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RSD Versus IM240 Fleet Average Correlations

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RSD Versus IM240 Fleet Average Correlations

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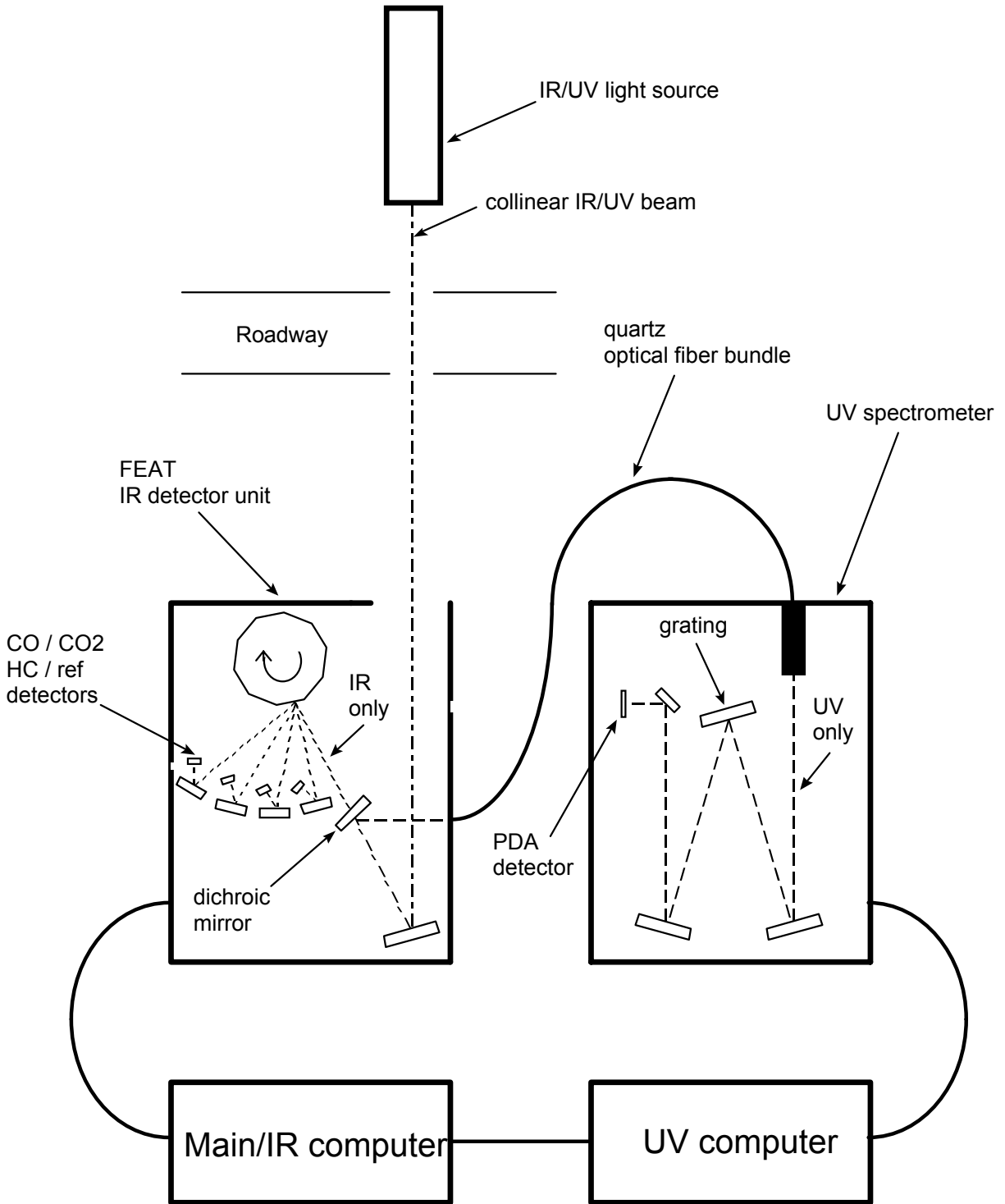
INTRODUCTION

Two modes of emissions monitoring are Remote Sensing Devices (RSD), which measures vehicle emissions as they drive by on the road, and Inspection and Maintenance (I/M) programs, where vehicles report to centralized stations for scheduled testing of their emission levels. RSDs are able to obtain independent I/M program evaluation information, since actual on-road emissions can be monitored. To use RSD data in the evaluation of an I/M program, the on-road data must be averaged. Averaging is important because of the high variability in automobile emissions and because I/M programs are designed to reduce average emissions.

