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Intensive Field Trial of Ethanol/Petrol Blend in Vehicles

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Petrohol In-Service Vehicle Emissions Study

Report No: MV-A-35

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Abstract

Sixty in-service light-duty passenger vehicles were tested for regulated exhaust and evaporative emissions, aldehydes, air toxics, ozone formation potential, fuel consumption and engine performance, while operating on both petrol and petrohol (a 10% ethanol/ petrol blend).

A sub-set of vehicles was tested prior to and following servicing. Another sub-set was tested on two separate occasions, twelve months apart.

The test protocols and methods are outlined, test results are displayed in graphical form, data are analysed statistically and a number of key findings are provided.

ACKNOWLEDGMENTS

The NSW EPA Project Team wishes to acknowledge the considerable efforts of all those who became involved in the study – the Project Steering Committee members, APACE, CSIRO, NRMA, and particularly the laboratory testing staff who worked long and hard under what were at times difficult conditions to make this study a success.

As well as those directly involved with the study, the owners of sixty vehicles who entrusted their cars to the EPA for testing must be acknowledged.

Our sincere thanks.

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Glossary

ADR	Australian Design Rule
ADR 27A	Australian Design Rule 27A: Emission Control for Light Vehicles, introduced in 1976. For this report ADR 27A denotes ADR 27 A, B (introduced 1978) and C (introduced 1981)
ADR 37/00	Australian Design Rule 37/00: Emission Control for Light Vehicles, introduced from 1 February 1986, superseded by ADR 37/01which is being phased in from 1 January 1997
AGL	AGL Gas Company (NSW) Ltd. - also known as The Natural Gas Co.
AIP	Australian Institute of Petroleum
Air Toxics	a large number of toxic air pollutants emitted by motor vehicles and other sources. In this report, air toxics mean the toxic hydrocarbons 1,3-butadiene, benzene, toluene and xylene
Aldehydes	a range of organic species emitted by motor vehicles and other sources. In this report, aldehydes means formaldehyde, acetaldehyde and acrolein
APACE	APACE Research Ltd.
AS 2877	Australian Standard 2877-1986: Methods of Test for Fuel Consumption of Motor Vehicles Designed to Comply with Australian Design Rules 37 and 40
BF	Base Fleet vehicle
BFS	Base Fleet Sub-set vehicle
BOGAS	Bowen Petroleum Services - a distributor of Petrohol fuel to service station outlets
CO	carbon monoxide - a regulated motor vehicle pollutant emission
CO_2	carbon dioxide - a greenhouse gas emitted by motor vehicles and other sources, not a regulated pollutant but is listed with the regulated pollutants in this report
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Division of Coal and Energy Technology
CT	the cold-start transient phase of the ADR 37/00 exhaust emissions test
CVS	constant volume sampler, used in exhaust emissions testing
DEST	Department of Environment, Sport and Territories

DPIE	Department of Primary Industries and Energy
E70	a defining property of petroleum fuel, equals volume percentage evaporated at 70°C
EMS	engine management system
EPA (VIC)	Environment Protection Authority of Victoria
ERDC	Energy Research and Development Corporation
FBP	a defining property of petroleum fuel, equals final boiling point
FCAI	Federal Chamber of Automotive Industries
FORS	Federal Office of Road Safety
FVI	a defining property of petroleum fuel, equals flexible volatility index
HC	hydrocarbons - a range of emissions from motor vehicles, regulated as total hydrocarbons
HT	the hot-start transient phase of the ADR 37/00 exhaust emissions test
IBP	a defining property of petroleum fuel, equals initial boiling point
In-Service	a registered in-use motor vehicle
LP	leaded petrol
LTIS	Long Term In-Service vehicle
MIR	maximum incremental reactivity
MON	motor octane number
MPI	multi-point injection (fuel injection system)
NATA	National Association of Testing Authorities
NISE Study	the National In-Service Vehicle Emissions Study carried out by FORS (Report titled "Motor Vehicle Pollution in Australia", 1996)
NOx	oxides of nitrogen - a range of emissions from motor vehicles, regulated as total oxides of nitrogen
NRMA	National Roads and Motorists Association
NSW EPA	New South Wales Environment Protection Authority

Ozone	a pollutant formed in the atmosphere by a series of complex reactions between NOx and reactive organic compounds under the influence of strong sunlight – a measure of photochemical smog
Ozone reactivity	ozone formation potential of a reactive organic compound
Petrohol	fuel which is a blend of ethanol and petrol, in this report 10% v/v ethanol/ petrol
Pre-1986 model	vehicle manufactured prior to 1 February 1986 that operates on leaded petrol, which in this report complies with ADR 27 A, B or C
Post-1986 model	vehicle manufactured on or after 1 February 1986 that operates on unleaded petrol, which in this report complies with ADR 37/00
RAF	reactivity adjustment factor
ROC	reactive organic compound
RON	research octane number
RVP	a defining property of petroleum fuel, equals Reid Vapour Pressure
S	the stabilised phase of the ADR 37/00 exhaust emissions test
SHED	Sealed Housing for Evaporative Determination
TBI	throttle body injection (fuel injection system)
Transmission	number of gears (3/4/5), manual or automatic (M/A), overdrive (O)
ULP	unleaded petrol

Executive Summary

INTRODUCTION

As part of its lead abatement strategy the Federal Government in its 1993/94 Budget committed funds for new Government measures to reduce lead pollution. One of these measures involved the funding of research and development on ethanol-blended motor fuels with a view to reducing dependence on imported petroleum-based fuels and reducing air pollutants. Four work programs were developed by the Department of Primary Industries and Energy (DPIE) and the Department of the Environment, Sport and Territories (DEST) to assess the potential of ethanol petrol blends as an alternative fuel for motor vehicles.

The Energy Research and Development Corporation (ERDC) was engaged to oversee the management of the four work programs. APACE Research Ltd (APACE) was awarded the contract to undertake Work Program 1: "Intensive Field Trials of Ethanol Blends in Motor Vehicles".

This report relates to several objectives in Work Program 1 and specifically to that work carried out by the NSW EPA, under contract to APACE. The work involved the testing of a range of "in-service" passenger vehicles on "petrohol" (a 10% v/v ethanol/ petrol blend) and on neat petrol to compare vehicle emissions, fuel consumption and engine performance. The test methods, equipment used, test results, statistical analyses and key findings are presented in this report.

OBJECTIVES

The objectives for Work Program 1 are listed below.

1. **Establish the contribution of ethanol/ petrol blend in reducing greenhouse gas and noxious emissions.**

2. **Compare in-service fuel consumption of ethanol/ petrol blend to that of neat petrol.**

3. Compare vehicle driveability on ethanol/ petrol blend to that on neat petrol under various climatic conditions.

4. **Measure engine performance** and establish road octane number **of ethanol/ petrol blend**.

5. Examine the fuel system component materials for compatibility with ethanol/ petrol blend and conformity to international standards.

6. Compare engine wear with ethanol/ petrol blend to that with neat petrol.

7. Examine water tolerance issues arising from storage, distribution and use of ethanol/ petrol blend.

In October 1995 the NSW EPA entered into a contract with APACE to undertake work relating to objectives 1, 2 and part of 4 (as highlighted above) such that the following three primary areas of interest could be addressed:

- the emissions, fuel consumption and engine performance of vehicles operating on ethanol/ petrol blend compared with neat petrol,

- the effectiveness of maintenance in reducing emissions when operating on ethanol/ petrol blend and on neat petrol,

- the deterioration in emissions, if any, over a 12 month period due to the use of ethanol/ petrol blend.

A Project Steering Committee comprising ERDC (Chair), EPA (VIC), APACE, FCAI, AIP and BOGAS was assembled to oversee the study and to ensure that the objectives were met.

METHODOLOGY

The Petrohol In-Service Vehicle Emissions Study involved testing 60 in-service light-duty passenger vehicles from five manufacturers, operating on both petrohol and petrol, to support examination of the impact of petrohol on emissions and engine performance. Emissions testing commenced in November 1995 and concluded in May 1997. The vehicles were tested in a number of different conditions such that a total of 188 complete emissions test sequences were carried out.

In order for the test sample to be representative of the in-service passenger vehicle fleet, APACE selected the vehicles such that the sample covered:

- the major vehicle makes and models manufactured between 1979 and 1995,
- low and high "mileage" vehicles having travelled between 7,000 and 440,000 kilometres,
- leaded and unleaded vehicles,
- carburettor and fuel injection vehicles,
- vehicles already operating on petrohol, mainly from the Newcastle and Central Coast regions of NSW, where petrohol is commercially available.

Vehicles were divided into the following three categories to assess the three primary areas of interest (general emissions comparison, effect of maintenance and emissions deterioration):

- **General Emissions Comparison - Base Fleet (BF) vehicles (37 vehicles):**
  Vehicles (26 post-1986 and 11 pre-1986 models) were tested once on petrohol and once on petrol in the "post-tune" condition (i.e. after servicing) so as to compare the emissions performance of the two fuels. Each vehicle was tested for the regulated exhaust and evaporative emissions, aldehyde exhaust emissions and fuel consumption.

- **Effect of Maintenance - Base Fleet Sub-set (BFS) vehicles (12 vehicles):**
  Vehicles (6 post-1986 and 6 pre-1986 models) were tested twice on each fuel, once "as received" (i.e. pre-tune) and then in the post-tune condition, to examine the effect of maintenance (or vehicle servicing). Each vehicle was tested for the regulated exhaust and evaporative emissions, aldehyde exhaust emissions and fuel consumption. All vehicles were serviced by the NRMA, with most having air, oil and fuel filters, engine oil, spark plugs, and points (if fitted) replaced. The engine tune settings were adjusted to the manufacturer's specifications. Some minor repairs were also carried out to enable the vehicles to be tested safely.

- **Emissions Deterioration - Long Term In-Service (LTIS) vehicles (11 vehicles):** Vehicles (9 post-1986 and 2 pre-1986 models) were tested three times on each fuel, once at the start of the project in the post-tune condition and again after a twelve-month period in both pre-tune and post-tune conditions, to monitor any deterioration in emissions over that time. The original intention was to test each LTIS vehicle for regulated exhaust and evaporative emissions, aldehyde exhaust emissions, toxic exhaust and evaporative emissions, fuel consumption and engine performance (power/ torque). However, owing to changes made to the pre-conditioning sequence, as well as efforts made to maximise the range of parameters analysed for the limited resources available, several of the above emissions/performance measures were not recorded on all three occasions.

The test vehicles were supplied by APACE and were tested on both petrohol and petrol in any one condition. Published test methods were followed as far as practicable. The following parameters were measured:

(1) **Regulated exhaust and evaporative emissions**. Tests were conducted by the EPA in accordance with Australian Design Rule (ADR) 37/00;
(2) **Aldehyde exhaust emissions** during the ADR 37/00 test sequence. Samples were collected by the EPA and analysed by the CSIRO – Division of Coal and Energy Technology;
(3) **Air toxics emissions** during the ADR 37/00 test sequence. Samples were collected by the EPA and analysed by the CSIRO – Division of Coal and Energy Technology;
(4) **Ozone formation potential** of the volatile organic compounds emitted during the ADR 37/00 test sequence. Samples were collected by the EPA and analysed by the CSIRO – Division of Coal and Energy Technology;
(5) **Fuel consumption**. Tests were conducted by the EPA in accordance with Australian Standard (AS) 2877-1986;
(6) **Engine performance**. Tests were conducted by the EPA using a procedure developed specifically for the project.

The testing methodologies adopted were generally consistent with those used in the Federal Office of Road Safety (FORS) National In-Service Emissions (NISE) study, but were extended to cover items (2), (3), (4) and (6) above.

Two modifications were made to the NISE study test protocols following recommendations from APACE. Specifically, the modifications related to the vehicle pre-conditioning requirements and the location of the fuel temperature measuring thermocouple. The changes were endorsed by the Project Steering Committee.

As a consequence of these changes, evaporative emission tests performed to the original protocol were deemed by the Project Steering Committee to be invalid. Therefore, evaporative emission data from those tests have not been included in this report. The changes to the protocol were deemed not to affect exhaust emissions or fuel consumption test results.

Petrohol (10% v/v ethanol/ petrol) was produced by splash blending anhydrous ethanol with the base petrol (leaded and unleaded). This was carried out by APACE prior to the commencement of the study. Ampol supplied the base petrol as two batches (one leaded and one unleaded). The base petrol was representative of commercial grade fuel.

KEY FINDINGS

Analysis of Results

Results have been analysed in a way that allowed a series of key findings to be made in each of the three primary areas of interest (general emissions comparison, effect of maintenance and emissions deterioration).

For most of the parameters measured, statistical analyses were carried out on the differences between the paired results for the following comparisons:

- **petrohol** to **petrol** in the "**All"** group, **post-1986** models and **pre-1986** models (post-tune condition only).
- **post-tune** condition to **pre-tune** condition for each fuel (post-1986 and pre-1986 models combined).
- **LTIS second series** to **LTIS first series** of testing for each fuel (post-1986 and pre-1986 models combined).

Note: The three comparisons above correspond with the three primary areas of interest.

Statistical analyses enabled inferences to be made about the likely impacts on the vehicle fleet from which the sample was drawn, primarily the in-service light-duty passenger vehicle fleet in the Newcastle/ Central Coast regions. For each of the comparisons listed above, the key findings include the 95% confidence limits.

For each parameter, the difference (i.e. the impact) for the fleet was estimated as the mean difference calculated from the vehicle sample tested, while the associated confidence interval was determined by using the *t* statistic based on the paired differences in the sample. When reporting on the significance of an increase or decrease, a 95% two-tailed test was used. Such a test detects a change in either direction.

Where a mean difference was not significant at the 95% confidence level, in most instances this was associated with large inter-vehicle variability relative the mean difference (i.e. 95% confidence limit was larger than the mean difference). In these instances, it is suspected that some of the trends may have been real, but there was insufficient statistical power in the experimental design (i.e. insufficient "replicates" – in this case, vehicles in the sample) to enable this to be demonstrated.

The extrapolation of these results to a wider geographic area (e.g. NSW or Australia) depends on how well the vehicles drawn from the Newcastle/ Central Coast regions for the study reflect the fleet composition of the wider area. Before extrapolating the findings presented in this report, a comparison should be made to ascertain the appropriateness of such a procedure.

General Emissions Comparison

Table A provides a summary of the impacts of petrohol on the parameters measured. Two aspects of the results are presented:

- the mean differences between fuels obtained from the sample of vehicles tested; and
- the range of uncertainties (95% confidence limits).

Impacts in **bold** were derived from all vehicles tested (pre-1986 and post-1986 vehicles) in the post-tune condition.

The numbers of vehicles included in the calculations are indicated in the third column of the table.

For each parameter, the impact is expressed as the percentage difference between the mean of all results on petrohol and the mean of all results on petrol (baseline is petrol). The 95% confidence limits are also indicated.

Table A: Impacts of Petrohol
(Percentages have been rounded to the nearest whole number)

PARAMETERS MEASURED	% DIFFERENCE: MEAN PETROHOL COMPARED TO PETROL (95% CONFIDENCE LIMITS)	NUMBERS OF VEHICLES INCLUDED (POST-TUNE)
Regulated Exhaust Emissions		
Hydrocarbons (HC)	⇓ **12** ± 4	59
Oxides of Nitrogen (NOx)	⇑ **3** ± 4[#]	59
Carbon Monoxide (CO)	⇓ **32** ± 9	59
Carbon Dioxide (CO_2) [1]	⇑ **1** ± 1	59
Regulated Evaporative Emissions		
Hydrocarbons (HC)	⇑ **27** ± 12	56
Exhaust Aldehyde Emissions		
Formaldehyde (CH_2O)	⇑ **27** ± 12	56
Acetaldehyde (C_2H_4O)	⇑ **215** ± 58	53
Acrolein (C_3H_4O)	⇑ **12** ± 18[#]	55
Exhaust Toxic Emissions		
1,3-Butadiene (C_4H_6)	⇓ **21** ± 36[#]	10
Benzene (C_6H_6)	⇓ **23** ± 12	11
Toluene (C_7H_8)	⇓ **21** ± 13	11
Xylene (C_8H_{10})	⇓ **20** ± 12	11
Ozone Formation Potential [2]		
Exhaust Ozone Potential	⇓ **20**	11
Evaporative Ozone Potential	⇑ **17**	11[3]
Fuel Consumption		
City Fuel Consumption	⇑ **2** ± 1	59
Highway Fuel Consumption	⇑ **3** ± 1	54
Power [2]	⇔ Negligible change	10

Notes: ⇑ ⇓ Arrows denote increase or decrease.
[#] The difference (increase or decrease) is not statistically significant at the 95% confidence level.
[1] CO_2 has been included with the regulated exhaust emissions for convenience.
[2] No statistical analyses were carried out on the Ozone Formation Potential or Power results.
[3] Vehicles are in pre-tune condition.

When operating on petrohol compared to petrol, exhaust hydrocarbons, carbon monoxide and exhaust toxics (except 1,3-butadiene) emissions decreased, while evaporative hydrocarbons and exhaust aldehydes (except acrolein) emissions increased.

There were only very small increases in carbon dioxide emissions and fuel consumption. Exhaust ozone formation potential appeared to decrease, while evaporative ozone formation potential appeared to increase, but these trends were not verified statistically. Oxides of nitrogen, acrolein and 1,3-butadiene emissions and engine power did not change.

Tables B and C provide a summary of the impacts of petrohol on the post-1986 and pre-1986 vehicle categories.

Table B: Impacts of Petrohol (Post-1986 Vehicles)
(Percentages have been rounded to the nearest whole number)

PARAMETERS MEASURED	% DIFFERENCE: MEAN PETROHOL COMPARED TO PETROL (95% CONFIDENCE LIMITS)	NUMBERS OF VEHICLES INCLUDED (POST-TUNE)
Regulated Exhaust Emissions		
Hydrocarbons (HC)	⇓ **13** ± 5	41
Oxides of Nitrogen (NOx)	⇑ **5** ± 7[#]	41
Carbon Monoxide (CO)	⇓ **27** ± 11	41
Carbon Dioxide (CO_2) [1]	⇑ **1** ± 1[#]	41
Regulated Evaporative Emissions		
Hydrocarbons (HC)	⇑ **22** ± 17	39
Exhaust Aldehyde Emissions		
Formaldehyde (CH_2O)	⇑ **27** ± 24	39
Acetaldehyde (C_2H_4O)	⇑ **213** ± 93	36
Acrolein (C_3H_4O)	⇑ **8** ± 19[#]	38
Exhaust Toxic Emissions		
1,3-Butadiene (C_4H_6)	⇓ **9** ± 23[#]	8
Benzene (C_6H_6)	⇓ **28** ± 15	9
Toluene (C_7H_8)	⇓ **26** ± 15	9
Xylene (C_8H_{10})	⇓ **24** ± 12	9
Ozone Formation Potential [2]		
Exhaust Ozone Potential	⇓ **23**	9
Evaporative Ozone Potential	⇑ **16**	9[3]
Fuel Consumption		
City Fuel Consumption	⇑ **3** ± 1	41
Highway Fuel Consumption	⇑ **3** ± 1	36
Power [2]	⇔ Negligible change	8

Notes: ⇑ ⇓ Arrows denote increase or decrease.
[#] The difference (increase or decrease) is not statistically significant at the 95% confidence level.
[1] CO_2 has been included with the regulated exhaust emissions for convenience.
[2] No statistical analyses were carried out on the Ozone Formation Potential or Power results.
[3] Vehicles are in pre-tune condition.

Table C: Impacts of Petrohol (Pre-1986 Vehicles)
(Percentages have been rounded to the nearest whole number)

PARAMETERS MEASURED	% DIFFERENCE: MEAN PETROHOL COMPARED TO PETROL (95% CONFIDENCE LIMITS)	NUMBERS OF VEHICLES INCLUDED (POST-TUNE)
Regulated Exhaust Emissions		
Hydrocarbons (HC)	⇓ **11** ± 5	18
Oxides of Nitrogen (NOx)	⇓ **1** ± 6#	18
Carbon Monoxide (CO)	⇓ **37** ± 10	18
Carbon Dioxide (CO_2) [1]	⇑ **2** ± 1	18
Regulated Evaporative Emissions		
Hydrocarbons (HC)	⇑ **33** ± 17	17
Exhaust Aldehyde Emissions		
Formaldehyde (CH_2O)	⇑ **27** ± 12	17
Acetaldehyde (C_2H_4O)	⇑ **217** ± 47	17
Acrolein (C_3H_4O)	⇑ **15** ± 30#	17
Exhaust Toxic Emissions		
1,3-Butadiene (C_4H_6)	⇓ **25** ± 210#	2
Benzene (C_6H_6)	⇓ **18** ± 85#	2
Toluene (C_7H_8)	⇓ **17** ± 34#	2
Xylene (C_8H_{10})	⇓ **17** ± 45#	2
Ozone Formation Potential [2]		
Exhaust Ozone Potential	⇓ **19**	2
Evaporative Ozone Potential	⇑ **17**	2[3]
Fuel Consumption		
City Fuel Consumption	⇑ **1** ± 1	18
Highway Fuel Consumption	⇑ **2** ± 1	18
Power [2]	⇔ Negligible change	2

Notes: ⇑ ⇓ Arrows denote increase or decrease.
The difference (increase or decrease) is not statistically significant at the 95% confidence level.
[1] CO_2 has been included with the regulated exhaust emissions for convenience.
[2] No statistical analyses were carried out on the Ozone Formation Potential or Power results.
[3] Vehicles are in pre-tune condition.

Effect of Maintenance

Servicing tended to reduce the mean emissions for most of the parameters measured and to increase those of a few, but none of these changes were significant at the 95% confidence level.

Emissions Deterioration

Mean emissions for the regulated pollutants tended to increase over the twelve-month period, but the changes were not significant at the 95% confidence level.

Main Report

1. INTRODUCTION

The emissions performance, fuel consumption and power from 60 in-service light-duty passenger vehicles, operating on both petrol and petrohol (a 10% ethanol/petrol blend) were evaluated. Tests were conducted for regulated exhaust and evaporative emissions, aldehydes, air toxics, ozone formation potential, fuel consumption and engine performance. A sub-set of vehicles was tested on each fuel prior to and following servicing and another sub-set was tested on two separate occasions, twelve months apart.

In this report, the authors outline the test protocols and methods used, present the results in graphical form, provide statistical analyses of the data and make a number of key findings.

1.1 Background

As part of its lead abatement strategy, the Federal Government in its 1993/94 Budget committed $36 million in funds for new Government measures to reduce lead pollution. One of these measures involved the provision of $29 million over three years to accelerate the market penetration and acceptance of motor fuels blended with ethanol as a way of reducing dependence on imported petroleum-based fuels and reducing emissions of greenhouse gases and other air pollutants.

Funding included the provision of:

- a $25 million bounty to support the production of ethanol for use as a transport fuel,
- $3.94 million to support research and development of ethanol-blend motor fuels.

From the $3.94 million in funding provided for research and development, the following four work programs were developed:

1. Intensive Field Trials of Ethanol Blends in Motor Vehicles
2. Ethanol Fuel Blends
3. Ethanol Production
4. Engineering Study

The funding and execution of the work programs was overseen by the Energy Research and Development Corporation (ERDC) on behalf of the Department of Primary Industries and Energy (DPIE) and Department of the Environment, Sport and Territories (DEST).

In May 1995, APACE Research Ltd was awarded a contract for $750,000 to undertake Work Program 1: "Intensive Field Trials of Ethanol Blends in Motor Vehicles".

1.2 Objectives

The objectives for Work Program 1 are listed below.

1. **Establish the contribution of ethanol/ petrol blend in reducing greenhouse gas and noxious emissions.**

2. **Compare in-service fuel consumption of ethanol/ petrol blend to that of neat petrol.**

3. Compare vehicle driveability on ethanol/ petrol blend to that on neat petrol under various climatic conditions.

4. **Measure engine performance** and establish road octane number **of ethanol/ petrol blend**.

5. Examine the fuel system component materials for compatibility with ethanol/ petrol blend and conformity to international standards.

6. Compare engine wear with ethanol/ petrol blend to that with neat petrol.

7. Examine water tolerance issues arising from storage, distribution and use of ethanol/ petrol blend.

In October 1995 the NSW EPA entered into a contract with APACE to undertake work relating to objectives 1, 2 and part of 4 (as highlighted above). This work involved testing a range of in-service light-duty passenger vehicles such that the following three primary areas of interest could be addressed:

- the emissions, fuel consumption and engine performance of vehicles operating on ethanol/ petrol blend compared with neat petrol,

- the effectiveness of maintenance in reducing emissions when operating on ethanol/ petrol blend and on neat petrol,

- the deterioration in emissions, if any, over a 12 month period due to the use of ethanol/ petrol blend.

The vehicles, supplied by APACE, were tested while operating on both petrohol and petrol, for the following:

(1) regulated exhaust and evaporative emissions, in accordance with ADR 37/00,
(2) aldehyde emissions during the ADR 37/00 test sequence,
(3) air toxics emissions during the ADR 37/00 test sequence,
(4) ozone formation potential of the volatile organic compounds emitted during the ADR 37/00 test sequence,
(5) fuel consumption, in accordance with AS 2877,
(6) power/ torque.

The testing methodologies adopted were consistent with those used in the Federal Office of Road Safety (FORS) National In-Service Emissions (NISE) study, but were extended to cover items (2), (3), (4) and (6) above.

1.3 Parties Involved

A project steering committee comprising ERDC (Chair), NSW EPA, EPA (VIC), APACE, FCAI, AIP and BOGAS was assembled to oversee the study and to ensure that the objectives of the project were met.

The roles of the organisations that participated in the study are listed below:

APACE Research Ltd.

- APACE was the project manager responsible for formulating the testing program, sourcing vehicles, supplying the fuel, oil and parts, organising vehicle servicing, data analysis and reporting.
- A member of and contributor to the steering committee.

NSW Environment Protection Authority

- NSW EPA was contracted to APACE to undertake emissions testing, fuel consumption and power testing of the test vehicles.
- Reporting the results of testing to APACE.
- A member and contributor to the steering committee prior to being replaced by EPA (VIC) midway through the study.

CSIRO

- CSIRO, Division of Coal and Energy Technology was subcontracted to the NSW EPA to analyse aldehyde and hydrocarbon species in samples collected by the NSW EPA, calculate the level of air toxics and the ozone formation potential/reactivity for both exhaust and evaporative emissions.

NRMA

- NRMA was subcontracted to APACE to service the vehicles as required by the test program and to install fuel tank thermocouples prior to testing.

2. STUDY OUTLINE

2.1 Scope

The Petrohol In-Service Vehicle Emissions Study involved testing 60 in-service light-duty passenger vehicles from five manufacturers, operating on both petrohol and petrol, to support examination of the impact of petrohol on emissions and engine performance. Emissions testing commenced in November 1995 and concluded in May 1997. The vehicles were tested in a number of different conditions such that a total of 188 complete emissions test sequences were carried out. Thirty-four evaporative emissions tests carried out early in the project were deemed by the Project Steering Committee to be invalid, due to the introduction of two significant modifications to the testing procedures (refer to Section 3.1.1 for details). Those test results are not included in this report.

2.2 Parameters Measured

During the project the following parameters were measured:

1. Regulated Exhaust Emissions on each vehicle
   - Hydrocarbons (HC)
   - Oxides of nitrogen (NOx)
   - Carbon monoxide (CO)
   - Carbon dioxide (CO_2)

2. Regulated Evaporative Emissions on each vehicle
   - Hydrocarbons (HC)

3. Aldehyde Exhaust Emissions on each vehicle
   - Formaldehyde (CH_2O)
   - Acetaldehyde (C_2H_4O)
   - Acrolein (C_3H_4O)

4. Toxic Exhaust and Evaporative Emissions on a subset of vehicles
   - 1,3-butadiene (C_4H_6)
   - Benzene (C_6H_6)
   - Toluene (C_7H_8)
   - Xylene (C_8H_{10})

5. Ozone Formation Potential (Exhaust and Evaporative) on a subset of vehicles
   - C_1 to C_{10} hydrocarbon species

6. Fuel Consumption on each vehicle
   - City and Highway Cycles

7. Engine Performance on a subset of vehicles
   - Chassis Power and Torque

2.3 Test Sample Design

The test vehicles were supplied by APACE. In order for the test sample to be representative of the in-service vehicle fleet, APACE selected the vehicles such that the sample covered:

- major vehicle makes and models,
- low and high mileage vehicles,
- new and old vehicles,
- leaded and unleaded vehicles,
- carburettor and fuel injection vehicles,
- vehicles already operating on petrohol.

2.4 Vehicles Tested

A summary of the vehicles tested is provided in Table 1. For a more detailed vehicle listing, refer to Appendix 1.

Table 1: Vehicles Tested

MANUFACTURER	MODEL	VEHICLE VINTAGE		YEARS OF MANUFACTURE (RANGE)	ODOMETER (RANGE) (km)
		Post-1986	Pre-1986		
Ford	Falcon	9	4	1983 – 1993	49,000 – 275,000
	Laser	1	2	1983 - 1994	38,000 – 248,000
Holden	Apollo	1	0	1995	17,000
	Camira	1	1	1985 - 1987	230,000 – 272,000
	Commodore	9	5	1979 - 1993	26,000 – 440,000
Mitsubishi	Magna	8	0	1987 - 1995	5,100 – 259,000
	Sigma	1	3	1980 - 1986	172,000 – 319,000
Nissan	Skyline	1	0	1986	301,000
Toyota	Camry	5	0	1987 - 1993	55,000 – 221,000
	Corolla	3	2	1984 - 1992	57,000 – 144,000
	Corona	0	2	1980 - 1984	175,000 – 258,000
	Lexcen	2	0	1995	7,000 – 45,000

APACE supplied the vehicles progressively throughout the study. Individual vehicles were sourced from regular customers of BOGAS service stations in the Newcastle and Central Coast regions, where petrohol is commercially available. Vehicles were supplied for testing in either an "as received" condition or a "tuned" condition and included vehicles manufactured between 1979 and 1995 that had travelled between 7,000 and 440,000 km.

2.5 Vehicle Categories

Of the 60 vehicles tested, 41 were post-1986 vehicles (unleaded petrol) and 19 were pre-1986 vehicles (leaded petrol). Vehicles were divided into the following three categories to address the three primary areas of interest:

1. BF (Base Fleet) vehicles - general emissions comparison
2. BFS (Base Fleet Sub-set) vehicles - effect of maintenance
3. LTIS (Long Term In-Service) vehicles - emissions deterioration

Vehicle models tested in the three categories are listed in Table 2.

Table 2: Vehicle Categories

VEHICLE VINTAGE	BF	BFS	LTIS
Post-1986	Apollo (1) Camira (1) Camry (4) Commodore (6) Corolla (1) Falcon (5) Lexcen (1) Magna (5) Sigma (1) Skyline (1)	Commodore (2) Corolla (1) Falcon (2) Magna (1)	Camry (1) Commodore (1) Corolla (1) Falcon (2) Laser (1) Lexcen (1) Magna (2)
Pre-1986	Camira (1) Commodore (2) Corona (2) Falcon (2) Laser (2) Sigma (2)	Commodore (2) Corolla (2) Falcon (1) Sigma (1)	Commodore (1) Falcon (1)

Note: The numbers in brackets indicate the number of vehicles tested in each category.

A summary of the tests conducted for each category is shown in Table 3.

Table 3: Tests Conducted

	BF	BFS	LTIS
Regulated Exhaust Emissions (ADR 37/00)	Yes	Yes	Yes
Regulated Evaporative Emissions (ADR 37/00)	Yes	Yes	Yes
City & Highway Fuel Consumption (AS 2877)	Yes	Yes	Yes
Aldehyde Exhaust Emissions	Yes	Yes	Yes
Toxic Exhaust & Evaporative Emissions	No	No	Yes
Ozone Formation Potential (Exhaust & Evaporative)	No	No	Yes
Power Testing	No	No	Yes
Total Number of Vehicles	37	12	11
Number of Post-1986 Vehicles	26	6	9
Number of Pre-1986 Vehicles	11	6	2

2.5.1 BF vehicles - (Base Fleet vehicles)

Thirty-seven vehicles (26 post-1986 and 11 pre-1986 vehicles) were tested once only in a post-tune condition to provide a comparison between emissions on each fuel. Each vehicle was tested for regulated exhaust and evaporative emissions, aldehyde exhaust emissions and fuel consumption.

This is shown schematically in Figure 2.1.

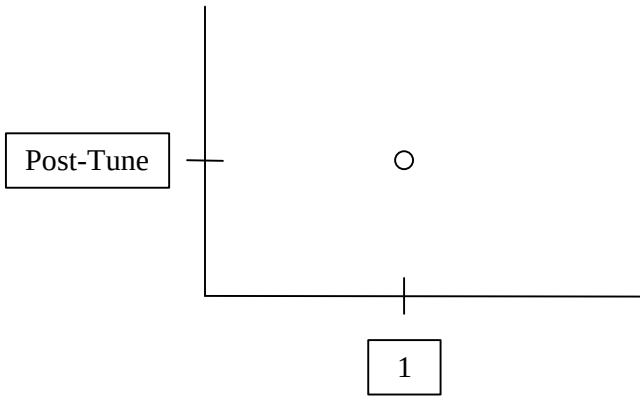

Figure 2.1: BF Vehicles

2.5.2 BFS vehicles - (Base Fleet Sub-set vehicles)

Twelve vehicles (6 post-1986 and 6 pre-1986 vehicles) were tested twice on each fuel, once in pre-tune and then in post-tune condition, to examine the effect of maintenance/servicing. Each vehicle was tested for regulated exhaust and evaporative emissions, aldehyde exhaust emissions and fuel consumption.

This is shown schematically in Figure 2.2.

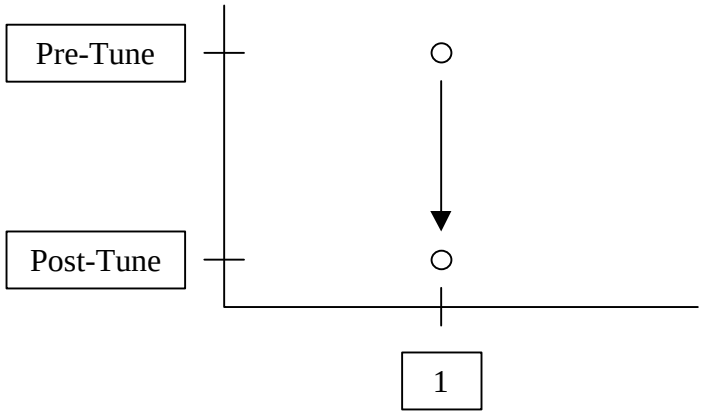

Figure 2.2: BFS Vehicles

2.5.3 LTIS vehicles - (Long Term In-Service vehicles)

These vehicles were tested three times on each fuel, once at the start of the project in post-tune condition and again after a twelve-month period in both pre- and post-tune conditions, to monitor any deterioration in emissions over that time. This is shown schematically in Figure 2.3.

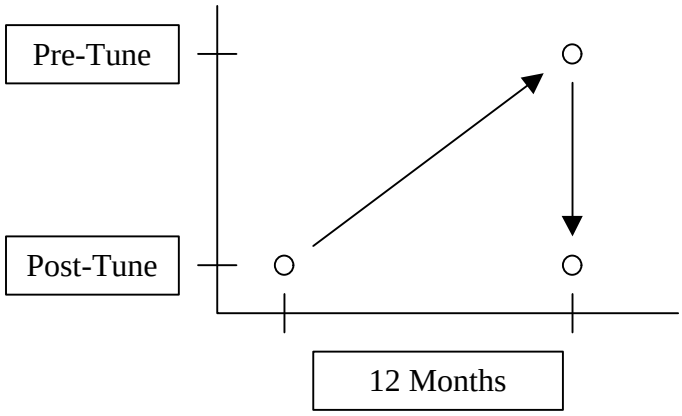

Figure 2.3: LTIS Vehicles

Initially, 13 vehicles were tested in a post-tune condition (denoted LTIS series 1). Of these, 11 vehicles (9 post-1986 and 2 pre-1986 vehicles) returned 12 months later to be re-tested in both a pre-tune and post-tune condition (denoted LTIS 2). The remaining two vehicles were placed in the Base Fleet (BF) vehicle category due to engine problems not associated with the use of petrohol that prevented them from remaining within this category. Those two vehicles have been included in the BF category described above (i.e. total of 37 vehicles).

During the 12-month period between tests, vehicles were returned to their private owners who operated them on commercially available petrohol.

The original intention was to test each LTIS vehicle for regulated exhaust and evaporative emissions, aldehyde exhaust emissions, toxic exhaust and evaporative emissions, fuel consumption and engine performance (power/ torque). However, owing to changes made to the pre-conditioning sequence, as well as efforts made to maximise the range of parameters analysed for the limited resources available, several of the above emissions/performance measures were not recorded on all three occasions:

- evaporative emission tests (including toxic evaporative emissions) from the first series of tests (LTIS 1) were deemed invalid when the pre-conditioning sequence was modified (see Section 3.1.1 for details),
- toxic evaporative emissions were not determined for the post-tune condition of LTIS 2 vehicles,
- power measurements were not made on any LTIS 2 vehicles.

The Project Steering Committee agreed to the changes.

2.6 Vehicle Servicing

The NRMA serviced each vehicle in accordance with the manufacturer's specifications in the same manner as performed in the FORS NISE study. This work included, but was not limited to, the following:

- replacement of air, oil and fuel filters,
- replacement of spark plugs and points,
- replacement of engine oil,
- diagnosis of EMS fault codes and rectification of problems,
- adjustment of engine tune settings to manufacturer's specification.

This work was carried out while the vehicle was operating on petrohol. However, no specific adjustments were made to optimise performance on that fuel.

In conjunction with APACE, NRMA was also responsible for the installation of thermocouples into the vehicle fuel tanks for the purpose of measuring the fuel temperature during evaporative emissions tests. The NSW EPA inspected each vehicle and tested each fuel tank prior to the emissions testing as a final check of the work carried out (refer to Section 3.2.1 for details).

2.7 Test Fuel

Petrol (leaded and unleaded)
Petrol was supplied as two batches (one leaded and one unleaded) by Ampol Ltd. and stored in 205-litre drums at the BP Australia Ltd. site in Silverwater. The petrol was representative of commercial grade fuel.

Petrohol (leaded and unleaded)
Petrohol (10% v/v ethanol/ petrol) was produced by splash blending anhydrous ethanol with the base petrol (leaded and unleaded). This was carried out by APACE prior to the commencement of the study. Petrohol was also stored in 205-litre drums at the BP site in Silverwater.

The properties of the test fuel are shown in Table 4.

Table 4: Fuel Properties

		ULP	ULP PETROHOL	LP	LP PETROHOL
RON		91.9	95.5	96	98.7
MON		82.9	84.1	86.7	87.6
Density @ 15 °C (kg/L)		0.7329	0.7376	0.7369	0.7406
Density @ 20 °C (kg/L)		0.7284	0.7331	0.7324	0.7361
FVI		102	119	102	119
E70 (%v)		30	48.6	28.2	45.8
RVP (kPa)		80.6	85.4[1]	82.3	87.4[1]
Benzene (%v)		2.12	1.91[2]	2.26	2.04[2]
Distillation (% Evaporated)					
IBP	°C	30.7	32.3	30.7	33.0
5%	°C	42.1	42.7	41.4	42.9
10%	°C	48.7	47.2	48.7	48.0
20%	°C	59.0	54.0	59.8	55.0
30%	°C	70.0	60.2	72.3	61.5
40%	°C	82.2	65.3	85.1	66.7
50%	°C	95.2	72.5	98.1	79.7
60%	°C	108.1	103.1	111.0	106.4
70%	°C	121.8	116.9	124.0	119.7
80%	°C	137.6	134.1	138.1	134.7
90%	°C	161.9	159.5	157.1	156.4
95%	°C	182.4	180.8	175.5	172.5
FBP	°C	207.3	204.0	206.1	202.4

Notes: [1] Values for the petrohol blends have been expressed as RVP "wet method" equivalent, following determination by a "dry" procedure.
[2] Values have been calculated from the quantity of benzene in the base fuel.

The distillation curves are displayed in Figures 2.4 and 2.5.

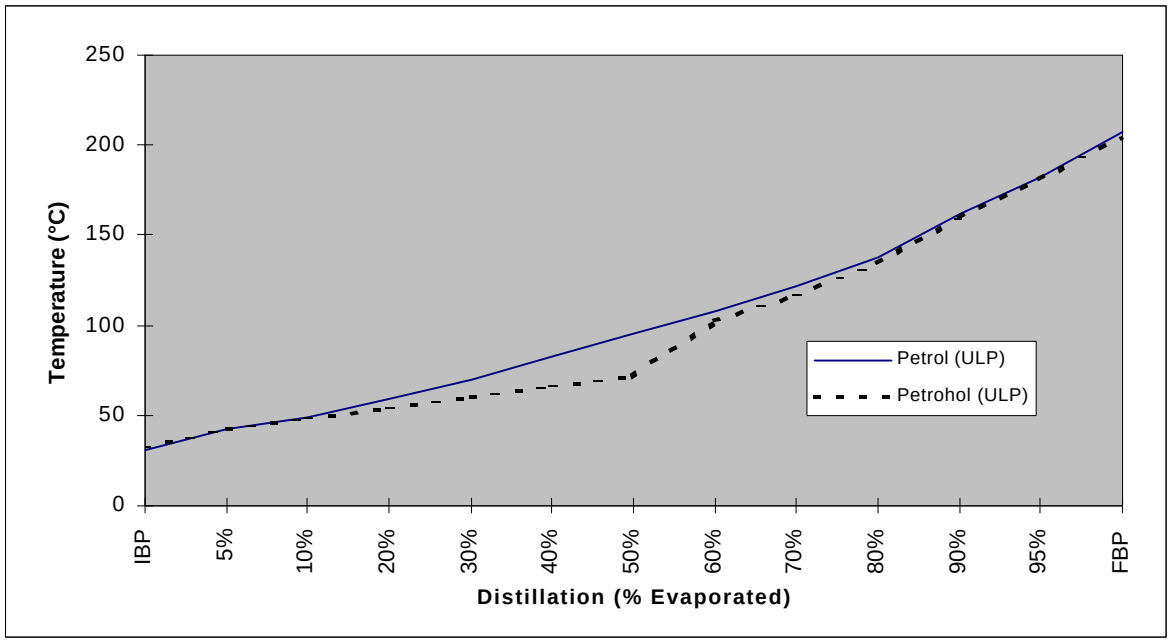

Figure 2.4: ULP Distillation Curves

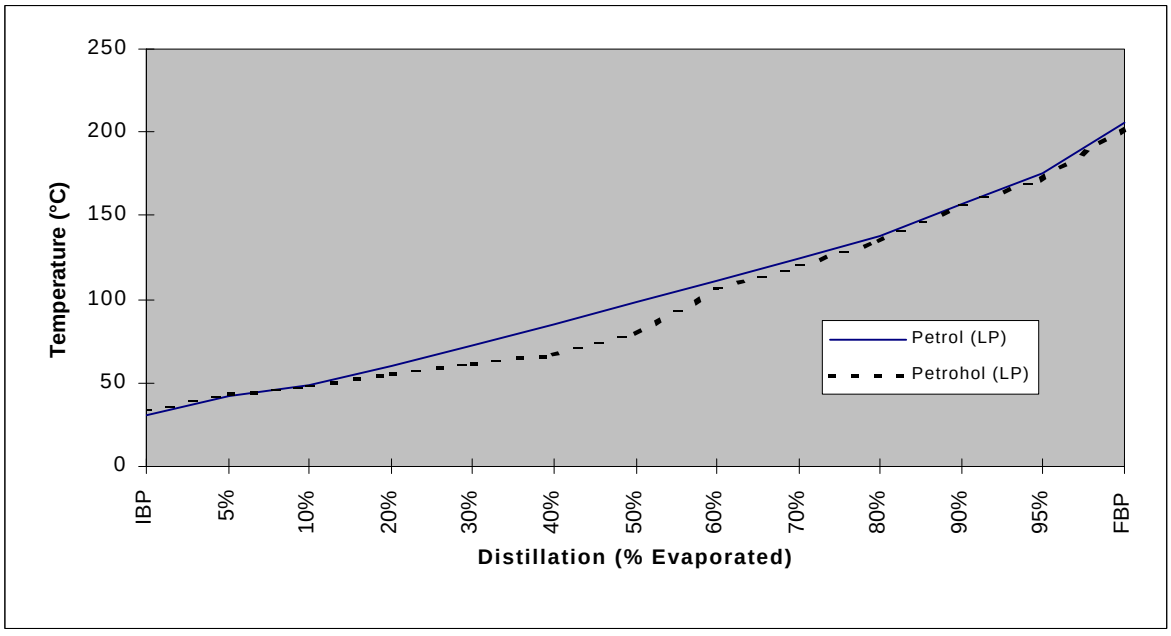

Figure 2.5: LP Distillation Curves

Fuel was delivered to the NSW EPA Motor Vehicle Testing Facility at Lidcombe as required. Upon delivery, each drum of fuel was labelled with a drum number and fuel type. Fuel used for testing was then stored in a cool room at temperatures below 10°C. Fuel used only for vehicle pre-conditioning was stored in the general fuel store at ambient temperatures. Samples of fuel were taken from each 205-litre drum and provided to APACE for analysis (refer to Section 3.2.1 for further details).

3. TEST PROGRAM

The emissions and engine performance testing program was developed by APACE in conjunction with the NSW EPA and refined by members of the Project Steering Committee (refer to Section 1.3 for member listing).

Following commencement of the test program, the Steering Committee agreed to certain modifications being made to the test protocols. These involved:

- the procedures for vehicle pre-conditioning, and
- the method of fuel temperature measurement.

As a consequence, a number of early evaporative emission tests were deemed to be invalid. Data from those tests are not included in this report. The modifications to the test protocols are discussed in Section 3.1.1.

3.1 Test Protocols

The testing methodologies adopted for this study by the Project Steering Committee were generally consistent with those used during the FORS NISE study. However, a number of additional tests were carried out. The test protocols adopted for this study are summarised below:

1. Test vehicles were to be, where practicable, representative of the in-service light-duty passenger vehicle fleet. The vehicle sample was obtained by APACE and included:
   - the major vehicle makes and models,
   - low and high mileage vehicles,
   - a range of vehicle vintages (pre-1986 and post-1986),
   - leaded and unleaded vehicles,
   - carburettor and fuel injection vehicles,
   - vehicles already operating on the relevant grade of petrohol (leaded or unleaded).

2. Test fuels were to be made up in quantities sufficient for the entire testing program. The test fuels included:
   - petrol grades (both leaded and unleaded) representative of commercial grade petrol,
   - petrohol fuels (both leaded and unleaded) made by splash blending ethanol with the base petrol to 10% by volume.

3. Each vehicle was to be tested on both fuels (petrol and petrohol) in any one condition.

4. The effectiveness of maintenance in reducing emissions was to be assessed by conducting emissions tests on a sub-set of vehicles in an "as received" condition (denoted “pre-tune”) and then re-tested following a regular service (denoted “post-tune”).

5. Deterioration in emissions control was to be assessed by conducting emissions tests on a sub-set of vehicles firstly in a post-tune condition, and again after a twelve month period in both pre-tune and post-tune conditions.

6. Test vehicles were to be grouped into three categories to assess the impact of petrohol in key areas of interest:
   - Base Fleet (BF): the general emissions comparisons,
   - Base Fleet Subset (BFS): the effectiveness of maintenance,
   - Long Term In-Service Fleet (LTIS): the deterioration in emissions.

7. Vehicle servicing was to be carried out in the same manner to that in the NISE study. Servicing was carried out by NRMA and included:
- a mandatory replacement of the oil filter,
- a mandatory change of the engine oil,
- optional replacement of air and fuel filters, spark plugs and points (if applicable), depending on condition,
- adjustment of engine tune to manufacturer's specifications,
- repair or replacement of faulty items such as exhaust pipes, brakes and tyres etc. that would affect the ability to carry out emissions testing.

8. Exhaust and evaporative test procedures and calculation of results were to follow ADR 37/00. Unlike the NISE study, each vehicle (rather than a subset) was to undergo an evaporative emission test in conjunction with the exhaust emissions test.

9. Fuel consumption test procedures and calculation of results were to follow AS 2877. Unlike the NISE study, each vehicle was to undergo a highway fuel consumption test.

10. Other fuel and vehicle performance parameters (not specified in the ADR or AS testing procedures nor measured in the NISE study) were to be measured including:
    - aldehyde emissions – exhaust only,
    - air toxics emissions – exhaust and evaporative,
    - ozone formation potential (HC speciation re-activity) – exhaust and evaporative,
    - engine performance (power/ torque).

3.1.1 Modifications to the FORS NISE Study Test Protocols

Two modifications were made to the NISE study test protocols following recommendations from APACE. Specifically, these modifications relate to the vehicle pre-conditioning requirements and the location of the fuel temperature measuring thermocouple for the ADR37 tests. The changes were endorsed by the Project Steering Committee.

Vehicle Pre-conditioning

It is necessary to pre-condition each vehicle prior to conducting an ADR 37/00 emissions test. Pre-conditioning is intended to stabilise the vehicle on a particular fuel type while purging the carbon canister to a level that would occur during normal operation (i.e. neither abnormally purged nor abnormally loaded). In ADR 37/00, the pre-conditioning involves draining the vehicle fuel tank, re-fuelling with test fuel (at ambient temperature not more than 30^{o}C) to 40% of the tank's nominal capacity and driving the vehicle over a 'simulated trip' on the dynamometer. A 'simulated trip' is the first 1372 seconds of the ADR 37/00 driving cycle (equivalent to the ADR 27A cycle). For the purposes of certification, ADR 37/00 gives the manufacturer the option of driving up to three additional simulated trips prior to draining the tank in the above pre-conditioning sequence. The simulated trip is illustrated in Figure 3.1.

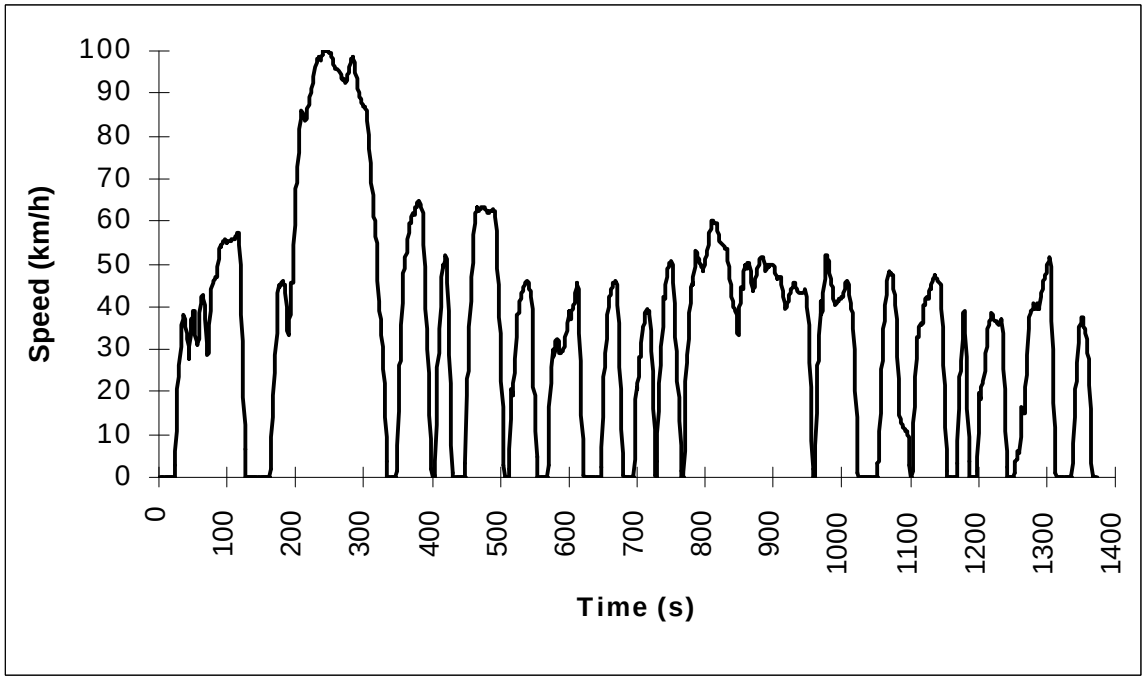

Figure 3.1: Simulated Trip (ADR 27A Drive Cycle)

Originally, a single simulated trip was to be used in this study (as per the NISE study). However, after testing had been under-way for several weeks, it was found that one simulated trip was insufficient to purge the carbon canister to a stable level. Also, the sequencing of testing (i.e. petrol-then-petrohol or petrohol-then-petrol) influenced the result, as the second fuel tested benefited from the preceding two highway cycles at the end of the testing sequence on the first fuel. The additional purging during the highway cycles reduced the weight of the canister below that of the initial test when only one simulated trip was used to pre-condition the vehicle. The original testing sequence is illustrated in Figure 3.2.

Whilst pre-conditioning the vehicle with one simulated trip met the requirements of ADR 37/00, it was not appropriate for this fuel evaluation program. As a result, a Steering Committee directive was given to perform additional pre-conditioning cycles.

Following investigative tests by the NSW EPA on a number of vehicles it was established that four highway cycles would be adequate to pre-condition the carbon canisters to stable levels. Thus the procedure was modified so that the pre-conditioning commenced with two highway cycles using the fuel already in the vehicle (i.e. ‘as received’). The fuel tank was then drained and refuelled with test fuel at ambient temperature, followed by another two highway cycles and then the simulated trip, as shown in Figure 3.3.

The Project Steering Committee endorsed the revised pre-conditioning procedures.

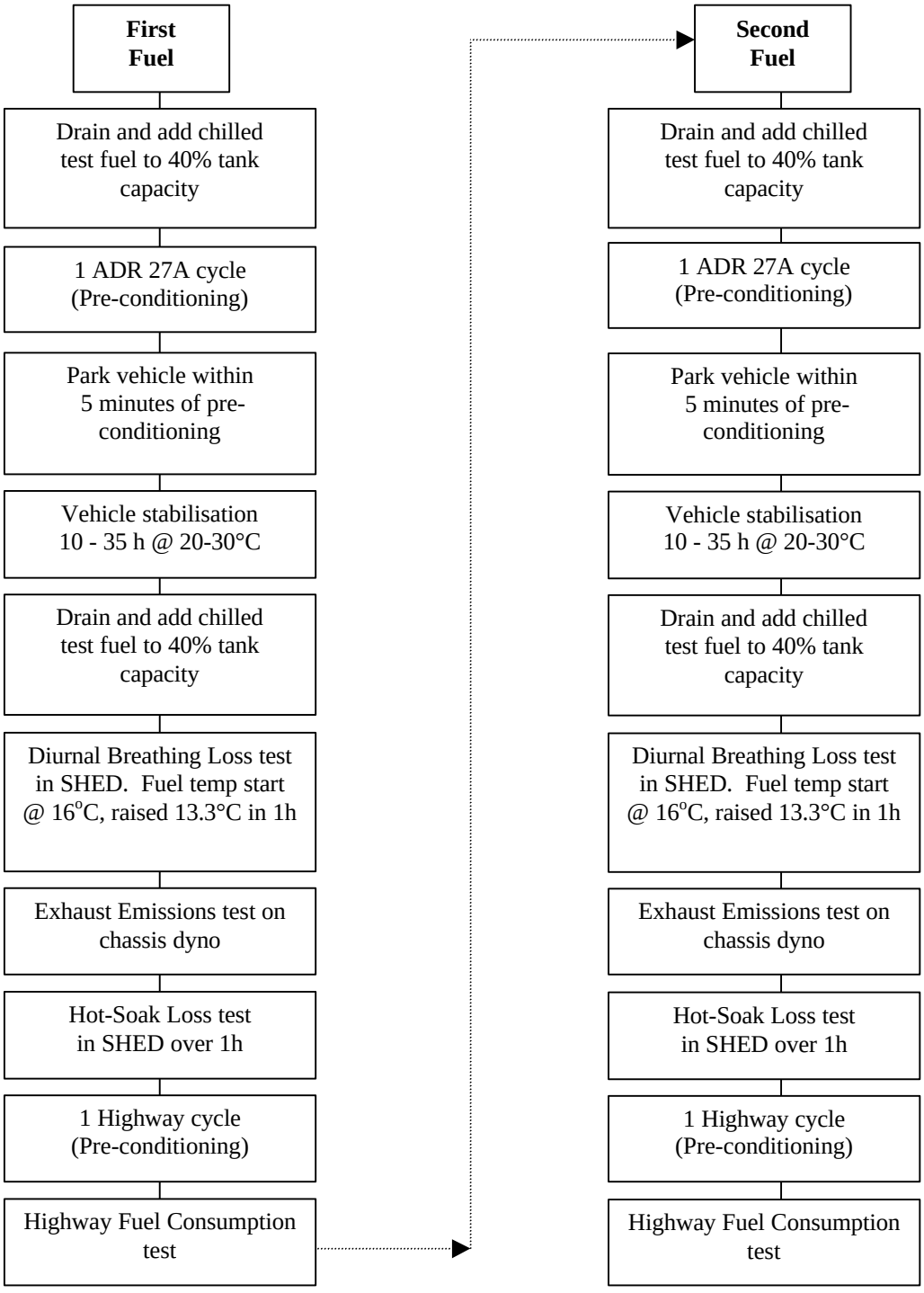

Figure 3.2: Original Testing Sequence

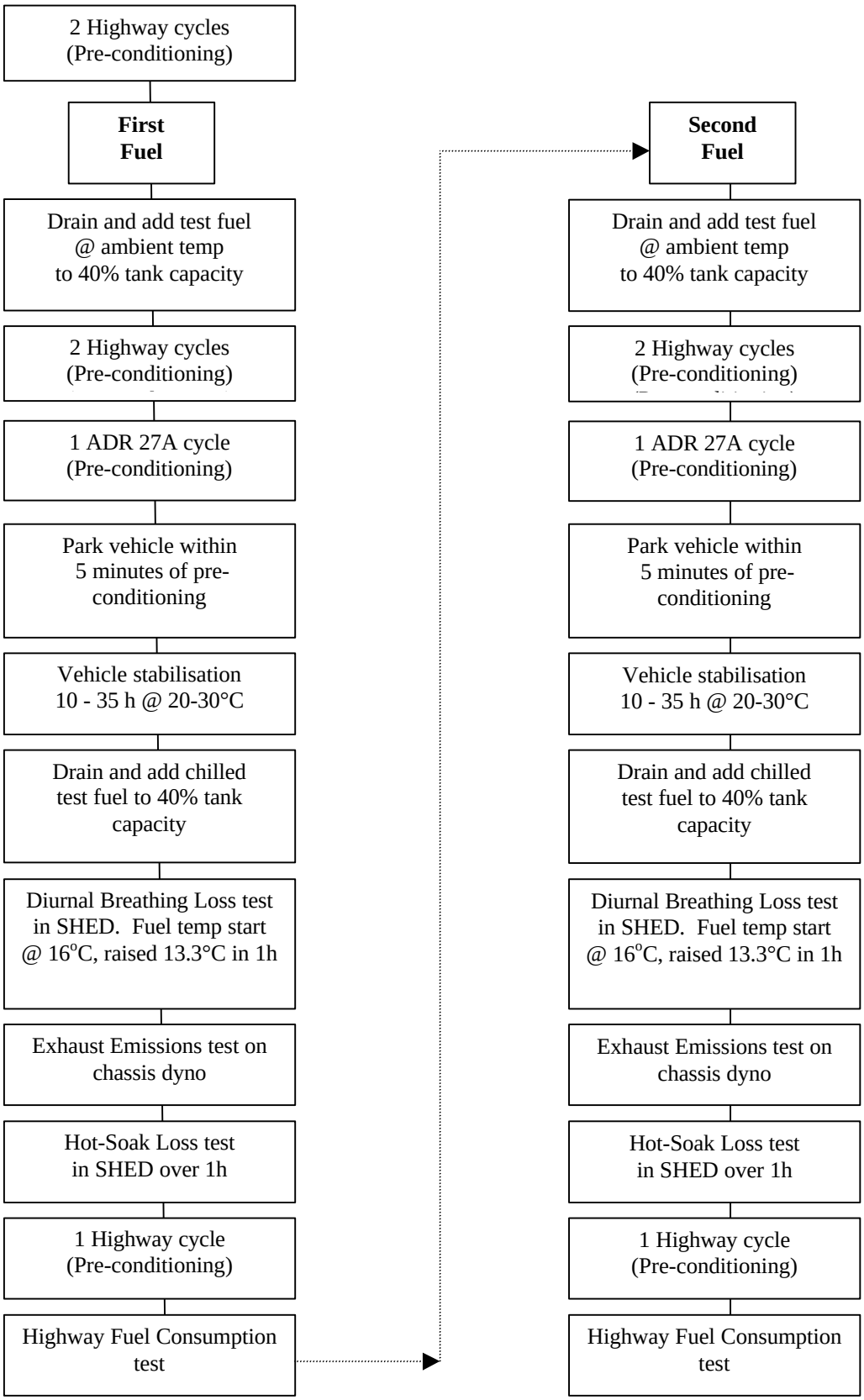

Figure 3.3: Revised Testing Sequence

Fuel Temperature Measurement

ADR 37/00 requires that, during the diurnal breathing loss phase of an evaporative emissions test, the fuel temperature be measured "at approximately the mid-volume of the fuel at tank fuel volume". The 'tank fuel volume' is defined as "the volume of fuel in the fuel tank(s), which is determined by multiplying the vehicle's 'nominal fuel tank(s) capacity' by 0.40, the result being rounded to the nearest 0.5 litre". This typically requires the installation of a shielded thermocouple through the fuel tank sender unit such that its tip is in the fuel.

For in-service testing it is common practice to use an external thermocouple bonded to the outside of the fuel tank at the approximate midpoint (in elevation) of the fuel level when filled to 40% nominal capacity. This method was used in the NISE study and was the method originally followed in this study. The ease of application of this method facilitates the testing of large numbers of in-service vehicles and eliminates the potential for introducing leaks into the fuel and evaporative emissions control systems before testing, as well as during removal of the thermocouple. However, due to concerns raised by APACE regarding the possible effect on petrohol evaporative emissions as a result of the difference between the temperature of the tank skin and the temperature of the fuel itself, the method was abandoned in favour of the APACE recommendation that each vehicle fuel tank be fitted with an internal thermocouple prior to testing.

The Project Steering Committee endorsed the recommendation.

To accommodate the change in protocol, the NRMA in conjunction with APACE, inserted a J-type thermocouple through the fuel tank sender unit of each vehicle such that the tip was at approximately the mid-volume of the fuel (at 40% nominal capacity).

The installation of the thermocouple involved:

- removing the fuel sender unit from the fuel tank,
- drilling a hole into the sender unit base plate,
- installing a brass swagelok bulkhead fitting,
- inserting the thermocouple through the fitting and tightening,
- re-installing the sender unit into the fuel tank, with a new gasket if necessary, and checking for leaks.

Following delivery to the EPA testing facility, each vehicle was subjected to a fuel tank pressure test to assure the integrity of the fuel system and a thermocouple positioning check to assure the tip was correctly positioned (refer to Section 3.2.1).

Consequences of the Changes to Test Protocols

Evaporative emission tests performed to the original protocol (i.e. all tests conducted prior to test number 21670) were deemed by the Project Steering Committee to be invalid. Therefore, evaporative emission data from those tests have not been included in this report. This included results from 11 LTIS vehicles in the first series of tests, two BF and two BFS category vehicles.

The changes to the protocol were deemed not to affect exhaust emissions or fuel consumption test results.

3.2 Test Methods

Published test methods were followed as far as practicable. Methods followed on each of the tests are summarised below:

- **Test Preparation**
  Test preparation protocols were developed by NSW EPA and APACE and endorsed by the Project Steering Committee.

- **Regulated Exhaust and Evaporative Emissions Tests**
  Tests were conducted by NSW EPA in accordance with ADR 37/00: Emission Control for Light Vehicles. This method was also used for vehicles manufactured to comply with ADR 27A, B & C (i.e. pre-1986 vintage).

- **Reactive Organic Compounds (ROCs)**
  Exhaust samples were collected by NSW EPA on "Waters Sep-Pak" cartridges during the ADR 37/00 tests. Samples were analysed for **aldehydes** by the CSIRO using high performance liquid chromatography (HPLC).

  Exhaust and evaporative emission samples were collected by NSW EPA in "Summa" canisters during the ADR 37/00 tests. Samples were analysed for a range of species including **air toxics** by the CSIRO using gas chromatography (GC).

  The **Ozone Formation Potential** of exhaust and evaporative emissions samples were calculated by the CSIRO using the Maximum Incremental Reactivity (MIR) scale (according to Carter).

- **Fuel Consumption Tests**
  Tests were conducted by NSW EPA in accordance with Australian Standard 2877: Methods of Test for Fuel Consumption of Motor Vehicles Designed to Comply with Australian Design Rules 37 and 40. This method was also used for vehicles manufactured to comply with ADR 27A, B & C (i.e. pre-1986 vintage).

- **Engine Performance**
  Chassis Power and Torque were measured by NSW EPA using an eddy current power dynamometer owned by AGL.

3.2.1 Test Preparation

Prior to emissions testing, each vehicle was subjected to a sequence of checks and conditioning activities as outlined below.

i) Pre-Test Inspection

A pre-test inspection was conducted on each vehicle to ensure that it was suitable for testing. Checks were carried out on specific items in the following areas:

Safety
- condition of tyres,
- engine oil, transmission fluid, radiator coolant and battery electrolyte levels,
- condition of exhaust system,
- absence of major oil leaks,
- condition of drive-line and brakes,
- front wheel drive vehicle steering geometry and front suspension,
- inflate driving wheel tyres to 240 kPa.

Operation
- condition of spark plugs, points, distributor, leads, air and fuel filters,
- condition of carburettor (if applicable),
- level of battery charge,
- condition of engine management system,
- emission control systems (EGR, catalytic converter, oxygen sensor, evap control canister and hoses).

State of Tune
- measure idle speed,
- measure ignition timing,
- measure exhaust HC, CO, CO_2 and O_2 concentrations at idle,
- measure resistance of high tension leads.

Fuel System
- condition of fuel tank, fuel filler cap, fuel lines and canister,
- check thermocouple placement.

Vehicles that were found to be incorrectly serviced or unsafe to test were returned to the NRMA for rectification.

ii) Thermocouple Positioning Check

Following adoption of changes to the test protocol (refer to Section 3.1.1), each vehicle was delivered to the NSW EPA testing facility with a J-type stainless steel braided thermocouple fitted into the fuel tank sender unit. To assure correct placement of the thermocouple tip, a check was carried out during the test preparation.

At the time when the fuel tank was first drained, following the first two pre-conditioning highway cycles using "as-received" fuel, a voltmeter was connected to the output of the thermocouple. As the test fuel was slowly added to the tank the response on the voltmeter was observed. Whilst the fuel being added was at ambient temperature, invariably there was some difference in temperature between thermocouple and fuel. If the response occurred when a volume equal to approximately 20% of the fuel tank nominal capacity had been added, it was assumed that the thermocouple position was correct.

This positioning check was made during each refuelling step to ensure that the thermocouple had not been moved or damaged in the process of draining the tank.

iii) Fuel and Evaporative Emission Control Systems Check

Prior to conducting an emissions test, the fuel tank of each vehicle was pressure tested to ensure that its integrity had not been compromised during the thermocouple installation and to ensure

that no part of the evaporative emission control system was leaking excessively. This check also proved a useful tool in highlighting missing or damaged fuel vapour lines.

The check entailed:
- disconnecting the fuel tank vapour line from the carbon canister,
- crimping the fuel supply and return lines (rubber hoses),
- pressurising the system by applying workshop air at approximately 30 inches of water (7.5 kPa) via the fuel tank vapour line and observing the pressure drop on a manometer,
- checking for leaks with soap solution and a hydrocarbon analyser while the system was still pressurised. The fuel cap, fuel tank sender unit, fuel filler neck and associated fuel vapour lines were the main areas examined.

At the completion of this check, the air supply was removed and the vapour lines reconnected. Major problems detected (e.g. fuel leaks, broken or missing vapour lines and badly fitting fuel caps) were rectified by NRMA before the vehicle was accepted for testing.

iv) Draining and Filling Vehicle Fuel Tanks

Prior to pre-conditioning each vehicle in readiness for testing, the fuel tank was drained by inserting a hose into the fuel tank filler neck and drawing the fuel out with a pneumatically powered suction pump. It was necessary to manoeuvre the suction hose into all areas of the fuel tank to ensure that draining was as complete as possible. This fuel was placed into relevant containers (leaded or unleaded) and returned to the vehicle only after all tests on it had been completed.

Following the draining process, a quantity of test fuel (at ambient temperature) equivalent to 40% of the tank's nominal capacity was dispensed from a 205-litre drum. Two pneumatically powered fuel dispensers were used for this purpose; one each for leaded and unleaded fuel types. The fuel pumps and hoses were drained of fuel at the completion of each tank draining and refuelling step to minimise cross-contamination of the petrol and petrohol grades. Drums of test fuel used in the exhaust and evaporative emissions testing were stored in the Laboratory cool room (at temperatures below 10^{o}C) while fuel used for pre-conditioning was stored in the general fuel store at ambient temperatures.

v) Fuel and Oil Sampling

Fuel and oil samples were taken from each vehicle as well as from each test fuel and oil drum during the study. These were stored in the cool room until they were collected by APACE for analysis.

Fuel samples were taken from:
- each vehicle in the "as received" condition,
- each drum of test fuel when first opened.

Oil samples were taken from:
- each vehicle in the "as received" condition (if serviced on EPA premises),
- each drum of oil used during servicing (if performed on EPA premises),
- each vehicle upon completion of testing.

The NRMA was responsible for taking samples when the vehicle was serviced at its premises.

vi) Dynamometer Loading

The dynamometer was loaded prior to each exhaust emissions test by selecting the equivalent test inertia and road power absorber setting corresponding to the reference mass of the vehicle. Values tabulated in Table 8.2 of the ADR 37/00 document were used. The reference mass was obtained by weighing the vehicle on a set of floor scales, adding the number of kilograms equivalent to the mass of additional fuel needed to fill the fuel tank to its nominal capacity and then adding 136 kg. For those vehicles fitted with air conditioning, a factor of 10% was added to the road power absorber setting and the vehicle tested with its air conditioning system switched off (as per ADR 37/00).

vii) Vehicle Pre-conditioning

Each vehicle was pre-conditioned according to the revised testing sequence summarised in Figure 3.3. Vehicles with automatic transmission were operated in "D" (drive) and vehicles with manual transmission operated in such a way that the shift speeds were equal to the default speeds published in ADR 37/00. Air conditioning and power options, if fitted, were disengaged.

The vehicle with "as received" fuel was initially driven over two highway cycles. The vehicle's fuel tank was then drained and refuelled with the test fuel that had been stored at ambient temperature. Another two highway cycles and a 'simulated trip' of 1372 seconds duration (i.e. ADR 27A cycle) completed the pre-conditioning.

The carbon canister was weighed at the completion of the pre-conditioning sequence to ensure that its final mass was within $\pm$5g on subsequent cycles. If the mass differential was greater then 5g, then additional simulated trips were driven until this was achieved.

Within 5 minutes of completing the pre-conditioning sequence, the vehicle was removed from the dynamometer and placed in the vehicle soak area with its engine switched off. The vehicle was then allowed to soak overnight in the air-conditioned environment where temperatures were maintained between 21^{o}C and 25^{o}C. Typically, soak periods ranged between 15 and 25 hours.

ADR 37/00 requires that ambient temperatures encountered by the vehicle throughout the test sequence be between 20^{o}C and 30^{o}C. The ADR also specifies that the diurnal breathing loss test must start not less than 10 hours or more than 35 hours after the end of the pre-conditioning procedure.

3.2.2 Regulated Exhaust and Evaporative Emissions Tests

Having completed all preparation and pre-conditioning, each vehicle was tested for regulated exhaust and evaporative emissions in accordance with the procedures specified in ADR 37/00.

This involved:

- placing the vehicle in the SHED and conducting a ***diurnal breathing loss test*** (first part of the evaporative emissions test),
- removing the vehicle from the SHED and conducting an ***exhaust emissions test*** on the dynamometer,
- placing the vehicle back into the SHED and conducting a ***hot-soak loss test*** (second part of the evaporative emissions test).

Brief descriptions of the procedures followed in this study are given below. It must be stressed that the descriptions given here are in outline form only and do not represent a complete

statement of the procedures prescribed by ADR 37/00. For the complete description, the reader is referred to the ADR document itself.

i) Diurnal Breathing Loss Test

After the vehicle had been soaked for the required period of time, it was manoeuvred manually (engine switched off) into the Fuel Handling Room in preparation for refuelling. The SHED was purged of background hydrocarbons, the mixing fans turned on and the hydrocarbon analyser zeroed, spanned and re-zeroed in readiness for the commencement of the evaporative emissions test.

Immediately prior to testing, the vehicle was drained and refuelled with chilled test fuel to 40% of its nominal fuel tank capacity. In each case the chilled test fuel, when dispensed, was in the temperature range 10°C to 14°C. The fuel filler cap was left off at this stage.

The vehicle was then pushed into the SHED and the following activities carried out:

- a temperature controlled 1500 W electrical heating mat was carefully placed underneath the fuel tank and held in position by an inflated air bag,
- the in-tank thermocouple was connected to the temperature recording system,
- the doors and luggage compartment of the vehicle were opened.

The fuel tank was heated until the fuel reached a temperature of 15 ± 1°C, at which point the fuel cap was installed, the purge fan turned off and the SHED door closed. When the fuel temperature reached 16 ± 1°C, the initial time, SHED HC concentration and air temperature, vehicle fuel temperature and laboratory barometric pressure readings were recorded and the wattmeter (measuring power delivered to the heating mat) was zeroed.

The fuel in the vehicle fuel tank was heated at a steady rate from 16 $\pm$ 1°C through a temperature rise of 13.3 $\pm$ 0.5°C over a period of 60 $\pm$ 2 minutes, in accordance with ADR 37/00. The HC concentration and fuel temperature were recorded continuously on a chart throughout the test.

At the end of the test, the final time, SHED HC concentration and air temperature, vehicle fuel temperature, laboratory barometric pressure and wattmeter readings were recorded and the test result calculated. Measurement of the total power delivered to the heating mat during the test is not required by ADR 37/00 and was not used in the calculation. However, the power values were of interest to APACE.

A portable HC analyser was used at the completion of the test to identify the areas in the vehicle's fuel and evaporative emission control systems where hydrocarbons may have been escaping and to gauge their relative magnitude. The fuel cap, tank sender unit, fuel filler neck, top and bottom of the carbon canister, carburettor and inlet air manifold were the principle components investigated.

The vehicle was then removed from the SHED in preparation for an exhaust emissions test. The SHED was purged of hydrocarbons and the HC analyser purged with zero gas.

Diurnal test results, expressed in grams, were calculated in accordance with ADR 37/00 using the formulae shown in Section 3.4.2.

ii) Exhaust Emissions Test

The vehicle, with engine off, was pushed onto the dynamometer and prepared for testing as follows:

- the driving wheels were positioned squarely on the dynamometer rolls and, for front-wheel-drive vehicles, the sub-frame was secured with chains to prevent excessive side-ways movement,
- the non-driving wheels were securely chocked,
- the vehicle exhaust pipe was connected to the exhaust gas sampling system,
- a constant speed cooling fan was positioned in front of the vehicle,
- the ADR 37/00 drive cycle trace was loaded into the driver's aid computer,
- the sample collection bags (3 dilute exhaust bags and 3 background air bags) were evacuated,
- the dynamometer was set to the equivalent inertia and road power absorber settings for the vehicle being tested,
- the dynamometer was calibrated to the set inertia and a coast-down sequence carried out to assure the load curve was correct.

The exhaust emissions test was commenced within one hour of the completion of the diurnal breathing loss test (as specified in ADR 37/00). The ADR 37/00 drive cycle is illustrated in Figure 3.4.

As can be seen from Figure 3.4, the entire ADR 37/00 exhaust test sequence takes about 42 minutes to complete and comprises three phases, with a 9 -11 minute 'soak' between phases 2 and 3. The test sequence is summarised below:

Phase 1 - Cold-start transient phase when the exhaust sample is collected in Bag #1 (0 to 505 seconds),
Phase 2 - Stabilised phase when the exhaust sample is collected in Bag #2 (505 to 1372 seconds),
Nine to eleven-minute soak period (engine off),
Phase 3 - Hot-start transient phase when the exhaust sample is collected in Bag #3 (repeat of Phase 1 driving sequence).

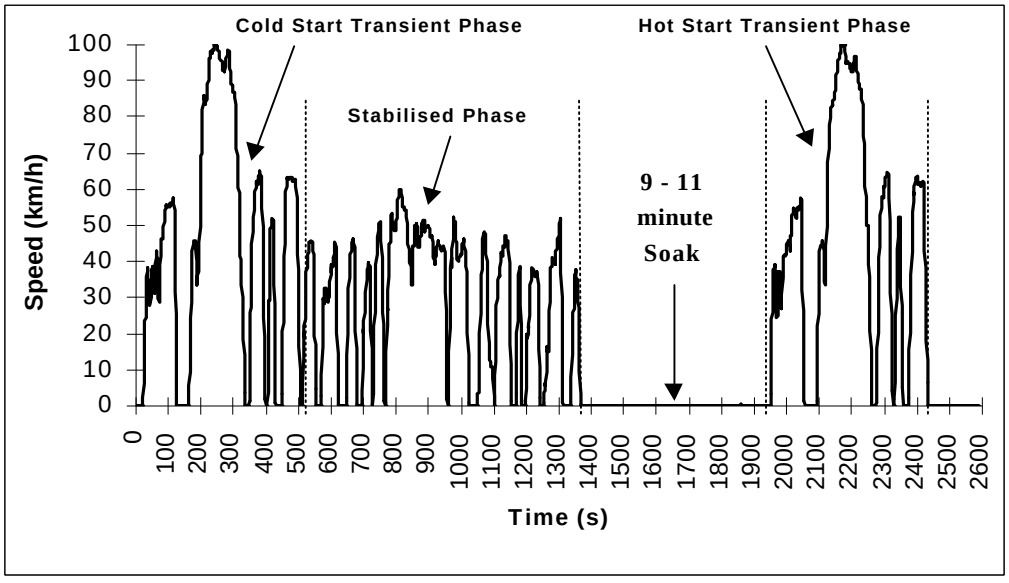

Figure 3.4: ADR 37/00 Exhaust Emissions Drive Cycle

For each of the three emission sampling phases, dilute exhaust and background air samples are collected and stored in separate Tedlar bags. A schematic of the exhaust emissions sampling system is shown in Figure 3.5.

