



# MOTOR VEHICLE POLLUTION IN AUSTRALIA

Report on the National In-Service  
Vehicle Emissions Study

prepared by the

Federal Office of Road Safety

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## **A BRIEF NOTE FROM THE FORS PROJECT TEAM**

*This report is the culmination of two years' hard work by a great bunch of people.*

*We all hear a lot of talk about the need for cooperation between governments, industry and business. This project shows what good cooperation can achieve.*

*In 1991, FORS started to gauge what level of interest might exist for a project that would get to grips with car pollution in Australia. The initial response was most heartening.*

*When we came forward with concrete proposals, the reaction from all quarters was overwhelming. Virtually every organisation we approached offered support by way of people, services or products. Overall, our budget was boosted by several hundred thousand dollars through their generosity and enthusiasm.*

*As well as the visible contributions, everyone who became involved in the project - laboratory staff, mechanics, industry bodies, motoring clubs, contractors and the people from other State and Federal government bodies - all worked long and hard, often behind the scenes, to make this project happen.*

*To all of you, our heartfelt thanks.*

**Peter Anyon**

**Deborah Jones**

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**Robert Jamieson**

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- Mitsubishi Motors Australia Ltd;
- Toyota Motor Corporation Australia Ltd
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# Contents

	Page
<b>EXECUTIVE SUMMARY</b>	i
INTRODUCTION	i
OBJECTIVES OF THE STUDY	ii
METHODOLOGY	ii
KEY FINDINGS	iii
POTENTIAL FOR EMISSION REDUCTIONS	ix
EFFECTIVENESS OF SHORT TESTS IN IDENTIFYING HIGH POLLUTERS	xii
FUEL EFFICIENCY ISSUES	xv
COST OF REPAIRS AND MAINTENANCE	xv
SUMMARY	xvi

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## MAIN REPORT

1. INTRODUCTION	
1.1 Overview and Objectives	1
1.2 Background	1
1.3 Phases of the Study	2
1.3.1 Sample Design Phase	3
1.3.2 Sourcing & Surveys Phase	3
1.3.3 Testing Phase	4
1.3.4 Data Analysis Phase	6
2. RESULTS	
2.1 INTRODUCTION	7
2.1.1 Australian Design Rules (ADRs)	7
2.1.2 Baseline Test Cycle - Exhaust Emissions	7
2.1.3 Evaporative Emissions Measurement	8
2.1.4 Australian Design Rule Limits	9
2.1.5 Tuning, Repair and Maintenance	9
2.1.6 The Test Fuel	10

	Page
2.2 FLEET PERFORMANCE, EXHAUST (TAILPIPE) EMISSIONS	11
2.2.1 How well (or badly) do cars perform when compared with standards to which they were originally built?	11
2.2.2 How does this translate into actual emissions?	17
2.2.3 How much do pollution control systems deteriorate in-service?	20
2.2.4 Does maintenance and tuning reduce car pollution?	23
2.2.5 What parts were replaced most often and what was the cost of tuning/maintenance?	35
2.2.6 Summary of the exhaust emissions picture	36
2.3 FLEET PERFORMANCE, EVAPORATIVE EMISSIONS	37
2.3.1 What is the status of the fleet's evaporative emissions performance?	37
2.3.2 Are evaporative emissions limits met in practice?	38
2.3.3 Why are the SHED results so high?	41
2.3.4 Summary of the evaporative emissions picture	43
2.4 EMISSIONS PERFORMANCE OF OTHER VEHICLE GROUPS	45
2.4.1 Description of other groups	45
2.4.2 Do cars with modified engines & exhausts generate excessive pollution?	45
2.4.3 Are older cars a major source of pollution?	48
2.4.4 Is there a pollution problem from newer cars?	49
2.5 FUEL CONSUMPTION ISSUES	52
2.5.1 What is the fuel consumption performance of the car population?	52
2.5.2 Does tuning improve fuel consumption?	52
2.5.3 Summary of fuel consumption picture	54

	Page	
2.6	ADDITIONAL TESTS	
2.6.1	Introduction	55
2.6.2	Catalyst integrity test	55
2.6.3	Catalyst temperature test	55
2.6.4	Fuel filler cap sealing test	56
2.6.5	Carbon Clean treatment	56
2.6.6	Hydrocarbons emissions speciation	56
2.7	EFFECTIVENESS OF SHORT TESTS	59
2.7.1	Introduction	59
2.7.2	IM240 test results	61
2.7.3	ASM 25/25 test results	65
2.7.4	SS60 test results	69
2.7.5	High Idle test results	73
2.7.6	Idle test results	76
2.7.7	Effectiveness at predicting emission reductions	78
2.8	HOUSEHOLD SURVEY RESULTS	88

### **3. DISCUSSION OF RESULTS**

3.1	EMISSIONS FROM AUSTRALIA'S CAR POPULATION	89
3.1.1	Deterioration of emissions performance	89
3.1.2	Distribution of pollution	89
3.1.3	Evaporative emissions	90
3.2	POTENTIAL FOR EMISSION REDUCTIONS	92
3.2.1	Effect of tuning and maintenance on tailpipe emission levels	92
3.2.2	Effect of tuning and maintenance on evaporative emissions	93

	Page
3.3 EFFECTIVENESS OF SHORT TESTS	94
3.3.1 Correlation between short tests and FTP test results	94
3.3.2 Effectiveness of short tests	95
3.3.3 Fuel consumption issues	96
3.3.4 Cost of repairs and maintenance	96
3.4 SUMMARY	96



# **EXECUTIVE SUMMARY**

## **INTRODUCTION**

In recent years motor vehicle pollution levels in Australia have been reduced through the progressive introduction of increasingly stringent standards for exhaust emissions from both petrol and diesel engines.

But tighter standards for new vehicles address only one aspect of the problem. Once in service, vehicles can gradually deteriorate and, inevitably, some will be subject to abuse and tampering.

For these reasons, environmental planners have long suspected that the key to achieving acceptable air quality goals lies as much with ensuring that vehicles are well maintained as it does with introducing tighter new vehicle standards.

This issue has recently gained some prominence as regulators begin to understand that the current trend towards cleaner air may be reversed within the coming decade. Increases both in car usage and in the total vehicle population will start to outweigh the benefits of tighter standards unless more is done to control emissions.

One of the difficulties in establishing programs to manage pollution from cars, after they have entered service, has been an acute shortage of data on the emission characteristics of Australia's vehicle population, and on the extent to which pollution control systems deteriorate over time.

To address this shortcoming, the Federal Government allocated \$1.75 million to the Federal Office of Road Safety to undertake a comprehensive study on the emissions performance of Australia's current passenger car fleet.

The National In-Service Emissions (NISE) study commenced in May 1994 and was completed on time, on budget in April 1996.

## **OBJECTIVES OF THE STUDY**

The principal objectives of the Study were to:

- estimate the total emissions of the current passenger car fleet, and of specified sub-sets of the fleet, before and after tuning
- assess the extent of emission control system deterioration and failure
- assess the emission performance of vehicles with reference to their original requirements
- identify the likely causes of vehicles' poor emissions performance
- assess the potential for reductions in emissions from the in-service fleet from regular maintenance/repair
- assess the need for inspection programs including the effectiveness and relative cost of a range of possible tests and inspections aimed at identifying high-polluting vehicles
- establish a statistical base for projecting future emission levels of passenger cars.

## **METHODOLOGY**

The Study is based on a comprehensive program of standardised tests performed on a total of 640 privately owned passenger cars; conducted in specialist emission laboratories in Sydney and the Melbourne area.

Tests ranged from the most complex and time-consuming certification-level protocols down to the simplest checks which can be done with minimal equipment at the local repair shop.

The main test sample comprised some 540 cars from the 1980-91 age group and were sourced via a random survey of householders in the Sydney and Melbourne metropolitan areas, using a robust statistical sample design.

Each vehicle was tested both in its "as delivered" condition, and then again after tuning and minor repairs to the fuel and ignition systems.

Exhaust emissions of hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO<sub>x</sub>) were measured for all vehicles. Evaporative hydrocarbon emissions were also measured for around 40% of the tested vehicles.

Additional smaller sets of vehicles were also subjected to the same testing regime as the main set. These groups included

old (1970-1979) models, newer (1992-1993) models and cars with modified engines.

All testing was done using test fuels with consistent specifications (one leaded, one unleaded) which were drawn from normal "summer grade" commercial production and drummed for use over the duration of the project.

Around 300 data items were collected on each vehicle tested. In addition, a considerable amount of information on travelling and maintenance patterns was collected from the 6000 households also surveyed as part of the project.

Overall, this study represents the most comprehensive vehicle emissions research ever undertaken in Australia.

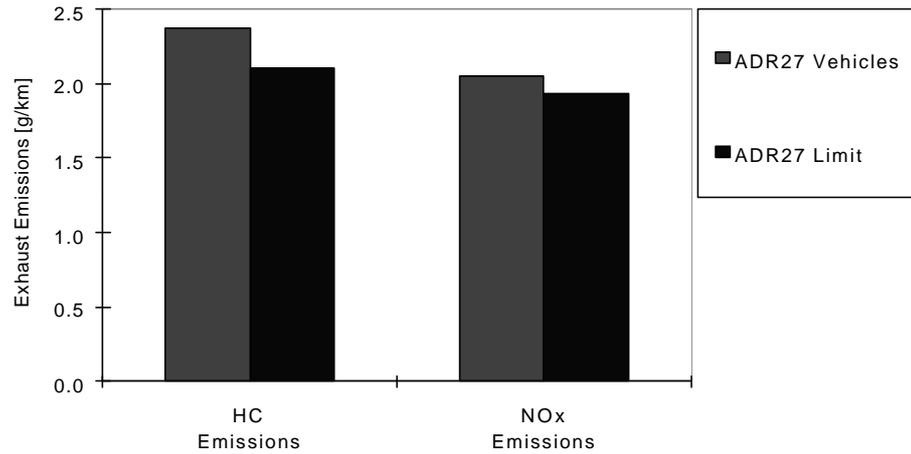
**Note:** Cars tested in the NISE study fall into two distinct groups that are generally treated separately when analysing test data:

- (a) Vehicles manufactured after January 1986 were built to comply with Australian Design Rule ADR 37/00 and run only on unleaded petrol. They generally have computer-controlled engine management systems, fuel injection, and are fitted with catalytic converters.
- (b) Cars made between 1974 and 1986 were designed to meet the less stringent ADR 27 and run on leaded petrol, do not have catalytic converters and generally have carburettors rather than fuel injection systems.

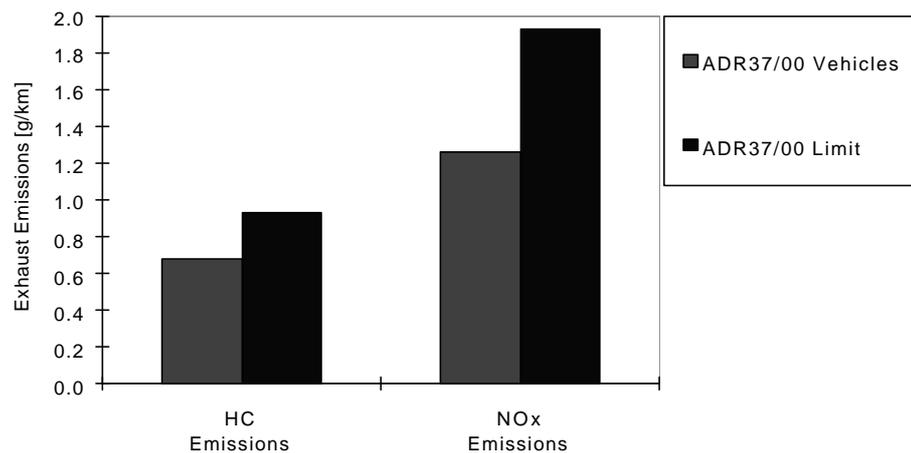
## **KEY FINDINGS**

### **DETERIORATION IN EMISSIONS PERFORMANCE**

At first sight, overall emission levels from Australia's cars appear to be quite good in comparison with the standards to which they were originally designed (See Figures (i) and (ii) ). These highly aggregated charts should be used with great caution, however, as they mask a lot of important factors. Closer inspection shows that there are many areas for potential improvements and some of great concern.



**Figure (i) Average 1980-1985 Car Emissions (HC & NOx) vs ADR 27 Limits**



**Figure (ii) Average 1986-91 Car Emissions (HC & NOx) vs ADR37/00 Limits**

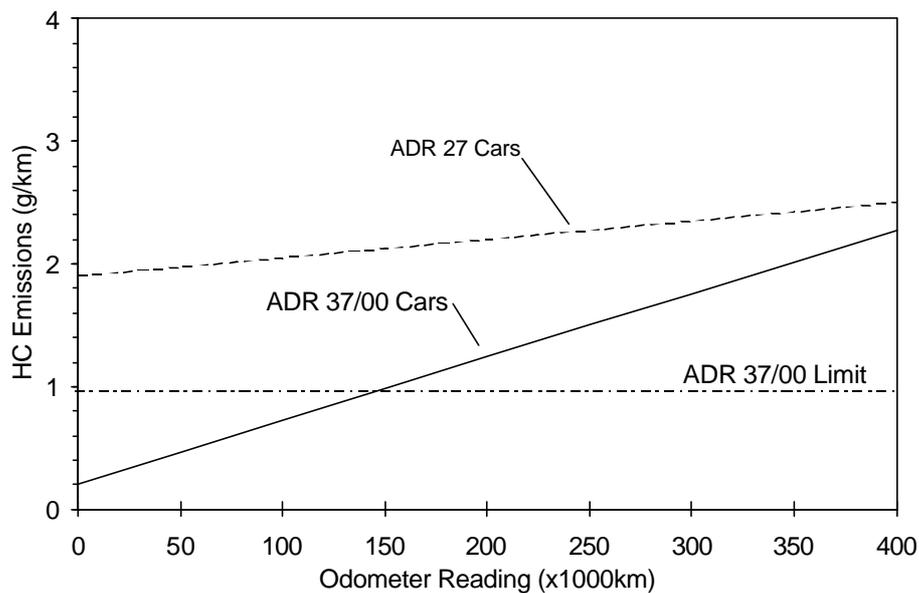
Not surprisingly, there is clear evidence that exhaust pollution levels from cars increase with age and kilometres travelled. This deterioration, however, varies widely among individual vehicles.

Embedded in the general picture are several interesting findings:

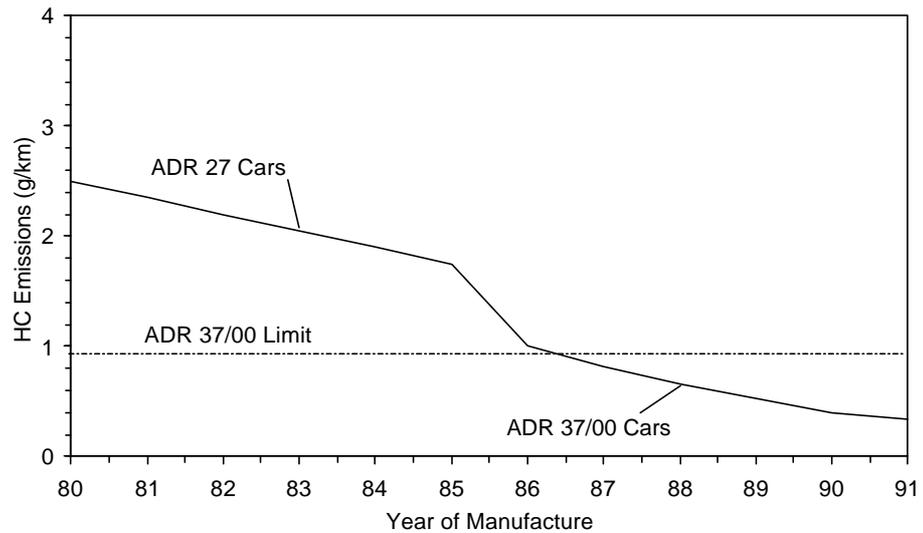
- all cars up to 10 years old are fitted with catalysis, yet very few (less than 4%) had catalysis which were identified as totally non-operational
- most ADR37/00 cars still complied with the exhaust emission limits after the 80,000km mark nominated in the ADRs (this is not the case with evaporative emissions)

- catalyst equipped vehicles can have emission levels just as high as non-catalyst vehicles, and the worst catalyst equipped vehicles exceed the ADR limits by a wide margin.

Modern cars rely heavily on “active” systems to control pollution levels (catalytic converters, on-board computers and sensors, etc). From data collected in the NISE project, it appears that these vehicles tend, on average, to deteriorate at a greater rate than older, pre-catalyst vehicles, whose emission levels were more dependent on intrinsic design features. Figures (iii) and (iv) illustrate this point for hydrocarbon emissions.



**Figure (iii) Hydrocarbon Emissions by Odometer Reading (linear fit)**



**Figure (iv) Hydrocarbon Emissions by Year of Manufacture (smoothed data)**

As a result, while new vehicles start from a much lower base, their higher deterioration rates could mean that the advantages of tighter new car standards may not be sustained in the longer term unless steps are taken to keep these cars in good condition.

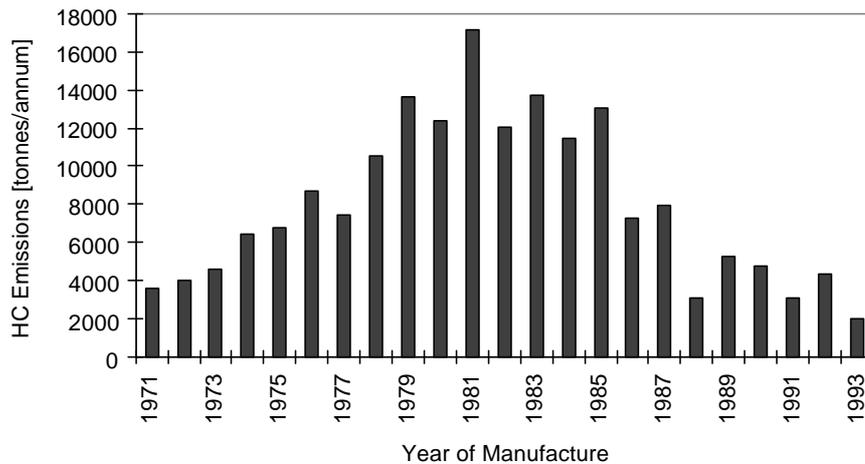
Moreover, with even tighter standards and, possibly, extended durability requirements already on the horizon, manufacturers may be facing a considerable technological challenge to build vehicles that will continue to meet future standards for the duration of their service life.

#### **DISTRIBUTION OF POLLUTION BY VEHICLE AGE**

By combining, for each year of manufacture:

- (a) the average emissions of the group,
- (b) the number of cars in the group and
- (c) average annual kilometres travelled by cars in that group, then the relative (and absolute) contribution of each age group of cars to total pollution levels can be calculated.

Cars 10 to 16 years old currently dominate the pollution scene for hydrocarbon (HC) and carbon monoxide (CO) tailpipe emissions. This phenomenon was less evident for oxides of nitrogen (NO<sub>x</sub>). Figure (v) illustrates the distribution of annual hydrocarbon tailpipe emissions for Australia.



**Figure (v) Example - Total Annual HC Exhaust Emissions by Model Year (All Australia)**

Cars in the middle age group tend to stand out because they:

- (a) have fairly high average emissions;
- (b) are still driven fairly intensively; and
- (c) are still very numerous because of Australia's extremely low fleet turnover rate.

Newer cars, while accounting for higher average annual travel, have generally low average emissions provided they are well maintained.

However, given the elevated deterioration rates observed in catalyst equipped vehicles, it is possible that cars in this group may become a significant problem as they get older unless steps are taken to maintain the functionality of their emission control systems.

Older vehicles tend to have rather high individual emission levels, but contribute a diminishing amount to total pollution levels because of the generally low annual distances travelled by this group.

No group can be totally discounted, however, as individual vehicles in all groups were found to emit extremely high levels of pollution (up to 100 times typical new car levels) and these should be rectified regardless of age or usage.

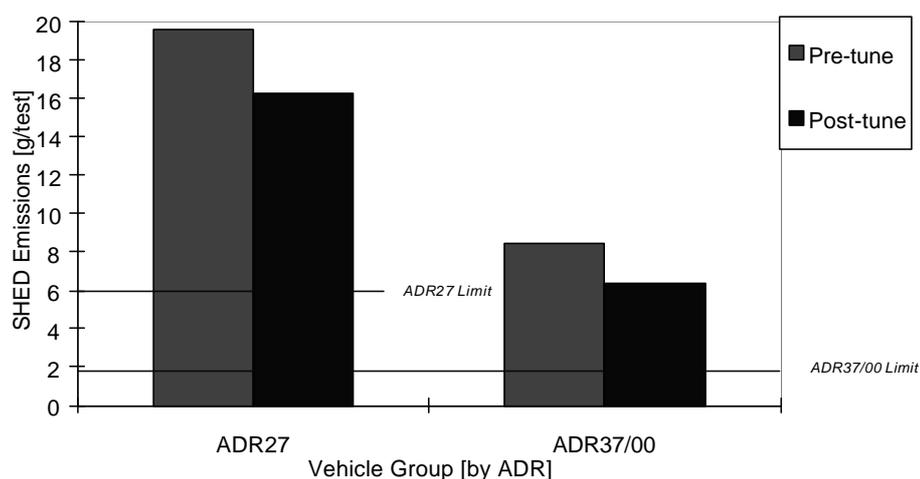
## EVAPORATIVE EMISSIONS

In the past, regulators and researchers have tended to focus on what comes out of the exhaust pipe. The NISE project has raised a number of serious concerns about “real world” levels of evaporative emissions.

These concerns relate both to the relevance of current test procedures (particularly the certification test fuel) and to the durability of evaporative emission control systems fitted to cars.

Using the NISE test fuel, which is typical of summer grade commercial gasoline, evaporative emission levels were found to be many times the maximum permitted ADR levels.

Even modern ADR 37/00 vehicles tested in the main sample had evaporative emissions that averaged four times the ADR limit. (See Figure (vi).)



**Figure (vi) 1980-91 Vehicles - Average Evaporative HC Emissions (pre & post tune)**

The reasons for this are not entirely clear, but certainly the substantial difference in vapour pressure between certification test fuel and typical pump petrol (used in the NISE study) plays a major role.

In limited back-to-back tests using both certification test fuel and the NISE test fuel on a small group of cars, recorded emission levels were consistently much higher for the NISE fuel.

Some commentators have suggested that the activated charcoal in a car's vapour collection canister becomes contaminated by oil fumes or other residues in a relatively short time, greatly reducing the adsorption capacity of the charcoal canister.

The durability of fuel filler cap seals also appears to have a significant influence on the pressure integrity of cars' fuel systems. Replacement of the fuel filler cap on those cars with high evaporative emissions had a marked effect on test results.

In view of the above findings, some fundamental re-calibration may be required in some computer models used to predict airshed pollution.

The high levels of evaporative emissions found in the NISE study should be a cause of concern to regulators, the oil industry and the vehicle manufacturing industry alike.

*Footnote: The Federal Government is already funding a complementary study into evaporative emissions, which may shed further light on the causes of high evaporative emissions, and may lead the way towards possible solutions.*

## POTENTIAL FOR EMISSION REDUCTIONS

### EFFECT OF TUNING AND MAINTENANCE ON TAILPIPE EMISSIONS

The results of testing done in the NISE study clearly demonstrate that substantial reductions in pollution levels can be achieved through good maintenance practices.

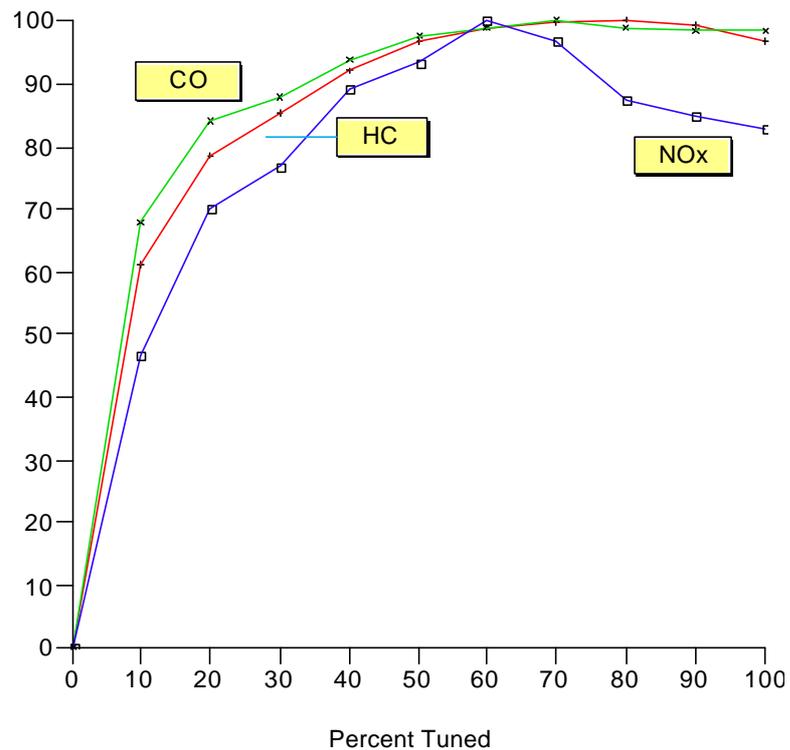
The overall levels of improvement are tabulated below:

#### Average Reductions in Emissions from Tuning and Maintenance

	<i>All Cars in Study</i>	<i>ADR27 Cars</i>	<i>ADR37/00 Cars</i>
<b>HC</b>	16%	14%	21%
<b>CO</b>	25%	26%	24%
<b>NOx</b>	9%	8%	9%

However, the gains are not uniformly distributed, with most of the available improvements coming from a relatively small proportion of the total car population.

Typically, around 80% of the total emissions reductions available from tuning were delivered by only 20% of the cars in the NISE study sample (Figure (vii) ).



**Fig (vii) Effect of Identifying and Rectifying the Worst Emitters - 1986-91 Cars.**

Given this finding, one of the key policy issues to be faced by regulators in considering options for emission reduction programs will be whether to:

- (a) subject all vehicles to an inspection and maintenance regime;
- (b) only include pre-defined groups selected by age, kms travelled, etc; or
- (c) target vehicles to be included by some filtering mechanism such as remote sensing or a short test.

The choice of approach will effect the cost-effectiveness of any future programs.

### **EFFECT OF TUNING ON EVAPORATIVE EMISSIONS**

The extremely high evaporative emission test results indicate that the current regime for controlling these emissions is not working in practice, particularly as it appears that emissions can often be substantially reduced by replacing key components.

Those cars with very high evaporative emissions tended to respond strongly to the fitment of a new, properly sealing fuel filler cap.

Because of cost constraints, only a small sub-set of six cars had a new charcoal canister fitted. All six showed a dramatic decrease in emissions with the new canister: some by a factor of seven or more. (Readers should note, however, that the statistical validity of this finding is limited by the small sample size).

The Study's findings suggest that the issue of testing and design for evaporative emissions should be reviewed. The complementary study already underway on this issue may assist in resolving some of the questions raised in the NISE study.

### **WHAT ABOUT STANDARDS FOR NEW VEHICLES?**

Deterioration trends identified by the NISE research clearly show that tighter new standards are only of lasting value if vehicles are maintained in such a way as to retain, so far as possible, new car performance. The data also suggest that modern vehicles deteriorate at a faster rate than older cars.

One could argue, therefore, that tighter new car standards have actually increased rather than diminished the need for in-service maintenance programs.

It should also be appreciated that, because of Australia's extremely low vehicle turnover and scrappage rates, the effects of changes to new car standards take many years to significantly penetrate the fleet.

To illustrate this point, the project team calculates that, in one year, **tuning the existing car population would achieve a reduction in HC emissions ten times greater than would be achieved by requiring all new cars sold in 1997 to be zero emission vehicles!**

# EFFECTIVENESS OF SHORT TESTS IN IDENTIFYING HIGH POLLUTERS

## INTRODUCTION

To demonstrate compliance with the relevant ADRs, exhaust emissions are measured using a rolling road (*chassis*) dynamometer capable of simulating engine load / speed conditions similar to those typically found in city driving conditions.

By “driving” the car on the dynamometer to a pre-determined and tightly controlled cycle of acceleration, cruise and braking together with idle periods to simulate stationary traffic periods, an accurate and repeatable measurement of exhaust emissions can be made. Several such test cycles are used around the world.

The ADRs (in common with the US Federal Emission Standards) require that certification testing be done using the **FTP (Federal Test Procedure)** cycle, which simulates driving a distance of about 15km at speeds up to 94km/h. This is the **baseline test** cycle used in the FORS study as it allows a direct comparison of a vehicle’s current exhaust emissions performance with the levels it had to meet when new.

A long-standing goal for governments seeking to reduce vehicle pollution has been to develop a short test that reliably identifies high polluting vehicles.

Ideally, such a test would have the following characteristics:

- good correlation with certification test results
- ability to identify those cars whose emissions will be most reduced by tuning
- take only a few minutes to perform
- cost no more than, say, \$30 on a commercial basis
- preferably be capable of being done at distributed or roadside locations as well as in centralised facilities.

To address the above, a number of short tests of varying simplicity have been developed in recent years. All vehicles in the NISE study were tested using all the available short tests both prior to and after tuning. These tests were:

### **IM-240** - Modified IM240 (Inspection & Maintenance) Test Procedure

This test is based on the first four minutes of the FTP (ADR37/00) cycle but only covers about 2km total distance. Emission results are converted to grams per kilometre for HC, CO and NOx.

**ASM** - Acceleration Simulation Mode Test Procedure (ASM2525)

The vehicle is driven on a chassis dynamometer at a speed of 40km/h. Concentrations of raw exhaust emissions of HC, CO and NOx are measured.

**SS60** - Steady State Loaded 60km/h

The vehicle is driven on a chassis dynamometer at a constant 60km/h. Emissions of HC, CO and NOx are measured.

**HIGH IDLE** - Steady State High Idle Test Procedure

With the engine running at a speed of 2500 rpm the concentrations of raw exhaust emissions are measured for HC and CO.

**IDLE** - Steady State Idle Test Procedure

With the engine running at idle speed (accelerator not depressed) the concentrations of raw exhaust emissions are measured for HC and CO.

For each vehicle tested, the results of all short tests have been compared with results obtained for the same vehicles using the FTP test. The results of these comparisons follow.

**CORRELATION BETWEEN SHORT TESTS AND FTP TEST RESULTS**

This issue has pre-occupied many researchers, particularly in the USA, over recent years. Not surprisingly, the NISE study found that, in general, loaded (dynamometer) tests provide better correlation than non-loaded (idle) tests, although there were a few exceptions. The correlations are summarised below.

**Correlations Between Short Tests and ADR Test Results**

	ADR 27			ADR 37/00		
	HC	CO	NOx	HC	CO	NOx
<b>IM240</b>	0.80	0.93	0.91	0.94	0.90	0.90
<b>ASM</b>	0.52	0.71	0.69	0.64	0.78	0.68
<b>SS60</b>	0.62	0.80	0.74	0.80	0.84	0.72
<b>Hi Idle</b>	0.49	0.71	N/A	0.70	0.62	N/A
<b>Idle</b>	0.44	0.55	N/A	0.72	0.67	N/A

The IM240 test achieved by far the highest correlation with the FTP test for all gases, and for both ADR27 and ADR37/00 cars. The consistent second best correlation was provided by the SS60 test, which performed better on ADR37/00 vehicles than on ADR27 cars.

The ASM test, which was expected to provide good correlation, came a fairly poor third and, in one case, had a lower correlation than the idle tests.

The two idle tests had the lowest correlation with FTP results, with neither showing a particular benefit over the other.

In summary, while the IM240 test showed the best correlation, it is only suited to a centralised approach, with high capital costs and specialist operator skills. The ASM and the two idle tests all had inferior correlation levels and some were incapable of measuring NO<sub>x</sub> levels at all.

The SS60 test appears to provide the most practicable option for a short test, demonstrating good correlation with FTP results yet being suited to both centralised or distributed operation with relatively low capital costs.

## **EFFECTIVENESS OF SHORT TESTS**

Correlation with the FTP cycle is only one part of the story. The bottom line for governments is the impact that an emissions reduction program will have on overall pollution levels and at what cost.

The relative effectiveness of each short test was assessed by analysing the actual emission reductions achieved through tuning vehicles picked out as the highest emitters by each of the five short tests.

The IM240 test was the clear winner in this area, with only a relatively small but varying difference between the effectiveness of the other tests.

However, all the tests were quite effective at selecting those cars that delivered the greatest tuning effect (noting that the idle tests are not suitable for measuring NO<sub>x</sub> emissions).

Regardless of which test is used as an indicator of emission levels, it is clear that there is very little marginal gain in tuning more than the worst 40% of cars. Detailed cost-benefit studies may suggest an even lower proportion.

The question of which short test might provide the optimum solution will receive intensive further analysis by environmental and transport planners.

## FUEL EFFICIENCY ISSUES

Although the main focus of the NISE study was to investigate pollution levels, the ADR 37/00 test cycle is identical to that used in Australian Standard AS2877 to measure fuel consumption.

The results of testing show that tuning cars can deliver fuel consumption benefits as well as reductions in emissions.

An overall improvement of around 1.5% was recorded on the main test sample. This would translate to annual fuel cost savings in the region of \$200 million if applied to the Australian car population.

Moreover, it was again the highest polluters that gave the greatest fuel consumption reductions from tuning and maintenance. The highest 10% of polluters gave a fuel consumption gain of over 5% after tuning.

## COST OF REPAIRS AND MAINTENANCE

It should be stressed that the NISE study focused on the benefits to be gained from following the routine maintenance and tuning procedures recommended by vehicle manufacturers. The study was not an exercise in extracting every possible gain, regardless of cost.

In general, items replaced in the NISE study vehicles were restricted to normal service items such as spark plugs, filters, points and plug leads. Only in a very few cases were high cost items such as catalysis replaced.

Thus the tuning effects measured in the study reflect those that would be encountered by typical private owners maintaining their cars to normal service industry standards.

The average commercial cost of the materials and labour to repair, adjust and tune the test cars averaged around \$200 per vehicle. Little variation was encountered, on average, between older and more modern vehicles.

## SUMMARY

The following points summarise Australia's car pollution situation and the potential for improvement:

- A well maintained passenger car fleet could reduce pollution to between 9% and 25% below existing levels
- These reductions would be accompanied by substantial greenhouse gas reductions and fuel savings of around \$200 million per annum
- The average cost of servicing, repairing and adjusting a car to achieve the above results is around \$200 at typical 1996 motor vehicle repair industry rates
- Evaporative emissions of hydrocarbons appear to create a major problem and there is some doubt as to whether the current certification test sets adequate "real world" design criteria for manufacturers to follow
- Relatively low cost, effective tests are available to identify high polluting cars

One simple dynamometer-based test (SS60 test) appears to offer the optimum combination of correlation with the ADRs and capability to select cars that will benefit most from tuning.

It is important to note that there are two key aspects of this study :

1. Do cars generally continue to meet the ADRs?
2. Can emission levels be reduced by maintenance?

While the first question is important in assessing the performance of vehicles (and manufacturers) against new car standards, the second is the relevant issue for planners - can simple tuning measures reduce the effect of vehicles on urban air quality?

This study shows that the answer to the second question is 'yes'. It also gives guidance on various other approaches.

Consideration of the study findings lead to the conclusion that managing urban air quality from the vehicle perspective requires a careful balance of new car standards and in-service management policies.

The NISE study report provides a solid foundation for developing these policies.

# MAIN REPORT

## 1. INTRODUCTION

### 1.1 OVERVIEW AND OBJECTIVES

In December 1992, the then Prime Minister announced, in his Statement on the Environment, the Government's intention to undertake a \$1.75 million study to determine the emission performance of Australia's current passenger car population. The Federal Office of Road Safety was given the responsibility for managing the Study, which formally commenced in May 1994 and was completed in December 1995.

The principal objectives of the Study were to:

- estimate the total emissions of the current passenger car fleet, and of specified sub sets of the fleet, before and after tuning
- assess the extent of emission control system deterioration and failure
- assess the emission performance of vehicles with reference to their original requirements
- identify the likely causes of vehicles' poor emissions performance
- assess the potential for reductions in emissions from the in-service fleet from regular maintenance/repair
- assess the need for inspection programs including the effectiveness and relative cost of a range of possible tests and inspections aimed at identifying high-polluting vehicles
- establish a statistical base for projecting future emission levels of passenger cars.

### 1.2 BACKGROUND

Australia has made significant improvements in the control of pollution from new motor vehicles, including the mandatory use of unleaded petrol since 1986, and the progressive introduction of tighter standards on both noise, exhaust and evaporative emissions. However, the tighter standards on new cars will only have a small impact on urban air quality in the short term, because new cars can take many years to significantly penetrate the vehicle fleet.

To address today's urban air quality problems there is perceived to be a need in the transport sector to focus on vehicles already on the road. It is generally agreed that the (elusive) key to reducing vehicle related pollution is to identify and rectify those in-service vehicles which make an excessive contribution to air pollution. There are little current data, however, on the actual emissions performance of the current fleet and on the potential improvements that could be effected.

The National In-Service Emissions (NISE) Study involves a program of standardised tests on a broad sample of vehicles utilising suitable testing laboratories, together with a survey of vehicle owners.

The data obtained from the Study will be used by the Federal Government, working with the States and Territories, to assess the magnitude of the problem, and if necessary, develop and introduce practical and cost-effective programs for improving the performance of those vehicles on our roads which are contributing more than they should to air pollution.

### **1.3 PHASES OF THE STUDY**

The NISE Study comprised 4 phases:

1. Sample Design:  
the design of the framework and benchmarks;
2. Sourcing and Surveys:  
survey of householders, sourcing of test vehicles; on-going consultation with the survey consultant and testing laboratories regarding availability of test vehicles; collection, replacement, delivery and return of test vehicles to householders;
3. Testing:  
vehicle testing, incorporating general inspection and tuning/repair of test vehicles; on-going consultation with testing laboratories; and data collection;

#### 4. Data Analysis and Reporting.

To ensure a quality output for the Study as a whole, contractors who are experts in their fields were engaged for each of the phases. The data analyst also had considerable input into the sample design phase to ensure that the results could be effectively analysed at the completion of the Study.

##### **1.3.1 Sample design phase**

The Sample Design Phase was required to ensure an appropriate sample of vehicles for testing, and to set an overall framework for the Study. The details of this phase are contained in Appendix IV. EK Foreman and Associates was engaged for this phase.

Quotas in the sample design were based around a sample of 600 vehicles. The focus of the sample is on the major makes and models supplied to the Australian market by local manufacturers over the 1980-91 period. This focus was deliberate, as we did not want the presence of small volume or exotic vehicles to have an impact on the results. Thus it needs to be remembered that although the sample is statistically robust and representative of the vehicles which dominate the fleet, there are makes and models which were excluded from the sample. It is also the largest sample of vehicles ever tested in Australia for in-service emissions.

The Sample Design incorporated a pilot test phase to verify the sample. This was conducted by the survey consultant and emissions testing laboratories in April 1994. The data resulting from the pilot phase were also assessed by the Study's data analysis consultant.

##### **1.3.2 Sourcing & surveys phase**

The sourcing of vehicles for testing through the random survey of householders in the Sydney and Melbourne metropolitan areas was a vital phase in the program. The details of this phase are contained in Appendix V.

The survey consultant for this phase, AGB McNair Pty Ltd, obtained information on vehicle use, type, and frequency of maintenance from householders approached as part of the Study, including test vehicle owners. This was achieved through the use of an introductory letter which introduced the Study to the householder, followed up by direct telephone contact.

Once test vehicles were identified, the survey consultant notified test laboratories of the necessary details. Vehicle coordinators from each of the testing laboratories then made the necessary arrangements for collection of vehicles from owners. Replacement vehicles were supplied to householders for their use while their car was being tested.

In addition to the vehicles randomly sourced as outlined above, several “targeted” groups of vehicles were tested to compare their emissions with the general fleet. These groups are as follows:

- New (1992-93) cars - 46 vehicles
- Older (1970-79) cars - 22 vehicles
- Poorly maintained cars - 10 vehicles
- Modified cars (head, cams, carburettor etc) - 10 vehicles

Although the number of vehicles tested in the targeted groups may not provide statistically robust data, the testing will provide an indication of whether they may have higher emissions than the fleet as a whole, and whether further work should be done in this area.

### ***1.3.3 Testing phase***

The testing phase of the study was undertaken by 3 specialist emission laboratories run by the NSW Environment Protection Authority, the Environment Protection Authority of Victoria and the Ford Motor Company. To ensure consistency of operations between the laboratories a testing group with representatives from each of the laboratories and chaired by FORS met a number of times during the testing phase. In addition correlation vehicles circulated between the laboratories on 6 occasions over the testing phase to validate the consistency of test procedures.

The details of the testing procedures, including tuning/repair procedures and the correlation process, are contained in Appendices VIII and X.

The testing phase is briefly described below.

#### *Outline of Testing Phase*

Vehicles are tested both as received and again after tuning/repair to manufacturers' specifications (so far as is possible). This gives an indication of the maximum achievable reduction in emissions from the fleet. The emissions tests conducted and types of emissions recorded are detailed in Table 1.1.

**Table 1.1 Emission Tests Conducted in the NISE Study**

<b>Name of Test</b>	<b>Data Recorded</b>
ADR27 exhaust emissions (ADR27 cars only)	CO, HC, NOx, Fuel Consumption
ADR27 evaporative emissions (ADR27 cars only)	HC
ADR37/00 exhaust emissions	CO, HC, NOx, Fuel Consumption, *Benzene, *1, 3-Butadiene, *Toluene, *Xylenes
ADR37/00 evaporative emissions	HC
IM 240	CO, HC, NOx, Purge Flow
Acceleration Simulation Mode	CO, HC, NOx
Steady State Loaded (60 km/h)	CO, HC, NOx
Steady State (High Idle 2500 rev/min)	CO, HC
Steady State (Idle)	CO, HC

\* The analyses for these specific hydrocarbon emissions was undertaken by the CSIRO on behalf of the Environment Protection Agency (Commonwealth) and detailed results have been published in a report available from the EPA.

Prior to testing, the state of the engine and general condition of the vehicle were recorded. In addition to the main emissions tests conducted above, the following additional tests were conducted (at least on some vehicles):

- Fuel Filler Cap Sealing Test
- Catalyst Temperature Test
- Catalyst Integrity Test
- Chemical Treatment Process

Tuning of vehicles was undertaken at the testing stations by a mechanic provided by the NSW and Victorian motoring organisations and conducted in accordance with set guidelines (see Appendix VIII).

The data for the testing phase were collected using initially *Microsoft Excel* and later *Microsoft Access* software.

#### **1.3.4 Data analysis phase**

The emissions data from the vehicle testing, and data from householder surveys, were analysed on a regular basis by the Study's data analysis consultant, ANUTECH Pty Ltd, in consultation with FORS. Major analyses were done at several stages during the testing phase of the Study so that early trends could be examined and issues not identified in the original design of the Study could be explored, if possible, before the Study was completed.

In the interests of public debate and discussion, all the raw data collected in the study are contained in the enclosed compact disk in *Microsoft Excel* format. There is a file on the CD which identifies the contents of each of the data files.

All reasonable attempts have been made to ensure the accuracy of the data, but in a study of this scope and size it is possible that errors have been made and not detected. The analyses in this report are made on the assumption that the data on the enclosed disk are correct.

There are additional analyses contained on the CD-ROM which accompanies this report.

## 2. RESULTS

### 2.1 INTRODUCTION

The National In-Service Emissions (NISE) Study was commissioned to answer a number of questions about the scale, distribution and nature of pollution from cars on Australian roads, and to assess what scope exists to identify and rectify high polluting vehicles in a cost-effective way.

Rather than present a mountain of detailed results and calculations, we have chosen to analyse the data collected during the study in a way that addresses those questions of particular importance to policy-makers and planners.

This report does not pretend to give pre-packaged analyses of every facet of in-service emissions, emissions testing or the effects of tuning and maintenance. By providing all relevant components of the Study database on CD-ROM, researchers will be free to explore a wide range of trends, relationships and characteristics to suit their own needs and interests. You are all encouraged to make full use of the data (provided, of course, that you acknowledge the source in any published material).

Before considering the outcomes of the Study, it may be worthwhile to clarify the context in which test data is presented. This brief introduction may be particularly useful to those readers not familiar with vehicle emission testing standards and protocols.

#### **2.1.1 Australian Design Rules (ADRs)**

Except for the very small number of pre-1974 cars, every vehicle in this study was required, when new, to comply with a performance standard (ADR) that set limits for exhaust emissions of

- Hydrocarbons (HC)
- Oxides of Nitrogen (NO<sub>x</sub>); and
- Carbon Monoxide (CO).

The Australian Design Rules also set maximum limits for evaporative emissions of hydrocarbons, ie the vaporisation of petrol from the fuel tank, engine and fuel system, as opposed to gases emitted from the exhaust pipe as products of combustion.

#### **2.1.2 Baseline test cycle - exhaust emissions**

To demonstrate compliance with the relevant ADRs, exhaust emissions are measured using a rolling road (*chassis*) dynamometer capable of simulating engine load/speed conditions similar to those typically found in city driving conditions.

By “driving” the car on the dynamometer to a pre-determined and tightly controlled cycle of acceleration, cruise and braking together with idle periods to simulate stationary traffic periods, an accurate and repeatable measurement of exhaust emissions can be made. Several such test cycles are used around the world.

The ADRs (in common with the US Federal Emission Standards) require that certification testing be done using the **FTP** (**Federal Test Procedure**) cycle, which simulates driving a distance of about 12km at speeds up to 94km/h. It is described fully in Appendix VIII. This is the baseline test cycle used in the FORS study as it allows a direct comparison of a vehicle’s current exhaust emissions performance with the levels it had to meet when new.

All references in the report to “**FTP**” refer to this test cycle. Any exhaust emissions data presented without reference to a specific test protocol have been generated using the FTP cycle. The only exception to this is where ADR27 vehicles alone are being compared with ADR27 emission limits. In this case, the results are from the ADR27 emissions test, which is an earlier version of the FTP test.

### ***2.1.3 Evaporative Emissions Measurement***

As previously indicated, new vehicles are also required to undergo a test to measure evaporative emissions of hydrocarbons. These emissions are measured by placing the vehicle in a sealed “room” and sampling the levels of hydrocarbons in the room’s atmosphere after specified periods. The test is known as a “**SHED**” test which is an acronym for the room which is technically described as a **S**ealed **H**ousing for **E**vaporative **D**etermination. The test is conducted in 2 parts.

The first part (known as the "Diurnal Soak") simulates the effect of a cold parked vehicle gradually heating up as a summer day warms up. After a pre-conditioning process and after the vehicle has stood for at least 12 hours at ambient conditions, the vehicle tank is part filled with the specified test fuel. The vehicle is then moved, without starting the engine, into the SHED, the SHED is closed and the fuel in the tank is heated from 16°C to 30°C over one hour, usually using an electric blanket placed adjacent to the tank. At the end of the hour the concentration of hydrocarbons in the SHED’s atmosphere is recorded.

The second part (known as the "Hot Soak") simulates the effect of parking a hot vehicle at the end of a journey (from home to the shops, for example). In this part of the test the engine obviously needs to be hot, so it is conducted immediately after the driving cycle in the FTP test is completed. At the end of the driving cycle, the vehicle is placed in the SHED, the SHED is closed, and after an hour the increase in concentration of hydrocarbons in the SHED’s atmosphere is recorded.

The results for the 2 parts are summed and the total recorded as the result in grams of hydrocarbons per test.

#### **2.1.4 Australian Design Rule Limits**

Cars tested in this study were covered by two Australian Design Rules:

- ADR 27 (including 27A, 27B and 27C) applied to vehicles manufactured from 1974 to end 1985.
- ADR37/00 covers the period from 1986 to the present. The use of unleaded petrol in these vehicles was also mandated from 1986.

An even more stringent standard, ADR37/01, comes into effect from 1997.

The emission limits set by these standards are:

<b>Standard</b>	<b>HC (g/km)</b>	<b>CO (g/km)</b>	<b>NOx (g/km)</b>	<b>Evap (g/test)</b>
ADR27*	2.1	24.2	1.9	6.0**
ADR37/00	0.93	9.3	1.93	2.0
ADR37/01***	0.26	2.1	0.63	2.0

\* From 1/7/76 only (test used between 1/1/74 and 30/6/76 was based on UN ECE R15 and cannot readily be correlated with FTP test protocol)

\*\* From 1/1/82 only (different test method prior to that date)

\*\*\* Phased in from 1/1/97

#### **2.1.5 Tuning, repair and maintenance**

All vehicles in the NISE Study were tested both in the “as received” condition and then again after being restored, so far as was practicable, to manufacturers’ specifications.

The restoration process involved replacing normal service items such as air and fuel filters, checking and replacing/adjusting spark plugs, plug leads, timing, points and other components that influence emissions performance. The ignition and fuel management systems were then checked and adjusted to bring them, as far as possible, within manufacturers’ specifications. All cars had their engine oil and oil filter changed.

Cars with poor evaporative emissions performance also had their fuel filler cap replaced where it was clearly sub-standard, fuel lines tested for integrity and, in a small number of cases, the charcoal canister replaced.

High cost emission control items, such as catalysts or oxygen sensors were generally replaced only if they were clearly non-operational and if spares were readily available. As a result, only around 4% of ADR37/00 cars were fitted with a new catalyst, and only 2% with a new oxygen sensor.

**Note:** In the body of the report, the term “tuning” is, unless otherwise qualified, meant to cover all the above activities, which extend beyond the normal meaning of the word.

### **2.1.6 The test fuel**

The properties of the fuel used in a vehicle can have a significant impact on a vehicle's emissions. Typically the emissions testing done in the past has used the FTP specified fuel - known as certification fuel. However, there are differences between certain parameters of certification fuel and the fuel which you would obtain from the local service station - with volatility being the key factor affecting emissions.

As the focus of the NISE study was to obtain "real world" data on the Australian car fleet, it was important that the fuels (leaded and unleaded) used in the Study were drawn from normal commercial production. In addition, because of the emphasis on photochemical smog control in air quality programs, and given that smog is principally a summertime problem, the fuel was specified to be consistent with that typically supplied in summer.

To ensure that all vehicles were tested on the same fuel, a single batch of leaded fuel and a single batch of unleaded fuel were drawn from normal commercial production at the Mobil refinery in Melbourne, Victoria. The fuel was then drummed and stored, to be called on as required throughout the study.

A quality assurance program was also put into place to ensure that the fuel did not deteriorate and its specification remained constant over the life of the project

The specifications of the NISE test fuel, and the FTP certification fuel, are detailed in Appendix VII.

## 2.2 FLEET PERFORMANCE, EXHAUST (TAILPIPE) EMISSIONS

### **2.2.1 How well (or badly) do cars perform when compared with the standards to which they were originally built?**

Cars designed to meet ADR 27 perform, on average, very creditably in their exhaust emission tests given that they are now between 10 and 20 years old (see Figures 2.1 and 2.2).

