COMMONWEALTH DEPARTMENT OF
TRANSPORT AND
REGIONAL SERVICES

COMPARATIVE VEHICLE EMISSIONS STUDY

Prepared by the
Department of Transport and Regional Services

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This report is also available from the Department's website at:
http://www.dotrs.gov.au/land/environment/index.htm

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Jon Real
Project Manager
Comparative Vehicle Emissions Study

CONTENTS

EXECUTIVE SUMMARY

Introduction

In 1998, the Department of Transport and Regional Services, with financial support from Environment Australia, commissioned a vehicle emissions test program to support the development of new vehicle emissions standards in Australia . A total of 45 vehicles were tested – 39 passenger cars, and 6 four wheel drive (4WD) and light commercial vehicles (LCV). The vehicles were essentially new, with an odometer reading of between 3,000 and 15,000km.

The main objective of the Comparative Vehicle Emissions Study was to assess the relative stringency of the light duty vehicle emission test cycles adopted by the United Nation's Economic Commission for Europe (UN ECE) with the current US Environment Protection Authority (EPA) test adopted in Australian Design Rule (ADR) 37/01 *Emission Control for Light Vehicles.* The project also provides useful indicative data on the emissions performance of the current light vehicle fleet in Australia and information on fuel consumption.

Testing

The testing was conducted in two stages over a 21 month period starting in October 1998 and concluding in July 2000. The principal test procedures used during the program were:

- The US EPA Federal Test Procedure (FTP 75) referenced in the current emissions standard for light vehicles (ADR37/01);
- The emissions test in ECE Regulation 83/04 (*Euro 2*) which is referenced in the new emissions standard for light vehicles which takes effect from 2003 (ADR79/00); and
- The emissions test in the EC Directive 98/69/EC (*Euro 3*) which is referenced in the new emissions standard for light vehicles which takes effect from 2005 (ADR79/01).

All these tests include the measurement of noxious emissions of carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NOx), "city cycle" fuel consumption and evaporative emissions of hydrocarbons, although only a sub-set of vehicles in the Study were tested for evaporative emissions.

The exhaust emission and fuel consumption testing was done on a single batch of commercial petrol. The evaporative emission testing was done on ADR37/01 certification fuel.

Results

Most vehicles tested in this Study were designed to comply with ADR37/01, so in interpreting the results from the other tests, it needs to be remembered that these vehicles were not explicitly designed to meet these requirements. This is especially the case with respect to the Euro 3 test to be adopted in ADR79/01 from 2005, where many vehicles have a level of technology below what is required to meet the limits imposed in this test.

Table ES1 shows the regulated limits for current and future ADRs evaluated in this Study.

Table ES1 – Regulated Emission Limits under Current and Future ADRs

Exhaust Gas	ADR37/01 (FTP) g/km	ADR79/00 (Euro2) g/km	ADR79/01 (Euro 3) g/km
CO	2.1	2.2	2.3
HC	0.26		0.2
HC + NOx		0.5	
NOx	0.63		0.15

In the case of those 4WDs and light commercials which meet ADR36/00[1], the technology gap is even more stark, as ADR36/00 is a much less stringent standard than ADR37/01 and vehicles do not need a catalytic converter to comply with ADR36/00.

The results should be viewed as addressing 2 main questions:

- How do current technology vehicles perform under current and future ADR standards ?
- What is the relative stringency of the future standards compared to the current ADR ?

The results on the future *Euro* tests should not be used to categorise vehicles as "good" or "bad" performers, as the bulk of the vehicles were not specifically designed to meet those standards. Nevertheless these results give an indication of the likely magnitude of benefits which will flow from compliance with these standards in the future.

1 ADR36/00 *Exhaust Emission Control for Heavy Duty Vehicles* applies to petrol engined vehicles over 2.7 tonnes GVM.

How do the Vehicles Perform on the Current Emission Standards ?

ADR37/01 Vehicles

The results from testing on the current ADR37/01 emissions test illustrate that almost all of the vehicles met the emission limits in ADR37/01, but there was nevertheless considerable variability in emission levels from model to model and across emission type. In particular, a number of models had quite high NOx emissions relative to the limit (see Figure ES1).

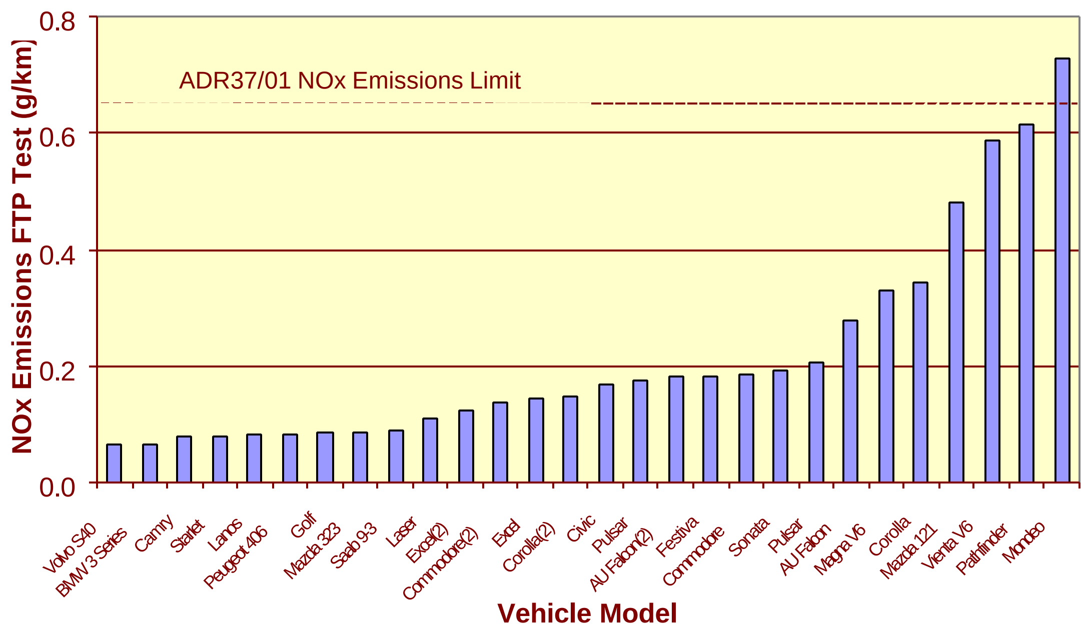

Figure ES1 NOx Emissions from ADR37/01 Vehicles on the ADR37/01 Test

Figure ES2 compares the averages from the ADR37/01 test on each of the three gases as a percentage of the limits, indicating that on average the emission rates were more than 60% below the limits. This sort of margin is normal manufacturing practice to ensure the 80,000 km durability requirements in ADR37/01 are met.

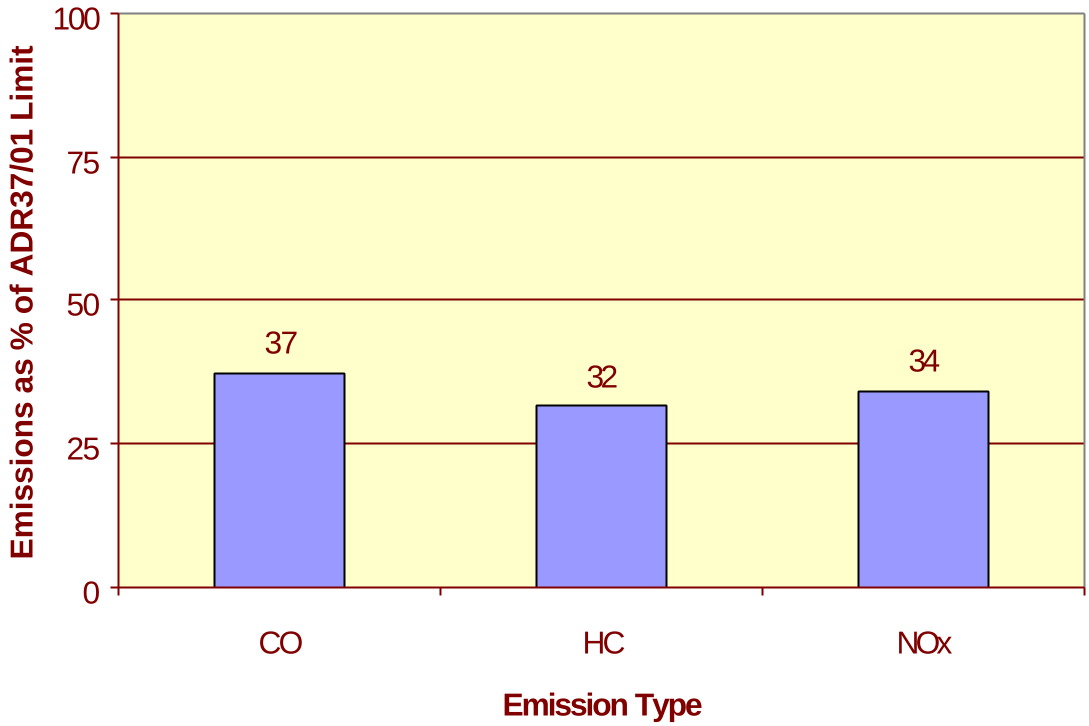

Figure ES2 **Average Emission from ADR37/01 Vehicles as a Proportion of the Current Limits**

ADR36/00 Vehicles

A small sample (6) of four wheel drive (4WD) and light commercial vehicles (LCV's) was tested. All of these vehicles were certified to ADR36/00. Some of the vehicles in this category are high volume sellers on the Australian market, with a number of the models falling in the top 20. Given this significant representation, and the growing popularity of 4WDs as urban passenger vehicles, it was decided to include this group to gain an indicative assessment of their relative emissions performance. With such a small sample, caution must be exercised in assessing the results.

The ADR36/00 emissions test is quite different from the FTP test in ADR37/01. In order to provide a common basis for comparison, the ADR36/00 vehicles were subjected to the ADR37/01 FTP test cycle.

Figure ES3 illustrates that the ADR36/00 vehicles, as expected, did have higher average emission rates relative to the ADR37/01 group. It also illustrates the efficacy of catalytic converters, with the catalyst equipped ADR36/00 vehicles having average emission rates not much higher than the ADR37/01 group, while the non-catalyst equipped vehicles were well above the ADR37/01 averages.

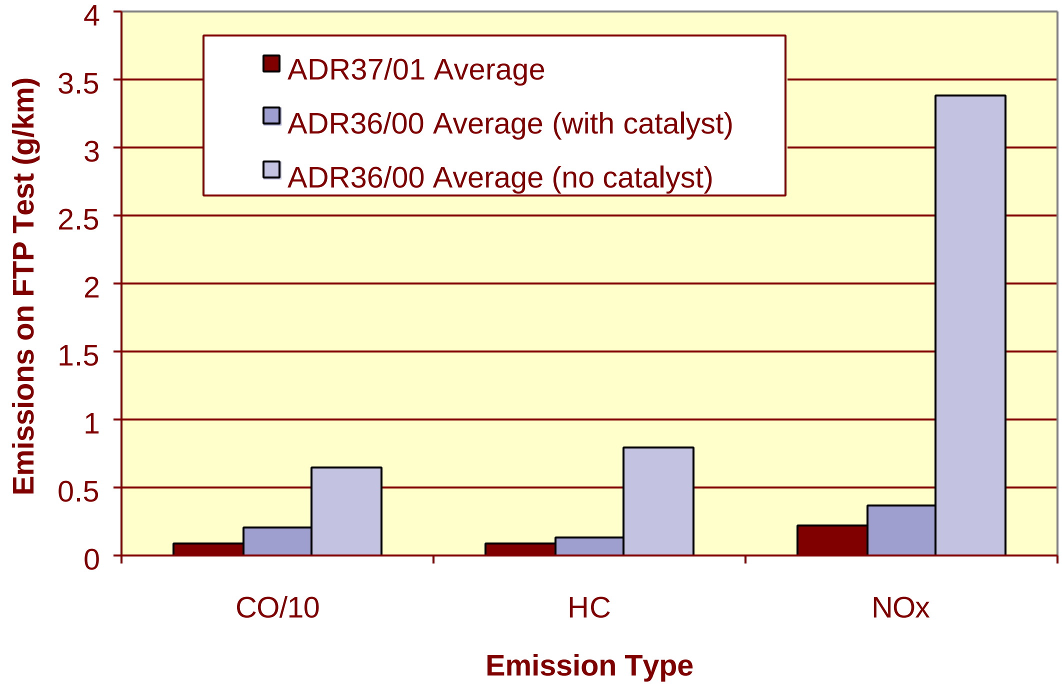

Figure ES3 Comparison of Emissions Performance of ADR36/00 Vehicles with the ADR37/01 Group

How do the Vehicles Perform on the Future Emission Standards ?

The other key aspect of this Study was to examine the impact of the new *Euro 2* and *Euro 3* emission tests. Again it is important to remember that the vehicles were designed to meet current standards, and thus failure to meet an emission limit under *Euro 2* or *Euro 3* does not indicate an unsatisfactory emissions performance. The aim of testing these vehicles against the new test procedures is to obtain an assessment of the stringency of the new standards, and an indication of what magnitude of improvements will be required in the current fleet to meet the new standards.

Manufacturers building vehicles to comply with a standard always aim to have production vehicles' emission rates well below the regulated limit to allow for production variability and in-service deterioration. As illustrated in Figure ES2, current vehicles have, on average, emission rates around 60% below the nominated ADR37/01 limits.

When these vehicles are subject to the new *Euro 2* and *Euro 3* emission test cycles the margin between the emission results and the limits is much reduced (see Figure ES4). In the case of NOx emissions, the ADR37/01 vehicles on average actually exceeded the limits (around 15% above the HC+NOx limit for *Euro 2* and 180% above the *Euro 3* NOx limit).

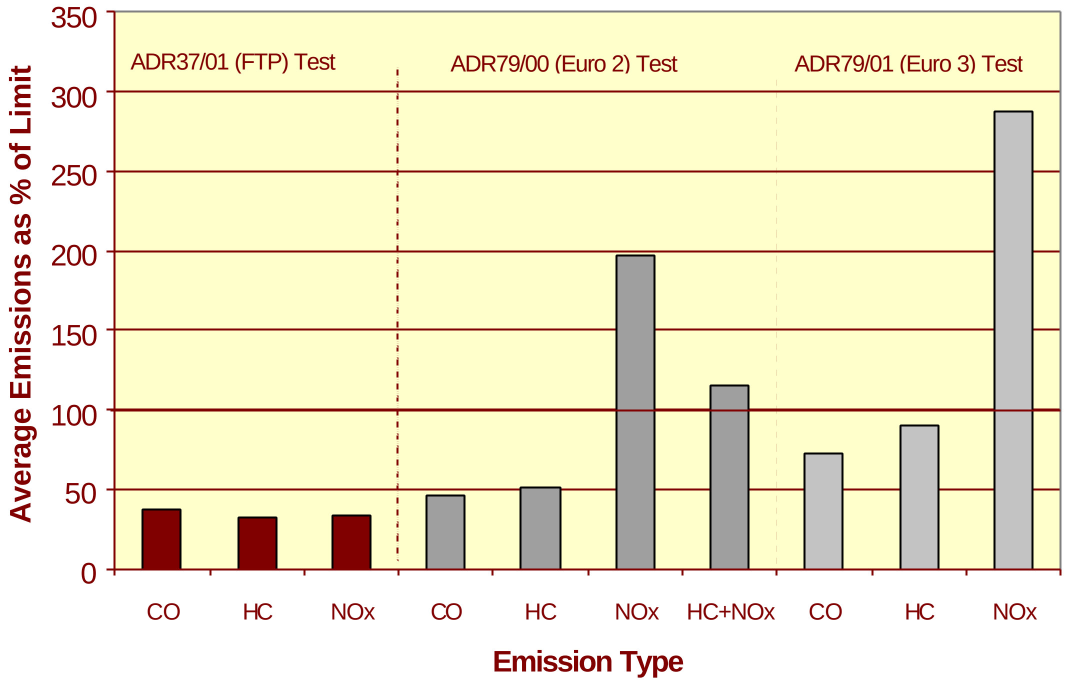

Figure ES4 Comparison of Emissions Performance of ADR37/01 Vehicles under Current and Future Standards

However, it is not only the emission limits which determine the stringency of standards, but also how “tough” the emissions test is *viz* how demanding it is on the vehicle in relation to each of the regulated emissions.

The Study attempted to address this issue by comparing the emission results of each vehicle in the ADR37/01 group on one test, with its results on another test. Where the emission result on one test is higher than the other, this is taken to mean that the test which produces the higher result is the more stringent test for that vehicle. When all the data are plotted in this way, it is possible to draw some conclusions about the stringency of the test for the overall group.

The key findings from the comparisons of the current ADR37/01 test and the ADR79/00 (Euro 2 test) are that:

- On CO and HC emissions, the *Euro 2* test is more demanding for most vehicles, but almost all the test vehicles complied with the *Euro 2* test limits, albeit with varying margins for deterioration.
- On NOx emissions, the *Euro 2* test is also more demanding on almost all of the vehicles, with a small number of vehicles having very high NOx emissions on the *Euro 2* test relative to the FTP test. In addition around 50% of the vehicles did not meet the *Euro 2* NOx emission limit.

Having examined the relationship between the emission test used in the current ADR37/01 and the *Euro 2* test to be adopted in the next ADR (ADR79/00), the Study then examined whether the move to the *Euro 3* test requirement in ADR79/01 in 2005 will result in a further increase in stringency.

The key findings from this second analysis are that:

- On CO and HC emissions, the *Euro 3* test is more demanding than the *Euro 2* test for virtually all of the test vehicles, with the magnitude of the difference between the two tests varying considerably. Most of the test vehicles complied with the *Euro 3* CO limits, although there was little room for deterioration in many of the vehicles. Around 50% of the vehicles had HC emission values above, or very close to, the *Euro 3* limit.
- On NOx emissions, there is little difference between the results on the *Euro 2* and *Euro 3* tests. Most of the sample (around 80%) had NOx emission values above or very close to the *Euro 3* limit, with some exceeding the limit by a very significant margin.

The likely technical reasons underlying these results are examined in section 3.4.3 of the main report.

How do Current Vehicles Perform on Evaporative Emissions ?

A total of 12 vehicles were tested for evaporative HC emissions under the ADR37/01 test and the ADR79/00 (*Euro 2*) test. At the time of testing there were no facilities available in Australia able to undertake the more complex *Euro 3* evaporative emissions test.

The ADR37/01 and ADR79/01 evaporative emissions tests are almost identical, except that under the *Euro 2* test adopted in ADR79/01, the carbon canister on the vehicle is partially "loaded" prior to the commencement of the test. The aim of the testing was to see if these differences between the test requirements had a significant impact on the results. These tests were performed using ADR37/01 certification fuel, rather than a commercial grade of petrol, to minimise any fuel effects.

All vehicles (except one) - even the ADR36/00 models which are not required to meet evaporative emission standards - met the 2g limit under both standards.

It needs to be remembered that commercial fuel traditionally has a higher vapour pressure than ADR certification fuel, and previous research has demonstrated that this can have a significant impact on evaporative emissions. Measures are now in place (or planned) in a number of Australian States to reduce the vapour pressure of "summer grade" commercial petrol to levels much closer to that of ADR certification fuel.

How do Current Vehicles Perform on Fuel Consumption ?

Vehicle fuel economy is not regulated like the noxious emissions which are addressed in the ADRs. The vehicle industry in Australia has operated for many years under a voluntary code of practice which sets targets for the National Average Fuel Consumption (NAFC). NAFC is a sales weighted average. The Federal Government is negotiating with the industry to secure a 15% improvement in NAFC by 2010 compared with business as usual projections.

An important component of the NAFC calculation is the fuel consumption value derived from the "city cycle" test, which is essentially the same as the exhaust emission test used in ADR37/01. This value is also used in the fuel consumption label required under ADR81/00[2]. The Study collected fuel consumption data from all

2 ADR81/00 *Fuel Consumption Labelling for Light Vehicles*

vehicles. As vehicle mass has a significant impact on fuel consumption, the test vehicles were subdivided into 5 mass groupings, generally in line with the recognised industry categories.

Figure ES5 illustrates the average fuel consumption performance of the vehicles in each of the categories. The results are not surprising and reflect the considerable variation in fuel consumption rates of passenger vehicles and "commercial" vehicles – some of which are widely used as passenger vehicles.

