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On-Road Remote Sensing of Automobile Emissions in the Los Angeles Area: Year 1

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EXECUTIVE SUMMARY

The University of Denver conducted a nine-day remote sensing study in the Los Angeles, CA area in the summer of 1999. The remote sensor used in this study is capable of measuring the ratios of CO, HC, and NO to CO_2 in motor vehicle exhaust. From these ratios, we calculate the percent concentrations of CO, CO_2, HC and NO in motor vehicle exhaust which would be observed by a tailpipe probe, corrected for water and any excess oxygen not involved in combustion. The system used in this study was also configured to determine the speed and acceleration of the vehicle, and was accompanied by a video system to record the license plate of the vehicle.

Nine days of fieldwork between June 28 - July 7, 1999 were conducted on the uphill exit ramp from 91N to 60W in Riverside, CA. A database was compiled containing 18,752 records for which the State of California provided make and model year information. All of these records contained valid measurements for at least CO and CO_2, 18,348 contained measurements for HC and 18,740 for NO data.

The mean percent CO, HC, and NO were determined to be 0.55%, 0.020%, and 0.037%, respectively with an average model year of 1992.4. The mean emissions in gm/kg of fuel consumed for CO, HC and NO were 67.3, 4.1 and 5.2. The fleet emissions measured in this study exhibit a gamma distribution, with the dirtiest 10% of the fleet responsible for 70%, 53%, and 51% of the CO, HC, and NO emissions, respectively.

The majority of vehicles (64%) at this location were measured once. The remaining 36% of the measurements were of vehicles measured at least twice. By removing all of the repeat measurements from the database and allowing each vehicle to appear only once, we have shown that these repeat measurements are not skewing the results and that the full database is statistically representative of the actual fleet at the measurement site. This was the first year of a five-year continuing study to characterize motor vehicle emissions and deterioration in the Los Angeles area.

INTRODUCTION

Many cities in the United States are in violation of the air quality standards established by the Environmental Protection Agency. Carbon monoxide (CO) levels become elevated primarily due to direct emission of the gas, and ground-level ozone, a major component of urban smog, is produced by the photochemical reaction of nitrogen oxides (NO_x) and hydrocarbons (HC). As of 1996, on-road vehicles were the single largest source for the major atmospheric pollutants, contributing 60% of the CO, 29% of the HC, and 31% of the NO_x to the national emission inventory.[1]

According to Heywood[2], carbon monoxide emissions from automobiles are at a maximum when the air/fuel ratio is rich of stoichiometric, and are caused solely by a lack of adequate air for complete combustion. Hydrocarbon emissions are also maximized with a rich air/fuel mixture, but are slightly more complex. When ignition occurs in the combustion chamber, the flame front cannot propagate within approximately one millimeter of the relatively cold cylinder wall. This results in a quench layer of unburned fuel mixture on the cylinder wall, which is scraped off by the rising piston and sent out the exhaust manifold. With a rich air/fuel mixture, this quench layer simply becomes more concentrated in HC, and thus more HC is sent out the exhaust manifold by the rising piston. There is also the possibility of increased HC emissions with an extremely lean air/fuel mixture, when a misfire occurs and an entire cylinder of unburned fuel mixture is emitted into the exhaust manifold. Nitric oxide (NO) emissions are maximized at high temperatures when the air/fuel mixture is slightly lean of stoichiometric, and are limited during rich combustion by a lack of excess oxygen and during extremely lean combustion by low flame temperatures. In most vehicles, practically all of the on-road NO_x is emitted in the form of NO.[2] Properly operating modern vehicles with three-way catalysts are capable of partially (or completely) converting engine-out CO, HC and NO emissions to CO_2, H_2O and N_2.[2]

Control measures to decrease mobile source emissions in non-attainment areas include inspection and maintenance (I/M) programs, oxygenated fuel mandates, and transportation control measures, but the effectiveness of these measures remains questionable. Many areas remain in non-attainment, and with the new 8-hour ozone standards introduced by the EPA in 1997, many locations still violating the standard may have great difficulty reaching attainment.[3]

The remote sensor used in this study was developed at the University of Denver for measuring the pollutants in motor vehicle exhaust, and has previously been described in the literature.[4,5] The instrument consists of a non-dispersive infrared (IR) component for detecting carbon monoxide, carbon dioxide (CO_2), and hydrocarbons, and a dispersive ultraviolet (UV) spectrometer for measuring nitric oxide. The source and detector units are positioned on opposite sides of the road in a bi-static arrangement. Collinear beams of IR and UV light are passed across the roadway into the IR

detection unit, and are then focused onto a dichroic beam splitter, which serves to separate the beams into their IR and UV components. The IR light is then passed onto a spinning polygon mirror, which spreads the light across the four infrared detectors: CO, CO_2, HC and reference.

The UV light is reflected off the surface of the beam splitter and is focused into the end of a quartz fiber-optic cable, which transmits the light to an ultraviolet spectrometer. The UV unit is then capable of quantifying nitric oxide by measuring an absorbance band at 226.5 nm in the ultraviolet spectrum and comparing it to a calibration spectrum in the same wavelength region.

The exhaust plume path length and density of the observed plume are highly variable from vehicle to vehicle, and are dependent upon, among other things, the height of the vehicle's exhaust pipe, wind, and turbulence behind the vehicle. For these reasons, the remote sensor can only directly measure ratios of CO, HC or NO to CO_2. The ratios of CO, HC, or NO to CO_2, termed Q, Q' and Q" respectively, are constant for a given exhaust plume, and on their own are useful parameters for describing a hydrocarbon combustion system. This study reports measured emissions as %CO, %HC and %NO in the exhaust gas, corrected for water and excess oxygen not used in combustion. However, these percent emissions can be directly converted into mass emissions per gallon or kilogram of fuel used. We now prefer to use the g/kg of fuel conversion since they do not require any assumptions about the fuel density. These equations are shown below:

$$\text{gm CO/kg} = (28 \times \%CO/\%CO_2 \,/\, (\%CO/\%CO_2 + 1 + 3\times\%HC/\%CO2)) \,/\, 0.014$$

$$\text{gm HC/kg} = (48 \times \%HC/\%CO_2 \,/\, (\%CO/\%CO_2 + 1 + 3\times\%HC/\%CO2)) \,/\, 0.014$$

$$\text{gm NO/kg} = (30 \times \%NO/\%CO_2 \,/\, (\%CO/\%CO_2 + 1 + 3\times\%HC/\%CO2)) \,/\, 0.014$$

where the 28, 48 and 30 are grams/mole for CO, HC (as propane) and NO respectively and 0.014 is the kg of fuel per mole of carbon assuming gasoline is stoichiometrically CH_2. It turns out that gm/kg of fuel calculations are very insensitive to the small changes observed in the carbon to hydrogen ratio because in all cases the majority of the fuel mass is the (measured) carbon component. Gm/gallon calculations are effected linearly by changes in fuel density which are however also quite small.