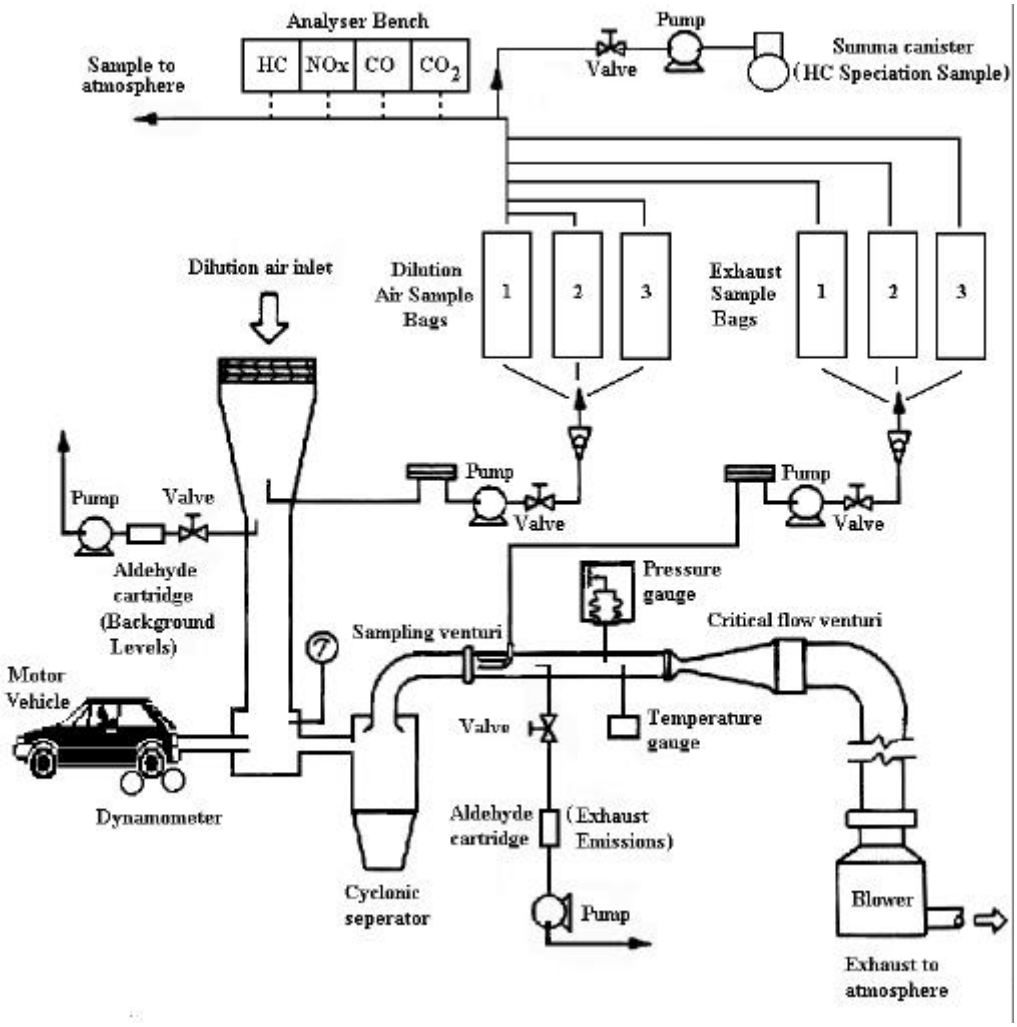

Figure 3.5: Exhaust Emissions Sampling System

Within 20 minutes of completion of each phase, the sample in each bag was analysed for:

- hydrocarbons (HC) using a flame ionisation detector (FID),
- oxides of nitrogen (NOx) using a chemiluminescent analyser (CL),
- carbon monoxide (CO) using a non-dispersive infra-red analyser (NDIR),
- carbon dioxide (CO_2) using a non-dispersive infra-red analyser (NDIR).

Exhaust emissions test results, expressed in grams per kilometre, were calculated according to the formulae shown in Section 3.4.1.

iii) Hot-Soak Loss Test

Immediately prior to completion of the exhaust emissions test, the SHED was purged of background hydrocarbons, the mixing fans turned on and the SHED HC analyser zeroed, spanned and re-zeroed in readiness for the commencement of the hot-soak test. Upon completion of the ADR 37/00 driving cycle, the vehicle was disconnected from the sampling system and driven off the dynamometer with minimum use of throttle, the engine turned off and the vehicle allowed to "coast" into the SHED. The vehicle doors and luggage compartment were opened and the SHED door closed.

Closing of the SHED door constitutes the start of the one-hour hot-soak test. The initial time, SHED HC concentration and air temperature, and laboratory barometric pressure readings were recorded.

On completion of the test, the final time, SHED HC concentration and air temperature, and the laboratory barometric pressure readings were recorded.

The hot-soak test result and the complete evaporative emission test result, expressed in grams, were calculated according to the formulae shown in Section 3.4.2.

3.2.3 Reactive Organic Compounds (ROCs)

During the ADR 37/00 tests, samples were collected for the determination of aldehydes and $C_1$to C_{10} hydrocarbon species (including the air toxics 1,3-butadiene, benzene, toluene and xylene). Analyses and calculations were performed by the CSIRO.

The sampling and analytical methods are outlined below.

i) Sampling for Aldehydes

Samples were collected from each vehicle during the exhaust emissions test. This involved drawing a representative sample from the exhaust sampling system and pumping it through a Waters Sep-Pak Aldehyde Sampler during the relevant phase of the test (refer to Figure 3.5).

Five aldehyde samples were collected for each exhaust emissions test:

- one dilute exhaust sample during each phase of the test (i.e. Phase 1, 2 & 3)
- one dilution air sample during the hot-start transient phase (i.e. Phase 3)
- one background air sample (cartridge exposed to the laboratory atmosphere, not connected to pump).

Prior to starting the test, the relevant aldehyde-sampling pump was turned on and checked to ensure that it was operating at a flow rate of one litre per minute. It was then placed in a pause mode while an aldehyde cartridge was installed between the inlet to the pump and the sampling venturi. The sampling was allowed to proceed for the entire test phase duration. Aldehyde cartridges were stored in a freezer prior to being sent to the CSIRO for analysis, typically no longer than two days after sample collection.

ii) Analysis of Aldehydes

Exhaust samples were analysed for aldehydes using a high performance liquid chromatograph (HPLC) with an ultra violet (UV) detector (GBC L1150 pump and Jasco UVIDEC-100-V detector). The aldehyde samples adsorbed on the Waters Sep-Pak Aldehyde Sampler were eluted by purging the sampler with 10 mls of acetonitrile over 3 minutes. This extract was then mixed with equal parts of water by volume and a sample was injected into the HPLC.

The aldehyde species were separated in a C185 micron column (length 150 mm, ID 4.6 mm) and the eluted species detected using a UV detector (wavelength 365 nm). A mobile phase, initially comprising 65% methanol and 35% water, was pumped through the column with a flow rate of 10 mls/min and the ratio of the mobile phase mixture was varied linearly to 85% methanol and 15% water over 10 minutes. The HPLC was calibrated by injecting synthesised hydrazones enabling identification and quantifying of each aldehyde species.

iii) Sampling for Air Toxics and Other C_1 - C_{10} Hydrocarbon Species

Samples for hydrocarbon speciation were taken only from LTIS vehicles. Both ***exhaust*** and ***evaporative*** emissions were sampled. This involved drawing a small sample from the line supplying the analysers and filling a Summa canister for each phase of the test (refer to Figure 3.5).

Prior to sampling, all sample pumps were turned on and checked to ensure that the systems did not leak and a maximum delivery pressure of 20 psi could be maintained. A portion of the gas to be sampled was then run through the sampling system, prior to filling the canister, to ensure that any residual gas from previous samples had been completely removed.

The Summa canisters were couriered to the CSIRO immediately upon completion of the test.

Sampling the Exhaust Emissions

During the bag analysis sequence of the exhaust emissions test, four samples were taken for HC speciation:

- one dilute exhaust sample for each phase of the test (i.e. Bags 1, 2 & 3),
- one dilution air sample for the hot-start transient phase (i.e. Bag 3).

Sampling commenced once all of the analysers were registering a constant reading for a particular exhaust or dilution air bag. The sample pump was turned on and the Summa canister filled from a vacuum to a pressure of 10 psi over a period of approximately two minutes.

Sampling the Evaporative Emissions

During evaporative emissions tests, two samples were taken for HC speciation:

- one SHED sample for the diurnal breathing loss test,
- one SHED sample for the hot-soak loss test.

Sampling commenced at the 50-minute mark of the SHED test and continued for three minutes, filling the canister from a vacuum to a pressure of approximately 14 psi.

iv) Analysis of Hydrocarbon Species

HC analyses were carried out by the CSIRO on the same day as the samples were collected.

All samples were analysed for hydrocarbons using Hewlett Packard 5890 and 5830 gas chromatographs (GC) both equipped with flame ionisation detectors (FID). The C_1-C_3 hydrocarbons were analysed on the HP 5830 GC using a 3.1 mm ID column packed with activated alumina and the C_4-C_{10} hydrocarbons were analysed on the HP 5890 GC using a capillary column (HP-1 column: 50m length, 0.32 mm ID) composed of fused silica coated with cross linked methyl siloxane.

The gas samples were analysed by injection of 2.4 ml from the SUMMA canisters using a GC sample injection loop. After introduction of the sample to the HP 5890 GC, the column temperature was maintained at -60^{o}C for 5 minutes and then increased in two stages; a 7.5^{o}C/min temperature ramp to 20^{o}C followed by heating at 5^{o}C/min to a final temperature of 155^{o}C. After introducing a sample to the HP 5830 GC using a procedure similar to that used for the HP 5890 GC the column temperature was raised immediately from 120^{o}C to 250^{o}C at a ramp rate of 30^{o}C/min.

The HP 5890 GC, used for the C_4-C_{10} hydrocarbon analysis, was calibrated using two different National Bureau of Standards hydrocarbon mixtures (4.05 ± 0.04 ppm methane plus 0.991 ± 0.001 ppm propane in air; and 9.42 ± 0.09 ppm propane in nitrogen). Calibrations for other hydrocarbons were obtained from published response factors. The HP 5830 GC, used for the C_1-C_3 analysis, was calibrated using the same standard mixtures.

Peak identifications were confirmed using a combined gas chromatography/mass spectrometry (GC/MS) system (Varian Saturn 3).

The mass emissions of C_1 - C_{10} hydrocarbon species, including the nominated air toxics, were reported.

Reactivities were calculated using Carter fractions, and reported.

3.2.4 Fuel Consumption Tests

i) City Fuel Consumption

The city fuel consumption was calculated from the results obtained in the exhaust emissions test (according to AS 2877). Formulae used to calculate the city fuel consumption are summarised in Section 3.4.3.

ii) Highway Fuel Consumption

The highway fuel consumption test on each vehicle was carried out after the completion of the hot-soak loss test. One highway cycle (illustrated in Figure 3.6) was first driven to bring the vehicle up to normal operating temperature. Whilst differing from the pre-conditioning requirements of AS 2877, the highway cycle was considered to be an appropriate pre-conditioning cycle for this study and endorsed by the Project Steering Committee.

A second highway cycle was then driven and the exhaust gases sampled. The highway test is a one-phase test that requires only one set of Tedlar bags to be utilised (i.e. one exhaust sample bag and one dilution air bag).

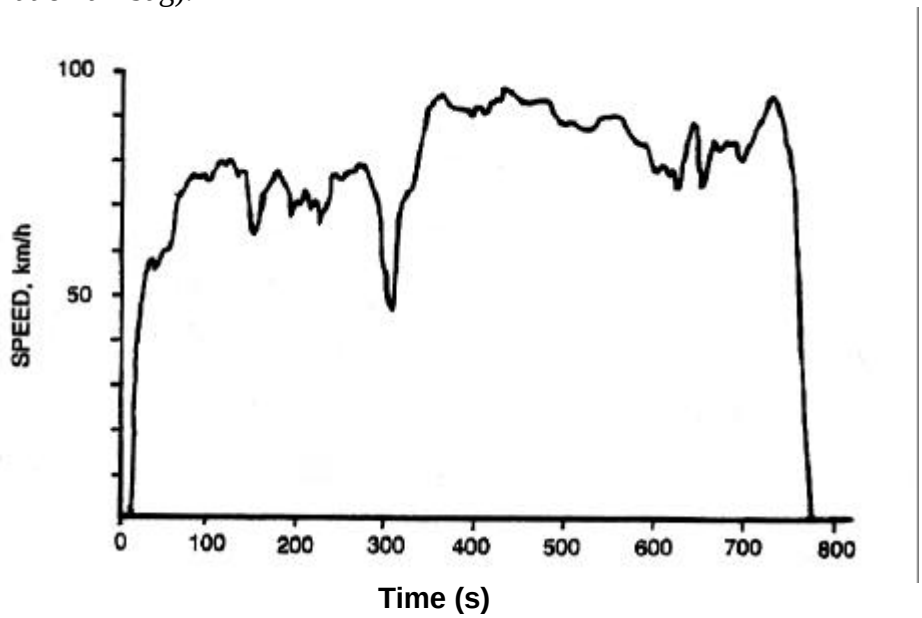

Figure 3.6: Highway Fuel Consumption Cycle

Within 20 minutes of the completion of the driving cycle, each bag was analysed for HC, NOx, CO and CO_2. Bag concentrations were converted to masses and these were used to calculate highway cycle emissions results from which the fuel consumption result was obtained. Highway fuel consumption results are expressed in litres per one hundred kilometres. For a summary of the formulae used to calculate these results, refer to Section 3.4.3.

3.2.5 Engine Performance - Power Testing

Power testing was conducted on 10 vehicles only (one BFS pre- and post-tune, and 9 LTIS series 1 vehicles), using the power dynamometer at the AGL testing facility in Auburn.

Each vehicle was fuelled with petrohol and driven from the NSW EPA test facility at Lidcombe to AGL in Auburn, a distance of seven kilometres. This drive served to stabilise the vehicle on petrohol in preparation for the power testing.

Testing was carried out using:
- petrohol from the vehicle fuel tank, and,
- petrol from a fuel container that bypassed the fuel delivery system of the vehicle, while still delivering fuel at the correct pressure and flow rate.

The vehicle was secured onto the dynamometer and driven for 10 minutes at 80 km/h, with a power output of 10 kW for 4 cylinder vehicles and 20 kW for 6 cylinder vehicles. This warmed up the tyres and helped to reduce tyre slip during the power test.

A schematic of the testing sequence is shown in Figure 3.7.

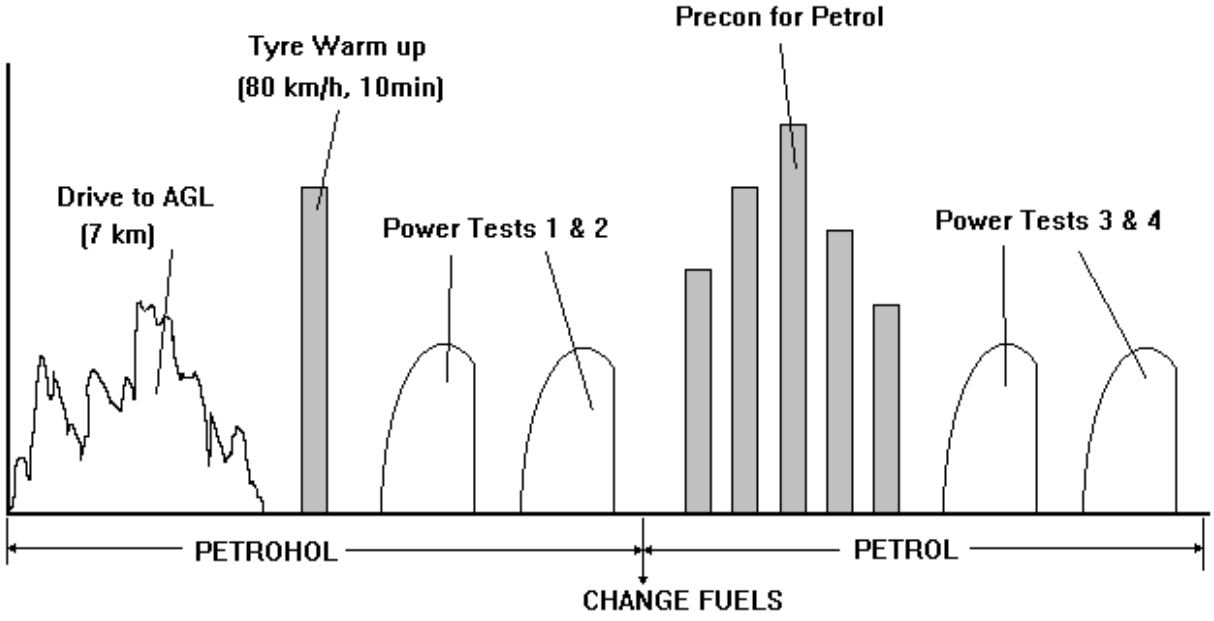

Figure 3.7: Power Testing Sequence

Power testing involved driving the vehicle at full throttle, in either 2nd or 3rd gear, with the dynamometer locked on a particular speed. The dynamometer speed was initially set at 40 km/h and measurements taken when the instrument readings had stabilised. The speed was increased in increments of 10 km/h up to 110 km/h. However, not all vehicles were operated through this range, particularly if it was considered that damage might be caused to the vehicle by the high speeds and loads.

The vehicle was allowed to idle on the dynamometer for a period of 5 minutes while the engine temperature stabilised. A repeat power test was then carried out.

During the power tests the following measurements were recorded:
- engine speed (rpm),
- vehicle speed (km/h),
- tractive effort (N),
- air inlet dry and wet bulb temperatures (°C),
- barometric pressure (mbar),
- relative humidity (%).

Following the two power tests on petrohol, the vehicle was allowed to cool (engine off) for a period of 10 minutes. It was then connected to the fuel trolley for the comparative power tests on petrol. A pre-conditioning sequence was driven on the dynamometer to stabilise the vehicle on petrol prior to conducting a further two consecutive power tests. The pre-conditioning sequence consisted of seven constant speed/ load steps, each of 30 seconds duration, separated by 30-second idle periods (refer to Figure 3.8).

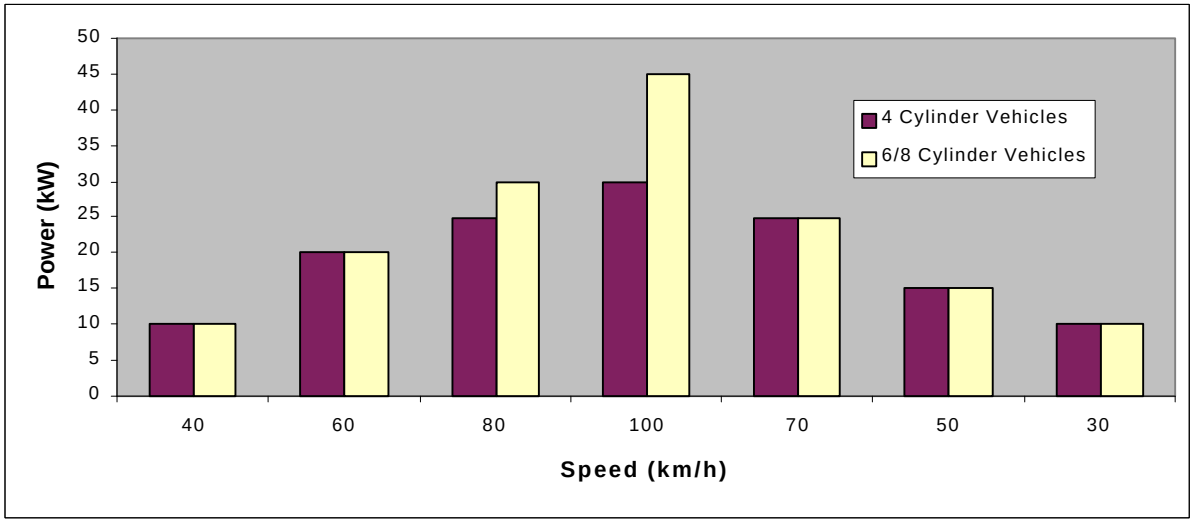

Figure 3.8: Power Testing Pre-conditioning Cycle

The average observed power was calculated for each set of tests (i.e. petrohol and petrol) and the results expressed in kilowatts. Each result was also corrected for ambient conditions. For a summary of the formulae used to calculate these results, refer to Section 3.4.4.

3.3 Quality Assurance Procedures

The NSW EPA Motor Vehicle Testing Laboratory has a quality system in place and is currently seeking registration as a NATA approved testing authority for the following tests and methods:

- ADR 37/00: Emission Control for Light Vehicles,
- ADR 37/01: Emission Control for Light Vehicles,
- AS 2877 – 1986: Methods of Test for Fuel Consumption of Motor Vehicles Designed to Comply with Australian Design Rules 37 and 40.

A Quality Manual contains the Laboratory's quality policies, procedures for verification of test results, test procedures, calibration procedures and safety procedures. Calibration and maintenance of Laboratory equipment are scheduled at weekly, monthly, three-monthly and yearly intervals. Table 5 provides a summary of the Laboratory's calibration and maintenance schedule.

Table 5: Laboratory Calibration and Maintenance Schedule

INTERVAL	WORK CONDUCTED
Weekly	Preventative maintenance (clean sampling system, etc.) NOx converter efficiency test Propane recovery for CVS sampling system verification Correlation vehicle testing for entire test cell verification
Monthly	Calibrate all gas analysers Check dynamometer power absorption Check Lab environment monitors (single point) Check stop watches (three time periods) SHED retention test & calibration Calibrate fuel flow meters in Fuel Handling Room Work included in weekly check-list
Three-monthly	Calibrate temperature probes and pressure transducers Service dynamometer & speed check SHED emissions test Work included in monthly check-list
Yearly	Calibrate Constant Volume Sampler (CVS) Calibrate scales & balance Inter-laboratory correlation program Work included in monthly check-list

All test results, including calibrations, are checked for accuracy at least three times. At the conclusion of each test/calibration, a Laboratory test operator, not involved in the original recording of the data, checks the hand-written data sheets as well as the transcription of all data to computer. This involves:

- verifying that all relevant data have been recorded on chart (e.g. test type, vehicle details, date of test, analyser ranges),
- verifying that the charts have been read accurately (e.g. bag divisions & zero/span levels),
- verifying that the chart traces have been marked clearly at the point of reading,
- verifying that all data entries to computer have been transcribed accurately.

A computer calculates test results for the regulated exhaust and evaporative emissions as well as fuel consumption. Any errors detected are immediately corrected and the result re-calculated. Any abnormalities in the chart traces or final test results are reported immediately to the Testing Supervisor.

When satisfied that all data recorded for a particular test are correct the operator signs off each data sheet and test report. At the completion of all testing on a particular vehicle a Summary Report is generated and all the reports, data sheets and chart recordings are placed in a test envelope and forwarded to the Testing Supervisor who then repeats the verification steps above.

When satisfied that the final results of all testing on the one vehicle are accurate the Testing Supervisor signs off each report, including the Summary Report, "closes off" the set of tests on computer and forwards the envelope to the Project Officer. The Project Officer then re-formats the test summary report according to the client's specifications and, on a monthly basis, forwards an electronic copy as well as a hard copy to the client.

In addition, the Quality Assurance Officer performs a monthly audit of test/calibration results. This is usually done in the week following the calibration week in order to pick up any abnormalities that may have been overlooked in the preceding verification processes.

The Laboratory also has an independent computer routine that will, for any vehicle selected, take the raw data from the database, independently re-calculate the final test results and compare them with the final results already in the database. In the Petrohol Study, this independent calculation routine was run for each and every regulated exhaust and evaporative emissions test.

3.4 Test Calculations

3.4.1 Exhaust Emissions

All exhaust emissions results were calculated using the equations provided in ADR 37/00 and AS 2877. These equations are summarised below.

To obtain the exhaust emissions results, firstly the masses of the individual compounds produced in each test phase (i.e. cold-start transient, stabilised & hot-start transient phases) are calculated. For each test phase, Equation 1 applies.

Equation 1 -

$$HC\,mass(g) = Vmix(L) * Density\,HC(g/L) * HCconc(ppm\ C) * 10^{-6}$$

$$CO\,mass(g) = Vmix(L) * Density\,CO(g/L) * COconc(ppm\ ) * 10^{-6}$$

$$NOx\,mass(g) = Vmix(L) * Density\,NOx(g/L) * NOxconc(ppm) * Kh * 10^{-6}$$

$$CO_2\,mass(g) = Vmix(L) * Density\,CO_2(g/L) * CO_2conc(\%) * 10^{-2}$$

Where:
Vmix = the volume of gas passing through the CVS unit during the test phase (in litres)
Density = density of the component at 293.15 Kelvin & 101.3 kPa:

Density HC = 0.577 g/L
Density CO = 1.164 g/L
Density NOx = 1.913 g/L
Density CO_2 = 1.830 g/L

conc = concentration of dilute exhaust sample corrected for background (in ppm)
Kh = the humidity correction factor

For aldehydes and toxic compounds the calculations are not covered in ADR 37/00, so the formulae were adapted as shown in Equation 2.

Equation 2 -

$$Mass\ of\ \ Emission\ (g) = Vmix(L) * Density\ compound\ \ (g/L) * Emission\ conc(ppmC) * 10^{-6}$$

With the density of the compound being calculated from Equation 3.

Equation 3 -

$$Density\ compound\,(g/L) = \frac{MP}{\overline{R}T} = \frac{M * 101.3}{8.3144 * 293.15}$$

Where:
M = molecular weight of the compound
P = reference pressure of 101.3 kPa
$\overline{R}$ = universal gas constant
T = reference temperature of 293.15 Kelvin (20°C)

The properties of each compound are shown in Table 6.

Table 6: Compound Properties (Exhaust Emissions)

Compound	MW	Density (g/L)
Formaldehyde	30.027	1.248
Acetaldehyde	44.053	1.831
Acrolein	56.065	2.331
1,3-Butadiene	54.092	2.249
Benzene	78.115	3.247
Toluene	92.142	3.831
Xylene	106.169	4.414

The individual bag results were used to calculate the total cycle emissions for the vehicle.

All vehicles tested had total cycle emissions results calculated from all three phases of the test (i.e. all 3 bags), as shown in Equation 4.

Equation 4 - $$Emission\ (g/km) = 0.43*\left(\frac{(Yct+Ys)}{(Dct+Ds)}\right)+0.57*\left(\frac{(Yht+Ys)}{(Dht+Ds)}\right)$$

For vehicles manufactured prior to 1986, emissions results were ***also*** calculated from the first two phases of the test to enable comparisons to be made with the certification limits in ADR 27A. This formula is shown in Equation 5.

Equation 5 - $$Emission\ (g/km) = \left(\frac{(Yct+Ys)}{(Dct+Ds)}\right)$$

Where,
Yct = mass of emission from the 'cold-start transient' phase (g)
Ys = mass of emission from the 'stabilised' phase (g)
Yht = mass of emission from the 'hot-start transient' phase (g)

Dct = distance travelled during the 'cold-start transient' phase (km)
Ds = distance travelled during the 'stabilised' phase (km)
Dht = distance travelled during the 'hot-start transient' phase (km)

3.4.2 Evaporative Emissions

All evaporative emissions results were calculated using the equations provided in ADR 37/00. These equations are summarised below.

The hydrocarbon emissions for both the diurnal and hot-soak losses were calculated using Equation 6.

Equation 6 -

$$HCmass(g) = K*V(m^3)*10^{-4}*\left(\frac{HCf(ppmC)*Pf(kPa)}{Tf(^{\circ}K)}-\frac{HCi(ppmC)*Pi(kPa)}{Ti(^{\circ}K)}\right)$$

Where,
V = net internal volume of the SHED (m^3)
(assume nominal volume of vehicle is 1.42 m^3)
HCi = initial hydrocarbon concentration (ppm carbon equivalent)
HCf = final hydrocarbon concentration (ppm carbon equivalent)
Ti = initial SHED temperature (°K)
Tf = final SHED temperature (°K)
Pi = initial laboratory barometric pressure (kPa)
Pf = final laboratory barometric pressure (kPa)
K = 17.20 (Diurnal), 17.04 (Hot-soak)

For toxic compounds the value of K is not given in ADR 37/00, so Equation 7 was utilised.

Equation 7 - $$K = 1.2 * \left(12 + \frac{H}{C}\right)$$

Where H/C is the nominal hydrogen-to-carbon ratio of the compound analysed. The properties of each toxic compound are shown below in Table 7.

Table 7: Compound Properties (Evaporative Emissions)

Compound	H/C	K
1,3-Butadiene	1.5	16.2
Benzene	1	15.6
Toluene	1.143	15.77
Xylene	1.25	15.9

The total evaporative emissions from each vehicle was calculated by:

Equation 8 - $$HC\,total\,(g) = HC\,diurnal\,(g) + HC\,hot\,soak\,(g)$$

3.4.3 Fuel Consumption

City Fuel Consumption

The city fuel consumption was calculated by Equation 9, which utilises the weighted mass emissions (in g/km over the city driving cycle) obtained from Equation 4.

Equation 9 -
$$FC = \frac{(HCwmass\ *\ fraction\,HC) + (COwmass\ *\ fraction\,CO) + (CO_2 wmass\ *\ fraction\,CO_2)}{(fraction\,HC\ *\ r_f\ *10)}$$

Where,
HC wmass = weighted mass of hydrocarbon emissions over city driving cycle (g/km)
CO wmass = weighted mass of carbon monoxide emissions over city driving cycle (g/km)
CO_2 wmass = weighted mass of carbon dioxide emissions over city driving cycle (g/km)
fraction HC = fraction of carbon by mass in the fuel (petrol - 0.866, petrohol - 0.829)

fraction CO = fraction of carbon by mass in carbon monoxide emissions (0.4288)
fraction CO_2 = fraction of carbon by mass in carbon dioxide emissions (0.2729)
r_f = standard density of test fuel at 20°C (kg/L)
(ULP - 0.7284, ULP petrohol - 0.7331, LP - 0.7324 & LP petrohol - 0.7361)

Highway Fuel Consumption

The highway fuel consumption was calculated from Equation 10.

Equation 10 -

$$FC = \frac{(HCmass * fraction\ HC) + (COmass * fraction\ CO) + (CO_2 mass * fraction\ CO_2)}{(fraction\ HC * r_f * 10)}$$

Where,
HC mass = mass of hydrocarbon emissions over highway cycle (g/km)
CO mass = mass of carbon monoxide emissions over highway cycle (g/km)
CO_2 mass = mass of carbon dioxide emissions over highway cycle (g/km)

All other parameters are identical to those used in the city fuel consumption calculation.

3.4.4 Power

The power output for each vehicle was calculated from Equation 11.

Equation 11 - $Corrected\ Power\ (kW) = a * Observed\ Power\ (kW)$

Where the atmospheric correction factor (α) was calculated from Equation 12.

Equation 12 - $$Atmospheric\ Correction\ Factor\ (a) = \left(\frac{99}{P_d}\right)^{1.2} * \left(\frac{T_d + 273}{298}\right)^{0.6}$$

Where,
T_d = dry bulb temperature (°C) at air inlet to vehicle engine
P_d = saturated vapour pressure (kPa) at the ambient dry bulb temperature

The observed power was calculated from Equation 13.

Equation 13 -

$$Observed\ Power\ (kW) = Tractive\ Effort\ (N) * Indicated\ Vehicle\ Speed\ (km/h) * 0.0002777$$

4. RESULTS

4.1 Tests Conducted

Test results have been calculated using data obtained from vehicle testing by the NSW EPA (regulated exhaust and evaporative emissions, fuel consumption and engine performance) and sample analysis by the CSIRO (aldehydes, air toxics and ozone formation potential). The vehicles tested were summarised in Section 2.4 and the vehicle categories were defined in Section 2.5. However, Table 8 below provides the actual numbers of vehicles that were tested in those vehicle categories. Each vehicle was tested on both petrohol and petrol in any one condition.

Table 8: Vehicles Tested in each Vehicle Category

Tests Conducted	All[1]	BF	BFS		LTIS		
	Post-Tune	Post-Tune	Pre-Tune	Post-Tune	LTIS 1 Post-Tune	LTIS 2 Pre-Tune	LTIS 2 Post-Tune
Regulated Exhaust and Evaporative Emissions, City and Highway Fuel Consumption	60	37	12	12	11[5]	11	11
Aldehyde Exhaust Emissions	60	37	12	12	11	11	11
Exhaust Toxic Emissions	13	2	-	-	11	11	11
Evaporative Toxic Emissions	13[2]	2[5]	-	-	11[5]	11	-
Ozone Formation Potential (Exhaust Emissions)	11	-	-	-	11	11	11
Ozone Formation Potential (Evaporative Emissions)	11[3]	-	-	-	11[5]	11	-
Power / Torque	10[4]	-	1	1	9	-	-
Post-1986 Vehicles [1]	*41*	*26*	*6*	*6*	*9*	*9*	*9*
Pre-1986 Vehicles [1]	*19*	*11*	*6*	*6*	*2*	*2*	*2*
Total Vehicles	*60*	*37*	*12*	*12*	*11*	*11*	*11*

Notes: [1] For most tests conducted, the **All**, **Post-1986** and **Pre-1986** groups contain vehicles in the **BF**, **BFS** and **LTIS 2** categories in the **post-tune** condition only, as indicated by the underlines.

[2] The **All** group for Evaporative Toxic Emissions contains **pre-tune LTIS 2** vehicles.

[3] The **All** group for Evaporative Ozone Formation Potential contains **pre-tune LTIS 2** vehicles.

[4] The **All** group for Power/ Torque contains **post-tune LTIS 1** vehicles.

[5] All of the evaporative emission results from the **LTIS 1** vehicles, as well as those from two **BF** vehicles, were deemed invalid when the testing protocols were modified (refer to Section 3.1.1 for details).

4.2 Overview of Results

Table 9 provides a summary of the impacts of using petrohol on the parameters measured. Impacts in **bold** were derived from the **All** group, as defined in Table 8. For each parameter, the impact is expressed as the percentage difference between the mean of all results on petrohol and the mean of all results on petrol (baseline petrol). The numbers of vehicles included in the calculations are indicated in the third column of Table 9 and the reason for discrepancies between these numbers and those in Table 8 are provided on the next page.

Statistical analyses were carried out to determine how representative the impacts derived from the vehicles tested are to the fleet from which they were sampled. The uncertainties indicated in Table 9 represent the 95% confidence limits.

Table 9: Impacts of Petrohol

PARAMETERS MEASURED	% DIFFERENCE: MEAN PETROHOL COMPARED TO PETROL (95% CONFIDENCE LIMITS)	NUMBERS OF VEHICLES INCLUDED (POST-TUNE)
Regulated Exhaust Emissions		
Hydrocarbons (HC)	⇓ **12** ± 4	59
Oxides of Nitrogen (NOx)	⇑ **3** ± 4[#]	59
Carbon Monoxide (CO)	⇓ **32** ± 9	59
Carbon Dioxide (CO_2) [1]	⇑ **1** ± 1	59
Regulated Evaporative Emissions		
Hydrocarbons (HC)	⇑ **27** ± 12	56
Exhaust Aldehyde Emissions		
Formaldehyde (CH_2O)	⇑ **27** ± 12	56
Acetaldehyde (C_2H_4O)	⇑ **215** ± 58	53
Acrolein (C_3H_4O)	⇑ **12** ± 18[#]	55
Exhaust Toxic Emissions		
1,3-Butadiene (C_4H_6)	⇓ **21** ± 36[#]	10
Benzene (C_6H_6)	⇓ **23** ± 12	11
Toluene (C_7H_8)	⇓ **21** ± 13	11
Xylene (C_8H_{10})	⇓ **20** ± 12	11
Ozone Formation Potential [2]		
Exhaust Ozone Potential	⇓ **20**	11
Evaporative Ozone Potential	⇑ **17**	11[3]
Fuel Consumption		
City Fuel Consumption	⇑ **2** ± 1	59
Highway Fuel Consumption	⇑ **3** ± 1	54
Power [2]	⇔ Negligible change	10

Notes: ⇑ ⇓ Arrows denote increase or decrease. Percentages have been rounded to the nearest whole number.
[#] The difference (increase or decrease) is not statistically significant at the 95% confidence level.
[1] CO_2 has been included with the regulated exhaust emissions for convenience.
[2] No statistical analyses were carried out on the Ozone Formation Potential or Power results.
[3] Vehicles are in pre-tune condition.

Results from pre-1986 and post-1986 vehicles have been combined in the table above. For this analysis, the regulated exhaust emissions for both pre-1986 and post-1986 vehicles have been calculated in accordance with ADR 37/00 (i.e. the 3-bag result) and fuel consumption results calculated according to AS2877.

For many of the parameters listed in Table 9 the numbers of vehicles included in the calculation of means are lower than the numbers given in Table 8. One reason for this is that if one test result in a pair of results (i.e. petrohol and petrol) was found to be invalid for some reason, the other result in the pair was also excluded from the analysis. This was done to eliminate any undue "weighting" of the mean by either the petrohol or petrol test results and also because the appropriate statistical test uses paired differences. Other reasons for excluding data from the calculation of means are given in the relevant sections below.

While Table 9 provides a summary of the testing carried out it does not show the specific trends associated with the different vehicle groups evaluated. Analyses of these groups are given in the relevant sections below.

4.3 Emissions Limits

Pre-1986 and post-1986 vehicles were required by ADR 27A and ADR 37/00 respectively to be designed such that, when tested in accordance with the relevant standard, the emission rates of a number of pollutants do not exceed specified limits. These limits were intended to apply to each vehicle for a period of use of five years or 80,000 km, whichever came first. Whilst not a stated objective of this study, the test results obtained are compared here to the relevant emission limits.

The regulated exhaust emissions (HC, NOx, and CO) and evaporative emissions (HC) from the vehicles tested are compared to the relevant emission limits in Figures 4.1 to 4.4 below. Results from all vehicles tested in the **post-tune** condition are plotted against vehicle odometer reading to illustrate the ranges of emissions and distances accumulated. Each vehicle is represented by two symbols in each scatter plot, once when tested on petrohol and once on petrol. Examining the paired test results (i.e. petrohol and petrol) at the same (approximate) odometer reading gives an indication of the impact of petrohol on those vehicles tested.

For this analysis, pre-1986 vehicle test results were calculated in accordance with ADR 27A (i.e. the 2-bag result) while post-1986 vehicle results were calculated according to ADR 37/00 (i.e. the 3-bag result). The 3-bag results for all vehicles tested are listed in Appendix 2 while the 2-bag results for the pre-1986 vehicles only are listed in Appendix 3.

It should be noted that the specifications for the base petrol (leaded and unleaded) used in this study were different to those of the ADR reference fuel used by vehicle manufacturers in the process of new model certification. The base petrol grades in this study had higher vapour pressures, in line with the fuels available at the service stations (refer to Section 2.7). Thus, the results displayed in the figures below provide a guide to the emissions performance of the test vehicle sample in "real world" conditions as opposed to certification test conditions.

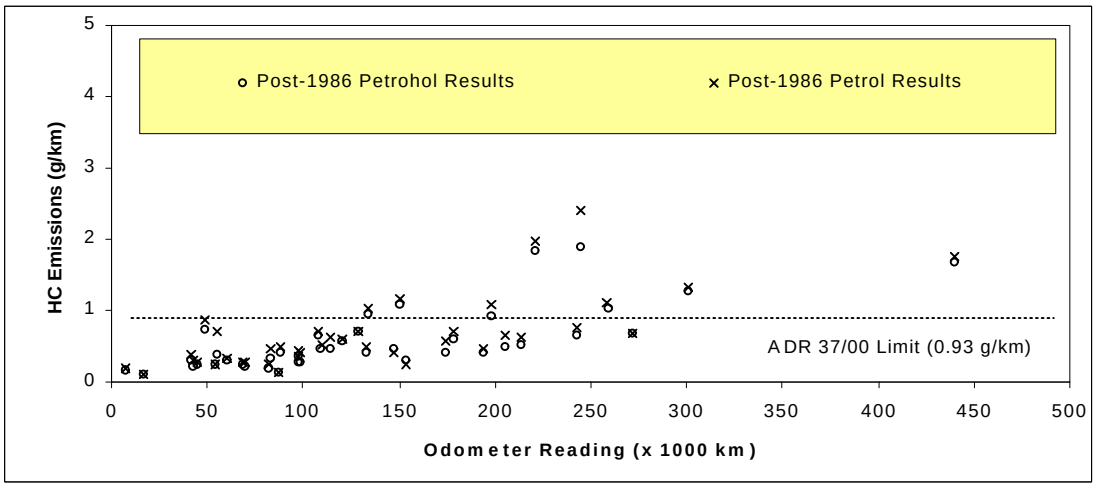

Figure 4.1a: Regulated Exhaust HC Emissions vs Odometer Reading (Post-1986 Vehicles)

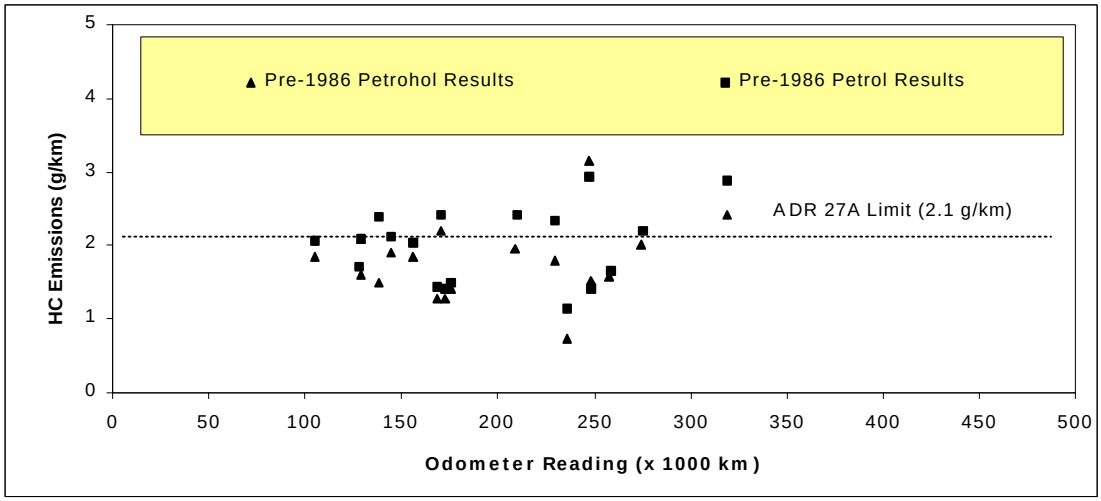

Figure 4.1b: Regulated Exhaust HC Emissions vs Odometer Reading (Pre-1986 Vehicles)

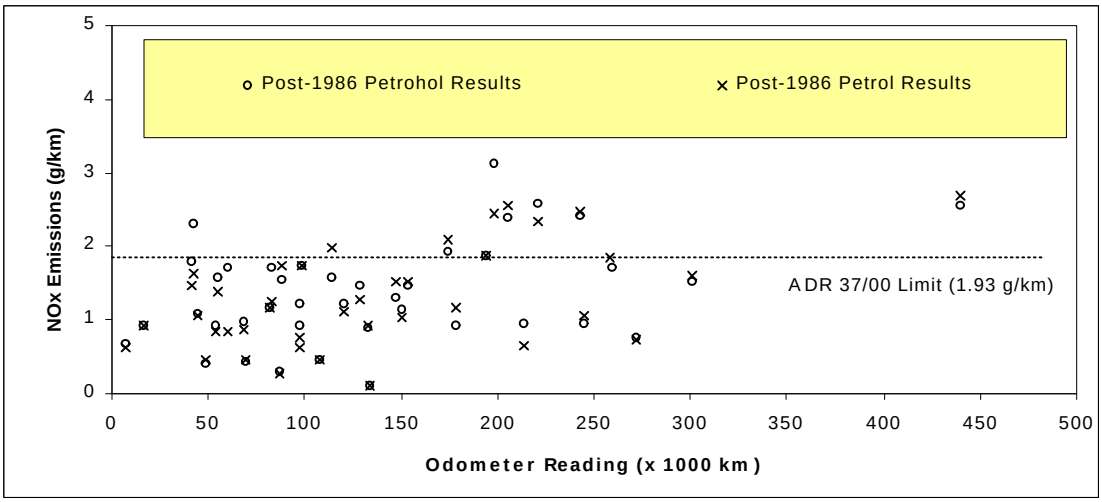

Figure 4.2a: Regulated NOx Emissions vs Odometer Reading (Post-1986 Vehicles)

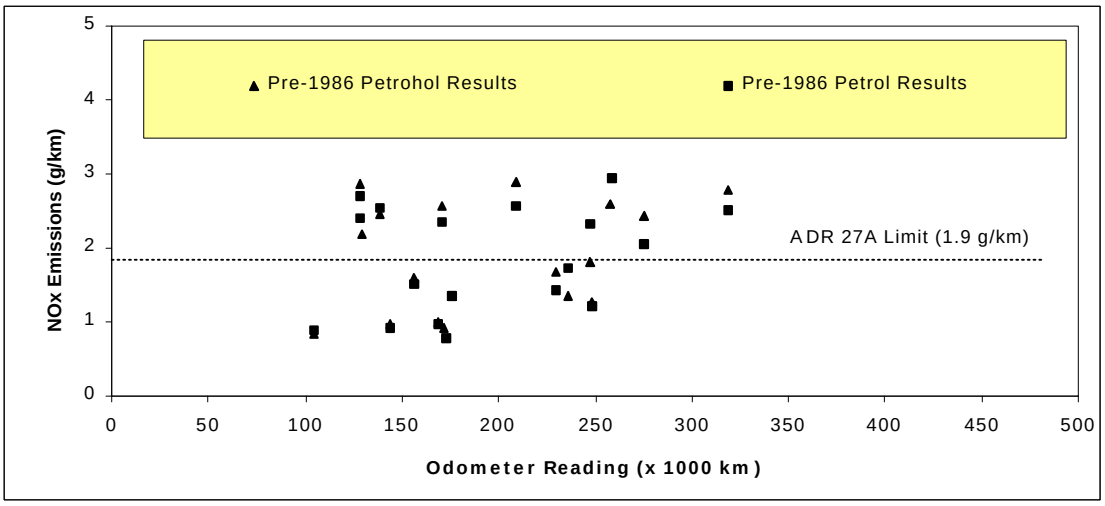

Figure 4.2b: Regulated NOx Emissions vs Odometer Reading (Pre-1986 Vehicles)

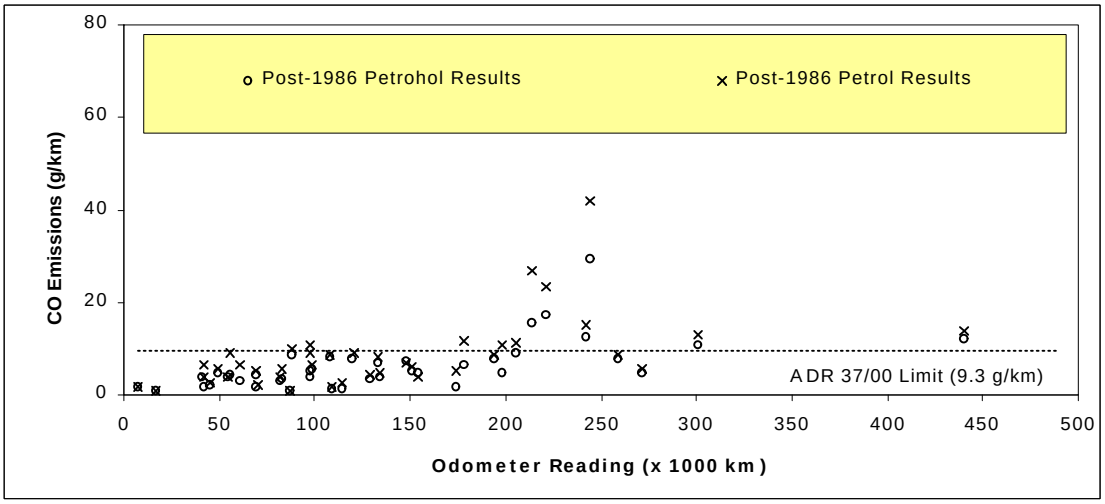

Figure 4.3a: Regulated CO Emissions vs Odometer Reading (Post-1986 Vehicles)

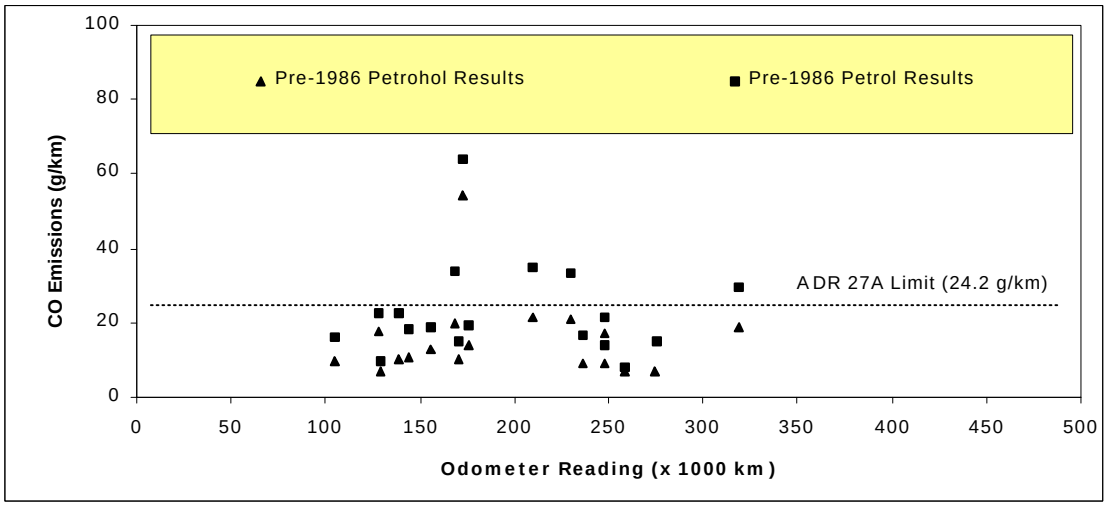

Figure 4.3b: Regulated CO Emissions vs Odometer Reading (Pre-1986 Vehicles)

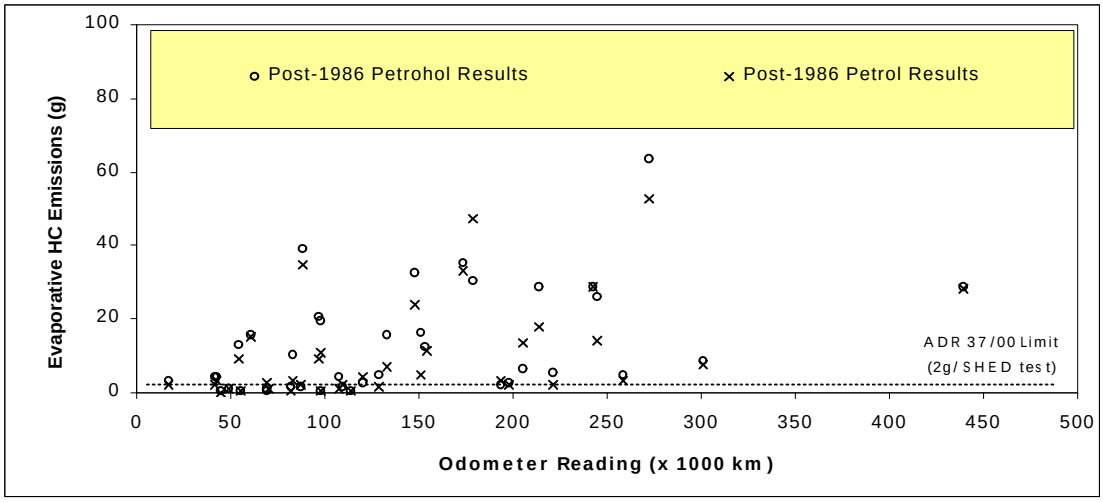

Figure 4.4a: Regulated Evaporative HC Emissions vs Odometer Reading (Post-1986 Vehicles)

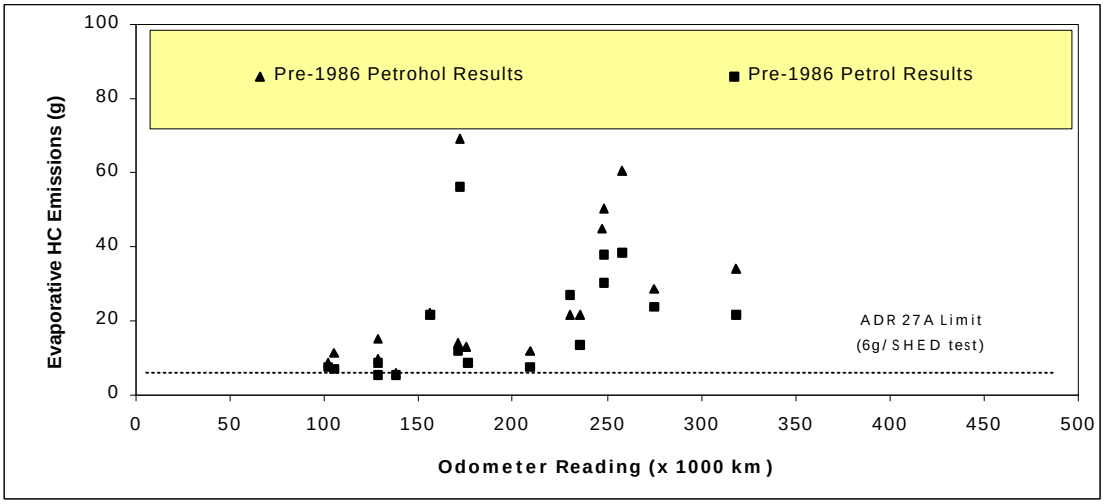

Figure 4.4b: Regulated Evaporative HC Emissions vs Odometer Reading (Pre-1986 Vehicles)

Key Findings:

- Regulated emissions varied considerably from vehicle to vehicle. There was some evidence that emissions increase with distance accumulated.
- Of the **post-1986** vehicles tested, 11 were under the five years or 80,000 kilometre criteria of ADR 37/00. The following number exceeded the limits:
  - 1 out of the 11 vehicles tested exceeded the **NOx limit** on **petrohol**,
  - 5 out of 10 vehicles tested exceeded the **evaporative HC limit** on both **petrol** and **petrohol**.
- The percentage of all **post-1986** vehicles tested (total of 41) that exceeded the ADR 37/00 emission limits were:
  - for exhaust **HC** emissions, 20% on petrol and 17% on petrohol,
  - for **NOx** emissions, 20% on petrol and 20% on petrohol,
  - for **CO** emissions, 27% on petrol and 15% on petrohol,
  - for **evaporative HC** emissions, 74% on petrol and 74% on petrohol (total of 39).

- The percentage of all **pre-1986** vehicles tested (total of 18) that exceeded the ADR 27A emission limits were:
  - for exhaust **HC** emissions, 44% on petrol and 17% on petrohol,
  - for **NOx** emissions, 50% on petrol and 44% on petrohol,
  - for **CO** emissions, 28% on petrol and 6% on petrohol,
  - for **evaporative HC** emissions, 88% on petrol and 100% on petrohol (total of 17).

Note: All vehicles analysed above were in the **post-tune** condition.

4.4 Analysis of Results

Results have been analysed in a way that allows a series of key findings to be made in each of the following three primary areas of interest:

- the emissions, fuel consumption and engine performance of vehicles operating on ethanol/ petrol blend compared with neat petrol,

- the effectiveness of maintenance in reducing emissions when operating on ethanol/ petrol blend and on neat petrol,

- the deterioration in emissions, if any, over a 12-month period due to the use of ethanol/ petrol blend.

In order for this to be done, results were aggregated into seven major groups (**All**, **Post-1986**, **Pre-1986**, **Pre-Tune**, **Post-Tune**, **LTIS 1** and **LTIS 2**). These groups are defined below:

1. **All**: This group contains, for most tests conducted, the results from vehicles in the **BF**, **BFS** and **LTIS 2** categories in the **post-tune** condition only. Exceptions to this are given in the footnotes to Table 8 above.
2. **Post-1986**: This group contains results from the **post-1986** vehicles in the **BF**, **BFS** and **LTIS 2** categories in the **post-tune** condition.
3. **Pre-1986**: This group contains results from the **pre-1986** vehicles in the **BF**, **BFS** and **LTIS 2** categories in the **post-tune** condition.
4. **Pre-Tune**: This group contains results from vehicles in the **BFS** and **LTIS 2** categories in the **pre-tune** condition (pre-1986 and post-1986 results combined).
5. **Post-Tune**: This group contains results from vehicles in the **BFS** and **LTIS 2** categories in the **post-tune** condition (pre-1986 and post-1986 results combined).
6. **LTIS 1**: This group contains results from vehicles in the **LTIS 1** (first series) category in the **post-tune** condition (pre-1986 and post-1986 results combined).
7. **LTIS 2**: This group contains results from vehicles in the **LTIS 2** (second series of tests after 12 months) category in the **post-tune** condition (pre-1986 and post-1986 results combined).

In each of the following major sections (**Regulated Exhaust Emissions, Regulated Evaporative Emissions, Exhaust Aldehydes and Toxic Emissions, Evaporative Toxic Emissions, Ozone Formation Potential, Fuel Consumption** and **Engine Performance**), the results are summarised as a table of means. Specific notes or points of clarification are given below each table.

In each sub-section dealing with the individual parameters measured, the results are presented graphically in two different ways to illustrate two aspects of the data and a series of key findings are given. In each key finding, the impact is expressed as a percentage difference

(increase or decrease) between the mean values obtained from the sample of vehicles tested, plus or minus the uncertainties (representing the 95% confidence limits) when extrapolating the results to the fleet. Those increases or decreases that are not significant at the 95% confidence level are identified by a hash (#) in the key findings.

At the end of each major section, the results are discussed further and comparisons are made with findings from other relevant studies.

4.4.1 Format of Graphs

For each parameter measured, two graphs have been prepared. The graphs display:

- the mean emission results (in a bar chart), and,
- the "scatter" in the results (in a "box and whisker" plot).

The bar charts display mean results for the vehicles tested while the box and whisker plots give an indication of the scatter in the data. Figure 4.5 provides the format of the box and whisker plots used throughout this report. Brief explanations of the terms used in the box and whisker plots are given below.

a) Median - 50% of the data set falls above the median and 50% below.

b) Lower Quartile (Q1) - 25% of the data set has a value equal to or less than the lower (or first) quartile.

c) Upper Quartile (Q3) - 25% of the data set has a value equal to or greater than the upper (or third) quartile.

d) Possible Outlier - an extreme value that lies outside the upper and lower whiskers, as indicated below. In this study, all extreme values have been included in the analyses.

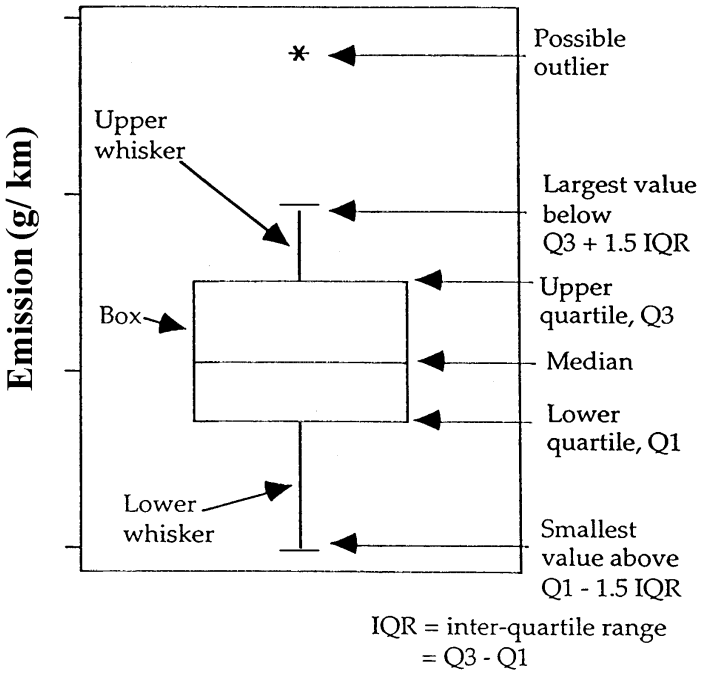

Figure 4.5: Format of the Box and Whisker Plot

4.4.2 Statistical Analysis

For most of the parameters measured, statistical analyses were carried out on the differences between the paired results for the following comparisons:

- **petrohol** to **petrol** (with **petrol** as the base) in the **All, post-1986**, and **pre-1986** groups.
- **post-tune** to **pre-tune** (with **pre-tune** as the base) for each fuel.
- **LTIS 2** to **LTIS 1** (with **LTIS 1** as the base) for each fuel.

Note: *The three comparisons above correspond with the three primary areas of interest. The paired comparisons displayed in the tables and charts in the following sections do not correspond exactly with the above three comparisons. Rather, they display* ***petrohol*** *to* ***petrol*** *paired comparisons for the seven major results groups defined in Section 4.4 above.*

The statistical analyses carried out to derive confidence intervals addresses the issue of determining whether or not significant differences occur in the in-service vehicle fleet, primarily in the Newcastle/ Central Coast regions, based on the evidence from the vehicles tested. In cases where the sample size is small, the confidence interval for the location of the fleet parameter is large, indicating a great uncertainty in the estimate. At the same time the ability to detect statistically significant differences is slender.

For each parameter, the difference (i.e. the impact) for the fleet was estimated as the mean difference calculated from the vehicle sample tested, while the associated confidence interval was determined by using the *t* statistic based on the paired differences in the sample. When reporting on the significance of an increase or decrease, a 95% two-tailed test was used. Such a test detects a change in either direction.

Where an increase or decrease is marked as not significant at the 95% confidence level, this does not necessarily imply that such an effect is not present, rather that the sample failed to supply sufficient evidence of such an effect. This could be the case when either the effect was not present or there were insufficient observations, considering the vehicle-to-vehicle variations that were measured.

The extrapolation of these results to a wider geographic area (e.g. NSW or Australia) depends on how well the vehicles drawn from the Newcastle/ Central Coast regions for the study reflect the fleet composition of the wider area. Before extrapolating the findings presented in this report, a comparison should be made to ascertain the appropriateness of such a procedure.

4.5 Regulated Exhaust Emissions

4.5.1 Summary of Results

Table 10 summarises the mean regulated exhaust emissions results for the seven major groups. While CO_2 emissions and fuel consumption are not regulated, they have been included in this summary for convenience. Fuel consumption results are analysed fully in Section 4.10. Emissions results used in the analyses that follow have been calculated in accordance with ADR 37/00 (including the pre-1986 vehicles). Individual test results are listed in Appendix 2.

Table 10: Exhaust Emissions Summary - Mean Results

Results Group	Exhaust (ADR 37/00 - 3 Bag Results)							
	No. of Tests	HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)	No. of Tests	Hwy Fuel (L/100 km)
Petrol (All)	59	1.02	1.53	11.71	261.6	12.3	54	8.9
Petrohol (All)	59	0.90	1.57	7.98	264.3	12.6	54	9.1
Petrol (Post-1986)	41	0.66	1.39	8.45	264.4	12.1	36	8.8
Petrohol (Post-1986)	41	0.57	1.46	6.18	266.2	12.5	36	9.0
Petrol (Pre-1986)	18	1.86	1.84	19.13	255.1	12.6	18	9.1
Petrohol (Pre-1986)	18	1.66	1.83	12.06	259.9	12.7	18	9.3
Petrol (Pre-Tune)	22	1.24	1.68	14.95	254.7	12.2	20	8.8
Petrohol (Pre-Tune)	22	1.15	1.77	12.36	256.4	12.5	20	9.1
Petrol (Post-Tune)	22	1.05	1.65	10.13	259.5	12.0	20	8.8
Petrohol (Post-Tune)	22	0.95	1.72	6.92	261.2	12.3	20	9.1
Petrol (LTIS 1)	10	0.49	1.30	5.67	264.9	11.9	8	9.3
Petrohol (LTIS 1)	10	0.40	1.42	3.93	264.0	12.2	8	9.5
Petrol (LTIS 2)	10	0.49	1.43	6.83	266.7	12.1	8	9.1
Petrohol (LTIS 2)	10	0.42	1.62	5.00	268.6	12.5	8	9.4

Notes: The **All, Post-1986** and **Pre-1986** groups contain results from vehicles in the BF, BFS and LTIS 2 categories in the **post-tune** condition only.
Pre-Tune contains results from vehicles in the BFS and LTIS 2 categories in the **pre-tune** condition (pre-1986 and post-1986 combined).
Post-Tune contains results from vehicles in the BFS and LTIS 2 categories in the **post-tune** condition (pre-1986 and post-1986 combined).
LTIS 1 contains results from vehicles in the LTIS 1 category in the **post-tune** condition (pre-1986 and post-1986 combined).
LTIS 2 contains results from vehicles in the LTIS 2 category in the **post-tune** condition (pre-1986 and post-1986 combined).

Clarification:

1. All exhaust emission and fuel consumption results from a Pre-1986 Ford Falcon (Vehicle Reference No. 4374) in the LTIS category have been excluded from the analyses, as after servicing, the vehicle's CO emissions substantially decreased on petrohol and substantially increased on petrol. It is unknown whether this anomaly was the result of poor vehicle servicing or due to vehicle instability. One pre-tune and two post-tune pairs of tests (petrohol and petrol) were excluded.

2. All highway fuel consumption results for three BF post-1986 vehicles (Ref No.s 4418, 4421 and 4448) and two LTIS vehicles (Ref No.s 4370 and 4379) have been excluded due to problems experienced in undertaking the tests. When one result in a test pair (petrohol and petrol) is deemed invalid, all results for that parameter are excluded from the analysis.

4.5.2 Exhaust HC Emissions

Figures 4.6 and 4.7 display graphically the mean exhaust HC emissions and the scatter in the results for each of the seven major groups.

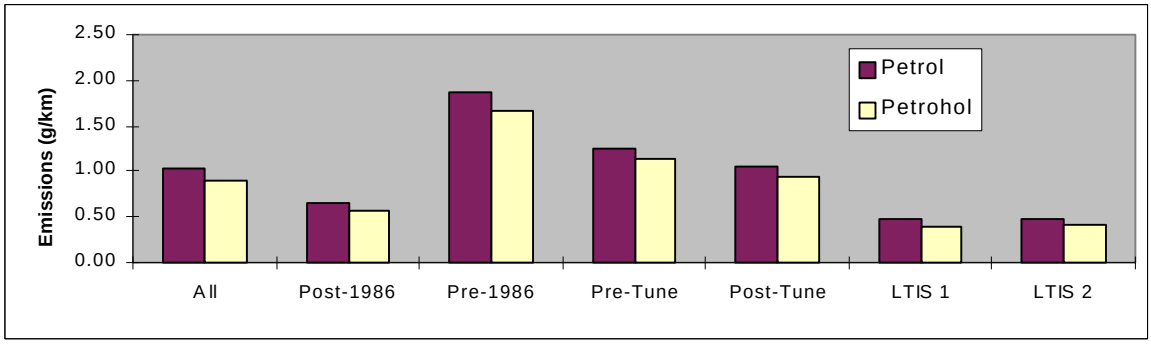

Figure 4.6: Mean Exhaust HC Emissions

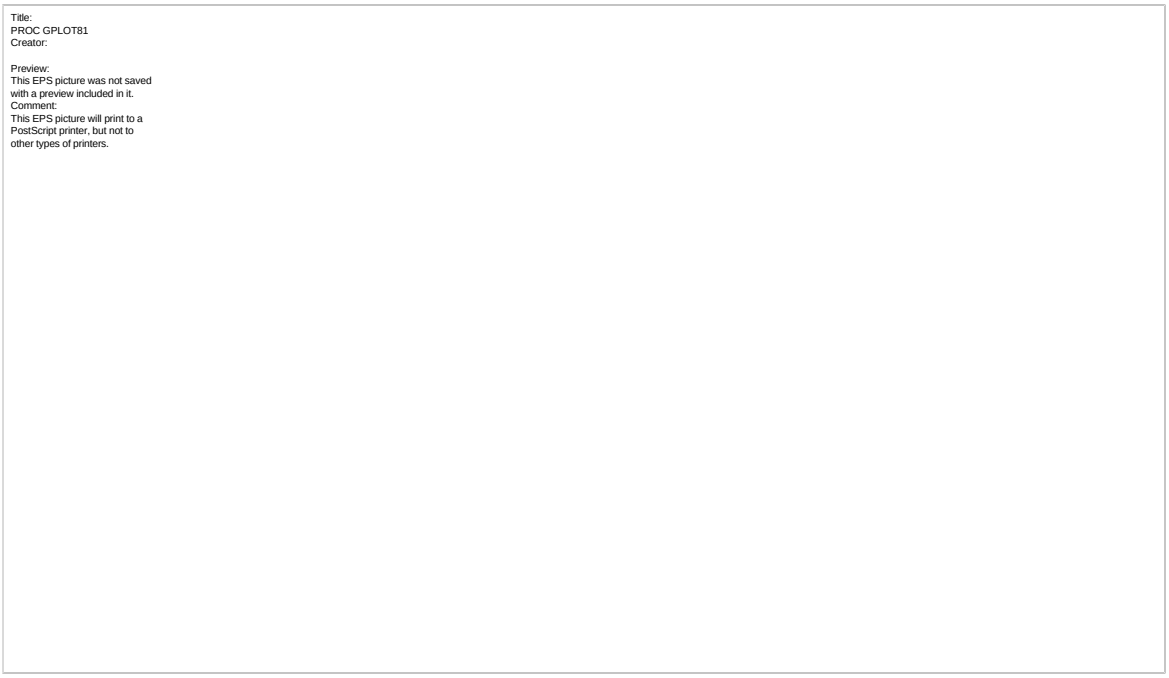

Figure 4.7: Exhaust HC Emissions Box & Whisker Plot

Key Findings:

- A reduction of 12% ± 4% in the mean HC emissions for **post-tune** vehicles, when operating on petrohol.
- Reductions in the mean HC emissions of 13% ± 5% for **post-1986** vehicles and 11% ± 5% for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean HC emissions of 16% ± 22%[#] on petrol and 17% ± 17%[#] on petrohol, following vehicle **servicing**.
- Increases in the mean HC emissions of 0% ± 15%[#] on petrol and 4% ± 14%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

4.5.3 NOx Emissions

Figures 4.8 and 4.9 display graphically the mean NOx emissions and the scatter in the results for each of the seven major groups.

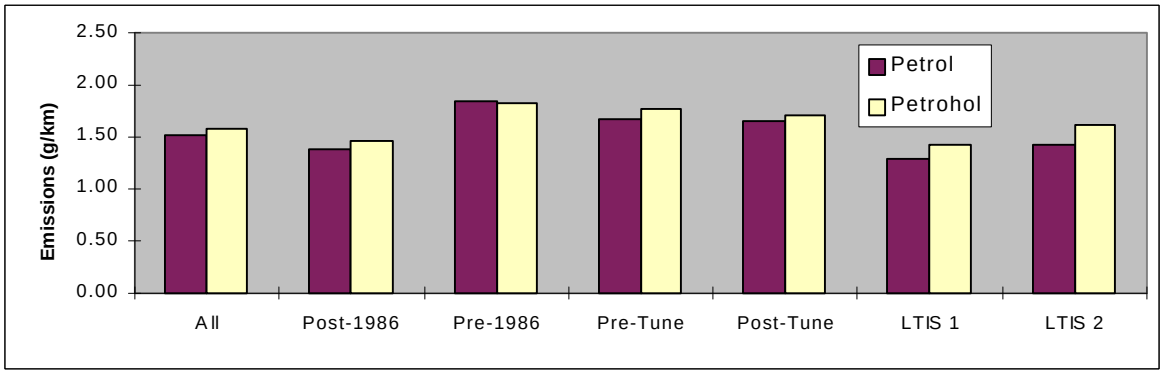

Figure 4.8: Mean NOx Emissions

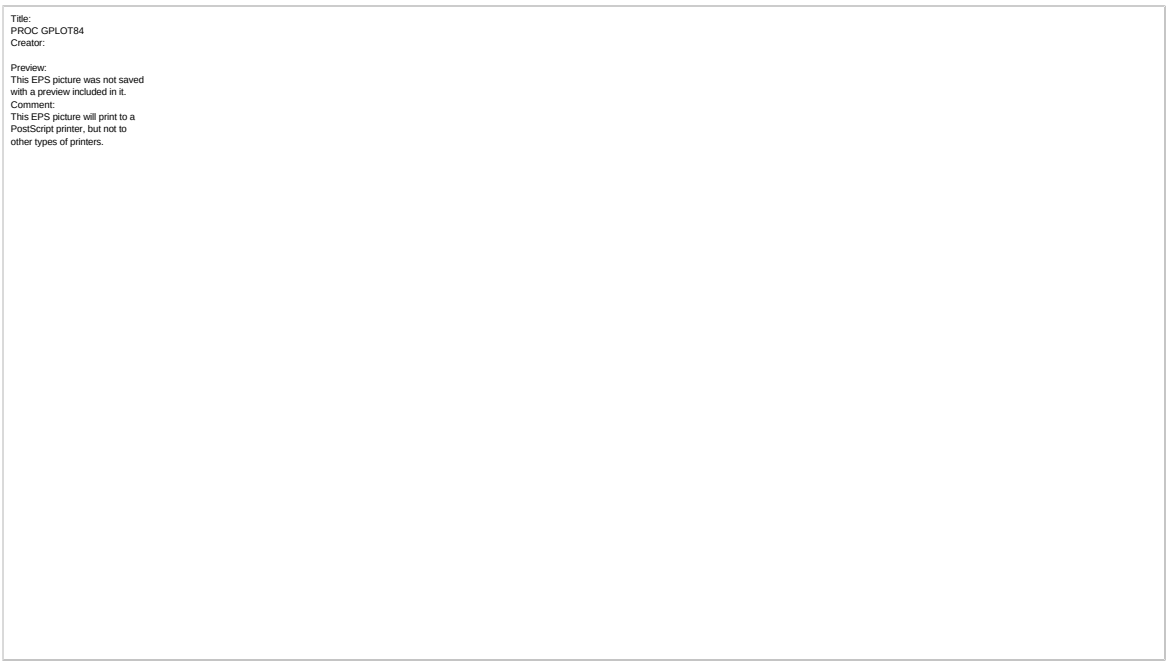

Figure 4.9: NOx Emissions Box & Whisker Plot

Key Findings:

- An increase of 3% ± 4%[#] in the mean NOx emissions for **post-tune** vehicles, when operating on petrohol.
- An increase in the mean NOx emissions of 5% ± 7%[#] for **post-1986** vehicles and a decrease of 1% ± 6%[#] for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean NOx emissions of 2% ± 10%[#] on petrol and 3% ± 10%[#] on petrohol, following vehicle **servicing**.
- Increases in the mean NOx emissions of 10% ± 26%[#] on petrol and 14% ± 24%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

4.5.4 CO Emissions

Figures 4.10 and 4.11 display graphically the mean CO emissions and the scatter in the results for each of the seven major groups.

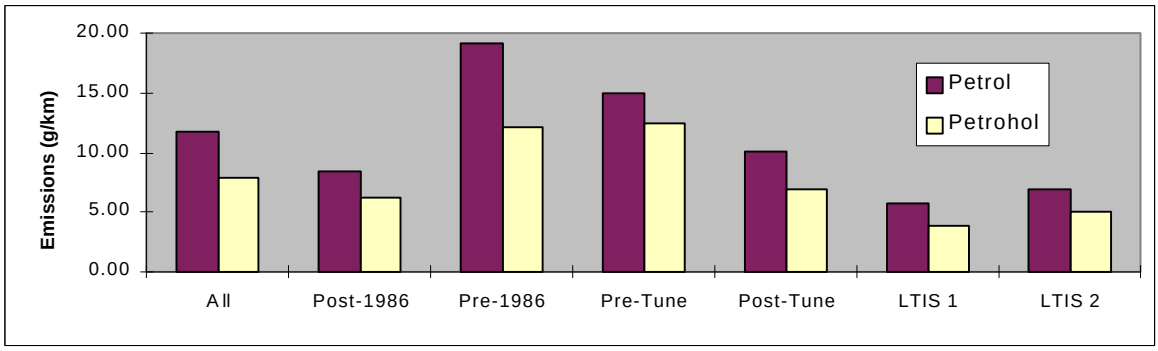

Figure 4.10: Mean CO Emissions

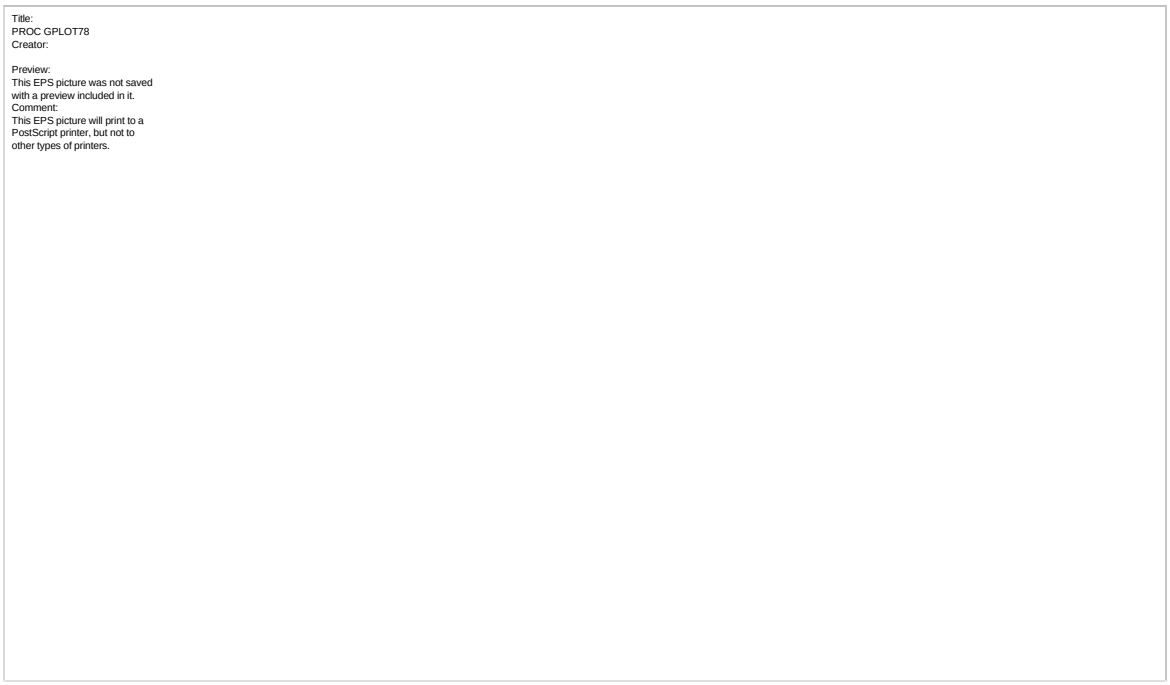

Figure 4.11: CO Emissions Box & Whisker Plot

Key Findings:

- A reduction of 32% ± 9% in the mean CO emissions for **post-tune** vehicles, when operating on petrohol.
- Reductions in the mean CO emissions of 27% ± 11% for **post-1986** vehicles and 37% ± 10% for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean CO emissions of 32% ± 35%[#] on petrol and 44% ± 48%[#] on petrohol, following vehicle **servicing**.
- Increases in the mean CO emissions of 20% ± 18% on petrol and 27% ± 28%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

4.5.5 CO_2 Emissions

Figures 4.12 and 4.13 display graphically the mean CO_2 emissions and the scatter in the results for each of the seven major groups.

