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Melbourne Automobile Emissions Study

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Introduction

The University of Denver's remote sensor (FEAT) was used for an on-road motor vehicle carbon monoxide (CO) and hydrocarbon (HC) emissions survey in Australia during April and May, 1992. Twelve locations in Melbourne area were selected as the survey sites. Most of these locations were the on or off ramp of a freeway or a two way road divided by a solid or painted traffic island. The raw data from Royal Automobile Club of Victoria (RACV) Ltd and Victorian Automobile Chamber of Commerce were 22,800 records. After eliminating those data with %HC less than -1.0 (2,403 records) or greater than 4.0, %CO greater than 17.0, %CO₂ less than 1.0 or greater than 16.0 (over 1,000 records), and model year less than or equal to zero, valid data for CO, HC and CO₂ emissions were obtained on a total of 15,908 vehicles with an average model year of 1983.

This report presents the measurement results based on the 15,908 record data set to identify the statistical distribution and characteristics of the automobile emissions in Melbourne, Australia. Comparisons of the emission characteristics between these Australian automobiles and U.S.A. automobiles are also presented.

Overall Results

The mean CO emission of the data set was 1.42 %CO, while the median vehicle emitted 0.57 %CO. The median value more closely approximates what a typical vehicle emits while the mean value is heavily influenced by the relatively few gross polluters which are referred to the part of the fleet which is responsible for half of that fleet's total emissions. In Melbourne, half of the CO emissions were produced by 1,978 gross polluters (about 12.43% of the fleet) which were emitting in excess of 3.52 %CO. Figures 1 and 2 show the distributions of the Melbourne emissions data in two ways. Figure 1 shows the distribution of CO emitters (black bars) by percent CO category. The clear bars show the percentage of the total CO emissions from each %CO category. It can be seen that more than 60% of the 15,908 vehicles emit less than 1 %CO and are responsible for only about 12% of the total CO emissions. For figure 2, the fleet was rank ordered by CO emissions from the lowest to the highest, then divided into deciles, groups containing one tenth of the fleet. Each bar corresponds to the average %CO emissions within each decile. Note that the cleanest seven bars have been averaged together. This has been done because the tiny differences between low emission averages of the cleanest 70% of the fleet are within the error bars of the FEAT measurement capability. Again it can be seen that the CO emissions

of the clean 70% of the fleet are dwarfed by the average emissions of the vehicles in the tenth decile. Both figures illustrate the mobile source CO emissions inventory is dominated by a relatively small number of high emitters.

The mean HC emission of the Melbourne data set was 0.107 %HC, while the median was 0.058. Gross polluters for HC emitters can be defined just as for CO emitters. Half of the HC emissions were produced by only 1,758 vehicles (about 11.05% of the fleet) with emissions greater than 0.187 %HC. The data for HC emissions are presented graphically in figures 3 and 4 in the same manner as that for CO emissions. The figures present a similar illustration of the significant contribution to the mobile source HC emissions inventory by a relatively small number of high polluters as in the CO case, however, the HC data are more skewed than CO data.

Quintile Investigation

For each model year the on-road CO and HC emissions are divided into five groups (quintile) in ascending order of emission levels. Examination of the quintile emission factor distributions from the CO data (figure 5a) shows that the value of the mean %CO rises smoothly as the age increases. The quintile plot shows no obvious sign of any sharp break between 1986 and 1985 model years in emission factor to coincide with the introducing of catalytic converters in Australia in 1986. The second panel, figure 5b, shows the observed age distribution of the surveyed fleet. The observed age distribution depends on the combined effects of recessions, rust and riches (socioeconomic status) of the locations chosen. In this study, the most abundant vehicles are from 1989 and 1990 model years. When the emission factor is multiplied by the fleet age distribution, the result is the percentage of the total CO emitted for each quintile of each model year, figure 5c. The cleanest forty percent of the vehicles, regardless of the model year, make an essentially negligible contribution to the total CO emissions. The greatest contribution is from the dirtiest twenty percent of the vehicles between 1979 and 1990 model years. This is due to the large number of vehicles dating from this period, combined with the relatively high emissions of the dirtiest twenty percent of these vehicles. The dirtiest twenty percent of the new vehicles is dirtier than the cleanest forty percent of any model year.

