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On-Road Carbon Monoxide and Hydrocarbon Remote Sensing in the Chicago Area

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ON-ROAD CARBON MONOXIDE AND HYDROCARBON REMOTE SENSING IN THE CHICAGO AREA

Final Report

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EXECUTIVE SUMMARY

The University of Denver remote sensor for motor vehicle carbon monoxide (CO) and hydrocarbon (HC) emissions was utilized for seven days in the Chicago area in October, 1990. The system also recorded vehicle speed, an estimate of acceleration and a freeze-frame video picture of the rear of the vehicle from which the license plate was read. The remote sensor measures the CO/CO_2 (carbon dioxide) and HC/CO_2 ratio from which the exhaust %CO and %HC are calculated which would have been measured had the vehicle been equipped with a tailpipe probe. The instantaneous mass emissions in grams CO or HC per gallon of gasoline used can also be determined.

For five of the days the system was used to monitor the on and off freeway ramps at the intersection of I-290 (the Eisenhower Expressway) with Central Avenue in Cicero. In addition, two more days of CO only measurements were made at the I-88 eastbound to I-355 southbound interchange on August 25 and 26, 1990. Over 21,000 valid CO and HC emission measurements were made.

When the videotapes had been read and returned to the State for matching, the total number of vehicles both measured and matched with the license plate data base was over 13,000. When the data were analyzed, overall half the CO was emitted by 9.4% percent of the vehicles, the gross polluters, with %CO greater than 3.5%. Most new vehicles were so clean that their emissions were almost negligible. Half of the HC was emitted by 14.25 percent of the vehicles with %HC greater than 0.23%. Again, a small fraction of the fleet is responsible for most of the HC emissions. Most of the deterioration in air quality arises from the emissions of the dirtiest 20% of the vehicles. However, new vehicles were not as uniformly clean as was found for %CO, and in fact the %HC showed only a slight model year dependence. The average CO emissions for the measured fleet was 1.10 %CO, which corresponds to approximately 425 grams CO per gallon of gasoline consumed. The average emission of hydrocarbons (in propane equivalents) was 0.139 %HC, or 84 grams HC per gallon of gasoline. For both HC and CO the dirtiest 20% of the one year old fleet was dirtier than the cleanest 20% of all model years regardless of age and emissions control technology.

Comparison of I-290 with I-88/I-355 data suggests that no more than 38% of the measured CO emissions could arise from vehicles in either a cold start or an off-cycle acceleration mode. An independent age based analysis of the data indicates an upper limit of 46%. Other data suggests that 15% is a more nearly correct fraction.

An analysis of the 235 vehicles measured for HC four or more times revealed that only 38 (16%) exceeded the 0.23 %HC cut point two or more times. This 16% of the fleet contributed 33% of the total HC emissions. Of the subfleet of 235 vehicles measured four or more times, there were 187 vehicles (80%) which never exceeded the CO gross polluter cut point, and an additional 28 which exceeded the cut point only once. Only 30 vehicles (13%) exceeded the cut point two or more times, but this 13% contributed 50% of the total CO emitted.

Although the speed/acceleration system was more error prone than the emissions measurement an analysis of several thousand vehicle emissions could be carried out in comparison to valid speed/acceleration data. The results were that the dependence of average fleet emissions on speed and acceleration at this site was small, and in the direction of higher emissions at lower speed/acceleration. At the on-ramp site, because of the ramp metering in the morning, speed and acceleration were well correlated and thus could not be separated in their effects. Since high CO emissions are well correlated with tampered emission control systems the higher than average CO readings for late model vehicles at this site may be a result of higher tampering rates compared with other U.S. cities.

These results imply that an inspection and maintenance program incorporating remote sensing has the potential to identify a significant fraction of the on-road CO and HC emissions while inconveniencing only a small fraction of all vehicle owners. If the pass/fail cut points are set to a percentage of the total observed emissions at a given site, the failure rate would be fixed, and the program would automatically tighten up the absolute standards as the emissions of the fleet are reduced. This study is a follow up to the 1989 study of CO emissions only, the addition of hydrocarbon data adds a new dimension scientifically although the essential conclusions remain the same.

The on road data have been compared to the Illinois I/M emissions data for the same vehicles. The results confirm California studies that on-road and reported I/M emissions readings show no significant correlation. Notwithstanding the lack of on-road emissions correlation, vehicles identified by the I/M program as having problems do show higher on-road emissions than the remainder of the fleet.

I. INTRODUCTION

Urban air quality does not meet the federal standards in many cities. Violations of the ozone standard arise from photochemical transformation of oxides of nitrogen (NO_x) and hydrocarbons (HC). Carbon monoxide (CO) standards are primarily violated as a result of direct emission of the gas. Although there are differences between compounds, and between different urban areas, mobile sources are a major factor in all urban emissions inventories for carbon monoxide, hydrocarbons, and oxides of nitrogen.

Air pollution control measures taken to mitigate mobile source emissions in non-attainment areas include inspection and maintenance (I/M) programs, oxygenated fuels mandates and transportation control measures. Nonetheless many areas of non-attainment remained after the 1987 deadline, and some are projected to remain in non-attainment for several more years despite the measures currently undertaken. The remote sensing techniques discussed in this report may have the potential to contribute to further control measures in non-compliance areas.

The 1990 U. S. Clean Air Act amendments require non-attainment areas to include "on-road emissions monitoring" in their post-1990 I/M programs. This language, the "Barton Clean Air Smog Trap Amendment" was included based on literature and demonstrations of remote sensing to the U. S. Congress by the University of Denver.

With initial support from the Colorado Office of Energy Conservation in 1987, the University of Denver developed an infra-red (IR) remote monitoring system for automobile carbon monoxide (CO) exhaust emissions. Significant fuel economy improvements result if rich-burning (high CO emissions) or misfiring (high HC emissions) vehicles are tuned to a more stoichiometric and more efficient air/fuel (A/F) ratio. Therefore, the University of Denver CO/HC remote sensor is named Fuel Efficiency Automobile Test (FEAT). The basic instrument measures the carbon monoxide to carbon dioxide ratio (CO/CO_2) in the exhaust of any vehicle passing through an Infra-Red (IR) light beam which is transmitted across a single lane of roadway. An additional channel to measure hydrocarbon emissions has been developed and tested successfully.

Figure 1 shows a schematic diagram of the instrument. The IR source sends a horizontal beam of radiation across a single traffic lane, approximately 10 inches above the road surface. This beam is picked up by the detector on the opposite side and split into four wavelength channels; CO, CO_2, HC, and reference. Data from all four channels are fed to a computer for analysis. The calibration gases (mixtures of CO, propane and CO_2 in nitrogen) are used as a daily quality assurance check on the system.

The instrument determines the CO/CO_2 and HC/CO_2 ratios. This ratio is itself a useful parameter to describe the combustion system. Most vehicles show ratios close to zero. When CO/CO_2 ratios greater than zero are observed the engine must be operating with a fuel rich air/fuel ratio. In the case of a large HC/CO_2 ratio, a fuel lean air/fuel ratio which is causing a misfire is also a possibility, particularly under deceleration conditions. In addition, for either case the emission control system is not fully operational.

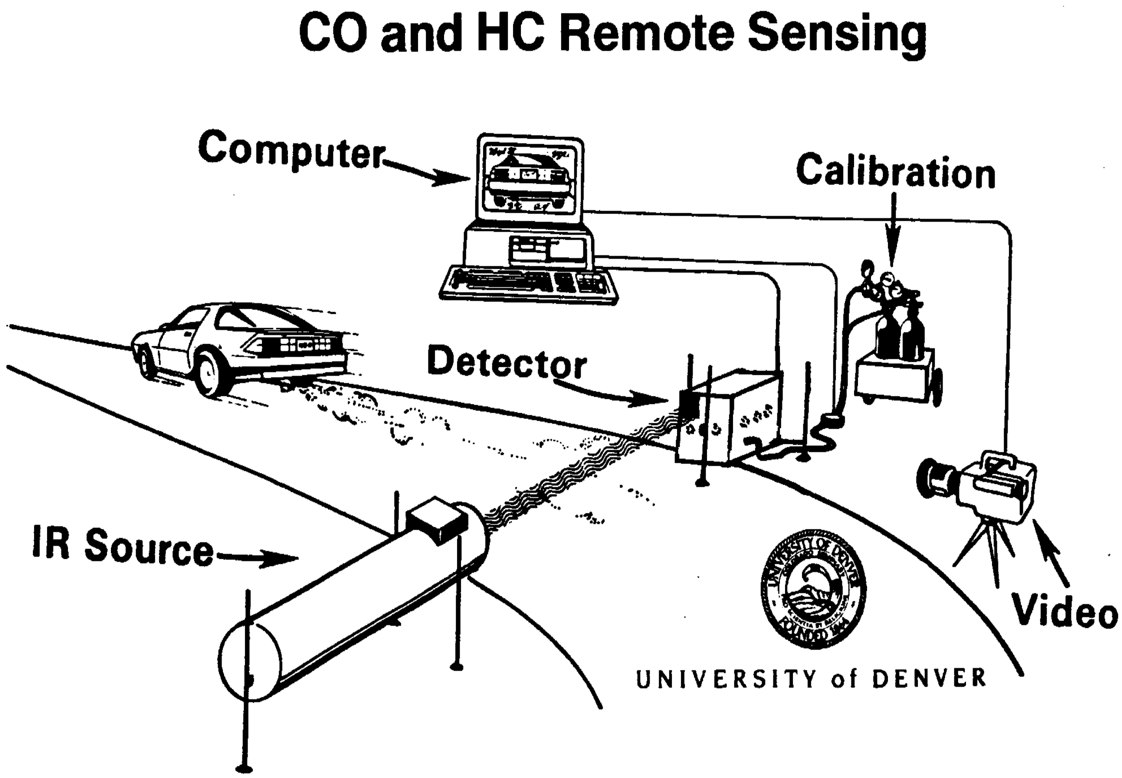

Figure 1. A schematic diagram of the University of Denver on-road emissions monitor. It is capable of monitoring emissions at vehicle speeds between 2.5 and 150 mph in under one second per vehicle.

With a fundamental knowledge of combustion chemistry, many parameters of the vehicle and its emissions system can be determined, including the instantaneous air/fuel ratio, grams of CO or HC emitted per gallon of gasoline and the percentage of CO or HC which would be measured by a tailpipe probe.

A. Chemistry of CO and HC Emissions from Automobiles

This section is a short summary of the parameters which influence the HC and CO emissions from automobiles. The reader should consult one of the text books on the subject, for instance Heywood (1988) for more details. HC and CO emissions in the exhaust manifold are a function of the air to fuel ratio at which the engine is operating. These "engine out" emissions are further altered by any tailpipe emission controls which may be present. Figure 2 shows an approximate diagram of engine out emissions as a function of air to fuel ratio where 7.09 (14.7% air to fuel by weight) is the stoichiometric ratio at which there is exactly enough air to fully burn the fuel to carbon dioxide and water. Carbon monoxide emissions, as explained in another report (Stedman and Bishop, 1990, pp. 3-6), are caused solely by the lack of adequate air for complete combustion. The CO is formed uniformly throughout the volume of the combustion chamber if the air/fuel mix is uniform.

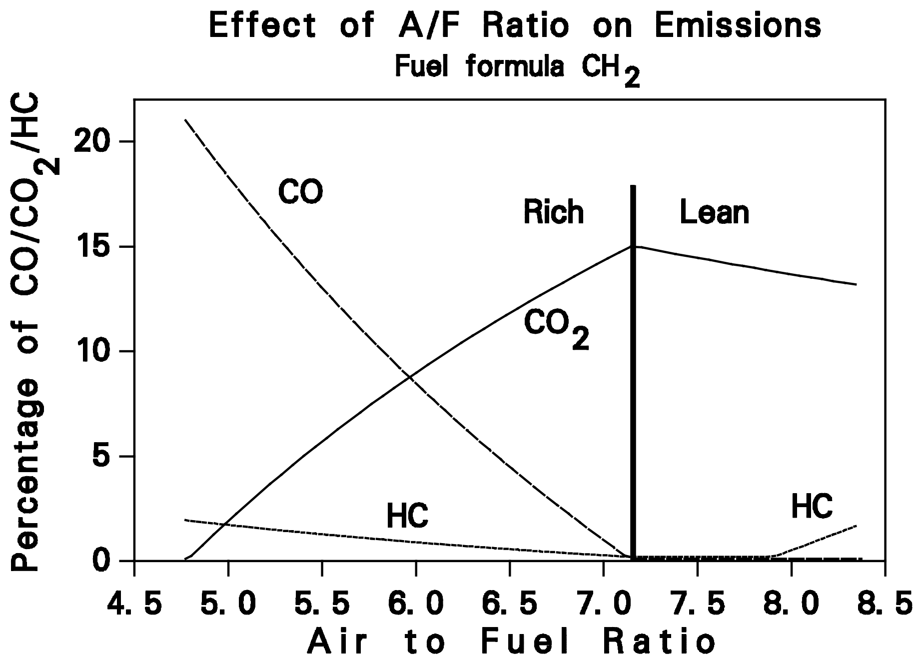

Figure 2. An approximate diagram showing the relative concentrations of CO and HC produced by a spark ignited engine as a function of air/fuel ratio by moles. Air to fuel ratio by weight is approximately double.

For HC the situation is more complex. In the main part of the combustion chamber away from the walls essentially all the HC is burnt, however the flame front initiated by the spark plug can not continue to propagate within about one millimeter of the relatively cold cylinder walls. This phenomenon causes a "quench layer" next to the walls which is a thin layer of unburnt air/fuel mix. The opening exhaust valve and the rising piston scrape this layer off the walls and send it out the exhaust manifold. As the mixture becomes richer, the quench layer contains more HC, thus more HC is emitted when the vehicle is operating with rich mixtures. There is a second peak in HC emissions indicated on the right hand (fuel lean) side of the diagram. This phenomenon is known as "lean burn misfire" or "lean miss", it is the cause of the hesitation experienced at idle before a cold vehicle has fully warmed up. When this misfiring occurs a whole cylinder full of unburnt air/fuel mix is emitted into the exhaust manifold. Misfiring also occurs if a spark plug lead is missing, or the ignition system to one cylinder is otherwise fatally compromised. Severe gas mileage loss occurs when significant misfiring is taking place.

The fact that there are two regions of high HC and only one of high CO already shows that one would not expect a high correlation between HC and CO. High HC would be expected for very low CO vehicles as well as for high CO vehicles. One would not expect to see very many very low HC readings in the presence of high CO. This conclusion of lack of correlation is further

confounded by the presence of catalytic convertors in the exhaust system. If a vehicle which is running with a rich mixture has a functioning air injection system and catalyst then both the HC and CO will be removed. If the catalyst is functioning but there is no air injection then some or all of the HC will be converted to CO but the CO will remain since there is inadequate oxygen for its oxidation. For this reason it is possible for a catalyst equipped vehicle which is in fact in the lean burn misfire region to emit CO into the air even though it was not emitting CO into its own exhaust manifold.

B. Remote Sensing Equations

FEAT can measure the CO and HC emissions in all vehicles, including gasoline and diesel-powered vehicles, as long as the exhaust plume exits the vehicle within a few feet of the ground. Due to the current height of the sensing beam, FEAT will not register emissions from exhausts which exit from the top of vehicles such as heavy duty diesel vehicles. Carbon monoxide and hydrocarbon emissions from diesel vehicles are in any case relatively negligible.

The mechanism by which FEAT measures a ratio is explained in Bishop et al. (1989). The CO/CO_2 and HC/CO_2 ratios can be determined by remote sensing, independent of wind, temperature, and turbulence in 0.9 seconds per passing car. Other peer-reviewed publications describing remote sensing are listed in the references. FEAT has been shown to give correct readings for CO by means of double-blind studies of vehicles both on the road and on dynamometers (Lawson et al. 1990; Stedman and Bishop, 1991). The HC channel has been subjected to similar rigorous testing in California in May of 1991. The data are in the process of analysis.

The mass emissions in grams CO per gallon of gasoline burned can be derived from

$$gCO/gal = 15{,}800 * \%CO/(42 - 1.07 * \%CO)$$

The gHC/gal can be estimated from

$$gHC/gal = 1.57 * gCO/gal * \%HC / \%CO$$

The average %CO for the fleet of 13,640 vehicles measured in October 1990 is 1.10%. This translates into 425 gCO/gallon. If mass emissions in g/mile are required then g/gallon must be converted to g/mile by means of gas mileage data. If we assume an average gas mileage of 17 mpg, then the average emissions of 1.10 %CO corresponds to an average emission of 25 gCO/mile. The mean %HC is 0.139. This converts to 84 gHC/gal and 5 gHC/mile. For the purposes of obtaining emissions inventories it is likely that accurate data on gallons of gasoline sold are more easily obtainable than accurate vehicle miles travelled data.

The FEAT remote sensor is accompanied by a video system when license plate information is required. The video camera is coupled directly into the data analysis computer so that the image of each passing vehicle is frozen onto the video screen. The computer writes the date, time and

the calculated exhaust CO, HC, and CO_2 percentage concentrations at the bottom of the image. These images are stored on videotape or digital storage media.

A radar system has also been developed which is capable of determining both the speed and acceleration of passing vehicles during the same fraction of a second that the emissions are measured. The radar readings are stored in the database with the other emissions information. The speed data are reasonably reliable. The acceleration data are more difficult to interpret because incorrect readings of apparent acceleration arise from the necessary placement of the radar at the side of the road, and the changing angle at which the radar beam hits the vehicle.

FEAT is effective across traffic lanes of up to 40 feet in width. However, it can only operate across a single lane of traffic if one wishes to positively identify and video-record each vehicle with its exhaust. FEAT operates most effectively on dry pavement. Rain, snow, and very wet pavement cause scattering of the IR beam. These interferences cause the frequency of invalid readings to increase, ultimately to the point that all data are rejected as being contaminated by too much "noise". At suitable locations we have monitored exhaust from over one thousand vehicles per hour. FEAT has been used to measure the emissions of more than 500,000 vehicles in Denver, Chicago, the Los Angeles Basin, Toronto, the United Kingdom, and Mexico.

HC data are calibrated with and reported as percent propane. The more commonly used "hexane equivalent" can be obtained approximately by division of the propane percentage values by an interconversion factor of 1.8.

The purpose of this report is to describe the measurements made by means of remote sensing in the Chicago area in the fall of 1990 and compare the results from those from 1989, from other locations, and to provide information potentially useful for decision makers charged with the responsibility to both evaluate and reduce on-road motor vehicle emissions.

II. RESULTS AND DISCUSSION

In October, 1990, five days of measurements were carried out at the intersection between I-290 (Eisenhower Expressway) and Central Avenue in Cicero Illinois (see Figure 3). The morning location was the same as studied in 1989 and reported in ILENR/RE-AQ-90/05 by Stedman and Bishop (1990). The afternoon location was the corresponding off-ramp for vehicles returning in the evening from the downtown area. Each beam block initiates an analysis for vehicle exhaust. Error checking routines in the FEAT computer eliminate invalid data caused by pedestrians, bicyclists, etc. The video tapes were read for license plate identification and the plates which appeared to be in-state and readable were forwarded to the State to determine make and model year information. This resulted in 13,640 records with make and model year information and valid CO and HC data. In view of the large data set we chose only to analyze data for which both parameters were valid.

The Illinois EPA supplied 12,200 Inspection and Maintenance (I/M) records for 8,971 of these vehicles which were analyzed for their comparison to the on-road readings.

The two days in Naperville at the I-88 and I-355 interchange in August resulted in 1980 records with valid %CO and make and model year information. This site is quite different than the Central and Eisenhower site; there are comparatively fewer records, and only CO data were taken. Therefore, these data were analyzed separately from the October data. Except as noted, all references are to the 13,640 valid records with make and model year information taken at the on and off-ramps in October.

A. Overall Results

Figure 4 shows the distribution of CO emissions (solid bars) by percent CO category from the set of 13,640 vehicles measured at the two ramps in the Chicago area in October, 1990. The hatched bars show the overall CO emissions for each category. The mean %CO is 1.10%, with a variance of 3.3%, while the median is only 0.37 %CO. Not only are more than 70% of the 13,640 vehicles very low emitters, the skewed nature of the distribution is such that more than half the emissions come from 9.4 percent of the vehicles with emissions greater than 3.5 %CO or 1446 gCO per gallon of gasoline. We use the term "gross CO polluters" for those vehicles identified in that category. For comparison, the later panels in Figure 4 show that the 1990 Chicago CO data are very similar in distribution to that from Chicago in 1989, Denver, and Los Angeles (Stedman et al, 1991a).

As illustrated by Figure 4, motor vehicle emissions are gamma distributed rather than gaussian distributed. Therefore, outliers can not be eliminated based on classical (normal) statistics. Robust analysis of emissions data requires large population N values since the emissions picture is dominated by only a small number of high emitters.

Figure 5 illustrates the fleet shown in Figure 4 in a different way. The ten bars show the emissions which a fleet of ten vehicles would have in order to exactly match the statistics of the observed

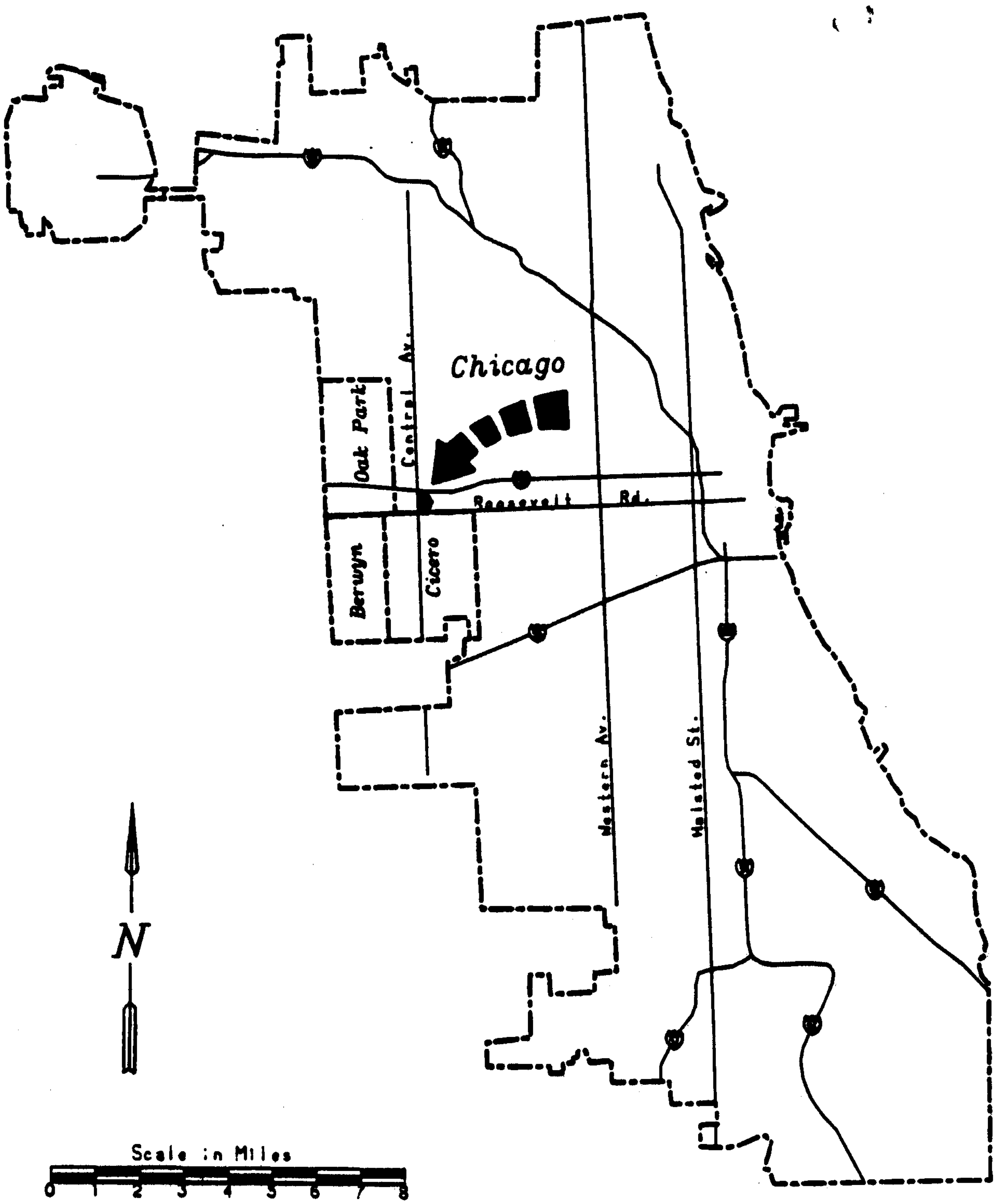

Figure 3. Location of remote sensing site.