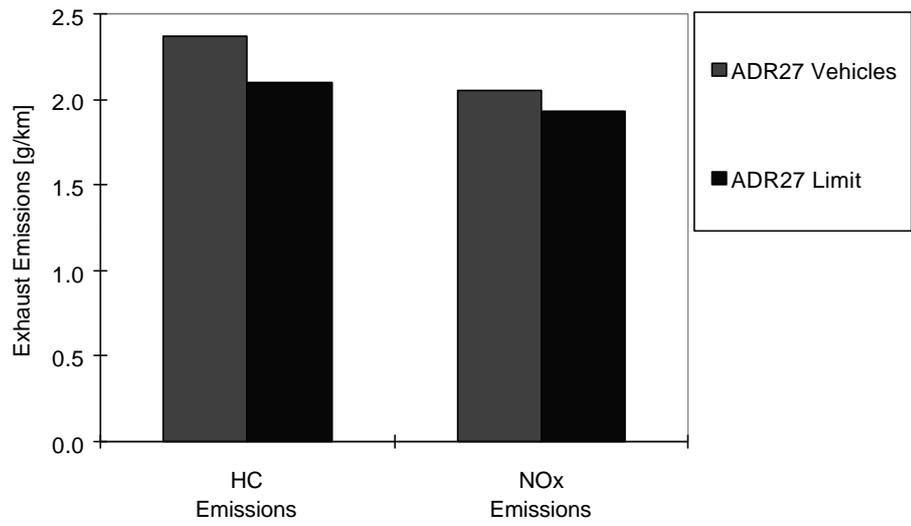
**(Technical note:** When comparing ADR27 vehicle test results with the ADR27 limit, the test data obtained were generated using the ADR27 test procedure. When comparing these ADR27 vehicles with the car population as a whole, their performance was measured on the ADR37/00 test cycle to provide a common reference. The only substantial difference between the two test cycles is the inclusion of a 10 minute “engine off” period and a hot start in the ADR37/00 cycle, making ADR27 a slightly more stringent test).

The ADR37/00 cars tested have, on average, HC and NO<sub>x</sub> emissions well below the mandated standard, with CO levels slightly above the maximum permitted new car levels. (Figures 2.3 and 2.4). Readers should note, however, that in recent years car manufacturers have progressively incorporated new emission control technologies. As a consequence, a large proportion of more recent cars have met the ADR limits by a very wide margin - typically emitting only around 30% of the maximum permitted levels.

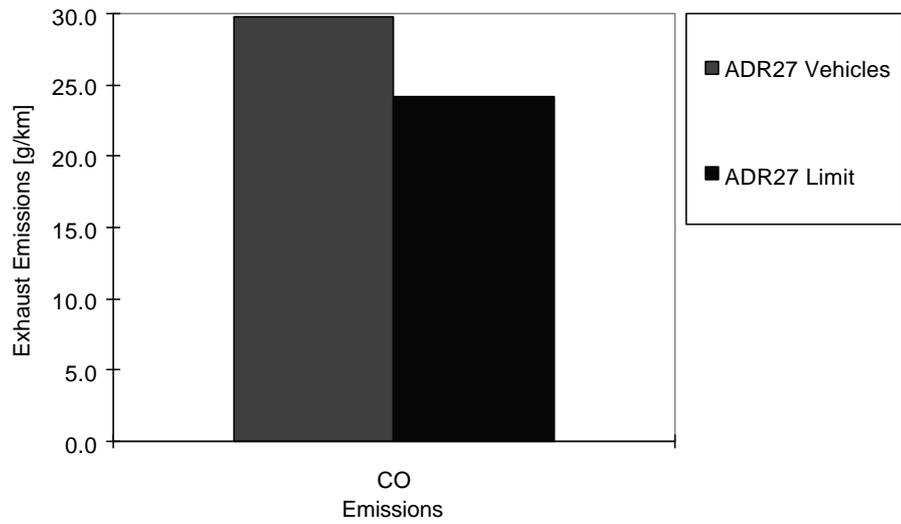
*Many modern cars,  
when new, met current  
ADR emission standards  
by a wide margin*

Again, caution should be used in interpreting these averaged data, as this process masks the very wide differences between individual vehicles. Many achieve results well below the regulated limit, but some produce extremely high levels of pollution.

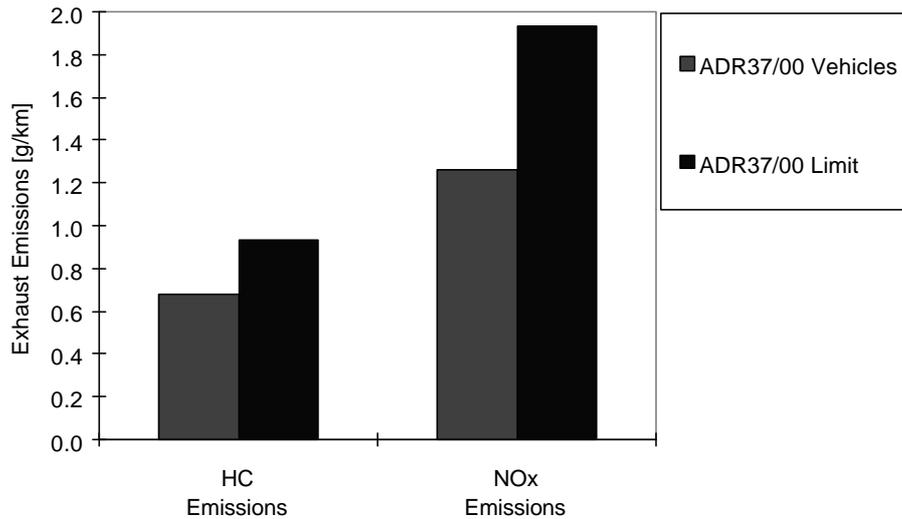
The impacts of this highly skewed emissions distribution are explored in later sections.



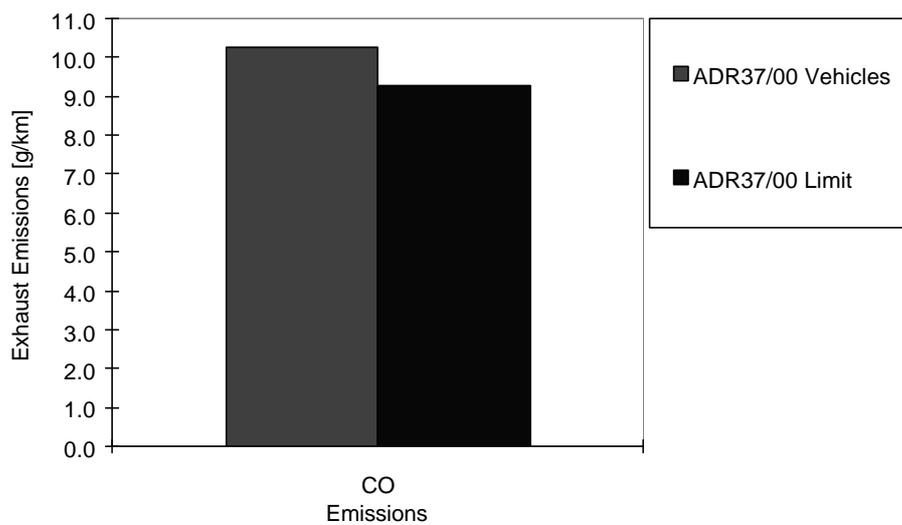
**Figure 2.1 Average 1980-1985 Car Emissions (HC & NOx) vs ADR 27 Limits**



**Figure 2.2 Average 1980-85 Car Emissions (CO) vs ADR 27 Limits**

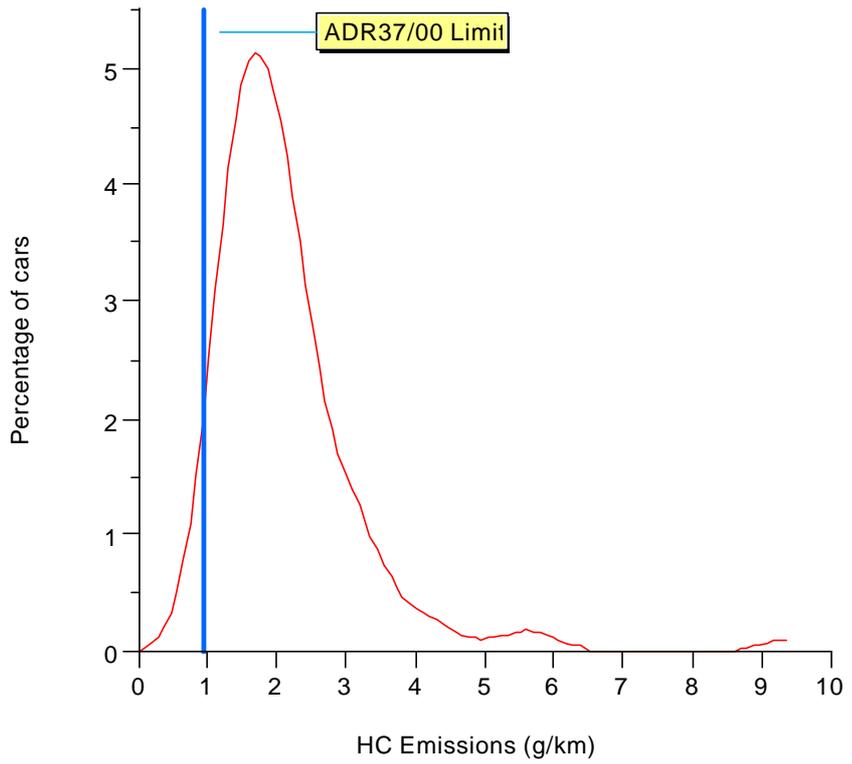


**Figure 2.3 Average 1986-91 Car Emissions (HC & NOx) vs ADR37/00 Limits**

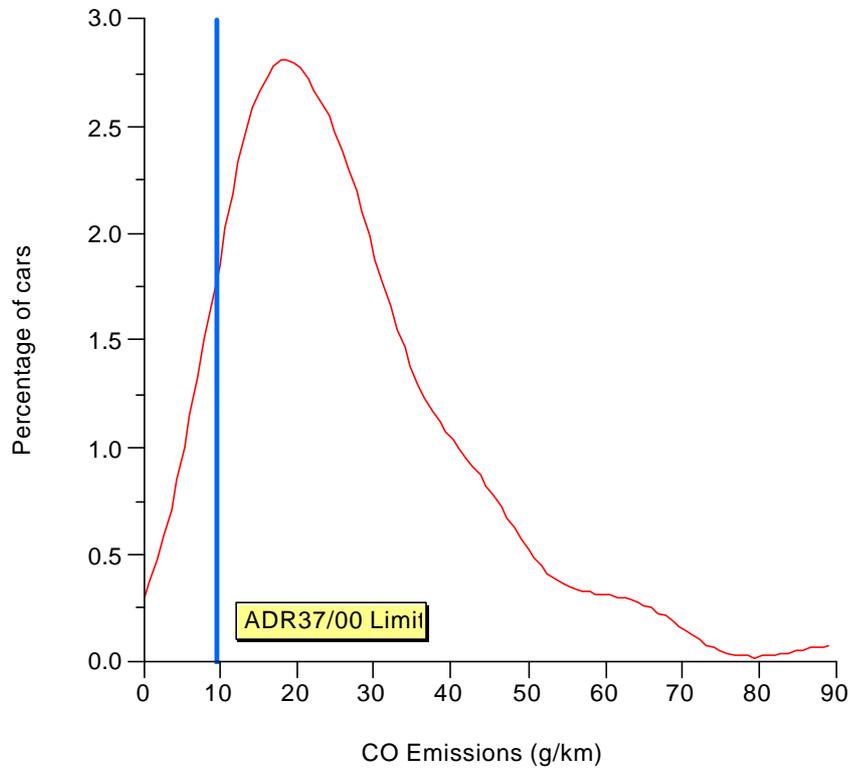


**Figure 2.4 Average 1986-91 Car Emissions (CO) vs ADR37/00 Limits**

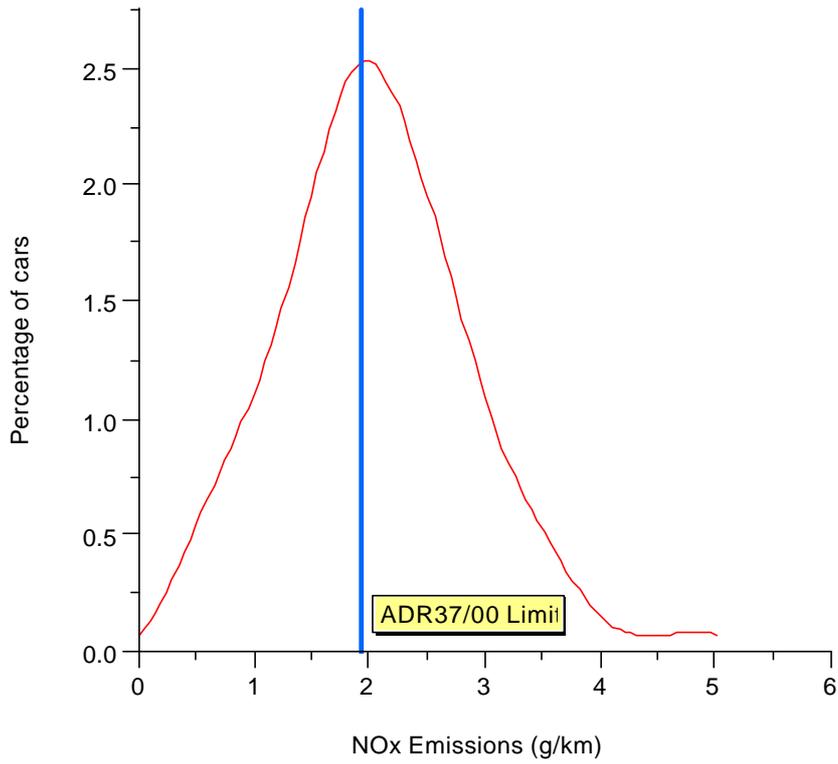
The pre tune distributions for ADR27 and ADR37/00 vehicles are also shown below (Figures 2.5 - 2.10). To enable you to consider the ADR27 and ADR37/00 vehicles in relation to the same benchmark, both sets of charts include the current (ADR37/00) new vehicle limits for each of the 3 gases - just remember that the ADR27 vehicles were not designed to meet these limits. The curves in these Figures have been derived from histogram distributions and hence the values on the vertical axes should be used as a relative rather than absolute measure.



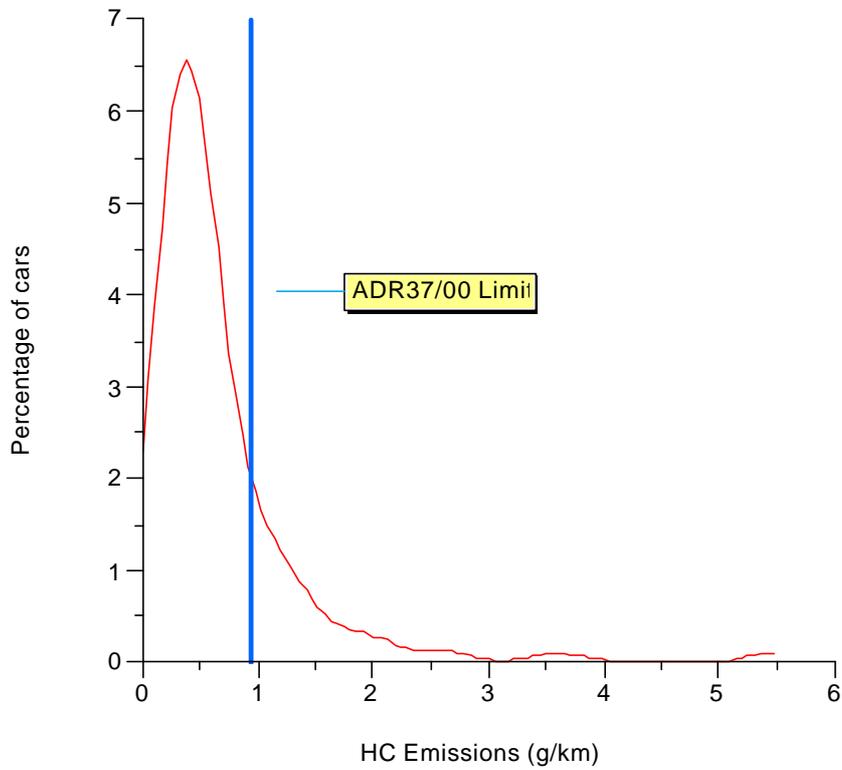
**Fig 2-5 % Distribution of HC (pre-tune) Emissions from 1980-85 Cars**



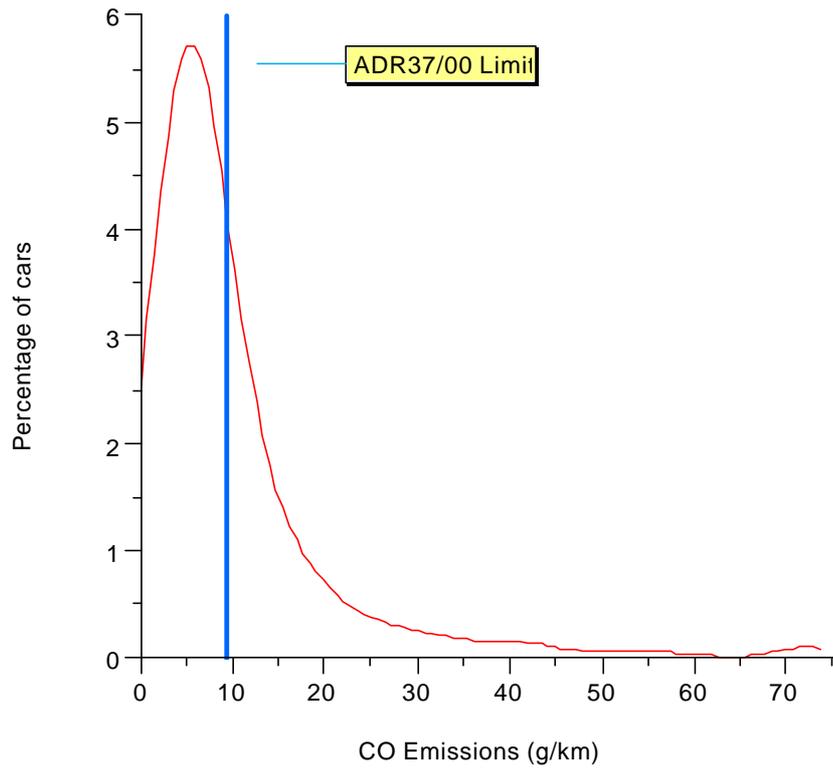
**Fig 2-6 % Distribution of CO (pre-tune) Emissions from 1980-85 Cars**



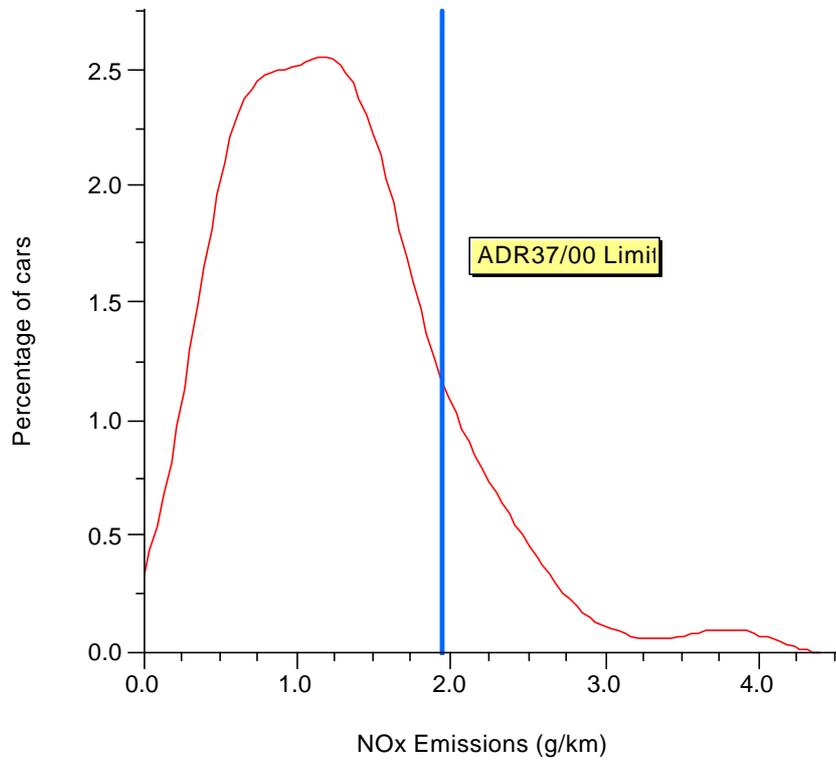
**Fig 2-7 % Distribution of NOx (pre-tune) Emissions from 1980-85 Cars**



**Fig 2-8 % Distribution of HC (pre-tune) Emissions from 1986-91 Cars**



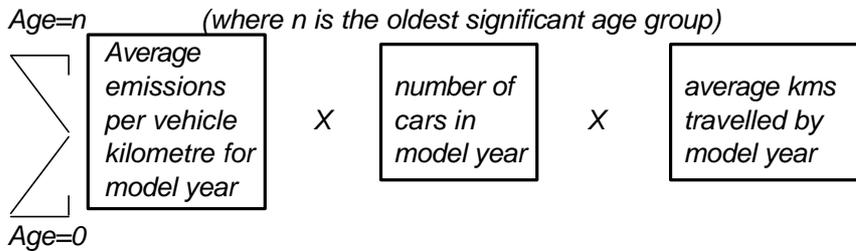
**Fig 2-9 % Distribution of CO (pre-tune) Emissions from 1986-91 Cars**



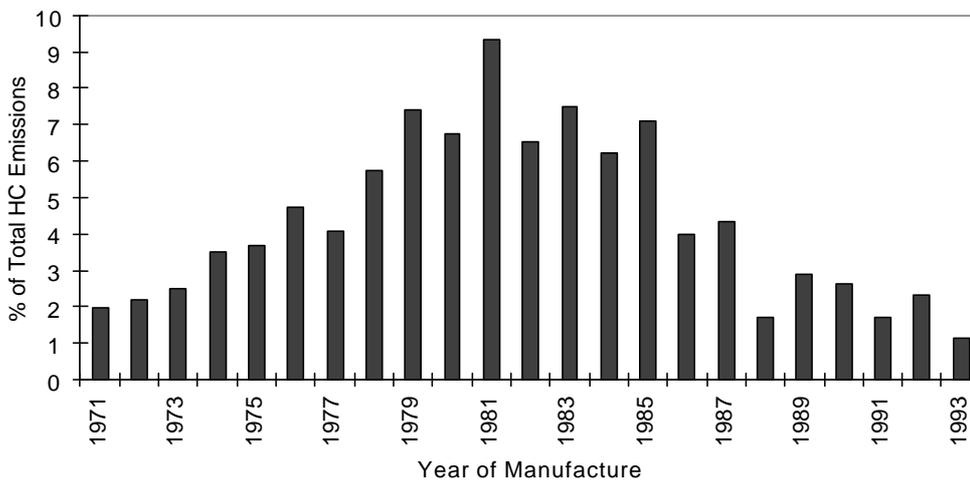
**Fig 2-10 % Distribution of NOx (pre-tune) Emissions from 1986-91 Cars**

### 2.2.2 How does this translate into actual emissions?

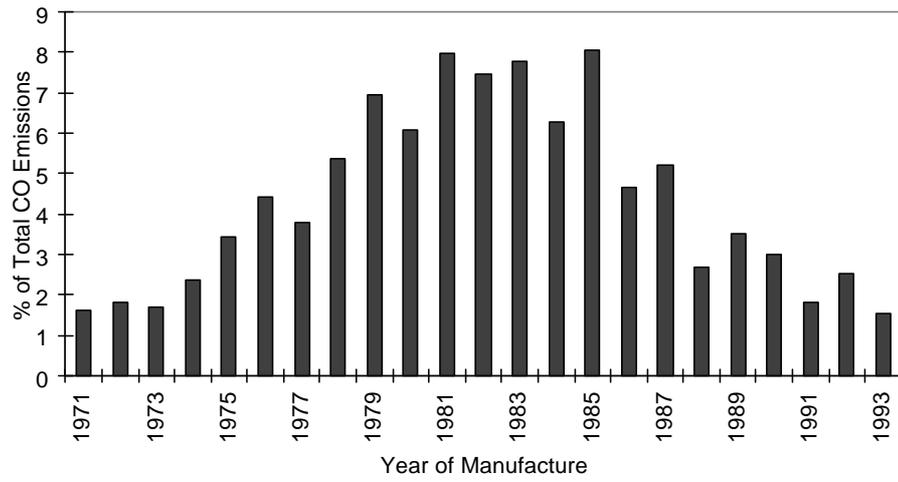
Total periodic (daily, annual etc) emissions of exhaust gases can be estimated by summing, for each year of manufacture, the average emissions per kilometre of the gas under consideration multiplied by the total kilometres travelled by that age group in the period under consideration, ie



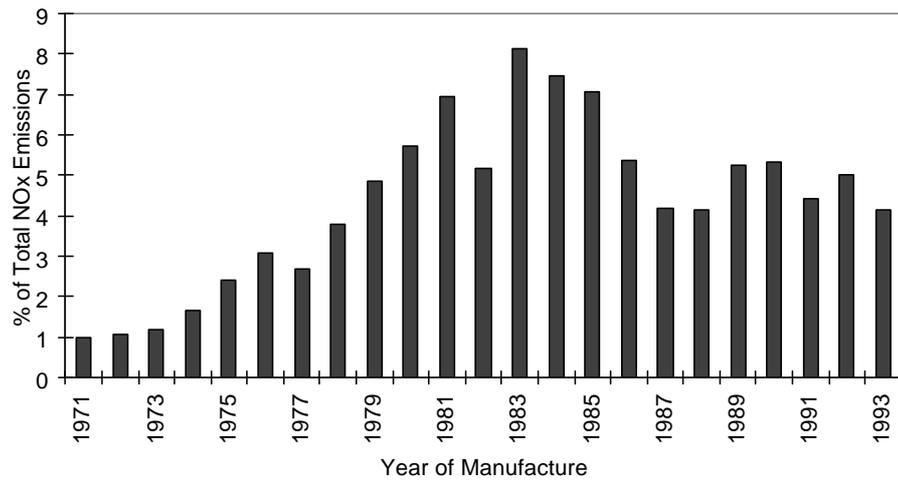
Figures 2-11 to 2-14 show the results of this calculation performed for model years 1971 to 1993. It clearly shows which ages of vehicles account for the greatest amount of pollution in a typical urban environment. It should be noted that only the data for the 1980-91 model years are based on a robust statistical sample. The data for the 1970's vehicles, and the 1992-3 vehicles, are based on samples of 22 and 46 vehicles, respectively.



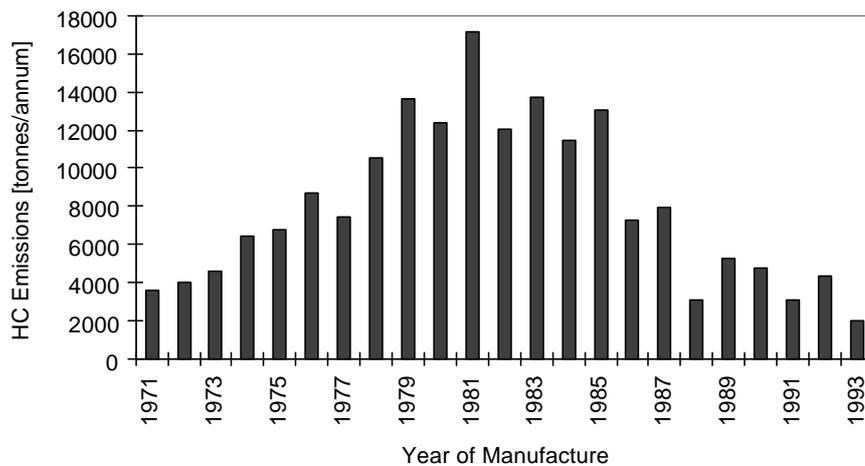
**Fig 2-11 Relative Contribution of Each Model Year to Total HC Emissions.**



**Fig 2-12 Relative Contribution of Each Model Year to Total CO Emissions**



**Fig 2-13 Relative Contribution of Each Model Year to Total NOx Emissions.**



**Fig 2-14 Example - Total Annual HC Exhaust Emissions by Model Year (All Australia).**

Older cars are often blamed for air quality problems, and it is true that individual vehicles can be very high emitters. For instance, some older vehicles had HC and CO emissions up to 100 times greater than typical new car levels, so some form of targeted approach to identifying such vehicles may be warranted.

*Some older cars had HC and CO emissions up to 100 times greater than new car levels*

These cars, however, account for only a very small proportion of the total population, and they are generally driven only for short distances.

At the other end of the age spectrum, more modern vehicles are both the most numerous group and cover the highest annual kilometres per vehicle. Emissions are generally very low for most of this group. Together, these factors mean that cars in the 1988-93 age group contribute only around 12% of the total car pollution (using HC emissions as the example), even though they account for around 42% of total kilometres travelled.

On the other hand, cars produced between 1980 and 1987 are still fairly numerous and are driven quite intensively, yet can have high levels of emissions. In combination, these factors clearly show that “middle aged” cars are the greatest source of exhaust pollutants.

*'Middle aged' cars are the greatest source of exhaust pollutants*

It is worth noting that, of the ten worst HC emitters in the 540 cars tested in the mainstream 1980-91 group, two were vehicles made in 1987 and fitted with catalytic converters and computerised engine management systems.

The implications of this set of data are very significant for transport and environmental policy makers. They will be discussed in more detail in Section 2.2.7, where the effects of maintenance and tuning are taken into consideration.

### 2.2.3 How much do pollution control systems deteriorate in service?

Cars tested in the NISE Study exhibited wildly varying levels of deterioration

Vehicles tested in the NISE Study exhibited wildly varying levels of deterioration, although there are clear underlying trends. Not surprisingly, there is a correlation between vehicle kilometres travelled and emission levels, except in the case of NO<sub>x</sub> emissions from ADR27 vehicles which remain quite stable. Figures 2-15 to 2-17 typify the rate of increase in HC, CO and NO<sub>x</sub> emissions for cars designed to meet ADR 27 and ADR37/00.

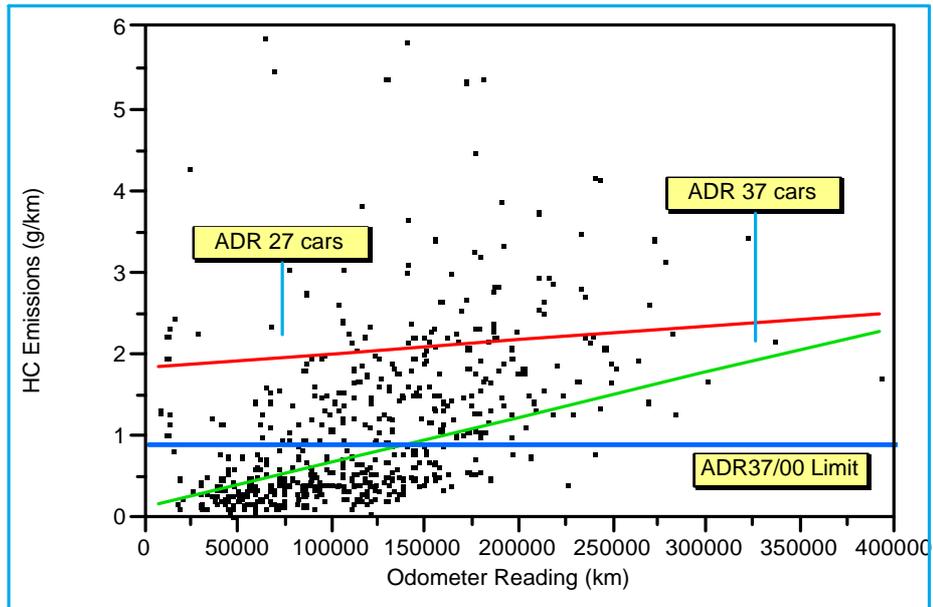


Fig 2-15 HC Emissions by Odometer Reading (ADR 27 and ADR37/00 vehicles).

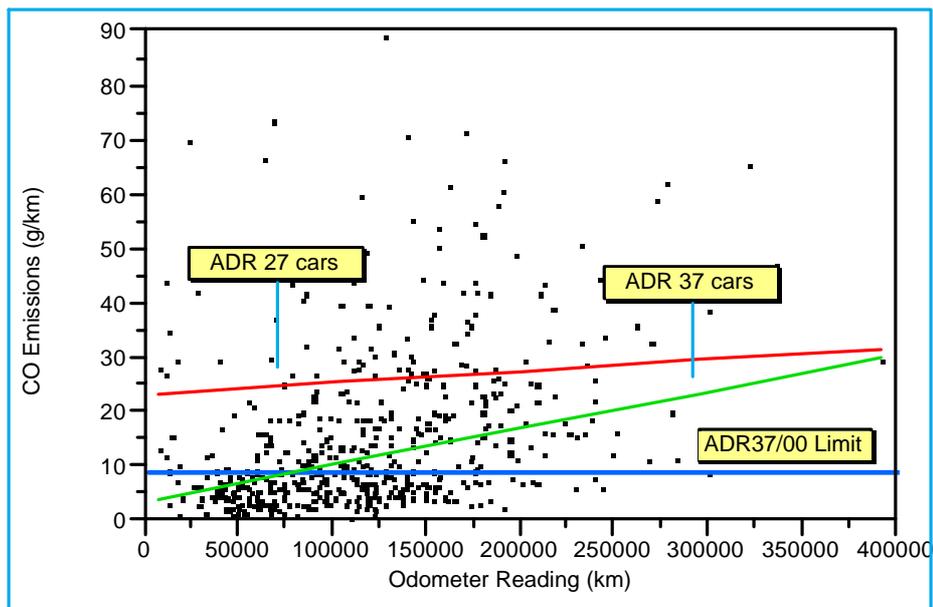
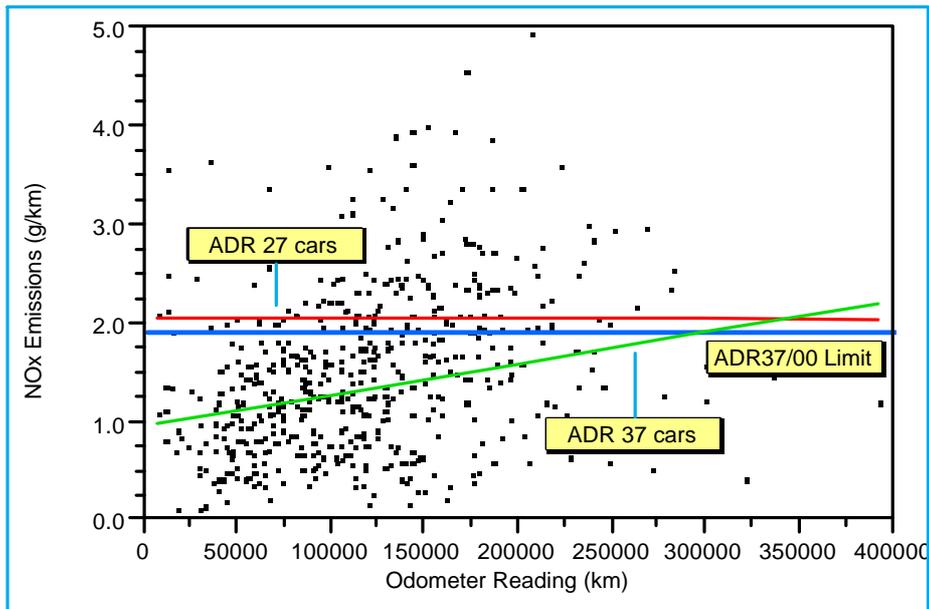


Fig 2-16 CO Emissions by Odometer Reading (ADR 27 and ADR37/00 vehicles).



**Fig 2-17 NOx Emissions by Odometer Reading (ADR 27 and ADR37/00 vehicles).**

Although the data set is highly scattered, the lines of best fit in the above Figures are consistent with known vehicle characteristics.

For instance, ADR37/00 cars have typical HC emissions when new of around 0.3 to 0.4 g/km (the regression line for the test vehicles gives 0.31g/km at zero kilometres).

It is also reasonable to expect compliance with the ADR limit to be met for a substantial period beyond the mandated 80,000 km durability requirement, to allow for variability in production and vehicle use patterns.

Both the ADR 27 and ADR37/00 regression lines demonstrate, overall, a comfortable margin of ADR compliance beyond the 80,000 km durability limit. Given however, the significant number of vehicles tested that exceeded ADR limits, there is no room for complacency on the part of vehicle manufacturers.

The regression lines show a greater rate of deterioration for catalyst equipped vehicles than for earlier, non-catalyst equipped cars. This may reflect, in part, the greater reliance placed on active systems in newer vehicles.

*Testing shows a greater rate of deterioration for catalyst equipped cars*

If future models continue to exhibit the rate of deterioration found in the test sample, meeting durability requirements for the much lower emission limits of ADR37/01 may pose a significant challenge.

When the data are plotted against year of manufacture (see Figures 2-18 - 2-20), there is a similar pattern to that shown in the above figures.

Note: in considering the lines of best fit plotted in the following figures, you should ignore that part of the line for ADR27 vehicles for 1986-91, and conversely, ignore the line for ADR37/00 vehicles prior to 1986. The lines were generated by the statistical software and were not able to be started or stopped at the 1986 breakpoint.

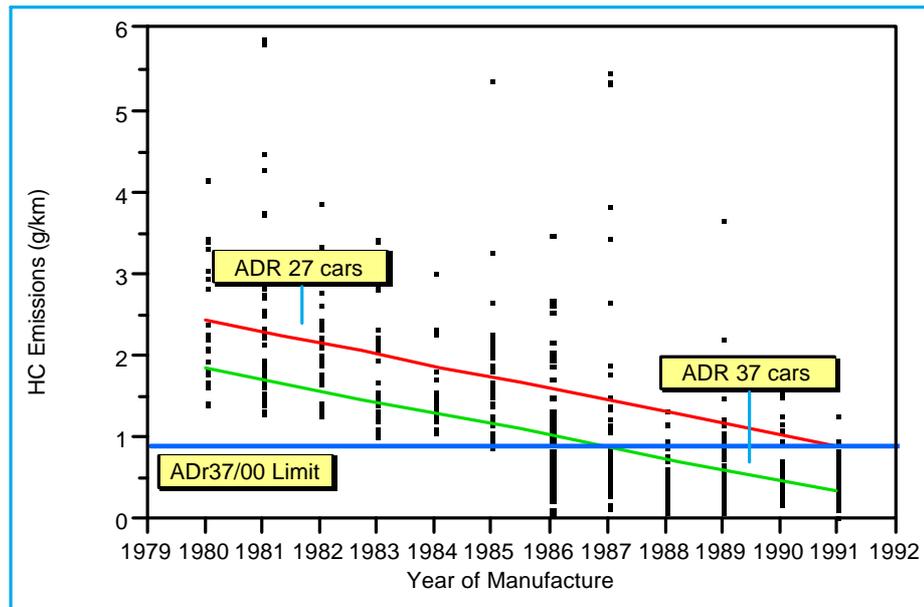


Figure 2.18 HC Emissions by Year of Manufacture

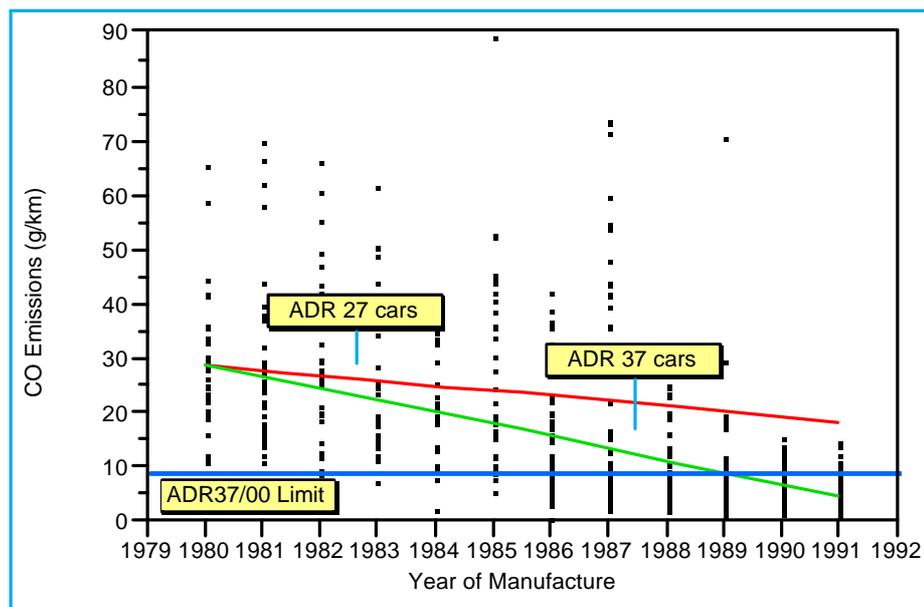
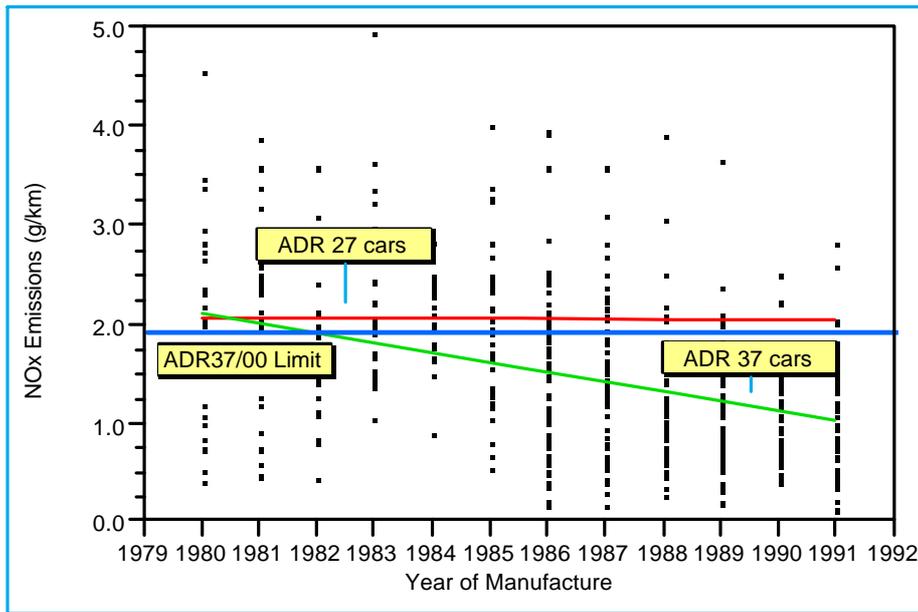


Figure 2.19 CO Emissions by Year of Manufacture



**Figure 2.20 NOx Emissions by Year of Manufacture**

**2.2.4 Does maintenance and tuning reduce car pollution?**

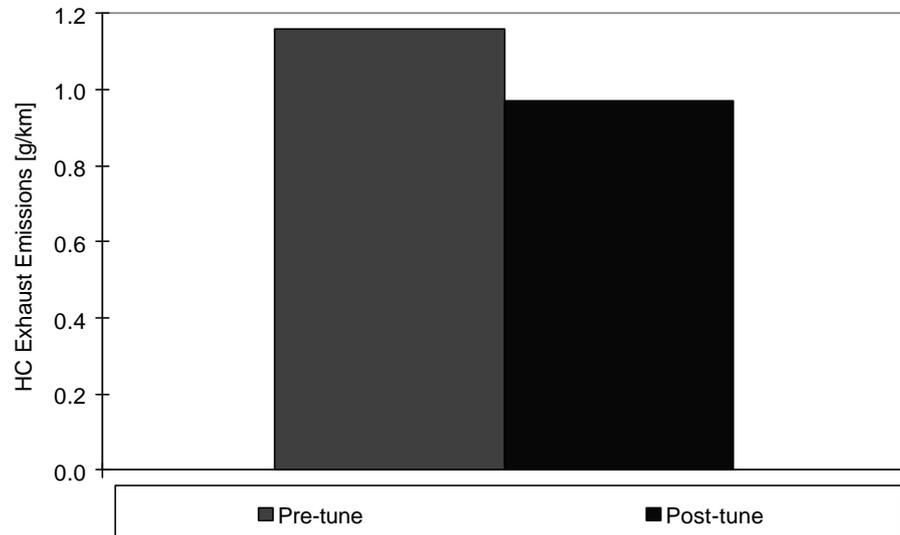
This is the key factor in any decisions on the introduction of inspection and maintenance programs. From a technical and economic standpoint, it is important to carefully assess just how much benefit can be derived from which groups of vehicles and at what cost. This section deals with the benefits; following sections address the cost issues.

Looking first at the mainstream (1980-1991) car fleet sampled in the study, Table 2.1 shows a clear reduction in overall emissions for all three regulated gases (HC, CO, and NO<sub>x</sub>).

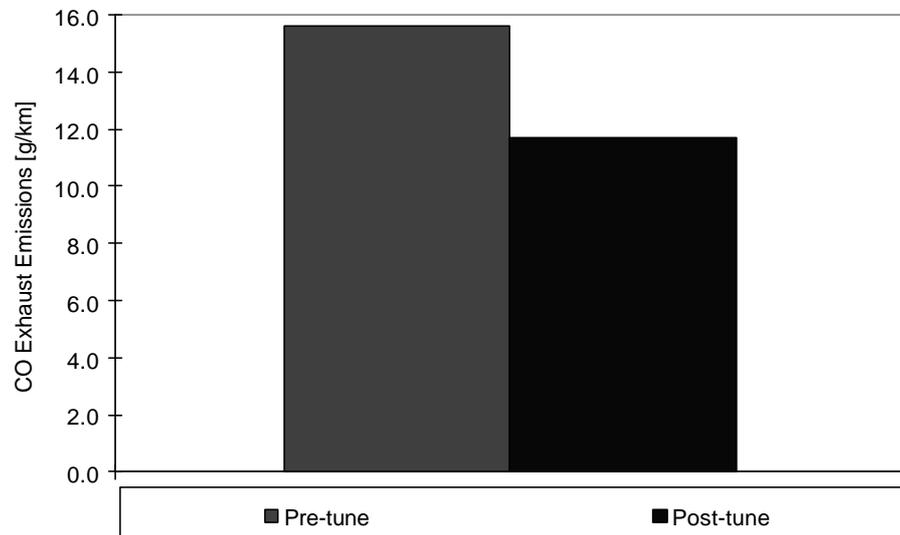
**Table 2.1 Average Reductions in Emissions from Tuning.**

<i>Emission Type</i>	<i>Percentage Reduction</i>		
	<i>All Cars</i>	<i>ADR27 Cars</i>	<i>ADR37/00 Cars</i>
HC	16%	14%	21%
CO	25%	26%	24%
Nox	9%	8%	9%

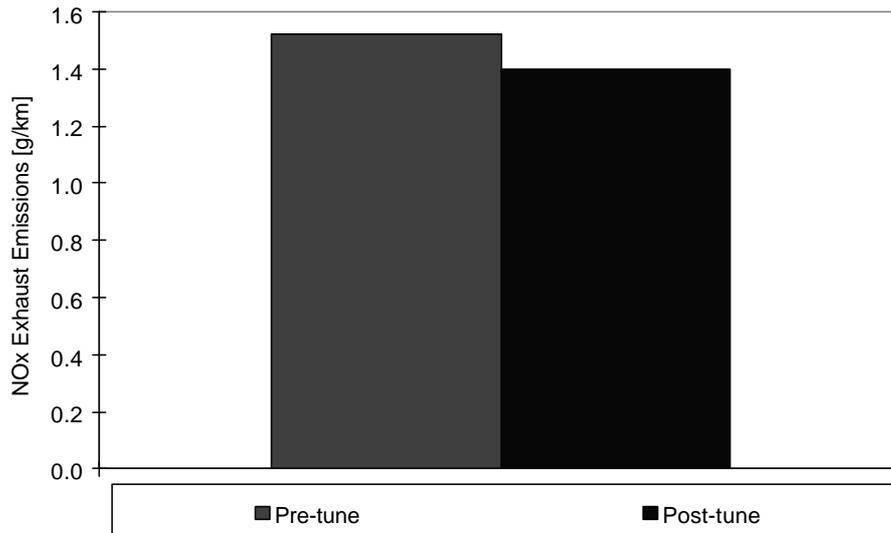
Figs 2.21 to 2.23 show in graphical form the overall pre and post tuning emission levels for each regulated gas.



**Figure 2.21 Effect of Tuning on Average HC Emissions - 1980-91 Vehicles**



**Figure 2.22 Effect of Tuning on Average CO Emissions - 1980-91 Vehicles**



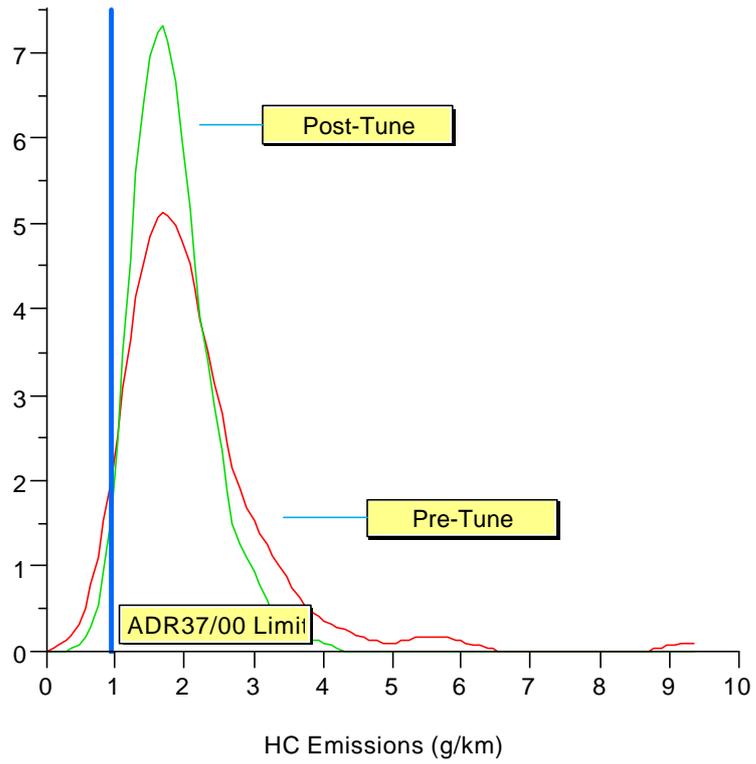
**Figure 2.23 Effect of Tuning on Average NOx Emissions - 1980-91 Vehicles**

To put these reductions into perspective they would, if applied to all cars, have a greater effect in one year than the cumulative effect over many years of the more stringent 1997 new car standard (ADR37/01). This would, however, be a one-off occurrence, with maintenance and tuning thereafter simply maintaining the benefit rather than adding to it.