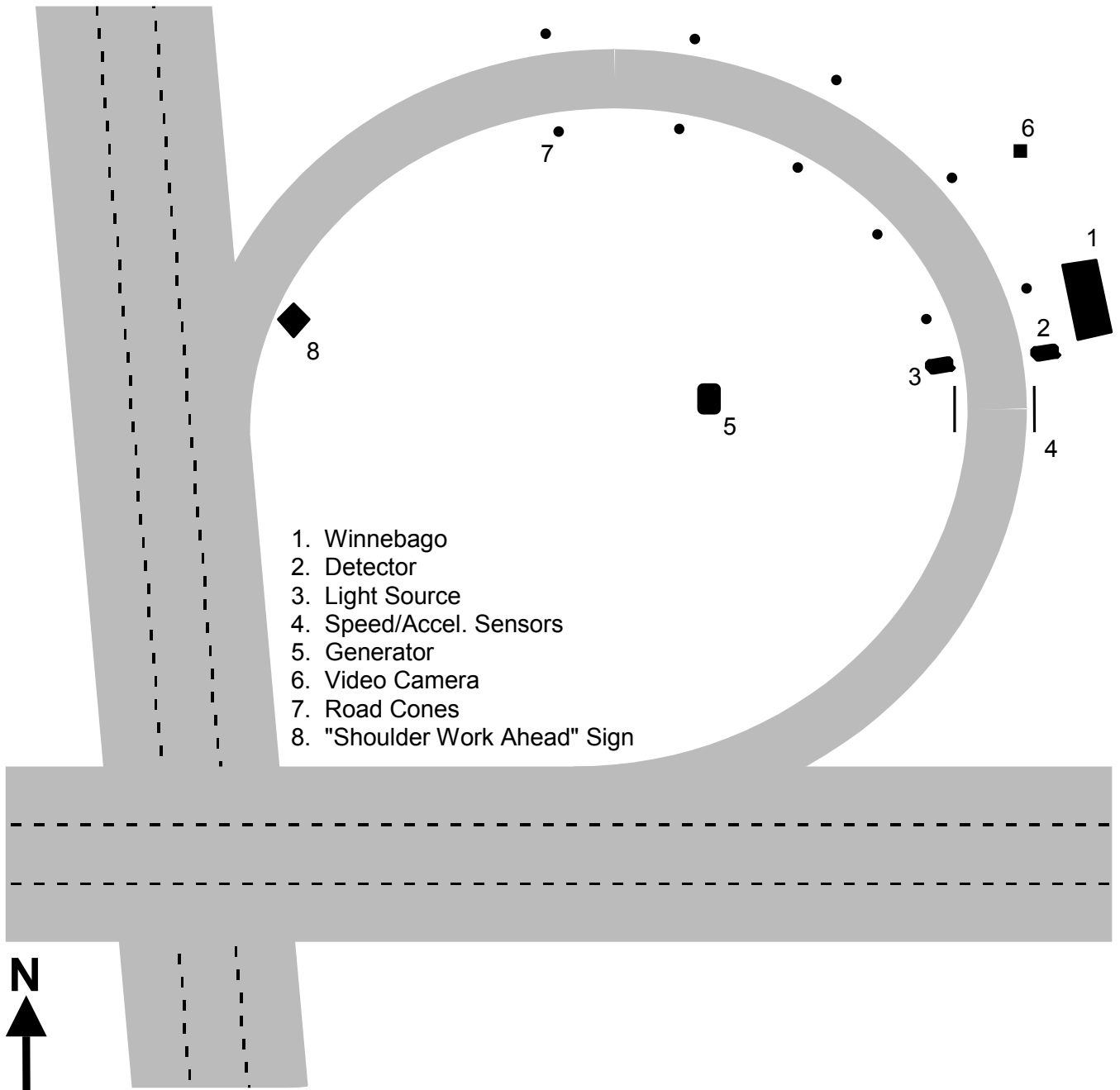
The remote sensor used in this study was developed at the University of Denver for measuring the pollutants in motor vehicle exhaust. (See diagrams). The instrument directly measures ratios of CO, HC or NO to CO₂ because of variable dilution of exhaust plumes. The ratios are constant for a given exhaust plume, and on their own are useful parameters for describing a hydrocarbon combustion system. The ratios can be converted directly into grams emissions per kilogram of fuel and are thus reported here.

The I/M data used in this study are all enhanced IM240 test data. IM240 involves measuring total mass emissions in a 240 second test cycle by a flame ionization detection (FID) method. The test cycle may actually be stopped before the complete 240 s if the outcome of the full test can be positively extrapolated (Fast-Pass) (Ando, Harrington and McConnell, 1999). The data are then reported in grams per mile.

INSTRUMENTATION



INSTRUMENT SETUP



METHOD

Convert RSD and I/M to g of pollutant per kg of fuel

IM240 data reported in g/mi

Convert by multiplying first by the miles per gallon (measured during IM240) and then by the inverse of the density of gasoline (0.33295 gal/kg).

Convert RSD data to g/kg by first converting the pollutant ratio readings to the moles of pollutant per mole of carbon in the exhaust from the following equation:

$$\frac{\text{moles pollutant}}{\text{moles C}} = \frac{\text{pollutant}}{\text{CO} + \text{CO}_2 + 3\text{HC}}$$
$$= \frac{(\text{pollutant}/\text{CO}_2)}{(\text{CO}/\text{CO}_2) + 1 + 3(\text{HC}/\text{CO}_2)}$$

Next, moles of pollutant are converted to grams by multiplying by molecular weight, and the moles of carbon in the exhaust are converted to kilograms by multiplying the denominator by 0.014 kg of fuel per mole of carbon in fuel, assuming gasoline is stoichiometrically CH₂.

RESULTS AND DISCUSSION

This analysis showed that fleet averaged on-road remote sensing data correlate very well versus fleet average IM240 data. We have demonstrated this with three data sets from Denver: RSD January 1999, RSD January 1997 and RSD January 1996 correlated versus IM240 results for the whole year in 1998, 1996 and 1995, respectively. The Figures (1-3) show average emissions for each measured model year. There are many more cars in the newest model years. The plots illustrate that, though the slopes of the correlations are not all one, the relationships are mostly linear. Furthermore, the reproducibility of the excellent correlations (R^2 in every case greater than 0.95) during the three separate years of study is evident.

In each of the three years of study, the entire IM240 database, including the calculated FAST-PASS emissions, was used. Thus, in each case that gave approximately 1,000,000 measurements. The remote sensing data consisted of about 25,000 measurements in 1999 and 1996 and about 35,000 in 1997.

There is a slight curvature in the NO data which may be due to temperature effects. Since all RSD data were obtained during the winter when ambient temperatures are low and oxygenated fuel is mandated in Denver, a correlation study was done with the RSD data and IM240 data from January and the first half of February. When this temperature and oxy-fuel difference is accounted for, the curvature of the NO correlation plot is diminished (Figure 4).

The CO plots show negligible intercepts. The HC and NO plots do show intercepts. The intercept does not detract from the excellent correlations but does mean that the relationship needs to be treated with this intercept in mind for each species separately. The intercepts may arise from different driving modes or from a remote sensing offset, which applies to all vehicles regardless of emissions or model year.