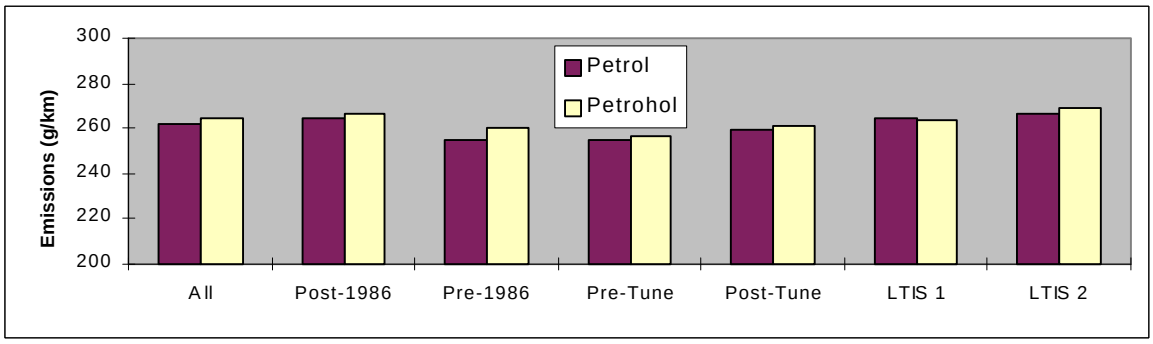

Figure 4.12: Mean CO_2 Emissions

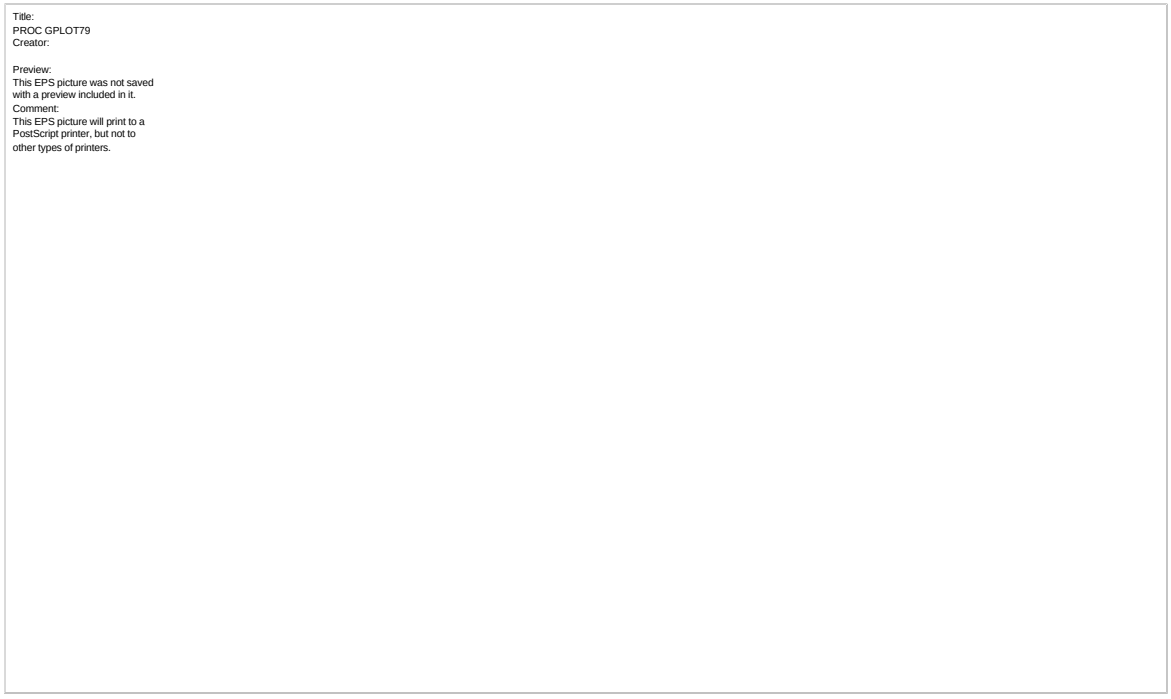

Figure 4.13: CO_2 Emissions Box & Whisker Plot

Key Findings:

- An increase of 1% ± 1% in the mean CO_2 emissions for **post-tune** vehicles, when operating on petrohol.
- Increases in the mean CO_2 emissions of 1% ± 1%[#] for **post-1986** vehicles and 2% ± 1% for **pre-1986** vehicles, when operating on petrohol.
- Increases in the mean CO_2 emissions of 2% ± 3%[#] on petrol and 2% ± 2%[#] on petrohol, following vehicle **servicing**.
- Increases in the mean CO_2 emissions of 1% ± 3%[#] on petrol and 2% ± 3%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase is not statistically significant at the 95% confidence level.

4.5.6 Discussion of Results

It can be seen from the preceding analyses that the trends in exhaust emissions results were consistent, albeit at various levels, across all vehicle categories. When operating on petrohol, compared to petrol, vehicles experience reductions in hydrocarbon and carbon monoxide emissions while experiencing a small increase in carbon dioxide emissions and no significant increase in oxides of nitrogen emissions.

These findings are explained further in the discussion below.

Impacts of Petrohol

In summary, the use of petrohol yielded the following impacts:

- Reduction of 12% ± 4% in the mean exhaust HC emissions (13% ± 5% post-1986 and 11% ± 5% pre-1986),
- Increase of 3% ± 4%[#] in the mean NOx emissions (5% ± 7%[#] post-1986 and -1% ± 6%[#] pre-1986),
- Reduction of 32% ± 9% in the mean CO emissions (27% ± 11% post-1986 and 37% ± 10% pre-1986),
- Increase of 1% ± 1% in the mean CO_2 emissions (1% ± 1%[#] post-1986 and 2% ± 1% pre-1986).

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

These results are consistent with other comparative studies that have been conducted on petrol/ ethanol fuels [6,7], as shown in Table 11.

Table 11: Impacts of Petrohol on Exhaust Emissions - Other Studies

Exhaust Emissions	US Government Report [6]	SAE Paper [7]
Hydrocarbons (HC)	⇓ 4.8 ± 2.6%	-
Oxides of Nitrogen (NOx)	⇑ 5.2 ± 4.1%	⇑ 15%
Carbon Monoxide (CO)	⇓ 13.3 ± 4.8%	⇓ 26%

These and other studies have shown that:

a) Oxygenated fuels lean the air/ fuel ratio in vehicles that are equipped with carburettors (as in most **pre-1986** vehicles) [4,5]. These vehicles are designed for use on neat petrol only and without any form of feedback system they are unable to correct for the stoichiometric air/ fuel ratios of different fuels unless modified or specifically adjusted for them.

   The use of petrohol in **pre-1986** vehicles is therefore expected to cause:
   - reductions in hydrocarbon emissions,
   - small increases in oxides of nitrogen emissions,
   - substantial reductions in carbon monoxide emissions,
   - small increases in carbon dioxide emissions.

   However, vehicles that operate close to the lean limit can sometimes misfire, causing an increase in hydrocarbon emissions when oxygenated fuels are used [4].

b) Oxygenated fuels perform differently in vehicles equipped with fuel injection and closed loop engine management systems (as in most **post-1986** vehicles). These vehicles maintain a near stoichiometric air/ fuel ratio under cruise and light acceleration modes by monitoring the oxygen content of the exhaust gas. However, they normally operate under open loop (rich) conditions during idle and high acceleration modes, and while the catalyst is warming up. In these modes, the leaning effect of the oxygenated fuel may be apparent.

The use of petrohol in **post-1986** vehicles is therefore expected to cause:

- reductions in hydrocarbon emissions,
- small increases in oxides of nitrogen emissions,
- substantial reductions in carbon monoxide emissions (though somewhat less than in pre-1986 vehicles),
- small increases in carbon dioxide emissions (though somewhat less than in pre-1986 vehicles).

Effect of Maintenance

In summary, servicing the vehicles yielded the following impacts:

- Reductions in the mean exhaust HC emissions of 16% ± 22%[#] on petrol and 17% ± 17%[#] on petrohol,
- Reductions in the mean NOx emissions of 2% ± 10%[#] on petrol and 3% ± 10%[#] on petrohol,
- Reductions in the mean CO emissions of 32% ± 35%[#] on petrol and 44% ± 48%[#] on petrohol,
- Increases in the mean CO_2 emissions of 2% ± 3%[#] on petrol and 2% ± 2%[#] on petrohol.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

These results are consistent with the findings of the FORS NISE Study [(3)], where servicing of the group of vehicles tested produced an average reduction of 16% in HC, 9% in NOx and 25% in CO emissions.

Emissions Deterioration

The deterioration in the emissions over a 12-month period may be summarised as follows:

- Increases in the mean exhaust HC emissions of 0% ± 15%[#] on petrol and 4% ± 14%[#] on petrohol,
- Increases in the mean NOx emissions of 10% ± 26%[#] on petrol and 14% ± 24%[#] on petrohol,
- Increases in the mean CO emissions of 20% ± 18% on petrol and 27% ± 28%[#] on petrohol,
- Increases in the mean CO_2 emissions of 1% ± 3%[#] on petrol and 2% ± 3%[#] on petrohol.

Note: [#] The increase is not statistically significant at the 95% confidence level.

The magnitude of the increases in emissions that were experienced in the LTIS vehicle category over the 12-month period appears to be inconsistent (insignificant increases in HC and substantial increases in CO). It is thought that the increases in CO are not due to the use of petrohol alone, rather more likely due to one or more of the following possibilities:

- General deterioration: Some of the vehicles tested in the LTIS category travelled up to 56,000 kilometres in the 12-month period between testing, which could have caused a deterioration in both the engine and emission control equipment over that period.

- Effects of servicing: Some vehicles experienced higher emissions after servicing, as found in the NISE study [3]. The NISE report stated that "tuning well-maintained cars can increase emissions".

- Small sample size: As only 10 vehicles were tested in the LTIS category, the average result for each fuel is influenced by large variations in the individual results.

4.6 Regulated Evaporative Emissions

4.6.1 Summary of Results

Table 12 summarises the mean regulated evaporative emissions results (SHED tests) for the seven major groups. Individual test results are listed in Appendix 2.

Table 12: Evaporative Emissions Summary - Mean Results

Results Group	No. of Tests	Evaporative Diurnal (g)	Evaporative Hot Soak (g)	Evaporative Total (g)
Petrol (All)	56	8.19	5.08	13.27
Petrohol (All)	56	9.53	7.30	16.83
Petrol (Post-1986)	39	7.50	3.03	10.54
Petrohol (Post-1986)	39	8.78	4.06	12.84
Petrol (Pre-1986)	17	9.78	9.76	19.54
Petrohol (Pre-1986)	17	11.25	14.73	25.98
Petrol (Pre-Tune)	21	6.88	3.12	10.00
Petrohol (Pre-Tune)	21	7.86	4.42	12.28
Petrol (Post-Tune)	21	6.38	3.09	9.47
Petrohol (Post-Tune)	21	6.91	4.60	11.51
Petrol (LTIS 1)	0	NA	NA	NA
Petrohol (LTIS 1)	0	NA	NA	NA
Petrol (LTIS 2)	11	5.43	2.95	8.39
Petrohol (LTIS 2)	11	5.43	3.63	9.06

Notes: The **All, Post-1986** and **Pre-1986** groups contain results from vehicles in the BF, BFS and LTIS 2 categories in the **post-tune** condition only.
Pre-Tune contains results from vehicles in the BFS and LTIS 2 categories in the **pre-tune** condition (pre-1986 and post-1986 combined).
Post-Tune contains results from vehicles in the BFS and LTIS 2 categories in the **post-tune** condition (pre-1986 and post-1986 combined).
LTIS 1 normally contains results from **post-tune** LTIS 1 vehicles – NA denotes not available (see Clarification below).
LTIS 2 contains results from vehicles in the LTIS 2 category in the **post-tune** condition (pre-1986 and post-1986 combined).

Clarification:

The evaporative emissions results for all LTIS 1 category vehicles (11 vehicles), two BF vehicles (Vehicle Ref No.s 4300 and 4377) and two BFS vehicles (Vehicle Ref No.s 4380 and 4383) have been excluded from the analyses because they were deemed to be invalid when the testing protocols were modified (refer to Section 3.1.1 for details). Mean results shown in Table 12 have been derived from tests performed to the modified protocols.

Figures 4.14 and 4.15 display graphically the mean evaporative HC emissions and the scatter in the results for each of six major groups (LTIS 1 group excluded). Without the LTIS 1 group, no findings could be made in relation to deterioration. Note that the scatter is not shown for the LTIS 2 group either. However, post-tune LTIS 2 vehicles are included in most of the other groups.

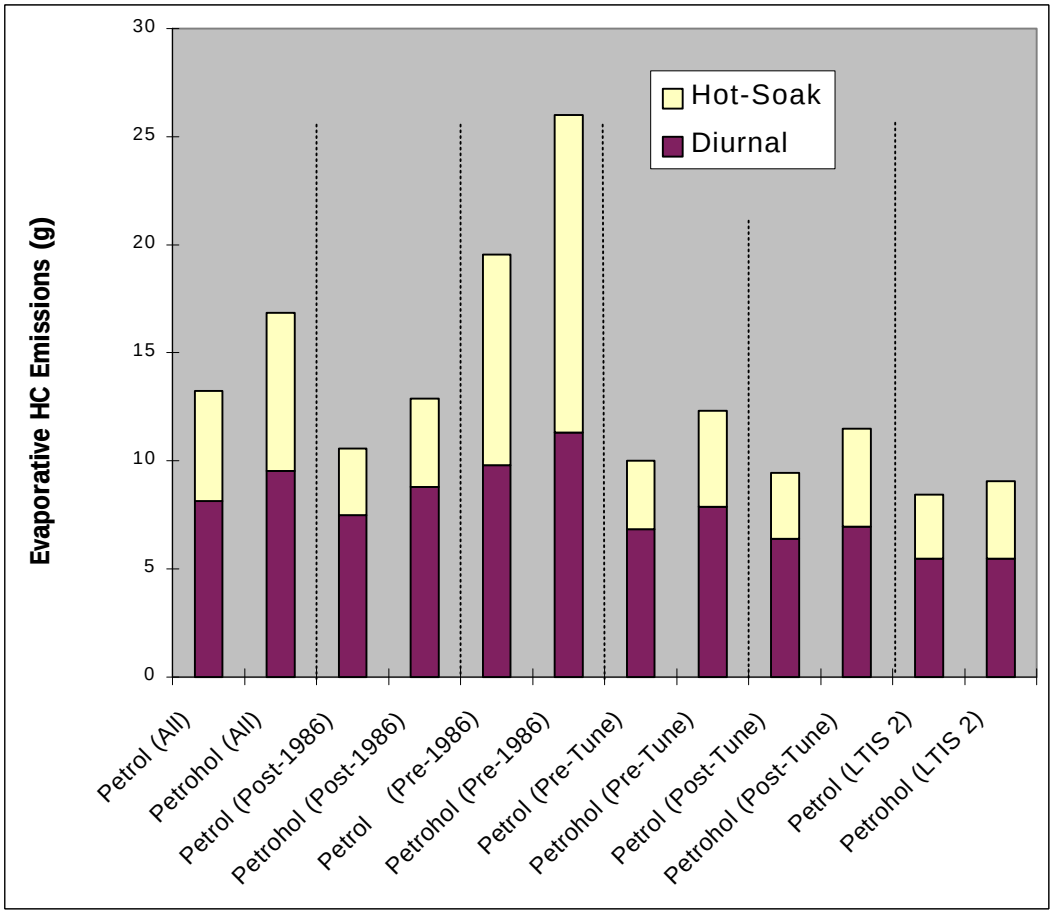

Figure 4.14: Mean Evaporative HC Emissions

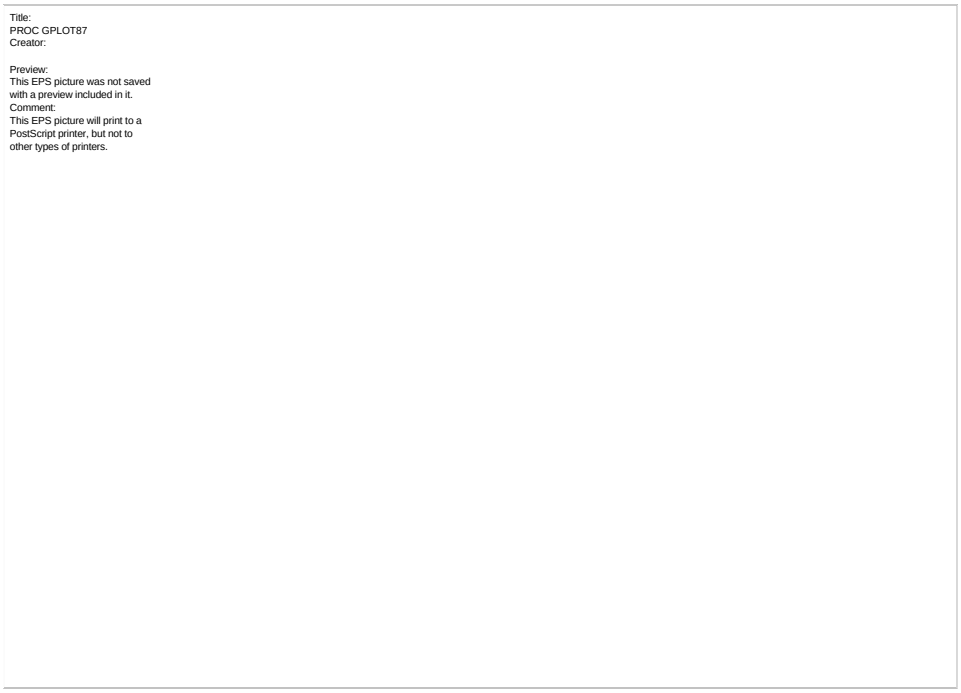

Figure 4.15: Evaporative HC Emissions Box & Whisker Plot

Key Findings:

- An increase of 27% ± 12% in the mean evaporative HC emissions for **post-tune** vehicles, when operating on petrohol.
- An increase in the mean evaporative HC emissions of 22% ± 17% (17% ± 16% diurnal, 34% ± 28% hot-soak) for **post-1986** vehicles, when operating on petrohol.
- An increase in the mean evaporative HC emissions of 33% ± 17% (15% ± 15% diurnal, 51% ± 30% hot-soak) for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean evaporative HC emissions of 5% ± 17%[#] on petrol and 6% ± 14%[#] on petrohol, following vehicle **servicing**.
- The diurnal loss accounted for more than half the total evaporative emissions for **post-1986** vehicles.
- The hot-soak loss accounted for more than half the total evaporative emissions for **pre-1986** vehicles.

Note: [#] The reduction is not statistically significant at the 95% confidence level.

4.6.2 Discussion of Results

It can be seen from the preceding analyses that the trends in evaporative emissions results were consistent, albeit at various levels, across all vehicle categories. When operating on petrohol, compared to petrol, vehicles experienced increases in both diurnal and hot-soak evaporative emissions.

Vehicles Exceeding the ADR Emission Limits

It was found that 74% of the **post-1986** vehicles and 88% of the **pre-1986** vehicles tested yielded evaporative HC results on petrol that were above the relevant limits (see findings in Section 4.3). This is consistent with the findings of the FORS NISE Study [(3)], where over 60% of post-1986 vehicles and over 80% of pre-1986 vehicles tested exceeded their respective evaporative emission limits.

New vehicles are designed to meet emission limits when operating on the ADR certification fuel. ADR fuel has a lower vapour pressure and a lower mid-range distillation characteristic when compared to the commercial grade petrol used in this and the NISE studies. Consequently, it would be expected that evaporative emissions results would be substantially higher in these studies than encountered during certification testing.

In these studies, it was also found that large proportions of in-service vehicles produce very high evaporative emissions for one or more of the following reasons [(3)]:

- Poor condition of evaporative emission control equipment (i.e. fuel cap, carbon canister, vapour recovery lines, fuel filler neck connections, carburettor gaskets, etc.),
- Poor quality of replacement parts (e.g. fuel cap),
- Insufficient purge rate of the carbon canister,
- Loading of the carbon canister prior to commencement of the test,
- For post-1986 vehicles, the large volume of hot fuel returning from injector rail to fuel tank.

Impacts of Petrohol

In summary, the use of petrohol yielded the following impacts:

- Increase of 27% ± 12% in the mean evaporative HC emissions (22% ± 17% post-1986, 33% ± 17% pre-1986),

- Increase of 16% ± 11% in the mean diurnal HC emissions (17% ± 16% post-1986, 15% ± 15% pre-1986),
- Increase of 44% ± 22% in the mean hot-soak HC emissions (34% ± 28% post-1986, 51% ± 30% pre-1986).

Note: All increases above are statistically significant at the 95% confidence level.

This is consistent with other comparative studies [5,7], as shown in Table 13. In these studies it was found that the higher evaporative emissions from petrohol resulted from higher vapour pressure and different distillation characteristics compared to the base petrol.

Table 13: Impact of Petrohol on Evaporative Emissions - Other Studies

Evaporative Emissions	SAE Paper [5]	SAE Paper [7]
Hydrocarbons (HC)	⇑ 51%	⇑ 65%

For both post-1986 and pre-1986 vehicles the use of petrohol is expected to [5]:
- Increase the diurnal hydrocarbon evaporative emissions due to the higher vapour pressure of petrohol,
- Increase hot-soak emissions due to the distillation characteristic for petrohol being significantly lower in the 50°C to 120°C region resulting in more vapour being generated.

It is also expected, irrespective of the fuel used, that:
- **Pre-1986** vehicles (mostly with carburettors) will typically emit a greater portion of their total evaporative emissions from the hot-soak loss phase due to fuel boiling in the carburettor bowl as well as fuel leaking around the carburettor and inlet manifold.
- **Post-1986** vehicles (almost all with fuel injection) will typically emit less total evaporative emissions as the fuel delivery systems on these vehicles are better sealed. These vehicles were also designed to meet the more stringent ADR 37/00 evaporative emission standard.

Effect of Maintenance

In summary, vehicle servicing yielded the following impacts:
- Reductions in the mean total evaporative HC emissions of 5% ± 17%[#] on petrol and 6% ± 14%[#] on petrohol,
- Reductions in the mean diurnal loss emissions of 7% ± 24%[#] on petrol and 12% ± 18%[#] on petrohol,
- Reductions in the mean hot-soak loss emissions of 1% ± 24%[#] on petrol and an increase of 4% ± 14%[#] on petrohol.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

These results are not consistent with the findings of the NISE Study [3], where servicing of the vehicles tested produced an estimated reduction in total evaporative HC emissions of 20%.

Emissions Deterioration

An examination of the deterioration in evaporative emissions could not be made as the testing protocols for the project were modified between the first round of testing (LTIS 1) and the return testing 12 months later (LTIS 2). The first series of results were deemed invalid and could not be used in the analysis (refer to Section 3.1.1 for details).

4.7 Exhaust Aldehydes and Toxic Emissions

4.7.1 Summary of Results

Exhaust aldehyde emission results were obtained from 94 test pairs (petrohol and petrol) on the 60 test vehicles (see Table 8). Several of the test pairs were excluded from the calculation of means for the reasons given in the Clarification below. Exhaust toxic emission results were obtained from 35 test pairs on 13 vehicles. Several of these test pairs were also excluded from the calculation of means as indicated below.

Table 14 summarises the mean exhaust aldehyde and toxic emission results for the seven major groups. Individual test results are listed in Appendix 5.

Table 14: Exhaust Aldehyde and Toxic Emissions Summary – Mean Results

	Exhaust (ADR 37/00 - 3 Bag Results)											
	Aldehydes						Air Toxics					
Results Group	No. of Tests	CH_2O (mg/km)	No. of Tests	C_2H_4O (mg/km)	No. of Tests	C_3H_4O (mg/km)	No. of Tests	C_4H_6 (mg/km)	No. of Tests	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
Petrol (All)	56	13.59	53	3.95	55	1.866	10	4.80	11	23.54	36.21	28.94
Petrohol (All)	56	17.24	53	12.46	55	2.089	10	3.79	11	18.16	28.50	23.11
Petrol (Post-1986)	39	5.64	36	2.24	38	1.138	8	1.35	9	14.36	19.21	16.17
Petrohol (Post-1986)	39	7.16	36	7.00	38	1.227	8	1.23	9	10.35	14.17	12.29
Petrol (Pre-1986)	17	31.85	17	7.58	17	3.493	2	18.60	2	64.83	112.71	86.43
Petrohol (Pre-1986)	17	40.38	17	24.04	17	4.017	2	14.02	2	53.30	93.02	71.77
Petrol (Pre-Tune)	21	16.88	19	4.79	20	2.417	8	1.68	9	18.80	28.83	25.16
Petrohol (Pre-Tune)	21	17.57	19	16.35	20	2.156	8	1.38	9	15.66	24.06	20.40
Petrol (Post-Tune)	21	16.05	19	4.40	20	2.217	8	1.77	9	17.87	26.66	22.20
Petrohol (Post-Tune)	21	18.80	19	13.87	20	2.118	8	1.47	9	13.65	20.47	17.60
Petrol (LTIS 1)	9	5.52	8	1.82	8	-0.031	8	11.67	9	30.46	43.52	36.12
Petrohol (LTIS 1)	9	6.90	8	5.06	8	0.552	8	10.10	9	23.74	34.37	30.39
Petrol (LTIS 2)	9	5.38	8	1.09	8	0.598	8	1.77	9	17.87	26.66	22.20
Petrohol (LTIS 2)	9	6.75	8	4.30	8	0.865	8	1.47	9	13.65	20.47	17.60

Notes: The **All, Post-1986** and **Pre-1986** groups contain results from vehicles in the BF, BFS and LTIS 2 categories in the **post-tune** condition only.
Pre-Tune contains results from vehicles in the BFS and LTIS 2 categories in the **pre-tune** condition (pre-1986 and post-1986 combined).
Post-Tune contains results from vehicles in the BFS and LTIS 2 categories in the **post-tune** condition (pre-1986 and post-1986 combined).
LTIS 1 contains results from vehicles in the LTIS 1 category in the **post-tune** condition (pre-1986 and post-1986 combined).
LTIS 2 contains results from vehicles in the LTIS 2 category in the **post-tune** condition (pre-1986 and post-1986 combined).

CH_2O = Formaldehyde
C_2H_4O = Acetaldehyde
C_3H_4O = Acrolein
C_4H_6 = 1,3-butadiene
C_6H_6 = Benzene
C_7H_8 = Toluene
C_8H_{10} = Xylene

Clarification:

1. All exhaust aldehydes and toxic emission results from a Pre-1986 Ford Falcon (Vehicle Reference No. 4374) in the LTIS category have been excluded from the analysis, as after servicing, the vehicle's CO emissions substantially decreased on petrohol and substantially increased on petrol. It is unknown whether the anomaly was the result of poor vehicle servicing or due to vehicle instability. All exhaust emission results from this vehicle were excluded.

2. Other exhaust aldehydes and toxic emission results have been excluded due to problems encountered by the EPA in collecting the samples or to problems encountered by the CSIRO in analysing the samples. When one result in a test pair (petrohol and petrol) is invalid or not available, all results for that parameter are excluded from the analysis. The following results have been excluded:

- Formaldehyde results from two BF vehicles (Vehicle Ref No.s 4415 and 4444) and one LTIS vehicle (Ref No. 4371),
- Acetaldehyde results from three BF vehicles (Ref No.s 4415, 4432 and 4444), one BFS vehicle (Ref No. 4430) and two LTIS vehicles (Ref No.s 4370 and 4371),
- Acrolein results from two BF vehicles (Ref No.s 4415 and 4444) and two LTIS vehicles (Ref No.s 4370 and 4371),
- 1,3-Butadiene results from one LTIS vehicle (Ref No. 4379),
- All exhaust toxic results from one LTIS vehicle (Ref No. 4367).

3. Some individual exhaust aldehyde and toxic emission results are negative due to the fact that, in those cases, concentrations of vehicle emissions were lower than the background concentrations in the test cell. Exhaust emissions were always corrected for background. Negative results can occur because the background concentration is only measured during Bag 3 of the exhaust emissions test, when the background concentrations are typically at their highest level.

Exhaust Aldehydes

4.7.2 Formaldehyde

Figures 4.16 and 4.17 display graphically the mean formaldehyde emissions and the scatter in the results for each of the seven major groups.

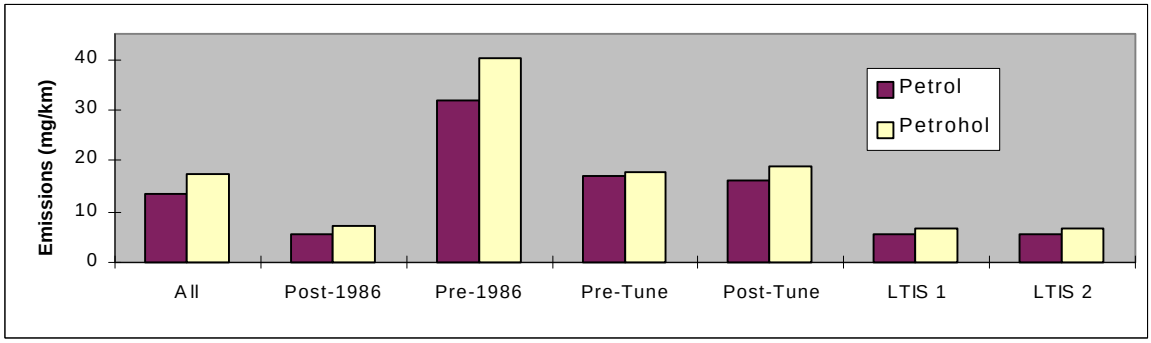

Figure 4.16: Mean Formaldehyde Emissions

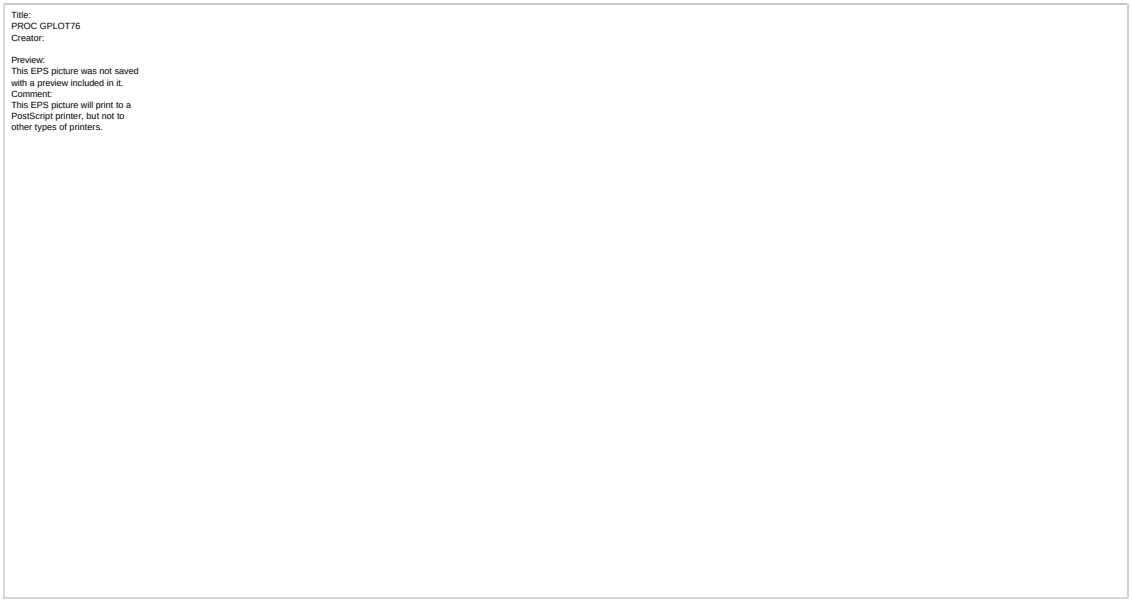

Figure 4.17: Formaldehyde Emissions Box & Whisker Plot

Key Findings:

- An increase of 27% ± 12% in the mean formaldehyde emissions for **post-tune** vehicles, when operating on petrohol.
- Increases in the mean formaldehyde emissions of 27% ± 24% for **post-1986** vehicles and 27% ± 12% for **pre-1986**, when operating on petrohol.
- A reduction in the mean formaldehyde emissions of 5% ± 26%[#] on petrol and an increase of 7% ± 38%[#] on petrohol, following vehicle **servicing**.
- Reductions in the mean formaldehyde emissions of 2% ± 18%[#] on petrol and 2% ± 14%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

4.7.3 Acetaldehyde

Figures 4.18 and 4.19 display graphically the mean acetaldehyde emissions and the scatter in the results for each of the seven major groups.

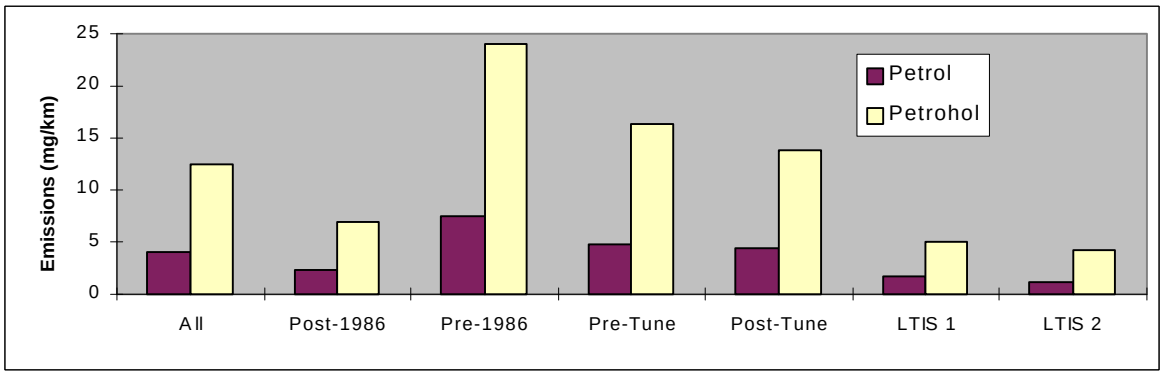

Figure 4.18: Mean Acetaldehyde Emissions

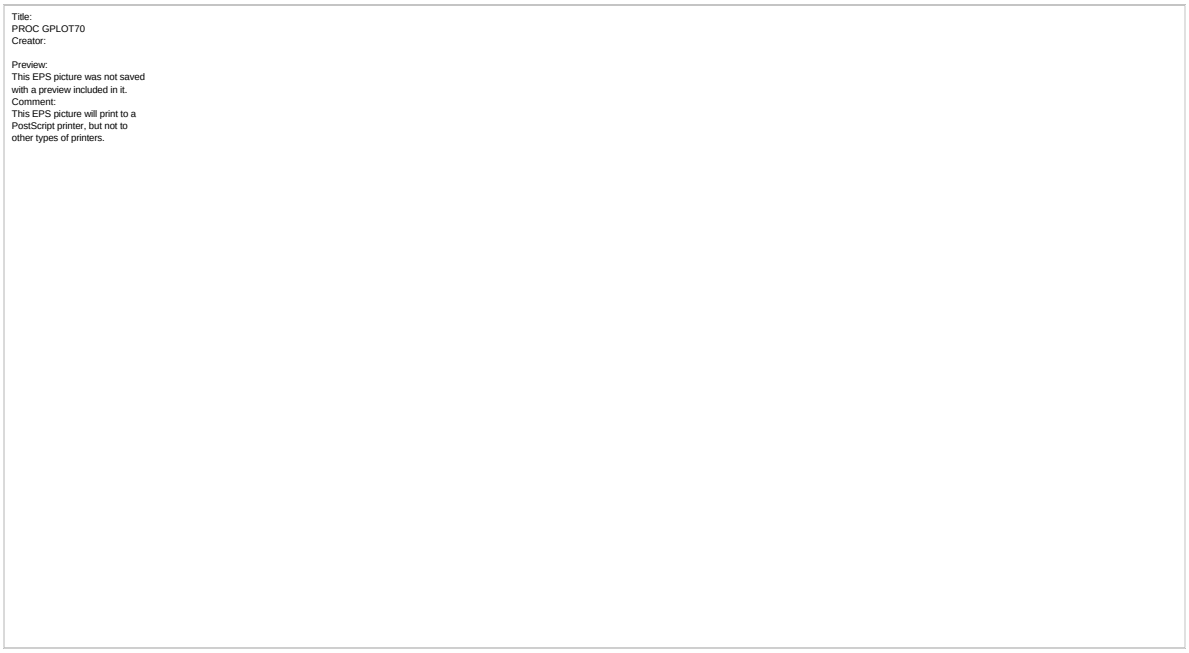

Figure 4.19: Acetaldehyde Emissions Box & Whisker Plot

Key Findings:

- An increase of 215% ± 58% in mean acetaldehyde emissions for **post-tune** vehicles, when operating on petrohol.
- Increases in the mean acetaldehyde emissions of 213% ± 93% for **post-1986** vehicles and 217% ± 47% for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean acetaldehyde emissions of 8% ± 24%[#] on petrol and of 15% ± 39%[#] on petrohol, following vehicle **servicing**.
- Reductions in the mean acetaldehyde emissions of 40% ± 78%[#] on petrol and 15% ± 49%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The reduction is not statistically significant at the 95% confidence level.

4.7.4 Acrolein

Figures 4.20 and 4.21 display graphically the mean acrolein emissions and the scatter in the results for each of the seven major groups.

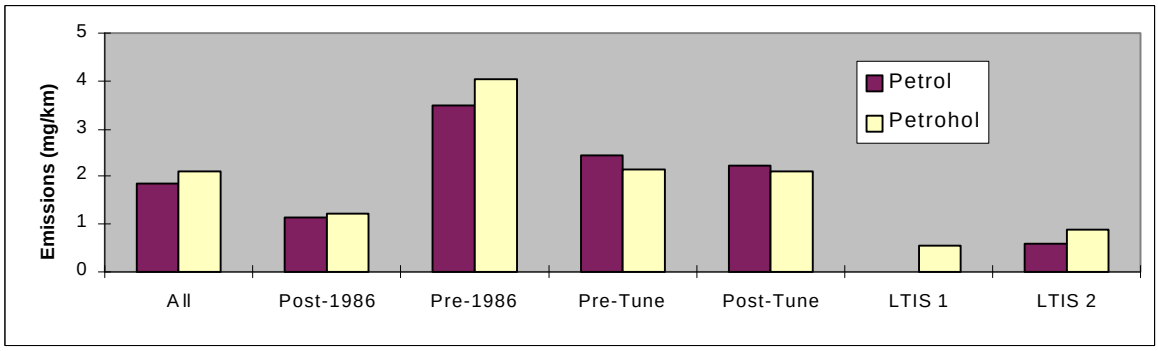

Figure 4.20: Mean Acrolein Emissions

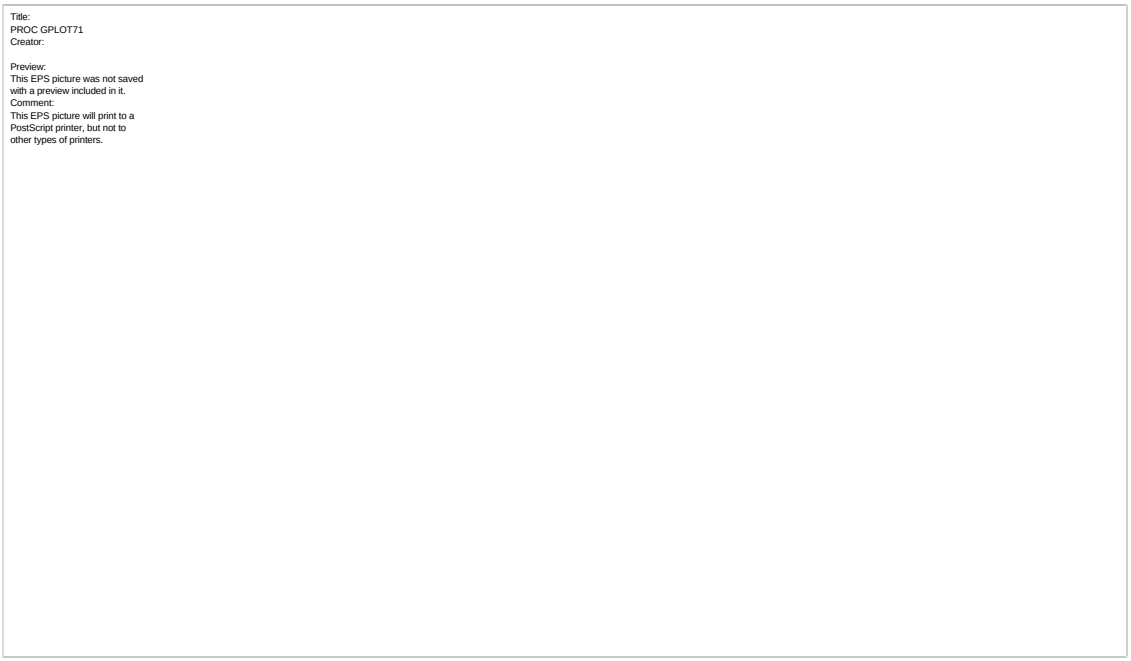

Figure 4.21: Acrolein Emissions Box & Whisker Plot

Key Findings:

- An increase of 12% ± 18%[#] in the mean acrolein emissions for **post-tune** vehicles, when operating on petrohol.
- Increases in the mean acrolein emissions of 8% ± 19%[#] for **post-1986** vehicles and 15% ± 30%[#] for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean acrolein emissions of 8% ± 38%[#] on petrol and 2% ± 35%[#] on petrohol, following vehicle **servicing**.
- An increase in the mean acrolein emissions of 57% ± 49% on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

Exhaust Toxics

4.7.5 1,3-Butadiene

Figures 4.22 and 4.23 display graphically the mean exhaust 1,3-butadiene emissions and the scatter in the results for each of the seven major groups.

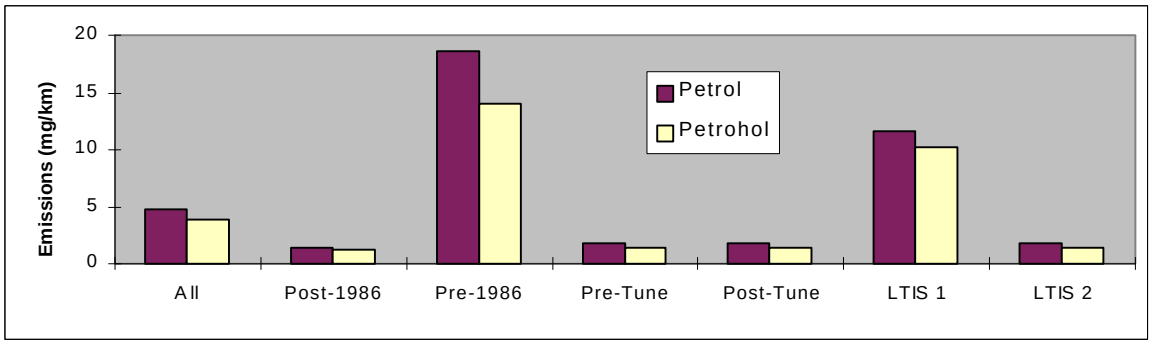

Figure 4.22: Mean Exhaust 1,3-Butadiene Emissions

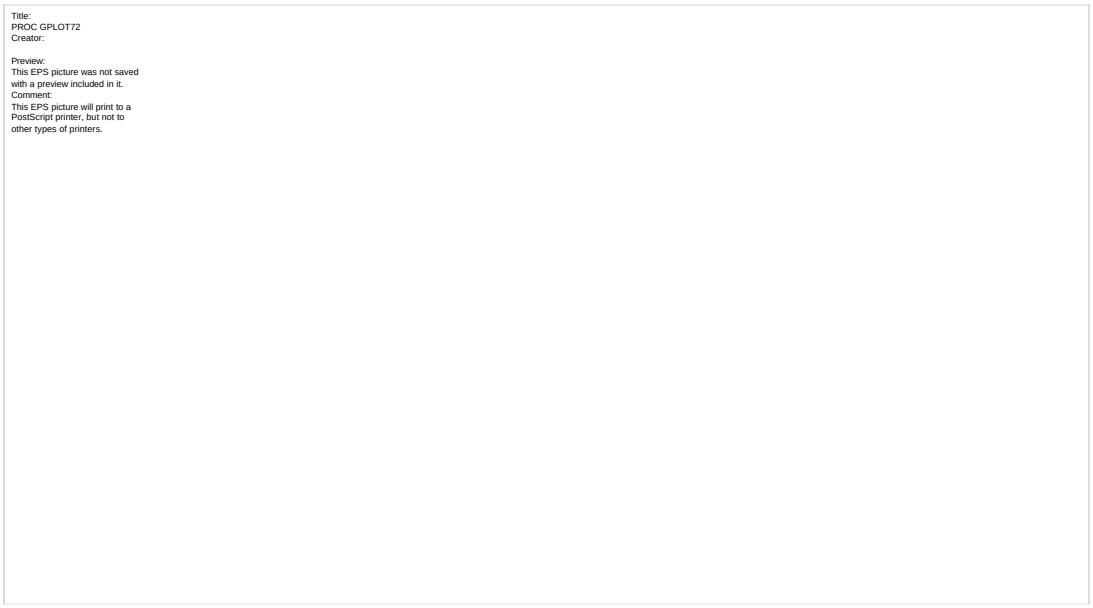

Figure 4.23: Exhaust 1,3-Butadiene Emissions Box & Whisker Plot

Key Findings:

- A reduction of 21% ± 36%[#] in the mean 1,3-butadiene emissions for **post-tune** vehicles, when operating on petrohol.
- Reductions in the mean 1,3-butadiene emissions of 9% ± 23%[#] for **post-1986** vehicles and 25% ± 210%[#] for **pre-1986** vehicles, when operating on petrohol.
- Increases in the mean 1,3-butadiene emissions of 5% ± 40%[#] on petrol and 6% ± 39%[#] on petrohol, following vehicle **servicing**.
- Reductions in the mean 1,3-butadiene emissions of 85% ± 68% on petrol and 85% ± 76% on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

4.7.6 Benzene

Figures 4.24 and 4.25 display graphically the mean exhaust benzene emissions and the scatter in the results for each of the seven major groups.

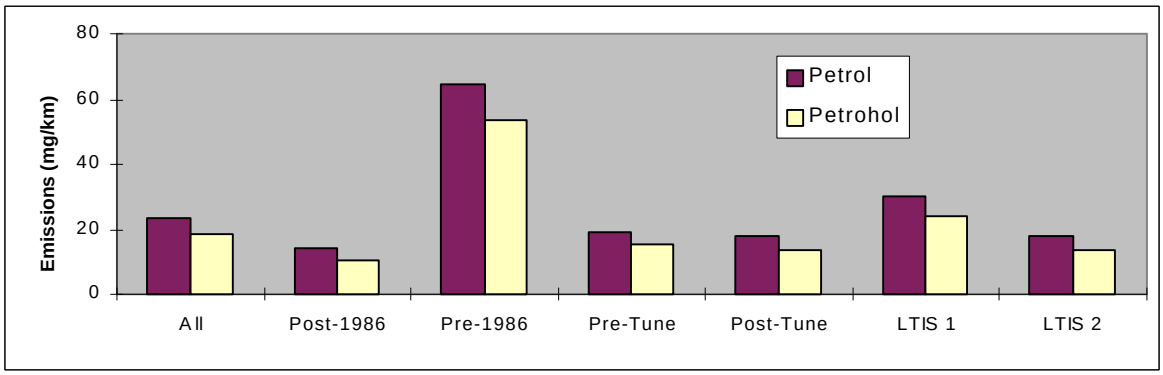

Figure 4.24: Mean Exhaust Benzene Emissions

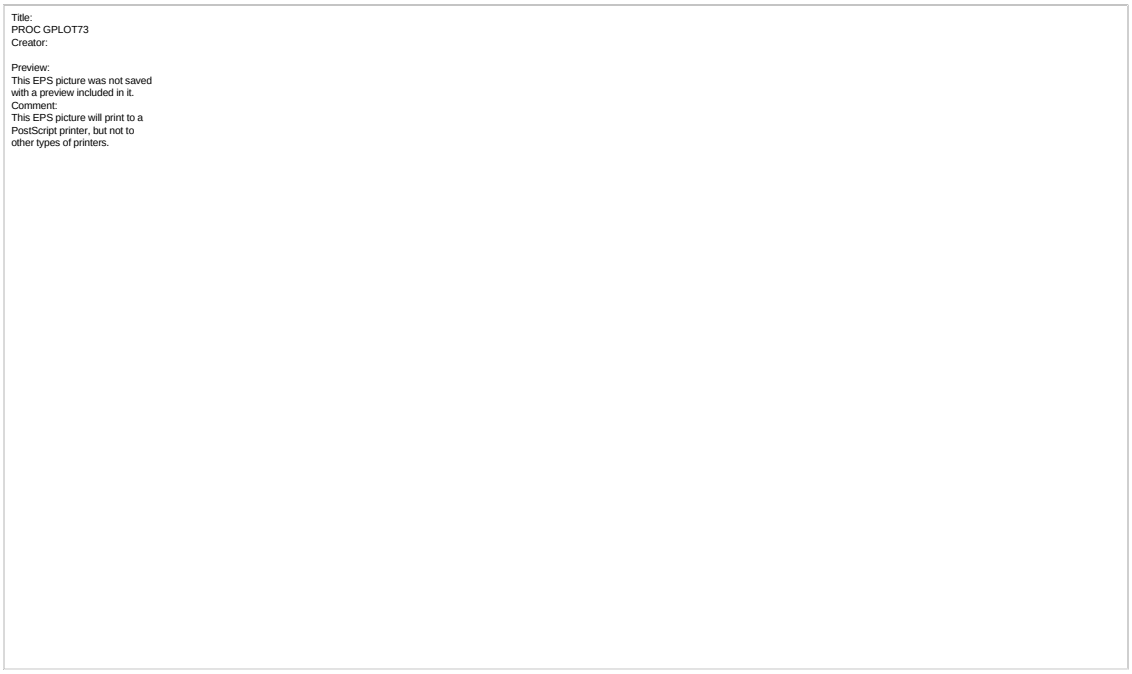

Figure 4.25: Exhaust Benzene Emissions Box & Whisker Plot

Key Findings:

- A reduction of 23% ± 12% in the mean benzene emissions for **post-tune** vehicles, when operating on petrohol.
- Reductions in the mean benzene emissions of 28% ± 15% for **post-1986** vehicles and 18% ± 85%[#] for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean benzene emissions of 5% ± 13%[#] on petrol and 13% ± 15%[#] on petrohol, following vehicle **servicing**.
- Reductions in the mean benzene emissions of 41% ± 37% on petrol and 43% ± 36% on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The reduction is not statistically significant at the 95% confidence level.

4.7.7 Toluene

Figures 4.26 and 4.27 display graphically the mean exhaust toluene emissions and the scatter in the results for each of the seven major groups.

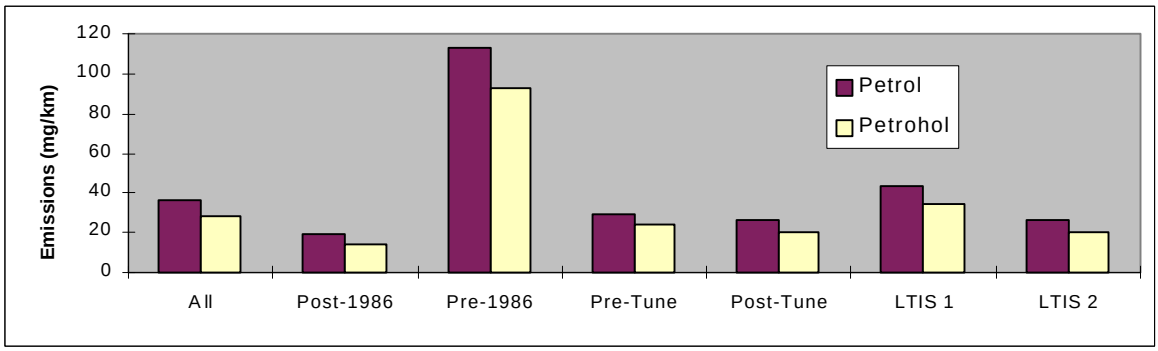

Figure 4.26: Mean Exhaust Toluene Emissions

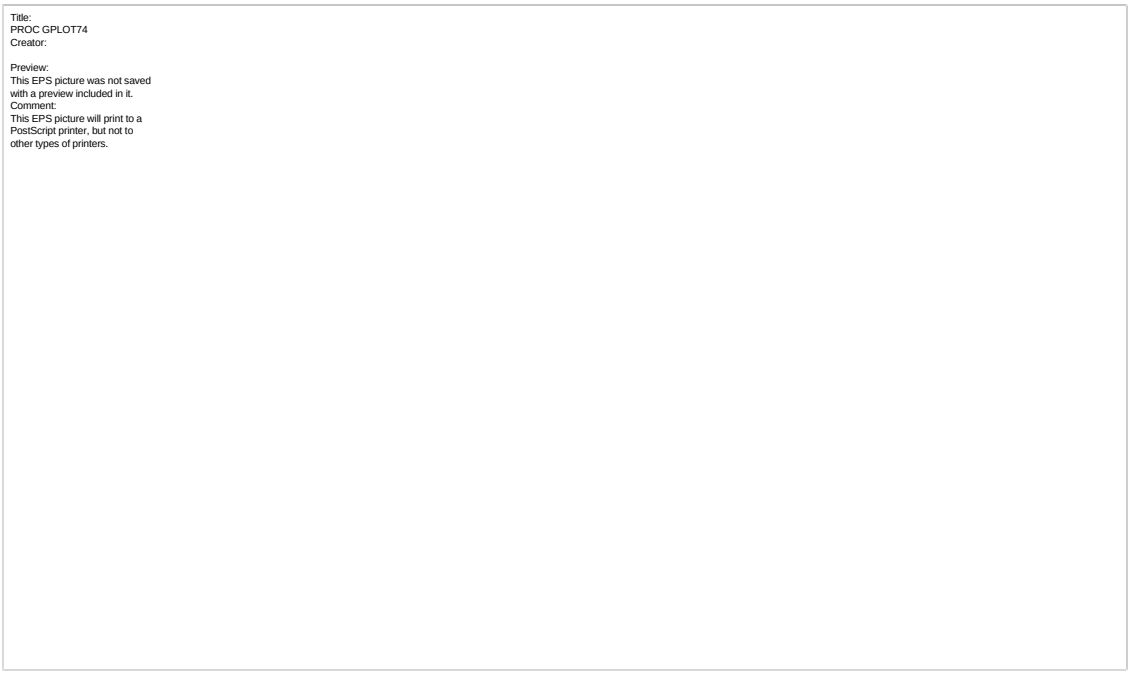

Figure 4.27: Exhaust Toluene Emissions Box & Whisker Plot

Key Findings:

- A reduction of 21% ± 13% in the mean toluene emissions for **post-tune** vehicles, when operating on petrohol.
- Reductions in the mean toluene emissions of 26% ± 15% for **post-1986** vehicles and 17% ± 34%[#] for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean toluene emissions of 8% ± 24%[#] on petrol and 15%± 26%[#] on petrohol, following vehicle **servicing**.
- Reductions in the mean toluene emissions of 39% ± 45%[#] on petrol and 40%± 50%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The reduction is not statistically significant at the 95% confidence level.

4.7.8 Xylene

Figures 4.28 and 4.29 display graphically the mean exhaust xylene emissions and the scatter in the results for each of the seven major groups.

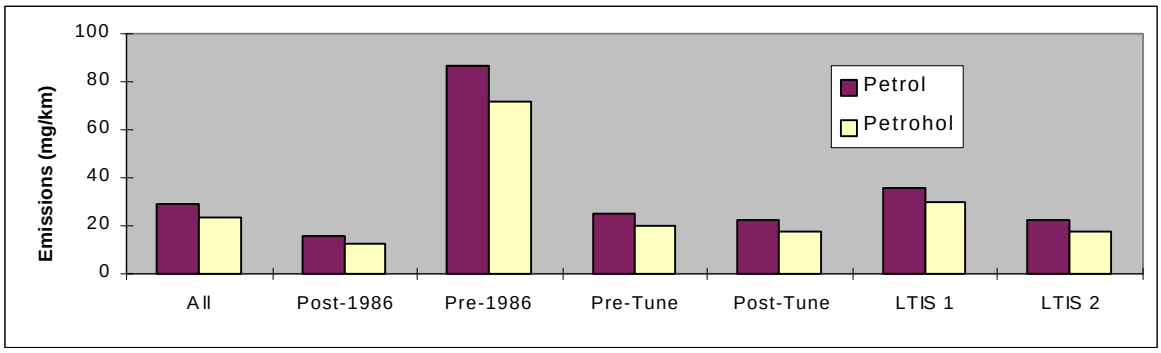

Figure 4.28: Mean Exhaust Xylene Emissions

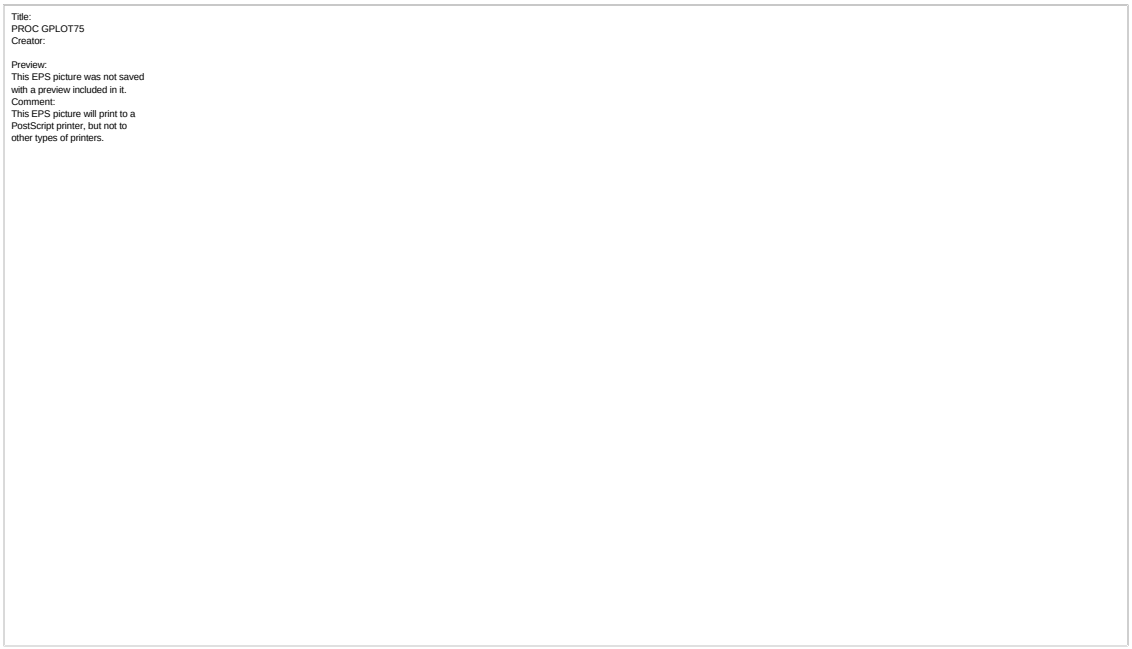

Figure 4.29: Exhaust Xylene Emissions Box & Whisker Plot

Key Findings:

- A reduction of 20% ± 12% in the mean xylene emissions for **post-tune** vehicles, when operating on petrohol.
- Reductions in the mean xylene emissions of 24% ± 12% for **post-1986** vehicles and 17% ± 45%[#] for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean xylene emissions of 12% ± 29%[#] on petrol and 14% ± 27%[#] on petrohol, following vehicle **servicing**.
- Reductions in the mean xylene emissions of 39% ± 39%[#] on petrol and 42% ± 43%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The reduction is not statistically significant at the 95% confidence level.

4.7.9 Correlation of Exhaust Toxics to Total Hydrocarbons

In this section the correlations between the exhaust toxic parameters and total hydrocarbon (THC) emissions are examined. The relationships are displayed graphically in Figures 4.30 to 4.33. Regression lines have been fitted through the data points and the R^2 values indicated on the graphs.

Results from two BF and nine LTIS vehicles have been included in the benzene, toluene and xylene analyses while two BF and only eight LTIS vehicles have been analysed for 1,3-butadiene (one set of results deemed invalid, refer to Table 14). In order to obtain a reasonable sample, results from both the first and second series of testing on LTIS vehicles have been included (in the **post-tune** condition only). That is, each LTIS vehicle is represented twice in the following graphs (LTIS 1 post-tune & LTIS 2 post-tune).

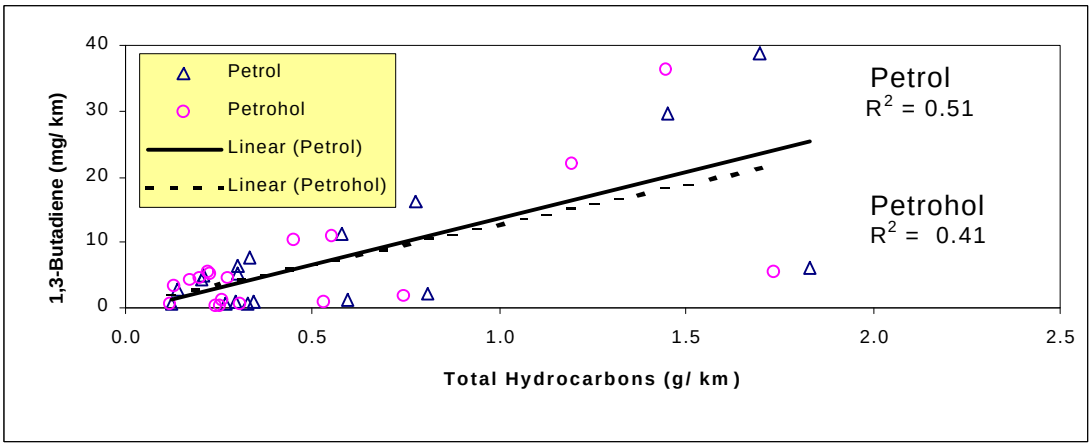

Figure 4.30: Relationship between Exhaust 1,3-Butadiene and THC Emissions

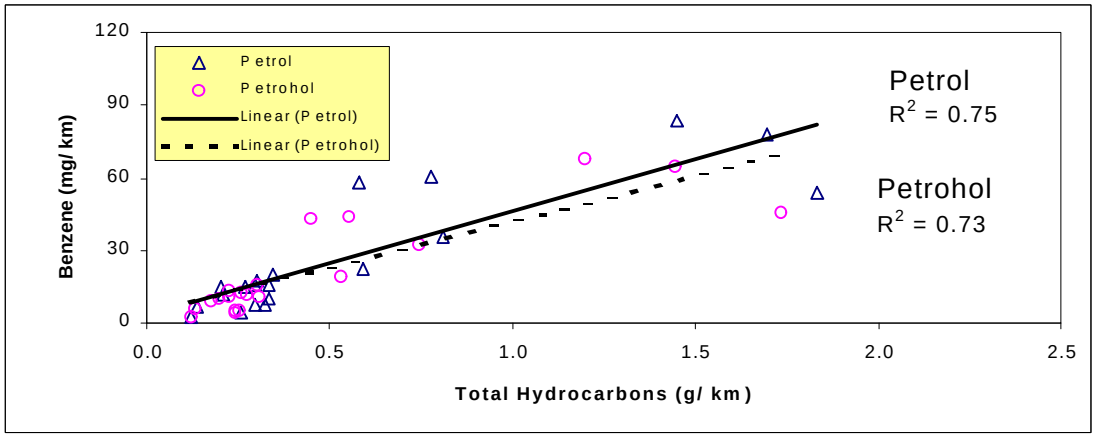

Figure 4.31: Relationship between Exhaust Benzene and THC Emissions

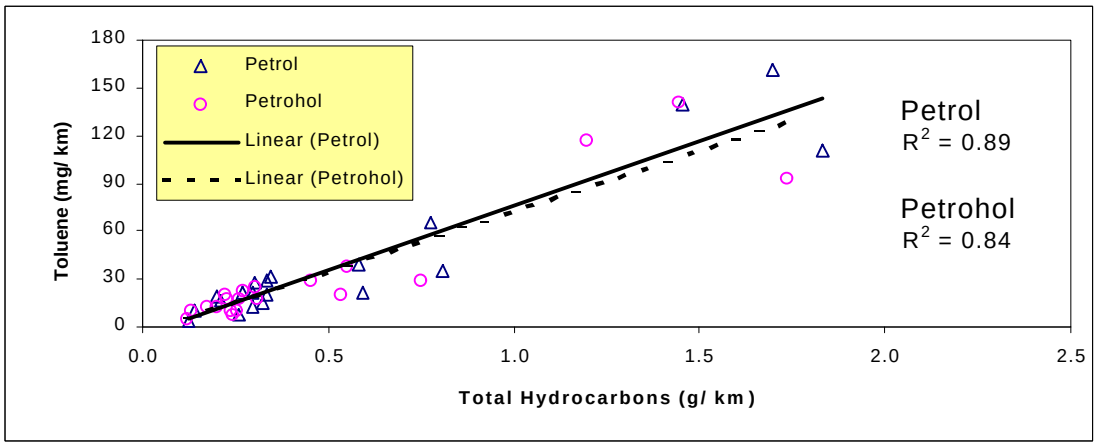

Figure 4.32: Relationship between Exhaust Toluene and THC Emissions

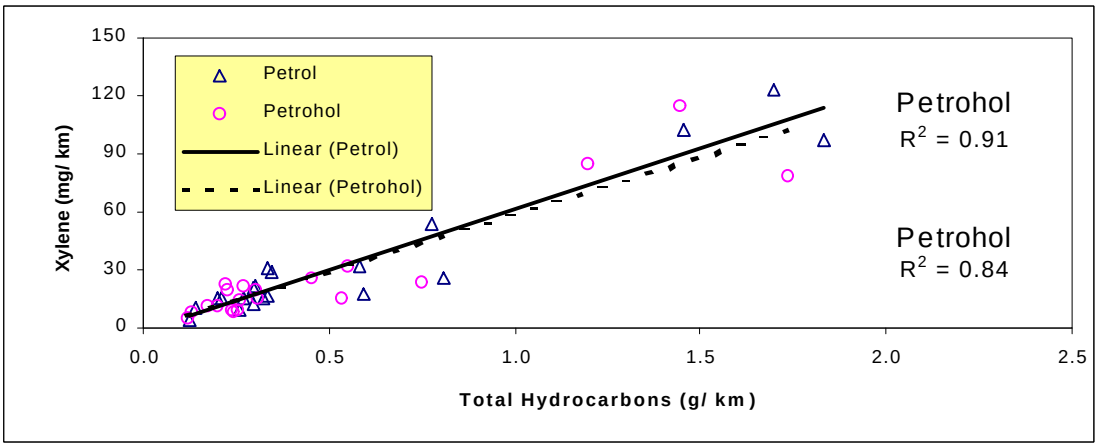

Figure 4.33: Relationship between Exhaust Xylene and THC Emissions

Key Findings:

- The correlations between exhaust toxics and total hydrocarbons are essentially the same for petrohol and petrol.
- Good correlations exist between exhaust benzene and THC, exhaust toluene and THC, and exhaust xylene and THC for both petrohol and petrol.
- Relatively poor correlations exist between exhaust 1,3-butadiene emissions and THC for both petrohol and petrol.

4.7.10 Discussion of Results

It can be seen from the preceding analyses that the trends in exhaust aldehydes and toxic emission results were consistent, albeit at various levels, across all vehicle categories. When operating on petrohol, compared to petrol, vehicles experienced increases in all three aldehydes (formaldehyde, acetaldehyde and acrolein) and decreases in the exhaust toxics (1,3-butadiene, benzene, toluene and xylene).

Impacts of Petrohol

In summary, the use of petrohol yielded the following impacts:

Exhaust Aldehydes

- Increase of 27% ± 12% in the mean formaldehyde emissions (27% ± 24% post-1986 & 27% ± 12% pre-1986),
- Increase of 215% ± 58% in the mean acetaldehyde emissions (213% ± 93% post-1986 & 217% ± 47% pre-1986),
- Increase of 12% ± 18%[#] in the mean acrolein emissions (8% ± 19%[#] post-1986 & 15% ± 30%[#] pre-1986).

Exhaust Toxics

- Reduction of 21% ± 36%[#] in the mean 1,3-butadiene emissions (9% ± 23%[#] post-1986 & 25% ± 210%[#] pre-1986),
- Reduction of 23% ± 12% in the mean benzene emissions (28% ± 15% post-1986 & 18% ± 85%[#] pre-1986),
- Reduction of 21% ± 13% in the mean toluene emissions (26% ± 15% post-1986 & 17% ± 34%[#] pre -1986),
- Reduction of 20% ± 12% in the mean xylene emissions (24% ± 12% post-1986 & 17% ± 45%[#] pre-1986).

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

The reductions in the individual exhaust toxics were comparable to the reduction of 15% in the mean regulated exhaust THC emissions for vehicles in the LTIS 2 category (being almost all of the vehicles for which toxics were analysed).

These results are consistent with other comparative studies that have been conducted on petrol/ ethanol fuels [6,7], as shown in Table 15.

Table 15: Impacts of Petrohol on Exhaust Aldehydes and Toxic Emissions – Other Studies

Emission	US Government Report [6]	SAE Paper [7]
Formaldehyde	⇑ 19.2 ± 31%	-
Acetaldehyde	⇑ 159 ± 44%	-
Total Aldehydes	-	⇑ 46%
1,3-Butadiene	⇓ 5.9 ± 5.6%	-
Benzene	⇓ 11± 6%	-

These and other studies [4,6,7,8] have shown that:

- **Aldehydes**: The use of petrohol in both pre-1986 and post-1986 vehicles is expected to cause a substantial increase in aldehyde emissions, as ethanol is a better precursor for aldehydes than non-oxygenated hydrocarbon fuels [4,7]. In addition, the absolute level of aldehyde emissions from post-1986 vehicles would be substantially less than from pre-1986 vehicles as the aldehydes are readily oxidised by the catalytic converter [8].

- **Exhaust toxics**: The use of petrohol in both pre-1986 and post-1986 vehicles is expected to substantially reduce exhaust toxics as a result of the lower levels of the toxic compounds in

the fuel [4,8]. In this study, 10% of every litre of the base petrol has been replaced by ethanol. The use of petrohol also reduces the exhaust total hydrocarbon emissions.

Effect of Maintenance

In summary, servicing the vehicles yielded the following impacts:

Exhaust Aldehydes

- Reduction in the mean formaldehyde emissions of 5% ± 26%[#] on petrol and an increase of 7% ± 38%[#] on petrohol,
- Reductions in the mean acetaldehyde emissions of 8% ± 24%[#] on petrol and 15 % ± 39%[#] on petrohol,
- Reductions in the mean acrolein emissions of 8% ± 38%[#] on petrol and 2% ± 35%[#] on petrohol.

Exhaust Toxics

- Increases in the mean 1,3-butadiene emissions of 5% ± 40%[#] on petrol and 6% ± 39%[#] on petrohol,
- Reductions in the mean benzene emissions of 5% ± 13%[#] on petrol and 13 % ± 15%[#] on petrohol,
- Reductions in the mean toluene emissions of 8% ± 24%[#] on petrol and 15 % ± 26%[#] on petrohol,
- Reductions in the mean xylene emissions of 12% ± 29%[#] on petrol and 14 % ± 27%[#] on petrohol.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

No literature was found to give comparative results from other studies. However, the benefits obtained appear consistent with the reductions in the regulated emissions. The reductions in the individual exhaust toxics following vehicle servicing were consistent with corresponding reductions of 16% and 17% in the mean regulated exhaust THC emissions on petrol and petrohol respectively.

Emissions Deterioration

An examination of the results found substantial apparent increases in acrolein and decreases in most of the other exhaust aldehydes and toxics, both on petrol and on petrohol, from vehicles in the LTIS category over the 12-month period. However, few of these results are statistically significant due to the small sample size (only 8 or 9 vehicles) and the large variations in the individual results.

Correlation with THC

A comparison between the individual exhaust toxic emissions and THC found that:

- Good correlations exist between exhaust benzene, toluene and xylene emissions and THC on both petrol and petrohol,
- Relatively poor correlations exist between exhaust 1,3-butadiene and THC on both petrol and petrohol.

It was expected that a good correlation would exist between each of the exhaust toxic emissions and total hydrocarbons. However, for 1,3-butadiene this correlation was less evident.

4.8 Evaporative Toxic Emissions

4.8.1 Summary of Results

Evaporative toxic emissions results were obtained from 24 test pairs (petrohol and petrol) on 13 test vehicles (see Table 8). Twenty of the test pairs were excluded from the analyses for the reasons given in the clarification below. Statistical analyses were not carried out as only four test pairs remained.

Individual test results are listed in Appendix 6.

Clarification:

1. The evaporative emissions results for all LTIS 1 category vehicles (11 vehicles), two BF vehicles (Ref No.s 4300 and 4377) and two BFS vehicles (Ref No.s 4380 and 4383) have been excluded from the analysis because they were deemed to be invalid when the test protocols were modified (refer to Section 3.1.1 for details).

2. The evaporative toxic emissions results from a Post-1986 Ford Laser (Vehicle Ref No. 4376) in the LTIS group were excluded as the total evaporative emissions result was not a typical result when compared to the rest of the vehicles tested and would unduly influence this smaller sub-set of vehicles.

3. The evaporative toxic emissions results from two LTIS vehicles (Ref No.s 4365 and 4370) were excluded as the data were incomplete.

4. The evaporative toxic emissions results from four LTIS vehicles (Ref No.s 4369, 4372, 4375 and 4379) were excluded because background HC levels were high when these vehicles were tested. Background HC concentrations in the SHED prior to the start of test were not collected for speciation analysis in this part of the study (see Section 3.2.3).

Figures 4.34 to 4.37 display the evaporative toxic emissions from the four vehicles with valid results. Those four vehicles belonged in the LTIS 2 category and were tested in the **pre-tune** condition only.

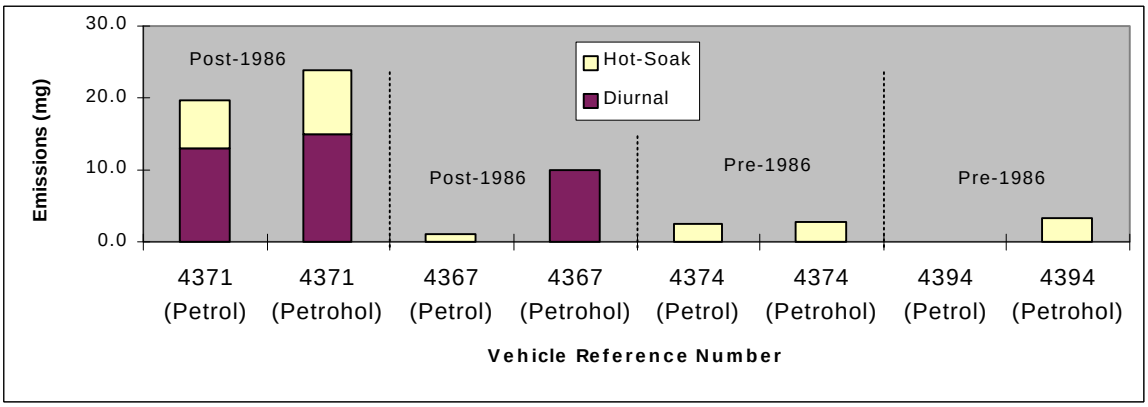

Figure 4.34: Evaporative 1,3-Butadiene Emissions

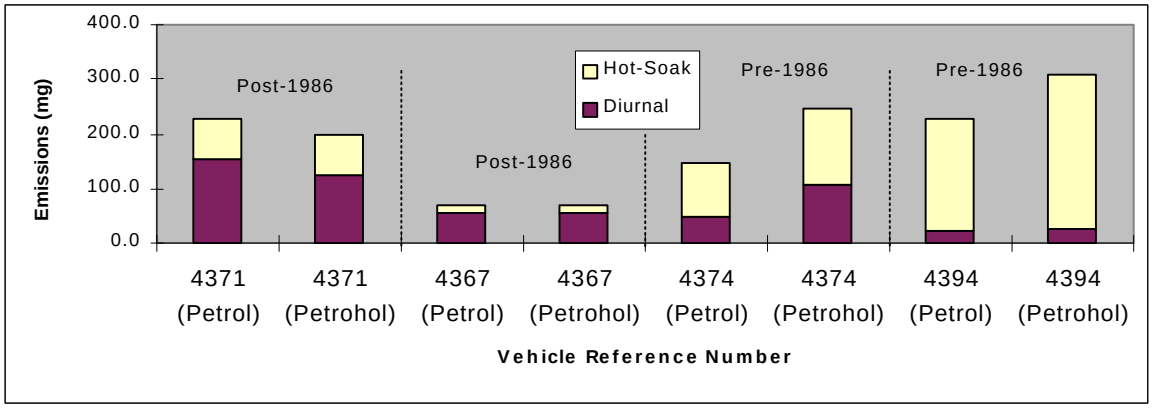

Figure 4.35: Evaporative Benzene Emissions

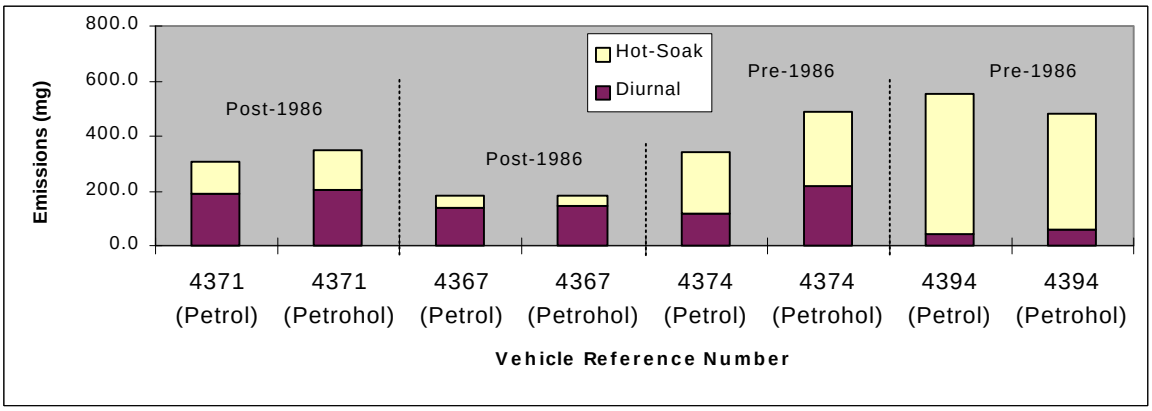

Figure 4.36: Evaporative Toluene Emissions

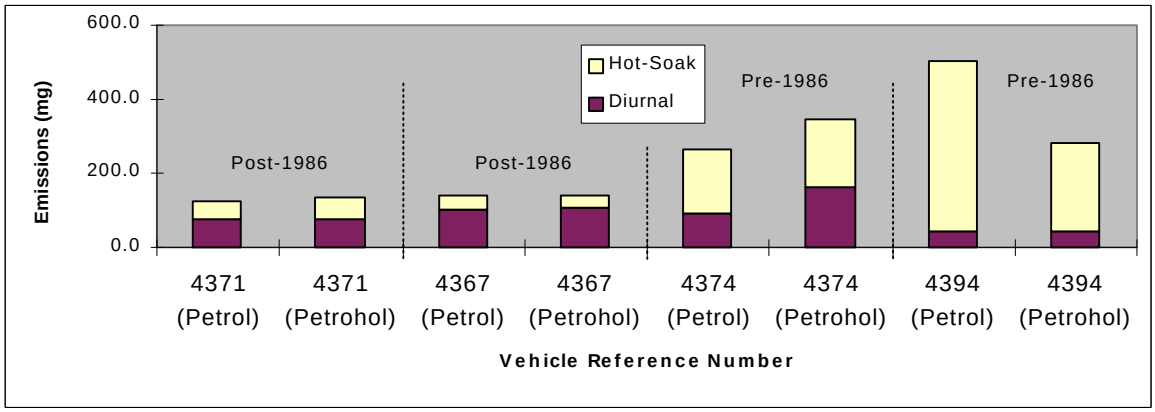

Figure 4.37: Evaporative Xylene Emissions

4.8.2 Discussion of Results

Owing to the very limited data set, no valid findings can be made. The use of petrohol resulted in the evaporative toxic emissions being higher for some vehicles and lower for others. No consistent trends are apparent.

