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TNO report

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In-use compliance programme passenger cars - Annual report 2002

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Summary

This report presents a general overview of the results of the Dutch In-Use Compliance programme for passenger cars over the year 2002. The work in this year has been executed under a contract with the Dutch Ministry of Housing, Spatial Planning and the Environment for the period 2000-2003. The passenger car in-use compliance programme basically assesses the emission performance of passenger cars in use, against the corresponding emissions legislation. In addition relevant data for emission modelling purposes are gathered and the work in the EU 5th framework project ARTEMIS was undertaken. The data gathered are additionally used for supporting the Dutch Government on national and international policy issues. The results presented in this report are anonymised, since it is not the purpose of this report to point out typical manufacturer related issues, but to give an overview of the vehicle emission situation. Nevertheless some typical problems with certain technologies are discussed in this report, but again on an anonymous base.

During the year 2000 the Euro 3 emission legislation and limits entered into force. In the year 2001 the in-use compliance programme therefore focused on gathering information on the emission performance of this new generation of vehicles. For administrative reasons, LPG vehicles were not included in the 2001 vehicle selection. The focus of the year 2002 was on the completion of the selection of Euro 3 vehicles and on the inclusion of LPG vehicles. The next table gives an overview of the vehicles tested in 2002.

Table 1 Vehicles tested in 2002

	Vehicle types (number)	Vehicles (number)	Tests (number)
Petrol	8	24	50
Diesel	3	9	20
LPG	5	18	45
TOTAL	17	54	115

Looking at the emission results of the initial (EU-type) test of the cars tested in 2002, it becomes clear that petrol passenger cars have become very clean under Euro 3 legislation, in most cases even being well below the Euro 4 limit values (not including the –7 °C testing). In most cases the cold start emissions (at 20 °C) are the most important emission source during the procedure, where Euro 4 vehicles seem to have a smaller cold start emission than Euro 3 vehicles. The emission results of the diesel passenger cars tested in 2002 were rather good, with one exception. The problems of 2001 regarding the PM emissions which were in many cases too high did not occur however. This could indicate that the manufacturers have their technology under control.

The emission results of the LPG cars tested in 2002 showed a somewhat mixed result, with some vehicles complying very well with the limits, and other vehicles that didn't. One Euro 2 vehicle even had difficulties in meeting the Euro 2 limits when running on petrol. Because of the concerns about the real-world emission benefits of LPG vehicles, measurements on this category of vehicles will continue in 2003. Therefore general conclusions on the environmental performance of LPG passenger cars can only be drawn when the 2003 measurements have been completed.

Additional to checking under type approval test conditions, further testing was done to establish real-world emission factors of passenger cars in order to understand the mechanisms that lead to differences between Type Approval (TA) and real-world testing. These insights are also important for emission factors modelling purposes. For this purpose additional tests were executed using two sets of special test cycles:

- Motorway traffic situations, using the categorisation from the Dutch Emissions & Congestion project, in order to extend the existing emission database with Euro 3 data (initially only Euro 1 and 2 were included).
- General real-world emissions, using the Common Artemis Driving Cycle (CADC), in order to establish emission data under dynamic circumstances for the purpose of advanced emission modelling closely linked to other European research work.

The differences in emissions between real-world driving and the TA procedure are considerable and not constant.

Based on the information gathered by using real-world driving cycles in the IUC programme for a number of years now, a first assessment is made of real-world emissions versus TA emissions of passenger cars. An important issue is the progress of emission legislation versus the developments in actual emissions of vehicles on the road. It was decided to correlate the EUDC (Extra Urban Driving Cycle) part of the European type approval cycle with categories 2C and 1C from the "Emission and Congestion" project, all being driving cycles with a warm start.
For the regulated emissions of petrol fuelled vehicles it seems that the actual effect of lower emission limits by tightened emission legislation has gradually lost its intended effect on the warm emissions in practice. One of the main reasons of this behaviour could be the European TA driving cycle that is not sufficiently representative of real-world driving. The stylistic shape and low dynamics of this cycle give the manufacturers the possibility to optimise the emissions dedicated to this procedure, instead of towards real-world driving. This effect will be further investigated in a separate effort, also for diesel- and LPG-fuelled vehicles. The results of these analyses will be reported in a separate report.
In contrast with the regulated emissions, the CO_2-emission (and thus fuel consumption) of a vehicle is much more linked to the driving energy of the cycle. In that respect, the EUDC part of the TA cycle on average correlates with (warm start) real-world driving for all legislative categories. The CO_2-emissions measured on the EUDC are comparable to the figures measured on the 2 real-world cycles.
Since the comparisons are based on warm start driving cycles in extra urban and motorway conditions, the effect of cold start on the emissions and the situation in urban conditions are not included here and should be further investigated.
It will be clear that the fact that the emissions (except CO_2) of modern vehicles do no longer correlate with the driving energy does have important consequences for present and future emission modelling techniques.

Next to the information of in-use emission performance, valuable information is gathered for supporting policy makers. This is made available by means of the Dutch emission model VERSIT and some additions to the model. For instance the Dutch annual traffic emissions are calculated using this model by input given to RIVM trough the channels of the Dutch "Taakgroep Verkeer". Typical dedicated insights from the IUC programme have been used to evaluate the environmental benefits of the traffic measures taken at Rotterdam Overschie

Further dissemination is achieved by TNO-Automotive actively taking part in ARTEMIS workshops and the DACH+NL group. Furthermore, publications have been made which were presented at the annual Transport and Air Pollution conference.

Contents

1 Introduction

This report presents a general overview of the results of the Dutch In-Use Compliance programme for passenger cars over the year 2002. The work in this year was executed under a contract with the Dutch Ministry of Housing, Spatial Planning and the Environment for the period 2000-2003. The passenger car in-use compliance programme basically assesses car emission performance in use, against the corresponding emissions legislation. In addition relevant data for emission modelling purposes are gathered and work in the EU 5th framework project ARTEMIS was undertaken. The results presented in this report are anonymised, since it is not the purpose of this report to point out typical manufacturer related issues, but to give an overview of the vehicle emission situation. Nevertheless some typical problems with certain technologies are discussed in this report, but again on an anonymous base.

The passenger car in-use compliance programme was started in 1986 in order to obtain objective relevant data on the environmental performance of the then sold first generation of "clean" vehicles. These vehicles received a tax incentive based on the expected environmental benefits, but these benefits still had to be proven in real-world use. This basic concept of vehicles proving their actual environmental performance in real-world use, is still utilised in the ongoing programme for the years 2000-2003, but with evolving vehicle technology and legislation over the years, the set-up of the in-use compliance programme has changed also. A major point that has gained importance over the years is real-world driving conditions during testing. In this respect the European Type Approval Procedure proves to be little representative for real-world driving. Therefore next to testing vehicles on the type approval procedure, additional tests are conducted to gain insight into the real-world emission behaviour of passenger cars. The data gained from testing have proved to be very useful for emission modelling purposes. Therefore gathering information on the real-world emission behaviour of passenger cars has become one of the basic targets of the Dutch in-use compliance programme.

The basic programme consists of testing about 50 different types of vehicles per year (tested basically in threefold per type). The selection of the vehicles actually tested is based on the actual sales (in the year before) of certain engine families. Generally relatively young cars are tested (usually below 35,000 kilometres in the so-called initial test) in order to check whether the cars that have actually been sold during the last years meet their emission limits "in use" also. Executing the in-use compliance programme in this set-up for many executive years now supplies a valuable database on the emission performance of the Dutch passenger car fleet. In addition to the "initial vehicles", vehicles with a higher age and mileage are tested to check whether the durability of exhaust aftertreatment systems meet the durability requirements.

During the year 2000 the Euro 3 emission legislation and limits entered into force. In the year 2001 the in-use compliance programme therefore focused on gathering information on the emission performance of this new generation of vehicles. For administrative reasons, LPG vehicles were not included in the 2001 vehicle selection. The focus of the year 2002 was on the completion of the selection of Euro 3 vehicles and on the inclusion of LPG vehicles. The next table gives an overview of the vehicles tested in 2002.

Table 2 Vehicles tested in 2002

	Vehicle types (number)	Vehicles (number)	Tests (number)
Petrol	8	24	50
Diesel	3	9	20
LPG	5	18	45
TOTAL	17	54	115

In the next chapters the results of the IUC testing are presented.

2 Petrol passenger cars

2.1 Initial tests

As explained in the introduction in principle only passenger cars meeting Euro 3 emission standards (i.e. post 2000) were tested in 2002. On some markets, however, tax incentives are given to vehicle types that already meet the 2005 Euro 4 limits. As a result of these initiatives a significant number of pre-Euro 4 vehicles also became available on the Dutch market. These vehicles were further stimulated by a tax incentive introduced by the Dutch government in 2001. In addition to this incentive, grants for economical vehicles based on the 'economy labelling' system were introduced in 2001. These incentives were granted from July 2001 until the end of 2002. Because the pre-Euro 4 versions of cars replaced their earlier Euro 3 versions completely, pre-Euro 4 vehicles were also included in the 2002 selection. Each Euro 4 vehicle in the 2002 selection (see below) had been granted this incentive.

The emission limit values in force for the petrol vehicles tested in the 2002 programme are shown in table 3.

Table 3 Emission limits type approval of passenger cars on petrol

Emission component	Euro 3 limit value (g/km)	Euro 4 limit value (g/km)
CO	2,3	1,0
HC	0,20	0,10
NO_x	0,15	0,08

The exhaust emissions are measured using the standard Euro 3 test procedure with a cold start at 20 °C. Since the –7 °C test was not yet applicable to any of the vehicles tested, the tests executed represent the full type approval test set-up for exhaust emissions.

The vehicle selection for 2002 was based on the best selling engine types/vehicles in the years 2001 and 2002. In line with discussions with the Ministry of the Environment about the IUC programme being able to address typical current topics, two vehicle types have been tested with a manual and an automatic transmission. More of these vehicles will follow in 2003 and will be separately reported in order to evaluate the effect of various forms of automatic transmissions.

Table 4 shows the 8 vehicle types that were tested in 2002.

Table 4 Vehicle types tested in 2002 (petrol)

Vehicle make	Vehicle type	Euro 3	Euro 4
Alfa Romeo	147 1.6 77 kW	X	
Citroën	Xsara Picasso 1.8I 16V	X	
Hyundai	Trajet 2.0I	X	
Opel	Corsa Z1.2XE		X
Opel	Corsa Z1.2XE Easytronic		X
Volkswagen	Polo 55 kW		X
Volkswagen	Polo 55 kW Automatic Transmission		X
Volvo	S60 2.4 103 kW	X	

In the next figure, the average emissions test results (for 3 vehicles tested per vehicle type) of each vehicle type are plotted in comparison with the Euro 3 and Euro 4 limits. For reasons of clarity the HC-and NO_x-emissions are added together, although the emission legislation treats them separately.

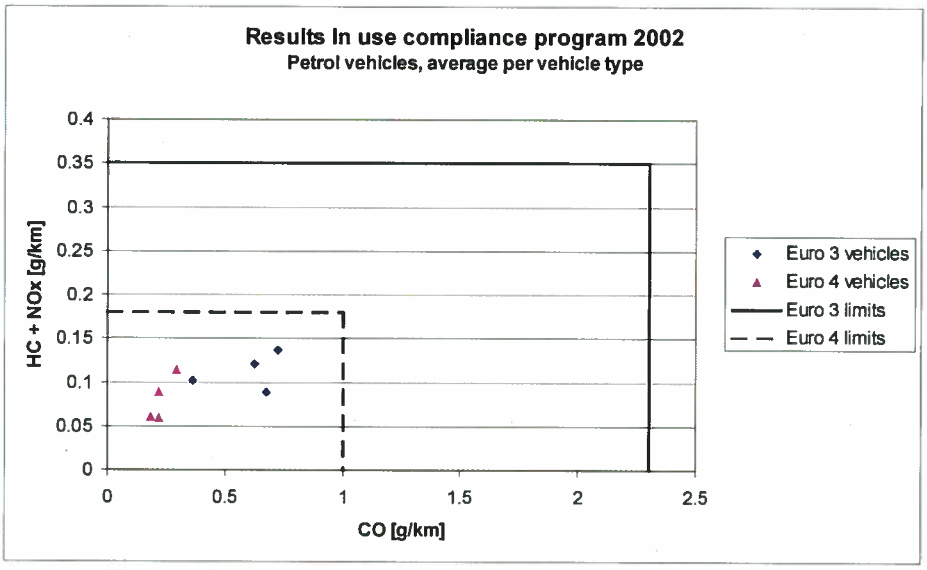

Figure 1 Results of in-use petrol passenger car types during the standard type approval test procedure.

As can be seen in figure 1, all vehicle types met the Euro 3 limits with a large margin. Likewise all Euro 4 certified vehicles met the Euro 4 limits, as did every Euro 3 vehicle. This again confirms the conclusions from earlier investigations that state that petrol vehicles are in general "one legislation step ahead of their time". Possible difficulties with petrol cars in meeting the Euro 4 limits by means of additional technologies such as HC traps, are not apparent at these low mileages. The current refined technology with high-speed lambda control, electronic throttle actuation and high catalyst activity seems already very well up to the job. The long-term durability of this technology however has still to be proven and is becoming more and more important.

All individual petrol vehicles tested in 2002 complied with the Euro 4 emission standards during initial testing; the Euro 3 vehicles perhaps with a somewhat tight margin and the Euro 4 vehicles with a very comfortable margin. This is a satisfying

result that already could be observed over the last years. Passenger car petrol technology seems to be a mature technology even shortly after the introduction of tighter emission limitations.
The investigation of the topic of "automatic transmission" proved that the vehicle equipped with a conventional automatic transmission was very sensitive for the way the throttle was operated. When the throttle was operated in such a way that the 'kick-down' was avoided, the vehicle complied perfectly. However, in the case when the 'kick-down' did occur this led to an increase of HC and CO emissions to levels higher than the limit values. The vehicle seems to be deliberately calibrated for fuel enrichment when the 'kick-down' is activated, but when driving the Eurotest there seems to be a tight margin between activating or not activating the 'kick-down'.

Figure 2 shows that the results of the individual vehicles (3 per vehicle type) do not deviate significantly from the average results per vehicle type.

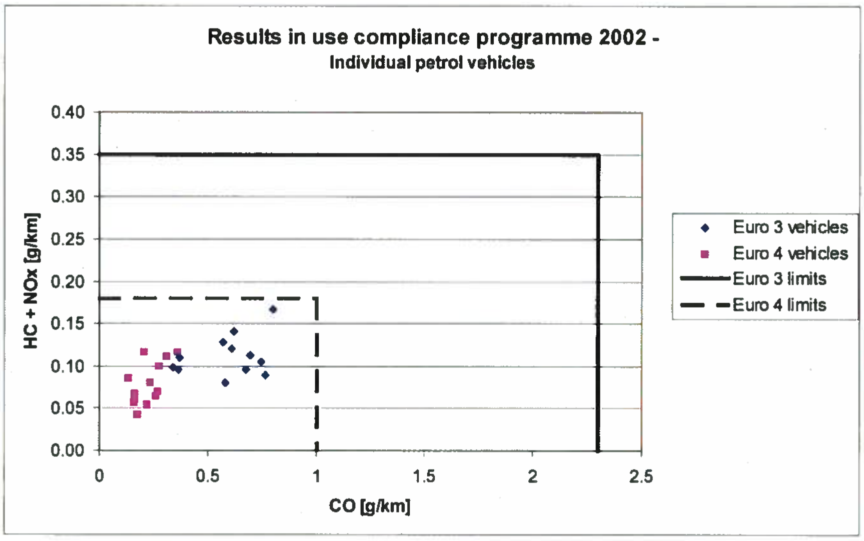

Figure 2: Results of individual in-use petrol passenger cars during the standard type approval test procedure

During the evaluation of the measurement data, additional attention has been paid to the reproducibility of modern car emissions. With absolute emissions going down to very low levels, there is some concern about the value of the data gathered on a limited number of vehicles. The emissions from Euro 3 and Euro 4 petrol vehicles are sometimes mentioned in a context of being more or less random (but below the limit values). In order to analyse this issue in more detail the triplicate measurements per vehicle type were used.