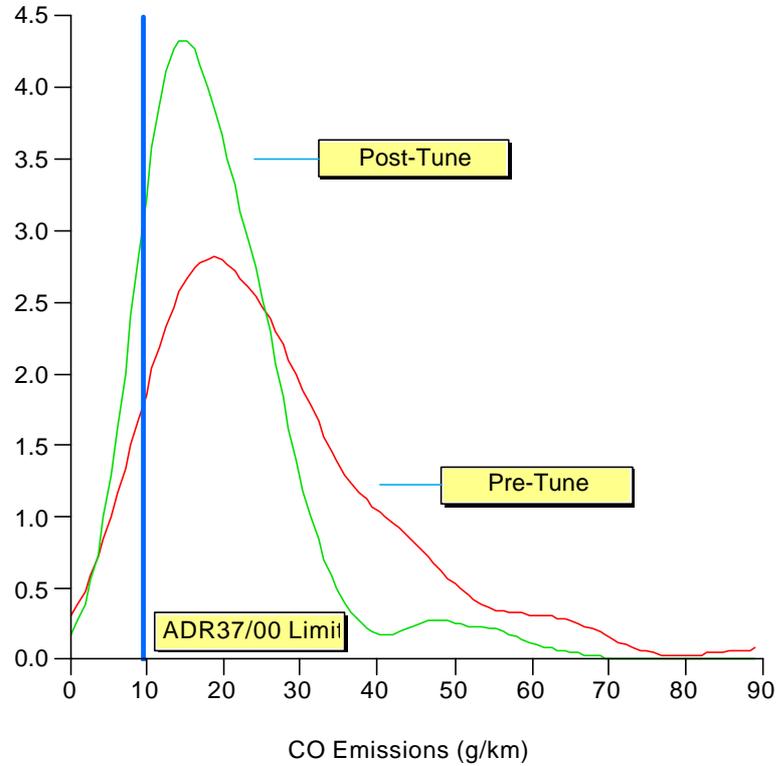
*Tuning the existing car population would have a greater effect in one year than the 1997 new car standards will have over many years*

When the distribution of emissions are examined on a pre- and post-tune basis, the analysis indicates that the principal effect is to bring in the "tail" of the fleet - those vehicles which are the worst performers. As indicated previously, the benefits in reducing NOx emissions are less than that for HC and NOx. The pre- and post-tune distributions for ADR27 and ADR37/00 vehicles are shown below (Figures 2-24 - 2-29). Again, the curves in these Figures have been derived from histogram distributions and hence the values on the vertical axes should be used as a relative rather than absolute measure.

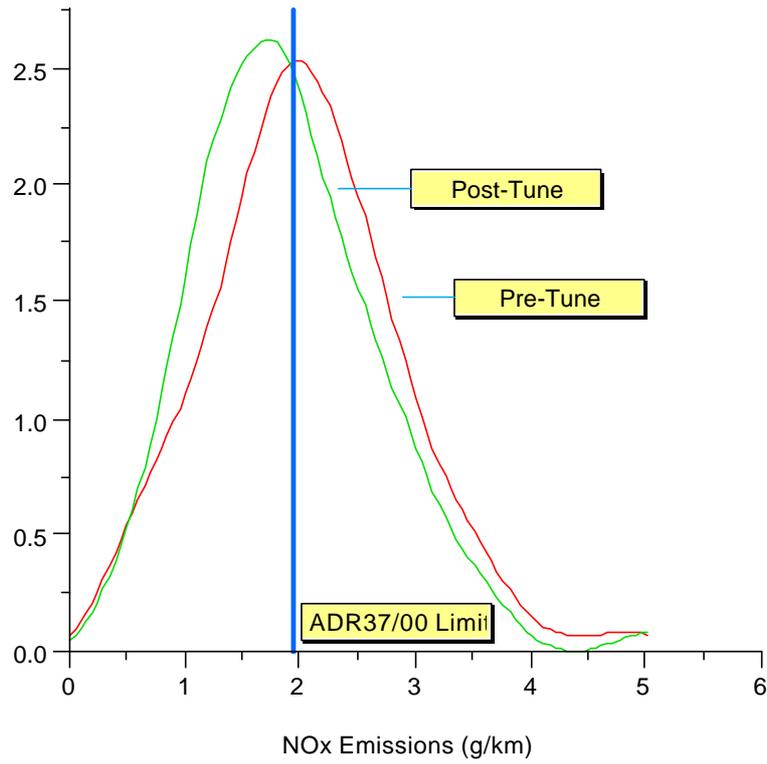
To provide a common reference, both sets of charts include the current (ADR37/00) new vehicle limits for each of the three gases. Please note however that the ADR27 vehicles were not designed to meet these limits.



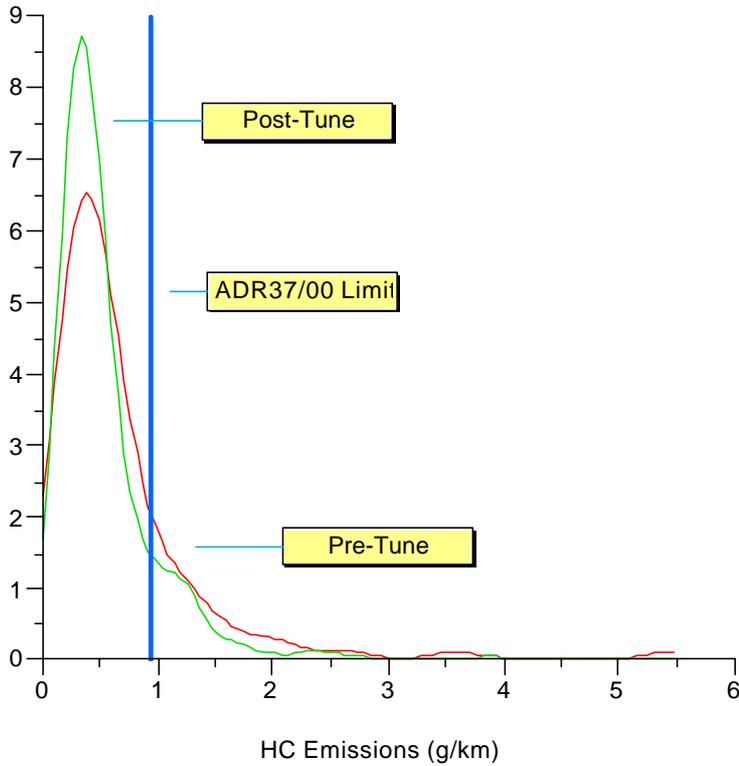
**Figure 2.24 Pre and Post Tune % Distribution of ADR27 Vehicles (HC FTP Emissions)**



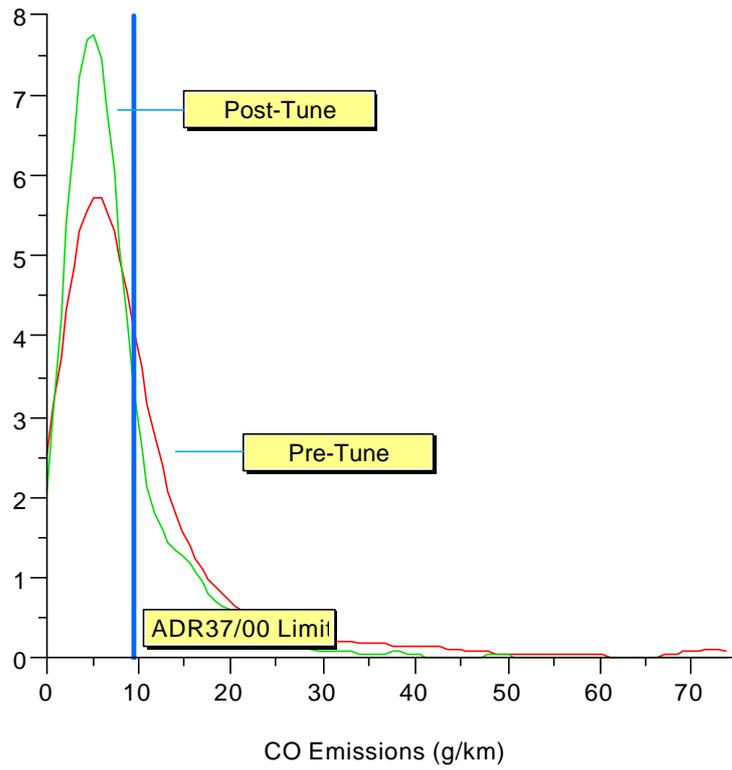
**Figure 2.25 Pre and Post Tune % Distribution of ADR27 Vehicles (CO FTP Emissions)**



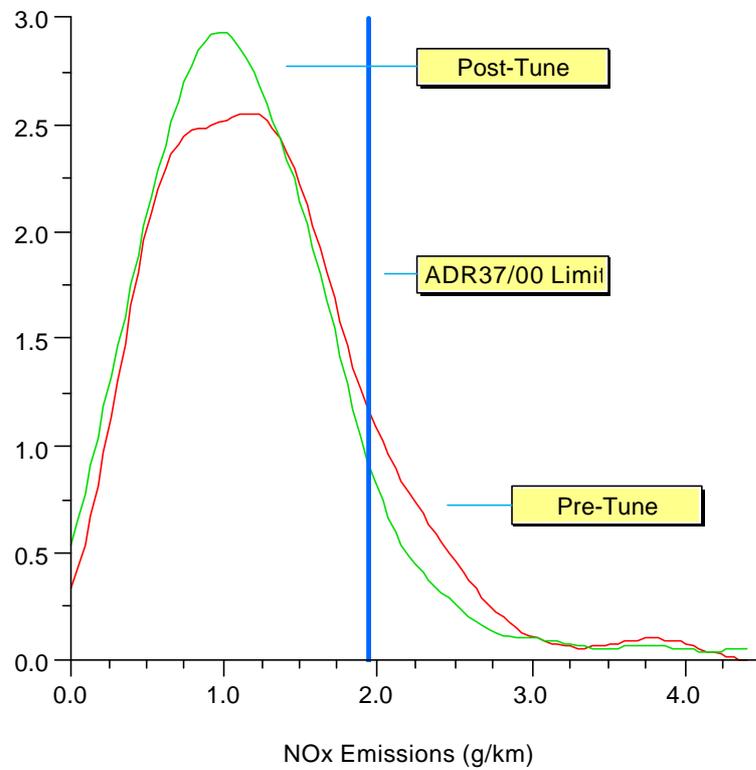
**Figure 2.26 Pre and Post Tune % Distribution of ADR27 Vehicles (NOx FTP Emissions)**



**Figure 2.27 Pre and Post Tune % Distribution of ADR37 Vehicles (HC FTP Emissions)**



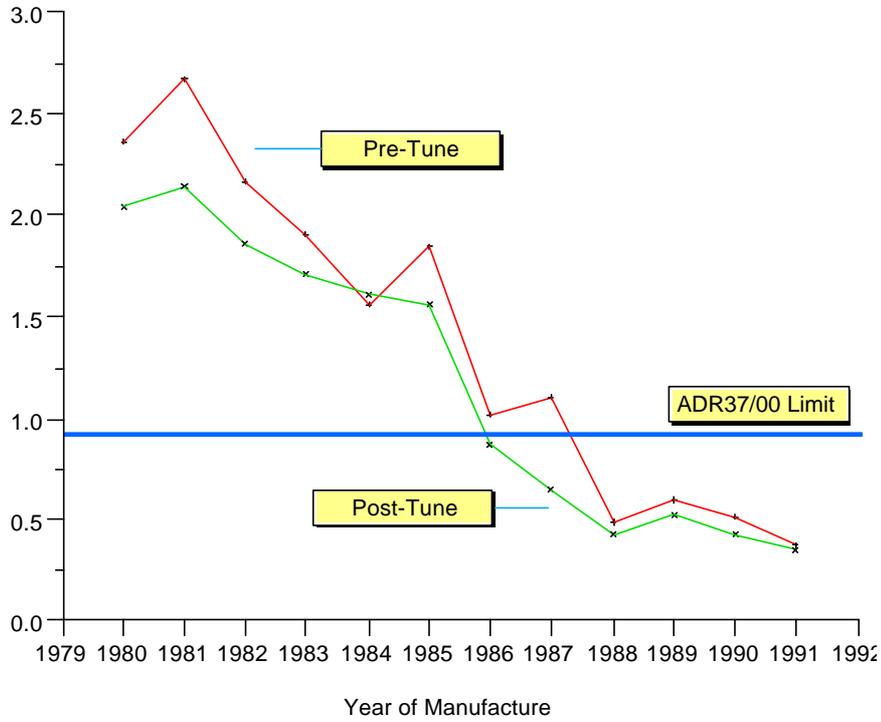
**Figure 2.28 Pre and Post Tune % Distribution of ADR37 Vehicles (CO FTP Emissions)**



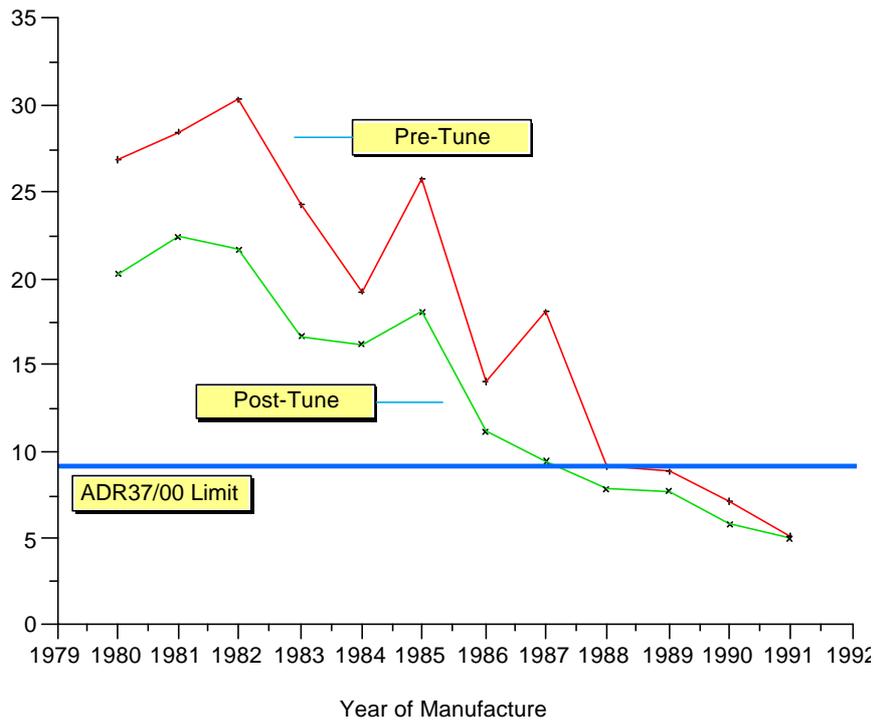
**Figure 2.29 Pre and Post Tune % Distribution of ADR37 Vehicles (NOx FTP Emissions)**

Looking at the tuning effect on a model year basis, it is clear that the potential for reducing total emissions is not uniformly distributed across the age spectrum. Figs 2-30 to 2-33 illustrate the tuning effect by model year for the sample tested.

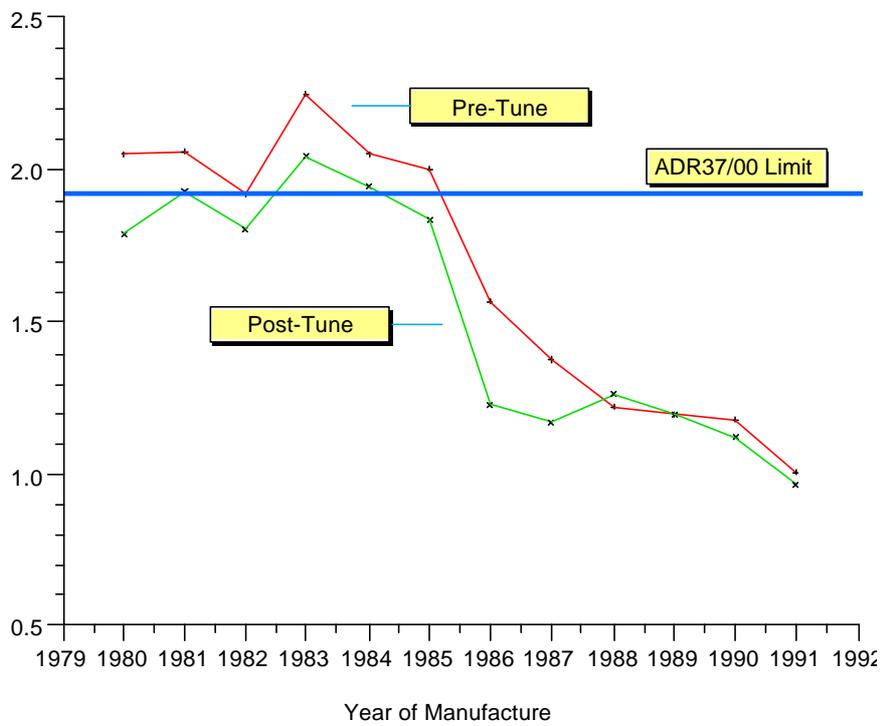
*The potential for reducing total emissions is not uniformly distributed across the age spectrum*



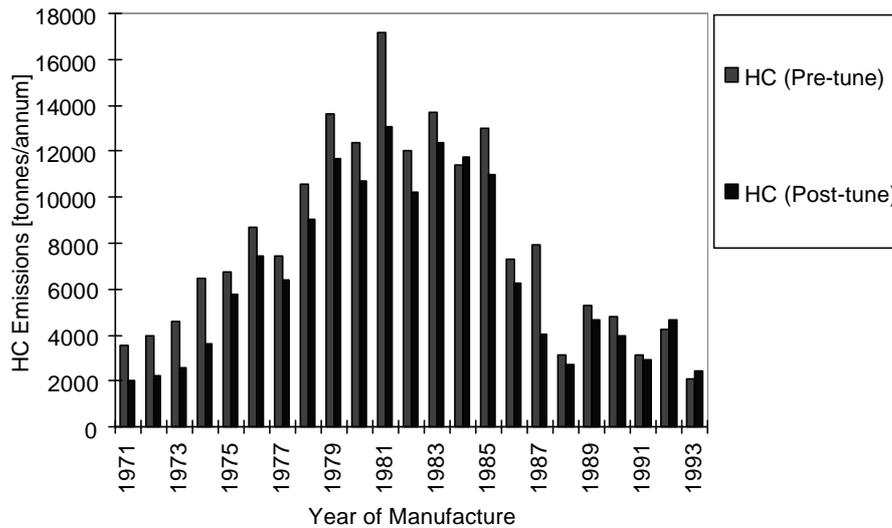
**Fig 2-30 Effect of Tuning on Average HC Emissions by Model Year**



**Fig 2-31 Effect of Tuning on Average CO Emissions by Model Year**



**Fig 2-32 Effect of Tuning on Average NOx Emissions by Model Year**

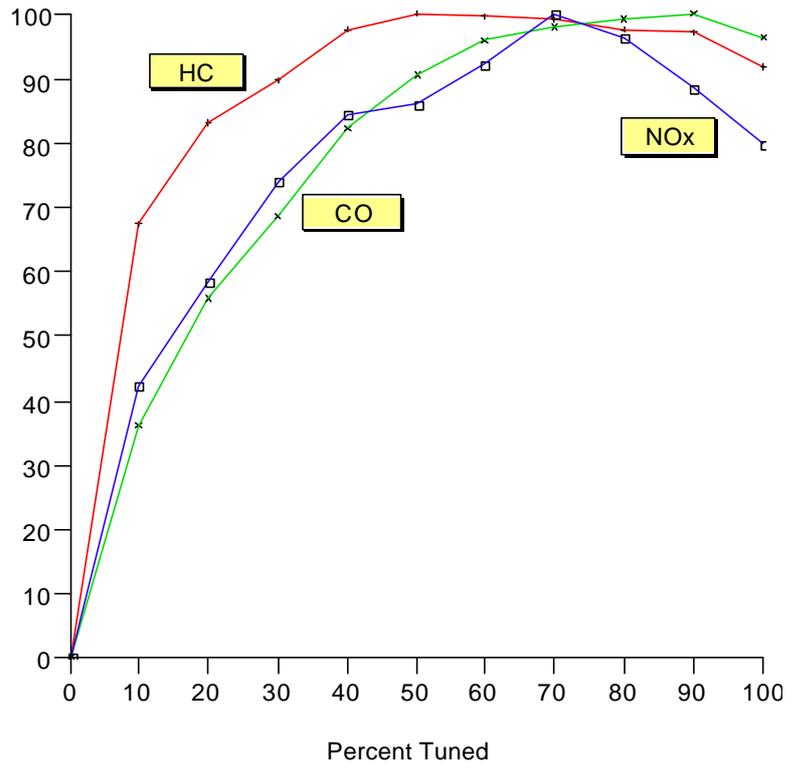


**Fig 2-33 Example - Effect of Tuning on Total Annual HC Emissions by Model Year**

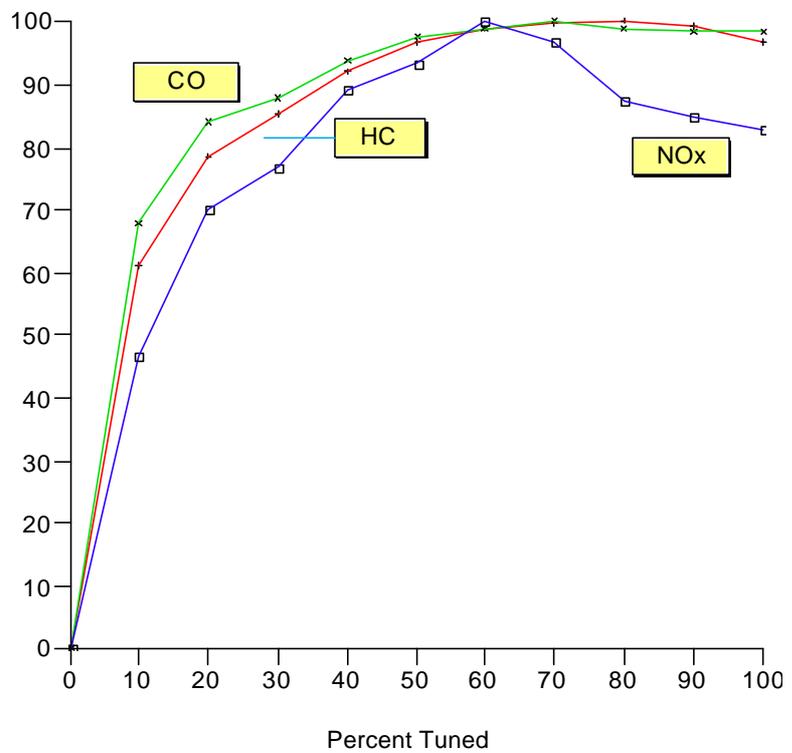
Instead of focusing on model year, it is interesting to analyse the effect of tuning and repairing only the worst percentile emitters. This form of analysis shows a strong “Pareto” effect, where most of the total achievable reductions in emissions are obtained by rectifying a relatively small proportion of the fleet (Figures 2-34 and 2-35).

Taking hydrocarbon emissions from ADR27 cars as an example, rectifying the worst 20% of the vehicles delivers 85% of the total reductions that could be achieved if all vehicles were tuned.

*Most of the total emissions reductions are obtained by rectifying a relatively small proportion of the car population*



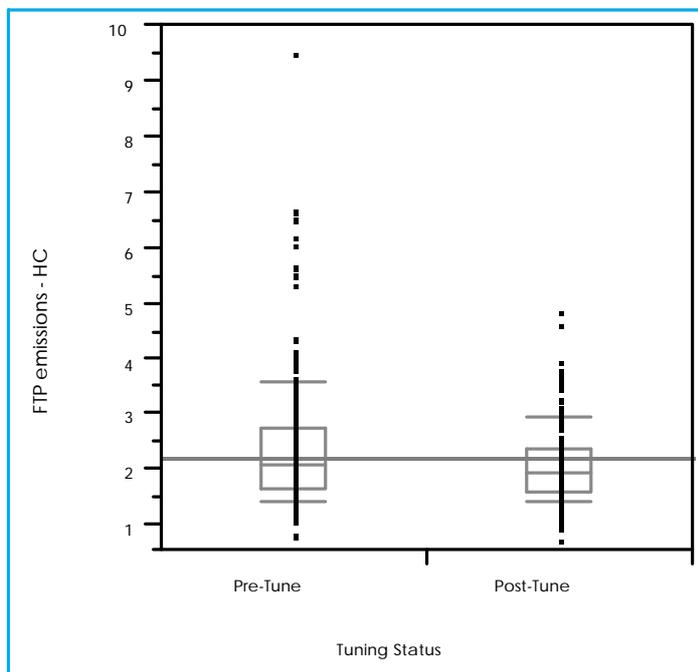
**Fig 2-34 Effect of Identifying and Rectifying the Worst Percentile Emitters - ADR27 Cars**



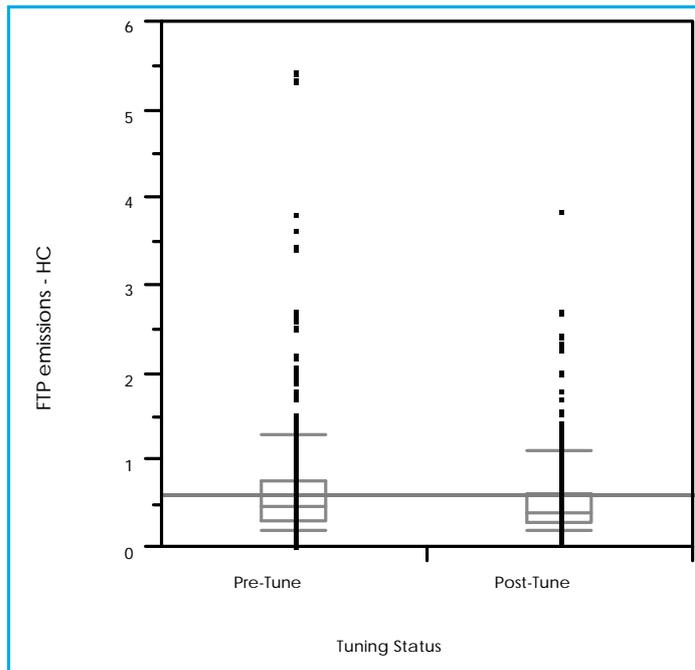
**Fig 2-35 Effect of Identifying and Rectifying the Worst Percentile Emitters - ADR37/00 Cars.**

The above scenarios presume, however, that some method can be readily used to estimate the FTP emissions performance of individual vehicles with an acceptably high degree of accuracy. This issue is dealt with in Section 2.7

A complementary effect of tuning is to greatly reduce the variability of emissions performance within vehicle groups (Figures 2-36 and 2-37 illustrate the effect for HC emissions). In particular, very high emitters are brought down much closer to the median levels, consistent with the “Pareto” effect noted above. Note: the horizontal line shown in Figures 2-36 and 2-37 should be ignored.



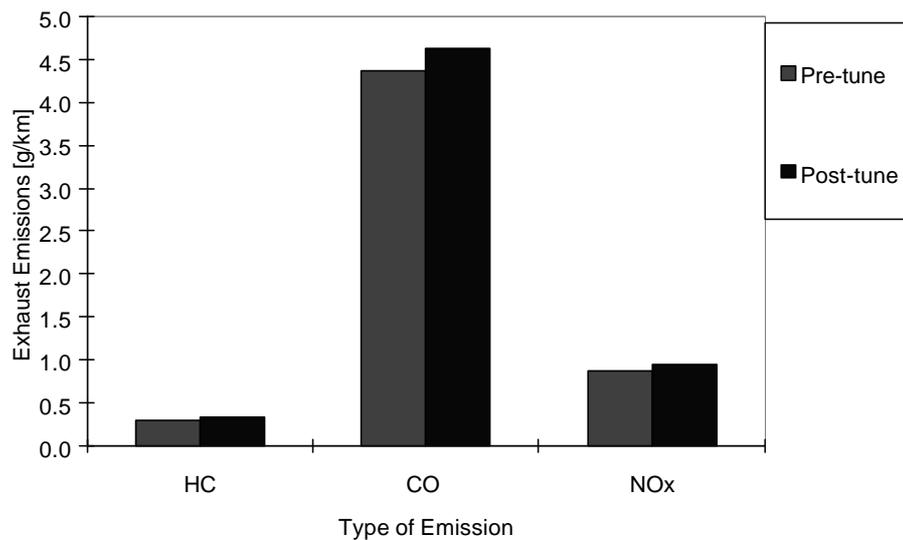
**Fig 2-36 Effect of Tuning on the Scatter of HC Emissions - ADR 27 Vehicles**



**Fig 2-37 Effect of Tuning on the Scatter of HC Emissions - ADR 37/00 Vehicles**

*Tuning well-maintained cars can increase emissions*

Newer cars need to be treated with caution. In the group of 46 1992-3 cars tested, tuning had the net effect of increasing tailpipe emissions of all three regulated gases (see Figure 2-38). Only the relatively few badly maintained cars in this group showed any substantial improvement in emission levels. This finding may reflect that, in the main, cars in this group are maintained in accordance with manufacturers' schedules.



**Figure 2.38 Effect of Tuning on Average FTP Emissions - 1992-3 Vehicles**

**2.2.5 What parts were replaced most often and what was the cost of tuning/maintenance ?**

The parts most commonly replaced in the tuning/repair procedures used in the study are listed in Table 2.2. As previously indicated, oil and air filters, engine oil and points (where applicable) were automatically replaced.

**Table 2.2 List of Most Commonly Replaced Parts**

<i>Part</i>	<i>No. Replaced</i>	<i>Proportion of Relevant Vehicles where Part Replaced</i>
Spark Plugs (set)	503	93%
Fuel Filter	382	70%
High Tension Leads	130	24%
Fuel Cap	86	35%*
Distributor Cap	74	14%
Rotor Button	70	13%
Catalyst	15	4%
Oxygen Sensor	4	2%

\*Note in the vast majority of cases, filler caps were only replaced on the 247 vehicles undergoing the SHED test, hence the proportionally larger percentage.

The above Table indicates that, on average, the emissions benefit gained from the tuning/repair procedures used in this Study does not require the replacement of major or expensive parts. When the costs are examined in more detail, the average cost to undertake the tuning/repair regime used in the Study is around \$200 for both ADR27 and ADR37/00 vehicles. This cost is based on the parts cost recorded in the Study, plus 20% sales tax (where this was not paid by the 2 Government run test laboratories), plus 20% for retail price, plus a fixed \$90 for labour (assuming 1.5hrs labour).

### **2.2.6 Summary of the exhaust emissions picture**

**In summary**, three key findings emerge:

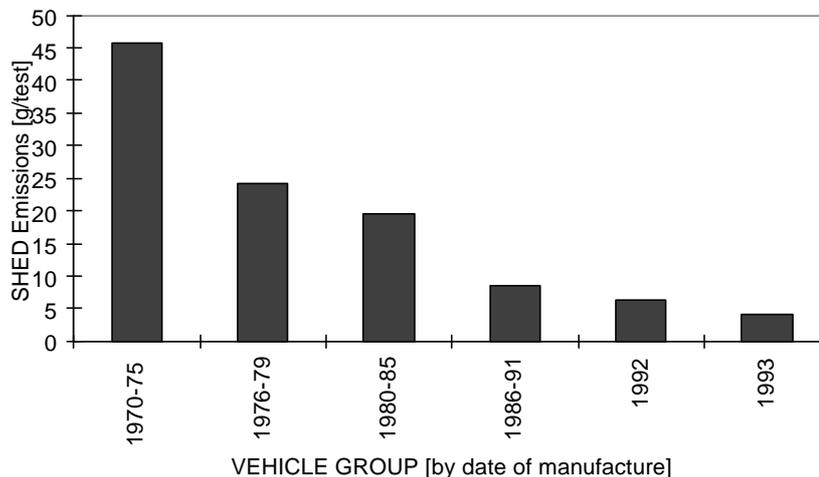
- Substantial reductions in total emissions can be achieved through good maintenance;
- For each gas of interest, most of these reductions were delivered by around 20% of the vehicles in the test sample; and
- Cars less than four years old that have been well maintained are unlikely to show significant emission reductions from tuning.

## 2.3 FLEET PERFORMANCE, EVAPORATIVE EMISSIONS

### 2.3.1 What is the status of the fleet's evaporative emissions performance?

In addition to exhaust emissions tests, around 40% of the vehicles tested in the NISE Study were also subjected to the SHED test for evaporative hydrocarbon emissions - this test aims to estimate the emissions of petrol vapour which evaporate from both cold and hot vehicles when they are parked. Until the NISE Study there was virtually no data available in Australia on the evaporative emissions from our in-service fleet, as virtually all the testing for evaporative emissions has been done on the fuel used for new vehicle certification under the ADRs. As discussed later in this section, certification fuel is markedly different from normal commercial fuel that you buy at the local service station, particularly in relation to its volatility.

Figure 2-39 illustrates the great variability in average evaporative emissions from the in-service fleet, which reflect the changes in evaporative emissions control introduced since 1976. Readers should note that only the data for the 1980-91 model years are based on a robust statistical sample. The data for the 1970's vehicles, and the 1992-3 vehicles, are based on samples of 22 and 46 vehicles, respectively.

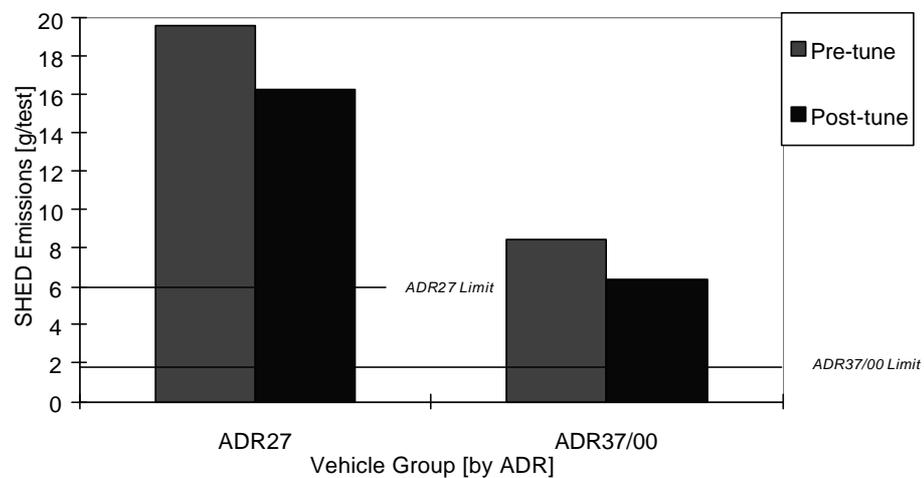


**Figure 2-39 All Age Groups - Average SHED Emissions (pre tune)**

*Both ADR 27 and ADR 37/00 cars had, on average, evaporative emissions many times the regulated levels*

### 2.3.2 Are evaporative emissions limits met in practice ?

Although there is wide variability in the fleet's performance, it is the results of the SHED test for the main data set, and the newer vehicles, which are of most interest. As Figure 2-40 shows, when tested on a commercial fuel typical of that which would be supplied to the Australian market in summer, both ADR27 vehicles and ADR37/00 vehicles, on average, exceed the relevant limit by a considerable margin. While the tuning and maintenance regime used in the NISE Study did improve the situation, the average emissions of post tune vehicles were still well in excess of the new vehicle limits.



**Figure 2-40 1980-91 Vehicles - Average SHED Emissions (pre & post tune)**

While some deterioration in emissions control effectiveness may be expected as vehicles age, Table 2.3 indicates that some 80% of ADR27 vehicles exceeded the 6g/test limit by more than 20%, while over 60% of ADR37/00 vehicles exceeded the 2g/test limit by more than 20%. The proportions of vehicles having emissions **twice** that of the limits were still very high - 63% for ADR27 vehicles, 57% for ADR37/00 vehicles. While the tuning/maintenance undertaken in the Study provides some reduction in the **average** evaporative emissions as shown in Figure 2-40, around half of the vehicles in both groups are still more than twice the limit after tuning.

Note: While we have confidence in the validity of the SHED results, some caution should be exercised in the assessment of the **post-tune** results, because in a number of vehicles, the SHED result on the vehicle after tuning was considerably higher than the pre-tune result. The reasons for this were not always clear, although in some cases minor fuel leaks following work on the vehicle, and use of hydrocarbon solvents in repair work, were suspected. The condition of the carbon canister was also unknown.

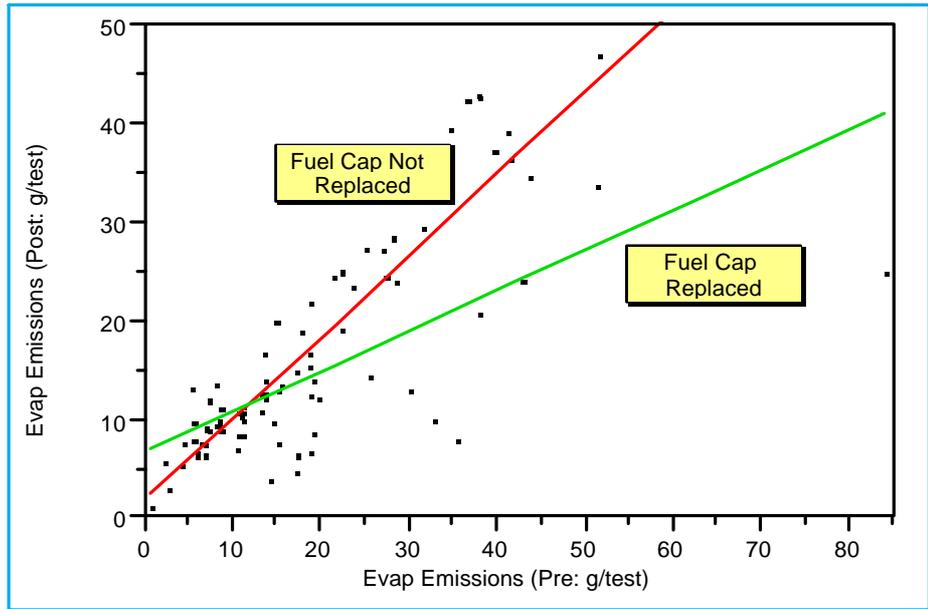
**Table 2.3 Proportion of Vehicles Exceeding Evaporative Emissions Limits**

<b>Vehicle Group</b>	<b>Proportion above ADR Limit (%)</b>		
	<i>Absolute</i>	<i>&gt;20% above</i>	<i>&gt;50% above</i>
ADR27 pre tune	87	80	63
ADR27 post tune	93	85	51
ADR37/00 pre tune	68	64	57
ADR37/00 post tune	65	61	51

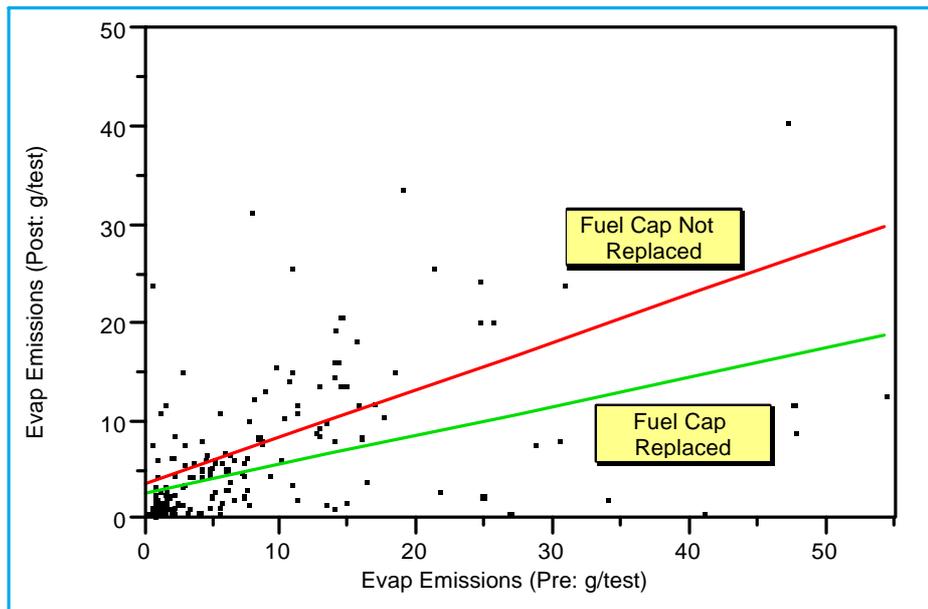
As most of the tuning process for the NISE Study would be expected to have little impact on evaporative emissions, we examined those steps undertaken between the pre and post tune tests that may have been significant contributors to the reduction in post tune evaporative emissions. The most likely candidate appeared to be the fuel filler cap which was replaced in 86 vehicles (38 ADR27 vehicles, 48 ADR37/00 vehicles). The basis for replacement was either the presence of a clearly non-standard cap (a number of vehicles were fitted with temporary plastic caps) or a high reading from the hand held hydrocarbons detector in the vicinity of the fuel cap.

An analysis of the pre and post SHED results for those vehicles indicates that the replacement of the filler cap did have a statistically significant effect on the post tune SHED results (see Figures 2-41 and 2-42). This effect was more pronounced in the ADR37/00 vehicles.

*Replacement of non-standard and defective fuel filler caps significantly reduced evaporative emissions*



**Figure 2-41 Impact of Replacement of Fuel Filler Caps on SHED Emissions (ADR27 Vehicles)**



**Figure 2-42 Impact of Replacement of Fuel Filler Caps on SHED Emissions (ADR37 Vehicles)**

### **2.3.3 Why are the SHED results so high ?**

Having noted these high SHED results part way through the NISE Study, we then set about trying to determine what might be the explanation - particularly for the newer 1992-3 vehicles, and those in the main 1980-91 group, which on average were exceeding the limits by a wide margin.

The investigation centred around the 2 major factors affecting evaporative emissions from motor vehicles:

- the volatility of the fuel (ie how rapidly it is going to evaporate)
- the design of the vehicle (ie how effectively the vehicle's technology controls evaporative emissions).

#### *The Fuel*

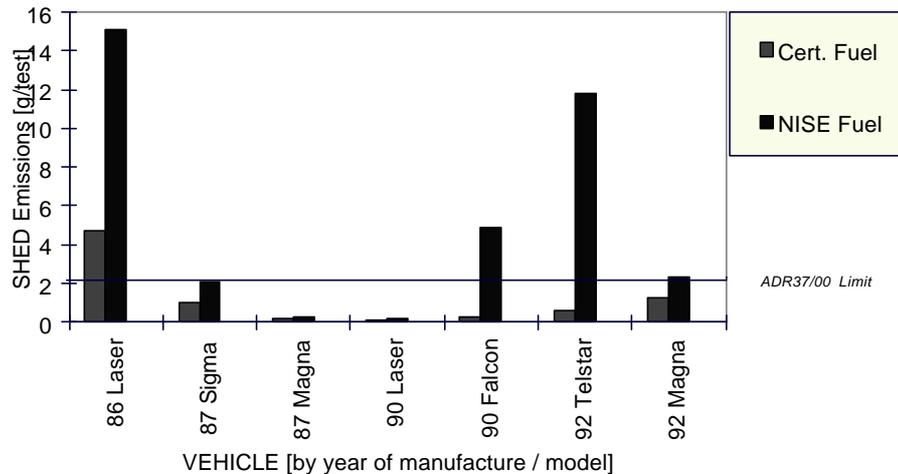
Firstly let's look at the fuel. To determine compliance with the evaporative emission standards in the ADRs, new vehicles are tested using a certification fuel which has strictly defined properties which can make it considerably different from commercial "pump" fuel. The property of petrol which has most effect on evaporative emissions is its volatility, which is measured by a parameter called the Reid Vapour Pressure (RVP).

The RVP of the certification fuel must lie with a range of 60.0 - 63.4 kPa. This is considerably lower than the RVP of pump fuels, which when supplied by the Australian petroleum industry, meet (under a voluntary arrangement) the requirements of the Australian Standard AS1876-1990 *Petrol (gasoline) for Motor Vehicles*. AS1876 is not intended to be a comprehensive specification, and does not specifically address vehicle emissions issues. The volatility of petrol supplied to the Australian market is agreed between the companies and is adjusted monthly for each of 11 regions across Australia, according to weather records and vehicle driveability requirements.

To assess the role the fuel may play in the high evaporative emissions results, a small number of ADR37/00 vehicles were subject to "back to back" testing on both certification fuel and the pump fuel obtained for the NISE Study. The certification fuels had an RVP of 62.5-63kPa, while the Study's unleaded pump fuel had an RVP of 76.5kPa.

*Fuel specification can have a significant effect on evaporative emissions*

While it is recognised that the number of vehicles is small and no claims are made for the statistical robustness of the tested group, the data illustrated in Figure 2-43 indicate that in the vehicles tested the fuel can have a significant effect on the some vehicle's evaporative emissions results under the SHED test. The evaporative emissions from some of the vehicles are not worse on the more volatile pump fuel, but most of the tested vehicles have considerably higher emissions on the "pump" fuel.



**Figure 2-43 Comparison of SHED Emissions on Certification and NISE Fuels**

### *Vehicle Technology*

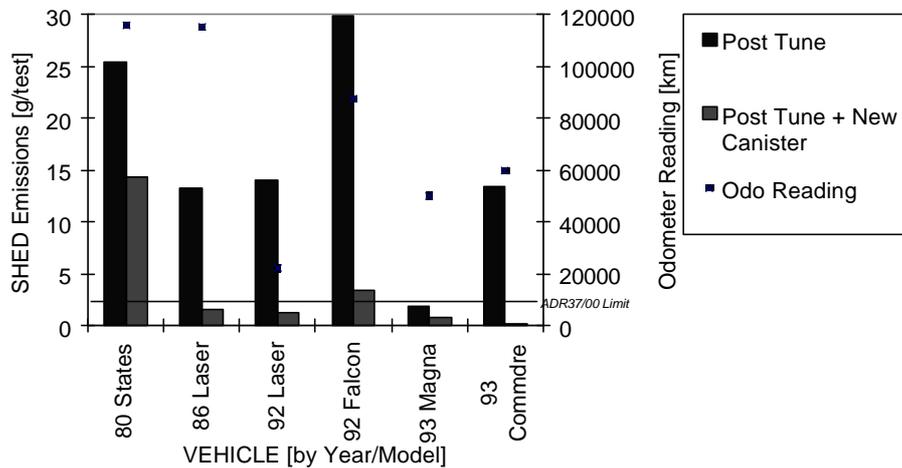
The next thing to examine is the vehicle technology. Modern petrol engined vehicles use a number of strategies to limit evaporative hydrocarbon emissions, including electronic engine management systems, purge flow controls, sealed petrol caps and carbon canisters. The key component in this strategy is the carbon canister. The canister contains activated carbon and works by adsorbing petrol vapours which evaporate from the fuel supply system and engine. These vapours increase when the ambient temperature is higher eg. in the summer months. The vehicle “reclaims” these adsorbed vapours by drawing air through the canister into the engine when the vehicle is running.

To assess the role of the canister in evaporative emission control, a small number of vehicles were selected for testing with replacement canisters. The vehicles were selected on the basis of a “sniffer” test in the vicinity of the carbon canister - the sniffer test is a simple assessment of hydrocarbon concentrations in the air in the vicinity of the canister using a hand held hydrocarbon detector. The selected vehicles had relatively high sniffer test results.

*Replacement of the carbon canister can lead to marked reductions in evaporative emissions*

The selected vehicles were then fitted with a new carbon canister and subject to the standard SHED test. The results of this SHED test were compared to the result for that vehicle from the SHED test undertaken as part of the normal post tune test program. The results of this comparison are illustrated in Figure 2-44. As with the back to back fuels testing, only a small number of vehicles were subject to this testing. Nevertheless the results indicate that in

all the tested vehicles, the installation of new canister alone in vehicles with apparently high evaporative losses in the vicinity of the canister, leads to a marked reduction in the evaporative emissions. This occurs regardless of how old the vehicle is or how far it has travelled.



**Figure 2-44 Effect on SHED Emissions from Fitting a New Canister to Vehicles with High Canister Sniff Results**

### **2.3.4 Summary of the evaporative emissions picture**

In summary the evaporative emissions picture looks like this:

- in the “real world” the average evaporative hydrocarbon emissions of the tested vehicles, both old and new, exceed the limits they were designed to meet as new, usually by a considerable margin
- the volatility of pump fuel is significantly higher than certification fuel, and on the basis of limited testing, reducing the fuel volatility can considerably reduce the evaporative emissions from some vehicles
- the effectiveness of a vehicle’s carbon canister and sealing of the fuel filler cap also appear to play a significant role in the level of evaporative emissions
- basic vehicle maintenance can reduce average emissions on most vehicles, with the replacement of faulty fuel filler caps having a significant impact on evaporative emissions from individual vehicles.

*The Federal  
Government is funding  
further research into  
evaporative emissions  
from cars*

Partly in response to the questions on fuel volatility and canister operation, the Federal Government is funding a research project which will examine the role of fuel volatility and evaporative emissions in more detail. That project is now underway and is expected to be completed by the end of 1996.

## **2.4 EMISSIONS PERFORMANCE OF OTHER VEHICLE GROUPS**

### ***2.4.1 Description of other groups***

As indicated in the Introduction, a number of smaller target groups of vehicles were tested in addition to the main data set of 1980-91 vehicles. These vehicles were subjected to the same test procedures as the main data set.

These groups were:

- 1970's cars - 22 tested
- 1992-3 cars - 46 tested
- Modified cars - 10 tested
- "Poorly Maintained" cars - 10 tested

The first 2 groups were sourced using the normal household survey methods conducted for the main data set. The modified and poorly maintained cars were obtained by one of the emissions testing facilities through personal and company contacts.

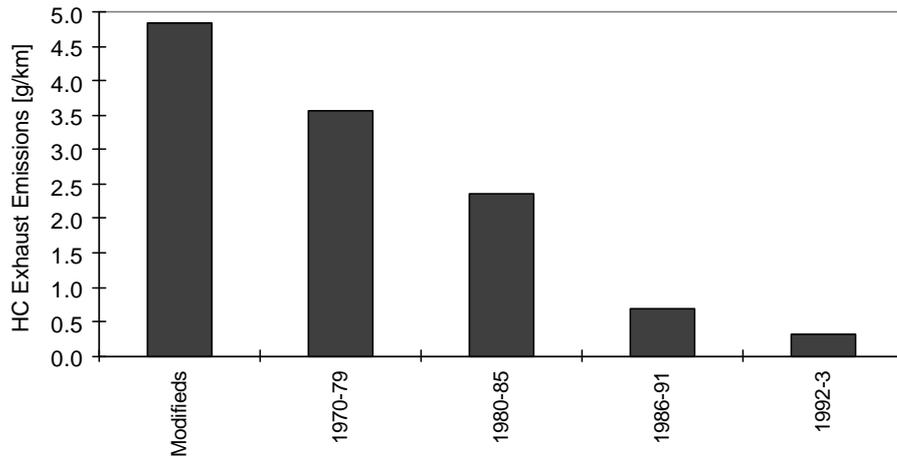
While the selection of the modified vehicles was done on quite clear criteria, the poorly maintained vehicles was based on the owner's assessment of the level of maintenance, and thus there is considerable doubt about the reliability of this group. As part of the pre-test inspection information from the main part of the Study a considerable amount of detail was recorded on the state of the vehicles. There would appear to be scope for further analysis of this information to more objectively identify poorly maintained vehicles and the relationship of this to emission levels.