Correlation studies were also conducted on data from Phoenix, Arizona and Chicago, Illinois from 1998 (Figures 5-7). The R^2 values are not as good as those in Denver, but the slopes correspond. An exception is the CO plot for Chicago, where the slope is somewhat higher than in the other CO plots. One reason for this noise in the data may be the fact that the N values for I/M data in these two studies were much lower than in Denver. While RSD N values were similar (18,000 in Phoenix and 24,000 in Chicago), the I/M data were averaged from only 14,000 measurements in Phoenix and 58,000 in Chicago (random full IM240 samples) compared to one million in Denver. Because of the skewed nature of vehicle emissions, such decreases in N values can increase uncertainty significantly. The Phoenix comparison looks better than reported by Wenzel (1999) for a similar study, perhaps because a more modern on-road remote sensor was used.

A summary of the slopes of the various correlations is given in Table 1. The relationship between IM240 and RSD emissions measurements is quite constant for each pollutant.

One exception is CO in Chicago, where it is likely that a difference in vehicle load at that remote sensing site may have increased the measured CO values and, thus, increased slope. Such differences in load also account for the slopes not all being one. Because the driving mode on the IM240 cycle differs from the driving mode at the RSD site, the model year averaged emissions are not equal. Finally, the HC slopes remain very constant at 0.4. The small slope is explained by the Singer and Harley factor (Singer, 1998), which relates HC measurements from NDIR (remote sensing) to those from FID (IM240).

Correlations where measurements were binned by make were also attempted. Such correlations were not as good as those averaged by model year. Averaging by make divides up the data to a greater extent so that each bin contains fewer measurements and the precision decreases. Furthermore, model year is such a significant factor in a vehicle's emissions that differences in model year distributions between IM240 and RSD within the various makes causes significant discrepancies in average emissions. Figure 8 is an example of such a plot, where the makes are arranged by their emission levels in the IM240 test.

Table 1: Slopes of Correlations

	Denver			Phoenix	Chicago
	1996	1997	1999		
CO	0.53	0.66	0.68	0.62	0.98
HC	0.40	0.40	0.41	0.40	0.41
NO	1.2	0.99	1.1	0.98	
Cold NO	1.1	0.92	0.98		

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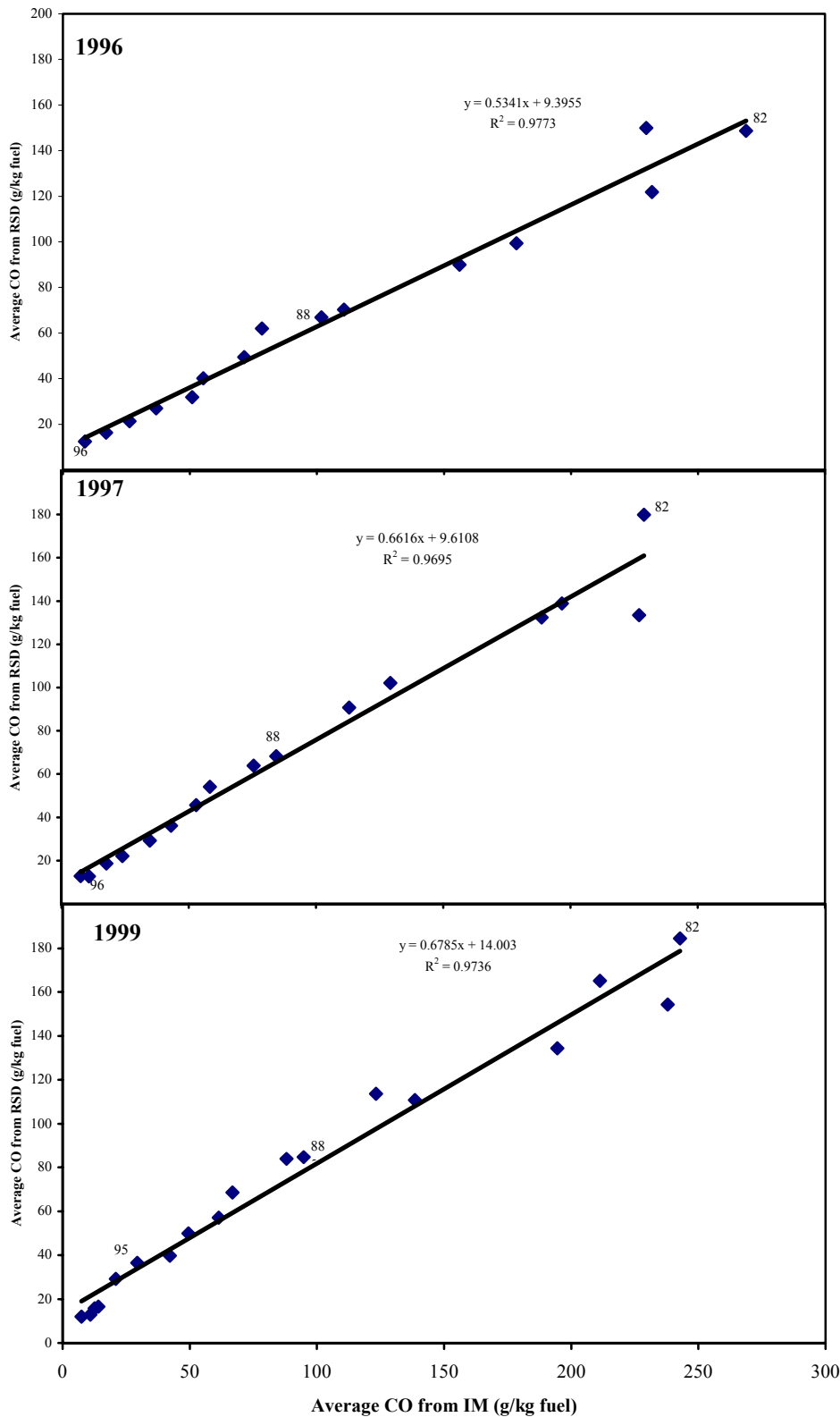


Figure 1: Correlation plots for CO between Denver IM240 and RSD for three separate years. The IM240 data are from a whole year of testing before the RSD data collection, which consisted of a week of measurements in the January of the year labeled on the plot. Each point represents a model year. Three model years are labeled.