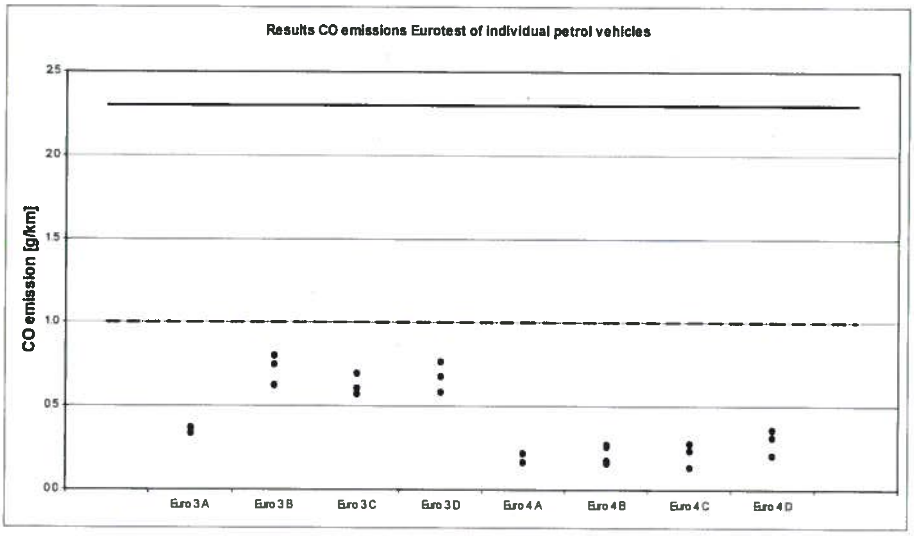

Figure 3: CO-emission of individual petrol vehicles

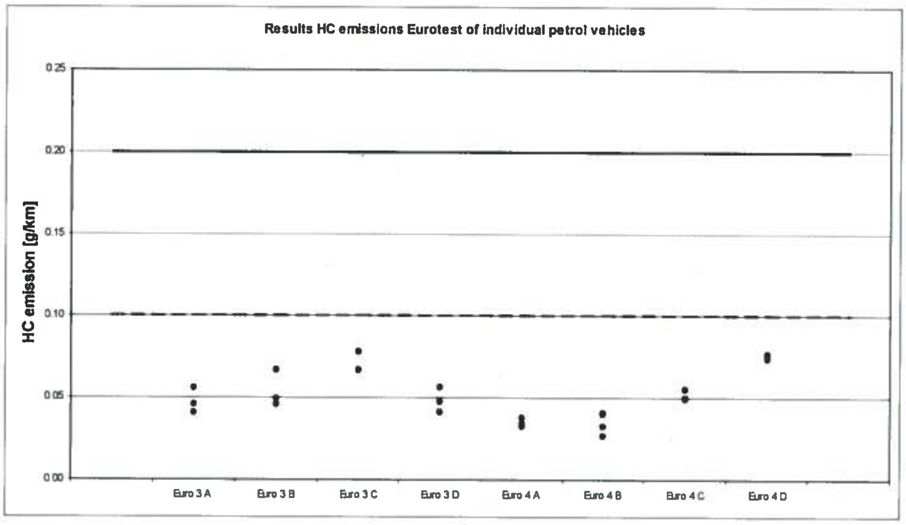

Figure 4: HC-emission of individual petrol vehicles

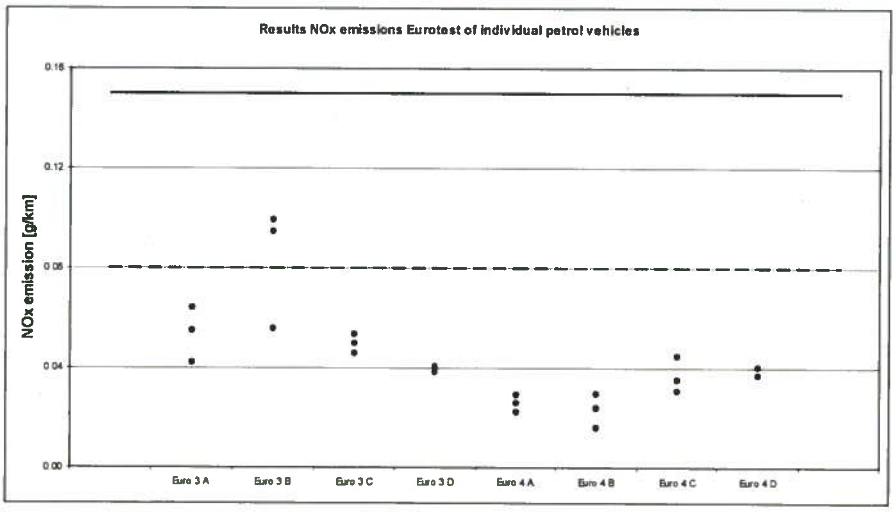

Figure 5: NO_x-emission of individual petrol vehicles

The graphs above clearly show a rather small spread for CO and HC between the three vehicles of the same type tested, and do not indicate any randomness in vehicle emissions per type. Whereas the bandwidth for CO and HC is small, for some types the bandwidth for NO_x is wider. For NO_x it is again confirmed that for some vehicle types the differences between vehicles of the same type may be in the same range as the differences in emissions between vehicles from different makes. This fact has clear implications for the way conclusions should be drawn concerning emission behaviour from small vehicle samples.

In this presentation the large "safety margin" for all vehicles relative to the limit values is again clearly visible.

2.2 Cold start emissions

Apart from executing the standard Euro 3 testcycle with a 20 °C cold start, one vehicle per vehicle type underwent an additional test to collect data on the effects of a cold start on emissions. For this purpose, the urban part of the Eurotest was driven twice: (1) with a cold start from 20 °C and (2) with a hot start (conditioned on a full UDC + EUDC). The difference between the two values is the "cold start emission factor" in g/cold start or g/km after cold start. This value is important for emission modelling purposes. The differences in emissions between cold and hot start are mainly caused by the time it takes for catalyst to reach light-off temperature from cold start. Additional the cold start enrichment (and therefore non $\lambda=1$ operation) will most probably play no role of any importance, since at or above 20 °C this way of fuelling is not often utilised anymore in modern multipoint injected engines. In the next figures, the results for petrol engines are plotted per emission component.

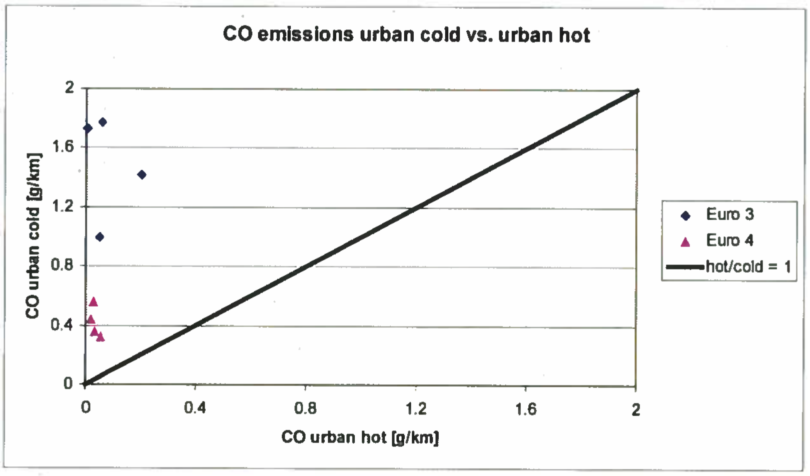

Figure 6: UDC cold start emissions versus UDC hot start emissions: CO

As can be concluded from this figure, the CO emissions after hot start are mostly close to zero, whereas the cold start emissions are higher and vary considerably from 0,3 g/km to 1,7 g/km. Apparently the 'hot' and 'cold' emissions have no direct relation to each other and differ considerably from car type to car type. Euro 3 and Euro 4 vehicle types can be clearly distinguished, the Euro 4 vehicles having a much smaller increase of emissions under cold start conditions. These vehicles have clearly an optimised cold start strategy for meeting the type approval test at –7 °C. This effect is enabled by a fast catalyst light-off. For modelling purposes the average "extra cold start emission" is calculated as one single figure per vehicle class.

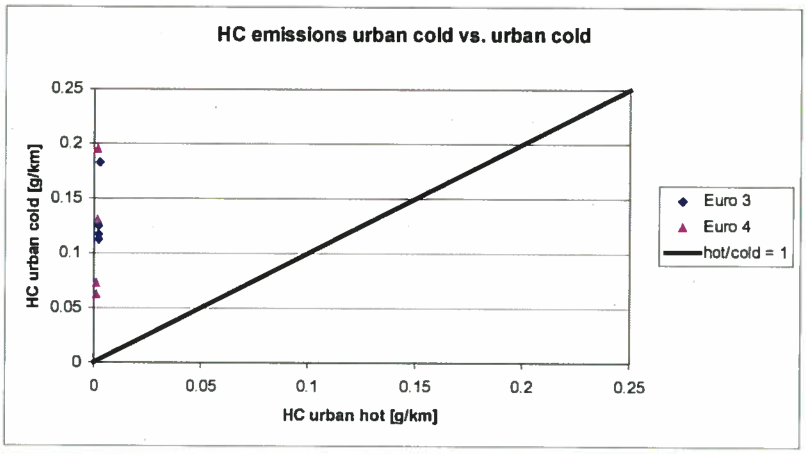

Figure 7: UDC cold start emissions versus UDC hot start emissions: HC

Even more pronounced as for CO emissions, the HC emissions under hot conditions are at an extremely low level, whereas the cold emissions are considerably higher and vary considerably from 0,06 g/km to 0,2 g/km. However, Euro 3 and Euro 4 vehicles do not show any remarkable differences, as was the case for CO.

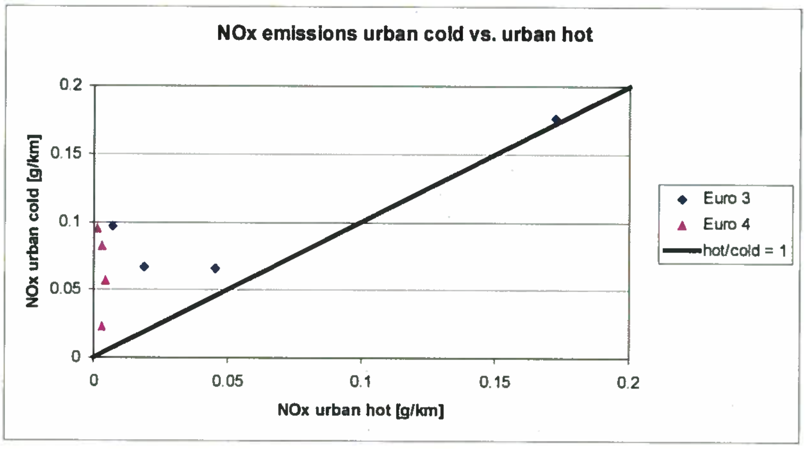

Figure 8: UDC cold start emissions versus UDC hot start emissions: NO_x

Looking at the cold start and hot start NO_x emissions of Euro 3 vehicles, the influence of a cold start seems to be much smaller than for CO and HC emissions. Note that the values are relatively low (because of the low loads and engine temperatures in the urban part of the UDC). The Euro 4 vehicles show a cold start behaviour that resembles the CO and HC cold start effect, which indicates much progress has been made on early (after cold start) catalyst light off.

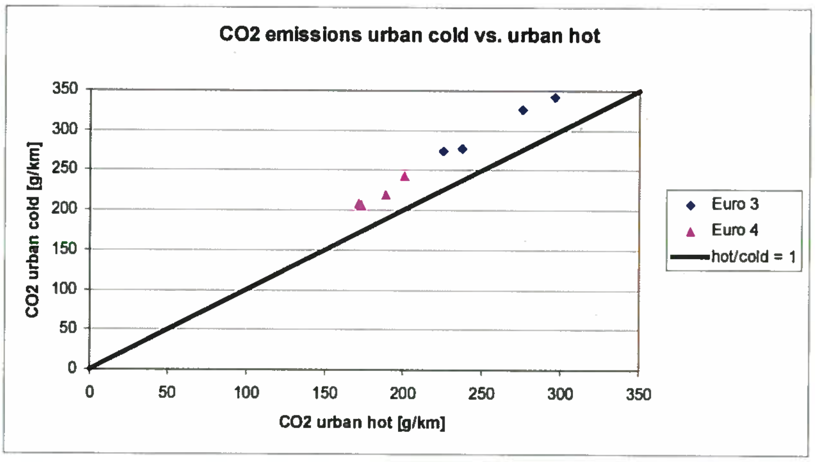

Figure 9: UDC cold start emissions versus UDC hot start emissions: CO_2

CO_2-emission increase at cold start shows a stable picture, averaging at an increase of 19 %. This effect points at increased friction at a 20 °C start and probably some minor cold start enrichment effects. Euro 3 and Euro 4 vehicles do not show any significant differences.

2.3 Discussion of results petrol

From the previous section can be concluded that new petrol vehicles have very low emission levels. All of the vehicles tested in 2002 complied with the pre-Euro 4 limits (without the –7 °C test), even the Euro 3 vehicles. What also became more apparent from the cold start test at 20 °C was the fact that petrol vehicle emissions are to a large extend caused by the cold start.

3 Diesel passenger cars

3.1 Initial tests

As explained in the introduction only Euro 3 diesel vehicles were tested in 2002. The selection consisted of only 3 types since only a few new (not earlier tested) diesel engine types were introduced in 2001. In some foreign markets, grants are given to vehicle types that already meet the 2005 Euro 4 limits. However, since diesel technology is struggling much more with Euro 3 emission limits that petrol technology, there was only one small, Euro 4 diesel car on the market in 2002 (VW Lupo 3L), this category was not tested in 2002.

The emission limit values in force for diesel Euro 3 vehicles are shown in table 5

Table 5 Emission limits type approval of passenger cars on diesel.

Emission	Euro 3 limit value (g/km)
CO	0,64
NO_x	0,50
HC + NO_x	0,56
PM	0,05

The exhaust emissions are measured using the standard Euro 3 test procedure. The vehicle selection 2002 was based on the best selling vehicles in the years 2001 / 2002.

Table 6 shows 3 vehicle types that were tested in 2002.

Table 6 Vehicle types tested in 2002 (diesel)

Vehicle make	Vehicle type
Opel	Vectra Y2.2DTR
Renault	Laguna 1.9 DCI EURO 2000
Volvo	S60 D5

In the next figures, the average results of each vehicle type are plotted in relation to the Euro 3 limits. Later in this section actual problems encountered with Euro 3 diesel cars will be further discussed.

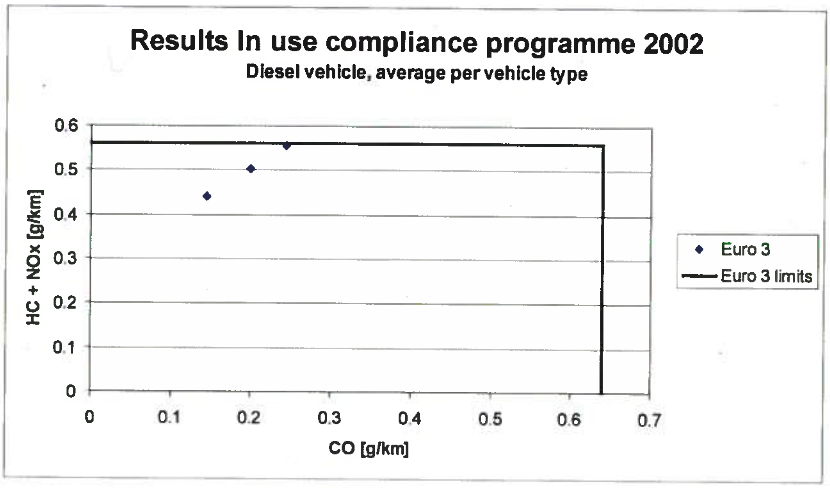

Figure 10:Results of in-use diesel passenger car types during the standard type approval test procedure: CO and HC+NO_x

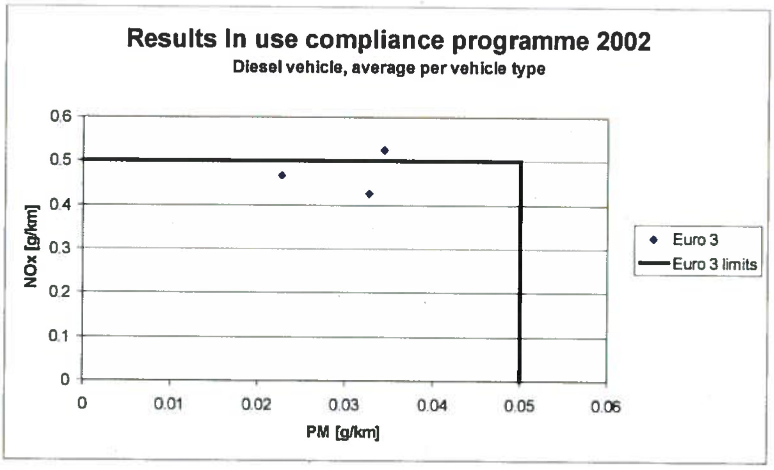

Figure 11:Results of in-use diesel passenger car types during the standard type approval test procedure: PM and NO_x

From these figures it can be concluded that the tested vehicles performed close or even above the HC+NO_x and NO_x limit. In contrast to the 2001 vehicles, the PM limit was no problem for the 2002 vehicle selection. Meeting the CO limit proved to be no problem at all.