Quality assurance calibrations are performed as dictated in the field by the atmospheric conditions and traffic volumes. A puff of gas containing certified amounts of CO, CO_2, propane and NO is released into the instrument's path, and the measured ratios from the instrument are then compared to those certified by the cylinder manufacturer (Praxair). These calibrations account for day-to-day variations in instrument sensitivity and variations in ambient CO_2 levels caused by atmospheric pressure and instrument path length. Since propane is used to calibrate the instrument, all hydrocarbon measurements reported by the remote sensor are as propane equivalents.

Studies sponsored by the California Air Resources Board and General Motors Research Laboratories have shown that the remote sensor is capable of CO measurements that are correct to within ±5% of the values reported by an on-board gas analyzer, and within ±15% for HC.[6,7] The NO channel used in this study has been extensively tested by the University of Denver, but we are still awaiting the opportunity to participate in an extensive blind study and instrument intercomparison to have it independently validated. Tests involving a late-model low-emitting vehicle indicate a detection limit ($\pm 3\sigma$) of 25 ppm for NO, with an error measurement of ±5% of the reading at higher concentrations. Appendix A gives a list of the criteria for valid/invalid data.

The remote sensor is accompanied by a video system to record a freeze-frame image of the license plate of each vehicle measured. The emissions information for the vehicle, as well as a time and date stamp, are also recorded on the video image. The images are stored on videotape, so that license plate information may be incorporated into the emissions database during post-processing. A device to measure the speed and acceleration of vehicles driving past the remote sensor was also used in this study. The system consists of a pair of infrared emitters and detectors (Banner Industries) which generate a pair of infrared beams passing across the road, 6 feet apart and approximately 2 feet above the surface. Vehicle speed is calculated from the time that passes between the front of the vehicle blocking the first and the second beam. To measure vehicle acceleration, a second speed is determined from the time that passes between the rear of the vehicle unblocking the first and the second beam. From these two speeds, and the time difference between the two speed measurements, acceleration is calculated, and reported in mph/s.

The purpose of this report is to describe the remote sensing measurements made in the Los Angeles, CA area in June/July 1999, under CRC contract no. E-23-4. Measurements were made for 9 days between Monday, June 28 to Wednesday, July 7 (excluding the holidays Sunday 7/3 and Monday 7/4), on the uphill exit ramp (slope of 4.35°) from 91N to 60W in Riverside, CA (see Figure 1). The site measurements were generally made between the hours of 7:30 and 19:00. The physical locations of the source and detector units are marked with paint on the pavement to enable the exact relocation of the equipment in the following years. This was the first year of a 5-year study to characterize motor vehicle emissions and deterioration in the Los Angeles area.

RESULTS AND DISCUSSION

Following the nine days of data collection in June/July of 1999, the videotapes were read for license plate identification. Plates which appeared to be in-state and readable were sent to the California Bureau of Automotive Repair to be matched against