Figure 6 shows the same investigation for hydrocarbon emissions. It shows a similar picture as CO emissions, but with different vertical scaling.

Discussion

The pattern of the Melbourne emissions data look very much like the data we have acquired elsewhere in U.S. (e.g. Los Angeles, Chicago, Atlanta, Denver). That pattern consists of a very skewed distribution with most vehicles contributing very little to mobile source emissions inventories. At the other extreme lies the small number of vehicles with

high emissions contributing a disproportionate high share of the total emissions.

A fleet from Chicago, June 1992 is chosen as a typical U.S. fleet to be compared with the Melbourne fleet. These two fleets are comparable because of the similar metropolitan status, the close measuring data, and the similar average fleet age. The typical U.S. fleet has an average %CO emission value of 1.04, with a median of 0.25 %CO. More than 76% of the fleet emit less than 1 %CO. It is apparent that the U.S. fleet distribution is lower emitting and more skewed than the Melbourne fleet distribution. In the U.S. fleet, half of the total CO emissions arises from about 8% of the fleet, with a gross polluter cut-point around 4 %CO. The U.S. cut-point is slightly different from the Melbourne cut-point, but the percentage of the gross polluters is much lower in U.S.. For HC data, the U.S. fleet has an average %HC emission value of 0.088, with a median of 0.058 %HC, which is also lower than the Melbourne data.

The observed higher emissions in Melbourne are caused by a combination of two factors: the lack of adequate maintenance (as we have observed in the U.S.) and the lack of emissions control equipment (catalytic converters were only introduced in Australia in 1986). Among these two factors, improving the fleet maintenance would immediately reduce the fleet average emissions. Especially, the removal or repair of those gross polluters would nearly halve the amount of total emissions.

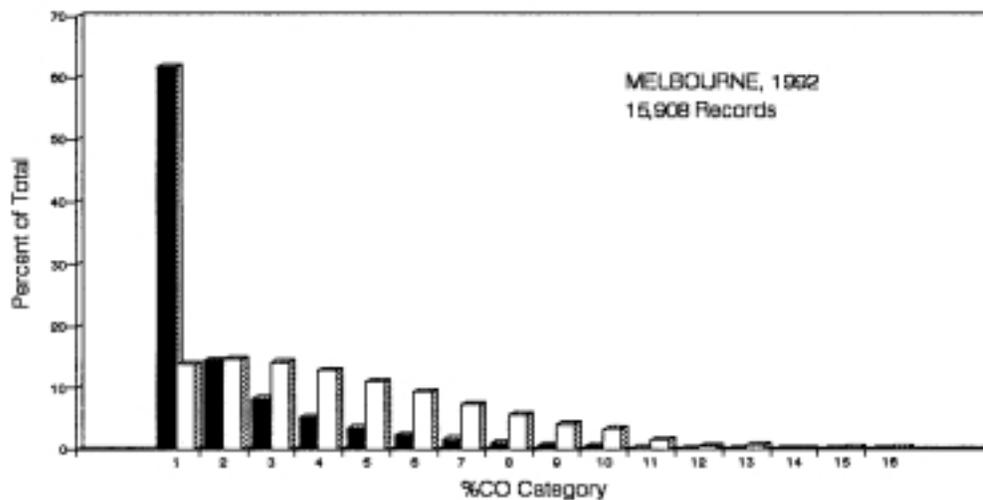


Figure 1. Normalized histogram showing as clear bars the percentage of the total CO emissions. Black bars show the percentage of the fleet of vehicles with emissions less than the stated %CO category.