The results of the individual vehicles tested are displayed in the next two figures.

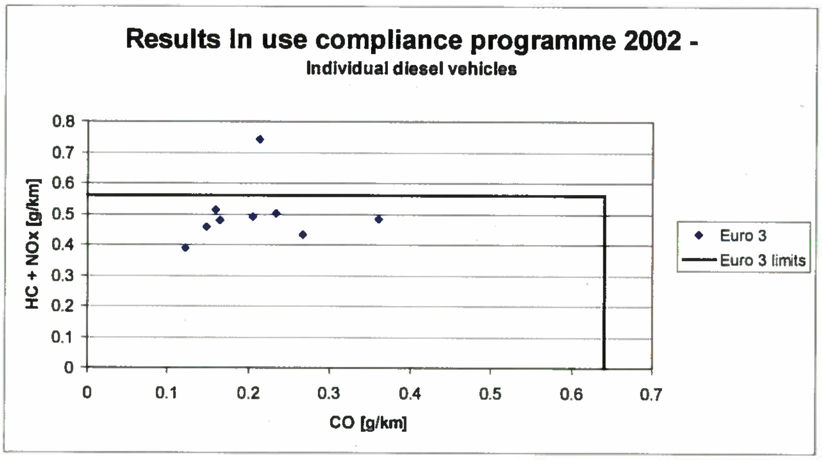

Figure 12: Results of individual in-use diesel passenger cars during the standard type approval test procedure: CO and HC+NO_x

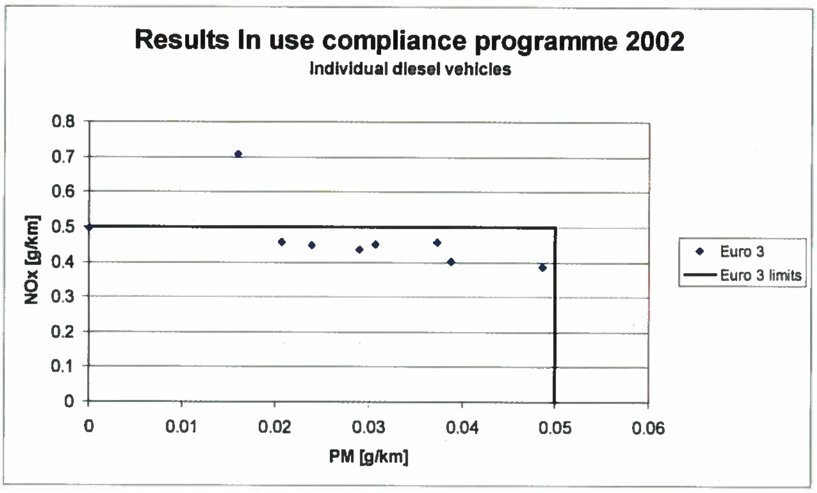

Figure 13: Results of individual in-use diesel passenger cars during the standard type approval test procedure: PM and NO_x

The results of the individual vehicles show the same picture as the average results per vehicle type. Only one vehicle exceeded the NO_x limit. It was decided to include 2 more vehicles of this type in the 2003 vehicle selection to analyse if this should be regarded as an incident or if there is a more structural problem.

The detailed analyses of the emission performance of vehicles from the same type (as shown below), show a different situation than was the case for petrol cars. NO_x and sometimes PM emissions are rather close to the limits. One type only passed the NO_x limit because the average of 3 cars was below the limit. The bandwidths of PM and CO are rather large and the NO_x emissions seem rather stable, as shown below.

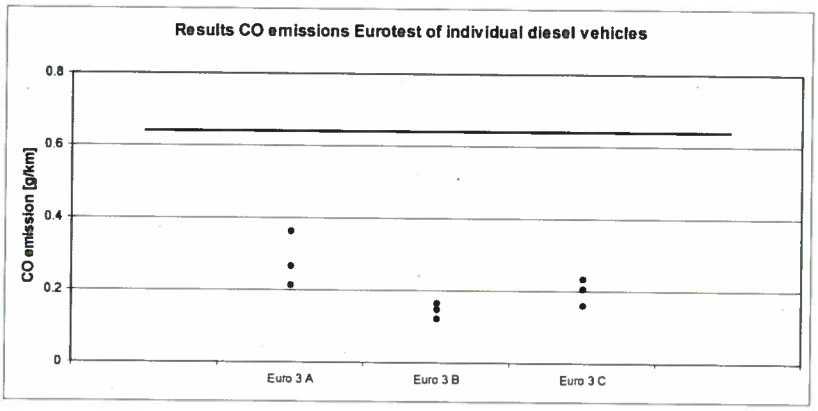

Figure 14:CO-emission of individual diesel vehicles

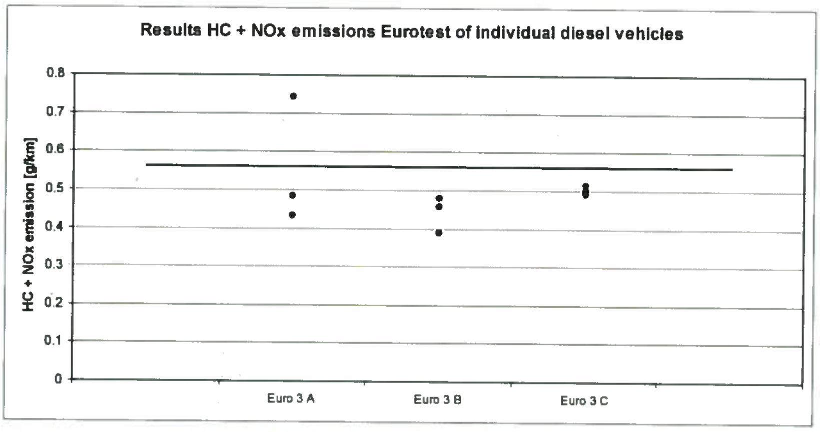

Figure 15: HC + NO_x-emission of individual diesel vehicles

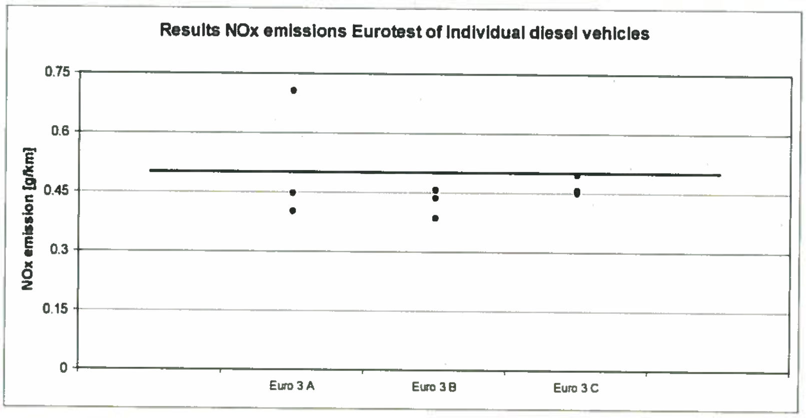

Figure 16:NO_x-emission of individual diesel vehicles

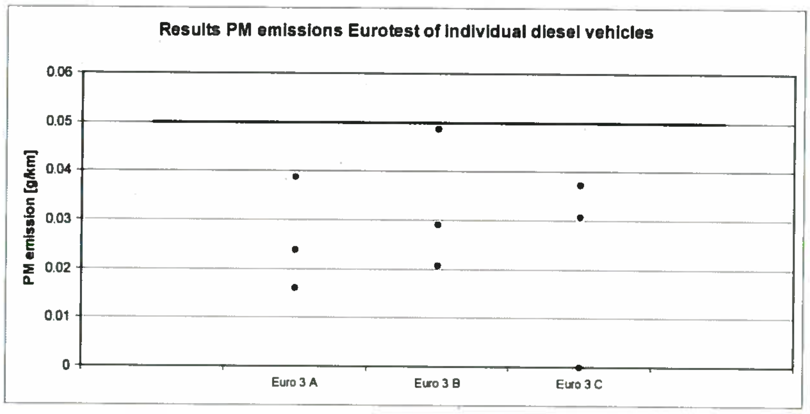

Figure 17:PM-emission of individual diesel vehicles

3.2 Cold start emissions

For the same reason as for petrol cars, the additional emissions due to a 20 °C cold start were measured. The results are presented below.

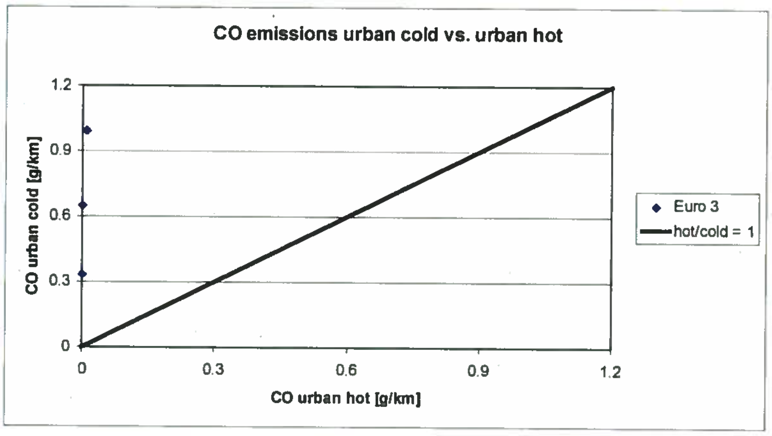

Figure 18:Diesel UDC cold start emissions versus UDC hot start emissions: CO

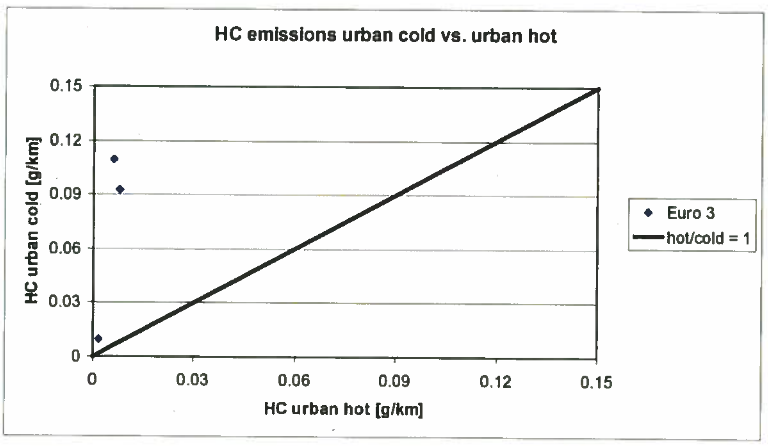

Figure 19:Diesel UDC cold start emissions versus UDC hot start emissions: HC

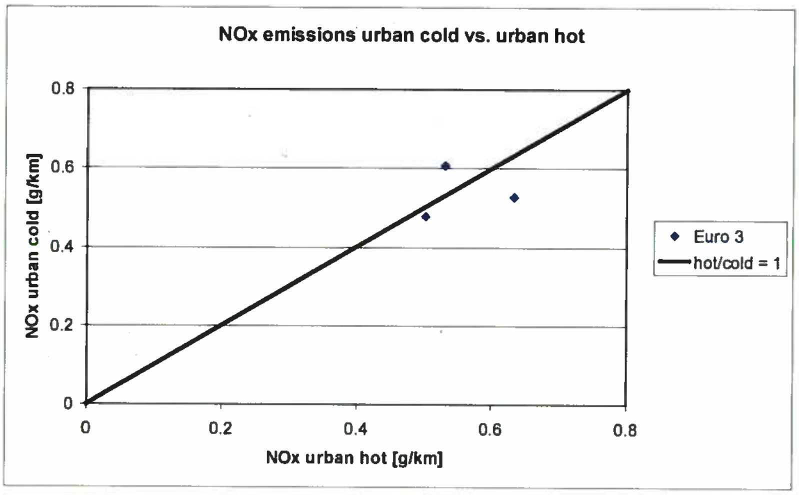

Figure 20:diesel UDC cold start emissions versus UDC hot start emissions: NO_x

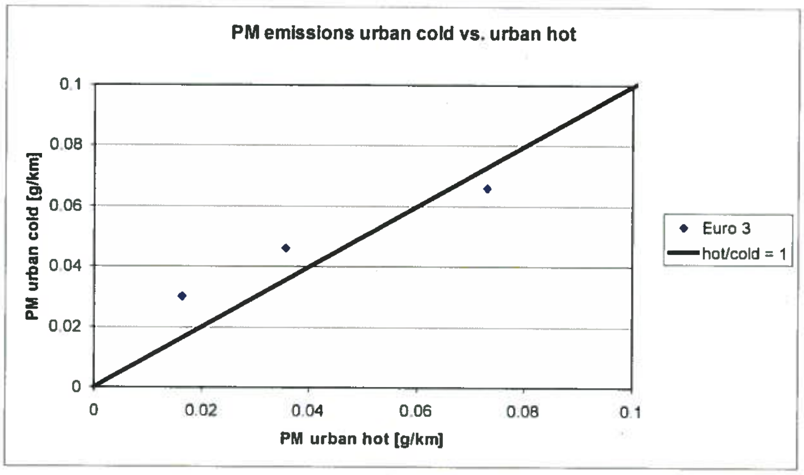

Figure 21:Diesel UDC cold start emissions versus UDC hot start emissions: PM

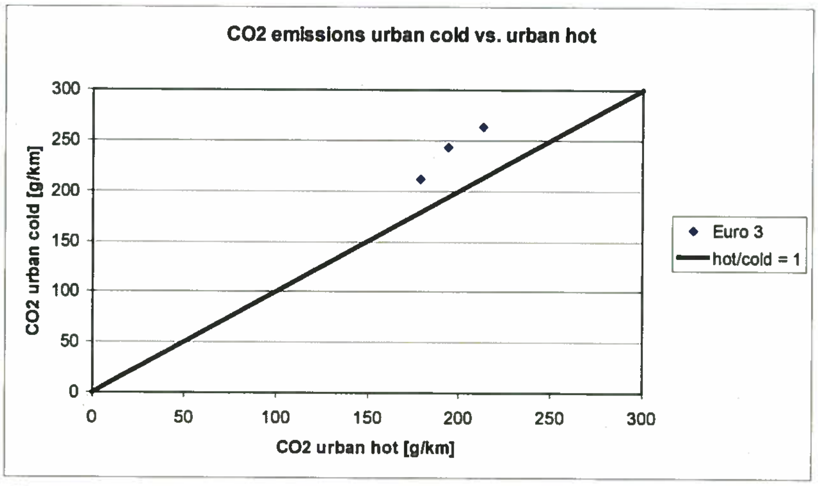

Figure 22:Diesel UDC cold start emissions versus UDC hot start emissions: CO_2

From the graphs presented above it can be concluded that the HC and CO emissions of diesel cars are always nearly close to zero, but the cold emissions vary a lot. The cause for this is (in analogy with petrol vehicles) the period until light-off of the catalyst (in this case an oxidation type), during which products of incomplete combustion are not oxidised in the catalyst before being emitted. After light-off of the catalyst emissions drop to almost “0”. For PM there seems to be almost no cold start increase of emissions which indicates that the combustion properties of modern diesel engines appear to be optimal directly after cold start.

NO_x emissions prove not to be affected by the cold start, which is rather logical, taking into account that there was no thermal aftertreatment system for NO_x in the tested vehicles that could be subject to heating up effects. The NO_x reduction of the vehicles tested is obtained by exhaust gas recirculation, the effectiveness of which in theory can be dependant on the exhaust gas and engine temperature, but this factor seems to play an unimportant role at cold start. Future technology (particulate traps and NO_x-storage systems) will most probably be more affected by cold start, but this is something that at this moment in time is only brought on the market by one manufacturer and will be dealt with in the 2003 programme.