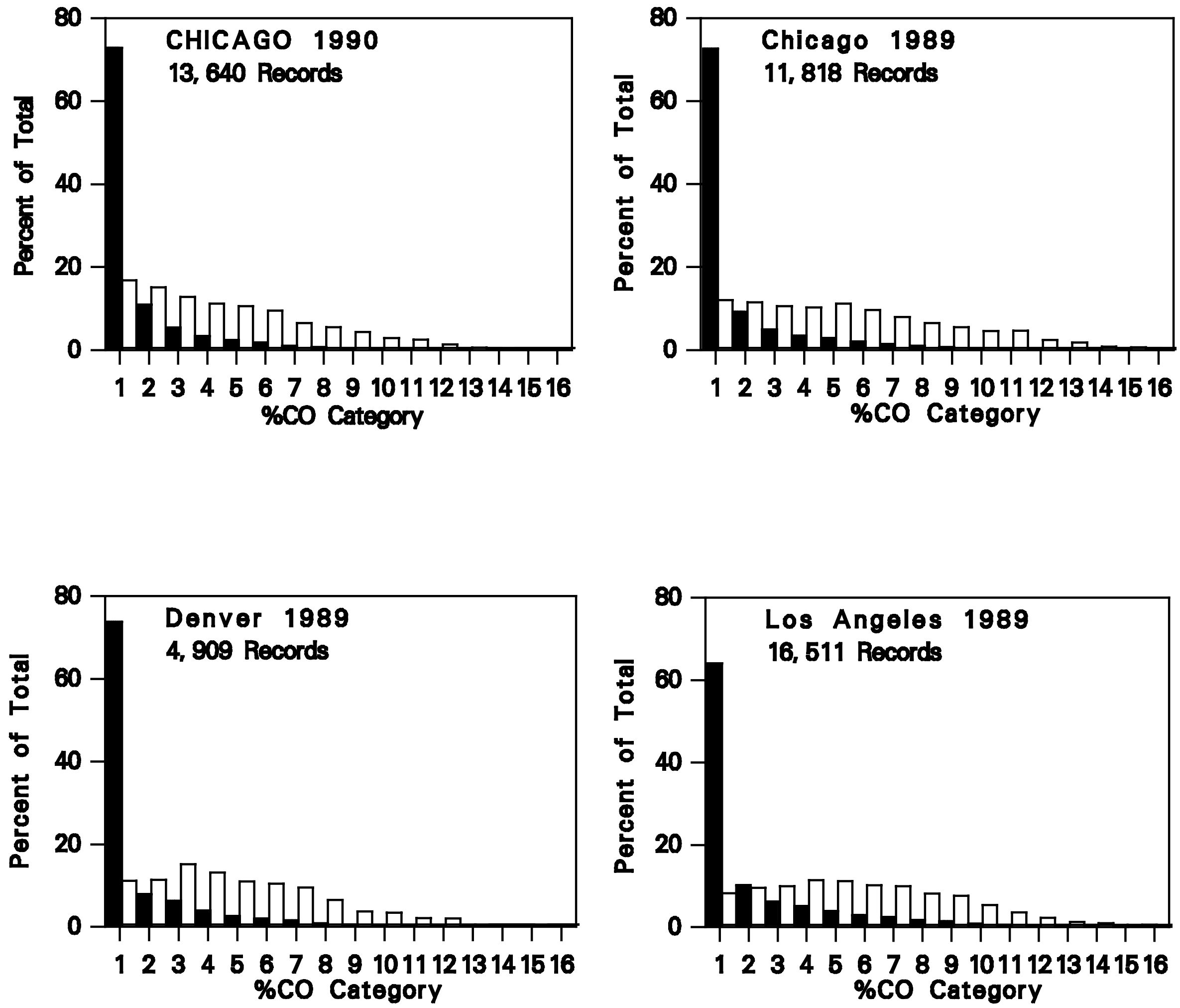

Figure 4. Normalized histogram showing as black bars the percentage of the fleet of vehicles with emissions less than the stated %CO category. Clear bars show the percentage of emissions.

data. In each case the lowest 70% of the fleet (the leftmost seven bars) all represent vehicles with CO emissions less than 1%. All seven have been given the average since we do not claim that the small distinctions which would arise from one to the next are significant. The later panels again show that the Chicago fleet emissions are very similar to those from other locations, even though the altitude (5,000 ft) in Denver and the I/M programs are quite different. The I/M programs in Denver and LA are decentralized, annual in Denver, biennial in LA. The I/M program in the Chicago area is centralized, and at the time of this study was annual for all vehicles.

Figure 6 shows the distribution of HC emissions (clear bars) by percent HC category for the Chicago, 1990 data set. The average %HC in propane equivalents is 0.139% with a median value of 0.087. The hatched bars show the overall HC emissions for each category. As with the CO emissions, the distribution is skewed such that more than half the emissions come from 14.25 percent of the vehicles with emissions greater than 0.23 %HC or 150 gHC per gallon of gasoline (the gross HC polluters).

B. Representativeness of the Data

This analysis is to determine the extent to which the distribution of emissions in the final registration matched data set is the same as the distribution in the entire data set. That is, after eliminating measurements for which we could not find State registration information, is the remaining data set a representative sample?

Unreadable plates were sometimes the result of the vehicle position in the video field at the instant of instrument triggering. This effect randomly removes vehicles, and so will not affect the statistics of the remaining data. However, older vehicles have a higher probability of damaged or unreadable plates. This will remove older and therefore on average higher polluting cars. The third principle cause of unreadable plates was lighting difficulties during the low light periods of operation. Overall then, there is a cumulative effect of removal of older or dirtier cars and thus a lowering of the means. Analysis of data from taken from the Chicago and Los Angeles areas reveals that although the difference is small, it is detectable. The small difference which accumulates through the high polluting tail of the population can show up as a considerable difference in the means of the two data sets. The corrected FEAT mean %CO for Chicago is 1.13%. This is the data with only invalid records removed, and corrected for the daily calibration factors. This is higher than the final license plate matched data set at 1.10 %CO. As the later analysis of the data will show, this effect would be observed if the cars lost were only an average of two months older than the average car matched. The FEAT corrected mean %HC is 0.148, and the matched fleet mean is 0.139 %HC. This analysis shows that unreadable plates do correspond to higher emitting vehicles, however most high emitting vehicles do have readable license plates.

The matched Chicago fleet of 13,640 records is believed to be a representative sample of the total fleet except that there are likely to be a few more dirty vehicles in the total fleet than in the matched fleet. In view of the fact that we measure statistically similar data everywhere in North America we believe that our results are representative of the total fleet in the Chicago area. The only correction necessary would be for the relative age of the fleet at any other location.

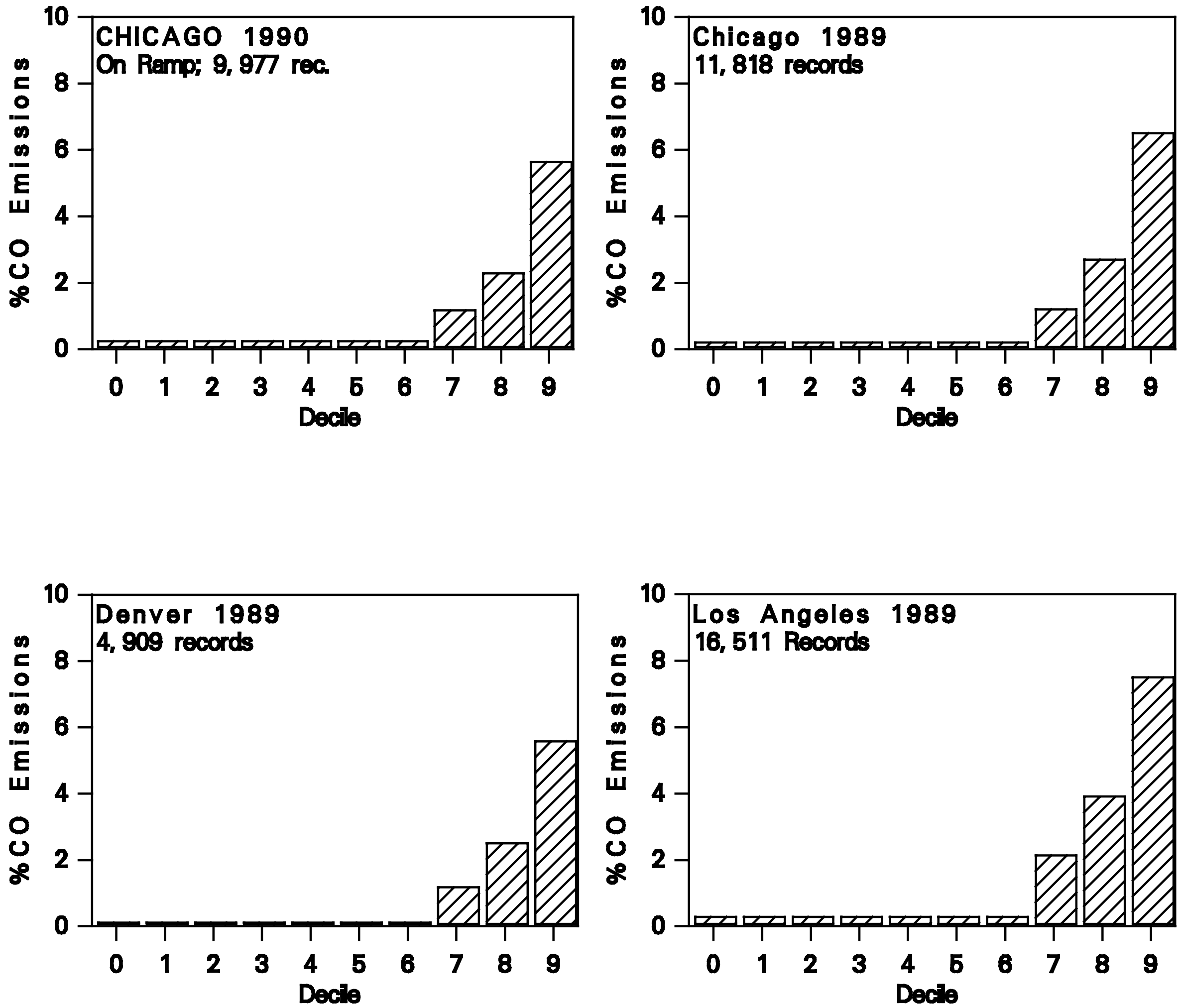

Figure 5. **Percent CO emissions organized into deciles which match the observed fleets for Chicago 1990 & 1989, Denver and LA. The cleanest seven deciles are given the average of all seven since the differences are negligible.**

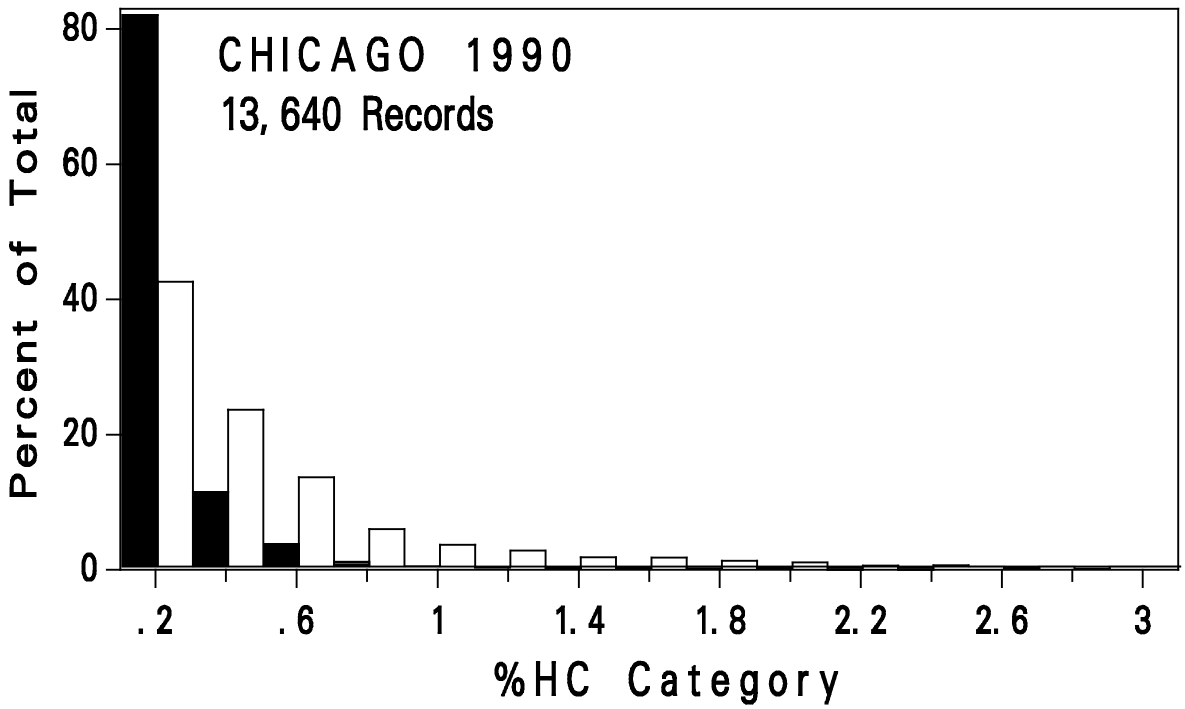

Figure 6. Normalized histogram showing as black bars the percentage of the fleet of vehicles with emissions less than the stated %HC (propane equivalents) category. Clear bars show the percentage of emissions.

The 1990 Chicago data base is available upon request in electronic format from Dr. William Denham of the Illinois Department of Energy and Natural Resources.

C. Differences Between Locations

Remote sensing on-road data sets are now available from several locations in the US. The data are broken into blocks of one hour collection times beginning on the half hour. All the available data as of April 1, 1991 are shown in Figure 7a with last year's Chicago data highlighted. Using only the data collected below 7,000 feet altitude and for those sets containing at least 100 records, a weighted correlation was run of mean % CO versus average age weighted by the number of vehicles in each hourly bin. The data are shown in Figure 7b. A regression line of slope 0.23 %CO per year and an intercept at 1.1 years has an r^2 of 0.78. Figure 7a which shows all data irrespective of altitude, load and number of vehicles measured in the given hour, not surprisingly evidences more scatter, but the underlying correlation is still clear. Figure 7c shows the 1990 Chicago data and the data from the Naperville site with the regression line superimposed. The data cluster around the regression line, and are within the ranges of all the prior measured data given in Figure 7b. The fact that average age is the dominant variable effecting CO emissions

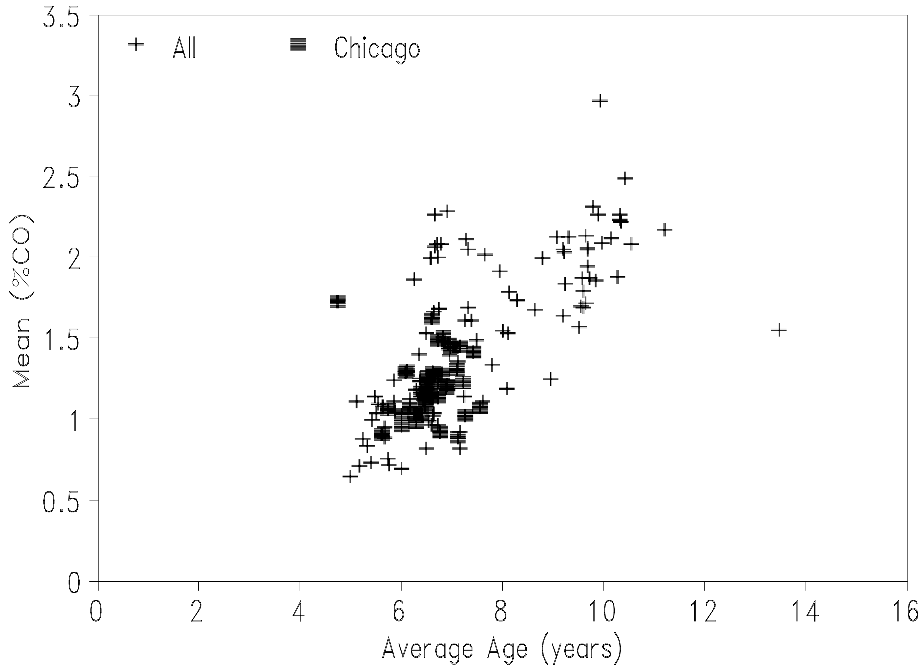

Figure 7a. Hourly averaged %CO emissions plotted against hourly averaged fleet age for all of the available data from US sites with data from Chicago, IL 1989 highlighted as squares.

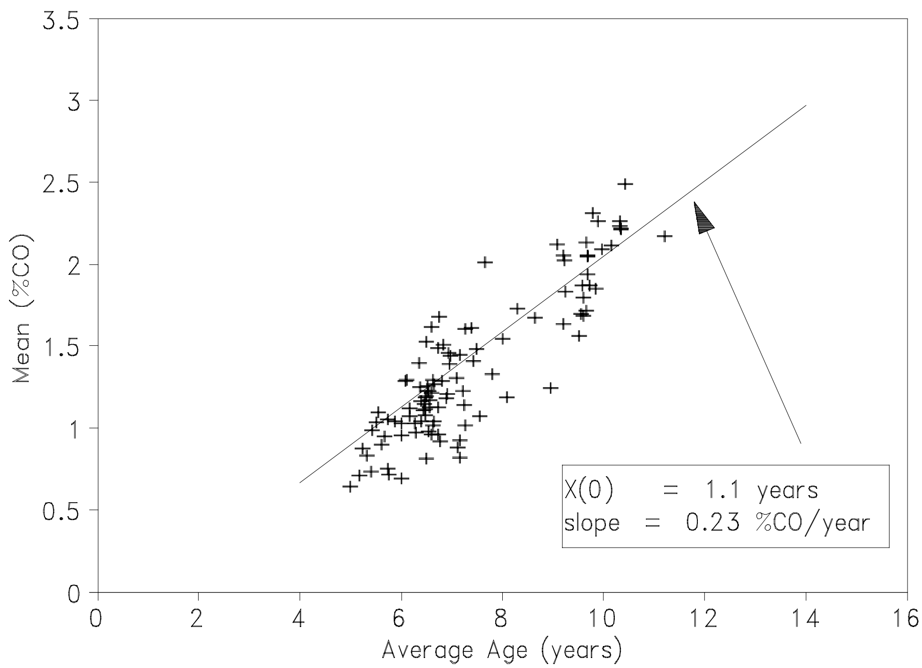

Figure 7b. A subset of Figure 7a, where only hourly averages which contain more than 100 vehicles and were collected below 7000 ft. in altitude remain. The regression line is weighted according to the number of vehicles in each point.

is apparent. There is no evidence of significantly different average emission factors among LA, Denver, Chicago or Toronto when age is taken into account.

In Chicago in 1989 the data all came from a single site. One day was different from the other four in mean %CO. All data were collected from the morning rush hour through the noon %CO peak. On one day, an hour was lost around noon. This showed up as a seemingly anomalous low CO day (Thursday). In Chicago, as we have also discovered in Los Angeles, variation in sampling times can lead to a different fleet average age, and hence to different CO means for the day. Starting late or stopping early for the remote sensor measurements will change the average age of the sampled fleet and correspondingly alter the mean emissions.

The 1990 Chicago measurements are separated into those records taken during the morning/noon time slot at the on-ramp and those records taken during the evening at the off-ramp. The morning (on-ramp) records were typically taken from 0600 to 1330 hours, resulting in 9,997 records with valid CO and HC data. It was an uphill on-ramp to the Eisenhower Expressway from Central Avenue with the vehicles accelerating. The evening (off-ramp) data were taken from 1500 to 1800 hours, resulting in 3663 records with valid CO and HC data. The vehicles were decelerating to merge while approaching a traffic light controlled intersection.