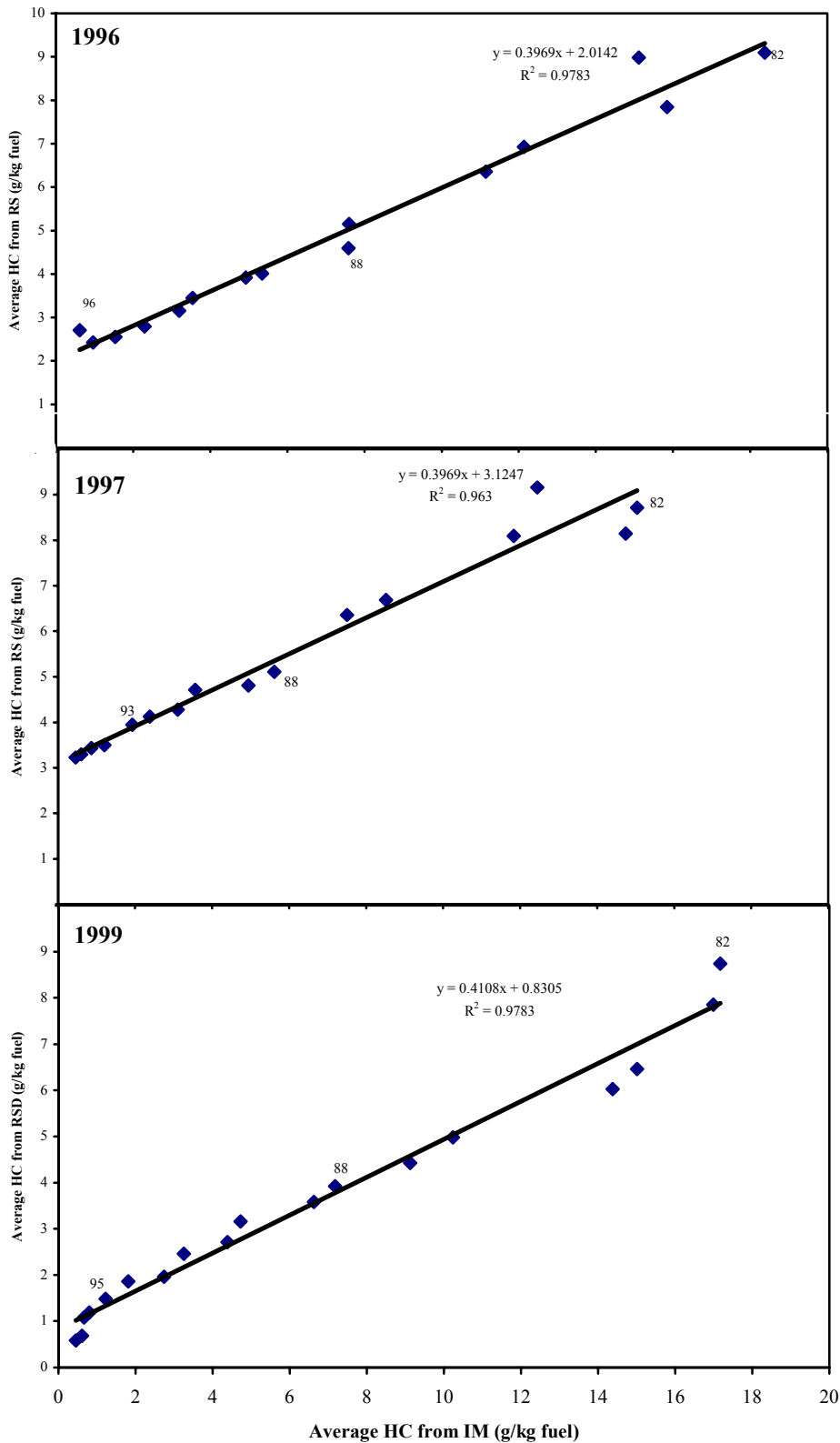


Figure 2: Correlation plots for HC between Denver IM240 and RSD for three separate years. The IM240 data are from a whole year of testing before the RSD data collection, which consisted of a week of measurements in the January of the year labeled on the plot. Each point represents a model year. Three model years are labeled.