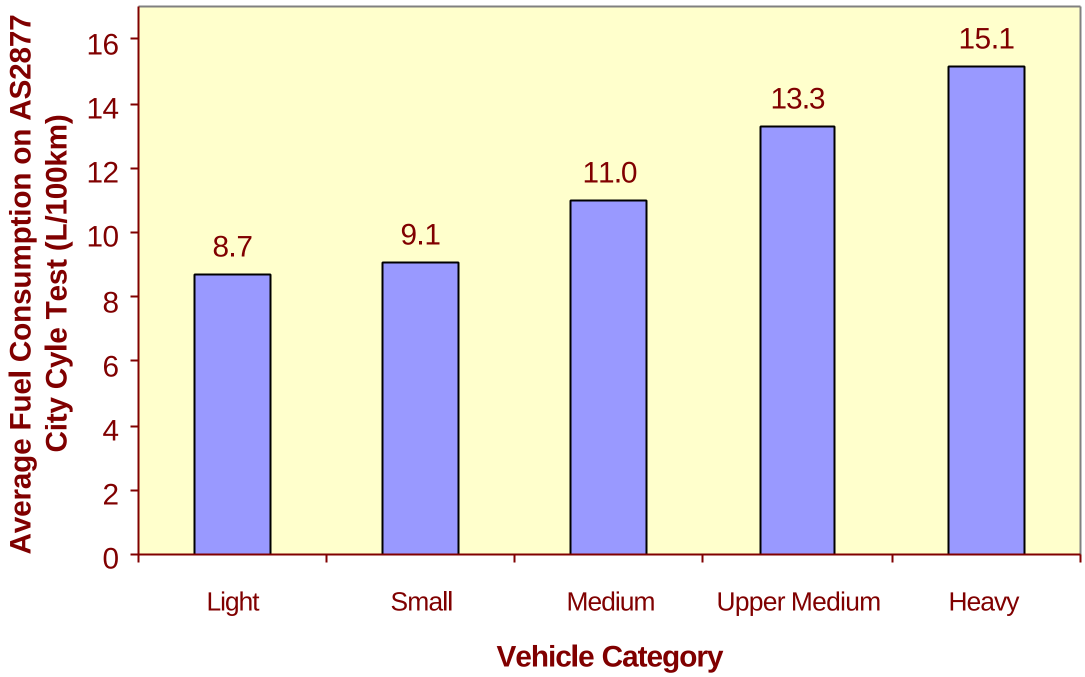

Figure ES5 Average Fuel Consumption of All Test Vehicles

The Study also examined the changes in average fuel consumption performance over the past few years. Using data from the 1996 National In-service Emissions Study for 1992-3 model vehicles, the Study compared the average fuel consumption of the categories for which the earlier data is available. The results indicate that on average, there has been only a modest improvement in fuel consumption in these categories of passenger cars over the past 6-7 years (approximately 3% for the small vehicle group, 6% for the medium and 2% for the upper medium).

Summary

The results from this Study indicate that most current model passenger cars on the Australian market are likely to meet the current emission standards in ADR37/01 by a comfortable margin. Some of the light commercial and 4WD vehicles certified to ADR36/00 have very high emissions relative to passenger cars.

The data also indicate that the new *Euro 2* and *Euro 3* emission tests which will be adopted in Australia from 2003 and 2005, respectively, will lead to significant improvements in the emissions performance of passenger cars, 4WDs and light buses and trucks. These improvements will be delivered through a combination of lower emission limits and more demanding test procedures. The major benefits from *Euro 2* will be in lower NOx emissions, while the *Euro 3* standards are expected to deliver reductions in all emissions.

MAIN REPORT

1. INTRODUCTION

1.1 Overview and Objectives

In 1998, the Department of Transport and Regional Services, with financial support from Environment Australia, commissioned a vehicle emissions test program to support the development of new vehicle emissions standards in Australia . The program was undertaken in 2 stages from late 1998 until mid 2000 by the Ford Motor Company's Emission Laboratory at Lara, Victoria.

The first stage involved exhaust emission testing of 27 passenger vehicles. The second stage included both exhaust and evaporative emission testing of 18 vehicles, including a limited number of 4WDs and light commercial vehicles (LCVs).

The main objective of this project was to assess the relative stringency of the light duty vehicle emission test cycles adopted by the United Nation's Economic Commission for Europe (UN ECE) with the current US Environment Protection Authority (EPA) test adopted in Australian Design Rule (ADR) 37/01 *Emission Control for Light Vehicles.* The project also provides useful indicative data on the emissions performance of the current light vehicle fleet in Australia and information on fuel consumption.

2. OUTLINE OF STUDY

2.1 Sample Design

The available budget was not sufficient to enable a statistically valid sample of the fleet to be tested, so the aim was to test a *representative* sample of current model vehicles supplied to the Australian market.

When Stage 1 of the test program was developed in 1998, the target vehicles were 1997-98 models reflecting the biggest selling models in 1997 (based on new vehicle sales data for 1997). Some small volume European vehicles were also included, to assess the performance of vehicles assumed to be designed to comply with the UN ECE emission test cycle. From an original target of 30 vehicles, 27 were tested in all (see Table 1). The vehicles were essentially new vehicles with an odometer reading of between 3,000 and 15,000km[3]. A mix of manual and automatic vehicles were tested.

Apart from the European vehicles, the basis of selection was that the proportion of that model in total passenger car sales in 1997 was 1% or greater. On this basis, the 30 target models accounted for some 75% of all passenger cars sold in 1997. It had been anticipated that all the vehicles would comply with ADR37/01, but ultimately 7 of the vehicles supplied complied with the earlier ADR37/00. All but one of the ADR37/01 vehicles was built in 1998 or 1999.

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[3] 4 vehicles were marginally over the 15,000km mark (Excel, both Lasers, Vienta), while 3 vehicles which were difficult to source had odometer readings of 16-20,000 km (LPG Commodore, Patrol, Navara).

Table 1 – Vehicles Tested in Stage 1 of Study

Make	Model	Test Fuel[4]
ADR37/00 Vehicles		
Ford	Falcon	ULP
Ford	Laser	ULP
Mitsubishi	Lancer	ULP
Mitsubishi	Magna 4 cyl	ULP
Mitsubishi	Magna 6 cyl	ULP
Mitsubishi	Mirage	ULP
Volvo	S40	ULP
ADR37/01 Vehicles		
BMW	3 Series	ULP
BMW	5 Series	PULP
Daewoo	Lanos	ULP
Ford	AU Falcon	ULP
Ford	Festiva	ULP
Ford	Mondeo	ULP
Holden	VT Commodore	ULP
Honda	Civic	ULP
Hyundai	Excel	ULP
Hyundai	Sonata	ULP
Mazda	121	ULP
Mazda	323	ULP
Nissan	Pulsar	ULP
Peugeot	406	PULP
Saab	9-3	ULP
Toyota	Camry	ULP
Toyota	Corolla	ULP
Toyota	Starlet	ULP
Toyota	Vienta	ULP
Volkswagen	Golf	PULP

With additional funding from Environment Australia, Stage 2 was able to be commissioned. The aim in Stage 2 was to provide some additional information on vehicles and tests not addressed in Stage 1 and to fill some gaps in Stage 1.

4 ULP = Unleaded Petrol (91 Research Octane Number)
PULP = Premium Unleaded Petrol (95 Research Octane Number)

18 vehicles were tested in all (see Table 2), coming from the following categories:

- vehicles to replace the ADR37/00 vehicles tested in Stage 1 with the ADR37/01 equivalents (where possible);
- some low emission vehicles;
- two LPG fuelled vehicles; and
- six 4WD and light commercial vehicles (certified to ADR36/00[5]).

In addition to exhaust emission testing, evaporative emission tests were conducted on six cars and six 4WDs and LCVs.

Table 2 – Vehicles Tested in Stage 2 of Study

Make	Model	Test Fuel[6]
ADR37/01 Vehicles (Petrol)		
Ford	AU Falcon	ULP
Ford	Laser	ULP
Holden	Commodore	ULP
Honda	Accord	ULP
Hyundai	Excel	ULP
Mitsubishi	Magna V6	ULP
Nissan	Pathfinder 4WD	ULP
Nissan	Pulsar	ULP
Toyota	Corolla	ULP
Volvo	S40	ULP
ADR37/01 Vehicles (LPG)		
Ford	Falcon Utility	LPG
Holden	Commodore	LPG
ADR36/00 Vehicles		
Ford	Transit Van	ULP
Mitsubishi	Triton 4WD	ULP
Nissan	Navara	ULP
Nissan	Patrol 4WD	ULP
Toyota	Prado 4WD	ULP
Toyota	Hilux	ULP

Appendix A contains a more a detailed listing of the test vehicles selected for each Stage, as well as the tests performed on each vehicle.

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5 ADR36/00 *Exhaust Emission Control for Heavy Duty Vehicles* applies to petrol engined vehicles over 2.7 tonnes GVM and is a much less stringent standard than ADR37/01 (see section 3.3.5)

6 ULP = Unleaded Petrol (91 Research Octane Number)
PULP = Premium Unleaded Petrol (95 Research Octane Number)

2.2 Testing

2.2.1 Overview

The testing was conducted in 2 stages over an 21 month period starting in October 1998 and concluding in July 2000. A series of test procedures were used during the program (refer to Appendix B for a more detailed description).

The tests were:

- The US EPA Federal Test Procedure (FTP 75) referenced in the current emissions standard for light vehicles (ADR37/01[7]). This is referred to as the "*FTP*" test;
- The UN ECE Type I emissions test in UN ECE Regulation 83/04[8] which is referenced in the new emissions standard for light vehicles, and which takes effect from 2003 (ADR79/00). This is referred to as the "*Euro 2* " test;
- The UN ECE Type I emissions test in the EC Directive 98/69/EC[9] which is referenced in the new emissions standard for light vehicles, and which takes effect from 2005 (ADR79/01). This is referred to as the "*Euro 3* " test;
- The Australian Urban Cycle (AUC) developed by Professor Harry Watson of the University of Melbourne. This test is not adopted in any ADRs. This is referred to in this report as the "*AUC*" test; and
- The highway cycle from AS2877-1986[10] for measuring fuel consumption.

All the ADR tests include tests for noxious emissions, "city cycle" fuel consumption and evaporative emissions of hydrocarbons, although only a sub-set of vehicles in Stage 2 were tested for evaporative emissions. The *AUC* measures both noxious emissions and fuel consumption.

2.2.2. Description of Emission and Fuel Consumption Test Cycles

ADR37/01 (Figure 1) – This is the current Australian test cycle and is the same as the US Federal Test Procedure (*FTP*) laid down by the US Environmental Protection Agency (US EPA). All vehicles were subject to this test cycle for both emissions and fuel economy testing.

7 ADR37/01 *Emission Control for Light Vehicles*

8 UN ECE Regulation 83 *Uniform Provisions Concerning the Approval of Vehicles with Regard to the Emission of Pollutants According to Engine Fuel Requirements*

9 European Council Directive 98/69/EC, *Relating To Measures To Be Taken Against Air Pollution By Emissions From Motor Vehicles*, amending Directive 70/220/EEC

10 Australian Standard 2877-1986 *Methods of Test for Fuel Consumption of Motor Vehicles Designed to Comply with Australian Design Rules 37 and 40*

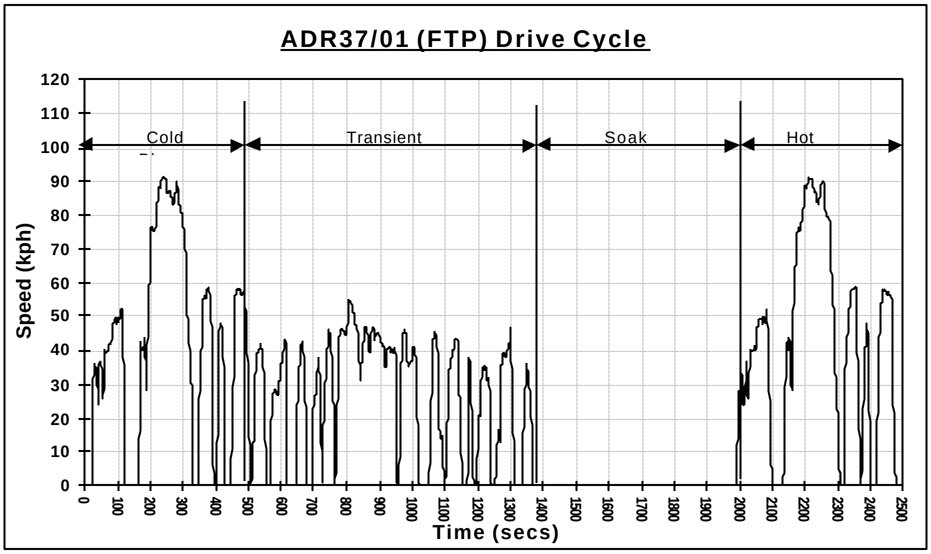


Figure 1 – ADR37/01 (*FTP*) Drive Cycle

ECE R83/04 (*Euro 2* – Figure 2) – This will be the drive cycle adopted for ADR compliance in Australia from 2003 (under ADR79/00). Unlike the *FTP* cycle above, this cycle allows a 40 second idle at the start of the test before gas sampling starts. This test cycle is also called up in UN ECE R101 which is the ECE fuel consumption test. All vehicles were subject to this test cycle for both emissions and fuel consumption testing.

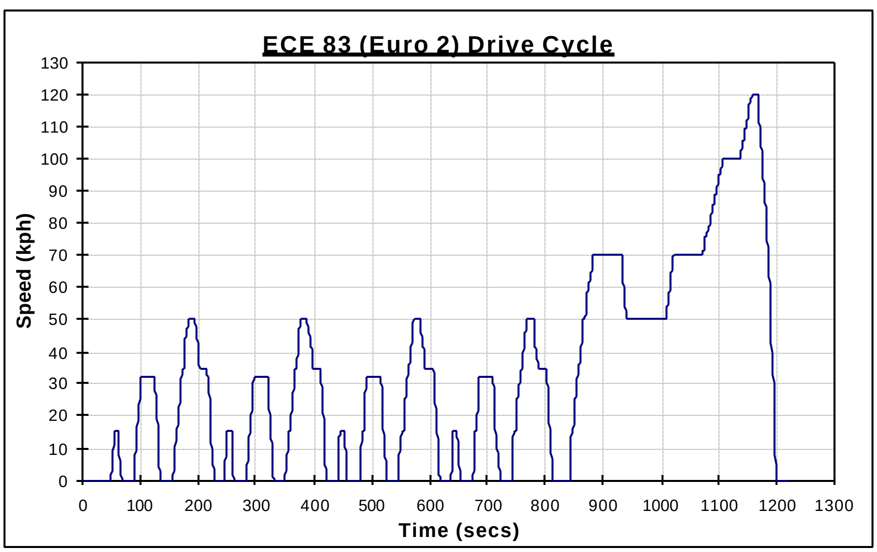


Figure 2 – ADR79/00 (*Euro 2*) Drive Cycle

Revised ECE R83 (*Euro 3* – Figure 3) – This is the same test cycle as ECE R83/04 (*Euro 2*) except that the gas sampling starts at time zero i.e. as soon as the vehicle is cranked, and not after a 40 second idle. This test cycle will be adopted for ADR compliance in Australia from 2005 (under ADR79/01). This test cycle will also be used in the future for ECE R101 which is the European fuel economy test. All Stage 1 and most Stage 2 vehicles were subjected to this test cycle.

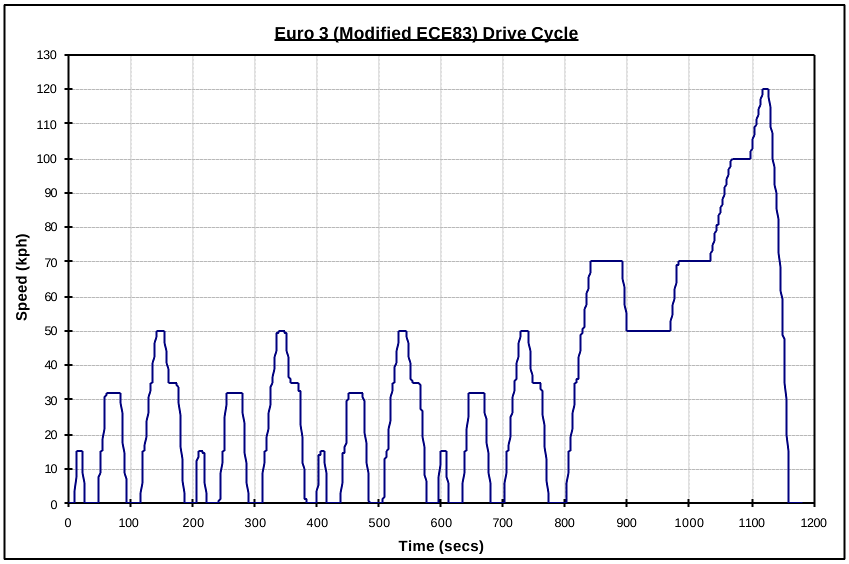


Figure 3 – ADR79/01 (*Euro 3*) Drive Cycle

Australian Urban Cycle (*AUC* – Figure 4): This cycle was developed by Professor Harry Watson of the University of Melbourne, based on "real world" Melbourne driving conditions. This cycle is not adopted in any regulatory standards (such as the ADRs) and was included for comparative purposes only. Eleven Stage 1 and seven Stage 2 vehicles were subjected to this test cycle.

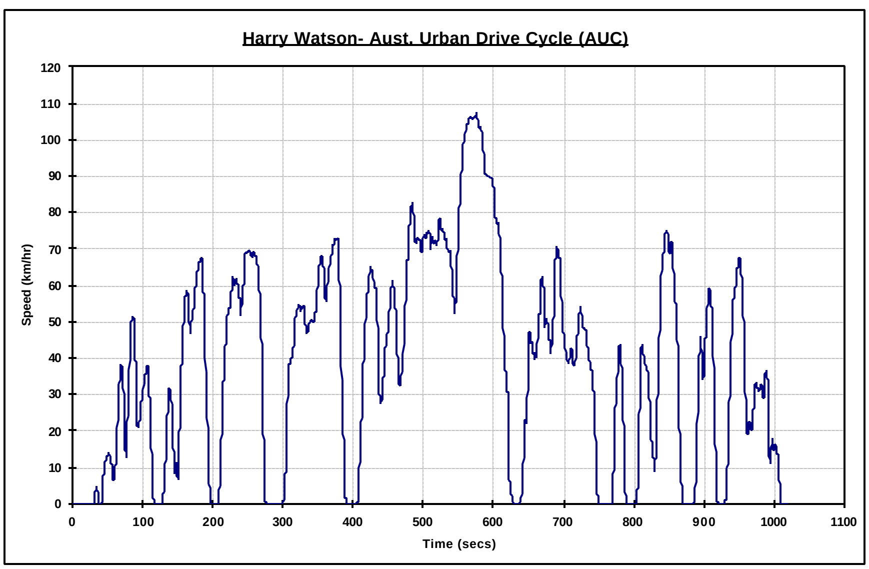


Figure 4 – Australian Urban Drive Cycle

Highway Fuel Consumption (AS2877-1986 – Figure 5): This cycle is used to generate an estimate of highway fuel consumption. This test was performed on all test vehicles.

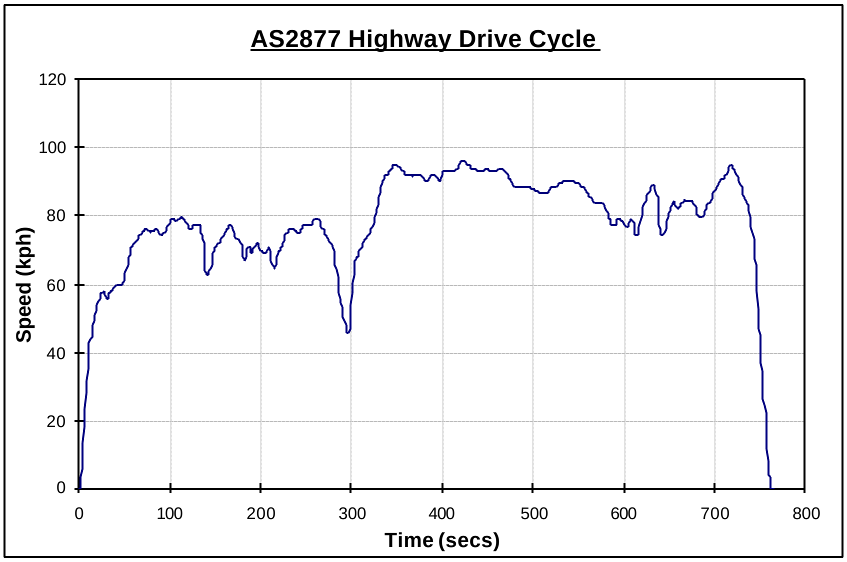


Figure 5 – Highway Fuel Consumption Drive Cycle (AS2877)

2.2.3 Test Fuels

For the exhaust emission tests, all vehicles were tested on a single batch of commercially available unleaded petrol (ULP), except 3 European vehicles (BMW 5 Series, Peugeot 406, VW Golf) which were tested on commercially available high octane "premium" unleaded petrol (PULP), because the manufacturer's manual specifically stated they should be operated on PULP. A further 8 vehicles from Stage 1 (1 ADR37/00 & 7 ADR37/01) also had an additional *Euro 2* test conducted on PULP.

Two dual fuelled petrol/LPG vehicles were tested on LPG only. This fuel was a 50/50 blend of propane and butane.