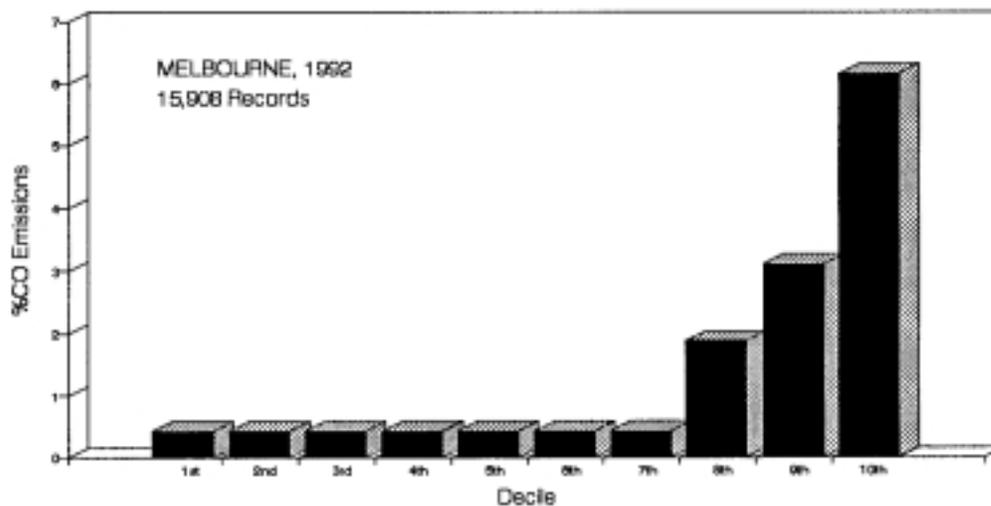


Figure 2. Mean %CO organized into deciles. The cleanest seven deciles are given the average of all seven since the differences are negligible.

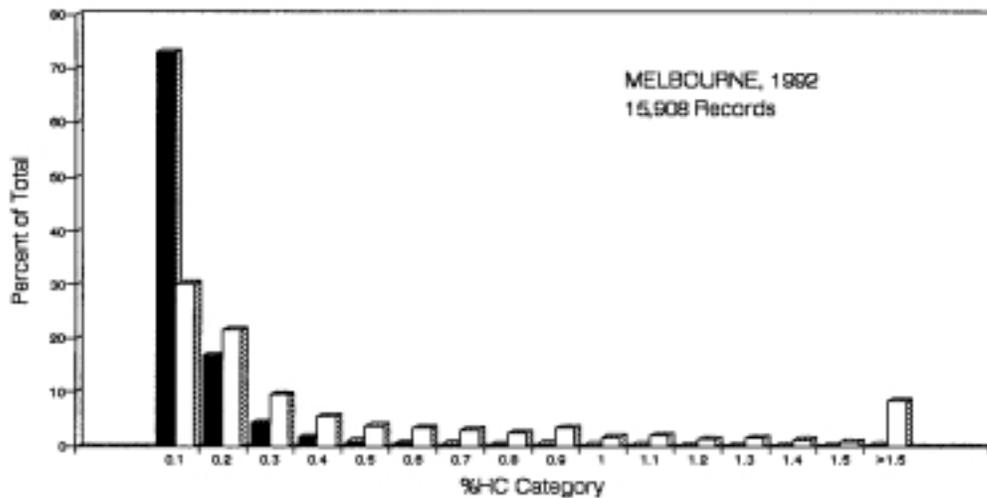


Figure 3. Normalized histogram showing as clear bars the percentage of the total HC emissions. Black bars show the percentage of the fleet of vehicles with emissions less than the stated %HC category.

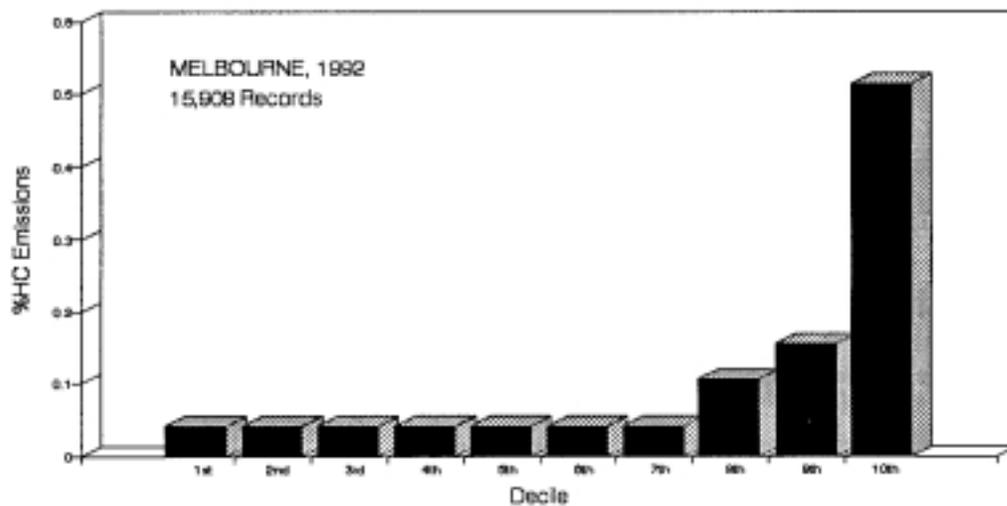


Figure 4. Mean %HC organized into deciles. The cleanest seven deciles are given the average of all seven since the differences are negligible.