A comparison of the on and off-ramp data is given in Table I. The off-ramp data have fewer records, and the vehicles are slightly older, on average, than the on-ramp data. As expected,

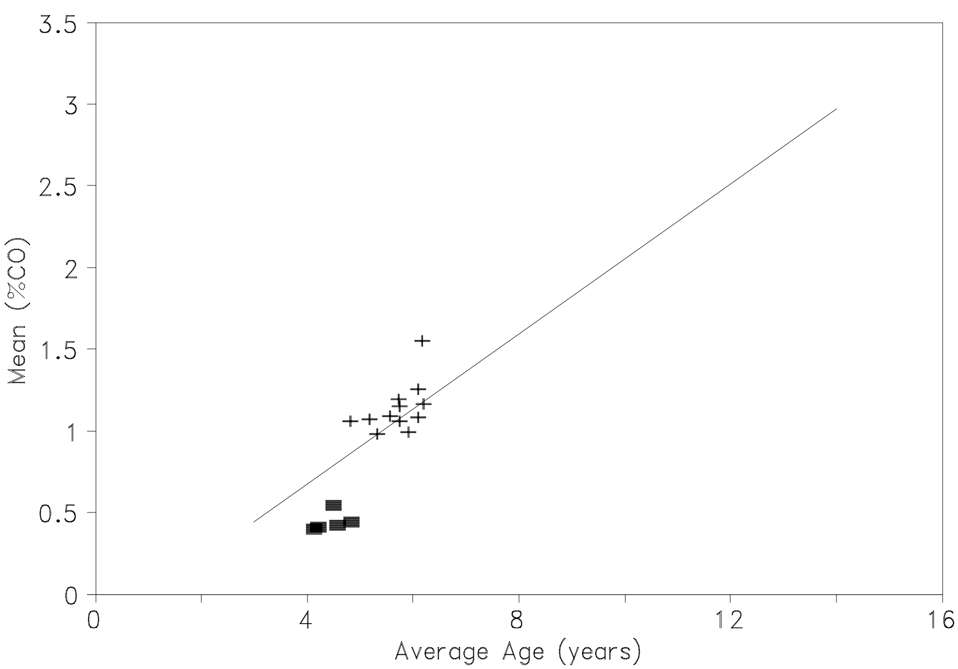

Figure 7c. The 1990 data plotted on the regression line shown in Figure 7b. The plus symbols (+) are data from Central and Eisenhower and the solid squares (■) are data collected at the Naperville sites.

Table I. Chicago, 1990 data for the on-ramp and off-ramp sites.

	On-ramp		Afternoon Off-ramp	
	%CO	%HC	%CO	%HC
Mean	1.08	0.119	1.15	0.198
Median	0.37	0.077	0.40	0.134
Percent of total emissions from dirtiest 20% of fleet	73	58	73	53
Percent of fleet responsible for 50% of emissions	9.3	14.1	9.7	17.9
Fleet emission 50 percent cut points	3.43	0.185	3.80	0.323
Number of records	9,977		3,663	
Average fleet age(years)	5.2		6.3	

the off-ramp data are slightly dirtier for both CO and HC. Considering that the average age of the off-ramp fleet is about 1.1 years older than that of the on-ramp fleet, it would be expected to have an increased %CO emission of 0.25%, based upon the formula given earlier. In fact, the difference is 0.07%. The small discrepancy is most likely due differences in vehicle load as mentioned above. The on-ramp fleet was accelerating, while the off-ramp fleet was decelerating, giving rise to slightly greater or lesser emissions, respectively, than would be expected under a steady cruise.

The off-ramp data for HC is also higher than the on-ramp data. We do not yet have enough data to determine any age-related increase in %HC. This data set implies only a slight age dependence for on-road fleet HC emissions.

Figure 8 shows the percentage of vehicles in each CO category and the percentage of the total emissions due to each CO category for the on-ramp and off-ramp data, respectively. Most noteworthy are the similarities between the 2 sites: over 70% of the vehicles are quite clean, emitting less than 1% CO and contributing only 15-20% of the total emissions.

Figure 9 shows the mean and median CO emissions as a function of model year. Figure 10 shows similar data for HC. Figure 11 shows the contribution to the total CO emission for each quintile,

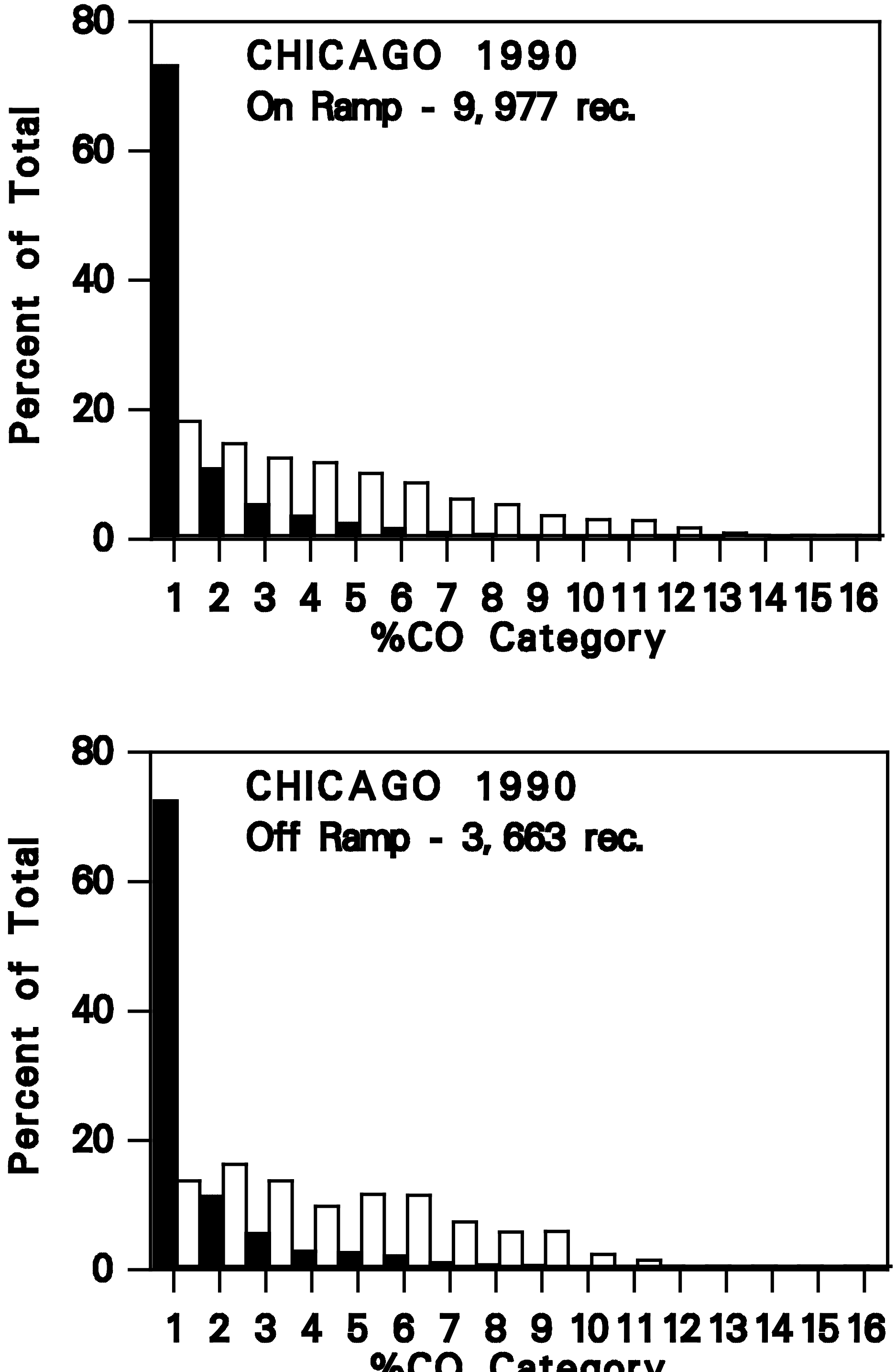

Figure 8. Normalized histograms showing as black bars the percentage of the fleet of vehicles with emissions less than the stated %CO category. Clear bars show the percentage of emissions. (upper) on-ramp, (lower) off-ramp.

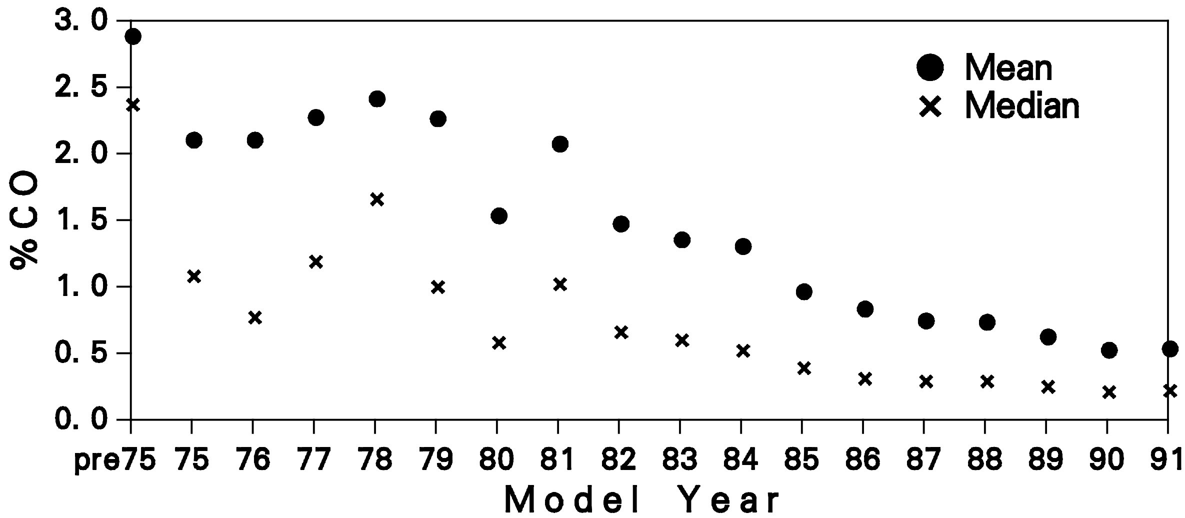

Figure 9. Mean and median carbon monoxide emission factors for the 1990 Chicago fleet.

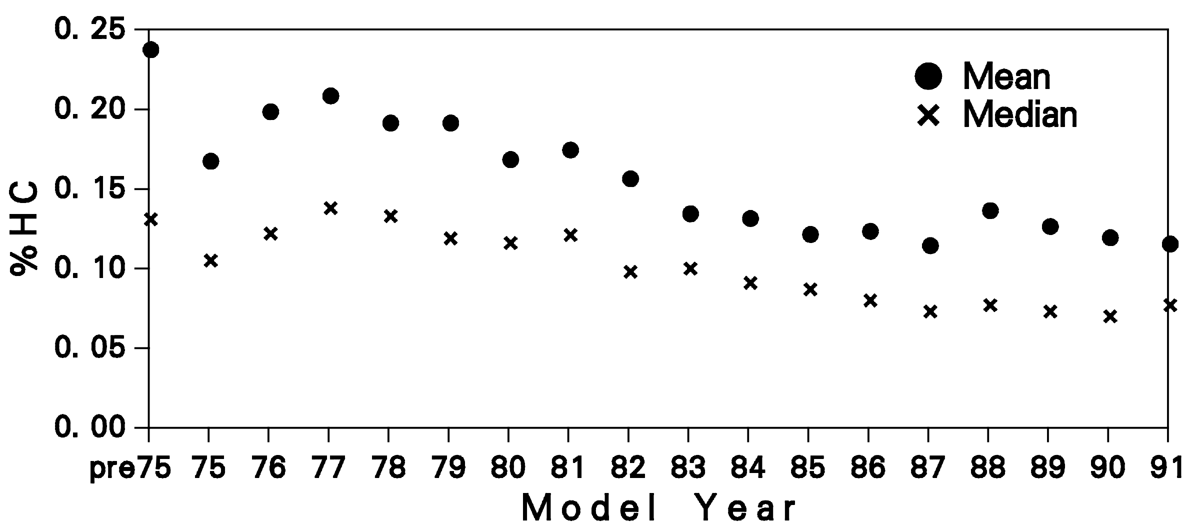

Figure 10. Mean and median hydrocarbon (percent propane equivalents) emission factors for the 1990 Chicago fleet.

weighted by the vehicle population. Figure 11a gives the age/%CO quintile distribution. When this is multiplied by the fleet age distribution (Figure 11b) the result is the percentage of the total CO emitted for each quintile of each model year, Figure 11c. This shows that the cleanest 40% of the vehicles, regardless of the model year, make an essentially negligible contribution to the CO emitted at this site. The greatest contribution is from the dirtiest 20% of the vehicles newer than 1980. This is due to the large number of vehicles dating from 1980, combined with the relatively high emission of the dirtiest 20% of these vehicles. Figure 12 is an equivalent presentation of HC data as the CO data presented in Figure 11. The data and conclusions are quite similar.

Figure 12 shows the quintile plots for the HC data. The dirtiest 20% of the new cars is dirtier than the cleanest 40% of any model year. This clean 40% makes a negligible contribution to the total HC emitted, when weighted for vehicle population. Since the men %HC shows very little variation with age, the percentage of total emission shows a distribution similar to the age distribution.

For HC, the dirtiest 20% of the on-ramp records contributes 58% of the total HC emitted, compared to 53% for the off-ramp fleet. The HC cut points (Table I) differ only slightly between the two sites, with less than 18% of either fleet contributing 50% of the total HC emitted.

In both cases, the dirtiest 20% of the fleet contributes nearly 3/4 of the total CO emitted, and encompasses both new and old vehicles. The CO gross polluter cut points are similar for both data sets: 3.43% and 3.80%. Less than 10% of either fleet exceeds their respective cut point. Figure 13 shows that the CO data obtained in Chicago in 1990 are very comparable to the data obtained in Chicago in 1989, and to other studies in LA and Denver. The major noticeable difference is that the newest vehicles in Chicago are not as overall clean as they are in Denver and LA.

D. Comparison of Data to Chicago, 1989 and to Other Locations.

Among the three cities Chicago, Denver, and Los Angeles, examination of the %CO quintile distributions (Figure 13) from the three cities shows that for each model year the emission factors are similar.

The three fleets are very similar when compared on a model year basis. The Denver data are more variable because the sample size is smaller. Among the older cars, L.A. emissions are greater than Chicago, but apparently not significantly different than the Denver fleet. In summary, the major differences between locations tested is the average age of the tested fleet. Driving mode, presence or absence of an I/M program, and possibly altitude of the measurements when above 7,000 ft show lesser effects. Table II compares the Chicago, 1989 data to the current 1990 data taken at the same site. The 1990 fleet is slightly newer and slightly cleaner. It is nearly identical when adjusted for fleet age according to the equation given in Figure 7b. The 1990 fleet is, however, one model year newer. Therefore, some old pre-control cars have been replaced by emission controlled vehicles, and some previously controlled vehicles are now suffering from

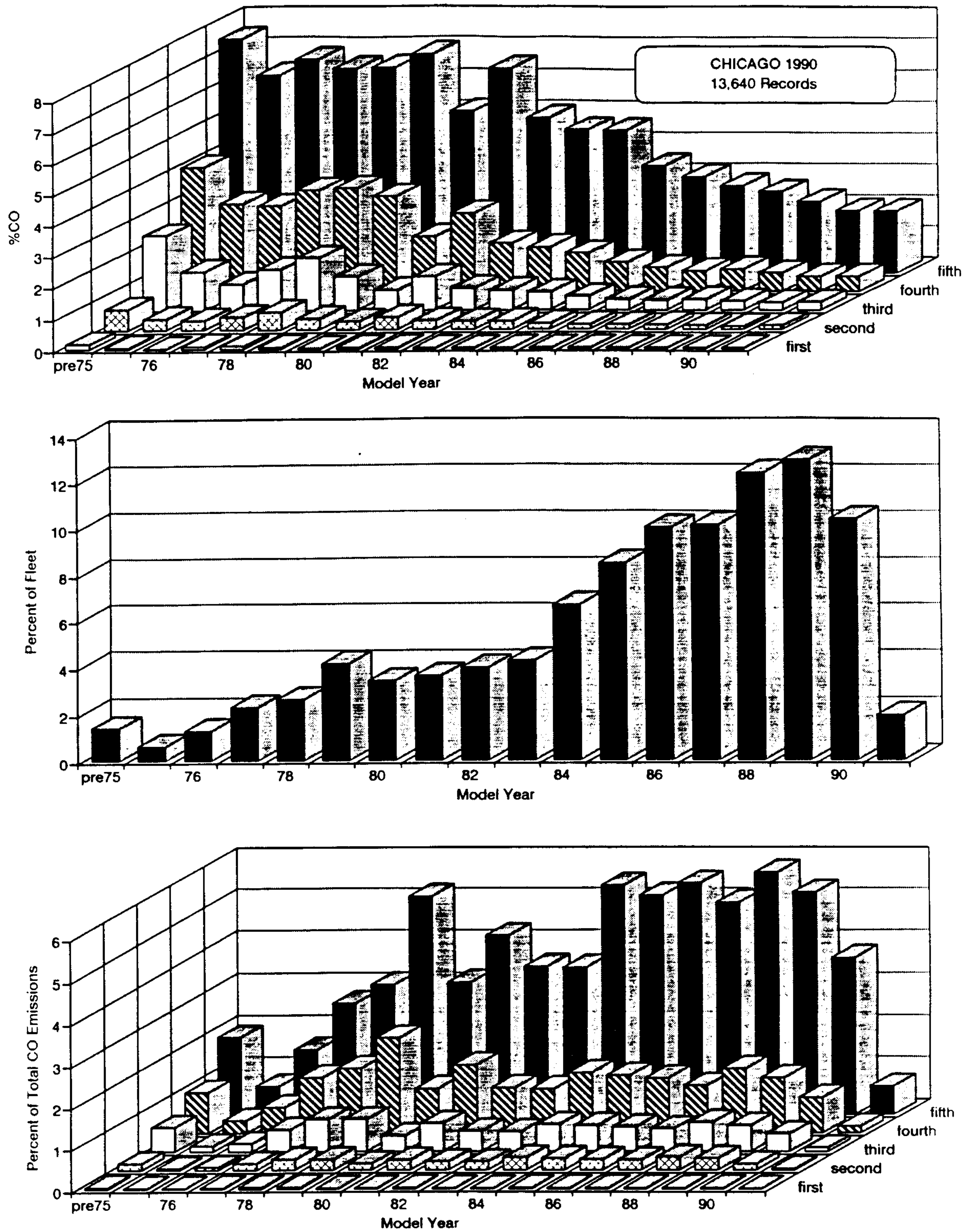

Figure 11. The top panel is the CO emission factors divided into quintiles. The middle panel shows the fleet age distribution and the lower panel is the product of both. Note that the dirtiest 20% of the newer vehicles dominates in every case.

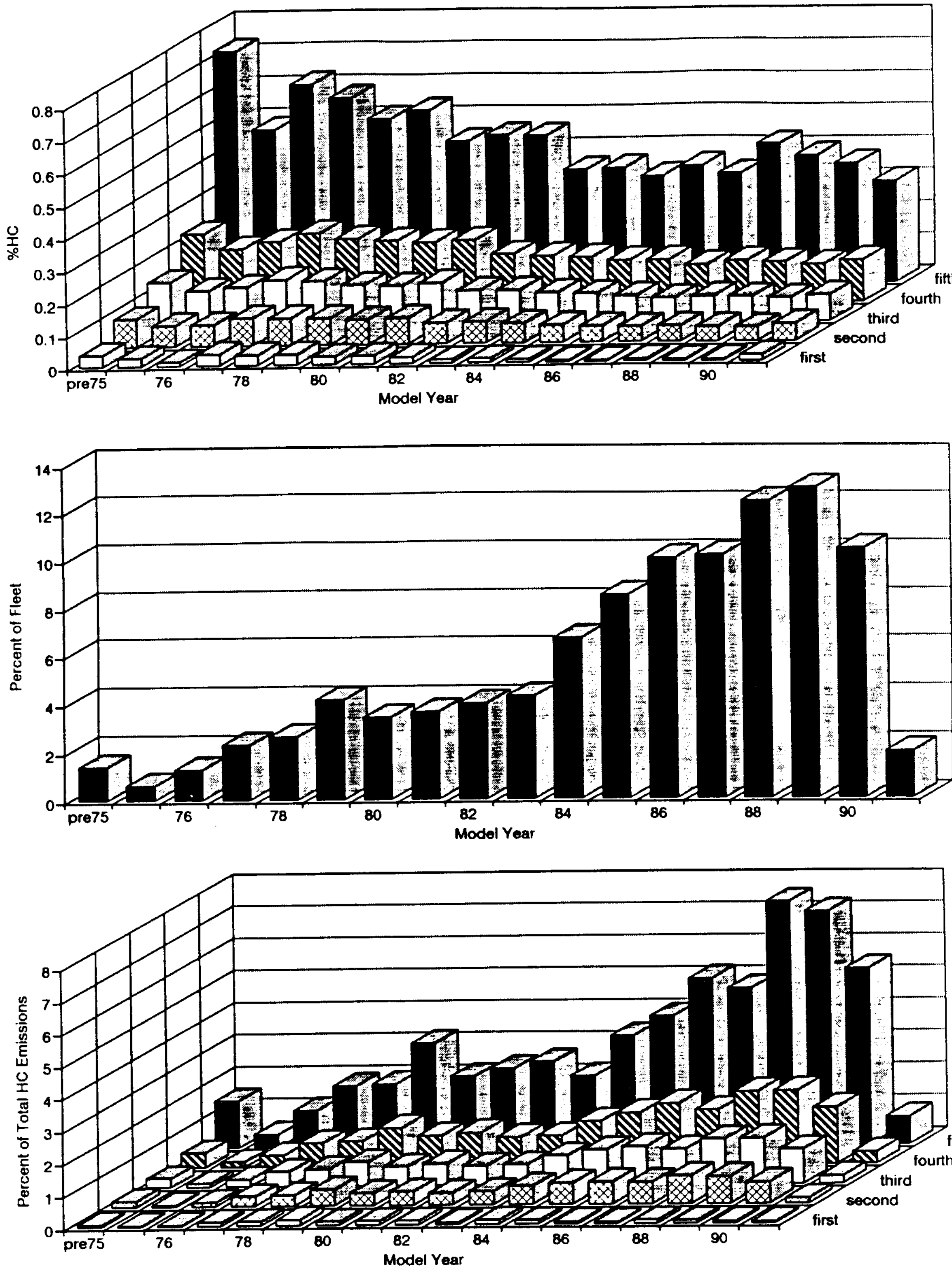

Figure 12. The top panel is the HC (propane equivalents) emission factors divided into quintiles. The middle panel shows the fleet age distribution and the lower panel is the product of both showing overall emission contributions.