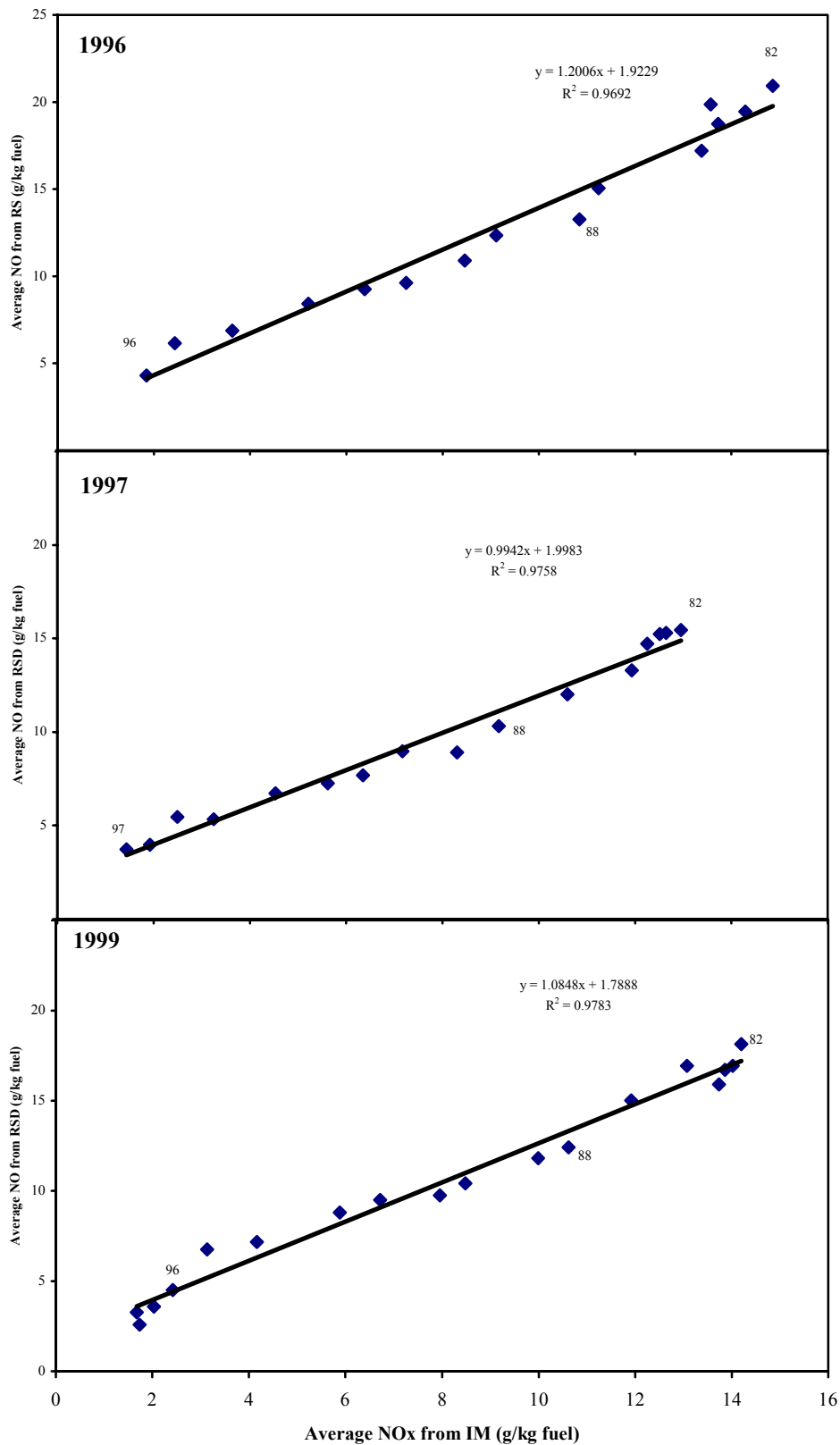


Figure 3: Correlation plots for NO between Denver IM240 and RSD for three separate years. The IM240 data are from a whole year of testing before the RSD data collection, which consisted of a week of measurements in the January of the year labeled on the plot. Each point represents a model year. Three model years are labeled.

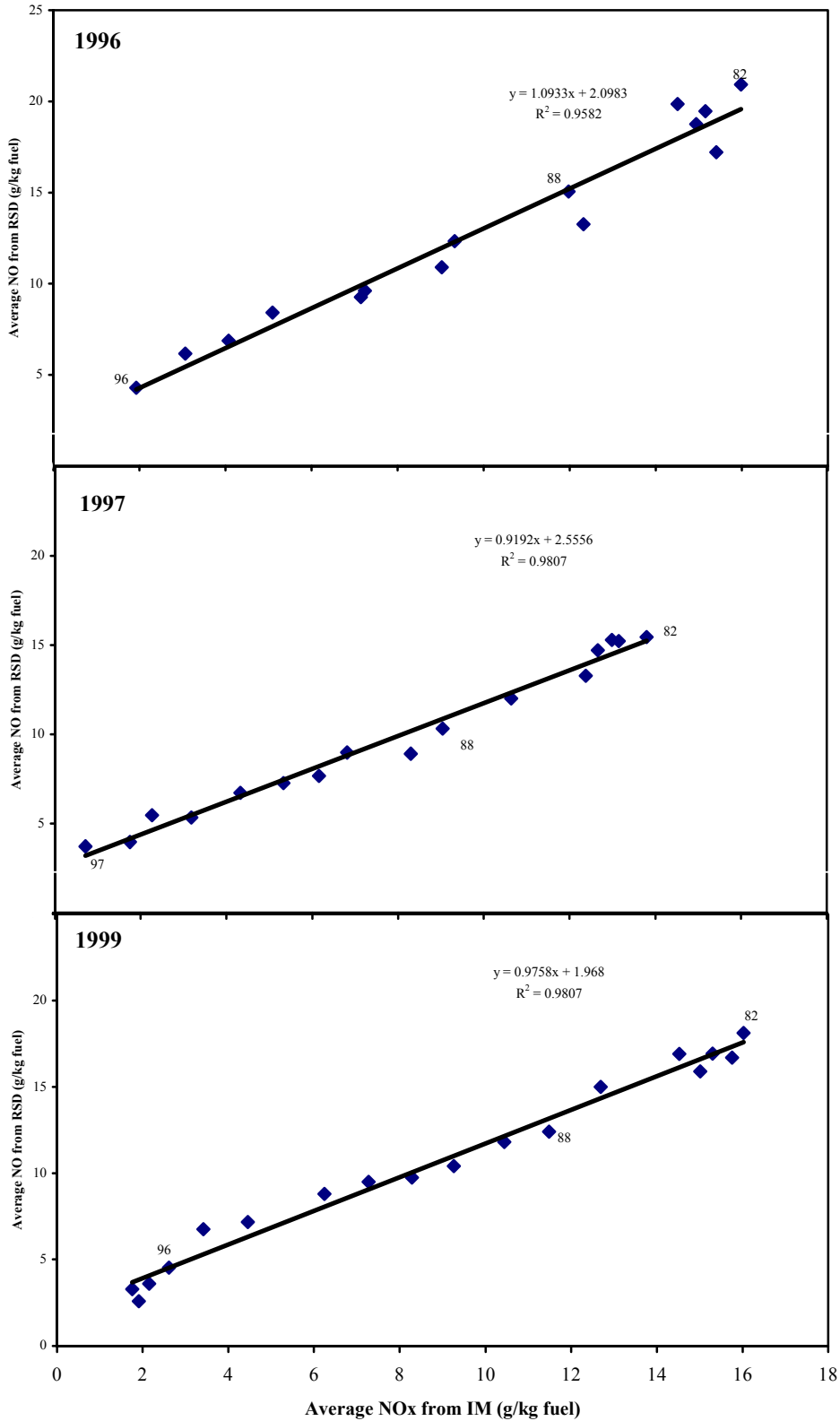


Figure 4: Correlation plots for NO during cold months between Denver IM240 and RSD for three separate years. The IM240 data are from January and February before the RSD data collection, which consisted of a week of measurements in the January of the year labeled on the plot. Each point represents a model year. Three model years are labeled.