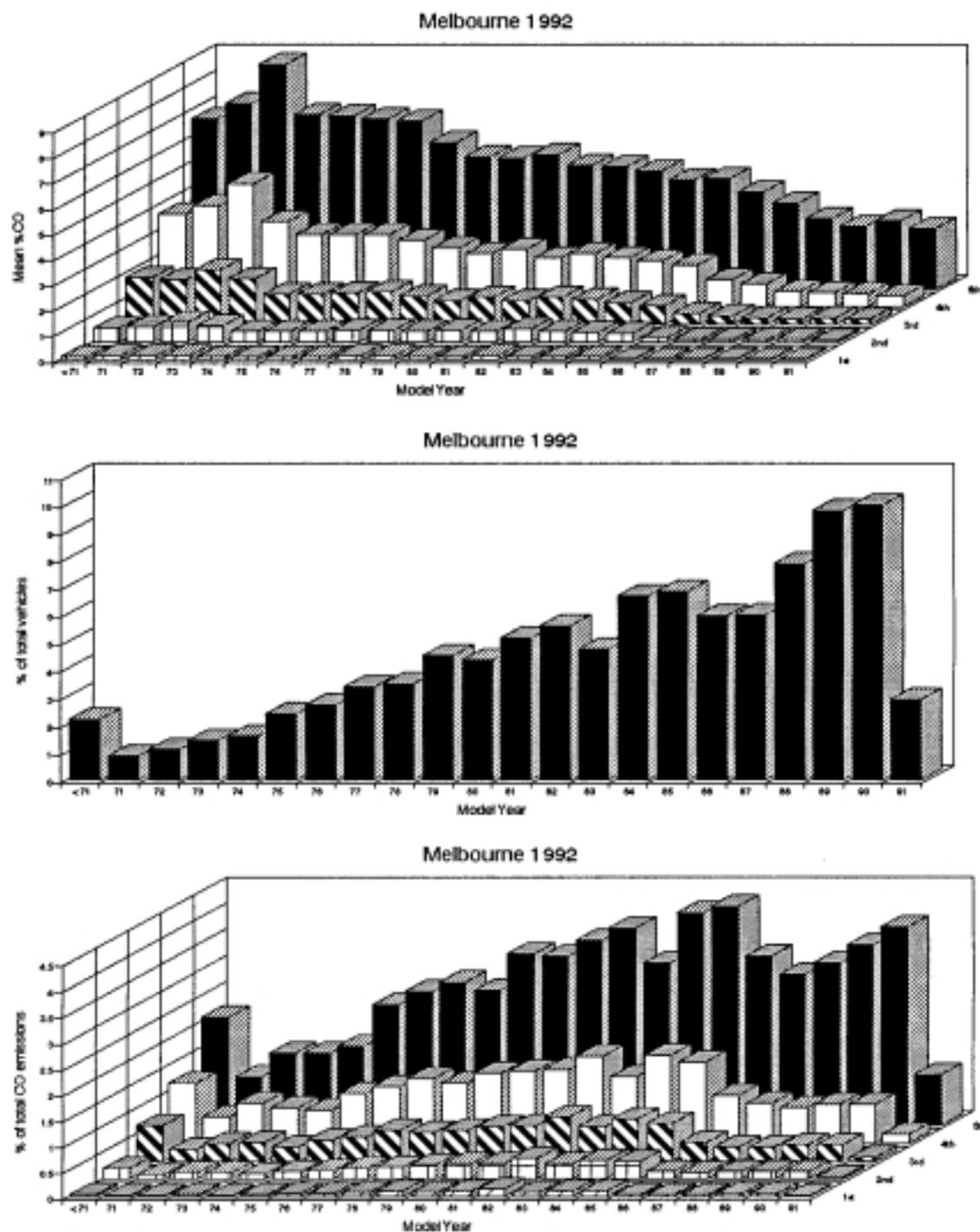


Figure 5. The 1992 Melbourne %CO data presented as: a) emission factors by model year divided into quintiles, b) fleet model year distribution and c) the percentage of the total CO emissions for each quintile of each model year.