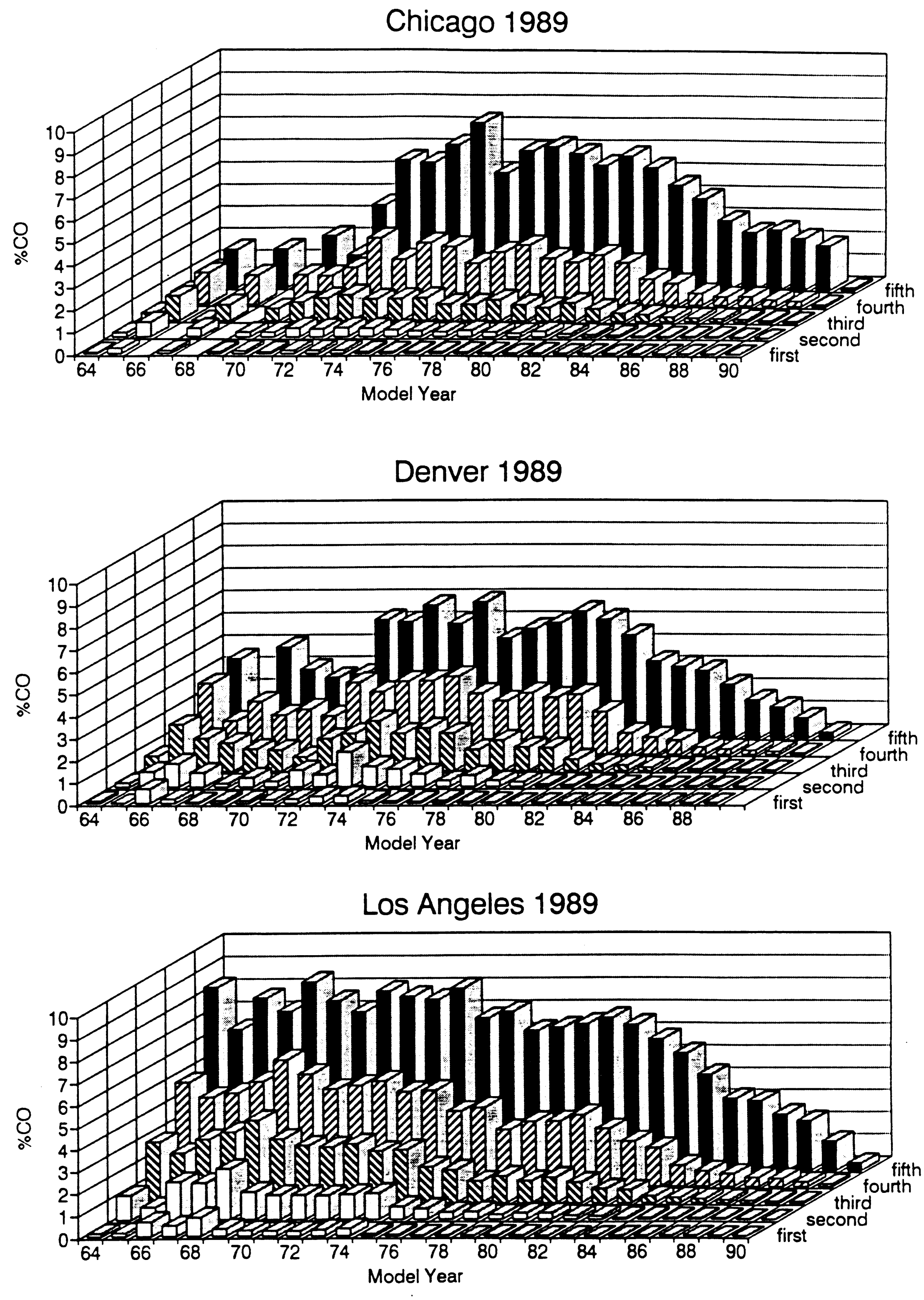

Figure 13. Quintile plots for %CO as a function of model year for the following sites: (upper) Chicago 1989, (middle) Denver 1989 and (lower) Los Angeles 1989.

Table II. Chicago 1989 data and Chicago 1990 morning data collected at the same site.

Fleet	1990 On-ramp	1989	1989 Age Adjusted
Number of records	9,977	11,818	
Average fleet age(years)	5.35	5.5	5.35
Mean %CO	1.08	1.17	1.13
Percent of fleet responsible for 50% of emissions	9.3	8.2	
Fleet emission percentage gross polluter cut points	3.43	4.48	

The data taken at the interchange in August are given in Table III, along with the overall October data. Only CO data were taken at the August site. This fleet is newer, and cleaner than the Central and Eisenhower fleet. Adjusting the August data for the average age eliminates about half of the difference in the mean %CO measured. There is no possibility of either cold vehicle operation or hard acceleration at the interchange site. If all the residual difference were ascribed to cold vehicle or hard acceleration effects then an upper limit of 35% of the CO observed in October arises from these causes.

E. Repeat Measurements of the Same Vehicle.

During the study, 235 vehicles were detected four or more times with valid CO and HC measurements. The mean of this subfleet is 1.23 %CO and 0.153 %HC, with an average age of 5.75 years. This subfleet is slightly older and subsequently slightly higher in emissions levels than the entire fleet. These vehicles are listed in Appendix A.

Of these 235 vehicles, 89 (38%) never emitted more than 1 %CO. This 38% of the vehicles emit only 6.25% of the total CO. At the other extreme lie 10 vehicles (4.25% of the subfleet) which were always in the gross polluting category (greater than 3.5 %CO). These 10 vehicles emitted more CO than all the 89 clean vehicles put together and were responsible for 20% of the total CO emissions. There were 48 vehicles which had variable emissions, meaning that some readings were over the cut point and some readings were below the cut point. Of these, 20 were over the gross polluter cut point at least twice. These vehicles measured as gross polluters at least twice are responsible for 30% of the total CO emissions. As will be discussed later, it can be shown that only a fraction of the vehicles identified as highly variable can be ascribed to cold start or to off-cycle hard accelerations.

Table III. Chicago 1990 (Central and Eisenhower) and Naperville 1990 (I-88 and I-355) data.

	Chicago 1990	Naperville 1990	Age adjusted Naperville data
Number of records	13,640	1,548	
Average fleet age(years)	5.5	4.1	5.5
Mean %CO	1.10	0.44	0.76
Median	0.37	0.08	
Percentage of total emissions from dirtiest 20% of Fleet	73	88	
Percentage of fleet responsible for 50% of emissions	9.4	5.0	
Fleet emissions 50 percent cut points	3.5	2.33	

The analysis of the multiply measured vehicles for HC emissions showed that only 58 vehicles (16% of the fleet) exceeded the gross polluter cut point two or more times. The HC distribution is not quite as skewed as the CO distribution, nevertheless this 16% of the fleet contribute 33% of the total HC emitted.

These data indicate that nearly half of the CO and one third of the HC emissions could be eliminated if the small number of vehicles that have been measured in excess of the cut point two or more times were repaired. The second report in this volume discusses options and systems by means of which a notification and repair program might be carried out (Lyons and Stedman, 1991). If the cut point for notification is defined as a constant fraction of the measured fleet, rather than a fixed emissions rate, then as the fleet emissions are cleaned up, a similar small fraction of the vehicle owners would receive notification, and the absolute values of the standards would gradually tighten as the fleet emissions are reduced.

According to Austin et al (1988) many vehicles enter a "power enrichment" mode when under heavy acceleration. The next section indicates that the power enrichment effect is probably not a dominant contributor to these data. Power enrichment is also termed "off cycle", since the Federal Test Procedure cycle used to certify new vehicle emissions does not include hard (> 3.3 mph/sec) accelerations. We present evidence that the data are not dominated by vehicles whose emissions are large only because of anomalous conditions occurring at the time of the

measurement. In short vehicles are "gross polluters" when they are malmaintained, not when they are merely accelerating.

F. Radar System and Power Enrichment

The radar system to monitor speed and acceleration has been built and tested. The unit was based on a standard police radar model K15-2 by MPH Industries. Despite the fact that MPH stated that this unit had an analog output which could be directly interfaced to our data acquisition system there turned out to be a continuing series of difficulties which necessitated our rebuilding a number of the circuits which had been originally sold to us. The major problem was that the radar suffered from too much signal when looking at vehicles from the short range (20 to 50 ft) which we use. The option to go to longer ranges is not usable at busy ramps since the beam spreads enough that any one of a row of vehicles could be the one which the radar is looking at. The radar gun response to signal overload is to drop the output level to zero occasionally then return the signal to the correct speed. Since the internal gun logic provides a readout of the maximum speed in a given time interval, this dropout is no problem for law enforcement. It is a major problem if one wishes (as we did) to take fifty speed readings in 0.5 seconds, and plot them versus time. The computer then determined the slope of the resultant scatter plot, and if within acceptable error bounds reported a successful measurement of acceleration. When we rewired the system to decrease the input gain, and partially eliminated the dropout problem, the system was then usable. Speed measurements can be obtained easily on more than 80% of the passing vehicles. Acceleration determination depends on the ability to determine, with reasonable accuracy, the first derivative of the (already fairly noisy) speed information. Acceleration is, therefore, reported on approximately 50% of the fleet. In view of these difficulties and the fact that angle, change, and heavy traffic also interfere with the data, we believe that a two-beam optical system under construction will be an improvement.

The angle change causes problems because of the limited range that we employ in the measurement of the speed of the automobiles, in the time taken for the radar to collect the speed data the automobile can travel as much as 40 feet. The computer starts to collect data when the infra red light beam is blocked and continues the data collection for the duration of the half second period after the beam is cleared by the automobile. Therefore we can see that a fifteen foot automobile moving at 30 miles an hour can move 37 feet in the time that the data is collected. If the vehicle point of radar reflection is moving parallel to the side of the road at a distance of five feet, then the approach angle(Θ) to the radar gun will change from 5.7° to 21°. Since the measured speed is proportional to cosine Θ it will change from 29.8 mph to 28.0 mph during the time elapsed for the data collection (0.84 seconds). A crude calculation lets us estimate that the approximate deceleration is 2.1 mph/second. However if we do the same series of calculations for the same vehicle following the same path at forty mph then we get an apparent deceleration of 12 mph/sec. These calculations are approximate since the radar reflection is not from an infinitesimal point. Similar apparent accelerations are calculated if the radar beam is looking at the rear of the vehicle receding. Figure 14 shows a series of curves calculated for vehicles traveling at different speeds and distances from the side of the road, the apparent decelerations were determined from a series of points calculated for the vehicles as they moved along their

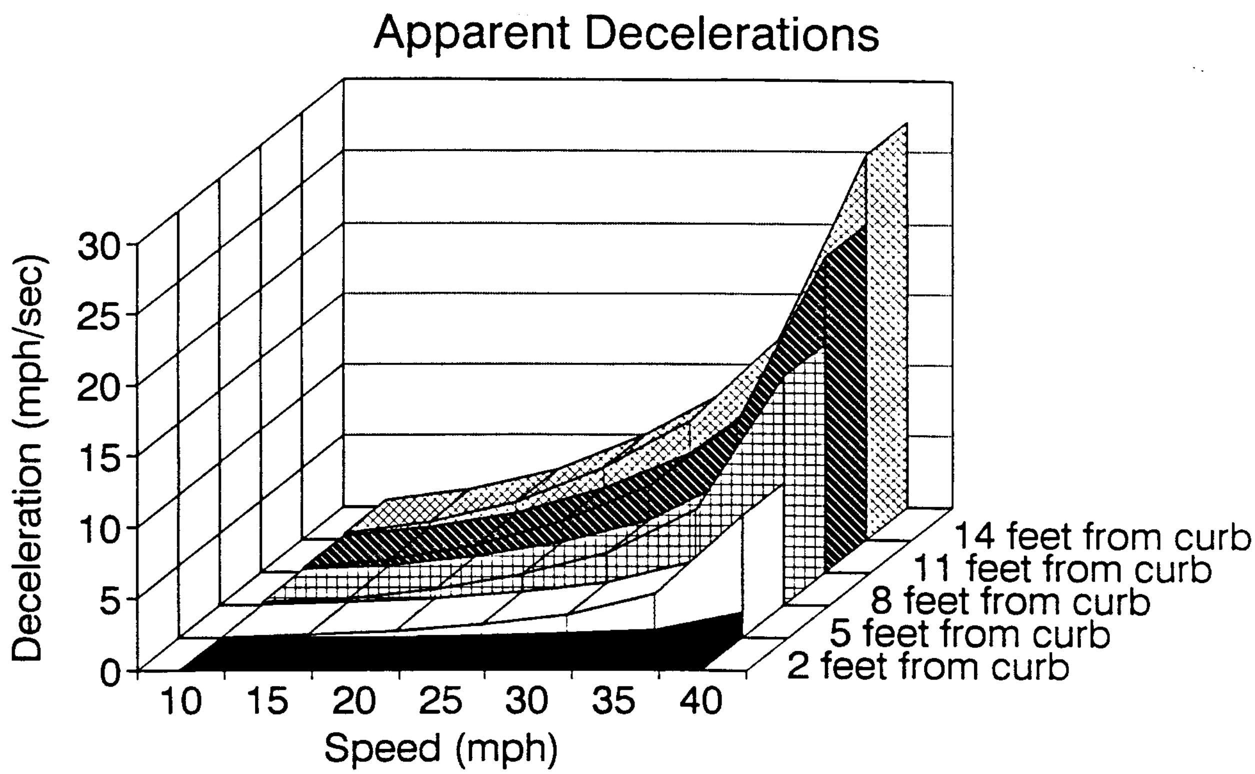

Figure 14. Graph showing the relationship between speed, distance from the side of the road and the apparent deceleration.

is looking at the rear of the vehicle receding. Figure 14 shows a series of curves calculated for vehicles traveling at different speeds and distances from the side of the road, the apparent decelerations were determined from a series of points calculated for the vehicles as they moved along their path during the data collection period. The apparent deceleration effect becomes severe at higher speeds and distances from the side of the road.

We conclude that the speed reported for the vehicles is largely unaffected by the cosine Θ effect since the difference in the speeds reported, except in extreme cases, is changed by only 1 or 2 mph, but the acceleration data except for slow moving vehicles does not have the degree of accuracy which one would like.

A two beam optical system could measure speed from the front and then the rear of each vehicle, and hence determine from the average, the speed and from the difference, the acceleration. Further development of this system will be a valuable addition to the current CO/HC remote sensing capability.

Despite these problems we have recorded a large database of successful measurements of speed and acceleration from the 1990 Illinois study. Table IV shows a summary of some of the data obtained. Accelerations are in mph/sec and speeds in mph. In this data set of over 3,000 vehicles the bias on the acceleration data is not large since most vehicles are observed between zero and two mph/sec. Not surprisingly in view of the controlled nature of the on-ramp there is

Table IV. Data summaries showing the effect of acceleration and speed on in-use CO and HC emissions. Chicago 1990, on-ramp with traffic control at Entry

Range of Accel	Count	Speed Mph		Acceleration Mph/Sec		%CO		%HC	
		AVG	σ	AVG	σ	AVG	σ^2	AVG	σ^2
< -6	1	29.4		-6.7		1.01		0.1	
< -5	4	20.6	5.4	-5.5	0.3	0.59	0.4	0.15	0.02
< -4	3	15.3	3.5	-4.3	0.2	1.54	1.2	0.1	0
< -3	11	17.7	5.5	-3.3	0.2	1.64	1.3	0.28	0.14
< -2	56	18.1	3.8	-2.4	0.3	1.48	1.4	0.18	0.06
< -1	202	19.5	4	-1.4	0.3	1.72	1.5	0.19	0.07
< 0	581	19.5	3.9	-0.4	0.3	1.45	1.5	0.17	0.08
< 1	1260	20.8	3.4	0.6	0.3	0.89	1.2	0.11	0.04
< 2	1197	22.2	3.1	1.4	0.3	0.95	1.3	0.10	0.02
< 3	285	23.7	3.3	2.4	0.3	0.98	1.3	0.11	0.07
< 4	55	22.8	4.4	3.3	0.3	0.7	0.9	0.08	0.02
< 5	18	23.8	4	4.4	0.3	1.6	1.4	0.11	0.07
< 6	6	22.5	5	5.3	0.1	0.37	0.6	0.07	0.02
< 7	1	29.6		6.1		0.47		0.02	
< 8	4	21,6	6	7.3	0.3	0.7	0.6	0.07	0
< 9	3	20.7	3.3	8.4	0.4	3.32	2.1	0.14	0.02
< 10	1	23.3		9.1		4.05		1.07	
Range of Speed	**Count**	**Speed Mph**		**Acceleration Mph/Sec**		**%CO**		**%HC**	
		AVG	σ	AVG	σ	AVG	σ^2	AVG	σ^2
10-15	266	13.1	1.1	-0.1	1.5	1.24	1.4	0.15	0.13
< 20	920	17.9	1.4	0.3	1.2	1.17	1.4	0.11	0.17
< 25	1964	22.4	1.4	0.9	1.1	0.99	1.3	0.11	0.03
< 30	534	26.3	1.1	1.3	1.3	1.05	1.3	0.12	0.01
< 35	6	30.8	0.5	2.2	1.6	2.00	1.9	0.13	0.01

emissions on average with increasing speed/acceleration. No conclusive inferences can be drawn from average emissions numbers for data sets with less than fifty data entries. The fact that nine vehicles were assigned accelerations greater than seven mph/sec is quite likely to represent errors in our ability to determine acceleration rather than a few high performance vehicles

operating in a flat-out mode. Data summarizing the effect of acceleration and speed on in-use CO and HC emissions are shown in Table IV.

This leaves us with CO emission measurements which are higher on average for late model cars in Chicago than in any of the other U.S. cities that measurements have been made and speed and accelerations cannot be used to explain them. We are convinced that high CO readings are highly correlated with tampered vehicles (Lawson et al 1990). It is therefore possible, since Illinois has only recently instituted a tamper survey in its I/M program, that tamper rates are higher for late model cars in Chicago than in the other U. S. cities.

G. Vehicle Emissions After One Year

In order to evaluate the effect of aging on a fleet, a subset of 70 vehicles was examined. These vehicles were measured 7 or more times, with some records from 1989 and some from 1990. An analysis of the difference in means (paired) showed a change in emissions of -0.071 %CO with a standard deviation of 1.559 %CO. This difference is statistically insignificant. It is generally assumed that the rate of emissions of a fleet of vehicles will increase as the fleet gets older. The paired analysis difference of means is small and negative. There is no sign that the fleet has become dirtier.

A closer look at the individual difference in means shows 7 of the seventy vehicles had absolute difference of means greater than 2.0. Six of these vehicles showed significant improvement in mean CO emission rate, while only one appeared to deteriorate. Elimination of a single vehicle, an unidentified 1988 vehicle license number MY2834, would change the average difference in means from -0.071 to +0.049 %CO. The vehicles in this small sample have had the same owner for the time period in question and appear at similar times and locations one year later. In that year the mean emissions showed essentially no change. The fleet measured in 1990 in Chicago is slightly cleaner than the fleet measured in 1989. It is also slightly newer. The deterioration with age applies to fleet averages. From the limited study of 70 vehicles it does not appear to apply to individual vehicles as long as the owner and usage remains the same.

Another study was carried out looking at 135 vehicles measured at least twice on the on-ramp both in 1989 and 1990. The change in %CO was + 0.077 ± 1.4. While looking at this fleet we noticed that 27 vehicles had the same license plates but were in fact different vehicles. Twenty-six of twenty-seven were newer models. This fleet of "updated vehicles reduced their %CO emissions by 0.106 ± 1.2, as would be expected.

H. Video Tape Reading Errors.

There are several ways to check on the accuracy with which the video tapes have been read, and the accuracy with which the Secretary of State's records reflect the on-road fleet. Previous studies have shown that the combined rate of tape reading errors and registration errors in Illinois was less than 3%.

III. INSPECTION AND MAINTENANCE

One of the principles of I/M programs is the idea that a vehicle's emission rate might increase with time from the last check-up and repair. Periodic inspections and prescribed emissions maintenance are intended to keep the level of emissions below a maximum limit. If this is true then there will be a relationship between the emission rate and the time since the last I/M test. Using the data gathered in the Chicago 1990 study, 8971 vehicle emission readings were correlated with time since their most recent I/M results. The emission rates were the mean %CO and ppmHC corrected to hexane. The data show no correlation between time from last I/M test and the on-road measured rate of emission for either CO or total HC. The Illinois I/M records include emissions data at idle (Idle CO) and at 2500 rpm (High CO). We searched for a correlation between on-road CO and both High CO and Idle CO, as well as the equivalent HC measurements. The data show no correlation between any of the I/M test variables and on-road measured rate of emission for either CO or total HC.

From the gamma distribution of emission rates, a large majority of vehicles have very low emissions that vary through a small range. This large number of clean vehicles will dominate any determination of correlation for the entire fleet. More variable cars could be represented by those cars that have failed to pass the I/M test at least twice before passing the most recent test. If some vehicles fail with time, then those vehicle should be members of this subfleet. The correlation between elapsed time since last I/M test vs on-road measured CO and HC were determined for this subfleet. The low values of the statistical parameters, $r^2 = 0.001, 0.005$; df = 401, respectively, again show no evidence of correlation.

For over 10% of the vehicles the last reported I/M test was failed. High emission rates on a failed I/M test with no proof of repair or maintenance should correlate with high on-road emission rates. The greatest correlation is between Idle HC and on-road HC ($r^2 = 0.085$; df = 914). Still there is a better than 90% probability that this correlation could be randomly generated.

Although there is no correlation between I/M test values and equivalent on-road measurements, the I/M behavior does have some predictive power. The vehicles that passed the I/M test after failing at least twice, passed I/M with values more that 100% higher than the average pass values (see Table V). These same vehicles had 50% higher on-road readings. These average values were almost as high as the values for the subfleet that had failed the most recent I/M test. This result is encouraging since it indicates that vehicles which, according to the records, have trouble passing the I/M have a reasonable likelihood of higher average on-road emissions.

This study has shown that the both the CO and HC distributions are highly skewed, with most vehicles operating cleanly, and only a few vehicles contributing a disproportionate amount of the total CO or HC emitted into the Chicago area. It therefore would seem to be a good idea to attack this high-emission tail of the distribution, which remote sensing can accomplish.

The data herein imply that the Illinois I/M program is correctly identifying vehicles with emission problems, but on-road emissions are not being reduced. Recent data from California also show

Table V. Data showing that the Illinois I/M program identifies by failure vehicles with higher than average on-road emissions.

Mean Values			
	All	**Failed > Twice**	**Failed Last**
On-road CO (1)	**1.02**	**1.5**	**1.6**
High CO	**0.57**	**2.2**	**2.6**
Idle CO	**0.64**	**1.5**	**2.3**
On-road HC (2)	**673**	**969**	**850**
High HC	**61**	**125**	**199**
Idle HC	**136**	**300**	**400**

(1) All CO data are reported as %CO.
(2) On-road HC data converted to ppm hexane, I/M data in ppm hexane.

that their I/M program does not effect on-road emissions (Ashbaugh et al 1990, C.A.R.B. 1990, and C.A.R.B. 1991). When a remote sensing study was carried out in Colorado there was also much less difference between I/M and non-I/M fleets than predicted by the EPA computer models (Stedman et al 1991b). Cheating and the "Pass the Test" mentality are some of the potential reasons that on-road emission levels are not effected by scheduled I/M programs. If remote sensing were a major component of an I/M program it would be much harder to cheat.

The other major advantage of remote sensing as a component of an I/M program is that the data (i.e. the fleet average emissions) can be used as a test of the efficacy of the program. Remote sensing can provide the necessary information over time to determine whether the actions taken are producing the desired reduction in total vehicle emissions. Also, this evaluative information would come from direct measurement of on-road emissions rather than a computer model.