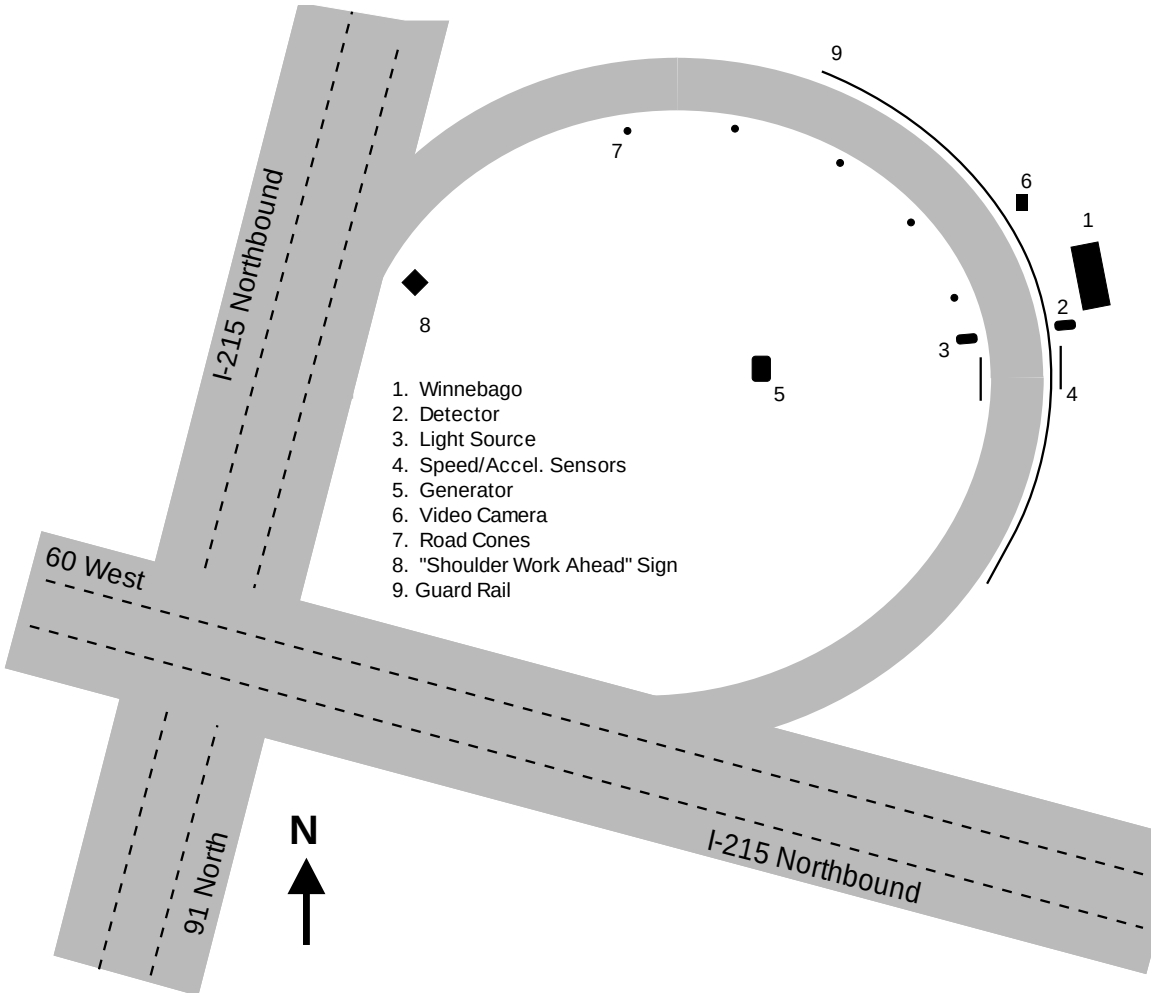

Figure 1. Schematic representation of the remote sensing site in Riverside, CA.

registration records. The resulting database contained 18,752 records with registration information and valid measurements for at least CO and CO_2. Some of these records also contained valid measurements for HC and NO (see Table I). The table describes the data reduction process beginning with the number of attempted measurements and ending with the number of records containing both valid emissions measurements and vehicle registration information. An attempted measurement is defined as a beam block followed by a half second of data collection. If the data collection period is interrupted by another beam block from a close following vehicle, the measurement attempt is aborted and an attempt is made at measuring the second vehicle. In this case, the beam block from the first vehicle is not recorded as an attempted measurement. Invalid measurement attempts arise when the vehicle plume is highly diluted, or the reported error in the ratio of the pollutant to CO_2 exceeds a preset limit (see Appendix A). The complete structure of the database and the definition of terms is included in Appendix B. The temperature and humidity data were recorded manually at the site during the measurements and are listed in Appendix C.

Table I. Data Summary

	CO	HC	NO
Attempted Measurements	26,001		
Valid Measurements Percent of Attempts	24,217 93.1%	23,995 92.3%	24,199 93.1%
Submitted Plates Percent of Attempts Percent of Valid Measurements	20,117 77.4% 83.1%	19,866 76.4% 82.8%	20,033 77.0% 82.8%
Matched Plates Percent of Attempts Percent of Valid Measurements Percent of Submitted Plates	18,752 72.1% 77.4% 93.2%	18,348 70.6% 76.5% 92.4%	18,740 72.1% 77.4% 93.5%
Mean (%) (gm/kg of fuel)	0.55 (67.3)	0.020 (4.1)	0.037 (5.2)
Median (%) (gm/kg of fuel)	0.09 (12)	0.011 (2.4)	0.010 (1.3)
Percent of Total Emissions from Dirtiest 10% of the Fleet	69.6	52.8	51.1
Mean Model Year	1992.4		
Mean Speed (mph)	24.1		
Mean Accel (mph/sec)	0.43		

The layout and grade at this site are almost identical to the sampling site which we are using in Denver, CO. All of the traffic at this site consists of fully warmed up vehicles operating under a well controlled, loaded driving mode resulting in a high successful measurement rate for all species. One difference between this site and the one in Denver is that the traffic volume is much lower (400 to 500 vehicles per hour versus 1200 to 2000 vehicles per hour) and the resulting lack of congestion on the Riverside ramp produces vehicle specific powers which are rarely negative. The other major difference at this site was the high temperatures experienced during the data collection (see Appendix C). Many days saw the temperatures reach the upper 90's and it would be expected that most of the vehicles so equipped would be using air conditioning at all of the data collection times.

The largest drop-off in recoverable data for this site occurred between the number of valid measurements and readable plates. This data loss is much larger than at any of the other sites and resulted in the final database being less than the desired number of 20,000 measurements. Two factors we have identified which contributed to this are the readability of the older yellow on blue California plates (these plates are usually only readable for an hour or two a day when the plates are illuminated by direct sunlight) and the large number of light-duty trucks and SUV's which have trailer balls attached to their bumpers blocking the plate. To remedy this in the future years we will have to acquire additional measurements.

Figure 2 shows the distribution of CO, HC, and NO emissions by percent category from the data collected in this study. The solid bars show the percentage of the fleet in a given emissions category, and the shaded bars show the percentage of the total emissions contributed by the given category. This figure illustrates the skewed nature (gamma distributed) of automobile emissions, showing that the lowest emission category for each of three pollutants is occupied by no less than 70% of the fleet (for HC), and as much as 87% of the fleet (for CO). The fact that the cleanest 87% of the vehicles are responsible for only 23% of the CO emissions further demonstrates how the emissions picture can be dominated by a small number of high emitting vehicles.

Figure 3 illustrates the data in a different manner. The fleet is divided into deciles, showing the mean measurement for each decile. The ten bars illustrate the emissions that a fleet of ten vehicles would have if it were statistically identical to the observed fleet. For CO and HC the lowest five deciles are each given the average of all five. For NO the first four are given the average of all four, since we do not claim that the small differences that arise from one category to the next are significant.

The inverse relationship between vehicle emissions and model year has been observed at a number of locations around the world, and Figure 4 shows that the fleet reported in this study is not an exception.[4] The plot of %NO vs. model year appears to be nearly linear and does not show any asymptotic tendencies at either age extreme when compared to the plots for CO and HC. Unlike data collected in Chicago, only the NO emissions show a tendency for the mean emissions to increase slightly for the 1999 model year[8]. There were 1,372 1999 model year vehicles measured compared to 1,923 1998 model year vehicles giving each year a large enough fleet to eliminate a possible sampling bias. Because the median is not affected, this may truly be a result of differences in driving mode, however the mean and median vehicle specific powers are nearly identical for the two model years. Further examination reveals that in model year 1999 127 out of 1,372 (9.3%) vehicles are listed as diesel compared with only 2.8% in 1998. The model year with the next highest percentage of diesels is model year 1995 with 5% and the average for the entire database is 4%. The observed emissions increase in the newest model year does not appear to be related to that observed in the Chicago measurements but due to the fleet makeup.