There is also an effect on the CO_2-emissions resulting from the cold start (+23%), caused by increased friction directly after cold start. Fuel enrichment is no issue for diesel engines.

3.3 Discussion of results diesel

The Euro 3 diesel-vehicle emissions proved to be within the limits, with one exception. The problems encountered during 2001 regarding PM emissions did not occur in 2002. In fact, there was only one vehicle that had a PM emission close to the limit, the others performed well below the limit. The NO_x emissions were all close to the limit, with one vehicle exceeding the limit. Although only three vehicle types were tested in 2002, this could indicate that manufacturers have developed their injection systems to such level that the PM emission is fully under control. This allows them to optimise their engines towards a lower fuel consumption by allowing a NO_x emission close to the limit.

4 LPG passenger cars

4.1 Initial tests

In the Netherlands, the third 'mainstream' fuel for passenger cars, next to petrol and diesel, is LPG. Although the LPG market share has decreased during the last decade, vehicles equipped with a LPG system (mostly retrofitted) form a considerable share of the Dutch vehicle fleet (± 10% of total mileage driven). Therefore LPG vehicles are also included in the In-Use compliance programme.

In order to be granted with the incentives from the Dutch government in the form of road tax reduction, LPG vehicles have to meet the so-called G3 specifications. In relation to the limits this means that the emissions should be below 70% of the Euro 2 petrol vehicle limits of 1997. This implicates that the LPG vehicles have to be tested on the 'old' Eurotest including 40 seconds idling before the measurements start. In the current Euro 3 procedure the measurements start directly after the engine is started.
Euro 3 petrol cars have been tested on the new Euro 3 test procedure, without 40 seconds idling. Therefore the LPG G3 emission values can't be compared directly with the Euro 3 emission values of petrol.

The emission limit values in force for the LPG vehicles tested in the 2002 programme are shown in table 7.

Table 7 Emission limits G3 specifications of passenger cars on LPG

Emission component	G3 specification (= 70% of Euro 2) (g/km)
CO	1,54
$HC+NO_x$	0,35

The vehicle selection 2002 was based on the best selling combination of engine type/vehicle and LPG retrofit system in the years 2001 and 2002.

Table 8 shows the following 5 vehicle types that were tested in 2002:

Table 8 Vehicle types tested in 2002 (LPG)

Vehicle make	**Vehicle type**	**LPG equipment manufacturer**	**legislation category of reference petrol vehicle**	
			Euro 2	**Euro 3**
Alfa Romeo	147 1.6 77 kW	Vialle		X
Citroën	Xsara Picasso 1.8l 16V	Autogas Holland		X
Mitsubishi	Carisma 1.6	Vialle	X	
Renault	Megane Scenic 1.6 16v	Eurogas		X
Volvo	S60 2.4 103 kW	Vialle		X

In the next figure, the average results (for 3 vehicles tested per vehicle type) of each vehicle type are plotted in comparison with the G3, Euro 2 and Euro 3 limits, where applicable. In the case when a LPG vehicle exceeded the Euro 2 limit (not the G3 specification) a correction on the vehicle was performed after which the vehicle was tested a second time.

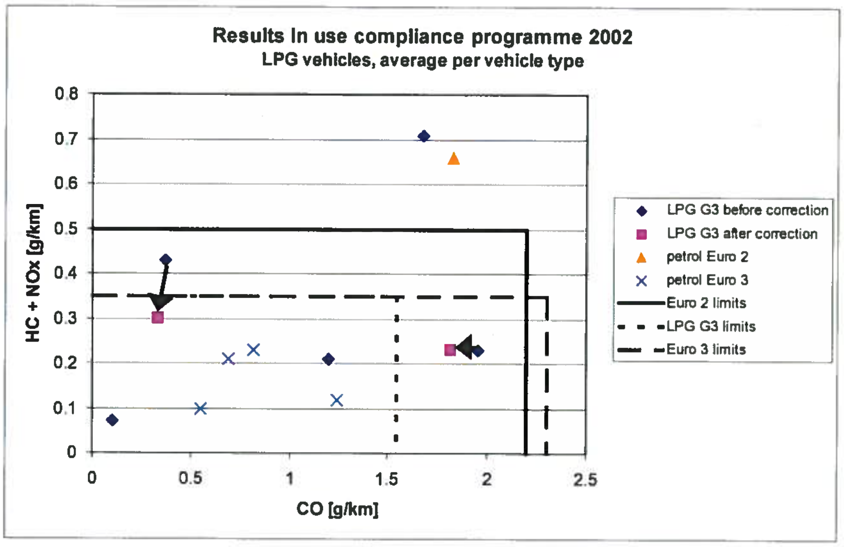

Figure 23:Results of in-use LPG passenger car types during the standard type approval test procedure

The figure above shows a large variation of the results. The Euro 3 petrol tests showed that these vehicles met the corresponding limits with a large margin. The Euro 2 vehicle however, exceeded the HC+NO_x limit quite excessively on petrol. Consequently, when this vehicle was tested on LPG it failed also. Furthermore it is not clear how this Euro 2 vehicle could have been put on the road on LPG in 2001 when the Euro 3 legislation was already in force. It was decided not to retest these vehicles after correction.
Two out of the other four LPG vehicle types performed well and very well. The last two LPG vehicle types exceeded the G3 limit values on the initial test, one of which passed the test after correction. For both vehicle types it was decided to test 2 more vehicles in the 2003 programme.

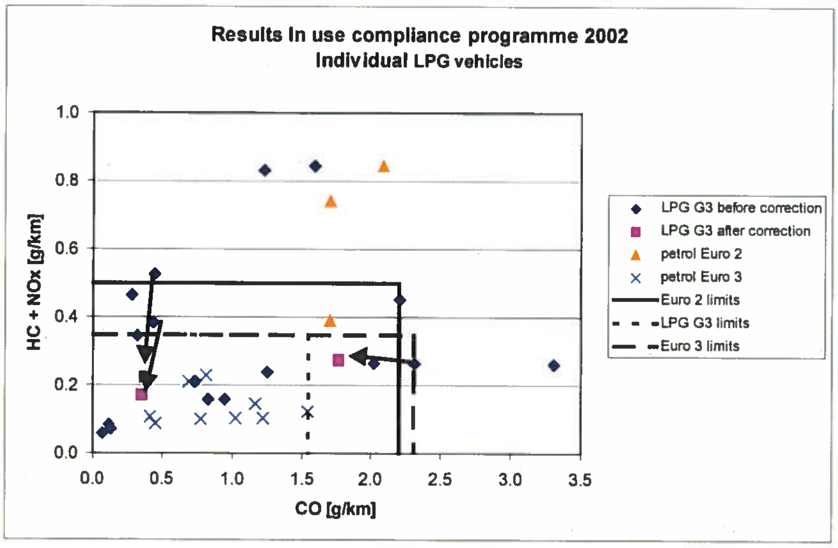

Figure 24:Results of individual in-use LPG passenger cars during the standard type approval test procedure

The emission results of the individual vehicles shows the same picture as the aggregated results per vehicle type.

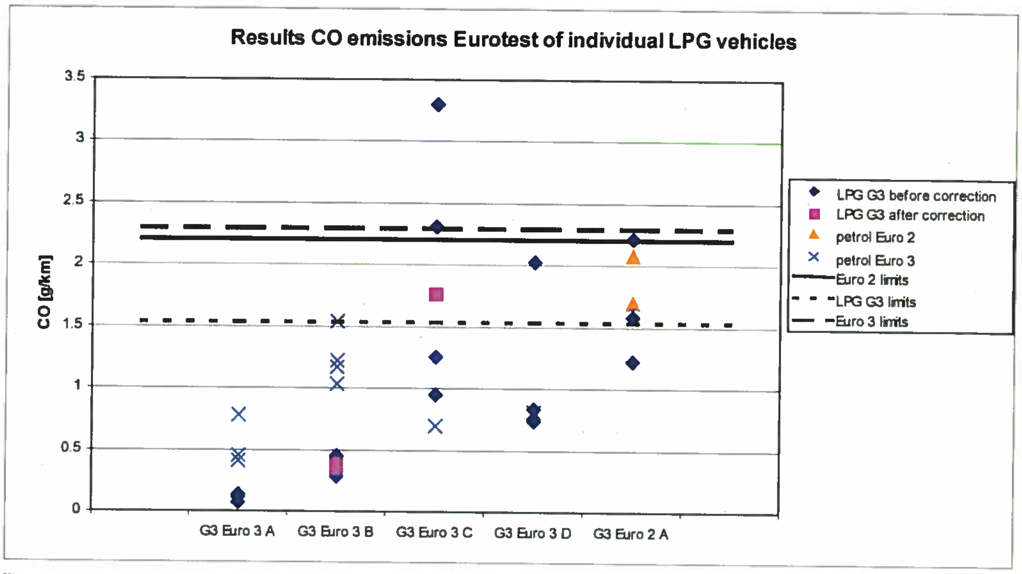

Figure 25:CO-emission of individual LPG vehicles

From the figure above it can be concluded that vehicle Euro 3 A and Euro 3 B complied very well with their respective CO-limit. Because of the differences between the Euro 2 and Euro 3 testprocedure it is not possible to compare the LPG and petrol results, however. Vehicles Euro 3 C and Euro 3 D complied well with the Euro 3 petrol CO-limits, but not every vehicle running on LPG passed the initial test. As already mentioned, two more vehicles of both types will be tested in the year 2003. The Euro 2 vehicle performed the same on both petrol and LPG; one vehicle almost exceeded the petrol Euro 2 CO-limit and two LPG vehicles not meeting the LPG G3 CO-limit.

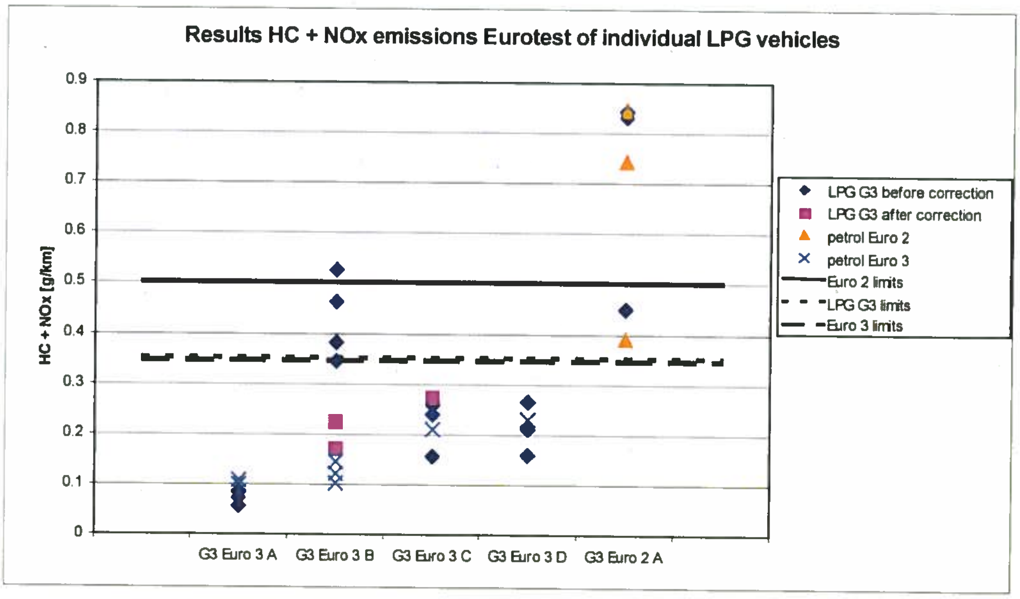

Figure 26:HC+NO_x-emission of individual LPG vehicles

From this figure it can be concluded that vehicle Euro 3 A, Euro 3 C and Euro 3 D complied well with their respective HC+NO_x-limit. Because of the differences between the Euro 2 and Euro 3 testprocedure it is not possible to compare the LPG and petrol results however, just as in the case of the CO results. Vehicle Euro 3 B failed in three cases on the initial test, but gave satisfactory results after correction. Two out of three Euro 2 vehicles did not meet the Euro 2 petrol HC+NO_x-limit, and none of them met the LPG G3 HC+NO_x-limit.

4.2 Cold start emissions

Apart from executing the standard Euro 2 testcycle from cold start, one vehicle per vehicle type underwent an additional test to collect data on the effects on emissions of a cold start. For this purpose, the urban part of the Eurotest was driven twice: (1) with a cold start from 20°C and (2) with a hot start (conditioned on a full UDC + EUDC). The differences in emissions are mainly caused by the time it takes to reach catalyst light-off temperature from cold start. The difference between both figures gives the additional emission during a cold start. This value is important for emission modelling purposes. In the next figures, the results for LPG vehicles are plotted per emission component.

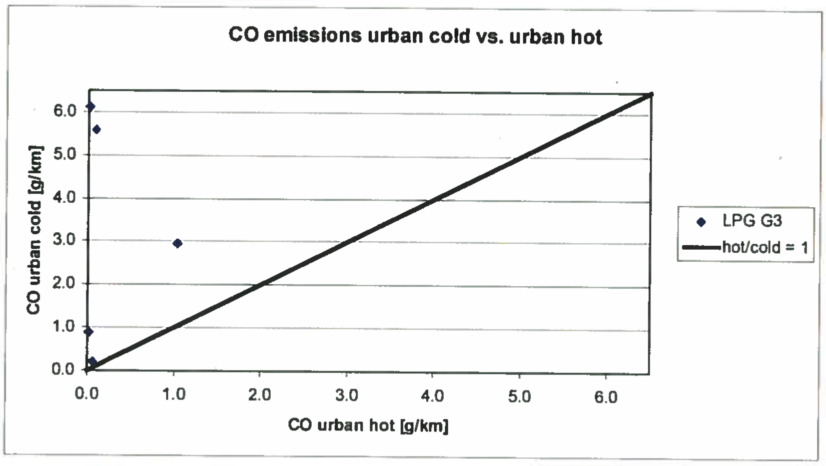

Figure 27:LPG UDC cold start emissions versus UDC hot start emissions: CO

As can be concluded from this figure, the CO emissions after a hot start are close to zero, whereas the cold start emissions are higher and vary considerably, just like the effects observed with the petrol vehicles.

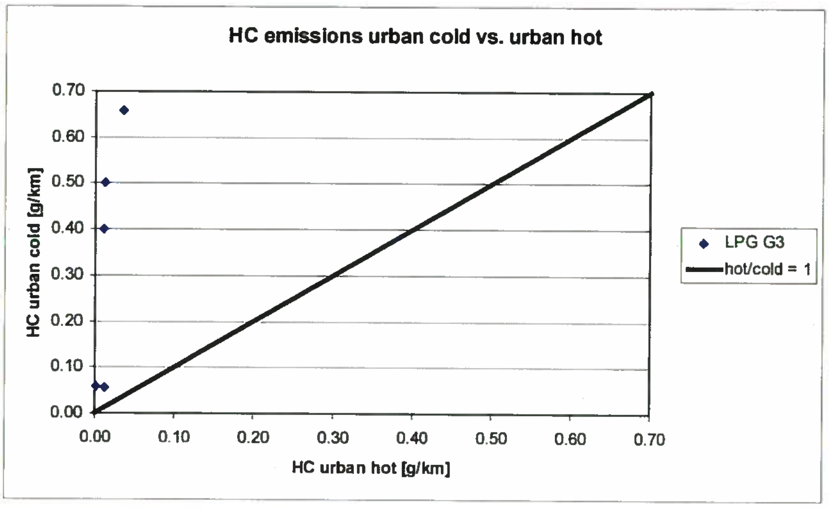

Figure 28:LPG UDC cold start emissions versus UDC hot start emissions: HC

Just as for CO emissions, the HC emissions under hot conditions are at a very low level, whereas the cold emissions are considerably higher and vary considerably.