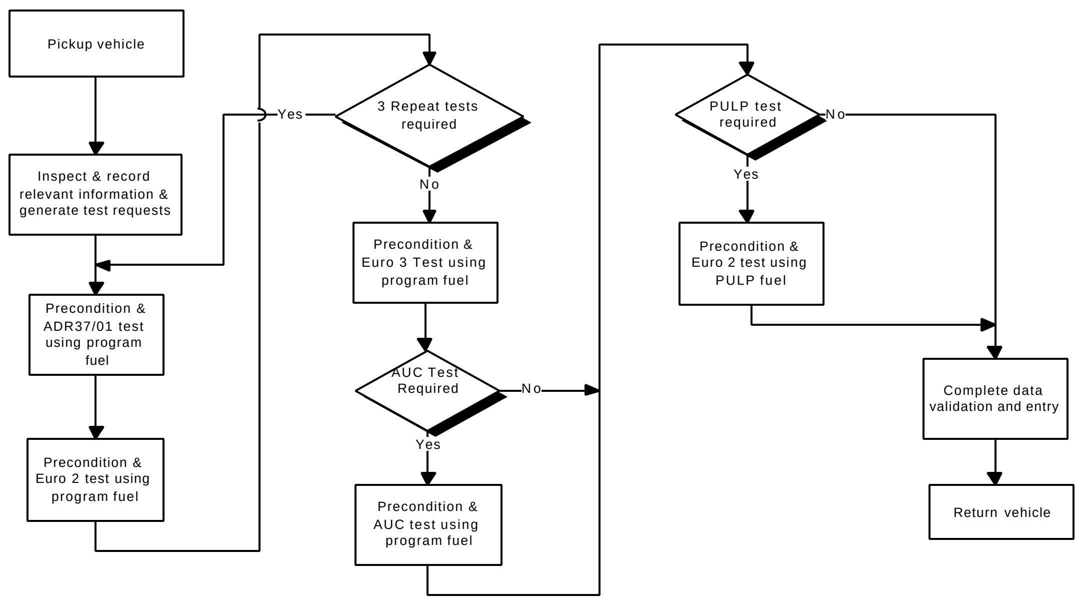
The 13 vehicles that underwent evaporative emissions testing used a common batch of ADR37/01 certification fuel (ie a fuel meeting the test fuel requirements for ADR37/01 certification, not a commercial blend).

Refer to Appendix C for the relevant fuel analyses.

2.2.4 Test Program

Stage 1 Test Program

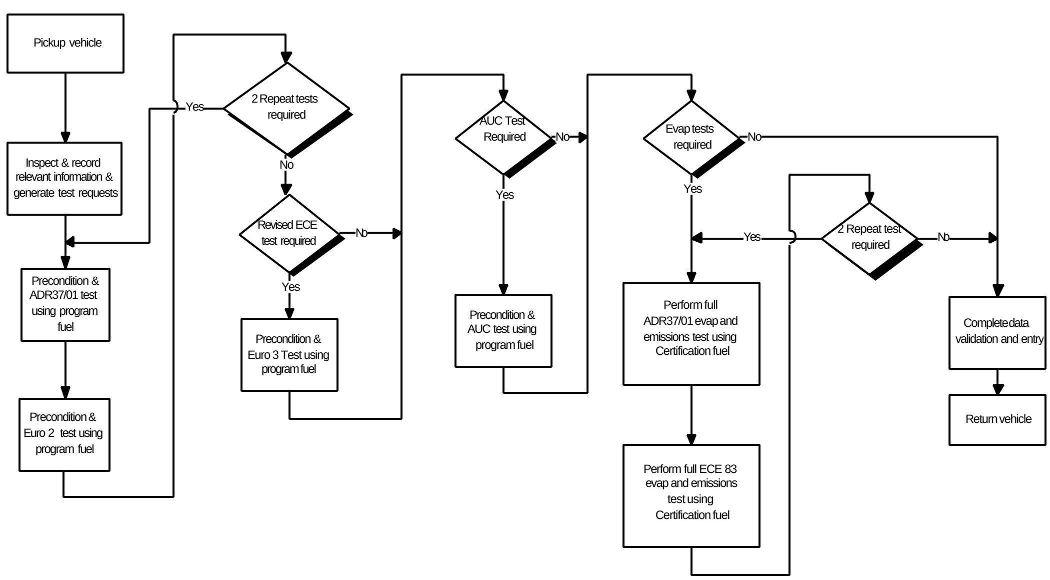
The Stage 1 testing sequence is outlined in the simplified flow chart below.



Simplified Test Sequence - Stage 1

Stage 2 Test Program

The Stage 2 testing sequence, which includes evaporative emission testing for some vehicles, is outlined in the simplified flow chart below.



Simplified Test Sequence - Stage 2

Refer to Appendix D for flow charts describing both Stage 1 and 2 testing in more detail.

2.2.5 Vehicle Sourcing

In the majority of cases the test vehicles were loaned to the laboratory direct from vehicle manufacturers or importers. Where particular makes and models could not be supplied from this source, test vehicles were hired from rental companies, and in one case the vehicle was loaned by the NSW Environment Protection Agency.

2.2.6 Initial Inspections

An initial pre-test inspection was conducted at the laboratory to ensure the vehicle was suitable for testing and to gather relevant descriptive data. Refer to Appendix B and the "All Data" file on the enclosed CD for the list of information recorded for each vehicle.

2.2.7 Data Collection

All pre-test and test data is presented as single line entry for each vehicle on an *Excel* spreadsheet. The data is incorporated in the CD enclosed with this report. The "All Data" file on the CD contains all the pre-test information on each vehicle, plus all the test results for each vehicle. The "Summary Data" file contains a subset of the basic pre-test information and the key exhaust and fuel consumption data for each vehicle. Individual emission and fuel consumption charts have also been produced for each vehicle and are included on the "Individual Model Reports" file on the CD.

3. RESULTS

3.1 Putting the Results in Context

All the vehicles tested in this Study were designed to comply with either ADR37/00 or ADR37/01, or in the case of the heavier 4WDs and LCVs, with ADR36/00. Consequently, in interpreting the results from the other emission tests, it needs to be remembered that these vehicles were not explicitly designed to meet these requirements. An inability to meet the limits under another test procedure may reflect the level of emission control technology, but regardless of the technology, the calibration of the engine and emission control system can also have a significant impact on the emissions outcome. In the case of the *Euro 3* test in particular, many vehicles are likely to have a level of engine and emissions control technology below what is required to meet the limits imposed under this standard.

Table 3 shows the regulated limits for current and future ADRs evaluated in this Study. The limits for ADR36/00 are expressed in different units and are not comparable. The ADR36/00 vehicles tested in this Study will be covered by ADR79/00 from 2003.

As it is not called up in regulations, the *AUC* test does not have any compliance limits.

Table 3 – Regulated Emission Limits under Current and Future ADRs

Exhaust Gas	ADR37/01 (*FTP*) g/km	ADR79/00 (*Euro 2*) g/km	ADR79/01 (*Euro 3*) g/km
CO	2.1	2.2	2.3
HC	0.26		0.2
HC + NOx		0.5	
NOx	0.63		0.15

In the case of those 4WDs and light commercials which meet ADR36/00, the technology gap is even more stark, as ADR36/00 is a much less stringent standard than ADR37/01, and vehicles do not even need a catalytic converter to comply with ADR36/00.

Thus the results which follow should be viewed as addressing two main questions:

- How do current technology vehicles perform under current and future ADR standards ?
- What is the relative stringency of the new standards compared to the current ADR standards ?

The results on the *Euro 2* and *Euro 3* tests in particular, should not be used to categorise vehicles as “good” or “bad” performers, as the bulk of the vehicles were not specifically designed to meet those standards. Nevertheless, these results give an indication of the likely magnitude of benefits which will flow from compliance with these standards in the future.

3.2 Data Reliability

As a check on both vehicle and test laboratory repeatability, a total of 10 vehicles from Stage 1, and one from Stage 2 repeated the standard ADR37/01 (*FTP*), ADR79/00 (Euro2) and associated fuel consumption tests twice (giving a total of 3 tests per vehicle). Independent statistical analysis concluded that the variability in the repeat testing was sufficiently small to not require further repeat testing. For these 11 vehicles, the average of the 3 tests has been used in the analyses presented in this report. The data from all repeat tests is available on the enclosed CD.

During the test program the laboratory continued to perform normal equipment calibration and quality control activities as specified in the ADR37/01 regulations and the NATA Laboratory Quality Manual.

The uncertainty of measurement of the test laboratory data is outlined in Table 4.

Table 4 – Measurement Uncertainty[11] in Test Laboratory

HC (g/km)	CO (g/km)	NOx (g/km)	CO_2 (g/km)	Fuel Consumption (L/100km)	SHED (g/test)
+/- 0.0017	+/- 0.01387	+/- 0.01162	+/- 4.21	+/- 0.179	+/- 0.022

The above data confirm that the individual vehicle results can be considered reliable, and enable valid comparisons between different emission tests, and indicative assessments of the emissions performance of current model vehicles. Nevertheless, the relatively small sample size means that the results, while based on a representative sample, should be used cautiously in attempting to draw any conclusions about the emissions performance of the wider passenger vehicle fleet in Australia.

3.3 How do the Vehicles Perform on Current Emission Standards ?

3.3.1 ADR37/00 Petrol Vehicles

Seven Stage 1 vehicles (although filling the 1997-8 model criteria) were actually certified to ADR37/00, and therefore are reported as a separate group due to the difference in base emission limits they had to meet (although the test procedure is identical to ADR37/01).

All the ADR37/00 vehicles met the ADR37/00 emission limits, with most of the 7 vehicles having emission rates 70-80 % below the regulated limits[12]. Figure 6 indicates the average results compared to the limits.

11 The uncertainty is at 95% confidence using a coverage factor of 1.96.

12 Note – in this and some other charts in this report, the CO results are presented in terms of the CO result divided by 10. This is done simply to put the CO results on a similar scale to the HC and NOx values.

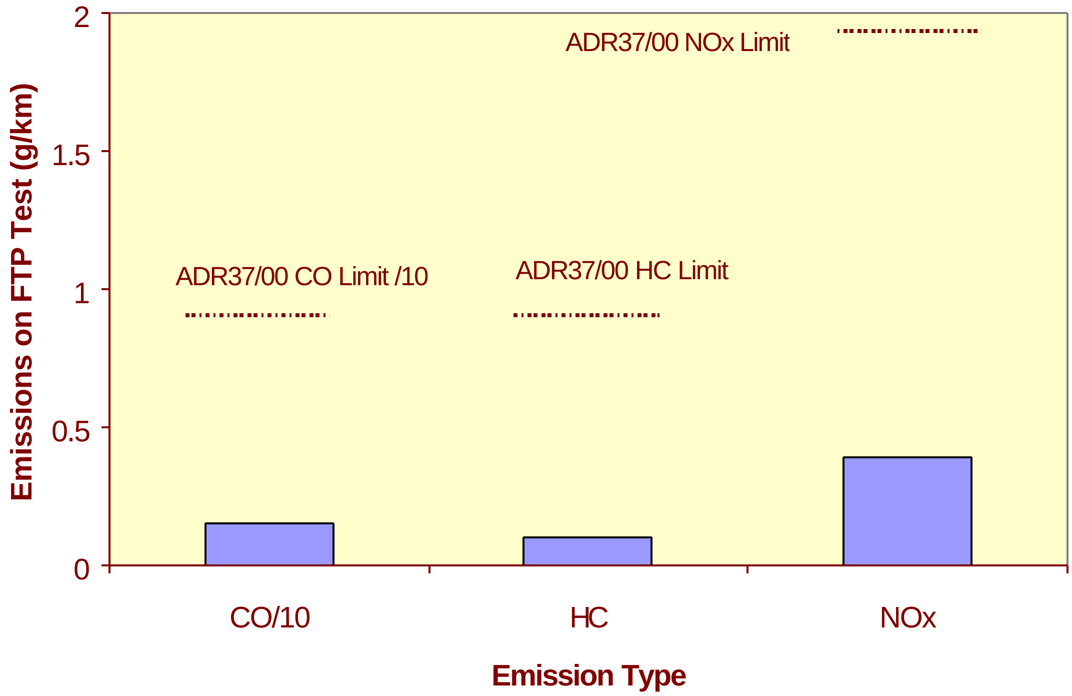


Figure 6 – Average Emission Levels of ADR37/00 Compliant Vehicles

Later replacement models for 4 of the 7 ADR37/00 vehicles were tested during Stage 2 of the program. These later models complied with ADR37/01. Figure 7 compares the average emission results for the ADR37/00 and ADR37/01 versions of the 4 vehicles. The results clearly show the improvements in emissions performance in these models from ADR37/00 to ADR37/01.

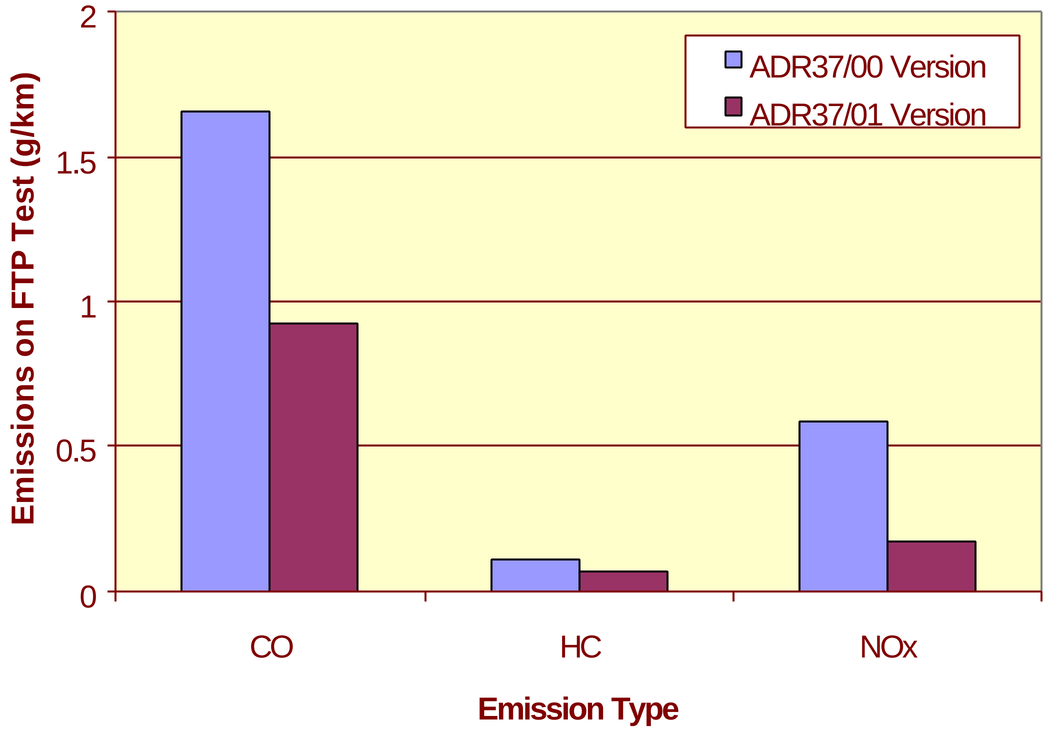


Figure 7 Comparison of Average Emissions Performance for 4 ADR37/00 and ADR37/01 Models

3.3.2 ADR37/01 Petrol Vehicles

A total of 30 ADR37/01 certified vehicles (comprising 26 different models) were tested on the ADR37/01 *FTP* test cycle. Two of these vehicles (the BMW 5 series and the Honda Accord) are treated separately in the emissions analyses as low emission vehicles.

The following 3 charts (Figures 8-10[13]) illustrate that, as expected, all of the vehicles (except one model on NOx emissions) met the emission limits in ADR37/01, but there is nevertheless considerable variability in emission levels from model to model and across emission type. In particular, a number of models have quite high NOx emissions relative to the limit.

13 In these and other charts where individual ADR37/01 models are listed, the appearance of a "(2)" after a model name indicates that 2 representatives of that vehicle model were tested (one in Stage 1, one in Stage 2).

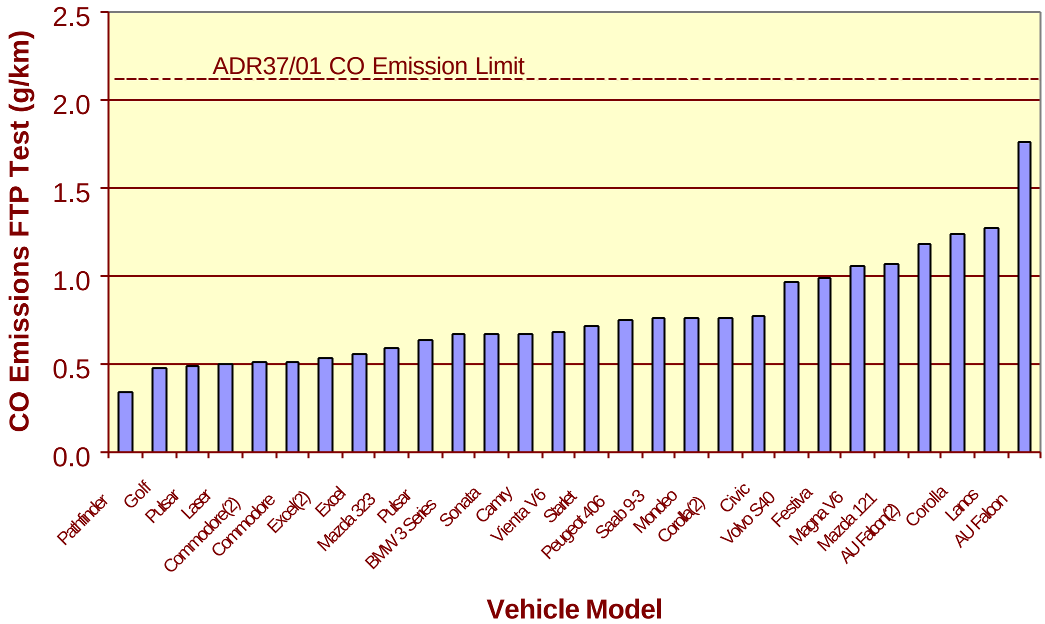


Figure 8 **CO Emission Rates of ADR37/01 Vehicles on the ADR37/01 (*FTP*) Test**

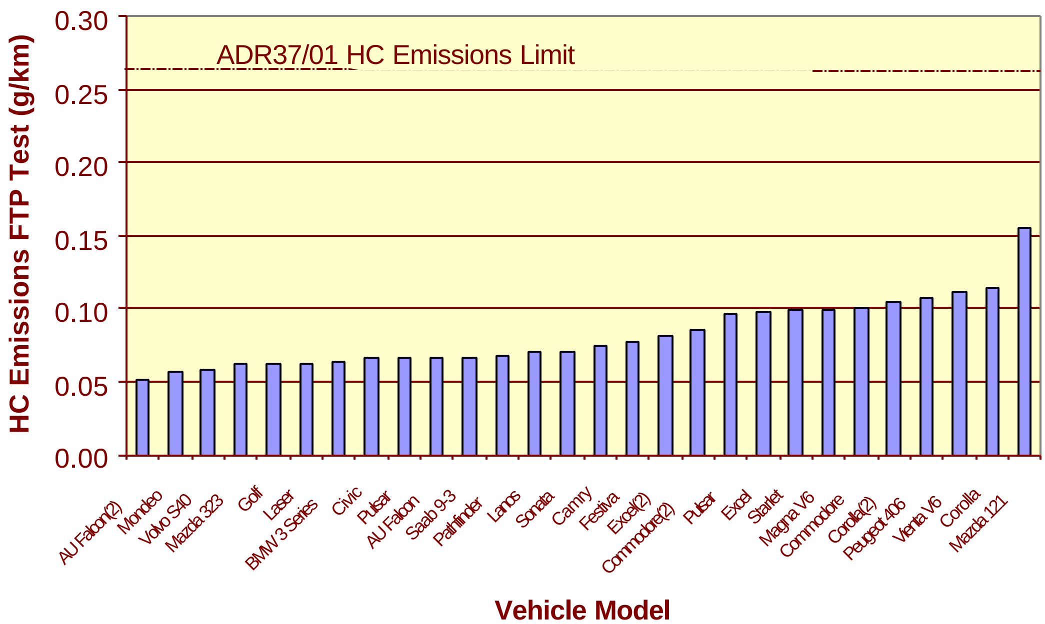


Figure 9 **HC Emission Rates of ADR37/01 Vehicles on the ADR37/01 (*FTP*) Test**

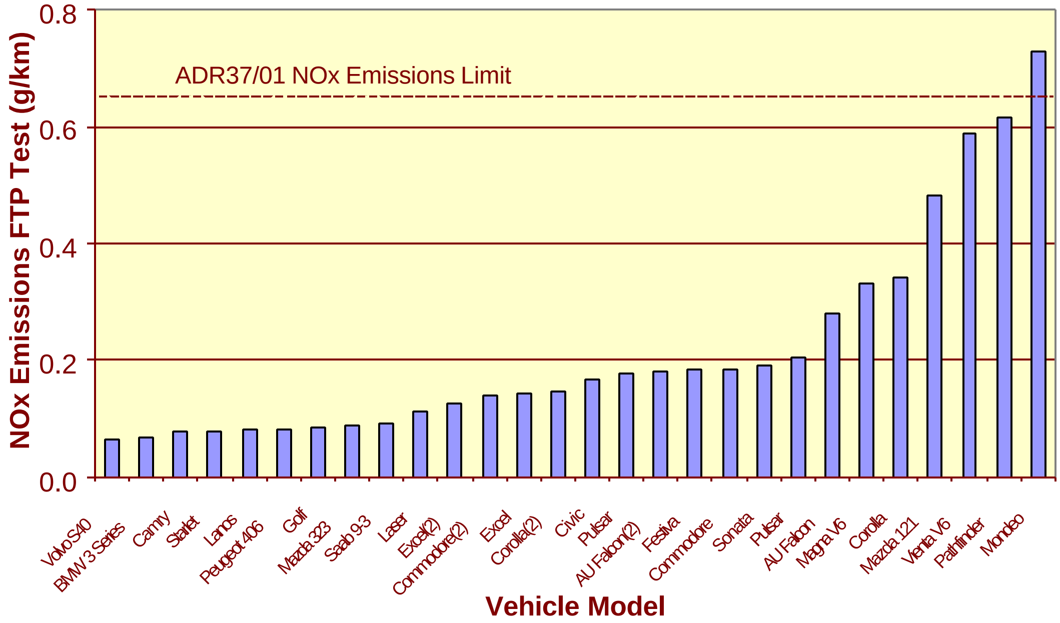


Figure 10 **NOx Emission Rates of ADR37/01 Vehicles on the ADR37/01 (*FTP*) Test**

As a measure of the variability illustrated in Figures 8 to 10, a comparison of the average emission rates of the five lowest emitting vehicles on one emission, with the five highest on the same emission was undertaken. As the above figures illustrate, the distribution of vehicle models from lowest to highest changes depending on the emission type, so the vehicles in the "lowest five" and "highest five" groups varies with the emission type. Table 5 confirms that the variability in the HC and CO emissions was relatively low, but the NOx emissions between the lowest and highest emitters varied by a factor of more than 7.