Appendix B lists the fifty cleanest, dirtiest, oldest and newest vehicles measured in October. Note that for the dirtiest HC it is possible to be clean for CO, even though many are quite dirty while the dirtiest for CO are almost never clean for HC. This result arises from the fact that the high CO (rich) side of engine operation almost always entails high HC, whereas high HC can also arise from the lean side of the diagram where CO emission may be negligible. Even though the oldest vehicles are certainly higher emitters for CO and HC than the average fleet, it is interesting to note that only two of the fifty dirtiest CO and a different two of the fifty dirtiest HC vehicles are old.

Amongst the listed dirtiest HC vehicles are 16 which are 1989 or 1990 model year. In view of the fact that these vehicles should have functional catalysts we do not know how they have managed to get into this category. Non-catalyst equipped vehicles or vehicles whose catalysts are no longer operational show high HC (often > 1% HC) and no CO emissions when an intentional ignition misfire is induced. On late model vehicles with three-way catalysts the vast majority of cars are no longer equipped with air pumps. This might lead to a situation where a misfire or an excessive evaporative canister purge can overload the catalyst with fuel and no excess air to oxidize the fuel, in effect shutting the catalyst off and allowing the unburned fuel to exit the vehicle. All of these new vehicles were measured at the on-ramp during morning rush hour and thus were involved in an entrance wait of one to five minutes. This may be a contributing cause for these observations. Similar emissions of high HC with low CO on late model vehicles have been reported by Austin et al (1988).

IV. REFERENCES

L.L. Ashbaugh, B.E. Croes, E.M. Fujita, and D.R. Lawson. "Emission Characteristics of California's 1989 Random Roadside Survey", Presented at NAMVECC, Tampa, Fl., (1990).

T.C. Austin, H.A. Ashby, and T.R. Carlson. "An Evaluation of Loaded Mode I/M Testing at Service Stations", Report #SR88-12-02, (1988).

G.A. Bishop, J.R. Starkey, A. Ihlenfeldt, W.J. Williams, and D.H. Stedman. "IR Long-Path Photometry, A Remote Sensing Tool For Automobile Emissions", Anal. Chem.,61, 671A-677A, (1989).

G.A. Bishop and D.H. Stedman. "Oxygenated Fuels, A Remote Sensing Evaluation", Society for Automotive Engineers, Technical Paper, Series #891116, (1989).

California Air Resources Board. "Report on the ARB/BAR 1989 Random Roadside Inspection Survey", MS-90-14, (1990).

California Air Resources Board. "Report on the ARB/BAR 1990 Random Roadside Inspection Survey", MS-91-06, (1991).

J.B. Heywood, "Internal Combustion Engine Fundamentals." McGraw Hill, (1988).

D.R. Lawson, P.J. Groblicki, D.H. Stedman, G.A. Bishop and P.L. Guenther, "Emissions from In-use Motor Vehicles in Los Angeles: A Pilot Study of Remote Sensing and the Inspection and Maintenance Program", J. Air Waste Manage. Assoc., 40, 8, (1990).

C.E. Lyons and D.H. Stedman, "Remote Sensing-Enhanced Motor Vehicle Emissions Control For Pollution Reduction in the Chicago Metropolitan Area: Siting and Issue Analysis", Report prepared for the Illinois Department of Energy and Natural Resources, In press, (1990).

D.H. Stedman, "Automobile Carbon Monoxide Emission", Env. Sci. Tech., 23, 147-149, (1989).

D.H. Stedman and G.A. Bishop, "Remote Sensing for Mobile Source CO Emission Reduction", Final Report EPA 600/4-90/032, (1991).

D.H. Stedman and G.A. Bishop, "An Analysis of On-Road Remote Sensing As A Tool For Automobile Emissions Control," Illinois Department of Energy and Natural Resources, Report # ILENR/RE-AQ-90/05, (1990).

D.H. Stedman, G.A. Bishop, J.E. Peterson, and P.L. Guenther. "On-Road Remote Sensing of CO Emissions in the Los Angeles Basin", Final report to the California Air Resources Board under Contract Number A932-189, (1991a).

D.H. Stedman, G.A. Bishop, and J.E. Peterson. "On-Road Remote Sensing and Motor Vehicle Inspection and Maintenance Programs", To be Published, Chapman and Hall, London, (1991b).

V. APPENDICES

APPENDIX A: Repeat Vehicles

235 vehicles which were measured more than four times at the Central Ave. and I-290 on and off-ramps from 10/22/90 to 10/26/90.

Date	Time	License	Make	Year	%CO	%HC(propane)
10/22/90	17:54:22	10065	FORD	86	0.10	0.108
10/23/90	17:44:15	10065			0.04	0.028
10/24/90	17:51:42	10065			0.97	0.460
10/26/90	17:50:25	10065			0.34	0.190
10/22/90	16:56:51	103666	CHEVROLET	89	0.00	0.085
10/24/90	08:15:15	103666			0.51	0.073
10/25/90	08:14:12	103666			0.45	0.182
10/26/90	08:16:25	103666			0.29	0.009
10/23/90	18:11:08	160472	VOLKSWAGEN	87	0.06	0.063
10/24/90	07:53:05	160472			0.57	0.079
10/24/90	17:38:53	160472			0.65	0.388
10/25/90	08:02:56	160472			0.84	0.089
10/26/90	08:07:32	160472			0.13	0.052
10/22/90	16:45:50	211631	CHEVROLET	86	-0.06	0.019
10/24/90	07:14:54	211631			0.07	0.020
10/26/90	07:12:54	211631			1.49	0.057
10/26/90	16:53:25	211631			0.89	0.431
10/22/90	17:32:29	235469		85	1.31	0.160
10/23/90	17:15:53	235469			0.08	0.027
10/25/90	17:31:44	235469			0.36	0.078
10/26/90	17:40:22	235469			1.81	0.054
10/22/90	17:51:07	27770	TOYOTA	82	0.59	0.261
10/24/90	07:37:32	27770			1.90	0.064
10/25/90	09:45:15	27770			1.60	0.146
10/25/90	16:01:12	27770			0.91	0.056
10/22/90	17:51:13	384372	BUICK	85	0.15	0.046
10/24/90	11:47:36	384372			0.02	0.023
10/24/90	17:43:23	384372			0.07	0.085
10/25/90	09:19:48	384372			1.67	0.065
10/22/90	18:00:52	4007AC-B	CHEVROLET	87	0.65	0.193
10/23/90	17:25:01	4007AC-B			0.20	0.036
10/24/90	08:05:05	4007AC-B			0.15	0.051
10/25/90	07:29:15	4007AC-B			0.55	0.047
10/26/90	07:39:45	4007AC-B			0.26	0.018
10/22/90	17:36:55	401998	MAZDA	86	2.36	0.338
10/24/90	08:03:14	401998			0.25	0.061
10/24/90	17:26:33	401998			0.33	0.217
10/25/90	08:08:20	401998			1.82	0.132

10/23/90	18:07:00	413461	HONDA	86	0.25	0.103
10/24/90	09:54:08	413461			0.17	0.054
10/25/90	10:06:27	413461			0.10	0.063
10/26/90	07:23:21	413461			0.66	0.076
10/24/90	16:51:36	416668	FORD	86	1.32	0.651
10/25/90	07:33:27	416668			0.25	0.158
10/25/90	16:51:55	416668			-0.14	0.144
10/26/90	07:30:12	416668			0.00	0.052
10/26/90	12:48:13	416668			0.27	-0.039
10/22/90	17:11:44	443024	FORD	86	0.07	0.092
10/24/90	07:51:42	443024			4.69	0.111
10/25/90	07:43:55	443024			10.15	0.503
10/26/90	07:43:26	443024			12.33	0.712
10/22/90	17:46:39	467253		88	0.22	0.019
10/24/90	07:44:02	467253			0.08	0.044
10/25/90	07:42:08	467253			0.37	0.109
10/25/90	18:22:17	467253			0.75	0.383
10/26/90	07:42:30	467253			0.10	0.027
10/22/90	18:04:11	592225	DODGE	89	-0.05	0.062
10/23/90	18:00:08	592225			0.56	0.349
10/24/90	09:26:49	592225			0.45	0.091
10/25/90	16:27:12	592225			-0.53	-0.008
10/22/90	16:37:21	598669	HONDA	86	0.07	0.015
10/24/90	07:54:57	598669			0.35	0.114
10/24/90	17:56:28	598669			0.04	0.203
10/25/90	08:12:22	598669			0.04	0.033
10/26/90	07:53:08	598669			0.29	0.161
10/22/90	16:48:29	601474	TOYOTA	89	0.13	0.200
10/24/90	07:53:31	601474			0.21	0.044
10/24/90	16:39:22	601474			0.58	0.211
10/25/90	07:27:14	601474			0.13	0.077
10/25/90	16:20:30	601474			0.01	0.239
10/22/90	17:10:48	608983	VOLKSWAGEN	86	-0.03	0.099
10/23/90	17:20:05	608983			0.83	0.263
10/24/90	17:12:29	608983			0.98	0.075
10/25/90	17:31:29	608983			0.79	0.171
10/22/90	17:21:37	6113FE-B	FORD	90	-0.10	0.029
10/23/90	18:18:20	6113FE-B			0.04	0.116
10/24/90	07:30:33	6113FE-B			0.05	0.047
10/24/90	17:29:07	6113FE-B			-0.35	0.071
10/25/90	17:38:46	6113FE-B			0.74	0.333

10/22/90	16:26:58	61709		86	-0.13	-0.057
10/24/90	11:57:30	61709			0.45	0.046
10/25/90	09:14:33	61709			-0.14	-0.024
10/26/90	11:42:00	61709			0.03	-0.011
10/26/90	16:11:23	61709			-0.02	0.105
10/23/90	17:42:42	672026	HONDA	85	0.69	0.323
10/25/90	08:50:32	672026			3.84	0.085
10/25/90	18:07:42	672026			0.04	0.034
10/26/90	08:25:15	672026			3.28	0.216
10/24/90	07:28:44	6780EG-B	MITCHELL	85	1.62	0.086
10/24/90	17:21:04	6780EG-B			0.20	0.242
10/26/90	07:46:29	6780EG-B			0.30	0.009
10/26/90	17:14:45	6780EG-B			1.75	0.299
10/22/90	16:49:15	79013RV	CHEVROLET	85	0.02	0.152
10/23/90	16:34:44	79013RV			0.41	0.380
10/24/90	16:41:27	79013RV			0.32	0.038
10/25/90	16:33:34	79013RV			-0.02	0.046
10/23/90	16:52:40	814686		87	5.60	0.233
10/24/90	07:35:01	814686			6.77	0.086
10/25/90	07:39:32	814686			5.40	0.171
10/26/90	07:34:43	814686			6.10	0.192
10/22/90	17:42:19	8191EC-B		89	0.04	0.036
10/24/90	09:04:50	8191EC-B			-0.36	0.029
10/24/90	17:33:46	8191EC-B			0.34	0.210
10/25/90	09:52:32	8191EC-B			0.24	0.125
10/26/90	08:47:58	8191EC-B			0.64	0.035
10/26/90	18:01:59	8191EC-B			0.42	0.104
10/22/90	16:14:21	819DT-B	FORD	89	1.53	0.804
10/24/90	06:41:38	819DT-B			0.18	0.060
10/24/90	16:40:14	819DT-B			1.86	0.643
10/25/90	07:47:20	819DT-B			-0.07	0.084
10/25/90	16:22:23	819DT-B			0.14	0.077
10/22/90	16:52:36	977298	BUICK	88	0.42	0.217
10/24/90	07:51:54	977298			0.15	0.038
10/25/90	07:53:37	977298			0.08	0.078
10/26/90	07:36:05	977298			0.32	0.090
10/24/90	07:43:08	AN748		88	0.06	0.056
10/24/90	17:27:13	AN748			0.22	0.155
10/25/90	07:29:47	AN748			9.18	0.297
10/26/90	07:26:15	AN748			0.63	0.215

10/24/90	07:51:05	AU9129	BUICK	86	-0.05	0.011
10/25/90	07:47:30	AU9129			0.20	0.012
10/26/90	07:45:14	AU9129			0.05	0.086
10/26/90	16:08:08	AU9129			-0.18	0.028
10/22/90	17:18:27	BAZ82	PONTIAC	82	0.32	0.091
10/24/90	17:07:22	BAZ82			0.06	0.152
10/25/90	09:04:09	BAZ82			0.07	0.052
10/25/90	17:19:18	BAZ82			0.28	0.386
10/26/90	08:35:43	BAZ82			0.16	0.036
10/22/90	17:06:20	BF1993	FORD	87	0.03	-0.007
10/24/90	08:06:21	BF1993			0.48	0.019
10/25/90	08:13:15	BF1993			1.85	0.128
10/25/90	17:11:34	BF1993			1.62	0.658
10/26/90	08:12:13	BF1993			0.86	0.058
10/22/90	16:33:24	BG9443	MAZDA	89	2.57	0.958
10/23/90	17:24:41	BG9443			-0.02	0.144
10/24/90	09:17:38	BG9443			1.26	0.139
10/25/90	09:22:44	BG9443			0.70	1.229
10/26/90	08:35:27	BG9443			3.61	1.562
10/24/90	09:58:18	BPA431	FORD	88	0.30	0.076
10/25/90	08:14:58	BPA431			5.16	0.338
10/26/90	08:05:57	BPA431			0.57	0.083
10/26/90	16:22:13	BPA431			0.09	0.047
10/22/90	17:19:19	BT5033	FORD	90	-0.27	0.040
10/24/90	07:38:47	BT5033			0.10	-0.008
10/25/90	07:32:56	BT5033			0.25	0.166
10/26/90	17:21:50	BT5033			0.27	0.129
10/24/90	10:05:21	BT9015	VOLKSWAGEN	88	0.35	0.215
10/24/90	18:14:08	BT9015			1.58	0.228
10/25/90	10:02:13	BT9015			-0.01	0.092
10/26/90	10:12:30	BT9015			0.82	0.584
10/23/90	17:38:48	BY2141	OLDSMOBILE	86	0.18	0.110
10/24/90	09:08:07	BY2141			0.11	0.080
10/25/90	09:15:30	BY2141			-0.06	0.049
10/26/90	17:48:38	BY2141			-0.21	0.023
10/22/90	17:15:34	CAR316	CHEVROLET	85	-0.53	-0.061
10/23/90	17:05:57	CAR316			0.06	0.050
10/24/90	17:14:14	CAR316			0.11	0.161
10/25/90	17:14:34	CAR316			0.61	0.243

10/23/90	18:38:05	CK4324	OLDSMOBILE	78	2.29	0.185
10/24/90	10:18:56	CK4324			-0.02	0.060
10/25/90	10:24:06	CK4324			-0.09	0.055
10/26/90	10:26:29	CK4324			2.31	0.060
10/22/90	17:18:38	CL7858	CHEVROLET	86	0.00	0.056
10/24/90	07:52:34	CL7858			0.15	0.028
10/24/90	17:14:21	CL7858			-0.34	0.038
10/25/90	07:46:08	CL7858			-0.01	0.036
10/25/90	17:16:56	CL7858			0.57	0.155
10/26/90	17:23:56	CL7858			1.62	0.193
10/24/90	07:59:14	CM6671	FORD	91	0.39	0.132
10/24/90	17:38:17	CM6671			0.35	0.138
10/25/90	07:56:16	CM6671			-0.08	0.045
10/26/90	07:52:38	CM6671			-0.01	0.087
10/23/90	17:03:00	CM9448	HONDA	88	0.66	0.266
10/24/90	09:54:03	CM9448			-0.17	0.105
10/25/90	09:52:24	CM9448			0.24	0.066
10/25/90	16:54:22	CM9448			0.89	0.083
10/22/90	18:04:01	CR6467	PLYMOUTH	88	0.14	0.112
10/24/90	17:46:14	CR6467			0.74	0.335
10/25/90	18:10:45	CR6467			0.96	0.303
10/26/90	07:07:48	CR6467			4.69	0.214
10/22/90	16:48:25	CVZ195	BUICK	84	-0.11	0.074
10/24/90	07:19:45	CVZ195			0.82	0.066
10/25/90	16:49:24	CVZ195			0.86	0.361
10/26/90	07:14:25	CVZ195			0.97	0.065
10/26/90	16:56:55	CVZ195			-0.23	0.119
10/24/90	07:24:10	CX8554	FORD	83	0.31	0.081
10/24/90	17:21:32	CX8554			-0.14	0.059
10/25/90	17:29:23	CX8554			-0.50	0.133
10/26/90	17:31:36	CX8554			0.04	0.031
10/22/90	16:56:19	DA2217	PLYMOUTH	89	0.25	0.040
10/23/90	16:47:31	DA2217			0.22	0.039
10/25/90	16:57:48	DA2217			0.51	0.142
10/26/90	17:07:25	DA2217			2.77	0.253
10/24/90	07:28:57	DA5309	CADILLAC	90	-0.09	0.009
10/24/90	17:48:32	DA5309			1.31	0.243
10/25/90	08:16:34	DA5309			-0.05	0.045
10/26/90	07:28:53	DA5309			0.19	0.023

10/23/90	18:24:55	DANEEN	PONTIAC	88	0.09	0.073
10/24/90	08:09:44	DANEEN			0.59	0.076
10/24/90	18:29:33	DANEEN			0.05	0.087
10/26/90	08:03:47	DANEEN			0.57	0.119
10/23/90	17:52:27	DC4976	OLDSMOBILE	86	1.98	0.515
10/24/90	06:54:00	DC4976			0.19	0.068
10/24/90	18:28:09	DC4976			0.12	0.029
10/26/90	07:01:28	DC4976			0.47	0.033
10/22/90	17:27:07	DLB306	TOYOTA	75	2.61	0.170
10/24/90	09:16:45	DLB306			0.92	0.082
10/26/90	09:28:30	DLB306			0.23	0.037
10/26/90	17:30:38	DLB306			3.03	0.650
10/22/90	17:01:42	DS2868	MERCEDES-BENZ	75	2.87	0.358
10/24/90	08:18:31	DS2868			0.83	0.086
10/24/90	17:12:27	DS2868			6.68	0.147
10/25/90	08:09:58	DS2868			9.53	0.289
10/23/90	17:12:09	DW5089	OLDSMOBILE	76	1.05	0.545
10/24/90	06:45:39	DW5089			0.09	0.052
10/24/90	17:15:18	DW5089			1.12	0.123
10/26/90	17:01:05	DW5089			-0.24	0.126
10/22/90	17:24:47	DZ2646	CHEVROLET	86	0.42	0.189
10/24/90	07:42:43	DZ2646			0.10	0.059
10/24/90	17:22:45	DZ2646			-0.12	0.042
10/25/90	07:47:36	DZ2646			0.00	0.044
10/26/90	07:51:26	DZ2646			0.13	0.081
10/22/90	17:25:44	EA5568	CHEVROLET	88	1.84	0.565
10/24/90	07:50:51	EA5568			0.50	0.055
10/24/90	17:30:06	EA5568			0.71	0.130
10/25/90	07:49:37	EA5568			2.16	0.137
10/22/90	16:46:01	EB5698	CHEVROLET	86	0.02	0.066
10/24/90	08:13:29	EB5698			0.17	0.053
10/25/90	08:03:19	EB5698			0.65	-0.015
10/26/90	08:09:27	EB5698			0.25	0.131
10/22/90	18:00:22	EB6709	BUICK	87	0.25	0.025
10/23/90	17:56:37	EB6709			0.78	0.138
10/24/90	08:24:21	EB6709			0.33	0.099
10/25/90	08:20:44	EB6709			0.65	0.111
10/26/90	08:22:12	EB6709			2.17	0.025
10/24/90	08:52:54	ECX539	CHEVROLET	89	0.39	0.034
10/25/90	09:13:55	ECX539			0.56	0.076
10/25/90	18:30:19	ECX539			0.23	0.140
10/26/90	18:10:25	ECX539			0.02	0.111

10/24/90	07:37:14	ED9233	FORD MUSTANG	83	-0.04	0.038
10/25/90	07:43:08	ED9233			6.02	0.233
10/25/90	16:34:51	ED9233			0.28	0.131
10/26/90	07:40:15	ED9233			0.17	0.104
10/22/90	17:33:57	EDW116	FORD	89	1.20	0.088
10/24/90	07:57:02	EDW116			0.07	0.076
10/24/90	17:33:06	EDW116			0.89	0.373
10/25/90	08:02:00	EDW116			0.05	0.833
10/22/90	17:13:56	EU8272	MAZDA	82	0.21	0.106
10/24/90	08:56:46	EU8272			0.04	0.049
10/25/90	08:44:40	EU8272			1.85	0.008
10/26/90	11:50:39	EU8272			1.69	0.066
10/22/90	16:51:28	EV1657	DODGE	89	-0.13	0.019
10/23/90	16:46:52	EV1657			0.22	0.062
10/24/90	07:14:36	EV1657			0.17	0.087
10/24/90	16:57:37	EV1657			-0.06	0.100
10/24/90	11:17:59	EVA369	HONDA	87	0.20	-0.020
10/25/90	09:36:48	EVA369			1.09	0.058
10/25/90	18:12:55	EVA369			0.21	0.131
10/26/90	11:15:17	EVA369			0.17	0.067
10/26/90	18:14:15	EVA369			0.66	0.220
10/24/90	17:51:50	EXG497	HONDA	86	0.00	0.078
10/25/90	07:41:08	EXG497			0.57	0.197
10/26/90	07:47:43	EXG497			0.33	0.149
10/26/90	17:25:56	EXG497			1.28	0.193
10/22/90	17:20:03	EXR493	DODGE	85	5.84	0.561
10/25/90	07:51:24	EXR493			0.25	0.153
10/25/90	17:21:14	EXR493			-0.01	0.165
10/26/90	07:50:46	EXR493			0.86	0.112
10/24/90	08:54:07	EY1142	BUICK	86	0.28	0.140
10/25/90	08:39:12	EY1142			0.16	0.085
10/25/90	17:27:10	EY1142			0.02	0.097
10/26/90	08:59:09	EY1142			0.26	0.065
10/22/90	17:10:33	EY2602	CHEVROLET	89	1.23	0.498
10/23/90	17:06:03	EY2602			0.22	0.046
10/24/90	07:14:26	EY2602			0.42	0.071
10/24/90	17:10:38	EY2602			0.33	0.143
10/22/90	17:31:57	EZ332	OLDSMOBILE	84	0.87	0.129
10/23/90	17:28:42	EZ332			-0.04	0.023
10/24/90	18:17:15	EZ332			-0.19	0.022
10/26/90	17:39:51	EZ332			1.27	0.277