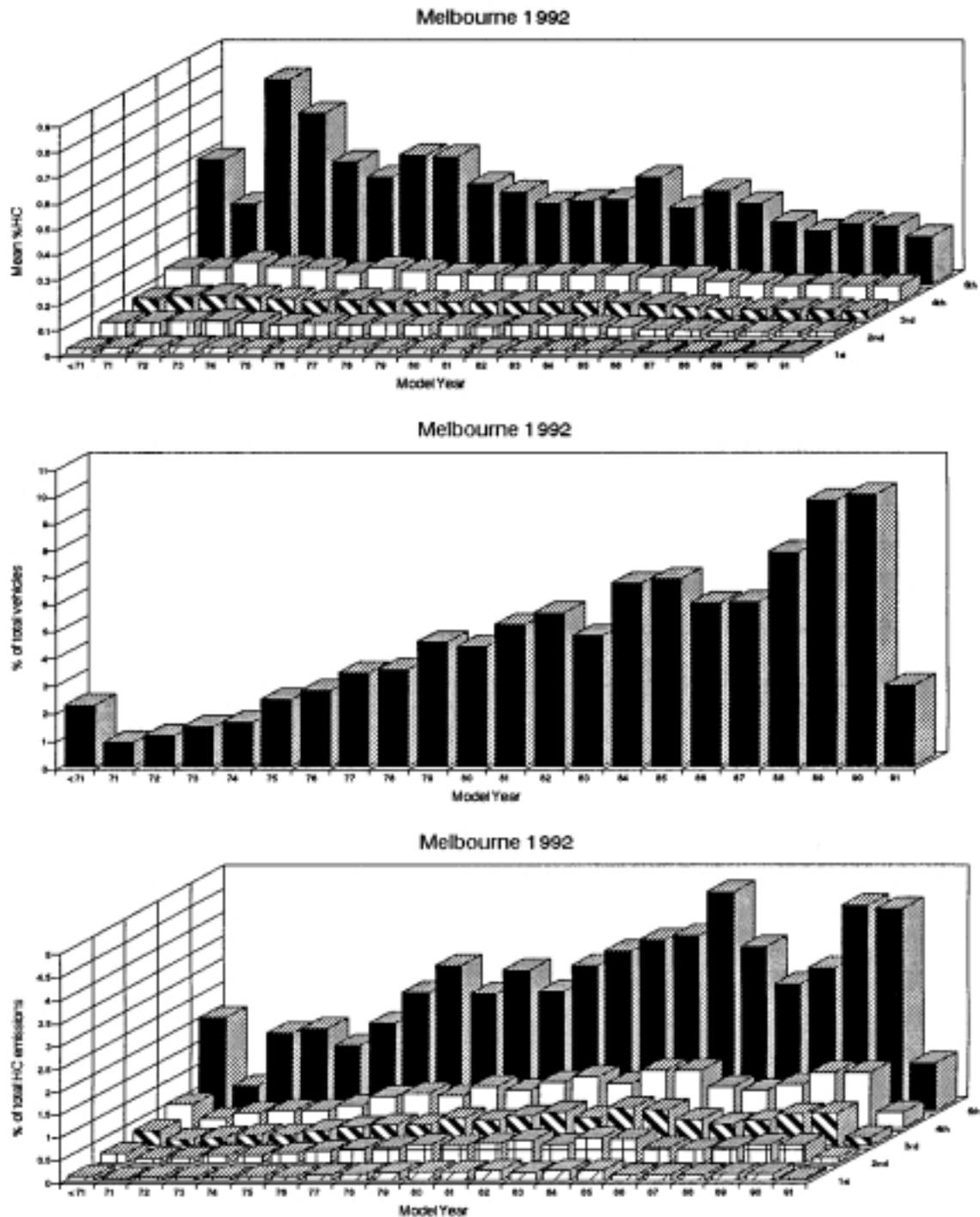


Figure 6. The 1992 Melbourne %HC data presented as: a) emission factors by model year divided into quintiles, b) fleet model year distribution and c) the percentage of the total HC emissions for each quintile of each model year.