Table 5 **Comparison of Emission Rates of ADR37/01 Vehicles on the ADR37/01 (*FTP*) Test**

ADR37/01 (*FTP*) Test	CO (g/km)	HC (g/km)	NOx (g/km)
Average Emissions of Lowest 5 Vehicles	0.47	0.06	0.1
Average Emissions of Highest 5 Vehicles	1.31	0.12	0.55
Ratio of Highest 5 : Lowest 5	*2.81*	*2.05*	*7.45*

Figure 11 compares the averages from the ADR37/01 test on each of the three gases as a percentage of the limits, indicating that on average the emission rates are more than 60% below the limits. This sort of margin is normal manufacturing practice to ensure the 80,000 km durability requirements in ADR37/01 are met.

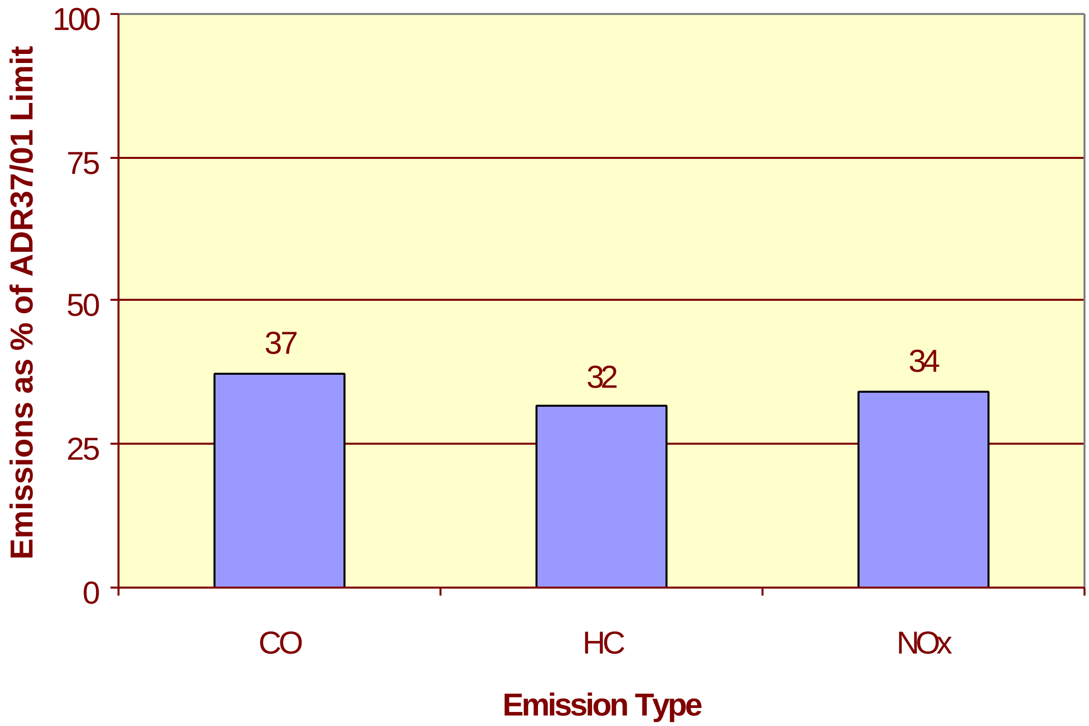


Figure 11 **Average Emission Rates of ADR37/01 Vehicles on the ADR37/01 (*FTP*) Test as a Proportion of the ADR37/01 Limits**

3.3.3 ADR37/01 LPG Vehicles

Two duel fuelled (petrol/LPG) vehicles, an AU Falcon utility and VT Commodore, were tested during Stage 2 to provide an indication of their relative performance. Figure 12 is a comparison of the dual fuelled models tested on LPG with equivalent petrol models. The data must be treated with extreme caution due to the single tests on only 2 vehicles, however it indicates that the emissions from the LPG variants is roughly equivalent or slightly higher than the petrol versions. Figure 12 also indicates that both LPG and petrol models met the ADR37/01 emission limits, even though under current requirements, LPG vehicles are not covered by ADR37/01.

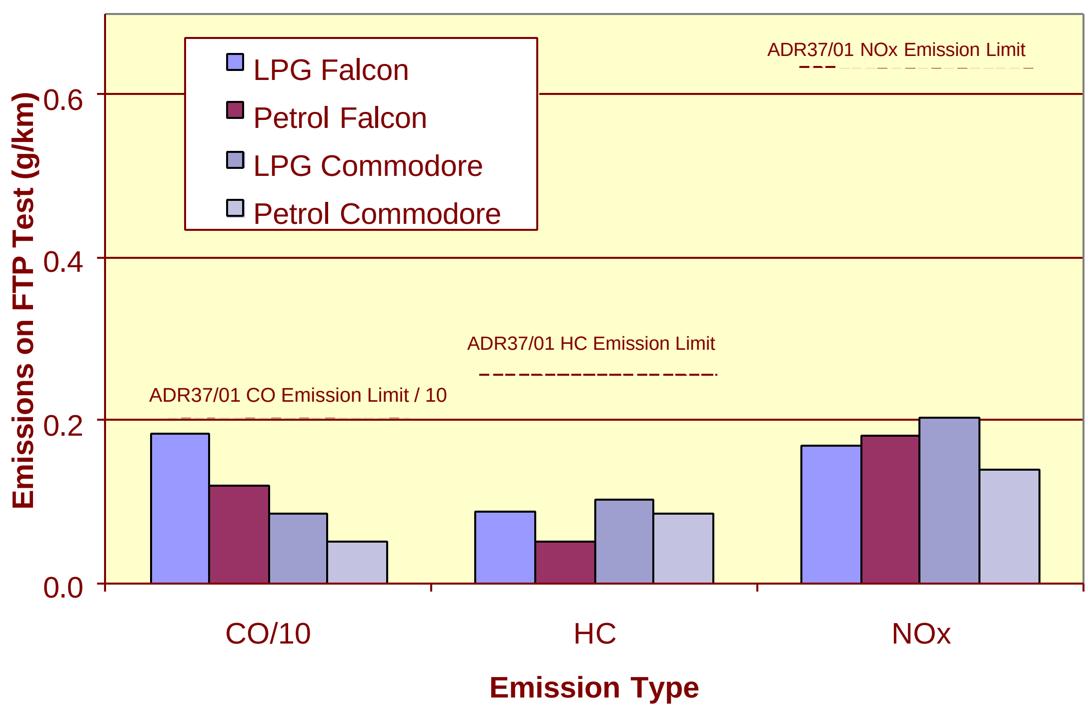


Figure 12 Comparison of Emissions Performance on Petrol and LPG under ADR37/01

3.3.4 "Low Emission" Petrol Vehicles

Two vehicles were specifically identified as meeting international standards for low emission vehicles. The Honda Accord meets the US EPA's Low Emission Vehicle (LEV) standard, and the BMW 5 series meets the *Euro 3* standards.

Figure 13 indicates that, with the exception of the Accord's CO emissions, the emission levels of these vehicles were much lower (50-90%) than the average of the ADR37/01 group. As with the LPG vehicles, caution must be exercised with only two vehicles involved.

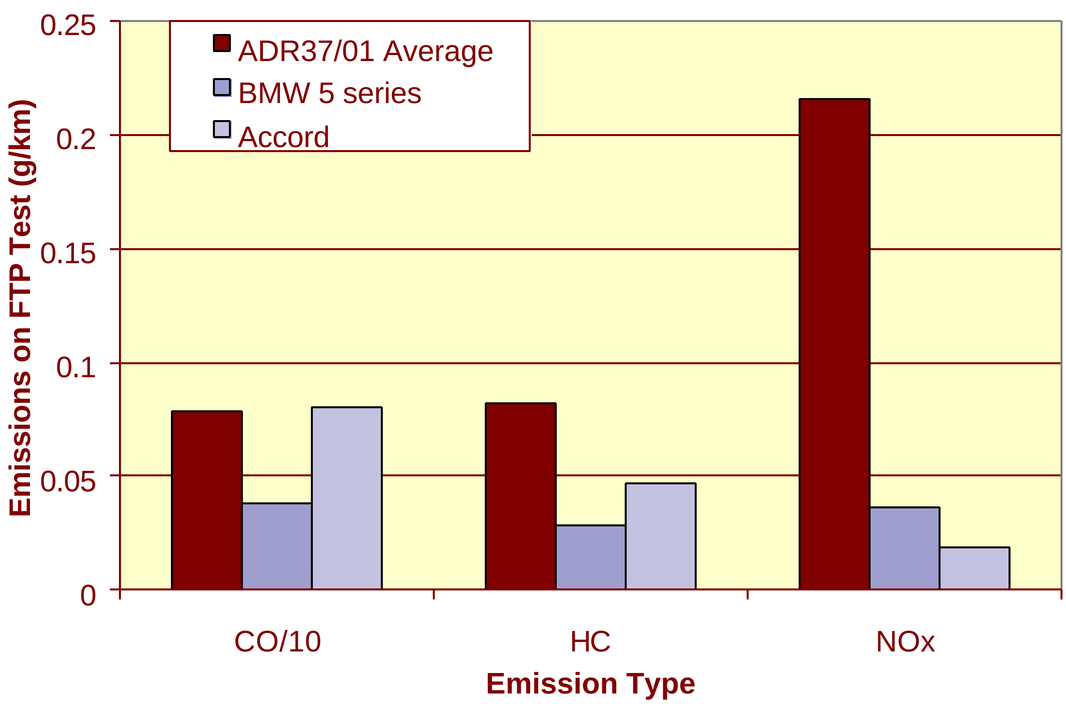


Figure 13 Comparison of Emissions Levels of 2 Low Emission Vehicles with ADR37/01 Group on ADR37/01 (*FTP*) Test

3.3.5 ADR36/00 Vehicles

As part of Stage 2, a small sample (6) of four wheel drive (4WD) and light commercial vehicles (LCV's) was tested. All of the vehicles had a GVM of more than 2.7 tonnes and as such were certified to ADR36/00. Some of the vehicles in this category are high volume sellers on the Australian market, with a number of the models falling in the top 20 selling models. Given this significant representation, and the growing popularity of 4WDs as urban passenger vehicles, it was decided to include this group to gain an indicative assessment of their relative emissions performance. With such a small sample, caution must be exercised in assessing the results.

The ADR36/00 emissions test[14] is quite different from the *FTP* test in ADR37/01. In order to provide a common basis for comparison, the ADR36/00 vehicles were subjected to the ADR37/01 *FTP* test cycle. As previously noted, ADR36/00 vehicles are not designed to comply with the ADR37/01 test, and given that many are not fitted with catalytic converters it is likely that they will have relatively high emissions.

Figure 14 illustrates that the ADR36/00 vehicles had higher average emission rates relative to the ADR37/01 group. It also illustrates the efficacy of catalytic converters, with the catalyst equipped ADR36/00 vehicles having average emission rates not much higher than the ADR37/01 group, while the non-catalyst equipped vehicles are well above the ADR37/01 averages. The averages mask considerable variability, with the non-catalyst equipped vehicles having CO emissions ranging from 3.9 g/km to 9.3 g/km, and NOx rates from 2.3 g/km to 4.9 g/km.

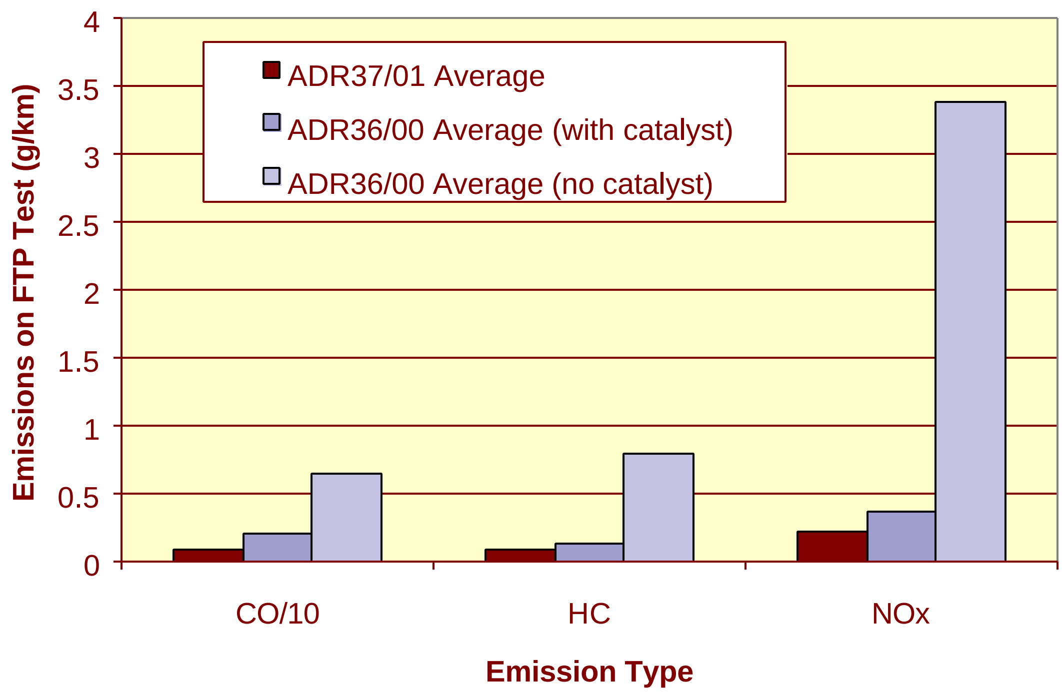


Figure 14 Comparison of Average Emissions Performance of 6 ADR36/00 Vehicles with the ADR37/01 Group on the ADR37/01 (*FTP*) Test

3.4 How do the Vehicles Perform on Future Emission Standards ?

3.4.1 Introduction

The analyses in this section are aimed at examining the relative stringency of the new *Euro 2* and *Euro 3* emission tests. For the purposes of the analyses, only the ADR37/01 group and the ADR36/00 group are included. Again it is important to remember that the vehicles were designed to meet current standards, and thus failure

[14] The ADR36/00 emissions test is performed using an engine dynamometer at constant rpm, and varying the manifold vacuum (load) over a 9 mode cycle. This is repeated 4 times and the final result in ppm HC and % vol CO is calculated. NOx is not measured. A catalyst is usually not required to comply with the emission limits.

to meet an emission limit under *Euro 2* or *Euro 3* does not indicate an unsatisfactory emissions performance. The aim of testing these vehicles against the new test procedures is to obtain an assessment of the stringency of the new standards and an indication of what magnitude of improvements will be required in the current fleet to meet the new standards.

Any assessment of stringency needs to consider:

- the emission limits; and
- the demands of the emission test cycle.

3.4.2 Assessment Against the Limits

ADR37/01 Vehicles

Manufacturers building vehicles to comply with a standard always aim to have production vehicles' emission rates well below the regulated limit to allow for production variability and in-service deterioration. As previously illustrated (Fig 15), current vehicles (built to meet ADR37/01) have emission rates well under the nominated ADR37/01 limits – typically more than 60% below the limits.

When these vehicles were subjected to the *Euro 2* and *Euro 3* emission tests, the margin between the emission results and the limits was much reduced. In the case of NOx emissions, the ADR37/01 vehicles, on average, actually exceeded the limits (around 15% above the HC+NOx limit for *Euro 2*, and 180% above the *Euro 3* NOx limit).

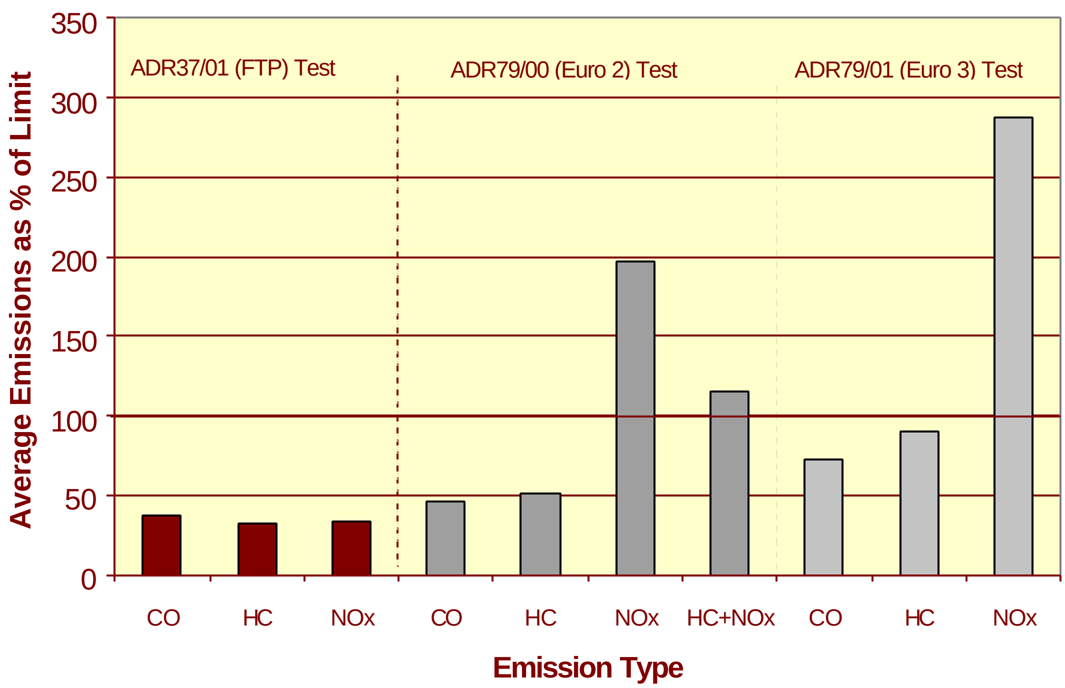


Figure 15 Comparison of Average Emissions Performance of ADR37/01 Vehicles with Limits under Current and Future Standards[15]

[15] The comparisons are between the average emission results on the particular test with the limits applicable to that test (see Table 2). In the case of *Euro 2*, there is no separate HC and NOx

It should be noted that the averages for HC+NOx (*Euro 2*) and NOx (*Euro 3*) in the above figure include two models which exceeded the *Euro 2* HC+NOx limits by at least 100%. Even when these vehicles are excluded, the sample average is still around 80% of the *Euro 2* HC+NOx standard and 110% above the *Euro 3* NOx limit.

<u>ADR36/00 Vehicles</u>

In relation to vehicles which comply with ADR36/00, the discussion in section 3.3.5 indicated that the average emission rates from these vehicles, unless fitted with a catalyst, were much higher that passenger vehicles certified to ADR37/01. Figure 16 illustrates that the emission rates of these vehicles, particularly those without a catalytic converter, can be much higher than those covered by the current ADR37/01 requirements for lighter "commercial" vehicles. These vehicles would certainly not comply with the limits imposed on these sorts of vehicles in the *Euro 2* or *Euro 3* standards (which they will have to meet in ADR79/00 and ADR79/01).

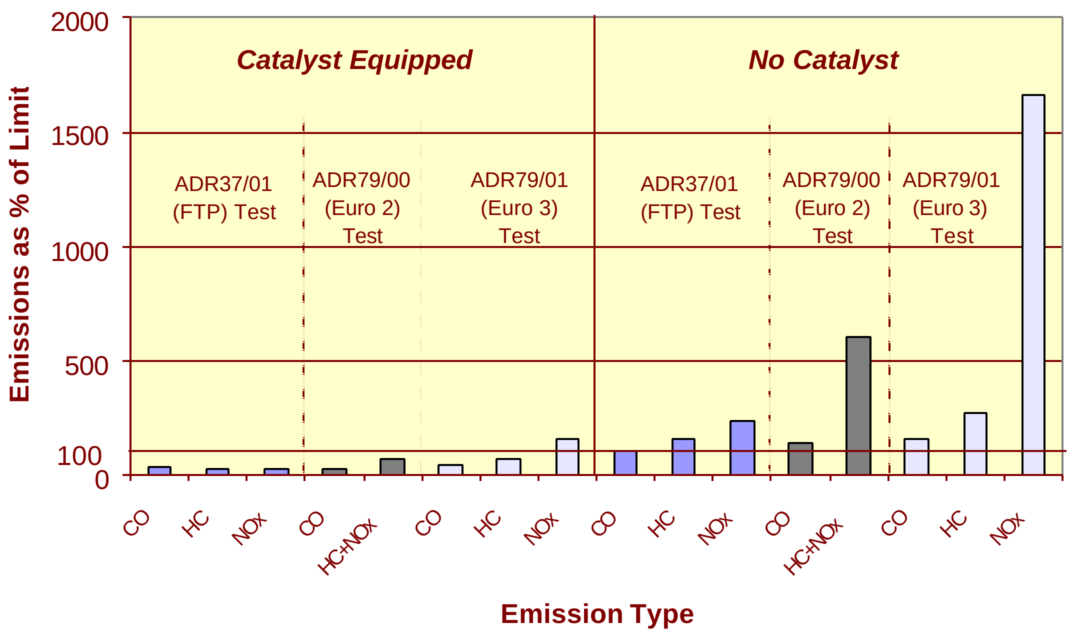


Figure 16 Comparison of Average Emissions Performance of ADR36/00 Vehicles with Limits [16] under ADR37/01 and Future Standards

limits, but comparison against a nominal 55:45 (HC:NOx) split is included to illustrate that NOx emissions dominate the combined HC+NOx value.

