or older models.

Table 4-4: High Emitters with Two Measurements

VIN	MY	Make	Mod	Fuel	HC Cutpoint	HC ppm	CO Cutpoint	%CO	NO Cutpoint	ppm NO	Smoke Cutpoint	UV Smoke
1GCHC231X3F147017	2003	CHEV	SLV	D	500	295	3	0.1	2000	671	0.75	1.12
1GCHC231X3F147017	2003	CHEV	SLV	D	500	228	3	0.1	2000	652	0.75	0.84
1GNDX03E4XD311817	1999	CHEV	VEN	G	500	136	3	0.1	2000	2293	0.75	-0.03
1GNDX03E4XD311817	1999	CHEV	VEN	G	500	319	3	0.2	2000	2324	0.75	-0.04
1HGCD5651RA082167	1994	HOND	ACC	G	500	43	3	1.1	2000	2208	0.75	-0.01
1HGCD5651RA082167	1994	HOND	ACC	G	500	58	3	0.1	2000	3402	0.75	-0.01
1J4FJ68SXSL540743	1995	JEEP	CHK	G	500	293	3	0.8	2000	3599	0.75	0.21
1J4FJ68SXSL540743	1995	JEEP	CHK	G	500	282	3	0.5	2000	3378	0.75	0.14
1J4FJ78SXWL180546	1998	JEEP	CHK	G	500	108	3	1.5	2000	2152	0.75	0.11
1J4FJ78SXWL180546	1998	JEEP	CHK	G	500	60	3	2.8	2000	2130	0.75	0.18
1JCMT7544JT013250	1988	JEEP	WAG	G	500	287	3	1.1	2000	3263	0.75	0.13
1JCMT7544JT013250	1988	JEEP	WAG	G	500	91	3	0.6	2000	2167	0.75	0.07
2B4FK25K3LR655531	1990	DODG	CVN	G	500	169	3	0.4	2000	2304	0.75	0.14
2B4FK25K3LR655531	1990	DODG	CVN	G	500	139	3	0.4	2000	2628	0.75	0.12
2GTEC19W8T1555426	1996	GMC	SIE	G	500	109	3	0.8	2000	2385	0.75	0.11
2GTEC19W8T1555426	1996	GMC	SIE	G	500	72	3	1.0	2000	2199	0.75	0.07
SAJEB52D24XE08868	2004	JAGU		G	500	328	3	1.5	2000	2064	0.75	0.16
SAJEB52D24XE08868	2004	JAGU		G	500	281	3	0.3	2000	3977	0.75	0.16
WBABB2309KEC18003	1989	BMW	32I	G	500	546	3	0.5	2000	1108	0.75	0.07
WBABB2309KEC18003	1989	BMW	32I	G	500	583	3	0.1	2000	1251	0.75	0.07
WDBCA35E4MA604388	1991	MERZ	420	G	500	1106	3	0.6	2000	-14	0.75	-0.02
WDBCA35E4MA604388	1991	MERZ	420	G	500	658	3	0.3	2000	17	0.75	0.02

5. FINDINGS

Following are the results of the RSD survey:

- Average emissions of Delaware registered light vehicles were 25 ppm HC hexane, 0.10% CO and 142 ppm NO.
- Tier 2 models, 2004 and newer, appear so far to have very well controlled emissions.
- Contributions of on-road emissions were skewed towards the older vehicles. Among Delaware registered light vehicles, 2002 and older models accounted for 21% of on-road activity and for 52%, 45% and 61% of the HC, CO and NO emissions respectively.
- A small fraction of vehicles had very high emissions and contributed a substantial portion of light vehicle emissions:
    - 240 (2.3%) of vehicles had HC greater than 500 ppm or CO emissions greater than 3% or NO greater than 2000 ppm or smoke greater than 0.75 RSD smoke factor.
    - These high emitting vehicles emitted up to 33%, 19% and 30% of all light vehicle HC, CO and NO.
- Eighty four percent of vehicles measured at the survey locations were registered in Delaware, 5% were from Pennsylvania, 4% from Maryland, 3% from New Jersey, 1% from Virginia, less than 1% from New York and 2% other states.