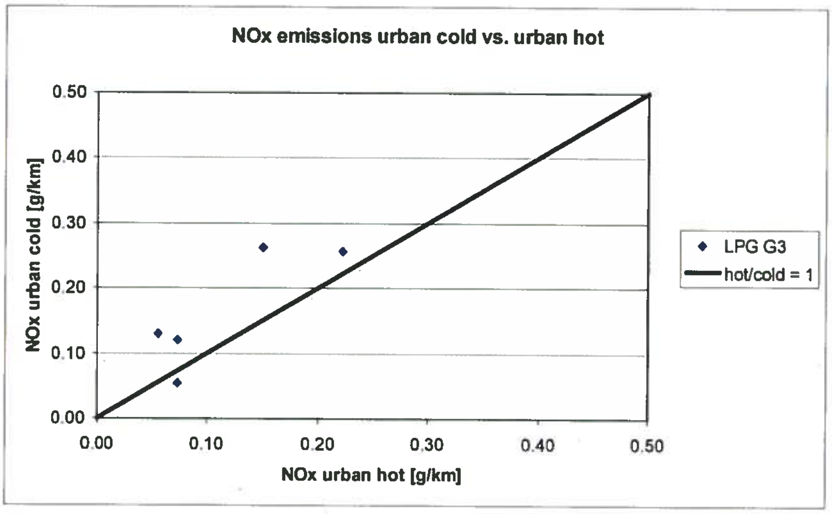

Figure 29:LPG UDC cold start emissions versus UDC hot start emissions: NO_x

The differences between cold start and hot start NO_x emissions are smaller when compared to the CO and HC emissions. In one case the cold start emission even appeared to be marginally lower than the hot start emission. A possible explanation could be a rather high cold start enrichment effect, when starting on petrol fuel.

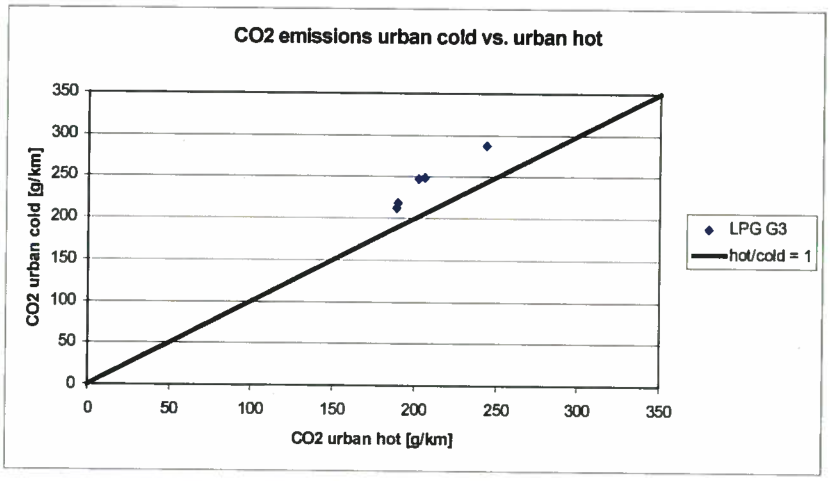

Figure 30:LPG UDC cold start emissions versus UDC hot start emissions: CO_2

CO_2 emission increase at cold start shows a stable picture, averaging at an increase of 18 %. This effect points at increased friction at a 20 °C start and probably some minor cold start enrichment effects. The figure is comparable to the effect of petrol cars.

4.3 Discussion of results LPG

Because these tests were part of a LPG test programme that runs in 2002 and 2003 it is too early yet to draw any conclusions on the vehicles tested in 2002. As soon as the LPG vehicle selection is completed with five more vehicle types in 2003, all results will be presented in a separate report.

5 Real-world emissions

Another, and increasingly important, objective of the Dutch in-use compliance programme is to gather information on the real-world emission behaviour of vehicles on the road. With changing situations on the roads, and vehicle technology being able to adapt to these changed situations, the data gathered using the European type approval procedure is more and more losing its value as representative emission data. These data were not really meant to be used for this purpose, but have been used as (a basis for) emission factors for a long time, since little else was available and originally they could be used for this purpose without much error. More recently the increasing discrepancy between type approval testing and real-world emissions has been acknowledged by some European research institutes, leading to a demand for real-world test procedures (starting with real-world test cycles). These test cycles have their origin in a large amount of real-world recorded trip data, which have been "compressed" to short test cycles to be driven on a chassis dynamometer.

For the purpose of deriving real-world emission factors for the Dutch national situation, in fact two things are needed: 1) Dutch real-world driving cycles, and 2) data of a representative Dutch vehicle sample. The second issue is easy to solve within the Dutch in-use compliance programme, since one of the main ideas behind the programme is exactly to test a sample that is representative for the Dutch fleet. The first issue is more difficult to address, since there is no national average set of real-world driving patterns. The only option at this moment close to a national set, is a set of 11 different driving patterns that have been recorded on Dutch motorways in 1999 (Emissions and congestion project). For the urban and rural part of real-world driving the Common Artemis Driving Cycles (CADC) were added to the 2002 testprogram, and the MODEM/HYZEM cycles, used until 2001, were dropped. The CADC cycles have been developed in the European 5th Framework project Artemis in which all prominent European institutes participated. As a result, these cycles are considered representative for the average European real-world driving.

In summary, it was decided to use:
1 the 'Emissions and congestion' test cycles
2 the Common Artemis Driving Cycles (CADC)
for determining the real-world emissions of the Dutch car fleet as sold in 2001 and 2002. In practice this meant that from every vehicle type selected one vehicle was additionally tested on test 1, and another one was additionally tested on test 2.

The results from using both test cycles will be further discussed in the following sections.

5.1 Emissions and congestion

On behalf of the Transport Research Centre of the Dutch Ministry of Transport and the Dutch Ministry of Housing, Spatial planning and the Environment, TNO carried out a research programme in order to determine the effects of road traffic congestion on exhaust gas emissions and fuel consumption of road vehicles on motorways. The need for information on this topic occurred when policy makers wanted to know what the benefits for emissions could be of decreasing traffic congestion by using traffic management measures. As a result an extensive research programme was executed in 1999 and 2000, that is described in the reports [1, 2, 3, 4]. Important milestones in this project were the development of test cycles that represent Dutch motorway traffic and an extensive measurement campaign in which 19 vehicles were tested in the TNO laboratory on these test cycles. Table 3 shows the congestion categorisation used in the project.

Table 9 Congestion categorisation as used in the study

Congestion category	*Definition*
1aa	Speed <10 km/h; 'stop and go'
1ab	Speed between 10 and 25 km/h
1a	1aa and 1ab combined, speed between 0 en 25 km/h
1b	Speed between 25 and 40 km/h
1c	Speed between 40 and 75 km/h
2a	Speed 75-120 km/h, traffic volume over 1000 vehicles per lane per hour, speed limit = 100 km/h
2b	Speed 75-120 km/h, traffic volume over 1000 vehicles per lane per hour, speed limit = 120 km/h
2c	Speed 75-120 km/h, traffic volume below 1000 vehicles per lane per hour, speed limit = 100 km/h
2d	Speed 75-120 km/h, traffic volume below 1000 vehicles per lane per hour, speed limit = 120 km/h
2e	Speed over 120 km/h, independent of traffic volume
3	Traffic jam 'avoidance' route

When the emission results were weighted for their share in the Dutch vehicle fleet of 1998, the following relatively weighted 'bathtub-shaped' emission correction curves were constructed for the national Dutch vehicle fleet. Driving pattern 2C is put at 100%.

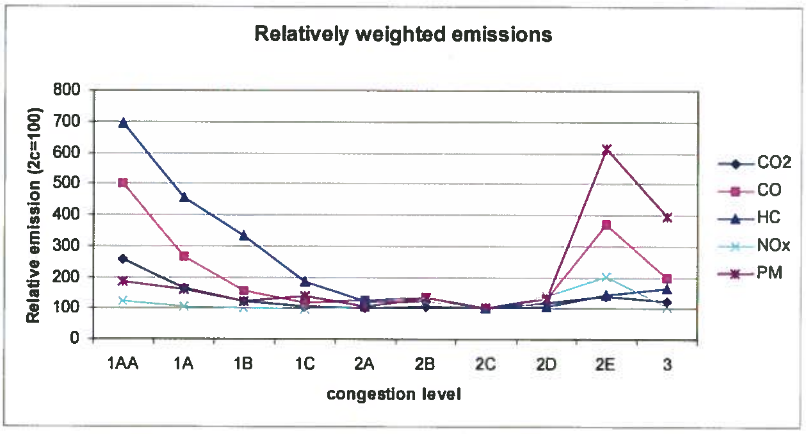

Figure 31:Relative emission profile total Dutch fleet in 2000 (2C=100)

The vehicle selection used in the study mentioned only consisted of cars up to Euro 2. In order to gain more insight into the actual situation on the road and to make the predictions for the future more accurate, it was decided to subject the 2001 and 2002 Euro 3 and Euro 4 vehicle selection to these real-world motorway test cycles in order to update these curves. The next figures show the overall relative results of the 2001 and 2002 vehicle selection together, also showing the results of the Euro 1 and 2 technology cars tested earlier.

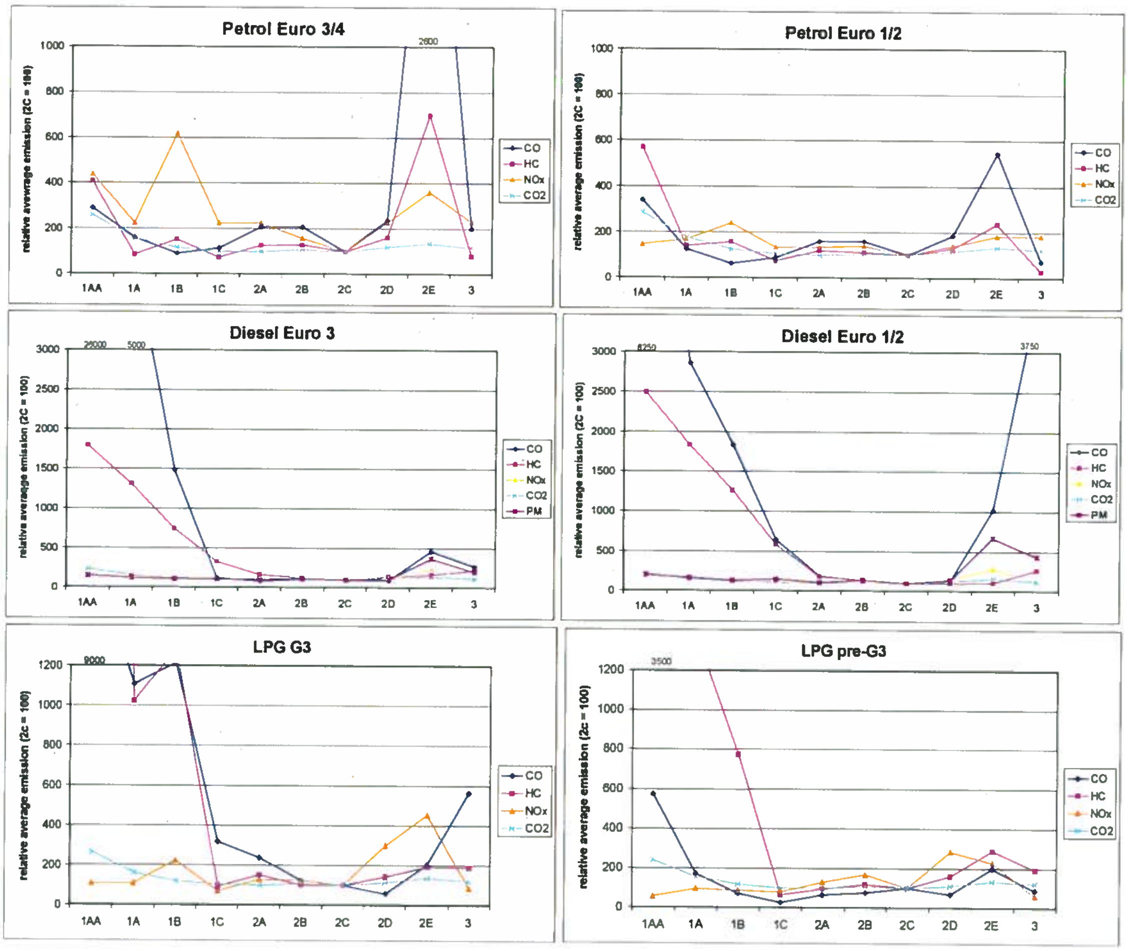

Figure 32: Relative average emission profiles of all separate vehicle categories (2C is 100%)

Looking at the results of the latest investigation using the "Emissions and Congestion" test cycles, for the first time involving Euro 3 and Euro 4 cars, some clear trends can be observed.
The "bathtub" shaped emissions profile going from "stop and go" to "free flow on motorway" is still present, although for petrol cars there seems to be a slight increase in sensitivity towards different driving patterns. This is especially the case for HC and CO, which points to periods of Lambda being <1 (rich) for some time. For diesel cars the increase of CO and PM at high-speed driving seems to be limited for Euro 3 technology. For LPG vehicles, the same pattern remains apparent. Only the CO emissions have become somewhat more sensitive for driving patterns with high dynamics.

More detailed results can be found in Appendix A.

In addition to the relative behaviour of emission patterns as a result of different types of real-world driving behaviour (as shown in the graphs above), it is interesting to evaluate the absolute differences in emissions between past (Euro 1+2) and present engine technology (Euro 3+4). This effect is presented in the next tables.

Table 10 The differences between Euro 3/4 vehicles and Euro 1/2 vehicles, compared to the emission value of Euro 1/2 for that cell (% decrease/increase) ***Petrol vehicles.***

	Differences in emissions, Euro 3 and 4 vehicles versus Euro 1 and 2 vehicles, petrol (%)									
	1AA	1A	1B	1C	2A	2B	2C	2D	2E	3
CO	-48	-24	-14	-22	-21	-22	-38	-23	144	75
HC	-66	-73	-55	-56	-50	-46	-52	-41	42	28
NO_x	-8	-55	-27	-50	-54	-65	-76	-52	-35	-69
CO_2	-9	-10	-8	-5	1	3	2	3	2	-6

Table 11 The differences between Euro 3/4 vehicles and Euro 1/2 vehicles, compared to the emission value of Euro 1/2 for that cell (% decrease/increase)) ***Diesel vehicles.***

	Differences in emissions, Euro 3 and 4 vehicles versus Euro 1 and 2 vehicles, diesel (%)									
	1AA	1A	1B	1C	2A	2B	2C	2D	2E	3
CO	-54	-84	-92	-98	-95	-91	-90	-92	-95	-99
HC	-82	-82	-85	-86	-76	-76	-74	-64	-60	-78
NO_x	15	13	2	-14	4	0	5	-9	-12	-7
CO_2	2	3	-1	-7	-3	-6	-5	-8	-15	-8
PM	-69	-70	-65	-70	-61	-66	-58	-67	-77	-80

Table 12 The differences between Euro 3/4 vehicles and Euro 1/2 vehicles, compared to the emission value of Euro 1/2 for that cell (% decrease/increase) ***LPG vehicles.***

	Differences in emissions, LPG G3 2002 vehicles versus LPG G3 1996-200 vehicles, LPG (%)									
	1AA	1A	1B	1C	2A	2B	2C	2D	2E	3
CO	-85	-71	-13	-48	-70	-84	-89	-91	-90	-54
HC	-66	-88	-57	-78	-65	-76	-69	-72	-80	-84
NO_x	-5	-34	49	-57	-47	-62	-49	-26	28	-49
CO_2	-8	-14	-14	-10	-10	-11	-10	-8	-11	-15

For petrol and diesel the conclusions remain the same as in the 2001 annual report: The absolute levels of emissions under real-world circumstances have dropped significantly with the introduction of Euro 3 legislation. All effects do indicate optimised fuelling strategies for this type of vehicles. The positive effect of the latest legislation on PM of diesel cars is very clear, but on the other hand the NO_x of these cars only shows a rather small decrease. Obviously the trade-off between NO_x and PM emissions of diesel cars has been selected towards lower PM, allowing NO_x to be closer to the limit value.
For LPG vehicles also the absolute levels of emissions under real-world circumstances have dropped significantly through the progress of technology, especially for CO and HC. For NO_x an overall decrease can be observed, but for some driving patterns an increase of emissions occurred, for which no obvious explanation can be found. Probably the small vehicle sample plays a role here.

The CO_2 emissions must be regarded in the light of the average weight of the vehicle sample per category, which is summarised in the table below.

Table 13 Average weight of vehicle selection

	Average weight Euro 1/2 (kg)	Average weight Euro 3/4 (kg)	Difference (%)
Petrol	1140	1100	-3,5%
Diesel	1230	1285	+4,5%
LPG	1365	1265	-7,5%

On average, the Euro 3/4 petrol selection is somewhat lighter than the Euro 3/4 selection. This effect cannot be clearly observed in the comparison of CO_2 emissions, which have decreased for the low speed/high dynamics test cycle and increased a little for the high speed/low dynamics test cycles.
Despite of a weight increase for the Euro 3/4 diesel selection versus the Euro 1/2 selection, the CO_2 results showed a decrease on almost every testcycle, which is an indication for the improved efficiency of diesel engines over both generations.
The lower weight of the LPG selection is reflected in the lower CO_2 emission.