4.9 Ozone Formation Potential

4.9.1 CSIRO Analysis

The ozone formation potential of each fuel was calculated by the CSIRO using the Maximum Incremental Reactivity (MIR) method for determining ozone impacts. The method is outlined in the CSIRO supplementary report at Appendix 7.

Two key elements are used in this method:

- Mass emission of each VOC species within a given sample,
- Reactivity of individual NMOC species (approximately 50 measured).

Samples were collected during both the exhaust and evaporative emissions tests.

A summary of the CSIRO results for both exhaust and evaporative emissions is provided under the respective headings within this section. However, for details of the MIR scale, test data, ozone formation calculations, and individual NMOC reactivities and their percentage contribution to the ozone formation, the reader is referred to the CSIRO report (Appendix 7).

The ozone formation potential of the NMOC compounds emitted from the combustion or evaporation of each fuel is calculated by multiplying the total mass emissions (mg NMOC) by the total reactivity (mg ozone per mg NMOC). In the case of exhaust emissions this value is then divided by the distance travelled by the vehicle during the test to give a result in milligrams per kilometre (mg/km). Details of the calculation are provided in the CSIRO report.

Ethanol was not measured as one of the species. As stated in the CSIRO report "ethanol was not measured during these tests and thus the results must be treated with some caution. To perform a more comprehensive reactivity calculation, it would be ideal to have a sampling and analysis program for ethanol. However, ethanol has a fairly low MIR value of 1.34 and constitutes only 10% of the total fuel. An estimate of the likely impact of ethanol on the reactivity calculation can be made by considering the total ozone reactivities of the exhaust and evaporative emissions. For exhaust these fall in the range 3.6-4.8 mg O3/ mg NMOC emitted, and for evaporative emissions in the range from 2.5-3.6 mg O3/ mg NMOC emitted. As the specific reactivity of ethanol is significantly less than this (at 1.34 mg O3/ mg ethanol emitted) even if ethanol emissions amounted to 10% of total emissions (possible in the evaporative SHED tests, but not in the exhaust gases since ethanol will be more easily combusted and destroyed on the catalyst than most hydrocarbon species in the fuel) the effect on the calculated reactivity would be small".

Mass Emissions

The mass emissions of each of the individual HC species were measured for each of the three phases of the exhaust emissions test (refer to the CSIRO report at Appendix 7 for a listing). The test cycle average result was calculated using the same bag “weightings” required by ADR37/00.

Mass emission results of the individual HC compounds from each SHED test phase (diurnal and hot-soak) and from the total SHED test are also provided.

Ozone Reactivity

For each NMOC species, the reactivity (mg ozone/ mg VOC) of the emissions is found by multiplying the MIR factor by the respective mass fraction (mg VOC/ mg total HC). For the entire sample, the reactivities of all species are summed to provide the total reactivity number for the sample. The MIR values are listed for each HC species in the CSIRO report. Ozone reactivity values are provided for each of the four combinations of vehicle vintage (post-1986 & pre-1986) and fuel (petrohol & petrol). Note that the unidentified compounds in the vehicle exhaust and evaporative emissions are referred to as the "residual hydrocarbons" and generally represent between 10 and 20% of the total mass of hydrocarbons emitted. For the residual hydrocarbons, the average MIR and average molecular weight of all NMOC species are used.

4.9.2 Summary of Results

Exhaust Ozone Formation Potential

The emissions of 46 non-methane organic compounds (NMOC) were analysed from the three phases of the ADR 37/00 tests for nine post-1986 and two pre-1986 vehicles making up the LTIS vehicle category.

Table 16 summarises the mean exhaust ozone formation potential for the seven major groups. Individual results are listed in Appendix 7.

Table 16: Exhaust Ozone Formation Potential Summary – Mean Values[1]

Results Group	Exhaust (3 Bag Results)			
	No. of Tests	NMOC (g/km)	Emission Reactivity	Ozone formation (g/km)
Petrol (All)	22	0.59	4.03	2.43
Petrohol (All)	22	0.46	4.02	1.93
Petrol (Post-1986)	18	0.34	3.96	1.34
Petrohol (Post-1986)	18	0.27	3.92	1.04
Petrol (Pre-1986)	4	1.69	4.36	7.34
Petrohol (Pre-1986)	4	1.35	4.45	5.98
Petrol (Pre-Tune)	11	0.49	4.20	2.14
Petrohol (Pre-Tune)	11	0.46	4.14	2.01
Petrol (Post-Tune)	11	0.51	4.15	2.21
Petrohol (Post-Tune)	11	0.39	4.13	1.71
Petrol (LTIS 1)	11	0.66	3.91	2.66
Petrohol (LTIS 1)	11	0.53	3.89	2.16
Petrol (LTIS 2)	11	0.51	4.15	2.21
Petrohol (LTIS 2)	11	0.39	4.13	1.71

Notes: [1] No statistical analyses were performed on these values.
The **All**, **Post-1986** and **Pre-1986** groups contain results from vehicles in the LTIS 1 and LTIS 2 categories in the **post-tune** condition only.
Pre-Tune contains results from vehicles in the LTIS 2 category in the **pre-tune** condition (pre-1986 and post-1986 combined).
Post-Tune contains results from vehicles in the LTIS 2 category in the **post-tune** condition (pre-1986 and post-1986 combined).
LTIS 1 contains results from vehicles in the LTIS 1 category in the **post-tune** condition (pre-1986 and post-1986 combined).
LTIS 2 contains results from vehicles in the LTIS 2 category in the **post-tune** condition (pre-1986 and post-1986 combined).

Figure 4.38 displays the mean exhaust ozone formation potential for each of the seven major groups.

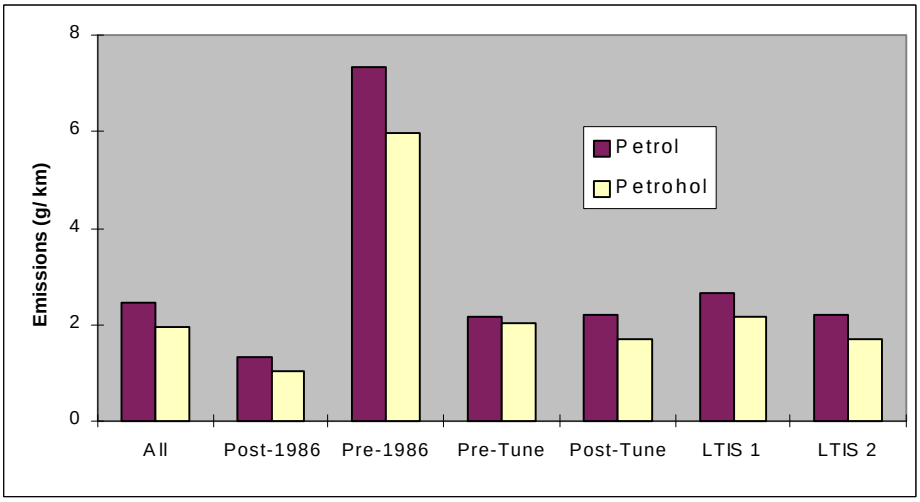

Figure 4.38: Mean Exhaust Ozone Formation Potential

Key Findings:

- A reduction of 20% in the mean exhaust ozone formation potential for the 11 vehicles tested (**LTIS** category), when operating on petrohol.
- Reductions in the mean exhaust ozone formation potential of 23% for **post-1986** vehicles and 19% for **pre-1986** vehicles, when operating on petrohol.
- An increase in the mean exhaust ozone formation potential of 3% on petrol and a reduction of 15% on petrohol, following vehicle **servicing**.
- Reductions in the mean exhaust ozone formation potential of 17% on petrol and 21% on petrohol, after operating on petrohol for a **12-month period**.

Evaporative Ozone Formation Potential

The same LTIS vehicles (9 post-1986 and 2 pre-1986) tested for exhaust ozone formation potential were tested for evaporative ozone formation potential. The 11 test pairs from the first series (LTIS 1) were deemed to be invalid when the testing protocols were modified (see Section 3.1.1 for details). Therefore, results from the second series (LTIS 2) are analysed here. Since it was expected that vehicle servicing would not substantially affect evaporative emissions, the 11 vehicles in the LTIS 2 category were sampled only in the **pre-tune** condition. Results from four of those vehicles were deemed to be invalid because of high background readings in the SHED (see Clarification below).

Individual results are listed in Appendix 7.

Table 17 summarises the mean evaporative ozone formation potential for three groups (no impacts of servicing or deterioration). In order to enhance the robustness of the data set, the reactivities derived from the seven vehicles with valid results were applied to the evaporative total hydrocarbon mass emissions from all vehicles tested (see Clarification below).

Table 17: Evaporative Ozone Formation Potential Summary – Mean Values[1]

	Evaporative									
		Diurnal			Hot-Soak			Total		
Results Group	No. of Tests	THC (g)	Emission Reactivity	Ozone (g)	THC (g)	Emission Reactivity	Ozone (g)	THC (g)	Emission Reactivity	Ozone (g)
Petrol (All)	56	8.19	2.80	22.98	5.08	3.17	16.10	13.27	2.95	39.08
Petrohol (All)	56	9.53	2.52	24.06	7.30	2.95	21.56	16.83	2.71	45.62
Petrol (Post-1986)	39	7.50	2.66	19.96	3.03	3.37	10.22	10.54	2.86	30.18
Petrohol (Post-1986)	39	8.78	2.56	22.48	4.06	3.10	12.59	12.84	2.73	35.07
Petrol (Pre-1986)	17	9.78	3.06	29.93	9.76	3.03	29.57	19.54	3.05	59.50
Petrohol (Pre-1986)	17	11.25	2.46	27.68	14.73	2.86	42.13	25.98	2.69	69.81

Clarification:

1. No statistical analyses were performed on the ozone formation potential.

2. The mean emission reactivity values listed in Table 17 were obtained from seven vehicles (five post-1986 and two pre-1986). These reactivities were multiplied by the relevant mean evaporative THC emissions from the entire test sample of 56 vehicles (39 post-1986 and 17 pre-1986 vehicles - refer to Table 12) to obtain mean ozone formation potential.

3. Results from four LTIS vehicles (Ref No.s 4369, 4372, 4375 and 4379) have been excluded from the analyses due to unknown background levels. Background samples in the SHED prior to the start of the test were not collected for speciation analysis in this part of the study (see Section 3.2.3). An examination of the test reports found that, in the SHED tests for the four vehicles above, the background THC levels were substantial. This does not affect the normal SHED test results as they are always corrected for background THC. However, since the background species are unknown, it was agreed to exclude the ozone formation potential calculations on those four vehicles.

Figure 4.39 displays the mean evaporative ozone formation potential for three major groups (no impacts of servicing or deterioration).

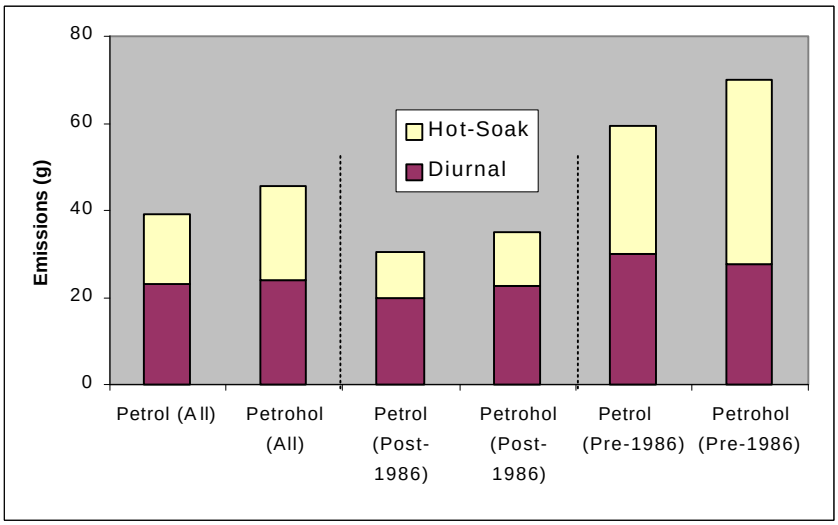

Figure 4.39: Mean Evaporative Ozone Formation Potential

Key Findings:

- An increase of 17% in the mean evaporative ozone formation potential from the vehicles tested, when operating on petrohol.
- Increases in the mean evaporative ozone formation potential of 16% for **post-1986** vehicles and 17% for **pre-1986** vehicles, when operating on petrohol.

4.9.3 Discussion of Results

Impacts of Petrohol

In summary, the use of petrohol in the vehicles tested yielded the following impacts:

- Reduction of 20% in the mean exhaust ozone formation potential (23% post-1986 & 19% pre-1986).

- Increase of 17% in the mean evaporative ozone formation potential (16% post-1986 & 17% pre-1986).

As the mean reactivities of the **exhaust** emissions from both fuels are similar (refer to Table 16), the reduction in mean exhaust ozone formation potential is due to the lower mass of NMOC produced when operating on petrohol.

As the mean **evaporative** reactivity for petrohol is less than the corresponding reactivity for petrol in all groups (refer to Table 17), the increases in mean evaporative ozone formation potential are not as high as the increases in the mass of evaporative NMOC on petrohol.

4.10 Fuel Consumption

4.10.1 Summary of Results

The mean city and highway fuel consumption results were presented in Table 10 of Section 4.5.1.

4.10.2 City Fuel Consumption

Figures 4.40 and 4.41 display graphically the mean city fuel consumption and the scatter in the results for each of the seven major groups.

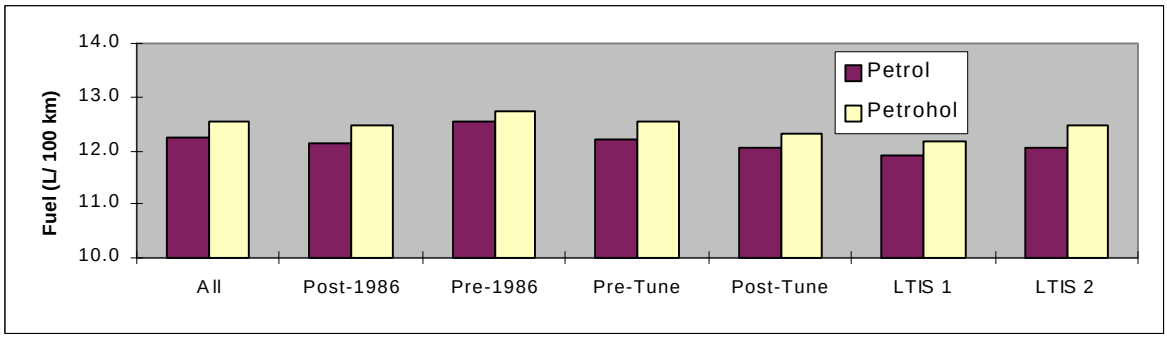

Figure 4.40: Mean City Fuel Consumption

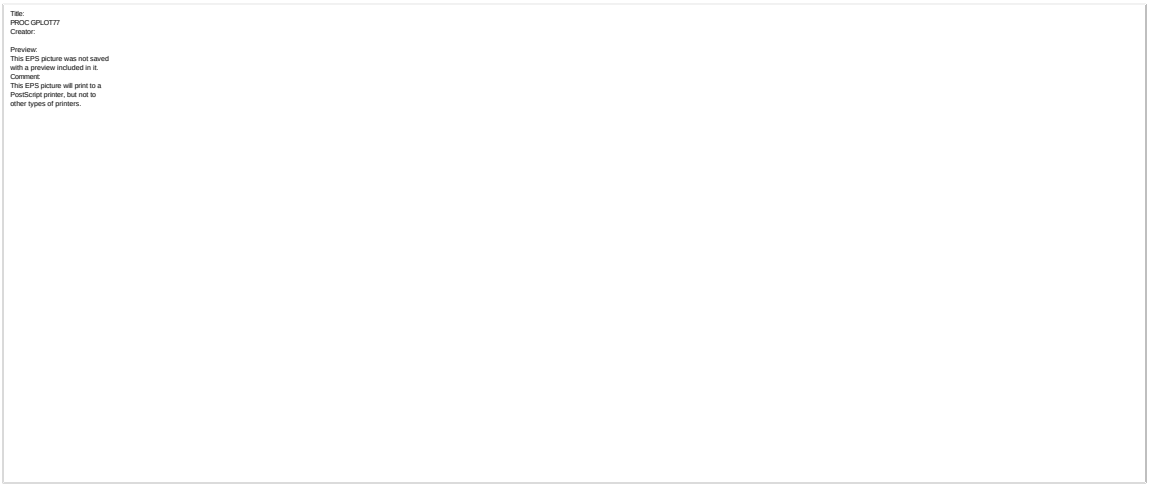

Figure 4.41: City Fuel Consumption Box & Whisker Plot

Key Findings:

- An increase of 2% ± 1% in the mean city fuel consumption for **post-tune** vehicles, when operating on petrohol.
- Increases in mean city fuel consumption of 3% ± 1% for **post-1986** vehicles and 1% ± 1% for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean city fuel consumption of 1% ± 2%[#] on petrol and 2% ± 3%[#] on petrohol, following vehicle **servicing**.
- Increases in the mean city fuel consumption of 1% ± 3%[#] on petrol and 2% ± 3%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

4.10.3 Highway Fuel Consumption

Figures 4.42 and 4.43 display graphically the mean highway fuel consumption and the scatter in the results for each of the seven major groups.

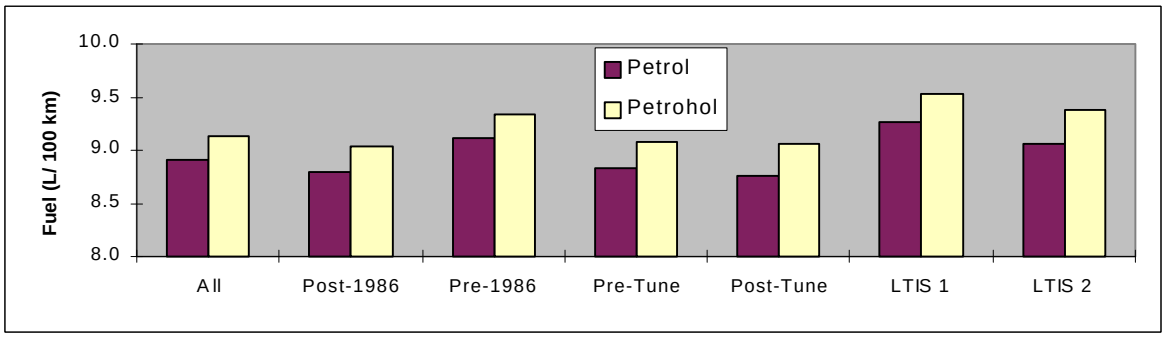

Figure 4.42: Mean Highway Fuel Consumption

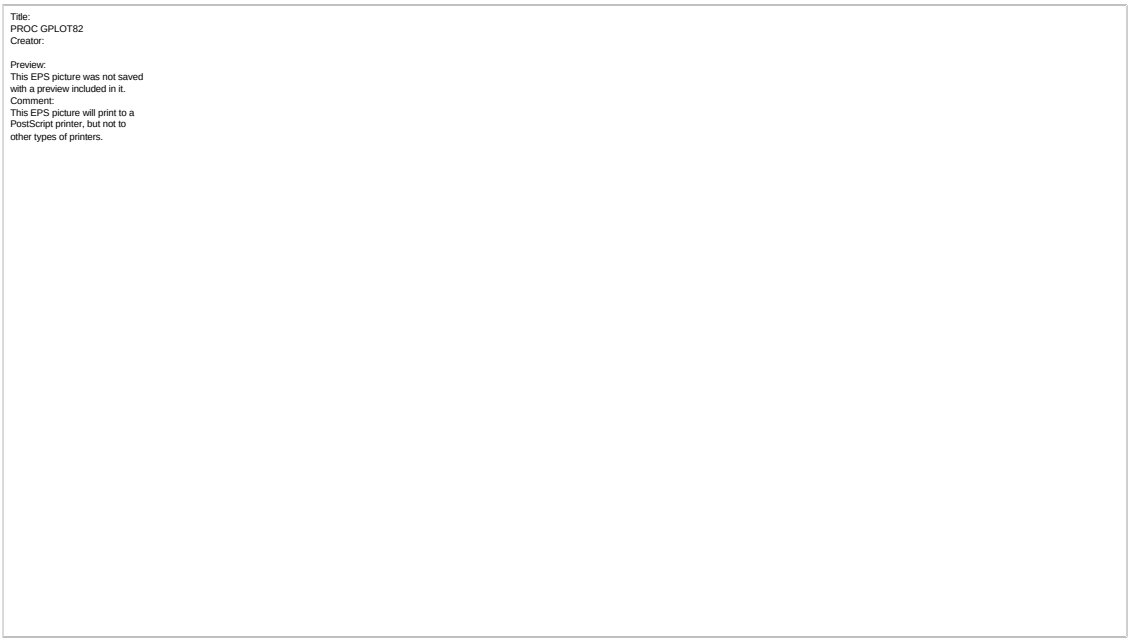

Figure 4.43: Highway Fuel Consumption Box & Whisker Plot

Key Findings:

- An increase of 3% ± 1% in the mean highway fuel consumption for **post-tune** vehicles, when operating on petrohol.
- Increases in the mean highway fuel consumption of 3% ± 1% for **post-1986** vehicles and 2% ± 1% for **pre-1986** vehicles, when operating on petrohol.
- Reductions in the mean highway fuel consumption of 1% ± 1%[#] on petrol and 0% ± 1%[#] on petrohol, following vehicle **servicing**.
- Reductions in the mean highway fuel consumption of 2% ± 5%[#] on petrol and 2% ± 5%[#] on petrohol, after operating on petrohol for a **12-month period**.

Note: [#] The reduction is not statistically significant at the 95% confidence level.

4.10.4 Discussion of Results

It can be seen from the preceding analyses that the trends in fuel consumption were consistent, albeit at various levels, across all vehicle categories. Vehicles operating on petrohol, compared to petrol, experienced increases in city and highway fuel consumption.

Impacts of Petrohol

In summary, the use of petrohol yielded the following impacts:

- Increase of 2% ± 1% in the mean city fuel consumption (3% ± 1% post-1986 and 1% ± 1% pre-1986),
- Increase of 3% ± 1% in the mean highway fuel consumption (3% ± 1% post-1986 and 2% ± 1% pre-1986).

The increases in fuel consumption are due primarily to petrohol having a lower energy content than neat petrol (about 3.5% lower). Therefore, more fuel is required by the engine to perform the same amount of work.

These results are consistent with overseas studies [5] which have shown increases of between 0.9% and 3.7% in fuel consumption when using a 10% ethanol/ petrol blend.

The Effect of Maintenance

In summary, servicing the vehicles yielded the following impacts:

- Reductions in the mean city fuel consumption of 1% ± 2%[#] on petrol and 2%± 3%[#] on petrohol,
- Reduction in the mean highway fuel consumption of 1% ± 1%[#] on petrol and 0% ± 1%[#] on petrohol.

Note: [#] The reduction is not statistically significant at the 95% confidence level.

These results are consistent with the findings of the NISE Study [3], where servicing of the group of vehicles tested yielded reductions in average city fuel consumption of 1% for post-1986 vehicles and 2% for pre-1986 vehicles.

Fuel Consumption Deterioration

The deterioration in the fuel consumption over a 12-month period may be summarised as follows:

- Increases in the mean city fuel consumption of 1% ± 3%[#] on petrol and 2% ± 3%[#] on petrohol,
- Reductions in the mean highway fuel consumption of 2%± 5%[#] on petrol and 2% ± 5%[#] on petrohol.

Note: [#] The increase/reduction is not statistically significant at the 95% confidence level.

Such small variations in fuel consumption may be caused as much by the variation in the state of tune of the vehicles as by deterioration through distance accumulation.

4.11 Engine Performance - Power Testing

4.11.1 Summary of Results

Figure 4.44 displays the maximum power output for each of the vehicles tested and Figure 4.45 displays the mean power at different speeds. Individual results are listed in Appendix 4.

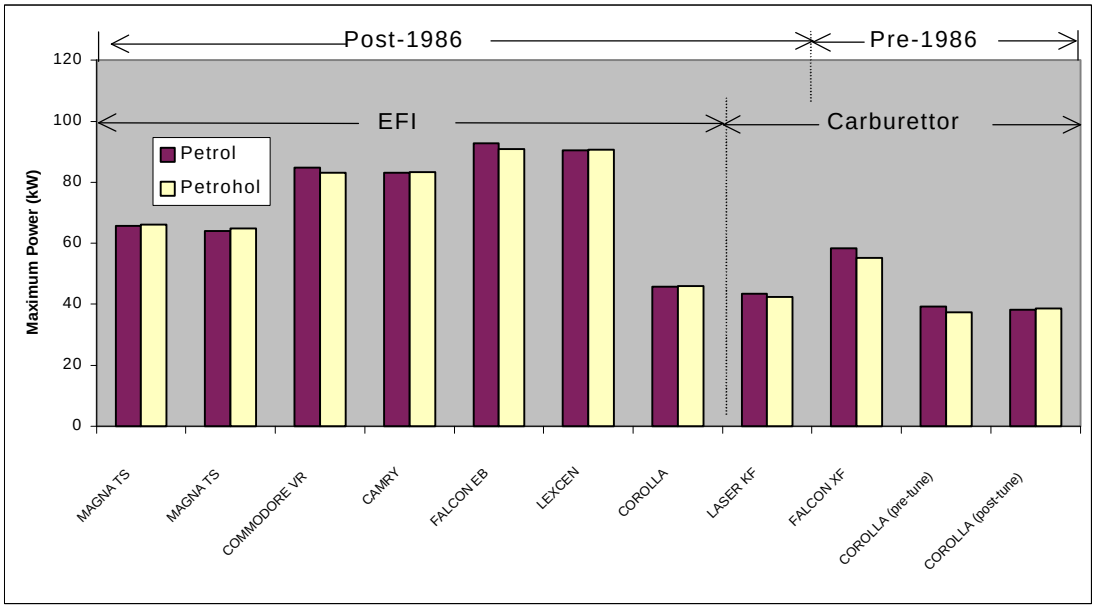

Figure 4.44: Maximum Power Output

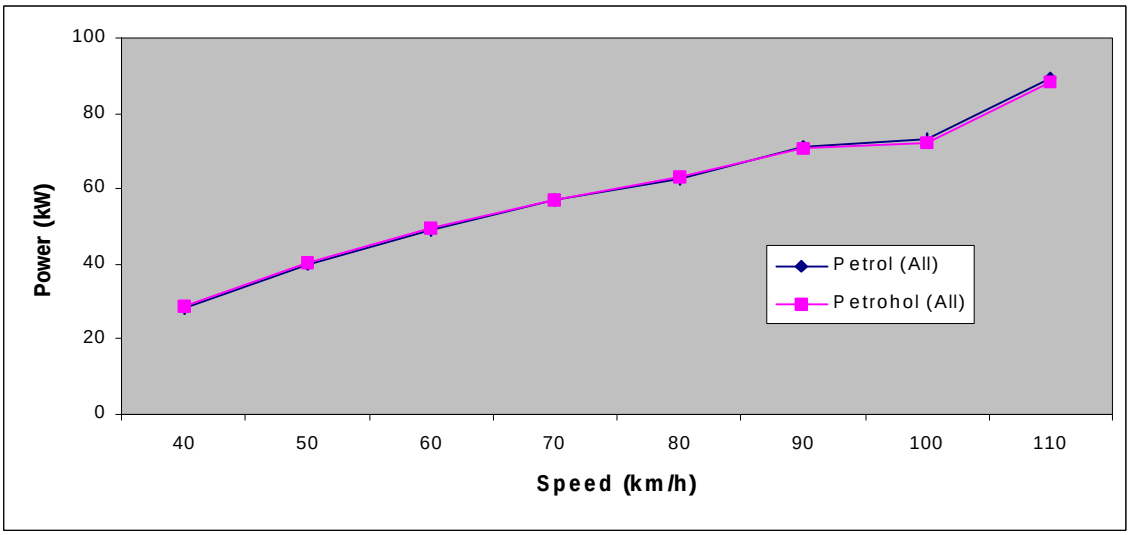

Figure 4.45: Mean Power of Vehicles Tested

Key Finding:

- There was negligible change in the power output of either the post-1986 or the pre-1986 vehicles, when operating on petrohol.

4.11.2 Discussion of Results

Power tests were conducted on 10 vehicles, of which:

- 8 were post-1986 vehicles (7 fuel injected),
- 2 were pre-1986 vehicles (both carburetted).

Tests were conducted at full throttle in either 2nd or 3rd gear, at 40 km/hr and in 10 km/hr increments to 110 km/hr. For safety reasons, not all tests were run to the highest speeds. Consequently, maximum engine power may not have been reached on some tests.

There was only a minimal change in the indicated performance of vehicles operating on petrohol. In most cases, the indicated change was within the test-to-test variation that might be expected. In no case was any change in performance noticeable to the driver of the vehicle. This finding appears logical as petrohol contains only 10% by volume ethanol and it would not be expected to cause a substantial variation in performance.

The small indicated changes, to the extent they may have been real, may have been due to one or more of the following factors:

- The lower energy content of petrohol, which may slightly reduce power at a given fuel flow,
- The leaning effect of petrohol, which would be expected to reduce power slightly, particularly on carburetted vehicles,
- The higher octane number of petrohol, which may reduce knock and misfire, and thus increase power on some vehicles.

5. SUMMARY

In this study, results were analysed in a way that allowed a series of key findings to be made in each of the three primary areas of interest (general emissions comparison, effect of maintenance and emissions deterioration).

5.1. General Emissions Comparison

Table 18 provides a summary of the impacts of petrohol on the parameters measured. Impacts in **bold** were derived from all vehicles tested in the post-tune condition. For each parameter, the impact is expressed as the percentage difference between the mean of all results on petrohol and the mean of all results on petrol (baseline is petrol). The 95% confidence limits are given.

Table 18: Impacts of Petrohol

PARAMETERS MEASURED	% DIFFERENCE: MEAN PETROHOL COMPARED TO PETROL (95% CONFIDENCE LIMITS)	NUMBERS OF VEHICLES INCLUDED (POST-TUNE)
Regulated Exhaust Emissions		
Hydrocarbons (HC)	⇓ **12** ± 4	59
Oxides of Nitrogen (NOx)	⇑ **3** ± 4[#]	59
Carbon Monoxide (CO)	⇓ **32** ± 9	59
Carbon Dioxide (CO_2) [1]	⇑ **1** ± 1	59
Regulated Evaporative Emissions		
Hydrocarbons (HC)	⇑ **27** ± 12	56
Exhaust Aldehyde Emissions		
Formaldehyde (CH_2O)	⇑ **27** ± 12	56
Acetaldehyde (C_2H_4O)	⇑ **215** ± 58	53
Acrolein (C_3H_4O)	⇑ **12** ± 18[#]	55
Exhaust Toxic Emissions		
1,3-Butadiene (C_4H_6)	⇓ **21** ± 36[#]	10
Benzene (C_6H_6)	⇓ **23** ± 12	11
Toluene (C_7H_8)	⇓ **21** ± 13	11
Xylene (C_8H_{10})	⇓ **20** ± 12	11
Ozone Formation Potential [2]		
Exhaust Ozone Potential	⇓ **20**	11
Evaporative Ozone Potential	⇑ **17**	11[3]
Fuel Consumption		
City Fuel Consumption	⇑ **2** ± 1	59
Highway Fuel Consumption	⇑ **3** ± 1	54
Power [2]	⇔ Negligible change	10

Notes: ⇑ ⇓ Arrows denote increase or decrease. Percentages have been rounded to the nearest whole number.

[#] The difference (increase or decrease) is not statistically significant at the 95% confidence level.

[1] CO_2 has been included with the regulated exhaust emissions for convenience.

[2] No statistical analyses were carried out on the Ozone Formation Potential or Power results.

[3] Vehicles are in pre-tune condition.

Trends in exhaust and evaporative emissions results were consistent, albeit at differing magnitudes, across all vehicle categories. When operating on petrohol compared to petrol, exhaust hydrocarbons, carbon monoxide and exhaust toxics (except 1,3-butadiene) emissions decreased, while evaporative hydrocarbons and exhaust aldehydes (except acrolein) emissions increased. There were only very small increases in carbon dioxide emissions and fuel consumption. Exhaust ozone formation potential appeared to decrease, while evaporative ozone formation potential appeared to increase, but these trends were not verified statistically. Oxides of nitrogen, acrolein and 1,3-butadiene emissions and engine power did not change.

5.2 Effect of Maintenance

Table 19 provides a summary of the effects of maintenance/ vehicle servicing on emissions. The effects of servicing are listed for both petrol and petrohol operation. Effects in **bold** were derived from all vehicles tested in the BFS and LTIS vehicle categories. For each parameter, the impact is expressed as the percentage difference between the mean of all results in post-tune condition and the mean of all results in pre-tune condition (baseline is pre-tune).

Table 19: Effects of Vehicle Servicing

PARAMETERS MEASURED	PETROL	PETROHOL	NUMBERS OF VEHICLES INCLUDED
	% DIFFERENCE: MEAN POST-TUNE COMPARED TO MEAN PRE-TUNE (95% CONFIDENCE LIMITS)		
Regulated Exhaust Emissions			
Hydrocarbons (HC)	⇓ **16** ± 22#	⇓ **17** ± 17#	22
Oxides of Nitrogen (NOx)	⇓ **2** ± 10#	⇓ **3** ± 10#	22
Carbon Monoxide (CO)	⇓ **32** ± 35#	⇓ **44** ± 48#	22
Carbon Dioxide (CO_2) [1]	⇑ **2** ± 3#	⇑ **2** ± 2#	22
Regulated Evaporative Emissions			
Hydrocarbons (HC)	⇓ **5** ± 17#	⇓ **6** ± 14#	21
Exhaust Aldehyde Emissions			
Formaldehyde (CH_2O)	⇓ **5** ± 26#	⇑ **7** ± 38#	21
Acetaldehyde (C_2H_4O)	⇓ **8** ± 24#	⇓ **15** ± 39#	19
Acrolein (C_3H_4O)	⇓ **8** ± 38#	⇓ **2** ± 35#	20
Exhaust Toxic Emissions			
1,3-Butadiene (C_4H_6)	⇑ **5** ± 40#	⇑ **6** ± 39#	8
Benzene (C_6H_6)	⇓ **5** ± 13#	⇓ **13** ± 15#	9
Toluene (C_7H_8)	⇓ **8** ± 24#	⇓ **15** ± 26#	9
Xylene (C_8H_{10})	⇓ **12** ± 29#	⇓ **14** ± 27#	9
Fuel Consumption			
City Fuel Consumption	⇓ **1** ± 2#	⇓ **2** ± 3#	22
Highway Fuel Consumption	⇓ **1** ± 1#	⇓ **0** ± 1#	20

Notes: ⇑ ⇓ Arrows denote increase or decrease. Percentages have been rounded to the nearest whole number.
The difference (increase or decrease) is not statistically significant at the 95% confidence level
[1] CO_2 has been included with the regulated exhaust emissions for convenience.

Servicing tended to reduce the mean emissions for most of the parameters measured and to increase those of a few, but none of these changes were significant at the 95% confidence level.

5.3 Emissions Deterioration

Table 20 provides a summary of the deterioration in emissions. Effects in **bold** were derived from all vehicles tested in the LTIS vehicle category, tested 12 months apart. For each parameter, the impact is expressed as the percentage difference between the mean of all results in the LTIS 2 category and the mean of all results in the LTIS 1 category (baseline is LTIS 1).

Table 20: Emissions Deterioration

PARAMETERS MEASURED	PETROL	PETROHOL	NUMBERS OF VEHICLES INCLUDED
	% DIFFERENCE: MEAN LTIS 2 COMPARED TO MEAN LTIS 1 (95% CONFIDENCE LIMITS)		
Regulated Exhaust Emissions			
Hydrocarbons (HC)	⇑ **0** ± 15#	⇑ **4** ± 14#	10
Oxides of Nitrogen (NOx)	⇑ **10** ± 26#	⇑ **14** ± 24#	10
Carbon Monoxide (CO)	⇑ **20** ± 18	⇑ **27** ± 28#	10
Carbon Dioxide (CO_2) [1]	⇑ **1** ± 3#	⇑ **2** ± 3#	10
Fuel Consumption			
City Fuel Consumption	⇑ **1** ± 3#	⇑ **2** ± 3#	10
Highway Fuel Consumption	⇓ **2** ± 5#	⇓ **2** ± 5#	8

Notes: ⇑ ⇓ Arrows denote increase or decrease. Percentages have been rounded to the nearest whole number.
The difference (increase or decrease) is not statistically significant at the 95% confidence level.
[1] CO_2 has been included with the regulated exhaust emissions for convenience.

Mean emissions for the regulated pollutants tended to increase over the twelve-month period, but the changes were not significant at the 95% confidence level.

6. REFERENCES

1. Australian Design Rule 37/00 - Emission Control for Light Vehicles, Motor Vehicle Standards Act, 1989.

2. Australian Standard AS 2877 - Methods of Test for Fuel Consumption of Motor Vehicles Designed to Comply with Australian Design Rules 37 and 40, Standards Association of Australia, 1986.

3. Motor Vehicle Pollution in Australia - A Report on the National In-Service Vehicle Emissions Study, FORS, Australian Government Publishing Service, 1996.

4. Automotive Fuels Reference Book - Second Edition, Keith Owen and Trevor Coley, SAE 1995.

5. Evaporative and Exhaust Emissions from Cars fuelled with Gasoline Containing Ethanol or Methyl tert-Butyl Ether, Robert L. Furey and Jack B. King, SAE, 1980.

6. Interagency Assessment of Oxygenated Fuels, National Science and Technology Council, 1997.

7. Fuel Alternatives for the 80's - SP~527, L.S Bernstein, N.D Brinkman and R.R Carlson, SAE, 1982.

8. Emissions from Ethanol and LPG Vehicles, Mark E. Pitstick, 1993.

7. APPENDICES

7.1 Overview of the Appendices

Individual test results are presented sequentially by test number in the appendices. Shading has been used to facilitate the comparisons of the back-to-back tests on each vehicle (i.e. petrol and petrohol).

NSW EPA data on individual vehicles are provided in Appendices 1 through 4 as follows:

- **Appendix 1**: Test Vehicle General Information – includes all vehicles tested
- **Appendix 2**: Regulated Exhaust and Evaporative Emissions Test Results – includes all vehicles tested - results have been calculated in accordance with ADR 37/00 (i.e. 3-bag result)
- **Appendix 3**: Regulated Exhaust Emissions Results for Pre-1986 vehicles only - calculated on the basis of the first two phases of the ADR 37/00 exhaust emissions test (i.e. 2-bag result)
- **Appendix 4**: Power Test Results

CSIRO results are provided in Appendices 5 through 7 as follows:

- **Appendix 5**: CSIRO Exhaust Aldehydes and Toxic Emissions Results
- **Appendix 6**: CSIRO Evaporative Toxic Emissions Results from LTIS 2 vehicles (pre-tune condition only)
- **Appendix 7**: CSIRO Ozone Formation Potential Report and Results, including the methods of analysis and calculation - masses of the speciated hydrocarbons and their reactivities

7.2 Legend for Tables in Appendices

The following legend applies to the tables of results in the appendices:

BF	Base Fleet vehicle
BFS	Base Fleet Sub-set vehicle
LTIS 1	Long Term In-Service vehicle – first series of testing
LTIS 2	Long Term In-Service vehicle – second series of testing following 12-months operation on petrohol
B	denotes results have not been corrected for ***Background*** levels, which has resulted in their removal
TP	denotes results not provided due to change in ***Test Procedure*** (pre-conditioning sequence and thermocouple positioning)
NR	denotes ***No Result*** due to tests having been carried out on LTIS vehicles only
I	denotes ***Invalid*** result due to a problem in undertaking the test or in collecting the sample
P	denotes a ***Power*** result could not be obtained due to the vehicle not reaching the target speed or the automatic transmission shifting down to "low" at the lower speeds.
MPI	multi-point injection (fuel injection system)
TBI	throttle body injection (fuel injection system)
Transmission	number of gears (3/4/5), manual or automatic (M/A), overdrive (O)
MIR	maximum incremental reactivity
RAF	reactivity adjustment factor
CT	cold-start transient phase of the ADR 37/00 exhaust emissions test
S	stabilised phase of the ADR 37/00 exhaust emissions test
HT	hot-start transient phase of the ADR 37/00 exhaust emissions test
Avg	denotes an average ADR 37/00 cycle result

APPENDIX 1

TEST VEHICLE GENERAL INFORMATION ALL VEHICLES TESTED (IN TEST NUMBER SEQUENCE)

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
21543	TOYOTA	LEXCEN	11/07/95	4300	7372	ULP	MPI	3.8	4A	1564	BF	Post
21544	TOYOTA	LEXCEN	11/07/95	4300	7469	Petrohol	MPI	3.8	4A	1564	BF	Post
21545	MITSUBISHI	MAGNA TS	1/06/95	4370	8786	ULP	MPI	2.6	3AO	1636	LTIS 1	Post
21546	MITSUBISHI	MAGNA TS	1/06/95	4370	8885	Petrohol	MPI	2.6	3AO	1636	LTIS 1	Post
21550	MITSUBISHI	MAGNA TS	1/05/95	4365	5115	ULP	MPI	2.6	3AO	1546	LTIS 1	Post
21551	MITSUBISHI	MAGNA TS	1/05/95	4365	5224	Petrohol	MPI	2.6	3AO	1546	LTIS 1	Post
21552	HOLDEN	COMMODORE VR	1/02/94	4367	26560	ULP	MPI	3.8	4A	1576	LTIS 1	Post
21553	HOLDEN	COMMODORE VR	1/02/94	4367	26675	Petrohol	MPI	3.8	4A	1576	LTIS 1	Post
21562	FORD	FALCON EB	1/11/92	4371	186691	Petrohol	MPI	4.0	4A	1772	LTIS 1	Post
21564	TOYOTA	CAMRY	1/07/93	4372	57565	ULP	MPI	3.0	3AO	1579	LTIS 1	Post
21565	TOYOTA	CAMRY	1/07/93	4372	57662	Petrohol	MPI	3.0	3AO	1579	LTIS 1	Post
21571	FORD	FALCON EB	1/11/92	4371	186595	ULP	MPI	4.0	4A	1772	LTIS 1	Post
21574	FORD	FALCON XF	1/12/85	4374	91016	Leaded	Carburettor	4.1	4M	1521	LTIS 1	Post
21575	FORD	FALCON XF	1/12/85	4374	91116	Petrohol	Carburettor	4.1	4M	1521	LTIS 1	Post
21577	FORD	FALCON EB	1/10/92	4375	150072	ULP	MPI	4.0	4A	1788	LTIS 1	Post
21578	FORD	FALCON EB	1/10/92	4375	150168	Petrohol	MPI	4.0	4A	1788	LTIS 1	Post
21582	FORD	LASER KF	1/01/94	4376	37685	ULP	Carburettor	1.6	5M	1186	LTIS 1	Post
21583	FORD	LASER KF	1/01/94	4376	37781	Petrohol	Carburettor	1.6	5M	1186	LTIS 1	Post
21585	HOLDEN	COMMODORE	1/01/79	4377	168379	Leaded	Carburettor	3.3	3A	1284	BF	Post
21586	HOLDEN	COMMODORE	1/01/79	4377	168477	Petrohol	Carburettor	3.3	3A	1284	BF	Post
21589	TOYOTA	LEXCEN	11/07/95	4369	8960	ULP	MPI	3.8	4A	1564	LTIS 1	Post
21590	TOYOTA	LEXCEN	11/07/95	4369	9573	Petrohol	MPI	3.8	4A	1564	LTIS 1	Post
21591	TOYOTA	COROLLA	1/01/92	4379	57203	ULP	MPI	1.6	3AO	1238	LTIS 1	Post
21592	TOYOTA	COROLLA	1/01/92	4379	57301	Petrohol	MPI	1.6	3AO	1238	LTIS 1	Post
21595	HOLDEN	COMMODORE VL	1/01/87	4380	133733	ULP	MPI	3.0	5M	1583	BFS	Pre
21596	HOLDEN	COMMODORE VL	1/01/87	4380	133828	Petrohol	MPI	3.0	5M	1583	BFS	Pre

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
21603	HOLDEN	COMMODORE VL	1/01/87	4380	134013	ULP	MPI	3.0	5M	1583	BFS	Post
21604	HOLDEN	COMMODORE VL	1/01/87	4380	134108	Petrohol	MPI	3.0	5M	1583	BFS	Post
21608	TOYOTA	COROLLA	1/03/85	4383	143969	Petrohol	Carburettor	1.6	5M	1152	BFS	Pre
21609	TOYOTA	COROLLA	1/03/85	4383	144064	Leaded	Carburettor	1.6	5M	1152	BFS	Pre
21612	TOYOTA	COROLLA	1/03/85	4383	144155	Leaded	Carburettor	1.6	5M	1152	BFS	Post
21613	TOYOTA	COROLLA	1/03/85	4383	144253	Petrohol	Carburettor	1.6	5M	1152	BFS	Post
21636	HOLDEN	COMMODORE VH	1/09/81	4394	121985	Leaded	Carburettor	3.3	3A	1451	LTIS 1	Post
21637	HOLDEN	COMMODORE VH	1/09/81	4394	122084	Petrohol	Carburettor	3.3	3A	1451	LTIS 1	Post
21670	TOYOTA	CAMRY	1/02/92	4402	55244	Petrohol	MPI	2.0	3AO	1407	BF	Post
21671	TOYOTA	CAMRY	1/02/92	4402	55327	ULP	MPI	2.0	3AO	1407	BF	Post
21698	TOYOTA	CAMRY	1/02/90	4412	114055	Petrohol	MPI	2.0	5M	1417	BF	Post
21709	TOYOTA	CORONA	1/04/80	4415	258177	Petrohol	Carburettor	1.9	3A	1289	BF	Post
21710	TOYOTA	CORONA	1/04/80	4415	258320	Leaded	Carburettor	1.9	3A	1289	BF	Post
21711	TOYOTA	CAMRY	1/02/90	4412	114240	ULP	MPI	2.0	5M	1417	BF	Post
21715	FORD	FALCON EA	1/12/90	4416	87897	ULP	TBI	3.9	4A	1700	BF	Post
21716	FORD	FALCON EA	1/12/90	4416	87995	Petrohol	TBI	3.9	4A	1700	BF	Post
21717	HOLDEN	COMMODORE VN	1/03/90	4418	132787	ULP	MPI	3.8	3AO	1578	BF	Post
21718	HOLDEN	COMMODORE VN	1/03/90	4418	132886	Petrohol	MPI	3.8	3AO	1578	BF	Post
21726	FORD	FALCON ED	1/01/93	4421	48959	Petrohol	MPI	5.0	5M	1699	BF	Post
21732	FORD	FALCON ED	1/01/93	4421	49057	ULP	MPI	5.0	5M	1699	BF	Post
21761	HOLDEN	COMMODORE VL	1/12/87	4423	150739	Petrohol	MPI	3.0	5M	1439	BF	Post
21762	HOLDEN	COMMODORE VL	1/12/87	4423	150884	ULP	MPI	3.0	5M	1439	BF	Post
21763	FORD	FALCON EA	1/12/88	4424	244465	Petrohol	TBI	3.9	4A	1632	BF	Post
21764	FORD	FALCON EA	1/12/88	4424	244562	ULP	TBI	3.9	4A	1632	BF	Post
21768	FORD	FALCON EB	1/11/92	4371	242360	Petrohol	MPI	4.0	4A	1772	LTIS 2	Pre
21769	FORD	FALCON EB	1/11/92	4371	242459	ULP	MPI	4.0	4A	1772	LTIS 2	Pre

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
21770	FORD	FALCON EB	1/11/92	4371	242556	Petrohol	MPI	4.0	4A	1772	LTIS 2	Post
21771	FORD	FALCON EB	1/11/92	4371	242653	ULP	MPI	4.0	4A	1772	LTIS 2	Post
21776	MITSUBISHI	MAGNA TR	1/09/92	4426	83098	Petrohol	MPI	2.6	4A	1564	BF	Post
21777	MITSUBISHI	MAGNA TR	1/09/92	4426	83001	ULP	MPI	2.6	4A	1564	BF	Post
21778	HOLDEN	COMMODORE VR	1/02/94	4367	54158	Petrohol	MPI	3.8	4A	1576	LTIS 2	Pre
21779	HOLDEN	COMMODORE VR	1/02/94	4367	54253	ULP	MPI	3.8	4A	1576	LTIS 2	Pre
21780	HOLDEN	COMMODORE VR	1/02/94	4367	54351	Petrohol	MPI	3.8	4A	1576	LTIS 2	Post
21781	HOLDEN	COMMODORE VR	1/02/94	4367	54448	ULP	MPI	3.8	4A	1576	LTIS 2	Post
21782	HOLDEN	CAMIRA JD	1/09/85	4422	229858	Petrohol	MPI	1.8	5M	1191	BF	Post
21783	HOLDEN	CAMIRA JD	1/09/85	4422	229957	Leaded	MPI	1.8	5M	1191	BF	Post
21786	FORD	FALCON EA	1/03/90	4430	97857	Petrohol	MPI	3.9	4A	1650	BFS	Pre
21787	FORD	FALCON EA	1/03/90	4430	97954	ULP	MPI	3.9	4A	1650	BFS	Pre
21788	FORD	FALCON EA	1/03/90	4430	98052	Petrohol	MPI	3.9	4A	1650	BFS	Post
21789	FORD	FALCON EA	1/03/90	4430	98140	ULP	MPI	3.9	4A	1650	BFS	Post
21792	FORD	FALCON XE	1/09/84	4431	274884	Petrohol	Carburettor	4.1	3A	1517	BF	Post
21793	FORD	FALCON XE	1/09/84	4431	274978	Leaded	Carburettor	4.1	3A	1517	BF	Post
21797	HOLDEN	APOLLO JK	1/11/95	4432	16737	Petrohol	MPI	2.2	4A	1356	BF	Post
21798	HOLDEN	APOLLO JK	1/11/95	4432	16827	ULP	MPI	2.2	4A	1356	BF	Post
21804	MITSUBISHI	MAGNA TS	1/06/95	4370	41896	Petrohol	MPI	2.6	3AO	1636	LTIS 2	Pre
21805	MITSUBISHI	MAGNA TS	1/06/95	4370	41995	ULP	MPI	2.6	3AO	1636	LTIS 2	Pre
21806	MITSUBISHI	MAGNA TS	1/06/95	4370	42092	Petrohol	MPI	2.6	3AO	1636	LTIS 2	Post
21807	MITSUBISHI	MAGNA TS	1/06/95	4370	42192	ULP	MPI	2.6	3AO	1636	LTIS 2	Post
21810	FORD	LASER KA	1/03/83	4436	248115	Petrohol	Carburettor	1.3	4M	1032	BF	Post
21811	FORD	LASER KA	1/03/83	4436	248196	Leaded	Carburettor	1.3	4M	1032	BF	Post
21823	TOYOTA	COROLLA	1/01/92	4379	69419	Petrohol	MPI	1.6	3AO	1238	LTIS 2	Pre
21824	TOYOTA	COROLLA	1/01/92	4379	69517	ULP	MPI	1.6	3AO	1238	LTIS 2	Pre

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
21825	TOYOTA	COROLLA	1/01/92	4379	69615	Petrohol	MPI	1.6	3AO	1238	LTIS 2	Post
21826	TOYOTA	COROLLA	1/01/92	4379	69741	ULP	MPI	1.6	3AO	1238	LTIS 2	Post
21827	TOYOTA	CAMRY	1/07/87	4438	109404	Petrohol	MPI	2.0	4A	1439	BF	Post
21828	TOYOTA	CAMRY	1/07/87	4438	109501	ULP	MPI	2.0	4A	1439	BF	Post
21831	TOYOTA	CAMRY	1/07/93	4372	86986	Petrohol	MPI	3.0	3AO	1579	LTIS 2	Pre
21832	TOYOTA	CAMRY	1/07/93	4372	87065	ULP	MPI	3.0	3AO	1579	LTIS 2	Pre
21833	TOYOTA	CAMRY	1/07/93	4372	87162	Petrohol	MPI	3.0	3AO	1579	LTIS 2	Post
21834	TOYOTA	CAMRY	1/07/93	4372	87260	ULP	MPI	3.0	3AO	1579	LTIS 2	Post
21839	NISSAN	SKYLINE	1/08/86	4441	301237	Petrohol	MPI	3.0	5M	1531	BF	Post
21840	NISSAN	SKYLINE	1/08/86	4441	301334	ULP	MPI	3.0	5M	1531	BF	Post
21842	MITSUBISHI	MAGNA TN	1/04/88	4442	258599	ULP	MPI	2.6	4A	1563	BFS	Pre
21843	MITSUBISHI	MAGNA TN	1/04/88	4442	258694	ULP	MPI	2.6	4A	1563	BFS	Post
21844	MITSUBISHI	MAGNA TN	1/04/88	4442	258834	Petrohol	MPI	2.6	4A	1563	BFS	Post
21845	MITSUBISHI	SIGMA GH	1/06/81	4443	17227	Petrohol	Carburettor	2.0	4A	1328	BF	Post
21846	MITSUBISHI	SIGMA GH	1/06/81	4443	172477	Leaded	Carburettor	2.0	4A	1328	BF	Post
21847	MITSUBISHI	MAGNA TN	1/04/88	4442	258504	Petrohol	MPI	2.6	4A	1563	BFS	Pre
21851	FORD	FALCON EB	1/10/92	4375	205142	Petrohol	MPI	4.0	4A	1788	LTIS 2	Pre
21852	FORD	FALCON EB	1/10/92	4375	205241	ULP	MPI	4.0	4A	1788	LTIS 2	Pre
21853	FORD	FALCON EB	1/10/92	4375	205340	Petrohol	MPI	4.0	4A	1788	LTIS 2	Post
21854	FORD	FALCON EB	1/10/92	4375	205437	ULP	MPI	4.0	4A	1788	LTIS 2	Post
21855	HOLDEN	CAMIRA JE	1/11/87	4444	271886	Petrohol	MPI	2.0	5M	1262	BF	Post
21856	HOLDEN	CAMIRA JE	1/11/87	4444	271982	ULP	MPI	2.0	5M	1262	BF	Post
21862	HOLDEN	COMMODORE VP	1/05/92	4447	107590	Petrohol	MPI	3.8	4A	1594	BF	Post
21863	HOLDEN	COMMODORE VP	1/05/92	4447	107775	ULP	MPI	3.8	4A	1594	BF	Post
21864	TOYOTA	CAMRY	1/11/87	4448	220860	Petrohol	MPI	2.0	5M	1375	BF	Post
21865	TOYOTA	CAMRY	1/11/87	4448	220959	ULP	MPI	2.0	5M	1375	BF	Post

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
21866	FORD	FALCON XF	1/12/85	4374	101755	Petrohol	Carburettor	4.1	4M	1521	LTIS 2	Pre
21867	FORD	FALCON XF	1/12/85	4374	101857	Leaded	Carburettor	4.1	4M	1521	LTIS 2	Pre
21868	FORD	FALCON XF	1/12/85	4374	101958	Petrohol	Carburettor	4.1	4M	1521	LTIS 2	Post
21869	FORD	FALCON XF	1/12/85	4374	102054	Leaded	Carburettor	4.1	4M	1521	LTIS 2	Post
21872	TOYOTA	COROLLA	1/04/90	4449	97156	Petrohol	Carburettor	1.6	5M	1201	BF	Post
21873	TOYOTA	COROLLA	1/04/90	4449	97255	ULP	Carburettor	1.6	5M	1201	BF	Post
21876	FORD	LASER KF	1/01/94	4376	60244	Petrohol	Carburettor	1.6	5M	1186	LTIS 2	Pre
21877	FORD	LASER KF	1/01/94	4376	60330	ULP	Carburettor	1.6	5M	1186	LTIS 2	Pre
21878	FORD	LASER KF	1/01/94	4376	60429	Petrohol	Carburettor	1.6	5M	1186	LTIS 2	Post
21879	FORD	LASER KF	1/01/94	4376	60528	ULP	Carburettor	1.6	5M	1186	LTIS 2	Post
21880	HOLDEN	COMMODORE VR	23/12/93	4450	68741	Petrohol	MPI	3.8	4A	1629	BF	Post
21881	HOLDEN	COMMODORE VR	23/12/93	4450	68838	ULP	MPI	3.8	4A	1629	BF	Post
21884	MITSUBISHI	SIGMA GK	1/02/85	4451	170629	Petrohol	Carburettor	2.0	4A	1377	BFS	Pre
21885	MITSUBISHI	SIGMA GK	1/02/85	4451	170732	Leaded	Carburettor	2.0	4A	1377	BFS	Pre
21886	MITSUBISHI	SIGMA GK	1/02/85	4451	170821	Petrohol	Carburettor	2.0	4A	1377	BFS	Post
21887	MITSUBISHI	SIGMA GK	1/02/85	4451	170897	Leaded	Carburettor	2.0	4A	1377	BFS	Post
21888	HOLDEN	COMMODORE VN	1/08/88	4452	153699	Petrohol	MPI	3.8	4A	1553	BF	Post
21889	HOLDEN	COMMODORE VN	1/08/88	4452	153796	ULP	MPI	3.8	4A	1553	BF	Post
21892	FORD	FALCON EA	1/07/88	4453	147576	Petrohol	TBI	4.0	3A	1680	BF	Post
21893	FORD	FALCON EA	1/07/88	4453	147674	ULP	TBI	4.0	3A	1680	BF	Post
21896	TOYOTA	COROLLA	1/05/90	4455	97458	Petrohol	Carburettor	1.6	5M	1192	BFS	Pre
21897	TOYOTA	COROLLA	1/05/90	4455	97561	ULP	Carburettor	1.6	5M	1192	BFS	Pre
21898	TOYOTA	COROLLA	1/05/90	4455	97655	Petrohol	Carburettor	1.6	5M	1192	BFS	Post
21899	TOYOTA	COROLLA	1/05/90	4455	97752	ULP	Carburettor	1.6	5M	1192	BFS	Post
21902	HOLDEN	COMMODORE VH	1/09/81	4394	128110	Leaded	Carburettor	3.3	3A	1451	LTIS 2	Pre
21903	HOLDEN	COMMODORE VH	1/09/81	4394	128209	Petrohol	Carburettor	3.3	3A	1451	LTIS 2	Pre

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
21904	HOLDEN	COMMODORE VH	1/09/81	4394	128303	Leaded	Carburettor	3.3	3A	1451	LTIS 2	Post
21905	HOLDEN	COMMODORE VH	1/09/81	4394	128404	Petrohol	Carburettor	3.3	3A	1451	LTIS 2	Post
21908	FORD	LASER KB	1/03/85	4456	155917	Petrohol	Carburettor	1.3	4M	1031	BF	Post
21909	FORD	LASER KB	1/03/85	4456	156009	Leaded	Carburettor	1.3	4M	1031	BF	Post
21914	HOLDEN	COMMODORE VL	1/09/86	4457	439557	Petrohol	MPI	3.0	3A	1550	BFS	Pre
21915	HOLDEN	COMMODORE VL	1/09/86	4457	439657	ULP	MPI	3.0	3A	1550	BFS	Pre
21916	HOLDEN	COMMODORE VL	1/09/86	4457	439756	Petrohol	MPI	3.0	3A	1550	BFS	Post
21917	HOLDEN	COMMODORE VL	1/09/86	4457	439851	ULP	MPI	3.0	3A	1550	BFS	Post
21918	MITSUBISHI	MAGNA TN	1/07/87	4458	178330	Petrohol	Carburettor	2.6	4A	1430	BF	Post
21919	MITSUBISHI	MAGNA TN	1/07/87	4458	178419	ULP	Carburettor	2.6	4A	1430	BF	Post
21920	HOLDEN	COMMODORE VH	1/07/82	4459	138195	Petrohol	Carburettor	3.3	3A	1435	BFS	Pre
21921	HOLDEN	COMMODORE VH	1/07/82	4459	138293	Leaded	Carburettor	3.3	3A	1435	BFS	Pre
21922	HOLDEN	COMMODORE VH	1/07/82	4459	138382	Petrohol	Carburettor	3.3	3A	1435	BFS	Post
21923	HOLDEN	COMMODORE VH	1/07/82	4459	138481	Leaded	Carburettor	3.3	3A	1435	BFS	Post
21928	MITSUBISHI	SIGMA GN	1/01/86	4460	197706	Petrohol	Carburettor	2.6	5M	1324	BF	Post
21929	MITSUBISHI	SIGMA GN	1/01/86	4460	197804	ULP	Carburettor	2.6	5M	1324	BF	Post
21938	TOYOTA	COROLLA	1/07/84	4467	128478	Petrohol	Carburettor	1.3	5M	1120	BFS	Pre
21939	TOYOTA	COROLLA	1/07/84	4467	128575	Leaded	Carburettor	1.3	5M	1120	BFS	Pre
21940	TOYOTA	COROLLA	1/07/84	4467	128936	Petrohol	Carburettor	1.3	5M	1120	BFS	Post
21941	TOYOTA	COROLLA	1/07/84	4467	128810	Leaded	Carburettor	1.3	5M	1120	BFS	Post
21944	MITSUBISHI	MAGNA TR	1/12/92	4468	119983	Petrohol	MPI	2.6	4A	1542	BF	Post
21945	MITSUBISHI	MAGNA TR	1/12/92	4468	120124	ULP	MPI	2.6	4A	1542	BF	Post
21948	HOLDEN	COMMODORE VP	16/06/93	4469	82056	Petrohol	MPI	3.8	4A	1610	BF	Post
21949	HOLDEN	COMMODORE VP	16/06/93	4469	82185	ULP	MPI	3.8	4A	1610	BF	Post
21952	TOYOTA	CORONA	1/12/84	4470	175659	Petrohol	Carburettor	2.0	3A	1293	BF	Post
21953	TOYOTA	CORONA	1/12/84	4470	175756	Leaded	Carburettor	2.0	3A	1293	BF	Post

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
21957	HOLDEN	COMMODORE VH	1/06/83	4471	236016	Petrohol	Carburettor	3.3	3A	1499	BF	Post
21958	HOLDEN	COMMODORE VH	1/06/83	4471	236151	Leaded	Carburettor	3.3	3A	1499	BF	Post
21965	FORD	FALCON EA	1/05/88	4472	173834	Petrohol	MPI	3.9	3A	1743	BF	Post
21966	FORD	FALCON EA	1/05/88	4472	173919	ULP	MPI	3.9	3A	1743	BF	Post
21971	MITSUBISHI	MAGNA TR	1/01/92	4473	128612	Petrohol	MPI	2.6	3AO	1768	BF	Post
21972	MITSUBISHI	MAGNA TR	1/01/92	4473	128706	ULP	MPI	2.6	3AO	1768	BF	Post
21977	HOLDEN	COMMODORE VK	1/12/84	4474	247635	Petrohol	Carburettor	3.0	5M	1512	BFS	Pre
21978	HOLDEN	COMMODORE VK	1/12/84	4474	247727	Leaded	Carburettor	3.0	5M	1512	BFS	Pre
21979	HOLDEN	COMMODORE VK	1/12/84	4474	247822	Petrohol	Carburettor	3.0	5M	1512	BFS	Post
21980	HOLDEN	COMMODORE VK	1/12/84	4474	247918	Leaded	Carburettor	3.0	5M	1512	BFS	Post
21983	FORD	FALCON XE I	1/08/83	4475	209279	Petrohol	MPI	4.1	3A	1741	BFS	Pre
21984	FORD	FALCON XE I	1/08/83	4475	209360	Leaded	MPI	4.1	3A	1741	BFS	Pre
21985	FORD	FALCON XE I	1/08/83	4475	209447	Petrohol	MPI	4.1	3A	1741	BFS	Post
21986	FORD	FALCON XE I	1/08/83	4475	209518	Leaded	MPI	4.1	3A	1741	BFS	Post
21988	MITSUBISHI	MAGNA TN	1/06/88	4476	213580	Petrohol	Carburettor	2.6	4A	1282	BF	Post
21989	MITSUBISHI	MAGNA TN	1/06/88	4476	213677	ULP	Carburettor	2.6	4A	1282	BF	Post
21991	FORD	FALCON EA	1/11/89	4477	193480	Petrohol	TBI	3.9	4A	1597	BFS	Pre
21992	FORD	FALCON EA	1/11/89	4477	193563	ULP	TBI	3.9	4A	1597	BFS	Pre
21993	FORD	FALCON EA	1/11/89	4477	193630	Petrohol	TBI	3.9	4A	1597	BFS	Post
21994	FORD	FALCON EA	1/11/89	4477	193697	ULP	TBI	3.9	4A	1597	BFS	Post
21997	FORD	FALCON XF	1/12/85	4310	104863	Petrohol	Carburettor	4.1	4M	1521	BF	Post
21998	FORD	FALCON XF	1/12/85	4310	104962	Leaded	Carburettor	4.1	4M	1521	BF	Post
21999	MITSUBISHI	MAGNA TS	1/05/95	4365	41130	Petrohol	MPI	2.6	3AO	1546	LTIS 2	Pre
22000	MITSUBISHI	MAGNA TS	1/05/95	4365	41229	ULP	MPI	2.6	3AO	1546	LTIS 2	Pre
22001	MITSUBISHI	MAGNA TS	1/05/95	4365	41325	Petrohol	MPI	2.6	3AO	1546	LTIS 2	Post
22002	MITSUBISHI	MAGNA TS	1/05/95	4365	41421	ULP	MPI	2.6	3AO	1546	LTIS 2	Post

Test No.	Make	Model	Compliance Date	Vehicle Ref No.	Odometer (km)	Fuel Type	Fuel System	Engine Size (L)	Transmission	Reference Mass (kg)	Vehicle Category	Tune Condition
22005	MITSUBISHI	SIGMA GH	1/05/80	4478	318909	Petrohol	Carburettor	2.0	5M	1358	BF	Post
22006	MITSUBISHI	SIGMA GH	1/05/80	4478	318988	Leaded	Carburettor	2.0	5M	1358	BF	Post
22011	TOYOTA	LEXCEN	11/07/95	4369	44827	Petrohol	MPI	3.8	4A	1564	LTIS 2	Pre
22012	TOYOTA	LEXCEN	11/07/95	4369	44924	ULP	MPI	3.8	4A	1564	LTIS 2	Pre
22013	TOYOTA	LEXCEN	11/07/95	4369	45020	Petrohol	MPI	3.8	4A	1564	LTIS 2	Post
22014	TOYOTA	LEXCEN	11/07/95	4369	45119	ULP	MPI	3.8	4A	1564	LTIS 2	Post

APPENDIX 2

NSW EPA
REGULATED EXHAUST AND EVAPORATIVE EMISSIONS TEST RESULTS (ADR 37/00)
ALL VEHICLES TESTED

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)	Hwy Fuel (L/100 km)	Evaporative Diurnal (g)	Hot Soak (g)	Total (g)
21543	LEXCEN	11/07/95	4300	ULP	MPI	0.20	0.62	1.55	274.4	12.0	8.1	TP	TP	TP
21544	LEXCEN	11/07/95	4300	Petrohol	MPI	0.17	0.69	1.57	274.4	12.5	8.5	TP	TP	TP
21545	MAGNA TS	1/06/95	4370	ULP	MPI	0.33	0.80	3.58	272.7	12.1	9.6	TP	TP	TP
21546	MAGNA TS	1/06/95	4370	Petrohol	MPI	0.22	1.11	1.59	271.5	12.3	9.5	TP	TP	TP
21550	MAGNA TS	1/05/95	4365	ULP	MPI	0.30	1.48	4.59	282.6	12.6	10.9	TP	TP	TP
21551	MAGNA TS	1/05/95	4365	Petrohol	MPI	0.22	1.89	2.40	284.2	13.0	11.0	TP	TP	TP
21552	COMMODORE VR	1/02/94	4367	ULP	MPI	0.20	0.73	2.65	273.0	12.0	8.3	TP	TP	TP
21553	COMMODORE VR	1/02/94	4367	Petrohol	MPI	0.18	0.72	2.46	267.8	12.2	8.6	TP	TP	TP
21562	FALCON EB	1/11/92	4371	Petrohol	MPI	0.45	2.13	10.78	280.1	13.4	9.5	TP	TP	TP
21564	CAMRY	1/07/93	4372	ULP	MPI	0.14	0.15	0.93	288.3	12.6	10.3	TP	TP	TP
21565	CAMRY	1/07/93	4372	Petrohol	MPI	0.13	0.16	0.73	283.7	12.8	10.7	TP	TP	TP
21571	FALCON EB	1/11/92	4371	ULP	MPI	0.58	2.19	11.70	279.7	13.0	9.2	TP	TP	TP
21574	FALCON XF	1/12/85	4374	Leaded	Carburettor	2.83	0.52	36.80	272.7	14.6	10.0	TP	TP	TP
21575	FALCON XF	1/12/85	4374	Petrohol	Carburettor	1.99	0.61	14.10	297.4	14.6	10.1	TP	TP	TP
21577	FALCON EB	1/10/92	4375	ULP	MPI	0.78	2.21	11.94	289.7	13.5	9.7	TP	TP	TP
21578	FALCON EB	1/10/92	4375	Petrohol	MPI	0.55	2.12	9.43	290.2	13.8	10.2	TP	TP	TP
21582	LASER KF	1/01/94	4376	ULP	Carburettor	0.30	0.67	4.91	200.5	9.1	6.6	TP	TP	TP
21583	LASER KF	1/01/94	4376	Petrohol	Carburettor	0.27	1.54	2.46	199.0	9.1	6.6	TP	TP	TP
21585	COMMODORE	1/01/79	4377	Leaded	Carburettor	1.45	0.84	33.10	302.4	15.5	11.2	TP	TP	TP
21586	COMMODORE	1/01/79	4377	Petrohol	Carburettor	1.20	0.91	19.00	319.4	15.8	11.5	TP	TP	TP
21589	LEXCEN	11/07/95	4369	ULP	MPI	0.21	0.63	1.84	277.3	12.2	8.3	TP	TP	TP
21590	LEXCEN	11/07/95	4369	Petrohol	MPI	0.20	0.65	1.53	275.7	12.5	8.7	TP	TP	TP
21591	COROLLA	1/01/92	4379	ULP	MPI	0.33	0.36	2.27	207.2	9.2	8.3	TP	TP	TP
21592	COROLLA	1/01/92	4379	Petrohol	MPI	0.30	0.31	1.56	208.7	9.5	8.6	TP	TP	TP
21595	COMMODORE VL	1/01/87	4380	ULP	MPI	3.73	1.15	52.32	243.1	14.6	10.2	TP	TP	TP
21596	COMMODORE VL	1/01/87	4380	Petrohol	MPI	2.87	1.23	40.33	252.2	14.6	10.5	TP	TP	TP

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)	Hwy Fuel (L/100 km)	Evaporative Diurnal (g)	Hot Soak (g)	Total (g)
21603	COMMODORE VL	1/01/87	4380	ULP	MPI	1.02	0.10	4.70	297.8	13.4	9.2	TP	TP	TP
21604	COMMODORE VL	1/01/87	4380	Petrohol	MPI	0.95	0.11	3.95	295.7	13.7	9.7	TP	TP	TP
21608	COROLLA	1/03/85	4383	Petrohol	Carburettor	1.81	1.85	9.64	165.9	8.3	6.9	TP	TP	TP
21609	COROLLA	1/03/85	4383	Leaded	Carburettor	1.75	1.94	15.70	168.0	8.5	6.6	TP	TP	TP
21612	COROLLA	1/03/85	4383	Leaded	Carburettor	1.86	0.95	14.20	167.2	8.4	6.7	TP	TP	TP
21613	COROLLA	1/03/85	4383	Petrohol	Carburettor	1.73	0.97	7.23	159.7	7.9	6.7	TP	TP	TP
21636	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	1.70	3.73	12.30	277.8	13.0	10.7	TP	TP	TP
21637	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	1.45	3.57	6.32	278.9	13.1	10.9	TP	TP	TP
21670	CAMRY	1/02/92	4402	Petrohol	MPI	0.38	1.58	4.15	221.3	10.5	9.3	0.19	0.43	0.62
21671	CAMRY	1/02/92	4402	ULP	MPI	0.69	1.38	8.94	212.2	10.4	9.0	0.15	0.36	0.51
21698	CAMRY	1/02/90	4412	Petrohol	MPI	0.45	1.59	1.23	226.1	10.3	7.5	0.14	0.25	0.40
21709	CORONA	1/04/80	4415	Petrohol	Carburettor	1.44	2.55	5.76	222.4	11.1	8.4	27.43	33.07	60.50
21710	CORONA	1/04/80	4415	Leaded	Carburettor	1.91	2.88	6.84	223.8	10.8	8.4	23.08	15.43	38.51
21711	CAMRY	1/02/90	4412	ULP	MPI	0.62	1.99	2.47	229.6	10.2	7.6	0.22	0.17	0.39
21715	FALCON EA	1/12/90	4416	ULP	TBI	0.47	1.75	9.86	323.0	14.7	9.8	27.43	7.38	34.81
21716	FALCON EA	1/12/90	4416	Petrohol	TBI	0.42	1.55	8.45	304.2	14.3	10.0	30.59	8.62	39.22
21717	COMMODORE VN	1/03/90	4418	ULP	MPI	0.49	0.92	8.30	285.3	13.0	I	5.83	1.05	6.88
21718	COMMODORE VN	1/03/90	4418	Petrohol	MPI	0.40	0.89	7.00	288.5	13.5	I	13.99	1.95	15.95
21726	FALCON ED	1/01/93	4421	Petrohol	MPI	0.73	0.42	4.78	357.2	16.5	I	0.40	0.43	0.84
21732	FALCON ED	1/01/93	4421	ULP	MPI	0.86	0.47	5.47	357.0	15.9	I	0.86	0.36	1.22
21761	COMMODORE VL	1/12/87	4423	Petrohol	MPI	1.08	1.13	5.21	253.3	11.9	8.1	15.91	0.34	16.25
21762	COMMODORE VL	1/12/87	4423	ULP	MPI	1.16	1.04	6.03	252.7	11.5	7.8	4.82	0.32	5.14
21763	FALCON EA	1/12/88	4424	Petrohol	TBI	1.89	0.95	29.25	270.3	14.5	11.0	16.19	9.64	25.83
21764	FALCON EA	1/12/88	4424	ULP	TBI	2.41	1.06	42.15	259.7	14.4	10.7	9.58	4.32	13.90
21768	FALCON EB	1/11/92	4371	Petrohol	MPI	0.75	2.00	13.97	276.5	13.5	9.7	24.40	13.39	37.80
21769	FALCON EB	1/11/92	4371	ULP	MPI	0.81	2.30	14.56	280.9	13.3	9.3	18.87	9.75	28.61