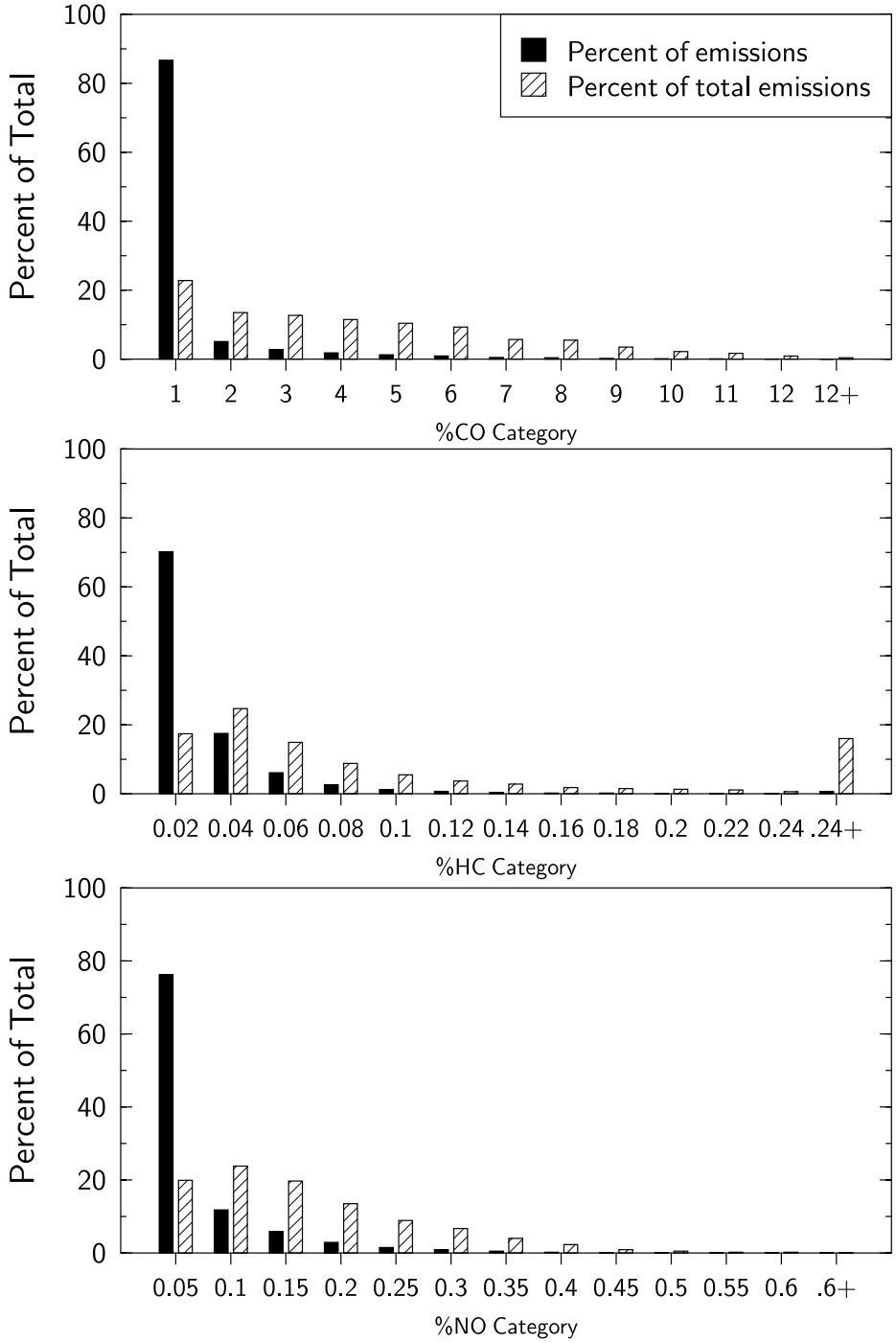

Figure 2. Emissions distributions showing the percentage of the fleet in a given emissions category (solid bars) and the percentage of the total emissions contributed (shaded bars).