5.2 Common Artemis Driving Cycles

As explained earlier, in 2002 the MODEM/HYZEM cycles have been replaced by the Common Artemis Driving Cycles (CADC) for producing information on the real-world emission behaviour of cars in comparison to the Type Approval testing. The CADC consists of an urban part, an extra-urban part and a highway part.

Comparing the data from the CADC-cycles with the approval test data gives relevant information on the transient behaviour of vehicle emissions outside the type approval test window. This information is also essential for emission modelling purposes. The following figures shows the test results of the vehicle types in the 2002 vehicle selection, compared with the urban (hot) part and extra-urban part of the standard EU type approval test.

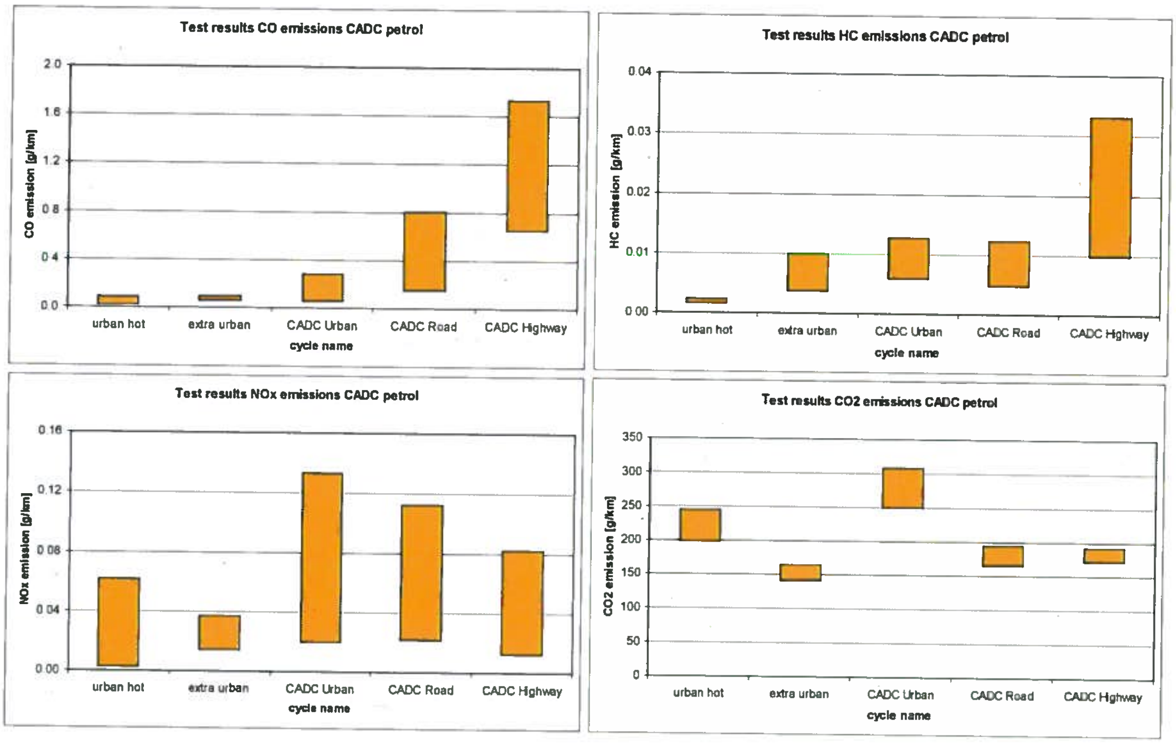

Figure 33 Emission results from the CADC cycles compared to the 'urban hot' and 'extra urban' ECE cycles for petrol vehicles

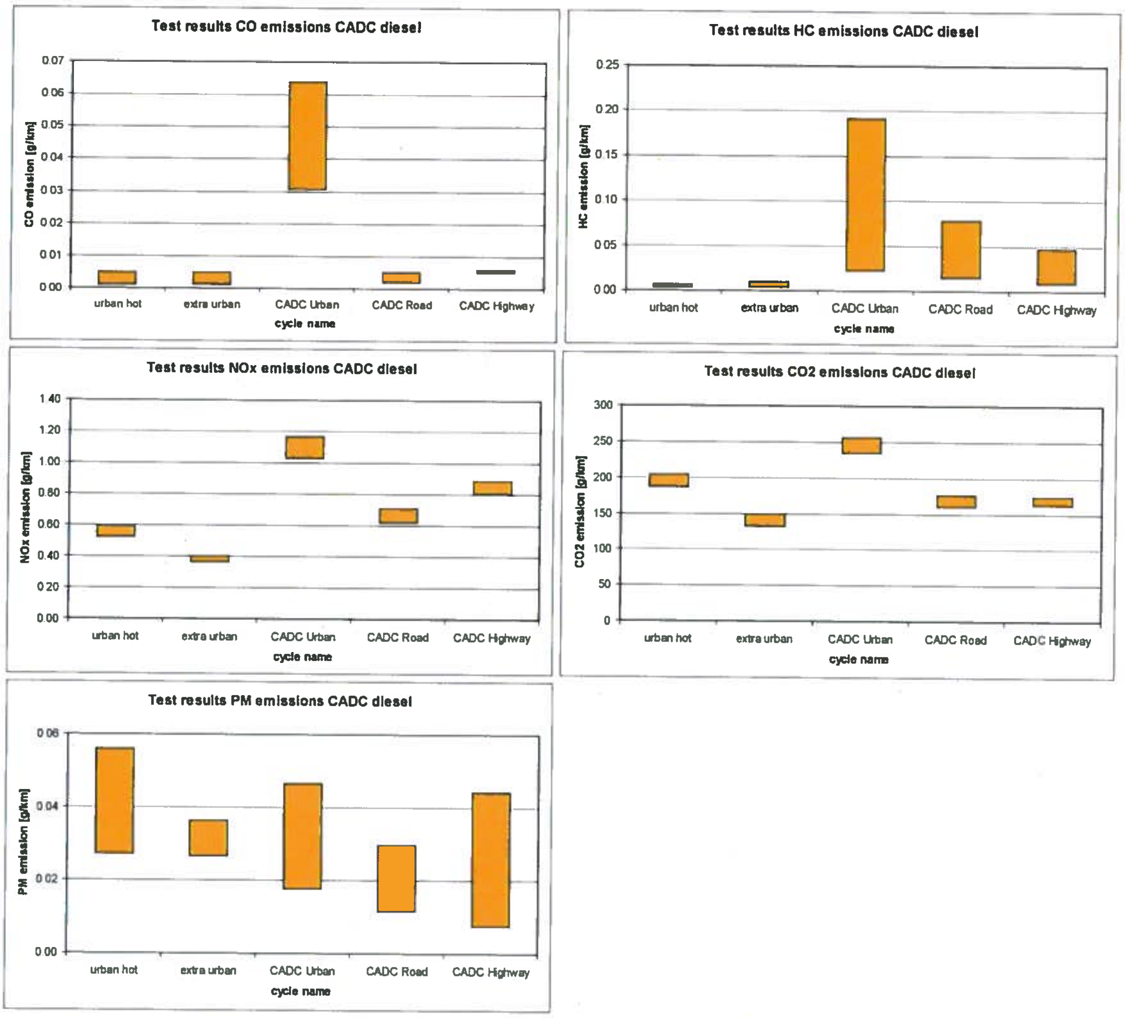

Figure 34 Emission results from the CADC cycles compared to the 'urban hot' and 'extra urban' ECE cycles for diesel vehicles

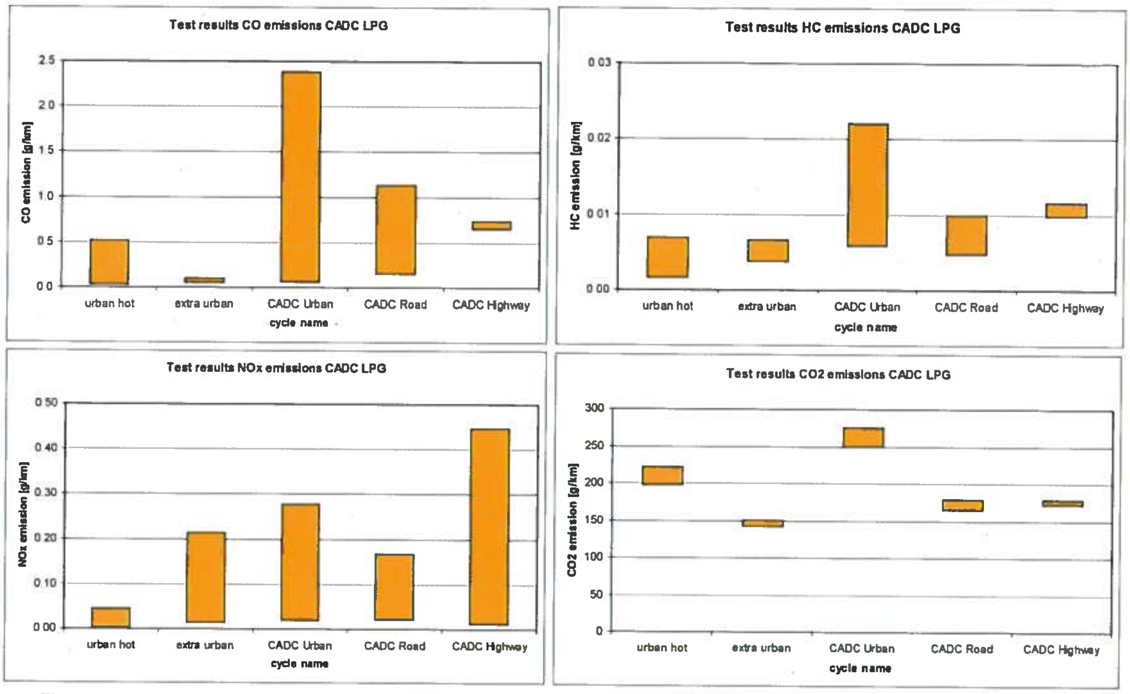

Figure 35 Emission results from the CADC cycles compared to the 'urban hot' and 'extra urban' ECE cycles for LPG vehicles

Just as the comparisons with the MODEM/HYZEM cycles in 2001, the comparisons presented above also point out that the Type Approval test procedure seems to be no longer representative for real-world driving. The differences in emissions between real-world driving and the TA procedure are considerable and not constant.

In the next paragraph this behaviour will be investigated in more detail.

5.3 Real-world versus type approval over the years

Based on the information gathered by using real-world driving cycles in the IUC programme for a number of years now, a first assessment is made of real-world emissions versus type approval (TA) emissions of passenger cars. An important issue is the progress of emission legislation versus the developments in actual emissions of vehicles on the road. Doing this for a large number of vehicles (types and ages) will give a good insight if this is in line with each other.

For the assessment, two issues are important:
- The availability and consistency of emission data for all (Euro 0 to pre-Euro 4) vehicle categories;
- The cycle parameters of the TA driving cycle and the selected real-world driving cycle.

Taking these issues into account, it was decided to correlate the EUDC (Extra Urban Driving Cycle) part of the European type approval cycle with categories 2C and 1C from the "Emission and Congestion" project (E&C, see also Paragraph 5.1 and Table 9), all 3 being driving cycles with a warm start. The choice for the E&C cycles was evident because these cycles are the only type for which a database ranging from Euro 0 to pre-Euro IV vehicles is available (the prefered CADC data is only available from Euro II onwards). A good fit in vehicle speed and driving dynamics with the EUDC cycle however is difficult to obtain. Therefore two typical E&C driving cycles are used for the assessment: 1C with equivalent average vehicle speed but with much more driving dynamics, and 2C with a much higher average vehicle speed (no stops included) but with lower driving dynamics. The effect of these differences on the driving energy (at the wheels) is presented in Table 20. As can be seen, the energy values, required to drive the cycle with an average vehicle, are comparable.

Table 14 Cycle parameters of EUDC and E&C driving cycles

Cycle type	V_{avg} (km/h)	RPA (m/s^2)	Driving energy (kWh/km)
EUDC	62.6	0.09	0.124
E&C 2C	98.1	0.06	0.133
E&C 1C	57.4	0.16	0.112

RPA: a measure for driving dynamics

Figure 36 shows the correlation between the type approval emissions (EUDC) and real-world emissions (E&C 2C and 1C) on a logarithmic scale. Only the regulated emissions (including CO_2) of petrol fuelled passenger cars are presented here, as only for this fuel category sufficient data are available for a relevant assessment.

In the figures of the regulated components trendlines are added in order to visualise possible trends that occur. The trendlines are linear fits through data points in the lower 2 decades of the emission values. The higher decades are not taken into account, since in that case the shape of the curve would be dominated by the results of Euro 0 and Euro I vehicles. Also, it is assumed that the discrepancy between TA testing and real-world driving will mainly occur with the latest vehicle technology (and therefore lowest emissions). **It must be clearly stated that the trendlines presented here under no circumstances are meant for mathematic correction of TA data into real-world data.** As can be seen in the figures, the quality of the correlation is rather poor due to the large spread in emission results. The trendlines are presented only to give some visual insight into the effect of real-world emissions versus TA testing.

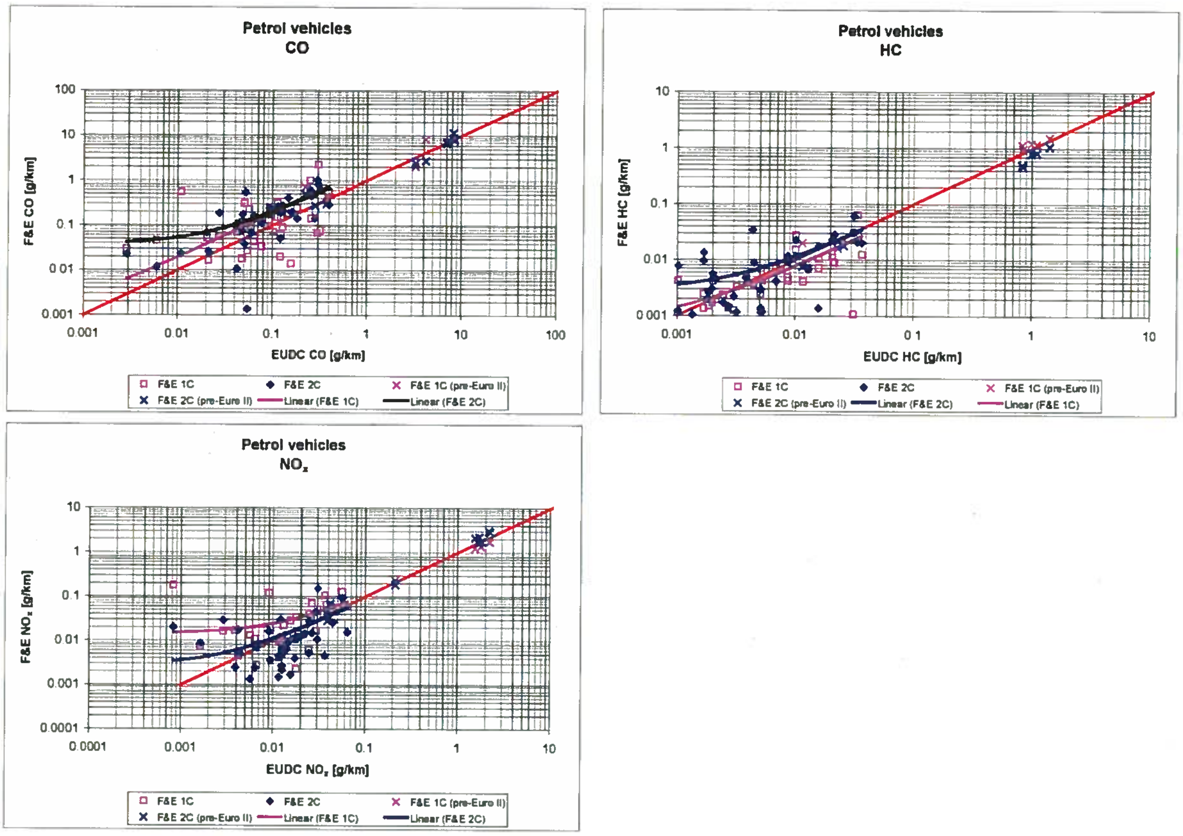

Figure 36 Emissions of EUDC TA driving cycle versus real-world F&E driving cycles

From Figure 36 a trend can be observed with respect to the actual effect of vehicle emission legislation over the years. The emissions from petrol fuelled passenger cars have decreased significantly over the years due to tightened emission legislation. However the one-to-one relation between TA and real-world emissions from the earlier years of emissions legislation is not apparent anymore when dealing with the latest vehicle (emission legislation) categories. The discrepancy in CO- and HC-emissions tends to be more affected by higher driving speeds (2C) wereas the discrepancy in NO_x-emissions seems to by more affected by the driving dynamics (1C).