In considering the following discussion on various aspects of these group's emission performance, readers should always keep in mind the small size of the groups and their lack of statistical robustness.

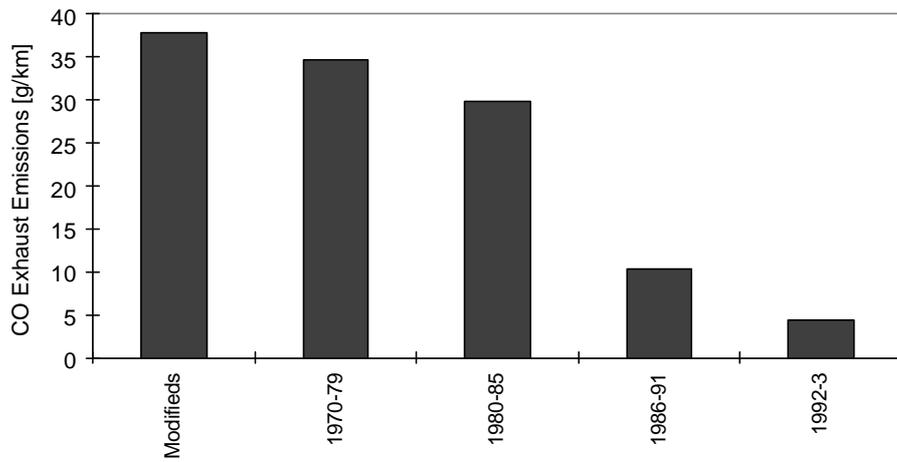
### ***2.4.2 Do cars with modified engines and exhausts generate excessive pollution?***

A number of vehicles on Australian roads have been modified in ways that could affect their emissions performance. Typically, they may have non-standard cylinder heads, pistons, valves, camshafts, fuel systems or exhausts.

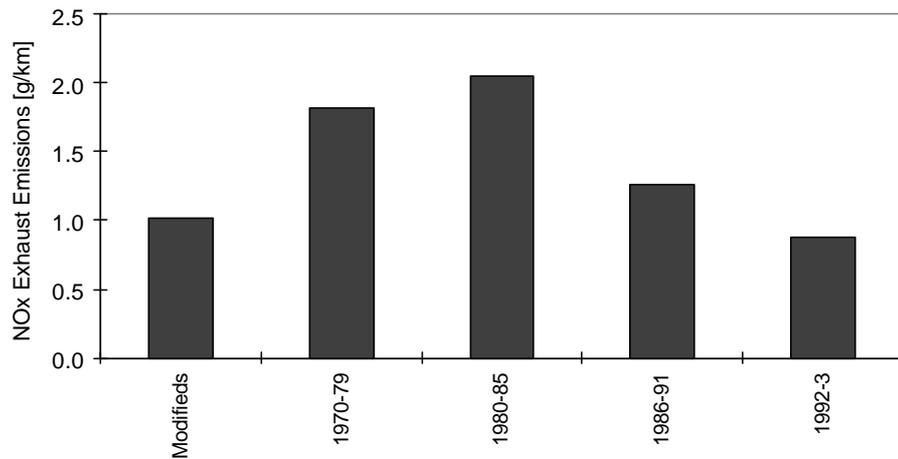
To gain some understanding of the effect of these modifications, a 10 cars in this category were sourced (non-randomly) and tested using the same methodologies employed for the mainstream vehicle sample. (Figures 2-45 to 2-47).



**Figure 2-45 Modified Vehicle HC Emissions vs other Sample Groups**



**Figure 2-46 Modified Vehicle CO Emissions vs other Sample Groups**



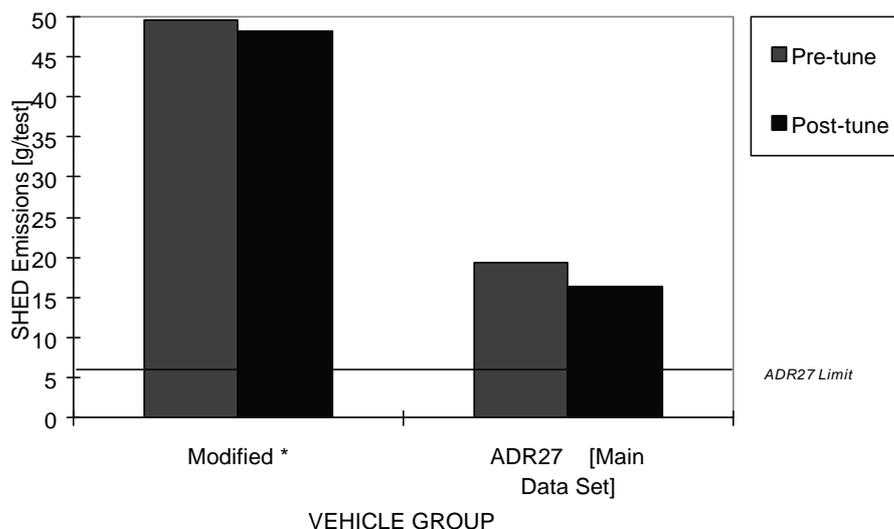
**Figure 2-47 Modified Vehicle NOx Emissions vs other Sample Groups**

*The modified cars tested had very high CO and HC emissions*

Hydrocarbon levels were, on average, more than four times higher than the fleet average and around 50% higher than the small sample of pre-1980 vehicles tested. Oxides of nitrogen were lower than most other groups, indicating possible over-rich air/fuel ratio, which is consistent with high HC and CO levels recorded.

*Evaporative emissions from modified cars were extremely high and did not respond to maintenance/tuning*

In relation to evaporative HC emissions, the picture for heavily modified vehicles is very stark (see Figure 2-48). The modified vehicles tested have extremely high evaporative emissions compared to the ADR27 vehicles in the main data set (1980-91), most likely because of major modifications to the fuel system common to these vehicles. The modified vehicle group does not respond to tuning.



**Figure 2-48 Modified Vehicle SHED Emissions vs ADR27 Vehicles from Main Data Set (pre & post tune)**

\* 9 of the 10 modified vehicles were ADR27 vehicles

As only 10 modified vehicles were tested, and all but one of these were ADR27 vehicles, care should be exercised in interpreting the results. This small sample was tested to provide an indication of whether the emissions performance of modified cars may differ substantially from standard vehicles of a similar type.

The very limited test data indicate that individual modified vehicles may be a substantially greater source of HC pollution, in particular, than comparable “standard” examples of that model and age. There are no statistics, however, to indicate what proportion of vehicles on Australian roads can be classed as “modified”.

*The limited test data indicate that modified vehicles may be a substantially greater source of pollution than comparable "standard" cars*

### **2.4.3 Are older cars a major source of pollution?**

For the purposes of this study, “old” cars are considered to be those manufactured between 1970 and 1979. Vehicles in this age group were not included in the mainstream sample group, as they represent only a small proportion of the total vehicle kilometres travelled (VKT).

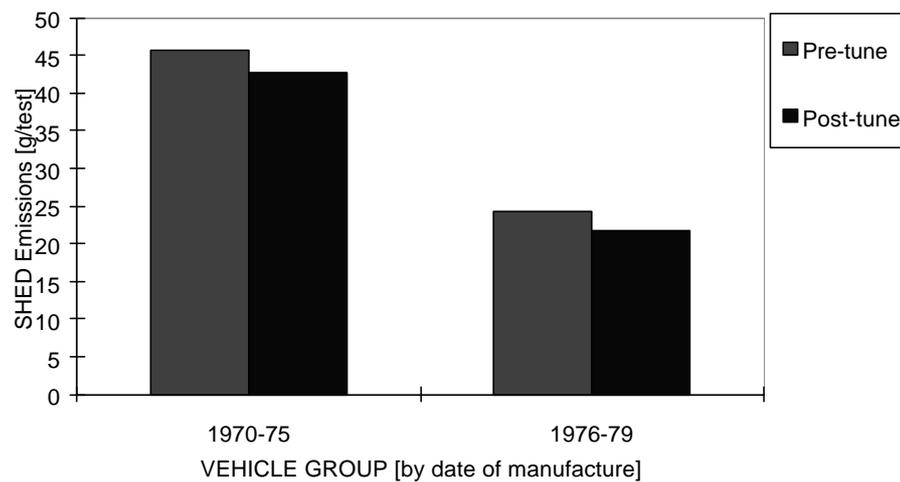
Nevertheless, recognising the frequent media attention given to these vehicles and their prominence in “cash for clunkers” proposals, the project team decided to include a small sample (22) of the most popular 1970-1979 cars to see if their emissions performance appeared to differ significantly from post-1979 cars. The test results and comparisons with other vehicle groups are shown in the previous Figures 2-45 to 2-47.

*Old cars did not stand out as significantly higher polluters than other non-catalyst vehicles*

In general, HC and CO emissions from this group of vehicles were higher than from the 1980-85 cars, but not to an extent that makes them stand out as a significantly different class of vehicles. NOx emissions were actually lower than the 1980-85 cars and were not significantly higher than the overall fleet average.

Overall, emissions from the small sample taken from this group of vehicles appear to reflect a gradual deterioration with age, rather than any quantum difference relative to the rest of the fleet.

As far as evaporative HC emissions are concerned, Figure 2-49 shows that older vehicles also had very high evaporative emissions, but until mid 1976, these vehicles were not required to meet any evaporative emission limits. The effect of the first evaporative emission standards is quite clearly shown in this Figure.



**Figure 2-49 Old Vehicles - Average SHED Emissions (pre & post tune)**

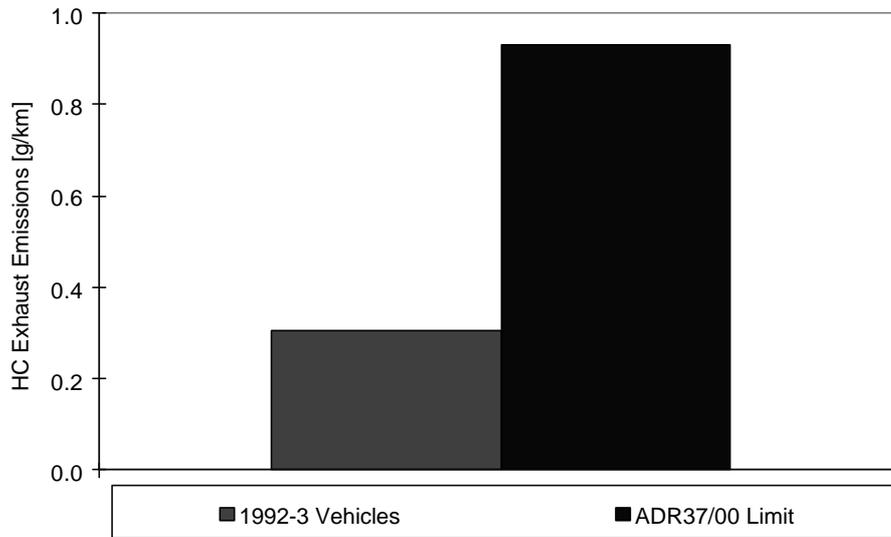
#### ***2.4.4 Is there a pollution problem from newer cars?***

When designing the study in 1992, the project team decided not to include vehicles manufactured later than 1991, anticipating that they were unlikely to be a major source of pollution.

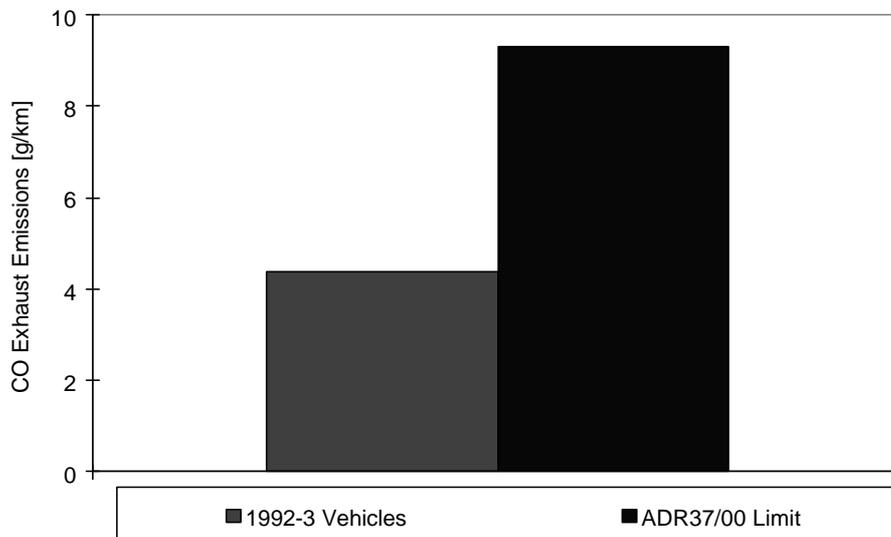
For completeness, however, we later decided to test a sample of 46 cars manufactured in 1992 and 1993, to the same protocols as the main sample. Although the cell sizes are proportionately smaller than those of the main sample, the results provide an indication of the performance of newer cars.

Typical emission levels for all gases are relatively low, averaging from one third to one half of the regulated values (see Figures 2-50 to 2-52). These test results are consistent with typical new car levels,

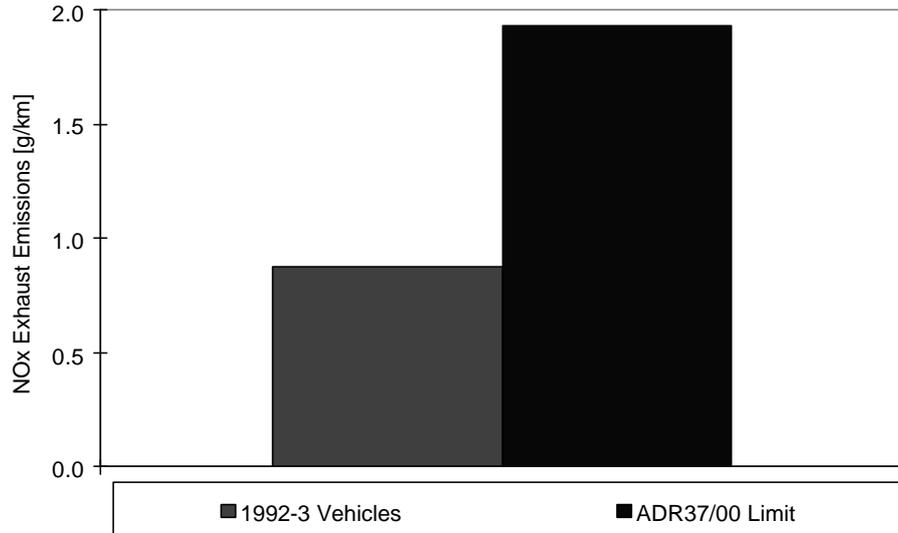
indicating that this group of vehicles has, on average, deteriorated very little.



**Figure 2-50 Average 1992-3 Car Emissions (HC) vs ADR37/00 Limit**

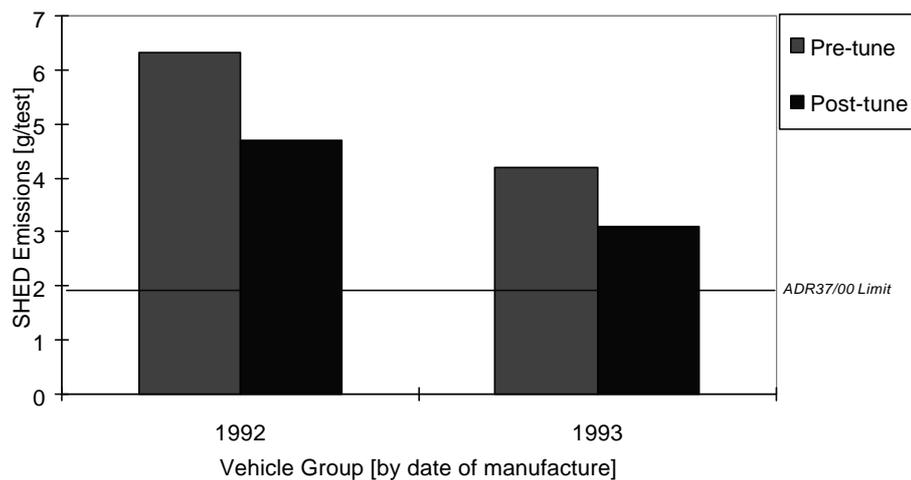


**Figure 2-51 Average 1992-3 Car Emissions (CO) vs ADR37/00 Limit**



**Figure 2-52 Average 1992-3 Car Emissions (NOx) vs ADR37/00 Limit**

While the exhaust emission results for the newer cars are quite favourable, the picture for evaporative HC emissions is not. Figure 2-53 illustrates that even the relatively new vehicles from the 1992-3 group also failed, on average, to meet the limit. The possible explanation for this is explored in the main discussion on evaporative emissions at 2.3.3.



**Figure 2-53 New Vehicles - Average SHED Emissions (pre & post tune)**

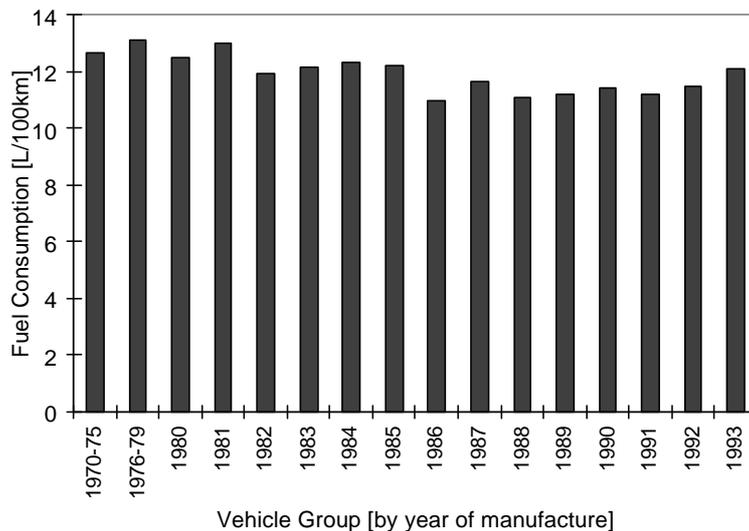
## 2.5 FUEL CONSUMPTION ISSUES

### 2.5.1 What is the fuel consumption performance of the car population ?

As part of the FTP test, the carbon dioxide emissions are measured, and from that the vehicle's fuel consumption in L/100km can be calculated. This method is equivalent to that used by manufacturers to provide a fuel consumption figure for new vehicles which is published in the annual Fuel Consumption Guide produced by the Department of Primary Industries and Energy.

While noxious emissions (ie those that lead to air pollution), and not fuel consumption, were the major focus of the NISE Study, it was considered important to explore fuel consumption issues, as vehicles are a major contributor to greenhouse gas emissions and this is directly related to fuel consumption.

The average fuel consumption of the various age groups of vehicles making up the fleet is illustrated in Figure 2-54. The figure indicates that the average fuel consumption of the fleet had not improved significantly over the 24 years covered by the NISE Study, although caution must be exercised with the data for the older 1970's vehicles particularly as only 22 vehicles were tested in this group.

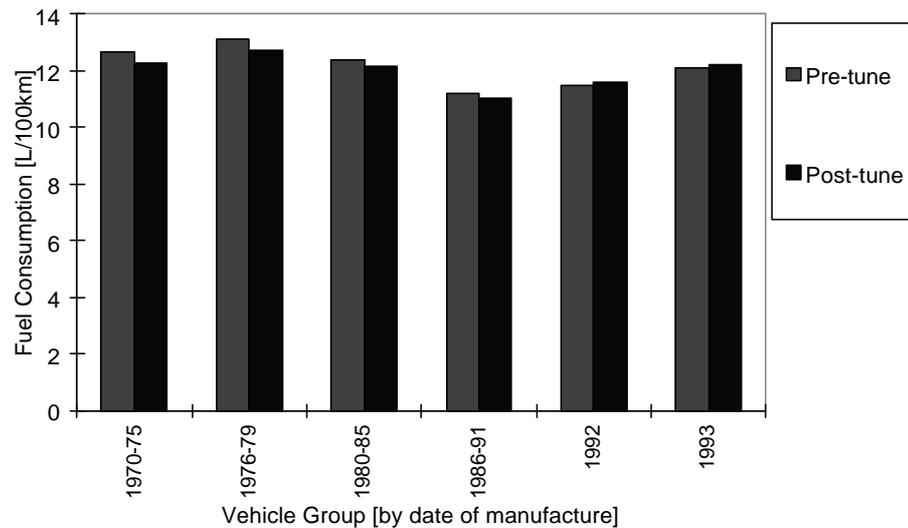


**Figure 2-54 All Age Groups - Average Fuel Consumption (pre tune)**

### 2.5.2 Does tuning improve fuel consumption?

When looking at the overall percentage improvements for the test vehicles, the answer to this question is clearly “yes” - tuning does make a difference.

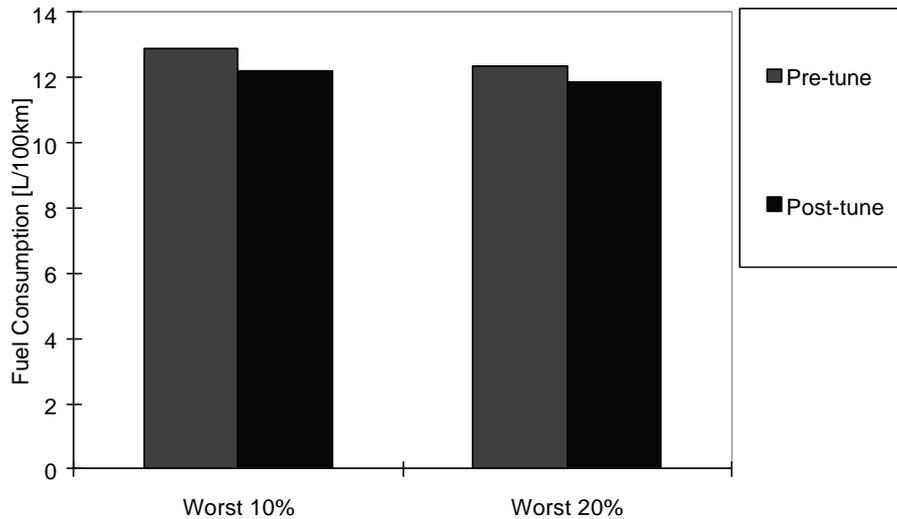
Figure 2-55 indicates that the tuning and basic repair procedures undertaken in this Study have a measurable effect on fuel consumption. In the main data set covering 1980-91, the average improvement in fuel consumption for ADR27 vehicles was around 2%, and for ADR37/00 vehicles just over 1%.



**Figure 2-55 All Age Groups - Average Fuel Consumption (pre and post tune)**

If, however, we focus on those vehicles which require attention because of high noxious emissions, then the picture is a little different. Figure 2-56 illustrates the tuning benefit on fuel consumption in those vehicles from the main data set which have the worst hydrocarbon exhaust emissions. In these two cases, the fuel consumption improvement from tuning was a little over 5% for the worst 10% of the vehicles, and almost 4% for the worst 20%.

Note: Analysis of the data shows that these percentage improvements, although numerically small, are statistically valid.



**Figure 2-56 Worst Emitters\* from 1980-91 Vehicles - Average Fuel Consumption (pre and post tune)**

\*based on HC emissions from FTP test.

While the percentage improvements are small, the total impact of these improvements on total fuel consumption if applied to the Australian car population is substantial. Using the 1995 figures for fuel consumption supplied by the Department of Primary Industries and Energy, a 2% across the board improvement for ADR27 vehicles, and a 1% improvement for ADR37/00 vehicles, would mean a reduction in total fuel sales of around 250 million litres per annum-which represents a total saving approaching \$200 million per annum to vehicle owners.

*Fuel savings of \$200 million per annum can be achieved from good car maintenance*

### **2.5.3 Summary of fuel consumption picture**

The fuel consumption of NISE Study vehicles has not decreased much between 1970 and 1993. These results are consistent with the new vehicle fuel consumption figures reported for these vehicles.

The tuning and maintenance regime undertaken in the NISE Study appears to have a positive effect on fuel consumption. While there may not be a dramatic effect on individual vehicles' fuel consumption, the economic savings on a national scale are potentially in the order of \$200 million.

The fuel consumption benefits are also significantly increased for those vehicles with poor hydrocarbon emissions performance.

## 2.6 ADDITIONAL TESTS

### 2.6.1 Introduction

Under the NISE study there were a number of additional tests and analyses undertaken to address specific issues. These were:

- Catalyst integrity test
- Catalyst temperature test
- Fuel filler cap sealing test
- "Carbon Clean" treatment
- Hydrocarbon emissions speciation.

The outcome of these tests is reported below.

### 2.6.2 Catalyst integrity test

*Physically shaking a catalyst gives no indication of its effectiveness*

This test was conducted as part of the pre test inspection. It simply involved the test personnel shaking the catalyst vigorously while the vehicle was on the hoist and recording whether an audible rattle was present. The assumption was that the rattle indicated a fractured catalyst bed which would cause exhaust gas to bypass the catalyst bed. The objective was to ascertain whether this simple test provided a good indicator of an ineffective catalyst and thus higher than expected exhaust emissions.

Analysis of the data reveals that there is virtually no correlation between the presence of a rattle and emission levels, and thus the test appears to be of no value.

### 2.6.3 Catalyst temperature test

*Measurement of catalyst inlet and outlet temperatures by non-contact means was not an effective method of determining catalyst operation.*

This test involved the use of an infra-red thermometer to measure the surface temperature of the exhaust pipe at the inlet and outlet points of the catalytic converter casing.

The objective was to provide a quick method of measuring the temperature differential between the inlet and outlet of the catalyst, as an indicator of catalyst operation. Limited testing by the NSW EPA using thermocouples attached to the inlet and outlet points indicated that a temperature differential of up to 30°C was achieved on a vehicle with an operational catalyst running under the NISE test program.

The infra red based test was difficult to conduct consistently as accurate sighting of the infra red beam was not easy, and the

presence of shrouding on the catalyst fitted to many vehicles made it impossible to measure the

temperature at the surface of the exhaust pipe. Because of the variability of measurement, the analysis revealed no correlation between temperature differential and exhaust emission levels. The test does not appear to be an effective way to assess catalyst operation.

#### **2.6.4 Fuel filler cap sealing test**

This test was conducted on those vehicles which underwent the SHED test. It was done at the completion of the heat build for the SHED test. It involved the use of a hand held hydrocarbons detector to sample the air close to the fuel filler cap (when firmly closed). The objective of the test was to see if leaking fuel filler caps were a significant factor in vehicles with high evaporative emissions.

The analysis of the results of this test indicated that there was no correlation between high HC readings from this test and high overall SHED results. This test does not appear to offer a method for identifying vehicles with high evaporative emissions.

#### **2.6.5 "Carbon Clean" treatment**

A small number of vehicles (6) were retested after the completion of the normal pre- and post-tuning tests, using a proprietary chemical process known as "Carbon Clean". This process claims to remove carbon, fuel residues and other deposits on engine components, fuel injectors and other parts of the fuel system, which are frequently cited as the cause of poor emissions and fuel consumption performance. The inclusion of this process in the NISE Study does not represent any form of endorsement of the product. It was included because of its use in some government emission control programs overseas.

No clear trend in emissions performance change was evident from the testing. As only six vehicles were subjected to this process, no valid conclusions could be drawn on its effectiveness.

#### **2.6.6 Hydrocarbons emissions speciation**

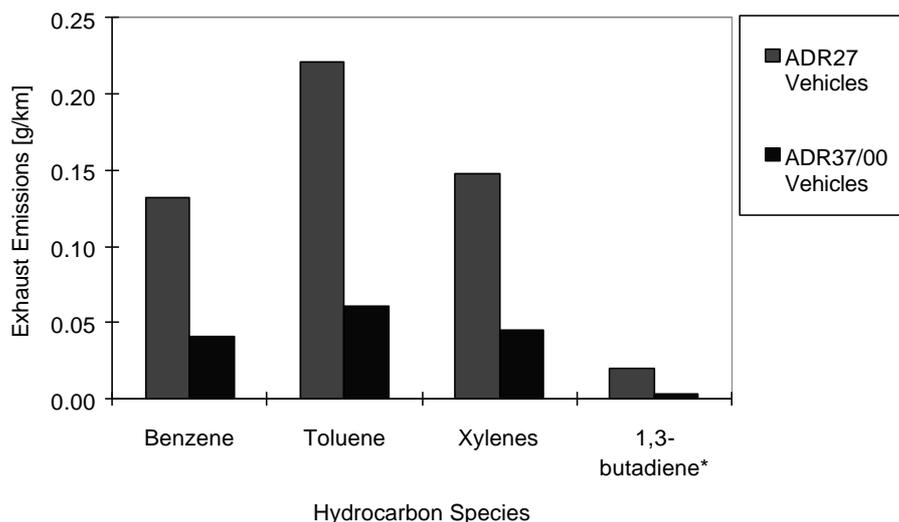
There has been growing interest in the control of specific hydrocarbons, known as "air toxics", in recent years, but little information is available on emissions of these substances in Australia. In an effort to address these gaps in our knowledge, the Environment Protection Agency (Commonwealth) engaged the CSIRO to take samples from 66 vehicles (10 ADR27, 56 ADR37/00) during the FTP test in the NISE Study. These samples were then analysed for the following hydrocarbons which have been designated as "air toxics" in the US:

*Hydrocarbon "sniffers" do not provide a reliable test for identifying cars with high evaporative emissions*

*Test results on the effect of chemical cleaning systems on emissions and fuel consumption were inconclusive*

- Benzene
- Toluene
- Xylenes
- 1,3-Butadiene.

The levels of these hydrocarbons in the emissions from the FTP test are illustrated in Figure 2-57. It clearly indicates that the catalyst equipped vehicles in the ADR37/00 group are quite effective in reducing average levels of these hydrocarbons. In considering the levels of these emissions, it should be noted that the aromatic content of the test fuels is higher than the industry average, at least on the benzene content, which was 4.1-4.2% for the NISE Study fuels compared to the industry average of around 2.5% (in 1994).



\* the 1,3-butadiene results are derived from 8 ADR27 and 48 ADR37/00 vehicles

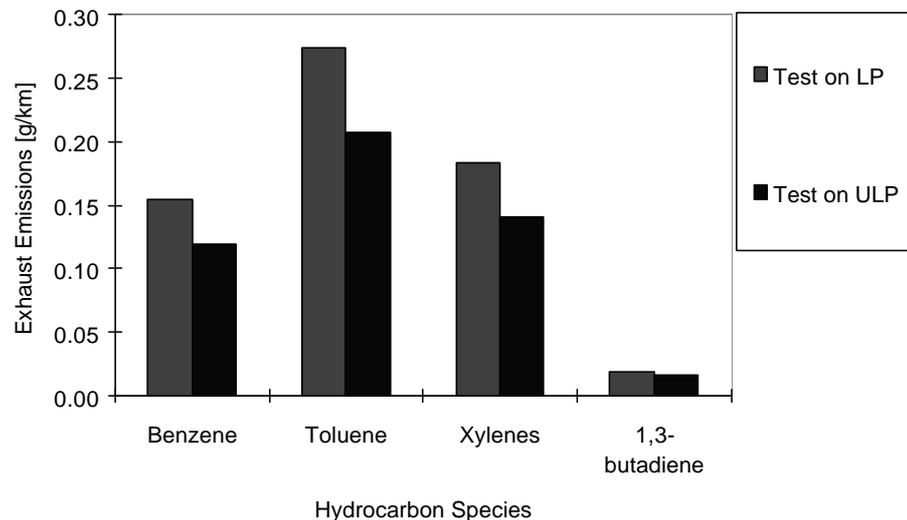
**Figure 2-57 Average FTP Emissions (pre tune) of Specific Hydrocarbons**

In addition to the general concerns about “air toxics”, there has been some commentary in the media about the possible adverse impacts of using unleaded petrol in ADR27 vehicles which are not fitted with a catalyst. As part of the effort to reduce the use of leaded petrol, this practice has been encouraged in certain ADR27 vehicles which have been identified as being able to operate successfully on unleaded petrol.

In order to assess whether “air toxics” are in fact worse when ADR27 vehicles are operated on unleaded petrol, a small number (6) of vehicles was subjected to the FTP test on unleaded petrol, prior to undergoing the normal NISE Study test program (which, of course, for ADR27 vehicles is conducted on leaded petrol).

*The use of unleaded petrol instead of leaded petrol appears to reduce emissions of "air toxics" when typical Australian specification fuels are used*

The results of this testing indicate that total hydrocarbons are lower when the vehicle is operated on unleaded petrol, and the proportional reduction in the specific hydrocarbons measured was considerably greater (see Figure 2-58 for reductions in the specific hydrocarbons). The reasons for this are not clear, but, while great caution must be used given the small number of vehicles tested, the results appear to indicate that the use of unleaded petrol in suitable ADR27 vehicles will not lead to an increase in hydrocarbon emissions, and may even reduce them.



**Figure 2-58 Average FTP Emissions (pre tune) of Specific Hydrocarbons from Selected ADR27 Vehicles Tested on Leaded and Unleaded Petrol**

The detailed results from the CSIRO analysis have been printed in a separate report which is available from the Environment Protection Agency (Commonwealth).

## 2.7 EFFECTIVENESS OF SHORT TESTS

### 2.7.1 Introduction

Certification level tests using the FTP cycle provide the best available indication of a vehicle's on-road emissions performance. The full FTP test is not, however, practicable for use in a broad-based emissions reduction program because:

- it is very expensive (typically around \$1,000 per test)
- it is very time consuming (up to 24 hours for pre-conditioning), and
- there are only a few suitable test facilities.

A long-standing goal for governments seeking to reduce vehicle pollution has been to develop a short test that reliably identifies high polluting vehicles.

Ideally, such a test would have the following characteristics:

- good correlation with FTP test results
- ability to identify those cars whose emissions will be most reduced by tuning
- take only a few minutes to perform
- cost no more than, say, \$30 on a commercial basis
- preferably be capable of being done at distributed or roadside locations (ie not only in centralised facilities).

Until recently, the only short test commonly in use was to measure the concentrations of CO and/or HC in the tailpipe when the vehicle is idling (Idle Test). Alternatively, the engine could be run at a more elevated speed, usually 2500rpm (High Idle Test).

However, the idle tests have some drawbacks that may limit their usefulness in testing current technology cars.

Most importantly, a car's catalytic converter and computerised engine management systems only become fully operational when the vehicle is being driven under load.

In addition, as NO<sub>x</sub> is only produced when the engine is running against a load, idle tests cannot be used to test for this gas. Since NO<sub>x</sub> levels are critical to the formation and extent of photochemical smog, idle tests are seriously deficient in this respect.

*Idle tests cannot be used  
to effectively measure  
NO<sub>x</sub> levels*

To address the above shortcomings, several short dynamometer-based tests have been developed in recent years. All vehicles in the NISE study were tested using all the available short tests (idle and loaded) both prior to and after tuning. The tests are briefly described below and fully specified in Appendix VIII.

**IM-240** - Modified IM240 (Inspection & Maintenance) Test

This is based on the test prescribed by the US EPA for vehicle inspection and maintenance programs. The test involves a short (240 second) driving cycle which is similar to the start of the FTP (ADR37/00) cycle but only covers about 2km total distance. Results are recorded in grams per kilometre for HC, CO and NOx.

**ASM** - Acceleration Simulation Mode Test (ASM2525)

The vehicle is driven on a chassis dynamometer set to 25% of the vehicle's power at a speed of 40km/h (manual vehicles in 2nd gear). Concentrations of raw exhaust emissions are measured using infra-red analysers. The results are recorded in parts per million for HC and NOx and % volume for CO.

**SS60** - Steady State Loaded 60km/h

The vehicle is driven on a chassis dynamometer at a constant 60km/h. The emissions are collected over the measurement phase of the test and the results are recorded in grams per minute for HC, CO and NOx.

**HIGH IDLE** - Steady State High Idle Test Procedure

The vehicle is stationary and the engine is run at a speed of 2500 rpm. The concentrations of raw exhaust emissions are measured using infra-red analysers. The results are recorded in parts per million for HC and % volume for CO.

**IDLE** - Steady State Idle Test Procedure

The vehicle is stationary and the engine is run at idle speed (accelerator not depressed).. The concentrations of raw exhaust emissions are measured using infra-red analysers. The results are recorded in parts per million for HC and % volume for CO.

For each vehicle tested, the results of all short tests have been compared with results obtained for the same vehicles using the FTP test. The results of these comparisons follow.

Scatter charts containing the FTP and Short Test data pairs for all vehicles are used to illustrate the level of correlation between the tests. For reference purposes, the correlation coefficients ( r ) are also shown.

**Please note** that correlation coefficients are provided for reference purposes only. Although it falls outside the scope of this study to explore what might be appropriate cut points (test limits) for any in-service test programs that might be introduced, preliminary work has shown that methods other than simple correlation analysis may generate more effective and reliable limits.

A more meaningful measure of short test efficiency has been developed by the project team that measures how effective each short test is at identifying vehicles that will give the greatest emissions reductions from tuning (the *NISE efficiency factor*).

Take, for instance, a scenario where it is decided to require tuning and repair of all vehicles identified by the ASM test as being in the highest 20% emitters. The efficiency of the ASM test in this case would be:

$$\eta_{\text{ASM}20} = \frac{\text{FTP emission reduction from tuning highest 20\% ASM cars}}{\text{Maximum achievable FTP emission reduction}}$$

This approach allows regulators to assess the likely results of taking a particular approach, rather than focusing on correlation issues which may have a lesser bearing on the achievement of air quality improvement goals.

It is important to recognise that the NISE efficiency factor measures the effectiveness of any given test as **a predictor of emissions reductions**. This is very different to measuring or correlating absolute emission levels.

A preferred short test would be effective at selecting both those vehicles with high absolute emission values and those likely to improve most from tuning.

The following sections present graphical and numerical data on the correlation of all short tests with the FTP test, for each gas of interest. Overall comparisons of the NISE efficiency factors are presented at the end of this section.

### **2.7.2 IM240 test results**

As a sub-set of the full FTP test, it is not surprising to find that the IM240 test has the best correlation with FTP test results (see Table

*A preferred short test would be effective at selecting both those vehicles with high emissions and those likely to improve most from tuning*

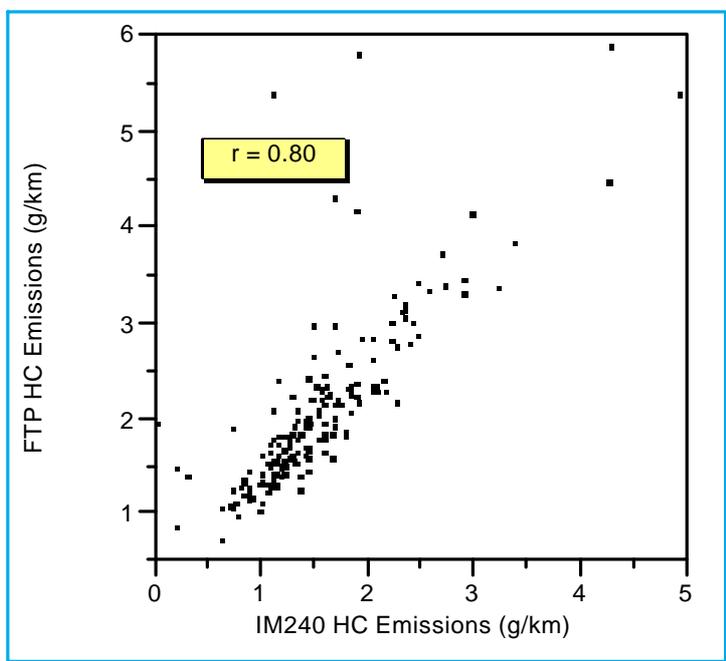
2.4). Figures 2-59 to 2-64 show the relatively tight distribution of data for this test.

*The IM240 test was the  
most effective short test  
in the NISE Study*

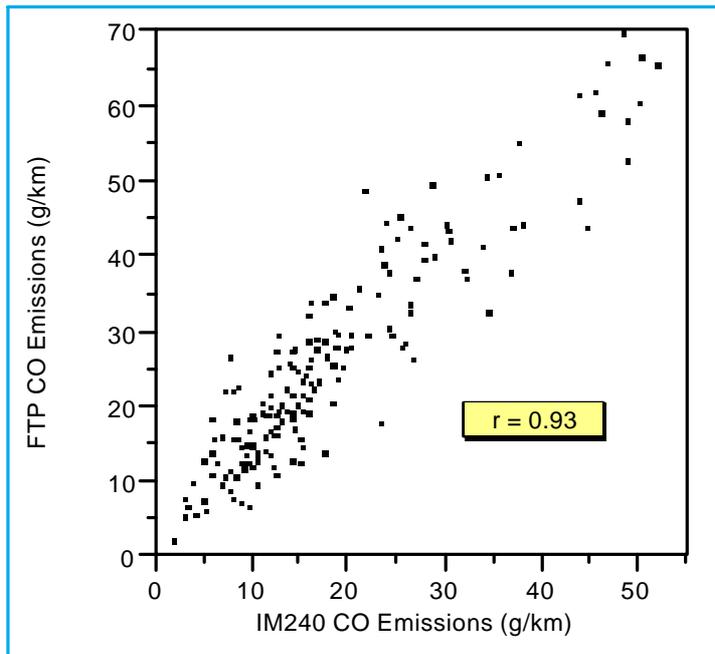
The IM240 test was also effective at detecting the highest emitters and those cars most likely to yield a large reduction in emissions when tuned.

**Table 2.4 Correlation (r) of IM240 Test Results with FTP Tests**

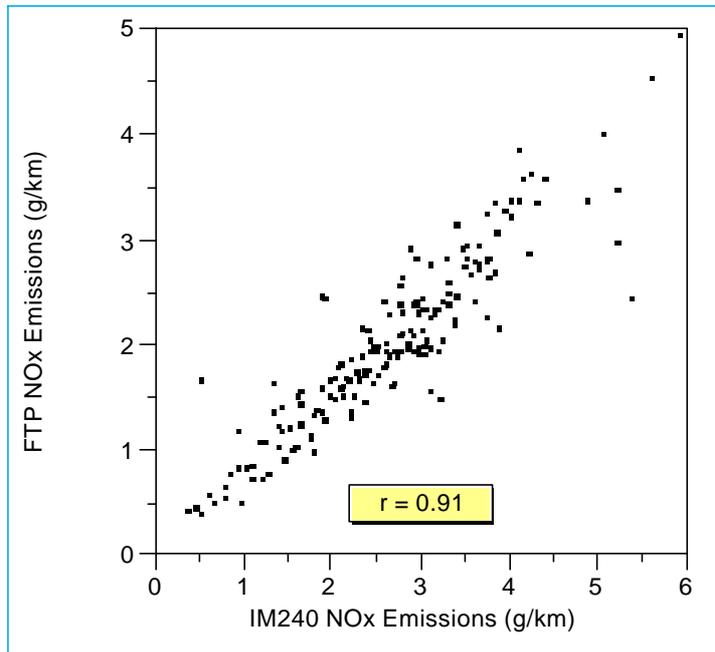
<i>Emission Type</i>	<i>ADR 27 Cars Correlation (r)</i>	<i>ADR37/00 Cars Correlation (r)</i>
HC	0.80	0.94
CO	0.93	0.90
NOx	0.91	0.90



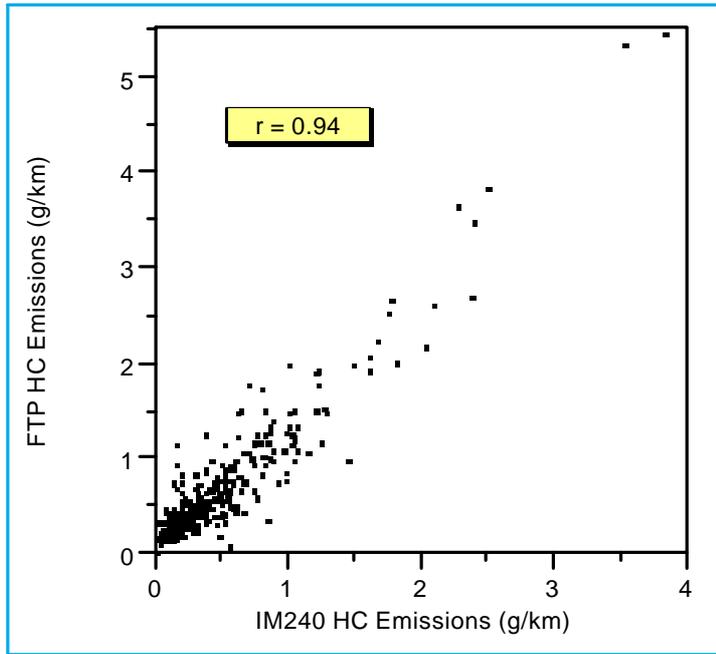
**Fig 2-59 IM240 vs FTP Test Results for HC - ADR 27 Vehicles**



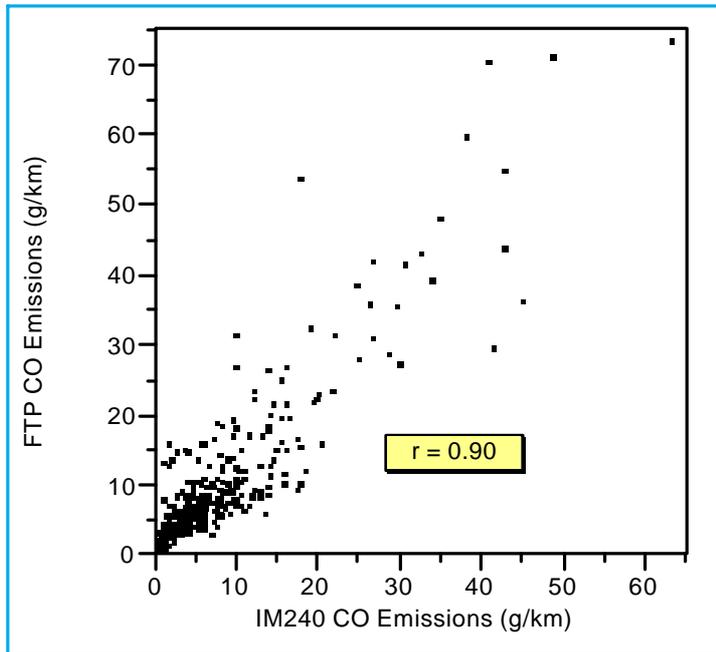
**Fig 2-60** IM240 vs FTP Test Results for CO - ADR 27 Vehicles



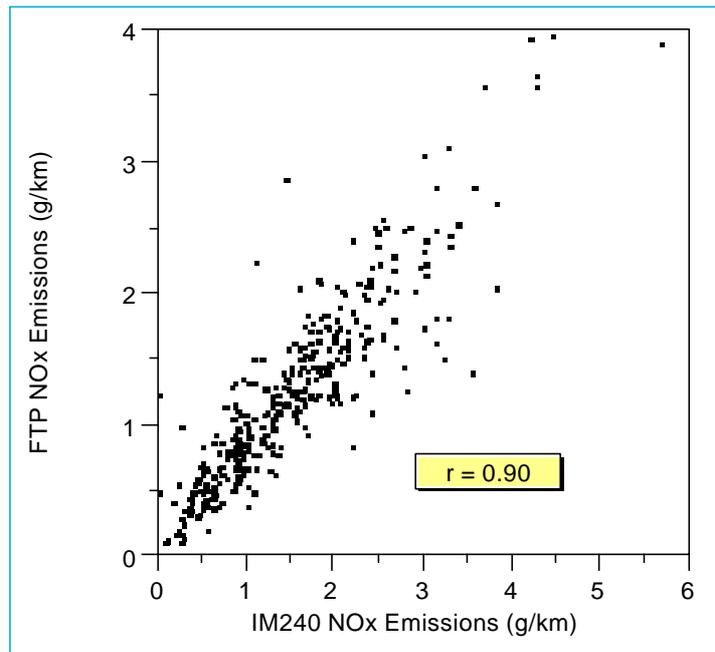
**Fig 2-61** IM240 vs FTP test Results for NO2 - ADR 27 Vehicles



**Fig 2-62** IM240 vs FTP Test Results for HC - ADR37/00 Vehicles



**Fig 2-63** IM240 vs FTP Test Results for CO - ADR37/00 Vehicles



**Fig 2-64 IM240 vs FTP Test Results for NOx - ADR37/00 Vehicles**

In considering the usefulness of the IM240 test, however, readers should be aware of the high capital costs of establishing a facility to do these tests (typically well over \$200,000 per lane, excluding the building).

While the USA experience has shown that IM240 facilities may be commercially viable, practical difficulties surrounding the logistics of centralised systems, coupled with some client resistance, have resulted in some IM240 schemes being less successful than anticipated.

### **2.7.3 ASM 25/25 test results**

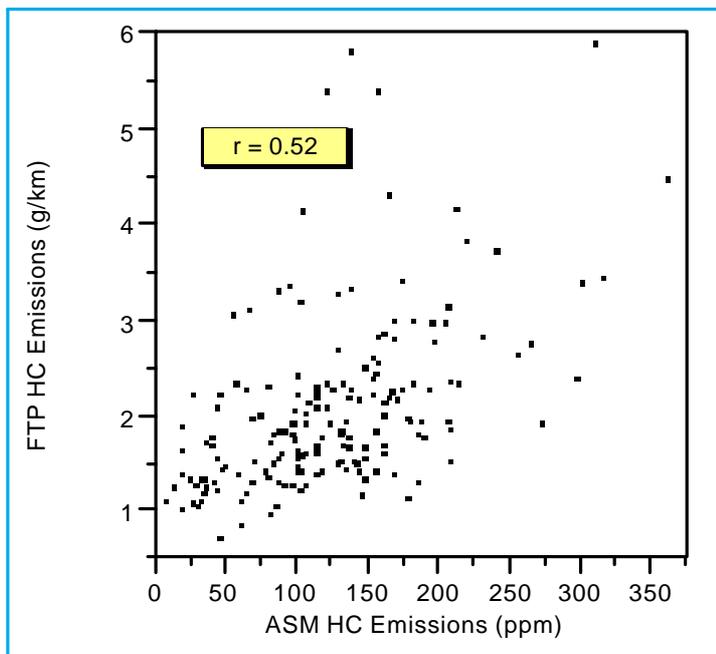
The ASM test is being widely adopted or considered for adoption into inspection and maintenance programs around the world. Together with the Australian-developed SS60 test, it is the shortest and least capital-intensive dynamometer based emissions test.