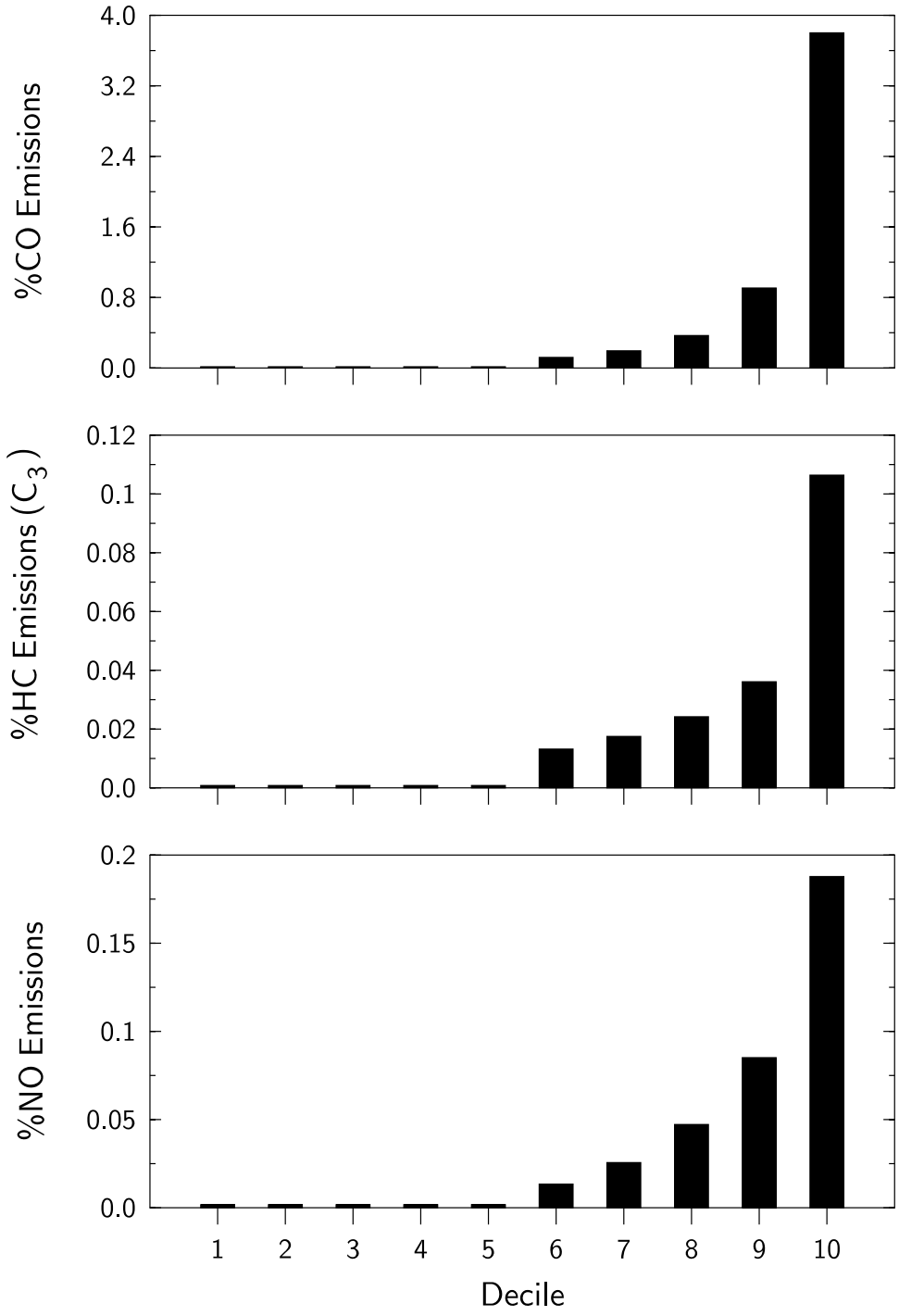

Figure 3. Fleet emissions organized into deciles. For CO and HC the lowest seven deciles and the NO the lowest six deciles are represented by the average of the group.

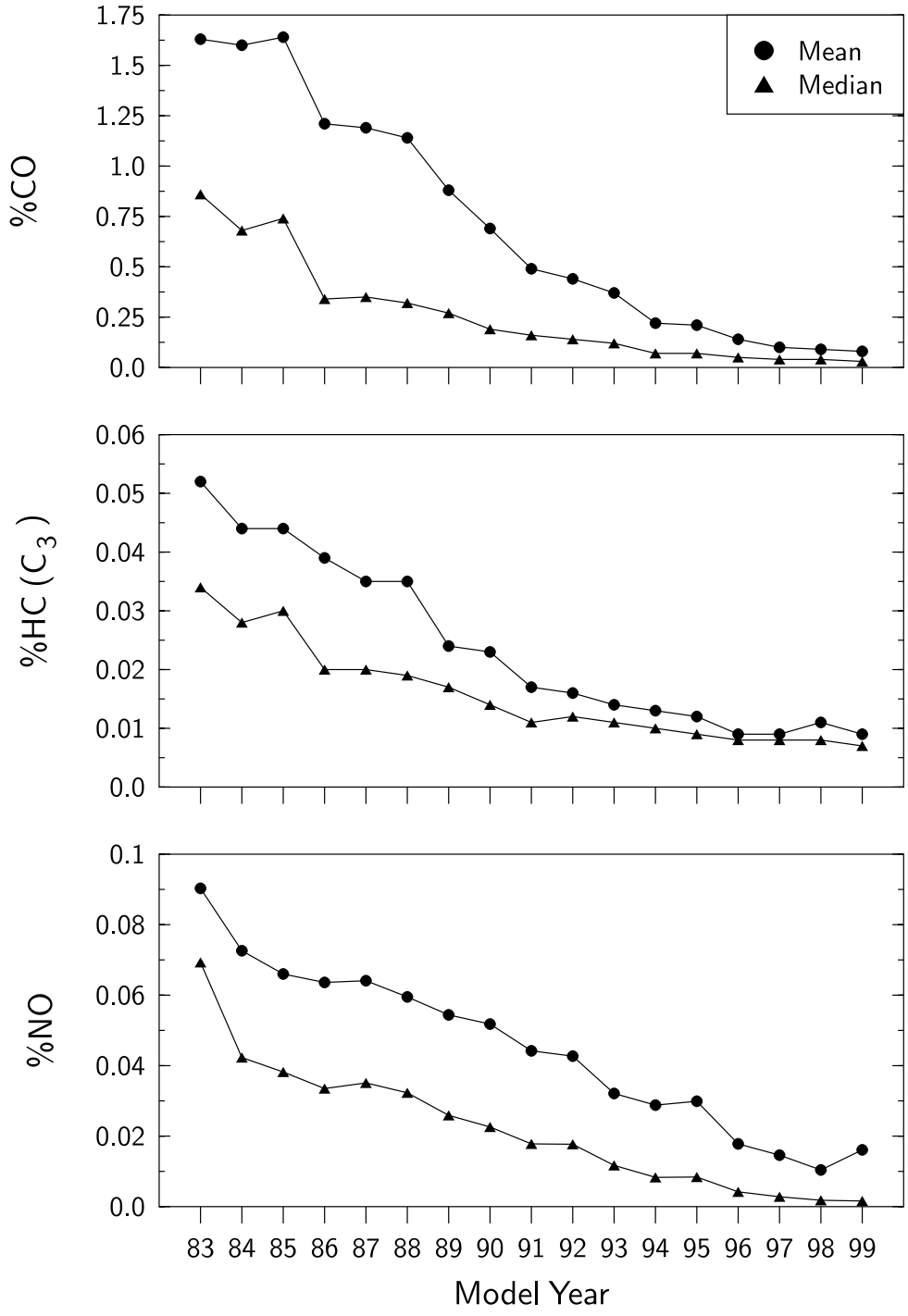

Figure 4. Mean and median emissions illustrated as a function of model year.