10/23/90	17:28:44	FJ5942	OLDSMOBILE	88	1.08	0.382
10/24/90	07:03:27	FJ5942			0.43	0.055
10/24/90	17:09:00	FJ5942			0.27	0.158
10/26/90	07:08:11	FJ5942			-0.12	0.092
10/22/90	16:57:55	FNB265	OLDSMOBILE	85	0.32	0.170
10/24/90	06:56:07	FNB265			0.14	0.083
10/24/90	17:27:02	FNB265			0.92	0.208
10/26/90	17:07:48	FNB265			1.30	0.153
10/23/90	16:44:02	GCY138	CADILLAC	78	5.59	0.179
10/24/90	16:07:15	GCY138			2.73	0.142
10/25/90	15:56:23	GCY138			3.05	0.160
10/26/90	16:09:32	GCY138			2.01	0.160
10/22/90	17:28:46	GL4670	DODGE	85	0.47	0.148
10/25/90	08:10:02	GL4670			-0.02	0.070
10/25/90	16:27:35	GL4670			1.09	0.326
10/26/90	08:06:17	GL4670			-0.23	-0.063
10/23/90	16:59:35	GT1640	SUBARU	89	0.32	0.064
10/24/90	07:06:10	GT1640			0.17	0.073
10/25/90	17:35:48	GT1640			-0.26	0.051
10/26/90	07:07:45	GT1640			0.14	0.066
10/22/90	16:44:51	GWA256	CHEVROLET	84	3.42	0.034
10/24/90	08:02:38	GWA256			0.51	0.076
10/24/90	16:45:28	GWA256			0.29	0.128
10/26/90	07:59:07	GWA256			0.35	0.044
10/23/90	18:01:46	HJM141	FORD	88	0.20	-0.051
10/24/90	09:05:42	HJM141			1.80	0.038
10/24/90	17:45:10	HJM141			2.43	0.194
10/25/90	08:55:25	HJM141			3.62	0.243
10/25/90	18:12:46	HJM141			1.81	0.330
10/26/90	18:08:10	HJM141			1.87	0.323
10/23/90	17:51:32	HKW181	FORD	88	0.72	0.057
10/24/90	07:28:26	HKW181			1.51	0.102
10/24/90	17:59:58	HKW181			0.53	0.152
10/26/90	07:28:23	HKW181			0.76	0.068
10/22/90	17:17:04	HL6375	FORD	87	1.07	0.448
10/24/90	07:41:29	HL6375			2.01	0.047
10/24/90	17:19:38	HL6375			0.16	0.157
10/25/90	07:43:11	HL6375			1.74	0.216
10/26/90	07:39:41	HL6375			1.61	0.081

10/22/90	17:36:50	HV3618	BUICK	88	0.33	0.143
10/24/90	07:20:21	HV3618			0.10	0.040
10/25/90	07:44:04	HV3618			0.56	0.077
10/25/90	16:30:37	HV3618			3.21	0.253
10/26/90	08:10:35	HV3618			0.73	0.202
10/22/90	16:52:56	HXG604	FORD	78	-0.23	0.021
10/23/90	16:48:21	HXG604			2.60	0.080
10/24/90	07:22:16	HXG604			0.23	0.046
10/24/90	16:54:04	HXG604			6.19	0.161
10/26/90	07:19:09	HXG604			0.05	-0.026
10/24/90	07:48:21	HZ8091	HONDA	88	2.99	0.079
10/24/90	16:23:43	HZ8091			1.98	0.243
10/25/90	16:25:16	HZ8091			1.69	0.356
10/26/90	07:45:40	HZ8091			3.06	0.300
10/22/90	17:49:11	IA382	FORD	87	0.20	0.179
10/24/90	08:26:51	IA382			1.47	0.157
10/25/90	08:27:17	IA382			3.83	0.134
10/26/90	17:50:27	IA382			0.35	0.174
10/22/90	18:13:03	IR7790	CHEV CAMARO	85	-0.34	0.183
10/23/90	18:23:58	IR7790			0.05	0.080
10/24/90	08:25:59	IR7790			1.29	0.106
10/25/90	08:31:59	IR7790			2.23	0.143
10/26/90	08:18:22	IR7790			0.72	0.076
10/26/90	18:12:21	IR7790			0.20	-0.046
10/23/90	17:31:49	IS5003	PONTIAC	84	0.12	0.066
10/24/90	09:03:00	IS5003			1.21	0.156
10/24/90	17:36:11	IS5003			1.58	0.492
10/25/90	09:01:40	IS5003			0.31	0.060
10/26/90	08:58:36	IS5003			2.06	0.120
10/26/90	17:48:47	IS5003			0.63	0.160
10/24/90	08:15:50	JDB435	AUDI	87	0.19	0.089
10/24/90	17:25:49	JDB435			0.91	0.320
10/25/90	08:12:15	JDB435			4.72	0.071
10/25/90	17:17:31	JDB435			0.14	0.074
10/26/90	07:34:54	JDB435			0.17	0.082
10/22/90	17:05:35	JEF555	BUICK	90	0.16	0.037
10/24/90	10:36:49	JEF555			-0.09	0.050
10/24/90	18:06:03	JEF555			-0.13	0.089
10/25/90	10:20:30	JEF555			0.05	0.071
10/25/90	18:31:19	JEF555			0.78	0.219

10/23/90	17:20:30	JK8217	PONTIAC	78	5.69	0.229
10/24/90	17:26:45	JK8217			5.25	0.409
10/25/90	08:45:18	JK8217			5.60	0.115
10/26/90	08:43:32	JK8217			5.22	0.129
10/23/90	18:20:50	JMX838	CADILLAC	82	0.10	0.051
10/24/90	08:08:08	JMX838			0.76	0.063
10/24/90	18:08:43	JMX838			0.04	0.039
10/25/90	08:02:15	JMX838			0.14	0.040
10/26/90	08:05:19	JMX838			1.35	0.092
10/22/90	18:11:01	JN6586	TOYOTA	76	-0.12	0.009
10/24/90	09:23:31	JN6586			0.24	-0.002
10/25/90	09:00:22	JN6586			0.35	0.023
10/25/90	18:30:13	JN6586			0.09	0.167
10/22/90	17:23:30	JN8705	VOLVO	87	0.04	0.463
10/24/90	08:28:17	JN8705			0.12	0.045
10/25/90	07:47:40	JN8705			2.69	1.500
10/26/90	07:51:15	JN8705			0.29	0.147
10/22/90	17:26:54	JNJ143	DODGE	90	0.64	0.128
10/23/90	17:25:13	JNJ143			0.00	-0.038
10/25/90	08:04:54	JNJ143			-0.03	0.024
10/25/90	17:22:15	JNJ143			1.32	0.506
10/26/90	08:21:45	JNJ143			0.14	0.061
10/23/90	16:53:05	JNP131	PONTIAC	81	1.51	0.145
10/25/90	08:12:11	JNP131			2.22	0.108
10/25/90	16:56:13	JNP131			-0.03	0.021
10/26/90	08:14:28	JNP131			0.13	0.075
10/24/90	08:10:42	JR4725	OLDSMOBILE	66	2.90	0.127
10/24/90	16:31:25	JR4725			6.11	0.140
10/25/90	17:24:17	JR4725			3.65	0.088
10/26/90	17:59:43	JR4725			4.26	0.316
10/22/90	18:08:17	JT1519	MERCURY	79	0.54	0.099
10/24/90	17:48:46	JT1519			4.48	0.149
10/25/90	08:41:44	JT1519			7.78	1.437
10/26/90	09:39:36	JT1519			3.14	0.250
10/22/90	16:25:02	JW7052	HONDA	87	0.01	-0.028
10/24/90	07:35:54	JW7052			0.15	0.035
10/24/90	16:35:27	JW7052			0.23	0.121
10/25/90	09:54:55	JW7052			1.53	0.053
10/26/90	07:41:40	JW7052			3.69	0.108

10/24/90	08:24:52	JWG293	FORD	88	0.29	0.138
10/24/90	17:10:44	JWG293			0.48	0.183
10/25/90	08:21:09	JWG293			0.28	0.075
10/26/90	08:31:16	JWG293			0.41	0.099
10/24/90	08:01:04	JY6627	BUICK	89	1.41	0.077
10/25/90	08:06:11	JY6627			0.15	0.042
10/26/90	08:00:53	JY6627			0.75	0.178
10/26/90	17:27:36	JY6627			0.42	0.238
10/22/90	16:59:33	JY7781	PLYMOUTH	87	-0.22	0.004
10/23/90	16:52:15	JY7781			0.68	0.190
10/24/90	16:52:22	JY7781			-0.29	-0.009
10/26/90	16:31:30	JY7781			-0.09	-0.022
10/22/90	16:55:05	KAN846	CHRYSLER	86	0.27	0.044
10/24/90	07:42:41	KAN846			-0.07	0.027
10/25/90	07:40:07	KAN846			0.26	0.123
10/26/90	08:46:21	KAN846			-0.03	0.098
10/22/90	18:02:35	KD9310	PONTIAC	89	-0.34	0.121
10/23/90	18:18:10	KD9310			-0.09	0.030
10/24/90	07:58:07	KD9310			0.14	0.035
10/25/90	08:04:57	KD9310			-0.01	0.033
10/26/90	08:13:35	KD9310			0.52	0.144
10/22/90	17:52:06	KH5632	FORD	87	0.67	0.164
10/24/90	08:05:51	KH5632			5.70	0.123
10/24/90	17:15:26	KH5632			-0.18	0.116
10/25/90	08:16:45	KH5632			0.80	0.126
10/23/90	17:21:43	KJ514	FORD	78	4.11	0.149
10/24/90	07:40:48	KJ514			6.53	0.064
10/25/90	07:36:24	KJ514			2.85	0.336
10/25/90	17:40:47	KJ514			4.78	0.290
10/26/90	07:38:50	KJ514			7.70	0.079
10/26/90	17:07:54	KJ514			4.22	0.432
10/24/90	07:54:51	KNU561	FORD	89	-0.26	0.167
10/24/90	17:21:38	KNU561			0.26	0.021
10/25/90	07:54:30	KNU561			0.79	0.299
10/26/90	09:37:25	KNU561			0.16	0.088
10/23/90	16:53:06	KZ5523	PONTIAC	87	0.13	0.053
10/24/90	17:14:05	KZ5523			-0.18	0.097
10/25/90	08:32:21	KZ5523			0.07	0.016
10/25/90	17:15:12	KZ5523			0.12	0.098

10/22/90	16:52:16	LBS273	DODGE	86	1.86	0.203
10/25/90	09:01:00	LBS273			3.90	0.340
10/26/90	09:35:38	LBS273			6.16	0.133
10/26/90	18:01:02	LBS273			2.61	0.127
10/22/90	17:07:09	LP4215	MERCURY	79	4.58	0.425
10/24/90	07:12:38	LP4215			3.60	0.064
10/24/90	16:57:16	LP4215			5.17	0.237
10/26/90	07:14:32	LP4215			5.32	0.017
10/24/90	07:20:44	LRW154	TOYOTA	88	0.32	0.126
10/25/90	16:40:00	LRW154			0.40	0.212
10/26/90	07:19:00	LRW154			0.33	0.085
10/26/90	15:57:58	LRW154			2.54	0.691
10/22/90	16:39:11	LT7961	SAAB	86	-0.04	0.124
10/23/90	17:39:27	LT7961			0.11	0.016
10/24/90	08:25:53	LT7961			0.17	0.044
10/24/90	18:28:10	LT7961			0.42	0.313
10/25/90	08:40:58	LT7961			0.25	0.074
10/25/90	17:45:07	LT7961			-0.42	0.186
10/26/90	08:47:15	LT7961			3.53	0.248
10/22/90	17:17:15	LW6211	FORD	77	2.11	0.103
10/24/90	08:08:12	LW6211			0.51	0.123
10/24/90	16:47:07	LW6211			2.39	0.222
10/25/90	07:58:13	LW6211			2.21	0.099
10/25/90	17:25:27	LW6211			2.03	0.071
10/26/90	08:02:12	LW6211			0.52	0.250
10/26/90	17:55:25	LW6211			2.63	0.080
10/22/90	17:12:06	LYH397		86	0.47	0.114
10/24/90	08:08:58	LYH397			0.00	0.053
10/24/90	17:15:59	LYH397			0.04	0.035
10/25/90	08:08:17	LYH397			0.33	0.074
10/25/90	17:19:40	LYH397			0.04	0.092
10/26/90	08:06:02	LYH397			0.35	0.065
10/23/90	17:33:04	LYH568	PLYMOUTH	88	0.05	0.076
10/24/90	08:02:56	LYH568			0.28	0.043
10/24/90	17:36:23	LYH568			1.07	0.331
10/25/90	17:38:34	LYH568			2.02	0.631
10/24/90	09:05:36	MAR192	PONTIAC	88	5.27	0.045
10/25/90	07:39:43	MAR192			0.49	0.123
10/26/90	07:43:32	MAR192			0.37	0.035
10/26/90	09:38:49	MAR192			0.57	0.067

10/24/90	08:26:04	MARG424	VOLVO	81	0.71	0.073
10/25/90	07:29:36	MARG424			2.80	0.333
10/26/90	07:23:56	MARG424			0.77	0.023
10/26/90	16:32:24	MARG424			1.43	0.677
10/23/90	18:12:32	MC3899	OLDSMOBILE	79	1.76	0.081
10/24/90	06:53:20	MC3899			12.30	0.261
10/24/90	16:24:45	MC3899			0.51	0.134
10/26/90	16:53:15	MC3899			1.42	0.063
10/23/90	17:24:30	MJR75	PONTIAC	86	-0.31	0.034
10/24/90	08:13:45	MJR75			1.81	0.123
10/24/90	16:26:09	MJR75			0.27	0.144
10/25/90	08:02:13	MJR75			-0.09	0.031
10/26/90	08:13:25	MJR75			0.29	0.078
10/22/90	17:45:02	MOC89	HONDA	88	1.09	0.045
10/24/90	08:15:51	MOC89			-0.05	0.041
10/25/90	08:13:52	MOC89			0.24	0.039
10/26/90	07:44:24	MOC89			0.20	0.082
10/22/90	17:02:01	MUSAAB1	PLYMOUTH	79	3.23	1.605
10/24/90	08:18:26	MUSAAB1			6.43	0.138
10/24/90	18:03:36	MUSAAB1			7.37	1.184
10/26/90	08:50:15	MUSAAB1			7.08	0.163
10/24/90	08:03:08	MV583	VOLKSWAGEN	89	0.17	0.033
10/24/90	16:51:11	MV583			-0.07	-0.001
10/25/90	08:18:09	MV583			-0.12	0.018
10/26/90	08:14:25	MV583			0.40	0.065
10/26/90	16:34:42	MV583			0.16	0.081
10/22/90	16:37:23	MXD433		85	-0.12	0.093
10/24/90	09:12:24	MXD433			0.94	0.088
10/25/90	09:08:09	MXD433			0.83	0.036
10/25/90	16:31:56	MXD433			-0.03	-0.040
10/26/90	15:53:46	MXD433			0.66	0.197
10/24/90	07:35:22	MY2834		88	5.04	0.101
10/25/90	18:08:10	MY2834			0.17	0.065
10/26/90	08:00:55	MY2834			0.32	0.039
10/26/90	16:38:25	MY2834			0.04	0.115
10/22/90	17:16:19	NAON	PONTIAC	86	-0.06	0.057
10/24/90	08:33:01	NAON			1.16	0.016
10/24/90	17:30:00	NAON			-0.20	0.075
10/25/90	08:36:21	NAON			0.29	0.028

10/22/90	17:31:15	NEL270	CADILLAC	79	0.00	0.049
10/24/90	06:53:37	NEL270			0.01	0.070
10/24/90	16:34:55	NEL270			0.41	0.167
10/25/90	07:48:22	NEL270			0.81	0.073
10/26/90	07:22:06	NEL270			0.19	0.138
10/24/90	07:02:37	NIC667	PONTIAC	79	1.17	0.065
10/24/90	16:21:36	NIC667			1.16	0.129
10/25/90	16:27:42	NIC667			1.37	0.119
10/26/90	07:01:31	NIC667			6.88	0.219
10/26/90	16:27:55	NIC667			0.89	0.100
10/24/90	12:27:16	NKS771	CHEVROLET	89	0.17	0.056
10/25/90	08:16:29	NKS771			0.18	-0.005
10/25/90	16:56:30	NKS771			-0.19	0.003
10/26/90	08:04:21	NKS771			0.48	0.255
10/22/90	17:33:34	NMF903	BUICK	86	0.19	0.095
10/24/90	07:54:59	NMF903			0.05	0.032
10/24/90	18:29:58	NMF903			0.29	0.135
10/25/90	17:16:44	NMF903			-0.15	0.101
10/22/90	17:16:43	NR6481	PLYMOUTH	74	5.05	0.188
10/23/90	16:51:51	NR6481			2.63	0.175
10/24/90	18:23:15	NR6481			3.94	0.078
10/25/90	16:59:33	NR6481			7.38	0.265
10/26/90	07:13:50	NR6481			10.70	0.135
10/26/90	16:46:01	NR6481			5.39	0.168
10/22/90	17:57:47	NT5920	JAGUAR	87	0.67	0.156
10/23/90	17:53:25	NT5920			0.21	0.113
10/24/90	08:20:32	NT5920			-0.05	0.003
10/24/90	17:33:59	NT5920			-0.12	-0.046
10/26/90	08:42:35	NT5920			0.07	0.035
10/22/90	17:34:34	NU5930	BUICK	83	1.06	0.482
10/23/90	17:23:04	NU5930			0.00	0.111
10/24/90	08:20:50	NU5930			0.51	0.059
10/24/90	17:28:40	NU5930			0.36	0.128
10/25/90	08:23:08	NU5930			1.04	-0.005
10/26/90	08:17:56	NU5930			0.67	0.158
10/22/90	17:08:11	NXP208		85	0.42	0.353
10/24/90	07:35:44	NXP208			0.43	0.035
10/25/90	07:35:33	NXP208			0.86	0.093
10/25/90	17:09:00	NXP208			2.43	0.250
10/26/90	07:37:38	NXP208			0.42	0.046

10/23/90	16:54:28	OG6131	OLDSMOBILE	87	0.05	0.028
10/24/90	11:13:44	OG6131			-0.03	0.057
10/25/90	10:58:45	OG6131			0.08	0.050
10/26/90	10:42:18	OG6131			0.02	0.083
10/24/90	08:09:07	OR9425	CHEVROLET	88	0.40	0.093
10/24/90	18:19:28	OR9425			-0.36	-0.020
10/25/90	08:05:49	OR9425			-0.20	-0.030
10/25/90	17:15:53	OR9425			0.82	0.742
10/22/90	17:25:41	PEARCE	CADILLAC	90	0.02	0.157
10/23/90	17:22:18	PEARCE			0.31	0.025
10/24/90	07:41:04	PEARCE			0.09	0.059
10/24/90	17:23:21	PEARCE			0.24	0.118
10/25/90	07:41:42	PEARCE			-0.18	0.134
10/26/90	07:34:13	PEARCE			0.36	0.121
10/22/90	17:44:56	PJ106	CHRYSLER	81	4.23	0.274
10/23/90	17:18:06	PJ106			4.89	0.058
10/24/90	17:21:53	PJ106			7.34	0.271
10/25/90	17:25:29	PJ106			7.42	0.322
10/26/90	17:31:45	PJ106			7.32	0.447
10/23/90	16:45:25	PJGAD	VOLVO	89	-0.19	0.041
10/24/90	09:20:15	PJGAD			-0.06	0.067
10/24/90	16:57:08	PJGAD			0.12	0.093
10/25/90	09:02:36	PJGAD			0.17	0.065
10/23/90	16:44:58	PN3584	BUICK	76	1.01	0.020
10/24/90	08:19:33	PN3584			-0.10	-0.048
10/25/90	08:21:55	PN3584			-0.05	0.020
10/26/90	08:16:31	PN3584			0.02	0.099
10/24/90	08:29:32	PRB	MERCEDES-BENZ	86	5.50	0.125
10/25/90	08:34:31	PRB			3.43	0.176
10/26/90	08:33:36	PRB			6.54	0.135
10/26/90	17:18:21	PRB			3.48	0.351
10/23/90	17:20:42	PRD387	CHEVROLET	88	0.19	0.027
10/24/90	08:31:46	PRD387			0.03	0.021
10/25/90	08:30:13	PRD387			0.92	0.079
10/26/90	08:30:49	PRD387			0.08	0.011
10/22/90	17:36:42	PS3256	PONTIAC	89	-0.03	0.095
10/24/90	08:02:09	PS3256			0.93	0.039
10/24/90	17:32:15	PS3256			-0.27	0.083
10/26/90	17:42:59	PS3256			1.11	0.112

10/23/90	17:52:34	PS8954	FORD	90	1.77	0.344
10/24/90	07:13:11	PS8954			0.17	0.064
10/24/90	17:42:42	PS8954			-0.06	0.109
10/25/90	07:54:05	PS8954			0.04	0.048
10/25/90	16:32:28	PS8954			-0.18	0.023
10/26/90	07:30:03	PS8954			0.16	-0.014
10/23/90	17:06:06	PXX503	FORD	88	1.24	0.073
10/24/90	07:31:47	PXX503			3.33	0.083
10/25/90	08:11:19	PXX503			0.66	0.108
10/26/90	18:03:10	PXX503			0.65	-0.013
10/23/90	18:25:53	QA5297	CHEVROLET	79	6.65	0.509
10/24/90	10:06:35	QA5297			0.40	0.131
10/25/90	10:01:03	QA5297			2.59	0.174
10/26/90	10:10:17	QA5297			0.03	0.022
10/22/90	17:27:33	QA7015	FORD	83	-0.03	0.045
10/23/90	16:41:52	QA7015			0.53	0.177
10/24/90	16:50:27	QA7015			-0.33	-0.010
10/25/90	10:25:05	QA7015			0.24	0.129
10/25/90	16:52:51	QA7015			0.32	0.223
10/26/90	16:57:03	QA7015			-0.07	0.023
10/23/90	17:21:23	QE882	MERCURY	79	0.18	0.116
10/24/90	07:25:08	QE882			0.04	0.042
10/24/90	17:25:23	QE882			0.24	0.043
10/25/90	07:28:37	QE882			-0.03	0.038
10/24/90	10:20:45	QR5150	CHEVROLET	84	1.62	0.085
10/24/90	17:14:25	QR5150			2.02	0.253
10/25/90	09:18:12	QR5150			0.38	0.018
10/25/90	17:00:40	QR5150			1.09	0.519
10/26/90	11:34:14	QR5150			1.56	0.427
10/24/90	08:27:33	QS1895	TOYOTA	86	0.23	0.065
10/25/90	08:42:02	QS1895			2.32	0.178
10/25/90	16:46:19	QS1895			0.53	0.149
10/26/90	08:44:25	QS1895			0.65	0.134
10/24/90	08:57:30	QX4085	DODGE	82	0.05	-0.040
10/24/90	17:07:34	QX4085			0.13	0.204
10/25/90	08:56:52	QX4085			-0.02	0.005
10/26/90	08:56:30	QX4085			0.08	0.069
10/24/90	08:12:50	QX952	DODGE	89	0.02	0.018
10/24/90	17:35:39	QX952			0.68	0.271
10/25/90	08:01:40	QX952			-0.16	0.014
10/26/90	08:05:59	QX952			0.28	0.172