16 In the *Euro 2* and *Euro 3* standards less stringent limits apply to vehicles over 2.5 tonnes GVM and to off road vehicles and light trucks. This chart is based on a comparison of the average emission results on the particular test with those less stringent requirements as per the standard.

3.4.3 The "Toughness" of the Emission Test

Introduction

It is not only the emission limits which determine the stringency of standards, but also how "tough" the emissions test is *viz* how demanding it is on the vehicle in relation to each of the regulated emissions.

This section of the report attempts to address this by comparing the emission results for each vehicle in the ADR37/01 group on one test, with its results on another test. Where the emission result on one test is higher than the other, this is taken to mean that the test which produces the higher result is the more stringent test for that vehicle. When all the data are plotted in this way, it is possible to draw some conclusions about the stringency of the test for the overall group.

The analyses in this section have been set up as scatterplots of the paired data for each vehicle on each emission type. To assist in a visual analysis, a 45^o split line has been included. If the majority of the data points are above the split line, this indicates that the standard shown on the vertical (Y) axis had higher reading (ie more stringent) that the horizontal (X) axis standard – and vice versa. Where the data points are more evenly spread either side of the split line then both standards are approximately of equivalent stringency of the group as a whole. The charts also include a line marking the emission limits under the two emission standards, which helps to identify the distribution of the vehicles in relation to the limits.

FTP v *Euro 2*

Figures 17 to 19 explore the relationship between the current ADR37/01 (*FTP*) test and the *Euro 2* test which is adopted in ADR79/00. As stated earlier, the *Euro 2* standard does not require separate compliance with HC and NOx standards (it has a combined HC+NOx standard of 0.5g/km), but for the purposes of the analysis a split of 55:45 (HC:NOx) is assumed.

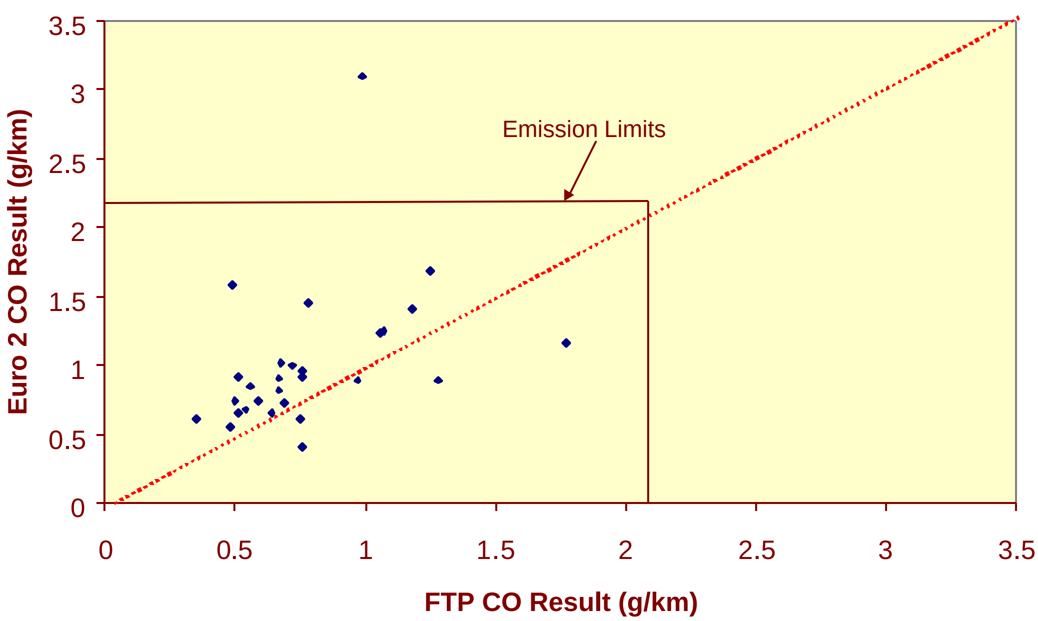


Figure 17 Comparison of CO Emission Rates of ADR37/01 Vehicles on the *FTP* and *Euro 2* Emission Tests

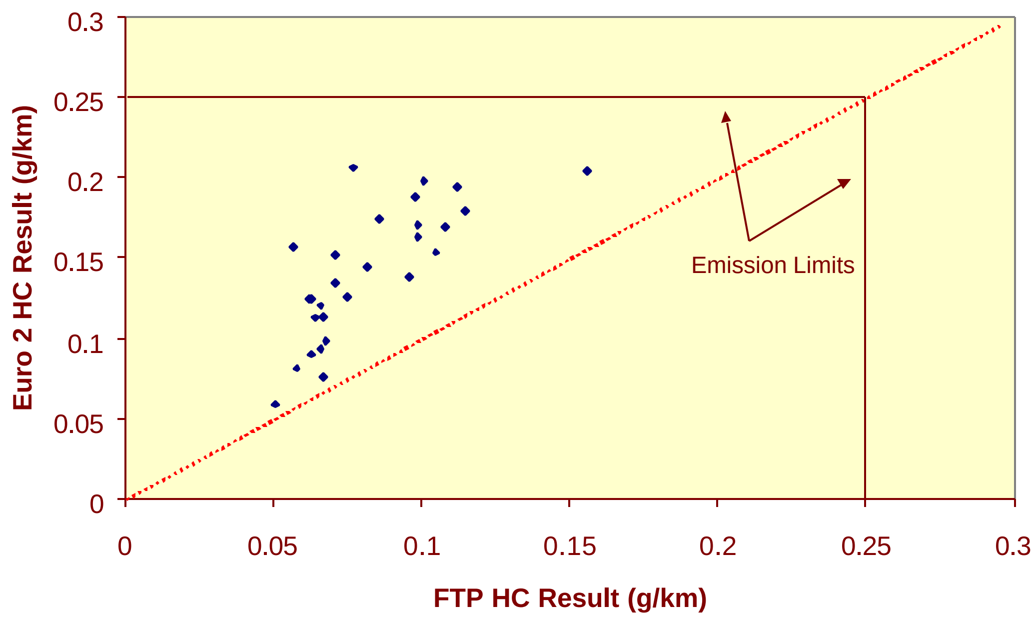


Figure 18 Comparison of HC Emission Rates of ADR37/01 Vehicles on the *FTP* and *Euro 2* Emission Tests

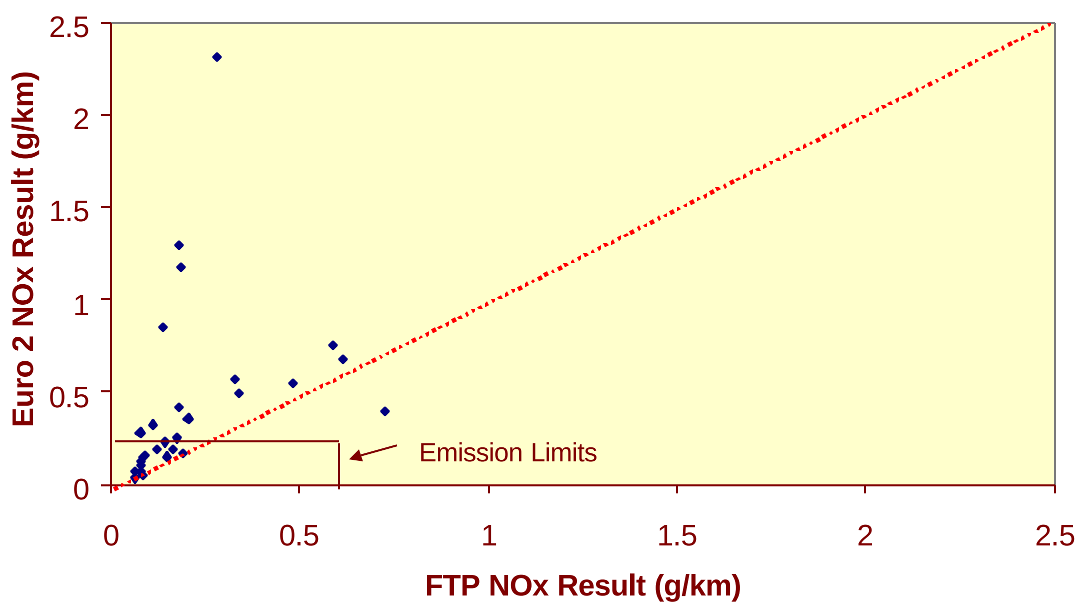


Figure 19 Comparison of NOx Emission Rates of ADR37/01 Vehicles on the *FTP* and *Euro 2* Emission Tests

The key findings from the above comparisons of the ADR37/01 (*FTP*) test and the ADR79/00 (*Euro 2*) test are that:

- On CO emissions, the *Euro 2* test is more demanding for most vehicles, but with one exception, all the test vehicles complied with the *Euro 2* test limits;
- On HC emissions, the *Euro 2* test is significantly more demanding for many vehicles, and while all complied with the *Euro 2* limits, there is little room for deterioration in a number of cases; and
- On NOx emissions, the *Euro 2* test is also more demanding on almost all of the vehicles, with a small number of vehicles having very high NOx emissions on the *Euro 2* test relative to the *FTP* test. In addition around 50% of the vehicles did not meet the *Euro 2* NOx emission limit.

The likely technical reasons underlying these results are as follows:

- The vehicles have been calibrated to comply with the ADR37/01 (*FTP*) drive cycle. This is most evident in the NOx results which indicate at least 4 vehicles probably have lean cruise calibrations designed to maximise fuel consumption during steady driving at high speeds. This driving pattern is not addressed in the *FTP* cycle.
- NOx emissions tend to increase at higher speeds and dynamometer loads. The high speed ("Extra Urban") section of the *Euro 2* drive cycle (see drive cycle trace in section 2.2.2), peaks at 120 kph (compared to the *FTP*'s 92 kph) and is maintained for a longer period than the *FTP*. This will tend to produce higher NOx emissions on the *Euro 2* test in most vehicles and will compound any lean burn calibration effect discussed above.
- The slow catalyst warm-up of the *Euro 2* cycle means that the catalyst has not reached it's optimum conversion temperatures until later in the cycle. Figures 20 and 21 record typical warm-up data for both drive cycles which shows both the delayed catalyst heating as well as a lower overall average operating temperature. Typically, as the catalyst approaches optimal operating temperature, NOx is the first to reach a high conversion efficiency followed by CO and then HC, so unless these characteristics are taken into account in the calibration, higher HC and CO readings can be expected.
- The same applies to the engine coolant warm-up period. This temperature directly influences the engine calibration and as can be seen in Figures 20 and 21, the *Euro 2* is slower to achieve operating temperature and the average temperature is lower than the ADR37/01 cycle temperature. This can be expected to influence both HC and CO. The step change in coolant temperature trace is the thermostat opening.

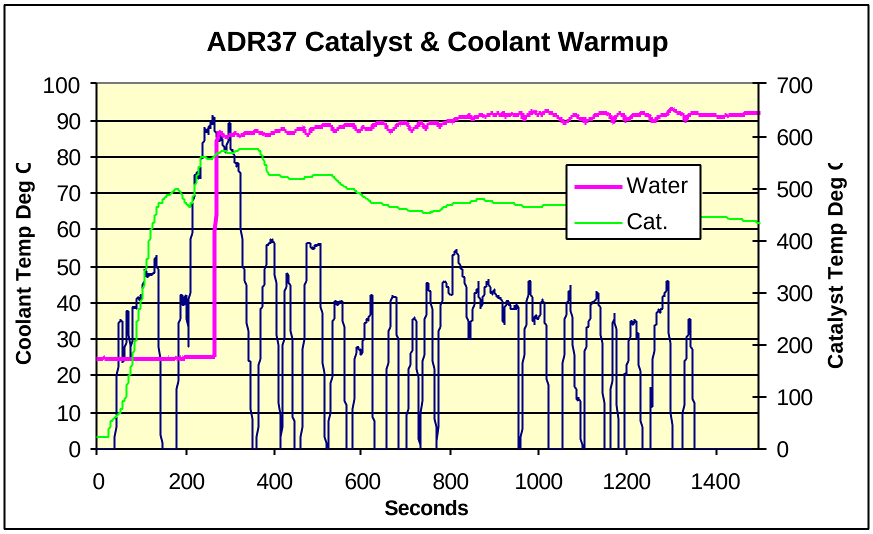


Figure 20 **Catalyst and Coolant Temperature Changes over *FTP* Test Cycle**

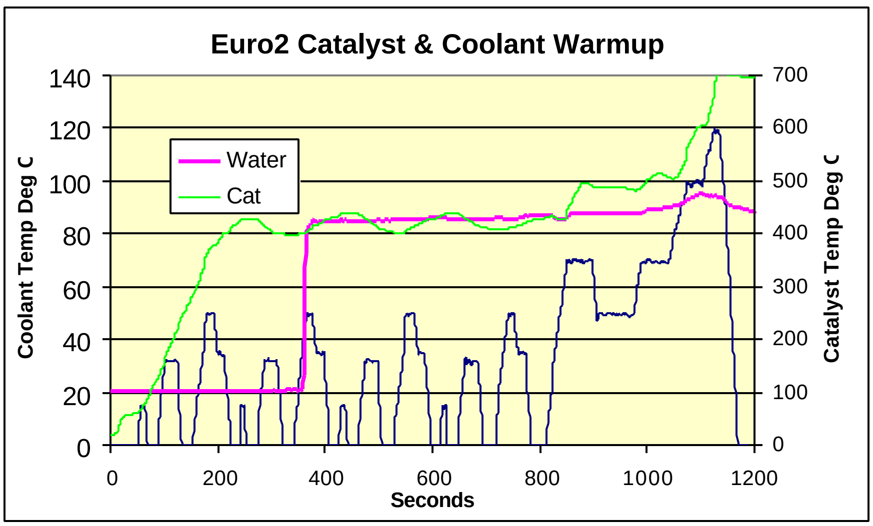


Figure 21 **Catalyst and Coolant Temperature Changes over *Euro 2* Test Cycle**

<u>*Euro 2* v *Euro 3*</u>

Having examined the relationship between the *FTP* test used in the current ADR37/01 and the *Euro 2* test to be adopted in the next ADR (ADR79/00), it is appropriate to consider whether the move to the *Euro 3* test requirement in ADR79/01 in 2005 will result in a further increase in stringency. Figures 22 to 24 compare CO, HC and NOx emissions on the *Euro 2* test relative to the *Euro 3* test.

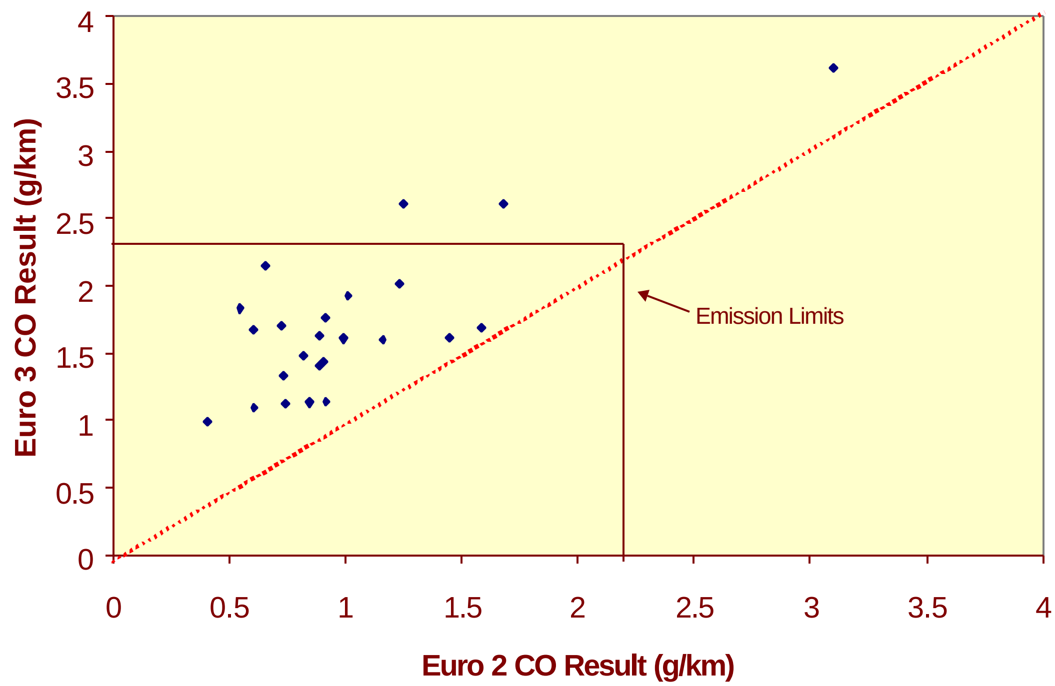


Figure 22 Comparison of CO Emission Rates of ADR37/01 Vehicles on the *Euro 2* and *Euro 3* Emission Tests

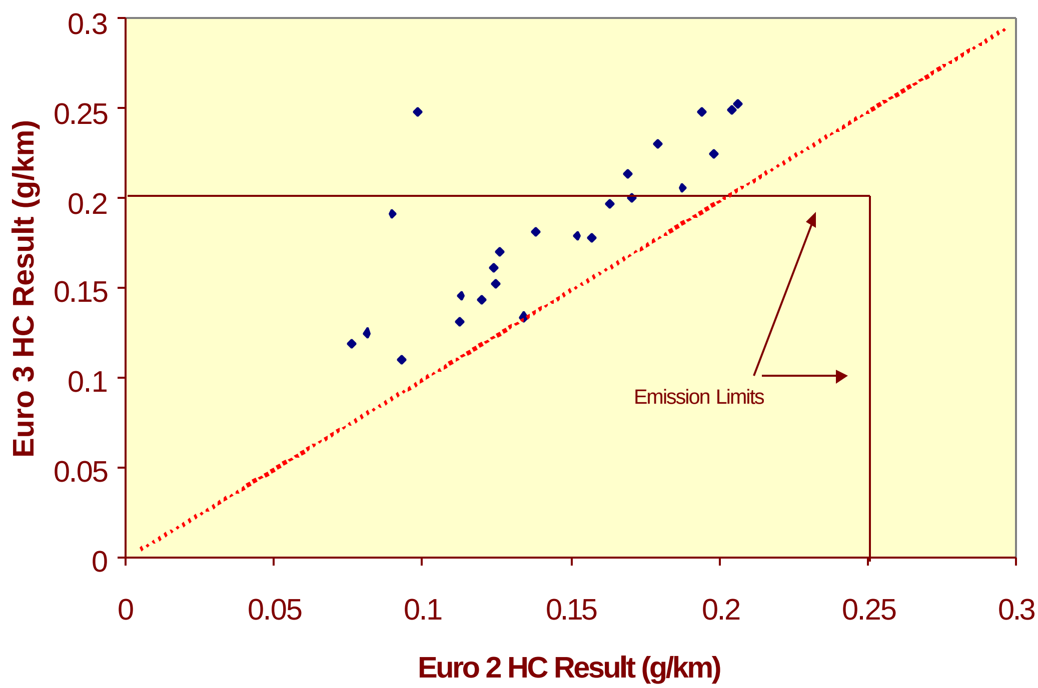


Figure 23 Comparison of HC Emission Rates of ADR37/01 Vehicles on the *Euro 2* and *Euro 3* Emission Tests

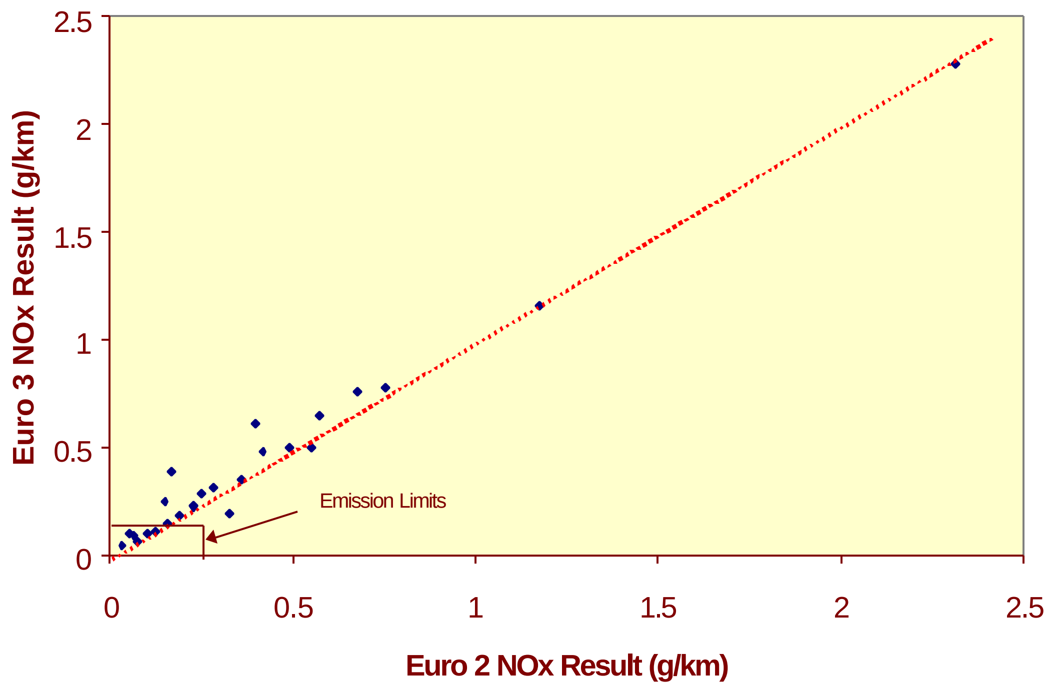


Figure 24 Comparison of NOx Emission Rates of ADR37/01 Vehicles on the *Euro 2* and *Euro 3* Emission Tests

The key findings from the above comparisons of the ADR79/00 (*Euro 2*) and ADR79/01 (*Euro 3)* tests are that:

- On CO emissions, the *Euro 3* tests is more demanding for all of the test vehicles, but the magnitude of the difference between the two tests varies considerably. Most of the test vehicles complied with the *Euro 3* test limits, although there is little room for deterioration in many of the vehicles;
- On HC emissions, the *Euro 3* test is more demanding for almost all of the test vehicles, but the magnitude of the difference between the two tests varies considerably. A significant proportion of the sample (around 50%) had HC emission values above or very close to the *Euro 3* limit; and
- On NOx emissions, there is little difference between the results on the *Euro 2* and *Euro 3* tests. Most of the sample (around 80%) had NOx emission values above or very close to the *Euro 3* limit, with some exceeding the limit by a very significant margin.