Plotting vehicle emissions by model year, with each model year divided into emission quintiles results in the plots shown in Figure 5. Very revealing is the fact that, for all three major pollutants, the cleanest 40% of the vehicles, regardless of model year, make an essentially negligible contribution to the total emissions. This observation was first reported by Ashbaugh and Lawson in 1991[9]. The results shown here continue to demonstrate that broken emissions control equipment has a greater impact on fleet emissions than vehicle age.

An equation for determining the instantaneous power of an on-road vehicle has been proposed by Jimenez[10], which takes the form

$$SP = 4.364 \times \sin(slope) \times v + 0.22 \times v \times a + 0.0657 \times v + 0.000027 \times v^3$$

where SP is the vehicle specific power in kW/metric tonne, *slope* is the slope of the roadway (in degrees), v is vehicle speed in mph, and a is vehicle acceleration in mph/s. Using this equation, vehicle specific power was calculated for all measurements with valid speed and acceleration in the database. The emissions data were binned according to vehicle specific power, and illustrated in Figure 6. The solid line in Figure 6 provides the number of measurements in each bin. Unlike all of the other sites these plots are less pronounced with both the HC and NO plots being rather flat, and only at very high vehicle specific powers is an increase in emissions for CO and NO observed. As mentioned previously, the lack of congestion at this site has eliminated almost all vehicles which had a negative vehicle specific power (only 802 vehicles out of 16,956 or 4.73%) and thus very few decelerations are observed at this ramp. This helps to explain the flatness in the HC plot. The rise in NO concentrations at low vehicle specific powers in the NO plot cannot be explained by the presence of diesels and at this time is unexplained.

Table II provides an analysis of the number of vehicles that were measured repeatedly, and the number of times they were measured. Of the 18,752 records used in this fleet analysis, 14,536 (76%) were contributed by vehicles measured once, and the remaining 4,216 (24%) records were from vehicles measured at least twice.

CONCLUSION

The University of Denver successfully completed the first year of a 5-year remote sensing study in the Los Angeles area to investigate trends and other characteristics of on-road emissions. Nine days of fieldwork (June 28 - July 7, 1999) were conducted on the uphill exit ramp from 91N to 60W in Riverside, CA. A database was compiled containing 18,752 records for which the State of California provided make and model year information. All of these records contained valid measurements for at least CO and CO_2, and 18,348 contained measurements for HC and 18,740 contained NO data.

The mean measurements for CO, HC, and NO were determined to be 0.55%, 0.020% and 0.037%, respectively with an average model year of 1992.4. The mean emissions

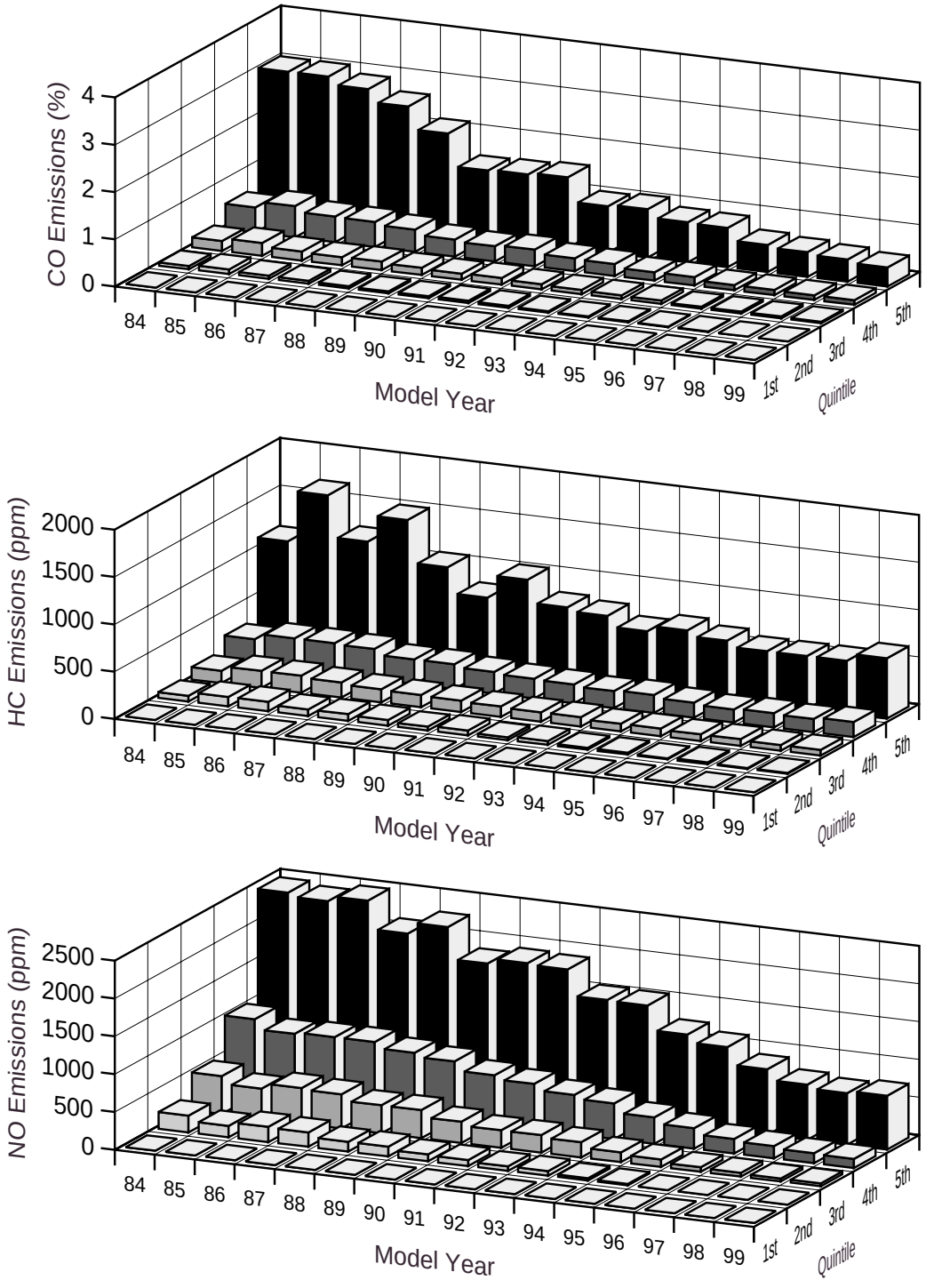

Figure 5. Vehicle emissions by model year, divided into quintiles.