Overall, the ASM 25/25 test demonstrated a reasonable correlation with FTP test results on most gases (see Table 2.5), and some competency at detecting high emitting vehicles, but not to the extent achieved by the SS60 or IM240 tests (see Figures 2-65 to 2-70).

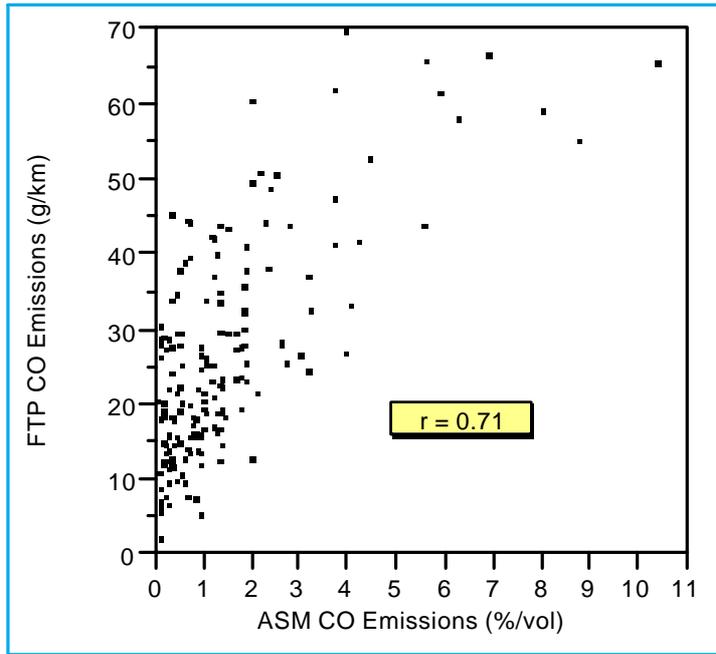
*Although widely adopted overseas, the ASM test provided only mediocre results in the NISE Study*

**Table 2.5 Correlation of ASM Test Results with FTP Tests**

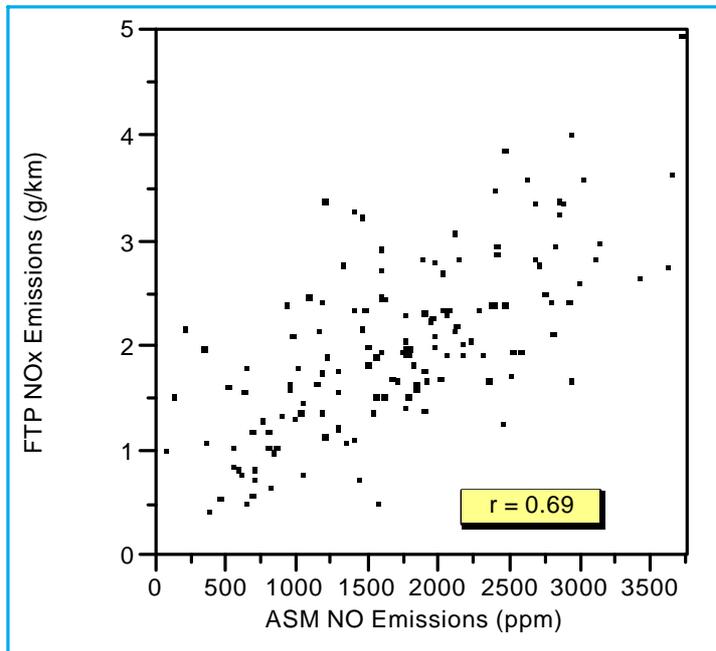
<i>Emission Type</i>	<i>ADR 27 Cars Correlation (r)</i>	<i>ADR37/00 Cars Correlation (r)</i>
HC	0.52	0.64
CO	0.71	0.78
NOx	0.69	0.68



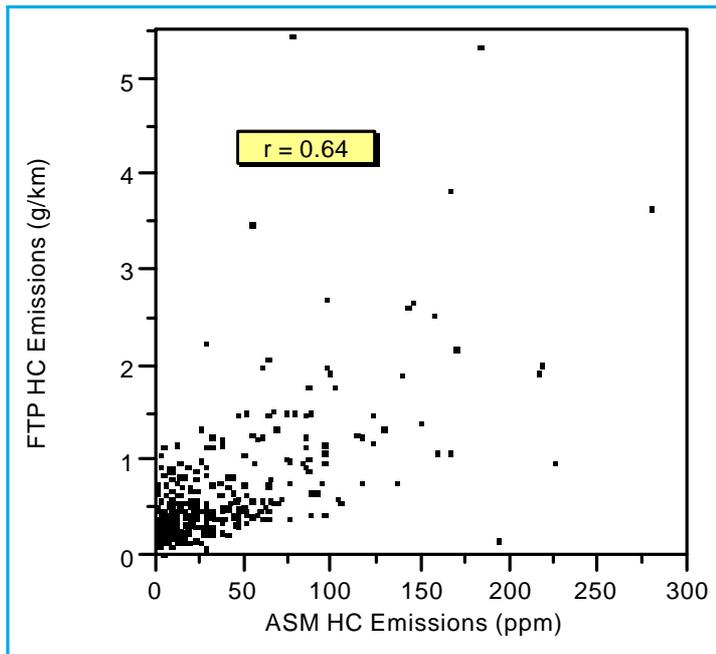
**Fig 2-65 ASM vs FTP Test Results for HC - ADR 27 Vehicles**



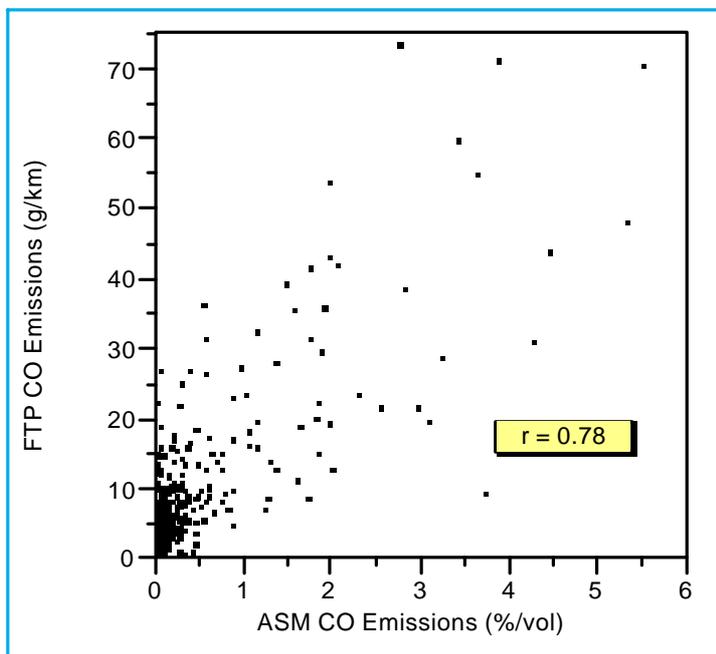
**Fig 2-66** ASM vs FTP Test Results for CO - ADR 27 Vehicles



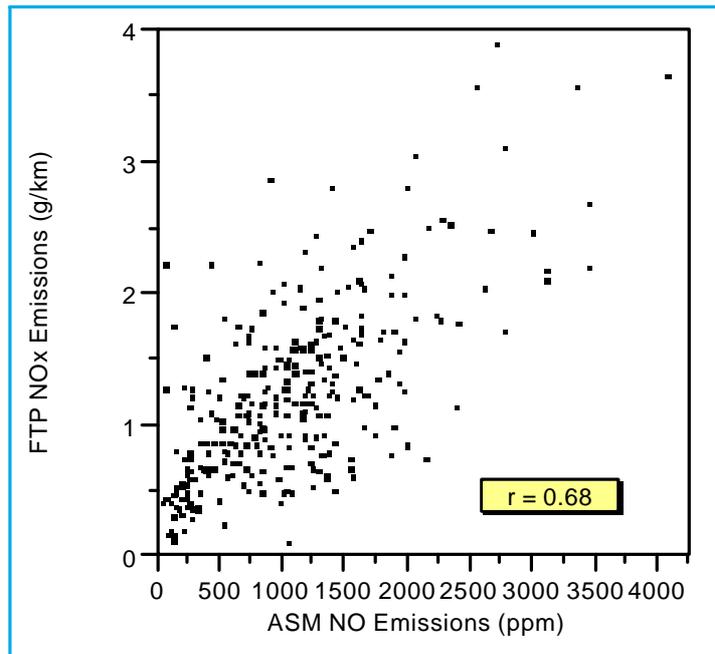
**Fig 2-67** ASM vs FTP Test Results for NO - ADR 27 Vehicles



**Fig 2-68** ASM vs FTP Test Results for HC - ADR37/00 Vehicles



**Fig 2-69** ASM vs FTP Test Results for CO - ADR37/00 Vehicles



**Fig 2-70 ASM vs FTP Test Results for NO - ADR37/00 Vehicles**

**2.7.4 SS60 test results**

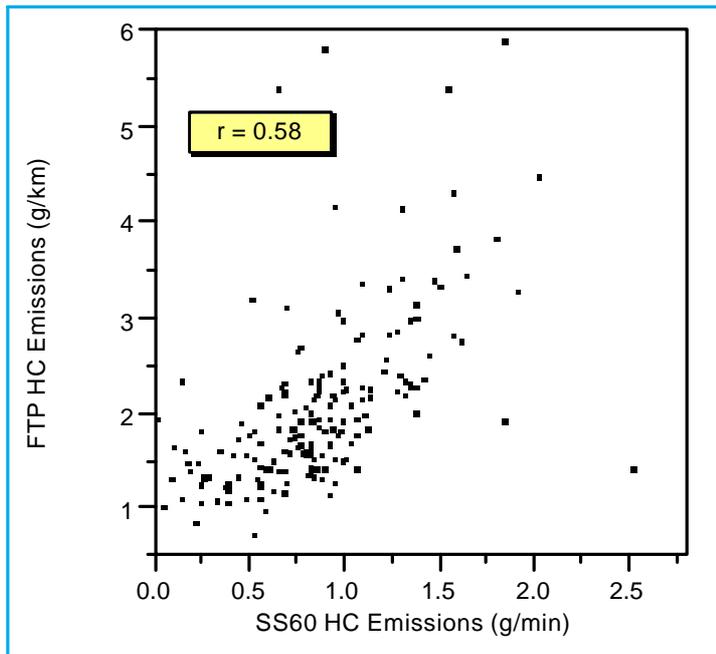
*The SS60 test was the more effective constant load dynamometer test*

The SS60 test, like the ASM, is a constant speed (60km/h), constant load dynamometer based test capable of being performed at the service station level.

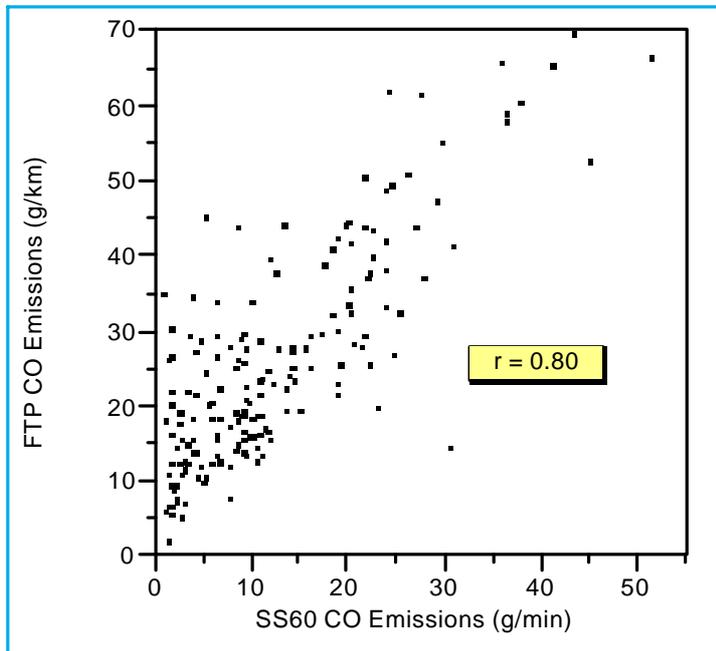
Data generated by this test generally showed higher correlation with FTP results than was achieved by the ASM test, but lower than that of IM240 (see Table 2.6 and Figures 2-71 to 2-76).

**Table 2.6 Correlation of SS60 test Results with FTP Tests**

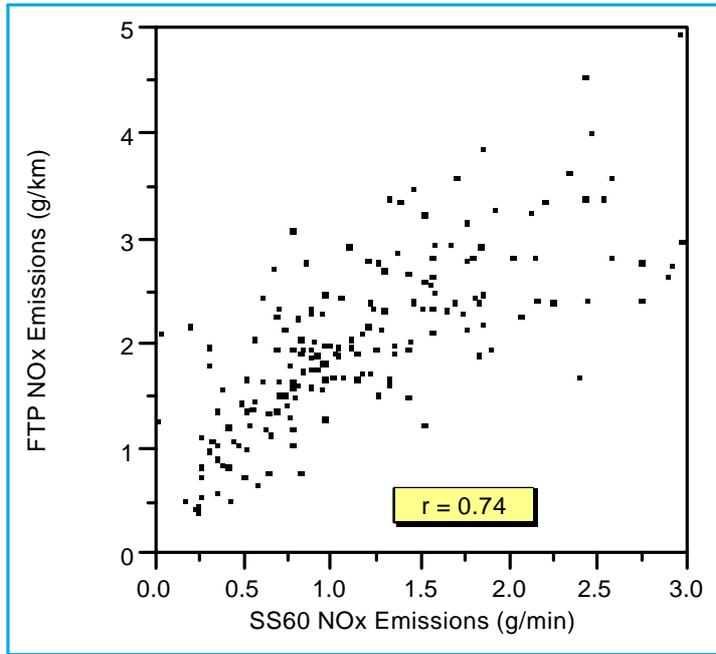
<b><i>Emission Type</i></b>	<b><i>ADR 27 Cars Correlation (r)</i></b>	<b><i>ADR37/00 Cars Correlation (r)</i></b>
HC	0.58	0.80
CO	0.80	0.84
NOx	0.74	0.72



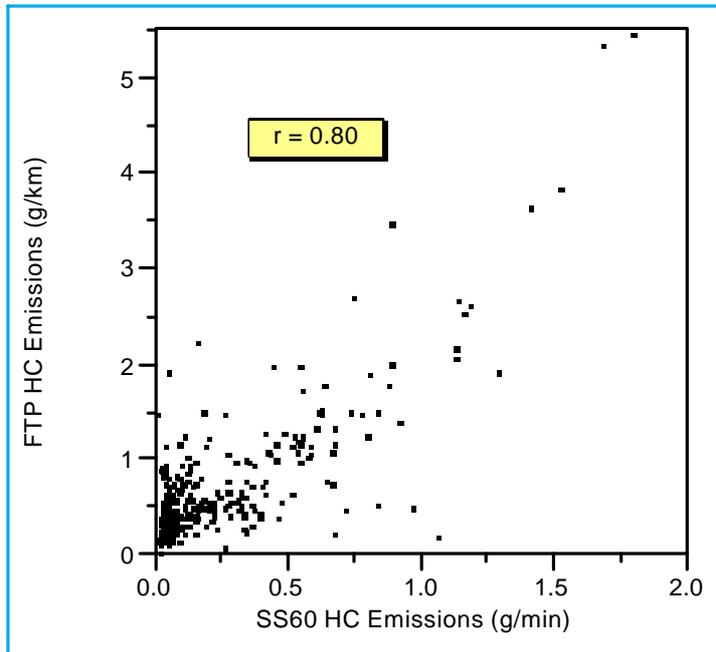
**Fig 2-71 SS60 vs FTP Test Results for HC - ADR 27 Vehicles**



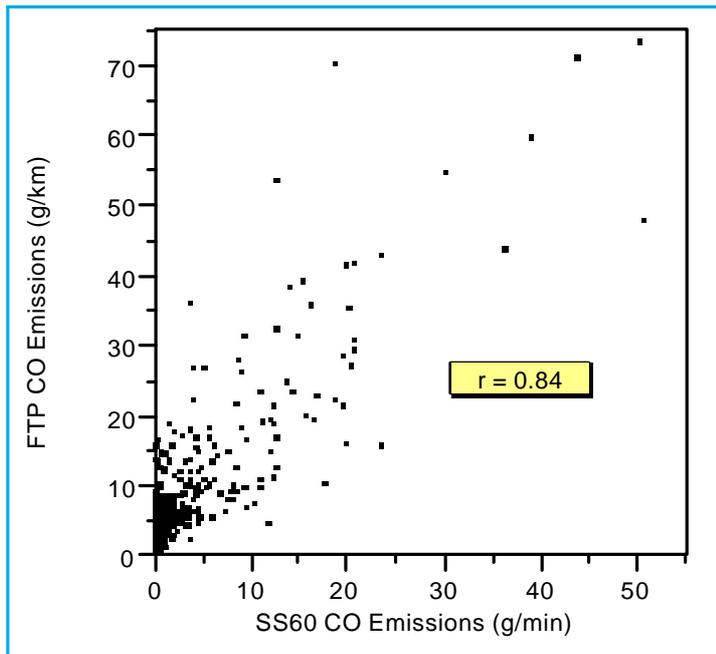
**Fig 2-72 SS60 vs FTP Test Results for CO - ADR 27 Vehicles**



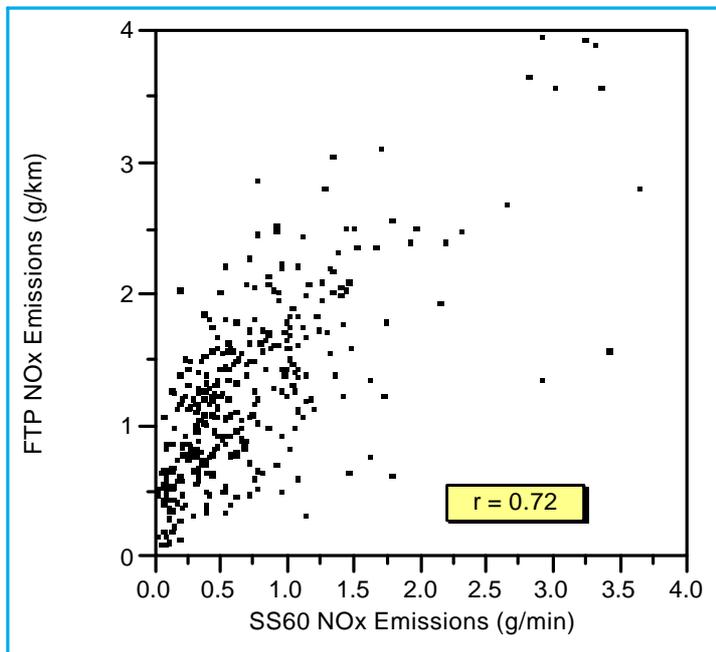
**Fig 2-73 SS60 vs FTP Test Results for NOx - ADR 27 Vehicles**



**Fig 2-74 SS60 vs FTP Test Results for HC - ADR37/00 Vehicles**



**Fig 2-75 SS60 vs FTP Test Results for CO - ADR37/00 Vehicles**



**Fig 2-76 SS60 vs FTP Test Results for NOx - ADR37/00 Vehicles**

### **2.7.5 High Idle test results**

*Idle tests performed least well in the NISE Study and were not suitable for measuring NOx levels*

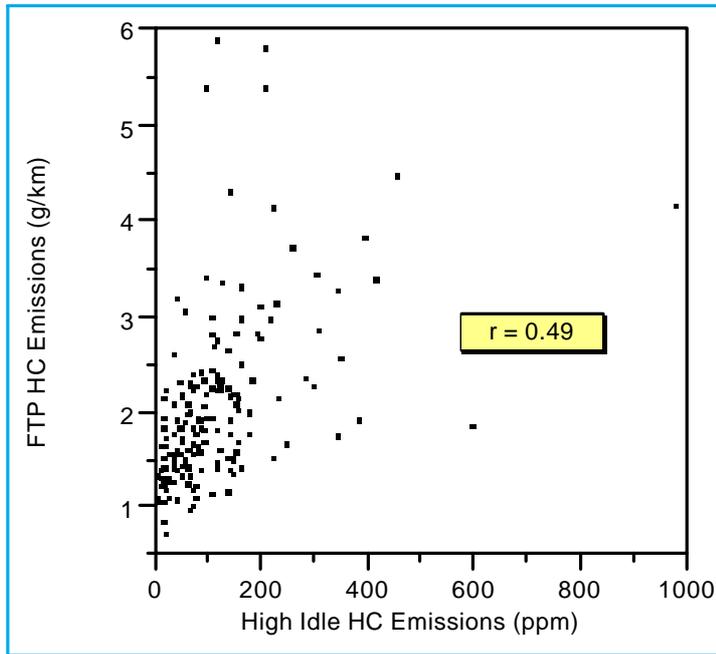
Idle tests have, until recently, been the only practicable short test capable of being performed at low cost in a workshop or test station. The equipment required is relatively inexpensive, operator training requirements are minimal and there is no need to dedicate space for a chassis dynamometer.

As noted earlier, however, idle tests suffer from two major drawbacks. Firstly, a car's catalytic converter and computerised engine management systems only become fully operational when the vehicle is being driven under load. Secondly, as NOx is only produced when the engine is running against a load, idle tests cannot be used to test for this gas.

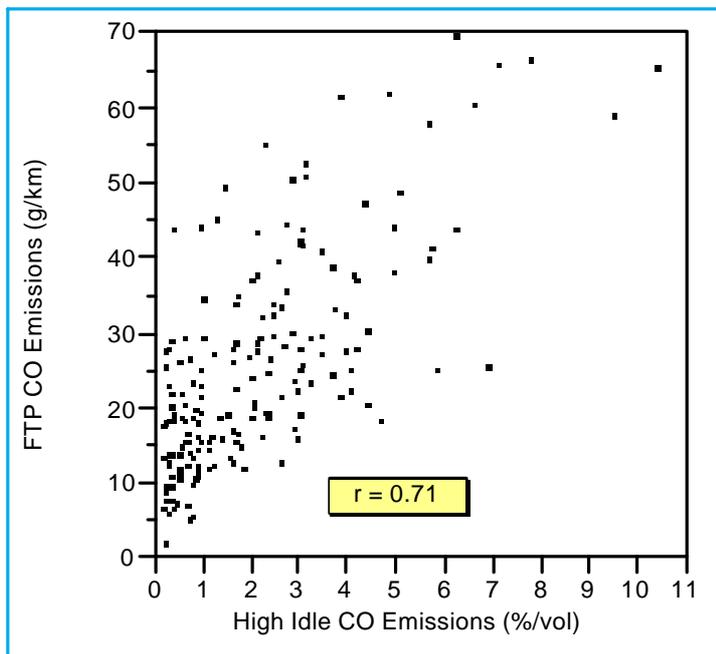
Overall, the High Idle test had lower correlation with FTP results than the loaded short test (see Table 2.7 and Figures 2-77 to 2-80). The one exception was in comparison with the ASM test, which rather surprisingly gave a lower correlation than the High Idle for ADR 27 vehicles.

**Table 2.7 Correlation of High Idle Test Results with FTP Tests**

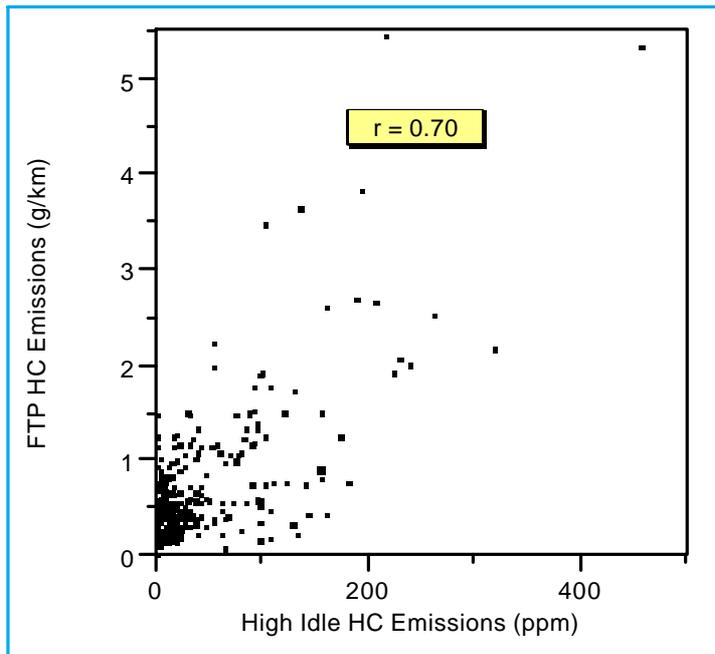
<b><i>Emission Type</i></b>	<b><i>ADR 27 Cars Correlation (r)</i></b>	<b><i>ADR37/00 Cars Correlation (r)</i></b>
HC	0.49	0.70
CO	0.71	0.62
NOx	N/A	N/A



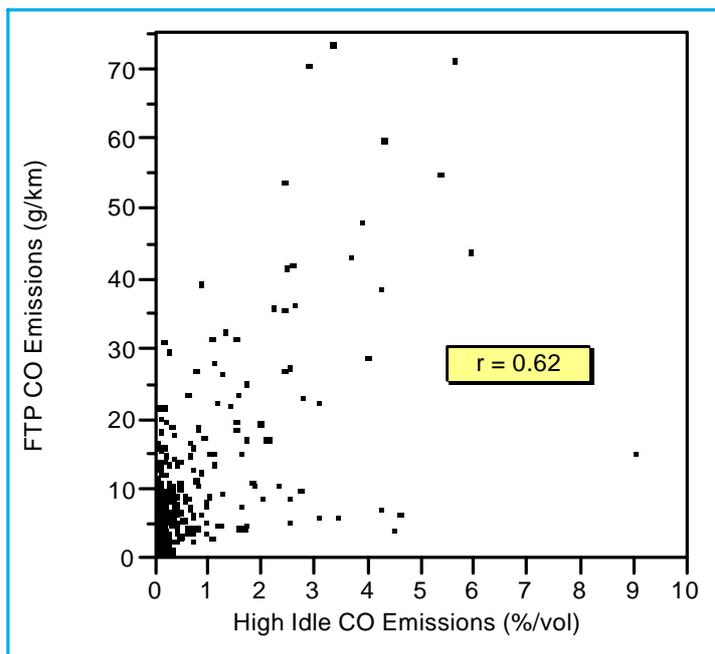
**Fig 2-77 High Idle vs FTP Test Results for HC - ADR 27 Vehicles**



**Fig 2-78 High Idle vs FTP Test Results for CO - ADR 27 Vehicles**



**Fig 2-79 High Idle vs FTP Test Results for HC - ADR37/00 Vehicles**



**Fig 2-80 High Idle vs FTP Test Results for CO - ADR37/00 Vehicles**

### 2.7.6 Idle test results

Normal idle test data generally delivered correlations lower than High Idle for ADR27 vehicles, except for correlating better than High Idle in relation to ADR37/00 cars (see Table 2.8 and Figures 2-81 to 2-84).

This latter finding runs counter to logic, that would normally predict High Idle tests on ADR37 vehicles to correlate better than Normal Idle, as the engine management systems would generally be running in closed loop mode at the 2500rpm High Idle test speed. At Normal Idle, typically around 800rpm, the fuel management systems are in open loop (no feedback), so less controls are applied to the system. The project team has no explanation for this finding.

Table 2.8 Correlation of Idle Test Results with FTP Tests

<i>Emission Type</i>	<i>ADR 27 Cars Correlation (r)</i>	<i>ADR37/00 Cars Correlation (r)</i>
HC	0.44	0.72
CO	0.55	0.67
NOx	N/A	N/A

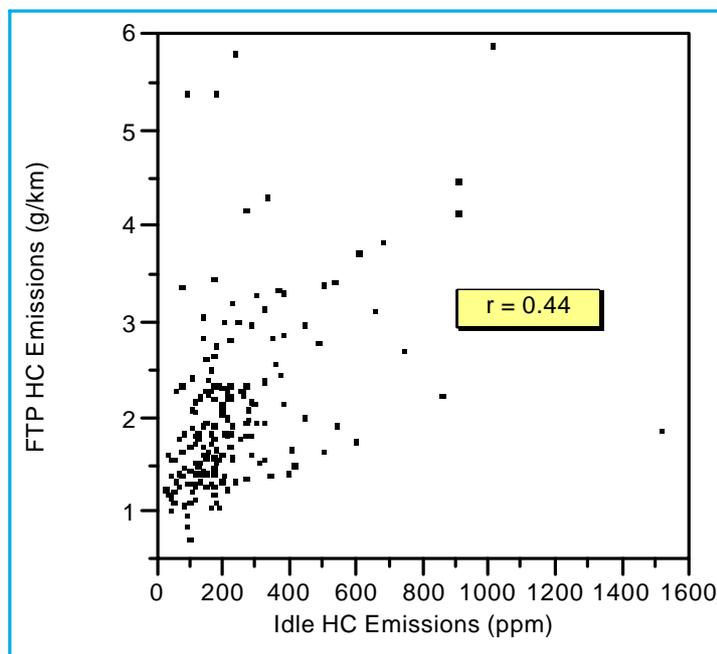
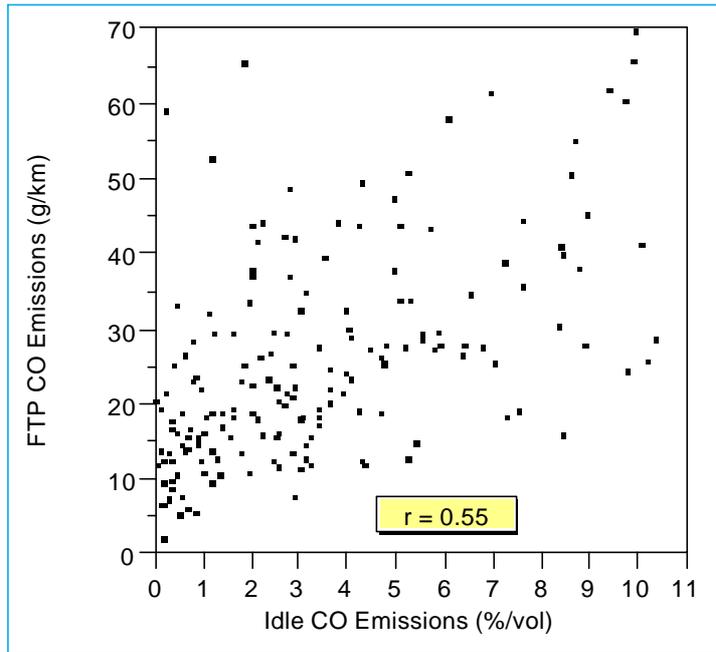
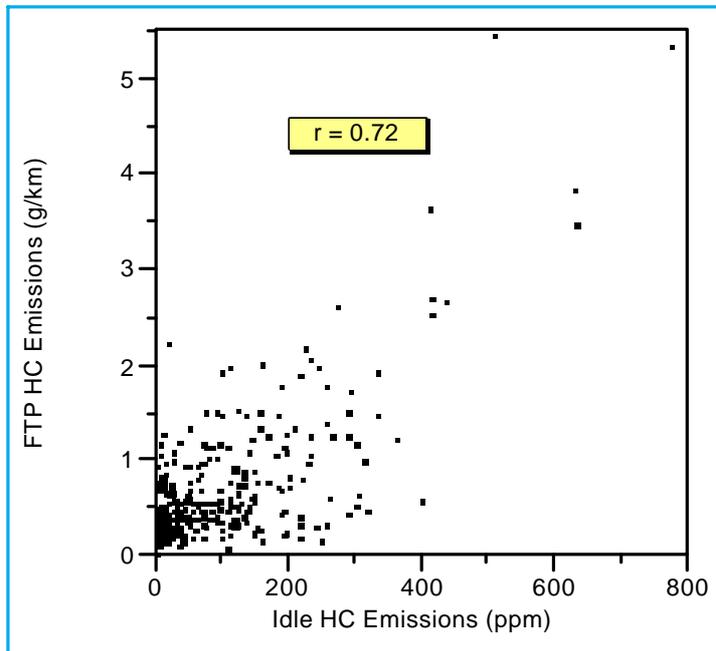


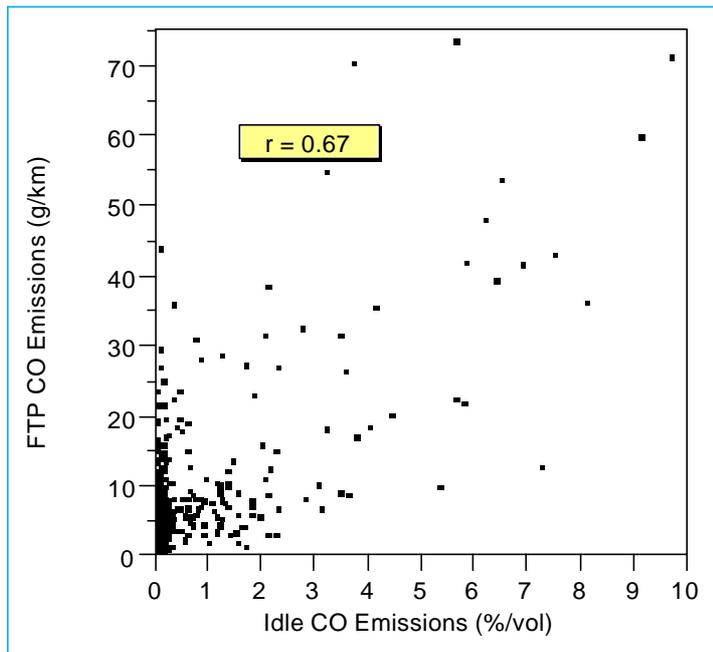
Fig 2-81 Idle vs FTP Test Results for HC - ADR 27 Vehicles



**Fig 2-82 Idle vs FTP Test Results for CO - ADR 27 Vehicles**



**Fig 2-83 Idle vs FTP Test Results for HC - ADR37/00 Vehicles**



**Fig 2-84 Idle vs FTP Test Results for CO - ADR37/00 Vehicles**

### ***2.7.7 Effectiveness at predicting emission reductions***

The following pages contain the NISE Efficiency Factor graphs, which illustrate the effectiveness of each short test as a predictor of emissions reductions from tuning. The X-Axis “% Worst Vehicles Tested” is a descending ranking of the vehicles which each short test identified as the highest polluters.

Correlation with the FTP cycle is only one part of the story. The bottom line for environmental planners is the impact that an emissions reduction program will have on overall pollution levels and at what cost.

Hence it is important to look carefully at the effectiveness of the various short tests in picking out those cars that will deliver the greatest reductions in emission levels when tuned. Costs are covered in a later section.

The relative effectiveness of each short test was assessed by analysing the actual emission reductions achieved through tuning vehicles picked out as the highest emitters by each of the five short tests.

For each short test, the database was sorted to identify vehicles with the highest test results then, by reading across to the FTP test results for each car, the actual emissions reduction from tuning was tabulated.

On a cumulative basis, the emission reductions achieved by each short test relative to the maximum achievable reductions was calculated and plotted on common axes. For reference purposes, the NISE efficiency factor for the FTP test was also plotted (Figures 2-85 to 2-92).

The FTP test stands out as consistently identifying the small percentage of cars that will give the biggest tuning effect, with the IM240 test a clear second. What greatly surprised the project team was the relatively small and varying differentiation between the effectiveness of the other tests included in the NISE study.

Of the remaining short tests, the SS60 protocol appeared to give the best combination of correlation with FTP results and ability to identify those cars that would most benefit from tuning.

All the tests were quite effective at selecting those cars that delivered the greatest tuning effect (noting that the idle tests are not suitable for measuring NOx emissions).

The general shape of the effectiveness curves generated by this process show a steep initial slope, indicating high emission reductions from a small number of cars. The slope gradually flattens as those cars less responsive to tuning are picked up.

None of the tests were particularly effective at predicting the negative tuning effect evident in some vehicles, which is clearly apparent in the “maximum achievable” curve for each gas.

To a greater or lesser extent, depending on the efficiency of the test, the negative results tended to be distributed through the sample. Hence the less discriminating tests exhibited a flatter profile and a lower efficiency factor.

Regardless of which test is used as an indicator of emission levels, it is clear that there is very little marginal gain in tuning more than the worst 40% of cars. Detailed cost-benefit studies may suggest an even lower proportion.

The question of which short test might provide the optimum solution will receive intensive further analysis by environmental and transport planners. Further comment on this issue falls outside the scope of this study.

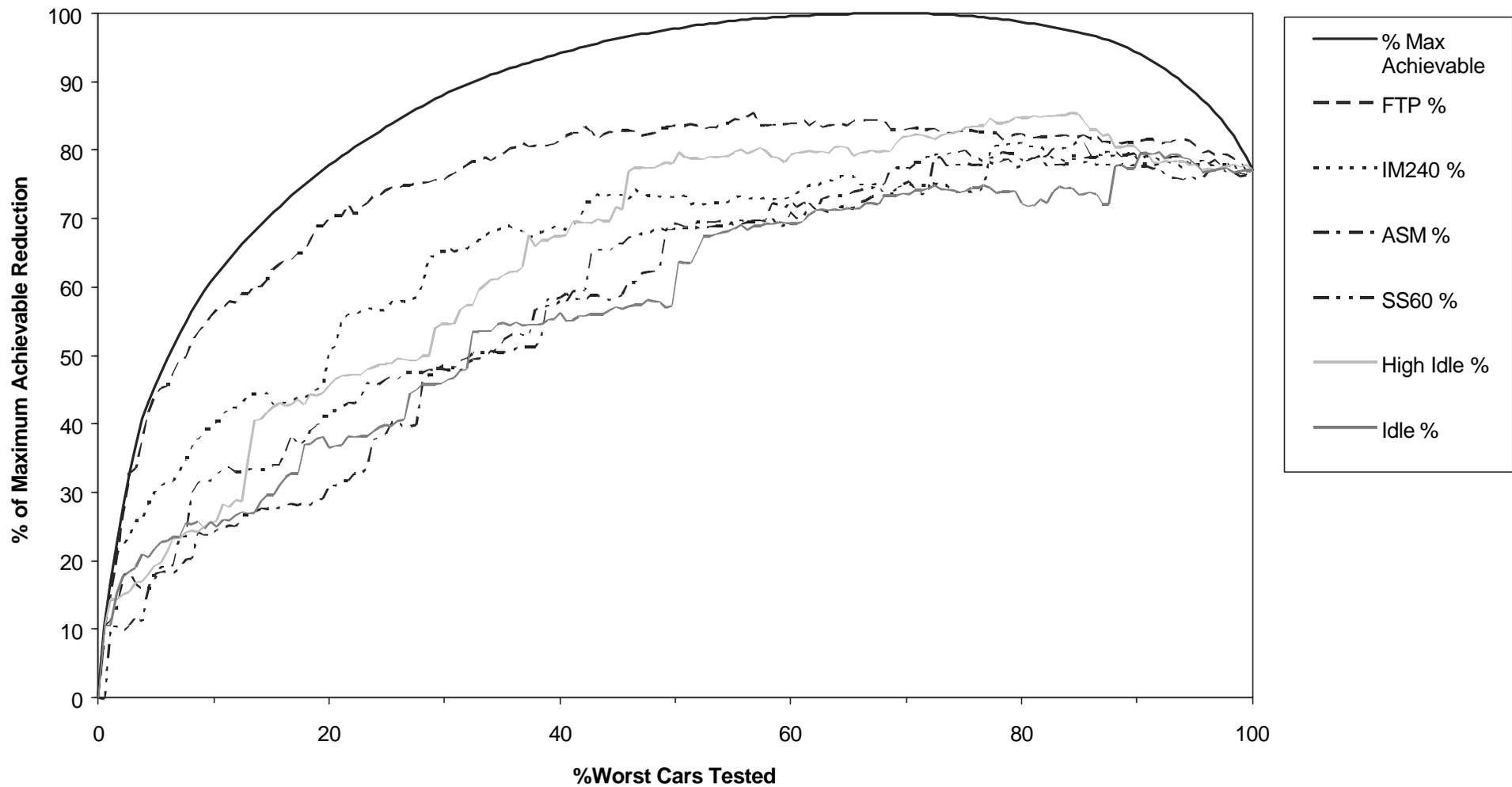


Figure 2-85 Relative Effectiveness of FTP and Short Tests at Predicting Emissions Reductions from Tuning (ADR27 Cars, HC Emissions)

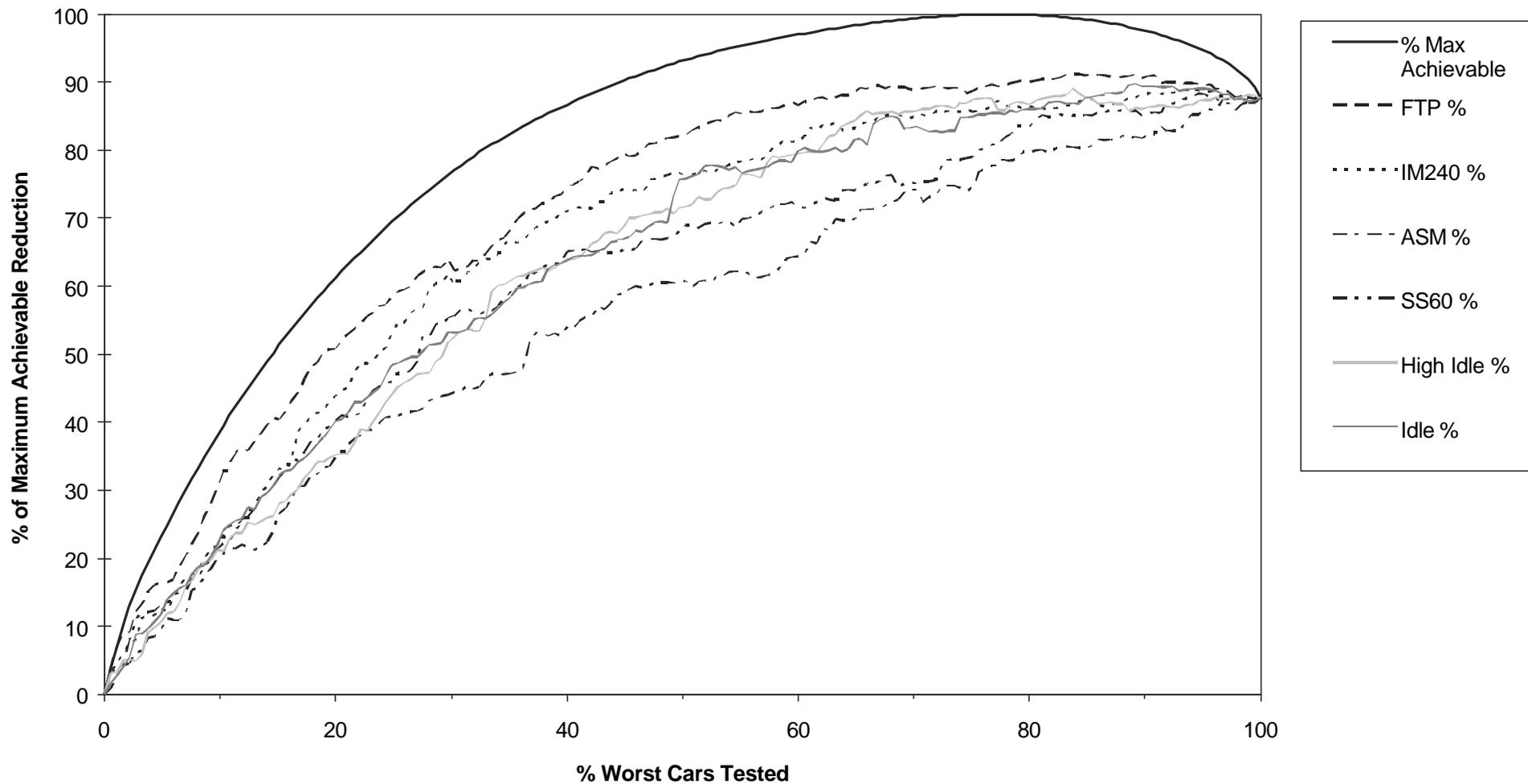


Figure 2-86 Relative Effectiveness of FTP and Short Tests at Predicting Emissions Reductions from Tuning (ADR27 Cars, CO Emissions)

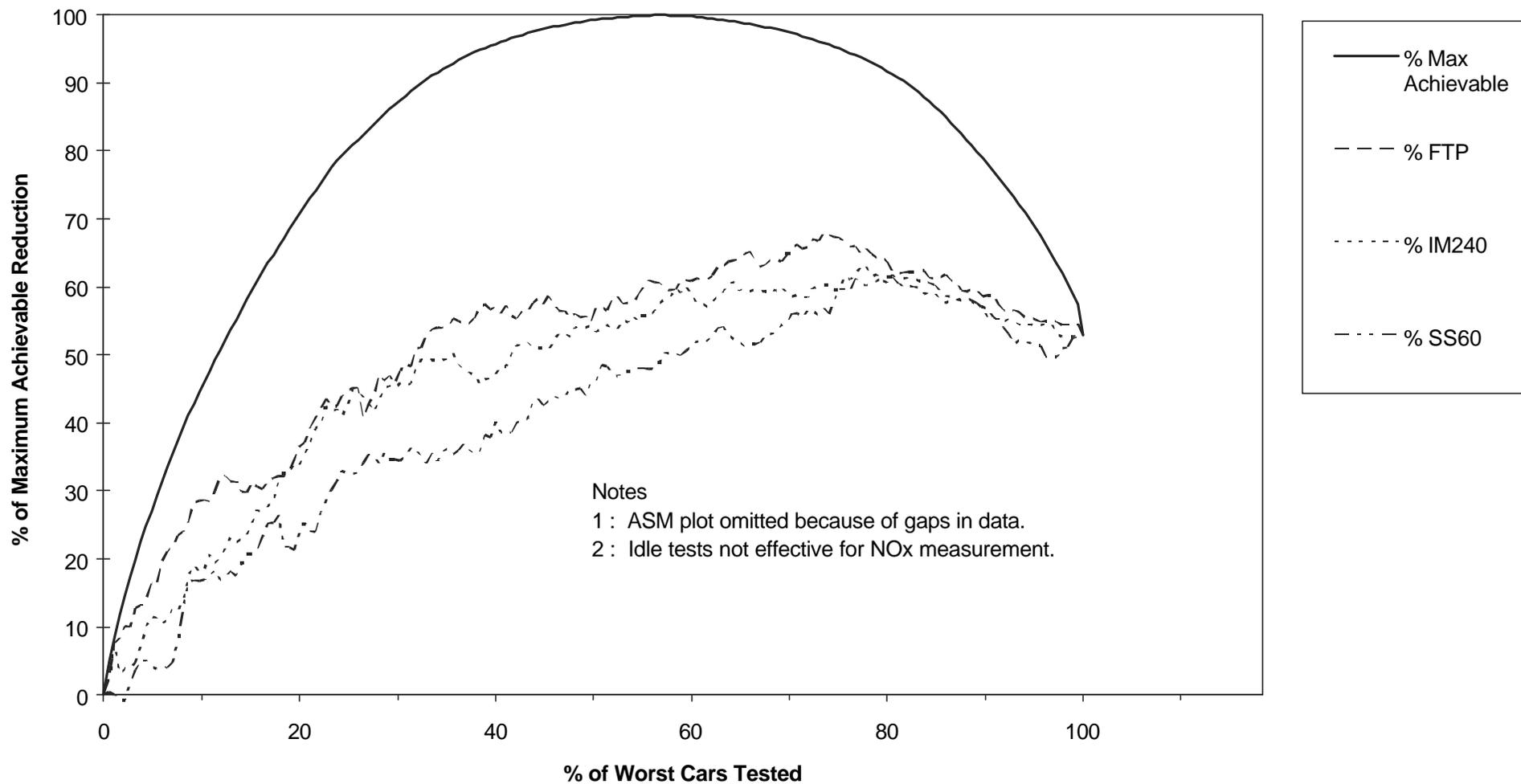


Figure 2-87 Relative Effectiveness of FTP and Short Tests at Predicting Emissions Reductions from Tuning (ADR27 Cars, NOx Emissions)

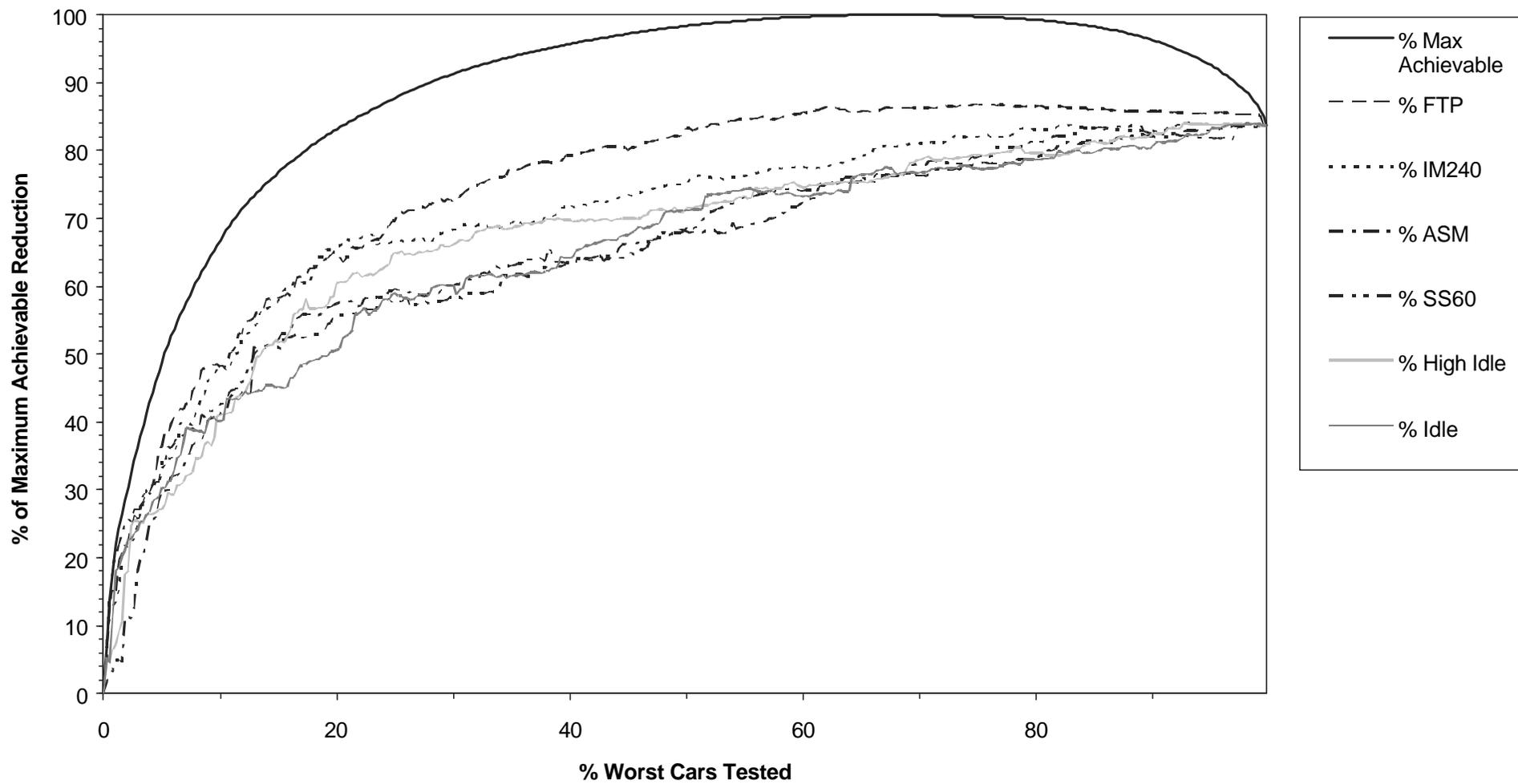


Figure 2-88 Relative Effectiveness of FTP and Short Tests at Predicting Emissions Reductions from Tuning (ADR37 Cars, HC Emissions)