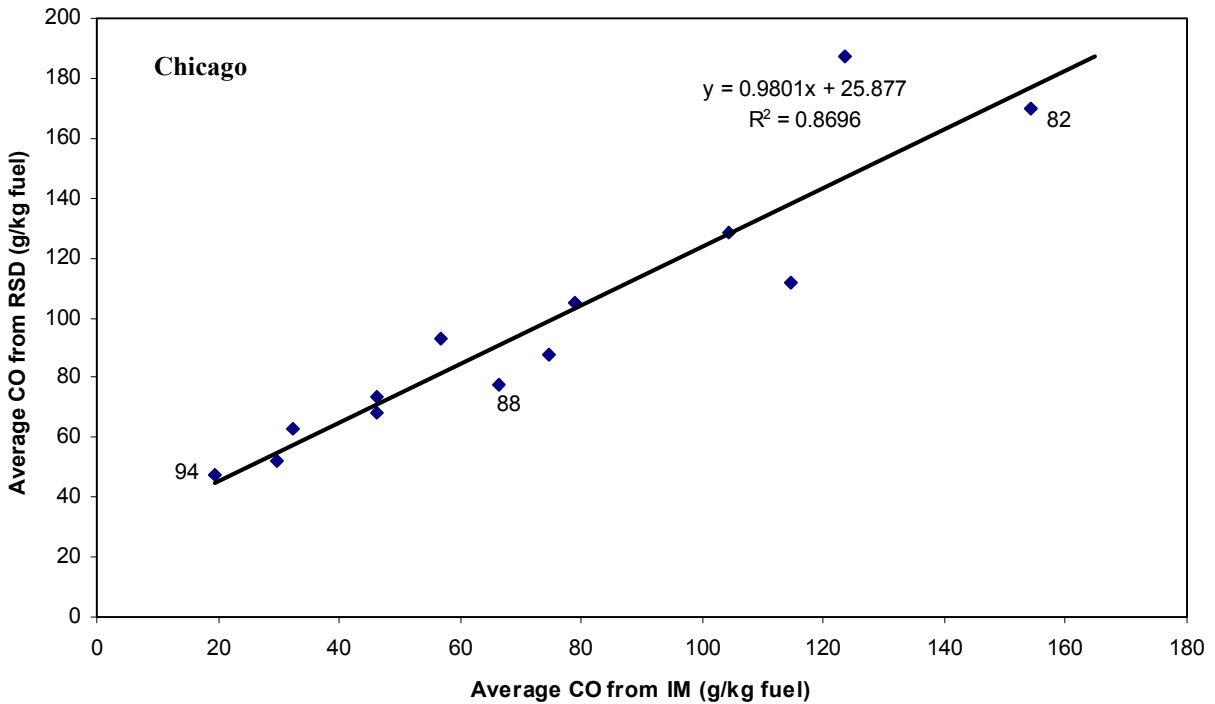
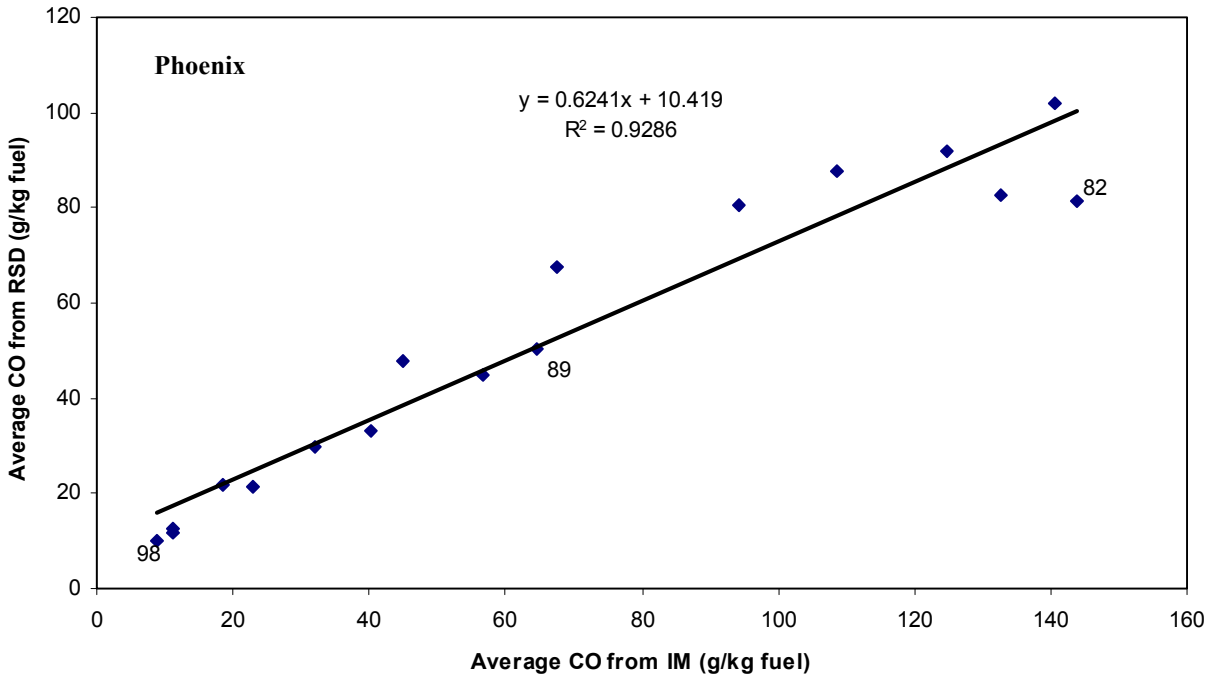


Figure 5: Correlation plots for CO between IM240 and RSD for Phoenix and Chicago in 1998. The IM240 data are from a whole year of testing, while the RSD data are from a week in September and November in Chicago and Phoenix, respectively. Each point represents a model year. Three model years are labeled.