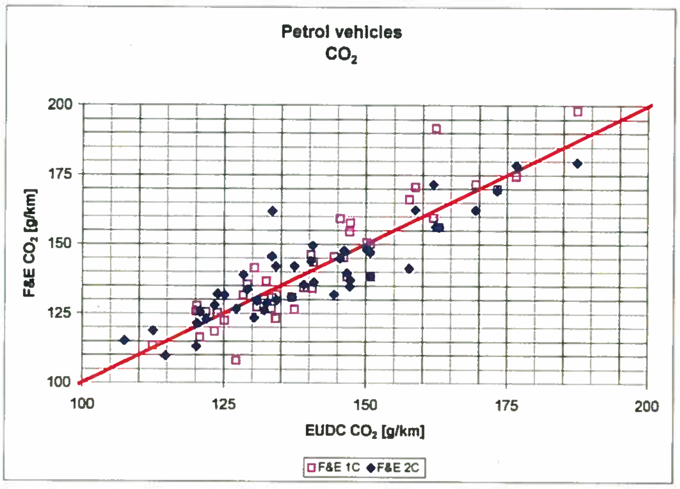

Figure 37 CO_2-emission of EUDC TA driving cycle versus E&C driving cycles

Figure 37 shows the correlation between the CO_2-emissions during the TA test and real-world driving, in this case on a linear scale. Since it are all warm start cycles, the effect of cold start on the CO_2-emission is not included here.

For all vehicles there seems to be a good match between type approval testing and real-world CO_2-emissions. This match can be explained by the fact that CO_2-emissions are (much more than the regulated emissions) linked to the driving energy of the cycle. As can be seen in Table 20 the driving energy of the three cycles is comparable. This means that for warm start CO_2-emission calculations the EUDC part of the TA driving cycle on average can still be used.

Conclusions:
For the regulated emissions of petrol fuelled vehicles it seems that the actual effect of lower emission limits by tightened emission legislation has gradually lost its intended effect on the warm emissions in practice. One of the main reasons of this behaviour could be the European TA driving cycle that is not sufficiently representative of real-world driving. The stylistic shape and low dynamics of this cycle give the manufacturers the possibility to optimise the emissions dedicated to this procedure, instead of towards real-world driving. This effect will be further investigated in a separate effort, also for diesel- and LPG-fuelled vehicles. The results of these analyses will be reported in a separate report.

In contrast with the regulated emissions, the CO_2-emission (and thus fuel consumption) of a vehicle is much more linked to the driving energy of the cycle. In that respect, the EUDC part of the TA cycle on average correlates with (warm start) real-world driving for all legislative categories. The CO_2-emissions measured on the EUDC are comparable to the figures measured on the real-world cycles.

Since the comparisons are based on warm start driving cycles in extra urban and motorway conditions, the effect of cold start on the emissions and the situation in urban conditions are not included here and should be further investigated.

It will be clear that the fact that the emissions (except CO_2) of modern vehicles do no longer correlate with the driving energy does have important consequences for present and future emission modelling techniques.

6 Durability

In 2002 one diesel passenger car and one petrol passenger car were tested on their emission durability: a Volkswagen Passat TDI 66 kW Euro 2, and an Opel Omega 2.5 Automatic Euro 2.

The following tests during the lifetime of the Volkswagen Passat were conducted:

1st at 54.782 km (19-11-2001)
2nd at 75.427 km (12-06-2002)

The emission results over this lifetime are displayed in the figures below.

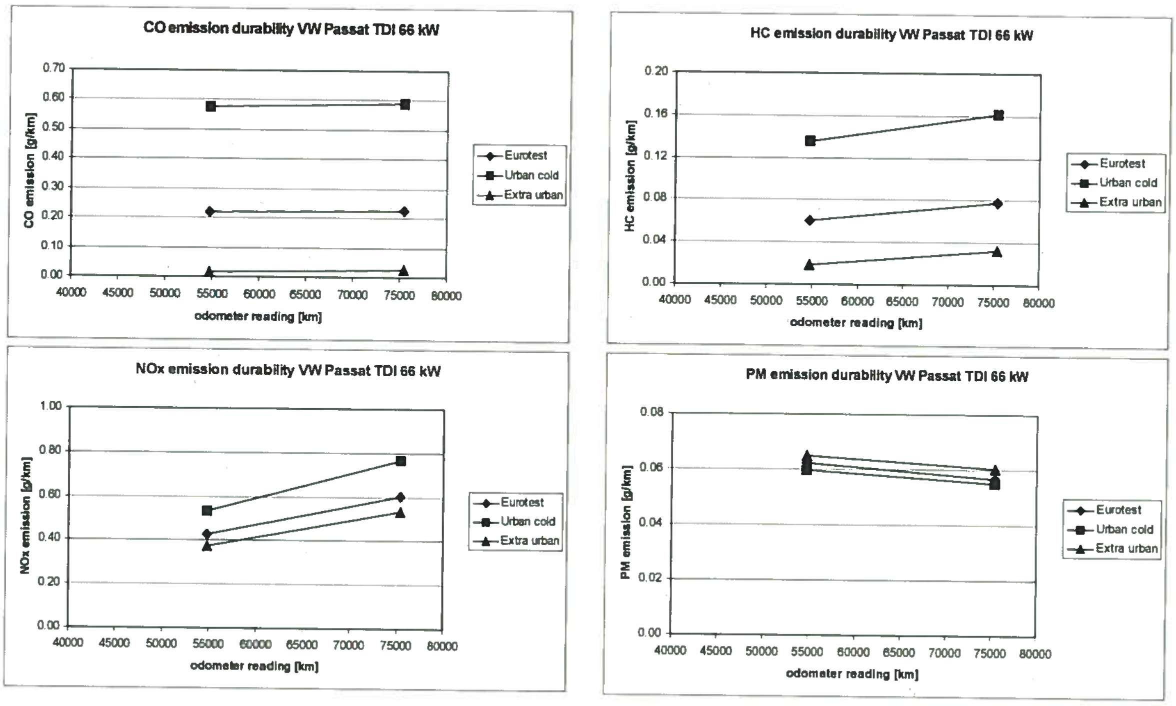

Figure 38 Emissions over the lifetime of a Volkswagen Passat TDI 66 kW

The durability test results of the VW Passat show increased emissions over the mileage range covered. All trends are stable for all 3 test types used. The NOx emission has increased somewhat, in combination with a small decrease of the PM emission. This change however seems to be caused by resetting the injection timing in the cause of changing the timing belt of the engine at 75000 km. The increase in HC emissions may be caused by a slight increase in lubricant oil consumption, which occurred during the mileage accumulated. All emissions however are below the applicable Euro 2 limit values.

The following tests during the lifetime of the Opel Omega were conducted:

1st at 25.007 km (29-03-2000)
2nd at 50.272 km (22-11-2000)
3rd at 119.039 km (23-08-2002)

The emission results over this lifetime are displayed in the figures below.

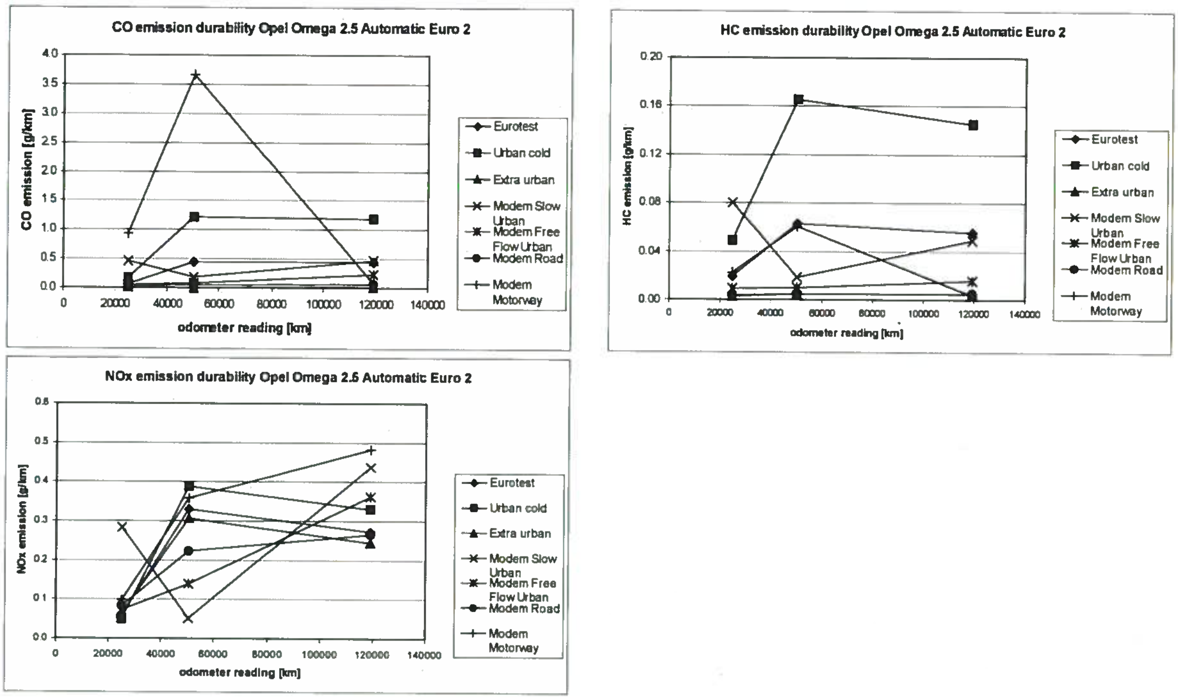

Figure 39 Emissions over the lifetime of an Opel Omega 2.5 Automatic

The durability test results of the Opel Omega generally show an increase of emissions over the first 50.000 km, and a stabilisation after that. All emissions remain well below the Euro 2 limit values though. The 'strange' result at 50.000 km on the MODEM Highway test is probably either due to high load enrichment, or due to the not deliberate activation of the 'kick-down' of the automatic gearbox, or a combination of both effects.

7 Artemis participation

The ARTEMIS project is part of the 5th framework project of the European commission during 2002. ARTEMIS stands for **A**ssessment and **R**eliability of **T**ransport **E**mission **M**odels and **I**nventory **S**ystems. Its objective is the development of a harmonised emission model for all transport modes, with the aim to provide consistent emission estimates at the international, national and regional level. This goal is very close to one of the goals of the Dutch in-use compliance programme. Therefore the participation in the 5th framework project was co-financed by the Dutch government.

In this chapter the work executed by TNO-Automotive in the ARTEMIS project is presented as part of the passenger car in-use compliance programme in the year 2002, in so far as it falls within the context of the present report. It consisted of work in Work Package 300 (on passenger cars) and Work Package 500 (on motorcycles). Next to participating to workshops and co-ordination meetings, TNO actually executed 1 task in the passenger cars Work Package (WP300) and made major progress in the TNO lead motorcycle Work Package (WP500). Next a distribution is given of the work executed, without providing numeric results. The latter is not permitted by the European Commission until the end of the project.

7.1 WP300 – Passenger cars

In 2002 work has been done for several subtasks within Work Package 300 'Artemis Passenger Cars'. This work mainly existed of designing and execution of testprogrammes and examining the testdata. The following testprogrammes were carried out:

- Emission measurements on 1 passenger car over 16 different testcycles. The data gathered are an addition to the Artemis database of emission factors, and will mainly be used to analyse the dependency of emission factors on cycle parameters.
- Measurement of time-lag in the emission measurement set up. These data will be used for the determination of an algorithm to correct online emission data for static and dynamic delays in the measurement system. An online emission signal that is corrected is needed for modelling emissions on a second to second basis because the online emission must be synchronised exactly with an 'action' of the vehicle, such as acceleration or throttle operation.
- Measurement of emissions of one light duty van on dedicated testcycles. In 2001 already three vans have been measured. The results are an addition to the Artemis database.

Moreover, a large amount of emission data of these and previous test programmes has been converted to the Artemis data format and sent to the Artemis partners.

7.2 WP500 – Motorcycles

In the past, emission factors for motorcycles have almost always been derived from the measurement results of ECE 40 type approval tests and for relative new vehicles. In order to derive real-world emission factors for PTWs, an analysis of the European motorcycle fleet and an inventory of real-world driving cycles and their appropriateness for this purpose was required. The results of both studies were integrated in the definition of the measurement programme in which 92 motorcycles were tested. Before the measurement programme started, a round robin test programme was conducted in order to determine the reliability of chassis dynamometer measurements over Europe. In addition to the determination of basic emission factors for CO, HC, NO_x and CO_2, also the influence on these emissions of cold start, fuel properties and inspection and maintenance was addressed in WP500.

WP 500 consisted of the following work sub-packages:

- WP 510: The determination of real-world driving cycles that could be used.
- WP 520: The determination of a useful categorisation of 2-wheelers for emission factor use.
- WP 530: The determination of the reliability of dynamometer measurements over Europe.
- WP 540: The measurement of emission factors for CO, HC, NO_x and CO_2 on real-world driving cycles for different 2-wheeler categories and different road types.
- WP 550: Addressing the influence of cold start, fuel properties and I&M.
- WP 560: The modelling of emission factors.

In 2002, the participants that collaborated in the measurement programme of ARTEMIS WP500 carried out a large number of measurements (92 motorcycles). The results of this measurement programme led to a significant increase of real-world emission factors of motorcycles since most emission factors that were available were based on the type approval driving cycle (ECE 40). Below, the activities and achievements of the sub workpackages of WP500 are summarised.

7.2.1 *WP 510: Driving cycles*

In order to set-up the ARTEMIS WP500 measurement programme, a number of parameters of different driving cycles and real-world recorded data were analysed in order to select representative driving cycles to derive real-world and cold start emission factors for motorcycles. For this case 8 driving cycles were selected, being:

Type approval:

1 Cold started pre-conditioning driving cycle (2 times sub-cycle of 195 seconds)
2 Type approval driving cycle (UDC)

Real-world motorcycle driving cycles:

1 Fachhochschule Biel – Urban driving cycle (Zentrum)
2 Fachhochschule Biel – Ring-road driving cycle (Peripherie)
3 Fachhochschule Biel – Rural driving cycle (Ueberland)

Traffic conditions driving cycles (CADC – common ARTEMIS driving cycle)

1 CADC Urban
2 CADC Road
3 CADC Motorway (maximum vehicle speed 130 km/h)

The WMTC driving cycle seemed to be appropriate to be included in the project. Unfortunately, this driving cycle was not official at the time the measurement programme started and was therefore excluded from further analysis.

7.2.2 *WP 520: Vehicle classification*

From different sources (e.g. magazines, statistic summaries and fleet composition data delivered by the project participants, etc.) a motorcycle classification matrix has been developed. Main parameters are:

- Engine capacity (cm^3)
- Engine principle (2- or 4-stroke)
- Exhaust gas aftertreatment system
- Model (scooter, chopper, tour, naked, sports)
- Age
- Odometer reading

The vehicle classification matrix is used for the purpose of selecting vehicles in the measurement programme and is also valid to categorise different types of motorcycles in the emission model.

7.2.3 *WP 530: Round robin*

This sub Work-Package was finished in December 2001 by the delivery of a detailed report. A number of conclusions and recommendations have been taken into account in order to define the measurement programme. Furthermore, the KTI laboratory has been upgraded using the recommendations that were stated in the report.

7.2.4 *WP 540: Measurement programme*

The partners KTI (10), TÜV Nord (20) and TNO (60) completed the measurement campaign in which in total 92 motorcycles were subject of an extensive test programme. Before this campaign started, a detailed test protocol had been developed in order to assure that all tests were executed on the same basis. The test protocol contained information about the driving cycle selection (depending on the maximum speed of the vehicle), brake load and mass specification, gear shift procedure (taken from WMTC project) and general conditions which were the result of the round robin test programme. For the purpose of data collection, a test report template was defined in which a number of characterisations of the vehicle and the test could be filled in. In this file, the procedure of calculation was also automated. The ambient conditions, the distance driven and the results of the raw bag analysis were directly translated into emissions in unit grams per kilometer.

7.2.5 *WP 550: Cold start, fuel properties and I&M*

Each of the topics included in this sub Work Package is discussed separately.