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)	Hwy Fuel (L/100 km)	Evaporative Diurnal (g)	Hot Soak (g)	Total (g)
21770	FALCON EB	1/11/92	4371	Petrohol	MPI	0.64	2.42	12.53	279.3	13.5	9.8	18.18	10.77	28.95
21771	FALCON EB	1/11/92	4371	ULP	MPI	0.75	2.46	15.34	285.5	13.5	9.5	17.96	10.99	28.95
21776	MAGNA TR	1/09/92	4426	Petrohol	MPI	0.32	1.72	3.46	279.6	12.8	9.5	3.17	7.17	10.34
21777	MAGNA TR	1/09/92	4426	ULP	MPI	0.45	1.25	5.79	257.7	11.6	9.3	2.45	0.95	3.40
21778	COMMODORE VR	1/02/94	4367	Petrohol	MPI	0.20	0.86	3.29	273.4	12.5	9.1	12.28	0.39	12.67
21779	COMMODORE VR	1/02/94	4367	ULP	MPI	0.23	0.84	4.10	276.6	12.3	8.7	8.41	0.39	8.80
21780	COMMODORE VR	1/02/94	4367	Petrohol	MPI	0.24	0.91	3.88	270.6	12.5	9.1	12.93	0.35	13.28
21781	COMMODORE VR	1/02/94	4367	ULP	MPI	0.24	0.86	3.84	252.4	11.2	8.5	8.93	0.36	9.28
21782	CAMIRA JD	1/09/85	4422	Petrohol	MPI	1.51	1.72	15.42	210.1	10.7	7.3	17.01	4.43	21.44
21783	CAMIRA JD	1/09/85	4422	Leaded	MPI	1.93	1.46	28.90	200.3	10.8	7.2	16.14	10.73	26.87
21786	FALCON EA	1/03/90	4430	Petrohol	MPI	0.66	1.64	9.51	288.2	13.7	9.8	0.22	0.37	0.59
21787	FALCON EA	1/03/90	4430	ULP	MPI	0.64	1.70	8.89	287.2	13.1	9.5	0.24	0.35	0.59
21788	FALCON EA	1/03/90	4430	Petrohol	MPI	0.27	1.73	5.69	291.7	13.5	9.7	0.27	0.34	0.61
21789	FALCON EA	1/03/90	4430	ULP	MPI	0.41	1.73	6.47	290.3	13.1	9.5	0.40	0.37	0.78
21792	FALCON XE	1/09/84	4431	Petrohol	Carburettor	1.96	2.35	4.94	308.7	14.4	10.6	14.93	13.95	28.89
21793	FALCON XE	1/09/84	4431	Leaded	Carburettor	2.05	2.02	10.80	308.5	14.3	10.5	17.58	6.28	23.86
21797	APOLLO JK	1/11/95	4432	Petrohol	MPI	0.11	0.94	0.98	237.5	10.8	7.9	1.97	1.21	3.18
21798	APOLLO JK	1/11/95	4432	ULP	MPI	0.10	0.92	0.76	237.3	10.3	7.7	1.43	0.72	2.15
21804	MAGNA TS	1/06/95	4370	Petrohol	MPI	0.24	2.06	2.02	286.5	13.0	10.9	3.77	0.57	4.34
21805	MAGNA TS	1/06/95	4370	ULP	MPI	0.32	1.33	4.19	276.2	12.3	10.7	2.06	0.48	2.54
21806	MAGNA TS	1/06/95	4370	Petrohol	MPI	0.22	2.30	1.89	281.1	12.8	I	2.87	1.26	4.13
21807	MAGNA TS	1/06/95	4370	ULP	MPI	0.30	1.63	3.90	277.4	12.3	I	2.33	0.98	3.31
21810	LASER KA	1/03/83	4436	Petrohol	Carburettor	1.26	1.29	8.47	186.5	9.1	6.7	15.32	34.92	50.24
21811	LASER KA	1/03/83	4436	Leaded	Carburettor	1.23	1.24	12.65	181.2	8.8	6.5	16.84	20.96	37.80
21823	COROLLA	1/01/92	4379	Petrohol	MPI	0.24	0.43	1.57	210.0	9.6	8.5	1.14	0.34	1.48
21824	COROLLA	1/01/92	4379	ULP	MPI	0.26	0.38	1.83	210.6	9.3	8.1	2.90	0.29	3.19

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)	Hwy Fuel (L/100 km)	Evaporative Diurnal (g)	Hot Soak (g)	Total (g)
21825	COROLLA	1/01/92	4379	Petrohol	MPI	0.23	0.45	1.66	210.9	9.6	I	0.59	0.25	0.84
21826	COROLLA	1/01/92	4379	ULP	MPI	0.28	0.45	2.07	210.2	9.3	I	0.67	0.25	0.92
21827	CAMRY	1/07/87	4438	Petrohol	MPI	0.47	5.13	1.16	223.3	10.2	8.7	1.32	0.39	1.71
21828	CAMRY	1/07/87	4438	ULP	MPI	0.51	5.39	1.60	226.7	10.0	8.4	1.59	0.45	2.04
21831	CAMRY	1/07/93	4372	Petrohol	MPI	0.12	0.30	0.82	287.1	13.0	9.1	0.50	0.33	0.82
21832	CAMRY	1/07/93	4372	ULP	MPI	0.12	0.28	0.68	289.0	12.6	8.8	0.44	0.31	0.75
21833	CAMRY	1/07/93	4372	Petrohol	MPI	0.12	0.30	0.71	293.2	13.2	9.2	1.47	0.28	1.75
21834	CAMRY	1/07/93	4372	ULP	MPI	0.14	0.27	1.03	293.5	12.8	8.9	2.09	0.29	2.37
21839	SKYLINE	1/08/86	4441	Petrohol	MPI	1.27	1.53	10.99	273.9	13.2	9.6	8.17	0.77	8.94
21840	SKYLINE	1/08/86	4441	ULP	MPI	1.33	1.60	12.91	280.0	13.2	9.2	6.95	0.75	7.70
21842	MAGNA TN	1/04/88	4442	ULP	MPI	1.39	1.79	17.07	255.6	12.4	8.8	2.75	0.45	3.19
21843	MAGNA TN	1/04/88	4442	ULP	MPI	1.12	1.83	8.76	265.0	12.2	8.8	3.21	0.30	3.51
21844	MAGNA TN	1/04/88	4442	Petrohol	MPI	1.04	1.71	7.78	267.7	12.7	9.2	3.97	0.78	4.75
21845	SIGMA GH	1/06/81	4443	Petrohol	Carburettor	1.51	0.89	43.90	288.6	16.1	12.7	39.37	29.61	68.98
21846	SIGMA GH	1/06/81	4443	Leaded	Carburettor	1.63	0.76	57.40	271.0	15.8	12.5	35.11	21.08	56.18
21847	MAGNA TN	1/04/88	4442	Petrohol	MPI	1.16	1.82	8.39	263.6	12.6	9.0	3.82	0.85	4.67
21851	FALCON EB	1/10/92	4375	Petrohol	MPI	0.53	2.41	9.55	295.5	14.0	10.2	8.78	0.30	9.08
21852	FALCON EB	1/10/92	4375	ULP	MPI	0.59	2.51	9.77	294.1	13.5	9.8	3.76	0.21	3.97
21853	FALCON EB	1/10/92	4375	Petrohol	MPI	0.49	2.40	8.90	293.2	13.9	10.2	6.32	0.21	6.54
21854	FALCON EB	1/10/92	4375	ULP	MPI	0.66	2.55	11.20	290.4	13.4	9.9	13.51	0.21	13.73
21855	CAMIRA JE	1/11/87	4444	Petrohol	MPI	0.68	0.77	4.96	225.8	10.6	7.0	41.92	21.61	63.53
21856	CAMIRA JE	1/11/87	4444	ULP	MPI	0.68	0.74	5.58	227.3	10.3	6.7	37.32	15.54	52.87
21862	COMMODORE VP	1/05/92	4447	Petrohol	MPI	0.64	0.47	8.11	288.1	13.6	9.4	3.39	1.22	4.61
21863	COMMODORE VP	1/05/92	4447	ULP	MPI	0.71	0.47	8.84	290.3	13.3	9.2	0.72	0.21	0.93
21864	CAMRY	1/11/87	4448	Petrohol	MPI	1.85	2.57	17.17	203.3	10.6	I	4.60	0.60	5.20
21865	CAMRY	1/11/87	4448	ULP	MPI	1.96	2.33	23.47	201.3	10.6	I	1.73	0.47	2.20

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21866	FALCON XF	1/12/85	4374	Petrohol	Carburettor	1.85	1.61	16.20	262.8	13.1	8.7	7.24	6.18	13.41
21867	FALCON XF	1/12/85	4374	Leaded	Carburettor	1.81	1.67	26.10	253.7	12.9	8.6	2.25	3.71	5.96
21868	FALCON XF	1/12/85	4374	Petrohol	Carburettor	1.67	0.92	12.60	271.1	13.2	9.3	2.29	6.16	8.45
21869	FALCON XF	1/12/85	4374	Leaded	Carburettor	0.99	0.77	36.70	257.9	13.7	9.2	2.33	5.02	7.35
21872	COROLLA	1/04/90	4449	Petrohol	Carburettor	0.26	0.94	5.09	203.9	9.6	7.5	11.69	9.12	20.82
21873	COROLLA	1/04/90	4449	ULP	Carburettor	0.35	0.64	10.96	203.7	9.6	7.6	6.11	3.29	9.41
21876	LASER KF	1/01/94	4376	Petrohol	Carburettor	0.25	1.73	2.72	192.8	8.9	6.5	9.46	4.85	14.32
21877	LASER KF	1/01/94	4376	ULP	Carburettor	0.29	0.96	4.81	192.7	8.7	6.4	18.60	2.65	21.25
21878	LASER KF	1/01/94	4376	Petrohol	Carburettor	0.30	1.72	3.02	197.4	9.1	6.7	11.36	4.27	15.63
21879	LASER KF	1/01/94	4376	ULP	Carburettor	0.33	0.83	6.37	199.6	9.1	6.6	9.38	6.07	15.45
21880	COMMODORE VR	23/12/93	4450	Petrohol	MPI	0.23	0.99	4.46	282.5	13.0	9.0	0.24	0.13	0.37
21881	COMMODORE VR	23/12/93	4450	ULP	MPI	0.27	0.87	5.22	281.7	12.6	8.7	2.65	0.14	2.79
21884	SIGMA GK	1/02/85	4451	Petrohol	Carburettor	2.04	2.49	10.40	257.8	12.5	8.6	6.69	3.98	10.67
21885	SIGMA GK	1/02/85	4451	Leaded	Carburettor	2.34	2.30	16.05	248.8	12.1	8.5	2.74	3.06	5.80
21886	SIGMA GK	1/02/85	4451	Petrohol	Carburettor	2.04	2.47	8.64	257.2	12.4	8.2	7.44	6.45	13.89
21887	SIGMA GK	1/02/85	4451	Leaded	Carburettor	2.22	2.35	13.18	248.7	11.9	7.9	9.17	2.49	11.66
21888	COMMODORE VN	1/08/88	4452	Petrohol	MPI	0.29	1.46	4.60	276.3	12.8	8.6	11.38	1.08	12.46
21889	COMMODORE VN	1/08/88	4452	ULP	MPI	0.25	1.52	3.93	278.2	12.3	8.1	8.40	2.81	11.21
21892	FALCON EA	1/07/88	4453	Petrohol	TBI	0.46	1.31	7.51	321.4	15.0	10.8	25.31	7.10	32.41
21893	FALCON EA	1/07/88	4453	ULP	TBI	0.42	1.52	7.12	315.8	14.2	10.4	18.49	5.42	23.91
21896	COROLLA	1/05/90	4455	Petrohol	Carburettor	0.39	1.21	3.95	202.5	9.4	7.5	8.79	5.53	14.32
21897	COROLLA	1/05/90	4455	ULP	Carburettor	0.44	0.74	9.68	204.1	9.5	7.4	8.59	7.11	15.70
21898	COROLLA	1/05/90	4455	Petrohol	Carburettor	0.35	1.23	3.82	202.2	9.4	7.2	10.06	9.67	19.73
21899	COROLLA	1/05/90	4455	ULP	Carburettor	0.42	0.75	9.07	202.2	9.4	7.4	8.14	2.53	10.67
21902	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	1.83	3.28	19.40	276.3	13.5	10.1	1.51	8.61	10.11
21903	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	1.74	3.28	11.70	275.7	13.4	10.4	1.97	12.62	14.59

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21904	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	1.52	2.73	15.50	304.6	14.4	10.3	1.22	7.47	8.69
21905	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	1.39	2.83	11.30	306.2	14.7	10.7	1.69	13.63	15.32
21908	LASER KB	1/03/85	4456	Petrohol	Carburettor	1.73	1.68	10.60	163.2	8.3	6.6	13.72	8.20	21.92
21909	LASER KB	1/03/85	4456	Leaded	Carburettor	1.94	1.62	16.20	159.7	8.2	6.2	12.34	9.41	21.76
21914	COMMODORE VL	1/09/86	4457	Petrohol	MPI	1.68	2.56	11.75	241.7	11.9	8.3	30.21	3.28	33.49
21915	COMMODORE VL	1/09/86	4457	ULP	MPI	1.77	2.45	13.81	244.8	11.8	7.9	29.47	5.59	35.06
21916	COMMODORE VL	1/09/86	4457	Petrohol	MPI	1.68	2.56	12.18	246.4	12.2	8.5	25.33	3.25	28.58
21917	COMMODORE VL	1/09/86	4457	ULP	MPI	1.75	2.69	13.77	247.0	11.9	8.0	25.88	2.39	28.28
21918	MAGNA TN	1/07/87	4458	Petrohol	Carburettor	0.59	0.91	6.57	268.9	12.6	8.8	11.52	18.74	30.25
21919	MAGNA TN	1/07/87	4458	ULP	Carburettor	0.70	1.16	11.85	267.5	12.5	8.4	22.91	24.37	47.28
21920	COMMODORE VH	1/07/82	4459	Petrohol	Carburettor	2.33	1.62	60.50	267.8	16.5	10.1	0.83	5.28	6.11
21921	COMMODORE VH	1/07/82	4459	Leaded	Carburettor	1.79	2.07	36.60	277.5	14.7	9.9	0.64	3.54	4.19
21922	COMMODORE VH	1/07/82	4459	Petrohol	Carburettor	1.36	2.29	8.72	286.9	13.6	10.2	0.96	5.13	6.09
21923	COMMODORE VH	1/07/82	4459	Leaded	Carburettor	1.91	2.39	19.30	282.1	13.7	9.7	0.69	4.53	5.22
21928	SIGMA GN	1/01/86	4460	Petrohol	Carburettor	0.93	3.14	4.80	231.9	10.9	7.9	1.27	1.36	2.63
21929	SIGMA GN	1/01/86	4460	ULP	Carburettor	1.09	2.45	10.62	232.4	10.9	7.9	1.27	0.86	2.14
21938	COROLLA	1/07/84	4467	Petrohol	Carburettor	1.90	2.37	8.37	175.2	8.7	6.6	1.21	8.24	9.45
21939	COROLLA	1/07/84	4467	Leaded	Carburettor	1.95	2.15	14.20	170.7	8.6	6.7	0.63	4.68	5.31
21940	COROLLA	1/07/84	4467	Petrohol	Carburettor	2.00	1.89	5.64	179.6	8.7	6.7	1.07	8.81	9.88
21941	COROLLA	1/07/84	4467	Leaded	Carburettor	1.94	2.44	8.11	179.2	8.5	6.6	0.63	4.79	5.42
21944	MAGNA TR	1/12/92	4468	Petrohol	MPI	0.57	1.21	7.66	272.9	12.9	9.5	1.87	1.04	2.91
21945	MAGNA TR	1/12/92	4468	ULP	MPI	0.59	1.11	8.94	273.9	12.5	9.5	3.14	1.10	4.24
21948	COMMODORE VP	16/06/93	4469	Petrohol	MPI	0.19	1.16	2.99	300.5	13.7	9.4	0.72	1.17	1.89
21949	COMMODORE VP	16/06/93	4469	ULP	MPI	0.23	1.18	3.81	302.7	13.4	9.1	0.35	0.24	0.60
21952	CORONA	1/12/84	4470	Petrohol	Carburettor	1.21	1.25	9.88	229.3	11.1	9.2	0.35	12.48	12.82
21953	CORONA	1/12/84	4470	Leaded	Carburettor	1.27	1.32	14.40	224.7	10.8	8.9	0.39	7.99	8.38

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)	Hwy Fuel (L/100 km)	Evaporative Diurnal (g)	Hot Soak (g)	Total (g)
21957	COMMODORE VH	1/06/83	4471	Petrohol	Carburettor	0.71	1.25	8.20	322.2	15.1	10.8	0.73	20.66	21.39
21958	COMMODORE VH	1/06/83	4471	Leaded	Carburettor	1.03	1.62	13.10	313.8	14.5	10.7	0.63	12.97	13.61
21965	FALCON EA	1/05/88	4472	Petrohol	MPI	0.41	1.94	1.87	306.5	14.0	10.4	25.06	10.21	35.27
21966	FALCON EA	1/05/88	4472	ULP	MPI	0.57	2.09	5.08	284.6	12.7	10.2	21.92	11.08	32.99
21971	MAGNA TR	1/01/92	4473	Petrohol	MPI	0.70	1.48	3.67	290.9	13.4	9.8	1.49	3.23	4.71
21972	MAGNA TR	1/01/92	4473	ULP	MPI	0.71	1.28	4.17	286.5	12.8	9.8	0.74	0.76	1.50
21977	COMMODORE VK	1/12/84	4474	Petrohol	Carburettor	3.40	1.55	31.00	253.6	14.0	9.3	17.52	20.31	37.84
21978	COMMODORE VK	1/12/84	4474	Leaded	Carburettor	3.85	1.71	40.00	243.3	13.7	9.0	20.23	12.21	32.44
21979	COMMODORE VK	1/12/84	4474	Petrohol	Carburettor	3.13	1.92	13.40	262.5	13.1	9.2	23.88	20.90	44.78
21980	COMMODORE VK	1/12/84	4474	Leaded	Carburettor	2.88	2.29	19.40	264.0	13.1	8.7	16.75	13.63	30.38
21983	FALCON XE I	1/08/83	4475	Petrohol	MPI	1.55	2.94	10.70	322.5	15.4	11.0	12.89	1.72	14.61
21984	FALCON XE I	1/08/83	4475	Leaded	MPI	1.65	2.89	16.83	318.9	15.1	10.9	8.90	1.05	9.95
21985	FALCON XE I	1/08/83	4475	Petrohol	MPI	1.74	2.85	17.40	312.6	15.4	11.2	10.68	1.02	11.69
21986	FALCON XE I	1/08/83	4475	Leaded	MPI	2.20	2.64	29.00	308.1	15.5	11.2	6.47	0.94	7.41
21988	MAGNA TN	1/06/88	4476	Petrohol	Carburettor	0.51	0.95	15.78	251.1	12.5	9.4	12.81	16.07	28.88
21989	MAGNA TN	1/06/88	4476	ULP	Carburettor	0.63	0.65	26.87	244.4	12.5	9.4	8.80	9.12	17.92
21991	FALCON EA	1/11/89	4477	Petrohol	TBI	0.79	1.62	15.01	294.9	14.4	9.6	9.05	0.41	9.46
21992	FALCON EA	1/11/89	4477	ULP	TBI	0.96	1.52	19.67	291.9	14.1	9.2	6.87	0.46	7.33
21993	FALCON EA	1/11/89	4477	Petrohol	TBI	0.40	1.88	7.85	297.8	14.0	9.4	1.65	0.42	2.07
21994	FALCON EA	1/11/89	4477	ULP	TBI	0.46	1.87	8.55	290.0	13.2	9.1	2.92	0.42	3.34
21997	FALCON XF	1/12/85	4310	Petrohol	Carburettor	1.73	0.82	7.47	392.4	18.3	12.1	2.45	8.96	11.41
21998	FALCON XF	1/12/85	4310	Leaded	Carburettor	1.88	0.89	13.00	388.5	17.9	11.8	1.06	6.19	7.25
21999	MAGNA TS	1/05/95	4365	Petrohol	MPI	0.30	1.86	4.56	281.9	13.0	10.9	3.52	3.69	7.21
22000	MAGNA TS	1/05/95	4365	ULP	MPI	0.34	1.56	6.14	278.4	12.5	10.9	2.40	0.36	2.76
22001	MAGNA TS	1/05/95	4365	Petrohol	MPI	0.28	1.80	3.97	283.0	13.0	11.0	1.72	2.54	4.26
22002	MAGNA TS	1/05/95	4365	ULP	MPI	0.37	1.45	6.56	279.9	12.6	10.7	1.21	0.72	1.93

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)	Hwy Fuel (L/100 km)	Evaporative Diurnal (g)	Hot Soak (g)	Total (g)
22005	SIGMA GH	1/05/80	4478	Petrohol	Carburettor	2.17	2.95	11.10	270.4	13.2	9.1	11.98	22.02	34.00
22006	SIGMA GH	1/05/80	4478	Leaded	Carburettor	2.56	2.72	19.30	263.8	13.0	9.0	5.82	16.01	21.83
22011	LEXCEN	11/07/95	4369	Petrohol	MPI	0.26	1.06	2.15	275.8	12.6	8.5	0.70	0.17	0.87
22012	LEXCEN	11/07/95	4369	ULP	MPI	0.27	1.06	2.52	275.1	12.1	8.1	2.30	0.17	2.47
22013	LEXCEN	11/07/95	4369	Petrohol	MPI	0.24	1.08	2.17	271.4	12.4	8.4	0.36	0.17	0.53
22014	LEXCEN	11/07/95	4369	ULP	MPI	0.27	1.05	2.48	273.4	12.0	8.2	0.12	0.14	0.26

APPENDIX 3

NSW EPA
REGULATED EXHAUST EMISSIONS
TEST RESULTS
PRE-1986 VEHICLES (2-BAG RESULTS)

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (2 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)
21574	FALCON XF	1/12/85	4374	Leaded	Carburettor	3.11	0.55	39.1	271.3	14.7
21575	FALCON XF	1/12/85	4374	Petrohol	Carburettor	2.21	0.61	15.7	301.4	14.9
21585	COMMODORE	1/01/79	4377	Leaded	Carburettor	1.45	0.99	34.0	313.5	16.0
21586	COMMODORE	1/01/79	4377	Petrohol	Carburettor	1.27	1.00	19.8	331.2	16.4
21608	COROLLA	1/03/85	4383	Petrohol	Carburettor	2.07	1.78	13.6	168.6	8.8
21609	COROLLA	1/03/85	4383	Leaded	Carburettor	2.06	1.79	20.5	167.6	8.9
21612	COROLLA	1/03/85	4383	Leaded	Carburettor	2.13	0.91	18.2	169.2	8.8
21613	COROLLA	1/03/85	4383	Petrohol	Carburettor	1.91	0.97	10.6	162.3	8.3
21636	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	1.78	3.78	13.0	288.2	13.5
21637	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	1.53	3.65	7.0	288.6	13.6
21709	CORONA	1/04/80	4415	Petrohol	Carburettor	1.57	2.60	7.2	233.0	11.1
21710	CORONA	1/04/80	4415	Leaded	Carburettor	1.66	2.94	8.1	234.0	10.8
21782	CAMIRA JD	1/09/85	4422	Petrohol	MPI	1.80	1.68	20.9	213.5	11.3
21783	CAMIRA JD	1/09/85	4422	Leaded	MPI	2.34	1.44	33.5	203.6	11.3
21792	FALCON XE	1/09/84	4431	Petrohol	Carburettor	2.02	2.44	7.1	317.4	15.0
21793	FALCON XE	1/09/84	4431	Leaded	Carburettor	2.20	2.05	14.8	314.3	14.8
21810	LASER KA	1/03/83	4436	Petrohol	Carburettor	1.52	1.27	9.2	191.0	9.4
21811	LASER KA	1/03/83	4436	Leaded	Carburettor	1.43	1.22	13.8	185.2	9.1
21845	SIGMA GH	1/06/81	4443	Petrohol	Carburettor	1.29	0.91	54.1	303.8	17.6
21846	SIGMA GH	1/06/81	4443	Leaded	Carburettor	1.41	0.78	63.9	284.1	16.7
21866	FALCON XF	1/12/85	4374	Petrohol	Carburettor	1.61	1.68	19.1	268.1	13.6
21867	FALCON XF	1/12/85	4374	Leaded	Carburettor	1.92	1.73	29.7	256.1	13.3
21868	FALCON XF	1/12/85	4374	Petrohol	Carburettor	1.45	0.95	15.2	273.1	13.5
21869	FALCON XF	1/12/85	4374	Leaded	Carburettor	1.08	0.85	39.3	259.0	14.0
21884	SIGMA GK	1/02/85	4451	Petrohol	Carburettor	2.24	2.52	12.8	265.8	13.1
21885	SIGMA GK	1/02/85	4451	Leaded	Carburettor	2.63	2.37	18.0	256.6	12.6

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (2 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)
21886	SIGMA GK	1/02/85	4451	Petrohol	Carburettor	2.21	2.56	10.3	265.9	12.9
21887	SIGMA GK	1/02/85	4451	Leaded	Carburettor	2.41	2.36	15.3	251.2	12.2
21902	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	2.03	3.38	24.9	285.3	14.2
21903	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	1.83	3.31	17.1	281.7	14.1
21904	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	1.71	2.70	22.5	307.9	15.0
21905	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	1.61	2.86	17.9	311.8	15.4
21908	LASER KB	1/03/85	4456	Petrohol	Carburettor	1.85	1.59	12.7	165.3	8.5
21909	LASER KB	1/03/85	4456	Leaded	Carburettor	2.05	1.52	18.8	162.7	8.6
21920	COMMODORE VH	1/07/82	4459	Petrohol	Carburettor	2.49	1.75	63.7	280.2	17.4
21921	COMMODORE VH	1/07/82	4459	Leaded	Carburettor	1.84	2.11	35.3	291.1	15.2
21922	COMMODORE VH	1/07/82	4459	Petrohol	Carburettor	1.49	2.47	10.0	296.6	14.2
21923	COMMODORE VH	1/07/82	4459	Leaded	Carburettor	2.39	2.54	22.6	291.3	14.4
21938	COROLLA	1/07/84	4467	Petrohol	Carburettor	2.10	2.35	9.7	179.3	9.0
21939	COROLLA	1/07/84	4467	Leaded	Carburettor	2.08	2.15	16.4	174.7	8.9
21940	COROLLA	1/07/84	4467	Petrohol	Carburettor	2.08	2.20	6.8	185.2	9.0
21941	COROLLA	1/07/84	4467	Leaded	Carburettor	2.08	2.42	9.6	184.0	8.9
21952	CORONA	1/12/84	4470	Petrohol	Carburettor	1.41	1.34	13.9	238.0	11.8
21953	CORONA	1/12/84	4470	Leaded	Carburettor	1.49	1.35	19.4	231.8	11.5
21957	COMMODORE VH	1/06/83	4471	Petrohol	Carburettor	0.73	1.34	9.2	335.5	15.8
21958	COMMODORE VH	1/06/83	4471	Leaded	Carburettor	1.14	1.74	16.7	325.3	15.3
21977	COMMODORE VK	1/12/84	4474	Petrohol	Carburettor	3.10	1.50	31.4	263.2	14.4
21978	COMMODORE VK	1/12/84	4474	Leaded	Carburettor	3.53	1.75	39.9	253.8	14.1
21979	COMMODORE VK	1/12/84	4474	Petrohol	Carburettor	3.15	1.81	17.0	271.8	13.8
21980	COMMODORE VK	1/12/84	4474	Leaded	Carburettor	2.94	2.32	21.5	273.3	13.6
21983	FALCON XE I	1/08/83	4475	Petrohol	MPI	1.69	3.09	13.1	330.2	15.9
21984	FALCON XE I	1/08/83	4475	Leaded	MPI	1.85	2.92	20.2	324.4	15.6

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (2 Bag Results) HC (g/km)	NO_x (g/km)	CO (g/km)	CO_2 (g/km)	City Fuel (L/100 km)
21985	FALCON XE I	1/08/83	4475	Petrohol	MPI	1.96	2.89	21.7	318.5	16.0
21986	FALCON XE I	1/08/83	4475	Leaded	MPI	2.41	2.58	35.0	311.4	16.1
21997	FALCON XF	1/12/85	4310	Petrohol	Carburettor	1.85	0.84	9.6	395.8	18.6
21998	FALCON XF	1/12/85	4310	Leaded	Carburettor	2.06	0.91	16.2	390.4	18.2
22005	SIGMA GH	1/05/80	4478	Petrohol	Carburettor	2.41	2.77	18.7	273.9	13.9
22006	SIGMA GH	1/05/80	4478	Leaded	Carburettor	2.87	2.51	29.6	266.4	13.9

APPENDIX 4

NSW EPA
POWER TEST RESULTS

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Transmission	Gear	Corrected Average Power (kW) 40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h
21545	MAGNA TS	1/06/95	4370	ULP	MPI	3AO	2nd	38.1	43.6	51.7	61.6	65.8	64.5	P	P
21546	MAGNA TS	1/06/95	4370	Petrohol	MPI	3AO	2nd	39.7	44.8	52.9	61.7	66.1	65.3	P	P
21550	MAGNA TS	1/05/95	4365	ULP	MPI	3AO	2nd	37.1	42.8	51.0	59.9	63.9	63.7	P	P
21551	MAGNA TS	1/05/95	4365	Petrohol	MPI	3AO	2nd	36.7	42.4	50.2	59.8	64.8	64.9	P	P
21552	COMMODORE VR	1/02/94	4367	ULP	MPI	4A	2nd	P	56.9	65.8	73.9	79.7	84.8	P	P
21553	COMMODORE VR	1/02/94	4367	Petrohol	MPI	4A	2nd	P	55.9	64.5	73.7	79.3	83.2	P	P
21564	CAMRY	1/07/93	4372	ULP	MPI	3AO	2nd	P	51.5	59.4	67.4	77.9	83.2	82.7	P
21565	CAMRY	1/07/93	4372	Petrohol	MPI	3AO	2nd	P	55.0	61.9	69.2	79.6	83.4	81.6	P
21577	FALCON EB	1/10/92	4375	ULP	MPI	4A	2nd	P	P	64.8	76.0	85.2	92.7	92.7	88.6
21578	FALCON EB	1/10/92	4375	Petrohol	MPI	4A	2nd	P	P	64.2	75.8	85.0	90.9	90.3	87.0
21589	LEXCEN	11/07/95	4369	ULP	MPI	4A	2nd	P	56.8	66.4	76.5	84.9	87.7	89.7	90.5
21590	LEXCEN	11/07/95	4369	Petrohol	MPI	4A	2nd	P	56.9	66.7	76.2	84.9	87.6	90.7	90.3
21591	COROLLA	1/01/92	4379	ULP	MPI	3AO	2nd	27.0	29.8	35.4	41.3	45.7	P	P	P
21592	COROLLA	1/01/92	4379	Petrohol	MPI	3AO	2nd	26.9	29.7	36.2	41.0	45.8	P	P	P
21582	LASER KF	1/01/94	4376	ULP	Carburettor	5M	3rd	20.0	25.1	31.0	36.1	39.4	41.4	43.4	P
21583	LASER KF	1/01/94	4376	Petrohol	Carburettor	5M	3rd	20.3	25.5	31.7	35.8	38.7	40.9	42.3	P
21574	FALCON XF	1/12/85	4374	Leaded	Carburettor	4M	3rd	P	29.8	35.9	42.6	47.6	52.6	58.3	P
21575	FALCON XF	1/12/85	4374	Petrohol	Carburettor	4M	3rd	P	29.1	35.3	41.7	47.3	51.1	55.1	P
21608	COROLLA	1/03/85	4383	Petrohol	Carburettor	5M	3rd	19.8	24.4	30.1	34.4	37.2	37.3	P	P
21609	COROLLA	1/03/85	4383	Leaded	Carburettor	5M	3rd	20.0	25.2	30.7	35.3	38.6	39.3	P	P
21612	COROLLA	1/03/85	4383	Leaded	Carburettor	5M	3rd	19.7	24.9	30.7	35.2	38.2	P	P	P
21613	COROLLA	1/03/85	4383	Petrohol	Carburettor	5M	3rd	19.5	24.7	30.5	35.3	38.6	P	P	P

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Transmission	Gear	Uncorrected Average Tractive Effort (N) 40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h
21545	MAGNA TS	1/06/95	4370	ULP	MPI	3AO	2nd	3400	3110	3070	3125	2910	2530	P	P
21546	MAGNA TS	1/06/95	4370	Petrohol	MPI	3AO	2nd	3550	3195	3135	3125	2925	2560	P	P
21550	MAGNA TS	1/05/95	4365	ULP	MPI	3AO	2nd	3325	3075	3050	3075	2870	2540	P	P
21551	MAGNA TS	1/05/95	4365	Petrohol	MPI	3AO	2nd	3260	3015	2975	3035	2875	2555	P	P
21552	COMMODORE VR	1/02/94	4367	ULP	MPI	4A	2nd	P	4075	3930	3785	3565	3365	P	P
21553	COMMODORE VR	1/02/94	4367	Petrohol	MPI	4A	2nd	P	4030	3880	3795	3570	3330	P	P
21564	CAMRY	1/07/93	4372	ULP	MPI	3AO	2nd	P	3795	3645	3545	3580	3395	3035	P
21565	CAMRY	1/07/93	4372	Petrohol	MPI	3AO	2nd	P	4065	3815	3655	3675	3420	3005	P
21577	FALCON EB	1/10/92	4375	ULP	MPI	4A	2nd	P	P	3950	3975	3905	3785	3410	2965
21578	FALCON EB	1/10/92	4375	Petrohol	MPI	4A	2nd	P	P	3945	3995	3920	3730	3335	2920
21589	LEXCEN	11/07/95	4369	ULP	MPI	4A	2nd	P	4060	3955	3905	3790	3475	3195	2925
21590	LEXCEN	11/07/95	4369	Petrohol	MPI	4A	2nd	P	4080	3990	3900	3800	3465	3230	2920
21591	COROLLA	1/01/92	4379	ULP	MPI	3AO	2nd	2445	2160	2135	2135	2065	P	P	P
21592	COROLLA	1/01/92	4379	Petrohol	MPI	3AO	2nd	2430	2150	2185	2120	2065	P	P	P
21582	LASER KF	1/01/94	4376	ULP	Carburettor	5M	3rd	1785	1790	1835	1830	1745	1625	1530	P
21583	LASER KF	1/01/94	4376	Petrohol	Carburettor	5M	3rd	1805	1820	1885	1825	1725	1620	1505	P
21574	FALCON XF	1/12/85	4374	Leaded	Carburettor	4M	3rd	P	2215	2225	2265	2210	2170	2165	P
21575	FALCON XF	1/12/85	4374	Petrohol	Carburettor	4M	3rd	P	2155	2180	2205	2190	2100	2040	P
21608	COROLLA	1/03/85	4383	Petrohol	Carburettor	5M	3rd	1730	1705	1750	1715	1625	1445	P	P
21609	COROLLA	1/03/85	4383	Leaded	Carburettor	5M	3rd	1695	1705	1730	1705	1630	1475	P	P
21612	COROLLA	1/03/85	4383	Leaded	Carburettor	5M	3rd	1820	1840	1885	1855	1760	P	P	P
21613	COROLLA	1/03/85	4383	Petrohol	Carburettor	5M	3rd	1805	1830	1880	1865	1785	P	P	P

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Transmission	Gear	Average Engine Speed (rpm) 40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h
21545	MAGNA TS	1/06/95	4370	ULP	MPI	3AO	2nd	2725	2705	3250	3780	4320	4820	P	P
21546	MAGNA TS	1/06/95	4370	Petrohol	MPI	3AO	2nd	2730	2790	3245	3780	4315	4840	P	P
21550	MAGNA TS	1/05/95	4365	ULP	MPI	3AO	2nd	2690	2720	3220	3770	4245	4810	P	P
21551	MAGNA TS	1/05/95	4365	Petrohol	MPI	3AO	2nd	2680	2730	3235	3765	4295	4810	P	P
21552	COMMODORE VR	1/02/94	4367	ULP	MPI	4A	2nd	P	2815	3190	3560	3985	4415	P	P
21553	COMMODORE VR	1/02/94	4367	Petrohol	MPI	4A	2nd	P	2825	3195	3600	4010	4395	P	P
21564	CAMRY	1/07/93	4372	ULP	MPI	3AO	2nd	P	3125	3510	4005	4485	4985	5455	P
21565	CAMRY	1/07/93	4372	Petrohol	MPI	3AO	2nd	P	3190	3540	3990	4505	4985	5475	P
21577	FALCON EB	1/10/92	4375	ULP	MPI	4A	2nd	P	P	2835	3210	3595	3980	4360	4750
21578	FALCON EB	1/10/92	4375	Petrohol	MPI	4A	2nd	P	P	2850	3210	3600	3965	4345	4740
21589	LEXCEN	11/07/95	4369	ULP	MPI	4A	2nd	P	2820	3205	3620	4065	4410	4830	5185
21590	LEXCEN	11/07/95	4369	Petrohol	MPI	4A	2nd	P	2855	3215	3620	4030	4440	4810	5200
21591	COROLLA	1/01/92	4379	ULP	MPI	3AO	2nd	3035	3410	3930	4500	5060	P	P	P
21592	COROLLA	1/01/92	4379	Petrohol	MPI	3AO	2nd	3055	3450	4005	4490	5085	P	P	P
21582	LASER KF	1/01/94	4376	ULP	Carburettor	5M	3rd	1940	2425	2905	3450	3890	4385	4880	P
21583	LASER KF	1/01/94	4376	Petrohol	Carburettor	5M	3rd	1995	2440	2945	3425	3915	4385	4860	P
21574	FALCON XF	1/12/85	4374	Leaded	Carburettor	4M	3rd	P	1650	1980	2290	2615	2960	3285	P
21575	FALCON XF	1/12/85	4374	Petrohol	Carburettor	4M	3rd	P	1625	1970	2300	2635	2955	3270	P
21608	COROLLA	1/03/85	4383	Petrohol	Carburettor	5M	3rd	1990	2460	2970	3480	3920	4450	P	P
21609	COROLLA	1/03/85	4383	Leaded	Carburettor	5M	3rd	1970	2485	2945	3460	3940	4435	P	P
21612	COROLLA	1/03/85	4383	Leaded	Carburettor	5M	3rd	2030	2490	2995	3495	4010	P	P	P
21613	COROLLA	1/03/85	4383	Petrohol	Carburettor	5M	3rd	1995	2490	2995	3490	3990	P	P	P

APPENDIX 5

CSIRO EXHAUST ALDEHYDES & TOXIC EMISSIONS RESULTS

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
21543	LEXCEN	11/07/95	4300	ULP	MPI	2.30	1.08	0.086	4.30	14.57	19.15	15.98
21544	LEXCEN	11/07/95	4300	Petrohol	MPI	2.31	2.52	0.095	4.23	9.24	12.81	10.98
21545	MAGNA TS	1/06/95	4370	ULP	MPI	1.68	1.01	0.168	7.68	15.43	29.46	30.65
21546	MAGNA TS	1/06/95	4370	Petrohol	MPI	3.27	2.42	0.113	5.16	10.77	18.22	20.12
21550	MAGNA TS	1/05/95	4365	ULP	MPI	5.00	0.48	0.145	6.36	17.59	27.17	21.50
21551	MAGNA TS	1/05/95	4365	Petrohol	MPI	5.62	1.46	0.104	5.48	13.57	20.38	23.12
21552	COMMODORE VR	1/02/94	4367	ULP	MPI	3.48	1.07	0.152	5.51	9.63	16.16	15.68
21553	COMMODORE VR	1/02/94	4367	Petrohol	MPI	2.50	2.63	0.162	5.01	7.09	12.68	9.81
21562	FALCON EB	1/11/92	4371	Petrohol	MPI	2.53	2.45	0.057	10.24	43.21	29.49	25.38
21564	CAMRY	1/07/93	4372	ULP	MPI	2.31	0.42	0.134	2.84	6.87	10.46	10.39
21565	CAMRY	1/07/93	4372	Petrohol	MPI	2.40	1.57	0.058	3.46	5.99	10.65	8.09
21571	FALCON EB	1/11/92	4371	ULP	MPI	3.36	0.72	0.012	11.23	58.29	38.61	31.96
21574	FALCON XF	1/12/85	4374	Leaded	Carburettor	20.34	6.06	1.376	39.37	145.16	293.05	249.78
21575	FALCON XF	1/12/85	4374	Petrohol	Carburettor	20.76	25.08	2.892	33.14	91.82	188.54	171.54
21577	FALCON EB	1/10/92	4375	ULP	MPI	3.72	1.88	0.238	16.27	60.74	66.07	54.31
21578	FALCON EB	1/10/92	4375	Petrohol	MPI	3.05	3.19	0.093	10.89	43.99	37.53	32.38
21582	LASER KF	1/01/94	4376	ULP	Carburettor	0.92	0.51	0.044	5.21	15.79	21.92	21.19
21583	LASER KF	1/01/94	4376	Petrohol	Carburettor	3.45	1.71	0.006	4.58	11.43	22.55	21.92
21585	COMMODORE	1/01/79	4377	Leaded	Carburettor	13.43	5.69	0.328	29.57	83.52	139.23	102.57
21586	COMMODORE	1/01/79	4377	Petrohol	Carburettor	17.36	13.95	0.603	21.91	67.66	116.48	84.83
21589	LEXCEN	11/07/95	4369	ULP	MPI	1.88	1.15	0.056	4.92	11.79	16.84	15.44
21590	LEXCEN	11/07/95	4369	Petrohol	MPI	2.02	2.23	0.062	4.51	9.55	12.64	11.44
21591	COROLLA	1/01/92	4379	ULP	MPI	1.10	0.50	-0.038	4.03	9.66	20.34	16.66
21592	COROLLA	1/01/92	4379	Petrohol	MPI	0.78	1.64	0.001	4.70	10.39	17.23	15.89
21595	COMMODORE VL	1/01/87	4380	ULP	MPI	10.02	7.38	0.648	NR	NR	NR	NR
21596	COMMODORE VL	1/01/87	4380	Petrohol	MPI	9.44	54.49	1.000	NR	NR	NR	NR

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
21603	COMMODORE VL	1/01/87	4380	ULP	MPI	0.81	0.51	0.031	NR	NR	NR	NR
21604	COMMODORE VL	1/01/87	4380	Petrohol	MPI	0.74	2.36	0.124	NR	NR	NR	NR
21608	COROLLA	1/03/85	4383	Petrohol	Carburettor	15.40	21.93	0.074	NR	NR	NR	NR
21609	COROLLA	1/03/85	4383	Leaded	Carburettor	17.56	6.25	0.558	NR	NR	NR	NR
21612	COROLLA	1/03/85	4383	Leaded	Carburettor	13.26	8.84	0.001	NR	NR	NR	NR
21613	COROLLA	1/03/85	4383	Petrohol	Carburettor	20.70	26.40	0.658	NR	NR	NR	NR
21636	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	29.54	8.58	-0.977	38.80	77.98	160.81	122.99
21637	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	39.03	26.08	3.931	36.47	64.74	140.63	115.13
21670	CAMRY	1/02/92	4402	Petrohol	MPI	2.85	2.61	1.316	NR	NR	NR	NR
21671	CAMRY	1/02/92	4402	ULP	MPI	2.88	1.73	2.287	NR	NR	NR	NR
21698	CAMRY	1/02/90	4412	Petrohol	MPI	12.40	6.32	3.108	NR	NR	NR	NR
21709	CORONA	1/04/80	4415	Petrohol	Carburettor	I	I	I	NR	NR	NR	NR
21710	CORONA	1/04/80	4415	Leaded	Carburettor	I	I	I	NR	NR	NR	NR
21711	CAMRY	1/02/90	4412	ULP	MPI	12.18	3.25	3.460	NR	NR	NR	NR
21715	FALCON EA	1/12/90	4416	ULP	TBI	0.40	0.09	0.273	NR	NR	NR	NR
21716	FALCON EA	1/12/90	4416	Petrohol	TBI	0.64	1.53	0.102	NR	NR	NR	NR
21717	COMMODORE VN	1/03/90	4418	ULP	MPI	3.80	0.99	0.479	NR	NR	NR	NR
21718	COMMODORE VN	1/03/90	4418	Petrohol	MPI	1.08	2.93	0.526	NR	NR	NR	NR
21726	FALCON ED	1/01/93	4421	Petrohol	MPI	2.69	2.40	0.318	NR	NR	NR	NR
21732	FALCON ED	1/01/93	4421	ULP	MPI	1.07	0.67	0.402	NR	NR	NR	NR
21761	COMMODORE VL	1/12/87	4423	Petrohol	MPI	5.47	11.34	1.323	NR	NR	NR	NR
21762	COMMODORE VL	1/12/87	4423	ULP	MPI	2.52	1.43	1.281	NR	NR	NR	NR
21763	FALCON EA	1/12/88	4424	Petrohol	TBI	1.49	20.77	2.029	NR	NR	NR	NR
21764	FALCON EA	1/12/88	4424	ULP	TBI	1.52	3.17	1.160	NR	NR	NR	NR
21768	FALCON EB	1/11/92	4371	Petrohol	MPI	3.67	0.85	0.399	1.74	32.39	29.41	23.85
21769	FALCON EB	1/11/92	4371	ULP	MPI	2.19	0.08	0.214	2.19	35.82	35.50	25.90

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
21770	FALCON EB	1/11/92	4371	Petrohol	MPI	I	I	I	0.55	24.64	22.81	17.80
21771	FALCON EB	1/11/92	4371	ULP	MPI	I	I	I	1.25	31.35	30.17	22.06
21776	MAGNA TR	1/09/92	4426	Petrohol	MPI	1.54	2.15	0.611	NR	NR	NR	NR
21777	MAGNA TR	1/09/92	4426	ULP	MPI	1.35	0.37	0.475	NR	NR	NR	NR
21778	COMMODORE VR	1/02/94	4367	Petrohol	MPI	2.20	1.70	0.374	0.85	4.17	6.84	6.62
21779	COMMODORE VR	1/02/94	4367	ULP	MPI	2.45	1.43	0.429	1.04	4.82	8.08	7.31
21780	COMMODORE VR	1/02/94	4367	Petrohol	MPI	4.06	3.95	0.032	I	I	I	I
21781	COMMODORE VR	1/02/94	4367	ULP	MPI	1.60	0.51	0.480	I	I	I	I
21782	CAMIRA JD	1/09/85	4422	Petrohol	MPI	27.45	15.72	2.215	NR	NR	NR	NR
21783	CAMIRA JD	1/09/85	4422	Leaded	MPI	19.87	6.30	1.214	NR	NR	NR	NR
21786	FALCON EA	1/03/90	4430	Petrohol	MPI	1.40	2.42	0.738	NR	NR	NR	NR
21787	FALCON EA	1/03/90	4430	ULP	MPI	0.75	-0.06	0.248	NR	NR	NR	NR
21788	FALCON EA	1/03/90	4430	Petrohol	MPI	1.00	I	0.273	NR	NR	NR	NR
21789	FALCON EA	1/03/90	4430	ULP	MPI	1.30	I	-0.007	NR	NR	NR	NR
21792	FALCON XE	1/09/84	4431	Petrohol	Carburettor	43.57	26.08	4.768	NR	NR	NR	NR
21793	FALCON XE	1/09/84	4431	Leaded	Carburettor	26.89	7.93	1.535	NR	NR	NR	NR
21797	APOLLO JK	1/11/95	4432	Petrohol	MPI	1.70	I	0.159	NR	NR	NR	NR
21798	APOLLO JK	1/11/95	4432	ULP	MPI	1.76	I	-0.060	NR	NR	NR	NR
21804	MAGNA TS	1/06/95	4370	Petrohol	MPI	3.34	0.96	0.508	0.40	5.25	10.10	9.30
21805	MAGNA TS	1/06/95	4370	ULP	MPI	1.89	-1.35	0.330	0.75	7.73	14.87	15.15
21806	MAGNA TS	1/06/95	4370	Petrohol	MPI	2.45	I	I	0.23	5.04	9.52	9.86
21807	MAGNA TS	1/06/95	4370	ULP	MPI	2.45	I	I	0.35	7.37	14.52	14.51
21810	LASER KA	1/03/83	4436	Petrohol	Carburettor	28.62	11.37	1.265	NR	NR	NR	NR
21811	LASER KA	1/03/83	4436	Leaded	Carburettor	24.04	4.85	0.817	NR	NR	NR	NR
21823	COROLLA	1/01/92	4379	Petrohol	MPI	1.54	0.47	-0.124	0.49	3.76	7.42	7.88
21824	COROLLA	1/01/92	4379	ULP	MPI	1.22	-0.24	0.410	0.59	4.44	7.97	9.17

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
21825	COROLLA	1/01/92	4379	Petrohol	MPI	1.34	1.03	0.373	I	3.49	6.54	6.85
21826	COROLLA	1/01/92	4379	ULP	MPI	0.61	0.33	0.508	I	4.62	8.78	8.63
21827	CAMRY	1/07/87	4438	Petrohol	MPI	17.02	11.69	2.951	NR	NR	NR	NR
21828	CAMRY	1/07/87	4438	ULP	MPI	15.19	2.81	2.663	NR	NR	NR	NR
21831	CAMRY	1/07/93	4372	Petrohol	MPI	1.22	0.17	0.296	0.59	2.15	4.67	5.03
21832	CAMRY	1/07/93	4372	ULP	MPI	2.77	-0.31	0.438	0.64	2.18	3.50	4.51
21833	CAMRY	1/07/93	4372	Petrohol	MPI	1.69	1.64	0.837	0.66	2.42	3.10	4.33
21834	CAMRY	1/07/93	4372	ULP	MPI	1.45	-3.64	-2.186	0.25	2.64	4.74	5.26
21839	SKYLINE	1/08/86	4441	Petrohol	MPI	13.72	17.61	3.219	NR	NR	NR	NR
21840	SKYLINE	1/08/86	4441	ULP	MPI	8.20	7.07	4.139	NR	NR	NR	NR
21842	MAGNA TN	1/04/88	4442	ULP	MPI	5.59	4.68	2.436	NR	NR	NR	NR
21843	MAGNA TN	1/04/88	4442	ULP	MPI	5.63	4.86	1.919	NR	NR	NR	NR
21844	MAGNA TN	1/04/88	4442	Petrohol	MPI	4.88	11.43	1.789	NR	NR	NR	NR
21845	SIGMA GH	1/06/81	4443	Petrohol	Carburettor	10.94	17.40	1.121	NR	NR	NR	NR
21846	SIGMA GH	1/06/81	4443	Leaded	Carburettor	10.27	2.62	1.064	NR	NR	NR	NR
21847	MAGNA TN	1/04/88	4442	Petrohol	MPI	7.36	10.21	1.950	NR	NR	NR	NR
21851	FALCON EB	1/10/92	4375	Petrohol	MPI	4.85	3.09	0.466	0.99	18.81	19.77	15.83
21852	FALCON EB	1/10/92	4375	ULP	MPI	2.64	0.03	0.416	1.13	22.47	21.78	17.19
21853	FALCON EB	1/10/92	4375	Petrohol	MPI	2.56	1.45	0.213	0.84	15.73	16.59	14.32
21854	FALCON EB	1/10/92	4375	ULP	MPI	2.05	1.54	0.848	1.11	24.28	26.28	21.04
21855	CAMIRA JE	1/11/87	4444	Petrohol	MPI	I	I	I	NR	NR	NR	NR
21856	CAMIRA JE	1/11/87	4444	ULP	MPI	I	I	I	NR	NR	NR	NR
21862	COMMODORE VP	1/05/92	4447	Petrohol	MPI	0.86	3.32	0.772	NR	NR	NR	NR
21863	COMMODORE VP	1/05/92	4447	ULP	MPI	1.13	0.73	0.162	NR	NR	NR	NR
21864	CAMRY	1/11/87	4448	Petrohol	MPI	7.88	22.99	3.406	NR	NR	NR	NR
21865	CAMRY	1/11/87	4448	ULP	MPI	4.80	11.17	3.424	NR	NR	NR	NR

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
21866	FALCON XF	1/12/85	4374	Petrohol	Carburettor	34.15	21.02	4.260	12.26	64.96	126.10	112.87
21867	FALCON XF	1/12/85	4374	Leaded	Carburettor	22.99	5.91	4.543	9.98	70.86	138.01	121.38
21868	FALCON XF	1/12/85	4374	Petrohol	Carburettor	33.95	18.23	1.949	14.20	51.48	95.52	81.25
21869	FALCON XF	1/12/85	4374	Leaded	Carburettor	23.47	4.51	3.791	17.30	76.52	149.65	126.96
21872	COROLLA	1/04/90	4449	Petrohol	Carburettor	5.64	1.46	0.363	NR	NR	NR	NR
21873	COROLLA	1/04/90	4449	ULP	Carburettor	3.87	1.05	-0.031	NR	NR	NR	NR
21876	LASER KF	1/01/94	4376	Petrohol	Carburettor	4.32	1.60	0.070	0.19	4.78	9.70	8.97
21877	LASER KF	1/01/94	4376	ULP	Carburettor	2.07	0.70	0.238	0.95	7.62	12.47	12.11
21878	LASER KF	1/01/94	4376	Petrohol	Carburettor	2.57	2.23	0.414	0.43	6.21	16.06	15.56
21879	LASER KF	1/01/94	4376	ULP	Carburettor	1.84	1.16	0.544	0.82	10.40	15.37	15.54
21880	COMMODORE VR	23/12/93	4450	Petrohol	MPI	1.35	1.54	-0.086	NR	NR	NR	NR
21881	COMMODORE VR	23/12/93	4450	ULP	MPI	0.75	0.75	-0.274	NR	NR	NR	NR
21884	SIGMA GK	1/02/85	4451	Petrohol	Carburettor	50.40	27.04	3.860	NR	NR	NR	NR
21885	SIGMA GK	1/02/85	4451	Leaded	Carburettor	34.37	6.33	1.304	NR	NR	NR	NR
21886	SIGMA GK	1/02/85	4451	Petrohol	Carburettor	45.02	23.67	2.375	NR	NR	NR	NR
21887	SIGMA GK	1/02/85	4451	Leaded	Carburettor	37.83	7.94	2.637	NR	NR	NR	NR
21888	COMMODORE VN	1/08/88	4452	Petrohol	MPI	4.20	1.55	-0.069	NR	NR	NR	NR
21889	COMMODORE VN	1/08/88	4452	ULP	MPI	3.94	0.29	0.083	NR	NR	NR	NR
21892	FALCON EA	1/07/88	4453	Petrohol	TBI	2.17	3.29	0.228	NR	NR	NR	NR
21893	FALCON EA	1/07/88	4453	ULP	TBI	1.04	0.70	0.306	NR	NR	NR	NR
21896	COROLLA	1/05/90	4455	Petrohol	Carburettor	3.38	2.94	1.348	NR	NR	NR	NR
21897	COROLLA	1/05/90	4455	ULP	Carburettor	2.17	1.50	0.872	NR	NR	NR	NR
21898	COROLLA	1/05/90	4455	Petrohol	Carburettor	3.32	2.72	1.315	NR	NR	NR	NR
21899	COROLLA	1/05/90	4455	ULP	Carburettor	2.19	1.42	0.917	NR	NR	NR	NR
21902	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	57.76	9.78	9.059	6.07	53.97	110.47	97.54
21903	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	79.30	31.68	6.506	5.46	45.24	92.81	78.24

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
21904	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	29.38	5.96	2.583	7.64	46.13	86.19	70.28
21905	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	39.54	18.48	3.837	6.13	38.93	69.56	58.71
21908	LASER KB	1/03/85	4456	Petrohol	Carburettor	70.61	27.78	9.637	NR	NR	NR	NR
21909	LASER KB	1/03/85	4456	Leaded	Carburettor	42.77	3.42	3.592	NR	NR	NR	NR
21914	COMMODORE VL	1/09/86	4457	Petrohol	MPI	23.02	42.59	3.798	NR	NR	NR	NR
21915	COMMODORE VL	1/09/86	4457	ULP	MPI	23.34	8.93	3.925	NR	NR	NR	NR
21916	COMMODORE VL	1/09/86	4457	Petrohol	MPI	24.77	37.83	3.917	NR	NR	NR	NR
21917	COMMODORE VL	1/09/86	4457	ULP	MPI	24.19	9.35	4.311	NR	NR	NR	NR
21918	MAGNA TN	1/07/87	4458	Petrohol	Carburettor	38.75	8.80	4.695	NR	NR	NR	NR
21919	MAGNA TN	1/07/87	4458	ULP	Carburettor	34.25	8.26	4.051	NR	NR	NR	NR
21920	COMMODORE VH	1/07/82	4459	Petrohol	Carburettor	36.47	24.40	3.705	NR	NR	NR	NR
21921	COMMODORE VH	1/07/82	4459	Leaded	Carburettor	47.87	9.34	5.621	NR	NR	NR	NR
21922	COMMODORE VH	1/07/82	4459	Petrohol	Carburettor	55.47	24.57	4.492	NR	NR	NR	NR
21923	COMMODORE VH	1/07/82	4459	Leaded	Carburettor	41.41	8.41	5.863	NR	NR	NR	NR
21928	SIGMA GN	1/01/86	4460	Petrohol	Carburettor	25.55	25.03	4.175	NR	NR	NR	NR
21929	SIGMA GN	1/01/86	4460	ULP	Carburettor	19.97	6.32	4.627	NR	NR	NR	NR
21938	COROLLA	1/07/84	4467	Petrohol	Carburettor	31.84	23.21	6.854	NR	NR	NR	NR
21939	COROLLA	1/07/84	4467	Leaded	Carburettor	27.06	8.23	5.606	NR	NR	NR	NR
21940	COROLLA	1/07/84	4467	Petrohol	Carburettor	35.06	27.33	4.891	NR	NR	NR	NR
21941	COROLLA	1/07/84	4467	Leaded	Carburettor	37.56	10.32	6.889	NR	NR	NR	NR
21944	MAGNA TR	1/12/92	4468	Petrohol	MPI	9.12	6.50	1.797	NR	NR	NR	NR
21945	MAGNA TR	1/12/92	4468	ULP	MPI	5.15	2.39	0.979	NR	NR	NR	NR
21948	COMMODORE VP	16/06/93	4469	Petrohol	MPI	2.17	1.71	0.376	NR	NR	NR	NR
21949	COMMODORE VP	16/06/93	4469	ULP	MPI	4.56	0.67	0.263	NR	NR	NR	NR
21952	CORONA	1/12/84	4470	Petrohol	Carburettor	30.75	20.68	4.761	NR	NR	NR	NR
21953	CORONA	1/12/84	4470	Leaded	Carburettor	24.01	6.75	4.083	NR	NR	NR	NR

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
21957	COMMODORE VH	1/06/83	4471	Petrohol	Carburettor	32.47	15.66	2.861	NR	NR	NR	NR
21958	COMMODORE VH	1/06/83	4471	Leaded	Carburettor	32.83	7.45	2.794	NR	NR	NR	NR
21965	FALCON EA	1/05/88	4472	Petrohol	MPI	41.72	8.59	1.765	NR	NR	NR	NR
21966	FALCON EA	1/05/88	4472	ULP	MPI	17.80	2.28	1.015	NR	NR	NR	NR
21971	MAGNA TR	1/01/92	4473	Petrohol	MPI	8.60	8.58	1.754	NR	NR	NR	NR
21972	MAGNA TR	1/01/92	4473	ULP	MPI	6.47	2.38	1.516	NR	NR	NR	NR
21977	COMMODORE VK	1/12/84	4474	Petrohol	Carburettor	52.32	36.70	5.331	NR	NR	NR	NR
21978	COMMODORE VK	1/12/84	4474	Leaded	Carburettor	45.29	11.46	5.386	NR	NR	NR	NR
21979	COMMODORE VK	1/12/84	4474	Petrohol	Carburettor	85.24	44.49	10.888	NR	NR	NR	NR
21980	COMMODORE VK	1/12/84	4474	Leaded	Carburettor	72.81	13.77	9.281	NR	NR	NR	NR
21983	FALCON XE I	1/08/83	4475	Petrohol	MPI	24.01	11.37	4.070	NR	NR	NR	NR
21984	FALCON XE I	1/08/83	4475	Leaded	MPI	57.99	10.76	6.419	NR	NR	NR	NR
21985	FALCON XE I	1/08/83	4475	Petrohol	MPI	56.61	25.43	4.245	NR	NR	NR	NR
21986	FALCON XE I	1/08/83	4475	Leaded	MPI	50.39	9.01	7.543	NR	NR	NR	NR
21988	MAGNA TN	1/06/88	4476	Petrohol	Carburettor	11.25	3.64	0.723	NR	NR	NR	NR
21989	MAGNA TN	1/06/88	4476	ULP	Carburettor	8.35	1.60	0.924	NR	NR	NR	NR
21991	FALCON EA	1/11/89	4477	Petrohol	TBI	6.00	10.70	1.810	NR	NR	NR	NR
21992	FALCON EA	1/11/89	4477	ULP	TBI	3.81	2.71	1.613	NR	NR	NR	NR
21993	FALCON EA	1/11/89	4477	Petrohol	TBI	1.21	2.87	0.470	NR	NR	NR	NR
21994	FALCON EA	1/11/89	4477	ULP	TBI	1.33	0.44	0.176	NR	NR	NR	NR
21997	FALCON XF	1/12/85	4310	Petrohol	Carburettor	21.77	28.95	3.392	NR	NR	NR	NR
21998	FALCON XF	1/12/85	4310	Leaded	Carburettor	19.16	8.04	3.232	NR	NR	NR	NR
21999	MAGNA TS	1/05/95	4365	Petrohol	MPI	5.24	2.88	0.453	0.60	15.88	24.74	20.16
22000	MAGNA TS	1/05/95	4365	ULP	MPI	2.87	0.62	1.975	0.97	19.98	31.32	29.15
22001	MAGNA TS	1/05/95	4365	Petrohol	MPI	3.10	2.63	0.646	1.52	14.89	23.54	20.57
22002	MAGNA TS	1/05/95	4365	ULP	MPI	5.35	1.07	0.538	1.12	20.37	34.71	28.03

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Exhaust (ADR 37/00 - 3 Bag Results)						
						Aldehydes			Air Toxics			
						CH_2O (mg/km)	C_2H_4O (mg/km)	C_3H_4O (mg/km)	C_4H_6 (mg/km)	C_6H_6 (mg/km)	C_7H_8 (mg/km)	C_8H_{10} (mg/km)
22005	SIGMA GH	1/05/80	4478	Petrohol	Carburettor	65.21	40.63	6.272	NR	NR	NR	NR
22006	SIGMA GH	1/05/80	4478	Leaded	Carburettor	45.52	11.52	5.931	NR	NR	NR	NR
22011	LEXCEN	11/07/95	4369	Petrohol	MPI	5.91	3.44	0.544	1.08	12.66	17.94	14.32
22012	LEXCEN	11/07/95	4369	ULP	MPI	5.00	1.39	0.743	0.71	14.96	21.56	15.69
22013	LEXCEN	11/07/95	4369	Petrohol	MPI	3.50	2.97	0.567	1.36	11.46	16.53	10.38
22014	LEXCEN	11/07/95	4369	ULP	MPI	3.72	1.77	1.470	1.60	13.64	19.22	14.45

APPENDIX 6

CSIRO
EVAPORATIVE TOXIC EMISSIONS RESULTS

Test No.	Model	Compliance Date	Vehicle Ref No.	Fuel Type	Fuel System	Evaporative											
						Air Toxics (Diurnal)				Air Toxics (Hot Soak)				Air Toxics (Total)			
						C_4H_6 (mg)	C_6H_6 (mg)	C_7H_8 (mg)	C_8H_{10} (mg)	C_4H_6 (mg)	C_6H_6 (mg)	C_7H_8 (mg)	C_8H_{10} (mg)	C_4H_6 (mg)	C_6H_6 (mg)	C_7H_8 (mg)	C_8H_{10} (mg)
21768	FALCON EB	1/11/92	4371	Petrohol	MPI	15.1	123.6	206.7	73.6	8.9	75.7	141.1	59.7	24.0	199.3	347.8	133.3
21769	FALCON EB	1/11/92	4371	ULP	MPI	13.1	153.8	191.7	75.5	6.7	72.0	113.0	47.8	19.8	225.8	304.7	123.3
21778	COMMODORE VR	1/02/94	4367	Petrohol	MPI	10.1	53.5	142.0	106.1	0.0	15.3	42.0	31.9	10.1	68.8	184.0	138.0
21779	COMMODORE VR	1/02/94	4367	ULP	MPI	ND	55.9	137.2	104.0	1.1	13.3	41.3	36.3	1.1	69.2	178.5	140.3
21823	COROLLA	1/01/92	4379	Petrohol	MPI	B	B	B	B	0.2	11.7	35.2	29.0	B	B	B	B
21824	COROLLA	1/01/92	4379	ULP	MPI	B	B	B	B	ND	5.8	19.9	16.0	B	B	B	B
21831	CAMRY	1/07/93	4372	Petrohol	MPI	B	B	B	B	0.2	13.5	38.5	29.3	B	B	B	B
21832	CAMRY	1/07/93	4372	ULP	MPI	B	B	B	B	ND	17.1	53.3	44.5	B	B	B	B
21851	FALCON EB	1/10/92	4375	Petrohol	MPI	B	B	B	B	0.7	10.1	32.5	29.3	B	B	B	B
21852	FALCON EB	1/10/92	4375	ULP	MPI	B	B	B	B	0.3	7.0	23.2	20.5	B	B	B	B
21866	FALCON XF	1/12/85	4374	Petrohol	Carburettor	ND	108.2	216.8	161.4	2.9	137.1	269.3	185.7	2.9	245.3	486.1	347.1
21867	FALCON XF	1/12/85	4374	Leaded	Carburettor	ND	49.0	113.2	93.7	2.5	96.9	230.6	169.7	2.5	145.9	343.8	263.4
21876	LASER KF	1/01/94	4376	Petrohol	Carburettor	12.4	27.6	59.3	53.5	6.2	37.5	101.8	95.3	18.6	65.1	161.1	148.8
21877	LASER KF	1/01/94	4376	ULP	Carburettor	13.9	176.6	178.0	80.2	4.4	33.4	82.1	71.6	18.3	210.0	260.1	151.8
21902	COMMODORE VH	1/09/81	4394	Leaded	Carburettor	ND	22.6	44.3	41.8	ND	204.4	510.3	463.5	ND	227.0	554.6	505.3
21903	COMMODORE VH	1/09/81	4394	Petrohol	Carburettor	ND	27.1	59.6	42.6	3.3	282.3	421.9	237.5	3.3	309.4	481.5	280.1
22012	LEXCEN	11/07/95	4369	ULP	MPI	B	B	B	B	ND	5.2	13.4	13.1	B	B	B	B

APPENDIX 7

CSIRO
OZONE FORMATION POTENTIAL
REPORT AND RESULTS

Quantifying Ozone Impacts for the Petrohol Study

A report to APACE Pty. Ltd. and the NSW Environment Protection Authority
by
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INTRODUCTION AND BACKGROUND

The formation of ground-level ozone is a serious air pollution problem. Ozone is not emitted directly, but is formed from the photochemical interactions of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x). Organic compounds differ significantly in how rapidly they react in the atmosphere and the extent to which their reactions contribute to (or inhibit) ozone formation. These differences in the effects on ozone formation are referred to as the ozone "reactivities" of the VOCs. In the past, the reactivities of different organic species have been neglected and attempts to reduce ozone formation have relied largely on reducing the overall mass emissions of the VOCs into the atmosphere (such as the introduction of catalytic converters). More recently, however, control strategies aimed at reducing the reactivity of organic emissions, in addition to reducing the overall mass emission rates, are being considered as cost-effective methods of reducing ozone formation. Various methods have been developed for ranking photochemical ozone formation reactivities of VOCs (Carter, 1994). In the regulatory arena, the Californian Air Resources Board (CARB) has adopted the Maximum Incremental Reactivity (MIR) scale for determining ozone impacts for alternatively-fuelled vehicles. It is proposed to use this scale in the evaluation of the reactivities of the exhaust and evaporative emissions analysed in the "Petrohol" project.

Reactivity Scales

The reactivity of an organic species is generally defined as the change in ozone levels in a given airshed (hydrocarbon-NO_x-air mixture) caused by a change in the emissions of that compound in the airshed. The effect of changing the emissions of a given VOC will depend on the magnitude and direction (addition or subtraction) of the emission change. Therefore, "incremental reactivity" is often used to quantify ozone impacts of VOCs. This is defined as the change in ozone caused by adding an arbitrarily small amount of the test VOC to the emissions in the pollution episode, divided by the amount of test VOC added. This could not be used to predict the effects of large changes in emissions, as might occur, for example, if all motor cars in an airshed were converted to another type of fuel. However Chang and Rudy (1990) found that incremental reactivities give good approximations to effects on ozone of alternative fuel substitution scenarios involving changes of up to 30% of the total VOC emissions. In any case, incremental reactivities will predict the direction of an initial ozone trend which results when a control strategy is being phased in.

The reactivity of an organic species will be affected not only by its atmospheric reaction rates and mechanisms, but also by the characteristics of the environment into which it is emitted. A realistic pollution episode will have dynamic injections of pollutants (organics emitted into the airshed), and time-varying changes to inversion heights, photolysis rates, temperatures, humidities, dilution rates and NO_x availabilities.

The availability of NO_x in the environment is the single most important factor affecting reactivity rankings. NO_x availability has traditionally been measured by the ratio of total emissions of reactive organic gases (ROG) to NO_x.

In general, VOCs have the largest incremental reactivities under relatively high NO_x conditions (i.e., low ROG/NO_x ratios) where the amount of ozone formed is determined by the levels of radicals produced from the reactions of VOCs. Reactivities can be much lower, and in some cases even negative, under conditions where NO_x is limited (high ROG/NO_x ratios).

The fact that incremental reactivities are so highly dependent on environmental conditions means that ***no single scale can predict reactivities***. Details of some alternative approaches to developing reactivity scales are given elsewhere (Carter, 1994) and are discussed briefly in the next section.

Reactivity Assessment and the MIR Scale

Carter (1994) discusses various methods for ranking photochemical ozone formation reactivities of VOCs. Carter (1994) used photochemical mechanisms for the atmospheric reactions of 118 VOCs to calculate their effects on ozone formation under various NO_x conditions in model scenarios (environmental conditions) representing 39 urban areas. Their effects on ozone were used to derive 18 different ozone reactivity scales, one of which is the Maximum Incremental Reactivity (MIR) scale. These scales are based on three different methods for quantifying ozone impacts and on six different approaches for dealing with the dependencies of reactivity on NO_x.

Under high NO_x conditions where VOCs have their greatest effect on ozone, which is the basis for deriving the MIR scale, the relative reactivities are not strongly affected by how ozone is quantified and are also relatively insensitive to other scenario conditions. Scales based on peak ozone levels were highly dependent on NO_x , but those based on integrated ozone were found to be less sensitive to NO_x and tended to be similar to the MIR scale.

Carter (1994) concluded that the MIR scale, or one based on integrated ozone, is appropriate for applications requiring use of a single reactivity scale.

CARB Regulations for alternatively fuelled vehicles

Despite the complexities associated with developing reactivity scales they have, nonetheless, been used in some regulatory applications. One example is the CARB regulations for "Low Emission Vehicles and Clean Fuels". In this case, non-methane organic gas (NMOG) exhaust standards for alternatively fuelled vehicles are determined using reactivity adjustment factors (RAFs). The mass emissions of exhaust from alternatively-fuelled vehicles are multiplied by these RAFs to place them on the same ozone impact basis as emissions from vehicles using conventional gasoline. The RAFs are calculated from the ratios of incremental reactivities (as grams of ozone produces per gram of NMOG emitted) for the exhaust mixtures from alternatively-fuelled vehicles, relative to that for a mixture characteristic of exhaust from vehicles using industry-average gasoline. The regulations as adopted use the Maximum Incremental Reactivity (MIR) scale to calculate these RAFs.

The MIR Scale and its assumptions (Carter, 1994)

Model Simulations: Incremental reactivities in a given scenario (set of environmental conditions) are calculated by conducting model simulations of ozone formation in the scenario and then repeating the calculations with a small amount of the test VOC added. The EKMA modelling approach was used which involves using single cell box models to simulate how ozone formation in one-day episodes is affected by changes in ROG and NO_x inputs.

Base case scenarios: Briefly, 39 urban centres in the US were selected based on geographical representativeness of ozone non-attainment areas and data availability, and a representative high ozone episode was selected for each. These were based on 1968-1988 data. Several changes to the scenario inputs were made based on consultation with CARB (see Carter (1994)).

Base ROG Mixture: The base ROG mixture is the mixture of reactive organic gases used to represent the chemical composition of the initial and emitted anthropogenic ROGs from all sources in the scenarios. The speciation of the mixture was derived from an analysis of the EPA database for the hydrocarbons (Jeffries *et al.*, 1989) and the 1987 Southern Californian Air Quality Study (SCAQS) for the oxygenates (Croes *et al.*, 1994; Lurman and Main, 1992).

Adjusted NO_x scale: Since incremental reactivities are highly dependent on NO_x and considering that NO_x conditions in the base cases are highly variable, NO_x inputs were adjusted to yield consistent NO_x conditions. In the MIR scenario case, the NO_x level is adjusted to where the ROG input has the highest incremental reactivity.

Quantification of Ozone Formation: In the MIR scale, the incremental reactivities are based on VOCs quantified on a mass basis, i.e., by the amount of ozone formed per gram of VOC added. This is the most relevant basis for control strategies concerning motor vehicles as VOCs are generally quantified by mass in the standard Federal Test Procedures.

Calculations for Vehicle Emissions

Total ozone reactivities of the exhaust or evaporative emissions are calculated by:

$$\text{g } O_3 \text{ / gNMOG emit.} = \sum_{i=1}^{n} \frac{gVOC_{(i)}}{gNMOG} X \frac{gO_3}{gVOC_{(i)} emit.} \qquad (1)$$

where VOC(i) refers to the i'th individual non-methane organic compound and n is the number of compounds in the exhaust or evaporative emissions, and "g O_3 / g VOC(i) emit." is the gram based MIR of the VOC(i). MIR values for a number of organic species are given in the Appendices. These values have been adopted by CARB and will be used in any calculations performed to estimate reactivities for the Petrohol project.

The total per-mile emissions are calculated by:

$$\text{g } O_3 \text{ / mile travelled} = \frac{\text{g NMOG}}{\text{mile travelled}} \times \frac{\text{g } O_3}{\text{g NMOG emit.}} \qquad (2)$$

The corresponding RAF for the petrohol fuel can be calculated using the following equation:

$$\text{RAF (Petrohol)} = \frac{\text{g } O_3 \text{ / gNMOG emit. (petrohol)}}{\text{g } O_3 \text{ / gNMOG emit. (standard gasoline)}} \qquad (3)$$

RESULTS AND DISCUSSION

Average mass emissions

Exhaust emissions of approximately 50 compounds (hydrocarbons and oxygenated organics) were measured during the three phases of the Australian Design Rule 37/00 (ADR 37) for 2 pre-1986 and 9 post-1986 (catalyst-equipped) vehicles. The vehicles were tested with both standard petrol and a "petrohol" mixture (nominally 10% ethanol and 90% standard petrol). The pre-1986 vehicles were fuelled with leaded petrol whereas the newer vehicles were tested using unleaded petrol. The exhaust emission measurements on the vehicles were also repeated after a period of about 12 months to look at changes due to performance deterioration during that period; on the latter occasion the vehicles were tested twice: as received and after tuning. In the attached summary of the results these three vehicle tests are reported separately as, phase 1 study (initial tests) for post tuned vehicles, phase 2 study (tests repeated after about 12 months) for pre tuned and post tuned vehicles.

Evaporative emissions were also measured, but the results for the first phase of the study were not considered accurate enough for further use and only the second phase results are included here. In addition since it was expected that vehicle tuning would not significantly affect evaporative emissions, the vehicles were only tested in the as received condition.

Hydrocarbon concentrations were determined by sampling the contents of each of the exhaust gas sampling bags which collect samples from the three phases of the ADR37 drive cycle. One background sample (of the gas used to dilute samples from the hot transient phase) was collected to determine background concentrations of hydrocarbons. Average mass emissions of each of the individual compounds during the three different phases of the ADR 37 drive cycle (as well as the average ADR 37 emissions) for the pre-1986 vehicles fuelled with leaded petrol, the pre-1986 vehicles fuelled with a petrohol mix, the post-1986 vehicles fuelled with unleaded petrol, and the post-1986 vehicles fuelled with a petrohol mix, are presented. Total amounts of non-methane organic compounds (NMOC) were calculated using these values; good agreement was observed between the CSIRO NMOC concentrations and the EPA measurements of total hydrocarbons (THCs).

In the case of the evaporative emissions a single sample was collected between the 50 - 53 minute mark of the test for the two phases (diurnal and hot soak) of the SHED tests. This methodology complicated the determination of the reactivity of the evaporative emissions significantly for two main reasons:

(1) no background sample was collected due to budgetary constraints. In the case of high emitting vehicles this presented no problem but in some cases the concentrations of hydrocarbons in the background air in the SHED immediately before the diurnal or hot soak test represented a significant fraction of the concentrations measured in the sample collected between the 50 - 53 minute mark of the test.
(2) in some cases the concentrations of total hydrocarbons (THC) measured continuously by the EPA increased substantially in the last 5 minutes of the test.

Hence for these two reasons the mass emissions calculated based on the samples collected 5 minutes before the end of the test may in some cases be under or over estimated. In order to address the first of these problems the tests were sorted into 2 groups: in the first all tests were included, and in the second only those test for which the background contributions were small compared to the contributions made during the test procedure (this was determined based on the EPA THC monitor).

Average mass emissions, so determined, of each of the individual compounds during the two different phases of the SHED tests (diurnal and hot soak phases) for the pre-1986 vehicles fuelled with leaded petrol, the pre-1986 vehicles fuelled with a petrohol mix, the post-1986 vehicles fuelled with unleaded petrol, and the post-1986 vehicles fuelled with a petrohol mix are presented for both the complete data set, and for the data with small backgrounds relative to the test contributions in order to evaluate this first problem.

In the case of the second problem the calculation of MIRs results in the determination of a factor (the reactivity adjustment factor, RAF) which can be used to compare hydrocarbon emissions on a reactivity corrected basis. The RAFs calculated are based on the composition of the emissions determined 5 minutes before the end of the tests, when total emissions have not reached their peak values. In this case the best procedure would seem to be the use of the RAFs combined with the EPA measurements of the total mass emissions of hydrocarbons (based on their THC monitor) to assess the effects of petrohol on the ozone forming potential of evaporative emissions. This is further discussed below.

Reactivity calculations

Exhaust emissions

The MIR for each identified compound, the average mass of each individual compound per total mass of NMOC emitted (mg VOC(i)/mg NMOC), the mass of ozone per mass of each individual compound emitted (mg O_3/mg VOC(i) emit.), and the percentage contribution that each species makes to the overall reactivity have been calculated for each of the four combinations of vehicle age and fuel type detailed above. Note that the average mass of each individual compound per total mass of VOC emitted (mg VOC(i)/mg Total HC) is calculated by averaging, for each test, the mass of each individual compound per total mass of total HC emitted for that test (ie by averaging the compositions), and NOT by normalising the average mass emissions. This form of average enables each test/vehicle to have an equivalent influence on the average composition calculated. In the case of normalising the average mass emissions the vehicles with higher mass emissions tend to dominate the average composition. The averaging procedure adopted was thought to be preferable in a study with a relatively small vehicle population.