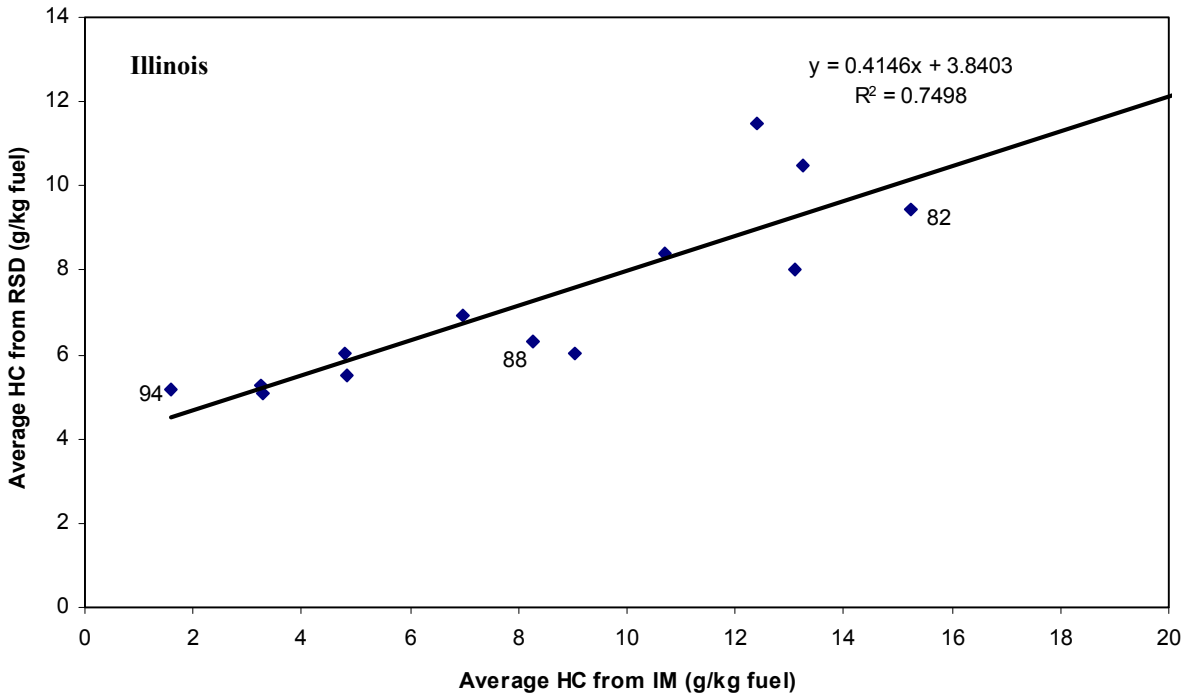
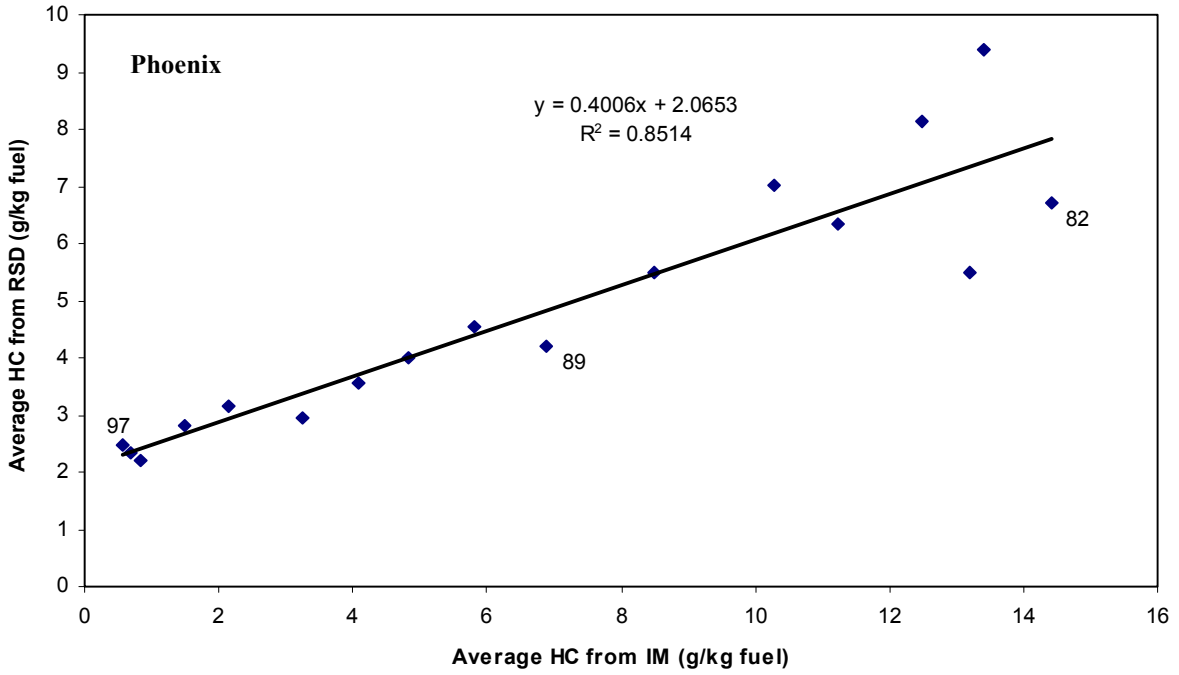


Figure 6: Correlation plots for HC between IM240 and RSD for Phoenix and Chicago in 1998. The IM240 data are from a whole year of testing, while the RSD data are from a week in September and November in Chicago and Phoenix, respectively. Each point represents a model year. Three model years are labeled.