10/22/90	16:32:32	QY5108	FORD	79	4.79	0.241
10/24/90	16:35:56	QY5108			4.96	0.330
10/25/90	16:18:56	QY5108			0.94	0.083
10/26/90	16:44:30	QY5108			0.81	0.253
10/24/90	07:27:14	QZ4428	FORD	84	2.45	0.036
10/24/90	17:28:35	QZ4428			0.58	0.098
10/25/90	07:33:59	QZ4428			0.92	0.104
10/26/90	07:43:12	QZ4428			0.50	0.200
10/24/90	08:30:42	QZ520		82	0.71	0.006
10/24/90	17:38:31	QZ520			0.03	0.068
10/25/90	08:28:40	QZ520			0.20	-0.001
10/26/90	08:33:47	QZ520			-0.05	0.128
10/24/90	08:29:37	QZ908	DODGE	89	0.34	0.046
10/26/90	08:41:29	QZ908			3.89	0.653
10/26/90	09:35:53	QZ908			0.05	0.019
10/26/90	17:33:35	QZ908			0.98	0.169
10/24/90	16:35:00	RB8237	CHRYSLER	84	0.53	0.223
10/25/90	08:43:58	RB8237			0.84	0.369
10/25/90	17:03:27	RB8237			0.27	0.086
10/26/90	08:48:07	RB8237			0.68	0.110
10/22/90	17:59:08	RB8993	CHEVROLET	81	0.56	0.334
10/23/90	17:58:11	RB8993			1.03	0.591
10/24/90	17:16:55	RB8993			1.08	0.435
10/25/90	08:27:07	RB8993			1.30	0.182
10/26/90	08:13:44	RB8993			1.10	0.085
10/23/90	17:16:57	RE2250		89	0.39	0.131
10/24/90	09:19:48	RE2250			0.06	0.064
10/24/90	17:31:35	RE2250			0.12	0.055
10/25/90	09:05:06	RE2250			0.19	0.061
10/26/90	07:56:35	RE2250			0.26	0.075
10/26/90	17:27:47	RE2250			-0.02	0.106
10/22/90	17:01:18	RG4539	MERCURY	86	0.39	0.401
10/23/90	16:38:41	RG4539			0.93	0.001
10/24/90	16:58:11	RG4539			0.38	0.177
10/26/90	16:54:52	RG4539			0.61	0.315
10/22/90	17:49:59	RJ3823	FORD	87	-0.13	0.056
10/24/90	07:18:21	RJ3823			5.49	0.077
10/24/90	17:56:30	RJ3823			-0.02	0.110
10/26/90	07:11:42	RJ3823			4.03	0.116

10/22/90	18:16:25	RJ6451	LINCOLN	88	0.12	0.092
10/25/90	07:51:27	RJ6451			0.04	0.055
10/25/90	16:29:13	RJ6451			0.12	0.116
10/26/90	10:34:01	RJ6451			0.04	0.103
10/23/90	17:46:17	RJ7841	DODGE	72	4.46	0.204
10/24/90	18:16:04	RJ7841			4.80	0.354
10/25/90	18:20:43	RJ7841			7.06	0.685
10/26/90	18:02:39	RJ7841			5.56	0.691
10/23/90	17:35:02	RL8019	BUICK	84	0.53	0.188
10/24/90	07:35:09	RL8019			3.23	0.162
10/25/90	07:35:16	RL8019			2.63	0.269
10/26/90	07:38:54	RL8019			2.42	0.299
10/22/90	17:31:59	RZK444	HONDA	87	0.12	0.090
10/23/90	17:23:37	RZK444			2.16	0.490
10/24/90	08:06:18	RZK444			0.15	0.064
10/25/90	08:03:24	RZK444			0.05	0.014
10/26/90	08:00:47	RZK444			0.42	0.055
10/22/90	17:06:00	RZT517	FORD	90	0.21	0.271
10/24/90	08:24:43	RZT517			0.34	0.034
10/25/90	17:09:46	RZT517			0.55	0.249
10/26/90	08:30:52	RZT517			0.21	0.077
10/22/90	17:14:22	RZZ637	CHEVROLET	82	0.53	0.265
10/24/90	16:20:13	RZZ637			-0.27	0.063
10/25/90	17:01:36	RZZ637			0.72	0.339
10/26/90	16:54:56	RZZ637			0.66	0.207
10/22/90	17:00:59	SALS2	OLDSMOBILE	88	0.47	0.075
10/23/90	17:26:38	SALS2			0.62	0.272
10/24/90	06:39:45	SALS2			0.12	0.075
10/24/90	17:04:32	SALS2			0.42	0.251
10/22/90	17:05:30	SD3473	BUICK	86	0.06	-0.009
10/23/90	17:28:27	SD3473			-0.13	0.127
10/24/90	08:17:52	SD3473			0.16	-0.040
10/26/90	08:47:48	SD3473			0.29	-0.056
10/24/90	07:49:46	SHULTS	FORD	85	-0.10	0.026
10/24/90	16:48:49	SHULTS			0.22	0.208
10/25/90	08:03:10	SHULTS			0.19	0.089
10/26/90	16:36:29	SHULTS			-0.08	0.063
10/24/90	08:26:01	SM1442	PLYMOUTH	90	0.23	0.068
10/24/90	16:59:35	SM1442			0.75	0.204
10/25/90	08:09:54	SM1442			1.73	0.117
10/25/90	17:09:54	SM1442			-0.42	0.359

10/24/90	08:11:40	SOSEXY1	MAZDA	90	3.30	0.187
10/24/90	17:11:33	SOSEXY1			0.28	0.143
10/25/90	08:29:19	SOSEXY1			-0.10	0.009
10/26/90	08:15:52	SOSEXY1			3.39	0.202
10/22/90	18:08:45	SP1090	CHEVROLET	80	0.30	0.270
10/24/90	07:53:45	SP1090			0.45	0.121
10/24/90	17:43:27	SP1090			1.80	0.448
10/25/90	07:56:08	SP1090			4.73	0.257
10/26/90	17:47:06	SP1090			1.12	0.472
10/22/90	17:21:32	SS2032	CHRYSLER	86	0.59	0.182
10/24/90	08:32:38	SS2032			0.58	0.120
10/24/90	17:15:44	SS2032			1.09	0.210
10/26/90	09:01:17	SS2032			4.29	0.025
10/26/90	17:00:09	SS2032			3.78	0.108
10/22/90	17:39:23	SS6438	CHEVROLET	89	-0.20	-0.035
10/23/90	17:31:58	SS6438			-0.02	-0.021
10/24/90	17:20:58	SS6438			0.11	0.106
10/26/90	17:49:07	SS6438			1.67	-0.011
10/22/90	16:17:55	SS8808	CHEVROLET	89	-0.03	0.160
10/23/90	18:09:42	SS8808			-0.01	0.035
10/24/90	18:08:27	SS8808			0.07	0.086
10/25/90	18:14:21	SS8808			0.15	0.249
10/23/90	16:57:56	ST2578	PONTIAC	80	1.88	0.068
10/24/90	16:21:41	ST2578			0.05	0.087
10/25/90	08:36:02	ST2578			0.24	0.026
10/25/90	17:07:00	ST2578			1.49	0.405
10/23/90	17:02:47	STR115	FORD	85	-0.27	-0.019
10/24/90	08:16:47	STR115			-0.28	0.026
10/25/90	17:11:11	STR115			3.41	0.534
10/26/90	08:21:36	STR115			-0.08	0.041
10/26/90	17:28:28	STR115			0.21	-0.034
10/22/90	16:38:52	STRIVEN	MAZDA	89	0.95	0.108
10/24/90	16:43:23	STRIVEN			0.57	0.148
10/25/90	16:49:16	STRIVEN			0.43	0.216
10/26/90	17:17:15	STRIVEN			-0.13	0.023
10/23/90	18:21:53	SUA945	OLDSMOBILE	80	0.32	0.123
10/24/90	09:42:58	SUA945			5.91	0.095
10/25/90	09:44:52	SUA945			3.53	0.062
10/25/90	18:34:30	SUA945			3.04	0.057
10/26/90	09:40:14	SUA945			2.07	0.207

10/23/90	17:04:53	SV384	CHEVROLET	72	0.97	0.403
10/25/90	07:58:04	SV384			1.21	0.126
10/26/90	07:20:15	SV384			1.64	0.160
10/26/90	17:40:26	SV384			0.42	0.103
10/23/90	16:34:08	SW5053	BUICK	84	0.54	0.048
10/24/90	07:46:57	SW5053			1.03	0.078
10/24/90	17:27:14	SW5053			1.03	0.342
10/25/90	08:45:42	SW5053			2.98	0.111
10/24/90	07:54:49	SW6376	OLDSMOBILE	85	-0.03	0.006
10/24/90	17:01:11	SW6376			0.31	0.175
10/25/90	07:44:07	SW6376			0.29	0.089
10/26/90	07:59:01	SW6376			0.10	0.047
10/24/90	16:41:40	SY6764	BUICK	85	0.40	0.227
10/25/90	07:28:51	SY6764			0.47	0.023
10/25/90	16:01:40	SY6764			2.36	0.653
10/26/90	07:20:58	SY6764			0.71	0.144
10/22/90	17:08:09	SZB556	CHEVROLET	87	0.42	0.052
10/23/90	16:59:03	SZB556			0.19	0.014
10/25/90	07:27:42	SZB556			1.32	0.104
10/26/90	07:31:13	SZB556			0.53	0.214
10/24/90	08:12:26	SZT651	CADILLAC	84	0.82	0.129
10/25/90	07:59:35	SZT651			0.51	0.168
10/25/90	17:38:39	SZT651			0.24	0.075
10/26/90	08:03:55	SZT651			0.62	0.136
10/22/90	16:56:22	TA8889	CHEVROLET	84	0.51	0.008
10/23/90	17:13:12	TA8889			-0.63	0.100
10/24/90	07:16:04	TA8889			0.21	0.030
10/25/90	07:51:31	TA8889			0.06	0.046
10/24/90	07:33:46	TC4745	FORD	89	0.16	0.070
10/24/90	18:02:37	TC4745			0.30	0.131
10/25/90	07:28:05	TC4745			0.49	0.086
10/26/90	07:20:05	TC4745			0.10	0.033
10/24/90	08:31:52	TFV115	TOYOTA	79	3.19	0.015
10/25/90	08:27:31	TFV115			5.16	0.100
10/25/90	18:24:55	TFV115			4.45	0.158
10/26/90	08:07:52	TFV115			5.01	0.286
10/22/90	16:50:12	TH5747		89	0.30	-0.034
10/24/90	07:54:15	TH5747			0.08	0.043
10/24/90	16:54:13	TH5747			1.88	0.169
10/25/90	08:07:44	TH5747			0.12	0.059
10/26/90	07:37:19	TH5747			0.61	0.150
10/26/90	17:20:40	TH5747			1.44	0.300

10/22/90	17:08:33	TH7443	DODGE	89	0.25	0.021
10/24/90	07:16:57	TH7443			0.94	0.997
10/24/90	17:05:28	TH7443			0.32	0.203
10/25/90	17:17:30	TH7443			-0.27	0.000
10/26/90	07:25:48	TH7443			0.68	1.357
10/24/90	07:35:03	TJ1627	CHEVROLET	90	0.44	0.073
10/24/90	16:31:50	TJ1627			0.12	-0.014
10/25/90	07:41:30	TJ1627			1.63	0.109
10/25/90	16:35:25	TJ1627			0.32	0.251
10/26/90	07:44:27	TJ1627			0.11	0.049
10/23/90	17:28:35	TJ7350	PLYMOUTH	86	2.58	0.087
10/24/90	07:56:21	TJ7350			0.17	0.019
10/25/90	07:59:25	TJ7350			2.74	1.076
10/25/90	17:36:30	TJ7350			4.04	0.219
10/26/90	07:58:09	TJ7350			-0.02	0.037
10/24/90	09:21:58	TLU751	HONDA	83	0.06	0.026
10/24/90	12:41:16	TLU751			0.80	0.136
10/24/90	17:53:20	TLU751			1.27	0.688
10/26/90	12:07:20	TLU751			0.10	0.024
10/24/90	10:32:25	TLW318	OLDSMOBILE	82	1.53	0.130
10/24/90	16:45:56	TLW318			-0.16	0.099
10/25/90	10:27:02	TLW318			-0.01	0.069
10/25/90	17:43:53	TLW318			0.21	0.091
10/26/90	11:10:17	TLW318			5.04	0.172
10/22/90	17:09:19	TT305	HONDA	87	0.93	0.586
10/23/90	17:05:36	TT305			-0.04	0.003
10/24/90	07:48:03	TT305			0.26	0.039
10/24/90	17:09:40	TT305			-0.03	0.032
10/25/90	08:19:31	TT305			0.74	0.219
10/25/90	17:22:13	TT305			0.04	0.090
10/26/90	07:38:17	TT305			1.67	0.127
10/22/90	16:41:54	TU3346	PLYMOUTH	89	0.93	0.186
10/23/90	17:11:38	TU3346			0.03	0.060
10/25/90	07:59:08	TU3346			0.32	0.049
10/25/90	16:54:50	TU3346			1.36	0.547
10/26/90	07:49:42	TU3346			2.01	0.092
10/22/90	17:20:36	TZ3516	FORD	85	0.22	0.013
10/24/90	08:08:24	TZ3516			6.77	0.111
10/24/90	17:35:55	TZ3516			-0.31	-0.014
10/25/90	08:01:36	TZ3516			5.72	0.138
10/26/90	09:01:07	TZ3516			1.05	0.078

10/22/90	17:37:28	UA2931	VOLVO	90	0.78	0.141
10/23/90	18:02:49	UA2931			0.07	0.099
10/24/90	08:55:20	UA2931			0.12	0.080
10/26/90	08:53:54	UA2931			0.07	0.049
10/22/90	16:58:35	UA4453	CHRYSLER	79	8.54	0.445
10/24/90	07:16:23	UA4453			1.47	0.076
10/24/90	16:57:09	UA4453			8.54	0.372
10/25/90	17:01:30	UA4453			9.15	0.474
10/26/90	07:29:36	UA4453			2.03	0.107
10/24/90	08:09:00	UA8968	CADILLAC	83	0.41	0.057
10/24/90	17:29:34	UA8968			1.02	0.272
10/25/90	08:01:31	UA8968			1.02	0.126
10/26/90	07:49:26	UA8968			1.18	0.119
10/22/90	18:16:39	UAK105	TOYOTA	90	0.13	0.079
10/24/90	08:09:22	UAK105			0.27	0.075
10/24/90	17:26:41	UAK105			0.22	0.082
10/25/90	08:10:14	UAK105			0.17	0.090
10/26/90	07:47:08	UAK105			0.07	0.119
10/26/90	17:50:05	UAK105			0.26	0.100
10/24/90	07:36:47	UAK144	LINCOLN	89	-0.08	0.047
10/24/90	16:59:00	UAK144			-0.04	0.061
10/25/90	08:21:49	UAK144			0.07	-0.004
10/26/90	07:48:23	UAK144			0.23	0.118
10/22/90	17:28:44	UB6580	PONTIAC	79	4.95	0.185
10/24/90	07:54:04	UB6580			-0.26	0.189
10/25/90	07:58:58	UB6580			0.83	0.276
10/25/90	15:46:45	UB6580			0.49	0.211
10/26/90	08:00:57	UB6580			0.41	0.211
10/22/90	18:13:02	UBB163	CHEVROLET	78	-0.45	0.041
10/23/90	18:09:10	UBB163			0.37	0.151
10/24/90	06:55:09	UBB163			0.76	0.020
10/26/90	07:16:13	UBB163			0.32	0.022
10/22/90	16:29:29	UBC713	BUICK	80	0.46	0.087
10/23/90	18:06:17	UBC713			1.58	0.143
10/24/90	16:34:23	UBC713			0.58	0.319
10/26/90	16:37:05	UBC713			0.78	0.106
10/22/90	17:27:59	UC4761	CHEVROLET	90	0.37	0.181
10/23/90	17:18:08	UC4761			0.20	0.021
10/24/90	08:25:24	UC4761			0.15	0.087
10/26/90	08:19:26	UC4761			0.10	0.103

10/22/90	18:14:17	UD3327	CHEVROLET	81	4.15	0.292
10/23/90	18:19:00	UD3327			3.88	0.178
10/24/90	17:46:52	UD3327			5.75	0.204
10/25/90	07:30:42	UD3327			3.90	0.230
10/25/90	17:46:31	UD3327			5.13	0.240
10/26/90	07:29:53	UD3327			3.31	0.179
10/24/90	11:06:24	UD5906	TOYOTA	84	0.19	0.058
10/25/90	09:44:33	UD5906			-0.18	0.006
10/26/90	12:11:10	UD5906			0.25	0.070
10/26/90	16:34:40	UD5906			-0.09	0.002
10/23/90	18:08:46	UF9201	OLDSMOBILE	90	1.05	0.312
10/24/90	07:59:00	UF9201			0.36	0.081
10/24/90	17:57:12	UF9201			-0.11	0.077
10/25/90	08:01:25	UF9201			-0.07	0.017
10/25/90	17:46:54	UF9201			-0.12	0.158
10/26/90	08:02:42	UF9201			0.15	0.064
10/26/90	17:54:38	UF9201			0.04	0.245
10/22/90	17:21:08	UG9712	VOLKSWAGEN	90	0.31	0.216
10/23/90	17:07:17	UG9712			0.14	0.056
10/24/90	17:18:22	UG9712			0.23	0.044
10/25/90	17:25:21	UG9712			1.31	0.582
10/24/90	07:52:56	URBS2	MERCURY	85	1.54	0.137
10/25/90	07:50:22	URBS2			1.60	0.076
10/25/90	17:25:32	URBS2			0.96	0.336
10/26/90	07:44:58	URBS2			0.25	0.093
10/22/90	17:33:09	UX8235	BUICK	90	0.46	0.212
10/24/90	08:01:01	UX8235			-0.03	0.022
10/24/90	17:28:22	UX8235			0.06	0.061
10/25/90	08:03:28	UX8235			-0.04	0.021
10/26/90	08:03:18	UX8235			0.29	0.107
10/22/90	17:20:49	VJ4002	HONDA	86	0.25	0.300
10/24/90	07:52:06	VJ4002			0.99	0.014
10/25/90	08:25:00	VJ4002			3.51	0.123
10/26/90	08:34:31	VJ4002			1.08	0.031
10/26/90	12:10:22	VJ4002			0.31	0.013
10/24/90	08:13:51	VM3046	CHEVROLET	70	3.79	0.061
10/24/90	16:56:58	VM3046			8.73	0.312
10/25/90	08:41:37	VM3046			10.20	0.294
10/25/90	16:57:16	VM3046			8.58	0.181
10/22/90	16:54:42	VM4075	MERCURY	81	7.13	0.274
10/23/90	16:47:19	VM4075			7.56	0.543
10/24/90	06:54:20	VM4075			4.43	0.171
10/25/90	16:51:13	VM4075			6.58	0.177

10/24/90	07:39:46	VN3202	OLDSMOBILE	85	0.04	0.110
10/25/90	16:58:50	VN3202			0.16	0.194
10/26/90	08:45:03	VN3202			0.39	0.095
10/26/90	18:07:37	VN3202			0.22	0.100
10/22/90	17:18:12	VR3225		90	0.42	0.149
10/23/90	17:11:40	VR3225			0.13	0.025
10/24/90	17:24:10	VR3225			0.18	0.130
10/25/90	08:47:20	VR3225			-0.03	-0.009
10/24/90	16:46:54	VR7270	FORD	89	1.13	0.271
10/25/90	09:41:03	VR7270			0.57	0.271
10/25/90	17:19:35	VR7270			1.78	0.513
10/26/90	08:49:41	VR7270			-0.08	0.391
10/22/90	17:33:46	VS5141	DODGE	86	-0.01	0.065
10/24/90	08:01:36	VS5141			0.57	0.143
10/24/90	17:02:19	VS5141			0.49	0.306
10/25/90	08:03:49	VS5141			0.50	0.184
10/25/90	07:40:32	VS748	MERCEDES-BENZ	74	0.57	0.070
10/25/90	17:24:08	VS748			0.27	0.123
10/26/90	07:28:49	VS748			0.40	0.162
10/26/90	17:26:34	VS748			3.93	0.276
10/22/90	17:04:08	VT5360	FORD	87	1.54	0.486
10/23/90	17:34:16	VT5360			1.36	0.155
10/24/90	16:14:13	VT5360			0.59	0.051
10/25/90	08:00:48	VT5360			1.02	0.144
10/25/90	16:39:15	VT5360			4.44	0.345
10/24/90	06:55:48	VT8980	FORD	89	0.32	0.031
10/25/90	09:46:01	VT8980			0.90	0.126
10/26/90	08:14:53	VT8980			0.42	0.097
10/26/90	15:55:28	VT8980			2.32	0.364
10/24/90	08:09:42	VW6504	PLYMOUTH	88	0.40	0.157
10/25/90	08:11:39	VW6504			0.32	0.154
10/25/90	18:36:11	VW6504			0.85	0.214
10/26/90	08:09:03	VW6504			0.13	-0.021
10/24/90	07:52:51	VX410	TOYOTA	85	2.39	0.120
10/24/90	17:07:49	VX410			1.60	0.318
10/25/90	08:12:00	VX410			0.83	0.116
10/26/90	07:45:07	VX410			0.20	-0.030
10/22/90	17:00:01	VY2261	CHRYSLER	89	-0.14	0.003
10/24/90	07:47:50	VY2261			0.15	0.033
10/24/90	16:54:02	VY2261			0.37	0.149
10/25/90	07:48:34	VY2261			0.29	0.037