The likely technical reasons underlying these results are as follows:

- The *Euro 2* test has 40 second idle period before starting to sample the exhaust gas. This idle period allows the catalyst to start warming up before sampling starts. In the *Euro 3* test there is no non-sampling period, so the sampling starts with a cold catalyst, which results in higher CO and HC results.
- There is little change in NOx emissions as the catalyst is at normal operating temperatures (best conversion efficiency) in both test cycles when the majority of the NOx is being generated i.e. during the high speed portions of the test cycle.

ADR Tests v *AUC*

The Australian Urban Cycle was conducted on a subset of the vehicles as an indication of more realistic driving behaviour in Australian cities (it is based on Melbourne). The *AUC* test is not used as a certification test, but it is useful to see how closely the emission results on the ADR test cycles compare to the *AUC* test.

Figure 25 shows the average emission rates on the three ADR tests against the *AUC* test. On the *AUC* test, the ADR37/01 vehicles had significantly higher levels of CO than on all the ADR tests, and higher HC emissions than on the *FTP* and E2 tests. There is little difference between the HC emissions on the *Euro 3* and *AUC* test, and while the average *AUC* NOx emissions are equivalent to the *Euro 2* and *Euro 3* tests, they are much higher than the *FTP*.

The principal reason for the higher emissions is likely to be the severity of the *AUC* drive cycle which has harsher and more frequent accelerations (approaching wide open throttle conditions) than both the *FTP* and Euro tests and also has a higher average speed. The higher NOx emissions relative to the *FTP* are most likely caused by the same reasons that the *Euro 2/3* test produces produce higher NOx than the *FTP* (see discussion in section 3.4.3)

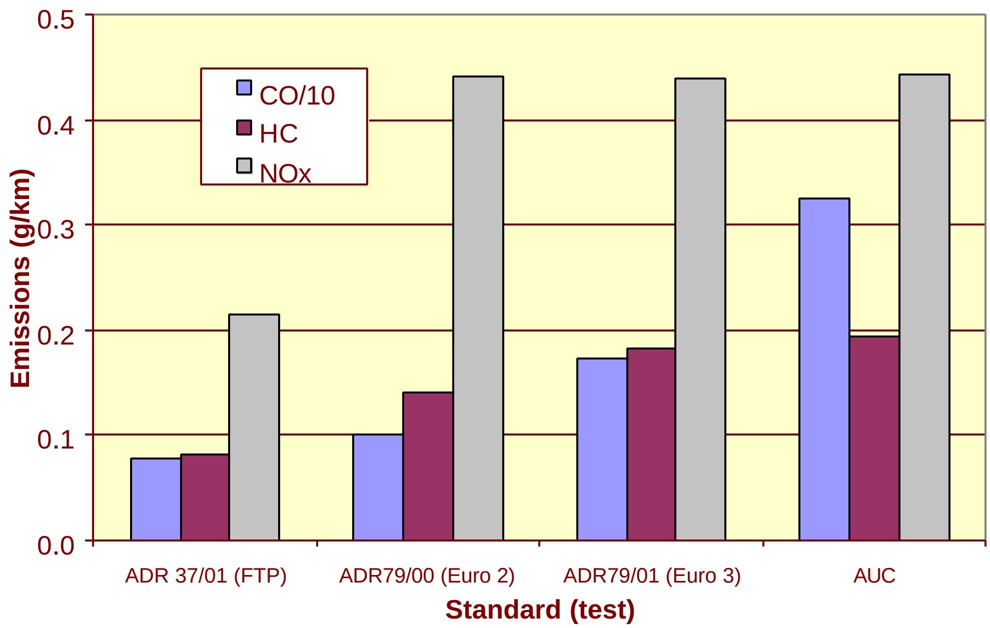


Figure 25 Comparison of Average Emissions from ADR37/01 Vehicles on the ADR Tests and the *AUC* Test

These results suggest that if the *AUC* is a more accurate representation of "real world" driving in Australian cities, then of all the ADR tests, the one that produces most similar results is the Euro 3 test. This relationship can be illustrated by examining the ratio of the average emission results on each of the tests, where a value close to unity indicates a good relationship. Table 6 illustrates that none of the ADR tests have particularly good relationship with the *AUC* test on CO, but the *Euro 3* test in particular relates well in HC and NOx emission terms with the *AUC* test.

Table 6 Ratio of Average Emissions of ADR37/01 Vehicles on ADR Tests and *AUC*

Test Comparison	CO Ratio	HC Ratio	NOx Ratio
AUC : FTP	4.2	2.4	2.1
AUC : Euro 2	3.2	1.4	1.0
AUC : Euro 3	1.9	1.1	1.0

3.4.4 Emissions Performance of ULP Vehicles on PULP

As indicated in Table 1, a number of European vehicles have been certified under ADR37/01 as requiring to be operated on PULP. However, there is a popular perception that the higher octane PULP is a "better" fuel and that a driver will get better performance out of any vehicle if it is operated on PULP. In order to assess this view – at least in emissions terms – eight of the ADR37/01 vehicle group (certified for ULP operation) were re-tested at the completion of their normal test program on Premium Unleaded Petrol (PULP). Figure 26 indicates that on average, the fuel change had only minor effects on emissions. In analysing the full data set, some vehicles' emission levels improved, while others were worse.

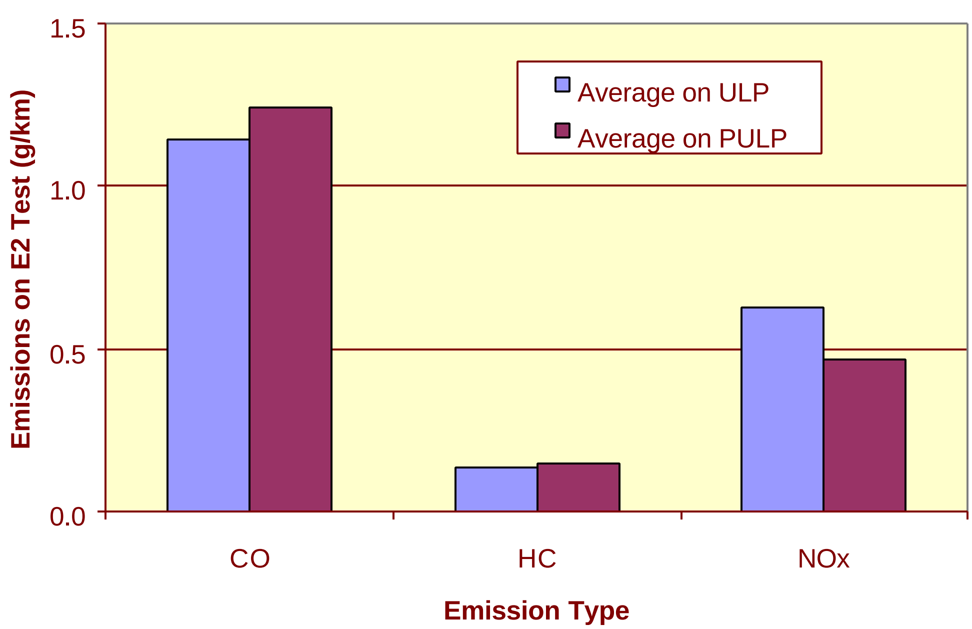


Figure 26 Comparison of Emission Levels of 7 ADR37/01 Vehicles Tested on ULP and PULP on the *Euro 2* Test

3.5 How do the Vehicles Perform on Evaporative Emissions ?

3.5.1 Introduction

As part of Stage 2, a total of 12 vehicles (seven ADR37/01, five ADR36/00) vehicles were tested for evaporative HC emissions under the ADR37/01 (*FTP*) test and the ADR79/00 (*Euro 2*) test. At the time of testing there were no facilities available in Australia able to undertake the more complex *Euro 3* evaporative emissions test[17].

Both the *FTP* and *Euro 2* test methods use the same test enclosure (known as a SHED – Sealed Housing for Evaporative Determination), and have the same test limit (2g of HC per test). The SHED test procedure is also the same except for the following main differences :

- The filler cap goes on at 14+/-1 ^{o}C in *Euro 2*, compared to 15+/-1 ^{o}C in the *FTP*;
- *Euro 2* specifies a 30 minute at 60 kph test load dynamometer drive to purge the canister (this is not specified in the *FTP)*
- *Euro 2* specifies two heat builds prior to starting the actual test sequence to partly load the canister, whereas the *FTP* test has no additional drive or loading stages prior to the test precondition; and
- *Euro 2* precondition cycle allows for 1 low speed and 2 high speed cycles (this is not specified in the *FTP).*

The aim of the testing was to see if these differences between the test requirements had a significant impact on the results. These tests were performed using ADR37/01 certification fuel, rather than a commercial grade of petrol, to minimise any fuel effects (see Appendix C for fuel analysis).

3.5.2 Data Reliability

The sample which underwent SHED testing is small, so caution must be exercised in interpreting the results. To obtain some assurance of test to test reliability, one vehicle (AU Falcon) underwent repeat tests on both test cycles by running three full SHED tests sequentially i.e. three *FTP* followed by three *Euro 2* tests.

Table 7 shows the SHED results for these tests. It can be seen that for both test methods the repeatability of the results is very close and doesn't show any canister loading effect as the sequence progresses. The results confirm that the test program procedure of a 30 minute drive between tests was suitable for purging the canister.

Table 7 Repeat Testing of an ADR37/01 Vehicle on *FTP* and *Euro 2* Evaporative Emission Tests

Test No	HC Emissions from *FTP* Test (g/test)			HC Emissions from *Euro 2* Test (g/test)		
	Diurnal	Hot Soak	Total	Diurnal	Hot Soak	Total
Test 1	0.51	0.51	1.02	0.40	0.39	0.79
Test 2	0.48	0.45	0.93	0.47	0.37	0.84
Test 3	0.49	0.47	0.95	0.47	0.33	0.80
Average	**0.49**	**0.48**	**0.97**	**0.45**	**0.36**	**0.81**

17 The European vehicle industry estimates that the *Euro 3* evaporative emissions test, with its more severe canister loading requirements and 24 hour duration, equates to an 80% increase in stringency over the *Euro 2* test.

3.5.3 Assessment Against the Limits

As indicated above both the *FTP* and *Euro 2* tests set the same limit of 2g of total HC per test. Figure 27 indicates that all but one of the vehicles[18], even the ADR36/00 models (which are not required to meet evaporative emission standards) met the 2g limit under both standards. In addition, for most vehicles, there is little difference in the level of emissions on both tests.

It needs to be remembered that commercial fuel traditionally has a higher vapour pressure than ADR certification fuel, and previous research[19] has demonstrated that this can have a significant impact on evaporative emissions. Measures are now in place (or planned) in a number of Australian States to reduce the vapour pressure of "summer grade" commercial petrol to levels much closer to that of ADR certification fuel.

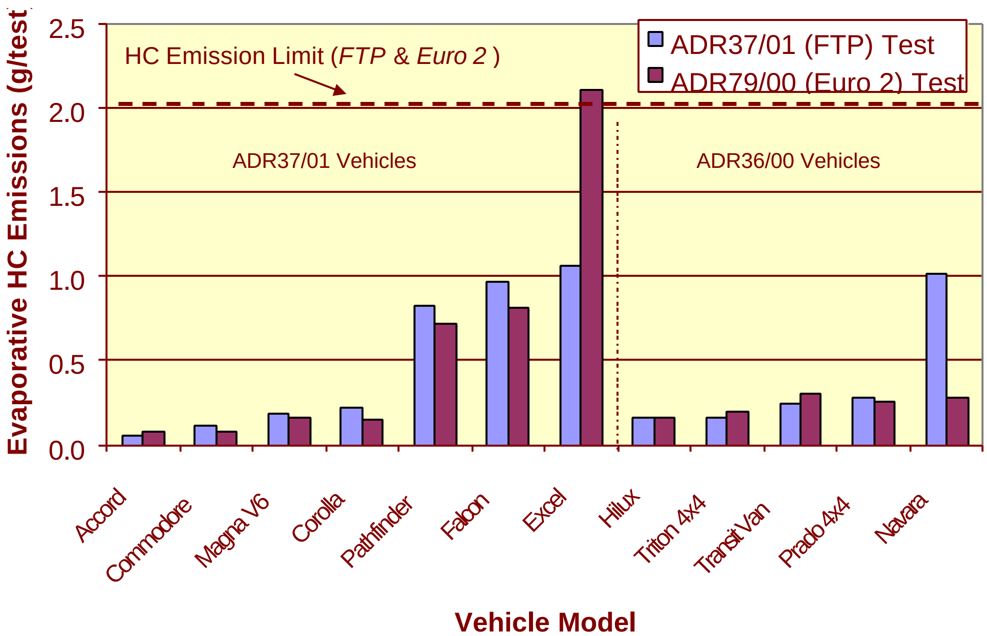


Figure 27 Evaporative HC Emission Rates of ADR37/01 and ADR36/00 Vehicles on *FTP* and *Euro 2* Tests

18 The test laboratory suspects the Excel had a canister loading/purging problem which lead to the high *Euro 2* evaporative emissions result.

19 National In-service Emissions Study – published as *Motor Vehicle Pollution in Australia* (1996) and its Supplementary Report No 2 *Petrol Volatility Project (1997)*, by the then Federal Office of Road Safety, and available at www.dotrs.gov.au/land/environment/index.htm.

3.6 How do the Vehicles Perform on Fuel Consumption ?

3.6.1 Introduction

Vehicle fuel economy is not regulated like noxious emissions - which are limited by the ADRs. The vehicle industry in Australia has operated for many years under a voluntary code of practice which sets targets for the National Average Fuel Consumption (NAFC). The NAFC is a sales weighted average. Under its Environmental Strategy for the Motor Vehicle Industry (Item 5.10 of the National Greenhouse Strategy) the Federal Government is negotiating with the industry to secure a 15% improvement in NAFC by 2010 compared with business as usual projections.

A new ADR requiring fuel consumption labelling (ADR81/00 *Fuel Consumption Labelling for Light Vehicles*) will commence on 1 January 2001. The data required for the ADR81/00 label is derived from the "city cycle" fuel consumption test in AS2877[20], which is equivalent to the *FTP* test used in the current ADR37/01.

The government has indicated its intention to issue a replacement ADR (ADR81/01) in 2003 to coincide with the introduction of ADR79/00. ADR81/01 will derive its fuel consumption value from the test referenced in UN ECE Regulation 101. R101 uses the *Euro 2* exhaust emissions test in ADR79/00 for calculating fuel consumption.

The aim of the fuel consumption testing was twofold:

- To report the fuel consumption performance of current model vehicles; and
- To assess the fuel consumption performance of the vehicles on the current and future test methods.

3.6.2 Fuel Consumption on Current Test Procedure

As fuel consumption is not regulated under the ADRs, it was decided to combine all the test vehicles (except the LPG vehicles) into one group for the fuel consumption analyses only.

In addition, as vehicle mass has a significant impact on fuel consumption, the test vehicles were then subdivided into 5 mass groupings, generally in line with the recognised industry categories. Some variations have been made in order to incorporate the ADR 36/00 vehicles, and the vehicles classified as "luxury" or "prestige", into categories appropriate for this Study. Table 8 indicates the models included in each category.

[20] AS2877-1986 *Methods of Test for Fuel Consumption of Motor Vehicles Designed to Comply with Australian Design Rules 37 and 40.*

Table 8 Distribution of Vehicle Models by Vehicle Category for Fuel Consumption Analyses

Category	Vehicles Included
Light	Festiva, Mazda 121, Starlet
Small	Civic, Corolla, Excel, Golf, Lanos, Laser, Mazda 323, Pulsar
Medium	Accord, BMW 3 Series, Camry, Hilux 2x4, Magna 4, Mondeo, Navara 2x4, Saab 9-3, Sonata, Volvo S40
Upper Medium	BMW 5 series, Commodore, Falcon, Magna V6, Pathfinder, Peugeot 406, Triton 4x4, Vienta V6
Heavy	Patrol 4x4, Prado 4x4, Transit Van

Figure 28 illustrates the average fuel consumption performance of the vehicles in each of the categories. The results are not surprising and reflect the considerable variation in fuel consumption rates of passenger vehicles and "commercial" vehicles – some of which are widely used as passenger vehicles.

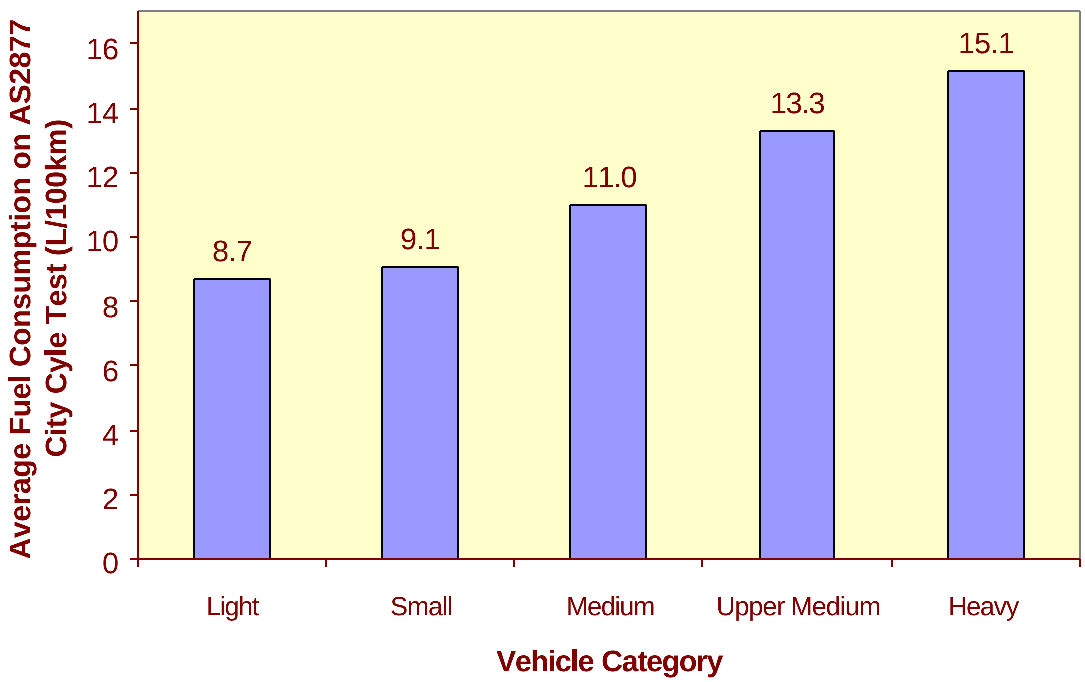


Figure 28 Average Fuel Consumption of ADR37/00, ADR37/01 and ADR36/00 Vehicles on AS2877 City Cycle Test

It is also of interest to assess how average fuel consumption performance has changed over the past few years. Using data from the 1996 NISE Study [21] for 1992-3 model vehicles, Figure 29 compares the average fuel consumption of the categories for which the earlier data is available. The results should be considered as indicative only, as the NISE Study vehicles were only sourced from the 5 major vehicle manufacturers, and were largely locally produced vehicles, whereas the current program includes a significant number of imported and relatively low volume vehicles. Nevertheless, the results indicate that on average, there has been only a modest improvement in fuel consumption in these categories over the past 6-7 years (approximately 3% for the small vehicles, 6% for the medium and 2% for the upper medium).