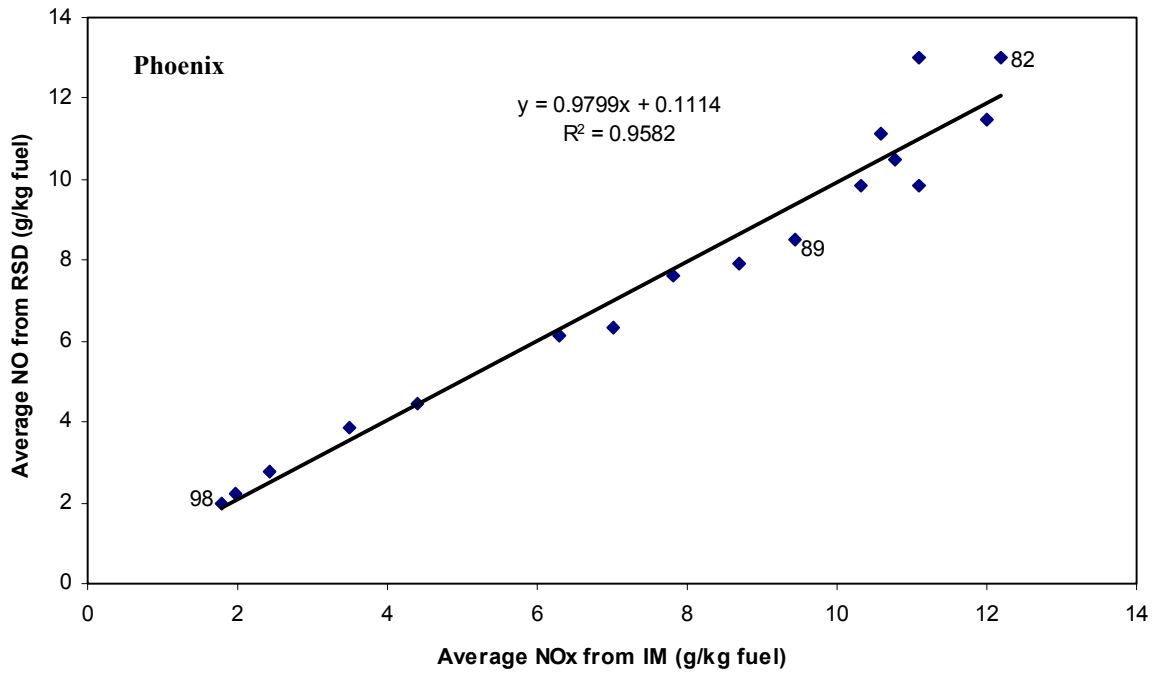


Figure 7: Correlation plot for NO between IM240 and RSD for Phoenix in 1998. The IM240 data are from a whole year of testing, while the RSD data are from a week in November. Each point represents a model year. Three model years are labeled.

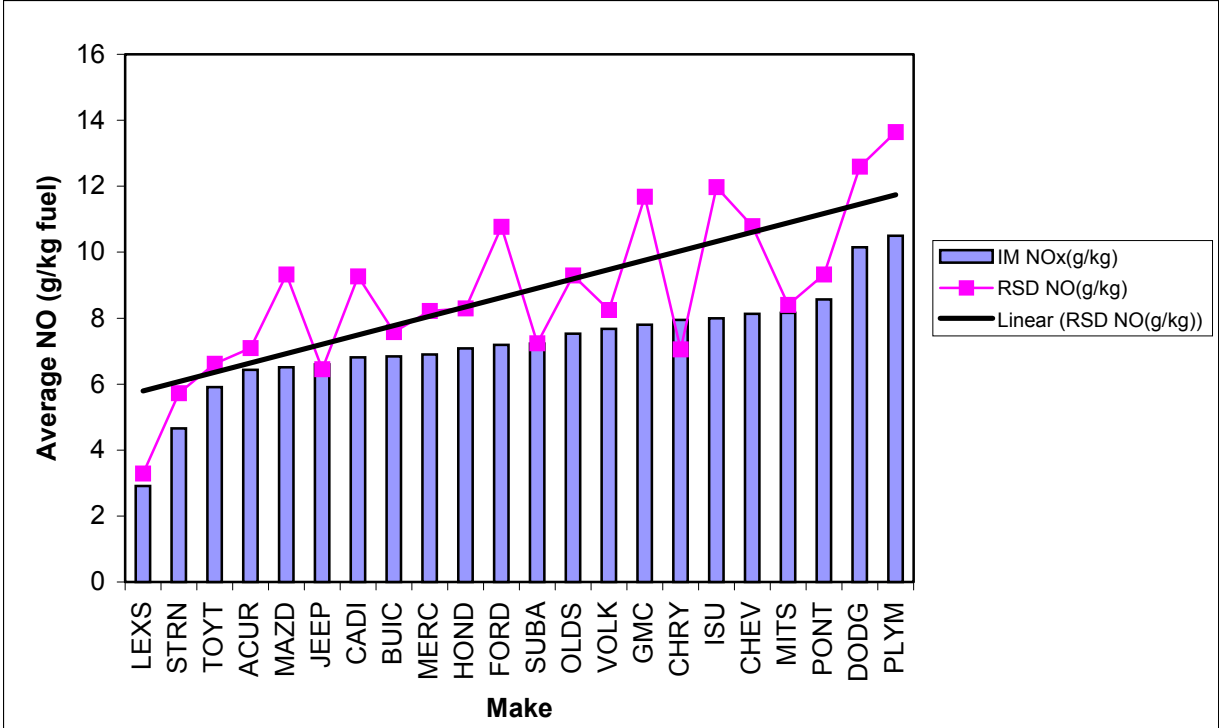


Figure 8: Average percent NO from different makes in RSD measurement (Denver: Jan. 1999) sorted by average emissions in IM240 (Denver 1998). Model years are limited to 1988-1995.