Cold start

Apart from carrying out the work in the measurement programme, measurements were also performed in order to determine the effects of cold start and of fuel properties on the exhaust gas emissions of motorcycles. A joint project executed in Switzerland by the Fachhochschule Biel and EMPA Dübendorf provides extra emission factors on the topic of cold start emissions. The results of this study will be available in 2003. Also the results of earlier measurement programmes executed by FHB and EMPA were integrated in the ARTEMIS WP500 project.

Fuel properties
In collaboration with WP300, which supplied the analysis results of different petrol fuels on the market in Europe, the influence of a number of fuel properties was evaluated by using the EPEFE formulas (from the European AutoOil programme).

On the other hand, an indication of the effect on the emissions of current and future fuel is also of high importance. Therefore it was decided to set-up a measurement campaign that incorporates:

- Hungarian market fuel with high aromatics and high sulphur content
- Future fuel that meet the 2005 requirements (low aromatics and sulphur content)

In 2002, 2 of 5 motorcycles were tested at the KTI laboratory. The test results will be available in 2003. TNO and KTI have put much effort in the definition of a measurement programme to address the effect of fuel properties.

Inspection and maintenance
Due to the close co-operation with the CITA study on motorcycle exhaust gas emissions and noise, also knowledge was gained about the effect of Inspection and Maintenance on the emissions.

7.2.6 *WP 560: Emission factors and modelling*

It was recognised that there is a number of different emission modelling approaches that could form the basis for the ARTEMIS model. For example, these could include average speed or instantaneous approaches, or incorporate some other technical features to classify the operation of the engine. This workpackage reviewed the various model options, and identified the most significant parameters, which may be used to characterise emissions. This review also identified suitable interfaces with model input data, such as traffic characterisation and presentational and analysis tools such as GIS (Geographical Information System). Given this review process, the ARTEMIS emission model and database will be optimised to incorporate the most significant parameters and approaches.

8 Additional work

Apart from the work described in this report, several other topics were carried out in 2002 on behalf on the In-Use Compliance Programme.

8.1 Taakgroep Verkeer & Vervoer

Just like previous years, in 2002 TNO Automotive participated in the "Taakgroep Verkeer & Vervoer", in which also the Dutch Institute for Public Health and Environment (RIVM) and the Dutch Statistics Institute (CBS) participate. The goal of this workgroup is gathering emission data on transport for the annual Dutch emission inventory. TNO Automotive delivers emission data for passenger cars, light duty vans and heavy duty vehicles. These data are derived from the emission results gathered in the In-Use Compliance programme.
Apart from its basic task, the workgroup also acts as a discussion forum for any topic on (transport) emissions.

8.2 DACH+NL

Germany, Austria and Switzerland also run an In-Use Compliance programme. In order to be able to exchange ideas and results between those countries and to increase the international harmonisation of emission factors, a discussion forum was set up in 1998. In 1999 the Netherlands also became a member of the group, that meets two or three times annually.

8.3 Air quality in 'Overschie'

In May 2002, the Dutch authorities introduced a pilot on highway A13 directed to maintain the maximum speed at 80 km/h. One of the purposes of this measure was to improve the air quality in Overschie, a municipality of Rotterdam. A "trajectory control" system was set up over a 3 km stretch of the A13 in Overschie. A constant traffic flow was ensured by an automatic speed check when the limit of 80 km/h over the 3 km stretch was exceeded (average speed). Next, by assignment of the Dutch Road Directorate RWS, TNO Environment, Energy and Process Innovation in co-operation with the Environmental Protection Agency DCMR carried out a study on the impact of the "80 km/h-measure" on the air quality in Overschie. In this study the air pollutants NO_2 and PM_{10} were highlighted. TNO Automotive participated in this study by providing tail pipe emission factors of the traffic passing at Overschie before and after the measure was introduced. These emission factors were derived from the knowledge gathered in the research on "emissions and congestion", see also chapter 5.1.

The results of this research are described in the TNO report R2003/258 titled "Onderzoek naar effecten van de 80 km/u-maatregel voor de A13 op de luchtkwaliteit in Overschie".

9 References

[1] *"Emissies en Files – Definitief rapport fase 1"* (Emissions and congestion – Final report phase 1).
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[2] *"Emissies en Files – Bepalen van emissiefactoren, Eindrapportage fase 2"* (Emissions and congestion – Determination of the emission factors, Final report phase 2).
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Report nr.: 01.OR.VM.043.1/NG

[3] *"Emissies en Files – Ophoging van emissies naar traject- en landelijk niveau, Eindrapportage fase 3"* (Emissions and congestion – Transfer of the emissions to a trajectory or national level – Final report phase 3).
TNO-Inro, Delft, April 2001.
Report nr.: V+V/2001-26

[4] .: *"Emissions and congestion – Estimation of emissions on road sections and the Dutch motorway network - Executive summary"*.
TNO-Automotive, Delft, May 2001.
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A Emissions & Congestion: detailed results

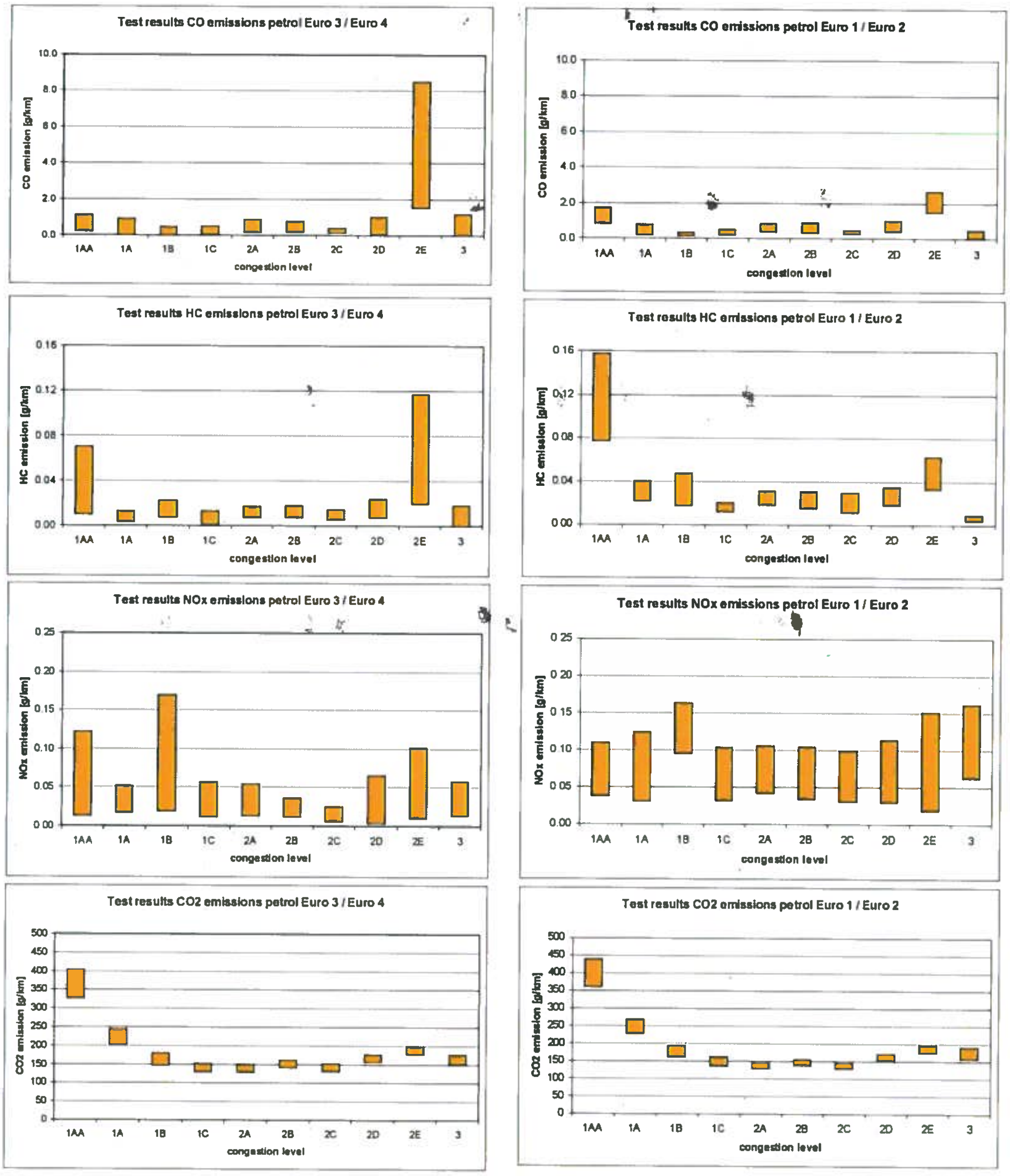

Figure A1 Petrol fuelled passenger cars Euro 3 and 4 (left) and Euro 1 and 2 (right) respectively.

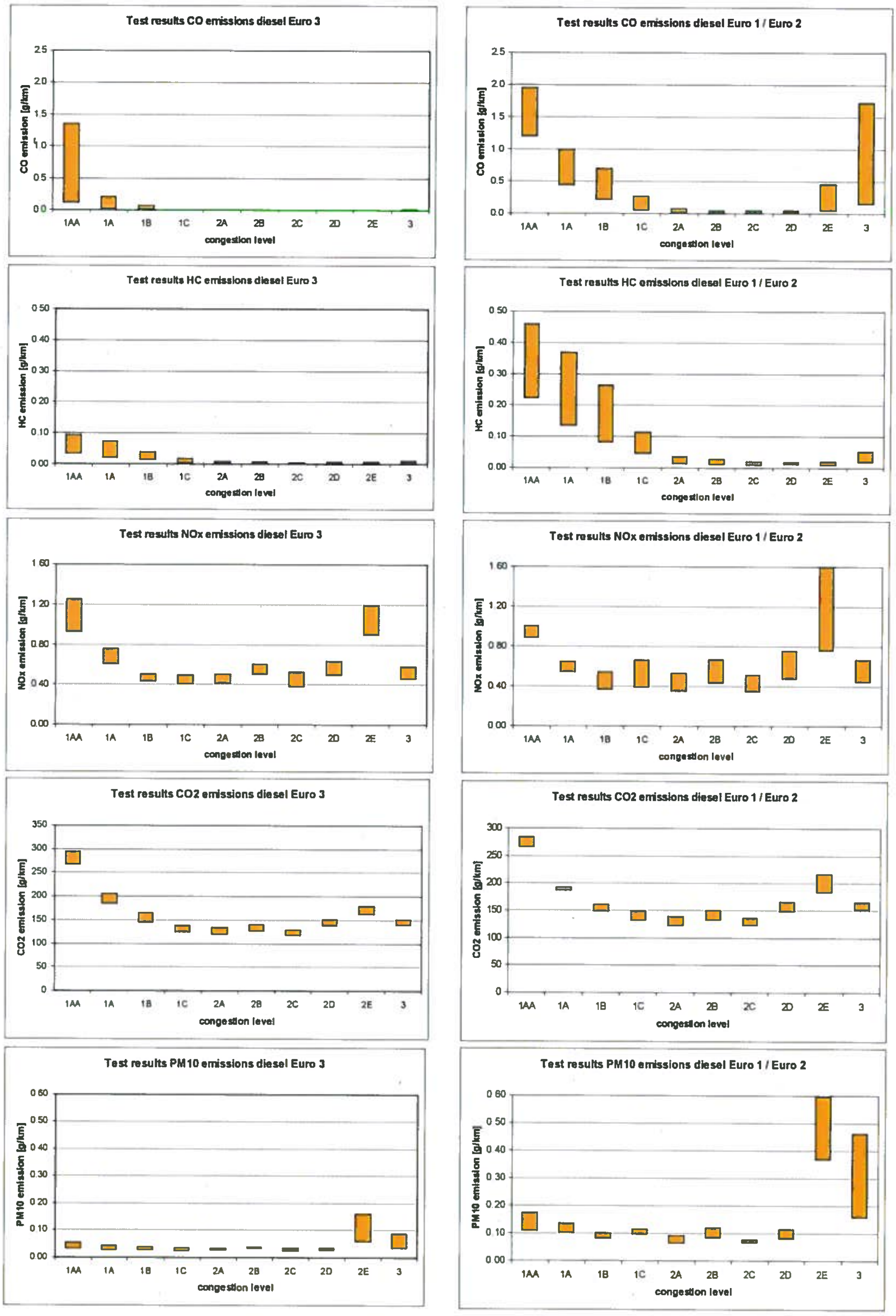

Figure A2 Diesel fuelled passenger cars Euro 3 (left) and Euro1 and 2 (right) respectively.

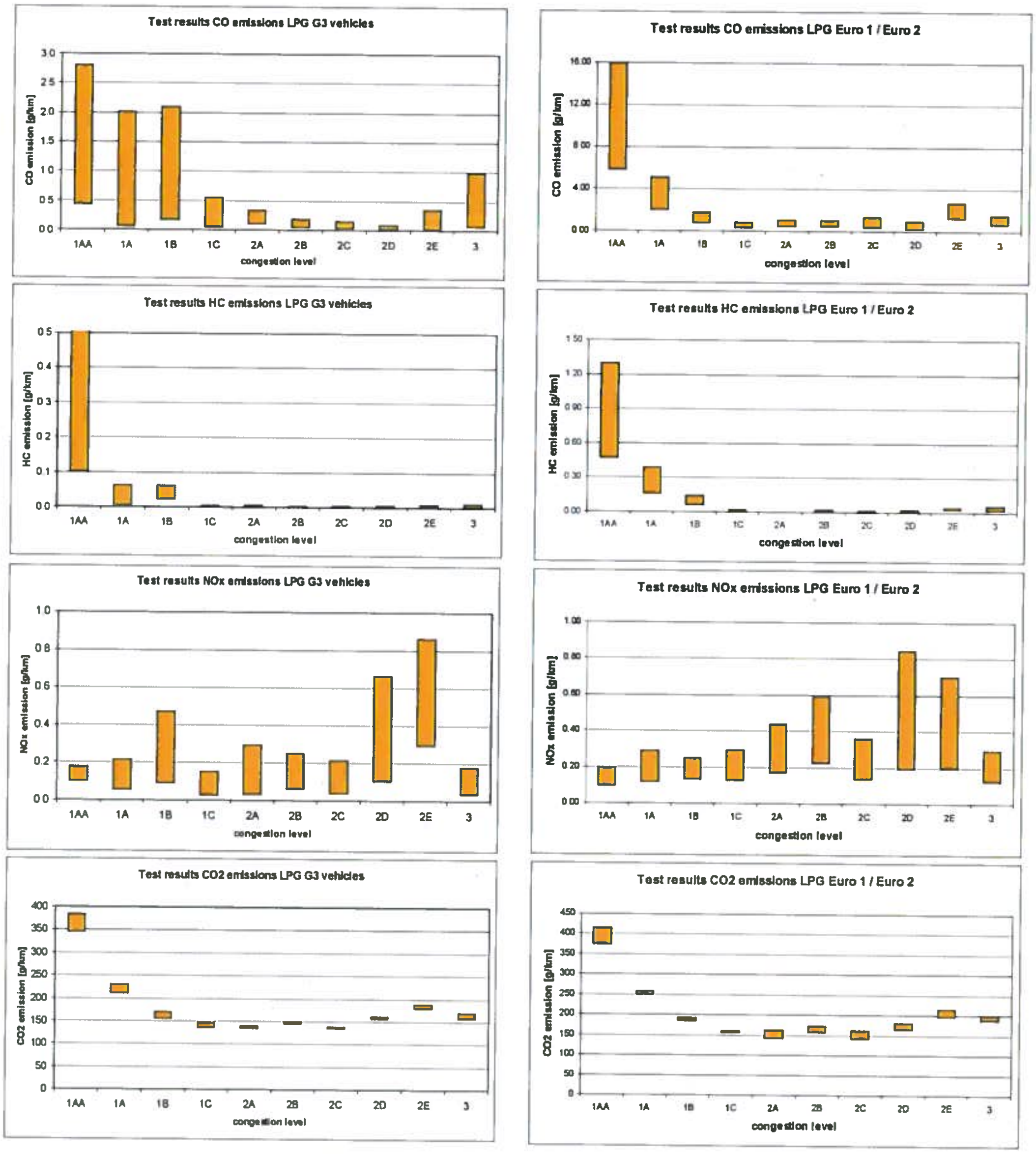

Figure A3 LPG fuelled passenger cars G3 (left) and Euro1 and 2 (right) respectively.