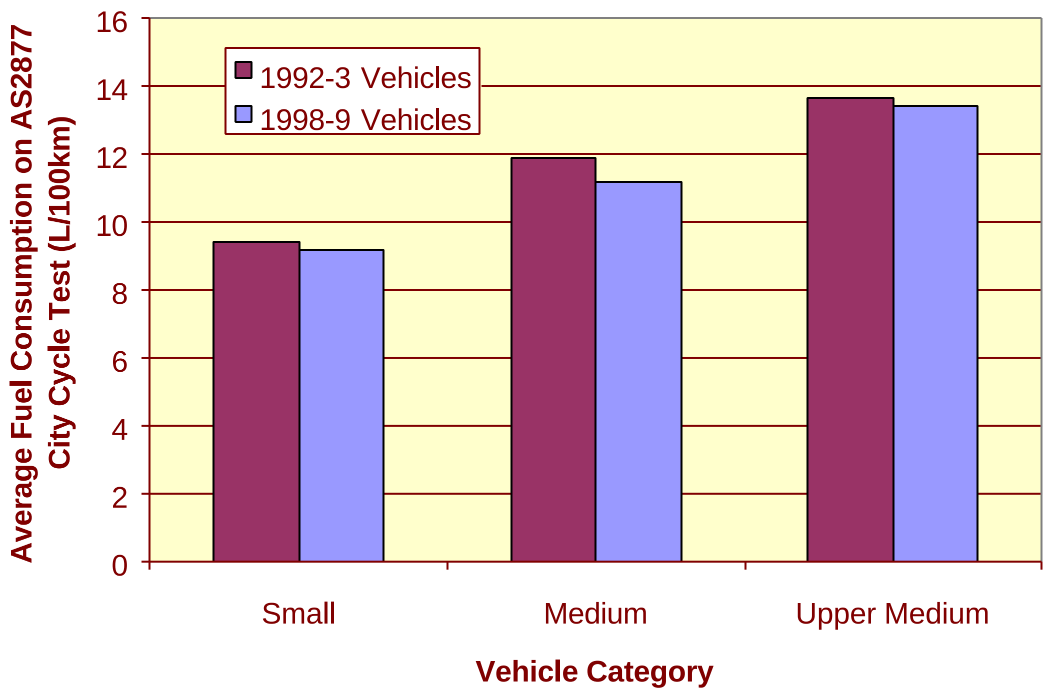


Figure 29 Comparison of Average Fuel Consumption of ADR37/01 (1998-9 Models[22]) with 1992-3 Model Vehicles on AS2877 City Cycle Test

3.6.3 Fuel Consumption on Future Test Procedures

As indicated in section 3.6.1, future testing for the fuel consumption label under ADR81/01 will be based on the UN ECE Regulation 101 [23] which uses the emission test cycle in the *Euro 2* test (and in the future, the *Euro 3* test). Thus it is important to know what fuel consumption values are obtained on the *Euro 2* and *Euro 3* tests relative to the current *FTP* test (which is the basis of the city cycle test in AS2877).

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21 National In-service Emissions Study – published as *Motor Vehicle Pollution in Australia* (1996) by the then Federal Office of Road Safety, and available at www.dotrs.gov.au/land/environment/index.htm.

22 All but one of the ADR37/01 vehicles had 1998 or 1999 build dates.

23 {insert full name of ECE 101 here}

It should be noted that ECE R101 has a broader range of dynamometer inertia values than values used in this Study which were taken from the version of ECE R83 available at the time (the dynamometer settings in ECE R83 and ECE R101 have since been aligned). However, to avoid the requirement for an additional test on every vehicle just to calculate fuel consumption, it was decided to use the results from the *Euro 2* emissions test which are derived from the more limited dynamometer inertias. This is not likely to have a significant difference overall, but may affect the fuel consumption of some vehicles depending on whether they had lower or higher dynamometer loads relative to the R101 settings. A table of the relevant inertias and road loads used can be found in Appendix E. The actual inertia and road load settings used for each vehicle are recorded in the “All Data” file on the enclosed CD.

Figure 30 indicates that the differences in average fuel economy for ADR37/01 and ADR36/00 vehicles is relatively small across the *FTP*, *Euro 2* and *Euro 3* tests. The average results on the *AUC* cycle are considerably higher. This is due to the *AUC* cycle having more frequent and more severe acceleration modes (for the smaller and heavier vehicles, this usually means that the vehicle approaches wide open throttle, significantly increasing fuel demand). The *AUC* also has a higher average speed of almost 38km/hr compared to around 32-34km/hr on the other cycles.

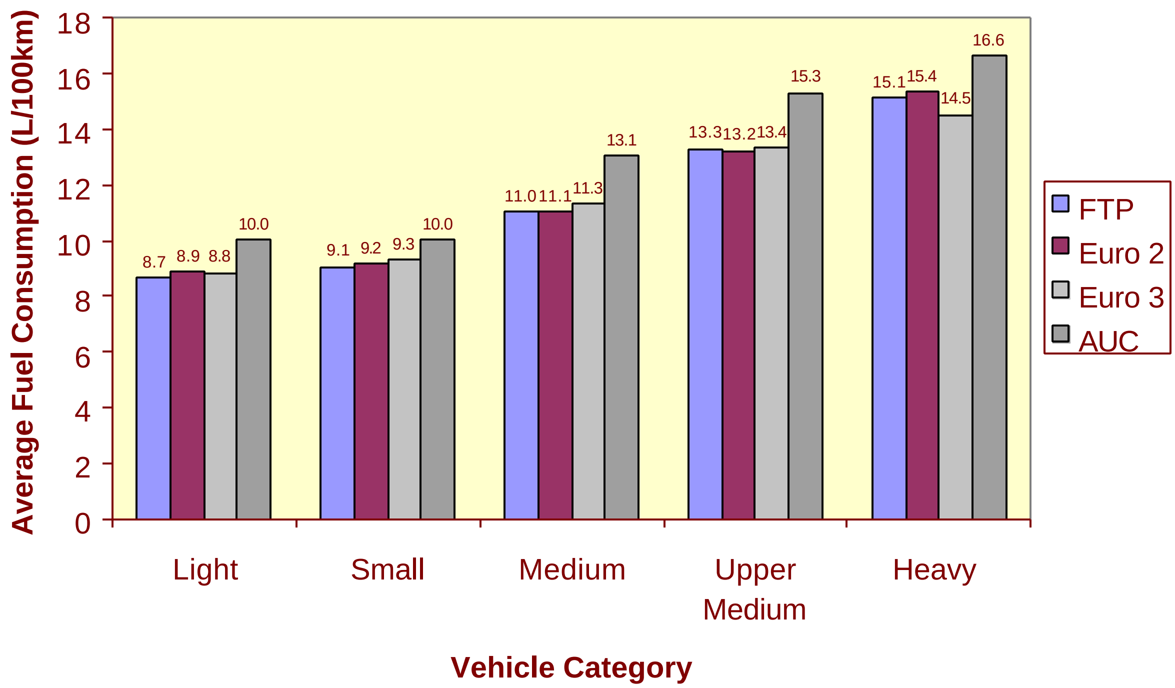

Figure 30 Comparison of Average Fuel Consumption of the Test Vehicles on Current and Future Test Procedures

In order to get a measure of the relationship between the three fuel consumption test methods which form the basis of current and future ADRs for fuel consumption labelling (and presumably the basis of future NAFC calculations), the results on each of the *FTP*, *Euro 2* and *Euro 3* were compared using scatterplots.

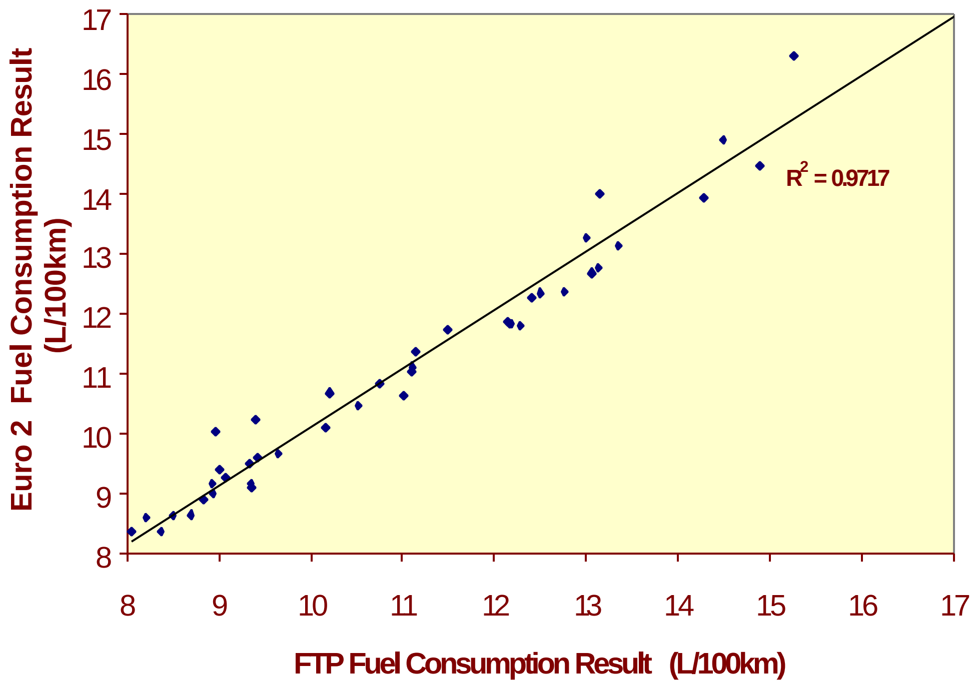

Figure 31 Relationship between *FTP* and *Euro 2* Tests for Fuel Consumption for All Test Vehicles

Figure 31 indicates that there is a very good correlation overall between the fuel consumption results on the *FTP* test relative to the *Euro 2* test. Nevertheless, a small number of vehicles (6 in a sample of 43 vehicles) exhibit reasonably large differences between the tests of 0.5 - 1 L/100km, with the higher result usually occurring on the *Euro 2* test. Expressed in percentage terms, only 4 vehicles differed from each other by more than 5%.

Figure 32 illustrates that the correlation between the *Euro 2* and *Euro 3* test is, not surprisingly, also strong. Again a small number of vehicles (8 in this case) differ by 0.5 - 1 L/100km, with one other vehicle having a difference of approximately 2L/100km. Expressed in percentage terms, only 5 vehicles differed from each other by more than 5%. The differences between the *Euro 2* and *Euro 3* data can possibly be attributed to the 40 second idle being removed at the start of the *Euro 3* test, as this effects the emissions which are subsequently used in the fuel consumption calculation.

However, with only single tests being conducted, the small percentage differences in the bulk of the vehicles in both sets of comparisons are just as likely to be attributable to "test to test" variability.

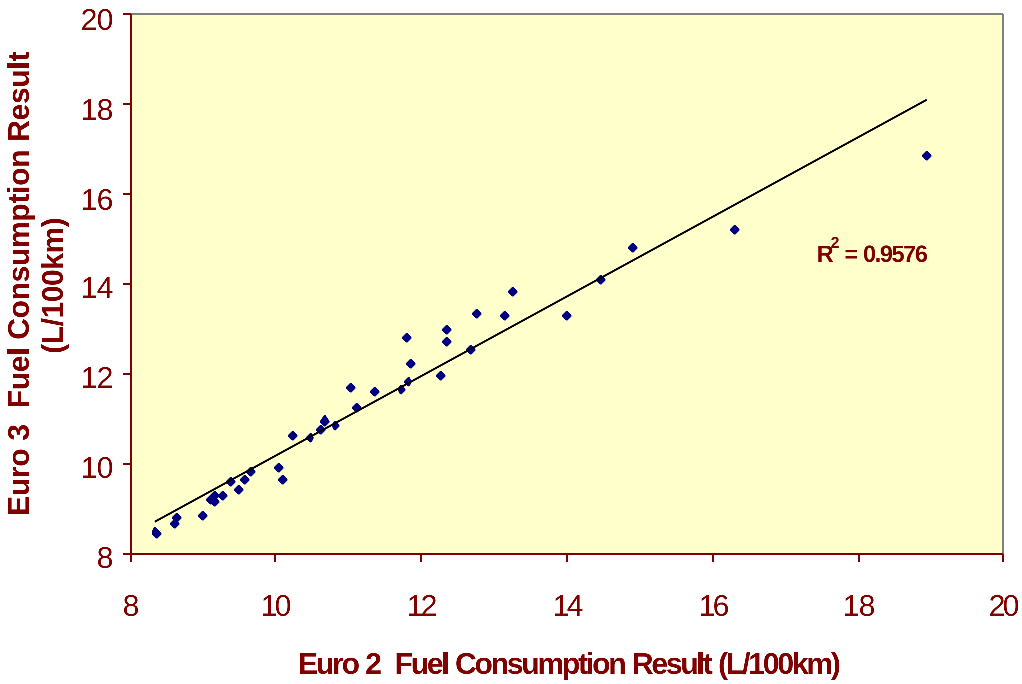

Figure 32 Relationship between *Euro 2* and *Euro 3* Tests for Fuel Consumption for All Test Vehicles

3.6.4 Comparison of Fuel Consumption on ULP and PULP

As indicated in section 3.4.4, a small number of vehicles (8) were tested on both ULP and PULP on the *Euro 2* emissions and fuel consumption test. Similar to the findings for the noxious emissions (Figure 26), the results illustrated in Figure 33 indicate that fuel consumption is not significantly changed by operating a ULP certified vehicle on PULP. The difference on average is just over 1% with the largest difference being around 3.5%. It is of interest to note that the three vehicles from European manufacturers in the group (BMW, Saab, Volvo) all had improved fuel consumption on PULP. This may indicate that the engines, which were originally designed for the European market where PULP is the "standard" commercial fuel, are equipped with engine knock sensors or similar technology which enables the engines to adapt to changes in fuel octane.

Nevertheless, on the basis of this, albeit limited, testing, there would seem to be little value in operating ULP certified vehicles on PULP, unless they have an adaptive engine management system which can respond to changes in fuel octane.

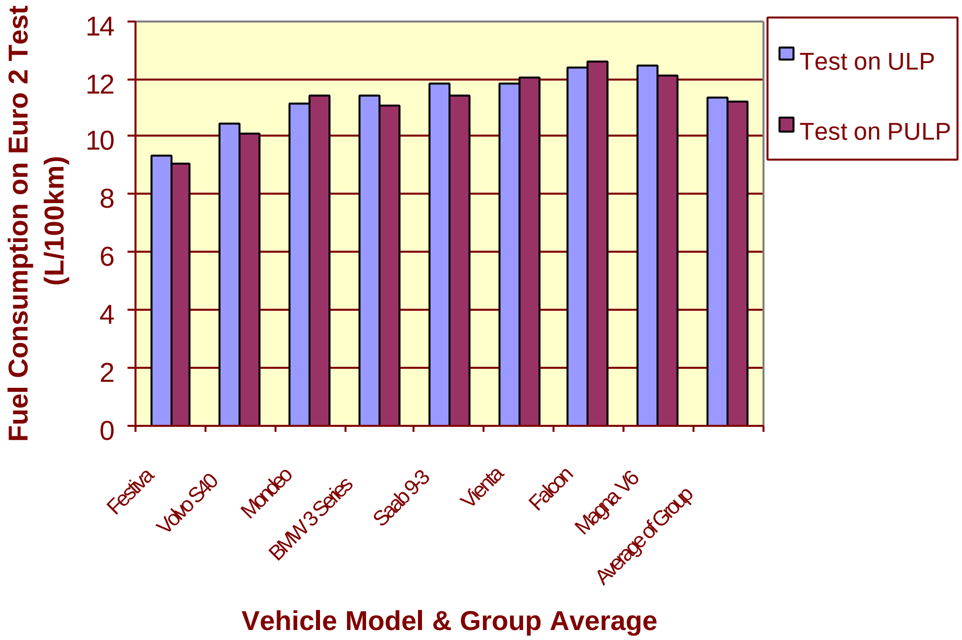

Figure 33 – Comparison of Fuel Consumption of 7 ADR37/01 Vehicles Tested on ULP and PULP on the *Euro 2* Test

4 SUMMARY

4.1 Key Findings

The Comparative Vehicle Emissions Study provides valuable information on the emission and fuel consumption performance of the current passenger car and light commercial fleet in Australia. It also provides an indication of the stringency of the new emission standards which will be introduced under ADR79/00 and ADR79/01 in 2003 and 2005, respectively.

The key findings of the Study are:

Exhaust Emissions

- Most vehicles comfortably comply with the current emission standards, with emission rates on average 60% below the regulated limits. Nevertheless, there is considerable variability in emission levels, with some vehicles having quite high NOx emissions relative to the limit.
- Vehicles certified to the basic requirements of ADR36/00 can have very high emissions, particularly those not fitted with a catalyst.
- When tested against the new *Euro 2* emission test in ADR79/00, most vehicles had higher emissions for all three of the regulated emissions (CO, HC and NOx), and while most met the *Euro 2* limits for CO and HC, around 50% of the vehicles did not meet the *Euro 2* NOx limit (assuming a nominal 55:45 [HC:NOx] split of the HC+NOx limit). Some vehicles have very high NOx emissions on the *Euro 2* test, reflecting "lean burn" fuel consumption strategies in their engine management systems.
- The *Euro 3* test is even more demanding than the *Euro 2* test, with the combination of lower emission limits for HC and NOx and a change to the emissions cycle, leading to higher CO and HC emissions on the *Euro 3* test relative to the *Euro 2* test. Most vehicles still met the CO limit on *Euro 3,* but with little margin for deterioration. Around 50% of the vehicles had HC emission values above or very close to the limit, with the proportion rising to 80% for NOx.
- Using the Australian Urban Cycle as a guide, the *Euro 3* test appears to be the best of the three ADR cycles in replicating "real word" emissions.

Evaporative Emissions

- On evaporative emissions, the *Euro 2* test does not increase the stringency of the current requirements, which most vehicles, including the ADR36/00 models, met comfortably (albeit on certification fuel).
- Testing was not able to be conducted on the more complex *Euro 3* evaporative emissions test, which is significantly more stringent than the *Euro 2* test.

Fuel Consumption

- On fuel consumption, there is, not surprisingly, a wide variation in performance across the test vehicles, ranging from an average of around 9L/100km for smaller 4 cylinder models to 13-15L/100km for larger 6 cylinder cars and 4WDs.
- There have only been modest improvements of 2-6% in passenger car fuel consumption over the past 6-7 years.
- There is a good correlation between the fuel consumption test used in ADR37/01 and the *Euro 2* and *Euro 3* tests which will be used as the basis of the calculation for fuel consumption labelling under ADR81/01.

4.2 Conclusions

The results from this Study indicate that most current model passenger cars on the Australian market are likely to meet the current emission standards in ADR37/01 by a comfortable margin. Some of the light commercial and 4WD vehicles certified to ADR36/00 have very high emissions relative to passenger cars.

It can reasonably be concluded from the Study, that the adoption of the *Euro 2* and *Euro 3* standards in ADR79/00 and ADR79/01, respectively, will lead to a significant reduction in emission levels from the Australian passenger car, light commercial and 4WD fleet. The emission reductions will be due to a combination of factors, principally:

- the lower emission limits for HC and NOx emissions;
- the more demanding test cycles, particularly for NOx; and
- the inclusion of vehicles currently certified to ADR36/00 within the scope of the new standards for lighter vehicles, albeit with more lenient emission limits.

In order to meet the new standards - particularly *Euro 3* - it is anticipated that vehicle manufacturers will have to upgrade the level of vehicle emissions control technology, and recalibrate the engine and emission control systems.

APPENDICES

APPENDIX A - TARGET TEST VEHICLES

APPENDIX B - PRE-TEST INSPECTION AND TEST PROGRAM

APPENDIX C - ANALYSIS OF TEST FUELS

APPENDIX E - DYNAMOMETER INERTIAS & ROAD LOADS

APPENDIX D - DETAILED FLOW CHARTS OF TEST PROGRAMS

APPENDIX A - TARGET TEST VEHICLES

The following tables are derived from the Study brief and indicate the target vehicles. Some of the target vehicles were not able to be obtained for testing, and in some cases, vehicles not on the original target list were substituted.