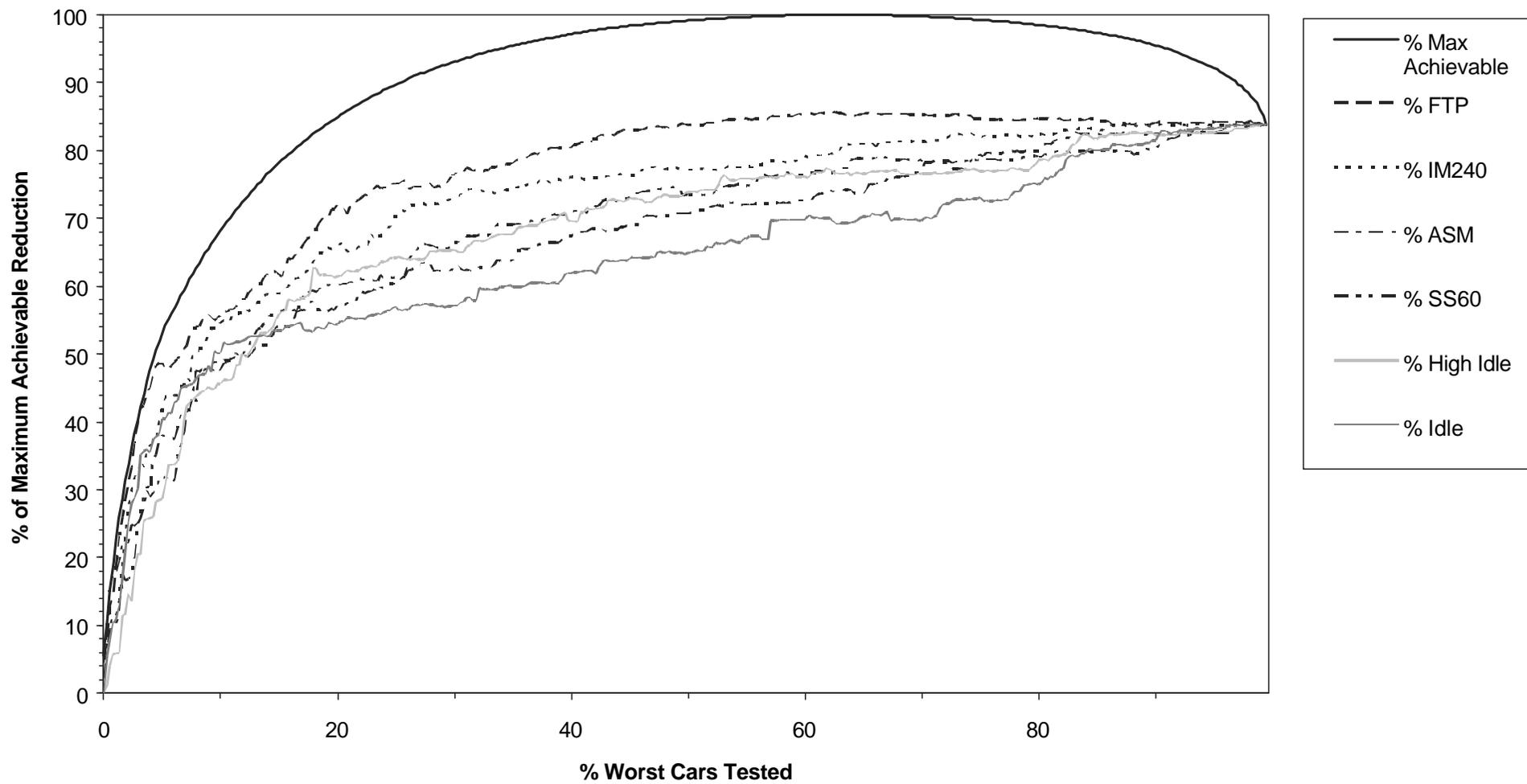


Figure 2-89 Relative Effectiveness of FTP and Short Tests at Predicting Emissions Reductions from Tuning (ADR37 Cars, CO Emissions)

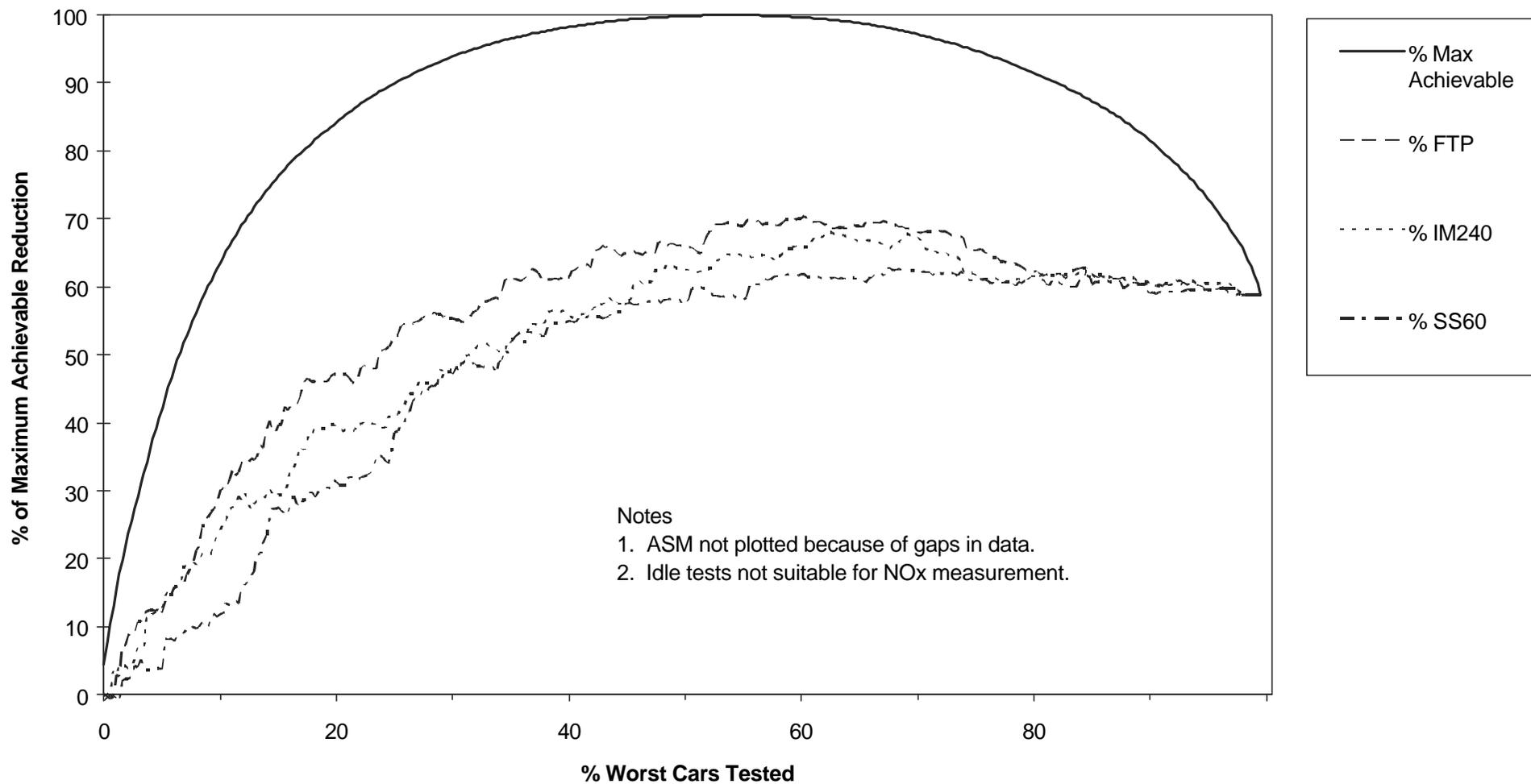


Figure 2-90 Relative Effectiveness of FTP and Short Tests at Predicting Emissions Reductions from Tuning (ADR37 Cars, NOx Emissions)

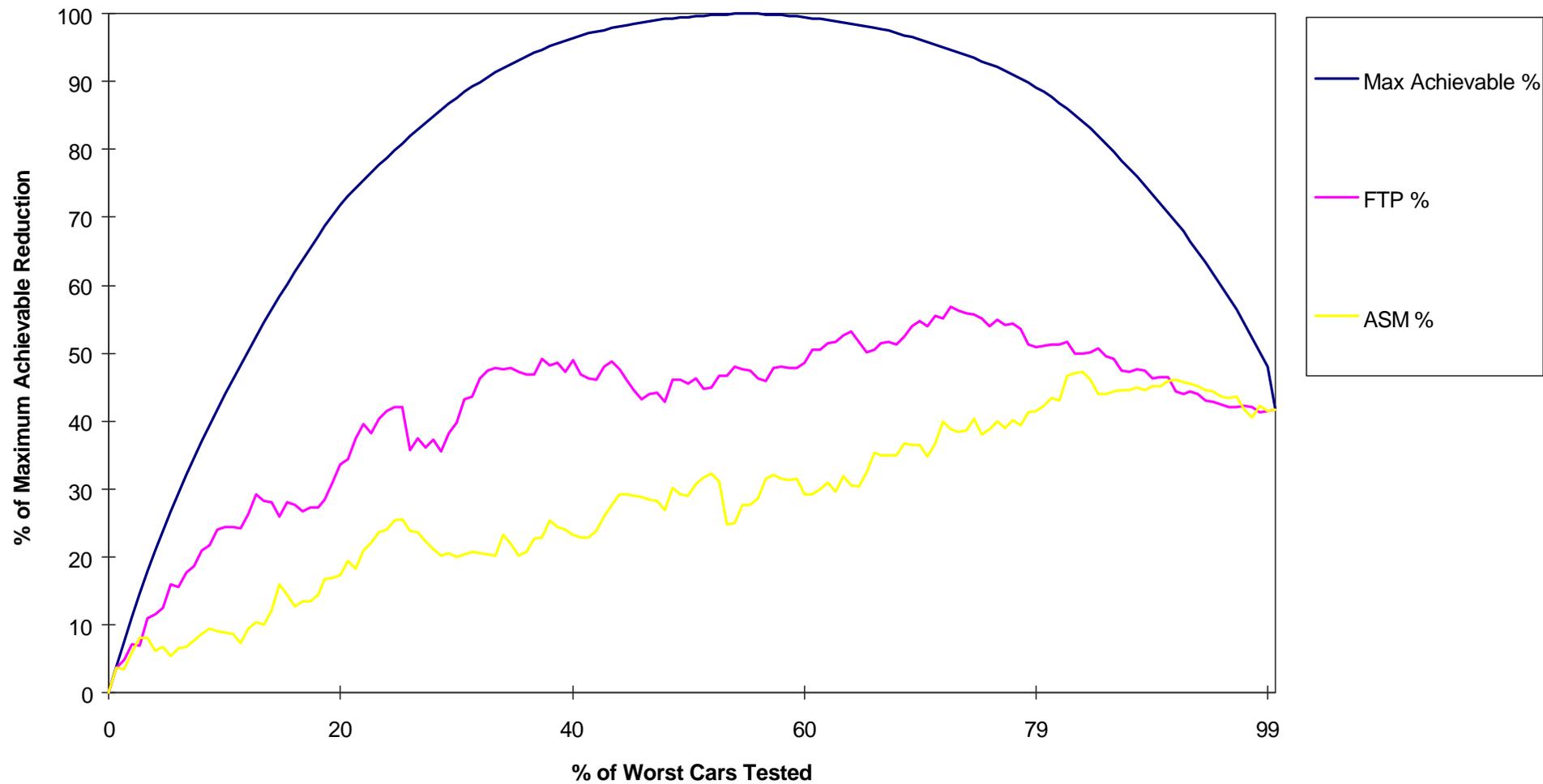


Figure 2-91 Relative Effectiveness of FTP and ASM Tests at Predicting Emissions Reductions from Tuning (ADR27 Cars, NOx Emissions)

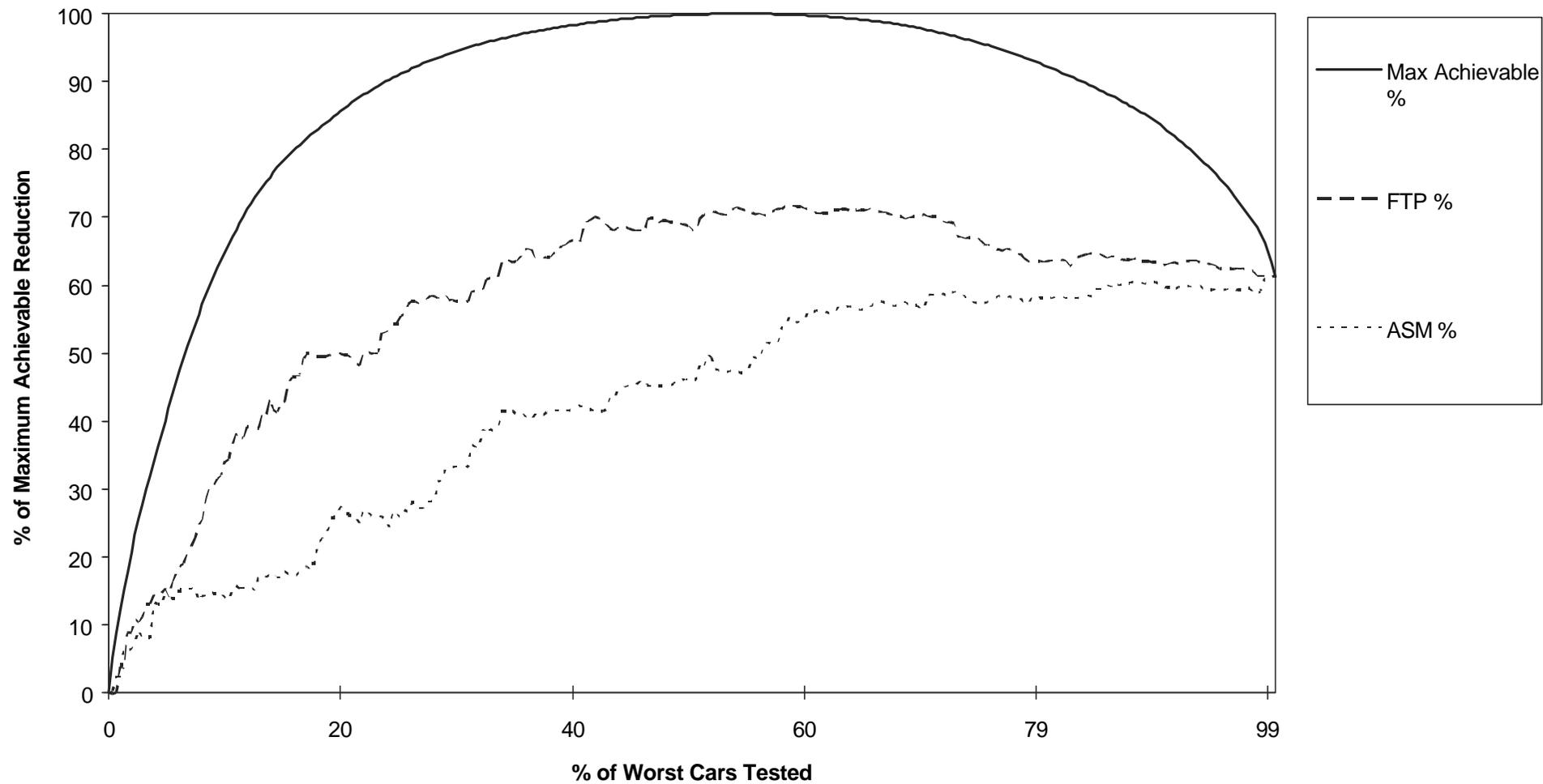


Figure 2-92 Relative Effectiveness of FTP and ASM Tests at Predicting Emissions Reductions from Tuning (ADR37/00 Cars, NOx Emissions)

## **2.8 HOUSEHOLD SURVEY RESULTS**

As explained in the introduction, almost all of the vehicles for the NISE Study were sourced via telephone surveys of households in the Sydney and Melbourne metropolitan areas. In conducting the surveys the contractor collected information on a range of matters relating to the vehicle owner and their use and maintenance of their vehicle. An assessment of the aspects of these data which would appear to have the potential to affect vehicle emissions, was undertaken. This analysis indicated that the only factor which appears to have an impact on emissions is the way in which the vehicle is maintained. In this analysis, those vehicles which were regularly serviced by a dealer had, on average, lower emissions than comparable vehicles that were serviced by a local garage or by the owner or a friend of the owner. The details of this analysis are on CD-ROM.

A copy of the questionnaire used in the survey is at Appendix V. The raw data from the household survey are also included on the compact disk version of the report, so that users can examine other relationships not considered in this report.

### 3. DISCUSSION OF RESULTS

#### 3.1 EMISSIONS FROM AUSTRALIA'S CAR POPULATION

##### **3.1.1 *Deterioration in emissions performance***

At first sight, overall emission levels from Australia's cars appear to be quite good in comparison with the standards to which they were originally designed. Closer inspection, however, shows that there are many areas for potential improvements and some of great concern.

Not surprisingly, there is clear evidence that exhaust pollution levels from cars increase with age and kilometres travelled. This deterioration varies widely among individual vehicles. A large number of cars continue to emit well below the mandated levels, while a small percentage exceed the allowable limits by a wide margin.

If emissions from the high polluters can be brought back to levels close to the current average, it will be possible to achieve substantial reductions in overall car pollution, with corresponding improvements in urban air quality.

Modern cars rely heavily on "active" systems to control pollution levels (catalytic converters, on-board computers and sensors, etc). From data collected in the NISE project, it appears that these vehicles tend, on average, to deteriorate at a greater rate than older, pre-catalyst vehicles, whose emission levels were more dependent on intrinsic design features (see Figures 2-15 to 2-17).

As a result, while new vehicles start from a much lower base, their higher deterioration rates could mean that the advantages of tighter new car standards may not be sustained in the longer term unless steps are taken to keep these cars in good condition.

Moreover, with even tighter standards and, possibly, extended durability requirements already on the horizon, manufacturers may be facing a considerable technological challenge to build vehicles that will continue to meet future standards for the duration of their service life.

##### **3.1.2 *Distribution of pollution***

If we know the average emissions from cars by year of manufacture, the average kilometres travelled by cars in each age group and the actual number of cars in each age group, we can easily calculate the relative (and absolute) contribution of each age group of cars to total pollution levels.

Coupling the emission data obtained through the NISE research with Australian Bureau of Statistics figures on vehicle usage and age distribution, Figures 2-11 and 2-12 show that vehicles aged 10 to 16 years currently dominate the pollution scene for hydrocarbon (HC) and carbon monoxide (CO) tailpipe emissions.

This phenomenon was less evident for oxides of nitrogen (NO<sub>x</sub>). See Figure 2-13.

Cars in the middle age group tend to stand out because they:

- (a) have fairly high average emissions;
- (b) are still driven fairly intensively; and
- (c) are still very numerous because of Australia's extremely low fleet turnover rate.

Newer cars, while accounting for higher average annual travel, have generally low average emissions provided they are well maintained.

However, given the elevated deterioration rates observed in catalyst equipped vehicles, it is possible that cars in this group may become a significant problem as they get older unless steps are taken to maintain the functionality of their emission control systems.

Older vehicles tend to have rather high individual emission levels, but contribute a diminishing amount to total pollution levels because of the generally low annual distances travelled by this group.

No group can be totally discounted, however, as individual vehicles in all groups were found to emit extremely high levels of pollution (up to 100 times typical new car levels) and these should be rectified regardless of age or usage.

### **3.1.3 *Evaporative Emissions***

In the past, regulators and researchers have tended to focus on what comes out of the exhaust pipe. The NISE project has raised a number of serious concerns about "real world" levels of evaporative emissions.

These concerns relate both to the relevance of current test procedures (particularly the certification test fuel) and to the durability of evaporative emission control systems fitted to cars.

Using the NISE test fuel, which is typical of summer grade commercial gasoline, evaporative emission levels were found to be many times the maximum permitted ADR levels.

Even modern ADR 37/00 vehicles tested in the main sample had evaporative emissions that averaged four times the ADR limit.

The reasons for this are not entirely clear, but certainly the substantial difference in vapour pressure between certification test fuel and typical pump petrol plays a major role.

In limited back-to-back tests using both certification test fuel and the NISE test fuel on a small group of cars, recorded emission levels were consistently much higher for the NISE fuel (typical pump petrol). See Figure 2-43.

Huge differences were also observed in the performance of individual vehicles.

Some commentators have suggested that the activated charcoal in the vapour collection canister becomes contaminated by oil fumes or other residues in a relatively short time, greatly reducing the adsorption capacity of the charcoal canister.

The durability of fuel filler cap seals also appears to have a significant influence on the pressure integrity of cars' fuel systems. Replacement of the fuel filler cap on those cars with high evaporative emissions had a marked effect on test results (see Figures 2-41 and 2-42).

As most airshed models tend to use the certification limit for estimates of evaporative emissions, it would seem that some fundamental re-calibration of the computer models may be necessary in the light of what is now known about the car fleet's characteristics.

The gross levels of evaporative emissions found in the NISE study should be a cause of great concern to regulators, the oil industry and the vehicle manufacturing industry alike.

**Note:** The Federal Government is already funding a complementary study into evaporative emissions, which may shed further light on the causes of high evaporative emissions, and may lead the way towards possible solutions.

## 3.2 POTENTIAL FOR EMISSION REDUCTIONS

### 3.2.1 *Effect of tuning and maintenance on tailpipe emission levels*

The results of testing done in the NISE study clearly demonstrate that substantial reductions in pollution levels can be achieved through good maintenance practices.

The overall levels of improvement are tabulated below:

	<i>All Cars in Study</i>	<i>ADR27 Cars</i>	<i>ADR37/00 Cars</i>
<b>HC</b>	16%	14%	21%
<b>CO</b>	25%	26%	24%
<b>NOx</b>	9%	8%	9%

However, the gains are not uniformly distributed, with most of the available improvements coming from a relatively small proportion of the total car population (Figures 2-34 and 2-35).

Typically, around 80% of the total emissions reductions available from tuning were delivered by only 20% of the cars in the NISE study sample.

Given this finding, one of the key policy issues to be faced by regulators in considering options for emission reduction programs will be whether to:

- (a) subject all vehicles to an inspection and maintenance regime;
- (b) only include pre-defined groups selected by age, kilometres travelled, etc; or
- (c) target vehicles to be included by some filtering mechanism such as remote sensing or a short test.

Detailed analysis of these options falls outside the terms of reference of the NISE study, but it is clear that the choice of approach may impact heavily on the cost-effectiveness of any future programs. (The relative effectiveness of most of the eligible short tests and the costs of tuning and maintenance are, nevertheless, covered extensively in this report and are discussed in following sections).

A further issue that has been a matter of some contention between various agencies, is whether it would be more effective to focus on introducing more

stringent standards for new cars, instead of trying to clean up existing vehicles.

Deterioration trends identified by the NISE research clearly shows that tighter new standards are only of lasting value if the vehicle is maintained in such a way as to retain, so far as possible, the new car performance. The data also suggest that modern vehicles deteriorate at a faster rate than older cars.

One could argue, therefore, that tighter new car standards actually increase rather than diminish the need for in-service maintenance programs.

*Tuning existing cars would achieve a reduction in HC emissions ten times greater than that from requiring all new cars sold in 1997 to have zero emissions*

It should also be appreciated that, because of Australia's extremely low vehicle turnover and scrappage rates, the effects of changes to new car standards take many years to significantly penetrate the fleet.

To illustrate this point, the project team calculates that, in one year, tuning the existing car population would achieve a reduction in HC emissions ten times greater than would be achieved by requiring all new cars sold in 1997 to be zero emission vehicles!

### **3.2.2 Effect of tuning and maintenance on evaporative emissions**

In respect of evaporative emissions, the extremely high test results clearly indicate a need for action, particularly as it appears that emissions can often be substantially reduced by replacing key components.

Those cars with particularly high evaporative emissions tended to respond strongly to the fitment of a new, properly sealing fuel filler cap.

Because of cost constraints, only a small sub-set of six cars had a new charcoal canister fitted. All six showed a dramatic decrease in emissions with the new canister: some by a factor of seven or more. (Readers should note, however, that the statistical validity of this finding is limited by the small sample size).

The whole issue of testing and design for evaporative emissions should be reviewed in the light of this study's findings. A complementary study into evaporative emissions, funded by the Federal Government, may assist in resolving some of the questions raised in the NISE study.

### 3.3 EFFECTIVENESS OF SHORT TESTS

#### 3.3.1 Correlation between short tests and FTP test results

This issue has pre-occupied many researchers, particularly in the USA, over recent years. Not surprisingly, the NISE study found that, in general, loaded (dynamometer) tests provide better correlation than non-loaded (idle) tests, although there were a few exceptions. The correlations are summarised below.

	ADR27			ADR37		
	HC	CO	NOx	HC	CO	NOx
<b>IM240</b>	0.80	0.93	0.91	0.94	0.90	0.90
<b>SS60</b>	0.62	0.80	0.74	0.80	0.84	0.72
<b>ASM</b>	0.52	0.71	0.69	0.64	0.78	0.68
<b>Hi Idle</b>	0.49	0.71	N/A	0.70	0.62	N/A
<b>Idle</b>	0.44	0.55	N/A	0.72	0.67	N/A

The NISE results do not, however, reflect the results of recent research in the USA<sup>(1)</sup> which demonstrated almost identical and extremely high correlations for the IM240 and ASM (Acceleration Simulation Mode) tests relative to the FTP test.

The IM240 test achieved by far the highest correlation with the FTP test for all gases, and for both ADR27 and ADR37/00 cars. The consistent second best correlation was provided by the SS60 test, which performed better on ADR37/00 vehicles than on ADR27 cars.

The ASM test, which was expected to provide good correlation, came a fairly poor third and, in one case, had a lower correlation than the idle tests.

The two idle tests had the lowest correlation with FTP results, with neither showing a particular benefit over the other.

In summary, while the IM240 test showed the best correlation, it is only suited to a centralised approach, with high capital costs and specialist operator skills. The ASM and the two idle tests all had inferior correlation levels and some were incapable of measuring NOx levels at all.

The SS60 test appears to provide the most practicable option for a short test, demonstrating good correlation with FTP results yet being suited to both centralised or distributed operation with relatively low capital costs.

### 3.3.2 Effectiveness of short tests

Correlation with the FTP cycle is only one part of the story. The bottom line for environmental planners is the impact that an emissions reduction program will have on overall pollution levels and at what cost.

Hence it is important to look carefully at the effectiveness of the various short tests in picking out those cars that will deliver the greatest reductions in emission levels when tuned. Costs are covered in a later section.

The relative effectiveness of each short test was assessed by analysing the actual emission reductions achieved through tuning vehicles picked out as the highest emitters by each of the five short tests.

For each short test, the database was sorted to identify vehicles with the highest test results then, by reading across to the FTP test results for each car, the actual emissions reduction from tuning was tabulated.

On a cumulative basis, the emission reductions achieved by each short test relative to the maximum achievable reductions was calculated and plotted on common axes. For reference purposes, the NISE efficiency factor for the FTP test was also plotted. (Figures 2-85 to 2-92)

The FTP test stands out as consistently identifying the small percentage of cars that will give the biggest tuning effect, with the IM240 test a clear second. What greatly surprised the project team was the relatively small and varying differentiation between the effectiveness of the other tests included in the NISE study.

*The IM240 test was the most effective short test for identifying those cars likely to give the most benefit from tuning*

*Of the steady state  
namometer tests, the  
'60 protocol appeared  
be the most effective*

Of the remaining short tests, the SS60 protocol appeared to give the best combination of correlation with FTP results and ability to identify those cars that would most benefit from tuning.

All the tests were quite effective at selecting those cars that delivered the greatest tuning effect (noting that the idle tests are not suitable for measuring NOx emissions).

The general shape of the effectiveness curves generated by this process show a steep initial slope, indicating high emission reductions from a small number of cars. The slope gradually flattens as those cars less responsive to tuning are picked up.

None of the tests were particularly effective at predicting the negative tuning effect evident in some vehicles, which is clearly apparent in the "maximum achievable" curve for each gas.

To a greater or lesser extent, depending on the efficiency of the test, the negative results tended to be distributed through the sample. Hence the less discriminating tests exhibited a flatter profile and a lower efficiency factor.

Regardless of which test is used as an indicator of emission levels, it is clear that there is very little marginal gain in tuning more than the worst 40% of cars. Detailed cost-benefit studies may suggest an even lower proportion.

*There is little to be gained from tuning more than the worst 40% of cars, regardless of which test is used.*

The question of which short test might provide the optimum solution will receive intensive further analysis by environmental and transport planners. Further comment on this issue falls outside the scope of this study.

### **3.3.3 Fuel consumption issues**

The good news on the fuel consumption front is that even though the focus of the tuning/repair procedures employed in this Study was to reduce the emissions contributing to air pollution, these steps also lead to improvements in average fuel consumption. While these benefits were small in percentage terms, the impact of these sorts of tuning practices, if applied to the whole of the Australian car fleet, would lead to significant reductions in total petrol consumption, and thus annual operating costs to vehicle owners.

### **3.3.4 Cost of repairs and maintenance**

The Study revealed that, on average, the emissions benefit gained from the tuning/repair procedures used in this Study does not require the replacement of major or expensive parts. The average cost to undertake the tuning and minor repair procedures in the Study is estimated at around \$200 (including labour) for both ADR27 and ADR37/00 vehicles.

## **3.4 SUMMARY**

The following points summarise Australia's car pollution situation and the potential for improvement:

- A well maintained passenger car fleet could reduce pollution to between 9% and 25% below existing levels.
- These reductions would be accompanied by substantial greenhouse gas reductions and fuel savings of up to \$200 million per annum.
- The average cost of servicing, repairing and adjusting a car to achieve the above results is around \$200 at typical 1996 motor vehicle repair industry rates.

- Evaporative emissions of hydrocarbons appear to create a major problem and there is some doubt as to whether the current certification test sets adequate “real world” design criteria for manufacturers to follow.
- Relatively low cost, effective tests are available to identify high polluting cars.
- One simple dynamometer-based test (SS60 test) appears to offer the best combination of correlation with the ADRs and capability to select cars that will benefit most from tuning.

Cost-effective policies for pollution control will rely on a carefully balanced combination of new car standards and workable in-service maintenance programs. Neither approach alone will deliver the goods.

The NISE study report provides a solid foundation for developing these policies.

**National In-Service  
Vehicle Emissions Study**

**APPENDICES**

# Contents

	<b><u>Page</u></b>
Appendix I Contributors and Contractors to the NISE Study	A-1
II Sources of Air Pollution	A-5
III Managing Authority & Phases of the NISE Study	A-8
IV Sample Design Phase - brief description	A-12
- Sample Design [on CD-ROM only]	
V Sourcing & Survey Phase :	A-14
- Attachment A : Introductory &	
Confirmation letters	A-21
- Attachment B : Survey Questionnaire	A-26
VI Testing Quotas :	A-35
1. the original testing quota :	
600 vehicles (1980-1991)	A-36
2. extension of the original testing quota :	
description of groups of additional	
88 vehicles	A-37
VII Testing Phase Overview :	A-43
- Test fuel specification	A-45
VIII Vehicle Testing & Tuning :	A-46
PART 1 : Pre-test and Test Procedures	A-49
PART 2 : Vehicle Inspection and Test Sequence	A-77
PART 3 : Tuning Specifications	A-79
IX Data from Testing and Inspection	A-81
X Correlation Vehicle Procedures	A-87

# **APPENDIX I**

## **CONTRIBUTORS & CONTRACTORS**

### **NISE Study**

# **National In-Service Vehicle Emissions Study**

## **CONTRIBUTORS**

### **SUPPLY OF REPLACEMENT VEHICLES**

- Toyota Motor Corporation Australia Ltd (special thanks to Tony Jeffery)
- Mitsubishi Motors Australia Ltd (special thanks to Rex Keily)
- General Motors-Holden's Automotive Ltd (special thanks to Ty Halsted)
- Ford Motor Company of Australia Ltd (thanks to John McKeown)
  
- DASFleet (particular thanks to Bevan Liebke for his generosity and understanding)

### **COMPREHENSIVE INSURANCE COVER**

NRMA Ltd (special thanks to Jack Haley and Cheryl Ayres)

### **VEHICLE TUNING & ROAD SERVICE**

NRMA Ltd (thanks to Jack Haley and NRMA mechanics)

RACV Ltd (special thanks to Bob Powell, Michael Case and RACV mechanics)

### **SUPPLY OF CATALYSTS**

Manumatic Industries [thanks to Ron Matz]

# **National In-Service Vehicle Emissions Study**

## **CONTRACTORS**

The late E K Foreman - Sample Designer

AGB McNair Pty Ltd - household survey, vehicle sourcing  
[thanks to Phil Hughes, Craig Evesson & AGB McNair staff]

Ford Motor Company of Australia Ltd - vehicle testing  
[thanks to John McKeown and staff at the Ford lab]

Environment Protection Authority of NSW - vehicle testing  
[thanks to Wayne Scott & staff and the EPA NSW lab]

Victorian Environment Protection Authority - vehicle testing  
[thanks to Stewart McDonald & staff at the Vic EPA lab]

ANUTECH Pty Ltd - data analysis  
[thanks to Ray Chambers for his devotion to duty both here & abroad]

Mobil Oil Australia Ltd - provision of test fuel  
[thanks to Tony Stone]

## **PROJECT MANAGEMENT**

Peter Anyon [FORS] : Project Director

Deborah Jones [FORS] : Manager, Sourcing & Survey Phase; and  
Workshop organiser

Jon Real [FORS] : Manager, Testing & Data Collection Phase; and  
Convenor, Testing Group

Robert Jamieson [FORS] : Technical Advisor / data analysis

John Weatherstone [FORS] : Project management

Lisi Bromley [Public Affairs] : Artwork / report cover design

# **National In-Service Vehicle Emissions Study**

## **ADVISORY COMMITTEE**

[excluding FORS]

ANUTECH Pty Ltd [Dr Ray Chambers]

Environment Protection Authority NSW  
[Chris Eiser / Vera Ballantyne / Wayne Scott]

Ford Motor Company of Australia [John McKeown]

Federal Chamber of Automotive Industries  
[represented by Mr John McKeown, Ford]

Victorian Environment Protection Authority [Doug Munro]

Royal Automobile Club of Victoria (RACV) [Bob Powell / Michael Case]

NRMA Ltd [Jack Haley]

Australian Institute of Petroleum [Rod Corinaldi / Barry Challenger]

Mobil Australia [Gary Jackson]

Motor Trades Association, NSW [Frank Davis / Chris Dunstan]

Australian Automobile Association [Brian Wells]

Commonwealth Environment Protection Agency  
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National Road Transport Commission [Ross McArthur]

AGB McNair Pty Ltd [Craig Evesson]

Roads & Traffic Authority, NSW [Bruce Dowdell]

# **APPENDIX II**

## **SOURCES OF AIR POLLUTION**

## SOURCES OF AIR POLLUTION

Atmospheric pollutants have effects both on human health and on the environment and are derived from a wide variety of anthropogenic and natural sources. Fossil fuel combustion, particularly by motor vehicles, has been identified as the largest single contributor.

Engines used for transport activities are responsible for almost all of the lead and carbon monoxide pollution and around half of the hydrocarbons and nitrogen oxides. Stationary sources, such as industrial processes, domestic heating and electricity generation from fossil fuels, account for the remainder. Evaporation into the atmosphere of volatile fuels and solvents is a major non-combustion source of air pollution.

## NATURE OF POLLUTANTS

Air pollutants can be divided into two broad categories. Those directly emitted from the source (such as carbon monoxide, lead and particulates) are described as primary pollutants. Derived or secondary pollutants are those formed by chemical reactions in the atmosphere, such as photochemical oxidants (eg. ozone).

The effects of primary pollutants are generally localised around the emission sources, for example, in areas adjacent to traffic corridors and industrial sites.

Secondary pollutants, such as photochemical oxidants, can be transported over long distances, and their effects are felt not only in the source vicinity but also in relatively remote areas.

For typical developed, industrialised countries, the total environmental damage costs due to all sources of air pollution have been estimated to be around one to two per cent of national GDP. In Australia this would be around \$4.8 billion.

Atmospheric pollutants cause a range of effects on human health (irritation of respiratory, eye, or other systems; acute toxic systemic effects; mutagenic or carcinogenic actions; adverse effects on defence mechanisms against infections) and on the environment (material soiling; corrosion; decreased visibility).

Certain of these effects may be immediately apparent and relatively easily traceable to the source. The odour of diesel vehicles is an illustration of these. Other effects may occur in the short term, but the precise contribution the various sources is not always clear. Examples are the toxic effects of atmospheric lead on children, or the link between oxides of nitrogen emissions and respiratory tract irritation.

Some effects may take a long time to become apparent, making it difficult to draw a causal link between various emissions. Further problems are sometimes introduced by a lack of complete scientific understanding of the process.

## CONTROL STRATEGIES AND LIMITATIONS

Australia has made significant improvements in the control of pollution from motor vehicles, including the mandatory use of unleaded petrol since 1986, and the progressive introduction of tighter standards on both tailpipe exhaust and evaporative emissions.

A new standard for diesel engined vehicles was published in September 1993, and a new standard for petrol-engined vehicles was published in 1995. These changes will keep Australian standards for new vehicles in line with international best practice.

However, tighter standards for new cars will have only a small impact on today's urban air quality problem because new cars can take up to 5-7 years to significantly penetrate the fleet. To address today's problems we need to focus on the vehicles already on the road.

The key to reducing vehicle related pollution in the short term is first to identify, and then rectify those vehicles which have poor emissions performance. These are the vehicles which are badly maintained, or have faulty, or tampered with, emission control systems.

# **APPENDIX III**

## **MANAGING AUTHORITY AND PHASES OF THE IN-SERVICE STUDY**

## MANAGING AUTHORITY

The Federal Office of Road Safety, within the Department of Transport managed the National In-Service Vehicle Emissions Study (NISE Study).

Several State and non-government organisations were contracted to perform testing for the Study, and widespread support has been received from the vehicle industry and motoring organisations.

## ADVISORY COMMITTEE

An Advisory Committee met quarterly to

- review progress
- ensure that the project remains focussed on its objectives
- consider any changes to the program that may improve its outcomes.

This Committee was Chaired by the Project Director, Mr Peter Anyon, Federal Office of Road Safety, who had primary responsibility for the Study.

The Advisory Committee was composed of representatives from the major participating organisations in the Study, as follows :

- Federal Office of Road Safety
- ANUTECH Pty Ltd
- AGB McNair Pty Ltd
- Environment Protection Authority NSW
- Ford Motor Company of Australia
- Victorian Environment Protection Authority
- Royal Automobile Club of Victoria (RACV)
- NRMA Ltd
- Australian Institute of Petroleum
- Mobil Australia
- Motor Trades Association, NSW
- Australian Automobile Association
- Commonwealth Environment Protection Agency
- National Road Transport Commission
- Federal Chamber of Automotive Industries

## TESTING GROUP

The Study's Testing Group met on an 'as required' basis to

- Oversight and co-ordinate testing procedures, correlation between test laboratories, and data collection; and
- resolve any particular difficulties relating to testing procedures and/or data collection.

Members of this Group comprise representatives from organisations contracted to perform the emissions testing, as well as the project's contracted data analyst, and was convened by the Manager of the Testing and Data Collection Phase of the Study, Mr Jon Real [Regulation Policy and Projects Section, FORS].

## SOURCING AND SURVEYS

The Manager of the Sourcing and Survey Phase of the Study, Ms Deborah Jones [Regulation Policy and Projects Section, FORS], has been responsible for overseeing matters relating to vehicle sourcing, owner surveys, the provision of replacement vehicles and delivery of test vehicles to and from testing laboratories, vehicle insurance and the tuning of vehicles.

The management of these services has been conducted through close liaison with the Study's survey contractor [AGB McNair Pty Ltd], the vehicle co-ordinators from each of the emissions testing laboratories, the Study's data analyst, and with organisations such as the NRMA, RACV and DASFLEET.

Reports on the progress of the Sourcing and Survey Phase were presented quarterly to the Study's Advisory Committee.

## PHASES OF THE STUDY - PROJECT STRUCTURE

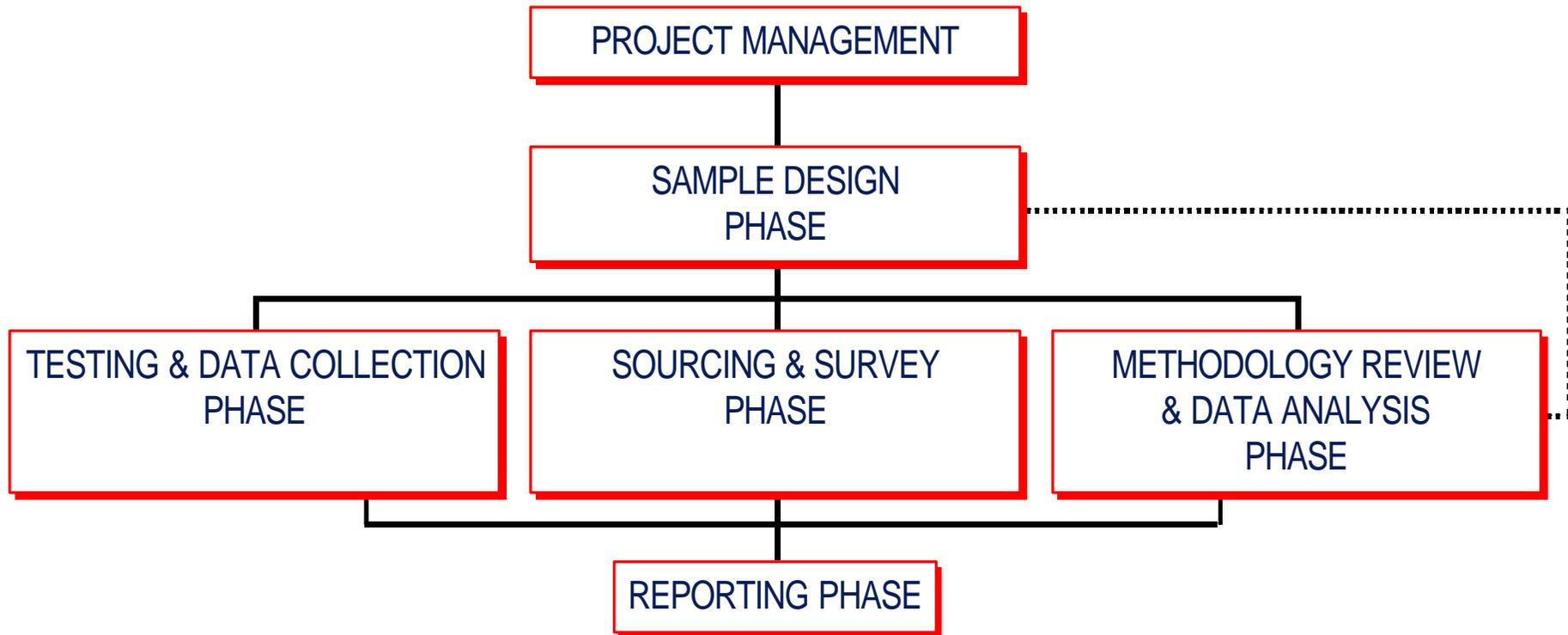
The National In-Service Emissions Study comprised four (4) basic phases:

1. Sample Design : the design of the framework and benchmarks for the Study;
2. Sourcing and Surveys : survey of householders, sourcing of test vehicles; on-going consultation with the survey consultant and testing laboratories re availability of test vehicles; collection, replacement, delivery and return of test vehicles; vehicle insurance; vehicle tuning;
3. Testing : vehicle testing, incorporating general inspection and tuning of test vehicles; on-going consultation with testing laboratories; and data collection;
4. Data Analysis and Reporting.

Phases 1 to 3 are discussed in detail in the following Appendices. Outcomes of Phase 4, Data Analysis & Reporting, are exhibited throughout the main report, with some additional analysis (not used in the main report) embodied on CD-ROM.

# PROJECT STRUCTURE

## In-Service Vehicle Emissions Study



# **APPENDIX IV**

## **SAMPLE DESIGN**

## **SAMPLE DESIGN**

The Sample Design Phase was required to ensure an appropriate sample of vehicles is provided for testing, and to set an overall framework for the Study.

Budgetary constraints limited the number of vehicles which can be tested to around 600 and quotas in the sample design were based on this number.

The Sample Design incorporated a pilot test phase of 22 vehicles to verify the sample. This was conducted by the survey consultant and emissions testing laboratories in March-April 1994. The data resulting from the pilot phase was also assessed by the Study's data analysis consultant.

The Sample Design was prepared by the late Mr Ken Foreman in October 1993 and can be viewed on the CD-ROM which is enclosed with the main Report.

# **APPENDIX V**

## **SOURCING & SURVEY PHASE**

## SOURCING AND SURVEY PHASE

### 1. CONTRACTOR

AGB McNair Pty Ltd, based in North Sydney, was commissioned in January 1994 by the Federal Office of Road Safety (FORS) to undertake the Sourcing and Survey Phase of the In-Service Vehicle Emissions Study.

Vehicle sourcing commenced on 22 March 1994, when the pilot test for the study took place.

### 2. SCOPE OF THE SOURCING & SURVEY PHASE

AGB McNair were commissioned to provide a series of staged household interviews over a period of approximately 20 months to :

- i. locate a statistically valid sample of owners/operators of vehicles that meet a set of criteria for emission testing, and who are prepared to release their vehicle for testing;
- ii. complete a short questionnaire on the use and maintenance of vehicle(s) in the household;
- iii. on a staged basis, provide testing laboratories with the addresses and related details of vehicles which are available for testing [vehicle owners were contacted by the testing contractors regarding pick-up times etc.]; and
- iv. on a staged basis, provide the data from the questionnaire to an independent analyst.

It was estimated that a total of 6,000 interviews would be need to be conducted in Melbourne and Sydney to obtain the required number of vehicles for testing. This number later proved to be correct, with a total of 5,900 interviews being conducted.

### 3. METHODOLOGY OVERVIEW

The following paragraphs provide a general outline of how the survey and sourcing phase operates. Subsequent sections provide more detail.

- A sample of potential respondents were selected randomly from OZ on Disk (an electronic telephone number listing).
- The potential respondents were then sent an introductory letter (**Attachment A**) outlining the study and stating that the survey is being undertaken by AGB McNair.
- A telephone survey was then conducted in which respondents answered a series of questions about usage and maintenance of each vehicle belonging to their household and some basic demographic information about each resident. (Questionnaire at **Attachment B**).

- If any of the vehicles were in the testing quota the respondent was given more detail about the testing process and asked if they would be willing to submit their vehicle for testing. (Testing Quota Table at **Appendix VI : Testing Quotas and Timelines**).
- Respondents who agreed to participate in the testing phase were then sent a confirmation letter (**Attachment A**) outlining the vehicle pick-up and return process. The letter also provided a contact name at the laboratory for any questions the respondent may have.
- AGB McNair then notified each laboratory of the vehicle selected for them to test.
- This process was repeated each week.
- AGB McNair sources a total of 650 vehicles over the course of the NISE Study.

### 3.1 COMPUTER ASSISTED TELEPHONE INTERVIEWING (CATI)

A CATI interview was selected as the medium for the survey and sourcing for several reasons:

- telephone interviewing provides a more cost effective approach than does face to face interviewing because of the low rate of incidence of the vehicles suitable for testing;
- The CATI facility allows all quotas to be rigidly controlled thus avoiding the inefficiencies of running over quota limits (this can be a problem in face to face surveys where complex quotas are set);
- The CATI facility enables the flexibility required for vehicle sourcing where vehicles may drop out of the testing phase at short notice (eg mechanically unsound, respondent refusals etc), or where laboratories require increases or decreases in the number of vehicles for testing.

### 3.2 TELEPHONE SURVEY SAMPLE DESIGN

The OZ on Disk facility was used to draw the sample frame. OZ on Disk is the Telecom White Pages from all over Australia entered onto CD ROM. The information for each person is the information in the White Pages - Name, Address and Telephone Number - enhanced with the addition of Postcode.

This method was appropriate because it allowed a random sample frame to be selected which could be sent an introductory letter prior to an interview being attempted. This would not have been possible had a random sample been drawn using a random digit dialling technique.

### 3.3 INTRODUCTORY AND CONFIRMATION LETTERS

In order to maximise the level of co-operation of respondents to, firstly, complete the survey and, secondly, to offer their vehicle for the testing phase an introductory letter was sent on FORS letterhead and signed by the FORS Project Director. The main objective of the introductory letter was to enhance the survey's credibility. This was especially

necessary in a survey where the ultimate aim was to 'borrow' someone's private vehicle for a period of several days.

The introductory letter outlined the objectives of the study, introduced AGB McNair as the research agency carrying out the telephone survey, explained the types of questions to be asked and briefly described the testing phase and the incentives to participate.

Although the introductory letter was addressed personally to the name listed in the White Pages, the main objective was to link the address with the telephone number so that anyone in the household with a vehicle had the opportunity to read the letter. The telephone survey was not necessarily completed by the actual person that the letter was addressed to.

The confirmation letter was sent to those respondents to the telephone survey who agreed to have their vehicle undergo the testing phase. The letter, again from the FORS Project Director, gave more detail about the actual testing procedures, information about the pick-up and return of their vehicle and contact details of the laboratory at which their vehicle is to be tested. The object of this letter was to provide further information and to confirm once again the credentials of the study, thereby minimising the dropout rate at this stage.

Copies of the Introductory and Confirmation letters appear as **Attachment A** to this Appendix.