10/23/90	18:35:54	W-7281	TOYOTA	85	0.78	0.275
10/24/90	09:10:13	W-7281			0.23	0.073
10/24/90	18:27:45	W-7281			0.19	0.371
10/25/90	09:11:01	W-7281			0.18	0.102
10/25/90	18:35:59	W-7281			1.61	0.359
10/23/90	17:54:04	WGW130		89	-0.04	0.174
10/24/90	06:41:07	WGW130			0.14	0.076
10/24/90	08:55:38	WGW130			3.41	0.053
10/25/90	08:39:00	WGW130			1.44	0.189
10/22/90	16:57:08	WH5852	CADILLAC	90	0.68	0.041
10/24/90	07:50:13	WH5852			0.19	0.070
10/24/90	16:57:29	WH5852			0.21	0.081
10/25/90	07:44:27	WH5852			-0.27	-0.046
10/26/90	07:47:38	WH5852			0.56	0.251
10/24/90	07:27:28	WLP178	TOYOTA	79	0.88	0.088
10/24/90	16:54:37	WLP178			1.86	0.242
10/25/90	07:29:57	WLP178			0.63	0.095
10/26/90	07:26:33	WLP178			2.08	0.188
10/22/90	18:16:14	XAA155	PLYMOUTH	81	1.52	0.218
10/23/90	18:35:15	XAA155			5.31	0.245
10/24/90	07:48:11	XAA155			1.05	0.058
10/25/90	08:11:45	XAA155			0.32	-0.003
10/26/90	08:02:21	XAA155			0.82	0.277
10/22/90	16:56:53	XBT211	FORD	85	-0.14	-0.021
10/23/90	17:51:29	XBT211			0.47	0.338
10/24/90	09:49:28	XBT211			-0.14	0.007
10/25/90	10:10:01	XBT211			-0.13	-0.019
10/26/90	08:28:04	XBT211			0.10	0.105
10/22/90	17:40:32	XCM746	BUICK	82	0.25	-0.032
10/24/90	17:25:53	XCM746			5.32	0.292
10/26/90	07:23:14	XCM746			0.67	0.285
10/26/90	17:37:49	XCM746			1.75	0.609
10/24/90	08:04:53	XE228	CHEVROLET	76	0.18	0.028
10/25/90	08:11:52	XE228			0.16	0.064
10/25/90	10:03:02	XE228			-0.03	-0.033
10/26/90	07:54:00	XE228			-0.06	0.013
10/26/90	12:05:42	XE228			0.52	-0.063
10/23/90	17:42:29	XEV427	JEEP	90	0.22	0.095
10/24/90	08:26:11	XEV427			0.25	0.015
10/24/90	17:54:45	XEV427			0.10	0.101
10/25/90	08:42:17	XEV427			0.49	0.056

10/24/90	17:40:22	XG4097	VOLVO	86	0.33	0.130
10/25/90	08:26:59	XG4097			0.18	0.044
10/26/90	08:30:07	XG4097			2.33	0.107
10/26/90	17:51:21	XG4097			-0.09	0.065
10/22/90	16:49:42	XGR826	CHEVROLET	78	3.68	0.220
10/23/90	16:46:04	XGR826			2.82	0.200
10/24/90	16:46:18	XGR826			4.02	0.115
10/26/90	17:07:34	XGR826			4.46	0.353
10/24/90	08:29:03	XHF807	CHEVROLET	88	3.53	0.080
10/25/90	08:36:05	XHF807			2.94	0.116
10/25/90	17:32:57	XHF807			0.65	0.317
10/26/90	08:20:45	XHF807			8.90	2.643
10/22/90	17:59:39	XHT684	TOYOTA	90	-0.19	0.072
10/24/90	17:53:02	XHT684			0.10	0.153
10/25/90	17:00:22	XHT684			0.48	0.284
10/26/90	08:41:02	XHT684			0.03	0.054
10/22/90	16:41:42	XNJ314	OLDSMOBILE	73	6.04	0.265
10/23/90	16:36:56	XNJ314			5.20	0.110
10/24/90	16:47:46	XNJ314			4.76	0.098
10/25/90	16:48:16	XNJ314			4.72	0.213
10/24/90	09:01:16	XSN378	CHEVROLET	81	6.85	0.099
10/25/90	07:51:06	XSN378			7.57	0.314
10/26/90	08:19:38	XSN378			9.78	0.098
10/26/90	11:39:22	XSN378			3.17	0.181
10/22/90	17:44:08	XUN947	OLDSMOBILE	85	0.99	0.069
10/24/90	08:09:53	XUN947			0.65	0.074
10/24/90	17:45:18	XUN947			0.49	0.300
10/25/90	07:39:27	XUN947			1.16	0.133
10/26/90	07:39:19	XUN947			0.48	0.064
10/22/90	17:36:07	XUP553	CHEVROLET	80	5.14	0.578
10/23/90	17:24:19	XUP553			5.68	0.251
10/24/90	07:01:18	XUP553			1.10	0.664
10/24/90	17:37:09	XUP553			7.70	0.500
10/22/90	16:33:07	YQK28	GMC	76	5.07	0.422
10/23/90	18:12:19	YQK28			3.88	0.083
10/24/90	07:31:00	YQK28			6.23	0.228
10/24/90	16:36:04	YQK28			5.69	0.161
10/25/90	16:36:28	YQK28			10.36	0.132
10/26/90	07:24:05	YQK28			7.05	0.146

APPENDIX B: Oldest, Cleanest, and Dirtiest

For the entire measurement period, the fifty oldest, fifty cleanest (CO & HC) and fifty dirtiest (CO & HC) vehicles are listed. It is important to note that the cleanest vehicles, typically listed as negative values, are all zero %CO or %HC emitters. They are not claimed to be either a) cleaning the air or b) any different from the large number of vehicles measured at or near zero. They serve to illustrate the make, model year, and age distribution of the rest of the many clean vehicles. The fifty oldest vehicles are listed to emphasize that old vehicles are not necessarily high emitters relative to the rest of the fleet. This list can be compared to the fifty dirtiest, which are by no means all old.

Oldest

License	Make	Model	Year	%CO	%HC (propane)
SR5546	PORSCHE	COUPE	62	5.81	0.119
SR5546	PORSCHE	COUPE	62	6.88	0.361
XED764	CHEVROLET	4 DOOR	63	0.81	0.080
FY7250	BUICK	4 DOOR	63	2.33	0.413
XED764	CHEVROLET	4 DOOR	63	5.60	0.259
JR4725	OLDSMOBILE	4 DOOR	66	2.90	0.127
JR4725	OLDSMOBILE	4 DOOR	66	3.65	0.088
66TRK-B	CHEVROLET	PICKUP	66	3.69	0.177
JR4725	OLDSMOBILE	4 DOOR	66	4.26	0.316
JR4725	OLDSMOBILE	4 DOOR	66	6.11	0.140
AE7376	MG	CONVTBLE	66	6.43	0.163
AE7376	MG	CONVTBLE	66	6.51	0.406
UB3537	CHEVROLET	4 DOOR	66	9.21	0.830
7280DH-B	FORD	PANEL	67	0.15	0.020
5544EM-B	FORD	PICKUP	67	1.71	0.071
SN3598	BUICK	4 DOOR	67	2.78	0.164
ART1967	BUICK	CONVTBLE	67	2.81	0.064
XK9310	CHEVROLET	4 DOOR	67	5.43	0.278
RT8951	PLYMOUTH	4 DOOR	67	9.71	0.385
NC1282	FORD MUSTANG	CONVTBLE	68	0.38	0.154
9720DM-B	CHEVROLET	PICKUP	68	0.91	0.132
YKV400	PLYMOUTH	SEDAN	68	1.53	-0.007
JG9449	CHEVROLET	4DR SEDAN	68	2.55	-0.063
VF9270	BUICK	CONVTBLE	68	8.94	2.332
VF9270	BUICK	CONVTBLE	68	9.06	0.468
ON1720	RAMBLER	2 DOOR	68	9.08	1.768
ON1720	RAMBLER	2 DOOR	68	10.67	0.616
LTN642	BUICK	STA WAGON	69	-0.25	0.084
XJ7336	MERCEDES-BENZ	2 DOOR	69	0.34	0.177
IZ7483	BUICK	4 DOOR	69	0.43	0.068
ED4642	SAAB	2 DOOR	69	2.47	0.139
ED4642	SAAB	2 DOOR	69	3.10	0.191
VS7338	VOLKSWAGEN	2 DOOR	69	3.88	0.267
QF523	CADILLAC	COUPE	70	0.10	0.071
46406D	FORD	PICKUP	70	0.20	0.106
SU331	MERCURY	2 DR HT	70	0.51	0.153
SU331	MERCURY	2 DR HT	70	2.27	0.233
FZ8346	VOLKSWAGEN	2 DOOR	70	2.32	0.173
VX2620	CADILLAC	4 DR HT	70	3.10	0.057
VM3046	CHEVROLET	COUPE	70	3.79	0.061
TE8855	CHEVROLET	4 DOOR	70	5.09	0.288
SMX191	PLYMOUTH	4 DOOR	70	6.18	0.204
VM3046	CHEVROLET	COUPE	70	8.58	0.181
VM3046	CHEVROLET	COUPE	70	8.73	0.312
VM3046	CHEVROLET	COUPE	70	10.20	0.294
FVS394	OLDSMOBILE	2 DOOR	71	-0.07	0.083
QF7559	PONTIAC	2 DR HT	71	-0.06	-0.014
RH8293	BUICK	STA WAGON	71	0.17	0.049
FVS394	OLDSMOBILE	2 DOOR	71	0.17	-0.023
NZN734	PONTIAC	2 DR HT	71	0.24	0.053

Cleanest CO

License	Make	Model	Year	%CO	%HC (propane)
TA8889	CHEVROLET	HATCHBACK	84	-0.63	0.100
XQT685	CHEVROLET	STA WAGON	81	-0.62	0.012
128650	DODGE	HATCHBACK	88	-0.62	0.012
TDLJR	HONDA	HATCHBACK	90	-0.61	1.575
UE7222	FORD	2 DOOR	81	-0.58	0.078
XE3818	FORD	4 DOOR	90	-0.58	-0.036
HV2176	VOLKSWAGEN	4 DOOR	87	-0.57	-0.028
VH5445	BUICK	4 DOOR	81	-0.57	-0.014
MBH218		4DR SEDAN	89	-0.57	0.003
XJ9437	MAZDA	HATCHBACK	90	-0.57	0.050
NN2438	PONTIAC	HATCHBACK	88	-0.56	-0.021
FLY898		STA WAGON	86	-0.56	1.947
QV2089	DODGE	2 DR HT	83	-0.55	-0.045
CAR316	CHEVROLET	COUPE	85	-0.53	-0.061
WTO75	FORD	2 DOOR	89	-0.53	1.655
592225	DODGE	VAN	89	-0.53	-0.008
ST5534	FORD	HATCHBACK	84	-0.53	0.064
MWY316	MAZDA	HATCHBACK	89	-0.51	2.311
SAT133	CADILLAC	COUPE	87	-0.51	-0.056
XCN773	CHEVROLET	COUPE	90	-0.51	-0.020
ST4569	THUNDERBIRD	2 DOOR	83	-0.51	0.006
CX8554	FORD	4 DOOR	83	-0.50	0.133
DATSCAR	CHEVROLET	4 DOOR	85	-0.50	0.154
DCM145	CHEVROLET	PANEL	91	-0.49	-0.034
PN8151	HONDA	4 DOOR	89	-0.48	1.612
DB8192	PONTIAC	4 DOOR	90	-0.48	-0.014
HB5293	DODGE	4 DOOR	88	-0.48	-0.030
ES4552	FORD	4 DOOR	85	-0.47	0.173
AIIMS	MERCEDES-BENZ	4DR SEDAN	80	-0.47	0.016
CL7864	CHEVROLET	VAN	87	-0.47	0.014
YXJ118	CHEVROLET	COUPE	85	-0.46	0.092
IC2403	FORD	HATCHBACK	88	-0.46	0.007
FX5914	BUICK	4 DOOR	86	-0.46	0.007
UBB163	CHEVROLET	4 DOOR	78	-0.45	0.041
TON112	FORD	HATCHBACK	89	-0.45	0.124
CP1901	MERCURY	4 DOOR	86	-0.45	-0.041
SS5916	ALFA ROMEO	ROADSTER	89	-0.45	0.009
MA3447	FORD	4 DOOR	88	-0.44	-0.005
HN1286	MERCURY	2 DOOR	84	-0.44	0.130
253929	CHEVROLET	STA WAGON	88	-0.44	0.014
JT5638	CHEVROLET	4 DOOR	85	-0.44	-0.047
OV7155	PONTIAC	4 DOOR	79	-0.43	0.022
478TX	CHEVROLET	4 DOOR	90	-0.43	0.014
JZH807	CHEVROLET	4 DOOR	85	-0.43	-0.053
7173BR-B	CHEVROLET	VAN	86	-0.42	0.011
FYX239	VOLVO	4 DOOR	90	-0.42	0.024
BCR4982	LINCOLN	4 DOOR	90	-0.42	0.140
TOY107	TOYOTA	SEDAN	87	-0.42	0.044
FSB	LINCOLN	4 DOOR	89	-0.42	-0.046
SM1442	PLYMOUTH	VAN	90	-0.42	0.359

Dirtiest CO

License	Make	Model	Year	%CO	%HC (propane)
1469PT	DODGE	VAN	87	13.59	1.123
SDZ803	CHEVROLET	4 DOOR	85	13.26	0.201
984CT-B	FORD	PICKUP	75	13.21	0.487
NH6895	BUICK	COUPE	88	12.96	0.293
BIG176	CADILLAC	4 DOOR	78	12.95	0.237
SU1517	BUICK	4 DOOR	84	12.88	0.453
OE7404	FORD	2 DOOR	88	12.73	0.500
696032	OLDS CUTLASS	2 DOOR	80	12.72	0.490
443024	FORD	4 DOOR	86	12.33	0.712
MC3899	OLDSMOBILE	COUPE	79	12.30	0.261
VW6627	CHEVROLET	4 DOOR	78	12.19	0.292
JLB431		4 DOOR	83	12.00	0.533
DR6821	BUICK	SEDAN	79	11.98	0.227
XBL775	CHRYSLER	HATCHBACK	86	11.95	1.160
TRIB80	CHEVROLET	4 DOOR	78	11.90	0.371
XSH816	FORD	STA WAGON	79	11.83	0.170
XAJ405	CHEVROLET	HATCHBACK	84	11.75	0.315
FC2199	BUICK	COUPE	86	11.73	0.376
WHW124	FORD	STA WAGON	82	11.72	0.227
QE1061	CHEVROLET	COUPE	76	11.59	1.707
FYF598		2 DOOR	86	11.41	0.686
XGY481	CHEVROLET	4 DOOR	82	11.37	0.602
PT9264	FORD	2 DR HT	79	11.27	0.180
81017RV	CHEVROLET	CAMPER	79	11.26	0.242
226210B	GENERAL MOTOR	VAN	77	11.24	2.066
GODIS11		COUPE	87	11.23	1.093
3101AN-B	FORD	TRUCK	79	11.23	0.197
CM8237	OLDSMOBILE	COUPE	81	11.18	0.442
XL150		2 DOOR	89	11.18	0.556
YB4778	VOLKSWAGEN	HATCHBACK	83	11.12	0.116
VN3934	DODGE	VAN	79	11.03	0.365
RZH744	FORD	2 DOOR	86	11.03	0.354
DB3583	CHEVROLET	HATCHBACK	80	10.88	0.366
ED60	LINCOLN	4 DOOR	82	10.86	0.559
XNJ268	MERCURY	4 DOOR	86	10.80	0.243
PP312	CHEVROLET	4 DOOR	83	10.80	0.248
NE9813	PONTIAC	4 DOOR	79	10.79	0.519
GF6861	MERCURY	4 DOOR	78	10.76	0.553
WAB127	MERCURY	4 DOOR	85	10.76	0.601
NR6481	PLYMOUTH	2 DR HT	74	10.70	0.135
FYR291	FORD	2 DOOR	86	10.68	0.394
ON1720	RAMBLER	2 DOOR	68	10.67	0.616
ON1721	FORD	4 DOOR	86	10.64	0.290
GE1524	FORD	2 DOOR	81	10.61	0.249
LYJ812	OLDS CUTLASS	4DR SEDAN	81	10.57	0.252
UW9383	FORD	2 DOOR	86	10.55	0.098
OR6871	FORD	HATCHBACK	80	10.51	0.234
BT4537	LINCOLN	4 DOOR	82	10.51	0.301
GE1524	FORD	2 DOOR	81	10.49	1.228
OX3047	FORD	2 DR HT	79	10.39	0.498

Cleanest HC

License	Make	Model	Year	%CO	%HC (propane)
DKR182	CHEVROLET	4 DOOR	91	0.69	-0.064
OK587	RENAULT	2 DOOR	86	0.62	-0.063
PXK236	CHRYSLER	CONVTBLE	89	-0.06	-0.063
JG9449	CHEVROLET	4DR SEDAN	68	2.55	-0.063
XE228	CHEVROLET	4 DOOR	76	0.52	-0.063
JJ7389	CHEVROLET	4 DOOR	88	0.19	-0.063
SEC49	VOLVO	PASSENGER	86	2.92	-0.063
GL4670	DODGE	VAN	85	-0.23	-0.063
DTV898	CHEVROLET	VAN	87	-0.03	-0.062
RA8347	CHEVROLET	4 DOOR	86	-0.38	-0.062
XGJ395	CADILLAC	4 DOOR	86	-0.28	-0.062
MZ3024	CHEVROLET	PASSENGER	84	-0.40	-0.062
OK4838	OLDSMOBILE	4 DOOR	89	-0.32	-0.062
ED7624	CHEVROLET	4 DOOR	89	-0.32	-0.062
GD1868	FORD	HATCHBACK	89	-0.16	-0.061
ET399	OLDSMOBILE	4 DOOR	84	0.06	-0.061
BN4321	CHEVROLET	STA WAGON	87	0.90	-0.061
FNJ215	LINCOLN	4 DOOR	88	-0.14	-0.061
JTSI		HATCHBACK	87	-0.33	-0.061
SYZ827	FORD	STA WAGON	90	-0.26	-0.061
CAR316	CHEVROLET	COUPE	85	-0.53	-0.061
LBV782	FORD	4 DOOR	88	-0.23	-0.060
JK4663	MERCURY	4 DOOR	87	-0.37	-0.060
PS1566	CHEVROLET	STA WAGON	85	-0.04	-0.060
CZ4957	CADILLAC	4 DOOR	77	0.32	-0.060
MN2276	PEUGEOT	4 DOOR	85	-0.08	-0.060
LVJ956	DODGE	VAN	87	0.04	-0.060
ADS184	PLYMOUTH	VAN	87	-0.10	-0.060
XF8652	FORD	HATCHBACK	85	0.14	-0.060
XAE342	CHEVROLET	4 DOOR	89	0.08	-0.060
BF5170	BUICK	4 DOOR	84	-0.03	-0.060
RA2045	CADILLAC	4 DOOR	90	-0.23	-0.060
XDY638	CHEVROLET	HATCHBACK	90	1.03	-0.059
7726EG-B	FORD	PICKUP	90	-0.13	-0.059
JE5532	VOLVO	4 DOOR	88	0.25	-0.059
OH8447	TOYOTA	VAN	89	-0.10	-0.058
W-17398	DODGE	PICKUP	83	0.17	-0.058
JJ8035	HONDA	4 DOOR	89	3.24	-0.058
UH8005	DODGE	HATCHBACK	90	0.52	-0.057
RDZ830	BUICK	COUPE	83	0.15	-0.057
61709		2 DOOR	86	-0.13	-0.057
843989	CHEVROLET	VAN	86	0.15	-0.056
LVB717	FORD	HATCHBACK	89	-0.25	-0.056
XUD871	CHEVROLET	4 DOOR	84	-0.28	-0.056
FZH620	FORD	HATCHBACK	89	0.29	-0.056
SD3473	BUICK	4 DOOR	86	0.29	-0.056
8738DA-B	FORD	VAN	88	1.40	-0.056
SAT133	CADILLAC	COUPE	87	-0.51	-0.056
NFZ629	BUICK	4 DOOR	90	-0.17	-0.055
JZL708		COUPE	83	0.33	-0.055

Dirtiest HC

License	Make	Model	Year	%CO	%HC (propane)
VJ8686	DODGE	VAN	74	9.22	3.031
XET276	SUBARU	STA WAGON	79	7.23	2.755
XHF807	CHEVROLET	4 DOOR	88	8.90	2.643
PE8529	HONDA	HATCHBACK	90	0.86	2.539
ST6915	MERCURY	HATCHBACK	82	7.87	2.466
6451	FORD	PASSENGER	87	0.59	2.419
TG2173	CHEVROLET	4 DOOR	82	10.18	2.374
QL2873	FORD	HATCHBACK	89	-0.26	2.362
EUW993	HONDA	HATCHBACK	88	1.49	2.357
VF9270	BUICK	CONVTBLE	68	8.94	2.332
MWY316	MAZDA	HATCHBACK	89	-0.51	2.311
EVL204		HATCHBACK	88	-0.04	2.289
IX9965	HONDA	4 DOOR	88	4.31	2.275
IB2722	TOYOTA	STA WAGON	87	-0.05	2.165
FX6546	HONDA	HATCHBACK	88	0.88	2.164
MX6309	FORD	4 DOOR	85	7.31	2.113
DC5606	BUICK	COUPE	82	10.32	2.108
226210B	GENERAL MOTOR	VAN	77	11.24	2.066
XNT461	CHEVROLET	STA WAGON	79	-0.30	2.065
MM8999	BUICK	4 DOOR	87	2.17	2.008
MBF54	TOYOTA	4 DOOR	89	1.16	1.985
HHT4	HONDA	STA WAGON	89	3.97	1.978
CWW105	CHEVROLET	STA WAGON	87	-0.10	1.961
PP266	BUICK	4 DOOR	88	0.35	1.954
WB8566		4 DOOR	90	0.26	1.952
FLY898		STA WAGON	86	-0.56	1.947
XCT533	PONTIAC	COUPE	78	10.01	1.909
VT2837	TOYOTA	2 DOOR	79	6.95	1.884
QZ5251	TOYOTA	4 DOOR	88	7.64	1.882
DW8178	TOYOTA	4 DOOR	88	-0.27	1.870
BYY889	HONDA	HATCHBACK	90	0.37	1.808
UM8749	HONDA	4 DOOR	90	2.54	1.788
HXH106	OLDSMOBILE	4 DOOR	85	4.03	1.785
NW4944	HONDA	HATCHBACK	88	0.35	1.779
ON1720	RAMBLER	2 DOOR	68	9.08	1.768
JLY603	TOYOTA	STA WAGON	88	0.76	1.755
TG8911	RENAULT	2 DOOR	86	2.52	1.708
QE1061	CHEVROLET	COUPE	76	11.59	1.707
BSL839	FORD	2 DOOR	79	3.67	1.673
VL3181	PLYMOUTH	COUPE	79	10.13	1.666
DUV873	HONDA	4 DOOR	89	-0.04	1.659
WTO75	FORD	2 DOOR	89	-0.53	1.655
CARNAC	HONDA	4 DOOR	90	-0.01	1.648
102749	HONDA	HATCHBACK	89	0.58	1.639
NKM646	PLYMOUTH	HATCHBACK	89	0.11	1.635
PN8151	HONDA	4 DOOR	89	-0.48	1.612
MUSAAB1	PLYMOUTH	2 DOOR	79	3.23	1.605
FFZ330	HONDA	4 DOOR	88	0.31	1.593
TRIMER1	CHEVROLET	HATCHBACK	90	0.68	1.588
148976RV	CHEVROLET	CAMPER	90	1.53	1.587