Stage 1 - Target Vehicles

Vehicle Class[24]	Make	Model	Tested [25]	ADR37 Level[26]	Applicable Test Program[27]				
					2A	2B	2C	2D	2E
Light									
	Ford	Festiva	✓	01	✓	✓	✓	✓	✓
	Holden	Barina	✗		✓		✓		✓
	Mazda	121	✓	01	✓		✓		
	Toyota	Starlet	✓	01	✓	✓	✓	✓	
Small									
	Daewoo	Lanos	✓	01	✓		✓		
	Ford	Laser	✓	00	✓		✓		
	Honda	Civic	✓	01	✓		✓		
	Hyundai	Excel	✓	01	✓	✓	✓	✓	
	Hyundai	Lantra	✗		✓		✓		
	Mazda	323	✓	01	✓		✓		
	Mitsubishi	Lancer	✓	00	✓		✓		
	Mitsubishi	Mirage	✓	00	✓		✓		
	Nissan	Pulsar	✓	01	✓		✓		
	Toyota	Corolla	✓	01	✓		✓	✓	
	Volkswagen	Golf	✓	01	✓		✓		
Medium									
	Ford	Mondeo	✓	01	✓		✓	✓	✓
	Hyundai	Sonata 4cyl	✓	01	✓		✓		
	Mitsubishi	Magna 4cyl	✓	00	✓		✓		
	Toyota	Camry 4cyl	✓	01	✓		✓	✓	
Upper Medium									
	Ford	Falcon 6cyl	✓	00	✓	✓	✓	✓	
	Ford	Falcon AU 6cyl	✓	01	✓		✓		✓
	Holden	Commodore 6cyl	✓	01	✓	✓	✓	✓	
	Holden	Commodore 8cyl	✗		✓		✓		✓
	Mitsubishi	Magna 6cyl	✓	00	✓		✓	✓	✓
	Toyota	Vienta 6cyl	✓	01	✓		✓		✓
Prestige									
	BMW	3-series 4cyl	✓	01	✓	✓	✓	✓	✓
	BMW	540I (99 model)	✓	01	✓		✓		
	Saab	900	✓	01	✓		✓		✓
	Peugeot	406	✓	01	✓		✓		
	Volvo	S40	✓	00	✓		✓		✓

24 As per VFACTS classification

25 ✓means the vehicle was tested; ✗ means the vehicle was not able to be sourced for testing

26 identifies whether the tested vehicle was certified to ADR 37/00 or ADR37/01

27 Refer Part 2 of Appendix B, where 2A = Standard Test Program; 2B = Repeat Test Program; 2C = Modified UN ECE Test Program; 2D = Australian Urban Cycle Test Program; 2E = High Octane Petrol Test Program

Stage 2 - Target Vehicles

Vehicle Group	Make	Model	Tested [28]	ADR Level [29]	Applicable Test Program[30]			
					2A	2C	2D	2F
37/00 & Untested								
	Ford	Laser	✓	01	✓	✓		
	Holden	Barina or Vectra	✗		✓	✓		
	Hyundai	Lantra	✗		✓	✓		
	Mitsubishi	Mirage	✗		✓	✓		
	Nissan	Pulsar	✓	01	✓	✓		
	Mitsubishi	Magna 6cyl	✓	01	✓	✓		
	Volvo	S40	✓	01	✓	✓		
High Volume								
	Hyundai	Excel	✓	01	✓			✓
	Toyota	Corolla	✓	01	✓			✓
	Ford	Falcon AU 6cyl	✓	01	✓			✓
	Holden	Commodore 6cyl	✓	01	✓			✓
(same vehicle as above)	Mitsubishi	Magna 6cyl	✓	01	✓			✓
Low Emission								
	Toyota	Prius	✗		✓	✓		✓
	Honda	Accord (LEV)	✓	01	✓	✓		✓
Alternative Fuel								
	Ford	Falcon LPG	✓	01	✓	✓		
	Holden	Commodore LPG	✓	01	✓	✓		
4WDs (test 3)					✓	✓	✓	✓
	Toyota	Landcruiser						
	Toyota	Hilux 4x4						
	Nissan	Patrol Wagon	✓	36				
	Toyota	Prado	✓	36				
	Holden	Rodeo 4x4						
	Mitsubishi	Pajero						
	Land Rover	Discovery						
	Mitsubishi	Triton 4x4	✓	36				
LCVs (test 3)					✓	✓	✓	✓
	Holden	Rodeo 4x2						
	Toyota	Hilux 4x2	✓	36				
	Toyota	Hi-Ace Van						
	Mitsubishi	Express						
	Ford	Transit	✓	36				
	Ford	Courier 4x2						
	Nissan	Navara 4x2	✓	36				

28 ✓ means the vehicle was tested; ✗ means the vehicle was not able to be sourced for testing

29 "01" means the tested vehicle was certified to ADR37/01; "36" means the vehicle was certified to ADR36/00

30 Refer Part 2 of Appendix B, where 2A = Standard Test Program; 2C = Modified UN ECE Test Program; 2D = Australian Urban Cycle Test Program; 2F = Evaporative Test Program.

APPENDIX B - PRE-TEST INSPECTION AND TEST PROGRAM

PRE-TEST INSPECTION

The following information was collected on every vehicle prior to testing.

Item	Information Recorded
Rego Number	
Make & Model	
Compliance Plate Date	........../............../............
VIN	
Vehicle mass	................kg (as delivered)
Odometer reading	.........................km
Tyres	Condition - *good/fair/poor*
Engine displacement	L
No of cylinders	*4 / 6 / 8*
Engine configuration	*Inline / V*
Transmission & No of Gears	*Man / Auto* & *3 / 4 / 5*
Fuel system	*Carburettor / MPI / TBI*
Air conditioning	*Yes / No*
Engine Oil	Oil level –OK/low
Transmission Fluid	Fluid level – OK/low
Radiator	Coolant level – OK/low
Battery	Electrolyte level – OK/low Charge – OK/low
EEMS	Yes/no
Catalyst Type	Single 3 way / Pre + main cat / Other
Safety Issues	Is the vehicle in a satisfactory condition for testing - *yes/no*.

TEST PROGRAM DESCRIPTION

The study brief specified a number of test programs, designated 2A to 2E, to be undertaken on the vehicles. All vehicles underwent the 2A program, with the other programs being applied to a subset of the vehicles. A description of each of the test programs follows.

2A – STANDARD TEST PROGRAM

All vehicles shall be subject to the Standard Test Program in accordance with the procedures specified below.

Name of Test	***Test Procedure***
ADR37/01[31] Exhaust Emissions	Determine the exhaust emissions of carbon monoxide, hydrocarbons, oxides of nitrogen and carbon dioxide as follows: Conduct the tests as set out in Clauses 9, 10 & 11 of ADR37/01, subject to the following conditions: [1] The heat build and associated drain and fill of the petrol tank shall not be conducted, except where the vehicle is to undergo the Evaporative Emissions Test Program (2F). [2] The vehicle shall be weighed in its "as delivered" condition, and the road power absorber setting shall be the appropriate value from Table 4 of ADR37/01 [3] If the vehicle is fitted with air conditioning, the road power absorber setting shall be increased by 10% and the air conditioning unit switched off. [4] The ADR37/01 default speeds shall be used to determine manual gear change points. [5] The actual distance recorded in the test shall be used to calculate emissions in g/km.
AS2877-1986[32] Fuel Consumption	Determine the fuel consumption of the vehicle as follows: ▪ Calculate the city cycle fuel consumption by the Exhaust Gas Analysis Method in E1.1 of Appendix E of AS2877, using the results from the ADR37/01 test. ▪ Conduct the Highway Driving Cycle test as set out in Appendix C of AS2877, and calculate the fuel consumption by the Exhaust Gas Analysis Method in E1.1 of Appendix E of AS2877.
UN ECE R83/03[33] Exhaust Emissions	Determine the exhaust emissions of carbon monoxide, hydrocarbons, oxides of nitrogen and carbon dioxide as follows: Conduct the Type I exhaust emission tests as set out in Annex 4 of R83 (refer to Appendix 3).
UN ECE R101[34] Fuel Consumption	Determine the fuel consumption of the vehicle as follows: Calculate fuel consumption in accordance with Annex 4 of R101, using the results from Type I test conducted under R83.

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31 Australian Design Rule [ADR] 37/01 *Emission Control for Light Vehicles*

32 Australian Standard 2877-1986 *Methods of Test for Fuel Consumption of Motor Vehicles Designed to Comply with Australian Design Rules 37 and 40*

33 UN ECE Regulation 83 *Uniform Provisions Concerning the Approval of Vehicles with Regard to the Emission of Pollutants According to Engine Fuel Requirements*

34 UN ECE Regulation 101 *Uniform Provisions Concerning the Approval of Passenger Cars Equipped with an Internal Combustion Engine with Regard to the Measurement of the Emission of Carbon Dioxide and Fuel Consumption*

2B –REPEAT TEST PROGRAM

To establish an indication of test to test variability, a number of vehicles will be subject to repeat testing. These vehicles will simply be required to repeat the test sequence in the Standard Test Program (2A) twice (ie 3 completed 2A test sequences in all).

2C –MODIFIED UN ECE TEST PROGRAM

The *Euro 3* emissions test is equivalent to the *Euro 2* test in ECE R83/04 except that the cycle has been amended to remove the 40 seconds idle period prior to the commencement of the driving cycle and emissions sampling. In order to assess the impact of this change, all vehicles will be required to repeat the UN ECE R83/03 test once, except that in conducting the Type I test, Part One of the driving cycle is to start immediately after ignition and sampling is to also start immediately after ignition.

2D –AUSTRALIAN URBAN CYCLE TEST PROGRAM

A number of vehicles will also be subject to the Australian Urban Cycle (AUC). It is to be conducted after the completion of test program 2C. Preconditioning for the AUC is to be in accordance with the preconditioning requirements for the ADR37/01 test.

2E – HIGH OCTANE PETROL TEST PROGRAM

A number of vehicles including those which are manufactured in Europe will be subject to the UN ECE Type I test and the test fuel used shall be high octane unleaded petrol. It is to be conducted after the completion of all other testing.

2F – EVAPORATIVE EMISSIONS TEST PROGRAM

A number of vehicles will be subject to the evaporative emissions tests for total hydrocarbons in ADR37/01 and the Type IV test in ECE R83/03. The test fuel used shall be certification test fuel complying with the requirements of the regular unleaded petrol specification in ADR37/01.

APPENDIX C - ANALYSIS OF TEST FUELS

The test fuels were supplied and analysed by Mobil Oil Australia.

UNLEADED PETROL ANALYSIS

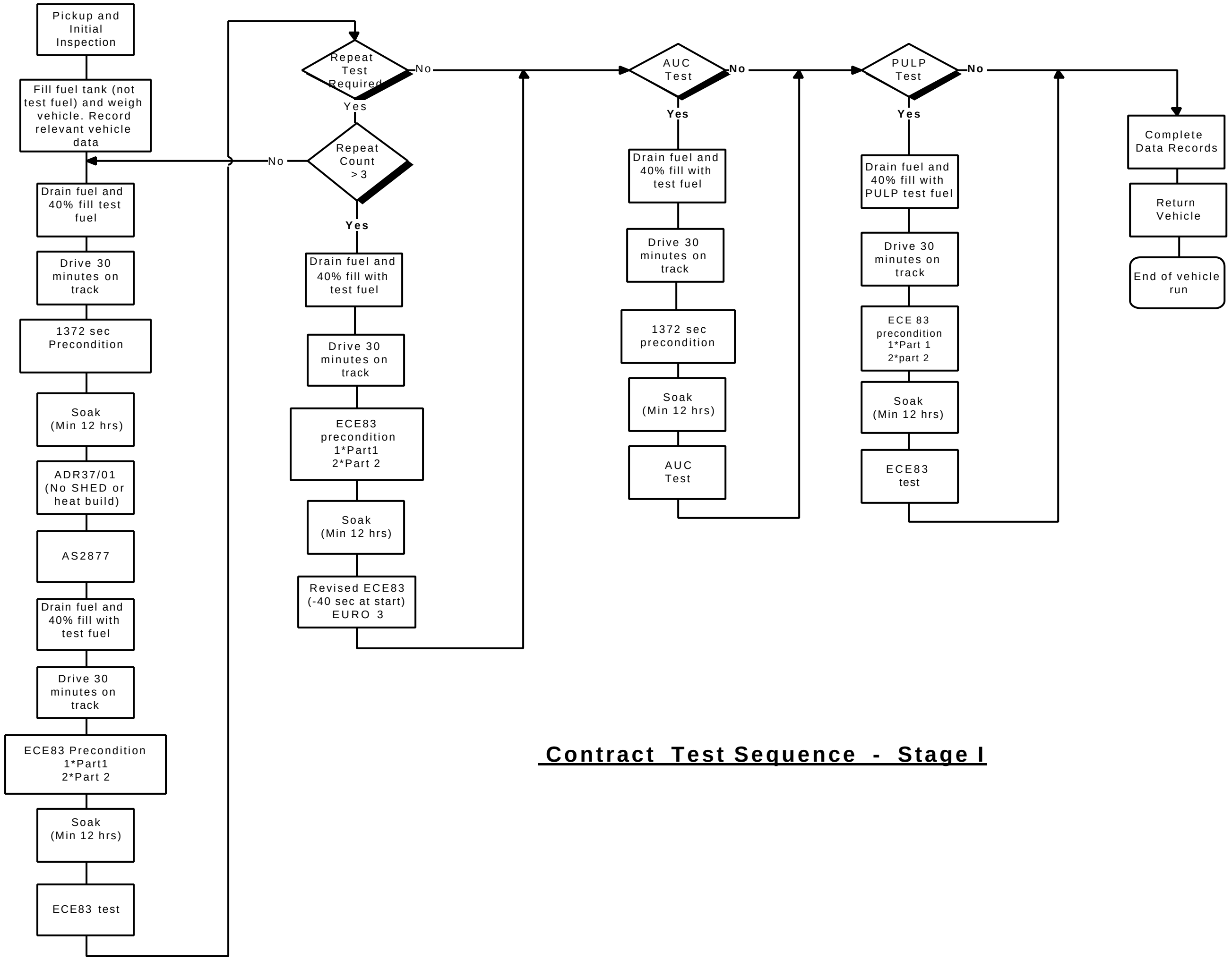
Parameter	Method	Test Result
Research Octane Number	ASTM D2699	91
Motor Octane Number	ASTM D2700	82
Reid Vapour Pressure (kPa)	ASTM D323	80.25
Distillation (^oC)	ASTM D86	
IBP		28.6
10% Received		45.5
50% Received		84.7
90% Received		156.7
FBP		197.3
Density @ 15^oC (g/ml)	ASTM 4052	0.7248
Density @ 20^oC (g/ml)	Calculated	0.7203
Hydrocarbon Composition (%)	ASTM 1319	
Aromatics		28.9
Olefins		6.1
Saturates		65.0
Lead (g/L)	IP352	<0.001
Sulphur (wt%)	IP336	0.01
Phosphorous (g/L)	ASTM D3231	<0.0002
Carbon Hydrogen Ratio		1 : 1.77

PREMIUM UNLEADED PETROL ANALYSIS

Parameter	Method	Test result
Research Octane Number	ASTM D2699	95.4
Motor Octane Number	ASTM D2700	84.8
Reid Vapour Pressure (kPa)	ASTM D323	79.0
Distillation (^oC)	ASTM D86	
IBP		30.1
10% Received		52.6
50% Received		98.5
90% Received		148.8
FBP		193.9
Density @ 15^oC (g/ml)	ASTM D4052	0.7400
Density @ 20^oC (g/ml)	ASTM D4052	0.7355
Hydrocarbon Composition (%)	ASTM D1319	
Aromatics		33.7
Olefins		8.4
Saturates		57.9
Lead (g/L)	IP352	0.002
Sulphur (wt%)	IP336	0.01
Phosphorous (g/L)	MM71	<0.0003

APPENDIX D - DETAILED FLOW CHARTS OF TEST PROGRAMS

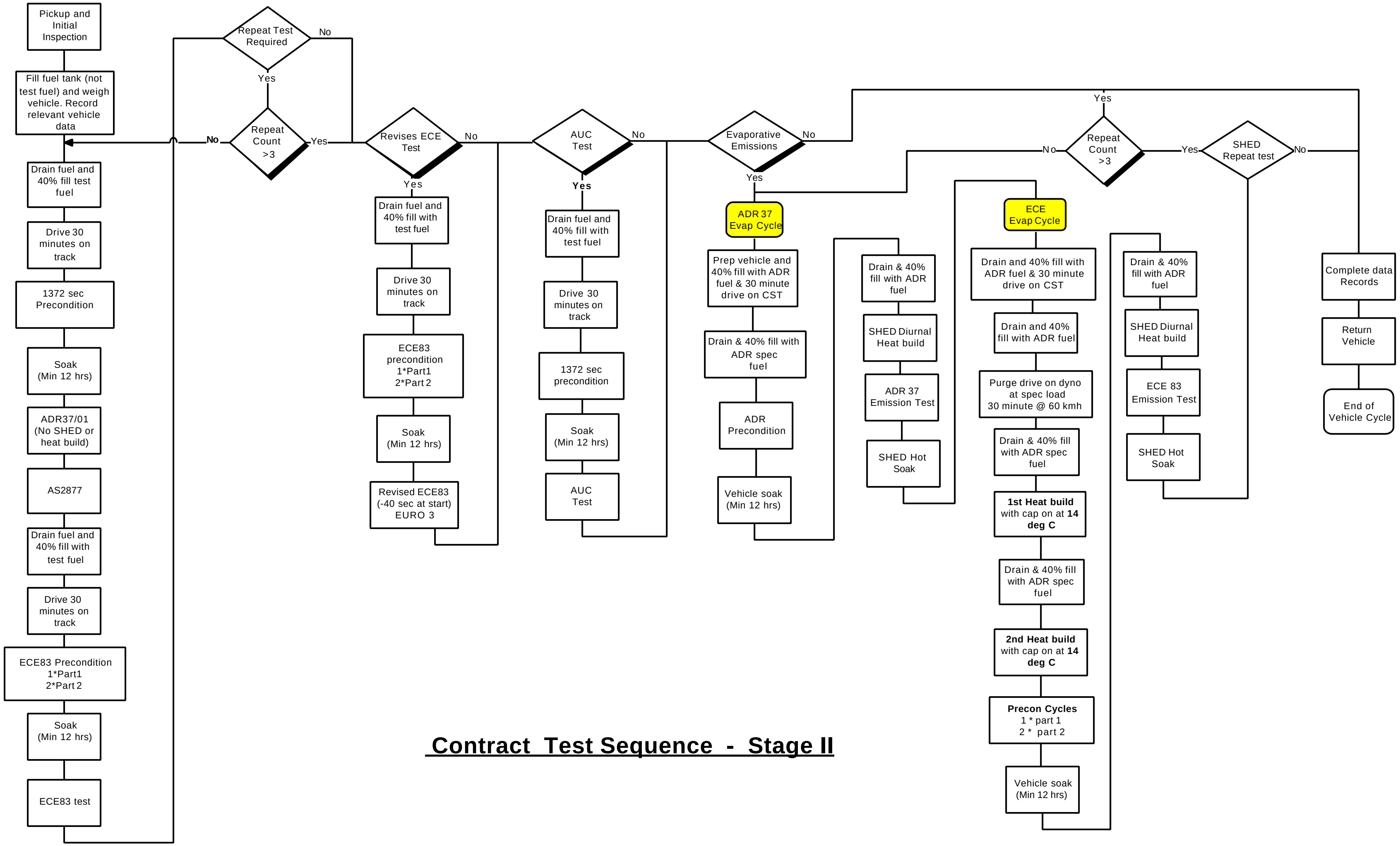
The attached flow charts detail each of the steps in the testing sequence for Stage 1 and Stage 2 of the Study. The principal difference between Stage 1 and 2 is the inclusion of evaporative emission testing in Stage 2.



Contract Test Sequence - Stage I

Note: All 40% fuel fills use chilled test fuel

Contract Test Sequence - Stage II



Note: All 40% fuel fills use chilled test fuel

APPENDIX E - DYNAMOMETER INERTIAS & ROAD LOADS

The tables below show the ADR37/01 and UN ECE R83 (Euro2 & 3) range of inertia settings and subsequent road load power settings used in the Study. The ECE R101 (fuel economy) test has a similar range of inertia settings to the ADR test, but for simplicity of testing, it was decided that ECE R101 tests would be based on ECE R 83 inertia settings to reduce the overall number of tests required for the program.

The inertia and road load settings used for the AUC cycle were based on the ADR table.

The Study used the mass of the vehicle with a full tank plus 136 kg (as per the ADR) to determine the reference mass for the ADR37/01 test. For ECE R83 (Euro 2&3), the mass of the vehicle was as above, but with 100kg added as per the standard.

ADR37/01 Settings

Reference Mass (kg)	Equivalent Inertia (kg)	Road Power (kW)
936 to 992	964	6.4
993 to 1,048	1,021	6.6
1,049 to 1,105	1,077	6.8
1,105 to 1,162	1,134	7.0
1,163 to 1,219	1,191	7.2
1,220 to 1,275	1,247	7.4
1,276 to 1,332	1,304	7.6
1,333 to 1,389	1,361	7.7
1,390 to 1,445	1,417	7.9
1,446 to 1,502	1,474	8.0
1,503 to 1,559	1,531	8.2
1,560 to 1,615	1,588	8.4
1,616 to 1,672	1,644	8.5
1,673 to 1,729	1,701	8.6
1,730 to 1,786	1,758	8.8
1,787 to 1,871	1,814	9.0
1,872 to 1,984	1,924	9.2
1,985 to 2,097	2,041	9.5
2,098 to 2,211	2,155	9.7
2,212 to 2,324	2,268	10.0
2,325 to 2,438	2,381	10.2
2,439 to 2,608	2,495	10.4

ECE Settings

Reference Mass (kg)	Equivalent Inertia (kg)	Road Power (kW)
850 to 1,020	910	5.6
1,020 to 1,250	1,130	6.3
1.250 to 1,470	1,360	7.0
1,470 to 1,700	1,590	7.5
1,700 to 1,930	1,810	8.1
1,930 to 2,150	2,040	8.6
2,150 to 2,380	2,270	9.0
2,380 to 2,610	2,270	9.4
> 2610	2,270	9.8