### 3.4 QUESTIONNAIRE DESIGN

Development of the questionnaire centred on the following areas:

- designing an appropriate introduction for respondents who have read the introductory letter and those who had not read it;
- interviewing the resident(s) of the household who would be most appropriate for answering the vehicle questions and who could make a decision about submitting the chosen vehicle for the testing phase;
- structuring the questionnaire so that the same series of questions could be asked about each of the household's vehicles;
- structuring the questionnaire so that the same series of questions could be asked about each resident of the household;
- specifying definitions for - type of registration, traffic conditions, vehicle maintenance regime, dwelling.

A copy of the questionnaire appears in **Attachment B** to this Appendix.

### 3.5 VEHICLE TESTING QUOTA

Vehicles suitable for testing were required to fall within the following parameters:

- i. Year of manufacture : 1980 to 1991;
- ii. Manufacturer : General Motors Holden, Ford, Toyota, Mitsubishi and Nissan;
- iii. City : Melbourne or Sydney metropolitan areas.

In cases where there was more than one suitable vehicle in the household a random selection was made (the next vehicle due to registration) in terms of which to recruit for testing. This was also necessary so that respondents did not bias the sample by selecting which vehicle they would offer for testing.

### 3.6 TRANSFER OF VEHICLE INFORMATION TO LABORATORIES

After each recruitment wave, details of the recruited vehicles were faxed to the appropriate laboratories. The particular details were:

- AGB McNair ID number, name, address and telephone number of vehicle owners (part way through the pilot survey, business numbers were collected as well as home numbers to allow a higher level of 'contactability' with householders); vehicle manufacturer and model; date of recruitment; registration number; and year of manufacture.

The laboratories in turn informed AGB McNair of any vehicles which dropped out of the testing phase, due to householder changing their mind, or were unable to be tested due to unsafe condition of vehicle - the latter was determined when laboratories went to pick up a vehicle.

### 3.7 AGB MCNAIR IDENTIFICATION NUMBER

Each vehicle sourced by AGB McNair was allocated an AGB Identification Number (AGB ID number). This ID number has been used as the main identifier in the NISE Study.

At the end of the NISE Study all personal identification details such as name, address, telephone number of householders, and registration number of test vehicles will be discarded. The AGB ID number will be the sole identifier for each individual vehicle, linking each vehicle's test data and associated household data.

## 4. PILOT TEST

A pilot test was conducted by AGB McNair over several weeks with the first week of recruitment being 22 March 1994.

The main objectives of the pilot test were to:

- test all aspects of the questionnaire;
- assess the effectiveness of the introductory letter, particularly whether respondents took the opportunity to record vehicle details in readiness for the interview;

- establish the maximum time lapse between the introductory letter and the telephone interview before response rates begin to drop;
- measure the willingness of respondents to submit their vehicle for testing, identify any reasons for refusal to submit vehicles for testing and formulate appropriate changes;
- assess the effectiveness of the confirmation letter sent to respondents who agree to have their vehicle tested;
- test the transfer of vehicle information from AGB McNair to each testing laboratory; and
- measure the drop out rate of vehicles at the vehicle collection stage (undertaken by the laboratories).

#### 4.1 PILOT TEST RESULTS

There are two response rates to consider in the NISE Study. The first response rate, referred to as the 'telephone interview response rate', is the number of telephone interviews achieved from the number of telephone numbers in the sample. The second rate is the number of respondents who agree to have their vehicle tested, compared with the total number of respondents who have a vehicle valid for testing. This is the acceptance rate.

##### **4.1.1 Telephone interview response rates**

The introductory letter was well received by respondents and seemed to have a significant positive effect on the response rates achieved in the pilot test (this was the feeling of the interviewers).

Over the course of the pilot test respondents were telephoned up to 5 weeks after receiving the introductory letter. The response rate did not decrease as the time lapse increased.

A total of 178 interviews were obtained from the 411 households that were sent introductory letters - a rate of 43%. This number of interviews was adequate to thoroughly test the interview questionnaire and to ensure recruitment of enough vehicles for testing.

Completed interviews	178	43%
No. of vehicles in household	43	10%
Refusals	102	25%
Non contacts*	88	21%

\*Non contacts include - repeated no answers, repeatedly engaged, dead numbers, business numbers and respondents who speak no English.

##### **4.1.2 Acceptance Rate**

Without any previous experience in recruiting vehicles from the public for a project of this type the acceptance rate could only be estimated prior to the pilot test. It was thought that 10% was a reasonable estimate. In actual fact the acceptance rate in the pilot test

was a lot better than this estimate with approximately 80% of respondents who had a suitable vehicle agreeing to participate in the testing phase.

A total of 28 vehicles were recruited for the pilot test with each week's workload varying as the laboratories sorted out teething problems. None of the vehicles recruited for the pilot test dropped out of the testing phase at a latter date (it was expected that some respondents would change their minds about participating or that a vehicle may prove unroadworthy when being picked up).

#### **4.1.3 Changes to the questionnaire and CATI Program**

After the pilot test several changes were made to the questionnaire and CATI program resulting in the recording of more accurate data.

## 4.2 CONCLUSION

The pilot test proved to be a useful exercise in sorting out several teething problems with the survey design. Particularly in terms of the questionnaire and CATI program and response rates.

The introductory and confirmation letters promoted the authenticity of the survey and thereby had a positive impact on response rates. It was also found that many respondents took time to record vehicle information before the interviewer rang as suggested in the introductory letter. This minimised time spent waiting for respondents to collect vehicle information during the actual interview.

Respondents were found to be generally quite keen to participate in the telephone survey and the testing phase. A combination of advance knowledge of the survey, official verification of the survey's authenticity via the introductory and confirmation letters, minimisation of inconvenience to respondents, incentives such as the loan of a new model replacement vehicle, petrol and so on, and a positive attitude to the aims of the survey all contributed to the higher than expected response and acceptance rates.

The acceptance rate for the NISE Study continued to be very high throughout the full course of the project - with virtually no 'changes of mind' by respondents.

**ATTACHMENT A**  
**to Appendix V**

**INTRODUCTORY & CONFIRMATION LETTERS**

In-Service Vehicle Emissions Study

## **In-Service Vehicle Emissions Study**

### **INTRODUCTORY LETTER**

#### **Dear Car Owner**

As well as promoting safe use of our roads, the Federal Office of Road Safety has responsibility for a number of environmental issues relating to motor vehicles. At present, we are managing a national study to gather information about the relationships between motor vehicles and the air quality of our cities.

As part of the study, we are contacting a number of households in Sydney and Melbourne to gather some basic information on cars of various makes and ages, and how they are operated. The data from this study will be used to develop strategies for maintaining healthy air quality in Australian cities.

Your household has been selected at random from the telephone directory and the Federal Office of Road Safety is inviting you to participate in the study. At this stage we have no idea of what vehicles you may have, but this letter is intended to introduce you to the study and to give you some information on what sort of assistance we are seeking.

The study involves a short telephone interview with car owners and/or drivers. The Federal Office of Road Safety has engaged AGB McNair Pty Ltd, a company specialising in telephone surveys, to conduct these interviews. AGB McNair will be contacting you by telephone in the next two weeks.

The questions are quite simple and cover topics such as:

- make, model and year of manufacture of car (if you are not sure, these details can be found on your vehicle's registration document);
- how many kilometres it has travelled;
- how you maintain the vehicle;
- what are your usual driving conditions.

At the end of this letter you will find a space to write these details. Doing so may save you time and help you respond more easily to the telephone interview.

Depending on what car you drive, you may also be asked to participate in the second stage of the study, which involves some simple tests to measure fuel consumption and gases in the car's exhaust. These tests will tell us how engines operate in the driving conditions typically encountered in our cities.

Testing will replicate typical urban driving patterns, and will be done in a specially equipped laboratory under the supervision of highly qualified engineers. No actual road testing will be involved. We will, of course, make every effort to ensure you are not inconvenienced by supporting this project.

If you agree to participate in the testing phase, your car will be returned with a full tank of petrol, will receive an oil change and a tune-up to the manufacturer's specifications, and will be washed and cleaned. We will provide you, free of charge, with a current-model vehicle during the time we will have your car (probably around three days). When your vehicle is returned, you will receive a report detailing the exhaust gas and fuel consumption measurements, both before and after its tune-up.

If, for some reason, a vehicle does not fully meet normal roadworthy requirements, we will tell you what needs to be rectified. This is purely advisory and no action will be taken against any owner. Your responses to the questionnaire will be strictly confidential and not linked to you in any way.

If you are not a car owner or driver, we ask that you please show this letter to any person living at this address who might be able to participate in the study.

I hope you find this study interesting and can contribute to its success. Thank you for taking the time to read this letter.

Yours sincerely

Peter Anyon  
Project Director

#### **VEHICLE DETAILS**

Vehicle Make eg. Ford, Toyota	
Vehicle Model eg. Falcon	
Year of Manufacture	
Number of kilometres travelled	

## **In-Service Vehicle Emissions Study**

### **CONFIRMATION LETTER**

Dear Car Owner

The Federal Office of Road Safety has been greatly encouraged by the positive response from car owners throughout the Sydney and Melbourne metropolitan areas to our request to participate in this important study.

I wish to take this opportunity to thank you for offering your vehicle as part of the testing program and to provide you with details on the procedures which now need to be followed throughout the testing period.

#### **Contact from the Testing Stations**

An officer from the ..... Testing Laboratory will contact you to arrange a suitable day to pick up your vehicle and to provide you with a late model replacement vehicle.

#### **Testing of Your Vehicle**

As indicated in my introductory letter, testing will be undertaken in a specially equipped laboratory under the supervision of highly qualified engineers. No actual road testing will be involved.

Although we will need your car for approximately 3-5 days, the actual testing is quite short, involving a pre-tune and then a post-tune test of some 2-3 hours. However the preparation, conditioning, tuning and checking of the vehicle between the two tests is quite extensive and accounts for most of the time we will have your car.

#### **Insurance**

Arrangements have been made through the NRMA, as well as the Commonwealth and the Testing Stations to have insurance cover on all the vehicles involved in testing.

While your vehicle is with the laboratory it will be covered by that organisation's insurance cover. This cover will extend to the collection and delivery of your vehicle.

During the testing period your vehicle will be held in the secure premises of the testing stations. However the test station will be responsible for any fines or penalties that may occur during the collection or delivery of your vehicle.

The replacement vehicle provided to you over the testing period will be covered by a standard NRMA comprehensive insurance policy with normal excess being covered by the Commonwealth Government.

## **Replacement Vehicle**

The replacement vehicle provided will be a current model family sedan.

There will of course be a few minor formalities to be dealt with at handover. These are standard requirements and we ask that you read the conditions prior to handover of your vehicle and keep a signed copy for your own purposes.

It is essential that the driver of the replacement vehicle have a current driver's licence.

## **Handover Document**

The handover document contains an outline of the obligations of the driver whilst the replacement vehicle is in his or her care. This includes such items as compliance with all road laws, not driving whilst under the influence of alcohol or drugs, and an expectation that you will look after the vehicle. Once again you should read this prior to signing.

## **Check List on Condition of Your Vehicle**

A check sheet on the condition of your vehicle is also to be filled out by the officer collecting your vehicle and signed by you or your authorised agent at the time of collection and return of your vehicle.

## **Return of Your Vehicle**

Every effort has been made to ensure you are not inconvenienced throughout the test period and to make your contribution to the study worthwhile.

The Federal Office of Road Safety will do this by providing your vehicle with a tune-up, including an oil change and in addition the car will be cleaned and filled with petrol before it leaves the testing station.

On the return of your vehicle you will be given a report summarising the test results. If you have any inquiries either prior to the tests or regarding the summary report please call ..... at the ..... testing laboratory on Phone .....

Thank you once again for participating in this study.

Yours sincerely

Peter Anyon  
Project Director  
National In-Service Vehicle Study

**ATTACHMENT B  
To Appendix V**

**SURVEY QUESTIONNAIRE**

In-Service Vehicle Emissions Study

# VEHICLE EMISSIONS SURVEY

## SCREENER

- i. Good morning/afternoon, my name is ..... from AGB McNair, the market research company. This morning/evening we are conducting a survey on behalf of the Federal Office of Road Safety. The survey involves a few straight forward questions about the cars at your household.

May I speak with someone in your household who could answer some simple questions about the car or cars normally parked at this address?

- |                                     |   |   |
|-------------------------------------|---|---|
| Yes                                 | 1 |   |
| Yes, I'll get owner for you         | 2 | <b>RE-INTRODUCE YOURSELF<br/>&amp; GO TO ii</b> |
| There are no cars at this household | 3 | <b>TERMINATE &amp; RECORD</b>                   |
| No                                  | 4 | <b>NON-RESPONSE CODE</b>                        |

- ii. You should recently have received a letter from the Federal Office of Road Safety regarding the survey? Did you receive this letter? (It may have not been addressed to you personally)

- |     |   |                   |
|-----|---|-------------------|
| Yes | 1 |                   |
| No  | 2 | <b>GO TO Q.iv</b> |

- iii. Would you like me to recap the contents of the letter?

- |     |   |                        |
|-----|---|------------------------|
| Yes | 1 | <b>READ INFO BELOW</b> |
| No  | 2 | <b>GO TO Q.v</b>       |

- iv. Would you like me to explain what the letter was about?

**CHOOSE "SEND LETTER" ONLY IF THE RESPONDENT ASKS FOR IT.**

- |             |   |                        |
|-------------|---|------------------------|
| Yes         | 1 | <b>READ INFO BELOW</b> |
| No          | 2 | <b>GO TO Q.v</b>       |
| Send letter | 3 |                        |

**INFO** The Federal Office of Road Safety is managing a national study to gather information about how car engines perform, and how performance may change during the life of a vehicle.

The data from the study will be used to develop strategies to improve the operation of cars in the future, the ultimate goal being to decrease motor vehicles' contribution to air pollution.

Your household was randomly selected from the Sydney/Melbourne telephone book to be part of the survey sample - there is no other reason for your selection.

The study involves a short telephone interview with car owners and/or drivers. The questions are quite simple and cover topics such as the number of kilometres travelled, maintenance and usual driving conditions.

- v. Do you have a few minutes to answer some questions about your household car(s) - included as cars are passenger vans, utes and panel vans.

**IF RESPONDENT NOT AVAILABLE NOW SUSPEND INTERVIEW AND ARRANGE FOR CALL BACK**

- |         |   |                              |
|---------|---|------------------------------|
| Yes     | 1 | <b>GO TO Q.1</b>             |
| No      | 2 | <b>ARRANGE CALLBACK</b>      |
| Refused | 3 | <b>THANK &amp; TERMINATE</b> |

- vi How many registered motor vehicles of any kind are regularly garaged or parked at your address? (Count all passenger vehicles including vans and motor cycles)

Number of vehicles \_\_\_\_\_

## QUESTIONNAIRE

**Q.1 IF MORE THAN 1 CAR IS ANSWER AT Q.vi THEN SAY:**

We will take one car at a time starting with the oldest. I will be asking the same series of questions for each vehicle.

**REMINDEE RESPONDENT THAT HE/SHE CAN REFER TO THE INFO SHEET PROVIDED AT BOTTOM OF PRELIMINARY LETTER - IF HE OR SHE RECEIVED THE LETTER AND FILLED IN THE DETAILS**

**Q.2 How is the car registered? Is it.....(READ OUT)**

- |  |                            |
|--|----------------------------|
| Privately registered                         | 1                          |
| Household business registered                | 2                          |
| Other business registered<br>eg. by employer | 3                          |
| Don't know/not stated                        | 4 <b>(DO NOT READ OUT)</b> |

**Q.3 What is the make of the car? (eg. Ford, Holden, Toyota, etc)**

SEE CODE FRAME

**Q.4 And what model is it? (eg. Telstar, Barina, Celica etc)**

SEE CODE FRAME

**Q.5 What year was the car manufactured? ..... \_\_\_\_\_**

**Q.6 What type of fuel does the car use? (If necessary read out options)**

- |                        |  |
|------------------------|--|
| Leaded (Super)         | 1  |
| Unleaded               | 2  |
| Leaded and/or unleaded | 3  |
| Diesel                 | 4 }  |
| LPG/LNG                | 5 } <b>4,5,6, not suitable for testing</b> |
| Other                  | 6 }  |

**Q.7 How many kilometres has the car travelled since new? If uncertain please given an estimate**

Kms : \_\_\_\_\_



Q.14 Who maintains/services the car? (READ OUT)

- |  |   |
|--|---|
| Yourself/another householder/friend    | 1 |
| Local service station or mechanic      | 2 |
| Franchised dealer for that make of car | 3 |

Q.14a When did the vehicle (make, model) last get a tune-up?

- |                          |   |
|--------------------------|---|
| Less than a month ago    | 1 |
| Less than 6 months ago   | 2 |
| Six months ago or longer | 3 |

**RETURN TO Q.2 IF ANOTHER CAR IS TO BE ASKED ABOUT**

Q.15a Now I need to ask a couple of questions about you and your household to ensure that we are approaching a good cross section of households

How many people are usual residents of this dwelling?

Number : \_\_\_\_\_

Q.15b Beginning with yourself, who are the usual residents of this dwelling?

**IT IS IMPORTANT THAT THE FIRST ENTRY IS THE PERSON YOU ARE TALKING TO**

Could I start with the name please?

RESPONDENT NAME : \_\_\_\_\_ AGE : \_\_\_\_\_

SEX: M \_\_\_\_\_ F \_\_\_\_\_

What is the name of other usual residents of this dwelling?

And what is the age of that person?

And of what gender would that person be?

RESPONDENT NAME : \_\_\_\_\_ AGE : \_\_\_\_\_

SEX: M \_\_\_\_\_ F \_\_\_\_\_

RESPONDENT NAME : \_\_\_\_\_ AGE : \_\_\_\_\_

SEX: M \_\_\_\_\_ F \_\_\_\_\_

RESPONDENT NAME : \_\_\_\_\_ AGE : \_\_\_\_\_

SEX: M \_\_\_\_\_ F \_\_\_\_\_

RESPONDENT NAME : \_\_\_\_\_ AGE : \_\_\_\_\_

SEX: M \_\_\_\_\_ F \_\_\_\_\_

RESPONDENT NAME : \_\_\_\_\_ AGE : \_\_\_\_\_

SEX: M \_\_\_\_\_ F \_\_\_\_\_

Q.16 The following question relates to household income. This question helps ensure that a broad cross section of households are represented in the survey. Into which of the following categories does your household income fall?

Less than \$5 000	01
\$ 5 000 - \$12 000	02
\$12 001 - \$20 000	03
\$20 001 - \$30 000	04
\$30 001 - \$40 000	05
\$40 001 - \$50 000	06
\$50 001 - \$60 000	07
\$60 001 - \$70 000	08
\$70 001 - \$80 000	09
\$80 001 - \$90 000	10
\$90 001 - \$120 000	11
\$120 000	12
Don't know	13
(DO NOT READ OUT)	
Refused	14
(DO NOT READ OUT)	

**PROCEED ACCORDING TO QUOTA RULES**

**IF NOT IN QUOTA - THANK AND TERMINATE**

**IF IN QUOTA**

Q.17a INTERVIEWER

IF ONLY ONE CAR, CHOOSE THE CAR AND CONTINUE.

IF NO CARS THEN CHOOSE "No vehicle" AND CONTINUE.

**IF MORE THAN 1 CAR READ OUT THE FOLLOWING:**

Can you tell me which one of these cars is next due for registration?

SEE CODE FRAME

Q.17b What year was the car manufactured?..... \_\_\_\_\_

**IF YEAR OF MANUFACTURE AT Q17.b NOT THE SAME AS YEAR OF MANUFACTURE AT Q.5, THEN SAY:**

**EARLIER YOU SAID YOUR VEHICLE WAS MANUFACTURED IN ... (REPEAT YEAR AT Q.5)... AND JUST NOW YOU SAID IT WAS MANUFACTURED IN ... (REPEAT YEAR AT Q.17b)... WHICH IS THE CORRECT YEAR FOR THE MANUFACTURE OF YOUR VEHICLE?**

Q.17c My records indicate that the ...(model)... is a suitable model to take part in the Study's testing program. As we are now recruiting vehicles to take part in the testing program, I now need to talk to the owner of that vehicle.

**IF NECESSARY, SUSPEND AND ARRANGE A CALLBACK TO SPEAK TO THE OWNER AND ASK RESPONDENT TO EXPLAIN WHAT HAS OCCURRED SO FAR TO THE OWNER.**

I would like to explain the testing procedures to you to see if you would be willing to have your car tested.

The testing laboratory will require your car for 1 to 3 days and during this time you will be supplied with a current model replacement vehicle (VR Commodore with airbag, Ford Falcon, Toyota Camry, Mitsubishi Magna - all sedans). The replacement vehicle will be delivered to you at a time and place convenient to you.

Your replacement vehicle will be fully insured for the period that you have it. Your own car will also be fully insured. The actual testing procedure will involve measuring engine performance and certain components of the vehicle's exhaust emissions whilst being driven on a chassis dynamometer so as to simulate typical suburban driving conditions. The test will not involve any high speeds, high loads or harsh acceleration and no road testing will be carried out. **NOTE: an information sheet is to be provided by the Federal Office of Road Safety.**

Your own car will be given a tune up to the manufacturers specification during testing then be returned to you washed and vacuumed and with a full tank of petrol. You will also receive a detailed report on the results of the tests and a technician from the laboratory will be available to explain the results.

Are there any questions you would like to ask?

**USE INTERVIEWER INSTRUCTIONS TO ANSWER ANY QUESTIONS - IF YOU CANNOT ANSWER ASK YOUR SUPERVISOR IMMEDIATELY.**

Would you like to participate in the vehicle testing phase of the survey?

- |     |   |                   |
|-----|---|-------------------|
| Yes | 1 | <b>GO TO Q.19</b> |
| No  | 2 | <b>GO TO Q.18</b> |

Q.18 Why wouldn't you like to participate?

..... TERMINATE

**ARRANGE CALLBACK IF POSSIBLE TO TEST AT A LATER DATE**

Q.19 **IF MORE THAN ONE CAR FITS THE QUOTA ASK:**

You have two vehicles in your household which are suitable for testing - in order that we have a random selection we are to select the vehicle which is the next one to be registered.

Could you please tell me the registration number of that car?

REGISTRATION NUMBER .....

Q.20 In which State is the vehicle registered?

- NSW 1
- VIC 2
- QLD 3
- SA 4
- TAS 5
- ACT 6
- NT 7

Q.21 A representative from the ..... testing laboratory will call you shortly to arrange with you a suitable time in the next 2-3 weeks to test your car. At this stage I will send out some information clarifying the details which we have discussed. Can I just confirm your name and address? Is your address **CONFIRM ADDRESS & NUMBER.**

Can I also have the telephone number at which the laboratory can contact you during business hours?

INCLUDE STD IN PHONE NUMBER (.....).....

The laboratories have requested that your vehicle not be tuned before testing unless it is part of your usual tuning schedule. The reason for this is that we wish to test vehicles at various degrees of tuning. As part of the test vehicles your vehicle will be tested twice, once before the laboratory tunes your vehicle to the manufacturer's specifications and again after the testing.

**Thank you very much for your co-operation. The information I send to you will have a contact name and telephone number of the laboratory co-ordinator. If you have any questions or need to discuss anything they would be happy to speak to you.**





# **APPENDIX VI**

## **TESTING QUOTAS & TIMELINES**

**[for vehicles tested  
as part of the  
In-Service Vehicle Emissions Study]**

## THE TESTING QUOTAS

### 1. THE ORIGINAL TESTING QUOTA

Due to the considerable cost of emissions testing of individual vehicles, the original number of cars to be tested was limited to a maximum of 600.

The sample of vehicles selected for testing reflected the most common makes and models, manufactured in Australia, during the period 1980-1991 inclusive, ie. Ford, GMH, Toyota, Mitsubishi and Nissan. These vehicles provided a sample that statistically characterised the composition of the current Australian passenger car fleet (with some constraints).

The reason for selecting vehicles in the 1980-1991 timeframe was based on the belief that those years would be the most relevant for projecting emission levels for future years.

Approximately 40 percent of vehicles were tested for evaporative emissions.

The following Quota Table was prepared on the basis of 600 vehicles being tested and indicates numbers of vehicles to be tested by year and manufacturer. The number of evaporative emission tests are also indicated in brackets:

MODEL YEAR	VEHICLE QUOTA FROM EACH MANUFACTURER			
	Total [proportion to undergo evap testing]			
	GMH	FORD	TOYOTA	MITSUBISHI & NISSAN
1980 + 1981	19 [8]	19 [8]	20 [8]	9 [4]
1982 + 1983	16 [7]	20 [8]	12 [5]	18 [8]
1984 + 1985	14 [6]	21 [9]	11 [5]	21 [9]
1986	12 [5]	26 [11]	14 [6]	15 [6]
1987	13 [5]	23 [10]	15 [6]	15 [6]
1988	12 [5]	20 [8]	18 [7]	17 [7]
1989	12 [5]	21 [9]	18 [7]	16 [7]
1990	12 [5]	18 [7]	19 [8]	16 [7]
1991	13 [5]	18 [7]	21 [9]	15 [6]

## 2. EXTENSION OF THE ORIGINAL TESTING QUOTA

In April 1995, it became apparent that sufficient funds would be available to enable FORS to extend the national In-Service Vehicle Emissions Testing Program to include a number of additional tests, as follows:

- 50 newer model vehicles (1992-93)
- 18 vehicles 1970-1980 model years
- 10 vehicles in poorly maintained condition
- 10 modified vehicles
- 10 vehicles with in-line fuel treatment (these vehicles were drawn from the original testing quota of 600 vehicles)

The additional tests allowed FORS to complete tests on over 600 vehicles and at the same time cover a broader range of vehicles.

Whilst the number of vehicles in several of the 'groups' of additional vehicles were small, it was believed that the testing of these cars would at least provide an indication of the emissions performance for each 'group' (ie. modifieds, poorly maintained, 1970s vehicles).

To accommodate the additional testing, the In-Service Testing Program was extended from the original completion date of 31 August 1995 to 18 December 1995.

## 3. SUMMARY OF ADDITIONAL TESTING PROGRAM

Details on the additional 88 vehicles to be tested are as follows :

TEST GROUP	NO. VEHICLES	NORMAL FORS TEST PROGRAM	
		EXH. TESTS	SHED TESTS
1992-93 vehicles	50	X	X
1970-1979 vehicles	18	X	X
Poorly maintained vehicles	10	X	X
Highly Modified vehicles	10	X	X

**X** = to be done

### 3.1 Details on 10 Vehicles from Existing Quota to Undergo Additional Test

TEST GROUP	NO. VEHICLES	3RD PHASE TEST [exhaust only]
1980-91 Quota Vehicles	10	Fuel Line Break-in [Carbon Clean]

\* These vehicles were drawn from the main pool of quota vehicles [600 vehicles], so they will undergo the normal FORS program, but not as part of the additional testing.

## 4. DESCRIPTION OF GROUPS OF ADDITIONAL 88 VEHICLES

Below is a description of each of the groups of additional vehicles tested.

### 4.1 Extra vehicles from 1992-93 model years

50 vehicles were sourced by AGB McNair in the usual way to provide additional data on newer vehicles with relatively low odometer readings. The vehicles underwent testing procedures, including SHED tests.

Sample was drawn in accordance with the following quota table:

MODEL YEAR	VEHICLE QUOTA FROM EACH MANUFACTURER			
	[50 vehicles in total]			
	[all vehicles to be evap tested]			
	<i>GMH</i>	<i>Ford</i>	<i>Toyota</i>	<i>Mitsubishi &amp; Nissan</i>
1992	7	8	5	6
1993	6	8	5	5

\* see **Figure 1 (of this Appendix)** for basis of quota.

The models for 1992-1993 were the same as that in the list for the 1980-1991 category, except for the following new models which were added to the list used by AGB McNair:

- Mitsubishi - Verada
- Toyota - Vienta

#### **4.2 "Common" 1970-1979 Vehicles**

18 vehicles were sourced by AGB McNair in the usual way and subjected to normal testing procedures, including SHED tests.

Sample was drawn in accordance with the following quota table:

MODEL YEAR	VEHICLE QUOTA FROM EACH MANUFACTURER & ACCEPTABLE MODELS					
	[18 vehicles in total]					
	[all vehicles to be evap tested]					
	<i>GMH</i>	<i>Ford</i>	<i>Chrysler</i>	<i>Toyota</i>	<i>Mitsubishi/Chrysler</i>	<i>Datsun</i>
	Kingswood, Belmont, Premier	Falcon, Fairmont	Valiant, Regal	Corolla, Corona	Sigma	180B, 200B
1970-73	1	1	1	1	-	1
1974-79	2	2	2	2	3	2

#### **4.3 Poorly Maintained 1980-1991 Vehicles**

10 vehicles were sourced by the Ford Motor Company [who were also contracted to test the vehicles], from the Melbourne metropolitan area. The vehicles were subject to normal testing procedures, including SHED tests - broken-up as follows:

- 3 x 1980-1985 models; and
- 7 x 1986-1991 models.

#### **4.4 Modified 1970-1991 Vehicles**

10 vehicles were sourced by the Ford Motor Company [who were also contracted to test the vehicles], from the Melbourne metropolitan area. The vehicles were subject to normal testing procedures, including SHED tests.

The focus was on Commodores/Kingswoods and Falcons, avoiding exotic models. Otherwise, there was no specific model quota applied. Vehicles with major modification to heads ['Yella Terras' etc], carburetion, and other items likely to have a significant impact on emissions performance were specifically targeted.

## 5. DESCRIPTION OF ADDITIONAL TESTS ON 10 QUOTA VEHICLES

### 5.1 Fuel Line Break-In Additives

10 vehicles from the normal Study quota had a proprietary product [Carbon Clean] added to the fuel line at the end of the normal study test program, and then subjected to one extra round of standard FORS tests [no SHED].

Focus was on a spread of makes and models [ $3 < 1986$ ,  $7 \geq 1986$ ] with reasonable mileage, as the purpose of the product was to clean out built up deposits etc. There was also some focus on vehicles which, when tested, showed little improvement after tuning. Owner's permission was sought by Ford prior to undertaking this procedure.

\*\* \*\* \* \*\* \* \*\* \*

<i>MAKE / MODEL</i>	<i>GMH</i>	<i>Ford</i>	<i>Toyota</i>	<i>Mitsubishi &amp; Nissan</i>
% of 1992 sales*	20	23	15	17
% of 1993 sales*	20	24	17	17
<i>% of sales after pro-rata reallocation of balance of other makes</i>				
% of 1992 sales*	25	28.75	18.75	21.25
% of 1993 sales*	24.4	29.28	20.74	20.74
<i>No of vehicles to be tested [average 25 per year]</i>				
1992	6.25	7.19	4.69	5.31
1993	6.10	7.32	5.19	5.19
<i>Adjustment to total 50 over 2 years</i>				
1992	7	8	5	6
1993	6	8	5	5

\*Data taken from *Black and White Data* books 1993-94

**Figure 1 : Basis of Quota Guide for 50 x 1992-93 vehicles**

## 6. TESTING TIMELINES

The vehicle emissions testing program officially commenced on 2 May 1994 and concluded on 20 December 1995.

## 7. CONCLUSION

At the completion of testing in late December 1995, a total of 652 vehicles had been tested in the national In-Service Vehicle Emissions Testing Program.

The Testing Program remained on target and within budget for its duration.

# **APPENDIX VII**

## **TESTING PHASE**

# OVERVIEW

## TESTING PHASE

### 1. TESTING CONTRACTORS

In January 1994 three emissions testing laboratories were commissioned by the Federal Office of Road Safety to undertake the Testing Phase of the NISE Study. The laboratories are:

- Ford Motor Company Emissions Testing Laboratory, based outside Geelong in Victoria near the Ford Proving Ground.
- The Victorian Environment Protection Authority (Vic EPA) Vehicle Testing Facility, Altona, Victoria; and
- The NSW Environment Protection Authority (NSW EPA) Vehicle Testing Facility, Lidcombe, NSW.

Vehicle testing commenced at all three facilities during May 1994.

### 2. SCOPE OF THE TESTING PHASE

The Testing Phase included the following elements:

- delivery / return of test and replacement vehicles;
- vehicle testing and data collection.

#### **2.1 Pick-up, Replacement, Delivery, and Return of Test Vehicles**

Each laboratory was required to manage the pick-up, replacement and delivery of test vehicles in a timely and well co-ordinated manner, as outlined below:

- contact the test vehicle owner from list provided and arrange suitable pick-up date and time. Owners were asked to have vehicle petrol tank only about ¼ full if possible at time of pickup.
- deliver the replacement vehicle to the test vehicle owner for their use during the testing period
  - the replacement vehicle was delivered to the test vehicle owner in a clean condition inside and out, and with a full tank of petrol.
- on arrival at owners premises, the external and internal condition of the test vehicle was recorded in agreement with the vehicle owner. The person representing the testing contractor who picked up the vehicles was authorised to reject a potential

test vehicle, if in that person's judgement, the vehicle would be unsafe for testing, or, because of faults in the exhaust system.

- collect the test vehicle from the owner and deliver to the test facility
  - at the completion of testing, return the test vehicle to the owner
    - the test vehicle was returned in a clean condition inside and out, and with a full tank of petrol\*.
    - a written summary of the vehicle's test results and tuning details was provided to the owner for their information
    - the test contractor's representative provided a verbal explanation of their vehicle's test results, in addition to the above written summary, and answered questions on the test results.
  - pick-up the replacement vehicle from the owner of the test vehicle.
- \* Fuel drained from test vehicles was used to refill test and/or replacement vehicles.

## **2.2 Testing of Vehicles**

The successful tenderers undertook the test program detailed in **Appendix VIII**.

## **2.3 Data Collection**

Analysis of the data generated from the testing was undertaken by a separate contractor.

The data generated from the vehicle testing was provided in accordance with the requirements of **Appendix IX** so that it would be in a format conducive to ready analysis, using commonly available spreadsheet/datasheet software.

The test data was provided to FORS / data analyst on a regular basis on computer disk.

## 3. CORRELATION VEHICLE

An independent "correlation vehicle" was provided by the project manager. This vehicle was used to assess the consistency of results from the successful tenderers in Melbourne and Sydney. The correlation vehicle visited the test facilities every 3-4 months [refer **Appendix X - Correlation Procedures**].

## 4. TEST FUEL

Test fuel was supplied to the testing laboratories in 200L drums, derived from normal commercial fuel production, which the testing laboratories used for testing purposes only, as required. The drums were stored under cover away from the elements.

The following table gives the specifications for certification and pump fuel used for the NISE Study:

## FUEL SPECIFICATIONS OF CERTIFICATION FUEL AND NISE FUELS

Parameters	FTP Certification Fuel [Unleaded]	NISE Fuel [Unleaded]	NISE Fuel [Leaded]
Research Octane No.	91 min - 93 max	91.3	96
Lead [g/L]	0.013 max	0.002	0.201
Sulfur [% by mass]	0.05 max	0.02	0.032
Reid Vapour Pressure [kPa]	60.0 - 63.4	76.5	73.5
Fuel Volatility Index (RVP in kPa + 0.7*E <sub>70</sub> where E <sub>70</sub> = % evaporated at 70°C.)	-	102.8	99.7
Benzene Content [vol %]	-	4.1	4.2
Density @ 15°C [g/ml]	-	.7343	.7373

### 5. VEHICLE TUNING

All vehicles were tuned/serviced and repaired, where necessary, by NRMA (NSW) and RACV (Victoria) mechanics who were provided free-of charge by those organisations in support of the project.

### 6. REPLACEMENT VEHICLES

A number of vehicles were required to replace householder's cars whilst being tested. All 'replacement' vehicles were new-model cars which acted as an incentive for householders to agree to having their car tested, and to help to eliminate any inconvenience to test car owners.

At the peak of the testing program 12 replacement cars were in operation. These cars were obtained through the support of vehicle manufacturers and Dasfleet who made their new-model cars available for use for the duration of the NISE Study.

### 7. VEHICLE INSURANCE

All replacement vehicles used in the NISE Study were comprehensively insured by the NRMA. The NRMA provided this insurance coverage in support of the Study.

All householder's vehicles were covered by the relevant test laboratory's insurance, whilst being tested and whilst being driven to and from the householder's residence.

In a further gesture of support for the Study, the NRMA and the RACV provided roadside-service coverage for all replacement vehicles over the duration of the project.

# **APPENDIX VIII**

## **VEHICLE TESTING AND TUNING**

## 1. TESTING OVERVIEW

Vehicles were tested both as-received and again after tuning (so far as is possible) to manufacturers' specifications. This gave an indication of the maximum achievable reduction in emissions from the fleet. Tests included:

- ADR27 and ADR 37/00 exhaust emissions (CO, total HC,NOx,CO<sub>2</sub>, Fuel Economy, \*Benzene, \*1, 3-Butadiene, \*Toluene, \*Xylenes).
- ADR 37/00 Evaporative [SHED] emissions (total HC, \*Benzene, \*1, 3-Butadiene, \*Toluene, \*Xylenes).
- IM 240 (CO,HC,NOx, Purge Flow).
- Steady State (Idle)(CO, HC).
- Steady State (High Idle 2500 rev/min)(CO,HC).
- Steady State Loaded (60 km/hr)(CO,HC,NOx).
- Acceleration Simulation Mode (CO,HC, NOx).

\* [Collection of samples for analysis for these specific hydrocarbons was funded by the Environment Protection Agency (Commonwealth)].

### **General Inspection**

- Underhood and general condition of the vehicle.
- Fuel Filler Cap Sealing.
- Catalyst Temperature Test.
- Catalyst Integrity.

### **Sequencing**

This is in accordance with the Test Specifications.

### **Tuning**

Tuning of vehicles was undertaken at the testing stations and conducted in accordance with set guidelines.

### **Test Data**

All data collected during the project was collected, verified and stored in a standard format.

## 2. VEHICLE TESTING & TUNING

Vehicle testing was undertaken strictly in accordance with the specified procedures in the following Parts :

- **PART 1 : Pre-test and Test Procedures**
- **PART 2 : Inspection and Test Sequence.**

The vehicles were tuned by an independent contractor in accordance with :

- **PART 3 : Tuning Specifications.**

## PART 1 : PRE-TEST AND TEST PROCEDURES

### 1. PRE-TEST INSPECTION

The attached check list shall be completed before testing is commenced. Record the details requested, or circle the correct option, as appropriate. See also "Other Tests" on pA2[5] as some tests are required to be commenced or undertaken before the first round of tests.

Any work in the shaded area of the "Action" column is to be completed by the tuning contractor after completion of the first [pre-tune] round of tests. To assist the supply of parts to the tuning contractor, the person undertaking the pre-test inspection should identify any items which need replacing, provided they fall within the scope of the tuning contractor's approved activities [see Part 3 : Tuning Specifications]. Apart from any adjustments to enable safe operation of the vehicle during the test, the person undertaking the pre test inspection shall not undertake any work to alter the "as delivered" condition of the vehicle, as this would defeat the objective of the pre tune test program.

ITEM	INSERT ANSWER or SELECT CORRECT OPTION	ACTION
Rego Number*		
Make & Model		
Body Type	<i>Sedan/Wagon/Utility</i>	
Compliance Plate Date	<i>...../...../.....</i>	
VIN		
Vehicle mass**	<i>.....kg</i>	
Odometer reading	<i>.....km</i>	
Tyres	<i>Condition - good/fair/poor</i>	Inflate if necessary for safe testing
Engine displacement	<i>.....L</i>	
No of cylinders	<i>4 / 6 / 8</i>	
Engine config.	<i>Inline / V</i>	
Transmission & No of Gears	<i>Man / Auto &amp; 3 / 4 / 5</i>	
Fuel system	<i>Carburettor / MPI / TBI</i>	
Air conditioning	<i>Yes / No</i>	
Engine oil	<i>Level - ok/low</i>	Replace
Oil filter		Replace
Trans. fluid	<i>Level - ok/low</i>	Top up - <i>yes/no</i>
Radiator	<i>Water level - ok/low</i>	Top up - <i>yes/no</i>
Battery	<i>Water level - ok/low</i> <i>Charge - ok/low</i>	Top up - <i>yes/no</i>
Spark plugs	<i>Condition - good/fair/poor</i>	Replaced - <i>yes/no</i> Gap .....mm
Points	<i>Condition - good/fair/poor</i>	Gap.....mm Replace
Distributor	<i>Condition - good/fair/poor</i>	Dwell .....deg
Plug & Dist Leads	<i>Resistance - ok/hot ok</i>	Replaced - <i>yes/no</i>

\*Registration No. to include State/Territory prefix NSW[N],Vic[V],Qld[Q],WA[W],SA[S],Tasmania[T],ACT[A],NT[X].

\*\* Weigh as delivered, regardless of fuel level in tank, accessories etc, but remove any large loose objects not associated with the vehicle which may be in the boot. Do not add 136kg or any other factors.

<i>ITEM</i>	<i>INSERT ANSWER or SELECT CORRECT OPTION</i>	<i>ACTION</i>
<b>Fuel Filter</b>	Condition - <i>good/fair/poor</i>	Replaced - <i>yes/no</i>
<b>Air filter</b>	Condition - <i>good/fair/poor</i>	Replace
<b>Timing</b>	Manufacturer's Spec..... <sup>0</sup>	Measured/adjusted ..... <sup>0</sup>
<b>Idle Mixture</b>	Manufacturer's Spec / NA CO .....% HC .....ppm O <sub>2</sub> .....% CO <sub>2</sub> .....%	Measured/adjusted CO .....% HC .....ppm O <sub>2</sub> .....% CO <sub>2</sub> .....%
<b>Idle Speed</b>	Manufacturer's Spec.....rpm	Measured/adjusted .....rpm
<b>Electronic Engine Management System</b>	<i>Operation &amp; type / NA</i>  Interrogate - identify faults	Replace items within budget
<b>Drive line</b>	Operation & Condition <i>Safe for test / unsafe</i>	<b>Reject for test if unsafe</b>
<b>Brakes</b>	Serviceability / drag <i>Safe for test / unsafe</i>	<b>Reject for test if unsafe</b>
<b>Exhaust system</b>	Security - <i>secure/loose</i> Leakage - <i>not leaking/leaking</i>	Secured <i>yes/no</i> <b>Reject for test if leaking</b>
<b>Emission control system</b>	Type - <i>pre cat/2way/3way</i>	
	EGR - <i>working/not working</i> Evap canister & hoses - <i>present/missing/disconnected</i> Air preheat - <i>present/missing/disconnected</i> Oxygen sensor - <i>working/not working</i> Catalytic converter - <i>NA/present</i> if present - <i>rattle/no rattle</i> [see test procedure below] Air pump - <i>working/not working</i> Vacuum hoses - <i>ok/replace</i> Switches - <i>ok/replace</i> Solenoids - <i>ok/replace</i>	Replaced - <i>yes/no</i>  Replaced - <i>yes/no</i> Replaced - <i>yes/no</i> Replaced - <i>yes/no</i>
<b>Summary of items for mechanic's attention at tuning stage</b>		Parts required [subject to budget]:
<b>Total Parts Cost</b>		\$
<b>Safety Issues</b>	Is the vehicle in a satisfactory condition for testing - <i>yes/no</i> .	<b>If yes</b> , vehicle should proceed to next stage. <b>If no</b> , vehicle should be tuned, cleaned, filled with petrol, and returned to vehicle owner with a copy of the completed checklist [including tuning information]

## 2. SUMMARY OF TESTS

The following tests shall be undertaken in accordance with the specified procedures:

<b>NAME OF TEST</b>		<b>TEST PROCEDURE</b>
<b>EMISSIONS TESTS</b>		
ADR37/00 EMISSIONS	EXHAUST	As set out in Clauses 37.6 to 37.8 of Australian Design Rule [ADR] 37/00 <i>Emission Control for Light Vehicles</i> , subject to the following conditions: <ol style="list-style-type: none"> <li>[1] Where the vehicle is not going to be subject to the ADR37/00 evaporative emissions test, the heat build and associated drain and fill of the petrol tank shall not be conducted</li> <li>[2] The vehicle shall be weighed in its "as delivered" condition, and the road power absorber setting shall be the appropriate value from Table 8.2 of ADR37/00</li> <li>[3] If the vehicle is fitted with air conditioning, the road power absorber setting shall be increased by 10% and the air conditioning unit switched off.</li> <li>[4] The ADR37/00 default speeds shall be used to determine manual gear change points.</li> <li>[5] The actual distance recorded in the test shall be used to calculate emissions in g/km.</li> </ol>
ADR37/00 EMISSIONS	EVAPORATIVE	As set out in Clauses 37.6 to 37.7 of Australian Design Rule [ADR] 37/00 <i>Emission Control for Light Vehicles</i> , subject to the following condition: <ol style="list-style-type: none"> <li>[1] The attachment of a fuel temperature sensor to the outside surface of the fuel tank is an acceptable alternative method to that specified in ADR37/00, provided it can be established that this method provides equivalent results to the method specified in the ADR.</li> </ol>
ACCELERATION SIMULATION [ASM2525]	MODE	As set out in 2.2.

STEADY STATE [IDLE] As set out in 2.3.

STEADY STATE [HIGH IDLE] As set out in 2.4.

---

<b>NAME OF TEST</b>	<b>TEST PROCEDURE</b>
---------------------	-----------------------

**EMISSIONS TESTS** [cont]

STEADY STATE LOADED [60km/hr] As set out in 2.5.

IM240 [including purge test] As set out in 2.6.

---

**OTHER TESTS**

CATALYST TEMPERATURE	<p><i>Timing</i> The painting of the target shall be done at the time of the pre-test inspection. The test itself is to be conducted at the end of the Steady State [High Idle] test, using a remote Raynger PM4 infra-red detector with laser sighting, or infra red detector of equivalent standard.</p> <p><i>Procedure</i> Paint a circle of approximately 20mm diameter onto the centre of the exhaust pipe as close as possible [within 100mm] to the front and rear of the vehicle's catalytic converter. Using the laser sighting, measure the exhaust pipe surface temperature at the centre of the 2 painted targets. Record the two temperatures, and the difference between them [in °C].</p>
----------------------	---

CATALYST INTEGRITY	<p><i>Timing</i> This test is to be conducted as part of the pre test inspection.</p> <p><i>Procedure</i> While the vehicle is on the hoist, grab the exhaust pipe firmly in your hands at the front and rear of the catalytic converter and shake vigorously for a few seconds. Record the presence or absence of any rattles emanating from the catalytic converter.</p>
--------------------	--

FUEL FILLER  
SEALING

CAP *Timing*

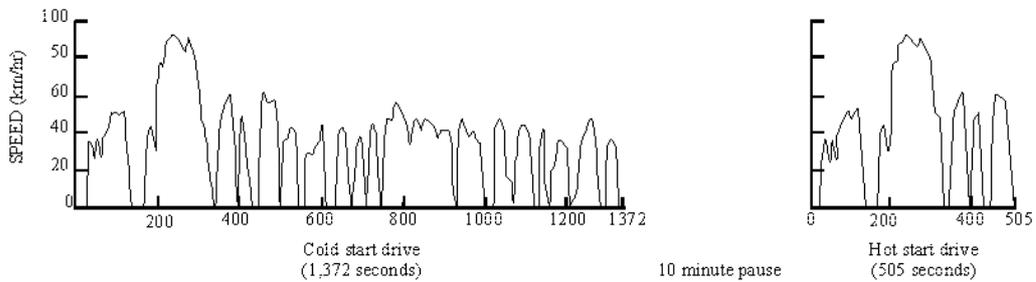
This test is only conducted on vehicles undergoing the ADR37/00 Evaporative Emissions test, and is to be conducted at the completion of the heat build, after the SHED has been purged, but while the vehicle is still in the SHED.

*Procedure*

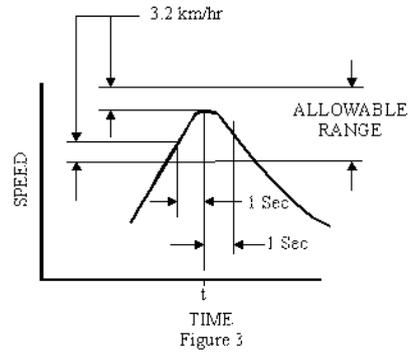
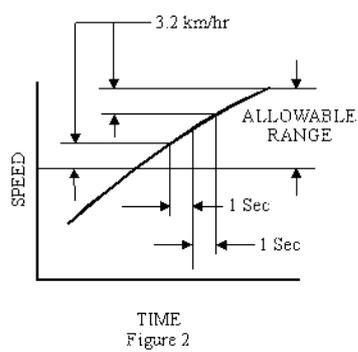
Ensure the fuel filler cap is properly closed. Connect a flexible hose to the SHED hydrocarbons analyser. Turn on the analyser and using the flexible hose, sample the air within 50mm of the petrol filler cap using a circular action. Record the hydrocarbon concentration at the end of 20 seconds

## 2.1 FTP Test Cycle

Figure 1 describes the drive cycle which vehicles undergo in the ADR37/00 test cycle. The ADR27 test cycle is described by the figure labelled as the Cold start drive. Figures 2 and 3 indicate the vehicle speed tolerances for the cycle.



CVS-CH DRIVING SCHEDULE  
FIGURE 1



## **2.2 Acceleration Simulation Mode Test Procedure [ASM2525]**

The Acceleration Simulation Mode Test shall be conducted in accordance with the following procedures:

1. The vehicle is placed on the dynamometer and driven to the target speed of 40km/hr  $\pm$  1km/hr.
2. Vehicle load is determined by the formula -

$$\frac{\text{Equivalent Test Inertia Weight [lbs]}}{300}$$

300

- where the horsepower is determined at 25mph [possible values range from 6-20hp at 25mph]. The load applied simulates 25% of the power required to accelerate the vehicle at 3.3mph/second at 25mph.

The load applied to the dynamometer at 40km/hr shall be taken from Table 1 below. Flywheels, electrical devices or other means of simulating *Equivalent Test Inertia Weight* [mass] shall be used.

3. Maintain test condition for 1 minute.
4. For vehicles with manual transmissions, the vehicle is tested in 2nd gear, for automatics in Drive.
5. The exhaust emissions are collected after a minimum of 10 seconds of operation in the speed window. If the emission readings are stable the test is completed and readings recorded. If the readings are unstable [ $\pm 20$ ppm HC,  $\pm 0.20\%$  CO,  $\pm 150$ ppm NO<sub>x</sub>] continue the test for 60 seconds and collect the sample within the last 10 seconds and record the result.
6. The raw exhaust measurements of HC [in ppm] and CO [in %vol] shall be recorded using a calibrated non-dispersive infrared analyser at least equivalent to a BAR90 3-gas smart bench. The raw exhaust measurements of NO<sub>x</sub> [recorded as NO in ppm] shall be recorded using a calibrated Horiba VIA 300 non-dispersive infra red analyser or equivalent.