In addition the results from the two phases, and for the pre and post tuned vehicles from phase 2 were combined in a variety of ways. The results for phase 1, and for phase 2 (separated into pre and post tune tests) are given in Appendix A. Note that the unidentified compounds in the vehicle exhaust and evaporative emissions are referred to as the residual hydrocarbons and generally represent between 10 and 20% of the total mass of hydrocarbons emitted. Average values were used for both the MIR and molecular weights for the residual hydrocarbon species.

Summaries of the results are presented in Tables 1-4 where the results from phase 1 and phase 2, and of the pre and post tuned results from phase 1 are combined in a variety of ways. Clearly, the reactivities (mg O_3/mg NMOC emit.) of the exhaust emissions do not vary significantly between the petrol and the petrohol fuels for either vehicle age group, or for either phase of the study, or for pre or post tuned vehicles. This is reflected in the reactivity adjustment factors (RAF) for petrohol which are close to one in all cases (1.00 ± 0.03). This is not particularly surprising as ethanol represents only 10% of the fuel.

The composition of the fuel does, however, affect the overall mass emission rates (mg NMOC emit./km). For both pre- and post-1986 vehicles, average mass emission rates per km over the ADR 37 drive cycle are about 20% lower when using petrohol compared to petrol. Thus, the lower mass emissions of ozone per km (see Tables 1-4) observed when the vehicles are fuelled with petrohol were a direct result of the lower mass emissions of NMOCs, and not a result of any significant reduction in exhaust reactivity.

Evaporative emissions

The measurement methodology adopted for the SHED tests created some complications for the MIR calculations for the evaporative emissions, as detailed above. Results for the complete data set, and for the subset of data less affected by the background concentrations at the start of the test are given in Appendix B. This data has been used to calculate RAFs for petrohol, and these are summarised in Table 5. Apart from one case the RAFs for petrohol for evaporative emissions are close to 1; exclusion of some of the data due to the background problems noted above results in a slight decrease in the RAFs (from 0.98 to 0.96 for the diurnal phase; from 0.98 to 0.92 for the hot soak phase). The one exception is for the diurnal phase of the pre-catalyst group (where RAF is 0.80; ie the specific reactivity of the evaporative emissions from the petrohol tests is significantly lower than that from the leaded petrol; however in this case only 2 vehicles were tested so this result would need to be confirmed by additional tests on more vehicles).

In the case of evaporative emissions, the total hydrocarbon concentrations calculated based on summing the concentrations of the hydrocarbon species (ΣVOC(i)) in the samples collected at the 50 - 53 minute mark of the test are significantly lower, in some cases, than the those measured by the EPA. This probably results from rapid increases in the SHED concentrations due to the opening of a fuel seal, etc. For this reason the summed concentrations (ΣVOC(i)) should not be used to evaluate the ozone forming potential of the emissions.

Instead the following approach is suggested. Mass evaporative emissions are obtained from the EPA data and corrected for reactivity effects using the RAFs presented in Table 5. As in most cases the RAFs are close to 1 the ozone potential will be largely determined by the mass emissions rather than the reactivity.

Effects of ethanol on reactivity calculations

Note that ethanol was not measured during these tests and thus the results must be treated with some caution. To perform a more comprehensive reactivity calculation, it would be ideal to have a sampling and analysis program for ethanol. However, ethanol has a fairly low MIR value of 1.34 and constitutes only 10% of the total fuel. An estimate of the likely impact of ethanol on the reactivity calculation can be made by considering the total ozone reactivities of the exhaust and evaporative emissions. For exhaust these fall in the range 3.6-4.8 mg O_3/ mg NMOC emit, and for evaporative emissions in the range from 2.5-3.6 mg O_3/ mg NMOC emit. As the specific reactivity of ethanol is significantly less than this (at 1.34 mg O_3/ mg ethanol emit) even if ethanol emissions amounted to 10% of total emissions (possible in the evaporative SHED tests, but not in the exhaust gases since ethanol will be more easily combusted and destroyed on the catalyst than most hydrocarbon species in the fuel) the effect on the calculated reactivity would be small.

Conclusions

Exhaust emissions

1. The reactivities (mg O_3/mg NMOC emit.) of the exhaust emissions do not vary significantly between the petrol and the petrohol fuels for either vehicle age group. Consequently, the reactivity adjustment factor (RAF) for petrohol is close to one for both pre- and post-1986 vehicles.

2. For both pre- and post-1986 vehicles, average mass emission rates per km over the ADR 37 drive cycle are about 20% lower when using petrohol compared to standard petrol.

3. Lower mass emissions of ozone per km were observed when the vehicles are fuelled with petrohol and are a direct result of the lower mass emissions of NMOCs, not a significant reduction in exhaust reactivity.

Evaporative emissions

1. The reactivities (mg O_3/mg NMOC emit.) of the evaporative emissions were comparable for petrol and the petrohol fuels, resulting in RAFs close to 1 (0.92-0.98, depending on the phase of the SHED test and on the data included). This result is similar to that observed for the exhaust emissions. The one exception to this observation (RAF = 0.80 for diurnal emissions from the pre-1986 vehicles) is based on results from only 2 vehicles and would need to be tested by additional tests on more vehicles.

2. Since ethanol was not measured in these tests care should be taken to consider how it may influence the results. It may be present in significant concentrations in the evaporative emissions. However given its relatively low MIR value of 1.34, and its proportion (10%) in the petrohol fuel its impact on the calculated reactivity is likely to be small.

3. The EPA measurements of the total mass of hydrocarbons in the SHED emissions should be used with the RAFs calculated for evaporative emissions to evaluate the effects of petrohol on the reactivity of the evaporative emissions.

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Exhaust Emissions Results Summary (LTIS Vehicles)

1. All Results - Phase 1 and Phase 2 Post -Tune Results

Table 1 - All Results Summary

	Pre-1986				Pre-1986				Post-1986				Post-1986			
	LP				LP Petrohol				ULP				ULP Petrohol			
	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.
mg NMOC emit. per km	1933	1699	1505	1694	1689	1273	1247	1352	649	261	248	339	567	172	214	266
mg ozone/mg NMOC emit.	4.32	4.38	4.38	4.36	4.41	4.51	4.39	4.45	4.32	3.59	3.77	3.96	4.30	3.46	3.74	3.92
mg ozone per km travelled	8283	7412	6534	7341	7436	5682	5439	5975	2788	937	930	1341	2424	596	797	1037
RAF - Pre-1986 [a]	1.02															
RAF - Post-1986 [a]	0.99															

2. Phase 1 Post-Tune Results

Table 2 - Phase 1 Post-Tune Results Summary

	Pre-1986				Pre-1986				Post-1986				Post-1986			
	LP				LP Petrohol				ULP				ULP Petrohol			
	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.
mg NMOC emit. per km	2299	1960	1785	1983	1963	1518	1445	1591	757	244	278	363	668	178	236	296
mg ozone/mg NMOC emit.	4.12	4.26	4.17	4.20	4.35	4.25	4.19	4.27	4.15	3.51	3.69	3.85	4.14	3.36	3.68	3.81
mg ozone per km travelled	9477	8343	7439	8329	8548	6460	6055	6787	3141	857	1024	1399	2768	600	869	1128
RAF - Pre-1986 [a]	1.02															
RAF - Post-1986 [a]	0.99															

3. Phase 2 Results

A. Pre-Tune Results

Table 3 - Phase 2 Pre-Tune Results Summary

	Pre-1986				Pre-1986				Post-1986				Post-1986			
	LP				LP Petrohol				ULP				ULP Petrohol			
	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.
mg NMOC emit. per km	1722	1373	1243	1410	1607	1399	1196	1386	545	206	219	280	518	166	231	257
mg ozone/mg NMOC emit.	4.62	4.73	4.61	4.67	4.60	4.65	4.60	4.62	4.48	3.73	3.87	4.10	4.47	3.82	3.93	4.03
mg ozone per km travelled	7956	6487	5725	6583	7399	6506	5497	6407	2440	769	849	1147	2313	635	908	1034
RAF - Pre-1986 [a]	0.99															
RAF - Post-1986 [a]	0.98															

[a] Based on exhaust emissions averaged over the three dynamometer phases

B. Post-Tune Results

Table 4 - Phase 2 Post -Tune Results Summary

	Pre-1986 LP				Pre-1986 LP Petrohol				Post-1986 ULP				Post-1986 ULP Petrohol			
	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.	CT	S	HT	AVG.
mg NMOC emit. per km	1567	1439	1226	1406	1414	1027	1049	1113	541	278	217	316	467	166	191	235
mg ozone/mg NMOC emit.	4.52	4.50	4.59	4.52	4.47	4.77	4.60	4.64	4.50	3.66	3.85	4.07	4.46	3.57	3.79	4.02
mg ozone per km travelled	7089	6480	5628	6354	6323	4904	4822	5163	2436	1018	835	1284	2080	593	726	945
RAF - Pre-1986 [a]	1.03															
RAF - Post-1986 [a]	0.99															

[a] Based on exhaust emissions averaged over the three dynamometer phases

Evaporative Emissions Results Summary (LTIS Vehicles)

1. Phase 2 Pre-Tune Results

Table 5 - Phase 2 Pre-Tune Reactivity Adjustment Factors

SHED Phase	Vehicles	RAF All data included	RAF Data with significant background contribution excluded
Diurnal	Pre 1986	0.80	0.80
	Post 1986	0.98	0.96
Hot soak	Pre 1986	0.95	0.95
	Post 1986	0.98	0.92

APPENDIX A

MIR CALCULATIONS OF EXHAUST EMISSIONS

PETROHOL STUDY

Appendix A1
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	841.31			
ethane	0.25	142.81	0.013	0.003	0.077
ethylene	7.40	1074.47	0.101	0.750	17.208
acetylene	0.50	566.30	0.050	0.025	0.580
propane	0.48	25.59	0.003	0.001	0.028
propylene	9.40	486.44	0.046	0.436	10.005
i-butane	1.21	136.33	0.013	0.015	0.354
n-butane	1.02	266.94	0.023	0.023	0.545
trans-2-butene	10.00	74.69	0.007	0.072	1.656
cis-2-butene	10.00	51.96	0.005	0.047	1.101
C4 olefins !	9.02	246.13	0.023	0.204	4.733
i-pentane	1.38	452.85	0.041	0.057	1.313
1-pentene	6.20	34.55	0.003	0.020	0.462
n-pentane	1.04	203.92	0.018	0.019	0.434
trans-2-pentene	8.80	53.70	0.005	0.043	0.993
cis-2-pentene	8.80	35.25	0.003	0.029	0.675
2-methyl-2-butene	6.40	42.52	0.004	0.027	0.606
2,3-dimethylbutane	1.07	58.96	0.005	0.006	0.132
2-methylpentane	1.50	230.53	0.020	0.031	0.714
3-methylpentane	1.50	162.10	0.014	0.021	0.498
1-hexene	4.40	34.98	0.003	0.014	0.325
n-hexane	0.98	141.40	0.012	0.012	0.283
C5 and C6 olefins !	6.82	78.14	0.007	0.046	1.073
methylcyclopentane	2.80	93.42	0.008	0.023	0.535
benzene	0.42	538.42	0.047	0.020	0.460
2-methylhexane	1.08	150.84	0.013	0.014	0.324
3-methylhexane	1.40	119.72	0.010	0.014	0.337
2,2,4-trimethylpentane	0.93	98.86	0.008	0.008	0.182
n-heptane	0.81	60.53	0.005	0.004	0.089
C8 alkanes !	1.19	216.19	0.019	0.022	0.520
toluene	2.70	1197.70	0.103	0.279	6.493
n-octane	0.60	51.34	0.004	0.003	0.059
ethylbenzene	2.70	223.76	0.019	0.052	1.215
m,p-xylenes !	7.40	931.48	0.082	0.605	14.005
styrene	2.20	52.22	0.004	0.009	0.219
o-xylene	6.50	273.76	0.023	0.151	3.527
n-nonane	0.54	20.87	0.002	0.001	0.024
n-propylbenzene	2.10	44.64	0.004	0.008	0.191
m,p-ethyltoluenes	6.50	222.74	0.019	0.122	2.833
1,3,5-trimethylbenzene	10.10	77.46	0.007	0.068	1.572
o-ethyltoluene	6.50	57.73	0.005	0.033	0.754
1,2,4-trimethylbenzene	8.80	218.69	0.019	0.165	3.825
C10 aromatics+aliphatics	6.50	175.40	0.016	0.102	2.340
formaldehyde	7.20	142.51	0.014	0.101	2.329
acetaldehyde	5.50	43.64	0.004	0.023	0.538
acrolein (2-propenal)	6.50	14.28	0.001	0.009	0.212
Residual hydrocarbons	4.11	1622.65	0.142	0.586	13.620
Sum		11249.41		4.32	
Sum/ phase distance (km)		1933			
mg NMOC emit. per km					1933
mg ozone/mg NMOC emit.					4.32
mg ozone per km travelled					**8283**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A2
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	808.31			
ethane	0.25	168.48	0.018	0.004	0.099
ethylene	7.40	1204.47	0.117	0.865	19.682
acetylene	0.50	785.73	0.070	0.035	0.796
propane	0.48	18.14	0.002	0.001	0.019
propylene	9.40	543.02	0.054	0.506	11.491
i-butane	1.21	103.42	0.010	0.012	0.271
n-butane	1.02	237.36	0.021	0.022	0.497
trans-2-butene	10.00	69.14	0.007	0.072	1.630
cis-2-butene	10.00	49.26	0.005	0.048	1.105
C4 olefins !	9.02	226.89	0.022	0.200	4.579
i-pentane	1.38	338.40	0.033	0.045	1.029
1-pentene	6.20	33.00	0.003	0.021	0.480
n-pentane	1.04	168.73	0.016	0.017	0.385
trans-2-pentene	8.80	48.33	0.005	0.042	0.951
cis-2-pentene	8.80	25.07	0.003	0.022	0.504
2-methyl-2-butene	6.40	41.51	0.004	0.028	0.638
2,3-dimethylbutane	1.07	46.60	0.004	0.005	0.103
2-methylpentane	1.50	166.99	0.016	0.024	0.541
3-methylpentane	1.50	121.82	0.012	0.017	0.397
1-hexene	4.40	37.53	0.004	0.016	0.360
n-hexane	0.98	108.06	0.010	0.010	0.226
C5 and C6 olefins !	6.82	106.44	0.010	0.069	1.561
methylcyclopentane	2.80	70.30	0.007	0.019	0.425
benzene	0.42	567.87	0.052	0.022	0.498
2-methylhexane	1.08	119.52	0.011	0.012	0.271
3-methylhexane	1.40	89.07	0.008	0.012	0.266
2,2,4-trimethylpentane	0.93	73.05	0.007	0.006	0.144
n-heptane	0.81	102.46	0.009	0.007	0.165
C8 alkanes !	1.19	171.50	0.016	0.019	0.438
toluene	2.70	1102.94	0.101	0.273	6.269
n-octane	0.60	31.74	0.003	0.002	0.040
ethylbenzene	2.70	195.14	0.019	0.050	1.149
m,p-xylenes !	7.40	810.61	0.077	0.566	12.936
styrene	2.20	68.07	0.006	0.014	0.316
o-xylene	6.50	196.96	0.018	0.119	2.743
n-nonane	0.54	14.45	0.001	0.001	0.018
n-propylbenzene	2.10	24.26	0.002	0.005	0.108
m,p-ethyltoluenes	6.50	174.06	0.016	0.105	2.422
1,3,5-trimethylbenzene	10.10	60.21	0.006	0.057	1.319
o-ethyltoluene	6.50	90.13	0.008	0.054	1.222
1,2,4-trimethylbenzene	8.80	173.77	0.016	0.143	3.285
C10 aromatics+aliphatics	6.50	186.12	0.018	0.116	2.633
formaldehyde	7.20	162.83	0.018	0.128	2.909
acetaldehyde	5.50	37.43	0.004	0.022	0.496
acrolein (2-propenal)	6.50	13.17	0.001	0.009	0.206
Residual hydrocarbons	4.11	1301.06	0.131	0.540	12.379
Sum		10485.09		4.38	
Sum/ phase distance (km)		1699			
mg NMOC emit. per km					1699
mg ozone/mg NMOC emit.					4.38
mg ozone per km travelled					**7412**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A3
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	613.77			
ethane	0.25	134.83	0.014	0.003	0.079
ethylene	7.40	1051.33	0.114	0.844	19.147
acetylene	0.50	516.38	0.054	0.027	0.609
propane	0.48	23.67	0.002	0.001	0.026
propylene	9.40	456.04	0.051	0.475	10.783
i-butane	1.21	115.28	0.013	0.016	0.375
n-butane	1.02	225.93	0.025	0.026	0.595
trans-2-butene	10.00	62.24	0.008	0.083	1.868
cis-2-butene	10.00	35.28	0.005	0.053	1.192
C4 olefins !	9.02	181.20	0.020	0.179	4.081
i-pentane	1.38	368.26	0.043	0.059	1.356
1-pentene	6.20	25.23	0.003	0.021	0.488
n-pentane	1.04	154.97	0.018	0.019	0.437
trans-2-pentene	8.80	38.73	0.005	0.043	0.984
cis-2-pentene	8.80	33.09	0.004	0.036	0.841
2-methyl-2-butene	6.40	45.53	0.006	0.037	0.837
2,3-dimethylbutane	1.07	40.94	0.004	0.004	0.095
2-methylpentane	1.50	170.22	0.019	0.028	0.643
3-methylpentane	1.50	118.13	0.013	0.020	0.452
1-hexene	4.40	19.94	0.002	0.011	0.247
n-hexane	0.98	102.98	0.011	0.011	0.252
C5 and C6 olefins !	6.82	48.74	0.006	0.039	0.899
methylcyclopentane	2.80	67.74	0.007	0.021	0.474
benzene	0.42	462.12	0.049	0.021	0.476
2-methylhexane	1.08	111.59	0.012	0.013	0.299
3-methylhexane	1.40	82.34	0.009	0.012	0.285
2,2,4-trimethylpentane	0.93	63.24	0.007	0.006	0.145
n-heptane	0.81	38.40	0.004	0.003	0.074
C8 alkanes !	1.19	146.56	0.016	0.019	0.445
toluene	2.70	934.36	0.097	0.263	6.049
n-octane	0.60	32.33	0.003	0.002	0.046
ethylbenzene	2.70	164.07	0.017	0.047	1.075
m,p-xylenes !	7.40	683.28	0.072	0.531	12.129
styrene	2.20	44.63	0.004	0.009	0.208
o-xylene	6.50	197.81	0.020	0.133	3.060
n-nonane	0.54	14.80	0.002	0.001	0.019
n-propylbenzene	2.10	28.67	0.003	0.006	0.143
m,p-ethyltoluenes	6.50	169.22	0.017	0.114	2.634
1,3,5-trimethylbenzene	10.10	56.40	0.006	0.059	1.348
o-ethyltoluene	6.50	43.19	0.004	0.029	0.669
1,2,4-trimethylbenzene	8.80	174.81	0.018	0.154	3.538
C10 aromatics+aliphatics	6.50	203.26	0.022	0.140	3.247
formaldehyde	7.20	133.45	0.018	0.129	2.929
acetaldehyde	5.50	37.49	0.005	0.027	0.613
acrolein (2-propenal)	6.50	11.53	0.002	0.010	0.226
Residual hydrocarbons	4.11	1206.28	0.145	0.596	13.581
Sum		9076.55		4.38	
Sum/ phase distance (km)		1505			
mg NMOC emit. per km					1505
mg ozone/mg NMOC emit.					4.38
mg ozone per km travelled					**6534**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A4
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted Average VOC(i) emit. (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	1474.25			
ethane	0.25	296.54	0.016	0.004	0.088
ethylene	7.40	2212.26	0.113	0.834	19.027
acetylene	0.50	1293.20	0.063	0.031	0.715
propane	0.48	40.66	0.002	0.001	0.023
propylene	9.40	991.73	0.051	0.483	11.013
i-butane	1.21	228.24	0.011	0.014	0.320
n-butane	1.02	481.61	0.023	0.023	0.536
trans-2-butene	10.00	138.86	0.007	0.075	1.700
cis-2-butene	10.00	95.67	0.005	0.050	1.134
C4 olefins !	9.02	430.39	0.022	0.195	4.481
i-pentane	1.38	743.58	0.037	0.051	1.182
1-pentene	6.20	63.99	0.003	0.021	0.480
n-pentane	1.04	347.91	0.017	0.018	0.410
trans-2-pentene	8.80	94.99	0.005	0.043	0.975
cis-2-pentene	8.80	60.26	0.003	0.028	0.636
2-methyl-2-butene	6.40	87.37	0.005	0.030	0.679
2,3-dimethylbutane	1.07	92.05	0.004	0.005	0.109
2-methylpentane	1.50	359.59	0.018	0.026	0.609
3-methylpentane	1.50	256.87	0.013	0.019	0.436
1-hexene	4.40	64.51	0.003	0.014	0.328
n-hexane	0.98	225.38	0.011	0.011	0.246
C5 and C6 olefins !	6.82	168.31	0.008	0.057	1.301
methylcyclopentane	2.80	147.39	0.007	0.020	0.464
benzene	0.42	1049.87	0.050	0.021	0.485
2-methylhexane	1.08	245.30	0.012	0.013	0.292
3-methylhexane	1.40	185.44	0.009	0.012	0.288
2,2,4-trimethylpentane	0.93	150.46	0.007	0.007	0.153
n-heptane	0.81	150.54	0.007	0.006	0.128
C8 alkanes !	1.19	345.30	0.017	0.020	0.460
toluene	2.70	2115.81	0.101	0.271	6.265
n-octane	0.60	70.95	0.003	0.002	0.046
ethylbenzene	2.70	379.23	0.018	0.050	1.144
m,p-xylenes !	7.40	1569.25	0.076	0.565	12.976
styrene	2.20	112.60	0.005	0.011	0.263
o-xylene	6.50	419.67	0.020	0.129	2.984
n-nonane	0.54	30.95	0.002	0.001	0.019
n-propylbenzene	2.10	58.29	0.003	0.006	0.136
m,p-ethyltoluenes	6.50	361.32	0.017	0.110	2.561
1,3,5-trimethylbenzene	10.10	123.01	0.006	0.060	1.375
o-ethyltoluene	6.50	137.78	0.007	0.044	0.994
1,2,4-trimethylbenzene	8.80	358.10	0.017	0.149	3.432
C10 aromatics+aliphatics	6.50	369.05	0.018	0.120	2.741
formaldehyde	7.20	306.22	0.017	0.121	2.769
acetaldehyde	5.50	79.08	0.004	0.023	0.535
acrolein (2-propenal)	6.50	26.06	0.001	0.010	0.213
Residual hydrocarbons	4.11	2696.11	0.136	0.558	12.847
Sum		20261.76		4.36	
Sum/ Total cycle distance (km)		1694			
mg NMOC emit. per km					1694
mg ozone/mg NMOC emit.					4.36
mg ozone per km travelled					**7341**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A5
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrohol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	617.19			
ethane	0.25	105.08	0.011	0.003	0.064
ethylene	7.40	964.49	0.100	0.742	17.158
acetylene	0.50	522.28	0.060	0.030	0.694
propane	0.48	40.68	0.003	0.001	0.034
propylene	9.40	455.32	0.045	0.422	9.768
i-butane	1.21	157.04	0.014	0.017	0.401
n-butane	1.02	267.56	0.024	0.025	0.579
trans-2-butene	10.00	74.48	0.008	0.079	1.815
cis-2-butene	10.00	54.99	0.006	0.058	1.337
C4 olefins !	9.02	207.80	0.023	0.204	4.762
i-pentane	1.38	429.29	0.042	0.058	1.340
1-pentene	6.20	33.60	0.003	0.021	0.491
n-pentane	1.04	182.74	0.018	0.018	0.432
trans-2-pentene	8.80	50.41	0.005	0.044	1.022
cis-2-pentene	8.80	30.14	0.003	0.029	0.692
2-methyl-2-butene	6.40	33.24	0.004	0.026	0.606
2,3-dimethylbutane	1.07	50.40	0.005	0.006	0.131
2-methylpentane	1.50	131.17	0.020	0.030	0.700
3-methylpentane	1.50	135.13	0.014	0.021	0.489
1-hexene	4.40	33.71	0.003	0.014	0.329
n-hexane	0.98	114.90	0.012	0.012	0.274
C5 and C6 olefins !	6.82	63.36	0.007	0.046	1.083
methylcyclopentane	2.80	74.71	0.008	0.022	0.519
benzene	0.42	277.86	0.046	0.019	0.450
2-methylhexane	1.08	81.44	0.012	0.013	0.313
3-methylhexane	1.40	94.85	0.010	0.014	0.326
2,2,4-trimethylpentane	0.93	79.19	0.008	0.008	0.179
n-heptane	0.81	47.00	0.005	0.004	0.089
C8 alkanes !	1.19	185.18	0.018	0.022	0.510
toluene	2.70	895.81	0.098	0.264	6.194
n-octane	0.60	41.40	0.004	0.002	0.057
ethylbenzene	2.70	171.81	0.018	0.050	1.168
m,p-xylenes !	7.40	709.77	0.077	0.568	13.249
styrene	2.20	41.69	0.004	0.009	0.218
o-xylene	6.50	211.02	0.022	0.144	3.371
n-nonane	0.54	16.57	0.002	0.001	0.022
n-propylbenzene	2.10	36.66	0.004	0.008	0.183
m,p-ethyltoluenes	6.50	192.56	0.018	0.116	2.704
1,3,5-trimethylbenzene	10.10	61.11	0.006	0.063	1.478
o-ethyltoluene	6.50	47.01	0.005	0.031	0.718
1,2,4-trimethylbenzene	8.80	172.29	0.018	0.155	3.623
C10 aromatics+aliphatics	6.50	154.93	0.015	0.096	2.229
formaldehyde	7.20	190.90	0.018	0.127	2.926
acetaldehyde	5.50	147.00	0.010	0.055	1.256
acrolein (2-propenal)	6.50	21.77	0.002	0.011	0.244
Residual hydrocarbons	4.11	1664.77	0.143	0.590	13.774
Sum		9755.05		4.41	
Sum/ phase distance (km)		1689			
mg NMOC emit. per km					1689
mg ozone/mg NMOC emit.					4.41
mg ozone per km travelled					**7436**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A6
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrohol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	447.03			
ethane	0.25	95.81	0.013	0.003	0.070
ethylene	7.40	804.45	0.107	0.795	17.414
acetylene	0.50	351.21	0.045	0.022	0.489
propane	0.48	17.48	0.002	0.001	0.024
propylene	9.40	354.81	0.048	0.448	9.829
i-butane	1.21	87.60	0.011	0.013	0.290
n-butane	1.02	195.15	0.023	0.023	0.532
trans-2-butene	10.00	60.77	0.008	0.082	1.788
cis-2-butene	10.00	33.87	0.004	0.043	0.958
C4 olefins !	9.02	172.21	0.022	0.198	4.412
i-pentane	1.38	290.42	0.036	0.050	1.109
1-pentene	6.20	28.45	0.004	0.024	0.532
n-pentane	1.04	124.74	0.015	0.015	0.347
trans-2-pentene	8.80	35.22	0.004	0.039	0.874
cis-2-pentene	8.80	18.62	0.002	0.021	0.463
2-methyl-2-butene	6.40	34.45	0.005	0.030	0.654
2,3-dimethylbutane	1.07	34.03	0.004	0.005	0.101
2-methylpentane	1.50	134.82	0.016	0.024	0.546
3-methylpentane	1.50	97.97	0.012	0.018	0.398
1-hexene	4.40	23.74	0.003	0.013	0.286
n-hexane	0.98	83.27	0.010	0.010	0.221
C5 and C6 olefins !	6.82	61.02	0.007	0.051	1.135
methylcyclopentane	2.80	51.16	0.006	0.017	0.389
benzene	0.42	368.63	0.045	0.019	0.425
2-methylhexane	1.08	81.99	0.010	0.011	0.242
3-methylhexane	1.40	66.97	0.008	0.011	0.251
2,2,4-trimethylpentane	0.93	57.27	0.007	0.006	0.142
n-heptane	0.81	35.53	0.004	0.003	0.072
C8 alkanes !	1.19	138.20	0.017	0.020	0.451
toluene	2.70	761.48	0.093	0.251	5.626
n-octane	0.60	29.56	0.003	0.002	0.047
ethylbenzene	2.70	144.06	0.018	0.048	1.073
m,p-xylenes !	7.40	563.08	0.071	0.523	11.618
styrene	2.20	56.52	0.007	0.016	0.348
o-xylene	6.50	166.40	0.020	0.132	2.955
n-nonane	0.54	13.09	0.002	0.001	0.020
n-propylbenzene	2.10	26.91	0.003	0.007	0.157
m,p-ethyltoluenes	6.50	162.44	0.020	0.130	2.910
1,3,5-trimethylbenzene	10.10	49.55	0.006	0.062	1.376
o-ethyltoluene	6.50	39.54	0.005	0.032	0.707
1,2,4-trimethylbenzene	8.80	161.34	0.020	0.175	3.894
C10 aromatics+aliphatics	6.50	148.34	0.019	0.123	2.706
formaldehyde	7.20	201.92	0.028	0.204	4.443
acetaldehyde	5.50	129.25	0.017	0.091	2.022
acrolein (2-propenal)	6.50	21.49	0.003	0.019	0.415
Residual hydrocarbons	4.11	1323.83	0.167	0.685	15.241
Sum		7938.64		4.51	
Sum/ phase distance (km)		1273			
mg NMOC emit. per km					1273
mg ozone/mg NMOC emit.					4.51
mg ozone per km travelled					**5682**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A7
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrohol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	333.51			
ethane	0.25	76.65	0.011	0.003	0.062
ethylene	7.40	737.82	0.106	0.786	17.775
acetylene	0.50	269.99	0.038	0.019	0.428
propane	0.48	16.21	0.002	0.001	0.026
propylene	9.40	309.64	0.045	0.423	9.556
i-butane	1.21	117.04	0.016	0.020	0.455
n-butane	1.02	205.59	0.028	0.029	0.659
trans-2-butene	10.00	62.50	0.009	0.092	2.066
cis-2-butene	10.00	50.85	0.008	0.076	1.706
C4 olefins !	9.02	158.23	0.022	0.198	4.523
i-pentane	1.38	332.24	0.046	0.064	1.464
1-pentene	6.20	26.30	0.004	0.024	0.535
n-pentane	1.04	136.84	0.018	0.019	0.442
trans-2-pentene	8.80	38.45	0.005	0.047	1.080
cis-2-pentene	8.80	23.30	0.003	0.028	0.650
2-methyl-2-butene	6.40	30.75	0.005	0.029	0.656
2,3-dimethylbutane	1.07	38.33	0.005	0.006	0.129
2-methylpentane	1.50	139.03	0.019	0.028	0.654
3-methylpentane	1.50	95.13	0.013	0.019	0.443
1-hexene	4.40	23.12	0.003	0.014	0.316
n-hexane	0.98	88.29	0.012	0.012	0.274
C5 and C6 olefins !	6.82	40.65	0.005	0.036	0.835
methylcyclopentane	2.80	52.63	0.007	0.020	0.458
benzene	0.42	342.23	0.046	0.019	0.445
2-methylhexane	1.08	77.70	0.011	0.011	0.262
3-methylhexane	1.40	61.82	0.008	0.011	0.264
2,2,4-trimethylpentane	0.93	64.13	0.009	0.008	0.185
n-heptane	0.81	57.45	0.008	0.007	0.152
C8 alkanes !	1.19	105.60	0.014	0.017	0.394
toluene	2.70	639.91	0.085	0.231	5.312
n-octane	0.60	27.46	0.004	0.002	0.051
ethylbenzene	2.70	116.34	0.016	0.042	0.969
m,p-xylenes !	7.40	446.44	0.061	0.450	10.307
styrene	2.20	34.75	0.005	0.010	0.237
o-xylene	6.50	137.54	0.018	0.119	2.737
n-nonane	0.54	11.04	0.002	0.001	0.019
n-propylbenzene	2.10	22.00	0.003	0.006	0.145
m,p-ethyltoluenes	6.50	131.28	0.017	0.113	2.612
1,3,5-trimethylbenzene	10.10	40.44	0.005	0.055	1.261
o-ethyltoluene	6.50	31.93	0.004	0.028	0.643
1,2,4-trimethylbenzene	8.80	120.46	0.016	0.142	3.269
C10 aromatics+aliphatics	6.50	125.44	0.017	0.113	2.572
formaldehyde	7.20	194.24	0.028	0.205	4.618
acetaldehyde	5.50	122.33	0.017	0.094	2.149
acrolein (2-propenal)	6.50	21.35	0.003	0.020	0.455
Residual hydrocarbons	4.11	1208.43	0.169	0.696	15.750
Sum		7209.88		4.39	
Sum/ phase distance (km)		1247			
mg NMOC emit. per km					1247
mg ozone/mg NMOC emit.					4.39
mg ozone per km travelled					**5439**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A8
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Pre-1986 vehicles with leaded petrohol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted			% Contribution
		Average	Average [a]	mg Ozone per	
		VOC(i) emit.	mg VOC(i) per	mg VOC(i) emit.	
		(mg)	mg NMOC		
methane	0.02	902.52			
ethane	0.25	184.68	0.012	0.003	0.066
ethylene	7.40	1639.74	0.106	0.786	17.525
acetylene	0.50	729.68	0.046	0.023	0.515
propane	0.48	44.21	0.003	0.001	0.031
propylene	9.40	727.09	0.047	0.445	9.930
i-butane	1.21	221.84	0.014	0.017	0.375
n-butane	1.02	427.39	0.025	0.026	0.590
trans-2-butene	10.00	128.42	0.008	0.084	1.868
cis-2-butene	10.00	86.50	0.006	0.056	1.244
C4 olefins !	9.02	351.76	0.022	0.197	4.440
i-pentane	1.38	664.38	0.041	0.056	1.273
1-pentene	6.20	57.89	0.004	0.023	0.521
n-pentane	1.04	281.32	0.017	0.017	0.393
trans-2-pentene	8.80	78.81	0.005	0.043	0.966
cis-2-pentene	8.80	44.86	0.003	0.024	0.549
2-methyl-2-butene	6.40	66.27	0.004	0.028	0.626
2,3-dimethylbutane	1.07	77.55	0.005	0.005	0.114
2-methylpentane	1.50	270.46	0.017	0.025	0.560
3-methylpentane	1.50	210.30	0.013	0.019	0.427
1-hexene	4.40	51.41	0.003	0.013	0.306
n-hexane	0.98	183.00	0.011	0.011	0.244
C5 and C6 olefins !	6.82	111.43	0.007	0.045	1.023
methylcyclopentane	2.80	113.28	0.007	0.019	0.430
benzene	0.42	683.18	0.042	0.018	0.396
2-methylhexane	1.08	161.29	0.010	0.011	0.241
3-methylhexane	1.40	142.99	0.008	0.012	0.266
2,2,4-trimethylpentane	0.93	127.88	0.007	0.007	0.159
n-heptane	0.81	88.48	0.005	0.004	0.094
C8 alkanes !	1.19	278.02	0.017	0.020	0.448
toluene	2.70	1511.42	0.090	0.243	5.508
n-octane	0.60	63.01	0.004	0.002	0.050
ethylbenzene	2.70	284.26	0.017	0.046	1.039
m,p-xylenes !	7.40	1122.75	0.068	0.507	11.400
styrene	2.20	94.26	0.006	0.013	0.283
o-xylene	6.50	335.54	0.020	0.129	2.929
n-nonane	0.54	26.51	0.002	0.001	0.020
n-propylbenzene	2.10	55.21	0.003	0.007	0.159
m,p-ethyltoluenes	6.50	320.07	0.019	0.123	2.800
1,3,5-trimethylbenzene	10.10	98.88	0.006	0.060	1.352
o-ethyltoluene	6.50	77.95	0.005	0.030	0.686
1,2,4-trimethylbenzene	8.80	304.09	0.018	0.160	3.612
C10 aromatics+aliphatics	6.50	286.46	0.018	0.115	2.578
formaldehyde	7.20	394.72	0.026	0.189	4.196
acetaldehyde	5.50	262.18	0.016	0.090	2.024
acrolein (2-propenal)	6.50	43.02	0.003	0.018	0.406
Residual hydrocarbons	4.11	2728.49	0.166	0.681	15.340
Sum		16242.94		4.45	
Sum/ Total cycle distance (km)		1352			
mg NMOC emit. per km					1352
mg ozone/mg NMOC emit.					4.45
mg ozone per km travelled					**5975**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A9
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	377.73			
ethane	0.25	63.06	0.018	0.004	0.102
ethylene	7.40	327.77	0.089	0.656	15.091
acetylene	0.50	52.64	0.015	0.007	0.167
propane	0.48	7.17	0.002	0.001	0.022
propylene	9.40	140.14	0.039	0.370	8.524
i-butane	1.21	45.88	0.012	0.014	0.331
n-butane	1.02	84.24	0.021	0.022	0.511
trans-2-butene	10.00	24.02	0.006	0.064	1.490
cis-2-butene	10.00	23.93	0.006	0.062	1.423
C4 olefins !	9.02	93.33	0.025	0.223	5.179
i-pentane	1.38	162.73	0.042	0.057	1.333
1-pentene	6.20	14.01	0.004	0.025	0.572
n-pentane	1.04	92.06	0.023	0.024	0.558
trans-2-pentene	8.80	18.43	0.005	0.042	0.986
cis-2-pentene	8.80	11.02	0.003	0.025	0.592
2-methyl-2-butene	6.40	17.89	0.005	0.032	0.733
2,3-dimethylbutane	1.07	21.29	0.005	0.006	0.136
2-methylpentane	1.50	82.19	0.021	0.031	0.726
3-methylpentane	1.50	55.92	0.014	0.021	0.498
1-hexene	4.40	12.09	0.003	0.014	0.331
n-hexane	0.98	51.11	0.013	0.013	0.296
C5 and C6 olefins !	6.82	32.39	0.009	0.059	1.382
methylcyclopentane	2.80	32.76	0.008	0.024	0.548
benzene	0.42	197.60	0.050	0.021	0.486
2-methylhexane	1.08	48.87	0.013	0.014	0.313
3-methylhexane	1.40	38.67	0.010	0.014	0.319
2,2,4-trimethylpentane	0.93	64.69	0.017	0.016	0.363
n-heptane	0.81	22.76	0.005	0.004	0.102
C8 alkanes !	1.19	88.16	0.024	0.028	0.651
toluene	2.70	343.55	0.090	0.243	5.631
n-octane	0.60	17.84	0.005	0.003	0.064
ethylbenzene	2.70	68.03	0.018	0.048	1.122
m,p-xylenes !	7.40	259.91	0.071	0.524	12.105
styrene	2.20	15.12	0.004	0.009	0.211
o-xylene	6.50	90.23	0.024	0.153	3.561
n-nonane	0.54	6.14	0.002	0.001	0.022
n-propylbenzene	2.10	11.27	0.003	0.007	0.151
m,p-ethyltoluenes	6.50	69.31	0.018	0.119	2.761
1,3,5-trimethylbenzene	10.10	26.17	0.007	0.071	1.635
o-ethyltoluene	6.50	19.77	0.005	0.034	0.796
1,2,4-trimethylbenzene	8.80	80.52	0.022	0.192	4.431
C10 aromatics+aliphatics	6.50	82.46	0.023	0.148	3.404
formaldehyde	7.20	32.94	0.010	0.071	1.644
acetaldehyde	5.50	14.94	0.005	0.025	0.576
acrolein (2-propenal)	6.50	5.11	0.002	0.012	0.276
Residual hydrocarbons	4.11	679.38	0.187	0.769	17.845
Sum		3749.50		4.32	
Sum/ phase distance (km)		649			
mg NMOC emit. per km					649
mg ozone/mg NMOC emit.					4.32
mg ozone per km travelled					**2788**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A10
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	324.75			
ethane	0.25	34.66	0.024	0.006	0.168
ethylene	7.40	77.16	0.038	0.278	7.735
acetylene	0.50	19.32	0.013	0.006	0.174
propane	0.48	3.65	0.002	0.001	0.030
propylene	9.40	21.68	0.011	0.104	2.893
i-butane	1.21	28.94	0.020	0.024	0.661
n-butane	1.02	41.96	0.028	0.028	0.789
trans-2-butene	10.00	6.72	0.005	0.052	1.445
cis-2-butene	10.00	7.16	0.006	0.058	1.619
C4 olefins !	9.02	21.21	0.012	0.107	2.978
i-pentane	1.38	73.13	0.047	0.065	1.827
1-pentene	6.20	3.23	0.003	0.020	0.554
n-pentane	1.04	37.72	0.025	0.026	0.714
trans-2-pentene	8.80	3.87	0.003	0.024	0.679
cis-2-pentene	8.80	2.80	0.003	0.023	0.641
2-methyl-2-butene	6.40	6.70	0.005	0.033	0.920
2,3-dimethylbutane	1.07	9.95	0.007	0.007	0.209
2-methylpentane	1.50	31.02	0.020	0.030	0.853
3-methylpentane	1.50	20.86	0.014	0.020	0.573
1-hexene	4.40	3.70	0.004	0.016	0.447
n-hexane	0.98	20.23	0.013	0.013	0.366
C5 and C6 olefins !	6.82	8.50	0.007	0.047	1.314
methylcyclopentane	2.80	11.97	0.009	0.024	0.682
benzene	0.42	93.22	0.050	0.021	0.587
2-methylhexane	1.08	17.93	0.012	0.013	0.364
3-methylhexane	1.40	12.98	0.009	0.012	0.335
2,2,4-trimethylpentane	0.93	24.14	0.016	0.015	0.419
n-heptane	0.81	35.56	0.031	0.025	0.698
C8 alkanes !	1.19	41.99	0.032	0.038	1.071
toluene	2.70	87.31	0.053	0.142	3.974
n-octane	0.60	7.26	0.006	0.003	0.094
ethylbenzene	2.70	15.81	0.011	0.029	0.808
m,p-xylenes !	7.40	55.34	0.035	0.261	7.304
styrene	2.20	4.96	0.003	0.007	0.201
o-xylene	6.50	21.11	0.014	0.091	2.533
n-nonane	0.54	3.15	0.003	0.001	0.039
n-propylbenzene	2.10	2.51	0.002	0.004	0.116
m,p-ethyltoluenes	6.50	15.04	0.011	0.074	2.060
1,3,5-trimethylbenzene	10.10	6.73	0.005	0.053	1.496
o-ethyltoluene	6.50	4.35	0.003	0.021	0.577
1,2,4-trimethylbenzene	8.80	20.09	0.015	0.136	3.808
C10 aromatics+aliphatics	6.50	30.94	0.027	0.177	4.939
formaldehyde	7.20	10.19	0.009	0.063	1.748
acetaldehyde	5.50	2.74	0.002	0.010	0.269
acrolein (2-propenal)	6.50	1.88	0.001	0.008	0.225
Residual hydrocarbons	4.11	604.85	0.333	1.371	38.062
Sum		1616.15		3.59	
Sum/ phase distance (km)		261			
mg NMOC emit. per km					261
mg ozone/mg NMOC emit.					3.59
mg ozone per km travelled					**937**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A11
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	253.62			
ethane	0.25	43.83	0.033	0.008	0.219
ethylene	7.40	134.77	0.084	0.620	16.420
acetylene	0.50	19.96	0.015	0.007	0.197
propane	0.48	3.37	0.003	0.001	0.036
propylene	9.40	42.26	0.028	0.262	6.937
i-butane	1.21	28.05	0.021	0.025	0.668
n-butane	1.02	43.93	0.032	0.033	0.868
trans-2-butene	10.00	9.25	0.006	0.064	1.698
cis-2-butene	10.00	8.19	0.006	0.056	1.491
C4 olefins !	9.02	32.28	0.021	0.190	5.046
i-pentane	1.38	79.38	0.056	0.077	2.053
1-pentene	6.20	4.14	0.003	0.019	0.492
n-pentane	1.04	41.08	0.028	0.029	0.786
trans-2-pentene	8.80	5.82	0.004	0.035	0.927
cis-2-pentene	8.80	3.33	0.002	0.019	0.519
2-methyl-2-butene	6.40	7.49	0.005	0.034	0.889
2,3-dimethylbutane	1.07	9.81	0.007	0.007	0.195
2-methylpentane	1.50	33.89	0.023	0.035	0.927
3-methylpentane	1.50	22.61	0.015	0.023	0.614
1-hexene	4.40	3.63	0.002	0.011	0.289
n-hexane	0.98	22.15	0.015	0.015	0.400
C5 and C6 olefins !	6.82	9.96	0.007	0.048	1.269
methylcyclopentane	2.80	11.64	0.008	0.023	0.601
benzene	0.42	84.68	0.053	0.022	0.598
2-methylhexane	1.08	17.51	0.012	0.013	0.357
3-methylhexane	1.40	13.80	0.010	0.013	0.359
2,2,4-trimethylpentane	0.93	25.05	0.017	0.016	0.425
n-heptane	0.81	24.61	0.027	0.022	0.568
C8 alkanes !	1.19	37.18	0.029	0.034	0.901
toluene	2.70	97.66	0.065	0.177	4.699
n-octane	0.60	6.03	0.005	0.003	0.074
ethylbenzene	2.70	21.71	0.014	0.039	1.025
m,p-xylenes !	7.40	67.84	0.047	0.349	9.270
styrene	2.20	4.91	0.003	0.007	0.198
o-xylene	6.50	23.31	0.016	0.102	2.724
n-nonane	0.54	2.70	0.002	0.001	0.031
n-propylbenzene	2.10	2.83	0.002	0.004	0.117
m,p-ethyltoluenes	6.50	14.36	0.010	0.065	1.732
1,3,5-trimethylbenzene	10.10	7.00	0.005	0.051	1.355
o-ethyltoluene	6.50	4.65	0.003	0.021	0.569
1,2,4-trimethylbenzene	8.80	18.51	0.014	0.120	3.181
C10 aromatics+aliphatics	6.50	22.30	0.017	0.109	2.877
formaldehyde	7.20	10.04	0.007	0.053	1.406
acetaldehyde	5.50	8.22	0.006	0.035	0.916
acrolein (2-propenal)	6.50	3.51	0.003	0.019	0.503
Residual hydrocarbons	4.11	286.99	0.207	0.850	22.573
Sum		1426.21		3.77	
Sum/ phase distance (km)		248			
mg NMOC emit. per km					248
mg ozone/mg NMOC emit.					3.77
mg ozone per km travelled					**930**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A12
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted Average VOC(i) emit. (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	634.08			
ethane	0.25	87.13	0.022	0.006	0.139
ethylene	7.40	296.91	0.070	0.519	13.085
acetylene	0.50	53.55	0.014	0.007	0.175
propane	0.48	8.69	0.002	0.001	0.026
propylene	9.40	106.55	0.027	0.254	6.391
i-butane	1.21	64.96	0.016	0.019	0.485
n-butane	1.02	103.83	0.025	0.026	0.650
trans-2-butene	10.00	22.41	0.006	0.058	1.475
cis-2-butene	10.00	22.20	0.006	0.059	1.483
C4 olefins !	9.02	80.19	0.020	0.177	4.480
i-pentane	1.38	189.50	0.045	0.063	1.586
1-pentene	6.20	11.66	0.003	0.021	0.522
n-pentane	1.04	101.36	0.024	0.025	0.642
trans-2-pentene	8.80	15.18	0.004	0.034	0.871
cis-2-pentene	8.80	9.48	0.003	0.022	0.568
2-methyl-2-butene	6.40	18.73	0.005	0.031	0.790
2,3-dimethylbutane	1.07	24.84	0.006	0.007	0.166
2-methylpentane	1.50	86.20	0.021	0.031	0.788
3-methylpentane	1.50	58.14	0.014	0.021	0.534
1-hexene	4.40	11.00	0.003	0.013	0.340
n-hexane	0.98	55.18	0.013	0.013	0.333
C5 and C6 olefins !	6.82	28.19	0.008	0.052	1.316
methylcyclopentane	2.80	32.88	0.008	0.023	0.578
benzene	0.42	228.22	0.051	0.021	0.542
2-methylhexane	1.08	49.14	0.012	0.013	0.330
3-methylhexane	1.40	37.72	0.009	0.013	0.325
2,2,4-trimethylpentane	0.93	66.63	0.016	0.015	0.386
n-heptane	0.81	59.54	0.017	0.014	0.340
C8 alkanes !	1.19	101.52	0.026	0.031	0.785
toluene	2.70	292.15	0.071	0.192	4.863
n-octane	0.60	18.46	0.005	0.003	0.073
ethylbenzene	2.70	57.71	0.014	0.039	0.988
m,p-xylenes !	7.40	206.72	0.052	0.385	9.733
styrene	2.20	14.34	0.004	0.008	0.199
o-xylene	6.50	73.54	0.018	0.119	3.010
n-nonane	0.54	7.35	0.002	0.001	0.027
n-propylbenzene	2.10	9.00	0.002	0.005	0.127
m,p-ethyltoluenes	6.50	53.26	0.014	0.089	2.258
1,3,5-trimethylbenzene	10.10	22.06	0.006	0.058	1.465
o-ethyltoluene	6.50	15.56	0.004	0.026	0.658
1,2,4-trimethylbenzene	8.80	65.50	0.017	0.149	3.774
C10 aromatics+aliphatics	6.50	79.35	0.021	0.140	3.517
formaldehyde	7.20	30.20	0.008	0.059	1.485
acetaldehyde	5.50	13.88	0.004	0.020	0.512
acrolein (2-propenal)	6.50	6.08	0.002	0.011	0.274
Residual hydrocarbons	4.11	1063.65	0.260	1.070	26.904
Sum		4060.31		3.96	
Sum/ Total cycle distance (km)		339			
mg NMOC emit. per km					339
mg ozone/mg NMOC emit.					3.96
mg ozone per km travelled					**1341**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A13
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrohol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	315.46			
ethane	0.25	53.96	0.017	0.004	0.098
ethylene	7.40	273.01	0.085	0.632	14.611
acetylene	0.50	50.32	0.016	0.008	0.190
propane	0.48	6.26	0.002	0.001	0.021
propylene	9.40	108.96	0.035	0.329	7.629
i-butane	1.21	46.93	0.014	0.017	0.394
n-butane	1.02	76.07	0.022	0.023	0.536
trans-2-butene	10.00	22.55	0.007	0.070	1.618
cis-2-butene	10.00	21.16	0.006	0.064	1.484
C4 olefins !	9.02	80.98	0.025	0.225	5.253
i-pentane	1.38	135.71	0.040	0.055	1.283
1-pentene	6.20	12.92	0.004	0.025	0.583
n-pentane	1.04	77.39	0.022	0.023	0.539
trans-2-pentene	8.80	17.73	0.005	0.046	1.087
cis-2-pentene	8.80	12.30	0.003	0.029	0.692
2-methyl-2-butene	6.40	18.20	0.006	0.037	0.852
2,3-dimethylbutane	1.07	19.79	0.006	0.006	0.142
2-methylpentane	1.50	69.58	0.020	0.030	0.706
3-methylpentane	1.50	46.61	0.014	0.020	0.477
1-hexene	4.40	11.67	0.003	0.015	0.354
n-hexane	0.98	43.93	0.013	0.012	0.290
C5 and C6 olefins !	6.82	30.17	0.009	0.060	1.409
methylcyclopentane	2.80	24.97	0.007	0.021	0.489
benzene	0.42	160.24	0.047	0.020	0.461
2-methylhexane	1.08	41.07	0.012	0.013	0.299
3-methylhexane	1.40	32.51	0.009	0.013	0.304
2,2,4-trimethylpentane	0.93	58.08	0.017	0.016	0.363
n-heptane	0.81	22.43	0.006	0.005	0.120
C8 alkanes !	1.19	73.24	0.022	0.027	0.621
toluene	2.70	285.58	0.086	0.232	5.407
n-octane	0.60	16.27	0.005	0.003	0.066
ethylbenzene	2.70	62.13	0.019	0.051	1.180
m,p-xylenes !	7.40	204.84	0.063	0.468	10.897
styrene	2.20	12.67	0.004	0.009	0.213
o-xylene	6.50	76.21	0.023	0.149	3.477
n-nonane	0.54	7.38	0.002	0.001	0.028
n-propylbenzene	2.10	10.61	0.003	0.007	0.160
m,p-ethyltoluenes	6.50	56.68	0.017	0.110	2.578
1,3,5-trimethylbenzene	10.10	23.24	0.007	0.071	1.650
o-ethyltoluene	6.50	17.37	0.005	0.034	0.802
1,2,4-trimethylbenzene	8.80	68.48	0.021	0.187	4.349
C10 aromatics+aliphatics	6.50	75.06	0.023	0.152	3.524
formaldehyde	7.20	34.77	0.012	0.089	2.062
acetaldehyde	5.50	29.39	0.009	0.052	1.203
acrolein (2-propenal)	6.50	3.67	0.001	0.009	0.199
Residual hydrocarbons	4.11	638.40	0.202	0.831	19.296
Sum		3271.48		4.30	
Sum/ phase distance (km)		567			
mg NMOC emit. per km					567
mg ozone/mg NMOC emit.					4.30
mg ozone per km travelled					**2424**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A14
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrohol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	309.49			
ethane	0.25	32.35	0.029	0.007	0.208
ethylene	7.40	52.75	0.034	0.249	7.156
acetylene	0.50	20.74	0.017	0.009	0.250
propane	0.48	2.97	0.002	0.001	0.029
propylene	9.40	9.78	0.006	0.057	1.626
i-butane	1.21	30.64	0.031	0.037	1.074
n-butane	1.02	38.80	0.037	0.037	1.086
trans-2-butene	10.00	6.58	0.007	0.066	1.914
cis-2-butene	10.00	5.65	0.006	0.058	1.664
C4 olefins !	9.02	18.05	0.014	0.125	3.604
i-pentane	1.38	58.98	0.052	0.071	2.081
1-pentene	6.20	2.68	0.003	0.016	0.477
n-pentane	1.04	30.64	0.027	0.029	0.833
trans-2-pentene	8.80	3.63	0.004	0.032	0.926
cis-2-pentene	8.80	1.55	0.002	0.014	0.402
2-methyl-2-butene	6.40	5.37	0.005	0.031	0.907
2,3-dimethylbutane	1.07	8.65	0.008	0.009	0.265
2-methylpentane	1.50	22.86	0.020	0.030	0.867
3-methylpentane	1.50	16.27	0.014	0.021	0.619
1-hexene	4.40	3.83	0.005	0.023	0.680
n-hexane	0.98	17.48	0.016	0.016	0.460
C5 and C6 olefins !	6.82	4.89	0.005	0.031	0.913
methylcyclopentane	2.80	8.15	0.007	0.020	0.575
benzene	0.42	63.03	0.043	0.018	0.528
2-methylhexane	1.08	13.09	0.012	0.013	0.363
3-methylhexane	1.40	9.09	0.008	0.011	0.308
2,2,4-trimethylpentane	0.93	19.69	0.017	0.016	0.457
n-heptane	0.81	36.14	0.036	0.029	0.817
C8 alkanes !	1.19	29.94	0.027	0.033	0.945
toluene	2.70	50.32	0.041	0.112	3.236
n-octane	0.60	5.27	0.005	0.003	0.088
ethylbenzene	2.70	10.05	0.009	0.025	0.715
m,p-xylenes !	7.40	34.76	0.032	0.233	6.751
styrene	2.20	4.02	0.004	0.009	0.251
o-xylene	6.50	12.47	0.012	0.075	2.170
n-nonane	0.54	3.28	0.003	0.002	0.048
n-propylbenzene	2.10	3.60	0.004	0.008	0.241
m,p-ethyltoluenes	6.50	9.63	0.010	0.062	1.798
1,3,5-trimethylbenzene	10.10	5.29	0.006	0.057	1.644
o-ethyltoluene	6.50	3.83	0.004	0.024	0.698
1,2,4-trimethylbenzene	8.80	14.87	0.016	0.137	3.962
C10 aromatics+aliphatics	6.50	26.87	0.029	0.188	5.413
formaldehyde	7.20	10.06	0.012	0.083	2.410
acetaldehyde	5.50	4.29	0.004	0.022	0.636
acrolein (2-propenal)	6.50	1.12	0.001	0.005	0.148
Residual hydrocarbons	4.11	295.26	0.319	1.312	37.757
Sum		1069.27		3.46	
Sum/ phase distance (km)		172			
mg NMOC emit. per km					172
mg ozone/mg NMOC emit.					3.46
mg ozone per km travelled					**596**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A15
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrohol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	234.73			
ethane	0.25	34.89	0.030	0.008	0.201
ethylene	7.40	108.12	0.076	0.561	14.991
acetylene	0.50	18.09	0.015	0.008	0.206
propane	0.48	3.27	0.003	0.001	0.033
propylene	9.40	31.74	0.023	0.218	5.832
i-butane	1.21	27.70	0.023	0.028	0.760
n-butane	1.02	41.08	0.035	0.035	0.947
trans-2-butene	10.00	8.59	0.007	0.069	1.839
cis-2-butene	10.00	7.65	0.006	0.061	1.636
C4 olefins !	9.02	27.92	0.021	0.187	5.007
i-pentane	1.38	71.57	0.058	0.080	2.150
1-pentene	6.20	3.57	0.003	0.018	0.485
n-pentane	1.04	36.45	0.029	0.030	0.817
trans-2-pentene	8.80	5.20	0.004	0.037	0.986
cis-2-pentene	8.80	2.87	0.002	0.020	0.529
2-methyl-2-butene	6.40	6.44	0.006	0.036	0.950
2,3-dimethylbutane	1.07	8.11	0.006	0.007	0.184
2-methylpentane	1.50	28.93	0.023	0.034	0.909
3-methylpentane	1.50	19.83	0.016	0.024	0.634
1-hexene	4.40	3.11	0.003	0.012	0.317
n-hexane	0.98	19.88	0.016	0.016	0.417
C5 and C6 olefins !	6.82	6.67	0.006	0.044	1.188
methylcyclopentane	2.80	11.12	0.009	0.025	0.672
benzene	0.42	66.42	0.048	0.020	0.537
2-methylhexane	1.08	15.41	0.012	0.013	0.356
3-methylhexane	1.40	11.37	0.009	0.013	0.342
2,2,4-trimethylpentane	0.93	22.19	0.017	0.016	0.436
n-heptane	0.81	19.60	0.025	0.020	0.529
C8 alkanes !	1.19	31.19	0.027	0.032	0.867
toluene	2.70	78.21	0.059	0.160	4.294
n-octane	0.60	5.02	0.004	0.003	0.067
ethylbenzene	2.70	18.34	0.014	0.038	1.024
m,p-xylenes !	7.40	52.66	0.042	0.312	8.353
styrene	2.20	4.98	0.004	0.008	0.222
o-xylene	6.50	19.51	0.015	0.097	2.612
n-nonane	0.54	2.54	0.002	0.001	0.033
n-propylbenzene	2.10	2.58	0.002	0.005	0.124
m,p-ethyltoluenes	6.50	12.69	0.011	0.070	1.867
1,3,5-trimethylbenzene	10.10	5.67	0.005	0.047	1.258
o-ethyltoluene	6.50	3.63	0.003	0.020	0.537
1,2,4-trimethylbenzene	8.80	14.80	0.012	0.109	2.920
C10 aromatics+aliphatics	6.50	19.36	0.018	0.114	3.042
formaldehyde	7.20	12.34	0.011	0.077	2.063
acetaldehyde	5.50	13.96	0.011	0.059	1.584
acrolein (2-propenal)	6.50	1.49	0.001	0.006	0.166
Residual hydrocarbons	4.11	264.87	0.228	0.937	25.075
Sum		1231.64		3.74	
Sum/ phase distance (km)		214			
mg NMOC emit. per km					214
mg ozone/mg NMOC emit.					3.74
mg ozone per km travelled					**797**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A16
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 and 2 post-tune results combined
Post-1986 vehicles with unleaded petrohol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted			% Contribution
		Average	Average [a]	mg Ozone per	
		VOC(i) emit.	mg VOC(i) per	mg VOC(i) emit.	
		(mg)	mg NMOC		
methane	0.02	578.93			
ethane	0.25	75.44	0.023	0.006	0.147
ethylene	7.40	231.78	0.068	0.500	12.739
acetylene	0.50	52.69	0.016	0.008	0.209
propane	0.48	7.53	0.002	0.001	0.026
propylene	9.40	74.73	0.023	0.220	5.597
i-butane	1.21	66.61	0.021	0.025	0.644
n-butane	1.02	94.93	0.029	0.029	0.757
trans-2-butene	10.00	21.17	0.007	0.068	1.740
cis-2-butene	10.00	19.11	0.006	0.062	1.588
C4 olefins !	9.02	68.79	0.021	0.189	4.845
i-pentane	1.38	158.12	0.047	0.065	1.655
1-pentene	6.20	10.27	0.003	0.021	0.539
n-pentane	1.04	84.69	0.025	0.026	0.668
trans-2-pentene	8.80	14.22	0.005	0.040	1.024
cis-2-pentene	8.80	8.48	0.003	0.023	0.599
2-methyl-2-butene	6.40	16.87	0.005	0.035	0.892
2,3-dimethylbutane	1.07	21.78	0.007	0.007	0.179
2-methylpentane	1.50	69.26	0.021	0.031	0.790
3-methylpentane	1.50	47.62	0.014	0.021	0.544
1-hexene	4.40	10.62	0.004	0.015	0.400
n-hexane	0.98	47.71	0.014	0.014	0.363
C5 and C6 olefins !	6.82	21.67	0.007	0.049	1.258
methylcyclopentane	2.80	25.23	0.008	0.021	0.544
benzene	0.42	169.80	0.047	0.020	0.507
2-methylhexane	1.08	39.53	0.012	0.013	0.332
3-methylhexane	1.40	29.55	0.009	0.012	0.316
2,2,4-trimethylpentane	0.93	57.31	0.017	0.016	0.411
n-heptane	0.81	56.95	0.020	0.017	0.417
C8 alkanes !	1.19	79.21	0.025	0.030	0.763
toluene	2.70	217.70	0.067	0.180	4.603
n-octane	0.60	15.13	0.005	0.003	0.074
ethylbenzene	2.70	47.22	0.015	0.040	1.029
m,p-xylenes !	7.40	152.86	0.049	0.361	9.226
styrene	2.20	12.30	0.004	0.009	0.224
o-xylene	6.50	56.36	0.018	0.114	2.926
n-nonane	0.54	7.91	0.003	0.001	0.035
n-propylbenzene	2.10	9.63	0.003	0.007	0.181
m,p-ethyltoluenes	6.50	41.24	0.013	0.086	2.201
1,3,5-trimethylbenzene	10.10	18.52	0.006	0.060	1.531
o-ethyltoluene	6.50	13.37	0.004	0.028	0.715
1,2,4-trimethylbenzene	8.80	52.76	0.017	0.152	3.881
C10 aromatics+aliphatics	6.50	70.18	0.023	0.153	3.887
formaldehyde	7.20	32.05	0.011	0.080	2.049
acetaldehyde	5.50	24.89	0.008	0.045	1.155
acrolein (2-propenal)	6.50	3.54	0.001	0.007	0.182
Residual hydrocarbons	4.11	720.74	0.244	1.004	25.607
Sum		3178.04		3.92	
Sum/ Total cycle distance (km)		266			
mg NMOC emit. per km					266
mg ozone/mg NMOC emit.					3.92
mg ozone per km travelled					**1037**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A17
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	695.56			
ethane	0.25	121.49	0.009	0.002	0.055
ethylene	7.40	1046.09	0.080	0.591	14.349
acetylene	0.50	662.50	0.046	0.023	0.559
propane	0.48	22.87	0.002	0.001	0.021
propylene	9.40	472.92	0.037	0.350	8.488
i-butane	1.21	156.17	0.012	0.015	0.353
n-butane	1.02	350.02	0.025	0.026	0.623
trans-2-butene	10.00	71.91	0.006	0.057	1.385
cis-2-butene	10.00	65.09	0.005	0.051	1.232
C4 olefins !	9.02	300.12	0.024	0.214	5.181
i-pentane	1.38	528.23	0.040	0.055	1.335
1-pentene	6.20	40.32	0.003	0.020	0.481
n-pentane	1.04	277.83	0.021	0.022	0.533
trans-2-pentene	8.80	67.41	0.005	0.046	1.114
cis-2-pentene	8.80	49.92	0.004	0.037	0.902
2-methyl-2-butene	6.40	34.82	0.003	0.017	0.415
2,3-dimethylbutane	1.07	72.57	0.006	0.006	0.145
2-methylpentane	1.50	290.64	0.022	0.033	0.802
3-methylpentane	1.50	206.89	0.016	0.023	0.566
1-hexene	4.40	48.08	0.004	0.017	0.413
n-hexane	0.98	183.00	0.014	0.013	0.327
C5 and C6 olefins !	6.82	100.88	0.007	0.051	1.226
methylcyclopentane	2.80	116.16	0.009	0.024	0.589
benzene	0.42	693.23	0.052	0.022	0.525
2-methylhexane	1.08	191.46	0.014	0.015	0.360
3-methylhexane	1.40	161.01	0.012	0.017	0.409
2,2,4-trimethylpentane	0.93	140.95	0.010	0.010	0.237
n-heptane	0.81	118.82	0.009	0.007	0.173
C8 alkanes !	1.19	271.96	0.020	0.024	0.580
toluene	2.70	1564.26	0.115	0.311	7.550
n-octane	0.60	70.38	0.005	0.003	0.073
ethylbenzene	2.70	292.21	0.022	0.058	1.416
m,p-xylenes !	7.40	1076.80	0.078	0.576	13.984
styrene	2.20	66.82	0.004	0.010	0.237
o-xylene	6.50	355.36	0.026	0.167	4.046
n-nonane	0.54	18.77	0.001	0.001	0.018
n-propylbenzene	2.10	46.62	0.003	0.007	0.169
m,p-ethyltoluenes	6.50	282.47	0.019	0.127	3.070
1,3,5-trimethylbenzene	10.10	88.58	0.006	0.063	1.538
o-ethyltoluene	6.50	69.46	0.005	0.033	0.789
1,2,4-trimethylbenzene	8.80	254.81	0.018	0.157	3.802
C10 aromatics+aliphatics	6.50	168.45	0.012	0.075	1.829
formaldehyde	7.20	152.78	0.013	0.095	2.297
acetaldehyde	5.50	51.77	0.004	0.024	0.590
acrolein (2-propenal)	6.50	11.18	0.001	0.006	0.144
Residual hydrocarbons	4.11	2026.27	0.151	0.621	15.071
Sum		13460.37		4.12	
Sum/ phase distance (km)		2299			
mg NMOC emit. per km					2299
mg ozone/mg NMOC emit.					4.12
mg ozone per km travelled					**9477**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A18
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	790.19			
ethane	0.25	143.69	0.012	0.003	0.071
ethylene	7.40	1178.32	0.098	0.723	16.977
acetylene	0.50	614.85	0.046	0.023	0.539
propane	0.48	17.90	0.002	0.001	0.018
propylene	9.40	500.66	0.043	0.409	9.603
i-butane	1.21	127.86	0.011	0.013	0.313
n-butane	1.02	349.20	0.028	0.029	0.679
trans-2-butene	10.00	59.68	0.005	0.052	1.216
cis-2-butene	10.00	54.33	0.005	0.047	1.094
C4 olefins !	9.02	279.21	0.024	0.219	5.146
i-pentane	1.38	422.71	0.036	0.049	1.159
1-pentene	6.20	28.58	0.002	0.015	0.361
n-pentane	1.04	222.33	0.019	0.020	0.460
trans-2-pentene	8.80	50.12	0.004	0.038	0.882
cis-2-pentene	8.80	25.62	0.002	0.019	0.449
2-methyl-2-butene	6.40	31.69	0.003	0.017	0.398
2,3-dimethylbutane	1.07	48.64	0.004	0.004	0.088
2-methylpentane	1.50	213.68	0.018	0.027	0.638
3-methylpentane	1.50	150.22	0.013	0.019	0.449
1-hexene	4.40	29.23	0.003	0.011	0.261
n-hexane	0.98	139.92	0.012	0.012	0.270
C5 and C6 olefins !	6.82	79.56	0.007	0.045	1.063
methylcyclopentane	2.80	85.33	0.007	0.020	0.468
benzene	0.42	733.03	0.059	0.025	0.580
2-methylhexane	1.08	134.70	0.011	0.012	0.276
3-methylhexane	1.40	115.49	0.010	0.014	0.320
2,2,4-trimethylpentane	0.93	100.05	0.008	0.008	0.184
n-heptane	0.81	83.74	0.007	0.006	0.133
C8 alkanes !	1.19	197.83	0.016	0.019	0.453
toluene	2.70	1441.35	0.117	0.316	7.429
n-octane	0.60	49.40	0.004	0.002	0.057
ethylbenzene	2.70	248.71	0.021	0.057	1.339
m,p-xylenes !	7.40	930.16	0.076	0.562	13.215
styrene	2.20	92.07	0.007	0.016	0.367
o-xylene	6.50	299.60	0.025	0.160	3.748
n-nonane	0.54	16.28	0.001	0.001	0.018
n-propylbenzene	2.10	24.00	0.002	0.003	0.082
m,p-ethyltoluenes	6.50	276.99	0.023	0.150	3.513
1,3,5-trimethylbenzene	10.10	81.53	0.007	0.067	1.568
o-ethyltoluene	6.50	64.41	0.005	0.035	0.814
1,2,4-trimethylbenzene	8.80	258.24	0.021	0.181	4.259
C10 aromatics+aliphatics	6.50	169.06	0.013	0.086	2.022
formaldehyde	7.20	148.54	0.013	0.097	2.269
acetaldehyde	5.50	41.42	0.004	0.021	0.488
acrolein (2-propenal)	6.50	3.54	0.000	0.002	0.036
Residual hydrocarbons	4.11	1758.96	0.147	0.606	14.232
Sum		12122.43		4.26	
Sum/ phase distance (km)		1960			
mg NMOC emit. per km					1960
mg ozone/mg NMOC emit.					4.26
mg ozone per km travelled					**8343**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A19
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	547.36			
ethane	0.25	109.49	0.011	0.003	0.064
ethylene	7.40	953.53	0.094	0.694	16.652
acetylene	0.50	493.47	0.047	0.024	0.564
propane	0.48	19.68	0.002	0.001	0.023
propylene	9.40	419.76	0.042	0.396	9.500
i-butane	1.21	150.73	0.015	0.018	0.442
n-butane	1.02	316.66	0.031	0.031	0.753
trans-2-butene	10.00	54.97	0.005	0.055	1.314
cis-2-butene	10.00	40.44	0.004	0.040	0.965
C4 olefins !	9.02	194.34	0.019	0.169	4.062
i-pentane	1.38	463.20	0.046	0.064	1.528
1-pentene	6.20	30.55	0.003	0.019	0.460
n-pentane	1.04	218.67	0.022	0.022	0.538
trans-2-pentene	8.80	49.68	0.005	0.044	1.046
cis-2-pentene	8.80	52.08	0.006	0.049	1.170
2-methyl-2-butene	6.40	51.79	0.005	0.032	0.765
2,3-dimethylbutane	1.07	52.39	0.005	0.006	0.134
2-methylpentane	1.50	213.95	0.021	0.032	0.761
3-methylpentane	1.50	147.44	0.015	0.022	0.526
1-hexene	4.40	24.58	0.002	0.011	0.254
n-hexane	0.98	131.66	0.013	0.013	0.303
C5 and C6 olefins !	6.82	56.14	0.005	0.037	0.880
methylcyclopentane	2.80	81.11	0.008	0.022	0.532
benzene	0.42	570.16	0.055	0.023	0.555
2-methylhexane	1.08	139.73	0.014	0.015	0.354
3-methylhexane	1.40	105.77	0.010	0.014	0.347
2,2,4-trimethylpentane	0.93	85.80	0.008	0.008	0.185
n-heptane	0.81	75.16	0.007	0.006	0.142
C8 alkanes !	1.19	173.74	0.017	0.020	0.486
toluene	2.70	1136.45	0.109	0.295	7.087
n-octane	0.60	39.65	0.004	0.002	0.054
ethylbenzene	2.70	199.06	0.019	0.052	1.252
m,p-xylenes !	7.40	732.29	0.070	0.520	12.478
styrene	2.20	45.86	0.004	0.009	0.210
o-xylene	6.50	243.25	0.023	0.152	3.651
n-nonane	0.54	12.71	0.001	0.001	0.016
n-propylbenzene	2.10	29.49	0.003	0.006	0.143
m,p-ethyltoluenes	6.50	230.57	0.022	0.145	3.479
1,3,5-trimethylbenzene	10.10	62.62	0.006	0.060	1.446
o-ethyltoluene	6.50	50.48	0.005	0.031	0.754
1,2,4-trimethylbenzene	8.80	196.93	0.018	0.162	3.897
C10 aromatics+aliphatics	6.50	253.77	0.026	0.169	4.066
formaldehyde	7.20	146.47	0.015	0.110	2.630
acetaldehyde	5.50	45.81	0.005	0.026	0.624
acrolein (2-propenal)	6.50	4.05	0.000	0.002	0.054
Residual hydrocarbons	4.11	1332.75	0.130	0.536	12.854
Sum		10238.89		4.17	
Sum/ phase distance (km)		1785			
mg NMOC emit. per km					1785
mg ozone/mg NMOC emit.					4.17
mg ozone per km travelled					**7439**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A20
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted			% Contribution
		Average	Average [a]	mg Ozone per	
		VOC(i) emit.	mg VOC(i) per	mg VOC(i) emit.	
		(mg)	mg NMOC		
methane	0.02	1401.27			
ethane	0.25	258.33	0.011	0.003	0.065
ethylene	7.40	2171.65	0.092	0.684	16.280
acetylene	0.50	1181.01	0.046	0.023	0.553
propane	0.48	38.95	0.002	0.001	0.020
propylene	9.40	943.28	0.042	0.391	9.316
i-butane	1.21	280.93	0.012	0.015	0.356
n-butane	1.02	680.20	0.028	0.029	0.685
trans-2-butene	10.00	121.94	0.005	0.054	1.279
cis-2-butene	10.00	105.38	0.005	0.046	1.094
C4 olefins !	9.02	519.04	0.023	0.204	4.852
i-pentane	1.38	913.87	0.039	0.054	1.296
1-pentene	6.20	63.33	0.003	0.017	0.415
n-pentane	1.04	466.44	0.020	0.021	0.497
trans-2-pentene	8.80	107.43	0.005	0.041	0.979
cis-2-pentene	8.80	76.78	0.004	0.031	0.748
2-methyl-2-butene	6.40	76.18	0.003	0.021	0.491
2,3-dimethylbutane	1.07	109.70	0.004	0.005	0.114
2-methylpentane	1.50	460.61	0.020	0.030	0.707
3-methylpentane	1.50	323.22	0.014	0.021	0.496
1-hexene	4.40	63.92	0.003	0.012	0.294
n-hexane	0.98	293.66	0.012	0.012	0.292
C5 and C6 olefins !	6.82	154.94	0.006	0.044	1.053
methylcyclopentane	2.80	181.51	0.008	0.022	0.513
benzene	0.42	1356.11	0.056	0.024	0.561
2-methylhexane	1.08	296.68	0.012	0.013	0.316
3-methylhexane	1.40	245.01	0.010	0.015	0.348
2,2,4-trimethylpentane	0.93	209.56	0.009	0.008	0.196
n-heptane	0.81	177.67	0.007	0.006	0.144
C8 alkanes !	1.19	413.81	0.017	0.021	0.492
toluene	2.70	2761.76	0.115	0.309	7.365
n-octane	0.60	102.26	0.004	0.003	0.060
ethylbenzene	2.70	487.83	0.021	0.056	1.333
m,p-xylenes !	7.40	1810.59	0.075	0.554	13.200
styrene	2.20	146.94	0.006	0.012	0.295
o-xylene	6.50	591.05	0.025	0.159	3.792
n-nonane	0.54	31.60	0.001	0.001	0.017
n-propylbenzene	2.10	60.85	0.002	0.005	0.119
m,p-ethyltoluenes	6.50	529.88	0.022	0.143	3.402
1,3,5-trimethylbenzene	10.10	155.32	0.006	0.064	1.529
o-ethyltoluene	6.50	123.05	0.005	0.033	0.792
1,2,4-trimethylbenzene	8.80	480.06	0.019	0.170	4.050
C10 aromatics+aliphatics	6.50	386.15	0.016	0.106	2.532
formaldehyde	7.20	297.72	0.014	0.100	2.371
acetaldehyde	5.50	89.79	0.004	0.023	0.547
acrolein (2-propenal)	6.50	10.66	0.000	0.003	0.065
Residual hydrocarbons	4.11	3389.93	0.144	0.591	14.080
Sum		23746.56		4.20	
Sum/ Total cycle distance (km)		1983			
mg NMOC emit. per km					1983
mg ozone/mg NMOC emit.					4.20
mg ozone per km travelled					**8329**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A21
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrohol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	455.77			
ethane	0.25	104.35	0.010	0.002	0.055
ethylene	7.40	948.46	0.088	0.653	14.995
acetylene	0.50	442.51	0.037	0.019	0.431
propane	0.48	46.20	0.005	0.002	0.052
propylene	9.40	483.55	0.047	0.440	10.096
i-butane	1.21	179.40	0.017	0.020	0.462
n-butane	1.02	344.46	0.031	0.031	0.720
trans-2-butene	10.00	67.38	0.006	0.061	1.410
cis-2-butene	10.00	57.51	0.005	0.052	1.199
C4 olefins !	9.02	240.65	0.022	0.198	4.551
i-pentane	1.38	504.07	0.046	0.063	1.446
1-pentene	6.20	37.74	0.003	0.021	0.492
n-pentane	1.04	250.13	0.022	0.023	0.537
trans-2-pentene	8.80	62.41	0.006	0.050	1.146
cis-2-pentene	8.80	40.41	0.004	0.034	0.771
2-methyl-2-butene	6.40	21.26	0.002	0.013	0.306
2,3-dimethylbutane	1.07	60.81	0.005	0.006	0.132
2-methylpentane	1.50	117.26	0.012	0.018	0.421
3-methylpentane	1.50	170.57	0.015	0.023	0.517
1-hexene	4.40	47.21	0.004	0.019	0.429
n-hexane	0.98	147.97	0.013	0.013	0.293
C5 and C6 olefins !	6.82	76.57	0.007	0.045	1.031
methylcyclopentane	2.80	91.26	0.008	0.022	0.512
benzene	0.42	231.95	0.024	0.010	0.231
2-methylhexane	1.08	73.74	0.007	0.008	0.174
3-methylhexane	1.40	126.61	0.011	0.015	0.352
2,2,4-trimethylpentane	0.93	110.86	0.010	0.009	0.204
n-heptane	0.81	92.02	0.008	0.006	0.146
C8 alkanes !	1.19	235.87	0.020	0.024	0.544
toluene	2.70	1140.77	0.098	0.265	6.076
n-octane	0.60	57.57	0.005	0.003	0.066
ethylbenzene	2.70	219.93	0.019	0.051	1.160
m,p-xylenes !	7.40	805.31	0.068	0.502	11.521
styrene	2.20	50.45	0.004	0.009	0.204
o-xylene	6.50	271.34	0.023	0.148	3.408
n-nonane	0.54	15.29	0.001	0.001	0.016
n-propylbenzene	2.10	39.11	0.003	0.007	0.157
m,p-ethyltoluenes	6.50	254.45	0.021	0.140	3.209
1,3,5-trimethylbenzene	10.10	71.24	0.006	0.060	1.375
o-ethyltoluene	6.50	57.91	0.005	0.032	0.726
1,2,4-trimethylbenzene	8.80	202.45	0.017	0.147	3.366
C10 aromatics+aliphatics	6.50	162.92	0.014	0.089	2.047
formaldehyde	7.20	202.35	0.020	0.140	3.226
acetaldehyde	5.50	166.98	0.015	0.084	1.933
acrolein (2-propenal)	6.50	24.32	0.002	0.015	0.346
Residual hydrocarbons	4.11	2227.24	0.185	0.762	17.512
Sum		11382.80		4.35	
Sum/ phase distance (km)		1963			
mg NMOC emit. per km					1963
mg ozone/mg NMOC emit.					4.35
mg ozone per km travelled					**8548**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A22
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrohol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	411.30			
ethane	0.25	88.56	0.010	0.002	0.056
ethylene	7.40	739.77	0.080	0.592	13.912
acetylene	0.50	288.03	0.030	0.015	0.350
propane	0.48	21.58	0.002	0.001	0.027
propylene	9.40	335.32	0.037	0.346	8.128
i-butane	1.21	113.70	0.012	0.014	0.340
n-butane	1.02	297.21	0.032	0.032	0.756
trans-2-butene	10.00	56.12	0.006	0.060	1.416
cis-2-butene	10.00	41.71	0.004	0.044	1.035
C4 olefins !	9.02	209.23	0.022	0.203	4.770
i-pentane	1.38	362.96	0.038	0.053	1.242
1-pentene	6.20	28.11	0.003	0.019	0.439
n-pentane	1.04	187.08	0.020	0.021	0.483
trans-2-pentene	8.80	43.70	0.005	0.041	0.954
cis-2-pentene	8.80	23.17	0.002	0.022	0.507
2-methyl-2-butene	6.40	33.74	0.004	0.023	0.540
2,3-dimethylbutane	1.07	44.63	0.005	0.005	0.119
2-methylpentane	1.50	184.94	0.020	0.029	0.688
3-methylpentane	1.50	138.22	0.015	0.022	0.517
1-hexene	4.40	34.29	0.004	0.016	0.377
n-hexane	0.98	115.54	0.012	0.012	0.281
C5 and C6 olefins !	6.82	81.47	0.009	0.059	1.391
methylcyclopentane	2.80	67.81	0.007	0.020	0.470
benzene	0.42	464.81	0.049	0.021	0.485
2-methylhexane	1.08	111.43	0.012	0.013	0.304
3-methylhexane	1.40	96.53	0.010	0.014	0.336
2,2,4-trimethylpentane	0.93	83.74	0.009	0.008	0.193
n-heptane	0.81	69.11	0.007	0.006	0.139
C8 alkanes !	1.19	180.07	0.019	0.023	0.533
toluene	2.70	1006.99	0.107	0.289	6.800
n-octane	0.60	42.56	0.005	0.003	0.064
ethylbenzene	2.70	187.93	0.020	0.054	1.274
m,p-xylenes !	7.40	662.07	0.070	0.520	12.230
styrene	2.20	60.20	0.006	0.014	0.327
o-xylene	6.50	223.04	0.024	0.154	3.621
n-nonane	0.54	13.65	0.001	0.001	0.019
n-propylbenzene	2.10	30.44	0.003	0.007	0.159
m,p-ethyltoluenes	6.50	221.51	0.023	0.153	3.590
1,3,5-trimethylbenzene	10.10	61.92	0.007	0.066	1.551
o-ethyltoluene	6.50	50.56	0.005	0.035	0.819
1,2,4-trimethylbenzene	8.80	197.47	0.021	0.183	4.292
C10 aromatics+aliphatics	6.50	158.03	0.017	0.108	2.535
formaldehyde	7.20	163.25	0.018	0.128	3.020
acetaldehyde	5.50	151.32	0.016	0.089	2.094
acrolein (2-propenal)	6.50	18.71	0.002	0.013	0.310
Residual hydrocarbons	4.11	1600.27	0.171	0.702	16.508
Sum		9392.49		4.25	
Sum/ phase distance (km)		1518			
mg NMOC emit. per km					1518
mg ozone/mg NMOC emit.					4.25
mg ozone per km travelled					**6460**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A23
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrohol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	327.38			
ethane	0.25	73.49	0.009	0.002	0.052
ethylene	7.40	716.53	0.086	0.639	15.257
acetylene	0.50	273.38	0.032	0.016	0.380
propane	0.48	16.93	0.002	0.001	0.024
propylene	9.40	299.58	0.037	0.344	8.199
i-butane	1.21	144.97	0.018	0.021	0.508
n-butane	1.02	272.78	0.033	0.033	0.793
trans-2-butene	10.00	54.90	0.007	0.066	1.580
cis-2-butene	10.00	46.05	0.006	0.055	1.324
C4 olefins !	9.02	191.68	0.023	0.208	4.958
i-pentane	1.38	404.65	0.049	0.067	1.601
1-pentene	6.20	27.63	0.003	0.021	0.494
n-pentane	1.04	195.99	0.023	0.024	0.583
trans-2-pentene	8.80	48.11	0.006	0.051	1.218
cis-2-pentene	8.80	31.71	0.004	0.034	0.813
2-methyl-2-butene	6.40	28.21	0.003	0.022	0.519
2,3-dimethylbutane	1.07	51.22	0.006	0.007	0.158
2-methylpentane	1.50	182.02	0.022	0.033	0.777
3-methylpentane	1.50	129.59	0.015	0.023	0.553
1-hexene	4.40	33.10	0.004	0.018	0.420
n-hexane	0.98	110.19	0.013	0.013	0.307
C5 and C6 olefins !	6.82	60.13	0.007	0.049	1.159
methylcyclopentane	2.80	71.38	0.009	0.024	0.570
benzene	0.42	451.75	0.054	0.023	0.537
2-methylhexane	1.08	104.66	0.013	0.014	0.324
3-methylhexane	1.40	89.76	0.011	0.015	0.356
2,2,4-trimethylpentane	0.93	92.78	0.011	0.010	0.247
n-heptane	0.81	66.65	0.008	0.006	0.153
C8 alkanes !	1.19	129.89	0.015	0.018	0.435
toluene	2.70	875.80	0.104	0.280	6.688
n-octane	0.60	37.20	0.004	0.003	0.063
ethylbenzene	2.70	155.57	0.018	0.050	1.186
m,p-xylenes !	7.40	551.12	0.065	0.482	11.491
styrene	2.20	36.85	0.004	0.009	0.220
o-xylene	6.50	193.01	0.023	0.149	3.549
n-nonane	0.54	12.41	0.001	0.001	0.019
n-propylbenzene	2.10	26.51	0.003	0.007	0.158
m,p-ethyltoluenes	6.50	187.04	0.022	0.144	3.433
1,3,5-trimethylbenzene	10.10	53.71	0.006	0.064	1.534
o-ethyltoluene	6.50	41.92	0.005	0.032	0.768
1,2,4-trimethylbenzene	8.80	156.06	0.018	0.161	3.850
C10 aromatics+aliphatics	6.50	150.78	0.018	0.117	2.788
formaldehyde	7.20	179.90	0.022	0.159	3.788
acetaldehyde	5.50	139.23	0.017	0.092	2.196
acrolein (2-propenal)	6.50	19.51	0.002	0.015	0.363
Residual hydrocarbons	4.11	1171.37	0.139	0.570	13.606
Sum		8387.70		4.19	
Sum/ phase distance (km)		1445			
mg NMOC emit. per km					1445
mg ozone/mg NMOC emit.					4.19
mg ozone per km travelled					**6055**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A24
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Pre-1986 vehicles with leaded petrohol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted Average VOC(i) emit. (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	793.88			
ethane	0.25	175.32	0.009	0.002	0.055
ethylene	7.40	1556.03	0.083	0.618	14.476
acetylene	0.50	634.14	0.032	0.016	0.377
propane	0.48	51.09	0.003	0.001	0.032
propylene	9.40	714.01	0.039	0.367	8.606
i-butane	1.21	273.47	0.014	0.018	0.411
n-butane	1.02	600.81	0.032	0.032	0.754
trans-2-butene	10.00	116.38	0.006	0.062	1.453
cis-2-butene	10.00	92.69	0.005	0.049	1.144
C4 olefins !	9.02	421.97	0.022	0.203	4.749
i-pentane	1.38	810.35	0.043	0.059	1.378
1-pentene	6.20	60.09	0.003	0.020	0.465
n-pentane	1.04	406.35	0.021	0.022	0.520
trans-2-pentene	8.80	97.96	0.005	0.045	1.065
cis-2-pentene	8.80	58.62	0.003	0.028	0.646
2-methyl-2-butene	6.40	58.96	0.003	0.020	0.471
2,3-dimethylbutane	1.07	99.97	0.005	0.006	0.132
2-methylpentane	1.50	339.11	0.018	0.027	0.631
3-methylpentane	1.50	285.44	0.015	0.022	0.525
1-hexene	4.40	73.46	0.004	0.017	0.400
n-hexane	0.98	241.98	0.013	0.012	0.290
C5 and C6 olefins !	6.82	148.67	0.008	0.053	1.241
methylcyclopentane	2.80	147.74	0.008	0.022	0.505
benzene	0.42	822.04	0.043	0.018	0.426
2-methylhexane	1.08	202.79	0.011	0.012	0.274
3-methylhexane	1.40	202.13	0.011	0.015	0.345
2,2,4-trimethylpentane	0.93	184.30	0.010	0.009	0.210
n-heptane	0.81	146.67	0.008	0.006	0.145
C8 alkanes !	1.19	355.54	0.018	0.022	0.513
toluene	2.70	1996.73	0.104	0.281	6.591
n-octane	0.60	88.52	0.005	0.003	0.064
ethylbenzene	2.70	371.17	0.019	0.052	1.226
m,p-xylenes !	7.40	1322.49	0.069	0.508	11.896
styrene	2.20	102.89	0.005	0.011	0.268
o-xylene	6.50	449.73	0.023	0.152	3.560
n-nonane	0.54	27.30	0.001	0.001	0.018
n-propylbenzene	2.10	62.37	0.003	0.007	0.159
m,p-ethyltoluenes	6.50	437.54	0.023	0.148	3.459
1,3,5-trimethylbenzene	10.10	123.16	0.006	0.064	1.505
o-ethyltoluene	6.50	99.35	0.005	0.033	0.784
1,2,4-trimethylbenzene	8.80	373.47	0.019	0.169	3.950
C10 aromatics+aliphatics	6.50	314.03	0.016	0.106	2.474
formaldehyde	7.20	352.80	0.019	0.139	3.254
acetaldehyde	5.50	302.48	0.016	0.088	2.071
acrolein (2-propenal)	6.50	40.29	0.002	0.014	0.330
Residual hydrocarbons	4.11	3225.66	0.168	0.689	16.150
Sum		19068.08		4.27	
Sum/ Total cycle distance (km)		1591			
mg NMOC emit. per km					1591
mg ozone/mg NMOC emit.					4.27
mg ozone per km travelled					**6787**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A25
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	374.12			
ethane	0.25	64.81	0.015	0.004	0.090
ethylene	7.40	332.15	0.074	0.551	13.282
acetylene	0.50	54.83	0.013	0.006	0.151
propane	0.48	7.49	0.002	0.001	0.020
propylene	9.40	141.10	0.033	0.309	7.456
i-butane	1.21	54.65	0.012	0.015	0.352
n-butane	1.02	112.24	0.026	0.026	0.628
trans-2-butene	10.00	27.83	0.006	0.063	1.530
cis-2-butene	10.00	26.17	0.006	0.058	1.404
C4 olefins !	9.02	111.34	0.026	0.230	5.554
i-pentane	1.38	197.01	0.044	0.060	1.449
1-pentene	6.20	15.32	0.004	0.023	0.549
n-pentane	1.04	123.28	0.027	0.029	0.689
trans-2-pentene	8.80	22.91	0.005	0.046	1.107
cis-2-pentene	8.80	14.36	0.003	0.029	0.706
2-methyl-2-butene	6.40	14.48	0.003	0.021	0.508
2,3-dimethylbutane	1.07	26.47	0.006	0.006	0.153
2-methylpentane	1.50	101.34	0.022	0.034	0.811
3-methylpentane	1.50	69.75	0.016	0.023	0.563
1-hexene	4.40	15.92	0.004	0.017	0.400
n-hexane	0.98	70.94	0.016	0.016	0.374
C5 and C6 olefins !	6.82	42.18	0.010	0.068	1.634
methylcyclopentane	2.80	39.74	0.009	0.025	0.597
benzene	0.42	238.03	0.052	0.022	0.528
2-methylhexane	1.08	56.28	0.012	0.013	0.322
3-methylhexane	1.40	54.67	0.012	0.017	0.413
2,2,4-trimethylpentane	0.93	79.03	0.018	0.017	0.410
n-heptane	0.81	37.76	0.008	0.007	0.165
C8 alkanes !	1.19	103.26	0.023	0.028	0.671
toluene	2.70	401.13	0.091	0.245	5.918
n-octane	0.60	24.49	0.006	0.003	0.080
ethylbenzene	2.70	80.86	0.018	0.049	1.185
m,p-xylenes !	7.40	291.95	0.066	0.490	11.822
styrene	2.20	19.66	0.005	0.010	0.250
o-xylene	6.50	107.70	0.024	0.159	3.836
n-nonane	0.54	5.22	0.001	0.001	0.016
n-propylbenzene	2.10	11.38	0.003	0.005	0.132
m,p-ethyltoluenes	6.50	89.27	0.020	0.133	3.200
1,3,5-trimethylbenzene	10.10	28.79	0.007	0.067	1.615
o-ethyltoluene	6.50	22.46	0.005	0.034	0.811
1,2,4-trimethylbenzene	8.80	86.83	0.020	0.177	4.259
C10 aromatics+aliphatics	6.50	81.65	0.019	0.122	2.940
formaldehyde	7.20	35.41	0.009	0.065	1.566
acetaldehyde	5.50	14.62	0.004	0.019	0.469
acrolein (2-propenal)	6.50	2.21	0.001	0.004	0.085
Residual hydrocarbons	4.11	813.73	0.195	0.800	19.300
Sum		4372.71		4.15	
Sum/ phase distance (km)		757			
mg NMOC emit. per km					757
mg ozone/mg NMOC emit.					4.15
mg ozone per km travelled					**3141**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A26
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	337.10			
ethane	0.25	34.46	0.023	0.006	0.161
ethylene	7.40	83.08	0.033	0.245	6.982
acetylene	0.50	11.32	0.007	0.003	0.098
propane	0.48	2.23	0.001	0.000	0.013
propylene	9.40	22.34	0.009	0.088	2.505
i-butane	1.21	27.48	0.018	0.022	0.625
n-butane	1.02	48.69	0.031	0.032	0.897
trans-2-butene	10.00	7.09	0.006	0.056	1.603
cis-2-butene	10.00	6.11	0.005	0.052	1.483
C4 olefins !	9.02	24.78	0.012	0.106	3.015
i-pentane	1.38	91.30	0.056	0.078	2.214
1-pentene	6.20	3.91	0.004	0.023	0.657
n-pentane	1.04	47.67	0.029	0.030	0.858
trans-2-pentene	8.80	4.60	0.003	0.029	0.834
cis-2-pentene	8.80	3.36	0.003	0.025	0.723
2-methyl-2-butene	6.40	6.62	0.005	0.030	0.851
2,3-dimethylbutane	1.07	13.71	0.009	0.010	0.284
2-methylpentane	1.50	41.47	0.027	0.040	1.133
3-methylpentane	1.50	27.10	0.017	0.025	0.713
1-hexene	4.40	5.57	0.005	0.024	0.686
n-hexane	0.98	24.81	0.015	0.015	0.418
C5 and C6 olefins !	6.82	12.66	0.011	0.073	2.072
methylcyclopentane	2.80	15.06	0.010	0.029	0.812
benzene	0.42	125.70	0.061	0.026	0.731
2-methylhexane	1.08	23.16	0.015	0.016	0.465
3-methylhexane	1.40	19.32	0.012	0.017	0.489
2,2,4-trimethylpentane	0.93	31.57	0.020	0.018	0.522
n-heptane	0.81	16.55	0.013	0.010	0.295
C8 alkanes !	1.19	52.98	0.041	0.048	1.377
toluene	2.70	112.77	0.064	0.172	4.889
n-octane	0.60	9.34	0.007	0.004	0.125
ethylbenzene	2.70	19.02	0.012	0.033	0.947
m,p-xylenes !	7.40	65.98	0.040	0.295	8.400
styrene	2.20	6.71	0.004	0.009	0.265
o-xylene	6.50	25.59	0.016	0.106	3.030
n-nonane	0.54	2.95	0.003	0.002	0.046
n-propylbenzene	2.10	3.22	0.003	0.005	0.155
m,p-ethyltoluenes	6.50	18.96	0.014	0.090	2.559
1,3,5-trimethylbenzene	10.10	8.21	0.007	0.067	1.901
o-ethyltoluene	6.50	5.04	0.004	0.023	0.667
1,2,4-trimethylbenzene	8.80	24.31	0.019	0.166	4.721
C10 aromatics+aliphatics	6.50	30.45	0.028	0.179	5.109
formaldehyde	7.20	9.67	0.010	0.068	1.949
acetaldehyde	5.50	1.82	0.001	0.005	0.150
acrolein (2-propenal)	6.50	0.16	0.000	0.001	0.030
Residual hydrocarbons	4.11	327.18	0.269	1.108	31.539
Sum		1506.09		3.51	
Sum/ phase distance (km)		244			
mg NMOC emit. per km					244
mg ozone/mg NMOC emit.					3.51
mg ozone per km travelled					**857**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A27
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	266.45			
ethane	0.25	41.17	0.028	0.007	0.191
ethylene	7.40	133.78	0.071	0.528	14.337
acetylene	0.50	17.00	0.012	0.006	0.157
propane	0.48	1.93	0.001	0.000	0.012
propylene	9.40	39.66	0.023	0.220	5.972
i-butane	1.21	31.20	0.022	0.026	0.707
n-butane	1.02	53.07	0.036	0.037	0.992
trans-2-butene	10.00	9.97	0.006	0.063	1.722
cis-2-butene	10.00	9.00	0.005	0.055	1.479
C4 olefins !	9.02	37.55	0.022	0.201	5.463
i-pentane	1.38	97.56	0.063	0.086	2.341
1-pentene	6.20	4.42	0.003	0.018	0.483
n-pentane	1.04	53.51	0.034	0.035	0.961
trans-2-pentene	8.80	7.28	0.005	0.040	1.096
cis-2-pentene	8.80	4.28	0.003	0.023	0.626
2-methyl-2-butene	6.40	7.63	0.005	0.030	0.807
2,3-dimethylbutane	1.07	12.87	0.008	0.009	0.242
2-methylpentane	1.50	43.03	0.027	0.040	1.097
3-methylpentane	1.50	28.66	0.018	0.027	0.721
1-hexene	4.40	5.03	0.003	0.014	0.377
n-hexane	0.98	27.85	0.017	0.017	0.463
C5 and C6 olefins !	6.82	13.33	0.009	0.059	1.592
methylcyclopentane	2.80	15.11	0.009	0.026	0.702
benzene	0.42	104.57	0.060	0.025	0.682
2-methylhexane	1.08	22.56	0.014	0.015	0.412
3-methylhexane	1.40	19.80	0.012	0.017	0.469
2,2,4-trimethylpentane	0.93	31.11	0.019	0.018	0.487
n-heptane	0.81	14.47	0.009	0.007	0.202
C8 alkanes !	1.19	39.12	0.026	0.030	0.827
toluene	2.70	114.43	0.070	0.188	5.112
n-octane	0.60	8.03	0.005	0.003	0.087
ethylbenzene	2.70	26.47	0.016	0.042	1.144
m,p-xylenes !	7.40	75.62	0.046	0.343	9.319
styrene	2.20	6.33	0.004	0.009	0.233
o-xylene	6.50	28.10	0.017	0.111	3.022
n-nonane	0.54	2.38	0.002	0.001	0.023
n-propylbenzene	2.10	3.02	0.002	0.004	0.112
m,p-ethyltoluenes	6.50	18.01	0.012	0.076	2.051
1,3,5-trimethylbenzene	10.10	8.34	0.006	0.056	1.521
o-ethyltoluene	6.50	5.20	0.003	0.022	0.590
1,2,4-trimethylbenzene	8.80	20.77	0.014	0.121	3.284
C10 aromatics+aliphatics	6.50	21.60	0.014	0.091	2.475
formaldehyde	7.20	12.38	0.009	0.063	1.702
acetaldehyde	5.50	5.63	0.004	0.020	0.545
acrolein (2-propenal)	6.50	0.47	0.000	0.002	0.043
Residual hydrocarbons	4.11	317.33	0.207	0.852	23.118
Sum		1600.64		3.69	
Sum/ phase distance (km)		278			
mg NMOC emit. per km					278
mg ozone/mg NMOC emit.					3.69
mg ozone per km travelled					**1024**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A28
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted Average VOC(i) emit. (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	654.54			
ethane	0.25	86.54	0.020	0.005	0.128
ethylene	7.40	306.14	0.063	0.469	12.182
acetylene	0.50	45.01	0.011	0.005	0.136
propane	0.48	6.64	0.001	0.001	0.017
propylene	9.40	106.68	0.024	0.230	5.956
i-butane	1.21	69.39	0.016	0.019	0.492
n-butane	1.02	128.41	0.029	0.030	0.772
trans-2-butene	10.00	24.93	0.006	0.062	1.609
cis-2-butene	10.00	22.66	0.006	0.056	1.466
C4 olefins !	9.02	94.97	0.021	0.192	4.989
i-pentane	1.38	233.93	0.052	0.071	1.849
1-pentene	6.20	13.10	0.003	0.022	0.563
n-pentane	1.04	132.46	0.030	0.031	0.800
trans-2-pentene	8.80	18.74	0.005	0.041	1.056
cis-2-pentene	8.80	12.06	0.003	0.027	0.696
2-methyl-2-butene	6.40	17.34	0.004	0.026	0.666
2,3-dimethylbutane	1.07	32.72	0.008	0.008	0.210
2-methylpentane	1.50	110.62	0.025	0.037	0.967
3-methylpentane	1.50	74.13	0.017	0.025	0.646
1-hexene	4.40	15.35	0.004	0.018	0.468
n-hexane	0.98	71.88	0.016	0.016	0.410
C5 and C6 olefins !	6.82	38.57	0.010	0.069	1.780
methylcyclopentane	2.80	41.13	0.009	0.026	0.683
benzene	0.42	291.19	0.059	0.025	0.643
2-methylhexane	1.08	60.67	0.014	0.015	0.389
3-methylhexane	1.40	54.60	0.012	0.017	0.451
2,2,4-trimethylpentane	0.93	84.09	0.019	0.018	0.466
n-heptane	0.81	41.37	0.010	0.008	0.207
C8 alkanes !	1.19	120.53	0.028	0.034	0.880
toluene	2.70	353.39	0.080	0.215	5.573
n-octane	0.60	24.64	0.006	0.004	0.093
ethylbenzene	2.70	69.42	0.016	0.043	1.125
m,p-xylenes !	7.40	236.51	0.054	0.401	10.408
styrene	2.20	18.93	0.004	0.010	0.251
o-xylene	6.50	88.61	0.020	0.133	3.452
n-nonane	0.54	6.58	0.002	0.001	0.024
n-propylbenzene	2.10	9.90	0.002	0.005	0.132
m,p-ethyltoluenes	6.50	68.08	0.016	0.106	2.752
1,3,5-trimethylbenzene	10.10	25.49	0.006	0.063	1.643
o-ethyltoluene	6.50	17.78	0.004	0.028	0.720
1,2,4-trimethylbenzene	8.80	73.96	0.018	0.158	4.090
C10 aromatics+aliphatics	6.50	78.35	0.019	0.127	3.283
formaldehyde	7.20	32.20	0.008	0.061	1.579
acetaldehyde	5.50	11.38	0.003	0.016	0.405
acrolein (2-propenal)	6.50	1.39	0.000	0.002	0.062
Residual hydrocarbons	4.11	864.12	0.214	0.880	22.834
Sum		4336.59		3.85	
Sum/ Total cycle distance (km)		363			
mg NMOC emit. per km					363
mg ozone/mg NMOC emit.					3.85
mg ozone per km travelled					**1399**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A29
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrohol

COLD START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	321.52			
ethane	0.25	56.15	0.014	0.004	0.087
ethylene	7.40	269.19	0.069	0.513	12.385
acetylene	0.50	49.12	0.013	0.007	0.159
propane	0.48	5.86	0.001	0.001	0.016
propylene	9.40	111.09	0.030	0.280	6.745
i-butane	1.21	58.68	0.015	0.018	0.439
n-butane	1.02	101.65	0.027	0.027	0.656
trans-2-butene	10.00	26.06	0.007	0.068	1.634
cis-2-butene	10.00	23.89	0.006	0.061	1.481
C4 olefins !	9.02	97.58	0.026	0.233	5.625
i-pentane	1.38	165.44	0.042	0.058	1.391
1-pentene	6.20	14.77	0.004	0.024	0.576
n-pentane	1.04	105.97	0.027	0.028	0.672
trans-2-pentene	8.80	23.43	0.006	0.054	1.297
cis-2-pentene	8.80	18.21	0.004	0.038	0.922
2-methyl-2-butene	6.40	17.84	0.005	0.029	0.711
2,3-dimethylbutane	1.07	26.56	0.007	0.007	0.172
2-methylpentane	1.50	89.37	0.022	0.034	0.814
3-methylpentane	1.50	59.38	0.015	0.023	0.547
1-hexene	4.40	16.78	0.004	0.019	0.461
n-hexane	0.98	61.28	0.016	0.015	0.368
C5 and C6 olefins !	6.82	43.96	0.011	0.077	1.850
methylcyclopentane	2.80	31.25	0.008	0.023	0.549
benzene	0.42	197.99	0.050	0.021	0.507
2-methylhexane	1.08	53.70	0.013	0.014	0.345
3-methylhexane	1.40	46.27	0.012	0.016	0.396
2,2,4-trimethylpentane	0.93	74.21	0.018	0.017	0.411
n-heptane	0.81	34.07	0.009	0.007	0.167
C8 alkanes !	1.19	86.59	0.022	0.027	0.643
toluene	2.70	347.45	0.090	0.242	5.839
n-octane	0.60	23.15	0.006	0.004	0.085
ethylbenzene	2.70	78.73	0.020	0.055	1.332
m,p-xylenes !	7.40	243.46	0.063	0.468	11.282
styrene	2.20	15.22	0.004	0.009	0.226
o-xylene	6.50	93.58	0.024	0.158	3.812
n-nonane	0.54	8.70	0.002	0.001	0.029
n-propylbenzene	2.10	12.10	0.003	0.007	0.159
m,p-ethyltoluenes	6.50	74.67	0.020	0.127	3.062
1,3,5-trimethylbenzene	10.10	27.89	0.007	0.073	1.753
o-ethyltoluene	6.50	20.70	0.005	0.035	0.851
1,2,4-trimethylbenzene	8.80	76.68	0.020	0.176	4.239
C10 aromatics+aliphatics	6.50	79.95	0.021	0.134	3.245
formaldehyde	7.20	38.64	0.011	0.081	1.960
acetaldehyde	5.50	35.01	0.009	0.052	1.257
acrolein (2-propenal)	6.50	1.58	0.000	0.003	0.076
Residual hydrocarbons	4.11	705.43	0.189	0.778	18.769
Sum		3849.27		4.14	
Sum/ phase distance (km)		668			
mg NMOC emit. per km					668
mg ozone/mg NMOC emit.					4.14
mg ozone per km travelled					**2768**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A30
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrohol

STABILISED PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	322.91			
ethane	0.25	31.96	0.026	0.007	0.194
ethylene	7.40	51.68	0.029	0.214	6.369
acetylene	0.50	14.05	0.012	0.006	0.183
propane	0.48	1.15	0.001	0.000	0.010
propylene	9.40	8.43	0.004	0.041	1.215
i-butane	1.21	31.27	0.032	0.038	1.139
n-butane	1.02	45.67	0.044	0.045	1.337
trans-2-butene	10.00	5.96	0.007	0.069	2.062
cis-2-butene	10.00	4.28	0.005	0.049	1.461
C4 olefins !	9.02	19.55	0.014	0.123	3.649
i-pentane	1.38	76.11	0.066	0.091	2.698
1-pentene	6.20	2.77	0.003	0.017	0.518
n-pentane	1.04	40.12	0.036	0.037	1.109
trans-2-pentene	8.80	4.35	0.005	0.041	1.205
cis-2-pentene	8.80	2.29	0.002	0.022	0.649
2-methyl-2-butene	6.40	5.22	0.005	0.030	0.880
2,3-dimethylbutane	1.07	12.17	0.012	0.013	0.388
2-methylpentane	1.50	30.27	0.026	0.039	1.153
3-methylpentane	1.50	21.82	0.019	0.028	0.839
1-hexene	4.40	6.15	0.009	0.040	1.181
n-hexane	0.98	20.72	0.019	0.018	0.549
C5 and C6 olefins !	6.82	7.33	0.007	0.048	1.426
methylcyclopentane	2.80	9.22	0.008	0.022	0.644
benzene	0.42	82.07	0.053	0.022	0.656
2-methylhexane	1.08	16.07	0.014	0.015	0.454
3-methylhexane	1.40	12.79	0.010	0.014	0.424
2,2,4-trimethylpentane	0.93	25.23	0.021	0.020	0.586
n-heptane	0.81	11.38	0.011	0.009	0.258
C8 alkanes !	1.19	32.53	0.030	0.036	1.079
toluene	2.70	55.78	0.046	0.124	3.680
n-octane	0.60	5.69	0.005	0.003	0.091
ethylbenzene	2.70	9.13	0.009	0.023	0.691
m,p-xylenes !	7.40	36.67	0.033	0.242	7.207
styrene	2.20	4.52	0.004	0.010	0.292
o-xylene	6.50	13.36	0.013	0.082	2.446
n-nonane	0.54	2.56	0.003	0.001	0.043
n-propylbenzene	2.10	2.41	0.003	0.006	0.168
m,p-ethyltoluenes	6.50	10.13	0.010	0.067	1.984
1,3,5-trimethylbenzene	10.10	6.01	0.007	0.070	2.070
o-ethyltoluene	6.50	2.93	0.003	0.021	0.623
1,2,4-trimethylbenzene	8.80	15.34	0.017	0.148	4.411
C10 aromatics+aliphatics	6.50	21.34	0.024	0.158	4.688
formaldehyde	7.20	9.34	0.012	0.087	2.600
acetaldehyde	5.50	2.75	0.003	0.014	0.431
acrolein (2-propenal)	6.50	0.05	0.000	0.000	0.004
Residual hydrocarbons	4.11	271.69	0.280	1.152	34.255
Sum		1102.36		3.36	
Sum/ phase distance (km)		178			
mg NMOC emit. per km					178
mg ozone/mg NMOC emit.					3.36
mg ozone per km travelled					**600**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A31
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrohol

HOT START TRANSIENT PHASE					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		bag (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	247.55			
ethane	0.25	36.30	0.028	0.007	0.187
ethylene	7.40	100.21	0.062	0.460	12.519
acetylene	0.50	14.04	0.011	0.006	0.151
propane	0.48	2.43	0.002	0.001	0.024
propylene	9.40	28.00	0.019	0.178	4.832
i-butane	1.21	29.14	0.023	0.028	0.761
n-butane	1.02	47.36	0.037	0.038	1.040
trans-2-butene	10.00	9.07	0.007	0.070	1.904
cis-2-butene	10.00	8.32	0.006	0.063	1.724
C4 olefins !	9.02	32.89	0.023	0.204	5.552
i-pentane	1.38	83.77	0.062	0.086	2.344
1-pentene	6.20	3.94	0.003	0.019	0.526
n-pentane	1.04	45.79	0.034	0.035	0.965
trans-2-pentene	8.80	6.35	0.005	0.044	1.194
cis-2-pentene	8.80	3.69	0.003	0.025	0.677
2-methyl-2-butene	6.40	6.44	0.005	0.034	0.918
2,3-dimethylbutane	1.07	10.82	0.008	0.008	0.227
2-methylpentane	1.50	35.48	0.025	0.038	1.033
3-methylpentane	1.50	24.36	0.018	0.027	0.726
1-hexene	4.40	4.29	0.003	0.015	0.411
n-hexane	0.98	24.33	0.017	0.017	0.461
C5 and C6 olefins !	6.82	8.59	0.007	0.049	1.321
methylcyclopentane	2.80	13.43	0.010	0.027	0.730
benzene	0.42	81.96	0.054	0.023	0.622
2-methylhexane	1.08	18.03	0.013	0.014	0.376
3-methylhexane	1.40	16.00	0.011	0.016	0.435
2,2,4-trimethylpentane	0.93	27.35	0.020	0.018	0.501
n-heptane	0.81	12.99	0.010	0.008	0.214
C8 alkanes !	1.19	33.59	0.025	0.030	0.814
toluene	2.70	90.33	0.064	0.173	4.708
n-octane	0.60	6.81	0.005	0.003	0.082
ethylbenzene	2.70	21.94	0.016	0.044	1.189
m,p-xylenes !	7.40	62.43	0.046	0.337	9.169
styrene	2.20	6.94	0.005	0.011	0.294
o-xylene	6.50	23.86	0.017	0.112	3.035
n-nonane	0.54	2.73	0.002	0.001	0.032
n-propylbenzene	2.10	2.92	0.002	0.005	0.126
m,p-ethyltoluenes	6.50	15.87	0.013	0.082	2.234
1,3,5-trimethylbenzene	10.10	6.89	0.005	0.053	1.452
o-ethyltoluene	6.50	3.78	0.003	0.019	0.512
1,2,4-trimethylbenzene	8.80	15.46	0.012	0.104	2.828
C10 aromatics+aliphatics	6.50	18.75	0.014	0.093	2.521
formaldehyde	7.20	14.83	0.013	0.091	2.482
acetaldehyde	5.50	14.10	0.011	0.059	1.605
acrolein (2-propenal)	6.50	0.23	0.000	0.001	0.033
Residual hydrocarbons	4.11	280.87	0.219	0.902	24.510
Sum		1357.69		3.68	
Sum/ phase distance (km)		236			
mg NMOC emit. per km					236
mg ozone/mg NMOC emit.					3.68
mg ozone per km travelled					**869**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A32
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 1 post-tune results
Post-1986 vehicles with unleaded petrohol

AVERAGE ADR CYCLE					
Compound	MIR	Weighted Average VOC(i) emit. (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	602.27			
ethane	0.25	76.80	0.020	0.005	0.133
ethylene	7.40	224.55	0.057	0.424	11.119
acetylene	0.50	43.18	0.012	0.006	0.158
propane	0.48	5.05	0.001	0.001	0.016
propylene	9.40	72.16	0.020	0.190	4.985
i-butane	1.21	73.11	0.021	0.025	0.668
n-butane	1.02	116.37	0.033	0.034	0.890
trans-2-butene	10.00	22.33	0.007	0.068	1.791
cis-2-butene	10.00	19.30	0.006	0.059	1.545
C4 olefins !	9.02	80.26	0.022	0.201	5.274
i-pentane	1.38	195.00	0.053	0.073	1.914
1-pentene	6.20	11.36	0.003	0.021	0.556
n-pentane	1.04	111.79	0.031	0.032	0.841
trans-2-pentene	8.80	18.04	0.005	0.048	1.258
cis-2-pentene	8.80	12.23	0.004	0.032	0.844
2-methyl-2-butene	6.40	16.56	0.005	0.031	0.807
2,3-dimethylbutane	1.07	29.76	0.008	0.009	0.233
2-methylpentane	1.50	88.92	0.024	0.037	0.959
3-methylpentane	1.50	61.24	0.017	0.025	0.664
1-hexene	4.40	15.81	0.005	0.022	0.580
n-hexane	0.98	60.94	0.017	0.017	0.433
C5 and C6 olefins !	6.82	31.13	0.010	0.066	1.725
methylcyclopentane	2.80	30.31	0.008	0.023	0.604
benzene	0.42	213.92	0.054	0.023	0.595
2-methylhexane	1.08	49.44	0.014	0.015	0.390
3-methylhexane	1.40	41.81	0.012	0.016	0.423
2,2,4-trimethylpentane	0.93	72.73	0.020	0.019	0.491
n-heptane	0.81	33.44	0.009	0.008	0.201
C8 alkanes !	1.19	88.91	0.026	0.030	0.797
toluene	2.70	256.67	0.072	0.196	5.130
n-octane	0.60	19.53	0.006	0.003	0.089
ethylbenzene	2.70	55.49	0.016	0.044	1.150
m,p-xylenes !	7.40	176.95	0.051	0.375	9.837
styrene	2.20	15.03	0.004	0.010	0.254
o-xylene	6.50	67.20	0.019	0.126	3.299
n-nonane	0.54	7.86	0.002	0.001	0.033
n-propylbenzene	2.10	9.28	0.003	0.006	0.155
m,p-ethyltoluenes	6.50	51.28	0.015	0.099	2.588
1,3,5-trimethylbenzene	10.10	21.93	0.007	0.066	1.723
o-ethyltoluene	6.50	13.99	0.004	0.027	0.715
1,2,4-trimethylbenzene	8.80	57.13	0.017	0.149	3.918
C10 aromatics+aliphatics	6.50	66.41	0.020	0.127	3.336
formaldehyde	7.20	34.41	0.011	0.078	2.033
acetaldehyde	5.50	25.84	0.008	0.044	1.141
acrolein (2-propenal)	6.50	0.86	0.000	0.002	0.049
Residual hydrocarbons	4.11	735.12	0.219	0.902	23.655
Sum		3531.43		3.81	
Sum/ Total cycle distance (km)		296			
mg NMOC emit. per km					296
mg ozone/mg NMOC emit.					3.81
mg ozone per km travelled					**1128**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A33
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrol

COLD START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	823.51	987.06						
ethane	0.25	127.21	164.13	0.013	0.003	0.070	0.018	0.004	0.099
ethylene	7.40	1110.25	1102.84	0.112	0.832	18.005	0.123	0.908	20.066
acetylene	0.50	209.35	470.10	0.021	0.011	0.232	0.054	0.027	0.601
propane	0.48	32.14	28.31	0.003	0.002	0.034	0.003	0.002	0.034
propylene	9.40	505.42	499.95	0.051	0.481	10.418	0.055	0.521	11.523
i-butane	1.21	133.83	116.49	0.014	0.016	0.357	0.013	0.016	0.354
n-butane	1.02	209.69	183.85	0.021	0.022	0.471	0.021	0.021	0.468
trans-2-butene	10.00	89.62	77.47	0.009	0.091	1.971	0.009	0.087	1.927
cis-2-butene	10.00	45.70	38.83	0.005	0.046	1.006	0.004	0.044	0.971
C4 olefins !	9.02	212.43	192.14	0.022	0.194	4.208	0.021	0.194	4.286
i-pentane	1.38	439.21	377.47	0.045	0.062	1.334	0.042	0.058	1.291
1-pentene	6.20	34.11	28.78	0.003	0.022	0.466	0.003	0.020	0.443
n-pentane	1.04	151.07	130.02	0.015	0.016	0.345	0.015	0.015	0.334
trans-2-pentene	8.80	45.96	39.98	0.005	0.041	0.890	0.004	0.039	0.872
cis-2-pentene	8.80	23.69	20.57	0.002	0.021	0.459	0.002	0.020	0.448
2-methyl-2-butene	6.40	54.38	50.23	0.006	0.035	0.764	0.006	0.036	0.798
2,3-dimethylbutane	1.07	52.76	45.35	0.005	0.006	0.124	0.005	0.005	0.119
2-methylpentane	1.50	198.19	170.41	0.020	0.030	0.652	0.019	0.028	0.626
3-methylpentane	1.50	137.70	117.32	0.014	0.021	0.453	0.013	0.019	0.430
1-hexene	4.40	25.62	21.88	0.003	0.011	0.248	0.002	0.011	0.237
n-hexane	0.98	114.86	99.80	0.012	0.011	0.246	0.011	0.011	0.239
C5 and C6 olefins !	6.82	64.56	55.40	0.007	0.045	0.965	0.006	0.042	0.920
methylcyclopentane	2.80	82.03	70.68	0.008	0.023	0.503	0.008	0.022	0.481
benzene	0.42	418.59	383.60	0.042	0.018	0.385	0.042	0.018	0.394
2-methylhexane	1.08	131.48	110.21	0.013	0.014	0.311	0.012	0.013	0.288
3-methylhexane	1.40	93.51	78.43	0.009	0.013	0.286	0.009	0.012	0.266
2,2,4-trimethylpentane	0.93	70.65	56.78	0.007	0.007	0.144	0.006	0.006	0.128
n-heptane	0.81	3.42	2.23	0.000	0.000	0.006	0.000	0.000	0.004
C8 alkanes !	1.19	198.77	160.43	0.020	0.024	0.516	0.017	0.021	0.460
toluene	2.70	932.00	831.14	0.094	0.254	5.491	0.091	0.246	5.437
n-octane	0.60	38.83	32.30	0.004	0.002	0.051	0.003	0.002	0.046
ethylbenzene	2.70	181.77	155.32	0.018	0.049	1.071	0.017	0.046	1.014
m,p-xylenes !	7.40	915.82	786.16	0.092	0.682	14.770	0.086	0.634	14.026
styrene	2.20	28.31	37.62	0.003	0.006	0.136	0.004	0.009	0.200
o-xylene	6.50	227.95	192.16	0.023	0.149	3.229	0.021	0.136	3.008
n-nonane	0.54	29.32	22.96	0.003	0.002	0.034	0.002	0.001	0.029
n-propylbenzene	2.10	52.44	42.66	0.005	0.011	0.239	0.005	0.010	0.214
m,p-ethyltoluenes	6.50	163.60	163.01	0.016	0.107	2.313	0.018	0.117	2.597
1,3,5-trimethylbenzene	10.10	79.58	66.34	0.008	0.081	1.746	0.007	0.073	1.606
o-ethyltoluene	6.50	54.44	46.00	0.005	0.036	0.770	0.005	0.033	0.719
1,2,4-trimethylbenzene	8.80	215.86	182.57	0.022	0.191	4.126	0.020	0.174	3.848
C10 aromatics+aliphatics	6.50	221.57	182.36	0.022	0.144	3.123	0.020	0.129	2.852
formaldehyde	7.20	150.54	132.25	0.016	0.116	2.694	0.015	0.107	2.361
acetaldehyde	5.50	42.52	35.51	0.005	0.025	0.600	0.004	0.022	0.485
acrolein (2-propenal)	6.50	20.62	17.39	0.002	0.014	0.341	0.002	0.013	0.280
Residual hydrocarbons	4.11	1355.11	1219.02	0.142	0.585	13.399	0.134	0.551	12.170
Sum		9726.48	9038.45		4.62			4.52	
Sum/ phase distance (km)		1722	1567						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1722			1567
mg ozone/mg NMOC emit.						4.62			4.52
mg ozone per km travelled						**7956**			**7089**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A34
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrol

STABILISED PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	733.05	826.44						
ethane	0.25	139.91	193.28	0.017	0.004	0.088	0.023	0.006	0.128
ethylene	7.40	1100.86	1230.62	0.130	0.966	20.435	0.136	1.008	22.386
acetylene	0.50	403.88	956.61	0.048	0.024	0.507	0.095	0.047	1.053
propane	0.48	21.19	18.39	0.003	0.001	0.026	0.002	0.001	0.021
propylene	9.40	455.80	585.39	0.054	0.508	10.758	0.064	0.603	13.380
i-butane	1.21	81.85	78.98	0.010	0.012	0.249	0.009	0.010	0.229
n-butane	1.02	129.60	125.53	0.015	0.016	0.332	0.014	0.014	0.315
trans-2-butene	10.00	75.05	78.60	0.009	0.089	1.884	0.009	0.092	2.044
cis-2-butene	10.00	32.41	44.19	0.004	0.039	0.815	0.005	0.050	1.116
C4 olefins !	9.02	173.36	174.57	0.021	0.186	3.929	0.020	0.181	4.012
i-pentane	1.38	268.21	254.08	0.032	0.044	0.930	0.029	0.040	0.899
1-pentene	6.20	23.64	37.43	0.003	0.017	0.368	0.004	0.027	0.599
n-pentane	1.04	89.14	115.13	0.011	0.011	0.233	0.013	0.014	0.310
trans-2-pentene	8.80	28.90	46.54	0.003	0.030	0.639	0.005	0.046	1.020
cis-2-pentene	8.80	15.59	24.52	0.002	0.016	0.345	0.003	0.025	0.559
2-methyl-2-butene	6.40	40.84	51.32	0.005	0.031	0.657	0.006	0.040	0.877
2,3-dimethylbutane	1.07	31.54	44.55	0.004	0.004	0.085	0.005	0.005	0.118
2-methylpentane	1.50	121.59	120.31	0.014	0.022	0.458	0.013	0.020	0.445
3-methylpentane	1.50	85.71	93.41	0.010	0.015	0.323	0.010	0.016	0.345
1-hexene	4.40	15.64	45.82	0.002	0.008	0.173	0.005	0.021	0.459
n-hexane	0.98	72.69	76.19	0.009	0.008	0.179	0.008	0.008	0.182
C5 and C6 olefins !	6.82	42.29	133.33	0.005	0.034	0.725	0.014	0.093	2.059
methylcyclopentane	2.80	52.51	55.27	0.006	0.017	0.369	0.006	0.017	0.381
benzene	0.42	388.88	402.71	0.046	0.019	0.410	0.045	0.019	0.417
2-methylhexane	1.08	82.44	104.33	0.010	0.011	0.224	0.011	0.012	0.266
3-methylhexane	1.40	59.25	62.65	0.007	0.010	0.208	0.007	0.010	0.212
2,2,4-trimethylpentane	0.93	43.17	46.05	0.005	0.005	0.101	0.005	0.005	0.104
n-heptane	0.81	2.11	121.17	0.000	0.000	0.004	0.011	0.009	0.196
C8 alkanes !	1.19	129.48	145.17	0.015	0.018	0.387	0.016	0.019	0.423
toluene	2.70	775.40	764.53	0.092	0.248	5.256	0.085	0.230	5.108
n-octane	0.60	25.28	14.09	0.003	0.002	0.038	0.002	0.001	0.024
ethylbenzene	2.70	144.46	141.57	0.017	0.046	0.980	0.016	0.043	0.960
m,p-xylenes !	7.40	709.45	691.06	0.084	0.623	13.183	0.077	0.570	12.658
styrene	2.20	53.81	44.07	0.006	0.014	0.297	0.005	0.012	0.265
o-xylene	6.50	169.36	94.31	0.020	0.131	2.765	0.012	0.078	1.738
n-nonane	0.54	19.29	12.62	0.002	0.001	0.026	0.001	0.001	0.018
n-propylbenzene	2.10	32.69	24.52	0.004	0.008	0.172	0.003	0.006	0.133
m,p-ethyltoluenes	6.50	124.06	71.12	0.015	0.096	2.025	0.009	0.060	1.332
1,3,5-trimethylbenzene	10.10	59.24	38.88	0.007	0.071	1.503	0.005	0.048	1.070
o-ethyltoluene	6.50	41.37	115.85	0.005	0.032	0.675	0.011	0.073	1.630
1,2,4-trimethylbenzene	8.80	171.24	89.29	0.020	0.179	3.783	0.012	0.104	2.311
C10 aromatics+aliphatics	6.50	186.78	203.18	0.022	0.144	3.047	0.022	0.146	3.243
formaldehyde	7.20	292.46	177.12	0.035	0.251	5.306	0.022	0.160	3.549
acetaldehyde	5.50	46.23	33.44	0.005	0.030	0.640	0.004	0.023	0.504
acrolein (2-propenal)	6.50	53.87	22.79	0.006	0.042	0.882	0.003	0.017	0.376
Residual hydrocarbons	4.11	1315.12	843.16	0.156	0.642	13.578	0.115	0.474	10.525
Sum		8427.63	8847.75		4.73			4.50	
Sum/ phase distance (km)		1373	1439						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1373			1439
mg ozone/mg NMOC emit.						4.73			4.50
mg ozone per km travelled						**6487**			**6480**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A35
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrol

HOT START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	563.60	680.19						
ethane	0.25	131.61	160.18	0.016	0.004	0.087	0.017	0.004	0.094
ethylene	7.40	1006.94	1149.12	0.131	0.972	21.113	0.134	0.994	21.643
acetylene	0.50	554.75	539.29	0.053	0.026	0.575	0.060	0.030	0.654
propane	0.48	15.70	27.66	0.003	0.001	0.026	0.003	0.001	0.030
propylene	9.40	435.06	492.33	0.059	0.555	12.058	0.059	0.554	12.067
i-butane	1.21	61.71	79.84	0.011	0.013	0.293	0.012	0.014	0.308
n-butane	1.02	100.90	135.20	0.018	0.019	0.403	0.020	0.020	0.438
trans-2-butene	10.00	65.25	69.50	0.010	0.104	2.249	0.011	0.111	2.422
cis-2-butene	10.00	25.02	30.11	0.006	0.056	1.219	0.007	0.065	1.420
C4 olefins !	9.02	138.08	168.05	0.021	0.187	4.056	0.021	0.188	4.101
i-pentane	1.38	212.83	273.32	0.037	0.051	1.115	0.039	0.054	1.183
1-pentene	6.20	17.70	19.90	0.003	0.020	0.426	0.004	0.024	0.516
n-pentane	1.04	82.68	91.27	0.014	0.015	0.318	0.015	0.015	0.336
trans-2-pentene	8.80	22.96	27.78	0.004	0.036	0.785	0.005	0.042	0.921
cis-2-pentene	8.80	12.73	14.11	0.002	0.020	0.443	0.003	0.023	0.511
2-methyl-2-butene	6.40	29.89	39.27	0.005	0.031	0.667	0.007	0.042	0.909
2,3-dimethylbutane	1.07	27.30	29.49	0.002	0.002	0.052	0.002	0.003	0.056
2-methylpentane	1.50	102.50	126.49	0.016	0.024	0.523	0.016	0.024	0.526
3-methylpentane	1.50	72.14	88.82	0.011	0.017	0.368	0.012	0.017	0.378
1-hexene	4.40	13.88	15.29	0.002	0.010	0.219	0.003	0.011	0.240
n-hexane	0.98	62.70	74.30	0.010	0.009	0.203	0.009	0.009	0.201
C5 and C6 olefins !	6.82	35.14	41.35	0.006	0.042	0.917	0.006	0.042	0.918
methylcyclopentane	2.80	44.82	54.37	0.007	0.019	0.408	0.007	0.019	0.416
benzene	0.42	337.87	354.09	0.045	0.019	0.407	0.043	0.018	0.397
2-methylhexane	1.08	73.80	83.44	0.011	0.012	0.254	0.010	0.011	0.245
3-methylhexane	1.40	52.37	58.91	0.008	0.011	0.233	0.007	0.010	0.222
2,2,4-trimethylpentane	0.93	37.22	40.68	0.006	0.005	0.114	0.005	0.005	0.105
n-heptane	0.81	1.90	1.65	0.000	0.000	0.005	0.000	0.000	0.006
C8 alkanes !	1.19	119.15	119.37	0.018	0.021	0.462	0.016	0.018	0.403
toluene	2.70	664.35	732.27	0.089	0.240	5.206	0.085	0.230	5.011
n-octane	0.60	20.96	25.02	0.003	0.002	0.037	0.003	0.002	0.037
ethylbenzene	2.70	121.65	129.08	0.017	0.045	0.975	0.015	0.041	0.899
m,p-xylenes !	7.40	600.06	634.27	0.079	0.588	12.768	0.073	0.541	11.779
styrene	2.20	34.20	43.40	0.003	0.008	0.165	0.004	0.010	0.207
o-xylene	6.50	143.22	152.38	0.019	0.124	2.697	0.017	0.113	2.469
n-nonane	0.54	15.32	16.89	0.002	0.001	0.025	0.002	0.001	0.022
n-propylbenzene	2.10	25.47	27.84	0.002	0.004	0.089	0.003	0.007	0.144
m,p-ethyltoluenes	6.50	100.85	107.88	0.010	0.067	1.460	0.013	0.082	1.788
1,3,5-trimethylbenzene	10.10	46.90	50.19	0.006	0.065	1.415	0.006	0.057	1.251
o-ethyltoluene	6.50	33.22	35.91	0.003	0.018	0.390	0.004	0.027	0.585
1,2,4-trimethylbenzene	8.80	139.68	152.69	0.010	0.088	1.905	0.017	0.146	3.180
C10 aromatics+aliphatics	6.50	155.40	152.75	0.018	0.116	2.527	0.017	0.112	2.428
formaldehyde	7.20	131.23	120.43	0.027	0.195	4.240	0.021	0.148	3.229
acetaldehyde	5.50	35.22	29.17	0.006	0.035	0.754	0.005	0.028	0.601
acrolein (2-propenal)	6.50	23.58	19.01	0.004	0.025	0.547	0.003	0.018	0.399
Residual hydrocarbons	4.11	1014.97	1079.81	0.166	0.682	14.801	0.160	0.657	14.307
Sum		7200.86	7914.20		4.61			4.59	
Sum/ phase distance (km)		1243	1226						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1243			1226
mg ozone/mg NMOC emit.						4.61			4.59
mg ozone per km travelled						**5725**			**5628**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A36
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrol

AVERAGE ADR CYCLE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Weighted	Weighted						
		Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		(mg)	(mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	1358.00	1547.22						
ethane	0.25	259.77	334.76	0.015	0.004	0.083	0.020	0.005	0.111
ethylene	7.40	2111.99	2252.86	0.126	0.932	19.962	0.133	0.984	21.775
acetylene	0.50	710.07	1405.40	0.042	0.021	0.453	0.079	0.040	0.877
propane	0.48	45.28	42.38	0.003	0.001	0.028	0.002	0.001	0.026
propylene	9.40	912.97	1040.19	0.055	0.513	10.978	0.061	0.574	12.709
i-butane	1.21	184.52	175.54	0.011	0.013	0.286	0.011	0.013	0.284
n-butane	1.02	293.43	283.03	0.018	0.018	0.384	0.017	0.017	0.387
trans-2-butene	10.00	155.56	155.78	0.009	0.093	1.991	0.010	0.096	2.122
cis-2-butene	10.00	74.75	85.97	0.004	0.045	0.960	0.005	0.053	1.175
C4 olefins !	9.02	348.70	341.74	0.021	0.188	4.029	0.021	0.186	4.110
i-pentane	1.38	607.73	573.28	0.036	0.050	1.076	0.035	0.048	1.068
1-pentene	6.20	51.13	64.66	0.003	0.019	0.407	0.004	0.025	0.546
n-pentane	1.04	211.14	229.39	0.013	0.013	0.282	0.014	0.015	0.324
trans-2-pentene	8.80	65.31	82.56	0.004	0.034	0.737	0.005	0.044	0.972
cis-2-pentene	8.80	35.15	43.73	0.002	0.019	0.397	0.003	0.024	0.524
2-methyl-2-butene	6.40	83.66	98.55	0.005	0.032	0.686	0.006	0.039	0.867
2,3-dimethylbutane	1.07	63.31	74.39	0.004	0.004	0.087	0.004	0.005	0.103
2-methylpentane	1.50	271.87	258.58	0.016	0.024	0.523	0.015	0.023	0.511
3-methylpentane	1.50	190.70	190.51	0.011	0.017	0.366	0.011	0.017	0.375
1-hexene	4.40	35.93	65.10	0.002	0.009	0.203	0.004	0.016	0.362
n-hexane	0.98	160.73	157.10	0.010	0.009	0.202	0.009	0.009	0.201
C5 and C6 olefins !	6.82	95.13	181.68	0.006	0.039	0.831	0.010	0.070	1.548
methylcyclopentane	2.80	115.03	113.28	0.007	0.019	0.412	0.007	0.019	0.415
benzene	0.42	750.09	743.62	0.045	0.019	0.402	0.044	0.018	0.409
2-methylhexane	1.08	182.97	193.93	0.011	0.012	0.253	0.011	0.012	0.268
3-methylhexane	1.40	130.49	125.87	0.008	0.011	0.234	0.007	0.010	0.228
2,2,4-trimethylpentane	0.93	96.50	91.36	0.006	0.005	0.115	0.005	0.005	0.110
n-heptane	0.81	4.78	123.42	0.000	0.000	0.005	0.006	0.005	0.112
C8 alkanes !	1.19	287.53	276.79	0.017	0.020	0.438	0.016	0.019	0.428
toluene	2.70	1536.76	1469.85	0.092	0.248	5.303	0.086	0.233	5.165
n-octane	0.60	53.54	39.64	0.003	0.002	0.041	0.002	0.001	0.032
ethylbenzene	2.70	290.11	270.64	0.017	0.047	1.002	0.016	0.043	0.956
m,p-xylenes !	7.40	1425.97	1327.90	0.085	0.630	13.490	0.078	0.576	12.752
styrene	2.20	80.04	78.26	0.005	0.010	0.224	0.005	0.010	0.231
o-xylene	6.50	344.98	248.29	0.021	0.134	2.867	0.015	0.098	2.176
n-nonane	0.54	40.41	30.30	0.002	0.001	0.028	0.002	0.001	0.021
n-propylbenzene	2.10	63.24	55.73	0.004	0.008	0.170	0.003	0.007	0.153
m,p-ethyltoluenes	6.50	236.56	192.75	0.014	0.092	1.964	0.012	0.078	1.719
1,3,5-trimethylbenzene	10.10	119.66	90.70	0.007	0.072	1.545	0.005	0.055	1.221
o-ethyltoluene	6.50	76.09	152.51	0.005	0.029	0.631	0.008	0.054	1.195
1,2,4-trimethylbenzene	8.80	304.96	236.15	0.018	0.160	3.421	0.014	0.127	2.814
C10 aromatics+aliphatics	6.50	354.91	351.96	0.021	0.137	2.944	0.021	0.133	2.950
formaldehyde	7.20	474.72	314.71	0.029	0.206	4.405	0.020	0.143	3.168
acetaldehyde	5.50	93.08	68.37	0.006	0.031	0.658	0.004	0.024	0.523
acrolein (2-propenal)	6.50	79.83	41.46	0.005	0.031	0.668	0.003	0.016	0.361
Residual hydrocarbons	4.11	2628.04	2002.29	0.157	0.646	13.828	0.128	0.525	11.614
Sum		16739.09	16776.96		4.67			4.52	
Sum/ Total cycle distance (km)		1410	1406						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1410			1406
mg ozone/mg NMOC emit.						4.67			4.52
mg ozone per km travelled						**6583**			**6354**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A37
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrohol

COLD START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	649.31	778.60						
ethane	0.25	105.40	105.81	0.012	0.003	0.064	0.013	0.003	0.073
ethylene	7.40	989.97	980.51	0.115	0.849	18.435	0.121	0.893	19.966
acetylene	0.50	411.06	602.05	0.042	0.021	0.451	0.074	0.037	0.828
propane	0.48	33.71	35.15	0.004	0.002	0.043	0.004	0.002	0.046
propylene	9.40	434.26	427.09	0.050	0.472	10.247	0.053	0.494	11.048
i-butane	1.21	131.79	134.67	0.016	0.019	0.415	0.017	0.020	0.448
n-butane	1.02	203.01	190.67	0.024	0.024	0.530	0.023	0.024	0.535
trans-2-butene	10.00	83.76	81.57	0.010	0.097	2.098	0.010	0.100	2.245
cis-2-butene	10.00	100.95	52.46	0.012	0.123	2.661	0.006	0.065	1.443
C4 olefins !	9.02	191.82	174.95	0.022	0.200	4.336	0.022	0.194	4.342
i-pentane	1.38	412.00	354.51	0.048	0.066	1.433	0.044	0.060	1.346
1-pentene	6.20	33.39	29.46	0.004	0.024	0.523	0.004	0.022	0.502
n-pentane	1.04	148.62	115.34	0.017	0.018	0.381	0.014	0.015	0.330
trans-2-pentene	8.80	45.27	38.41	0.005	0.046	0.994	0.005	0.042	0.930
cis-2-pentene	8.80	23.88	19.87	0.003	0.024	0.519	0.002	0.022	0.481
2-methyl-2-butene	6.40	55.65	45.22	0.006	0.040	0.875	0.006	0.036	0.796
2,3-dimethylbutane	1.07	48.45	39.99	0.006	0.006	0.129	0.005	0.005	0.118
2-methylpentane	1.50	186.17	145.08	0.021	0.031	0.683	0.018	0.027	0.599
3-methylpentane	1.50	129.78	99.68	0.015	0.022	0.474	0.012	0.018	0.411
1-hexene	4.40	25.91	20.20	0.003	0.013	0.280	0.002	0.011	0.245
n-hexane	0.98	112.66	81.82	0.012	0.012	0.265	0.010	0.010	0.221
C5 and C6 olefins !	6.82	65.54	50.15	0.007	0.049	1.072	0.006	0.042	0.941
methylcyclopentane	2.80	78.75	58.16	0.009	0.024	0.526	0.007	0.020	0.448
benzene	0.42	385.97	323.77	0.043	0.018	0.390	0.040	0.017	0.374
2-methylhexane	1.08	130.05	89.14	0.014	0.015	0.331	0.011	0.012	0.265
3-methylhexane	1.40	92.18	63.08	0.010	0.014	0.303	0.008	0.011	0.243
2,2,4-trimethylpentane	0.93	68.61	47.52	0.008	0.007	0.152	0.006	0.005	0.122
n-heptane	0.81	4.68	1.98	0.000	0.000	0.008	0.000	0.000	0.004
C8 alkanes !	1.19	194.55	134.49	0.021	0.025	0.536	0.017	0.020	0.441
toluene	2.70	866.02	650.86	0.094	0.253	5.503	0.080	0.216	4.838
n-octane	0.60	37.52	25.22	0.004	0.002	0.052	0.003	0.002	0.042
ethylbenzene	2.70	168.09	123.70	0.018	0.049	1.057	0.015	0.041	0.919
m,p-xylenes !	7.40	855.91	614.22	0.091	0.676	14.685	0.076	0.559	12.514
styrene	2.20	30.72	32.92	0.003	0.007	0.152	0.004	0.009	0.200
o-xylene	6.50	214.82	150.70	0.023	0.149	3.231	0.019	0.121	2.697
n-nonane	0.54	28.23	17.84	0.003	0.002	0.034	0.002	0.001	0.027
n-propylbenzene	2.10	50.70	34.20	0.005	0.011	0.242	0.004	0.009	0.198
m,p-ethyltoluenes	6.50	149.99	130.67	0.016	0.103	2.245	0.016	0.105	2.338
1,3,5-trimethylbenzene	10.10	74.20	50.97	0.008	0.078	1.689	0.006	0.063	1.418
o-ethyltoluene	6.50	50.89	36.11	0.005	0.035	0.758	0.004	0.029	0.646
1,2,4-trimethylbenzene	8.80	200.10	142.14	0.021	0.184	3.993	0.017	0.154	3.445
C10 aromatics+aliphatics	6.50	213.86	146.94	0.022	0.146	3.165	0.018	0.118	2.630
formaldehyde	7.20	226.21	179.46	0.027	0.195	4.242	0.022	0.159	3.556
acetaldehyde	5.50	145.08	127.02	0.017	0.093	2.026	0.016	0.086	1.923
acrolein (2-propenal)	6.50	24.35	19.21	0.003	0.019	0.410	0.002	0.015	0.344
Residual hydrocarbons	4.11	929.49	1102.30	0.082	0.339	7.361	0.136	0.558	12.477
Sum		9194.03	8127.31		4.60			4.47	
Sum/ phase distance (km)		1607	1414						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1607			1414
mg ozone/mg NMOC emit.						4.60			4.47
mg ozone per km travelled						**7399**			**6323**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A38
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrohol

STABILISED PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	548.04	482.77						
ethane	0.25	117.77	103.05	0.014	0.003	0.074	0.016	0.004	0.084
ethylene	7.40	955.99	869.13	0.112	0.829	17.810	0.135	0.999	20.917
acetylene	0.50	686.75	414.38	0.080	0.040	0.865	0.060	0.030	0.629
propane	0.48	26.16	13.38	0.003	0.001	0.032	0.002	0.001	0.021
propylene	9.40	539.90	374.30	0.063	0.594	12.776	0.059	0.550	11.530
i-butane	1.21	83.29	61.51	0.010	0.012	0.254	0.009	0.011	0.239
n-butane	1.02	129.60	93.10	0.015	0.015	0.333	0.014	0.015	0.308
trans-2-butene	10.00	77.48	65.42	0.009	0.091	1.951	0.010	0.103	2.159
cis-2-butene	10.00	38.19	26.02	0.004	0.045	0.961	0.004	0.042	0.881
C4 olefins !	9.02	165.92	135.19	0.019	0.175	3.767	0.021	0.194	4.054
i-pentane	1.38	282.48	217.87	0.033	0.046	0.981	0.034	0.047	0.975
1-pentene	6.20	26.79	28.80	0.003	0.019	0.418	0.005	0.030	0.625
n-pentane	1.04	83.95	62.41	0.010	0.010	0.220	0.010	0.010	0.212
trans-2-pentene	8.80	33.62	26.74	0.004	0.035	0.745	0.004	0.038	0.793
cis-2-pentene	8.80	17.91	14.07	0.002	0.018	0.397	0.002	0.020	0.419
2-methyl-2-butene	6.40	43.52	35.16	0.005	0.033	0.701	0.006	0.037	0.769
2,3-dimethylbutane	1.07	30.91	23.43	0.004	0.004	0.083	0.004	0.004	0.083
2-methylpentane	1.50	126.56	84.69	0.015	0.022	0.478	0.013	0.019	0.404
3-methylpentane	1.50	81.79	57.72	0.010	0.014	0.309	0.009	0.013	0.279
1-hexene	4.40	19.04	13.18	0.002	0.010	0.211	0.002	0.009	0.195
n-hexane	0.98	72.58	50.99	0.008	0.008	0.179	0.008	0.008	0.161
C5 and C6 olefins !	6.82	49.92	40.56	0.006	0.040	0.857	0.006	0.042	0.879
methylcyclopentane	2.80	50.81	34.50	0.006	0.017	0.358	0.005	0.015	0.308
benzene	0.42	336.25	272.45	0.039	0.017	0.356	0.042	0.017	0.366
2-methylhexane	1.08	78.71	52.55	0.009	0.010	0.214	0.008	0.009	0.180
3-methylhexane	1.40	55.55	37.42	0.007	0.009	0.196	0.006	0.008	0.166
2,2,4-trimethylpentane	0.93	50.64	30.80	0.006	0.006	0.119	0.005	0.004	0.092
n-heptane	0.81	2.87	1.94	0.000	0.000	0.006	0.000	0.000	0.005
C8 alkanes !	1.19	123.11	96.33	0.014	0.017	0.369	0.015	0.018	0.368
toluene	2.70	663.07	515.96	0.078	0.210	4.507	0.079	0.212	4.451
n-octane	0.60	22.80	16.56	0.003	0.002	0.034	0.002	0.001	0.031
ethylbenzene	2.70	127.22	100.20	0.015	0.040	0.865	0.015	0.042	0.871
m,p-xylenes !	7.40	607.75	464.08	0.071	0.527	11.322	0.071	0.525	11.005
styrene	2.20	56.44	52.85	0.007	0.015	0.313	0.008	0.018	0.369
o-xylene	6.50	144.72	109.77	0.017	0.110	2.368	0.017	0.109	2.288
n-nonane	0.54	16.99	12.53	0.002	0.001	0.023	0.002	0.001	0.021
n-propylbenzene	2.10	29.42	23.38	0.003	0.007	0.156	0.004	0.007	0.155
m,p-ethyltoluenes	6.50	108.25	103.37	0.013	0.082	1.771	0.016	0.106	2.229
1,3,5-trimethylbenzene	10.10	49.40	37.18	0.006	0.058	1.256	0.006	0.057	1.201
o-ethyltoluene	6.50	40.13	28.52	0.005	0.031	0.657	0.004	0.028	0.595
1,2,4-trimethylbenzene	8.80	153.48	125.21	0.018	0.158	3.400	0.019	0.167	3.496
C10 aromatics+aliphatics	6.50	167.84	138.65	0.020	0.128	2.746	0.021	0.137	2.876
formaldehyde	7.20	435.02	240.59	0.051	0.367	7.883	0.039	0.280	5.865
acetaldehyde	5.50	178.43	107.17	0.021	0.115	2.470	0.017	0.093	1.950
acrolein (2-propenal)	6.50	39.88	24.27	0.005	0.030	0.652	0.004	0.025	0.520
Residual hydrocarbons	4.11	1309.85	1047.40	0.153	0.631	13.559	0.162	0.667	13.974
Sum		8538.74	6484.79		4.65			4.77	
Sum/ phase distance (km)		1399	1027						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1399			1027
mg ozone/mg NMOC emit.						4.65			4.77
mg ozone per km travelled						**6506**			**4904**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A39
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrohol

HOT START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	374.54	339.64						
ethane	0.25	89.65	79.82	0.013	0.003	0.071	0.013	0.003	0.072
ethylene	7.40	826.33	759.11	0.119	0.883	19.211	0.126	0.933	20.294
acetylene	0.50	406.41	266.59	0.059	0.030	0.643	0.044	0.022	0.477
propane	0.48	18.27	15.50	0.003	0.001	0.027	0.003	0.001	0.027
propylene	9.40	359.04	319.70	0.052	0.486	10.581	0.053	0.502	10.913
i-butane	1.21	94.83	89.12	0.014	0.016	0.356	0.015	0.018	0.401
n-butane	1.02	148.92	138.39	0.021	0.022	0.471	0.024	0.024	0.526
trans-2-butene	10.00	73.87	70.11	0.011	0.106	2.313	0.012	0.117	2.551
cis-2-butene	10.00	81.71	55.65	0.012	0.116	2.518	0.010	0.096	2.089
C4 olefins !	9.02	147.53	124.78	0.021	0.191	4.161	0.021	0.188	4.088
i-pentane	1.38	294.65	259.82	0.042	0.058	1.264	0.044	0.061	1.328
1-pentene	6.20	26.41	24.97	0.004	0.023	0.509	0.004	0.026	0.576
n-pentane	1.04	94.57	77.69	0.014	0.014	0.306	0.013	0.014	0.300
trans-2-pentene	8.80	33.27	28.79	0.005	0.042	0.911	0.005	0.043	0.941
cis-2-pentene	8.80	17.26	14.89	0.002	0.022	0.473	0.003	0.022	0.487
2-methyl-2-butene	6.40	39.50	33.28	0.006	0.036	0.789	0.006	0.036	0.793
2,3-dimethylbutane	1.07	31.10	25.44	0.004	0.005	0.104	0.004	0.005	0.100
2-methylpentane	1.50	118.81	96.04	0.017	0.026	0.556	0.016	0.024	0.531
3-methylpentane	1.50	83.47	60.67	0.012	0.018	0.391	0.010	0.015	0.333
1-hexene	4.40	17.70	13.14	0.003	0.011	0.243	0.002	0.010	0.212
n-hexane	0.98	68.40	66.39	0.010	0.010	0.209	0.011	0.011	0.242
C5 and C6 olefins !	6.82	43.20	21.16	0.006	0.042	0.920	0.003	0.023	0.511
methylcyclopentane	2.80	48.15	33.88	0.007	0.019	0.421	0.006	0.016	0.346
benzene	0.42	276.88	232.70	0.040	0.017	0.366	0.039	0.016	0.352
2-methylhexane	1.08	75.45	50.74	0.011	0.012	0.255	0.008	0.009	0.199
3-methylhexane	1.40	52.91	33.88	0.008	0.011	0.232	0.006	0.008	0.172
2,2,4-trimethylpentane	0.93	41.57	35.48	0.006	0.006	0.121	0.006	0.006	0.122
n-heptane	0.81	2.31	48.25	0.000	0.000	0.006	0.009	0.007	0.152
C8 alkanes !	1.19	117.70	81.31	0.017	0.020	0.440	0.014	0.016	0.352
toluene	2.70	560.55	404.01	0.081	0.219	4.756	0.067	0.181	3.937
n-octane	0.60	20.02	17.71	0.003	0.002	0.038	0.003	0.002	0.039
ethylbenzene	2.70	104.35	77.11	0.015	0.041	0.885	0.013	0.035	0.752
m,p-xylenes !	7.40	501.36	341.76	0.072	0.536	11.659	0.057	0.419	9.123
styrene	2.20	23.47	32.66	0.003	0.008	0.165	0.005	0.012	0.254
o-xylene	6.50	122.57	82.07	0.018	0.115	2.503	0.014	0.088	1.925
n-nonane	0.54	14.76	9.66	0.002	0.001	0.025	0.002	0.001	0.019
n-propylbenzene	2.10	27.20	17.49	0.004	0.008	0.180	0.003	0.006	0.132
m,p-ethyltoluenes	6.50	88.02	75.52	0.013	0.083	1.799	0.013	0.082	1.791
1,3,5-trimethylbenzene	10.10	40.68	27.17	0.006	0.059	1.293	0.004	0.045	0.989
o-ethyltoluene	6.50	29.27	21.95	0.004	0.028	0.599	0.004	0.024	0.517
1,2,4-trimethylbenzene	8.80	112.98	84.87	0.016	0.144	3.134	0.014	0.123	2.687
C10 aromatics+aliphatics	6.50	130.75	100.09	0.019	0.123	2.679	0.017	0.108	2.356
formaldehyde	7.20	236.58	208.57	0.034	0.244	5.303	0.035	0.250	5.448
acetaldehyde	5.50	121.08	105.43	0.017	0.096	2.086	0.018	0.097	2.102
acrolein (2-propenal)	6.50	22.36	23.20	0.003	0.021	0.458	0.004	0.025	0.547
Residual hydrocarbons	4.11	1050.70	1245.50	0.152	0.624	13.570	0.200	0.822	17.895
Sum		6936.59	6032.06		4.60			4.60	
Sum/ phase distance (km)		1196	1049						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1196			1049
mg ozone/mg NMOC emit.						4.60			4.60
mg ozone per km travelled						**5497**			**4822**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A40
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Pre-1986 vehicles with leaded petrohol

AVERAGE ADR CYCLE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Weighted	Weighted						
		Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		(mg)	(mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	1040.73	1011.16						
ethane	0.25	214.19	194.04	0.013	0.003	0.070	0.014	0.004	0.078
ethylene	7.40	1852.68	1723.45	0.113	0.833	18.023	0.129	0.954	20.573
acetylene	0.50	1095.16	825.22	0.066	0.033	0.712	0.061	0.030	0.654
propane	0.48	51.07	37.33	0.003	0.002	0.033	0.003	0.001	0.030
propylene	9.40	931.28	740.18	0.057	0.534	11.544	0.056	0.522	11.255
i-butane	1.21	194.01	170.22	0.012	0.014	0.313	0.013	0.016	0.339
n-butane	1.02	301.78	253.97	0.019	0.019	0.409	0.019	0.020	0.426
trans-2-butene	10.00	155.60	140.45	0.009	0.095	2.050	0.011	0.106	2.283
cis-2-butene	10.00	128.17	80.30	0.008	0.079	1.716	0.006	0.062	1.343
C4 olefins !	9.02	332.50	281.55	0.020	0.183	3.964	0.021	0.192	4.130
i-pentane	1.38	627.59	518.41	0.038	0.053	1.147	0.039	0.054	1.169
1-pentene	6.20	56.20	55.70	0.003	0.021	0.463	0.004	0.027	0.577
n-pentane	1.04	201.76	156.29	0.012	0.013	0.278	0.012	0.012	0.266
trans-2-pentene	8.80	72.05	59.67	0.004	0.039	0.842	0.005	0.040	0.867
cis-2-pentene	8.80	38.01	31.10	0.002	0.021	0.444	0.002	0.021	0.452
2-methyl-2-butene	6.40	89.96	73.58	0.006	0.035	0.765	0.006	0.036	0.781
2,3-dimethylbutane	1.07	69.48	55.13	0.004	0.005	0.098	0.004	0.004	0.096
2-methylpentane	1.50	274.34	201.82	0.017	0.025	0.545	0.015	0.023	0.489
3-methylpentane	1.50	185.17	135.17	0.011	0.017	0.367	0.010	0.015	0.328
1-hexene	4.40	40.27	29.36	0.002	0.011	0.235	0.002	0.010	0.212
n-hexane	0.98	160.01	124.01	0.010	0.010	0.207	0.009	0.009	0.198
C5 and C6 olefins !	6.82	102.72	74.18	0.006	0.043	0.925	0.005	0.037	0.804
methylcyclopentane	2.80	112.12	78.82	0.007	0.019	0.414	0.006	0.016	0.354
benzene	0.42	660.04	544.32	0.040	0.017	0.363	0.040	0.017	0.366
2-methylhexane	1.08	177.64	119.80	0.011	0.012	0.252	0.009	0.010	0.207
3-methylhexane	1.40	125.35	83.85	0.008	0.011	0.231	0.006	0.009	0.188
2,2,4-trimethylpentane	0.93	103.83	71.45	0.006	0.006	0.128	0.005	0.005	0.107
n-heptane	0.81	6.20	30.30	0.000	0.000	0.007	0.002	0.002	0.043
C8 alkanes !	1.19	273.85	200.50	0.017	0.020	0.428	0.015	0.018	0.383
toluene	2.70	1354.97	1026.12	0.082	0.222	4.797	0.076	0.205	4.425
n-octane	0.60	50.35	37.50	0.003	0.002	0.040	0.003	0.002	0.036
ethylbenzene	2.70	258.98	197.34	0.016	0.042	0.917	0.015	0.040	0.853
m,p-xylenes !	7.40	1261.57	923.00	0.076	0.566	12.238	0.068	0.506	10.903
styrene	2.20	83.02	85.62	0.005	0.011	0.237	0.006	0.014	0.297
o-xylene	6.50	306.96	221.35	0.019	0.121	2.617	0.016	0.107	2.297
n-nonane	0.54	37.55	25.71	0.002	0.001	0.026	0.002	0.001	0.022
n-propylbenzene	2.10	66.73	48.05	0.004	0.008	0.184	0.004	0.007	0.160
m,p-ethyltoluenes	6.50	222.92	202.60	0.014	0.088	1.899	0.015	0.099	2.140
1,3,5-trimethylbenzene	10.10	104.50	74.59	0.006	0.064	1.381	0.006	0.056	1.198
o-ethyltoluene	6.50	78.70	56.56	0.005	0.031	0.669	0.004	0.027	0.587
1,2,4-trimethylbenzene	8.80	303.92	234.71	0.018	0.162	3.494	0.017	0.152	3.273
C10 aromatics+aliphatics	6.50	334.33	258.88	0.020	0.132	2.845	0.019	0.124	2.682
formaldehyde	7.20	667.14	436.65	0.041	0.298	6.446	0.033	0.238	5.137
acetaldehyde	5.50	309.84	221.89	0.019	0.105	2.267	0.017	0.092	1.977
acrolein (2-propenal)	6.50	63.09	45.75	0.004	0.025	0.546	0.003	0.022	0.482
Residual hydrocarbons	4.11	2308.43	2231.32	0.140	0.575	12.426	0.164	0.674	14.529
Sum		16446.03	13417.81		4.62			4.64	
Sum/ Total cycle distance (km)		1386	1113						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						1386			1113
mg ozone/mg NMOC emit.						4.62			4.64
mg ozone per km travelled						**6407**			**5163**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A41
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrol

COLD START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	337.38	381.34						
ethane	0.25	60.51	61.31	0.020	0.005	0.114	0.020	0.005	0.113
ethylene	7.40	323.57	323.38	0.103	0.760	16.981	0.103	0.760	16.900
acetylene	0.50	53.27	50.44	0.018	0.009	0.198	0.017	0.008	0.184
propane	0.48	8.01	6.84	0.003	0.001	0.028	0.002	0.001	0.024
propylene	9.40	130.36	139.17	0.043	0.406	9.072	0.046	0.432	9.592
i-butane	1.21	45.80	37.10	0.014	0.017	0.382	0.012	0.014	0.311
n-butane	1.02	62.06	56.25	0.019	0.020	0.437	0.017	0.018	0.395
trans-2-butene	10.00	24.14	20.20	0.008	0.076	1.703	0.007	0.065	1.450
cis-2-butene	10.00	23.89	21.69	0.007	0.068	1.527	0.006	0.065	1.442
C4 olefins !	9.02	75.50	75.32	0.024	0.218	4.866	0.024	0.216	4.804
i-pentane	1.38	125.34	128.45	0.039	0.053	1.193	0.040	0.055	1.216
1-pentene	6.20	13.73	12.69	0.004	0.027	0.598	0.004	0.027	0.595
n-pentane	1.04	63.63	60.83	0.019	0.020	0.445	0.018	0.019	0.427
trans-2-pentene	8.80	14.23	13.94	0.004	0.039	0.863	0.004	0.039	0.864
cis-2-pentene	8.80	7.77	7.68	0.002	0.021	0.465	0.002	0.022	0.478
2-methyl-2-butene	6.40	22.64	21.29	0.007	0.045	1.016	0.007	0.043	0.959
2,3-dimethylbutane	1.07	14.32	16.11	0.005	0.005	0.108	0.005	0.005	0.118
2-methylpentane	1.50	60.53	63.04	0.018	0.028	0.619	0.019	0.029	0.641
3-methylpentane	1.50	39.50	42.09	0.012	0.018	0.410	0.013	0.019	0.433
1-hexene	4.40	8.52	8.27	0.003	0.011	0.256	0.003	0.012	0.262
n-hexane	0.98	38.80	31.29	0.012	0.011	0.252	0.010	0.010	0.218
C5 and C6 olefins !	6.82	21.89	22.60	0.007	0.048	1.077	0.007	0.051	1.131
methylcyclopentane	2.80	24.88	25.79	0.008	0.022	0.480	0.008	0.022	0.499
benzene	0.42	148.17	157.17	0.045	0.019	0.423	0.048	0.020	0.444
2-methylhexane	1.08	39.80	41.46	0.012	0.013	0.291	0.013	0.014	0.305
3-methylhexane	1.40	21.09	22.67	0.007	0.009	0.211	0.007	0.010	0.225
2,2,4-trimethylpentane	0.93	50.01	50.35	0.015	0.014	0.313	0.015	0.014	0.317
n-heptane	0.81	28.27	7.76	0.007	0.005	0.120	0.002	0.002	0.039
C8 alkanes !	1.19	79.53	73.05	0.025	0.029	0.655	0.024	0.028	0.632
toluene	2.70	264.87	285.96	0.084	0.226	5.053	0.089	0.240	5.343
n-octane	0.60	13.72	11.19	0.004	0.003	0.056	0.004	0.002	0.048
ethylbenzene	2.70	53.21	55.20	0.017	0.046	1.026	0.018	0.048	1.059
m,p-xylenes !	7.40	231.52	227.87	0.074	0.549	12.273	0.075	0.557	12.387
styrene	2.20	13.72	10.58	0.005	0.010	0.223	0.004	0.008	0.173
o-xylene	6.50	67.63	72.76	0.021	0.140	3.118	0.023	0.148	3.286
n-nonane	0.54	7.27	7.07	0.002	0.001	0.029	0.002	0.001	0.028
n-propylbenzene	2.10	10.57	11.17	0.003	0.007	0.163	0.004	0.008	0.170
m,p-ethyltoluenes	6.50	50.96	49.34	0.016	0.104	2.315	0.016	0.104	2.322
1,3,5-trimethylbenzene	10.10	23.74	23.56	0.007	0.075	1.673	0.007	0.074	1.656
o-ethyltoluene	6.50	18.61	17.08	0.006	0.037	0.823	0.005	0.035	0.781
1,2,4-trimethylbenzene	8.80	71.44	74.20	0.023	0.205	4.588	0.024	0.207	4.604
C10 aromatics+aliphatics	6.50	82.99	83.27	0.027	0.178	3.978	0.027	0.174	3.868
formaldehyde	7.20	31.42	30.47	0.012	0.088	1.959	0.011	0.078	1.723
acetaldehyde	5.50	12.68	15.25	0.005	0.027	0.600	0.006	0.031	0.682
acrolein (2-propenal)	6.50	7.79	8.02	0.003	0.020	0.441	0.003	0.021	0.466
Residual hydrocarbons	4.11	556.72	545.03	0.180	0.742	16.578	0.179	0.737	16.390
Sum		3148.63	3126.29		4.48			4.50	
Sum/ phase distance (km)		545	541						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						545			541
mg ozone/mg NMOC emit.						4.48			4.50
mg ozone per km travelled						**2440**			**2436**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A42
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrol

STABILISED PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	320.54	312.39						
ethane	0.25	35.33	34.86	0.028	0.007	0.190	0.026	0.006	0.176
ethylene	7.40	78.64	71.23	0.039	0.287	7.701	0.042	0.311	8.489
acetylene	0.50	24.63	27.33	0.019	0.009	0.248	0.018	0.009	0.250
propane	0.48	4.65	5.06	0.003	0.002	0.042	0.004	0.002	0.046
propylene	9.40	21.06	21.02	0.011	0.102	2.719	0.013	0.120	3.281
i-butane	1.21	34.20	30.39	0.029	0.035	0.935	0.021	0.026	0.696
n-butane	1.02	42.27	35.24	0.032	0.033	0.877	0.024	0.025	0.680
trans-2-butene	10.00	13.44	6.35	0.011	0.111	2.962	0.005	0.047	1.288
cis-2-butene	10.00	7.84	8.21	0.007	0.065	1.752	0.006	0.064	1.755
C4 olefins !	9.02	21.19	17.63	0.016	0.146	3.919	0.012	0.108	2.940
i-pentane	1.38	60.87	54.95	0.042	0.058	1.543	0.038	0.053	1.439
1-pentene	6.20	5.94	2.55	0.005	0.028	0.761	0.003	0.017	0.451
n-pentane	1.04	29.47	27.77	0.020	0.021	0.560	0.020	0.021	0.570
trans-2-pentene	8.80	3.87	3.14	0.003	0.025	0.674	0.002	0.019	0.523
cis-2-pentene	8.80	1.57	2.23	0.001	0.007	0.194	0.002	0.020	0.559
2-methyl-2-butene	6.40	6.59	6.77	0.005	0.034	0.909	0.006	0.036	0.990
2,3-dimethylbutane	1.07	5.61	6.18	0.004	0.004	0.107	0.005	0.005	0.134
2-methylpentane	1.50	22.68	20.56	0.014	0.022	0.581	0.014	0.021	0.574
3-methylpentane	1.50	15.16	14.62	0.010	0.015	0.401	0.011	0.016	0.433
1-hexene	4.40	1.57	1.84	0.001	0.005	0.124	0.002	0.008	0.207
n-hexane	0.98	16.66	15.64	0.012	0.012	0.319	0.012	0.012	0.314
C5 and C6 olefins !	6.82	5.27	4.34	0.004	0.025	0.682	0.003	0.020	0.556
methylcyclopentane	2.80	8.96	8.88	0.006	0.017	0.457	0.007	0.020	0.552
benzene	0.42	64.12	60.74	0.036	0.015	0.402	0.039	0.016	0.444
2-methylhexane	1.08	13.51	12.69	0.009	0.010	0.272	0.009	0.010	0.264
3-methylhexane	1.40	7.50	6.63	0.005	0.007	0.188	0.005	0.007	0.182
2,2,4-trimethylpentane	0.93	14.53	16.70	0.009	0.008	0.225	0.012	0.012	0.316
n-heptane	0.81	43.11	54.57	0.071	0.058	1.542	0.050	0.040	1.101
C8 alkanes !	1.19	30.15	31.01	0.022	0.026	0.686	0.024	0.028	0.765
toluene	2.70	64.53	61.84	0.041	0.109	2.931	0.041	0.112	3.059
n-octane	0.60	5.52	5.18	0.004	0.003	0.069	0.004	0.002	0.063
ethylbenzene	2.70	14.30	12.59	0.011	0.031	0.821	0.009	0.025	0.669
m,p-xylenes !	7.40	56.72	44.70	0.041	0.302	8.087	0.031	0.227	6.208
styrene	2.20	4.78	3.21	0.004	0.008	0.219	0.002	0.005	0.136
o-xylene	6.50	15.81	16.63	0.012	0.075	2.021	0.011	0.075	2.037
n-nonane	0.54	3.54	3.35	0.003	0.002	0.049	0.002	0.001	0.032
n-propylbenzene	2.10	2.19	1.79	0.002	0.004	0.110	0.001	0.003	0.077
m,p-ethyltoluenes	6.50	10.01	11.12	0.009	0.062	1.649	0.009	0.057	1.560
1,3,5-trimethylbenzene	10.10	6.02	5.26	0.005	0.053	1.421	0.004	0.040	1.092
o-ethyltoluene	6.50	6.62	3.66	0.007	0.045	1.204	0.003	0.018	0.488
1,2,4-trimethylbenzene	8.80	16.27	15.88	0.015	0.129	3.462	0.012	0.106	2.894
C10 aromatics+aliphatics	6.50	37.22	31.43	0.043	0.283	7.569	0.027	0.175	4.770
formaldehyde	7.20	12.98	10.71	0.015	0.106	2.827	0.008	0.057	1.548
acetaldehyde	5.50	6.70	3.66	0.012	0.066	1.764	0.003	0.014	0.389
acrolein (2-propenal)	6.50	5.20	3.59	0.007	0.046	1.236	0.002	0.015	0.419
Residual hydrocarbons	4.11	373.15	882.51	0.296	1.217	32.588	0.397	1.633	44.586
Sum		1281.95	1726.22		3.73			3.66	
Sum/ phase distance (km)		206	278						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						206			278
mg ozone/mg NMOC emit.						3.73			3.66
mg ozone per km travelled						**769**			**1018**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A43
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrol

HOT START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	238.70	240.79						
ethane	0.25	37.06	46.48	0.033	0.008	0.212	0.038	0.009	0.247
ethylene	7.40	131.91	135.77	0.090	0.663	17.127	0.096	0.712	18.504
acetylene	0.50	43.30	22.92	0.032	0.016	0.410	0.018	0.009	0.238
propane	0.48	4.42	4.82	0.004	0.002	0.045	0.005	0.002	0.061
propylene	9.40	46.02	44.86	0.032	0.302	7.792	0.032	0.304	7.902
i-butane	1.21	30.37	24.90	0.025	0.030	0.783	0.020	0.024	0.629
n-butane	1.02	37.92	34.78	0.031	0.032	0.827	0.028	0.029	0.743
trans-2-butene	10.00	9.23	8.54	0.007	0.068	1.766	0.006	0.064	1.674
cis-2-butene	10.00	9.08	7.37	0.007	0.068	1.746	0.006	0.058	1.503
C4 olefins !	9.02	28.93	27.00	0.021	0.190	4.900	0.020	0.178	4.628
i-pentane	1.38	62.92	61.20	0.050	0.069	1.782	0.049	0.068	1.765
1-pentene	6.20	4.17	3.87	0.003	0.019	0.487	0.003	0.019	0.501
n-pentane	1.04	28.87	28.65	0.023	0.024	0.611	0.023	0.023	0.611
trans-2-pentene	8.80	4.41	4.37	0.003	0.028	0.717	0.003	0.029	0.758
cis-2-pentene	8.80	2.73	2.39	0.002	0.014	0.362	0.002	0.016	0.412
2-methyl-2-butene	6.40	7.53	7.35	0.006	0.037	0.955	0.006	0.037	0.971
2,3-dimethylbutane	1.07	6.73	6.74	0.005	0.006	0.145	0.005	0.006	0.149
2-methylpentane	1.50	24.54	24.76	0.019	0.028	0.723	0.019	0.029	0.757
3-methylpentane	1.50	16.51	16.56	0.013	0.019	0.492	0.013	0.020	0.507
1-hexene	4.40	2.15	2.22	0.002	0.007	0.184	0.002	0.008	0.200
n-hexane	0.98	14.11	16.44	0.012	0.012	0.303	0.013	0.013	0.336
C5 and C6 olefins !	6.82	5.23	6.59	0.004	0.029	0.747	0.005	0.036	0.945
methylcyclopentane	2.80	9.52	8.17	0.007	0.020	0.526	0.007	0.019	0.500
benzene	0.42	63.80	64.78	0.044	0.019	0.481	0.047	0.020	0.513
2-methylhexane	1.08	14.45	12.45	0.011	0.012	0.305	0.011	0.012	0.302
3-methylhexane	1.40	7.74	7.81	0.007	0.009	0.236	0.007	0.010	0.249
2,2,4-trimethylpentane	0.93	19.70	18.99	0.015	0.014	0.367	0.015	0.014	0.364
n-heptane	0.81	19.21	34.74	0.028	0.023	0.588	0.044	0.036	0.935
C8 alkanes !	1.19	34.88	35.23	0.030	0.036	0.932	0.032	0.038	0.976
toluene	2.70	80.22	80.89	0.058	0.157	4.050	0.061	0.165	4.285
n-octane	0.60	4.93	4.03	0.005	0.003	0.075	0.004	0.002	0.062
ethylbenzene	2.70	16.77	16.96	0.012	0.033	0.859	0.013	0.035	0.906
m,p-xylenes !	7.40	59.08	60.06	0.048	0.354	9.136	0.048	0.355	9.221
styrene	2.20	3.68	3.48	0.003	0.007	0.169	0.003	0.006	0.164
o-xylene	6.50	19.36	18.52	0.015	0.096	2.479	0.014	0.093	2.426
n-nonane	0.54	2.91	3.03	0.003	0.001	0.038	0.003	0.002	0.039
n-propylbenzene	2.10	3.02	2.65	0.003	0.005	0.139	0.002	0.005	0.122
m,p-ethyltoluenes	6.50	11.15	10.71	0.009	0.058	1.501	0.008	0.054	1.413
1,3,5-trimethylbenzene	10.10	6.01	5.67	0.005	0.048	1.239	0.005	0.046	1.189
o-ethyltoluene	6.50	4.67	4.10	0.004	0.024	0.632	0.003	0.021	0.548
1,2,4-trimethylbenzene	8.80	16.68	16.24	0.014	0.122	3.140	0.013	0.118	3.079
C10 aromatics+aliphatics	6.50	25.52	22.99	0.022	0.145	3.750	0.019	0.126	3.279
formaldehyde	7.20	8.47	7.71	0.008	0.058	1.489	0.006	0.043	1.110
acetaldehyde	5.50	5.93	10.80	0.007	0.038	0.994	0.009	0.050	1.287
acrolein (2-propenal)	6.50	4.51	6.54	0.005	0.035	0.891	0.006	0.037	0.963
Residual hydrocarbons	4.11	267.24	256.66	0.215	0.886	22.870	0.206	0.848	22.029
Sum		1267.56	1251.77		3.87			3.85	
Sum/ phase distance (km)		219	217						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						219			217
mg ozone/mg NMOC emit.						3.87			3.85
mg ozone per km travelled						**849**			**835**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A44
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrol

AVERAGE ADR CYCLE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Weighted	Weighted						
		Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		(mg)	(mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	601.67	613.62						
ethane	0.25	82.48	87.71	0.025	0.006	0.154	0.024	0.006	0.150
ethylene	7.40	292.96	287.67	0.079	0.586	14.292	0.077	0.569	13.988
acetylene	0.50	72.22	62.08	0.021	0.010	0.256	0.017	0.009	0.213
propane	0.48	10.61	10.75	0.003	0.001	0.035	0.003	0.001	0.035
propylene	9.40	103.35	106.43	0.030	0.285	6.950	0.030	0.278	6.827
i-butane	1.21	71.21	60.53	0.021	0.026	0.623	0.016	0.019	0.477
n-butane	1.02	90.57	79.25	0.026	0.026	0.645	0.021	0.022	0.529
trans-2-butene	10.00	29.08	19.90	0.009	0.087	2.119	0.005	0.055	1.342
cis-2-butene	10.00	23.29	21.74	0.007	0.067	1.638	0.006	0.061	1.501
C4 olefins !	9.02	70.15	65.41	0.021	0.189	4.598	0.018	0.162	3.972
i-pentane	1.38	150.63	145.07	0.042	0.058	1.424	0.039	0.054	1.323
1-pentene	6.20	14.22	10.21	0.004	0.026	0.624	0.003	0.020	0.480
n-pentane	1.04	73.29	70.26	0.020	0.021	0.518	0.019	0.020	0.484
trans-2-pentene	8.80	12.50	11.62	0.004	0.032	0.780	0.003	0.028	0.686
cis-2-pentene	8.80	6.29	6.90	0.002	0.015	0.372	0.002	0.018	0.441
2-methyl-2-butene	6.40	20.62	20.11	0.006	0.040	0.974	0.006	0.037	0.914
2,3-dimethylbutane	1.07	15.60	16.95	0.004	0.005	0.116	0.005	0.005	0.122
2-methylpentane	1.50	62.69	61.78	0.017	0.026	0.635	0.017	0.025	0.609
3-methylpentane	1.50	41.56	42.16	0.012	0.017	0.426	0.011	0.017	0.423
1-hexene	4.40	6.46	6.66	0.002	0.008	0.204	0.002	0.009	0.211
n-hexane	0.98	41.39	38.47	0.012	0.012	0.283	0.011	0.010	0.256
C5 and C6 olefins !	6.82	17.66	17.81	0.005	0.037	0.905	0.005	0.035	0.852
methylcyclopentane	2.80	25.08	24.62	0.007	0.020	0.487	0.007	0.019	0.474
benzene	0.42	164.20	165.25	0.043	0.018	0.436	0.043	0.018	0.441
2-methylhexane	1.08	38.86	37.62	0.011	0.012	0.289	0.010	0.011	0.271
3-methylhexane	1.40	20.99	20.83	0.006	0.009	0.211	0.006	0.008	0.200
2,2,4-trimethylpentane	0.93	47.27	49.17	0.013	0.012	0.299	0.013	0.013	0.307
n-heptane	0.81	66.21	77.71	0.030	0.024	0.596	0.024	0.019	0.472
C8 alkanes !	1.19	84.23	82.50	0.025	0.030	0.727	0.024	0.028	0.690
toluene	2.70	224.15	230.91	0.064	0.173	4.217	0.063	0.169	4.154
n-octane	0.60	14.23	12.29	0.005	0.003	0.066	0.004	0.002	0.053
ethylbenzene	2.70	46.74	46.00	0.014	0.038	0.932	0.013	0.035	0.851
m,p-xylenes !	7.40	189.95	176.92	0.057	0.423	10.330	0.050	0.368	9.058
styrene	2.20	12.77	9.74	0.004	0.009	0.215	0.003	0.006	0.147
o-xylene	6.50	55.92	58.47	0.017	0.108	2.638	0.016	0.104	2.567
n-nonane	0.54	8.33	8.11	0.003	0.001	0.037	0.002	0.001	0.031
n-propylbenzene	2.10	8.46	8.10	0.003	0.006	0.141	0.002	0.005	0.121
m,p-ethyltoluenes	6.50	38.28	38.44	0.012	0.078	1.909	0.011	0.072	1.765
1,3,5-trimethylbenzene	10.10	19.66	18.62	0.006	0.062	1.500	0.005	0.052	1.286
o-ethyltoluene	6.50	17.29	13.34	0.006	0.037	0.902	0.004	0.024	0.597
1,2,4-trimethylbenzene	8.80	56.49	57.05	0.018	0.159	3.874	0.016	0.141	3.457
C10 aromatics+aliphatics	6.50	87.45	80.34	0.031	0.199	4.848	0.023	0.153	3.752
formaldehyde	7.20	31.32	28.20	0.012	0.083	2.033	0.008	0.057	1.392
acetaldehyde	5.50	15.54	16.38	0.007	0.039	0.955	0.005	0.025	0.618
acrolein (2-propenal)	6.50	11.12	10.76	0.005	0.030	0.739	0.003	0.020	0.486
Residual hydrocarbons	4.11	764.87	1263.17	0.230	0.945	23.046	0.306	1.260	30.975
Sum		3358.20	3784.03		4.10			4.07	
Sum/ Total cycle distance (km)		280	316						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						280			316
mg ozone/mg NMOC emit.						4.10			4.07
mg ozone per km travelled						**1147**			**1284**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A45
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrohol

COLD START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	300.67	309.39						
ethane	0.25	51.86	51.77	0.018	0.005	0.103	0.020	0.005	0.110
ethylene	7.40	279.17	276.84	0.093	0.691	15.460	0.101	0.750	16.838
acetylene	0.50	62.68	51.53	0.024	0.012	0.268	0.020	0.010	0.222
propane	0.48	8.19	6.66	0.003	0.001	0.032	0.002	0.001	0.026
propylene	9.40	113.20	106.84	0.041	0.390	8.726	0.040	0.379	8.514
i-butane	1.21	32.83	35.18	0.011	0.014	0.303	0.013	0.016	0.348
n-butane	1.02	49.12	50.50	0.017	0.017	0.377	0.018	0.019	0.416
trans-2-butene	10.00	19.65	19.04	0.007	0.070	1.571	0.007	0.071	1.602
cis-2-butene	10.00	18.69	18.43	0.007	0.066	1.467	0.007	0.066	1.488
C4 olefins !	9.02	62.75	64.38	0.022	0.197	4.407	0.024	0.218	4.882
i-pentane	1.38	109.72	105.98	0.036	0.050	1.120	0.038	0.052	1.175
1-pentene	6.20	11.79	11.06	0.004	0.027	0.601	0.004	0.026	0.590
n-pentane	1.04	52.65	48.81	0.017	0.018	0.402	0.017	0.018	0.407
trans-2-pentene	8.80	13.16	12.02	0.005	0.040	0.899	0.004	0.039	0.877
cis-2-pentene	8.80	6.94	6.39	0.002	0.021	0.479	0.002	0.021	0.463
2-methyl-2-butene	6.40	19.51	18.56	0.007	0.044	0.993	0.007	0.044	0.994
2,3-dimethylbutane	1.07	14.16	13.02	0.005	0.005	0.111	0.005	0.005	0.113
2-methylpentane	1.50	52.13	49.78	0.017	0.025	0.571	0.018	0.027	0.599
3-methylpentane	1.50	35.38	33.84	0.011	0.017	0.386	0.012	0.018	0.408
1-hexene	4.40	7.98	6.55	0.003	0.012	0.276	0.002	0.011	0.246
n-hexane	0.98	33.01	26.58	0.011	0.010	0.235	0.010	0.009	0.212
C5 and C6 olefins !	6.82	19.37	16.38	0.007	0.046	1.041	0.006	0.043	0.968
methylcyclopentane	2.80	22.87	18.68	0.007	0.021	0.468	0.007	0.019	0.429
benzene	0.42	129.14	122.49	0.041	0.017	0.389	0.044	0.018	0.414
2-methylhexane	1.08	35.59	28.45	0.012	0.013	0.280	0.010	0.011	0.252
3-methylhexane	1.40	19.87	18.75	0.007	0.009	0.206	0.007	0.009	0.212
2,2,4-trimethylpentane	0.93	44.04	41.95	0.015	0.014	0.302	0.015	0.014	0.316
n-heptane	0.81	32.71	10.79	0.013	0.010	0.232	0.004	0.003	0.074
C8 alkanes !	1.19	73.32	59.88	0.025	0.030	0.677	0.022	0.027	0.600
toluene	2.70	227.71	223.70	0.077	0.209	4.671	0.082	0.222	4.975
n-octane	0.60	11.77	9.40	0.004	0.003	0.058	0.003	0.002	0.047
ethylbenzene	2.70	51.63	45.52	0.017	0.047	1.048	0.017	0.046	1.029
m,p-xylenes !	7.40	213.15	166.21	0.072	0.535	11.969	0.063	0.468	10.512
styrene	2.20	12.49	10.11	0.005	0.010	0.223	0.004	0.009	0.199
o-xylene	6.50	61.52	58.83	0.021	0.134	2.989	0.022	0.140	3.143
n-nonane	0.54	8.81	6.07	0.003	0.001	0.031	0.002	0.001	0.027
n-propylbenzene	2.10	12.79	9.12	0.004	0.008	0.182	0.003	0.007	0.162
m,p-ethyltoluenes	6.50	50.78	38.69	0.018	0.114	2.551	0.014	0.093	2.094
1,3,5-trimethylbenzene	10.10	23.09	18.60	0.007	0.074	1.647	0.007	0.069	1.546
o-ethyltoluene	6.50	18.06	14.05	0.006	0.038	0.847	0.005	0.034	0.753
1,2,4-trimethylbenzene	8.80	71.43	60.29	0.023	0.204	4.566	0.023	0.199	4.460
C10 aromatics+aliphatics	6.50	109.39	70.17	0.034	0.219	4.891	0.026	0.169	3.803
formaldehyde	7.20	43.97	30.89	0.015	0.109	2.439	0.013	0.096	2.164
acetaldehyde	5.50	32.49	23.78	0.012	0.064	1.425	0.009	0.051	1.149
acrolein (2-propenal)	6.50	6.51	5.75	0.003	0.017	0.383	0.002	0.014	0.322
Residual hydrocarbons	4.11	604.40	571.37	0.192	0.791	17.698	0.215	0.883	19.822
Sum		2991.48	2693.69		4.47			4.46	
Sum/ phase distance (km)		518	467						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						518			467
mg ozone/mg NMOC emit.						4.47			4.46
mg ozone per km travelled						**2313**			**2080**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A46
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrohol

STABILISED PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	299.29	296.06						
ethane	0.25	33.50	32.74	0.033	0.008	0.218	0.032	0.008	0.222
ethylene	7.40	64.77	53.82	0.040	0.299	7.818	0.038	0.283	7.943
acetylene	0.50	13.16	27.42	0.011	0.006	0.150	0.023	0.011	0.318
propane	0.48	4.13	4.79	0.004	0.002	0.049	0.003	0.002	0.047
propylene	9.40	32.19	11.14	0.033	0.308	8.048	0.008	0.073	2.036
i-butane	1.21	21.93	30.02	0.025	0.030	0.785	0.030	0.036	1.008
n-butane	1.02	29.73	31.93	0.030	0.031	0.813	0.029	0.030	0.835
trans-2-butene	10.00	6.18	7.21	0.008	0.078	2.036	0.006	0.063	1.765
cis-2-butene	10.00	4.92	7.03	0.006	0.059	1.536	0.007	0.067	1.867
C4 olefins !	9.02	13.32	16.55	0.013	0.117	3.049	0.014	0.127	3.560
i-pentane	1.38	46.14	41.85	0.041	0.057	1.483	0.038	0.052	1.464
1-pentene	6.20	7.89	2.59	0.007	0.041	1.075	0.003	0.016	0.436
n-pentane	1.04	25.79	21.15	0.022	0.023	0.609	0.019	0.020	0.557
trans-2-pentene	8.80	3.56	2.91	0.003	0.030	0.779	0.003	0.023	0.647
cis-2-pentene	8.80	1.57	0.81	0.001	0.010	0.269	0.001	0.006	0.155
2-methyl-2-butene	6.40	6.22	5.53	0.007	0.042	1.097	0.005	0.033	0.935
2,3-dimethylbutane	1.07	4.85	5.13	0.004	0.005	0.125	0.005	0.005	0.142
2-methylpentane	1.50	14.72	15.44	0.012	0.018	0.471	0.014	0.021	0.582
3-methylpentane	1.50	10.20	10.73	0.009	0.013	0.334	0.009	0.014	0.399
1-hexene	4.40	0.94	1.51	0.001	0.004	0.092	0.001	0.006	0.179
n-hexane	0.98	12.67	14.25	0.012	0.012	0.301	0.013	0.013	0.370
C5 and C6 olefins !	6.82	4.56	2.45	0.004	0.029	0.760	0.002	0.014	0.399
methylcyclopentane	2.80	7.40	7.09	0.007	0.019	0.494	0.006	0.018	0.506
benzene	0.42	51.39	44.00	0.035	0.015	0.383	0.034	0.014	0.399
2-methylhexane	1.08	10.65	10.11	0.009	0.010	0.261	0.009	0.010	0.273
3-methylhexane	1.40	5.62	5.39	0.005	0.007	0.179	0.005	0.007	0.193
2,2,4-trimethylpentane	0.93	15.15	14.14	0.013	0.012	0.318	0.013	0.012	0.328
n-heptane	0.81	57.31	60.89	0.080	0.065	1.701	0.061	0.049	1.375
C8 alkanes !	1.19	25.22	27.34	0.025	0.029	0.763	0.024	0.029	0.811
toluene	2.70	50.22	44.86	0.039	0.106	2.770	0.037	0.100	2.792
n-octane	0.60	2.83	4.85	0.003	0.002	0.047	0.005	0.003	0.084
ethylbenzene	2.70	11.27	10.97	0.010	0.028	0.730	0.010	0.026	0.739
m,p-xylenes !	7.40	44.74	32.86	0.038	0.284	7.435	0.030	0.224	6.295
styrene	2.20	3.93	3.51	0.004	0.008	0.220	0.003	0.008	0.211
o-xylene	6.50	13.41	11.57	0.012	0.077	2.005	0.010	0.068	1.894
n-nonane	0.54	2.82	4.01	0.003	0.002	0.041	0.003	0.002	0.053
n-propylbenzene	2.10	1.99	4.79	0.002	0.004	0.115	0.005	0.011	0.314
m,p-ethyltoluenes	6.50	9.01	9.13	0.010	0.064	1.664	0.009	0.057	1.612
1,3,5-trimethylbenzene	10.10	4.86	4.58	0.005	0.051	1.344	0.004	0.043	1.219
o-ethyltoluene	6.50	4.05	4.72	0.005	0.029	0.770	0.004	0.028	0.773
1,2,4-trimethylbenzene	8.80	14.85	14.40	0.016	0.143	3.752	0.014	0.125	3.514
C10 aromatics+aliphatics	6.50	44.16	32.40	0.053	0.344	9.009	0.034	0.219	6.137
formaldehyde	7.20	16.97	10.79	0.018	0.129	3.376	0.011	0.079	2.220
acetaldehyde	5.50	7.22	5.82	0.007	0.036	0.940	0.005	0.030	0.841
acrolein (2-propenal)	6.50	2.31	2.19	0.003	0.019	0.500	0.002	0.010	0.292
Residual hydrocarbons	4.11	263.37	318.82	0.272	1.119	29.285	0.358	1.471	41.258
Sum		1033.71	1036.17		3.82			3.57	
Sum/ phase distance (km)		166	166						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						166			166
mg ozone/mg NMOC emit.						3.82			3.57
mg ozone per km travelled						**635**			**593**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A47
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrohol

HOT START TRANSIENT PHASE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		bag (mg)	bag (mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	221.75	221.91						
ethane	0.25	33.10	33.48	0.029	0.007	0.183	0.033	0.008	0.214
ethylene	7.40	117.39	116.04	0.079	0.586	14.894	0.090	0.662	17.463
acetylene	0.50	20.43	22.14	0.017	0.009	0.221	0.020	0.010	0.262
propane	0.48	5.21	4.11	0.004	0.002	0.046	0.003	0.002	0.043
propylene	9.40	66.75	35.47	0.033	0.314	7.979	0.028	0.259	6.833
i-butane	1.21	24.03	26.26	0.020	0.025	0.623	0.024	0.029	0.758
n-butane	1.02	33.33	34.81	0.028	0.029	0.737	0.032	0.032	0.855
trans-2-butene	10.00	11.84	8.10	0.009	0.090	2.283	0.007	0.067	1.773
cis-2-butene	10.00	8.67	6.98	0.008	0.076	1.923	0.006	0.059	1.547
C4 olefins !	9.02	26.06	22.95	0.020	0.177	4.495	0.019	0.169	4.461
i-pentane	1.38	58.56	59.36	0.047	0.064	1.633	0.054	0.074	1.956
1-pentene	6.20	5.02	3.20	0.004	0.025	0.624	0.003	0.017	0.445
n-pentane	1.04	29.07	27.11	0.023	0.024	0.606	0.024	0.025	0.668
trans-2-pentene	8.80	5.12	4.06	0.004	0.034	0.861	0.003	0.030	0.779
cis-2-pentene	8.80	2.41	2.05	0.002	0.014	0.359	0.002	0.014	0.380
2-methyl-2-butene	6.40	8.36	6.45	0.007	0.044	1.111	0.006	0.037	0.982
2,3-dimethylbutane	1.07	5.83	5.40	0.005	0.005	0.129	0.005	0.005	0.142
2-methylpentane	1.50	23.15	22.37	0.018	0.027	0.677	0.020	0.030	0.785
3-methylpentane	1.50	15.98	15.30	0.012	0.018	0.467	0.014	0.021	0.541
1-hexene	4.40	2.56	1.92	0.002	0.009	0.227	0.002	0.008	0.224
n-hexane	0.98	17.54	15.43	0.014	0.014	0.356	0.014	0.014	0.374
C5 and C6 olefins !	6.82	5.15	4.75	0.004	0.027	0.692	0.006	0.040	1.055
methylcyclopentane	2.80	9.62	8.80	0.008	0.021	0.536	0.008	0.023	0.614
benzene	0.42	56.18	50.88	0.038	0.016	0.402	0.041	0.017	0.453
2-methylhexane	1.08	14.03	12.79	0.011	0.012	0.308	0.012	0.013	0.336
3-methylhexane	1.40	7.40	6.74	0.006	0.009	0.223	0.007	0.009	0.249
2,2,4-trimethylpentane	0.93	18.29	17.03	0.014	0.013	0.342	0.015	0.014	0.371
n-heptane	0.81	31.19	26.22	0.033	0.027	0.682	0.040	0.032	0.844
C8 alkanes !	1.19	39.72	28.80	0.036	0.042	1.078	0.029	0.035	0.919
toluene	2.70	73.30	66.10	0.054	0.145	3.693	0.055	0.147	3.881
n-octane	0.60	5.67	3.23	0.006	0.003	0.086	0.003	0.002	0.053
ethylbenzene	2.70	16.35	14.74	0.012	0.033	0.828	0.012	0.033	0.860
m,p-xylenes !	7.40	51.62	42.88	0.042	0.309	7.849	0.039	0.286	7.537
styrene	2.20	4.11	3.02	0.003	0.007	0.189	0.003	0.006	0.151
o-xylene	6.50	17.32	15.16	0.013	0.086	2.195	0.013	0.083	2.189
n-nonane	0.54	2.95	2.35	0.003	0.001	0.035	0.002	0.001	0.034
n-propylbenzene	2.10	2.58	2.24	0.002	0.005	0.119	0.002	0.005	0.123
m,p-ethyltoluenes	6.50	10.57	9.52	0.009	0.059	1.503	0.009	0.057	1.500
1,3,5-trimethylbenzene	10.10	5.53	4.45	0.005	0.047	1.185	0.004	0.040	1.065
o-ethyltoluene	6.50	4.73	3.49	0.004	0.026	0.659	0.003	0.021	0.563
1,2,4-trimethylbenzene	8.80	14.66	14.14	0.012	0.106	2.704	0.013	0.114	3.011
C10 aromatics+aliphatics	6.50	26.99	19.96	0.023	0.152	3.873	0.021	0.135	3.564
formaldehyde	7.20	11.34	9.86	0.010	0.073	1.845	0.009	0.062	1.644
acetaldehyde	5.50	11.14	13.83	0.009	0.052	1.317	0.011	0.059	1.562
acrolein (2-propenal)	6.50	3.11	2.74	0.003	0.022	0.548	0.002	0.011	0.298
Residual hydrocarbons	4.11	368.19	248.87	0.255	1.049	26.675	0.237	0.973	25.640
Sum		1332.11	1105.59		3.93			3.79	
Sum/ phase distance (km)		231	191						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						231			191
mg ozone/mg NMOC emit.						3.93			3.79
mg ozone per km travelled						**908**			**726**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix A48
MIR calculations of reactivity of dynamometer exhaust emissions
Phase 2 pre-tune and post-tune results
Post-1986 vehicles with unleaded petrohol

AVERAGE ADR CYCLE									
		Pre Tune	Post Tune	Pre Tune			Post Tune		
Compound	MIR	Weighted	Weighted						
		Average	Average	Average [a]		% Contribution	Average [a]		% Contribution
		VOC(i) emit.	VOC(i) emit.	mg VOC(i) per	mg Ozone per		mg VOC(i) per	mg Ozone per	
		(mg)	(mg)	mg NMOC	mg VOC(i) emit.		mg NMOC	mg VOC(i) emit.	
methane	0.02	554.97	555.59						
ethane	0.25	74.66	74.08	0.031	0.008	0.194	0.026	0.007	0.162
ethylene	7.40	251.72	239.00	0.079	0.587	14.560	0.078	0.577	14.360
acetylene	0.50	51.76	62.19	0.016	0.008	0.193	0.021	0.010	0.260
propane	0.48	10.62	10.00	0.002	0.001	0.027	0.003	0.001	0.037
propylene	9.40	118.92	77.29	0.035	0.329	8.165	0.027	0.249	6.208
i-butane	1.21	49.75	60.12	0.028	0.034	0.832	0.021	0.025	0.619
n-butane	1.02	69.85	73.49	0.027	0.028	0.696	0.025	0.025	0.623
trans-2-butene	10.00	21.38	20.01	0.009	0.090	2.245	0.007	0.068	1.690
cis-2-butene	10.00	17.89	18.93	0.006	0.058	1.450	0.007	0.065	1.630
C4 olefins !	9.02	55.16	57.32	0.025	0.227	5.629	0.020	0.177	4.416
i-pentane	1.38	126.70	121.25	0.047	0.066	1.626	0.041	0.056	1.396
1-pentene	6.20	15.82	9.17	0.009	0.058	1.442	0.003	0.021	0.521
n-pentane	1.04	65.00	57.59	0.027	0.029	0.708	0.019	0.020	0.495
trans-2-pentene	8.80	12.14	10.39	0.005	0.043	1.077	0.004	0.032	0.791
cis-2-pentene	8.80	5.93	4.72	0.003	0.024	0.606	0.002	0.014	0.353
2-methyl-2-butene	6.40	19.37	17.18	0.006	0.040	0.994	0.006	0.039	0.978
2,3-dimethylbutane	1.07	14.27	13.81	0.006	0.006	0.149	0.005	0.005	0.126
2-methylpentane	1.50	50.33	49.60	0.017	0.026	0.647	0.017	0.025	0.622
3-methylpentane	1.50	34.53	34.00	0.012	0.018	0.439	0.011	0.017	0.425
1-hexene	4.40	5.83	5.43	0.002	0.010	0.258	0.002	0.009	0.220
n-hexane	0.98	36.86	34.47	0.007	0.007	0.167	0.012	0.012	0.293
C5 and C6 olefins !	6.82	15.83	12.20	0.000	0.000	0.000	0.005	0.032	0.792
methylcyclopentane	2.80	22.72	20.14	0.009	0.024	0.601	0.007	0.019	0.483
benzene	0.42	138.95	125.67	0.046	0.019	0.475	0.040	0.017	0.419
2-methylhexane	1.08	33.95	29.63	0.013	0.015	0.361	0.010	0.011	0.273
3-methylhexane	1.40	18.38	17.29	0.002	0.003	0.071	0.006	0.008	0.209
2,2,4-trimethylpentane	0.93	44.51	41.88	0.016	0.014	0.359	0.014	0.013	0.331
n-heptane	0.81	89.15	80.47	0.007	0.006	0.150	0.031	0.025	0.633
C8 alkanes !	1.19	79.38	69.51	0.011	0.013	0.313	0.025	0.029	0.728
toluene	2.70	189.91	178.73	0.068	0.182	4.523	0.061	0.164	4.076
n-octane	0.60	11.13	10.73	0.002	0.001	0.024	0.004	0.002	0.060
ethylbenzene	2.70	42.79	38.94	0.021	0.057	1.415	0.014	0.036	0.908
m,p-xylenes !	7.40	165.82	128.77	0.019	0.143	3.559	0.047	0.346	8.614
styrene	2.20	11.64	9.58	0.005	0.010	0.247	0.004	0.008	0.195
o-xylene	6.50	49.73	45.51	0.018	0.116	2.888	0.016	0.103	2.554
n-nonane	0.54	8.28	7.95	0.003	0.002	0.041	0.003	0.001	0.036
n-propylbenzene	2.10	8.96	9.98	0.002	0.005	0.113	0.004	0.008	0.208
m,p-ethyltoluenes	6.50	36.87	31.19	0.010	0.064	1.584	0.011	0.073	1.814
1,3,5-trimethylbenzene	10.10	17.94	15.11	0.005	0.053	1.308	0.005	0.054	1.338
o-ethyltoluene	6.50	14.52	12.75	0.005	0.030	0.754	0.004	0.029	0.715
1,2,4-trimethylbenzene	8.80	53.92	48.38	0.014	0.128	3.165	0.018	0.154	3.844
C10 aromatics+aliphatics	6.50	106.58	73.95	0.017	0.109	2.696	0.027	0.178	4.437
formaldehyde	7.20	42.34	29.69	0.017	0.120	2.971	0.012	0.083	2.064
acetaldehyde	5.50	27.54	23.93	0.012	0.063	1.575	0.009	0.047	1.170
acrolein (2-propenal)	6.50	6.89	6.22	0.003	0.020	0.485	0.002	0.013	0.315
Residual hydrocarbons	4.11	733.13	706.36	0.276	1.137	28.218	0.269	1.107	27.558
Sum		3079.35	2824.65		4.03			4.02	
Sum/ Total cycle distance (km)		257	235						
						Pre Tune			**Post Tune**
mg NMOC emit. per km						257			235
mg ozone/mg NMOC emit.						4.03			4.02
mg ozone per km travelled						**1034**			**945**

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

APPENDIX B

MIR CALCULATION OF EVAPORATIVE EMISSIONS

PETROHOL STUDY

Appendix B1
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Pre-1986 vehicles with leaded petrol
All data included

DIURNAL SHED					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		shed (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	53.09	0.032	0.015	0.503
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	162.37	0.099	0.120	3.919
n-butane	1.02	185.81	0.114	0.116	3.787
trans-2-butene	10.00	39.12	0.024	0.240	7.839
cis-2-butene	10.00	27.82	0.017	0.171	5.579
C4 olefins !	9.02	30.21	0.019	0.167	5.464
i-pentane	1.38	195.94	0.120	0.166	5.428
1-pentene	6.20	9.78	0.006	0.037	1.220
n-pentane	1.04	60.26	0.037	0.038	1.255
trans-2-pentene	8.80	17.13	0.011	0.092	3.023
cis-2-pentene	8.80	9.93	0.006	0.054	1.758
2-methyl-2-butene	6.40	22.88	0.014	0.090	2.938
2,3-dimethylbutane	1.07	17.84	0.011	0.012	0.388
2-methylpentane	1.50	41.24	0.025	0.038	1.244
3-methylpentane	1.50	25.41	0.016	0.023	0.764
1-hexene	4.40	6.25	0.004	0.017	0.552
n-hexane	0.98	26.23	0.016	0.016	0.517
C5 and C6 olefins !	6.82	21.32	0.013	0.089	2.908
methylcyclopentane	2.80	14.57	0.009	0.025	0.817
benzene	0.42	30.19	0.018	0.008	0.252
2-methylhexane	1.08	15.53	0.010	0.010	0.338
3-methylhexane	1.40	9.71	0.006	0.008	0.273
2,2,4-trimethylpentane	0.93	10.68	0.007	0.006	0.202
n-heptane	0.81	51.55	0.033	0.027	0.875
C8 alkanes !	1.19	24.57	0.015	0.018	0.592
toluene	2.70	65.75	0.040	0.108	3.519
n-octane	0.60	7.95	0.005	0.003	0.098
ethylbenzene	2.70	14.56	0.009	0.024	0.788
m,p-xylenes !	7.40	57.08	0.035	0.257	8.396
styrene	2.20	4.15	0.003	0.006	0.188
o-xylene	6.50	16.63	0.010	0.066	2.164
n-nonane	0.54	5.65	0.003	0.002	0.061
n-propylbenzene	2.10	4.32	0.003	0.006	0.181
m,p-ethyltoluenes	6.50	9.27	0.006	0.037	1.219
1,3,5-trimethylbenzene	10.10	4.89	0.003	0.031	0.999
o-ethyltoluene	6.50	5.17	0.003	0.021	0.686
1,2,4-trimethylbenzene	8.80	12.82	0.008	0.069	2.261
C10 aromatics+aliphatics	6.50	25.41	0.016	0.101	3.317
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	287.38	0.176	0.725	23.688
Emission Reactivity					
(mg ozone/mg NMOC emit.)				3.06	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B2
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Pre-1986 vehicles with leaded petrol
All data included

HOT SOAK SHED					
Compound	MIR	Average VOC(i) emit. shed (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	26.35	0.008	0.004	0.121
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	259.84	0.067	0.082	2.696
n-butane	1.02	427.34	0.106	0.108	3.575
trans-2-butene	10.00	71.91	0.018	0.177	5.851
cis-2-butene	10.00	57.66	0.014	0.142	4.687
C4 olefins !	9.02	50.24	0.013	0.115	3.801
i-pentane	1.38	684.36	0.157	0.216	7.149
1-pentene	6.20	28.17	0.007	0.040	1.333
n-pentane	1.04	240.75	0.055	0.057	1.892
trans-2-pentene	8.80	64.50	0.015	0.130	4.288
cis-2-pentene	8.80	33.17	0.008	0.067	2.200
2-methyl-2-butene	6.40	86.28	0.020	0.125	4.131
2,3-dimethylbutane	1.07	67.14	0.014	0.015	0.484
2-methylpentane	1.50	194.45	0.042	0.063	2.085
3-methylpentane	1.50	118.74	0.026	0.039	1.277
1-hexene	4.40	18.10	0.004	0.017	0.572
n-hexane	0.98	106.50	0.023	0.022	0.742
C5 and C6 olefins !	6.82	64.08	0.014	0.095	3.138
methylcyclopentane	2.80	61.74	0.013	0.038	1.241
benzene	0.42	106.97	0.025	0.010	0.346
2-methylhexane	1.08	72.88	0.015	0.016	0.543
3-methylhexane	1.40	50.94	0.011	0.015	0.489
2,2,4-trimethylpentane	0.93	42.85	0.008	0.008	0.257
n-heptane	0.81	64.61	0.010	0.008	0.278
C8 alkanes !	1.19	83.89	0.017	0.020	0.670
toluene	2.70	263.24	0.061	0.164	5.421
n-octane	0.60	22.48	0.004	0.003	0.085
ethylbenzene	2.70	42.08	0.009	0.025	0.838
m,p-xylenes !	7.40	225.81	0.050	0.369	12.184
styrene	2.20	6.62	0.001	0.003	0.087
o-xylene	6.50	54.57	0.012	0.076	2.510
n-nonane	0.54	9.09	0.002	0.001	0.033
n-propylbenzene	2.10	14.13	0.003	0.006	0.203
m,p-ethyltoluenes	6.50	48.57	0.009	0.061	2.015
1,3,5-trimethylbenzene	10.10	19.55	0.004	0.039	1.289
o-ethyltoluene	6.50	18.03	0.003	0.022	0.727
1,2,4-trimethylbenzene	8.80	52.92	0.011	0.097	3.208
C10 aromatics+aliphatics	6.50	60.06	0.012	0.077	2.536
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	457.56	0.110	0.454	15.016
Emission Reactivity					
(mg ozone/mg NMOC emit.)				3.03	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B3
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Pre-1986 vehicles with leaded petrohol
All data included

DIURNAL SHED					
Compound	MIR	Average VOC(i) emit. shed (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	243.79	0.091	0.044	1.772
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	403.91	0.170	0.206	8.368
n-butane	1.02	351.41	0.158	0.161	6.547
trans-2-butene	10.00	50.48	0.022	0.224	9.114
cis-2-butene	10.00	33.65	0.016	0.156	6.323
C4 olefins !	9.02	50.01	0.022	0.197	8.005
i-pentane	1.38	277.79	0.137	0.189	7.694
1-pentene	6.20	9.67	0.005	0.029	1.179
n-pentane	1.04	84.14	0.039	0.041	1.651
trans-2-pentene	8.80	20.05	0.009	0.083	3.354
cis-2-pentene	8.80	10.42	0.005	0.042	1.708
2-methyl-2-butene	6.40	27.43	0.013	0.083	3.362
2,3-dimethylbutane	1.07	14.59	0.007	0.007	0.296
2-methylpentane	1.50	54.20	0.025	0.037	1.513
3-methylpentane	1.50	33.12	0.015	0.023	0.918
1-hexene	4.40	5.50	0.002	0.011	0.446
n-hexane	0.98	32.30	0.016	0.016	0.633
C5 and C6 olefins !	6.82	13.54	0.005	0.035	1.424
methylcyclopentane	2.80	16.76	0.007	0.021	0.853
benzene	0.42	32.79	0.014	0.006	0.245
2-methylhexane	1.08	14.57	0.007	0.007	0.302
3-methylhexane	1.40	9.55	0.004	0.006	0.256
2,2,4-trimethylpentane	0.93	9.90	0.005	0.005	0.205
n-heptane	0.81	29.23	0.021	0.017	0.677
C8 alkanes !	1.19	16.27	0.008	0.009	0.382
toluene	2.70	67.60	0.030	0.081	3.300
n-octane	0.60	4.14	0.002	0.001	0.054
ethylbenzene	2.70	10.66	0.005	0.013	0.524
m,p-xylenes !	7.40	49.70	0.022	0.162	6.598
styrene	2.20	1.55	0.001	0.002	0.073
o-xylene	6.50	11.84	0.005	0.036	1.446
n-nonane	0.54	2.53	0.001	0.001	0.024
n-propylbenzene	2.10	3.12	0.001	0.003	0.118
m,p-ethyltoluenes	6.50	6.99	0.003	0.022	0.913
1,3,5-trimethylbenzene	10.10	3.75	0.002	0.019	0.766
o-ethyltoluene	6.50	2.38	0.001	0.008	0.306
1,2,4-trimethylbenzene	8.80	10.29	0.005	0.042	1.699
C10 aromatics+aliphatics	6.50	17.14	0.009	0.057	2.298
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	213.53	0.088	0.361	14.656
Emission Reactivity					
(mg ozone/mg NMOC emit.)				2.46	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B4
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Pre-1986 vehicles with leaded petrohol
All data included

HOT SOAK SHED					
Compound	MIR	Average VOC(i) emit. shed (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	42.71	0.007	0.004	0.126
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	413.04	0.068	0.082	2.857
n-butane	1.02	690.53	0.110	0.112	3.929
trans-2-butene	10.00	116.98	0.018	0.185	6.455
cis-2-butene	10.00	91.55	0.014	0.143	5.016
C4 olefins !	9.02	79.50	0.013	0.115	4.023
i-pentane	1.38	1205.21	0.182	0.251	8.781
1-pentene	6.20	48.71	0.007	0.045	1.582
n-pentane	1.04	405.27	0.060	0.063	2.196
trans-2-pentene	8.80	111.82	0.017	0.147	5.137
cis-2-pentene	8.80	57.59	0.009	0.075	2.628
2-methyl-2-butene	6.40	151.76	0.023	0.144	5.049
2,3-dimethylbutane	1.07	87.93	0.013	0.014	0.485
2-methylpentane	1.50	335.26	0.049	0.073	2.563
3-methylpentane	1.50	208.98	0.030	0.046	1.594
1-hexene	4.40	30.34	0.004	0.019	0.671
n-hexane	0.98	166.10	0.025	0.024	0.841
C5 and C6 olefins !	6.82	106.40	0.016	0.109	3.820
methylcyclopentane	2.80	103.33	0.015	0.043	1.493
benzene	0.42	146.07	0.022	0.009	0.327
2-methylhexane	1.08	104.50	0.015	0.017	0.582
3-methylhexane	1.40	69.31	0.010	0.014	0.502
2,2,4-trimethylpentane	0.93	49.02	0.008	0.007	0.245
n-heptane	0.81	2.89	0.000	0.000	0.012
C8 alkanes !	1.19	73.10	0.011	0.013	0.456
toluene	2.70	240.58	0.039	0.104	3.636
n-octane	0.60	12.25	0.002	0.001	0.039
ethylbenzene	2.70	29.39	0.005	0.013	0.452
m,p-xylenes !	7.40	147.23	0.024	0.181	6.325
styrene	2.20	1.93	0.000	0.001	0.022
o-xylene	6.50	33.65	0.006	0.036	1.265
n-nonane	0.54	6.78	0.001	0.001	0.021
n-propylbenzene	2.10	8.31	0.001	0.003	0.098
m,p-ethyltoluenes	6.50	17.39	0.003	0.019	0.663
1,3,5-trimethylbenzene	10.10	8.09	0.001	0.014	0.472
o-ethyltoluene	6.50	5.60	0.001	0.006	0.209
1,2,4-trimethylbenzene	8.80	26.62	0.004	0.039	1.378
C10 aromatics+aliphatics	6.50	25.34	0.004	0.027	0.932
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	1083.85	0.161	0.661	23.121
Emission Reactivity					
(mg ozone/mg NMOC emit.)				2.86	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B5
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrol
All data included

DIURNAL SHED				
Compound	MIR	Average	Average [a]	
		VOC(i) emit.	mg VOC(i) per	mg Ozone per
		shed (mg)	mg NMOC	mg VOC(i) emit.
methane	0.02	0.00		
ethane	0.25	0.00	0.000	0.000
ethylene	7.40	0.00	0.000	0.000
acetylene	0.50	0.00	0.000	0.000
propane	0.48	179.00	0.060	0.029
propylene	9.40	0.00	0.000	0.000
i-butane	1.21	576.27	0.171	0.206
n-butane	1.02	544.59	0.159	0.162
trans-2-butene	10.00	106.15	0.033	0.334
cis-2-butene	10.00	78.65	0.024	0.241
C4 olefins !	9.02	143.43	0.045	0.403
i-pentane	1.38	468.96	0.138	0.190
1-pentene	6.20	25.49	0.008	0.048
n-pentane	1.04	175.17	0.051	0.053
trans-2-pentene	8.80	46.59	0.012	0.108
cis-2-pentene	8.80	25.13	0.007	0.065
2-methyl-2-butene	6.40	63.93	0.019	0.119
2,3-dimethylbutane	1.07	19.54	0.005	0.006
2-methylpentane	1.50	70.16	0.019	0.029
3-methylpentane	1.50	40.57	0.011	0.017
1-hexene	4.40	9.07	0.003	0.013
n-hexane	0.98	35.23	0.011	0.010
C5 and C6 olefins !	6.82	24.89	0.009	0.062
methylcyclopentane	2.80	17.74	0.005	0.014
benzene	0.42	28.22	0.011	0.005
2-methylhexane	1.08	14.08	0.005	0.005
3-methylhexane	1.40	8.58	0.003	0.004
2,2,4-trimethylpentane	0.93	10.32	0.004	0.004
n-heptane	0.81	7.22	0.003	0.002
C8 alkanes !	1.19	12.92	0.007	0.008
toluene	2.70	41.36	0.024	0.065
n-octane	0.60	2.50	0.001	0.001
ethylbenzene	2.70	5.66	0.004	0.010
m,p-xylenes !	7.40	26.65	0.019	0.144
styrene	2.20	0.91	0.000	0.001
o-xylene	6.50	6.52	0.005	0.032
n-nonane	0.54	0.93	0.001	0.000
n-propylbenzene	2.10	1.30	0.001	0.002
m,p-ethyltoluenes	6.50	3.15	0.003	0.017
1,3,5-trimethylbenzene	10.10	1.46	0.001	0.012
o-ethyltoluene	6.50	1.52	0.001	0.007
1,2,4-trimethylbenzene	8.80	5.35	0.004	0.037
C10 aromatics+aliphatics	6.50	12.30	0.007	0.047
formaldehyde	7.20	0.00	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000
Residual hydrocarbons	4.11	241.65	0.104	0.426
Emission Reactivity				
(mg ozone/mg NMOC emit.)				2.94

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B6
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrol
All data included

HOT SOAK SHED				
Compound	MIR	Average	Average [a]	
		VOC(i) emit.	mg VOC(i) per	mg Ozone per
		shed (mg)	mg NMOC	mg VOC(i) emit.
methane	0.02	0.00		
ethane	0.25	0.00	0.000	0.000
ethylene	7.40	0.00	0.000	0.000
acetylene	0.50	0.00	0.000	0.000
propane	0.48	40.17	0.019	0.009
propylene	9.40	0.00	0.000	0.000
i-butane	1.21	217.12	0.077	0.093
n-butane	1.02	234.08	0.077	0.078
trans-2-butene	10.00	45.39	0.017	0.173
cis-2-butene	10.00	34.66	0.014	0.141
C4 olefins !	9.02	59.66	0.022	0.202
i-pentane	1.38	217.43	0.080	0.111
1-pentene	6.20	10.95	0.005	0.030
n-pentane	1.04	81.35	0.029	0.031
trans-2-pentene	8.80	19.27	0.009	0.078
cis-2-pentene	8.80	10.39	0.005	0.040
2-methyl-2-butene	6.40	26.01	0.012	0.077
2,3-dimethylbutane	1.07	10.22	0.004	0.004
2-methylpentane	1.50	37.13	0.015	0.022
3-methylpentane	1.50	21.61	0.009	0.014
1-hexene	4.40	4.17	0.003	0.011
n-hexane	0.98	20.64	0.012	0.012
C5 and C6 olefins !	6.82	11.73	0.009	0.060
methylcyclopentane	2.80	9.98	0.006	0.018
benzene	0.42	20.02	0.028	0.012
2-methylhexane	1.08	9.09	0.006	0.006
3-methylhexane	1.40	6.37	0.005	0.007
2,2,4-trimethylpentane	0.93	5.43	0.006	0.005
n-heptane	0.81	12.08	0.027	0.022
C8 alkanes !	1.19	12.67	0.016	0.019
toluene	2.70	48.52	0.082	0.222
n-octane	0.60	2.77	0.004	0.003
ethylbenzene	2.70	7.85	0.014	0.039
m,p-xylenes !	7.40	38.08	0.073	0.537
styrene	2.20	0.64	0.001	0.002
o-xylene	6.50	9.48	0.019	0.121
n-nonane	0.54	1.90	0.004	0.002
n-propylbenzene	2.10	1.77	0.004	0.008
m,p-ethyltoluenes	6.50	4.35	0.008	0.052
1,3,5-trimethylbenzene	10.10	2.17	0.004	0.042
o-ethyltoluene	6.50	1.78	0.003	0.023
1,2,4-trimethylbenzene	8.80	6.97	0.014	0.121
C10 aromatics+aliphatics	6.50	9.62	0.019	0.123
formaldehyde	7.20	0.00	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000
Residual hydrocarbons	4.11	214.91	0.239	0.984
Emission Reactivity				
(mg ozone/mg NMOC emit.)				3.56

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B7
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrohol
All data included

DIURNAL SHED				
Compound	MIR	Average	Average [a]	
		VOC(i) emit.	mg VOC(i) per	mg Ozone per
		shed (mg)	mg NMOC	mg VOC(i) emit.
methane	0.02	0.00		
ethane	0.25	0.00	0.000	0.000
ethylene	7.40	0.00	0.000	0.000
acetylene	0.50	0.00	0.000	0.000
propane	0.48	192.97	0.050	0.024
propylene	9.40	0.00	0.000	0.000
i-butane	1.21	663.40	0.200	0.242
n-butane	1.02	558.34	0.176	0.180
trans-2-butene	10.00	97.01	0.032	0.323
cis-2-butene	10.00	68.71	0.023	0.228
C4 olefins !	9.02	145.62	0.046	0.418
i-pentane	1.38	395.15	0.129	0.177
1-pentene	6.20	17.77	0.006	0.038
n-pentane	1.04	137.46	0.041	0.043
trans-2-pentene	8.80	30.86	0.011	0.097
cis-2-pentene	8.80	15.80	0.005	0.048
2-methyl-2-butene	6.40	38.37	0.014	0.090
2,3-dimethylbutane	1.07	13.69	0.004	0.004
2-methylpentane	1.50	51.51	0.013	0.020
3-methylpentane	1.50	29.38	0.009	0.014
1-hexene	4.40	4.97	0.002	0.008
n-hexane	0.98	25.54	0.007	0.007
C5 and C6 olefins !	6.82	13.56	0.006	0.038
methylcyclopentane	2.80	12.06	0.004	0.012
benzene	0.42	17.59	0.009	0.004
2-methylhexane	1.08	11.26	0.004	0.005
3-methylhexane	1.40	7.08	0.002	0.003
2,2,4-trimethylpentane	0.93	6.26	0.003	0.003
n-heptane	0.81	1.45	0.001	0.001
C8 alkanes !	1.19	13.59	0.009	0.010
toluene	2.70	34.63	0.021	0.057
n-octane	0.60	2.94	0.002	0.001
ethylbenzene	2.70	5.27	0.004	0.009
m,p-xylenes !	7.40	23.04	0.015	0.111
styrene	2.20	0.84	0.001	0.001
o-xylene	6.50	6.20	0.005	0.029
n-nonane	0.54	1.27	0.001	0.000
n-propylbenzene	2.10	1.28	0.001	0.002
m,p-ethyltoluenes	6.50	2.70	0.002	0.013
1,3,5-trimethylbenzene	10.10	1.50	0.001	0.012
o-ethyltoluene	6.50	1.41	0.001	0.006
1,2,4-trimethylbenzene	8.80	4.78	0.004	0.033
C10 aromatics+aliphatics	6.50	8.56	0.005	0.034
formaldehyde	7.20	0.00	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000
Residual hydrocarbons	4.11	235.53	0.131	0.538
Emission Reactivity				
(mg ozone/mg NMOC emit.)				2.89

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B8
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrohol
All data included

HOT SOAK SHED				
Compound	MIR	Average	Average [a]	
		VOC(i) emit.	mg VOC(i) per	mg Ozone per
		shed (mg)	mg NMOC	mg VOC(i) emit.
methane	0.02	0.00		
ethane	0.25	0.00	0.000	0.000
ethylene	7.40	0.00	0.000	0.000
acetylene	0.50	0.00	0.000	0.000
propane	0.48	55.88	0.020	0.010
propylene	9.40	0.00	0.000	0.000
i-butane	1.21	287.89	0.073	0.089
n-butane	1.02	316.91	0.075	0.077
trans-2-butene	10.00	61.35	0.017	0.169
cis-2-butene	10.00	45.57	0.013	0.131
C4 olefins !	9.02	79.36	0.022	0.202
i-pentane	1.38	301.34	0.093	0.128
1-pentene	6.20	14.08	0.006	0.035
n-pentane	1.04	107.32	0.031	0.032
trans-2-pentene	8.80	24.25	0.009	0.082
cis-2-pentene	8.80	12.83	0.005	0.043
2-methyl-2-butene	6.40	31.09	0.013	0.084
2,3-dimethylbutane	1.07	13.02	0.004	0.005
2-methylpentane	1.50	49.84	0.016	0.025
3-methylpentane	1.50	27.10	0.010	0.015
1-hexene	4.40	5.03	0.004	0.018
n-hexane	0.98	26.75	0.016	0.016
C5 and C6 olefins !	6.82	11.97	0.007	0.048
methylcyclopentane	2.80	11.59	0.007	0.019
benzene	0.42	21.64	0.030	0.012
2-methylhexane	1.08	11.87	0.007	0.007
3-methylhexane	1.40	7.94	0.005	0.007
2,2,4-trimethylpentane	0.93	6.12	0.006	0.006
n-heptane	0.81	6.86	0.012	0.010
C8 alkanes !	1.19	13.84	0.017	0.020
toluene	2.70	53.38	0.082	0.222
n-octane	0.60	3.24	0.005	0.003
ethylbenzene	2.70	8.23	0.014	0.037
m,p-xylenes !	7.40	36.13	0.057	0.424
styrene	2.20	0.98	0.002	0.004
o-xylene	6.50	9.77	0.017	0.114
n-nonane	0.54	1.56	0.003	0.002
n-propylbenzene	2.10	1.82	0.003	0.007
m,p-ethyltoluenes	6.50	4.51	0.008	0.051
1,3,5-trimethylbenzene	10.10	2.29	0.004	0.041
o-ethyltoluene	6.50	1.87	0.003	0.022
1,2,4-trimethylbenzene	8.80	7.29	0.013	0.113
C10 aromatics+aliphatics	6.50	9.71	0.016	0.101
formaldehyde	7.20	0.00	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000
Residual hydrocarbons	4.11	248.45	0.253	1.042
Emission Reactivity				
(mg ozone/mg NMOC emit.)				3.47

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B9
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrol
Data with significant background at start of SHED test excluded

DIURNAL SHED					
Compound	MIR	Average VOC(i) emit. shed (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	333.84	0.090	0.043	1.628
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	1065.64	0.228	0.276	10.363
n-butane	1.02	983.05	0.182	0.186	6.998
trans-2-butene	10.00	187.22	0.034	0.338	12.721
cis-2-butene	10.00	139.41	0.025	0.247	9.293
C4 olefins !	9.02	258.09	0.051	0.458	17.234
i-pentane	1.38	818.73	0.121	0.167	6.271
1-pentene	6.20	44.37	0.007	0.041	1.535
n-pentane	1.04	306.15	0.046	0.048	1.792
trans-2-pentene	8.80	83.18	0.012	0.108	4.061
cis-2-pentene	8.80	43.98	0.006	0.057	2.130
2-methyl-2-butene	6.40	112.40	0.017	0.106	3.982
2,3-dimethylbutane	1.07	34.97	0.005	0.006	0.209
2-methylpentane	1.50	125.69	0.019	0.028	1.048
3-methylpentane	1.50	72.49	0.011	0.016	0.604
1-hexene	4.40	15.64	0.002	0.011	0.405
n-hexane	0.98	62.30	0.010	0.010	0.369
C5 and C6 olefins !	6.82	41.75	0.006	0.043	1.611
methylcyclopentane	2.80	32.02	0.005	0.014	0.513
benzene	0.42	45.97	0.008	0.003	0.123
2-methylhexane	1.08	23.63	0.003	0.004	0.139
3-methylhexane	1.40	14.73	0.002	0.003	0.111
2,2,4-trimethylpentane	0.93	17.29	0.003	0.003	0.105
n-heptane	0.81	13.28	0.005	0.004	0.142
C8 alkanes !	1.19	18.72	0.004	0.004	0.159
toluene	2.70	58.86	0.012	0.033	1.230
n-octane	0.60	3.59	0.001	0.001	0.020
ethylbenzene	2.70	7.78	0.002	0.006	0.215
m,p-xylenes !	7.40	33.73	0.009	0.066	2.471
styrene	2.20	1.49	0.001	0.001	0.045
o-xylene	6.50	8.16	0.002	0.014	0.513
n-nonane	0.54	1.18	0.000	0.000	0.005
n-propylbenzene	2.10	1.71	0.000	0.001	0.032
m,p-ethyltoluenes	6.50	3.49	0.001	0.006	0.227
1,3,5-trimethylbenzene	10.10	1.68	0.000	0.005	0.172
o-ethyltoluene	6.50	1.98	0.000	0.003	0.112
1,2,4-trimethylbenzene	8.80	6.46	0.002	0.014	0.508
C10 aromatics+aliphatics	6.50	17.60	0.004	0.024	0.892
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	370.00	0.065	0.266	10.009
Emission Reactivity					
(mg ozone/mg NMOC emit.)				2.66	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B10
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrol
Data with significant background at start of SHED test excluded

HOT SOAK SHED					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		shed (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	78.45	0.033	0.016	0.473
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	423.54	0.127	0.153	4.548
n-butane	1.02	455.01	0.118	0.120	3.562
trans-2-butene	10.00	87.11	0.024	0.244	7.231
cis-2-butene	10.00	65.83	0.019	0.190	5.625
C4 olefins !	9.02	115.49	0.035	0.312	9.255
i-pentane	1.38	411.42	0.092	0.128	3.784
1-pentene	6.20	20.40	0.005	0.033	0.988
n-pentane	1.04	154.07	0.035	0.036	1.065
trans-2-pentene	8.80	35.82	0.010	0.087	2.583
cis-2-pentene	8.80	19.29	0.005	0.043	1.282
2-methyl-2-butene	6.40	48.30	0.014	0.087	2.581
2,3-dimethylbutane	1.07	19.42	0.005	0.005	0.144
2-methylpentane	1.50	69.77	0.017	0.025	0.741
3-methylpentane	1.50	40.29	0.010	0.015	0.443
1-hexene	4.40	7.55	0.003	0.013	0.391
n-hexane	0.98	36.56	0.011	0.011	0.314
C5 and C6 olefins !	6.82	20.60	0.010	0.066	1.970
methylcyclopentane	2.80	17.57	0.006	0.016	0.484
benzene	0.42	28.21	0.021	0.009	0.263
2-methylhexane	1.08	16.03	0.005	0.005	0.155
3-methylhexane	1.40	10.76	0.004	0.005	0.152
2,2,4-trimethylpentane	0.93	8.37	0.005	0.004	0.132
n-heptane	0.81	1.69	0.002	0.002	0.058
C8 alkanes !	1.19	17.76	0.013	0.016	0.464
toluene	2.70	60.32	0.058	0.157	4.656
n-octane	0.60	3.22	0.002	0.001	0.038
ethylbenzene	2.70	8.96	0.010	0.027	0.804
m,p-xylenes !	7.40	44.24	0.053	0.392	11.626
styrene	2.20	0.95	0.001	0.003	0.077
o-xylene	6.50	10.91	0.013	0.086	2.564
n-nonane	0.54	1.80	0.002	0.001	0.038
n-propylbenzene	2.10	1.86	0.002	0.005	0.140
m,p-ethyltoluenes	6.50	5.12	0.005	0.035	1.039
1,3,5-trimethylbenzene	10.10	2.55	0.003	0.031	0.910
o-ethyltoluene	6.50	2.01	0.002	0.016	0.467
1,2,4-trimethylbenzene	8.80	7.98	0.010	0.085	2.513
C10 aromatics+aliphatics	6.50	10.82	0.011	0.074	2.194
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	296.20	0.199	0.818	24.246
Emission Reactivity					
(mg ozone/mg NMOC emit.)				3.37	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B11
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrohol
Data with significant background at start of SHED test excluded

DIURNAL SHED					
Compound	MIR	Average VOC(i) emit. shed (mg)	Average [a] mg VOC(i) per mg NMOC	mg Ozone per mg VOC(i) emit.	% Contribution
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	336.13	0.083	0.040	1.549
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	1102.92	0.274	0.331	12.924
n-butane	1.02	904.76	0.213	0.217	8.463
trans-2-butene	10.00	153.23	0.035	0.349	13.618
cis-2-butene	10.00	108.58	0.024	0.241	9.414
C4 olefins !	9.02	236.45	0.057	0.512	19.966
i-pentane	1.38	613.67	0.115	0.159	6.200
1-pentene	6.20	27.14	0.005	0.032	1.260
n-pentane	1.04	216.39	0.038	0.039	1.527
trans-2-pentene	8.80	46.35	0.009	0.077	3.000
cis-2-pentene	8.80	23.88	0.004	0.039	1.509
2-methyl-2-butene	6.40	56.65	0.010	0.066	2.567
2,3-dimethylbutane	1.07	21.59	0.003	0.003	0.133
2-methylpentane	1.50	82.81	0.012	0.019	0.729
3-methylpentane	1.50	44.99	0.007	0.010	0.396
1-hexene	4.40	7.26	0.001	0.005	0.199
n-hexane	0.98	39.93	0.006	0.006	0.224
C5 and C6 olefins !	6.82	19.38	0.003	0.024	0.919
methylcyclopentane	2.80	17.63	0.003	0.007	0.289
benzene	0.42	22.95	0.004	0.002	0.067
2-methylhexane	1.08	16.35	0.003	0.003	0.106
3-methylhexane	1.40	10.83	0.002	0.002	0.094
2,2,4-trimethylpentane	0.93	8.21	0.001	0.001	0.048
n-heptane	0.81	1.64	0.000	0.000	0.013
C8 alkanes !	1.19	15.34	0.003	0.003	0.124
toluene	2.70	43.70	0.009	0.025	0.963
n-octane	0.60	3.87	0.001	0.000	0.014
ethylbenzene	2.70	6.30	0.001	0.004	0.150
m,p-xylenes !	7.40	28.83	0.007	0.052	2.037
styrene	2.20	1.05	0.000	0.000	0.015
o-xylene	6.50	7.00	0.002	0.011	0.423
n-nonane	0.54	1.71	0.000	0.000	0.009
n-propylbenzene	2.10	1.50	0.000	0.001	0.030
m,p-ethyltoluenes	6.50	2.97	0.001	0.004	0.176
1,3,5-trimethylbenzene	10.10	1.62	0.000	0.004	0.155
o-ethyltoluene	6.50	1.72	0.000	0.002	0.095
1,2,4-trimethylbenzene	8.80	5.10	0.001	0.011	0.422
C10 aromatics+aliphatics	6.50	10.72	0.002	0.015	0.566
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	302.06	0.060	0.246	9.606
Emission Reactivity					
(mg ozone/mg NMOC emit.)				2.56	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.

Appendix B12
MIR calculations of reactivity of SHED evaporative emissions
Phase 2 pre-tune results
Post-1986 vehicles with unleaded petrohol
Data with significant background at start of SHED test excluded

HOT SOAK SHED					
Compound	MIR	Average	Average [a]		% Contribution
		VOC(i) emit.	mg VOC(i) per	mg Ozone per	
		shed (mg)	mg NMOC	mg VOC(i) emit.	
methane	0.02	0.00			
ethane	0.25	0.00	0.000	0.000	0.000
ethylene	7.40	0.00	0.000	0.000	0.000
acetylene	0.50	0.00	0.000	0.000	0.000
propane	0.48	110.75	0.037	0.018	0.574
propylene	9.40	0.00	0.000	0.000	0.000
i-butane	1.21	566.30	0.122	0.148	4.784
n-butane	1.02	621.30	0.117	0.119	3.851
trans-2-butene	10.00	118.77	0.023	0.234	7.563
cis-2-butene	10.00	88.13	0.018	0.183	5.891
C4 olefins !	9.02	154.19	0.033	0.294	9.485
i-pentane	1.38	575.67	0.117	0.162	5.213
1-pentene	6.20	26.38	0.007	0.042	1.355
n-pentane	1.04	205.24	0.037	0.038	1.227
trans-2-pentene	8.80	45.40	0.010	0.092	2.957
cis-2-pentene	8.80	23.96	0.005	0.046	1.485
2-methyl-2-butene	6.40	57.94	0.015	0.095	3.051
2,3-dimethylbutane	1.07	24.83	0.006	0.006	0.201
2-methylpentane	1.50	94.95	0.020	0.030	0.978
3-methylpentane	1.50	51.11	0.011	0.017	0.556
1-hexene	4.40	8.75	0.005	0.022	0.704
n-hexane	0.98	48.48	0.019	0.018	0.596
C5 and C6 olefins !	6.82	20.65	0.006	0.042	1.360
methylcyclopentane	2.80	20.56	0.007	0.019	0.612
benzene	0.42	29.08	0.022	0.009	0.296
2-methylhexane	1.08	21.36	0.008	0.008	0.271
3-methylhexane	1.40	13.96	0.005	0.007	0.240
2,2,4-trimethylpentane	0.93	10.05	0.007	0.006	0.203
n-heptane	0.81	12.62	0.021	0.017	0.547
C8 alkanes !	1.19	19.83	0.013	0.016	0.517
toluene	2.70	65.23	0.056	0.150	4.854
n-octane	0.60	4.96	0.005	0.003	0.101
ethylbenzene	2.70	9.23	0.009	0.023	0.753
m,p-xylenes !	7.40	43.29	0.043	0.316	10.204
styrene	2.20	1.12	0.001	0.003	0.100
o-xylene	6.50	10.48	0.011	0.073	2.362
n-nonane	0.54	1.53	0.001	0.001	0.025
n-propylbenzene	2.10	1.92	0.002	0.004	0.128
m,p-ethyltoluenes	6.50	5.44	0.006	0.042	1.359
1,3,5-trimethylbenzene	10.10	2.54	0.003	0.028	0.891
o-ethyltoluene	6.50	1.99	0.002	0.015	0.478
1,2,4-trimethylbenzene	8.80	7.48	0.007	0.064	2.056
C10 aromatics+aliphatics	6.50	11.25	0.010	0.067	2.151
formaldehyde	7.20	0.00	0.000	0.000	0.000
acetaldehyde	5.50	0.00	0.000	0.000	0.000
acrolein (2-propenal)	6.50	0.00	0.000	0.000	0.000
Residual hydrocarbons	4.11	363.07	0.151	0.620	20.018
Emission Reactivity					
(mg ozone/mg NMOC emit.)				3.10	

[a] calculating by averaging , for each test, the mass of each individual compound per total mass of NMOC emitted for that test, and not by normalising the average mass emissions.