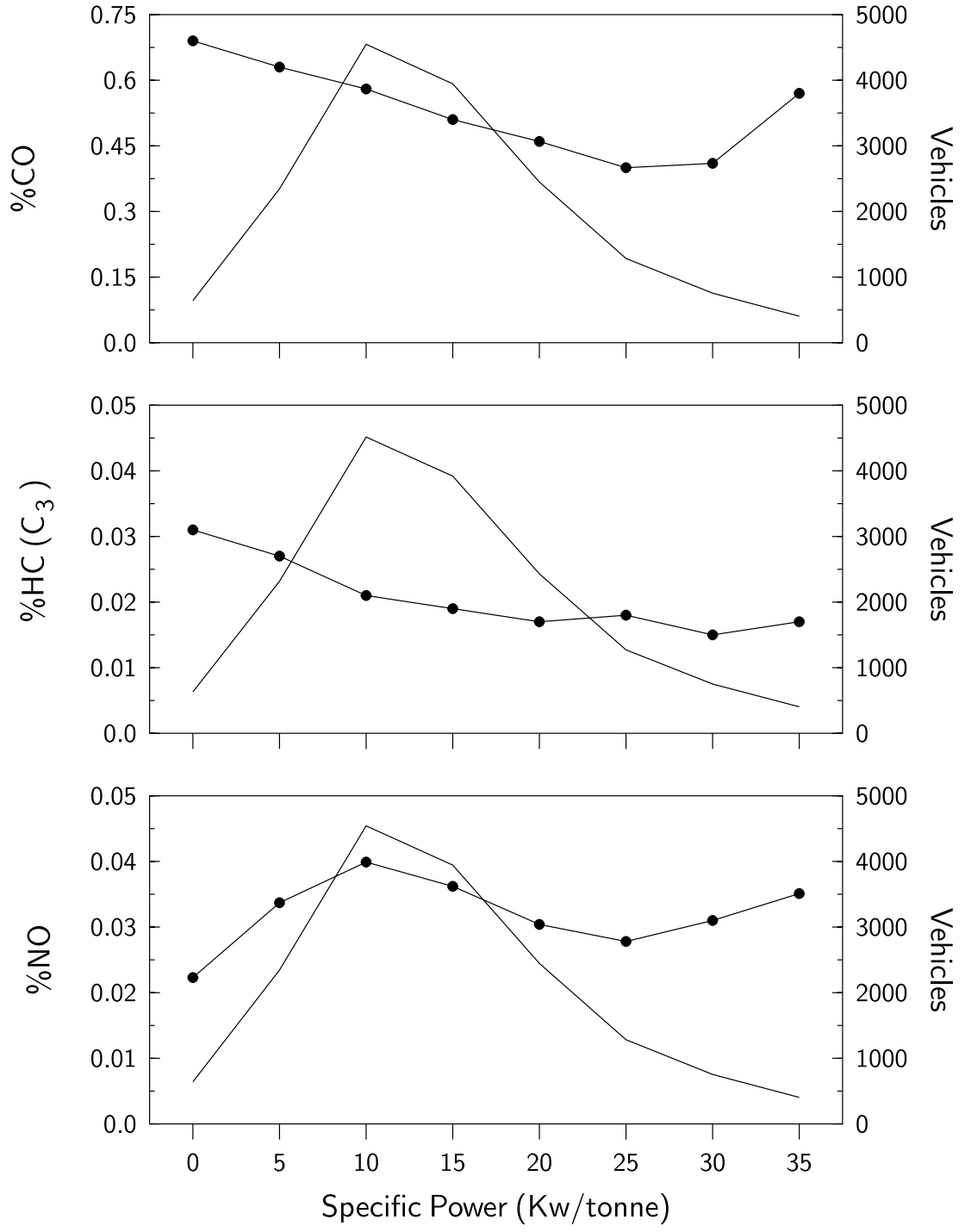

Figure 6. Vehicle specific power (filled circles) for the three measured emission species. The solid line shows the number of vehicles averaged into each vehicle specific power bin.

Table II. Number of measurements on repeat vehicles.

Number of Times Measured	Number of Vehicles
1	12,009
2	1,567
3	538
4	249
5	103
6	41
7	18
8	4
9	2
10	1
11	1
12	1
13	0
14	1
15	1

in gm/kg of fuel consumed for CO, HC and NO were 67.3, 4.1 and 5.2. As expected, the fleet emissions observed in this study exhibited a typical gamma distribution, with the dirtiest 10% of the fleet contributing 70%, 53%, and 51% of the CO, HC, and NO emissions, respectively. An analysis of emissions as a function of model year showed a typical inverse relationship. Measured emissions as a function of vehicle specific power revealed that fuel specific CO emissions occur relatively independent of vehicle specific power and that HC shows a slight negative correlation which was decreased at this site due to the lack of deceleration at this site. More striking is the lack of a relationship between NO emissions and vehicle specific power at this location which is in contrast to our other locations. Of the 18,752 records in the database 36% arise from vehicles measured more than once.

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APPENDIX A: FEAT criteria to render a reading "invalid" or not measured.

Not measured:

1) vehicle with less than 0.5 seconds clear to the rear. Often caused by elevated pickups and trailers causing a "restart" and renewed attempt to measure exhaust. The restart number appears in the data base.

2) vehicle which drives completely through during the 0.4 seconds "thinking" time (relatively rare).

Invalid :

1) insufficient plume to rear of vehicle relative to cleanest air observed in front or in the rear; at least five, 10ms averages > 0.25% CO_2. Often HD diesel trucks, bicycles.

2) too much error on CO/CO_2 slope, equivalent to $\pm$20% for %CO. >1.0, 0.2%CO for %CO<1.0.

3) reported %CO , <-1% or >21%. All gases invalid in these cases.

4) too much error on HC/CO_2 slope, equivalent to $\pm$20% for HC >2500ppm propane, 500ppm propane for HC <2500ppm.