**Table 1 - Determination of Load**

Reference Weight [Mass] *		Equivalent Test Inertia Weight [Mass]		Dynamometer Load Setting	
lbs	kg	lbs	kg	hp	kW
≤ 1062	≤ 481	1000	454	3.3	2.5
1063-1187	482-538	1125	510	3.8	2.8
1188-1312	539-595	1250	567	4.2	3.1
1313-1437	596-652	1375	624	4.6	3.4
1438-1562	653-708	1500	680	5.0	3.7
1563-1687	709-765	1625	737	5.4	4.0
1688-1812	766-822	1750	794	5.8	4.4
1813-1937	823-878	1875	850	6.3	4.7
1938-2062	879-935	2000	907	6.7	5.0
2063-2187	936-992	2125	964	7.1	5.3
2188-2312	993-1048	2250	1021	7.5	5.6
2313-2437	1049-1105	2375	1077	7.9	5.9
2438-2562	1106-1162	2500	1134	8.3	6.2
2563-2687	1163-1219	2625	1191	8.8	6.5
2688-2812	1220-1275	2750	1247	9.2	6.8
2813-2937	1276-1332	2875	1304	9.6	7.1
2938-3062	1333-1389	3000	1361	10.0	7.5
3063-3187	1390-1445	3125	1417	10.4	7.8
3188-3312	1446-1502	3250	1474	10.8	8.1
3313-3437	1503-1559	3375	1531	11.3	8.4
3438-3562	1560-1615	3500	1588	11.7	8.7
3563-3687	1616-1672	3625	1644	12.1	9.0
3688-3812	1673-1729	3750	1701	12.5	9.3
3813-3937	1730-1786	3875	1758	12.9	9.6
3938-4125	1787-1871	4000	1814	13.3	9.9
4126-4375	1872-1984	4250	1928	14.2	10.6
4376-4625	1985-2097	4500	2041	15.0	11.2
4626-4875	2098-2211	4750	2155	15.8	11.8
4876-5125	2212-2324	5000	2268	16.7	12.4
5126-5375	2325-2438	5250	2381	17.5	13.1
5376-5750	2439-2608	5500	2495	18.3	13.7
> 5750	> 2608	6000	2722	20.0	14.9

\* Reference weight = weight [mass] of the vehicle as presented + weight [mass] of fuel for full tank of petrol + 300lbs [136kg]

### **2.3 Steady State [Idle] Test Procedure**

The Steady State [Idle] Test shall be conducted in accordance with the following procedures:

1. Immediately before the test, the engine must be brought to normal operating temperature.
2. The engine is started and kept running throughout the test, with the accelerator pedal **not** depressed.
3. For vehicles with manual transmissions, the vehicle shall be in neutral gear with the clutch engaged. For vehicles with automatic or semi-automatic transmissions, the gear selector shall be in the Drive position and the handbrake placed in the fully "on" position.
4. For vehicles equipped with a manual choke, the choke must be in the "off" position.
5. The inlet probe of the sampling probe of a calibrated<sup>1</sup> non-dispersive infrared analyser shall be positioned in the exhaust pipe at any point between 350mm and 500mm from the discharge end of the exhaust pipe. For the purposes of the test, the pipe may be extended by use of an extension piece connected to the vehicle's discharge outlet with a suitable connection which does not allow dilution of the exhaust gases by air. Where the vehicle is fitted with more than one exhaust pipe, the concentration shall be measured in each pipe.
6. The raw exhaust measurement shall be recorded as the maximum value of the concentration of CO [in %vol] and total HC [in ppm] as determined by the analyser over a period of between 30 and 60 seconds, beginning not earlier than 60 seconds after the probe has been inserted in the exhaust pipe. Where the vehicle is fitted with more than one exhaust pipe, the maximum value shall be the highest value from either pipe.

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<sup>1</sup> The analyser shall be calibrated within the preceding 30 days by being zeroed with dry nitrogen which contains less than 10ppm CO, or 6ppm total HC [equivalent carbon response], as applicable, and spanned with a CO or total HC mixture, as applicable, which will result in a response equivalent to not less than 70% of the full scale deflection. The instrument must be zeroed and spanned using a secondary electronic or mechanical system prior to each measurement.

## **2.4 Steady State [High Idle] Test Procedure**

The Steady State [High Idle] Test shall be conducted in accordance with the following procedures:

1. Immediately before the test, the engine must be brought to normal operating temperature.
2. The engine is started and kept running throughout the test, with the accelerator pedal depressed until the engine rotational speed has stabilised at 2500 rpm  $\pm$ 50rpm.
3. For vehicles with manual transmissions, the vehicle shall be in neutral gear with the clutch engaged. For vehicles with automatic or semi-automatic transmissions, the gear selector shall be in the neutral position and the handbrake placed in the fully "on" position.
4. For vehicles equipped with a manual choke, the choke must be in the "off" position.
5. The inlet probe of the sampling probe of a calibrated<sup>1</sup> non-dispersive infrared analyser shall be positioned in the exhaust pipe at any point between 350mm and 500mm from the discharge end of the exhaust pipe. For the purposes of the test, the pipe may be extended by use of an extension piece connected to the vehicle's discharge outlet with a suitable connection which does not allow dilution of the exhaust gases by air. Where the vehicle is fitted with more than one exhaust pipe, the concentration shall be measured in each pipe.
6. The raw exhaust measurement shall be recorded as the maximum value of the concentration of CO [in %vol] and total HC [in ppm] as determined by the analyser over a period of between 30 and 60 seconds, beginning not earlier than 60 seconds after the sampling has commenced and the engine speed has stabilised. Where the vehicle is fitted with more than one exhaust pipe, the maximum value shall be the highest value from either pipe.

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<sup>1</sup> The analyser shall be calibrated within the preceding 30 days by being zeroed with dry nitrogen which contains less than 10ppm CO, or 6ppm total HC [equivalent carbon response], as applicable, and spanned with a CO or total HC mixture, as applicable, which will result in a response equivalent to not less than 70% of the full scale deflection. The instrument must be zeroed and spanned using a secondary electronic or mechanical system prior to each measurement.

## **2.5 Steady State Loaded [60 km/hr] Test Procedure**

The Steady State Loaded [60 km/hr] Test shall be conducted in accordance with the following procedures.

### **2.5.1. THE TEST**

The test consists of driving the vehicle on a chassis dynamometer with the aid of a driving schedule indicator so that the vehicle speed, as measured from the dynamometer rolls, is at a constant speed of 60 km/hr.

The test is to consist of 2 phases -

- (a) a preconditioning phase of 5 minutes at 60 km/hr;
- (b) a measurement phase.

The exhaust emissions must be diluted with air to a constant volume. A portion of the diluted mixture must be sampled continuously during the measurement phase of the test and collected in a bag for subsequent analysis. A parallel sample of the dilution air must also be collected during this phase for analysis.

The concentrations of carbon dioxide, carbon monoxide, hydrocarbons and oxides of nitrogen in the samples collected are determined by the methods described in 5. The test results must be calculated in accordance with the methods described in 6.

### **2.5.2. TEST CONDITIONS**

The test must be carried out under the following conditions -

- (a) The test vehicle must be preconditioned as described above
- (b) The vehicle must be tested at an ambient air temperature between 20°C and 30°C.
- (c) The deviation in speed at any given time during the measurement phase must not exceed 1 km/hr.
- (d) The road load power setting shall be determined by reference to the vehicle's engine capacity and dynamometer inertia setting as specified in the table below. If the vehicle is equipped with air conditioning, the air conditioner must be switched off during the test.

**Table - Calculation of Dynamometer Road Load Setting**

<i>Engine Capacity of Test Vehicle [L]</i>	<i>Inertia Setting [kg]</i>	<i>Road Load Power [kW]</i>
≤ 1.7	794	5.7
> 1.7 ≤ 2.9	1134	7.0
> 2.9	1474	8.0

- (e) An auxiliary fan with a capacity of not more than 2.5 cubic metres per second must be used to cool the engine.
- (f) Prior to the test the air pressure in the tyres on the drive wheels of the vehicle must be equal to or greater than the pressure recommended, if any, in the owner's manual and, in any case, must be less than 310 kilopascals.
- (g) The constant volume sampling unit must be connected to the vehicle exhaust pipe or pipes and turned on, the cooling fan must be turned on and the engine compartment cover must be raised before the beginning of the test.

The measurement phase of the test and the collection of samples are to begin after the preconditioning phase has ended. The engine ignition must not be turned off at the end of the measurement phase.

- (h) The engine must be started according to the procedures recommended, if any, in the owner's manual. If the engine fails to start, the starting procedure must be repeated. A vehicle equipped with an automatic choke must be operated according to the procedures recommended, if any, in the owner's manual. If no recommendation is made as to the time at which the accelerator pedal is to be depressed in order to return the engine to normal idle speed, that time must be 13 seconds after the engine starts. A vehicle equipped with a manual choke must be operated according to the procedures recommended, if any, in the owner's manual. If no recommendation is made as to manual choke operation, the choke must be operated to maintain engine idle speed between 1050 and 1150 R.P.M. during the first 20 seconds of the preconditioning phase and used during the remainder of the phase if considered necessary by the person performing the test to keep the engine running.

- (i) If the owner's manual does not recommend a procedure for starting a warm engine, the engine (whether equipped with automatic or manual choke) can be started by depressing the accelerator pedal through about half of the available distance and cranking the engine until it starts.
- (j) The following driving requirements must be met during the test -
  - (i) The transmission must be placed in the gear recommended in the owners manual for the speed of 60 km/hr.
  - (ii) A vehicle equipped with a freewheeling or overdrive unit must be tested with the freewheeling or overdrive unit placed out of operation.

### **2.5.3. EXHAUST COLLECTION AND SAMPLING**

A connecting tube must be used to connect the vehicle exhaust pipe or pipes to a constant volume sampling unit, which must dilute the exhaust gases to a constant volume of diluted mixture with dilution air which has been drawn through a charcoal filter. The filter assembly must be sized and maintained so that the pressure in the area where the exhaust gases mix with dilution air is less than 0.25 kilopascals below ambient air pressure when the constant volume sampling unit is in operation.

If the sampling unit employs a positive displacement pump, the temperature of the diluted mixture immediately before it enters the pump must not vary by more than 12°C during the test.

The sampling unit must have a capacity of not less than 0.09 cubic metres per second. The total volume of diluted gases, corrected to 20°C and 101.325 kilopascals, passed through the sampling unit during each phase of the test must be measured.

A constant proportion of the flow of diluted exhaust gases must be sampled at a rate of not less than 0.08 litres per second and collected in a separate collection bag for the measurement phase of the test. Dilution air must be sampled at a constant flow rate and similarly collected during the test.

### **2.5.4. ANALYSIS**

Within 10 minutes of the conclusion of the measurement phase of the test, the concentration of hydrocarbons, expressed as propane, in the samples of diluted exhaust gases and dilution air collected during that phase must be determined using flame ionization detector analysis, the concentrations of carbon monoxide and carbon dioxide in the samples must be determined using non-dispersive infrared analysis and the concentration of oxides of nitrogen in the samples must be determined using chemiluminescent analysis.

The hydrocarbon analyser must be fuelled with a mixture of between 38% and 42% by volume hydrogen, with the balance being helium. The hydrocarbon analyser must be zeroed with air and the carbon monoxide,

carbon dioxide and oxides of nitrogen analysers must be zeroed with either air or nitrogen. The concentration of impurities in the zero gas or gases must not exceed 6 p.p.m. hydrocarbons (expressed as propane), 10 p.p.m. carbon monoxide and 1 p.p.m. nitric oxide. For the purposes of this analysis air

includes a blend made of nitrogen and oxygen with the oxygen concentration between 18% and 21% by volume. The hydrocarbon analyser must be spanned with a propane and air mixture which will result in a response equivalent to not less than 70% of the full scale deflection. The carbon monoxide analyser must be spanned with a carbon monoxide and nitrogen mixture which will result in a response equivalent to not less than 70% of the full scale deflection. The carbon dioxide analyser must be spanned with a carbon dioxide and nitrogen mixture which will result in a response equivalent to not less than 70% of the full scale deflection. The oxides of nitrogen analyser must be spanned with a nitric oxide and nitrogen mixture which will result in a response equivalent to not less than 70% of the full scale deflection. At least 3 gas mixtures must be used to calibrate each of the analysers.

### 2.5.5. COMPUTATION

The following formula is to be used to determine the test results -

$$(a) \quad Y_t = \frac{Y_{ss}}{\text{Time Unit}}$$

The symbols in formulas have the following meaning -

$Y_t$  = Total rate of emission of a pollutant, in grams per time unit.

$Y_{ss}$  = Mass emission of a pollutant during the measurement phase in grams.

The mass emission of each pollutant for the measurement phase of the test is determined as follows:

$$HC_{\text{mass}} = V_{\text{mix}} \times \text{Density}_{\text{HC}} \times HC_{\text{conc}} \times 10^{-6}$$

$$CO_{\text{mass}} = V_{\text{mix}} \times \text{Density}_{\text{CO}} \times CO_{\text{conc}} \times 10^{-6}$$

$$NO_x \text{ mass} = V_{\text{mix}} \times \text{Density}_{\text{NO}_2} \times K_H \times NO_x \text{ conc} \times 10^{-6}$$

where:

$HC_{\text{mass}}$  = Hydrocarbon emissions, in grams per phase.

$\text{Density}_{\text{HC}}$  = Density of exhaust hydrocarbons, assuming an average carbon to hydrogen ratio of 1:1.85, in grams per litre at 20°C and 101.325 kilopascals pressure = 0.577g/litre.

$HC_{\text{conc}}$  = Hydrocarbon concentration of the dilute exhaust sample corrected for background, in p.p.m. carbon equivalent as determined by the formula-

$$HC_e - HC_d \times (1 - \underline{1})$$

DF

where -

HC<sub>e</sub>=Hydrocarbon concentration of the dilute exhaust sample, in p.p.m. carbon equivalent.

HC<sub>d</sub>=Hydrocarbon concentration of the dilution air sample, in p.p.m. carbon equivalent.

DF=Dilution factor as determined by the formula -

$$\frac{13.4}{\text{CO}_{2e} + (\text{HC}_e + \text{CO}_e) \times 10^{-4}}$$

$$\text{CO}_{2e} + (\text{HC}_e + \text{CO}_e) \times 10^{-4}$$

where -

CO<sub>2e</sub>=Carbon dioxide concentration of the dilute exhaust sample, in volume percent

CO<sub>e</sub>=Carbon monoxide concentration of the dilute exhaust sample corrected for water vapour and CO<sub>2</sub> extraction, in p.p.m. as determined by the formula:

$$(1 - 0.01925 \text{ CO}_{2e} - 0.000323 R_a) \text{ CO}_{em}$$

if the analyser responds to CO<sub>2</sub>

and water vapour.

where -

R<sub>a</sub> = Relative humidity of the ambient air, in percent.

CO<sub>em</sub>=Carbon monoxide concentration of the dilute exhaust sample, in p.p.m..

CO<sub>mass</sub>=Carbon monoxide emissions, in grams per phase.

Density<sub>co</sub> = Density of carbon monoxide, in grams per

litre at 20°C and 101.325 kilopascals pressure = 1.164 g/litre.

CO<sub>conc</sub> = Carbon monoxide concentration of the dilute exhaust sample corrected for background, water vapour and CO<sub>2</sub> extraction, in p.p.m. as determined by the formula -

$$\text{CO}_e - \text{CO}_d \times (1 - \frac{1}{DF})$$

DF

where :

$CO_d$  = Carbon monoxide concentration of the dilution air sample corrected for water vapour extraction, in p.p.m. as determined by the formula -

$$(1 - 0.000323 R_a) CO_{dm}$$

if the analyser responds to water vapour.

$CO_{dm}$  = Carbon monoxide concentration of the dilution air sample, in p.p.m.

$NO_x \text{ mass}$  = Oxides of nitrogen emissions, in grams per phase.

$Density_{NO_2}$  = Density of exhaust oxides of nitrogen, assuming they are in the form of nitrogen dioxide, in grams per litre at 20°C and 101.325 kilopascals pressure = 1.913 g/litre.

$NO_x \text{ conc}$  = Oxides of nitrogen concentration of the dilute exhaust sample corrected for background, in p.p.m. as determined by the formula -

$$NO_{xe} - NO_{xd} \times (1 - \frac{1}{DF})$$

DF

$NO_{xe}$  = Oxides of nitrogen concentration of the dilute exhaust sample, in p.p.m.

$NO_{xd}$  = Oxides of nitrogen concentration of the dilution air sample, in p.p.m.

$V_{mix}$  = Total dilute exhaust volume in litres per phase, corrected to 20°C and 101.325

kilopascals.

$K_H$  = Humidity correction factor as determined  
by the formula -

$$\frac{1}{1 - 0.0329 (H - 10.71)}$$

where:

$H$  = Absolute humidity, in grams of water per  
kilogram of dry air as determined by the  
formula -

$$\frac{(6.211) R_a \times P_d}{P_B - (P_d \times R_a / 100)}$$

where:

$P_d$  = Saturated vapour pressure, in kilopascals  
at the ambient dry bulb temperature.

$P_B$  = Barometric pressure, in kilopascals.

## **2.6 Modified IM240 Test Procedure [including Purge Test]**

The modified IM240 Test, including the purge test, was conducted in accordance with the attached procedures.

- 2.6.1 INTRODUCTION
  
- 2.6.2 CALCULATION OF EMISSIONS
  - Equations
  - Meaning of Terms
  
- 2.6.3 IM240 AND PURGE TEST PROCEDURE
  - General Requirements
  - Pre-inspection and Preparation
  - Equipment Positioning and Settings
  - Vehicle Preconditioning
  - Vehicle Emission Test Sequence
  - Emission Measurements
  
- 2.6.4 IM240 EQUIPMENT SPECIFICATIONS
  - Dynamometer Specifications
  - Constant Volume Sampler
  - Analytical Instruments
  
- 2.6.5 EVAPORATIVE PURGE SYSTEM INSPECTION EQUIPMENT
  - Evaporative Purge System
  - Specifications
  - Auto Operation
  - Adaptability
  - Purge Analysis System Flow Checks

## 2.6.1 INTRODUCTION

This test procedure is a modification of the US Environment Protection Agency's IM240 and Purge Test procedures [ref: EPA-AA-EPD-IM-93-1 of July 1993]. The modifications reflect the fact that the test is being used in this study for data collection and comparative purposes, not for assessing a vehicle against certain pass/fail criteria which have been implemented in the US for inspection and maintenance programs. Detailed equipment specifications have been deleted as these are essentially the same as those required for testing under ADR37/00. The evaporative pressure system check has also been deleted, because of possible concerns as to the impact of pressurising in-service vehicle systems, and lack of information in the documentation as to the conduct of the test.

## 2.6.2 CALCULATION OF EMISSIONS

### Equations

The mass emission of each pollutant for the measurement phase of the test is determined as follows:

$$\begin{aligned} \text{HC}_{\text{mass}} &= V_{\text{mix}} \times \text{Density}_{\text{HC}} \times \text{HC}_{\text{conc}} \times 10^{-6} \\ \text{CO}_{\text{mass}} &= V_{\text{mix}} \times \text{Density}_{\text{CO}} \times \text{CO}_{\text{conc}} \times 10^{-6} \\ \text{NO}_{\text{xmass}} &= V_{\text{mix}} \times \text{Density}_{\text{NO}_2} \times K_{\text{H}} \times \text{NO}_{\text{x conc}} \times 10^{-6} \\ \text{CO}_{2\text{mass}} &= V_{\text{mix}} \times \text{Density}_{\text{CO}_2} \times \text{CO}_{2\text{conc}} \times 10^{-6} \end{aligned}$$

### Meaning of Terms

The meaning of the terms used in the equations in clause 1.1 are defined below.

**V<sub>mix</sub>**=Total dilute exhaust volume in L/phase, corrected to 20°C and 101.3 kPa.

**HC<sub>mass</sub>** = Hydrocarbon emissions, in g/phase.

**Density<sub>HC</sub>** = Density of exhaust HC, assuming an average C:H ratio of 1:1.85, in g/L at 20°C and 101.3 kPa = 0.577g/L.

**Hc<sub>conc</sub>** = HC concentration of the dilute exhaust sample corrected for background, in ppm C equivalent as determined by the formula-

$$\text{HC}_e - \text{HC}_d \times (1-1/\text{DF})$$

where -

HC<sub>e</sub>=HC concentration of the dilute exhaust sample, in ppm C equivalent.

HC<sub>d</sub>=HC concentration of the dilution air sample, in ppm C equivalent.

DF=Dilution factor as determined by the formula -

$$\frac{13.4}{\text{CO}_{2e} + (\text{HC}_e + \text{CO}_e)10^{-4}}$$

where -

$CO_{2e}$ =CO<sub>2</sub> concentration of the dilute exhaust sample, in volume %

$CO_e$ =CO concentration of the dilute exhaust sample corrected for water vapour and CO<sub>2</sub> extraction, in ppm as determined by the formula -

$$(1-0.01925 CO_{2e} - 0.000323 R_a) CO_{em}$$

if the analyser responds to CO<sub>2</sub> and water vapour.

where -

$R_a$ =Relative humidity of the ambient air, in %.

$CO_{em}$ =CO concentration of the dilute exhaust sample, in ppm.

**CO<sub>mass</sub>**=Carbon monoxide emissions, in g/phase.

**Density<sub>CO</sub>**=Density of CO, in g/L at 20°C and 101.3 kPa = 1.164 g/L.

**CO<sub>conc</sub>**=CO concentration of the dilute exhaust sample corrected for background, water vapour and CO<sub>2</sub> extraction, in ppm as determined by the formula -

$$CO_e - CO_d \times (1 - 1/DF)$$

where :

$CO_d$ =CO concentration of the dilution air sample corrected for water vapour extraction, in ppm as determined by the formula -

$$(1-0.000323 R_a) CO_{dm}$$

if the analyser responds to water vapour.

where :

$CO_{dm}$ =CO concentration of the dilution air sample, in ppm.

**NO<sub>x mass</sub>**=Oxides of nitrogen emissions, in g/phase.

**Density<sub>NO<sub>2</sub></sub>**=Density of exhaust NO<sub>x</sub>, assuming they are in the form of nitrogen dioxide, in g/L at 20°C and 101.3 kPa = 1.913 g/L.

**NO<sub>x conc</sub>**=NO<sub>x</sub> concentration of the dilute exhaust sample corrected for background, in ppm as determined by the formula -

$$NO_{xe} - NO_{xd} \times (1-1/DF)$$

where :

$NO_{xe}$  =NO<sub>x</sub> concentration of the dilute exhaust sample, in ppm

$NO_{xd}$ =NO<sub>x</sub> concentration of the dilution air sample, in ppm

**K<sub>H</sub>**=Humidity correction factor as determined by the formula -

$$\frac{1}{1-0.0329 (H-10.71)}$$

where:

H=Absolute humidity, in g of water per kg of dry air as determined by the formula -

$$\frac{6.211 \times R_a \times P_d}{P_B - (P_d \times R_a)} \times 100$$

where:

$P_d$ =Saturated vapour pressure, in kPa at the ambient dry bulb temperature.

$P_B$ =Barometric pressure, in kPa.

**CO<sub>2</sub>mass**=Carbon dioxide emissions in g/phase.

**Density CO<sub>2</sub>**=Density of CO<sub>2</sub> at 293K and 101.3kPa = 1.83g/L

**CO<sub>2</sub>conc**=CO<sub>2</sub> concentration of the dilute exhaust sample corrected for background in mole % as determined by the formula -

$$CO_{2e} - CO_{2d}(1-1/DF)$$

where :

CO<sub>2e</sub> = CO<sub>2</sub> concentration of the dilute exhaust sample, in mole %

CO<sub>2d</sub> = CO<sub>2</sub> concentration of the dilution air, in mole %

## **2.6.3 IM240 AND PURGE TEST PROCEDURE**

### **General Requirements**

#### *Ambient Conditions*

The ambient temperature, absolute humidity, and barometric pressure shall be recorded continuously during the transient driving cycle or as a single set of readings up to 4 minutes before the start of the transient driving cycle.

#### *Restart*

If shut off, the vehicle shall be restarted as soon as possible before the test and shall be running at least 30 seconds prior to the transient driving cycle.

### **Pre-inspection and Preparation**

#### *Accessories*

All accessories (air conditioning, heat, demisters, radio, automatic traction control if switchable, etc.) shall be turned off.

#### *Leaks*

The vehicle shall be inspected for exhaust leaks. Audio assessment while blocking exhaust flow or gas measurement of CO<sub>2</sub> or other gases shall be acceptable. Vehicles with leaking exhaust systems shall be rejected from testing.

#### *Operating Temperature*

The vehicle temperature gauge, if equipped and operating, shall be checked to assess temperature. Vehicles in overheated condition shall be rejected from testing.

#### *Tyre Condition*

Vehicles shall be rejected from testing if the tyre cords are visible. Vehicle tyres shall be visually checked for adequate pressure level. Drive wheel tyres that appear low shall be inflated to approximately 30 psi, or to tyre sidewall pressure, or the manufacturer's recommendation.

#### *Ambient Background*

Background concentrations of HC, CO, NO<sub>x</sub>, and CO<sub>2</sub> shall be sampled as specified in ADR37/00 to determine background concentration of CVS dilution air. The sample shall be taken for a minimum of 15 seconds within 120 seconds of the start of the transient driving cycle, using the same analysers used to measure tailpipe emissions. Average readings over the 15 seconds for each gas shall be recorded in the test record. Testing shall be prevented until the average ambient background levels are less than 20 ppm HC, 30 ppm CO, and 2 ppm NO<sub>x</sub> or outside ambient air levels, whichever are greater.

#### *Sample System Purge*

While a lane is in operation, the CVS shall continuously purge the CVS hose between tests, and the sample system shall be continuously purged when not taking measurements.

#### *Negative Values*

Negative gram per second readings shall be integrated as zero and recorded as such.

### **Equipment Positioning and Settings**

#### *Purge Equipment*

If an evaporative system purge test is to be performed:

- [a] The evaporative canister shall be checked unless the canister is inaccessible. A missing or obviously damaged canister shall result in failure of the purge test and purge flow measurement shall not be taken.
- [b] The evaporative system shall be visually inspected for the appearance of proper hose routing and connection of hoses, unless the canister is inaccessible. If any evaporative system hose is disconnected, then the vehicle shall fail the test. All hoses shall be reconnected after a purge flow test is performed.
- [c] The purge flow measurement equipment shall be pneumatically connected in series between the evaporative canister and the engine, preferably on the canister end of the hose.

#### *Roll Rotation*

The vehicle shall be manoeuvred onto the dynamometer with the drive wheels positioned on the dynamometer rolls. Prior to test initiation, the rolls shall be rotated until the vehicle laterally stabilises on the dynamometer. Drive wheel tyres shall be dried if necessary to prevent slippage during the initial acceleration.

#### *Cooling System*

Testing shall not begin until the test cell cooling system is positioned and activated. The cooling system shall be positioned to direct air to the vehicle cooling system, but shall not be directed at the catalytic converter, where fitted.

### *Vehicle Restraint*

Testing shall not begin until the vehicle is restrained. Any restraint system shall meet the requirements of ADR37/00.

### *Dynamometer Settings*

Dynamometer power absorption and inertia weight settings shall be those appropriate to the vehicle as specified in Table 1. If the vehicle is fitted with air conditioning, the road power absorber setting shall be increased by 10% and the air conditioning unit switched off.

**Table 1 - Determination of Dynamometer Settings**

<b>No. Of Cylinders</b>	<b>Actual Road Load [hp]</b>	<b>Test Inertia Weight [lbs]</b>
4	9.4	2500
5	10.3	3000
6	10.3	3000
8	11.2	3500

### *Exhaust Collection system*

The exhaust collection system shall be positioned to ensure complete capture of the entire exhaust stream from the tailpipe during the transient driving cycle. The system shall meet the requirements of ADR37/00.

### **Vehicle Preconditioning**

The vehicle shall be preconditioned by driving the vehicle on the dynamometer at 30 miles per hour for up 90 seconds at road load.

## Vehicle Emission Test Sequence

### Transient Driving Cycle

The vehicle shall be driven over the cycle in Table 2.

**Table 2 - Transient Driving Cycle**

<i>Time</i>	<i>Speed</i>								
[s]	[mph]								
0	0	48	25.7	96	0	144	24.6	192	54.6
1	0	49	26.1	97	0	145	24.6	193	54.8
2	0	50	26.7	98	3.3	146	25.1	194	55.1
3	0	51	27.5	99	6.6	147	25.6	195	55.5
4	0	52	28.6	100	9.9	148	25.7	196	55.7
5	3	53	29.3	101	13.2	149	25.4	197	56.1
6	5.9	54	29.8	102	16.5	150	24.9	198	56.3
7	8.6	55	30.1	103	19.8	151	25	199	56.6
8	11.5	56	30.4	104	22.2	152	25.4	200	56.7
9	14.3	57	30.7	105	24.3	153	26	201	56.7
10	16.9	58	30.7	106	25.8	154	26	202	56.3
11	17.3	59	30.5	107	26.4	155	25.7	203	56
12	18.1	60	30.4	108	25.7	156	26.1	204	55
13	20.7	61	30.3	109	25.1	157	26.7	205	53.4
14	21.7	62	30.4	110	24.7	158	27.3	206	51.6
15	22.4	63	30.8	111	25.2	159	30.5	207	51.8
16	22.5	64	30.4	112	25.4	160	33.5	208	52.1
17	22.1	65	29.9	113	27.2	161	36.2	209	52.5
18	21.5	66	29.5	114	26.5	162	37.3	210	53
19	20.9	67	29.8	115	24	163	39.3	211	53.5
20	20.4	68	30.3	116	22.7	164	40.5	212	54
21	19.8	69	30.7	117	19.4	165	42.1	213	54.9
22	17	70	30.9	118	17.7	166	43.5	214	55.4
23	14.9	71	31	119	17.2	167	45.1	215	55.6
24	14.9	72	30.9	120	18.1	168	46	216	56
25	15.2	73	30.4	121	18.6	169	46.8	217	56
26	15.5	74	29.8	122	20	170	47.5	218	55.8
27	16	75	29.9	123	20.7	171	47.5	219	55.2
28	17.1	76	30.2	124	21.7	172	47.3	220	54.5
29	19.1	77	30.7	125	22.4	173	47.2	221	53.6
30	21.1	78	31.2	126	22.5	174	47.2	222	52.5
31	22.7	79	31.8	127	22.1	175	47.4	223	51.5
32	22.9	80	32.2	128	21.5	176	47.9	224	50.5
33	22.7	81	32.4	129	20.9	177	48.5	225	48
34	22.6	82	32.2	130	20.4	178	49.1	226	44.5
35	21.3	83	31.7	131	19.8	179	49.5	227	41
36	19	84	28.6	132	17	180	50	228	37.5
37	17.1	85	25.1	133	17.1	181	50.6	229	34
38	15.8	86	21.6	134	15.8	182	51	230	30.5
39	15.5	87	18.1	135	15.8	183	51.5	231	21
40	17.7	88	14.6	136	17.7	184	52.2	232	23.5
41	19.8	89	11.1	137	19.8	185	53.2	233	20
42	21.6	90	7.6	138	21.6	186	54.1	234	16.5
43	23.2	91	4.1	139	22.2	187	54.6	235	13
44	24.2	92	0.6	140	24.5	188	54.9	236	9.5
45	24.6	93	0	141	24.7	189	55	237	6
46	24.9	94	0	142	24.8	190	54.9	238	2.5
47	25	95	0	143	24.7	191	54.6	239	0

### *Driving Trace*

The inspector shall follow an electronic, visual depiction of the time/speed relationship of the transient driving cycle (hereinafter, the trace). The visual depiction of the trace shall be of sufficient magnification and adequate detail to allow accurate tracking by the driver and shall permit the driver to anticipate upcoming speed changes. The trace shall also clearly indicate gear shifts as specified in clause 2.5.3.

### *Shift Schedule*

For vehicles with manual transmissions, the operator shall shift gears according to the shift schedule in Table 3. Gear shifts shall occur at the points in the driving cycle where the specified speeds are obtained. For vehicles with fewer than six forward gears the same schedule shall be followed with shifts above the highest gear disregarded.

**Table 3 - Shift Schedule**

<b>Shift Sequence [gear no.]</b>	<b>Speed [mph]</b>	<b>Nominal Cycle Time [s]</b>
1 - 2	15	9.3
2 - 3	25	47.0
De-clutch	15	87.9
1 - 2	15	101.6
2 - 3	25	105.5
3 - 2	17	119.0
2 - 3	25	145.8
3-4	40	163.6
4 - 5	45	167.0
5 - 6	50	180.0
De-clutch	15	234.5

### *Speed Excursion Limits*

Speed excursion limits shall apply as follows:

- [a] The upper limit is 2 mph higher than the highest point on the trace within 1 second of the given time.
- [b] The lower limit is 2 mph lower than the lowest point on the trace within 1 second of the given time.
- [c] Speed variations greater than the tolerances are acceptable provided they occur for no more than 2 seconds on any occasion.
- [d] Speeds lower than those prescribed during accelerations are acceptable provided the vehicle is operated at maximum available power during such accelerations until the vehicle speed is within the excursion limits.
- [e] Exceedences of the limits in [a] through [c] of this paragraph shall automatically result in a void test. The test facility manager can override the automatic void of a test if the manager determines that the conditions specified in paragraph [d] occurred. Tests shall be aborted if the upper excursion limits are exceeded. Tests may be aborted if the lower limits are exceeded.

### *Speed Variation Limits*

A linear regression of feedback value on reference value shall be performed on each transient driving cycle for each speed using the method of least squares, with the best fit equation having the form:  $y = mx + b$ , where:

$y$  = the feedback (actual) value of speed;

$m$  = the slope of the regression line;

$x$  = the reference value; and

$b$  = the y-intercept of the regression line.

The standard error of estimate (SE) of  $y$  on  $x$  shall be calculated for each regression line. A transient driving cycle that exceeds the following criteria shall be void and the test shall be repeated:

SE = 2.0 mph maximum;

$m = 0.96-1.01$ ;

$r^2 = 0.97$  minimum; and

$b = \pm 2.0$ mph.

### *Distance Criteria*

The actual distance travelled for the transient driving cycle and the equivalent vehicle speed (ie., roll speed) shall be measured. If the absolute difference between the measured distance and the theoretical distance for the actual test exceeds 0.05 miles, the test shall be void.

### *Vehicle Stalls*

Vehicle stalls during the test shall result in a void and a new test. More than 3 stalls shall result in test failure.

### *Dynamometer Controller Check*

For each test, the measured horsepower, and inertia if electric simulation is used, shall be integrated from 55 seconds to 81 seconds (divided by 26 seconds), and compared with the theoretical road-load horsepower (for the vehicle selected) integrated over the same portion of the cycle. The same procedure shall be used to integrate the horsepower between 189 seconds to 201 seconds (divided by 12 seconds). The theoretical horsepower shall be calculated based on the observed speed during the integration interval. If the absolute difference between the theoretical horsepower and the measured horsepower exceeds 0.5 hp, the test shall be void. For vehicles over 8500 pounds GVWR, if the absolute difference between the theoretical horsepower and the measured horsepower exceeds 2 hp, the test shall be void.

The dynamometer controller check in this clause 2.5.8 is not required, provided the dynamometer is checked at least daily as part of the laboratory's normal quality assurance program

### *Inertia Weight Selection*

Operation of the inertia weight selected for the vehicle shall be verified as specified in ADR37/00. For systems employing electrical inertia simulation, an algorithm identifying the actual inertia force applied during the transient driving cycle shall be used to determine proper inertia simulation. For all dynamometers, if the observed inertia is more than 1% different from the required inertia, the test shall be void.

### *CVS Operation*

The CVS operation shall be verified throughout the test by monitoring the difference in pressure from atmosphere for a CFV-type CVS or the difference in pressure between upstream and throat pressure on a SSV-type CVS. The minimum values

shall be determined from system calibrations. Monitored pressure differences below the minimum values shall void the test.

## **Emission Measurements**

### *Exhaust Measurement*

The emission analysis system shall sample and record dilute exhaust HC, CO, CO<sub>2</sub>, and NO<sub>x</sub> during the transient driving cycle as described in ADR37/00.

### *Purge Measurement*

The analysis system shall record the total volume of flow in litres over the course of the actual driving cycle as described in part 4.

## **2.6.3 IM240 EQUIPMENT SPECIFICATIONS**

### **Dynamometer Specifications**

The dynamometer shall meet the requirements specified in ADR37/00.

### **Constant Volume Sampler**

A constant volume sampling (CVS) system of the critical flow venturi (CFV) or the subsonic venturi (SSV) type shall be used to collect vehicle exhaust samples. The CVS system and components shall conform to the specifications in ADR37/00. A continuous dilute sample shall be provided for integration by the analytical instruments in a manner similar to the method for collecting bag samples as described in ADR37/00.

### **Analytical Instruments**

The emission analysis system shall automatically sample, integrate, and record the specified emission values for HC, CO, CO<sub>2</sub>, and NO<sub>x</sub> in the manner, and using the equipment, specified in ADR37/00. Performance of the analytical instruments with respect to accuracy and precision, drift, interferences, noise, etc. shall be similar to instruments used for testing exhaust emissions under ADR37/00.

### **Maintenance of Equipment**

Dynamometer, CVS and associated analytical equipment shall be maintained and calibrated in accordance with manufacturer's requirements and in accordance with ADR37/00.

## **2.6.4 EVAPORATIVE PURGE SYSTEM INSPECTION EQUIPMENT**

### **General Requirements**

The evaporative purge analysis system shall compute the total volume of the flow in standard litres over the transient driving cycle.

### **Specifications**

The purge flow measuring system shall comply with the following requirements.

- [a] Flow Capacity - 0.56 - 10 L/min.

- [b] Pressure Drop - Maximum of 16 inches of water at 10 L/min for the complete system including hoses necessary to connect the system to the vehicle.
- [c] Totalised Flow - 0 to 100 L of volume
- [d] Response time - 410 ms maximum to 90% of a step change between approximately 2 and 10 L/min measured with air.
- [e] Accuracy -
  - ±5% at 3 L/min (over 4 minute period)
  - ±5% at 5 L/min (over 4 minute period)
  - ±5% at 7 L/min (over 4 minute period)
- [f] Noise - The maximum noise shall be less than 0.001 L per second
- [g] Calibration Gas - Air

### **Automatic Operation**

The total volume of vehicle purge flow shall be monitored with an Emco Flowmeter, Model no. TLG05 with FR93 "Genius" Flow Processor fitted with a bypass for flow rates greater than 10L/min, or equivalent.. In determining the total volume of flow, the monitoring system shall not count signal noise as flow volume. The test sequence shall be initiated when the transient driving cycle test is initiated.

### **Adaptability**

The purge flow system shall have sufficient adaptors to connect in a leak-tight manner with the variety of evaporative systems and hose deterioration conditions in the vehicle fleet. The purge measurement system shall not substantially interfere with purge flow.

### **Purge Analysis System Flow Checks**

#### *Daily Check*

Each flow meter used to measure purge flow shall be checked each operating day with simulated purge flow (e.g., auxiliary pneumatic pump) against a reference flow measuring device with performance specifications equal to or better than those specified for the purge meter. The check shall include a mid-scale rate check, and a total flow volume check between 10 and 20 L. Deviations greater than ±5% of full scale shall require corrective action.

#### *Monthly Check*

Except as specified in clause 4.5.3, on a monthly basis, the calibration of purge meters shall be checked for total volume of flow at 12, 20, and 28 L over 4 min. Deviations exceeding 25% of point in 4 min, or 1 L in 4 min, whichever is less, shall require corrective action.

#### *Alternative Check procedure*

The monthly flowmeter check specified in 4.5.2 need not be carried out on a monthly basis, but calibration against the reference flowmeter shall be carried out as part of the correlation vehicle arrangement specified in Attachment 4 to these tender specifications, or as requested by one or more of the testing contractors.

## **PART 2 : INSPECTION AND TEST SEQUENCE**

The sequence of the testing program is as follows.

1. Inspect vehicle as received in accordance with PART 1 of this Attachment.
  - **If suitable** for testing, go on to item 2 and provide report on pre-test inspection, including advice of parts required for tuning, and other matters requiring attention by tuning contractor.
  - **If not suitable** for testing, vehicle should be tuned, cleaned [washed externally and vacuumed & wiped over inside], filled with petrol, and returned to vehicle owner with a copy of the completed checklist [including tuning information]
2. Prepare and precondition vehicle in accordance with ADR37/00, including requirements for evaporative emissions test, where applicable.
3. Overnight temperature soak as specified in ADR37/00.
4. Commence ADR37/00 test sequence as specified in PART 1 above.
5. At completion of heat build [where required] conduct Fuel Filler Cap Sealing test.
6. Complete ADR37/00 drive cycle.
- 7A. For vehicles undergoing ADR37/00 Evaporative Emissions test, complete test in accordance with ADR37/00 procedures and then return vehicle to dynamometer. Immediately prior to commencing the Acceleration Simulation Mode [ASM] Test at Step 8, bring vehicle to normal operating temperature by running vehicle at the ASM speed and load for 5 minutes.
- 7B. For vehicles not undergoing ADR37/00 Evaporative Emissions test, leave vehicle on the dynamometer. If the vehicle does not immediately proceed to the Acceleration Simulation Mode [ASM] Test at Step 8, bring vehicle to normal operating temperature by running vehicle at the ASM speed and load for 5 minutes immediately prior to commencing the ASM test..
8. Conduct Acceleration Simulation Mode test.
9. Conduct Steady State Loaded [60km/hr] test.
10. Conduct Steady State [High Idle] test and immediately the test is completed conduct the Catalyst Temperature test.
11. Conduct the Steady State [Idle] test.
12. Conduct the IM240 [including purge] test.

13. Provide vehicle to separate contractor for tune/repair as defined in PART 3.
14. Repeat steps 2 to 12 of the above sequence.
15. Prepare summary sheet for vehicle owner.
16. Forward/store data required for analysis.
17. Testing completed - vehicle returned to owner in accordance with contract requirements.

## ***PART 3 : TUNING SPECIFICATIONS***

### *General Requirements & Costs*

The tuning was undertaken by a separate contractor but on the tenderer's premises in accordance with sub-section 4.3 of the tender document. When the tuning contractor arrived to tune a vehicle, the tenderer provided the tuning contractor with the pre-test inspection checklist [see PART 1 of this Attachment] for that vehicle and any replacement parts specifically ordered for the vehicle as a result of the pre-test inspection.

The parts budget for the tuning was set at a maximum of \$150 per vehicle. Where it was considered necessary to replace expensive parts such as the oxygen sensor, and the total parts budget for the vehicle, as a result, exceeded \$150, the tenderer was authorised to approve additional parts expenditure, subject to an absolute maximum of \$200 [except where specifically approved by the Project Manager], and provided that such extra expenditure did not lead to total parts expenditure exceeding an average of \$150 per vehicle.

### *Procedure*

The vehicle was tuned to manufacturer's specifications.

The tuning was limited to the following items [where applicable]:

- Replace points and air filter
- Replace fuel filter [if necessary]
- Replace oil [using SG20W-50 oil] and oil filter.
- Check spark plug condition and gap, and adjust or replace as necessary
- Check distributor condition and operation and adjust as necessary
- Check and adjust idle mixture and speed
- Check and replace spark plug and distributor leads as necessary
- Check and replace hoses and other minor items in fuel/electrical/emission control systems as necessary, subject to budget
- Interrogate vehicle diagnostics and replace faulty components, subject to budget detailed above.

*Note* Failed or malfunctioning catalytic converters cannot normally be replaced because of budgetary limitations, but faulty oxygen sensors should be replaced where possible, if within running budget.

The transmission, radiator and battery fluids were topped up if necessary.

Details of all work undertaken were recorded on the shaded area of the pre-inspection check list in PART 1.

*Range of Vehicles to be Tuned*

The vehicles presented for testing/tuning came from the following group [date of manufacture 1980-1991]:

Ford	Falcon/Fairmont/Fairlane Telstar Laser/Meteor Cortina Escort
Holden	Commodore/Berlina/Calais/Vacationer Statesman Camira Apollo Astra Nova Torana/Sunbird
Nissan	Pintara Bluebird Pulsar Datsun 120Y Datsun 200B
Mitsubishi	Magna Sigma Colt
Toyota	Lexcen Camry Corona Corolla

# **APPENDIX IX**

## **DATA FROM TESTING & INSPECTION**

# **DATA FROM TESTING & INSPECTION**

The data required is detailed in **PARTS 1-3**. The format of the presented data complied with **PART 4**.

## **PART 1**

### **SUMMARY SHEET FOR OWNER**

The vehicle owner was provided with a summary sheet which incorporates the following information:

- Repairs/replacements/adjustments made as part of the tuning [ a copy of the completed pre-test inspection sheet, with the information from the tuning contractor, may be provided as a means of meeting this requirement]
- Results from the ADR37/00 Exhaust Emissions test [including fuel economy] **after** tuning, with a comparison of these results with the ADR27 or ADR37/00 limits the vehicle was expected to meet as new.
- A brief statement thanking the vehicle owner for their participation in the study.

## ***PART 2***

### ***DESCRIPTIVE VEHICLE & ENGINE DATA, & TUNING DATA***

All of the information generated on the vehicle from the pre-test inspection checklist, plus the data which is added by the tuning contractor, was provided for use by the data analyst.

## PART 3

### TESTING DATA

The data obtained, and provided to the data analyst, from each of the tests specified in Attachment 1 are detailed below:

#### Emissions Tests

TEST	OUTPUT										
	HC		CO		NOx		CO2		Fuel Consumption		
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
ADR37/00 Exhaust Emissions											
Cold Start 505	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	L/100km	L/100km
Transient 867	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	L/100km	L/100km
Hot 505	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	L/100km	L/100km
Full Cycle	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	L/100km	L/100km
ADR37/00 Evaporative Emissions	g/test	g/test	-	-	-	-	-	-	-	-	-
Acceleration Simulation Mode	ppm	ppm	%vol	%vol	ppm	ppm	%vol	%vol	-	-	-
Steady State [Idle]	ppm	ppm	%vol	%vol	-	-	-	-	-	-	-
Steady State [High Idle]	ppm	ppm	%vol	%vol	-	-	-	-	-	-	-
Steady State Loaded [60km/hr]	g/min	g/min	g/min	g/min	g/min	g/min	-	-	-	-	-
IM240 Exhaust Emissions	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	g/km	-	-

"Pre" refers to the testing undertaken before the vehicle is tuned

"Post" refers to the testing undertaken after the vehicle is tuned  
"\_" means not applicable

**Other Tests**

<b>TEST</b>	<b>OUTPUT</b>
IM240 Purge	Total volume of flow [L]
Catalyst temperature	Temperature [°C] at inlet and outlet of catalytic converter and difference between two values.
Catalyst Integrity	Rattle/no rattle
Fuel Filler Cap Sealing	HC concentration [ppm]

## ***PART 4***

### ***FORMAT OF OUTPUT***

To enable ready analysis using widely used data analysis packages, the data outlined in Parts 1, 2 and 3 above was provided in a database format in *Microsoft Excel* or *Microsoft Access* as specified by the Project Manager.

# **APPENDIX X**

## **CORRELATION VEHICLE PROCEDURES**

# **CORRELATION PROCEDURES**

# **VEHICLE**

## ***Frequency***

The correlation procedure described below was conducted approximately every 4 months in accordance with the following schedule [with adjustments if necessary to accommodate FCAI rounds]:

Round 1	Commencing 1 July 1994
Round 2	Commencing 1 November 1994
Round 3	Commencing 1 March 1995
Round 4	Commencing 1 June 1995

## ***Procedure***

The correlation vehicle for each round was specified by the vehicle testing group.

The vehicle was filled with ADR37/00 certification test fuel, weighed and subjected to the following series of tests:

- ADR37/00 Exhaust Emissions [Cold Start]
- Dynamometer Speed Check [refer procedure below]
- ASM2525
- Steady State Loaded [60km/hr]
- Steady State [High Idle]
- Catalyst Temperature
- Steady State [Idle]
- IM240 [including purge]
- Coast Down Time Determination [refer procedure below]

The test series was repeated 5 times in the first test facility to establish the baseline data, and then repeated 3 times in the other facilities. The vehicle was then returned to the first test facility, where the test series is repeated a minimum of 2 times.

### Dynamometer Speed Check Procedure

This procedure for checking dynamometer speed was conducted by setting the dynamometer speed [rear roller] at 80km/hr and, when stable, recording the corresponding speed on the vehicle's speedometer.

### Coast Down Time Determination Procedure

The procedure for determining coast down time was conducted as follows:

- At the end of the IM240 test, accelerate the vehicle to 110km/hr and hold speed constant for at least 60 s.
- Remove foot from accelerator and place the transmission in neutral.
- Start a suitable timer at 100km/hr and continue to record the time in s until the speed falls to 10km/hr.
- Record the coast down time for each 10km/hr speed drop as follows:

100	to	90
90	to	80
80	to	70
70	to	60
60	to	50
50	to	40
40	to	30
30	to	20
20	to	10

### IR Detector Check

The Raynger PM4 IR detector was tested against the reference digital instrument accompanying the vehicle.

### Flowmeter Check

From Round 2 onwards, the reference flowmeter used in the IM240 test accompanied the correlation vehicle and the calibration outlined on A2[10] part [8] undertaken in each facility.

### Tachometer Check

A tachometer check on the raw analysis equipment was conducted as follows using the ONO-SOKKI device which accompanies the vehicle:

with the vehicle running at idle, the rpm reading from the tachometer on the raw analysis bench was recorded and at the same time the ONO-SOKKI hand held device was used to measure the rpm reading on the tachometer.

### Analyser Calibration

Cylinders of suitable gases also accompanied the vehicle to enable correlation of bag bench and raw analysis gas analyser equipment, in accordance with the test facility's standard calibration procedures for the equipment.

## Results

The following results were recorded by each test facility and forwarded to the person nominated by the project manager:

<i>Test</i>	<i>Results to be Recorded</i>
Weight of Vehicle [fuel tank full]	Weight in kg
ADR37/00 Exhaust Emissions [CS]	HC, CO, NOx, CO2, Fuel Consumption
ASM2525	HC, CO, NOx, CO2
Steady State Loaded [60km/hr]	HC, CO, NOx, CO2
Steady State [High Idle]	HC, CO
Catalyst Temperature	Temp in °C front & rear, and difference
Steady State [Idle]	HC, CO
IM240 [including purge]	HC, CO, NOx, CO2, Fuel Consumption Purge flow
Coast down	Time in s to go from 100km to 10km 10km increments
Dynamometer Speed Check	Dyno Speed [80km/hr] and corresponding vehicle speedometer reading [km/hr]
Flowmeter test	Total volume of flow [L] at specified points
Bag and raw analysis bench gas calibration	Readings for each cylinder from each bench
RPM Check	Raw analysis bench rpm reading at corresponding ONO-SOKKI reading
Infra-red Temperature Check [Raynger PM4 Detector]	Comparison of temperature reading between laboratory device and reference device

## ***Analysis***

The data from each round was provided to FORS/RACV for analysis. The objective was to have results from each round which fall within the following tolerances:

±5% on data from gas calibration of bag bench analysers

±10% on data from gas calibration of raw analysis bench analysers

±5% on mean of data from the vehicle from all laboratories .