5) reported HC <-1000ppm propane or >40,000ppm. HC "invalid".

6) too much error on NO/CO_2 slope, equivalent to $\pm$20% for NO>1500ppm, 300ppm for NO<1500ppm.

7) reported NO<-700ppm or >7000ppm. NO "invalid".

Speed/Acceleration valid only if at least two blocks and two unblocks in the time buffer and all blocks occur before all unblocks on each sensor and the number of blocks and unblocks is equal on each sensor and 100mph>speed>5mph and 14mph/s>accel>-13mph/s and there are no restarts, or there is one restart and exactly two blocks and unblocks in the time buffer.

APPENDIX B: Explanation of the La_99.dbf database.

The La_99.dbf is a Microsoft FoxPro database file, and can be opened by any version of MS FoxPro. The file can be read by a number of other database management programs as well, and is available on CD-ROM or FTP. The following is an explanation of the data fields found in this database:

License	California license plate
Date	Date of measurement, in standard format.
Time	Time of measurement, in standard format.
Percent_co	Carbon monoxide concentration, in percent.
Co_err	Standard error of the carbon monoxide measurement.
Percent_hc	Hydrocarbon concentration (propane equivalents), in percent.
Hc_err	Standard error of the hydrocarbon measurement.
Percent_no	Nitric oxide concentration, in percent.
No_err	Standard error of the nitric oxide measurement
Percent_co2	Carbon dioxide concentration, in percent.
Co2_err	Standard error of the carbon dioxide measurement.
Opacity	Opacity measurement, in percent.
Opac_err	Standard error of the opacity measurement.
Restart	Number of times data collection is interrupted and restarted by a close-following vehicle, or the rear wheels of tractor trailer.
Hc_flag	Indicates a valid hydrocarbon measurement by a “V”, invalid by an “X”.
No_flag	Indicates a valid nitric oxide measurement by a “V”, invalid by an “X”.
Opac_flag	Indicates a valid opacity measurement by a “V”, invalid by an “X”.
Max_co2	Reports the highest absolute concentration of carbon dioxide measured by the remote sensor over an 8 cm path; indicates plume strength.
Speed_flag	Indicates a valid speed measurement by a “V”, an invalid by an “X”, and slow speed (excluded from the data analysis) by an “S”.
Speed	Measured speed of the vehicle, in mph.
Accel	Measured acceleration of the vehicle, in mph/s.
Vin	Vehicle identification number.
Make	Manufacturer of the vehicle.
Exp_date	License expiration date.
Model	Manufacturer’s vehicle model.

Body_style	DMV designated body type.
Zip	Registrant's mailing zip code.
County	California county number vehicle is registered in.
Year	Vehicle model year.
Fuel	Fuel type G (gasoline), D (diesel) and N (natural gas).
GVW	Gross vehicle weight.
Smog_due	Date next smog check test is required.

APPENDIX C: 1999 Temperature and Humidity Data.

1999 Temperature and Humidity Data								
Time	6/28 °F	6/28 %RH	Time	6/29 °F	6/29 %RH	Time	6/30 °F	6/30 %RH
			9:15	73	65	9:09	74	56
			10:15	78	58	10:09	80	46
			11:15	84	41	11:09	84	40
11:42	84	42	12:15	89	33	11:26	85	38
12:34	88	37	12:34	90	30	12:28	90	34
13:34	93	29	13:34	93	26			
14:34	96	26	14:34	96	26	14:26	93	33
14:50	97	26	15:34	98	25	15:26	95	30
			16:34	97	25	16:26	93	31
			17:34	94	30	17:15	91	31
			18:34	90	35			
			19:00	89	35			

1999 Temperature and Humidity Data								
Time	7/1 °F	7/1 %RH	Time	7/2 °F	7/2 %RH	Time	7/3 °F	7/3 %RH
9:10	70	65	9:12	67	77	6:53	63	82
10:10	75	59	10:12	70	68	7:53	61	83
11:10	80	49	11:12	75	59	8:53	64	77
11:30	80	47	11:33	78	53	9:56	70	63
12:30	87	39	12:34	82	46	10:55	71	58
13:30	90	35	13:15	84	44			
14:32	93	30						
15:30	91	32						
16:30	90	34						
17:30	85	39						
18:30	82	43						
19:00	81	46						

1999 Temperature and Humidity Data					
Time	7/6 °F	7/6 %RH	Time	7/7 °F	7/7 %RH
9:06	77	55	9:13	78	59
10:10	83	46	10:15	83	55
11:06	87	38	11:13	85	53
11:18	88	36	11:26	86	52
12:18	91	36	12:30	87	49
13:18	95	34	13:26	91	47
13:34	96	32	13:34	92	46
14:34	97	30	14:37	93	44
15:34	97	27	15:41	94	38
16:36	95	24	16:34	92	40
17:36	90	32	17:35	89	41
18:36	87	38	18:30	88	40
19:00	86	40			

APPENDIX D: Field Calibration Record.

Date	Time	CO Cal Factor	HC Cal Factor	NO Cal Factor	CO_2/Ref Voltage Ratio
6/28	11:40	1.39	1.17	1.70	0.85
6/29	9:10	1.51	1.23	1.91	0.9
6/29	12:20	1.17	0.97	1.42	0.96
6/30	9:00	1.42	1.18	1.90	0.92
6/30	11:15	1.29	1.06	1.64	0.96
6/30	14:10	1.18	1.00	1.46	0.98
7/1	9:00	1.43	1.17	2.03	0.94
7/1	11:20	1.36	1.16	1.81	0.96
7/1	14:30	1.26	1.06	1.66	0.97
7/2	9:00	1.53	1.25	2.16	0.89
7/2	11:25	1.38	1.15	1.76	0.91
7/3	6:45	1.50	1.23	2.03	0.86
7/6	8:55	1.48	1.27	1.94	0.89
7/6	11:15	1.25	1.08	1.42	0.95
7/6	13:25	1.16	1.02	1.51	0.96
7/7	9:00	1.47	1.24	2.07	0.90
7/7	11:15	1.34	1.11	1.64	0.96
7/7	13:30	1.26	1.06	1.30	0.99